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Baroclinic initial-value problems with moisture

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Extra-tropical cyclones are of great importance to weather forecasting in the mid-latitudes. The observed behaviour can be simulated well by numerical weather prediction models, to the extent that storm forecasts are reliable for lead times out to a week. However, these numerical solutions cannot always be explained by existing theory. Two aspects are discussed.

The linear evolution of baroclinic systems (on any zonal jet) can be viewed as an interaction between two counter-propagating Rossby waves (CRWs). CRWs are generalisations of the well-known Rossby edge waves that play a role in the Eady model of baroclinic instability. However, part of general initial conditions does not project on to the CRWs. To account for such general initial conditions the CRW-framework has recently been extended. The key result is that the residual potential vorticity (PV) (left after subtracting the projection onto CRWs) to a large extent is simply advected by the zonal flow, giving rise to the "passively advected residual PV (PAR-PV) approximation". Examples are shown where the PAR-PV approximation accurately describes the evolution. In these cases it constitutes a significant reduction of the degrees of freedom. Some limitations of the PAR-PV approximations are also discussed.

A vital step in extending the CRW-description to real cyclone cases, is the inclusion of moist processes. The theory above could deal with a situation where PV anomalies have been created diabatically and then evolve as if dry. However, realistically condensational heating continues to modify PV in time. The simplest parametrisation relates heating to vertical velocity on the premise that ascending air saturates rapidly and experiences latent heat release. Two types of parametrisation have been investigated in the context of a simple baroclinic model: wave-CISK and large-scale rain. It is shown how the CRW-framework and the theory of the PAR-PV approximation can be extended to account for diabatically generated PV anomalies. The latent heat release effectively creates two new Rossby wave components, one focused in the lower troposphere and the other aloft. These structures propagate in a similar way as the dry CRWs on what could be interpreted as the diabatically induced PV gradient. Coupling can in principle occur between any pair of waves that have opposing phase speeds. Various parameter regimes are discussed where the growing baroclinic waves are structurally and energetically very dissimilar.