IOCCG Summer Lecture Series 2026

Frontiers in Ocean Optics and Ocean Colour Science

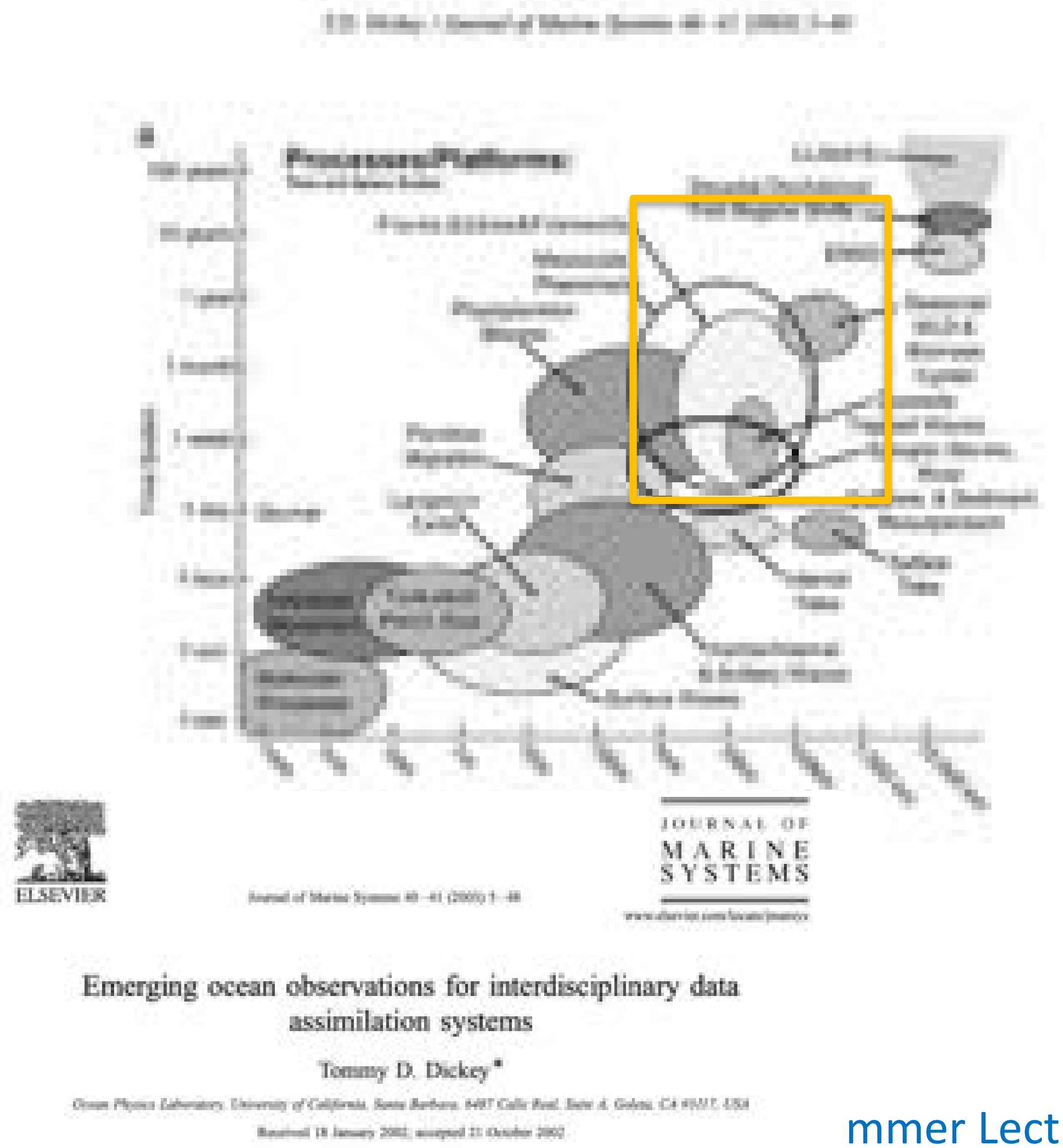
# Fine scale satellite oceanography - applications to turbid water

**Vittorio E. Brando**

**CNR-ISMAR, Rome, Italy**

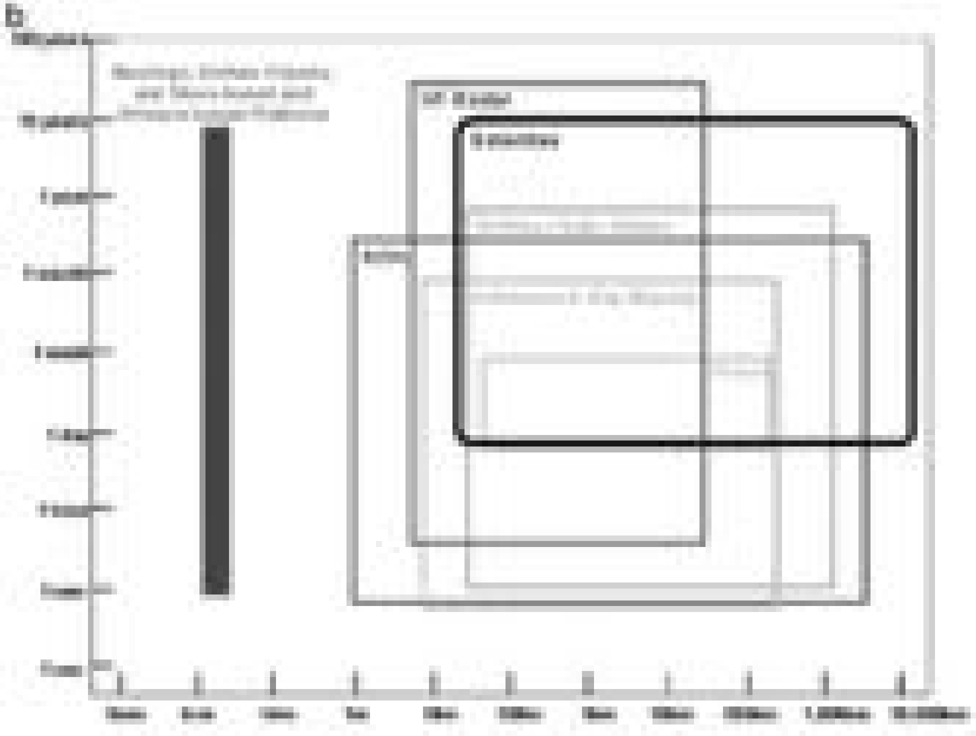
Venice, Italy - 9 July 2026

# Processes scales and observation resolutions




Time-horizontal space scale diagram illustrating several physical and biological processes in ovals.

and Rectangles indicate the approximate horizontal temporal sampling domain capabilities of several platforms at in **2002**.



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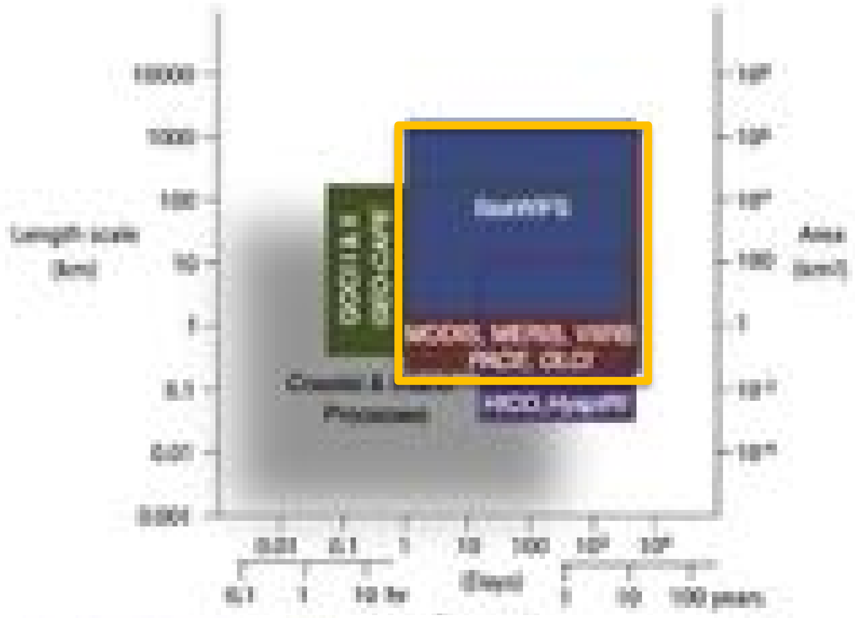



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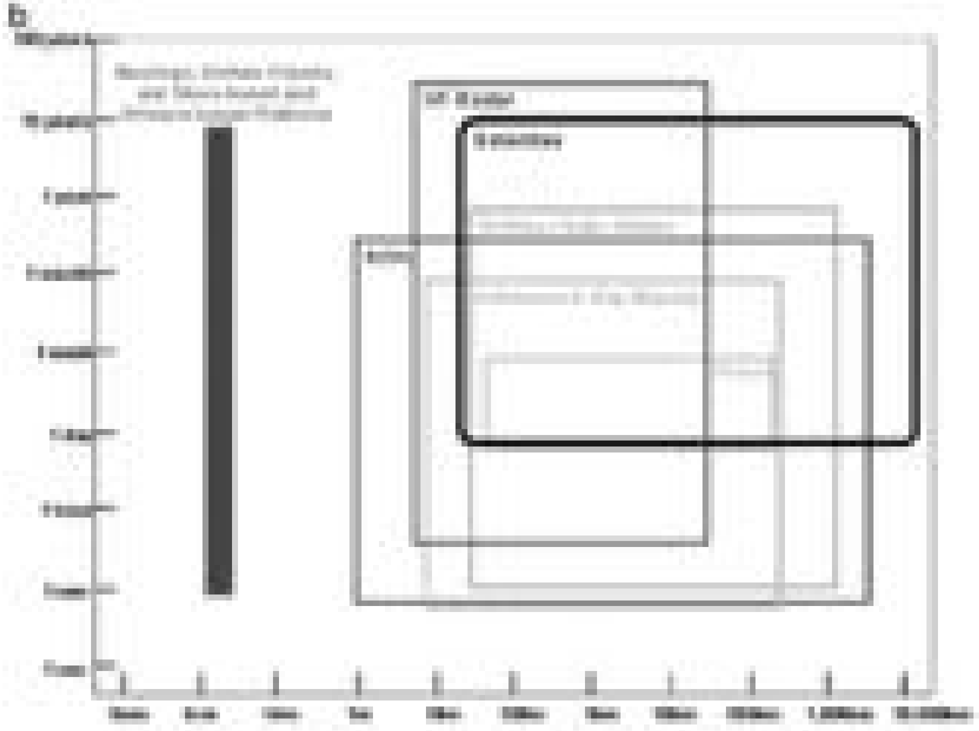

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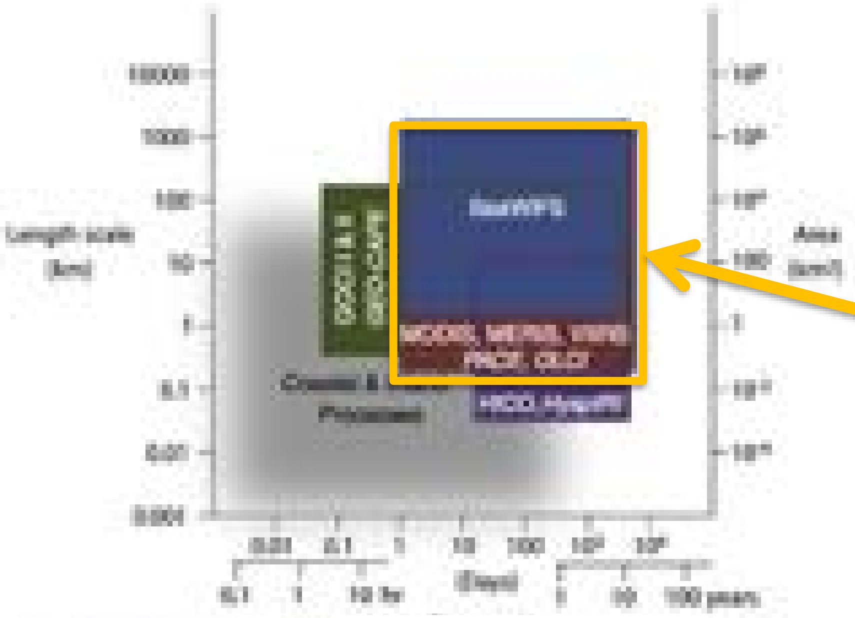



Remote Sensing of Environment 160 (2015) 15–30

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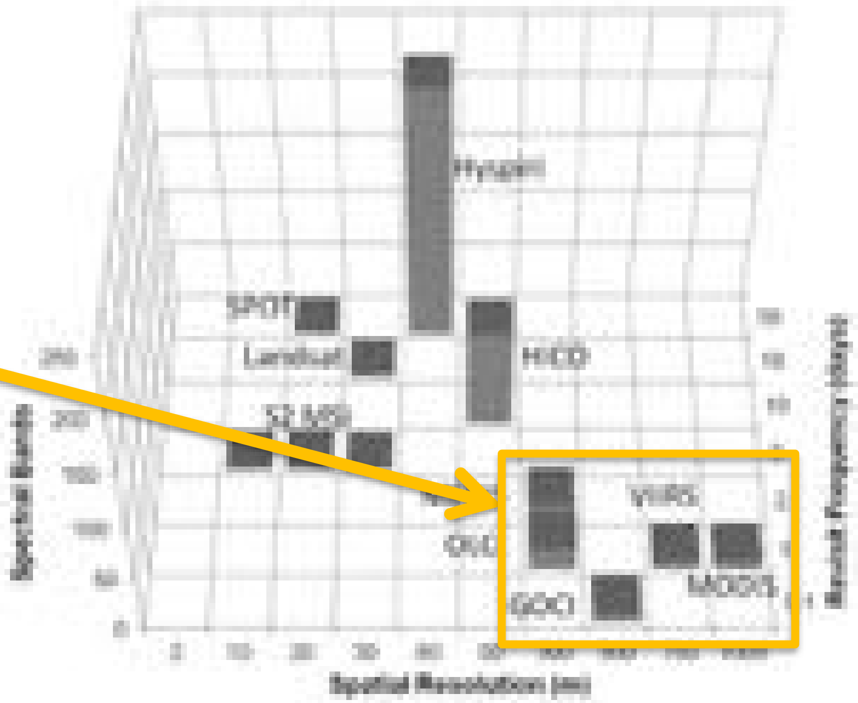



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Measuring freshwater aquatic ecosystems: The need for a hyperspectral global mapping satellite mission

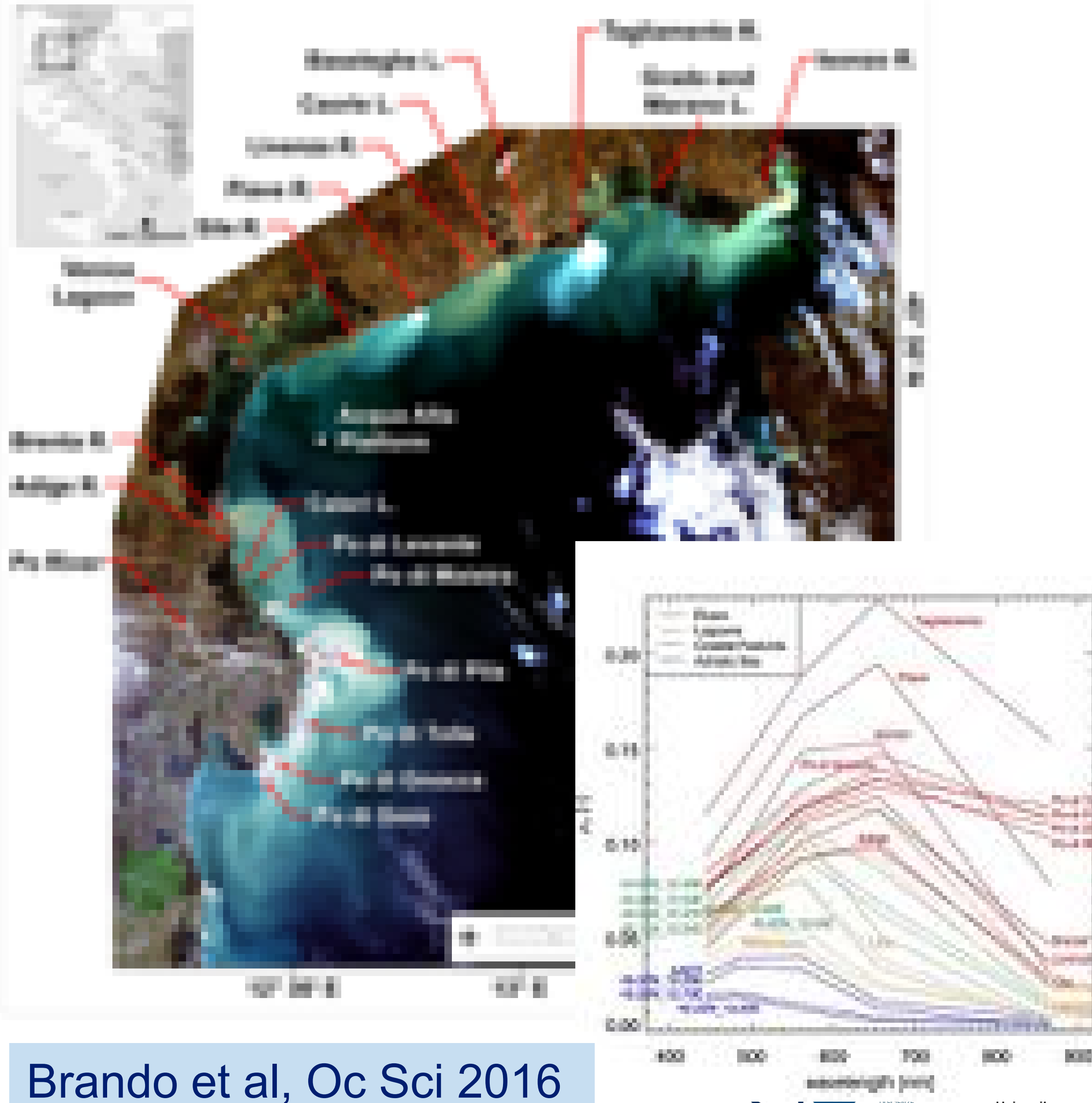

Erin Lee Hestir [a,b,*], Vittorio E. Brando [a,c], Mariano Bresciani [c], Claudia Giardino [c], Erica Matta [c], Paolo Villa [c], Arnold G. Dekker [a]

# Processes scales and observation resolutions

Inland and coastal waters are defined as “optically complex” as they are a mixture of:

- optically deep waters (with gradients of clear, turbid and productive waters)
- and optically shallow (with varying bottom visibility and gradients due to substrate type e.g. seagrass, corals  and status)

Schroeder et al., 2014



Brando et al, Oc Sci 2016

# Spatial resolution


You are here!

# Spatial resolution


You are here!

# Spatial resolution

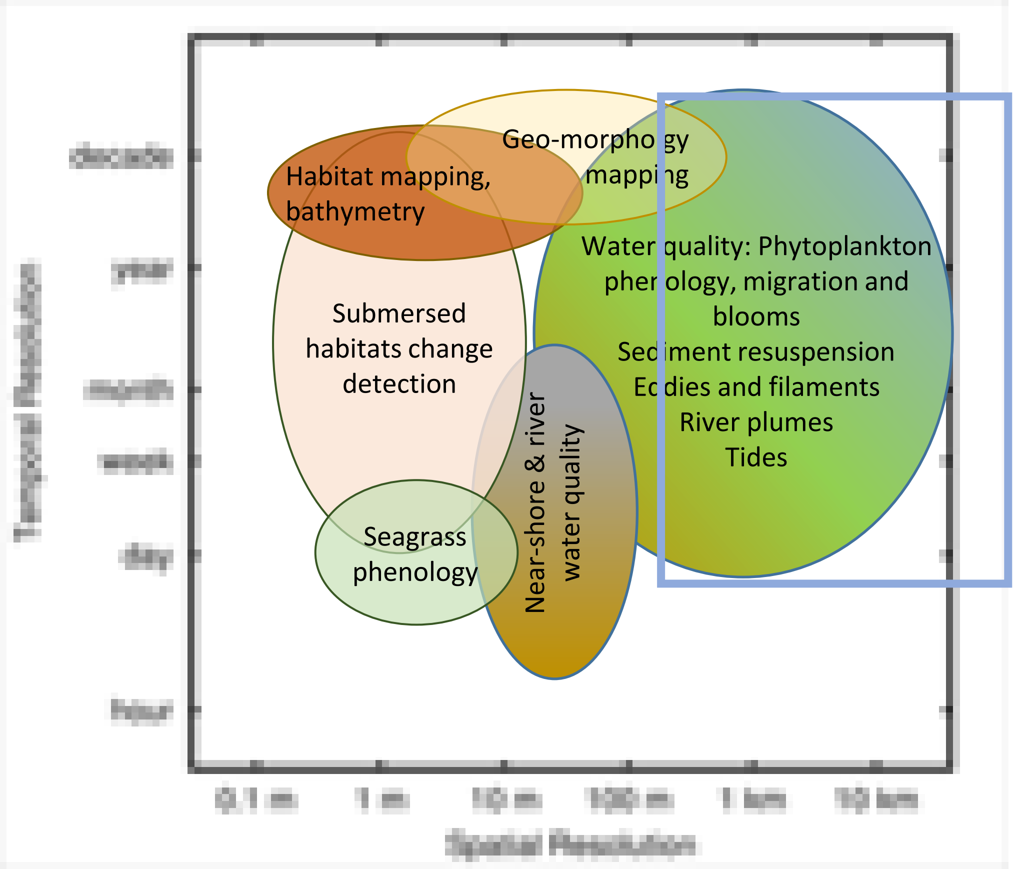

You are here!

# Spatial resolution


You are here!

# Processes scales and observation

Focus on inland/coastal processes




Focus on inland/coastal processes
Giardino and Brando, based on Hedley et al., RSE 2018 - *Modified*

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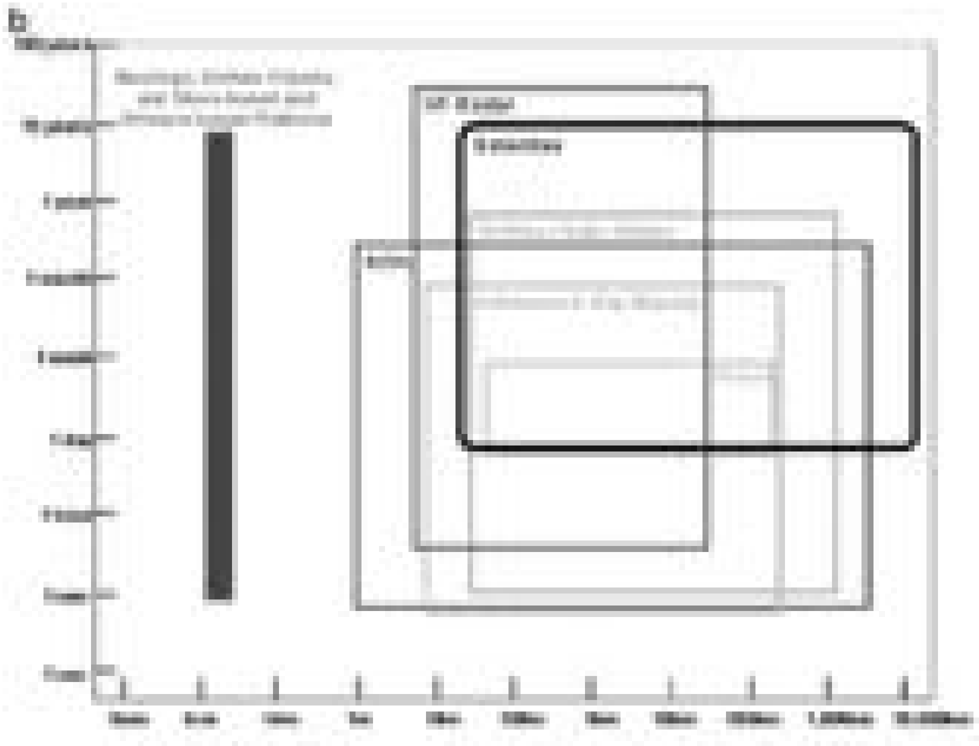


# Processes scales and observation: focus on inland/coastal processes

## Ocean Imagers

- ✓ Many spectral bands
- ✓ High radiometric fidelity
- ✓ Frequent revisit time (~daily)
- × Large pixels (300 m – 1 km)

## Land Imagers (< 2014)

- ✓ Small-medium pixels (10-30 m)
- × Just a few spectral bands
- × Lower fidelity
- × Low revisit time (16 days)

# Processes scales and observation: focus on inland/coastal processes

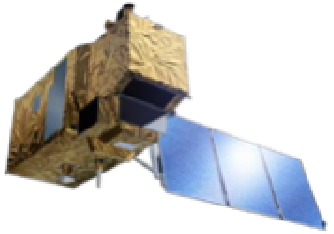
## Ocean Imagers

- ✓ Many spectral bands
- ✓ High radiometric fidelity
- ✓ Frequent revisit time (~daily)
- × Large pixels (300 m – 1 km)

## Land Imagers (S2+L8/9)

- ✓ Small-medium pixels (10-30 m)
- ✓ better revisit time (5 days or less with S2+L8/9)
- ✓ improved fidelity
- × Limited spectral bands

# Sentinel-2 Mission Key Features



Optical multi-spectral sensor for monitoring land & coastal areas

- Geometrical revisit: 5 days (at the Equator) with 2 satellites
- Spectral Bands: 13 spectral bands in the VNIR and SWIR
- Spatial Resolution: 10 m, 20 m, 60 m
- Nominal swath: 290 km, at 786 km altitude
- Local Time: 10:30 a.m. descending node
- Data Access: Free & open for a large range of applications

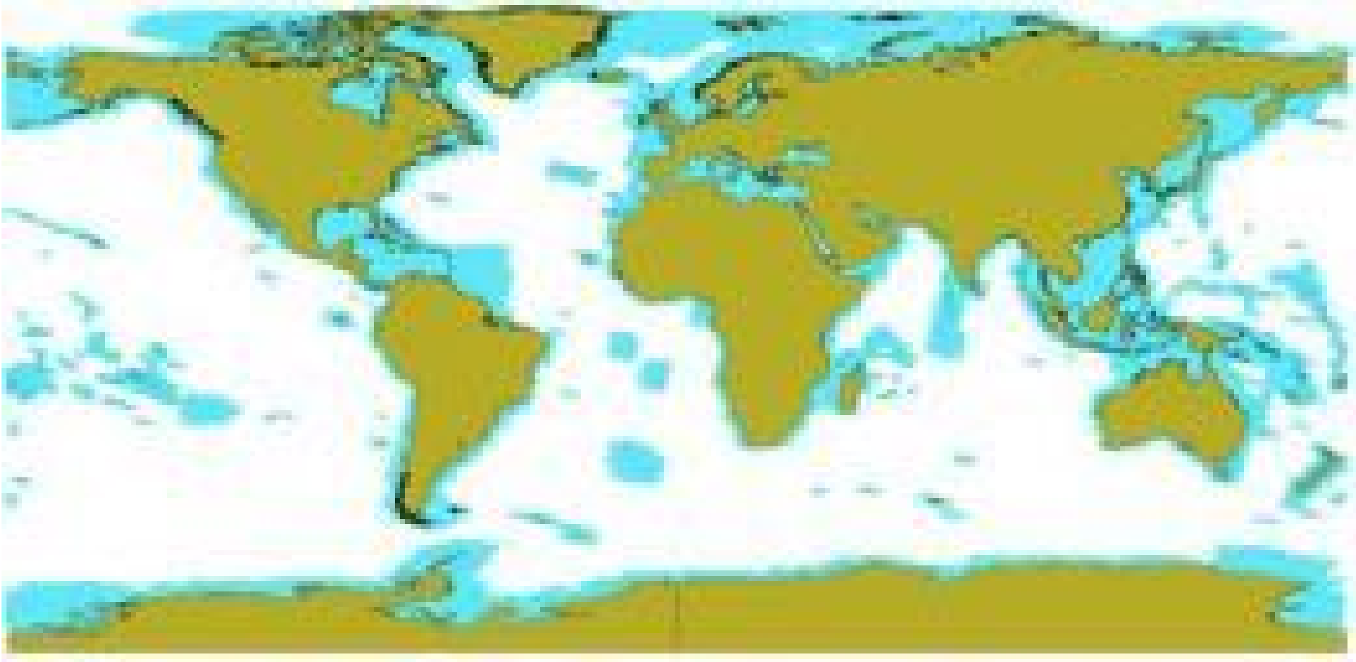
Credits: Ferran Gascon (ESA)

# Sentinel-2 coverage

Systematic coverage over the following areas:

- all continental land surfaces (including inland waters) between latitudes 56° South and 82.8° North
- all coastal waters up to 20 km from the shore
- all islands greater than 100 km2
- all EU islands
- the Mediterranean Sea
- all closed seas (e.g. Caspian Sea).

baseline scenario of MSI acquisitions (two satellites in orbit).

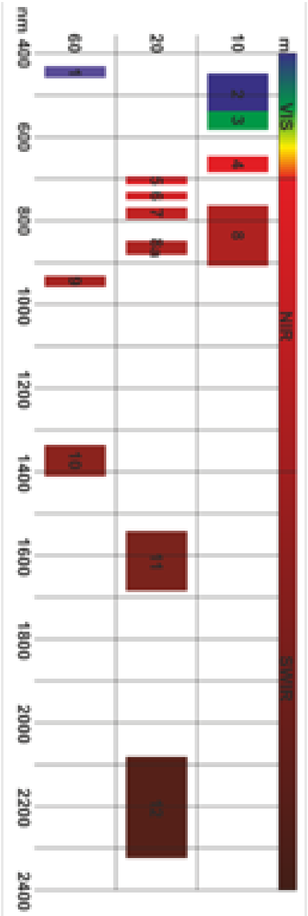


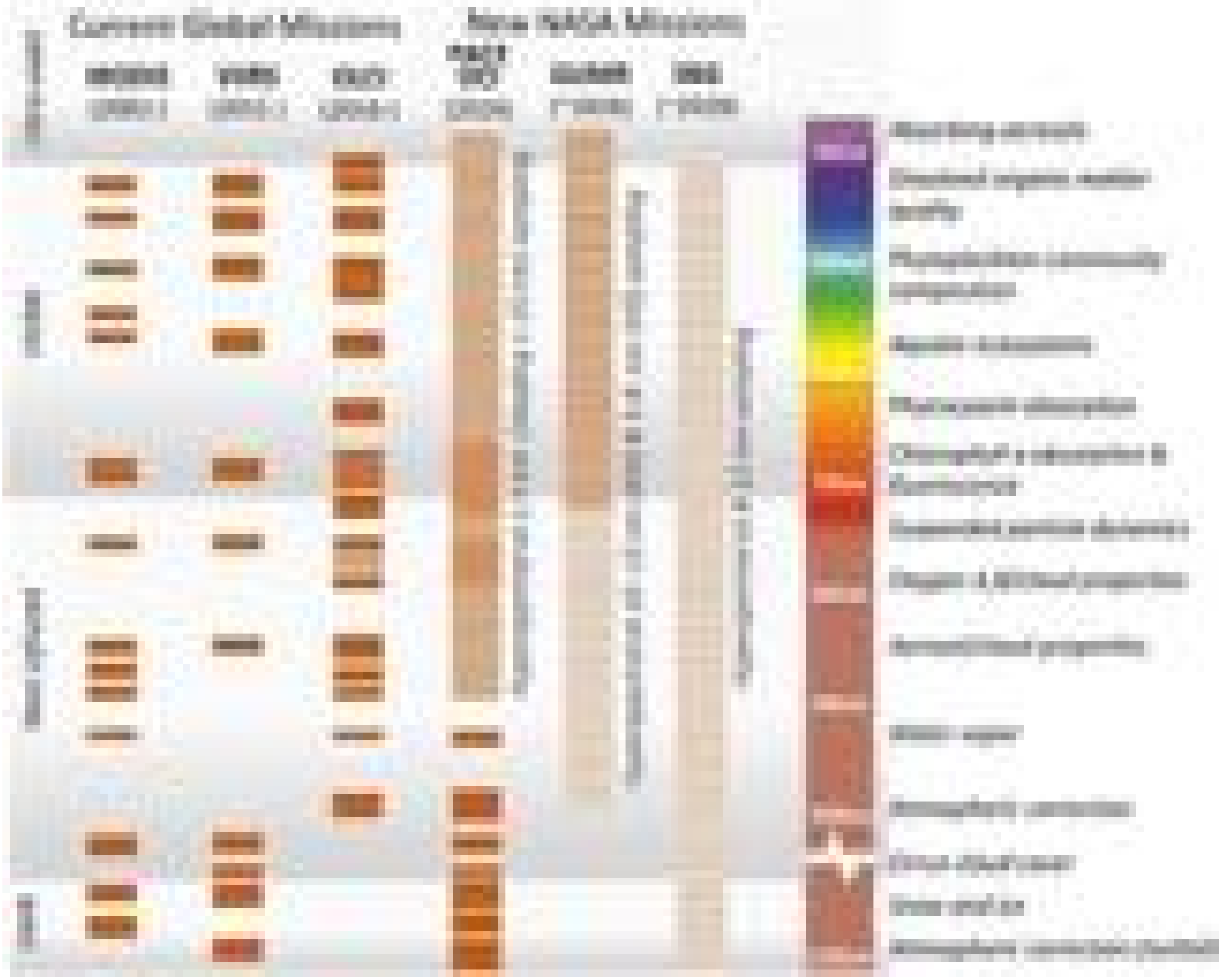
Water masses observed by Sentinel-2 are 37% since 2022

# Spectral resolution

- Ocean colour specific sensors always designed to capture key parts of ocean colour spectral variability.
- Other “non-OC” sensors have fewer/wider bands that can make their usage more challenging

S2/MSI

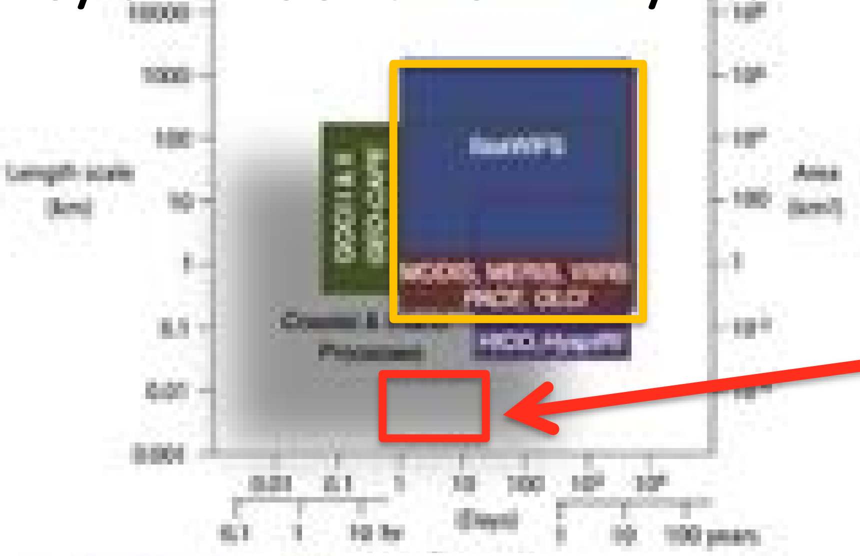


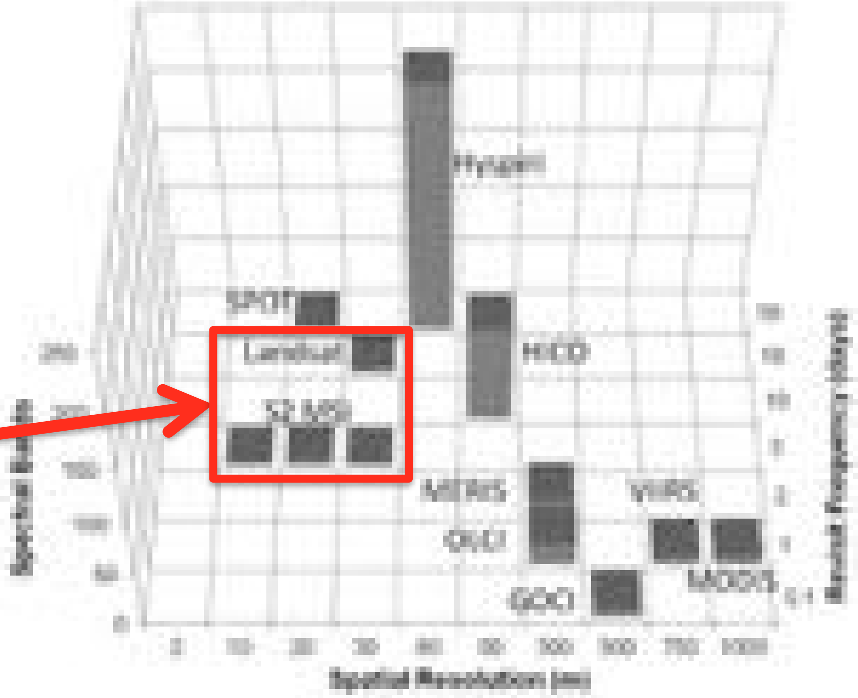



Dierssen et al., 2023

# Processes scales and observation: focus on inland/coastal processes

## New "observation class":
## Landsat-8+9/OLI + Sentinel-2AB/MSI

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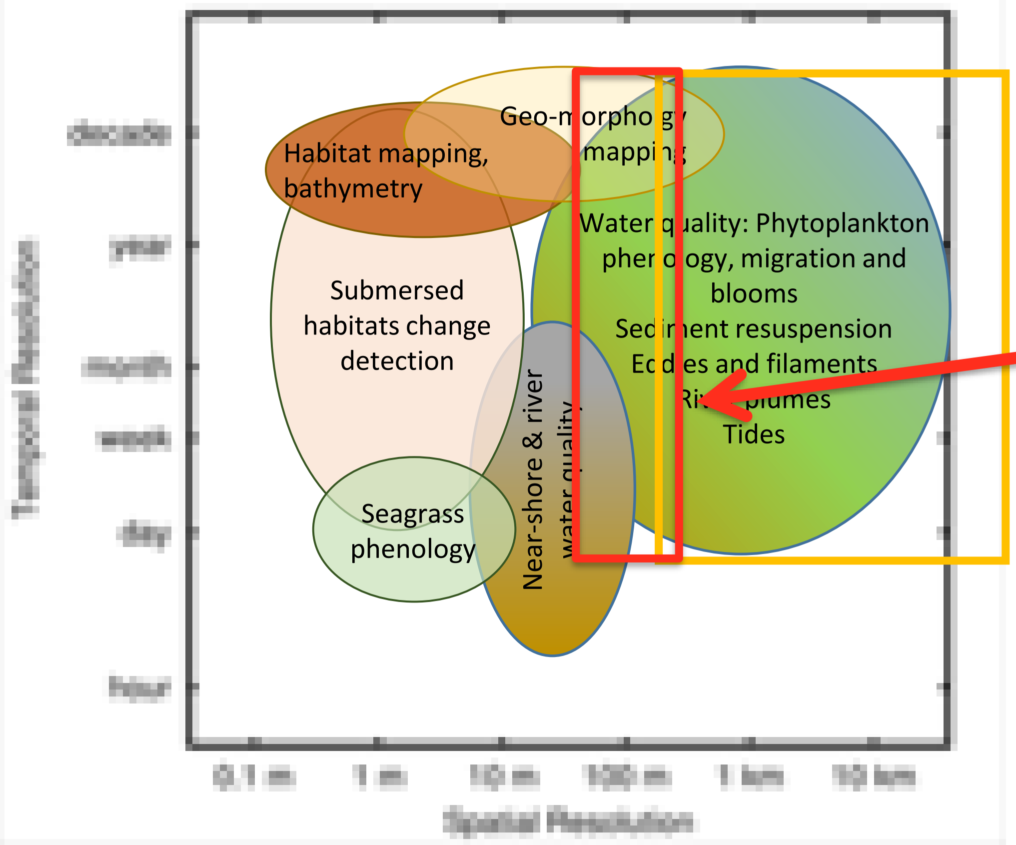


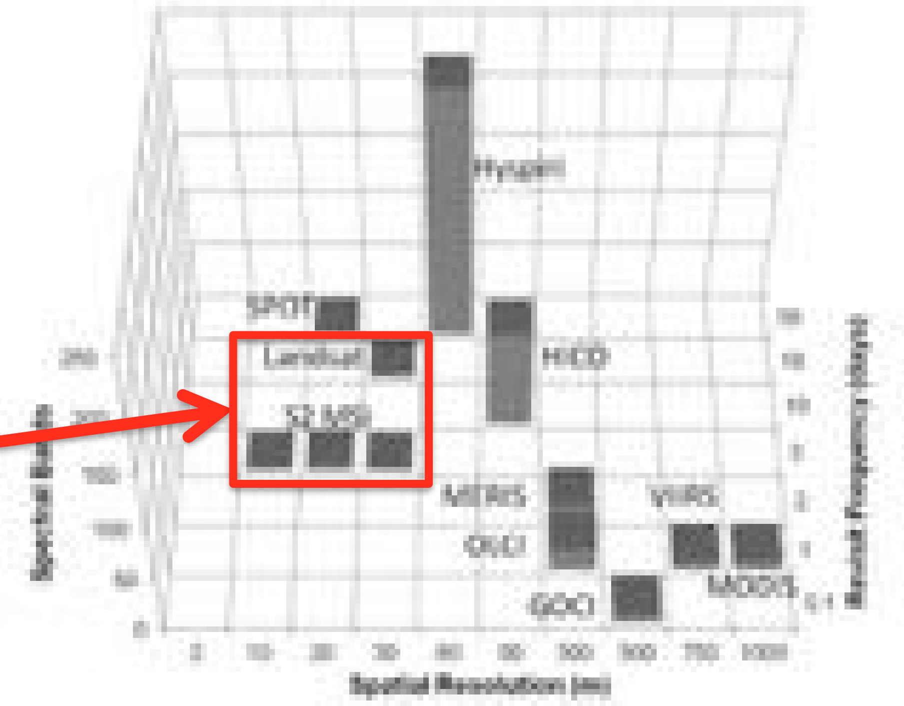


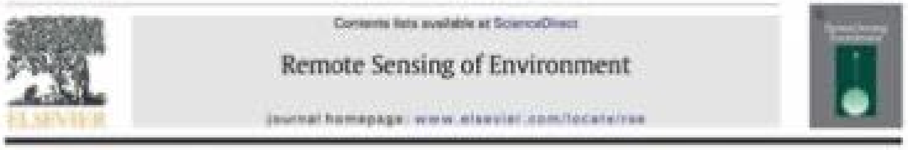
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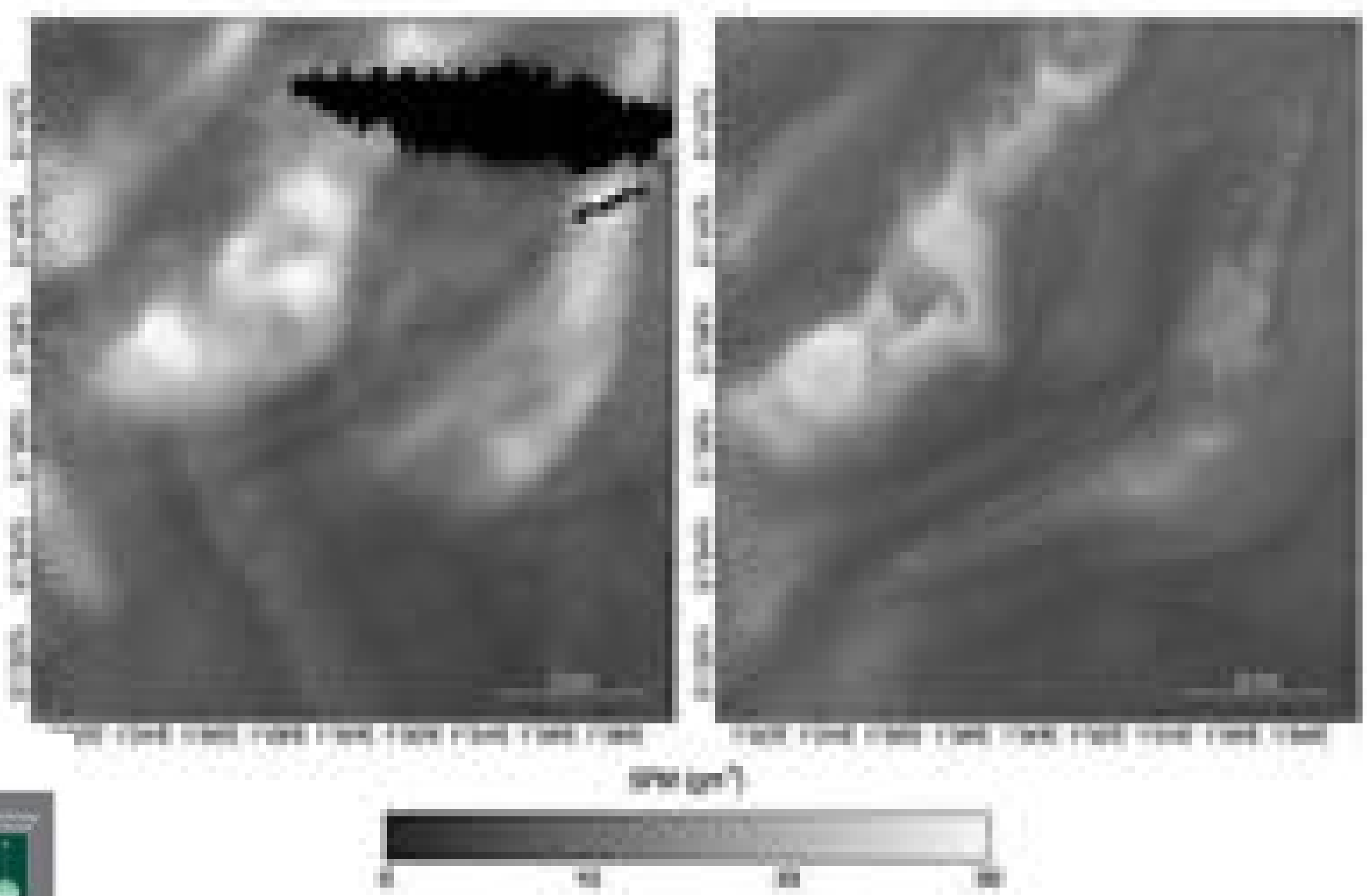
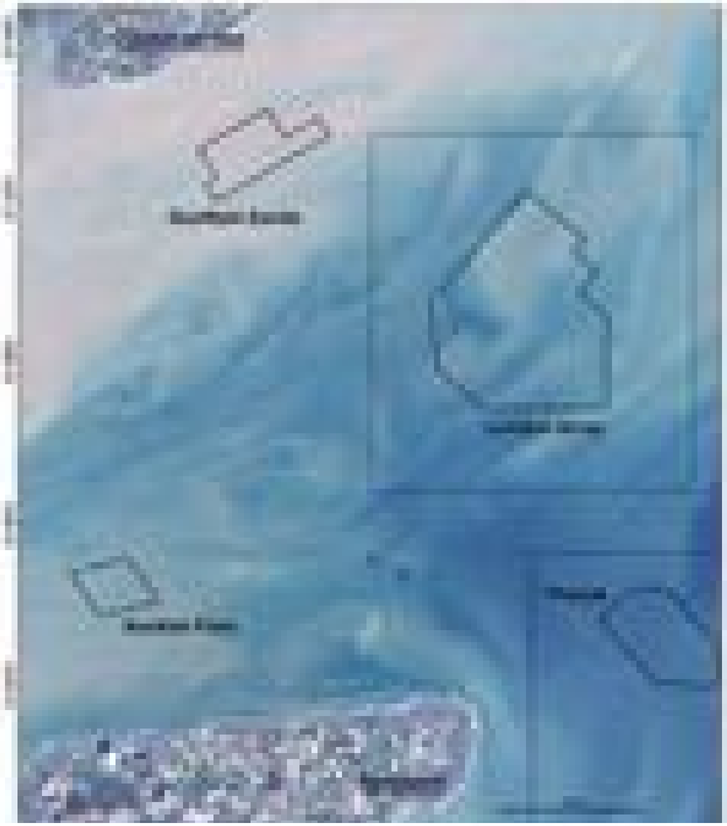


Remote Sensing of Environment

Turbid wakes associated with offshore wind turbines observed with Landsat 8

Quinten Vanhellemont *, Kevin Ruddick

# Processes scales and observation: focus on inland/coastal processes



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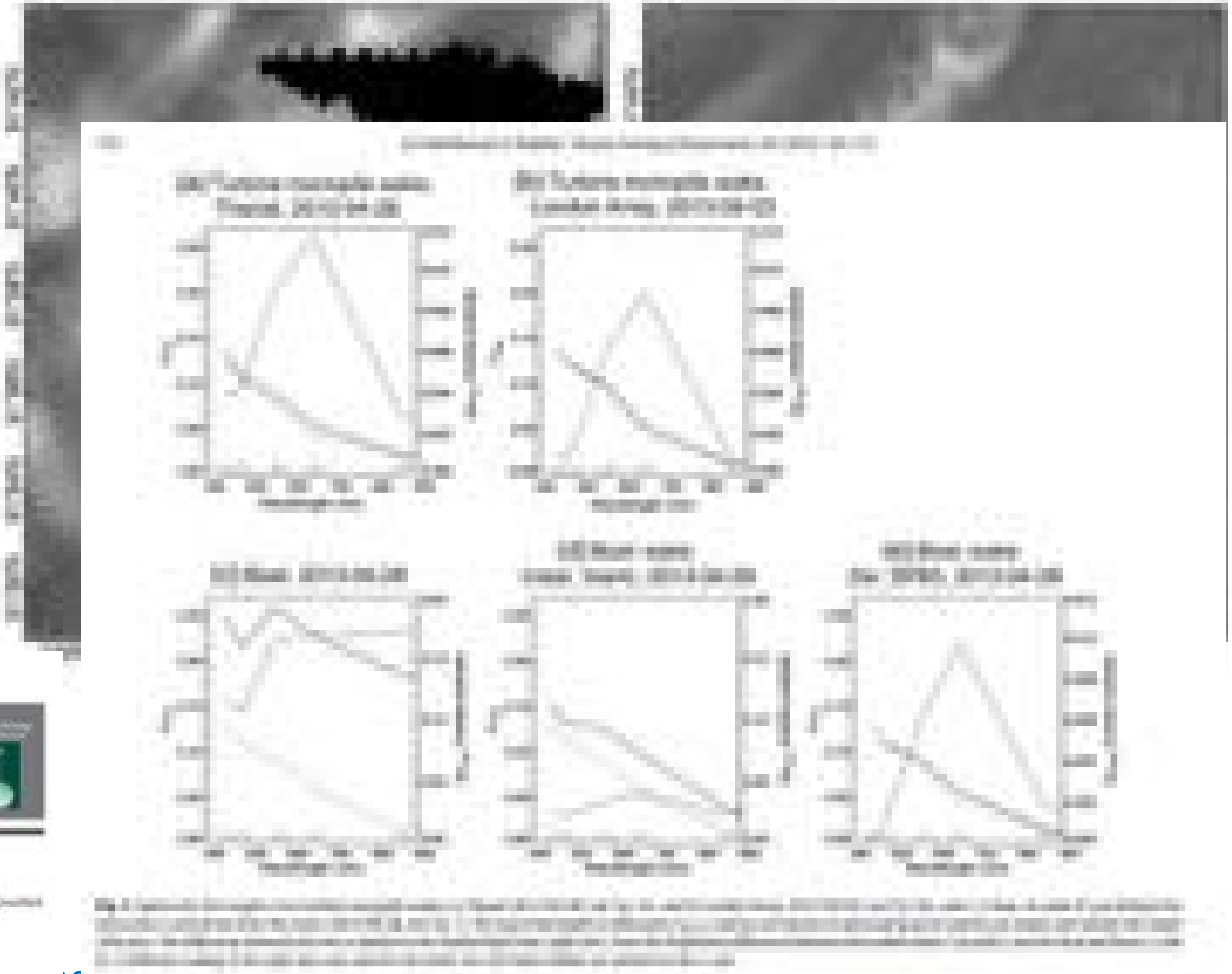


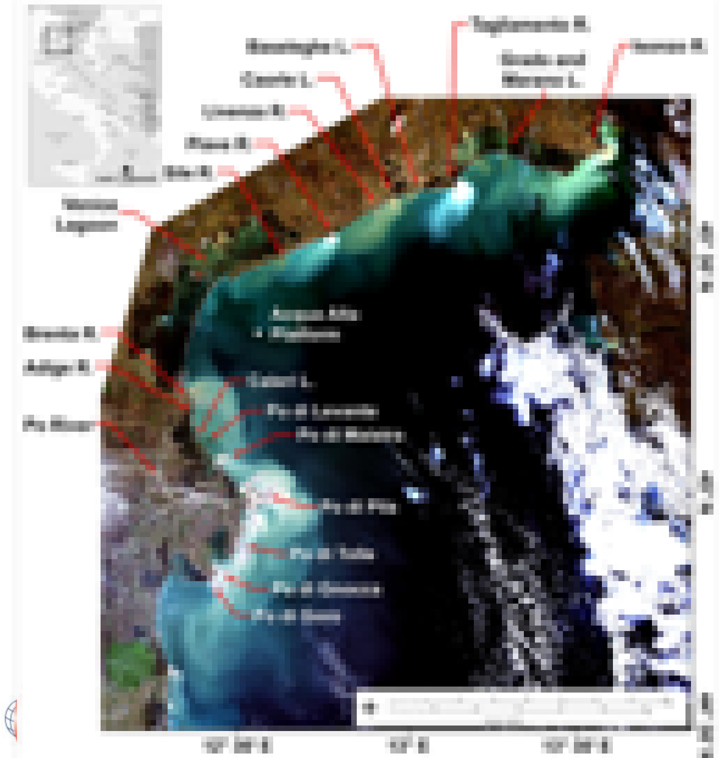
# Processes scales and observation: focus on inland/coastal processes

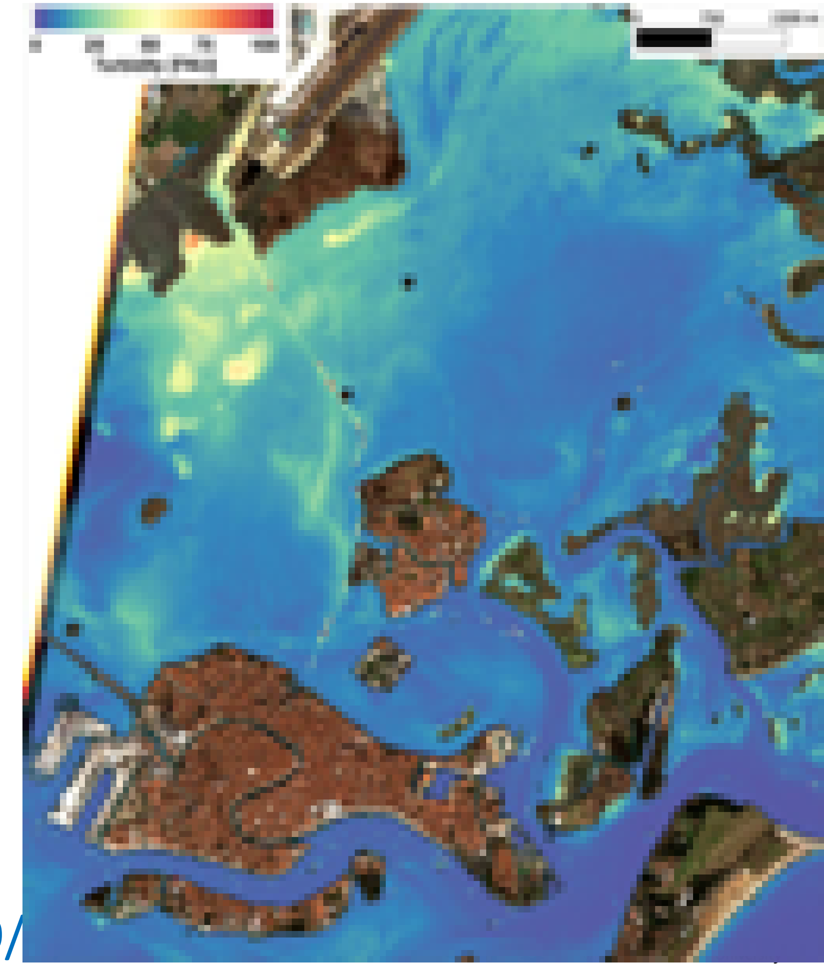
Two studies to showcase the use of the New “observation class” data (Landsat-8+9/OLI + Sentinel-2ABC/MSI) to describe fine scale oceanography processes

- Landsat-8/OLI :

  River Plume Interactions in the Northern Adriatic Sea
- Sentinel-2AB/MSI:

  Water transparency in the Venice Lagoon





# Using High Resolution Satellite Turbidity And Sea Surface Temperature imagery to Describe River Plume Interactions in the Northern Adriatic Sea

Part of this work was carried out as part of VEB's Senior Marie Curie Fellowship at CNR IREA in Milan supported by the RITMARE Flagship Project and the European Union (FP7-People Co-funding of Regional, National and International Programmes, GA no. 600407)

This study was also supported by the RITMARE Flagship Project, the Italian Space Agency (CLAM-PHYM project, contract no. I/015/11/0) and the EU FP7-SPACE INFORM Project (GA no 606865).

Ritmare

CNR Consiglio Nazionale delle Ricerche

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agenzia spaziale italiana

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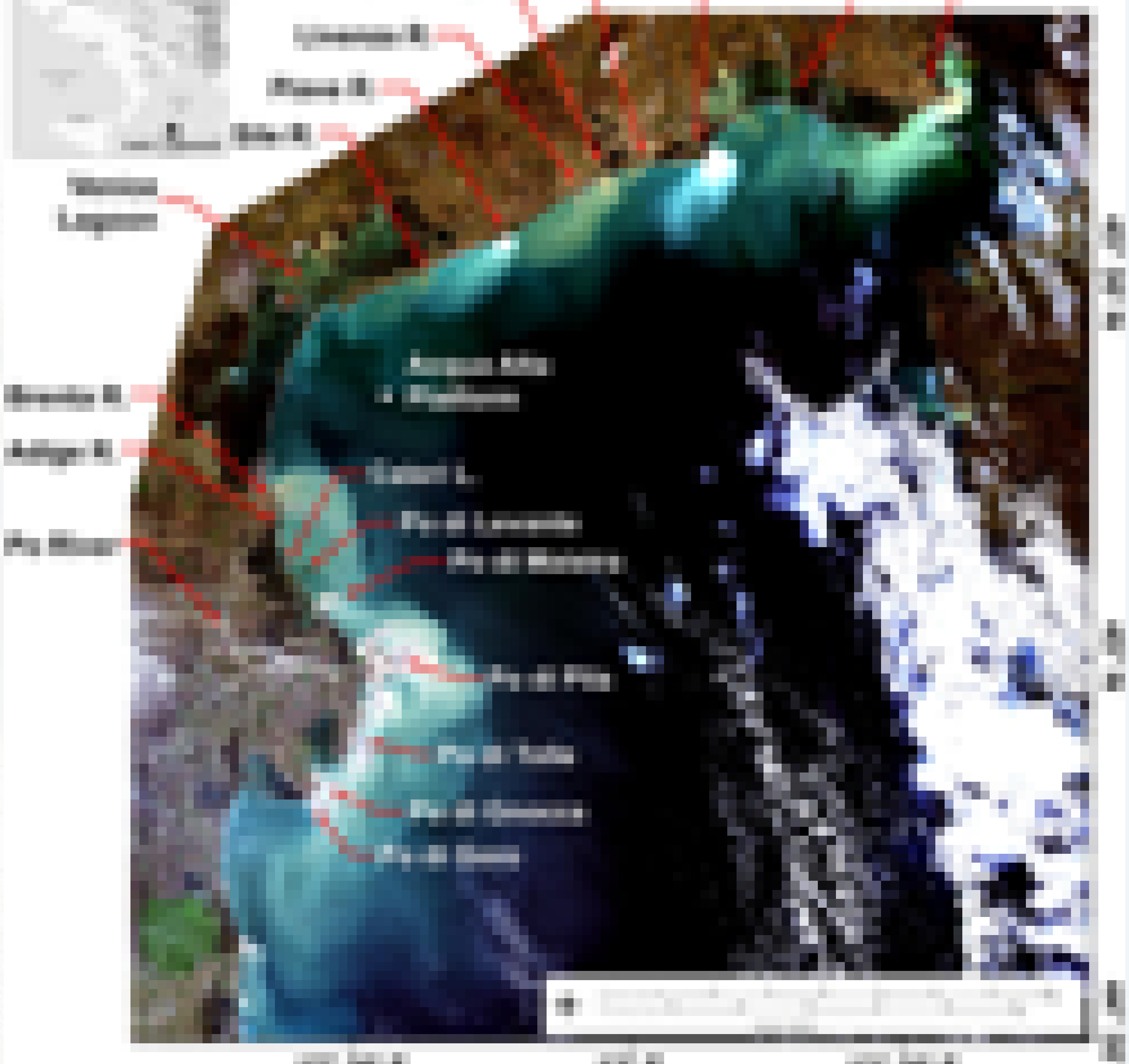


**Landsat 8 OLI imagery 19 November 2014**


Landsat 8
OLI imagery
19 November
2014

Ocean Sci., 11, 909–920, 2015
www.ocean-sci.net/11/909/2015/
doi:10.5194/os-11-909-2015



Ocean Science EGU

# High-resolution satellite turbidity and sea surface temperature observations of river plume interactions during a significant flood event


V. E. Brando, F. Braga, L. Zaggia, C. Giardino, M. Bresciani, E. Matta, D. Bellafiore, C. Ferrarin, F. Maicu, A. Benetazzo, D. Bonaldo, F. M. Falcieri, A. Coluccelli, A. Russo, and S. Carniel

# Outline of this presentation

- Background
  - North Adriatic Sea (NAS)
  - Plume morphologies
- Methods
  - Landsat 8 OLI & TIRS
- Results
  - NAS river plumes in a significant flood
  - Po River plume structure variability
- Summary

# References

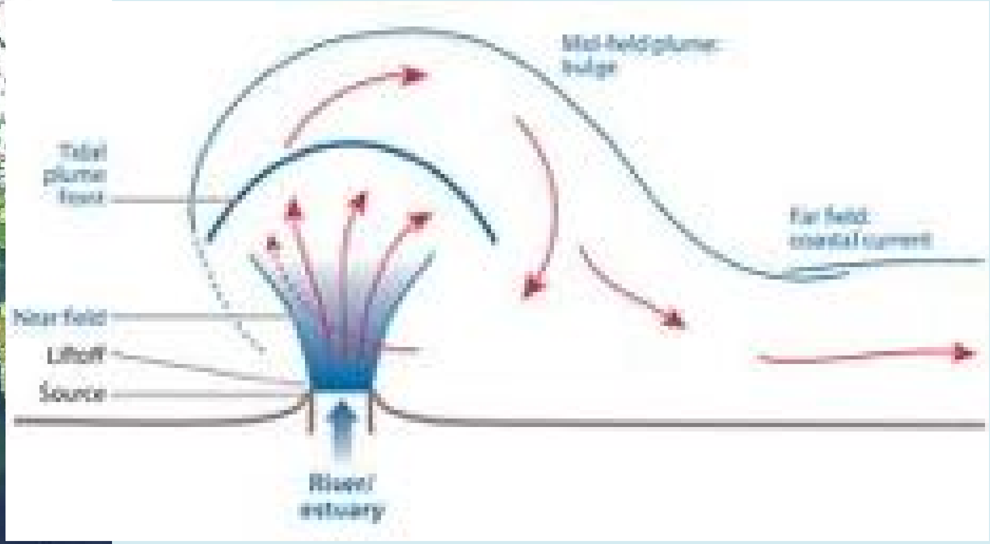

- Brando, V.E., F. Braga, L. Zaggia, C. Giardino, M. Bresciani, E. Matta, D. Bellafiore, C. Ferrarin, F. Maicu, A. Benetazzo, D. Bonaldo, F.M. Falcieri, A. Coluccelli, A. Russo, and S. Carniel, *High-resolution satellite turbidity and sea surface temperature observations of river plume interactions during a significant flood event.* Ocean Sci., 2015. **11**(6): p. 909-920.
- Braga, F., L. Zaggia, D. Bellafiore, M. Bresciani, C. Giardino, G. Lorenzetti, F. Maicu, C. Manzo, F. Riminucci, M. Ravaioli, and V.E. Brando, *Mapping turbidity patterns in the Po River prodelta using multi-temporal Landsat 8 imagery.* Estuarine, Coastal and Shelf Science, 2017. **198**: p. 555-567.
- Manzo, C. , F. Braga, L. Zaggia, Brando, V.E., C. Giardino, M. Bresciani, C. Bassani, *Spatio-temporal analysis of pro delta dynamics by means of new satellite generation: the case of Po River by Landsat-8 data*. International Journal of Applied Earth Observation and Geoinformation, 2018
- Giardino, C., M. Bresciani, F. Braga, I. Cazzaniga, L. De Keukelaere, E. Knaeps and V. E. Brando. *Bio-Optical Modelling of Total Suspended Solids.* Bio-Optical Modelling and Remote Sensing of Inland Waters. D. Mishra, I. Ogashawara and A. Gitelson Editors. 2017. Elsevier. 129-156.

# Background
# The North Adriatic Sea (NAS)

- NAS is presently the area, within the Mediterranean Sea, where river plumes show the most significant influence
- NAS is a river-dominated and very dynamic coastal system with a close coupling between the physical forcings and riverine inputs
- The Po, Adige and Brenta rivers produce almost a single freshwater plume that can influence the sub-basin and the whole basin
- The plume can drive the evolution of the biogeochemistry of this marine ecosystem, both on interannual and multidecadal scales.

MODIS Aqua
6-6-2013

# River plume morphologies




The river plume structures can be described in terms of four regions characterized by different dominant dynamical balances:

(1) the **source region**, where the buoyancy and momentum that initiate a river plume are determined by estuarine processes;

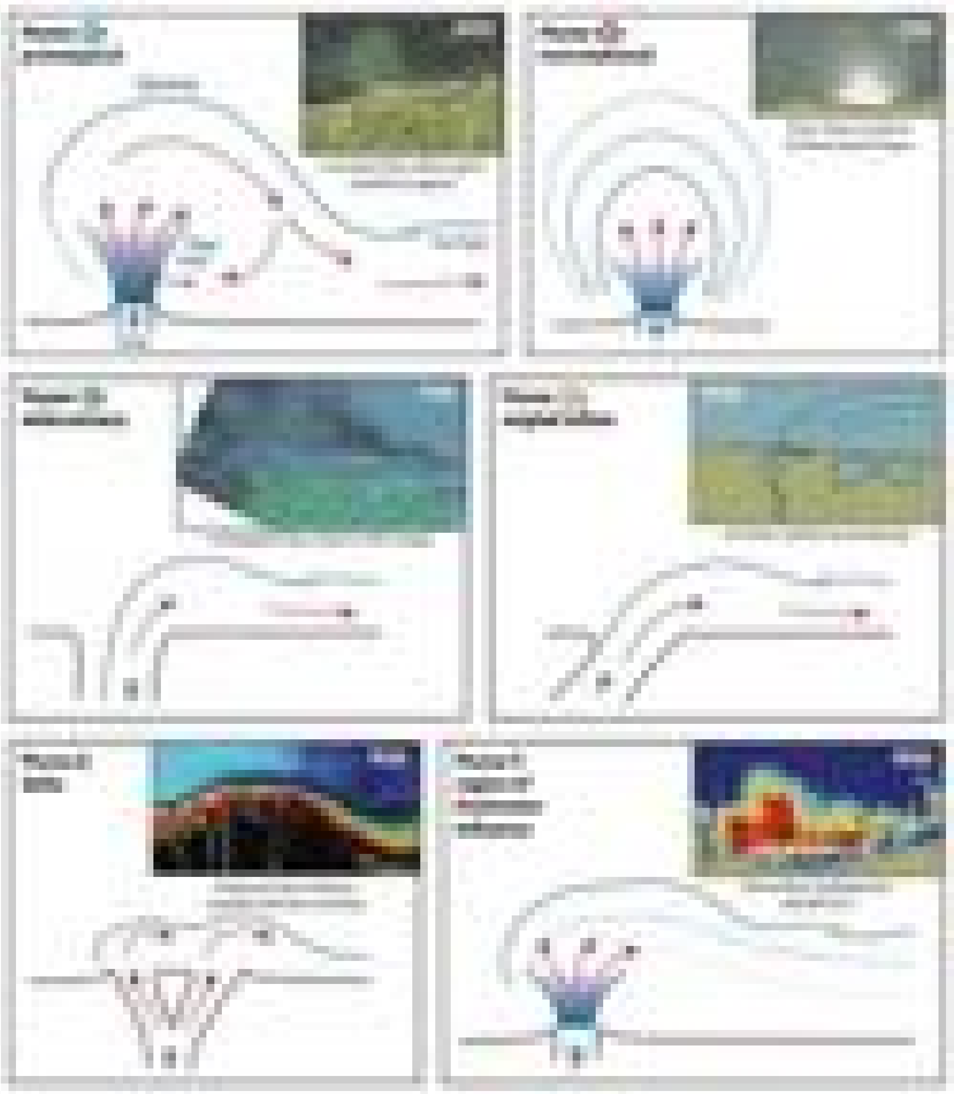
(2) a jet-like **near-field** region of initial plume expansion;

(3) an unsteady, anticyclonic eddy circulation, i.e. a "**bulge**", that accumulates a fraction of the river discharge; and

(4) a region beyond where the plume water has lost all memory of the inflow momentum but is still distinct from the ambient receiving water, i.e. a **far-field** plume or coastal current.

Horner-Devine, A. R., Hetland, R. D., and MacDonald, D. G.: Mixing and Transport in Coastal River Plumes, Annu. Rev. Fluid Mech, 47, 569–594, doi:10.1146/annurev-fluid-010313-141408, 2015.

# River plume morphologies



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(4) a region beyond where the plume water has lost all memory of the inflow momentum but is still distinct from the ambient receiving water, i.e. a **far-field** plume or coastal current.

**Based on the presence/absence of these four dynamical regions, Horner-Devine et al. (2015) proposed classification of six plumes' morphologies (plumes A-F).**

# Methods: Landsat 8 OLI & TIRS

- **OLI** data were converted into ρw (water-leaving radiance reflectance) with **ACOLITE** (Atmospheric Correction for OLI "lite").
  - automatic method for atmospheric correction designed specifically for OLI over turbid waters (Vanhellemmont and Ruddick, 2014, 2015)
  - **per-pixel variable aerosol type** was determined from the ratio of reflectances in the SWIR bands (1609, 2201 nm)
  - Pahlevan et al. (2014) **radiance gains** for radiometric calibration.
- ρw converted into **Turbidity (T)** expressed in formazin nephelometric unit (FNU) – (**Dogliotti et al. 2015**).
  - At higher T values, ρw (655 nm) starts to saturate while ρw (865 nm) still linearly increases with T.
  - switching scheme to avoid saturation at 655 nm and retrieve T accurately in the 1– 1500 FNU range.
- **SST** values were retrieved from top-of-atmosphere brightness temperature in the **TIRS** band 10 (10.9 µm) with a radiative-transfer-based atmospheric correction (Barsi et al., 2005, 2014).
- **TIRS 100 m** pixels are resampled and co-aligned with the **OLI 30 m** data.

# Methods: Landsat 8 OLI & TIRS

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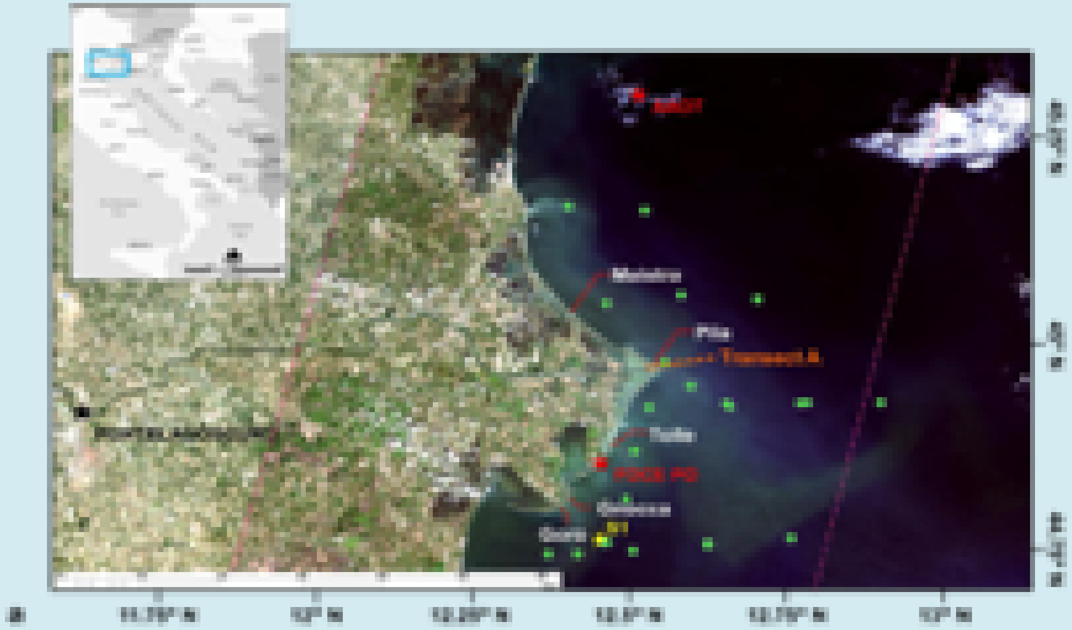
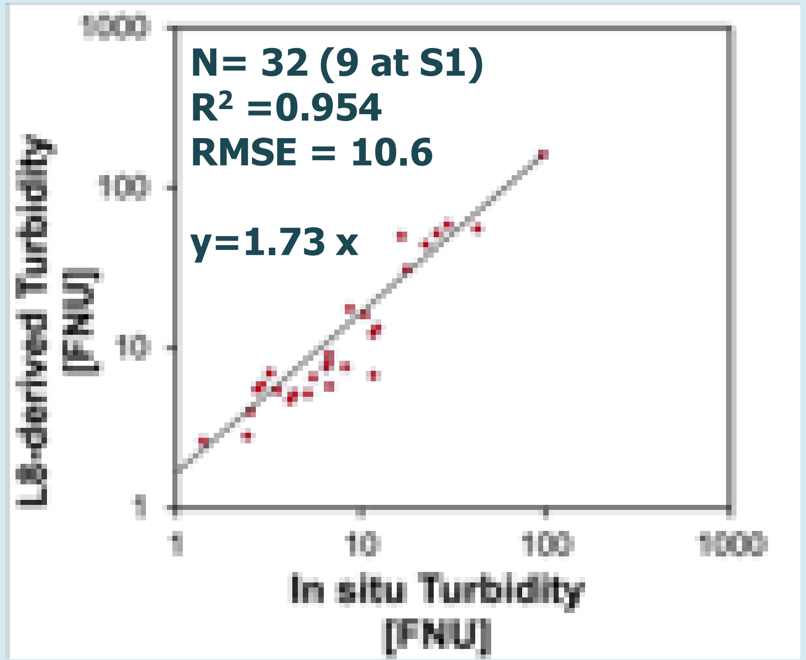


Braga et al, 2017 ECSS



# Methods: coupled ocean-wave model

- Operational implementation in the northern Adriatic basin of the Coupled Ocean–Atmosphere– Wave–Sediment Transport (**COAWST**, Warner et al., 2008)
  - Regional Ocean Modeling System **(ROMS**) and the Simulating Wave Nearshore (**SWAN**) model are two-way fully coupled (Russo et al.,2013).
  - horizontal spacing of **0.5 km** and 12 vertical terrain-following sigma levels
  - offline-nested to parent operational models covering the whole Adriatic and the Italian seas.
  - operational systems forced by the operational high-resolution (7 km x 7 km) meteorological model COSMO-I7.
- Freshwater discharge:
  - Daily time series from the Po River were imposed, while the remaining NAS rivers were prescribed based on monthly climatological estimates (Raicich, 1994).
  - To give a vertical structure to the plume, ~80 % of the freshwater discharge was injected at the river mouths' grid cells in the surface layers (~1.5 m, Hetland, 2005)
- To delineate the surface extent of river plumes and the freshwater influence in the basin, the daily averaged surface level of the **modelled salinity field** was considered as the sea surface salinity (SSS) field: **threshold 36 PSU** (Falcieri et al. 2014)

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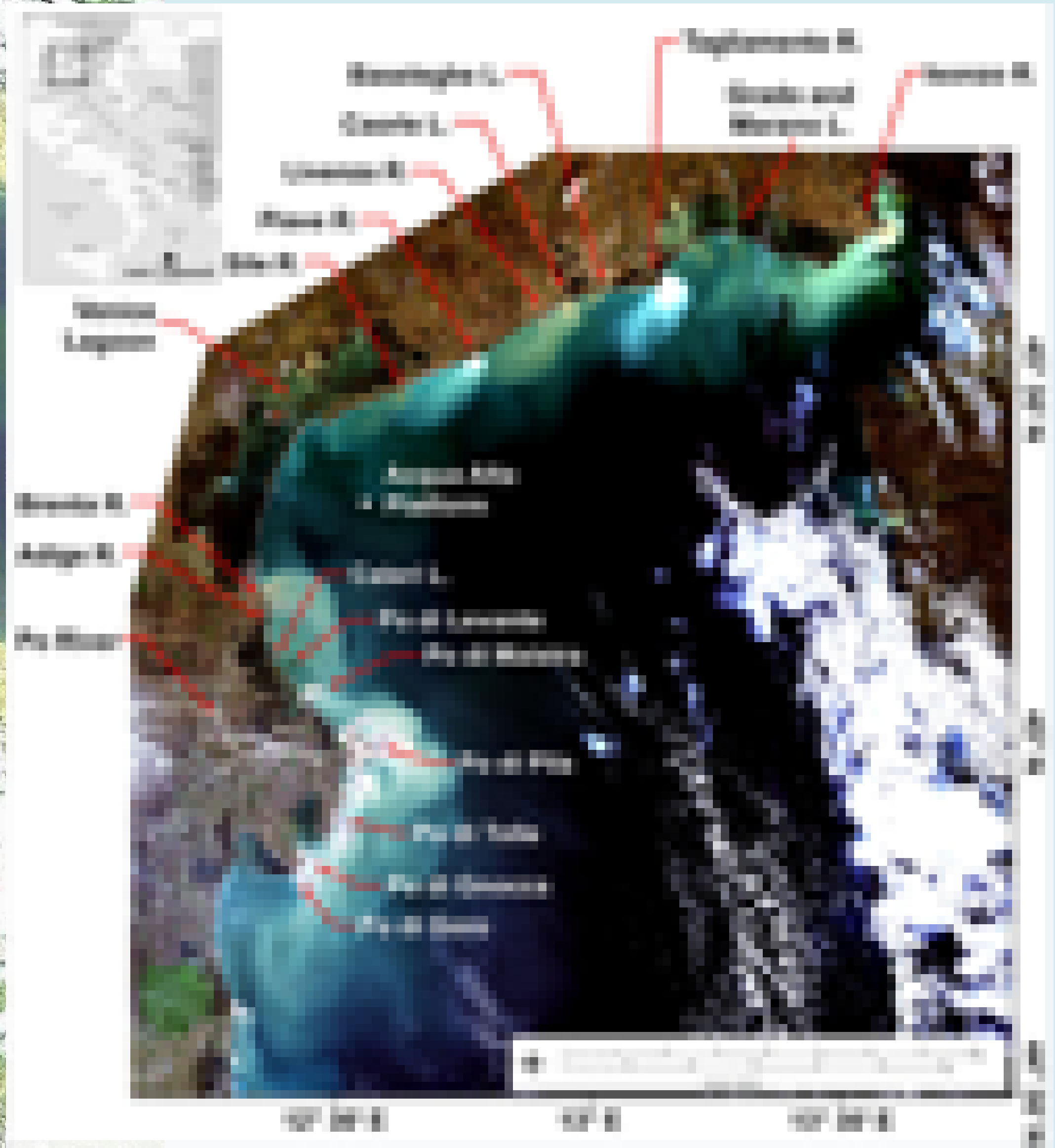
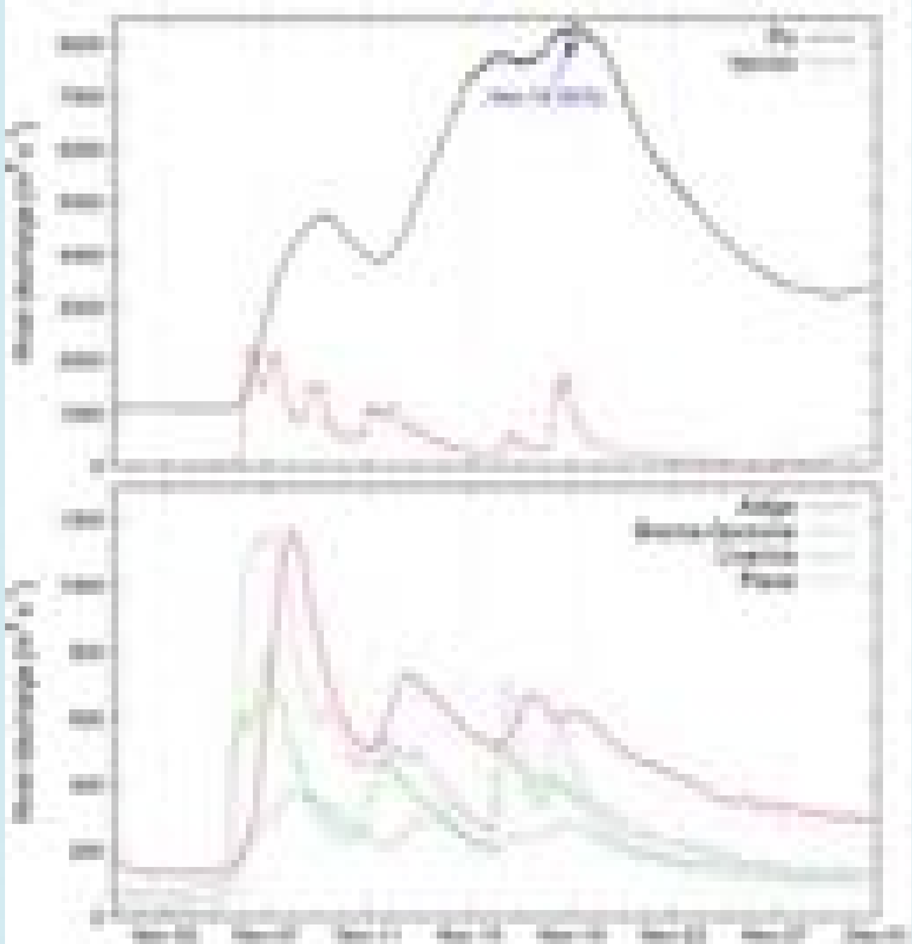
# NAS river plumes in a significant flood 19 November 2014

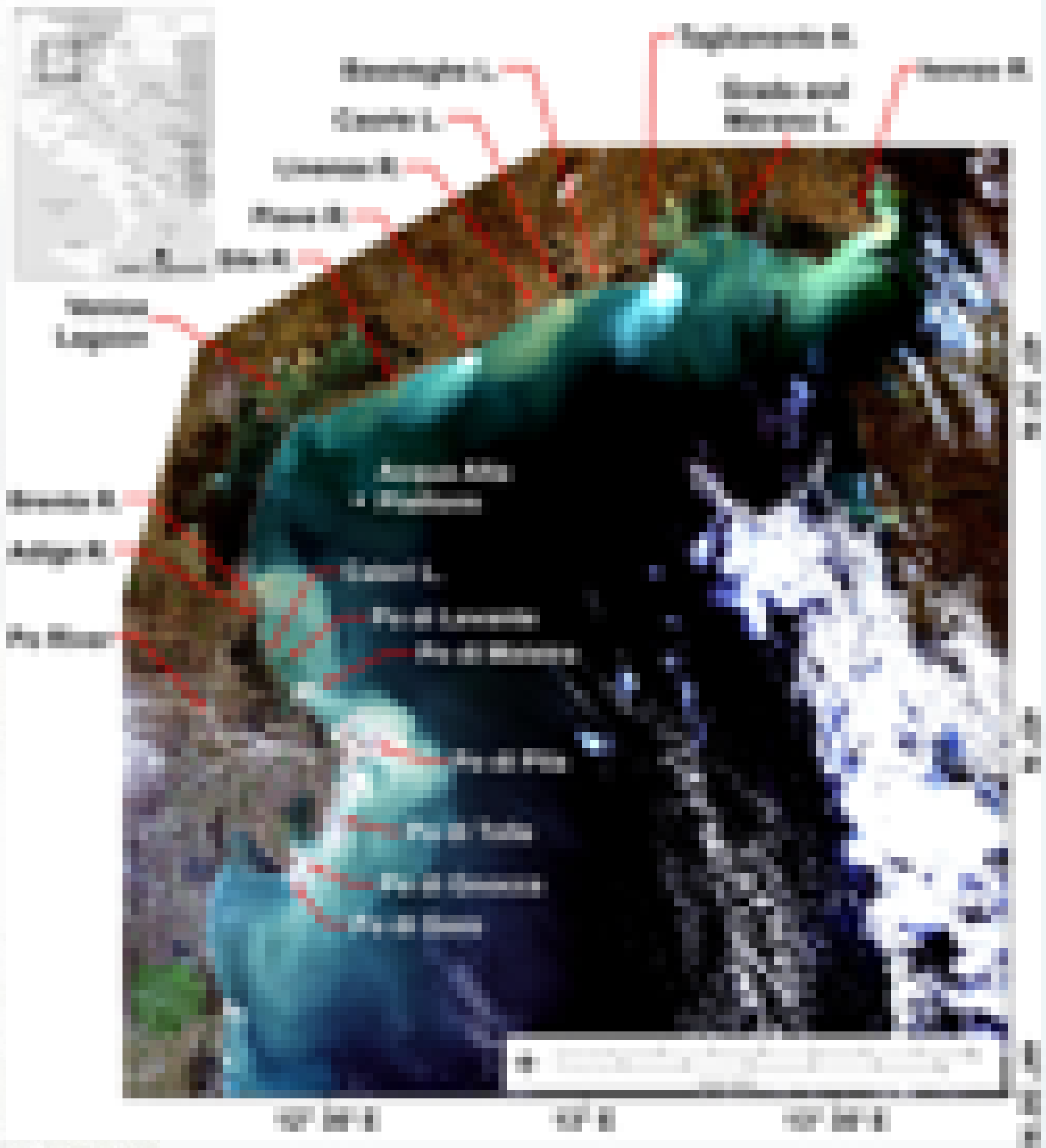
**Landsat 8 OLI imagery**



5th highest discharge for the Po River of the last 100 years
~10 km$^3$ of freshwater in NAS by 19/11/2014 (~1% of the basin volume)

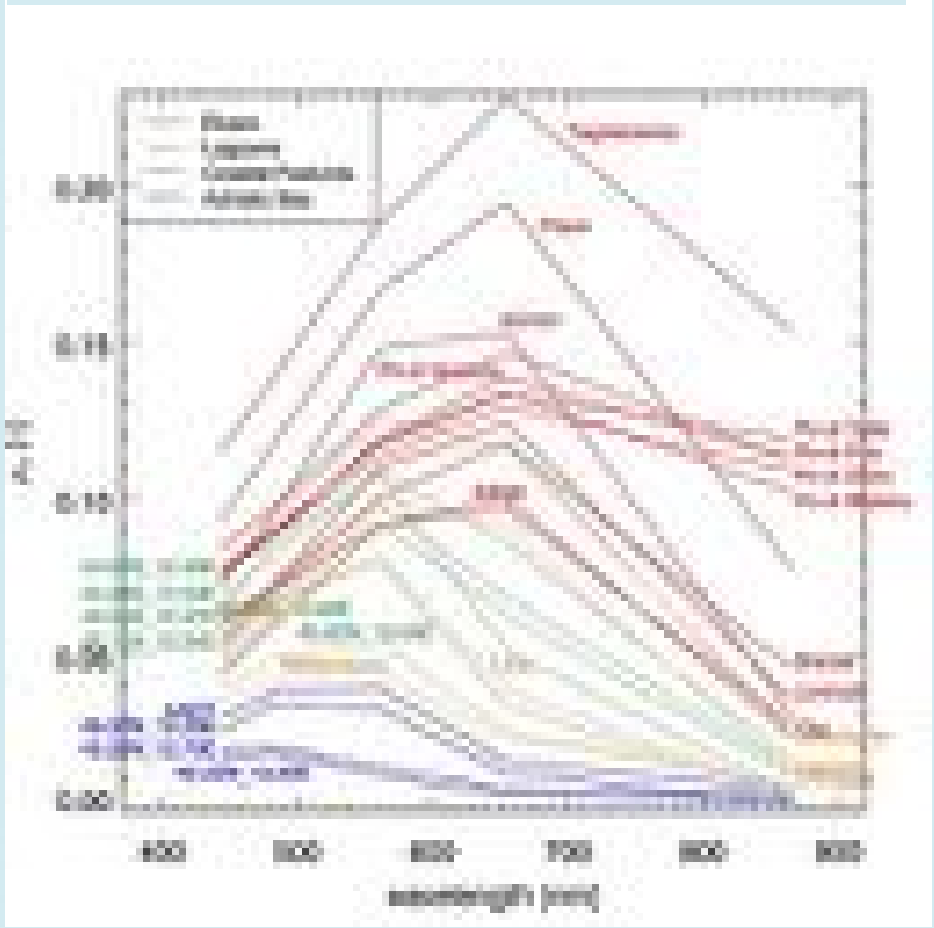


# NAS river plumes differ in optical properties reflecting the composition of the transported particulate matter



Isonzo, Tagliamento, and Piave: carbonate-rich sediments

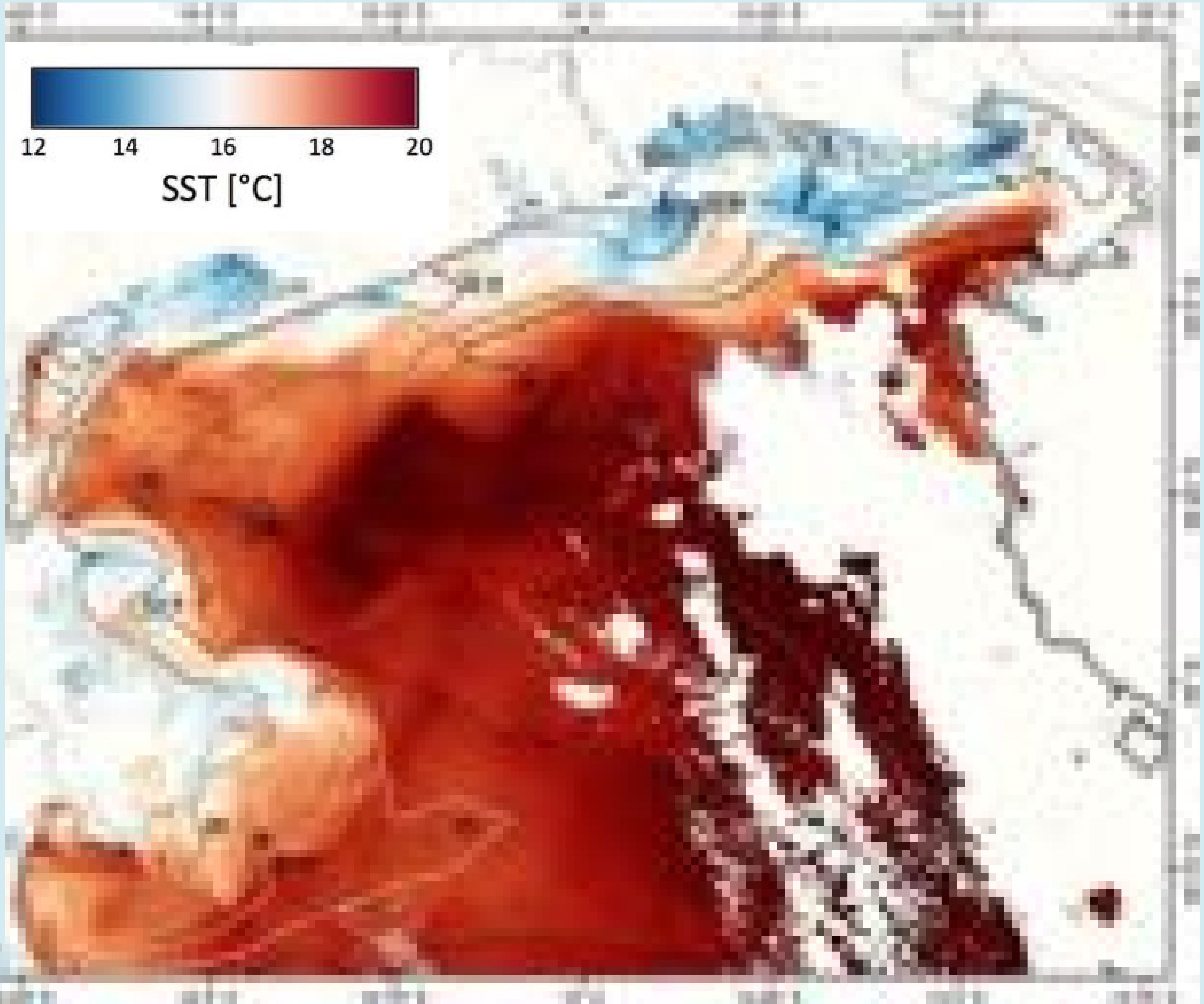
Other rivers more agricultural soils



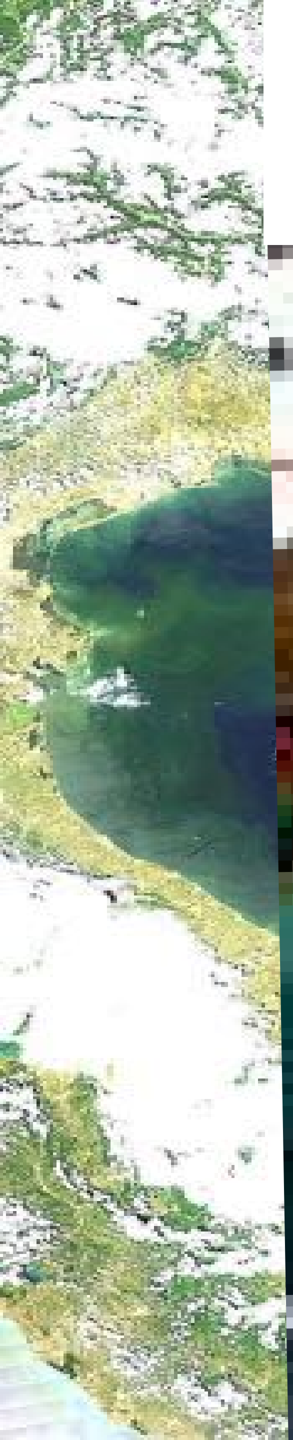
# Satellite SST + Modelled SSS

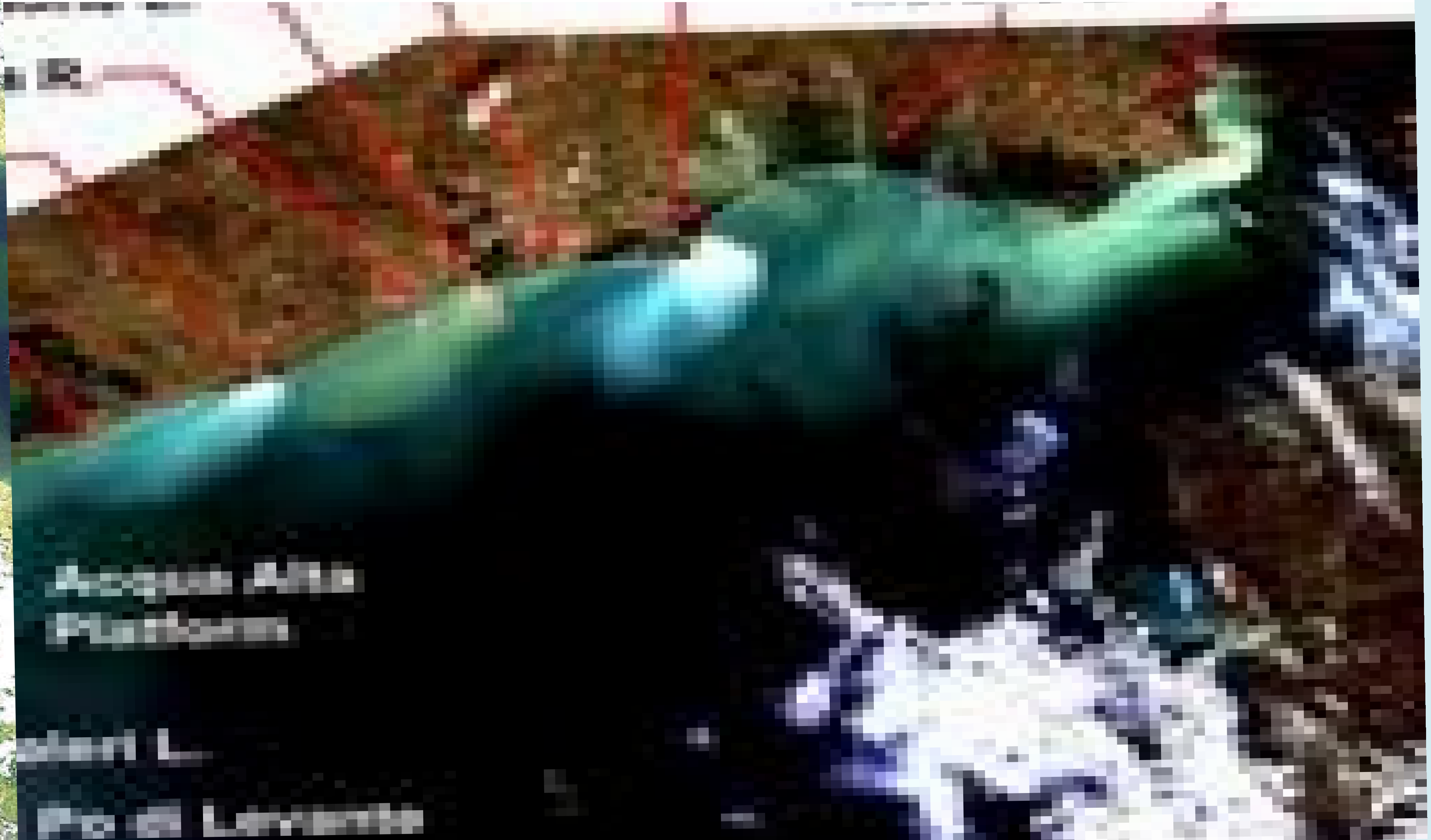
**freshwater influence**
**36 PSU** coincided with
**17.5◦C** for the northern rivers,
**19.5◦C** for Brenta, Adige, and Po rivers

**Fine scale:**
small near-shore trapped warm water parcels **NTWW** (SST~**17-19◦C**):
**warmer**,
**less turbid (greenish)**
than the adjacent plumes and the coastal current waters.

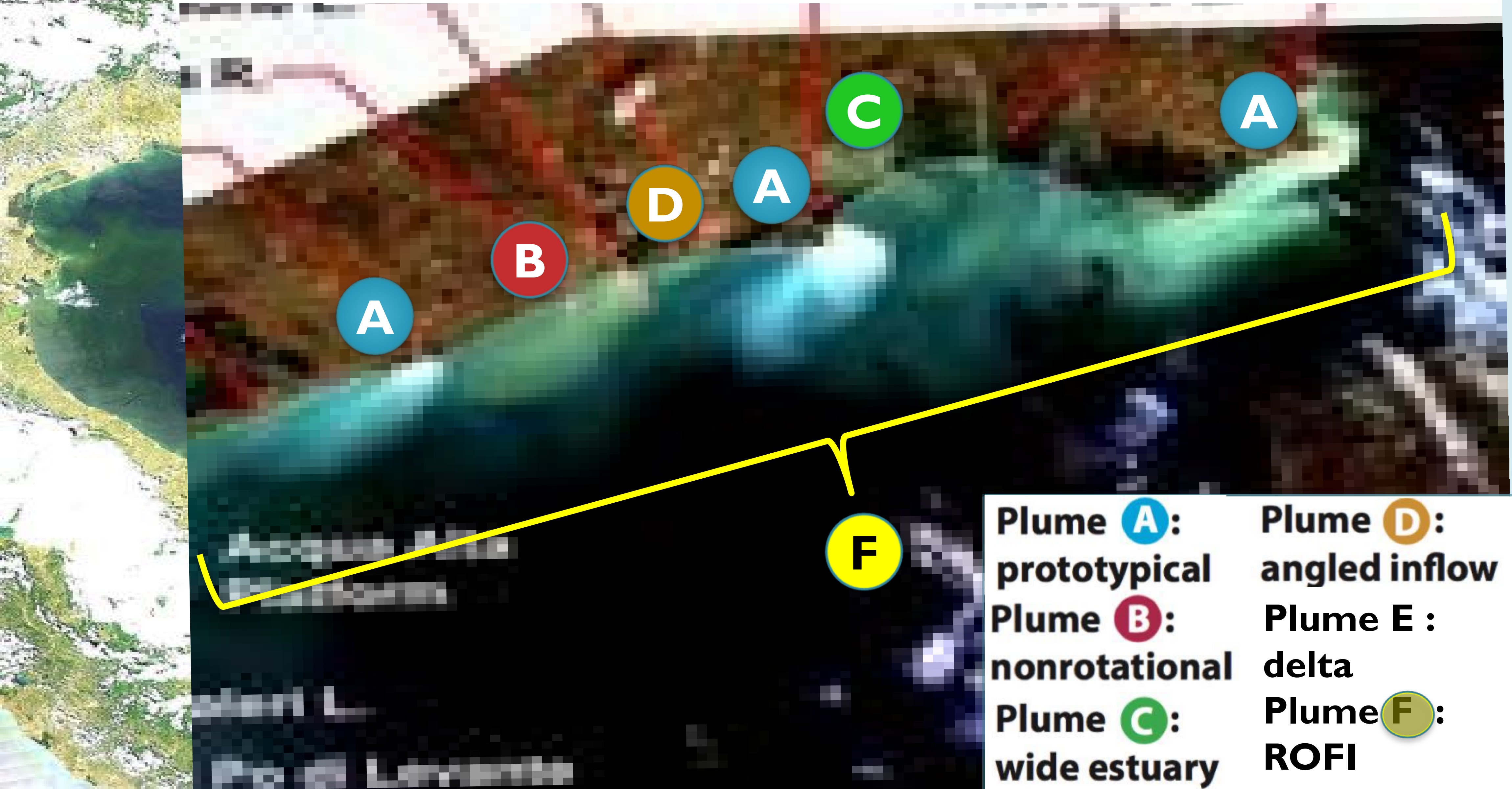


# Northern Rivers: RGB

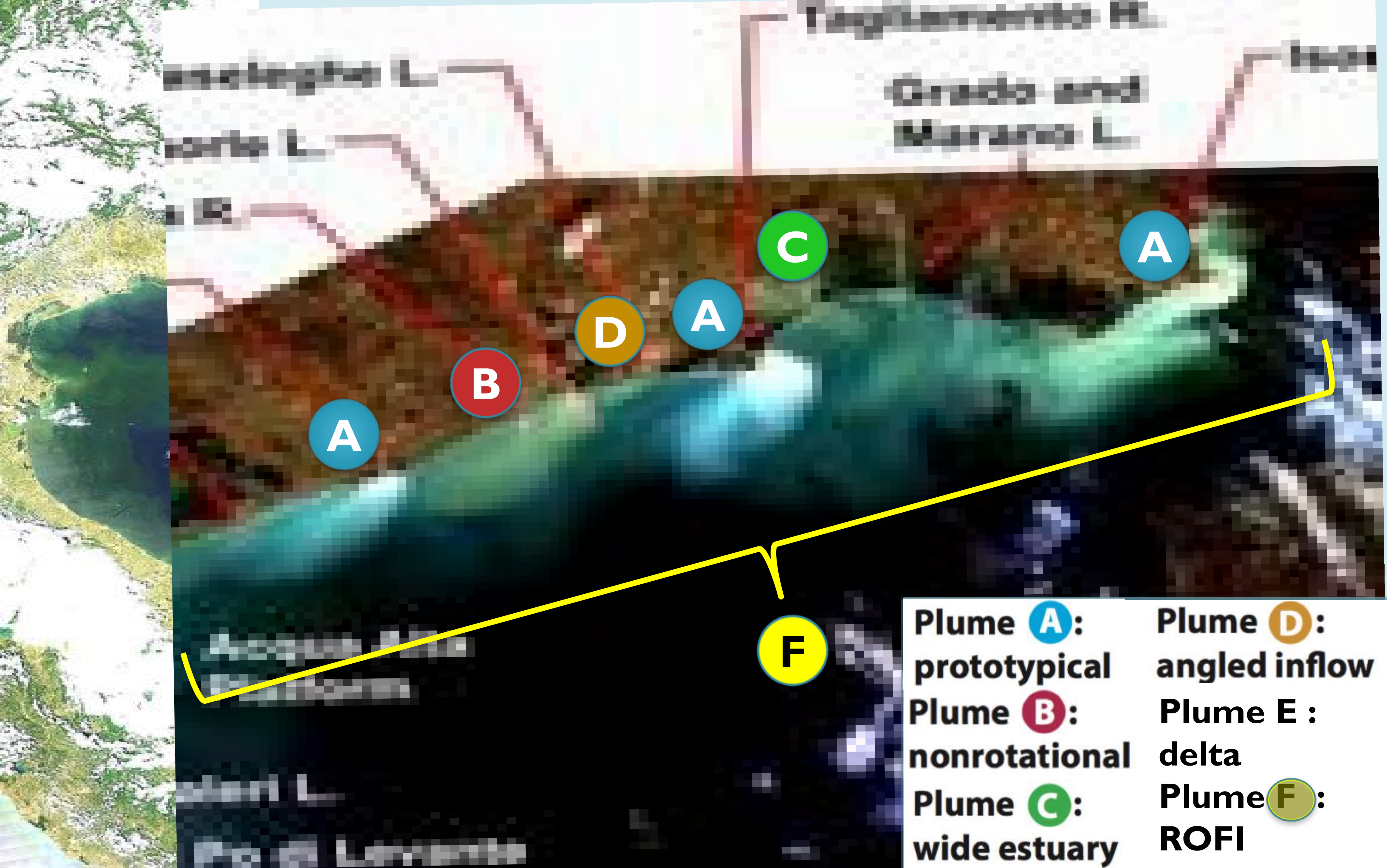




# Northern Rivers: RGB




Plume A: prototypical
Plume B: nonrotational
Plume C: wide estuary
Plume D: angled inflow
Plume E : delta
Plume F: ROFI




Plume A: prototypical

Plume B: nonrotational

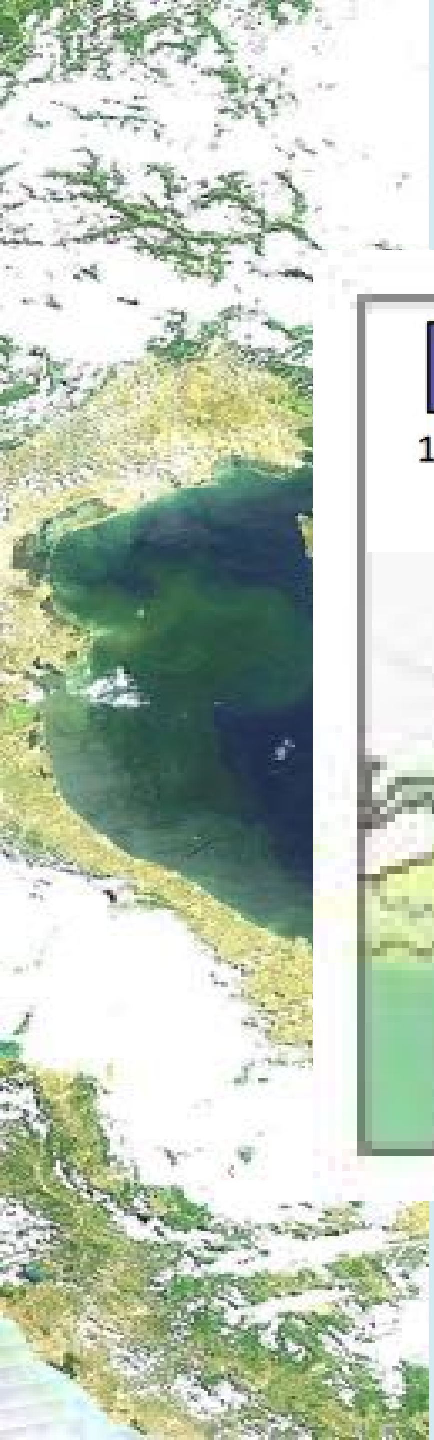
Plume C: wide estuary

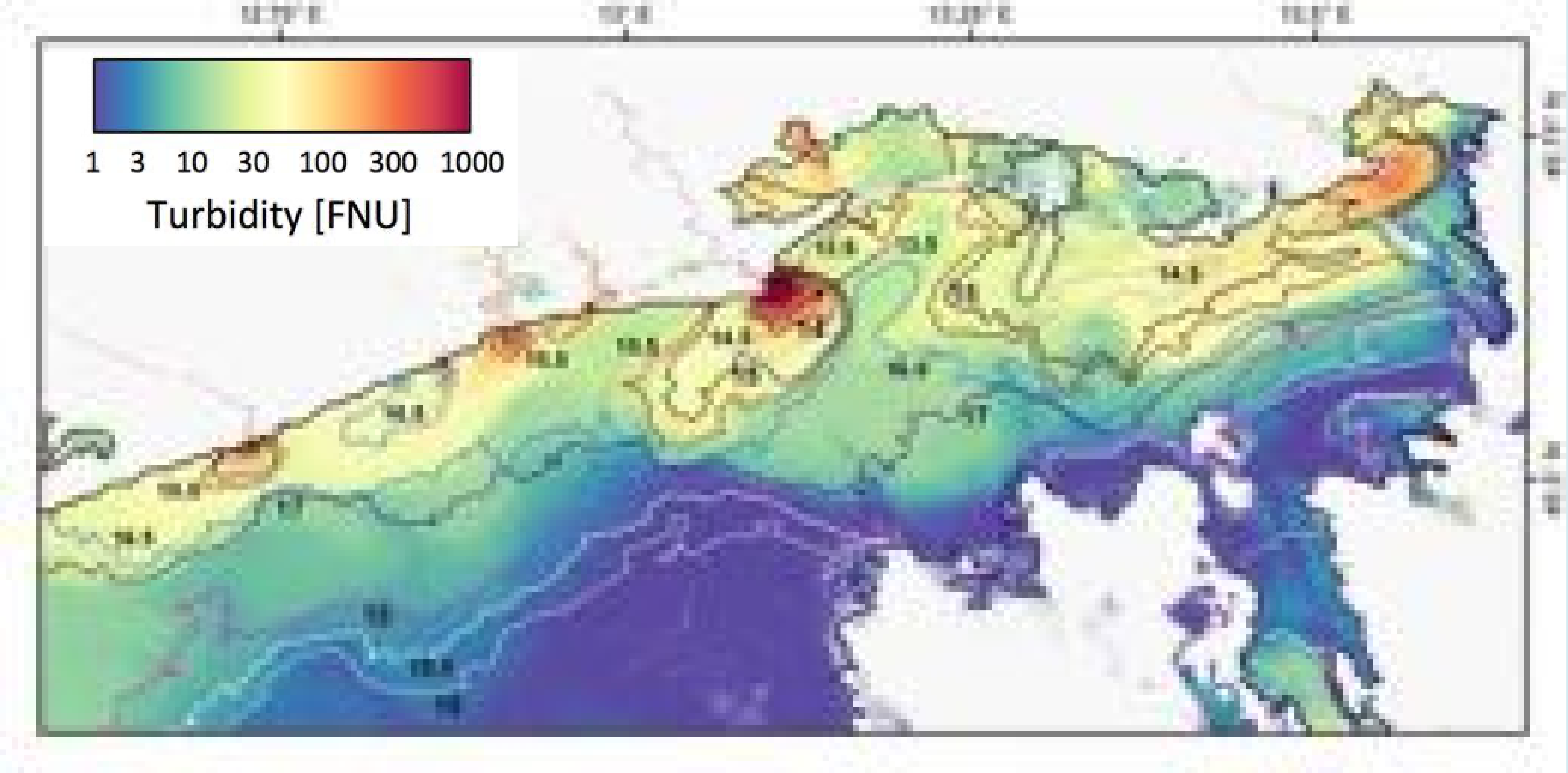
Plume D: angled inflow

Plume E : delta

Plume F: ROFI

# Northern Rivers: Turbidity + SST



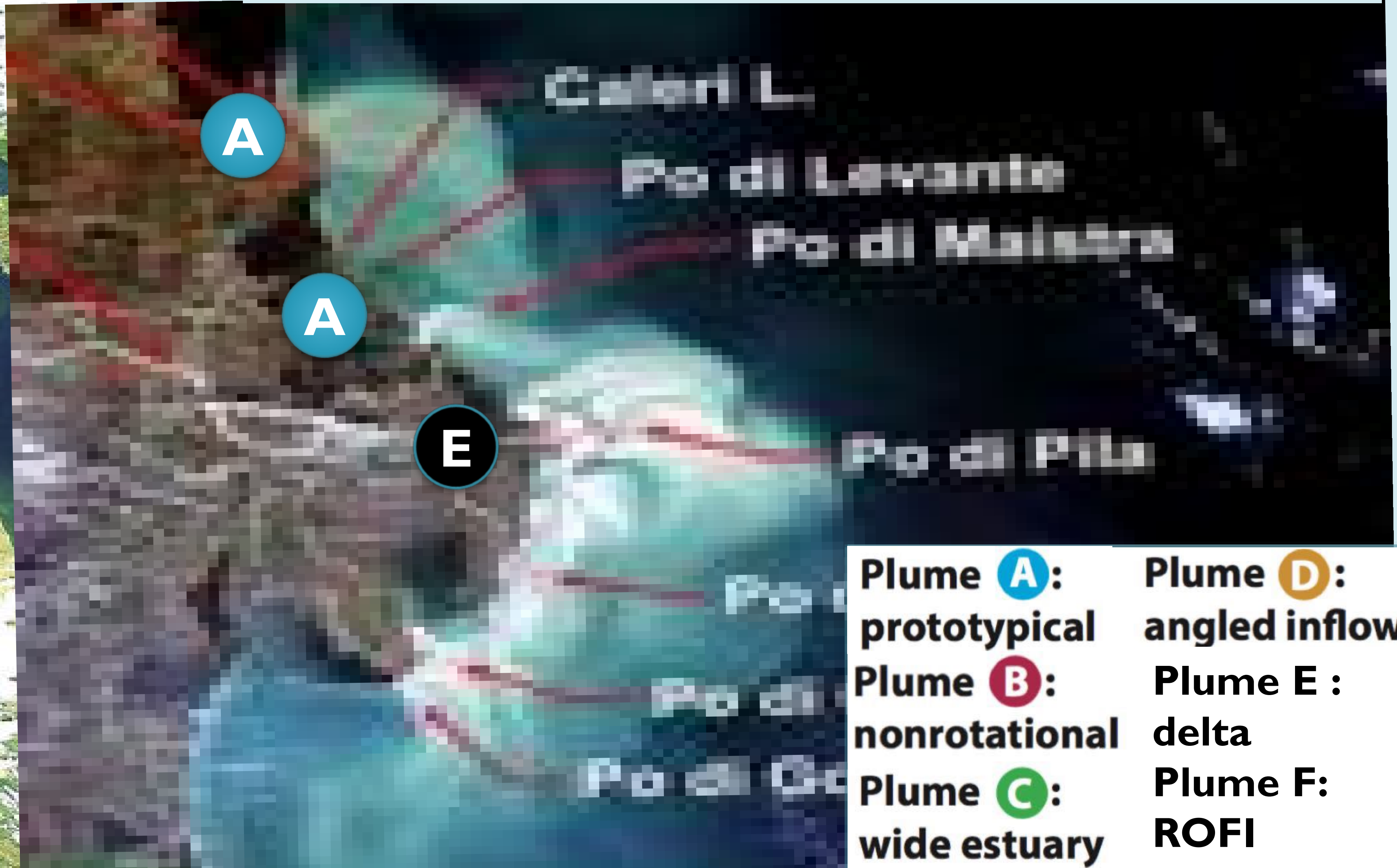



Wind and wave re-suspension was negligible during this event:
T is related to suspended particle load transported by the plumes
T > ~3–5 FNU indicative of terrestrial discharge in NAS

# Po river: RGB

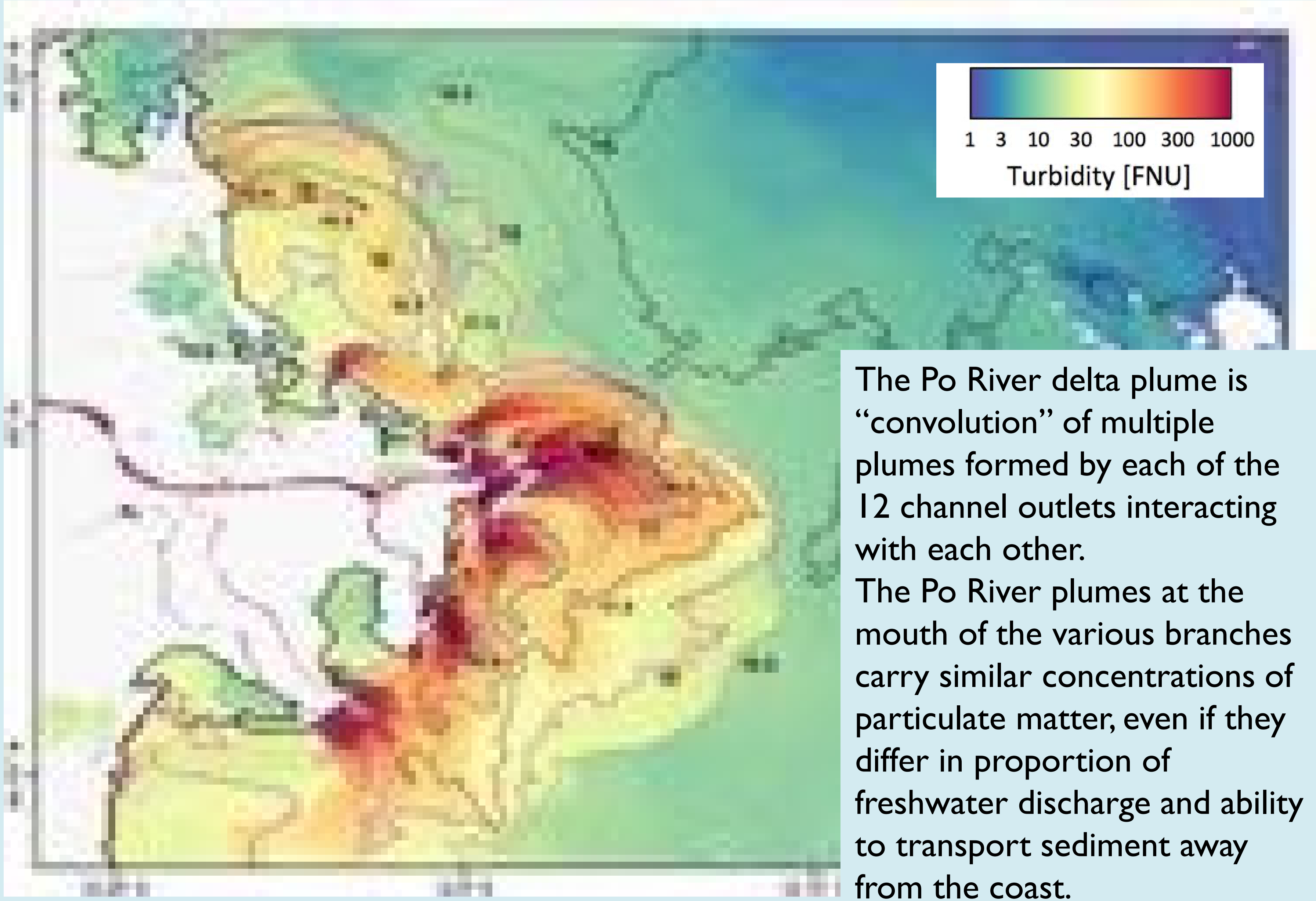

Caleri L.
Po di Levante
Po di Maistra
Po di Pila
Po di Tolle
Po di Gnocca
Po di Goro

# Po river: RGB




| | |
|---|---|
| Plume A: prototypical | Plume D: angled inflow |
| Plume B: nonrotational | Plume E : delta |
| Plume C: wide estuary | Plume F: ROFI |

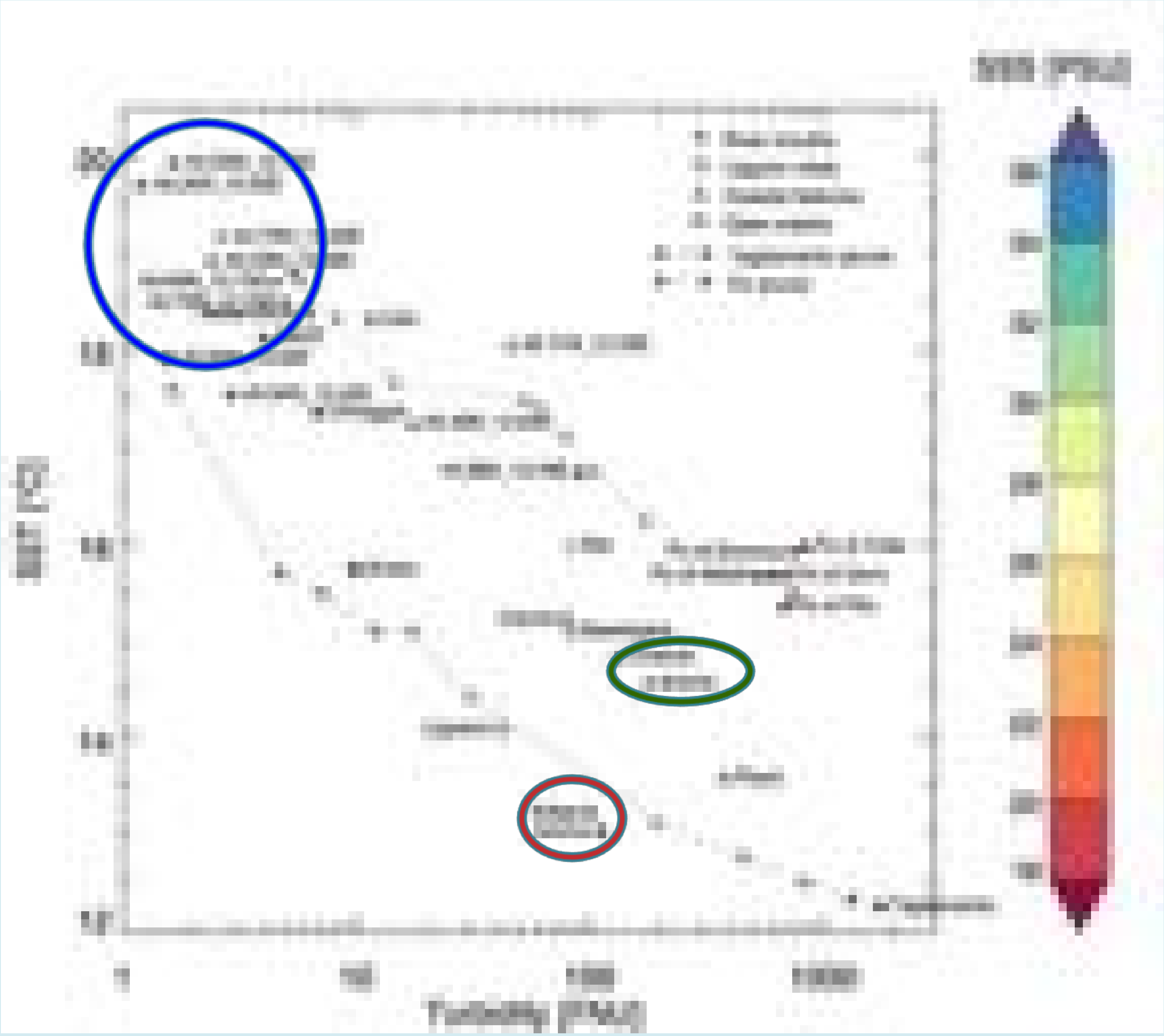
# Po river: Turbidity + SST (isotherms)




The Po River delta plume is "convolution" of multiple plumes formed by each of the 12 channel outlets interacting with each other.
The Po River plumes at the mouth of the various branches carry similar concentrations of particulate matter, even if they differ in proportion of freshwater discharge and ability to transport sediment away from the coast.

# Dilution of the terrestrial discharge

The dilution of **Po and Tagliamento** rivers towards **“clear” ocean waters** maintained a ~ 2.5 ◦C difference.
T and SST coupling at the river mouth does not reflect the composition of the transported particulate matter: **Livenza and Brenta** or **Adige and Isonzo** rivers have similar coupling but transport different material sources



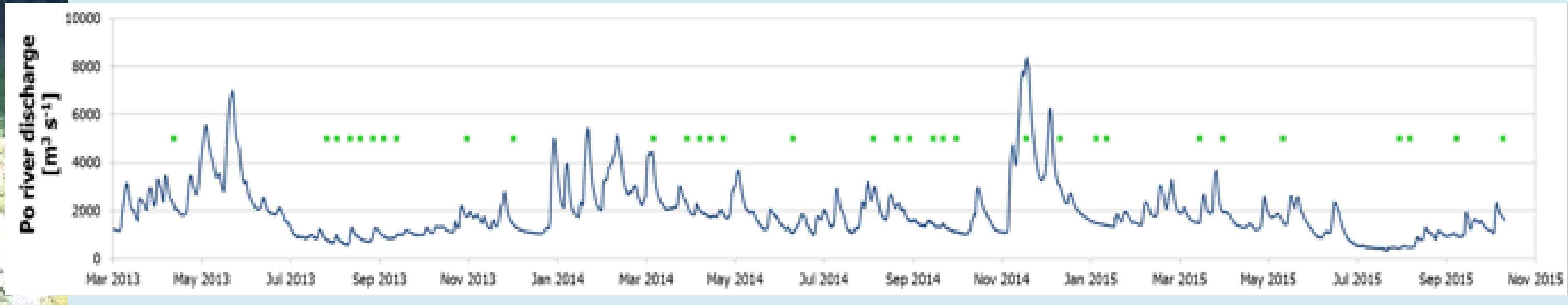

**Satellite Turbidity + SST & Modelled SSS**

# Outline of this presentation

- Background
  - North Adriatic Sea (NAS)
  - Plume morphologies
- Methods
  - Landsat 8 OLI & TIRS
- Results
  - NAS river plumes in a significant flood
  - Po River plume structure variability
- Summary

# Po river plume structure variability

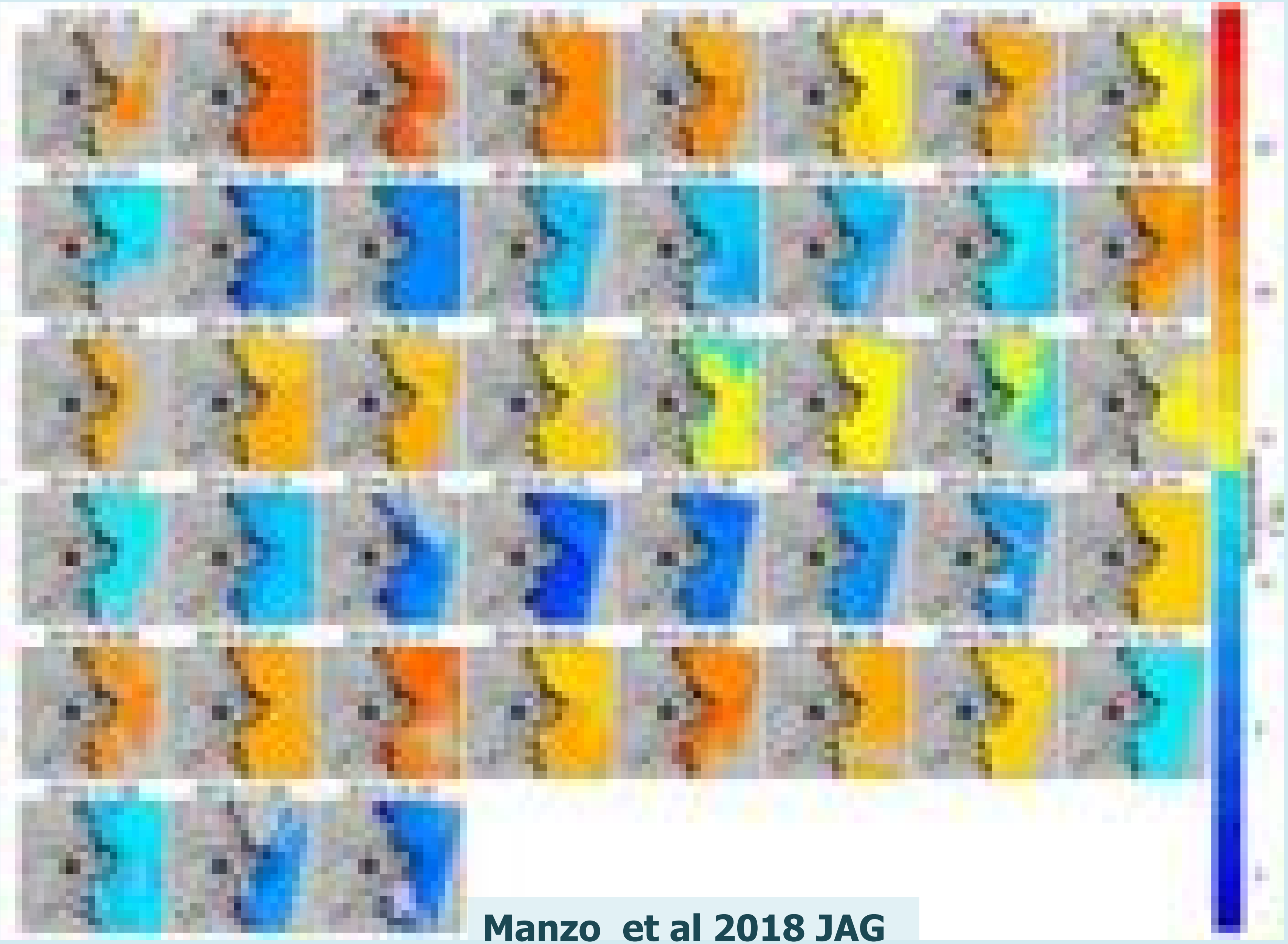
- For the study area, scenes from two paths were available. Hence the revisit time was 7-9 days, instead of the standard 16 days.
- 34 L-8 images selected, excluding those with clouds, sun glint, and thick aerosols
- T & SST patterns in the Po river prodelta as function of discharge, wind and wave




Po river discharge at Pontelagoscuro hydrologic station (ARPA-ER).

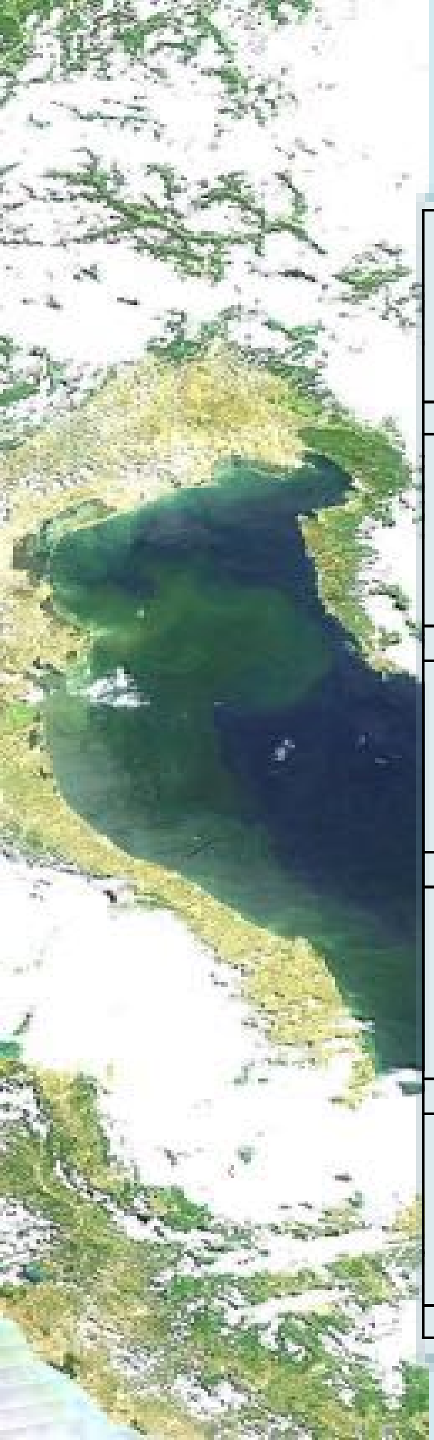
**Braga et al, 2017 ECSS**
**Manzo et al 2018, JAG**

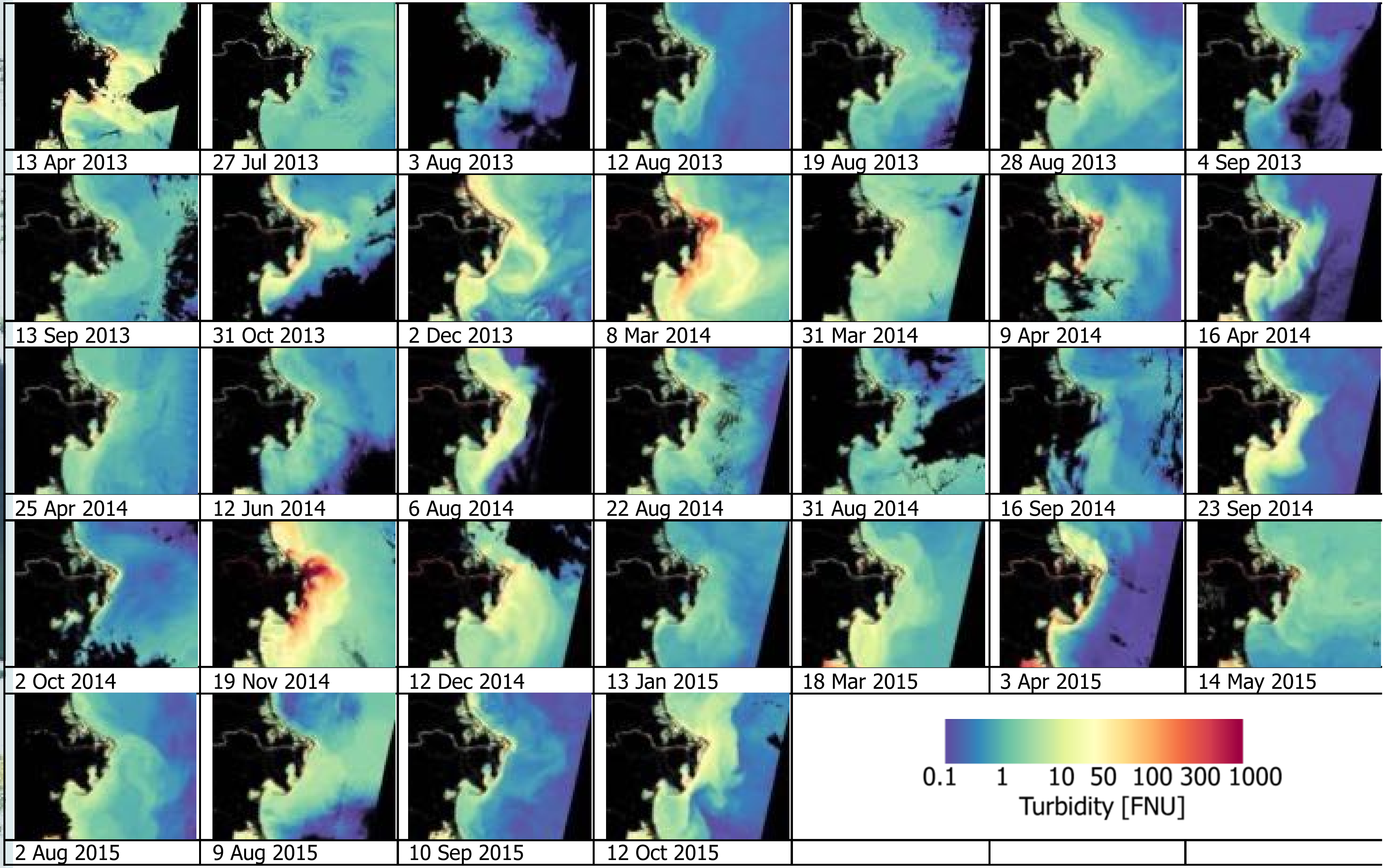
# Po river plume structure variability



Manzo et al 2018 JAG

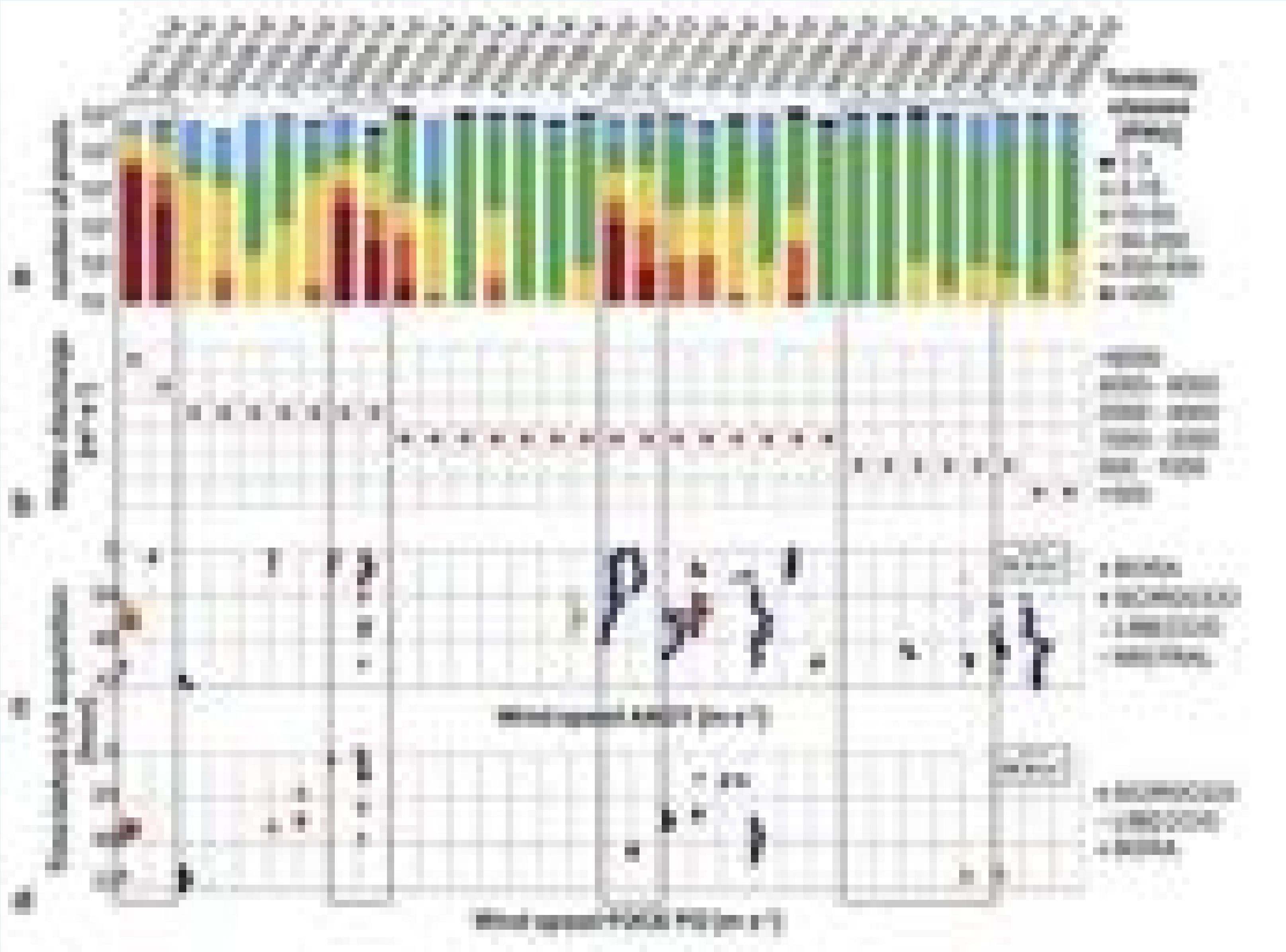
# Po river plume structure variability





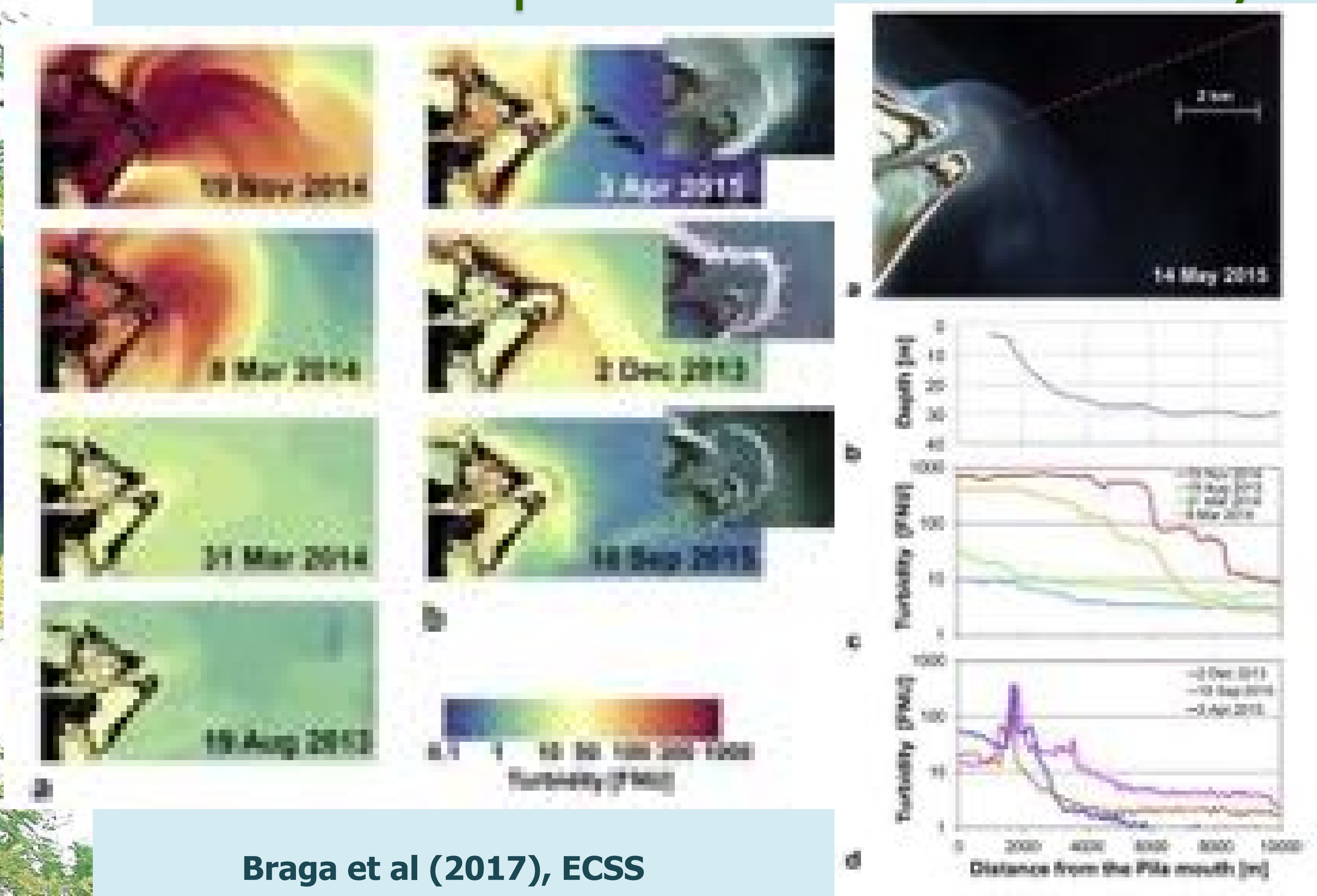

**Braga et al, 2017 ECSS**

# Po river plume structure variability



Braga et al, 2017 ECSS

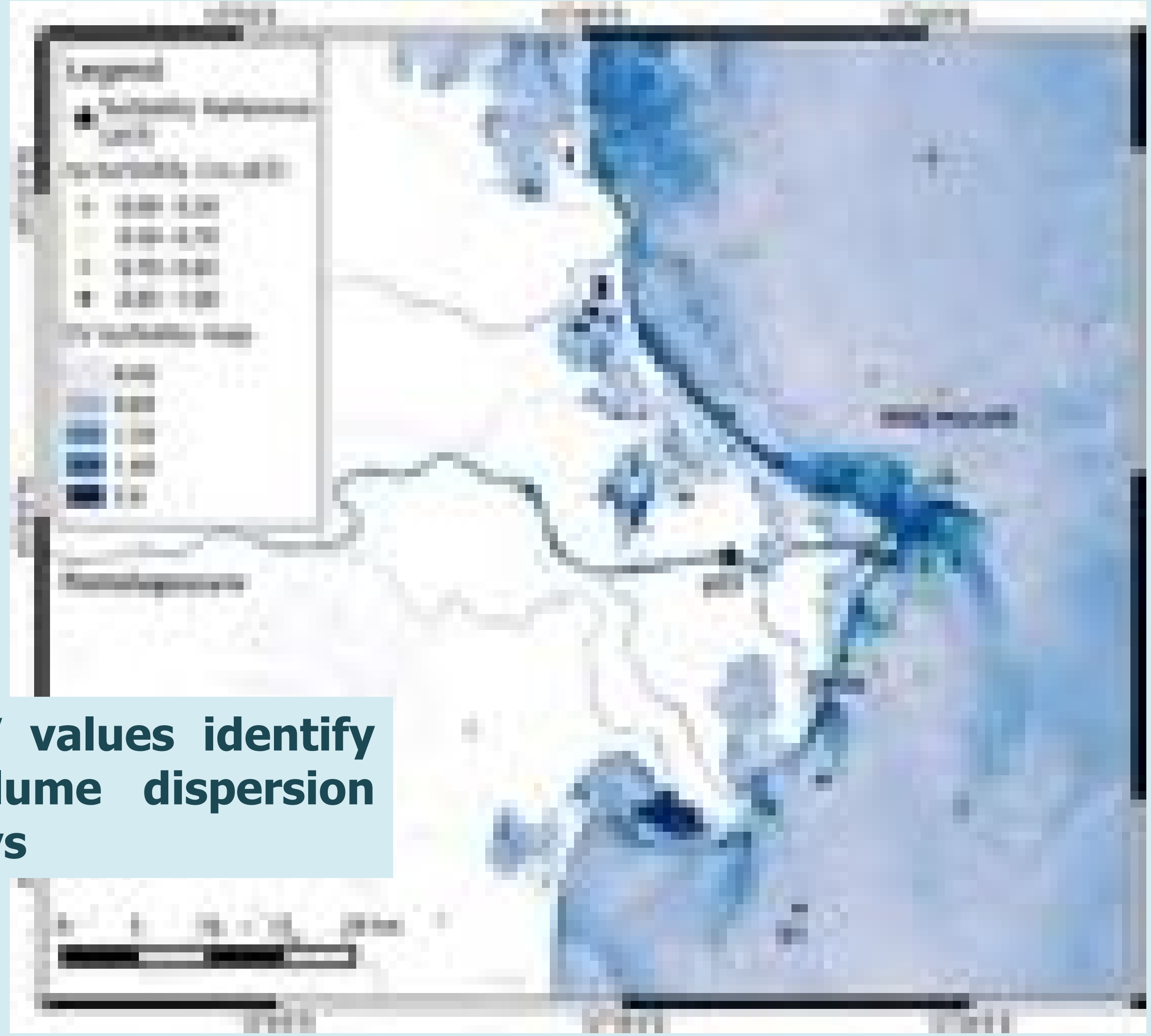
# Po river plume structure variability




**Braga et al (2017), ECSS**

# Po river plume structure variability

Coefficient of Variation of Turbidity

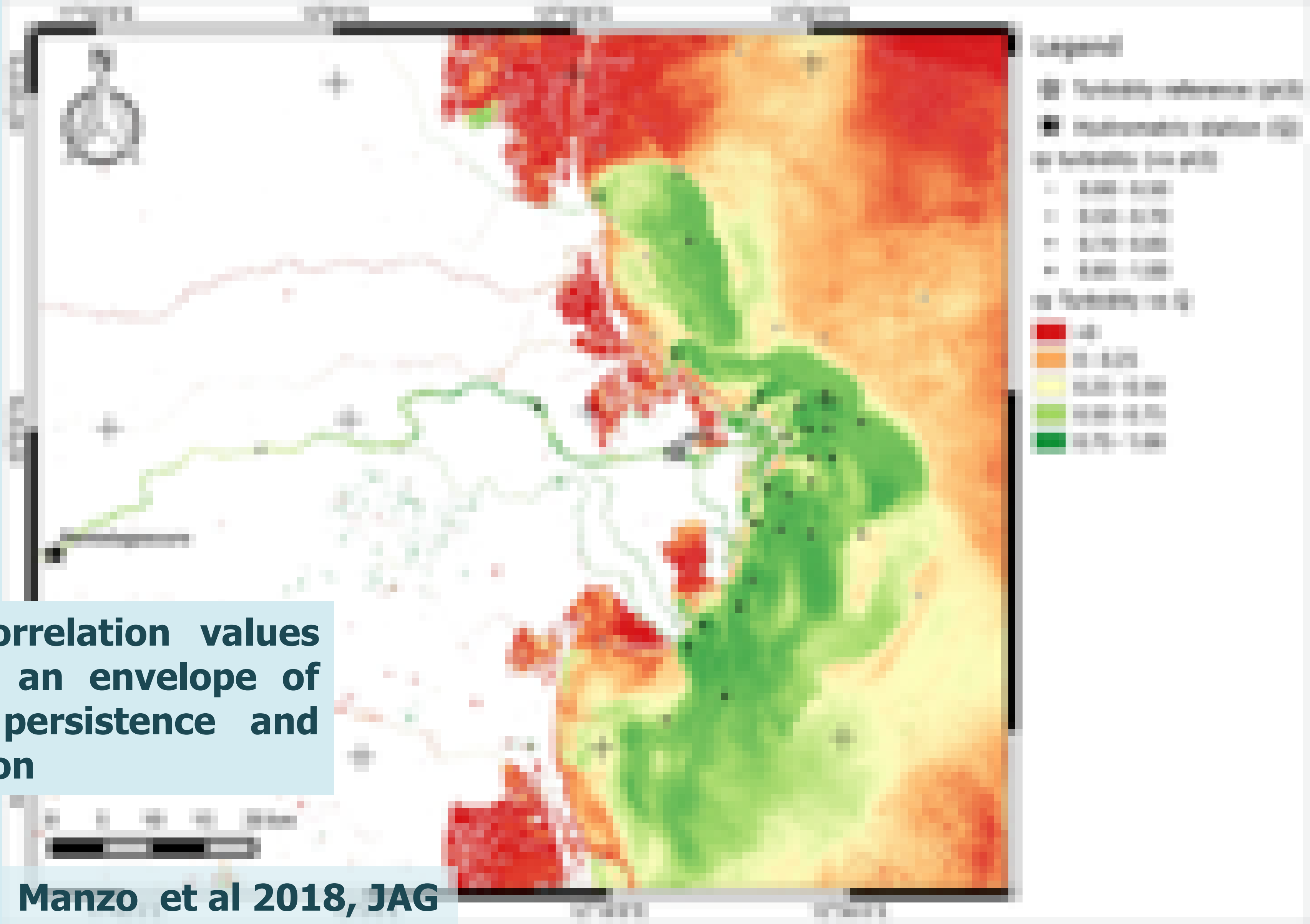


**High CV values identify main plume dispersion pathways**

**Manzo et al 2018, JAG**

# Po river plume structure variability

## Correlation Turdibity vs Discharge

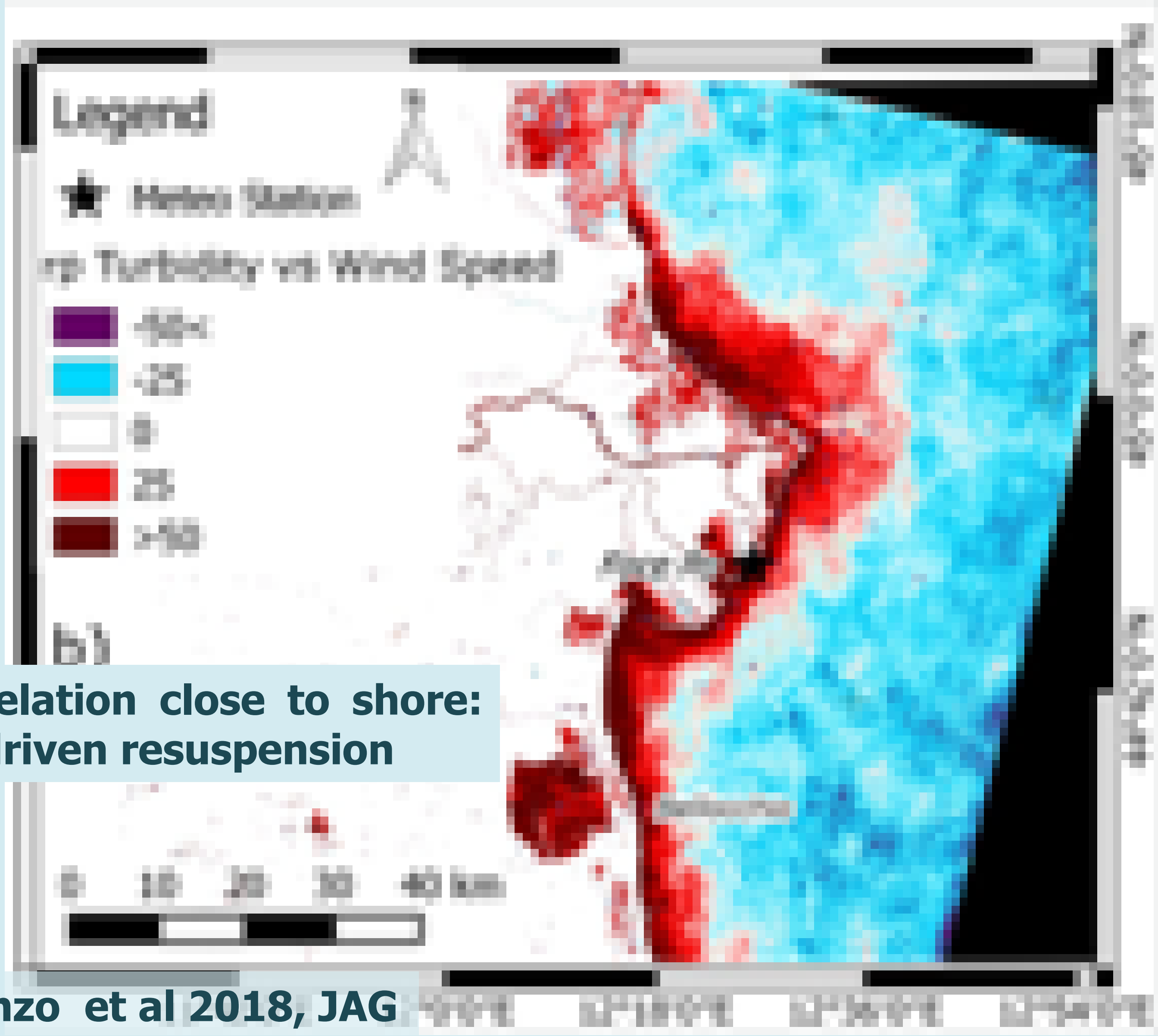


**High correlation values provide an envelope of plume persistence and extension**

**Manzo et al 2018, JAG**

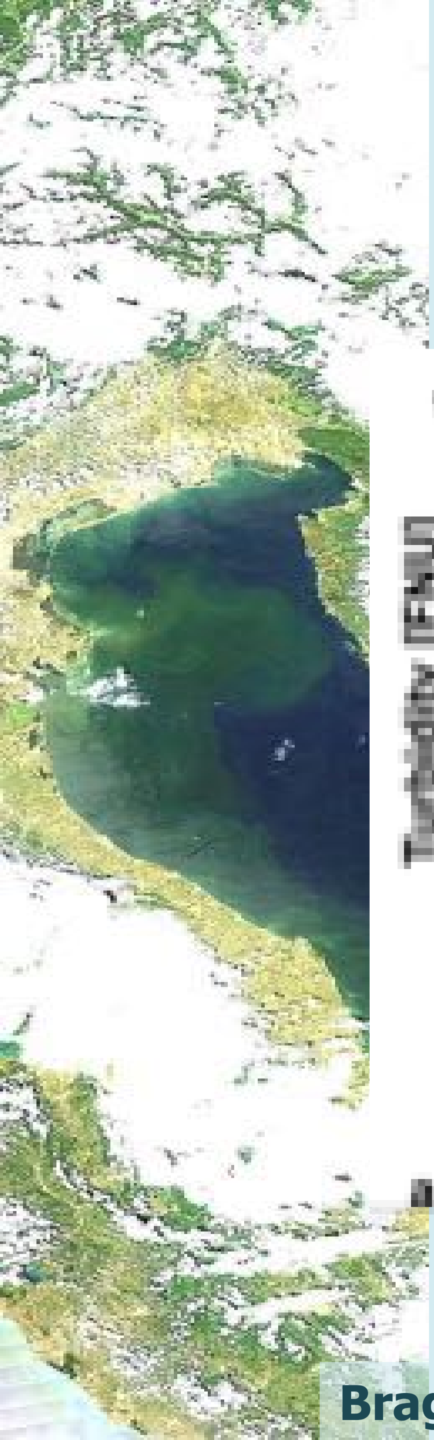
# Po river plume structure variability

Correlation: T vs windspeed



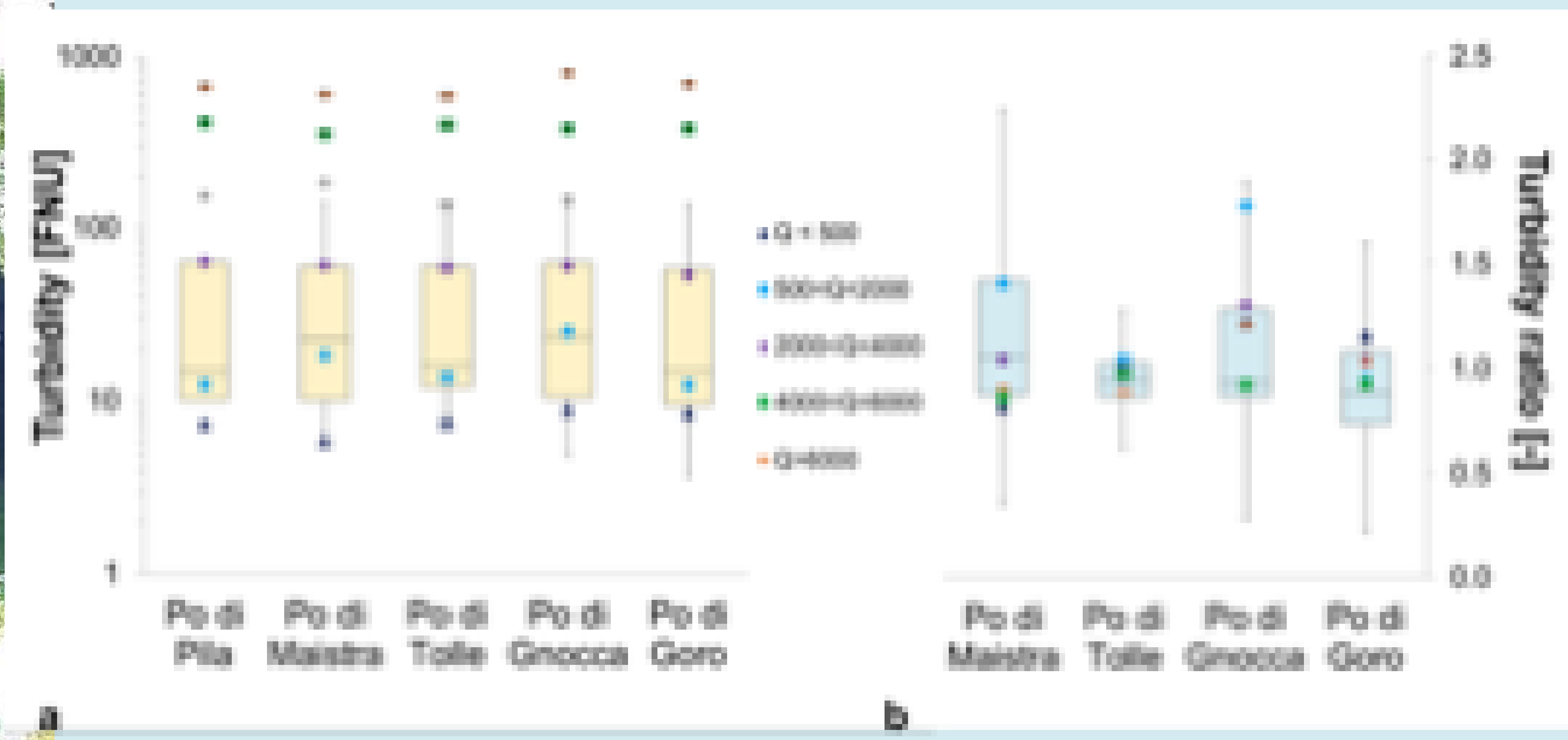

**Highest correlation close to shore: wind/wave driven resuspension**

**Manzo et al 2018, JAG**



# Po river plume structure variability

distribution of suspended sediment among the major branches of the Po River




**Braga et al (2017), ECSS**

Overcoming difficulties to perform simultaneous samplings at all branches in complex deltaic systems and extreme conditions

# Summary

- T and SST used as tracers for the **surface expression of the freshwater influence** in a significant flood event and for the characterization of plume structures.
  - high-resolution **OCR** and **SST** imagery enabled the identification of the dynamical regions at the **small scale** and **submesoscale** for all plume structures and their interactions in the NAS.
  - with the **7-9 days** resolution and the aid of **in situ data**, we can infer useful information on **forcings and physical processes** that control the **fate** of suspended sediments in the NAS
- Observed optical complexity of NAS due to the variability in composition of the particulate matter:
  - Need for **robust region-specific** relation between **T** and **suspended matter concentration** to supplement the Dogliotti et al. (2015) T retrievals.

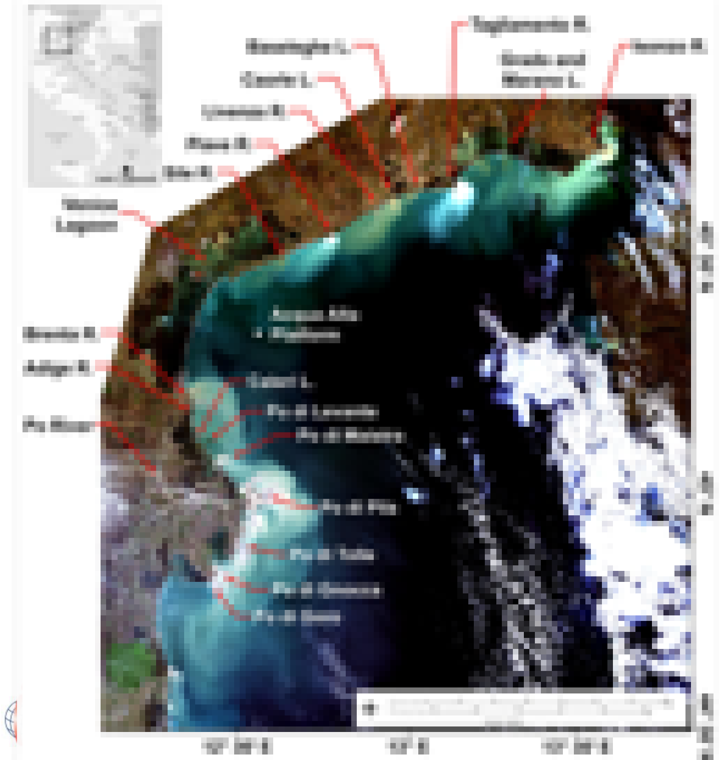
# Processes scales and observation: focus on inland/coastal processes

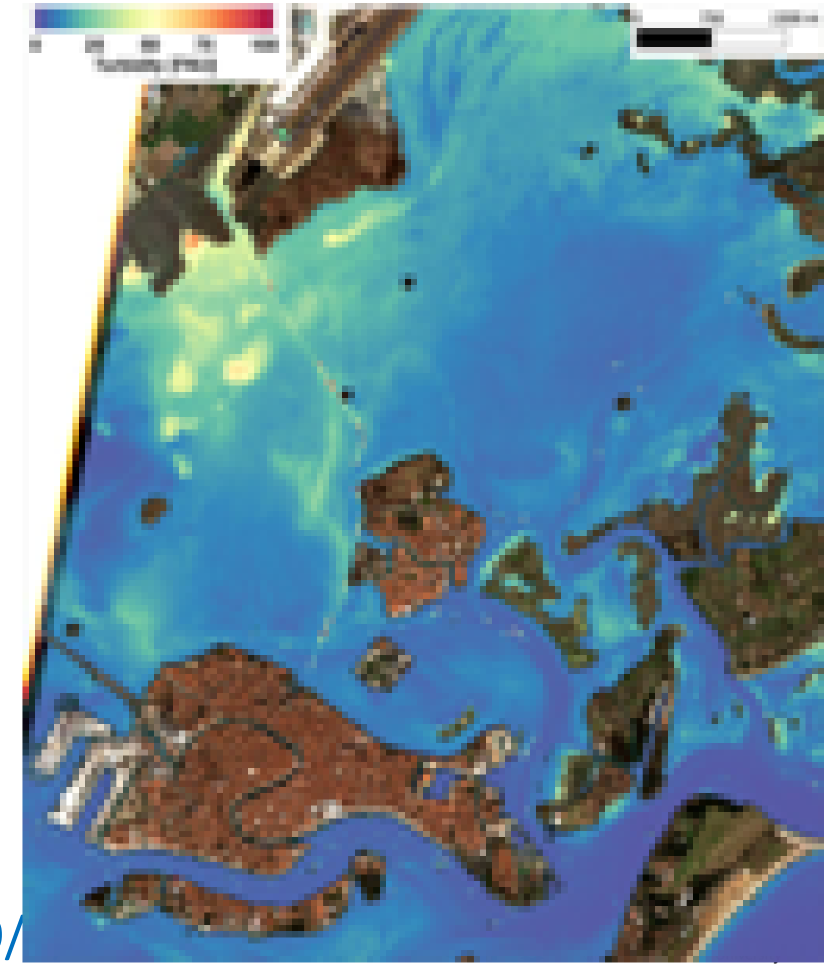
Two studies to showcase the use of the New “observation class” data (Landsat-8+9/OLI + Sentinel-2ABC/MSI) to describe fine scale oceanography processes

- Landsat-8/OLI :

  River Plume Interactions in the Northern Adriatic Sea
- Sentinel-2AB/MSI:

  Water transparency in the Venice Lagoon





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# COVID-19 lockdown measures reveal human impact on water transparency in the Venice Lagoon

Federica Braga [a,*], Gian Marco Scarpa [a], Vittorio Ernesto Brando [b], Giorgia Manfè [a], Luca Zaggia [c]

CNR ISMAR ISTITUTO DI SCIENZE MARINE

Istituto di Geoscienze e Georisorse

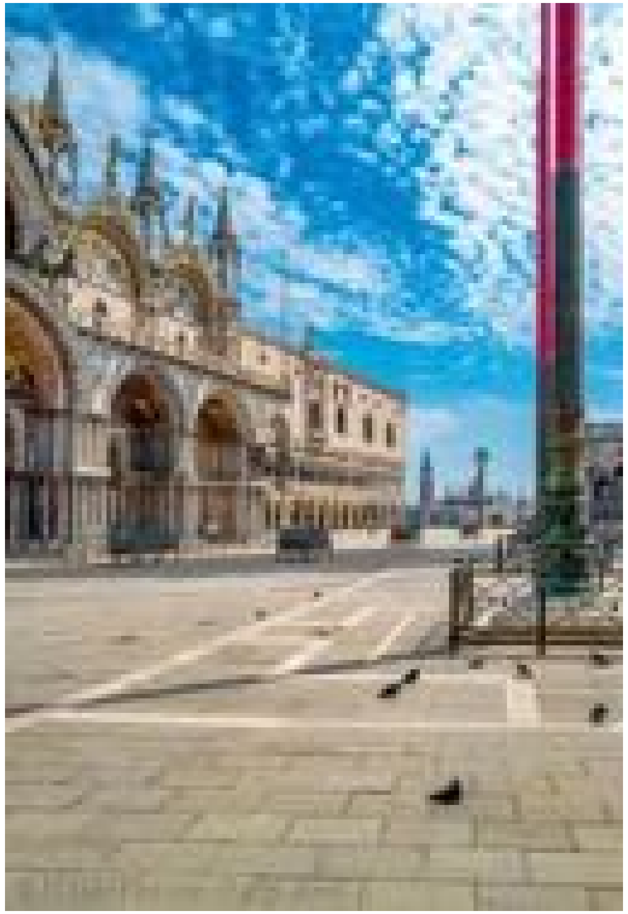
# Outline

- Introduction
- Data and Methods:
  - Satellite imagery
  - Ancillary data
- Results - Before and during the SARS-CoV-2 outbreak:
  - February – May 2020
  - April 2019 – April 2020
- Final remarks
- Conclusions

# Introduction

- When the first confirmed cases of COVID-19 were identified in Italy on Feb 23rd, 2020, the city of Venice was celebrating the last days of its famous Carnival with tens of thousands of revellers.
- Regional authorities cancelled all remaining events in an effort to halt the spread of coronavirus infections.
- Since March 10th, the Italian government announced widespread lockdown measures for the whole country, restricting social contacts, limiting the individual movement, and closing most businesses, with the exception of those essential to the country supply chains.
- The tourism industry in the city suddenly stopped and Venice experienced a major breakdown of its economy, that was mostly based on this single source of revenue.

# Introduction



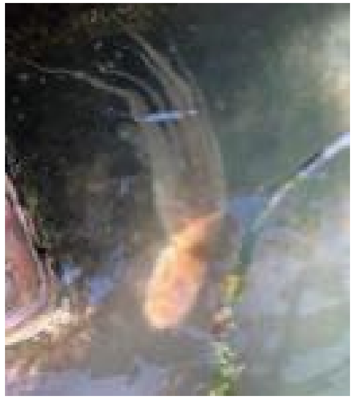
Pictures from the book “Venice Deserted”
Jonglez Publishing - Authors Danielle and Luc Carton

# Introduction

- As a consequence of the isolation measures and the reduction of the tourists, the ordinary urban water traffic around Venice, one of the major pressures in the lagoon, came to a halt.
- Public transportation services, tourist and leisure boats stopped completely, while commercial boats and other public boat services reduced their runs.
- The unprecedented water transparency in the city canals was widely covered by international news outlets and social media
- We used satellite imagery to describe the environmental effects of the lockdown measures on water transparency in the lagoon of Venice





# Introduction

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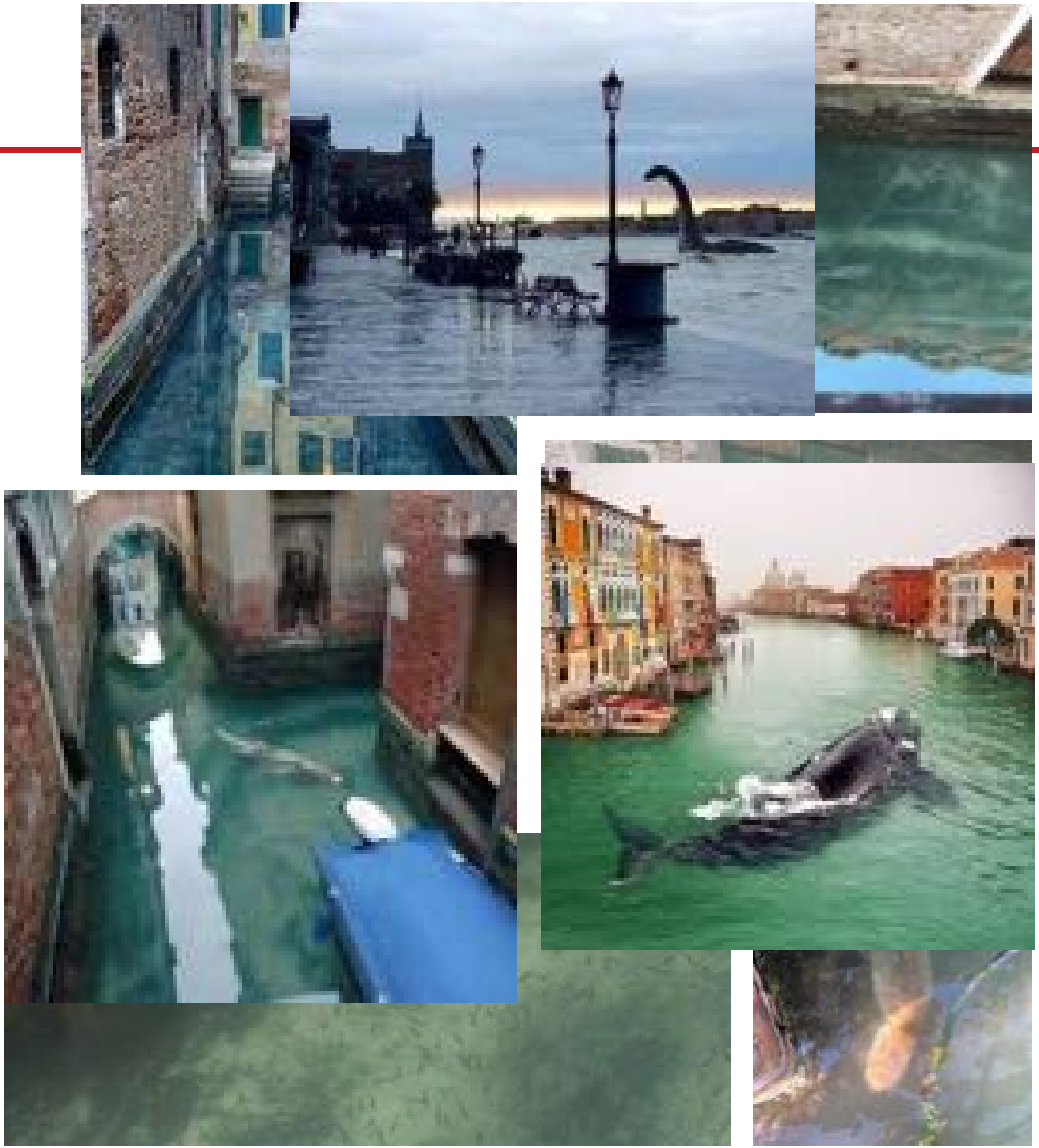
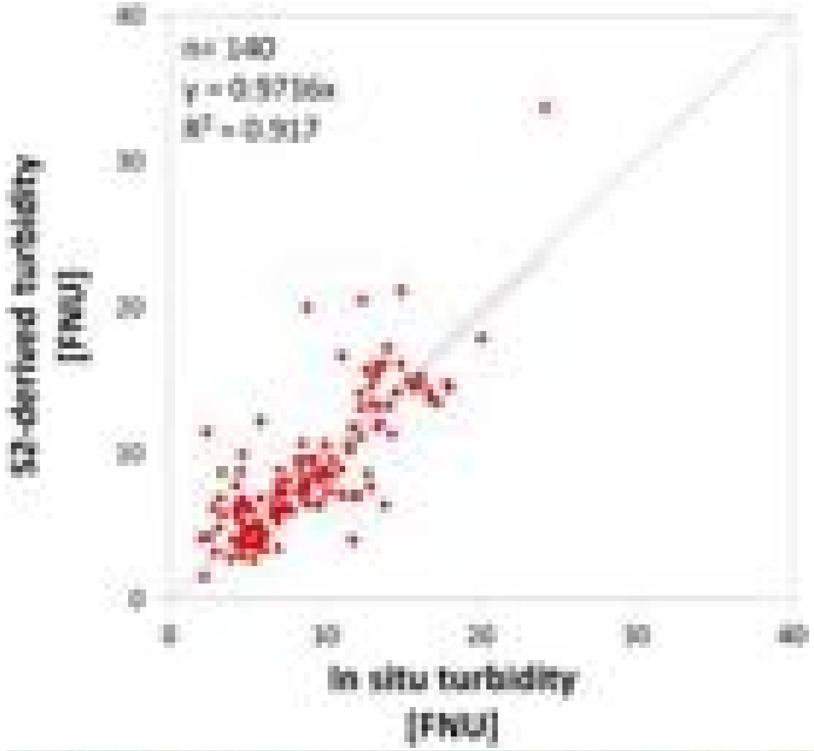


# Data and Methods: Satellite imagery

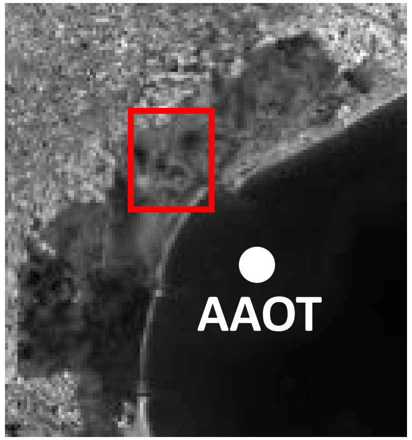
- Pseudo true-colour composites and turbidity maps at 10 m resolution were obtained from Sentinel-2 data.
- S2 imagery was radiometrically calibrated [1] and atmospherically corrected with ACOLITE, applying the dark spectrum approach [2,3].
- Pseudo true-colour composites with the same stretching were used for qualitative visual interpretation.
- Water leaving reflectances were converted into turbidity (expressed in FNU) [4] and validated with in situ data.
- A total of 14 cloud-free S2 images were acquired over the lagoon of Venice during the period from February to April 2020.
- A S2 image acquired on April 19th 2019 was also used to assess the situation of one year prior to the SARS-CoV-2 outbreak.

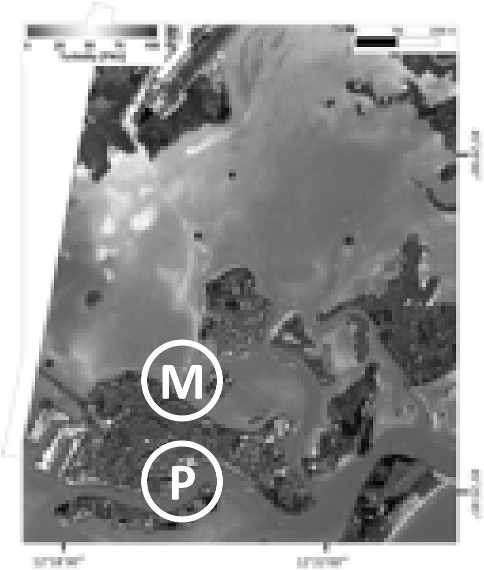



[1] Pahlevan et al. (2019); [2] Vanhellemont and Ruddick, 2018 [3] Vanhellemont, 2019 [4] Dogliotti et al. (2015)

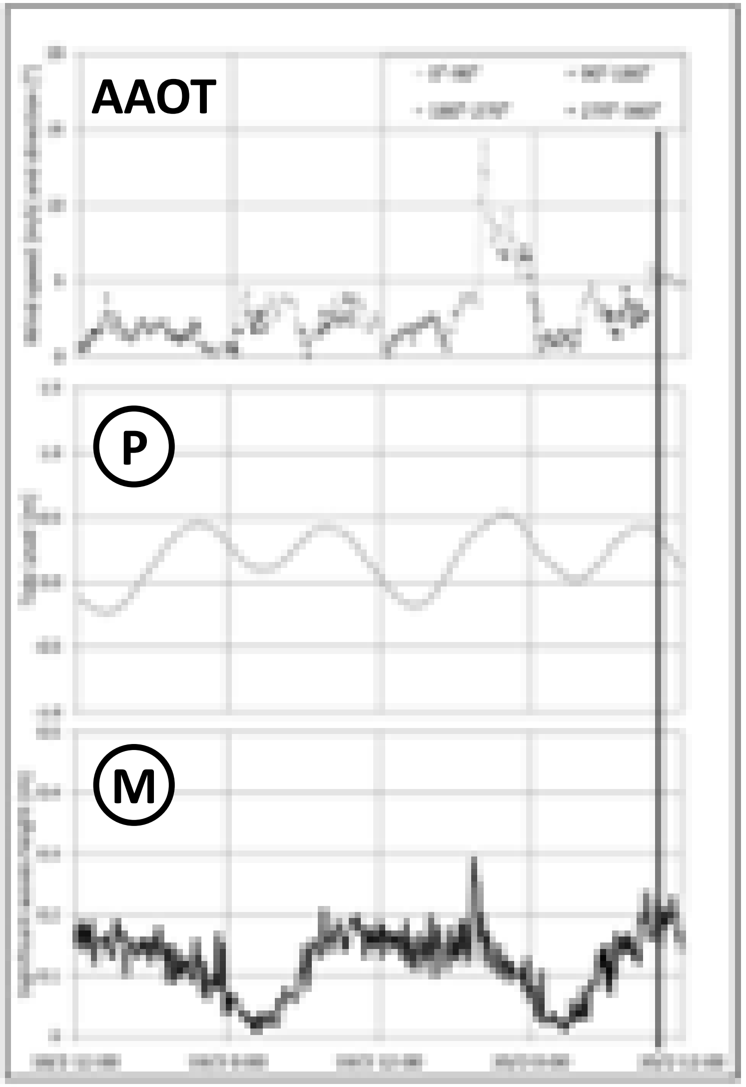
# Data and Methods: ancillary data

- Rainfall data for the city and tributary basin → runoff from lagoon tributaries
- Tide → selection of images with similar tidal level
- Wind → wind-driven resuspension across the lagoon and the canals
- Wave → proxy of the intensity of local water traffic and wake-driven resuspension in the lagoon and canals




February 20th 2020

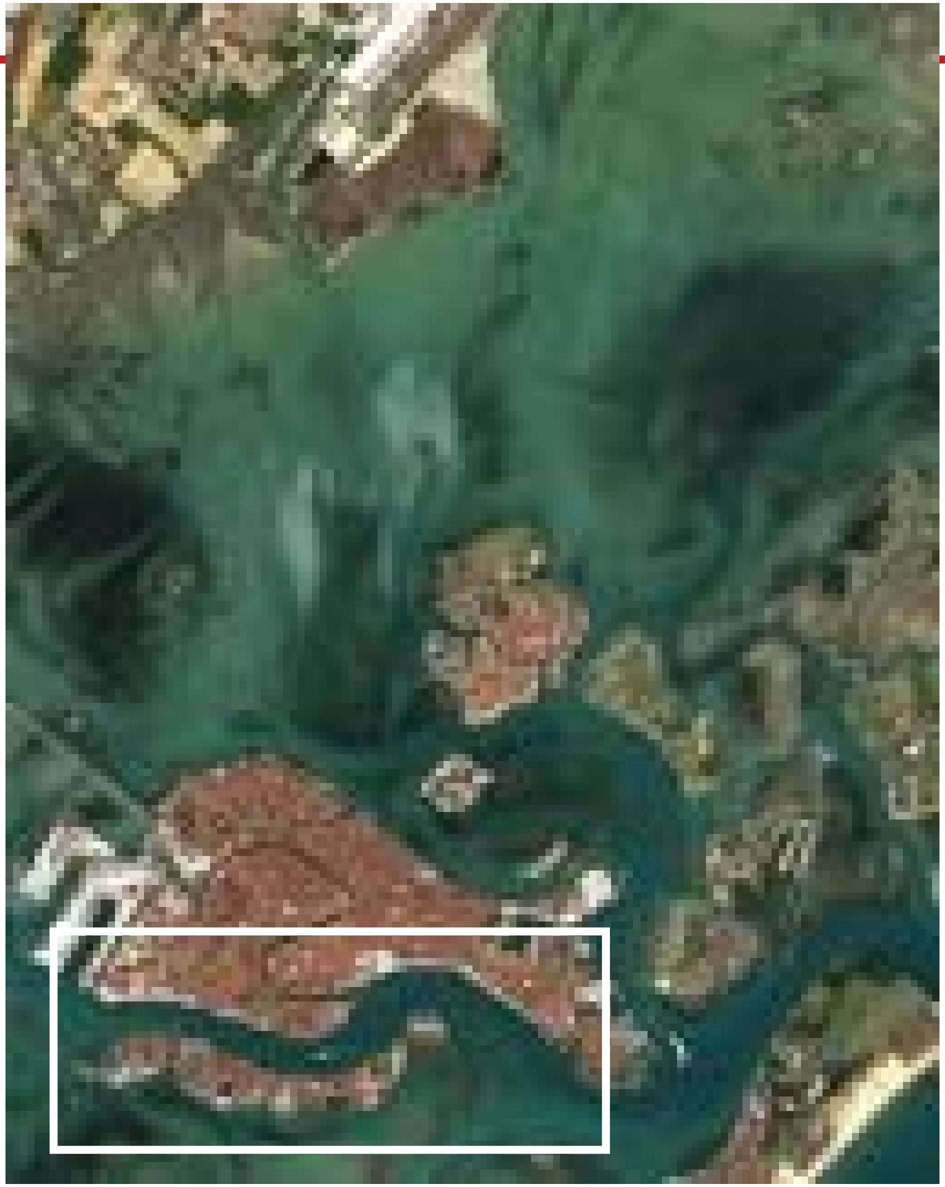



- Rainfall data were made available by ARPAV.
- Tidal levels, wind and wave data from gauge stations in the city centre (Punta Salute and Misericordia, respectively; P and M) and from the Acqua Alta Oceanographic Tower (AAOT, at 16 km off the coast of Venice) were provided by the Centro Previsione e Segnalazione Maree of the city of Venice.

# Results

**Can you spot all the differences?**


February 20th 2020: the last cloud-free image acquired before any restrictive measure



March 19th 2020: 1 week after the Italian lockdown began

# Results

On February 20th, the density of white wakes was relatively high alongside the large channels: Giudecca and the Grand Canal.


On March 19th, few boat wakes were still visible around the city of Venice.

# Results

## Can you spot all the differences?

February 20th 2020: the last cloud-free image acquired  before any restrictive measure

March 19th 2020: 1 week after the Italian lockdown began

# Results

On February 20th, particularly evident were also the wakes of speedboats and waterbuses connecting the city to the airport.

On March 19th, the lagoon water was clearer with less suspended matter in the channels surrounding the city and from Venice to the airport.

# Results

The comparison of the traffic intensity during the Easter weekend of 2019 and 2020, a typical period of peak tourism influx similar to the conditions during the summer months.

In the April 19th 2019 image, the boat traffic was more sustained than on February.

April 19th 2019

April 10th 2020

# Results

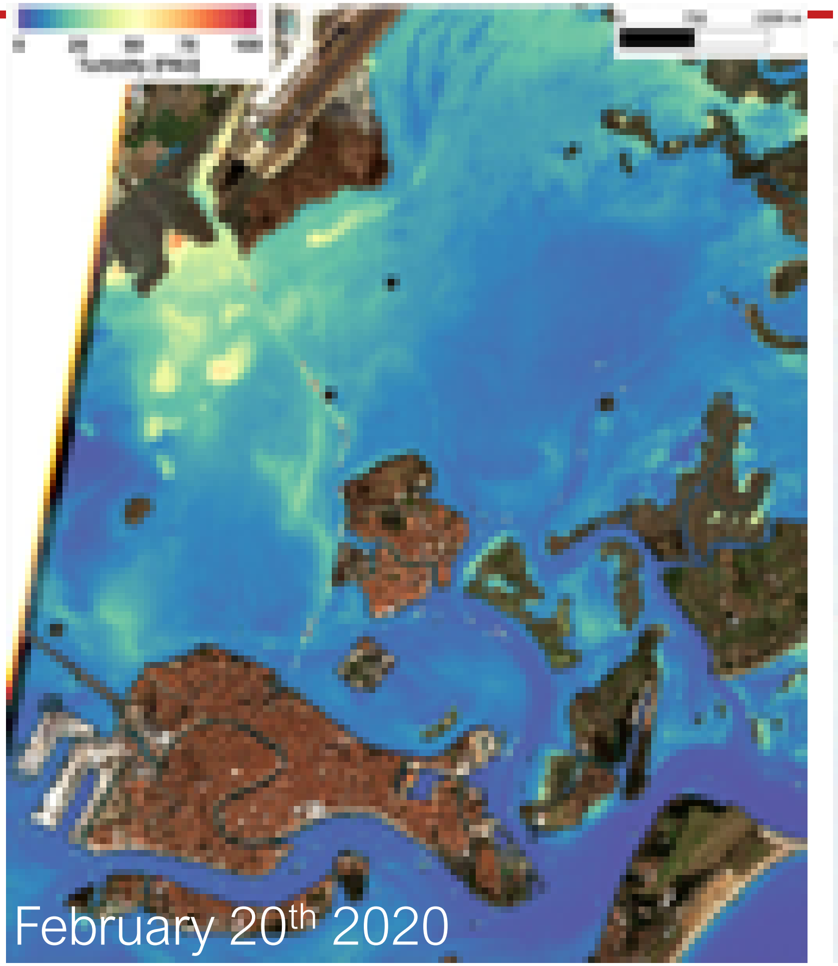
Cruise ships are visible in the passenger terminal on April 19th, 2019, and absent in the 2020 imagery.

In February 2020, the cruise season had not started yet and in the following months the cruise industry underwent a deep worldwide crisis.

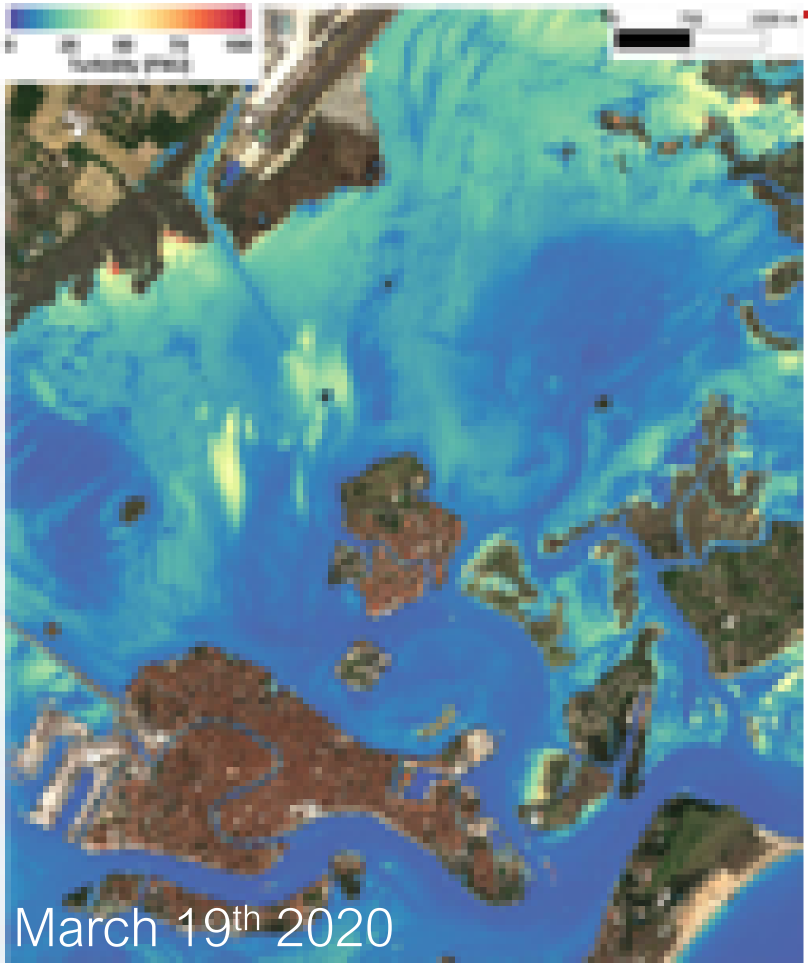
April 19th 2019

April 10th 2020

# Quantitative results



February 20$^{th}$ 2020

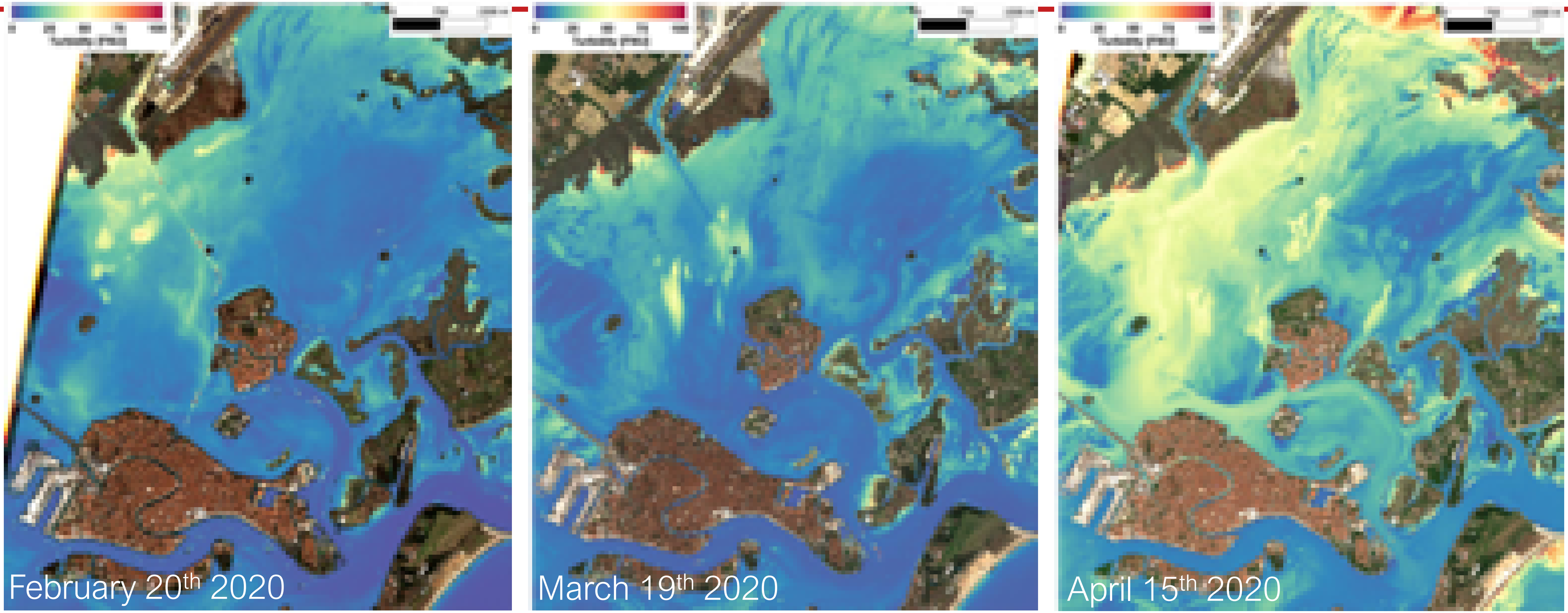


March 19$^{th}$ 2020

On February 20th 2020, the resuspension due to the wakes of speedboats, water taxis and airport shuttles, was quite intense in the channel connecting the airport water terminal to the city and in the nearest areas of the adjacent sub-tidal flats, where the turbidity reached about 50 FNU.

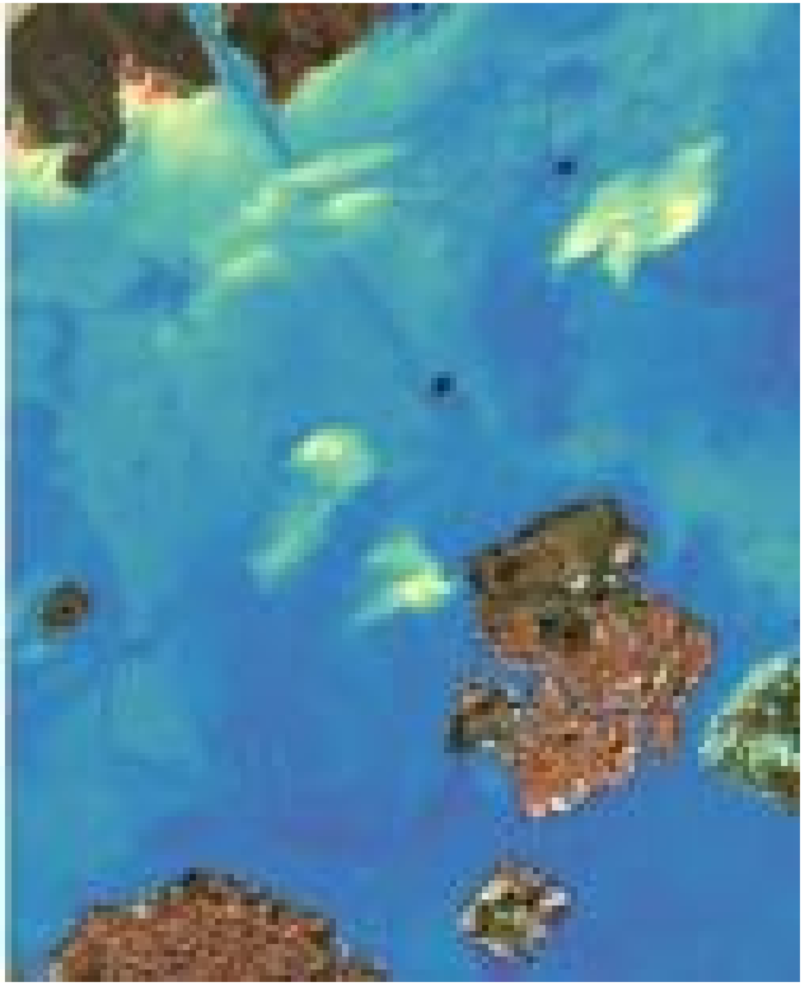
In the map of March 19th, when the lockdown was in place and boat traffic almost stopped, the turbidity in the channel and the airport harbour was comparable to that observed around the city (~5 FNU).

# Quantitative results

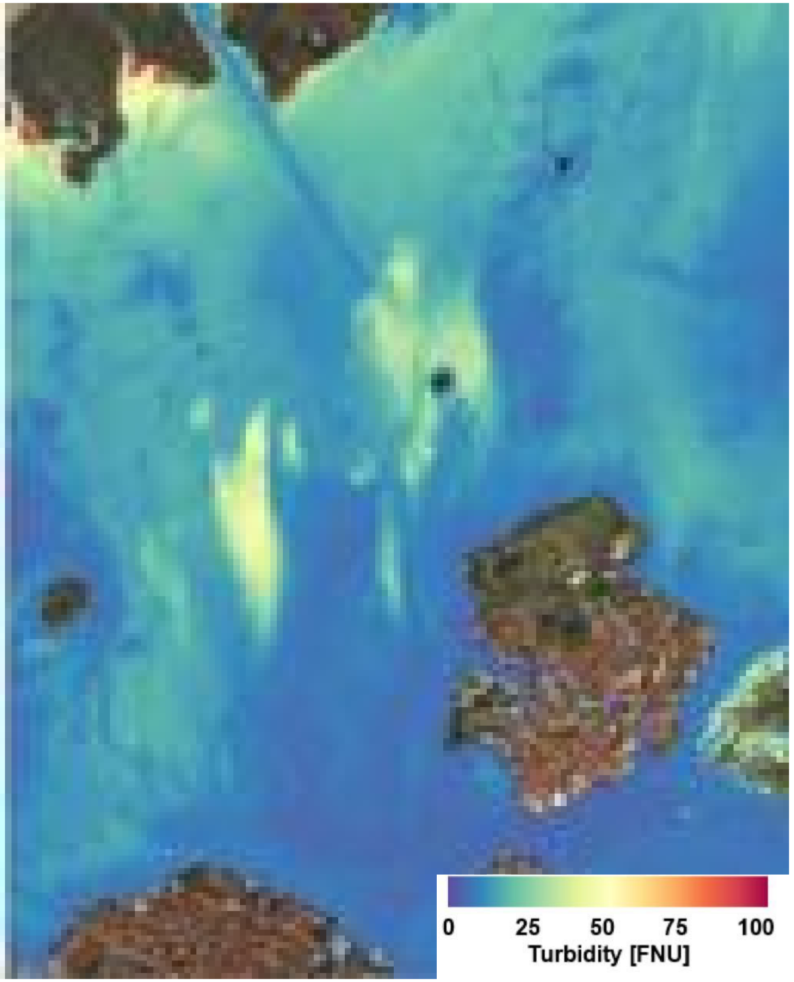



In the hours before the April 15th satellite overpass, northeasterly winds (Bora, N-NE) reached 20 m/s and determined a Hs of 0.3 m at the Misericordia gauge station. Wind- and wave-driven resuspension increased turbidity to a range of 25–50 FNU in the northern lagoon.

# Quantitative results



March 16th 2020




March 19th 2020

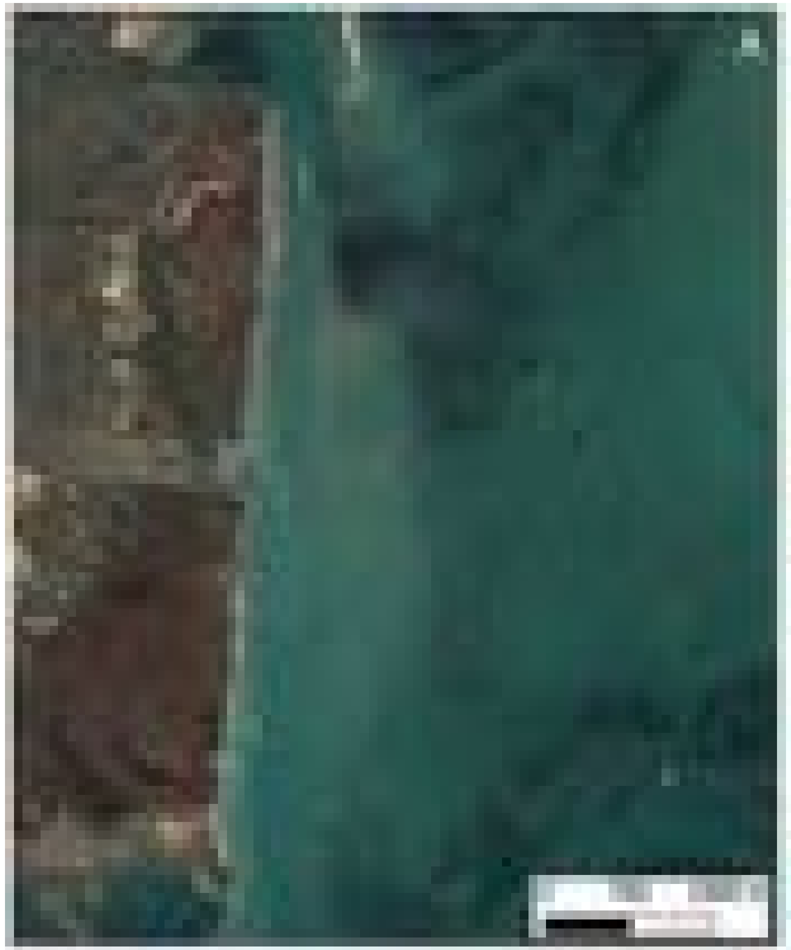
In the sub-tidal flats north of the Island of Murano, small plumes of brown and grey suspended sediments are visible in the true-colour composites and in the turbidity maps (35–50 FNU).

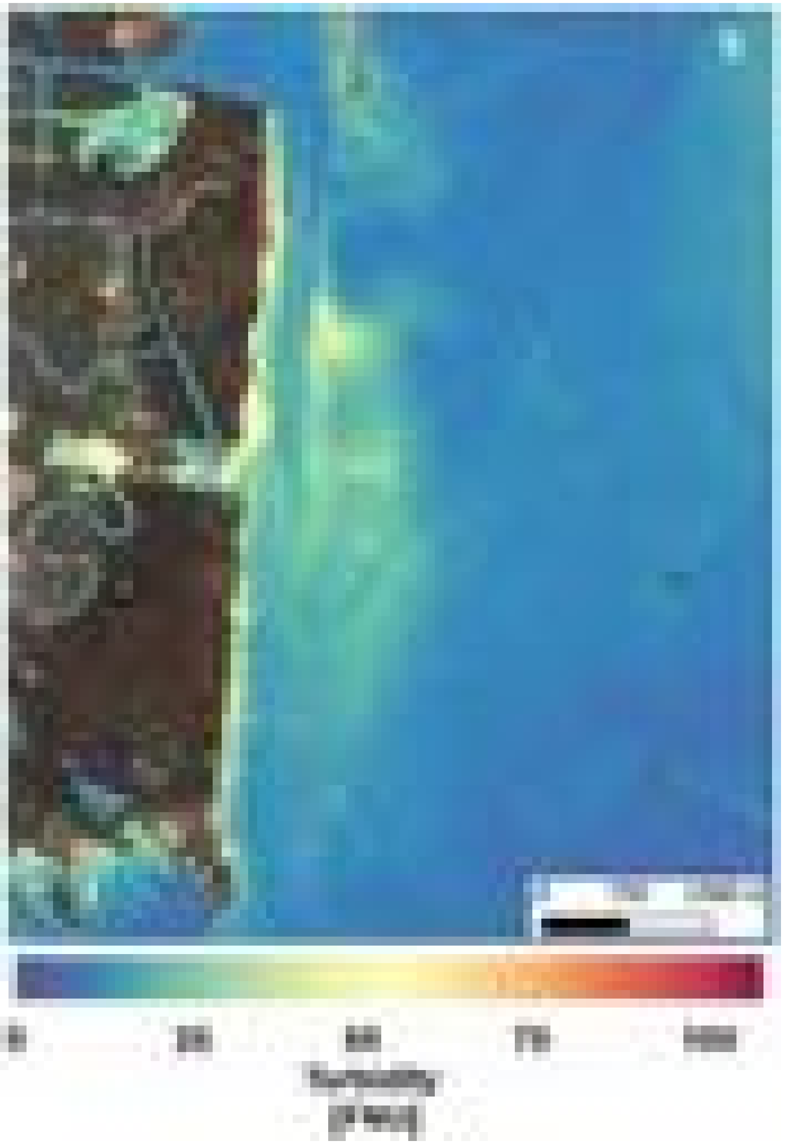
These originate within the clam harvesting concession areas where bottom sediments are mobilized by the shellfishing gears as point sources.

Clam harvesting was one of the essential activities that continued throughout the lockdown and was not subjected to restrictions.

IN VENICE S2 IS ACQUIRED EVERY 2-3 DAYS

# Quantitative results





April 3rd 2020

Commercial shipping was another essential activity not subjected to restrictions.

The ship wakes increased suspended sediment in the channel as well as on sub-tidal flats, and the impacts are visible both in the true-colour composite, as brown resuspended clouds, and in the turbidity map, as patches of high values exceeding 50 FNU.

The localized resuspension provides a synoptic demonstration of the effects of ship traffic on the morpho-dynamics [5, 6].

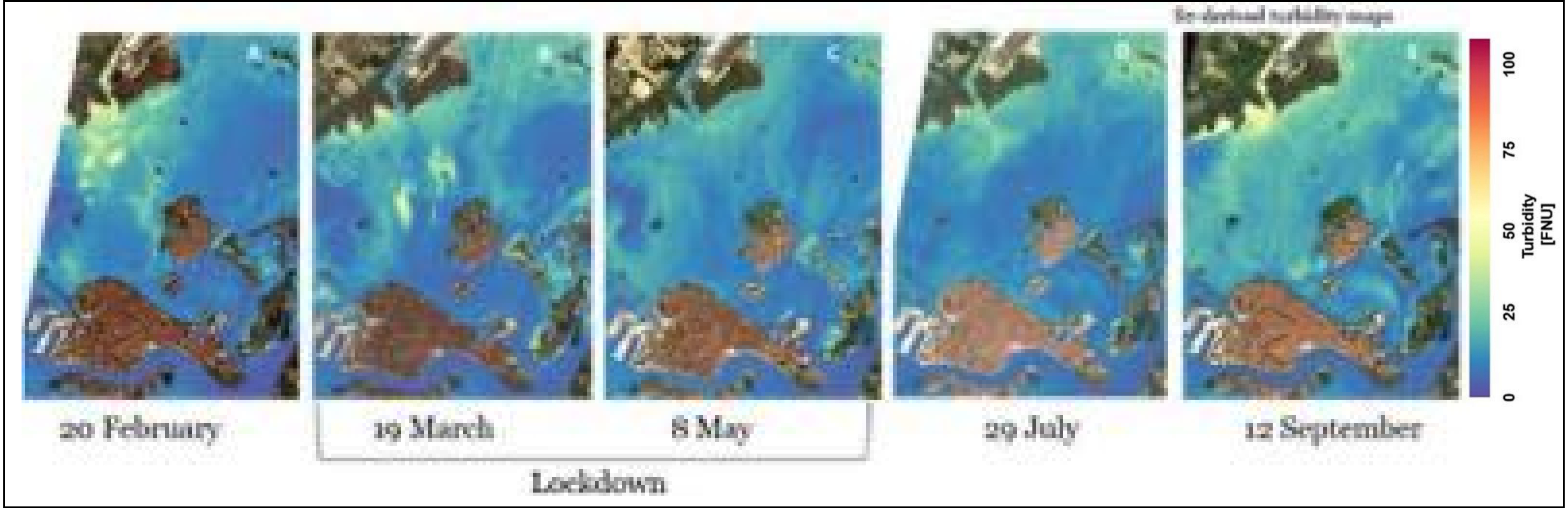
[5] Zaggia et al. (2017) [6] Scarpa et al. (2019)

# Final remarks

The high water transparency was considered as a ephemeral condition determined by a combination of natural seasonal factors and the effects of COVID-19 restrictions:

- The minimized impact of boat and cruise ship wakes, which generate erosion and particle resuspension;
- The release of the traffic pressure, which suggests a reduction of turbulence in the water column, potentially favouring particle settling and deposition.
- A decreased wastewater discharge in the canals, as it can be inferred from the halving of the apparent population to only the official residents.
- A lower runoff from lagoon tributaries. The first four months of 2020 were characterized by the lowest precipitation in the last two decades.
- The phytoplankton phenology, that is at the start of the growth cycle in late winter/early spring, leading to high water transparency in the lagoon and the Adriatic Sea.

# Final remarks




After the lifting of the lockdown in June, the situation slowly returned to pre-COVID-19 lockdown conditions.

# Conclusions

- The COVID-19 lockdown has provided a unique opportunity to observe the lagoon of Venice without water traffic, one of the main anthropic disturbances.
- The major environmental effect of the worldwide COVID-19 lockdown was reported in most cases as an improvement of air quality and environmental noise due to reduction in vehicular traffic. Here, we observed an increasing of water transparency.
- In terms of spatial, radiometric and temporal resolutions, Sentinel-2 imagery proved useful for qualitative visual interpretation and quantitative analysis of suspended matter patterns.

CoastObs Venezia2021 SOOM

# Fine scale oceanography from space

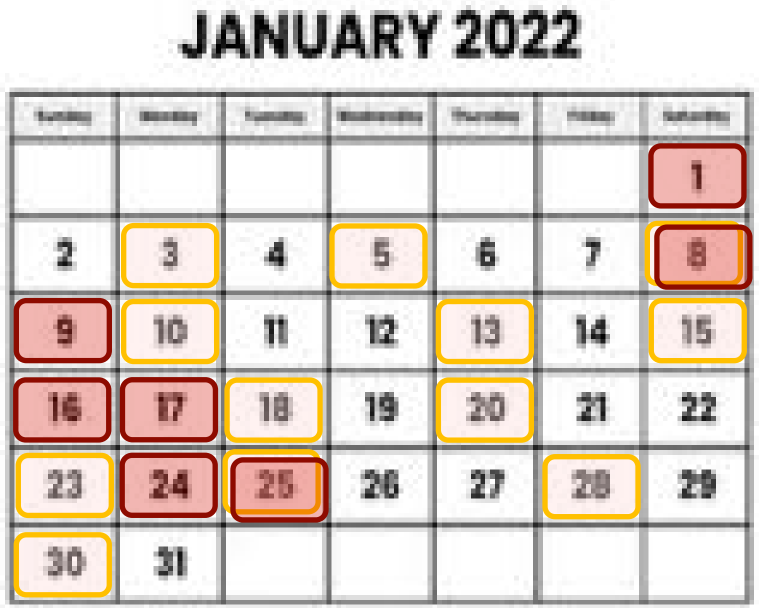
- The spatial, radiometric and temporal resolutions of Sentinel-2 and Landsat 8/9 imagery enable to study fine scale oceanographic processes
- For quantitative analysis, intercalibration among sensors needs to be carried out.

Sentinel-2 A&B

Sentinel-2 A&B

Landsat 8-9

Landsat 8-9

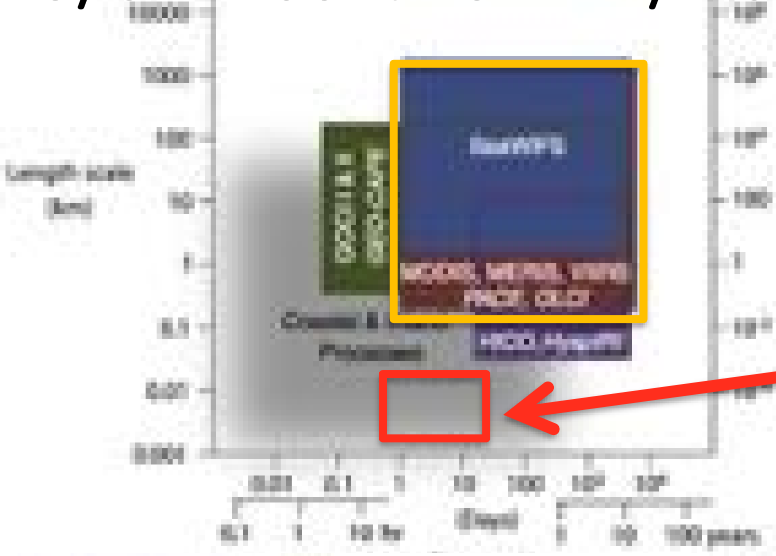


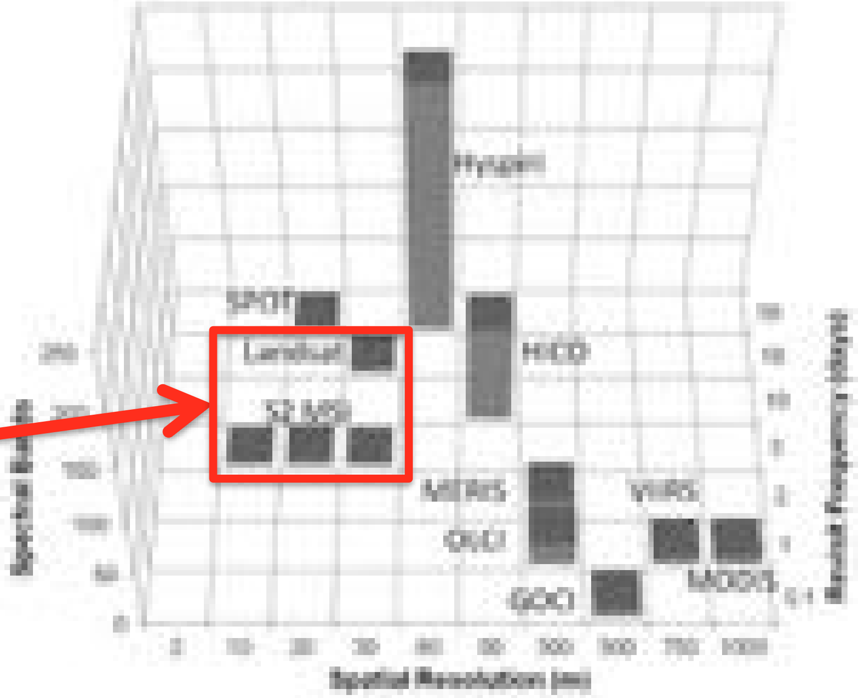

S2A&B L8-9

IN VENICE S2+L8/9 ARE ACQUIRED EVERY 1-2 DAYS

# Processes scales and observation: focus on inland/coastal processes

New “observation class”:
Landsat-8+9/OLI + Sentinel-2AB/MSI

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Review

Aquatic color radiometry remote sensing of coastal and inland waters: Challenges and recommendations for future satellite missions

Colleen B. Mouw, Steven Greb, Dirk Aurin, Paul M. DiGiacomo, Zhongping Lee, Michael Twardowski, Caren Binding, Chuanmin Hu, Ronghua Ma, Timothy Moore, Wesley Moses, Susanne E. Craig

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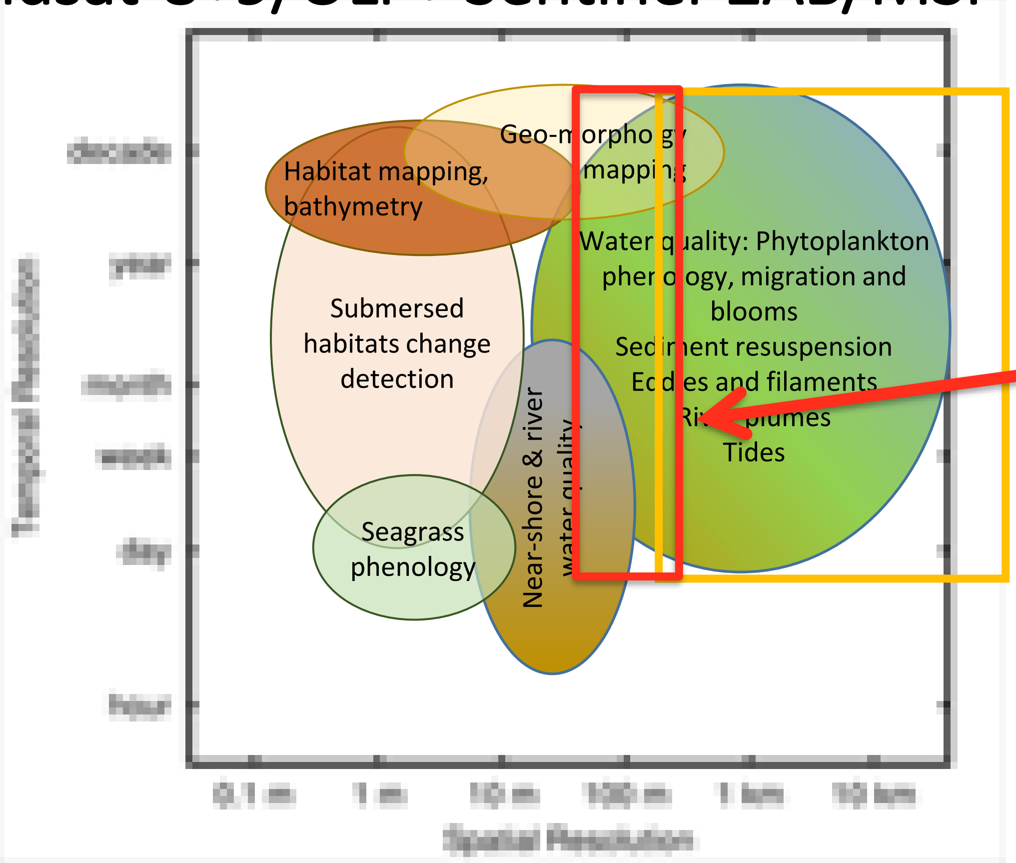
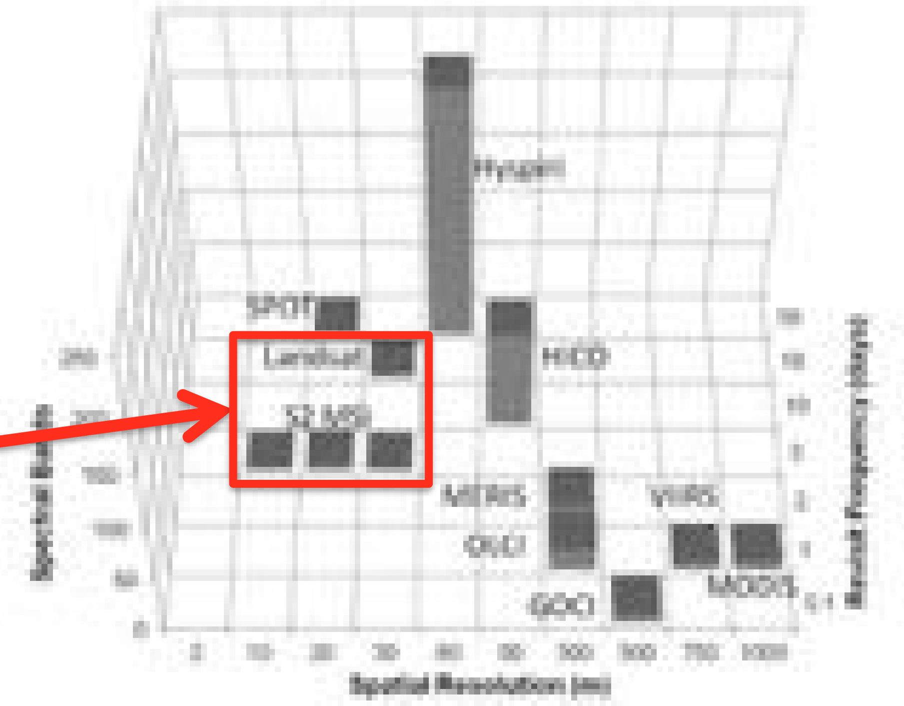
Measuring freshwater aquatic ecosystems: The need for a hyperspectral global mapping satellite mission

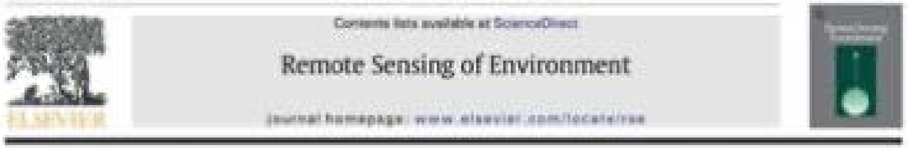
Erin Lee Hestir, Vittorio E. Brando, Mariano Bresciani, Claudia Giardino, Erica Matta, Paolo Villa, Arnold G. Dekker

# Processes scales and observation: focus on inland/coastal processes

## New “observation class”: Landsat-8+9/OLI + Sentinel-2AB/MSI



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Focus on inland/coastal processes
Giardino and Brando, based on Hedley et al., RSE 2018 - *Modified*

# OCTAC MSI multi-sensor products

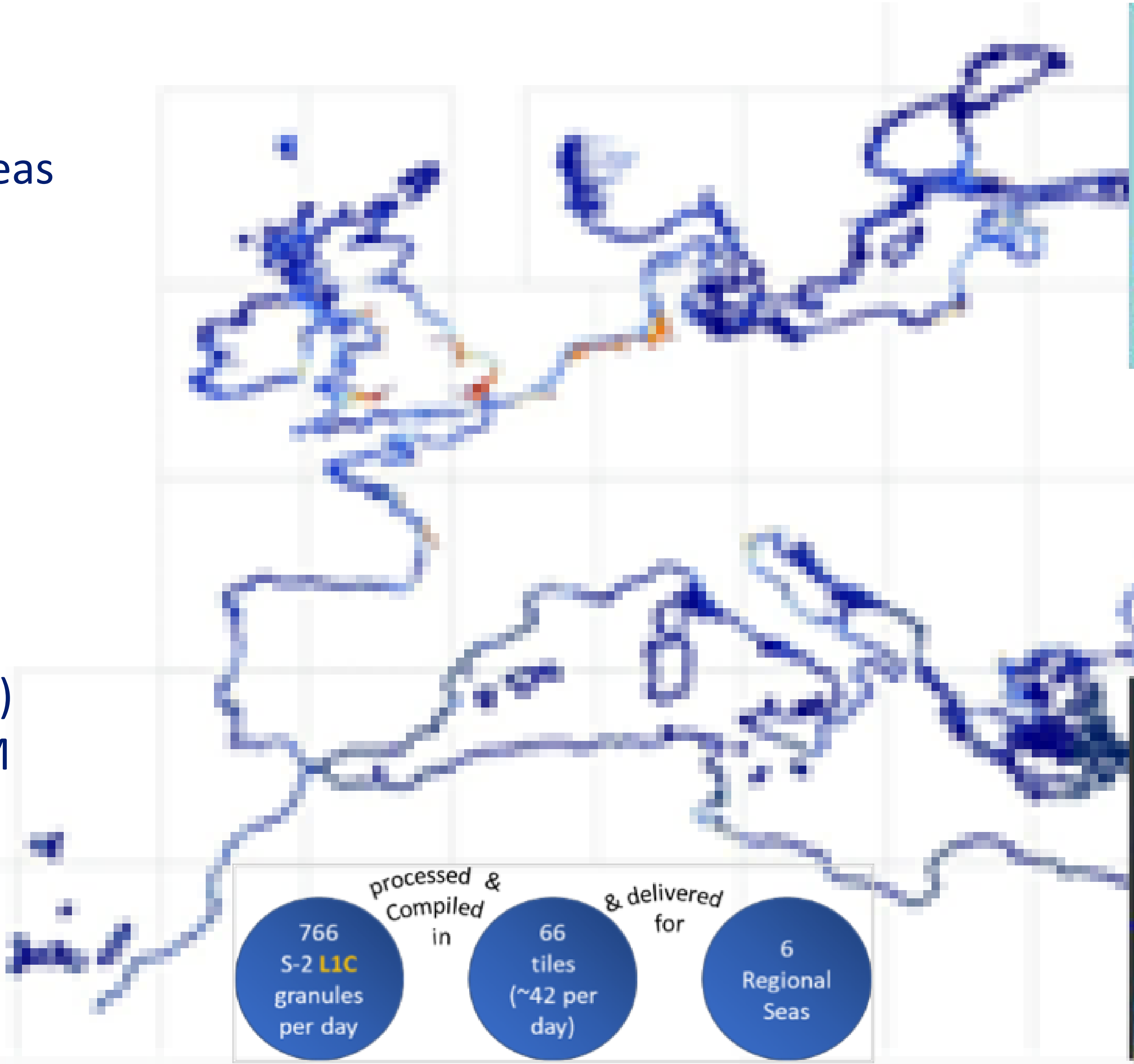
## S2 MSI

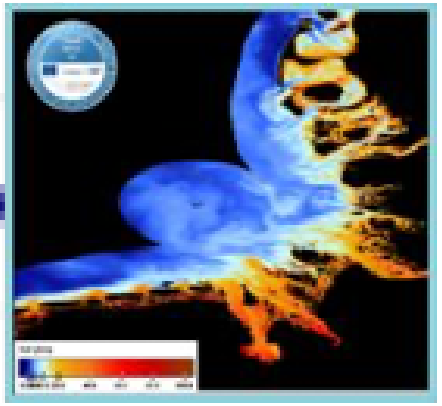
Coastal stripes of 20km for European Seas

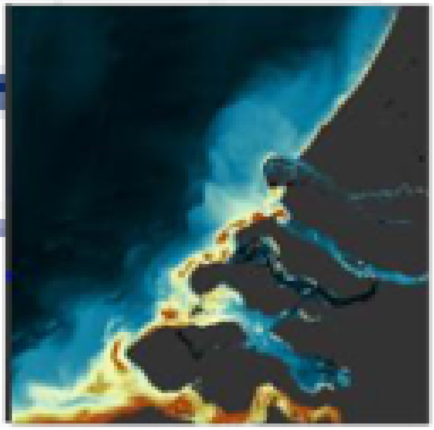
- S2 B&C at 100m resolution
- NRT 1/1/2020 ->
  - L3: daily;
  - L4: daily gap-filled and monthly averages

## Parameters

- Remote Sensing Reflectances - Rrs(λ)
- Suspended Particulate Matter – SPM
- Turbidity - TUR
- Particulate Backscatter - BBP(l)
- Chlorophyll Concentration – CHL (one algorithm for all European waters)





IOCCG Summer Lecture Series 2026

Frontiers in Ocean Optics and Ocean Colour Science

# Fine scale satellite oceanography - applications to turbid water

**Vittorio E. Brando**

**CNR-ISMAR, Rome, Italy**

Venice, Italy - 9 July 2026