COVARIANCE FUNCTIONS IN MULTIVARIATE ASSIMILATION SYSTEM WITH ENSEMBLE KALMAN FILTER

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1. Introduction

The results of data assimilation systems substantially depend on the determination of the error covariances of the first guess field (ECFG) [1]. In oceanographic applications, primarily due to the effect of coasts on the dynamics of processes developing in the ocean, ECFGs are non-homogeneous and anisotropic functions [5]. In general, these functions contain a multivariate component that plays an important role. It is responsible for transferring observational information between model variables, which is crucial for extracting information about unobserved variables from directly observed variables.

2. Ensemble Kalman filter

One of effective ways to take into account the above-mentioned features of ECFG in sequential data assimilation schemes is the widely-used local ensemble transform Kalman filter (LETKF), which can be implemented with PDAF software product [2, 3]; http://pdaf.awi.de).

The authors [4] studied the properties of LETKF used with the NEMO model on the base of several examples assimilating synthetic data. The properties of the analysis procedure can be most clearly illustrated using single-observation experiments [5]. It is known that the analysis increments corresponding to single observations are proportional to the ECFG on which the analysis is based.

3. Model configuration

Here we present such illustrations for the LETKF assimilation system, which uses the 4-th version NEMO model (Nucleus for European Models of the Ocean) coupled with the thermodynamic sea ice model SI3. The model uses the ORCA1 configuration with a global grid resolution of 1×1° (362×332 grid nodes) and 75 vertical levels [4]. The parameters of the LETKF were set to the following values: the ensemble has $N = 20$ members, the forgetting factor $\rho = 0.95$, the observations are weighted by the 5th-order polynomial with an influence radius of $R = 3.5°$.

4. Single-observation experiments

In the examples under consideration, the assimilation procedure was fed with isolated single observations of different variables in the form of their deviations from the first guess field (usually called innovations). The structure of the increments resulting from the procedure’s output gives a clear representation of the structure of the ECFG including its multivariate component. The Figure 1 shows the increments corresponding to innovations of sea level $\zeta = 10$ cm and of surface water temperature T_S=1°C located in different geographical areas. It is clearly seen that the structure of increments, and, consequently the ECFG, significantly depends on the geographical location.

There is also a close similarity between the shape of the sea level increments due to sea level innovations (Figure 1a) and to surface water temperature innovations (Figure 1b). This is explained by the fact that an increase in water temperature is accompanied by an increase in sea level ζ due to steric effects. For a typical value of the coefficient of thermal expansion of water $\alpha_T = 2{,}7\times10^{-4}$ K^{-1}, an increase in temperature by 1°C in the upper water layer of ~4 m corresponds to an increase of ζ by 1 cm that is in agreement with Figures 1a, b.

It should also be noted that in areas (regions 3, 4, 6, and 7 in Fig. 1b), where there are no significant temperature gradients or strong jet currents, the response to temperature changes reproduced by the assimilation system is weakly manifested, i.e., in regions with feeble dynamics, surface “delta-like observations” are weakened by the Kalman filter.

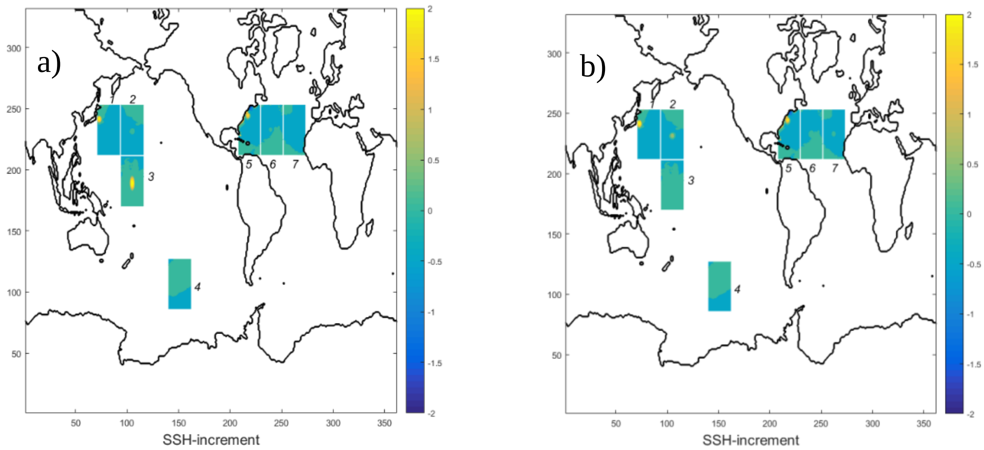

Figure 1. Sea level increments (in cm) corresponding to sea level innovations $\zeta = 10$ cm (a) and surface water temperature innovations $T_S = 1$°C (b) located in seven different geographical regions.

Similar features can be seen in the vertical distributions of the increments of other variables (water temperature, salinity and horizontal components of the current velocity), corresponding to innovations in sea level and surface water temperature. Like horizontal distributions, the vertical structure is characterized by significant inhomogeneity seen in significant differences from region to region, and anisotropy, manifested in noticeable differences between zonal and meridional distributions.

These features are most distinct in dynamically active areas: in the Kuroshio (region 1) and Gulf Stream (region 5). Besides, excluding the western part of the equatorial Pacific, velocity increments in the open ocean are significant only in the upper layer (~100m), while these increments are noticeably significant near the coastal regions to a depth of ~1500m and to a depth of ~ 2000m in the equatorial Pacific.

Thus, the results of experiments assimilating single observations using the local ensemble Kalman filter (LETKF) in the NEMO ocean model demonstrate the perspective of using PDAF for the assimilation of observational data in the NEMO model.

References:

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