Reflectance Anisotropy of Arctic Tundra Surfaces from Field Radiometry
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Introduction

The Arctic tundra biome is one of Earth’s three major carbon dioxide sinks. Over tens of thousands of years, the remains of plants have been locked in permafrost, sequestering large volumes of carbon. Recent warming at northern high latitudes - amplified by a reduction in the extent of sea ice - is causing tundra permafrost to thaw, potentially allowing the release of large volumes of methane and carbon dioxide into the atmosphere. Another result of the rapid warming is an increase in the abundance of shrubs, observed in Alaskan tundra over the last 60 years. While woody shrub biomass may become somewhat important as a terrestrial carbon sink, a shrub-caused reduction in albedo will enhance summer permafrost thawing further, increasing respiration and the rate at which carbon is returned to the atmosphere. Shrub expansion is also present over a very large area and are able to expand far more rapidly than trees, with consequences for ecosystem structure and function, hydrology, and thus feedbacks to climate. However the rate of expansion and increase in shrub abundance are not known: the goal of this research is to map large scale changes in Arctic tundra vegetation. We are working to track shrub expansion by exploiting the structural signal in remote sensing images from NASA’s Multispectral Imaging Spectroradiometer (MISR) and Moderate Resolution Imaging Spectroradiometer (MODIS) data. This study used radiometry from MODIS to enhance reflectance anisotropy. We have used multi-angle multispectral field radiometry to characterize the anisotropy of typical shrub-free tundra surfaces in order to examine the background contribution and compare with BRF patterns at the MISR observing scale.

Materials & Methods

Field Methods

A 21-day field campaign was carried out on the North Slope, AK during summer, 2010 (July 24-August 13) to gather structural and radiometric ground truthing data. A total of 14 sites were visited along the Chandler and Colville Rivers starting at 69°45’N, 152°18’-35.8°W and ending at 69°48’0.1’N, 151°50’30.7°W. Sampling plots were within 1.5 km from the river with dimensions of 250m x 250 m (Figure 3a). At each site, structural data of the woody vegetation was collected following a line intercept method. The radiometric data collected consist of ten sets of multiregional images of the surface taken with a Terracam ADC multispectral camera (green, red and near-infrared bands with CMOS detectors). The instrument was mounted on a frame at 3.6 m above the ground. Each set included two records of forward and backward-scattering reflectance in both the principal and perpendicular planes at view zenith angles of 70, 60, 45, 30, 20, and 0 degrees (Figure 2). Four large (10-12 inch) Spectralon calibration panels with 2%, 10%, 25% and 50% nominal reflectance values were placed within the field of view of the camera, allowing calibration of the image pixel values to spectral bidirectional reflectance factors (BRF).

Collation of Validation Data

Our field sites are located along the Chandler River, in the Anaktuvuk burn area, and along the Colville River (Figure 3). In order to validate shrub cover maps from GO model inversion and determine whether models can be adequately calibrated, oblique aerial and field photographs were acquired in the summer of 2009 and structural and radiometric reference data were acquired in the summer of 2010. High resolution satellite images (QuickBird, IKONOS) were also acquired for all sites. Estimates of shrub cover were obtained from the satellite imagery and used to make preliminary assessments of retrievals from inversion of the GO model. These first cover estimates were obtained using simple thresholding and will be refined through the use of the CANAPI (CANopy Analysis with Pandemic Imagery) code and with geometrically-corrected versions of the aerial photography that have much higher spatial resolution. With the background predictions from field, aerial and satellite imagery, it may be possible to invert a geometric-optical (GO) model to retrieve estimates of shrub crown fractional cover and shrub abundance with either a fixed or dynamic background.

Results

There was a quasi-linear relationship between the camera digital number and the standard reflectance value of the Spectron reflectance panels at nadir viewing angle (Figure 4). The data show that at-nadir red reflectance of non-shrub tundra varies from 3%-6%, depending on surface composition and plant species, which is in good agreement with other (sparse) field and airmounted measurements. An initial analysis of the trajectory BRF for the field radiometry data shows that BRF increases with the viewing zenith angle as expected, with a peak in the backsotting direction near the hot spot (Figure 5). Since one objective is to investigate the effects of shrub cover on bidirectional reflectance distribution function (BRDF) and surface albedo, we need to establish relationships between the proportions of different components (edges, shrubs, mosses, lichens) and reflectance magnitude and anisotropy. These surface data are very helpful, although scaling the field results to the MISR scale is difficult.

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References

The red channel of our BRDF/Albedo calibration was used to estimate the reflectance of the field sites (when scaled to the MISR footprint). The MISR reflectance data was obtained from the NASA Langley Scientific Visualization Studio. The BRDF/Albedo calibration was used to estimate the reflectance of the field sites (when scaled to the MISR footprint).