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The Role of Diabatic Processes in Explosive Cyclogenesis over the Eastern Atlantic Ocean and Western Europe

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A special version of the surface pressure tendency equation (SPTE), which allows for the separation into dynamical and thermodynamical contributions, is applied to five intense European winter storms: Lothar and Martin (both in December 1999), Kyrill (January 2007), Klaus (January 2009) and Xynthia (February 2010). The SPTE contains contributions from the geopotential height change at the upper boundary of the vertical column (DPHI), the impact of the vertically integrated temperature tendency (ITT), and net mass loss (increase) by surface precipitation (evaporation). Without net evaporation/precipitation and temperature changes, a descent of the upper boundary (DPHI) will cause a surface pressure fall due to dynamical mass evacuation and vice versa. If the upper boundary (DPHI) remains constant, warming results in expansion of the air column and therefore in a mass loss (negative ITT, i.e. pressure fall). In reality a combination of the above-described processes are found. The ITT term can be further separated into the effects of horizontal temperature advection (TADV), vertical motions (VM), diabatic heating (DIAB) and a term HUM that reflects impact of the vertical redistribution of water vapour on the surface pressure, neglecting the solid and ice phases. The term DIAB contains the influence of the diabatic processes, such as radiative warming/cooling, latent heat release due to condensation, diffusion and dissipation. Because of the lack of the diabatic heating profiles in the ERA-Interim analysis, DIAB has to be calculated as the residuum of the SPTE, neglecting the HUM term.

Results show that, with the exception of Xynthia, all storms underwent explosive cyclogenesis when they crossed the strong polar jet from the equatorward to its poleward flank. Xynthia developed in a favourable upper-level divergence environment as a consequence of a split jet structure. These are well-known dynamical factors favoring explosive cylcogenesis. During this process, but also before and after, the observed storms show different fractional contribution of diabatic processes (DIAB) to the surface pressure drop. Lothar, Klaus and Xynthia had up to a 60% share of the DIAB term to the surface pressure fall, the remaining fraction coming from warm TADV. This fraction was lower for Martin and Kyrill (around 30%). The absolute value of the equivalent-potential temperature at 850 hPa in the warm sector does not necessarily imply a high fractional contribution of DIAB (e.g. latent heat release) to the surface pressure fall. This is due to the fact that vertical motions counteract the falling tendency, imposed both by positive DIAB and warm TADV. The SPTE has the advantage to allow for the assessment of all terms from a three-dimensional analysis. Thus, this diagnostic tool enables a new look into the role of diabatic processes in explosive cylogenesis in model and analysis data.