Update on MODIS Snow and Sea Ice Products: March 2005

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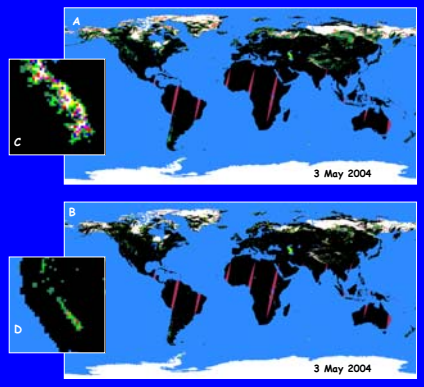
Abstract

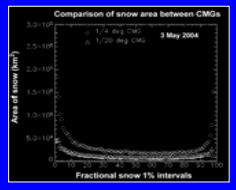
Recent and planned enhancements in the MODIS snow and ice product suite are shown. These enhancements are specifically targeted to provide products that are more useful to, and "friendly" for, modelers. Two new snow products are being developed: a climate-modeling grid (CMG) daily snow-map product as a flat-binary file at 0.25° resolution (1.), and a monthly snow cover CMG product at 0.05°-resolution (2.). Additionally, fractional-snow cover (FSC) for the 500-m resolution product has been developed (3.); both the monthly snow map and the FSC snow map for the 500-m product will be available in Collection 5, while the new 0.25° CMG product will initially be available via ftp in the summer of 2005. An algorithm is under development to separate snow cover from bare glacier ice on Greenland (4.) and is planned as a Collection 6 enhancement to the snow-mapping product. For sea ice, comparisons are being undertaken with the Advanced Microwave Scanning Radiometer-EOS (AMSR-E) ice-concentration product (5.).

1. New Product for GCM Modelers

In response to many requests, we are now producing an experimental product at 0.25° resolution that contains fractional snow cover (FSC). The daily MODIS snow CMG product, available for ordering through NSIDC, at 0.05° resolution, is useful for many applications and as input to models. However the resolution of that product is finer than is needed by many GCM and land-surface modelers who have found that they must first resample the data before using it (for example, see Rodell and Houser, 2005). Additionally, the HDF files are awkward for many modelers to ingest, so this experimental product will be provided as flat-binary files. The full time series of this product should be available during the summer of 2005 for testing purposes.



The standard snow CMG product at 0.05°-resolution (top, image "A") and the lower-resolution snow CMG product at 0.25°-resolution (bottom, image "B") both have the same general pattern of snow cover around the globe. Areas of nearly-100% snow cover (white) are consistent between the two maps. Differences between the maps occur at the edges of snow-covered regions. Snow-covered mountainous regions may exhibit significant differences between the two resolutions. On this date the Sierra Nevada Mountains were nearly completely snow covered as shown in the subimage (C) from the 0.05°-resolution CMG. However the 0.25°-resolution subimage (D) shows the Sierra Nevada Mountains with a much lesser amount of snow cover; the entire Sierra Nevada Mountains and approximately the southern half of California are shown in "D." Quantitative comparisons show that the new 0.25°-resolution product tends to overestimate snow because of the larger size of the grid cells.



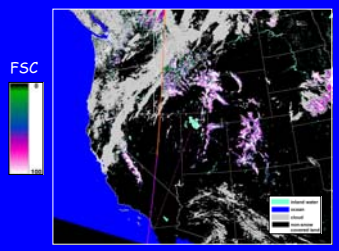
Right - Comparison of the 0.25° and 0.05° CMG for each 1% interval of snow cover from 1 - 100%. Snow-covered area (SCA) is plotted, based on latitude-adjusted cell area. SCA is consistent between the two resolutions with the greatest differences being across the 1-3% range and at 100%.

2. Monthly Snow Maps

A new product in Collection 5 will be MOD10CM which is the monthly snow map (including fractional snow cover) on the climate-modeling grid (CMG) at 0.05-degree resolution. This product is amenable to comparison with operational products such as those produced by the Rutgers University Climate Lab (RUCL) using NOAA/NESDIS data. It is expected that this product might become part of a climate-data record (CDR) that could employ RUCL maps and future National Polar Orbiting Environmental Satellite Service (NPOESS) maps.

3. Fractional Snow Cover MOD10_L2

An algorithm was developed to map fractional snow cover (FSC) using MODIS data at 500-m resolution using Terra MODIS data (Salomonson & Appel, 2003). The FSC algorithm utilizes MODIS band 6 as well as other bands. However, most of the band 6 detectors are non-functional on the Aqua MODIS sensor, so a new algorithm was developed using MODIS band 7 to apply to both Terra and Aqua MODIS data (Salomonson & Appel, submitted).



Fractional snow cover in the western United States, April 9, 2003

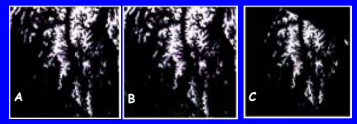
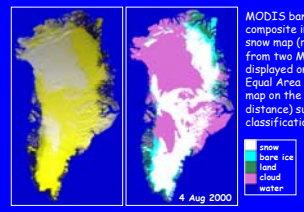


Image "A" is an FSC estimate (map) from the Terra MODIS for 500 m cells using an algorithm designed to work with the Terra MODIS (utilizing band 6). Image "B" is an FSC estimate using the an algorithm designed to work with both the Terra and Aqua MODIS instruments (using band 7). Image "C" is an image derived from Landsat-7 ETM+ and is shown here as "ground truth." Comparison of these three images shows a general correspondence in the results; quantitative comparisons may be found in Salomonson & Appel (submitted).

4. Mapping Snow on Greenland

Anomalously-warm summers have occurred recently on the Greenland Ice Sheet, exposing large areas of bare glacier ice at relatively high elevations on the ice sheet (Steffen et al., 2004). MODIS can be used to monitor changes in the amount of exposed ice on ice sheets. This has important climatic implications especially since the Greenland Ice Sheet has melted in the past (Koerner, 1989), and if it were to melt in the future, it would contribute ~6.5 m to sea-level rise.

The snow-mapping algorithm that is employed to map snow globally (see Riggs et al., 2003) was designed to map daily seasonal snow cover and was not designed to distinguish snow cover from bare ice on the Greenland Ice Sheet during the melt season. Therefore a separate algorithm is being developed that will distinguish snow from bare ice on Greenland; this algorithm will be embedded within the current snow-mapping algorithm and should be available for Collection 6.

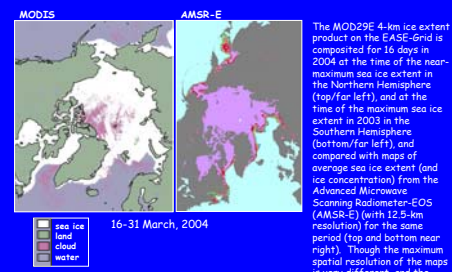


MODIS bands 1, 4, 6, color-composite image (left), and snow map (right) created from two MODIS swaths and displayed on an Albers Conical Equal Area projection. The map on the right is a (minimum distance) supervised classification.

5. Maximum Sea Ice Extent

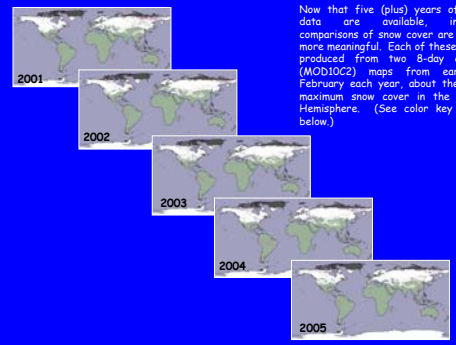
MODIS sea ice map products are available at 1-km and 0.05°-resolution (~4 km at the Equator) on the EASE-Grid projection, providing daily sea ice extent and ice-surface temperature (IST) at 1- and 4-km resolution (Hall et al., 2004). The MODIS maps are useful for determination of the ice edge, the amount and location of sea ice, and for inclusion in GCMs. It is also possible to map sea ice concentration from MODIS data (Drüe and Heinmann, 2005) though that is not part of the current suite of MODIS sea ice products.

With five years of MODIS data now available, it is interesting to map the interannual changes in maximum and minimum sea ice extent. This has been accomplished for many years using passive-microwave data through clouds and darkness albeit at a coarser resolution than is possible with MODIS.

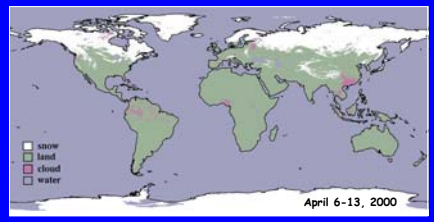


The MOD29E 4-km ice extent product on the EASE-Grid is composited for 16 days in 2004 at the time of the near-maximum sea ice extent in the Northern Hemisphere (top/far left), and at the time of the maximum sea ice extent in 2003 in the Southern Hemisphere (bottom/far left), and compared with maps of average sea ice extent (and ice concentration) from the Advanced Microwave Scanning Radiometer-EOS (AMSR-E) (with 12.5-km resolution) for the same period (top and bottom near right). Though the maximum spatial resolution of the maps is very different, and the MODIS map represents maximum sea ice extent for the period, and the AMSR map represents average sea ice extent (and concentration), the amount and location of sea ice that is mapped with each sensor is extremely close, providing a high level of confidence in both products. AMSR-E images courtesy of Don Cavalieri, NASA/GSFC, Cryospheric Sciences Branch.

Maximum Snow Cover 2001-2005



Now that five (plus) years of MODIS data are available, interannual comparisons of snow cover are becoming more meaningful. Each of these images is produced from two 8-day composite (MOD10C2) maps from early-to-mid February each year, about the time of maximum snow cover in the Northern Hemisphere. (See color key on CMG, below.)



Eight-Day Composite Global Climate Modeling Grid (CMG) Snow Map (MOD10C2) – 0.05° resolution (~5.6-km); MOD10C2 maps maximize snow cover and minimize cloud cover for the 8-day period.

References

Drüe, C. and G. Heinemann, 2005: Accuracy assessment of sea-ice concentrations from MODIS using in-situ measurements, *Remote Sensing of Environment*, 95(2):139-149.

Hall, D.K., J.Key, K.A. Casey, G.A. Riggs and D. Cavalieri, 2004: Sea ice surface temperature product from the Moderate-Resolution Imaging Spectroradiometer (MODIS), *IEEE Transactions on Geoscience and Remote Sensing*, 42(5):1076-1087.

Hall, D.K., G.A. Riggs, V.V. Salomonson, N.C. DiGirolamo and K.J. Bayr, 2002: MODIS snow cover products, *Remote Sensing of Environment*, 83:191-194.

Key, J., J. Collins, C. Fowler and R. Stone, 1997: High-latitude surface temperature estimates from thermal satellite data, *Remote Sensing of Environment*, 61:302-309.

Koerner, R.M., 1989, Ice core evidence for extensive melting of the Greenland ice sheet in the last interglacial: *Science*, 244:4907:964-968.

NSIDC, http://nsidc.org

Riggs, G.A., D.K Hall and V.V. Salomonson, 2003: The MODIS Snow Product User Guide for Collection 4 Data Products, http://modis-snow-ice.gsfc.nasa.gov.

Rodell, M., and P. Houser, 2005: Updating a land-surface model with MODIS-derived snow cover, *Journal of Hydrometeorology*, 5:1064-1075.

Salomonson, V.V. and I. Appel, 2004: Estimating the fractional snow covering using the normalized difference snow index, *Remote Sensing of Environment*, 89(3):351-360.

Salomonson, V.V. and I. Appel, submitted for publication: Development of the Aqua MODIS NDSI fractional snow cover algorithm and validation results.

Steffen, K., S. V. Nghiem , R. Huff, and G. Neumann, 2004: The melt anomaly of 2002 on the Greenland ice sheet from active and passive microwave satellite observations, *Geophysical Research Letters*, 31.