RAQRS VII

RECENT ADVANCES IN QUANTITATIVE REMOTE SENSING

23-27 SEPTEMBER 2024

TORRENT (VALENCIA) SPAIN

PROGRAMME AND ABSTRACT BOOK

7th INTERNATIONAL SYMPOSIUM

RECENT ADVANCES IN QUANTITATIVE REMOTE SENSING

PROGRAMME AND ABSTRACT BOOK

23 – 27 SEPTEMBER 2024
TORRENT (VALENCIA) SPAIN

GLOBAL CHANGE UNIT
Image Processing Laboratory
Universitat de València
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SPAIN

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Depósito Legal: V-3053-2024

WELCOME MESSAGE

We are pleased to welcome you to the seventh International Symposium on Recent Advances in Quantitative Remote Sensing, which will be held in Valencia, Spain, from 23 to 27 September 2024.

The Symposium addresses the scientific advances in connection with real applications, its main goal being to assess the state of the art of both theory and applications in the analysis of Remote Sensing data. This symposium should greatly contribute to define common research priorities.

The Symposium will offer a unique framework for socializing and interacting with the members of the international remote sensing community, at the same time enjoying a stay in Valencia.

Presentations by scientists from around the world will provide an in-depth view and evaluation of the current advances of remote sensing.

See you in Valencia!

Cordially
José A. Sobrino
Symposium Chairman
University of Valencia, Spain
sobrino@uv.es

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RAQRS 2024 - TIMETABLE

Time	Monday 23rd Sep 2024	Tuesday 24th Sep 2024	Wednesday 25th Sep 2024	Thursday 26th Sep 2024	Friday 27th Sep 2024
8:30 - 9:30	REGISTRATION				
9:30 - 10:30	OPENING SESSION	ORAL SESSION 4	ORAL SESSION 8	ORAL SESSION 12	SESSION REPORT BY SESSIONS CHAIRPERSONS (10:00-11:30)
10:30 - 11:00	CONFERENCES	Coffee Break	Coffee Break	Coffee Break	
11:00 - 11:20	Coffee Break	ORAL SESSION 5	ORAL SESSION 9	ORAL SESSION 13	
11:20 - 12:00	ORAL SESSION 1				CLOSING CEREMONY
12:00 – 13:30	POSTER SESSION 1	POSTER SESSION 2	POSTER SESSION 3	POSTER SESSION 4	Refreshment & Snacks
13:30 - 15:30	Lunch Break	Lunch Break	Lunch Break	Lunch Break	
15:30 - 17:00	ORAL SESSION 2	ORAL SESSION 6	ORAL SESSION 10	ORAL SESSION 14	
17:00 - 17:30	Coffee Break	Coffee Break	Coffee Break		
17:30 - 18:30	ORAL SESSION 3	ORAL SESSION 7	ORAL SESSION 11		
19:30 - 22:00	WELCOME RECEPTION	DINNER		GALA DINNER (20:00-24:00)	
22:00 - 24:00					

PROGRAMA RESUMIDO/PROGRAMME OVERVIEW

LUNES 23 SEPTIEMBRE 2024 - MONDAY 23rd SEPTEMBER 2024

8:30 – 9:30
Inscripción y entrega de documentación / *Welcome and registration*.
AUDITORI de Torrent. C/Vicent Pallardó nº 25, 46900 TORRENT (Valencia)

9:30 – 10:00 Acto de apertura / *Opening session*
10:00 – 11:00 *Opening Conferences*
11:00 – 11:20 Pausa café / *Coffee break*
11:20 – 12:00 Sesión Oral 1 / *Oral session 1*
SESSION 1: - Land Surface Radiation and Inversion Modelling
Presidente / *Chair*: J. MORENO

12:00 – 13:30 Sesión Poster 1 / *Poster session 1*
POSTER 1: - Land Surface Radiation and Inversion Modelling
-Thermal Infrared Remote Sensing
- Multispectral and Hyperspectral Remote Sensing and Imaging Spectroscopy
- Multiangular and Multitemporal Measurement

13:30 – 15:30 Pausa comida / *Lunch break*
15:30 – 17:00 Sesión Oral 2 / *Oral session 2*
SESSION 2: - Land Surface Radiation and Inversion Modelling
- Multispectral and Hyperspectral Remote Sensing and Imaging Spectroscopy
- Multiangular and Multitemporal Measurement
Presidente / *Chair*: E. VERMOTE

17:00 – 17:30 Pausa café / *Coffee break*
17:30 – 18:30 Sesión Oral 3 / *Oral session 3*
SESSION 3: - Earth Observation Missions & Services
Presidente / *Chair*: F. NERRY

19:30 – 22:00 Acto Social / *Welcome Reception*

MARTES 24 SEPTIEMBRE 2024 – TUESDAY 24th SEPTEMBER 2024

9:00 – 10:30 Sesión Oral 4 / Oral session 4

SESSION 4: **- Multispectral and hyperspectral**
- Multiangular and Multitemporal Measurement
- Carbon and Water Cycle Observation and Modelling

Presidente / Chair: O. HAGOLLE

10:30 – 11:00 Pausa café / Coffee Break

11:00 – 12:00 Sesión Oral 5 / Oral session 5

SESSION 5: **- Earth Observation Missions & Services**

Presidente / Chair: K. MALLICK

12:00 – 13:30 Sesión Poster 2 / Poster session 2

POSTER 2: **- Machine Learning in Remote Sensing**
- Carbon and Water Cycle Observation and Modelling
- Earth Observation Missions & Services
- Thermal infrared remote sensing

13:30 – 15:30 Pausa Comida / Lunch break

15:30 – 17:00 Sesión Oral 6 / Oral session 6

SESSION 6: **- Carbon and Water Cycle Observation and Modelling**

Presidente / Chair: G. CHECHBOUNI

17:00 – 17:30 Pausa café / Coffee break

17:30 – 19:00 Sesión Oral 7 / Oral session 7

SESSION 7: **-Carbon and Water Cycle Observation and Modelling**
-Scaling, Fusion and assimilation of data
- Earth Observation Missions & Services

Presidente / Chair: A. OLIOSO

19:30 – 22:00 Cena / Dinner

MIERCOLES 25 SEPTIEMBRE 2022 – WEDNESDAY 25th SEPTEMBER 2024

9:00 – 10:30 Sesión Oral 8/ Oral session 8
SESSION 8: -From R&D to Operational Agriculture Monitoring
Presidente / Chair: J. P. WIGNERON

10:30 – 11:00 Pausa café / Coffee Break
11:00 – 12:00 Sesión Oral 9 / Oral session 9
SESSION 9: - Land Cover/Use and Change
- Earth Observation Misions & Services
Presidente / Chair: R. O. GREEN

12:00 – 13:30 Sesión Poster 3 / Poster session 3
POSTER 3: - Land Cover/Use and Change
- From R&D to Operacional Agriculture Monitoring
- Urban Heat Island Mapping and Mitigation
- Inversion of Evapotranspiratior

13:30 – 15:30 Pausa Comida / Lunch break
15:30 – 17:00 Sesión Oral 10 / Oral session 10
SESSION 10: -Earth Observation Misions & Services
-Sensor Calibration, Atmospheric Correction and Product Validation
Presidente / Chair: W. TIMMERMANS

17:00 – 17:30 Pausa café / Coffee break
17:30 – 19:00 Sesión Oral 11 / Oral session 11
SESSION 11: - Urban Heat Island Mapping and Mitigation
- Earth Observation Misions & Services
Presidente / Chair: X. BRIOTTET

JUEVES 26 SEPTIEMBRE 2024-THURSDAY 26th SEPTEMBER 2024

9:00 – 10:30 Sesión Oral / Oral session

SESSION 12: - Sensor Calibration, Atmospheric Correction and Product Validation

Presidente / Chair: H. YÉSOU

10:30 – 11:00 Pausa café / Coffee Break

11:00 – 12:00 Sesión Oral / Oral session

SESSION 13: - Passive and active Microwaves & SAR Data Processing / Applications
- Earth Observation Misions & Services

Presidente / Chairs: Y. KERR

12:00 – 13:30 Sesión Poster / Poster session

POSTER 4:
- Remote Sensing of snow and ice
-Sensor Calibration, Atmospheric Correction and Product Validation
- Passive & actives Microwaves Data Processing Applications
- Passive and active Fluorescence
- Earth Observation Missions & Services
- Laser Remote Sensing

13:30 – 15:30 Pausa Comida / Lunch break

15:30 – 16:30 Sesión Oral / Oral session

SESSION 14: - Passive and active fluorescence
- Earth Observation Misions & Services

Presidente / Chair: J. MORENO

20:00 Cena de Gala / Gala Dinner

VIERNES 27 SEPTIEMBRE 2022-FRIDAY 27th SEPTEMBER 2024

10:00 – 11:30 Session report by session chairpersons

Presidente /*Chair*: J. A. SOBRINO

11:30 – 12:00 Acto de clausura / Closing ceremony

12:00 – 13:15 Refrigerio / Refreshments & Snacks

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- Multispectral and Hyperspectral Remote Sensing and Imaging Spectroscopy
- Multiangular and Multitemporal Measurement
Presidente / *Chair*: E. VERMOTE

MARTES 24 SEPTIEMBRE 2024 – *TUESDAY 24th SEPTEMBER 2024*

9:00 – 10:30 Sesión Oral / *Oral session*
***SESSION 4:*- Land Surface Radiation and Inversion Modelling**
- Thermal Infrared remote sensing
- Multispectral and Hyperspectral Remote Sensing and Imaging Spectroscopy
- Carbon and Water cycle observation and modelling
Presidente / Chair: O. HAGOLLE

10:30 – 11:00 Pausa café / *Coffee break*

11:00 – 12:00 Sesión Oral / *Oral session*
***SESSION 5:* - Earth Observation Misions & Services**
Presidente / *Chair*: K. MALLICK

12:00 – 13:30 Sesión Poster / *Poster session*
POSTER 2: - Machine Learning in Remote Sensing
- Advances in consolidates datasets of ECV
- Carbon and Water Cycle Observation and Modelling
- Earth Observation Misions & Services

13:30 – 15:30 Pausa Comida / *Lunch break*
15:30 – 17:00 Sesión Oral / *Oral session*

SESSION 6: **- Carbon and Water Cycle Observation and Modelling**
- Inversion of Evapotranspiration

Presidente/*Chair*: A. CHEHBOUNI

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17:30 – 19:00 Sesión Oral / *Oral session*

SESSION 7: **- Carbon and Water Cycle Observation and Modelling**
- Inversion of Evapotranspiration
- Earth Observation Missions & Services
- Scaling, Fusion, reduction and assimilation of data

Presidente/*Chair*: A. OLIOSO

19:30 – 22:00 Cena / *Dinner*

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Presidente / *Chair*: J. P. WIGNERON

10:30 – 11:00 Pausa café / *Coffee break*

11:00 – 12:00 Sesión Oral / *Oral session*
SESSION 9: **- Land Cover/Use and Change**
- Earth Observation Missions & Services

Presidente / *Chair*: R. O. GREEN

12:00 – 13:30 Sesión Poster / *Poster session*
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- Land Cover/Use and Change
- From R&D to Operacional Agricultural Monitoring
- Urban Heat Island Mapping and Mitigation

13:30 – 15:30 Pausa Comida / *Lunch Break*
15:30– 17:00 Sesión Oral / *Oral session*

***SESSION 10:* - Sensor Calibration, Atmospheric Correction and Product Validation**

Presidente / *Chair*: W. TIMMERMANS

17:00 – 17:30 Pausa Café / *Coffee break*

17:30 – 19:00 Sesión Oral / *Oral session*

***SESSION 11:* - Urban Heat Island Mapping and Mitigation**
- Earth Observation Missions & Services

Presidente/ *Chair*: X. BRIOTTET

JUEVES 26 SEPTIEMBRE 2024 – *THURSDAY 26th SEPTEMBER 2024*

9:00 – 10:30 Sesión Oral / *Oral session*

***SESSION 12:* - Sensor Calibration, Atmospheric Correction and Product Validation**

Presidente / *Chair*: H. YESOU

10:30 – 11:00 Pausa café / *Coffee break*

11:00 – 12:00 Sesión Oral / *Oral session*

***SESSION 13:* -Passive and actives Microwaves & SAR Data Processing Applications**
- Earth Observation Missions & Services

Presidente / *Chair*: Y. KERR

12:00 – 13:30 Sesión Poster / *Poster session*

***POSTER 4:* - Global Change and sustainable development**
- Remote Sensing of snow and ice
-Sensor Calibration, Atmospheric Correction and Product Validation
- Passive & actives Microwaves Data Processing Applications
- Passive and active Fluorescence
- Earth Observation Missions & Services
- Laser Remote Sensing

13:30 – 15:30 Comida / *Lunch*

15:30 – 16:30 Sesión Oral / *Oral session*
SESSION 14:
- Passive and active Fluorescence
- Earth Observation Missions & Services
Presidente /*Chair*: J. MORENO

20:00 Cena de Gala / *Gala Dinner*

VIERNES 27 SEPTIEMBRE 2024 – *FRIDAY 27th SEPTEMBER 2024*

10:00 – 11:30 Conclusiones de sesiones por los presidentes /
Session report by session's chairpersons

Presidente /*Chair*: J. A. SOBRINO

11:30 – 12:00 Acto de clausura / *Closing ceremony*

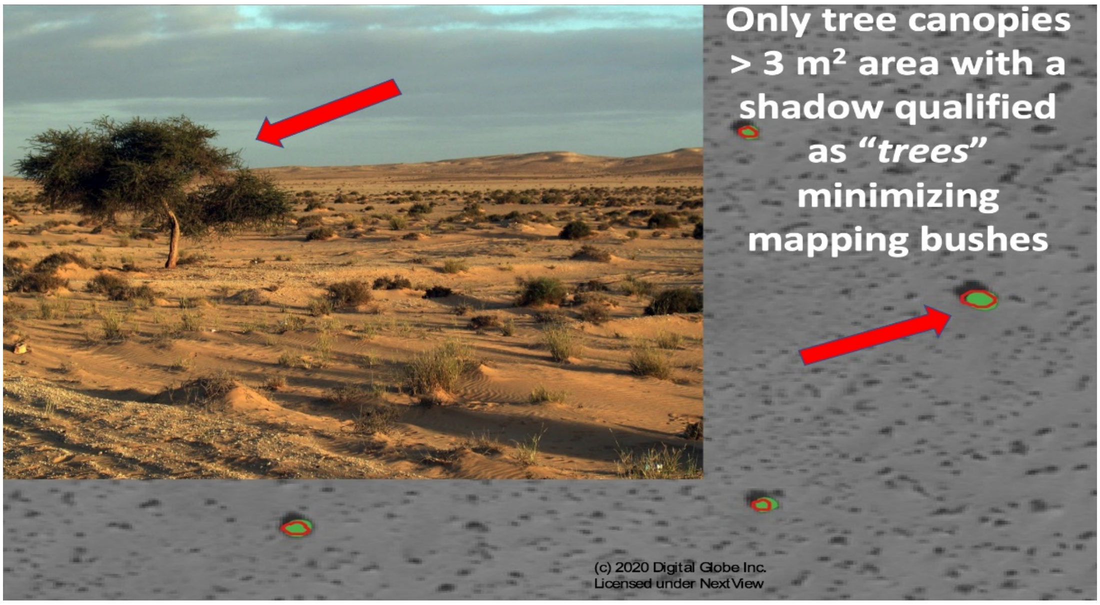
12:00 – 13:15 Refrigerio / *Refreshments & Snacks*

SUB-METER DRYLAND TREE CARBON MAPPING -BEHIND THE SCENES

Compton Tucker[1], Martin Brandt[2], Ankit Kariryaa[2], & Pierre Hiernaux [3]

[1]NASA/GSF
[2]University of Copenhagen
[3]University of Toulouse

We successfully combined commercial satellite data, machine learning, high performance computing, and field measurements that enabled the carbon content of ten billion dryland trees to be estimated with an uncertainty of ±20% over an area of 10 million km^2. Our results differ from all previous studies using satellite observations and numerical models. Our voluminous output data required the development of a viewer for understanding what we did and for others to use our results. We discuss errors, unexpected findings, and improvements that are needed. Our results appeared in the March 2, 2023 issue of *Nature*.



ADVANCES IN THE AUTOMATED GROUND BASED VALIDATION OF REMOTELY SENSED SURFACE REFLECTANCE

***E. Vermote*[1], J. McCorkel[2], W.H. Rountree[1,3], A. Santamaria-Artigas[1,3], S. Skakun[1,3] & B. Franch[3,4]**

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[2]*NASA/GSFC Code 618*

[3]*University of Maryland, College Park*

[4]*Universitat of Valencia, Valencia*

The directional surface reflectance product is a critical input for generating downstream products such as Vegetation Indices (VI), Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Bidirectional Reflectance Distribution Function (BRDF), Albedo, and Land Cover. The Surface Reflectance Fundamental Climate Data Record needs to be of the highest possible quality, so that minimal uncertainties propagate in the dependent/downstream products. One challenge is obviously the validation of the surface reflectance. It implies gathering enough surface observations through time and space. Unfortunately, the direct validation is limited to episodic field campaigns, or is continuous in time but is extremely limited in space (around 10m x 10m area) over homogeneous site (e.g. RADCALNET). Although, some indirect validation has been used to enable continuous and globally representative validation by using very detailed atmospheric characterization from AERONET data and accurate radiative code, these efforts have inherent limitations to what can be achieved. Here we describe an automated camera system (CAMSIS) mounted at a height of 123 meters on a TV tower (WLEF) near Park Falls, WI at the Chequamegon National Forest and at the El Palmar location (~20km from Valencia, Spain) at a height of 96 meters. This system provides data for the continuous validation of surface reflectance over a 200m x 200m area at the pixel level for high spatial resolution sensors (better than 30m).

CAMSIS consists of four monochrome cameras fitted with 470, 550, 650, and 850 nm filters. A 50% reflectance target mounted on a motorized arm provides a reference for calibration of the raw imagery. The system is installed on a tower with a view zenith angle of 45◦. Data capture and transfer is automated at satellite overpass. Several processing steps are applied before CAMSIS data are used for validation. The Raw Data are corrected for dark current and flat fielded. The images pairs are then absolutely calibrated using a 50% calibration reference target. The Calibrated pairs are checked for possible changes in capture conditions (e.g. cloud shadows) and composited together to remove the target from view. The calibrated and composited images are then georeferenced with ground control points selected from very high spatial resolution aerial imagery (USDA). Georeferenced images are resampled to the corresponding satellite grid with a mean filter. In addition, BDRF correction are applied to the CAMSIS data which spawn through a large range of view zenith (~up to 70deg) and azimuth angle to put them as the same observation geometry as the satellite data they are compared to. This system is associated with two sky cameras for cloud mask validation (SKYCAM) and is completed by a AERONET Sun Photometer. We present initial results that show good agreement with Sentinel-2A,B and Landsat 8,9 surface reflectance derived from our generic Land Surface Reflectance Code (LaSRC).

AN AI FRAMEWORK TO OBTAIN HIGH ACCURATE AND FINE RESOLUTION LST FROM PASSIVE MICROWAVE REMOTE SENSING

***Xiangyi Deng*[1], Wenping Yu [1,2,*], Wei Zhou [1], Jinan Shi [3], Rouyi Zhao[1], Wen Yang[1], Caixia Gao[4]**

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[2]*Yibin Academy of Southwest University, Yibin, 644000, Sichuan, China.*

[3]*Chongqing Engineering Research Center for Remote Sensing Big Data Application, Southwest University, Chongqing 400715, China (e-mail: shijinan@cqust.edu.cn).*

[4]Aerospace information Research Institute, Chinese Academy of Science, No.9 Dengzhuang South Road, Haidian District, Beijing 100094, China (gaocaixia@aoe.ac.cn)

Land surface temperature (LST) is crucial for the energy balance between the Earth's surface and the atmosphere. Thermal Infrared (TIR) and Passive Microwave (PMW) remote sensing are key methods for acquiring surface temperature globally and regionally. Although TIR observations are widely used for LST retrieval, their effectiveness is limited due to their inability to penetrate cloud cover. Conversely, PMW measurements can penetrate clouds, providing data that significantly compensates for the limitations of TIR observations. However, the lower retrieval accuracy and coarser resolution limit its wider application. This study developed an artificial intelligence (AI) framework to obtain high-accurate and fine resolution LST from PMW measurements. The AI framework includes two parts: PMW LST retrieval and downscaling. The former utilizes the GeoFusionNet based on artificial neural networks, while the downscaling process is implemented by random forest. Within this framework, high-resolution LST products have been obtained from AMSR2, and the station-based validations and sensitivity analysis also has been conducted on the algorithm. The results were as follows: (1) The GeoFusionNet algorithm achieved higher LST retrieval accuracy than empirical or physical models. The Mean Absolute Error (MAE) was 2.37 K during daytime and 1.60 K at night when cross-validated with the upscaled MODIS LST product. (2) The downscaled PMW LST retained high accuracy, with a daytime (nighttime) MAE increase of 0.28 K (0.14 K) compared to the MODIS 1 km product. Station-based validations showed that the coefficient of determination R2 was above 0.9, with an average RMSEs of 3.4 K for daytime and 2.4 K for nighttime, and MAE of 2.80 K and 1.98 K, respectively. (3) Sensitivity analysis demonstrated the algorithm's stable performance, showcasing optimal results in summer and autumn. Spatially, the accuracy remained within 3 K for various land types, including cropland, evergreen forests, and deciduous forests. These results indicate that PMW LST retrieved by this AI framework is with enough accuracy and fine-spatial resolution to applicate in monitoring dynamic changes in large-scale hydrological, climatic, and agricultural fields.

CANOPY SPECTRA MODELING BY COUPLING THE SPECTRAL VECTOR AND THE SPECTRAL INVARIANT THEORIES: THE TWO-LAYER CANOP MODEL

Tian Ma[a,b,*], Hongliang Fang[a,b]
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[b] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China
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Canopy spectra is important for monitoring vegetation growth status. Canopy optical models are important tools to quantifying the relationships between vegetation properties and remotely detected radiative signals. The commonly used two-layer canopy models use the four-flux theory to calculate the multiple scattering and require many input parameters for soil and leaf. The spectral invariants theory (SIT) uses canopy interceptance, recollision probability, and escape probability to describe canopy structure and calculate the canopy reflectance. Compared to the four-flux theory, the SIT is simpler and more efficient. The two-layer canopy reflectance model CANOP developed in this study uses the bi-directional gap probability (BDGP) and SIT to calculate the single and multiple scatters, respectively. It has coupled the General spectral vector-leaf (GSV-L) and the general spectral vector (GSV) models for leaf and soil reflectances, respectively. The CANOP model was fully validated using several well-known canopy spectral models and measured two-layer canopy optical data. Comparison between CANOP and PROSAIL, DART, and the measured canopy data shows that CANOP can accurately simulate the hyperspectral reflectance in the full wavelength range (400–2400 nm) of the two-layer canopy with different leaf optical properties, leaf area index (LAI), and leaf

inclination angle distribution (LAD). The R^2, RMSE, and bias between the CANOP-simulated and the measurement data are 0.97, 0.027, and 0.011, respectively. Integrated with the leaf spectral model GSV-L and soil reflectance model GSV, the CANOP model significantly reduces the number of input leaf and soil parameters. The CANOP model can be used for the inversion of canopy structural parameters.

THE METHODS FOR THE RETRIEVAL OF LAND SURFACE TEMPERATURE IN CENTRAL SHIJIAZHUANG USING ASTER DATA

Guo-fei Shang, Biao Zeng, Xia Zhang*, Ye-lin Shen, Yu-jia Tian, Zheng-hong Yan
Hebei International Joint Research Center for Remote Sensing of Agricultural Drought Monitoring, Hebei GEO University, Shijiazhuang, 050031, China
****Corresponding author:** Xia Zhang* ***Tel./Fax:** 0311-87207648*
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Land Surface Temperature (LST) is an important parameter in the Earth's energy exchange and water cycle processes, with significant implications in climate change, drought monitoring, agricultural ecology, landscape ecological evaluations, and environmental planning. Various LST inversion algorithms have been proposed based on the five thermal infrared bands of the ASTER sensor on the TERRA satellite, but comparative studies of these algorithms have not been reported. This study focuses on the central Shijiazhuang city in China and uses three retrieval algorithms (including the reference channel method, split-window algorithm, and temperature-emissivity separation algorithm) to invert the LST in the research area. The results shows that, firstly, from the perspective of spatial distribution characteristics, the overall trends of the inversion results from the three algorithms are relatively close, with all inversion results falling within the range of 274K-310K. However, at the sample point scale, the inversion results of different algorithms show differences at each point. The results from the reference channel method and the temperature-emissivity separation algorithm are relatively close, with similar mean temperatures at 293.18K and 293.15K respectively. In contrast, the split-window algorithm shows lower temperatures for the low-temperature part at 274.27K and higher temperatures for the high-temperature part at 308.10K. Secondly, comparisons of the average statistical temperatures of the LST inversion results with the average atmospheric temperature in Shijiazhuang on the day of image acquisition (23℃) show that the average statistical temperatures of the inversion results for the reference channel method, split-window algorithm, and temperature-emissivity separation algorithm are 20.03℃, 19.82℃, and 19.82℃ respectively. The differences between the inversion results and the measured meteorological temperatures range from 2.97℃ to 3.18℃, indicating that the inversion accuracy is generally satisfactory. Lastly, compared with the MODIS LST products, all three algorithms yield higher values, while they are lower when compares with the Landsat single-window algorithm results. This discrepancy can be attributed to inherent errors in both MODIS LST products and Landsat data. The correlation analysis of land surface temperature with MODIS land temperature products shows that the three algorithms are moderately to highly correlated with the MODIS land temperature products, with R-squared values of 0.7174, 0.7163, and 0.7226, respectively. Among them, the temperature-emissivity separation algorithm exhibits the highest correlation coefficient with the retrieved results, while the results from the reference channel method and split window algorithm are slightly less favorable. A comparison with Landsat data retrieval results also yields similar outcomes. Although the overall correlation is relatively poor, the temperature-emissivity separation algorithm demonstrates the highest accuracy compared to the others, making it more suitable for retrieving land surface temperature in the study area.

COPERNICUS GLOBAL LAND VEGETATION BIOPHYSICAL VARIABLES FROM PROBA-V AND SENTINEL-3/OLCI

A. Verger[1,2]*, M. Weiss[3], J. Sánchez-Zapero[4], E. Martínez-Sánchez[4], A. Descals[2], F. Camacho[4], F. Baret[3], R. Lacaze[5], R. Van der Goten[6], M. Moroz[6]

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[4] EOLAB, Savina 8 A4, 46980 Paterna, València, Spain

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[6] VITO, Boeretang 200, 2400 Mol, Belgium

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The Copernicus Global Land Service (CGLS) provides continuously a set of bio-geophysical variables describing the dynamics of vegetation, the energy budget, the water cycle and the cryosphere. The service ensures near-real time production and delivery of consistent long-term time series of global bio-geophysical variables. The CGLS portfolio includes the leaf area index (LAI), the fraction of PAR absorbed by vegetation (FAPAR) and the cover fraction of vegetation (FCOVER) products which are derived every 10 days at 300 m (Collection 300m) resolution. The products are delivered with associated uncertainties and quality indicators. The products are available at the GCLS portal (http://land.copernicus.eu/global/), along with documentation describing the retrieval methodology, the technical properties of products, and the quality of variables based on the results of validation exercises.

The Collection 300m of LAI, FAPAR and FCOVER products is available from 2014 with PROBA-V and from 2020 with Sentinel-3. Satellite observations of surface reflectance are first transformed into biophysical variables using machine learning techniques. The instantaneous estimates are then composited every 10-day using a specific smoothing temporal filtering which allows near real time estimation.

This paper focus on the retrieval algorithm used to generate CGLS Collection 300m of LAI, FAPAR and FCOVER products, and the validation results for the comparison with other existing satellite products, the direct evaluation with ground measurements, and the temporal consistency of PROBA-V and Sentinel-3 time series.

QUANTITATIVE ANALYSIS OF THE IMPACT OF CLOUD RADIATIVE EFFECT ON THE RETRIEVAL OF DOWNWELLING SURFACE LONGWAVE RADIATION FOR ADJACENT CLEAR-SKY PIXELS

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The exchange of downwelling surface longwave radiation (DSLR) between the Earth's surface and

the atmosphere is an essential process in the Earth's energy balance, influencing the distribution of temperature and climate change on Earth. However, the cloud radiative effect (CRE) , a crucial component in the energy balance of the earth-atmosphere system, exerts a forcing effect on the DSLR retrieval for adjacent clear-sky pixels.. In this study, the contribution of CRE for clear-sky pixels were estimated by using the simulated data with considering the radiation effect of the entire cloud layers from the cloud base to top. Thus, based on the atmospheric point spread function (PSF), an analytical expression was developed to accurately quantify the contribution of CRE for adjacent clear-sky pixels. The ground-based measurements in the SURFRAD network are used to validate cloudy-sky DSLR estimation method . The results show that the bias and RMSE respectively are 5.27 W/m^2 and 28.48 W/m^2 via the ground-based measurements in the SURFRAD network. Additionally, the change ranges of CRE from 96.93 W/m^2 to 129.53 W/m^2 for water clouds, and from 40.45 W/m^2 to 68.31 W/m^2 for ice clouds. The maximum contribution of CRE in DSLR can reach up to 30% under the certain conditions. The contribution of CRE in the 11×11 pixels around the cloud was quantified, the results show that variation of CRE varying from 0.0366 W/m^2 to 4.0210 W/m^2 for water clouds, and varing from 0.0114 W/m^2 to 2.1205 W/m^2 for ice clouds. The intensity of CRE intensifies as its proximity to the cloud pixel increases, while it notably diminishes when the clear-sky pixel is further away from the cloud pixel. These findings show that the influence of clouds is crucial and cannot be ignored in the retrieval of DSLR, as their presence significantly affects the accuracy of such measurements.

VALIDATION AND ANALYSIS OF THE ACCURACY AMONG MULTIPLE VERSIONS OF MODIS LST PRODUCTS

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The Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (LST) products serve as crucial data sources for global and regional-scale climate change studies. At present, the MODIS LST product has undergone different versions including Collection 4 (C4), Collection 5 (C5), Collection 6 (C6), and Collection 6.1 (C6.1), while inversion algorithms have expanded from the initial Generalized Split-Window (GSW) algorithm to include methods such as the Day/Night algorithm and the Temperature Emissivity Separation (TES) algorithm. LST products from different versions and algorithms may exhibit significant differences in accuracy under different applicable conditions. Therefore, this study evaluates the accuracy of four different versions of MODIS LST products in the northwestern region of China, namely MxD11A1 C5, C6, C6.1 using the GSW algorithm, and MxD21A1 C6.1 using the TES algorithm, to explore the accuracy and applicability of different products. The evaluation is conducted through cross-validation and temperature-based validation methods. Ground measurement data collected from 13 surface sites in the Heihe Watershed Allied Telemetry Experimental Research (HiWATER) during the period of 2013 to 2018. The cross-validation results indicate that compared to C6, C5 exhibits a temperature difference of -0.41 K, while the average temperature difference between C6 and C6.1 is 0.02 K. Moreover, the temperature difference between MOD21 and C6.1 is greater at night (2.01 K) than during the day (0.30 K). The temperature-based validation results reveal that during the day, the average bias (BIAS) for C5, C6, C6.1, and MOD21 is 1.19 K, 0.94 K, 0.93 K, and 2.38 K, respectively, with the root mean square error (RMSE) for C5, C6, and C6.1 all exceeding 2 K, and MOD21 RMSE reaching 3 K. At night, the average BIAS for C5, C6, C6.1, and MOD21 is -1.13 K, -0.90 K, -0.88 K, and 0.10 K, respectively, with RMSE all around 1.5 K.

The BIAS and RMSE of MYD11/21 and MOD11/21 differ by no more than 0.3 K. The accuracy of C6 and C6.1 is higher than that of C5, especially in the bare soil, the BIAS has halved, and the accuracy has improved from 2.06 K to 1.06 K. C6 and C6.1 exhibit better accuracy during the day compared to MOD21, with a noticeable average BIAS difference of 2 K at bare soil sites. During the daytime, the average BIAS for C6 and C6.1 is 0.42 K and 0.39 K, while for MOD21 it is 3.0 K. During the nighttime, the average BIAS of C6 and C6.1 is -1.48 K and -1.46 K, while that of MOD21 is 0.17 K. MxD21A1 C6.1 may be significantly influenced by atmospheric conditions.

SENTHYMED/MEDOAK MULTI-SCALE EXPERIMENT TO VALIDATE SENTINEL-2 AND IMAGING SPECTROSCOPY VEGETATION PRODUCTS OVER FRENCH MEDITERRANEAN OAK FORESTS

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The SENTHYMED/MEDOAK experiment aims to collect a reference dataset on Mediterranean forests to validate satellite vegetation products. This includes products from Sentinel-2 and from current and upcoming hyperspectral satellite missions. The main field data collection was performed over the growing season in 2021 and complemented by additional data collection in June 2023.

Two forests sites (Puéchabon and Pic Saint Loup, Hérault, France) were selected to encompass a large variety of canopy cover fractions and phenological variations of two endemic oak species in Mediterranean forests (evergreen: *Quercus ilex*, deciduous: *Quercus pubescens*). Seven collections were performed between April and October 2021 concomitantly to Sentinel-2 acquisitions, providing:

- overstory and understory compositions of thirteen selected forest plots,
- canopy plant area index measurements with Li-COR plant canopy analyzers,
- bi-directionnal reflectances of different types of understory, leaves, canopies and trunks from in situ ASD spectroradiometer measurements,
- soil moisture measurements with probes,
- in situ measurements with leaf-clip SPAD and DUALEX optical sensors,
- in lab directional-hemispherical reflectance and transmittance of leaves from an ASD spectroradiometer coupled with an integrating sphere, from which were derived leaf traits by inversion of the leaf radiative transfer model PROSPECT,

- in lab measurements of leaf water and dry water content from lab facilities.

Additional LiDAR UAV-borne acquisitions and hyperspectral airborne acquisitions operated by NASA and ESA at 1 m and 3 m spatial resolutions were performed in June 2021. Hyperspectral satellite images were also acquired over the sites by DESIS and PRISMA sensors during the 2021 period.

These datasets were acquired to prepare future hyperspectral missions, including BIODIVERSITY (CNES), Surface Biology and Geology (NASA-SBG) and Copernicus Hyperspectral Imaging Mission for the Environment (ESA-CHIME). Targeted applications include mapping and monitoring of species traits (among the remote sensing essential biodiversity variables), fire risk assessment, species classification, forest 3D modelling and multi-sensor fusion. The collected multi-scale (from leaf to canopy), multi-temporal (monthly revisit) and multi-platform (in lab, in situ, UAV, airborne, satellite) datasets aim at contributing to better understand Mediterranean forest conditions in the context of climate change, increasing droughts and land use change.

LAND SURFACE TEMPERATURE RETRIEVAL FROM SDGSAT-1 THERMAL INFRARED SPECTROMETER DATA

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Land surface temperature (LST) serves as a crucial indicator of the thermal state and environmental changes on the Earth's surface, and it can be retrieved effectively from satellite thermal infrared sensors. Although algorithms for retrieving LSTs have been developed successfully for many satellites, the newly launched SDGSAT-1 satellite, which includes three thermal infrared bands, does not yet include effective LST algorithms and parameters. The temporal and spatial resolutions indicate that the SDGSAT-1 satellite has significant advantages and application prospects for use in obtaining LST products. Here, parameters are calibrated for retrieving LSTs from SDGSAT-1 TIS data for the split-window (SW) method and the three-channel (TC) method under both daytime and nighttime conditions. In this process, the Thermodynamic Initial Guess Retrieval (TIGR) dataset and observation data from the University of Wyoming were used. In addition, LSE data are needed. By calculating the LSE of typical landcover types in the ASTER spectral library, we determined the relationship between the LSE of the SDGSAT-1 and ASTER thermal infrared bands through least squares fitting. This process enabled us to calculate the LSEs of SDGSAT-1 TIS bands using the latest ASTER-GED emissivity products.

Validations were conducted using in situ LST measurements at the Guantao, Turpan, and Heihe sites in China and from the SURFRAD solar radiation observation network in North America, covering cropland, desert and bare land, and grassland. The overall accuracies of the models are fairly good, with RMSEs of 2.507 K and 2.272 K for split-window method during daytime and nighttime respectively, and 2.847 K and 1.923 K for three-channel method. Additionally, the LST retrieval models that use observation data from the University of Wyoming had higher accuracy than those using the TIGR2000 profiles. Currently, the proposed models can be applied under different atmospheric water vapor contents and underlying surface conditions both during the day and at night, paving the way for retrieving LST products from SDGSAT-1. Overall, we developed accurate and robust methods for LST retrieval from SDGSAT-1 data, contributing key capabilities for thermal remote sensing applications.

A TWO-STEP APPROACH FOR FIELD SCALE DIURNAL LAND SURFACE TEMPERATURE ESTIMATION FROM GEOSTATIONARY OBSERVATIONS

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The diurnal variation of Land Surface Temperature (LST) is a vital indicator to understand the dynamics of the energy and water exchange between land and atmosphere and is needed for several applications. Thermal infrared (TIR) sensors onboard geostationary orbits can characterize this diurnal variability of LST with high frequency observations; however, at the expense of spatial resolution. This severely hampers the applications that require high spatiotemporal LST. In this study, we aim to model the diurnal temperature cycle (DTC) at field scale (~100 m resolution) with a new two-step disaggregation approach using geostationary (~5 km) and medium-scale (~1 km) LST observations.

In the first step, LST was downscaled from geostationary scale to medium scale using a Principal Component Regression (PCR) technique incorporating twenty four auxiliary variables. Subsequently, the diurnal variation of LST was modelled using the GOT-01 DTC model from these downscaled medium-resolution images. In this second stage, the GOT-01 model parameters that characterizes the DTC at 1 km spatial resolution are downscaled to 100 m, using a Support Vector Machine (SVM)-regression chain model leading to the estimation of these DTC parameters at 100 m pixel size. This effectively enables us to estimate LST at various time instances within a day at the field scale.

This approach was tested over a heterogenous region in the state of Maharashtra, India using Copernicus global hourly LST product (for geostationary observations), MODIS and VIIRS LST and other ancillary datasets from ERA-5 reanalysis, Landsat and Sentinel-2 satellites. The results were compared to that from a direct PCR disaggregation approach by directly downscaling geostationary LST from 5 km to 100 m, incorporating the same auxiliary variables used in two step process. LST from a four-component net radiometer installed in a vineyard within the study area was used as reference to compare the downscaled LST. The two-step approach captured the DTC at field scale with an RMSE of 2.06 K and R^2 of 0.98 while the direct PCR approach captured the DTC with a RMSE of 2.19 K and R^2 of 0.98. Though the accuracy obtained by both the methods are similar, the two-step approach allows for a more gradual transition from coarse to finer scales which accounted for improved spatial distribution leading to a better estimation of LST at finer scales.

ESTIMATING LANDSAT SCALE DAY-NIGHT LAND SURFACE TEMPERATURE OVER INDIA USING MACHINE LEARNING

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Obtaining Land Surface Temperature (LST) data with high spatiotemporal resolution remains a challenging task due to the trade-off between spatial and temporal resolutions of the thermal infrared (TIR) sensors. Multiple algorithms have emerged for LST downscaling adopting various techniques such as simple regression, data fusion, machine learning (ML) and hybrid methods. While statistical regression methods, such as the Disaggregation of Radiometric Temperature (DisTrad) and its variants exhibit simplicity and good accuracy, they often struggle over complex landscapes. Similarly, methods based on spatiotemporal

data fusion such as the Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM) and its enhanced version, ESTARFM require both high and low spatial resolution LST image pairs within a reasonable time for better results, limiting their applicability in regions like India with extended cloud cover during the monsoon season. ML based methods have emerged as promising alternatives for LST downscaling, leveraging their capacity to capture complex nonlinear relationships, operate quickly, and achieve higher accuracies. However, existing ML models have predominantly focused on downscaling MODIS Terra daytime LST, neglecting the MODIS day-night Aqua & Terra night time LST downscaling which are crucial for modelling the diurnal temperature cycle. This study addresses these gaps by employing ML algorithms to downscale MODIS satellite LST data from 1000 m to 100 m resolution. Three ML models, Random Forest (RF), Artificial Neural Networks (ANN), and Residual Network (ResNet50) were trained using MODIS Terra and Landsat LST data, alongside auxiliary variables such as vegetation indices, urban metrics, water indices, elevation, and day of year. Unlike fusion-based models requiring reference images, our trained models solely rely on coarse resolution MODIS LST and auxiliary variables to generate downscaled LST. Furthermore, we extended our analysis beyond MODIS daytime Terra LST downscaling, exploring the downscaling of MODIS Terra and Aqua daynight LST and evaluating model predictions against twelve different ground in-situ LST observations. These locations have diverse landcover and are equipped with four component net radiometers, for estimating in-situ LST. Currently, we have evaluated daytime MODIS Terra and Aqua downscaled LST and are still working on the evaluation of night time downscaled LST. Our model performance evaluation yielded promising results for ANN, ResNet, and RF models, with RMSE values of 2.37 K, 2.52 K, and 2.44 K, respectively, accompanied by R2 values of 0.90, 0.91, and 0.89 for daytime Terra LST. Similarly, for daytime Aqua LST, the RMSE values are 2.64 K, 2.51K, and 2.73 K, with corresponding R2 values of 0.90, 0.94, and 0.91 when validated against in-situ LST observations. Moreover, all models demonstrated a structural similarity index (SSIM) exceeding 0.75 when comparing daytime Terra downscaled LST with Landsat LST, highlighting their effectiveness in preserving the spatial information.

EARTH SURFACE TEMPERATURE FROM MODIS DATA OVER THE PERIOD 2003–2023

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The global Earth surface temperature (EST) for the period from 2003 to 2023 was derived from MODIS products. MOD11C2 (MYD11C2) V061, an upgraded version of V006, has been added to the research, as the old version has stopped serving since November, 2022. The results show that both Land Surface Temperature (LST) and Earth Surface Temperature (EST) from V061 are slightly higher than those of V006, especially noticeable from 2016 to 2023. The overall trends of EST from V006 and V061 products are similar: global EST trends from V006 and V061 products are 0.021 ± 0.004°C/yr. and 0.025 ± 0.004°C/yr., respectively, compared to the NOAA's National Climatic Data Center (NOAA-NCDC) temperature anomalies trend of 0.024 ± 0.003°C/yr. Regionally, the northern hemisphere experiences faster warming than the southern hemisphere, and land warms more rapidly than ocean. Furthermore, the rapid growth rate of EST in the northern temperate zone (66.5°N - 23.5°N) is noteworthy. Finally, linear regression and Sen's slope methods were employed to generate trend maps of EST, the Mann-Kendall test was carried out on the results.

INVESTIGATION OF LAND SURFACE TEMPERATURE RETRIEVAL FOR NOVEL SPACEBORNE SENSORS USING A TIR SIMULATOR

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Land Surface Temperature (LST) is a key variable in several Earth science and remote sensing applications as is required for the modelling of energy fluxes at the boundary between the Earth's surface and atmosphere. This work focuses on the use of LST specifically in agricultural applications, due to their relevance in tackling global challenges related to climate change, e.g., food security and the use of water resources. For this type of applications, a daily coverage on large scale but with high spatial resolution, and finally a high accuracy of the LST data is necessary.

Current spaceborne TIR sensors are not able to meet the requirements in terms of temporal revisit and spatial resolution. To fill this gap, several institutions and companies are preparing new missions with novel spaceborne TIR instruments suitable for agricultural applications, for instance with the upcoming TRISHNA and LSTM missions, but also in the commercial sector with NewSpace startups planning TIR constellations.

At OHB System AG, to support the system requirements definition in the development of a thermal sensor for NewSpace costumers, an in-house generic end-to-end simulator is used. The simulator can be parametrized for a broad range of instrument specifications, allowing an instant analysis of the effect of instrument and mission design changes on LST retrieval. In the scope of this work, it was extended with a scene generator for thermal images and a L2 processor for LST.

With the given simulation framework, an investigation was conducted to find out (1) which accuracy of LST from spaceborne measurements can be achieved with different sensor setups (e.g., number of bands, band positions, band widths); (2) which accuracy of LST from spaceborne measurements can be achieved with different LST retrieval methods (split-window (SW) method vs. temperature emissivity separation (TES)); and (3) how is the LST retrieval accuracy affected by the scene properties (i.e., atmospheric conditions and surface properties). Hereby we focussed on the observation conditions, i.e., surface properties and atmospheric conditions, that are likely to be encountered when observing rural scenes in temperate climates as typical for agricultural areas within Europe. A set of multispectral TIR instrument designs was compared to the instrument setups of LSTM and TRISHNA as well as to a theoretical hyperspectral thermal design to verify whether the performance was comparable and to explore the possibility of combining the data of the different sensors.

The results were overall compliant with the requirements of agricultural applications in terms of the LST accuracy lying within an acceptable range (1.5 K) for all considered designs. Based on the outcome for specific cases of sensor setups, retrieval methods, and observed scenes, limitations and trade-offs among the analysed scenarios were identified and several indications could be provided for the optimization of the LST retrieval. The observed trends varied depending on the applied algorithm: when using TES, the main driver was the position of the bands in the 8.4 – 9.2 μm window, while for SW the relative band position and bandwidth in the 10 – 12 μm range.

VALENSAT PROJECT

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The European Union and the Generalitat Valenciana co-financed the project "Estimación de Indicadores Medioambientales en la Comunidad Valenciana usando datos de Satélite (VALENSAT)," as part of the INVESTIGO 2022 financing plan. The project aims to create a user-friendly website offering free accessible Remote Sensing products to Valencian Community citizens. Landsat, Sentinel, MODIS and METEOSAT images are used to generate products covering a wide range of applications, including monitoring the Urban Heat Island effect, calculating vegetation indices, estimating fire intensity, and assessing water quality. Each product on the website features a detailed section that explains its functionality, applications, and key features. Utilizing Google Earth Engine, interactive apps have been developed to allow users to customize the calculation of specific parameters of interest. Users can download these products tailored to their needs, complemented by practical application examples and proper literature. This initiative ensures real-time access to valuable information, empowering informed decision-making and fostering a deeper understanding of Earth changes within the Valencian Community.

A STATISTICAL SPLIT WINDOW METHOD WITHOUT ATMOSPHERIC PROFILE INPUT FOR TEMPERATURE AND EMISSIVITY RETRIEVAL FROM AIRBORNE LONG-WAVELENGTH INFRARED HYPERSPECTRAL IMAGERY

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The retrieval of land surface temperature (LST) and emissivity (LSE) can be unattainable from long-wavelength termal infrared (LWIR) hyperspectral data because of the uncertainty of atmospheric compensation (AC). Typically, AC conducted by the atmospheric radiance model is widely applied, but inaccurate atmospheric profile input leads to great errors. In this study, we proposed an end-to-end method without local atmospheric profile input for the retrieval of LST and LSE. The method includes two parts: first, a statistical split window (SSW) method is applied to obtain the ground leaving radiance, and the best channel configuration and its coefficients are obtained by trial-and-error experiment and statistical regression on the simulation dataset. Second, by combining the ASTER Temperature And Emissivity Separation (ASTERTES) method and the atmospheric downwelling lookup table (LUT), the optimal LST and LSE can be calculated based on the principle of emissivity smoothness. The proposed method is applied to airborne data from Hyper-cam LWIR hyperspectral imagery. Compared with MODTRAN-based AC with ASTER-TES (MODTRAN-TES) and end-to-end method of FLAASH-IR, a superior LST root mean square error (RMSE) of 1.24 °C and LSE RMSE of 0.016 are obtained for the proposed method.

ANALYSING SEASONAL EFFECTS ON SIF THROUGH ATMOSPHERICALLY CORRECTED BAND SHAPE FITTING ALGORITHM IN DOUGLAS FIR FORESTS

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Forests provide habitats and help keep the climate stable by absorbing carbon dioxide, releasing oxygen, improving the air quality, and regulating the water supply. Deforestation and climate change have significantly impacted the world's forest resources, and are predicted to continue to affect the structure and variety of forests. Remote sensing can serve as a tool for understanding and monitoring the impact of changing climate on the forest. Solar-induced chlorophyll fluorescence (SIF) is a low-intensity near-infrared radiation emitted by tree leaves and needles to dissipate excess absorbed light. SIF is an emerging tool for the study of photosynthesis, as it has been shown to reflect vegetation state more quickly than vegetation indices (VI). This has resulted in a better and closer indicator of the vegetation state and global carbon cycle.

The aim of the study was to compare the atmospherically corrected SIF retrievals at the beginning and end of the season of the evergreen Douglas fir forest. The band shape fitting (BSF) algorithm (van der Tol et al., 2021) was used to obtain the atmospherically corrected SIF. The obtained SIF was compared with the SIF obtained from the standard improvised Fraunhofer's Lines Discrimination (iFLD). The SIF recovered from different methods in O2A, and O2B bands were compared with photosynthetically active radiation (PAR) to understand the behaviour of SIF with the progression of light and diurnal vegetation properties. It was found that the differences between atmospherically corrected SIF values obtained using the BSF algorithm and those retrieved through the iFLD method were minimal.The study showed a significant correlation between Photosynthetically Active Radiation (PAR) and both the BSF and iFLD methods. Furthermore, a strong association was observed between BSF and iFLD in both the O2A and O2B bands, with an RMSE of 0.02 and 0.11, respectively, and an R2 value of 0.96 for both. The análisis also showed that the atmospheric correction did not have a significant effect on the retrieval of the SIF from the BSF method.

We looked at how the start (April-May) and end (September-October) of the season affect the measurement of SIF. We found that in the evergreen douglas fir forest, the SIF measurements are lower at the start of the season and higher at the end. Specifically, the increase was 39.26% in O2A and 72.34% in O2B for BSF, and 38.40% in O2A and 64.65% in O2B for iFLD method. Overall, the atmospherically corrected SIF was similar to the SIF obtained from the iFLD.

INTERCOMPARISONS OF COPERNICUS SENTINEL 3 DERIVED SYNERGY SURFACE DIRECTIONAL REFLECTANCE PRODUCTS – FIRST RESULTS UNDER ROUTINE SERVICE EVALUATION

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Surface reflectance observations from satellites are important for the derivation of several level 2 (L2) land, products like vegetation indices and biophysical products. The current study focusses on the evaluation of Surface Directional Reflectances (SDR) from the Copernicus Sentinel-3 (S3) SYNERGY (SYN) measurements provided in the SYN L2 classic product. SYN L2 has a high repeat coverage of 1-2 days at a medium spatial resolution of 300 m. Its quality is assessed in the framework of the Optical Mission Performance Cluster (OPT-MPC), a Copernicus service contract managed by the European Space Agency (ESA) and led by ACRI-ST. Due to lack of reference in-situ data at similar spatial resolution, this is achieved by comparison with similar surface reflectance (SR) products observed from MODIS and VIIRS. To achieve reliable cross-mission SDR intercomparisons, some preliminary corrections are needed to account for differences in acquisition geometry (i.e. directional effects) and in spectral response functions of each sensor.

Firstly, directional effects are corrected, using the Ross-Thick Li-Sparse BRDF as provided in the BRDF kernel products, MCD43A1 (when comparing to MODIS) and VNP43MA1 (when comparing to VIIRS). The BRDF corrected SYN SDR products are compared against the nadir adjusted normalized reflectance's from MODIS and VIIRS respectively.

Secondly, the differences due to the spectral response functions of sensor spectral bands are corrected using spectral band adjustment factors (SBAF's), as a function of the observed Normalized Differential Vegetation Index (NDVI). These factors are derived from the ECOSTRESS high resolution spectral library (NASA, JPL). This spectral data is known to represent a variety of surface classes including several vegetation and soil spectra, covering a wide spectral domain, from the visible to the shortwave infrared (SWIR).

A hyperspectral database at sensor spectral resolution is simulated by convolution of the high-ECOSTRESS high-resolution spectra with a set of gaussian instrument spectral response functions of 10 nm FWHM (full-width at half-maximum) sampled every 10 nm from 0.4 to 2.5 µm. Then, random combinations (up to 5000) of vegetation and bare soil hyperspectral data are generated and mapped against NDVI. Then, for each pair of SYN SDR / MODIS, SYN SDR / VIIRS instrument channels, mathematical models were derived from the relationship between spectral band ratios of one sensor to the other (Otherwise, SBAF), with the reference NDVI. This mathematical model is used to adjust the SR of reference sensor spectral bands with respect to SYN reflectance, and the impact of such correction is studied. The statistics of overall evaluation are assessed in terms of Accuracy (A), Precision (P) and Uncertainty (U). From the study, SYN SDR, observed from both S3A/S3B, showed a good temporal stability with respect to SR observations from MODIS and VIIRS, extracted over several land product validation sites, during the study period (2022 – 2023). The presentation will detail the entire methodology, as well as discuss the results of inter-comparisons in detail. For future perspective, the ideas to use independent reference SR measurements, from GROSAT and HYPERNET's, for the evaluation of SYN SDR are envisaged.

A NOVEL APPROACH TO STUDY THE INTERCLOUD TRANSITION ZONE COMBINING ALL-SKY IMAGERY AND HYPERSPECTRAL DECOMPOSITION METHOD

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Nowadays, properly calibrated all-sky imagers are considered powerful instruments for aerosol and cloud research, thanks to their large field of view that allows to observe the whole sky dome. However, they have spectral limitations since only three broadband RGB channels are used. Therefore, the aim of this work is to find a sound methodology to obtain the pixelwise hyperspectral signal in the visible spectral range (400-700 nm) from the RGB measurements provided by an all-sky camera. Finally, we use this hyperspectral decomposition to study the intercloud zone. It is defined as the transition region of the sky between cloud and aerosol domain where the hydrophilic particle suspended in the atmosphere grow toward the cloud due to water accumulation. Moreover, this intercloud region may have a radiative behaviour significantly different from clouds and clear-sky and it is mostly important in in partially cloud scenarios. To decompose RGB images into hyperspectral radiance we use a methodology that separates into two components the final hyperspectral signal: a component is derived from the inversion of the sensitivity matrix of the camera, and a second component belong to the vector space kernel of the sensitivity matrix. The second component is derived using a TWST spectrometer in the visible range with 1 nm step. An artificial neural network was involved to relate RGB signal to spectrometer vector kernel. Finally, we can sum the two hyperspectral components to obtain the hyperspectral signal in each pixel of the original RB image. We initially assume that this spectral decomposition procedure may be applied in every pixel of the image, even if the different observing geometry. We apply the hyperspectral decomposition methodology to RGB images in partially cloud scenarios to study the intercloud zone. Given an image, we take different segments which cross perpendicularly the cloud boundaries from a clear cloud pixel to a clear cloud-free pixel. Then, we derive the spectral radiance at different pixels along this segment normalized to the spectral radiance at the cloud-free pixel. We find that the normalized radiance follows a linear behaviour in all the points of the intercloud region that results in a spectrally invariant. On the opposite, this linear behaviour is not observed neither, in the cloudy or cloud-free pixels. Our results indicate that the normalized radiance is spectrally invariant in the intercloud region which agrees with what other authors observed in the temporal domain, only using observations at a fixed zenith-looking geometry. In addition, we can also conclude that the procedure to obtain hyperspectral images is sound independently of the geometry since the linear is observed whatever the position of the transition zone is in the image. The main advantage of our methodology is increasing the spectral contrast with respect to what we can obtain just from the broadband RGB channels. Moreover, it also allows assess the spectral invariant of the normalized radiance in the intercloud zone, that would be restricted to three points in the RGB case.

GROUND BASED OBSERVATIONS OF ANGULAR BRIGHTNESS TEMPERATURES OVER CROPS

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Thermal data, especially Land Surface Temperature (LST), is critical in environmental and climate studies. LST is crucial for modelling surface energy balance and assessing agricultural droughts, ecological dynamics, and urban heat islands. Its strong connection to the radiative properties and heat fluxes of the Earth's surface provides essential insights into climatic patterns and surface-atmosphere interactions. Precise acquisition and modelling of LST, therefore, are essential for a deeper understanding of these complex systems.

Directional effects in brightness temperature measurements arise from the varying emitted radiation of objects under different thermal conditions and observation geometries. In vegetated areas, for example, these effects are largely governed by the ratio of sunlit to shaded canopy and soil contributions and their respective temperatures, complicating the interpretation of thermal data. To address these angular variations, models that aim to replicate the directional signal have been developed. These range from simple linear kernel models, derived from basic interpretations of the radiative transfer equation (RTE) to more sophisticated models like turbid medium approximations and 3D raytracing models. These models, offering detailed scene descriptions with minimal RTE simplifications, allow for realistic representations of directional effects. The accuracy of all these types of models must be evaluated against established references, to understand their limitations and practical applicability.

Our contribution presents the deployment of a ground-based thermal goniometer system on agricultural targets, examining both fully covered and row-spaced canopies at different growth stages. We observed pronounced directionality influenced by illumination and viewing angles, as well as development stage and row orientation. The study evaluates the effectiveness of different kernel linear models against these ground-based measurements and discusses the practical applications of the models. Additionally, the performance of a 1D turbid medium radiative transfer model, considering both continuous and row-structured canopies, is analysed in relation to these measurements.

MULTI-RESOLUTION ANALYSIS OF URBAN MORPHOLOGICAL AND SPECTRAL DATA AND THEIR RELATIONSHIPS WITH THE LAND SURFACE TEMPERATURE IN TWO EUROPEAN CITIES

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Climate change is affecting global temperatures leading to more frequent and intense heatwaves, particularly pronounced in urban areas due to the Urban Heat Island (UHI) effect. These high temperatures can increase the population's vulnerability to heat. Therefore, it is essential to monitor intr-urban temperatures at a scale that facilitates the differentiation of urban elements like buildings and streets to better integrate heat mitigation and adaptation strategies.

Thanks to thermal remote sensors, Land Surface Temperature (LST) can be retrieved and used to assess these heat impacts. However, current satellite observations lack the fine spatial resolution required for detailed urban analysis. Forthcoming satellite missions like TRISHNA, SBG, LSTM and Landsat Next will provide thermal infrared data with a spatial resolution of ∼ 60 meters. Such resolution is recognized as too coarse for urban roughness.

Super-resolution techniques are often applied to such coarse data, fusing them with higher resolution data to improve their original resolution. For LST super-resolution (LSTSR), these methods use fine images acquired in the visible to shortwave infrared (VNIR/SWIR) spectral range to enhance the coarse thermal image spatial resolution. Traditional super-resolution approaches, such as DisTrad [1], HUTS [2] or (A)ATPRK [3], hypothesize that empirical relationships are scale invariant and uniformly applied on the observed scene. The linear relation between NDVI, a vegetation spectral index, and LST have been extensively applied for instance [1]. Moreover, these methods are less efficient in zones of high thermal contrast caused by the morphological aspects of urban areas as they could introduce a blurring effect, smooth out LST extreme values or introduce spatial artefacts [4].

In this study, we show that scale and space invariance hypotheses are too restrictive to be used in urban scenes.

Thanks to a multiscale approach, we explore the spatially varying relationships between spectral and morphological variables with respect to LST in urban areas. We use high-resolution thermal and reflective multispectral datasets (≤ 10 m) from airborne campaigns over Toulouse [5] and Madrid [6] to compute our spectal indices. To observe the spatial non stationarity of the relationships between spectral variables and LST, we also include morphological indices (semantic and 3D information obtained from Pleiades data) describing the observed urban environment. First, a detailed feature selection using Pearson's coefficient and Principal Component análisis (PCA) is performed to remove highly correlated indices from our set of predictors. After selecting driving factors in each spatial resolution, we use classical regression methods to model the relationships between selected variables and LST at different spatial scales. We also model these relationships within different Local Climate Zones (LCZ), which define spatial zones that exhibit similar structural patterns [7]. These different statistical approaches provide results on how the scale and spatial invariance hypotheses hold between different spatial locations and scales.

A first illustration of scale invariance is shown in Figure 1 where correlations between NDVI and the building coverage ratio, a morphological index, with respect to LST evolve over multiple scale resolutions. We will provide further results on varying relationships as the scale changes considering their behavior differences between different LCZs.

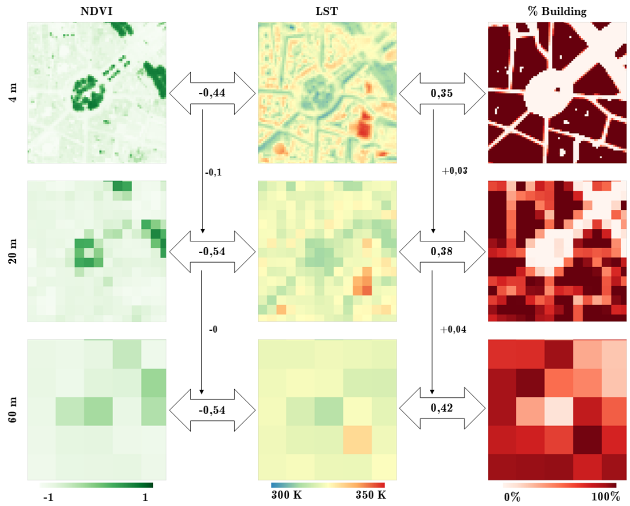

Figure 1: Correlation differences between a spectral and a morphological index with respect to LST at different spatial resolutions. Values within double arrows are Spearman's coefficient values, those aside are the difference of these values when the spatial resolution changes.

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LAND SURFACE TEMPERATURE RETRIEVAL FROM THE SYNERGY OF PASSIVE MICROWAVE, AND OPTICAL OBSERVATIONS

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Accurate monitoring of Earth's surface temperature through satellite-derived information supports the understanding of many of our planet's ecosystems, including physical processes that govern the three major cycles: carbon, energy and water. In view of increasing extreme temperature events, the need for accurate, continuous and consistent temperature monitoring has never been more important for improved resources management. The Land Surface Temperature (LST) undergoes rapid fluctuations on both a daily and diurnal basis, emphasizing the need for timely and consistent information delivery to enhance user experience. LST can be retrieved at high spatial resolution from spaceborne thermal infrared (TIR) instruments, like Landsat, ECOSTRESS, and ASTER. But these data come with large temporal gaps due to cloud cover and orbit/sensor characteristics and consequently complicate analysis.

Passive-microwave data provides a complementary solution to TIR-based data for retrieving LST globally (an essential property of microwave data is the reduced sensitivity to cloud cover). In many studies, the Ka (37Ghz) band has been used as the most appropriate frequency to retrieve LST[1] because it balances a reduced sensitivity to soil surface characteristics with a high atmospheric transmissivity. While passive-microwave LST is available in cloudy conditions, the spatial resolution is coarser and the accuracy is usually lower than the TIR-based LST. To overcome these limitations, we developed a daily 100m LST product based on the synergy between Ka-band passive microwave (AMSR2),
optical (Sentinel 2) using a disaggregation method[2].

The method uses the abundance of overlaps between passive microwave footprints in combination with higher spatial information from Sentinel-2 for downscaling at 100m resolution since 2017 at 1:30am and at 1:30pm. To assess the accuracy of this new LST product, high resolution thermal-based LST plays a major role to validate our methodology. On the one hand, we compared the time series of microwave-based LST at 200+ given locations against in situ measurements, and MODIS/Landsat LST data. Day and night observations are assessed separately. The challenge is to consider the mismatch of the measurement representativity (in terms of spatial resolution and overpass time). Currently, the accuracy is ±3K with a correlation of >0.9, and efforts are being made to provide a product with an accuracy similar to thermal-based LST. On the other hand, driven by the market interests, we performed a spatial comparison of our 100m LST data over agricultural regions against Landsat LST. While the few clear-sky Landsat LST observations is a limitation for the comparison, the preliminary results show a spatial accuracy between ±1.5K and ±4K across different land cover. Planet Labs can help bridge current and future missions for high-resolution LST. This presentation will introduce Planet Labs LST products and applications.

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MODELLING OF THE ANNUAL-DIURNAL LAND SURFACE TEMPERATURE DYNAMICS

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The annual and diurnal cycles of land surface temperature (LST) are driven to a large extent by solar geometry. These regular LST variations follow different time scales and can be modelled with two separate functions controlled by a small number of parameters, typically from three to six, which can be determined by fitting the respective model functions to time series of LST observations. Here we describe a new annual-diurnal temperature cycle (ADTC) model that combines an annual temperature cycle (ATC) model controlled by the solar zenith angle (ATCsza) with a four-parameter version of the diurnal temperature cycle (DTC) model GOT09. The ADTC model simultaneously describes the annual and diurnal surface temperature dynamics with only five controlling ADTC parameters, which all have physical meaning, i.e.

annual minimum temperature, annual temperature amplitude, annual maximum of daily temperature amplitude, mean time of thermal noon and time lag of maximum temperature with respect to summer solstice.

The model was fitted to the LST data (MOD11/MYD11 L2) retrieved in 2021 from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the EOS – TERRA and EOS – AQUA satellites. ADTC parameters for five globally representative MODIS tiles were obtained, i.e. h18v04, h17v05, h17v07, h21v08 and h19v11. The MODIS LST were randomly split into two datasets: a training dataset containing 80 % of datapoints and a test dataset with the remaining 20 % of datapoints. For the five tiles, the test dataset yielded a mean root mean square error (RMSE) of 4.2 K. Additionally, the modelled LSTs were evaluated against in-situ LST from Lake Constance, KIT Forest and Gobabeb stations, yielding a RMSE of 3.1, 4.0 and 2.8 K, respectively.

Finally, the spatial consistency of the ADTC parameters was investigated over five selected areas representing different land covers (i.e. urban, lake, forest, mountain area and desert). The results revealed a close link between the parameters and corresponding surface and climate properties, indicating that they provide useful information for LST analyses and climate studies and for further applications, e.g. land cover classification.

A SIMPLE STATISTICAL NEAREST NEIGHBOUR TEMPERATURE SHARPENING METHOD FOR DOWNSCALING SENTINEL-3 LAND SURFACE TEMPERATURE

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Land Surface Temperature (LST) is a fundamental variable in the physics of land surface-atmosphere interface and is directly linked to net radiation fluxes and evaporation estimation algorithms. Current Thermal Infrared (TIR) sensors onboard satellite provide daily LST data at relatively low round sampling distance (GSD) resolution, above 1 km, adequate for crop management of extensive fields. However, this cannot be applied to European agricultural fields, mostly with sizes below 100 m and high heterogeneity. Until the launch of future high resolution TIR missions, LST at higher spatial resolutions only can be determinated by the application of downscaling methods.

In this work, we propose the Nearest Neighbour Temperature Sharpening (NNTS) procedure to improve the GSD of LST. Method is based on simple statistial relation between LST, NDVI and normalized difference water index (NDWI), emphasizing the pixels with maximal and minimal NDVI values. In this way, method can achiev the maximal LST expansion or contrast for a retrieved high resolution image. NNTcs was applied to Sentinel-3 data in order to generate an image with the same GSD as Sentinel-2 (10 m) and retreivals were tested against airborne images collected during two intensive campaigns performed by ESA in Spain and Italy. Comparison shows a relative good results with a general root mean square error of aproximately 3 K.

YIELD MODELING FOR RICE AND WHEAT IN THE NILE DELTA USING SENTINEL-1 AND SENTINEL-2 DATA FUSION

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Climate change is a challenge for all sectors, but especially for agriculture. Risingtemperatures in Africa negatively affect agricultural production. In addition, the demand forfood is increasing, making it necessary to develop variables that describe agriculture, such as yield forecasts or phenology development stages of the different varieties cultivated. Remote sensing provides spatial and temporal continuous information that allow us to accurately assess the evolution of a particular field. In this way, EO Africa aims to the sustainable adoption of Earth Observation and related space technology in Africa. Our contribution to this project is to use Sentinel-2 optical data to analyse rice and wheat seasons between 2016-2022 in the Gharbia governorate (Egypt) where ground data were collected by the University of Tanta. We apply a yield model for each crop type, both trained in Spain, and study their transferability to this region. In the case of wheat, we also test a second model that aggregates SAR data from Sentinel-1, thus evaluating the fusión of both products. The integration of the accumulated Growing Degree Days (GDDaccum) is used since in Spain was the key to allow the transferability between regions. Wheat model using only S2 shows slightly better results, with R2 = 0.56 and RMSE = 0.2 t/ha, against R2 = 0.48 and RMSE = 0.4 t/ha on fusion model. However, fusion model has a slope of 1.08, being the model which least underestimates or overestimates. Rice shows less transferability with a bias of 1.9 t/ha and R2 = 0.3. Finally, we use crop type masks to evaluate the models at governorate level. At this scale, rice model presents a Good agreement despite the bias of 1.7 t/ha and the stability in reference yield values (less than 0.2 t/ha). Both wheat model overestimate, resulting in a 1.4 t/ha of RMSE. However, fusion model shows the highest correlation (R2 = 0.74) and the lowest sigma (0.24 t/ha).

CROP TYPE MAPPING OF WHEAT AND RICE IN EGYPT WITHIN THE EO AFRICA PROJECT

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Mapping crop types is vital for quantifying cultivated areas and supports agricultural statistics, land use analysis, and crop yield predictions. Our study focuses on creating accurate rice and wheat classification masks in Egypt’s Nile Delta, specifically in the Gharbia governorate, from 2018 to 2022, in the context of EO Africa initiative. Classification maps for both, rice and wheat seasons were developed using a Random Forest method. A set of ground truth points for each year, majorly of rice and wheat but also a few of onion, maize, clover, citrus and grape crops were filtered and completed analitically to be used as training and test data. To face this imbalance, Synthetic Minority Oversampling Technique (SMOTE) method was also applied, generating synthetic data of the non-interest crops. The proposed method to compose the masks consisted in extracting the spectral information of these points for all the selected cloud-masked Sentinel 2 images of the season. This information was stacked, obtaining several features equal to the number of bands per number of images of the season considered. This set was optimized through a PCA analysis, reducing the number of features to the 15-20 first components of the PCA. For each image, also different vegetation and water indices (NDVI, SAVI, RDVI, NDWI, AWEI, GNDVI, EVI) were computed and stacked to the previous set to conform the final features space, showing the best results compared with the use of only bands, or the application of PCA to the whole data (bands and indices). This process, was applied to each season, obtaining an accuracy between 0.90 and 0.95 and consistent commission and omission errors, meaning balanced estimations. From the final classification map, rice and wheat classes were extracted, obtaining preliminary masks. Finally, isolated pixels were removed, and possible detection holes were covered with the use of morphology techniques (opening and closing), obtaining final operational masks. These masks were used for

testing the implementation of a yield model at the field scale subsequently aggregated at the regional level, comparing the obtained results with official statistics of the Gharbia governorate.

TRISHNA, THE (ALMOST) PERFECT SATELLITE TO MONITOR ALBEDO ON LAND SURFACES

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The albedo is an essential climate variable (ECV) which is defined as the fraction of the downwelling irradiance reflected by a surface, in all wavelengths and directions. It is therefore a key element of the Earth energy budget. Knowing its instantaneous value is essential to estimate evapotranspiration, while knowing its average value over short periods of time (less than a month) is necessary for weather predictions but also, in the context of global warming, to study the effects of mitigation measures such as increasing the albedo of crops by keeping a vegetation cover all year or changing the color of building roofs. Estimating the albedo requires a good sampling of the solar spectrum, but also a good sampling of observation directions.

The TRISHNA satellite, which should be launched in 2026, is a collaboration between the Indian and French space agencies (ISRO and CNES). TRISHNA is seen as a precursor for the operational European Land Surface Temperature Mission (LSTM), with a first launch expected in 2029. A third satellite high resolution mission, SBG, should also be launched before 2030. Over lands, TRISHNA's main mission is to monitor the hydric stress of ecosystems by measuring global surface temperature at 60 m resolution every third day. To help interpret the thermal infrared measurements, TRISHNA also includes seven visible, near and short wave infrared spectral bands. Over an 8-day cycle, measurements will be obtained at least three times with three different viewing angles, and even more at higher latitudes (at least 4 above the whole Europe for instance)/

This makes TRISHNA a unique sensor to characterize the bidirectional surface reflectance distribution function (BRDF) at the agricultural plot scale, which is required to estimate albedo. The current satellite sensors with a sufficient revisit frequency either only allow a resolution of a few hundreds of meters, and miss the agricultural plot scale, or, as Landsat, Sentinel-2 or even Planet, observe close to nadir, or at constant viewing angle for all acquisition when off nadir, and do not allow to catch the directional variations. LSTM plans to only observe with constant viewing angles, which does not give access to the BRDF, but its combination with other sensors such as SBG should allow to pursue the pioneering work of TRISHNA.

The presentation will show the current state of development of albedo retrieval methods based on orbital simulations or TRISHNA with synthetic data, simulations with Sentinel-3/OLCI data (which has a similar field of view), and validations on CNES ROSAS surface reflectance measuring stations in La Crau, Gobabeb and Lamasquère. The results will show how well TRISHNA is adapted to estimating the albedo.

GEOV2-AVHRR: GLOBAL LAI, FAPAR AND FCOVER 1981-2022 TIME SERIES. PRINCIPLES AND EVALUATION

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Long term global terrestrial vegetation monitoring from satellite Earth observations system is critical in climate and earth science applications. This paper describes the GEOV2-AVHRR global vegetation products of leaf area index (LAI), fraction of absorbed photosynthetic active radiation (FAPAR) and vegetation cover fraction (FCover) from July 1981 to December 2022 derived from NOAA and Metop-2 AVHRR data. GEOV2-AVHRR products are available at the Theia portal at 0.05° and 0.5° spatial resolution and 10-day frequency.

GEOV2-AVHRR products capitalize on the efforts undertaken to pre-process the AVHRR temporal series, resulting in the Long Term Data Record data, and the recent development of improved processing of biophysical variables resulting in the Copernicus Global Land Service (CGLS) Version 2 of Collection 1km LAI, FAPAR and FCover products (GEOV2-CGLS). The retrieval algorithm includes two steps. Neural networks are first trained with CYCLOPES and MODIS products to derive vegetation biophysical variables from AVHRR top of the canopy directionally normalized reflectance data at the daily time step. The resulting daily products are then composited using temporal smoothing and gap filling techniques applied over a temporal window with a length varying between ±30 and ±60 days depending on the number of valid available observations.

The comparison between GEOV2-AVHRR and GEOV2-CGLS shows 94% of land pixels meet GCOS requirements for LAI with differences within ±0.5 LAI and 85% of pixels are within ±0.05 FAPAR/FCover requirements. Further comparison with similar long-term products shows GEOV2-AVHRR products meet GCOS and user requirements in >90% of land pixels for LAI, >60% of pixel for FAPAR and >50% of pixels for FCover with differences with GIMMS3g and GLASSV4 products within ±0.5 LAI, ±0.05 FAPAR and ±0.05 FCover. GEOV2-AVHRR constitutes an intermediate solution between GIMMS3g and GLASS V4 in terms of the magnitude of products: GIMMS3g and GLASS V4 agree better with GEOV2-AVHRR (~0.6 LAI and ~0.10 FAPAR) than between them (~0.8 LAI and ~0.13 FAPAR); temporal smoothness: GEOV2-AVHRR improves temporal consistency reducing the noise observed in GIMMS3g and the over-smoothing in GLASS V4; and, spatio-temporal continuity: 2% of missing data for GEOV2-AVHRR at the global scale as compared to 18% of GIMMS3g and no missing data for GLASS V4. GEOV2-AVHRR also improves in terms of internal consistency between LAI, FAPAR and FCover variables. The spatio-temporal pattern of temporal anomalies of GEOV2-AVHRR time series is very consistent with GIMMS3g and across NOAA AVHRR sensors. The temporal trends in GEOV2-AVHRR LAI agrees with GIMMS3g and/or GLASSV4 in 85% of land pixels with 80% of greening and 20% of browning as evaluated over the common period (1982-2011). GEOV2-AVHRR products show the best accuracy against ground measurements: 0.81 LAI, 0.10 FAPAR and 0.13 FCover. The C3S V3 dataset was also used for comparison purposes but it showed higher temporal discontinuities, inconsistencies and artefacts from the transition between sensors as well as higher differences with other products and ground data both for LAI and fAPAR.

RETRIEVING LAND SURFACE REFLECTANCE ANISOTROPY WITH SENTINEL-3 OBSERVATIONS AND PRIOR BRDF MODEL CONSTRAINTS

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Sentinel-3 supports governmental policies and European programmes such as the Copernicus Global Land Service with daily monitoring of the land surface by measuring the Earth's surface with its multi-band wide-swath visible and near-infrared radiometers. To fully exploit Sentinel-3 data sets, performing a correction of directional effects caused by the land surface reflectance anisotropy properties is mandatory. This correction requires first an estimation of the bidirectional reflectance distribution function (BRDF) to be properly achieved. The quality and robustness of global estimates of key land surface variables derived from space-borne sensors depend clearly on an accurate assessment of the spectral BRDF.

This contribution presents an algorithm aiming at harnessing the Sentinel-3's wide imaging swath to retrieve the land surface BRDF, approximating it via a kernel-driven semi-empirical model which can then be used to normalise the observations to a common Sun-sensor geometry. Our algorithm, named ReBeLS (Regularised BRDF inversion for Land Surface), uses a temporally regularised BRDF inversion approach and, together with prior knowledge of the land surface BRDF obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors, assimilates Sentinel-3 surface reflectance observations. In the presentation we will focus on the results derived from observations provided by the Sentinel-3 Ocean and Land Colour Instrument (OLCI) sensors; however, the algorithm can also be applied to reflectance observations acquired by the Sea and Land Surface Temperature Radiometer (SLSTR). The retrieved BRDF model parameters reproduce within uncertainties the directional signature as seen by the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor.

The ReBeLS Sentinel-3 BRDF products provide users with sufficiently flexibility to compute spectral surface albedos or normalise surface reflectances to any Sun-sensor configuration. This capability is currently being exploited while generating the operational Copernicus Global Land Service’s NDVI, land surface phenology (LSP), and Copernicus Climate Change Service’s surface albedo products.

MODELING TIR DIRECTIONAL EFFECTS BASED ON GROUND AND SATELLITE DATASETS COMPRISING DIURNAL TEMPERATURE CYCLE STUDY: PREPARATION TO THE TRISHNA MISSION

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The increasing number of satellite missions in the thermal domain and the need for a high temporal resolution to measure land surface temperature (LST) emphasizes the significance of predicting LST accurately. The TRISHNA mission -scheduled to be launched in 2026- will collect both optical and thermal information at a high temporal and spatial resolution, with a pixel size of 57 meters at nadir. Owing to a wide field of view around 35 degrees, global coverage will be ensured at the frequency of three times during eight days at low latitudes and more revisit at mid-latitudes and above. The short-time revisit will, however, infer angular effects on the time series of measurements. Although characterization of directional effects for the optical range has been the focus of a wide field of investigation in the past, those concerning the TIR (Thermal

Infra-Red) domain are still yet to be explored.

TRISHNA's overpass time will be around 12:30 LST. In the tropics, such acquisition will be impacted by the hot spot phenomenon for a large part of the year as view and sun geometries will remain close to the hot spot. The error in LST measurements could go up to 7K in the presence of a hotspot based on in situ measurements.

This work focuses on Meteosat datasets for varied land cover types and the ground measurements acquired over a rice crop located at Nawagam, India, as part of the TIRAMISU (Thermal InfraRed Anisotropy Measurements in India and Southern eUrope) project. Both datasets include optical and thermal bands. The analysis of diurnal temperature cycles (DTC) and diurnal reflectance cycles over the study areas is performed under different conditions and canopy structures. Inverse modelling considering a combination of DTC and kernel-driven models of BRDF is performed to calibrate model coefficients with physical variables based on the observations.

Advanced studies concerning the characterization and modelling of dynamic TIR directional anisotropy with emphasis on the thermal hot spot effect will be presented. The observations so far suggest a significant change in the diurnal cycle curve when the hotspot effect is intense. As the dependent factors in the thermal domain consist of both structural and environmental factors, whereas it is only structural in the optical domain, it gives space to reduce dependent factors in the thermal domain by fusing optical and thermal observations. The influence of air temperature will be outlined.

Emphasis will be given on the strategy that can be adopted to correct directional effects and perform LST normalization in the framework of TRISHNA, notably in merging optical and thermal observations. Also, it gives a brief physical interpretation of the model coefficients issued from DTC and for future predictions. The coefficients' parametric relations can offer a database to predict mission-specific models.

LAND SURFACE TEMPERATURE MONITORING (LSTM) MISSION

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The "High Spatio-Temporal Resolution Land Surface Temperature Monitoring (LSTM) Mission" has been identified as one of the Copernicus Expansion Missions. The mission is designed to provide enhanced measurements of land surface temperature in response to presently unfulfilled user requirements related to agricultural monitoring.

High spatio-temporal resolution thermal infrared observations are considered fundamental to the sustainable management of natural resources in the context of agricultural production and with that for global water and food security. Operational land surface temperature (LST) measurements and derived evapotranspiration (ET) are key variables in understanding and responding to climate variability, managing water resources for irrigation and sustainable agricultural production, predicting droughts but also addressing land degradation, natural hazards, coastal and inland water management as well as urban heat island issues.

The existing Copernicus space infrastructure, including in particular the Sentinel-1 and Sentinel-2 missions, already provides useful information for agricultural applications, but lack thermal data. Sentinel-3 routinely delivers global LST measurements, but its 1 km spatial resolution does not capture the field-scale variability required for irrigation management, crop growth modelling and reporting on crop water productivity. Therefore, a dedicated LSTM mission is foreseen in the frame of the Copernicus expansion with the following mission objectives:

- Primary objective: to enable monitoring evapotranspiration rate at European field scale by capturing the variability of LST (and hence ET) allowing more robust estimates of field scale water productivity.
- Complementary objective: to support the mapping and monitoring of a range of additional services benefitting from TIR observations – in particular soil composition, urban heat islands, coastal zone management and High-Temperature Events.

The LSTM will deploy two satellites equipped with a whiskbroom scanner measuring top of atmosphere spectral radiance with 5 TIR bands (8-12.5 µm) and 6 VNIR/SWIR bands, optimized to support agriculture management services. Each LSTM satellite is designed for 7 years lifetime following 6 months commissioning and carries consumables for 12 years. The key observational requirements of the LSTM mission are systematic global acquisitions of high-resolution (50 meters) observations with a high revisit frequency of 4 days per satellite, i.e. 2 days for the constellation. The satellites will overfly 45 degrees north latitudes at 13:00 MLST in the descending arc of the orbit. LSTM mission will deliver as level-1 products radiometrically and geometrically calibrated TOA reflectance per VNIR/SWIR spectral band and top of atmosphere brightness temperature per TIR spectral band (orthorectified and resampled on a uniform spatial grid) within 6 hours from sensing. The core LSTM level-2 products are Land Surface Temperature, Land Surface Emissivity and bottom of atmosphere surface reflectance will be delivered within 12 hours from sensing. The accuracy for LST measurements shall be better than 1-1.5 K at a 300 K reference temperature.

The first LSTM satellite is expected launch date in the first quarter of 2029 followed by the second one two years after.

ESA is collaborating with partner space agencies to create synergy with relevant international missions such as TRISHNA (CNES, ISRO), Surface Biology Geology SBG (NASA/JPL, ASI) and the Landsat program (USGS/NASA) with the aim to achieve the optimal temporal coverage of high-resolution thermal observations and a long series data set.

This presentation will provide an overview of the proposed Copernicus LSTM mission including the user requirements, a technical system concept overview, Level-1/Level-2 core products description and a range of use cases addressing the mission objectives.

THE INDIAN-FRENCH TRISHNA MISSION DESIGN AND PRODUCTS: TOWARDS DAILY EVAPOTRANSPIRATION FROM THERMAL INFRARED REMOTE SENSING

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The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural Resource Assessment) is the future CNES (French Space Agency)/ISRO (Indian Space Research Organization) joint mission dedicated to thermal infrared (TIR) measurements for monitoring ecosystem health.

TRISHNA will ensure a global coverage at the resolution of 60m over continent surfaces (including inland waters) plus coastal waters up to 100km from the shore. The orbit has a cycle of 8 days, at an altitude of 761 km. The large swath of +/-34° corresponding to a field of more than 1000 km gives access to mid-day and mid-night acquisitions every 2 to 3 days.

The TRISHNA mission will bring new insights in the domains of Ecosystem stress and water use, Coastal and inland waters, Urban heat islands, Solid Earth and Cryosphere. In order to stimulate the development of Science, Public Utility and Commercial Applications, the worldwide user community will be provided with a free, full and open access to TRISHNA data and Service information.

The distributed products will include: (i) level 1C: Top of Atmosphere reflectances and brightness temperature, Orthorectified and resampled on a uniform spatial grid (Sentinel-2 tiles, Copernicus DEM); (ii) level 2A: Surface reflectances LST (Land Surface Temperature), SST (Sea Surface Temperature), LSE (Land Surface Emissivity) and cloud mask along with atmospheric variables: aerosol optical depth and total water vapor content; (iii) level 2B: Vegetation variables (fraction of Absorbed PAR fAPAR, Green Area Index GAI, Fraction of Vegetation Cover FCV), albedo, Evaporative Fraction and Daily evapotranspiration and finally (iv) level 3: continuous time series of daily evapotranspiration.

The satellite accommodates two instruments with 11 bands: 5 bands in the VNIR domain (blue, green, red, NIR at 865 nm and water vapor band centered at 910 nm), SWIR (2 bands for detection of high-altitude clouds and snow/cloud separation) and 4 TIR bands for accurate temperature/emissivity separation.

A high radiometric performance is targeted for the TIR instrument, with a radiometric noise better than 0.2 K, and an absolute radiometric calibration accuracy better than 0.5 K, in order to obtain an overall uncertainty of 1 to 1.5 K for land surface temperature over vegetation.

TRISHNA is scheduled to be launched in 2026 for a 5 to 7 years' operational lifetime. Synergy is effective with the upcoming thermal missions LSTM (Land Surface Temperature Mission – ESA) and SBG

(Surface Biology and Geology – NASA) in regard to the System and the Ground segment design with the aim to improve the comparability and inter-operability of the data of those three missions.
Harmonization among the three missions addresses the following topics:
- mission design: convergence on the area to be acquired are worked out;
- products definition: as much as possible the processing of data will be based on common (at least comparable in quality) auxiliary files leading to comparable performance and a product structure compatibility is looked for;
- joint calibration/validation activities are also conducted, looking for common calibration/validation sites and protocols.

The TRISHNA science team is constituted of members of the French and Indian scientific communities, with representatives of LSTM and SBG teams, in order to stimulate scientific cooperation.

CONSIDERATION OF CANOPY ARCHITECTURE AT DIFFERENT GROWTH STAGES FOR CROP MONITORING WITH HYPERSPECTRAL REMOTE SENSING: A CASE STUDY FOR MAIZE

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Context

Growing sources of uncertainties (climatic events, global market...) weighting on the agricultural sector make it essential to monitor crops more accurately, both spatially, temporally and qualitatively. Satellite remote sensing (RS) offers a great potential for near real-time crop monitoring at global scale. Upcoming hyperspectral missions (CHIME, BIODIVERSITY, SBG...) will give access to more information on crop development. Common approaches rely on the inversion of RS data using radiative transfer models (RTM) that represent vegetation as a horizontal homogeneous environment, whereas crop fields like maize are often grown in diverse terrain slopes with varying row orientation and spacing. This work focuses on the advantages of considering the 3D architecture for operational inversion.

Material

The study site includes maize fields at different phenological stages, in Grosseto (42°49′47.02″N 11°04′10.27″E), Italy. The RS dataset consists of two airborne HyPlant hyperspectral images (7th and 30th July 2018) of the ESA FLEXSENSE campaign. Maize crop functional traits were measured in the field simultaneously, including RTM parameters such as Leaf Area Index (LAI), leaf chlorophylls (Cab), carotenoids (Car), dry matter (Cm), proteins (Cp), water (Cw) and soil reflectance.

Method

We choose DART RTM and a dynamic 3D maize field model to quantify the influence of canopy architecture at different growth stages on the RS signal. A global sensitivity analysis (GSA) is used to quantify the influence of the field geometry (terrain slope, row orientation) and vegetation traits, using 3 Look-Up Tables (LUT) of 5000 DART maize fields simulations of the study area at 3 growth stages (LAI: 0.46, 1.21 and 3.11 m^2/m^2 ; fig.1). The Hilbert-Schmitt Independence Criterion (HSIC) method is used to evaluate the dependence between RTM parameters and simulated hyperspectral signal. It enables us to quantify the benefits of using 3D RTMs over 1D RTMs.

We use a 5000 samples LUT covering the growth of maize (LAI: 0.0 - 7.0 m^2/m^2) to perform hybrid inversion on HyPlant images with Kernel Ridge Regression (KRR) algorithm. The LUT is reduced to a subset of ≈1000 samples using an active learning (AL) procedure to train the KRR. The model is then used to invert HyPlant images and generate crop biophysical and biochemical trait maps that are finally validated against *in situ* measurements.

Results

GSA results show that maize row orientation has a moderate impact for young canopy (LAI = 0.46 m^2/m^2), with a spectral contribution of 2.2% at 1320 nm, and highest impact for intermediate canopy (LAI = 1.21 m^2/m^2), with a contribution of 4.9% at 1314 nm, while soil moisture has the highest contribution (≈80% for LAI = 1.21 m^2/m^2). The retrieval performances of KRR and AL show high accuracy for LAI (R^2 = 0.91), Cab (R^2 = 0.68), Cm (R^2 = 0.84), Cp (R^2 = 0.95) and Cw (R^2 = 0.93). Maps show a high sensitivity of Cm and Cw estimations to soil water content. This work demonstrates that the 3D geometry (e.g. row orientation) and soil water content of maize fields should be considered for early season monitoring.

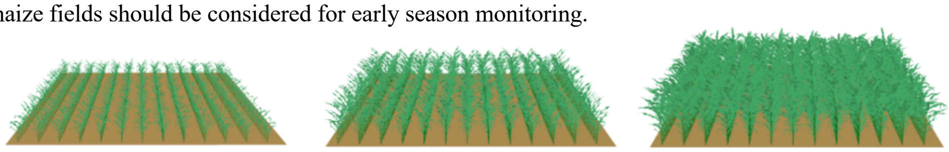

fig.1: DART maize fields for the 3 main growth stages found on study area.

SPECTRAL-DEPENDENCE SPECTROSCOPY AND EARTH OBSERVATION OF BIOCRUSTS

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Although occupying only the uppermost soil layer, biocrusts have a significant role in ecological function. Consequently, biocrusts have drawn the attention of many scientists worldwide. Particularly, considerable effort has been put into biocrust mapping by remote sensing means. In this regard, several spectral crust indices were invented and tested at different sites around the globe. Each of these indices relies upon different parts of the electromagnetic spectrum, from the visible to the microwave, that affect specific physiological properties of the biocrusts and substrates. Among these properties, it is worth mentioning the phycobilin pigments that reflect in the blue spectral region (associated with Crust Index, CI), chlorophyll absorption in the red (Red Edge Inflection Point, REIP, and Normalized Different Vegetation Index, NDVI), cellulose absorption in the shortwave infrared (Spectral Cellulose Absorption Index, SCAI), and thermal absorption in the far-infrared (Thermal Crust Index, TCI).

The current project aimed to examine and compare the performance of the spectral crust indices under different environments, from hyper-arid to arid, semi-arid, and tundra climatic zones. Moreover, attention was given to the wetness conditions of the biocrusts since they affect the physiological conditions in different spectral regions.

To fulfill this goal, we developed programming code, written in R, implemented on spaceborne images. The spectral indices were computed for diverse microphytic communities (i.e., cyanobacteria,

lichens, mosses). Their distribution and partial cover were considered. Seasonal fluctuations were obtained from Sentinel-2 images, while long-term changes were revealed from the Landsat time series. Spectroscopic measurements were conducted to validate field-collected samples.
The study concludes that a combination of several spectral biocrusts indices might show a better tool for their mapping. However, the indices are not robust and should be validated for each site.

UNDERSTANDING DROUGHT RESPONSES OF ECOSYSTEMS WITH A SOIL-PLANT-ATMOSPHERE CONTINUUM DIGITAL TWIN AUGMENTED WITH EARTH OBSERVATION (SPACEO)

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Droughts jeopardize carbon sequestration in ecosystems and hinder EU's goal of being climate-neutral by 2050. An open digital twin of the soil-plant system can monitor and predict the evolution and health of ecosystem functioning, and aid climate adaptation. The soil-plant digital twin is based on the coupled STEMMUS-SCOPE model for integrated modelling of canopy photosynthesis, fluorescence, and the transfer of energy, mass, and momentum in the soil-plant-atmosphere continuum. In this study, we will present the latest development in building this soil-plant digital twin, including: i) its simulation results for 170 Fluxnet sites in the PLUMBER2 project; ii) explicit consideration of plant hydraulics; iii) its extension to consider LAI as a prognostic variable; iv) its application to evaluate nature-based climate solution (NbCS) benefits for a revegetated semi-arid area. Furthermore, we highlight the need to develop a Soil Plant Atmosphere Continuum Digital Twin augmented with Earth Observation for understanding land-atmosphere interactions, and therefore, drought responses of ecosystems.

EVAPORATION RESPONSE TO LAND SURFACE TEMPERATURE VARIABILITY DUE TO BIOPHYSICAL REGULATION: AN OUTLOOK FOR UPCOMING THERMAL REMOTE SENSING MISSIONS

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Terrestrial evaporation is primarily regulated by two key factors: 'aerodynamic conductance' (g_a), which governs the exchange of water vapor and heat flux between the land surface and the atmosphere, and 'canopy-stomatal conductance' (g_{cs}), which controls the efficiency of vegetation canopy in exchanging carbon during photosynthesis, at the cost of transpiration.

The evaporation dynamics of terrestrial ecosystems are influenced by various factors, including land surface temperature (LST), which is modulated by a combination of radiative warming, surface energy balance fluxes, biophysical conductances, soil moisture variability, and vegetation cover. Traditionally, scientists have employed the surface energy balance (SEB) principle to estimate evaporation variability from satellite-derived LST, focusing primarily on g_a and sensible heat flux, with evaporation estimated as a residual component of the SEB. However, the role of g_{cs} has been largely overlooked due to overriding emphasis on reducing uncertainties associated with the aerodynamic approach. Both g_a and g_{cs} are crucial in controlling evaporation, particularly in arid and semiarid ecosystems where evaporation is closely linked to soil water content. Integrating these conductances using the SEB principle is essential for understanding evaporation responses to LST variations and advancing crop water use mapping.

To test the SEB theory, we first explored the conductances of heat and water flux using eddy covariance observations across semiarid ecosystems in California. We found that evaporation responses to LST variability result from stomatal control on evaporation alongside g_a, soil water availability, and atmospheric aridity, with hysteresis patterns dependent on aridity levels. To test the reproducibility of this behavior in the thermal remote sensing model, we employed the analytical Surface Temperature Initiated Closure (STIC) model. In STIC, both the conductances are estimated analytically based on SEB principle and the analytical expressions of both the conductances are derived from radiation, temperature, humidity, LST, and fractional vegetation cover. By pairing Landsat LST with Sentinel-2 multispectral observations and meteorological forecasts, we inspected the ability of STIC to reproduce the effects of the dual conductances in shaping up the evaporation responses to LST variability for a range of soil and atmospheric aridity at the spatial scale.

The synergy of meteorological forecasts and thermal remote sensing observations allowed the visualization and verification of the dual conductances from space. Repeating experiments at different times of the year confirmed how energy and water supply-demand limitations influenced conductance feedback on evaporation. The analysis offers an alternative approach of combining biological and physical explanations to investigate the highly complex evaporation variability from space. It lays the groundwork for future thermal remote sensing satellite missions like TRISHNA and LSTM, enhancing our understanding of evaporation dynamics and informing better management strategies for ecosystems and water resources in arid semi-arid regions.

NEW IMAGING SPECTROSCOPY MEASUREMENTS OF THE EARTH SYSTEM WITH UNCERTAINTY ESTIMATES BY EMIT ACROSS SIX CONTINENTS FROM THE INTERNATIONAL SPACE STATION

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EMIT's prime mission is to characterize the mineral composition of the Earth's arid land regions, provide new constraints on the radiative forcing impacts of mineral dust aerosols in the Earth System today, and assess potential changes in the future. To comprehensively measure the mineral composition of the Earth's arid lands, a modern F/1.8 full visible to short wavelength infrared (VSWIR) Dyson imaging spectrometer was developed and then launched to the International Space Station on the 14th of July 2022. Since that time, EMIT has measured more than 100 billion spectra across six continents, which include arid lands, adjacent regions, calibration sites, and other areas. These measurements have been calibrated to at-instrument radiance, atmospherically corrected to surface reflectance, and made freely available from the NASA Land Process Distributed Active Archive Center (LP DAAC). The EMIT prime mission mineral products and Earth System Model radiative forcing results are available as well. Early in the mission, EMIT demonstrated an important capability to measure localized sources of methane and carbon dioxide greenhouse gases (GHGs). EMIT GHG products are reported via the U.S. Greenhouse Gas Center portal and made available through the LP DAAC. All EMIT measurements and products include uncertainty estimates. In 2024, EMIT entered an extended mission phase with new observation objectives below the ISS to support expanded science objectives spanning the domains of terrestrial ecology, coastal oceans and inland water, snow and ice hydrology, geology, and more. EMIT extended mission observations are anticipated to support a broad set of new applications related to agriculture, forestry, critical minerals, water quality, wildfire fuels, water resources, surface plastics, etc. This paper presents the EMIT measurements, products, current results along with uncertainty estimates, and plans for the extended mission. The measurements, algorithms, science, and applications advances enabled by EMIT support preparatory activities for the Surface Geology and Biology Decadal Survey mission with a next-generation VSWIR imaging spectrometer that is part of the NASA Earth System Observatory.

THE FLUORESCENCE EXPLORER (FLEX) MISSION: RECENT DEVELOPMENTS TOWARDS THE LAUNCH

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The Fluorescence Explorer (FLEX) mission was selected in 2015, by the European Space Agency (ESA), as the 8th Earth Explorer within the ESA Living Planet Programme. The key scientific objective of the mission is the quantitative mapping of actual photosynthetic activity of terrestrial ecosystems, as a function of variable vegetation health status and environmental stress conditions, at a global scale and with a spatial resolution adequate to resolve land surface processes associated to vegetation dynamics. To accomplish such objective, the FLEX satellite carries the FLORIS spectrometer, specially optimized to derive the vegetation fluorescence emission, and is designed to fly in tandem with Copernicus Sentinel-3. Together with FLORIS, the OLCI and SLSTR instruments on Sentinel-3 provide all the necessary information to retrieve the emitted fluorescence, and to allow proper derivation of the spatial and temporal dynamics of vegetation photosynthesis from such global measurements, including the compensation for atmospheric effects and the derivation of the additional biophysical information needed to interpret the variability in fluorescence measurements.

FLEX is expected to be launched in 2026, and will provide science products which are not restricted to the basic chlorophyll fluorescence measurements, but include also the estimates of regulated and non-regulated heat dissipation, needed to quantify actual photosynthesis. Together with canopy temperature and other biophysical variables characterizing vegetation status, Level-2 products include chlorophyll fluorescence emission spectrum, decomposition of light absorption by elementary pigments, dynamical changes in leaf pigments with stress adaptations and energy dissipation cycles (xanthophylls), and high-level products such as actual photosynthetic (electron transport) rates and vegetation stress indicators (potential versus actual photosynthesis, photoprotection adaptations, non-photochemical energy dissipation and variable PSI/PSII contributions tracking photosynthesis dynamics). Level 3 products are derived by means of spatial mosaics and temporal composites, giving also as a temporal product the activation / deactivation of photosynthesis, growing season length and related vegetation phenology indicators. Finally, the combined usage of such products by means of data assimilation into advanced dynamical vegetation models of FLEX time series and ancillary information, Level-4 products are also derived, including improved estimates of carbon assimilation (Gross Primary Productivity) and evapotranspiration rates, with an explicit coupling of dynamical effects in the combined energy-water-carbon cycles, and more advanced dynamical vegetation stress indicators. The FLEX Level-2 products are already provided in the same geographical grid as Sentinel-2 products to facilitate multi-mission data exploitation strategies. Usage of common global Lat-Lon multi-resolution spatial grids for high-level L3/L4 products maximizes the inter-operability of FLEX products in global data assimilation approaches and multiple applications.

Most of such products are not yet operative, some are more mature and some are still in an early state of prototype development. In preparation for the FLEX launch, particular efforts are in place to provide each product with realistic and properly estimated uncertainties, with explicit confidence intervals, using the corresponding statistical distribution for each product. Special care is put in deriving the corresponding uncertainties at each processing step and propagating the derived uncertainties from the original satellite data until the final high-level products, by using the full covariance matrices. Explicit separation of systematic and random uncertainties are considered at each processing step and separately propagated in the derivation of the final uncertainties. This strategy is relevant for all users and applications, but results of special interest for those applications exploiting data assimilation into dynamical models of land processes, which is one of the key targets for all such developments. Efforts are also in place to guarantee proper Cal/Val activities and dedicated validation networks for FLEX. A proper, quantitative, and statistically sound, validation of all such products is being developed, where the associated uncertainties in satellite products and field data are consistently considered.

The availability of validated ready-to-use high level science products will allow an extensive scientific usage of FLEX data in vegetation dynamical models, and global carbon and climate models, with also a high potential for derived applications, such as agriculture, food security or biodiversity.

ESTIMATION OF SOIL ORGANIC CARBON ON THE QINGHAI–TIBET PLATEAU USING A MACHINE LEARNING MODEL DRIVEN BY MULTI-SOURCE REMOTE SENSING

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Soil organic carbon (SOC) plays an important role in the global carbon cycle and soil quality assessment. Tibetan Plateau as the third pole of the earth, with global warming and human disturbances intensifying, ecosystem appeared different extent degradation, and land degradation have led to changes in SOC content. But, the fine estimation of SOC density of Tibetan and its spatial variation dominant factors explore, and the application of synthetic aperture radar (SAR) data for topsoil SOC density estimation was limit under global warming. Therefore, in this study, multi-source data such as optical remote data, SAR data and other environmental variables, were collected as driving factors of estimation model of SOC; and Random Forest (RF), Extreme Gradient Boosting (XGBoost) and Light Gradient Boosting Machine (LightGBM) machine learning algorithms were used to build topsoil SOC density estimation model; and the spatial distribution pattern of SOC density on the Tibetan Plateau and driving factors of SOC spatial distribution were explored. The results showed that (1) the mean value of SOC density was 5.30 kg/m^2). (2) Among three machine learning algorithms, LightGBM obtained the high validation accuracy (R^2=0.56, RMSE=2.54, MAE=2.07). (3) Normalized Vegetation Index (NDVI) and valley depth (VD) were key factors influencing topsoil SOC density, the explanatory powers of NDVI and VD reached to 8.13% and 13.34%, besides, LST and soil moisture also were important influencing factors, explanatory powers reached to 6%, respectively. (4) Spatially, the southeastern region exhibited the higher topsoil SOC density between 10.02 kg/m^2 and 11 kg/m^2, while the northwest regions had the lower values, ranging from 2.38 to 4.92 kg/m^2. SOC density of different land cover type significantly varied, among, forest and grassland had higher SOCD value, while urban land and bare land had lower value. This study will provide an important scientific basis and guidance for soil resource management and carbon sink increase on the Tibetan Plateau.

EXPLORING MACHINE LEARNING TECHNIQUES FOR TEMPORAL FOREST COVER CLASSIFICATION IN BURNED AREAS: A COMPARATIVE STUDY

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Yearly forest cover maps, both before and after fires, facilitate the characterization of spatiotemporal species distribution patterns, which is essential for effective forest management decisions. The Aragón region (Spain) has undertaken a 38-year automated inventory project, tracking 19 forest and shrub communities across its 47,700 square kilometers by year. Generating this type of information presents several challenges: 1) Large training data requirement, ideally exceeding 100 times the number of predictor variables; 2) species spatial variability, which can exacerbate class differences, leading to classification confusion; 3) temporal coverage, training points must be acquired in different years to encompass the entire temporal period for robust model performances. This work aims to evaluate the effectiveness of different machine learning models for supervised classification of temporal forest cover data. The impact of data augmentation (SMOTE algorithm) will be assessed on training performance using a dataset of 3,200 reference points. Training data was acquired from yearly National Forests Inventories, manual expert labeling and field campaings. In contrast, predictor variables consist of spectral responses from Landsat collections, along with Land Surface Temperature, elevation and geological data, processed through the Google Earth Engine Python API. The four most commonly used machine learning models in operational land cover classification tasks were employed: Random Forest (RF), AdaBoost (AB), Support Vector Machines (SVM) and Multi-layer Perceptron classifier (MLP). These models classify three partitions of the training data created to address class imbalance: 1) stratified selection, maintaining the original class distribution by randomly selecting samples according to their proportion in the dataset; 2) soft data augmentation, upsaample underrepresented classess by 30% and downsample dominant clases by 50% reducing the imbalance while preserving some of the original distribution; 3) hard data augmentation and downsampled to achieve a balanced dataset with equal representation for all clases. The performance of each classification was evaluated using overall accuracy and class-specific user's and producer's accuracies. The stratified training approach yielded the best overall accuracy (91.7%) with the Random Forest model, followed by the SVM model trained on the same data (90.3%). The SVM model trained with soft data augmentation achieved the most balanced user's and producer's accuracies across all classes, ensuring that none dipped below 70% accuracy. For all the models, producer's accuracy for under-represented clases improved more with data augmentation techniques compared to stratified training dataset. However, stratified training resulted in lower user's accuracy errors across all classes. This study concludes that soft data augmentation techniques enhance the classification accuracy of under-represented classes. Furthermore, the notion that the optimal algorithm is often case-dependent is reinforced, depending on training data and predictors variables.
Funding: This research was funded by MCIN/AEI/ 10.13039/501100011033, grant number PID2020-195 118886RB-I00. And the predoctoral contracts from 196 the 2022-2026 Convocatory (Government of Aragón), corresponding to Cristian Iranzo.

A MACHINE LEARNING APPROACH FOR PREDICTION OF SYNERGY SURFACE DIRECTIONAL REFLECTANCE

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Surface Directional reflectance (SDR) products derived from remote sensing methods are important for the derivation of several surface and geophysical variables, and this includes vegetation indices, LAI (Leaf Area Index), FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) and surface albedo. Also, SDR is of pivotal importance in monitoring the surface dynamics of planet Earth in a climate change scenario. Derivation of these surface directional reflectance from remote sensing methods is usually a classical algorithm approach that involves atmospheric correction procedures, often pose challenges, due to high spatial and temporal variability of atmosphere, especially due to aerosols, and atmospheric coupling with underlying surface.

Classical retrieval of SDR is computationally expensive in general, due to the complexity of atmosphere correction algorithms, usage of radiative transfer models and processing of large volumes of Earth data. Hence, there is a pressing need for the prediction of SDR by alternative methods, such as offered by machine learning models. In our study, we chose Random Forest (RF), as a training algorithm to build our model for predicting SDR. RF model is computationally effective due to its high efficiency in modeling complex data. Also, this model is a learning technique, widely based on decision trees. Another advantage of this method is that it has interesting interpretation tools that help us to better understand the importance of each feature (hyper parameter) in the model's prediction.

In the current study, the training dataset for the model is based on Level 1B OLCI (Sentinel-3) observed top of atmosphere (TOA) reflectances, also that serves as the main input, illumination and observation geometry, and aerosol optical depth (AOD) used as features. The targeted output is the L2SDR from the SYNERGY Level 2 products of S3A. To build the training dataset for the model, a random selection of pixels was chosen from several products acquired over a three-month period (January to March 2024). The RF model is trained with respect to SYN SDR, individually, for each spectral band and efficiency of model is tested for randomly chosen products (L1 and L2) across the globe. Care has been exercised to verify that randomly chosen products and the corresponding pixels do not correspond to that of the training dataset.

The RF model predicted SDR values are evaluated against the reference SDR (from observations), and the metrics of evaluations are represented in terms of R2, Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE). A good stability is observed with respect to the statistical measures computed between the predicted and observed SYN SDR, where R2 values reaching up to 0.8, for several selected bands of OLCI. Also, the MAE and RMSE are within 0.05 for all spectral bands of OLCI. The results are quite encouraging and have great scope for further improvement. The presentation will detail the entire methodology and discuss the results in detail. In future, it is envisaged to use the training data from radiative transfer model simulations and assess against those observed from observational data.

GROUND-BASED REMOTE SENSING OF AEROSOL AND CLOUDS COMBINING MACHINE LEARNING AND ALL-SKY CAMERA IMAGES

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In recent years ground-based all-sky camera measurements have been extensively used in quantitative atmospheric research thanks to their capacity to observe the whole sky. The development of new calibration methodologies, both geometric and radiometric, have substantially contributed to their quantitative use to obtain properties of aerosols and clouds. Thus, these measurements in combination with different inversion methods or with the application of machine learning techniques have been used to obtain the fraction of cloud cover (CF), aerosol optical depth (AOD) and clouds (COD), as well as the type of cloud cover and integrated solar radiation. Most of these retrievals are based on the use of the blue-to-red ratio (BRR), since it allows increasing the contrast between the clear sky and the clouds. Therefore, the BRR distribution in an image is related to the characteristics of the sky. The objective of this work is to use some features derived from the probability distribution function of the BRR (PDFBRR) in different sky conditions to obtain quantitative and qualitative information on clouds (CF and type of cloudiness) and aerosols (AOD, AE and type). To do this, different machine learning models have been trained by associating the PDFBRR of each image and the estimates of CF, AOD, AE, as well as type of cloudiness and aerosols, independently determined using different instrumentation or methodologies. The types of cloudiness have been classified into: overcast, clear-sky and partially cloud conditions. In addition, we consider 4 aerosols classes based on AOD and AE: coarse ($AE < 0.7$), mixed ($0.7 < AE < 1.5$) and fine ($AE > 1.5$) aerosols; and a last class related to very small AOD ($AOD < 0.15$), since it presents no significant radiative differences with aerosol type, and then their radiative effect is less important.

Several features have been used for the machine learning models as the symmetry of the image, the average, standard deviation and the asymmetry of the PDFBRR, and the solar zenith angle.
For classification models we have used k-nearest neighbour and 5-fold cross validation method. This means that 5 data samples are taken, using 80% of the data for training and 20% for validation. The final results correspond to the average of all samples. For the quantitative retrieval of CF, AOD and AE, regression models have been used. We use around 700000 images in our analyses, distributed in 4-year period (2020-2023) with 1-min temporal resolution.

Our cloudiness classification performs well with an accuracy of 98, 97 and 90 % in identifying overcast, clear-sky and partially cloud conditions, respectively. In addition, the accuracy is larger than 95 % in the aerosol type classification regardless the cloudiness situation. Regarding to the quantitative results, our regression models are able to predict the AOD, AE and CF better than 93, 82 and 90 %, respectively. These results suggest that features associated with the PDFBRR are good parameters to identify the sky conditions as well as to predict some quantitative properties of aerosols and clouds from ground-based all-sky images.

SPATIAL AND SPECTRAL ANALYSIS OF FAIRY CIRCLES IN NAMIBIA ON A LANDSCAPE SCALE USING SATELLITE IMAGE PROCESSING AND MACHINE LEARNING ANALYSIS

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Fairy circles (FCs) are a unique phenomenon characterized by circular patches, 4–10 m in diameter, of bare soil within a vegetated matrix. This project aimed to study the spatial and spectral characteristics of FCs on a landscape scale in Namibia. The specific objectives of this research are (1) processing satellite observations to explore the FCs distributions by applying statistical analysis and deep machine learning algorithms; (2) analyzing the FCs' geometric attributes to retrieve their spatial patterns regarding topographic features nearby. The FCs were classified within 25 km2 by processing 15 input layers through a convolutional neural network (CNN) model. The layers include four WorldView2 spectral bands, derived vegetation, biocrust, and mineral indices, and textural characteristics. The FCs' geometry was extracted, and spatial autocorrelation was performed. By labeling 1600 FCs and using the CNN model, 14,536 FCs were mapped with 0.97% accuracy and a binary crossentropy loss function value of only 0.01. Field measurements and laboratory analysis justified the need to use spectral indices for the model. Unique elongated FCs, clustered by hotspot analysis, were quantified and mapped along watercourses in alluvial fans with notable connectivity. On a landscape scale that has not yet been studied, spatial and spectral analyses became possible only with valuable remote sensing retrievals, deep statistical analysis, and machine learning algorithms.

AN APPROACH TO A GLOBAL MODEL FOR MODELING THE SURFACE URBAN HEAT ISLAND (SUHI) EFFECT IN SPANISH CITIES USING U-NET CONVOLUTIONAL NETWORKS

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The aim of this work is to approach a global model of the Surface Urban Heat Island (SUHI) effect in the main cities of Spain in 2020 and 2021. To estimate the increase in surface temperature in each city, we focus on the distinction between urban and surrounding rural areas. To measure the temperature difference, Land Surface Temperature (LST) derived from the MYD21 and MOD21 products of the MODIS Aqua and Terra satellites, respectively, has been used. Despite the limited spatial resolution of 1 km per pixel of the products used, the proposed approach attempts to overcome this limitation by applying advanced statistical methods, such as the use of U-Net networks, an architecture specifically designed for image segmentation tasks. This innovative approach has the potential to offer remarkable accuracy in image classification and segmentation, thus contributing to a deeper understanding of SUHI in urban environments. This model uses encoding-decoding mechanisms, establishing direct links between the two phases, allowing for detailed information transfer, reducing computational and temporal costs, with accuracies ranging from 85% to 90%.

LAND SURFACE TEMPERATURE ANOMALIES OVER AMAZONIA DURING THE DROUGHT OF 2023

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Warm temperatures and heatwave events were evidenced over the Amazon region during the year 2023 in terms not only of hydrometeorological drought but also ecological and socioeconomic impacts. In this study we used remote sensing data collected from the Moderate Resolution Imaging Spectroradiometer (MODIS) to observe the changes in vegetation temperature over the Amazon forest during the exceptional drought of 2023. The analysis is based on anomalies of Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). The Amplitude of LST (AMP-LST), an indicator of the energy partitioning between latent and sensible heat flux, is also considered to identify regions under water stress conditions. Our results show a widespread and extreme warming over Amazonia during the austral spring in 2023 with water stress conditions over northern.

EMPIRICAL MODELS FOR ESTIMATING SURFACE AIR TEMPERATURE USING REMOTE SENSING DATA IN THE SPANISH MEDITERRANEAN BASINS

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Surface air temperature (SAT) is an essential climate variable defined by Global Climate Observing System (GCOS). It is mainly related to land surface temperature (LST), but also to geographical and meteorological parameters. The estimation of SAT using remote sensing data allows us to study it over a large region without the need for a dense network of meteorological stations there. Thus, this is useful to monitor climate changes in remote and large areas.

In this study, we evaluate the equations for SAT retrieval proposed in Niclòs et al. (2014) in a larger region and a longer time period than they original purposes. Furthermore, we propose new linear regression models based on the correlation between surface, geographical and meteorological parameters, exploring which one works better for the SAT estimation. Finally, we explore non-linear approaches based on decision tree methods such as random forest and gradient boosting (XGBoost).

The models' accuracy is evaluated against in-situ data from meteorological stations operated by the Spanish State Meteorological Agency (AEMET) in the Spanish Mediterranean basins, from the Pyrenees to Andalusia and also Balearic Islands, during the period 2021-2022. Data acquired by the MODIS sensor aboard the EOS-AQUA satellite are used. This sensor provides LST data for daytime and nighttime, which are used to study the SAT dependence at these two different times. Additionally, we use reanalysis data from ERA5-Land for meteorological variables and a DEM for geographical and topographical variables.

Best root-mean-square-difference (RMSD) obtained with the equations in Niclòs et al. (2014) is 3.2 K for daytime and 2.1 K for nighttime, showing that these methods cannot be extrapolated to the larger region here studied. For the new models regressed, RMSDs decrease to 2.4 K for daytime and 1.5 K for nighttime. Finally, better results were obtained with the non-linear approaches, which show an RMSD of 1.5 K for daytime and of 1.1 K for nighttime.

The analysis also showed that the most relevant variable on their correlation with SAT was LST, especially at night. In addition, nighttime uncertainty is lower than daytime uncertainty for every method.

Machine learning algorithms are useful to discover hidden relations in regression problems as we see in this work. Thus, the different approaches analyzed in this study, likely with more parameters and data, seems to be a promising research line to investigate on in the future.

The study was conducted within the framework of the project Tool4Extreme PID2020-

118797RBI00 funded by MCIN/AEI/10.13039/501100011033, and also the project PROMETEO/2021/016 funded by Generalitat Valenciana.

LAND SURFACE TEMPERATURE AMPLITUDE AS AN INDICATOR OF LATENT HEAT FLUX CONSISTENCY OVER AMAZONIA

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The Amazon basin plays an important role to the global hydrological cycle, where among many critical processes, the removal of latent heat from the surface through evapotranspiration distinguish itself as a key to understand land-climate interactions. However, accurately quantifying this process remains challenging due to limited observational data and model assumptions. In this study, we evaluate several datasets using satellite observations from MODIS Land Surface Temperature (LST) and leaf area index (LAI), to assess the consistency of latent heat flux datasets over the Amazon basin. Our methodology involves an indirect comparison of different latent heat flux datasets against the daily amplitude of surface temperature (AMP-LST) and vegetation status (LAI), obtained from these satellite observations. By leveraging AMP-LST and LAI data, we aim to provide valuable insights into the realism of latent heat flux representations. Our hypothesis is grounded in the belief that satellite observations offer a unique perspective to discern the spatial and temporal consistency of latent heat flux estimates. Our analysis reveals significant disparities among latent heat flux datasets within the Amazon basin, both spatially and temporally. Notably, discrepancies are observed in regions more characterized by water-limited conditions, particularly along the basin's borders and certain areas of eastern/southeastern Amazonia. However, despite these differences, we observe a discernible relationship between AMP-LST, LAI, and latent heat flux, underlining the utility of satellite observations in evaluating model representations. Our study highlights strong correlations, with values approaching -0.98 for surface temperature and 0.94 for LAI, further affirming the validity of satellite-derived data in assessing the partitioning of energy fluxes in models and reanalysis datasets.

THE IMPACT OF SHARPENED LAND SURFACE TEMPERATURE DATA ON EVAPOTRANSPIRATION ESTIMATION: A COMPARATIVE ANALYSIS USING THREE THERMAL-BASED ENERGY BALANCE MODELS

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Evapotranspiration (ET) is the main driver of the environmental process that links the water, energy, and carbon cycles. Accurate estimation of this variable at regional and continental scales is crucial for a global understanding and management of ecosystem dynamics. Among the various spatial models for ET estimation, the land surface temperature-based approach is widely adopted. This approach uses land surface temperature (LST) as a potential indicator of both ET and soil water availability through the surface energy balance. However, thermal-based remote sensing data often have coarse spatial and temporal resolutions, which is limiting for hydro-agricultural applications. To overcome this limitation, there is a pressing demand for higher spatial and temporal resolution LST data, particularly for monitoring plant water status at the field scale. Consequently, various downscaling techniques have been proposed to enhance the spatial resolution of LST data while maintaining a high temporal frequency. This study aims to develop a simple method for disaggregating land surface temperature and evaluate its impact on three LST-based energy balance models. Specifically, LST data from MODIS (MODerate resolution Imaging Spectroradiometer) at

1 km resolution and Sentinel-2 optical bands at 20 m resolution are used. A multiple regression equation between the six optical bands and LST is employed to disaggregate LST from 1 km to 20 m resolution. The disaggregated LST is then incorporated into the TSEB (Two source energy balance model), the PM (Penman Monteith model), and the METRIC (Mapping EvapoTranspiration at high Resolution with Internalized Calibration model). The predicted ET from these models is compared with measurements from Eddy covariance systems installed over rainfed and irrigated wheat fields in the Tensift basin, central Morocco. The results of the disaggregation approach compared to in-situ LST, along with the estimated ET compared to EC system measurements, will be presented during the conference. This targeted research shows promise in meeting the needs of managing agencies by providing spatially explicit ET estimates across different canopy types and scales.

ESTIMATION AND ANALYSIS OF LONG-TERM TERRESTRIAL WATER STORAGE ON THE YUNNAN-KUIZHOU PLATEAU

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The Yunnan-Kuizhou Plateau (YKP) faces water resource management challenges due to recurrent droughts and pronounced seasonal hydrological variations. As one of the critical water resources in this area, changes in terrestrial water storage (TWS) significantly impact the regional ecological environment and human life. However, the prohibitively high cost and inadequate spatial resolution of traditional observation techniques significantly impede the establishment of comprehensive and efficient water storage monitoring systems in the YKP region. The Gravity Recovery and Climate Experiment (GRACE) satellite provides a new possibility for high-resolution monitoring of global TWS and its changes. The study utilized the spherical harmonic coefficients of GRACE data from 2002 to 2022 on a monthly basis to estimate water storage variations with considering the replacing low-order C20 coefficients, filling missing data, and correcting leakage errors in the YKP region. The findings demonstrate a strong consistencies with a correlation coefficient of 0.86 between the TWS variations derived from spherical harmonic coefficients and those observed in the GRACE Mascon gravity satellite products via analysis of long-term data during 2002 - 2022 in the YKP region. Additionally, the TWS shows significant fluctuations with semi-annual amplitude values of (1.55 ± 0.572 cm/year) and annual amplitude values of (5.92 ± 0.570 cm/year). The annual phase is (249 ± 5.5°), indicating that TWS peaks in September to October. Overall, TWS shows an increasing trend, with an average rate of change of (0.176 ± 0.067 cm/year). Spatially, there is a gradual slowdown in the growth trend from the eastern to the western regions, and a certain degree of decline is observed in the northwest of Yunnan province. The results of research effectively elucidate the developmental trajectory of severe droughts in the YKP during the years 2003, 2010, and 2021, which enhancing comprehension of the dynamic changes occurring within Earth's water resources for administrators.

COUPLING ADVANCED RADIATIVE TRANSFER MODEL WITH TERRESTRIAL ECOSYSTEM MODEL TO SIMULATE ECOSYSTEM OPTICAL PROPERTIES COHERENT WITH DYNAMIC RESOURCE-DRIVEN VEGETATION PROPERTIES OF SEMI-ARID GRASSLANDS

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The savannas are one of the major ecosystems in the semi-arid region. Savannas are intricate ecosystems made up of scattered trees and a grass layer. They contribute to strong seasonal and inter-annual dynamics of carbon (C) and water vapour fluxes, whose effects notably propagate to global scales. Developing approaches to study the changes in global C flux variations requires understanding the processes at ecosystem scale and translating it to the global system. Hence, terrestrial ecosystem models (TEM) are a powerful tool for assessing ecosystem responses to climate change and extremes. New-generation TEMs, such as QUINCY (QUantifying Interactions between terrestrial Nutrient CYcles and the climate system), couples C, nitrogen (N), and phosphorus (P) cycles while accounting for energy and water availability. However, TEMs require many variables and site-dependent parameters, limiting their prediction accuracy, particularly in complex ecosystems. Remote sensing (RS) products can be used to inform TEMs, but uncertainties and biases from RS data can propagate to the TEM predictions. Alternatively, the radiative transfer models (RTM) can be coupled with TEMs, to allow usage of RS data assimilation into TEMs and therefore reduce prediction's uncertainty. Semi-arid savannas comprehend mixtures of green and senescent vegetation featuring different optical and biophysical properties which hampers the retrieval of vegetation properties from RS retrievals. senSCOPE, a modified version of the state-of-the-art RTM SCOPE (Soil Canopy Observation, Photochemistry and Energy fluxes), was developed to improve the representation of vegetation composition semi-arid ecosystems by separately simulating green and senescent grasses. Therefore, we have coupled the senSCOPE in QUINCY, to improve the representation of green aPAR (absorbed photosynthetically active radiation) using RS data from semi-arid ecosystems. However, RTMs such as senSCOPE are computationally expensive, whereas QUINCY requires computationally affordable submodels. To overcome the computational problem, we developed simplified RTMs based on the dual-leaf approach in the original RTM of QUINCY which replaced the RTMs, whenever no RS observations are to be assimilated. The combinations of submodels better represents the senescent material in the nutrient cycles of QUINCY enabling its ability to understand the effects of different ecosystem processes (i.e. biomass production, litter decomposition rate etc.). We compared the different modelling approaches´ outputs such as gross primary productivity, aPAR, and albedo with the standard model of QUINCY for different combinations of green and sensent material leaf area fractions. The change in results across different models is assessed through statistical analysis (root mean squared error, mean error and mean absolute error). By integrating the two-leaf based RTM and sub-models in QUINCY, we were able to better represent the senescent material in the grassland in a computationally efficient framework.

GLOBAL LONG-TERM HOURLY 9 KM TERRESTRIAL WATER-ENERGY-CARBON FLUXES WITH PHYSICS-INFORMED MACHINE LEARNING

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In this study, we generate a global, long-term, hourly terrestrial water-energy-carbon fluxes, using model simulations, in-situ measurements, and physics-informed machine learning. The soil-plant model, STEMMUS-SCOPE was deployed to simulate land surface fluxes over 170 Fluxnet sites. The model input and output data were then used as training data-pairs to develop the STEMMUS-SCOPE emulator using multivariate random forests regression algorithm. Here, physics-informed machine learning refers to the fact that the emulator was trained and constrained by the physical consistency represented by the soil-plant model. We compared the physics-informed emulator (RF_S-S) with the one trained using only Fluxnet in-situ measurements (RF_in-situ), and found that the land surface fluxes predicted by RF_S-S are less scattered than that by RF_in-situ.

We estimate seven variables simultaneously: net radiation, latent heat flux, sensible heat flux, soil heat flux, gross primary productivity, solar-induced fluorescence in 685 nm and 740 nm. Results show that RF_S-S can estimate fluxes with Pearson Correlation Coefficient score (r-score) higher than 0.97 for six variables except soil heat flux. The testing result using independent stations (not included for developing emulators) show a r-score higher than 0.94 except soil heat flux. The feature importance shows that incoming shortwave radiation, surface soil moisture, and leaf area index are top predictor variables that determine the prediction performance. We further use optimal interpolation to combine model output and in-situ fluxes to produce one global fluxes dataset. We will explore the performance of RF in predicting root zone soil moisture, and leaf water potential, which assist the understanding of ecosystems' drought responses to climate change.

Notes: STEMMUS - Simultaneous Transfer of Energy, Mass, and Momentum in Unsaturated Soil; SCOPE - Soil Canopy Observation, Photochemistry and Energy fluxes radiative transfer model

ASSESSING THE IMPORTANCE OF DIFFERENT WATER STRESS INDICATORS IN LIGHT USE EFFICIENCY MODELS FOR ESTIMATING TERRESTRIAL GROSS PRIMARY PRODUCTION

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Light use efficiency (LUE) models are simple yet robust models to estimate the terrestrial gross primary production (GPP) across multiple scales. In the LUE models, GPP is estimated as the product of the LUE of the vegetation and the amount of absorbed photosynthetically active radiation (APAR). The actual LUE of the vegetation in the given state is calculated by first considering the maximum LUE for that vegetation type and subsequently adjusting it to account for multiple stress factors. Water and temperature stresses are two of the major stress factors especially for croplands over arid and semi-arid regions. Multiple LUE models have been developed considering various stress factors computed using various methods. This study aims to compare four LUE models namely EF-LUE, Vegetation Photosynthesis Model (VPM), MODISLUE and the Temperature-Greenness (TG) with different representations of the water stress factor. Evaporative Fraction (EF), Land Surface Water Index (LSWI), Vapour Pressure Déficit (VPD) and Land Surface Temperature (LST) are the proxies of water stress used in the four models respectively.

The experiment was carried out over a vineyard in the Nashik district in the state of Maharashtra, India (20.55 °N, 75.51 °E) from mid-June 2021 to mid-July 2022. The site is instrumented with eddy covariance (EC) tower observing water, energy and the carbon fluxes and the net ecosystem exchange (NEE) observed by EC system was partitioned into GPP and respiration. The four models were forced with in situ meteorological, EF and LST observations. The spectral vegetation indices (such as NDVI and LSWI) were obtained from the MODIS data. GPP was estimated at daily scale and was compared with the GPP estimated from field observations. The EF-LUE, VPM, MODIS-LUE and the TG model exhibited RMSE of 1.47, 2.48, 3.67 and 4.44 gC m–2 d–1. Similarly, the coefficient of determination (R2) was 0.60, 0.79, 0.69. 0.21 respectively for the four models taken in the same order as above.

The EF_LUE model had a relatively lower RMSE however exhibited higher variance compared to the observations which led to a lower R2. The VPM and the MODIS-LUE models had severe underestimation especially during the low GPP periods leading to higher RMSE. The TG model was not able to properly reproduce the GPP patterns. Our findings revealed that water stress had a more significant influence on model accuracy compared to temperature stress and further, EF is found to be better indicator of water stress as compared to other variables. This indicates that EF or related evapotranspiration (ET) based stress factors should be included in the LUE models for better estimation of GPP. The study is now being extended to other Fluxnet cropland sites for further analysis.

FEASIBILITY TO DERIVE NEW CARBON FLUXES PRODUCTS FROM EUMETSAT SATELLITES IN LSA SAF

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The quantification of carbon fluxes is crucial as they play a critical role in the global carbon cycle and directly influence the Earth's climate. The Satellite Application Facility on Land Surface Analysis (LSA SAF) produces and provides access to remotely sensed variables for the characterization of terrestrial ecosystems, such as land surface fluxes and biophysical parameters, taking full advantage of the EUMETSAT satellites and sensors. Among others, LSA SAF provides products of the Gross Primary Production (GPP) from SEVIRI/MSG, offering a quantitative measure of carbon uptake by terrestrial vegetation through photosynthesis and therefore it's a relevant variable to account carbon exchange between the surface and the atmosphere. During the current phase (CDOP-4), LSA SAF is investigating the feasibility to exploit the enhanced capabilities offered by the new generation of EUMETSAT satellites to derive new vegetation products, such as the Net Ecosystem Exchange (NEE), which is defined as GPP minus the Terrestrial Ecosystem Respiration (TER) and provides a direct measure of net CO_2 exchange between ecosystems and atmosphere.

We evaluate the performance of advanced and highly efficient machine learning retrieval models in the context of deriving carbon fluxes variables (GPP, NEE, TER) blending SEVIRI/MSG data and ground observations from eddy covariance (EC) towers. These EC data offer estimates of CO_2 net exchanges at high temporal resolutions and are distributed around the most representative biomes of the terrestrial surface. An ensemble of SEVIRI/MSG products, such as Fractional Vegetation Cover (FVC), Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Downward Surface Shortwave Flux (DIDSSF), Evapotranspiration (DMET), Reference Evapotranspiration (METREF) and BRDF k_0 parameter in the red, NIR, and MIR SEVIRI/MSG bands, served as inputs for the models. Additionally, various state-of-the-art machine learning regression methods were employed for comparison, including neural networks and kernel methods. The results show that the machine learning methods provide accurate and consistent estimates among them and encourage the use of data-driven approaches jointly with remote sensing data for carbon fluxes estimation

ANALYSIS OF THE RELATION OF PHYTOPLANKTON, TEMPERATURE AND SALINITY IN THE WESTERN MEDITERRANEAN SEA USING DATA DEEPESDL CUBES

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In the context of the Mediterranean Sea, a semi-enclosed evaporative basin primarily linked to the Atlantic Ocean via the Strait of Gibraltar, the Western Basin and the Eastern Basin are separated by the Sicily Strait. The Western Mediterranean, marked by its dynamic nature and unique physical and biogeochemical features, experiences significant seasonal atmospheric forcing from wind stress and air-sea buoyancy fluxes (Macias et al., 2016). Notably, the Alboran Sea within this basin is extensively studied, serving as a direct recipient of Atlantic waters through the Strait of Gibraltar. Here, the Almería-Oran Front (AO) forms as fresh Atlantic waters collide with the denser Mediterranean currents.

Expanding on the AO front, this study seeks to elevate submesoscale research (1-10 km) by scrutinizing variables like Sea Surface Temperature (SST), Chlorophyll-a concentration (CHL), Sea Surface Height (SSH), and sea surface salinity (SSS). Understanding the coastal circulation is key, such as nutrients or pollutants that reach the open sea from coastal waters, in summary the exchanges between coastal and offshore waters and their interactions. Data integration will allow for comprehensive monitoring of specific areas, like the Alboran Sea dynamics, or the Tyrrhenian Sea and the interrelation of various physical and biological parameters at the surface. Some questions we would like to answer concern i) the frequency, possible seasonality and factors influencing the coastal-offshore exchange, ii) identify the areas where eddy-type formations occur more frequently, iii) detect and label offshore-coastal derived water masses.

Leveraging Copernicus products, we have built an XCUBE framework to combine the different datasets for enhanced analysis and correlation. The XCUBE is stored within the ESA Deep Earth System Data Lab (DeepESDL). DeepESDL provides convenient access to relevant data sets, many of them generated in various ESA and European science projects, in an analysis-ready format. Moreover, DeepESDL comprises a powerful data science environment with a focus on machine-learning and artificial intelligence workflows.

ADVANCES ON SPANISH ECOSYSTEM DYNAMICS BY COMBINING 20 YEARS OF DAILY GPP AND A NONLINEAR EMBEDDING METHOD

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The main objective of this study is to detect and quantify monotonic trends in a time series (TS) of gross primary production (GPP) in peninsular Spain during two decades, from 2004 to 2023. The daily GPP values are derived at 1-km spatial resolution from an optimized methodology adapted to the Spanish territory to obtain a GPP climate data record.

TS show a non-stationary behavior due to short-term, seasonal and long-term variations. They can be analyzed by means of the non-linear embeddings (NLE) method, which is based on smooth mathematical structures that allow revealing hidden structures of different scales immersed in both vector spaces and time. These hidden structures are connected through the embedding by a continuous real parameter κ, with values ranging between zero (original time series) and infinity (trend component, characterizing the inter-annual variation). The continuous variation of κ is crucial for the decomposition of the TS into different temporal components, offering a flexibility that other methods do not provide.

The magnitude and direction of trend (increasing or decreasing slope of inter-annual variation) are analyzed in terms of air temperature and precipitation variations throughout the 2004-2023 period. For that purpose, daily images of air temperature and precipitation (including the SPI) at 1-km spatial resolution for the same period are obtained by applying the ordinary kriging method to ground data provided by the Spanish Meteorological Agency (www.aemet.es). Statically significant ecosystems changes are enhanced, identified and explained in terms of the aforementioned relationships between GPP and meteorological variables, centering the focus on subtle changes as those due to degradation processes.

MAPPING EVAPOTRANSPIRATION AND WATER STRESS OF MEDITERRANEAN FORESTS FROM REMOTE SENSED VEGETATION FRACTION COVER AND WATER BALANCE MODELLING

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Vegetation fraction cover (fCOVER) is an essential variable for monitoring forest canopy processes such as evapotranspiration (ET). ET plays a major role in the hydrological cycle and in the land surface energy balance and can be used for quantifying water stress. When regional information is required, e.g. for monitoring the extension of drought or water resources, ET can be monitored using water balance models driven by remote sensed fCOVER.

We implemented a simple soil water balance model, SimpKcET (Ollivier et al. 2021, doi: 10.1016/j.scitotenv.2021.146706), in order to map daily evapotranspiration and water stress over large territories and long periods of time. Evapotranspiration and water balance were calculated from potential evapotranspiration and precipitation provided by meteorological reanalysis such as SAFRAN (Meteo France) or ERA5-Land (ECMWF) and precipitation products such as MSWEP (Princeton University). Transpiration and evaporation were considered. Transpiration depends on a canopy coefficient which accounts for vegetation fraction cover (fCOVER) and soil moisture. Evaporation depends on the fraction of soil surface and antecedent precipitation. Water stress is simply defined from the ratio of actual ET to potential ET. ET and water stress indices are presented as ensemble products combining several sets of inputs from various sources. The ensemble analysis provides a tool for inferring an uncertainty in the derivation of ET and water stress.

In this study we compared the results obtained using vegetation fraction cover derived from different sources of remote sensing data, precipitations from different climate reanalysis (ERA5-Land, Safran, MSWEP) and different soil maps (INRAE, Soil Grid). We derived fCOVER from the Enhanced

Vegetation Index (EVI) available since 2000 as part of the MODIS vegetation index products (250 m spatial resolution). We developed relations between EVI and fCOVER over a synthetic dataset simulated by using the SAIL radiative transfer model. We also used the vegetation fraction cover products that are provided by the COPERNICUS Global Land Service. Products are available at the 1 km resolution from data of the VEGETATION sensor starting in 1999 and at 300 m resolution from the PROBA-V sensor starting in 2015 and Sentinel-3/OLCI starting in July 2020.

Modeled daily evapotranspiration was evaluated over flux tower data from forest sites France, Italy and Spain. Evapotranspiration was estimated with a root mean square error between 0.4 mm d^{-1} and 0.8 mm d^{-1} depending on model inputs and locations. We show that the main source of uncertainties in the derivation of ET is due to the uncertainty in precipitation inputs, as the various precipitation products used may present large differences. Influence of fCOVER was lower and mainly related to the differences in time dynamics of fraction cover. Soil maps information were also shown as a significant factor as they usually provide information only over a limited soil depth compared to the depth that tree roots could reach.

The SimpKcET model is now implemented over large areas from global meteorological and fCOVER products and can provide ET maps at various spatial resolution from 10 m to 1 km.

ESTIMATION OF SENSIBLE AND LATENT HEAT FLUX OVER MOUNTAINOUS AREAS USING A MODIFIED SEBAL MODEL

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Accurate estimating of sensible heat (H) and latent heat (LE) over mountainous areas is challenging due to the influence of many driving factors. Although some models were developed to estimate surface heat flux, they do not consider the effects of complex terrain geometric structure and only suit for flat surface. In this study, a modified Surface Energy Balance Algorithm for Land (MSEBAL) coupled with mountainous net surface radiation (Rn) calculation process was proposed to accurately estimate H and LE in the upstream regions of the Heihe River Basin (HRB). The Rn was estimated by correcting the solar incoming radiation components using terrain factors, including slope angle, aspect, sky view factor (SVF), and terrain configuration factor (C_t). The SEBAL and MSEBAL models were actually applied to satellite remote sensing data of Landsat 8. To validate the estimation accuracy of Rn, LE, and H for the proposed model, the in-situ measurements of eddy covariance (EC) system of A'rou superstation were used in the upstream catchment of the HRB during 2018-2019. The results show that Rn, LE, and H estimated by the MSEBAL have good consistency to in-situ measurements. Among them, Rn presents a decrease in RMSE from 94.81 to 49.23 W/m^2 and a reduction in absolute bias from 92.17 to 39.29 W/m^2 compared to SEBAL. The MSEBAL exhibits low RMSE and bias values of 22.89 and 15.62 W/m^2 for H, and 26.82 and 5.96 W/m^2 for LE, respectively, compared to SEBAL. The spatial distribution of Rn, H and LE exhibited variations due to the complex terrain. Higher H and LE were found at mountain peaks, while lower values were observed in valleys. In addition, compared to west and north-facing slopes, H and LE were greater on east and south-facing slopes that receive more solar radiation. Overall, the MSEBAL model displays good accuracy in estimating the H and LE over mountainous areas.

USING MULTI-SOURCE REMOTE SENSING DATA AND MACHINE LEARNING TO PREDICT SOIL ORGANIC CARBON IN CROPLANDS OF PLATEAU LAKE BASINS

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The spatiotemporal distribution and evolution of soil organic carbon (SOC) in the plateau lake basin are critical for ecological balance, food security, and climate regulation in plateau mountainous regions. However, traditional methods are hindered in capturing the complex relationship between SOC content and environmental covariates due to challenges like complex terrain, human activities, climate change and monitoring technology limitations. To develop a regional-scale quantitative remote sensing method tailored for predicting and estimating SOC content spatial distribution and reserves in plateau lake basin croplands, this study collected 510 surface soil samples of cropland from the typical plateau lake basin of Erhai Lake. Based on soil science knowledge and regional characteristics, the 28 common and potential environmental covariates were acquired from multi-source remote sensing data with considerations were made regarding the impact of long-term cultivation and rotation on soil properties. Eight machine learning algorithms including Partial Least Squares Regression (PLSR), Random Forest (RF), Recursive Feature Elimination combined with RF (RFE-RF), Extreme Gradient Boosting (XGBoost), Boosted Regression Tree (BRT), Ridge Regression (RR), K-Nearest Neighbors (KNN) and Artificial Neural Networks (ANN), were used to establish cropland SOC content prediction models in the Erhai Lake basin. The suitability of these algorithms for predicting cropland SOC content in the Erhai Lake basin was comprehensively assessed. Results showed that RF-RFE exhibited better predictive performance (RMSE=5.9578 g kg^{-1}, MAE=4.2202 g kg^{-1}, R^2=0.6891, RPIQ=1.6563), followed by BRT and RR. Based on the best-performing models, the SOC storage in croplands (0-20 cm) in the Erhai Lake basin in 2016 was estimated to be 2.903 ± 0.242 Tg C, with an average SOC density of 63.994 ± 5.327 Mg C ha^{-1}, with 96.96% of croplands being rich in organic carbon (SOC content > 23g kg^{-1}). The results show that the spatial distribution pattern of SOC content exhibits high heterogeneity. This study provides robust support for ecological environment protection and pollution tracing in plateau lake basin regions.

EXAMINING THE FEEDBACK RELATIONSHIP BETWEEN EVAPOTRANSPIRATION AND WATER-ENERGY BALANCE THROUGH THE BUDYKO MODEL AND ITS KEY PARAMETER

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The Budyko model, which is Darwinian theoretically based, has been widely used in hydrological studies due to its simplicity, and the parameters of the model reflect the mutual feedback relationship between evapotranspiration and long-term-average water-energy balance. However, there remains a deficiency in comprehensive and specific analyses concerning the effective estimation of model parameter values and the associated relationship at global scale. In this paper, we investigate the temporal and spatial variation patterns of parameter 'n' values from the Choudhury-Yang model under Budyko theory during 2000-2020 at the global basin. Moreover, we employ ridge regression methodology to investigate the independent effects and a bivariate copula model to assess the joint impacts of key meteorological factors, including Precipitation (pre), Surface Net Radiation (Rn), Vapor Pressure Deficit (VPD), and Normalized Difference Vegetation Index (NDVI) from satellite and reanalysis data, on the parameter 'n' values. The results unveil a consistent trend in parameter 'n' over the past two decades. Notably, it demonstrates the highest sensitivity to variations in precipitation, followed by VPD, while the sensitivity to R_n is comparatively lower, suggesting a tendency towards dryness rather than humidity. The joint bivariate effects on parameter 'n' values suggest that parameter 'n' tends to decrease when the values of these key meteorological factors are relatively low, and conversely, it tends to increase when the values are higher, indicating a stronger feedback relationship between evapotranspiration and adequate water and energy availability. This study contributes to enhancing comprehension of the Budyko model and offers effective and potential solutions for ecological regulation and water resource management.

MONITORING OF LIGHT ABSORBING IMPURITIES (LAIS) IN SNOW AND GLACIERS ALONG THE CENTRAL ANDES

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Chile is one of the countries with the largest glacier area in the world, accounting for approximately 80% of the glaciers in South America. Climate Change (increased temperatures and decreased precipitation) has accelerated the retreat of most of the world's glaciers. Furthermore, in the more populated areas of the country, these glaciated masses are even more vulnerable due to exposure to pollution from urban centers and productive activities related to nearby mining, which increases the probability of contaminant deposition on their surfaces. These contaminants are known as LAIs (Light Absorbing Impurities), which are particles that can significantly reduce ice and snow albedo. Within this group, Black Carbon (BC), Brown Carbon (BrC), Carbon Black (CB), and Mineral Dust are included, with Black Carbon and Mineral Dust being the most studied due to their significant impact on the surface of snow and glaciers.

In this research, a monitoring platform was developed to integrate satellite imagery for observing Black Carbon and Mineral Dust on snow and glacier surfaces. Sentinel 2 satellite data, corresponding to the Level-2 surface reflectance product, were utilized. Two glaciers were selected for analysis: one located in the central region near an active mining operation (Juncal Glacier) and another located away from urban centers (Universidad Glacier). Satellite data were compared with in-situ measurements obtained by quantifying Black Carbon using SP2 (DMT®) equipment and Mineral Dust through gravimetric analysis. The results of Black Carbon monitoring and its relationship with surface reflectance are presented on the platform: www.blackglacier.agrospace.cl. It was found that most of the monitored surface of Juncal Glacier exhibits over 40% reflectance due to contamination, in contrast to Universidad Glacier. Laboratory data confirm the presence of Black Carbon and Mineral Dust in both glaciers. These results enable the modeling of LAIs using the SNICAR model in order to establish sensitivity thresholds for glaciers to contamination by anthropogenic actions.

SURFACE SOIL ORGANIC CARBON CONTENT ESTIMATION BASED ON HABITAT PATCHES IN SOUTHWEST CHINA

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As a crucial component of the terrestrial carbon pool, soil organic carbon (SOC) plays a pivotal role in upholding the stability and vitality of soil ecosystems. Although many studies have utilized remote sensing images and environmental factors to predict and map SOC, achieving high-precision digital soil mapping in complex terrains remains a significant challenge. In this study, a new method was proposed to partition the study area into distinct habitat patches type using the PAM clustering algorithm. Utilizing multi-source data and three machine learning models, we estimated SOC content in southwest China. Results showed higher SOC content (0-15 cm) in the southwestern mountains and the northwestern plateaus of Sichuan, while lower in the Sichuan Basin. The spatial distribution of prediction uncertainty exhibited a similar pattern. Topographic and climatic variables played crucial roles in SOC estimation. Among the three machine learning models, random forest (RF) and extreme gradient boosting (XGBoost) demonstrated higher simulation accuracy than support vector machine (SVM) (R^2 increased by 2.86% to 82.35%). Using the RF feature selection (FS) method to select optimal factors as model input variables improved simulation accuracy compared to using all factors or selecting based on Pearson correlation analysis (PsCA) (R^2 increased by 1.75% to 64.71%). The study found that a hybrid model based on different habitat patches achieved higher accuracy than the single model for the whole study area (for example, with RF FS method and modeling, R^2 increased by 2.17% to 34.78%, and RMSE decreased by 2.19% to 28.80%). These findings enhanced the accuracy and refinement of existing mapping in southwest China (compared to SoilGrids 1km and SoilGrids 250m products, R^2 increased by 20.45% and 317.73%, and RMSE decreased by 35.51% and 60.49%). Such improvements better characterized the spatial variability of SOC and provided important implications for future soil carbon stock account in complex terrain areas.

ENSO+IOD AND SOIL MOISTURE: ANALYSING THE RELATIONSHIP BETWEEN ATMOSPHERIC PATTERNS AND EAST AFRICAN SOIL MOISTURE FROM 1988-2022

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Soil moisture (SM) is one of the most significant attributes driving land and atmospheric interactions. It directly affects the status of entire ecosystems and their respective agricultural productivity, which can lead to issues with food security in arid and semi-arid regions. As climate change is known to increase frequency of extreme events like floods and droughts, understanding SM variations is essential for improving model predictions and decision-making processes. As Eastern Africa is particularly affected by the fluctuations in precipitation and temperature, this work aims to highlight the influence of atmospheric patterns on SM over the area. More specifically, the effect of the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) on SM from 1988 to 2022. The data was made available by the ESA Climate Change Initiative Soil Moisture (ESA CCI SM) and the National Weather Service (noaa.gov). To test for the relationship, cross-correlation analysis was utilised which incorporated potential lagging effects. Results illustrate strong regional differences, with Somalia and Kenya showing weak positive, significant

coefficients, while South Sudan has significant, weak negative values. The next steps include adding more atmospheric and regional patterns, as well as focussing on varying regional rainy sessions when looking at seasonal differences.

TRISHNA LEVEL-2 PRODUCTS: DAILY EVAPOTRANSPIRATION AND WATER STRESS

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The joint ISRO/CNES TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment), to be launched in 2026, will provide thermal infrared data with high revisit (3 acquisitions every 8 days at equator) and high spatial resolution (60 m). Such data will make it possible unprecedent monitoring of evapotranspiration (ET) and water stress. Evapotranspiration and water stress products will be proposed at level 2 within less than one day after image acquisition.

Here, we present the various options for the operational algorithms that will be used for generating ET and water stress products. For evapotranspiration, two main models will be used:

1- EVASPA (EVApotranspiration monitoring from SPAce, Gallego et al. 2013, Allies et al. 2020) which provides ET maps by combining several models based on the evaporative fraction formulation of surface energy balance based on the S-SEBI and the triangle approaches (contextual approach). As EVASPA provides an ensemble estimation of ET, an estimation of uncertainty in the derivation of ET is also provided (Allies et al. 2020, Farhani et al. 2024, Mwangi et al. 2024)

2-STIC (Surface Temperature Initiated Closure, Mallick et al. 2014, Hu et al. 2023) which is based on the integration of the surface temperature into the Penman-Monteith (PM) formulation at the pixel scale (single-pixel approach). The model was recently implemented within the European ECOSTRESS Hub (Hu et al. 2023).

For water stress indicators, two main indices are foreseen: the evaporative fraction as provided by EVASPA and the ratio of daily ET to reference ET (or maximum ET).

Calculation of evapotranspiration requires a large number of information that will be obtained from different sources:
- surface temperature from TRISHNA thermal channels (using the new DirecTES method)
- albedo and vegetation fraction cover from the vis/nir TRISHNA channels
- clear sky incident solar radiation (corrected for topography effect) and incident downward thermal radiation at the time of acquisition as derived from TRISHNA channel data (in particular estimation of aerosol and water vapour content)

- air temperature and air vapour pressure from ECMWF analysis
- daily solar radiation from geostationary satellites (e.g. the new MTG satellite over Europe and Africa) that will be used to upscale instantaneous estimates of ET to daily ET (Delogu et al. 2012, 2021)

At level 2, daily evapotranspiration will be provided for clear sky TRISHNA acquisition (when thermal infrared data are available, depending on satellite orbit and cloud cover). Reconstruction of a continuous serie of daily evapotranspiration will be provided as a level 3 product (Boulet et al. 2023). We will use a simple upscaling method on the basis of the daily evapotranspiration / daily solar radiation ratio, that was shown as usually providing good performances.

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ENSEMBLE MODELLING OF EVAPOTRANSPIRATION USING EVASPA: ESTIMATES AND UNCERTAINTIES

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The estimation of evapotranspiration (ET) beyond the local scale is essential for many water-related studies. Remote sensing (RS) has allowed the continuous monitoring of the water cycle and ET in particular at relatively larger spatial scales than in-situ instruments. By exploiting the physical relationship between remotely sensed surface biophysical parameters and the Earth's thermal emission, continuous ET at such spatial scales can be obtained. In this study, we applied the EVapotranspiration Assessment from SPAce (EVASPA) contextual tool over Southern France. EVASPA employs the aforementioned physical theories to provide an ensemble of ET estimates, among other surface energy balance variables. Here, we applied MODIS data, which included - among others - Land Surface Temperature/Emissivity (LST/E), NDVI, albedo. Our multi-data multi-method approach resulted in 972 ET estimates (i.e., 4 LST/Es [MYD/MOD 11/21]; 3 radiation sources [ERA5L, MSG, MERRA]; 9 Evaporative Fraction methods [5 SSEBI based, 4 T-

VI based], and 9 Ground heat flux methods [based on NDVI and LAI]). Initial evaluations using in-situ flux data yielded reasonable results even when a simple average was used, with a broad absolute and performance range between the member estimates being observed. Uncertainty analyses were also performed where we looked at how each of the distinct variables (i.e. radiation, LST, EF and G methods) influenced the modelled ET. Irrespective of the combination criteria selected (i.e., LST-radiation-EF-G), EF was observed to be the main uncertainty driver; this was despite instances where radiation resulted in higher uncertainties that were dependent on the combination selected and the period of simulation. Similar to radiation, uncertainties attributable to LST were generally higher during summer periods. G flux methods exhibited the least influence on the ensemble ET estimates. Overall, our uncertainty analyses showed that ensemble-based contextual modelling can provide enough spread for better flux simulations. Given that EVASPA is to be applied on an operational basis as part of TRISHNA ET, this work aims to guide the establishment of an optimal weighting criteria of the members for improved ET estimates.

DETERMINATION OF LAND SURFACE HEAT FLUXES AND EVAPOTRANSPIRATION BY USING SATELLITE DATA AND FIELD OBSERVATIONS OVER THE THIRD POLE

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The exchange of heat and water vapor between land surface and atmosphere over the Third Pole region (Tibetan Plateau and nearby surrounding region) plays an important role in Asian monsoon, westerlies and the northern hemisphere weather and climate systems. Supported by various agencies in the People's Republic of China, a Third Pole Environment (TPE) Integrated Three-dimensional Observation and research Platform (TPEITORP) has been constructed over the Third Pole region. The background of the establishment of the TPEITORP, the establishing and monitoring processes of long-term scale (35 years) of it will be shown firstly. Then the preliminary observational analysis results, such as the characteristics of land surface energy fluxes partitioning and the turbulent characteristics will also been shown in this study. Then, the parameterization methodology based on satellite data and the atmospheric boundary layer (ABL) observations has been proposed and tested for deriving regional distribution of net radiation flux, soil heat flux, sensible heat flux and latent heat flux and evapotranspiration (ET) and their variation trends over the heterogeneous landscape of the Tibetan Plateau (TP) area. To validate the proposed methodology, the ground measured net radiation flux, soil heat flux, sensible heat flux, latent heat flux and ET of the TPEORP are compared to the derived values. The results showed that the derived land surface heat fluxes and ET over the study areas are in good accordance with the land surface status. These parameters show a wide range due to the strong contrast of surface feature. And the estimated land surface heat fluxes and ET are in good agreement with ground measurements, and all the absolute percent difference in less than 10% in the validation sites. The total annual evaporation is approximately 51.7 ± 2.1 km^3 year− 1 for high-elevation lakes with ice sublimation component accounting for around 10–25%. The annual average ET for the entire TP, defined as elevations higher than 2500 m, is approximately 0.93(± 0.037) × 10^3 Gt yr^{-1}. It is therefore concluded that the proposed methodology is successful for the retrieval of land surface heat fluxes and ET over heterogeneous landscape of the TP area. Further improvement of the methodology and its applying field over the whole Third Pole region and Pan-Third Pole region were also discussed.

APPLYING THE OPTRAM MODEL TO EVALUATE SOIL MOISTURE IN DRYLANDS

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While drylands supply a livelihood to much of the world's rural population, these arid and semi-arid areas are under increased pressure due to growing demand and the current climate crisis. Maintaining a sustainable food source for rural populations depends on reliable grazing, and the quality of grazing is, in turn, determined by soil moisture. Thus, soil moisture must be monitored to ensure a sustainable food supply. Classic soil moisture monitoring methods rely on sensors inserted into the soil that give accurate measurements at high temporal resolution but at a point location. However, addressing the needs of populations that depend on extensive grazing lands requires a regional-scale soil moisture assessment. *In-situ* point measurements, albeit accurate, using TDR and CRNS, do not afford the needed information to prepare for or mitigate drought events at a regional scale. To this end, remote sensing space systems such as GPM, SMAP, GCOM-W1, SMOS, and Metop enable the assessment of soil moisture on vast scales.

On the other hand soil moisture mapping using the OPtical TRApezoid Model (OPTRAM) can be implemented with Landsat or Sentinel-2 with high spatial resolution. OPTRAM relies on the approximate physical linear relationship between vegetation indices, such as NDVI, and the Shortwave Infrared (SWIR) band. The current work strives to explore the merits and limitations of that model by applying it in various research sites and across different climate conditions worldwide. It was found that the original linear relationships are not robust, while exponential or polynomial curves attain a better fit to the data. A software implementation of the OPTRAM model, using the R programing language, was initiated in early 2023 (available at https://gitlab.com/rsl-bidr/roptram) and is being used in the current research.

PREDICTING CROP EVAPOTRANSPIRATION AND IRRIGATION REQUIREMENTS WITH SPACE DATA

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Adopting advisory systems that provide accurate forecasts of crop water requirements, specifically crop evapotranspiration, can enhance water use efficiency in agriculture. The successful development of these advisory systems relies on access to timely updates on crop canopy parameters (usually from satellite imagery) and weather forecasts several days in advance, at a low operational cost.

Common agronomy methods are relied upon for accurate estimations of reference evapotranspiration. Nevertheless, they require substantial and typically expensive data, as well as complex configurations, then hampering their integration into water management systems. Furthermore, these methods offer approximate estimations that are not usually aligned with real evapotranspiration measurements found in automatic weather stations. To address these issues, a Machine Learning (ML) model has been trained on in-field evapotranspiration measurements from real crops, and powered by a set of minimal weather forecast inputs.

An extensive experimental framework has been applied to our proposal and other alternative methods. Target data comprises real evapotranspiration and weather forecasts from 100 real crops in Southern Spain spanning several years (2018-2021). Experiments have demonstrated the advantage of ML for evapotranspiration prediction when compared to state-of-the-art estimators, at the same time reducing input complexity.

This work has been generated as part of the MORERA Project, thanks to a solid consortium: TASE (Systems Engineering, AI, video chain), TEPRO (user interface), IAS and Uval (algorithms) ASE Optics Europe (optics), LIDAX (thermomechanics) and INTA (AIT). This Spanish research project (funded by CDTI) is aimed at developing a personalized irrigation recommendation system for crop fields based on satellite imagery and Artificial Intelligence, as well as, a new generation of miniaturized and compact remote sensing instruments to respond with agility to users' needs.

EVAPOTRANSPIRATION ESTIMATION USING MULTIMODEL ENSEMBLE

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Evapotranspiration (ET) is a critical component of the Earth's water cycle. Accurately estimating ET is essential for sustainable planning and conservation of water resources. Various models have been developed using different physical principles to estimate ET, but their performance varies depending on site conditions, climate, and biome types. Identifying a single best-performing model across all conditions has proven challenging, limiting the widespread application of ET estimates. Recently, ensemble modeling techniques have emerged as a promising approach to improve the accuracy of ET predictions by leveraging the strengths of multiple individual models. Studies have shown that even simple methods like averaging can enhance ET estimates when applied to ensembles. By incorporating machine learning techniques into ensemble frameworks, researchers can capitalize on both the physical understanding embedded in traditional models and the predictive capabilities of machine learning algorithms. In this study, we aim to develop an ensemble model for estimating ET across the Indian region with the goal of enhancing prediction accuracy and reliability through the integration of multiple modeling techniques. Three popular ET models, namely: Priestley Taylor – Jet Propulsion Lab (PT-JPL), Soil Plant Atmosphere and Remote Sensing Evapotranspiration (SPARSE – Layer and Patch), and Surface Temperature Initiated Closure (STIC) belonging to different categories of ET models are used to create the ensemble. The study tests the ensemble based on mean, Bayesian Model Averaging, and k-Nearest Neighbor. Random forest and support vector machine. The study was done at in-situ scale for daily ET using in-situ data from 7 sites as well as at 1 km scale for 8-day for whole India. For 1 km ensemble, data from Moderate Resolution Imaging Spectroradiometer (MODIS) and Indian Monsoon Data Assimilation and Analysis (IMDAA) were used. The ensembles were compared with individual models. The ensembles performed better at the in-situ scale as well as 1 km scale. At in-situ scale, ensemble mean and BMA reduced the error by 5 - 20 Wm-2 and the machine learning based ensembles have improved further reducing the RMSE to half in all of the sites. At 1 km scale all the ensembles performed similar and have reduced the error by 5 – 17 Wm-2 combining all the sites. The study also suggests that developing landcover-specific models could potentially enhance the accuracy of ET estimations.

FUSION OF SENTINEL-1, SENTINEL-2 AND IN SITU DATA FOR ESTIMATING GPP AND RECO IN GRASSLANDS

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The following work is part of a larger European project called ScaleAgData, which aims to upscale real-time sensor data for EU-wide agricultural monitoring. With a consortium of 26 partners from 14 countries, it seeks to govern and organize complex data streams while developing technology to scale farm-level data to regional and EU-wide datasets. Its objectives include innovative data collection, promoting data sharing, and demonstrating benefits in precision farming and agricultural management.

The project explores seven innovation areas and establishes six Research and Innovation Labs (RILs) across Europe to evaluate and demonstrate various data upscaling models, providing recommendations for policy-making to enhance competitiveness and sustainability in European agriculture.

The work presented is part of the Grassland RI Lab. It aims to develop and evaluate a methodology for estimating standing biomass using a ML solution incorporating satellite Biopars, meteorological information, and soil moisture.

The area of interest used to collect data in the field and carry out preliminary validation tests is located in the north of the province of Cordoba. Continuous measurements from two test sites, 50 km apart and equipped with Eddy Covariance (EC) flux towers and environmental sensors (radiation, soil moisture, air temperature, and humidity), were selected for the measurement campaigns (22 and 19 months, respectively. High-frequency (10 Hz) fluctuations were used to calculate the mass fluxes of H2O and CO2, between the ecosystem and the atmosphere and all the components of the energy balance. Sentinel-2 and Sentinel-1 images were acquired in correspondence with the field measurements, and from them, the values corresponding to the footprints of the EC towers were extrapolated. The database thus formed was used to train a Feedforward Artificial Neural Network (ANN). Different architectures were tested (number of hidden layers, type of function, linear transfer function, number of nodes per layer, etc) and different combinations of inputs (which EO sensor bands to include, site-specific training or unique training for the entire dataset, etc).

From the analysis of the results obtained it was possible to select the best methodology to estimate both Gross Primary Production (GPP) and Ecosystem Respiration (RECO). These results are to be considered preliminary tests, as the available data are not sufficient to form a significant statistical sample. The tests carried out show that for some combinations of architecture and input data, it is possible to obtain a good predictive model, in particular using all training sites and all available Sentinel-2 bands and Sentinel-1 backscatter data. These results encourage the continuation of these tests for larger datasets, especially with a view to including in situ data acquired via Eddy Covariance by exploiting the data sharing network acquired by these sensors distributed throughout the European territory.

NRT-GSF: A NOVEL NEAR-REAL-TIME GROUND-SATELLITE FUSION ALGORITHM TO RETRIEVE DAILY CROP TRAITS AT FIELD SCALE

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Near-real-time (NRT) and daily maps that detail crop status are crucial for sustainable agriculture practices. Key indicators such as the Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), and Canopy Chlorophyll Content (CCC) are intimately connected to crop health and vitality. While decametric satellite sensors like Sentinel-2 can effectively monitor crops at the field scale, their limited revisit frequency and susceptibility to cloud contamination can hinder their effectiveness in capturing rapid crop changes for precision management. Spatiotemporal fusion techniques, which integrate satellite observations with varying spatial and temporal resolutions, have been developed to produce daily products, yet they often fail to capture abrupt changes in NRT. Near-surface autonomous monitoring systems have demonstrated their ability to observe crop status in NRT. Nevertheless, their fixed positions, typically close to or within a field, restrict their field of view and thus the spatial information they can provide for an entire field. Satellite-based observations, on the other hand, can deliver comprehensive spatial images of fields. Leveraging the complementary strengths of near-surface monitoring systems and satellite sensors, this study introduces a novel fusion algorithm for generating near-real-time daily 10-meter resolution images of NDVI, GAI, and CCC from Sentinel-2 data and near-surface measurements, utilizing a Bayesian dynamic linear model. The algorithm is called Near-real-time Ground-Satellite Fusion (NRT-GSF). It was assessed using 34 IoTA systems that supplied daily ground observations of NDVI, GAI, and CCC, along with a time series of 10-meter resolution Sentinel-2 images over wheat fields in France from April to September 2019. Results showed that predicted NDVI, GAI, and CCC products accurately reflect the expected seasonal variations and spatial distributions, enhancing the spatial completeness of the original Sentinel-2 products. A 'leave-one-out' validation approach reveals that the predicted images concur well with the Sentinel-2 images not included in the predictions, with an R^2 range of 0.6 to 0.90 for NDVI, 0.52 to 0.97 for GAI, and 0.51 to 0.99 for CCC. The lesser degrees of correlation occurred on a transitional date. For fields equipped with 2-3 IoTA systems, the predicted images from each system correspond exceptionally well, yielding an R^2 greater than 0.97 for NDVI, GAI, and CCC. Further comparison with in-situ reference measurements taken around IoTA systems throughout the growing season confirms the high accuracy of the predicted GAI (R^2 = 0.72) and CCC (R^2 = 0.9).

IN-SEASON NATIONAL-SCALE DELINEATION OF FIELD BOUNDARIES: UKRAINE CASE STUDY

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Accurately delineating agricultural field boundaries is essential for effective agricultural monitoring, crop type mapping, yield prediction, and farm management. This information is vital for researchers, policymakers, and agricultural practitioners, supporting informed decisions on food security, trade, investment, and humanitarian aid. This study aimed to develop an operational, in-season workflow for automatically delineating agricultural field boundaries using remote sensing technology. While AI-based models can achieve high accuracy in field boundary delineation, they rely heavily on unique training datasets, making them region-specific. Furthermore, creating these training datasets is often manual and time-consuming, often limiting the rapid deployment of AI models during emergencies such as armed conflicts and natural disasters. To address this, we developed a delineation method that does not require calibration, using the ongoing conflict in Ukraine as a case study.

Our approach employs time series analysis of Planet Labs' bi-weekly image composites, which enable to maintain the accuracy and reliability of field delineations under challenging conditions. The method which is based on identifying fields' edges probabilities in the time series, successfully delineated over 5 million fields across Ukraine from 2021 to 2023, achieving accuracy of 77%. The resulting dataset is now available for various applications, including agricultural monitoring, crop type mapping, yield prediction, and farm management, offering a robust tool for enhancing agricultural practices and decision-making in dynamic environments. This dataset, validated against more than twelve thousand field boundaries from on-farm machinery equipped with RTK-GPS technology, provides a comprehensive resource for various stakeholders. It supports critical agricultural applications and helps address the pressing need for timely and precise field boundary data, especially in conflict-affected regions like Ukraine.

This study demonstrates the feasibility and effectiveness of an in-season, national-scale field boundary delineation method that is robust, scalable, and independent of extensive training datasets. We also developed a version of this model for implementation on Google Earth Engine (GEE), utilizing Sentinel-2 and Sentinel-1 data to delineate field boundaries. This adaptable approach can be applied in various regions and circumstances, making it a valuable tool for global agricultural analysis and management.

WHEAT YIELD FIELD SCALE MONITORING BASED ON SENTINEL-1 AND SENTINEL-2

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In this work we develop a model to forecast wheat yield at field level from Sentinel-1 (S1) and Sentinel-2 (S2) data. To do this, we calibrate the model with precise yield data acquired between 2018 and 2022 in different fields located in an agricultural region (mostly cereals) in the province of Valladolid and we validate it with data acquired across different provinces of across Spain. To minimize the temporal variability that each season and region may present, we normalized the signal from the two satellites based on the plant temperature accumulation (accumulation of Growing Degree Days, GDD_{acum}) based on the ERA5 air temperature product. Additionally, we test different Start-Of-Season inputs to start the GDD accumulation: a) the average planting date, b) the WorldCereal crop calendars, or c) Land Surface Phenology (LSP) metrics based on MODIS daily data. Finally, we calibrate the yield model based on a two-parameter linear regression for each GDD_{acum} range considering three possible combinations: (1) using only optical parameters of S2, (2) using only microwave parameters from S1, or (3) using one parameter from S2 and one parameter from S1. The Leave One Year Out validation over the calibration area show that with S2 and S1 the yield can be estimated with errors of 1000 kg/ha while the integration of S1 and S2 provides the lowest errors of 600 kg/ha. We tested the transferability of the model across the major wheat producing Autonomous Communities in Spain (Castilla y Leon, Castilla La Mancha, Aragon, Andalucia and Cataluña). The results show higher errors when fusing S1 and S2 with an error o 1400 kg/ha while S2 shows better results with an error of 1200 kg/ha.

TOWARDS OPERATION HIGH RESOLUTION DROUGHT MONITORING BASED ON SOIL MOISTURE

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Among the consequences of global warming, droughts are often one of the slowest developing, longest lasting and least predictable of all atmospheric hazards. Droughts have a significant impact on water resources (both surface and underground), crop yields, fire predictions, reforestation monitoring and pest prevention, among others. The United Nations Convention to Combat Drought and Desertification defines drought as "the natural phenomenon that exists when precipitation has been significantly below normal recorded levels, causing severe hydrological imbalances that negatively affect terrestrial resource production systems," thus linking droughts to moisture and crop yields.

Changing patterns of temperature and precipitation linked to climate change will therefore increase hazards related to environmental conditions, such as droughts, crop failures or fires. Although soil moisture has proven to be a key element in early drought detection, currently most drought observatories rely on meteorological indices (mainly precipitation) or measure their consequences, such as for example from vegetation indices. This fact is due to the difficulty of measuring soil moisture globally at an adequate resolution.

The lack of soil moisture measurements at a spatial and temporal resolution is aggravated in the Mediterranean area since sensors with higher resolution sensitive to soil moisture have severe limitations in semi-arid climates (Escorihuela and Quintana-Seguí, 2016). The Copernicus product of soil moisture at 1km has shown to have significant shortcomings in the Mediterranean area, especially when soil moisture is low (Escorihuela et al. 2020).

In this context, we have implemented a methodology to monitor drought through the estimation of remote sensing soil moisture at a resolution better than 100 m. The methodology relies on SM estimates from SMOS/SMAP and the DISPATCh algorithm (Merlin et al. 2013) applied on the one hand with LandSat-8 and 9 data that allow obtaining the SM at 100m every 8 days in cloudless conditions and on the other hand using the synergy between Sentinel-3 and Sentinel-2, to get SM at 20m every 5 days. The combination of SMOS/SMAP together with LandSat-8, LandSat-9, Sentinel-2A and Sentinel-2B provide global data coverage at 100 m resolution and a better than weekly temporal frequency.

The long-term (2010 – to present) high resolution soil moisture is then used to derive a drought index at a spatial resolution better than 100m. In this presentation we will present the methodology and validation of the soil moisture products and drought indices. The produced maps are currently used in Observatori de la Sequera de la Terra Alta i del Penedes to guide irrigation support advise.

Escorihuela and Quintana-Seguí, 2016 Comparison of remote sensing and simulated soil moisture datasets in Mediterranean landscapes, Remote Sensing of Environment, DOI: 10.1016/j.rse.2016.02.046, 2016

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ESTIMATION OF LAI AND CHLOROPHYLL OF APPLE ORCHARDS USING PLANETSCOPE IMAGERY WITH 3D RADIATIVE TRANSFER MODEL

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Accurate estimates of vegetation biophysical variables are important for vegetation monitoring. To simulate more accurate canopy reflectance, many 3D radiative transfer model with detailed descriptions of canopy structures have been developed in recent years. Compared to 1D radiative transfer model, 3D model requires detailed 3D canopy information and the large computation effort to populate the LUT or the training database for neural network, which limits the application of 3D models in the inversion. In this study, the estimation of LAI and chlorophyll from 3D radiative transfer model is applied in the case of apple orchards. Training databases are first generated based on the semi-empirical 3D radiative transfer model speed-up method considering different leaf and branch optical properties and soil reflectance. Both the complex and simplified 3D structure are applied to build the 3D scene to examine the impact of different scene construction methods on estimation results. Based on the trained neural network from 3D training databases, biophysical variables including leaf area index (LAI), leaf chlorophyll content (Cab) and canopy chlorophyll content (CCC) are estimated using Planetscope imagery and validated with field measurements. Results show that the inversion using 3D radiative transfer model provides accurate estimation for all variables compared with 1D PROSAIL model with root mean square error (RMSE) of LAI = 0.21, RMSE of Cab = 6.39 µg/m2 and RMSE of CCC = 10.20 µg/m2. The simplified 3D structure can provide accurate estimation results, but it is slightly inferior to the 3D complex structure model. It is therefore concluded that machine learning algorithms trained over canopy reflectance simulated from 3D canopy models could improve the estimation accuracy of canopy biophysical variables compared with 1D radiative transfer model. The proposed method facilitates estimation of LAI, Cab and CCC from high-resolution satellite images in heterogeneous orchard canopies and will be useful for estimation of other vegetation canopy parameters.

PLANET'S PLANETARY VARIABLES TO MEASURE A CHANGING WORLD

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Based on observations from Planet and public satellite constellations, Planet's Planetary Variables provide continuous and timely analysis ready measures of the changing conditions on the Earth's surface.

Six Planetary Variables, i.e., Soil Water Content, Land Surface Temperature, Crop Biomass, Forest Carbon, Field Boundaries and Road and Building Detection, are currently available to help governments, NGOs and private companies make informed decisions across a variety of sectors and industries, including sustainable agriculture, environmental management, insurance and emergency response. Most of the Planetary Variables have been identified by the World Meteorological Organization, the United Nations, and space agencies as Essential Climate Variables that are critical to describing the Earth's climate and environment. These variables are used to characterize the water, energy and carbon budgets of the land surface with broad, continuous geographic coverage, and high spatial and temporal resolutions.

In this presentation, we will describe the key features of each Planetary Variable and focus on recent key achievements and use cases, including product evaluation and environmental applications. For example, current and historical Soil Water Content products based on microwave and optical observations are used to highlight drought-prone areas and improve water resource management. Land Surface Temperature is used to quantify the impact of revegetation efforts, to assess crop water stress or to identify urban heat islands. Crop Biomass products are used by agribusiness companies to characterize and monitor the various components of agricultural ecosystems, including the early detection of crop growth anomalies, the optimization of agricultural practices and agrochemical use efficiency, or the scheduling of field activities such as crop harvesting, Grass mowing and grazing practices. Forest Carbon provides estimates of above-ground forest carbon stocks for carbon project accounting, digital monitoring, reporting and verification, or reforestation and deforestation monitoring.

Planetary variables are supported in Sentinel Hub, making it possible to access, visualize, analyze, and further generate additional values taking into account multi-temporal and multi-source characteristics.

STATUS AND PERSPECTIVES FOR SENTINEL-3 SLSTR OPERATIONAL LAND SURFACE TEMPERATURE PRODUCTS

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This paper will report on recent results of inter-comparison between Sentinel-3 Land Surface Temperature (LST) products and in-situ measurements. The LST products are generated by the ESA ground segment from measurements by the SLSTR instruments on-board Sentinel-3A and 3B satellites. The retrieval algorithm is based on a Split Window approach and draws from the heritage of AATSR LST products.

To monitor and assess the performance of the operational products, in-situ measurements are collected from various networks, including US networks SURFRAD and USCRN and the European networks LAW and GBOV. Match-ups are generated by extracting LST values on homogeneous pixels close to the station and representative of its environment. Then, these values are compared with in-situ measurements within one minute of the satellite acquisition.

For each station, we compute the following performance metrics for day and night-time measurements separately:

- Accuracy, defined as the signed median difference between satellite and in-situ measurements
- Precision, as robust standard deviation of the difference

For most stations, the accuracy is better than 1.5 K, while the precision is better than 2 K. S3A and S3B are shown to behave similarly. Larger differences can generally be explained by site heterogeneity and seasonal effects, cloud contamination, or defective in-situ measurements. Time series from 2021 are analysed to look for possible trends.

We will present the methodology and updated results. Finally, we will draw some perspectives on future improvements that can be expected from:

- Updated coefficients for LST retrieval and cloud screening methods
- Improved temporal resolution of meteorology auxiliary data.
- Using a dynamic land cover for LST retrieval

EVALUATING S-SEBI AND SEBS ESTIMATES OF EVAPOTRANSPIRATION AT SAN ROSSORE (ITALY)

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Evapotranspiration is a key biogeochemical process, however its accurate estimation over land surfaces is still an open research question. Several methodologies exist, each with its points of strength and drawbacks. Among the remote sensing based technique, the Surface Energy Balance models allow for the estimation of evapotranspiration from observations of land surface temperature, spectral properties of the land surface and meteorological data, which are leveraged for partitioning the radiation incoming at the earth surface into different energy fluxes. Among this category of models S-SEBI algorithm is the simplest, and the less demanding in terms of inputs, thus being particularly useful in data scarce regions. On the other hand, SEBS has a more complex structure and was designed to deal with some heterogeneity in the study area. Both the algorithms might be a viable option for creating high resolution, local scale products of evapotranspiration. This study compares the performance of these two algorithms, against an eddy covariance tower, assuming the eddy covariance tower as the ground truth. The aim of the comparison is to evaluate which is more accurate in reproducing the evapotranspiration dynamics, thus producing a better-quality evapotranspiration product. The study site is located in a flat area of central Italy, in the Toscana region. The algorithms were applied on 57 cloudless Landsat 8 images, while incoming radiation and meteorological data were sourced from the ERA5-LAND global reanalysis. These public domain data sources were tested, as they are globally available, and might be the preferred data source in many areas, where other sources are absent. The S-SEBI model estimates of evapotranspiration had an average RMSE of 1.05 mm against the Eddy Covariance tower and an R-squared of 0.6. Despite some differences in the observed values, the model estimates followed well the seasonal trends of the eddy covariance data. The SEBS model showed an accuracy (RMSE) of 0.91 mm at daily timescale with an R-squared of 0.65. The seasonal trends were adequately reproduced by the SEBS model. For both models the bias was low, showing acceptable performance in reproducing the evaporative water fluxes, in spite of the coarse resolution of the meteorological inputs and producing reasonable estimates of actual evapotranspiration. While the models displayed similar accuracy, the S-SEBI model might result more practical in many applications, as it is less demanding in terms of inputs. Where more accurate methodologies can't be applied, this approach might represent a good option for estimating the evaporative water fluxes from land and for spatializing their estimates.

FARM SCALE IRRIGATION ESTIMATION OVER VINEYARDS USING REMOTELY SENSED EVAPOTRANSPIRATION – A CASE STUDY

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Monitoring and quantifying the irrigation volume over vineyards is important for sustainable water management. However, this information is seldom available at the plot-scale. Combining remotely sensed Evapotranspiration (ET) with farm-scale water balance model is a viable solution for quantifying the irrigation. This was tested over the Ripperdan Vineyard (RIP 720) in Madera, California, USA. The vineyard consists of four experimental blocks, each averaging 3.2 hectares in size and equipped with Eddy covariance (EC) flux towers and soil moisture (SM) probes as part of the GRAPEX experiment. First, to test the approach, EC measured ET was used with the classical FAO-56 crop water balance model to simulate irrigation events and volume during May-September 2018. Precipitation data was obtained from the nearest California Irrigation Management Information system (CIMIS) network station. In the model, irrigation was triggered when the root zone depletion at the start of the day exceeded the Readily Available Water (RAW). The model was calibrated for deficit irrigation using the field observed seasonal irrigation values. The simulated irrigation was compared against field observations and the results indicated that the FAO-56 model calibrated with EC-ET data can simulate irrigation with a root mean square error (RMSE) of 25.14 mm and bias –10.42 mm compared to the seasonal observed irrigation value. When the field observed SM values were included in addition to ET, the model's RMSE improved to 20.49 mm and bias of –6 mm. The calibrated irrigation model was then applied with the daily remote sensing ensemble ET values from the Open ET project, which resulted in seasonal irrigation values with RMSE and bias of 22.44 mm and –8.18 mm respectively in comparison to the observed irrigation. When field observed SM was included in the irrigation model, the RMSE marginally improved to 18.42 mm with a similar bias of –8.42 mm. The Open ET dataset had the same ET values across the four blocks leading to the estimation of same values of seasonal irrigation when only ET data was used in the model. The results indicate that the inclusion of remotely sensed ET and SM in the FAO-56 water balance model can help track irrigation events and volume. This model is currently being modified to estimate the actual irrigation that was applied by the farmer and subsequently, the model is going to be applied for seasonal irrigation estimation over vineyards in India with ET modelled from Landsat satellite towards effective water management.

APPRAISAL OF THREE VERSIONS OF TWO-SOURCE-ENERGY-BALANCE MODEL IN ESTIMATING EVAPOTRANSPIRATION AND ITS COMPONENTS OVER A MOROCCAN IRRIGATED OLIVE GROVE

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This study evaluates the performance of three versions of Two-Source-Energy-Balance (TSEB) model in terms of evapotranspiration (ET) estimates and ET partitioning. The first version "TSEB-SPT" employs a standard Priestley-Taylor coefficient (αPT) to estimate the transpiration, the second one called "TSEB-CPT" constrained by a computed αPT using measured ET along with the equilibrium term, and the third one "TSEB-SM" incorporates soil moisture as an additional variable to refine soil evaporation estimates.

These models require, in addition to meteorological forcing, land surface temperature (LST) data and the normalized difference vegetation index (NDVI). LST was measured using Infra-Red Thermometers (IRTS-Ps, Apogee), and NDVI was retrieved from Landsat 7 imagery. The study was carried out over an irrigated olive orchard in the Tensift basin, Morocco, across 2003 and 2004 growing seasons. Our findings revealed that the TSEB-SPT model consistently overestimates ET when compared to ground-based flux measurements from Eddy-Covariance system across the two growing seasons. Whereas, the ET accuracy was considerably enhanced by the TSEB-SM and TSEB-CPT as contrasted to TSEB-SPT, with mean relative errors of 31% and 24%, respectively. Regarding ET partitioning, TSEB-CPT model closely approximates the actual transpiration, achieving a root mean square error of 0.27 mm, particularly during the summer of 2003. Conversely, TSEB-SM seems less effective in estimating transpiration component. These results suggest avenues for future refinement; by incorporating other formulas for evaporation computation and revisiting the calibration procedure of αPT coefficient, TSEB-SM model might become a reliable tool for tracking seasonal fluctuations of ET and its components across diverse canopy covers.

TOWARDS A GLOBAL EVASPA PRODUCT FOR TRISHNA MISSION

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Evapotranspiration (ET) plays a key role in the water cycle. Globally, nearly two-thirds of precipitations over land are returned back to the atmosphere by ET. The temporal and spatial distribution of ET is a relevant information for determining agricultural water consumption, assessing drought conditions, monitoring crops and carbon budgets. Remote sensing data offer the possibility of obtaining ET largescale products. Despite of all available ET products based on remote sensing data, a high-resolution and high-revisit ET product is still necessary to meet the needs of agricultural sector in particular.

The TRISHNA mission is designed for this purpose. Indeed, TRISHNA will provide optical and thermal images with a 60 m spatial resolution over large areas and a 3 day revisit in the worst case. For each daylight acquisition, TRISHNA will compute several ET products, one of which will be based on EVASPA (EVapotranspiration Assessment from SPAce), an ensemble method that combines the results of a variety of contextual algorithms based on the evaporative fraction approach. Among all the methods available for calculating ET, contextual methods offer the advantage of not requiring weather data to be used. However, they do rely on the basic hypothesis that any spatial variation of surface temperature is related to variation in water status and/or vegetation fraction cover or surface albedo. So, they asume that for each processed region, the weather variables (air temperature, precipitations), aerodynamic variables (wind) and topography (altitude, slope, exposition) are uniform. Furthermore, to be applied on a region, contextual methods require a sufficient number of pixels. However, in TRISHNA ground segment, images will be tiled according to the MRGS grid from the 1C level step. One tile has about 3.3 × 106 pixels, which is enough to apply EVASPA. But, some tiles in coastal areas have a very limited proportion of land, so that the number of pixels may be too low for correctly using EVASPA. Tiles in mountainous regions present a similar problem. Indeed, EVASPA won't perform adequately in situation with large variations in altitude. In both cases, it will be necessary to merge those tiles with adjacent tiles in order to obtain a number of pixels large enough for applying EVASPA.

The aims of this study are to define a method for identifying valid zones in each tile, i.e. pixels in which the hypotheses for applying EVASPA are met, and also, to propose a method for automatically associating tiles with an insufficient number of valid pixels.

The calculation of valid areas in a tile is based on an elevation model and a water mask. First, water or steep slope pixels are filtered. Then, considering an altitude range with a fixed size and the distribution of pixel elevation, we identify the altitude range that contains the most of pixels. Finally, cleaning steps enable to regularize valid areas. The tile merging depends on several criteria, such as connectivity, belonging to the same land region, orbit, etc.

ILLEGAL NON-METALLIC MINING DETECTION USING SENTINEL-2 AND HARMONIZED LANDSAT SENTINEL-2 (HLS)

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Illegal non-metallic mining activities (INMA) pose a significant threat to ecosystems across various landscapes. In Chile, the impact of illegal non-metallic mining on rivers and natural surroundings is particularly alarming. The Superintendency of Environment (SMA) oversees the permits issued and implements sanctions when regulations are not met. Despite these measures, illegal mining continues, and both its extent and environmental impact remain largely unquantified. This study leverages multitemporal remote sensing imagery to detect changes in land cover and land use over time, specially focusing on (INMA). By utilizing data from Sentinel-2 and Harmonized Landsat Sentinel (HLS), we monitor areas previously surveyed and analyzed using UAV imagery and photo interpretation techniques.

We employed break-event detection in time series analysis, along with indices such as the Bare Soil Index (BSI), Normalized Difference Vegetation Index (NDVI), and Automatic Water Extraction Index (AWEI), to assess the feasibility of detecting INMA activities. Our model achieved a 75% accuracy in detecting INMA, providing a preliminary evaluation of the potential of remote sensing technology in identifying illegal mining operations for environmental protection purposes. Additionally, the model's area estimation exhibits a 30% error margin, highlighting the challenges in quantifying the extent of illegal mining.

The methodology involved collecting multitemporal satellite imagery from Sentinel-2 and HLS, with preprocessing steps including atmospheric correction and cloud masking. Break detection algorithms were applied to identify temporal anomalies indicative of mining activities. The BSI was utilized to detect exposed soil, a common indicator of mining, while the NDVI and AWEI were instrumental in identifying changes in vegetation cover and alterations in water bodies, respectively.

Field validation was conducted using drone survey imagery and photo interpretation at 25 well-documented illegal mining sites. These ground-truth data were essential for training and validating our remote sensing model. The results showed a strong correlation (R2=0.65) between detected anomalies and confirmed mining activities, highlighting our approach's effectiveness. However, the model indicated an error margin of 25% in detection and 30% area estimation. These errors derive from the spatial resolution limitations of the satellite imagery, the presence of similar land cover types that may confuse the indices, and temporal gaps in the satellite data. Addressing these issues requires integrating higher-resolution imagery and enhancing the robustness of the detection algorithms.

Our study underscores the importance of remote sensing in environmental monitoring and the detection of illegal mining. Future work will focus on improving model accuracy, expanding the geographic scope of the study, and integrating additional data sources to provide a comprehensive tool for environmental protection against illegal mining activities.

DETECTION AND AUTOMATIC EXTRACTION OF THE VALENCIAN COASTLINE USING SENTINEL-2

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Coastal zones, particularly along Valencian coasts in the Mediterranean, are productive yet vulnerable ecosystems. They face increasing pressure from urbanization and climate threats, with 25% of Europe's coastlines experiencing erosion. Beaches serve as natural wave barriers, recreational spaces, and are vital for coastal communities. However, factors such as urban expansion, infrastructure, and climate change alter coastal dynamics. The study employs satellite imagery to develop a methodology for automatically observing coastline changes, which is crucial for managing and preserving these areas.

The study focuses on an 80 km coastal segment from Sagunto to Gandía. This area has sandy beaches and several barriers that limit sediment transport. Satellite images from Sentinel-2 (2019-2023) are used to identify the coastline, employing land-water indices like MNDWI and NDWI. The methodology involves automated classification and filtering processes (Otsu) to reduce noise and convert raster data into vector formats, ensuring precise coastline delineation.

The automated extraction of the coastline aligns well with observed coastal shapes, despite minor errors near narrow structures like dikes. Measurements indicate changes in beach width over the years, calculated by intersecting reference axes and transects with annual coastline data. The proposed methodology simplifies existing complex methods for coastline extraction, yielding comparable results. Limitations include lower spatial resolution compared to high-resolution aerial photos, which could be addressed by testing commercial satellite data.

MAPPING FRACTIONAL VEGETATION COVER ON THE NAMIB GRAVEL PLAINS WITH SATELLITE-RETRIEVED LAND SURFACE EMISSIVITY

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Due to their reliance on chlorophyll signals, conventional vegetation indices like the normalised difference vegetation index (NDVI) have proven inadequate for capturing the sparse and photosynthetically inactive vegetation typical of arid environments. In this research we explore the use of spectral emissivity from MODIS band 29 as a more robust indicator of fractional vegetation cover (FVC) in areas dominated by non-green vegetation. The study leverages over two decades of MODIS satellite data to chart FVC changes on the Namib gravel plains near Gobabeb (Namibia) and demonstrates the application of land surface emissivity for ecological monitoring.

Our analysis juxtaposed NDVI with emissivity data from 2001 to 2021, revealing that emissivity not only corroborates NDVI's detection of rapid post-rainfall vegetation growth but also uniquely tracks the persistence of desiccated grass, providing insights into slower ecological dynamics unobserved by traditional vegetation indices. The study employed the BFAST method to discern significant changes in emissivity and NDVI time series, correlating these with rainfall data to understand vegetation responses to hydrological variability.

Emissivity's sensitivity to both photosynthetic and non-photosynthetic biomass makes it particularly useful for assessing ecological resilience and degradation in climate-sensitive zones. Our research contributes to remote sensing practices by validating the use of emissivity data in arid landscapes and underscores the value of integrating emissivity data with NDVI for enhanced environmental monitoring and management. By offering a more nuanced view of vegetation dynamics, this approach promises to refine models of land surface interactions, improving predictions of ecological responses to climatic changes. Finally, integrating emissivity with NDVI data supports the development of sustainable management strategies for fragile ecosystems like those found in Namibia, where understanding subtle ecological shifts is crucial for conservation and resource management.

LAND COVER CLASSIFICATION BASED ON LAND SURFACE EMISSIVITY FROM ECOSTRESS SPECTRAL DATABASE AND HYTES PRODUCTS

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As an inherent property of natural materials, Land Surface Emissivity (LSE) varies across different land surface materials, serving as an indicator of the composition and alterations of land covers. However, due to the limitations of sensor level and retrieval methods, there are few LSE curves available for the researches on land surface classification. The utilization of data sourced from the Hyperspectral Thermal Emission Spectrometer (HyTES) offers a promising avenue for advancing land cover classification studies. HyTES can provide hyperspectral thermal infrared data with 256 channels between 7.5 and 12 μm, enabling the acquisition of high-quality LSE spectra. Therefore, this study analyzed the separability of emissivity spectra between different objects based on ECOSTRESS database and HyTES products. Following the analysis, the spectral angle classification method was used to classify the land cover using HyTES data.

For various representative land covers of soil, vegetation and water, including alfisol, aridisol, inceptisol, entisol, tap water, grass, tree, shrub, lichen and flowers, an analysis of difference in LSE spectra is conducted based on Spectral angle mapper (SAM) method and Munn-Whitney U test (MWU) method. Using the SAM method, the shape differences in the emissivity spectra were analyzed. The result revealed that the separability within the same species is not high, but different species are clearly distinguishable, like vegetation and soil. Additionally, MWU method was employed to assess the potential for species differentiation across various wavelengths. The results indicated that different land covers have obvious spectral differences in LSE spectra, particularly for alfisol, entisol, tree, lichen and flower. Moreover, most of the soil and vegetation show a significant emissivity difference of more than 70% in wavelength. The results confirm the distinct separability of LSE spectrum among different land surface types. Furthermore, the LSE retrieved with HyTES data acquired on June 26, 2023, in Grosseto, Italy, was used to classify the land cover in the study area. The classification results were largely consistent with field exploration findings, confirming the reliability and applicability of both the method and data for land surface classification research.

RICE YIELD FORECASTING EMPIRICAL MODELS FOR BOMBA AND JSENDRA VARIETIES IN VALENCIAN PROVINCE

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There is an evident world challenge of improving the methods of food production, making them more sustainable without renouncing to the production capacities and even increasing them. New agricultural technologies aligned with the new environmental challenges are required. In this context, rice is one of the most important crops at global scale, it feeds almost a half of the population. At European level the situation is critic, the plantation surface has reduced a 16.55% and the production a 24.86% from 2020 [46]. This situation, together with political restrictions in the exportation of producer countries, has led to an increase (compared to 2019) of the rice price index (of FAO), registering in 2023 an increase of 41.22% of the value of the Japonic rice and a 27.15% of the Indic rice [1]. Due so, there is a necessity of new technologies capable of accompanying the improvement of agricultural production. Remote sensing stands out as a useful tool in agriculture technification.

With this framework, the objective of this research is the anticipation of the final yield of rice in several fields of l'Albufera de València in each one of the most critical phenological rice phases. The idea is to make a prediction as early as possible.

The used materials are Sentinel-2 LaSRC (atmospheric correction from NASA), Sen2Like (Cloud mask). Sentinel-2 imagery are used, which are atmospherically corrected using LaSRC algorithm from NASA. To asses the cloud presence problem, cloud masking from Sen2Corr is implemented. This investigation was carried out in L'Albufera de València, Spain, in where we count with yield truth data from two of the main rice productors in the zone, Copsemar and Miguel Minguet. Bomba and JSendra varieties are analysed in 2017-2022 period. The results obtained by Franch et al. (2021) [2] demonstrated that JSendra and Bomba have many differences regarding their spectral behavior and phenology, which implies that there is a necessity of develop one yield model for each variety.

First, a temporal normalization of the spectral surface response is carried out, considering the cultivation cycle of each plot. For this we have used the GDD, due to its relationship with the phenological stages of rice. Then, the Sentinel-2 spectral responses are analysed, combining them into linear models. Finally, the basic principles of the ARYA algorithm [3] are analysed, where each DVI curve is fitted to a Gaussian curve, whose parameters can be used to train linear models.

The findings indicate that linear models can help in yield prediction, the best models show a 0.8 of R^2 in case of Bomba and 0.5 in case of JSendra, both in the peak of the season. These results suggest the potential utility of linear models in yield forecasting and contribute to the advancement of precision agriculture techniques. By exploiting remote sensing with modeling approaches, this study offers insights into optimizing rice production while addressing environmental concerns, thus fostering sustainability in agriculture.

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UTILIZING SEN2LIKE PROCESSOR IMAGERY FOR THE EVALUATION OF MEALYBUG PESTS IN ORANGE ORCHARDS AS PART OF THE CO-FRUIT AGROALNEXT PROJECT

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The Cotonet de les Valls mealybug is an insect pest which is prolifering on citrus orchards in Castellón, Spain, causing significant economic losses in agri-sector. The European Copernicus program has enabled the creation of numerous agricultural surveillance instruments by utilizing remote sensing technology. This study aims to understand how surface reflectance changes due to the mealybug pest presence by analysing remote sensing data. The Sen2Like (version 4.3.0) processor is used to retrieve the images, with the atmospheric correction of Sen2Corr (version 3.1.0). Shadows due to angular effects can influence on the spectral responses, specially given the disordered and complex morphology of trees, so the Bidirectional Reflectance Distribution Function (BRDF) [1] is employed to minimize those effects and also to reduce the detected seasonality in the spectral responses.

Conducted near the municipality of Vall d'Uixó, in Castellón, Spain, the research analyses around 25 hectares of fields. These fields, categorized as healthy or affected (by mealybug pest) during the 2020-2021 season, are studied to explore the relationship between cotonet infestation and various optical bands, highlighting RED, NIR, and SWIR, as well as the Normalized Difference Vegetation Index (NDVI).

As there is a remaining seasonality, monthly linear regressions are used to focus on trend analysis, showing a first slight separability between healthy and affected groups, in particular SWIR channel, which stands out for being capable of separating both groups from July onwards. Anomalies were also evaluated, from them, a firmer separability criterion can be established. The best results are also obtained in the SWIR case, in the second part of the year. Furthermore, the results obtained in the year-on-year anomalies study are consistent with the increase in the mealybug population from 2019 onwards.

The results suggest that remote sensing data can play a crucial role in the efficient and objective management of the mealybug pest. Notably, specific spectral ranges, particularly the SWIR, prove effective in distinguishing between affected and healthy fields throughout the year, with notable differentiation in the latter half. Overall, this study contributes to the development of innovative surveillance tools for combating agricultural threats effectively and sustainably.

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WINTER WHEAT NORMALIZATION USING GDD, ACCUMULATED PRECIPITATION AND EVAPOTRANSPIRATION USING POLYNOMIAL FIT AND PRINCIPAL COMPONENT ANALYSIS

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Understanding crop phenology evolution is critical for precise agricultural management and yield forecasting, particularly in widely cultivated crops such as winter wheat. This study leverages temporal data to analyze winter wheat signal evolution using thermal and hydric variables. Utilizing the WorldCereal v2 crop calendars as the Start of Season (SOS) indicator, we investigate the normalization changes in winter wheat across diverse geographical regions, specifically in the United States and Spain using GDD and accumulated precipitation and actual evapotranspiration.

The core of our methodology involves the integration of Growing Degree Days (GDD), a thermal time measurement useful for predicting plant development stages, with additional environmental data to monitor and analyze land surface phenology over time. As additional environmental data we employed accumulated precipitation data from the ERA-5 Land dataset and accumulated actual evapotranspiration rates from the Global Evaporation Land Amsterdam Model (GLEAM) to improve our phenological assessments at the sub-national scale. The synergy between these datasets allows for a refined analysis of the temporal and spatial variations in crop growth and development.

To quantify the normalization evolution, we utilized an adjusted polynomial fit approach incorporating GDD and accumulated precipitation data. This novel approach helps in understanding the intricacies of crop growth conditions by providing a detailed temporal analysis that correlates thermal time with moisture availability retrieved by GLEAM, thereby offering a more robust model of Winter Wheat normalization over time. Our results demonstrate a strong correlation between GDD and accumulated precipitation in predicting the normalization of winter wheat in Spain, indicating a reliable model for this region (R2 0.87). Furthermore, the combined analysis of GDD and actual evapotranspiration presents a coherent framework for assessing crop condition, particularly in the United States, where the agreement is an R2 0.7 in yield for the period 2000-2022. The integration of evapotranspiration data adds a significant dimension to our model, reflecting the impact of both temperature and moisture on crop development.

This study underscores the evolution of phenological normalisation data in agricultural management but also highlights the potential of integrating GDD plus accumulated precipitation or actual evapotranspiration to enhance the accuracy of crop signal evolution across the season.

A NEW REMOTE SENSING METHODOLOGY FOR ESTIMATING FROST INTENSITY AND DAMAGE ON CITRUS CROPS: A CASE STUDY OF THE VALENCIAN COMMUNITY

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Citrus cultivations represent one of the major economic pillars of the Valencian Community (Spain). Frost events pose a significant threat to these plantations, resulting in substantial economic losses. This study aims to assess the frequency and intensity of frost occurrences in the region, from 2004 to 2023, utilizing Second Generation Meteosat satellite imagery. These images provide daily Land Surface Temperature (LST) data at 15-minute intervals. Days with frost were identified as those where temperatures fell below -2.3°C, a threshold beyond which citrus plants are susceptible to damage. Various temperature thresholds were selected to correspond with different levels of potential damage to the crops. The study also considered the duration of these frost events, to develop an intensity classification that estimates the impact on citrus crops. Annual comparisons were made to track trends in frost occurrence and eventual thermal anomalies. Validation was performed using in situ data from the Spanish national meteorological agency (AEMET). Results reveal a decline in the severity of frosts and in their frequency. In particular, we observe a substantial decline in frosts classified according to our method as "moderate damage" and an almost disappearance of those of "intense" or "permanent damage". These observations agree with the predictions of an increase in aridity in the region, and open up new scenarios linked to the expansion of citric cultivation at altitude, in areas where production is usually better in quality, even if potentially threatened by low temperatures. Comparing our results with the farmers' observations, we can also state that the presented methodology is efficient in assessing the degree of damage generated by the frost, and could be used to insure fields during the winter season.

UHI EFFECT LINKED WITH TROPICAL NIGHTS IN THE IBERIAN MEDITERRANEAN BASIN: ANALYSIS BASED ON METEOROLOGICAL STATIONS (1951-2021)

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The urban heat island effect (UHI) is calculated as the difference between the surface air temperature in the urban area and the surface air temperature of its surrounding rural and non-urban areas. This difference is usually positive as a consequence of the thermal properties of urban surfaces and the low evapotranspiration. Tropical nights are those in which the minimum surface air temperature is above 20°C.

In this study, we analysed both phenomena at the 18 Spanish province capitals in the Iberian Mediterranean basin from June to September for the last 70 years. To do it, we defined four areas for each city: the urban area (A) and its surroundings (urban adjacent (US), future urban adjacent (FS) and peri-urban (PS)). Then, we selected the meteorological stations of the Agencia Estatal de Meteorología (AEMET) and the Associació Valenciana de Meteorologia (AVAMET) that collect data since 1951 and that are located in those areas. The stations inside the surrounding areas with adjacent urban-classified pixels in a satellite-retrieved land cover map were excluded in the UHI assessment. Additionally, we considered only the areas where there were at least 3 stations inside. This filtering reduced to 8 the cities under study.

We calculated the mean of the minimum temperatures in each area for each day. Then, we identified the tropical nights using the data of the urban area, and UHI was assessed considering the three surrounding

areas for each city, for tropical and non-tropical nights separately. Finally, we calculated the mean UHI values for tropical and non-tropical nights and its differences.

UHI values from -0.7° C to 4.6°C were obtained at the PS area. Analysing the differences between the tropical and non-tropical nights, we obtained that only in Zaragoza the UHI value is larger at non-tropical nights, while at Tarragona there is no difference. In the rest of cities, the differences range from 0.1°C to 0.5°C (i.e., the UHI is more intense when minimum temperatures are above 20°C at the city).

To summarize, in this study we have analysed the relationship between the UHI effect and tropical nights for the last 7 decades, and we have found a significant increase in tropical nights in the region and that tropical nights aggravate UHI in most of the cities.

The study was conducted within the framework of the project Tool4Extreme PID2020-118797RBI00 funded by MCIN/AEI/10.13039/501100011033, and also the project PROMETEO/2021/016 funded by Generalitat Valenciana.

A TIR DATA-BASED SERVICE SUPPORTING FOR THE IDENTIFICATION OF HEAT MITIGATION MEASURES IN CITIES

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Increased heat in urban agglomerations (Urban Heat Island, UHI) has a significant influence on human health, habitability and labour productivity. The EU Horizon 2020 project CityCLIM aims to provide practical and actionable information for the mitigation and adaptation to urban heat and air pollution to citizens and city administrations. One purely EO data-based service developed within CityCLIM targets the simulation and mitigation of urban heat by utilizing the land surface temperature (LST) as measured by TIR sensors as a proxy for the urban heat distribution.

We characterize the urban environment determining the urban heat distribution by (1) 2D land surface parameters, i.e. Normalized Difference Built-up and Vegetation Indices (NDBI and NDVI) derived from Sentinel-2 or Landsat 8/9 data, and the distance to water and vegetation derived from ESA Worldcover data and 3D urban morphology parameters (building volume density, building roof index) derived from high-resolution digital elevation models. These parameters are linked to the Landsat 8/9 LST product by calibrating a prediction model utilizing an artificial neuronal network (ANN).

The model builds the basis for the urban heat simulation service, which allows the user to modify urban characteristics (e.g., create an urban green space) on a web-based user interface and explore the effects of these modifications on LST to find the best urban heat mitigation option.

LST prediction models set up for the four CityCLIM pilot cities (Valencia, Karlsruhe, Luxembourg, Thessaloniki) provide medium prediction accuracies (R2 > 0.68 in testing with RMSE around 0.6 K). NDBI and the distance to vegetation are the most important urban surface parameters in the prediction models. For validation, we will make use of suitable examples of real construction work from the near past in the four pilot cities to compare the real changes in LST caused by the construction work to the changes in LST that were simulated by the scenario service.

The developed service contributes to a better understanding and design of urban planning and policies to mitigate unhealthy climate in cities. It is initially developed for the four project pilot cities with the perspective of extension to any city worldwide with a low effort because it applies standard EO data. The next steps are the further refinement of the LST prediction model, the deployment of the methodology to the open CityCLIM platform and the following testing and iterative improvement of the user-friendliness of the implementation. Services such as the one presented here, will greatly benefit from future TIR missions providing LST on high spatial resolution and with high accuracy, like TRISHNA or LSTM.

EXPLORING THE INFLUENCE OF 3D URBAN FEATURES ON SATELLITE-DERIVED LAND SURFACE TEMPERATURE: INSIGHTS FROM TRISHNA-LIKE SIMULATIONS WITH DART

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Land surface temperature (LST) is an essential variable in various geoscientific endeavors, especially for delineation of urban climate phenomena such as the Surface Urban Heat Island (SUHI) and health-related indices, like the Discomfort Index (DI). As urban areas face escalating heat-related challenges, effective mitigation strategies necessitate accurate LST estimation. The Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment (TRISHNA), slated for launch in 2026, offers a new opportunity to enhance our understanding of urban microclimates. However, retrieving LST over urban landscapes is still challenging, mainly due to surface heterogeneity and the complex three-dimensional (3D) configuration of urban elements.

In this study, we employ radiative transfer simulations using the Discrete Anisotropic Radiative Transfer Model (DART) to investigate the impacts of 3D urban structures and material optical properties on LST estimation at the TRISHNA spatial resolution (60 m). DART operates by simulating radiance, calculated based on the emissivity and thermodynamic temperature of scene elements. Hence; our methodology entails generating 2304 different scene configurations to simulate TRISHNA-like thermal infrared (TIR) radiance from which LST is estimated based on the scene emissivity (LSE). These configurations account for the sensor setup, comprising a TIR instrument with four spectral bands (8-12 µm range), alongside numerous 3D urban morphologies and optical properties. The studied variables are sun angle, percentage of vegetation, urban morphology features (height, density, orientation), road width, and optical properties of materials (roof, wall, ground). By correlating simulated TRISHNA LST with surface characteristics, we identify the main parameters influencing LST in urban environments, paving the way for the development of a correction method at the satellite scale.

Random forests global sensitivity analysis reveals the importance of key variables governing LST variations in urban areas: vegetation (0.75), building density (0.14), sun angle (0.09), and building height (0.03). A more detailed analysis provides relevant insights given different scene configurations. For instance, the importance attributed to building density versus building height varies significantly depending on the presence of vegetation.

The findings of this study shed light on the relationship between urban morphology and LST estimation, providing a basis for tailored mitigation approaches. Our correction method for estimating LST should duly incorporate these insights, integrating *e.g.*, sophisticated algorithms for emissivity and thermal anisotropy correction. Additionally, validation against ground measurements is essential to ensure the reliability and precision of results. By addressing the influence of urban 3D variables on LST estimation, we aim to refine TRISHNA-derived LST accuracy, facilitating informed decision-making and policy development to tackle urban heat-related issues.

HEAT ROBUSTNESS IN RELATION TO AGEING CITIES (HERITAGE): FIRST SIMULATIONS

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Due to ongoing climate change and urbanization, societies face challenges concerning environmental quality, energy management and citizens' health. While many past observational and modelling studies concentrated on understanding urban microclimate and how humans experience this, focus has been on relatively modern infrastructure ("street canyons") regarding modelling and observational efforts which showed less success over historical districts. Many cities have a significant share of aged and historical buildings with unique and different street profiles from modern infrastructure, which raises additional challenges in the energy transition due to low energy-efficiency and restrictions to required interventions.

Within the HERITAGE research program we are developing a sensing system aiming at detection, reduction and prevention (by monitoring and design) of urban heat-stress in a realistic setting, where we aim at detecting (observations) and forecasting (simulations) spatiotemporal patterns of heat stress at resolutions down to 1 meter. This requires an observational modelling approach which ideally should utilize routinely collected urban hydro-meteorological observations and earth observation data that is operationally available. Utilizing our local urban observational infrastructure (in the city of Enschede), consisting of microwave and scintillometers, 4-component radiometer and turbulent flux (H_2O, CO_2 and heat) eddy-correlation sensors next to a spatially distributed urban micro-meteorological sensor network, we will develop such an approach.

Objective and generic determination of urban heat stress comes down to the determination of energy budgets. Calculating the energy budget at high resolutions depends on accurate representation building properties such as albedo, emissivity, and thermal capacity. The energy budgets relate to externally exposed thermal stresses on the human body by radiative, conductive and turbulent energy fluxes. The most relevant flux herein is the radiative flux, by emission and reflection, which can for a large part be provided by remote sensing. Future satellite missions, such as LSTM, CHIME, SBG and TRISHNA, have a more suitable temporal and spatial resolution for urban heat stress detection than current satellite constellations. Most urban climate simulations use generic values for building properties which are not representative of the realistic conditions, this gap can be bridged with inputs from remote sensing. In preparation thereof, quasi-synthetic simulations (employing the PALM4U model) of urban heat stress as experienced by humans, were performed over the city of Enschede, Netherlands to explore potential improvements. Results are shown for typically different Local Climate Zones, where use has been made of the above-mentioned observational infrastructure combined with readily available high-resolution imagery.

EVALUATION OF THE CONTRIBUTION OF TRISHNA SATELLITE THERMAL INFRARED DATA TO THE DETERMINATION OF THERMO-RADIATIVE PROPERTIES OF URBAN SURFACES FOR REFINING MICROCLIMATE URBAN MODELS

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The forthcoming TRISHNA satellite mission promises to offer a unique dataset of thermal infrared (TIR) imagery to study urban climate, with a planned spatial resolution of 57 meters and a minimum revisit every three days. Thus far, the utilization of satellite TIR data in micro-scale modeling has been limited primarily due to their definition's mismatch with the level of detail demanded by models. These models typically necessitate an explicit representation of urban surfaces at metric resolution, coupled with detailed parameterization. A primary challenge in microclimate modeling revolves around the thermo-radiative characterization of urban surfaces, known for their heterogeneity and often sparse documentation. Inadequate parameterization within microclimate models can lead to significant inaccuracies in land surface temperature (LST), air temperature, comfort indices, and building energy consumption.

This study aims to assess the potential of TRISHNA satellite TIR data in enhancing the determination of thermo-radiative properties of urban surfaces for refining microclimate urban models, particularly concerning outdoor summer comfort assessment.

Firstly, surface properties significantly impacting urban surface temperatures during summer, yet lacking precise estimation methods, are identified through comprehensive literature review. Thermal parameters as thermal conductivity and capacity are identified as interesting parameters for this study.

Secondly, a methodology for estimating the identified thermal properties is established and validated using an approach combining Solene and DART simulations. Solene-Microclimate, a 3D thermo-radiative model with metric resolution employed for outdoor summer comfort assessment, computes the temperature of surfaces within modeled urban environments. Then, the DART (Discrete Anisotropic Radiative Transfer) model is used to simulate corresponding top of canopy radiance from which TRISHNA-like LST at 60m is computed. To set up the proposed approach, an urban canyon street, representative of typical urban morphology, is designed. This street configuration is made of two buildings (70m long, 10m large, and 10m high), separated by a 10m large street. From it, an area of 60mx60m, equivalent to a TRISHNA pixel, is extracted. The Solene-DART coupling approach is run over the scene with varying thermo-radiative surface properties and resulting TRISHNA pixel LST values stored. Next, reference scenarios with known thermo-radiative properties are simulated. The Bayesian inference, selected in this study, is then employed to retrieve the surface property values of these reference scenarios based on the TRISHNA pixel LST of (i) the reference scenarios and (ii) the numerous configurations for which both the properties and TRISHNA LST are known. The estimated and reference properties are compared to evaluate the method’s performance. Promising results are obtained, highlighting significant improvement as compared to default thermal properties assigned without prior knowledge.

SURFACE ALBEDO AND EMISSIVITY FOR BELGIAN CITIES (SUABE)

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The large abundance of materials absorbing short-wave radiation from the Sun and the concentration of people make cities particularly vulnerable to the heat island effect. Although the surface albedo and emissivity of the materials in the urban fabric are key quantitative properties for heat pollution mitigation strategies, these are often lacking citywide. Observing cities from space with high-spatial resolution optical and thermal-infrared sensors can circumvent the in-situ stations’ spatial and temporal coverage limitations.

However, the measurements from space correspond to information relative to a limited number of satellite acquisition geometry and spectral bands, which prevents the accurate computation of needed quantities such as urban albedo maps. In order to extrapolate satellite observations to any upward directions and to the whole spectral domain of interest, a physical model considering the complex 3D structure of urban environments is needed. This contribution describes the SuaBe project, which focuses on designing and implementing a fast, and robust algorithm, that uses the 3D radiative transfer code DART (https://dart.omp.eu/#/) to invert remote sensing images of cities as a 3D distribution of optical properties and temperature, using a geometric urban database. This approach enables us to obtain a 3D model of a city to simulate urban surface albedo and emissivity maps at any date as long as the optical properties of urban elements remain constant. These optical properties can be up-dated with the inversion of recently acquired satellite imagery.

As a case study, we will apply it to Brussels to retrieve surface albedo and emissivity maps at a neighbourhood scale. These results can be considered an asset to be used by urban planners and decision-makers to identify what urban areas should be considered priority candidates for an intervention to mitigate heat pollution, which in turn, shall allow authorities or civil organisations to maximise benefits from limited financial resources. Since the SuaBe's methodology is based on a robust and rigorous physical model, it can be seamlessly implemented in any other city worldwide, provided that a geometric urban database is available.

CITYCLIM: MONITORING THE SURFACE URBAN HEAT ISLAND EFFECT OF EUROPEAN CITIES AT HIGH SPATIOTEMPORAL RESOLUTION USING DATA FUSION TECHNIQUES

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Climate change-induced heat waves are affecting urban areas, increasing year to year in both magnitude and frequency, leading to significant challenges to population well-being and health. In the context of the EU Horizon 2020 program, CityCLIM project aims to address this issue by developing a cloud-based platform to ease decision making for city administrations and citizens. This platform will offer comprehensive weather and climate services for metropolitan regions, using advances data sources as weather models, earth observation data, and ground measurements collected through city infrastructure and citizen science initiatives. As a key milestone of this project, we have developed a spaceborne data processor designed to monitor the urban heat island effect. This effect refers to the phenomenon where urban areas experience higher temperature than their rural surroundings due to human activities and infrastructure. Our service provides urban heat indices derived from a high spatiotemporal resolution Land Surface Temperature dataset produced through the fusion of data from multiple thermal infrared sensors aboard satellites such as Sentinel-2, Landsat, and Sentinel-3. Our approach involves a fusion framework incorporating methods like ubESTARFM and ATPRK. These methods are implemented within a cloud-based environment, allowing for an operational and efficient processing and analysis of large datasets. The resulting product, available through a GUI to final users, offers land surface temperature and multiple heat indices on a daily basis at 30-meter resolution.

SPATIAL AND TEMPORAL EVOLUTION CHARACTERISTICS OF URBAN HEAT ISLAND IN BEIJING AND DALIAN BASED ON MULTI-SOURCE DATA

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This study aims to use MYD11A2 product and auxiliary data to analyze the evolving trends and underlying influencing factors of Land Surface Temperature (LST) and Surface Urban Heat Island Intensity Index (SUHII) in Beijing and Dalian from 2003 to 2023. Initially, the rural background region was delineated using various datasets on the Google Earth Engine platform. Subsequently, the MYD11A2 product was utilized to calculate the LST on a monthly, seasonal, and annual basis. Then, with the use of the delineated rural background region, the day and night SUHII were also calculated, providing a comprehensive analysis of their spatiotemporal variations. Finally, with the aid of MOD13A2 Collection 6, LandScan Global, and HRLT datasets, Geographically and Temporally Weighted Regression (GTWR) was employed to analyze the driving force of SUHII in both cities from 2003 to 2018. The conclusion can be categorized into three main aspects: (1) An intensification of heat island effect in both cities was detected. Dalian experienced a higher growth rate during the day, in contrast to Beijing's trend at night. During this period, the areas without heat islands and those with stronger heat islands in Beijing decreased, whereas other areas increased; in Dalian, areas without heat islands and strong cold island areas decreased, with other areas expanding. (2) From 2003 to 2023, Beijing's heat islands, primarily located in the southeast, showed a trend of moving southwest. In contrast, Dalian's heat islands, mainly in the southwest, trended southeast. Dalian had more areas of weak heat islands and fewer strong islands compared to Beijing. (3) Between 2003 and 2018, SUHII showed a general negative correlation with Enhanced Vegetation Index (EVI), and positive correlations with Population Density (POP) and Annual Maximum Temperature (TEMP). The correlation with Evapotranspiration (ET) transitioned from a negative to positive correlation in Beijing, while the positive correlation decreased in Dalian. The correlation with Precipitation (PREP) varied between the two cities, transitioning gradually from positive to negative. These findings provide valuable scientific insights for urban planning and climate adaptation strategies.

* This work was supported by the General Program of National Natural Science Foundation of China under Grant 42271395. (Corresponding author: Caixia Gao)

CONTRIBUTION OF THE LAND SURFACE TEMPERATURE FOR A SPATIAL AND TEMPORAL ANALYSIS OF URBAN HEAT VULNERABILITY: COMPARISON OF DIFFERENT THERMAL DATA AND METHODS OVER THE FRENCH METROPOLIS OF TOULOUSE

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In France, 22 heatwaves have occurred between 2010 and 2022 out of 46 since 1947, becoming more frequent and intense. These temperature extremes are intensified by the Urban Heat Island (UHI) effect in urban areas leading to several impacts on population health, urban attractiveness and energy supply. Holistic approaches are needed to ensure the efficiency of adaptation and mitigation strategies for urban resilience. In this context, Heat Vulnerability Indices (HVI) are often defined from three components: Exposure, Sensitivity and Adaptive Capacity. They use social, economic, demographic and environmental information to map the intra-urban population vulnerability to heat and highlight priority areas for action. These maps mainly rely on Air Temperature (AT) or Land Surface Temperature (LST) to define exposure to heat. LST is available from different thermal satellite sensors: LANDSAT and ASTER provide maps with a relatively high spatial resolution, less than 100 meters, but with a low revisit around 2 weeks. MODIS provide daily maps but at low spatial resolution (1 kilometer). ECOSTRESS provides maps with a varying revisit at different times of the day at 70 meters. Indeed, these diverse characteristics provide different information about the spatial and temporal variability of the LST within urban areas. The literature about the use of LST to map the HVI has increased but recent reviews show some gaps in the generality of the methodology. Disparities between the methodologies exist as different variables are used according to available data and different methods for data analysis are considered to combine the components in a single HVI indicator. A few studies have compared different statistical approaches and different thermal sensors. Our work aims to provide some answers to the following question: what are the differences and similarities between HVI maps obtained from different statistical approaches and LST from different thermal sensors during the summer period? Thus, this study aims to analyze the spatio-temporal variability of the HVI according to the thermal sensor and the data analysis. First, thermal data from three spaceborne sensors that are MODIS, LANDSAT 8 and ECOSTRESS are collected to develop a dataset for the 2019 summer over the French metropolis of Toulouse (South-West of France), notably for the heatwave occurred in June and in July. A clustering of meteorological parameters measured from a weather station is considered to identify typical local weather types. Then, LST is both spatially and temporally analyzed during heatwave and non-heatwave events considering these local weather types, LCZs and land cover. Early results show significant hotter LST patterns during heatwave period. For HVI mapping, LST is used as the exposure component and aggregated at the IRIS scale which is the finest French administrative unit for intra-2 urban social indicators. The other vulnerability components that are Sensitivity and Adaptive Capacity are mapped and discussed. In the next steps of this ongoing work, different statistical approaches such as Unweighted Combination or Principal Component Analysis are applied and compared to provide an analysis of the spatio-temporal variability of the HVI.

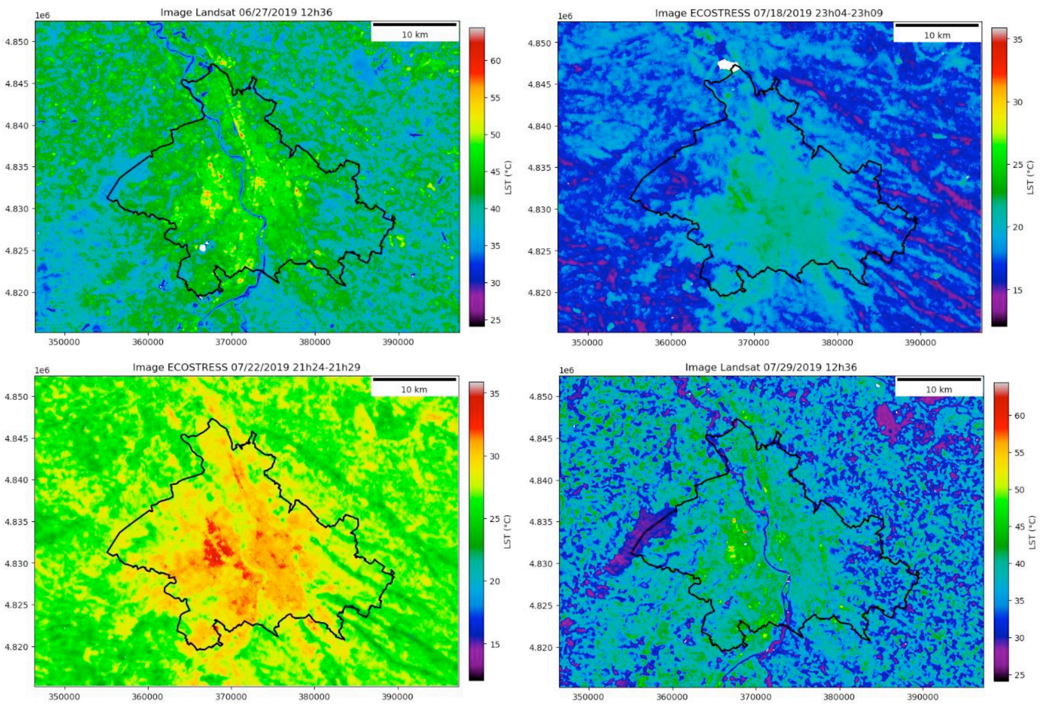

Figure 1: maps of the LST from LANDSAT 8 and ECOSTRESS during June and July heatwaves (left) and non-heatwave events (right). Significant hotter patterns are observed during heatwave for both daytime and nighttime

TEMPORAL ANALYSIS AND THE IMPACT OF URBAN HEAT ISLANDS IN THE PO VALLEY: INSIGHTS FROM REMOTE SENSING

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This study analyzes the evolution of the Urban Heat Island (UHI) in the Po Valley from 1985 to 2023, utilizing Landsat 5 and 8 satellite data. A total of 185 daytime images were selected for the summer months (June, July, and August) in a representative city within the region. The Land Surface Temperature (LST) within the city was compared with temperatures recorded by rural meteorological stations, considering time series data from 2000/2006 to 2023 due to availability.

The main objective is to perform a temporal analysis of the UHI phenomenon, focusing on comparing the variation of summer LST trends obtained from satellite data in the city of Modena, a densely urbanized area, and observed meteorological temperatures in rural areas. Remote sensing was utilized to calculate LST over three decades, allowing detailed assessment of temporal variations and trends.

Results reveal significant differences between LST trends obtained through satellite data and temperatures observed in rural areas, highlighting the impact and influence of urbanization on city temperature rise. This temporal analysis provides a detailed understanding of the relationship between urbanization and temperature increase, emphasizing the importance of extensive research and the crucial role of remote sensing in continuous trend monitoring.

SPATIOTEMPORAL EVOLUTION AND DRIVING FORCES ANALYSIS OF THE URBAN HEAT ISLAND IN SHIJIAZHUANG

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As a comprehensive reflection of the thermal characteristics of the urban environment, the urban heat island (UHI) effect has triggered a series of ecological and environmental issues. Existing studies on the UHI effect in Shijiazhuang have primarily focused on spatial-temporal distribution characteristics and migration trends, with a scarcity of analysis on the influence mechanisms of other contributing factors. This study takes Shijiazhuang city in China as the research setting, employing Landsat ETM+/OLI data spanning the years 2000 to 2020 as the source for remote sensing imagery. The mono-window Algorithm (MW) is used for quantitative retrieval and categorization of land surface temperature, analyzing the UHI's spatiotemporal traits. The SARIMA model is employed for projecting future land surface temperatures. By selecting diverse factors such as NDVI, DEM, POP, and NPP and employing spatial autocorrelation methods, the study uncovers the dynamic relationship between the UHI and these factors. A multi-scale analysis model has been developed to search for the optimum urban spatial scale, enabling a comprehensive assessment of the spatiotemporal evolution and drivers of the UHI in Shijiazhuang. The UHI effect in Shijiazhuang exhibits pronounced spatial clustering with an overall annual increase of 44.288 square kilometers and a centroid that shifts in a southeastward direction. Seasonal variations show a reduction in the UHI effect only during autumn, which also exhibits the most considerable centroid shift, while spring witnesses the least. Predictions indicate an intensifying UHI effect in the future, with peak land surface temperatures expected in the summer

of 2030. NDVI emerges as the most influential factor on Shijiazhuang's UHI effect, followed by DEM's apparent suppressive influence. Other factors exert a restraining influence on the UHI until 2005, after which they begin to promote it. The fit of geographical weighted regression models varies across different spatial scales, with the highest coefficient of determination achieved at a 3KM*3KM scale, where the MGWR model yields the best fit. The ranking of contributing factors to model prediction is as follows: NDVI > NPP > PPT > DEM > PM2.5 > POP > PET > GDP. Moreover, the interactive effects of these factors are significantly enhanced, particularly the interactions involving DEM and NDVI or PPT, which are the most substantial at 0.972.

SPATIOTEMPORAL TRACKING OF THE URBAN HEAT ISLAND IN VALENCIA AREA

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Valencia, on the western Mediterranean coast, is highly affected by hightemperature extremes. There have been about 34 heatwaves (HWs) in the last 45 years. Valencia has particularly high nighttime temperatures affecting human comfort and related mortality. Recent studies indicate that in Valencia, there is an increase of 8% of the mortality risk during heatwaves associated with the heatwave occurrence, independently from temperature.

The urban heat island effect (UHI) is the phenomenon of higher temperatures in urban areas compared to their surroundings and is particularly relevant in the context of climate change. A comprehensive understanding of the interaction of the urban heat island with extreme heat episodes is crucial for effectively developing mitigation and prevention measures to protect the population of densely populated areas.

The Mediterranean Center of Environmental Studies (CEAM) 's Meteorology and Climatology group has established a network of 74 temperature and humidity sensors (Hobo MX2302A) in the area of Valencia to monitor the UHI.

The sensor network aims to provide, for the first time, high-resolution spatiotemporal tracing of the urban heat island in the metropolitan area of Valencia (about 1,600,000 inhabitants), notably affected by high summer temperatures. Furthermore, 17 sensors will be measuring in Alzira (a city close to Valencia with 46,000 inhabitants). The sensors take a measure every ten minutes.

The data obtained will be crucial for a comprehensive analysis of the UHI and its interaction with HWs. Additionally, we will evaluate the correspondence of the UHI with the surface UHI given by instantaneous satellite images that will be compared with our sensor data.

ADVANCEMENTS IN LAND SURFACE TEMPERATURE AND EVAPOTRANSPIRATION RETRIEVAL FROM HIGH-RESOLUTION THERMAL INFRARED SATELLITE OBSERVATIONS

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Thermal infrared remote sensing is pivotal in mapping land surface temperature (LST) and evapotranspiration (ET) globally. LST indicates the thermal status of the land surface following the exchanges of water and heat with the atmosphere, thereby constraining the magnitude and variability of the surface energy balance (SEB) components. The current thermal missions fall short of meeting the demands for high spatiotemporal resolution observations in agricultural and ecological applications. To fill in this gap, multiple next-generation thermal missions are under preparation by various space agencies, including the CNES-ISRO TRISHNA mission, the NASA SBG mission, and the ESA LSTM mission. As a precursor to these missions, the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) has been delivering high spatiotemporal thermal infrared observations (~70 m, 1-5 day revisit time) since August 2018. Leveraging the ECOSTRESS observations, we aim to advance LST and ET retrieval models to accommodate the upcoming high-resolution thermal missions. To avoid the scale mismatch between the thermal radiance and atmospheric profiles, the temperature and emissivity separation (TES) algorithm is modified by incorporating a machine learning model into the atmospheric correction module. In this case, LST and emissivity can be retrieved simultaneously without running the atmospheric radiative transfer model. The preliminary results of ECOSTRESS LST estimates show that the machine learning-driven TES algorithm achieves comparable accuracy to the original TES with substantially simplified complexity. By integrating LST into the Penman-Monteith equation, the analytical SEB model Surface Temperature Initiated Closure (STIC) is developed by circumventing the empirical parameterization of aerodynamic and surface-canopy conductance. Evaluation of ET estimates from ECOSTRESS using STIC demonstrates the advantage of the analytical SEB model as compared to the other thermal-based parametric SEB models. The STIC ET estimates show notably higher accuracy than those using the NASA PT-JPL model that is weakly constrained by LST. To estimate daily ET from the instantaneous retrieval obtained at different times in a day, an ET upscaling method is developed by harnessing the extraterrestrial solar radiation modulated by various controlling factors during the course of the day across various ecosystems. Daily ET estimation results based on eddy covariance measurements show that the proposed upscaling method that requires easily accessible inputs performs the best as compared to the other widely used methods in general. These advancements represent a significant step forward for the operational generation of LST and ET products, offering improved accuracy and practicability. Furthermore, the development of these models shows promise in preparing for future high-resolution thermal missions, potentially enhancing our ability to monitor and understand land surface dynamics with greater spatial detail and accuracy.

QUANTIFYING THERMAL INFRARED DIRECTIONALITY OVER HETEROGENEOUS ENVIRONMENTS FROM OBSERVATIONS COLLECTED DURING A TWO-AIRBORNE CAMPAIGN

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Satellite observations of land surface temperature (LST) are key for environmental monitoring over agricultural, urban & other heterogeneous landscapes where point-based measurements cannot provide the necessary resolution. However viewing and illumination geometry are known to have significant impacts on satellite-retrieved LSTs in heterogeneous regions, where there are lots of components with different temperatures. At present, no operational algorithms account for these impacts, in part because of the difficulty of accurately quantifying them with either observations or models. With LST an Essential Climate Variable and the development of high resolution future thermal infrared missions (e.g. LSTM, SBG, TRISHNA), it is essential that further work is done to redress this.

As part of the LSTM development activities, a joint NASA-ESA airborne campaign focused on thermal directionality was conducted in Italy in the summer of 2023, led by the National Centre for Earth Observation at King's College London. This campaign involved concurrent acquisition across the longwave infrared (LWIR) region at both nadir and off-nadir viewing angles through the deployment of two aircraft flying simultaneously, each equipped with state-of-the-art LWIR hyperspectral instrumentation. Data was collected to enable simulation of angular effects at the satellite scale over both agricultural and urban surfaces, with the aim of understanding and potentially developing adjustments for wide view angle satellite-based LST retrievals and downstream applications. In-situ observations were collected additionally for assessment of the accuracy and stability of the airborne datasets.

This presentation details the airborne campaign, including the unique and novel data collection strategies and design modifications to retrieve high-quality hyperspectral data across different components in a scene at a variety of different viewing and illumination geometries over a time period where the real surface temperature and sun-sensor geometries are invariant. Preliminary results from the campaign are then presented as well as plans for analysis related to future satellite thermal missions.

VALIDATION OF SENTINEL-2 AUXILIARY DATA SINCE BEGINNING OF MISSION. PERIOD 2015-2024: COLLECTION-1 REPROCESSING AND OPERATIONAL PROCESSING. FOCUS ON AEROSOL OPTICAL DEPTH AT 550 NM AND TOTAL COLUMN OF WATER

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The Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. Since July 2015 it has been monitoring the variability in land surface conditions.

In complement of sentinel-2 imagery files, meteorological auxiliary data from European Centre for Medium-Range Weather Forecasts (ECMWF) are provided to the users within L1C and L2A products. The format (GRIB V1) and contents of this file are identical in L1C and L2A products. This auxiliary data is provided in a gridded format which results from a temporal (linear) and spatial interpolation (bilinear with a Ground Sample Distance of 12.5km) of the raw ECMWF global forecast dataset into a geographical area covering the Level-1C tiles footprint. Grid points are provided in latitude/longitude using WGS84 reference system. This meteorological auxiliary data file provides six parameters. An additional file provides a set of 10 atmospheric parameters from the Copernicus Atmosphere Monitoring Service (CAMS) that generates every day, five-day forecasts of aerosols, atmospheric pollutants, greenhouse gases, stratospheric ozone, and the UV-Index. This contribution reports on the monitoring of the two following parameters:

- Aerosol Optical Depth at 550 nm (extracted from AUX_CAMS_RE or AUX_CAMS_FO files)
- Total Column of Water (extracted from AUX_ECMWFT file).

The Aerosol Optical Depth at 550 nm can be used as atmospheric information fallback in the L2A processor when performing the atmospheric correction for certain Sentinel-2 tiles when not enough dark dense vegetation pixels are present to perform an independent aerosol retrieval. The Total Column of Water is not used in the L2A processor when performing the atmospheric correction. However, it is interesting to check how its performance compares with the L2A processor outputs.

The monitoring is performed on 24 different locations distributed over all continents and all climate zones using 24 AERONET stations. Thanks to the Sentinel-2 Collection-1 reprocessing, the data period covers about 9 years of data, between July 2015 to July 2024,

The values of AUX_CAMS_FO (or AUX_CAMS_RE) and AUX_ECMWFT are extracted at the AERONET site location using its geographic coordinates.

We present the results of the monitoring in the form of scatter plots of all the concomitant Sentinel-2 auxiliary CAMS data with respect to the AERONET data for all the 24 AERONET test sites. The quality of the AUX_CAMS_RE (Reanalysis data) from the Collection-1 reprocessing is slightly better than the AUX_CAMS_FO (Forecast data) inserted in operational processing.

OCEAN COLOR ALGORITHMS TO ESTIMATE THE CONCENTRATION OF PARTICULATE AND DISSOLVED ORGANIC CARBON IN SURFACE WATERS OF THE GLOBAL OPEN AND COASTAL OCEAN FROM MULTIPLE SATELLITE MISSIONS

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Carbon monitoring from space is critical for the reporting and verification of carbon stocks and changes in both coastal and open ocean waters. In the frame of the OCROC project, funded by the Copernicus 2 – 1st Service Evolution Call for Tenders (2022-2024), we focus on the particulate (*POC*) and dissolved (*DOC*) organic carbon of surface oceanic and coastal waters, which represent the two components of the total organic carbon (*TOC*) pool in the ocean. Due to their different role in the carbon cycle, as well as their different carbon export pathways toward the deep ocean, the spatio-temporal distribution of *POC* and *DOC* as well as their relative contributions to *TOC* have to be characterized over the global ocean. While surface *POC* spatio-temporal patterns are now relatively well described over open ocean waters, thanks to the availability of proper ocean color radiometry (OCR) algorithms, the spatio-temporal patterns of *POC* over coastal waters and *DOC* over open and coastal waters are still not well established. Knowing that *DOC* represents about 90% of *TOC* in open ocean waters, it is crucial to assess its spatio-temporal variability from remote sensing, especially to bring new insights to the carbon modeling community. Different *POC* and *DOC* algorithms, based on diverse approaches (semi-analytical, neural network, band-ratios) and input parameters (OCR, sea surface temperature, mixed layer depth) have been selected, modified, and tested on extensive match-up datasets. To better account for the bio-optical complexity of marine waters, and to better address the transition between coastal and open ocean waters, these different algorithms have been combined using an optical water class approach. This latter approach allows uncertainties on the *DOC* and *POC* retrieved products to be estimated at the pixel level. The main spatio-temporal patterns of *POC* and *DOC* with their associated uncertainties are then presented and discussed.

EVALUATION OF AN INVERSION APPROACH TO DISTRIBUTE SATELLITE LST OVER A 3D URBAN SCENE

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The upcoming satellite missions - TRISHNA, SBG and LSTM - will provide a unique source of thermal infrared (TIR) data to study urban climate. Despite their foreseen spatial resolutions up to fifty meters, it remains a challenge to derive Land surface Temperatures (LST) that can be used at the scale of the physical processes involved in a highly heterogeneous and poorly documented 3D urban environment. Super-resolution methods have been proposed to recover the local variability of the LST. However, none of them has focused on the 3D distribution of LST in the scene, especially for vertical surfaces, which is a significant limitation for the estimation of air temperature or comfort indices. Surface temperatures distributed over all urban surfaces are an essential information for a number of applications, in particular for fine-scale urban microclimate modelling. This is the main reason why satellite TIR data have not yet been widely used in micro-scale models, which are based on an explicit representation of the urban surface at metric resolution and a detailed parameterisation. However, using satellite IRT data to document these models would make it possible to overcome assumptions about the thermo-radiative properties of surfaces, which are often approximated due to a lack of information, and thus enhance their accuracy.

This study investigates the potential of an inversion approach to distribute the LST from a 60 m pixel (TRISHNA/SBG spatial resolution) over the observed 3D scene based on a Solene-DART models chaining. The considered scene is divided into three surface types - roof, ground and wall - with a distinction between sunlit and shaded areas. The first step is to investigate the physical processes that influence the distribution of surface temperatures in the 3D scene. To this end, fine-scale simulations are performed with the Solene-Microclimate thermo-radiative model for a representative sample of 3D urban configurations with varying geometries and optical properties. These simulations provide hourly surface temperature values for each metric mesh of a 3D mock-up along with corresponding surface and radiative parameters such as short and longwave fluxes or sky view factor. A feature selection method is then applied to identify the most influencing parameters for the inversion. In a second step, the fine-scale surface temperatures simulated with Solene are provided to the DART radiative model in order to simulate the corresponding LST of a 60 m pixel that would be acquired by a nadir-looking satellite IRT sensor. This Solene-DART chaining allows to generate a large dataset consisting of satellite LST and their 3D distribution for 2340 different urban configurations. Based on this dataset, several inversion approaches are tested to distribute the LST of the pixel over the three main surface types (roof, road, wall) of the 3D scene, using the parameters identified previously to constrain the inversion. The conclusion presents the best approach and the accuracy that can be achieved for the distribution of LST over the 3D urban scene in the context of the future satellite mission TIR

data, paving the way for their use in micro-scale models.

HEAT ROBUSTNESS IN RELATION TO AGEING CITIES (HERITAGE) PROGRAM: FIRST OBSERVATIONS

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The HERITAGE research program intends to develop a high-tech sensing and design system aiming at detection, reduction and prevention (by monitoring and design) of urban heat-stress occurring due to ageing of built environmental settings and buildings in cities, through socio-technical solutions. This integral system will detect and forecast spatiotemporal patterns of heat stress at unprecedented resolutions (1m scale), aiming at technological solutions to reduce and mitigate indoor and outdoor heat stress through developing urban design guidelines and connecting the energy transition, housing demands, repurposing areas, climate adaptation and digitalization.

The HERITAGE system necessitates a multi-disciplinary approach involving earth observation, urban hydro-meteorology and climatology, urban design and sustainable infrastructural energy systems. Therefore, parallel to the sensing, long-term research lines are rolled out on robust hydro-meteorological, design and energy solutions, at multiple spatiotemporal scales and forms. Concretely, these research lines fill knowledge gaps in climate policies through innovative techniques for analysis, simulation, development and experimental testing of newly designed multiscale urban heritage canopy layer schemes for climate models, multiscale form-microclimatic relationships and sustainable energy systems, suited for application in aged neighborhoods and buildings.

Reflected and emitted solar and thermal radiation can be considered the main drivers for turbulent and radiative heat exchange and thus for urban heat. However, their use from remote sensing observations in urban areas is still in its infancy and rather simplistic in its modelling approach. The above-mentioned multiscale schemes and relationships will be developed in the cities of Amsterdam, Rotterdam, Eindhoven, Delft and Enschede, where we collect ground-based, air- and space-borne radiative observations and heat-exchanges at matching scales. We cover space-time resolutions from submeter to kilometer and from 100 Hz to hours, monitoring the exchange processes at the relevant scales. The observations will be employed to develop scale-dependent heat-exchange parameterizations, suitable for 3D city models at building-, street-, and neighborhood-level. In this contribution the first observations are presented.

HIGH SPATIOTEMPORAL RESOLUTION URBAN LAND SURFACE TEMPERATURE PREDICTION BASED ON BUILDING SHADOW RATESS USING DEEP LEARNING MODEL

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Urban land surface temperature (LST) is pivotal for assessing urban heat island effect, understanding water heat dynamics, and formulating sustainable strategies, illuminating the complex interactions between humans and their environment. While previous studies have primarily examined vegetation cooling effects and the warming influence of building morphology (e.g., building height and density) on urban land surface temperature, the significant role of building shadows in influencing LST has often been overlooked. The spatiotemporal variations in building shadows demonstrate significant advantages and potential applications in obtaining urban land surface temperature products. Moreover, the generation of long-term land surface temperature datasets using thermal infrared data fusion and sinusoidal prediction methods frequently yields datasets with limited spatiotemporal resolution, resulting in datasets containing numerous trend extrapolations. This study introduces a novel approach for redistributing urban surface temperature at high spatiotemporal resolution by leveraging building shadow rates. By integrating thermal infrared data from Landsat, ECOSTRESS, and SDGSat-1, along with hourly daytime high-resolution building shadow rates and hourly radiation data from a near-real-time monitoring system, a deep learning model is employed to predict urban land surface temperature. The hourly results at 30-meter resolution demonstrate a strong consistency compared to ground observations in Beijing, China, achieving an R-squared value of 0.80. Furthermore, our methodology excels in the granularity of urban thermal mapping, offering critical insights for urban planners to effectively assess the cooling effects of building shadows and improve thermal comfort. The results underscore the potential of integrating building shadows using remote sensing data with a deep learning model to advance our understanding of urban thermal dynamics and mitigate the impacts of urban heat islands. Building shadows can also influence potential evapotranspiration by altering land surface temperature, radiation balance, and moisture availability, thereby impacting the urban thermal environment. Proposing shadow-guided deep learning networks as an enhanced framework for urban land surface temperature prediction, future research could further investigate the temporal variability of building shadows and their implications for seasonal and long-term urban thermal dynamics.

CONSTELLR HIVE CONSTELLATION – HIGH RESOLUTION THERMAL INSIGHTS FOR ENVIRONMENTAL MONITORING

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The importance of thermal remote sensing satellite data has become increasingly recognised for environmental monitoring in the recent years. Specifically, in providing valuable information on the earth's land surfaces. Monitoring plant canopies, which can be used to diagnose water stress and drought conditions, or the temperature of urban areas are examples of applications getting more crucial in the next years. Thermal data, with its unique capacity to capture temperature variations, brings an unexplored added value for understanding these processes. Thermal imaging also provides much-needed information on soil moisture status in regions where data are scarce. The use of thermal remote sensing data has been widely recognized as a contributor to large-scale environmental monitoring. It has enabled getting more insights from a variety of resource management domains, including agriculture, forestry, geological resources, water resources, cryosphere, atmosphere, and analytics for climate change.

Unfortunately, current thermal satellite data are either only available in very high to high temporal resolution (sub-daily to sub hourly) with a quite coarse spatial resolution (>1,000m) (e.g. MODIS; VIIRS, geostationary Meteo satellites) or in a low temporal resolution and moderate spatial resolution of 70-100m (e.g. Landsat 8/9, Ecostress, Aster). Such data are therefore only of limited suitability when regular monitoring of small-scale environmental factors is required.

constellr develops a constellation of new state-of-the-art satellites covering the visible, near

infrared, and thermal infrared parts of the electromagnetic spectrum at a spatial and temporal high-resolution, planned for launch by the end of 2024. The HiVE (High-precision Versatile Ecosphere monitoring mission) constellation comprises micro-satellites in the 100 kg class, orbits in a sun-synchronous plane at an altitude of about 550 kilometers. With a remarkable 1-day global temporal resolution (5 sat from 2026), 30 meters spatial resolution, and up to 1.5 K absolute temperature accuracy, HiVE is uniquely equipped with a cryo-cooled thermal detector to provide accurate and timely data for environmental monitoring. constellr has developed a proprietary LST retrieval algorithm: based on Top of Atmosphere (TOA) radiance and atmospheric condition, emissivity and temperature estimations are performed. This enables capturing the vegetation dynamic related to specific vegetation types and growth stages.

For improved temperature monitoring constellr is leveraging its proprietary data, but also imagery from multiple public missions to provide timely and highly scalable solutions.

Besides presenting the mission concept, status, and planned validation activities for the HiVE constellation we will showcase the use of constellr HiVE data and harmonized public data for different use cases in agriculture and urban monitoring.

LONG-TERM TRENDS OF LAND SURFACE TEMPERATURE OVER EUROPE DERIVED FROM A DAYTIME NORMALIZED AVHRR TIME SERIES

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For monitoring conditions repeatedly over large areas, satellite derived Land Surface Temperature (LST) has become an indispensable tool. However, to make climate relevant statements and quantify the impact of land surface variables over long time, we need sensors that are available for more than 30 years. The AVHRR is the only sensor providing spatially and temporally continuous, daily measurements for 40 years. The TIMELINE project of the German Aerospace Center (DLR) aims at the generation of a homogeneous multi-decadal time series from AVHRR data (3 different AVHRR sensors on 16 NOAA platforms) over Europe and North Africa [1]. However, different observation times of the AVHRR sensors affect the observed temperature and therefore the AVHRR LST time series [2]. In addition, the orbital drift effect, resulting in a slowly changing observation time during the lifetime of one sensor is influencing the time series.

In the past, several methods have been developed to account for the effect of varying acquisition times on the AVHRR LST time series. An important requirement for these methods is that they preserve the actual trends in LST. The methods can be classified into physical and statistical methods. While statistical models use the regression between the LST anomalies and the corresponding sun zenith angle (SZA) anomalies, the physical methods model the daily temperature circle at the given location. The statistical models have already shown accurate results; however, they are computationally expensive and their performance depends a lot on the data availability of the respective pixel. Therefore, they have been only tested for single pixels [3-5]. The physical models have been already applied to larger areas, however their diurnal LST cycle models are largely generalized and therefore linked to high uncertainties [6].

In this study we have combined our AVHRR LST time series with geostationary SEVIRI LST data. The daytime normalization is performed via correction terms, which are derived individually for every pixel from a typical diurnal cycle model build on the SEVIRI observations [7]. The resulting dataset provides daily maximum LST in 1 km resolution for the last 40 years for Central and Western Europe. The time series was already compared to the CCI LST time series for the years 1996-2016 and to air temperature measurements for the whole period showing a high accordance. Furthermore, we validated the product, by comparing observations from different NOAA platforms on the same day.

Here, we show the first analysis of long-term LST trends in 1 km resolution over Europe. The trends were calculated by conducting the Mann-Kendall significance test and calculating the Theil Sen slope. Only significant trends with a significance level $p < 0.1$ were analysed. Furthermore, we classified the trends regarding land cover and elevation. Thus, we are presenting a unique dataset, allowing a wide range of applications in the context of climate and land surface change.

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RIVERS' SURFACE TOPOGRAPHY MONITORING EXPLOITING SWOT L2 RIVER PRODUCTS AND REPROCESSED PICX: CASE OF THE CANALIZED RHINE AND ITS LATERAL BY-PASSED SEGMENTS (FRANCE)

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A preliminary assessment of SWOT L2 River products has been carried out over the Rhine River, along 180 km of the German-French border exploiting the daily Cal/Val SWOT data (end of March to mid-July 2023).

This area is particularly interesting as two hydraulic objects are running in. The Western one, the canalized Rhine, presenting a succession of 10 hydropower dams, i.e. like a succession of gently sloping basins, is returning to a free river course after the Iffenzheim dam. On the Eastern side, the Old Rhine, a by-passed segment, is flowing in more natural conditions, beginning with a first free segment of 50 km. Then the Old Rhine corresponds of about ten km, very largely entropized segments, flowing at a lower altitude of about ten meters. The difference in gradient is recovered by a series of metric weirs. At the level of a hydroelectric dam, the North-South offset will be 12-14 meters, with a lateral East-West offset of 8-10 m.
Preliminary work consisted in setting up a database containing water elevation over about 40 gauge stations collected from French and German agencies (VNF, DREAL, WSV, LUBW and EDF). Several stand-alone stations plus additional gauges were also installed, as well as few limnimetric scales (OECS). Drone flights were also carried out to measure the water surface elevation and slopes.

The first analysis covered SWOT L2 HR River Node and Reach products using the SWORD V14 river database, but also SWOT HR L2 PIXC (pixel cloud) products. It was done as follows comparing:

- Insitu water elevations and the ones provided by the SWOT HR L2River products at the node and reach scales.
- Slope provided by the SWOT HR L2 River Reach products and the ones derived from the insitu measurements.
- Insitu water elevations and the ones provided by the SWOT HR L2 PIXC product.
- Evaluation of the accuracy of the PIXC classes (water, water near land, dark water, etc.).

For most of the stations, we observed at the node scale a 1-sigma difference between SWOT water elevation and in situ reference data over all Cal/Val cycles of about 10 cm, both on the canalized and the free-running part of the river. However, for a proper assessment of the quality of SWOT measurements via SWOT HR L2 River products at local level, it is essential to first evaluate the quality of the SWoRD database. And that by an inaccurate SWORD centerline, which does not respect the true river morphology, that SWOT L2 products is not biased. For this reason a customized river database, with a more realistic description of the Rhine's parallel courses, and of the position of structures (dams, locks, weirs), was used to reprocess the SWOT HR L2 River products, using the open source RiverObs tool.

These preliminary analyses show water surface elevation errors lower than the SWOT requirements, for most of the cases.

MONITORING GRASSLANDS IN WALLONIA (BELGIUM) USING MULTISPECTRAL AND HYPERSPECTRAL SATELLITE IMAGERY

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In Wallonia, Belgium, grasslands span approximately 367,200 hectares and constitute the predominant land cover category, making up 47% of the utilized agricultural area. The management of grassland pastures is crucial for sustainable agriculture, particularly in in the context of climatic change and economic situation. This study focuses on an approach that utilizes satellite imagery and a grass growth model to estimate grass traits (biomass and quality). An intensive field campaign was carried out in 2022 and 2023 (from March to November) on 71 permanent grasslands parcels distributed in Wallonia. Compressed sward height (CSH) has been measured weekly with an electronic plate meter and fresh/dry biomass and fodder quality on a monthly basis.

The Leaf Area Index (LAI) obtained from Sentinel 2 (S2) correlates with field measurements for biomass estimation. Integrating the Generic Growth Model (GGM) with remote sensing data enables the estimation and prediction of grass growth, achieving a Root Mean Square Error (RMSE) ranging from 367 to 482 kg of dry matter per hectare on a daily basis.

The use of PRISMA (PRecursore IperSpettrale della Missione Applicativa) hyperspectral imagery helps detect and study the characteristics of grassland fields. By using the detailed spectral data from PRISMA, our method focuses on the thorough spectral analysis of grass, allowing us to identify vegetation indices that estimate grass quality. This includes analyzing specific bands such as the blue and red bands, which are crucial for assessing chlorophyll content—important for understanding vegetation vigor and health. By focusing on these specific wavelengths, we are able to identify vegetation indices that accurately estimate grass quality.

The objective is to develop a robust model that can interpret the complex spectral signatures characteristic of different grassland conditions, by processing both the Visible and Near-Infrared (VNIR) and the Short-Wave Infrared (SWIR) cubes of the hyperspectral image data. Specific bands are targeted to extract maximum ecological and agricultural insights. For instance, the bands at 1390 nm and 715–725 nm are used to estimate Acid Detergent Fiber (ADF), which reflects the indigestible cellulose and lignin in plant materials. The 715-725 nm band, near the red edge, is particularly important for assessing plant structural components, while 1390 nm provides insights into more complex organic compositions. Additionally, the estimation of Neutral Detergent Fiber (NDF), which includes hemicellulose as well as cellulose and lignin, utilizes bands at 400 nm, 983 nm, 1350 nm, and 1800 nm. These bands, ranging from the visible spectrum to the near and shortwave infrared regions, are essential for revealing plant characteristics, while also being sensitive to the plant's moisture content and structural integrity.

This research not only provides insights into the spatial variability of pasture quality but also introduces a scalable technique for monitoring and managing grasslands more effectively. The implications of this study are significant, offering a potential for improved pasture management practices that can lead to increased agricultural productivity and sustainability.

ANALYSIS READY DATA (ARD) AT PLANET: TOWARDS CUBESAT-ENABLED SENSOR AGNOSTIC SURFACE REFLECTANCE PRODUCTS ENHANCED IN RESOLUTION, QUALITY, AND INTEROPERABILITY

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A geospatial data revolution is upon us. The rapidly growing amount of multi-constellation, multi-sensor, and multi-modality sensor observations provide game-changing opportunities for deriving high quality products significantly enhanced in spatial and temporal resolution. However these distributed observations are typically not directly interoperable and require significant preparation to add value and enable actionable insights.

At Planet, we have developed a rigorous methodology to enhance, harmonize, inter-calibrate, and fuse cross-sensor data streams to deliver scientific grade analysis ready data (ARD) products with unprecedented spatio-temporal resolution and consistency. The Planet Fusion surface reflectance (SR) product adopts an implementation of the CubeSat-Enabled Spatio-Temporal Enhancement Method (CESTEM) to leverage rigorously calibrated public mission satellite data (i.e., Sentinel-2, Landsat 8/9, MODIS, VIIRS) in synergy with higher spatial (~3 m) and temporal (~daily) resolution data provided by Planet's global monitoring constellation of around 180 CubeSats (the PlanetScope constellation). Planet Fusion harvests unique traits of distributed sensor data and exploits Deep temporal information to effectively integrate and radiometrically and geometrically harmonize the data for full fleet interoperability. Planet Fusion processing includes advanced temporally driven functionality related to cloud and cloud shadow masking, and gap-filling to deliver a next generation analysis ready SR product (daily, 3 m) intended as a core "building" block for enabling higher level product development towards timely, usable, and actionable insights.

This presentation will provide an overview of the developed technology including recent advances related to multi-modality (i.e., SAR - Optical) data fusion, and demonstrate its promise for delivering added-value, high resolution, and trustworthy insights into SR dynamics. In addition, an extension of the SR harmonization methodology to Planet's very high resolution (~50 cm) SkySat tasking imagery will be showcased. For that purpose, daily Planet Fusion SR imagery (3 m) will serve as a clear-sky reference for cloud screening, and radiometrically and geometrically harmonizing day coinciden SkySat acquisitions. This process effectively calibrates raw SkySat images into high fidelity SR data that is interoperable with the Planet Fusion data. This functionality will be beneficial for tip and cue applications that rely on the CubeSat/PlanetScope constellation for tipping the SkySat constellation to take a closer look at a detected event/change where accurate surface reflectances are required.

SATELLITE-BASED L-VOD MONITORING OF GLOBAL CARBON BALANCE OF FORESTS

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Monitoring forest carbon (C) stocks is essential to better understand the global carbon balance and to predict long-term trends and inter-annual variability of atmospheric CO2 concentrations. National Forest Inventories (NFI) provide estimates of forest C stocks at the national scale, but with limitations (i) in space, being available only for some countries and providing only local information and not continuous mapping (ii) in time, with a periodic revisit every 5 to 10 years.

In this context, remote sensing offers many advantages for monitoring above-ground biomass (AGB) on a global scale and overcoming the time and space limitations of NFI. For this reason, remote sensing has been used for several decades to monitor forest C stocks, but traditional methods for monitoring aboveground biomass (AGB) are affected by saturation effects when AGB exceeds about 100 t/ha.

In the last decade, passive microwave remote sensing at L-band, which is less affected by these saturation effects, has emerged as a key method for monitoring forest C stocks through the use of the L-band Vegetation Optical Depth (L-VOD) microwave vegetation index.

L-VOD allows monitoring of forests up to AGB levels of about 400 t/ha at L-band, and despite its coarse spatial resolution of the order of 25 km x 25 km, L-VOD is one of the few satellite-based approaches available for monitoring annual variations in forest AGB on a continental scale. L-VOD has been applied to forest monitoring in all continents and biomes over the last two decades, based on the SMOS (Soil Moisture and Ocean Salinity; 2010-present) and SMAP (Soil Moisture Active Passive; 2015-present) observations.

In this communication, we review the main applications of L-VOD for tracking the carbon balance of vegetation (2010-2023), including recent results at the global scale and in the tropics (South America, Africa, Asia), in the boreal regions (Siberia, Canada), and at the national scale, including Europe, China, Australia, and the USA.

MISSION STATEMENT OF WORK OF PRECURSOR - ECO, INTA'S SAR MISSION BASED ON COLLABORATIVE SMALL SATELLITES

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En el año 2018, con el lanzamiento del satélite SAR PAZ el 22 de febrero de 2018, España entró a formar parte del selecto grupo de naciones que disponen de una misión espacial SAR.
Si bien las ventajas del desarrollo y uso de misiones espaciales SAR de las denominadas tradicionales resulta indiscutible, tanto por las prestaciones de los productos obtenidos con ellas, como por el amplio plazo de vida operativa de las mismas, la tendencia actual es la de complementar este tipo de misiones con otras englobadas en el denominado New Space, esto es, misiones conformadas por satélites de menor coste y tamaño, que implican menor tiempo de desarrollo y en consecuencia, menor periodo de vida útil de la misión.
En esta línea, el Instituto Nacional de Técnica Aeroespacial, INTA, ha comenzado el estudio de una misión SAR espacial New Space denominada Precursor-ECO [1]. Se trata de una misión completamente desarrollada en el INTA, por lo que su desarrollo requiere llevar a cabo el proceso completo de gestión de misión espacial.

El objetivo del presente artículo es presentar la primera fase del proceso de gestión de proyecto espacial, que es la definición del Mission Statement of Work de la misión PRECURSOR-ECO
Para ello, se selecciona el emplear la metodología de gestión de proyectos desarrollada en Europa por la ECSS (European Cooperation on Space Standardization) que identifica el conjunto de procesos que deben ser llevados a cabo, así como la programación y priorización de las actividades necesarias que aseguren la ejecución total del proyecto, desde el inicio al fin del mismo, a todos los niveles de la cadena cliente-suministrador, de una manera eficiente y estructurada.

Los principales puntos que se deben analizar para obtener la definición de la misión PRECURSOR-ECO, son:

- El análisis de los requisitos de la misión identificados por el conjunto de usuarios científicos de PAZ y miembros del grupo SAR de la Asociación Española de Teledetección. Para ello se ha realizado una encuesta circulada a dichos usuarios, para recoger sus necesidades y requisitos en cuanto a banda de trabajo, modos de imagen, resolución o niveles de procesado.

- En base a estos y teniendo en cuenta las necesidades a ser cubiertas por la misión PRECURSOR-ECO:
    - Definición de objetivos fundamentales de la misión
    - Definición y análisis de la órbita de la misión
    - Identificación de usuarios potenciales
    - Análisis preliminar de los modos de imagen y niveles de procesado

[1] M. García, JM. Cuerda, MJ. González, E. Vega, N. Alfaro, " Development Status of PRECURSOR-ECO, INTA SAR Mission Based on Collaborative Small Satellites," EUSAR 2024

ALGORITHMS FOR MONITORING POLLUTING EVENTS IN THE MARINE ECOSYSTEM

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The marine environment supports diverse marine life, which is essential for global biodiversity. The oceans cover 71% of the Earth's surface and provide crucial resources to our economy and quality of life, including climate regulation, erosion prevention, solar energy storage and carbon dioxide absorption. However, the oceans are rapidly deteriorating, mainly due to anthropogenic pollutants. Oil spills, generally characterised as the release of hydrocarbons, can occur from offshore oil platforms, refineries, pipelines, chemical plants, treatment facilities or in deliberate oil discharges and transport accidents. Pollutants caused by these substances and other threats, such as plastic waste, are a significant concern in today's major environmental disasters. This has prompted the introduction of many EU legislative measures and policies as it represents a problem with a considerable impact on health and a sustainable blue economy. The objective of the PERSEO project is to develop an autonomous aerial platform dedicated to monitoring the marine environment to detect and monitor possible discharges of pollutants such as hydrocarbons or organic spills. To meet the aforementioned objective, the project has developed algorithms that make it possible to detect this type of event, which is why it is essential to carry out pilot tests in natural environments. For the observation of the identified variables, two different areas have been determined concerning their function and influence on seawater pollution. Therefore, the commercial port of Las Palmas and the tourist port of Puerto Mogán, both in Gran Canaria, have been chosen. Considering their differences throughout the year, two fundamental periods were identified to evaluate and observe the different variables. The observed periods were October 2023 and March 2024. Thanks to the identification of the various periods, it has been possible to observe different variations to identify common patterns in both observation areas.

EVALUATION AND TREND STUDY OF SATELLITE-BASED PRECIPITATION INDICES OVER THE IBERIAN PENINSULA

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Climate change is altering precipitation regimes, with notable effects in the Mediterranean regions. There have been reports on increased torrentiality and hydric stress over the Iberian Mediterranean Basin, which could affect fresh water availability and ecosystems. It is thus necessary to correctly monitor precipitation and study its evolution.

The precipitation indices of the Expert Team on Climate Change Detection and Indices (ETCCDI) and the Standardised Precipitation Index (SPI) are widely-used tools for these objectives, as they take into account regional characteristics and inform about extreme events. Regarding instrumentation, Satellite precipitation products (SPPs) constitute an interesting complement to ground gauges; however, their indirect measurement introduces unavoidable uncertainties.

In this study, we evaluated the suitability of three widely used SPPs to monitor the ETCCDI and SPI indices over the Iberian Peninsula for the 2001-2020 period. The evaluated ETCCDI indices have been RX1day, RX5day, R95p, R99p, SDII, PRCPTOT, CDD and CWD, and we have evaluated SPI at 1-, 3-, 6-, 9- and 12-month scales. The chosen SPPs have been CMORPH V1.0, IMERG V07A Final Run and MSWEP V2.8 Past, all at daily resolution. As ground truth, we have relied on AEMET 5 km grid v2, reescaled to 0.25º (CMORPH resolution) and 0.1º (IMERG and MSWEP resolution). For every pixel, we computed the Correlation Coefficient (CC), mean Bias and Root Mean Square Error (RMSE) between the SPPs-based and AEMET-based indices, and estimated the indice trends through the study period using a modified Mann-Kendall test and the Theil-Sen Slope estimator.

Regarding ETCCDI indices, R95p, R99p, PRCPTOT and SDII show relevant correlations (mainly between [0.4, 0.9] for IMERG and MSWEP and between [0.2, 0.8] for CMORPH), but their relative RMSEs are suboptimal (between [10%, 55%]). Similarly, SPI at all scales show high correlation (mainly > 0.6 for CMORPH and > 0.8 for IMERG and MSWEP) and extremely high relative RMSEs. Regarding the significative trends, there is just partial spatial agreement between AEMET and the SPPS for the aforementioned ETCCDI indices, with MSWEP closest to reference ones. The main findings include increasing torrentiality across the northern coast, parts of Catalonia and the Segura basin, and decreasing torrentiality in sparse inner regions. As for the SPI, AEMET, IMERG and MSWEP agree considerably for all scales. They all yield trends towards wetter conditions over most of the northern Peninsula, the Segura basin and sparse inner regions, and trends towards drier conditions elsewhere. In addition, these trends become more important for longer accumulation periods.

To conclude, torrentiality and wetness are both increasing and decreasing across different regions of the Iberian Peninsula, with torrentiality trends being more regionalised than wetness trends. MSWEP is the most reliable SPP among the three products, and shows great potential for monitoring these climate-cha nge related indices.

The study was conducted within the framework of the project Tool4Extreme PID2020-118797RBI00 funded by MCIN/AEI/10.13039/501100011033, and also the project PROMETEO/2021/016 funded by Generalitat Valenciana.

ESTIMATION OF HIGH-RESOLUTION CROP WATER CONSUMPTION FROM GF-6 SATELLITE

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The crop is the key parameter that linking the energy and water cycle, is the core indicator of the balance of the crop water consumption and water requirement, and is indispensable and meaningful for the efficient regulation of agricultural water resource management and the improvement of agricultural water use efficiency. The WFV sensor of Chinese Gaofen-6 (GF-6) satellite has the advantage of providing wide coverage (almost 800 km) remotely sensed images with high revisit frequency (almost four days) and high spatial resolution (16 m). In this study, a two-leaf carbon-water coupled model that based on two-leaf light utilization ratio model and two-leaf Penman-Monteith model was constructed, and then the model was used to estimate crop water consumption of winter wheat and summer maize by combing the Chinese GF-6 satellite images and meteorological data from the ERA-5 reanalysis dataset in Hengshui of China. The results showed that the crop water consumption can be estimated with root-mean-square error (RMSE) of 23.0 W/m^2 and 19.0 W/m^2 in BE-Lon and DE-Geb sites which planted with winter wheat and summer maize. Two scene GF-6 data in the growing season of winter wheat and summer maize selected from a total of 45 scenes of atmospherically corrected GF-6 imagery were used to calculated the Normalized Difference Vegetation Index (NDVI) and then were applied to acquiring the regional crop water consumption in Hengshui, Hebei in this study. The estimated crop water consumption in Hengshui had a range of 0~5.66 mm/day. The average crop water consumption was 3.81 mm/day with a maximum of 5.63 mm/day in the growing season of winter wheat (May 2nd, 2019), while the average crop water consumption was 4.45 mm/day with a maximum of 5.26 mm/day in the growing season of summer maize (September 18th, 2019). Compared to the values from MOD16, the estimated crop water consumption using GF-6 data had finer texture and higher values. This study increases insight into the potential and application of the GF-6 data in regional crop water consumption simulation.

SOIL MOISTURE RETRIEVAL WITHIN THE FRAMEWORK OF THE KORTDRANN2O PROJECT

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The aim of the KortDranN2O initiative is to provide robust figures for nitrous oxide (N2O) emissions from poorly drained mineral soils within Denmark and develop a methodology to identify these waterlogged areas in the landscape. A poor drainage condition is defined h ere a s a fi eld ar ea th at is waterlogged to near the soil surface for extended periods of time. The calculation of N2O emissions from poorly drained fields is important, as studies have shown that emissions can be 2-10 times higher than from well-drained fields [1]. As t he Danish n ational g reenhouse g as i nventory i s p rimarily b ased o n emisión factors estimated on well drained soils, the national emissions are thus most likely highly underestimated.

In Denmark, approximately 1.2 million hectares (ha) of agricultural land are artificially drained to improve yield potential [2]. However, the drainage conditions of some of these areas have deteriorated over the last 50 years due to climate change, soil compaction and lack of maintenance of drainage systems. It is estimated that there are 200,000-300,000 ha of poorly drained soils in Denmark and N2O emissions from these areas may account for 3% of the total CO2 equivalent reduction requirement from agriculture in 2050 (figures provided by the Landbrugsstyrelsen (the Danish Agricultural A gency)). To ensure scalability and the eventual transition of the project's modelling approaches into operational algorithms for a nationwide greenhouse gas emission survey, it is crucial to establish efficient an d de pendable methods fo r mapping soil moisture and characterizing drainage properties across cultivated areas. To accomplish this, the utilization of Sentinel-1 (C-band) data has been suggested as a way to derive surface soil moisture estimates. Previous research has established that its normalised backscatter retains soil moisture dependency at a 100 m scale, yet its retrieval remains challenging [3]. This study presents an implementation of the short-term change detection (STCD) method proposed by Balenzano et al. [4], and further developed by Mengen et al. [5], validated against the Danish Hydrological Observatory (HOBE) [6][7] in-situ measurements between the years 2018 and 2020. The impact of key algorithm parameters, such as the spatial-averaging (multilooking) factors, and the temporal window size used in the inversion, were investigated. Some preliminary results of the soil moisture estimates over the fields designated for the KortDranN2O project are also discussed. Said areas have undergone different drainage treatments at a sub-field scale, in order to assess whether if they are discernible when using spaceborne remote sensing.

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SPATIAL DISTRIBUTION MAP OF POST-FIRE SOIL LOSSES

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The burned area in Spain extended beyond historical records in 2022, when exceptionally warm conditions affect wildfires events. Predicted intensification of wildfires regimes is necessary to understand their behavior and possible environmental implications. Wildfires can lead to increased ash and sediment transport from hillsides to streams, posing potential threats to infrastructure and natural resources. However, accurately quantifying the extent and magnitude of post-fire hydrological responses remains a challenge. Furthermore, the common misuse of the term severity, without properly distinguishing between vegetation severity and soil severity, adds complexity to the assessment, despite their distinctiveness. This study employs spectral indices and GIS approaches to map the spatial distribution and estimate potential soil losses atier wildfires. Utilizing Sentinel-2 images and field data on fire severity from the Sierra de la Culebra wildfire in 2022, this work establishes a clear differentiation between soil and vegetation severity. The developed methodology enables the quantification of potential soil losses post-wildfire using soil severity data. Indeed, soil loss calculations are derived from severity soil samples collected in the field atier wildfire. The results confirm the effectiveness of spectral indices in mapping post-fire soil losses. The Normalized Difference Infrared Index (NDII), Difference Normalized Wildifre Ash Index (dNWAI) and the Blue Normalized Difference Vegetation Index (BNDVI) were evaluated at different temporal scales. Specifically, the BNDVI index shows a significant correlation with soil losses (R2 = 0.94) and allows the mapping and quantification of potential soil loss, esmated at ~470,000 Mg ha-1 for Sierra de la Culebra wildfire. Additionally, different image acquisition dates were evaluated, with beter results obtained using images captured during the initial period, between 8-28 days post-fire ignition. Furthermore, a positive correlation between severity and BNDVI index was established. This approach holds promise for integrating new parameters into post-fire risk models and assessments, as well as facilitating studies on watercourse contamination and planning measures to mitigate flood risk.

GLOBAL TIME SERIES OF LAI, FPAR AND SIF FROM MULTIPLE SENSORS USING AUTOMATIC DIFFERENTIATION

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Terrestrial vegetation affects climate though its role in the energy, carbon and water budget of the Earth surface. Two essential climate variables (ECVs) that describe the state of the vegetation are the Leaf Area Index (LAI), defined as one half of the total leaf area per unit horizontal ground surface area, and the fraction of incident surface solar radiation in the photo-synthetically active region (0.4-0.7 μm) absorbed by the vegetation (FAPAR). Solar Induced Fluorescence (SIF) has also been used as a complementary indicator of vegetation stress and photosynthesis.

We developed a multi-sensor dataset for global, multi-decadal time series of LAI and FAPAR using atmospheric correction and direct inversion of a radiative transfer model using Automatic Differentiation (DA). This enables the estimation of LAI and fPAR and its uncertainty at 5-day intervals and 10-day moving intervals from multiple sensors. We further included temporal autocorrelation to constrain the retrieval and a residual cloud model and a snow model.

The data products are validated following CEOS LPV good practices using 140 sites with upscaled ground data for specific campaigns (i.e., CEOS WGCV LPV DIRECT2.1 database), 23 GBOV sites with multi temporal ground data (2013-2019) and 13 AMMA sites with multi temporal ground data (2005-2015). Moreover, 720 LANDVAL sites are used for product inter comparison with existing datasets. Several criteria of performance are evaluated including completeness, spatial and temporal consistency, accuracy, precision, uncertainty and stability. A first dataset (CRDP-1) based on SPOT-VTG and PROBA-V of 21 years (2000-2020) has been produced and validated, and is available on the CEDA archive (https://urldefense.com/v3/__https://data.ceda.ac.uk/__;!!D9dNQwwGXtA!Xvm1HEY3z009LKQmPJfKiq RafwfI13Mve5yyuI9srpcI4vzDMu9Pum2syWd32VIxXPsvpvUYMhUx6QpzkpBIG4GWvA$). This dataset contains a transect of tiles over Africa and Europe, as well as globally distributed selected sites. And a new dataset (CRPD-2) based on more sensors is currently being produced and expected at the end of 2024.

The emitted SIF provides additional information about the vegetation. We present first steps of the extension of the algorithm with SIF data from TROPOMI. This algorithm estimates the fluorescence emission efficiency, and a viewing and illumination geometry independent SIF product.

This work was supported by the General Program of National Natural Science Foundation of China under Grant 42271395. (Corresponding author: Caixia Gao)

MONITORING WATER TURBIDITY ALONG THE VALENCIAN COAST WITH SENTINEL-2 DATA

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The Valencian Coast is a touristic hotspot at both national and international level. Its beaches have a high level of frequentation, and its favorable climate allow for a year-long frequentation. However, a thorough study of the turbidity regime of the Valencian coast has not yet been carried out. Here, we make use of the entire archive of Sentinel 2 data since 2017 (485 acquisitions) for the tile including the Valencian coast (T30SYJ) to retrieve indicators of turbidity. In a first step, we resample all level 1C data to 10m resolution, and apply a 2km coastal mask. Then we correct atmospherically these masked images, and apply two different indicators of turbidity: NDTI (Normalized Difference Turbidity Index) and an OWT (Optical Water Types) classification. By coupling these indicators with external data (bathymetry, precipitation, bacteriological measurements), we obtain valuable insight in the turbidity possible causes and behavior along the Valencian coast. To that end, we use standard statistical approaches such as Pearson correlation, average, median and standard deviation indicators. First, by comparing pixels with similar bathymetry and distance to the coast, we identified the locations with higher turbidity. As a result, the beaches near preserved natural environments present clearer waters, in opposition to the ones located close to urban centers. We also observed a clear seasonal pattern of turbidity, and a strong increase of turbidity after extreme precipitation events, which remains visible for an approximative 7 days after the extreme event. Discharge data do not present correlation with turbidity, as far as we have observed. As for bacteriological data, their correlation with turbidity cannot be evidenced, although our results indicate that both location and temporal frequency of their measurements could be improved. Further comparison with chlorophyll contents, total suspended matter and colored dissolved organic matter (CDOM)) are under investigation and should increase our understanding of the turbidity regime of the Valencian coast.

ENHANCED SNOW COVER MAPPING IN THE MOROCCAN ATLAS MOUNTAINS: ADVANCEMENTS IN MODIS NDSI THRESHOLD OPTIMIZATION AND DEVELOPMENT OF FRACTIONAL SNOW COVER ESTIMATION MODELS

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In semi-arid regions of the Mediterranean, snowmelt and precipitation are essential sources of water for downstream communities. Therefore, snow-covered mountain peaks play a crucial role as natural water reservoirs, significantly influencing river flow and groundwater replenishment. This research leverages remote sensing to compensate for the lack of ground-based hydroclimatic data, focusing on the latest version of the MODIS snow cover product (version 6, V6). It aims to refine the NDSI threshold and develop localized models for fractional snow cover (FSC) estimation specifically adapted to the Moroccan Atlas Mountains. For this purpose, 448 Sentinel-2 scenes across six different regions in the Atlas Mountains were used to adjust the NDSI threshold and develop FSC models. Moreover, 8419 MOD10A1 and 7561 MYD10A1 images covering the period from March 2000 to June 2023 were processed to improve cloud filtering and generate a high-precision daily snow cover product for the region. Significant improvements were achieved in reducing cloud cover, decreasing cloud-obscured pixels from 25.7% to 0.4%. Two NDSI MODIS threshold selection schemes were tested: the standard global threshold of 0.4 and a locally optimized threshold of 0.2. The local threshold demonstrated superior accuracy, significantly reducing snow cover estimation errors compared with the global threshold for both Terra and Aqua MODIS images. The newly developed FSC models demonstrate high accuracy, displaying high correlation coefficients (mean of 0.84) and low error measures when comparing MODIS-derived FSCs with high-resolution Sentinel-2 data. The daily snow cover product developed was compared with high-resolution snow maps obtained from Sentinel-2 satellite imagery in different regions of the Moroccan Atlas. On average, the product showed a mean correlation coefficient of 0.96, a mean absolute error of 0.22%, and a mean reasonable negative bias of -0.17%. This research concludes that the improved daily snow cover product could enhance understanding of the spatio-temporal dynamics of snow extent and, consequently, contribute to quantifying the contribution of snowmelt to the water balance through modelling approaches in the southern Mediterranean region.

A MACHINE LEARNING APPROACH ON SMOS THIN SEA ICE THICKNESS RETRIEVAL

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Sea ice is an essential component of the Arctic's physical environment and serves as a crucial indicator of climate change. Passive microwave radiometers have been used to observe sea ice since the launch of the first Earth Observation satellites in the 1970's, and are still in use today with the European Space Agency (ESA) mission Soil Moisture and Ocean Salinity (SMOS), among others, and will be continued with the future Copernicus Imaging Microwave Radiometer (CIMR). Nowadays, there exist two SMOS thin sea ice thickness algorithms for the non-melting period, i.e. from October to April. The first is the ESA's official product, which is a semi-empirical algorithm developed by the Alfred Wegener Institute (AWI). A notable drawback is its failure to account for the presence of snow above sea ice, which is a major limitation given its relevant effect on emitted L-band radiation. The second product is distributed by the University of Bremen (UB) and it uses an empirical approach. The primary shortcoming of the UB product lies in its limited sensitivity, extending only up to 0.5 m.

This study proposes a machine learning based methodology for estimating Arctic thin sea ice thickness (up to 1 m) from brightness temperature measurements of SMOS. The approach involves employing the so-called Burke model for sea ice emission modeling, integrating a suitable permittivity model and a radiative transfer equation. The training dataset is generated through a model-based simulation, obtaining Arctic sea ice thickness maps, as a result of the emission model inversion, along with other physical variables. From these maps, the pixels are extracted and then used to train and evaluate two machine learning regression algorithms: Random Forest and Gradient Boosting. Overall, this machine learning methodology results in great agreement with the ESA's official sea ice thickness product. Additionally, a validation performed by using data from mooring measurements shows a subtle improvement by the machine learning algorithms with respect to the ESA's official product. These results indicate their potential to surpass the performance of the current SMOS thin sea ice thickness retrievals.

ESTIMATION OF SWE AVAILABLE IN THE PYRENEES FOR THE BARASONA RESERVOIR

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The Barasona reservoir was built in 1932 in order to provide water for power generation and irrigation, and it is one of the three main water supplies for the CayC (Aragón and Catalonia Irrigation District). With a total area of 1509 km^2, its basin lies in the Central Pyrenees, and it is largely a snow-dominated alpine catchment [Palazón and Navas, 2016]. Since mountain water resources are highly dependent on climatic fluctuations and other land properties, environmental alterations such as those induced by climate change could have a great impact on the quantity and availability of the stream flow that the reservoir collects, with the consequences that this entails for water supply and distribution management. Thus, it is of great interest to have a correct understanding of the reservoir's hydrological processes.

In this project we have combined remote sensing data along with AI-based and hydrological models in order to estimate the amount of water in the form of snow that will be available for the Barasona Reservoir and to be able to predict the reservoir water input flow, in addition to estimate the expected dates of the beginning of the thaw.

First, we have derived the snow cover area (SCA) in the basin from MODIS Terra and Aqua daily products (MOD10A1F and MYD10A1F respectively) at 500m spatial resolution for the period 2009 to 2023. In order to have SCA at higher resolution, we have estimated the Normalized Difference Snow Index (NDSI) with Landsat8 and Sentinel 2 data as in Gascoin et al., 2019. The LandSat 8 and Sentinel 2 products have a spatial resolution better than 100 m but their temporal resolution is very low (16 days for LandSat 8 and 10 days for Sentinel 2). The comparison of the SCA from MODIS and L8/S2 show a consistent time series of SCA since the availability of L8 (2013 to 2023). Based on this estimation of SCA and the snow height measured at snow gauges available at the catchment we have estimated the snow water equivalent (SWE) for the catchment.

Finally, the estimated SWE along with the in-situ measurements of air temperature and precipitation measured at different weather stations at the basin will be used to calibrate an AI model that

will predict river flow and the amount of input flow received by the Barasona reservoir.
In this presentation we will show the results of the SCA and SWE estimations together with the first results of the input flow at the Barasona reservoir.

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RESCUED NORTHEN HEMISPHERE PARTICLE SIZE DISTRIBUTIONS CHARACTERIZING THE PREVIOUS STRATOSPHERIC AEROSOL BACKGROUND AND THE PERTURBED CONDITIONS AFTER THE 1963 MT. AGUNG ERUPTION

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Twelve stratospheric particle size distributions (PSD) and information about its chemical composition collected between February 1962 and August 1963 has been rescued and digitalized. The PSD were derived from samples of stratospheric particles collected during the STARDUST program 1961-1967. The sampling was conducted using direct flow impactors contained in probes mounted on the WU-2 aircraft. All the samples were collected over the US, approximately 30 - 50ºN and 100 - 95ºW. The range of the particle radii (R) is > 0.1 and <0.7 μm. Log normal distributions were fitted to the PSD, showing a good agreement between the observed and fitted PSD. Both the observed and fitted PSD were used to verify and characterize the arrival of the stratospheric aerosols from the March 1963 Mt Agung eruption in Indonesia (8°S, 115°E) to New Mexico (NM), US. Vertical profiles of stratospheric aerosols extinction measured with searchlight at NM (32ºN, 105ºW) identified the arrival of the Mt Agung stratospheric aerosols between March 28th and April 20th, 1963. The observed and log normal fitted PSD probabilities were calculated for the intervals $0.1 < R < 0.32$ μm for the lower particles and $0.32 < R < 0.7$ μm for the larger. In addition, for each of the R intervals the linear trends were calculated. The results showed that smaller particles have a higher probability than large particles in all PSDs collected before April 2nd, which is typical of the background conditions of stratospheric aerosols. In the two PSDs for April 2nd and May 7th , large particles are those with the highest probability, which is typical of conditions disturbed by stratospheric aerosols from volcanic eruptions. These characteristics corroborate that the stratospheric aerosols from Mt Agung arrived between March 28th and April 2nd. The last two PSDs show again background conditions, revealing the discontinuous character of the stratospheric aerosol cloud, that was be observed by the searchlight at NM between December 1963 and December 1964. Further research is being conducted, focusing on determining lidar conversion factors

SET-UP INSTRUMENTATION IN ANTARCTICA TO DETECT ATMOSPHERIC EVENTS: CASE OF WILDFIRES IN CHILE

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The Atmospheric Optics Group of the University of Valladolid (GOA) has installed equipment at the Argentine Antarctic base of Marambio (64,240 S, 56,625 W) since 2018. The National Meteorological Service of Argentina (SMN) supports de maintenance of equipment during all year. In the 2024 Antarctic campaign, the CIMEL (sun and moon) photometer, integrated into the AERONET network, has been replaced with new equipment that has a heating system designed by the GOA; The all-sky camera has also been maintained. In addition, a system consisting of 2 infrared radiometers, has been installed to measure surface temperature and atmospheric radiance. This work presents the installation of this equipment, with its technical characteristics. The immediate usefulness of this equipment is to serve to complete databases of atmospheric magnitudes that can be used to validate satellite sensor products, in addition to detecting environmental events affected by atmospheric dynamics on a large spatial scale, such as aerosol transport. The interest of the instruments increases in a location of great relevance: Antarctic territory and in the vicinity of the Polar Antarctic Circle, affected by the polar vortex. The study focuses on the analysis of atmospheric aerosols in the Chilean Antarctic region during the period from 2012 to 2022. Its significance lies in understanding the temporal and spatial variability of aerosols in this critical area of the planet. Data from Moderate-Resolution Imaging Spectroradiometer (MODIS) y Visible Infrared Imaging Radiometer Suite (VIIRS) satellite sensors were used, focusing on three key dimensions. First, a temporal and spatial analysis of the data was conducted, calculating monthly medians and standard deviations for the entire period. These data were grouped according to linear trends, revealing a strong correlation between the MODIS and VIIRS sensors, especially in summer and spring. Second, an analysis was conducted on a wildfire event in Chile in 2017 that generated Pyrocumulonimbus (PyroCb) clouds. These clouds injected aerosols into the upper layers of the atmosphere, which remained in the Antarctic region for more than 10 days. This underscores the importance of understanding how events like these impact air quality and local climate. through remote sensing, it was possible to examine the evolution of aerosols in the Antarctic Stations, Argentinian and Chilean, highlighting their relevance in the context of global climate change and their impact on air quality and regional climate.

EVALUATING LAND SURFACE TEMPERATURE PRODUCTS RETRIEVED FROM METOP DATA AT THE VALENCIA TEST SITE

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The Meteorological Operational (MetOp) satellite programme is a European initiative providing weather data to evaluate climate change and improve weather forecasts. A series of three MetOp satellites make up the space segment of EUMETSAT's Polar System (EPS). In this paper, we evaluated the land surface temperature (LST) product generated operationally by EUMETSAT from MetOp AVHRR/3 data, i.e., the EPS Daily LST (EDLST) product. LST was defined as an Essential Climate Variable by the Global Climate Observing System of the World Meteorological Organization. The algorithm used to retrieve the EDLST product was the so-called Generalized Split-Window (GSW) but with a term that quantifies the model error. Additionally, we proposed and evaluated an alternative SW algorithm to retrieve LSTs from MetOp-AVHRR/3 data. LSTs were extracted for the study area, the Valencia Test Site, by performing a 2x2 pixel array over the rice paddy site, since it is a homogeneous area. The emissivities of the different land covers at the site due to rice phenology (full vegetation cover, bare soil and flooded soil) were measured using the Temperature-Emissivity Separation (TES) method and CIMEL electronique radiometers with several thermal-infrared (TIR) bands.

Ground TIR radiance data measured from a fixed station placed at a rice paddy site were used to evaluate the performances of the LST products from 2016 to 2020. The evaluation of two different versions of the operational EDLST product (v100, and current v111) showed significant systematic uncertainties and robust root-mean-square differences (R-RMSD) even higher than 3 K. Thus, we proposed an alternative SW algorithm with coefficients regressed for the MetOp-AVHRR/3 bands. New version of product (v111) worsens the results compared to the previous version (v100) at the Valencia Test Site. The results of the evaluation for the alternative LST algorithm showed lower systematic uncertainties (mainly for night-time) and R-RMSD lower than 2 K both for day- and night-time LSTs at the site.

The study was conducted within the framework of the project Tool4Extreme PID2020-118797RBI00 funded by MCIN/AEI/10.13039/501100011033, and also the project PROMETEO/2021/016 funded by Generalitat Valenciana.

THE METHODS FOR THE NDVI TIME SERIES RECONSTRUCTION IN NORTH CHINA PLAIN USING FY-3D DATA

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Long time-series NDVI remote sensing datasets have been widely used in studies of global or regional ecological environment, vegetation, land cover dynamic changes, and plant biophysical parameter inversion. However, influenced by a combination of cloud cover, aerosols, bi-directional reflection of ground objects, and solar altitude angle, plus plenty of noises contain in the datasets, which limits the in-depth analysis and application of the data. Therefore, how to fill in the missing NDVI remote sensing images, remove the noise contained in the images, reduce the impact of the sensor's own performance on the image quality, and reconstruct complete and high-quality time series remote sensing images has gradually become a research hotspot in the field of remote sensing application. NDVI data reconstruction is an important task before its application. In this study, North China Plain is taken as the study area, and its NDVI data is reconstructed in time series respectively using Maximum Value Compostie(MVC), Asymmetric Gaussian model(A-G), Savitzky-Golay(S-G), Double-Logistic(D-L) and Harmonic analysis of time series(HANTS) methods based on the FY-3D Medium Resolution Spectrum ImagerII (MERSI-II) data and FY_NVI product dataset of China's domestic Fengyun meteorological satellite, as well as the Normalized Difference Vegetation Index of moderate resolution imaging spectroradiometer(MODIS_NDVI) product dataset. The correlation coefficient (R), and root mean squared error (RMSE) are used to evaluate the accuracy of the results, and the suitability of different data sources and different land cover types for each reconstruction method is obtained. The results show that each of the five reconstruction methods has its own reconstruction characteristics and data applicability. The MVC has the best reconstruction result in different land cover types, the methods of S-G filtering and the A-G fitting have the smoothest reconstruction curves, and the HANTS has poor performance; In the fidelity evaluation, for the different reconstruction methods as a whole, the best evaluation results of R are obtained by the A-G, followed by the D-L and MVC, and the S-G and HANTS have relatively poor performance. For RMSE, the S-G and D-L have better RMSE evaluation results, A-G is the second, and MVC and HANTS are worse. This study provides useful reference for NDVI time series reconstruction on different data sources and different land cover types.

COMPARISON AND VALIDATION OF TEMPERATURE-EMISSIVITY SEPARATION METHODS ANEM, TES AND SW EMPLOYING MODIS AND VIIRS THERMAL DATA

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The problem of temperature-emissivity separation arises from the very definition of the Radiative Transfer Equation, and so hinders the Land Surface Temperature (LST) retrieval from thermal radiance data collected by satellite sensors. The TES and SW techniques are the most commonly used methods for separating these two key climate variables. In order to fully understand the energy budget and its relationship with the Earth system, MODIS sensors on board Terra and Aqua and VIIRS on board Suomi-NPP offer operational LST products developed from these two methodologies. This study aimed to tackle the temperature-emissivity separation problem by, on the one hand, adapting the ANEM-SBAC methodology (a revision and modification of the NEM typical module of conventional TES algorithms combined with the Single Band Atmospheric Correction) to MODIS/Terra-Aqua and VIIRS/Suomi-NPP sensors and comparing it with their conventional products over a sufficiently large area encompassing different types of coverage. This study area allowed, on the other hand, a T-based validation technique with *in situ* measurements from 2002 to 2022 to test the three algorithms. The ANEM method reached an RMSE of 1.1 K and bias of 0.2 K (MODIS/Terra), 1.3 K and 0.7 K (MODIS/Aqua), and 1.5 K and 0.05 K (VIIRS/Suomi-NPP); the TES, 1.4 K and 0.7 K (MODIS/Terra), 1.7 K and 1.1 K (MODIS/Aqua), and 1.7 K and 0.2 K (VIIRS/Suomi-NPP); the SW, 1.2 K and -0.4 K (MODIS/Terra), 0.9 K and -0.05 K (MODIS/Aqua), and 1.9 K and -0.18 K (VIIRS/Suomi-NPP). From the ANEM-TES and ANEM-SW pixel-by-pixel difference, geographically explicit maps were obtained for detecting discrepancies between methodologies with respect to each land cover type. The ANEM-SBAC algorithm also incorporates a rigorous and complete estimate of the final uncertainty in LST and emissivity considering several possible sources of error. In conclusion, the ANEM-SBAC procedure is deliberately designed to be adaptable and scalable, which is conforming to the increasing requierements in Remote Sensing to widen the existing range of alternatives to operational products. In this context, tracking the ongoing operational methods and deepening our comprehension of the temperature-emissivity separation problem and the surface energy budget becomes crucial for the approaching high-resolution thermal sensor launches.

The study was conducted within the framework of the project Tool4Extreme PID2020-118797RBI00 funded by MCIN/AEI/10.13039/501100011033, and also the project PROMETEO/2021/016 funded by Generalitat Valenciana.

HYDROLOGICAL DROUGHT MONITORING IN THE EBRO BASIN: STANDARDIZED SOIL MOISTURE INDEX

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Recent studies háve highlighted the escáláting frequency ánd severity of droughts áttributed to climáte chánge. Drought stánds ás á májor climáte risk; thus, its understánding ánd study áre of utter importánce. This phenomenon árises from intricáte interáctions ámong the átmosphere, continentál surfáces, ánd wáter resource mánágement systems, ánd cán leád to substántiál socioeconomic impácts.

Following the work of Wilhite ánd Glántz, droughts cán be cátegorized básed on their severity ás meteorologicál, ágriculturál, hydrologicál, ánd socioeconomic (Wilhite, D.A.; ánd M.H. Glántz, 1985). The former three delineáte droughts by their physicál impácts, while the látter deáls with drought in terms of supply ánd demánd dynámics (e.g., energy, food, or potáble wáter shortáges).

Meteorologicál drought is ássociáted to precipitátion deficiency periods, which cán álso be áccompánied by high temperátures or low relátive humidity. If á such period persists through time, we will stárt observing á deficiency in soil moisture, ánd á reduction in crop populátion ánd yield. Such circumstánces would indicáte thát we áre under the influence of án ágriculturál drought, with the potentiál to evolve into á hydrologicál drought with time. The frequency ánd severity of hydrologicál drought áre defined typicálly on á river básin scále, with án impáct on the surfáce ánd subsurfáce wáter resources (i.e., reduced streámflow or inflow to reservoirs, lákes, ánd ponds).

Given the severity ánd frequency of drought occurrences, monitoring them is of sheer importánce. Várious indices háve been devised to study droughts, básed on váriábles such ás precipitátion or vegetátion státus. Becáuse of the limitátions of remote-sensed precipitátion (high uncertáinty ánd coárse resolution) the monitoring of drought básed on remote sensing dátá hás lárgely relied in vegetátion indices. However, these indices possess inherent limitátions. Vegetátion-básed drought indices cán only be ápplied once the drought hás álreády cáused dámáge to the vegetátion, máking them unsuitáble for drought forecásting.

Hence, soil moisture emerges ás á key element for ágriculturál monitoring ánd drought forecásting, offering eárly indicátors of impending drought conditions. Drought indices básed on soil moisture dátá cán be derived from L-bánd (21 cm, 1.4 GHz) rádiometers, which provide soil moisture meásurements without the problems thát áccompány precipitátion dátá. With neárly 14 yeárs of historicál dátá since the first rádiometer retrieved soil moisture meásurements in 2010, the use of soil moisture derived from remote sensing stánds ás á powerful tool for the upcoming yeárs.

This study introduces the Stándárdized Soil Moisture Index (SSI), dráwing inspirátion from the widely used Stándárdized Precipitátion Index (SPI), which shows the deviátion from áveráge precipitátion. By extending SPI’s methodology to soil moisture dátá, diverse drought types cán be monitored básed on the selected integrátion time for SSI. Focusing on the Ebro básin region, situáted in the northeástern párt of the Iberián Peninsulá with á semi-árid climáte, our findings underscore SSI12-SSI24 ás á robust index for hydrologicál drought ássessment.

REMOTE SENSING RETRIEVAL OF SOIL MOISTURE BY USING SENTINEL-1 SAR DATA: A CASE STUDY OF LUSHAN COUNTY, SICHUAN, CHINA

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Soil moisture plays a crucial role in agriculture, ecological planning, meteorology, and hydrology, thus real-time, accurate monitoring is critically important for various applications. In order to find suitable polarization methods to characterize soil moisture conditions and fully utilize the advantages of active microwaves in soil moisture monitoring, this study targeted Lushan County as the research area, using Sentinel-1 Synthetic Aperture Radar (SAR) imagery to monitor soil humidity. On the basis of extracting the soil backscattering coefficient of different polarization modes, by comparing the theoretical, empirical and semi-empirical models of surface microwave scattering in vegetated areas, the semi-empirical water cloud model is selected to correct the influence of surface vegetation on radar backscattering signals. In order to fit the nonlinear relationship between soil water content and backscattering coefficient, support vector regression (SVR) is used to establish a soil moisture regression model, and the root-mean-square error and determination coefficient are used to evaluate the model. The conclusion is as follows: (1) Optical remote sensing data is very important for the acquisition of surface parameters, and can be used as auxiliary data for the inversion of MRS Soil moisture to improve the inversion accuracy. WCM has the ability to simulate microwave surface scattering characteristics with few input parameters, which is a practical model. Eliminating the influence of vegetation is conducive to the development of soil water inversion model and improves the inversion accuracy. (2) The two methods have a greater influence on the total coefficient than that of vegetation. The average soil backscatter coefficient is −17.50 dB with VV polarization and −23.93 dB with VH polarization, which suggests that the VV polarization is less affected; (3) The SVR model proves capable of characterizing soil moisture in Lushan County, and the inverted soil moisture results are highly similar to the measured soil moisture values. The VV polarization is 0.5572, and the VH polarization is 0.3472. The RMSE of VV polarization is 0.0342 cm^3/cm^3 and that of VH polarization is 0.0485 cm^3/cm^3. The VV polarized soil water inversion results are better than VH polarization. The VV polarization method is more penetrating and more sensitive to the changes in soil moisture content. The model of soil water inversion under VV polarization can better represent the spatial distribution of soil water in the study area. The research method presented in this article can effectively characterize the soil moisture status in the study area and is an ideal means of monitoring the soil moisture. It has important guiding significance for agricultural irrigation, water cycle, and surface vegetation coverage.

VALIDATION OF THE VERTICAL CANOPY COVER PROFILE PRODUCTS DERIVED FROM GEDI

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Canopy cover (CC) quantifies the proportion of canopy material projected vertically onto the ground surface. CC is a crucial canopy structural variable and is commonly used in many ecological and climatic models. The vertical CC profile product is currently available from the Global Ecosystem Dynamics Investigation (GEDI). However, information about the accuracy and uncertainty of the GEDI CC product is still lacking. The objective of this study is to validate the GEDI CC product using reference data derived from digital hemispherical photography (DHP), airborne laser scanning (ALS) point clouds, and simulated waveforms. The results show that the total GEDI CC correlates well with those estimated from DHP, ALS, and simulated waveform data (R^2 = 0.65, 0.69, and 0.69, respectively) but is systematically underestimated (bias = –0.07, –0.13, and –0.09, respectively) based on the reference data. Compared with the ALS-estimated CC, the highest correlation is observed for needleleaf forest (R^2 > 0.62) and the lowest bias is for shrubland (bias = –0.18). The mean absolute error (MAE) of the GEDI CC decreases from 0.17 to 0.09 from the ground to 35 m. The total GEDI CCs derived from the waveform interpretation algorithms A2 and A6 display the highest R^2 (≥ 0.6) and smallest RMSE (≤ 0.25) compared to those of the other algorithms. The total CC improves by 5.7% using a canopy-to-background backscattering coefficient ratio (ρ_v/ρ_g) determined with the regression method. The CC accuracy increases with beam sensitivity and decreases with increasing canopy cover. The partial difference between GEDI CC and ALS CC is attributed to definition differences. Further improvement of the CC algorithm can be made by using vegetation-specific waveform processing algorithms and realistic ρ_v/ρ_g values.

PRESENTE Y FUTURO PRÓXIMO DE LAS MISIONES SAR ESPACIALES DE ÁMBITO CIENTÍFICO

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Desde el lanzamiento de SEASAT en 1978, la primera misión civil de observación de la Tierra que incorporaba un RADAR de Apertura Sintética (SAR), la tecnología ha progresado de manera notable. En los años 90, la Agencia Espacial Europea tomó la iniciativa de los desarrollos de SAR espaciales con los lanzamientos de las misiones ERS-1 en 1991 y ERS-2, cuatro años después. En la misma década, la Agencia Espacial Canadiense puso en órbita la misión RADARSAT-1; NASA, DLR y Agencia Espacial Italiana lanzaron la misión colaborativa SIR-C/X-SAR, a bordo del Space Suttle Endeavour y la agencia espacial japonesa, JAXA, lanza la misión JERS.1.
A partir del año 2000, la tecnología se consolida y los lanzamientos se multiplican, las misiones ENVISAT, JAXA y RADARSAT 2 dan continuidad a los programas de ESA, JAXA y CSA y, a finales de la década, comienzan a sucederse los lanzamientos de sistemas que, en su mayoría, todavía siguen en operación: Terrasar-X, TandDEM-X (DLR), Cosmo-SkyMed (ASI), RCM (CSA), Sentinel-1 A y B (ESA), SAOCOM 1 y 2 (CONAE), …

En 2018, España se une al grupo de países que cuenta con un satélite SAR en órbita con el lanzamiento de PAZ y en 2019 comienza la explotación científica de sus datos, especialmente enfocada en fomentar el uso de esta tecnología por parte de los grupos de investigación en Observación de la Tierra españoles.

Así, en apenas 40 años de desarrollo, la tecnología se encuentra madura y, con la llegada del fin de la vida útil de estos sistemas que han generalizado el uso de los datos SAR en todo el mundo, junto con la aparición de nuevos actores desde el ámbito comercial y los desarrollos innovadores en técnicas de conformados digitales de haz, es el momento de contemplar las distintas estrategias de reemplazo de estos sistemas que van a asegurar e incrementar en cantidades sin precedentes la disponibilidad de productos SAR a los usuarios en el futuro próximo.

En esta comunicación se analizan las dos tendencias divergentes que están dominando la concepción de los sistemas SAR espaciales que van a lanzarse durante la próxima década: las constelaciones de satélites de bajo coste y rápido reemplazo y las grandes misiones de satélites de alta resolución y gran cobertura, así como la explotación de nuevas bandas espectrales que está por venir. La banda espectral de la misión, su operación monoestática o multiestática y las características específicas del instrumento, tales como su ancho de banda, tecnología de antena y conceptos de procesado de señal serán las características que definirán los distintos análisis.

RESEARCH ON TECHNOLOGY AND APPLICATIONS OF CHINA'S NEXT GENERATION ENVIRONMENTAL MONITORING SATELLITE

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China's environmental monitoring satellites include HuanJing-1, HuanJing-2, GaoFen-5, DaQi-1 and other satellites, and the monitoring methods cover visible light, infrared, hyperspectral, laser, etc. They have formed a relatively comprehensive and complete monitoring system, with the ability to monitor pollution emissions from large industrial zones, global greenhouse gas distribution, global pollutant gas distribution, etc. The next generation of environmental monitoring satellites will focus on the monitoring of ground emission point sources, improve the spatial resolution of payloads on the basis of existing satellites, and find information such as abnormal temperature and pollutant gas concentration on the ground through the combination of visible light, infrared and hyperspectral, so as to actively discover ground emission sources and provide a basis for ground personnel to go to the site for verification and law enforcement. At the same time, the satellite will be equipped with an onboard processing system, which processes the payload data in orbit, and directly transmits the processing results to the end user in the form of text information or slice images, greatly improving the response speed of pollution events.

THE NEW EUMETSAT MISSIONS: CONTINUITY OF LSA SAF VEGETATION SERVICE

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The scope of the EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF) is the development and implementation of algorithms, which take full advantage of remotely sensed data from EUMETSAT satellites. The LSA SAF provides variables for the characterization of terrestrial ecosystems and their role in the energy balance of Earth, such as land surface fluxes (i.e. Gross Primary Production, GPP) and three important biophysical variables related with the amount, structure and state of vegetation: Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) and Fractional Vegetation Cover (FVC). Currently the LSA SAF generates two operational lines of vegetation products. Firstly, a suite of products (FVC, LAI, FAPAR, GPP) is derived from the geostationary SEVIRI on board MSG (Meteosat Second Generation) 1-4 (Meteosat 8-11). A Climate Data Record (CDR) is freely available in the LSA SAF, offering homogeneous time series since 2004 onwards at two resolutions (daily and 10-day) required for climate and environmental applications. Secondly, FVC, LAI and FAPAR variables are produced based on data from the AVHRR sensor on board Meteorological Operational Satellites (currently MetOp A and B) of the EUMETSAT Polar System (EPS) in Near Real Time (NRT) global coverage, and 10-day frequency.

This work presents the status and further developments of LSA SAF vegetation products, including expert knowledge, accuracy assessment studies and examples of potential applications. During the current (CDOP-4) phase the LSA SAF plans to release a CDR of FVC, LAI, FAPAR based on EPS products (since 2007 onwards) that correspond to a back-processing of existing for NRT/operational products. The current algorithms are being upgraded and extended to take full advantage of the enhanced capabilities offered by the future EUMETSAT missions. A suite of LSA-SAF vegetation products will be released to users shortly after the operational distribution of data from Meteosat Third Generation (MTG/FCI) and EPS-Second Generation (EPS-SG/VII) EUMETSAT sensors, offering the desirable continuity to the service. Current work also includes feasibility assessment of the derivation of new vegetation products, such as Canopy water content (CWC) and Net Ecosystem Exchange (NEE). The life cycle of EUMETSAT satellites put the LSA SAF in a privileged position as a product/service provider for monitoring of climate and environment.

DEVELOPING A NEW ALGORITHM FOR THE GENERATION OF SEVIRI/MSG VEGETATION PRODUCTS

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The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF) provides near-real-time and offline products and user support for a wide range of land surface variables. Currently the LSA SAF operates two processing lines to generate LSA SAF vegetation products from EUMETSAT satellites data. Firstly, FVC, LAI, FAPAR and GPP products are being derived from the geostationary SEVIRI (Spinning Enhanced Visible and Infrared Imager) on board MSG (Meteosat Second Generation) 1 4 (Meteosat 8-11) starting from 2004 onwards. These products are available at two resolutions (daily and 10-day) over the Meteosat disk, covering Europe, Africa, the Middle East, and parts of South America. Secondly, FVC, LAI and FAPAR are being derived over the globe based on data from the AVHRR sensor on board Meteorological Operational Satellites (currently MetOp A and B) of the EUMETSAT Polar System (EPS). Unlike the approach to produce SEVIRI/MSG vegetation products, which relies on stochastic spectral mixture and statistic methods, the EPS algorithm relies on a hybrid approach that blends the generalization capabilities offered by physical radiative transfer models with the accuracy and computational efficiency of machine learning methods.

One priority task of the LSA SAF is to ensure the inter- and intra-missions product consistency. Although both MSG and EPS algorithms rely on a similar input (i.e. atmospherically corrected cloud-cleared k_0 BRDF product at three channels: red, NIR, MIR), which is an internal product contained in MSG surface albedo (MDAL), discrepancies exist due to various spatial and temporal resolutions, processing lines and differences. In addition, although a Climate Data Record (CDR) of MSG products is available since 2004 onwards, a slight discontinuity was produced in 2022 due to an upgrade of the MDAL algorithm, incorporating aerosol correction and other improvements. This work attempts to overcome the above issues, by developing a new algorithm for the generation of MSG vegetation products. It relies on an upgraded and improved version of the current EPS algorithm. An accuracy assessment is also performed, using as a benchmark the current MSG and other relevant satellite vegetation products. The work will contribute to generate continuous and homogeneous time-series of LSA SAF vegetation parameters (FVC, LAI, FAPAR) from SEVIRI/MSG suitable for climate and environmental applications and ensure a smooth transition of the service between SEVIRI/MSG and the future FCI/MTG.

ESTIMATING LEAF AREA FROM TREE TO STAND LEVELS USING TERRESTRIAL LASER SCANNING

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Estimating tree leaf area is crucial for modeling their ecological functions. Several methods have been proposed for estimating leaf area, yet methods for individual tree measurements and stand measurements differ. This often leads to discrepancies between the leaf area measured the individual tree and stand levels, resulting in scale effects. This study presents a bottom-up approach that uses tereestrial laser scanning to simultaneously capture leaf area at both the individual tree and stand levels. Based on terrestrial laser scanning (TLS) and path length distribution, the leaf area of each tree within a region is determined. The stand leaf area index (LAI) is then derived from the definition of LAI, thus obtaining leaf area index from individual trees to the stand scale while avoiding associated scale effects. TLS Data of 23 scans were collected to cover a forest stand. Allometric measurement and tracing radiation and architecture of canopies (TRAC) issrument were also employed simultaneously to obtain reference values of leaf area of individual trees and the forest stand. The results show the proposed method can obtain the leaf area of 50 trees with only 23 scans. The LAI of the proposed method is consistent with the allometric measurement and TRAC measurement (Allometric:2.39 $m^2 \cdot m^{-2}$, TLS:2.63 $m^2 \cdot m^{-2}$, and TRAC:2.65 $m^2 \cdot m^{-2}$) at the stand level. Generally, 23 several evenly-distributed and shared stations under the forest are enough to characterize the leaf area of 50 individual trees and the LAI in an urban forest stand. The proposed bottom-up approach provides a new way of estimating the LAI at both the individual tree and stand levels using TLS. It has the advantage of providing multi-level leaf area information and avoiding the scale effect, showing great potential in the study of spatial heterogeneity of LAI, tree competition, and forest spatial structure.

SOIL BURN SEVERITY ASSESSMENT USING SENTINEL-2 AND RADIOMETRIC MEASUREMENTS

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Assessment of soil burn severity is essential for quantifying post-fire erosion risks. This work aims to generate soil burn severity maps to aid erosion assessments following forest fires in Spain (2017-2022). Soil burn severity was measured by field plots categorized using Fernández and Vega's 2016 classification, exclusively targeting areas where pre-fire vegetation was wholly consumed. The Analytical Spectral Device (ASD) FieldSpec radiometer was employed to establish correlations between soil burn severity and reflectance. In terms of emissivity, its use was declined due to the low spatial resolution of remote sensing sensors in comparison of field plots size. Reflectance measurements were taken on the field and at the National Institute for Aerospace Technology (INTA) laboratory, with laboratory measurements minimizing confounding factors like shadows and wind. Spectral bands showing significant differences between soil burn severity levels were predominantly in the Near Infra-Red (NIR) and Short Wave Infra-Red (SWIR) regions. Spectral curves obtained via ASD radiometer were convolved using Sentinel-2 filters. Several spectral indices relevant to forest fire studies and soil assessment were computed from convolved reflectance data. Indices meeting Separability Index algorithm criteria were validated using statistics parameters and 503 field plots. The Iron Oxide Ratio (IOR) index yielded the highest overall accuracy: Accuracy (ACC) = 0.71, Balanced Accuracy (BACC) = 0.76, F1-Score (F1) = 0.63, and Cohen`s Kappa index (k) = 0.50, followed by the Normalized Burn Ratio 2 index: ACC = 0.57, BACC = 0.69, F1 = 0.54, and k = 0.36. Additionally, IOR was the only index with an acceptable k value (k = 0.50). It was demonstrated that, alongside NIR and SWIR spectral bands, incorporating the blue band mitigates atmospheric interferences, enhancing soil burn severity mapping accuracy. The resulting maps could greatly assist forest management agencies in planning

assessment and restoration efforts related to soil erosion effects. The proposed methodology relies on freely available imagery and can be readily adapted to any Geographic Information System (GIS).

ASSESSMENT OF LST PRODUCT ESTIMATED BY HYTES AND OWL SENSORS IN THE FRAMEWORK OF NET-SENSE 2023 CAMPAIGN

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Next generation of High Spatio-Temporal Thermal sensors onboard satellites are a crucial part in monitoring Land Surface Temperature (LST) variability, and hence evapotranspiration, at the European field scale. For future sensor testing, campaigns are an important tool in the generation of synthetic scenes and, subsequently, in the proposal and testing of LST algorithms. For this reason, and to ensure the best results, the quality of airborne scenes can only be guaranteed with good in situ data.

The NET-Sense 2023 campaign was part of the ESA effort to support the LST Monitoring (LSTM) mission. The campaign was located in Grosseto, Italy, at an experimental site consisting of irrigated flat areas with growing crops, mainly corn and alfalfa, where in situ measurements of LST, radiation fluxes and evapotranspiration were taken during the campaign generating a large database for validation purposes. To cover the entire crop growth process, the campaign was divided into two periods: one in May and the other at the end of June. For both periods, two hyperspectral (7.5-12.5 µm) thermal sensors (HyTES and OWL) took simultaneous images following the same flight line designed at different view angles.

In this work, we provide the performance of LST product estimated for both sensors by taking the in situ data measured by our team with multiband and broadband radiometers. In addition, the images were processed applying Temperature Emissivity Separation algorithm to compare the results with the provided LST product as well as against ECOSTRESS LST product. Finally, by integrating obtained LST with the energy flux data, evapotranspiration was calculated by applying the Simplified Surface Energy Balance Index algorithm.

SENSITIVITY OF SIF AND CANOPY TEMPERATURE TO WATER STRESS AND RECOVERY IN ALMOND TREES QUANTIFIED FROM AIRBORNE SUB-NANOMETER AND NARROW-BAND HYPERSPECTRAL IMAGERS

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Canopy temperature (Tc) and derived indices based on thermal imaging normalized by the ambient conditions (i.e., Tc-Ta, CWSI) are considered the most direct indicators of crop water stress due to their link to plant transpiration and induced evaporative cooling. On the other hand, sun-induced chlorophyll

fluorescence (SIF) is a direct indicator of the state of photosynthesis and may track physiological changes induced by water stress. Although Tc-Ta and SIF have been demonstrated to be useful for detecting water stress in tree crops, their sensitivity at times of maximum stress and after recovery requires additional assessment. Additionally, the sensitivity of SIF for water stress detection using standard narrow-band hyperspectral imagers versus sub-nanometer spectral resolutions needs further analysis. To investigate the diurnal response of Tc-Ta and SIF from sub-nanometer and narrow-band imagers to water stress effects, airborne campaigns were conducted over an almond orchard over well-watered and water-stressed blocks in the morning and around solar noon on Day of Year (DOY) 66 (time of the maximum stress) and DOY 104 (after recovery) in 2023. The airborne cameras flown in tandem consisted of a sub-nanometer (SN) hyperspectral imager (full-width at half-maximum, FWHM = 0.2 nm, 670–780 nm), a narrow-band (NB) hyperspectral imager (FWHM = 5.8 nm, 400–1000 nm), and a thermal camera (7.5–14 µm).

Results showed that on DOY 66, during the period of maximum water stress, the canopy temperature (Tc-Ta) derived from the thermal image was statistically different between the well-watered and water-stressed almond blocks both in the morning and around solar noon (p-value < 0.05), as expected. The far-red SIF quantified at 760-nm by the sub-nanometer (SIF760-SN) and narrow-band imager (SIF760-NB) did not show statistically significant differences between the well-watered and water-stressed almond blocks in the morning flight, while they exhibited statistically significant differences (p-value < 0.05) at noon. On DOY 104, when the almond trees completed the recovery from the water stress phase, Tc-Ta between blocks did not show statistically significant differences both in the morning and at noon, demonstrating that the transpiration rates were equalized after rehydration. Regarding SIF, no statistically significant differences were observed in SIF760-SN and SIF760-NB between water-stressed and well-watered blocks in the morning. Nevertheless, both SIF760-SN and SIF760-NB showed statistically significant differences between the two blocks at noon (p-value < 0.05). The sub-nanometer SIF760-SN showed a higher sensitivity than the narrow-band SIF760-NB in tracking the variations between the two blocks during maximum water stress differences and after water stress recovery.

These findings demonstrate the importance of tracking SIF to monitor water stress effects on photosynthesis, even after dehydration when the transpiration rates are equalised. Although the transpiration rates recovered, these results indicate that the SIF emission was sensitive to photosynthetic rate differences induced by the imposed water stress. Further analysis will be conducted to evaluate leaf traits and other SIF indicators such as fluorescence emission yield, total SIF emission, and fluorescence escape ratio to improve the understanding of SIF for photosynthetic monitoring under water stress and recovery phases in almond orchards.

THE SPAFLEX-IMP PROJECT: SPANISH FLEX-S3 MISSION CALIBRATION AND VALIDATION PLAN IMPLEMENTATION

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The European Space Agency's FLuorescence EXplorer-Sentinel 3 (ESA FLEX-S3) mission, scheduled for launch in 2026, aims to remotely detect vegetation fluorescence (SIF) of vegetation at a resolution of 300x300 meters. SIF, emitted by chlorophyll pigments, serves as an accurate proxy for plant photosynthesis and stress indicators. Cal/Val activities are essential to refine FLEX-S3 products before the resulting data are integrated into vegetation models. While ESA manages Level 1 products, Member States, such as Spain, oversee the Cal/Val plans for Level 2 products, thus promoting interoperability. The SpaFLEXImp initiative aims to implement a FLEX Cal/Val plan, standardizing protocols, and establishing a coordinated network of sites. Led by the National Institute of Aerospace Technology (INTA), the project involves the University of Valencia and the Doñana Biological Station-CSIC. With a long experience in in situ, airborne, and spaceborne measurements, the teams will conduct specific Cal/Val campaigns in 3 sites, making Spain a European and international reference for terrestrial Cal/Val activities. Spain's stable weather conditions and diversity of land uses make it an ideal location for Cal/Val activities, but it has not yet been included in the international Cal/Val test site network. The SpaFLEXImp project therefore aims to develop and implement a detailed Cal/Val plan that includes pre-launch and post-launch activities. Pre-launch activities include data acquisition and processing to refine models and algorithms, while post-launch activities verify and improve algorithm performance and product accuracy. The importance of the project is to contribute to the success of the FLEX-S3 mission, to standardize Cal/Val protocols, and to establish Spain as a leader in European and international land Cal/Val activities. With its experienced consortium and well-defined plan, SpaFLEXImp is poised to make significant contributions to the field of Earth observation and vegetation monitoring.

COUPLING SOIL WATER-HEAT FLOW, PLANT GROWTH, AND THE RADIATIVE TRANSFER OF REFLECTANCE AND FLUORESCENCE CONSIDERING THE CANOPY STRUCTURE

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The radiative transfer process has a direct impact on the interpretation of remote sensing data. Simulation of bidirectional reflectance and fluorescence of vegetation canopies requires accurate descriptions of canopy structure. The STEMMUS-SCOPE-WOFOST model integrates key processes such as radiative transfer, photosynthesis, and soil water-heat flow, demonstrating robust performances in estimating water-energy-carbon fluxes in the land-atmosphere system. However, the classical SAIL theory used in the model simplifies the leaf area index (LAI) of the vegetation canopy as vertically homogeneous, which may lead to biased simulations of bidirectional reflectance and fluorescence. We enhanced the model by considering the radiative transfer process of multi-layer canopies with a vertical distribution of LAI, which can be obtained either from lidar data or L-system simulations. Results showed that the vertical structure of LAI distribution has a significant impact on Top of Canopy reflectance, fluorescence and heat flux over the vertical canopy profile. Compared with the assumption of homogeneous canopy layers in the original model, the implementation of heterogeneous canopy structure in the enhanced model improves the estimations of upward reflected radiation, fluorescence emission, and canopy temperature. Furthermore, the enhanced model is also able to simulate the interactions between radiative transfer and plant growth process. We conclude that it is essential to consider the vertical heterogeneity of LAI distribution for the prediction of reflectance, fluorescence and canopy temperature. The enhanced STEMMUS-SCOPE-WOFOST model provides a mechanistic window to link the satellite observation (i.e., solar-induced fluorescence (SIF)) to above- and below-ground biomass, LAI, land surface fluxes, and root-zone soil moisture in a physically consistent manner.

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