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A modal view of atmospheric variability

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Eigensolutions of the linearized primitive equations, known as normal modes, have been in use for almost forty years. In particular, their application has been extensively pursued in eighties through the development of the nonlinear normal-mode initialization for numerical weather prediction. In addition, global horizontal structures of normal modes, known as Hough functions, have been used to identify the large-scale structure of some of the leading balanced (quasi-rotational or Rossby type) modes in the atmosphere. However, the main application of normal modes with respect to observations has been in the Tropics; here, the Kelvin, the mixed Rossby-gravity and the equatorially trapped Rossby and inertio-gravity (IG) modes with the lowest meridional mode have been associated with the most energetic modes of variability in both the atmosphere and the ocean.

Recently an application of 3D-orthogonal normal-mode function (NMF) formulation has been revived focusing on model levels in order to analyze in details data assimilation systems and analysis datasets (e.g. Zagar et a., 2013). A goal is to quantify the unbalanced component of global circulation and its role in data assimilation and predictability. Namely, today's global observing systems, data assimilation modelling and reanalysis datasets have reached a resolution and stage which allow realistic representation of gravity waves. The applied modal analysis provides an attractive way to quantify the IG component by splitting circulation into parts projecting on the vorticity-dominated and divergence-dominated (IG) components. The approach is particularly suitable for the tropics where the IG circulation dominates on all scales. Three-dimensional orthogonality allows quantification of energy in each horizontal and vertical scale and mode type therefore filtering the IG circulation, its variability and its comparison between reanalyses and climate models.
I would presents the modal view of time-averaged and time-dependent properties of large-scale circulation based on ERA-Interim reanalysis. In particular, I would discusses variability in the most energetic IG mode, the Kelvin wave, on the interannual and decadal time scales, and variability of tropical IG circulation as whole. The interpretation of extra-tropical variability modes in the modal space is also discussed. Results are furthermore provided based on a comparison between ERA-Interim reanalyses, ECMWF 20-century simulation and a climate model to illustrate the potential of normal modes as a verification tool for dynamical properties of climate models.