## Abstract

Daily snow and ice cover for Alberta is derived from the MODIS instrument onboard the Terra and Aqua satellites. Based on 500 m spatial resolution. The MODIS mission recently released two cloud gap filled (CGF) data products (MOD10A1F/ MYD10A1F) that are updated on a daily basis. This CGF NDSI snow cover has current day cloud observations replaced with a previous day non-cloud observation. The objective in new C6.1 collection is to minimize snow cover detection errors of omission and commission for the purpose of mapping snow cover extent (SCE) accurately on the global scale.

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### Purpose

The purpose of the snow cover product is to provide a synoptic, strategic-level estimate of snow and ice cover for Alberta on a daily basis.

## Description

The CGF snow cover map is an estimate of the snow cover that might exist under current cloud cover. Snow cover is detected using the NDSI ratio of the difference in MODIS VIS and SWIR reflectance:

NDSI = ((band 4-band 6) / (band 4 + band 6)).

Normalized Difference Snow Index (NDSI) is an index that is related to the presence of snow/ice in a pixel and it is the major parameter utilized to generate the MODIS CGF snow cover products. The CGF snow cover product is produced from the daily tiled M*D10A1 * and the previous day M*D10A1F. Daily gaps in observations caused by cloud cover are filled by retaining the previous clear view data for a cell if the current day is cloud obscured (Hall et al., 2010). A data layer that tracks the number of days since last clear view of a cell is included in the product and it is called "Cloud persistence". Cloud persistence is tracked by incrementing or resetting the count of consecutive days of cloud observed for a cell in the Cloud_Persistence dataset. Cloud tracking is done by incrementing the count of consecutive cloud days in M*D10A1F. If the current day is a cloud observation, then the count is incremented by one day. If the current day is a non-cloud observation then the cloud persistence count is reset to 0.

Snow cover is given in the range of 0-100%, which is the NDSI value of a pixel. The NDSI is effective at detecting snow cover on the landscape when skies are clear, and viewing geometry and solar illumination are good. As shown in the following figure 1, each data file includes three Scientific Data Sets (CGF_NDSI_Snow_Cover, Cloud Persistence, and MOD10A1_NDSI_Snow_Cover) and two quality fields (Basic_QA and Algorithm_Flags_QA).

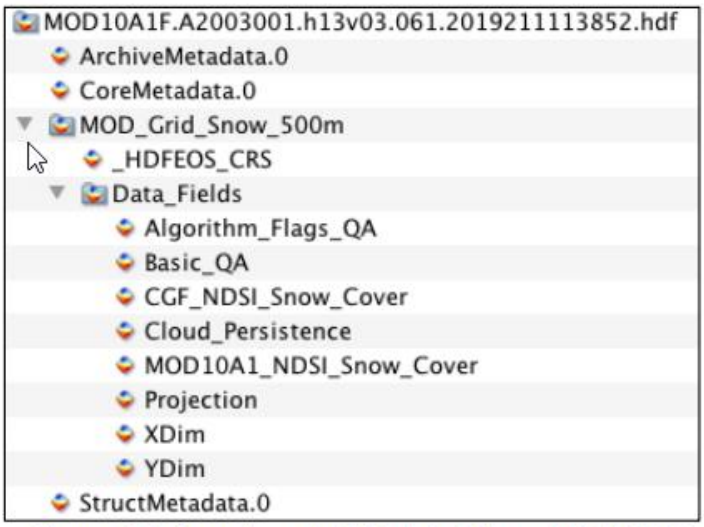


Figure 1. This figure shows the fields included in each MOD10A1F data file as displayed with Panoply software.

The NDSI_Snow_Cover data is the result of the NDSI snow detection algorithm with the cloud mask, ocean mask and night mask overlaid. The snow detection technique for M*D10A1F is based on the Normalized Difference Snow Index (NDSI) (Hall and Riggs, 2011) with data screens applied to alleviate snow detection commission errors and flag uncertain snow detection. The algorithm is the same as used in C6 with minor revisions made for the low visible reflectance screen.

The surface temperature screen is linked with surface height and is used to reverse snow detections at low elevations and to flag warm snow detections at high elevations.

| Parameter | Description | Values |
|---|---|---|
| CGF_NDSI_Snow_Cover | Cloud-gap-filled NDSI snow cover. | NDSI snow cover values and data flags values, stored as 8-bit unsigned integers.<br>0 - 100: NDSI snow cover (no snow to completely snow covered)<br>200: missing data<br>201: no decision<br>211: night<br>237: inland water<br>239: ocean<br>250: cloud<br>254: detector saturated<br>255: fill |

Figure 2. the figure shows value range for snow cover and other values pres

Data screens are applied for two purposes in the algorithm, one is to provide information specific to a snow or not snow result based on screens applied and the other is to provide other information relevant to evaluation of the snow cover product. Several data screens based on snow spectral features or other characteristics are applied in the algorithm to alleviate snow commission errors. Those screens are used to reverse snow cover detection or are used to flag uncertain, lower quality snow cover detection situations. All pixels were screaned for different flags from Basic QA band . The basic QA and the algorithm flags QA datasets in M*D10A1F are also set to the current day non-cloud observation corresponding QA data or replaced with previous day values if current day observation is cloud.

The M*D10A1F also contains a copy of the current day M*D10A1 NDSI_Snow_Cover data set to facilitate comparison with the CGF snow cover.On the first day of M*D10A1F production the CGF snow map will be the same as the M*D10A1; on successive days the cloud cover in the CGF will decline, eventually to zero, as non-cloud observations replace cloud observations over time. A reasonable estimate of the number of days to reach a nearly cloud free CGF is five to seven days, but is dependent on the season and location imaged

*Field observations*

For pixels with values between1 to 10, it can safely be assumed that 25 ha of a pixel area is free or almost completely free of snow.
Values 10-30 – there are some smaller patches of snow but majority is snow free.
Values 40-60 – area covered by snow and area free of snow is similar.
Values 60-80 - majority of the pixel area is under snow with some patches of exposed ground
Values > 80 - pixel area is completely or almost completely covered by snow.

Those evaluations hold ground more or less on the non-treed areas. In treed areas, accuracy would erode and presence/absence of snow should be taken with a reservations.

References


1. *Hall, D.K., and Riggs, G.A. 2011, Normalized-difference snow index (NDSI), Encyclopedia of Earth Sciences Series, Encyclopedia of Snow, Ice and Glaciers, doi 10.1007/978-90-481-2642-2_376. Hall, D.K. and Riggs, G.A. 2007. Accuracy assessment of the MODIS snow product. Hydrological Processes, 21, 1534-1547.*

2. Hall, D.K., G.A. Riggs, J.L. Foster and S.V. Kumar, 2010: Development and evaluation of a cloud-gap-filled MODIS daily snow-cover product, Remote Sensing of Environment, 114:496-503, doi:10.1016/j.rse.2009.10.007, doi:10.1016/j.rse.2009.10.007.


## Supplementary information


1. George A. Riggs Dorothy K. Hall Miguel O. Román ,April 2019: MODIS Snow Products Collection 6.1 User Guide *https://modis-snow-ice.gsfc.nasa.gov/uploads/snow_user_guide_C6.1_final_revised_april.pdf*



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[i] **M*D10A1*** is indicates both Terra and Aqua[i]