WAGENINGEN UNIVERSITY
ENVIRONMENTAL SCIENCES

Albedo Assessment and Evaluation over Arctic Siberian Tundra

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Motivation

Land surface albedo is one of the key drivers of the Earth's surface energy budget. To study the feedback of land surface albedo changes – as induced by surface changes (e.g., changing vegetation, soil moisture, thawing lake area) - to the climate in northern high latitudes, reliable albedo data fields are requested. This work aims at assessing and evaluating albedo as derived from the MODIS satellite sensor data, for the year 2000, as a first step towards a multiyear variation and sensor intercomparison analysis.

Methodology

The statistical analysis of the quality flags indicates the reliability of the corresponding albedo products. Consequently, only albedo data based on a full BRDF inversion were analysed.

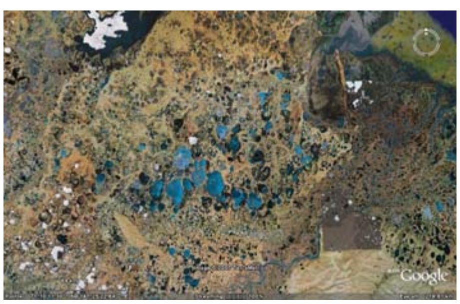
The difference of DHR and BHR_{iso} ($DHR-BHR_{iso}$) provide us with quantitative information on the importance of the distinction between the two physical properties with regard to their implementation in climate models.

Spatially averaged albedo products (DHR, BHR_{iso}, and BRDF parameters) are used to analyse the influence of the status of the snow cover and vegetation onto the scattering regime in different spectral ranges (blue, green, red, nir, and broadband shortwave albedo).

Data and Test Site

We analysed MOD43B1 (BRDF parameters) and MOD43B3 (DHR and BHR_{iso}) in combination with the quality flags MOD43B2, MODIS collection 5 data, 1km spatial resolution, of the year 2000. The albedo data are produced every 8 days and rely on a 16 days composite.

The test site is located in Northeastern Siberia, with a central coordinate of 147.5deg E, 71deg N. The site is covered by MODIS tile h22v01, from which we subsetted an area of about 27'000 km^2 for detailed analysis.



Results

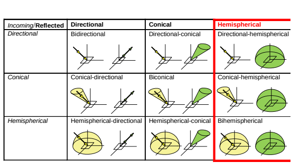
1. Quality flag analysis

- Generally, a large part of the albedo data rely on a magnitude inversion rather than on a full inversion of the BRDF model. Only from March to September, the observations allow a full inversion for a significant part of the selected area.
- During the main period of the growing season (mid June to August), more than 60 percent of the data are based on a full inversion.

2. Differences of DHR and BHRiso

- The differences averaged over the whole area are generally small (< 0.022).
- The average of the $DHR-BHR_{iso}$ difference throughout the year 2000 is 0.0026, with a standard deviation of 0.0061.
- DHR is increasing with solar zenith angle. Given the high latitude of the test site (71deg), the maximum difference of $DHR-BHR_{iso}$ (0.0216) is reached in February, the first data point of the year, with largest solar zenith angle observations (day of year 49 +-8 days).

During winter, the DHR is generally higher than the BHR_{iso}, whereas in summer, the albedo under direct illumination conditions (DHR) is generally lower than under diffuse illumination conditions (BHR_{iso}).
- The above behaviour of differences is in good agreement with findings of Lyapustin, 1999, stating that at solar zentih angles of 52-57deg, the albedo is least sensitive to atmospheric influence.



Albedo terminology after Schaepman-Strub et al., RSE, 103, 27-42, 2006.

BRDF	Bidirectional reflectance distribution function
BHR	Bihemispherical reflectance
BHR_{iso}	Bihemispherical reflectance under isotropic diffuse illumination (white-sky albedo - WSA)
DHR	Directional-hemispherical reflectance (black-sky albedo – BSA)

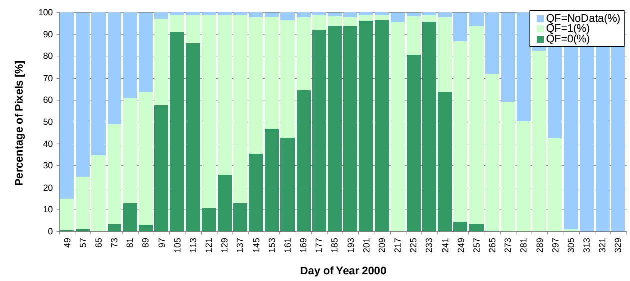


Figure 1: Analysis of quality flags (MOD43B2) of MODIS albedo data products. QF = 0 indicates that the albedo data relies on a full inversion of the BRDF model, whereas QF = 1 indicates a magnitude inversion. Quality flags of day of year 217 need further investigation.

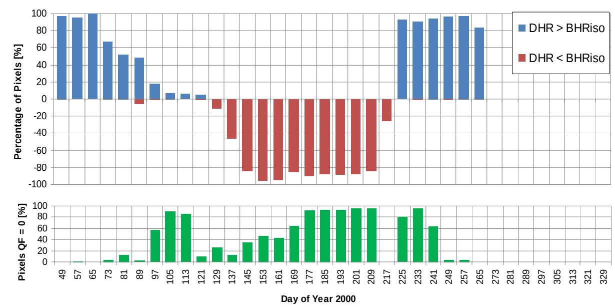


Figure 2: Analysis of the broadband (300-5000nm) DHR versus BHR_{iso}. The percentage of pixels with zero difference is omitted (adds up to hundred percent). During the winter period, the DHR generally shows higher values than the BHR_{iso}, whereas during summer months, the BHR_{iso} is higher than the DHR. This mostly reflects the dependence of the difference on the solar zenith angle.

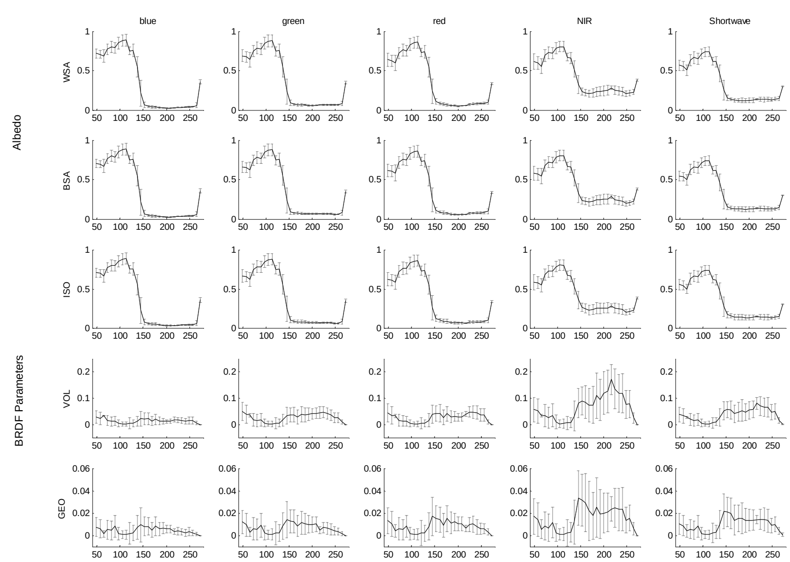


Figure 3: Variation of MODIS BHR_{iso} (WSA), DHR (BSA), and BRDF model parameters (iso = isotropic, vol = volumetric, geo = geometric) for the year 2000.

Narrowband albedo/ albedo parameter wavelength ranges: blue 459-479nm, green 545-565nm, red 620-670nm, nir 841-876nm.

Broadband albedo /albedo parameter wavelength range: shortwave 300-5000nm.

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Suggested conference theme: (1) Validation of remote sensing products, (2) Remote sensing applications to carbon cycle, biochemical and –physical cycles, plant ecology, ecosystems, snow, natural ecosystems, or (3) Earth System model approaches using remote sensing

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Recent studies have shown empirical evidence that the albedo over arctic tundra is changing and that this can contribute to climate warming through potentially large positive feedbacks (e.g., Chapin, 2005). This study aims in assessing and analyzing annual albedo trends over Arctic Siberian tundra. Main factors influencing the albedo at the remote test site (70.8° N, 147.5° E) are the fractional cover and the scattering properties of snow, thawing lakes and rivers, and the vegetation (tussock-sedge, dwarf-shrub, moss tundra), as well as the sun angle (BHR, DHR) and atmospheric conditions (BHR).
This contribution is showing the annual trend (2003/2004) of satellite data derived albedo, an intercomparison of the different available products per sensor (e.g., BHR, BHR(iso), DHR), as well as an intercomparison of the corresponding physical products of different sensors (e.g., DHR MISR vs. MODIS). Further, the BRDF parameters are analyzed to assess the quantitative contribution of different scattering properties of the surface (i.e., isotropic, volumetric, and geometrical scattering component) throughout the year. It is expected that during the snow-covered period, the forward scattering is most pronounced, whereas volumetric scattering and geometric effects are increasing after the onset of the melting, driven by the greening and growing vegetation. Lakes contribute to the forward scattering through their specular reflectance or sunglint. The spectral signature in the isotropic component is analyzed to assess the fractional cover of the main surface types (snow, lakes, vegetation).
We additionally retrieve fractional snow cover, grain size and snow albedo with the multiple endmember spectral mixture model (MODSCAG), coupled with MODIS surface reflectance products. In applying this subpixel model, the albedo of the fractional snow cover is retrieved rather than a pixel composite albedo that can be contaminated by subpixel coverage of vegetation or soil in the case of incomplete snow cover. This allows the assessment of snow characteristics during e.g., the melting process, excluding the influence of the decreasing fractional snow cover.
The analysis will help to interpret albedo changes using albedo products based on semi-empirical approaches. In a further step it is important to use the results to model albedo

changes using radiative transfer models. Based on different scenarios of vegetation, snow cover, and thawing lake dynamics induced by global warming, fields of predicted albedo can be calculated. These can serve as a direct input into regional and global climate models or as a tool to validate albedo fields derived from their land surface modules.