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Amplification of forecast errors in a quantitative PV framework

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Mid-latitude weather systems and high-impact weather events are often related to Rossby wave patterns near the tropopause. Their predictability is thus associated with the predictability of the tropopause development. The correct representation of this tropopause development, however, remains still an issue for medium-range weather forecasts.

Insight into the dynamics of forecast errors near the tropopause can be gained from the potential vorticity (PV) perspective. PV errors concentrate along the dynamical tropopause and often amplify within the near-tropopause Rossby wave patterns. Previous studies indicate the importance of specific processes such as baroclinic instability or diabatic processes to synoptic-scale error growth. The relative importance of the individual processes has, however, not been quantified yet.

We consider a PV-error budget equation to examine the error evolution near the tropopause. Based on this equation, the following four processes are identified: near-tropopause dynamics (influence of upper-level PV anomalies), tropospheric-deep interaction (influence of lower-level PV and potential temperature anomalies), upper-tropospheric divergence (mostly related to latent heat release below), and direct diabatic PV modification. Importantly, we focus here on the further amplification of preexisting errors and not on the origin of errors.

Error growth is analyzed for case studies from the operational ECMWF model, including one case related to a high-impact weather event in Sardinia and one case from the NAWDEX (North Atlantic Waveguide and Downstream Impact Experiment) campaign. In these cases, error growth is dominated by the contribution of near-tropopause dynamics, which highlights the importance of (nonlinear) Rossby wave dispersion to error growth. Significant contributions of tropospheric-deep interaction and upper-tropospheric divergence are associated with a misrepresentation of a surface cyclone. These contributions are, in general, of smaller importance to error growth than near-tropopause dynamics.