Predictability of Particle Trajectories in the Ocean

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LONG-TERM GOALS

The long term goal of this project is to determine optimal sampling strategies for drifting buoys, in order to enhance prediction of particle motion in the ocean, with potential applications to ecological, search and rescue, floating mine problems, design of observing systems and development of navigation algorithms.

OBJECTIVES

The specific scientific objective of the work done has been to determine the effectiveness of using in-situ Lagrangian measurements and data assimilation techniques in improving the prediction of particle trajectories.

APPROACH

The work is based primarily on stochastic models of particle motion and data assimilation strategies. It also involves the use of ocean general circulation models and processing of oceanic data such as drifter positions, ocean surface currents, and wind field.

WORK COMPLETED

1) Completion of the investigation of a prediction method based on assimilation of surrounding drifter positions using Kalman filtering into a Lagrangian particle model. This paper is published in the Journal of Physical Oceanography (Özgökmen et al., 2001).

2) Development of a new algorithm to specifically address short-term prediction problem. This method is tested using stochastic flow simulations and oceanic drifters. This paper is published in SIAM Journal of Applied Mathematics (Piterbarg and Özgökmen, 2002).

3) Publication of a review paper summarizing the Lagrangian research results presented in LAPCOD workshop. This paper is published in the Journal of Atmospheric and Oceanic Technology (Mariano et al., 2002).

4) Investigation of the impact of in-situ wind forcing on the reconstruction of drifter trajectories. This manuscript is submitted for publication (Paldor et al., 2002).

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14. ABSTRACT
The long term goal of this project is to determine optimal sampling strategies for drifting buoys, in order to enhance prediction of particle motion in the ocean, with potential applications to ecological, search and rescue, floating mine problems, design of observing systems and development of navigation algorithms.

15. SUBJECT TERMS

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RESULTS

One of the conclusions of Özgökmen et al. (2001) is that, during the initial period after the release of drifters, the center of mass method is found to perform nearly as well as the complex Kalman filtering technique. As the initial few days are the most important for practical applications (e.g., search and rescue), we developed a method based on a refinement of center of mass technique that is specifically designed to address short-term prediction.

In fact, this regression algorithm (RA) has several advantages with respect to the Kalman filtering (KF) method: (i) RA algorithm does not require any parameters, such as the Lagrangian parameters describing the characteristics of the underlying flow; the velocity correlation space scale R or the Lagrangian correlation time scale τ; (ii) RA does not utilize the mean flow field, the calculation of which requires large (Lagrangian or Eulerian) data sets, and space-time interpolation methods. The associated subgrid-scale variability introduces additional errors; (iii) RA does not need to be initialized with turbulent velocity fluctuations at the launch location; (iv) RA is not based on the integration of a velocity field to estimate the particle position, which necessarily leads to accumulation of velocity errors as errors of drifter location; (v) Consequently, RA is computationally far simpler than KF.

This method was tested extensively using stochastic simulations, and real ocean drifters, and its performance was compared to that of the KF technique. Some of the main results of this study are shown in Fig. 1. It is found that RA performs as good as or better than KF; both techniques provide improvement with respect to center of mass estimation, and prediction errors are far less than cluster dispersion, both for stochastic simulations, and oceanic clusters (Fig. 1a). It is found that at least 4 predictors are needed for RA to perform accurately. When the number of predictors is equal or less than 3, the accuracy of the method deteriorates drastically. However, there is little difference in the prediction accuracy, especially during the initial few days, when the number of predictors is equal or larger than 4 (Fig. 1b). The RA also indicates various strategies for sampling. It is found that the best sampling is obtained when the predictant is placed off the center of the cluster (Fig. 1c).

Given that for a variety of important practical applications, such as search and rescue missions, and dispersion of pollutants, the object of interest is near or at the surface of the ocean, it is inevitable that the wind stress plays an important, role in the dynamics of the object's motion. A simple dynamical method has been tested using 50 WOCE drifters, launched in the Equatorial Pacific, and the wind data taken from the US Navy Operational Global Atmospheric Prediction System (NOGAPS) and ECWMF. The investigation was conducted to find the optimal parameter range that minimizes the prediction error. While the drifter path prediction shows considerable improvement using individual optimal parameters with respect to that using just the mean oceanic flow field, the scatter of the parameters is quite high, and the improvement using one set of optimal parameters, averaged over the entire drifter data set, is in the range of 30-40% (Fig. 2).

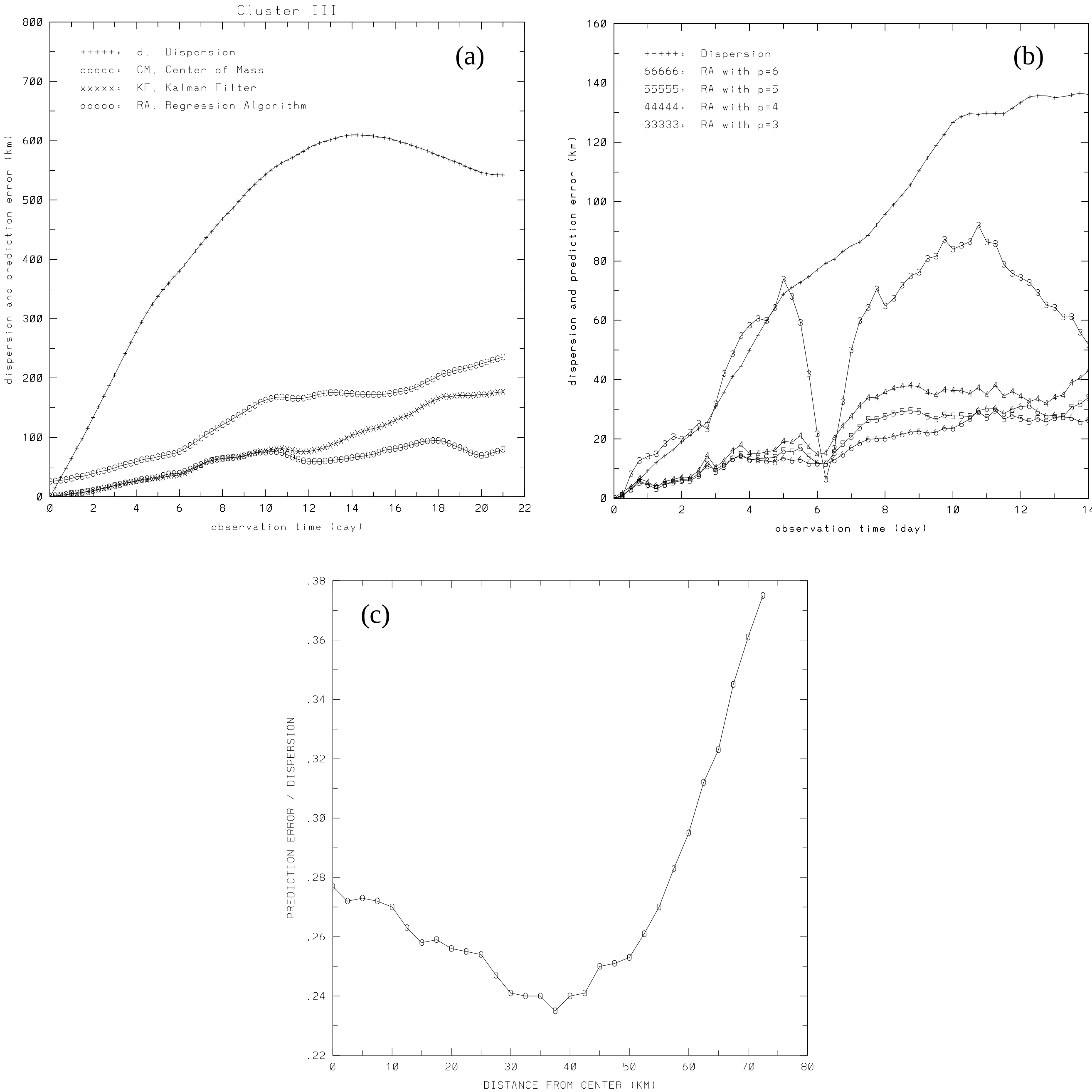

Figure 1: (a) Comparison of the performance of the regression method (RA) to that of Kalman filter assimilation (KF) and simple center of mass technique. The absolute dispersion of the drifter cluster is shown for reference. (b) Performance of the RA as a function of the number of predictant drifters. (c) Relative prediction error as a function of the location of the predicted particle. All figures are adapted from Piterbarg and Ozgökmen (2002).

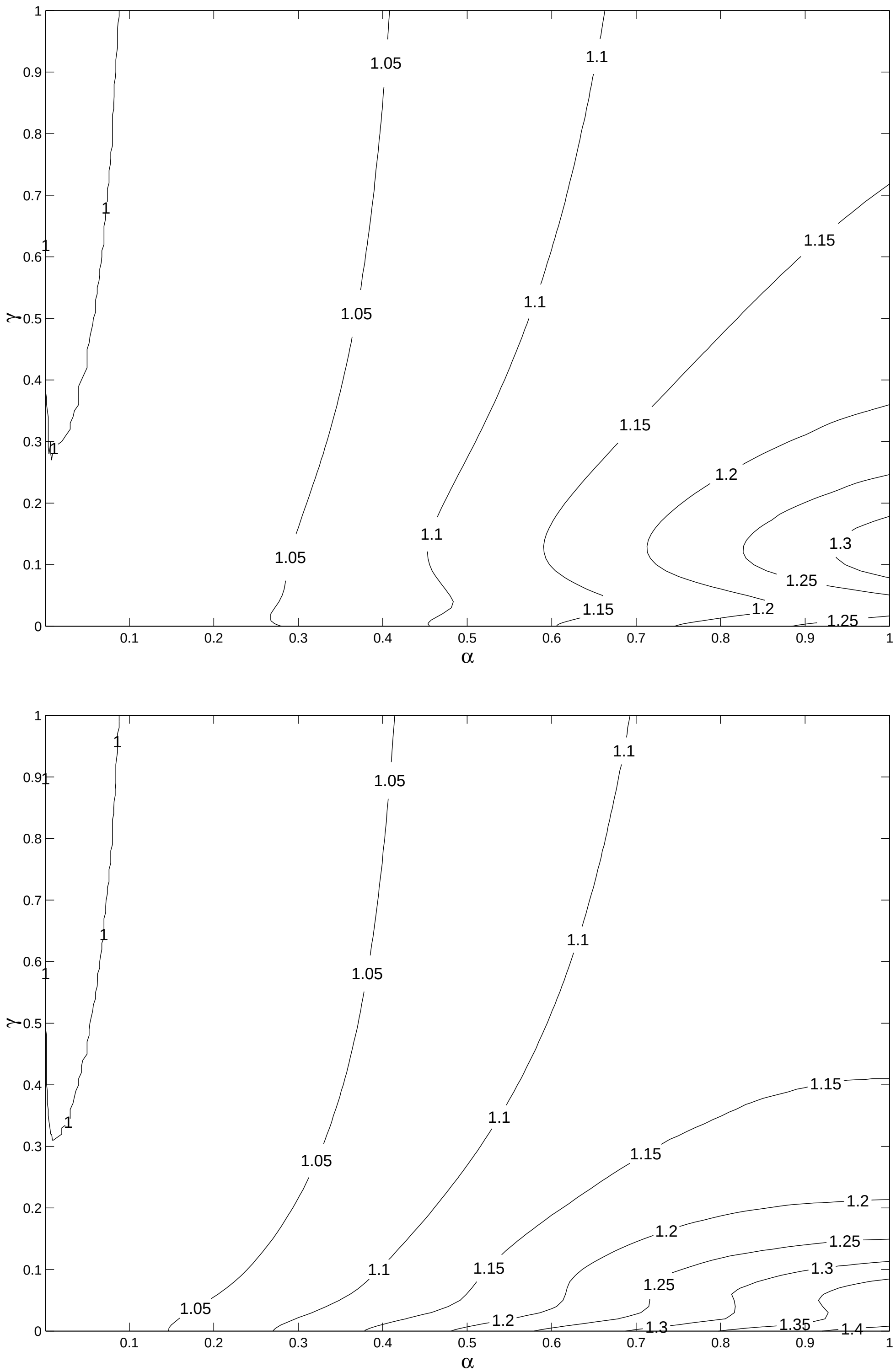

Figure 2: Prediction improvement factor as a function of correctional velocity coefficient α and friction coefficient γ using NOGAPS (upper panel) and ECWMF (lower panel) winds from 50 WOCE drifters in the Pacific Ocean. From Paldor et al. (2002).

IMPACT/APPLICATIONS

The investigation of the predictability of particle motion is an important area of study, with a number of potential practical applications at very different scales, including searching for persons or valuable objects lost at sea, tracking floating mines, ecological problems such as the spreading of pollutants or fish larvae, design of observing systems and navigation algorithms.

TRANSITIONS

Optimal sampling strategies are being developed with L.I. Piterbarg (University of Southern California). Also, we will collaborate with Dr. Piterbarg on optimal path or navigation problem.

RELATED PROJECTS

(i) Lagrangian turbulence and transport in semi-enclosed basins and coastal regions (PIs: A. Griffa, T.M. Özgökmen).

(ii) Statistical Problems in Ocean Modeling and Prediction (PI: L.I. Piterbarg).

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