Collaborative Research: Characterizing the Roles of Atmospheric Structure and Clouds on the Radiation and Precipitation Budgets at Summit, Greenland

INTELLECTUAL MERIT

Clouds contribute significantly to the surface energy and cryospheric mass budgets in the Arctic. Their roles are largely defined by cloud macro- and microphysical properties, which are intimately tied to atmospheric thermodynamics and dynamics on many scales. In spite of the obvious importance of these cloud-related processes, models continue to struggle to accurately represent cloud occurrence, vertical distribution, microphysical composition, and radiative properties across the Arctic and over the Greenland Ice Sheet (GIS). As a result, model simulations of surface energy budgets and precipitation are highly uncertain. Over the past decade, the effects of climate change have become quite apparent over the GIS where melt rates are large and increasing. However, due to a lack of observations and subsequent model deficiencies, the source of these changes is unclear as is their projection into the future. Significant GIS melt can have a dramatic potential impact on global sea-level and thus human populations and ecology. Thus, it is important to understand the cloud, atmosphere, precipitation, and radiation properties and processes that impact the GIS and the Arctic in general.

The research proposed here will focus on characterizing the interactions among the atmospheric state, cloud properties, radiation, and precipitation at Summit, Greenland. The objective is to investigate a number of important cloud-related processes, how these interact with the Arctic climate system, and their impact on the surface energy and mass budgets. Specific processes of focus will include:

1) Low-cloud persistence mechanisms that lead to long-lived Arctic stratiform clouds, which interact strongly with the atmospheric structure and surface energy budget;
2) Cloud-phase partitioning, which determines the cloud microphysical composition and, ultimately, the effects that clouds have on atmospheric radiation and the hydrologic cycle; and
3) Precipitation partitioning, in order to understand the different modes of precipitation at Summit and how these impact the total surface accumulation.

To address these important topics, this project will utilize detailed observations from an advanced suite of ground-based remote sensors deployed at Summit as part of the NSF/AON-funded ICECAPS project in combination with data from satellite-borne active remote sensors. High-resolution numerical modeling will also be used to investigate many of the fine-scale cloud processes and their mesoscale influences. These studies over the GIS will also be considered within the context of similar measurements and model studies made at other Arctic locations in order to understand these important processes over Summit and in a more general sense across the Arctic.

BROADER IMPACTS

The need to observe and understand Arctic cloud properties and processes is clearly outlined in the SEARCH implementation plan; other national and international agencies have also placed an intense focus on improving the understanding of Arctic processes. This proposed research project is the first of its kind over the GIS and will significantly enhance our generalized understanding of important Arctic climate processes. It is anticipated and intended that the results of this study will broadly impact the scientific community by contributing to an improved understanding of the basic climatology over Greenland and the broader Arctic Basin, and leading to improvements in cloud and atmosphere parameterizations used in regional and global climate models.

This project will provide important data analysis and integration experience for four new graduate students at the Universities of Oklahoma, Colorado, Idaho and Wisconsin. In addition, data and results from this study will be integrated into undergraduate coursework at the University of Idaho and summer workshops at the University of Wisconsin.