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Climate Impacts of Solar Variation-Induced Changes in Tropospheric Particle Formation, CCN, and Cloud Properties

The sun supplies most of the energy for the Earth's atmospheric and climate system. There is no doubt that links exist between solar variability and terrestrial climate on century, decade, and shorter times scales. However, the effect of measured ~0.1% level of the long-term total solar irradiance (TSI) variations on climate (i.e., solar direct effect) is generally considered to be too small to account for the observed changes in the Earth's climate. The necessity of amplifying TSI variation by a factor of ~ 3 to explain the amplitude of the 11-year solar signature on the temperature record has been noted in a number of previous studies. The correlation between observed historical solar and climate changes along with the need to amplify the solar irradiance effects to fit measured temperature data may imply that indirect solar forcing is unaccounted for. In order to clearly define the consequences of human activity on climate and accurately predict the climate change on decadal and longer time scales, possible indirect impacts of solar activity on Earth's climate have to be identified, formulated, and included in the climate impacts via solar variations-induced changes in atmospheric condensation nuclei (CN) formation, cloud condensation nuclei (CCN) abundance, and cloud properties.

We will first study solar variation induced changes in particle formation rate and CCN abundance, using a global chemistry model GEOS-Chem coupled with an advanced particle microphysics (APM) model developed by our group. Our second task is to incorporate the APM Community Earth System Model (CESM). The goal is to improve the capability of the CESM-CAM5 in studying the key processes involved in the Sun-CN-CCN-Cloud-Climate hypothesis. The particle properties predicted by CESM-CAM5 will be comprehensively assessed against a large set of land-, ship-, and aircraft- based measurements. Our last task is to use validated CESM-CAM5-APM to investigate the magnitude of solar indirect radiative forcing associated with Sun-CN-CCN-cloud pathway and 3-D spatial variations of such a forcing, under a variety of emission scenarios and climate states. Our study will improve the predictive capabilities of the Earth System Models and reduce uncertainties in climate change projection.

This project is highly relevant to the strategic objective of the Sun-Climate Theme of the NASA Living With a Star Program, which is to "*deliver the understanding of how and to what degree variations in the solar a radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales.*"