Extreme Suspended Particulate Matter concentration events at river mouths detected by the Sentiniel-3 satellite mission

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Introduction

Climate changes have an impact on all global systems and precipitation patterns are one of the most severely affected components, both in time and spatial dimension. While only small variations in annual precipitation quantity are foreseen, these are accompanied by an increase of the number of extreme weather events. Concentrated rain, both in space and time, generally leads to a more intense land surface runoff. These perturbations have significant impacts on river flow and subsequently on solid outputs into the coastal areas and inside associated wetlands. Such extraordinary events were well captured by the Ocean and Land Colour Instrument (OLCI) onboard Sentinel-3 in the Danube Delta coastal area, within the last few years. Images acquired during very high Suspended Particulate Matter (SPM) concentration situations help us quantify the effects of precipitation patterns changes on the rivers solid discharge characteristics and their impact on the coastal area.

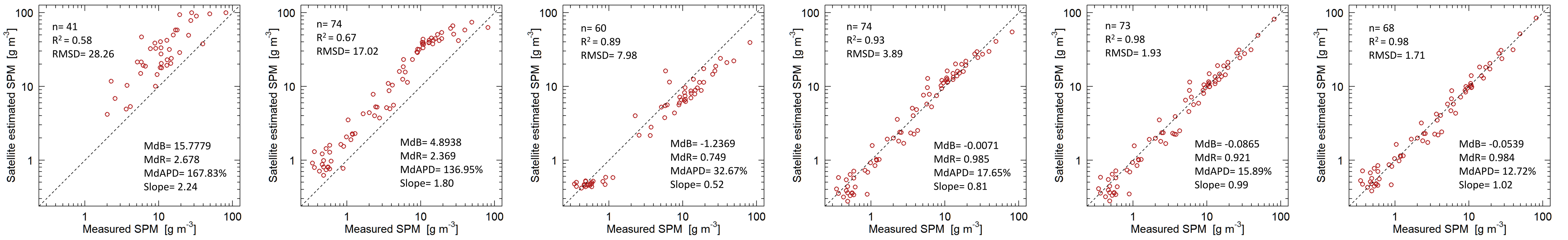
Data & Methods

Estimation of the Suspended Particulate Matter concentration (SPM) from satellite water reflectance

Match-ups between in-situ SPM data and satellite/in-situ water reflectance; in-situ dataset: SPM collected at Sfântu Gheorghe Marine and Fluvial Research Station (University of Bucharest); SPM and water reflectance available from MERMAID - PANGAEA database BIO-OPT Cruises (Valente et al., 2019).
Multiple inversion algorithms were tested:

- the C2RCC neural network (TSM_NN from standard OLCI Level 2 products)
- recalibrated Nechad approach by Han et al. (2016), based on the 665 nm band
- global algorithm proposed by Wei et al. (2021)
- Nechad et al. (2010): SPM= (A * ρ) / (1-(ρ /C)), where ρ is the water reflectance, with recalibrated coefficients - 665 nm: A=355.85, C=0.1725; 865nm: A= 2971.93, C=0.2115 (CMEMS, 2022); merging scheme between 665 nm and 865 nm bands
- regional calibrated Nechad approach; merging scheme between 665 nm and 865 nm bands (Coefficients - 665 nm: A=361, C=0.5; 865nm: A=2330.968, C=0.033)
- regional empirical algorithm (Danube Delta – DD); merging scheme between linear model using the 665 nm band and second polynomial model based on the 865 nm band (transition zone: 0.0162 < ρ(665) < 0.046)

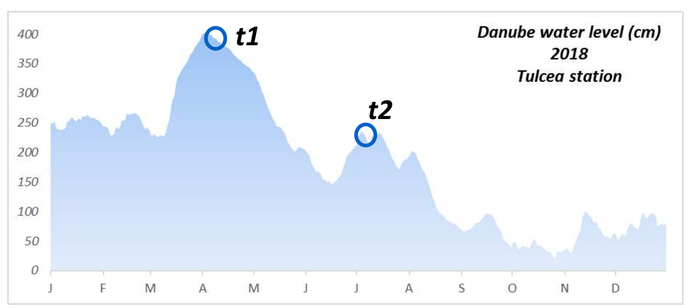
Sampling locations; yellow dots correspond to MERMAID campaign; red points – data collected at Sfântu Gheorghe Marine and Fluvial Research Station



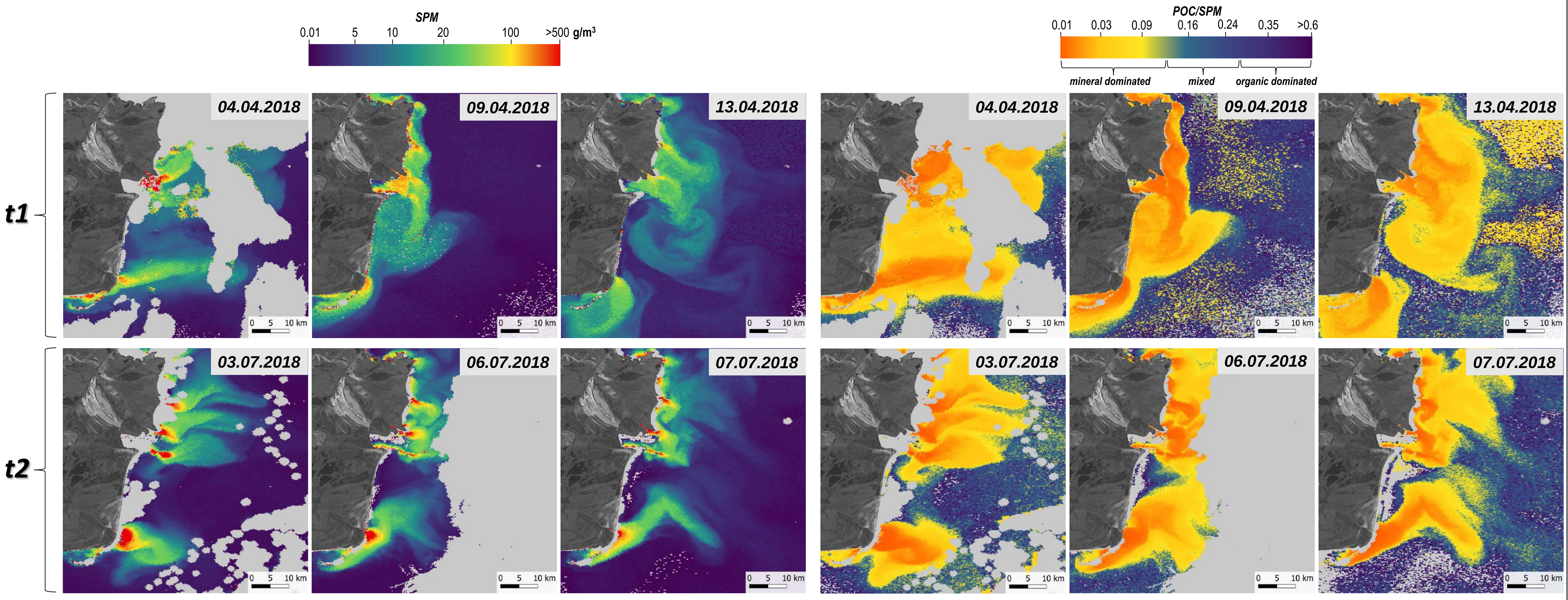
Estimation of the ratio between Particulate Organic Carbon (POC) and Suspended Particulate Matter (SPM) - The POC/SPM ratio is used as a proxy for particles assemblages composition. Mineral dominated, mixed and organic dominated classes can be detected. The products are computed based on the algorithm developed by Stramski et al. (in review), which uses spectral band in the following domains: 490 nm, 560 nm and 665 nm.

Results & Discussion

July 2018

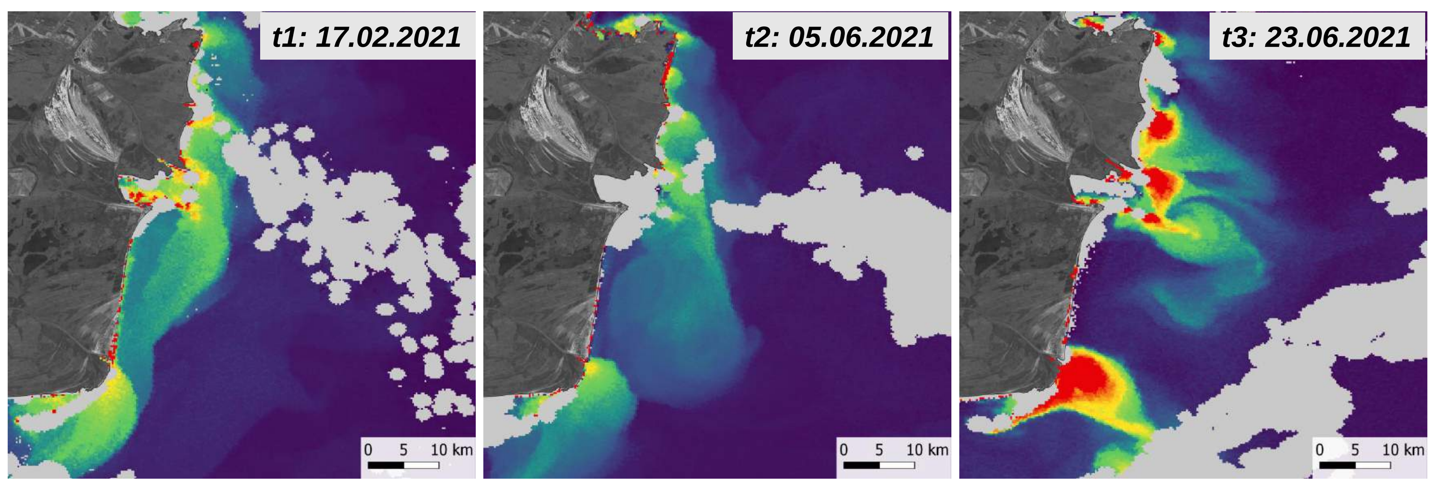


Higher SPM concentrations observed for t2, of more than 500 g/m³ close to river mouths. These extreme values were confirmed by in-situ data collected on July 6 and 8, on the southern branch of the Danube (Sfântu Gheorghe), less than 3 km upstream of the river mouth.
For t1, the SPM barely exceeds 200 g/m³ (April 4) and is less than 100 g/m³ at river mouths on April 13. The extent of mineral dominated waters tends to be larger for plumes associated with t1.

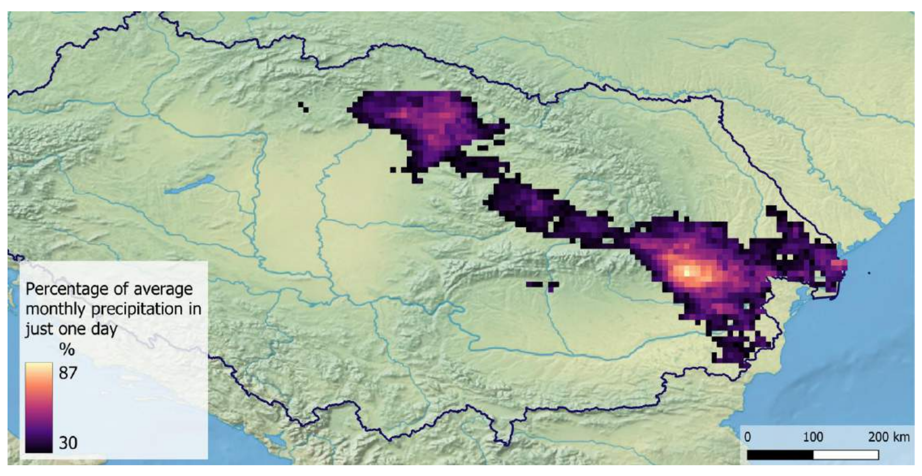


June 2021

SPM values are significant higher during t3, compared with t1 and t2, which are characterized by higher Danube water levels.



Precipitation intensity



The map shows the percentage of the multi-annual (2000-2021) monthly average precipitations for June that were registered in just one day (June 27, 2018 - few days before the high SPM values at river mouths from the beginning of July), in the eastern part of the Danube's hydrographic basin.

Only values above 30% are represented.

Source: Integrated Multi-satellitE Retrievals for GPM (IMERG).

Conclusions

Sentinel-3 OLCI products have the capability to detect and monitor extreme SPM concentration events in coastal areas. Adaptation of inversion algorithms is still required in order to derive accurate estimates of SPM. The Nechad approach, based on regional coefficients and the merging scheme between 665 nm and 865 nm bands, cannot resolve very high SPM values. The second order polynomial model, empirically determined, cannot predict very accurate for values outside of the training range (app. 100 g/m³). Still, it represents the best approximation available for such high concentrations.
The identified bursts of high SPM could be potentially linked with flash floods located in the Danube's lower hydrological basin (especially in the sub-basins of rivers downstream of the large dams from Portile de Fier I and II, such as Ialomita, Siret, Prut). They are not necessarily associated with high water levels on the Danube. The sediment plume during these events is characterized by steep SPM gradients at the margins. The same pattern can be observed also for indicators related to particles assemblage composition, such as the ratio between POC and SPM. A potential cause for the lower extent of the mineral dominated waters might be linked to different (higher) size of the particles brought by the river in such conditions.

Acknowledgements

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In-situ data collected at the Sfântu Gheorghe Marine and Fluvial Research Station, University of Bucharest.

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