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Nonlinear moist sensitivity of baroclinic systems

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The development of atmospheric perturbations is primary driven by baroclinic instability processes. However water vapour may play an important role in the formation of intense storms through the release of latent heat by large-scale precipitation. The paradigm of the diabatic Rossby wave (i.e. a baroclinic Rossby wave driven by latent heat release) has been invoked to explain why some intense storms (such as the European storms of December 1999) develop only in presence of water vapour. The processes involved in this dynamics are not completely understood yet. We investigate the mechanisms leading to the predictability of moist synoptic perturbations, and in particular the interaction between baroclinic and moist processes. Our aim is to understand how the spatial distribution of water vapour relatively to the characteristics of the large-scale jet affects the growth rate of synoptic perturbations.

For this purpose, we use a nonlinear optimization technique for determining the optimal water vapour distribution of the basic state giving rise to the largest growth of perturbations. The algorithm consists in maximizing the growth of dry perturbations with a given initial energy and for a given time interval in regards to the initial dry perturbation fields and to the initial basic state water vapour. Primitive-equation simulations show that there is no need to saturate the whole atmosphere to obtain the largest perturbation growth. Only a small area in the warm conveyor belt of the cyclone is important to double the amplification in energy of the perturbations. Results show a major impact of latent heat release processes for these optimal perturbations and a strong dependence on the sign of the perturbations indicating strong nonlinearities. Interpretation in terms of coupling between temperature and moisture transport is proposed.