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Potential impacts of a future Grand Solar Minimum on decadal regional climate change and interannual hemispherical climate variability

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The political, technical and socio-economic developments of the next decades will determine the magnitude of 21st century climate change, since they are inextricably linked to future anthropogenic greenhouse gas emissions. To assess the range of uncertainty that is related to these developments, it is common to assume different emission scenarios for 21st climate projections. While the uncertainties associated with the anthropogenic greenhouse gas forcing have been studied intensely, the contribution of natural climate drivers (particularly solar variability) to recent and future climate change are subject of intense debate. The past 1,000 years featured at least 5 excursions (lasting 60–100 years) of exceptionally low solar activity, induced by a weak magnetic field of the Sun, so called Grand Solar Minima. While the global temperature response to such a decrease in solar activity is assumed to be rather small, nonlinear mechanisms in the climate system might amplify the regional temperature signal. This hypothesis is supported by the last Grand Solar Minimum (the Maunder Minimum, 1645–1715) which coincides with the Little Ice Age, an epoch which is characterized by severe cold and hardship over Europe, North America and Asia. The long-lasting minimum of Solar Cycle 23 as well as the overall weak maximum of Cycle 24 reveal the possibility for a return to Grand Solar Minimum conditions within the next decades. The quantification of the implications of such a projected decrease in solar forcing is of ultimate importance, given the on-going public discussion of the role of carbon dioxide emissions for global warming, and the possible role a cooling due to decreasing solar activity could be ascribed to. Since there is still no clear consensus about the actual strength of the Maunder Minimum, we used 3 acknowledged solar reconstruction datasets that show significant differences in both, total solar irradiance (TSI) and spectral irradiance (SSI) to simulate a future Grand Solar Minimum under RCP6.0 conditions. The results obtained were compared to a RCP6.0 simulation that was carried out using the CCMI recommendations for a 21st century solar forcing. We used the ECHAM/MESSy Atmospheric Chemistry (EMAC) chemistry-climate model that incorporates interactive ozone chemistry, a high-resolution shortwave radiation scheme, a high model top (0.01 hPa) and is coupled to a 3D ocean general circulation model. We focused on the regional responses to a future Grand Solar Minimum and interannual variability patterns (i.e. the Northern and Southern Annular Mode (NAM/SAM)).