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Reduction of the unstable subspace dimension by observational forcing in a data-assimilation system

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The recently developed assimilation in the unstable subspace (AUS) is applied to a quasi-geostrophic model in an adaptive observation configuration.

The estimate of the unstable directions, consistent with the stability analysis of the data assimilation system, is obtained by a modified breeding technique, (BDAS), that naturally incorporates the information on the observational network, the assimilation system and its dynamical instabilities.

The ability of the BDAS technique to estimate the actual unstable modes of the assimilation system and the efficiency of the dynamically based assimilation (AUS) are demonstrated.

The key to this success is in the mutual enhancement of two beneficial effects obtained by:

-the strategy of observing the most unstable components of the data-assimilation system (BDAS);

-the effective reduction of the error in the unstable subspace achieved by the assimilation (AUS).

This is because, when errors in the unstable directions are efficiently reduced, the error becomes smaller and behaves more linearly. Therefore, the unstable directions themselves become more representative of the actual error, the unstable structures take a longer time to build up and a smaller number and lower frequency of observations becomes sufficient to control their growth.

As predicted by the theory, the observational forcing reduces the dimension of the unstable subspace and stabilizes the assimilation system. Results show that the number

of observations needed to stabilize the system is related to the instability properties of the free system, that is to the number and growth rate of the unstable modes.