Monitoring daily snow cover for disaster mitigation purposes

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A new multisensor technique combines infrared and microwave data from geostationary and polar-orbit satellites.

Snow cover is an important variable in studies of weather, climate change, water resources, and snow hazards. Satellites are used to monitor snow cover at regional and global scales. The most widely used product that relates to snow cover is from the Moderate-resolution Imaging Spectrometer (MODIS) optical sensor on both the Terra and Aqua satellites when they operate in clear-sky conditions. These products are generated over an eight-day timeframe to reduce the problem of cloud obscuration. However, snow cover mapping is required to identify disaster regions at time scales of no more than a day.

Geostationary satellites provide measurements with much higher temporal resolution (typically half or one hour) than do polar-orbit satellites, such as Terra and Aqua. Geostationary satellites therefore have the potential to minimize the cloud-cover problem and make observations of the ground surface for identifying snow. However, the products from geostationary satellites typically provide worse spectral information and radiometric accuracy than the same information from the polar-orbit satellites. In addition, due to the complexity of the spectral signatures from different land cover types, mapping snow cover with the geostationary satellites requires different instrument thresholds, as well as regional spectral information, for different land types. Passive microwave sensors can also be used to map snow cover with high temporal resolution, but such observations are limited to dry snow conditions since wet snow is indistinguishable from a soil surface. However, the coarse spatial resolution (~25km) of microwave sensors results in a significant mixed pixel problem. Snow mapping with passive microwave sensing is therefore typically limited in its accuracy. As such, a combination of optical sensors onboard geostationary satellites and passive microwave sensors will provide the most accurate information about snow cover.

In this work, we have evaluated and applied a multisensor technique for snow mapping at a daily temporal resolution, using the optical sensors of MODIS, the Visible and Infrared Spin Scan-Radiometer (VISSR) onboard the Chinese geostationary satellite FY-2E, and the Microwave Radiation Imager (MWRI) onboard the Chinese polar-orbit satellite FY-3B. VISSR has five wavelength channels: one visible, one mid-infrared, and two thermal infrared. The temporal resolution in its normal mode is one hour. All available daytime VISSR data were resampled to a latitude-longitude projection with a 0.05 degree grid size. MWRI/FY-3B has five frequencies with dual polarizations: 10.65, 18.7, 23.8, 36.5, and 89GHz. Its overpass is at 13:30 local time.

The snow cover algorithm of VISSR is a threshold method based on the different spectral properties of snow-covered surfaces, snow-free surfaces, and clouds. Detection of a snow-covered area is mainly based on high reflectance in the visible band (0.6/μm) and low reflectance in the near-infrared band (3.9/μm). Brightness temperature differences in the infrared bands (3.9, 10.9, and 12.0/μm) are used to discriminate clouds from snow-covered surfaces. In addition, to check the misclassification of clouds as snow cover, a surface-temperature climatology test was used for further investigation of the snow pixels.

Although the high temporal resolution of FY-2E can reduce cloud contamination significantly, there are still cloud detections that cannot be removed. Both spatial-temporal filtering and the combination of multisensors, including MWRI and VISSR, are therefore used to classify the remaining cloud-covered pixels. In the spatial-temporal filtering process, the eight neighboring pixels of each pixel are checked, and/or the results from the previous and next day are used. If cloud cover still remains, then microwave measurements from FY-3B/MWRI are applied to identify if it is actually snow cover. The FY-3B/MWRI snow cover algorithm is normally referred to as the Grody and Ba-sist algorithm, which is used in Interactive Multisensor Snow and Ice Mapping System (IMS) products to isolate snow-cover signatures. This method, however, is unable to detect wet snow surfaces because the presence of liquid water within snow creates a microwave brightness temperature that is similar to

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Figure 1. Maps of China showing snow cover on 21 January 2011, as derived from different datasets and according to different processing techniques. (A) From Moderate-resolution Imaging Spectrometer (MODIS) Terra daily snow cover products. (B) From MODIS Aqua daily snow cover products. (C) From original Visible and Infrared Spin-Scan Radiometer (VISSR) data. (D) From spatially and temporally filtered VISSR data. (E) From original Microwave Radiation Imager (MWRI) data. (F) From combined VISSR and MWRI data.

Table 1. Average cloud coverage and overall accuracy of the different snow cover map products that are shown and defined in Figure 1, from 1 January to 28 February 2011.

<table>
<thead>
<tr>
<th>Snow cover products</th>
<th>Cloud coverage [%]</th>
<th>Accuracy (clear-sky conditions) [%]</th>
<th>Accuracy (all-sky conditions) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOD10A1</td>
<td>58.44</td>
<td>97.18</td>
<td>37.75</td>
</tr>
<tr>
<td>MYD10A1</td>
<td>61.86</td>
<td>96.57</td>
<td>36.53</td>
</tr>
<tr>
<td>FY-2E/VISSR 1</td>
<td>23.82</td>
<td>95.11</td>
<td>71.16</td>
</tr>
<tr>
<td>FY-2E/VISSR 2</td>
<td>18.20</td>
<td>–</td>
<td>75.96</td>
</tr>
<tr>
<td>FY-2E/VISSR/FY-3B/MWRI</td>
<td>0.00</td>
<td>–</td>
<td>89.87</td>
</tr>
</tbody>
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that of a bare surface.\textsuperscript{5,6} We therefore introduced an additional wet-snow detection criterion to our algorithm. If snow is dry during the night and becomes wet during the day, then daytime brightness temperatures will be higher than those acquired at night. The horizontal polarization brightness temperature at 36.5 GHz has a large day-night difference, so we use differences of more than 10K in this measure to detect wet snow.

Figure 1 shows snow cover maps for China on 21 January 2011, a day of particularly heavy snowfall in southern China. These maps are derived using a variety of different methods. The MODIS daily snow cover maps shown for comparison are significantly contaminated with cloud detections. After our spatial-temporal filtering process has been applied (FY-2E/VISSR) the snow cover shows less cloud contamination. The map that combines the FY-2E/VISSR and FY-3B/MWRI snow cover maps completely removes cloud contamination.

We used snow depth observations from 699 weather stations to compare with the six snow cover maps (Figure 1) and to evaluate our technique. Table 1 shows the snow cover accuracy assessment results. All the optical sensors from MODIS and FY-2E/VISSR have high accuracy under clear-sky conditions, whereas under all-sky conditions, the combination of FY-2E/VISSR and FY-3B/MWRI shows the best performance.

Our study indicates the potential use of geostationary satellite data and microwave sensing information for monitoring snow cover, specifically over China. The technique significantly decreases cloud contamination and increases the temporal resolution of the monitoring. Another Chinese weather satellite, FY-2D, began operations in 2007. The combination of FY-2D and FY-2E will increase the possible measurement frequency to 30 minutes in rapid-scan observation mode. By integrating FY-2D/E and FY-3B-MWRI data, and improving our current passive microwave snow detection algorithms, we will continue to enhance our ability to monitor snow hazards in China.

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References