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Factors controlling sediment dynamics of a recently deposited mud layer over a sheltered sandy beach following a drastic regression of *Zostera* meadows (Arcachon Bay, France)

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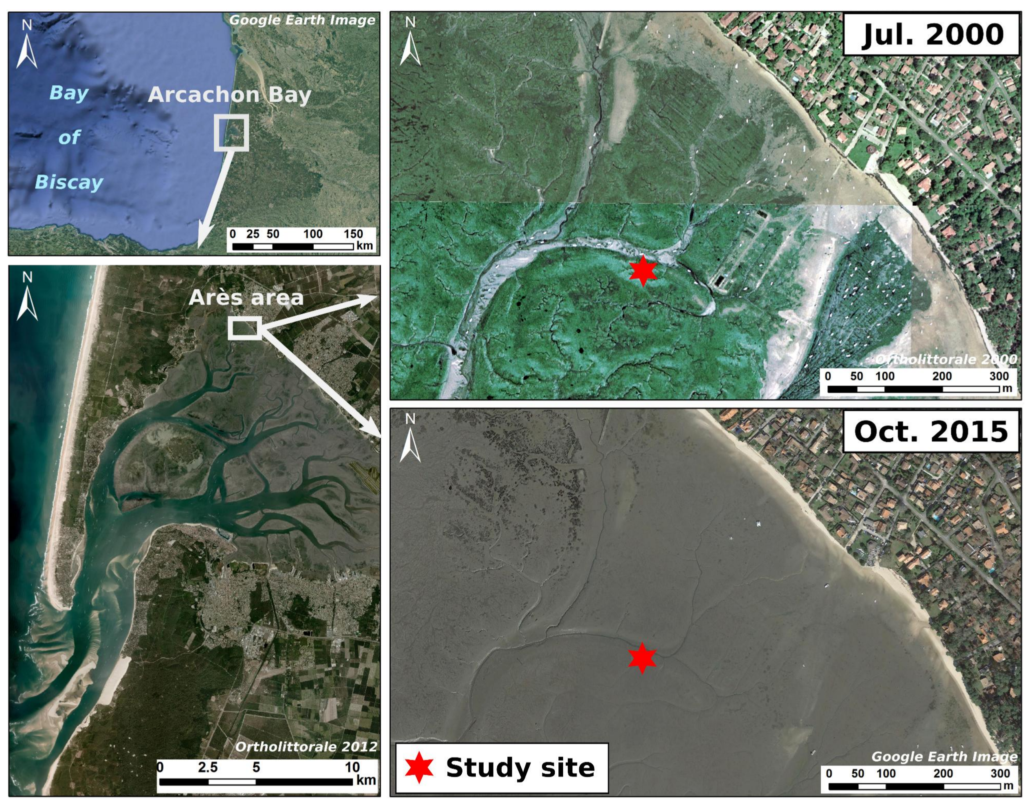
Context and Objectives

- **The sediment dynamics within the bay is dominated by tides (**tidal range from 1 to 5 m**) and by wind-waves (**dominant winds from NW to SW**).**
- **Until 2003, most of intertidal flats were colonized by *Zostera noltei*, while *Zostera marina* colonized most of channel edges.**
- **A drastic spatial regression of these species has occurred over the last 20 years.**
- **Increase of suspended sediment concentration and massive accumulation of mud over eastern tidal flats and beaches was observed simultaneously to seagrasses decline.**

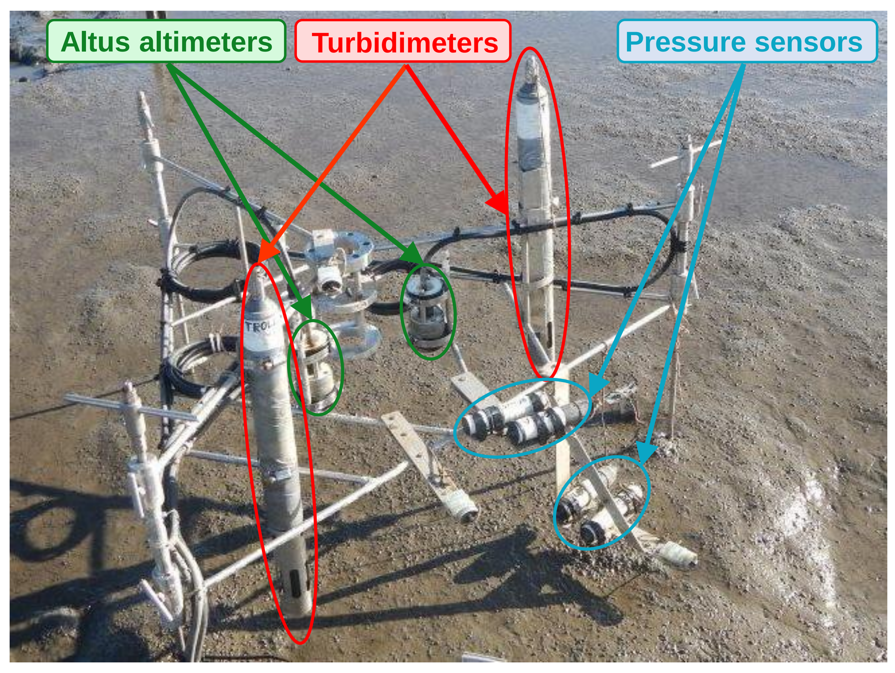


➔ *Which process controls the dynamics of recent fresh mud deposits in North-Eastern part of the Bay? What would be their origin and future?*

Methods

➢ Field survey (December 2016 – April 2017)

- **High frequency measurements:**
  - **Bed level (**H_{bed}, mm**) and fluid mud thickness (**H_{mud}, mm**) using NKE© Altus altimeter. Sampling at 1 Hz by bursts (**10 minutes length, spaced by 5 minutes**). For data verification, manual measurements of the distance between the bed and Altus transducers were performed weekly.**
  - **Suspended sediment concentrations (***Cspm*, mg.l^{-1}**) using In-Situ© TROLL turbidimeters (*preliminary calibrated*) at 5 and 30 cm above the bed. One sample every 5 minutes.**
  - **Water level (**H_{wat}, m**) using HOBO© UL pressure sensor. One sample every 5 minutes.**
  - **Significant wave height (**H_{wave}, m**) using NKE© SPT2 pressure sensor. Sampling at 2 Hz by bursts (**10 minutes length, spaced by 5 minutes**).**



- **Low frequency measurements (~weekly):**
  - **Surficial bed sediment samples for granulometry and dry density.**
  - **Sediment cores (**~20 cm length, 10 mm diameter**) for erodibility tests (**determination of the critical shear stress for erosion; see Le Hir et al. (2006) for further details**) on sediment-water interface.**

➢ Data analysis

- **For each single tide, computation of:**
  - **Bed level change (**ΔH_{bed}, mm.hour^{-1}**).**
  - **Tidal range (**A_{tide}, m**).**
  - **Tidal asymmetry indices (**γ_{tide}, -**) as described in Nidzieko and Ralston (2012).**
  - **Average suspended sediment concentration during the tidal flat immersion (*Cspm*$_{tide}$,** mg.l^{-1}**)**
  - **Averaged suspended sediment concentration and during the first (*Cspm*$_{wetting}$,** mg.l^{-1}**) and the last (*Cspm*$_{drying}$,** mg.l^{-1}**) 30 minutes of tidal flat immersion.**
  - **Cumulative wave energy (**E_{wave}, J.m^{-2}**):**

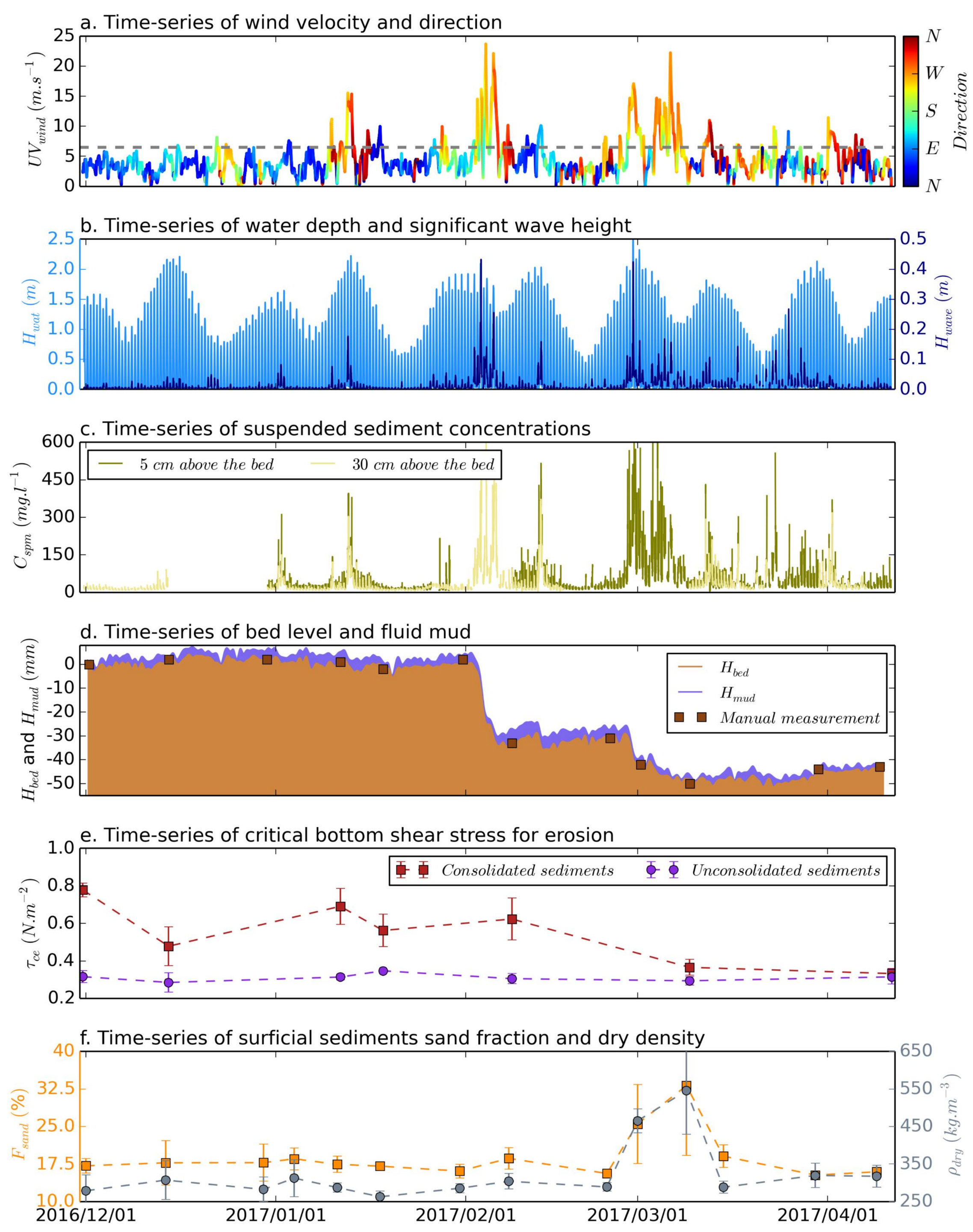
$$E_{wave} = \sum^{t} \frac{1}{8} \cdot 9.81 \cdot \rho_{wat} \cdot H_{wave}(t)^2$$

with ρ_{wat} the water density (1023 kg.m^{-3})

- **Division of the obtained dataset into two subsets, depending on cumulative wave energy by tide (H*wave*$_{tide}$):**
  - **Fair weather conditions (*FW*) for** $E_{wave}<1$ **J.m^{-2}.**
  - **Stormy weather conditions (*SW*) for** $E_{wave}>1$ **J.m^{-2}.**
- **Analysis of relationships between measured parameters to characterize the sediment dynamics of the area.**

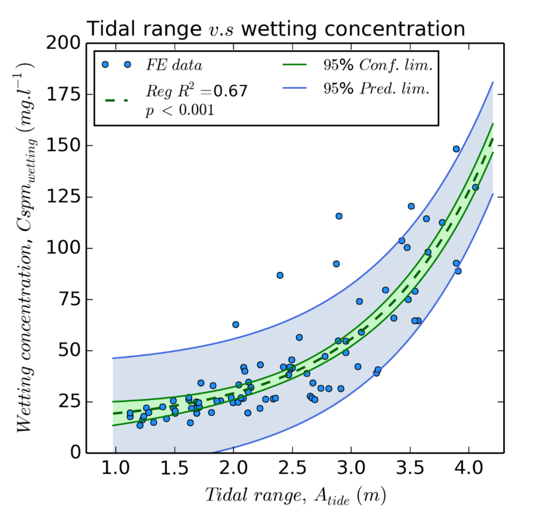
Results and Discussion

➢ Results overview

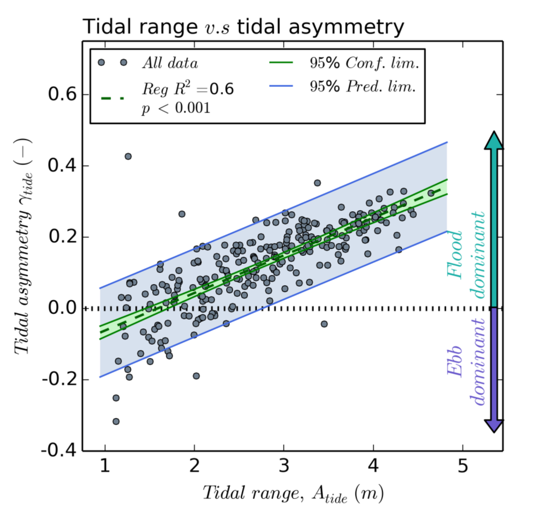


- **Winds coming from West to South and stronger than 6 m.s^{-1} generated significant waves (up to 0.5 m).**
- **During wave events, suspended sedimentation concentrations strongly increased (up to 600 mg.l^{-1}).**
- **Bed level was relatively stable during the first part of the survey (small erosion and deposition phases) while during the second part of the survey, two important erosion phases (up to -37 mm) occurred during the two strongest storms. These erosions phases were followed by slight but continuous accretions. Fluid mud layer was generally thicker during fair weather conditions than during storm events.**
- **Critical bottom shear stress for erosion was relatively constant (~0.3 N.m-2) for unconsolidated sediments while it tend to decreased along the survey for consolidated sediments.**
- **Both the sand fraction and the dry density were relatively constant during most of the survey. A significant increase of these parameters was however observed during the stormy period which occurred between the end of February and the beginning of March. After this period, these two parameters decreased and goes back to their previous values.**

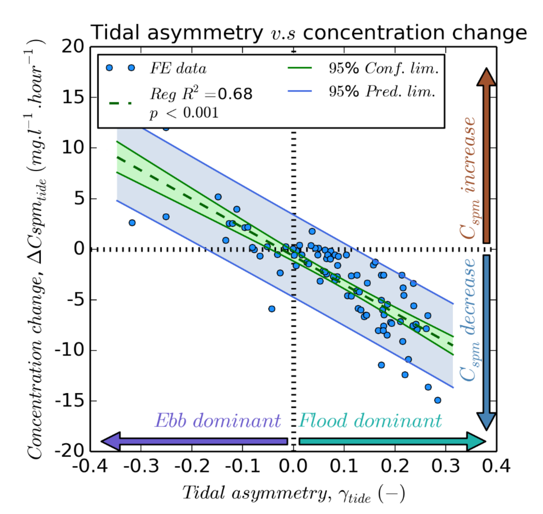
➢ Tide-induced sediment dynamics



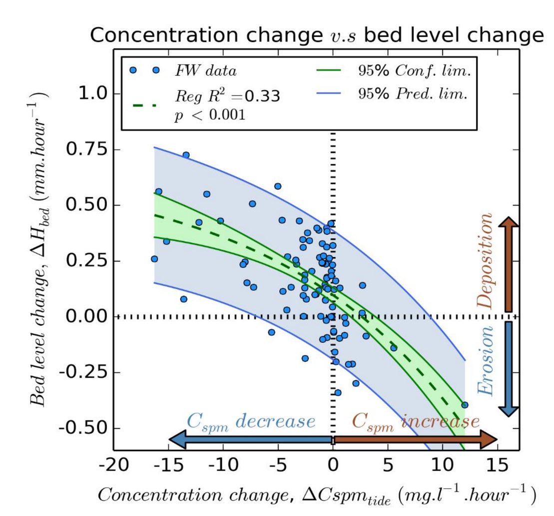
- **Suspended sediment concentration during the submersion of the tidal flat increases exponentially when the tidal range increase. This indicates higher sediment inputs in spring-tides than in neap-tides.**



- **Flood dominance (stronger currents during the flood than during the ebb) increases with the tidal range. This explains the strong increase in sediment concentration during spring-tides.**

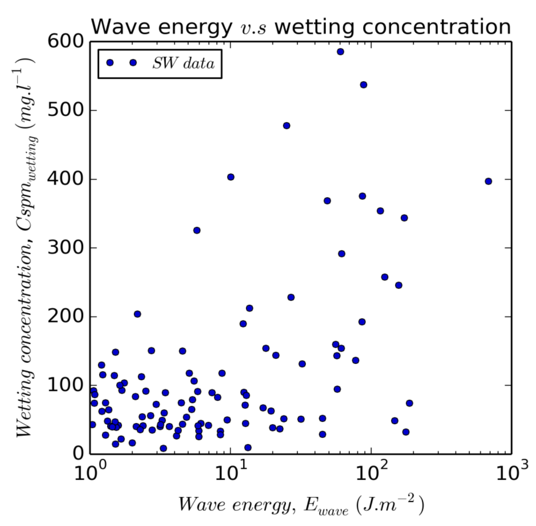


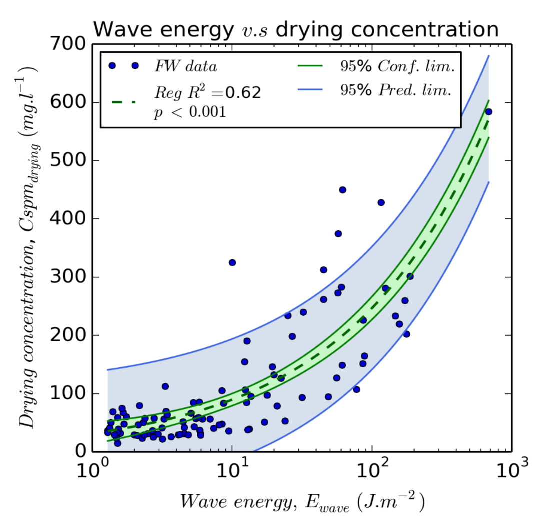
- **Suspended sediment concentration decreases (during each tide) proportionally with the increase of flood dominance. This may indicate more sediment deposition during high water slack during spring-tide.**

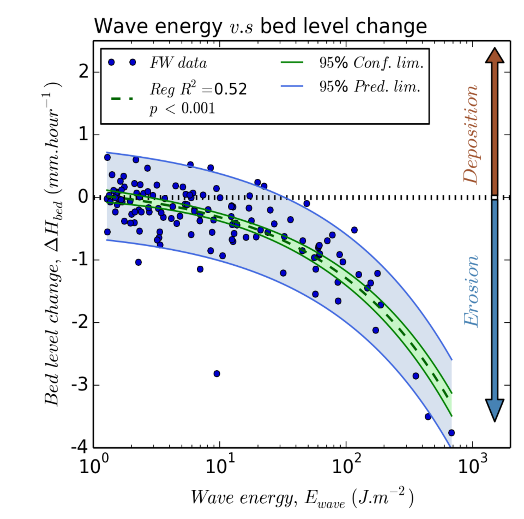


- **Generally, when suspended sediment concentration decreases during a tide there is accretion, while when it decreases there is erosion. This confirms the important role of tidal pumping on sediment dynamics.**

➢ Wave-induced sediment dynamics

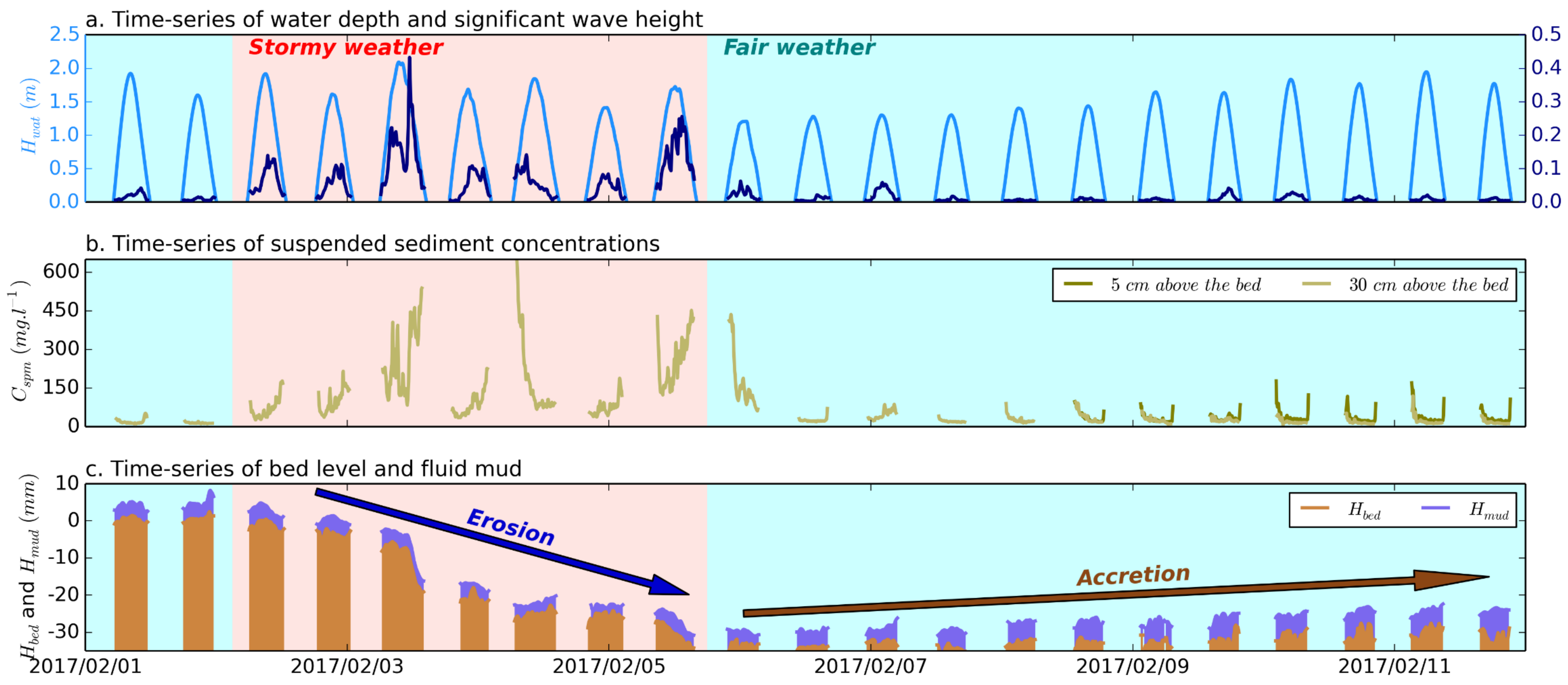






- **There is no relationship between wave energy and suspended sediment concentrations in the submersion of the flat, while an exponential relationship is found between wave energy and concentration during the emersion of the flat. This suggests that most of sediment are locally re-suspended by waves. This is confirmed by the exponential relationship found between wave energy and bed level change: erosion increases when wave energy increases.**

➢ Zoom on a storm event and the following fair weather period



- **Stormy weather conditions promote erosion. Due to the flood dominance in the area, locally eroded sediments cannot be exported and are likely to be re-deposited in the vicinity of their erosion area.**
- **Fair weather conditions promote accretion, mainly during spring-tides. Due to the flood dominance in the area, sediments eroded by tidal currents and previous storm events in other parts of the Bay are likely to be imported in the study area.**

Conclusions and Perspectives

This field survey highlights the relative role of tide and waves on sediment dynamics in the north-eastern part of the Arcachon bay. Our results suggest that tidal asymmetry promotes sediment inputs (coming from other parts of the bay) and bed accretion in the study area. By contrast, wind-waves promote erosion but locally eroded sediments could not be exported due to the tidal asymmetry. This implies that tidal processes could be the main cause of recent deposited mud layers in the study area. Wind-waves could be considered as an accelerator of tidal processes, even if during our winter survey we mostly recorded erosion during storms. Indeed, from spring to autumn, NW thermal breezes often occurred during fair weather conditions, leading to waves with sufficient height to cause sediment erosion within the bay but not in the study area which is sheltered from NW winds. The eroded sediments increase suspended sediment supply in the study area. Finally, because the sediment dynamics in the area begun to change a the same time as seagrasses regression and because *Zostera* spp. are known to protect the bed against erosion and promote sediment deposition, we can safely assume that most of muddy deposits in the study area come from formerly colonized areas.

References:

- Le Hir P., Cann P., Jestin H., Bassoullet P. (2006). Instrumentation légère pour la mesure de l'érodabilité des sediments vaseux ou sablo-vaseux. *Proceedings IXèmes Journées Nationales Génie Côtier-Génie Civil, L'Aber Wrac'h 2006.*
- Nidzieko N.J., Ralston D.K. (2012). Tidal asymmetry and velocity skew over tidal flats and shallow channels within a macrotidal river delta. *Journal of Geophysical research, 117:C03001.*

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