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Nonlinear moist sensitivity of baroclinic systems

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The development of midlatitude synoptic perturbations is primarily driven by baroclinic instability. Water vapour, which is absent from the standard model of baroclinic instability, 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) seem to be able to develop only in presence of water vapour. The processes at play in those situations are not completely understood yet. We investigate the mechanisms leading to the development of moist synoptic perturbations, and in particular the interaction between baroclinic and moist processes.

We compute the Conditional Nonlinear Optimal Perturbations of a primitive-equation model in order to determine the water vapour distribution of the basic state that leads to the largest growth of errors in the forecast. The maximization of the growth is performed, for given initial energy and time interval, with respect to both the initial perturbation fields and the initial basic state water vapour.

Results show that there is no need to saturate the whole atmosphere to obtain the largest perturbation growth. Saturation of only a small area in the warm conveyor belt of the cyclone below 750 hPa suffices to double the energy of the perturbations. Results show a major impact of latent heat release in the development of these optimal perturbations and a strong dependence on the sign of the perturbations, indicating significant nonlinearities. A physical interpretation, in terms of coupling between temperature and moisture transport within the perturbations, is proposed.