Assessment of Uncertainties in the New MODIS Cloud-Gap Filled Snow Maps

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EXTENDED ABSTRACT

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MODerate resolution Imaging Spectroradiometer (MODIS) cryosphere products that have been available since the launch of the Terra MODIS in 2000 and the Aqua MODIS in 2002 include snow-cover extent and daily snow albedo, as well as extent and ice-surface temperature (IST) of sea ice, and IST of the Greenland Ice Sheet. Reprocessing, from Collection 5 (C5) to Collection 6 (C6) and Collection 6.1 (C6.1), has led to improvements in the MODIS snow-cover extent, daily snow albedo and IST standard data products (Riggs et al., 2016; Riggs et al., 2017). Work is ongoing to evaluate and document uncertainties in the C6 suite of cryosphere products. Here, we focus on a new product, MOD/MYD10A1F, which is a daily, cloud-gap filled (CGF) snow-cover map (Hall et al., 2010).

Researchers have used various methods to reduce cloud cover in the MODIS snow maps. One common method is to combine Terra (MOD10A1) and Aqua (MYD10A1) snow maps for a given day. This takes advantage of the fact that the Terra and Aqua satellite overpasses occur at different times of the day and, since clouds move, oftentimes more snow cover or non-snow-covered land cover can be imaged and mapped by the snow-cover mapping algorithm, as compared to using the Terra or Aqua snow map alone. However, this method of cloud clearing is of limited utility because typically it does not allow a great deal more snow or non-snow-covered land to be observed/mapped on a given day.

As part of the C5 and C6 snow product suite, 8-day maximum snow-cover maps (MOD/MYD10A2) have been available to provide greatly-reduced cloud cover for the MODIS snow maps, but are available only once every eight days, and often retain some cloud cover which is not ideal for many users. Nevertheless, these snow maps have been useful in numerous research studies.

Cloud-gap filling is another common method that provides cloud-reduced or cloud-free snow maps. For C6 we have adopted this technique to enable fewer clouds, and more snow (or snow-free land), to be mapped on a given day (Figure 1). (It is expected that the new CGF maps will replace the MOD/MYD10A2 (8-day maps)). Though cloud-gap filling provides a cloud-free snow map every day, the accuracy of any given decision at the pixel level depends in part on the age of the snow/no-snow decision.

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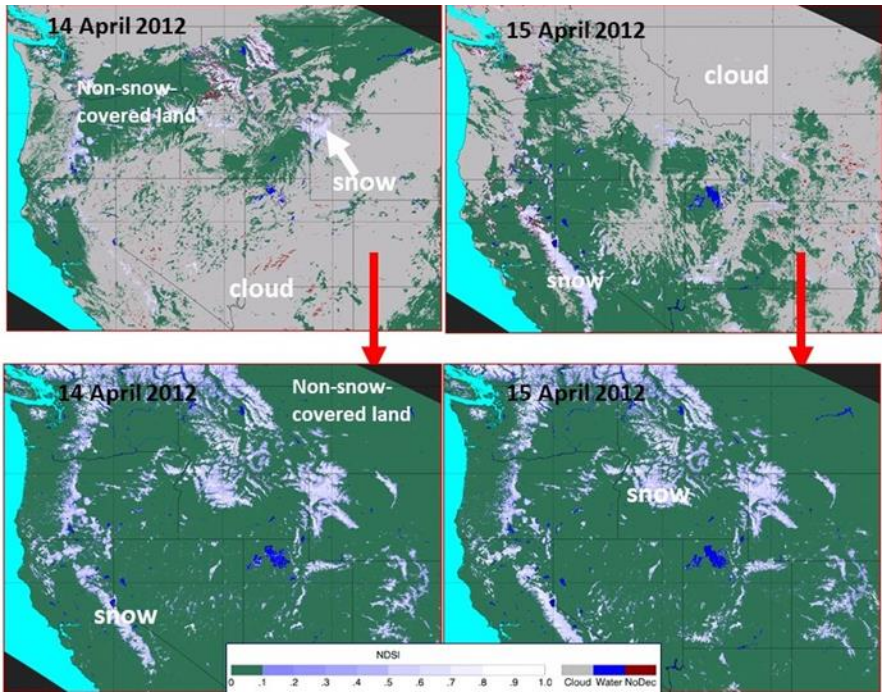

Figure 1. Examples of the MOD10A1 and the new MOD10A1F MODIS snow maps. Top row: Note the extensive cloud cover on 14 and 15 April 2012 on the MOD10A1 snow maps. Bottom row: The corresponding MOD10A1F, or cloud-gap filled (CGF) maps. Non-snow-covered land is shown in green.

A new feature of the C6 product suite provides the snow maps as normalized-difference snow index (NDSI) maps instead of fractional-snow cover (FSC) maps as was done in C5. This has the advantage of allowing a user to more-accurately determine FSC in their particular study area by applying a simple algorithm to derive FSC from the NDSI. The C5 global FSC algorithm was useful for estimating FSC for very large areas, but of more-limited utility for specific study areas.

For a time series of CGF snow maps extending from 1 February through 30 April 2012, comparisons have been conducted with other snow-cover maps such as those developed from the Visible Infrared Imaging Radiometer Suite (VIIRS) and from the National Ice Center's Interactive Multispectral Snow and Ice Mapping System (IMS), and with true-color images from satellites such as the Terra MODIS, Aqua MODIS, VIIRS and Landsat. Validation of snow-cover products with in situ meteorological-station data has also been conducted for some study areas.

Quality-assurance (QA) information can be exploited to help a user understand product uncertainties and has been available in all previous versions of the MODIS snow-cover mapping algorithms. In C6, a new QA map showing cloud-persistence count (CPC) on a per-pixel basis is available to go along with each CGF snow map. For example, for 19 March 2012, when CPC=0 this means that the reported NDSI value for that pixel was acquired on 19 March 2012. When CPC=1 this means that the reported NDSI value is one day old, hence it was acquired on 18 March, and so on (Figure 2). A user can decide how far back in time they would like to use a snow observation and can easily develop an appropriate CGF map for their application.

Another useful method in C6 for analysis of uncertainties is the ability to remove the cloud mask, MOD/MYD35, that is an input to the MODIS snow-mapping algorithm. In C6, the cloud mask can be 'removed' so that a user can visually see what is beneath the clouds. Sometimes the shape of features beneath clouds can be indicative of snow cover on terrain, and a user might make the assumption or decide that the cloud mask algorithm failed to properly distinguish snow and clouds

and thus incorrectly mapped cloud when the feature was really snow. The ability to remove the cloud mask may allow a user to view more snow cover but must be used with a great deal of caution.

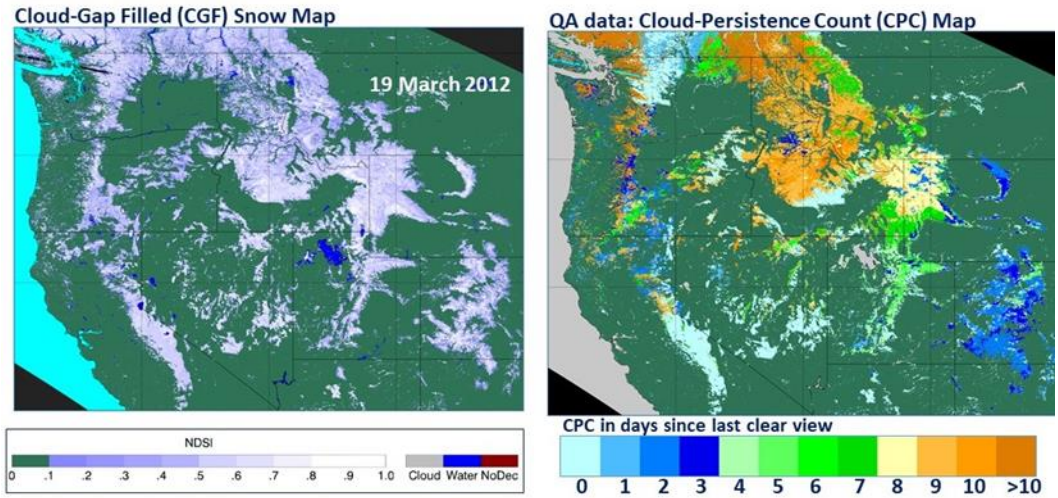

Figure 2. Left - Cloud-gap filled (CGF) MOD10A1F map for 19 March 2012. Right – Cloud-Persistence Count (CPC) map from the Quality Assurance (QA) information. Each CGF map comes with a CPC map so that a user may determine the age of the snow observation on a per-pixel basis.

Preliminary results demonstrate the great utility of the MODIS CGF maps as long as uncertainty information is understood by a user. The CGF product is scheduled to be available in the summer of 2018.

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