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Accumulation and dispersion dynamics of mud and sand particles in a continental shelf under estuarine influence: a numerical modelling analysis (Gironde, France)

INTRODUCTION

Coastal environments are directly influenced by terrigenous inputs coming from rivers through estuaries. Quantifying the amount of nutrients and contaminants brought by sediments from continental areas to the sea is of major interest for marine resource protection. The complexity of the intra-estuarine dynamics, associated with the strong variability of meteorological forcing makes it difficult to quantify the residence time of particles within the estuary and the accumulation and dispersion areas offshore the mouth. Moreover, the dynamics of fine sediment trapping areas in the adjacent continental shelf (e.g. temporary or permanent storage such as the "West-Gironde Mud Patch" (WGMP)) remains extremely challenging to address.

Based on a realistic process-based numerical model, the aim of this work is to investigate the dynamics of the sediment accumulation and dispersion areas in order:

- **To describe the role played by the intertidal mudflats and the subtidal mud patches on sediment trapping and further resuspension**
- **To investigate the influence of hydro- meteorological events (e.g. high/low river discharges, storms) on sediment fluxes.**

MODELING STRATEGY

• BATHYMETRY AND MESH GRID

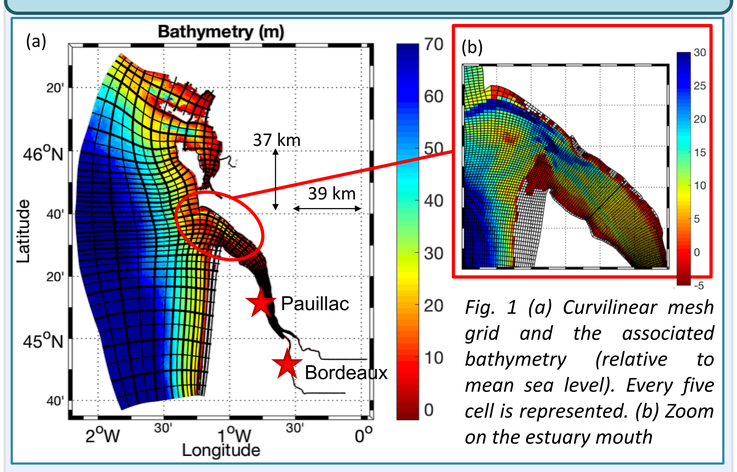
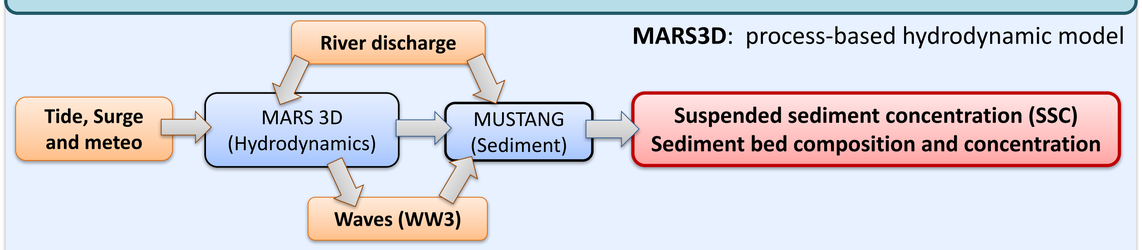


Fig. 1 (a) Curvilinear mesh grid and the associated bathymetry (relative to mean sea level). Every five cell is represented. (b) Zoom on the estuary mouth

- **Curvilinear** mesh grid (419*215 cells)
- **Resolution** : ~40 m*350 m in the river meanderings
  ~2 km*2 km offshore
- **10 vertical** sigma layers

• MODEL STRUCTURE



MARS3D: process-based hydrodynamic model

The **hydrodynamic and hydrological field** were **validated** by comparison with free surface elevation, velocity current and salinity measurements.

• SEDIMENT MODEL SETTINGS

MUSTANG: **Multi-layer multi-class sediment model** taking into account **erosion-suspension-deposition** and **consolidation** processes *(Le Hir et al., 2011; Grasso et al., 2015).*
5 classes of sediment : 1 gravel, 3 sands and 1 mud

Model results presented here were obtained after one year spin-up, meaning that the first year final state is used as initial condition for the reference year

• WGMP LOCATION

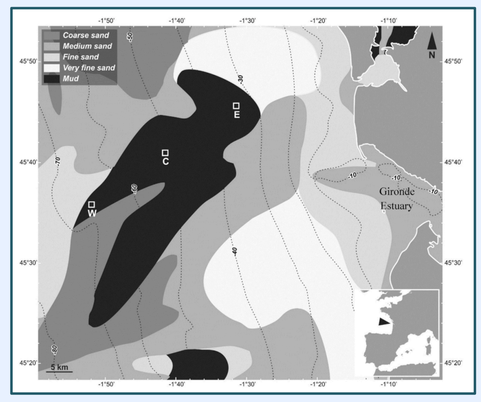


Fig. 2. Location of the West Gironde Mud Patch (WGMP) (from Massé et al., 2016)

RESULTS

• SEDIMENT FLUX SENSITIVITY

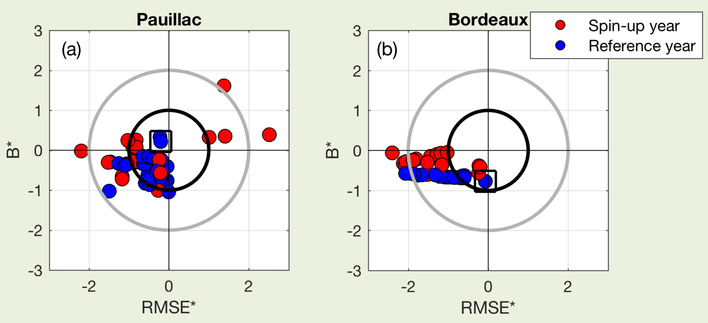


Fig. 3. Normalized target diagram for different key sediment parameters

Sensitivity of model outputs to key sediment parameters has been investigated using a target diagram normalized by the standard deviation of SSC measurements (*Joliff et al., 2016*).

- Model skills are sensitive to sediment model parameters.
- Given the configuration complexity, **SSC results are satisfactory** when located in the black circle at Pauillac and the grey circle at Bordeaux

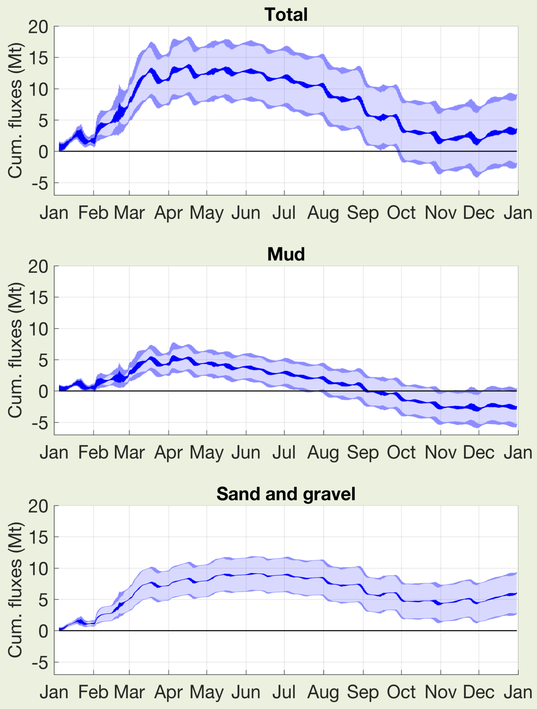


Fig. 4. Sensitivity of cum. sediment fluxes through the estuarine mouth to sediment parameters. Positive values represent import into and negative values export out of the estuary.

Mean sediment fluxes through the mouth and corresponding standard deviation for "satisfactory" runs are presented in fig. 4.

- **Strong seasonal and neap-spring dynamics**
- **General export of mud and import of sand and gravel**
- **Total sediment fluxes multiplied by 2.5 for different valid parameter sets.**

• WGMP DYNAMICS

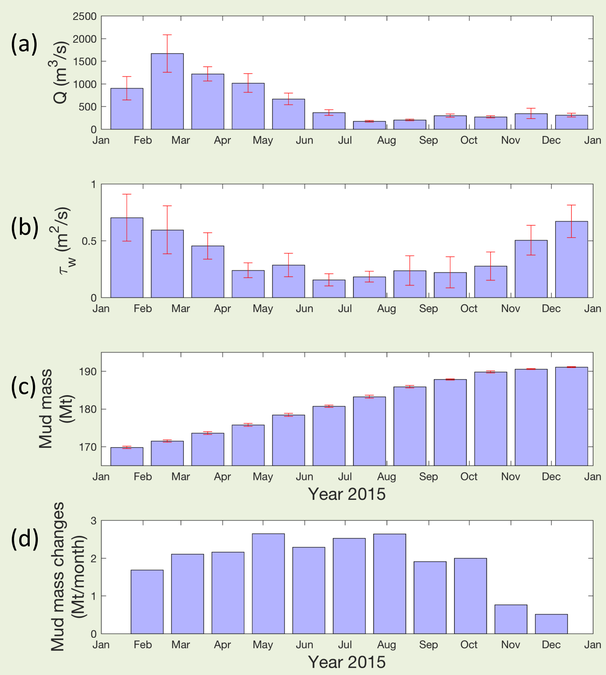
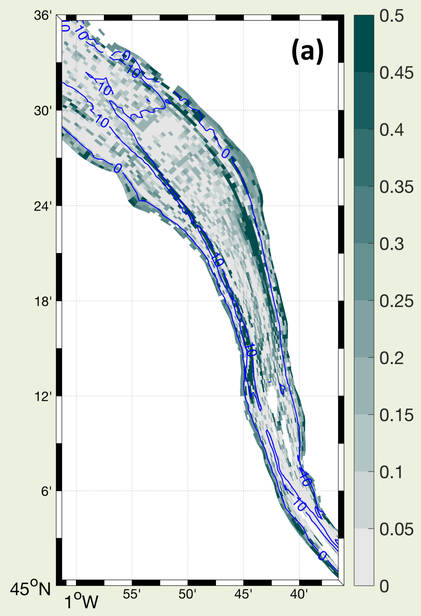


Fig. 6. Monthly averaged (a) river discharge Q, (b) wave-induced bed shear stress τ_w, (c) mud mass in the simulated WGMP and (d) mud mass changes.

• SIMULATED ACCUMULATION AREAS



Mud fraction in the surficial sediment is shown in fig. 5 along with the bathymetric contours (a) within the estuary and (b) on the adjacent continental shelf.

- Mud is trapped on the intertidal mudflats and in the channel (ETM location) within the estuary.
- Mud is trapped in a mud patch north-west of the mouth on the continental shelf, at ~30m depth, in agreement with the observed WGMP location.

Fig. 5. (a) Mud fraction in the surficial layer in the estuary

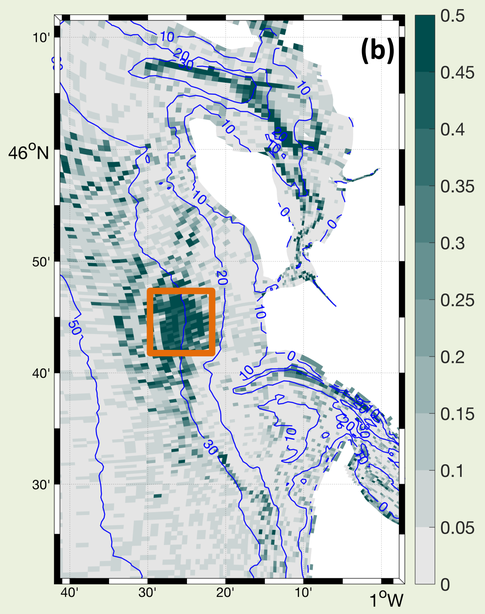
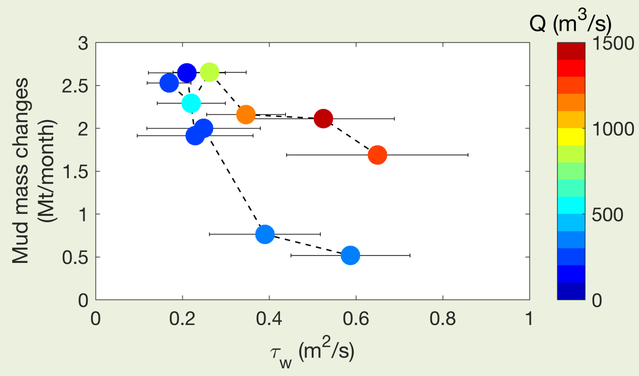


Fig. 5. (b) on the adj. continental shelf

Fig. 6 and 7 illustrates the impact of waves and river flow on mud trapping by the WGMP (defined by the orange square in fig.5 (b)).

- **Mud accumulates** over the year in the WGMP
- **Stormy events tend to reduce the mud trapping** by limiting deposition in this area
- **Wave impact is reduced during high river flow** due to growing export of sediment by the turbid estuarine plume.

Fig. 7. Monthly averaged mud mass changes versus the wave-induced bed shear stress, along with the corresponding river discharge.



CONCLUSIONS

Based on a **3D sediment transport model** of the Gironde Estuary and the adjacent continental shelf, **the dynamics of sediment accumulation and dispersion areas** has been studied.

- **Simulated fluxes at the mouth are sensitive to the sediment parameterization** (mud settling velocity, sediment erodibility, …)
- **Mud is trapped in intertidal and subtidal mud flats and in the channel** due to the ETM presence in the central estuary.
- The model reproduces the **mud accumulation in the West Gironde Mud Patch** with approximately the same location.
- The **mud storage in this area is reduced during stormy events** due to wave influence on sediment deposition**.** Storm effect on mud accumulation in the mud patch is **modulated by the river flow**: more deposition during stormy events when happening during high river flow due to enhanced export of sediment by the turbid plume.

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