Development of an hydro-sedimentary 3D model with sand-mud mixture - calibration and validation on 6 years evolution in the Seine Estuary

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Context

Scientific monitoring of the rehabilitation program of the mudflats of the Seine Estuary conducted between 2005 and 2010 revealed the hydro-sedimentary evolution of the mudflats. Furthermore, the biological surveys undertaken make it easier to identify the relationships between physical and biological environments and therefore appreciate the ecological impact of possible additional facilities. That is why the Grand Port Maritime du Havre (GPMH) has called for a study:

- to better understand the current hydro-sedimentary dynamics of mudflats and estuary, based on a hydro-sedimentary 3D modelling, including the dynamics of sand and mud, calibrated on the observations performed since 2005 (Step 1);
- to predict what might be their evolution without new work (Step 2);
- to design and test several hypotheses for further works and assess their impacts (Step 3);
- to define the preliminary project stage for works selected (Step 4).

This is the step 1 that is developed in this paper.

Description of the hydrodynamic 3D model

The Telemac-3D model of the Seine Estuary extends from the Poses dam upstream boundary to the maritime area downstream. Initial bathymetry of the model is representative of the year 2005. The horizontal mesh size of the model ranges from 20 to 100m (for the North channel and associated mudflat) to 5km (for maritime area).The model is forced with the daily discharge of the Seine River, the astronomical tide level, variation of mean sea level due to meteorological conditions, waves and wind conditions.
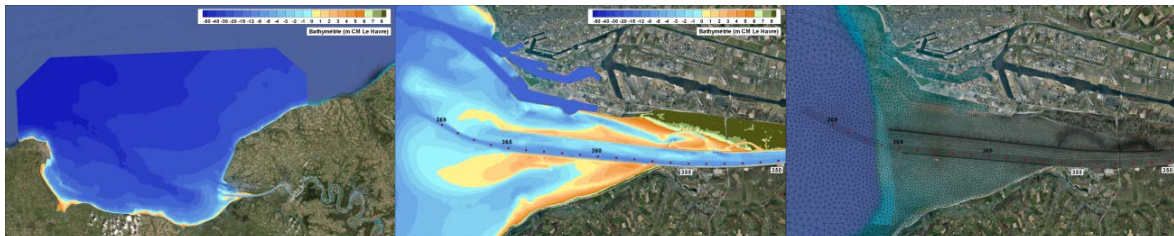

Fig. 1. General view of the 3D model, focus on bathymetry and mesh in interest area.

Calibration of the hydrodynamic model was achieved using measured levels of 19 tide gauges installed between Le Havre and Poses for different flow rates. The hydrodynamic model was then validated by comparison of 3D current results with several measurement campaigns (SHOM, GPMR, GPMH). Model validation for salinity was conducted using data from the network MAREL during one year (2006) at the Honfleur station but also from measurements (MODEL project of GIP Seine Aval program) made at the bottom and the surface at Tancarville Station during 6 months in 2010.

Calibration of the mud dynamic

At first, only mud was taken into consideration in the model. Calibration of the mud transport model consists primarily in the adjustment of different parameters in the model of consolidation, the laws of erosion and deposition and the fall velocity of the sediment. Most of the parameters have been calibrated using measurements from research programs Seine Aval 3 and 4. The model is now able to simulate a turbidity maximum in the range of 100,000 to 400,000 tonnes, which can be expelled after a flood and can grow again in the following months, as shown by turbidity measurements in Honfleur for several years. Seasonal dynamics is correctly reproduced a well as the shape of the turbidity plume.
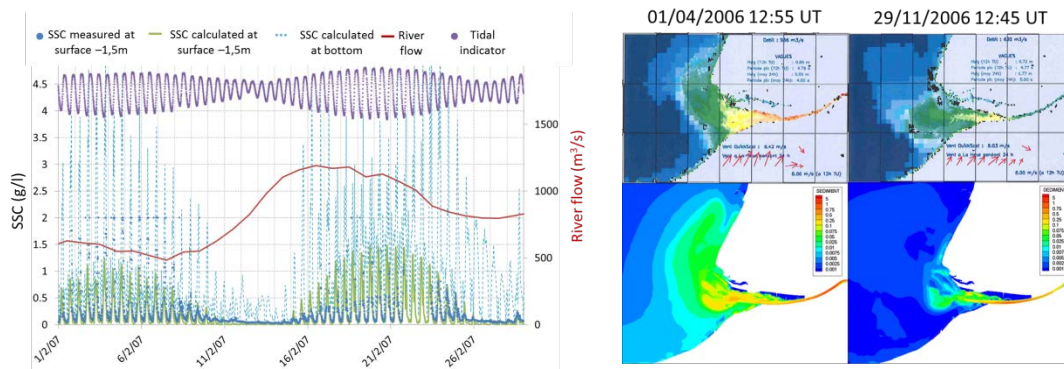
Fig. 2. Comparison of SSC at Honfleur station and comparison of turbidity plumes.

Calibration of mud-sand mixture dynamics

The hydro-sedimentary modeling used to calculate the morphological evolution of the Seine Estuary is based on the following principles:

- representation of sediment mixing with three classes of sand and a class of cohesive sediment ('mud');
- bed load transport and suspension of sand, suspended mud;
- temporal and spatial variation (horizontally and vertically) of the composition of the sediment mixture (% class% sand and mud);
- consolidation of silt deposited;
- consideration of the surface composition of the mixture of the sediment bed for the calculation of the critical stress for erosion.

A 3D model of the initial composition of the bed was made and adapted with measurements and results of simulation. Dredged process and dumping of Havre harbor and Rouen Harbor are included in the simulation. Many comparisons were made with measurement and sensitivity of the model was tested. The calibration of the model is the result of 2 years of work.
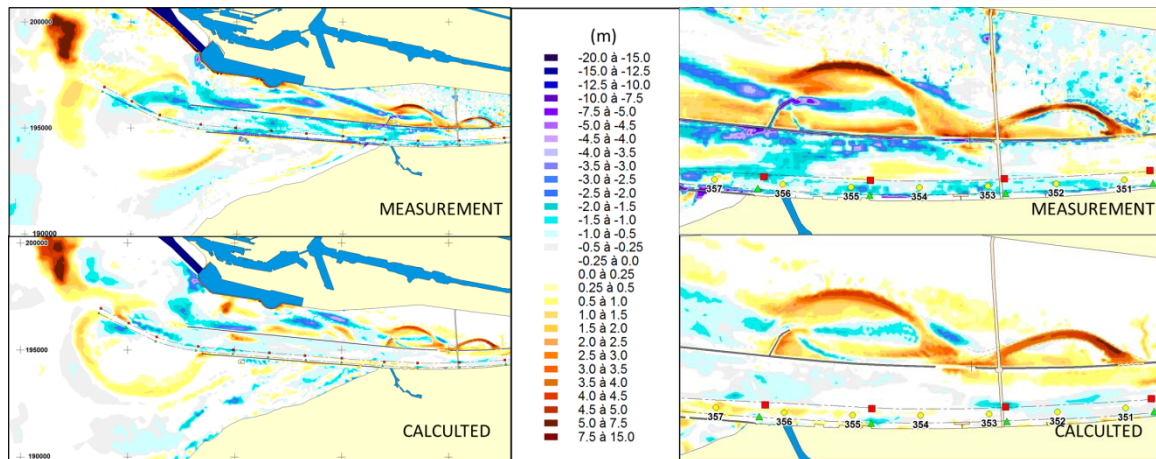

Fig. 3. Comparison of bathymetry evolution (2005-2011) between measurements and 3D model.