Geophysical Research Abstracts
Vol. 20, EGU2018-14876, 2018
EGU General Assembly 2018

Covariant Lyapunov vectors of a quasi-geostrophic baroclinic model: analysis of instabilities and feedbacks

Sebastian Schubert (1) and Valerio Lucarini (1,2,3)

(1) University Of Hamburg, Meteorological Institute, Hamburg, Germany (sebastian.schubert@uni-hamburg.de), (2) Department of Mathematics and Statistics, University of Reading, UK, (3) Centre for the Mathematics of Planet Earth, University of Reading, UK

The classical approach for studying atmospheric variability is based on defining a background state and studying the linear stability of the small fluctuations around such a state. Weakly nonlinear theories can be constructed using higher order expansion terms. While these methods undoubtedly have great value for elucidating the relevant physical processes, they are unable to follow the dynamics of a turbulent atmosphere. We provide a first example of the extension of classical stability analysis to a nonlinearly evolving quasi-geostrophic flow. The so-called covariant Lyapunov vectors (CLVs) provide a covariant basis describing the directions of exponential expansion and decay of perturbations to the nonlinear trajectory of the flow. We use such a formalism to re-examine the basic barotropic and baroclinic processes of the atmosphere with a quasi-geostrophic beta-plane two-layer model in a periodic channel driven by a forced meridional temperature gradient ΔT. We explore three settings of ΔT, representative of relatively weak turbulence, well-developed turbulence and intermediate conditions.

We construct the Lorenz energy cycle for each CLV describing the energy exchanges with the background state. A positive baroclinic conversion rate is a necessary but not sufficient condition for instability. Barotropic instability is present only for a few very unstable CLVs for large values of ΔT. Slowly growing and decaying hydrodynamic Lyapunov modes closely mirror the properties of the background flow. Following the classical necessary conditions for barotropic/baroclinic instability, we find a clear relationship between the properties of the eddy fluxes of a CLV and its instability. CLVs with positive baroclinic conversion seem to form a set of modes for constructing a reduced model of the atmospheric dynamics.