DTE Hydrology and landslide risk

Jacopo Dari

28/09/2023

THE DTE HYDROLOGY (EVOLUTION) PROJECT

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**

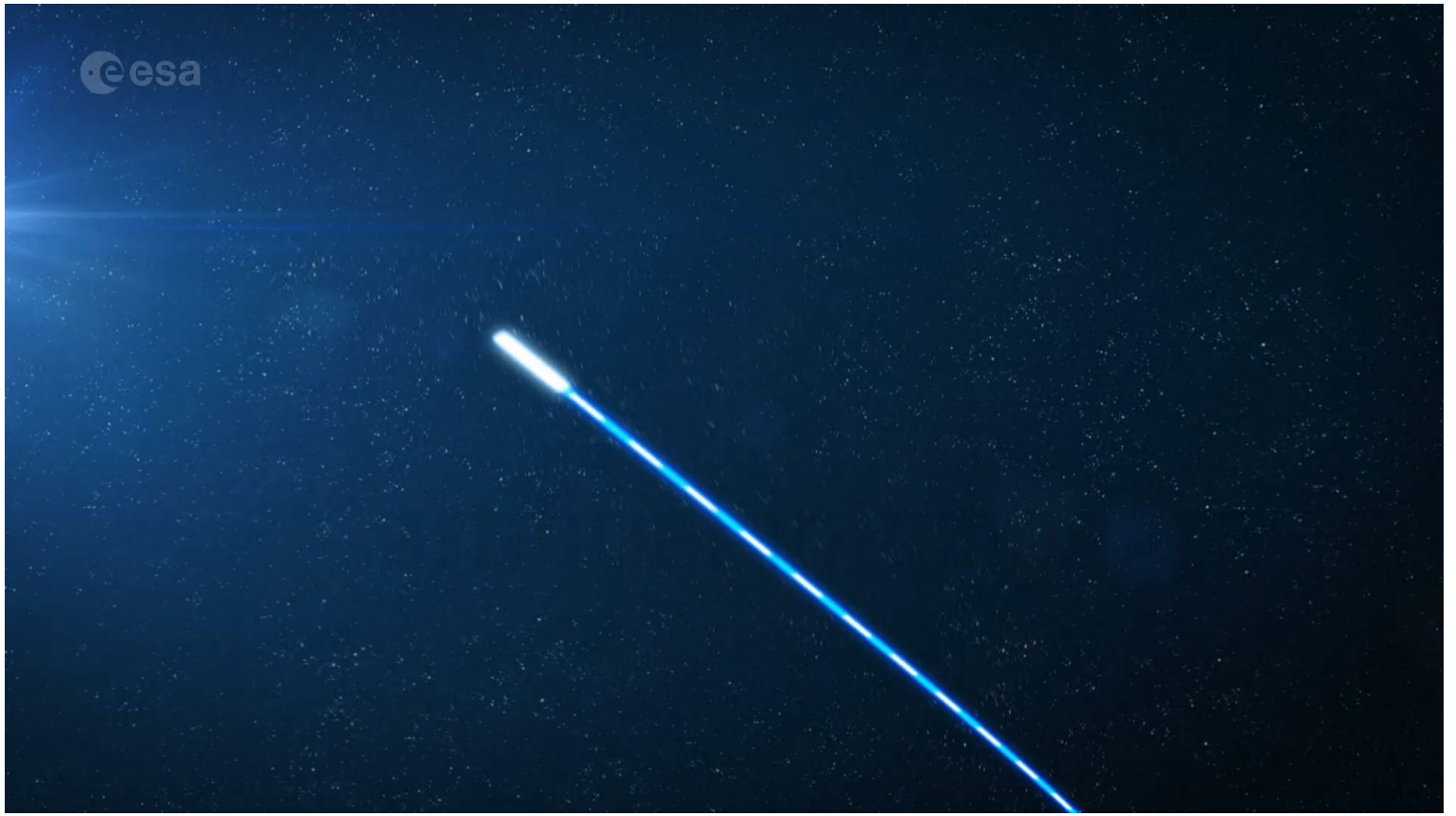
DTE Hydrology Evolution: implementation over the **Mediterranean basin**, applications and **what-if scenarios**

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:

zenodo

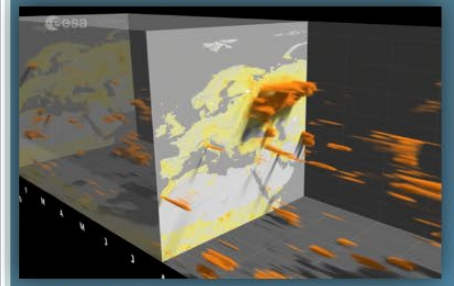
THE DTE HYDROLOGY (EVOLUTION) PROJECT

The DTE Hydrology (Evolution) project: concept

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

DTE Hydrology Datacube

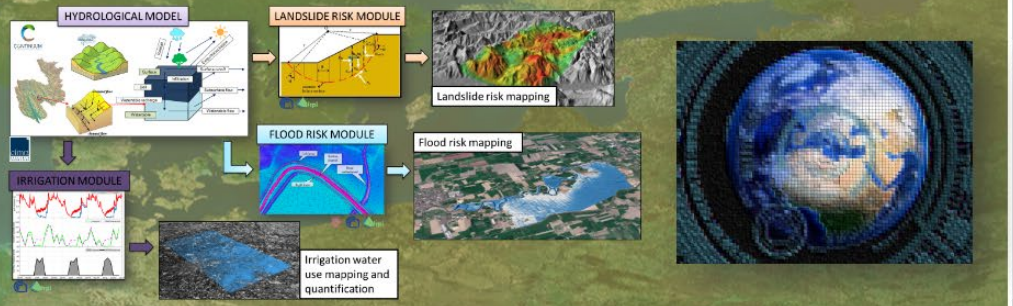
EO-based and in situ dataset



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.

European Union

ECMWF esa EUMETSAT

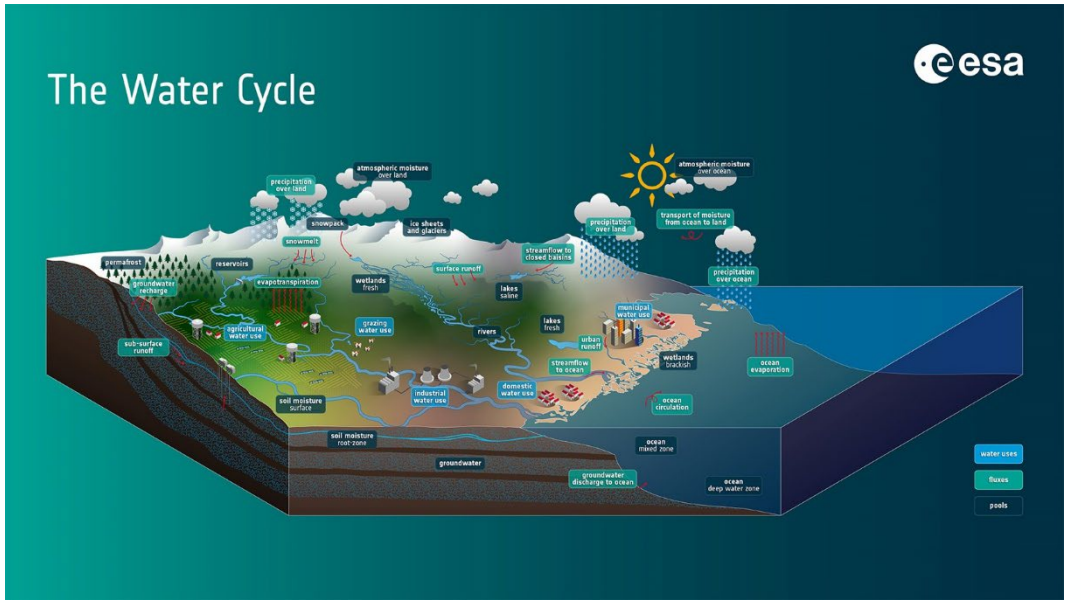
THE DTE HYDROLOGY (EVOLUTION) PROJECT

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 Barbetta[1], Stefania Camici[1], Luca Ciabatta[1], Jacopo Dari[1, 2], Paolo Filippucci[1], Christian Massari[1], Sara Modanesi[1], Angelica Tarpanelli[1], Bianca Bonaccorsi[1], Hamidrezza Mosaffa[1], Wolfgang Wagner[3], Mariette Vreugdenhil[3], Raphael Quast[3], Lorenzo Alfieri[4], Simone Gabellani[4], Francesco Avanzi[4], Dominik Rains[5], Diego G. Miralles[5], Simone Mantovani[6], Christian Brese[7], Alessio Domeneghetti[8], Alexander Jacob[9], Mariapina Castelli[9], Gustau Camps-Valls[10], Espen Volden[11], Diego Fernandez[11]



Requirements:

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

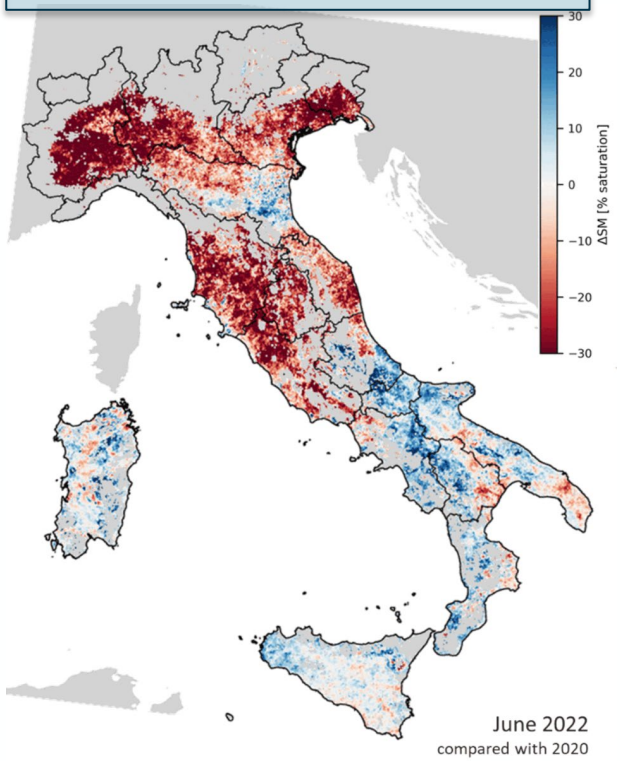
2. Representing **human activities**, which are absolutely not negligible at such scales

Remote sensing technology allows us to meet both requirements!

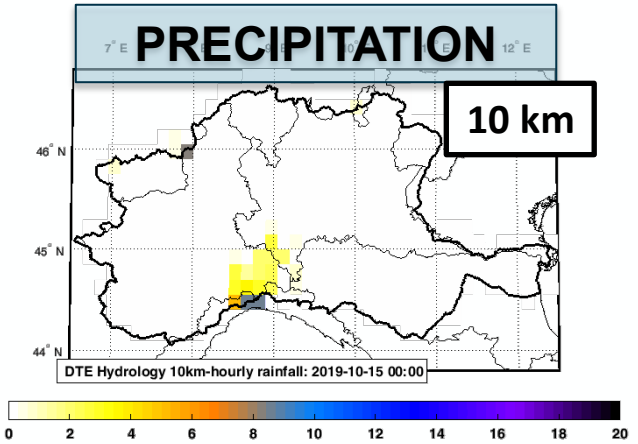
THE DTE HYDROLOGY (EVOLUTION) PROJECT

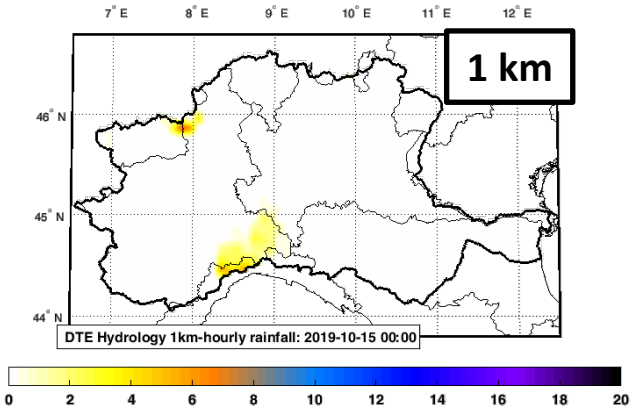
High-resolution data: a «new era» for hydrology

SOIL MOISTURE

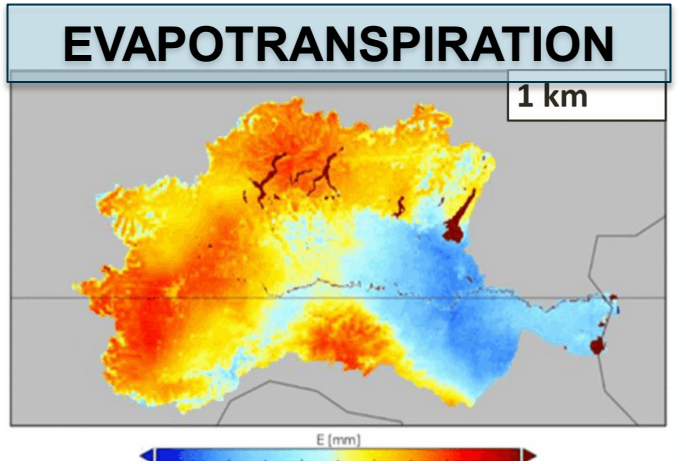


PRECIPITATION

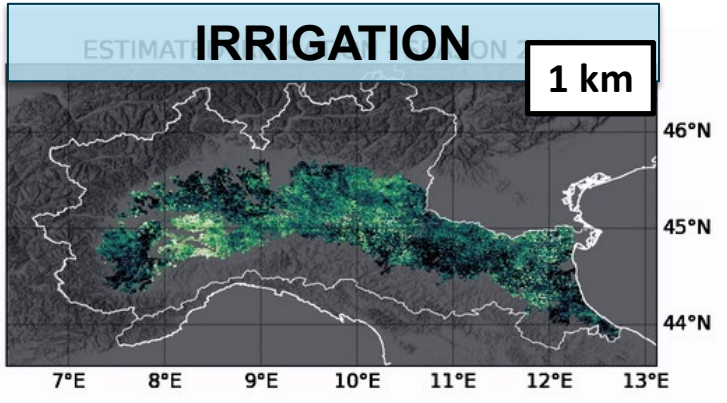




EVAPOTRANSPIRATION



IRRIGATION

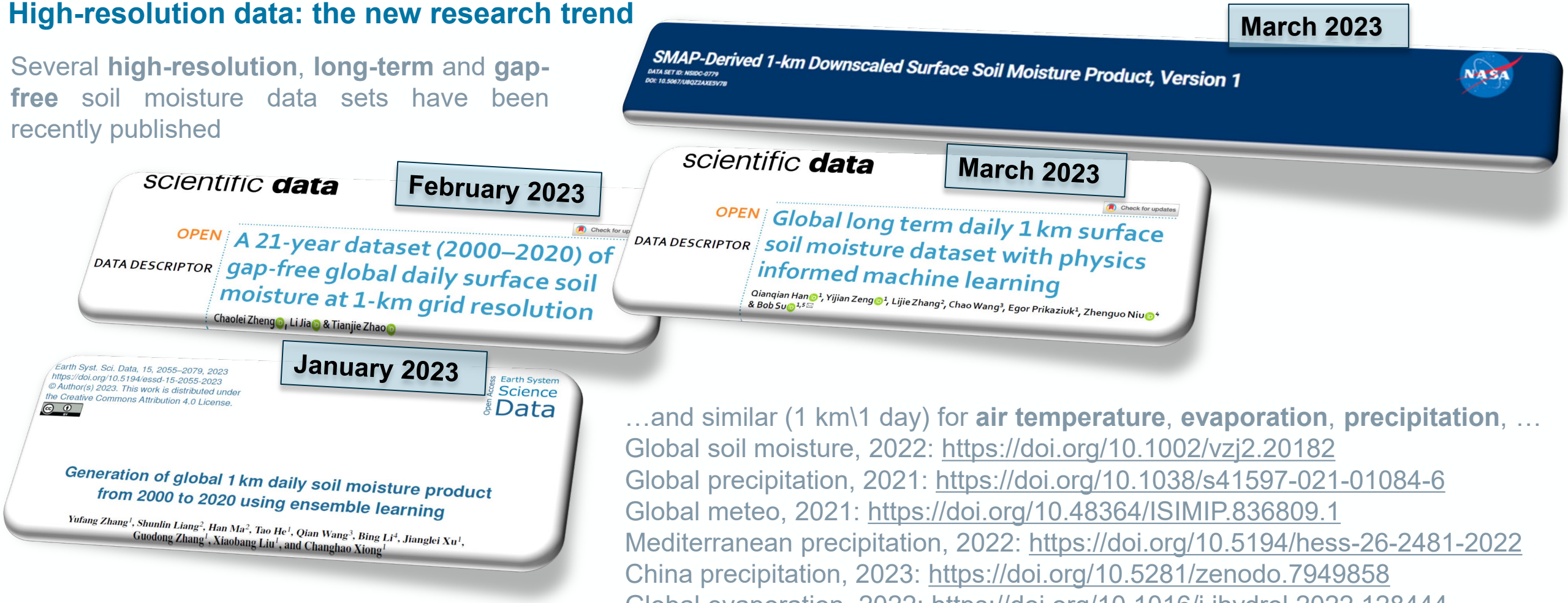


Only coarse resolution data were available up to few years ago (up to 2020)…
…now new satellite observations at 1 km and 1 hour\day resolution are available!

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

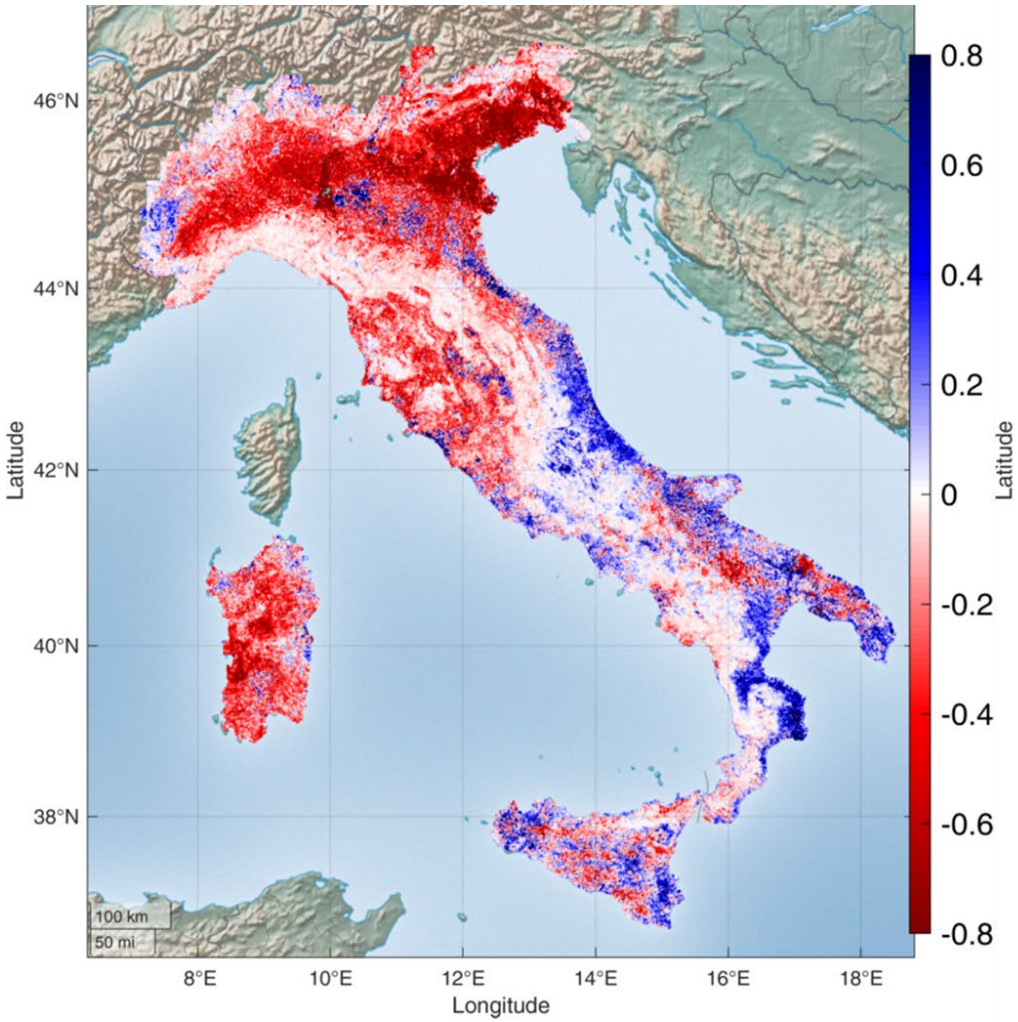


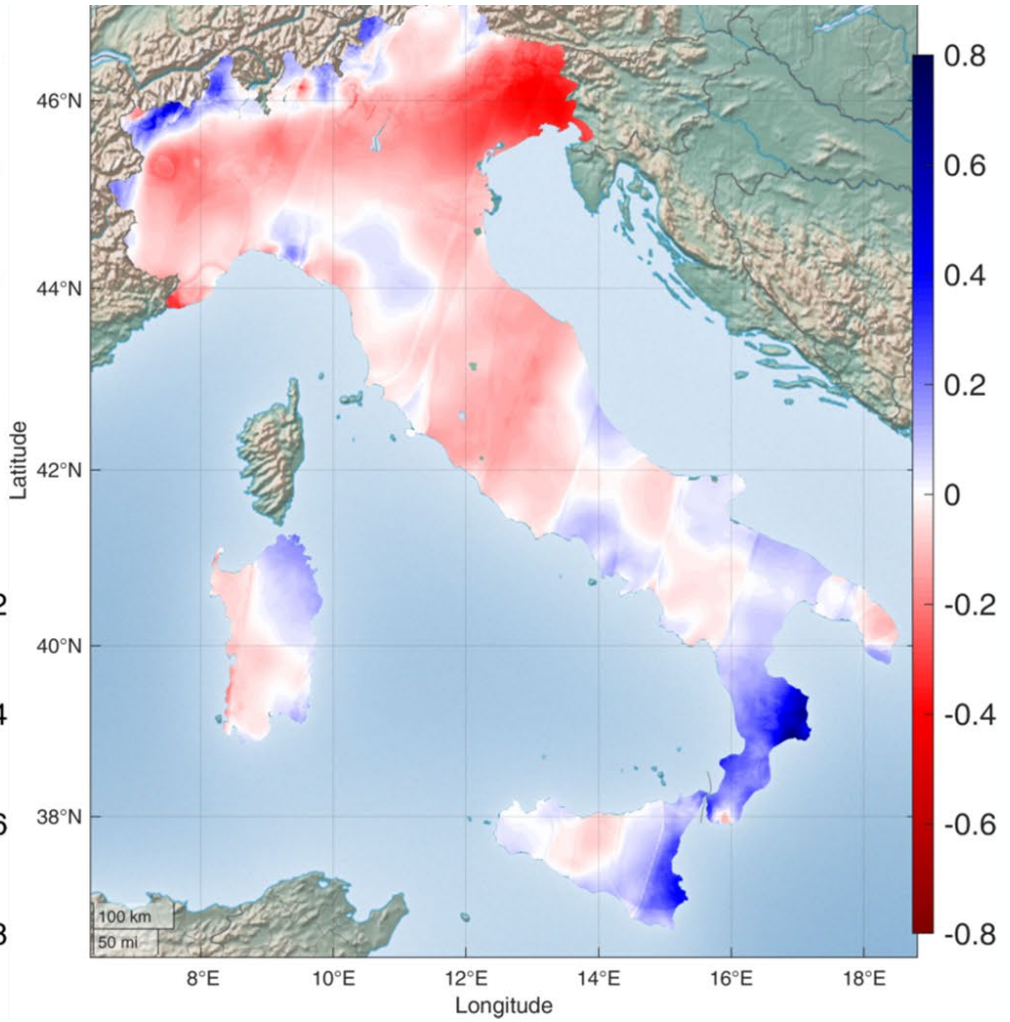
…and similar (1 km\1 day) for **air temperature**, **evaporation**, **precipitation**, …

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

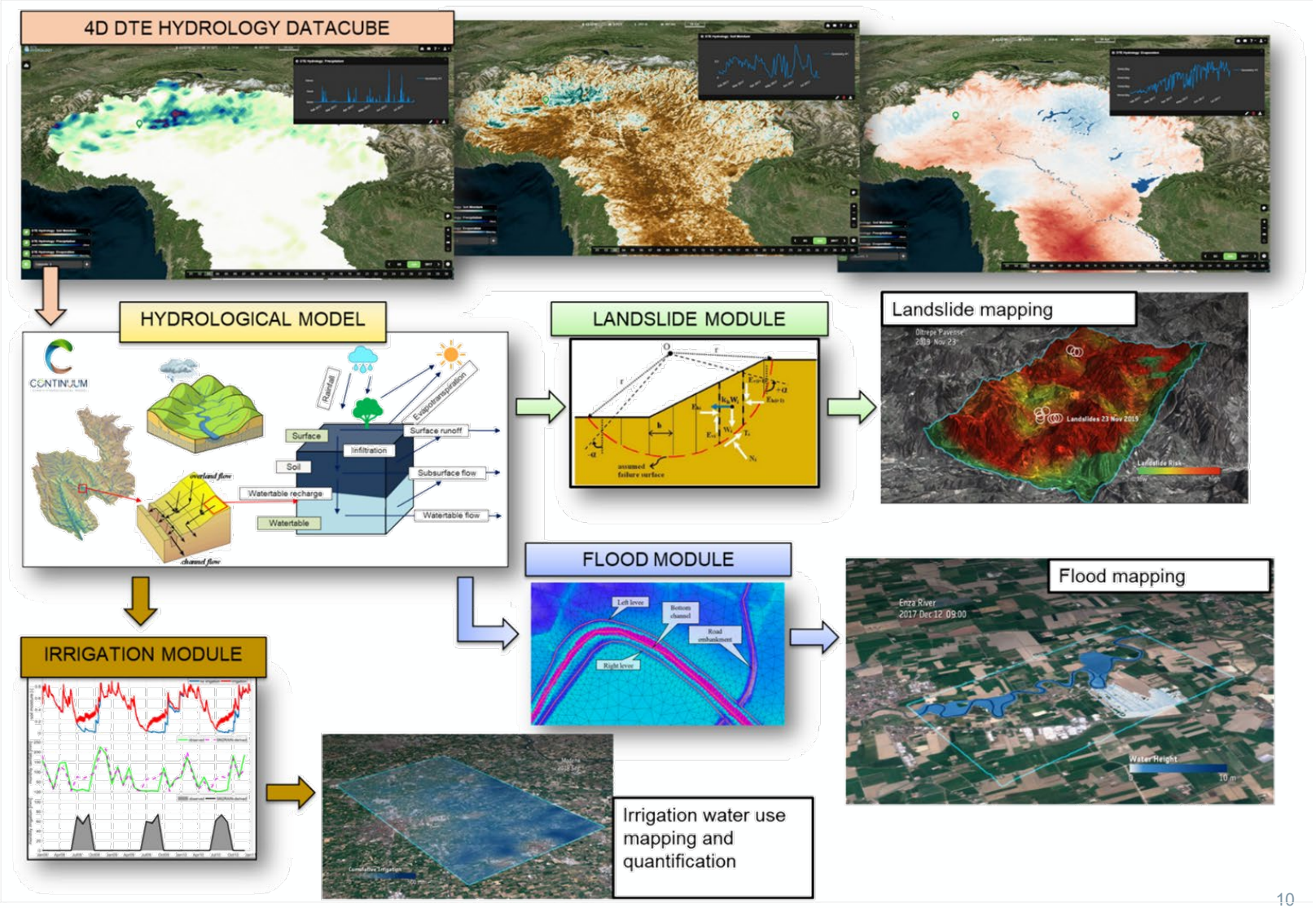
DTE Hydrology

First implementation over the **Po valley**, Northern Italy

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

3 case studies:

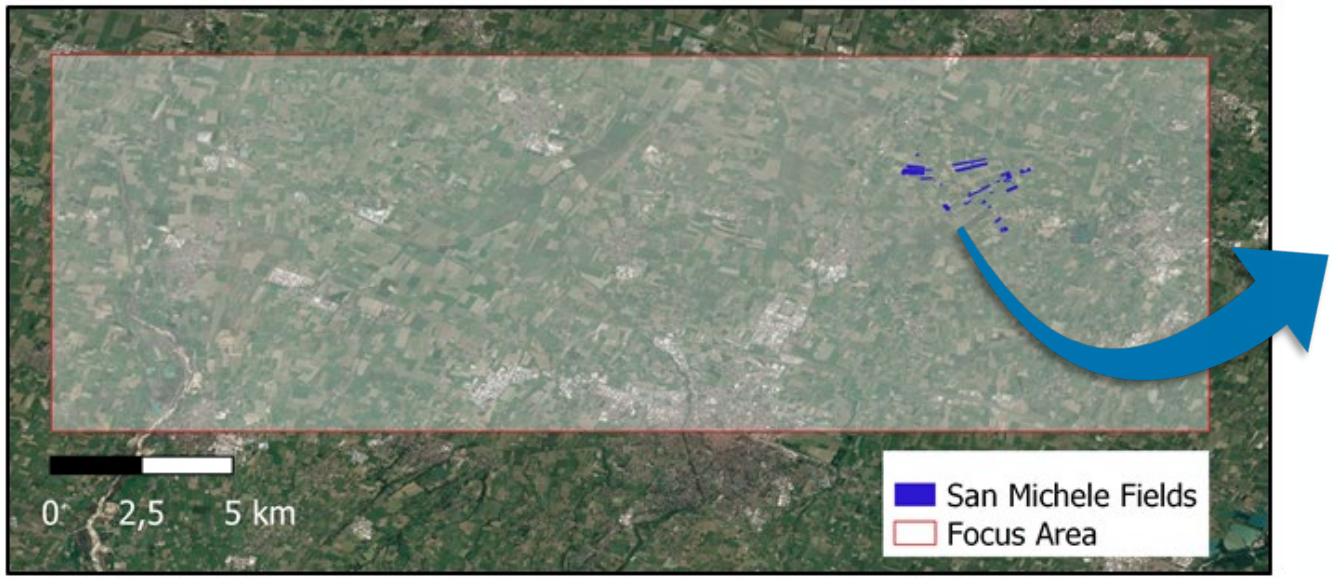
- Flood
- Irrigation
- Landslide

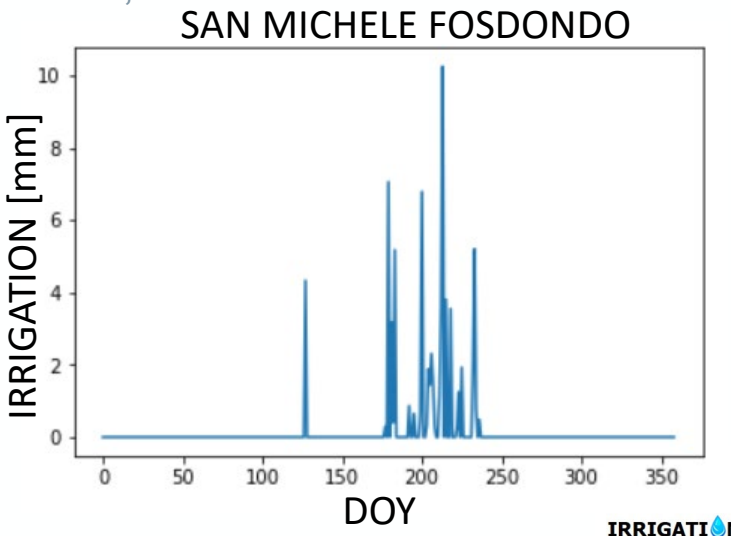


THE DTE HYDROLOGY PROJECT: CASE STUDIES

Irrigation water use mapping and quantification

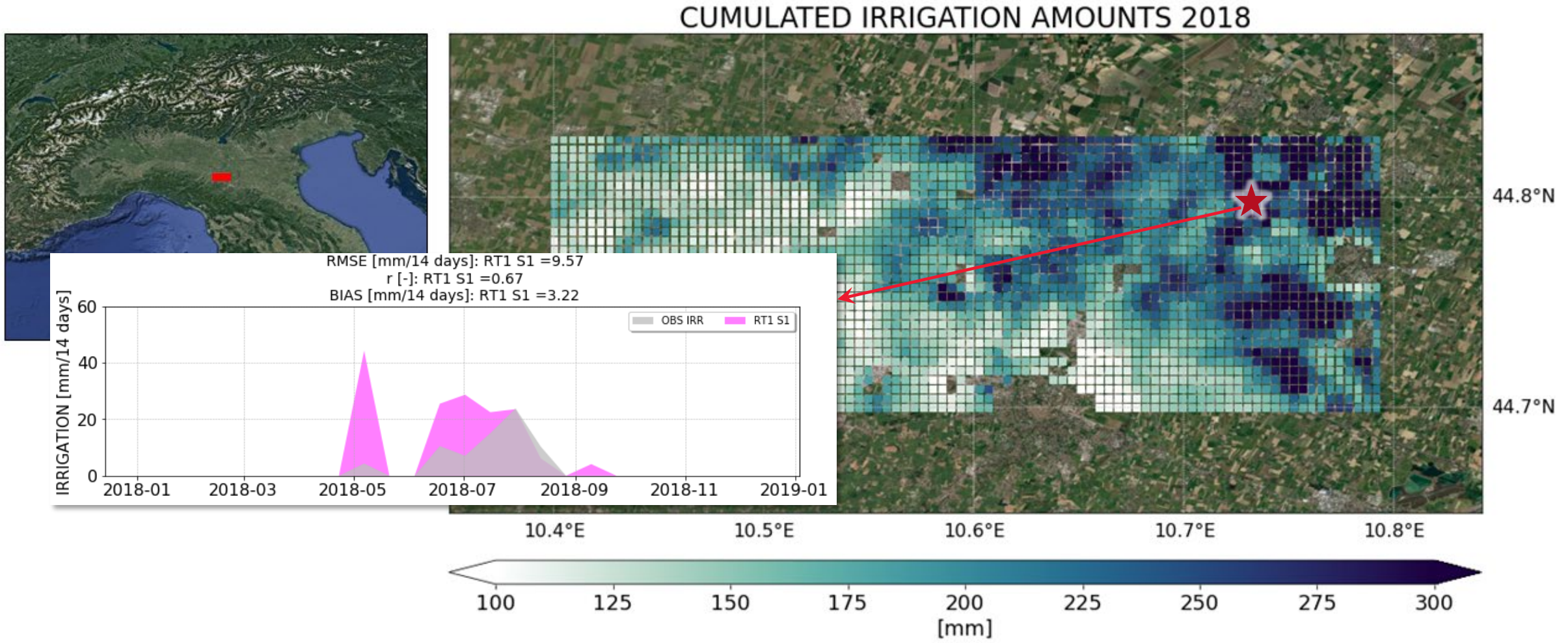
- **Method:** SM-based inversion approach;
- **Area:** ~450 km^2 box North of the Reggio Emilia city;
- **Products:** Soil moisture from **RT1 S1** data set, rainfall from **MCM**, and PET rates from **GLEAM**;
- **Period:** 2018.





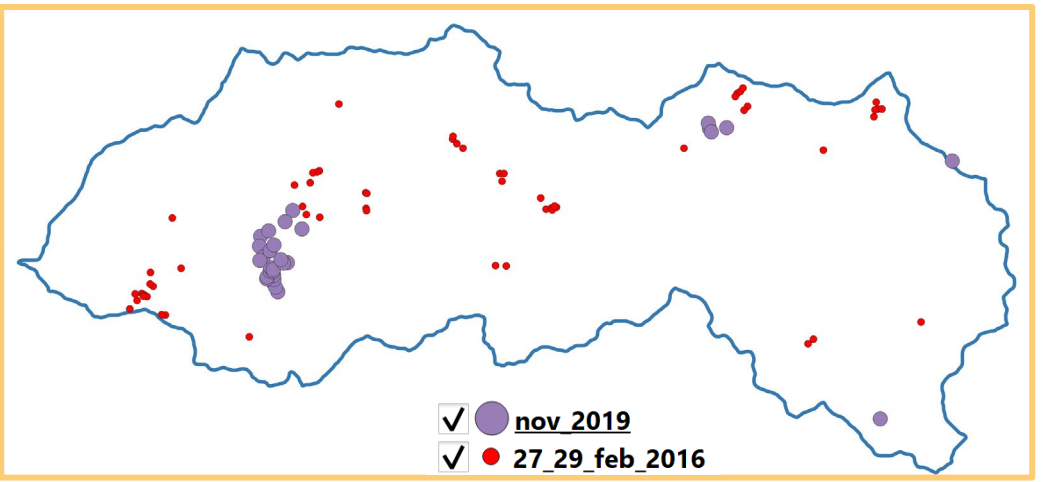
THE DTE HYDROLOGY PROJECT: CASE STUDIES

Irrigation water use mapping and quantification



THE DTE HYDROLOGY PROJECT: CASE STUDIES

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.

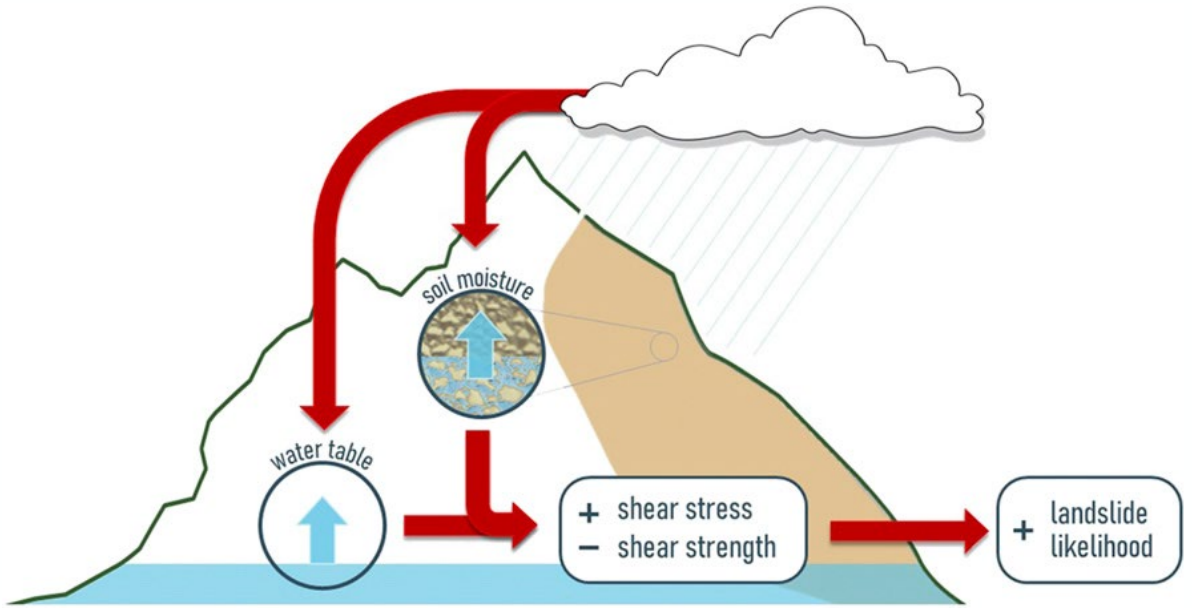
- 2 rainfall events over the Ardivestra catchment;
- About 100 landslides (10 m² – 20000 m²);
- Model parameters obtained through field campaign, lab tests, literature and high resolution digital elevation model.

Courtesy of L. Ciabatta

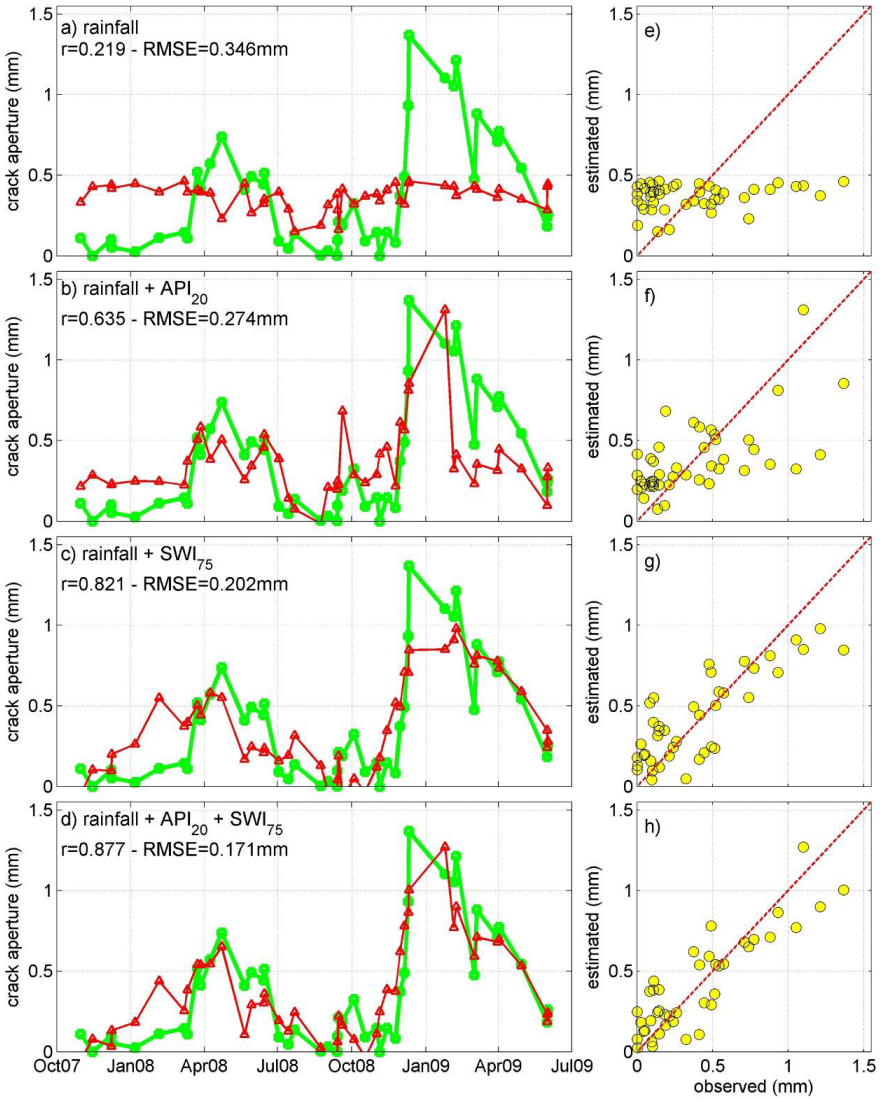
THE DTE HYDROLOGY PROJECT: CASE STUDIES

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

Courtesy of L. Ciabatta

THE DTE HYDROLOGY PROJECT: CASE STUDIES

Landslide mapping

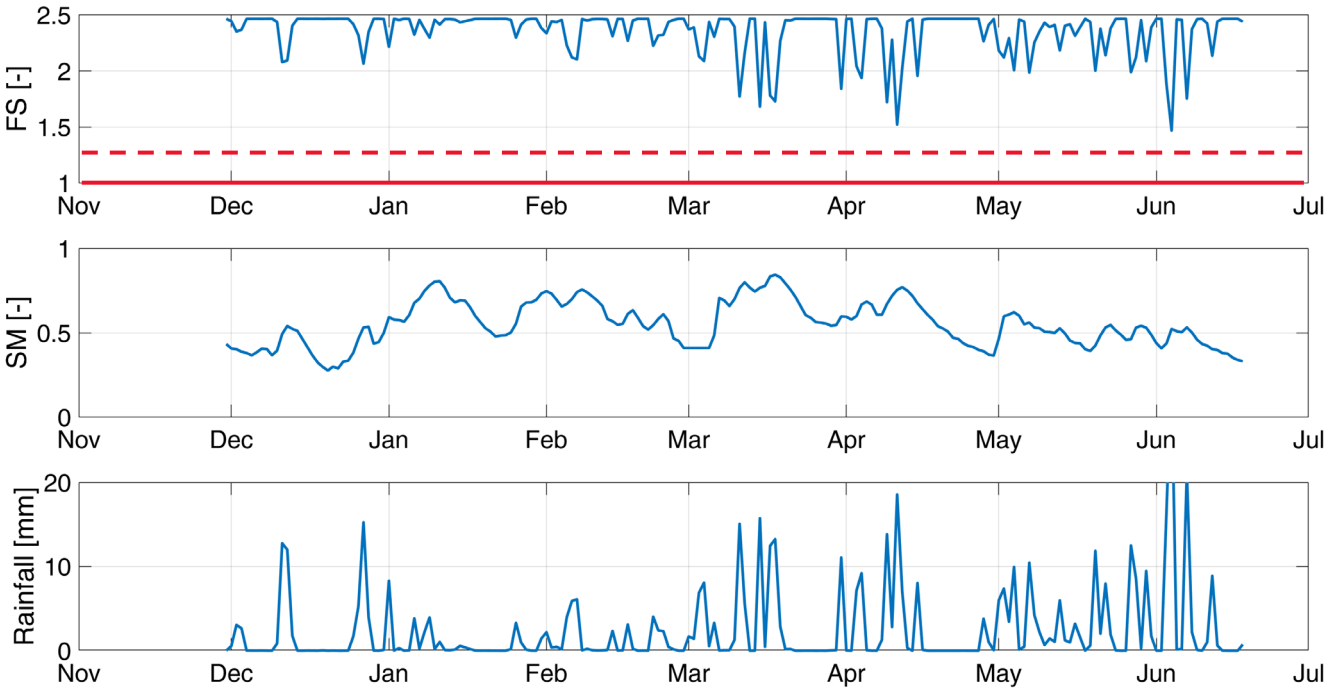
Lu and Godt, (2008), doi:10.1029/2008WR006976

$$FS = \underbrace{\frac{tan\varphi}{tan\beta}}_{\text{Linked to internal frictional resistance of soil}} + \underbrace{\frac{2c}{H_{ss}\gamma sin2\beta}}_{\text{Linked to cohesion}} - \underbrace{\frac{\sigma^s}{H_{ss}\gamma}(tan\beta + cot\beta)tan\varphi}_{\text{Linked to suction stress}}$$

Where:

φ is the angle of internal friction
β is the slope angel
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 }

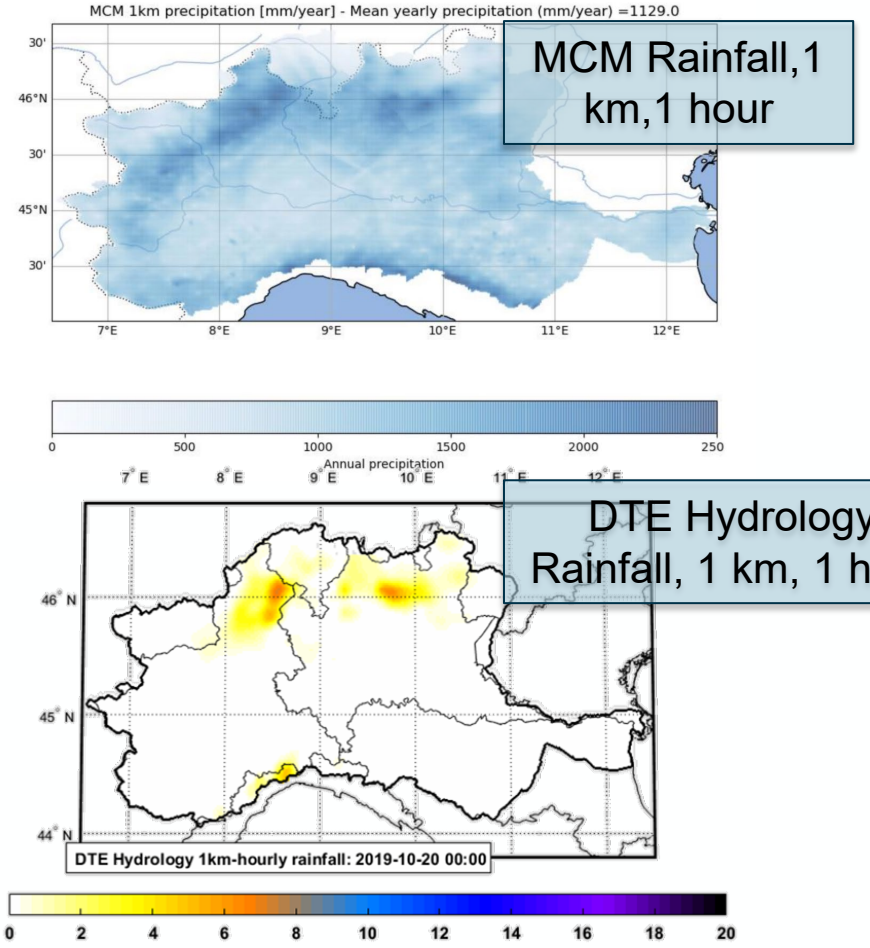


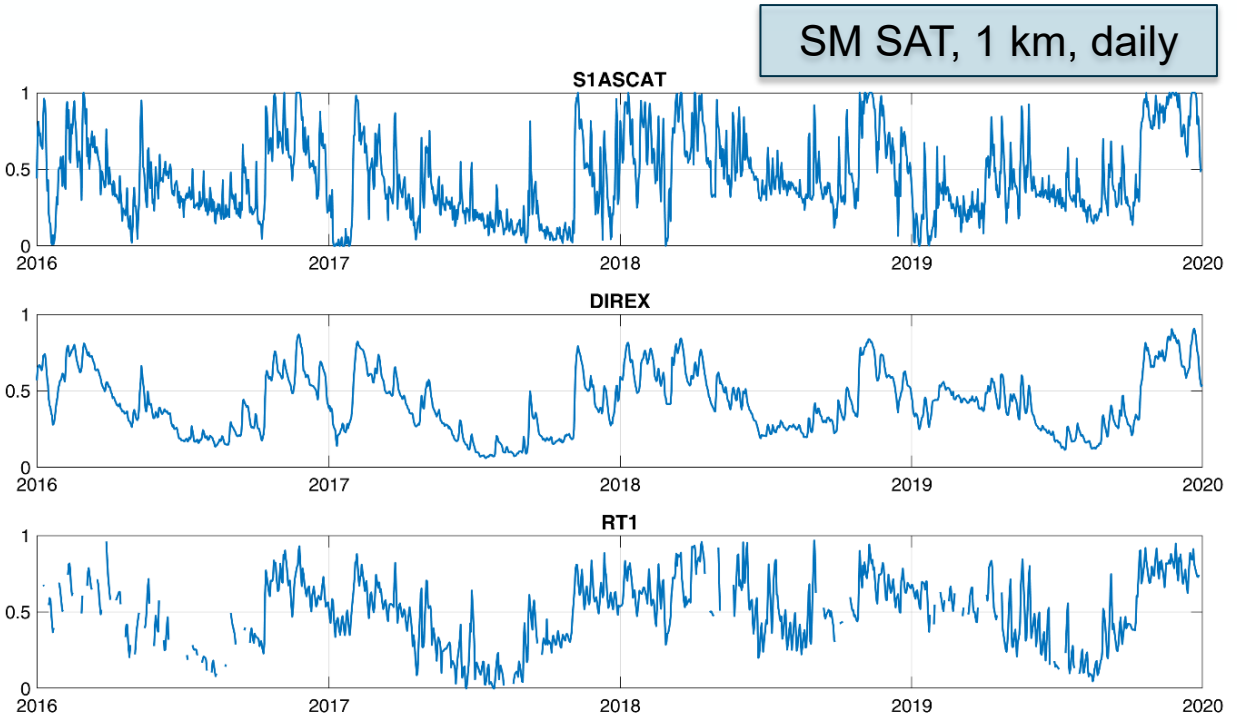
Courtesy of L. Ciabatta

THE DTE HYDROLOGY PROJECT: CASE STUDIES

Landslide mapping

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

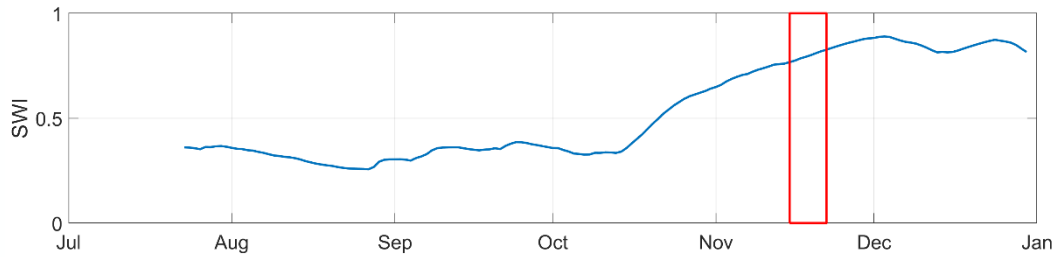


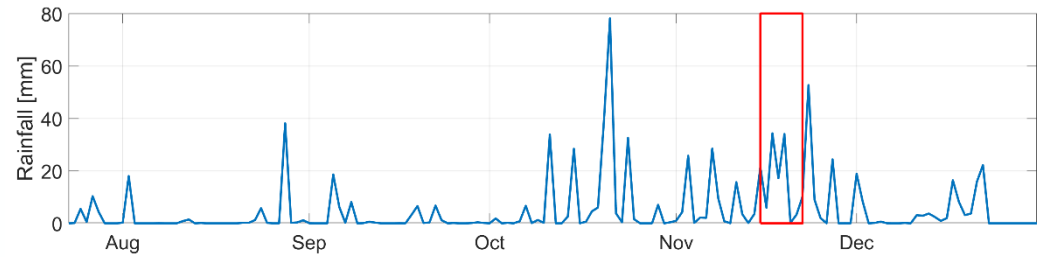


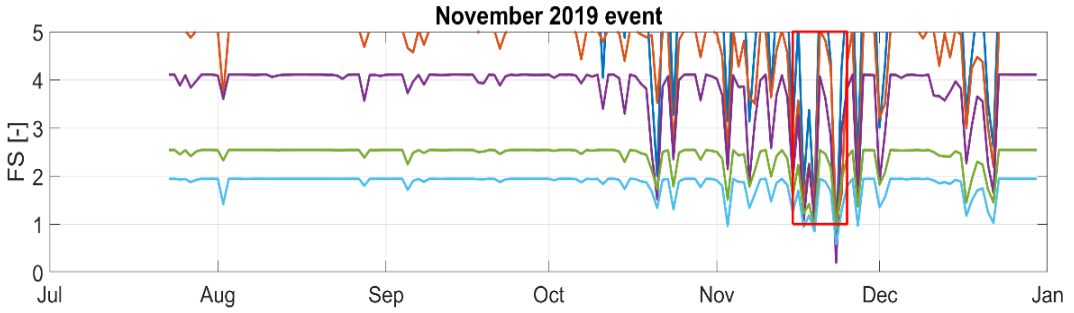
Courtesy of L. Ciabatta

THE DTE HYDROLOGY PROJECT: CASE STUDIES

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%

Courtesy of L. Ciabatta

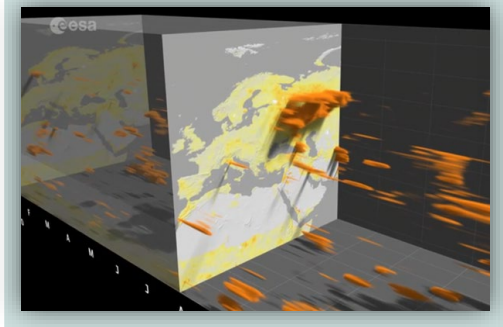
THE DTE HYDROLOGY EVOLUTION PROJECT

DTE Hydrology Evolution

Implementation over the whole **Mediterranean basin**

DTE Hydrology Datacube [1]

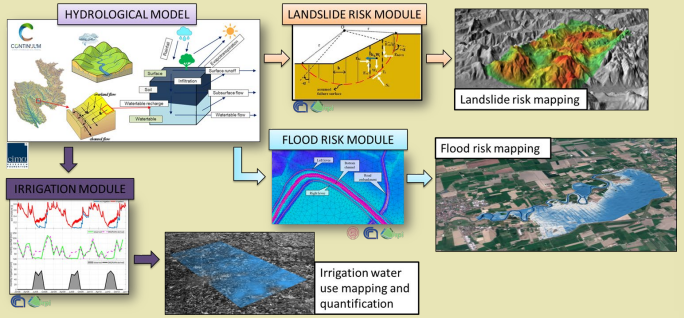
EO-based (1km, 1hour\1day) and in situ dataset

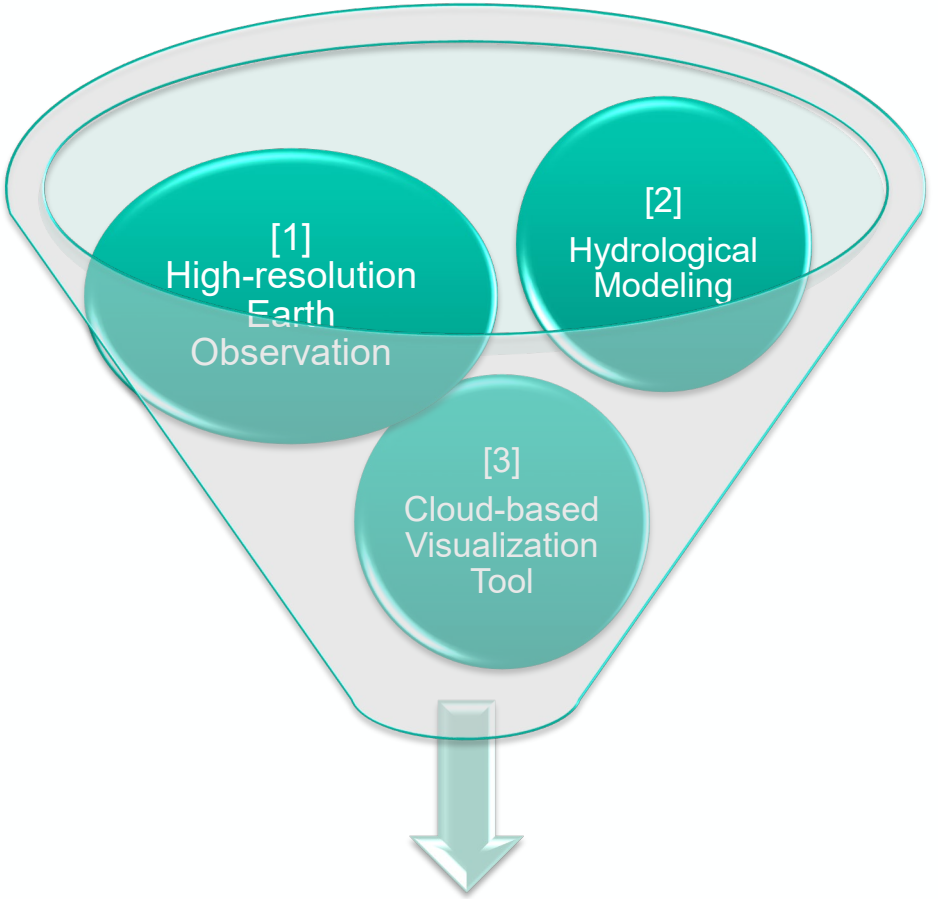


4DMED HYDROLOGY

DTE Hydrology Modelling System [2]

Physical modelling and Artificial Intelligence





THE DTE HYDROLOGY EVOLUTION PROJECT

DTE Hydrology Evolution

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

Applications:

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

THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE

DTE Hydrology datacube

SOIL MOISTURE

THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE

DTE Hydrology datacube

EVAPOTRANSPIRATION

GHENT UNIVERSITY

THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE

DTE Hydrology datacube

RAINFALL

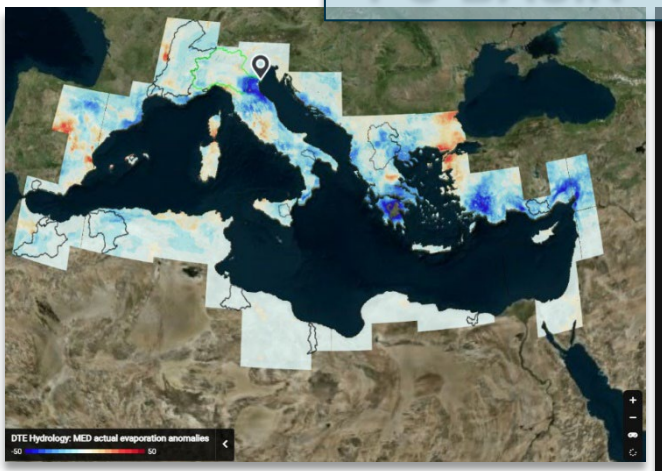
THE DTE HYDROLOGY EVOLUTION PROJECT: DATACUBE

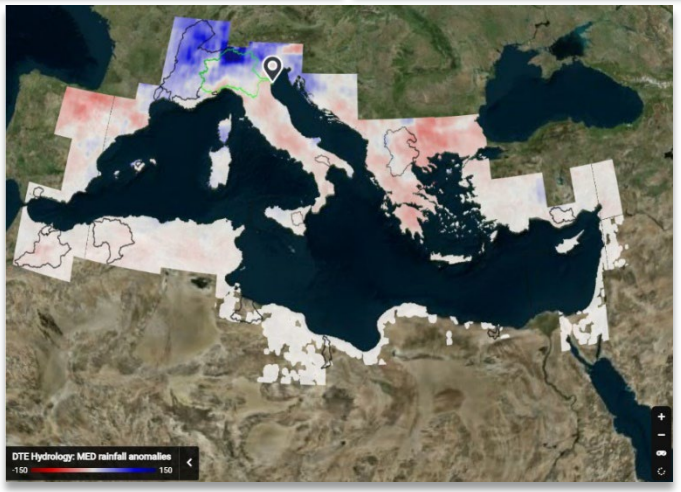
DTE Hydrology datacube

SNOW

THE DTE HYDROLOGY EVOLUTION PROJECT: APPLICATIONS

Large scale water balance assessment



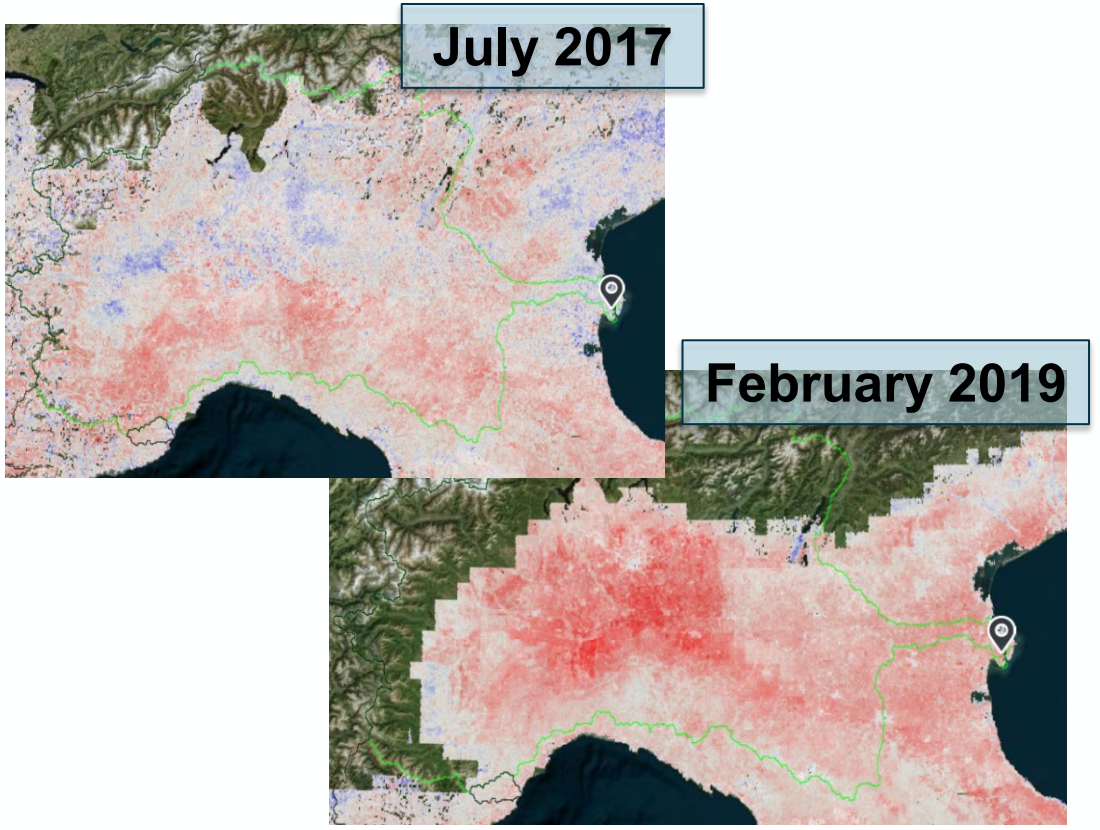


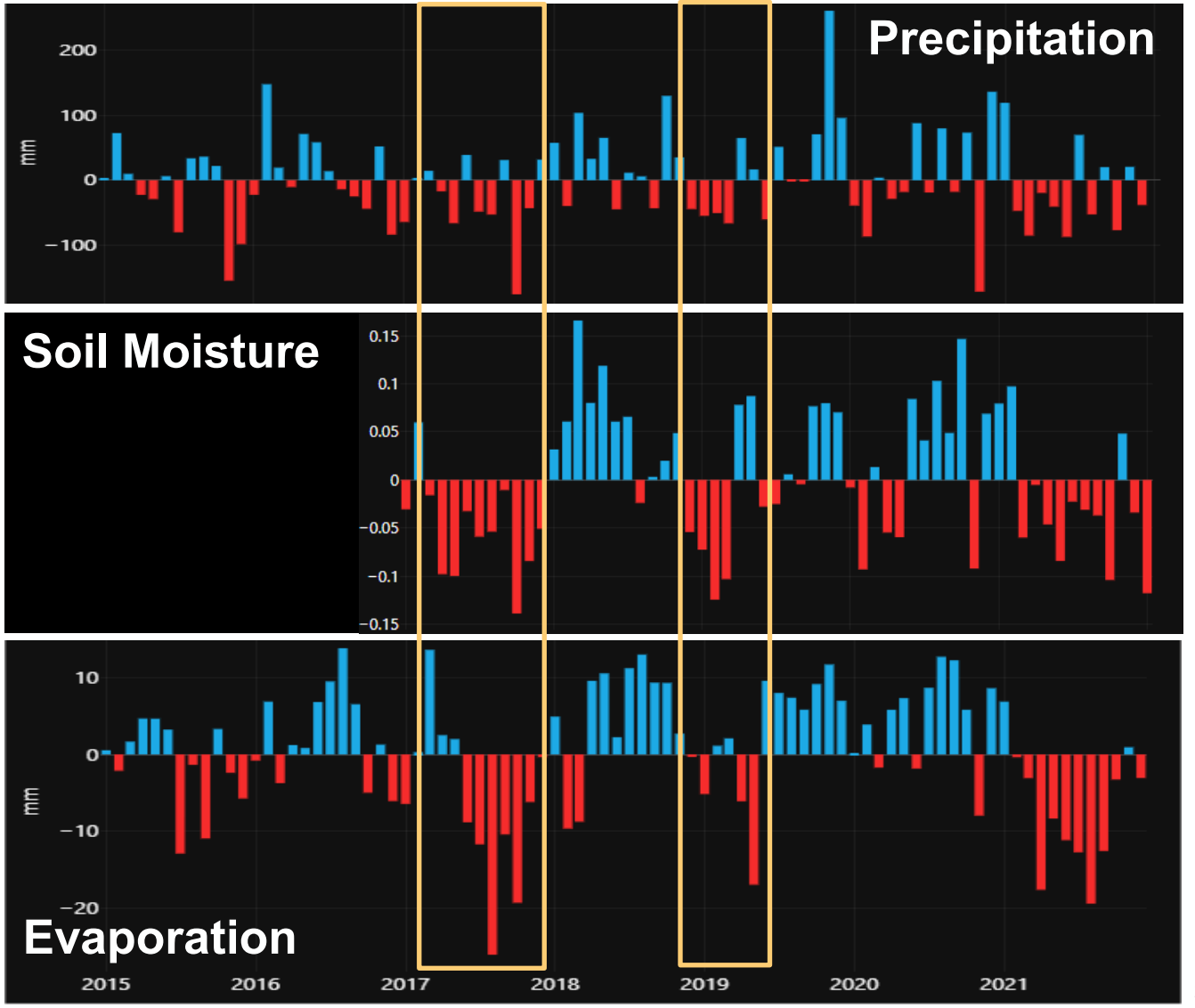
PO BASIN – JULY 2021

THE DTE HYDROLOGY EVOLUTION PROJECT: APPLICATIONS

PO BASIN

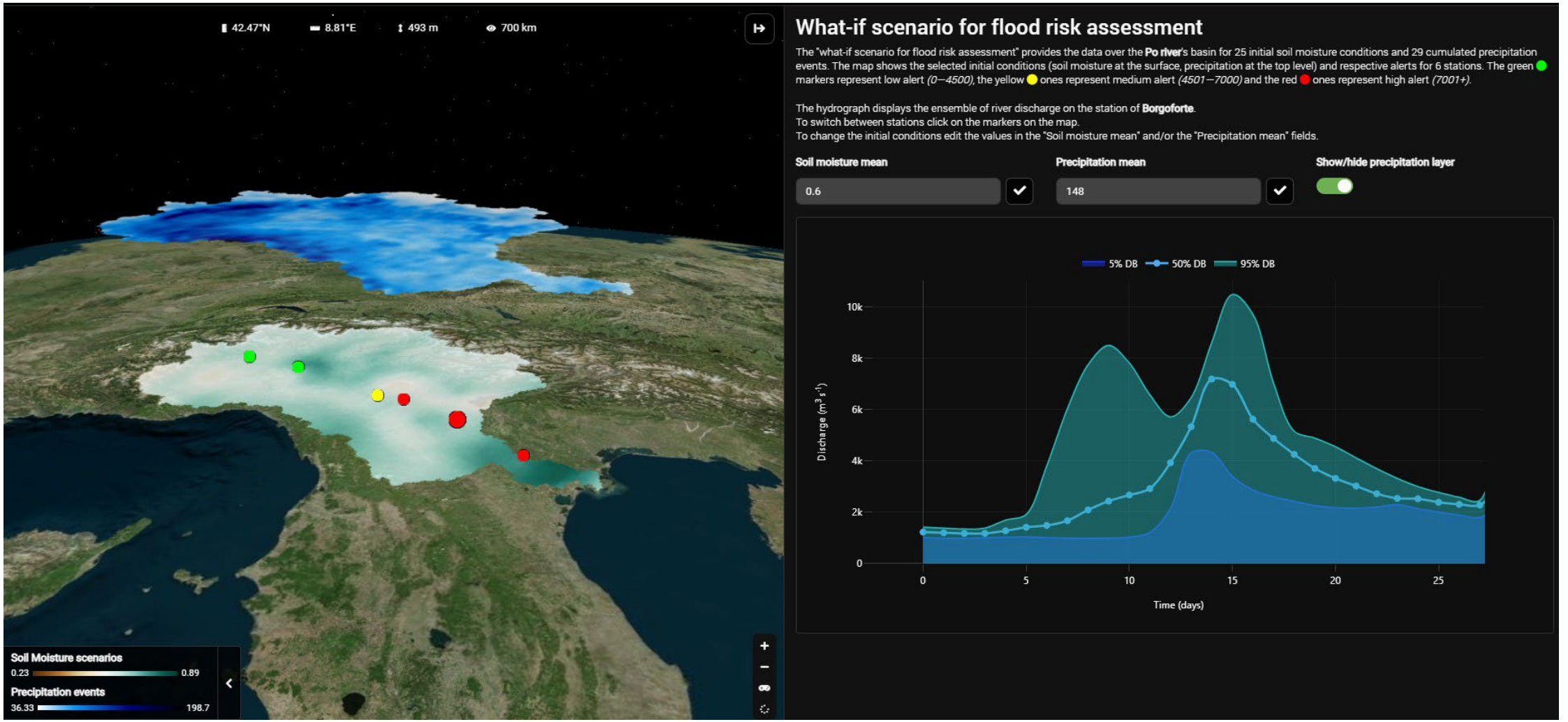
Time series of monthly anomalies for **drought** monitoring





THE DTE HYDROLOGY EVOLUTION PROJECT: WHAT-IF SCENARIOS

What if scenario for flood risk assessment



THE DTE HYDROLOGY EVOLUTION PROJECT: WHAT-IF SCENARIOS

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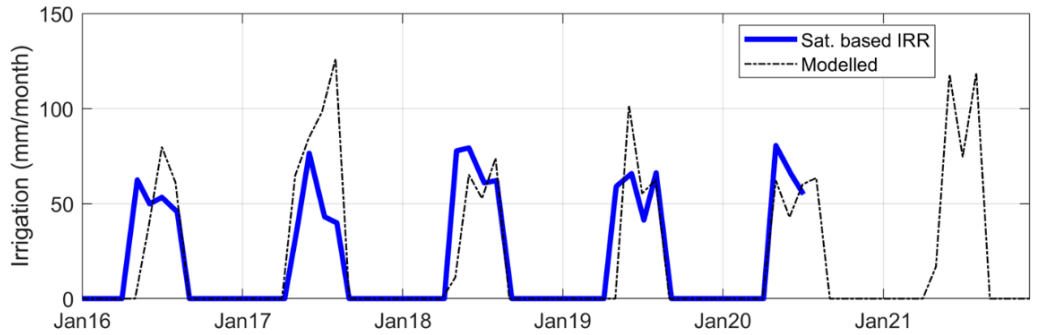
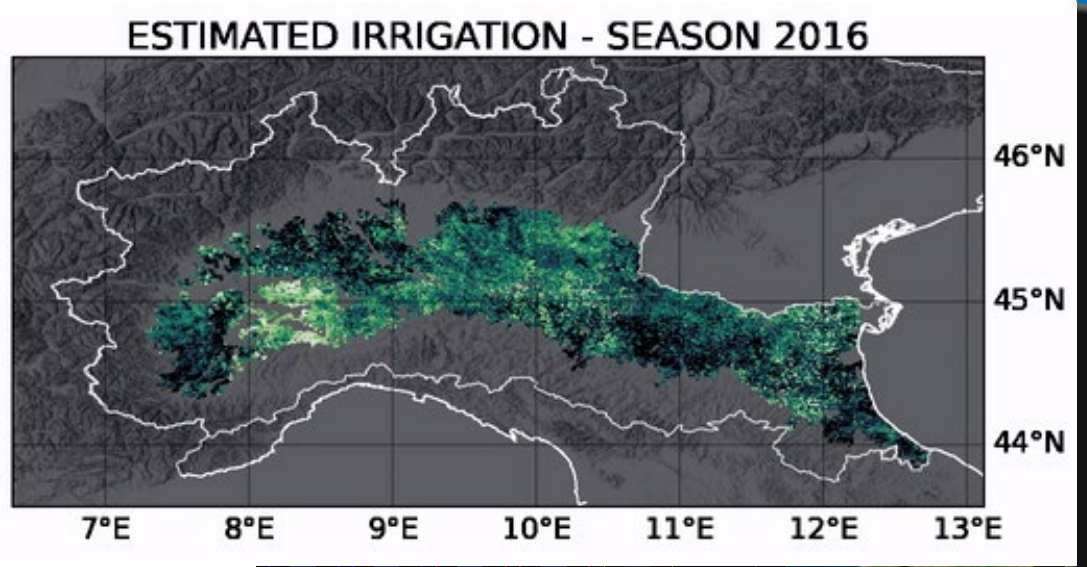
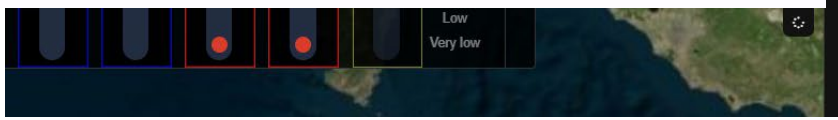
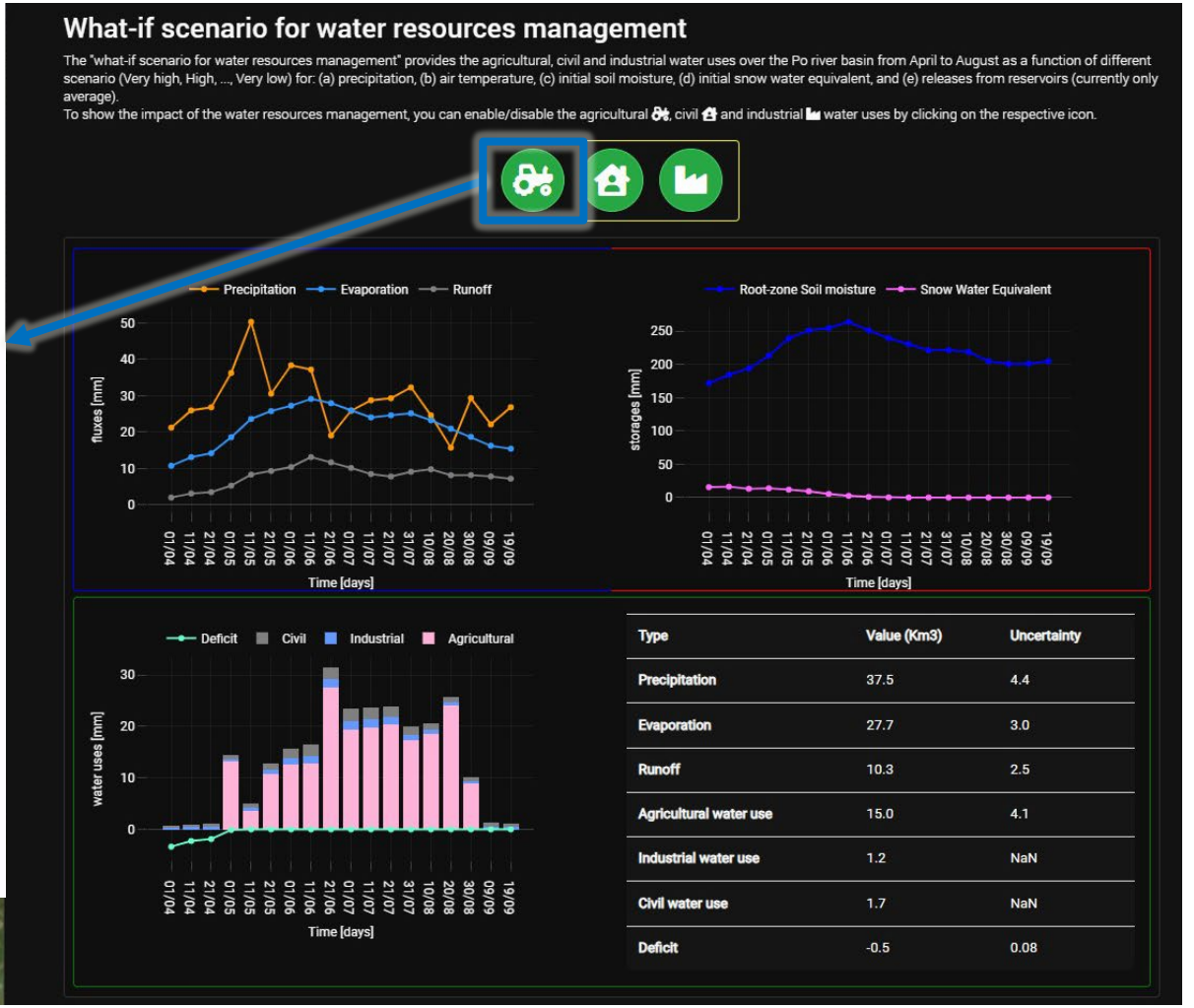








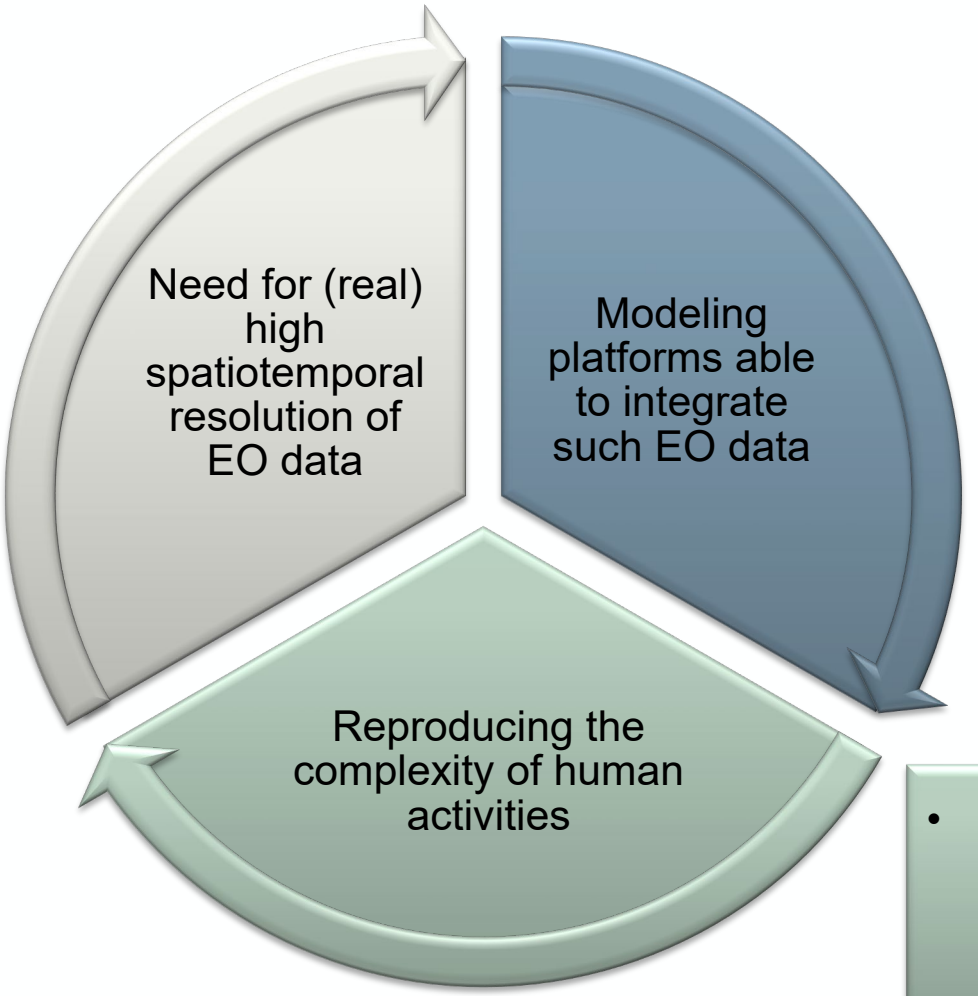
Type	Value (Km3)	Uncertainty
Precipitation	37.5	4.4
Evaporation	27.7	3.0
Runoff	10.3	2.5
Agricultural water use	15.0	4.1
Industrial water use	1.2	NaN
Civil water use	1.7	NaN
Deficit	-0.5	0.08

CONCLUSIONS AND OUTLOOK

Conclusions and outlook

Challenges to be still addressed

- Validation of novel EO data
- Managing uncertainties
- (Real) high resolution EO data for monitoring processess 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

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