The Brewer-Dobson Circulation in sensitivity simulations for the past and future with the Chemistry Climate Model EMAC-FUB

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Introduction and Motivation
Future global climate change due to anthropogenic activity is inevitable. The DFG Research Unit Stratospheric Change and its Role for Climate Prediction (SHARP) was founded in 2009 to improve understanding of the role of the stratosphere in future global climate change. Previous analyses of observations and results from numerical model simulations do not indicate a consistent picture of stratospheric circulation change. Radiosonde data show an annual mean cooling of the tropical lower stratosphere over the past few decades (Thompson and Solomon, 2002). Several independent model simulations indicate an acceleration of the Brewer-Dobson Circulation (BDC-Mechanism) due to higher greenhouse gas (GHG) concentrations with direct impact on the exchange of air masses between the troposphere and the stratosphere (e.g., Butchart et al., 2006, SPARC CCMVal, 2010). In contrast, from balloon-born measurements no significant acceleration of the BDC could be identified (Espel et al., 2000). This disagreement between observations and model simulations motivated further studies.

Here we compare sensitivity studies for past, present and future climate as well as one transient run regarding changes in the BDC through coordinated simulations with the Chemistry Climate Model (CCM) EMAC-FUB.

BDC-Mechanism
The Brewer-Dobson Circulation (BDC) is responsible for the net mass-transport between the tropics and high latitudes within the stratosphere. Ascending air in the tropics causes adiabatic cooling which results in the radiatively controlled temperatures. Polar latitudes are forced to temperatures above radiative equilibrium due to descending motion. The circulation is forced by large scale planetary waves penetrating from the troposphere into the stratosphere in the winter season. Transfer of momentum due to breaking waves decelerates the mean circulation and speeds up the BDC corresponding to convergence of the EP-flux (figure 1). The mechanism can be described with the help of the transformed Eulerian mean equations (TEMS) (Andrews et al., 1987).

Model and Experimental Design
Model simulations are performed with the coupled CCM EMAC-FUB (IACHMAMESSY with FUBRad radiation parameterisation) (Jöckel et al., 2006; Nissen et al., 2007). The version 1.7 is used with the horizontal resolution T42 (2.8° x 2.8°) and 39 levels in the vertical up to 0.01 hPa (~80 km). One transient and three timeslice simulations have been performed. The transient SCN-B2d-run was integrated from 1960 to 2100 following the recommendations of the SPARC CCMVal initiative (Kurylo et al., 2008). The sensitivity timeslice runs for the past (1865) and the future (2045) are used in comparison with the reference simulation (2000) to investigate past and future changes in the stratospheric meridional circulation due to changes in surface-temperature (ST), greenhouse gas (GHG) concentrations and chlorofluorocarbons (CFCs). The main features of the simulations are summarised in table 1.

Summary
Temperature changes as well as changes in trace gas distributions and mean age of stratospheric air from the past to the future are related to changes in the stratospheric residual circulation. In the EMAC-FUB CCM different diagnostics indicate a strengthening of the Brewer-Dobson Circulation from the past to the future. Temperature changes indicate future stratospheric cooling and tropospheric warming. Changes in tropical upwelling and EP-fluxes show an intensification of the BDC also supported by a decrease in the mean age of stratospheric air from the past to the future. One link between temperature and circulation is given by tropical upwelling which shifts towards the equator and stratospheric downwelling which causes warming of the respective region.

Open questions remain concerning the corresponding mechanisms of change. Accordingly several sensitivity simulations with EMAC-FUB CCM to narrow the range of possible parameters are planned in the scope of SHARP.

Acknowledgements
We thank the German Research Foundation (DFG) for financial support and the North-German Supercomputing Alliance (HLRN) as well as the Center for Advanced Weather and Climate Research (CAWCR) high-performance computing center in Reading for the computing time.

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