The influence of the spatial scale of initial-condition errors on atmospheric predictability

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Abstract:

One important limitation on the accuracy of weather forecasts is imposed by unavoidable errors in the specification of the atmosphere's initial state. Much theoretical concern has been focused on the limits to predictability imposed by small-scale errors, potentially even those on the scale of a butterfly. Very modest relative errors at much larger scales may nevertheless pose a more important practical limitation. We demonstrate the importance of large-scale uncertainty by analyzing ensembles of idealized simulations of mesoscale convective systems. We consider several environments with different low-level shears and pairs of ensembles with equal amplitude large- or small-scale perturbations in the surface moisture.

As foreshadowed by results obtained with a simple barotropic model in a largely overlooked section of Lorenz's classic 1969 paper "The predictability of a flow which possesses many scales of motion," equal-amplitude initial perturbations at wavelengths of 8 and 128 km produce identical losses of predictability after five hours of simulation. These results imply that minimizing initial errors on scales on the order of 100 km is at least as likely to extend the accuracy of forecasts at lead times longer than 4-5 hours than potentially expensive efforts to minimize initial errors on much smaller scales.

These simulations also demonstrate that convective systems, triggered in a horizontally homogeneous environment with no initial background circulations, can generate a background mesoscale kinetic energy spectrum with a slope proportional to the -5/3 power of the wave number, similar to that observed in the atmosphere. The horizontally divergent and rotational parts of the kinetic energy spectrum are examined along with their relative contributions to the -5/3 spectrum.