Associations between Stratospheric Wave activity and Tropical Convection in Various Reanalysis Datasets

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The temporal variability and vertical dependence of free stratospheric equatorial waves along with the 5-day external Rossby mode are studied in various reanalysis datasets, including JRA-2 and ERA-Interim. The scaling, structure and temporal variability of the waves are isolated through space-time spectra and EOF analyses of space-time filtered equatorial wind, temperature and geopotential fields. The activity of the equatorially-trapped Matsuno and external Rossby modes are also related to metrics of convective activity derived from satellite brightness temperature, and to basic state circulation changes including the QBO. The Principal Components (PCs) associated with each mode can then be used to establish its statistical structure by projecting global multilevel dynamical fields from reanalysis and satellite brightness temperature or precipitation onto the PCs in the time domain at lag. The square root of the squared sum of PC pairs also provides a convenient "activity index" for each of the modes. Here we study the change in the structure and temporal variability of the waves from the lower to the upper stratosphere, and the ability of various reanalysis products to represent these features. The spectral signals of Kelvin, n=0 mixed-Rossby/eastward inertia-gravity (MRG/EIG), and n=1 westward inertia-gravity (WIG) waves of Matsuno's (1966) theory can all be readily detected from the tropical tropopause layer (TTL) at 100 hPa all the way to the upper stratosphere at 1 hPa in the reanalysis data. At the TTL, these free waves scale to around a 50 m equivalent depth, in contrast to their convectively coupled counterparts in the troposphere which correspond to an equivalent depth closer to 25 m. The corresponding equivalent depths increase monotonically with height, reaching values of around 300 m at 1 hPa. This shift is assumed to be due to wave damping and filtering of lower frequency (slower) waves by the zonal wind (e.g. Garcia and Salby, 1987). Correspondingly, the waves become faster and progressively less trapped about the equator with height, as expected from linear theory. Strong space time spectral peaks also appear in zonal wind and geopotential associated with the first four meridional symmetric external Rossby modes, including the 5-day wave. It appears that the activity indices of many of the modes have strong spectral peaks in the range of the Madden-Julian Oscillation (MJO), particularly during northern winter. Additionally, the well-documented variability of many of the modes associated with the stratospheric QBO is also evident, as well large variability at interannual and seasonal time scales. The potential significance of tropospheric forcing of the stratospheric wave activity will be assessed using wave-activity flux diagnostics. Both the JRA2 and ERA Interim reanalyses yield reassuringly similar bulk statistics of the modes, with other reanalysis products such as MERRA and NCEP agreeing somewhat less on the wave properties and variability.

Key words: Equatorial waves, external Rossby modes, QBO

References

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