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Long-term changes in the three-dimensional Brewer-Dobson circulation

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The past and future evolution of the Brewer-Dobson circulation (BDC) is investigated in a three-dimensional (3D) framework to improve the current understanding of the role of the BDC in a changing climate. For this purpose we examine the CMIP5 simulations with the Earth-System Model MPI-ESM, simulations with the general circulation and chemistry model HAMMONIA, reanalysis (ERA-Interim) and 3D global wind fields derived from Aura/MLS satellite data. For diagnosis we use recent formulations of the 3D residual circulation providing evidence on the local wave driving processes beyond the usually used zonal mean framework.

The results reveal significant changes in the northern winter 3D BDC. For example, the quasi-biennal oscillation of the equatorial stratosphere (QBO) leads to a planetary wave one structure in the 3D BDC during QBO-East with a pronounced downwelling branch in the area of the stratospheric polar vortex over Northern Europe/West-Siberia, but a planetary wave two during QBO-West with a second downwelling branch over North-East Pacific/North-America. The corresponding change in the 3D wave flux divergence demonstrates that the QBO modulates the transient wave activity over North America affecting the vertical propagation of planetary Rossby waves excited by the Rocky Mountains, subsequently configuring the well-known corresponding QBO-signals in temperature and zonal wind, but also in the transport of stratospheric ozone and middle atmospheric water vapor. Based on a simplified approach, it is also demonstrated that the QBO-related variations in the downwelling may significantly contribute (by about 30-40%) to the strength of the northern winter geopotential surface high anomaly over Northern Europe/West-Siberian. Based on these results the examinations are extended on the influence of other natural variability modes (NAO, ENSO) and anthropogenic emissions on the long-term changes in the 3D BDC and associated effects on regional climate conditions.