INTERNATIONAL PACIFIC RESEARCH CENTER
IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAI'I AT MĀNOA

Intrinsic versus Practical Limits of Multi-Scale Atmospheric Predictability

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Abstract:

This presentation summarizes our recent findings on the limits of intrinsic versus practical predictability of multi-scale severe weather phenomena ranging from tornadic thunderstorms, hurricanes and winter cyclones through convection-permitting real-data case simulations and idealized "identical-twin" experiments. We seek to understand both the intrinsic limits of predictability of such severe weather events under nearly perfect initial conditions given a nearly perfect forecast model, and the practical limits of predictability given the current level of (practically large) uncertainties in the forecast model and initial conditions. Highlights will be given to the multi-scale error growth dynamics within idealized baroclinic waves with varying degree of convective instabilities. In the dry experiment free of moist convection, error growth is controlled primarily by baroclinic instability under which the forecast accuracy is inversely proportional to the amplitude of the baroclinically unstable initial condition error (and thus predictability can be continuously improved without limit through reducing the initial error). Under the moist environment with strong convective instability, rapid upscale growth from moist convection will lead to the forecast error being increasingly less sensitive to the scale and amplitude of the initial perturbations when the initial error amplitude is sufficiently small; this will ultimately impose a finite-time barrier to the forecast accuracy (limit of intrinsic predictability). However, if the initial perturbation is sufficiently large in scale and amplitude (which is likely the case for most current-day operational models), the baroclinic growth of large-scale finite-amplitude initial error will control the forecast accuracy at all scales for both dry and moist baroclinc waves; forecast accuracy can be improved (and thus limit of practical predictability can be extended) through reduction of initial condition errors, especially those at larger scales. The error growth characteristics derived from idealized baroclinic jet-front system have more recently been validated with a series of extremely high resolution ensemble and sensitivity simulations of real-world events using the ECMWF's 9-km operational global prediction system.