Analysis of Relative Errors in Snow Maps in North America, Winter 2001-02

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Abstract

Accurate snow maps are required for hydrological and climatological applications and by operational agencies to monitor snow conditions, and to predict spring water supply. Visible/near-infrared-based snow maps have the advantage that the spatial and temporal resolution is very good, and albedo can be measured, while passive-microwave snow maps have good temporal resolution, but poor spatial resolution.

Since November 1978, the Scanning Multichannel Microwave Radiometer (SMMR) instrument on the Nimbus-7 satellite, and the Special Sensor Microwave Imager (SSMI) on the Defense Meteorological Satellite Program (DMSP) series of satellites have been acquiring passive microwave data that can be used to estimate both snow extent and snow water equivalent (snow depth).

Snow crystals are effective scatterers of microwave energy for frequencies greater than 18 GHz. Sensors designed to operate from 18 to about 90 GHz are sensitive to most all snow conditions. The snow crystals scatter part of the cold sky radiation, which reduces the upwelling radiation measured with a radiometer. The deeper the snow, the more snow crystals are available to scatter the upwelling microwave energy, and thus it is possible to estimate the depth of the snow and the snow water equivalent. A snow/microwave algorithm developed by Chang et al. (1987), and similar algorithms employed by other snow researchers, uses the difference between the 37 GHz and 18 GHz channels (in the case of the SMMR instrument) to derive snow water equivalent information over pixels approximately 25 km by 25 km in size.

A tremendous advantage of passive-microwave sensors is that the potential exists to map snow depth and snow-water equivalent (SWE) as well as snow extent. Interpretation of

many operational snow maps is hampered by cloud obscuration and therefore the combined use of visible/near-infrared and passive-microwave data is under study by many investigators. NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) from the Terra and Aqua satellites, and the Advanced Microwave Scanning Radiometer (AMSR) currently produce or will produce snow maps. The Terra satellite, launched in December of 1999, has the MODIS as part of its payload of five instruments, while the Aqua satellite, launched in May, 2002, contains a second MODIS instrument, the AMSR-E and four other instruments. Snow maps have been produced since February 2000 from the MODIS sensor (Hall et al., in press A), and snow maps from the Defense Meteorological Satellite Program/Special Sensor Microwave/Imager (DMSP/SSM/I) have been produced since July 1987 (Chang et al., 1987; Foster et al., 1997). AMSR-derived snow maps will be available beginning in about the summer of 2002. From November 2001 through March 2002, MODIS snow maps at 0.05° (~5.6-km) resolution are compared with ~25-km resolution SSM/I-derived snow maps using a modified version of the Chang et al. (1987) algorithm (Kelly et al., in press; Kelly et al., submitted).

Revised versions of this algorithm have allowed for more reliable estimates of snow water equivalent over specific regions by including information on the fractional forest cover of a given microwave pixel and changes in snow crystals size from one region to another. Information about the evolution of the snow structure, especially the growth of depth hoar crystals has been shown to be very important in fine-tuning microwave algorithms since larger crystals are very effective scatterers of microwave radiation. As the crystals approach the size of the wavelength, more energy is scattered (Mie Scattering). Variations in crystal size have to be accounted for in different regions in order to better represent actual snow conditions.

Results confirm previous results by several authors (see Armstrong and Brodzik, 1999; Hall et al., in press B) that correspondence between the MODIS- and SSM/I-derived snow maps improves as the winter progresses. Early in the season, the SSM/I snow mapping algorithms are unable to identify shallow and wet snow as snow cover, while the MODIS snow maps perform well under those circumstances, but cannot map snow through clouds and cannot provide estimates of SWE. By January when the snow temperatures are colder, and liquid water in the snowpack is minimal, the agreement between MODIS- and SSM/I-derived snow maps improves.

The figures show a time series of MODIS and SSM/I difference maps. Clouds are mapped on MODIS only and those that lasted for the entire 8-day period are shown in pink. Snow that was mapped by both the SSM/I and the MODIS is white; snow mapped by MODIS only is blue and snow mapped by the SSM/I only is yellow.

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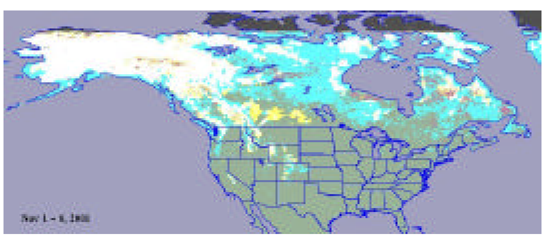
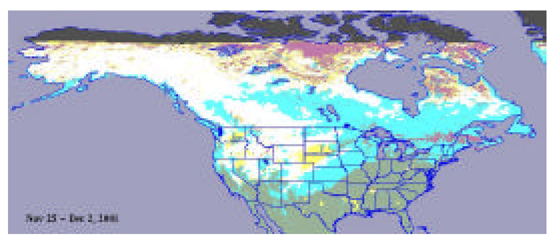
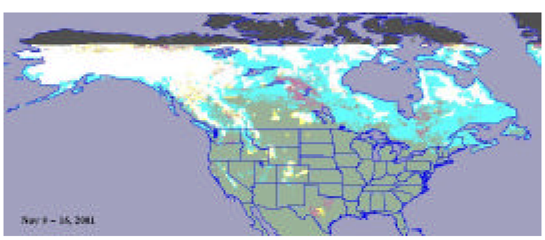
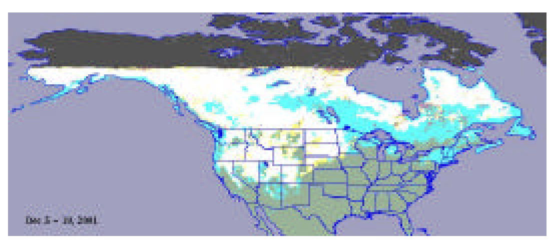
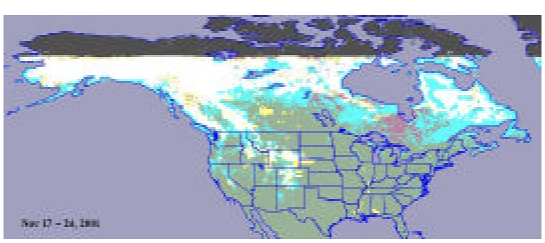
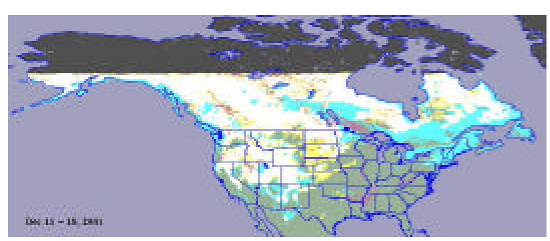

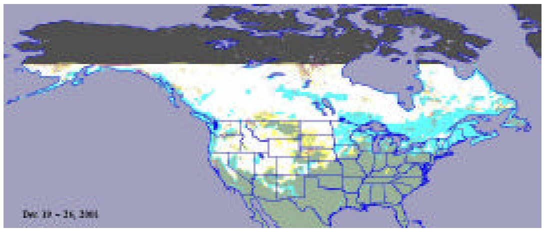
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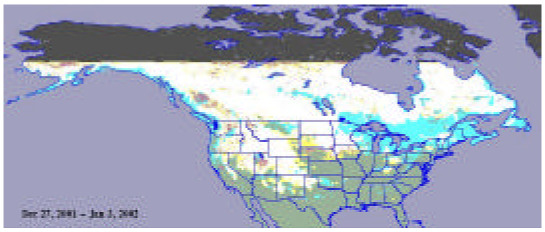
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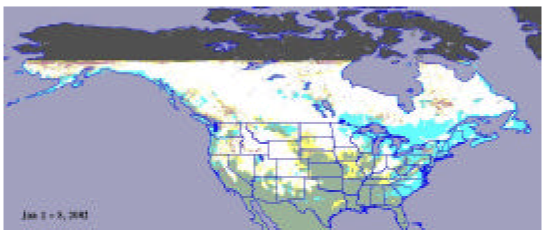
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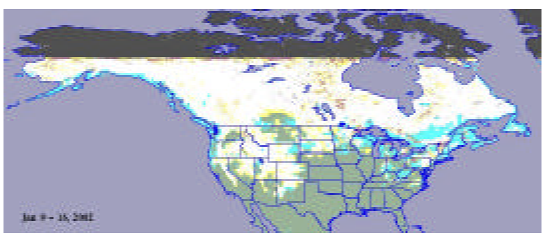
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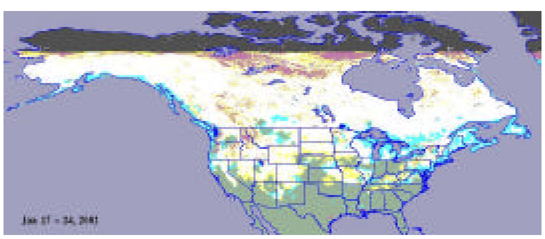
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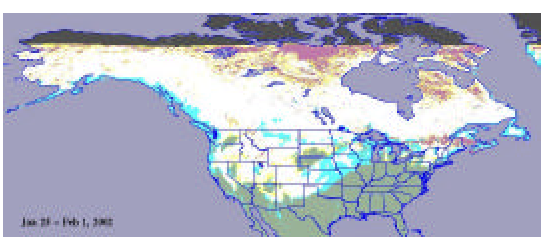
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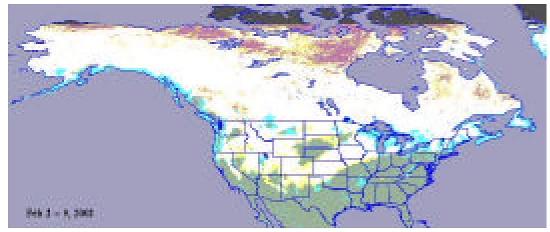
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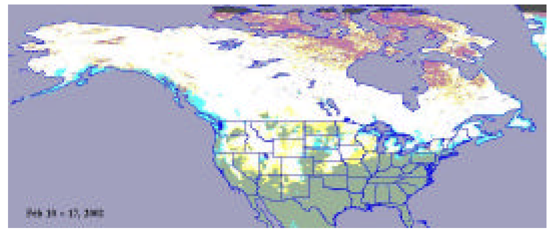
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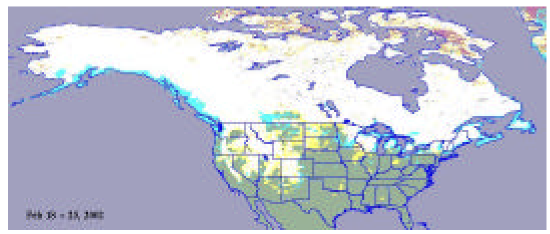
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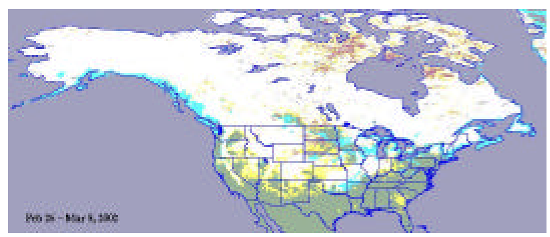
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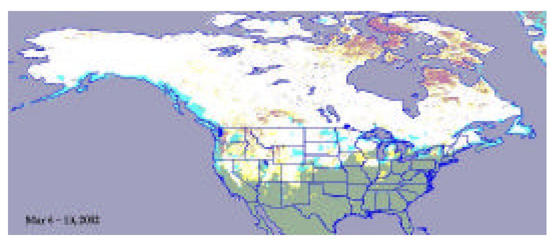
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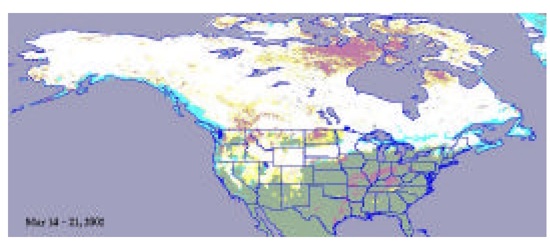
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