Sediments in motion

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A novel drifter platform was used to measure floc properties, turbulence, suspended sediment concentration (SSC), velocity and salinity in both Lagrangian and Eulerian frames of reference. In Lagrangian mode the system performed well in a heavily sediment-laden river, providing measurements over a large spatial scale. The platform navigated itself through a complex geometry encompassing many bends and significant depth changes. Observed velocities relative to the drifter indicated that the drifter motion was almost Lagrangian with minimal slippage between drifter and water motion. The small amount of slippage that did occur was sufficient to ensure that the drifter oriented itself into the oncoming flow. High-quality in-situ images of flocs were collected using a high-magnification floc camera (FlocCam). An automatic image analysis routine was developed to identify and characterise flocs within each FlocCam image. The results indicated that the FlocCam system had an upper working SSC limit of around 350 to 400mg L-1. The system captured the evolution of floc characteristics over short spatial scales (100s of meters). Median floc size (d50) was found to be positively correlated with SSC. No clear relationship between median floc size and dissipation rate of turbulent kinetic energy could be discerned.

Introduction
Floc size has been successfully measured in both the laboratory and the field in an Eulerian frame of reference using floc cameras and laser diffraction. However, it has been shown that fine sediments have a strong memory of previously encountered upstream conditions (such as turbulence and SSC), which can at least partially overwrite floc response to local conditions. Indeed Braithwaite *et al*. (2012) found that particle size predictions matched well with the Winterwerp (1998) dynamical flocculation model if a phase lag (representing the adjustment time to changes in turbulence conditions) was included. Therefore, quantifying fine-sediment particle dynamics requires following particles in a Lagrangian framework to account for antecedent conditions.

Drifter design
The FlocDrifter body (Fig. 1) consisted of an underwater housing for the FlocCam system which is connected to a stabilising tail which orientates the drifter into the oncoming flow. When deployed in Lagrangian mode, the drifter was tethered to a surface float to keep the drifter at a fixed depth. The design included purpose-built mounts for additional instruments: a Nortek Vector ADV, a 2MHz Nortek Aquadopp ADCP operating in pulse-to-pulse coherent mode. Additionally, a Seabird SBE-37 MicroCAT was mounted vertically at the end of the tail; above the camera housing optical backscatter was measured using a Seapoint turbidity sensor.
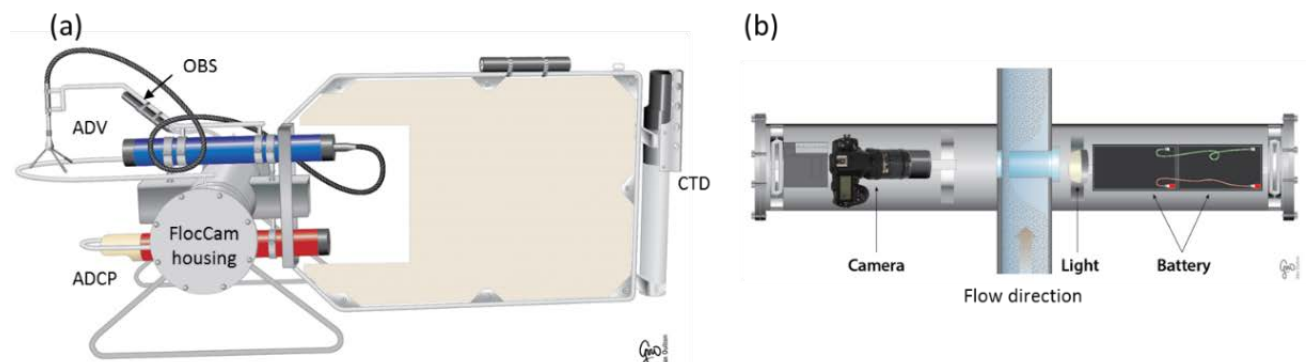

Fig. 1. Schematic of (a) FlocDrifter body and (b) FlocCam system in underwater housing.

Field site
The drifters were tested over multiple days in the heavily sediment-laden Kaipara River on the North Island of New Zealand. The Kaipara River flows into the southern end of the mesotidal Kaipara harbour. The river exhibits large bends, with frequent changes in direction and is characterised by average depths along the thalweg of around 3m. Deployments took place during a period of low
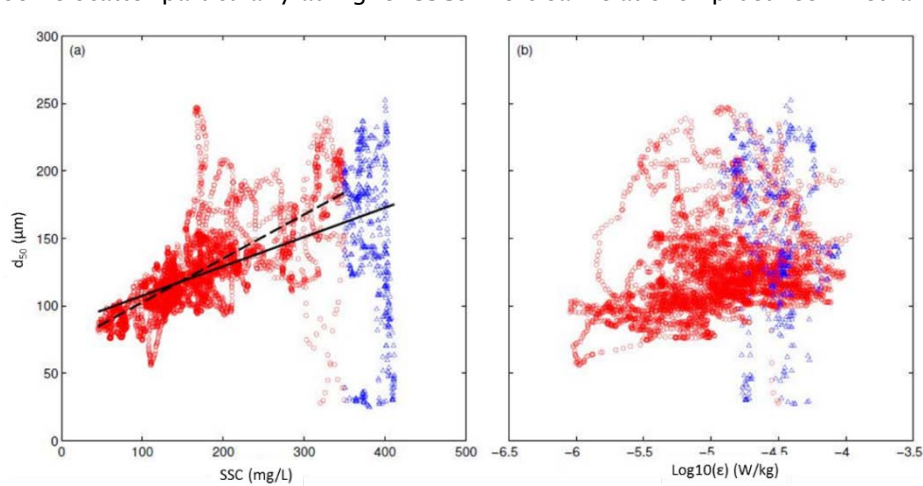
river flows over three days in October 2013. Up to three drifters were released shortly after high tide from varying locations, chosen to be sufficiently close together for sections of tracks to overlap, thus providing multiple measurements during different stages of the ebbing tide. Tracks covered 4.1km (with 3.8km of overlapping sections), 14.9km (6.4km overlapping) and 15.1km (9.2km overlapping) sections of river on days 1, 2 and 3, respectively.

Data analysis

ADCP velocities were recorded at 8Hz over a 0.73m vertical profile (25mm bin spacing) with a burst duration of 512s with a 3s interval between bursts. Estimates of the dissipation rate of turbulent kinetic energy (ε) were obtained using the structure function method of Wiles *et al.* (2006). Optical backscatter was recorded continuously at 5Hz, the voltage output by the optical backscatter sensor was related to SSC via a laboratory calibration. An automatic image analysis routine was developed to identify and characterise flocs within each FlocCam image. An Artificial Neural Network was employed to ensure that only in-focus particles were included in the analyses.

Results

The measurements revealed significant along-river variation over scales of a few hundred meters, which would unlikely to have been resolved without a very large array of Eulerian measurements, ε ranged from O(10^{-7}) to O($10^{-3.4}$) W/kg (corresponding to Kolmogorov length scales of ~ 200 to 1800µm). SSC estimates show that the drifters experience considerable variability in SSC as they were advected downstream. The variability in SSC most likely results from the spatial and temporal changes in sediment sources (e.g. erosion) and sediment sinks (e.g. deposition). Preliminary analysis indicates that median floc size is positively correlated with SSC (Fig. 2) although there is some scatter particularly at higher SSCs. No clear relationship between median floc size and ε could be discerned (Fig. 2).

Fig. 2. Median floc sizes d_{50} versus (a) SSC and (b) ε.

References

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