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FINAL TECHNICAL REPORT

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FOR

Research Entitled

**A STUDY OF SEDIMENT MOTIONS AND BOTTOM
LAYER DYNAMICS OVER THE
MIDDLE ATLANTIC BIGHT SHELF AND UPPER SLOPE**

for the period 1 June, 1992 - 31 May, 1995

by

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I. FINAL TECHNICAL REPORT ON: A Study of Sediment Motions and Bottom Layer Dynamics Over the Middle Atlantic Bight Shelf and Upper Slope

A. Research Summary 1 June, 1992 - 31 May, 1995

A study of sediment dynamics over the Middle Atlantic Bight (MAB) in the vicinity of the Cape Hatteras Confluence (CHC) (Figure 1), including the mouths of estuaries, the shelf and the slope, was carried out by investigators at North Carolina State University (L.J. Pietrafesa, lead PI) as part of the Department of Energy Ocean Margins Program. Studied were processes effecting sediment motion. In particular, the processes which determine rates of vertical transport of dissolved carbon dioxide and organic matter and particulates to and from the bottom by turbulent mixing resuspension and particulate sinking and vertical motions induced by BBL convergences; especially during periods of storm activity when both surface waves and currents are maxima

Overview of Pilot Field Efforts 1994-95 MMS, (NSF/CoOP and NSF/NOAA-NURP)

The Ocean Margins Program (OMP) was established by the U.S. Department of Energy to assess the role of the OCEAN MARGINS in the global cycling and transport of carbon. A central hypothesis of the program is that a significant quantity of the atmospheric carbon injected into coastal waters becomes isolated from the atmosphere through uptake by biota and subsequent transport to deep sea sediments. In cooperation with J. Churchill and S. Williams of WHOI, G. Weatherly of FSU, and C. Wirick and C. Flagg of BNL, NCSU was involved in the study of physical processes influencing carbon transport over the shelf and slope of the southernmost Mid-Atlantic Bight, the OMP's current geographic setting. The first phase of our study is directed at particulate carbon movement over both the inner shelf and the upper slope. The inner shelf region had received very little scientific scrutiny compared with other areas of the shelf while the upper slope region has not had a coordinated circulation - bio-geo chemical study, even exploratory. Nevertheless, it is clear that processes in both regions are important to the fate of marine carbon. Due to its limited depth, the near-shore zone can be highly productive, particularly during periods of upwelling. It is also a zone where very large particulate fluxes occur, especially during storms and events of heavy estuarine discharge. By the same token the proposed Mobil Drill Site Location in 900 m of water northeast of Cape Hatteras has been shown to have the largest fluxes, as well as accumulation rates of organic carbon, on the eastern U.S. ocean margin and is at a site of believed or suspected significant horizontal advection as well as highly energetic, perhaps episodic upwelling.

North Carolina State University's effort in near-shore fluid and carbon dynamics off the Carolina coast was coordinated with investigators of both an MMS and an NSF-sponsored Coastal Oceans Processes (CoOP) study. As part of these studies, intensive moored instrument and shipboard surveying field projects were carried out over the North Carolina inner shelf during winter of 1993 and then the late summer and early autumn of 1994.

NCSU's interests in upper slope organic carbon flux and accumulation of the Carolina coast was shared by investigators of an NSF-NOAA/NURP co-sponsored Fate of Algal Organic Carbon Study. As part of this study, a single moored instrument was deployed on the NC upper slope from June 94 - May 95.

1. OMPO was a one month deployment of the NCSU BASS tripod, OBS sensors and an S4 in the vicinity of Beaufort Inlet, NC to assess inner shelf sediment dynamics under controlled instrument package deployment/recovery conditions for NCSU technicians and PI. This study was coordinated with the Minerals Management Service tracking study (J. Churchill, PI).
2. OMP 1,2 1993-95 involved a five month field program coordinated with the National Science Foundation CoOP field program and conducted near Duck, NC, (coordinated with PI Dr. S. Lentz of the Woods Hole Oceanographic Institution). The NSF CoOP program was conducted in water ≤ 25 m deep, i.e., the inner shelf. The moored instrument portions of the CoOP Project garnered the majority of effort and is directed at understanding fluid and sediment dynamics in the BBL. Albeit, the measurement program extended upward throughout the water column and into the surface, navifacial atmospheric boundary layer. This broad vertical scope was deemed necessary because previous studies have shown the processes within the BBL are closely coupled with motions generated above the bottom boundary layer (i.e., mechanical wind forced currents and internal and surface gravity waves). The NCSU equipment to be deployed for the CoOP between July - November 1994 included 1 bottom-mounted Benthic Acoustic Stress Sensor (BASS) tripod with a large complement of sensors within 2.5m of the sea floor, 1-1200Khz bottom-mounted Acoustic Doppler Current Profiler (ADCP) in a new prototype trawler-proof housing, 1 meteorological toroidal buoy with 1 S4 current meter suspended near the sea surface and 1 taut-wire mooring equipped with 1 thermistor chain, a PCO₂ sensor (M. De Grandpre of WHOI) and an O₂ Sensor (C. Wirick of BNL).
3. OMP 3 involves a full year field effort coordinated with the NSF/National Oceanic and Atmospheric Administration/National Undersea Research Program field program conducted at the proposed Mobil Drill site to the northeast of Cape Hatteras. During the period June 94 - May 95, Drs. N. Blair and D. DeMaster (both NCSU) are and will deploy and recover ¹³C flux chambers at an 850 m upper slope site to the north and east of Cape Hatteras, to evaluate O₂ and ΣCO₂ respiration rates and ¹³CO₂ and B_r bioturbation rates. They will also deploy and recover background samples for ²³⁴Th particle flux experiments. In concert with these studies, and as part of our pilot OMP studies we deployed an S4 NCSU current meter. This is site OMP-3 and has been shown by DeMaster et. al. (1994) to have extraordinarily high rates of organic carbon flux and accumulation rates; i.e., ~150 g org C/m² /y and 160 cm/ky. The rate of organic carbon burial is one of the highest reported for the marine environment. Moreover, the C-14 age of organic matter in surface sediments is both "young" and "old", 1800 yr BP, indicating a significant proportion derived from perhaps terrigenous sources. Excess Th-234 inventories at this site indicate vertical

mixing rates in the surface sediments of $\sim 33 \text{ dpm/cm}^2$ down to 10 cm and an accumulation rate of 1.1 cm/y from 10-30 cm depths in the sediments.

4. The prototype trawler fishing proof ADCP housing developed at NCSU was field tested and deployed as part of the CoOP effort. This housing will be filed for a patent by NCSU and DOE. This will be done in 1997.
5. North Carolina State University students (E. Böhm and X.F. Li) supplied sea surface satellite imagery (AVHRR) on a two to three times daily schedule to all DOE-OMP investigators (eg. C. Wirick, C. Flagg, D. Wallace, D. Repeta, P. Santschi, etc.). These data are downloaded directly from NOAA satellites using an antenna atop the 6th floor roof of Jordan Hall (at NCSU). The data are collected along a swath which extends from the latitude of Cuba to that of the Greenland Sea. The 1.1 km resolution data are then processed in the NCSU Remote Sensing Lab using UMRSMAS DPS software and then sent real time via the information highway to the Brookhaven National Lab, the Woods Hole Oceanographic Institute, etc., for immediate display and hard copy. A grey scale FAX SST product capability has also been developed at NCSU, an example of which is presented in Figure 2. This product was also made available by FAX simply by dialing 919-515-1337 by mid-March, 1995.

6. References

DeMaster, D.J., R.H. Pope, L.A. Levin and N.E. Blair (1994)
Biological Mixing Intensity and Rates of Organic Carbon
Accumulation in North Carolina Slope Sediments. Submitted
to Deep-Sea Research.

Figure 1. Proposed Ocean Margins Program study area showing regional water masses and 27 mooring-array with complimentary measurements.

Figure 2. A grey scale SST product developed at NCSU for realtime, quick-faxing.

B. DOE Sponsored Publications from our Ocean Margins Research During the Project Period.

The following papers were published or are in press presently.

1. J.J. Cione, S. Raman and L.J. Pietrafesa, (1993). The Effect of Gulf Stream-induced Baroclinicity on the U.S. East Coast Winter Cyclones. *Monthly Weather Review*. February, 1993 Vol. 121(2): 421-430.
2. L.J. Pietrafesa, (1993). Atmospheric and Ocean Physical Interactions and Implications for Biology in the Coastal Zone, *Proceedings of the LOICZ Meeting*, pp. 39-50, May 18-21, Raleigh, NC.
3. L.C. Sun and L.J. Pietrafesa, (1993). Baroclinic-Barotropic Instabilities and Energy Transfers in the Gulf Stream, *Journal of Nonlinear Analysts*, Vol. 1, No. 1.
4. J.J. Govoni and L.J. Pietrafesa, (1994). Eulerian views of layered water currents, vertical distribution of some larval fishes, and inferred advective transport over the continental shelf off North Carolina, USA, in winter. *Fisheries Oceanography*, 3(2): 120-132.
5. K.-H. Su, P.-T. Shaw and L.J. Pietrafesa, (1994). The Origin of Low-Frequency Oscillations in the Southern Mid-Atlantic Bight. *Journal of Physical Oceanography*, 24(6): 1110-1119.
6. P.-T. Shaw, L.J. Pietrafesa, C.N. Flagg, R.W. Houghton and K.-H. Su, (1994). Low-Frequency oscillations on the outer shelf in the southern Mid-Atlantic Bight. *DEEP-SEA RESEARCH, PART II, SEEP II*, 41(2/3): 253-271.
7. R.W. Houghton, C.N. Flagg and L.J. Pietrafesa, (1994). Shelf-slope water frontal structure, motion and eddy heat flux in the Southern Middle Atlantic Bight. *DEEP-SEA RESEARCH, PART II, SEEP II*, 41(2/3): 273-306.
8. C.N. Flagg, R.W. Houghton and L.J. Pietrafesa, (1994). Summertime thermocline/salinity maximum intrusions in the Mid-Atlantic Bight. *DEEP SEA RESEARCH, PART II, SEEP II*, 41(2/3): 325-340.
9. L.J. Pietrafesa, J.M. Morrison, M.P. McCann, J.H. Churchill, E. Böhm and R.W. Houghton, (1994). Water mass linkages between the Middle and South Atlantic Bights. *DEEP SEA RESEARCH, PART II, SEEP II*, 41(2/3): 365-389.
10. L. Xie, L.J. Pietrafesa and S. Raman. (1995). Effects of along-shore wind stress and surface cooling on the formation of shelf sea fronts in a simple air-sea interaction model. *Environmental Modeling and Assessment*, in press.
11. G.S. Janowitz and L.J. Pietrafesa, (1994). Subtidal Frequency fluctuations in Coastal Sea Level in the Mid and South Atlantic Bights:

A Prognostic for Coastal Flooding. *Journal of Coastal Research*, in press.

12. L. Xie, L.J. Pietrafesa and S. Raman, (1995). Interaction between surface wind and ocean circulation in the Carolina Capes in a coupled low-order model. *Continental Shelf Research*, in press.
13. Nichols, C.R. and L.J. Pietrafesa (1994). Oregon Inlet: Hydrodynamic Volumetric Flux and Implications for Juvenile Fish Recruitment, submitted to *Journal of Geophysical Research*.

C. Presentations during the three year funded period and abstracts related to the DOE Ocean Margins Program are:

1. Summertime Cross-Frontal Intrusions in the Mid-Atlantic Bight. *EOS*, 72(44): 277, 052B-11, Oct. 29, 1991/Supplement. 1991 AGU Fall Meeting. (C.N. Flagg, R.W. Houghton and L.J. Pietrafesa)
2. Low-Frequency Oscillations on the Outer Shelf. *EOS*, 72(51): 85-86, 051C-01, December 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (P.-T. Shaw, L.J. Pietrafesa, K.-H. Su, C.N. Flagg and R.W. Houghton)
3. Shelf-Slope Water Mass and Heat Exchange in the Southern Middle Atlantic Bight. *EOS*, 72(51): 86, 051C-02, Dec. 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (R.W. Houghton, C.N. Flagg and L.J. Pietrafesa)
4. Circulation, Momentum Balances, Lidar and A Phytoplankton Bloom Events. *EOS*, 71(51): 86, 051C-03, Dec. 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (L.J. Pietrafesa, G.S. Janowitz, C.N. Flagg, R.W. Houghton, C. Wirick and F.E. Hoge)
5. Water Mass linkages Between the Middle and South Atlantic Bights. *EOS*, 72(51): 87, 051C-11, Dec. 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (J.M. Morrison, L.J. Pietrafesa, G.S. Janowitz, M.P. McCann, J.H. Churchill and R.W. Houghton)
6. The Influence of Gulf Stream Location on Offshore Storm Intensification. *EOS*, 72(51): 87, 051C-12, Dec. 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (J.J. Cione, L.J. Pietrafesa, S. Raman and J.H. Churchill)
7. Erosion and Upwelling Episodes Forced by Gulf Stream Flow Dynamics: Sensitive Indices for Recognizing Small-Scale Changes in Sea Level. 1992 GSA, Winston-Salem, NC (S.W. Snyder and L.J. Pietrafesa)
8. Alongshore Variations in Coastal Sea Level in the Mid Atlantic Bight. *EOS*, 72(51): 90, 052C-13, Dec. 17, 1991/Supplement. Jan. 27-31, 1992 AGU Ocean Sciences Meeting, New Orleans, LA. (G.S. Janowitz, L.J. Pietrafesa, and R.W. Houghton)

9. Gulf Stream Location and Mid-Latitude East Coast Atmospheric Climatology as Determined Using Remotely Sensed Imagery and coastal Observations. EOS, 73 (43): 76, A11B-13, Oct. 27/Supplement 1992 Fall Meeting. (L.J. Pietrafesa, S. Raman and J.J. Cione)
10. Low-Frequency Current Fluctuations in the Southern Mid Atlantic Bight. EOS, 73 (43): 89, A12E-01, Oct. 27/Supplement 1992 Fall Meeting. (K.-H. Su, P.-T. Shaw and L.J. Pietrafesa)
11. Energy Transfers in Gulf Stream Frontal Instabilities. Model Observations, First World Congress of Nonlinear Analysts. Tampa, FL, Aug. 19-26, 1992. (L.J. Pietrafesa, L.C. Sun and G.S. Janowitz)
12. Physical / Biological Interactions in the Coastal Zone, LOICZ Meeting, pp 39-50, May 18-21, 1993, Raleigh, NC. (L.J. Pietrafesa)
13. Low-Frequency Oscillations Generated by an Isolated Vortex. MABPOM Meeting, Nov. 5-6, 1993, Raleigh, NC. (K.-H. Su, P.-T. Shaw and L.J. Pietrafesa)
14. Wind-Induced SST Variability Over the Carolina Shelf, 1994 Ocean Sciences Meeting, San Diego CA, Feb. 21-25, 1994, EOS, Transactions/Supplement, AGU, 75(3):156, 0411-8, Jan. 18, 1994. (L.J. Pietrafesa and L. Xie)
15. A Mechanism for Coastal Frontogenesis in the Carolina Capes: Concepts, Evidence and Simple Model Results, 1994 Ocean Sciences Meeting, San Diego CA, Feb. 21-25, 1994, EOS, Transactions/Supplement, AGU, 75(3):192, 051A-5, Jan. 18, 1994. (L. Xie, L.J. Pietrafesa and S. Raman)
16. Evidence and a Mechanism of Synoptic-Time Scale Air-Sea Interaction off the East Coast, 1994 Spring AGU Meeting, 23-27 May, Baltimore, MD. EOS, Transactions/Supplement, 75(16):198, 021A-10. (L. Xie, L.J. Pietrafesa and S. Raman)
17. Interaction Between Low-Level Jet and Sea Surface Temperature Gradient in the Carolina Capes, 1994. Preprint, 2nd International Conference on Air-Sea Interaction and on Meteorology and Oceanography of the Coastal Zone, 21-28 Sept., Lisbon, Portugal. (L. Xie, L.J. Pietrafesa and S. Raman)
18. Assymetry of Surface Wind Field Forced by an Elongated Surface Heat Source, 1994. Preprint, 6th Conference on Mesoscale Meteorology, 18-22 July, Portland, OR. (Support from DOE Ocean Margins Program, Grant #DEFG0985ER60376 acknowledged). (L. Xie and Y.-L. Lin)
19. Physical Transport Processes Affecting the Transport and Fate of Carbon in the Southern Mid-Atlantic Bight, 1994, Fall AGU Meeting, 5-9 Dec. San Fransisco, CA. EOS, Transactions/Supplement, 75(44): 324, 012G-8. (L.J. Pietrafesa, J.H. Churchill, A.J. Williams and C. Wirick)

20. Data Requirements for a Coastal Atmosphere-Ocean Sound System Prediction Model, 1994, Fall AGU Meeting, 5-9 Dec. San Francisco, CA. EOS, Transactions/Supplement, 75(44): 324, 012G-8. (L. Xie, L.J. Pietrafesa, S. Raman and G.S. Janowitz)
21. Baroclinically Driven Estuarine Flow: A Perturbation Approach, 1994, Fall AGU Meeting, 5-9 Dec. San Francisco, CA. EOS, Transactions/Supplement, 75(44): 305, 011A-2. (E. Driscoll, G.S. Janowitz and L.J. Pietrafesa)
22. Modeling the Flooding Around the Pamlico-Albemarle Sounds Caused By Hurricanes. Part I: Model Development and Testing, Submitted to the 21st Conference on Hurricanes and Tropical Meteorology, April 1995, Miami, FL. (L.J. Pietrafesa, G.S. Janowitz, L. Xie and G.Q. Lin)
23. Modeling the Flooding Around the Pamlico-Albemarle Sounds Caused By Hurricanes. Part II: Predicting the Flooding Caused by Emily, Submitted to the 21st Conference on Hurricanes and Tropical Meteorology, April 1995, Miami, FL. (L.J. Pietrafesa and L. Xie)
24. The Coupling of Coastal Plain and Lagoonal Estuaries to Adjacent Shelf Water, 1st Biennial Conference on Southeast Coastal Ocean Research, SECOR, 17-20 Nov., Seabrook Island, SC. (L.J. Pietrafesa and L. Xie)
25. Hydrodynamic Coupling of Coastal to Estuarine Waters and Estuary to Estuary in the Region of the Cape Hatteras Confluence, National Ocean Survey, NOAA, Sept. 1992. (L.J. Pietrafesa)

D. Appendix

1. Publications B1 - B13
2. Presentations C1 - C25