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MULTIMODAL PARTICLE SIZE DISTRIBUTION IN A COASTAL ZONE

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INTRODUCTION

Particle Size Distributions (PSDs) of suspended particulate matters in a coastal zone are composed of multiple modal peaks (Mikkelsen et al., 2006). The mixing of differently sized particles/flocs, which is caused by erosion of large particles/flocs from the bed (Yuan et al., 2009) and/or flocculation of particles/flocs in the suspension (Li et al., 1993, Chen et al., 2005), results in multimodal PSDs in a coastal zone. With understanding the possible causes of the multimodal PSDs, one can use a time series of the multimodal PSDs to investigate the particle/floc dynamics in a coastal zone. A statistical method with a curve-fitting software (DistFit^{TM}, Chimera Technologies Inc., USA) (Whitby, 1978) was adopted to analyze and interpret a multimodal PSD of a coastal zone in a qualitative and systematic way.

METHODOLOGY

The study area is situated in the Belgian coastal zone facing the southern North Sea. A tripod with an ADV and LISST-100C was deployed at 0.2 m above the bed at about 1 km from the shore line. The ADV measured a time series of flow velocities and turbulence, and the LISST-100C measured particle size distributions (PSDs) in 32 logarithmically spaced size classes over the range 2.5 - 500 μm. A measured multimodal PSD was fitted to four-modal log-normal distribution function (Eq. (1)) and decomposed into four discrete particle/floc groups. The statistical properties of the geometric mean diameter ($D_{gm,i}$), is the geometrical standard deviation (σ_i) and the volumetric concentration (V_i) of the fitted and decomposed PSD were then used as the indicators of particle/floc dynamics in a coastal zone.

$$\frac{dV}{dD} = \sum_{i=1}^{4} \frac{V_i}{\sqrt{2\pi}\ln(\sigma_i)} \exp\left[-\frac{1}{2}\left(\frac{\ln(D/D_{gm,i})}{\ln(\sigma_i)}\right)^2\right] \quad (1)$$

RESULTS AND DISCUSSION

A time series of the fitted and decomposed PSDs showed that the multimodality of a PSD depends on (1) shear-dependent flocculation in a flood and ebb tidal current, (2) biomediated flocculation with temperature rise and (3) particle/floc influx through an oceanic current. Also, the multimodal PSDs were found to develop their unique characteristics in different tidal periods, such as (1) a spring tide with a symmetric tidal current, (2) a neap tide with an asymmetric tidal current, (3) a tide under algal bloom and (4) a storm surge.

While investigating the multimodal PSDs and reviewing current researches, we concluded that fine-grained cohesive sediments develop a multimodal PSD with single grains, microflocs, macroflocs and megaflocs, of which ordered structures in size and density are caused by not only turbulent shear but also solution/particle physicochemical and biological particle-binding properties (Fig. 1) (van Leussen, 1994). Single grains are fine particles with a wide size range (0.25 - 2.5 μm). Microflocs are hardly-breakable small aggregates with a median size of 10 ~ 20 μm, which are assembled by direct electrochemical attachment (e.g. face-to-edge attachment). Macroflocs are aggregates with a median

size of 20 ~ 200 μm, which are assembled by reduction of electrostatic repulsion between particles/flocs with particle charge-diluting counter ions (Lee et al., 2011). Megaflocs are aggregates with a median size over 200 μm, which are formed by the gluing capability of microbial exudates (EPS or TEP) (Chen et al., 2005). When fine-grained cohesive sediments are placed in a turbulent shear field of a coastal zone, they will soon develop the ordered structures of single grains, microflocs, macroflocs, and megaflocs, under the cooperative action of shear-dependent and physicochemically- and biologically-mediated flocculation with abundant salt ions and microbial exudates in the brackish water.

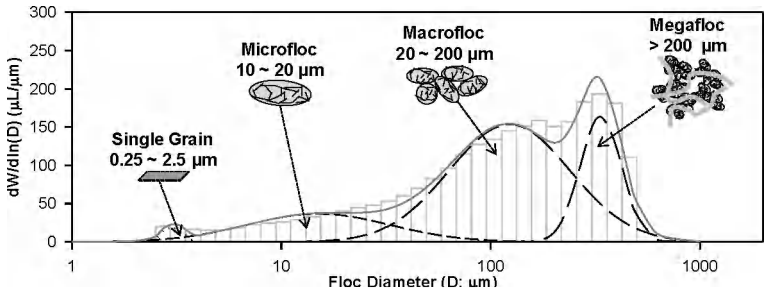

Fig. 1 A multimodal PSD and schematic diagrams of the discrete particle/floc groups

CONCLUSIONS

The dynamic behaviors of the multimodal PSDs in a coastal zone were successfully investigated and analyzed in a quantitative and systematic way with the new curve fitting analysis. This research also proved that a multimodal PSD could be discretized into single grains, microflocs, macroflocs and megaflocs for a practical purpose in modeling and simulation. This could be a theoretical background of the recently-developed flocculation model consisting of microflocs and macroflocs (Lee et al., 2011), for further applications as an easy alternative of elaborate flocculation models (Verney et al., 2009).

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