MODIS BRDF and Albedo in Global Land Models: Maximum Snow Albedo and Zenith Angle Dependence

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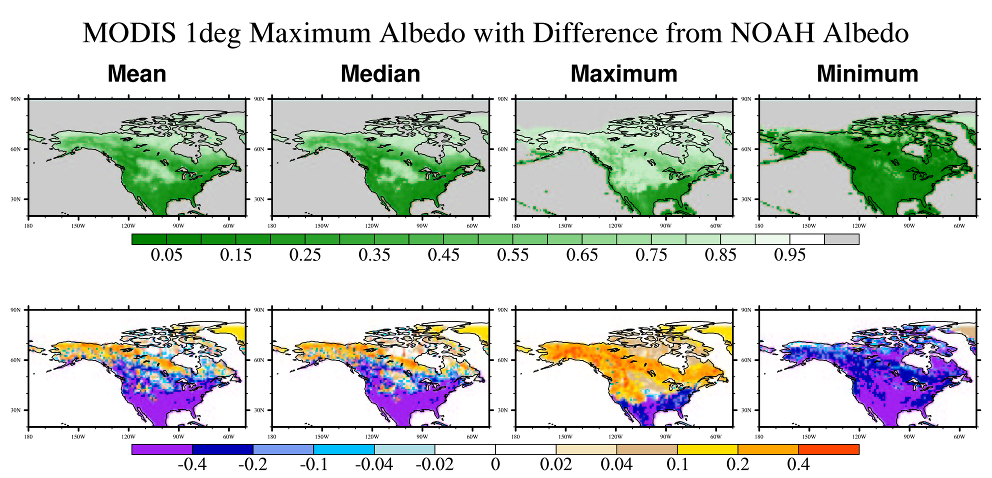
Maximum Snow Albedo

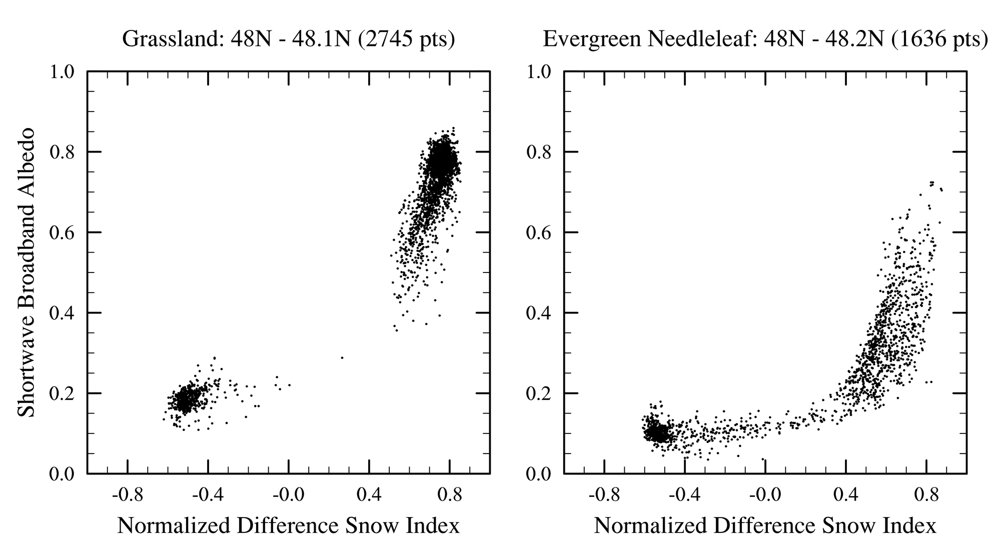
Maximum snow albedo is an important specified parameter in several land surface models (e.g., the NCEP NOAH model). The existing dataset of maximum snow albedo used in the operational NOAH model is from 1985, uses only one year of data, uses data only from northern high latitudes, and is available at 1^o resolution. Using global MODIS albedo data, we are creating a new maximum snow albedo database at 0.05^o resolution.

- MODIS "good quality" global 0.05^o albedo data(3 broadbands) are used from FEB 2000 – MAR 2004



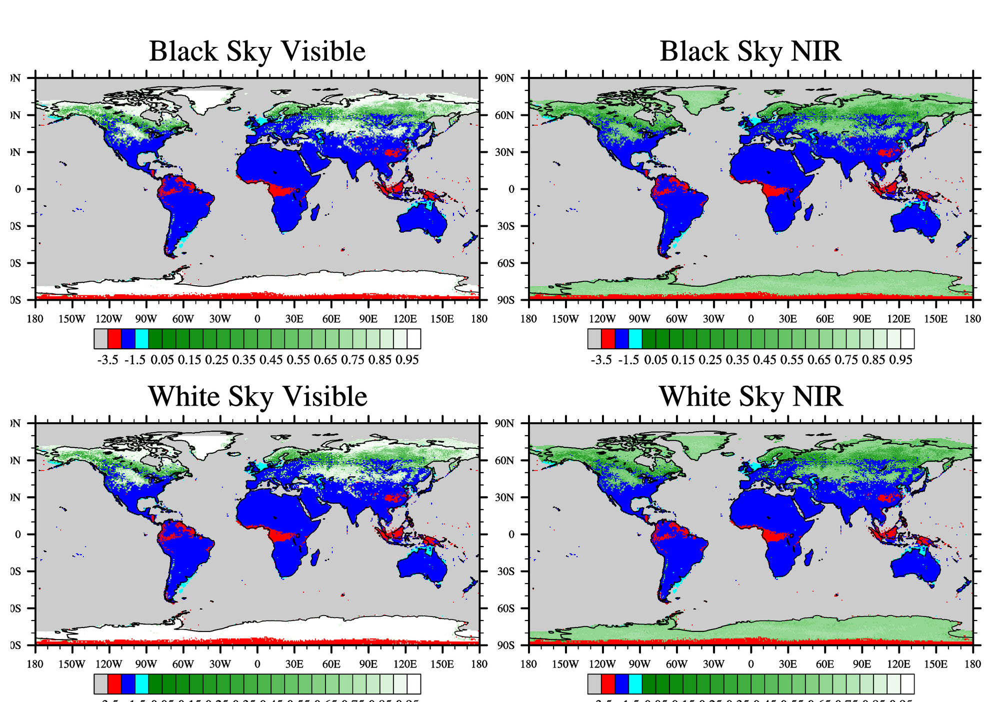
For each 1^o grid cell, maximum albedo is calculated using mean, median, maximum, or minimum or the corresponding 0.05^o cells. Comparison with NOAH dataset also shown.

- To discriminate snow vs. non-snow, we calculate NDSI using individual channel albedo. NDSI > 0.4 is considered snow-covered.
- MODIS IGBP land cover type at 1km resolution is used to determine vegetation dependence on maximum snow albedo.



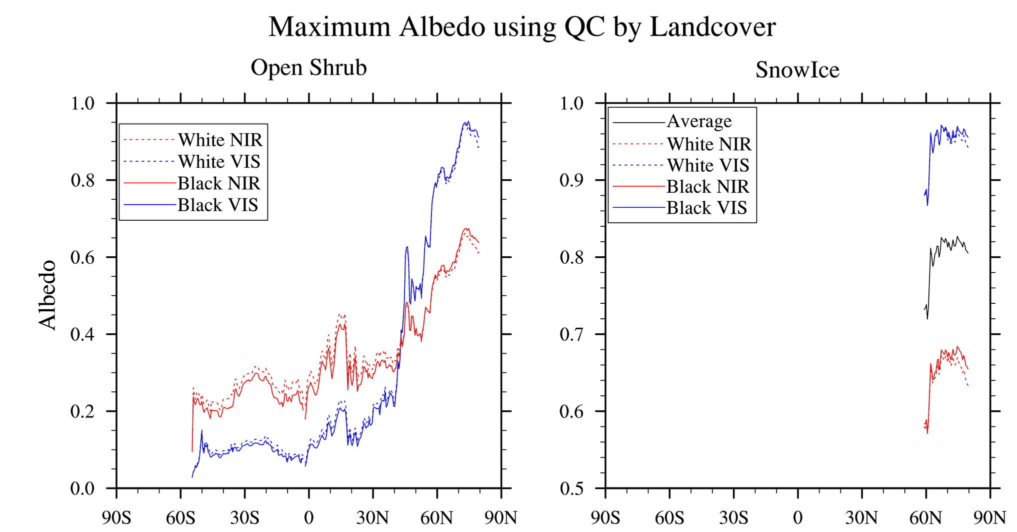
Shortwave broadband albedo versus NDSI for different land use types.

- Further restrictions using MODIS band 2 are used to eliminate water.



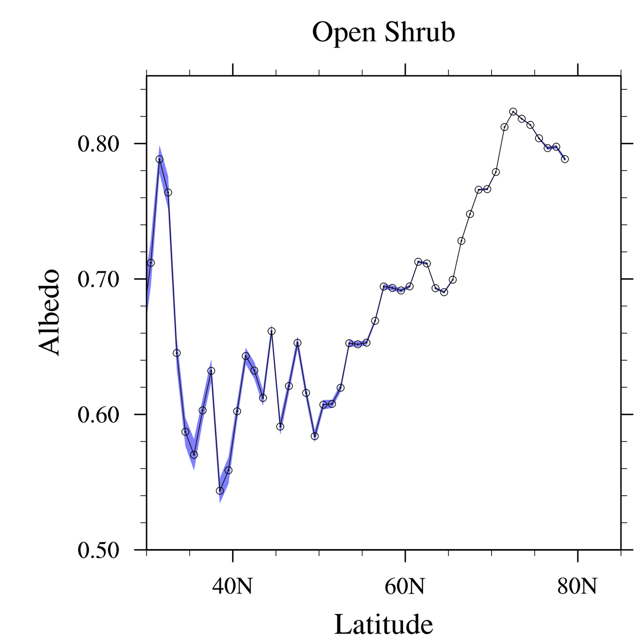
Global broadband maximum snow albedo. Gray are missing values or ocean, red indicates regions where no "good" albedo was measured during the 4 years, dark blue are regions where NDSI was never above 0.4, and light blue are regions removed by the water filter.

- Using MODIS IGBP land cover type at 1km resolution, we can determine latitudinal dependence of maximum snow albedo for different vegetation types.



Maximum broadband albedo for different land types as a function of latitude.

- 0.05^o albedo is an average over different land use types. Multiple linear regression is used to determine the best albedo value in latitude bands.



Best-fit values of maximum snow albedo as a function of latitude for open shrub. Light blue shading indicated 95% confidence interval.

Zenith Angle Dependence

Land surface albedo is strongly dependent on the solar zenith angle (SZA) and the 3-D structure of vegetation canopy. In climate models, it can be specified using empirical observations or computed based on a radiation submodel for canopy plus underlying soil. These approaches do not consider the 3-D structure of vegetation. To improve model treatment of surface albedo, the SZA dependence of albedo in the NCAR CCSM2 and model monthly averaged albedo are evaluated using the MODIS BRDF data (0.25^o, version 3).

The overall spatial pattern of model albedo is consistent with that of the MODIS data (Fig. 1). The CCSM2 albedo is lower by 0.05–0.2 over deserts in North Africa and the Middle East. The model albedo is higher by more than 0.05 over parts of the South America, southern Africa, and Australia. Over N.H. high latitudes, the model albedo in July is also higher by more than 0.05, because there are too many modeled snow-covered regions.

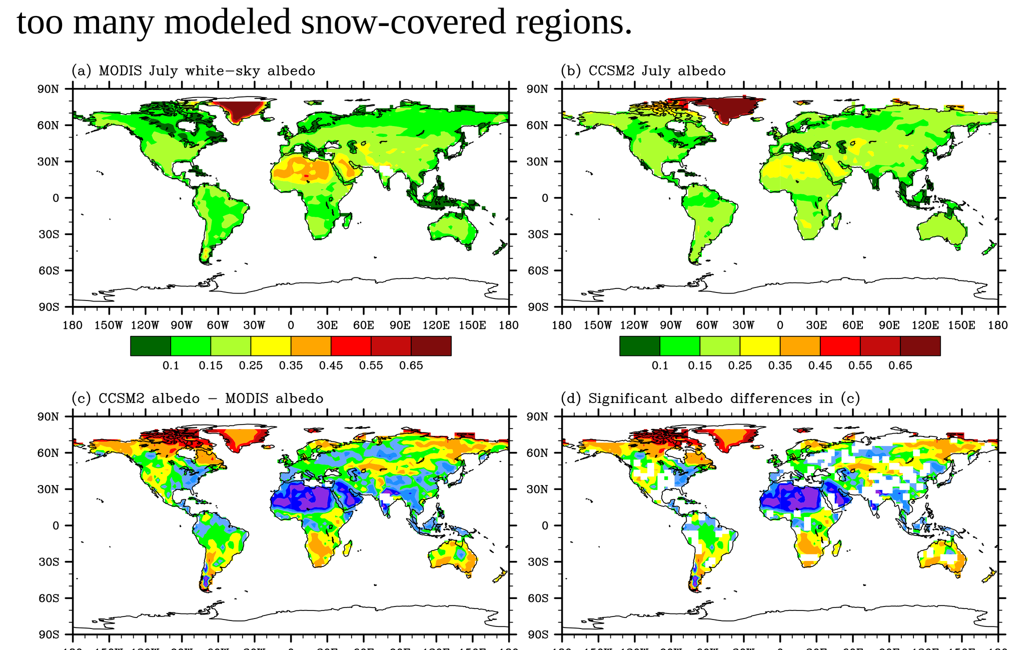


Fig. 1: The global distribution of land surface albedo in July. (a) MODIS white-sky albedo in 2001. (b) CCSM2 monthly albedo averaged over 10 years. (c) CCSM2 albedo - MODIS white-sky albedo. (d) significant (at 95% using student t-test) albedo difference in (c).

We evaluate the SZA dependence of the model albedo over 11 grid cells with different dominant PFTs. Fig. 2 shows that both model and MODIS direct albedos decreases with cos(SZA). However, the model direct albedo increases too fast with the SZA. This pattern is also evident for most PFTs.

Fig 3a shows that the difference between the 90th and the 10th percentiles for the VIS band is less than 0.02 for all grid cells except for PFT 13, while Fig. 3b demonstrates that the corresponding difference for the NIR band is less than 0.02 for only six cells (PFTs 2-4, 7, 10, and 11), and is as large as 0.1 for PFT 13 and 0.07 for PFT 12.

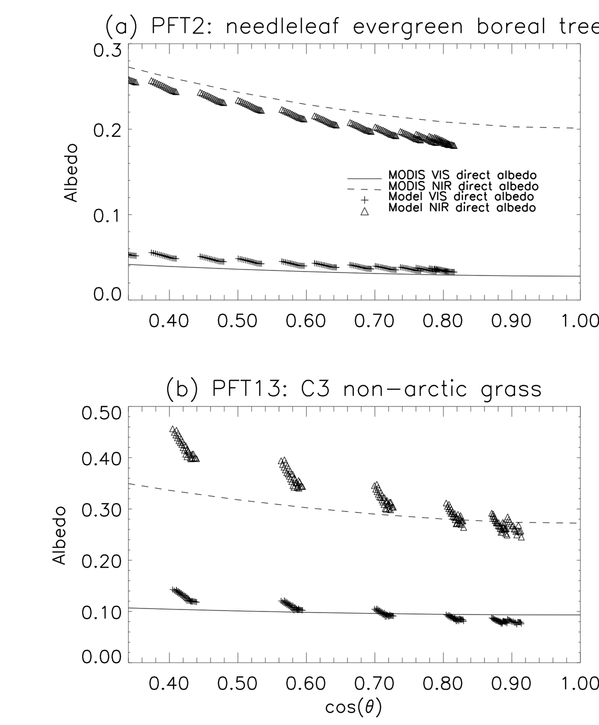


Fig. 2: Comparison of the solar zenith angle (SZA) dependence between the CAM2/CLM2 hourly direct albedo and MODIS direct albedo for (a) PFT 2, and (B) PFT 13. Only results for SZA < 70 deg shown. Model results are based on CAM2/CLM2 hourly output for a 16-day period (12-27 July 2001). The MODIS direct albedo are obtained from MODIS BRDF parameters for the same period.

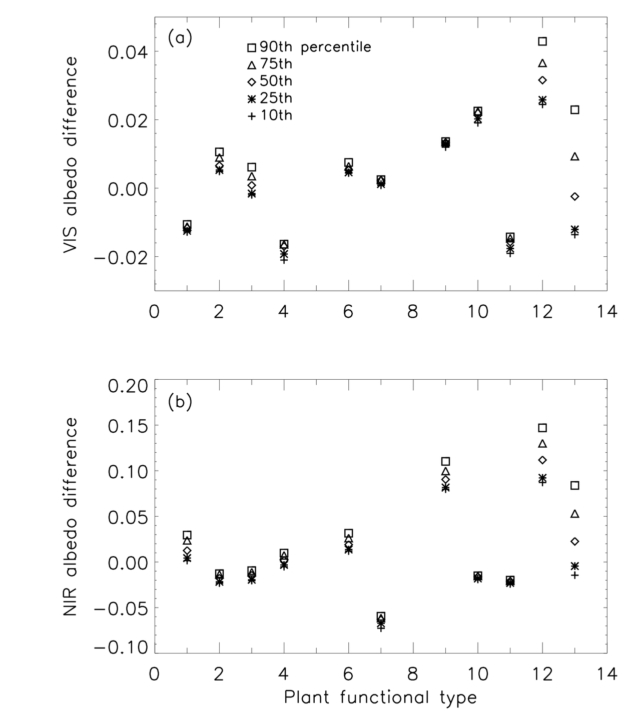


Fig. 3: The 10th, 25th, 50th, 75th, and 90th percentile of the differences between the CAM2/CLM2 hourly direct albedo and MODIS direct albedo (a) in the VIS band, and (b) in the NIR band for the 11 grid cells with different PFTs.

In most land surface models, the bare soil albedo is a function of soil color and soil moisture but independent of SZA. However, the SZA dependence of soil albedo should be considered due to the non-Lambertian properties. MODIS BRDF parameters (0.05^o, version 4) in 2001 are used to examine the SZA dependence for thirty pixels over desert locations with zero FVC (Fig. 4). A parameterization is adopted to describe the SZA dependence of albedo:

$$a(\theta) = a(\theta = 60^o)\frac{1+C}{1+2Ccos(\theta)}$$

where a is the black-sky albedo, theta is the SZA, $a(\theta = 60^o)$ is the black-sky albedo at 60^o SZA, and C is an empirical parameter. Briegleb et al. (1986) specified C to be 0.4 for desert. Based on MODIS data, we got C values using the weighted least square method. The average C value in VIS and NIR bands is 0.16. From Fig. 5, we can see that the simulated SZA dependence using the best-fit linear equation and the C value fixed at 0.16 are consistent with MODIS data at small SZA. The error in the simulated albedo with C=0.4 is beyond 0.02 at solar noon. Therefore, C is kept as constant (0.16) for simplicity. This proposed parameterization can be incorporated into land surface model to examine its impact on the surface energy balance.

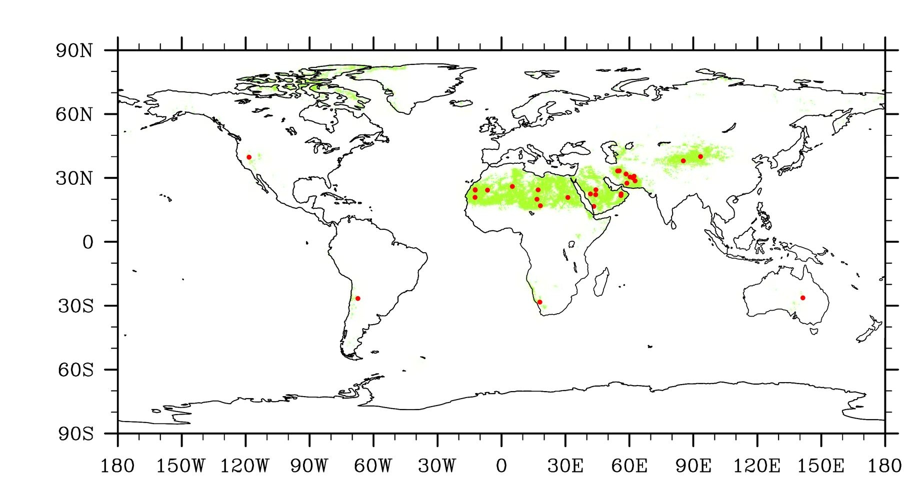


Fig. 4: The global distribution of desert (that is, the locations with fractional vegetation cover (FVC) less than 0.1). Solid dots mark the thirty pixels over the desert locations used in Figure 5.

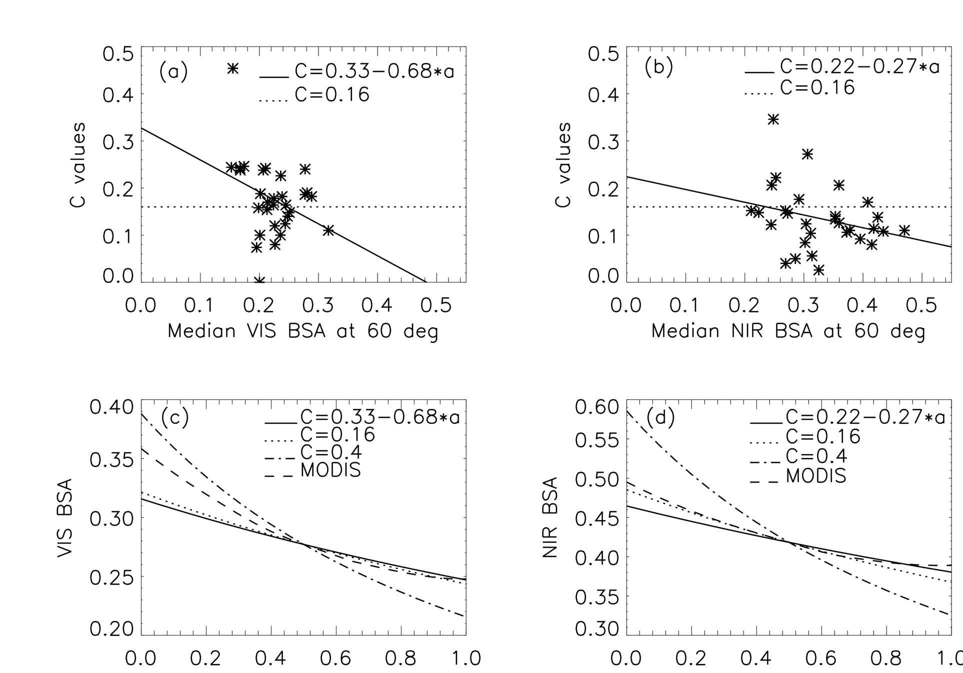


Fig. 5: Parameter C value versus the median of MODIS black-sky albedo at 60 deg SZA for 30 locations (a) in VIS band, (b) in NIR band (solid line: the best-fit linear function, dotted line: the average of C value in VIS and NIR bands). (c) The SZA dependence over (24.275N, 12.325W) based on MODIS data and different C values (the best-fit linear function or constant) in VIS band, (d) same as (c) except in NIR band.