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Dynamical Coupling Between the Stratosphere and the Troposphere: The Influence of External Forcings

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The dynamical coupling between the stratosphere and the troposphere is dominated by planetary waves that are generated in the troposphere by orography and land-sea contrasts. These waves travel upward into the stratosphere where they either dissipate or are reflected downward to impact the troposphere again. Through the interaction with the zonal mean flow planetary waves can induce stratospheric sudden warmings (SSWs), i.e. conditions during NH winter where the stratospheric polar vortex is disturbed so that the zonal mean zonal wind in the NH stratospheric jet becomes easterly and the polar cap meridional temperature gradient reverses. Since strong major SSWs can propagate down into the troposphere and even affect surface weather, SSWs present a strong and clear manifestation of the dynamical coupling in the stratosphere-troposphere system.

We will investigate the influence of some external forcings, namely sea surface temperatures (SSTs), anthropogenic greenhouse gases and the quasi-biennial oscillation (QBO), on these coupling processes. Thereby we are interested in how the distribution of SSWs in the winter months changes due to the different forcings, whether the events evolve differently, and whether they show differences in their preconditioning, e.g. a different wave geometry. We will also investigate whether and how vertical reflective surfaces in the stratosphere, which can reflect upward propagating planetary waves, influence the evolution of SSWs.

To address these questions, we performed a set of model simulations with NCAR's Community Earth System Model (CESM), a coupled model system including an interactive ocean (POP2), land (CLM4), sea ice (CICE) and atmosphere (NCAR's Whole Atmosphere Community Climate Model (WACCM)) component. Our control experiment is a 140-year simulation with the fully coupled atmosphere-ocean version of CESM. A second experiment is a 55-year simulation with only CESM's atmospheric component WACCM, a fully interactive chemistry-climate model extending from the Earth's surface through the thermosphere (about 140 km), with underlying climatological SSTs obtained from the coupled CESM control run. A third 55-year simulation is performed without the nudging of the equatorial QBO. All three simulations develop under conditions where greenhouse gases are held constant at the 1960 level. In a fourth simulations, the greenhouse gases follow the RCP8.5 scenario. From the differences of the individual simulations to the control experiment we can estimate the respective roles of SSTs, the QBO and anthropogenic greenhouse gases for the stratosphere-troposphere coupling. The model results will be compared to the Modern Era Retrospective-Analysis for Research and Applications (MERRA) dataset.