# Spatial and Temporal Variability in Coastal Grain Size due to River Floods and Storm Waves

Curt Storlazzi*, Joshua Logan, Christopher Conaway, Henry Chezar, and David Rubin
US Geological Survey, Pacific Science Center, Pacific Coastal and Marine Science Center, 400 Natural Bridges Drive, Santa Cruz, CA 95060
Phone: +1-831-427-4721 E-mail: cstorlazzi@usgs.gov

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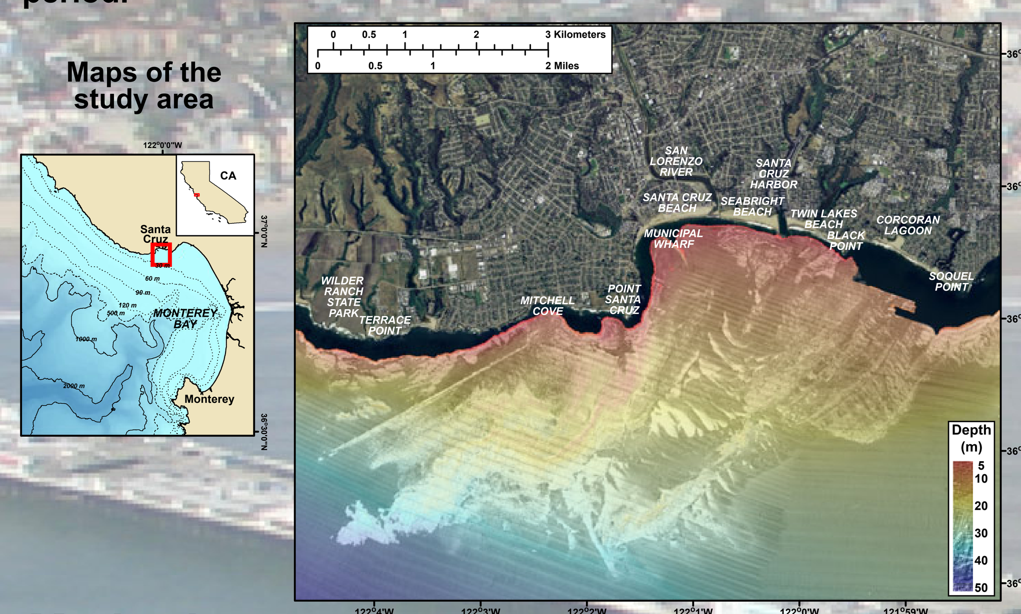
## Goals and Background

Rocky inner shelves characterize most of the Pacific basin and approximately half of the world's coastlines, however we have little understanding of their geomorphology and sedimentologic nature. Surficial sediment grain size was sampled at 8 beach and 42 seabed sites off the mouth of the San Lorenzo River in northern Monterey Bay, CA, USA, to determine the impact of river floods and winter storm waves on the temporal and spatial variability in seabed sediment grain size during the 2008 and 2009 winters. Northern Monterey Bay is characterized by an energetic (wave heights 1-9 m), emergent, rocky coastline where small, steep rivers and streams drain faulted sedimentary rocks. The greatest contributor of sediment to the nearshore is the San Lorenzo River, which discharged approximately 6,500 metric tons of sediment during the 2008-2009 winter, more than 95% of which of which came during three floods (25-68 $m^3/s$) in a 20-day period.

Maps of the study area

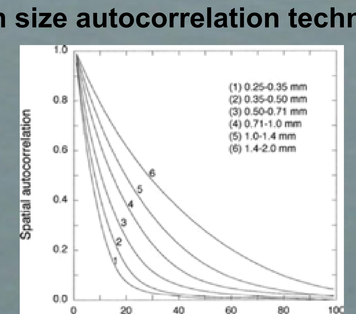


## Methods

Surficial sediment grain size was sampled using US Geological Survey "Eyeball" digital grain-size cameras (Chezar and Rubin, 2004; Rubin et al., 2007) at 8 beach and 42 seabed sites in a 2.4 km grid off the mouth of the San Lorenzo River in northern Monterey Bay, CA, USA. The "Flying Eyeball" surveys of surficial seabed sediment grain size were conducted 11 times between the 2008 and 2009 winters at 42 locations in water depths between 5 m and 25 m. These Flying Eyeball seabed samples were supplemented by "Beach Ball" (a hand-portable terrestrial version of the "Flying Eyeball") surveys conducted at 8 locations in the swash zone and along the wet/dry line in the fall of 2009.

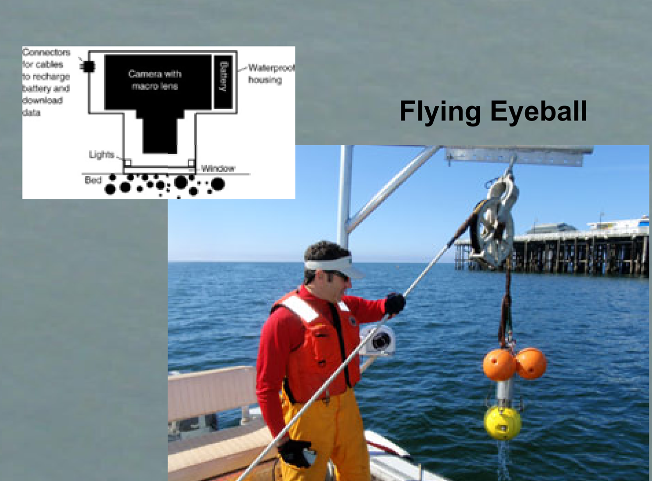
The "Eyeball" systems take a georeferenced magnified digital image of the sediment surface. At a minimum, 3 (usually 5) images were taken within a meter of so of one another at each sample location during each survey to increase robustness of the grain size calculations computed for each site. These images were then processed using the algorithms developed by Buscombe et al. (2010) to measure grain size after calibration with native sediment. Because the measurements are based only on the surface layer, these data are more accurate than grab samples that integrate both surface and subsurface grains. This makes the Eyeball systems uniquely suited to measure the active surface layer that (a) would result from any flood material settling on the seabed, and (b) interacts with flow.

Grain size autocorrelation technique:



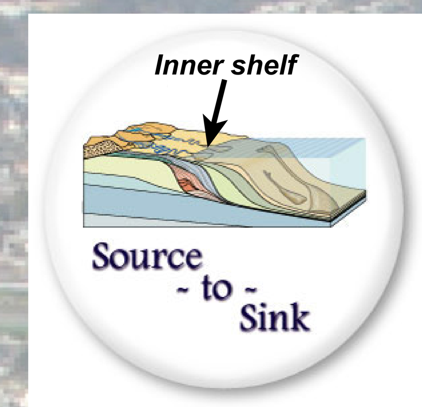
*Pixels in larger grains are more similar - for a longer distance across the image - than pixels in small grains*

Flying Eyeball



## Why Care About Grain Size on the Inner Shelf?

Because the inner shelf is the conduit between terrestrial sources and mid-shelf or deeper depocenters, understanding the processes controlling the introduction of, residence time in, and advection out of this zone are key components to understanding the linkages between terrestrial sediment sources and marine sinks.



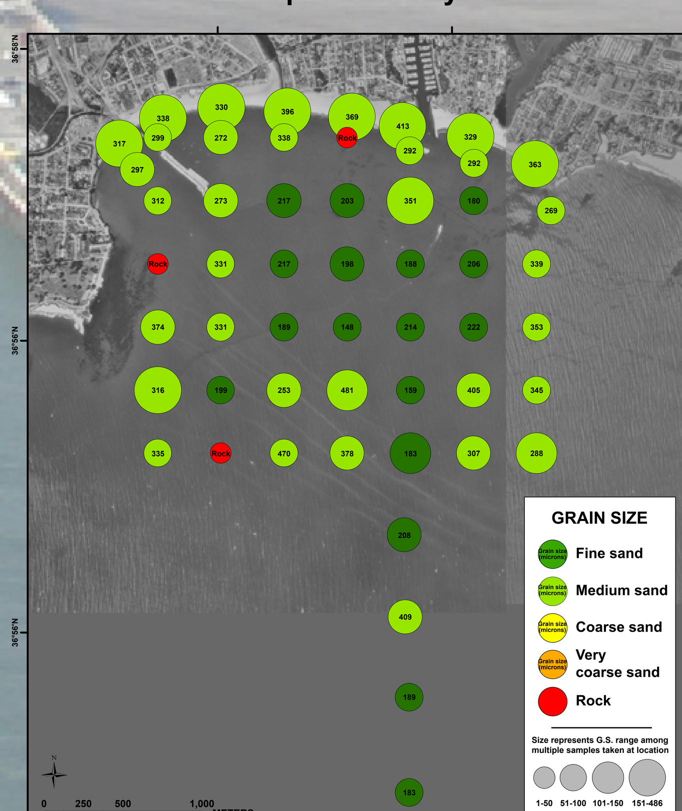

Furthermore, documenting the sedimentologic nature of these environments is key to accurately measuring and modeling the flux of sediment from land to sea:

$$Q_{sed} \sim \frac{(\tau_{current} + \tau_{wave})}{(\rho_{sed} - \rho_{fluid})g d_{sed}}$$

and

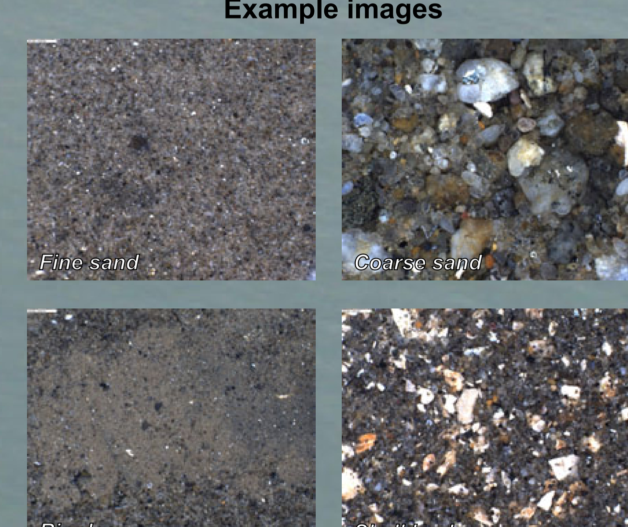
$$\tau \sim \rho_{fluid} g \left( \frac{\text{hydrodynamic roughness} \sim fn(d_{sed})}{\text{length scale of flow}} \right) U^2$$

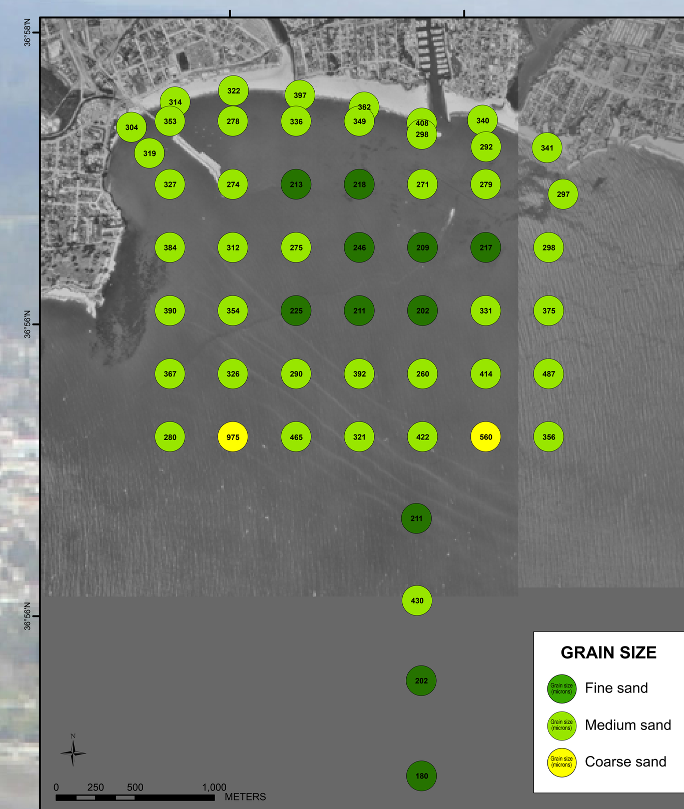
Example of survey data



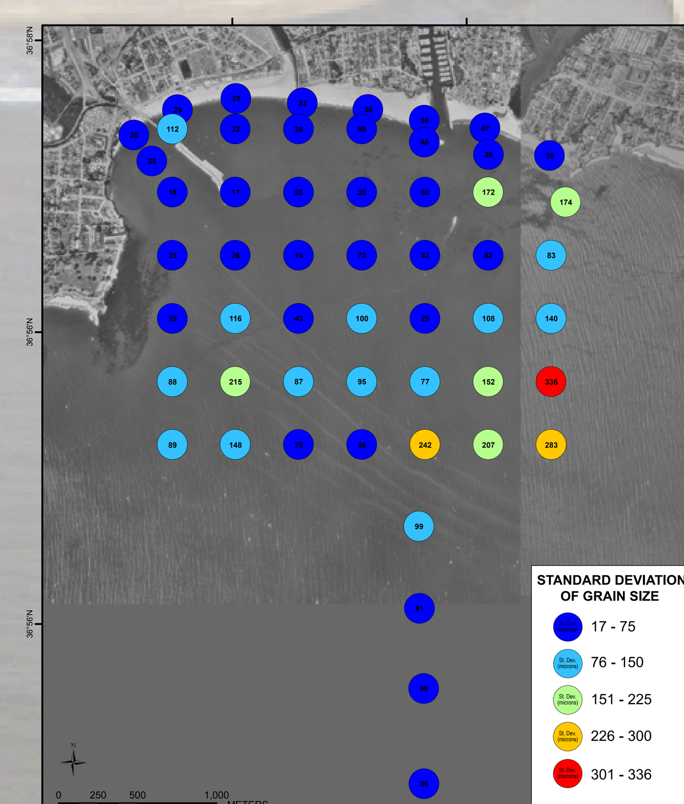

Surficial grain size measurements: 11/10/2009

Example images

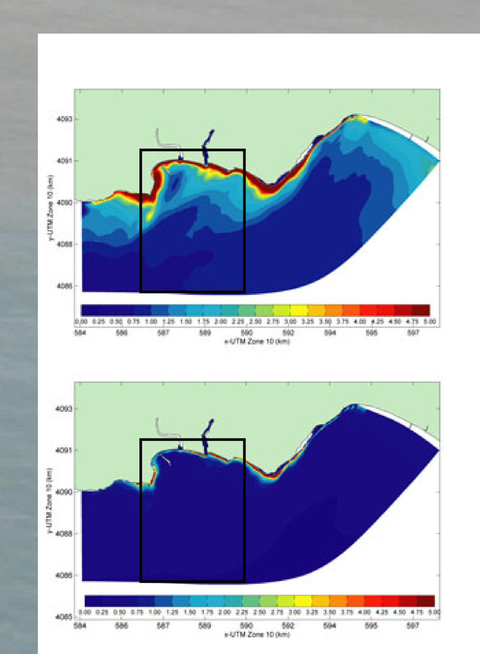


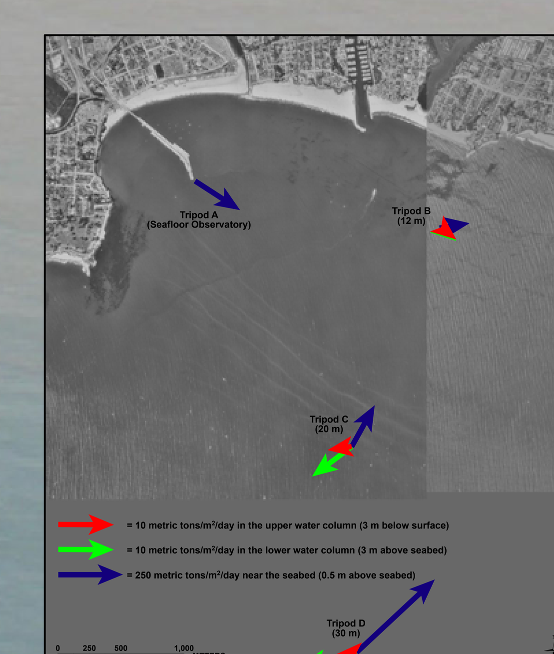

Mean grain size for all surveys




Variability in mean grain size for all surveys



Top 5% (top) and mean (bottom) modeled peak wave-driven shear stresses between surveys



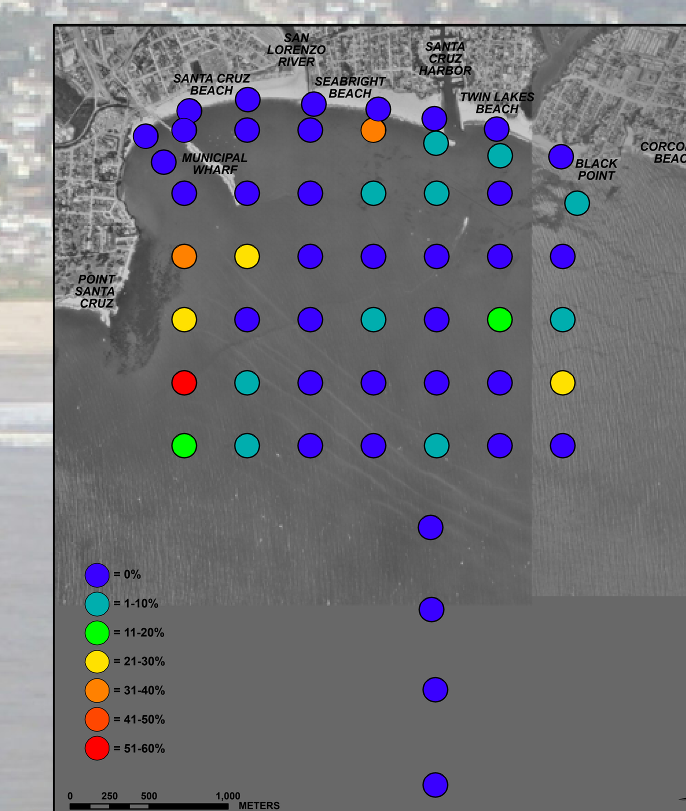
Suspended sediment fluxes computed from tripod measurements for period between surveys

The changes in surficial sediment grain size between subsequent surveys never followed a simple trend with distance from shore or with depth, likely due to the large gradients in wave energy and spatially-variable sediment tansport patterns in the study area.

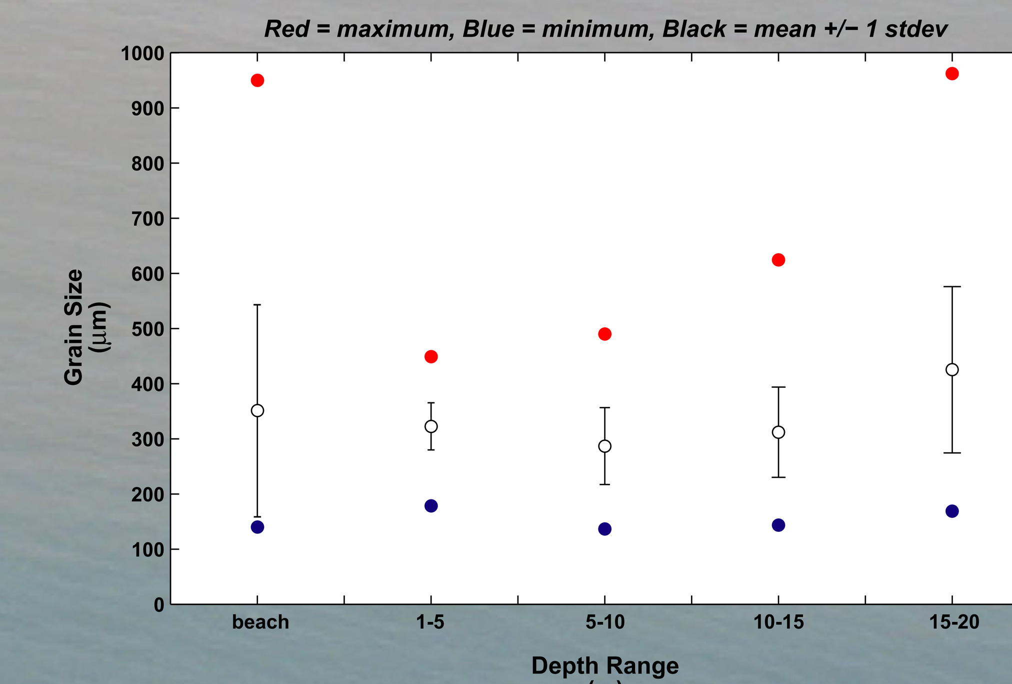
## Results

Mean grain size at the beach and nearshore sites ranged from 203 to 1055 µm and within-site variability ranged from 62 to 1284 µm. The extremely large variation in the beach samples was due to sampling of sediment from the swash zone, often along the crests and troughs of beach cusps that typify the area. The relatively low variability at shallow depths is interpreted to be due to hydrodynamic winnowing of the finer material, and this sediment is likely part of the very high (order ~250,000 $m^3$/yr) alongshore sediment transport in this area as interpreted from harbor dredge records.

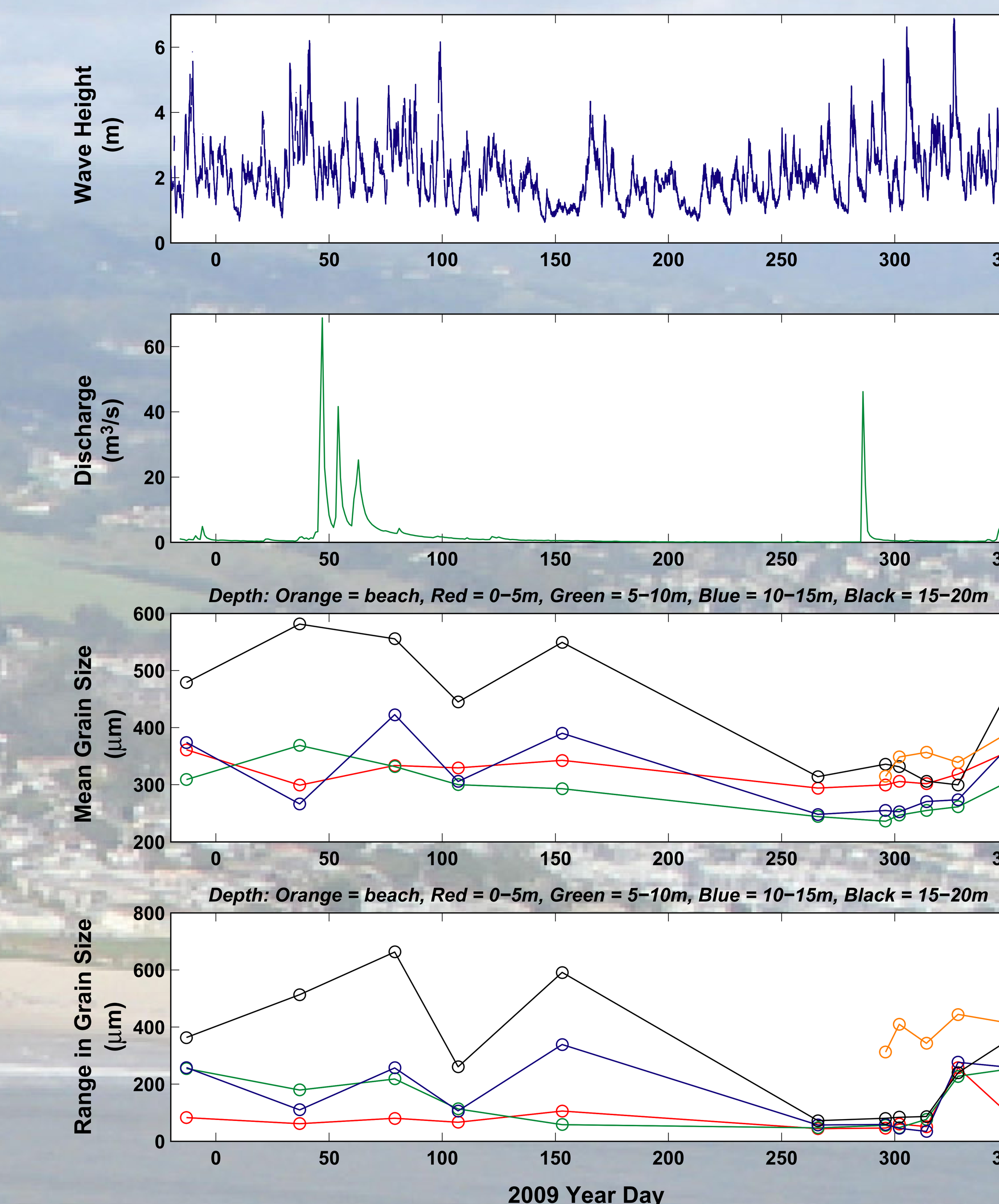
Frequency of bedrock exposure



The burial and exhumation of bedrock was a common occurrence in the study area, highlighting the often thin and transient nature of sediment cover in an relatively sediment-rich and oceanographically-energetic uplifting coastal system.

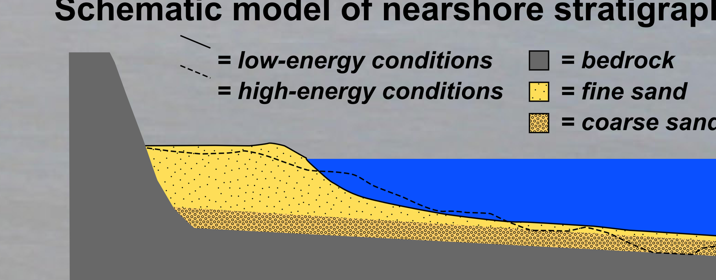



Mean grain size and grain size variability decreased from the beach out to water depths of 5-10 m, however these parameters increased between the 10-20 m isobaths. Whereas the decrease from the shoreline out to the 10 m isobath follows the trend of decreasing grain size with decreasing wave energy and shear stresses, the increase at greater depths suggests seabed stratigraphy influenced surficial sediment grain size, with a finer-grained sedimentary layer thinning offshore and periodically exposing an underlying coarse-grained lag.




Mean grain size and grain size variability from the beach out to depths of 20 m were greatest during the winter when the river was discharging sediment but storm waves were winnowing out the fine-grained flood material and eroding the beaches. Mean grain size and grain size variability were lower across the study area in the quiescent summer when shear stresses were lower, allowing finer-grained material to settle out of suspension.

Schematic model of nearshore stratigraphy




## Conclusions

These findings highlight (a) the response of the beach and inner shelf to discharges from small mountain rivers, where the sediment is generally discharged concurrently with energetic oceanographic conditions, and (b) the widely temporally- and spatially-varying sedimentary nature of energetic emergent shorelines that characterize much of the Pacific margin, which must be taken into account when trying to measure and model sediment fluxes across this relatively narrow interface.

## References

Buscombe, D., Rubin, D.M., and Warrick, J.A., 2010. A universal approximation to grain size from images of non-cohesive sediment. Journal of Geophysical Research, v. 115, F02015

Chezar, H., and Rubin, D.M., 2004. Underwater microscope system. U.S. Patent and Trademark Office, patent number 6,680,795, January 20, 2004, 9 p.

Rubin, D.M., Chezar, H., Harney, J.N., Topping, D.J., Melis, T.S., and Sherwood, C.R., 2007. Underwater microscope for measuring spatial and temporal changes in bed-sediment grain size. Sedimentary Geology, v. 202, no. 3, p. 402-408.