Floc Fraction in the Gulf of Lions

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LONG-TERM GOALS

The goal of this research is to develop greater understanding of the dynamics of fine-grained sediment and its role in the generation of sedimentary facies on the continental shelf. In particular, we seek greater understanding of the environmental processes that influence the degree of packaging of fine-grained sediment within flocs (floc fraction), and the role of boundary shear stress in determining the change in sediment size and sorting that makes the sand-mud transition recognizable acoustically as well as lithologically.

SCIENTIFIC OBJECTIVES

This research has three objectives:

- To determine floc fraction of sediment as it enters the coastal ocean from rivers
- To determine floc fraction of sediment in the bottom nepheloid layer
- To determine the role of floc fraction in the erosion of sediment from the seabed

APPROACH

We pursue two basic approaches to quantifying floc fraction. The first requires co-located measurements of in situ floc size and volume concentration and total suspended particulate mass (SPM) concentration. It also requires an in situ floc size versus settling velocity relationship, which is used to convert floc volume concentration to floc mass concentration. Floc fraction is derived by dividing floc mass concentration by total SPM concentration (e.g., Curran et al., 2002a). The second method applies an inverse model of sedimentation to disaggregated inorganic grain size (DIGS) distributions in the seabed to estimate the grain size for which flux to the seabed within flocs equals the

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single-grain flux. Paired with an estimate of mean floc settling velocity, this diameter, termed the “floc limit”, can be used to calculate floc fraction in suspension (Curran et al., 2004). Our recent work in the Po delta demonstrates remarkably good agreement between these methods (Fox et al., 2004b).

A new instrument called INSSECT, which stands for **IN** situ **S**ize and **SE**ttling **C**olumn **T**ripod, was designed to determine the size and settling velocity of suspended material in situ, as well as capture flocs (Mikkelsen et al., 2004). The package includes a digital floc camera to observe the ambient floc population, a digital video camera to measure the size and settling velocity in the settling column, and a timed sediment trap consisting of 24 programmable cups containing polyacrylamide gel to collect flocs intact. Also mounted on the INSSECT are a LISST, OBS, MAVS acoustic current meter, and a compass/tilt package. INSSECT was deployed on the Po prodelta and on the Apennine Margin in February and May 2003, and it will be deployed in the Gulf of Lions in 2004-2005.

All work is being conducted collaboratively between Tim Milligan of Bedford Institute of Oceanography (BIO) and Paul Hill of Dalhousie University (Dal). Milligan takes primary responsibility for equipment design, data acquisition, and particle size analysis. Hill takes primary responsibility for modelling, data analysis, and communication of results. Danish post-doctoral fellow Ole Mikkelsen has taken primary responsibility for deployment of INSSECT. Brent Law (BIO) and Kristian Curran (Dal) provide technical support in the laboratory and field. Helene Wipf was a graduate student on this project, but she left the MSc program at Dalhousie after a year.

WORK COMPLETED

Our EuroSTRATAFORM fieldwork in the Adriatic is complete, and during the past year we were engaged in data analysis and publication of results. We were also preparing for upcoming fieldwork in the Gulf of Lions. In addition, the DFC was deployed at stations off of the Tet River by researchers from the University of Perpignan.

Our work in the Adriatic comprised four sub-projects:

1. Documentation of particle packaging in the Po River plume;

2. Interpretation of the temporal evolution of seabed DIGS on the Po prodelta;

3. Characterization of the spatial and temporal variability of floc properties in the bottom boundary layer of the western Adriatic;

4. Mapping and dynamic interpretation of the position of the sand-mud transition on the Apennine margin.

An examination of in situ fine-grained sediment packaging and its effect on sediment transport on the Po prodelta has been completed, and the results have been published (Fox et al., 2004a; Fox et al., 2004b). Fox completed his MSc thesis on this work in spring 2003.

Analysis of the evolution of the DIGS of surficial sediment since the October 2000 flood of the Po River has been completed. Integration of these results with those of European colleagues is being carried out to examine the effect of floc fraction on the distribution of carbon on the Po prodelta.

To characterize floc properties in the bottom boundary layer, the INSSECT was deployed on the Po prodelta and near the mouths of the Chienti and Pescara Rivers on the Apennine margin in February and May 2003. The INSSECT gathered data on floc size versus settling velocity, in situ particle size as measured by our digital floc camera (DFC) and by a LISST-100, and current velocity and Reynolds stress during its two-day deployments. The rotating carousel of sediment-collecting cups was prone to contamination by horizontal advection of sediment into the cups, so the data cannot be used to constrain mass flux. Mikkelsen has submitted three manuscripts from this work. The first describes the INSSECT (Mikkelsen et al., 2004), the second combines LISST and DFC data to produce full particle size distributions (Mikkelsen et al., submitted), and the third develops size versus settling velocity relationships for flocs in the Adriatic (Mikkelesen et al., submitted).

Surficial sediment samples collected off of the Tronto and Pescara Rivers have been analyzed for DIGS, sediment specific surface area, clay mineralogy, carbonate content, and metals concentrations. Doug George completed his MSc thesis on these data in late 2003, and he submitted a manuscript for publication in June 2004.

Design and construction of a new Digital Floc Camera (DFC) was completed. The new camera integrates a commercially available Nikon D100 digital SLR camera with a custom designed control board. The control board provides flexibility in image acquisition in both moored and profiling modes. A telecentric lens has been added to improve particle resolution over a large depth of field. The configuration of the camera is the same as that of earlier silhouette floc cameras, with the flash located in a pressure housing directly opposite the camera. The flash unit has been redesigned to provide brighter and more even lighting. Particle resolution is on the order of 70 µm, an improvement of over 50% from the previous digital and film floc cameras. This camera will be used in Gulf of Lions field work.

Hill completed his "Master Volume" chapter summarizing the sediment delivery work carried out during the STRATAFORM project (Hill et al., submitted).

RESULTS

Investigation of particle packaging in the Po revealed that sediment is extensively flocculated, that flocs are pre-formed in the river, and that the flocculation causes rapid, proximal loss of sediment from the Po plume (Fox et al., 2004a). Comparison of suspension-based and bed-sediment-based estimates of floc fraction found good agreement (Fox et al., 2004b).

DIGS distributions have been measured at fixed depths within cores collected from 11 sites that were occupied in December 2000, June 2001, October 2001, November 2002, February 2003, and June 2003. These distributions indicate that flocculation played a bigger role in the deposition of surficial sediments on the prodelta immediately after the October 2000 flood than during later periods. This finding is consistent with the hypothesized positive correlation between sediment concentration and floc fraction that we proposed in our previous ONR-funded work (Curran et al., 2002b).

Results from the INSSECT demonstrate that size versus settling velocity relationships vary geographically and seasonally in the Adriatic, but they resemble relationships gathered in a variety of other environments (Mikkelesen et al., submitted). Comparison of LISST and DFC size distributions in their region of overlap indicates good agreement between size distributions. The estimated concentrations from the two instruments differ, however, by up to a factor of eight. A method for merging the size distributions has been developed (Mikkelsen et al., submitted). Establishing full in situ size distributions is vital for improvement of predictions of models of optical and acoustical properties of the water column.

Analysis of silhouette images of the ambient floc population obtained from the DFC shows that at low stresses floc size does not correlate with turbulent-kinetic-energy (tke) dissipation rate. At high stresses, however, floc scales with tke dissipation rate raised to the ¼ power, as predicted by some theory.

Mapping and interpretation of the dynamic controls on the depth of the sand-mud transition on the Apennine margin has been carried out using analysis of DIGS, sediment specific surface area, clay mineralogy, carbonate content, and metals concentrations in surficial sediment on the Pescara and Tronto shelves. This work confirms that the sand-mud transition marks an abrupt change in the flux of flocculated material to the seabed and that this change affects geochemical properties of the seabed. Dimensional analysis has been carried out using the depths of other sand-mud transitions reported in the literature. Results of this analysis suggest that except in the case of extremely high sediment concentrations, the depth of the sand mud transition is controlled by significant wave height (George et al., submitted).

IMPACT/APPLICATION

Observations are helping to refine understanding of modes of delivery of fine-grained sediment from rivers and its incorporation into the sedimentary record. These observations suggest that the sand-mud transition, characterized by an abrupt change in sediment size and sorting, is the result of bottom stresses that scale with significant wave height. With the exception of shelves dominated by rivers with very high fine-grained sediment loads that overwhelm resuspension by wave stresses, these findings appear to be universal. Characterization of the entire particle size distribution and of floc fraction in suspension will lead to improved models of sediment transport and of the optical and acoustical properties of the water column.

RELATED PROJECTS

We received funding from ONR Environmental Optics to deploy a camera at the Martha's Vineyard Cabled Observatory. The camera is co-deployed with acoustical and optical sensors (Emmanuel Boss, U. Maine) and with acoustic current meters (John Trowbridge, Woods Hole Oceanographic Institution).

The proposed parameterization of aggregation and disaggregation is being applied successfully to the interpretation of optical measurements gathered at the Coastal Mixing and Optics site by Oregon State University researchers. Collaborator is Emmanuel Boss (U.Maine)

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