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Identifying and Mapping Systematic Errors in Passive Microwave Snow Water Equivalent Observations

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ABSTRACT:

Understanding remote sensing retrieval errors is important for correct interpretation of observations, and successful assimilation of observations into numerical models. Passive microwave sensors onboard satellites can provide global snow water equivalent (SWE) observations day or night and under cloudy conditions. However, there are both systematic (bias) and random errors associated with the passive microwave measurements. These errors are well known but have thus far not been adequately quantified. This study uses standard error propagation theory, resulting in a more robust algorithm, to quantify these systematic errors – those that always overestimate (or underestimate) actual observations. An unbiased SWE dataset is produced and monthly SWE error maps (October-May) are derived for the Northern Hemisphere. The next step is to fine tune and test the bias-free algorithm, which will be used to estimate snow water equivalent (SWE) more reliably.

I.0 INTRODUCTION

Snow plays an important role in the global energy and water budgets, as a result of its high albedo and thermal and water storage properties. Snow is also the largest varying landscape feature of the Earth's surface. Thus, knowledge of snow extent and SWE are important for climate change studies and applications such as flood forecasting. Furthermore, snow depth and SWE, as well as snow cover extent, are important contributors to both local and remote.

Despite its importance, the successful forecasting of snowmelt using atmospheric and hydrologic models is challenging. This is due to imperfect knowledge of snow physics and simplifications used in the model, as well as errors in the model forcing data. Furthermore, the natural spatial and temporal variability of snow cover is characterized at space and time scales below those typically represented by models. Snow model initialization based on model spin-up will be affected by these errors. By assimilating snow observation products into Land Surface Models (LSMs), the effects of model initialization error may be reduced (Sun et al., 2003).

Passive microwave remote sensors onboard satellites provide an all-weather global SWE observation capability day or night. Brightness temperatures from different channels of satellite passive microwave sensors (hereafter referred to as PM) can be used to estimate the snow water equivalent (or snow depth with knowledge of the snow density), and hence snow cover extent. However, there are both systematic (bias) and random errors associated with the passive microwave measurements. In order for the remotely sensed SWE observations to be useful for climate modelers, water resource managers and flood forecasters, it is necessary to have both an unbiased SWE estimate and a quantitative, rather than qualitative, estimate of the uncertainty. This is a critical requirement for successful assimilation of snow observations into LSMs.

For most PM algorithms, the effects of vegetation cover and snow grain size variability are the main source of error in estimating SWE. Of lesser concern are the effects of topography and atmospheric conditions. A major assumption made in a number of PM algorithms is that vegetation cover does not affect the SWE estimates. In fact, it can have a significant impact on the accuracy of SWE estimates. In densely forested areas, such as the boreal forest of Canada, the underestimation of SWE from retrieval algorithms can be as high as 50% (Chang et al., 1996). Another major assumption is that snow density and snow crystal size remain constant throughout the snow season everywhere on the globe; in reality, they vary considerably over time and space. The PM algorithms are found to be very sensitive to snow crystal size (Foster et al., 1999).

The purpose of this paper is to present a methodology for deriving unbiased SWE estimates from PM observations. Systematic errors due to simplifying assumptions of the retrieval algorithm, and effects of vegetation cover and crystal size are quantified. Twenty years of are analyzed for SWE and its associated uncertainty throughout North America. This paper presents results for the snow season 1990-91 as an example, using Special Sensor Microwave/Imager (SSM/I) data.