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The response of the Brewer Dobson circulation to a quadruple CO2 increase in WACCM

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The Brewer-Dobson circulation is the mean meridional circulation in the stratosphere. It is important for the chemical distribution of trace gases in the stratosphere and its thermal structure. Chemistry climate models consistently project an acceleration of its shallow branch in response to increasing greenhouse gas concentrations, while changes in the deep branch have been much less explored. Most models agree that enhanced resolved wave forcing is the main driver of the trend in tropical upwelling in the lower stratosphere although the ultimate mechanism is not well understood. Both changes in wave generation and wave dissipation related to climate change can lead to increased wave driving and modeling results are not conclusive.

Here, we revisit this issue based on the timescales of the BDC response to an abrupt quadrupling of CO2 concentrations. We analyze CMIP5 and CMIP6 preindustrial, 4xCO2 and AMIP simulations of the Whole Atmosphere Community Climate Model (WACCM) to compare the fast and slow responses of the BDC to the increase in CO2. While the fast response is associated with the direct radiative forcing of increasing CO2, the slow response of the BDC is related to warmer sea surface temperatures. Our results show that the shallow branch is tightly coupled to the evolution of tropical surface temperature. About half of the response to an abrupt 4xCO2 increase occurs in the first 10 years in WACCM. In the deep branch, about half of the response of the tropical upwelling in the deep branch is due to warmer SSTs, the other half is radiatively-driven. The waves involved in driving these changes are also investigated together with possible mechanisms.