Characterization of Surface Albedo Over the ARM SGP CART and the NSA

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Introduction

Surface albedo is needed for satellite remote sensing of the surface radiation budget and for climate modelling. Determination of areal-mean surface albedo is challenging. Over the Southern Great Plains (SGP) site, a primary challenge lies in the inhomogeneity associated with different land cover types. Over the North Slope of Alaska (NSA) site, persistent cloud cover renders remote sensing of surface albedo difficult. We tackle both challenges following two different approaches. Over the SGP site, we use data collected at the extended facilities located within the Cloud and Radiation Testbed (CART) region to develop a climatology of spatially and seasonally variable surface albedo by combining ground-based observations with space-borne remote sensing. The diurnal and seasonal dependencies of surface albedo over different surface types (alfalfa, pasture, pasture/wheat, prairie, rangeland/grazed, rangeland/ ungrazed, wheat and wheat/soy) are obtained from ground-based upwelling and downwelling measurements, while satellite data from platforms such as the geostationary operational environmental satellite (GOES) and experiments such as the Clouds and Earth's Radiant Energy System (CERES) extend such point-specific observations to much larger areas. Comparison of modelled broadband downwelling fluxes using this surface albedo database (corrected for cloud cover) with broadband downwelling fluxes measured by the Solar Infrared Radiation Stations (SIRS) at the extended facilities will be shown. At the NSA site, we will apply the method proposed by Li et al. (2002) to infer areal-mean albedo from surface downwelling irradiances made under overcast conditions. The inferred albedos represent spatial means over distances comparable to cloud-bottom height. This method is particularly suitable over the NSA site where clear-sky conditions necessary for satellite remote sensing are rarely seen.

Methodology and Results at the SGP CART

Clear-sky surface albedos for twenty stations located with the CART were derived from measurements of upwelling and downwelling surface fluxes at each of the sites and subdivided by month. For each station and for each month, best-fit coefficients through the points were obtained, as well as the mean of the surface albedos for solar zenith angles (SZA) less than 60°. Figure 1 shows examples of the best-fit lines for surface albedos at stations representing different kinds of grassland surfaces for sample months representing the four seasons. There is some seasonal variability evident for the different surface types.

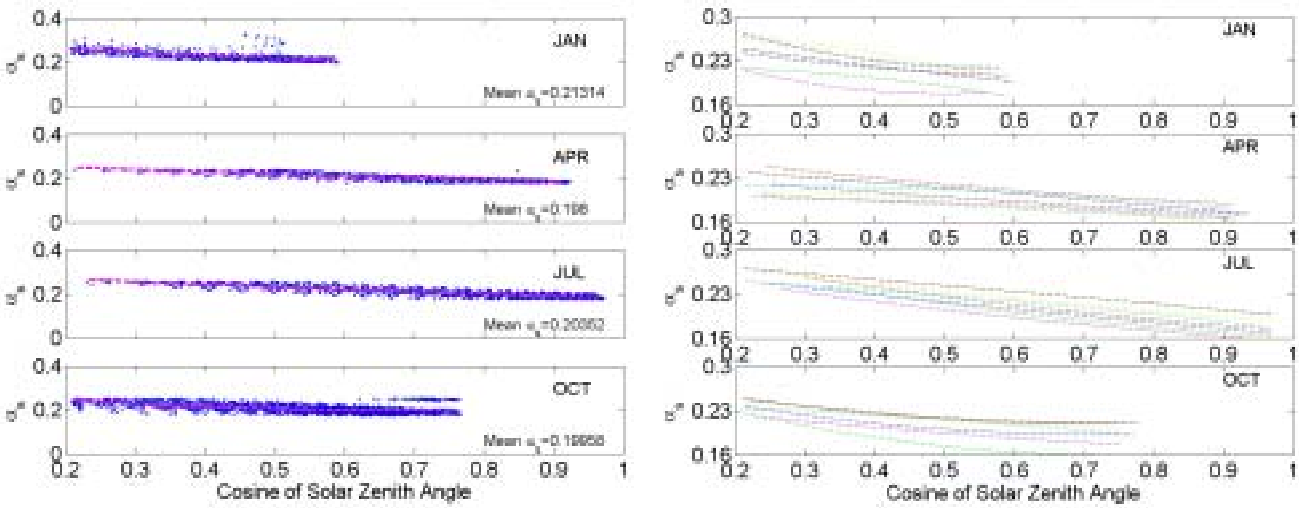

Figure 1. (Left panel) Clear-sky measurements of surface albedo for the four seasons over the pasture/wheat surface type. Magenta dashed lines are the "best-fits" through the data. Mean surface albedo calculated for cases when SZA <60°. (Right panel) "Best-fits" for wheat/soy (yellow), ungrazed rangeland (magenta), alfalfa (cyan), pasture (red), prairie (green), wheat (blue), and grazed rangeland (black).

Examples of the extension of point-specific observations of surface albedo to much larger areas, such as the SGP region, through use of satellite data are shown in Figure 2. The surface albedos here were derived using the model of Li and Garand (1994) with the following input parameters: GOES-retrieved top-of-the-atmosphere (TOA) albedos (at 0.5° x 0.5° resolution) and precipitable water amounts from the National Centers for Environmental Protection Reanalysis database. First, a relationship between derived clear-sky surface albedos and cosine of the SZA was calculated using all satellite data, then this information was used to apply a correction for cloud cover. The spatial distribution of the subsequent satellite-derived surface albedos is rather coarse, given the resolution of the satellite data used, but with higher resolution satellite data, a smoother distribution would be obtained. Satellite estimations of surface albedos can be useful to fill the gaps between widely spaced stations.

Using the monthly surface albedo database generated at each of the twenty extended facilities, broadband downwelling surface fluxes were obtained using the model of Li et al. (1993) with TOA albedo information from the CERES (averaged over a 10-km radius around a station) and corrections for aerosol, cloud-top height, and ozone from Masuda et al. (1995). Some comparisons to measured downwelling fluxes from the SIRS located at each facility are shown in Figure 3. For clear-sky instances, agreement with observations is within 5%; cloudy sky cases exhibit visibly more scatter.

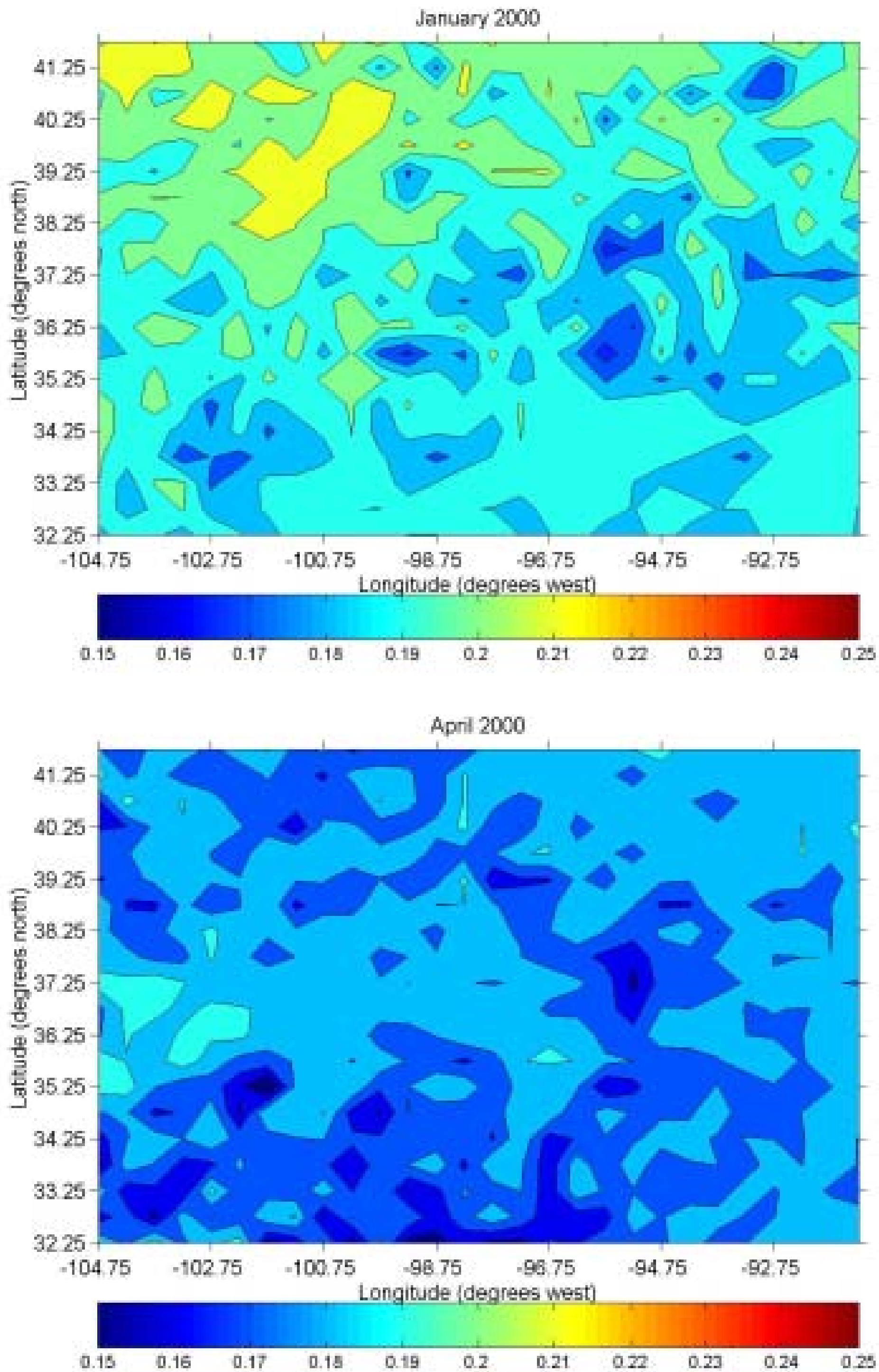

Figure 2. Examples of the spatial distribution of surface albedo over the SGP domain derived from GOES satellite data (0.5° x 0.5° resolution).

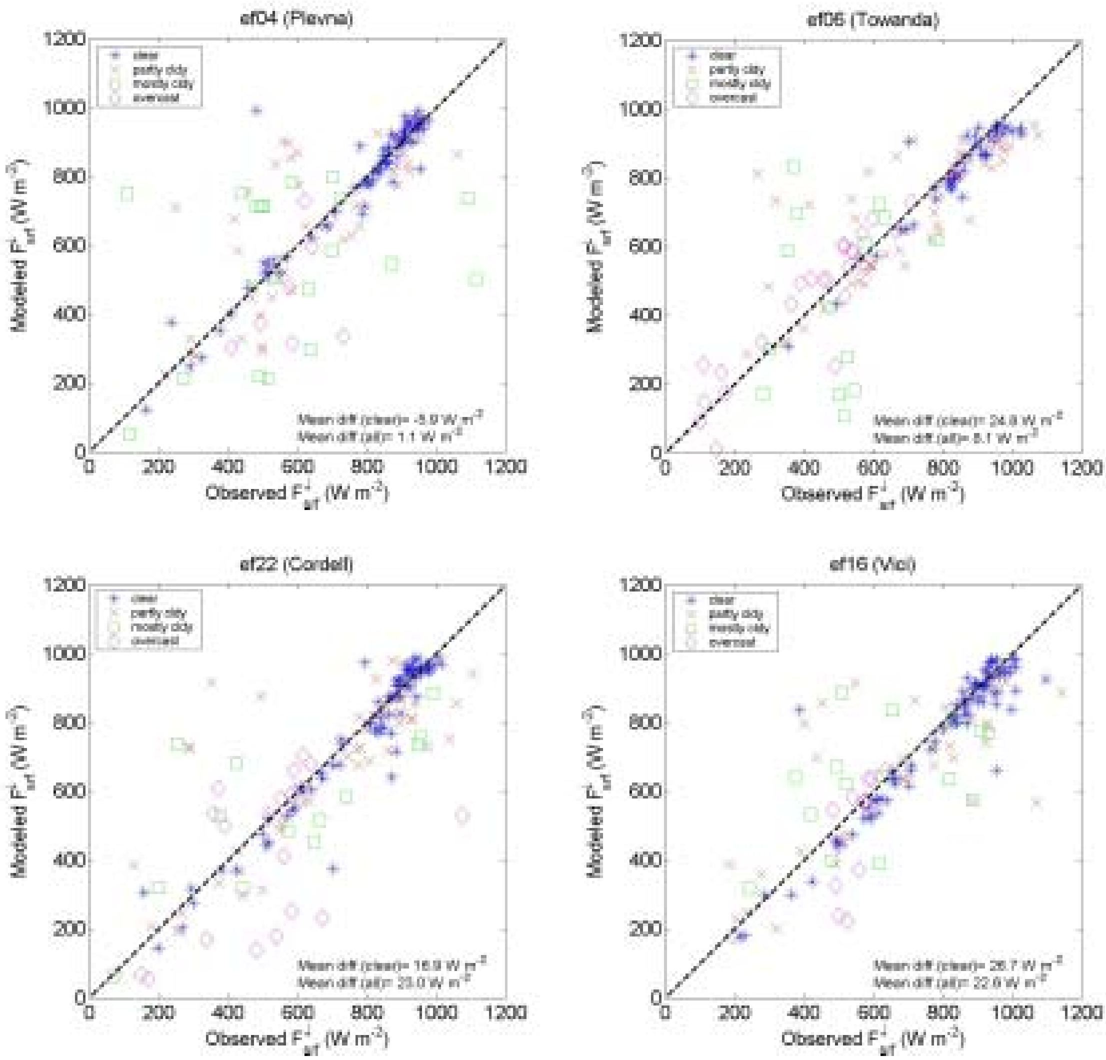

Figure 3. Comparison of modeled broadband downwelling fluxes (using CERES TOA albedo averaged over 10 km around site - aerosol, ozone, cloud-top height corrections applied - surface albedo database used) and SIRS measurements at four sample stations and for different cloud cover.

Methodology and Results at the NSA

At the NSA Barrow site, the method of Li et al. (2002) was used to determine areal-mean surface albedos for overcast cloudy cases and is dependent upon the availability of high-resolution solar spectral irradiance data from the rotating shadowband spectroradiometer (RSS) (360-1050 nm, 1024 channels), an instrument developed at the Atmospheric Sciences Research Center at the State University of New York in Albany and in operation at the Barrow site during the period of March to August 1999 (Harrison et al. 1998). Single-layer overcast cases were identified at the site through use of cloud radar "quicklooks" and cloud boundary information from the Active Remotely-Sensed Cloud Locations (ARSCL) value-added product. Cloud cases with cloud-top heights less than 3 km were selected to ensure that the cloud layer was not in a mixed/ice phase. Downwelling surface spectral fluxes were simulated using the moderate-resolution atmospheric radiance and transmittance model (MODTRAN)-4 software and input to the model included ozone column amount from the total ozone mapping spectrometer, water vapor column amount from microwave radiometer measurements at the site, and ARSCL cloud boundaries.

An initial set of surface spectral reflectances at 415, 499, 608, 664, 860, and 938 nm were generated from downwelling and upwelling measurements taken by upward- and downward-directed radiometers, respectively, and used in the model. Cloud microphysical properties were obtained by tuning the extinction coefficient at 500 nm so that agreement between simulated downward surface flux and RSS measurement at that wavelength was achieved. The areal-mean albedo was derived by first simulating downward surface fluxes at the RSS wavelengths using the observed point measurements of surface albedo. Based on the relative difference between modelled and observed fluxes, the spectral surface albedos were changed accordingly to obtain an improved set of surface albedos. Downward surface fluxes were recalculated using the improved surface albedos. Looping through each wavelength (as determined by the RSS), an iteration scheme was applied using these two sets of surface quantities (measured and improved) until convergence was achieved and a surface albedo was found such that the modelled flux agreed with the RSS measurement at that particular wavelength. The result was set of areal-mean surface albedos.

Figure 4 shows comparisons of RSS-measured downwelling surface fluxes with model results using observed and areal-mean surface albedos for two cases in May 1997 and two cases in July 1997. In these cases, both measured and areal-mean surface albedos agree reasonably well. This is not surprising given that the cloud-base heights were low, ranging from 60 m to 375 m, and that the vegetative surface immediately surrounding the Barrow site is relatively uniform. Estimation of areal-mean albedo is based on the idea that a uniformly overcast sky acts as a reflector of photons between the surface and the cloud base and that photons received at the RSS may have been reflected from vegetative surfaces at distances on the order of the cloud-base height. Since the surface within 375 m is relatively homogeneous, agreement between point measurements of surface albedo and derived areal-mean surface albedos is expected.

Summary

Seasonal variation of surface albedo over prairie and ungrazed rangeland is roughly the same, which is expected since both represent uncultivated land surfaces. For all seasons, the magnitudes of the mean albedos for these natural surface types is less than those of the other more cultivated surfaces by 0.01 to 0.05. Magnitudes of the differences in mean albedo between surface types such as pasture and pasture/wheat (and wheat, wheat/soybean surfaces) differ by less than 0.018, with the pasture and wheat surfaces darker in July, compared to the pasture/wheat (wheat/soybean) surfaces.

At the NSA Barrow site, measured surface albedo and areal-mean surface albedos agree reasonably well for the two albedo regimes (winter-like and summer-like) analysed here. The cases analysed in 1999 (when the RSS was deployed at Barrow) consisted of rather low-level clouds. Spatial means (representing surface albedo over distances comparable to cloud-bottom height) are similar to the radiometer-measured surface albedo because the same small surface area is seen by both methods.

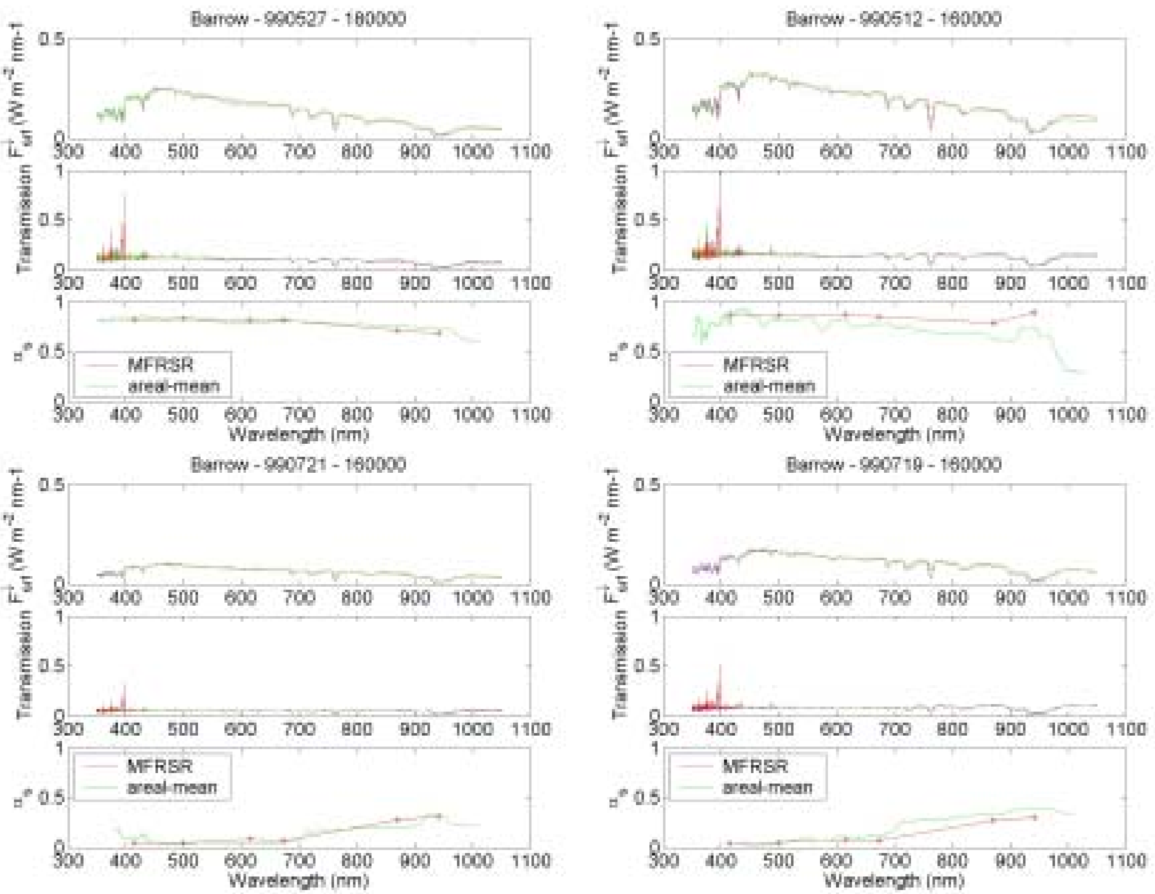

Figure 4. Comparison of measured downwelling surface fluxes from the RSS (blue lines) with model results using MFRSR (red lines) and areal-mean surface albedos (green lines) at the Barrow site. Top two panels: May 12 and 27, 1999. Bottom two panels: July 19 and 21, 1999. Cloud base heights range from 60 m to 375 m.

Given the proximity of the Barrow site to the Arctic Ocean, it would be interesting to obtain more case studies of overcast clouds possessing cloud bases between 2 km to 3 km. The areal-mean surface albedo would perhaps capture spectral information from the ocean that point measurements of surface albedo at the site would miss.

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