Project Details

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Project Title:
Investigating the Effect of Solar Activity During a Grand Minimum on Clouds

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Summary:
There is widespread, suggestive evidence for a correlation between solar activity and Earth s climate, and a variety of linkages have been proposed. The link addressed in this proposal connects galactic cosmic radiation flux, which is modulated by the solar wind and solar magnetic field, and cloud properties, which directly influence the Earth s albedo. The galactic cosmic radiation (GCR) flux to the Earth s atmosphere is a primary form of ionization, and these ions subsequently drift in the large-scale planetary electric field to form unipolar charge accumulations at cloud boundaries. We propose a laboratory and modeling study of the effect of cloud droplet charging on the formation of precipitation in stratocumulus clouds, and, in turn, on the large-scale dynamical structure and radiative properties of the clouds. The objectives of the proposed work are

1. Characterization and quantification of collision-coalescence kernels for charged cloud drops based on laboratory experiments and direct numerical simulation (J. Lu, R. Shaw). These experiments and simulations, which provide a detailed, particle-by-particle view of a cloud, will result in a kinetic theory describing the Coulomb interaction of cloud droplets in turbulence, in the presence of gravity.

2. Exploration and quantification of the sensitivity of drizzle formation to cloud drop charging using a detailed, cloud microphysical box model (G. Feingold, J. Kazil, J. Lu, R. Shaw). This will lead to development of a cloud-to-drizzle autoconversion algorithm accounting for droplet charge, suitable for use in cloud-resolving simulations.

3. Characterization of cloud drop charging in stratocumulus clouds, and of its effect on precipitation and cloud radiative properties using the WRF/Chem model in Large Eddy Simulation mode (J. Kazil, G. Feingold). The simulations will use solar activity levels and the resulting GCR ionization rates for the minimum and maximum of the decadal solar cycle, as well as for the conditions of a Grand Solar Minimum, with much enhanced GCR ionization.

One outcome of the work will be the development of an autoconversion algorithm that will connect the cloud-resolving simulations to larger scales, and lay the groundwork to investigations of the phenomenon in climate models. Although not explicitly proposed as part of this work, it is anticipated that this will enable using future implementations of whole-atmosphere models (e.g. WACCM), which will describe the global atmospheric electric circuit and its response to solar disturbances of the ionosphere, as input for cloud-resolved models.

In the proposed work, we will build on existing experimental and modeling tools to achieve the proposed objectives. A laboratory environment for the investigation of the effect of charge on the collision-coalescence of cloud droplets has been developed and used in the group of R. Shaw. In this system, where droplet size, droplet charge, and turbulence intensity can be externally controlled, cloud droplets are tracked in three dimensions using a digital holographic method. The experiments are complemented by a direct numerical simulation of turbulence, seeded with charged droplets. The resulting, modified collision rates will enable quantifying the effect of solar variability on cloud properties in Large Eddy Simulations of marine boundary layer clouds. The model that will be used for these simulation is WRF/Chem, in which a detailed representation of chemical, aerosol, and cloud processes, as well as of atmospheric ionization by GCR at different solar activity levels, has already been

implemented to investigate marine stratocumulus.

The proposed work will provide a quantifiable connection between solar activity and cloud properties. This is a necessary step in quantifying perturbations to Earth's radiative forcing by the decadal solar cycle, as well as by longer-term variations in solar activity (e.g., due to a Grand Solar Minimum).

Publication References:

no references