the Doppler shifts in the radiation transport and reflect large radial velocity gradients near the axis, not rotation or 3D turbulence.[3]

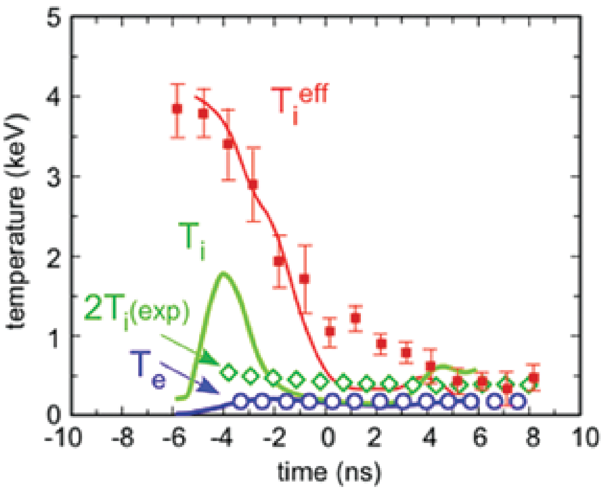

FIGURE 5
The symbols show the measured values for the electron (T_e), ion (T_i), and effective ion (T_i^{eff}) temperatures, and the solid lines are from the simulations. Along the ordinate, 1 keV equals 11 million degrees Kelvin. The modeling shows the large T_i^{eff} arises from Doppler shifts in the observed spectra of the imploding pinch.

Significance: Experiments on a university scale generator as discussed above are important because multiple experiments can be run with specialized diagnostics to build a large database. The largest currents for z pinches are produced on the ZR generator at Sandia National Laboratories and can reach >20 million A and produce hundreds of kilojoules of X rays. The above work describes fundamental research at NRL that contributes to improved understanding and performance of z pinches. These radiation sources are used to test components and enhance the overall stewardship of the U.S. nuclear deterrent.

[Sponsored by DOE National Nuclear Security Administration]

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From the Stream to the Shore: Forecasting Complex Ocean Environments in Trident Warrior '13

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Introduction: Navy ocean forecasts must support tactical and strategic Fleet decisions within the diverse range of environments Navy operations face. During July's Trident Warrior 2013 (TW13), researchers from the NRL Oceanography Division tested a suite of prediction capabilities spanning conditions from the swift Gulf Stream to waves breaking along the Virginia/Maryland shore. A hierarchy of computer models with increasingly fine resolution followed evolving ocean conditions, spanning from the 7 km global system to a 3 km nest over the Continental Shelf and nearby Gulf Stream to finer nests covering coupled air–sea interactions and culminating in a 50 m mesh detailing ocean waves approaching the Virginia shore. A series of NRL-directed AXBT (Airborne Expendable BathyThermograph) flights supplemented observations from satellite platforms and autonomous vehicles. Validation of the model forecasts relative to the in situ observations showed both the value of new assimilation capabilities and the fidelity of model forecasts supporting Navy decisions.

From the Globe to the Mouth of the Bay: NRL's support for TW13 included the first demonstration during a Navy exercise of a hierarchy of ocean models consistently nested from the global down to a local fine-scale model at 50 m resolution (Fig. 6(a)). In each stage of nesting, an outer model provides initial and boundary conditions to an inner nest covering a subset of the outer domain. For TW13, the Hybrid Ocean Model (HYCOM) from the Global Ocean Forecast System (GOFS 3.0) at the Naval Oceanographic Office (NAVO) provided the boundary/initial conditions for a 3 km nest of the Navy Coastal Ocean Model (NCOM[1]) that extends from the Carolinas to New Jersey and offshore to the Sargasso Sea. Both use 3D-variational Navy Coupled Ocean Data Assimilation (NCODA) systems to guide the ocean models toward ocean conditions observed from satellite and in situ platforms. The ocean models use atmospheric forcing from the Navy Global Environmental Model (NAVGEM) and regional implementations of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®). The NCOM cases also include tidal forcing. More detailed models

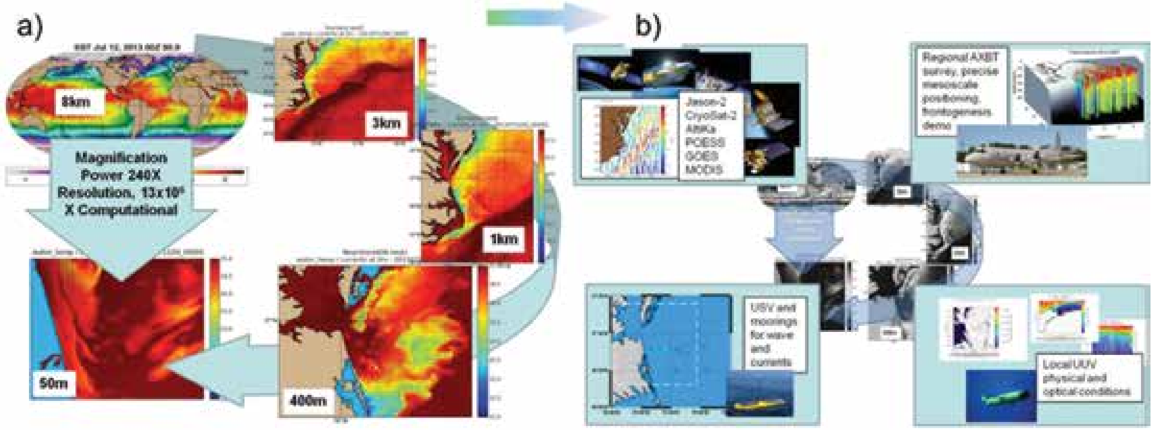

FIGURE 6
(a) TW 13 was the first demonstration during a Navy exercise of a consistently nested ocean modeling system spanning from the globe to a 50 m domain. (b) The corresponding observing system telescoped from global satellite altimeter and sea surface temperature measurements to regional AXBT coverage to local observations from moorings and unmanned underwater (UUV) and surface (USV) vehicles.

successively focus into the Continental Shelf in a 1 km NCOM to COAMPS ocean model covering the mouth of the Chesapeake Bay at 400 m and a portion of the Virginia coast at 50 m. The ocean modeling work demonstrated during TW13 reveals the Navy's operational capability to forecast complex ocean environments from scales from the globe to the Gulf Stream to the shore.

AXBT Survey: Accurate ocean model forecasting requires a complementary ocean observing system to feed the ocean data assimilation systems that guide the realistic forecasts toward the real ocean. Observations supporting TW13 include global and geostationary satellite systems, air-deployed instruments, unmanned autonomous vehicles, and moored observing networks (Fig. 6(b)). A key component consisted of 262 Airborne Expendable BathyThermographs deployed over four flights of a Navy P-3 operated out of the Patuxent River Naval Air Station on a series of legs extending from the slope waters east of Norfolk, Virginia, crossing the Gulf Stream and into the warm Sargasso Sea water between July 11, 2013 (prior to the intensive field program of Trident Warrior 2013) and July 18, 2013 (the end of the intensive field program). The AXBTs were deployed approximately every 16 km along tracks extending from the slope water across the Gulf Stream into the Sargasso Sea. On July 11, one leg followed a track of the AltiKa satellite altimeter (Fig. 7), while for the last flight on July 18, one leg followed a track of the Jason-2 altimeter. The AXBT temperature profiles were processed in near real time and transmitted to NAVO for assimilation into the real time forecast model runs and used as validation data to evaluate forecast skill.

The temperature profiles along the altimeter tracks provided data to evaluate the skill of a new vertical projection technique, Improved Synthetic Ocean Profiles (ISOP; Fig. 7), examined as a new capability in NCODA to replace the legacy Modular Ocean Data Assimilation System (MODAS) within the 3 km and 1 km NCOM nests. Only the ISOP cases are able to capture several aspects of the circulation important for Navy antisubmarine- and mine-warfare support, including accurate strength of the Gulf Stream front, temperature inversions in the mixing of fresher slope with salty Sargasso waters, and ageostrophic thinning of the layers offshore of the main front (Fig. 7). In addition, mixed layer depths from the temperature profiles are used to test a new hypothesis about conditional predictability of frontogenesis.[2]

Nearshore Modeling: The innermost TW13 model nests featured demonstrations of COAMPS and the Simulating Waves Nearshore (SWAN) model (Fig. 8). COAMPS uses NCOM to model the ocean and SWAN for the waves. As noted above, a two-way coupled NCOM-SWAN grid was set up with a 400 m grid, with NCOM boundary conditions from a host 1 km grid and SWAN boundary conditions from global WaveWatchIII. Figure 8 depicts the 400 m ocean–wave domain, which extends from the mouth of Chesapeake Bay to approximately 80 km east of the northern Virginia coast. The simulation accurately represented the increased stratification and shallowing of the mixed layer during a weakening of winds from July 10 to 14 (Fig. 8(a)). An additional implementation of SWAN during TW13 examined new wave data assimilation capabilities,[3] examining the impact of observations from an array of mini-wave buoys on wave forecasts along the shore south of Chesapeake Bay (Fig. 8(b)). From stream to shore, TW13 demonstrated the capabilities NRL has developed to forecast the broad range of complex ocean environments.

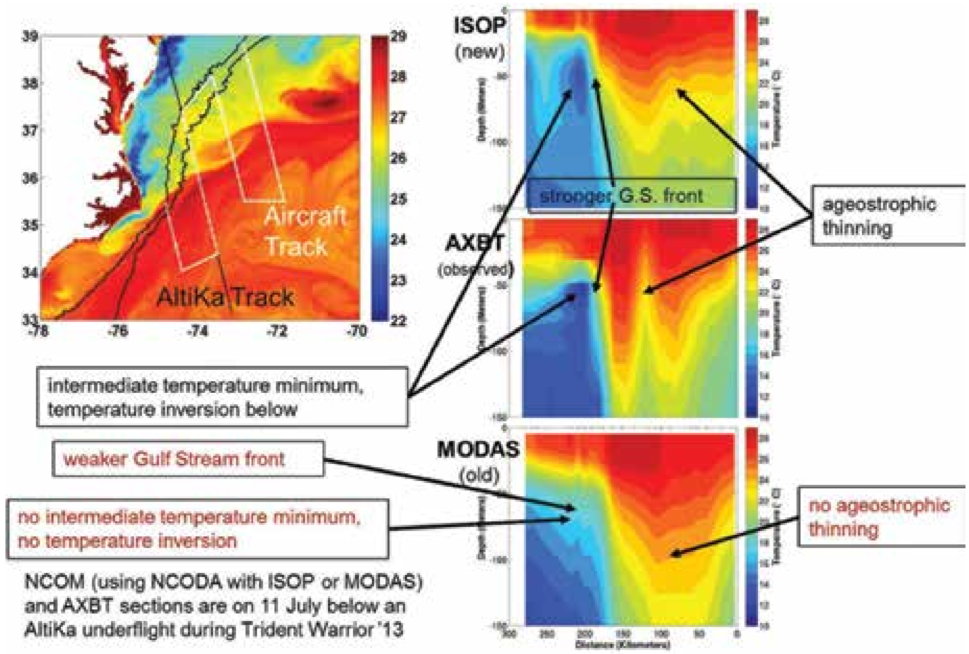

FIGURE 7
Temperature sections following an AltiKa underflight track on July 11 compare RELO NCOM forecasts to independent AXBT observations. Critical observed phenomena affecting acoustic antisubmarine warfare (intermediate temperature minimum, temperature inversion, Gulf Stream front strength, layer thinning) are forecast only when NCOM uses the new ISOP 1.0 with NCODA.

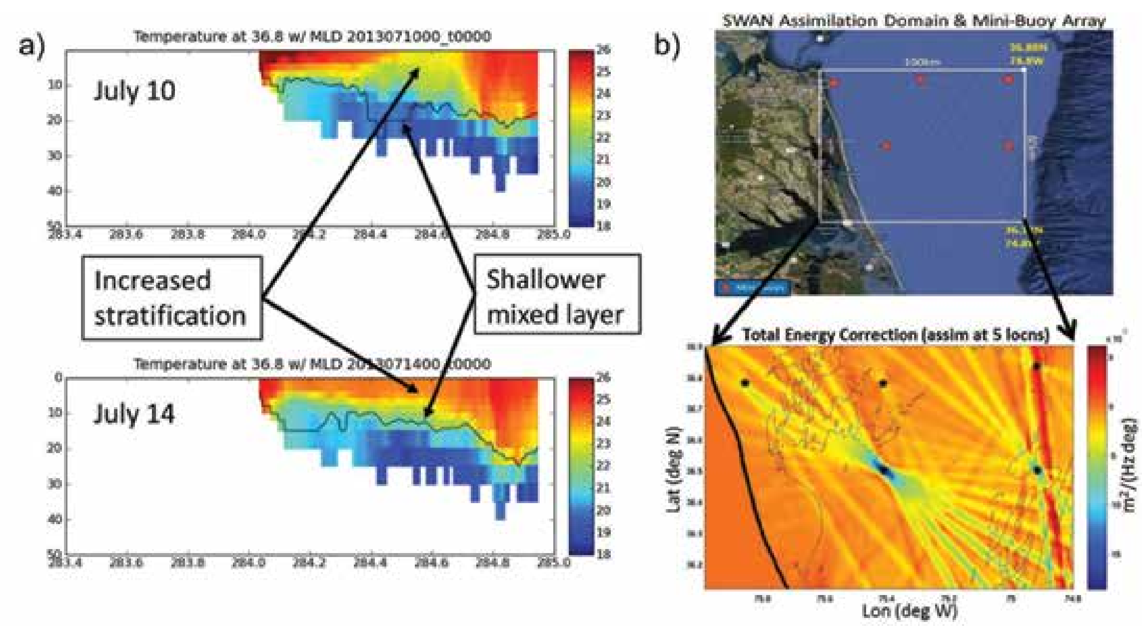

FIGURE 8
The highest resolution models capture processes important to the warfighter in the nearshore environment, including (a) shallowing of the mixed layer and increased stratification during a wind relaxation event forecast in the 400 m resolution air–sea COAMPS and (b) correction of total wave energy by assimilating wave buoy observations in the 50 m resolution nearshore SWAN.

Acknowledgments: Our work in Trident Warrior 2013 was made possible through the support of the Office of Naval Research (ONR) and its efforts to leverage this exercise to test a wide range of technologies being developed to support Navy and Air Force operations. We want to thank Jeffrey Kerling, Naval Oceanographic Office, Robert Liang, NRL, and Jaime Pupek, JP Technical Consulting, for collecting and processing the

AXBT data on the flights and Robert Barthelmes and the pilots and crews of VX-20 at Patuxent Naval Air Station for getting us in the air on P-3 774.

[Sponsored by ONR]

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Integrating the Marine Biosphere into Coupled Ocean–Atmosphere Models

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Introduction: Marine phytoplankton are vital to the functioning of Earth's biosphere. Whereas these ubiquitous microscopic organisms account for only ~1% of the Earth's photosynthetic biomass, they contribute to more than half of the global primary production. This fecund productivity forms the foundation for the marine food web and it is the requisite engine of biogeochemical cycling that enables life on Earth to flourish. Phytoplankton thrive precisely where atmospheric and oceanic planetary boundary layers meet. Exchanges of thermal energy and transfers of momentum impact the physical environment with which planktonic organisms must cope. Biological oceanography has thus been largely concerned with identifying how the physics of the ocean–atmosphere system determine microalgal prolificacy via turbulent mixing and the upwelling of deep ocean nutrients in zones of wind-forced hydrodynamic divergence.

Recently, however, numerical modeling studies[1,2] have revitalized a long dormant paradigm in oceanography: phytoplankton and associated organic detritus absorb a significant quantity of the Sun's radiant energy and this additional energy may have a net warming effect on the surface ocean, thereby impacting density gradients. Thus, phytoplankton are not merely passive recipients of the ocean's physical dynamics, they are instead active participants in those dynamics.

Integrated Modeling of the Maritime Battlespace Environment: Motivated by these findings, we have integrated a model of biochemical nitrogen cycling and attendant bio-optical dynamics into NRL's state-of-the-art Coupled Ocean–Atmosphere Mesoscale Prediction System (COAMPS®). This numerical forecasting system includes atmospheric and oceanic components that exchange information regarding transfers of heat and momentum at very high temporal frequency, such that the atmospheric and oceanic density fields develop concomitantly. We use the term "integrate" to emphasize that the surface biota absorb substantial quantities of solar shortwave energy that is accounted for in the modeling system (Fig. 9). Since it is the ocean biology that is driving this additional near-surface retention of thermal energy, we refer to this process as biothermal feedback.

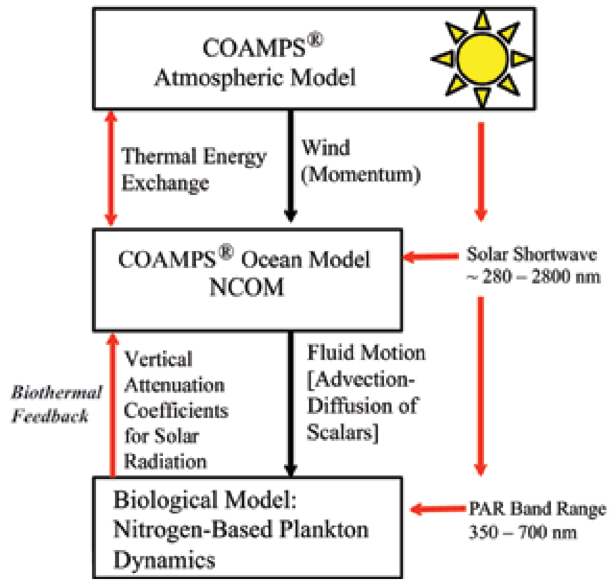

FIGURE 9
Schematic representation of COAMPS is shown with the integrated biological model using the photosynthetically available radiation (PAR) band fraction of the COAMPS solar shortwave and providing the Navy Coastal Ocean Model (NCOM) with the required optical attenuation coefficients.

Indeed, the integrated COAMPS–biology modeling results verify that biothermal feedback may influence the thermal variability of geophysical boundary layer fluids. A simulated phytoplankton bloom develops in northern Monterey Bay (Fig. 10(a)) as a result of coastal upwelling. In contrast to COAMPS simulations wherein no biothermal feedback is represented, the bio-optical properties of phytoplankton provide an additional ~1–2 °C of surface warming to the area (Fig. 10(b)). Elevated sea surface temperatures (SSTs) increase simulated latent heat flux transfers, resulting in a warmer, moister marine atmospheric boundary layer (MABL). The surface warming also increases the upper ocean thermal stratification. Since it is light rather than nitrogen that is most limiting to microalgal growth within this regime, improved vertical stability increases the photosynthetic yield by ~20%. Hence, the simulated thermal and biological fields evolve synergistically in time.

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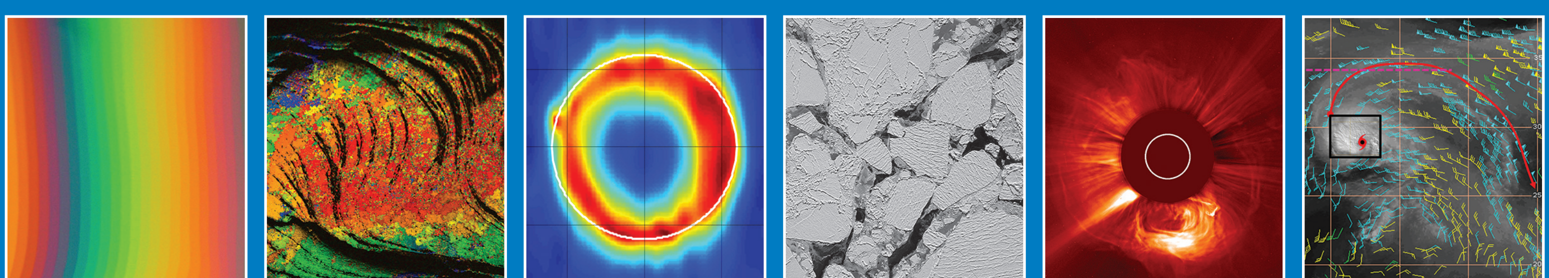

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