Atmosphere and Ocean Responses to Extreme Low Solar Activity and Their Hemispheric Differences

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The total solar irradiance (TSI) changes by ~0.1% during solar cycles. The impact of the change on tropospheric climate is small in comparison with the large climate variability. While the solar cycle variation of ultraviolet (UV) is larger, its downward effect on climate is also rather weak. It is thus challenging to clearly quantify the solar signal, and to investigate the processes involved in sun-climate connection. As a result, the climate sensitivity to solar forcing is poorly quantified and understood. In this study, we seek to overcome this difficulty by driving a coupled whole atmosphere-ocean model—the NCAR CESM Whole Atmosphere Community Climate Model (WACCM) with the interactive ocean model (POP2)—with an extreme low solar forcing. The TSI and solar spectral irradiance (SSI) are obtained from MHD simulations using the MURaM code, and the TSI/SSI values obtained can be regarded as a lower theoretical limit as allowed by known solar physics principles. With this hypothetical low solar forcing, significant and complex changes are seen throughout the atmosphere and also in the ocean circulation. While the surface generally cools during the 200-year simulation, the evolution path of the cooling and the cooling rates are very different between the two hemispheres. Our analysis suggests that the interplay between the radiative forcing and dynamical feedback determines the response, and the dynamical feedback from atmosphere and ocean coupling, in particular in the form of atmospheric waves, differ between the two hemispheres. Additional simulations with extreme low SSI forcing in the ultraviolet (UV) only and in the visible/infrared (VIR) only show that they can cause troposphere/ocean responses similar to the full forcing case, albeit with different magnitudes. The results unambiguously demonstrate the importance of middle atmosphere/lower atmosphere/ocean coupling in sun-climate connection and in studying the climate sensitivity to solar forcing.