Nantucket Sound Circulation – Observations, Analysis, and Model Development

I. Definition of the Marine Problem

Coastal waters in southern New England have exhibited significant warming in the last 40 years due to global atmospheric forcing. This warming trend is most noticeable in winter temperatures; in Woods Hole, the increase since 1965 is ~ 1.5 ^{o}C (Fig. 1; Nixon et al 2004). There is growing evidence that continued warming could lead to significant changes in coastal ecosystems. In particular, it is hypothesized that continued warming could cause the seasonal plankton cycle to shift from the present "cold" regime (with a distinct winter/spring phytoplankton bloom) to the "warm" regime (with increased zooplankton grazing preventing the formation of the winter/spring bloom and allowing only a late summer bloom) presently found in estuaries and embayments. The impact of this plankton regime change on higher trophic levels could be dramatic. Oviatt (2004) suggests that some of these changes have occurred in several recent warm winters in Narragansett and Massachusetts Bays.

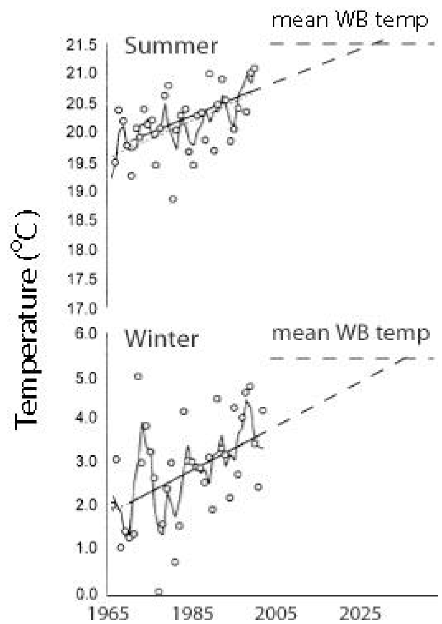

Fig. 1 Water temperatures in NS (Woods Hole MA), 1965-present, and possible future increases that might converge on the current mean temperatures in WB. (Modified from Nixon et al., 2004.)

One way to investigate the possible ecosystem effects of warmer water temperatures in local coastal waters is to understand better the processes that control observed differences in seasonal cycles of plankton. Located between Cape Cod, Martha's Vineyard and Nantucket

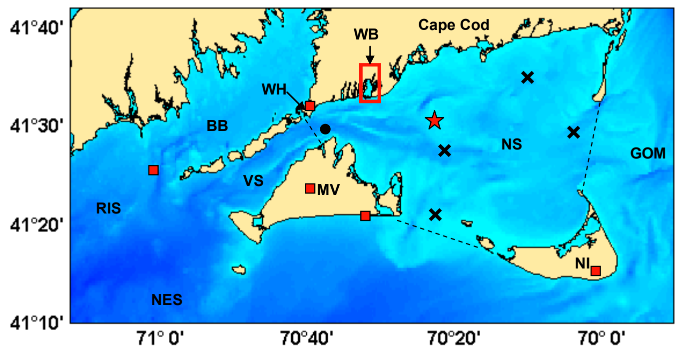

Fig. 2 Map of Nantucket Sound (NS) (defined by the dashed lines across its three openings) and adjacent waters. Place names: Waquoit Bay (WB), New England Shelf (NES), Gulf of Maine (GoM), Buzzards Bay (BB), Rhode Island Sound (RIS), Vineyard Sound (VS), Woods Hole (WH), Martha's Vineyard (MV), and Nantucket Island (NI). The black dot between WH and MV indicates the 2004 pilot study and proposed mooring site (site N), black crosses denote the initial surface drifter deployment pattern, and red squares indicate existing meteorological stations. Darker blues indicate deeper water. The red star near the center of NS denotes the site of the 60-m Cape Wind meteorological tower located on Horseshoe Shoal.

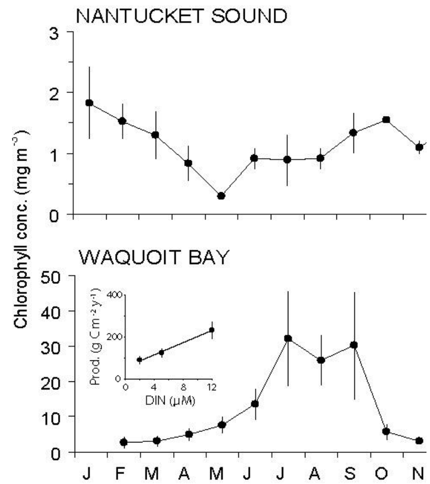

Fig. 3 Seasonal patterns of phytoplankton chlorophyll in NS (top) and WB (bottom). Data from Gilbert et al. (1982), Tomasky et al. (1999), and Valiela et al. (1992, 2000). The standard errors for WB data derive largely from differences in nutrient regime in the different sub-estuaries of WB (inset) (see Valiela et al., 2000).

Island (Fig. 2), Nantucket Sound (NS) is a representative "cold" plankton regime while Waquoit Bay (WB), a shallow Cape Cod bay that adjoins and shares water and biota with NS, is a representative "warm" plankton regime (Fig. 3). The aggregation of available data shown in Fig. 3 suggests that WB phytoplankton peak in late summer in contrast to the winter/spring peak in NS. Due in part to its very shallow depth and limited exchange with NS, WB water temperatures tend to warm up in winter/spring before NS waters, leading to a ~ 1-3 °C difference. It is hypothesized that the warmer winter/spring temperatures in WB increase grazing by zooplankton and other processes that combine to prevent a distinct phytoplankton bloom early in the year. If the warming trend in Woods Hole (Fig. 1) continues at the same rate for the next ~ 40 years, then we might expect that the same processes at work in WB could cause NS to switch permanently to the "warm" regime.

This proposal is one of four self-standing but coordinated proposals submitted to Sea Grant for innovative and multidisciplinary research in Nantucket Sound and Waquoit Bay designed to (a) improve understanding of the physics and biology of NS, in particular, the processes governing the coastal food web and seasonal plankton cycles, and (b) assess likely effects of future long-term warming scenarios on near-shore plankton using the coupled circulation/food-web model system developed as a result of this research effort.

We have chosen NS and WB for several reasons: (a) as described above, NS and WB exhibit the "cold" and "warm" plankton regimes characteristic of other NE coastal waters, (b) Nantucket Sound (as shown by the Woods Hole temperature record) is experiencing strong warming, making it representative of other NE coastal waters, (c) past Sea Grant research provides a basic understanding of plankton dynamics in WB, (d) new observational tools and new state-of-the-art numerical circulation model (Chen et al, 2003) make this study tractable, and (e) NS is a heavily exploited coastal water body with significant sport and commercial fishing, commercial and recreational boating activity, increasing nutrient loading from WB and other Cape Cod estuaries, and proposed wind farm and sand recovery operations.

The Nantucket Sound/Waquoit Bay Warming Study features four components (Table 1). While each component is complete and stand-alone, the four will be closely integrated in order to achieve the two "core" goals listed above. The work proposed in this proposal focuses on the physics of NS by making the moored and drifter measurements and collecting the meteorological and other supporting data needed to (a) describe NS circulation and its spatial and temporal variability, (b) investigate the dynamics of the observed currents and water properties, (c) combine the new in-situ oceanographic and surface forcing data with the Finite-Volume Coastal Ocean Model (FVCOM) model system proposed by Chen (UMASSD), (d) help interpret the NS ferry transect and moored physical/biological measurements proposed by Gallager, Limeburner, and Beardsley (WHOI), and (e) complement the physical and biological field and FVCOM food web model studies in WB and adjacent NS proposed by Valiela (BU), Davis and Ji (WHOI).

Table 1 Components of the Nantucket Sound/Waquoit Bay Warming Study.

PIs	Title
Limeburner, Beardsley *(MIT SG)*	Nantucket Sound Circulation – Observations, Analysis and Model Development
Chen *(MIT SG)*	Development of a Management Model System for the New England Shelf.
Gallager, Limeburner, Beardsley *(WHOI SG)*	A Comparison of the Plankton Dynamics in Nantucket Sound and Waquoit Bay Using Continuous Sampling from Moorings and Ships of Opportunity
Valiela, Davis, Ji *(WHOI SG)*	The Seasonal Plankton Cycle in Waquoit Bay: Understanding Implications of Global-driven Warming of Coastal Waters

II. Definition of the Approach

Background

NS is shallow (mean depth ~ 9 m), with openings to the west (Vineyard Sound-VS), the south (inner New England shelf-NES), and east (western Gulf of Maine-GoM) (Fig. 2). Located between the energetic GOM and weaker Mid-Atlantic Bight tidal regimes, tidal currents in NS are quite strong (the dominant M2 component has current amplitudes of ~ 1-3 m/s), generating sufficient turbulence to keep the local water column essentially vertically well mixed. Like many other New England sounds and bays, NS is a partial "flow-through" system, with two-way exchange of water, heat, salt, nutrients and biota through its three openings. A time sequence of depth-averaged tidal currents maps for NS and adjacent waters produced using the UMASSD regional GoM/GB/NES FVCOM (Chen et al, 2005a) illustrates the large tidal fluxes through each opening. Even with the relatively course model resolution of ~ 300-500 m in NS, the model shows good agreement and the few short-term tidal current measurements reported by Haight (1942) and illustrates the asymmetry between inflow and outflow through the eastern opening due to flow separation at both sides of its narrow restriction. Bi-monthly hydrographic

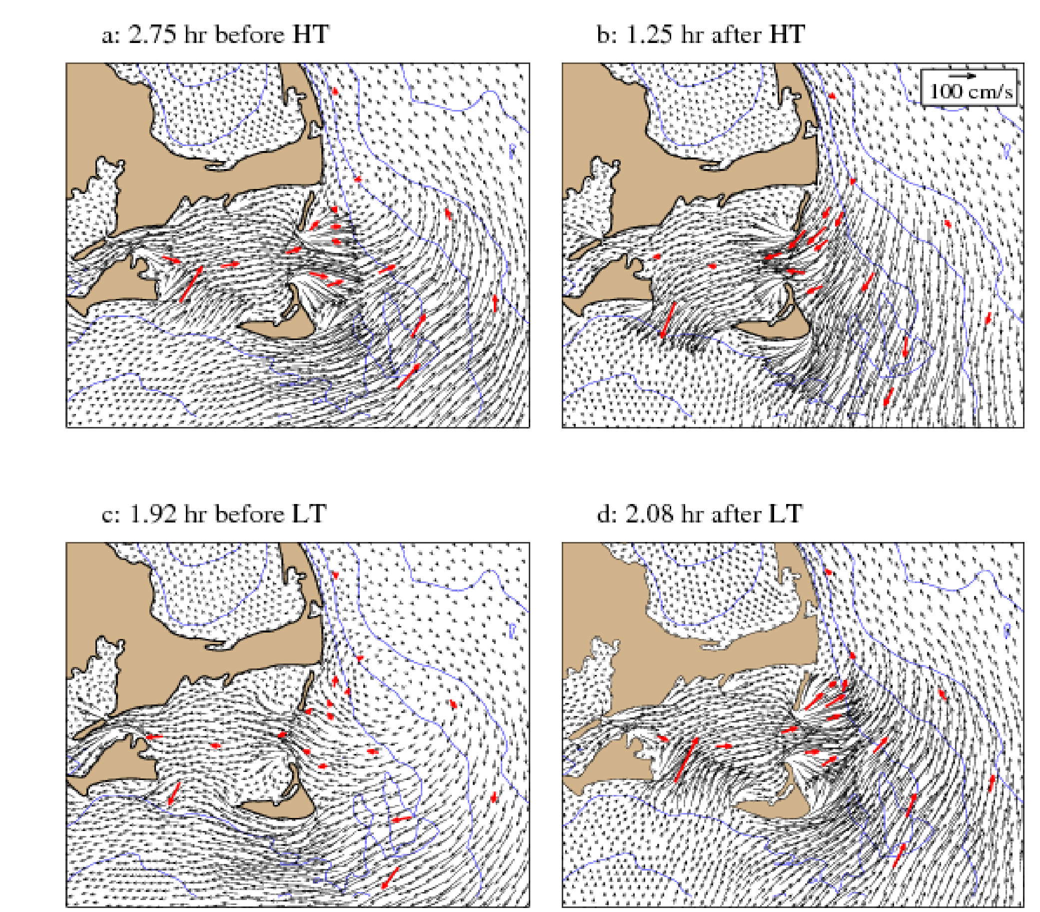

Fig. 4 Time sequence of FVCOM vertically-averaged tidal current vectors in NS over one tidal cycle relative to the water elevation at Boston. Red vectors: observed currents shown in Haight (1942). HT = High Tide; LT = Low Tide in Boston Harbor. (From Chen et al, 2005a.)

surveys made in 1978-79 over Nantucket Shoals (that included NS) show a persistent frontal zone in eastern NS between more saline western GoM and fresher NS waters (Limeburner and Beardsley, 1982). While clearly generated in part by mixing driven by the large tidal flux though this opening, it is unclear if this frontal zone requires a mean inflow of GoM water into NS.

Despite heavy use, there is *surprisingly* little known about currents in NS. Aside from Haight's (1942) tidal measurements, the subtidal flow is *virtually unknown* (not even the direction of flow through its three openings). Sanford and Flick (1975) report a mean *eastward* water flux though the Woods Hole (WH)/Martha's Vineyard (MV) opening in July 1970, while our pilot mooring (discussed next) in this opening showed a mean *westward* flow.

Pilot Field Study

In July 2004, we began a pilot field program to obtain long-term measurements of current and water properties in the narrow passage between NS and VS. A bottom tripod equipped with an upward-looking RDI 300 kHz Workhorse broadband Acoustic Doppler Current Profiler (ADCP), a Sea Bird SeaGauge 26 pressure and temperature recorder, and a Sea Bird MicroCAT 37 temperature and conductivity recorder was deployed about mid-way between WH and MV (site N, black dot in Fig. 2) in 26-m water depth on July 16 and returned a full dataset through October 14 when it was recovered. Wind data at the NOAA Buzzards Bay tower were obtained for the same period.

The currents were dominated by strong semidiurnal tides (Table 2), with maximum currents of ~ 200 cm/s at 4 m and ~170 cm/s at 22 m (4 m above the bottom) and a mean speed of ~ 80 cm/s. The depth-averaged currents were strongly polarized (major axis

Name	Period (hr)	Rank	Major Axis (cm/s)	Minor Axis (cm/s)	Inclination (°)	Phase (°G)
O1	25.82	6	7.6 ± 1.1	-0.3 ± 0.5	89.5 ± 3.7	57.4 ± 8.6
K1	23.93	4	11.8 ± 1.1	0.2 ± 0.6	80.4 ± 2.7	109.6 ± 5.7
N2	12.66	2	26.8 ± 2.2	-0.9 ± 0.7	76.9 ± 1.5	344.6 ± 5.1
M2	12.42	1	134.3 ± 2.3	-2.0 ± 0.7	77.2 ± 0.3	32.5 ± 0.9
L2	12.19	5	8.1 ± 2.2	0.3 ± 0.7	79.2 ± 4.6	120.2 ± 15.5
S2	12.00	3	22.1 ± 2.4	0.0 ± 0.6	77.5 ± 2.0	59.6 ± 6.0
M4	6.21	8	3.4 ± 0.5	2.6 ± 0.6	356.1 ± 35.2	93.9 ± 29.7
M6	4.14	7	4.5 ± 0.7	0.5 ± 0.3	87.6 ± 3.5	14.4 ± 9.5

Table 2 Dominant depth-averaged tidal current constituents at site N. Rank based on major axis size. Inclination of the major axis is measured in degrees clockwise with respect to North. Phase is given in degrees with respect to Greenwich (°G).

90.0 cm/s, minor axis 2.6 cm/s) with the major axis oriented towards 76°, roughly along the local bathymetry. The mean depth-averaged current was 3.3 cm/s oriented towards 283° (WNW) (Fig. 5). With such strongly nonlinear tidal currents (note the harmonics M4 and M6 in Table 2), it is likely that tidal rectification contributes to the mean current.

The subtidal flow in NS is thought to be driven by local surface wind forcing and pressure fluctuations at the three openings caused by larger-scale surface forcing and buoyancy forcing. To investigate local wind forcing, we show in Fig. 6 low-pass filtered time series of (a) the depth-averaged current component oriented along its major axis (76°) and (b) the wind component oriented towards 54°. This angle was chosen to

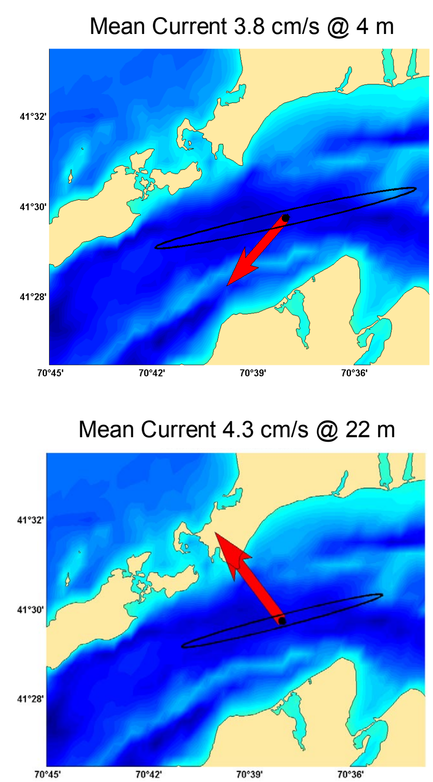

Fig. 5 Mean current vectors and subtidal current ellipses at 4 and 22 m over the 89.6 day measurement period.

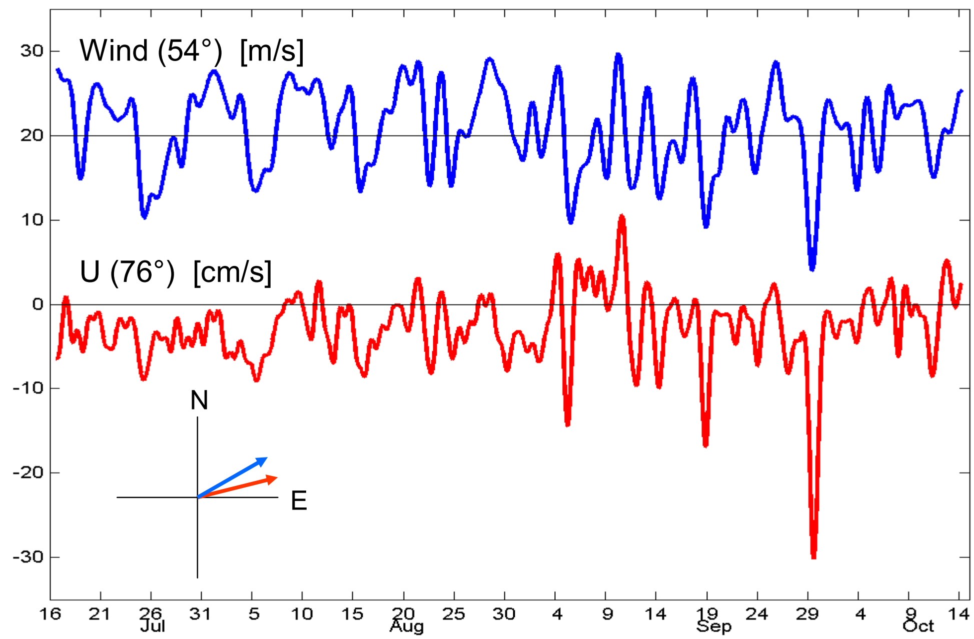

Fig. 6 Time series of wind component along 54° (blue) and depth-averaged ADCP current along 76° (red). The wind and current orientations are shown in the inset. Both series have been low-pass filtered (half-amplitude period 33 hrs) to emphasis the subtidal variability.

maximize the current-wind correlation (correlation coefficient squared $CC^2 = 0.37$). While a number of clear cases of strong wind forcing towards the SW driving strong currents towards the WSW occurred (e.g., August 9, September 29) occurred, there is a tendency for a weaker current response for winds towards the NE, and some current events with no obvious associated wind events. This supports the idea that local wind forcing plays an important but probably not dominant role in driving low-frequency flow in NS. This is consistent with the lack of any significant correlation between the subtidal surface elevation fluctuations at this site (standard deviation ~ 11 cm, maximum variation of 60 cm) and the subtidal current or winds, suggesting that the subtidal elevation (and presumably the surface pressure gradient) is strongly influenced by processes at larger scales than NS.

Proposed Research Program

We propose here a field and modeling study of circulation and water properties in NS. The field work includes (a) direct measurements of currents, temperature, salinity, and bottom pressure using a bottom-mounted ADCP/P/T/S tripod located at site N in the deep channel between WH and MV, (b) surface Lagrangian current measurements using low-cost satellite-tracked GPS drifters deployed in NS, and (c) collection of meteorological and other supporting data to quantify the surface atmospheric forcing (wind stress, heat and buoyancy fluxes) and sea surface temperature over NS. The modeling study will focus on using these new observations to help validate Chen's regional and local NS/WB FVCOM model system and develop a better quantitative understanding of circulation in NS and surrounding waters.

Moored Measurements: The bottom tripod will feature the same instrumentation as in the pilot study: an upward-looking RDI 300 kHz Workhorse broadband ADCP and Sea Bird pressure, temperature and conductivity recorders. We plan to deploy the tripod at site N in March 2006, recover and redeploy in September 2006 and March 2007, and recover in September 2007, thus obtaining an 18-month continuous record in the western NS opening while the other field components of the NS/WB Warming Study are conducted. The pilot study demonstrated that high-quality measurements can be made safely at this site (located in the main WH-MV ferry transit lane to prevent being hit by draggers and other commercial fishing activities) for a 6-month period without noticeable sensor degradation by bio-fouling. We plan to use the WHOI coastal research vessels RV *Tioga* and *Mytilus* for the mooring operations.

Surface Drifters: We propose Lagrangian measurements to (a) observe paths of near-surface fluid parcels in different tidal and wind conditions and (b) assess accuracy of FVCOM flow simulations. We will use the eMOLT low-cost satellite-tracked drifters recently developed by Manning (NMFS, Woods Hole). These drifters carry GPS receivers and transmit 5-min time series of position data so that tidal and other high frequency motion will be resolved in addition to subtidal flow. Drifters will be deployed on our mooring deployment/recovery cruises and Gallager's *Tioga* NS survey cruises and recovered if possible as they leave NS. The drifters will be released in two general patterns, one to sample larger scale flow in NS (black crosses in Fig. 2) and the second to resolve small-scale flow in and near WB.

Supporting Data: We plan to obtain meteorological data (winds, air temperature, RH, pressure, and sea surface temperature) from the Buzzards Bay entrance tower, Martha's Vineyard Coastal Observatory (MVCO) , and the Cape Wind 60-m meteorological monitoring tower, located in Horseshoe Shoal in central NS (red star in Fig. 2). Local short- and long-wave radiation data will be obtained from the WHOI long-term station on the roof of Clark Laboratory and WHOI sensors deployed on the MVCO tower and the Cape Wind tower. These data will allow accurate estimation of the surface pressure, PAR, wind stress, heat and moisture fluxes and precipitation minus evaporation (P-E) fields needed for data analysis, heat and salt budgets for NS, and modeling. The local mean P-E freshwater flux is roughly 21 m^3/s, about twice the flux (~12 m^3/s) that NS receives from Cape Cod and island groundwater (P. Weiskel, USGS, per. comm.). Determination of the freshwater fluxes from P-E, land freshwater and the open boundaries of NS will be needed to estimate the salt budget for NS.

As part of the NS/WB Warming Study, Gallager plans to deploy moorings in WB and near the Cape Wind tower and instrument ferries crossing NS to measure temperature, salinity and biological variables and telemeter the data back to WHOI. These hydrographic measurements will be very useful with our site N data to examine temporal/spatial variability in the water property fields over the 18-month period. We also plan to collect (a) all other available physical oceanographic time series data (e.g., surface elevation at coastal tide stations, temperature and salinity in WH, hydrographic data in WB collected by Waquoit Bay National Estuarine Research Reserve (WBNERR) staff, and moored bottom pressure and hydrographic data collected by Woods Hole Group at the Cape Wind tower site) and (b) satellite sea surface temperature data to help plan the *Tioga* NS surveys, identify persistent fronts and advective features, and interpret the survey and moored array data.

Data Analysis: The moored tripod data will be quickly processed after each deployment to allow scientific analysis to start. Much of the supporting meteorological and other data are available in near-real time on the web so that time series of surface forcing (barometric pressure, wind stress, heat and moisture fluxes, P-E) will be constructed starting September 2005 and kept up-to-date through September 2007 when the last tripod deployment ends. The drifter data will be collected in real-time during each drifter study, with final processing of position and Lagrangian current data completed quickly after each study. In collaboration with Gallager, we will use the near-real time ferry hydrographic measurements to construct a time sequence of temperature and salinity maps for NS.

Analysis of these data will provide the (a) first long-term (18-month) detailed description of Eulerian currents, bottom pressure, temperature and salinity at site N in NS and their temporal variability on hourly-to-annual time scales, and (b) first systematic observations of near-surface Lagrangian currents on horizontal scales of ~15 km and less and time scales from subhourly-to-days. Seasonal cycles in currents, temperature and salinity will be determined at site N, and the combined site N and Gallager's moored and ferry temperature and salinity data will be used to determine seasonal changes in these fields over NS and if possible, construct a time series of heat and salt content for NS. These seasonal changes will be compared with seasonal variations in local wind stress, heat and P-E fluxes (including local freshwater input from Cape Cod) to investigate to what degree NS responds to local surface forcing versus advective fluxes through its three openings from "upstream" sources.

As the 2004 pilot study suggests, the current and pressure response in the western NS near site N to wind forcing appears to be complex. Comparison of the surface winds and wind stress at the Cape Wind tower in central NS and the Buzzards Bay and MVCO towers should help determine spatial variability over the western NS/VS/BB region and how best to specify "local" forcing over NS. Statistical analysis between the final "local" wind stress and site N currents will quantify the relationship between wind forcing and flow and any seasonal variation. This final "local" wind stress will be used to investigate the role of wind forcing on the observed drifter motion during each of the drifter studies.

All results, including moored, drifter, and supporting data, drifter motion animations, and preliminary scientific analysis, will be posted on a WHOI program website (tentative title "Oceanography of Cape Cod and Islands") and shared with our NS/WB Warming Study collaborators and other researchers. We plan to meet frequently with our WHOI, BU, and UMASSD collaborators, WBNERR staff, and other interested researchers to discuss our field activities, measurements, and how our results might aid in their research efforts. We plan to include a WHOI summer (undergraduate) student fellow in our field and data analysis efforts each summer, and ask WHOI/MIT Joint Program graduate students to help with our mooring cruises. .

Modeling Study: We plan to work closely with Chen to use the moored and drifter data to test and validate his regional GoM/GB/NES FVCOM and proposed local NS-WB FVCOM models (Fig. 7). The new NS-WB model will have an initial horizontal resolution of ~300-500 m in the interior of NS, ~ 20-50 m around the coasts of MV, NI, WH and BB, and ~ 20-70 m in WB and other coastal inlets, bays and rivers. *First,* detailed comparison of the measured tidal currents at site N with his regional FVCOM will help determine what grid spatial resolution and bathymetric detail are needed to accurately simulate the key tidal constituents (including the higher harmonics of M2) in NS and surrounding waters. *Second,* the supporting meteorological data and derived surface forcing time series will

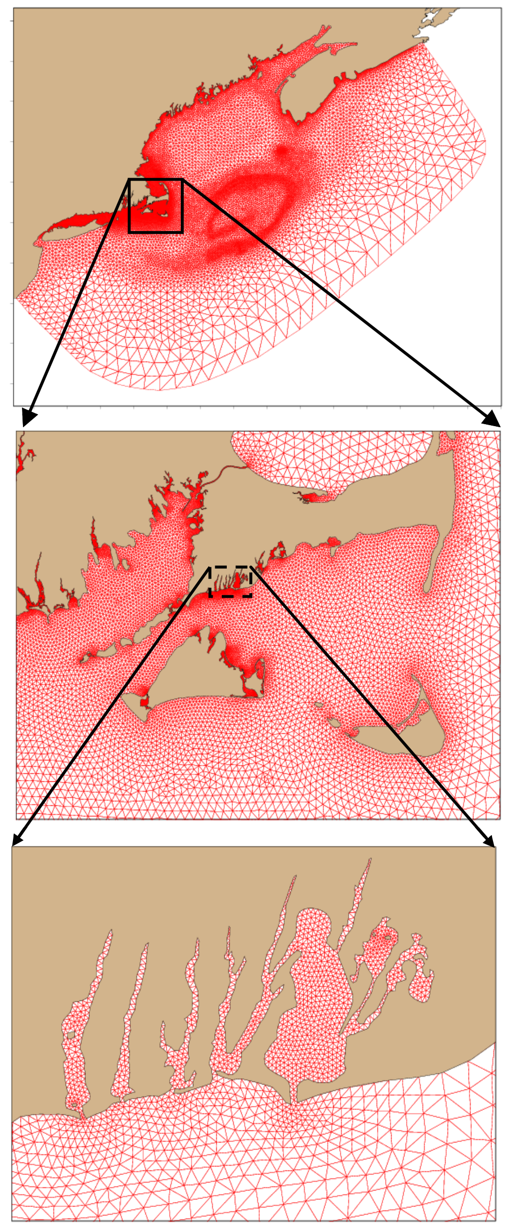

Fig. 7 Existing regional GoM/GB/NES FVCOM grid (upper two panels) and proposed local NS-WB FVCOM grid (bottom panel). The NS-WB model will be nested within the regional model.

be used to calibrate the "coastal" domain (3-km resolution) UMASSD GoM-MM5 surface fields that Chen will then use to drive both the regional and nested local NS-WB FVCOMs (Chen et al, 2005b). When driven by realistic local and larger-scale surface forcing and boundary conditions for the 18-month mooring deployment period, the regional FVCOM should also simulate the subtidal currents observed at site N and observed drifter motion inside NS. *Third*, experiments with realistic forcing and "one-way" and "two-way" coupling between the regional and local FVCOMs will help determine if (a) the local NS-WB model can predict drifter motion within WB and near its mouth, and (b) the relative importance of inclusion of WB and other major Cape Cod bays and inlets in circulation inside NS.

We will prepare the field data for comparison with the regional and local FVCOM model outputs and help Chen with the analysis and synthesis of results. The results of these and other comparisons planned by Chen provide objective tests of the local NS-WB and regional FVCOM models, the possible need for improved grid resolution, the nesting approaches used to link the two models, and data assimilation methods used in FVCOM. These tests are essential to determine the accuracy of the FVCOM current, temperature, and other physical fields to be used in the proposed WHOI/BU food web modeling.

III. Identification of Anticipated Benefits

This project has the following "products":

- detailed description of the Eulerian tidal and subtidal circulation in the western opening of NS over an 18-month period,
- series of Lagrangian near-surface circulation studies in NS,
- comprehensive description of the local surface forcing (pressure, wind stress, heat

and moisture fluxes, P-E) over NS,

- analysis and synthesis of these new data into a new quantitative understanding about NS physical oceanography and development of a project website at WHOI to post data and scientific results and links to related sites, and
- development of a tested prognostic FVCOM circulation model system with nested local and regional domains.

This FVCOM circulation model system is the core of the proposed coupled FVCOM circulation/food web model system for WB and NS. Both the FVCOM circulation model system and the coupled FVCOM model system will provide essential tools and building blocks for scientists, engineers, resource managers, and government officials to design new research projects, assess environmental impacts related to increasing human activity (including the proposed Cape Wind wind farm and sand recovery operations in NS), assist chemical spill tracking and prediction and search and rescue operations, and design ecosystem-based fisheries management systems.

In addition, our collaboration with Gallager will provide a time series description of the surface temperature and salinity fields in NS and heat and salt content that will allow investigation of the role of local surface forcing in the NS net heat and salt budgets. Our collaboration with Chen will help produce tested regional GoM/GB/NES FVCOM and local NS-WB FVCOM prognostic circulation model systems and the development of a tidal current prediction website ("Cape Cod Tidal Predictor") at UMASSD. Our joint analysis of the final FVCOM simulations for the 18-month field study will provide much insight into the circulation in NS and surrounding waters and a quantitative understanding of the relative roles of local surface forcing and boundary forcing (due to larger-scale surface forcing and "upstream" buoyancy forcing) in driving subtidal currents and circulation in NS. This new knowledge will be used in collaboration with Chen, Davis, Gallager, Ji, and Valiela to develop the first quantitative understanding of the biological workings of NS and an ability to predict how the local food web might change from "cool" to "warm" regimes if coastal waters in NE continue to warm.

This project will provide undergraduate and graduate training in interdisciplinary research using new state-of-the-art measurement and modeling approaches.

IV. Relevancy to Current Strategic Areas of the MIT Sea Grant Program

We propose work that will combine new in-situ oceanographic measurements, local meteorological observations, and satellite-based data with a new state-of-the-art physical circulation model (FVCOM) to provide the first detailed description and dynamical understanding of circulation in Nantucket Sound and Waquoit Bay. This new knowledge base is an essential first step in developing a tested prognostic coupled FVCOM circulation/food web model system for WB and NS that will provide the research, engineering and management community with an essential tool for environmental prediction (including currents, sediment transport, coastal water quality issues), ecosystem-based resource management, and many other important applications related to MIT Sea Grant's mission. Two specific applications are described next.

The anthropogenic stresses on Waquoit Bay (especially high nutrient input through river and groundwater sources, recreational boat concentration and usage) are intense and increasing, while water quality in WB has been declining. The proposed FVCOM WB-NS model system can easily include an existing FVCOM water quality component and be used to investigate specific water quality issues in WB (such as point versus non-point source pollution) and the possible outcomes of different remediation plans. The flexibility of the FVCOM unstructured grid approach would allow this FVCOM model system to be quickly configured to study water quality problems in many other Massachusetts bays and harbors under severe anthropogenic stresses (including modification of the bay and harbor geometry through development and dredging). The second (and quite new) application involves using a tested FVCOM circulation model system to provide realistic ocean current and density fields that scientists and engineers can use to investigate mission design (including sampling strategy) and platform performance for glider and AUV studies in specific regions. For example, a recent project plans to use gliders with passive acoustic recorders to listen for and locate whales east of Cape Cod. The tidal currents in this region are strong, and the wind- and density-driven currents change on synoptic (weather) and longer time scales. Since the glider speed is limited, the glider pilot approached us for realistic flow fields to test and refine the adaptive navigation scheme developed for the glider and practice different missions. We directed the pilot to Chen's regional GoM/GB/NES FVCOM hindcast simulations to obtain high-resolution x,y,z,t current and density fields. As the use of AUV's in coastal studies in Massachusetts waters increases, the need for realistic flow fields for testing and training (either pre- or during the field study) or to put the AUV results into a larger perspective should increase.

The low-cost GPS eMOLT drifters are new technology well-suited for use in NS and other coastal waters by Sea Grant and other researchers. These drifters were developed with NOAA funding by J. Manning (NMFS, Woods Hole); we will work with him to improve his design as needed (e.g., increase sample rate, increase drifter lifetime) to make the eMOLT drifter an even better tool for coastal application.

The proposed WHOI "Oceanography of Cape Cod and Islands" website and UMASSD "Cape Cod Tidal Predictor" website will provide excellent opportunities for research dissemination and public educational outreach. The WHOI website will (a) describe research goals, activities, results (including animations of observed currents and drifter motion), (b) serve our data, and (c) provide links to related projects and data sources. In 2007, a scientific and public workshop on the regional oceanography will be held and plans made to maintain this website as a comprehensive information source. Based on FVCOM results, the UMASSD website will present basic information about tides in NS and adjacent waters (including animations) and be interactive, showing plots of tidal currents and the tracks of model "surface drifters" deployed at any selected location, thus making it a potential tool in grade/high school and college marine science courses as well as for researchers and boaters. To our knowledge, this would be the first such website for tidal current prediction with such high spatial resolution in New England, and could serve as a model for application to other regions. We plan to provide a self-contained real-time version of this tidal current predictor program to A. Allen (Office of Search and Rescue, USCG, Groton, CN) for testing and use in homeland security and search-and-rescue applications in the NS/VS/BB/RIS region.

V. Contributions to the Basic Discipline and to General Sea Grant Goals

This project will significantly improve our knowledge of the physical oceanography of NS and WB, and help test and refine the UMASSD regional GoM/GB/NES and local NS-WB FVCOM model systems. We note that Sea Grant supported the initial development of FVCOM and the NOAA Coastal Ocean Program (through the U.S.

GLOBEC Georges Bank program) has supported (with other agencies) the continued development of FVCOM to its present state. Support of this WHOI and Chen's UMASSD Sea Grant proposals will advance FVCOM though the development and testing of "one-way" and "two-way" methods to nest the local FVCOM model within the regional FVCOM model. This capability will allow other local FVCOM models (e.g., Boston Harbor, Buzzards Bay) to be implemented by other groups and connected (using nesting) to the existing regional GoM/GB/NES FVCOM for scientific and management use. Thus we envisage the WHOI and UMASSD Sea Grant work as an essential step towards a prognostic high-resolution coastal ocean forecast/hindcast system for the Northeast region that spans across the shelf into the local bays and estuaries.

VI. Support and Collaboration with Industry/Government/Community Groups

We plan to use the WBNERR measurements and work closely with their staff on interchange of ideas, data, and dissemination of our results through links to their website. Under contract to Cape Wind, Woods Hole Group Inc (WHG) helped install the 60-m tower on Horseshoe Shoal (in central NS, Fig. 2) and is collecting high-quality meteorological data for the proposed NS wind power farm. We will work with WHG to obtain their data and plan to mount radiation sensors atop their tower so that all components of the surface heat flux can be accurately estimated during our field and modeling study. The U.S. Geological Survey has started a collaborative project with WHOI to investigate sediment transport processes in southern New England coastal waters. Our field data and FVCOM model results will contribute to this new effort. In particular, we anticipate that they will deploy an instrumented tripod to measure near-bottom flow and sediment transport at our site N during our field work, so that our measurements of water column currents and the FVCOM model results will provide the vertical and larger-scale context for their bottom measurements. A FVCOM sediment transport module (based on the USGS national sediment transport model system) is presently in development at UMASSD; the USGS measurements at site N will provide the field data to test and refine this new FVCOM module. This addition to the FVCOM family will open new applications for high-resolution studies involving sediment resuspension and transport in complex coastal areas.

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