Surface Albedo at the Southern Great Plains Cloud and Radiation Testbed Site as Retrieved from Advanced Very-High Resolution Radiometer Satellite Data and Observed by Unmanned Aerospace Vehicle Flights

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Introduction

Substantial variations in surface albedo across a large area may cause difficulty in estimating regional net solar radiation and atmospheric absorption of shortwave radiation if only a few point measurements of surface albedo are used to represent the whole area. Satellite measurements may generate more realistic average surface information (such as albedo) than ground point measurements can provide because the satellite samples a large area with a high spatial resolution.

Much effort has been devoted to the estimation of surface albedo from satellite observations. One popular approach is to use statistical matching to find an empirical relationship between the narrowband reflectance and the broadband reflectance and to use an empirical relationship to describe the dependence of bidirectional reflectance on the solar zenith angle (Ranson et al. 1991). This approach is simple, but it depends on preexisting knowledge about the atmospheric conditions, the underlying surface, and the solar zenith angle for determination of the coefficients in the empirical relationship.

In the first part of our study (Qiu and Gao 1997), we used a bidirectional reflectance model to retrieve surface properties such as leaf area index (LAI) and then calculated the bidirectional reflectance distribution by using the same radiation model. The advantage of the method is that it automatically senses the variation in surface conditions such as LAI, so that there is no need to specify the spatial and seasonal variation of LAI in the model.

In this study, we have extended the work and applied the scheme to advanced very-high-resolution radiometer (AVHRR) data over the Southern Great Plains (SGP) Cloud and Radiation Testbed site (CART) to estimate surface albedo along the flight track of an unmanned aerospace vehicle (UAV) during the ARM Enhanced Shortwave Experiment (ARESE) project in 1995.

Model and Method

An automatic inversion technique (Gao and Lesht 1997; Qiu et al. 1996) coupled with a bidirectional reflectance model was used to retrieve surface parameters. The radiation model (Gao 1993) uses a relatively simple approach to describe the first-order scattering and multiple scattering of solar beams within a plant canopy and the interaction of the canopy scattering with the reflectance from the soil surface for a horizontally uniform plant canopy. The model allows for fast computation of bidirectional reflectance and provides results that agree well with measurements (Gao 1993). The inversion scheme automatically adjusts each surface parameter (such as LAI) until the modeled reflectance matches the observed reflectance.

Because of the lack of information for initializing the leaf angle distribution index in the inversion model (Qiu et al. 1996) over such a large area, we applied a slightly different approach in the inversion scheme; that is, we used a combination of the red channel and the near infrared (NIR) channel reflectances to retrieve surface parameters (rather than a single channel). This combination greatly reduced the dependence of the retrieved surface parameters on the initial leaf angle distribution.

The spectral albedos were first integrated over 14 narrow bands in the shortwave region (0.3-3.0 mm) with a set of weighting functions determined with the output from an atmospheric radiation transfer model (LOWTRAN7). The surface albedo was then calculated by spherical integration of the broadband reflectance over the upper hemisphere.

The advantage of this method is that we can incorporate the bidirectional reflectance effect into the calculation of the surface albedo by using an automatic adjustment to local surface conditions, rather than an empirical relationship that does not account for changes in surface conditions.

Measurements and Results

A handheld multispectral radiometer (MSR87) was used to measure narrowband surface reflectances in eight wave bands ranging from visible to NIR regions. All MSR87 ground measurements were made at nadir viewing angle with various solar zenith angles (depending on the time of the measurement).

Measurements were made with this mobile radiometer during the period June 24-28, 1996, at 10 solar and infrared radiation observation stations (SIROS) across the CART site, where the SIROS systems operate on a long-term basis to measure upwelling and downwelling shortwave and longwave radiation. All SIROS stations are located over grassland or pasture where grass height varies widely, from about 0.05 m to 1.0 m.

The multispectral reflectance measurements taken with the MSR87 at each of these SIROS stations were used to estimate the surface albedo with the model-inversion-based scheme. The estimated surface albedo was then compared with the albedo derived from measurements of the upwelling and downwelling shortwave radiation from the corresponding SIROS stations.

Figure 1 compares the modeled albedo and the observed albedo at the SIROS radiation station at extended facility EF1. The modeled albedo is in good agreement with the field observation, with the best agreement near solar noon. Albedos at the other sites estimated from bidirectional reflectance measurements and calculated from the upward and downward radiant fluxes from SIROS stations are also in good agreement. Details of those comparisons are shown in another paper in these proceedings (Gao et al. 1997).

The UAV observation of upward and downward radiation fluxes during ARESE in October 1995 provided a good database for us to evaluate our scheme to estimate the surface albedo over a larger area with various types of surface conditions. The data set we used was obtained from a broadband radiometer on the Otter airplane that flew at heights between 900 m and 1700 m. The flight path running from the central facility of the SGP/CART site to almost the western edge of the CART site (as shown in Figure 2) provided a range of surface types with various radiative properties. The UAV

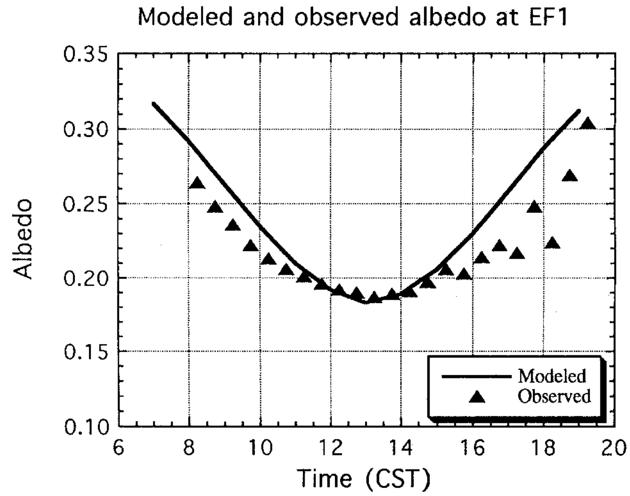

Figure 1. Comparison of modeled and observed surface albedos at extended facility EF1 of the CART site.

UAV Flight Path/NOAA 14 AVHRR Image over the SGP/CART Site - October 1995

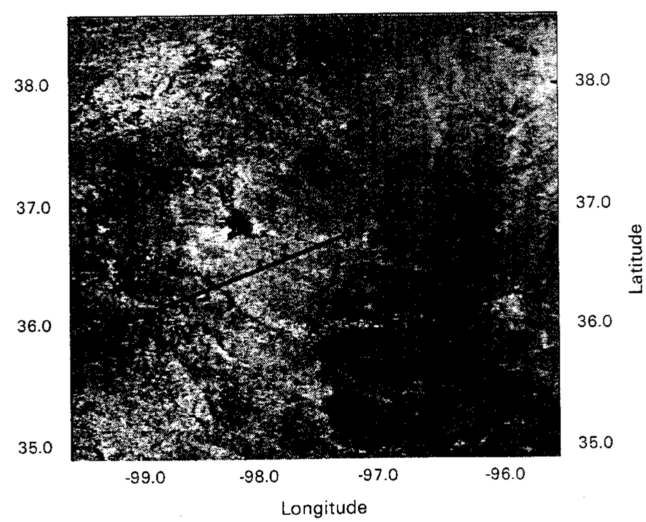

Figure 2. NOAA-14 AVHRR image over the SGP CART site during the ARESE project in October 1995. The thick line indicates the UAV flight path on October 11, 1995.

flight data are from 0900-1200 local time on October 11, 1995, and include four passes along the flight path. Spectral reflectance data were obtained from the AVHRR radiometer on the NOAA-14 polar orbiting satellite passing over the site at about 1300 CST on the same day. The AVHRR images provide spectral reflectances for the CART site with a spatial resolution of 1 km. The AVHRR data were first processed with atmospheric correction (with LOWTRAN7) to convert top-of-atmosphere reflectance to surface reflectance, so that the resulting albedo is comparable to the albedo from the UAV measurements. No atmospheric correction was made to the UAV data.

The LAI obtained from our model inversion scheme, shown in Figure 3, was plotted against longitude because the flight passes were oriented almost east to west. The change in UAV-measured albedo was inversely correlated with the change in surface vegetation density in terms of LAI and the normalized difference vegetation index (NDVI) from the AVHRR data. This inverse correlation is consistent with the understanding that higher vegetation density produces lower reflectances in the visible bands. However, the higher value in NDVI and LAI near longitude 98°W was not consistent with the corresponding UAV-measured albedo.

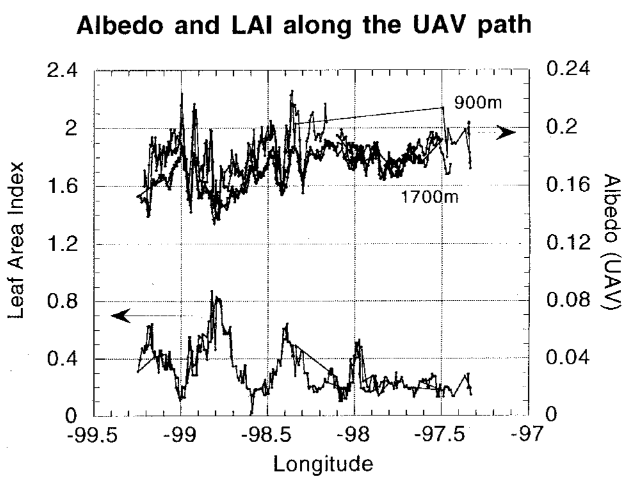

Figure 3. UAV-measured albedo and model-estimated LAI along the UAV flight path in the CART site.

Figure 4 shows the comparison between the UAV-measured albedo and the albedo calculated from the inversely retrieved LAI, along with the variation of AVHRR-derived red and NIR reflectances. The estimated surface albedo matched the UAV-measured albedo in magnitude, but did not reflect the detailed variation observed in the UAV-measured albedo, although the variation was also seen in the time trace of AVHRR channel 1 and channel 2 data. It is possible that the spatial variation in soil reflectance is not fully described by the model, which used a constant soil reflectance for the entire UAV pass. A closer examination shows that although the retrieved albedo does not reflect changes in albedo associated with variations in the surface conditions (LAI) at midmorning (around 0900 CST), the retrieved albedo reveals more of the

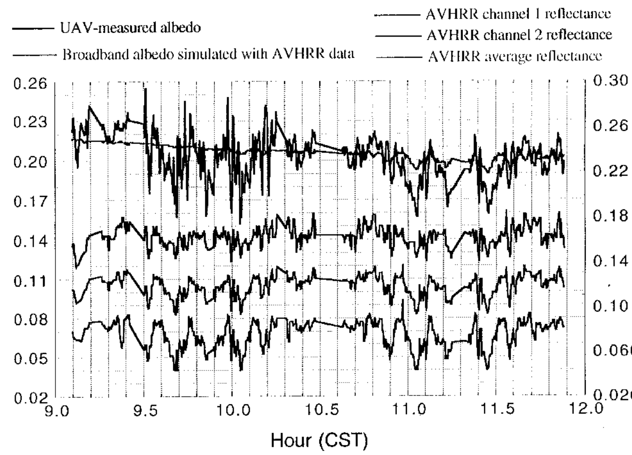

Figure 4. Time series of albedo measured by the UAV, albedo simulated with AVHRR data, and AVHRR channel 1 and 2 reflectances during the UAV flight.

changing pattern in surface albedo near noon, when the solar zenith angle is at a minimum. Further work is needed to investigate the cause of this discrepancy.

Conclusions

We have developed a scheme to estimate surface albedo on the basis of remotely sensed bidirectional reflectances. An inversion technique was used to retrieve automatically the surface parameters necessary for estimating spatial variations of surface albedo from the satellite-observed bidirectional reflectances. By using retrieved surface parameters such as LAI, one can take into account the bidirectional effect of the reflectance in the estimation of the albedo for various surface covers, because different bidirectional reflectances resulting from different vegetation densities can be included automatically in the model calculation without empirical assumptions. Ground measurements of spectral reflectances made with a handheld radiometer were incorporated into the scheme to estimate the surface albedo.

The model-estimated albedos are in general agreement with the measurements taken at the SIROS stations. The albedo estimated from the AVHRR data extracted for the CART site compares favorably in magnitude to the UAV-measured albedo, but fails to reveal the detailed changes in surface conditions. Further work is needed to improve the model, and further measurements of the spatial variation in soil reflectance are needed to improve the estimation of albedo.

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