Three dimensional structure of mean meridional circulations and their forcing

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The zonal mean meridional circulation in the stratosphere is called Brewer-Dobson circulation (BDC). It transports air masses upward in the tropics, poleward in mid-latitudes, and downward in the extratropics. In the winter troposphere, direct circulation is depicted in the extratropics by isentropic zonal means. However, longitudinal variation of these circulations is not fully understood. This study examines the three dimensional structure of BDC and extratropical direct (ETD) circulation based on mass-weighted isentropic time mean method.
The mass-weighted isentropic time mean method expands Mass-weighted isentropic zonal means (Iwasaki, 1989) longitudinally by substituting the time means for the zonal means. The longitudinal variation of the BDC and ETD circulation are depicted by mass-weighted isentropic time mean meridional winds and temporal change of potential temperature. The zonal momentum equation of the mass-weighted isentropic time mean is composed of Coriolis term, advection term, Eliassen-Palm flux (EP flux) divergence term, and residual term. The EP flux divergence term can be divided into form drag terms by stationary and transient waves and reynolds stress term. A momentum budget analysis shows the forcing term of mean meridional circulations.
Mass-weighted time mean meridional winds at 45N take a wave-number three pattern in the troposphere and a wave-number two pattern in the stratosphere. Compared with time mean meridional wind in pressure coordinates, it has strong northerly wind in the lower troposphere, which indicates time mean cold air outbreak from the northern high latitudes. The geographical patterns of the meridional winds are similar in the stratosphere. The momentum budget analysis shows that the form drag term induced by the stationary waves is almost balanced with the Coriolis term.

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