Modeling Circulation along the Vietnamese Coast Influenced by Monsoon Variability in Meteorology, River Discharge and Interactions with the Vietnamese East Sea

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LONG-TERM GOALS

An overarching goal of the project is development of robust ocean modeling systems suited to exploring interactions between submesoscale circulation on continental shelves and mesoscale variability in the adjacent deep ocean. Processes of interest include: wind-driven coastal currents, upwelling and downwelling; river plume dispersal; topographic control of exchange processes at the shelf-break; and optical signatures associated with sediments, terrestrial runoff, and local biological productivity. Advanced variational methods for the assimilation of satellite and in situ observations to achieve improved state estimation and subsequent forecast skill in real-time applications are a key component of the work.

A further goal of the project team is sustaining the Regional Ocean Modeling System (ROMS) international community User Portal (www.myroms.org) to provide tutorials, documentation, and user support for ROMS users worldwide. This effort promotes adoption by the broader international ocean modeling community of the capabilities developed and/or demonstrated in projects such as this.

OBJECTIVES

Our immediate objective for this project is to implement an ocean modeling system suited to representing the mesoscale to submesoscale dynamics of the South China Sea – with an emphasis on the environs of Luzon Strait so as to complement interpretation of observational studies of the Submesoscale Dynamics of the South China Sea (SDSCS) ONR project team.

It remains a secondary objective to also use the modeling system to explore interconnectedness of submesoscale coastal dynamics on the southern Vietnam continental shelf with mesoscale variability in the Vietnamese East Sea (VES). Processes of interest there are monsoon-driven coastal currents; identifying the Mekong River and upwelling source waters that impact shelf primary productivity; and the optical signature of fine sediments originating from the Mekong River.

APPROACH

A circulation model of the South China Sea (SCS) using the Regional Ocean Modeling System (ROMS) with Incremental Strong Constraint 4-Dimensional Variational (IS4DVAR) data assimilation will represent mean, seasonal, and mesoscale variability, with an emphasis on contrasting conditions during the different phases of the monsoon but including the capability to represent typhoon forcing. Two-way nesting of the SCS domain with higher resolution limited area sub-domains is being employed to represent deep ocean mesoscale to submesoscale interactions, and deep-ocean to coastal dynamics, i.e. down-scaling and upscaling. The modeling system developed here will be suited to subsequent implementation as an integrated predictive model for regional oceanographic studies.

The project team comprises researchers at three institutions: Rutgers University (J. Wilkin, J. Levin, H. Arango, J. Zavala-Garay), Woods Hole Oceanographic Institution (W. Zhang) and the University of Colorado (W. Han). The team responsibilities are:

(i) Regional mesoscale dynamics of the SCS: W. Han, J. Levin, H. Arango

(ii) Dispersal and across-shelf transport of river plumes: W. Zhang, J. Wilkin

(iii) 4DVAR data assimilation of satellite altimetry and surface temperature in mesoscale and shelf regimes: J. Zavala-Garay, J. Levin

(iv) ROMS nested and 2-way coupled grids: H. Arango

(v) Interaction and liaison with Vietnamese collaborators: J. Wilkin, J. Levin

Despite the change in scientific emphasis of the DRI that this project contributes to from Vietnamese coastal dynamics to submesoscale processes in the South China Sea, this team remains interested and committed to providing for instructing Vietnamese researchers and students on using, reconfiguring and enhancing ROMS for future studies.

WORK COMPLETED

The ROMS model for the entire SCS domain has been configured and initial simulations completed. The domain is indicated in Figure 1, which also depicts sea level anomaly (SLA) variance observed by the Jason satellite altimeter. The rotated geographic coordinate system was selected to efficiently encompass the dynamical regimes of interest (Luzon Strait and the Mekong River outflow) and to roughly align the eastern boundary with an altimeter ground-track so as to exert somewhat uniform mesoscale information in constraining this key open boundary via data assimilation. The model has approximately 7 km spatial resolution, demanding a grid of 470 x 300 points.

The initial configuration takes open boundary condition data from the European Mercator analysis/forecast system and surface meteorological forcing from ECMWF ERA-Interim reanalysis. These comprise a set of forcing data suited for retrospective reanalyses commencing Jan-2006 that will also be available for analyses of the 2013/2014 SCSCS field observation periods.

Jason-1/2 SLA have been accessed from the Radar Altimeter Database System (RADS) and prepared for ROMS 4DVAR assimilation and for evaluation of mesoscale energy in the initial free running trial simulations. Hydrographic data for assimilation have been identifed in the NODC World Ocean Database. An approach has been made to D. Rudnick (SIO) requesting AUV hydrography data during 2007-2008 for assimilation, and Prof. Sen Jan of the Institute of Oceanography, National Taiwan University, has been contacted to obtain access to the Taiwan national database of in situ hydrographic data for assimilation.

Trial forward simulations (without data assimilation) have been shared with SDSCS team members at MIT (T. Peacock) to prototype compuations of Lagrangian Coherent Strucutres in the Luzon Strait region.

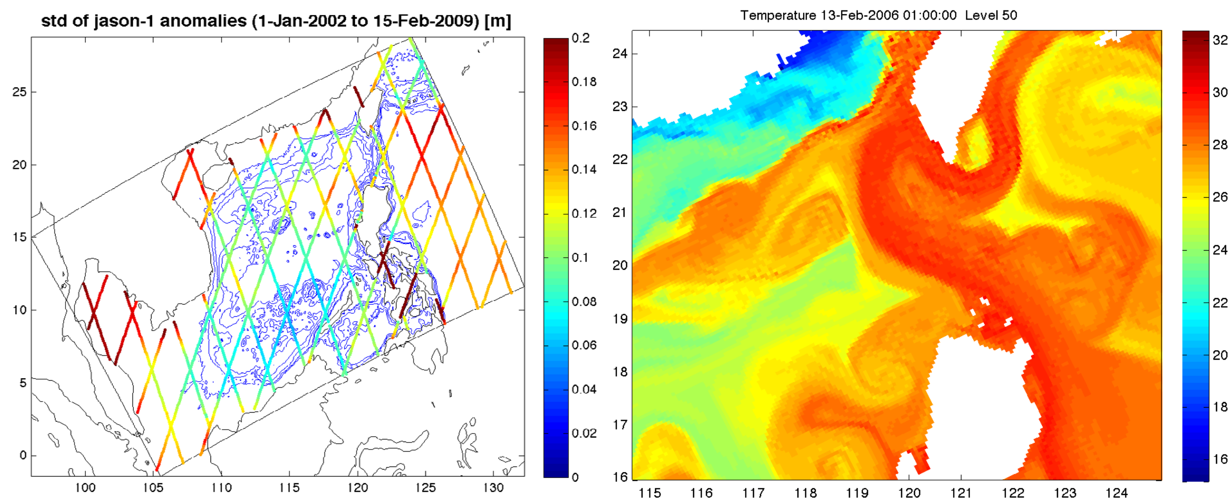

Figure 1. Left: South China Sea ROMS model domain and the pattern of Jason altimeter ground-tracks. Color indicates sea level variance. Right: Example of surface temperature in the environs of the Luzon Strait revealing mesoscale to submesoscale variability.

RESULTS

The change in emphasis of the DRI project from Vietnam coast shelf/deep-ocean exchange to Luzon Strait submesoscale dynamics necessitated a reworking of the SCS model configuration with greater attention paid to representing the steep bathymetry of the Luzon Strait sill, seamounts, and the southern China continental shelf. Intense currents at the southern entrance to the Luzon Strait dominate constraints on model stability but we have settled upon a grid resolution, vertical resolution, vertical coordinate stretching, and minimally smoothed bathymetry that allow for efficient 4DVAR assimilation analysis and adequate resolution of the upper ocean thermocline and surface and bottom boundary layers.

Analysis to date shows trial forward simulations suffer from excessive surface heating that we are remedying with a more appropriate optical model for solar radiation absorption. Comparison of the mesoscale SLA variance that is generated spontaneously by the model compares well to that observed by Jason altimeters, but does not reveal the corridor of high kinetic energy evident in drifter observations by L. Centurioni. We have formulated an analysis approach to focus on this process that removes low frequency variability to reveal the mesoscale. This is also a necessary precursor to characterizing model variance in comparison to observation error variance in 4DVAR assimilation.

Simulations show a rich eddy field arising spontaneously in the Luzon Strait region, with numerous small submeoscale features. This region will be the focus of a higher resolution 2-way nested downscaled domain that achieves ~2 km resolution of the submesoscale. The 2-way nesting coding is being evaluated and debugged in a related ONR project.

IMPACT/APPLICATIONS

The modeling system we are developing under this project will extend our experience with 4DVAR data assimilation in mesoscale boundary current regimes. Our experience to date is with energetic western boundary current regimes (the East Australian Current) and less energetic marginal shelf regimes (the Middle Atlantic Bight). The Vietnam shelf has similarities to the MAB but with significantly stronger local forcing in regard to river sources (Mekong River) and meteorology (monsoon). This places the circulation in a different dynamical regime and enriches the spectrum of experience with ROMS-4DVAR. The submesoscale cascade in the Luzon Strait region represents an interesting challenge for 4DVAR state estimation because the variance at this scale is not resolved by satellite altimetry, and therefore its occurrence in the model solutions will rely on (i) the ability of the model to represent the dynamical processes that ultimately generate the submesoscale cascade, and (ii) the ability of the model with 4DVAR assimilation to accurately represent the background mesoscale state that preconditions any “mean” (i.e. scales larger or slower than the submesoscale) to turbulent conversions.

RELATED PROJECTS

Downscaling to higher resoltuion shelf domains using 2-way nesting in ROMS is being protoyped in a related ONR MURI project Coastal ocena modeling of nonlinear internal-wave physical and acoutci effects N00014-11-1-0701.