Final Progress Report for
Alaska Regional Coastal Ocean Observation System
NOAA Award NA07NOS4730206
Period of Performance: October 1, 2007 – September 30, 2009

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This report describes the key outcomes and impact of the activities conducted through the NOAA-funded grant award NA07NOS4730206 in support of developing the Alaska Ocean Observing System (AOOS), and follows the format provided by the NOAA Coastal Services Center.

I. PROJECT SUMMARY

The Alaska Ocean Observing System (AOOS) is the regional association for managing the statewide and three regional coastal and ocean observing systems for the Alaska region. The systems and the regional association are collectively referred to as AOOS. The goals of AOOS are to provide quality processed and integrated data from a variety of sources and create information products and model forecasts to meet the needs of stakeholders including state and federal resource managers, commercial, subsistence and sport fishermen, oil and gas developers, shipping interests, Alaska Native communities, and researchers. The AOOS products are provided through a distributed, web-based information network.

The original 3-year AOOS proposal (requesting $2 million in Year 1) addressed a multitude of goals for developing and expanding ocean observing platforms, models and information products in Alaska's three Regional Coastal Ocean Observing Systems (RCOOS). This proposal was significantly scaled back to a 1-year only project for $750,000. This revised project focuses on:

- Continuing to further statewide capacity in data management, modeling and product visualization using the established (although somewhat reduced) data management team and Modeling and Analysis Group (DMAG) at the University of Alaska Fairbanks in conjunction with the Arctic Regional Supercomputing Center; and
- Continuing the implementation of the Prince William Sound (PWS) Ocean Observing System pilot project that collects observations for use by stakeholders and develops and tests forecast models as a demonstration of an end-to-end observing system in Alaska by focusing on continued development of a suite of forecast models for use in PWS and elsewhere in the state. Funds in this proposal complete development of a real-time data assimilated Regional Ocean Modeling System (ROMS) ocean circulation model and a Nutrient Phytoplankton Zooplankton (NPZ) biological model.

II. ACCOMPLISHMENTS AND LESSONS LEARNED

A. Data Management and Communications (DMAC), University of Alaska Fairbanks; Dr. Mark Johnson, PI

The Data Management and Analysis Group (DMAG) creates data management and communications products, data visualization tools, and selected satellite remote sensing products.

Accomplishments

AOOS DMAC is in the process of creating the Alaska Marine Information System (AMIS, http://ak.aoos.org/amis/), a project and metadata browser that provides a web-interface to search for research projects and ocean observing datasets within the Gulf of Alaska, Bering Sea, and Chukchi and Beaufort Seas. AMIS is co-funded by the North Pacific Research Board (NPRB). The project and metadata browser searches the AOOS data warehouse that stores data to national standards and returns data previews and data sets to users. Currently users can see station maps and extract transects and view vertical sections from CTD data sets. Search protocols are being refined to allow users to search within data sets to extract specific information limited by, for example, depth or zooplankton species. AMIS is searchable by a suite of variables including the PI name, dataset title, start and end dates, funding organization, keywords, Integrated Ocean Observing System (IOOS) core variables, study area, science platform or sensor, and similar variables in order to find projects and get PI and data information. Projects in the system have geographical bounds supplied by each project PI so the user can see on a map where projects are located and how different project areas may overlap. It is an ongoing process to work with the Principal Investigators (PIs) to ensure correct and/or updated information.

All data streams ingested into the AOOS data warehouse meet IOOS metadata standards. Although as much data as possible is acquired in native formats, some AOOS resources are used to write the metadata records that are searched by AMIS.

Significant real-time data is now on line and available to stakeholders as well, along with the popular web-cams from a number of statewide locations, plus a suite of physical oceanography data sets from the University of Alaska Fairbanks' (UAF) Institute of Marine Science, the AOOS Prince William Sound Field Experiment, and the NPRB's Bering Sea project. AOOS DMAC is ingesting Arctic Ocean Diversity (ARCOD) data and uploading biological sampling data into local databases and national archives. Examples of AOOS DMAC products are located at: www.ak.aoos.org/products.html.

AOOS DMAC Data Manager Rob Cermak serves on the national DMAC committee and has had a key role in writing DMAC planning documents. He recently helped the Great Lakes Observing System with their DMAC group and has been asked by the Caribbean group to help with theirs.

AOOS DMAC is part of the IOOS working group that is implementing the IOOS data backbone. A primary effort is making data available via nationally adopted protocols including WFS, WMS, SOS, DAP and WMS to search for files, transport data, and display data in a seamless national system. The Prince William Sound Field Experiment is used as a testbed to get data to the IOOS backbone. Example data streams include SNOTEL, ADCP, and CTD data plus data streams from national assets such as C-Man stations, NDBC buoys, and HADS. Presently, AOOS acts as "local knowledge" to ensure that these data streams meet the national IOOS standards in data format.

AOOS DMAC has acquired additional funding from NPRB to provide the data management services for the Bering Sea Integrated Ecosystem Research Program (BSIERP). These data include oceanographic data from CTDs, moorings, shipboard observations, meteorological observations, local and traditional knowledge, and other data streams.

Lessons Learned

A recurring issue that impacts data ingestion and access is the quality of the metadata. Data quality has not always been appropriately evaluated by the provider, and the metadata often needs additional attention. The historical data from the University of Alaska's CTD database, for example, have hardcopy data sheets that need to be transformed into electronic metadata files. This is a critical and necessary task but has taken a great deal of time. Other data often require up to several hours of dedicated AOOS technician time to review and revise metadata to meet the national standards established by IOOS. Future data management projects will require a dedicated focus to help PIs meet their metadata obligations.

The other major challenge that AOOS DMAC faces is determining the best and most efficient way to identify the user community and the data/information products they need. Over the past year the AOOS DMAC team has developed these products: web pages with tide tables and tide graphs in Prince William Sound; web access to weather forecast data from WRF; a web page for displaying and accessing the "best" products from each OOS; a Google Earth AOOS asset map; high frequency (HF) radar data mapped onto Google Earth in Cook Inlet; and education units for schoolchildren to identify marine mammals. The AOOS DMAC team has concluded that the key users returning to the data management site are scientists who want data for their research, to run and validate numerical models, and for other science purposes. With this in mind, the Data Team has updated the "Products" page (see http://ak.aoos.org/products.html) focusing on recurring users who want easy access to data and especially "power users" who want data to carry out their research tasks, often model validation and forecasting. One of the key efforts for AMIS is providing data previews to users who want to look at the data before ordering it.

The DMAC Team's conclusions regarding key users have not been reviewed by the AOOS DMAC Committee and the full AOOS Board. They will be part of a major review of the AOOS DMAC system to be conducted in 2010.

B. Prince William Sound Demonstration Project, Dr. Robert Campbell, Prince William Sound Science Center

AOOS has partnered with, and supplemented investments for the past four years by the Prince William Sound (PWS) Oil Spill Recovery Institute, the PWS Science Center, and the PWS Regional Citizens' Advisory Council, to demonstrate an end-to-end ocean observing system with a primary focus on forecasting surface currents (primarily for oil spill response and search and rescue), and a secondary goal of forecasting the timing and magnitude of spring plankton blooms for improved fishery and hatchery management. Funds from this grant were used to complete development of the nested assimilative ROMS (Regional Ocean Modeling System) circulation and NPZ (Nutrient Phytoplankton Zooplankton) biological forecasts.

Accomplishments

A major observing system field experiment (OSE) and evaluation occurred in 2009 to test high resolution wind, wave and ocean current forecast products and assess which observing system components are critical to the major stakeholder groups in PWS (e.g., coastal communities, oil and gas transportation industry and oil spill responders, commercial fishermen, recreational and commercial boaters, and Coast Guard search and rescue responders). The forecasts are designed to provide expanded and improved marine safety for recreational and commercial vessel operators and enhance the security to oil tanker traffic in PWS. Improved environmental and ecological forecasting products will enable resource managers, PWS hatchery and commercial fishing organizations to improve management decisions on fishing and human activities.

The two models funded through this grant, and the SWAN (Simulating Waves Nearshore) wave model and the WRF (Weather Research and Forecasting) model, funded under another grant, were all operational for the OSE. Deployment of an array of nearshore ocean sensors, as well as a high frequency radar array, provided real-time boundary conditions for model assimilation, and vessel surveys provided synoptic data for model validation.

The output of the ROMS model has been made available to the general public with a virtual drifter page (http://ourocean.jpl.nasa.gov/PWS/mangen_s.jsp). The user can select positions for virtual drifters, and then follow their projected path on a google map.

The ROMS model used is a data-assimilating 3-level nested ROMS configuration with a 1-km resolution domain covering the Prince William Sound. Nearly all the data gathered during the experiment were assimilated in real-time, including: HF radar surface currents, Ship CTD temperature and salinity profiles, Slocum glider and REMUS AUV (autonomous underwater vehicle) profiles, and Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) sea surface sea temperatures. ROMS nowcasts and forecasts were produced and images, analysis and model output provided to the field experiment community via the Jet Propulsion Laboratory (JPL) and AOOS experiment web sites beginning in early July. In addition, during the two weeks of the field experiment, a daily forecasting summary was provided with a synopsis of atmospheric and oceanic conditions in the Prince William Sound and a discussion of any changes forecast for the subsequent 24 to 48 hours. Preliminary results can be found at the JPL OurOcean/PWS portal (http://ourocean.jpl.nasa.gov/PWS).

During the field experiment, JPL developed a daily summary map showing the location of the most recent observational platforms. Figure 1 shows the locations of all the observational platforms during the 2-week period. JPL also developed an interactive wind page showing the hourly wind map provided by the WRF model (Figure 2a). Hourly wind speed and direction predicted by WRF can be directly compared against the buoy observations (Figure 2b).

With the observational data being assimilated into ROMS, the circulation in PWS (and its variability) was realistically forecasted during the field experiment. During the first week of the field experiment, the central sound was dominated by the easterly winds and northward surface current (Figure 3a). The wind weakened during the second week of the field experiment, and the central sound circulation was characterized by a cyclonic eddy (Figure 3b), which is very similar to observations made during the 2004 field experiment.

Associated with the Hinchinbrook Entrance, inflow of relatively high surface salinity waters (greater than 30 PSU) were advected into the central Sound. Figure 4 shows the surface salinity distribution as forecast by ROMS for July 25, 00 GMT. It shows a relatively narrow north-south tongue of high salinity in the central Sound. The purple line in this image shows the track of the CalPoly glider through this region during approximately the same time. Figure 5 compares this ROMS forecast salinity to that observed by the glider. It shows salinities in a longitude-depth cross-section. Near the surface, both observations and the ROMS forecast show salinities increasing from east to west, with the glider observations showing particularly strong gradients near 213.2E, implying that the tongue of high salinity is sharper than that seen in the ROMS forecast. Although the ROMS gradients are weaker than observed by the glider (in the vertical as well as the horizontal) the overall pattern is reproduced quite well.

The positive impact of the ship CTD data on the ROMS nowcast is shown in Figure 6. The temperature impact is relatively larger than the salinity, mostly due to the larger error in estimating the fresh-water input into the PWS.

A web-based interactive drifter trajectory tool was developed shortly before the field experiment. Users can release simulated drifters using the most updated ROMS hourly forecast. Toward the end of the field experiment, an ensemble ROMS forecast was also developed using slight different initial conditions. Figure 7 shows a set of simulated drifter trajectories using about a dozen ensemble ROMS forecasts that can be directly compared against the observed drifter trajectory.

As a part of PWS operational modeling activity, NPZ processes were incorporated into the ROMS circulation model. Dr. Fei Chai at the University of Maine collaborated with

Dr. Yi Chao and his group at University of California Los Angeles and JPL to successfully implement a NPZ model into ROMS. The NPZ model is based on the Carbon, Silicate, and Nitrogen Ecosystem model (CoSINE), which was developed for the equatorial Pacific and modified for the Gulf of Alaska and PWS. Several ROMS-CoSiNE model simulations were conducted, and preliminary analysis focused on the seasonal cycle of 2004.

During the past six months, ROMS-CoSINE model simulations were conducted in near real time, and the NPZ model was operated for the PWS field experiment during July 19-August 3, 2009. The ROMS-CoSINE model began running April 1 2009, saving the model output every 5 days. Starting June 1 2009, model results were outputted four times a day. During the first week of the field experiment, the weather was quite stormy with abundant rainfall, and good remote sensed ocean color images were not available. On August 2, the weather was clear and there was a good MODIS image showing surface chlorophyll distribution. Dr. Chai compared the modeled monthly (July) averaged chlorophyll with the MODIS derived chlorophyll, (Figure 8). Due to the cloud coverage, which reduces the surface light level, for the weeks before August 2, there is little information about temporal variation of chlorophyll and consequently, how phytoplankton growth evolved. In general, the model is able to reproduce a similar level of chlorophyll values for the PWS compared to the MODIS observations. Also, the modeled sea surface temperature (SST) compares very well with the AVHRR-derived SST. In part, this is due to the fact that the ROMS assimilates the observed information, including both in situ and remote sensing products, which constrains the physical processes in the ROMS. Due to a lack of biological observations, biological information was not assimilated into the model. Since it is difficult to compare biological model results with the observations for near real time conditions, a post hoc comparison is underway.

As well as comparing the modeled results with the remote sensing observations, the ROMS-CoSINE predictions were also compared with the in situ observations. Three moorings in Prince William Sound (at Esther Island, Naked Island and Port San Juan) collect continuous records of temperature and chlorophyll (Figure 9). Due to some technical and communication issues, the mooring data was not incorporated into the data stream until near the end of PWS field experiment, so a near real time model-data comparison was not possible. The ROMS-CoSINE modeled surface chlorophyll and SST was compared with the mooring observations at Esther Buoy (Figure 10), Naked Island (Figure 11), and Port San Juan (Figure 12). Overall, the ROMS reproduced the observed temperature quite well. For the chlorophyll comparisons, the ROMS-CoSINE is able to reproduce a similar order of chlorophyll level at all three locations, but the model could not capture the large temporal variation of chlorophyll at Naked Island and Port San Juan, especially during April and May.

An evaluation of the NPZ model is continuing along with comparisons with other types of observations. In collaboration with Dr. Rob Campbell at the PWS Science Center, Dr. Chai's team is comparing the nutrients, oxygen, and more chlorophyll observations with the modeled results, especially focusing on the sections where the field measurements were conducted. In the near future, based upon these model-data comparisons, they plan to re-run the ROMS-CoSINE model for the period from April to October 2009, which will include adjusting some parameter values to improve the model performance. Future plans for the ROMS-CoSINE modeling work during the next year include preparing a manuscript to document the model development and improvement with model-data comparisons for PWS. Most recently, the ROMS-CoSiNE model has been transferred to the University of Maine (it was previously run at JPL), so that model runs and modifications may be done more efficiently.

Lessons Learned

The results of the summer 2009 Field Experiment are now being analyzed and will be highlighted at a special session of the Alaska Marine Science Symposium on January 19, 2009 in Anchorage. A report on lessons learned is being prepared and when complete, will be available on the AOOS website.

A field experiment of this magnitude is very challenging. Funding the various field experiment components at the appropriate level to enable end-to-end integration well in advance of the field experiment was a major issue. In addition, the entire team was not available for a complete table-top exercise or a dry-run practice for several major subsystems of the field experiment. The end-to-end system was not available until a few days before the start of the field experiment. The pre-experiment survey was not as extensive as expected because of unexpected weather conditions (three winter scale storms in the first week).

A more complete summary of the lessons learned will be included in future RCOOS reports.

III. Financial Report

Final financial reports have been submitted to NOAA's Grants Management Division via Grants Online, and a final funding draw down has been made through the Automated Standard Application for Payments (ASAP).

IV. Equipment

No equipment was purchased using funds from this grant.

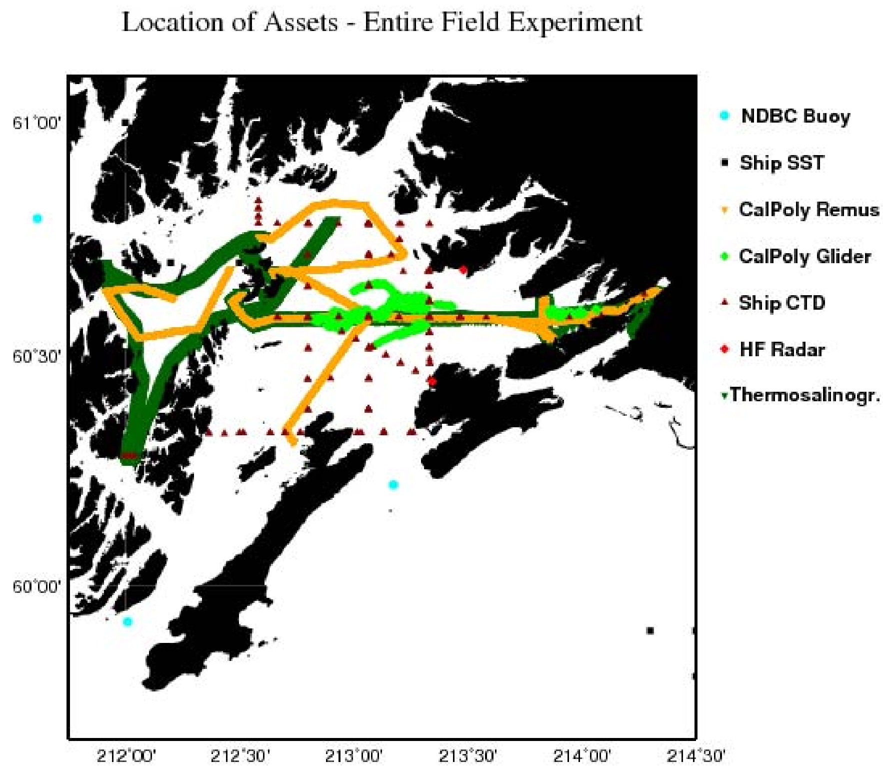

Figure 1. Locations of the in situ observational sensors and platforms during the 2009 field experiment.

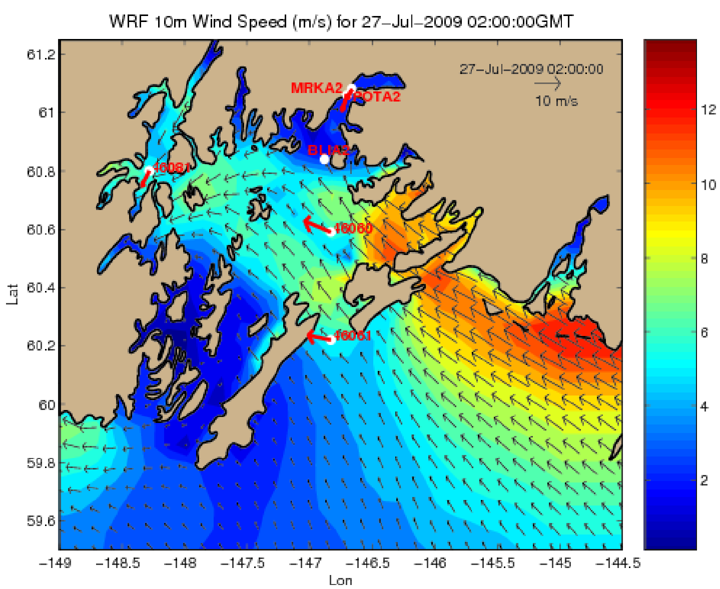

Figure 2a. A typical (2:00 GMT July 27, 2009) weather map being updated hourly during the 2009 field experiment showing the surface wind being predicted by the WRF model (black arrow and color contours) and measured by the ocean buoys (red arrow).

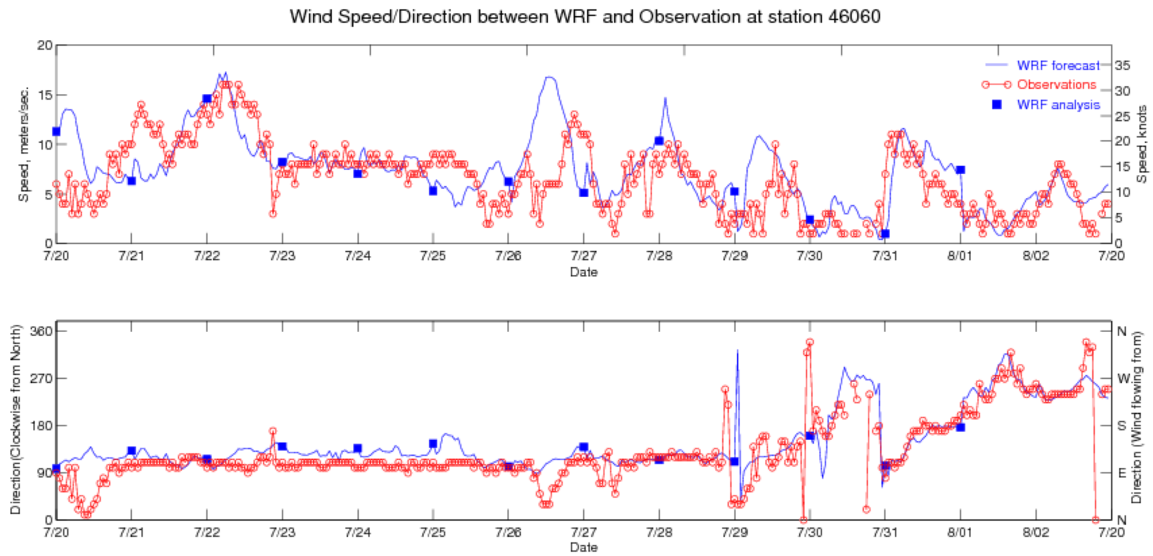

Figure 2b. Time series of the wind speed (top) and direction (bottom) during the 2-week field experiment as measured (red circles and line) and predicted by WRF (blue square is nowcast and blue line is hourly forecast) at the NDBC buoy 46069 location in the central sound.

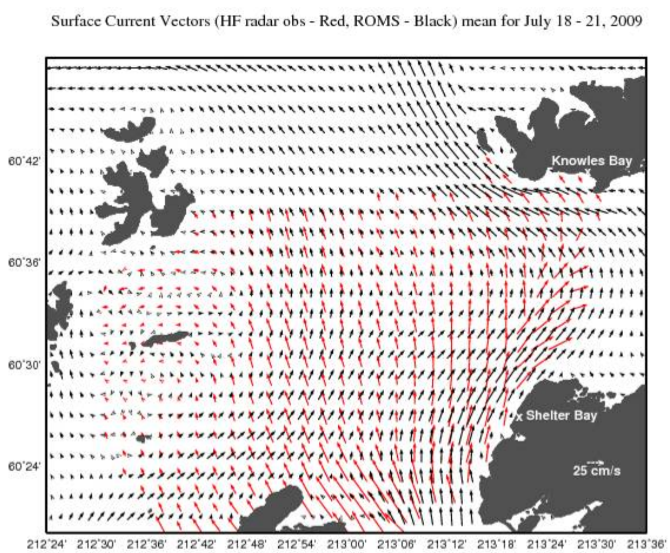

Figure 3a. Surface current map as measured by the HF radar (red arrow) and predicted by the 3D ROMS circulation model (black arrow) during the first week of the field experiment (July 18 – 21).

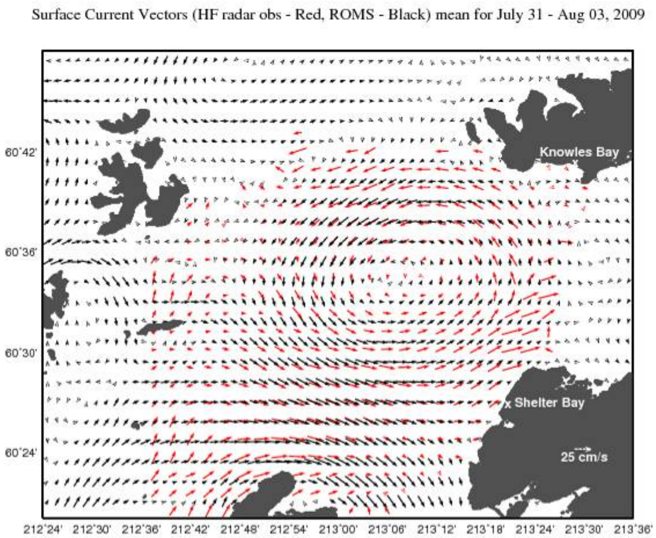

Figure 3b. Surface current map as measured by the HF radar (red arrow) and predicted by the 3D ROMS circulation model (black arrow) during the second week of the field experiment (July 31 – Aug 3).

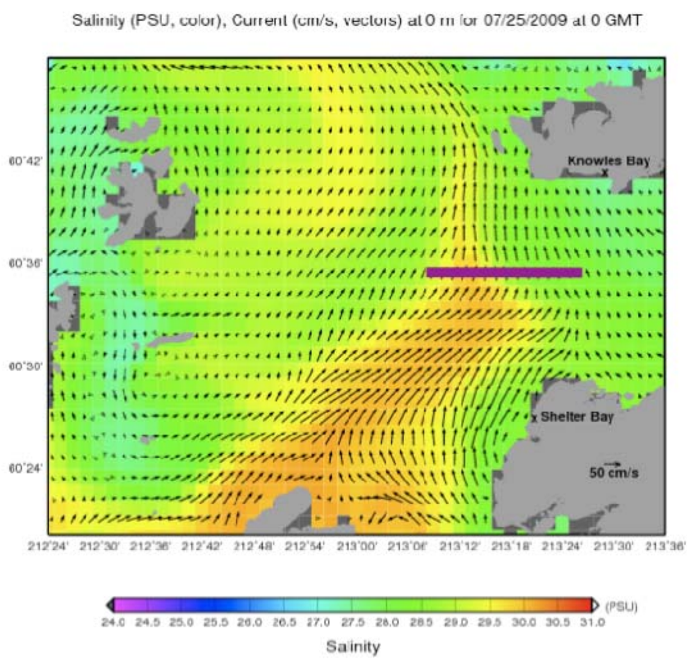

Figure 4. ROMS twenty-four hour forecast surface salinity (color, PSU) and surface current distribution for 25 July 2009, 00 GMT. The purple line represents the track taken by the Cal Poly glider at approximately the same time.

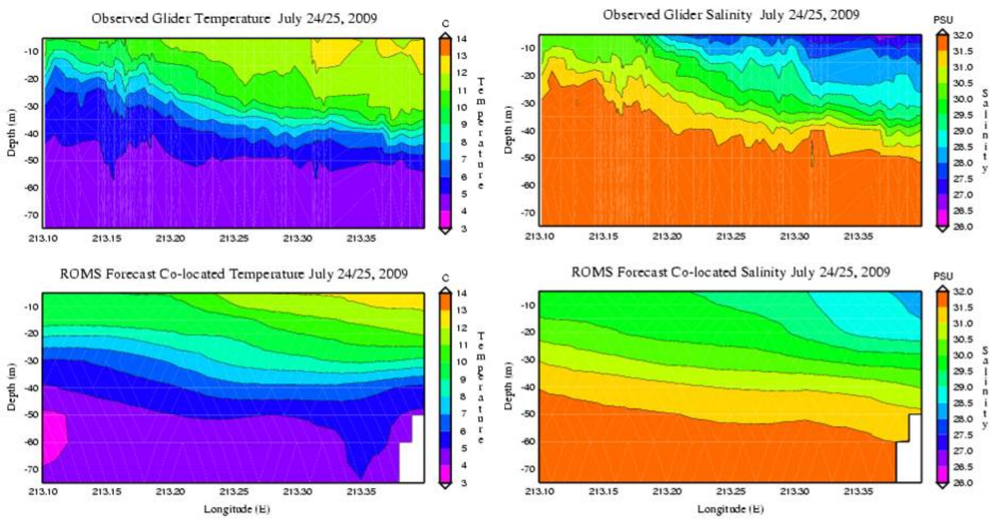

Figure 5. East-west section (along the line shown in Fig. 4) of the temperature (left) and salinity distributions as a function of depth as measured by the Slocum Glider (top) and predicted by the 3D ROMS model (bottom) during August 24-25.

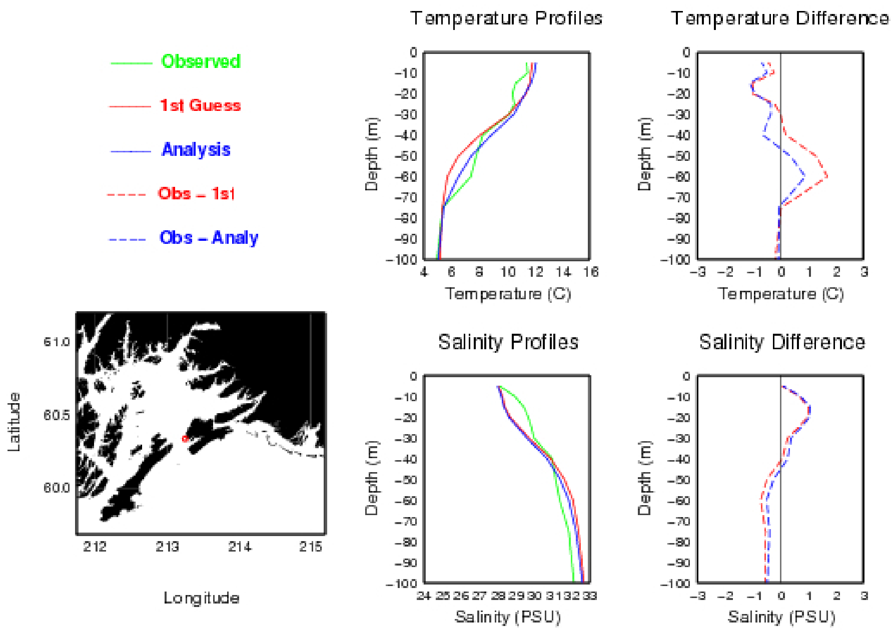

Figure 6. Typical vertical profiles of temperature and salinity as measured by the ship CTD and predicted by ROMS on July 28. The error plots show the positive impact of assimilating this particular ship CTD data into ROMS.

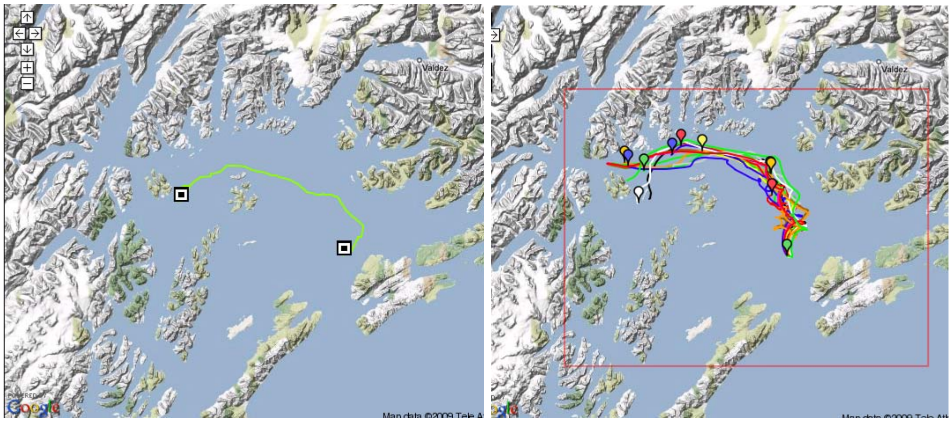

Figure 7. Drifter trajectories as measured from the released time of July 25 at 02 GMT and recovered time of July 28 at 02 GMT (left panel) and predicted by a cluster of ensemble ROMS forecasts with slightly different initial conditions (right panel).

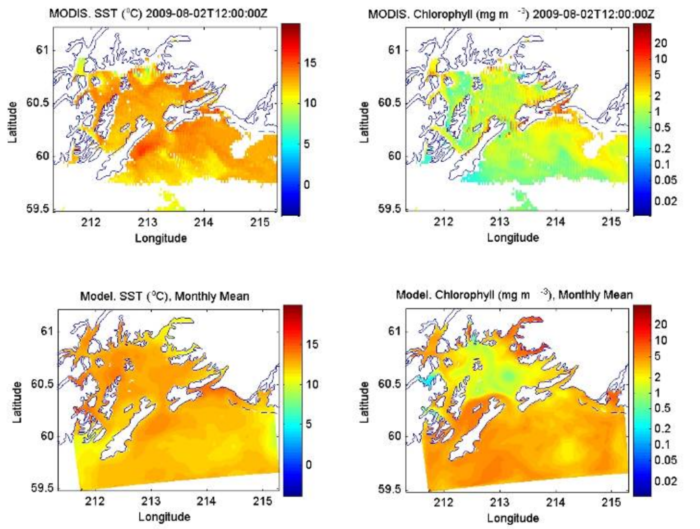

Figure 8. Comparison between the modeled sea surface temperature (SST) and chlorophyll (lower panels) and the satellite observed SST (AVHRR) and chlorophyll (MODIS) (top panels). The August 2, 2009 has a rarely clear day image for more than one month, so we used the monthly averaged model results for July 2009.

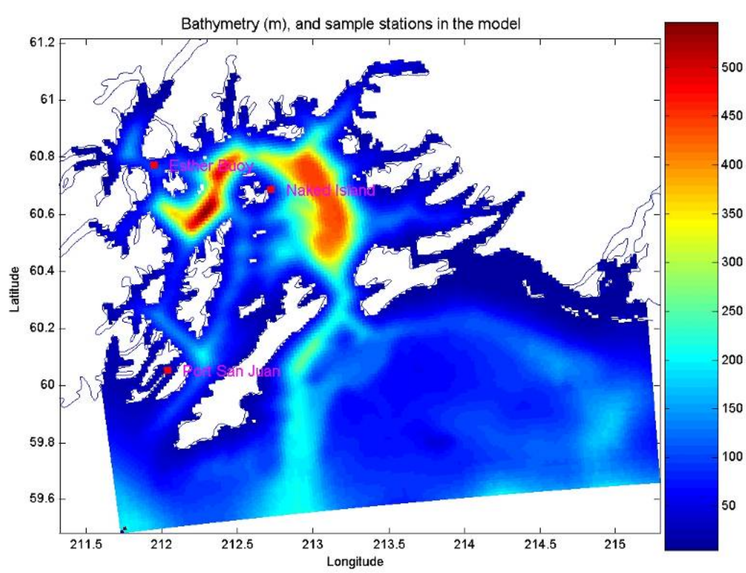

Figure 9. Bathymetry of Level-2 nested ROMS model and sample stations in the model (Esther Buoy, Naked Island, and Port San Juan). AMBCS (http://www.ambcs.org) has maintained a continuous buoy observation in these three locations since April 7, 2009.

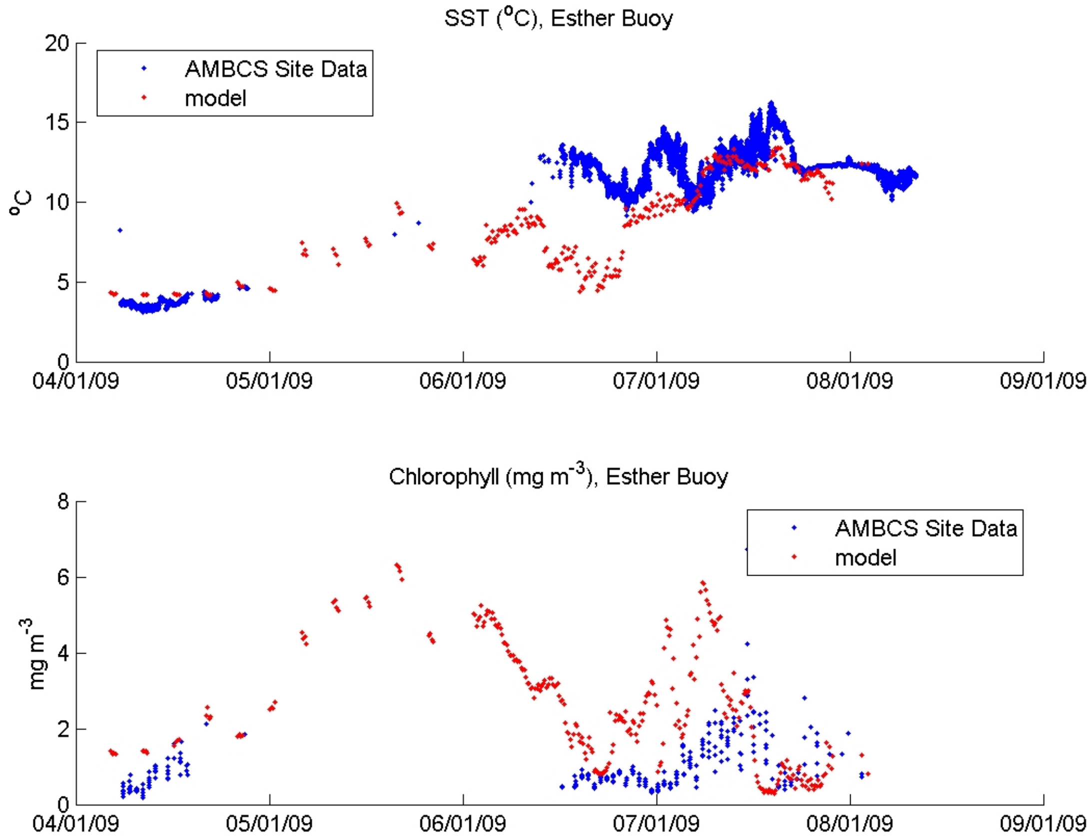

Figure 10. Comparison of SST and chlorophyll between in situ data and model output at Esther Buoy. For observed chlorophyll, only those data measured around mid-night are used and plotted. For the model results, in April and May, the model output is every five days. Starting 1 June 2009, the model output is saved 4 times every day.

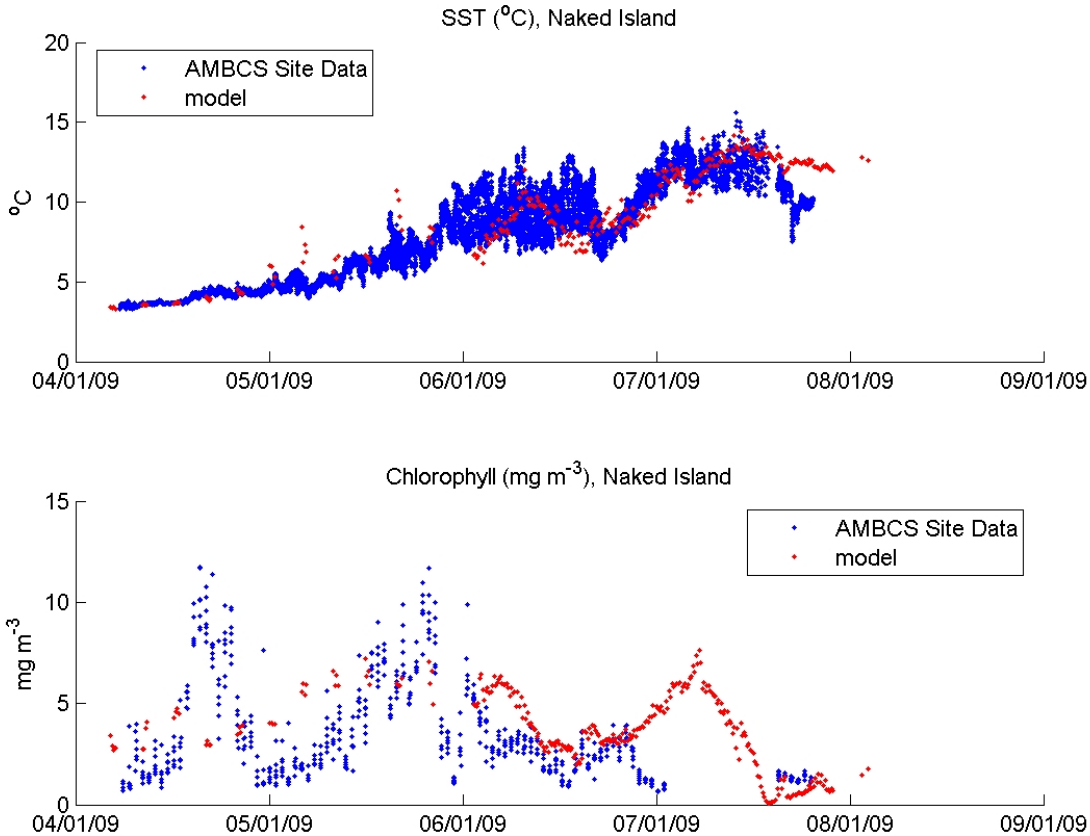

Figure 11. Comparison of SST and chlorophyll between in situ data and model output at Naked Island. For observed chlorophyll, only those data measured around mid-night are used and plotted. For the model results, in April and May, the model output is every five days. Starting 1 June 2009, the model output is saved 4 times every day.

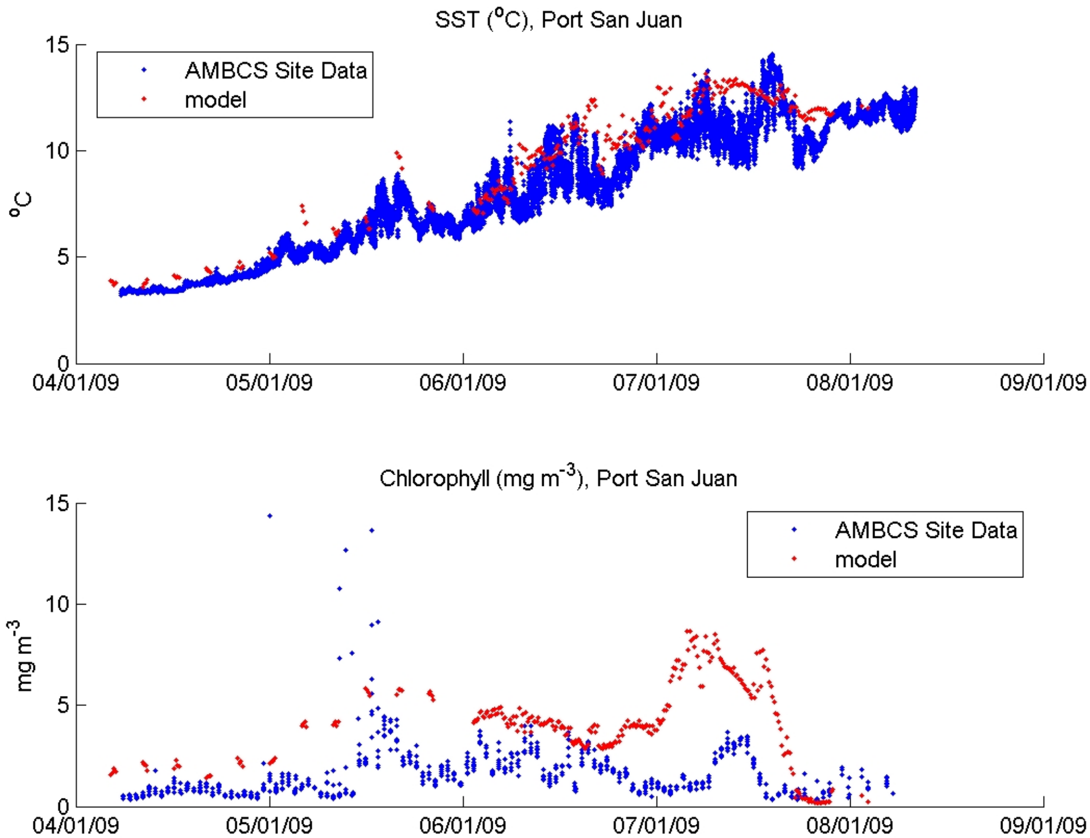

Figure 12. Comparison of SST and chlorophyll between in situ data and model output at Port San Juan. For observed chlorophyll, only those data measured around mid-night are used and plotted. For the model results, in April and May, the model output is every five days. Starting 1 June 2009, the model output is saved 4 times every day.