Effects of Greenhouse Gas Increase and Stratospheric Ozone Depletion on Brewer-Dobson Circulation in 1960-2010

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The strength of the stratospheric Brewer-Dobson circulation (BDC) in a changing climate has been extensively studied, but the relative importance of greenhouse gas (GHG) increase and stratospheric ozone depletion in driving the BDC changes in the past decades remains uncertain. This study separates the impacts of GHG and stratospheric ozone forcings on BDC in the 1960-2010 period using a coupled ocean Goddard Earth Observing System Chemistry-Climate model. Three 4-member ensembles of transient simulations were conducted with varying GHGs and ozone depleting substances (ODSs), varying ODSs but fixed 1960 levels of GHGs, and varying GHGs but fixed 1960 levels of ODSs.

The changes of the BDC are investigated using mean age of air and residual circulation. The model results show that GHG increase and stratospheric ozone depletion contribute nearly equally to the simulated mean age decrease in 1960-2010, but greenhouse gas increase accounts for about two thirds of the enhanced strength of the residual circulation. Consistent with its role in residual circulation acceleration, GHG forcing is more important than ozone depletion in driving the decrease of mean age difference between downwelling and upwelling regions.

A unique result from this study is an increase of mean age in the Antarctic summer lower stratosphere. This result demonstrates a special case that an enhanced BDC leads to an increase of mean age. It is found that this increase of mean age is caused by ozone depletion through two processes: (1) a seasonal delay in the Antarctic polar vortex breakup that inhibits older air inside the vortex from mixing with younger midlatitude air, and (2) enhanced Antarctic downwelling that brings older air from middle and upper stratosphere into the lower stratosphere.

Key words: mean age of air, residual circulation, mean age difference, ozone depletion, greenhouse gas increase

References

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