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Variability and trends of major stratospheric warmings in simulations under constant and increasing GHG concentrations

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Long-term trends and variability of sudden stratospheric warmings (SSWs) are assessed based on multi-century simulations. Simulations are based on EGMAM a middle atmosphere version of ECHO-G with 39 vertical levels (top level 0.01 hPa) and a better representation of the middle atmosphere dynamics. The period 1860-1999 is modeled using observed GHG concentrations. Future trends are evaluated from IPCC-SRES B1, A1B and A2 scenario simulations (2000-2100) with stabilisation up to 2300 thereafter. Each scenario is modeled three times to build a small ensemble. The automated algorithm to identify SSWs is based on 10hPa zonal mean zonal wind at 60° and the mean temperature gradient between 60° and the polar region. A climatological threshold is applied to separate SSWs from final warmings.

In comparison to observations the model underestimates the number of SSWs especially in early winter which is connected to an underestimation of tropospheric wave forcing. Future scenario experiments show an increase of SSWs. Despite the high internal variability statistical significant changes are found. The strongest increase appears in the A2 scenario experiment. Here, the multi-century means reveal a doubling in the number of SSW to roughly 4 events/decade until the end of the 21st century. Moreover, a linear relationship between the number of SSWs and the GHG concentrations exists. Changes in stratospheric dynamics as well as changes in tropospheric wave forcing are the main reasons for the increase of SSWs. While no change is found for the mean duration of SSWs there is a tendency towards less intense events.

Additionally, a multi-century long control simulation under constant pre-industrial conditions is investigated to estimate the internal natural variability in the number of SSWs. A wavelet-analysis of the SSW time series identifies significantly enhanced power at a period of 52 years. Further investigation show that the multi-decadal variability is generated within the ocean-troposphere-stratosphere system. A two-way interaction of the North Atlantic and the atmosphere buffers and amplifies stratospheric anomalies, leading to a coupled multi-decadal mode.