

High-Resolution Measurement of Sediment Concentration in Convectively Unstable Sediment Clouds

Jeff Parsons

University of Washington, School of Oceanography, Seattle WA 98195-7940
phone: (206) 221-6627, fax: (206) 616-1247, email: parsons@ocean.washington.edu

Award Number: N000140110922

<http://www.ocean.washington.edu/people/faculty/parsons/research>

LONG-TERM GOALS

To understand the mechanics of convective sedimentation (CS) and develop state-of-the-art technology to observe those mechanics in the field. CS represents an intriguing new process that has the potential to change the way the way we think about delivery of riverine material to the continental shelf and beyond. Despite substantial indirect evidence, CS has not been observed directly in the field; most likely a result of existing instrument limitations.

OBJECTIVES

- To measure the constituents (sediment concentration and salinity) in the water column of a realistic convecting system.
- To examine the effects that natural fine sediment (as opposed to manufactured materials) play on the dynamics of CS.
- To utilize new tools for the measurement of CS properties and dynamics. These instruments will be tested and calibrated such that they will ultimately be used for field measurement.

APPROACH

We have constructed a new experimental facility which produces a steady flow of fresh, sediment-laden fluid above a brine. The experimental conditions are such that the viscous dissipation rate is significantly lower than in previous gravity-current experiments and is more reflective of natural river plumes. The new facility complements an existing tank which has been used to examine CS in the absence of turbulence (Parsons et al., 2001). We will be using new instrumentation that measures water column characteristics (sediment concentration and salinity) that can be used to identify CS in field observations. The instrumentation, which has not been field-tested yet, may ultimately be used to observe CS directly or measure sediment concentration more accurately in other bottom-boundary-layer (fluid-mud) studies.

WORK COMPLETED

- Calibration of the new FOBS-7 probe to the manufactured sediments (crushed silicates) used in previous experiments of CS (Figure 1)

Report Documentation Page

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- Collection of approximately 100 kg of Eel canyon surficial sediments for use in future convective sedimentation experiments.
- Preliminary results indicating and documenting minor differences between artificial and natural sediments.
- Completion of a new experimental facility which more accurately simulates the turbulence structure of a highly-concentrated river mouth.
- Preliminary experiments in the new facility with existing sediment concentration instruments (OBS-1) exploring the lower sediment concentration limit required for CS (Figure 2).
- A theoretical analysis that predicts the lower sediment concentration limit for CS based upon basic fluid mechanical variables.

RESULTS

We have established that CS can occur at riverine sediment concentrations commonly measured on fluid-mud-producing margins (200-500 mg/L). The signature of sediment concentration in the water column of these convective systems appear qualitatively similar to some unpublished data of steep margins (i.e., the Sepik). These concentrations are also substantially less than what has been discussed previously in the literature (10 g/L, Maxworthy, 1999; 1 g/L, Parsons et al., 2001). Though we have not performed experiments with Eel canyon sediment at these low concentrations, other experiments at slightly larger concentrations (1 g/L) in the quiescent tank have produced CS. Oftentimes, the convection is more vigorous in natural materials owing to the poorly sorted grain-size distribution in those materials. A theoretical analysis has been developed that predicts the qualitative trends observed. That analysis, along with the substantiating experimental data, will be assembled into a manuscript for publication in the coming months.

Accompanying the ongoing analysis of the experimental data with existing instrumentation, we recently acquired a FOBS-7 sediment concentration probe. It has been calibrated to the crushed silica we use in many of our experiments (Figure 1). Older equipment (OBS-1) is capable of measuring general variability in the sediment concentration, but its indeterminate, and possibly large, sampling volume makes precise measurements of the small CS features impossible (Figure 2). We intend to adapt the FOBS-7 for measurement of CS and other fine-scale sediment structures in the field.

IMPACT/APPLICATIONS

The discovery of CS in turbulently mixed fluids at concentrations less 1 g/L represents a significant scientific finding. Most rivers – even benign, passive-margin rivers – produce these concentrations during floods. Though mouth geometry, tidal characteristics and estuarine mixing processes will most likely downplay the prevalence of CS in low-energy rivers, there are certainly numerous situations where conditions will be favorable for this transport mode. For instance, low-latitude rivers produce these concentrations consistently and for long durations. In these systems, distribution of material is likely affected by CS.

CS influences many related phenomena in the water column. For example, CS produces variability in sediment concentration and fluid motions that will alter measurements obtained from commonly used velocity and concentration tools (e.g., acoustic-Doppler current profilers, ADCPs). The variability also affects processes like flocculation that are dependent on particle-particle interactions. However, detecting these subtle features, distinguishing them from other types of known phenomena (e.g., nepheloid layers shed from the boundary layer) and assessing the overall importance of CS remains a significant challenge.

TRANSITIONS

The new instrumentation (the FOBS-7 probe) will be tested against existing technology in its ability to measure fine-scale structure in sediment concentration. The field-adapted device may be used in future field operations on the Apennine rivers as part of the EuroSTRATAFORM program.

We hope that the simple CS models we are developing will be used in conjunction with the margin models being developed to predict margin morphology and stratigraphy (e.g., Syvitski and Hutton, 2001).

RELATED PROJECTS

This project is closely related to fluid-mud experiments investigating the interactions of surface gravity waves and turbid bottom boundary layers. Details about the fluid-mud experiments can be found at: <http://www.ocean.washington.edu/people/faculty/parsons/research>.

Model results will be compared to field data acquired by Andrea Ogston as a part of the EuroSTRATAFORM program. Her study involves the seasonal delivery of sediment to the water column in the proximity of the Po and Apennine river systems. There is significant potential for the use of the FOBS-7 on future cruises. In addition, our findings are complementary to the examination of the 2000 Po flood deposit being performed by Chuck Nittrouer; again, in conjunction with the EuroSTRATAFORM program.

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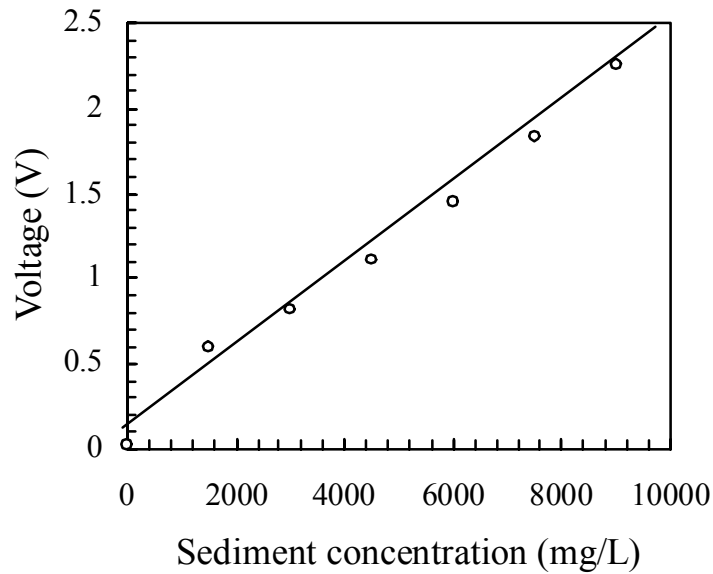


Figure 1. Initial calibration of the newly acquired FOBS-7 probe. The calibration shown is for low-gain mode and illustrates the large range of concentrations that can be measured with the probe. Lower concentrations (i.e., Figure 2) can be measured more precisely using a high-gain setting.

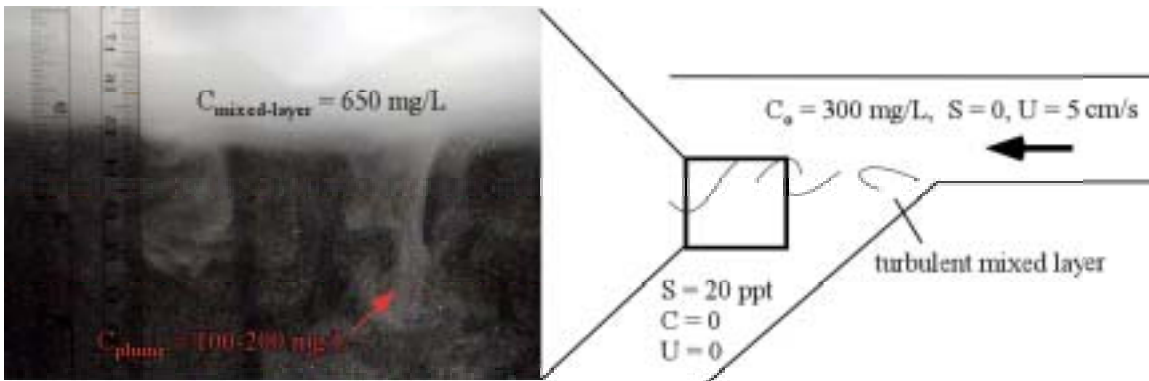


Figure 2. Photograph of convective sedimentation (CS) in a low concentration experiment. The concentrations were measured with a series of three OBS-1 probes (one in the upper fluid, one in the mixed layer and one in the proximity of the convective plumes). The concentrations are probably only accurate within 100-200 mg/L because of uncertainties in the location and size of the sampling volume.