Potential of satellite surface soil moisture products for spatially calibrating distributed eco-hydrological models

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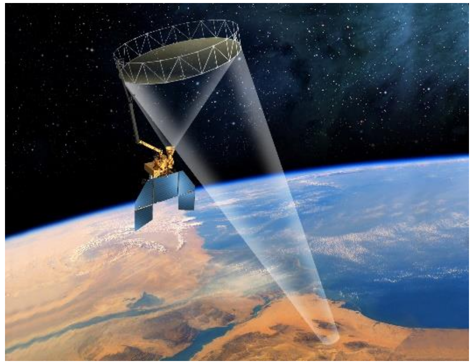
EGU General Assembly 2022

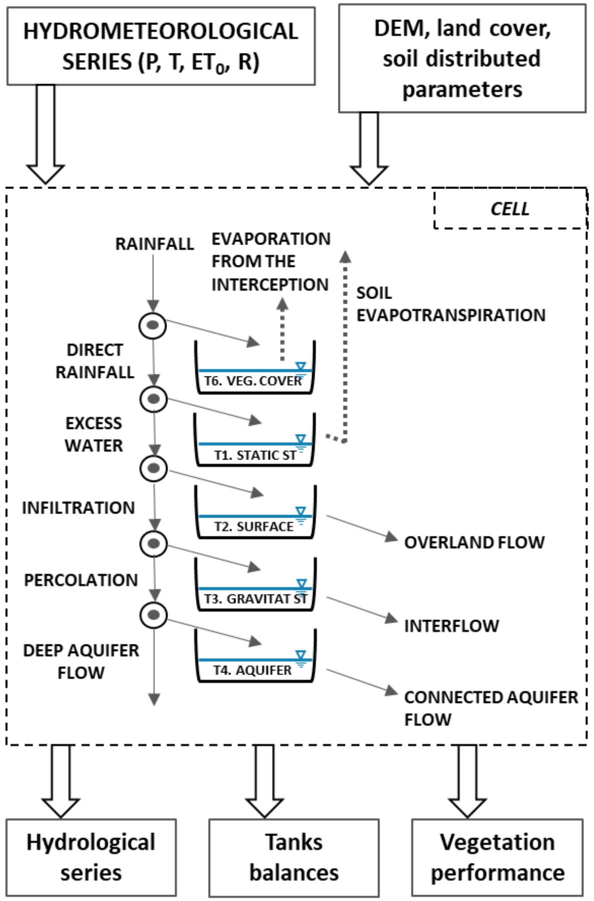
Introduction

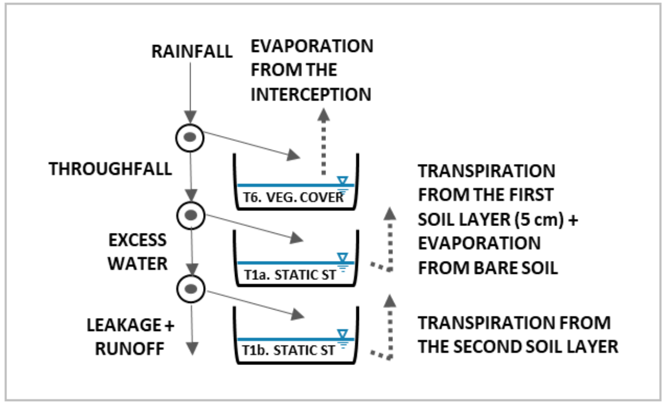
- Distributed eco-hydrological models (DEHM) can provide spatial description of hydrological processes
- Satellite information can be used for the spatial calibration of DEHM (*Ruiz-Pérez et al., 2017; Echeverría et al., 2019*)
- Sentinel-1, SMAP and SMOS surface soil moisture (SSM) products are available at 1km. However, they are not free from errors
- Research questions:
  - **How well do SSM products agree with DEHM?**
  - **Could they be useful for DEHM calibration?**



Tetis eco-hydrological model

❑ Hydrological sub-model





Hydrological Correction factors
FC1- Maximum Static storage
FC2 - Vegetation factor evapotranspiration
FC3 - Infiltration capacity
FC4 - Slope velocity
FC5 - Percolation capacity
FC6 - Interflow hydraulic capacity
FC7 - Deep aquifer percolation capacity
FC8 - Connected aquifer hydraulic conductivity
FC9 - Kinematic Geomorphological Wave

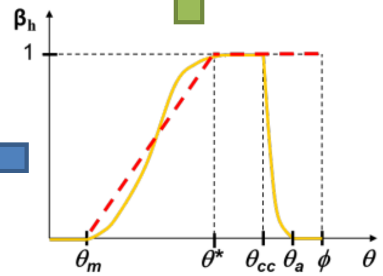
❑ Dynamic vegetation sub-model

$$\frac{dB_l}{dt} = (LUE \cdot \varepsilon \cdot PAR \cdot fPAR - Re) \cdot \varphi_l(B_l) - k_l B_l$$

✓ **State variable: leaf biomass** ✓ Based on LUE

Vegetation Parameters
β (-) Exponent in the soil water limitation function
ξ (-) Exponent in the vegetation water stress function
Imax (mm) Maximum leaf interception storage
Rd (%) Root distribution
k_l (-) Light extinction coefficient
T_{opt} (°C) Optimum temperature

Vegetation Parameters
LUE (gC/MJd) Light Use Efficiency
rr (gC/gN d) Respiration rate
k_d (-) Leaf natural decay factor
SLA (m^2/gC) Specific leaf area
LAI_{max} (m^2/m^2) Maximum LAI



✓ ε : stress factor including water

✓ $T_i = ET_0 \cdot f_c \cdot \min(1, LAI) \cdot \beta(H_i)$

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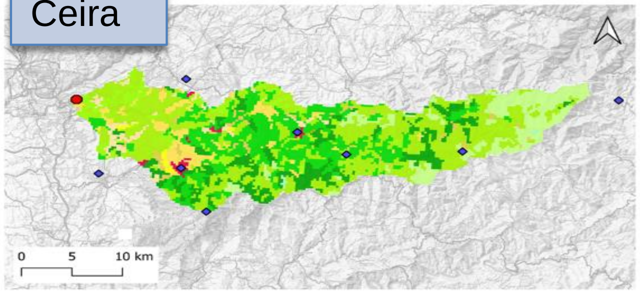
Iberian Mediterranean basins

✓ Representative of the climatology and hydrology of the Mediterranean Bio-geographical in the Iberian Peninsula

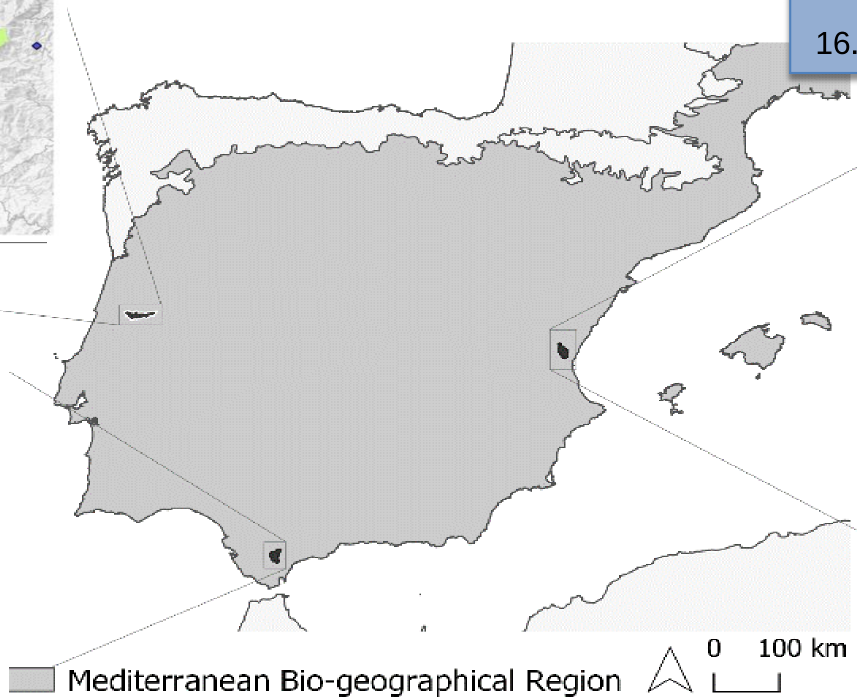
T (℃)	P (mm)	ETO (mm)
16.6 ± 0.1	373 ± 108	1142 ± 11

Ceira

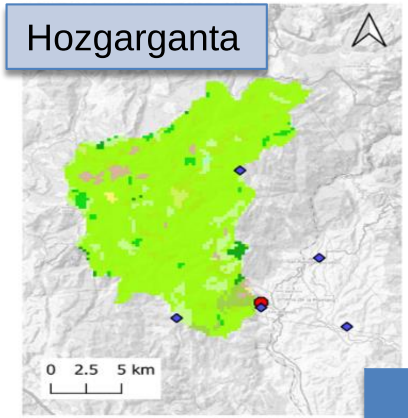


- 496.89 km^2
- 62-1380 m.a.s.l
- Forestry
- Dense vegetation +

T (℃)	P (mm)	ETO (mm)
14.0 ± 0.3	706 ± 328	412 ± 3



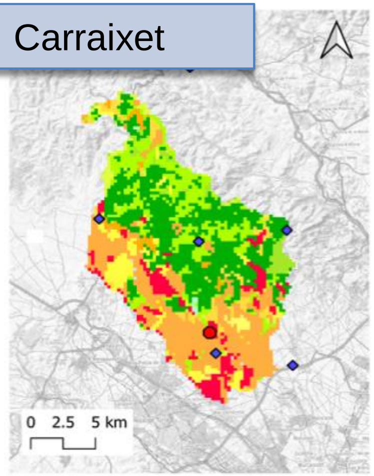
Hozgarganta



- 228.3 km^2
- 38-1042 m.a.s.l
- Forestry
- Dense vegetated +++

T (℃)	P (mm)	ETO (mm)
17.7±0.4	826 ± 278	1212 ± 41

Carraixet



- 236.5 km^2
- 55-898 m.a.s.l
- Forestry and agricultural
- Dense vegetation +
- Ephemeral river

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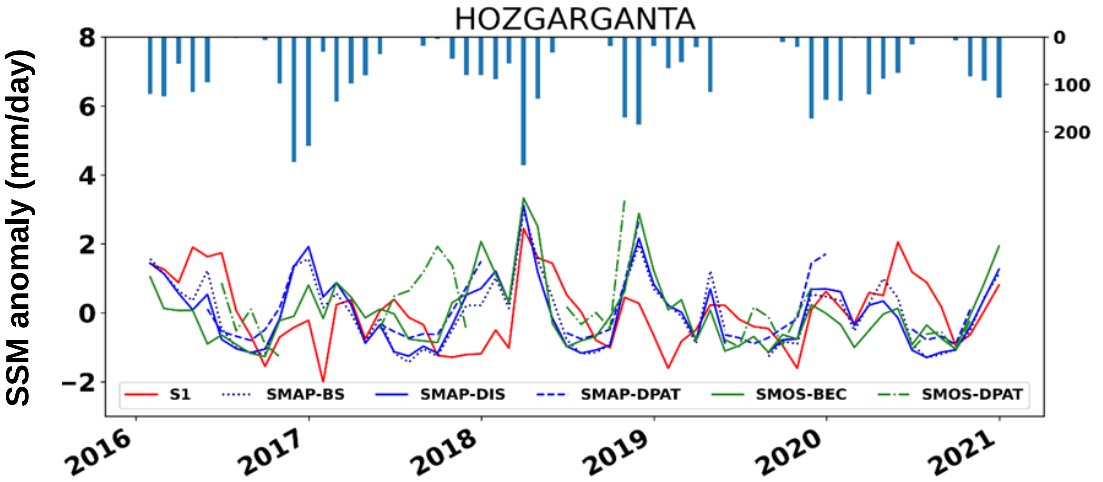
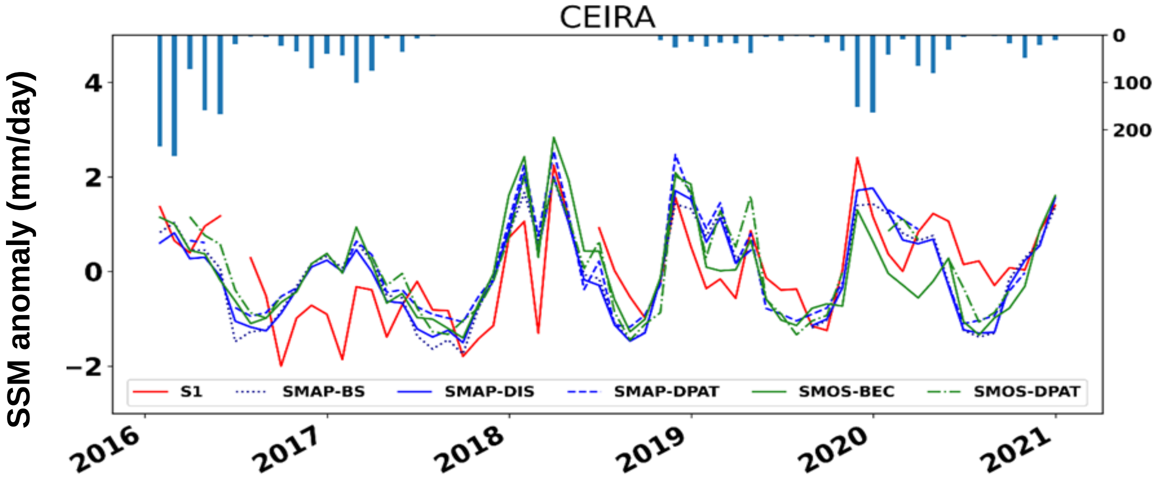
Satellite surface soil moisture

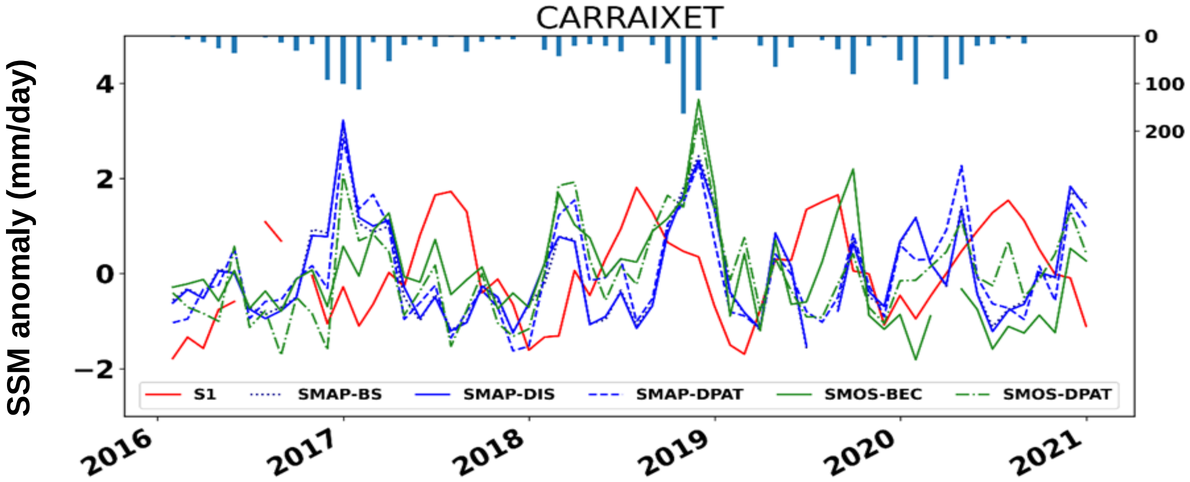
SSM is for first 5cm!

	Band	Spatial resolution	Retrieval method
Sentinel-1 **(S1)**	C	1 km	TU-Wien change detection method (Wagner, 1998)
SMAP/S1 (**SMAP-BS** & **SMAP-DIS**)	L+C	1 km	Passive (SMAP) + active (Sentinel-1) downscaling (Das et al., 2017)
SMOS-BEC	L	1 km	SMOS dissaggregation using LST and NDVI (Piles et al., 2011-2012).
SMAP-Dispatch (**SMAP-DPAT**)	L	1 km	SMAP and SMOS disaggregation of SSM using the soil evaporative efficiency (SEE). LST and NDVI are used as inputs (Merlin et al., 2013).
SMOS-Dispatch (**SMOS-DPAT**)	L	1 km	

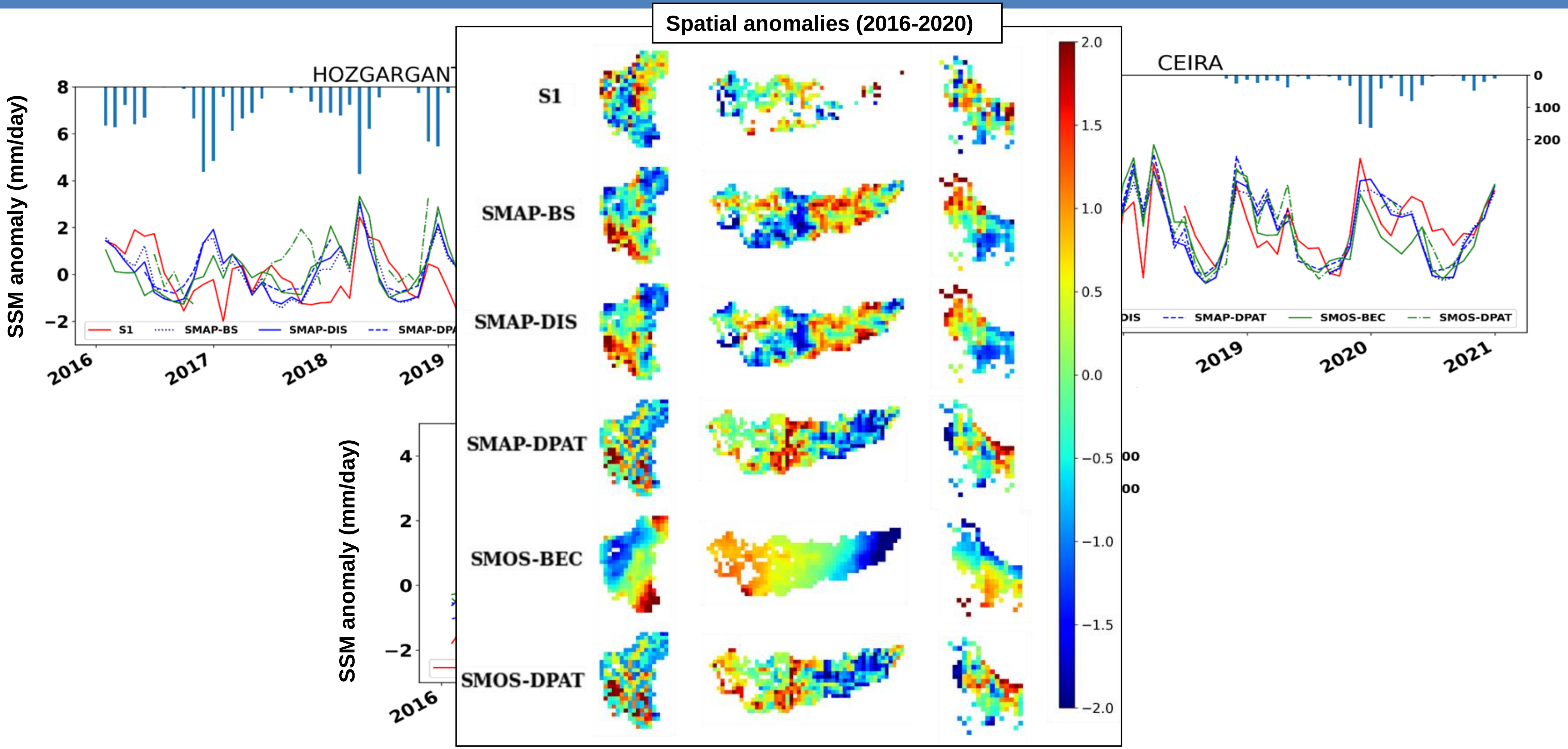
SSM products assessment







SSM products assessment



Multi-objective calibration (Q and SSM)

EUDEM + CORINE LAND COVER + 3D-EUROSOILS + GLHYMPS + SOILSGRIDS + LANDSAT + SiAR + SAIH-HIDROSUR + SAIH-JUCAR+SNIRH → TETIS → Sobol Sensitivity analysis → Multi-objective/variable calibration + validation

Sobol Sensitivity analysis → **Sensitive parameters + calibration ranges**

OF for Q:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Q_{s_i} - Q_{o_i})}{\sum_{i=1}^{n}(Q_{oi} - \overline{Q_o})}$$

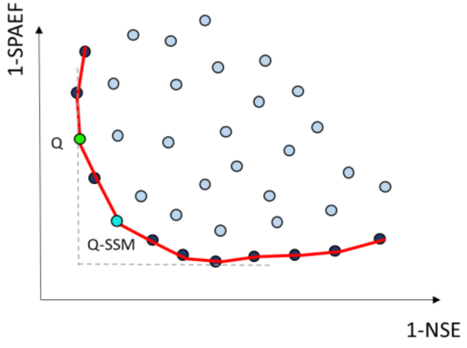
+

OF for satellite SSM:

$$SPAEF = 1 - \sqrt{(\alpha-1)^2 + (\beta-1)^2 + (\gamma-1)^2}$$

$$\alpha = \rho\,(\text{obs,sim}),\ \beta = \left(\frac{\sigma_{\text{sim}}}{\mu_{\text{sim}}}\right) / \left(\frac{\sigma_{\text{obs}}}{\mu_{\text{obs}}}\right) \text{ and } \gamma = \frac{\sum_{j=1}^{n} \min(K_j, L_j)}{\sum_{j=1}^{n} K_j}$$

→ **MOSCEM-UA** (Vrugt et al. 2003)



- ✓ Hoz+Carraixet: 2016-2017 (CAL) + 2018-2019 (VAL)
- ✓ Ceira: 08-2015/07-2017 (CAL) + 03-2019/07-2020 (VAL)
- ✓ NSE (1day) + SPAEF (1month)
- ✓ TETIS is run in natural mode (250 m)

- ✓ Optimum point: minimum Euclidean distance to the reference point

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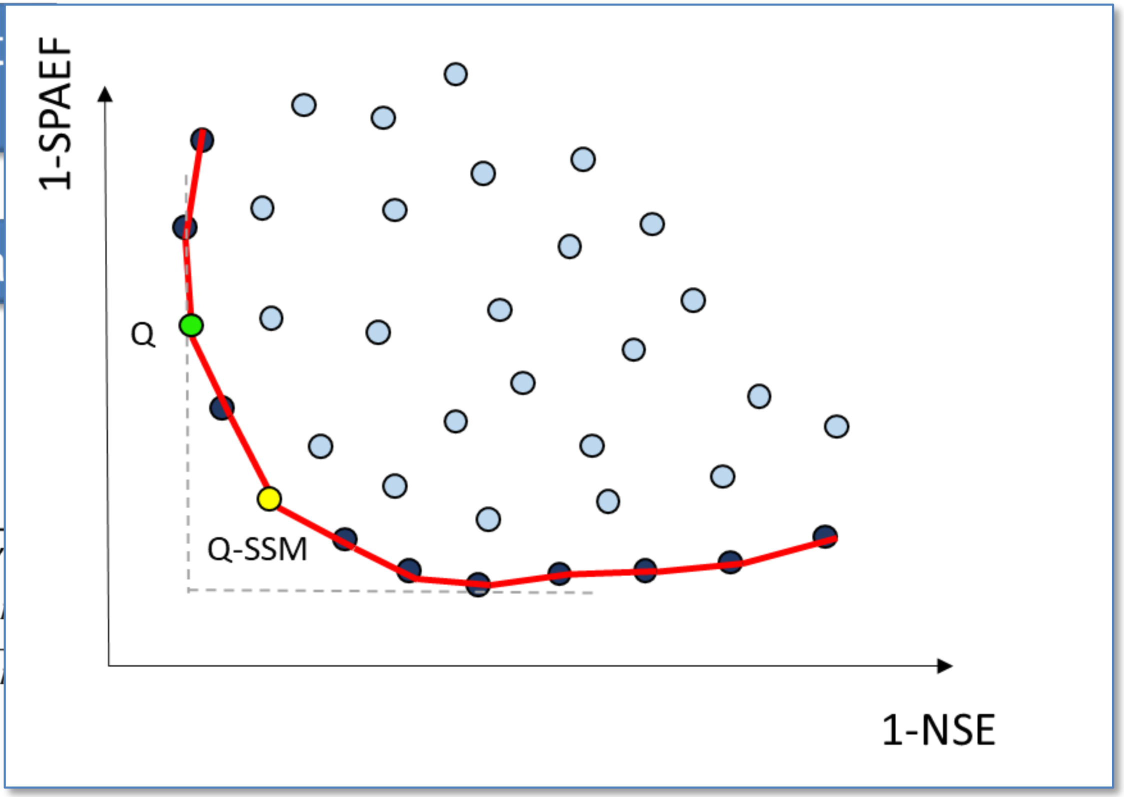
Multi-objective calibration (Q and SSM)

EUDEM + CORINE LAND COVER + 3D-EUROSOILS + GLHYMPS + SOILSGRIDS + LANDSAT + SiAR + SAIH-HIDROSUR + SAIH-JUCAR+SNIRH

TETIS

Sobol Sensitivit
analysis

Multi-objective/variable calibra



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- ✓ NSE (1day) + SPAEF (1month)
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Results: SSM products comparison

CALIBRATION

	HOZ			CEI			CAR		
	NSE	SPAEF	R	NSE	SPAEF	R	NSE	SPAEF	R
S1	++	-	-	+++	++	-	++	+++	-
SMAP-DIS	+++	-	+++	+++	-	+++	++	+	+++
SMAP-BS	+++	+	++	+++	-	+	++	+	+++
SMAP-DPAT	+++	+	+++	++	+	+++	++	+++	+++
SMOS-BEC	+++	-	++	++	++	+++	+++	-	+
SMOS-DPAT	+++	+	-	++	++	+++	++	+++	++

VALIDATION

	HOZ			CEI			CAR		
	NSE	SPAEF	R	NSE	SPAEF	R	NSE	SPAEF	R
S1	+	-	-	+	+	++	++	+++	-
SMAP-DIS	+++	-	+++	++	-	+++	+	+	+++
SMAP-BS	++	+	++	+	-	++	++	++	+++
SMAP-DPAT	++	+	++	++	+++	+++	+	+++	+++
SMOS-BEC	+	+	+++	+	+	++	++	-	++
SMOS-DPAT	++	-	+	++	+++	++	+	+++	++

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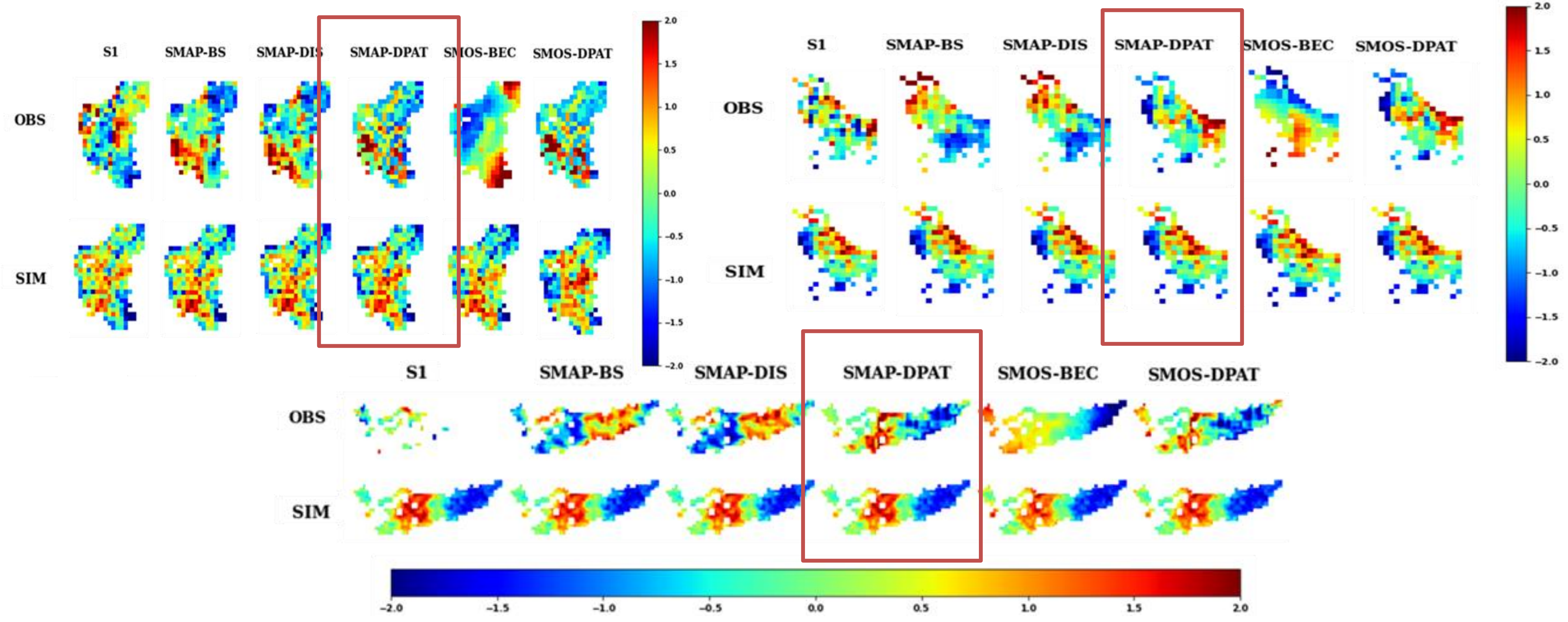
Results: SSM products comparison

Spatial anomalies Validation



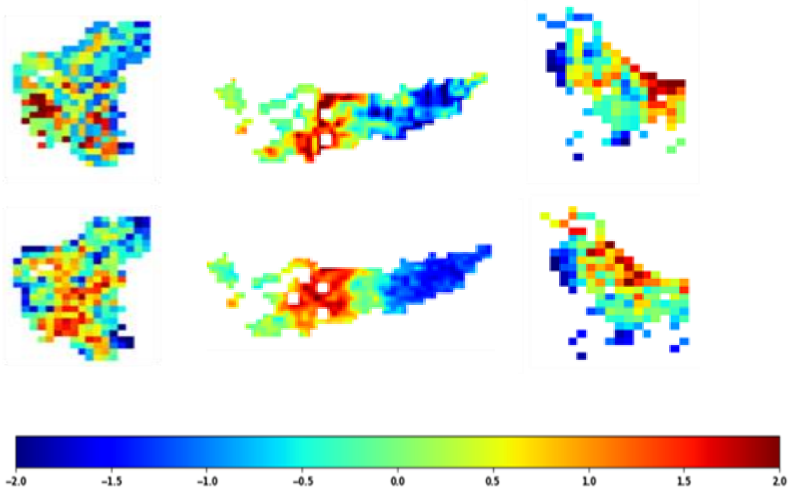
Results: SMAP-DPAT

Spatial anomalies

CALIBRATION

OBS

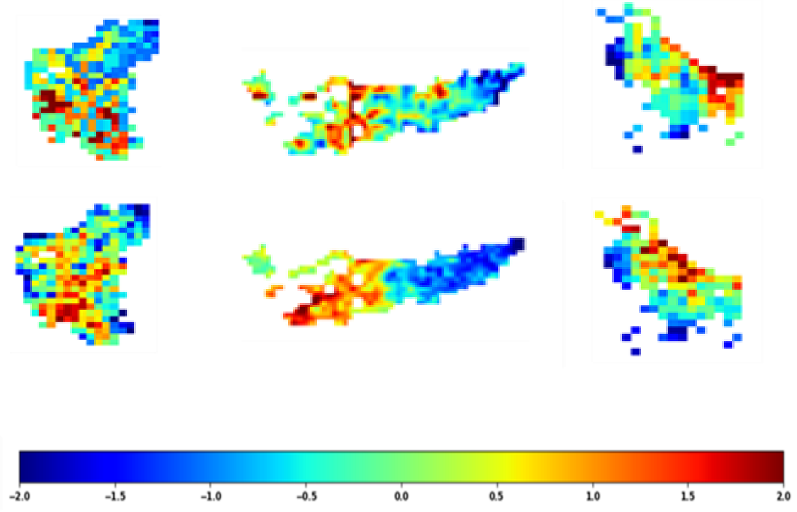
SIM



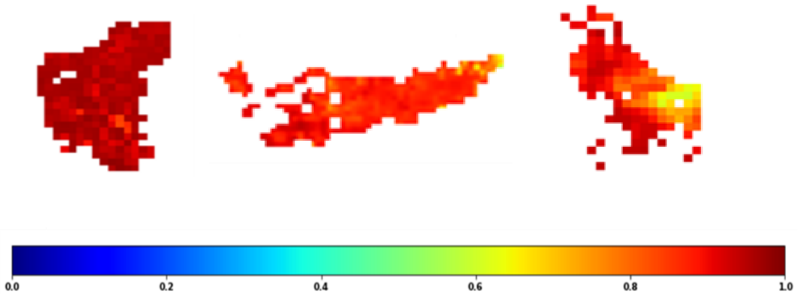
VALIDATION

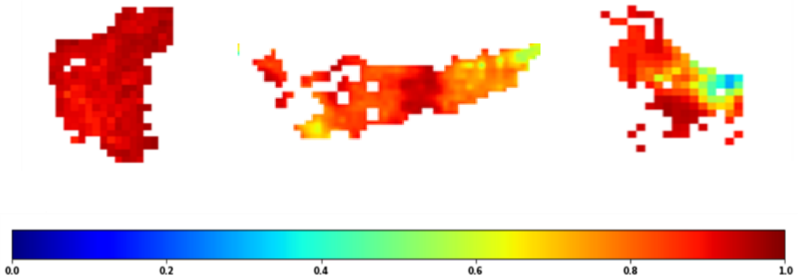
OBS

SIM

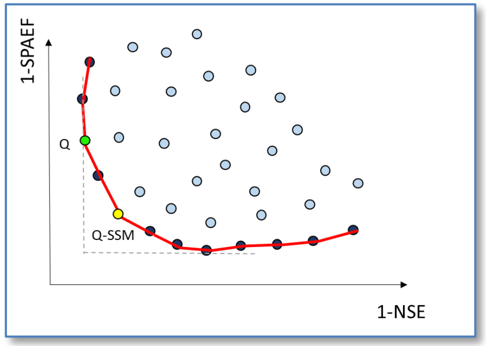


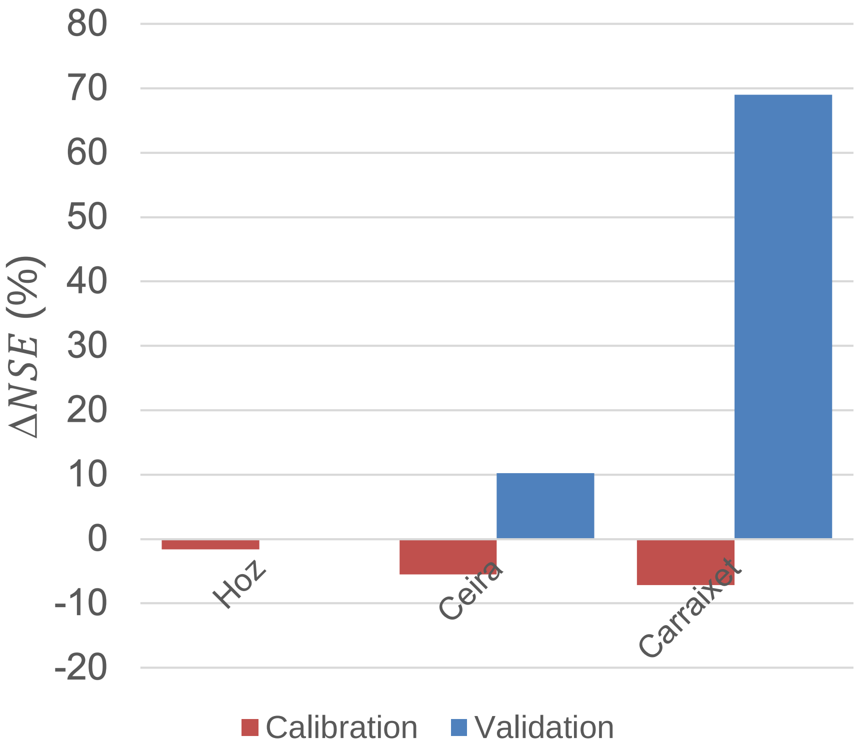
Temporal correlation

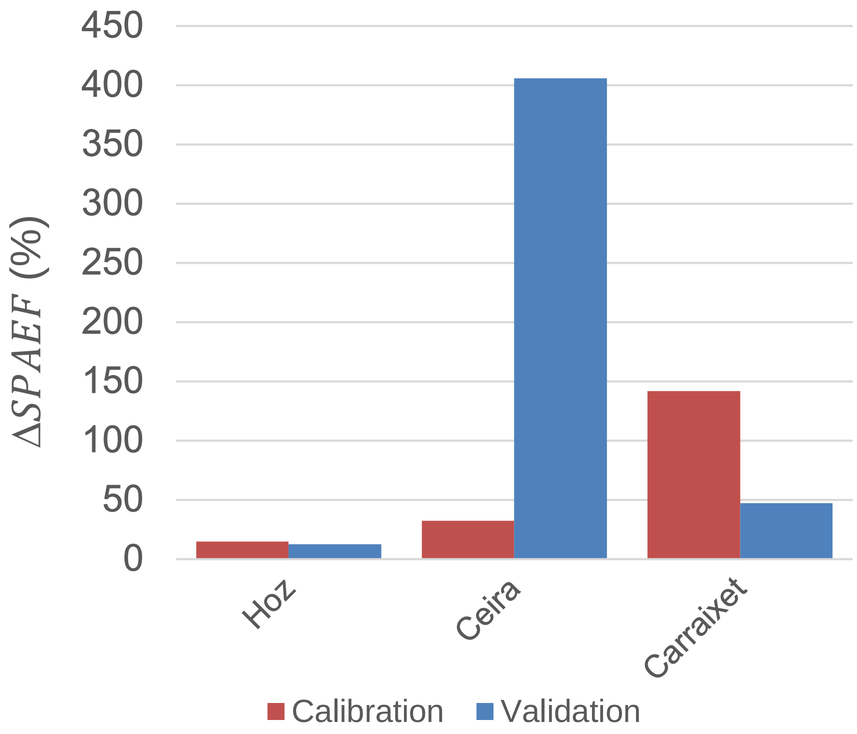




Results: influence of SSM







$$\Delta NSE = \frac{NSE_{Q-SSM} - NSE_Q}{NSE_Q}$$

$$\Delta SPAEF = \frac{SPAEF_{Q-SSM} - SPAEF_Q}{SPAEF_Q}$$

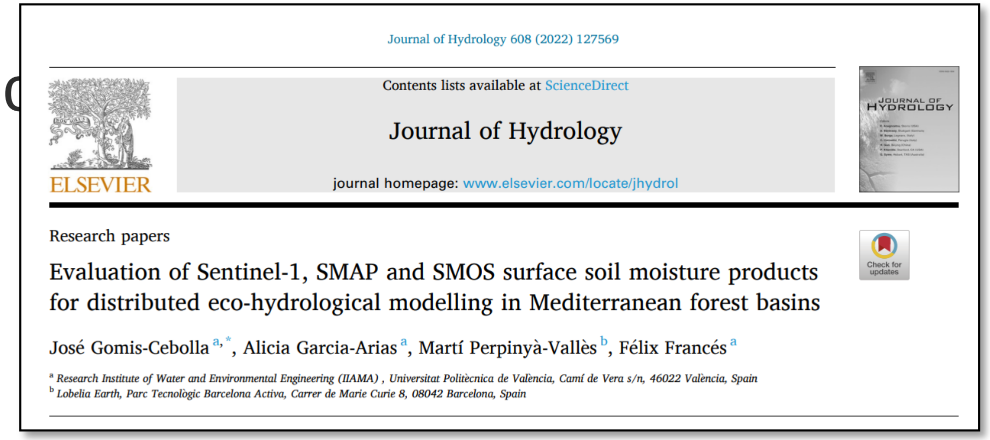
Conclusions

- We found **significant differences** in **temporal** and **spatial** dynamics of **SSM** products

- **Best** SSM products can be identified by the **spatial agreement** with **eco-hydrological modelling** estimates

  - **SMAP-Dispatch** provided the best spatial agreement with TETIS in the 3 study cases

- **Multi-objective calibration** (Q and SSM) inc
modelling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Research papers

Evaluation of Sentinel-1, SMAP and SMOS surface soil moisture products for distributed eco-hydrological modelling in Mediterranean forest basins

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Thank you for your attention

Prof. Dr. Félix Francés (ffrances@upv.es)

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