A study on interannual variation of the middle atmosphere including the mesosphere using MERRA-2 reanalysis

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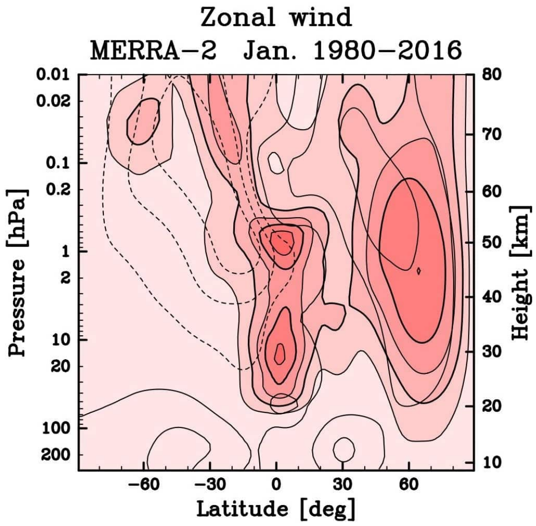
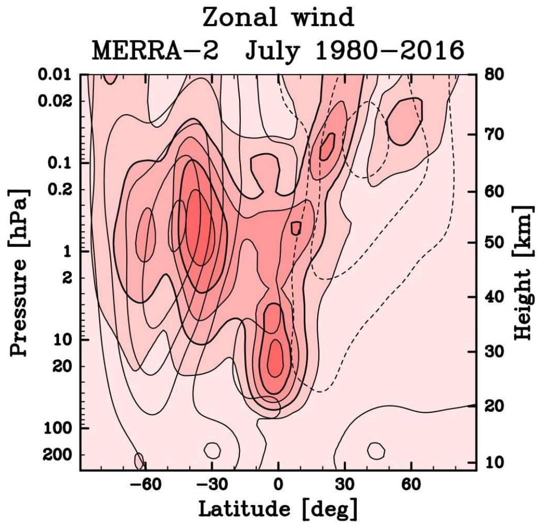
Recent studies using high-resolution GCMs, whole atmosphere models, and satellite observation reported interesting dynamical phenomena in the middle atmosphere, such as an interplay of Rossby waves and gravity waves in the momentum budget, an elevated stratopause event, and a stratospheric sudden warming event followed by the interhemispheric coupling. We used a MERRA-2 reanalysis data, which are distributed at a horizontal grid of 1.25°×1.25° and 72 pressure levels from 1000hPa to 0.01hPa. We divided all physical quantities into the zonal mean and deviation from the mean, and geopotential variance (Φ^2) as the Rossby wave activity, the Eliassen-Palm flux divergence (div*F*) as Rossby wave forcing, the residual mean flow (*v**), temperature (*T*), and zonal wind (*u*), where overlines show the zonal mean and monthly mean, and primes denote the deviations. The top of the figure shows the climatology of *u* and the standard deviation of the interannual variation of *u* (σ_u) in January and July. Five (six) local maxima of σ_u are observed in January (July). A pair of σ_u peaks near the stratopause in the Southern Hemisphere (SH) in July are located around the westerly jet peak and another pair are located near the easterly jet peak in the summer mesosphere in both hemisphere. The interannual variations of *u* at the two local maxima of each pair are negatively correlated, suggesting that each pair of σ_u peaks reflect interannual variation of the jet core latitude. The interannual variation of zonal mean zonal wind and zonal mean temperature are thought to be caused by that of wave forcing. First, we found that the peak of the interannual variation of Φ^2 is observed in Region A (50-70° in the winter hemisphere, 1-3hPa). Thus the correlation between Φ^2 and wave forcing interannual variations was examined. As a result, it is seen that the climatology of wave forcing takes a negative maximum in Region B (30-50° in the winter hemisphere, 0.3-1hPa). This means that the wave forcing corresponds well with the Rossby wave activity. The bottom of the figure shows the correlation coefficient between the wave forcing in Region B in the SH and *T* and *v** at each latitude and height for the austral winter. The correlation coefficient with *v** is significantly positive near B and is negative far above Region B. For the correlation coefficient with *T*, positive and negative values are distributed like a checkerboard pattern around Region B. It is important that the correlation with a statistical significance of 95% extends to the opposite hemisphere beyond the equator. When the wave forcing is negative in Region B, *v** anomaly is poleward in the winter upper stratosphere and equatorward in the winter mesosphere. The vertical flow associated with the characteristic *v** anomalies is consistent with the cheker pattern observed in *T*. An important feature is that the wave forcing is negative even in the winter mesosphere similar to that in Region B. Thus the equatorward *v** is the gravity wave forcing. Summary of this paper is in the following. The interannual variation of the middle atmosphere was examined using MERRA-2 reanalysis data. Obtained results strongly suggested that the interannual variation is mainly caused by the wave forcing and that the effect extends to the opposite hemisphere.

Keywords: the middle atmosphere


Zonal wind
MERRA−2 Jan. 1980−2016
Pressure [hPa]
Height [km]
Latitude [deg]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MERRA−2 July 1980−2016
Pressure [hPa]
Height [km]
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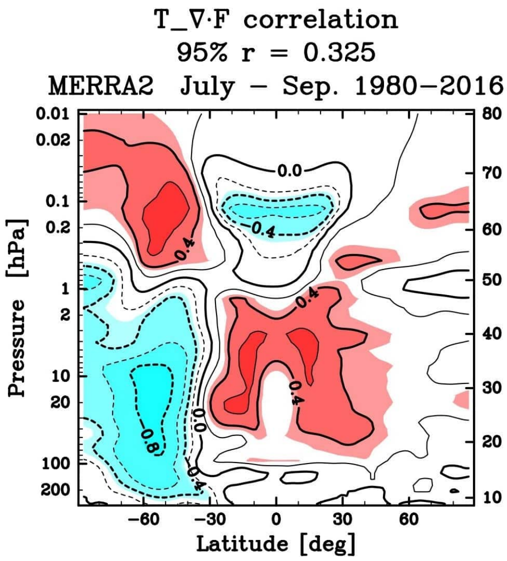
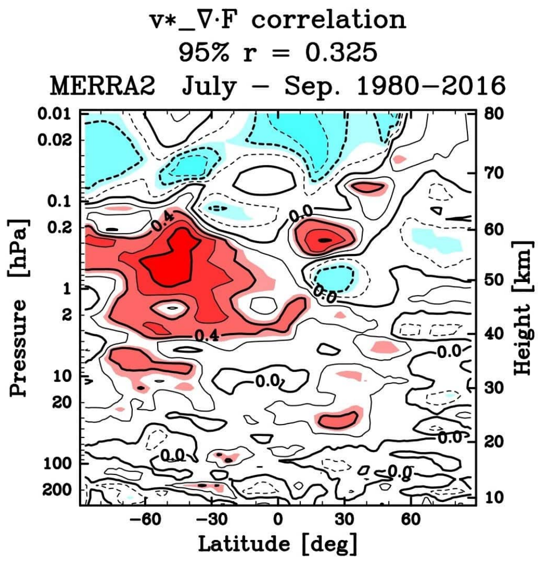

T_∇·F correlation
95% r = 0.325
MERRA2 July − Sep. 1980−2016
Pressure [hPa]
Height [km]
Latitude [deg]


v*_∇·F correlation
95% r = 0.325
MERRA2 July − Sep. 1980−2016
Pressure [hPa]
Height [km]
Latitude [deg]