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Optical methods for estimating apparent density of sediment in suspension

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HIGHLIGHTS

- Assessment of a new optical proxy for particle apparent bulk density (LD method).
- A comparison of the LD method to two established methods (SPM and DVC methods).
- To present time series of apparent density estimated using the LD method.
- Estimates from the LD method are correlated with estimates from the SPM method.
- Estimates from the LD method are not correlated with estimates from the DVC method.

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ABSTRACT

In most aquatic environments, suspended sediment is composed of loosely packed particle aggregates, termed flocs that have variable apparent densities. The apparent density of flocs, which is defined as particle dry mass over wet volume, is an important variable because it affects settling velocity and vertical sediment flux. Two established methods exist for measuring apparent density. One method uses physical measurements of sediment mass concentration combined with measurements of particle volume concentration from optical instruments to estimate apparent density. This method is laborious because it requires the collection of water samples, so it is not conducive to construction of high-resolution time series of density. Another method uses video observations of particles in a settling column to measure particle size and settling velocity. These measurements are used to solve for apparent density according to Stokes Law. The goal of this

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study is to develop a new method that uses the ratio of particulate beam attenuation to particle volume to estimate apparent density of sediment in suspension. Data from five studies are used to compare density estimates with the new method to the previous methods. The new optical method produces apparent densities that are correlated linearly with measurements of the ratio of dry mass to wet volume. However, the new optical method produces density estimates that do not correlate with video estimates of apparent density. This lack of correlation is due to sampling bias of the video method, which has a relatively large lower limit of resolution in particle size. Development of a higher resolution camera would eliminate the current bias in particle size and would enable further assessment of the new optical method as an accurate proxy for apparent density.

1. Introduction

Small sediment particles in marine environments are often flocculated, which means that small particles are aggregated into larger, composite particles, known as flocs (McCave, 1984; Hill et al., 2011). Measuring floc properties is difficult because flocs are fragile and easily altered during sampling due to increased fluid shear caused by sampling procedures (Winterwerp and van Kesteren, 2004). As a consequence, measurements must be carried out in situ and non-invasively in order to preserve natural particle size and apparent density.

Apparent density of particles in a suspension is the total dry mass concentration of particles divided by the total wet volume concentration of the particles. Apparent density affects average particle settling velocity, which is a fundamental variable for determining the vertical flux of sediment in suspension. Due to the variety of mechanisms and associated frequencies driving sediment transport (e.g., Ogston and Sternberg, 1999), long, high-resolution time series of apparent density are required to provide a better understanding of the variables that determine this parameter.

Two general methods have been applied to the estimation of apparent density. One method relies on collection and filtration of a known volume of water to estimate suspended particulate dry mass concentration (SPM, see Table 1 for notation) combined with particle sizing instruments to estimate particle volume concentration (e.g., Mikkelsen and Pejrup, 2000). The other method employs video imaging of settling particles to generate size versus settling velocity relationships that are used to reconstruct particle densities (e.g. Hill et al., 1998; Sternberg et al., 1999; Mikkelsen et al., 2004; Curran et al., 2007).

With these methods it is difficult to construct high-resolution time series of apparent density. Estimation of particle dry mass via collection and filtration of water is laborious, imposing limits on the number of estimates of apparent density that can be generated. Video techniques involve the isolation of a water parcel for fixed periods, again limiting the temporal resolution of density estimates. Limited temporal resolution hampers the development of predictive models of apparent density.

The primary goal of this research is to explore a new method for estimating apparent density that uses in situ optical instruments. This method uses a Sequoia Scientific LISST 100x laser particle sizer (LISST) and a digital floc camera (DFC) to estimate particle volume concentration and measure particle beam attenuation. The particle beam attenuation is proportional to suspended particle mass concentration (Snyder et al., 2008; Boss et al., 2009b; Neukermans et al., 2012). With this knowledge, the assumption can be made that the ratio of beam attenuation to particle volume concentration is proportional to apparent density. Apparent densities obtained using the new method are compared to those derived with the two established methods. The secondary goal of this research is to characterize the correlation between observed apparent density and the ratio of particle beam attenuation to