Observations and Modeling of the West Florida Continental Shelf Circulation

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LONG-TERM GOAL

My long-term goal is to contribute toward the understanding of how physical processes affect the distribution of material properties on the continental shelf. These include biological factors such as red-tide algae and fish larvae, chemical factors such as nutrients that promote phytoplankton blooms, and geological factors such as sediment resuspension that affects both inherent optical properties within the water column and erosion/accretion on the bottom, and the physical responses themselves that affect the currents and sea level responses to storms.

OBJECTIVES

To achieve the long-term goal I must accomplish a related set of objectives. In logical order these may be described as follows. 1) I am working toward a description of the seasonally varying circulations on the West Florida Continental Shelf (WFS). 2) Along with description I am attempting to develop an improved quantitative understanding of how the various forcing functions: tides; synoptic weather systems; and surface, coastal, and offshore buoyancy fluxes affect these WFS circulations. 3) With improved description and understanding, I want to determine how these processes affect both the along- and across-shelf transports of material properties, with particular emphasis of the role of the surface and bottom boundary layers. 4) Since large seasonal transitions occur, I want to assess the relative importances between the surface fluxes (of heat and fresh water) and the coastal ocean dynamics (through horizontal advection and upwelling) on the determination of WFS water properties. 5) Given better definition of the foregoing physical factors, I intend to relate these findings to questions of geological, biological and chemical importance; for example, storm surge prediction, sediment distributions and coastal erosion, nutrient distributions, species migrations and successions, the appearance of large scale regions of enhanced primary productivity (as evident in color imagery), red-tides, and how all of these factors affect inherent optical properties. 6) Since all of these objectives require adequate sampling over various time and length scales using a large assortment of instrumentation, I am working toward a prototype WFS Autonomous Ocean Sampling Network (AOSN) site south of Tampa Bay that may also be used for naval defense related experimentation and observations. 7) Thus, the capability to provide background environmental fields in real time in support of AUV operations, to test new environmental sensors, and to aid in the development of prognostic physical and biological models is an important objective. 8) An aspect of such real time monitoring is to develop an optical data transmission system to allow an AUV to access environmental data from a moored system quickly without docking. 9) A final objective is to provide information across the inner shelf regime on sediment resuspension and how this affects inherent optical properties.

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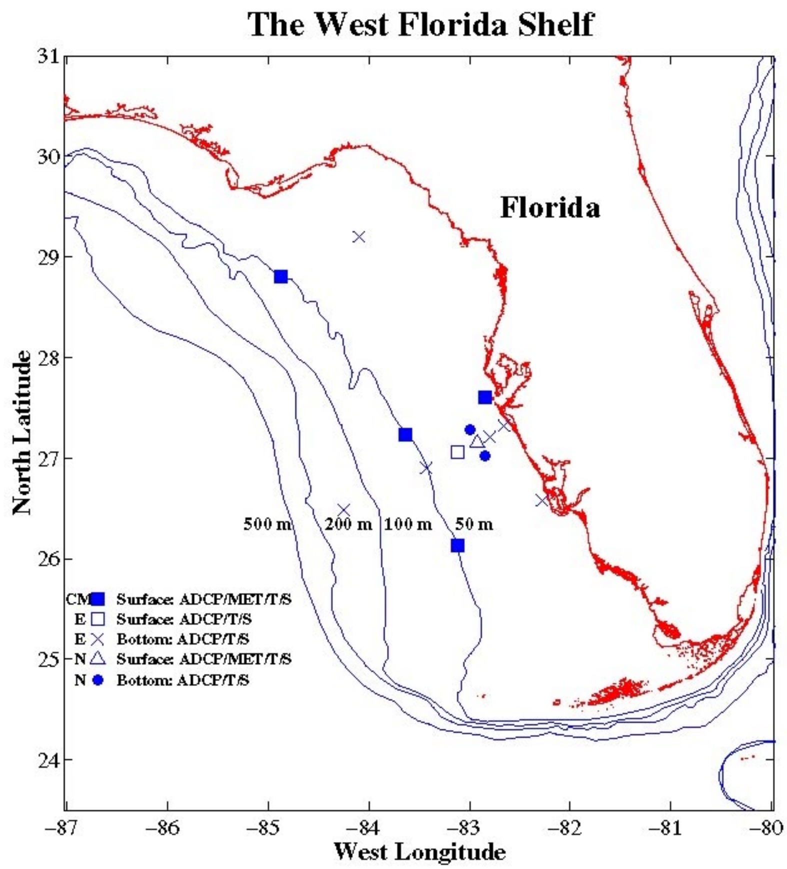
APPROACH

My approach combines *in situ* measurements, remote sensing, and numerical circulation modeling. Along with colleagues, I have marshaled resources from several related projects. The *in-situ* measurements consist of a moored array complemented by monthly hydrographic cruises. The moored array uses a combination of bottom mounted and surface buoy mounted acoustic Doppler current profilers (ADCP) for currents. The bottom moorings also include temperature, salinity, and pressure sensors, and a smaller subset of these will include sediment resuspension packages (each consisting of a near bottom vertical array of acoustic current meters and optical instruments). The surface moorings also include surface meteorological instruments and a vertically distributed set of temperature and salinity sensors. The planned array is shown in the accompanying Figure.



The goal is to sample both the inner shelf region and the spatial transitions that occur across the mid-shelf to shelf break regions. The main sampling line offshore from Sarasota FL is bounded by a control volume encompassing the region of Tampa Bay to Charlotte Harbor. Most of these measurements are by my Ocean Circulation Group (OCG) at USF. On sediment resuspension studies I am interacting with P. Howd at USF. Additional measurement sites are in the Florida Big Bend farther north (W. Sturges at FSU is collaborating), and communications exist with colleagues working farther south in the Florida Bay region (T. Lee at RSMAS). Our monthly hydrographic cruises extend to the shelf break with lines running offshore from Tampa Bay, Sarasota, and Charlotte Harbor (with G. Vargo and J. Walsh at USF). These are augmented by Mote Marine Laboratory (G. Kirkpatrick) bi-weekly cruises (weather permitting using smaller boats) offshore from Sarasota to the 30m isobath. Remote sensing includes regularly collected satellite AVHRR and ocean color imagery (by F. Muller Karger, USF Remote Sensing Lab). Numerical circulation modeling (within my OCG with the assistance of H. Yang and Z. Li) includes two versions of the Princeton Ocean Model (POM), one with a curvilinear coordinate system and another with a cartesian coordinate system. These models are limited to the WFS so collaborations are being developed with groups engaged in modeling the entire Gulf of Mexico (J. Herring, Dynalysis of Princeton, for instance) and with groups involved with smaller scales (in particular, the LES model of R. Garwood at NPS). Also at USF, J. Walsh is heading the biological aspects of modeling, K. Fanning is providing nutrient data, K. Carder anticipates deploying additional optics on the moorings, L. Langebrake [Center for Ocean Technology (COT)] is developing the optical data transmission link, and my co-investigator M. Luther is assisting with the Florida COMPS system and our capabilities to provide real time data via the internet.

WORK COMPLETED

Since the totality of this project includes other programs and funding sources, an overview is useful. I initiated a study on WFS circulation in 1993 in cooperation with the USGS Center for Coastal Geology. This study expanded with MMS and ONR support in 1995. The State of Florida approved a long-term plan by USF for a Comprehensive Ocean Monitoring and Prediction System (COMPS) for monitoring (with real time telemetry) currents and surface fluxes offshore, and sea level and winds along the coast. USF, in partnership with other State of Florida investigators, was then awarded an ECOHAB (Ecology of Harmful Algal Blooms) regional field study for the WFS by the NOAA/COP, and it is this evolution of resources that has allowed the effort just described to develop.

A pilot mooring with a downward looking 600 kHz ADCP was deployed at mid-shelf for the 16 month period: 10/5/93 to 1/26/95. These data helped define some of the relevant scales of motion and suggested that a seasonal cycle exists in the shelf-wide circulation. Some of these findings are presented in Weisberg et al. (1996a, b) and in an M.S. thesis by B. Black.

An array of moored ADCPs was then deployed over an 8-12 month period between the 300m and the 30m isobaths. Data are reported in Weisberg et al. (1997) and Siegel (1998). They help to define the different dynamical regions of the WFS. E. Siegel is preparing his M.S. thesis with these data.

To look more closely at the inner shelf, bottom mounted ADCPs were deployed offshore of Sarasota FL on the 20m and 25m isobaths in November 1996 as a precursor to the present array. They show the fully three-dimensional nature of the inner shelf and the importance of baroclinicity even in very shallow water. Seasonally, we observe a distinct modulation of the across shelf transports in response to wind forcing as the surface and bottom Ekman layers are impacted by stratification. A seasonal cycle is also evident in the alongshore currents as is a seasonal rectification of the alongshore currents to wind forcing. A data report and a manuscript are in preparation.

Satellite imagery is also important for this evolving program. Weisberg (1994) related SST patterns to loop current influence on the WFS. Siegel et al. (1998) expands on this, and such imagery along with in-situ data and a numerical model simulation is used in a case study of upwelling (Weisberg, et al., in preparation) that helped to motivate the physical hypothesis behind our ECOHAB regional field study.

Our numerical circulation model applications to the WFS are based on the public domain Princeton Ocean Model (POM) code of Blumberg and Mellor (1987). Eulerian and Lagrangian studies are in progress. Yang et al. (1998) describes Lagrangian experiments in an attempt to explain why surface drifters deployed by MMS in the northern WFS completely avoided the inner and mid-shelf regions south of Tampa Bay. Li and Weisberg (1998a, b) describe model responses to upwelling favorable winds. The flow field kinematics are fully three-dimensional with regional dependencies based upon the shoreline and isobath geometries. The flow field dynamics help to define the inner shelf through the momentum balances that obtain. These studies are providing an improved basis for understanding the in-situ observations and actual simulation studies are underway. One initial application is in collaboration with K. Fanning and J. Walsh in which we helped to address the observed evolution of the SF6 tracer data from the FSLE Project.

With regard to the array in the accompanying Figure, the OCG has deployed 8 of the 14 moorings shown, and we are scheduled to complete the array by December 1998. One additional mooring will also be deployed on the 75m isobath and we are replacing a bottom mounted mooring on the 50m isobath with a surface buoy in order to acquire additional water column density data for our control volume. The complete array consists of elements that either record internally or that also telemeter data in real time. The real time telemetry is by GOES satellite. Two moorings are presently transmitting surface meteorological data via GOES. We hired a project engineer who is in the process of implementing telemetry for both the ADCPs and in-line temperature/salinity measurements (by inductive modem). These applications require data logger improvements which are presently in design at the USF/COT. Thus, we will have fully telemetering surface meteorology as additional surface moorings are deployed, followed by telemetering currents and water column density. For receipt of telemetered data we will have both DOMSAT and DDRGS systems. The DOMSAT (to be delivered in December, 1998) acquires rebroadcast information while the DDRGS (to be installed in December, 1998) acquires digital data directly from the satellite. To support data dissemination we have implemented an SGI Origin 200 machine as a data server for COMPS. Our COMPS personnel hires were also completed. In our other related project, USF provided cost matching for an SGI Origin 2000 machine to be employed as a primary modeling tool, and for a shipboard ADCP for R/V SUNCOASTER to complement our monthly hydrographic cruises. The computer has been delivered and the ADCP has been ordered. L. Langebrake of the USF/COT is heading up the optical data transmission link for use with AUV. Hardware has been ordered and data logger developments are in parallel with our other telemetry applications. All of this should come together during spring 1999. Finally, with P. Howd, we are designing the sediment resuspension additions to the arrays. These additions should also be ready for spring 1999 deployments.

RESULTS

FY98 has primarily entailed the development of the field program and modeling capabilities. Some significant findings have nevertheless been achieved. Most importantly is the recognition that the inner shelf region is fully three-dimensional, even on this relatively simple, gently sloping WFS. Furthermore, that the circulation responses, even in such shallow water are highly density dependent and hence seasonally modulated. An observed result of this modulation in the alongshore direction is the appearance of rectified coastal jets. In the across shore direction the turning of the currents near the surface and the bottom (and hence the on or offshore transports of material properties) is highly seasonally dependent. Coupling these findings with the recognition that sediment resuspension and primary productivity are also seasonally dependent it becomes clear that the control of inherent optical properties is affected by these dynamical seasonally modulated inner shelf responses to both local forcing and larger scale shelf wide density variations. A case in point occurred during summer 1998 when our monthly hydrographic cruises showed stratification effects literally up to the beach (bathers in fact enjoyed rivulets of cold water amidst the hot summer waters). With this upwelling of shelf-scale proportion came large biological productivity evidenced in both fluorometry and in crud found in the surf zone as this stuff broke the surface. Clearly, an understanding of the fully three-dimensional circulation and how it impacts water properties, even in the shallows, is an important topic that our in-situ measurements and modeling will bear upon in future years.

IMPACT/APPLICATIONS

Our physical oceanographic results are necessary inputs to the biological models under development. The fully three-dimensional, regionally and seasonally dependent, responses of the WFS circulation, and in particular the inner shelf, largely determines the chemical, geological, and biological properties to be sampled by sensors aboard AUVs or flown on satellites, including the COIS instrument planned for the NEMO satellite. These factors will also determine the time dependent transitions that occur from optically deep to optically shallow water.

TRANSITIONS

The combined physical and biological modeling efforts will be used to develop a red-tide forecast model for the WFS as part of the NOAA/EPA ECOHAB Program. The physical measurements and models will also be used for improved coastal ocean preparedness and storm surge prediction as part of the COMPS Program.

RELATED PROJECTS

We are interacting with NOAA sponsored oceanographers to the south of us in Florida Bay (T. Lee) and with MMS sponsored oceanographers to the north of us in the Florida Big Bend and Panhandle (W. Sturges). The NOAA/EPA ECOHAB Program is co-located with our work (other P.I.s include J. Walsh, G. Vargo, K. Steidinger, G. Kirkpatrick). For HyCODE we are interacting with K. Carder and others, and on the larger Gulf of Mexico arena we are interacting with NOPP scientists (such as J. Herring).

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