Continental-scale albedo inferred from land cover class, field observations of typical BRDFs and AVHRR data

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Abstract – Field-observed BRDFs for different land cover types are employed to derive a global BRDF/albedo database from land cover classifications. In a second step, AVHRR reflectance observations are used to reintroduce within-class variations into this database by fitting the field-observed BRDFs to the observed bidirectional reflectances. These databases are useful precursors to future satellite-derived BRDF databases. [1]

INTRODUCTION

The radiometric properties of the Earth's land surface are an important influence on visible and near-infrared radiative fluxes in the atmosphere. They also determine the radiant energy input into the biosphere. Since land surface reflectance is dependent on viewing and solar illumination geometry, a global characterization of Earth surface radiometry requires specification of the bidirectional reflectance distribution function (BRDF) for each location in several wave bands.

Currently, no global databases of surface BRDF are available. However, techniques for deriving such databases from space-based reflectance observations have been developed in the past few years, and will lead to BRDF data products, especially from POLDER (launched 1996) and from the Earth Observing System MODIS and MISR sensors, to be launched in late 1998 (e.g., [1].) BRDF analysis of AVHRR data is also likely to be carried out more extensively than has been the case in the past.

As part of a larger collaborative project to better characterize the top-of-atmosphere reflected solar radiation flux, led by Ralph Kahn, we are developing a global BRDF data set that may be used to specify the lower boundary condition for atmospheric radiative transfer calculations. This paper presents work on initial versions of this database. Land surface directional-hemispherical albedos are derived from 10-day composited 8km AVHRR observations in the red and near-infrared by applying land cover-specific BRDF shape factors to the bidirectional reflectance observations of each pixel. The BRDF shape factors used are derived from ground-based field observations of the BRDFs of a variety of natural surfaces.

BRDF DATABASE OUTLINE AND METHOD

There will be three versions of this BRDF database.

• *BRDF database version 0*, mostly completed, is based only on landcover type and field-measured BRDFs. The latter are used to establish the BRDFs of each of 24 types of surfaces with different structural and optical properties. The types represented in any land cover map can be freely mapped to these BRDF types, and hence a BRDF, possibly with a seasonal or geographical dependence (e.g., a northern needleleaf forest landcover class might be mapped to BRDF types "sparse needleleaf trees on grass" or "sparse needleleaf trees on snow".) The 24 BRDF classes are a subset of a full 36-class BRDF classification scheme we have developed that may also be further collapsed to 12 primitive classes if necessary. The associated BRDFs are given in form of the three parameters of the Ambrals RossThick-LiSparse semiempirical BRDF model [2] at least in the red and the near-infrared. A version based on BRDFs derived from numerical simulations is planned as well.

• *BRDF database version 1*, nearing completion, is an enhancement of version 0 using maximum value-composited AVHRR data for each season or month of the year. For each pixel, the version 0 database BRDF associated with the landcover type of that pixel is fitted to the bidirectional reflectance observed by the AVHRR. Thus observed within-class variability is reintroduced into the purely landcover-based original BRDF database. Field-observed BRDFs, landcover class information and satellite-observed reflectances are fused, with the land cover class providing a pointer to the type of BRDF shape to be used and the reflectances indicating how to alter this shape and determining the BRDF magnitude.

This method we believe is the most direct way of obtain an approximate global BRDF database as a precursor to a satellite-derived BRDF data product, avoiding per-pixel BRDF inversions with their very strict multiangular data requirements, frequent cloud-related gaps, and large processing loads.

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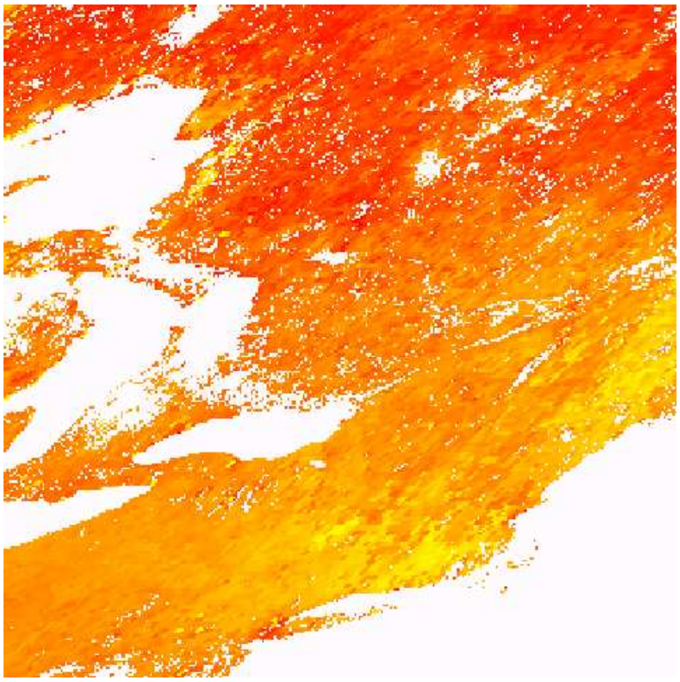

Figure 1: Directional-hemispherical albedo for a solar zenith angle of 30°.

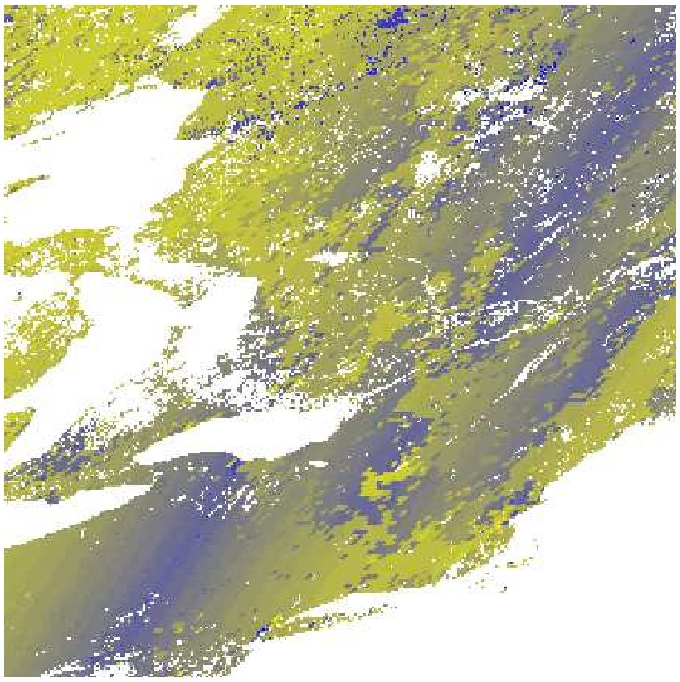

Figure 2: Ratio between the directional-hemispherical albedo and measured surface reflectance.

• *BRDF database version 2*, to be begun in 1999, will finally see the replacement of the land cover and AVHRR-based BRDFs of the earlier database versions by BRDFs derived from actual MODIS and MISR BRDF inversions with 1 km spatial resolution. When these BRDF inversions are judged to be reliable and are confirmed by repeat observations under different conditions, they will be parameterized and entered into the database for each respective season or month. However, the version 1 database will still be used to fill the gaps of the version 2 database as it evolves. Howqever, the version 1 database will now be fitted to MODIS-MISR observations instead of relying on AVHRR observations. As EOS progresses, several versions of this database will be subsequently released, establishing a best-knowledge, seasonally dependent global 1 km visible and near-infared BRDF and albedo database.

FIELD-OBSERVED BRDFS AND LANDCOVER USED

The field-observed BRDFs used to characterize the 24 BRDF classes used in this study were mostly, but not exclusively PARABOLA observations by Deering and coworkers (e.g., [3]). Despite the fact that a much larger number of BRDF observations is now available than was the case a few years ago, there are still gaps in terms of characterizing basic structural types. There is a particular scarcity of field-measured BRDF data sets for sparse discrete-crown vegetation such as brushlands or sparse forests, and for winter situations with a snow component. We are in the process of utilizing aircraft-based remote sensing data to provisionally close some of the resulting gaps.

In some cases, the scenes observed may not be the most ideal representations of their respective cover type. Nonetheless, the observed BRDFs are expected to capture the basic quality of a number of distinct types of volumetric and geometric scattering by the vegetated or barren Earth surface. Overall, measured BRDF datasets were used to characterize 16 of the 24 BRDF type classes used.

Software was created that automatically maps a given land cover classification to predicted bidirectional reflectance or albedo at a given solar zenith angle, using an adjustable look-up table between landcover class and BRDF type. For creating our version 0 BRDF database we are utilizing the global 1 km Olson classification by Loveland et al. produced at EDC [4].

APPLICATION TO AVHRR DATA

We are currently in the process of deriving a global version 1 BRDF database using four AVHRR Pathfinder datasets of 10-day composited GAC data representing the four seasons [5]. At this time we are using 8 km data but are also planning to use 1 km data later. The data are atmospherically corrected only for molecular scattering.

Figures 1 and 2 show an area of the United States and Canada in the Integerized Sinusoidal Grid; this projection is used for compatability with future EOS products. Figure 1 shows NIR directional-hemispherical albedo at a solar zenith of 30° derived from June 1984 AVHRR data using the method discussed above. A linear stretch has been applied to the image while black areas represent either water or landcover classes for which we do not, as yet, have a BRDF. Images for other solar zenith angles are easily derived.

Figure 2 shows a ratio image between the albedo shown in figure 1 and the AVHRR reflectances. The linear features lying in a NW-SE direction in this image are indicative of view geometry effects whereas pixel-size variations are landcover effects.

SUMMARY

By taking into account both variations in the shape of the BRDF with landcover type, and variations in reflectance with view and illumination geometry we may generate global albedo maps. These maps fuse landcover observations, field observations of typical BRDF shapes and AVHRR reflectance observations. If it can be shown that such a product is superior to other albedo maps currently used in surface modeling, studies of the impact of natural or anthropogenic albedo changes may follow.

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