Assimilation of Lagrangian Data into an ocean model

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Assimilation of Lagrangian data in oceanography

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Within the framework of Global Ocean Data Assimilation Experiment (GODAE), an increasing amount of data are available. A crucial issue for oceanographers is to exploit at best these observations, in order to improve models, climatology, forecasts, etc. Thanks to the international program Argo and to more localized experiments, a new type of data is now available: positions of floats drifting at depth in the ocean. Unlike other data, mainly Eulerian, these ones are Lagrangian: the measuring instrument move in the flow. I will briefly described methods about 4D-Var assimilation of Lagrangian data in the OPAVAR ocean model, and show some results assessing the complementarity with temperature data.

1 Presentation of the Method

1.1 Introduction to Data Assimilation for geophysical fluids

Geophysical fluids are chaotic, and consequently show high sensitivity to initial conditions. In order to do accurate forecasts, we need a very accurate estimate of the initial state of the system. Data Assimilation (DA) covers all theoretical and numerical mathematical methods which allow us to combine, as optimally as possible, all sources of information (model equations and observations) in order to produce a good initial state. There exist two main approaches to DA: sequential methods (Kalman filtering) and variational methods (optimal control: 3D or 4D-Var). Our work is based on the 4D-Var method [1].
In practical, variational assimilation aims to solve the following inverse problem: compute the initial state of the fluid from the observations and the model equations. In the following section we will present the ocean model and the Lagrangian observations. The details of the Lagrangian 4D-Var method are described in [3].

1.2 Model and data

We use the LODYC's **OPAVAR** 8.1 Primitive Equations ocean model (see [2] and [4]). It is configured in a rectangular, flat bottomed, rigid-lid, mid-latitude beta-plane domain of 3600 $\times$ 2800 km (20 km horizontal resolution). The ocean is 5 km deep, it has 11 levels in the vertical, with level thickness increasing from 300 to 700 m. The wind forcing varies sinusoidally with latitude and drives double-gyre circulation. The other forcings are neglected.

Lagrangian data are the positions of drifting floats. Real drifting floats provide very diversified datasets: the time sampling period of observations could be short (6 hours) (e.g. acoustic floats) or long (5-10 days) (e.g. Argo, Med-Argo floats), they have different numbers of floats and horizontal spacings and different drift depth. So we do not use real but simulated drifting floats, so that parameters (time sampling period, drift depth, number of floats) can be chosen. The simulated positions $\xi(t) = (\xi^1(t), \xi^2(t))$ of floats drifting at fixed depth z_0 are solutions of the floats advection equation $\frac{d\xi}{dt} = \mathbf{U}(t, \xi(t), z_0),\ \xi(0) = \xi_0$ with $\mathbf{U}$ the horizontal velocity.

2 Numerical Results

The framework of the experiments is the following. First we choose a given output of the model (called *true state*) to simulate two datasets: the first one is the positions every day of 1 000 floats drifting at 1 000 meters depth during ten days, the second is the vertical temperature profiles of these same floats starting from 2 000 meters deep up to the surface, and also sampled once a day. Then we do four different experiments: no Data Assimilation (called the background state, which is our control run), assimilation of the positions only, assimilation of the profiles only, and assimilation of both profiles and positions.
Figure 1 shows horizontal outputs (just below the surface, 300 meters deep) for temperature and horizontal velocities for the true state, the background state (no assimilation) and the analyzed state (obtained after DA of vertical temperature profiles and Lagrangian positions). We can see that the DA is able to reconstruct correctly the main patterns of the flow.
Figure 2 shows relative errors (compared to the true state) of the four experiments described before. On the first line we compute the total relative error (i.e. the error on the whole 3D grid) as a function of time, and on the second line we compute the relative error as a function of the vertical level at final time (i.e. the error is computed at level 1 on the horizontal 2D grid, then at level 2, and so on), where level 1 is the surface and 10 the bottom. The blue curve is the background experiment

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(no assimilation) , the light blue curve represents the ”floats-positions-only” experiment, the red curve is the ”profiles-only” experiment and the green curve is the ”floats-positions-plus-profiles” experiment. What we can see from the first line is that it is necessary to have temperature data in order to reconstruct even the velocities, and that it is better (in order to get the velocities right) to get both temperature and positions data. The second line confirms this, showing a clear complementarity between temperature data (improving upper levels) and floats positions (improving lower levels).

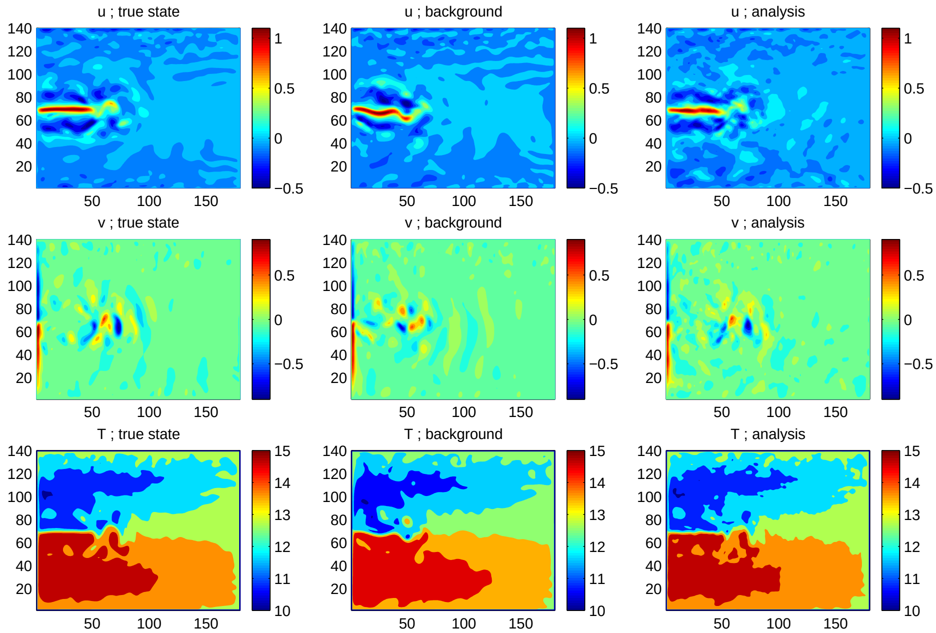

Fig. 1 Horizontal outputs of velocities and temperature

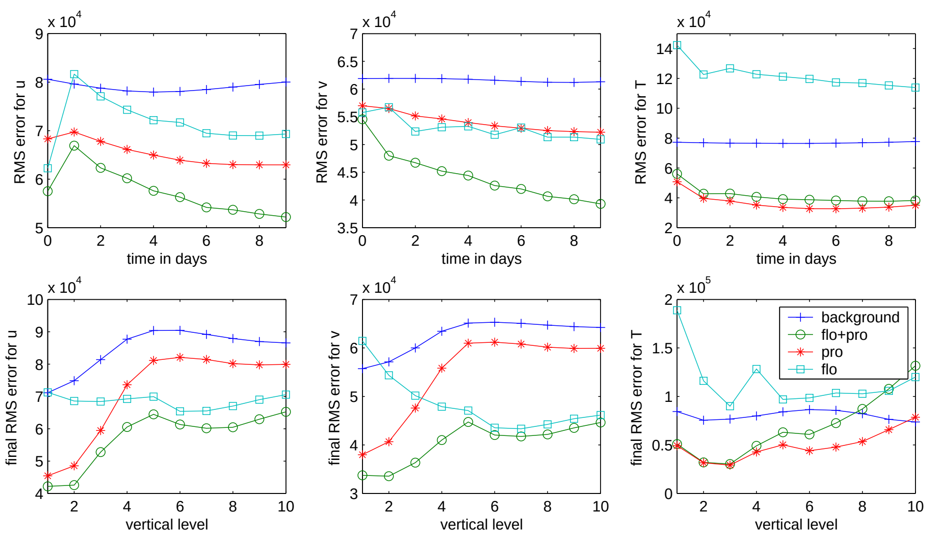

Fig. 2 Relative errors for velocities and temperature

References

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