Geophysical Research Abstracts
Vol. 18, EGU2016-14814-1, 2016
EGU General Assembly 2016

Climate variability related to the 11 year solar cycle as represented in different spectral solar irradiance reconstructions

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Advanced spectral solar irradiance (SSI) reconstructions differ significantly from each other in terms of the mean solar spectrum, that is the spectral distribution of energy, and solar cycle variability. Largest uncertainties – relative to mean irradiance – are found for the ultraviolet range of the spectrum, a spectral region highly important for radiative heating and chemistry in the stratosphere and troposphere.

This study systematically analyzes the effects of employing different SSI reconstructions in long-term (40 years) chemistry-climate model (CCM) simulations to estimate related uncertainties of the atmospheric response. These analyses are highly relevant for the next round of CCM studies as well as climate models within the CMIP6 exercise. The simulations are conducted by means of two state-of-the-art CCMs – *CESM1(WACCM)* and *EMAC* – run in "atmosphere-only"-mode. These models are quite different with respect to the complexity of the implemented radiation and chemistry schemes. *CESM1(WACCM)* features a chemistry module with considerably higher spectral resolution of the photolysis scheme while *EMAC* employs a radiation code with notably higher spectral resolution. For all simulations, concentrations of greenhouse gases and ozone depleting substances, as well as observed sea surface temperatures (SST) are set to average conditions representative for the year 2000 (for SSTs: mean of decade centered over year 2000) to exclude anthropogenic influences and differences due to variable SST forcing. Only the SSI forcing differs for the various simulations. Four different forcing datasets are used: NRLSSI1 (used as a reference in all previous climate modeling intercomparisons, i.e. CMIP5, CCMVal, CCMI), NRLSSI2, SATIRE-S, and the SSI forcing dataset recommended for the CMIP6 exercise. For each dataset, a solar maximum and minimum timeslice is integrated, respectively. The results of these simulations – eight in total – are compared to each other with respect to their shortwave heating rate differences (additionally collated with line-by-line calculations using *libradtran*), differences in the photolysis rates, as well as atmospheric circulation features (temperature, zonal wind, geopotential height, etc.).

It is shown that atmospheric responses to the different SSI datasets differ significantly from each other. This is a result from direct radiative effects as well as indirect effects induced by ozone feedbacks. Differences originating from using different SSI datasets for the same level of solar activity are in the same order of magnitude as those associated with the 11 year solar cycle within a specific dataset. However, the climate signals related to the solar cycle are quite comparable across datasets.