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# Cloud-resolving Models: the Linearity Trap

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It is well recognized that the atmosphere is a highly nonlinear and chaotic dynamical system. Nevertheless linear methodologies, in particular the tangent-linear approximation, play a vital role in current numerical weather prediction systems. Important applications include 4-dimensional variational data assimilation methodologies, and the use of singular vectors in the generation of ensembles. The validity of the underlying assumptions is well established for the synoptic scale, but largely untested in the context of cloud-resolving models.

Here we assess the validity of the linearity assumption for short-range cloud-resolving NWP systems. To this end, we conduct high-resolution ensemble simulations of three selected cases from the Mesoscale Alpine Programme (MAP). We are using a compressible non-hydrostatic model at a horizontal resolution of 2.2 km. The computational domain covers the entire Alpine region with 401x301x45 gridpoints. Ensemble integrations are used to investigate the propagation and growth of initial perturbations within this system. Results show: (1) Perturbation growth may be associated with horrific growth rates (doubling times in the order of a few hours), which may rapidly disrupt predictability. This behavior derives from the combination of two factors: the rapid propagation of perturbations (mostly through sound and gravity waves), and the effective triggering of moist convective cells. The resulting disruption of predictability may be highly relevant for practical forecasting applications . (2) Analysis of different simulations demonstrates that the validity of the tangent linear approximation is usually lost within a few hours. This result has important implications for cloud-resolving ensemble prediction systems: It questions the use of 4-dimensional variational data assimilation methodologies, and indicates that the generation of optimal initial perturbations for ensemble prediction systems is a challenging task. However, results also indicate that a comparatively small number of almost arbitrarily generated ensemble members may be sufficient to estimate the ensemble spread.