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Atmospheric predictability at synoptic versus cloud-resolving scales

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The development of high-resolution (cloud-resolving) NWP models and their associated short-range ensemble prediction systems raises a series of fundamental questions concerning the type of error growth and the validity of the tangent-linear approximation. To address these issues, a comparison between perturbed medium-range (10 day) synoptic-scale integrations (taken from the operational ECMWF EPS with a horizontal resolution of about 80 km) and short-range (1 day) high-resolution simulations (based on the non-hydrostatic COSMO model with a grid spacing of 2.2 km) is conducted.

Detailed analysis is performed of the growth rates (expressed in terms of doubling time) and the validity of the tangent-linear approximation (expressed in terms of tangent-linear time scale). We find error doubling times of 40 h and 4 h for the ECMWF and COSMO systems, respectively. This difference (a ratio of 10) is consistent with the baroclinic and convective growth rates at work. In terms of perturbation growth rates, a 10-day synoptic-scale integration may thus be seen to correspond to a 1-day cloud-resolving forecast. However, in light of the tangent-linear approximation, the two systems appear to differ much more strongly: We find tangent-linear time scales of 54 h and 1.5 h for ECMWF and COSMO, respectively (yielding a ratio of 36). In terms of nonlinearity, a 10-day synoptic-scale forecast thus equates to a cloud-resolving simulation with a lead time of merely 7 hours.

The results thus indicate that integrating a cloud-resolving forecasting system for 1 day is a fundamentally different task than performing a 10-day synoptic-scale simula-

tion (despite the corresponding scaling of the perturbation growth rates). In a cloud-resolving system, the linear relationship between initial and future states is lost much faster. The higher degree of nonlinearity associated with cloud-resolving simulations, even in a non-dimensional sense, may deteriorate the optimal performance of techniques relying on the tangent-linear approximation. This situation will likely affect the design of future assimilation and ensemble prediction systems.