Lagrangian Turbulence and Transport in Semi-Enclosed Basins and Coastal Regions

Annalisa Griffa, Tamay M. Özgökmen
Division of Meteorology and Physical Oceanography
Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Causeway, Miami, Florida 33149
phone: 305 361 4816, fax: 305 361 4696, email: agriffa@rsmas.miami.edu
Award #: N00014-97-1-0620

LONG-TERM GOALS

The long term goals of this project are the development and application of new methods of investigation for the use of Lagrangian data. Special attention is given to the combined use of data and models, with focus on applications to regional and coastal areas.

OBJECTIVES

1) To develop and apply new techniques for the assimilation of Lagrangian data in ocean general circulation models (OGCMs).

2) To improve previous results on statistical studies of particle motion using data and stochastic models.

APPROACH

The work involves a combination of numerical, analytical and statistical techniques.

WORK COMPLETED

1) Development of a Lagrangian data assimilation method and its application to a quasi-geostrophic model. The results are accepted for publication in J. Geophys. Res.

2) Analysis of drifter data and numerical results with application to large scale ocean flows (Tropical Pacific) and regional coastal flows (Sicily Channel). Results are published in J. Geophys. Res. and J. Mar. Sys.

RESULTS

Work in the present grant period has been focused on two main topics:

1) *A specific formulation for assimilation of Lagrangian data, which takes directly into account the nature of the measurements, i.e. the positions of drifting buoys. has been tested in the framework of a double-gure quasi-geostrophic (qg) model and of a primitive equation (MICOM) model*

A central problem in the assimilation of Lagrangian data is that there is a nonlinear relationship between the observed float positions and the model variables to be modified, i.e. the Eulerian velocities. In order to address this issue, a new formulation, in the framework of the Optimal

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE
Lagrangian Turbulence and Transport in Semi-Enclosed Basins and Coastal Regions

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Division of Meteorology and Physical Oceanography,,Rosenstiel School of Marine and Atmospheric Science,,4600 Rickenbacker Causeway,,Miami,,FL, 33149

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long term goals of this project are the development and application of new methods of investigation for the use of Lagrangian data. Special attention is given to the combined use of data and models, with focus on applications to regional and coastal areas.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Interpolation (OI) method, has been implemented in collaboration with L. Piterbarg (Molcard et al., 2002). Conceptually, the drifter position is forecasted by the model during the assimilation interval, and the model Eulerian velocity is corrected in order to minimize the distance betwen forecasted and observed positions.

A simplified version of the formulation (local in time in space) has been tested in the framework of a double-gyre qg model. An extensive study has been conducted to quantify the effectiveness of the assimilation using the twin experiment approach. The method is found effective in a vaste range of parameters, in terms of number of drifters, frequency of assimilation and uncertainties associated with the forcing functions driving the ocean model. The performance of the Lagrangian assimilation technique is also compared to that of conventional methods ("pseudo-Lagrangian") of assimilating drifters as moving current meters (e.g., Ishikawa et al., 1996). The fully Lagrangian assimilation provides better results in all the tested cases (Fig. 1).

The performance of the assimilation technique is presently tested in the framework of primitive equation models, using MICOM. A simultaneous correction of the layer thickness is also performed, using a dynamical relationship based on geostrophy. Results are very encouraging as shown in the example of Fig. 2.

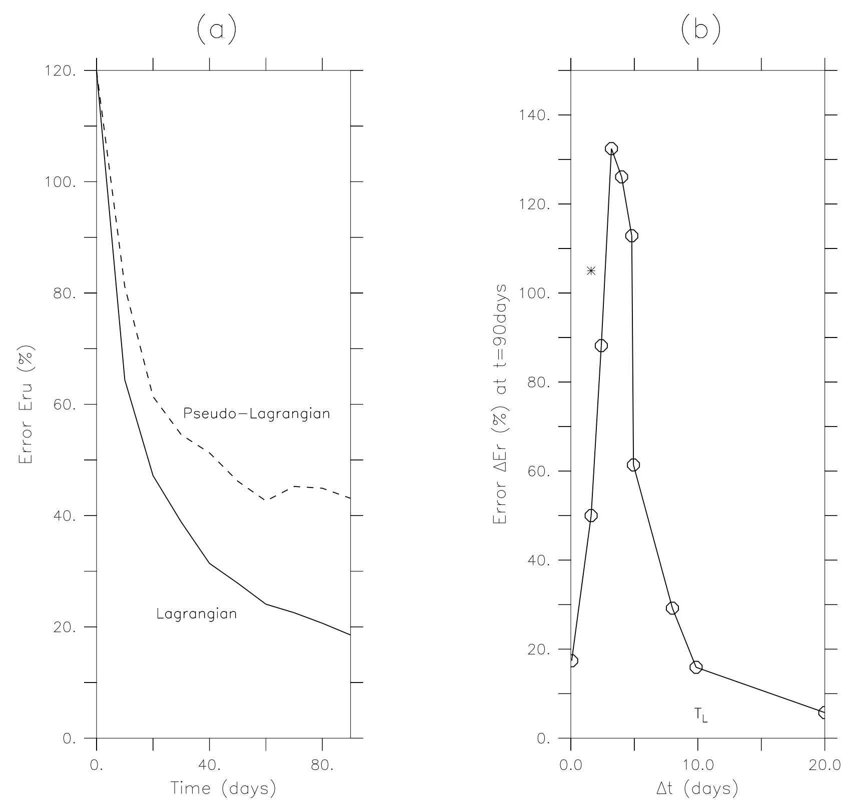

Figure 1: (a) Typical convergence error using fully Lagrangian (solid line) and pseudo-Lagrangian (dashed line) assimilation schemes. (b) Normalized error difference between Lagrangian and pseudo-Lagrangian methods as a function of assimilation period. The normalized error difference between the fully Lagrangian method and assimilation of current meter data is marked by (*) . The Lagrangian time scale is 10 days.

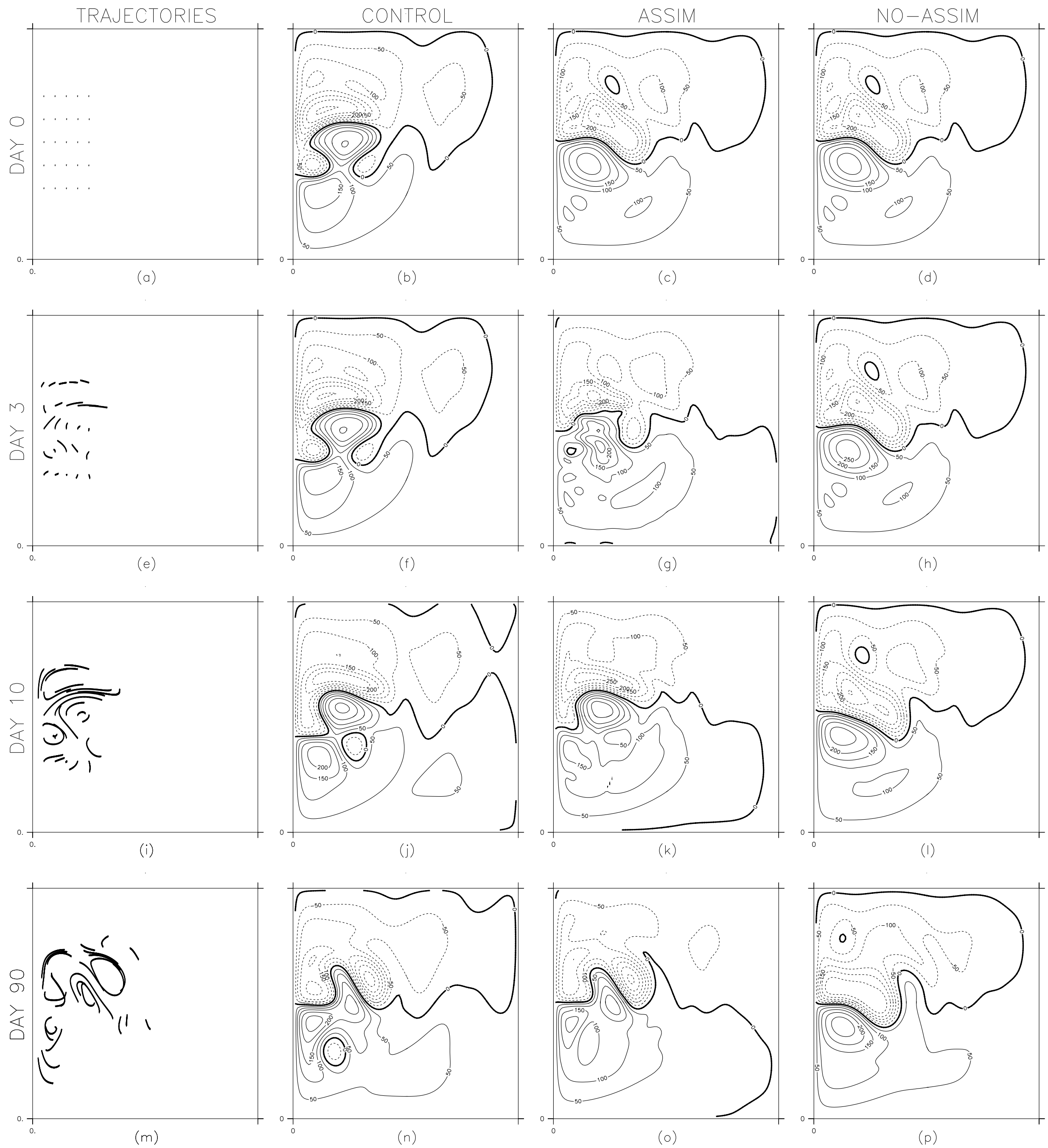

Figure 2: Results from Lagrangian data assimilation into MICOM. Drifter trajectories (25 launched in the energetic region of the jet) (first column), layer displacement (ci: 50 m) for the control (second column), assimilation (third column) and no-assimilation (fourth column) oceans at selected times (t=0, t=3, t=12, t=90 days).

2) *Study of transport properties and statistics of particle motion in the Adriatic Sea using a drifter data set (1990-1999).*

The work, performed in collaboration with P. Poulain and A. Maurizi, builds on previous results (Falco et al., 2000) obtained using a more restricted data set (1994-1996). The use of the extended data set (Poulain, 2001) allows to explore the effects of inhomogeneity and nonstationarity (Maurizi et al., 2002) which were neglected in Falco et al (2000). The Adriatic Sea have been partitioned into 3 zones based on eddy kinetic energy and topography, and the properties of the turbulent velocity have been studied separetely in each zone. In Fig. 3, the velocity autocorrelation of is shown. As it can be seen, at initial times, the autocorrelations are similar in the 3 zones and approximately exponential, while at longer times the autocorrelation in zone 2 shows a significantly different behaviour, and it is characterized by a longer time scale of the order of 15 days, reflecting also on the global average. Zone 2 corresponds to the most energetic, boundary coastal area in the southern-central Adriatic, which, as shown by Falco et al. (2000), is the most difficult zone to model in terms of transport properties. The existence of the secondary scale explains these difficulties and suggests a more complete transport parameterization.

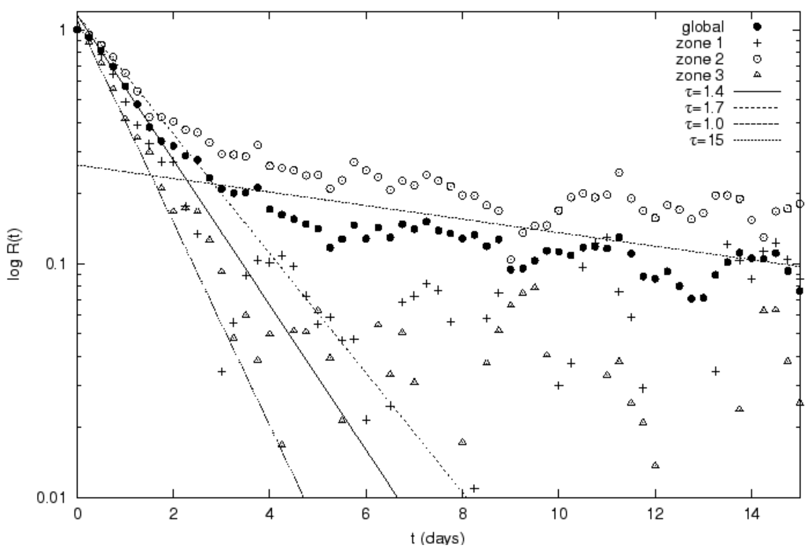

Figure 3. Log of turbulent velocity autocorrelations $R(t)$ computed in the 3 zones of the Adriatic Sea and over the whole basin (global). The three steepest lines indicates fits to data in the 3 zones at initial times (approximately first 3 days), while the fourth line indicates fit to data at longer times for zone 2. The slopes indicate e-folding time scales τ. All zones have initial time scales of order of 1.5 days. In zone 2, there is a second time scale of 15 days for global average.

IMPACT/APPLICATIONS

The assimilation of Lagrangian data is expected to have a direct impact on ocean prediction using OGCMs. The turbulent transport studies provide tools for parameterization and transport modeling.

TRANSITIONS

The Lagrangian assimilation results are planned to be used in OGCMs, such as a) MICOM/HYCOM, in collaboration with L. Piterbarg, A. Mariano and M. Chin; and b) OPA model of the Mediterranean Sea in collaboration with N. Pinardi. The transport study in the Mediterranean Sea will be carried out in collaboration with P. Poulain and E. Zambianchi.

RELATED PROJECTS

(i) Statistical problems in ocean modelling and prediction. PI: L. Piterbarg, ONR
(ii) Mediterranean forecasting project, PI: N. Pinardi, EU

REFERENCES

Falco P., A. Griffa, P.M. Poulain, E. Zambianchi, 2000. Transport properties in the Adriatic Sea as deduced from drifter data. *J. Phys. Oceanogr.*, **30**(8), 2055-2071.

Ishikawa Y, T. Awaji, K.Akitomo and B. Qiu, 1996. Successive correction of the mean sea surface height by the simultaneous assimilation of drifting buoys and altimetric data. *J. Phys. Oceanogr.*, **26**, 2381-2397.

Maurizi A., A. Griffa, P. Poulain and F. Tampieri, 2002. Inhomogeneous and nonstationary statistics of the Lagrangian turbulent velocity in the Adriatic Sea, as deduced by drifter data (1990-1999). In preparation.

Molcard A., L.I. Piterbarg, A. Griffa, T.M. Özgökmen, and A.J. Mariano, 2002. Assimilation of drifter positions for the reconstruction of the Eulerian circulation field. *J. Geophys. Res.*, accepted.

Poulain P.-M., 2001. Adriatic Sea surface circulation as derived from the drifter data between 1990-1999. *J. Mar. Sys.*, **29**, 3-32.

PUBLICATIONS (2001-2002)

Bellucci, A., G. Buffoni, A. Griffa and E. Zambianchi, 2001. Estimation of residence times in semi-enclosed basins with steady flows. *Dyn. Atmos. Ocean*, **33**, 201-218.

Garraffo Z., A. Mariano, A. Griffa, C. Veneziani and E. Chassignet, 2001. Lagrangian data in a high resolution model simulation of the North Atlantic. 1: Comparison with in-situ drifters. *J. Mar. Sys.*, **29**, 157-176

Garraffo Z., A. Mariano, A. Griffa and E. Chassignet, 2001. Lagrangian data in a high resolution model simulation of the North Atlantic. 2: Mean flow reconstruction and sampling effects. *J. Mar. Sys.*, **29**, 177-200.

Bauer S., M. Swenson, A. Griffa, 2002. Eddy-mean flow decomposition and eddy-diffusivity estimates in the Tropical Pacific Ocean. Part 2: diffusivities and heat flux calculations. *J. Geophys. Res.*, in press.

Molcard A., L. Gervasio, A. Griffa, G. Gasparini, L. Mortier, and T.M. Özgökmen, 2002. Numerical investigation of the Sicily Channel dynamics. 2. Density currents and water mass advection. *J. Mar. Sys.*, in press.

Molcard A., A. Griffa and L. Gervasio, 2002. Density currents and direct wind forcing in a numerical model of the Sicily Channel. Eulerian and Lagrangian statistics. *Ann. Univ. Nav.*, in press.

Molcard A., L.I. Piterbarg, A. Griffa, T.M. Özgökmen, and A.J. Mariano, 2002. Assimilation of drifter positions for the reconstruction of the Eulerian circulation field. *J. Geophys. Res.*, in press.