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Simulation of European winter climate from the Maunder Minimum to present day using different solar forcings

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The period from the Maunder Minimum (∼1700 AD) to present provides a case study to investigate the role of external forcing factors (e.g. GHG concentrations, solar activity, volcanic eruptions) for long term European winter climate variability. Here we use a coupled atmosphere-ocean general circulation model which includes a detailed representation of the stratosphere. Three simulations are performed using prescribed time dependent GHG concentrations, solar activity and volcanic eruptions. In the first simulation solar variability is introduced via prescribed total solar irradiance (TSI). The second simulation additionally accounts for solar induced variations in stratospheric short-wave heating rates by prescribing time dependent ozone concentrations. The third simulation uses an improved short-wave radiation code. Here the additional direct effect on stratospheric heating rates due to variations in the UV/visible part of the solar spectrum is introduced by prescribing spectrally high resolved solar irradiance. The change in TSI from the Maunder Minimum to present is 0.1 percent in the third simulation contrary to a 0.3 percent change used for the first two simulations.
Simulated long term changes in the strength of the stratospheric polar vortex reveal clear evidence for a solar impact. The simulations employing direct stratospheric solar forcing both show a distinct strengthening of the polar vortex during the 18th century. This strengthening is related to an increase in solar activity from the end of the Maunder Minimum onwards. The relationship of polar vortex strength to solar forcing is less clear during the 20th century. Here the increase in GHG concentration is related to a weakening of the polar vortex thereby counteracting the solar effect. Regarding changes in the troposphere all three simulations show a weakening of the zonal flow over the North Atlantic/European sector during the Late Maunder Minimum (1675-1715) when compared with a present climate (1960-1990). The amplitude and exact position of the simulated MSLP anomalies are found to be sensitive to both the simulated changes in the stratosphere and the amplitude of the used TSI forcing.