Propagating annular modes

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The leading "annular mode", defined as the dominant EOF of surface pressure or of zonal mean zonal wind variability, appears as a dipolar structure straddling the mean midlatitude jet and thus seems to describe north-south wobbling of the jet latitude. However, extratropical zonal wind anomalies frequently tend to migrate poleward. This behavior can be described by the first two EOFs, the first (AM1) being the dipolar structure, and the second (AM2) having a tripolar structure centered on the mean jet. Taken in isolation, AM1 thus describes a north-south wobbling of the jet position, while AM2 describes a strengthening and narrowing of the jet. However, despite the fact that they are spatially orthogonal, and their corresponding time series temporally orthogonal, AM1 and AM2 are not independent, but show significant lag-correlations which reveal the propagation.

The EOFs are not modes of the underlying dynamical system governing the zonal flow evolution. The true modes can be estimated using principal oscillation pattern (POP) analysis. In the troposphere, the leading POPs manifest themselves as a pair of complex conjugate structures with conjugate eigenvalues thus, in reality, constituting a single, complex, mode that describes propagating anomalies. Even though the principal components associated with the two leading EOFs decay at different rates, each decays faster than the true mode. These facts have implications for eddy feedback and the susceptibility of the mode to external perturbations. If one interprets the annular modes as the modes of the system, then simple theory predicts that the response to steady forcing will usually be dominated by AM1 (with the longest time scale). However, such arguments should really be applied to the true modes. Experiments with a simplified GCM show that climate response to perturbations do not necessarily have AM1 structures. Implications of these results for stratosphere-troposphere interactions are explored. The POP structures are shown to be independent of any weighting (unlike the EOFs, the structures and time scales of which change substantially with pressure weighting), a fact that is particularly important for a deep system such as the troposphere and stratosphere. The structure and time evolution of coupled modes of the troposphere-stratosphere system are studied.