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Ten-years sediment dynamics in northern Adriatic Sea investigated through optical Remote Sensing observations

Filipponi Federico[1,2], Taramelli Andrea[1,3], Zucca Francesco[2], Valentini Emiliana[1], El Serafy Ghada[4]

1. ISPRA, Institute for Environmental Protection and Research, Via Vitaliano Brancati 48, 00144 Roma, ITALY - federico.filipponi@gmail.com - 2. Department of Earth and Environment Science, University of Pavia, sec. Earth Science, Via Ferrata 1, 27100 Pavia, ITALY 3. IUSS Institute for Advanced Study, Piazza della Vittoria 15, 27100, Pavia, ITALY - 4. Marine and Coastal Systems, Deltares, Rotterdamseweg 185, PO Box 177, 2600 MH Delft, NETHERLANDS

ABSTRACT

Understanding the factors influencing sediment fluxes is a key issue to interpret the evolution of coastal sedimentation under natural and human impact and relevant for the natural resources management. Despite river plumes represent one of the major gain in sedimentary budget of littoral cells, complex behavior of coastal plumes, like river discharge characteristics, wind stress and hydro-climatic variables, has not been yet fully investigated. Use of Earth Observation data allows the identification of spatial and temporal variations of suspended sediments related to river runoff, seafloor erosion, sediment transport and deposition processes.

The objective of this study is to investigate superficial processes in sedimentary depositional marine environment integrating in-situ data and remote sensing data. The developed innovative approach allow quantitative evaluation of sediment dynamics using Earth Observation data, by relating spatial and temporal patterns of sediment dispersal with climatic forcings.

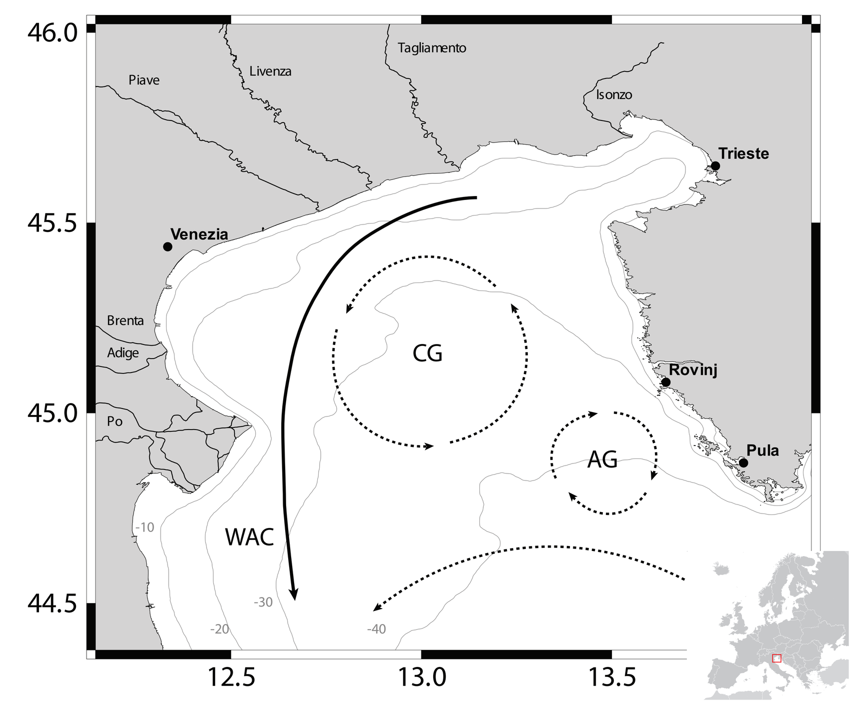


Figure 1 - Map of the northern Adriatic Sea. Main cities and rivers are shown on land side (gray area). Seaward, bathymetric contours are 10 m, surface circulation pattern during normal wind condition (solid arrow): Western Adriatic Current (WAC), surface circulation pattern during steady Bora wind condition (dashed arrows): Cyclonic Gyre (CG) and Anticyclonic Gyre (AG).

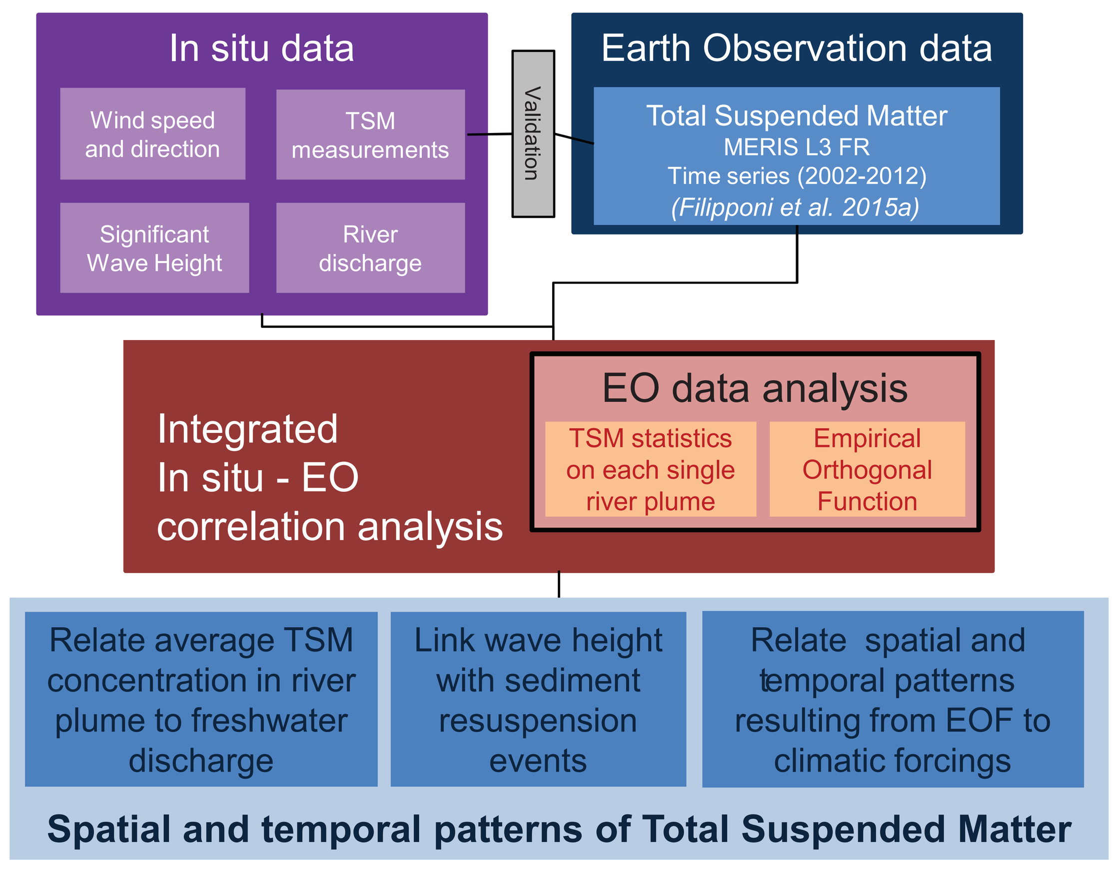
STUDY AREA

The Adriatic Sea is a shallow semi-enclosed shelf sea located between western and eastern parts of the Mediterranean Sea, it is about 800 Km long and 150 Km wide. Northern Adriatic Sea (Figure 1) occupy the northern and shallower area (depth < 100 m) and has a gentle slope (about 0.02°).Two distinct wind regimes, Bora and Sirocco, dominate conditions in NAS and influence basin-wide circulation. One of the major features is a coastal current along the western side of the basin, the Western Adriatic Coastal Current (WAC), driven by wind and thermohaline forcing. Circulation in the basin is altered during events of strong Bora wind, which provokes the formation of a double-gyre (cyclonic, Trieste, and anticyclonic, Rovinj).

In the NAS, two main classes of sediments can be identified (Brambati et al., 1973). The first class consists of coarser sediments of sand with grain size between 50 and 2000 μm, the second class is of finer materials of silt with grain size between 2 and 50 μm. It has long been recognized that the fine sediments such as fine sand, silt and clay are mainly supplied from the NAS rivers, and transported southward by the WAC (Brambati et al., 1973; Nittrouer et al., 2004).

Annual cycle of northern Adriatic Sea rivers is characterized by two low-discharge periods, in winter and summer, alternated by two high-discharge peaks, the first one during early spring due to melting snow, glacial ice and frontal rainfall and a second one during late autumn related to rainfall. Transport within the buoyant plume is important during floods, sediment transport rates and pathways are controlled by wave action and current direction (Bever et al., 2009). Mechanisms associated with river-derived sediments and wave resuspended sediments under strong winds, produced depositional patterns similar to the observed late Holocene deposits, suggesting that event scale models can provide insight about sedimentation on geologic timescales (Lee et al., 2005; Harris et al., 2008).

METHODOLOGY WORKFLOW



RESULTS

Empirical Orthogonal Function

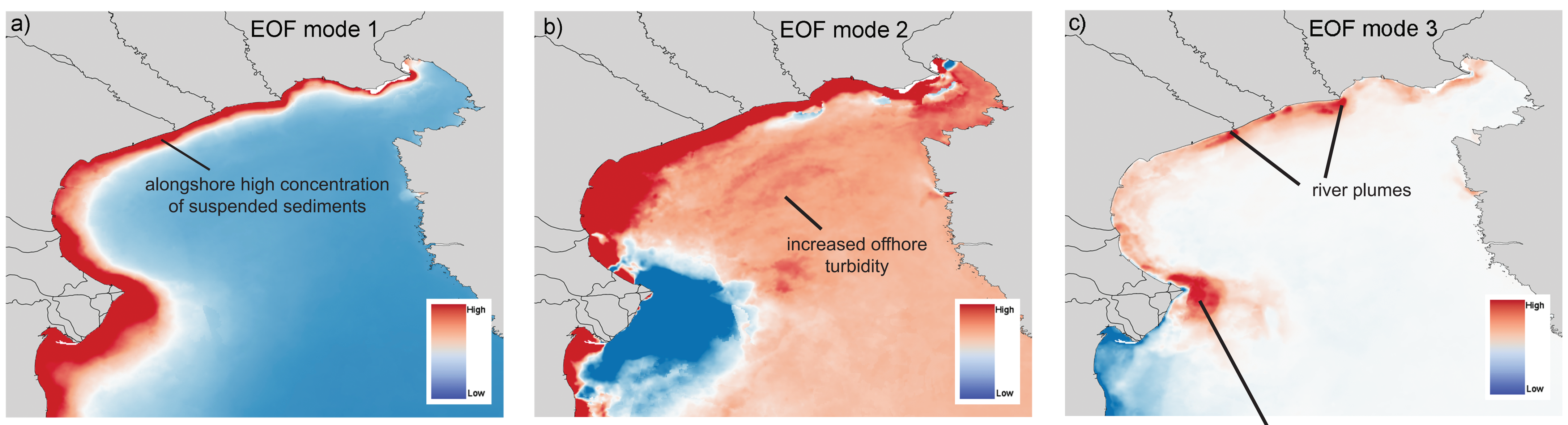


Figure 2. Spatial representation of Empirical Orthogonal function (a) mode 1 (b) mode 2 (c) mode 3.

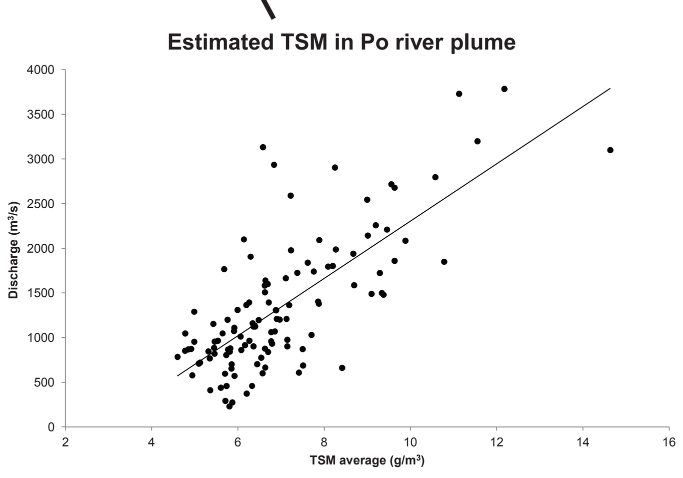


Figure 4. Relation between TSM average concentration in Po river plume and Po river discharge.

- TSM monthly averages show an evident **intra-annual variability**, with low concentrations during summer periods and high concentration in the period November-February (Figure 5).
- maximum concentrations of TSM are related to periods of high freshwater runoff (May, November, December),
- concentration of TSM is highly variable during March (Bora events), May and September months, and strongly related to peaks in freshwater discharge rates.
- December has been found to be the month with higher TSM concentration, due to combination of both peaks in freshwater discharge rates and sediment resuspension events.
- **Good correlation (R^2>0.55) has been found comparing TSM average concentration estimated from the plume and discharge** of main rivers acquired at satellite acquisition date (Figure 4).
- During intense Bora wind forcing over the basin, lasting for many days, increased wave height (**Gutierrez et al., 2015**) triggers resuspension of sediments, forming an alongshore pattern of high turbidity waters
- after some days of Bora wind forcing, circulation is altered with the formation of a double-gyre, which is exhibited by **increase in TSM concentration offshore** and have the ability of transport and **distribute sediments all over the basin** (Filipponi et al., 2015b).
- Empirical Orthogonal Functions (EOFs) generated from TSM monthly averages summarize spatial and temporal patterns of TSM in NAS basin.
- EOF mode 1 describes spatial patterns of high sediment concentration (Figure 2a), **expansion coefficient of EOF mode 1 shows the seasonality and trend** of the increased turbidity from suspended sediments in the basin
- **EOF mode 2 describe spatial patterns of sediment resuspension events** (Figure 2b), with high sediment concentration in the alongshore area and increased turbidity in the offshore area, highlighting the evidence of sediment transport driven by the altered circulation during intense wind forcing, which spreads sediment after the resuspension occurred.
- **EOF mode 3 describe spatial and temporal patterns of major river plumes** (Figure 2c), that are dispersed in the alongshore area according with the main circulation of the basin
- Comparison of EOF Expansion Coefficients (EC) temporal profiles (Figure 3) with wave field, and river discharge highlights that **EOF mode 1 is related with the wave field** and temporal variations of **EOF mode 2 and 3 with freshwater discharge rates**.

Temporal patterns from EOF and climatic forcing

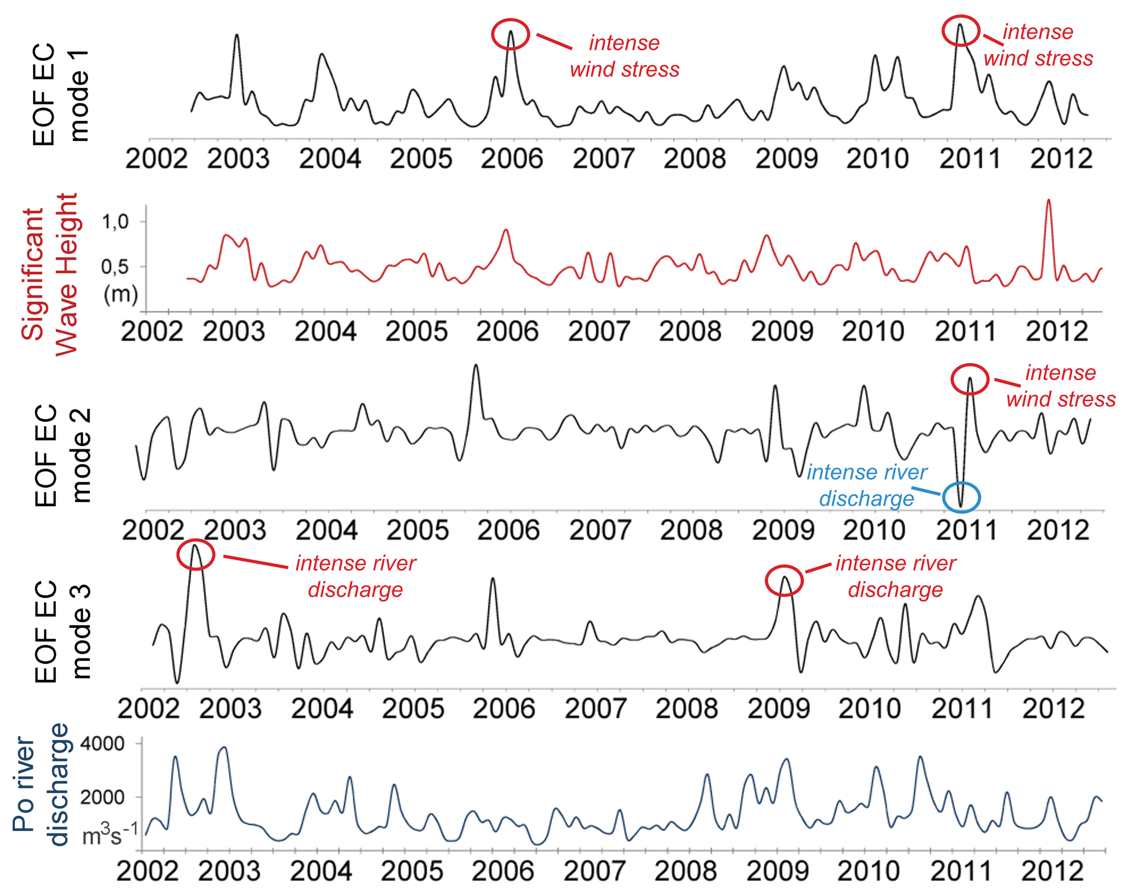


Figure 3. Expansion Coefficients of the first three Empirical Orthogonal Function modes in comparison to monthly averages Significant Wave Height and monthly averaged Po river discharge.

Total Suspended Matter by months

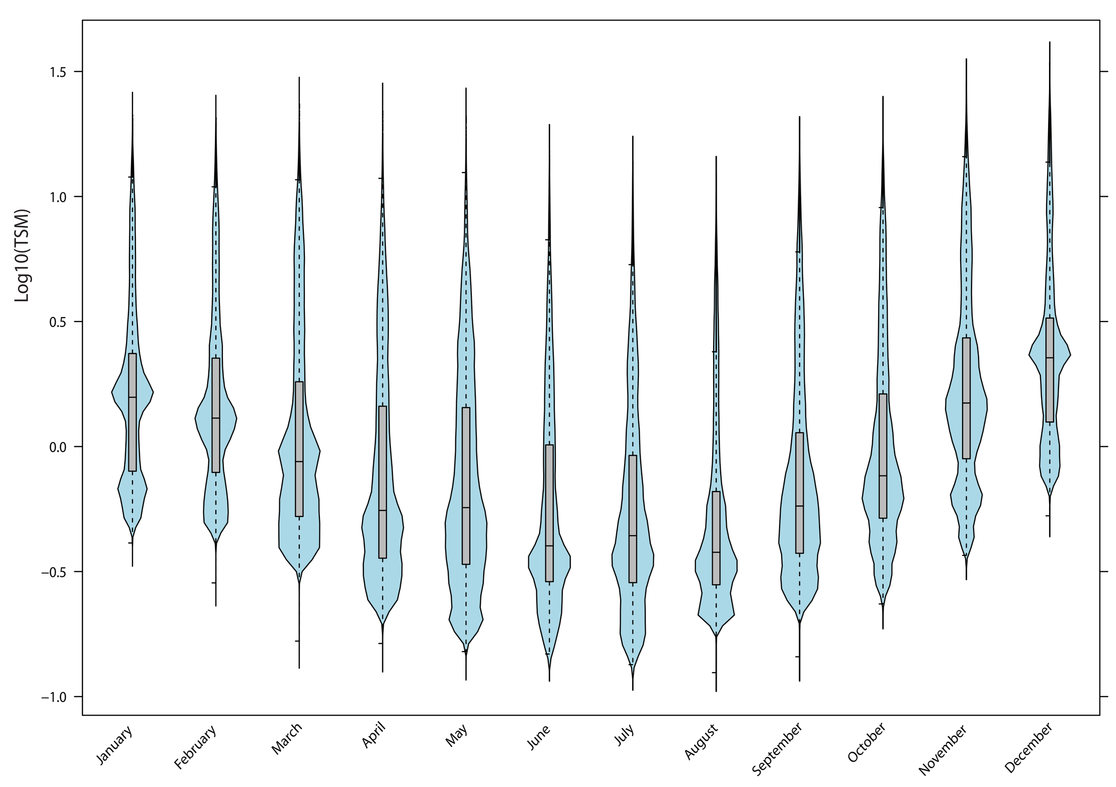


Figure 5 - Box and whisker plot of Total Suspended Matter monthly averages in northern Adriatic Sea for the period 2002-2012.

Acknowledgements

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