Comparison of Snow-Cover Maps Derived from Multiple Satellite Data Sets

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ABSTRACT

Snow-cover maps derived from different satellite sensors are compared digitally. Difficulties arise due to the fact that the sensors have different spatial resolutions, and sensors operate in different bands of the electromagnetic spectrum. Generally, the Landsat thematic mapper (TM)-derived maps at 30-m spatial resolution are the most accurate. NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC) 1-km resolution snow maps agree with the TM maps in terms of location of snow cover, but not in terms of total amount of snow cover. This is because the TM maps show detail, such as snow-free tree canopies, branches and stems, and the coarser-resolution data do not. Snow maps of the same areas using two different SSM/I algorithms are also discussed. The coarser-resolution data generally tend to overestimate the amount of snow cover in a scene.

Key words: snow mapping, MODIS, remote sensing

INTRODUCTION AND BACKGROUND

Efforts are ongoing to determine errors of satellite-derived snow-cover maps, in support of the Earth Observing System (EOS) Program which will launch the Terra and the PM-1 spacecraft in 1999 and 2000, respectively. EOS Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Microwave Scanning Radiometer (AMSR-E) snow-cover products will be produced. In this pre-launch time frame, we are studying methods for quantifying comparisons of snow-cover products. Toward this goal, snow maps covering the same areas acquired from different sensors were compared using different snow-mapping algorithms. Four locations were studied on different dates: southern Saskatchewan, a part of New England and eastern New York, central Idaho and western Montana, and a part of North and South Dakota.

Snow maps were produced using a prototype MODIS snow-mapping algorithm on Landsat Thematic Mapper (TM) scenes of each area at 30-m resolution (Hall et al. submitted). TM-derived maps were also produced at 1-km resolution by degrading the 30-m resolution data and then applying the same snow-mapping algorithm to the 1-km data. The MODIS prototype algorithm produces a binary snow-cover map; the MODIS maps will be daily, global maps at 500-m spatial resolution using the SNOWMAP algorithm (Hall et al. 1995; Klein et al.1998). National Operational Hydrologic Remote Sensing Center (NOHRSC) 30 arc-sec (or approximately 1-km resolution at the equator) snow maps, were also used. These maps are produced for approximately 4,000 – 6,000 basins in the United States and Canada on a weekly basis during the Northern Hemisphere winter and spring (Carroll 1990).

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Snow maps derived from ½° x ½° resolution Special Sensor Microwave Imager (SSM/I) data were produced using two different algorithms. The Grody and Basist (1996) method uses the difference between the microwave brightness temperature (T_B) at 37 and 19 GHz, and at 85 and 22 GHz vertical polarizations, and a decision tree whereby filters are used to isolate the snow-cover signature. The Chang et al. (1997) method (without forest-cover corrections) was also used. This is based on the difference between the 19 and 37 GHz channels,

$$SD = 1.6 * (19H - 37H) - 8.0 \qquad [1]$$

where SD is snow depth (in cm).

The TM, NOHRSC and two different SSM/I snow maps, were compared digitally (Table 1). In most cases, TM-derived maps at 30-m resolution show less snow cover than the coarser-resolution maps (Figure 1) because areas of incomplete snow cover in forests (e.g., tree canopies, branches and trunks) are seen in the TM data, but not in the coarser-resolution maps. The TM and NOHRSC snow maps generally agree with respect to the spatial variability, but not the amount, of snow cover.

Table 1. Percentage of snow cover as determined from the various snow maps. SSM/I-1 refers to the SSM/I-derived snow maps using the Grody and Basist (1996) algorithm, and SSM/I-2 refers to the SSM/I-derived snow maps using the Chang and others (1997) algorithm. TM-1 and TM-2 refer to the snow cover mapped by the TM, using the SNOWMAP algorithm, when the TM data were used at 30-m and degraded to 1 km resolution, respectively.

Location (and date of TM scene)	TM-1	TM-2	NOHRSC	SSM/I-1	SSM/I-2
Saskatchewan (27 January 1996)	70	86	100	100	100
New England (21 January 1997)	37	52	77	73	4
Idaho (28 January 1998)	62	81	87	77	67
North & South Dakota (7 February 1998)	64*	64*	57	89	86

* Though the TM-2 map mapped slightly more snow cover than did the TM-1 map, as a percentage of the total area of the scene, both rounded off to 64%.

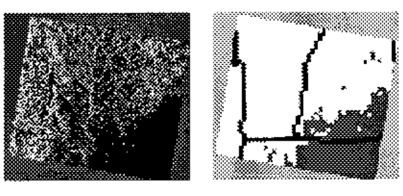

Figure 1. A snow map. covering parts of New England and eastern New York, produced from 30-m resolution TM data, acquired on 21 January 1997, is shown on the left. A weekly snow map (18-21 January 1997) produced by NOHRSC, of the same area, is shown on the right. White is snow cover on both scenes. On the TM scene, black represents non-snow-covered areas, and grey represents non-snow-covered areas on the NOHRSC map. Also shown on the NOHRSC map are state lines.

The 30-m resolution TM data generally provide the most accurate snow maps, and are thus used as the baseline for comparison with the other maps. Comparisons show that the percent change in amount of snow cover relative to the 30-m resolution TM maps is lowest using the TM

1-km resolution maps (Figure 2). The highest percent change is found in the New England study area, probably due to the presence of patchy snow cover. A scene with patchy snow cover, such as the New England scene (Figure 1) is more difficult to map accurately than is a scene with a well-defined snowline such as is found on the North and South Dakota scene (Figure 2).

Table 2. Percent change of the snow maps relative to the 30-m resolution maps.

	Saskatchewan	New England	Idaho	North & South Dakota
TM (1-km res)	23	41	31	0
NOHRSC	43	108	40	-11
SSMI-1	43	97	24	39
SSMI-2	43	-89	8	34

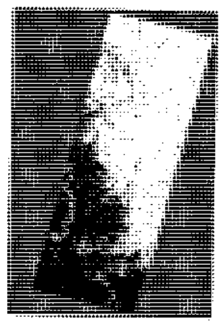

Figure 2. Landsat TM 30-m resolution images showing parts of North and South Dakota on 7 February 1998. A well-defined snowline may be seen in the lower half of the scene.

There are also some important differences in the amount of snow mapped using the two different SSM/I algorithms because they utilize different channels. Because the snow map based on the Grody and Basist (1996) method utilizes the 85 GHz channel, it tends to map more shallow snow cover than does the snow map based on the Chang et al. (1997) algorithm. But both SSM/I snow maps have difficulty mapping wet snow cover, and the Grody and Basist (1996) method maps, as non-snow cover, areas of apparent precipitation when they are actually snow covered. The coarse resolution (1/2° X 1/2°) of the SSM/I causes the derived snow maps to overestimate snow cover.

CONCLUSIONS

This study demonstrates some of the difficulties involved in intercomparing satellite-derived snow-cover maps. First, we do not know which map is the most accurate though we make the assumption, in this work, that the highest-resolution map (TM 30-m resolution) is the most accurate. In addition, since different satellite sensors are used to derive the maps, different algorithms are used. Furthermore, the maps are at different spatial resolutions, thus further complicating the comparisons. More such intercomparisons will be accomplished following the launch of the MODIS sensor on the Terra spacecraft in 1999. It will be possible to use Landsat-7 data to derive snow-cover maps and compare those with MODIS, SSM/I and AMSR-E maps. As the EOS MODIS and AMSR-E data sets become available, and such studies are repeated, we will be able to reduce the uncertainties in the accuracy assessments of various snow maps.

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