Investigating River-Sea water connectivity from remote sensing

Rossella Belloni

Docente Guida: Prof.ssa Claudia Adduce. Co-Docenti Guida: Federico Falcini, Rosalia Santoleri

Remote sensing is the science of obtaining information using sensors that are not in physical contact with the observed surface. Among the wide range of applications, the exploitation of satellite data in Earth science disciplines is one of the most important. Remote sensing, indeed, provides the **synoptic perspective** required for monitoring the spatiotemporal evolution of complex natural phenomena, overcoming the limitations of conventional monitoring techniques. All remote sensing systems rely on energy that is either diffusely reflected by or emitted from surface features. Current remote sensing systems fall into two categories on the basis of the source of the electromagnetic radiation, **passive and active sensors**.

PASSIVE SENSORS are instruments designed to measure reflactance, the ratio of the solar radiation reflected by the Earth's surface to the incident one. The spectral signatures produced by wavelength-dependent absorption provide the key to discriminating different constituents on the observed surface.

esa European Space Agency

SENTINEL-2 is an Earth observation mission from the **Copernicus Programme (ESA)** that systematically acquires optical imagery over land and coastal waters:

- **Spectral resolution** 13 bands (Multi-spectral sensor)
- **Spatial resolution** 10m, 20m, 60m
- **Temporal resolution** 5 days at the Equator

IMAGE COLLECTION

Sentinel-2 images are freely accessible from ***Copernicus Open Access Hub***

ATMOSPHERIC CORRECTION

Removal process of **atmosphere effects** on reflectance values measured by satellite

- **Rayleigh path reflectance**
- **Aerosol path reflectance**
- **Sun glint and Foam effects**

Water-leaving reflectance (ρw)

TURBIDITY MAPS (Dogliotti et al., 2015)

$$T = \frac{A_T^{\lambda}\rho_w(\lambda)}{(1-\rho_w(\lambda)/C^{\lambda})} \quad [FNU]$$

A_T^{λ} e C^{λ} calibration coefficients

- $\rho_w(664\ nm) < 0{,}05$ → $\rho_w(664\ nm)$
- $0{,}05 < \rho_w(664\ nm) < 0{,}07$ → $T = (1-w)T_{664} + wT_{865}$ → $w = a\,\rho_w + b$
- $\rho_w(664\ nm) < 0{,}07$ → $\rho_w(865\ nm)$

$w = 0$ if $\rho_w(664\ nm) = 0{,}05$

$w = 1$ if $\rho_w(664\ nm) = 0{,}07$

Processor for atmospheric correction and turbidity maps

ACOLITE (Atmospheric Correction for OLI 'lite'), automatic processor for atmospheric correction of Sentinel-2 (A/B) imagery oncoastal and inland waters (Vanhellemont and Ruddick, 2015)

museum

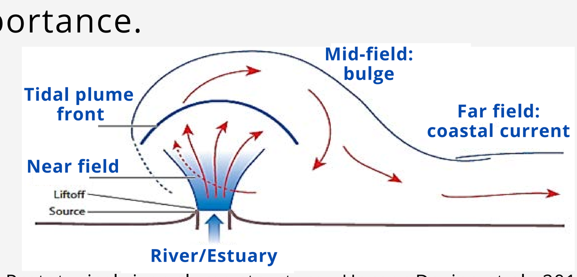
ANALYSIS OF RIVER PLUMES DISPERSAL ON NORTHEN ADRIATIC SEA

Roma Tre University, Department of Engineering

Institute of Marine Science, National Research Council

RESEARCH TOPIC

Freshwater discharged by rivers on continental shelves form **river plumes**, turbulent flows which disperse into coastal areas strongly affecting circulation, ecology and morphology. The assessment of the main processes contributing to the transport of plumes into coastal areas is of strong scientific interest and practical importance.



Prototypical river plume structure - Horner-Devine et al., 2015

METHOD

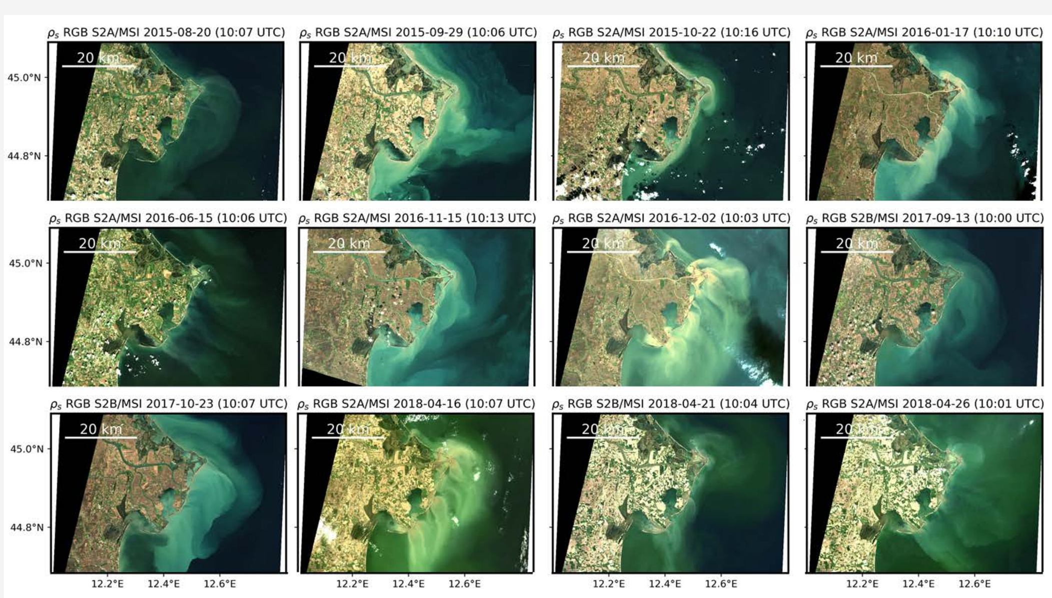
The overall coastal area affected by river plume dispersal was identified comparing turbidity values with a threshold established by considering the Adriatic Sea background turbidity (5-6 FNU).

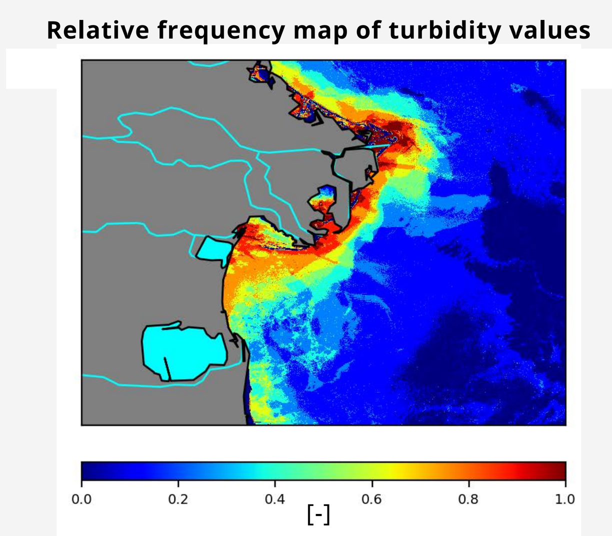
The geomorphological efficiency of the river plumes was evaluated considering the frequency of the suspended sediments dispersal in the alongshore direction.

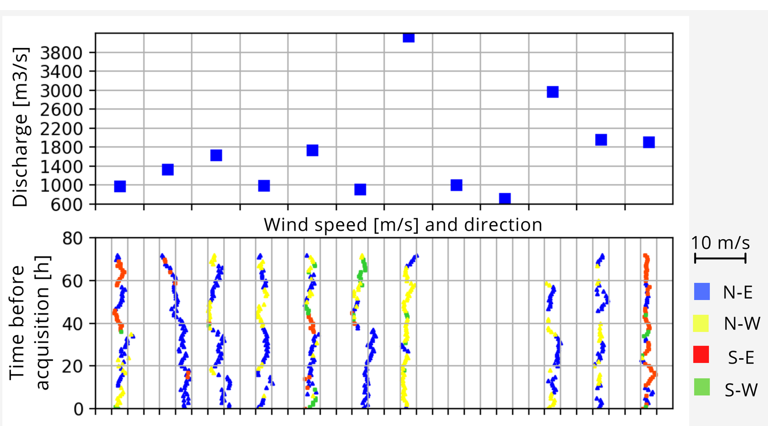
River plume patterns were then linked to environmental forcings that affect thier dispersal in northen Adriatic Sea (i.e wind and discharge)

Analysis time period: June 2015 - April 2018

RESULTS - PO RIVER







Data refer to a **temporal window of 72 hours before the satellite acquisition**

CONCLUSIONS

The analysis showed plume morphologies with a moderate spatio-temporal variability and confirmed the major role of river discharge and wind in affecting their overall structure, with a consequent impact on the geomorphological efficiency of the river.

HUMAN PREASSURES ON INLAND AND COASTAL WATER ECOSYSTEMS

Roma Tre University, Department of Engineering

Institute of Marine Science, National Research Council

RESEARCH TOPIC

On March 2020, Italy enters the lockdown phase due to the Sars-Covid19 infection. This radical choice has provided an unplanned experiment of drastic reduction of anthropic impacts on the environment, including the marine-coastal system, and especially in areas of significant inputs, represented by large urban and industrial agglomerations as well as river load runoffs. In such a context, environmental and EO scientists wonder about the real effects of the reduction of anthropogenic inputs in terms of water quality.

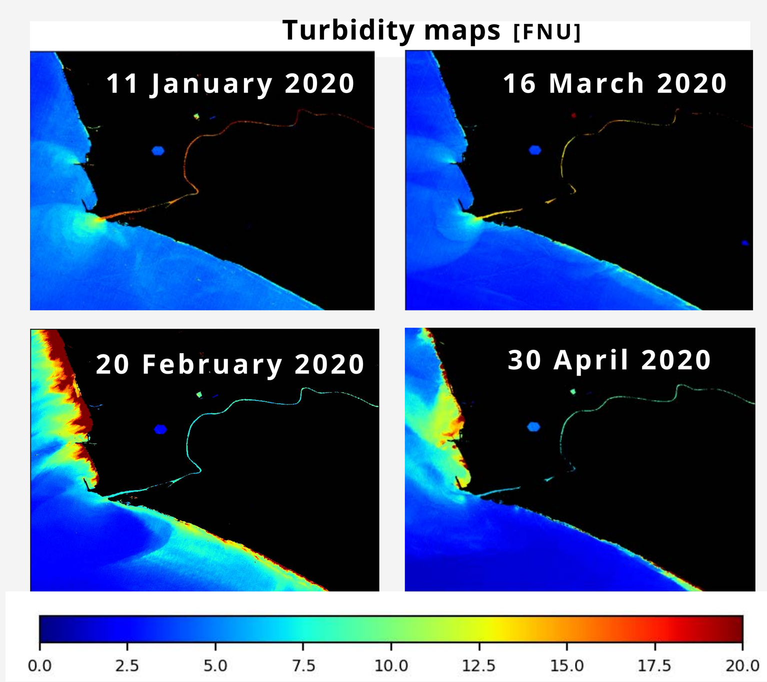
Analysis time period: January - May 2020

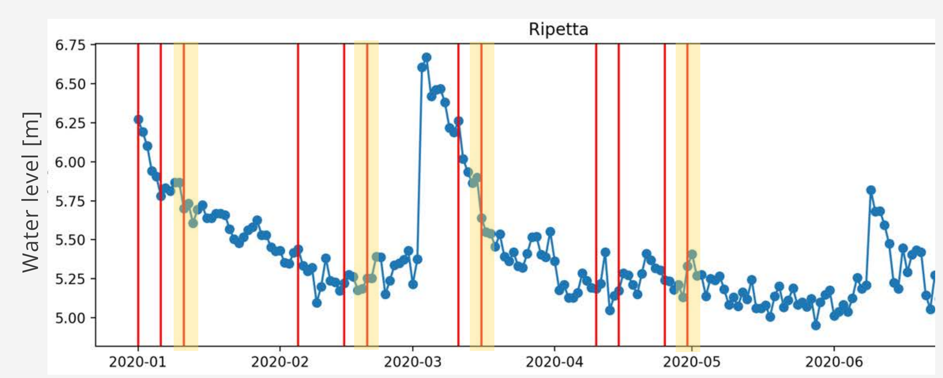
METHOD

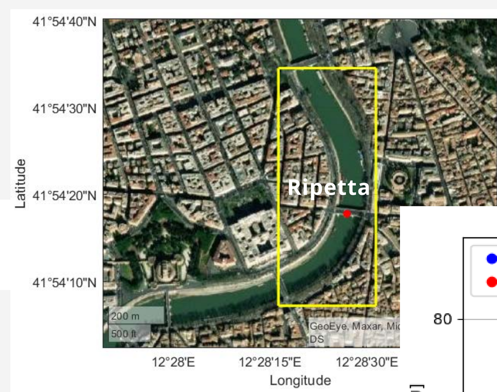
- Analyse satellite data for inland and coastal water quality parameters (Turbidity);
- Compare satellite data with in-situ water level measurements to allow disentangling changes in satellite products caused by actual changes in human activity from other factors as hydrology;
- Support investigation by independent indicators of anthropogenic activity (nutriens, metals, organic and microbiological pollutants);

IRSA CNR Istituto di Ricerca sulle Acque CONSIGLIO NAZIONALE DELLE RICERCHE · IAS

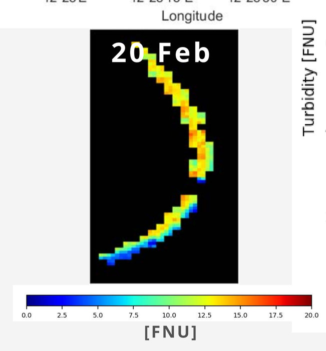
RESULTS - TIBER RIVER

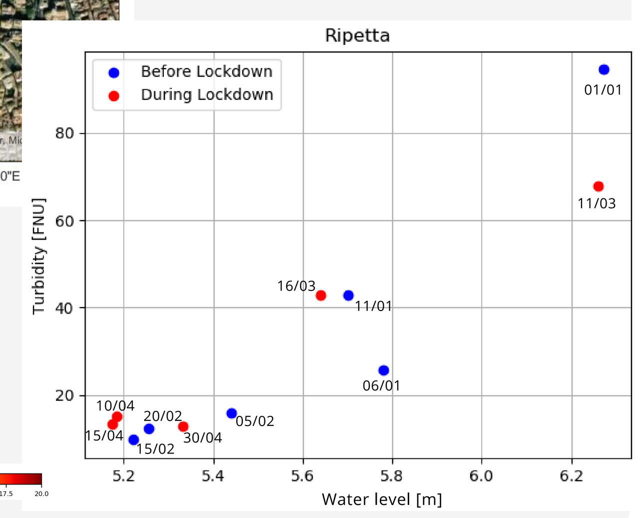






The scatter plot is obtained by averaging turbidty values within a box centered on the gauging station





CONCLUSIONS

Clearly covariation of turbidity and water level values. However, a hysteresis in the relationship between the two variables was expected as an insight of the reduction of anthropogenic impacts on water quality. A more robust inter-annual statistical analysis is required.

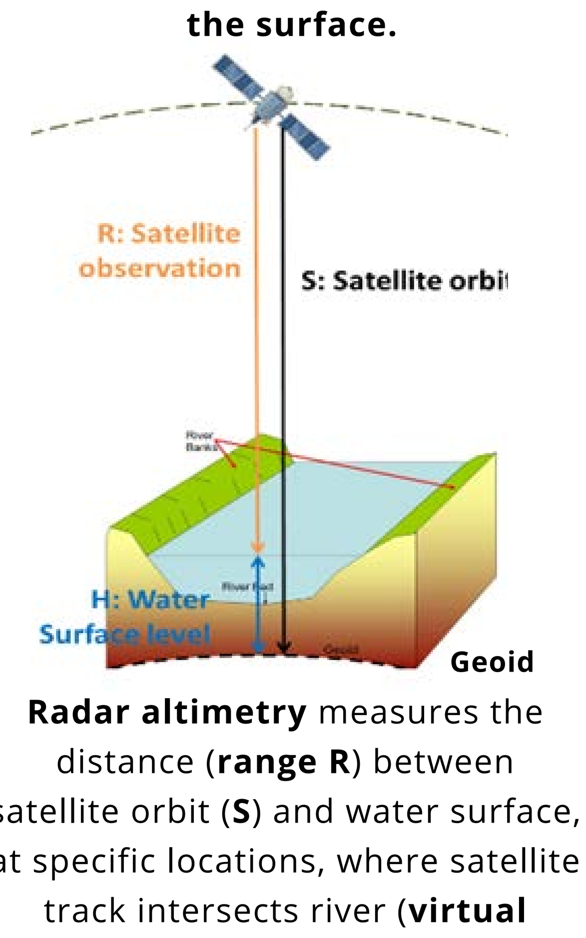
RIVER DISCHARGE ESTIMATION THROUGH SATELLITE RADAR ALTIMETRY

Roma Tre University, Department of Engineering

Research Institute for Geo-Hydrological Protection, National Research Council

EGU General Assembly 2020 · irpi

ACTIVE SENSORS emit a microwave radiation and analyse the return signal that bounces off the surface.



Radar altimetry measures the distance (**range R**) between satellite orbit (**S**) and water surface, at specific locations, where satellite track intersects river (**virtual stations**, **VSs**).

Water level = S - R

METHOD

Satellite-derived water levels (**Podaac, Dahiti, River& Lake, Hydroweb and Theia**) are used with in-situ discharge values to estimate **rating curves (RC):**

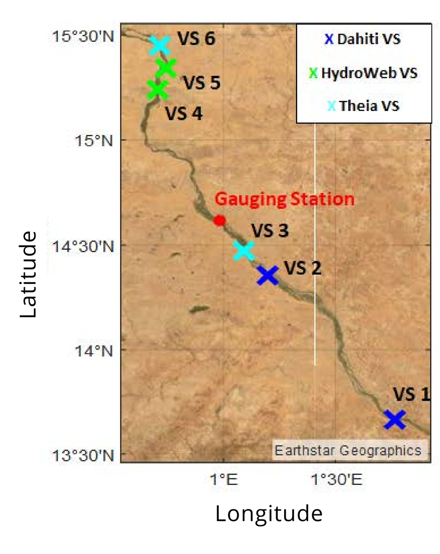
- **Empirical RC**, obtained by fitting a quadratic curve over a data sample of water level and discharge synchronous measurements;
- **Statistical RC** (Tourian et al., 2013), obtained through quantile functions of the two datasets instead of data themselves, allowing to obtain RC even without synchronous observations, common condition with satellite data.

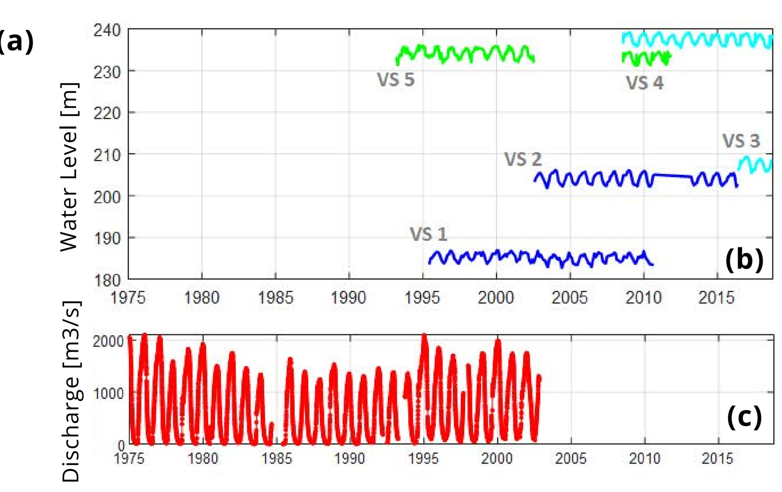
Rating curves are then used to extrapolate discharge data over the whole period of altimetry observations.

CONCLUSIONS

Discharge data can be reconstructed over a period from 14 years (2002-2016) to about 27 years (1993-2019) for those gauging stations where a notable amount of altimetry water level data is available

1

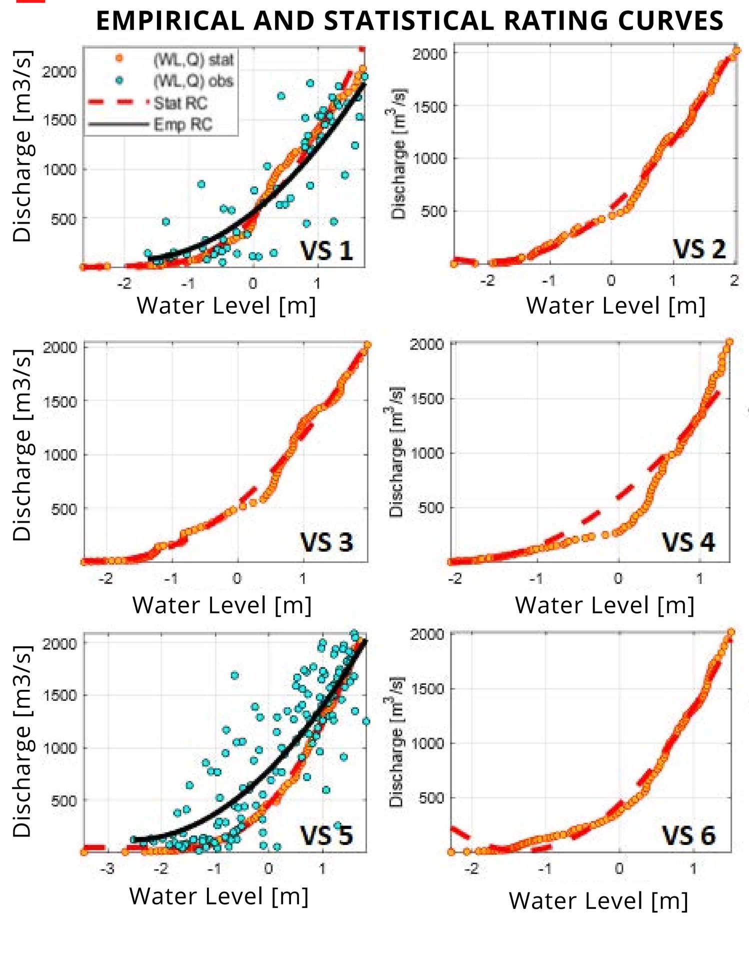




Nearest VSs to Kandaji gauging station (Niger River) (a). Satellite-derived water level time series for each VS (b) In situ discharge observations (c).

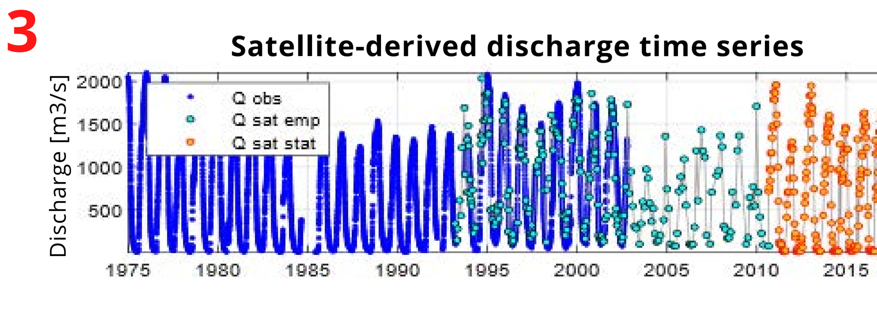
2

EMPIRICAL AND STATISTICAL RATING CURVES



3

Satellite-derived discharge time series



FUTURE PROSPECTS

Riverine transport is the primary direct impact of human activities on coastal environment. However, coastal management plans often lack of systematic process to assess land-based impacts. In such a context, the assessment of **river-sea system connectivity** play a fundamental role. System response to inputs of water and sediments, indeed, reflects river basin configuration and connectivity. Collecting sufficient data to quantitatively determine system connectivity is however extremely time and resource expensive. Satellite EO from multiple sensors provides a powerful tool to define a holistic approach for efficient integrated coastal management.

REFERENCES

1. *Dogliotti, A. I., Ruddick, K. G., Nechad, B., Doxaran, D., & Knaeps, E. (2015). A single algorithm to retrieve turbidity from remotely-sensed data in all coastal and estuarine waters. Remote sensing of environment, 156, 157-168.*
2. *Horner-Devine, A. R., Hetland, R. D., & MacDonald, D. G. (2015). Mixing and transport in coastal river plumes. Annual Review of Fluid Mechanics, 47, 569-594.*
3. *Tourian, M. J., Sneeuw, N., & Bárdossy, A. (2013). A quantile function approach to discharge estimation from satellite altimetry (ENVISAT). Water Resources Research, 49(7), 4174-4186.*
4. *Vanhellemont, Q., & Ruddick, K. (2015). Advantages of high quality SWIR bands for ocean colour processing: Examples from Landsat-8. Remote Sensing of Environment, 161, 89-106.*

CONFERENCE ABSTRACTS

Belloni, R., Camici, S. & Tarpanelli, A. (2020). Discharge estimation and monitoring extreme events by satellite altimetry. European Geoscience Union, General Assembly

Belloni, R., Adduce, C., Falcini, F., Brando, V. E. & Bracaglia M. (2020). A satellite-based analysis of the geomorphological efficiency of river plumes. 1st IAHR Young Professionals Congress