A New Look at the Energetics of Low-Frequency Variability

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In this study, we have used the multi-decade daily data from NCEP/NCAR Reanalysis to pinpoint some dynamical aspects of atmospheric variability in the Northern Hemisphere. In particular, energetics analysis is applied to understand different behaviors of the wintertime high-frequency (HF; <10 day) and low-frequency (LF; 10-90 day) eddies.

The energetics of HF eddies can be easily explained by the baroclinic instability theory. As in the literature, we confirm that LF eddies extract kinetic energy from background flow. However, it is found that LF eddies also extract potential energy from the basic flow as in the case of HF eddies. The baroclinic energy extraction rate by LF eddies is nearly as large as barotropical energy extraction. Furthermore, unlike HF eddies, there is little energy conversion from potential energy to kinetic energy for LF eddies. In light of these findings, we attempt to argue that in a three dimensional world purely barotropic instability may not be observable. We put forward a notion of "equivalent barotropic instability" to describe this type of mixed barotropic/baroclinic energy extraction from the mean flow without energy exchange between potential and kinetic energy. We argue that kinetic and potential energy extractions have to work together in order to maintain the equivalent barotropic structure of LF eddies. Results also show that kinetic energy extraction by LF eddies is primarily due to stretching deformation of the mean flow, consistent with the fact that LF eddies are primarily zonally elongated. This may explain why the maximum variability of LF eddies locates further downstream of the jet core, compared to HF eddies.

The feedback tendencies induced by LF and HF eddies have also been calculated. It is found that LF eddies act primarily to reduce zonal gradient associated with stationary waves whereas HF eddies tend to reduce meridional temperature gradient, particularly in the region where local meridional temperature is strongest due to modulation by stationary waves. This difference between HF and LF eddies seems to be related to the difference in shape, namely, LF eddies are zonally elongated and HF eddies are meridionally elongated. In other words, HF eddies primarily transport heat poleward and momentum into the jet stream; on the other hand, LF eddies mainly transport both heat and momentum in zonal direction, diminishing the amplitude of stationary waves.