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Organization: William & Mary Marine Inst

Cross-Shoreface Suspended Sediment Transport: A Response to the Intersection of Nearshore and Shelf Processes

Participant Individuals

Senior Personnel

Name: Friedrichs, Carl
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wright, L.
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Brubaker, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Vincent, Christopher
Worked for more than 160 Hours: No
Contribution to Project:
The project provided travel support for Dr. Vincent to visit VIMS. Dr. Vincent loaned us acoustic backscatter sensors which we deployed as part of our field work. Dr. Vincent is and will be a collaborator on resulting publications.

Post-doc

Graduate Student

Name: Lee, Guan-hong
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Battisto, Grace
Worked for more than 160 Hours: No
Contribution to Project:
Grace Battisto was supported by a U.S. Army Corps of Engineers project whose topic and field site largely coincided with this project. Ms. Battisto participated in field experiments associated with both projects and is a collaborator in the resulting publications.

Undergraduate Student

Partner Organizations

Department of Army Corps of Engineers
The U.S. Army Corps of Engineers, Waterways Experiment Station, funded a related project on sediment transport over the shoreface which also occurred at Duck, N.C., in 1997. The topics addressed by the Army Corps project and this NSF study largely overlapped and resources were shared between the two projects.

University of East Anglia
Dr. Chris Vincent of the School of Environmental Sciences, University of East Anglia, loaned us acoustic backscatter sensors which we deployed as part of our field work. We also used lab facilities at UEA to calibrate the sensors for our experiment. Dr. Vincent has visited VIMS and I have visited UEA to facilitate collaboration.

Other Collaborators

Other collaborators on publications resulting from this project include:

Arno de Kruif, Department of Geography, University of Utrecht
John L. Largier, Scripps Oceanographic Institution, University of California at San Diego
Herman C. Miller, Waterways Experiment Station, U.S. Army Corps of Engineers
Sarah E. Rennie, Applied Physics Laboratory, Johns Hopkins University
Donald T. Resio, Waterways Experiment Station, U.S. Army Corps of Engineers
Daan D. Rijks, Department of Geography, University of Utrecht

Activities and Findings

Research Activities:
The major research activities of this project were: (1) preparing and calibrating the instrumentation systems used in the field campaigns; (2) conducting field experiments on the shoreface at Duck, N.C.; (3) reduction and analysis of field data; (4) theoretical model development; and (5) presentation of results via scientific papers, abstracts and invited seminars. The first items on this list were accomplished primarily in the first and second years of the project, whereas the latter items were addressed in the second and third years and continue to be addressed beyond the project's funded duration.

1. Instrument Preparation and Calibration:

The instruments deployed on the VIMS bottom boundary layer tripods in the fall of 1996 and again in the summer and fall of 1997 included a suite of electromagnetic current meters (EMCMs), optical backscatter sensors (OBSs), conductivity-temperature-depth sensors (CTDs), pressure sensors, acoustic backscatter sensors (ABSs), acoustic Doppler current profilers (ADCPs), and an acoustic Doppler velocimeter (ADV). Before and after the deployment, the EMCMs, OBSs, and CTs were calibrated in the VIMS flume, sediment resuspension tanks, and against conductivity standards, respectively. The response of the ABSs was calibrated at the University of East Anglia, U.K., in May 1997 with the help of Dr. Christopher Vincent, the owner of the instruments, who generously loaned two ABS systems for use in our NSF field work. Acoustic current meters are not susceptible to the drift and offset problems common to EMCMs. Thus we relied primarily on factory calibrations of the ADV and ADCPs. Instruments deployed as part of the Sensor Insertion System (SIS) at the Duck research pier in the fall of 1997 included submersible pumps, heavy duty hose and a laser insitu scattering and transmissiometry unit (LISST). The LISST was calibrated after the 1997 experiment using the VIMS sediment resuspension tank.

2. Field Experiments:

In 1996 we completed a month-long field campaign which began in late September. We deployed a pair of instrumented bottom boundary layer tripods at two depths on the lower shoreface off Duck, N.C. The systems were located on the 12 m and 16 m isobaths at 36 deg 11.49'N, 75 deg 44.36'W, and 36 deg 11.54'N, 75 deg 43.54'W, respectively. Each tripod supported five OBSs (including two integral thermistors), two suspended sediment settling traps, two pressure sensors, two CTs, one ADV and one ADCP. In addition, the inshore tripod was equipped with five EMCMs and ABSs at three frequencies. The offshore tripod was equipped with four EMCMs and a digital sonar altimeter. We had high data return from the inshore pod. Unfortunately, neither the ADV nor the OBSs on the offshore tripod appear to have returned any usable data. The deployments (and subsequent retrievals) were performed from the R/V Sea Diver, which left Virginia Beach, Va., for the deployment site on the evening of September 25. As part of the 1996 cruises we also collected CTD between the mouth of the Chesapeake Bay to the tripod deployment site and repeatedly surveyed cross-shore CTD and bottom-tracking ADCP lines.

In 1997 we completed a nearly four month-long field campaign which began in mid-August and included cruises on the R/V Cape Hatteras in August, October and December. The primary objective of the August cruise was the deployment of a fully instrumented bottom boundary layer tripod on the lower shoreface off Duck, N.C. The tripod was deployed successfully on 20 August in ~11 m water depth at

36 deg 11.441'N 75 deg 44.399'W. This 'inshore' tripod supported four OBSs (including two integral thermistors), four suspended sediment settling traps, two pressure sensors, one CTD, one ADV, four EMCMs, and ABSs at three frequencies. About 3 m away from the main tripod, an upward-looking ADCP was deployed on a mini-pod.

The primary objectives of the October cruise were to (i) deploy the 1997 offshore tripod, (ii) retrieve the 1997 inshore tripod, (iii) download its data, replace its batteries, clean and repair it as necessary, and (iv) redeploy the inshore tripod. The offshore tripod was deployed successfully on 13 October in ~16 m water depth at 36 deg 11.668'N, 75 deg 43.401'W. The 'offshore' tripod supported two OBSs, two sediment traps, two pressure sensors, one CTD, two EMCMs, and ABSs at two frequencies. About 3 m away from the main tripod an upward-looking ADCP was deployed on a mini-pod. The inshore tripod was successfully recovered on 13 October. Data was down-loaded and batteries replaced. The ADV was found to be so badly damaged, presumably by fish, that it was removed from the tripod and not redeployed. The remaining instruments were cleaned or replaced and the inshore tripod was redeployed on 14 October in ~11 m water depth at 36 deg 11.409'N, 75 deg 44.380'W. As part of the August and October cruises we also collected CTD between the mouth of the Chesapeake Bay to the tripod deployment site and repeatedly surveyed cross-shore CTD and bottom-tracking ADCP lines.

The objectives of the December cruise were to retrieve the inshore and offshore tripods. When we occupied the site of the offshore deployment on 3 December, the ranging acoustic release on the offshore tripod indicated we were still 800 m away from it. Following the acoustic release to its ultimate source, we soon discovered that the offshore tripod had been structurally destroyed, presumably by an illegally fishing trawler. Fortunately, most of the loggers were successfully recovered at 36 deg 11.271'N, 75?43.221 W a site ~800 m SE of the original deployment location. Next we recovered the inshore tripod at its expected location without incident. The wreckage of the lower portion of the offshore tripod, along with an apparently undamaged ADCP mini-pod was then recovered at the original offshore deployment location thanks to an acoustic pinger on the ADCP.

In 1997 an opportunity arose to interact with U.S. Army Corps of Engineers (USACE) scientists stationed at the Duck Field Research Facility (FRF) to further study the response of acoustic versus optical observations of suspended sediment under combined waves and currents. Funding from the USACE and this project were combined to help support an additional VIMS graduate student along with two visiting graduate students from the Physical Geography Department, University of Utrecht, The Netherlands. Working with these students and USACE scientists, four submersible pumps were mounted to the superstructure of the SIS at the FRF research pier for the purpose of testing the accuracy of acoustic and optical sensors co-located with the pump intake approximately 10 to 20 cm above the bed in October 1997. The general sampling procedure for the SIS was to transect the shoreface and surf zone over the course of about three hours. About every 60 m, the SIS was deployed to collect a five minute burst of backscatter and current meter data along with pump samples. The pump hose terminated in a 'Y', with one branch passing through a flow-through chamber attached to a LISST instrument and the other leading into a 13 liter barrel. The water sample was then analyzed for mud concentration, sand concentration and sand size distribution.

3. Data reduction:

These experiments marked the first shoreface deployments of our tripods which included acoustic instruments for monitoring currents and sediment concentration. Thus we spent a significant amount of time in the first year familiarizing ourselves with the specifications, programming and data handling for the ABSs, ADVs and ADCPs which were deployed with the tripods.

Overall data return and quality was good from the 1996 field experiment, especially from the inshore tripod. There was an extended storm off Duck, lasting from October 3 to 8, which was recorded in the tripod data 170 to 300 hours into the deployment. Maximum mean currents were 53 cm/s and 34 cm/s at the 12 m and 16 m isobaths, while maximum rms orbital velocities were 73 cm/s and 65 cm/s. The lowermost OBS was buried around hour 180. All of the OBSs appear to have been overwhelmed by biofouling soon after hour 300. Perhaps the most exciting results from the 1996 data stem from the output of the ABSs. The ABS system worked flawlessly, recording sediment concentration at 1 cm intervals through the water column and doubling as a sonar altimeter. Acoustic techniques were also used during this deployment to measure velocity. An ADV was mounted low on each tripod in order to document near-bed turbulent structure. We also hope to use the intensity of the ADV returns to investigate the interaction of suspended sediment and turbulence. High quality data were obtained through part of the major storm, at which point the sensing volume was temporarily buried. The approach to burial itself should reveal interesting structure within the wave boundary layer. An upward-looking ADCP was also mounted near the top of each tripod to monitor mean velocity throughout the upper water column. The data from the 1996 experiment has now been entirely processed and has been published as a VIMS technical report (Hepworth et al., 1998).

Preliminary reduction of 1997 data set indicates that the overall data return and quality from the VIMS nearshore tripod was marginal during the August 1997 deployment. But the return from both tripods was remarkably good in October and November, especially considering that the offshore tripod was eventually destroyed. In August, the ADV and ABSs stopped recording data after only 5 and 6 days, respectively, and the OBSs were too fouled to be useful soon after that. Nonetheless, the first 5 days of the August produced a high quality data set describing typical fairweather, summer conditions. Right after the redeployment of 'fresh' tripods in October, there was a large storm off Duck, which lasted through 20 October. Furthermore, all the instruments on both tripods operated successfully well into November. Maximum near-bed mean currents during the August deployment were about 50 cm/s at the 11 m isobath, while maximum rms near-bed orbital velocities were about 40 cm/s. During the October deployment, maximum mean currents were about 95 cm/s and 40 cm/s at the 11 m and 16 m isobaths, respectively, while maximum rms orbital velocities were about 80 cm/s and 70 cm/s. Reduction of data collected in 1997 is nearly complete and will soon be published as a VIMS technical report (Hepworth et al., in prep).

4. Model development:

See 'Project Findings' section.

5. Presentation of results:

To date, this project has resulted in 12 published abstracts, 3 technical reports, 3 articles in conference proceedings volumes, and 2 articles for publication in peer-reviewed journals. (The number of peer-reviewed journal articles resulting from this project will accelerate in the near future, and NSF will be updated via additional progress reports.) The most important publications are listed in full in a later section of this report. Below are listed invited seminars that have been presented by the lead P.I. and abstracts and technical reports on the results of this project which are not listed in a later section of this report:

Apr 29, 1996, 'Physical oceanography and sediment transport on the shoreface (inner shelf) of the Middle Atlantic Bight', Topics in Atmospheric and Ocean Science Spring 1996 Seminar Series, Marine Sciences Research Center, State University of New York, Stony Brook.

May 29, 1996, 'Mean circulation of the shoreface (innermost shelf) of the Middle Atlantic Bight in fall', Applied Physics and Ocean Engineering Department Seminar Series, Woods Hole Oceanographic Institution, Woods Hole, MA.

Apr 30, 1997, 'Hydrodynamics and sediment dynamics of shallow tidal estuaries', hosted by the Earth Sciences Division of the Nicholas School of the Environment, Duke University, Durham, NH.

May 1, 1997, 'VIMS shoreface studies', Shoreface Workshop, hosted by the Army Corps of Engineers at North Carolina State University, Raleigh, NC.

Oct 27, 1998, 'Linkages to the offshore', Nearshore Research Workshop, sponsored by ONR and U.S.G.S., St. Petersberg Beach, FL.

Feb 26, 1999, 'Aspects of physical oceanography on the inner shelf of North Carolina', hosted by the Marine Sciences Department, University of North Carolina, Chapel Hill, NC.

May 4, 1999, 'Applications (and limitations) of new instrumentation for sediment transport in estuarine and coastal environments', Physical Ocean Science and Engineering Seminar Series, College of Marine Studies, University of Delaware, Newark, DE.

May 5, 1999, 'Applications (and limitations) of new instrumentation for sediment transport in estuarine and coastal environments', Spring Seminar Series, University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, MD.

Battisto, G.M., and C.T. Friedrichs, 1998. Laser in-situ scattering and transmissiometry observations in support of the sensor insertion system, Duck N.C., October 1997. VIMS Data Report No. 57, Virginia Institute of Marine Science, Gloucester Point, VA, 72 p.

Battisto, G.M., C.T. Friedrichs, A. de Kruif, and D.C. Rijks, 1998. Pump sampling and sediment analysis in support of the sensor insertion system, Duck N.C., April and October 1997. VIMS Data Report No. 56, Virginia Institute of Marine Science, Gloucester Point, VA, 67 p.

Battisto, G.M., C.T. Friedrichs, H.C. Miller, and D.T. Resio, 1998. Response of optical backscatter sensors to mixed grain-size suspensions during SandyDuck'97. EOS, Transactions, American Geophysical Union, 79 (No. 45, Suppl.): F452.

Brubaker, J.M., 1998. Stratification and stability of the water over the North Carolina inner shelf. Ocean Sciences Meeting, AGU-ASLO, San Diego, February 1998.

Brubaker, J.M., 1998. Variability of inner shelf stratification off the North Carolina coast. Middle Atlantic Bight Physical Oceanography and Meteorology meeting, St. Michaels, Maryland, October 1998.

Friedrichs, C.T., 1997. Inference of surface wind stress via measurement of bottom stress on the inner shelf of the Middle Atlantic Bight. 1997 Gordon Research Conference on Coastal Ocean Circulation, Colby-Sawyer, New Hampshire, 15-20 June, 1997.

Friedrichs, C.T., and J.M. Brubaker, 1996. Asymmetries in the response of the inner shelf to onshore and offshore directed wind stress. Eos, Transactions, American Geophysical Union, 77 (No. 17, Suppl.): S155.

Friedrichs, C.T., J.M. Brubaker, and S.E. Rennie, 1996. Dominant components of along- and across-shelf momentum and circulation on the innermost shelf off Duck, NC. Middle Atlantic Bight Physical Oceanography and Meteorology Workshop, Sponsored by the College of Marine Studies, University of Delaware, Newark, DE, 17-18 October, 1996.

Friedrichs, C.T., J.M. Brubaker, and S.E. Rennie, 1996. Mean circulation on the innermost shelf of the Middle Atlantic Bight in fall. EOS, Transactions, American Geophysical Union, 77 (No. 46, Suppl.): F421.

Lee, G., C.T. Friedrichs, and C.E. Vincent, 1998. Eddy diffusivity inferred from multi-transducer acoustic backscatter sensors during storm and swell events at Duck, North Carolina. Ocean Sciences Meeting, American Geophysical Union, San Diego, CA, 9-13 February, 1998.

Lee, G., L.D. Wright, and C.T. Friedrichs, 1996. Sediment convergence on upper shoreface during an extreme storm at Duck, North Carolina. 25th International Conference on Coastal Engineering, Orlando, FL, September.

Rennie, S.E., J.M. Brubaker and J.L. Largier, 1996. Meteorological control of Chesapeake Bay outflow: implications for plume variability on the inner shelf. EOS, Trans. American Geophysical Union, 77 (No. 17, Suppl.):S155.

Rennie, S.E., and C.T. Friedrichs, 1996. Offshore transport of low salinity coastal intrusions. Eos, Transactions, American Geophysical Union, 77 (No. 46, Suppl.): F420.

Rennie, S.E., and C.T. Friedrichs, 1996. Offshore transport of low salinity intrusions in the Middle Atlantic Bight. Middle Atlantic Bight Physical Oceanography and Meteorology Workshop, Sponsored by the College of Marine Studies, University of Delaware, Newark, DE, 17-18 October, 1996.

Research Findings:

Major findings of this project address (1) the physical oceanography of the shoreface/inner-shelf and (2) sediment transport processes on the shoreface/inner-shelf.

A published conference proceedings article (Friedrichs and Wright, 1998) and a journal article in revision (Friedrichs et al., in revision) have addressed the physical oceanography of the shoreface/innershelf. Based on time series collected by an upward looking ADCP, Friedrichs et al. (in revision) applied a lowest order analytical model to the tidally-averaged flow dynamics. Via scaling arguments, it was shown that the shoreface off Duck in fall is contained within a layer of constant along-shelf stress equal to the along-shelf wind stress. It was shown that tidally-averaged across-shelf momentum responds at lowest order to the along- and across-shelf wind, across-shelf pressure gradients, and wind waves. Across-shelf velocity, however, is dominated by across-shelf wind, sea surface slope, and return flow associated with Stokes transport by wind waves. Decoupling of the along-shelf momentum balance from across-shelf velocity allows derivation of simple analytical solutions for velocity assuming either constant or bilinear eddy viscosity (Av). Bilinear Av reproduces observed shear in along-shelf velocity (dv/dz) through most of the water column. Constant Av over-estimates dv/dz in the mid-water column which, in turn, over-emphasizes the importance of upwelling/downwelling due to the Coriolis effect. By including the return of wave induced Stokes drift, the bilinear Av model reasonably predicts the time variation of tidally-averaged across-shelf velocity in the upper half of the water column. Near the bed, the vertical structure of across-shelf velocity is not well reproduced, possibly because of the effects of unresolved baroclinic forcing.

The simplifications central to the analytical solution applied above rely on a lowest order balance between along shelf components of surface and bottom stress. The scaling which results in this balance is sensitive to the value of the wind drag coefficient just outside the surf zone. Thus Friedrichs and Wright (1998) evaluated the potential effects of shoreface wave conditions on the inner shelf wind drag coefficient. Observations of tidally-averaged current profiles collected near the sea bed on the inner-shelf off Duck as part of this project were used to derive best-fit wind drag coefficients (cds) as a function of wave properties assuming a balance between the along-shore components of bottom stress and wind stress measured at 19 m, 300 m offshore. The best-fit for cases associated with rms bottom orbital velocities (Uwave) > 35 cm/s is a very high Cds = 0.0052, suggesting input of momentum by occasional wave breaking outside the surf-zone. For cases with Uwave < 35 cm/s, Cds is found to be larger for cases associated with (i) greater wave age, (ii) smaller wave height, and (iii) larger wind-wave angle. However, the best predictor of Cds for cases with Uwave < 35 cm/s is whether the across-shore component of the wind is directed offshore (Cds = 0.0040) or onshore (Cds = 0.0010). Offshore directed winds on the inner shelf off Duck, N.C., may be associated with large Cds because intense wind turbulence associated with air flow over the barrier island may act to more effectively transfer momentum to the surface of the adjacent ocean. Essentially, when winds are directed offshore, the wind measurement site is still within the much rougher terrestrial boundary layer.

A conference proceedings article (Lee et al., in press) and a journal article about to be submitted (Lee et al., in prep.) have examined data collected as part of this project in the fall of 1996 which document extended periods of storm versus swell conditions. The resulting observations provide an opportunity to examine the applicability of turbulent diffusion versus advection based models for sediment suspension under storm versus swell conditions. To test the applicability of a diffusive balance, ABS data collected at 1 cm intervals were used to invert the vertical diffusion equation and solve for eddy diffusivity from 1 to 50 cm above the bed. Eddy diffusivity derived from the ABS was then compared to eddy viscosity inferred from mean current profiles observed between 30 and 90 cm ab and to eddy viscosity predicted by a wave-current interaction model both within and above the wave boundary layer (WBL). During the storm period, diffusivity derived from the ABS up to ~30 cmab agreed well with viscosity derived both from observed current profiles and from the model for current shear above the WBL. This indicates turbulent diffusion associated with the mean current above the WBL was the dominant mechanism for maintaining sediment in suspension during the storm. During the swell period, diffusivity derived from the ABS up to ~30 cmab did not agree with observed mean current shear above this level nor with the model for wave-current interaction above the WBL. Diffusivity did agree with modeled shear stress due to waves within the WBL extrapolated to a height greater than the modeled WBL. These two periods were distinguished via a scaling parameter, R, which is the ratio of vortex to cross-flow velocity. The storm period corresponds to low values of R (R<0.5), while the swell period corresponds to higher R-values (R>0.5). Higher R is the condition of weak currents and sediment advection by vortex shedding in the presence of bed forms. The shedding vortices appear to enhance mass and momentum exchange above the WBL, which explains why eddy diffusivity in the absence of a current agrees with eddy viscosity associated with waves above the predicted WBL. During the storm, two- and three-layered Rouse models and a combined diffusion and advection model with three-layered eddy viscosity reproduced the observed concentration well. During swell (weak current conditions), all the models considered underpredicted the observed concentration if applied with a standard WBL thickness. However, the Rouse models with enhance vertical exchange incorporated via a thickened WBL reproduced the observed concentrations remarkably well.

A conference proceedings article (Battisto et al., in press) summarizes collaborative work at Duck between this project and a projected funded by the Army Corps of Engineers. Submersible sediment pumps together with optical backscatter sensors (OBSs) were deployed in the nearshore by the USACE/WES Sensor Insertion System at Duck, N.C., during October 1997. The distinct scales of resuspension for sand and mud at this location allowed concentrations of both size classes to be determined simultaneously from a single OBS time series. For this study, OBSs were calibrated separately using sand and mud collected off Duck, N.C. OBS voltage gain associated with mud was found to be an order of magnitude larger than that for sand. Based on this calibration, it was shown that the mass concentrations of particles smaller than 63 microns pumped off Duck during October 1997 were consistent with the lowest 1st to 5th percentile of voltage recorded by the OBSs. Calibrated OBS response above this background turbidity was consistent with pumped sand concentration as long as corrections were made for (i) varying size of suspended sand, (ii) the precise time of pump sampling and (iii) for apparent noise in the OBS records. Correction for the smaller size of suspended sand relative to that used during calibration decreased OBS estimates of sand concentration by about 0.04 and 0.2 grams/liter during the first and second parts of the field experiment, respectively. This study also demonstrates that suspended sand and mud can be accurately pump sampled in the nearshore during storms using relatively inexpensive, commercially available equipment.

Research Training:
This project has directly supported a PhD student, Guan-hong Lee, by providing funding towards his stipend and tuition. To date, Mr. Lee has published two abstracts and a conference proceedings based on the results of this project, he is about to submit a journal article, and he expects to complete his dissertation on the subject by the end of the 1999 calendar year. Through this project, Mr. Lee has gained the research skills associated with independent graduate research and also acquired advanced technical skills associated with field instrument programming and complex data analysis. This project has indirectly supported a Masters student, Grace Battisto, by exchanging resources with the U.S. Army Corps of Engineers project which directly funds her graduate studies. Ms. Battisto participated in much of the field work associated with this NSF study and has gained skills associated with independent graduate research through her authorship of two abstracts, two technical reports and a conference proceedings related to the collaborative USACE project. In addition, two other graduate students from VIMS and two graduate students from the University of Utrecht gained valuable field experience from this project by participating in the field work. Finally, my own graduate teaching has directly benefited from this work, in that I have used data collected in this project to illustrate fundamental concepts in my graduate courses.

Education and Outreach:
The field work associated with this project was coordinated with the high profile 1997 SandyDuck experiment sponsored by the Office of Naval Research and the Army Corps of Engineers. The SandyDuck experiment as a whole was featured in the national media, including segments by the Weather Channel and articles in the New York Times science section. My component of the SandyDuck experiment was specifically described in two newspaper articles in 1997, one published locally in Norfolk, Virginia, and another which was picked up by the Associated Press.

Journal Publications

Friedrichs, C.T., J.M. Brubaker, and S.E. Rennie, "Mean circulation on the innermost shelf of the Middle Atlantic Bight in fall", *Continental Shelf Research*, p. , vol. , ().) reviewed and under revision

Lee, G., C.T. Friedrichs, and C.E. Vincent, "Examination of diffusion versus advection dominated suspension on the shoreface under storm and swell conditions, Duck, N.C.", *Journal of Geophysical Research*, p. , vol. , ().) to be submitted within a few months

Battisto, G.M., C.T. Friedrichs, H.C. Miller, and D.T. Resio, "Response of OBS to mixed grain-size suspensions during SandyDuck'97", *Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes*, p. in press, vol. , (1999).) Accepted

Friedrichs, C.T., and L.D. Wright, "Wave effects on inner shelf wind drag coefficients", *Ocean Wave Measurement and Analysis, Proceedings of the Third International Symposium*, p. 1033, vol. , (1998).) Published

Books or Other One-time Publications

Lee, G., C.T. Friedrichs, L.D. Wright and C.E. Vincent, "Diffusion versus advection dominated suspension on the inner shelf under storm and swell conditions, Duck, N.C.", (1999). *Conference Proceedings*, Accepted
Bibliography: Proceedings, Coastal Ocean Processes Symposium: A Tribute to William D. Grant, Woods Hole Oceanographic Institution Institution, Sponsored by the Office of Naval Res

Lee, G.H., "Cross-shore sediment transport modeling and its application to dynamic profile equilibrium", (1999). *Thesis*, To be completed within next few months
Bibliography: PhD Dissertation, School of Marine Science, College of William and Mary, Gloucester Point, VA

Hepworth, D.A., C.T. Friedrichs, and J.M. Brubaker, "Cross-shoreface suspended sediment transport: a response to the interaction of nearshore and shelf processes, Fall 1996 Duck, N.C. Field experiment", (1998). *Technical Report*, Published Bibliography: VIMS Data Report No. 58, Virginia Institute of Marine Science, Gloucester Point, VA, 160 p.

Web/Internet Sites

URL(s):
http:/www.vims.edu/physical/duck/duck.htm
Description:

Other Specific Products

Contributions

Contributions within Discipline:
This project contributes toward answering key unresolved scientific issues regarding physical oceanography and associated cross-shore sediment transport on energetic inner-shelves. A model which has been put forward over the last twenty years by geologists collecting field data on sediment suspension is that sediment transport on stormy inner-shelves such as the Middle Atlantic Bight occurs primarily during intense weather systems typically associated with onshore directed winds. It has been hypothesized that downwelling currents over the inner-shelf (landward of the separation of the surface and bottom Ekman layers) drive suspended sediment seaward, forming a transgressive sand sheet which spreads out onto the mid-shelf. Yet other geologists who study stratigraphy in these same environments strongly argue for net onshore transport of sand at this same depth, since they commonly observe erosional surfaces on the inner shelf, with sand trapped landward and mud dominating seaward.

This present study has highlighted limitations in simple models for net offshore suspended sediment transport by downwelling mean currents. Investigation of the physical oceanography of the inner shelf suggests the persistence of fresher water near the coast associated with resilient coastal currents may greatly reduce the intensity of downwelling. The lower density water resists subduction directly, and production of unstable stratification greatly enhances eddy viscosity, further reducing across shelf velocity. Friedrichs et al. (in revision) found that wind driven models for downwelling could predict cross-shore currents well near the surface, but could not reliably predict cross-shore currents deeper in the water column.

The first generation of instrumentation to directly observe sediment transport on the inner shelf emphasized suspended sediment transport by mean currents partly because it was the easiest transport mode to observe. Lee's doctoral dissertation (in prep) is quantifying the distinct contributions to cross-shoreface sediment transport associated with suspended and bedload transport. The observations collected by this project are being used to evaluate the likely contribution of currents and waves to suspended sediment transport, and it appears currents are indeed dominant here with regards to suspended sediment, as emphasized earlier by others. However, bedload transport is only beginning to be evaluated in a sufficiently quantitative fashion. The missing landward transport component may well consist of bedload driven onshore by a combination of wave asymmetry and constructive wave-current interaction.

Contributions to Other Disciplines:
A better understanding of the physics which govern sediment transport across the inner-shelf has potential applications to understanding the transfer of larvae back and forth across the inner-shelf as well. For example, economically important blue crab larvae hatch near the mouths of major estuaries along the Middle Atlantic Bight and then spend several months on the shelf before migrating back into the estuaries again to complete their adult life cycle. A better understanding of the processes that move these larvae back and forth across the inner shelf can help biologists and managers distinguish between stock variations due to natural fluctuations in physical forcing versus variations associated with anthropogenic effects such as overfishing or pollution.

This project may also contribute useful information to geomorphologists attempting to upscale quantitative relationships for sediment transport into long-term models for large scale coastal behavior and coastal evolution. For example, if wave-induced bedload transport is fundamental to maintaining innershelf sand bodies, can we estimate what change in forcing, such as rapidly rising sea level, might cause this sand reservoir to be left behind on the shelf? Are certain storm climates more likely to keep sand trapped on the inner shelf than others?

Contributions to Education and Human Resources:

This project directly supported a PhD student, Guan-hong Lee, by providing funding towards his stipend and tuition. Through this project, Mr. Lee has gained the research skills associated with independent graduate research and also acquired advanced technical skills associated with field instrument programming and complex data analysis. This project has indirectly supported a Masters student, Grace Battisto, by exchanging resources with the U.S. Army Corps of Engineers project which directly funds her graduate studies. Ms. Battisto participated in much of the field work associated with this NSF study and has also gained skills associated with independent graduate research. Women are underrepresented in physical oceanography, so Ms. Battisto's involvement has contributed toward improved access of women to research in this field. Also, one of the VIMS technicians who participated in our cruises is African American. In addition, two other graduate students from VIMS and two graduate students from the University of Utrecht gained valuable field experience from this project by participating in the field work. The students from Utrecht completed their Masters degree 'placement' (required practical experience outside their own university) as part of our research group. Finally, my own graduate teaching has directly benefited from this work, in that I have used data collected in this project to illustrate fundamental concepts in my graduate classes.

Contributions to Science and Technology Infrastructure:

Over the course this project we upgraded our benthic boundary layer tripod system to include acoustic instrumentation for observing velocity and sediment concentration. We now use acoustic backscatter sensors which sample at 5 Hz and at 1 cm intervals over the lower meter of the water column and acoustic doppler velocimeters which sample at up to 25 Hz and resolve turbulent velocities in three dimensions. Before this experiment our tripods used less sophisticated optical backscatter sensors for sediment concentration which sampled only at a single point at 1 Hz and were susceptible to burial and biofouling. Our previous electromagnetic sensors for current recorded only at 1 Hz and in two dimensions. This instrumentation continues to be used in other projects studying physical oceanography and sediment transport.

Beyond Science and Engineering:

The Sandyduck field experiment with which this NSF project was coordinated was a high profile event on the Outer Banks of North Carolina in the summer and fall of 1997. Public tours, newspaper coverage and television reports such as those featured on the Weather Channel helped inform the public about research being done to understand processes underlying beach erosion. There is significant public pressure to build hard structures along the coast of the Outer Banks to 'protect' the beach. So far official public policy in North Carolina has been able to resist this pressure and prevent construction of seawalls which might ultimately destroy the beach in an effort to protect it. A more informed public aware of research activities such as the Sandyduck experiment is more likely to understand and appreciate scientific and engineering arguments for and against the utility of hard shoreline protection.

Categories for which nothing is reported:

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