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A modal view of atmospheric predictability

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The normal-mode framework is developed for the representation of time-averaged and time-dependent structures of the global forecast errors. The applied methodology provides an attractive way to quantify the balance by splitting the forecast-error variances into parts projecting on the balanced and inertio-gravity (IG) circulations. The main difference between the normal-mode function expansion and the conventional approach to balance diagnosis in terms of vorticity and divergence is the simultaneous analysis of mass wind field in the normal-mode case, which allows a more complete physical interpretation of the balance. The approach is particularly suitable for the tropics where the IG circulation dominates on all scales and where the short-range forecast errors are largest.

This paper would present results from operational NWP and idealized data assimilation and ensemble forecasting experiments to show some important characteristics of the global forecast errors. In particular, the ECMWF 4D-Var ensemble is characterized by around 50% of the global forecast-error variance being unbalanced. The forecast-error variance growth between 3-hr and 12-hr range is substantially different in the balanced, eastward-propagating and westward-propagating IG modes. The balanced mid-latitude variance growth dominates while the variance growth in the IG modes is the most significant in the large-scale equatorial Kelvin waves. Results from the 4D-Var ensemble data assimilation are further complemented with the modal analysis of the operational 50-member ensemble to present the development of ensemble spread in the modal space. Finally, results from the ECMWF system are contrasted with the outputs from a perfect-model ensemble data assimilation experiment which assimilated globally homogeneous observations of dynamical variables by using the ensemble adjustment Kalman filter in the Community Atmosphere Model (DART/CAM).