The use of UAV and Copernicus Sentinel data for developing hydromorphological monitoring tools for medium-large river systems to support the implementation of the EU WFD 2000/60/EC and FD 2007/60/EC

IRIS

Italian Research and development Initiative for Spaceborne river monitoring

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iCUD Workshop – IMPEL Network, 18 October 2018, Lisbon, Portugal

ISPRA

ISPRA – Italian National Institute for Environmental Protection and Research was established in 2008 by integrating three technical-scientific Institutions of national level:

- ✓ **APAT,** the Agency for Environment and Technical Services that in 2002 merged the ANPA, National Environmental Agency, with Geological, Mareographical and Hydrographical National Services
- ✓ **ICRAM,** the Institute for Marine Environmental Research
- ✓ **INFS,** the Institute for the Wild Fauna

ISPRA is a public research body. It responds to the environmental protection obligations set by the national law, such as control, monitoring, assessment, prevention, inspection, technical and scientific advice, as well as information and communication, education and training.

The Institute acts under the vigilance and policy guidance of the Italian Ministry for the Environment and the Protection of Land and Sea.

http://www.isprambiente.gov.it/en/

ISPRA

ISPRA is the national reference institution for environmental protection from both a technical-scientific and a legal-institutional viewpoint.

Its research body characteristic allows the Institute to remain at the forefront of knowledge and technology, as well as to ensure freedom to act and to operate as an autonomous and unbiased organization.

ISPRA:

- Supports policies implementation
- Defines strategies
- Produces standards & methodologies for monitoring and evaluation of the environmental status
- Makes (new) methodologies applicable
- Provides training activity
- Collaborates with Institutions and organizations at local, regional, national, European, and international levels.

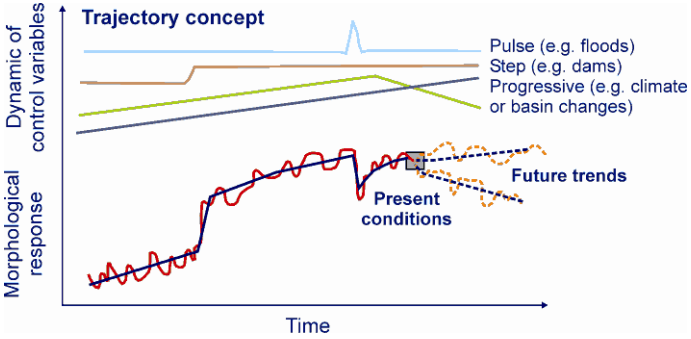
SNPA

ISPRA coordinates the **SNPA – National System for Environmental Protection** composed of the agencies from 19 Italian regions and 2 autonomous provinces. SNPA has a workforce of about 10,000 units.

Italian hydromorphological framework: IDRAIM

State of the art / User requirements

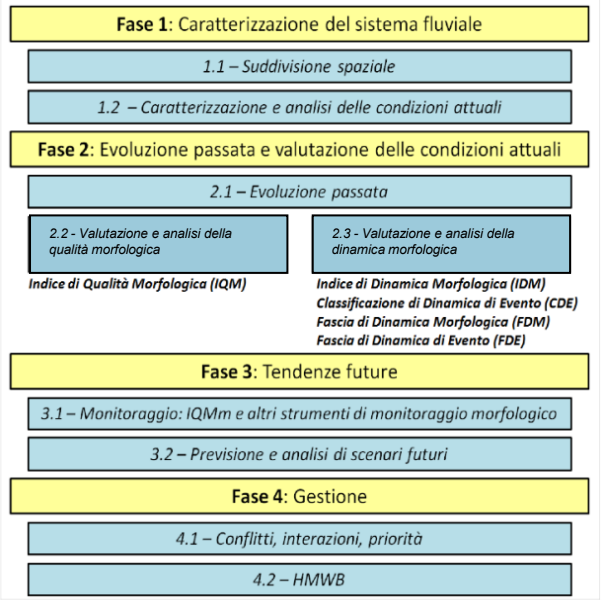
- National activity: Regional and local Authorithies responsible of the hymo monitoring, ISPRA and MATTM
- EU Commission activity: WG ECOSTAT (co-lead IT) & WG Floods of the *Common Implementation Strategy* for WFD and FD + Ad Hoc Task Group on Hydromorphology (co-lead IT)
- New European Standard on hymo – WG CEN
- EU project REFORM: review Hymo tool based on remote sensing data
- Research and scientific studies



Operational framework

- IDRAIM-stream hydromorphological evaluation, analysis and monitoring system, developped 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

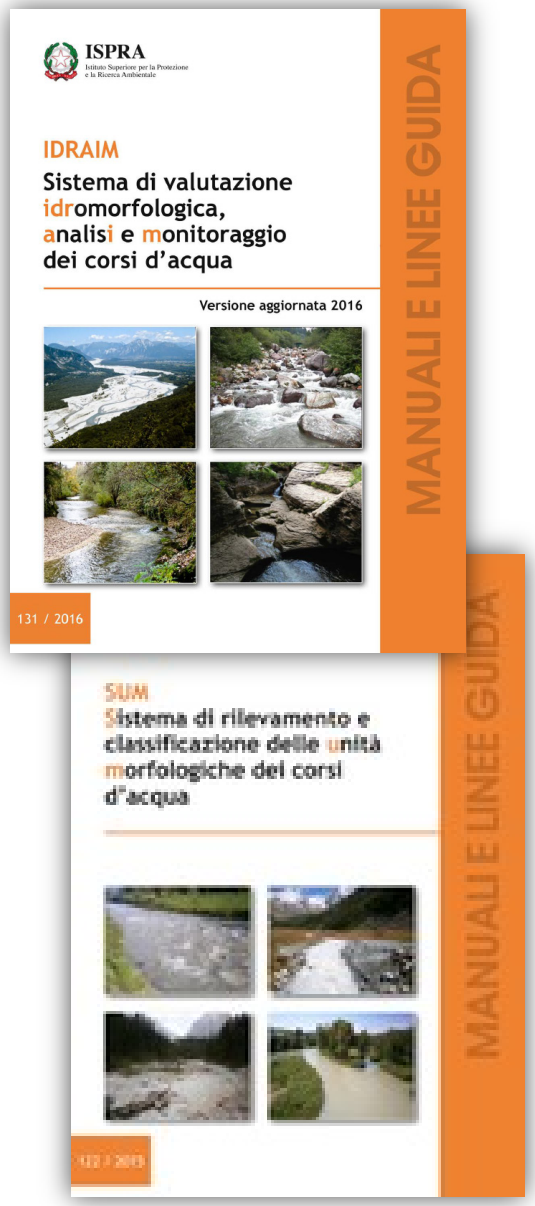
IDRAIM



New oper. tools & indicators based on Copernicus data

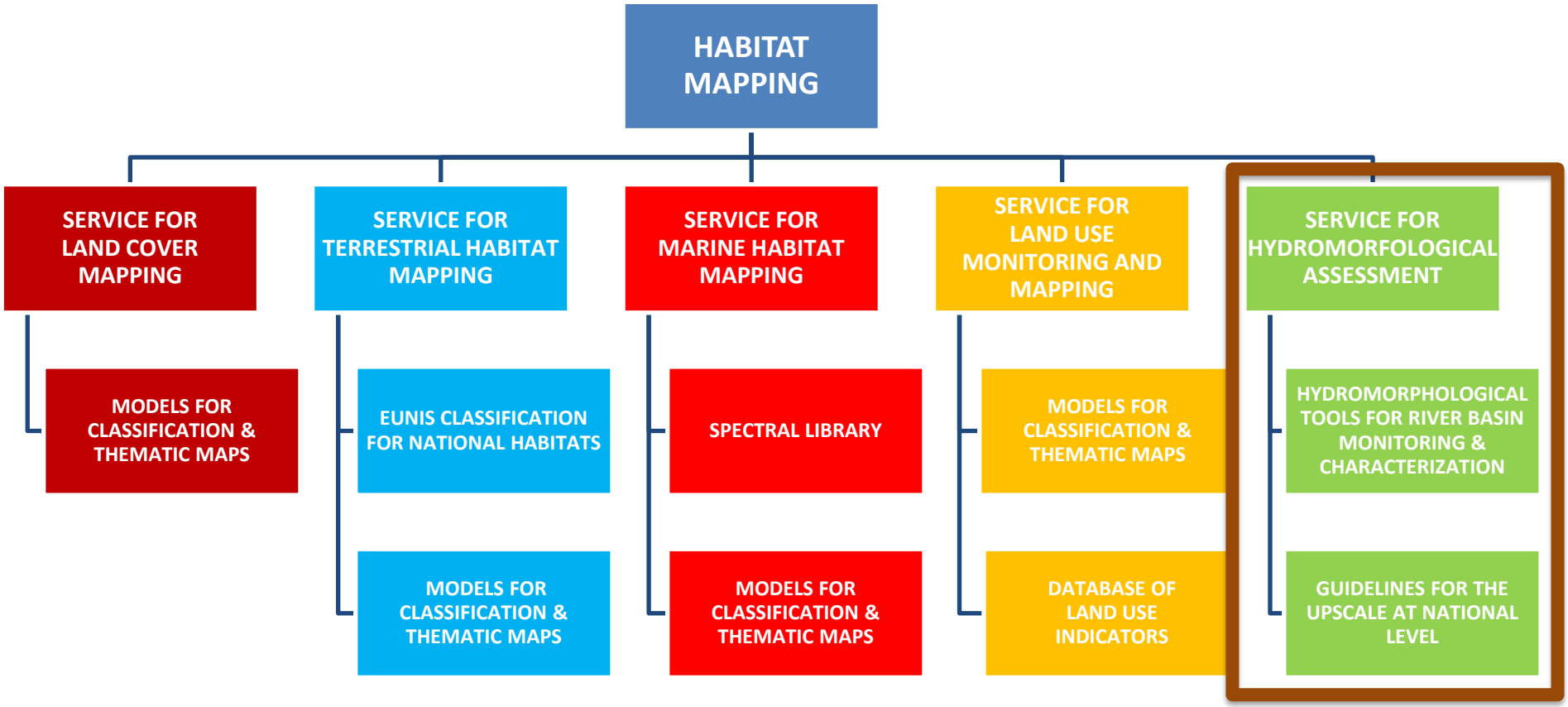
- Habitat Mapping project:
  - Developping operational tools and indicators for hymo monitoring based on Copernicus Sentinel 1 and 2 data in the framework of IDRAIM to support regional and local Authorities
  - Testing the operational tools and indicators on four river basins

Italian hydromorphological framework: IDRAIM



- **IDRAIM** is a comprehensive methodological framework developped by ISPRA and Universities of Florence, Padoa, and Bozen to support **integrated management of geomorphological river processes**.
- It accounts for the specific Italian context and the EU Directives, namely the **WFD 2000/60/EC** and **FD 2007/60/EC**, explicitly including consideration of fluvial hazard (**FD**).
- A system for the **classification and survey of geomorphic units**, named **GUS**, part of the IDRAIM framework, is used to identify, characterize and analyse the assemblage of geomorphic units within a given reach.
- The **e-MesoHABSIM** system is used for modeling and evaluating river habitat integrity.

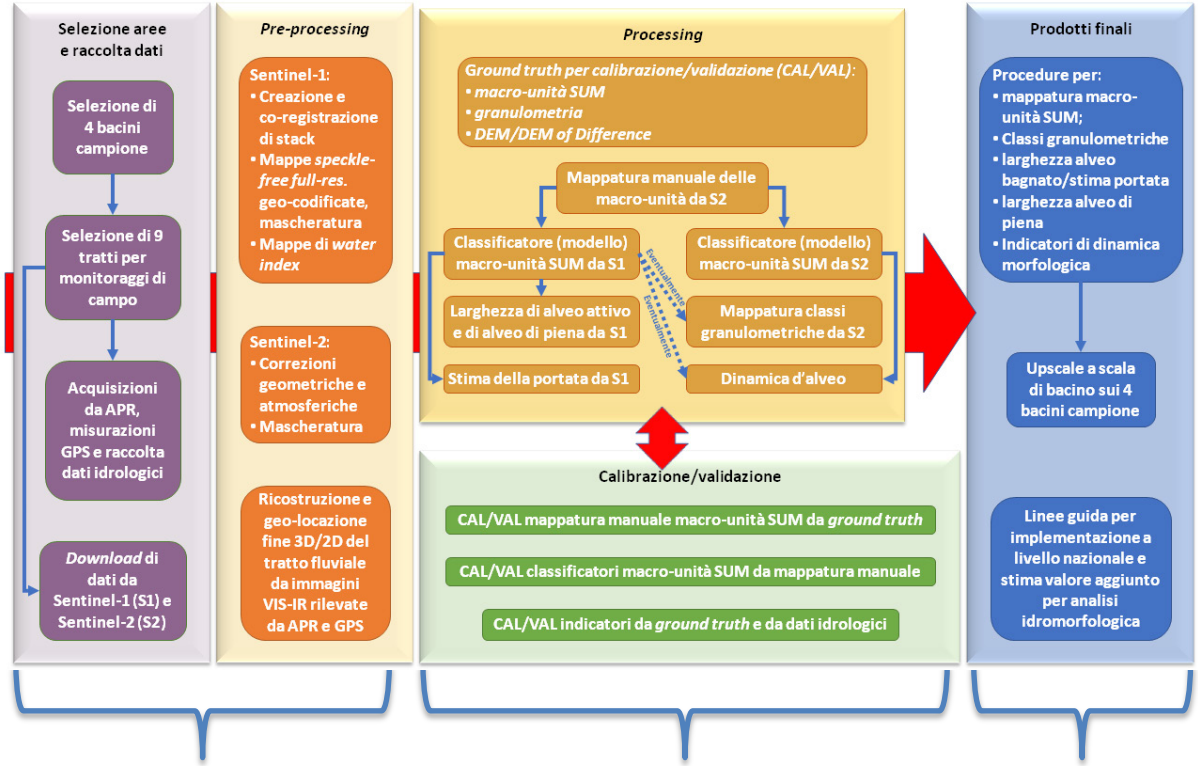
ASI-ISPRA project "HABITAT MAPPING"
Scientific coordination: Prof. A. Taramelli (IUSS Pavia & ISPRA)



Developing multi-scale HYMO tools for the assessment of medium-large river systems based on Copernicus Sentinel 1 and Sentinel 2 data

ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale · Sistema Nazionale per la Protezione dell'Ambiente · POLITECNICO MILANO 1863 · Durham University · agenzia spaziale italiana · Copernicus Europe's eyes on Earth

Flowchart for the development of operational hymo tools based on satellite data from EU Copernicus Sentinel 1 and 2



INPUT

Collecting data from:

- In-situ stream gauges
- GPS instruments
- Drone (UAV)
- Copernicus Sentinels

2 monitoring cycles, done

METHODOLOGY

Developing (semi-) automatic tools to classify Sentinel images, using in-situ data and drone images for calibration and validation

OUTCOMES

- Hymo maps & indicators over test sites
- Guidelines to extend the methodology

Test-bed sites

- ❑ **Po/Sesia** (3 river reaches), Padano river basin district
- ❑ **Tagliamento** (1 reach), Eastern Alps river basin district
- ❑ **Tevere/Paglia** (3 reaches), Central Apennine river basin district
- ❑ **Bonamico** (2 reaches), Southern Apennine river basin district

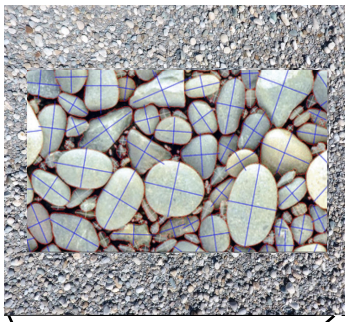
The idea: a multiscale river observatory platform which integrates low-cost drones and satellites from the EU Copernicus programme

Drones and traditional field techniques (e.g. RTK-GPS) are used to survey local river features, e.g., topography, sediment size, vegetation, morphological habitats, to provide ground truth

FULL ROBOTIC RIVER SURVEY
Carbonneau, Bizzi and Marchetti, 2017 (ESPL)

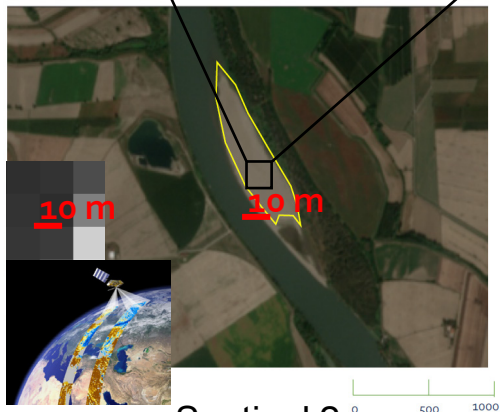
Example: Orbital grain size mapping
Marchetti et al (in prep.)

Hypothesis: roughness influences spectral reflectance

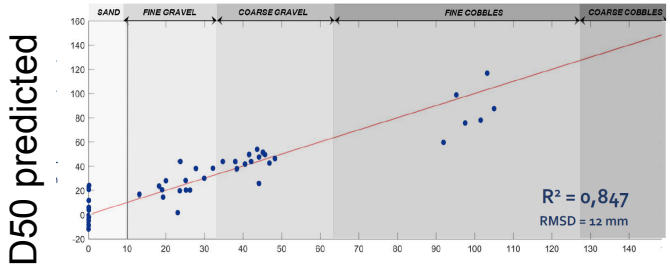


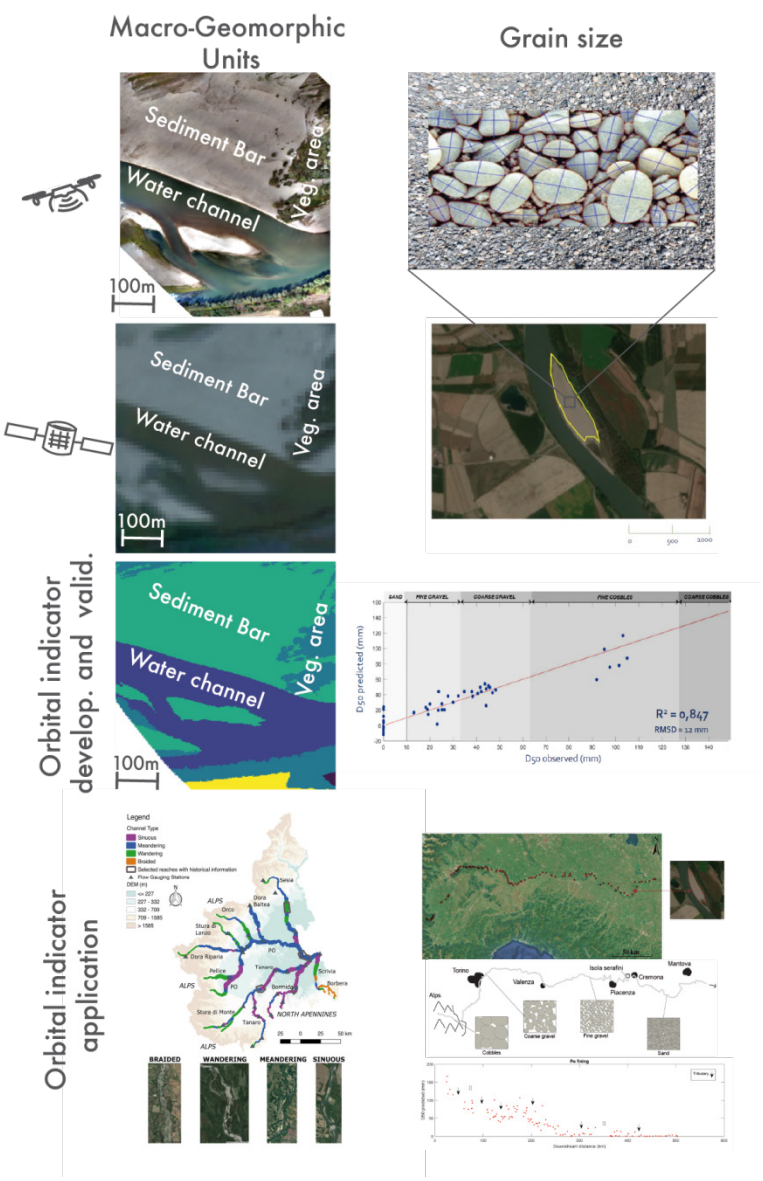
Ground-truth: Low-cost drone

Method: Looking for CORR between Sentinel 2 bands and drone derived sediment size



Sentinel 2





Orbital River Indicators explored:

1) Macro-geomorphic Unit Mapping
2) Grain size classes
3) Discharge
4) Area of erosion and deposition

If working, we open to the possibility not only to map these indicators on large scale (national, EU), but also to create historical trajectories of these variables with almost weekly frequency!

Not all will work. It is important to understand:

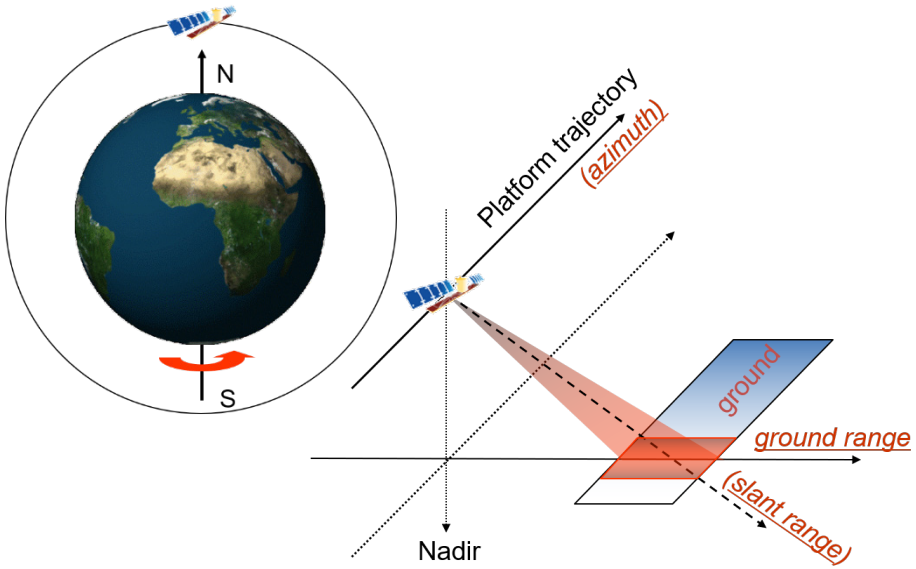
i) on what river size they will work (e.g., discharge estimation will work only on some channel type) and with what accuracy ??;

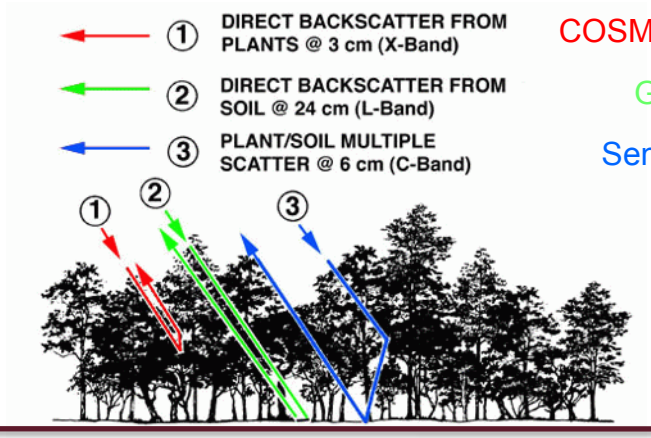
ii) the area of erosion and deposition is very explorative, we don't know if we will be able to measure degree of morphological changes. However, even simply an orbital indicator capable to identify areas where something notable 'occurred', it would be very useful to prioritize more accurate monitoring (e.g., with drones to create the DoD–Dem of Difference) .

SENTINEL 1: radar (SAR) C-Band

Pixel 20 x 5 m

Frequency of acquisition: 6 days

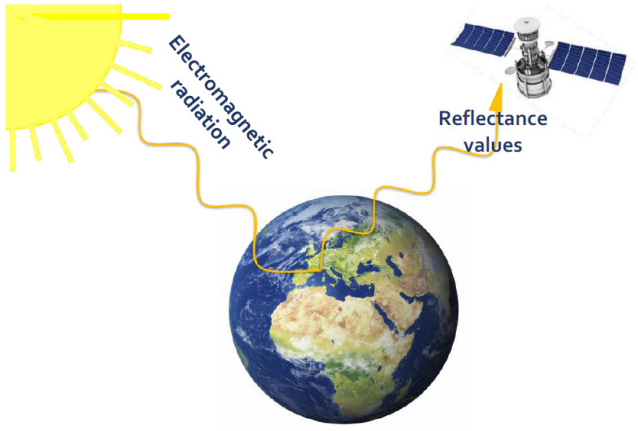


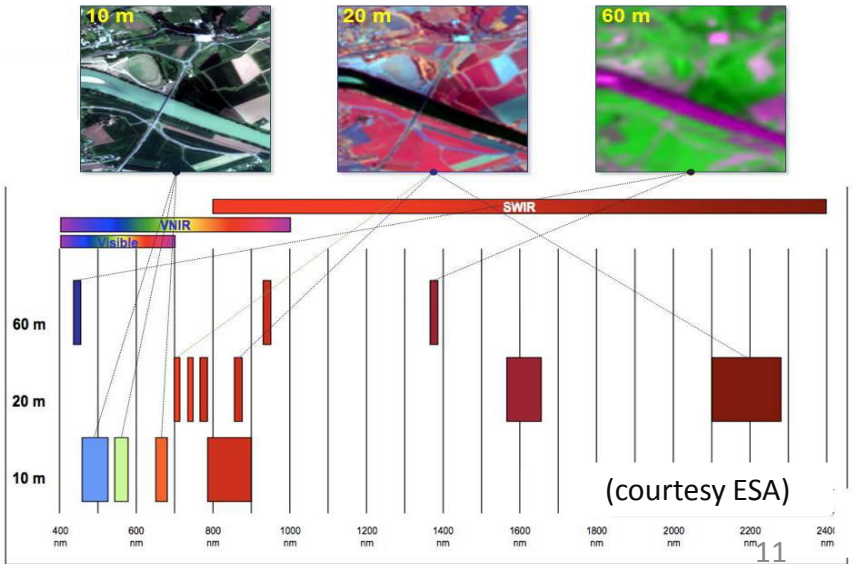


SENTINEL 2: Multispectral optical

Pixel 10x10 or 20x20

Frequency of acquisition: 5 days

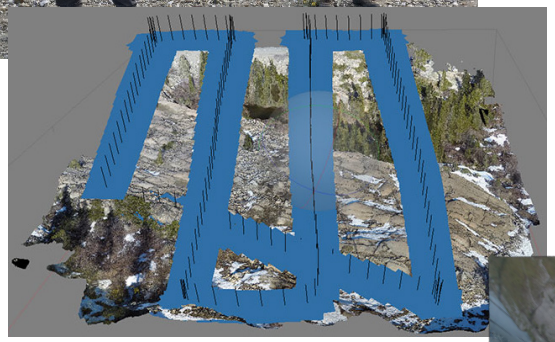


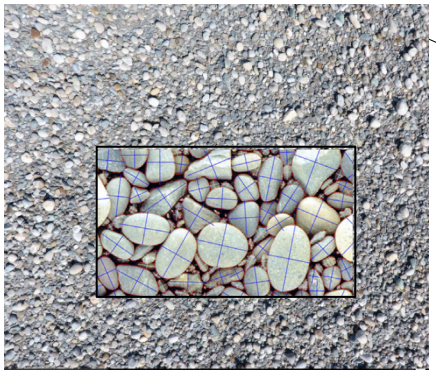


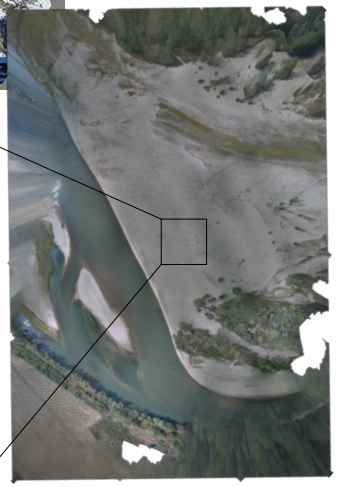
(courtesy ESA)

FIELD DATA

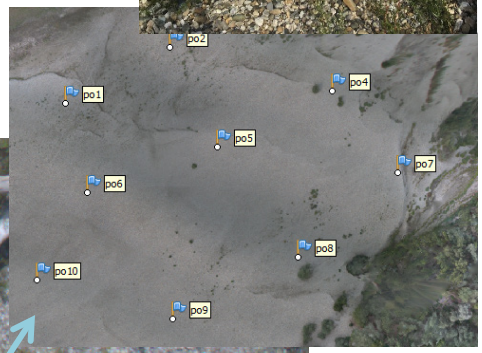
Very high resolution remote sensing data (UAV)

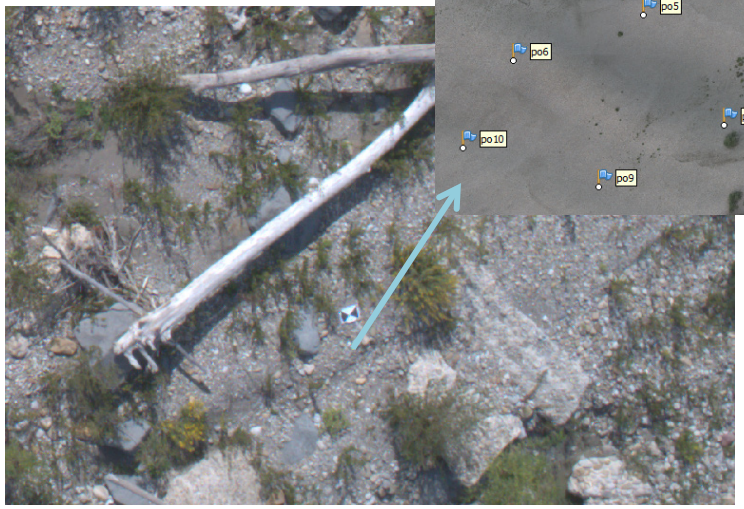






Very high resolution Topographic data (GPS)

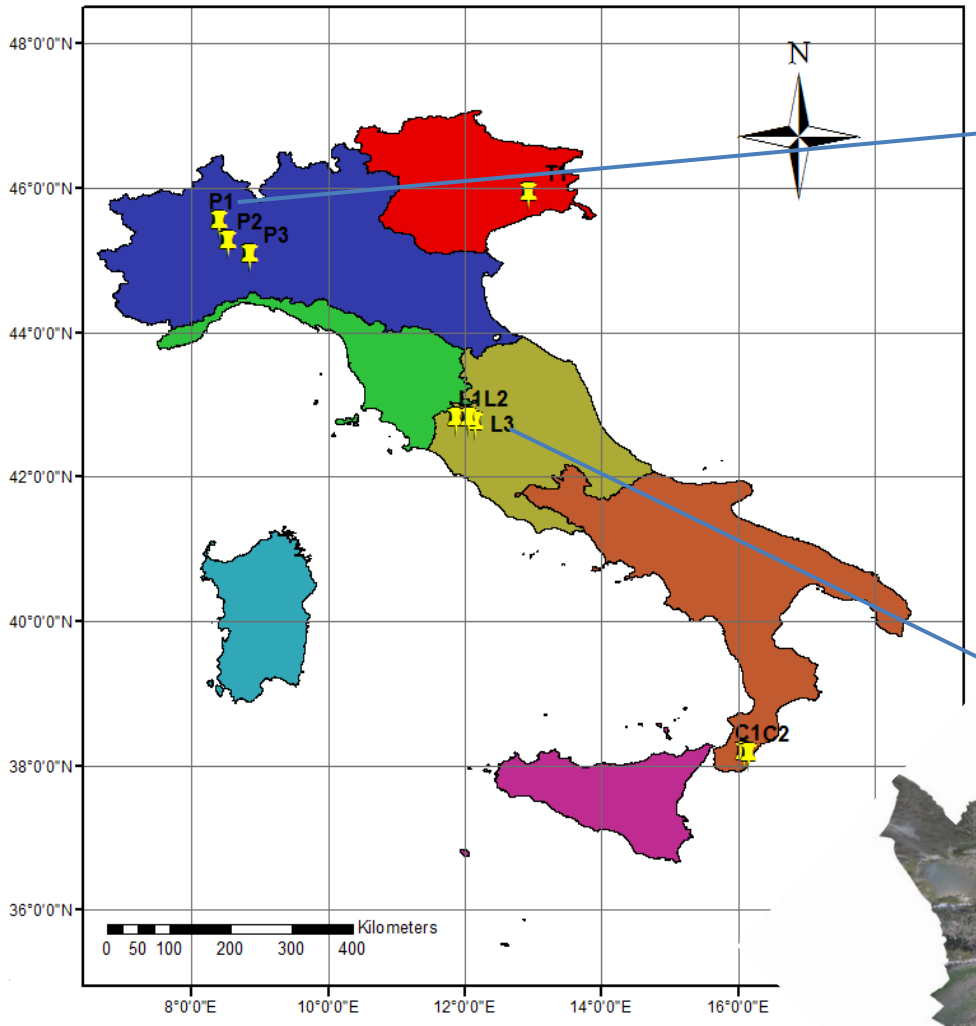




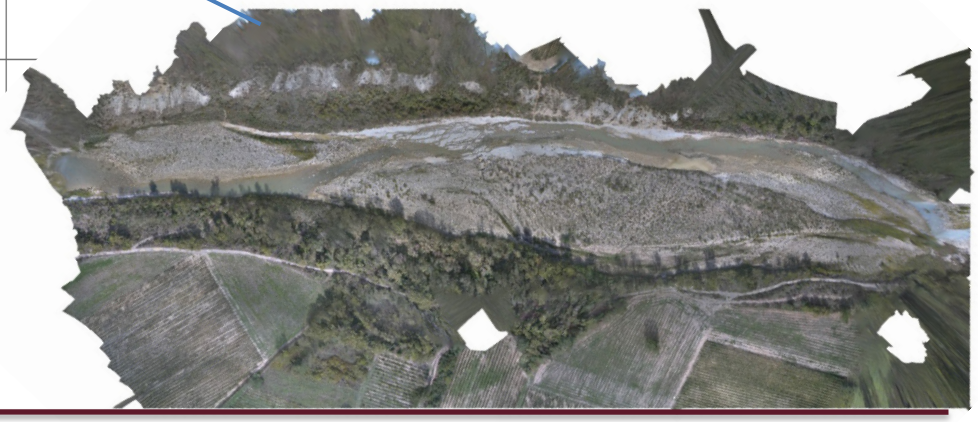
Ground truth to calibrate and validate satellite data

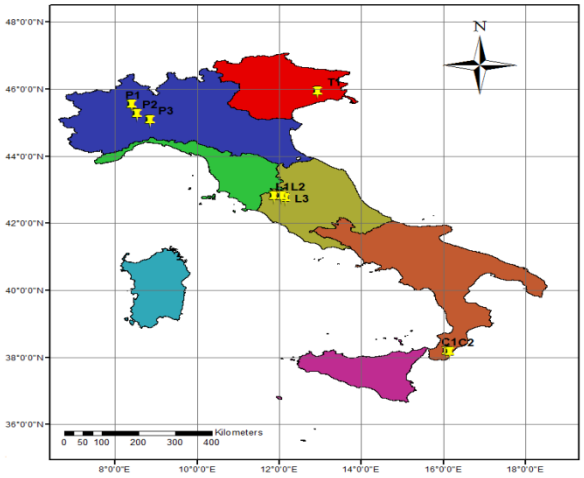
sUAV pre-processing

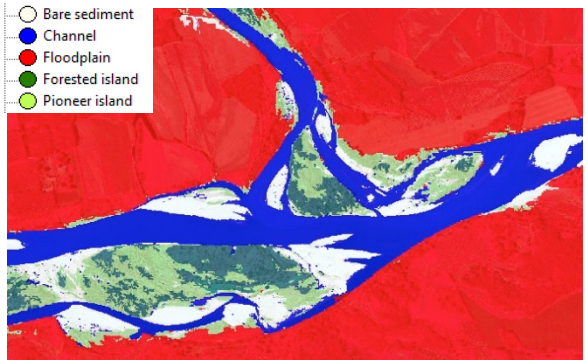
ORTOPHOTOS



PhotoScan
3D Modeling and Mapping





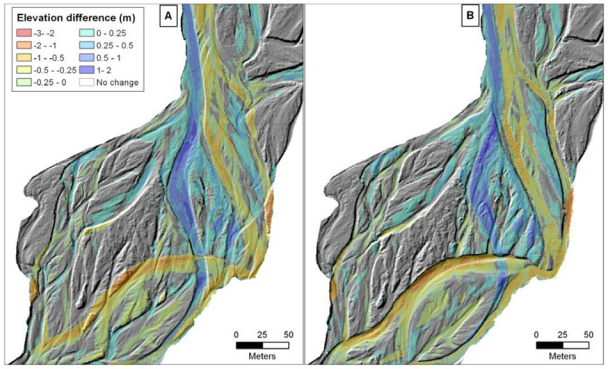


Habitat mapping

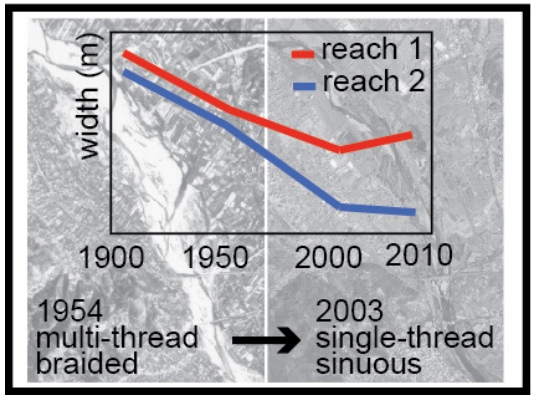
Sediment size classes

Hydromorphological indicators from satellite remote sensing

Water extraction



Indicators of processes

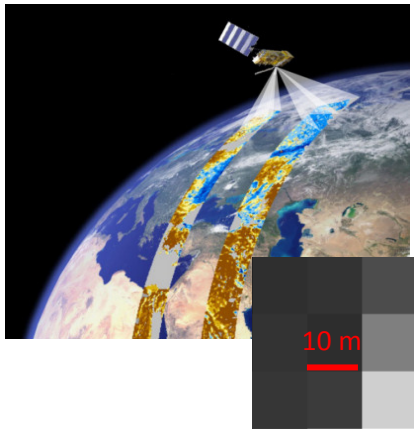


Overall grain size mapping: S2

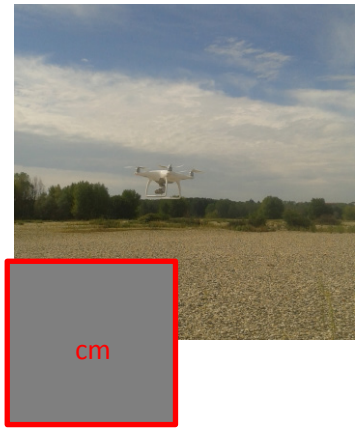
Grain size estimation

Multispectral satellite data with high repeat time

Indirect measurement
→ Reflectance values

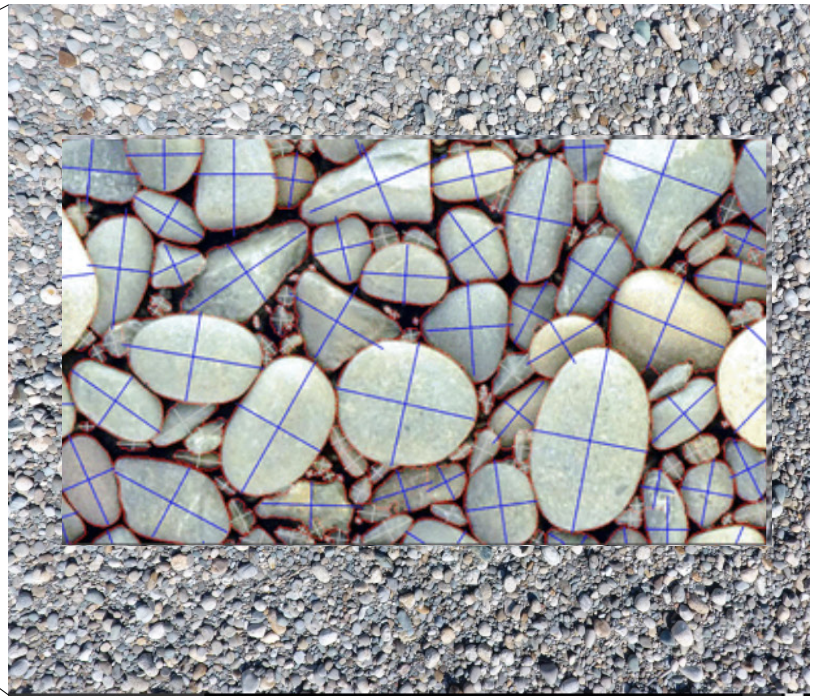


Grain size measurement



Low coast technology for calibration (sUAS)

Direct measurement
→ Photosieving technique
→ Grain size percentiles



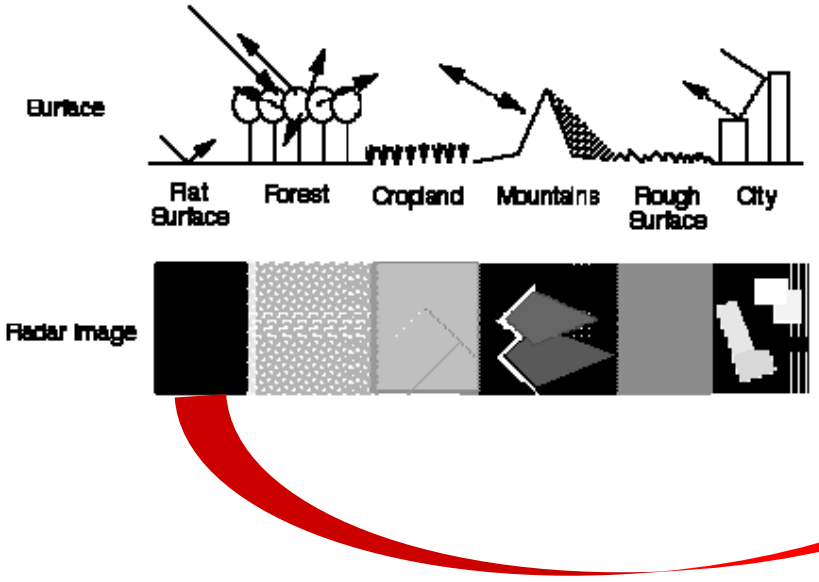
Marchetti et al. (in prep.)

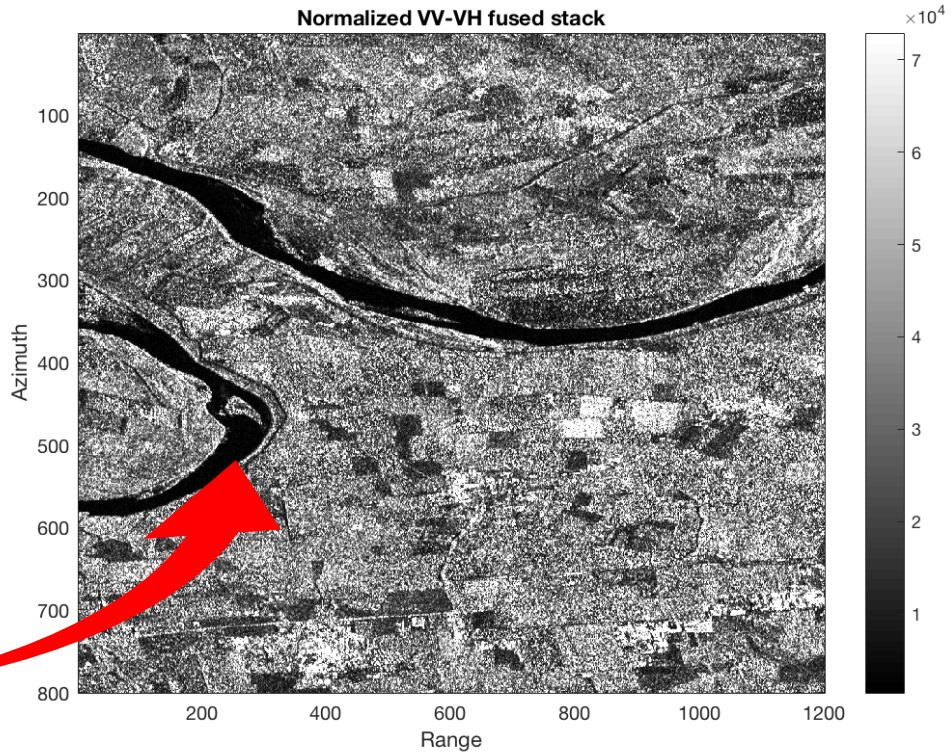
Carbonneau, Bizzi, Marchetti, 2017 (ESPL)

Water index: S1

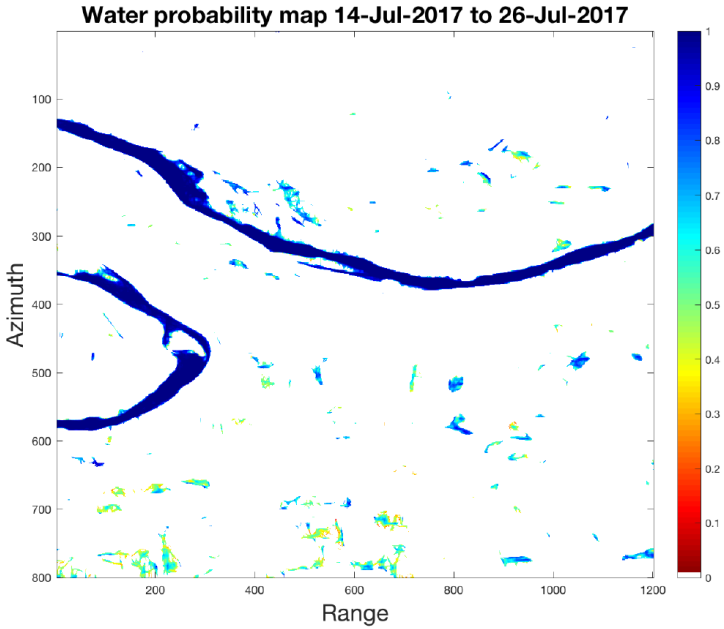
The intensity of a SAR image is strongly influenced by the terrain structure and **roughness**

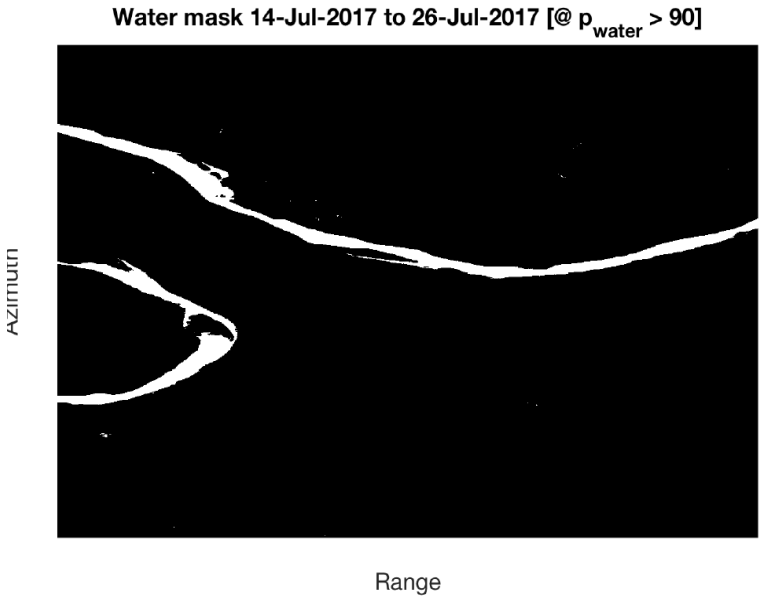
Water = no backscatter





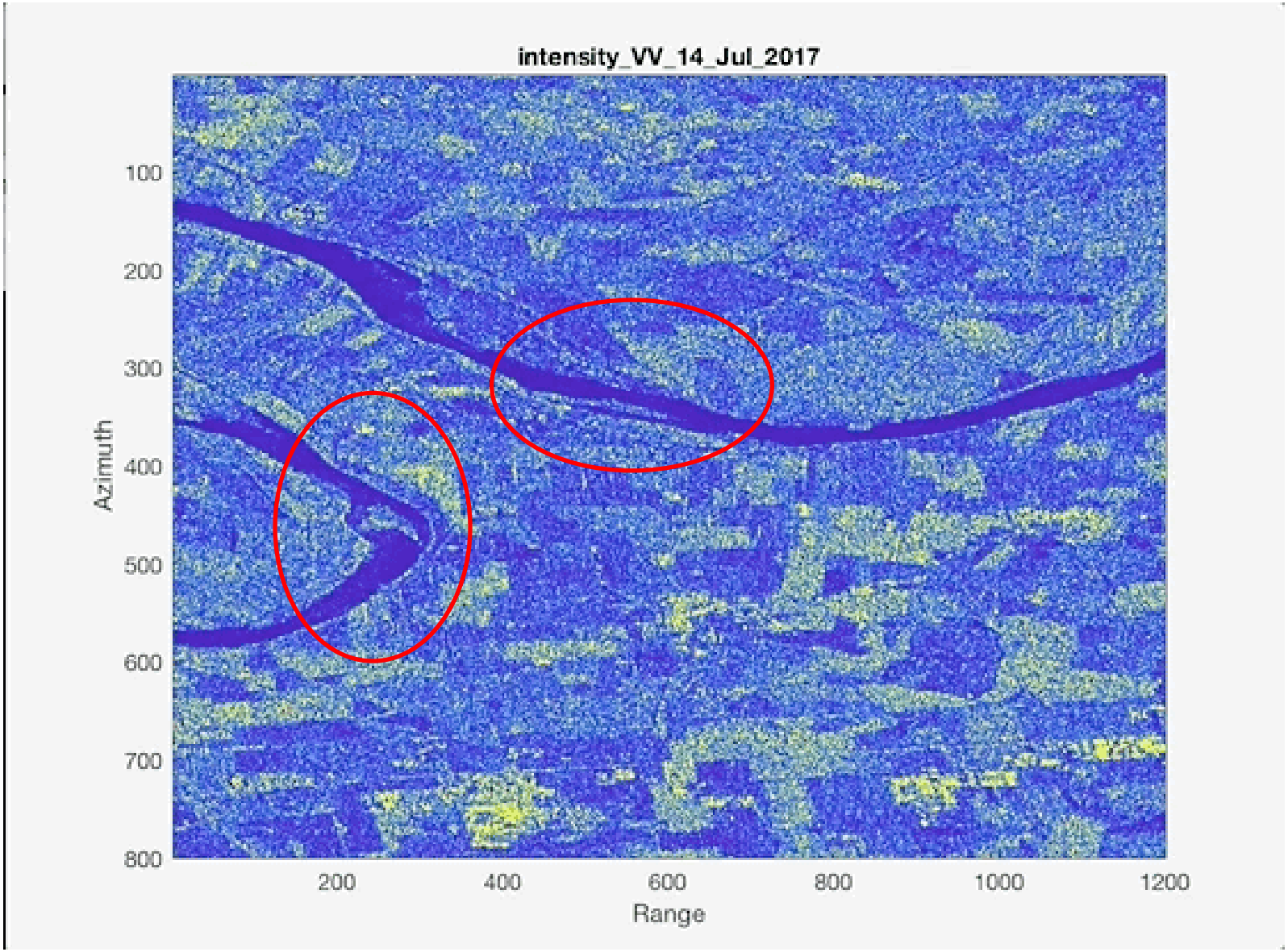
Water index: water probability map



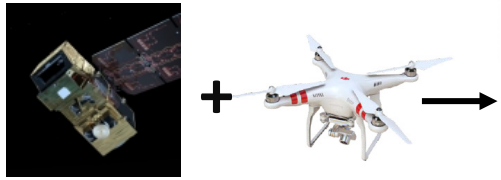


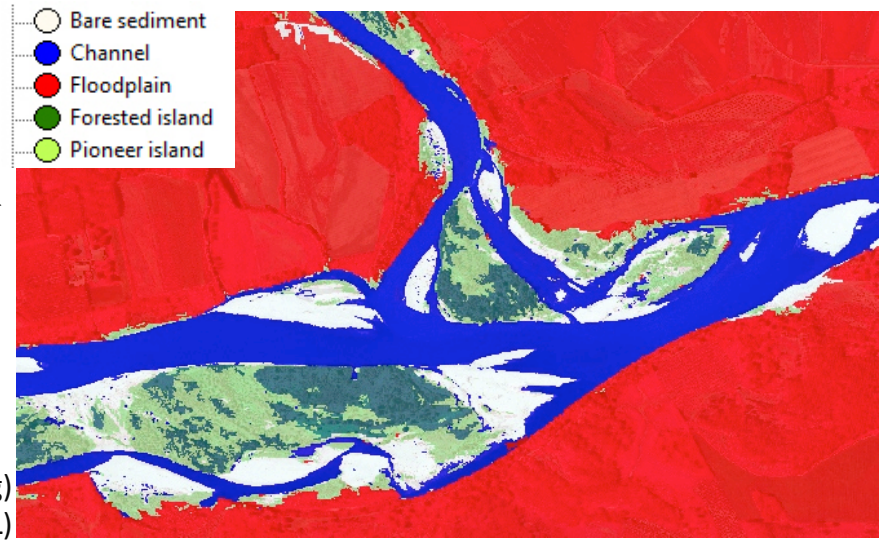
Asaro et al., 2017 (submitted IS.Rivers 2018)

Application: water discharge estimation



Habitat mapping: S2



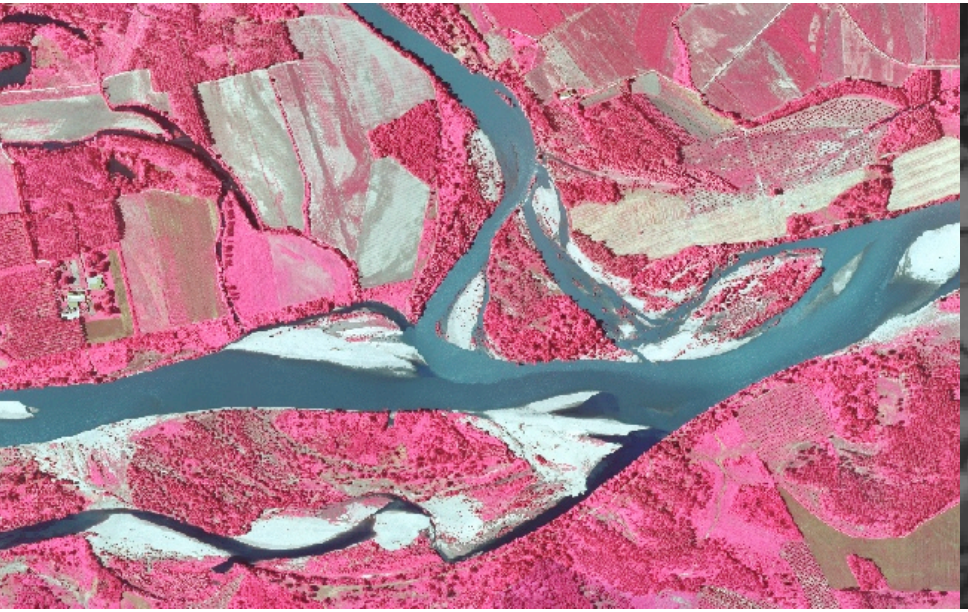


River features:
Geomorphic units

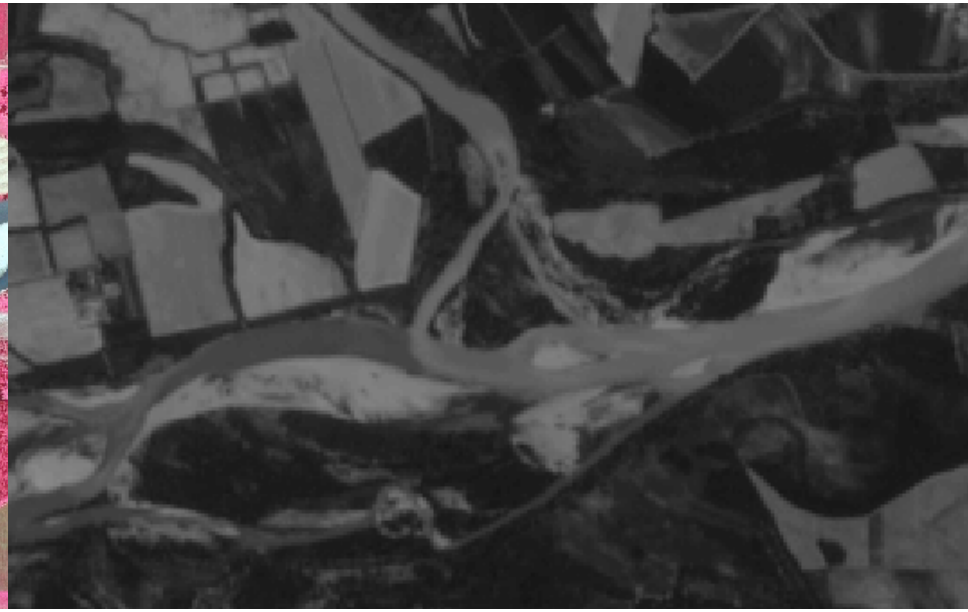
Demarchi et al., 2016 (Remote Sensing)
Demarchi et al., 2016 (ESPL)

PO/Dora Baltea Junction

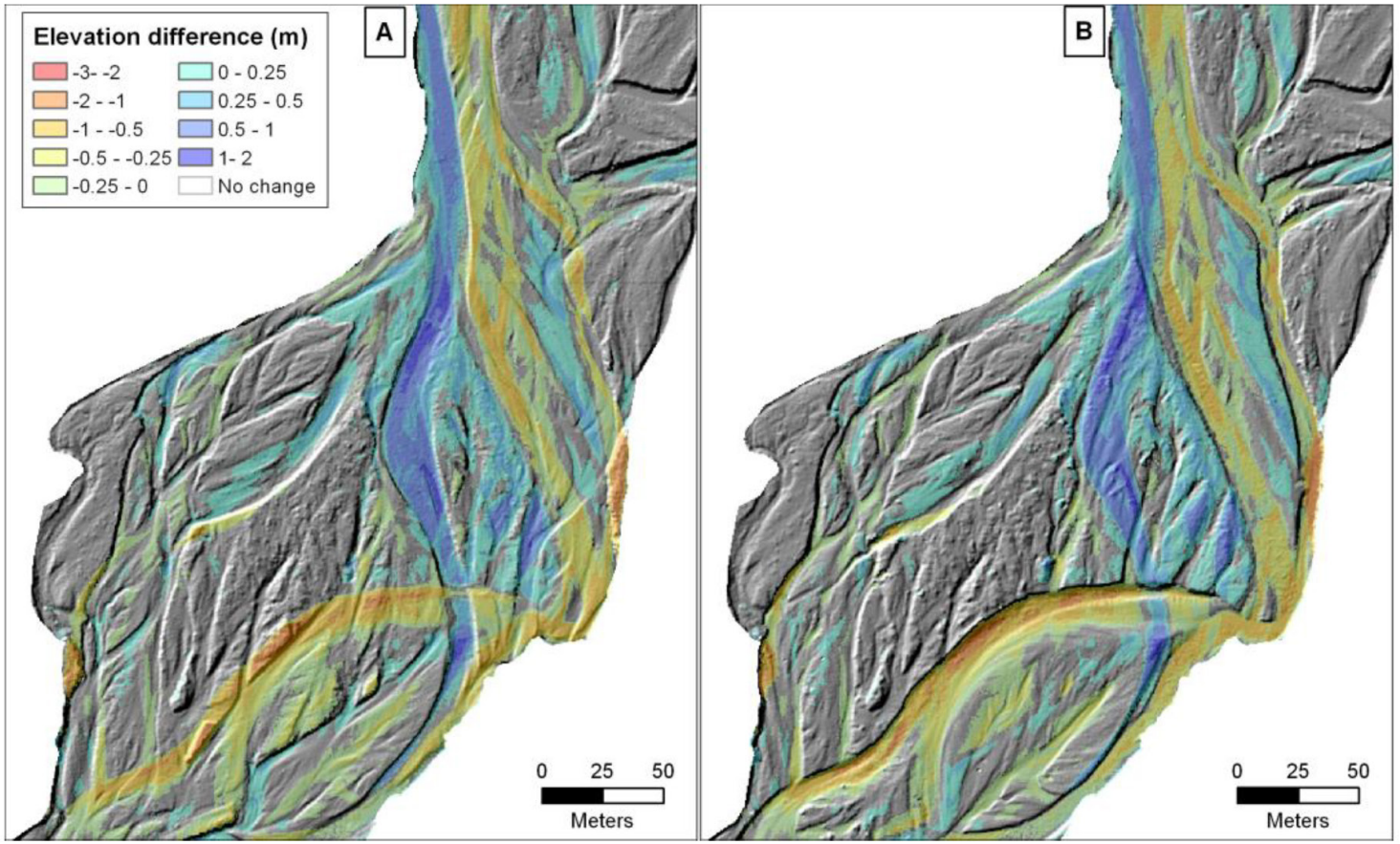
Aerial photo - NIR 40 cm



Sentinel 2 - Band 04 Red 10 m



Application: Habitat and processes mapping



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

DEM of Difference

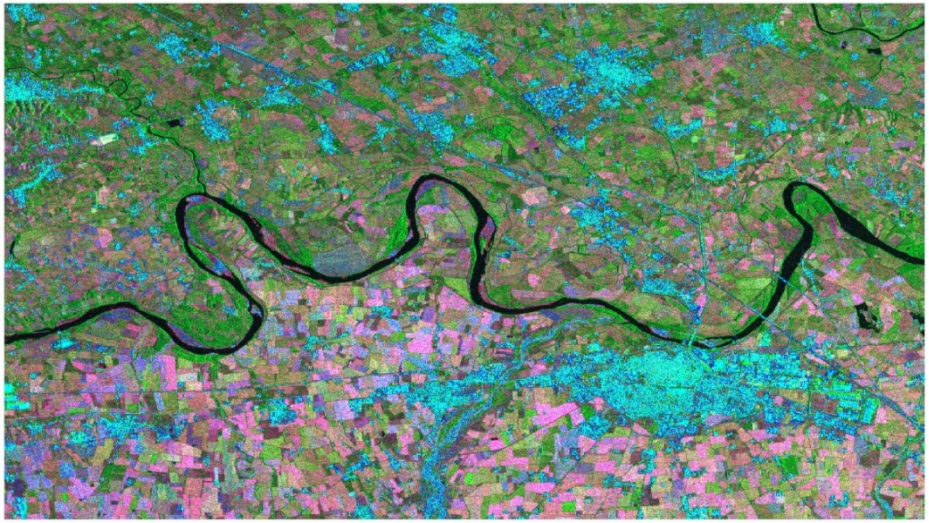
Sediment budget, river morphodynamics, etc.

Mapping river indicators towards processes monitoring…

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

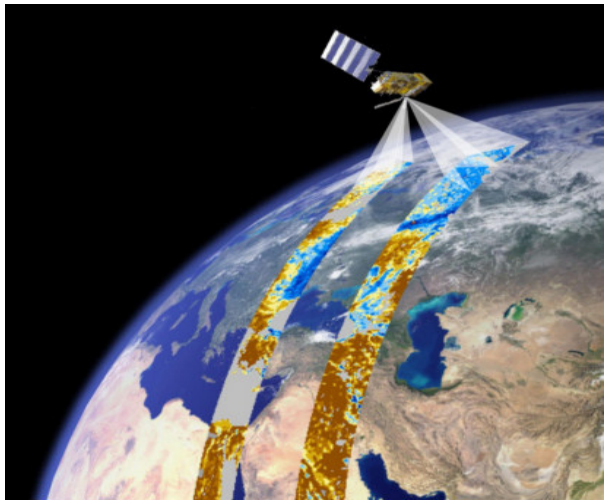
- ❑ the high temporal frequency of Copernicus Sentinel 1 and 2 data
- ❑ repeated field survey (GPS and drone) to built high resolution topographic data (DoD)

➔ Understand river and floodplain hymo processes at large scale

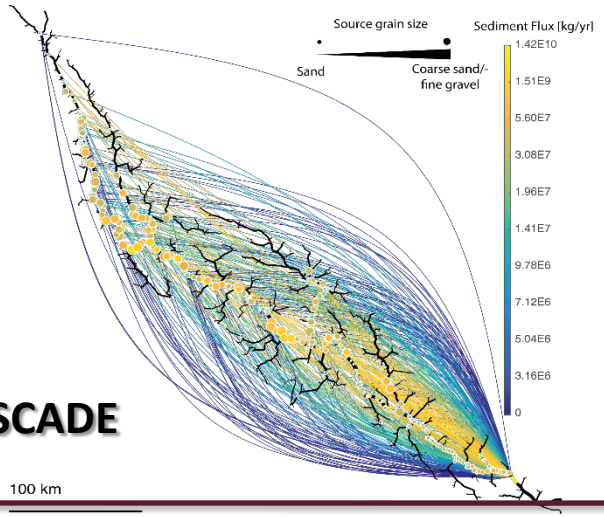


…and modeling at global scale

Low cost global river processes mapping, monitoring and modeling



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



CASCADE

Thanks for your kind attention!

IRIS

Italian Research and development Initiative for Spaceborne river monitoring

Dr. Stefano Mariani, ISPRA
stefano.mariani@isprambiente.it

IRIS projecthttps://www.researchgate.net/project/Italian-Research-and-development-Intiative-for-Spaceborne-river-monitoring-IRIS