Estimation of total evaporation in the Ebro River basin based on remote sensing and modelling Basin

Roger Clavera-Gispert [1], Pere Quintana-Seguí [1], Anaïs Barella-Ortiz [1], Simon Munier [2], Paulina Bartkowiak [3], Mariapina Castelli [3], Irina Petrova [4], Diego G. Miralles [4], Belén Martí [2], Aaron Boone [2], Christian Massari [5]

Affiliations of all authors:
1-**Observatori de l'Ebre** (Uni. Ramon Llull – CSIC), Roquetes, Spain.
2-Météo-France, CNRS, Toulouse, France.
3-Institute for Earth Observation, Eurac research, Bolzano, Italy.
4-Hydro-Climate Extremes Lab, Ghent, Belgium.
5-Research Inst. for Geo-Hydrological Protection, National Research Council, Perugia, Italy

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Objectives (1/1)

This work was part of the ESA 4DMED project

Case study: quantifying evapotranspiration at the Ebro basin scale

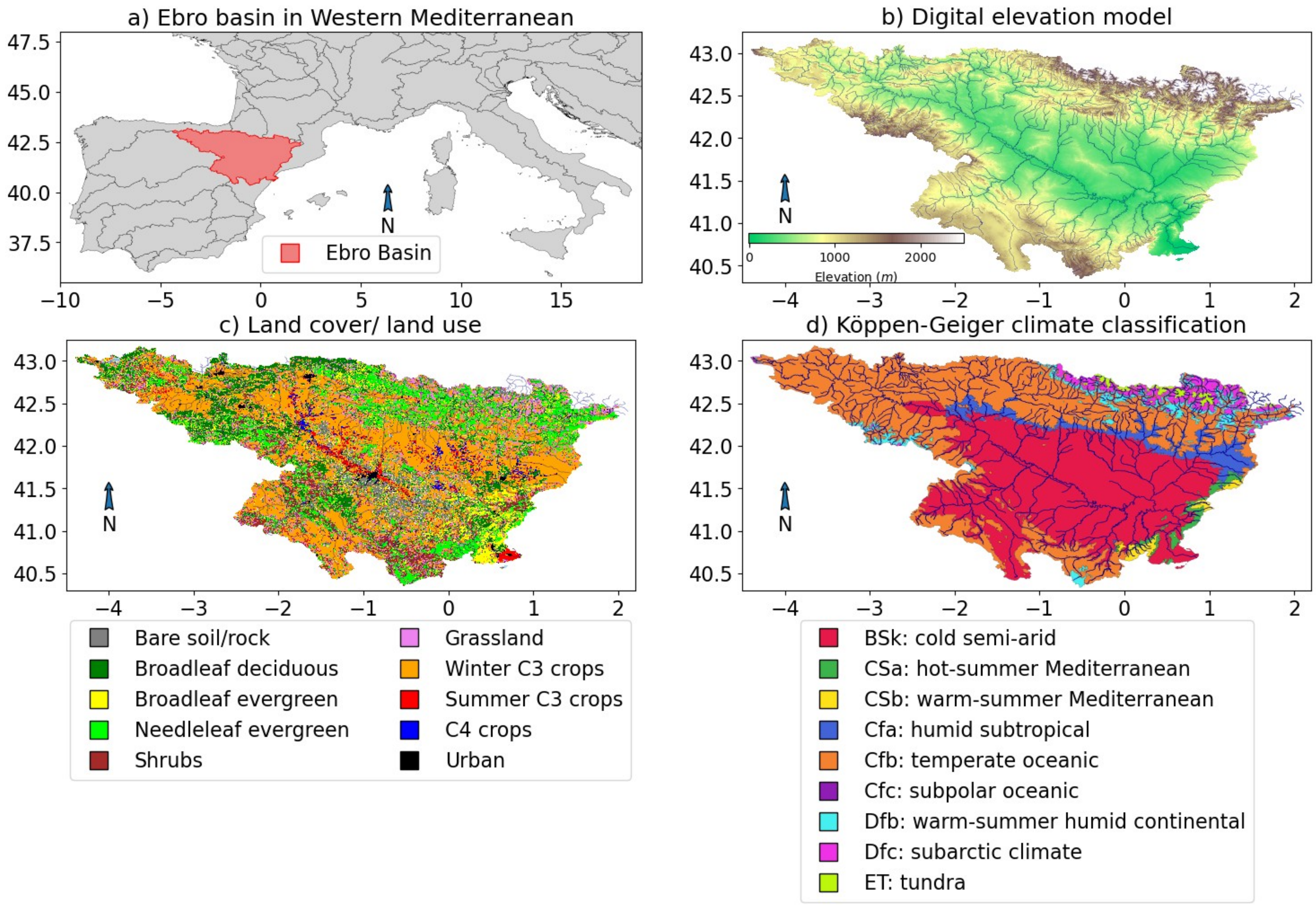
The analysis consisted of comparing the satellite products and a model (LSM), in order to determine their similarities and differences in both space and time.

Comparing:
- Climates.
- Land covers.

Ebro River Basin

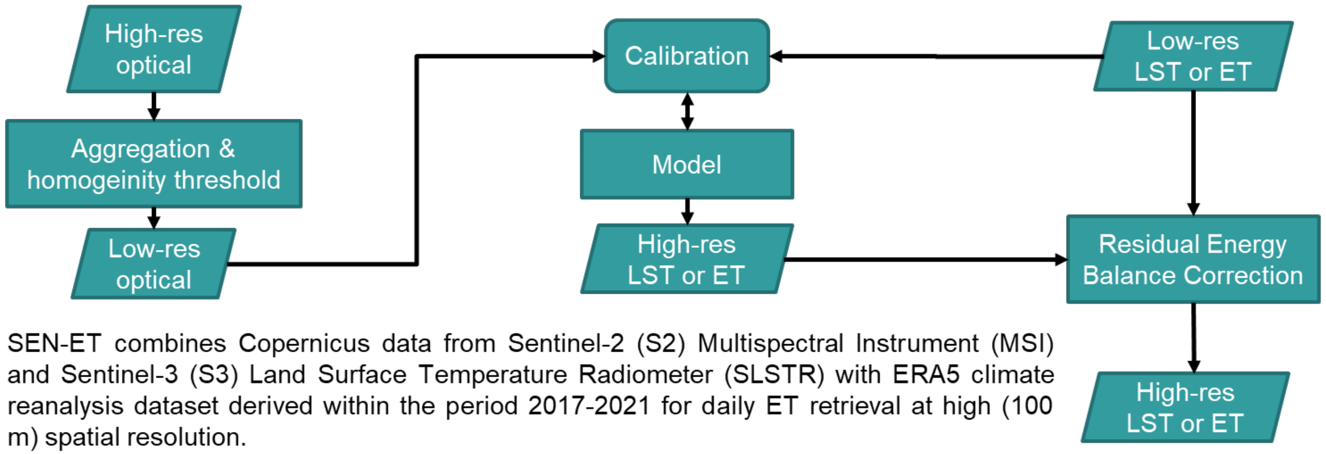
- Uneven distribution of precipitation and water resources.
- Large hydraulic network transports and stores the runoff generated on the Pyrenean slopes to the central valley.
- Large irrigation areas, both traditional and modernized.
- Forested area is increasing on the Pyrenean slopes and headwaters.
- Forests consume water.

The Water Basin Authority needs to track real water consumption (ET) by natural and human influenced covers.



Datasets (1/4)

SEN-ET

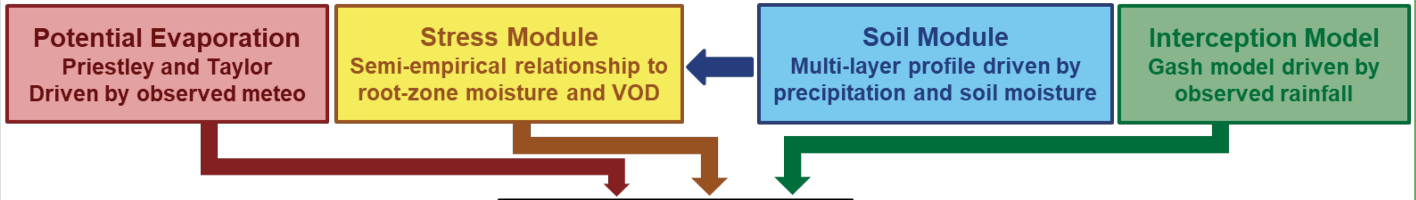


SEN-ET combines Copernicus data from Sentinel-2 (S2) Multispectral Instrument (MSI) and Sentinel-3 (S3) Land Surface Temperature Radiometer (SLSTR) with ERA5 climate reanalysis dataset derived within the period 2017-2021 for daily ET retrieval at high (100 m) spatial resolution.

Methodology described in detail in Guzinski et al. (2020) and Bartkowiak et al. (2023).

GLEAM

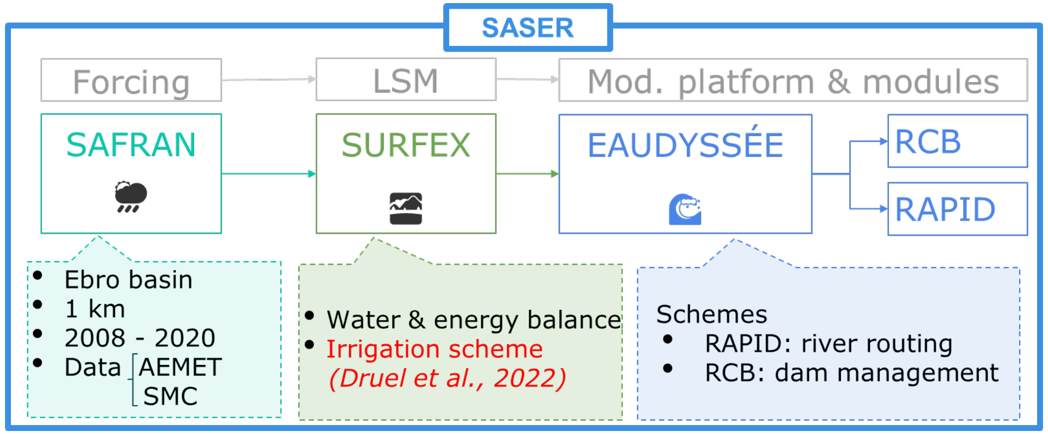
The Global Land Evaporation Amsterdam Model (GLEAM) is a set of algorithms that separately estimate the different components of land evaporation. In this work Actual Evaporation (E) is used.



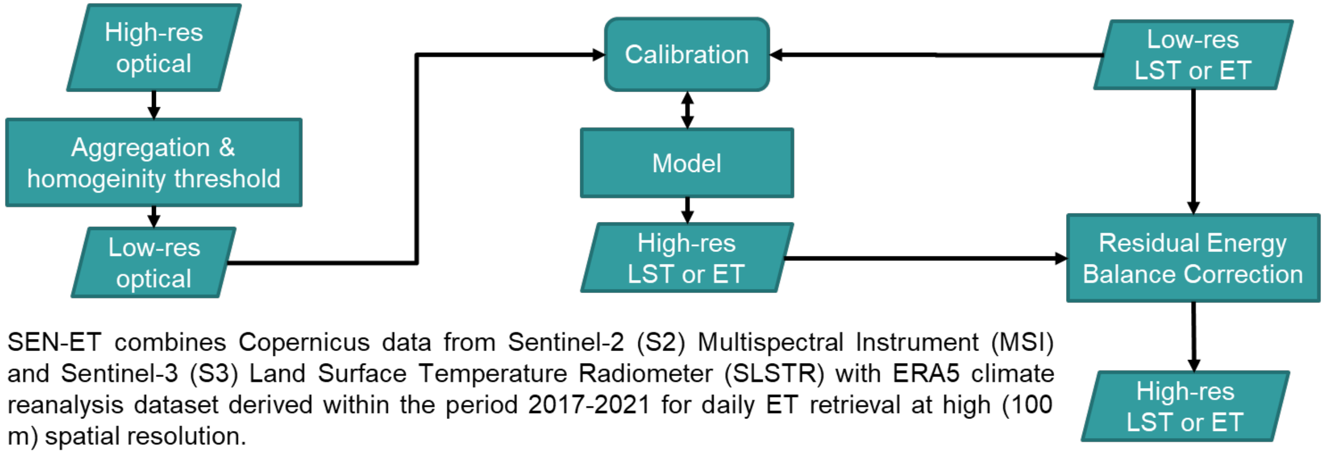
$$E = E_p \times S + E_i$$

The dataset is described in detail by Martens et al. (2017).

SASER



SEN-ET



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Methodology described in detail in Guzinski et al. (2020) and Bartkowiak et al. (2023).

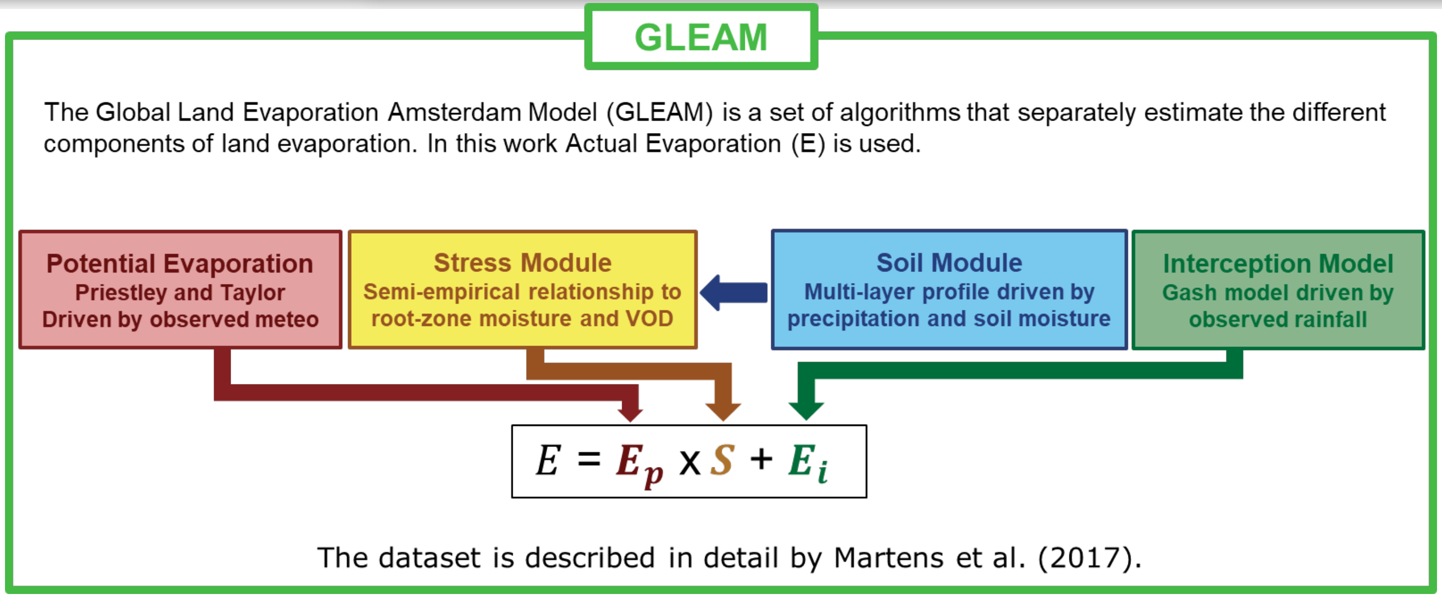
Sentinels for Evapotranspiration (SEN-ET) is a method that estimates daily ET at high spatial resolution using Sentinel-2 and Sentinel-3 data, together with ERA5. The methodology is detailed in Bartkowiak et al. (2023) and Guzinski et al. (2020).

The SEN-ET model uses an energy balance approach, combining observations of the Earth's surface temperature from satellites to improve the accuracy in estimating energy fluxes. To overcome the low spatial resolution of the available infrared thermal data, SEN-ET employs a downscaling technique to increase the resolution to 100m.

In the model, the radiometric temperature of each pixel is considered as a combination of soil and vegetation temperatures, which are estimated by an iterative process that adjusts the Priestley-Taylor equation until reasonable results are obtained.

The SEN-ET model faces challenges such as the dependence on the resolution of ERA5 and the affectation of observations by cloud cover. **The SEN-ET product used in the Ebro basin study covers the period from 2017 to 2021 with a spatial resolution of 100 m**.

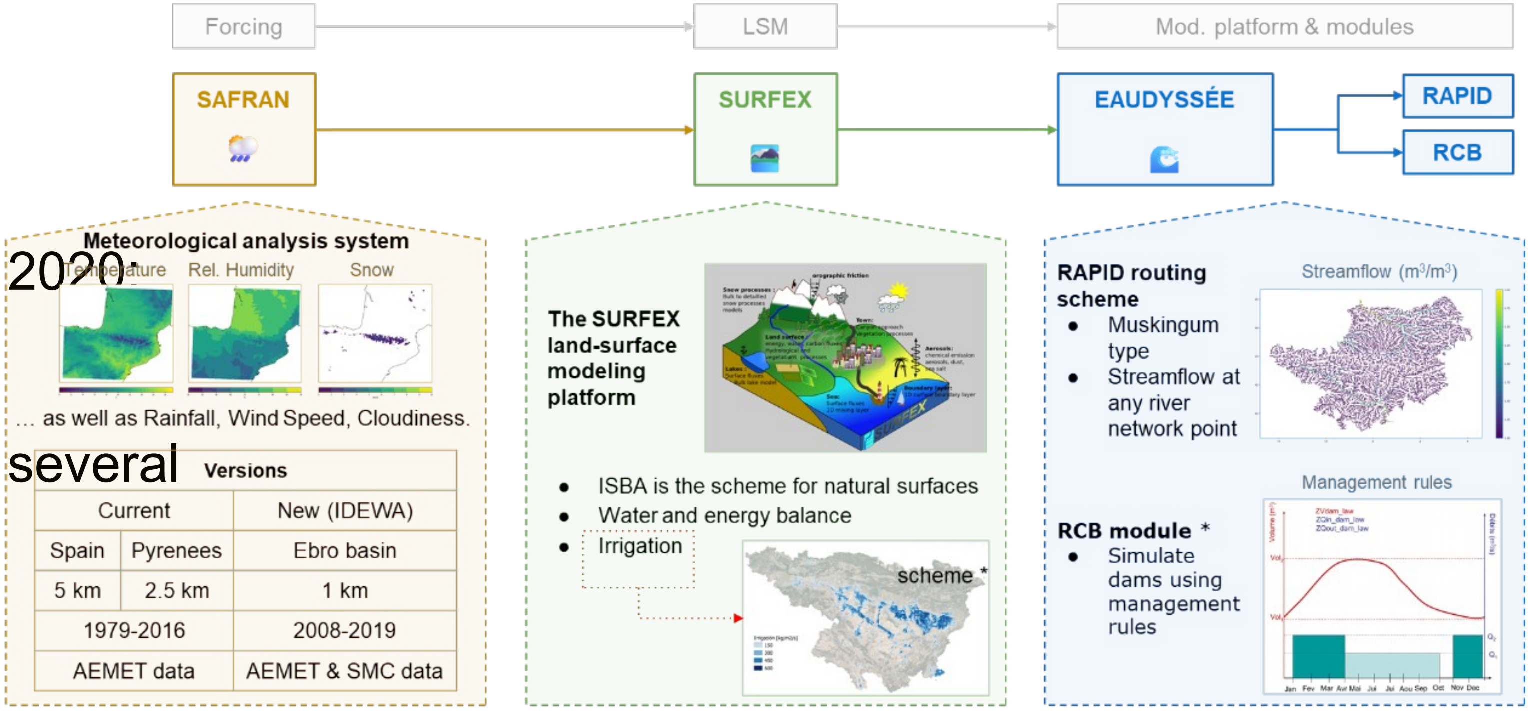
Datasets (3/4)



Global Land Evaporation Amsterdam Model (GLEAM) is a set of algorithms that estimate the different components of land evaporation.

GLEAM is based on soil moisture from **microwave data** and combines global satellite observations of meteorological variables (precipitation, net near-surface radiation and air temperature) and surface characteristics (soil and vegetation water content and snow water equivalents) to obtain estimates of evaporation. The model uses the Priestley-Taylor equation, adjusting estimates of potential evaporation according to soil moisture in the root zone. Interception loss is estimated independently using an analytical Gash model.

Although initially applied at low spatial resolutions for climate studies, in recent years GLEAM has been developed to reach higher resolutions up to 1 km (Hulsman et al., 2023).



Current		New (IDEWA)
Spain	Pyrenees	Ebro basin
5 km	2.5 km	1 km
1979-2016		2008-2019
AEMET data		AEMET & SMC data

* No link between irrigation and dam management

2020:

several

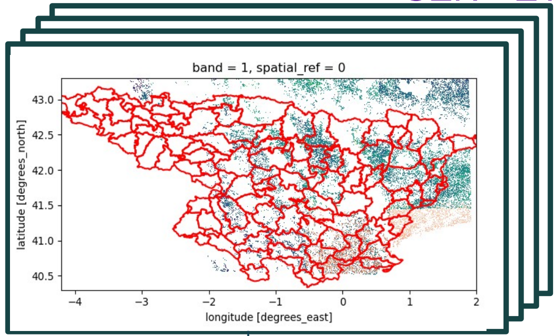
SURFEX (SURFace EXternalisée) (Le Moigne and Minvielle, Masson et al., 2013) is a land surface model (LSM) developed by Météo-France composed by physical models. In this case the ISBA SVAT scheme was used.

To force the hydrological and the atmospheric models, a gridded database developed for the Ebro basin using SAFRAN was used.

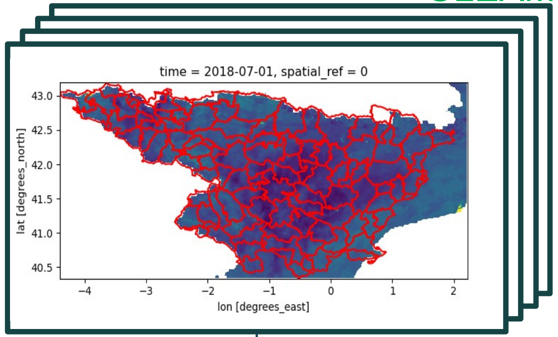
The SURFEX version used includes an irrigation scheme implemented by Druel et al. (2022)

Methodology (1/1)

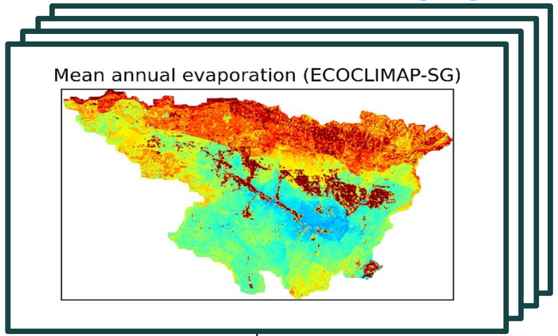
SEN - ET



GLEAM



SASER



Bring the data to a **common grid and period**.

- The satellite and modelled data will be interpolated to the spatial grid defined in the project
- The period of analysis will be from 2017 to 2019.
- Take the pixels common to the 3 products

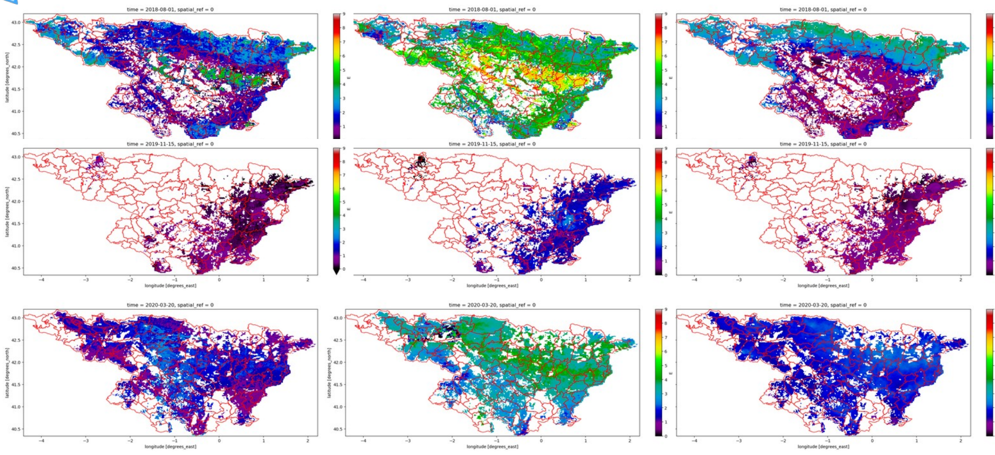
Available years per product

Product	Period
SEN-ET	2017 to 2021
GLEAM	2015 to 2021
SASER	2008 to 2019

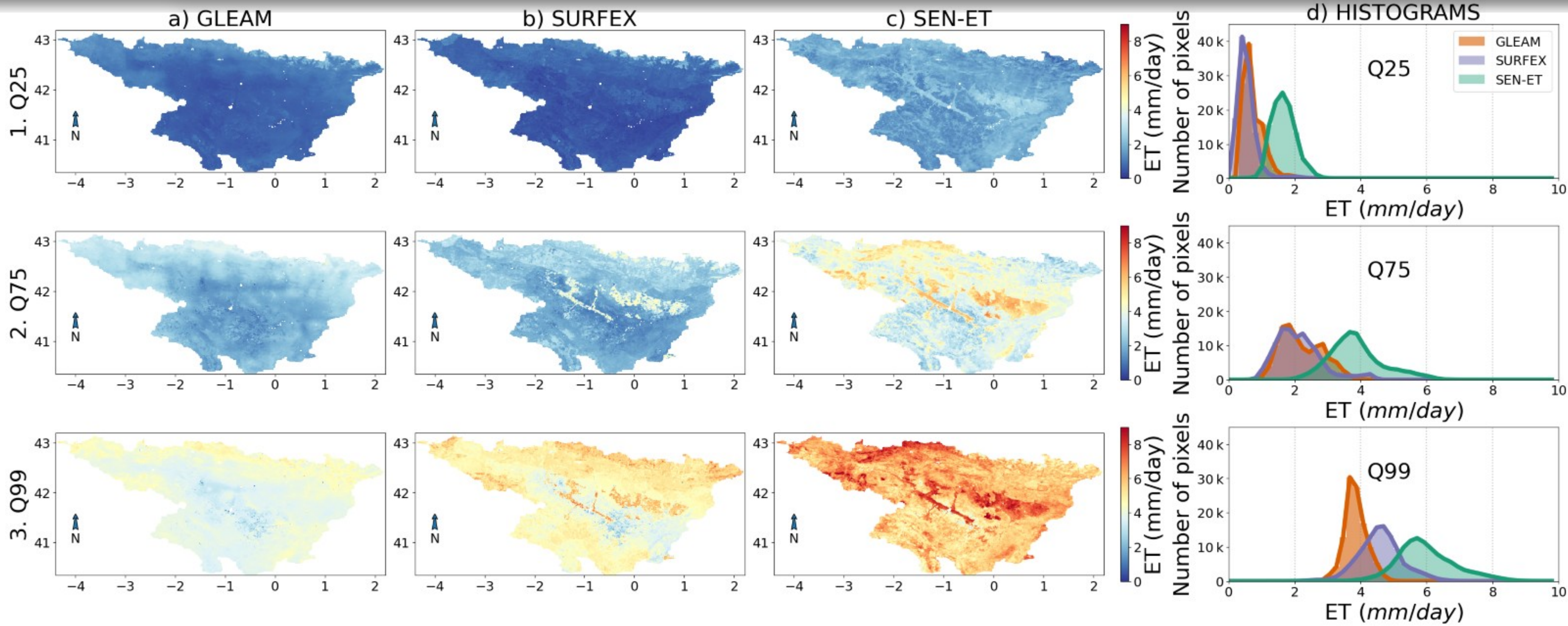
Statistical analysis:

- Descriptive statistics
- Spearman correlation coefficient
- Temporal series: Time aggregation due to gaps in data
- Analysis by land cover: using an improved physiographic map based on ECOCLIMAP-SG to mask the different land covers.

SASER SEN-ET GLEAM

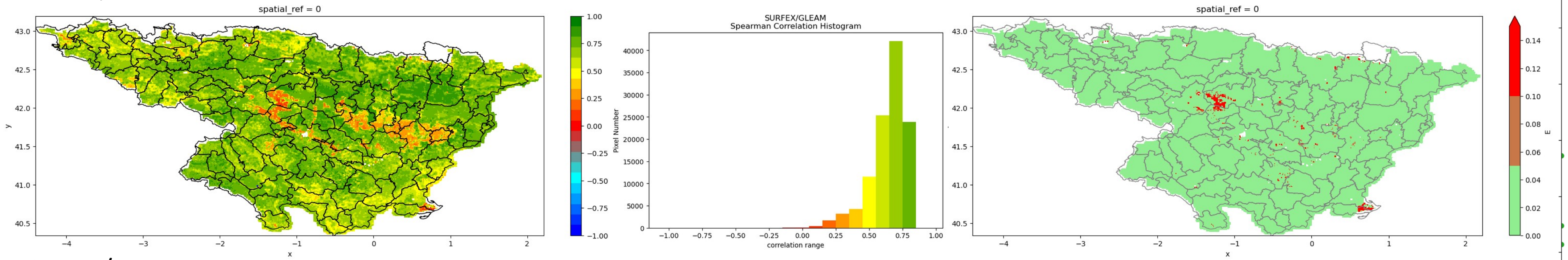


Results: Descriptive statistics (1/5)

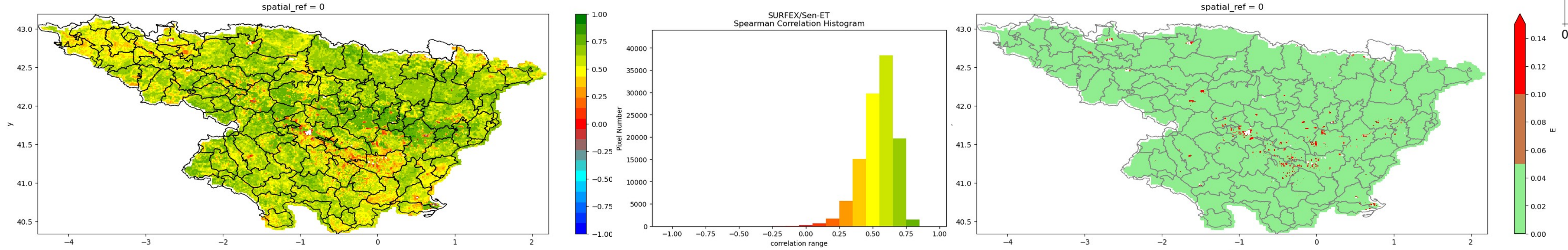


- *The mean ET values differ across the three products:1.50 mm/day for SURFEX, 1.56 mm/day for GLEAM, and 2.76 mm/day for SEN-ET.*
- *While lower quantiles are consistent across datasets, higher quantiles show greater variability, with SEN-ET exhibiting a notably wider range and distinct distribution.*
- *Median ET is lower than the mean for GLEAM and SURFEX (right-skewed distribution) but matches the mean for SEN-ET.*
- *Distinct populations in some quantiles suggest the influence of varying climatic zones and land covers within the Ebro basin, which are further explored in subsequent analyses and visually represented in maps.*

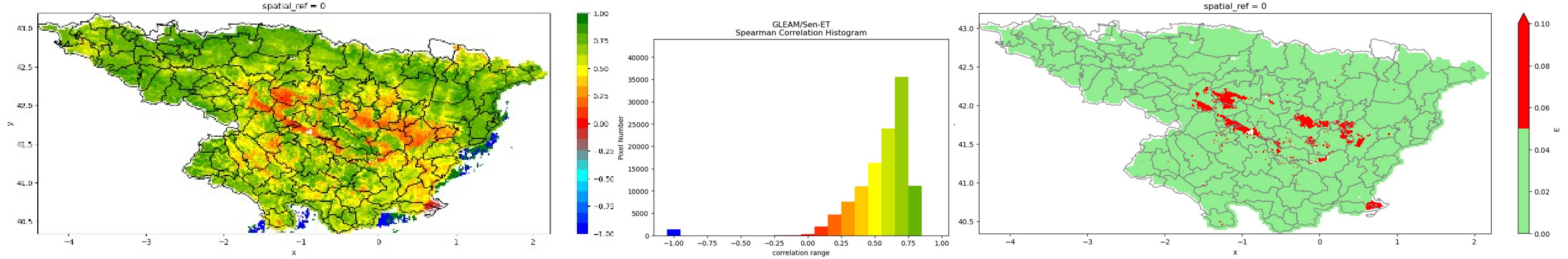
SASER/GLEAM

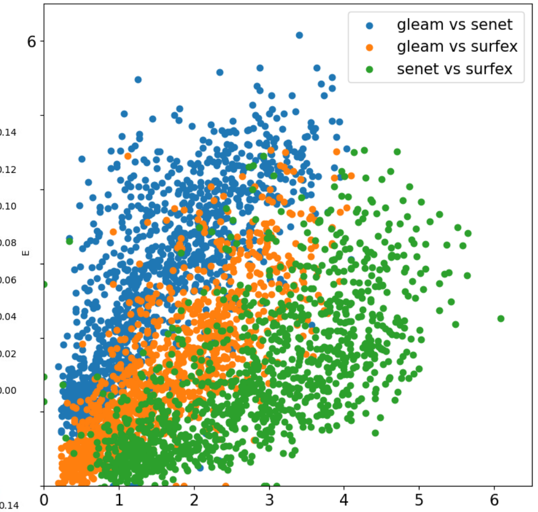


SASER/SEN-ET



GLEAM/SEN-ET

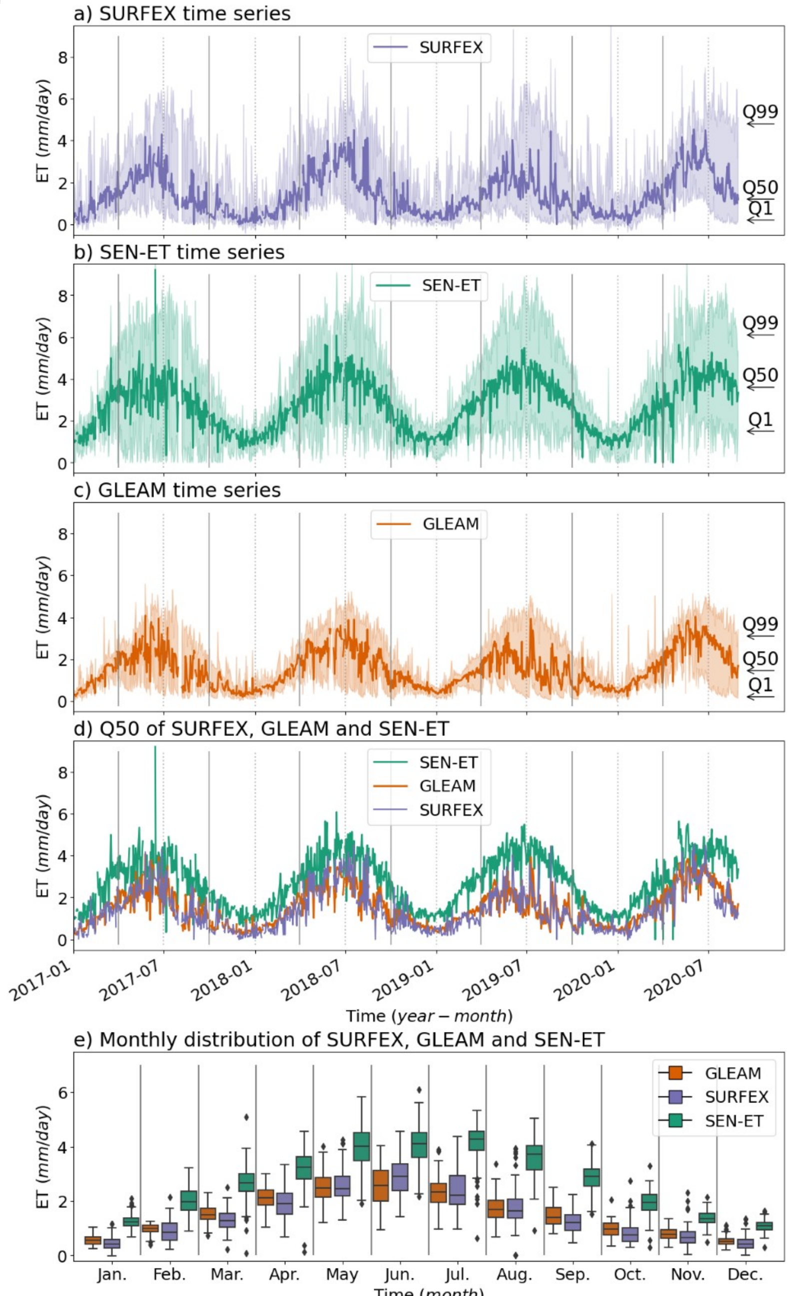




- The correlations with GLEAM have the worst values in irrigated areas.

- SASER/SEN-ET correlation has the best correlation in the irrigation area and the worst in the drier and semi-arid region.

Results: temporal analysis (3/5)

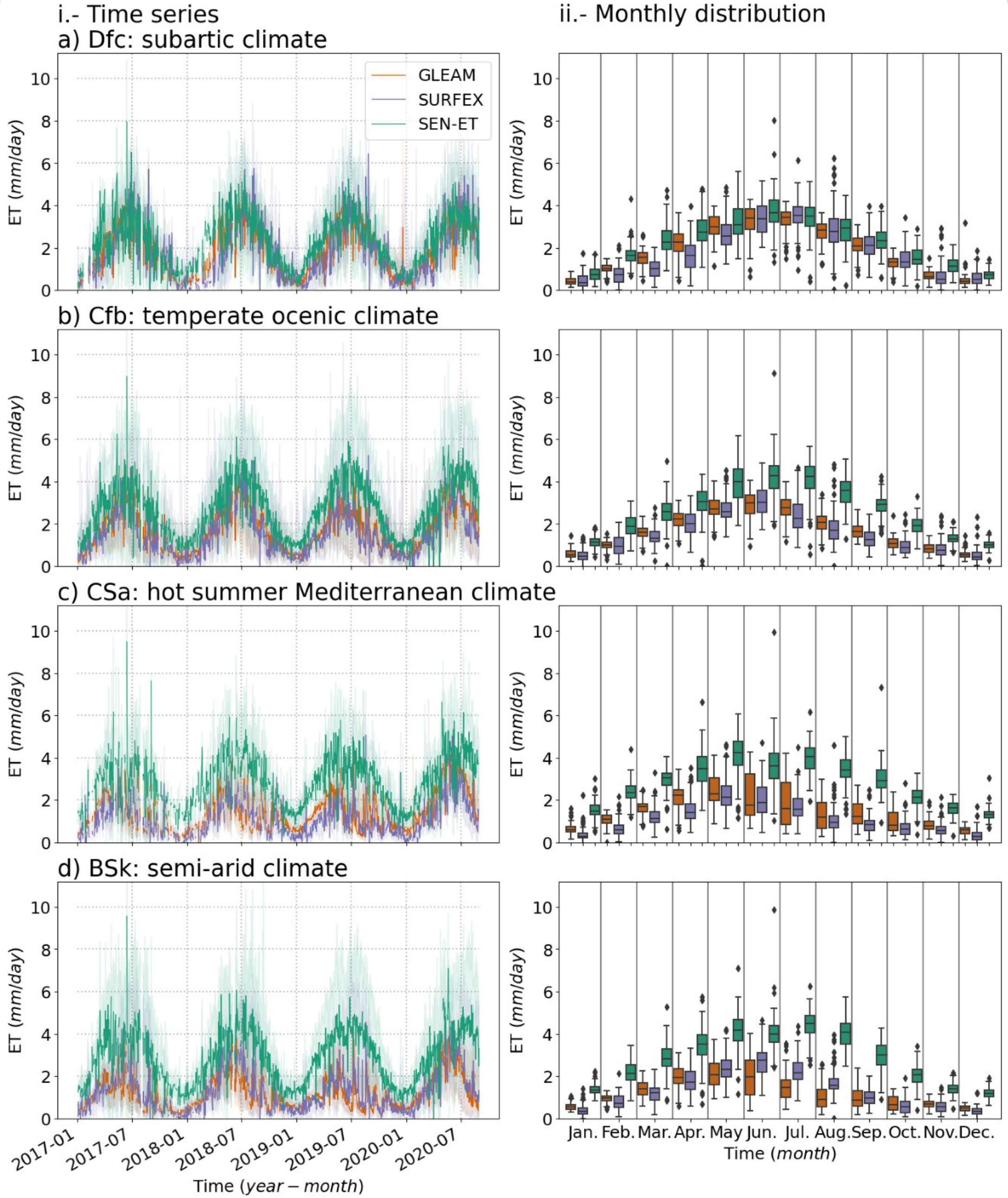


	Spring/Summer 01/04 to 30/08 Mean ET in mm/day			Fall/Winter 01/09 to 31/03 Mean ET in mm/day		
	SURFEX	**SEN-ET**	**GLEAM**	**SURFEX**	**SEN-ET**	**GLEAM**
2017	1.97	3.23	1.97	0.51	1.37	0.61
2018	2.31	3.69	2.29	0.73	1.45	0.82
2019	1.91	3.81	1.85	0.71	1.50	0.79
2020	2.47	3.94	2.54			

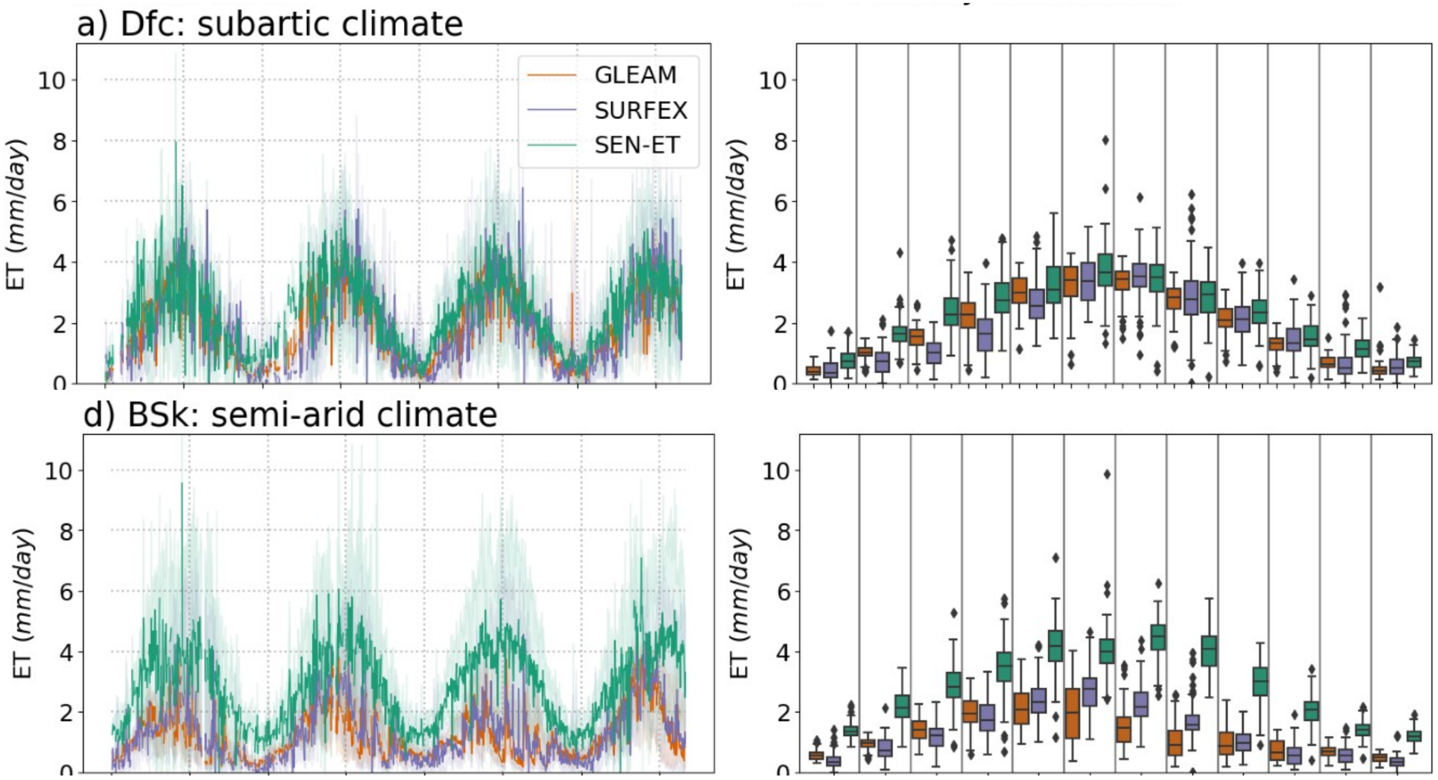
The comparison of ET time series over the Ebro Basin highlights seasonal variations with maximum ET in summer and minimum in winter. Differences exist among products, including value ranges and timing of peaks.

SEN-ET shows higher and symmetrical ET values, especially in June and July, differing from the asymmetrical patterns of SURFEX and GLEAM, which align closely.

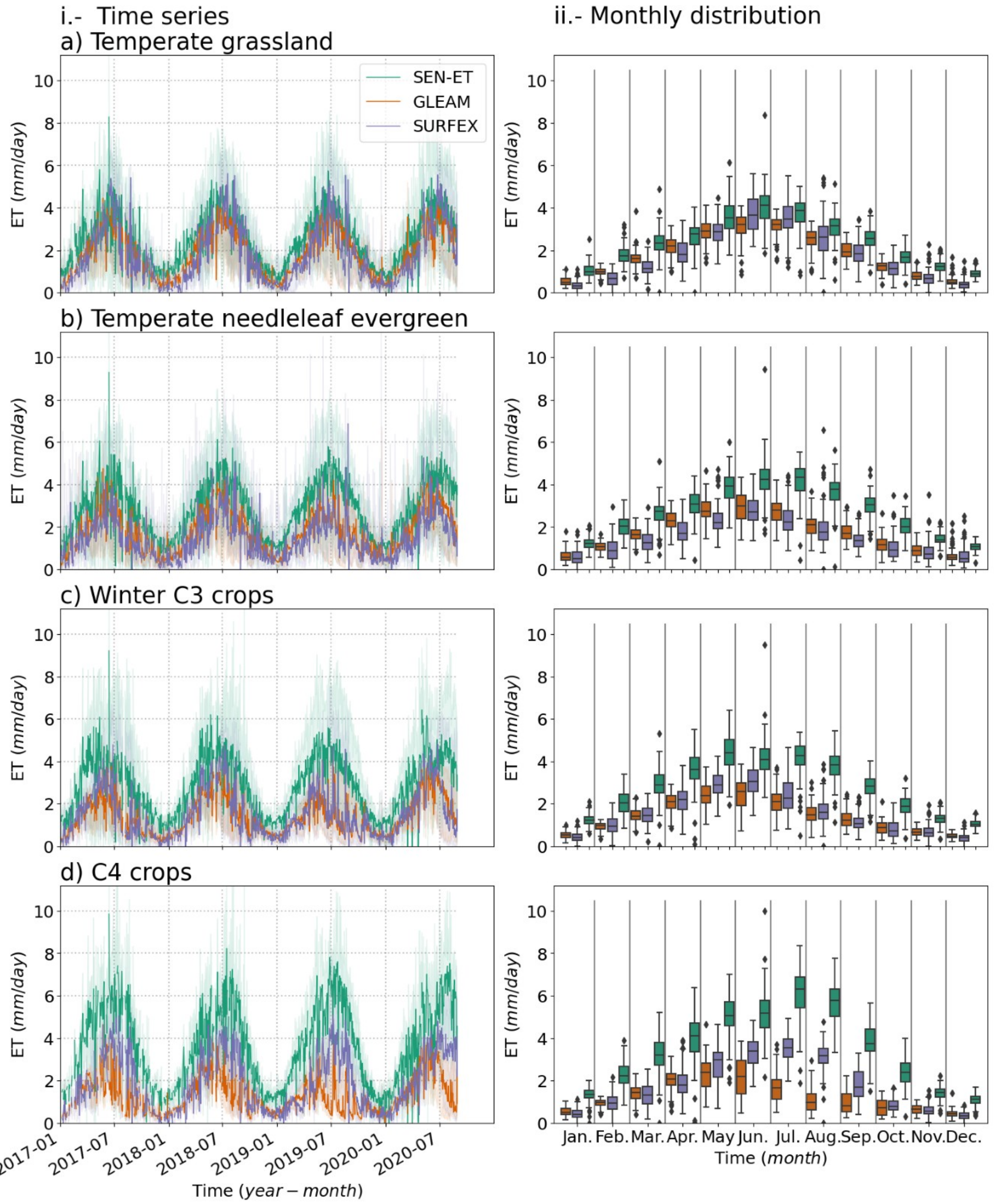
Results: analysis by climate (4/5)



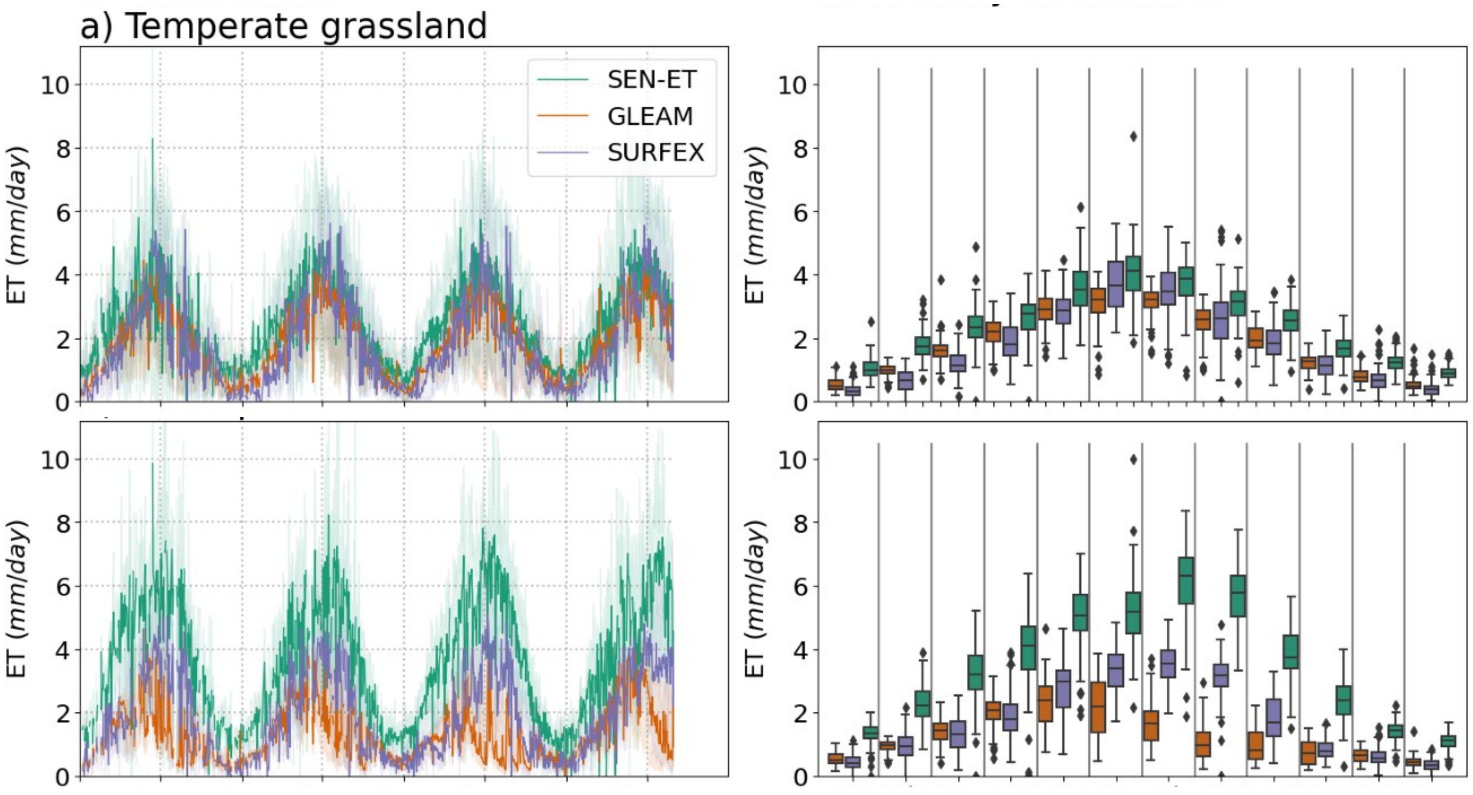
- **Subartic**: SURFEX shows lower ET values in spring, with a peak in July, while GLEAM and SEN-ET peak in June.
- **Oceanic**: exhibits higher ET values in winter and discrepancies in summer, with SEN-ET consistently higher.
- **Hot mediterranean**: increasing differences in ET, with SEN-ET peaking above 4 mm/day in May, unlike summer peaks in other climates.
- **Semi-arid:** lower correlations among the products. SEN-ET is consistently higher and monthly ET peaks vary between May, June, and July depending on the product.



Results: analysis by land cover (5/5)

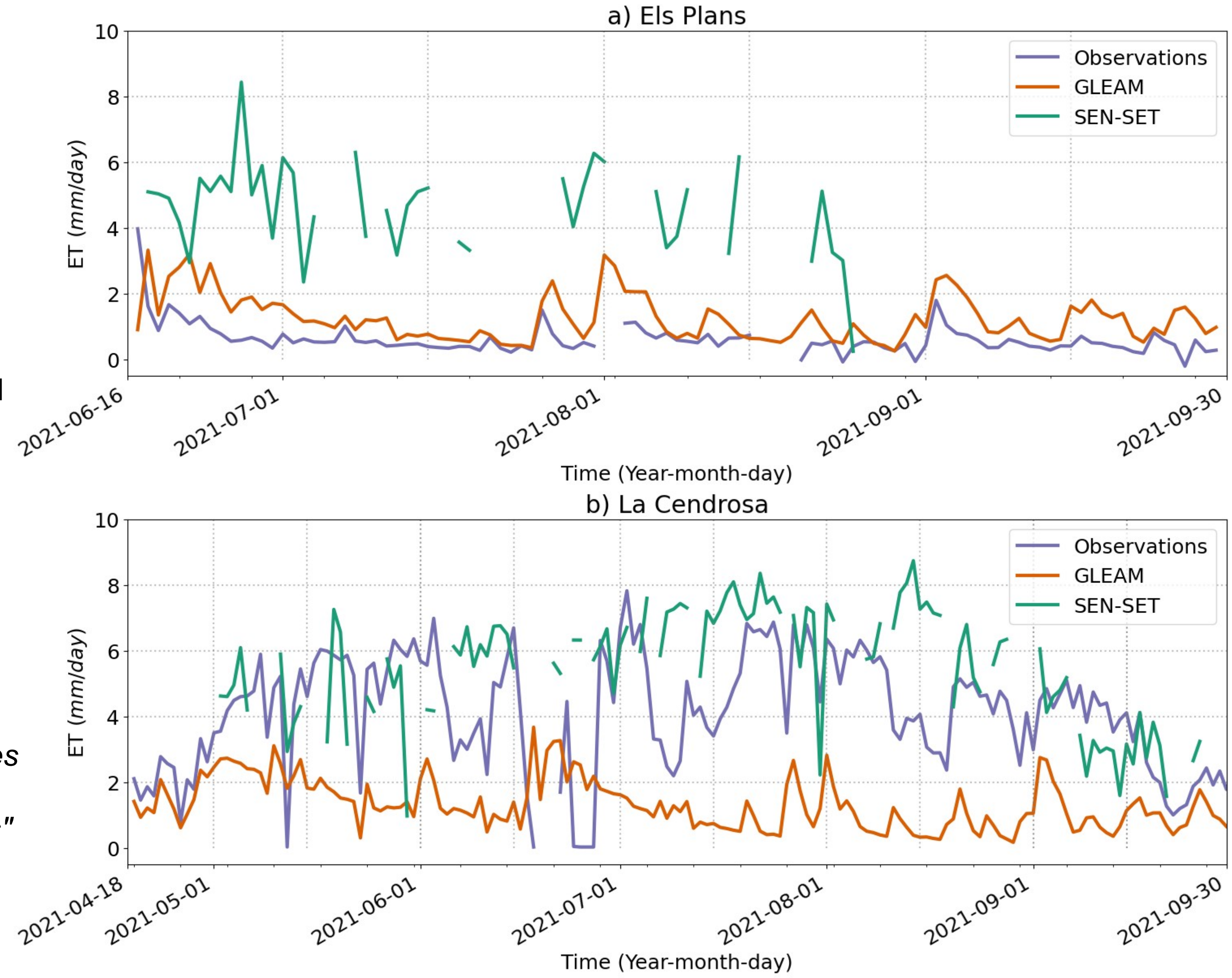


- **Grassland** (mainly in Pyrenees): all products show similar trends and peaks.
- **Needleleaf Evergreen** (covering major mountain ranges): discrepancies with SEN-ET consistently showing higher values and marked differences in spring months.
- **Winter C3 Crops** (dominant in the basin): reveal SEN-ET's higher evaporation values, especially during the 2019 drought, while SURFEX and GLEAM peak in June compared to SEN-ET's maximum in May.
- **C4 Crops** (located in irrigated areas): display the most divergence among products, GLEAM shows lower summer values, unlike SEN-ET's consistently higher peaks, and notable seasonal shifts in each product's distribution.



Satellite vs. Observations (1/1)

When comparing satellite products with LIAISE point observations in "Els Plans" (fallow area) and "La Cendrosa" (irrigated alfalfa field), GLEAM aligns well with "Els Plans" observations in magnitude, while SEN-ET overestimates ET values. In "La Cendrosa," SEN-ET generally agrees with measurements, detecting large-scale changes like post-rain ET increases but missing field-scale irrigation and harvest cycles. GLEAM underestimates ET in irrigated periods and responds primarily to rain events, highlighting its limitation in capturing fine-scale variations influenced by irrigation and land use.



Comparison of satellite-derived ET products with field observations from the LIAISE Project. This figure compares ET values from GLEAM and SEN-ET products with field observations at two locations in the Ebro basin: "Els Plans" (rainfed area) and "La Cendrosa" (irrigated area).

LIAISE

Discussion / Conclusions (1/2)

- Each product offers unique insights but varies in performance and suitability under different conditions.
- **GLEAM & SEN-ET**: Satellite-driven, providing high spatial/temporal resolution but affected by cloud cover, retrieval assumptions, and resolution limits.
- **SURFEX**: No direct satellite data; focuses on soil-vegetation-atmosphere interactions, limited by meteorological input quality.

Performance Insights:

- **SEN-ET**:
  - Overestimates ET, especially in irrigated areas and summer.
  - Strong in detecting irrigated crops but less accurate in drought conditions (e.g., 2017, 2019).
- **GLEAM**:
  - Underestimates ET in irrigated zones.
  - Struggles to capture irrigation impacts and summer ET dynamics.
- **SURFEX**:
  - Balanced results; close to GLEAM but with slightly higher values.
  - Effective in non-irrigated areas but less sensitive to drought conditions.

Discussion / Conclusions (2/2)

Climate Zone Analysis:

- **Colder, wetter climates (Dfc, Cfb)**: Similar ET patterns across products, reliable performance.
- **Warmer, arid climates (BSk, Csa)**: SEN-ET show higher ET, requiring adjustment in extreme conditions.

Land Cover Analysis:

- **Temperate grasslands**: Similar ET values across all products.
- **Needleleaf evergreen**: SEN-ET shows higher ET but struggles with drought detection.
- **Agricultural areas**:
  - SEN-ET: High sensitivity to irrigation, better for irrigated crops (C3, C4).
  - GLEAM: Underestimates irrigation impacts.

Field Observations: Validation with **LIAISE project data**:

- GLEAM performs better in dry conditions.
- SEN-ET excels in irrigated zones.

Key Takeaways:

- Strengths and limitations of each product must be acknowledged for informed application in water resource management.
- Refinement needed to improve sensitivity to irrigation and drought conditions.
- Validation with field data is crucial for accuracy and reliability.

Thank you for your attention!

rclavera@gencat.cat abarella@gencat.cat pquintana@gencat.cat

Generalitat de Catalunya
meteo.cat Servei Meteorològic de Catalunya
ICGC Institut Cartogràfic i Geològic de Catalunya
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