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A Comparative Study of ERA-40 and ERA-Interim Reanalyses: Uncertainties in Estimating Wave Forcing in Northern Winter

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The eddy heat flux is a fundamental quantity for understanding stratospheric variability. At 100 hPa it is a direct measure of the wave activity that propagates from the troposphere into the stratosphere. In the Northern winter it is dominated by the contribution from stationary waves and forms a significant component of the vertical Eliassen-Palm (E-P) flux. Based on the transformed Eulerian mean (TEM) equation, the divergence of the E-P flux acts as a body force on the mean flow and causes temperature variations in the stratosphere. Thus the accuracy and homogeneity of the heat flux and the associated E-P flux divergence are vital for studying stratospheric dynamics.

The objective of this study is to detect possible errors in these wave forcing parameters estimated from the widely used ERA-40 and ERA-Interim reanalysis data sets produced by the European Centre for Medium-range Weather Forecasts (ECMWF). We focus on the December to February mean, during which the magnitude and variation of the wave forcing are largest. We examine two types of discrepancies. The first is based on the simple composite difference between the two data sets across their common period of the 1979/1980-2001/2002 winters. The second is to detect a discontinuity, or a sudden change of mean in each data set.

We find four regions where significant discrepancies of zonal mean E-P flux divergence exist. They are: 1) polarward of 20˚N in the upper stratosphere where the discrepancies are found to be associated with both the eddy heat flux $\overline{v'T'}$and the eddy momentum flux $\overline{u'v'}$; 2) poleward of 45˚N in the middle to lower stratosphere where the discrepancies are primarily associated with the eddy heat flux $\overline{v'T'}$; 3) the tropical to subtropical upper troposphere where the discrepancies are mainly caused by the difference in vertical eddy flux $\overline{w'u'}$; and 4) the middle latitude upper troposphere where a large cancellation of error is detected between the vertical eddy flux $\overline{w'u'}$ and eddy heat flux $\overline{v'T'}$. It appears that these discrepancies are mainly related to analysis increments in the 3D variation assimilation used by the ERA-40 reanalysis. In addition, we find two significant sudden changes of mean in the eddy heat flux. The first change is marked by a significant sudden drop of ERA-40 stationary component of the eddy heat flux in 1991 over the latitude band of 10-30˚N and at 100hPa. The drop could be directly related to the contaminating effects of the major volcanic eruption of Mount Pinatubo and a lack of radiosonde measurements over the Pacific and Atlantic oceans. The second change is characterized by a sudden increase of eddy heat flux magnitude in both ERA-40 and ERA-Interim at 10hPa in 1998. This shift of the mean was associated with a significant drop of $\overline{v'T'}$ difference between ERA-40 and ERA-Interim poleward of 35˚N over the land surfaces. The implications of these discrepancies on the long-term trend of the Brewer-Dobson circulation and the annual cycle in tropical tropopause temperature are discussed.