

Copernicus data for hydrological and hydromorphological monitoring tools at national level

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ISPRA – Italian National Institute for Environmental Protection and Research

- National Institute acts under the vigilance and policy guidance of the Italian Ministry of Environment (MATTM)
- Part of a network known as National System for Environmental Protection (SNPA)
- Research Institute
- Supports policies implementation
 - ✓ Define strategies
 - ✓ Produce standards and methodologies for monitoring and evaluation of environmental status
 - ✓ Make methodologies applicable
 - ✓ Organize training activity
- It is the National focal point for EIONet of EEA



ISPR
Istituto Superiore per la Protezione
e la Ricerca Ambientale



SNPA – National System for Environmental Protection

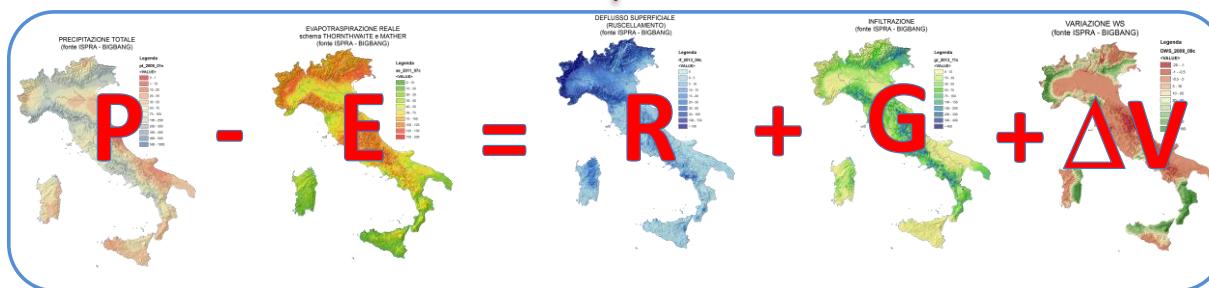


ISPR

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ISPR has recently developed a GIS based procedure, named “**BIGBANG – Nationwide GIS-based regular gridded hydrological water balance on a regular grid**”, to evaluate on a monthly scale the components of the water balance for the entirety of the Italian territory.



BIGBANG calculates the water balance equation on the 1-km EEA grid:

Total Precipitation (P)

Actual Evapotranspiration (E)

Runoff (R)

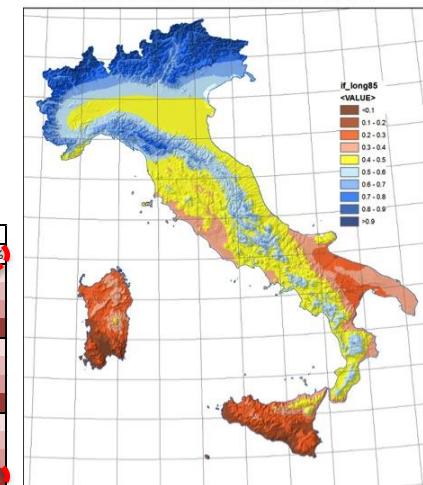
Groundwater recharge (G)

Variation of the soil water content (ΔV)

RIFERIMENTO	SCENARIO	VARIABLE	U.M.	PERIODO MEDIA	TERRITORIO MEDIA	MEDIA %
ISPR	HISTORICAL	PPT-AET	mm	1996-2015	ITALIA	392.1 100%
AR5	RCP-2.6	PPT-AET	mm	2020-2059	ITALIA	369.0 96%
AR5	RCP-4.5	PPT-AET	mm	2020-2059	ITALIA	346.6 88%
AR5	RCP-6.5	PPT-AET	mm	2020-2059	ITALIA	359.9 92%
AR5	RCP-8.5	PPT-AET	mm	2020-2059	ITALIA	369.0 94%
AR5	RCP-2.6	PPT-AET	mm	2040-2059	ITALIA	352.4 90%
AR5	RCP-4.5	PPT-AET	mm	2040-2059	ITALIA	325.8 83%
AR5	RCP-6.5	PPT-AET	mm	2040-2059	ITALIA	344.6 88%
AR5	RCP-8.5	PPT-AET	mm	2040-2059	ITALIA	328.9 84%
AR5	RCP-2.6	PPT-AET	mm	2080-2099	ITALIA	366.8 94%
AR5	RCP-4.5	PPT-AET	mm	2080-2099	ITALIA	324.2 83%
AR5	RCP-6.5	PPT-AET	mm	2080-2099	ITALIA	344.7 89%
AR5	RCP-8.5	PPT-AET	mm	2080-2099	ITALIA	230.2 59%

Projection over Italy of the internal flow (P – E) based IPCC scenarios

Rapporto tra la proiezione al periodo 2080-2099 relativa allo scenario IPCC RCP 8.5 e la media del periodo 1996-2015 dell'internal flow annuo (mm)



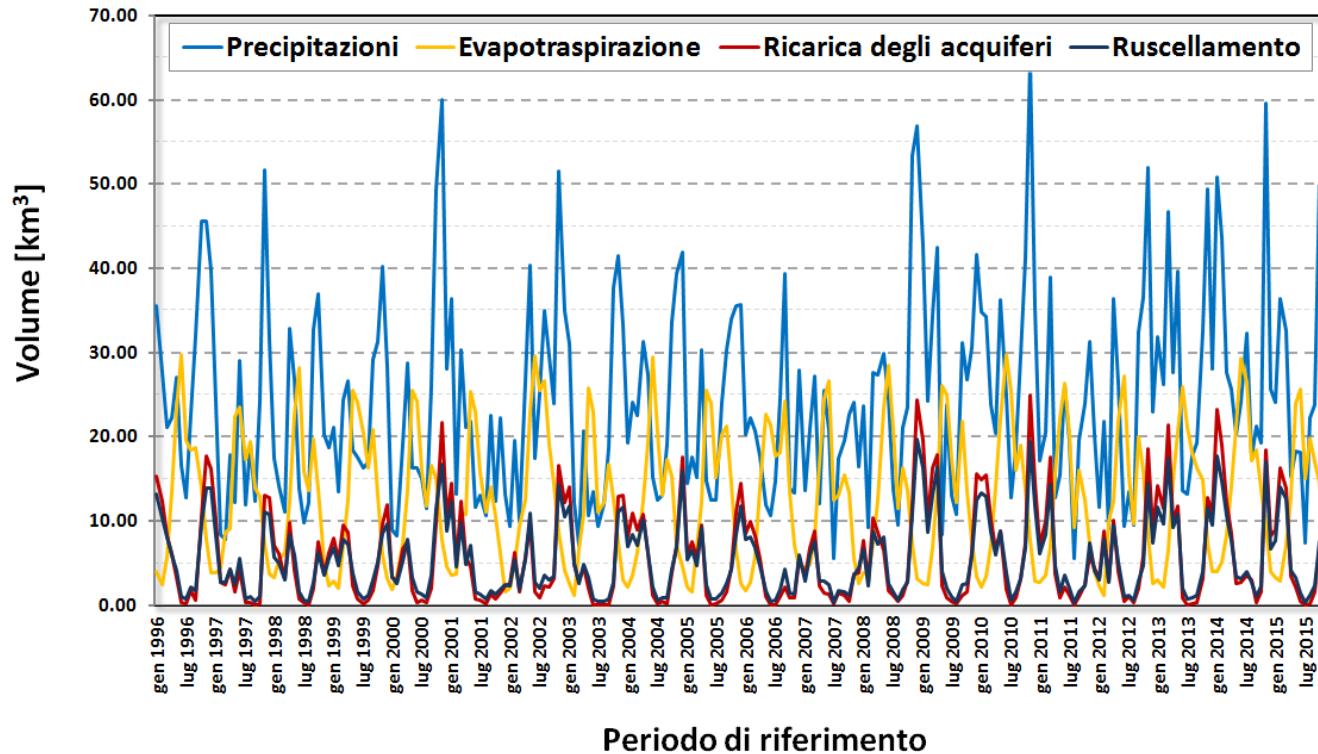
www.isprambiente.gov.it/pre_meteo/idro/BIGBANG_ISPRA.html
www.isprambiente.gov.it/pre_meteo/idro/BIGBANG_CC_ISPRA.html



BIGBANG 1.0 - Bilancio idrologico mensile (1996-2015)

ITALIA

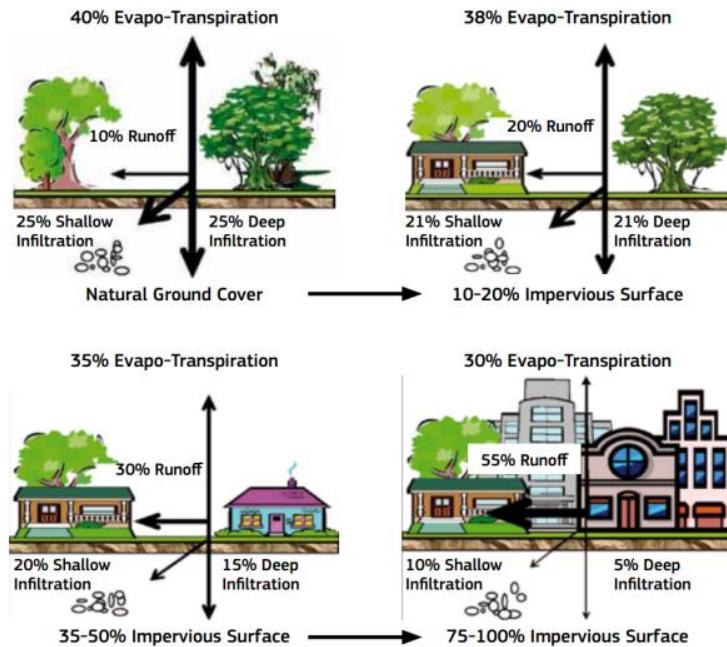
(schema Thornthwaite e Mather)



Braca, G. et al., 2018: *Evaluation of national and regional groundwater resources under climate change scenarios using a GIS-based water budget procedure*. XVIII Giornata Mondiale dell'Acqua, Lincei.

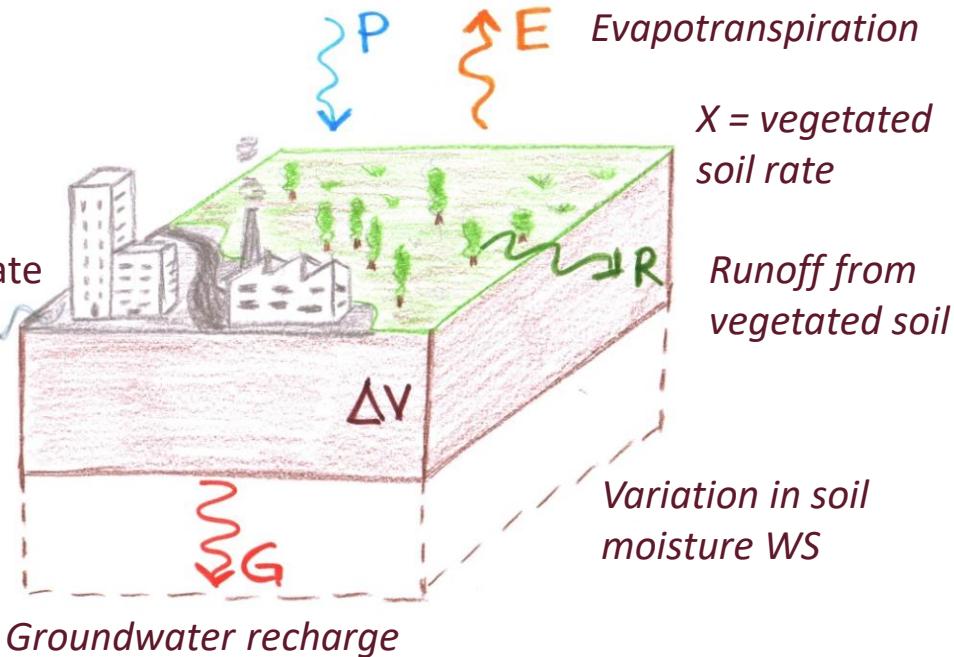
Braca, G., e Ducci, D., 2018: *Development of a GIS Based Procedure (BIGBANG 1.0) for Evaluating Groundwater Balances at National Scale and Comparison with Groundwater Resources Evaluation at Local Scale*. In *Groundwater and Global Change in the Western Mediterranean Area*, Springer.

BIGBANG schematizes a volume of soil of 1-km grid box for 1 m deep as a reservoir, whose maximum capacity is given by the available water storage (AWS) that depends on soil texture.



$1-X = \text{soil sealing rate}$
*Runoff from
impervious soil*

Total precipitation

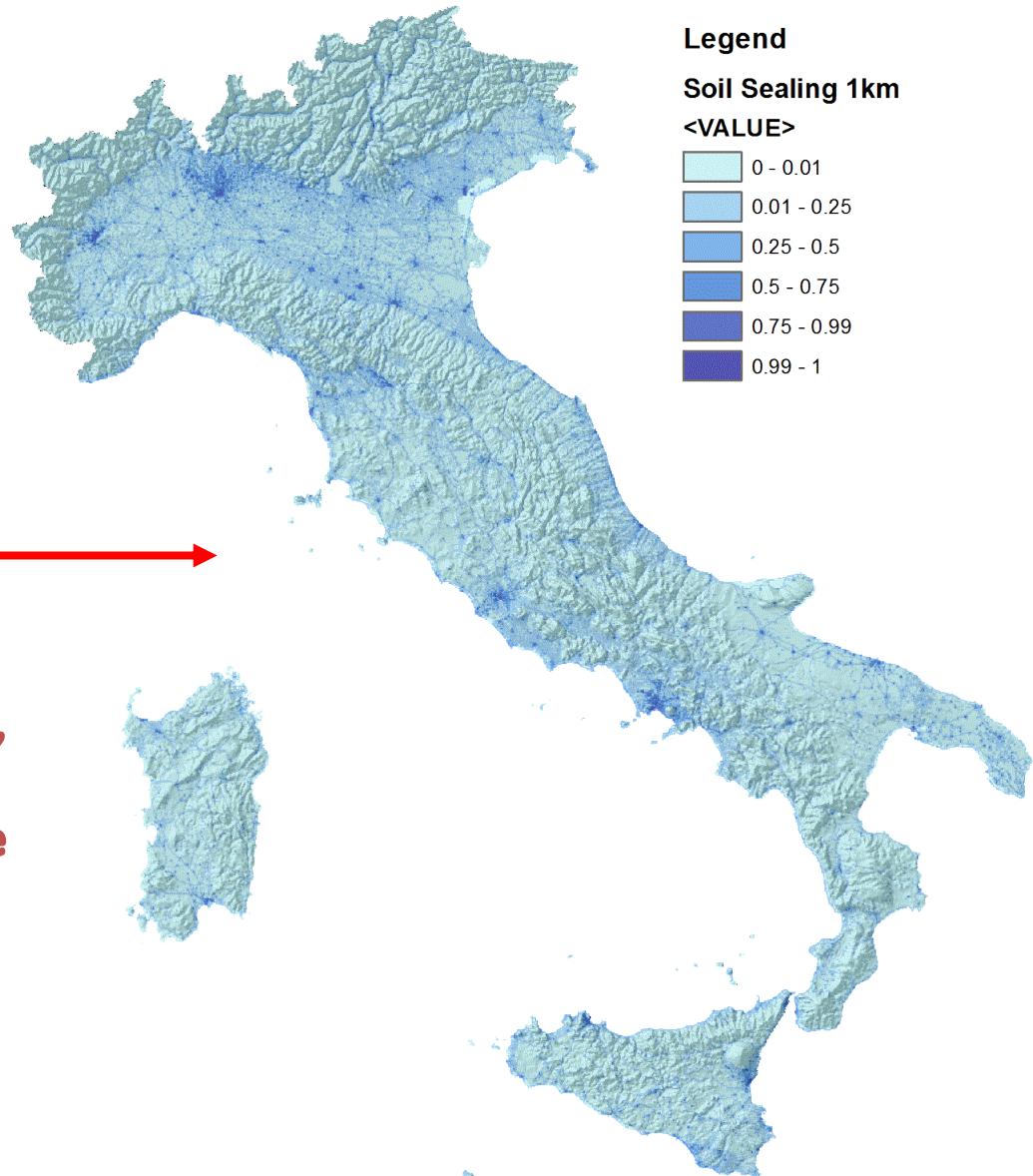


The gridded monthly actual evapotranspiration is calculated on the basis of the gridded PET through the soil water balance equation.

Groundwater recharge (G) and Surface Runoff (R) are estimated as function of the permeability of the outcropping hydro-geological units.

The BIGBANG procedure takes also into account in each cell the effect of the soil sealing rate (Munafò et al., 2013) obtained by lumping together over the 1-km grid the HRL at national level derived from the Copernicus Land Monitoring service product.

A severe problem arising from urbanisation is known as soil sealing, which is described by EU Commission (2011) as “the coverage of the soil with sealing materials such as concrete, metal, glass, asphalt, plastic in a way that inhibits the ecological functionality of the soil”, resulting in an irreversible loss of the biological characteristics of the soil and a loss of soil itself.

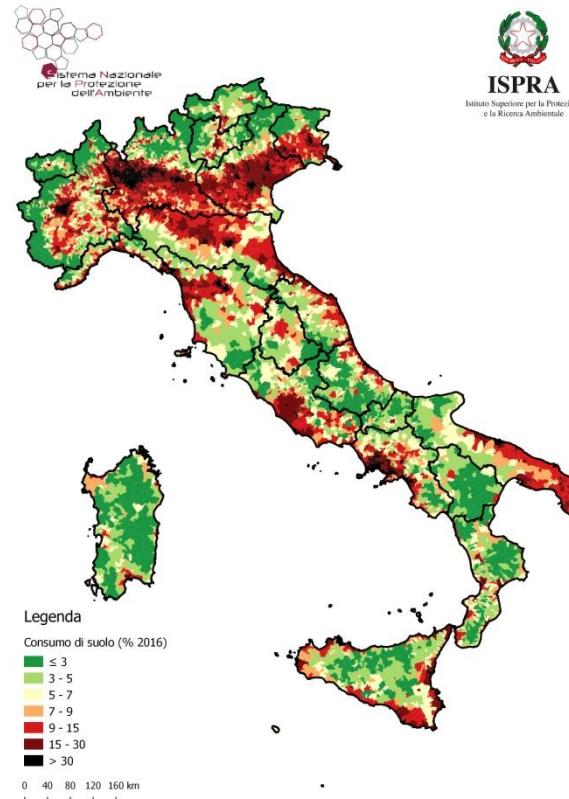


Classificazione della copertura del suolo

Cartografia tematica coerente con la direttiva 2007/2/CE, con il sistema di classificazione dei prodotti Copernicus High Resolution Layers (HRL) e con i prodotti Corine Land Cover di seconda generazione, progettando quindi un sistema di monitoraggio rapidamente aggiornabile

Monitoraggio del consumo di suolo

Sistema di monitoraggio del consumo di suolo rapidamente aggiornabile per le principali classi (aree artificiali impermeabilizzate, aree artificiali non impermeabilizzate) con una frequenza almeno annuale



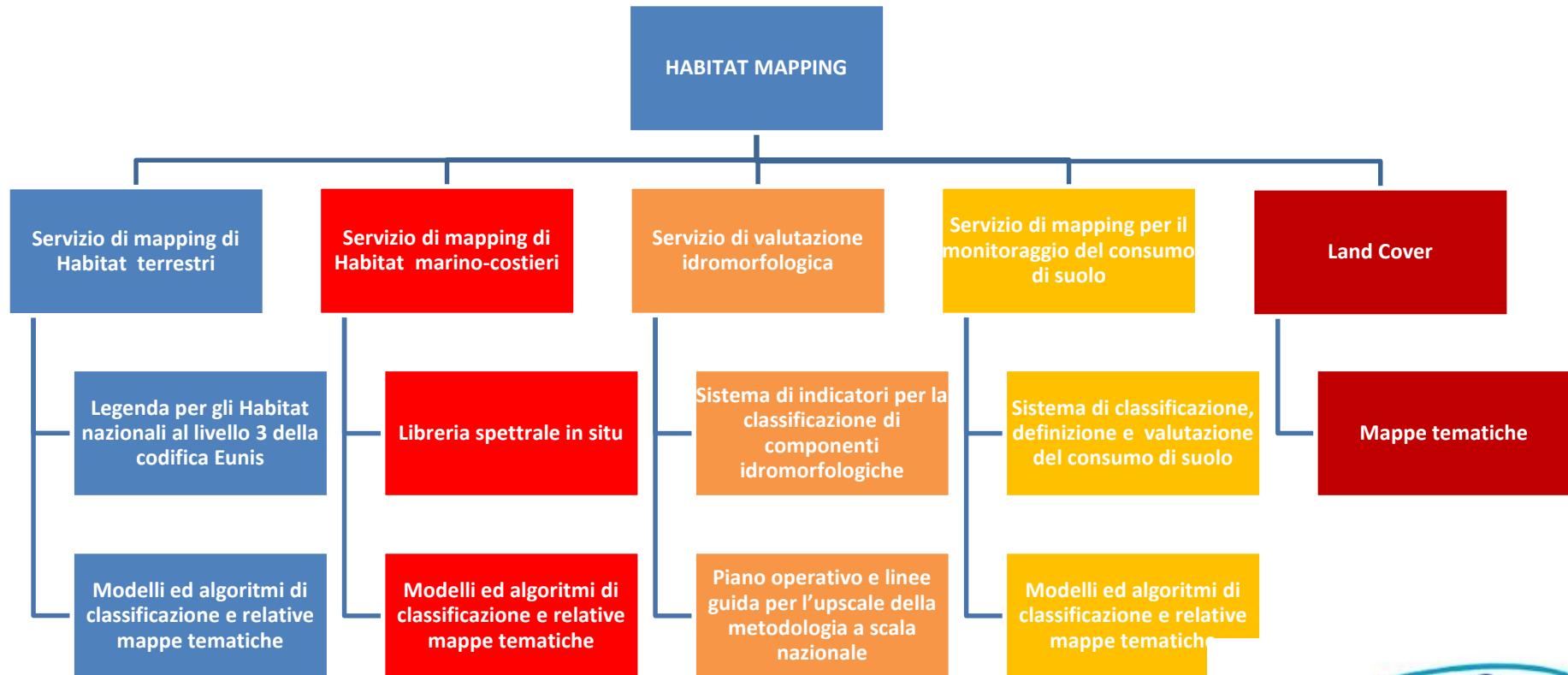
→ HABITAT MAPPING (HM)

ASI-ISPRRA project:

scient. coord. Andrea Taramelli



Prodotti Corine Land Cover di seconda generazione



HYMO: IDRAIM



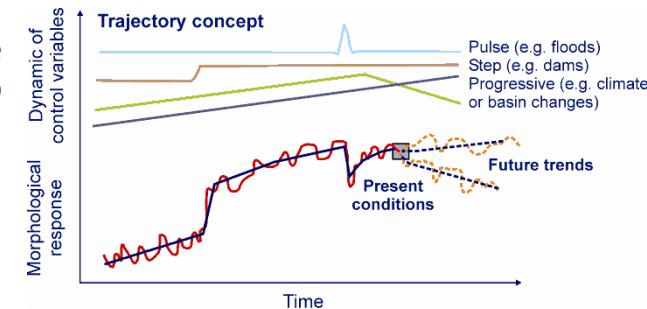
National activity: Regional and local Authorities responsible of the hymo monitoring, ISPRA and MATTM

EU Commission activity: **WG ECOSTAT** (co-lead IT) & **WG Floods of the Common Implementation Strategy for WFD and FD + Ad Hoc Task Group on Hydromorphology** (co-lead IT)

New European Standard on hymo – **WG CEN**

EU project **REFORM**: review tool Hymo based on remote sensing data

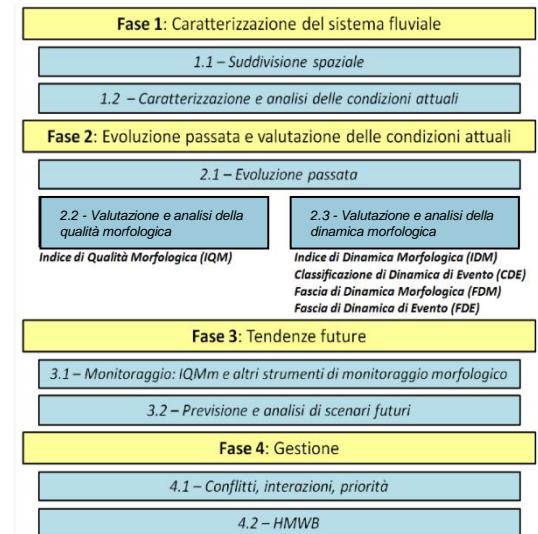
Research and scientific studies



- **IDRAIM**-stream hydromorphological evaluation, analysis and monitoring system, developed by ISPRA and Italian Universities
 - Morphological Quality Index (MQI)
- **SUM**–The Geomorphic Unit survey and classification System
- **e-MesoHABSIM** for modeling and evaluating river habitat integrity
- Specialized training by ISPRA

- **Habitat Mapping project:**
 - Developping operational tools and indicators for hymo monitoring based on Copernicus Sentinel 1 and 2 data in the framework of IDRAIM to support regional and local Authorities
 - Testing the operational tools and indicators on four river basins

IDRAIM



PURPOSES (Art.1)

FLOODS DIRECTIVE

The purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community.

PREVENT and REDUCE DAMAGE to:

- Human health,
- Environment,
- Cultural heritage
- Economic activity



WATER FRAMEWORK DIRECTIVE

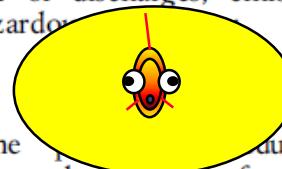
The purpose of this Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which:

- (a) prevents further deterioration and protects and enhances the status of surface waters, in particular those dependent directly or indirectly on their catchments;

ENVIRONMENTAL OBJECTIVES:

- prevent further deterioration, protect and enhance the status of aquatic ecosystem
- achieve good surface water status at the latest 15 years after the date of entry into force of the Directive

- (b) protects and promotes the sustainable use of surface waters, in particular by preventing progressive degradation of surface waters, ensuring the protection of the status of aquaculture and fisheries, and reducing the loss of biodiversity;
- (c) aims to reduce the pressure on aquaculture and fisheries for food security, and to reduce losses of biodiversity, by phasing-out of discharges, emissions and losses of the priority hazard;



- (d) ensures the protection, reduction or prevention of pollution of groundwater and prevents its further pollution, and

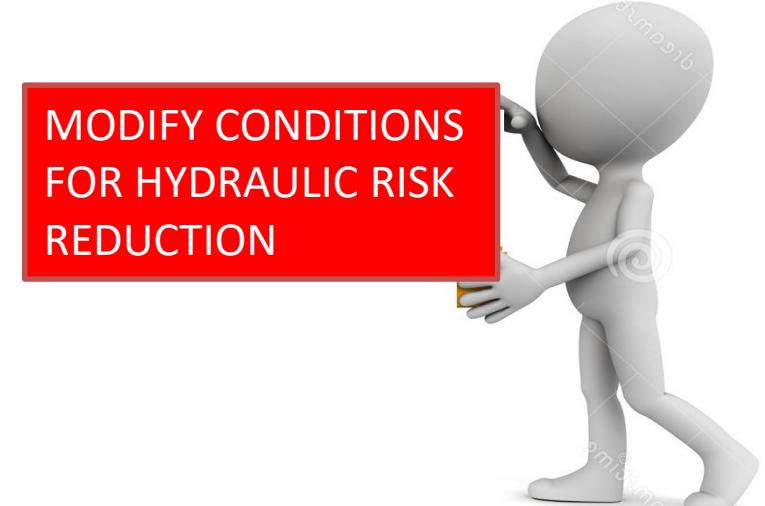
- (e) contributes to mitigating the effects of floods and droughts

EU Directives: potentially conflicting objectives...?

Water Framework Directive (WFD)



Floods Directive (FD)



IDRAIM AIM



IDRAIM is a comprehensive methodological framework to support integrated management of geomorphological river processes. It accounts for the specific Italian context and the European Directives (WFD & FD), explicitly including consideration of fluvial hazard (FD)

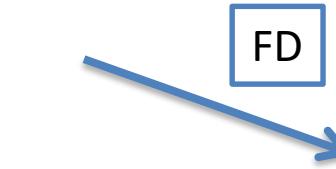
Reconstruction of evolutionary trajectories and interpretation of causes of changes

WFD



Assessment of morphological quality:
- Morphological Quality Index (MQI)

FD

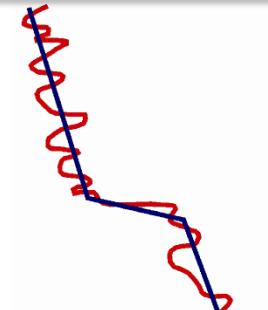


Assessment of channel dynamics (hazards):
- Morphological Dynamics Index (MDI)
- Event Dynamics Classification (EDC)
- Morphological river dynamics corridors (MDC, EDCo)

IDRAIM OVERALL STRUCTURE

Spatial context

Temporal context

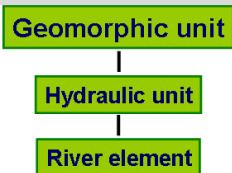


Rinaldi et al., 2013: A method for the assessment and analysis of the hydromorphological condition of Italian streams: the Morphological Quality Index (MQI). *Geomorphology*, 180, 96-108.

Rinaldi et al., 2015: A methodological framework for hydromorphological assessment, analysis and monitoring (IDRAIM) aimed at promoting integrated river management.

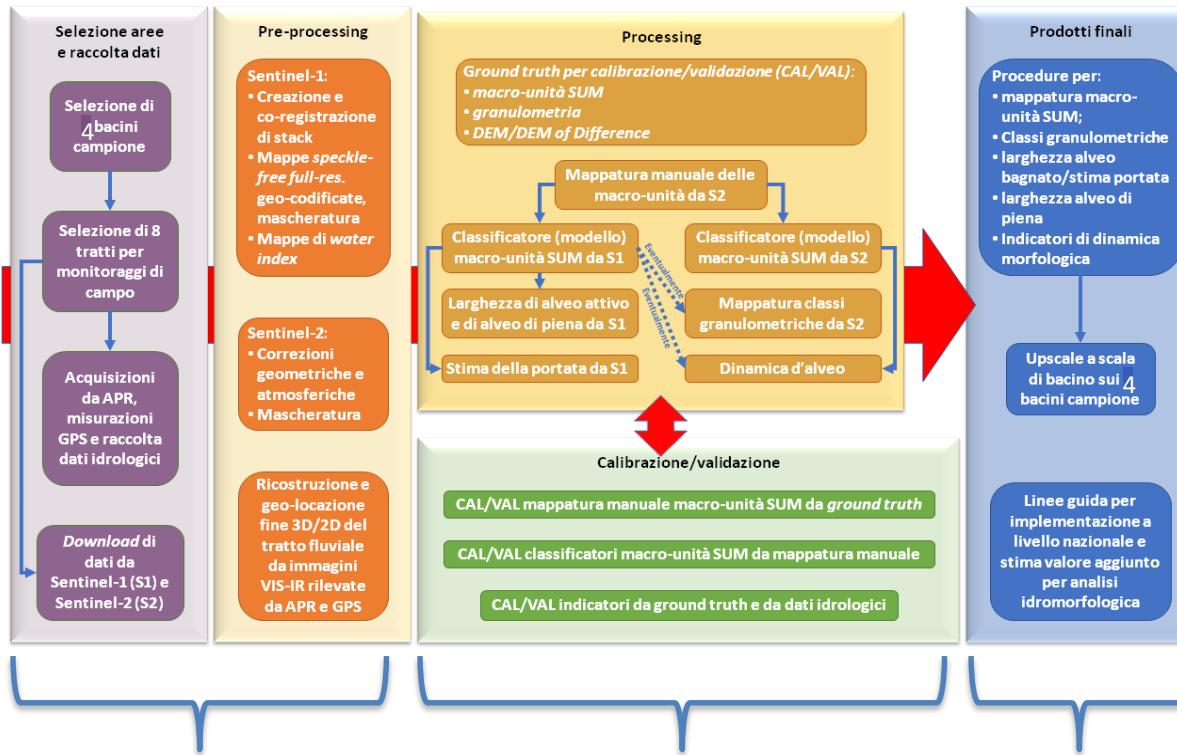
Geomorphology, 251, 122-136. Gurnell et al., 2016: multi-scale hierarchical framework for developing understanding of river behaviour to support river management. *Aquatic sciences*, 78 (1), 1-16.

Rinaldi et al., 2016: Classification of river morphology and hydrology to support management and restoration. *Aquatic sciences*, 78 (1), 17-33.



Phase 4: Management

Modello concettuale per le attività di sviluppo degli strumenti applicativi basati su dati Copernicus Sentinel 1 e 2



1° ciclo di monitoraggio completato

Attività in corso



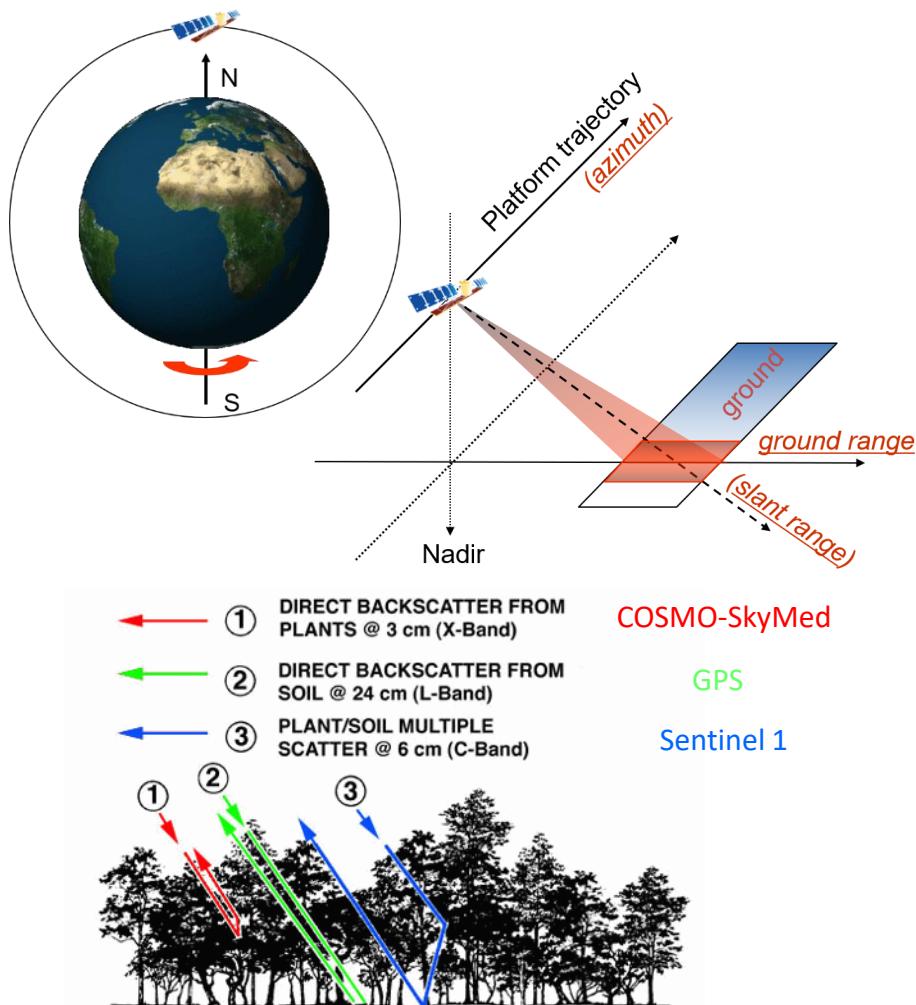
Bacini campione

- Po/Sesia** (3 tratti fluviali)
 - Distretto Idrografico Padano
- Tevere/Paglia** (3 tratti) – Distretto Idrografico Appennino Centrale
- Bonamico** (2 tratti) – Distretto Idrografico Appennino Meridionale
- Tagliamento** (1 tratto fluviali) – Distretto Idrografico Alpi Orientali

SENTINEL 1: radar (SAR) C-Band

Pixel 20 x 5 m

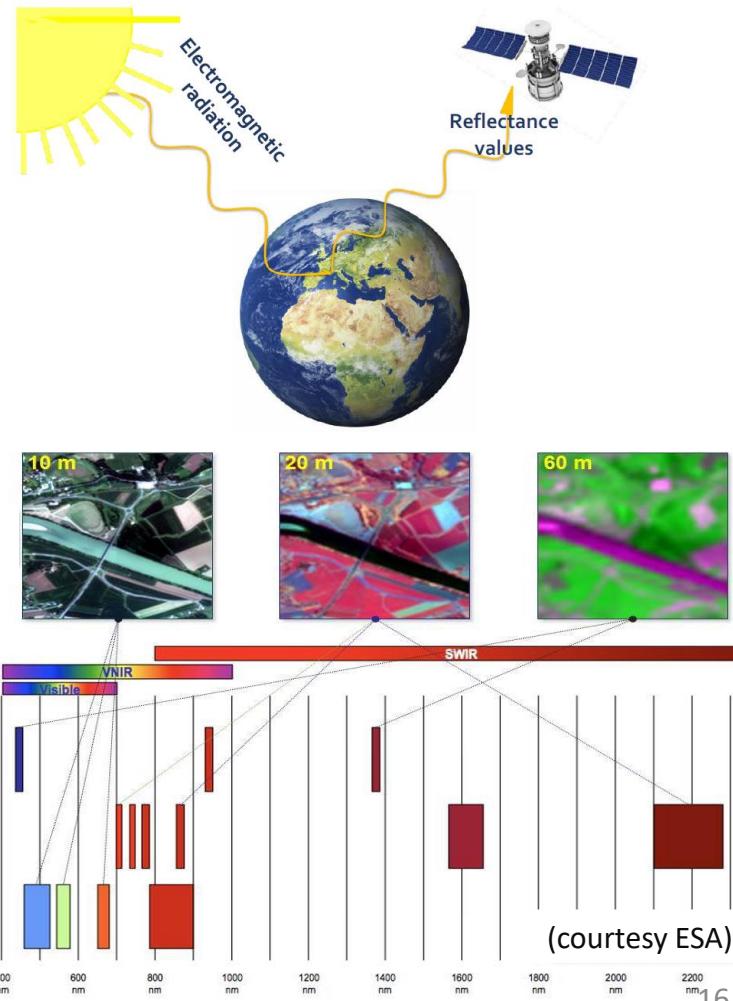
Frequency of acquisition: 6 days



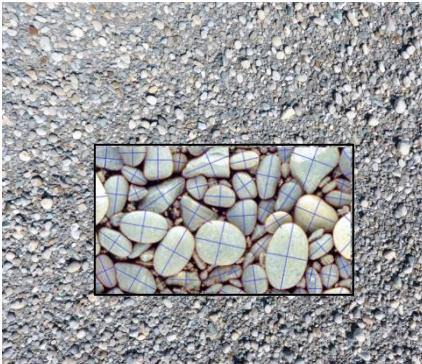
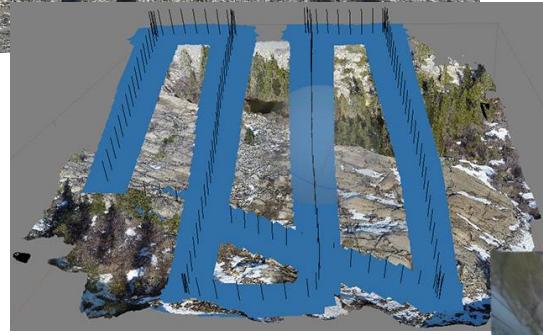
SENTINEL 2: Multispectral optical

Pixel 10x10 or 20x20

Frequency of acquisition: 5 days

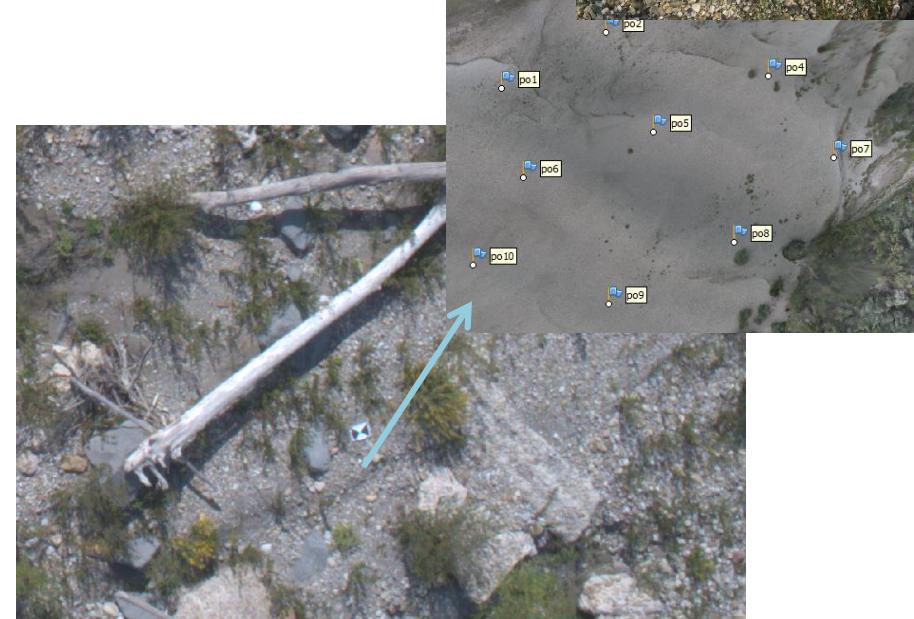


Very high resolution remote sensing data (UAV)

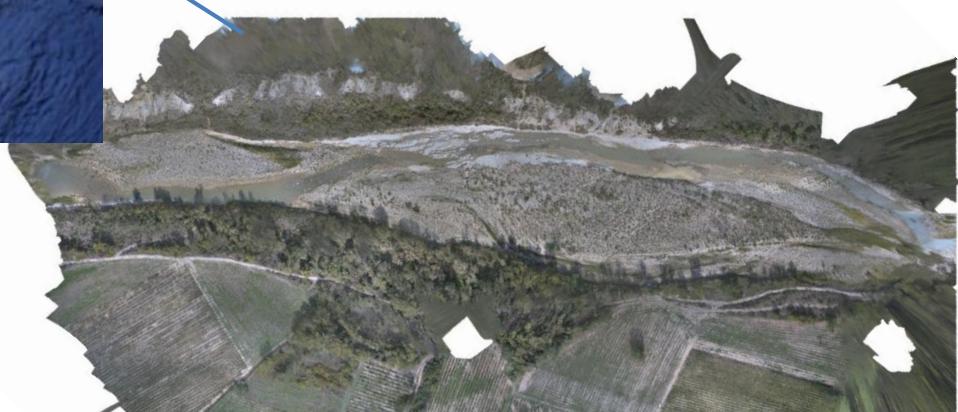


*Ground truth to calibrate and validate
satellite data*

Very high resolution Topographic data (GPS)



sUAS pre-processing



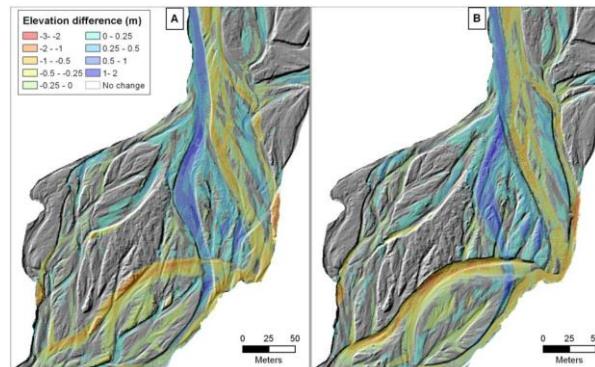


Habitat mapping

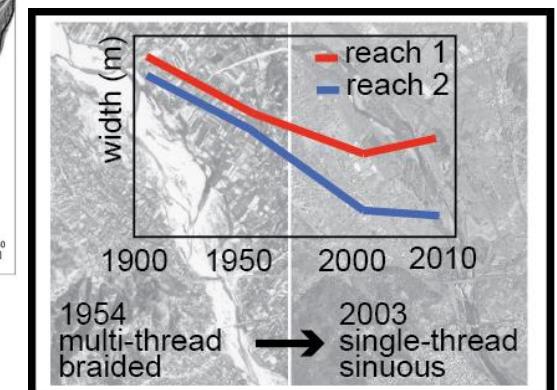
Sediment size classes

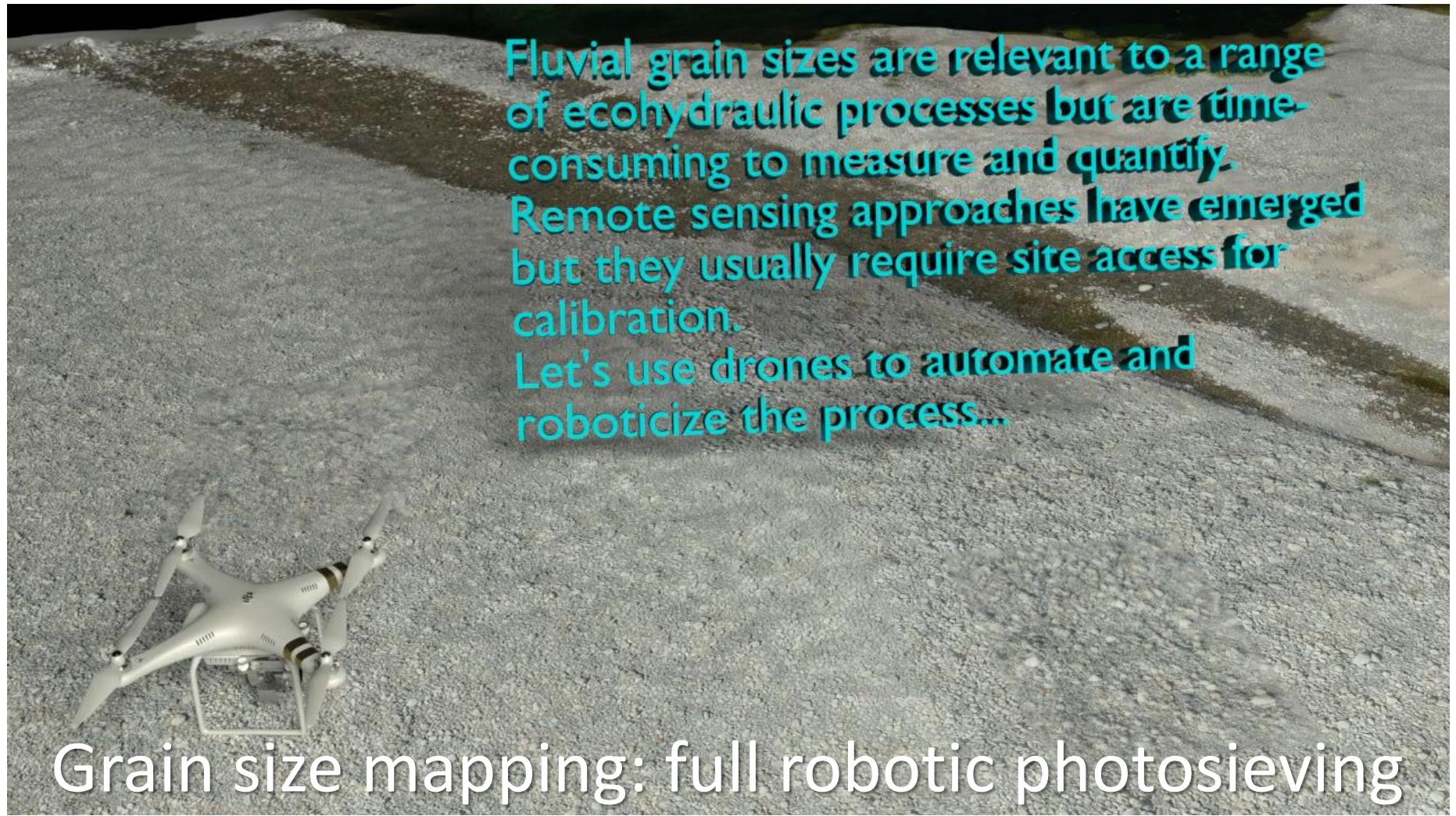
Hydromorphological indicators from satellite remote sensing

Water extraction



Indicators of processes





Fluvial grain sizes are relevant to a range of ecohydraulic processes but are time-consuming to measure and quantify. Remote sensing approaches have emerged but they usually require site access for calibration. Let's use drones to automate and roboticize the process...

Grain size mapping: full robotic photosieving

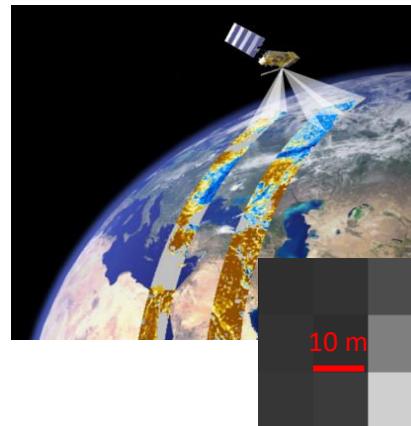
Carboneau, Bizzi and Marchetti, 2017 (ESPL)

(1) Overall grain size mapping: S2

Grain size estimation

Multispectral satellite data
with high repeat time

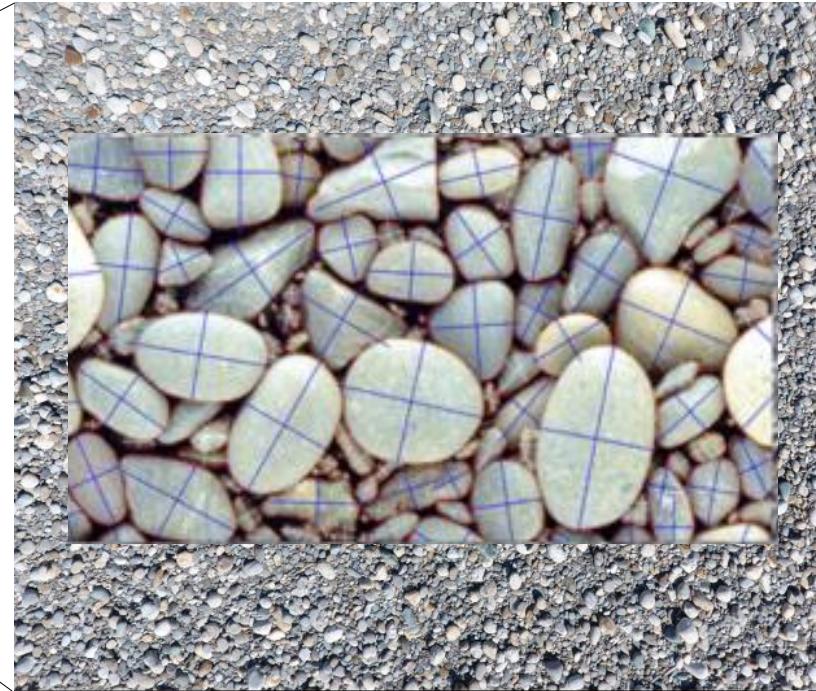
Indirect measurement
→ Reflectance values



Grain size measurement

Low cost technology for
calibration (sUAS)

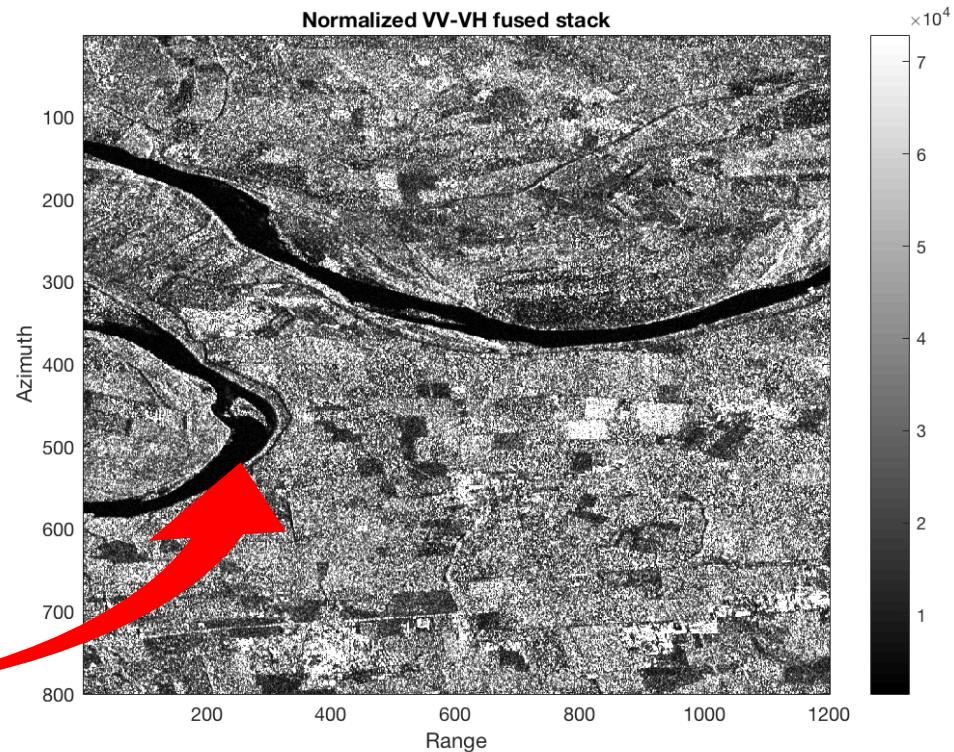
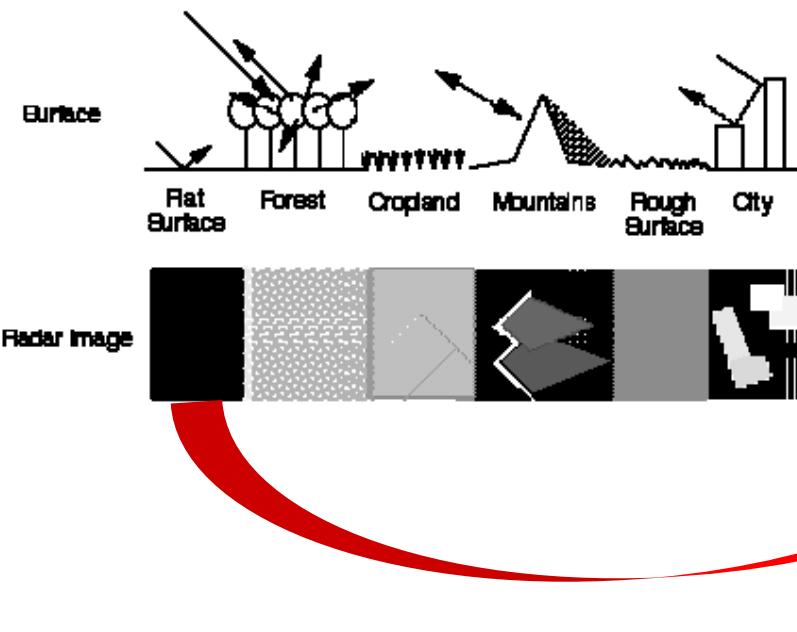
Direct measurement
→ Photosieving technique
→ Grain size percentiles



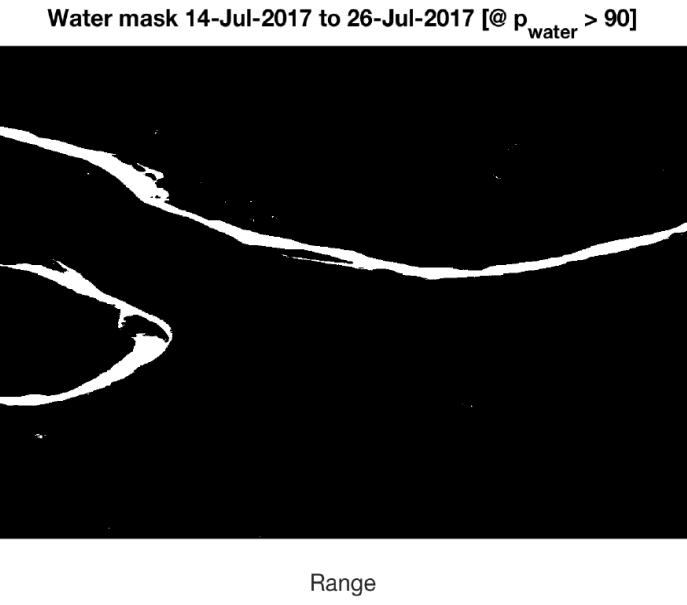
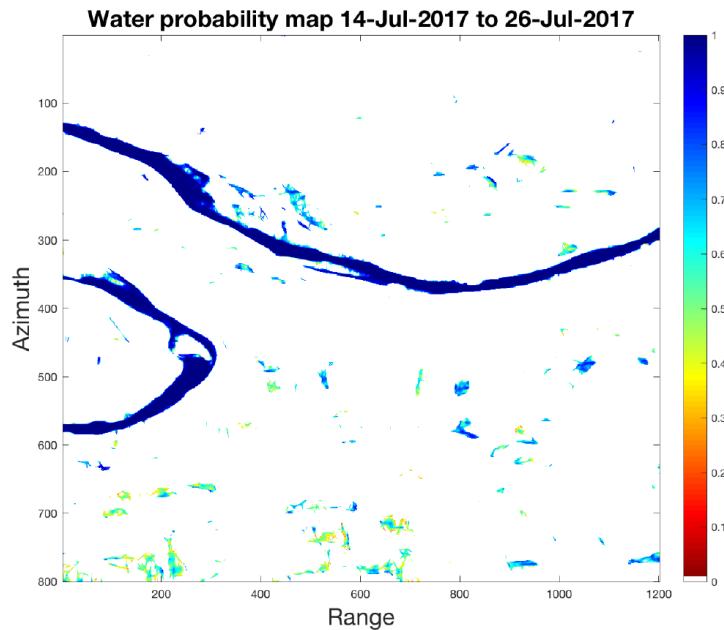
(2) Water index: S1

The intensity of a SAR image is strongly influenced by the terrain structure and **roughness**

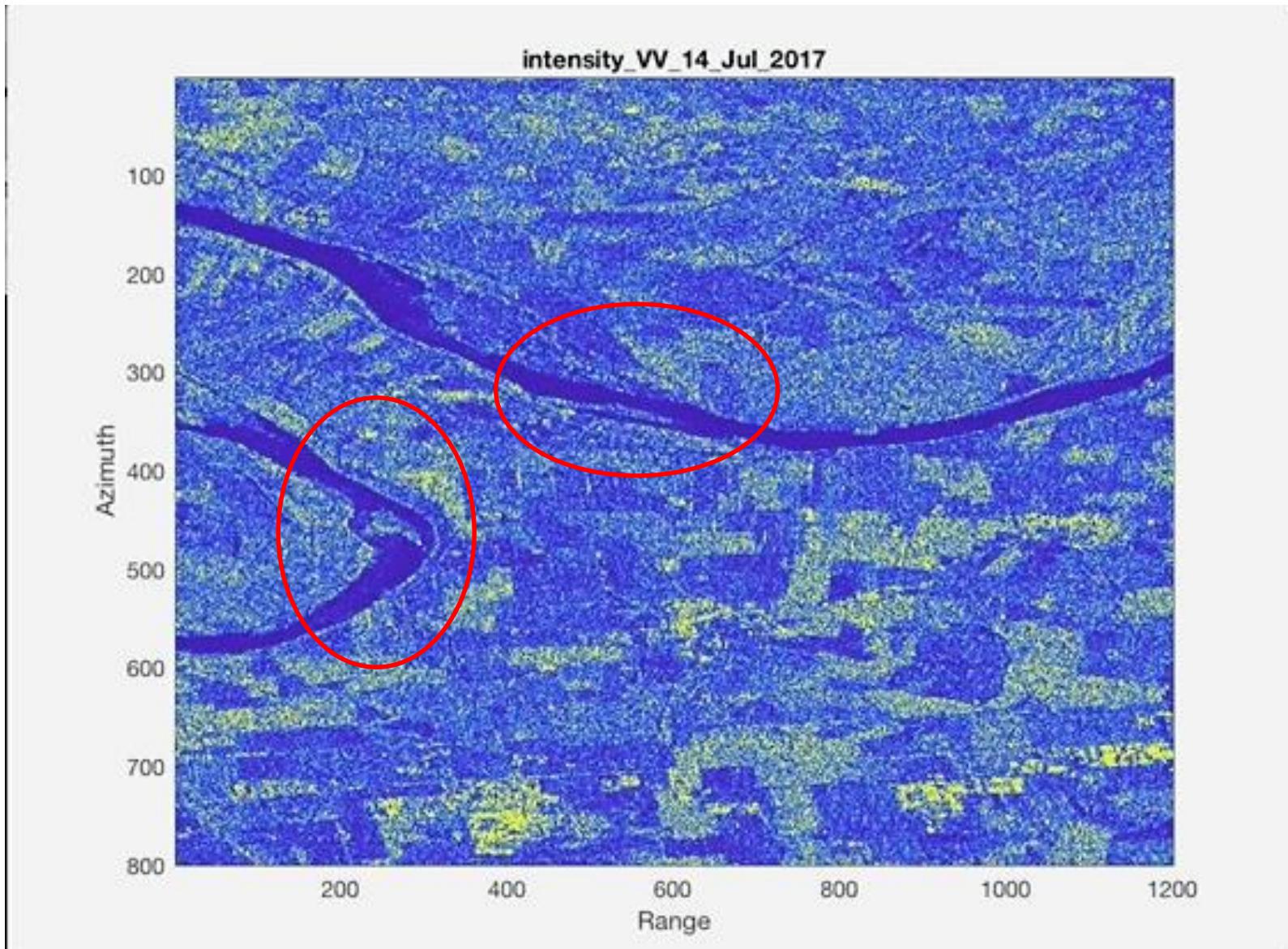
Water = no backscatter



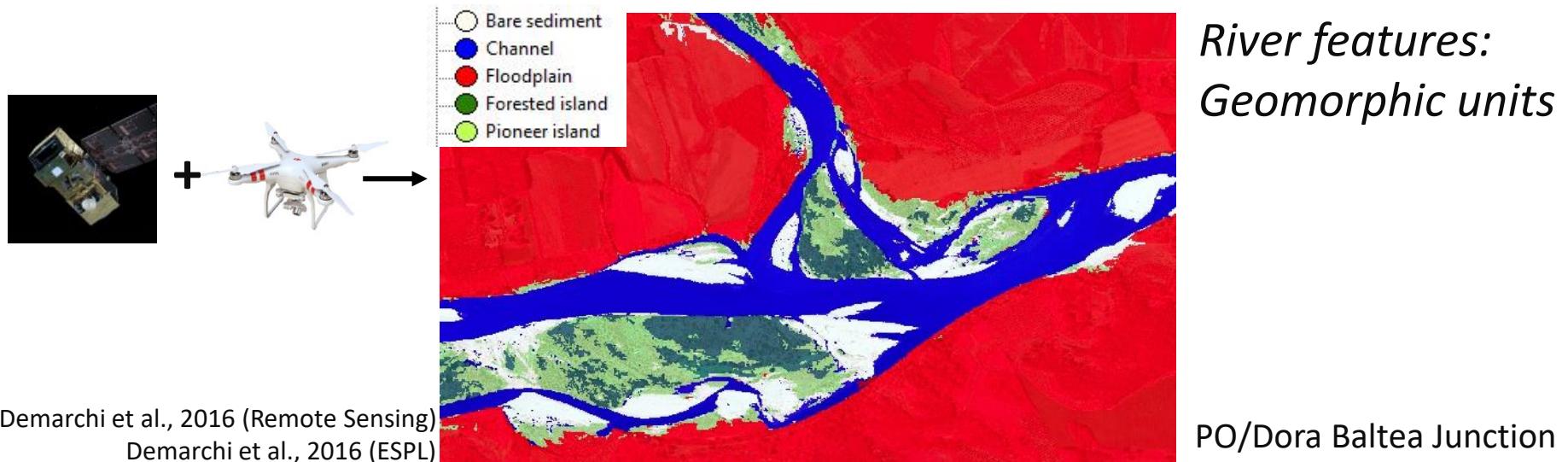
(2) Water index: water probability map



(2) Application: water discharge estimation



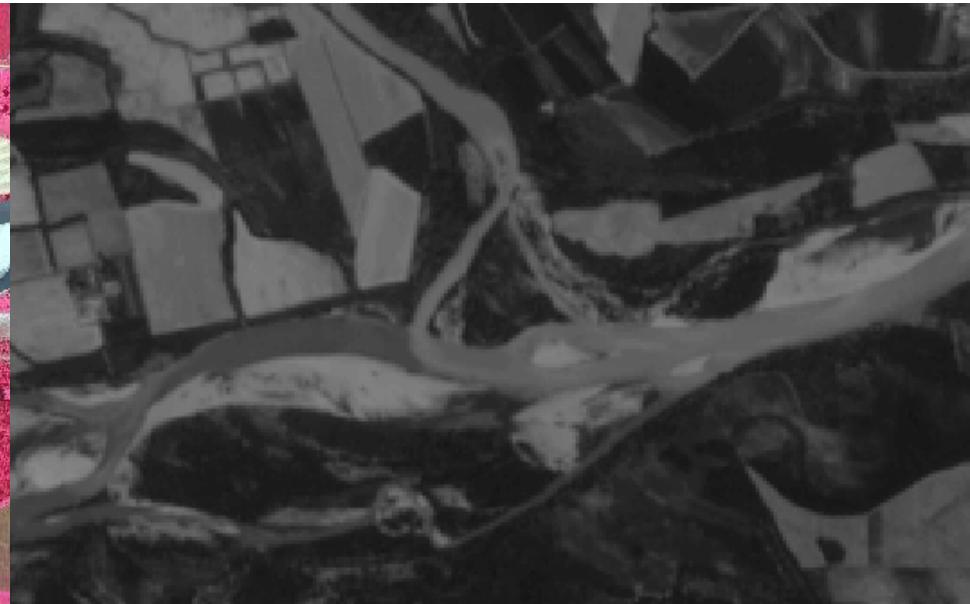
(3) Habitat mapping: S2



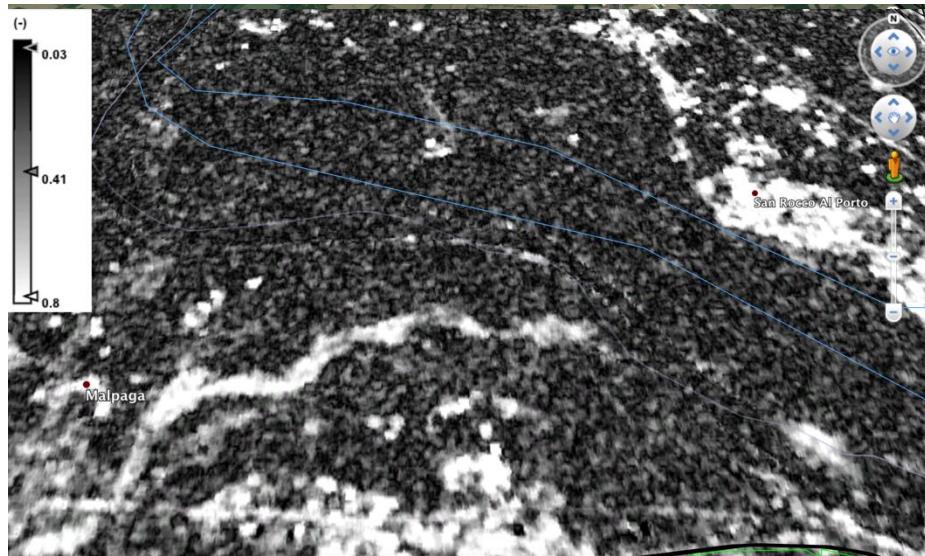
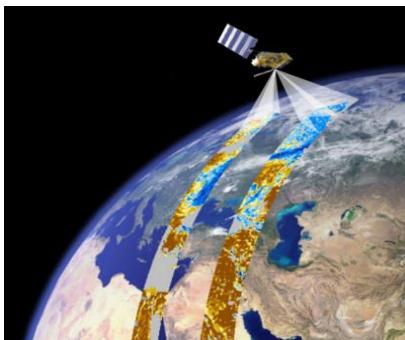
Aerial photo - NIR 40 cm



Sentinel 2 - Band 04 Red 10 m



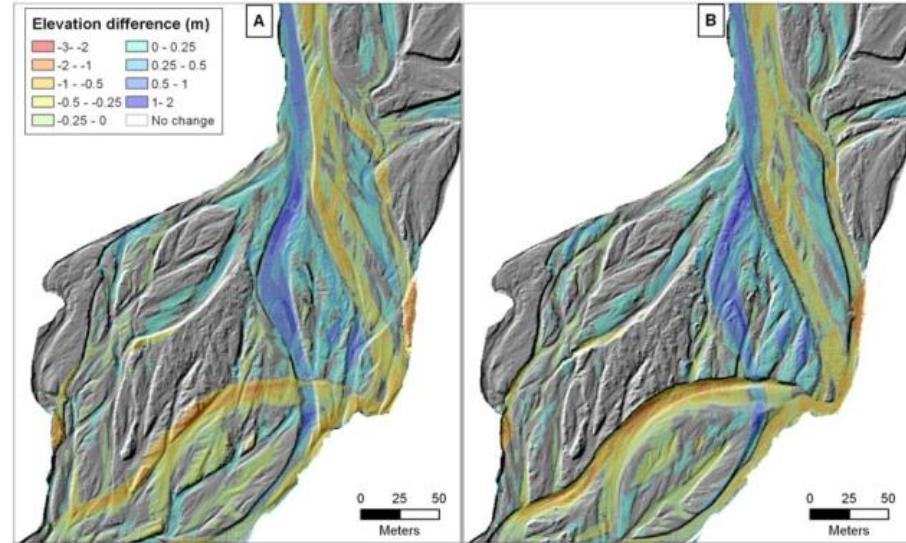
(3) Application: Habitat and processes mapping



(coherence between 04/06/17 and 10/06/17)

Coherence index

**Time correlation map of SAR
coherence**



(DoD on 2008 (A) and 2010 (B) DEMs ; Tacon, 2015)

DEM of Difference

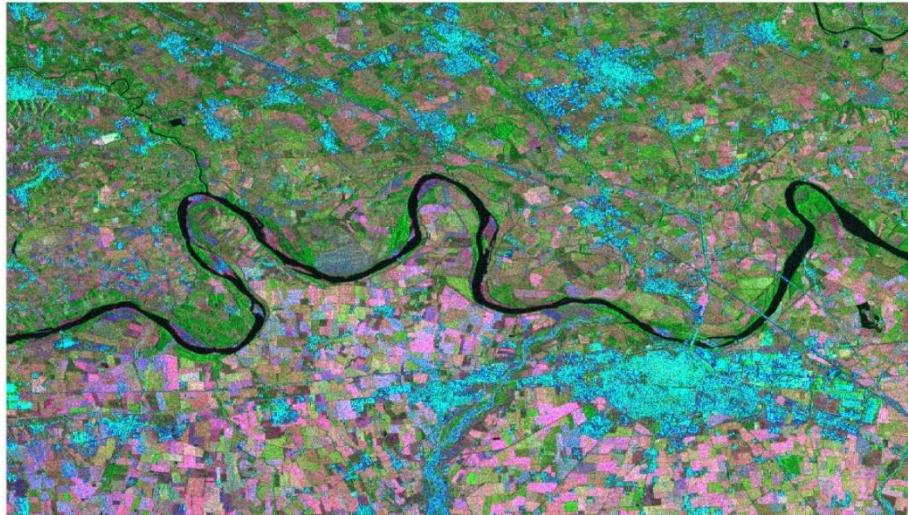
**Sediment budget,
river morphodynamics, etc.**

Mapping river indicators towards processes monitoring...

Monitoring of the evolutionary trajectories of indicators through time, by combining:

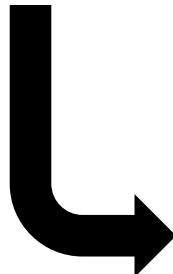
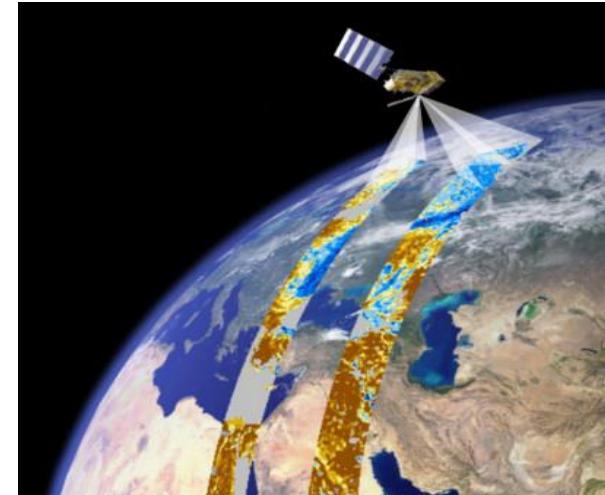
- the high temporal frequency of S1 and S2 data
- repeated field survey (GPS and drone) to built high resolution topographic data (DoD)

➔ Understand river and floodplain hydro processes at large scale

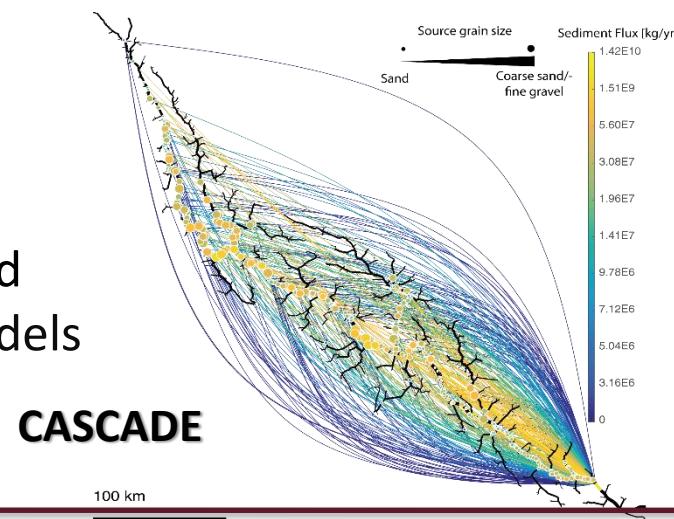


...and modeling at global scale

Low cost global river processes mapping, monitoring and modeling



Multiscale RS for calibration and validation of network-scale models of new generation



Thanks for your attention!



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