Polar-tropical coupling in the winter stratosphere

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A distinct pattern of enhanced equatorial potential vorticity gradients during QBO westerly anomalies, enhanced subtropical gradients during QBO easterlies, is used to motivate a new formulation of dynamical coupling between the tropics and winter polar vortex based on the remote transfer of a finite amplitude wave activity that is defined in terms of lateral potential vorticity displacements. While weak potential vorticity gradients in the surf zone imply laterally evanescent Rossby waves, transfer of wave activity from the polar vortex edge to the subtropical barrier or to the QBO westerly phase equatorial gradients arises from nonlocality of potential vorticity inversion and the large horizontal displacements of the vortex edge. Of importance is the intrinsic nonlinearity of the coupling, whereby wave transfer is enhanced for large amplitude waves due to the increased proximity of vortex edge to the subtropics. Additionally, geometric factors imply an enhanced transfer of wave activity from the planetary scale to synoptic scale. Our approach goes beyond the traditional description of the effect of QBO wind anomalies on linear wave propagation through the stratosphere via wave reflection at the zero wind line; linear wave theory is appealing but neglects the long horizontal and vertical wavelengths involved and the inhomogeneous background potential vorticity. A particular issue of outstanding interest is whether and how the relatively shallow QBO anomalies can influence the deep vertically propagating waves on the edge of the winter stratospheric polar vortex. Process studies with a mechanistic model with prescribed QBO and carefully controlled high-latitude wave forcing are analyzed, guided by a reexamination of meteorological reanalysis, to address how such a dynamical linkage may influence, in particular, the resonant excitation of the winter vortex and the occurrence of vortex-splitting sudden warming events. We quantify the associated transfer of wave activity from vortex edge to the tropics, consider under what conditions this becomes a significant source of easterly momentum in the driving of the QBO itself, and how the structure of the Brewer-Dobson circulation varies in response to the location of the QBO westerly winds in any given winter.

Key words: QBO, potential vorticity, wave propagation, dynamical coupling