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Optimal Perturbations Triggering Weather Regime Transitions: Onset of Blocking and Strong Zonal Flow

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In this talk we address the following question: assuming that we have some information on the initial perturbations, e.g. they belong to an ensemble, which consists of the perturbations whose magnitudes are less than a given value, how to find out the perturbations belonging to this ensemble and triggering the blocking and strong zonal flow onset. Applicability of linear singular vectors (LSVs) and conditional nonlinear optimal perturbations (CNOPs) is investigated by a T21L3 quasigeostrophic (QG) model and its tangent linear and adjoint versions. Particular attentions are focused on the roles of nonlinear processes and the importance of choosing a proper objective function.

LSVs stand for the fastest growing perturbations when the evolutions of the initial perturbations are well-described by the tangent linear version of the nonlinear model. CNOP is a natural generalization of LSV into the nonlinear category, which is the initial perturbation whose nonlinear evolution attains the maximum of the objective function at a prescribed forecast time under some initial constraint conditions. The results of this research show that in some cases for the given initial ensemble perturbations, when CNOP triggers a transition to some weather regime, whereas, LSV may not generate such a transition, which shows that nonlinear advection processes are fundamental for studying the weather regime transitions in the medium range.

By choosing two objective functions and investigating the resulted CNOPs, it is found that CNOP obtained from the objective function of blocking-index form (Type1-CNOP) may trigger a transition to a blocking or strong zonal flow regime under some circumstances, whereas the CNOP related to the streamfunction squared norm (Type2-CNOP) fails to yield such a corresponding transition. This demonstrates the importance of selecting a proper objective function when aiming at finding the perturbations yielding such a transition.

The mechanism of blocking onset triggered by perturbations is also explored. It is shown that the approach of Type1-CNOP remains a viable tool to capture the spatial structure of initial perturbations that trigger a blocking onset. The planetary-scale projection of the nonlinear interaction of such initial perturbations contributes to the amplification of the blocking downstream, and then triggers blocking onset according to Luo et al. (2001) and Luo (2005).