A study of the relationship between middle atmosphere interannual variability and wave forcing

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The interannual variability of the zonal mean field and wave forcing in the middle atmosphere is studied using Modern-Era Retrospective Analysis for Research and Application, version 2 (MERRA-2). Since the MERRA-2 includes the height range up to 0.01 hPa (-80 km), the middle atmosphere including the lower mesosphere can be analyzed. We focus on the latitude-pressure region of 0.3-1 hPa (approximately 48-64 km) and 30°S-50°S (region A), where the climatological wave forcing takes a local maximum in the austral winter (JJA). We calculate EP flux divergence averaged over the region A ($[\nabla \cdot \mathbf{F}]_A$) for each year. The correlations between $[\nabla \cdot \mathbf{F}]_A$ and zonal mean fields averaged over JJA (i.e. zonal mean temperature, zonal wind, residual mean circulation ($\overline{v}^*, \overline{w}^*$), and wave amplitude in geopotential height) are analyzed.

The correlation coefficient between $[\nabla \cdot \mathbf{F}]_A$ and zonal mean temperature in the latitude-height section exhibits a characteristic quadrupolar structure around the region A. In order to explore the quadrupolar structure, the correlation of $\overline{v}^*$ with $[\nabla \cdot \mathbf{F}]_A$ is calculated. The correlation between $[\nabla \cdot \mathbf{F}]_A$ and $\overline{v}^*$ is positive around the region A. This is consistent with the dynamical balance between $[\nabla \cdot \mathbf{F}]_A$ and $\overline{v}^*$. On the other hand, above the region A, the correlation between $[\nabla \cdot \mathbf{F}]_A$ and $\overline{v}^*$ is negative. This suggests that the circulation $\overline{v}^*$ there is driven by the unresolved wave forcing. Thus, this quadrupolar anomaly of zonal mean temperature is related not only to Rossby wave forcing, but also to gravity wave forcing. It is possible that the gravity wave forcing in the lower mesosphere is modified by the Rossby wave in the stratosphere.

Significant correlation between $[\nabla \cdot \mathbf{F}]_A$ and zonal mean temperature is also observed in Northern Hemisphere stratosphere. The analyses of the correlation coefficient distribution and the absolute angular momentum distribution indicate that this temperature anomaly in the Northern Hemisphere is also related to the residual mean circulation across the equator.