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The Role of the Stratosphere in Explosive Deepening of Extratropical Cyclones

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Using a combination of an automatic cyclone tracking method and a special version of the classical pressure tendency equation (PTE), changes in surface core pressure of extra-tropical cyclones can be related to contributions from horizontal temperature advection, vertical motion and diabatic processes, i.e. mainly latent heat release in clouds. Here, the PTE is evaluated in 3°x3° boxes located over the cyclone positions at 6-hourly basis, thus following the movement of a given storm at each time step. PTE calculations are performed from the surface to 100 hPa. Previous work has shown that this approach can be used to quantify the contribution of diabatic processes to cyclone deepening in an automated way, and can easily be applied to large gridded datasets, in this case ERA-Interim reanalyses.

In order to close the mass budget in the PTE, geopotential height tendencies at the upper integration boundary (usually 100 hPa) need to be taken into account. Older studies have assumed this term to be negligible, and this has been confirmed with modern re-analysis data for many explosively deepening storms. However, some historical storms show a remarkable contribution from this term, indicating a substantial warming of the levels above 100hPa. An outstanding example is the Braer Storm of January 1993, which reached a record minimum core pressure of 914 hPa near Iceland. A stepwise increase of the upper integration boundary reveals that substantial geopotential height tendencies reach above 1 hPa. This unusual behaviour appears to be related to the propagation of a deep planetary wave trough from North America towards the North Atlantic basin. A similar but somewhat less dramatic behaviour was found for cyclone Wiebke. Another interesting example is storm Emma, which managed to sustain substantial deepening rates despite adverse positive geopotential height tendencies at 100 hPa.

Future work will include a more robust statistical analysis of this problem and a better understanding of the nature and physical mechanism of the stratospheric influence on explosive cyclogenesis.