O1017 - MULTI CLASS FLOC SIZE DISTRIBUTIONS OF COHESIVE SEDIMENTS AT STATION XULIUJING OF THE CHANGJIANG RIVER ESTUARY
Suspended Matter and Flocculation

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Introduction

To manage coastal and estuarine waters, it is critical to accurately predict the movements of cohesive and non-cohesive sediments. There are well-established methods to estimate the behavior of non-cohesive sediments; however, without extensive knowledge on flocculation processes it remains difficult to predict the behavior of cohesive sediments. Flocculation is one of the main processes (e.g., erosion, deposition, settling, consolidation and flocculation) in cohesive sediment dynamics. The study of flocculation is an interdisciplinary work since it relates to various physical (e.g., transport, settling and deposition), chemical (e.g., contaminant uptake and transformation) and biological (e.g., community structure activities and metabolism) activities. Nevertheless, a widely-accepted flocculation model that can quantitative simulating the Floc Size Distributions (FSDs) for a relatively large study domain has not yet been fully developed. Recently, Lee et al. (2012) have pointed out that an observed FSD by LISST (Laser In Situ Scattering and Transmissometry) instrument can be decomposed into subordinate lognormal distributions for microflocs, macroflocs and megaflocs. With this three-class FSD decomposition, the accuracies of predicted settling velocities are largely enhanced compared with single-class approach. This method has been used in the well-mixed Belgian coast (Shen et al., 2018). Nevertheless, it is not clear if the FSDs in other regions can be analyzed and simulated in the same way for a broader application. Therefore, this study aims to implement an improved quadrature-based Population Balance Equation (PBE), based on that given by Shen and Maa (2015), on a 1-D vertical hydrodynamic model (Shao et al., 2017), to simulate the floc sub-populations in the Changjiang River Estuary. The long term target is to better investigate the FSDs and the particle dynamics in 3-D estuarine models.

Field measurements

Field work was carried out at station Xuliujing of the Changjiang River Estuary, in the wet season of the year 2016. In this study, navigation data of two typical tidal cycles that represents spring and neap tidal conditions respectively are highlighted to investigate the water levels, flow velocities, turbulences, salinities, suspended sediment concentrations (SSCs) and FSDs. Velocity profiles were collected by a shipboard downward-looking ADCP (Acoustic Doppler Current Profiler), the in-situ flocculated FSDs were measured with the LISST-100 (type C), and samples from different water levels were analyzed to determine the salinities, SSCs and primary particle size distributions. Notably, the measured FSDs were automatically decomposed into microflocs, macroflocs and megaflocs using the software DistFit (Lee et al., 2012).

Flocculation Model

The general transport equation (i.e., the PBE) that includes the kinetics of aggregation and breakage of flocs with size *L* can be expressed by:

$$\frac{\partial n(L,z,t)}{\partial t}+(w-w_s)\frac{\partial n(L,z,t)}{\partial z}-\frac{\partial}{\partial z}\left(\frac{\nu_t}{\sigma_t}\frac{\partial n(L,z,t)}{\partial z}\right)$$
$$=\frac{L^2}{2}\int_0^L\left[\frac{\beta\left((L^3-\lambda^3)^{1/3},\lambda\right)\cdot\alpha}{\left(L^3-\lambda^3\right)^{2/3}}\cdot n\left((L^3-\lambda^3)^{1/3},z,t\right)\cdot n(\lambda,z,t)\right]d\lambda$$
$$-n(L,z,t)\int_0^\infty \beta(L,\lambda)\alpha(L,\lambda)n(\lambda,z,t)d\lambda$$
$$+\int_L^\infty a(\lambda)\cdot b(L\,|\,\lambda)\cdot n(\lambda,z,t)d\lambda-a(L)\cdot n(L,z,t) \qquad (1)$$

where *n* (*L*, *z*, *t*) is the number density function defined on the basis of floc size *L* at any location *z* at time *t* with

$$n(z,L,t)=\sum_{i=1}^{3}w_i(z,t)\cdot\delta(L-L_i(z,t)) \qquad (2)$$

in which L_i and w_j (*i* = 1, 2, 3) are the representative sizes and weights of microflocs, macroflocs and macroflocs. Additionally, *w* is the vertical velocity along, w_s is the settling velocity, v_t is the eddy viscosity, σ_t is the turbulent Prandtl-Schmidt number, *β* is the collision frequency function, *α* is collision efficiency function, *a* is breakup frequency function and *b* is fragmentation distribution function. The right hand side of Eq. 1 include: (i) the birth of flocs with size *L* due to aggregation of smaller particles, (ii) the death of flocs with size *L* due to aggregation with other particles, (iii) the birth of flocs with size *L* due to fragmentation of bigger particles and (iv) the death of flocs with size *L* due to breakup into smaller particles. The left hand side terms include, from left-to-right, an unsteady term, an advection & settling term and a diffusion term, respectively.

Results

The results at a well-mixed estuary show that the 1-D vertical model in this study can reasonably reproduce the velocity profiles (Fig. 1). The model predicted sizes *L*1, *L*2 and $L3_3$ also match the sizes of microflocs, macroflocs and megaflocs of the observed FSD. Additional validations of subpopulations of FSDs in Changjiang River Estuary will be represented.

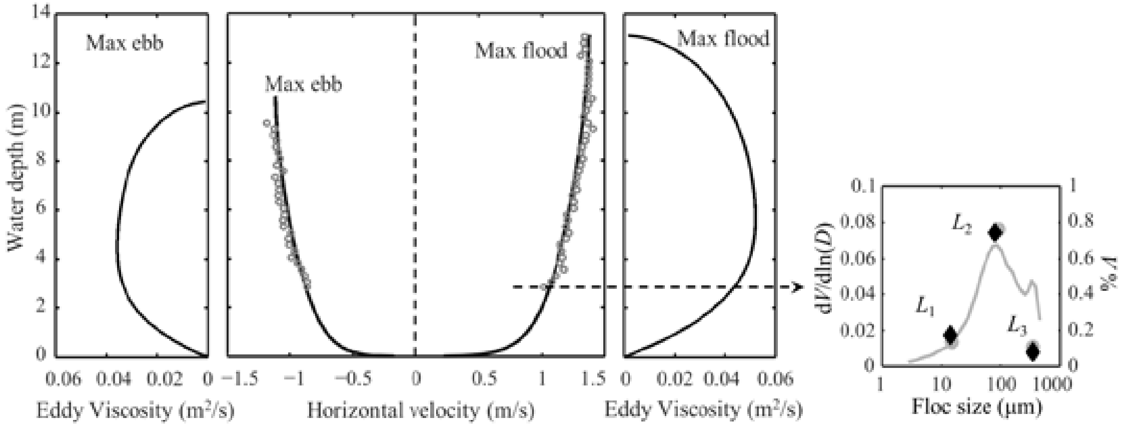

Fig. 1 An example of predicted velocity and eddy viscosity profiles at the maximum flood and the maximum ebb at a well-mixed estuary (modified from Shen et al., 2018). The FSD at a selected location is presented by subpopulations of microflocs (*L*1), macroflocs (*L*2) and megaflocs (*L*3). Symbols and lines in grey color are measurements and that in dark color are model predictions.

Conclusions

In summary, a framework is proposed based on implementing a quadrature-based PBE in a hydrodynamic model to mimic the representative sizes and their volume fractions of microflocs, macroflocs and megaflocs at station Xuliujing of the Changjiang River Estuary. This study, an integrated flow-turbulence-sediment model, although only validated in a 1-D vertical application at current stage, is a preliminary work to contribute to large scale simulations with comprehensive wave, suspended particles and water quality modules in the future.

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module in Telemac to model suspended sediment transport. The mud model is calibrated against the mass balance for the estuary, tidal ensembles of measured suspended sediment concentration (SSC) and estimates of siltation on intertidal flats in the Upper Sea Scheldt. It is important to note that the model does not include morphological feedback, or the effect of SSC on water density.

The effect of different human interventions needs to be quantified with the estuary in an estimated future state (2050). In order to deal with the uncertainty in autonomous development, runs are performed with an ensemble of boundary conditions that reflect different scenarios of climate change and evolution of tidal amplitude in the Scheldt estuary. Planned interventions (eg measures for safety against flooding) are included in the model.

Results

The model shows that the mud dynamics in the Upper Sea Scheldt are dominated by downstream advective transport. This corresponds with a recent sediment balance (mud and sand) for the upper and lower Sea Scheldt (Vandenbruwaene et al., 2017). This result is also checked against eight different measures of (eularian) tidal asymmetry.

When quantifying tidal asymmetry from a model run with limited temporal resolution in its output (1h intervals), the skewness of the distribution of the time derivative of water level is shown to be a good approximation of the ratio of duration of rising to falling tide, which loses a lot of its predictive power when the interval of model output becomes larger than 1h.

Total sediment transport [kg/s] is decomposed in sediment transport related to advection and tidal pumping by decomposition of the cross section, the cross-sectionally averaged velocity and cross-sectionally averaged sediment concentration into their tidal averages and its deviation. Model results are explained in terms of this decomposed sediment transport.

Deepening the Durme tributary (a human intervention, part of implementing a “sustainable bathymetry”) is expected to increase bottom shear stress (and thus resuspension capacity) downstream of the tributary and reduce it upstream. The implementation of a sluice at the upstream edge of the estuary, increases reflection of the tidal wave, and increases tidal amplitude.

Expected climate change is parametrised both at the downstream and upstream boundary of the model. Two scenarios for sea level rise are considered (+15cm and +40cm in 2050). The upstream boundaries of fresh water discharge (Q in Figure 1) is a synthetic timeseries that is perturbed due to climate change. The sediment concentrations at the model boundaries are assumed to stay the same. The perturbed fresh water discharge [m^3/s] is higher in the 2050 simulations then in the simulations of the current situation, which means higher downstream sediment transport and higher SSC in the Upper Sea Scheldt. The combination of the change in bathymetry and the change in boundary conditions together provide an estimate of the autonomous development in the zone of interest.

The human interventions that have been investigated in the project so far all include a deepening of a canalised river section at the upstream end of the estuary. This deepened section acts as a sediment trap, which dominates the initial response of the model. More sediment is retained upstream, lowering the expected SSC in the Upper Sea Scheldt.

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