Model Assessment and Deployment Strategies for Drifting Instruments

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LONG-TERM GOALS

This is part of a collaborative program Optimal Deployment of Drifting Acoustic Sensors, ODDAS, which involves academic, private sector, and Navy scientists. The long-term goal of ODDAS is to develop strategies for the deployment of drifting sensors that maximize the amount of environmental information collected with the fewest sensors. The primary long-term goal of our component is to quantify oceanic submesoscale stirring and advective transport processes and to assess their roles in the deployment strategies. The secondary goal is to develop novel and quantitative assessments of the ability of predictive models and real-time observations to determine the movement of sensors and the location of material boundaries or advective pathways in the ocean.

OBJECTIVES

Two objectives were pursued during FY06:

- Locate hyperbolic trajectories and calculate associated inflowing and outflowing manifolds in EAS16 hindcasts for the region around Taiwan.
- Assess the ability of EAS16 to predict the movement of drifting sensors.

APPROACH

As documented in publications and previous progress reports we have developed a variety of Lagrangian methods that quantify advective processes from synoptic velocity archives. These methods are used in this project to configure deployment schemes of drifting sensors so as to maximize data return from drifting sensor arrays with a minimum number of units. This requires meeting three diverse, and occassionally contradictory, user requirements. One is to maximize the spatial coverage for regions of interest. Another requirement is maintain array coherence for a specified time period. The third requirement is to sample denied areas. To meet these requirements it is also important to decide whether to deploy all sensors at one time or to use a time staggered strategy.

The key of our approach is the capability to locate critical regions from the synoptic velocity archives. These are usually found in regions where the velocity is small. However, small velocity regions in the

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ocean have vastly different characteristics. Hyperbolic regions, typically found in the nether region between ocean eddies, are characterized by strong shear. Deployment in these regions is appropriate for broad area data coverage and possibly access to denied regions. However, hyperbolic regions should be avoided when the primary goal is array coherence since these regions typically have extremely strong shear that produces extensive array distortion. See Toner and Poje (2004) for additonal discussion of the importance of hyperbolic regions on deployment strategies.

The data used in this effort comes from two sources. The model results come from the Navy EAS16 hindcasts for the region around Taiwan. Drifting sensor trajectories come from deployments by SIO and NAVAIR exercises. For the first project objective, EAS16 velocities are used to determine hyperbolic regions in the planned deployment areas and to assess the evolution of hypothetical deployment arrays. For the second objective we compare the predicted movements of individual drifting sensors from EAS16 with the observed trajectories. Two criteria are available for quantitative assessment. These are the Lagrangian error metrics proposed by Toner et al. (2001), and the accuracy of advective pathways predicted by inflowing and outflowing manifolds associated with hyperbolic trajectories.

The research on this effort is the result of collaboration with A. Poje at CUNY Staten Island, R. Allard and S. Riedlinger at NRL Stennis, the drifter group at SIO led by P. Niiler, D. Fenton and D. Hammond at NAVAIR, and R. Heitsenrether at APL JHU. The NRL group supplies model hindcasts from EAS16, NAVAIR and JHU supply data from fleet exercises. The primary responsibility of the group at the University of Delaware, working with A. Poje, is the Lagrangian analysis.

WORK COMPLETED

During this fiscal year we concentrated on finding ways to locate hyperbolic regions and calculate manifolds from the EAS16 model velocity fields. The problem is acute since the model fields contain a strong tide and inertial signal. These effects mask the separation of Eulerian and Lagrangian time scales necessary for present methods to work. Haller and Poje (2001) and Kirwan (2006) provide detailed technical discussions of this point. We had some success in locating these regions and growing the manifolds by working with daily averaged fields. The manifolds were then superposed on the hourly fields. Comparisons with model trajectories calculated from the hourly fields were then made. Preliminary results are summarized in the next section.

Hurricane Katrina slowed access to EAS16 model velocity fields.

RESULTS

Hyperbolic trajectories are located at the intersection of two material manifolds. These manifolds appear as curves on planar ocean surfaces, but in reality they are two dimensional fronts that extend well into the water column. They exist for finite periods of times, often of the order of a week or longer. During this period they may extend across several hundred kilometers of ocean. Since they are impervious to advection, they provide a qualitative template for parsing the origins and fates of particles. Fluid near the inflowing or “stable” manifold is drawn toward the hyperbolic trajectory while fluid near the outflowing or “unstable” manifold is repelled. Particles near each other, but on opposite sides of an inflowing manifold, will diverge exponentially in time as they approach the hyperbolic trajectory. As noted by Haller and Poje (2001) this produces a separation of Lagrangian and Eulerian timescales in hyperbolic regions. We, and others, have used this timescale separation effectively in locating hyperbolic trajectories.

Unfortunately, strong tides and inertial flows affect both the hyperbolic trajectory and the nearby particles, thus camouflaging the time scale separation. This has prevented us from finding hyperbolic trajectories in the EAS16 model field in the East Asia Sea. During this fiscal year we addressed this problem by searching for hyperbolic trajectories in daily averaged fields. Several were located west and south of Taiwan. The resulting manifolds were then superposed on the hourly EAS16 hourly velocities. The first test of this procedure was to determine if particles started near the hyperbolic trajectories followed the manifolds.

Figure 1 illustrates the findings. It shows a hyperbolic trajectory south of Taiwan determined from the daily averaged EAS16 current fields. A complete animation of this and a nearby hyperbolic trajectory is available at http://newark.cms.udel.edu/~mzweng/taiwan. The trajectory and inflowing/outflowing manifolds were located in these fields for over two weeks. In Figure 1, particle trajectories and manifolds are superposed on hourly model velocities. The simulated particles shown in Figure 1 were advected by the hourly fields so they respond to small time and space scale processes that are filtered out of the daily averaged fields which produced the manifolds. Thus this calculation represents a reasonable first test of our procedure. The movements of the simulated drifters are in excellent agreement with the manifolds. We did not observe any of them crossing the manifolds. Moreover, they generally followed the evolution of the manifolds. The next step is to compare the movement of real drifting sensors with hyperbolic trajectories and associated manifolds determined from the daily averaged velocity fields.

IMPACT/APPLICATIONS

We have established that the velocity correlation statistics from EAS16 generally agree with similar statistics from deployed drifting sensors. Surprisingly, the agreement between model and observed trajectories is poor. One obvious reason for this is that trajectories of real drifting sensors are very sensitive to subgrid scale processes, which are only parameterized in the model. The remedy for this is higher model resolution and assimilation of trajectory data in EAS16. However, there is another possibility; the hydrodynamic drag of drifting sensors causes the deviation. Rectifying this issue will require detailed knowledge of drag characteristics. Realistically, one expects that both reasons contribute to the model trajectory errors.

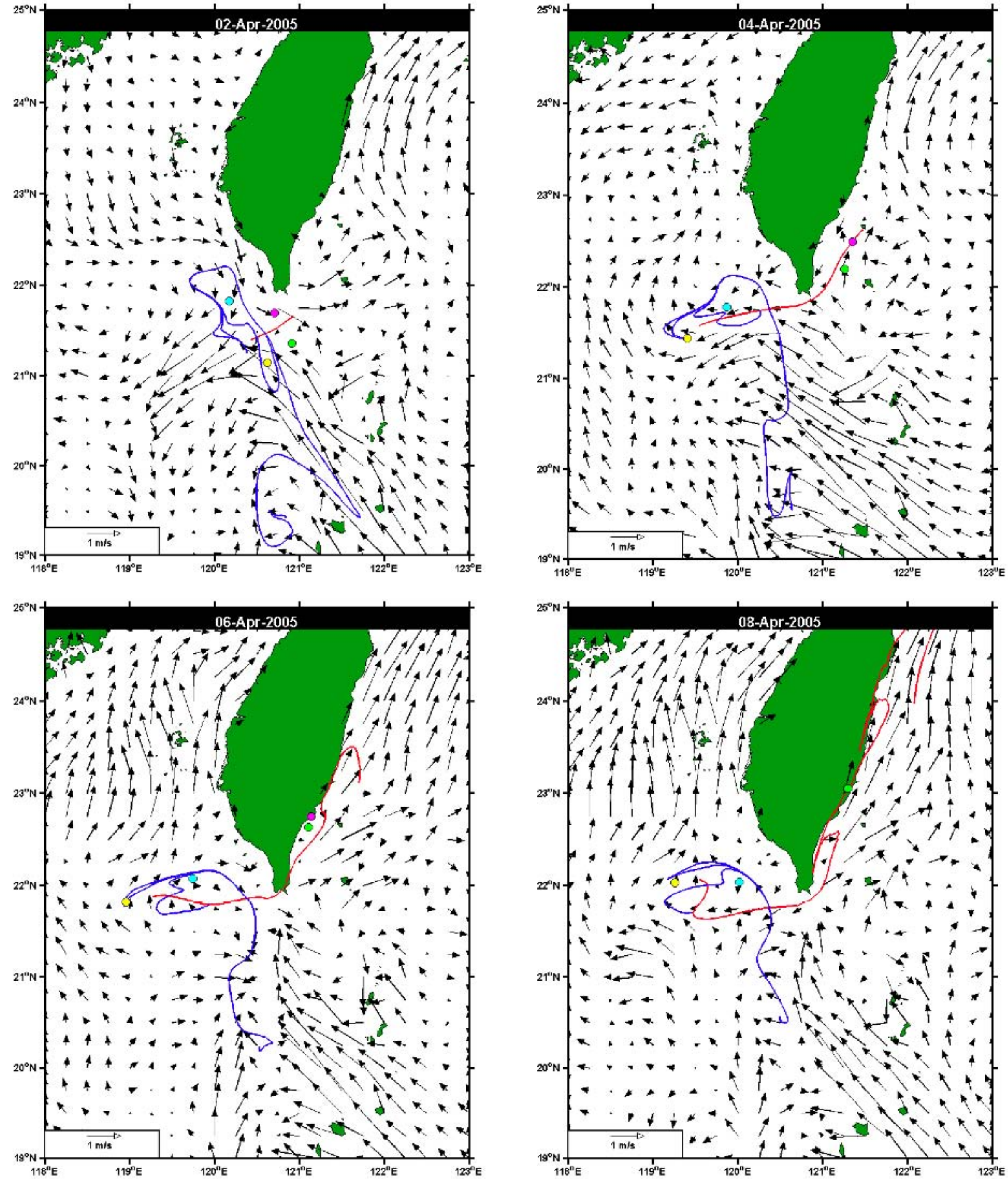

Figure 1: Inflowing (blue) and outflowing (red) manifolds computed from daily mean velocities near Taiwan from the Navy EAS16 model for the period 2-8 April 2005. Four particle positions, computed from hourly model velocities, are shown as colored circles. Hourly EAS16 velocities at a depth of one meter (subsampled at every fourth grid point) are also shown.

RELATED PROJECTS

This grant is closely connected with ONR grant N00014-05-1-0092. Most of the analysis methods used here are also used on the latter grant. The PI and CO-PI of the present grant are also the principals on the latter grant.

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