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Changes in the Brewer-Dobson Circulation During 1980-2009 Revealed in the MERRA Reanalysis Data

H.-Y. Chun and J.-Y. Kim
Yonsei University, Atmospheric Sciences, Seoul, Republic Of Korea (chunhy@yonsei.ac.kr)

Recent chemistry-climate models predict enhanced Brewer-Dobson (BD) circulation in response to climate change. However, the degree of enhancement differs significantly from each model, and the underlying mechanisms responsible for the changes are not well understood. To assess the changes in the BD circulation in the future climate, it is necessary to understand changes in the BD circulation revealed from the recent-year observations. In this study, we investigate the changes in the BD circulation and their causes during 1980-2009 using the MERRA reanalysis data. The strength of the BD circulation is estimated by net upward mass flux between turnaround latitudes where tropical upwelling changes extratropical downwelling, using the mass streamfunction obtained from the downward control principle. The enhancement of the BD circulation during the 30 years is shown in all seasons with a largest enhancement in the northern hemisphere (NH) wintertime (DJF). Among various wave forcings, contribution by the planetary waves through E-P flux divergence (EPD) is predominant with a minor contribution by the gravity waves. The causes to derive this change are investigated by considering differences in the activity and propagation condition of the planetary waves in the troposphere and stratosphere between first 15 years (P1) and last 15 years (P2) in which stratospheric temperature anomalies show clearly different signs (positive in P1 and negative in P2). In DJF, EPD increases in the NH high latitudes in P2, resulting in more frequent stratospheric sudden warmings (SSWs), and this is mainly due to the changes in the propagation condition of planetary waves rather than the enhancement of the wave activity in the troposphere. In the southern hemisphere (SH) polar region, EPD also increases in DJF in P2. This is because the zonal-mean zonal wind increases in the mid-to-high latitudes of the stratosphere associated with reduced temperature there by ozone depletion and resultant upward shift of the Rossby-wave critical layer allows more planetary waves propagate to the stratosphere. Contrary, in September, increases in EPD in the SH high latitudes in P2 is mainly due to the enhanced wave activity in the troposphere. In both hemispheres, transient planetary waves with zonal wavenumbers less than 4 contribute mostly to the enhanced EPD forcing. The increase in SSW frequency in P2 is due primarily to the enhancement of wavenumber-1 component of meridional heat flux in the upper troposphere and stratosphere in December.