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The Role of Models in Future Satellite Global Snow Products: a SnowEx Perspective

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Seasonal snow cover is the largest single component of the cryosphere in areal extent (covering an average of 46M km2 of Earth's surface (31 % of land areas) each year). Current space-based techniques underestimate storage of snow water equivalent (SWE) by as much as 50%. That number is likely to be greater in the boreal forest and other densely-forested areas around the globe, with the boreal forest being the largest land biome on Earth (20M km2). One of the key gaps in past NASA and ESA snow mission proposals has been the retrieval of SWE in forested areas because the snow mission proposals relied on a single sensor type: synthetic aperture radar (SAR), for which algorithms were not fully mature, and the footprints were large in comparison to trees and forest clearings. Newer lidar-based approaches might help reduce this limitation of SAR, but we do not have hard data with which to quantify the benefit of synergizing lidar with SAR. And, even more experimental techniques have recently been proposed to surmount these observational issues.

Other problems exist in the temporal domain, where the snow melt period, a period of rapid change in snow cover often coinciding with the maximum run-off, is of primary interest for water resource and weather applications. Wet snow is radiometrically "opaque" in the microwave frequencies, making measurements of SWE difficult, another gap in past NASA and ESA snow mission proposals. Again, in this case, lidar is insensitive to the snow wetness and can provide a measure of snow depth even when the snow surface contains a high fraction of liquid water.

Because of these and other considerations, such as the microwave capability (and lidar's inability) to pass through clouds, the snow community consensus is now that a multi-sensor approach is needed to adequately monitor snow, combined with modeling and data assimilation. However, it is recognized that modeling is required to fill the observational gaps in time and space.

The goal of SnowEx is to better identify the remote sensing plus modeling candidates for a future snow satellite mission and the trade space between various combinations of sensors and models. In keeping with this focus, Year 1 of SnowEx was organized around forest as a confounding factor. Forests confound our ability to sense snow in areas with thick snow and thin snow, flat terrain and complex terrain. Success in all of our past snow satellite mission proposals has been elusive in part due to problems associated with limitations of using remotely-sensed data in forest areas, therefore, we cannot ignore the challenges associated with the remote sensing of snow cover and SWE in forested areas. By ignoring the issues and challenges around snow remote sensing in forests, we would compromise the potential success of a space-based snow mission proposal. As the density of forest cover increases, and the various sensing techniques have decreasing ability to retrieve SWE directly, the importance of models must increase to maintain usable retrieval accuracy.

What remains to be determined is how best to combine and the various sensor observations with models in appropriate ways. That requires a careful and well thought-out effort to collect field measurements that will allow this combined system to be scoped and specified. NASA has recently completed Year 1 of the multi-year SnowEx field experiment to serve as a test-bed for these various snow remote sensing and modeling techniques. This paper will describe the data collected by the first year of SnowEx, including objectives, instruments, aircraft, ground truth, and sites, and then will explore how modeling can be brought to bear.