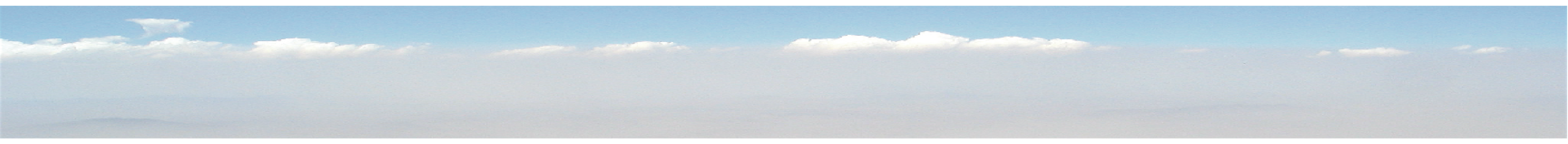


Observed Surface Reflectance Distributions in the Southern Great Plains During ALIVE

Kirk Knobelspiesse[1], Brian Cairns[1], Andrew Lacis[2], Mikhail Alexandrov[2], Barbara Carlson[2] and Beat Schmid[3]

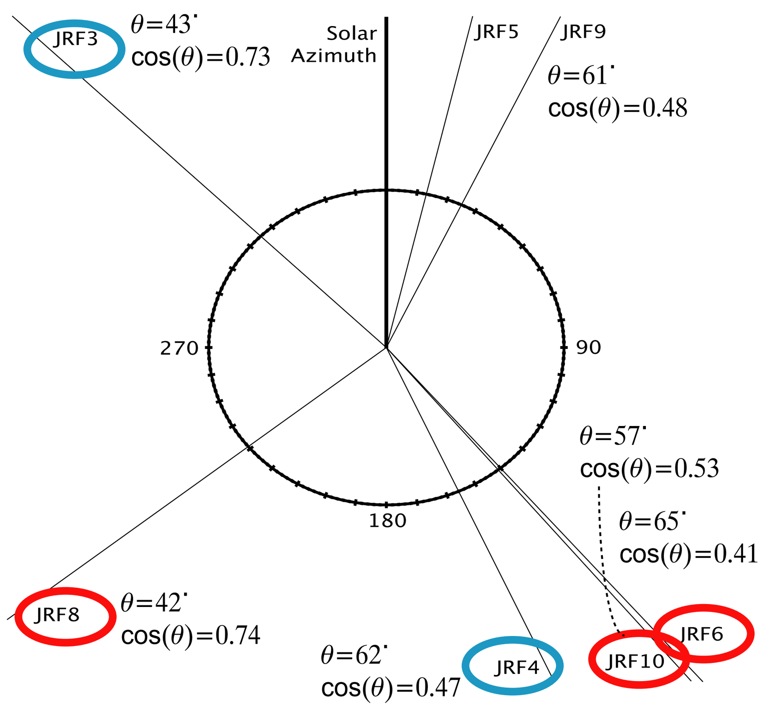
[1]Department of Applied Physics and Applied Mathematics, Columbia University

[2]NASA Goddard Institute for Space Studies [3]Pacific Northwest National Laboratory

Overview

- Surface albedo can be measured from the ground with broadband instruments.
- Albedo can be measured from space if the atmospheric effect is removed and many view geometries are available. The measured Bidirectional Reflectance Distribution Function (BRDF) is angularly integrated to compute the albedo.
- Studies of the former (Yang, 2006) and the latter (Liang et al. 2005; Wang et al. 2006) do not always agree.
- We investigate this issue using low altitude airborne measurements from the Research Scanning Polarimeter (RSP). RSP has a wide range of viewing geometries, and the low altitude flights provide for a simple atmospheric correction, while bridging the spatial resolution gap between satellite and ground measurements.

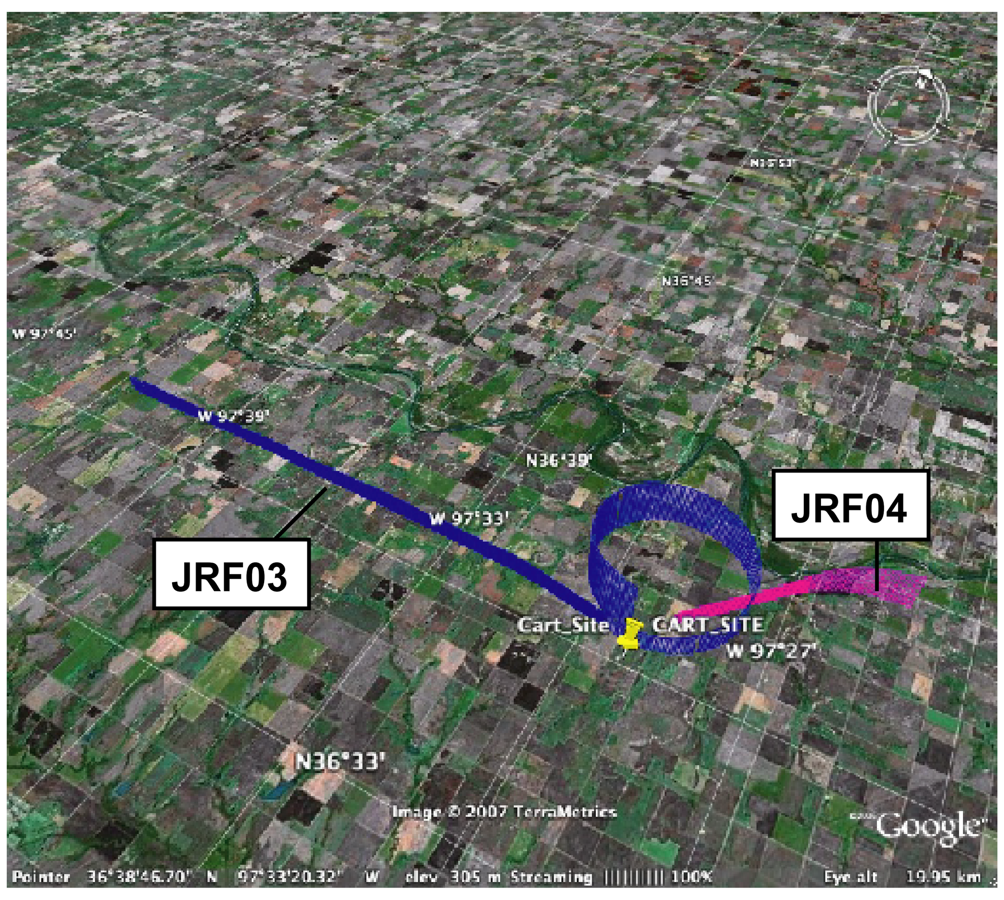
1. The RSP is used in the tail of a Jetstream-31



3. Relative solar- sensor azimuths for the cloud free (Blue) and cloudy (red) flights.

Data

- *Instrument* - Research Scanning Polarimeter (RSP): a 9 channel (downward) scanning polarimeter, with about +/- 50˚ view zenith angle range. Mounted in a Jetstream-31 aircraft. RSP is a prototype of the Aerosol Polarimetry Sensor (APS), an instrument on the upcoming NASA Glory mission.
- *Experiment* - Aerosol LIdar Validation Experiment (ALIVE), at the Southern Great Plains (SGP) site in September, 2005.
- *Data* - two low altitude (about 200m above ground) flights (JRF03 and JRF04) during cloudless days with low aerosol loading (AOT(500nm) = 0.06).
- *Atmospheric correction* - Extinction effect from Rayleigh, Aerosol (aircraft AATS-14), water vapor (ground MWR), NO2 (SCIAMACHY satellite climatology) and Ozone (TOMS satellite) removed from the direct beam. Diffuse downwelling neglected (for now).
- *Data* - Reshuffled to represent solar and view angular distribution about a ground point, and separated into two general surface type classes: 'Vegetation' and 'Soil'. Classification utilizes the Aerosol Resistant Vegetation Index (ARVI) (Kaufman and Tanré (1992)) and spatial homogeneity.



2. Google Earth map of flights JRF3 and JRF4 in the vicinity of the SGP site.

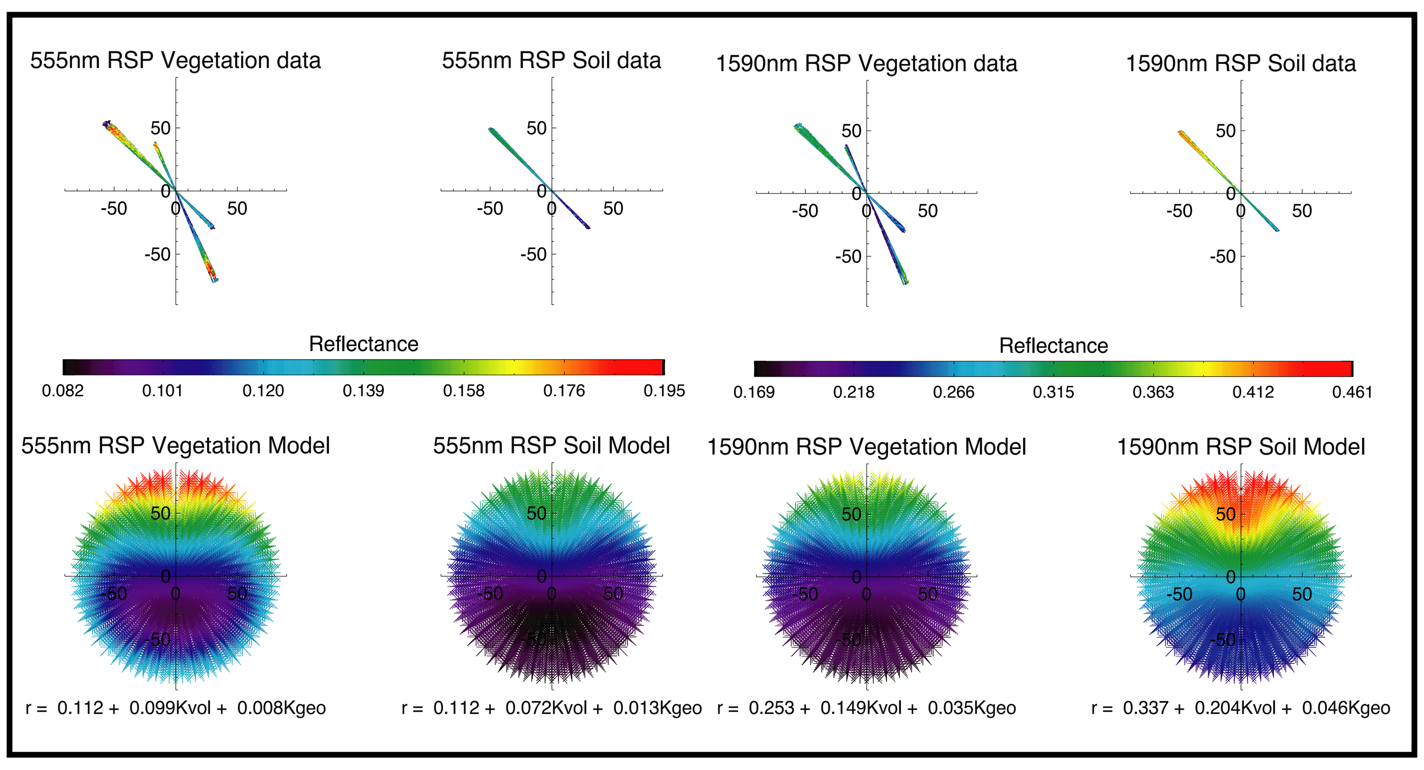
BRDF model fitting

- Data are fit to the "RossThick-LiSparse" kernel model employed by MODIS:

$$R(\theta,\vartheta,\phi,\Lambda) = f_{iso}(\Lambda) + f_{vol}(\Lambda)\, K_{vol}(\theta,\vartheta,\phi) + f_{geo}(\Lambda)\, K_{geo}(\theta,\vartheta,\phi)$$

parameters (f) represent the magnitude of isotropic, volumetric and geometric scattering and are found by fitting to kernels (K) expressing the geometric nature of that scattering.

- "Black-sky" albedo ($a_{bs}(\theta)$) is R integrated over relative azimuth (ϕ) and view zenith (ϑ). It is a function of solar zenith angle (θ). This is the albedo due to direct solar path alone.
- "White-sky" albedo (a_{ws}) is a scalar, a_{bs} integrated over solar zenith angle (θ). This is the diffuse albedo.
- Broadband albedos are averages of spectral albedos weighted for the downwelling spectrum in that band (Λ).



4. BRDF fitting examples: RSP data (top row) and model fits (bottom row) for 555nm (left plots) and 1590nm (right plots) bands.

Azimuth angle independence

- Can the albedo be consistently estimated using different view and solar relative azimuth angles? This is tested by fitting the BRDF model to the two cloud free flights (which have different relative azimuth angles) independently.
- Plot 5a shows the spectral BRDF model parameter values for the vegetation class from flights JRF03 and JRF04. Figure 5b is the spectral white-sky albedos computed from the BRDF models for each flight. Broadband white-sky albedos are 0.149 and 0.143 for JRF03 and JRF04 respectively. In this case, at least, the BRDF model and albedo appear independent of relative azimuth angle.

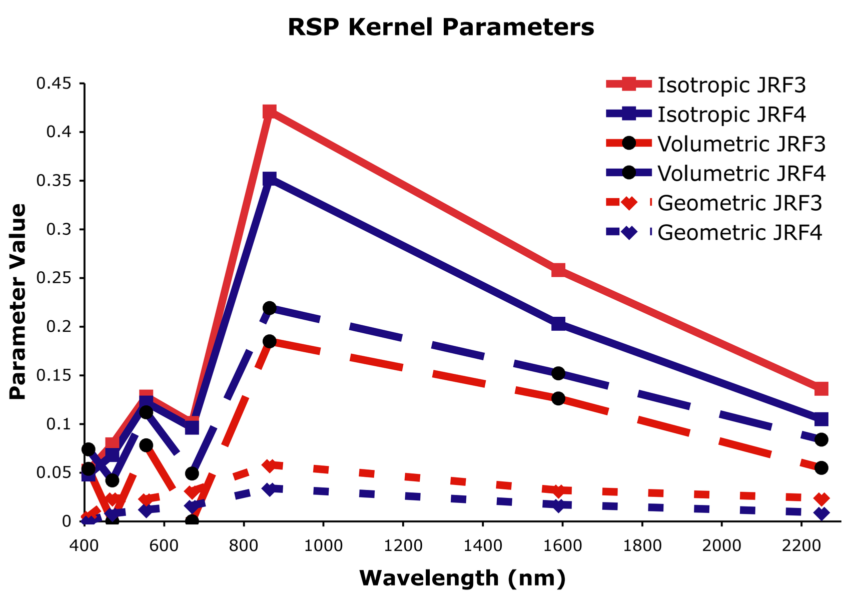


Figure 5a: spectral BRDF model parameters

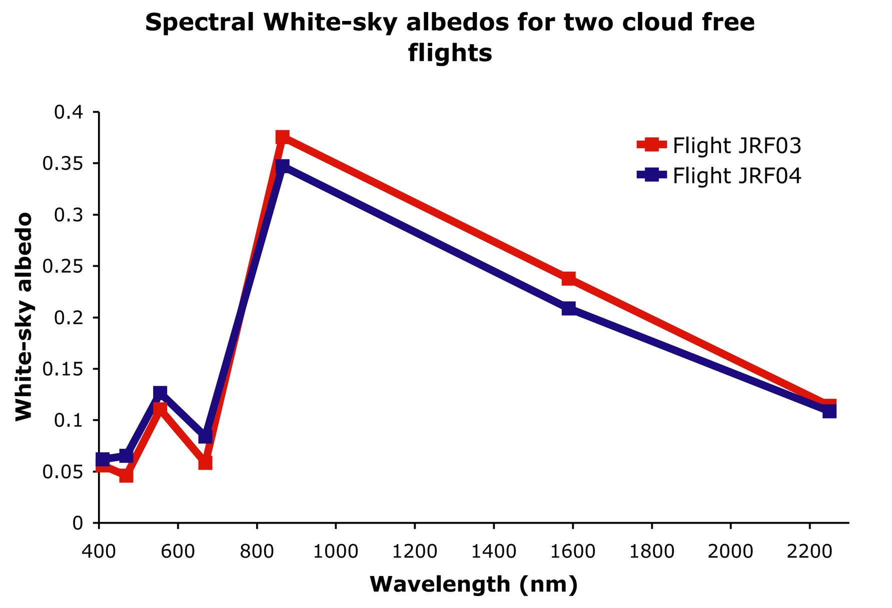


Figure 5b: spectral white-sky albedos from JRF03 & 04

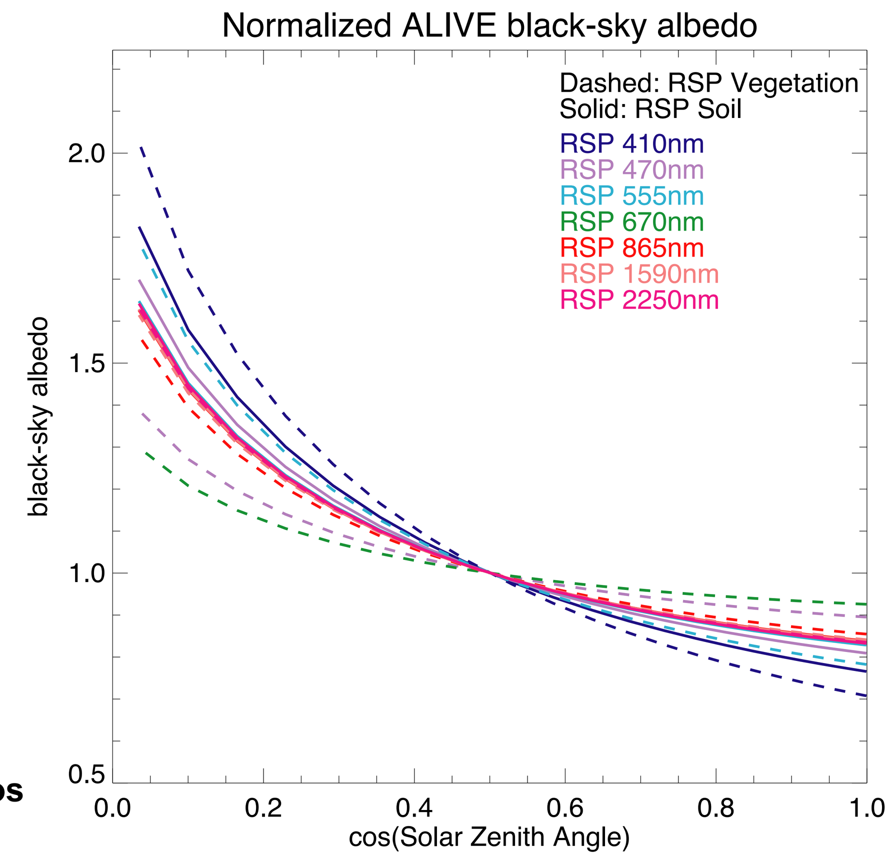
Black-sky albedo spectral dependence

• The shape of the black-sky albedo has generally been assumed to be independent of spectral band (Yang, (2006)). Figure 6 at the right is a plot of black-sky albedo for the 'vegetation' and 'soil' classes, normalized by the value at cos(θ=50˚).

• The 'soil' class shows very consistent values, with deviations at the shortest (and thus most Rayleigh affected) wavelength bands.

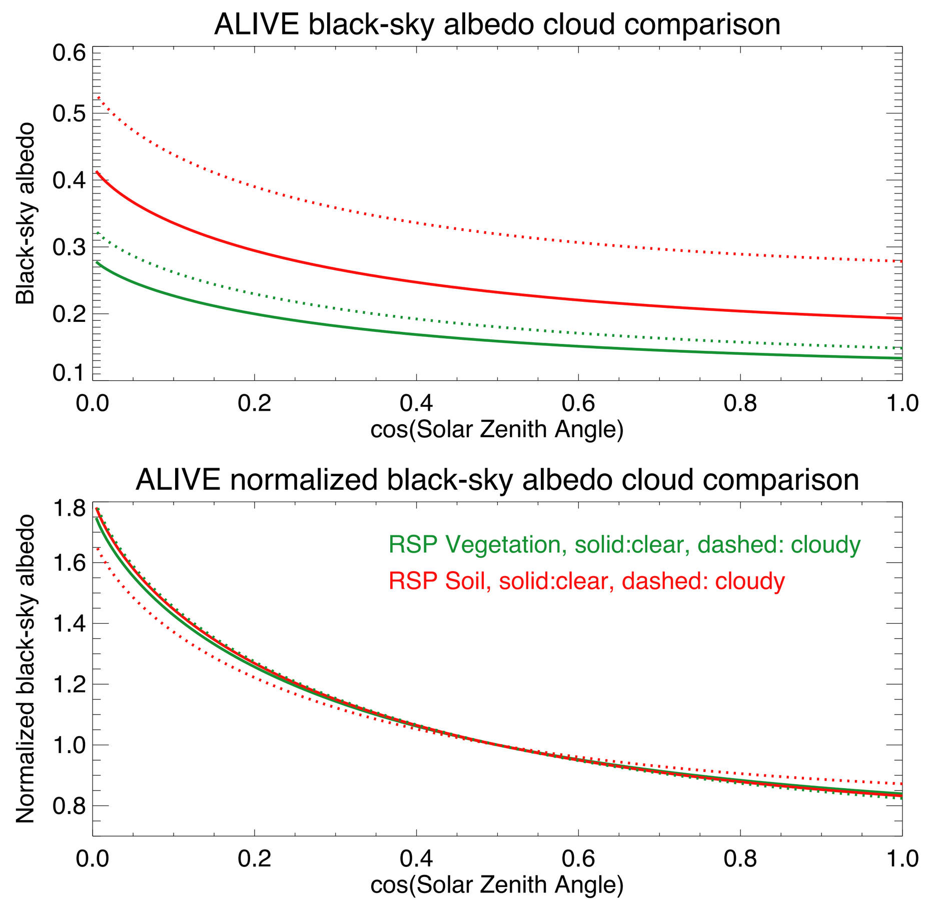
• The 'vegetation' class, on the other hand, shows a large, and unexpected, variation. Does this indicate problems with models that are specularly independent once normalized to the albedo at a solar zenith angle?

• MODIS operational products (not plotted) show similar soil-vegetation differences.



6: spectral normalized black-sky albedos

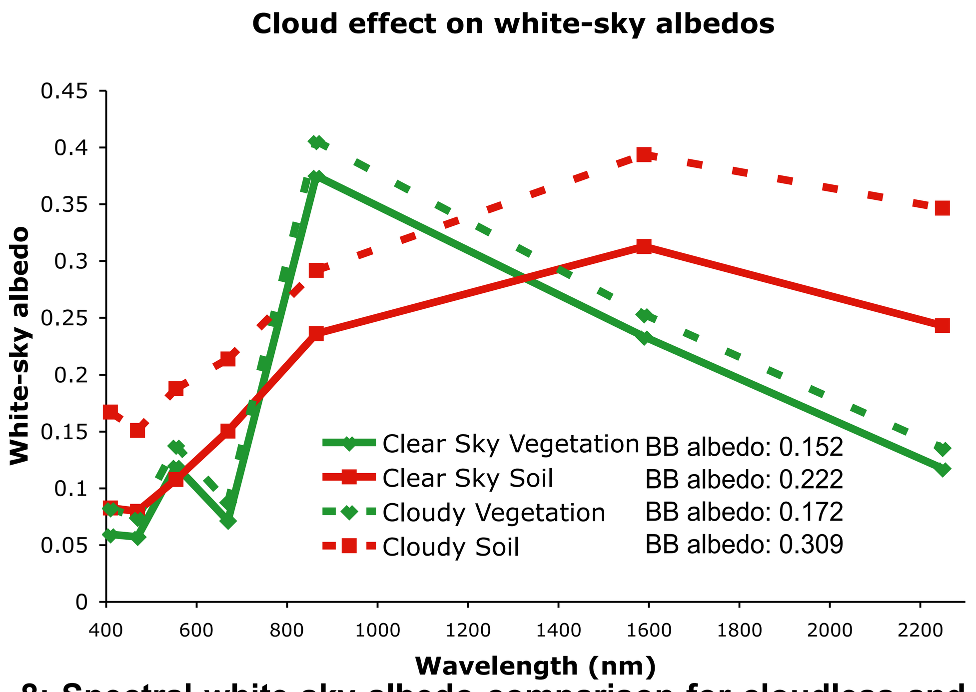
Diffuse downwelling effect on albedo



7: Broadband black-sky albedo comparison for cloud free and cloudy flights.

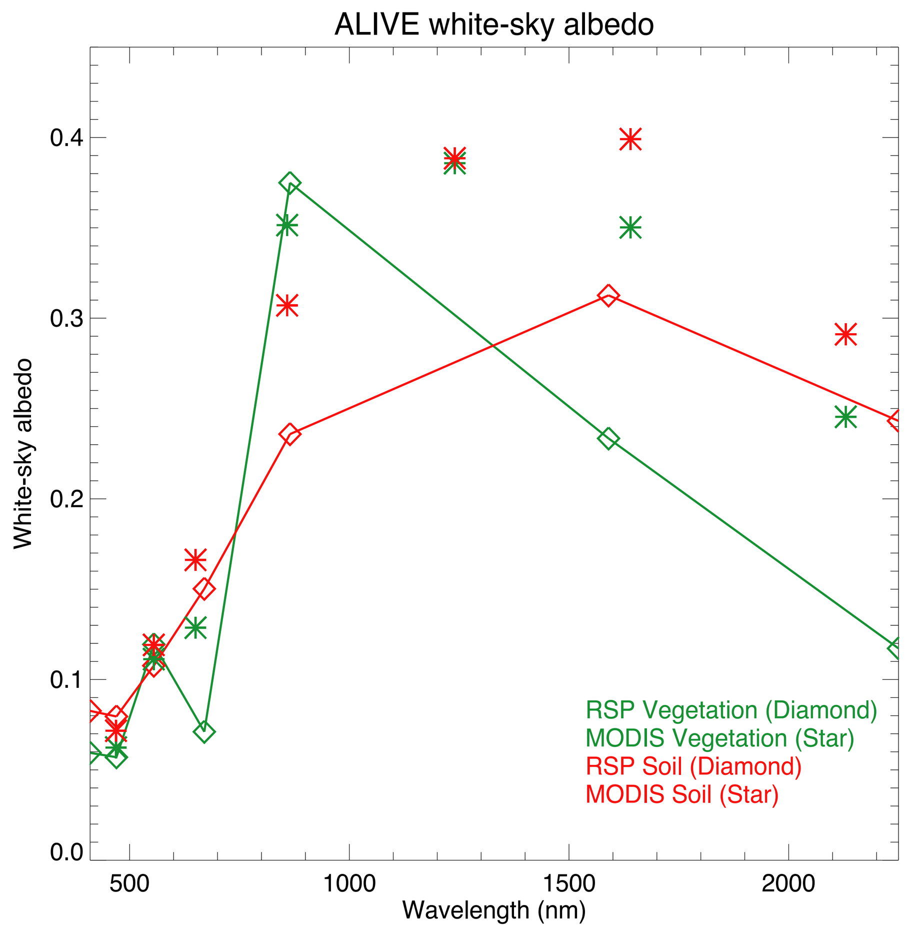
• In this preliminary experiment version, we do not account for diffuse downwelling (skylight) in our atmospheric correction. To test the potential effects of this, albedo results from cloud free (JRF03 and JRF04) flights are compared to flights JRF06, JRF08 and JRF10. The latter had scattered cirrus clouds (none occluding the direct solar beam) and at least twice the aerosol optical thickness in visible wavelengths. Thus, albedo comparisons between the two groups of flights reveal the role diffuse downwelling plays in albedo.

• Both black-sky (figure 7) and white-sky (figure 8) albedos show an offset between cloudless and cloudy data. Cloudy data albedos are uniformly higher both spectrally and with respect to solar zenith angle (figure 7). Normalized black-sky albedos (figure 7b) are nearly identical for both cloudy and cloudless datasets, indicating that diffuse downwelling only affects the isotropic component of albedo.



8: Spectral white-sky albedo comparison for cloudless and cloudy data. Broadband (BB) albedos are also given.

MODIS - RSP albedo comparison



• MODIS BRDF model parameters (f_{iso}, f_{vol} and f_{geo}) were acquired to compare to RSP data. The MODIS data (MCD43B1, version 5) is a 16 day binned Aqua and Terra composite with 1km spatial resolution. Matches to the 'vegetation' and 'soil' were found using the MODIS pixel with the highest and lowest Normalized Difference Vegetation Index (NDVI), respectively, that were adjacent to RSP flight paths.

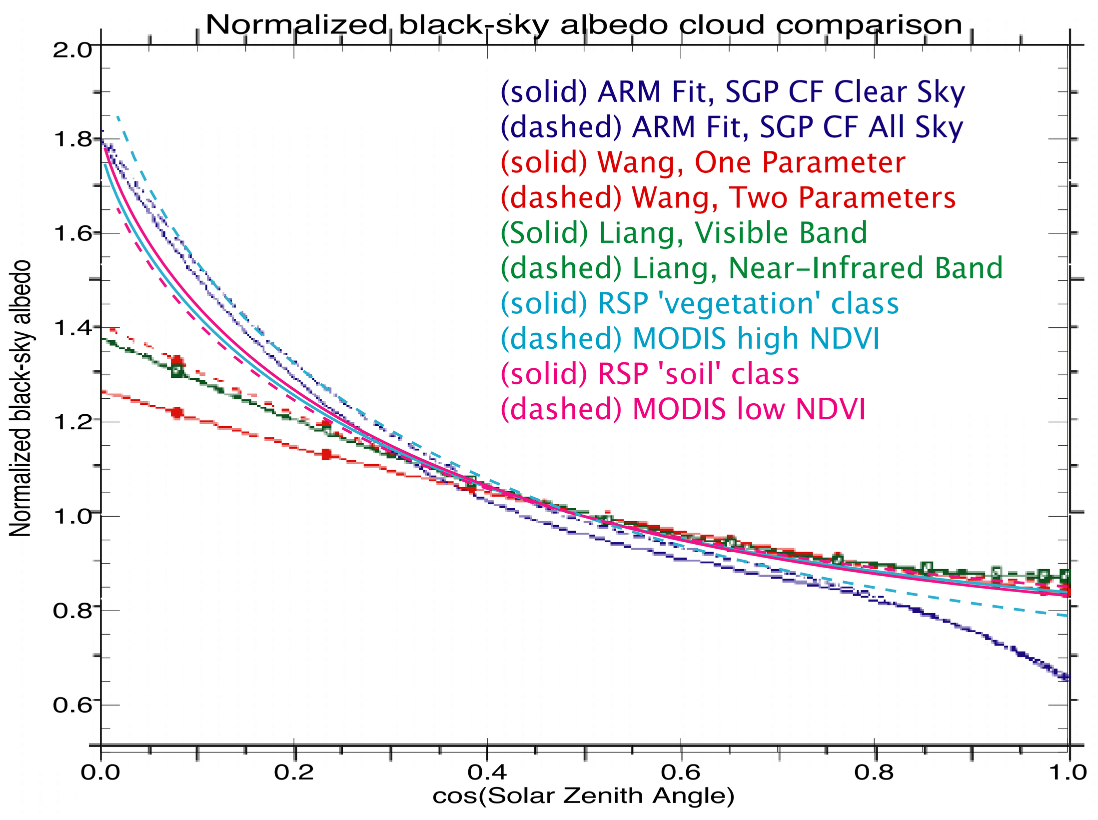
• Spectral white-sky albedos from both RSP and MODIS are shown in figure 9. Agreement is best at shorter wavelengths, and worse in wavelengths showing greater variability between surface class types. This stands to reason since the spatial resolution of MODIS is greater than the size of a particular vegetated or bare soil field, so pixels likely represent a less homogeneous surface type mixture than RSP data. In comparison, the RSP spatial resolution for the low altitude flights is about 2.8m at nadir.

9: Spectral white-sky albedos for RSP 'vegetation' (green) and 'soil' (red) classes, compared to MODIS data with high (green) and low (red) NDVI.

RSP/MODIS/ARM albedo comparison

• At the previous ARM Science Team meeting, Yang (2006) presented comparisons between albedos derived from ground instrumentation at the SGP site and MODIS albedos from Wang et al. (2006) and Liang et al. (2005). They found the MODIS albedos were lower than ARM measurements at high solar zenith angles, and higher at low solar zenith angles.

• Figure 10 is taken from Yang (2006) and modified to include our results. We show a much better agreement with SGP ground data at high solar zenith angles, while overestimation of albedo at low solar zenith angles remains. It is intriguing that operational MODIS BRDF products match the ARM data better at high solar zenith angles than either of the more recent models of Wang et al. (2006) and Liang et al. (2005).



10 (at right): Normalized black-sky albedos from MODIS, RSP and ARM ground data. This plot is a modification of figure 6b in Yang (2006), with a RSP and MODIS operational product plot overlay.

Acknowledgements and References

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Contact: Kirk Knobelspiesse at kdk2103@columbia.edu