Shallow Water Climatology and Analysis with Application to the Adriatic Sea

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LONG-TERM GOALS

Long-range operational goals are to:

- Establish methods for characterizing a variety of littoral environments based on a combination of dynamics and archived measurements. Because this requires an extensible system capable of treating a range of coastal dynamics, considerable understanding of specific processes (e.g. freshwater plumes, upwelling zones, shelfbreak fronts, near-inertial waves) will be essential.
- Develop methods for assimilating remotely sensed and *in situ* measurements to produce three-dimensional estimates of instantaneous variability.

These contribute to our long-term scientific efforts to understand:

- The mesoscale dynamics of coastal environments (e.g. fronts, upwelling/downwelling, buoyancy plumes).
- Interactions between coastal and oceanic waters.
- Data assimilation techniques as applied to the study of three-dimensional dynamics.

OBJECTIVES

This exploratory study will:

- Investigate new techniques for constructing climatologies in regions dominated by strong, episodic small- and meso-scale features, including compositing schemes based on dynamical regimes and retention of additional metrics for quantifying variability and errors.
- Extend the climatology with analysis products that employ remotely sensed and *in situ* measurements, climatological data and *a priori* assumptions regarding regional and temporal variations in the governing dynamics to produce estimates of instantaneous fields.
- Investigate how climatologies and analysis products might be used to optimize the deployment of limited in-situ sampling resources.

- Assemble archived data and develop a climatology for the Northern Adriatic Sea. This region will be used as a testbed for evaluating the techniques developed in the course of this study.

APPROACH

Improvements to the techniques used to quantify climatological fields in regions of strong variability represent a necessary first step towards improving the performance of nowcast/forecast efforts in shallow water environments. A simple extension will be the provision of metrics for expected variability about the climatological mean and for error estimates based on the underlying sampling. Although many climatologies provide seasonal (or sometimes monthly) estimates, informed selection of averaging intervals might produce more representative fields. Averaging periods will be chosen based on *a priori* knowledge of the dominant dynamics. This would separate periods dominated by upwelling and downwelling dynamics, or periods of high river run-off from those having low runoff. For example, in the wintertime Northern Adriatic we might form distinct estimates during Bora events and during periods of weaker atmospheric forcing, with the strength of the Po River runoff providing further differentiation. This differs from seasonal averaging because measurements from arbitrary times, but under specific dynamics, might form a single composite. The resulting mode-based climatology would be accessed by dynamic regime (and geographic location), rather than time.

Including additional *in situ* observations will probably always be the most effective way to improve nowcast/forecast accuracy. Thus, although we seek systems that minimize dependence on *in situ* measurements, part of this effort will examine techniques for assimilating *in situ* observations into the analysis. An extensive literature, including several textbooks, documents methods for mapping and assimilating observational data (see Robinson *et al.* 1998 for a review of applications in the coastal ocean). Most of these techniques rely on some combination of *a priori* statistical quantification of the variability and models of the relevant dynamics. The challenge will be to adapt methods that weight *in situ* measurements and climatological estimates in the context of prescribed dynamics while still being capable of real-time execution on modest computing resources.

A complementary avenue of investigation is the design of adaptive sampling strategies aimed at focusing a small number of *in situ* measurements towards locations that might yield the greatest improvements in nowcast accuracy. Results from Fox et. al. (2001) suggest that the availability of a small number of critically located (e.g. eddy centers and edges) *in situ* profiles could have dramatically reduced the errors exhibited by the MODAS-produced sections. Much of the nowcast error lay in poor reproduction of the vertical structure associated with two eddies. The availability of a single vertical profile within each feature might have eliminated much of the error by forcing the model to incorporate the pycnostads associated with the eddies rather than simply using the nearly linear stratification specified by climatology. In the absence of remotely sensed fields, error and variance metrics developed for the new climatology formulations will be adapted to guide sampling. One approach would use covariance function estimates and data error variance derived from the climatology to produce error maps using standard objective analysis techniques. When remotely sensed fields are available, differences between the remotely sensed SST/SSH and climatological values could be weighted and included in these calculations. Ultimately, this study aims to produce a system that would prescribe the deployment of an arbitrary (but probably small) number of *in situ* observational resources. These measurements would then be used to constrain the predictions generated from remotely sensed surface measurements and climatological data.

WORK COMPLETED

During this first year, efforts have focused on building scientific collaborations, compiling historical data and organizing a small workshop designed to define and evaluate potential research directions for improving analysis product performance in nearshore regimes.

Motivated by an active, ongoing research program and a large body of historical measurements, we have chosen the northern and central Adriatic Sea as a test bed for performing exploratory calculations and evaluating ideas and techniques. The Adriatic possesses an extended history of observations, with the literature pointing to numerous intensive field efforts undertaken by investigators from various nations over the past decade. Marlene Jeffries, a University of Washington graduate student working on this project, has compiled archived hydrographic data from a wide range of sources, including the Mediterranean Online Database, the National Ocean Data Center, the OGS- Trieste archives and the data holdings of IPREM-Ancona. Access to Italian (and soon, Croatian) archives has been generously granted as part of collaborative scientific efforts undertaken as part of our ongoing Adriatic Sea measurement program (ONR Grant #: N00014-02-1-0064). Ms. Jeffries is using this data, along with historical meteorological and river runoff records, to construct a climatology of the northern and central Adriatic. Using the resulting data set, we will work to relate patterns of mesoscale variability in the northern and central Adriatic to the anticipated dynamics (e.g. buoyant plumes and coastal filaments) and their response to local forcing. As expected, initial formulations that examine variability as a function of time (months and seasons) produce smoothed maps capturing only the most general features, such as dramatically reduced stratification during winter and strong, surface intensified stratification near the Italian coast due to the Po River plume. Over the coming months, we will focus on quantifying variance about these seasonal mean states and characterizing variability associated with specific combinations of geographic regions, dynamics and forcing. For example, we will attempt to characterize the Po River plume during weak and strong discharge periods, flowing into weak and strong ambient stratification and forced by Bora and Sirocco winds.

In October, 2002, we will gather a small group of coastal oceanographers and operational modelers for a workshop focused on defining new research directions for improving analysis product performance in nearshore environments. Although our original intent had been to hold this gathering in the first half of 2002, a variety of factors forced the choice of this later date. This meeting is being organized in collaboration with Drs. Ruth Preller and Clark Rowley at the Naval Research Laboratory, Stennis Space Center. Participants and invited speakers have been identified and meeting preparations are nearly complete.

RESULTS

No significant science results during the first year.

IMPACT/APPLICATION

None.

TRANSITIONS

None.

RELATED PROJECTS

Optical Dynamics in the Adriatic Sea: The Role of River Plumes, Filaments and Fronts in the Distribution, Advection and Transformation of Inherent and Apparent Optical Properties, B. Jones (USC).

Adriatic Mesoscale Experiment, P. Poulain (NPSG and OGS- Trieste).

East Adriatic Coastal Experiment (EACE), M. Orlic (Univ. of Zagreb).

Mesoscale Dynamics of the Adriatic Sea, B. Cushman-Roisin (Dartmouth).

The Adriatic Circulation Experiment, H, Perkins (NRL-Stennis), J. Miller (NRL- STennis) and R. Signell (SACLANTCEN).

REFERENCES

Fox, D. N., W. J. Teague, C. N. Baron, M. R. Carnes and C. M. Lee, 2001. The Modular Ocean Data Assimilation System (MODAS), submitted to the *Journal of Atmospheric and Oceanic Technology*.

Robinson, A. R., P. F. Lermusiaux and N. Q. Sloan , 1998. Data Assimilation. In *The Sea: The Global Coastal Ocean, Processes and Methods*, K. H. Brink and A. R. Robinson, eds. John Wiley and Sons Inc., New York, NY, 541-594.

PUBLICATIONS

None.