Fractional Resuspension and Sediment Flux on a Wave-Dominated, Non-Cohesive, Inner Continental Shelf: Santa Cruz, California.

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Research Question

How is bed and suspended sediment grain size best incorporated into models of sediment transport in the bottom boundary layer? Does this information improve predictions?

Site & Data Set

We report measurements from a tripod deployment in 10m water depth on the predominantly sandy inner shelf in Santa Cruz, California, collected over a several-day storm in February 2009. The observations are part of a longer-term cabled deployment.

The co-located hourly Eulerian observations include waves and currents, bed-sediment grain size, suspended sediment concentration and size-distribution, and bedforms.

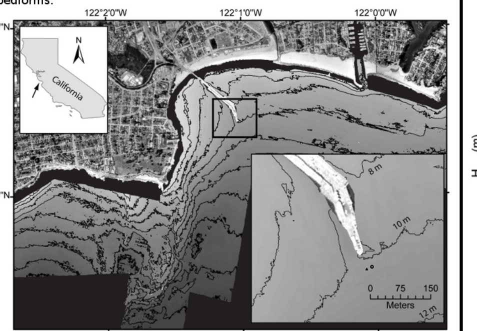

FIG 1 (above): Field site (2 tripods marked with star and square are the main instrument and poking eyeball tripods, respectively)

The novel aspect of our data set is the high-frequency concurrent measurements of bed mean grain size and distribution (from the POKING EYEBALL system - below), and suspended sediment grain-size distribution (from OBS and LISST instruments).

Such data have the potential to shed light on the mechanisms of the entrainment and resuspension of individual size-fractions within a seabed containing a mixture of grain sizes, and their relative contributions to total sediment flux in the shelf bottom boundary layer under different wave-energy conditions.

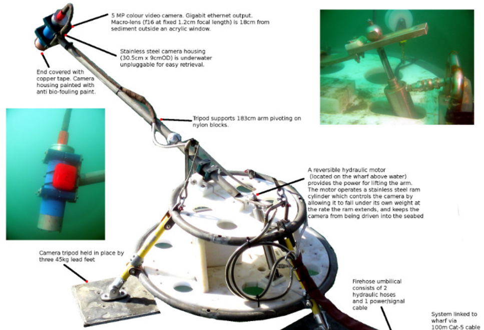

FIG 2 (above):
The Santa Cruz Poking Eyeball system returns hourly photos for grain size analysis using the methods of Rubin (2004) and Buscombe & Rubin (in prep.)

Storm, Feb. 2009

The storm consisted of southerly 15 s period swell, 2-3 m significant wave heights over 2 days.

Near-bed mean currents were weak (5-15 cm/s) whereas wave orbital velocities of up to 90 cm/s suggest highly significant near-bed shear

Three progressively decreasing peaks in wave energy were associated with three peaks in suspended sediment concentration of almost identical magnitude. We attempt to explain why suspended sediment concentrations were not commensurate with wave energy by combining observations of bed- and suspended-sediment grain size with estimates of seabed stresses and active layer depths using an existing one-dimensional wave-current bottom boundary layer model

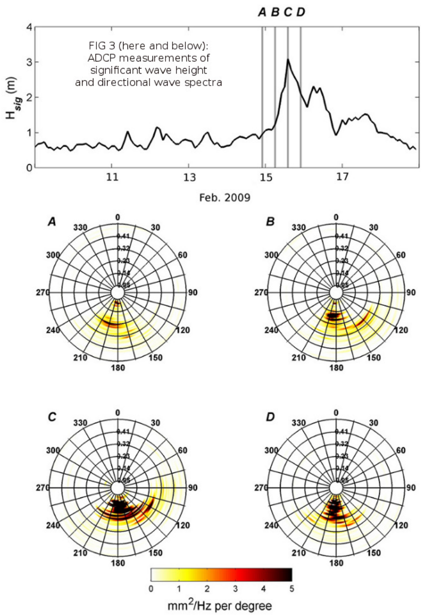

FIG 4 (above): sequence of bed images from a sector-scanning sonar, showing the wavelength and orientation of ripples before the storm; the destruction of the ripple field during; and the more irregular ripples which returned afterwards

Acknowledgements

Chris Sherwood (USGS) for discussions and ideas concerning the modelling of fractional resuspension. Jon Warrick (USGS Santa Cruz) for discussions concerning the analysis of images for grain size metrics. Theresa Fregoso (UCSC) created the map upon which Fig 1 is based. Andrew Stevens (USGS Menlo Park) carried out the analysis for Fig 3. Finally, thanks to Parker Allwardt for carrying out validative work for the digital grain size method.

References

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MODEL DETAILS: Smith & McLean (1977) reference concentration with the McLean (1992) weighting function for the presence of a size distribution. Bed roughness contains 1) skin friction; 2) bedform heights; and 3) sediment transport calculated following Xu & Wright (1993). Bedform heights were set at 2cm for before and after the storm conditions: the timings were assessed qualitatively from the sidescan sonar images. Sediment diffusion follows Rouse, and no correction is made for stratification. Eddy viscosity profile and bed shear velocities follow the linear approximation. Settling velocity and particle stresses based on Soulsby & Whitehouse (1997).

FIG 5 (right): time-series of waves, currents, and sediments

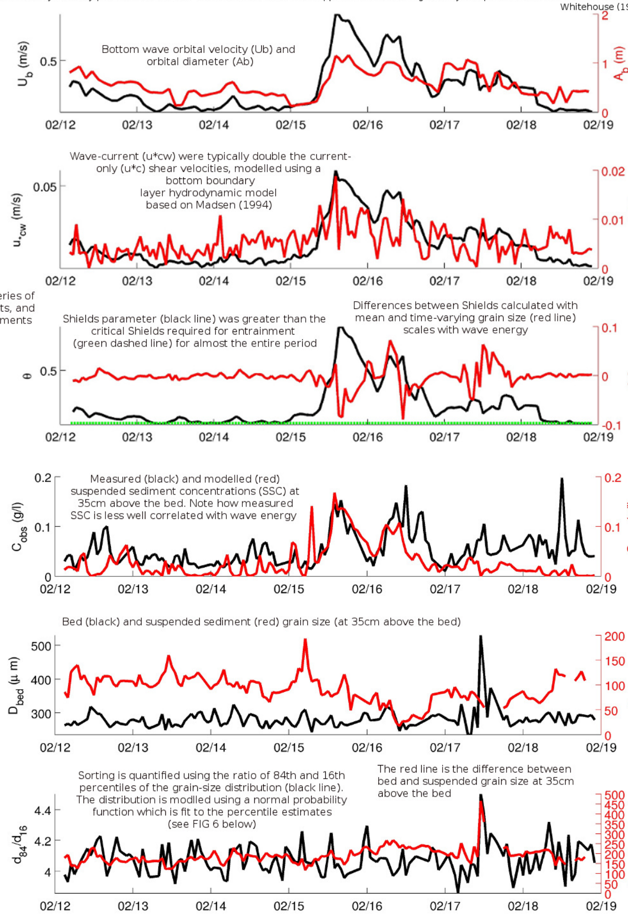
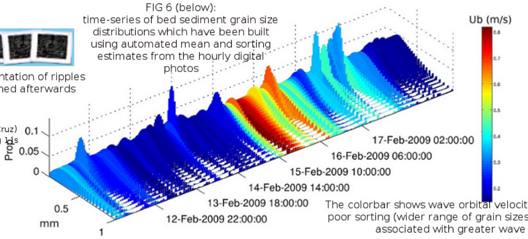


FIG 6 (below): time-series of bed sediment grain size distributions which have been built using automated mean and sorting estimates from the hourly digital photos



The colorbar shows wave orbital velocities. Qualitatively, poor sorting (wider range of grain sizes on the bed) are associated with greater wave energy

Analysis

Concentration profiles are diffused (Rouse style) from a reference concentration (Smith & McLean 1977) at a roughness level which depends on bedform dimensions, skin friction and sediment transport (15 x Shields: Xu and 1993). The model performed best if the McLean (1992) weighting function was applied to the reference concentration, which down-weights the proportion of coarse sediments in the suspensate.

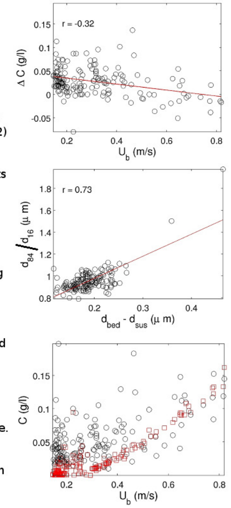


FIG 7 (right):
Top: the difference in observed and modelled SSC has a weak negative correlation with Ub. Time-varying gamma did not improve correlations. Time-varying bedform dimensions (roughness) might improve correlations.

Middle: bed sediment sorting is strongly correlated with the difference between bed and suspended grain size (at 35cm)

Bottom: whereas modelled SSC (red squares) are a direct function of wave energy, measured SSC values (black squares) show a much weaker dependence. The modelled estimates contained grain size information, so perhaps the discrepancy is due to bedforms or diffusion inadequately specified

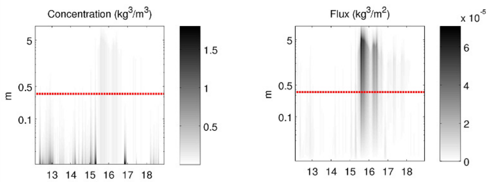
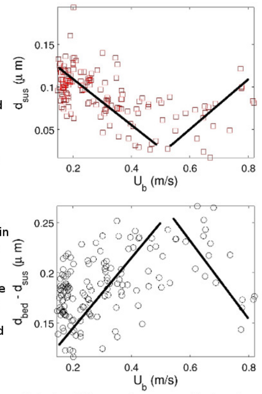


FIG 8 (above): modelled vertical profiles of SSC and flux during the event

Synthesis

A bottom boundary layer sediment transport model performs well with a measured time-series of grain size and sorting. Measured SSC at 35cm compares better to model outputs under high energy, prompting suggestion that grain size exerts more control on SSC under supply-limited conditions.

FIG 9 (right):
The trends in suspended sediment grain size (Ds) as a function of wave energy are consistent with local diffusive resuspension and bed winnowing. Ds fines as more fines are taken out of the bed, until Ub = 0.4 m/s, beyond which Ds coarsens because more of the coarse grain sizes are being suspended at this height.



Ub = 0.4m/s is also the point at which the difference between Dbed and Ds (right), increasing thus far, starts to get smaller. This corroborates the conclusions above.