Measurement and Error Analysis of Spectral Surface Albedo during MILAGRO

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Abstract

Spectral surface albedo is a boundary condition which needs to be known with high accuracy for aerosol remote sensing, surface aerosol forcing, and radiative transfer calculations. We use Solar Spectral Flux Radiometer (SSFR) measurements of upward and downward irradiance from onboard the Sky Research J-31 during Megacity Initiative: Local and Global Research Observations (MILAGRO) to determine the spectral surface albedo over the wavelength range between 350 and 2100 nm. Atmospheric measurements (P, T, and RH) as well as aerosol measurements (τ, ω, and g) are used as inputs into an SSFR specific radiative transfer model, which is then used iteratively in conjunction with the measurements to determine the contribution of the atmospheric layer between the flight altitude and the surface to the measured spectral surface albedo. The sensitivity of this approach to instrumental errors, atmospheric and aerosol correction, solar zenith angle and spatial heterogeneities are used for estimating the uncertainty in the derived surface albedo.

Instrument and Model Description

SSFR Instrument Specifications
300 nm to 2100 nm
4-8 nm resolution
zenith and nadir viewing
2π sr FOV (W m^{-2} nm^{-1})
3% accuracy; 0.5% precision

Model Description

An SSFR specific radiative transfer model is used for analysis of the SSFR data [2]. The model has been updated to contain 2201 bands of 1 nm width from 0.3-2.5µm. Properties of the model include the following:

1. Molecular Scattering and Absorption: Correlated k-distributions for O_2, O_3, CO_2, H_2O, and CH_4 [7]
2. Multiple Scattering: DISORT - Discrete Ordinates Radiative Transfer Program [10]
3. Solar Spectrum: Kurucz [6]
4. Filter functions from the SSFR [8]
5. Inputs into the model: vertical profiles of gases (radiosondes), aerosols (lidar and sunphotometer), and spectral scattering and absorption properties of aerosols (nephelometer and PSAP).

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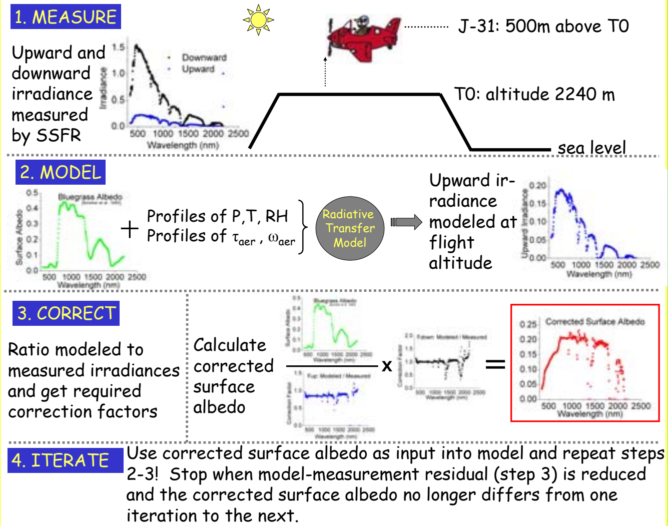
Iterative Approach Method

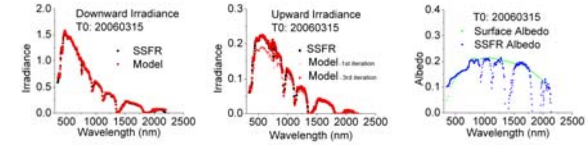


This method for retrieving surface albedo is adapted from Wendisch, M., et al. [11]

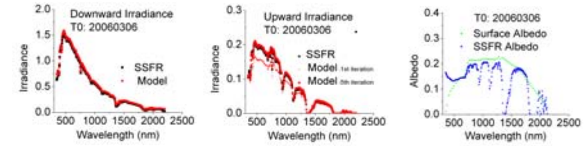
Results

Shown are model-measurement match in downward irradiance, conversion in upward irradiance using the iterative method described above, and retrieved spectral surface albedo (with corresponding SSFR albedo at flight level).

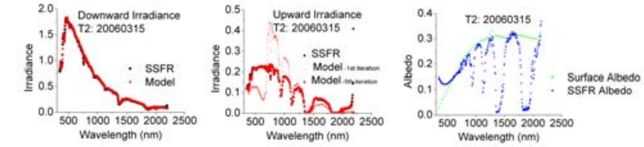
A) T0 Supersite is located in an urban area near the Mexico City Airport. J-31 aircraft was 500 m AGL when this data was taken. Mean aerosol properties between plane and ground were measured using AATS-14 [9], an Aeronet sunphotometer [5], and PSAP/nephelometer [1].



B) A second over-flight of T0 from 20060306. J-31 aircraft was 3800 m AGL when this data was taken. Mean aerosol properties between plane and ground were measured using an Aeronet sunphotometer [5].



C) T2 supersite is located approx. 60 km NE (downwind) of T0 on private ranch land (parched grass). J-31 aircraft was 3810 m AGL when this data was taken. Mean aerosol properties between plane and ground were measured using an Aeronet sunphotometer [5] and a PSAP/nephelometer [4].



Sensitivity Analysis

We used a two-stream formulation to address the sensitivity of retrieved surface albedo to the layer properties between the SSFR instrument and the ground. The equation as derived illustrates the dependency of retrieved surface albedo on τ_{aer}, ω_{aer}, g_{aer}, and cosine of solar zenith angle (µ).

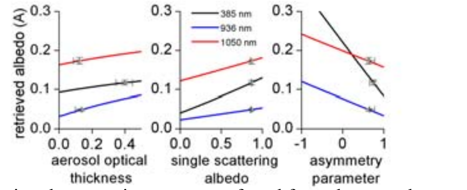
$$B = \beta + \gamma^2 \{A + A^2\beta + A^3\beta^2 + A^4\beta^3 + ...\}$$

where B = SSFR albedo at flight level and A = retrieved surface albedo

$$\beta = (1-t)\varpi_o b, \quad \gamma = \{t + (1-t)\varpi_o f\}^2$$

$$t = \exp^{-\frac{\tau}{\mu}}, \quad f = \frac{1+g}{2}, \quad b = \frac{1-g}{2}$$

This figure shows the sensitivity analysis for the T0 supersite (on 20060315) for one SSFR measurement at 3 wavelengths. **Black stars** show the parameters as measured for this site and date. **Grey horizontal bars** show the range in the parameters found. **Grey vertical bars** show the measurement uncertainty.



Projecting the range in parameters found from the x- to the y-axis allows one to compare the relative contributions of aerosol parameter uncertainty (horizontal bars) and measurement uncertainty (vertical bars) to retrieved surface albedo. The slope of the lines give the sensitivity of retrieved surface albedo to the optical properties. For this case, measurement uncertainty is a larger concern than range in aerosol optical depth (or changing path length) or single scattering albedo on retrieved surface albedo, but was on par with the range in asymmetry parameter.

Conclusions

1. We show SSFR measurement-model comparisons under polluted conditions for up- and down-welling irradiances, using AATS-14, sun-photometer, PSAP, and nephelometers to provide aerosol layer profiles into the model.
2. Our measurement-model comparisons are sufficiently accurate to screen cirrus cloud signals from our data.
3. We provide surface spectral albedo for the T0 and T2 ground sites.
4. We provide a sensitivity analysis of aerosol optical properties and solar zenith angle on spectral surface albedo.

References

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