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Diagnosing the Influence of Diabatic Processes on the Explosive Deepening of Extratropical Cyclones over the North Atlantic Ocean

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The relative roles of baroclinic and diabatic processes for explosive deepening of extratropical cyclones have been debated for a long time, mostly on the basis of case studies. Here we present a powerful diagnostic approach to the problem, which is based on a combination of an automatic cyclone tracking with a special version of the classical pressure tendency equation (PTE) that relates changes in surface pressure to contributions from horizontal and vertical temperature advection as well as diabatic processes, i.e. mainly latent heat release in clouds. Along the entire track of a cyclone, the PTE is evaluated in a 3°x3° box from the surface to 100 hPa centred on the location the storm is moving to within the next time step. The great advantage of this new approach is the easy applicability to large gridded datasets, even if diabatic tendencies are not explicitly available as in many reanalysis products.

The strengths and limitations of the method are illustrated here through application to several explosively deepening, damaging winter storms over the North Atlantic Ocean. Data used are 6-hourly ERA-Interim re-analyses. For better interpretation of the results, the PTE analysis is complemented with other classical cyclogenetic factors, i.e. the strength of the polar jet and the equivalent-potential temperature θe at 850 hPa in the warm sector. The main conclusions from this analysis are:

• The time evolutions of the actual core pressure of the storm and the 6-hourly pressure changes in the moving box used to evaluate the PTE show structural similarities that are dominated by the explosive deepening.
• The vertical advection term is positive throughout the entire lifecycle of all storms indicating the dominance of ascent downstream of the cyclone center. It is (over-) compensated by negative contributions through warm advection and diabatic heating.
• Storms “Martin” and “Kyrill” are dominated by baroclinic processes with contributions of diabatic processes to the total negative tendencies of around 30%.
• Despite comparable jet strengths, similar tracks relative to the jet, and equally high θe values at 850 hPa in the warm sector, storms “Lothar” and “Klaus” show much larger contributions from diabatic heating to the deepening of around 60%.
• Storm “Xynthia” stands out as a system with an unusual SW–NE track into Europe, which appears to have benefited from a complicated split jet structure in the later development stages. It is associated with high θe values and shows very large diabatic contributions.

In the long run, the PTE analysis will be applied to longer timeseries from both reanalysis and climate model data to generate robust statistics across a broader range of cyclone intensities and development types. This will for the first time allow a systematic investigation of the relative contribution of diabatic processes to storm intensification in recent and future climate conditions.