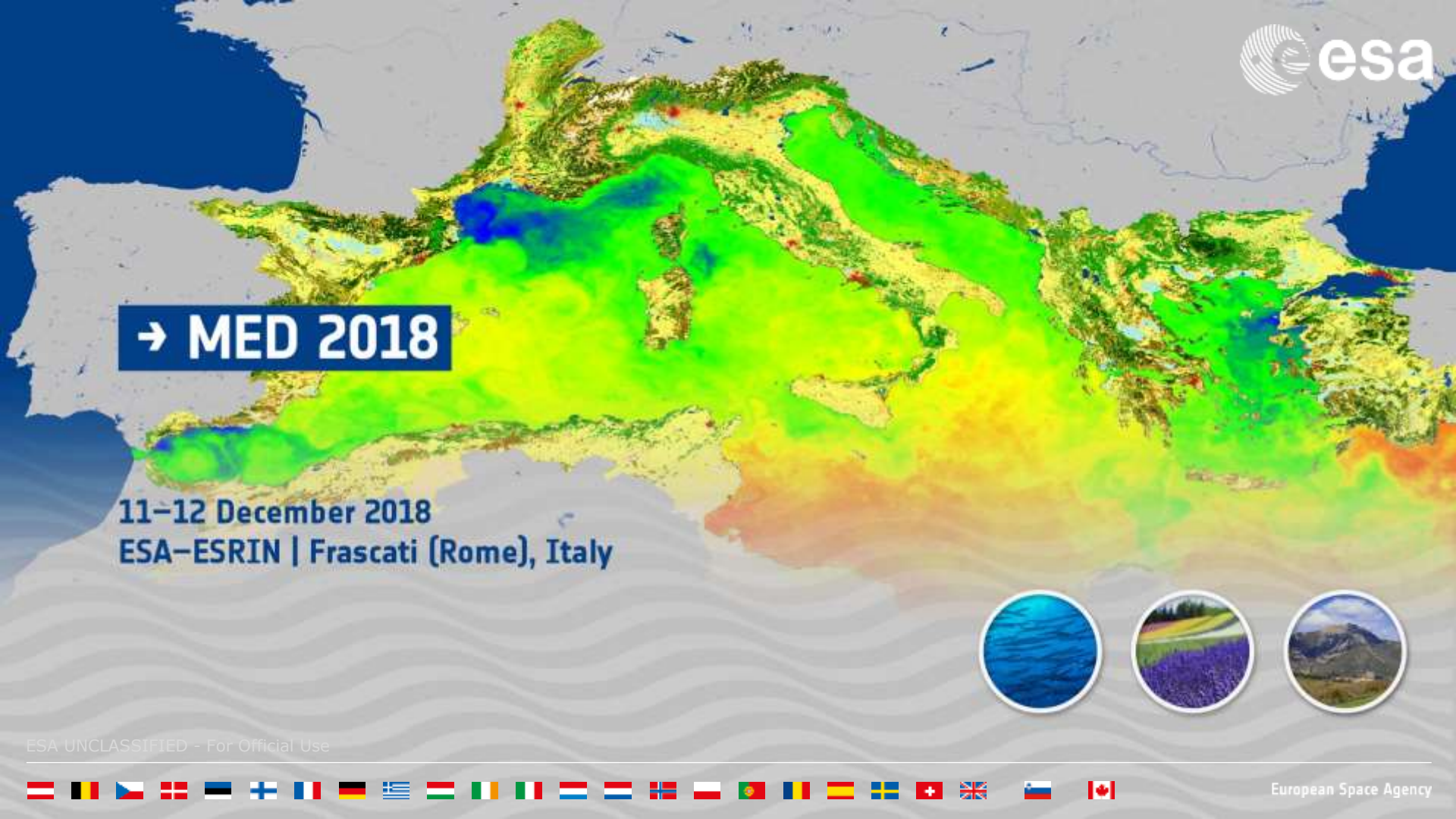

Sentinel-1 Soil Moisture Product At 1 km Resolution Over The Mediterranean Basin

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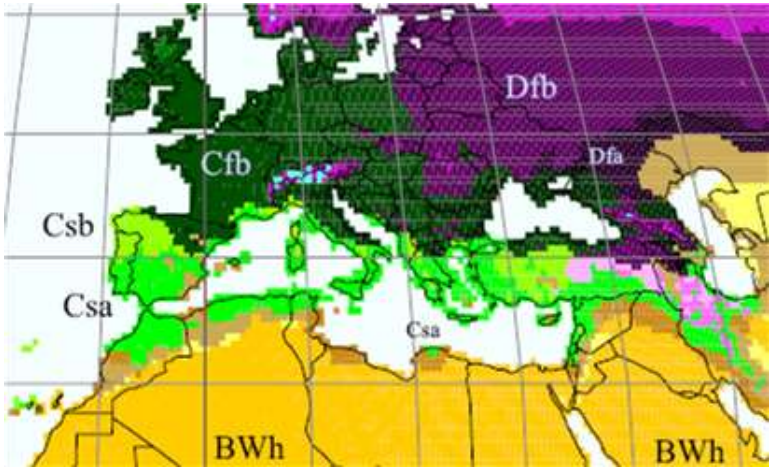
The Mediterranean basin is a fragile "eco-region"

- North-South economic and social tensions, **increasing anthropogenic pressure, highly variability of the hydrologic cycle and strong climate change threat** (IPCC, 2014 & 2018).
- Important challenges in terms of **water scarcity and hydro-meteorological extremes**, e.g., floods and droughts.
- **High temperatures & low precipitation**: a strong "**soil-moisture–temperature coupling**" → dryness increase → reduction in evaporative cooling (Stefanon et. al, 2014; Vogel et al., 2017; Bradford et al. 2017).



Climate zone (Köppen-Geiger climate classification), Csa= warm temperature, summer dry, hot summer (Kottek et al, 2006).

Soil moisture is a crucial environmental variable

- Soil moisture plays a key role in the **interactions between water, energy and biochemical fluxes**; forecasting of meteorological and hydrological events; crop yield prediction, etc.
- Earth Observation products of near surface soil moisture (SSM) content at low resolution are operationally delivered (e.g. **ESA SMOS, EUMETSAT ASCAT and NASA SMAP**)
- Mediterranean region: **small to medium size watersheds (e.g. from 500 km^2 to 5000 km^2)** → spatial resolution is a key factor to resolve processes at basin scale.

Objectives & Outline

Objectives

- Illustrate a pre-operational near surface soil moisture (SSM) product derived from Sentinel-1 (S-1) data over the Mediterranean basin
- Present examples of prospective applications

Outline

- Sentinel-1 (S-1) SSM product at 1km
- Evolution: S-1 & S-2 SSM product at “field scale”
- Examples of high resolution SSM product exploitation for Numerical Whether forecast, hydrological, and agricultural applications
- Conclusions & perspectives

S-1 SSM product at 1km

Soil **MO**isture retrieval from multi-temporal **SAR** data (**SMOSAR**) prototype is based on a **Short Term Change Detection Retrieval Model**

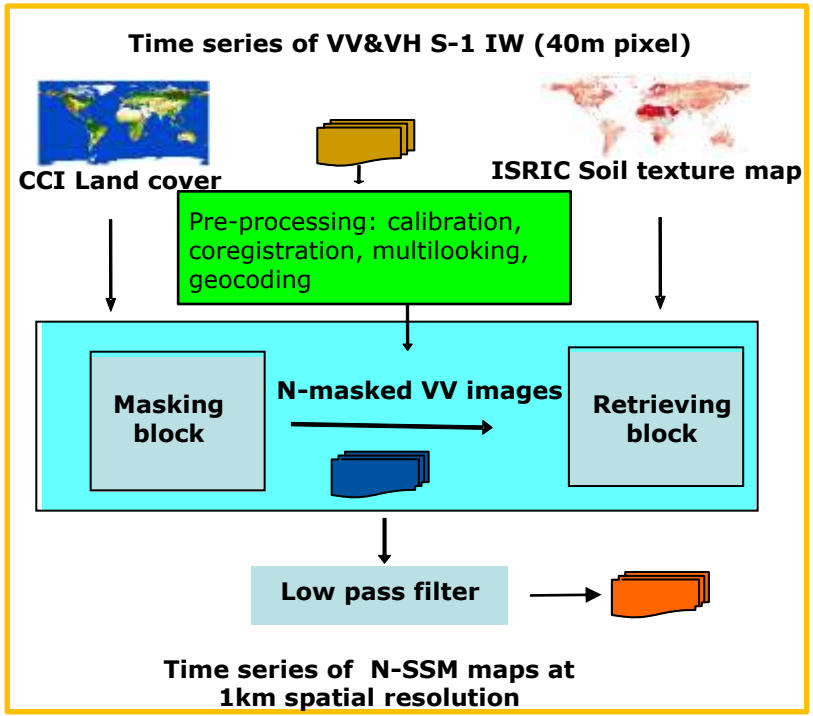
Physical approximations:

$$\sigma_0 \approx \tau^2 \cdot {\sigma_0}^{soil} \approx \tau^2 \cdot \left|\alpha_{pp}(\vartheta,\epsilon)\right|^2 \cdot F(\Omega,\vartheta,\lambda)$$

SAR response dominated by soil attenuated scattering

$$\frac{(\sigma_0)_{DoY(i+1)}}{(\sigma_0)_{DoY(i)}} \approx \frac{\left|\alpha_{pp}(\vartheta,\epsilon)\right|^2_{DoY(i+1)}}{\left|\alpha_{pp}(\vartheta,\epsilon)\right|^2_{DoY(i)}} \approx \frac{SSM_{DoY(i+1)}}{SSM_{DoY(i)}}$$

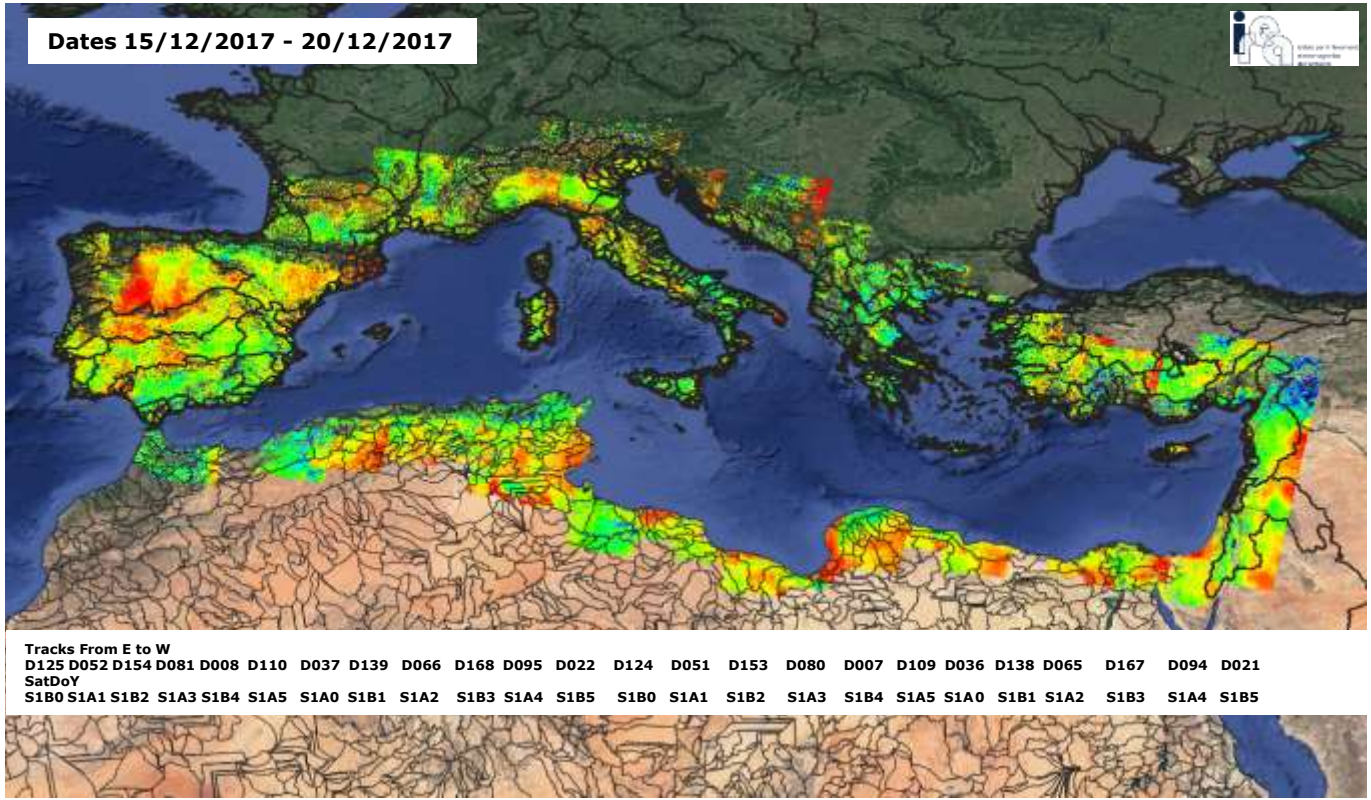
Backscatter temporal change depends solely on SSM



Exploit-S-1 Project

https://exploit-s-1.ba.issia.cnr.it

S-1 SMOSAR SSM map composite @1km resolution

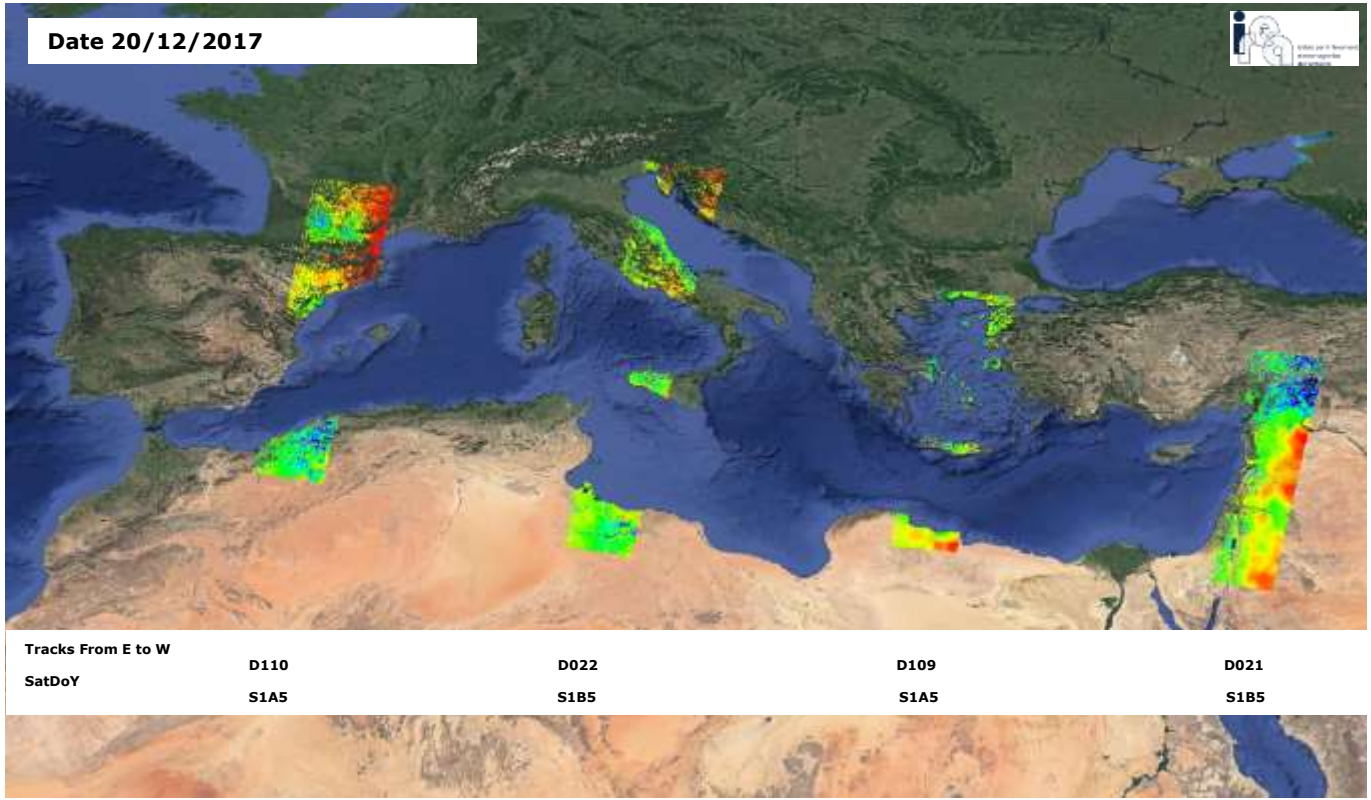


river basins
(JRC CCM v2.1 UNU WaterBase databases)

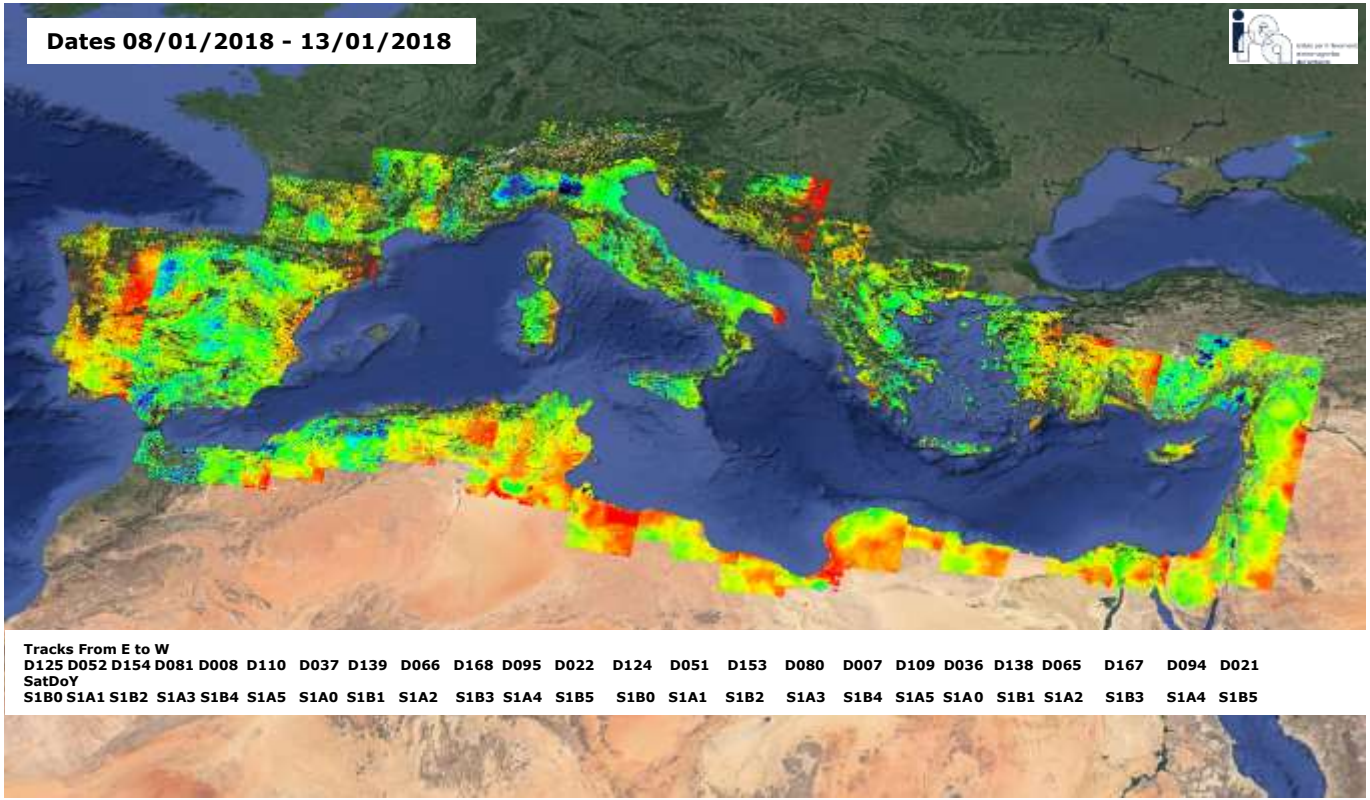
SSM Mean

0.05 m³/m³ 0.5

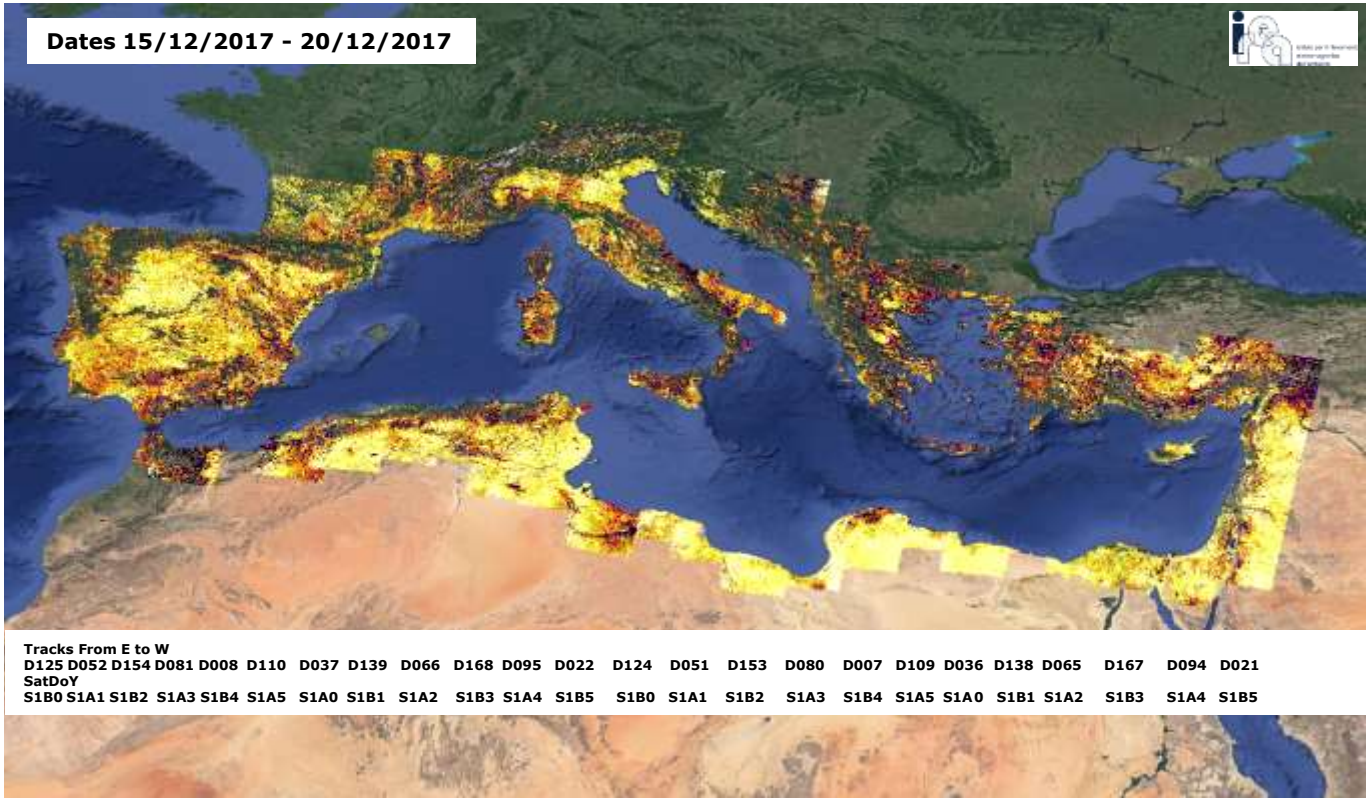
SMOSAR SSM map composite @1km resolution



SMOSAR SSM map composite @1km resolution

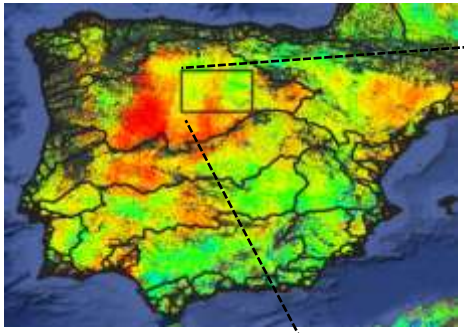


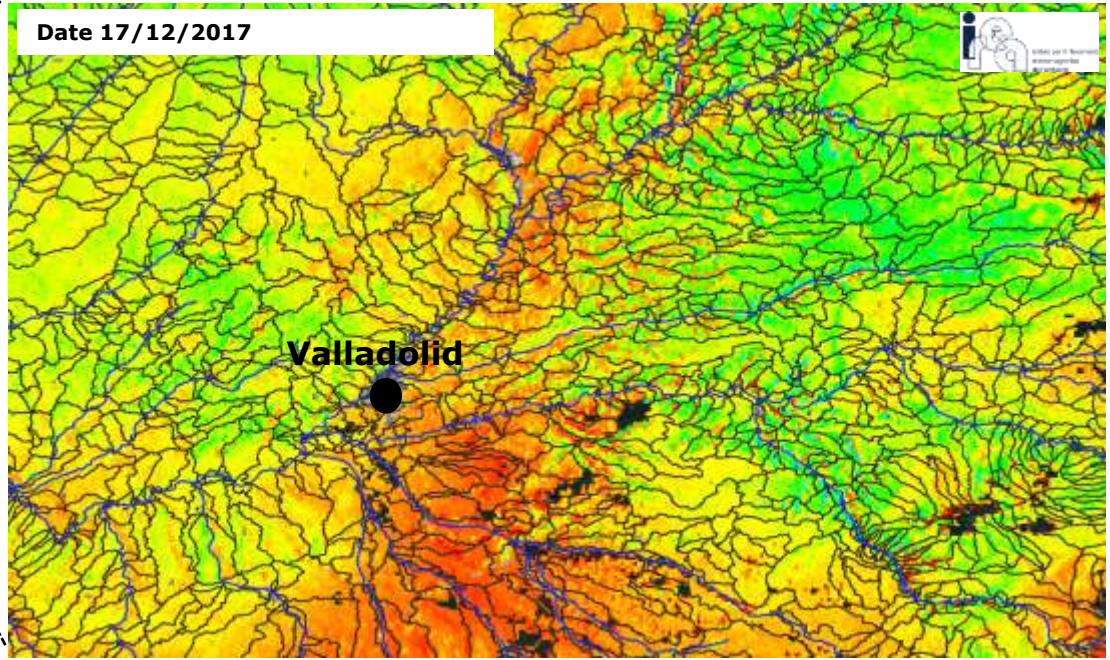
S-1 SMOSAR SSM standard deviation map composite @1km resolution



S-1 SMOSAR SSM map @1km resolution: subcatchment Duero Basin, Valladolid, Spain

Area ≈ 150 km x 110 km





Catchments
(JRC CCM v2.1)

main rivers

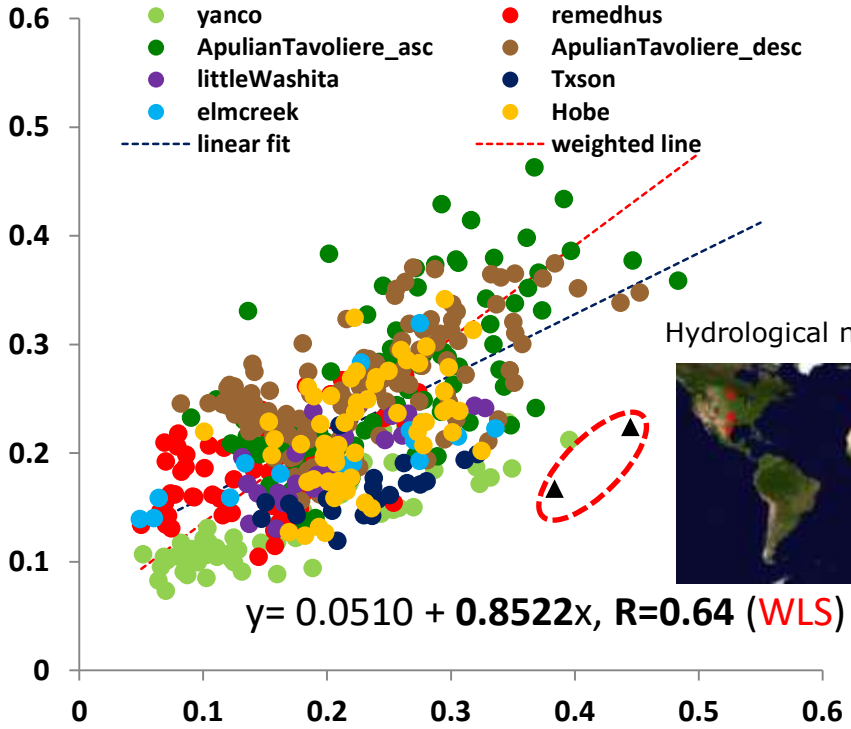
SSM Mean

0.05 m³/m³ 0.5

- SSM changes resolved at basin scale (e.g. soil texture, topography, land cover/use, etc.)

Status of S-1 SSM product validation over seven cal/val experimental sites

Retrieved vs observed SSM [m^3/m^3] at site scale



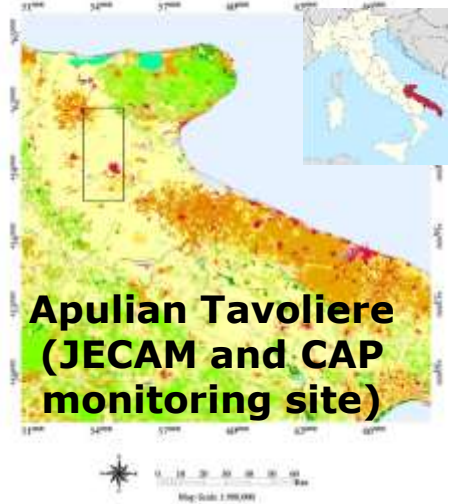
Hydrological network locations

Comparison at site scale between S-1, SMAP L3 36km, SMOS L3 25km, ASCAT L2 25km and *in situ* measurements

	S-1	SMAP	SMOS	ASCAT
# dates	475	333	313	138
Correlation (R)	0.64	0.78	0.72	0.77
rmse [m^3/m^3]	0.065	0.061	0.07	0.061
ubrmse [m^3/m^3]	0.064	0.054	0.068	0.061
Mean-x (<x>) [m^3/m^3]	0.2080	0.206	0.209	0.179
Mean-y (<y>) [m^3/m^3]	0.2198	0.177	0.191	0.186

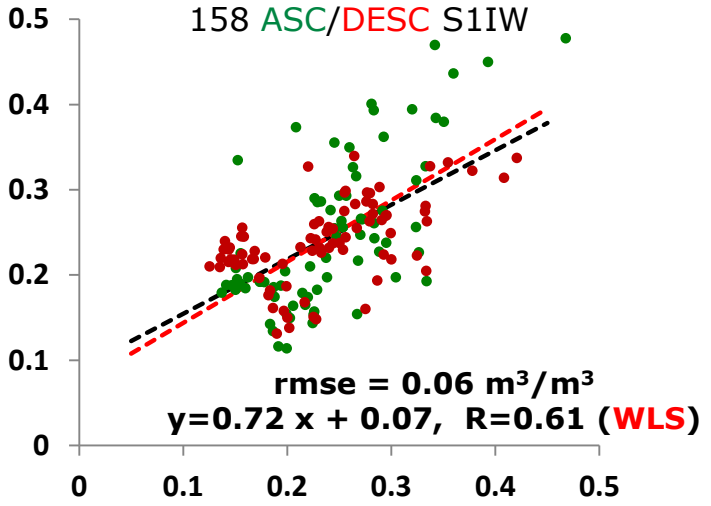
Dense hydrological network for S-1 SSM product validation

Agricultural areas (CORINE)



11 stations in Segezia site, approx. 2*2km^2 (spacing between stations ~500 m)

Retrieved vs observed SSM at 2*2km^2

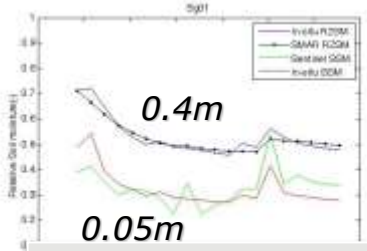


- at 1 km resolution, the impact of representative error for N=1 station cannot be disregarded -> **a validation strategy for S-1 SSM product(s) is required**

Examples of S-1 SSM exploitation in land applications

To estimate the root zone soil moisture

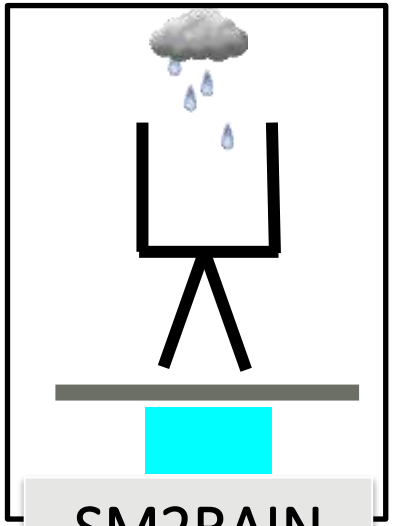
Example of SMAR application on S-1 SSM (rmse=0.02)



SMAR

Manfreda et al., 2014 HESS

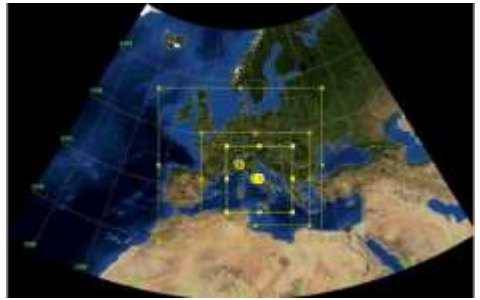
To estimate the accumulative rainfall



SM2RAIN

Brocca et al., 2014 JGR

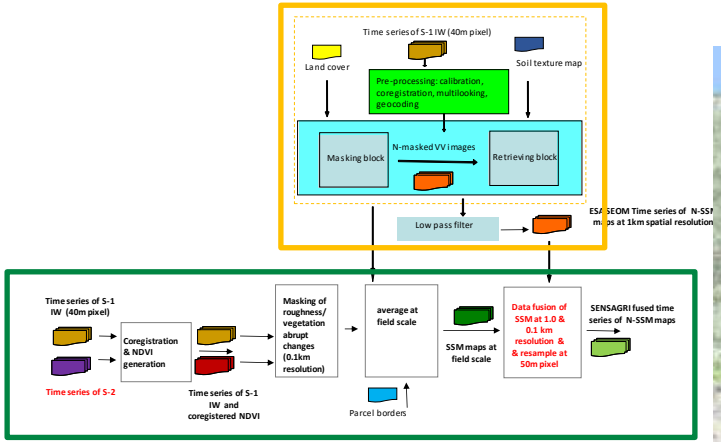
Ingestion in a high resolution Numerical Weather Prediction



ESA STEAM project

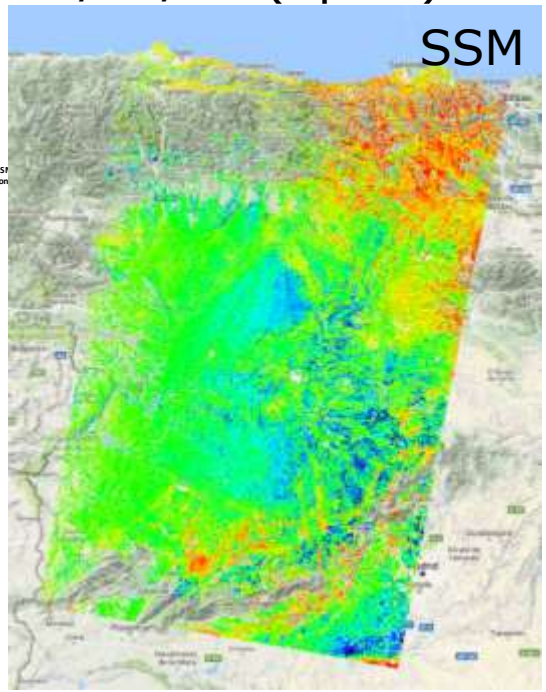
Tomorrow's presentation

Sentinel-1 & Sentinel-2 SSM product at field scale



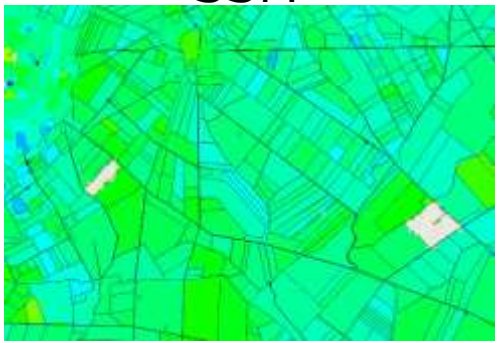
- S-2 NDVI and parcel borders (Land Parcel Identification System) to provide SSM estimates at field scale

18/10/17 (Spain)

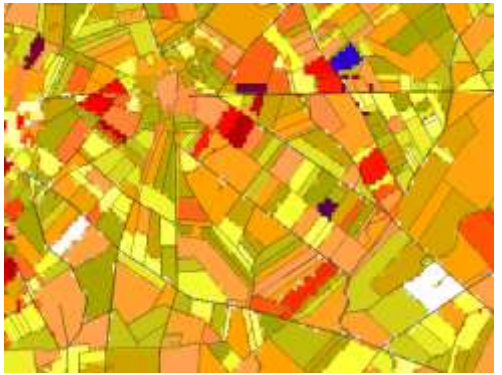


Area at north-west of Valladolid

SSM



Std dev SSM

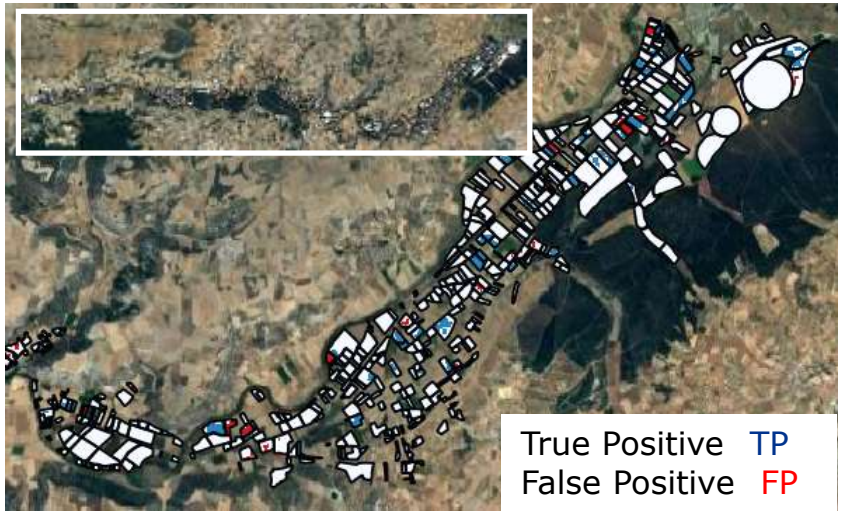


Detection of irrigation events

Segmentation S-1/S-2 SSM at high resolution (e.g. $\sim 100m$) to discriminate irrigated from not-irrigated fields

	9th April
OA	79.4%
TPR	61.6%
FPR	15.2%

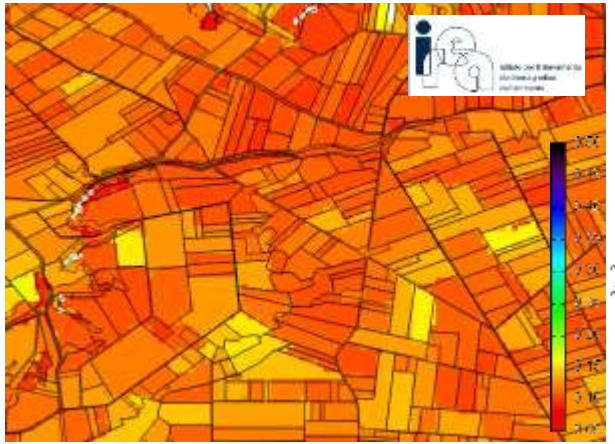
9th April	
Timespan before the S1 passage	TP(%)
Within 1 day	90.0
Within 2 - 1 days	64.6
Within 3 - 2 days	56.8



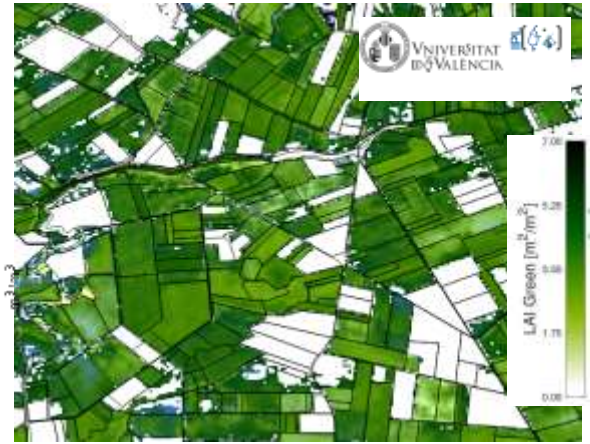
- SSM contrast depends on the balance between the amount of water supplied and the evapotranspiration rate
- S-1/S-2 SSM may support irrigation scheduling and/or water management (i.e. **improve estimate of water consumption)**

Consistent SSM & LAI products for yield forecast

SSM map on 15/04/17



LAI green map on 12/04/17

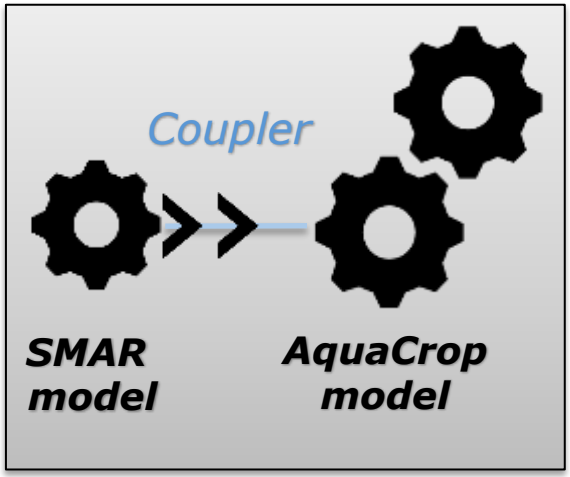


Sensagri

- Food security (production at regionale scale): support informed decision

Assimilation

Coupled SMAR-AquaCrop



Conclusions

- A S-1 SSM product at 1 km has been developed and validated at large scale: **case study Mediterranean basin**
  - applications, e.g., improvements of numerical weather prediction (NWP), early warning/monitoring hydrologic extremes, monitoring SSM-land-surface-temperature coupling at basin scale, etc.
- **Network of Mediterranean based EO validation sites needed**
- A follow-up product integrating S-1 & S-2 for SSM at **"field scale" resolution for agriculture application, e.g., irrigation events & water consumption; yield forecast**, etc.