Geophysical Research Abstracts
Vol. 15, EGU2013-5524, 2013
EGU General Assembly 2013

A new Approach to Estimate Initial Condition Uncertainty Structures in Mesoscale Models

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The assessment of uncertainties in the initial conditions for the numerical weather prediction is a main focus of ensemble data assimilation. A variety of different methods has been developed, e.g. the ensemble Kalman filter. A new approach to the estimation of fast growing error modes in the evolution of dynamical systems like numerical weather forecast models is based on the breeding of growing modes method (abbr. breeding). One advantage of the breeding technique is that no a priori information of the errors in model or background are needed. The method rather directly estimates the fastest-growing error modes related to the Lyapunov vectors of the dynamical system. In the conventional breeding method, a control run and perturbed ensemble members are integrated from one analysis time step to the next using the full non-linear model. Then, the increase in perturbation amplitude is measured and used to rescale the perturbations to the initial size and add them to the new analysis. However, when applying this technique to high-resolution limited-area models, the perturbations are quickly transported out of the domain and do therefore not have sufficient time to evolve into reliable assessments of atmospheric uncertainty structures.

The proposed technique – called self-breeding – uses no analysis state but only the control run as a reference and is therefore not restricted to certain, usually long time intervals between the analyses. This has proven to be beneficial regarding the implementation of breeding in limited-area models as the uncertainty structures can build up much faster compared to the conventional method.

Two variations of self-breeding are proposed: progressive and stationary. While the progressive variant is similar to classical breeding but makes use of much shorter rescaling intervals, stationary self-breeding applies the integration and rescaling to the same time period repeatedly. This can be used to target specific situations or events and to assess the corresponding uncertainty structures.

Through the use of diverse norms for the measurement of the perturbation growth and different rescaling interval lengths, the technique also allows for the estimation of uncertainty patterns related to specific phenomena like convection, turbulence or fronts.

Both a stationary and a progressive self breeding are implemented in a limitred-area, mesoscale NWP model. In several case studies (e.g., fronts, inversions, air mass convection) we present applications of the self-breeding technique to identify uncertainty structures on different temporal and spatial scales.