Field Measurements of Sediment Transport Processes in STRATAFORM: Extended Duration Observations

R.W. Sternberg, A.S. Ogston
University of Washington
School of Oceanography, Box 357940
Seattle, WA 98195-7940
Phone: (206) 543-0768 FAX: (206) 543-6073 email: ogston@ocean.washington.edu

Award #: N00014-95-1-0418
http://www.ocean.washington.edu

LONG-TERM GOAL

The long-term goal of the sediment dynamics component of STRATAFORM is to link sediment transport processes on the continental shelf and slope to the formation and preservation of event beds in sediment deposits.

OBJECTIVES

Our objective is to investigate sediment dispersal mechanisms on the continental shelf and slope. We have maintained long-term monitoring instrumentation in support of these investigations. In particular, the data obtained address the specific topics:

- temporal variability (intra- and inter-annual) of sediment flux on the continental shelf and slope,
- spatial variability (along- and across- shelf) of sediment flux on the continental shelf,
- relationship between the spatial variability of sediment flux and the accumulation rates of sediment on the shelf,
- existence and dynamics of fluid mud on temperate shelves,
- delivery of suspended sediment to the continental slope and the formation of bottom and intermediate nepheloid layers, and
- role of canyons on suspended sediment transport in the shelf/slope system, and subsequently on the sediment budget.

APPROACH

A shelf tripod in 60 m water depth (S60) and a slope mooring in 450 m (Y450) have completed their fifth year (five winters/four summers) of data collection. Additionally, instrumentation placed in the head of Eel Canyon provides an opportunity to investigate canyon processes over the winter period 99/00. These measurements of near-bed currents, water properties, suspended sediment concentration and suspended sediment properties have been supplemented by water column profiling and seabed coring. The long time-series data set is valuable for: analysis of inter-annual and seasonal transport patterns, establishing the dynamics of resuspension and transport over a variety of storm and flood

Report Documentation Page

Report Documentation Page			*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **Field Measurements of Sediment Transport Processes in STRATAFORM: Extended Duration Observations**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,,School of Oceanography, Box 357940,,Seattle,,WA,98195**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

conditions, evaluation of river discharge effects on transport mechanisms, and validation of circulation and sediment transport models. Extended duration observations at S60 also support the plume study and rapid response sampling. This includes observations to track the increases of nearbed suspended sediment, and net flow directions of nearbed fluid mud layers during storm and flood events, as well as, the correlation of the mud layers to strata development. The current and suspended sediment data from the Y450 subsurface mooring supplemented by CTD-Transmissometer profile data enables evaluation of the magnitude and mechanisms of particulate transport to the slope, and transport off the slope in the form of bottom and intermediate nepheloid layers. The winter canyon data set (both bottom boundary layer and water column) provides initial investigation of processes active in the canyon, and an estimate of the contribution of the canyon to off-shelf transport and to the sediment budget.

WORK COMPLETED

Maintenance of the S60 tripod and Y450 mooring continued in the past year providing a near continuous time-series of current, wave, and suspended sediment concentration data at the shelf and slope locations covering five years. In April 2000, the entire suite of instrumentation was retrieved, ending the long-term monitoring component of STRATAFORM. During the final deployments, the rotational equipment was deployed in the head of the Eel Canyon (mooring at A280 and tripod at A120) providing a winter data set to evaluate the role of the canyon in the Eel sediment dispersal system. CTD-Transmissometer surveys, both on the open slope and in the canyon, were continued in this past year, investigating seasonal changes in the nepheloid layer structure of the water column.

RESULTS

The five years of current, wave, and suspended sediment data have been preliminarily compiled, and the results show the significant temporal variability, both inter-annual and intra-annual, of sediment flux on the northern California continental shelf. Both the river discharge hydrograph and the atmospheric forcing varies inter-annually, and the last five years of data obtained includes an 80-year flood, and both El Nino and La Nina forcing. In the across-shelf direction, the flux is directed seaward during all five winters, whereas, in the along-shelf direction the flux direction differs between winters, with the resulting net transport over the five years approaching zero. Tripod arrays (across-shelf in 95/96 and alongshelf in 96/97) provided data to examine the relationship between the spatial variation of sediment flux and longer-term sediment accumulation rates. Summed over the entire winter deployment periods, in the across and along-shelf directions, there was a convergence of sediment flux between tripod locations. This flux convergence is co-located with the area of highest accumulation rates (Sommerfield and Nittrouer, 1999), i.e., between 60 and 70 m water depth, and between the K and S transect lines.

Variability in currents and sediment flux both temporally and spatially may be attributed to complex circulation on the shelf and slope in the study area. Interactions with physical oceanographic modelers using nested circulation models in the study area have shown that large-scale circulation at the instrumentation sites can be quite variable and is affected by flow separation around Cape Mendocino during wind reversals associated with typical winter storm systems on this coastline (Pullen and Allen, 2000). Potential effects of the overall circulation on the sediment transport environment include: enhancement of the offshelf flux of sediment due to downwelling during initial phase of storms, trapping of sediments on the inner shelf due to setup of a frontal system during floods and, convergence of sediment flux and formation of a depocenter of sediment accumulation due to alongshelf variability in alongshelf currents.

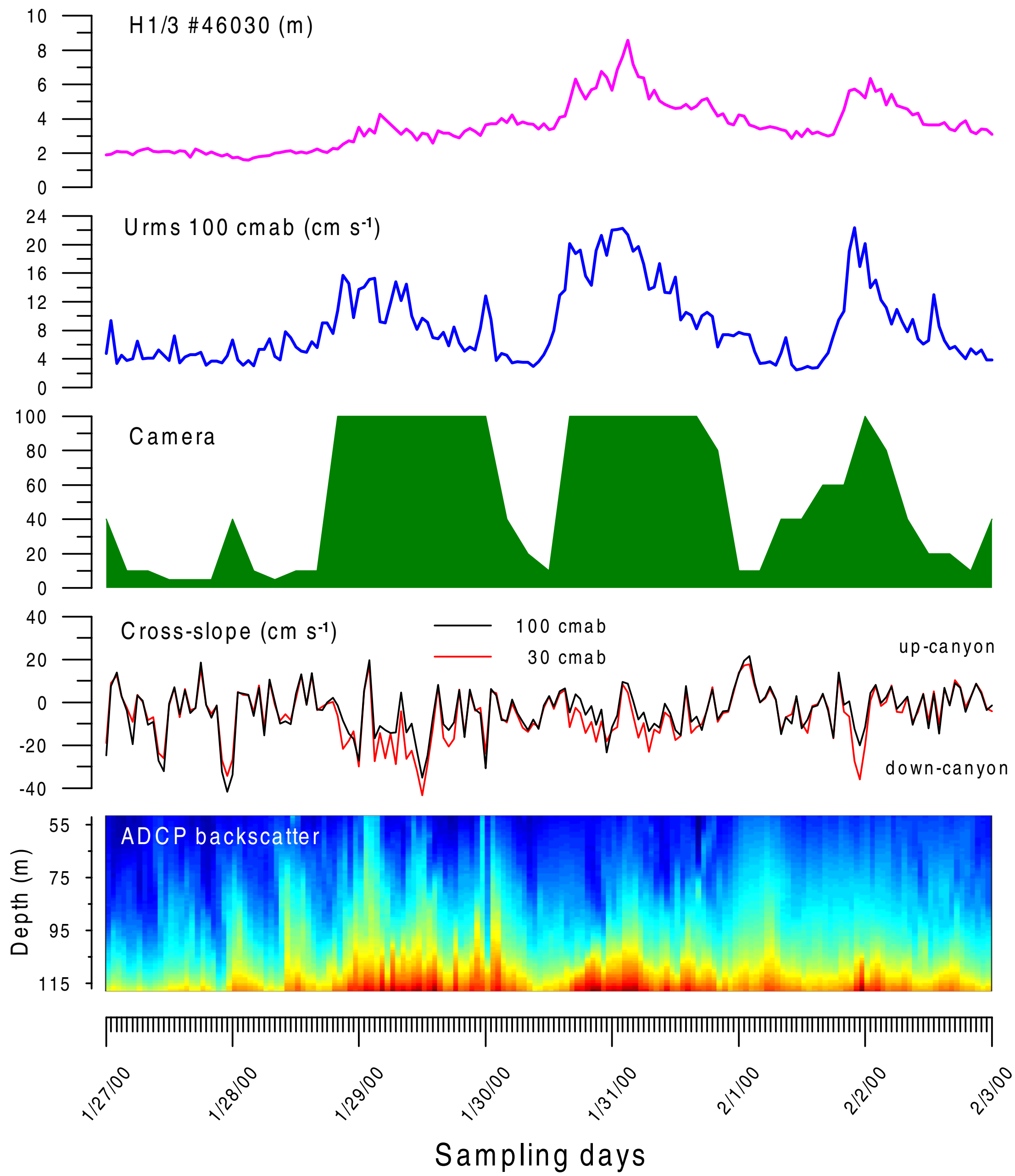

Figure 1. Eel Canyon tripod data. Note that although the wave orbital velocity is relatively low at this 120 m depth site, there is evidence of density driven flows down the canyon (currents at 30 cm flowing stronger down canyon than currents at 100 cmab). The ADCP backscatter signal agrees with the camera opaqueness (an estimate of SSC), and indicates that sediments may be suspended many meters into the water column.

During the winter of 96/97, we observed a thin layer of extremely high concentration suspended sediments (fluid mud) following a 30+year recurrence interval flood. A conceptual model was proposed in which river plume sediment is trapped on the inner shelf (either due to a weak front or the rapid input of sediment from a confined plume) and forms a thin layer of fluid mud. The fluid mud may then subsequently be transported seaward due to gravitational forcing on the densified fluid, providing a pathway for sediment between the surface plume and the observed flood deposit. Other investigators have observed similar events on this shelf (Traykovski et al., 2000). In the most recent winter deployment (99/00), a period of extreme wave energy (largest wave event on record) occurred which suspended large suspended-sediment concentrations. We are investigating whether this could have been a fluid mud event in the absence of river discharge. The high wave-orbital velocities observed may support the identification of a storm layer in the seabed.

Preliminary results from Eel canyon data set indicate that the increases of nearbed turbidity measured at the head of the canyon (120 m depth) were not directly related to the Eel River discharge, but were linked to the occurrence of storms causing sediment resuspension at the shelf. During those events, sediment transport at the head of the canyon took place as density-driven currents flowing down-canyon (Fig. 1). Superimposed on these mechanisms, periodic increases in water turbidity also were recorded at the canyon head at semidiurnal tidal frequencies, associated with decreases of water salinity and increases of temperature, suggesting a continuous off-shelf sediment transport mechanism associated with the tidal energy. Farther down thalweg, at 280 m depth, increases of turbidity associated with storm events and tides were also observed indicating a rapid cross-margin sediment transport toward deeper parts of the canyon. These increases were recorded dramatically near the bottom (15 m above the bottom), but also were observed at intermediate depths (115 m above the bottom), suggesting intense suspended-sediment transport linked to the presence of intermediate nepheloid layers within the canyon. The progressive vectors of the near-bottom currents recorded at both experimental sites (120 and 280 m depth) were clearly directed down-canyon, whereas in intermediate waters (above the canyon rims), currents were directed towards the north following the orientation of the adjacent shelf-break. These results corroborate previous findings that a substantial portion of the Eel River sediment discharge can be exported toward the Eel Canyon and provide observational evidence of the off-shelf sediment transport mechanisms acting at the head of a submarine canyon.

On the open slope, CTD-Transmissometer surveys show the geographic and seasonal distribution of intermediate nepheloid layers (INL). INLs could be classified as either shelf INLs, generated between 60 and 200 m depth, or slope INLs which detached from the continental slope at depths greater than 200 meters. Both shelf and slope INLs were often associated with regions of critical topography. Shelf INLs were strongest in winter, suggesting that their generation is associated with the supply of sediment from shelf wave resuspension. Internal wave reflection (which occurred in intermittent pulses on this slope) may be responsible for the generation of slope INLs. Results from laboratory experiments have investigated internal wave mixing on sloping boundaries and the generation of isopycnal intrusions from the boundary layer, perhaps a mechanism for INL formation. The subsurface mooring data from both the open slope and the head of Eel Canyon (99/00) will be used to investigate INL development and sediment dispersal mechanisms on the slope and in the canyon.

IMPACT/APPLICATION

The observed temporal variability of sediment flux supports the need for long-term monitoring of shelf and slope processes to evaluate sediment dispersal mechanisms. The finding of fluid mud on the Eel shelf suggests that our view of temperate shelf processes and resulting sediment transport has been too restrictive. Intermediate nepheloid layers generated from the slope due to internal wave mixing provides a mechanism for off-shelf and off-slope dispersal of sediment. The role of the canyon on this dispersal system is now recognized to be large.

REFERENCES

Pullen, J.D., Allen, J.S., 2000. Modeling studies of the coastal circulation off northern California: Shelf response to a major Eel River flood event. *Continental Shelf Research.* In press.

Sommerfield, C.K. and C.A. Nittrouer, 1999. Modern accumulation rates and a sediment budget for the Eel shelf: a flood-dominated depositional environment, *Marine Geology*, vol. 154. 227-241

Traykovski, P., Geyer, W.R., Irish, J.D., Lynch, J.F., 2000. The role of density driven fluid mud flows for cross-shelf transport on the Eel river continental shelf. *Continental Shelf Research.* In press.

PUBLICATIONS

Ogston, A.S., D.A. Cacchione, R.W. Sternberg and G.C. Kineke, 2000. Observations of storm and river flood-driven sediment transport on the northern California continental shelf. Flood sedimentation special volume, *Continental Shelf Research*. In press.

McPhee, E.E., 2000. Internal-wave mixing along sloping boundaries: a mechanism for generating intermediate nepheloid layers. PhD Dissertation to University of Washington.

McPhee, E.E. in prep. A Laboratory investigation of the horizontal intrusions generated by internal wave turbulence along a sloping boundary.

Abstracts

Sternberg, R.W., “Sediment Transport: Results from Different Shelf Settings”, AGU 2000 Fall Meeting, San Francisco.

Ogston, A.S., R.W. Sternberg, D.A. Cacchione and P.Puig, “Offshelf flux of suspended sediment on the northern California margin”, AGU 2000 Fall Meeting, San Francisco.

Drake, D.E., R.A. Wheatcroft, J. Borgeld and A.S. Ogston, “The formation and fate of flood and storm deposits on the Eel shelf”, AGU 2000 Fall Meeting, San Francisco.

P. Puig, A.S. Ogston, B.L. Mullenbach, C.A Nittrouer and. R.W. Sternberg, “Sediment transport processes at the head of the Eel submarine canyon”, AGU 2000 Fall Meeting, San Francisco.

Cacchione, D.A., L. Pratson and A.S. Ogston, “Internal Tides, Sedimentation, and Seafloor Slopes”, AGU 2000 Ocean Sciences Meeting, San Antonio.

McPhee, E.E., “Laboratory Experiments on Internal Wave Generation of Boundary-Layer Intrusions and Nepheloid Layer Detachment”, AGU 2000 Ocean Sciences Meeting, San Antonio.

Mullenbach, B.L, C.A. Nittrouer, and E.E. McPhee, “The Importance of Intermediate Nepheloid Layers in Sediment Export to the Eel Continental Slope”, AGU 2000 Ocean Sciences Meeting, San Antonio.

Ogston, A.S., D.A. Cacchione, J. Pullen and R.W. Sternberg, 2000, “Physical and sediment transport observations and modeling on the northern California shelf during storm and flood events”, AGU 2000 Ocean Sciences Meeting, San Antonio.