Comments on "Stratospheric Long Waves: Comparison of Thermal Structure in the Northern and Southern Hemispheres"

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In their analysis of Selective Chopper Radiometer data Leovy and Webster (1976) emphasize that the temperature perturbations associated with planetary waves in the stratosphere move eastward during periods when their amplitude attains its greatest values. As a possible explanation for the correspondence between eastward motion and large amplitude they suggest the interaction between eastward traveling normal modes and forced stationary modes. While it may be desirable to describe this phenomenon in terms of known components, it is not necessary to make such an interpretation and, as will be noted here, it is possible to understand these observations in purely mechanistic terms.

A fundamental explanation can be founded in the established relationship between westward slope of the height field and both upward energy flux and conversion from mean to eddy potential energy by planetary waves in the westerlies. This relation arises from the nearly hydrostatic and geostrophic nature of planetary waves and was first pointed out by Eliassen and Palm (1960) for stationary waves, but should be qualitatively correct more generally for planetary waves in the stratosphere. An incipient disturbance may experience a 180° westward phase shift between the troposphere and the top of the stratosphere. Associated with this structure are an upward flux of energy by the pressure interaction mechanism and, if the zonal wind increases with height, a conversion from mean to eddy potential energy. These two energy sources support the growth of the wave in the stratosphere. If this structure were maintained, the wave would continue to grow until it completely altered the mean flow (a major warming?) or until it reached an equilibrium between its energy sources and its energy sinks due to barotropic exchange and to dissipation. What is most commonly observed, however, is that the wave grows for a time but almost simultaneously reduces its own growth rate by altering its structure. The most natural way for this to be accomplished is for the portion of the wave in the stratosphere to move eastward relative to the portion in the troposphere until the height field of the wave no longer has any slope in the vertical. In this configuration the upward flux and baroclinic conversions of energy are cut off and the energy of the wave rapidly decreases, primarily as a result of barotropic exchange with the mean flow. If the tropospheric portion of the wave remains relatively stationary, as might be expected for waves forced by surface features, then an eastward movement would be observed in the stratosphere during periods when the wave amplitude is large. This eastward movement would be even more apparent in the temperature field than in the height field, since the temperature phase begins at a position to the west of the height field, as is required for a hydrostatic westward-sloping height field, and then travels eastward arriving at a position coincident with the height field when the wave becomes vertical. The temperature wave thus must move eastward a greater distance than the height field during a cycle of growth and decay. Observations depicting the sequence outlined above have been presented by Hartmann (1976).

A simple explanation has been provided which suggests why eastward motion should be expected to occur in association with episodes of growth and decay of planetary waves in the stratosphere. It is based on the relations between wave structure and energetics. Although this explanation is not necessarily contradictory to that of Leovy and Webster, it is well, perhaps, to include here a few comments as to why it should be kept in mind while the discussion in terms of normal modes continues. First, the data presented to date show evidence that the active periods in the stratosphere are not truly periodic. On the contrary, the active periods appear to be more in the nature of "events" which occur at irregular intervals. Second, although normal mode analysis is very productive of understanding, it is not capable of describing the changes in zonal-mean structure which result from active periods and which generally occur on a time scale comparable to that of the eddies. These zonal mean changes are one of the interesting aspects of stratospheric dynamics and, ideally, our interpretation of the active periods should be flexible enough to encompass them.

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