

DTE Hydrology and landslide risk



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28/09/2023

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DTE Hydrology: Create a digital replica of the Earth System for the **WATER CYCLE**

First implementation over the **Po valley** and case studies, with focus on **landslide risk assessment**

DTE Hydrology Evolution: implementation over the **Mediterranean basin**, applications and **what-if scenarios**

Conclusions and outlook

THE DTE HYDROLOGY (EVOLUTION) PROJECT

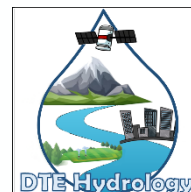


The DTE Hydrology (Evolution) project

To develop and demonstrate a **prototype of Digital Twin Earth** with focus on the **terrestrial water cycle** and hydrological processes by highlighting the huge potential of high-resolution Earth Observation (EO) products for predicting **hydrological extremes** (flood, landslide and drought) and **water resources management**



The final report is available at:

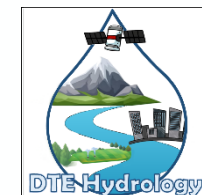


THE DTE HYDROLOGY (EVOLUTION) PROJECT

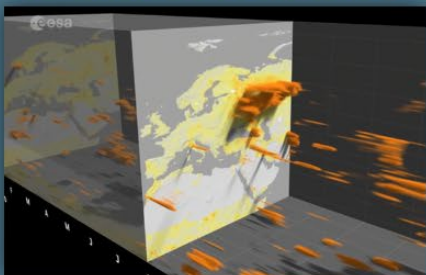


The DTE Hydrology (Evolution) project: concept

4D reconstruction of the water cycle at the decision making scale (1 km,1 hour)

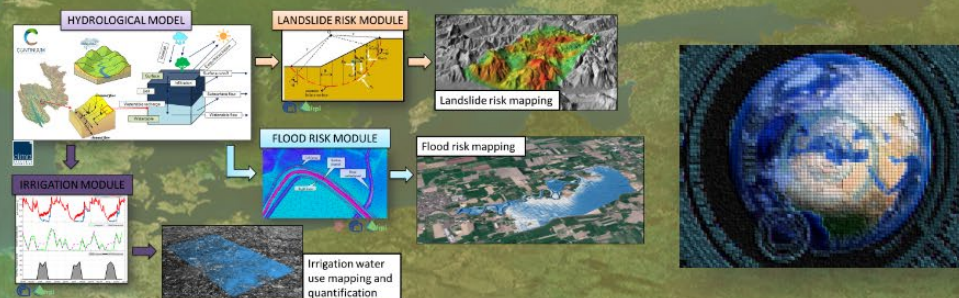


DTE Hydrology Datacube EO-based and in situ dataset



High resolution datacube (1km, 1hour\1day)

DTE Hydrology Modelling System Physical modelling and Artificial Intelligence



DTE Hydrology Open Science Platform (OSP)

An integrated platform including observations and modelling results as a community tool to foster science and applications.



Cloud-HPC infrastructure



DTE Hydrology Community



DESTINATION EARTH



UNLOCKING THE POTENTIAL OF DIGITAL MODELLING

Utilising high-performance computing, machine learning and satellite data, the digital twins of **Destination Earth** will provide us with an accurate representation of the past, present and future changes of our world.



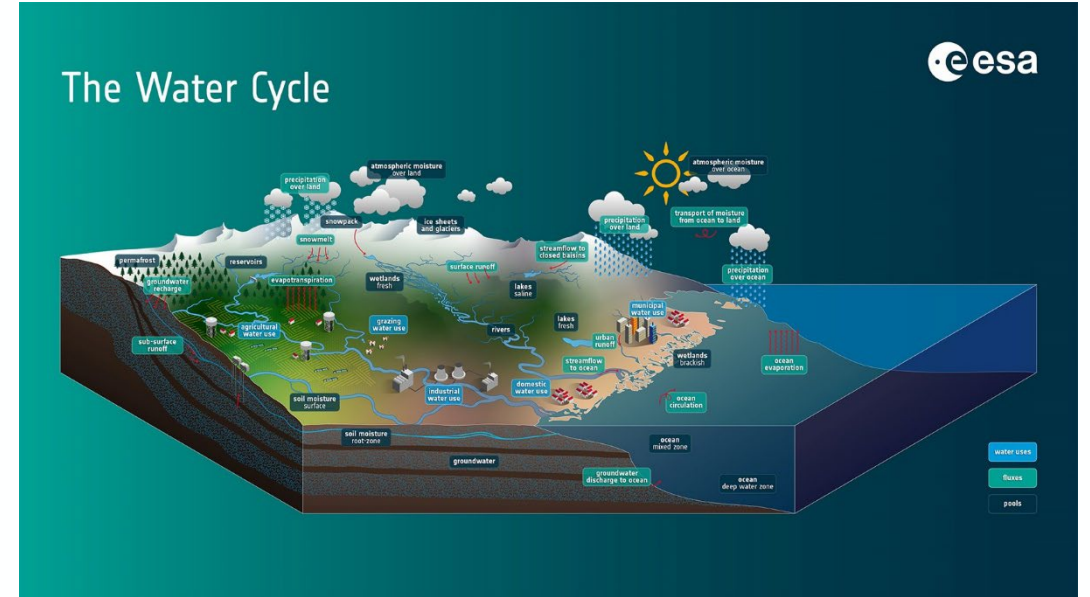


Create a digital replica of the Earth System for the **WATER CYCLE**

Brocca et al. (2023), under review in FiS

A Digital Twin of the water cycle: a glimpse into the future through high resolution Earth Observations


Luca Brocca^{1*}, Silvia Barbetta¹, Stefania Camici¹, Luca Ciabatta¹, Jacopo Dari^{1, 2}, Paolo Filippucci¹, Christian Massari¹, Sara Modanesi¹, Angelica Tarpanelli¹, Bianca Bonaccorsi¹, Hamidreza Mosaffa¹, Wolfgang Wagner³, Mariette Vreugdenhil³, Raphael Quast³, Lorenzo Alfieri⁴, Simone Gabellani⁴, Francesco Avanzi⁴, Dominik Rains⁵, Diego G. Miralles⁵, Simone Mantovani⁶, Christian Brese⁷, Alessio Domeneghetti⁸, Alexander Jacob⁹, Mariapina Castelli⁹, Gustau Camps-Valls¹⁰, Espen Volden¹¹, Diego Fernandez¹¹



Requirements:

1. Need for high spatiotemporal resolution of observations (≤ 1 km, ≤ 1 day) for both calibration and validation purposes

2. Representing **human activities**, which are absolutely not negligible at such scales



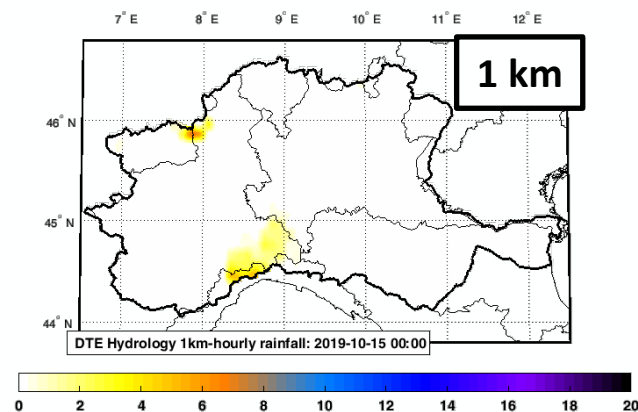
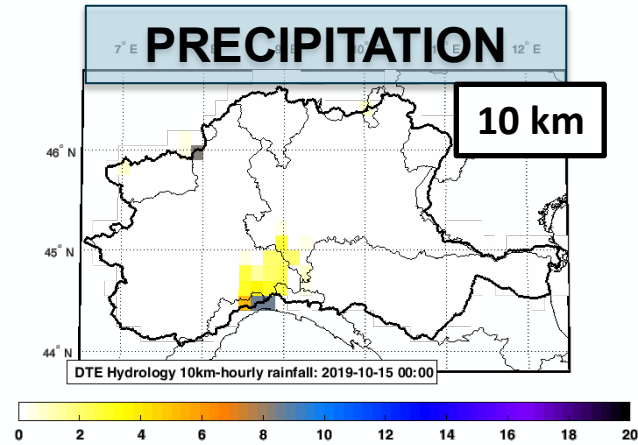
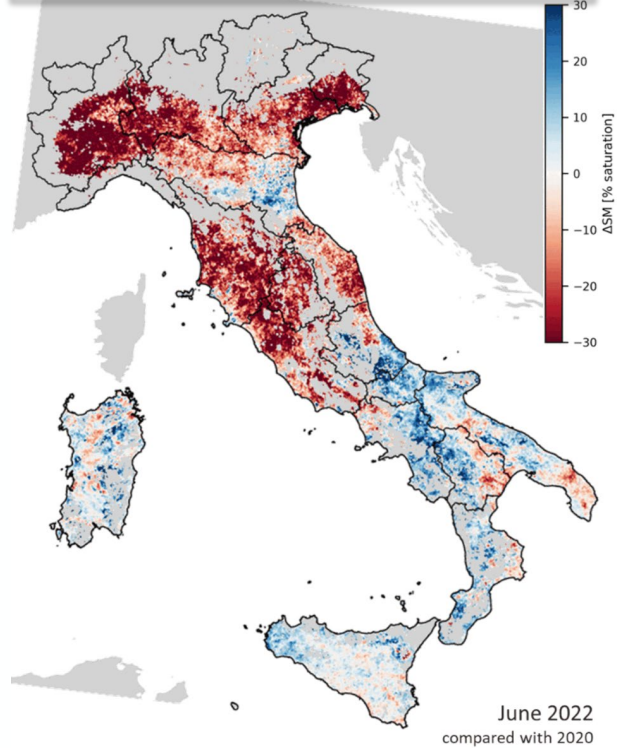
Remote sensing technology allows us to meet both requirements!

THE DTE HYDROLOGY (EVOLUTION) PROJECT

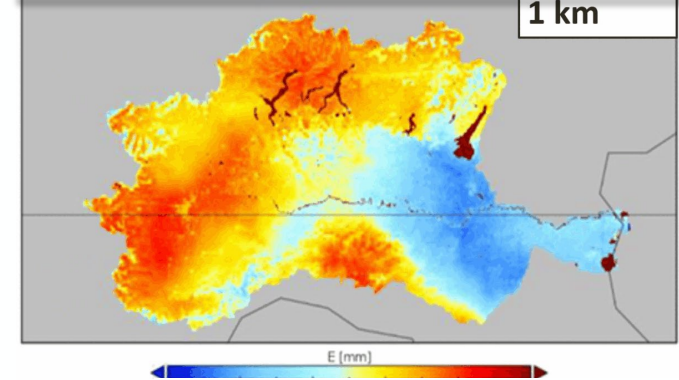


High-resolution data: a «new era» for hydrology

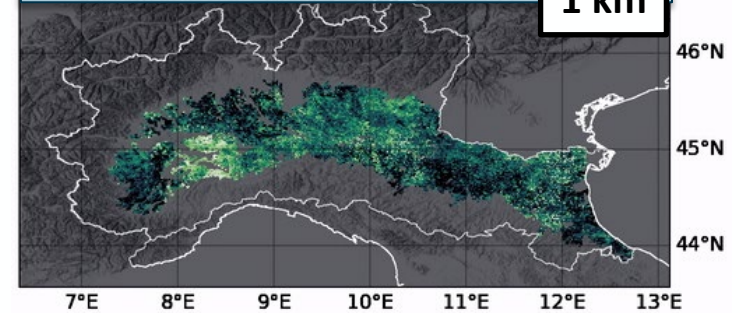
SOIL MOISTURE



EVAPOTRANSPIRATION



ESTIMATED IRRIGATION



Only coarse resolution data were available up to few years ago (up to 2020)...
...now new satellite observations at 1 km and 1 hour/day resolution are available!



THE DTE HYDROLOGY (EVOLUTION) PROJECT



High-resolution data: the new research trend

Several high-resolution, long-term and gap-free soil moisture data sets have been recently published

March 2023

SMAP-Derived 1-km Downscaled Surface Soil Moisture Product, Version 1



scientific data

March 2023

OPEN

DATA DESCRIPTOR

Global long term daily 1 km surface soil moisture dataset with physics informed machine learning

Qianqian Han¹, Yijian Zeng¹, Lijie Zhang², Chao Wang³, Egor Prikaziuk¹, Zhenguo Niu^{1*} & Bob Su^{1,5}

scientific data

February 2023

OPEN

DATA DESCRIPTOR

A 21-year dataset (2000–2020) of gap-free global daily surface soil moisture at 1-km grid resolution

Chaolei Zheng¹, Li Jia¹ & Tianjie Zhao¹

January 2023

Open Access Earth System Science Data

Earth Syst. Sci. Data, 15, 2055–2079, 2023
https://doi.org/10.5194/essd-15-2055-2023
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Generation of global 1 km daily soil moisture product from 2000 to 2020 using ensemble learning

Yufang Zhang¹, Shunlin Liang², Han Ma², Tao He¹, Qian Wang³, Bing Li⁴, Jianglei Xu¹, Guodong Zhang¹, Xiaobang Liu¹, and Changhao Xiong¹

...and similar (1 km\1 day) for air temperature, evaporation, precipitation, ...

Global soil moisture, 2022: <https://doi.org/10.1002/vzj2.20182>

Global precipitation, 2021: <https://doi.org/10.1038/s41597-021-01084-6>

Global meteo, 2021: <https://doi.org/10.48364/ISIMIP.836809.1>

Mediterranean precipitation, 2022: <https://doi.org/10.5194/hess-26-2481-2022>

China precipitation, 2023: <https://doi.org/10.5281/zenodo.7949858>

Global evaporation, 2022: <https://doi.org/10.1016/j.jhydrol.2022.128444>

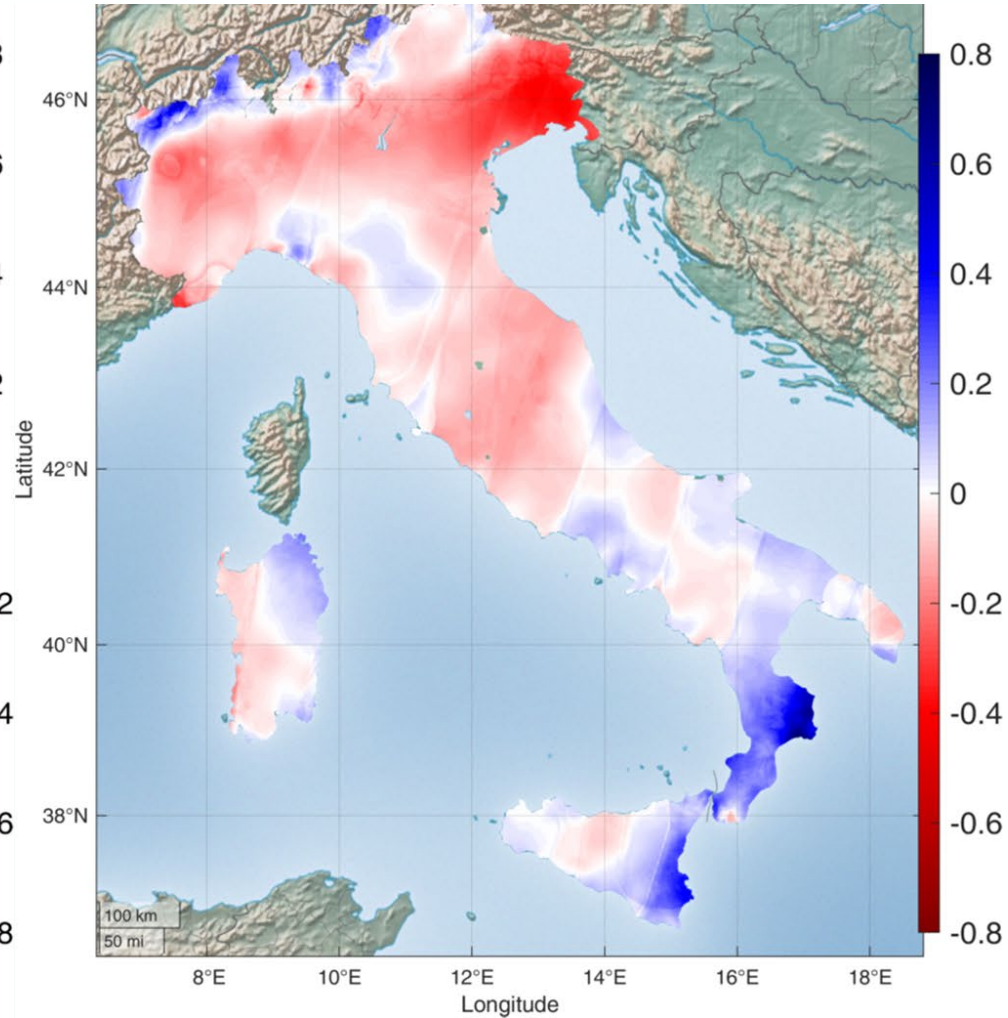
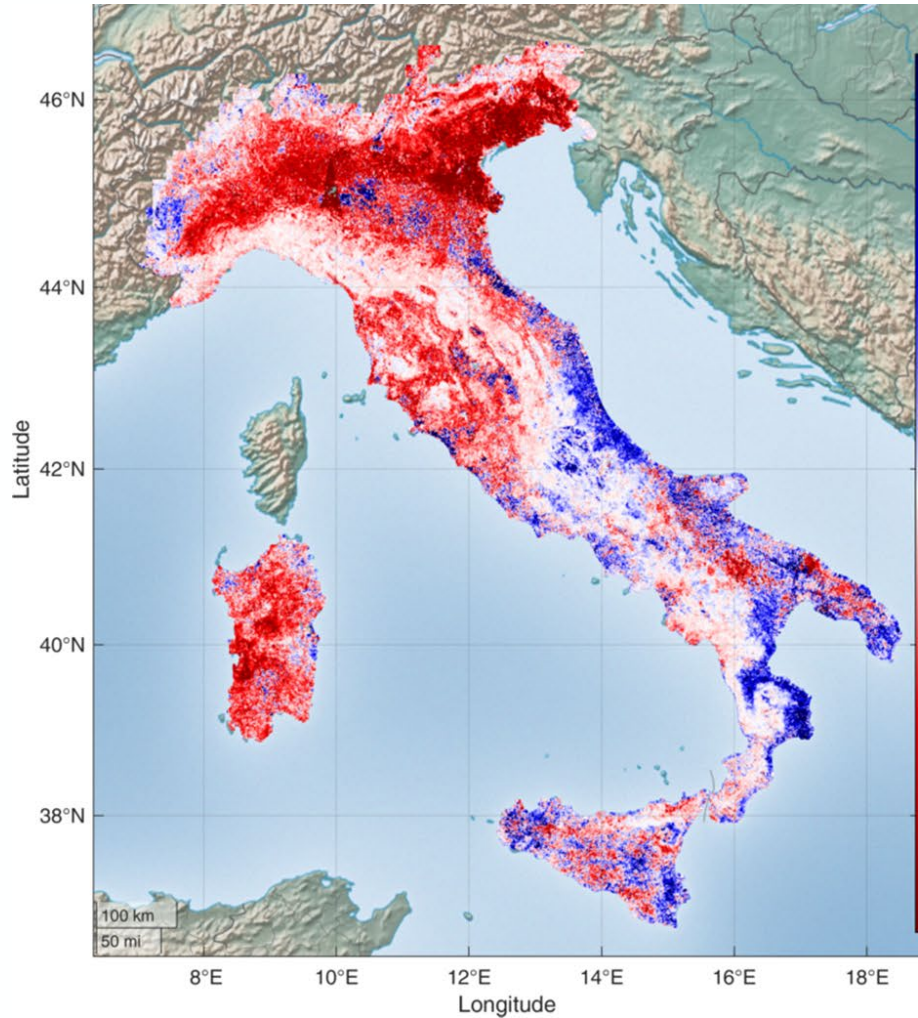
Europe meteo, 2023: <https://zenodo.org/record/8308359>



THE DTE HYDROLOGY (EVOLUTION) PROJECT



Is high-resolution always true?



Soil moisture anomalies, April 2020

Elab by



THE DTE HYDROLOGY PROJECT



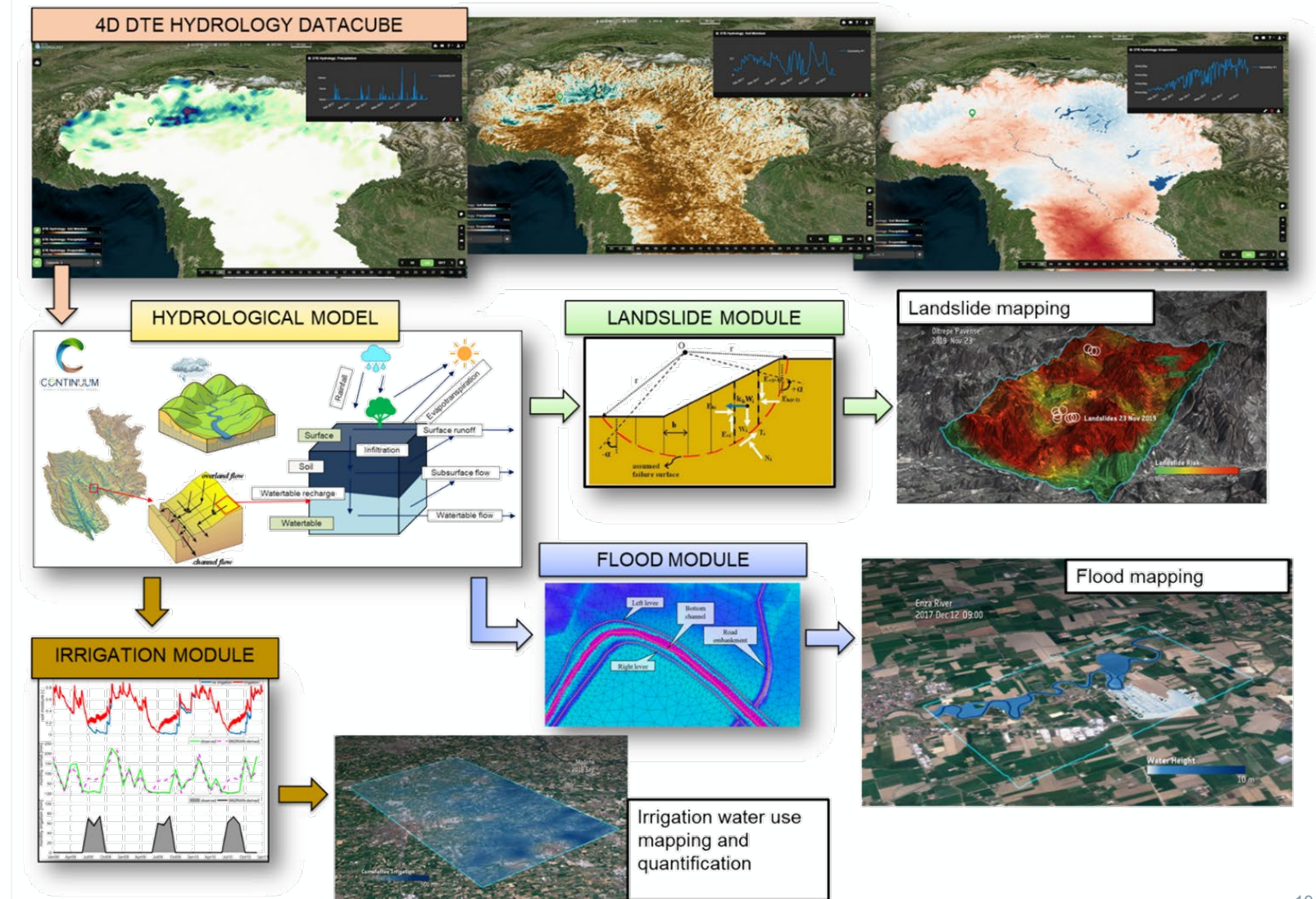
DTE Hydrology

First implementation over the Po valley, Northern Italy

- Longest Italian river
- Data-rich basin
- Strongly human-altered

3 case studies:

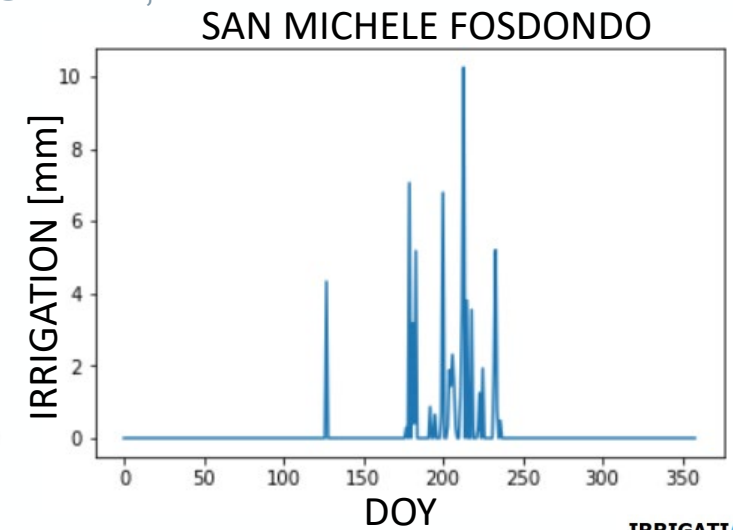
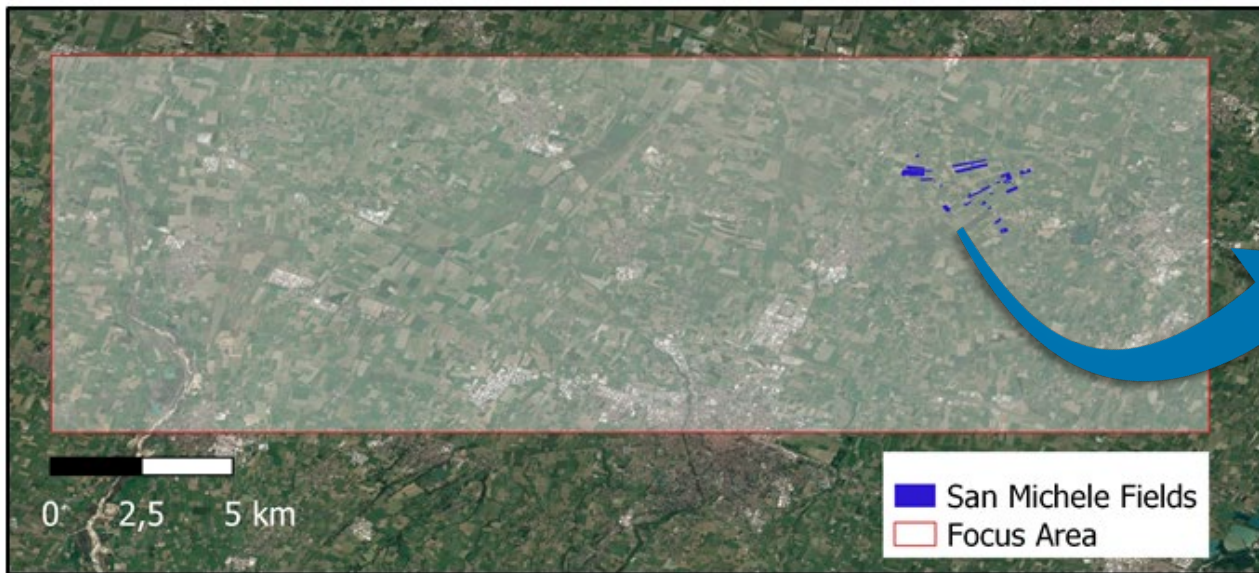
- Flood
- Irrigation
- Landslide





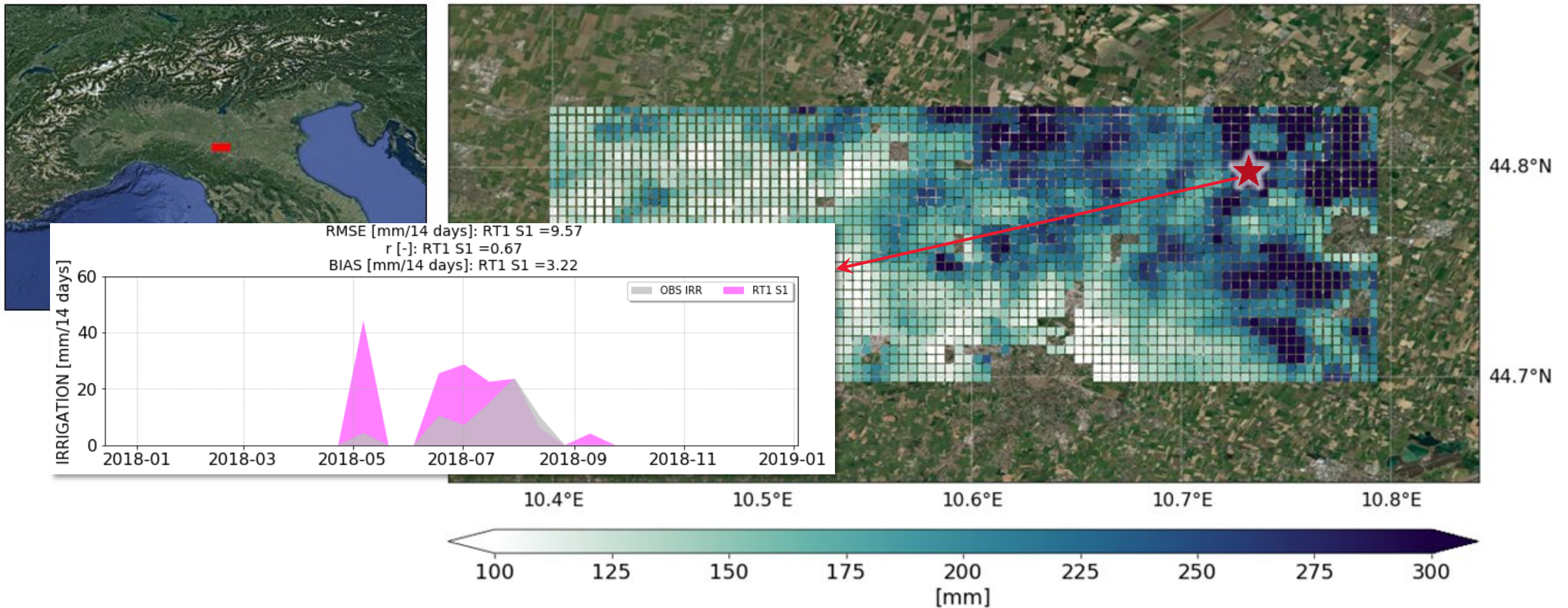
Irrigation water use mapping and quantification

- **Method:** SM-based inversion approach;
- **Area:** ~450 km² box North of the Reggio Emilia city;
- **Products:** Soil moisture from **RT1 S1** data set, rainfall from **MCM**, and PET rates from **GLEAM**;
- **Period:** 2018.

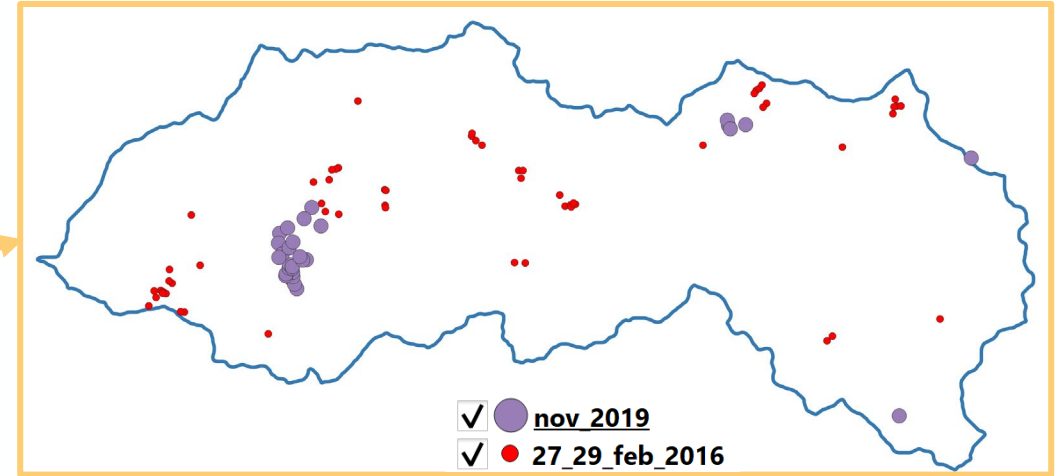
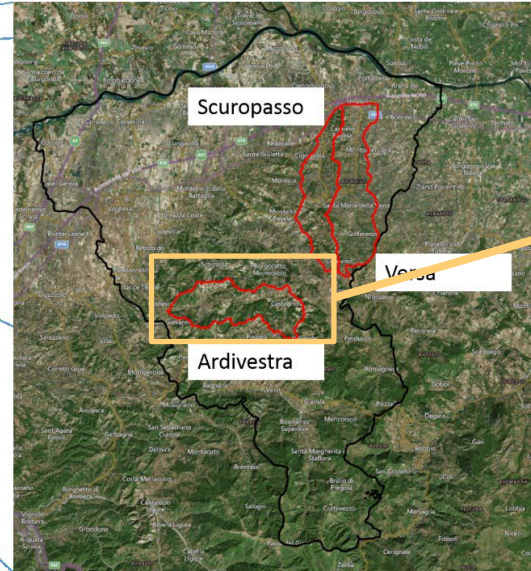
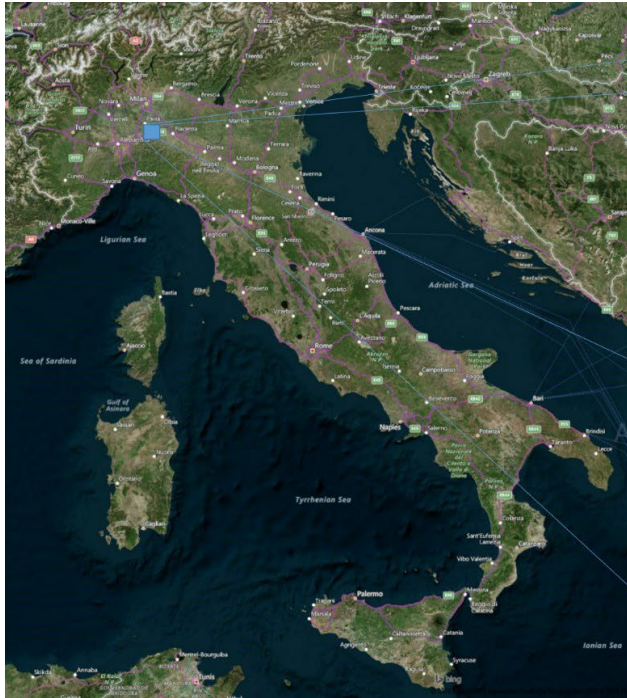


Irrigation water use mapping and quantification

CUMULATED IRRIGATION AMOUNTS 2018



Landslide mapping



Oltrepo Pavese, Ardivestra (47 km²) catchment

- Altitude ranges between 60 and 600 m asl;
- Mean yearly rainfall of about 680 mm;
- More than 2500 shallow landslides in the last 20 years.

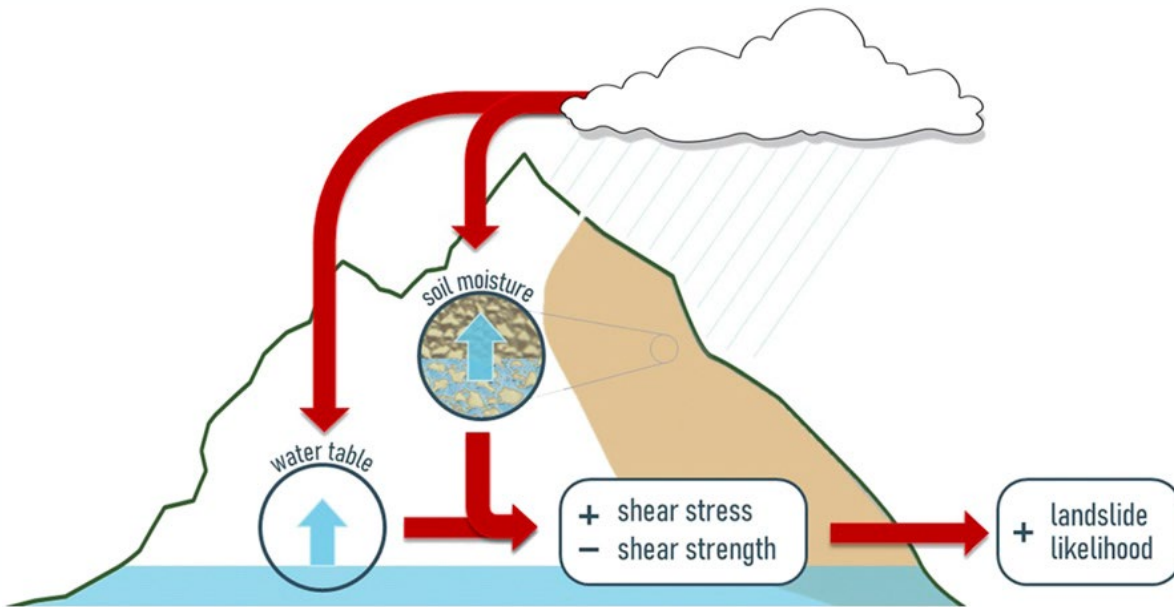
- 2 rainfall events over the Ardivestra catchment;
- About 100 landslides (10 m² – 20000 m²);
- Model parameters obtained through field campaign, lab tests, literature and high resolution digital elevation model.

Landslide mapping

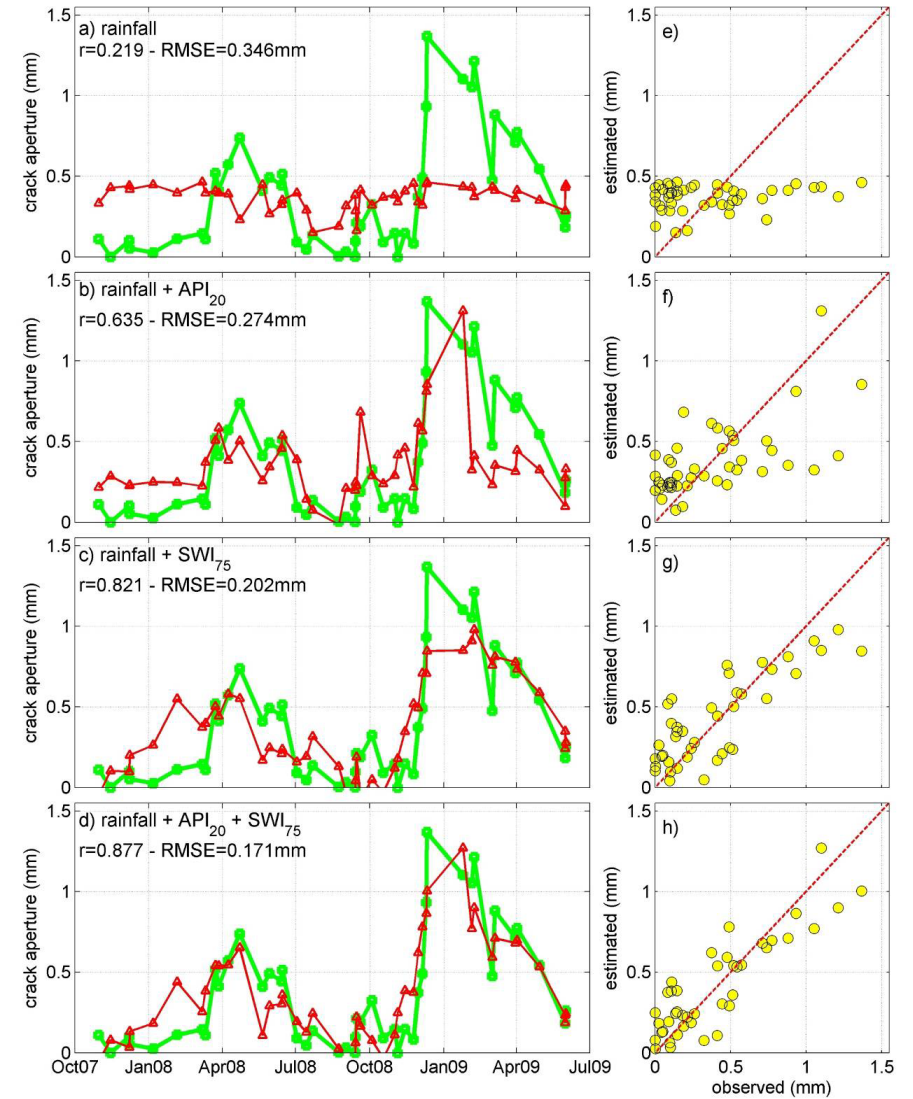


The importance of **soil moisture** for landslide hazard assessment

Felsberg et al. (2021), <https://doi.org/10.1175/JHM-D-20-0228.1>



Brocca et al. (2012), [doi:10.3390/rs4051232](https://doi.org/10.3390/rs4051232)



Landslide mapping

Lu and Godt, (2008),
doi:10.1029/2008WR006976

$$FS = \underbrace{\frac{\tan\varphi}{\tan\beta}}_{\text{Linked to internal frictional resistance of soil}} + \underbrace{\frac{2c}{H_{ss}\gamma\sin 2\beta}}_{\text{Linked to cohesion}} - \underbrace{\frac{\sigma^s}{H_{ss}\gamma}}_{\text{Linked to suction stress}} (\tan\beta + \cot\beta)\tan\varphi$$

Linked to internal frictional resistance of soil

Linked to cohesion

Linked to suction stress

Where:

φ is the angle of internal friction

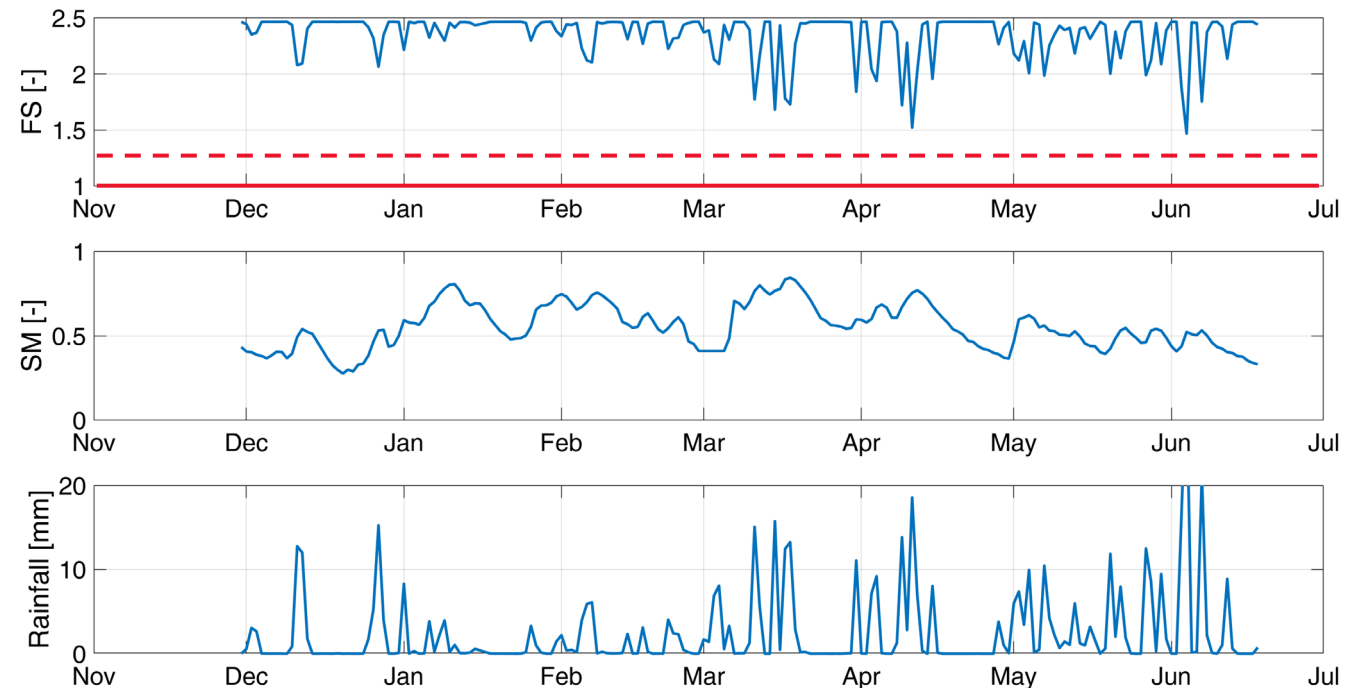
β is the slope angle

c is this soil cohesion

H_{ss} is the depth of the sliding surface

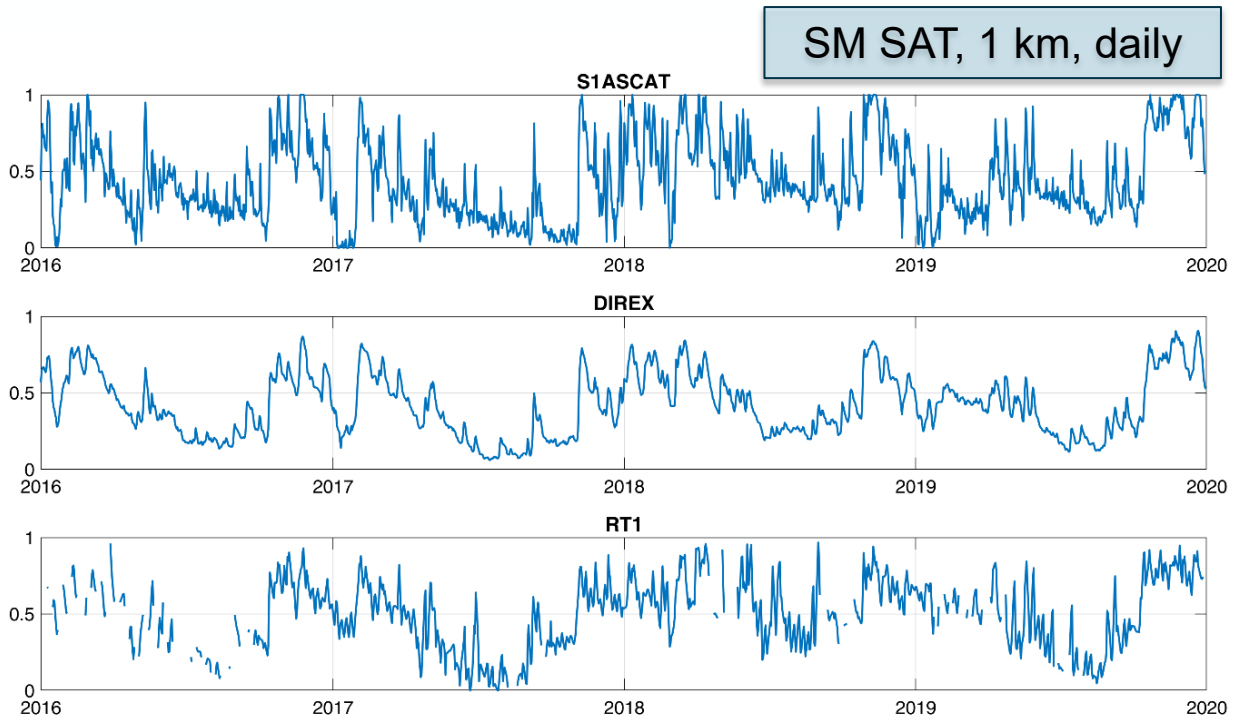
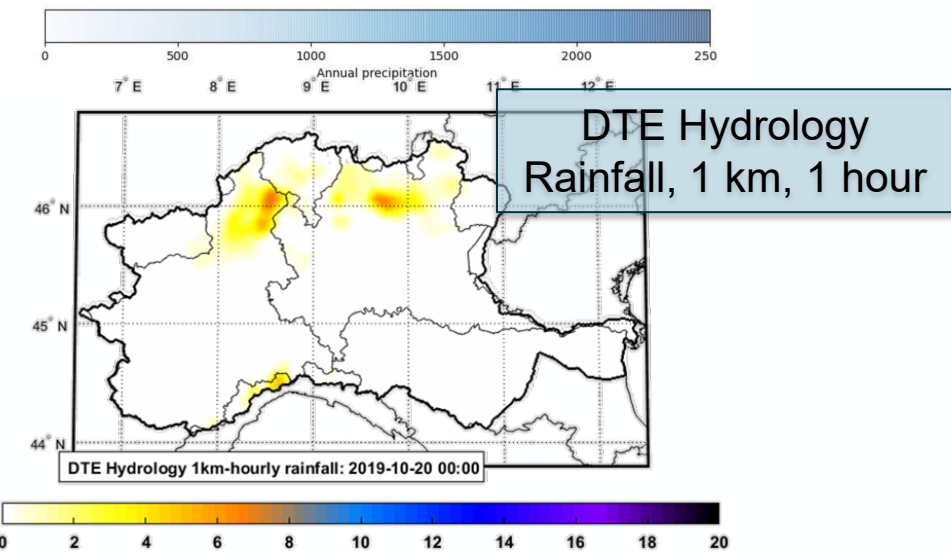
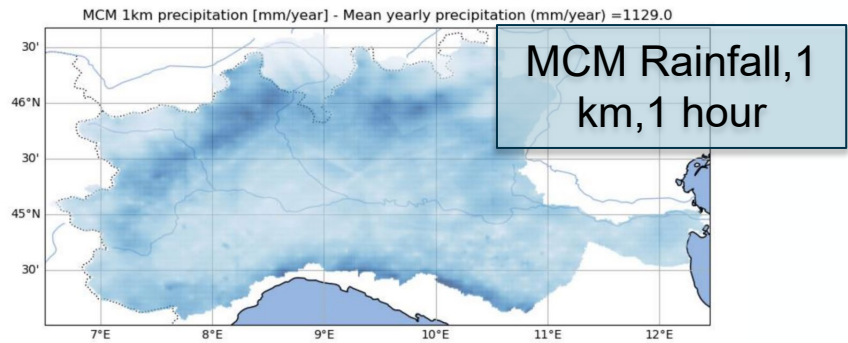
γ is the unit weight of soil

$\sigma^s \sim$ { soil moisture
rainfall through infiltration rate

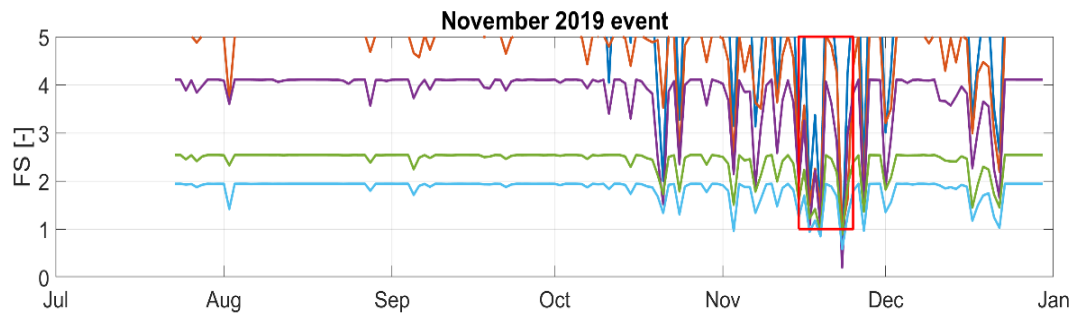
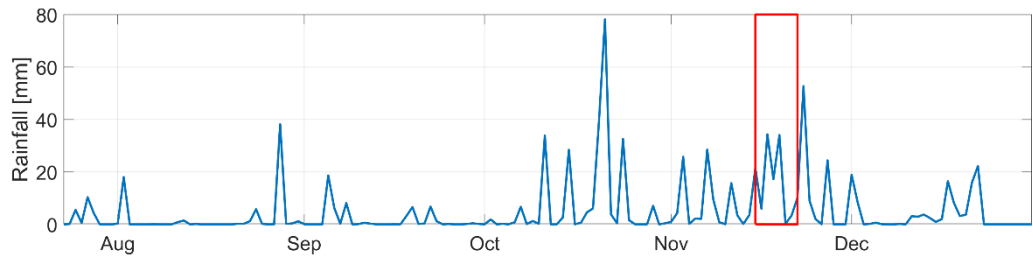
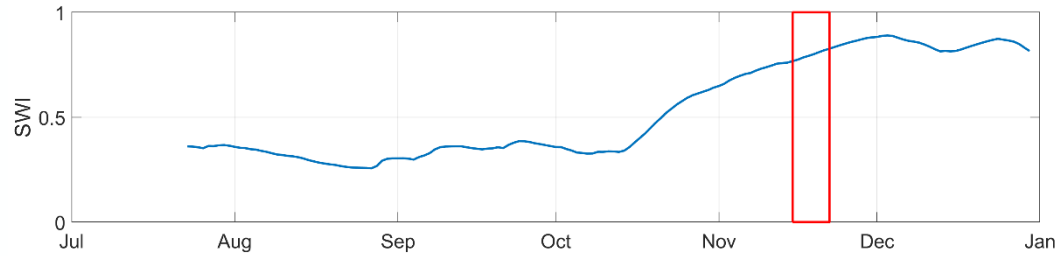


Landslide mapping

The model has been implemented with different **rainfall** and remotely sensed **soil moisture** data



Landslide mapping

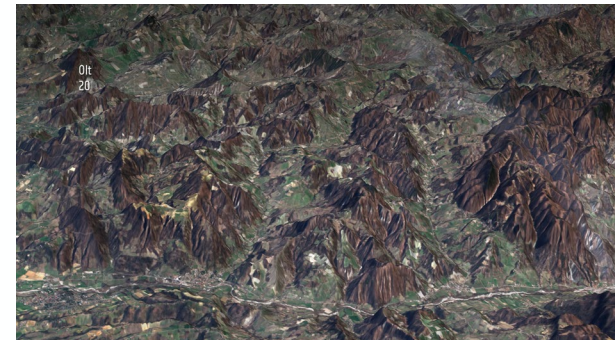


MCM Rainfall

November 2019 – 31 landslides		
S1ASCAT	28	90%
DIREX	29	93%
RT1	29	93%

DTE Hydrology Rainfall

November 2019 – 31 landslides		
S1ASCAT	21	68%
DIREX	20	64%
RT1	21	68%

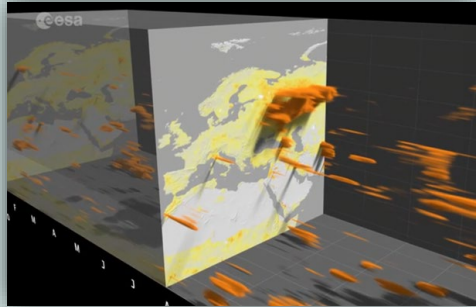


DTE Hydrology Evolution

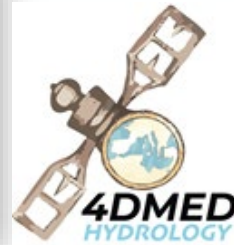
Implementation over the whole Mediterranean basin

DTE Hydrology Datacube [1]

EO-based (1km, 1hour\1day) and in situ dataset

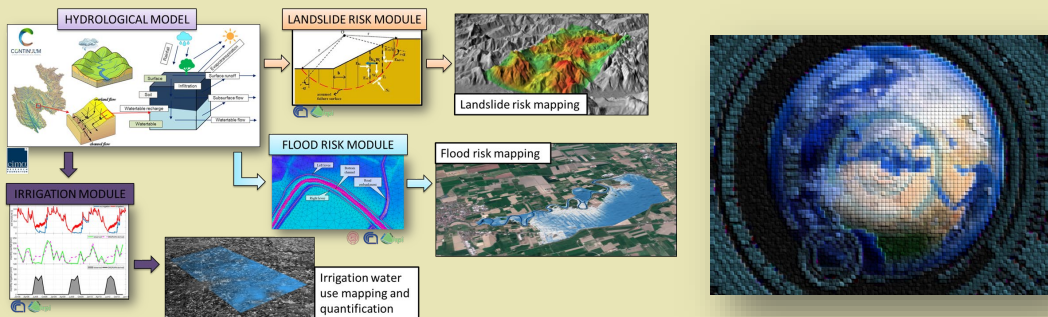


[1]

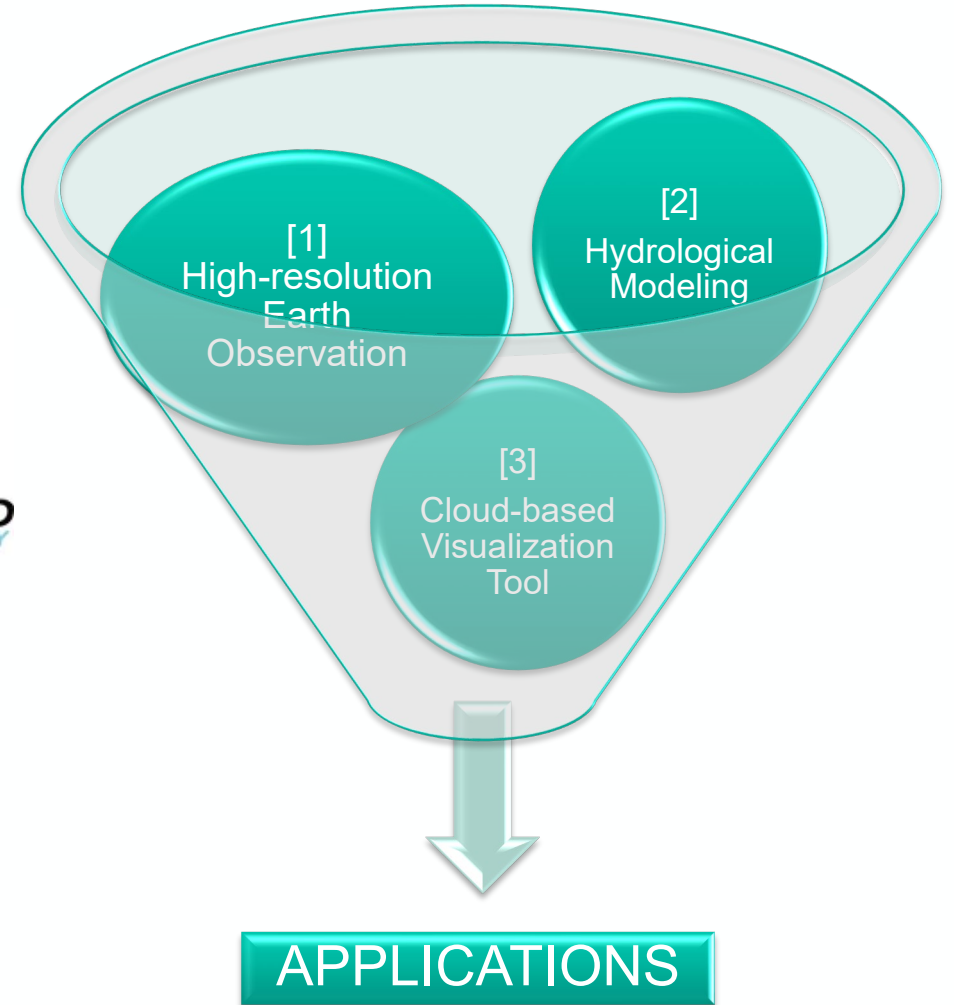


DTE Hydrology Modelling System [2]

Physical modelling and Artificial Intelligence



[2]



DTE Hydrology Evolution

[3] <https://explorer.dte-hydro.adamplatform.eu/>

Welcome to DTE Hydrology Platform

The European Space Agency (ESA) DTE Hydrology project aims at fostering a fast step forward towards establishing a solid scientific and technical basis to realise a Digital Twin Earth focused on the water cycle, hydrology and its different applications. The project will capitalise on existing developments and incorporate the necessary elements to prototype a first instance of Digital Twin Earth for hydrological processes, as an integrated and interactive system providing the best possible reconstruction and simulations of the water cycle and the hydrological processes and its interactions with human activities at unprecedented resolutions and accuracies.

Applications:

- Large scale water balance assessment
- High resolution flooding
- What-if scenario for flood risk and water resources management

PRACTICAL SESSION

Available Case Studies

DATA EXPLORATION SERVICE
Exploration of DTE Hydrology Datacube

Click to Enter

LARGE SCALE WATER BALANCE ASSESSMENT
Statistics of the different components of the water balance: precipitation, soil moisture, evaporation, snow water equivalent and runoff

Click to Enter

FLOOD/FLOODING PREDICTION
Flooding simulation for different extreme events (Medicane Apollo - October 2021; Enza levee breach - December 2017)

Click to Enter

WHAT-IF SCENARIO FOR FLOOD RISK ASSESSMENT
Synthetic flood database for operational flood forecasting: Po River Basin as case study

Click to Enter

WHAT-IF SCENARIO FOR WATER RESOURCES MANAGEMENT
Long-term (4-month) water uses scenario for water resources management: Po River Basin as case study

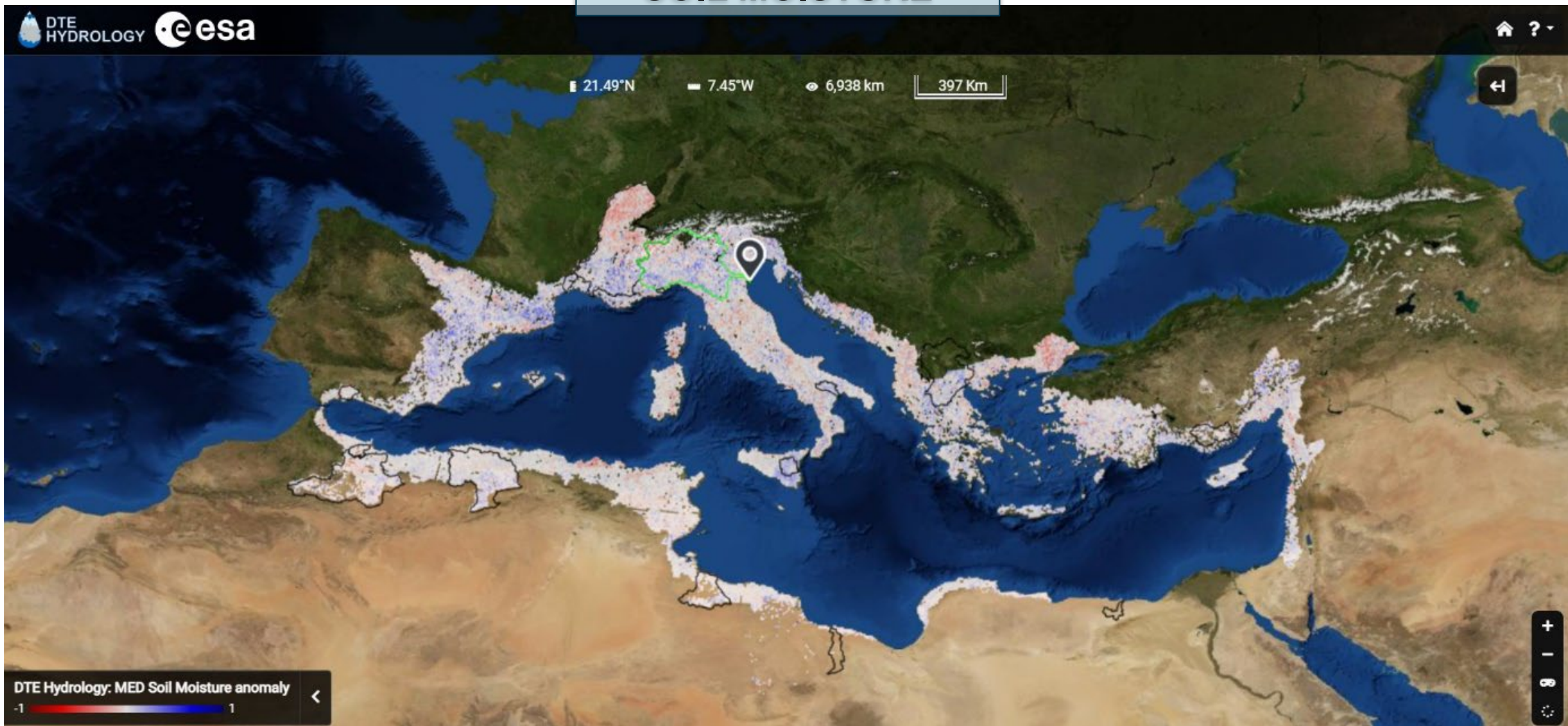
Click to Enter

THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE



DTE Hydrology datacube

SOIL MOISTURE



THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE



DTE Hydrology datacube

EVAPOTRANSPIRATION



THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE



DTE Hydrology datacube

RAINFALL

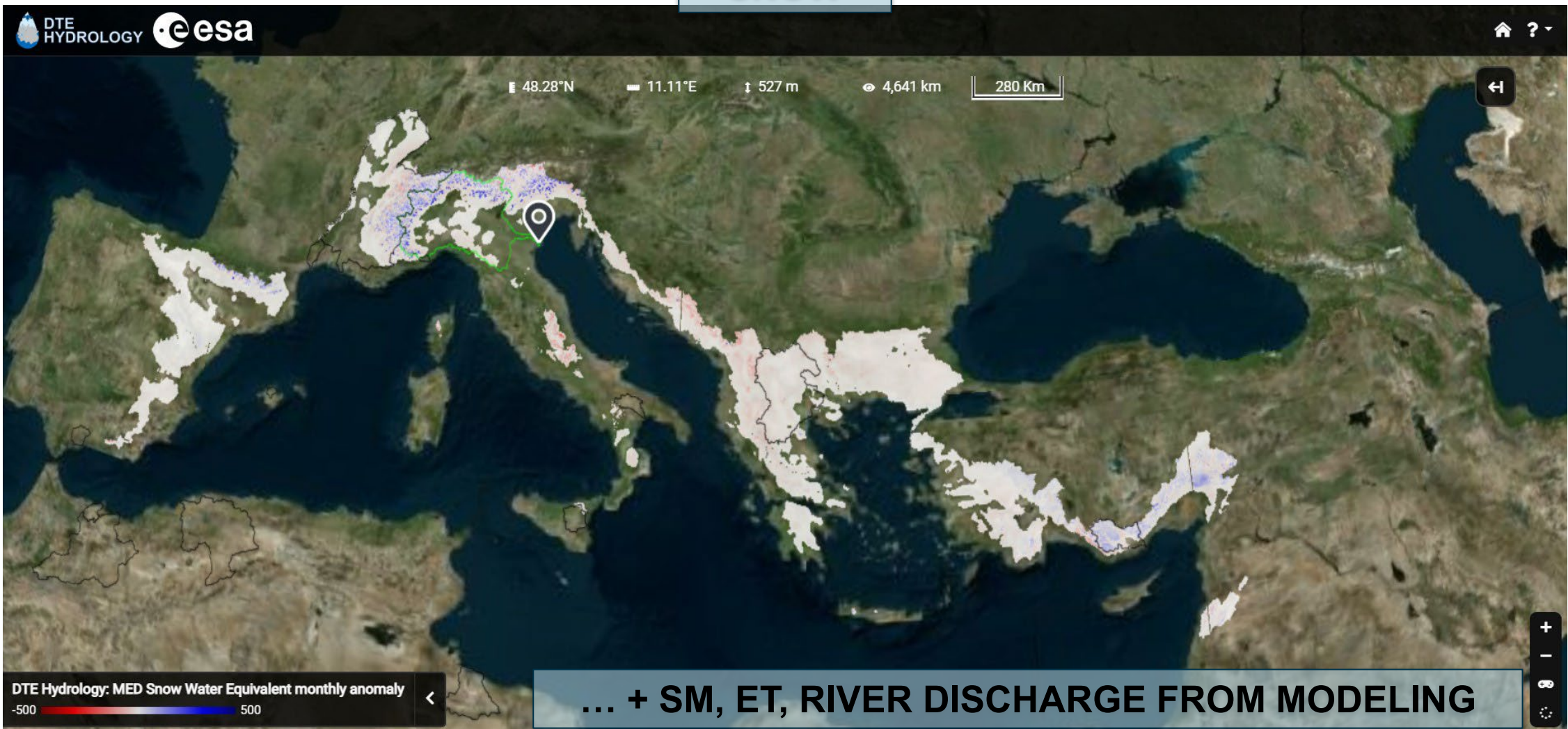


THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE



DTE Hydrology datacube

SNOW

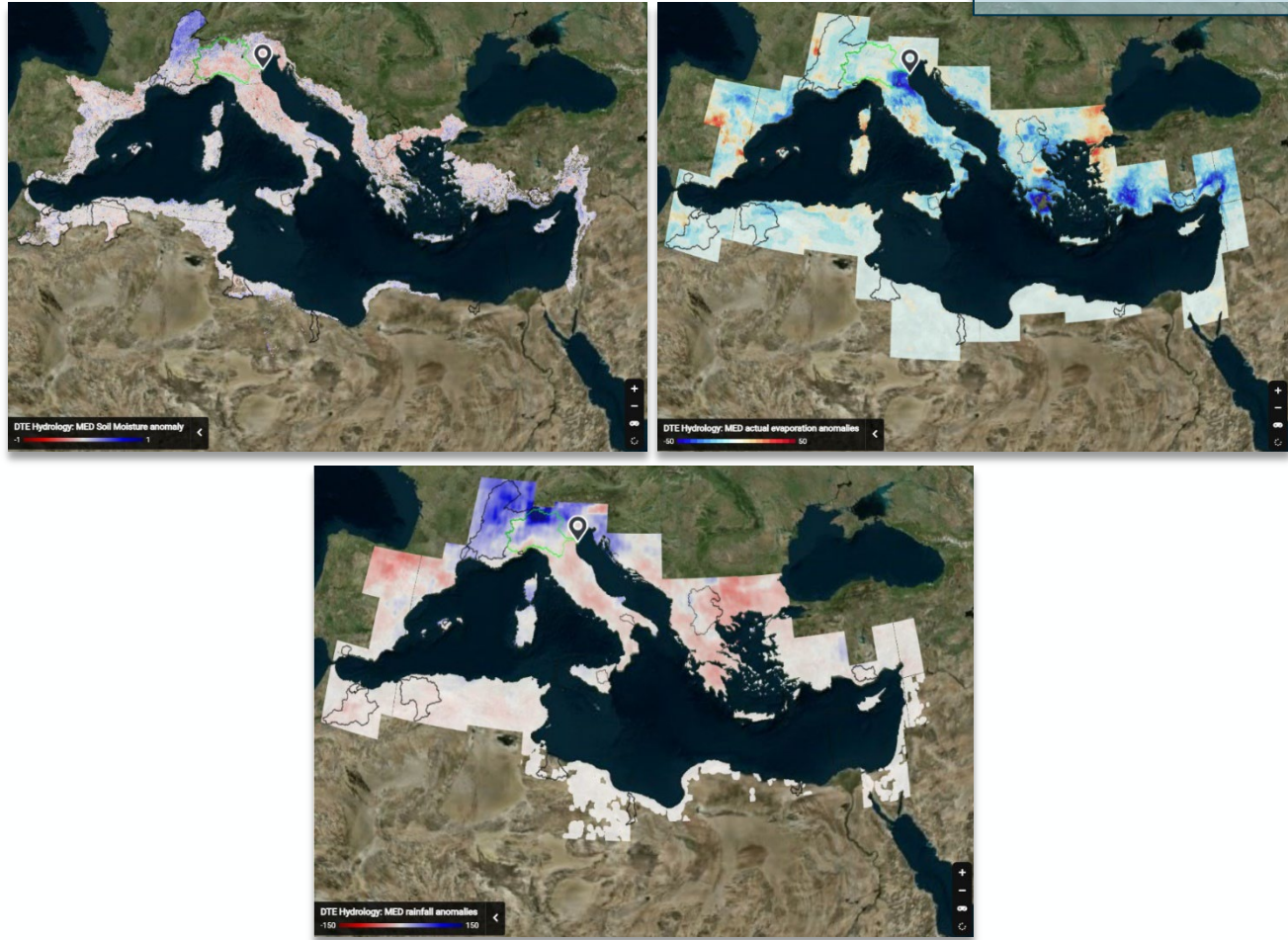


THE DTE HYDROLOGY EVOLUTION PROJECT: APPLICATIONS



Large scale water balance assessment

PO BASIN – JULY 2021

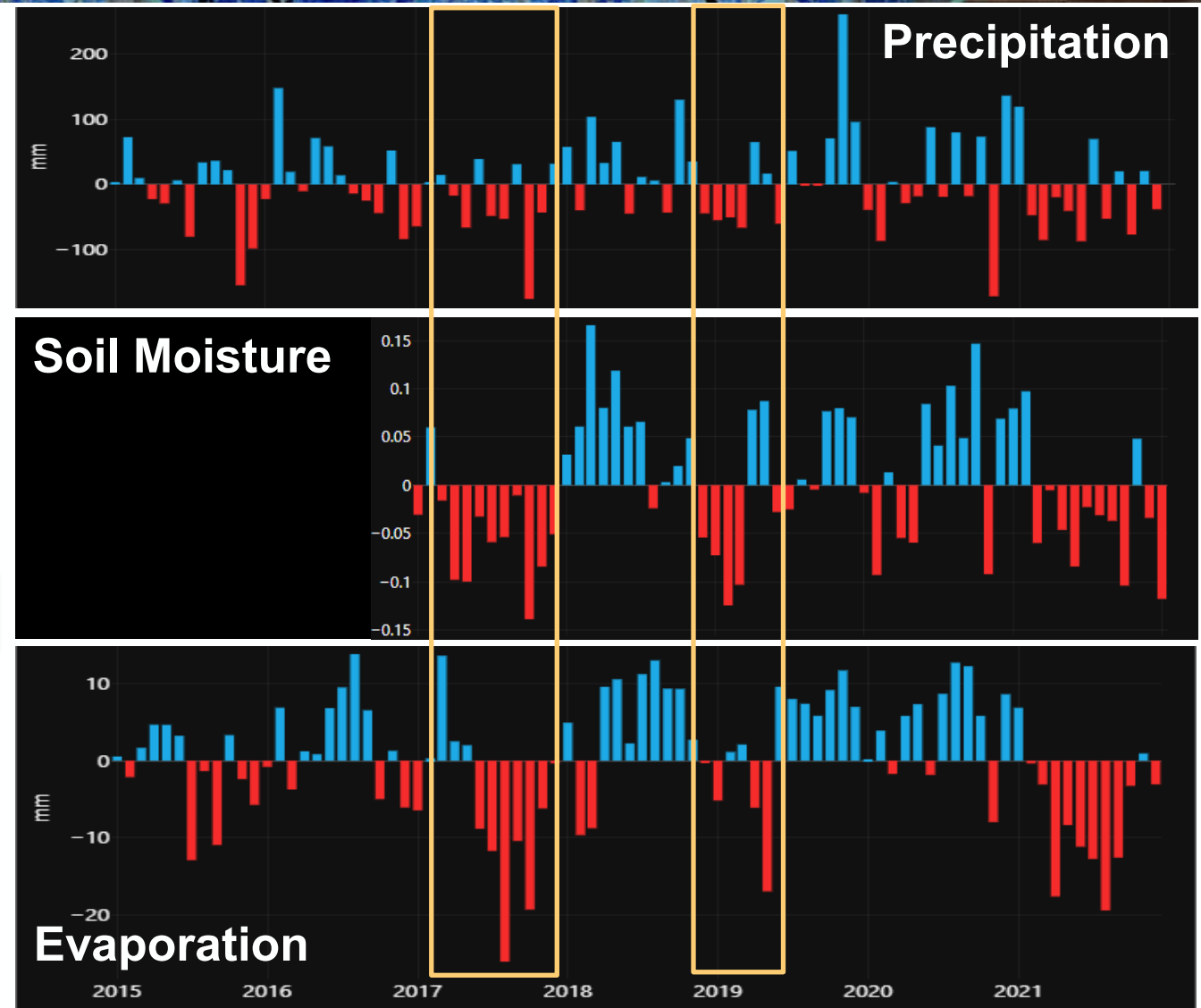
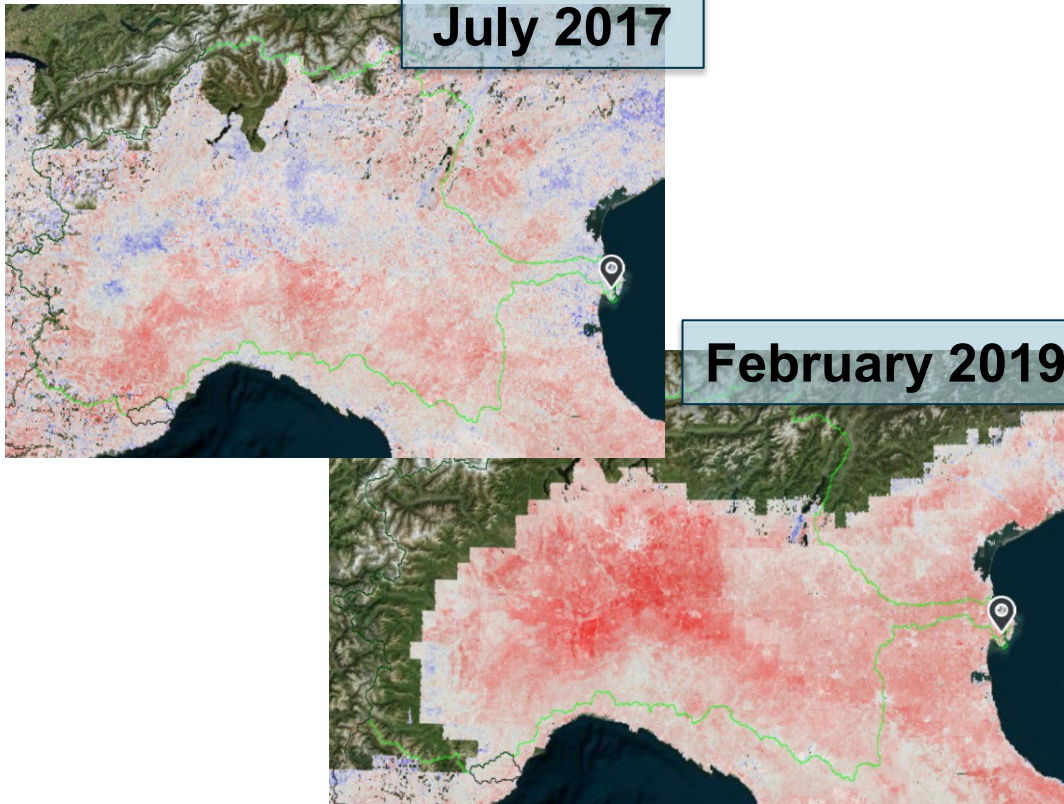


THE DTE HYDROLOGY EVOLUTION PROJECT: APPLICATIONS



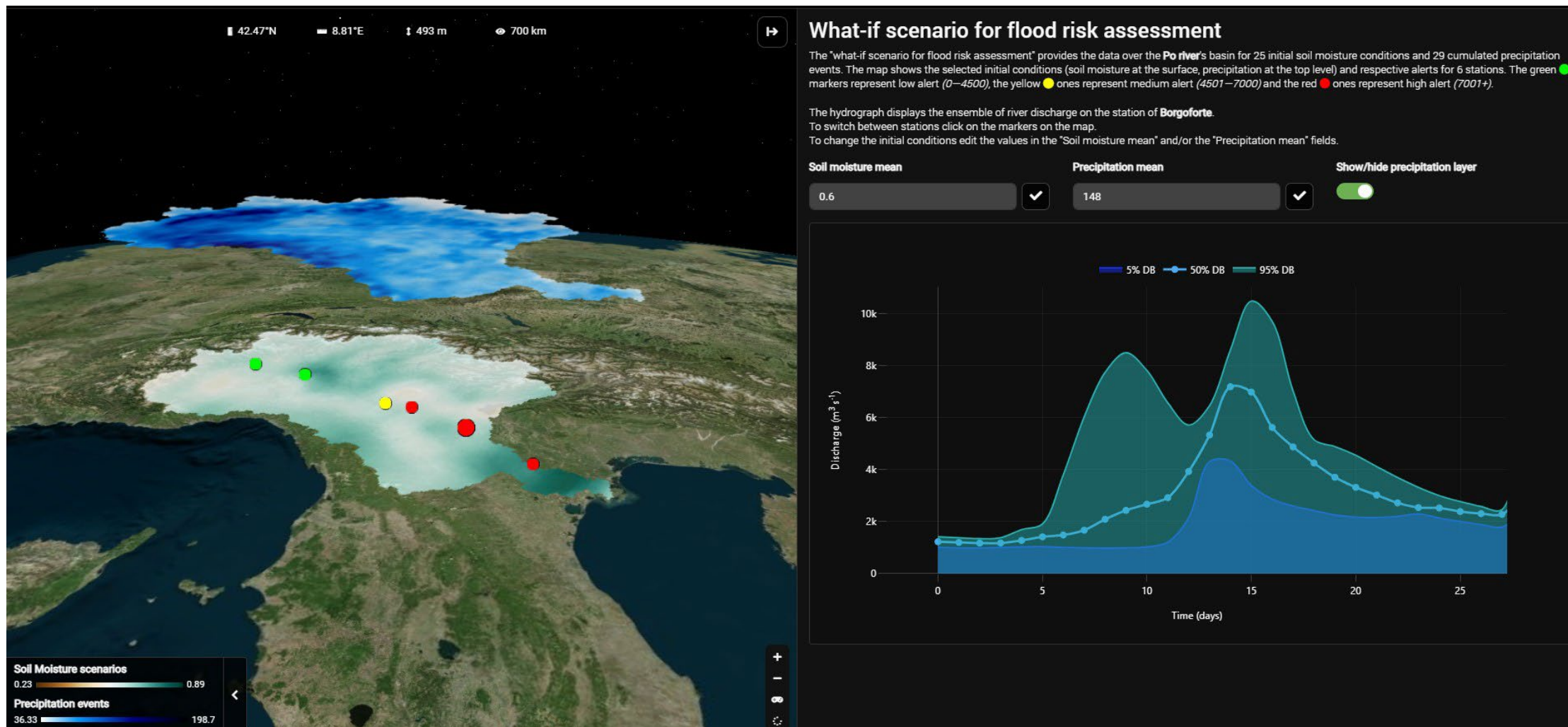
PO BASIN

Time series of monthly anomalies for drought monitoring



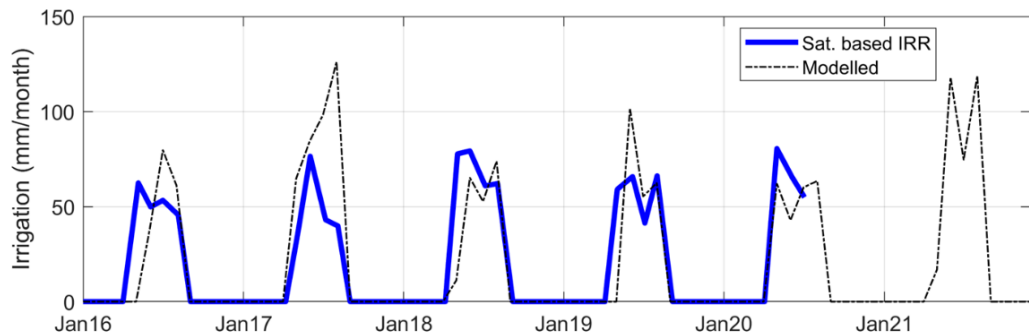
THE DTE HYDROLOGY EVOLUTION PROJECT: WHAT-IF SCENARIOS

What if scenario for flood risk assessment

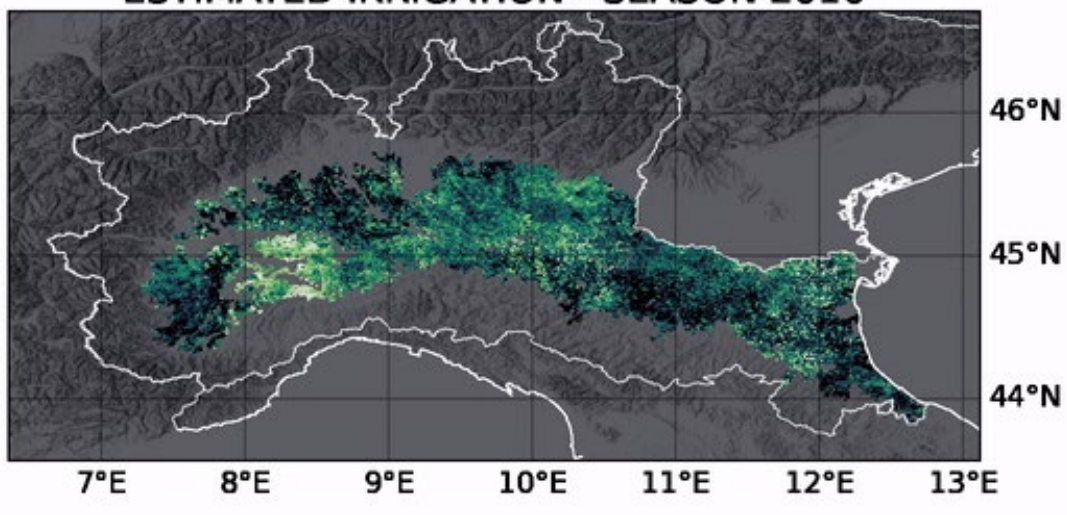


THE DTE HYDROLOGY EVOLUTION PROJECT: WHAT-IF SCENARIOS

What if scenario for flood risk assessment



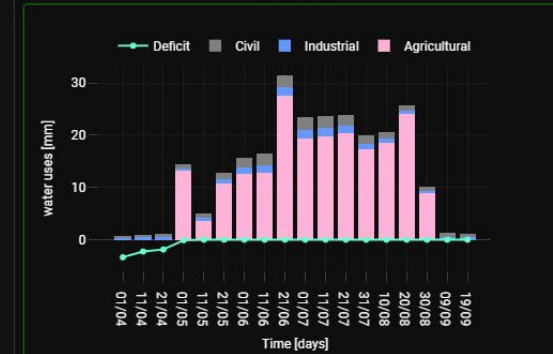
ESTIMATED IRRIGATION - SEASON 2016



What-if scenario for water resources management

The "what-if scenario for water resources management" provides the agricultural, civil and industrial water uses over the Po river basin from April to August as a function of different scenario (Very high, High, ..., Very low) for: (a) precipitation, (b) air temperature, (c) initial soil moisture, (d) initial snow water equivalent, and (e) releases from reservoirs (currently only average).

To show the impact of the water resources management, you can enable/disable the agricultural civil and industrial water uses by clicking on the respective icon.

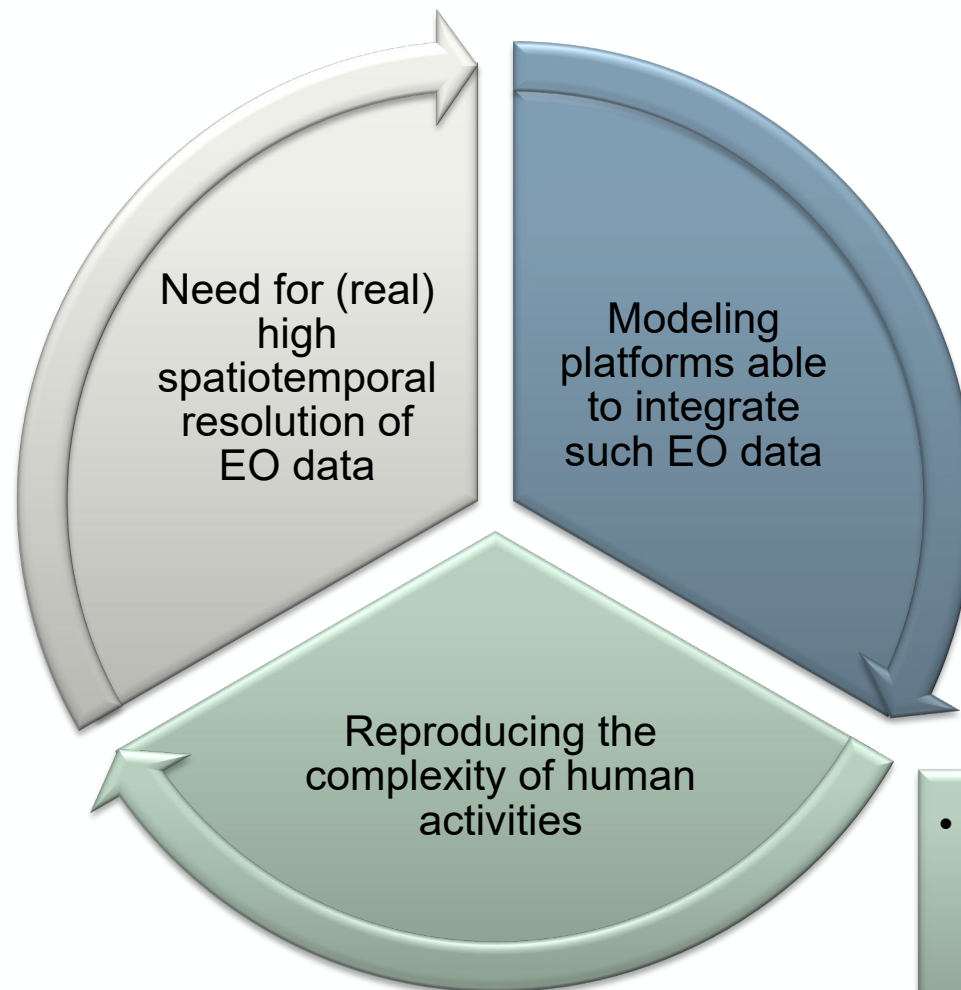


Type	Value (Km3)	Uncertainty
Precipitation	37.5	4.4
Evaporation	27.7	3.0
Runoff	10.3	2.5
Agricultural water use	15.0	4.1
Industrial water use	1.2	NaN
Civil water use	1.7	NaN
Deficit	-0.5	0.08

Conclusions and outlook

Challenges to be still addressed

- Validation of novel EO data
- Managing uncertainties
- (Real) high resolution EO data for monitoring processes occurring at the target scale
- In-situ networks
- New satellite missions



- Consistency between retrieval algorithms and modeling (e.g., using same ancillary information)
- Managing uncertainties
- Technical issues: improved computation capacities for reducing data latency, integration with AI/machine learning techniques

- Capability of tracking effects of human activities on the Earth system (EO data) and proper integration into modeling platforms

CONCLUSIONS AND OUTLOOK



https://www.esa.int/Applications/Observing_the_Earth/Destination_Earth



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Hydrology CNR-IRPI website:
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