

Evaluating turbidity maximum patterns and their variability in the Seine Estuary from metrics: associating observations and model results

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Context

Turbidity Maximum (TM) zones represent key sedimentary features in estuaries, whose dynamics are driven by small-scale processes (i.e. turbulence, flocculation, erosion), circulation patterns (tidal range, density stratification, flood/ebb dominance) and modulated by seasonal and inter-annual hydrological forcing. The HYMOSED project is aimed to investigate the TM dynamics in the Seine Estuary, from the tidal scale to pluri-annual and (ultimately) decadal scale, combining complementary sources of information: remote sensing ocean colour data, pluri-annual *in situ* measurements and numerical model results. The objectives are first to validate these tools, next to build simple metrics and finally to investigate their variability at various time scales.

Methods

NASA MODIS AQUA observations constitute the longest archive of ocean colour data (from 2002 to now), mainly used in the open ocean or coastal seas. Using MODIS FR observations (250m) in estuaries is a challenging issue, as suspended solid concentration (SSC) gradients are strong and usual 'generic' algorithms can generate large uncertainties. Based on similar experience in the Gironde Estuary, a dedicated field campaign was conducted in September 2014 to collect joint suspended sediment samples and radiances measurements at multiple wave lengths, in order to build a site-specific algorithm and evaluate uncertainties associated to ocean colour derived SSC.

These synoptic / surface / low frequency observations are complemented by the SYNAPSES monitoring network, providing time series of turbidity in 5 stations (surface or bottom/surface in the TM) along the different compartments of the estuary, operated since 2011. These measurements are not yet calibrated in SSC but field surveys are being conducted in 2015 for this purpose. A careful attention will be paid to the analysis of SSC from this network prior to 2015.

The MARS3D hydrodynamics and sediment transport numerical model was implemented in the Seine Estuary, using a specific curvilinear grid more suitable for estuarine geomorphologies (resolution down to 50mx200m within the TM zone). This model reproduces the estuarine circulation and the main sediment processes using the MIXSED module (Le Hir *et al.*, 2011) with 5 sediment classes (1 gravel, 3 sands, 2 muds). It is forced by daily river discharge measurements, METEOFRANCE ARPEGE model wind results and WAVEWATCHIII wave fields simulated on this typical configuration.

Results and conclusions

The TM is a full 4D structure, developing both spatially and temporally and driven by tidal, meteorological and hydrological forcings. Therefore, only numerical model can provide representative metrics (mass in suspension, position, extension and displacement of the TM)... However, models always simplify the complex dynamics of estuaries, and must be validated. In our study, we decided to build and evaluate metrics derived from times series of ocean colour and *in situ* measurements. In the mouth and the adjacent Seine Bay, we quantified the spatial extension, the central position and shape of the surface TM around low tide, tracking the pixels above SSC thresholds estimated from three percentiles of the SSC at the mouth. The same metrics are evaluated within the estuary, with a discussion on the reliability of satellite observations in sections

of 1 km width. From the monitoring network were estimated the percentiles (10, 50 and 90) of SSC during the 4 phases of the tidal cycles over several years, and the duration of period when SSC exceed key concentration levels (bottom and surface), i.e. 0.1 g.l^{-1} , 0.5 g.l^{-1} and 1 g.l^{-1} . All these metrics were analysed together with the main forcings, i.e. wind, waves (direction and height), river discharge, tidal range, and confronted to similar metrics estimated from the model. From the model itself are estimated the mass in suspension in the TM and its distribution within the water column.

These metrics are built to evaluate the TM and evaluate its variability. They are also useful to compare estuarine systems.

References

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