Floc dynamics at the interface between estuaries and coastal seas: from the tidal scale to the seasonal scale.

Chapalain Marion[1], Romaric Verney[1], Michael Fettweis[2], David Le Berre[1], Matthias Jacquet[1], Pierre Le Hir[1]

[1] IFREMER, DYNECO/DHYSED, CS10070, 29280 Plouzané, France

E-mail: romaric.verney@ifremer.fr

[2] Royal Belgian Institute of Natural Sciences (RBINS), Operational Directorate Natural Environment (OD Nature), Rue Vautier 29 / B-1000 Brussels, Belgium

E-mail : mfettweis@naturalsciences.be

Context

Suspended particulate matter (SPM) dynamics in tidal systems is driven by cyclic processes: erosion, advection, flocculation and deposition. Flocculation processes have been extensively studied over the last three decades, mainly in laboratory or in estuaries, where strong hydrodynamic and sediment concentration gradients are observed. These investigations identified turbulence, concentration as the primary controlling factors of aggregation and fragmentation, secondary modulated by salinity and potentially by organic matter content. The influence of the latter was demonstrated mainly in laboratory, and punctually observed in situ. In the present study we focused on the influence of organic matter content on flocculation processes in a pivotal environment, at the interface between estuaries and coastal seas and based on an original 3-year in situ dataset.

Methods

14 field campaigns were conducted from 2016 to 2018 within the Seine river plume and the near Seine Bay in order to investigate flocculation dynamics and the potential relationship with the OM content. These campaigns consisted of ship-based monitoring and sampling through 12-h tidal cycle cruises carried out along the annual cycle (~ every 2/3 months, mainly spring tides) at two fixed stations: La Carosse (LC), at the mouth of the Seine estuary in the turbid plume, and BS1, located more offshore. During these surveys, we used a floating platform equipped with two downward looking RDI 1200kHz and 600kHz ADCP continuously recording along the 12-h tidal cycle. Every hour, samples at the sub-surface and 1m above the bed were collected from a horizontal Niskin bottle sampler for quantifying suspended sediment concentration (SSC), TEP, total OM (loss of ignition method) and chlorophyll a concentration. Finally, a frame equipped with a CTD profiler, an OBS3+, a turbidity meter (Wetlabs FLNTU) and a LISST100X was deployed at 15-min intervals during the tidal cycles. Dedicated post-processing methods were developed for LISST analysis, especially in the salinity gradient (flagging the Schlieren effect), but also in low SSC conditions.

Results

At the tidal scale, the turbulence is the main driver of flocculation processes, whatever the season. The usual cycle “low turbulence / large floc” to “high turbulence / small flocs” is well observed, as illustrated in fig. 1B. The influence of SPM concentration is not straightforward, as dynamically correlated with turbulence and settling.

At the seasonal scale, the organic content is shown to modulate the flocculation dynamic, using both the OM fraction and the Chla concentration as proxy: on average, the larger the OM content, the larger the flocs (Figure 2). The influence of the organic content was also observed at the tidal scale: during spring/summer periods when OM content is the largest, flocs are more resistant to breakup for similar hydrodynamic conditions, illustrating the increased cohesiveness of the particles forming flocs due to OM coating. Flocs formed in high OM conditions are also shown to be less dense, either due to the contribution of organic (low density) particles to flocs or to the modification of the floc structure (Fig. 1B).

TEP concentration was also measured from samples, however it was not possible to use this parameter as a proxy for characterizing the SPM dynamics, probably due to the various organic sources contributing to TEP.

Conclusions

This original dataset was used to examine the flocculation dynamics from the tidal scale to the seasonal scale, emphasizing the primary control of floc size by turbulence and the importance of the OM content, enhancing the formation of floc size of lower density but more resistant to shear break. These results will next be used to revisit the flocculation numerical models and evaluate the influence of these OM/sediment interactions on sediment fluxes.

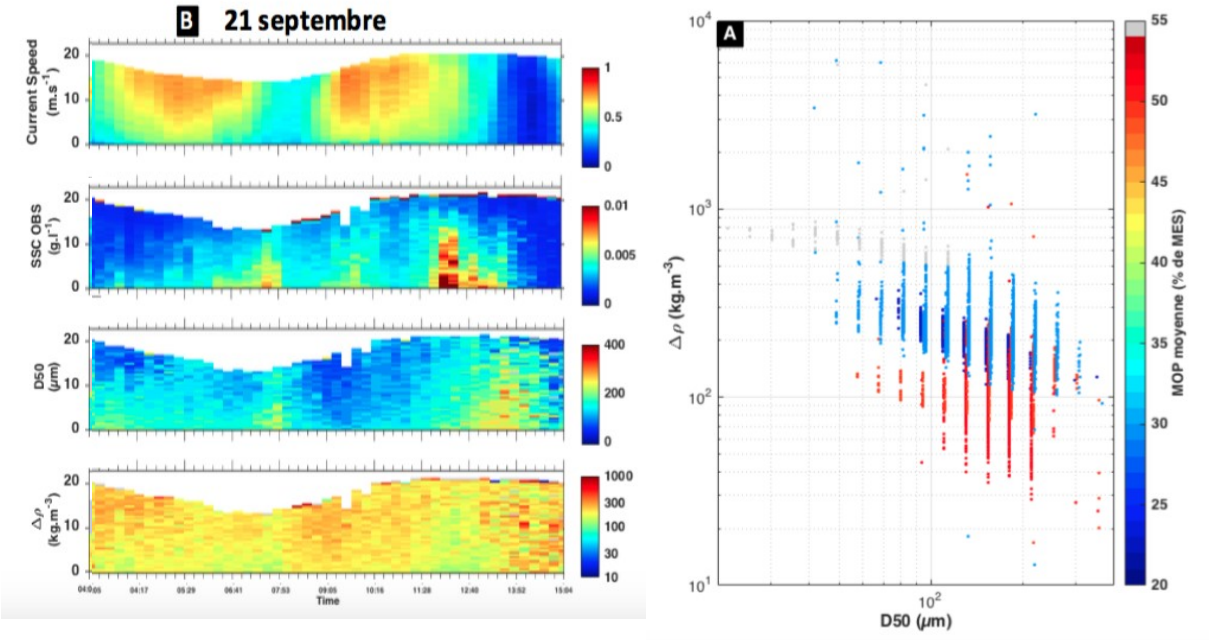

Fig. 1. Example of the SPM dynamics at the tidal scale (B) and seasonal floc population variability (A) at the interface between estuary and bay

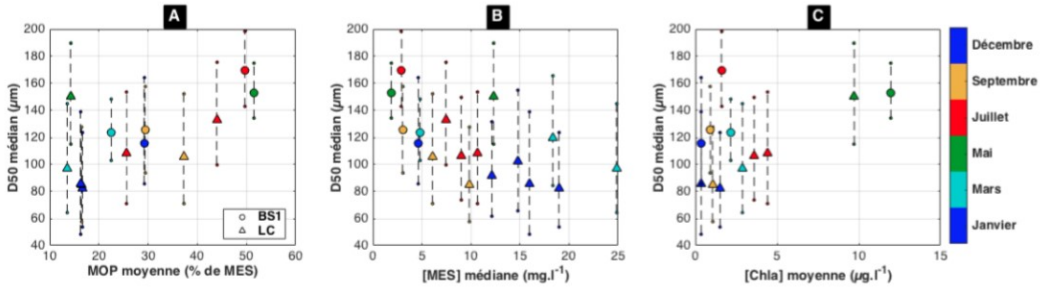

Fig. 2. Influence of organic content on floc size : average median flocs size versus chla concentration, SPM concentration and OM content (%)