

Three-dimensional modelling of Flocculation Processes

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Background

Water quality in coastal waters is dependent on the properties of cohesive material in suspension (suspended particulate matter, SPM) which mediates in primary productivity, biogeochemical cycling, pollutant dispersal, and ecosystem sustainability. Most estuarine SPM is in the form of flocs, which are low density aggregates made of organic matter, inorganic matter, and water (figure 1), and which are the carriers of particulate organic carbon (POC) through the estuarine system. SPM behaviour is determined by the size, structure, and settling rate of flocs. In particular, the properties of flocs control settling and resuspension of SPM. The quantity and quality of SPM, the impact of SPM on water quality and the transfer and fate of POC will change in response to climate-induced changes to fluvial and marine sources and forcings: e.g. changes to terrestrial sources, river flow, wave action, sea level, biological production. An important tool for management of estuarine water quality and ecosystem sustainability in response to climate change is thus numerical modelling of SPM in the coastal boundary zone. For example, net fluxes of suspended matter within and through estuaries are still largely unknown, and given the significant uncertainty on fluxes derived from observations, reasonable estimates can only be obtained by linking observations to appropriate three dimensional models. However, both vertical and lateral fluxes depend on the quality of SPM and cannot be estimated without quantified knowledge of floc properties, and hence, appropriate parameterization of turbulence induced flocculation and break-up processes.

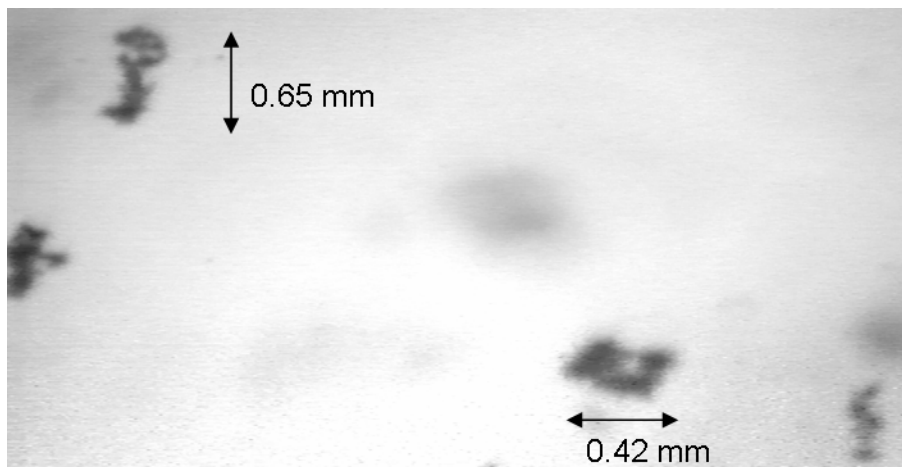


Figure 1: Examples of ragged clustered macrofloc (right) and small stringer flocs (left and far right).

In spite of this gap of knowledge for three-dimensional coastal zone models, turbulence induced flocculation and break-up has been investigated by a variety of researchers (e.g., Manning and Dyer, 1999, Thurston et al., 2008). In recent years flocculation models that aim to describe flocculation and break-up processes have been developed (e.g., Winterwerp, 2002, 2006; Sanford, 2008). However while some of these models have shown promise (such as the empirically-based formula developed by Manning, 2008) there is still no robust physically-based and widely applicable flocculation model available to the coastal modelling community. For this reason the implementation of floc formation and break-up in coastal zone models has been slow and patchy, although there are exceptions (e.g. Baugh and Manning, 2007).

Project description

We propose to implement cohesive sediment algorithms, including formulations for erosion / resuspension and turbulence induced flocculation and break-up, into the POL Coastal Ocean Model System (POLCOMS). The

project will thus provide a new model for studying cohesive sediment transport in coastal and estuarine waters, which could be able to be used as a basis for future investigations on mixed sediment modelling and dynamics. This would be an important step forward by building upon the pre-existing synergies of POLCOMS, which is a well established UK coastal ocean model, that already includes an advanced non-cohesive sediment transport model (Amoudry et al., 2009) and that can be coupled to a wave model, the turbulence model GOTM, and an ecosystem model.

The model developed during the project will be employed to provide valuable insight on important processes for sediment transport in estuaries. In particular we aim to investigate the impact of turbulence closures on cohesive sediment dynamics, and to compare purely empirical flocculation parameterizations with formulations that are based on process modelling.

Specific objectives

The student will implement cohesive sediment dynamics in a three-dimensional coastal ocean model:

- Implement an appropriate erosion formulation for cohesive sediments in POLCOMS and integrate a turbulence induced flocculation model in the POLCOMS system as coupled with the General Ocean Turbulence Model (GOTM)
- Test, calibrate and validate the model using field data.
- Compare the results obtained using purely empirical flocculation parameterizations with formulations that are based on process modelling
- Use the model developed to investigate the impact of turbulence closures on cohesive sediment dynamics.

Training

This project is a partnership between the University of Plymouth and the Proudman Oceanographic Laboratory (POL). The supervisors at Plymouth University and POL will ensure guidance and provide training in physical oceanography, and in particular on subjects crucial to the project, such as cohesive sediment dynamics, turbulence, and sediment transport modelling in a three-dimensional coastal ocean model (specifically POLCOMS for this project). We will encourage the student to attend the Estuarine & Coastal Fluid Dynamics Summer School in Washington, USA, which would be funded by POL and NERC. We will also encourage the student to attend national and international meetings.

This studentship has the potential to become a CASE studentship with HR Wallingford as the CASE partner who would contribute to the project according to NERC guidelines, including an extra £1000 in the stipend.

Recent publications relevant to the research area

- Amoudry, L. O.; A. J. Souza and J. T. Holt (2009) Sediment transport module for a B-grid coastal ocean model, Proceedings of Coastal Dynamics 2009: Impacts of Human Activities on Dynamic Coastal Processes' M. Mizuguchi & S. Sato (Eds.), World Scientific, doi: 10.1142/9789814282475_0090.
- Baugh, J.V. and Manning, A.J., 2007. An Assessment of a New Settling Velocity Parameterisation for Cohesive Sediment Transport Modelling. *Continental Shelf Research*, doi:10.1016/j.csr.2007.03.003.
- Manning A J and Dyer K R (1999) A laboratory examination of floc characteristics with regard to turbulent shearing, *Marine Geology*, 160 (1999), pp147-170.
- Manning, A.J., 2008. The development of algorithms to parameterise the mass settling flux of flocculated estuarine sediments. In: T. Kudusa, H. Yamanishi, J. Spearman and J.Z. Gailani, (eds.), *Sediment and Ecohydraulics - Proc. in Marine Science 9*, Amsterdam: Elsevier, pp. 193-210.
- Sanford, L. P. (2008) Modeling a dynamically varying mixed sediment bed with erosion, deposition, bioturbation, consolidation, and armoring. *Computers and Geosciences*, 34, 1263-1283.
- Thurston, W., A. Souza and M. Pritchard (2008) Observations of the effects of turbulence on particle size distributions in an estuarine bottom boundary layer, Proceedings of PECS 2008, A.J. Souza & A. Lane (Eds), <http://2008.pecs-conference.org/abstracts.html>
- Winterwerp, J. C. (2002) On the flocculation and settling velocity of estuarine mud. *Cont. Shelf Res.*, 22, 9, 1339-1360.