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Snow and Ice Radiative Forcing and Albedo (SIRFA) mission concept for understanding controls on Earth's melting snow and glaciers

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Decades of satellite, airborne, and ground observations clearly show increased melting of glaciers and ice sheets, declines in sea ice, and decreasing spring snow cover. This increased melting of cryosphere cover makes Earth more absorptive of sunlight and moves enormous volumes of stored water from frozen state to liquid, raising sea level and changing water availability to large populations. However, the distribution of forcings controlling this accelerated melting is poorly known.

Atmospheric warming from greenhouse gases is contributing to this acceleration but its magnitude is uncertain due to our uncertainties in the controls on the dominant contributor to annual melt, absorbed sunlight, itself controlled by albedo (Fig. D-1). Despite this crucial role of albedo and solar radiation in snow and ice melt, sparse measurements have kept us from understanding the global distribution of controls on albedo, grain size (GS) and impurities, and from accurately modeling melt processes worldwide. Such an understanding is crucial to determining cryosphere melt and projecting its future behavior.

Snow and glacier mass balance is the net outcome of mass gains by accumulation of snow and losses by melt runoff, sublimation, and evaporation, with runoff being the dominant term of loss. Snow and glacier melt comes from the total energy flux after snow and ice columns have reached 0°C and warming of the column is no longer possible. Atmospheric warming has a strong influence on melting through coarsening of snow GS and resulting decrease in albedo, but albedo is also strongly controlled by impurity deposition, such as dust, black carbon (BC), and organics.

With increased solar absorption, warming and melt commence markedly earlier in the snow season. Uncertainty in knowing the contributions of melt forcings comes from the fact that during the warming across the last century, Earth also experienced increased particulate emissions of dust and BC and resulting deposition to the cryosphere, leading to coincident increased melt by albedo decreases.

To understand the current distribution of these powerful forcings and their relative importance, we need visible through shortwave infrared spectroscopic measurements of the drivers of albedo changes across the global cryosphere at unprecedented spatial and spectral resolutions. Such measurements allow us to better understand these forcings globally over time, unveiling their interplay in melting.

Here we describe the spectroscopic retrievals of snow grain size, radiative forcing by dust and black carbon, spectral albedo, and broadband albedo as used with the airborne Snow Observatory and the airborne visible/Infrared imaging spectrometer (Classic and Next Generation). We present the uncertainties in Global to mesoscale climate modeling of snow melt from current uncertainties in grain size and radiative forcing. Finally, we present the mission concept for such retrievals in the context of the 2017 Decadal Survey Designated VSWIR imaging spectrometer mission.