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Trident Warrior 2013 Ocean Observation Impact on Ocean Forecasts

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LONG-TERM GOALS

Ocean environment state and error prediction for exploitation of tactically relevant features, error reduction through on scene observations and guidance for observation strategies to reduce forecast errors, particularly in relation to electromagetic (EM) propagation in the atmosphere.

OBJECTIVES

Understand the impact of on scene observations during Trident Warrior 2013 (TW13) from deep water to nearshore in collaboration with researchers deploying airborne expendable bathythermographs (AXBTs), in water gliders, acoustic doppler current profilers (ADCPs) and nearshore wave gauges. NRL suplemented other research data collection efforts with the deployment of 3 ocean gliders.

APPROACH

In addition to operationally available data streams, several parallel model experiments were set up to run in real time during the TW13 exercise. The details are listed in the table below:

Experiment reference and dynamical system	Horizontal resolution	Details of data and treatment	Operational (O) or Experimental (E)
Global HYCOM	12km	Standard operational data streams including satellite SSH, SST, in situ profile data. From TW13 data, AXBT data was received from VX-20 and assimilated. In situ data is used for -12 days to +12 hours in the assmilation cycle, and satellite data is used -36 hours to +36 hours. This has the effect of using the in situ data over many days.	O
USEAST, NCOM	3km	Standard operational data streams including satellite SSH, SST, in situ profile data. From TW13 data, AXBT data was received from VX-20 and assimilated. Only data received in the last 24 hours is used in the cycle	O
Standard nest 0, NCOM	3km	Standard operational data streams including satellite SSH, SST, in situ profile data. No data from TW13 was	E

		assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours.	
Standard nest 1, NCOM	1km	Standard operational data streams including satellite SSH, SST, in situ profile data. No data from TW13 was assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours.	E
Standard Plus nest 0, NCOM	3km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours.	E
Standard Plus nest 1, NCOM	1km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours.	E
UCUP nest 0, NCOM	3km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 7 days is used in the cycle conducted every 7 days.	E, UCUP also ran ensembles for forecast uncertainty
UCUP nest 1, NCOM	1km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 7 days is used in the cycle conducted every 7 days.	E, UCUP also ran ensembles for forecast uncertainty
ISOP nest 0, NCOM	3km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours. The covariances relating surface observations to subsurface are provided by the Improved Synthetic Ocean Profiles (ISOP) rather than MODAS.	E
ISOP nest 1, NCOM	1km	Standard operational data streams including satellite SSH, SST, in situ profile data. All AXBT and glider from TW13 was assimilated. Only data received in the last 24 hours is used in the cycle conducted every 24 hours. The covariances relating surface observations to subsurface are provided by the Improved Synthetic Ocean Profiles (ISOP) rather than MODAS.	E
Local area, coupled NCOM & SWAN	400m	No data assimilated. Boundary conditoins from 1km Standard run	E
Nearshore, coupled NCOM & SWAN	50m	No data assimilated. Boundary conditoins from 1km Standard run	E

GOST	N/A	Glider guidance using cost functions minimized through a genetic algorithm	E
SWAN Forward and Adjoint (SWANFAR)	N/A	Nearshore wave gauge observations. This is the one system not run in real time but run in hindcast.	E

These provide a consistent environment forecast of the state and uncertainty from the globe to the nearshore area. The UCUP system provided ensembles for which uncertainty and risk maps were constructed.

All assimilative model systems were initialized from global model conditions on May 1, 2012. The daily cycling updates were conducted up to the experiment time, and the systems were run until the end of July 2012. The non-assimilative systems were initialized July 1, 2012 from the high resolution assimilative system states at that time and run through the end of July 2012.

Work was conducted by Emanuel Coelho (Univ New Orleans) and Germana Peggion (Univ New Orleans) for UCUP, Pete Spence (Qinentiq North America) and Brent Bartels (Qinetiq North America) for Standard and Standard Plus runs and plotting, Dick Crout (NRL) and Sherwin Ladner (NRL) for glider deployments, Jim Richman (NRL) for AXBT data processing, Charlie Barron (NRL) and Lucy Smedstad (NRL) for Glider Observation Strategies, Tammy Townsend (NRL) for ISOP, Tim Campbell (NRL) and Travis Smith (NRL) for the 400m and 50m coupled NCOM/SWAN runs, Jay Veeramony (NRL) for the SWAN assimliation through SWANFAR.

WORK COMPLETED

All systems were run during TW13 and results made available, except for the SWANFAR that was run in hindcast mode. 3 NRL Slocum gliders were deployed. 2 returned data successfully. AXBT, and glider data were assimilated in real time. Other data sets including SHARC ADCP and nearshore wave gauge data have been processed and initial comparisons made. Nearshore wave guage data assimilation experiments were made.

RESULTS

The Standard and Standard Plus experiments were set up to be identical with the exception of the data used. The Standard Plus used all the AXBT and glider observations. Thus differences between the systems are due to the ability of the in situ sensors to constrain the numerical dynamical systems. Initial evaluations indicate the performance relative to the AXBT data. The HYCOM system performed well (Figure 1) as it uses the same in situ data 12 days in a row. Observations from the first aircraft flight have strong influence on subsequent days. The bias and standard deviations from HYCOM are quite small due to this. The implication is that observations in the ocean have long decorrelation time scales. This is a small but significant fact that should be considered in future assimilation system designs. There have been discussions regarding using observations multiple times, though the performance results indicate this is needed. Observations could be used only once while still having a long time influence and thus performance. The ISOP performance was quite good. ISOP is a new formulation of vertical covariance information and methodology for constructing subsurface T&S synthetic profiles from just surface height and temperature observations. ISOP was able to

recreate many of the subsurface temperature inversion events just off the shelf break north of the Gulf Stream, and these temperature inversions had been observed in the historical databases.

One pitfall that was discovered is the initialization of local area models from the global in coastal areas. Due to the relatively low resolution of the global model and treatment of river flows, the global model representation of the Chesapeake plume was poor with too saline water. Because of the low flow rates into the Chesapeake, a very long time period (a year or more) is necessary to flush the Chesapeake Bay and set up a realistic fresh water plume. Because of this, the higher resolution models had water too saline across the shelf and into the bay. This created a weaker than usual stratification. The assimilation of glider observed salinity produced fresh pools on the shelf.

Areas in which air-sea exchages are expected to be large are near land, and changes in the stratification appear to show possibilities for coupled feedbacks that could lead to changes in EM propagation. Figure 2 shows the sea surface temperature on July 10 and 14 of TW13, a time during which southwesterly winds were decreasing in strenght which in turn reduced the upwelling of cold water. The stratification across the shelf changes from weakly stratified water with a deep mixed layer to strongly stratified with a shallower mixed layer.

Evaluation of the AXBT data shows features consistent with the appearance of frontogenesis forced thinning of the mixed layer (Figure 3). Frontogenesis is one class of submesoscale processes in which confluence of water masses act to strengthen the horizontal buoyancy grandients. This strengthened gradient forces a secondary ageostrophic circulation that acts to degrade the horizontal buoyancy gradient. This is the mechanism of energy transfer from the mesoscale to submesoscale frontogenesis. The sencondary circulation creates upwelling in the more buoyant waters and downwelling in the less buoyant waters. The upwelling results in thinning of the mixed layer. The areas of strong frontogenesis outlined in Figure 3 are consistent with the positions of thinned mixed layer observed by the AXBT data. This is the first time a demonstration of predictability in real world situation has been conducted for frontogenesis.

Strong circulation wave coupling was observed to occur in the Chesapeake mouth where tidal flows would interact with the wave field coming from the deep ocean to produce higher wave heights during ebb tide and weaker wave heights during flood tide.

TW13 is the first demonstration of a consistent nesting from the globe to 50m nearshore, and the first time observations telescoping from the globe into a high resolution area of interest has been achieved.

TRANSITIONS

The nesting capabilities of the numerical models, the data assimilation advancements, the glider observation strategies and uncertainty prediction are all in transition to operational use through the Naval Oceanographic Office.

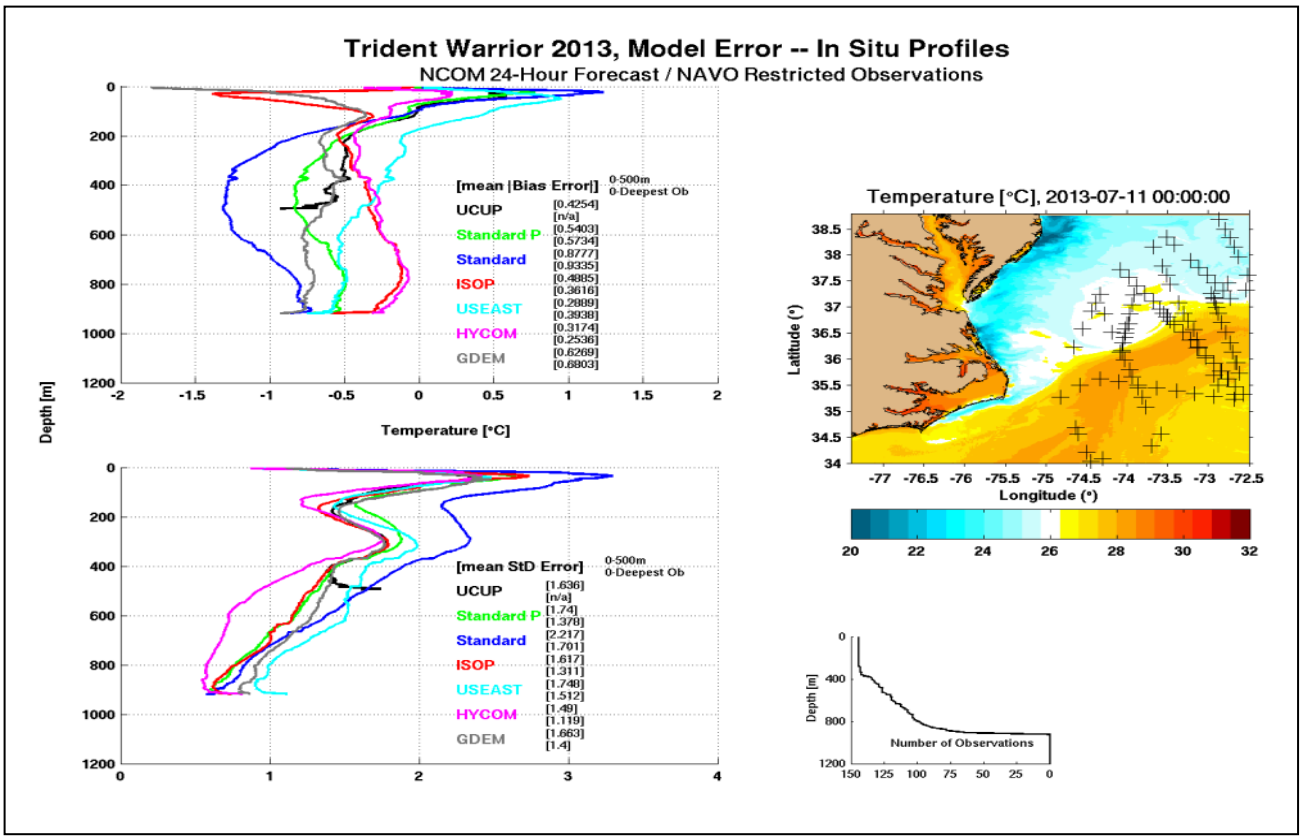

Figure 1. The mean bias (top left) and standard deviation of errors (bottom left) of AXBT observations covering the Gulf Stream area during TW13 (top right) provided a large number of validating data over depth (bottom right).

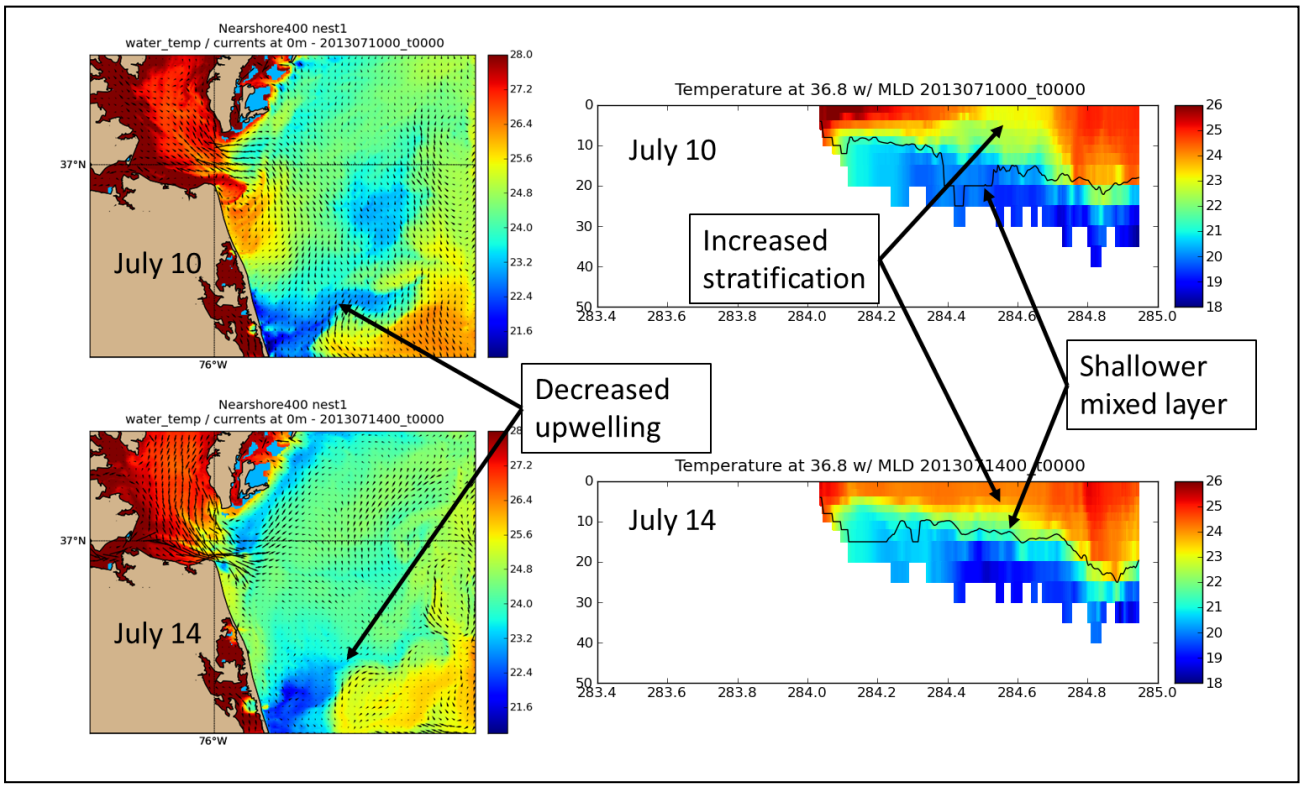

Figure 2. The sea surface temperature on July 10 (top left) indicates strong upwelling due to southwesterly winds, which weaken by July 14 and reduce the upwelling (bottom left). The response on stratification is a weak stratification with deep mixed layer (top right) changes to a strong stratification with shallower mixed layer (bottom right).

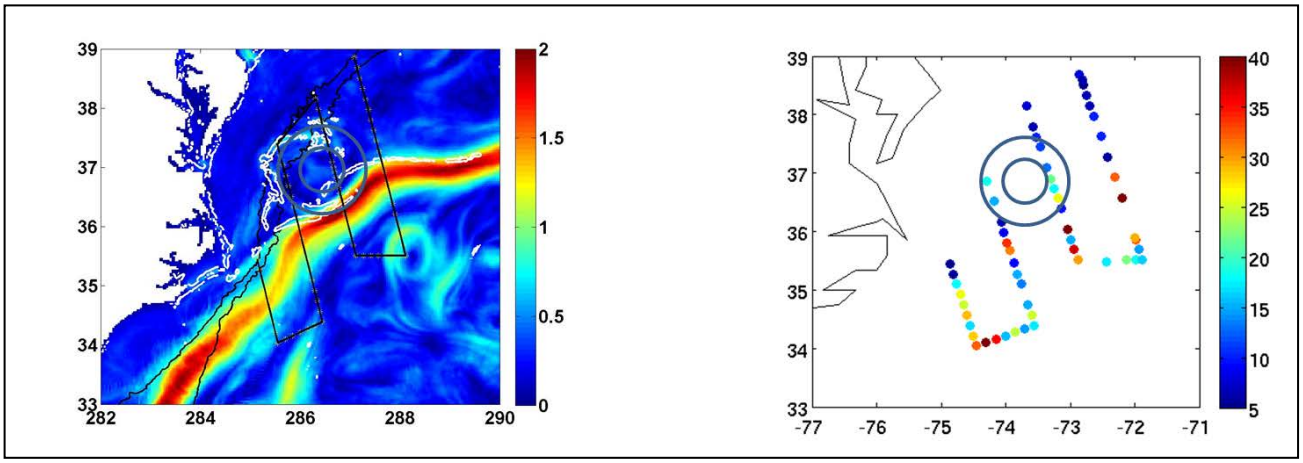

Figure 3. The surface current magnitude plotted in color overlaid with areas of high frontogenesis forcing (left) predicted in real time are compared with the observed mixed layer depth (right). The circle in both plots is the position of an anticyclone observed in satellite data and in the AXBT data and reproduced in the model forecasts. The area between the anticyclone and Gulf Stream has thinned mixed layer associated with the frontogenesis forcing.

RELATED PROJECTS

6.4 SPAWAR Small Scale Ocean Prediction

6.4 SPAWAR Large Scale Ocean Prediction

6.4 SPAWAR Ocean Data Assimilation

6.4 Glider Observation Strategies

6.2 NRL Wave assimilation