5.1 ENHANCEMENT OF THE MODIS DAILY SNOW ALBEDO PRODUCT

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1. INTRODUCTION

The MODIS daily snow albedo product is a data layer in the MOD10A1 snow-cover product that includes snow-covered area and fractional snow cover as well as quality information and other metadata (Riggs et al., 2006; Hall and Riggs, 2007). It was developed to augment the MODIS BRDF/Albedo algorithm (MCD43) that provides 16-day maps of albedo globally at 500-m resolution (Schaaf et al., 2002). But many modelers require daily snow albedo, especially during the snowmelt season when the snow albedo is changing rapidly. Many models have an unrealistic snow albedo feedback in both estimated albedo and change in albedo over the seasonal cycle context (Hall and Qu, 2006). Rapid changes in snow cover extent or brightness challenge the MCD43 algorithm; over a 16-day period, MCD43 determines whether the majority of clear observations was snow-covered or snow-free then only calculates albedo for the majority condition (Schaaf et al., 2008). Thus changes in snow albedo and snow cover are not portrayed accurately during times of rapid change, therefore the current MCD43 product is not ideal for snow work. The MODIS daily snow albedo from the MOD10 product provides more frequent, though less robust maps for pixels defined as "snow" by the MODIS snow-cover algorithm. Though useful, the daily snow albedo product can be improved using a daily version of the MCD43 product as described in this paper.

There are important limitations to the MOD10A1 daily snow albedo product, some of which can be mitigated. Utilizing the appropriate per-pixel Bidirectional Reflectance Distribution Functions (BRDFs) can be problematic, and correction for anisotropic scattering must be included. The BRDF describes how the reflectance varies with view and illumination geometry. Also, narrow-to-broadband conversion specific for snow on different surfaces must be calculated and this can be difficult. In consideration of these limitations of MOD10A1, we are planning to improve the daily snow albedo algorithm by coupling the periodic per-pixel snow albedo from MCD43, with daily surface reflectances. In this paper, we compare a daily version of MCD43B3 with the daily albedo from MOD10A1, and MCD43B3 with a 16-day average of MOD10A1, over Greenland. We also discuss some near-future planned enhancements to MOD10A1.

2. BACKGROUND

The MOD10A1 daily snow albedo algorithm was developed by Klein and Stroeve (2002), with heritage from the work of Stroeve et al. (1997), Liang (2000), and Nolin and Liang (2000). Several validation efforts have shown that the MODIS daily snow albedo product is useful over large, relatively-flat areas (e.g., Stroeve et al., 2006; Tekeli et al., 2006), but errors increase in more-complex terrain (Sorman et al., 2006). Daily snow albedo is calculated using inputs such as the MODIS surface reflectance product, BRDF, land cover product and a digital elevation model (DEM) (Klein and Stroeve, 2002). Models of the BRDF of snow are created using the discrete-ordinate radiative transfer (DISORT) model of Stamnes et al. (1988) to correct for anisotropic scattering effects over non-forested surfaces. A narrowband or spectral albedo is calculated for each of the shortwave MODIS bands then combined into a spectrally-integrated broadband albedo. Snow is treated as an anisotropic surface except in forests where it is treated as an isotropic surface.

The best way to compute albedo from space is by using multiple cloud-free observations of the same location on the Earth to estimate the surface anisotropy or BRDF as is done in MCD43. BRDF is not directly measurable, but it can be sampled by measuring surface reflectance, called Bidirectional Reflectance Factors (BRFs), at variable solar and observational angles. To maximize the number of observations, the standard MODIS albedo products (MCD43) are derived from both Terra and Aqua observations of each location on the Earth over a 16-day period (Schaaf et al., 2008). BRFs are input into a numerical model of BRDF called the Ross Thick Li Sparse Reciprocal (RTLSR) model which allows the user to fit a BRDF to measured BRFs, and then to determine albedo under any illumination condition. The output is a function estimating the surface BRDF. The operational MODIS BRDF/Albedo algorithm utilizes this kernel-driven, linear BRDF model which relies on the weighted sum of an isotropic parameter and two functions (or kernels) of viewing and illumination geometry to determine reflectance (Roujean et al., 1992; Schaaf et al., 2002). The BRDF/Albedo algorithm computes the spectral albedos in seven spectral bands (MODIS channels 1 – 7) and

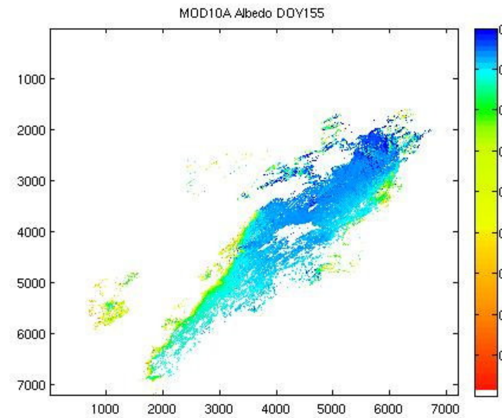

Figure 1a. MOD10A1 daily albedo map of Greenland, 4 June 2007.

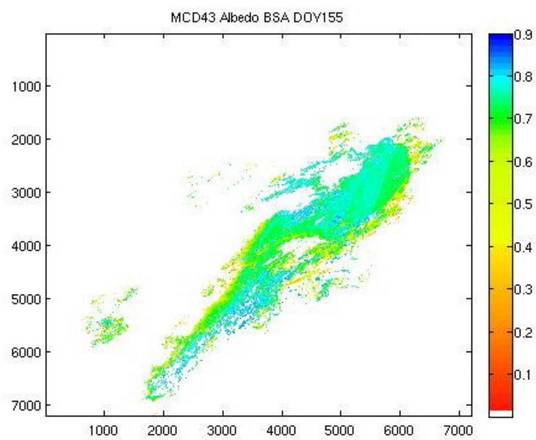

Figure 1b. MCD43B3 BSA map of Greenland using backup algorithm, 4 June 2007.

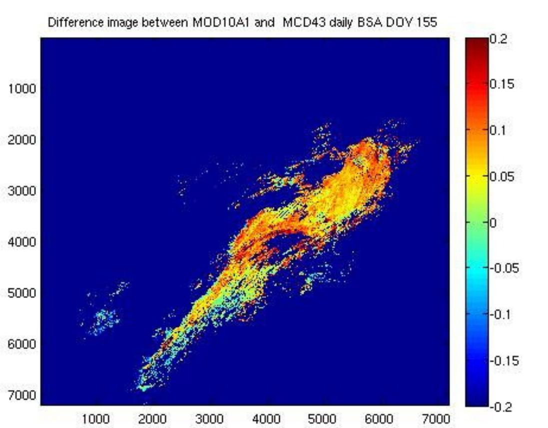

Figure 1c. MOD10A1 minus MCD43B3 difference map, 4 June 2007.

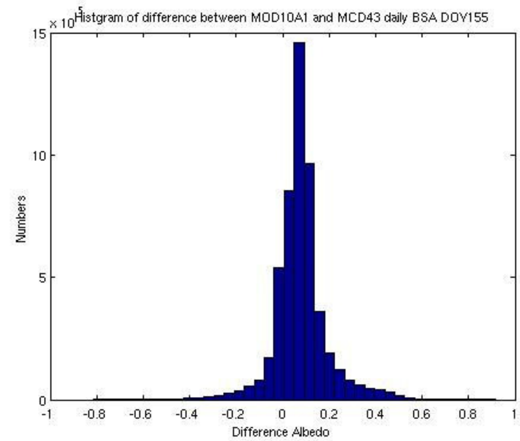

Figure 1d. Histogram of the difference between MOD10A1 and MCD43B3 for 4 June 2007.

three broadbands (0.3 – 0.7, 0.7 – 5.0 and 0.3 – 5.0 µm). Black-sky albedo (BSA), directional hemispherical albedo, is computed for the local noon solar zenith angle for each location. A per-pixel quality flag is included in the quality assurance (QA) metadata with the product.

The highest-quality BRDF/Albedo results are obtained if at least seven cloud-free observations of the surface are available during a 16-day period with sufficiently diverse angular sampling to capture the BRDF, and then a full model inversion is attempted in the MCD43 algorithm. If fewer or less well sampled input observations are available, a backup algorithm is employed. The backup method relies on an archetypal anisotropic model based on land cover and historical high-quality anisotropic model retrievals. A first guess at the anisotropy is made using this *a priori* data base with any available observations to constrain the model (Schaaf et al., 2008). Though the backup algorithm is considered a lower-quality result, the increased-frequency, i.e. daily, results from such backup retrievals can be extremely useful. This is the method that will be used to create the enhanced daily snow product, and is used in this work to compare with MOD10A1.

The MODIS BRDF/Albedo product has been validated at a number of field sites (most recently by Salomon et al. (2006)). Stroeve et al. (2005) compared the operational MODIS BRDF/Albedo high-quality retrievals at a number of field sites in Greenland and found good agreement. Although the polar regions are sampled frequently by MODIS, the extensive cloud cover and the restricted illumination angles reduce the number of high-quality retrievals obtained over these areas (Shuai et al., 2008). Therefore there may be less difference between the operational 16-day values which are primarily lower-quality backup retrievals, and daily retrievals obtained using the backup algorithm than would be the case over non-snow/ice surface types.

3. COMPARISON OF MODIS ALBEDO PRODUCTS OVER GREENLAND

Some preliminary comparisons were made of the daily snow albedo product (MOD10A1) and the daily version of the BSA from the 16-day albedo product (MCD43) using the MCD43 backup algorithm. We show difference maps and histograms for Greenland.

Figures 1a and 1b provide examples of a comparison of the daily snow albedo product, MOD10A1 (Figure 1a), and MCD43B3 (Figure 1b), over Greenland for 4 June 2007. The maps of Greenland are shown in the sinusoidal projection to which the products are mapped and thus appear distorted. Figure 1c is a difference map where the MCD43B3 BSA is subtracted from the MOD10A1 albedo on a per-pixel basis. A histogram of the difference between MOD10A1 and MCD43B3 is shown in Figure 1d. In general we find that MOD10A1 provides slightly higher albedo values than MCD43B3, especially in northern Greenland, and along the west coast. Parts of southern Greenland show slightly higher albedo values in the MCD43B3 product compared to MOD10A1. The greatest differences in albedo are seen in northern Greenland, and range generally from >0.1 to ~0.2 meaning that MOD10A1 provides higher values in those areas (Figure 1d). A similar pattern has been seen on 18 April 2007 (not shown).

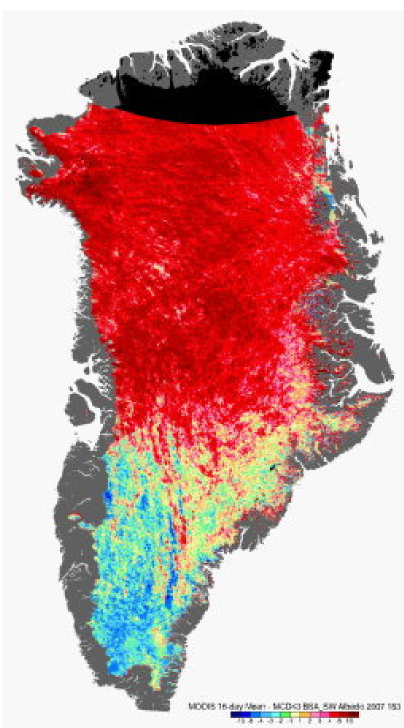

Figure 2. MOD10A1 (averaged for 16 days) minus MCD43B3 (start day – 1 June 2007).

In addition, we averaged 16 days of MOD10A1 daily data of Greenland (start day – 1 June 2007) to compare with MCD43B3 data from the standard 16-day algorithm (Figure 2). Large differences in albedo were seen especially in northern Greenland, while, on other dates particularly later during the melt season, differences in albedo are small (~≤0.10) in southern Greenland and along the coasts.

Some differences result from the two algorithms, MOD10A1 and MCD43B3, not using the same pixel observation; observation selection is currently different between the algorithms. MOD10B1 picks the observation nearest solar noon, closest to nadir and with most grid-cell coverage. The nearest-noon requirement is important in northern latitudes in summer when there can be several orbit coverages of the surface taken at low and high solar angles. Near nadir is the best illumination condition for the algorithm. MCD43 utilizes any observations with sufficient coverage of the pixel.

4. IMPROVED DAILY SNOW ALBEDO PRODUCT

The improved daily snow product, derived using the method of the BRDF/Albedo backup algorithm, will be computed in the following way to permit daily albedos to be calculated over snow-covered areas. Albedos will be retrieved for situations in which even only one direct reflectance observation is available. The method, described in Strugnell and Lucht (2001), uses *a priori* knowledge of the surface anisotropy from the periodic BRDFs retrieved from multiday results to compensate for the lack of directional information in the limited observation obtained each day (also see Strugnell et al., 2001).

5. DISCUSSION AND CONCLUSION

The backup MCD43B3 algorithm relies on daily MODIS data to estimate accurate pixel based BRDF models. Because it uses historical high-quality anisotropic model retrievals, the backup MCD43B3 algorithm may provide a more accurate “first guess” of surface anisotropy for retrieval of a daily quantity than model-based LUTs. While preliminary measurements show many similarities between the MOD10 and MCD43B3 daily results, there are also many differences that still need to be investigated.

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