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Toward a better understanding of explosive cyclogenesis: a potential vorticity view on optimal perturbation evolution

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It needs no further introduction that observed cases of explosive cyclogenesis often can be traced back to a well identifiable precursor disturbance, which via significant structural changes causes the rapid surface development. The work of Farrell on optimal growth and non-modal waves has emphasized the importance of these structural changes and of growth mechanisms differing from traditional normal-mode baroclinic instability to cyclogenesis. Nevertheless, fundamental understanding of the optimal perturbation evolution in terms of underlying (potential vorticity) dynamics is lacking.

We partially fill in the gap by investigating the mechanisms behind the growth and the propagation of optimal perturbations for a class of quasi-geostrophic models (two-layer Eady models on the f- or β-plane). These mechanisms can be made transparent by using potential vorticity as the fundamental quantity. Fairly general Green function techniques have been developed, which allow an otherwise difficult to realize, unambiguous partitioning of the different aspects of the optimal perturbation development and include the continuous spectrum in a natural way.

Results indicate that traditional normal-mode instability is unimportant for the optimal perturbations. Instead, the main cause for the explosive surface development is a resonance, which occurs between interior potential vorticity anomalies and edge waves propagating along the lower boundary.