USE OF PASSIVE MICROWAVE AND OPTICAL DATA FOR LARGE-SCALE SNOW-COVER MAPPING

V. V. Salomonson
Earth Sciences Directorate/Code 900
NASA/Goddard Space Flight Center
Greenbelt, MD 20771, U.S.A.

D. K. Hall
Hydrological Sciences Branch/Code 974
Laboratory for Hydrospheric Processes
NASA/Goddard Space Flight Center
Greenbelt, MD 20771, U.S.A

J. Y. L. Chien
General Sciences Corporation
Laurel, MD 20707, U.S.A.

Introduction

Satellite data from different sensors can be exploited to yield maximum information on snow cover, depth and reflectance. This paper reflects some rudimentary efforts to compare optical and passive-microwave data for mapping snow cover. In this paper, we discuss some of the advantages and difficulties in using optical and passive-microwave data, together, to map snow cover. The ability to use multiple data sets will be especially important when future Earth Observing System (EOS) sensors are launched with improved optical and microwave sensors in the late 1990s and early 21st century. Thus it is necessary to intercompare data sets now so that reliable algorithms will be in place at or near the time when EOS is launched.

Background

Maps of snow extent for the Northern Hemisphere have been produced using the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Frequency Radiometer (AVHRR) and other sensors. These maps have been available since 1966 (Matson et al., 1986). NOAA hemispheric-scale snow maps are digitized weekly using the National Meteorological Center's standard-analysis grid, an 89 X 89 cell Northern Hemisphere grid with polar-stereographic projection. Global snow maps have been produced using multichannel passive-microwave data since 1978, enabling the estimation of snow extent and depth at a 25 - 30 km resolution (at 37 GHz) through cloudcover and darkness (Kunzi et al., 1982; Foster et al., 1984).

Chang et al. (1987) studied six years of snow-cover maps derived from the Scanning Multichannel Microwave Radiometer (SMMR) and compared the derived snow extent with NOAA National Environmental Satellite Data and Information Service (NESDIS)- and U.S. Air Force Global Weather Center (USAFGWC)-derived snow-cover maps. They found that the total snow-covered area derived from SMMR is about 10 percent less than that derived from the other 2 products. This difference is attributed to the inability of the passive-microwave sensors, at the frequencies studied, to detect shallow, dry snow (less than about 3 cm deep).

Robinson et al. (1993) also compared NOAA and passive-microwave data of Northern Hemisphere snow extent. They found that the mean monthly snow extent for the Northern Hemisphere land areas (exclusive of Greenland), as determined from passive-microwave data, is from <1 million to as much as 13 million km^2 below the extent derived from the NOAA Northern Hemisphere snow charts for 9 years of coincident data. The differences were found to be greatest in the late fall and early winter. This difference was explained, in part, by wet and shallow snow being confused with unfrozen ground using passive-microwave data.

Data and Methodology

We have assembled a time series of both passive-microwave and NOAA Pathfinder data during the period 21-30 January 1988 for parts of North America. The Pathfinder data are AVHRR global area coverage (GAC), 4-km resolution data, gridded onto an 8-km resolution cylindrical-conical grid (Figure 1). No specific algorithm is applied to the data to map snow because of the difficulty in distinguishing snow and clouds using the Pathfinder data. The passive-microwave data are from the Special Sensor Microwave/Imager (SSM/I) which operates on-board the Defense Meteorological Satellite Program (DMSP) satellite, and has a spatial resolution of about 30 km. The algorithm developed by Chang et al. (1987) was used to map the snow extent as shown in Figure 2. The map shows snow cover as white and non-snow-covered land as dark gray. The Pathfinder and SSM/I data sets were registered using an image analysis computer system.

Also, for the period 27 January to 2 February 1993, SSM/I data were composited and a map was produced of the continental United States. This was compared with a NOAA/National Operational Hydrologic Remote Sensing Center (NOHRSC) map derived from the same time period for the United States. The maps were registered.

Results and Discussion

Using the time series of Pathfinder data, and a 'flicker' routine in the image-analysis software, a 'film loop' was generated, allowing us to identify clouds and distinguish them from snow because cloud motion is apparent when a time series of data are viewed in a looped format. A similar technique has been used by NESDIS to distinguish snow and clouds as an aid in mapping snow cover for generation of their weekly snow-cover product.

Figures 1 and 2 show digitally-registered Pathfinder and SSM/I data, respectively. January 27, 1988 is the best example of the co-registered data sets for the 10-day period that was studied. Analysis of daily AVHRR and SSM/I data from January 1988 has revealed good agreement between the data sets in the location of the snowline in the north-central United States (see arrows on Figures 1 and 2). Persistent clouds over much of the country during this 10-day time period made the comparison with the visible data especially difficult.

There are two basic reasons for a lack of agreement in the position of the snowline as measured on the different data sets. The first addresses the fact that different snow characteristics are measured by the different sensors, and the second is due to gridding and geolocation factors. As mentioned previously passive-microwave sensors do not detect thin, dry snow, or wet snow along the edges of snow-covered areas (i.e. wet snow and wet soil are not readily distinguishable) (Chang et al., 1987). And snow cover can be confused with frozen ground using passive-microwave data (Chang et al., 1992; and Grody and Basist, in press). This can be a factor in the vicinity of the snowline, and in high-elevation areas like the Tibet Plateau (Grody and Basist, in press). The very different spatial resolutions of the data sets (8 km for the Pathfinder data, and >30 km for the SSM/I data) causes some discrepancies in amount of snow mapped, especially near coastlines. In the near future when the data sets can be gridded onto a common grid, then some of these problems will be ameliorated.

The composited SSM/I and NOHRSC maps (not shown) for the week beginning January 27, 1993, were digitally registered and show some interesting differences. It is not possible to register the maps in the continental interior because the NOHRSC map shows state boundaries, but the SSM/I map does not and there are few suitable tie points in the continental interior with which to use in the registration process. This may account for some of the large differences that are observed in the snowline position in the continental interior on the two maps. Another reason for differences in the snowline position may be that the two products had a different compositing scheme. The SSM/I-compositing scheme maps the maximum snow extent for the period regardless of cloud-cover. The NOHRSC-compositing scheme represents the latest areal extent of snow cover conditions at 1800 GMT each Tuesday. The snow cover on the map is the last cloud-free image of each pixel on the map (Milan Allen/NOHRSC, personal communication, 1995). Differences between the SSM/I- and the NOHRSC-derived maps that result from the different compositing schemes are especially noteworthy as snow conditions may vary from day to day.

Conclusion

In spite of some difficulties, it is concluded that both optical and passive-microwave data should be used in synergy to provide optimum results in snow-cover mapping. Additional research will permit us to overcome some of the difficulties. In the future, the data sets will be gridded to a common grid to enable comparison and accurate registration of the data sets. Compositing schemes must also be compatible when possible. The passive-microwave data are invaluable under conditions of darkness and persistent cloud cover, while the optical data provide a high-resolution view of snow cover. The high-resolution optical data are particularly important near the snowline when thin, dry, or wet snow may not be mapped using passive-microwave techniques, or when snow and frozen ground have similar microwave signatures.

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Figure 1. Pathfinder data showing snow-covered area over the continental United States and part of Canada.

Figure 2. SSM/I data showing snow-covered area over the United States and Canada.