On the Consistency of TOA Fluxes from CERES and MISR

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Introduction

On NASA's EOS flagship satellite Terra, there are 3 instruments besides ASTER and MOPITT:

- **MODIS** scans the Earth in 36 spectral bands in wavelength from 0.4 to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km).

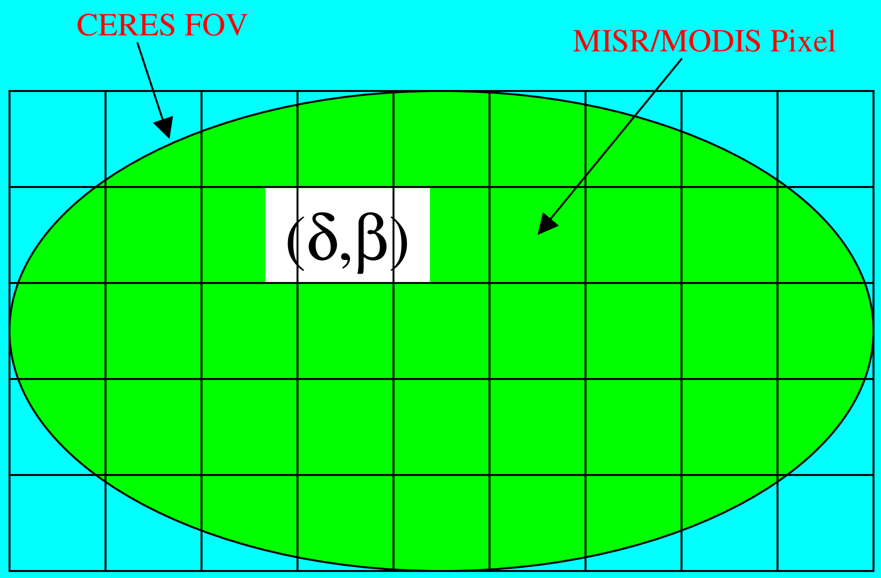
- **CERES** is a broadband scanning radiometer package working at 3 channels (SW measuring reflected sunlight, WN measuring Earth-emitted thermal radiation in the 8-12 µm "window" region, and a total channel for total radiation).

- **MISR** views the Earth with cameras pointed at 9 different angles and 4 wavelengths (blue, green, red, and near-infrared). One camera points toward nadir, and the others provide forward and afterward view angles, at the Earth's surface, of 26.1°, 45.6°, 60.0°, and 70.5°.

A dataset with coincident measurements of spectral and broadband radiances from MISR, CERES, and MODIS will enhance the applications of the MISR, CERES, and MODIS data on various atmospheric remote-sensing aspects and help in examination of the consistency of the data from different instruments.

The SSFM Dataset

The pixel-level radiances x(δ,β) in the MISR/MODIS Level 1 data are converted into the CERES-FOV-level radiances <x> with weight of the CERES Point Spread Function (PSF). This process results in the NASA SSFM dataset.



$$\langle x \rangle = \frac{\iint_{FOV} PSF(\delta,\beta)\, x(\delta,\beta) \cos\delta\, d\delta\, d\beta}{\iint_{FOV} PSF(\delta,\beta) \cos\delta\, d\delta\, d\beta}$$

where (δ,β) are the angular coordinates of a point in the CERES Field-Of-View (FOV).

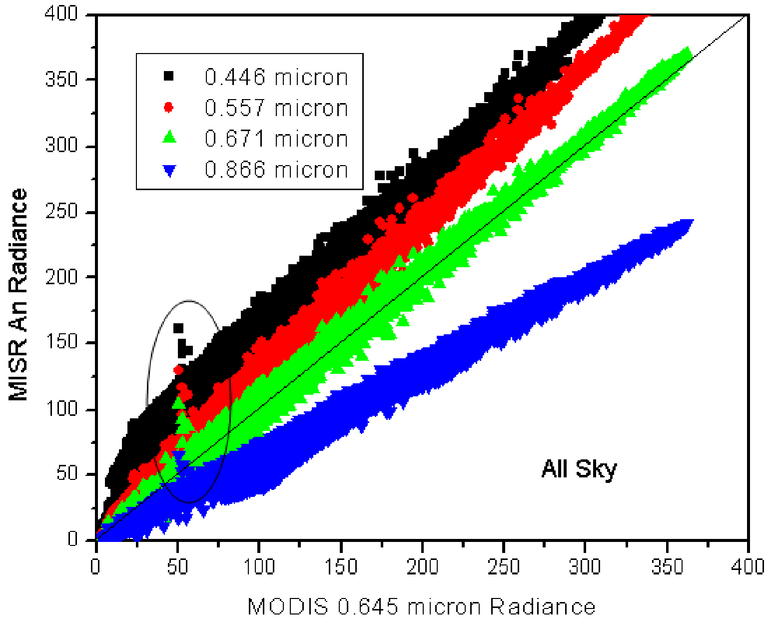
The SSFM Dataset (cont.)

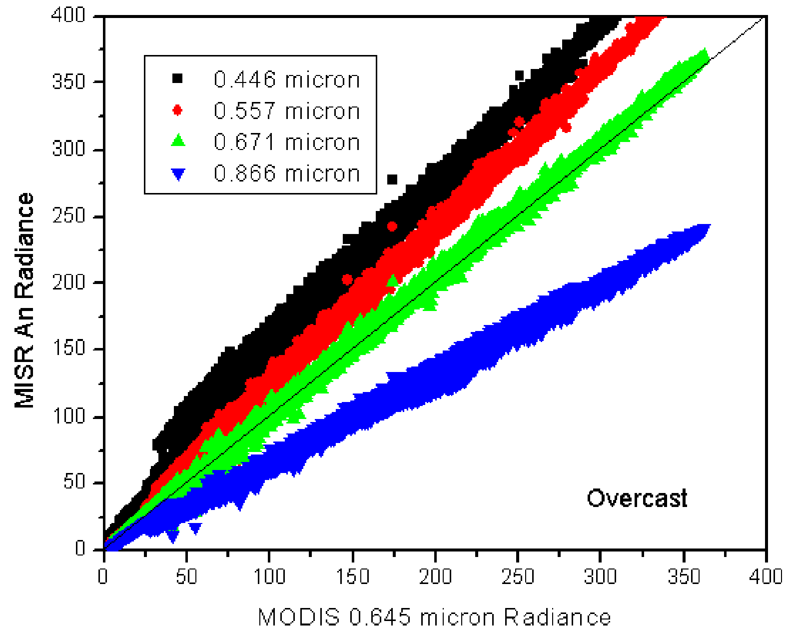
1. **The SSFM dataset is an expansion of NASA's Single-Scanner Footprint (SSF) dataset with MISR data.**

2. **The SSF contains CERES FOV geometry and viewing angles, radiance and flux, and area statistics. The SSF contains MODIS viewing angles, clear and cloudy area statistics for 2 cloud height layers, cloud overlap conditions, and MODIS radiance at 5 channels over the CERES FOV.**

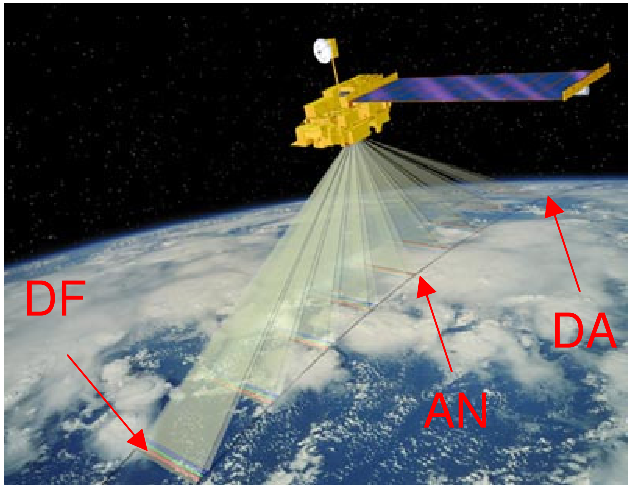
4. **The SSFM contains MISR radiance at 4 channels and 9 viewing angles over the CERES FOV.**

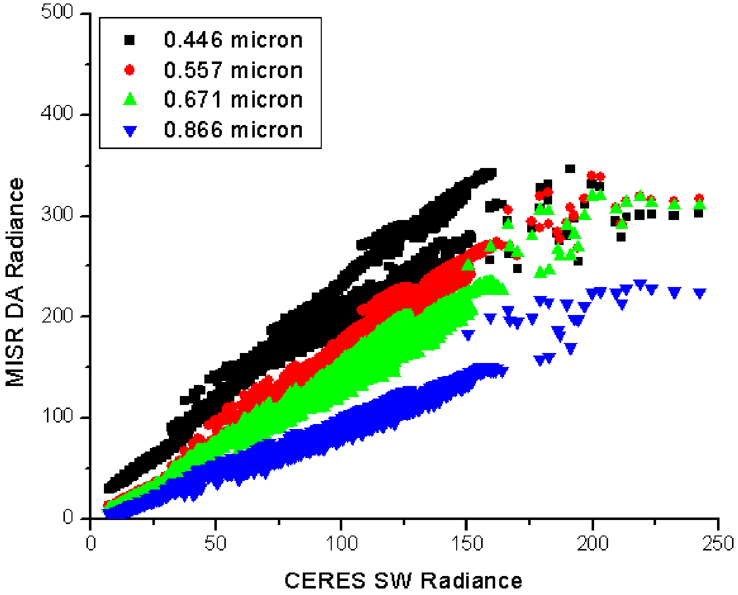
MISR and MODIS radiances in SSFM

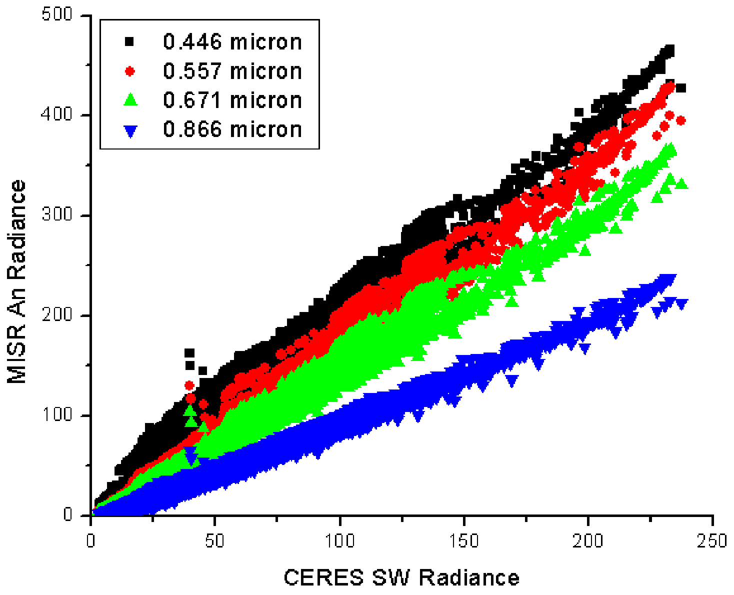


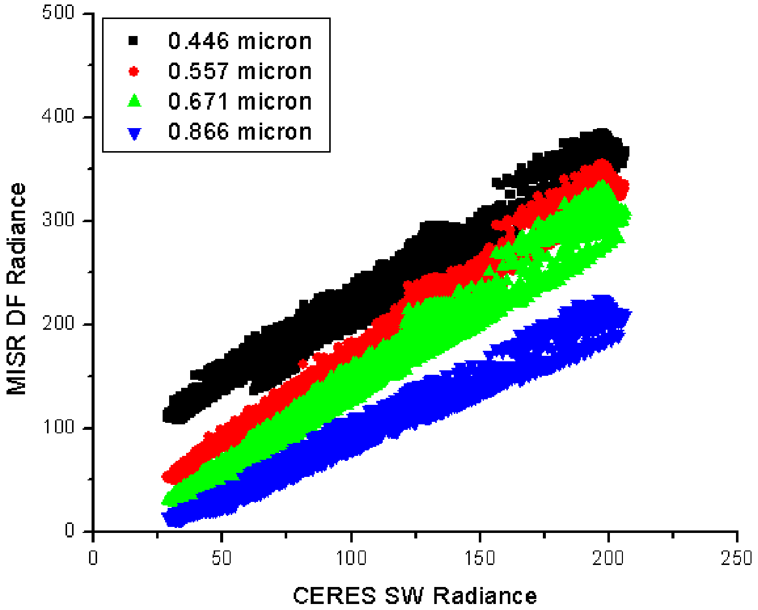


MISR and CERES SW Radiances in SSFM









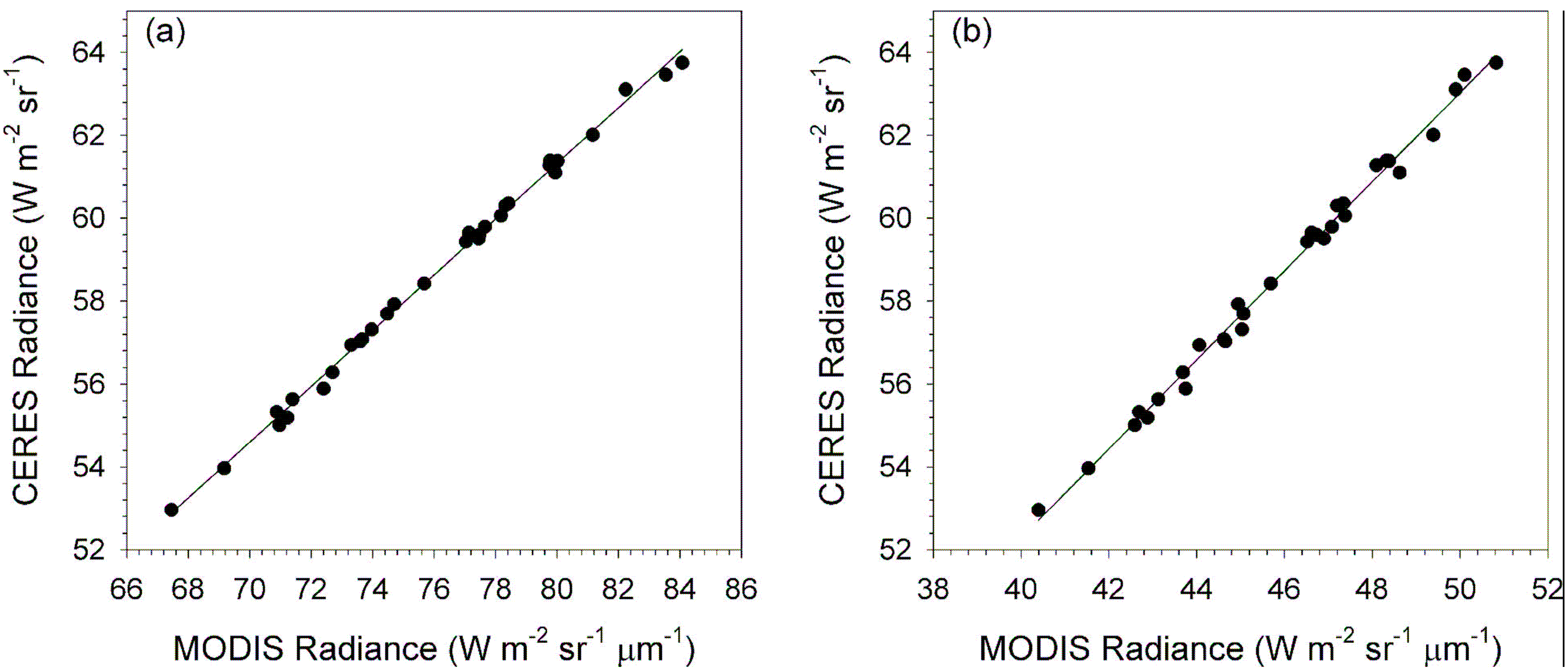
Cross-calibration of MISR Radiances with CERES and MODIS Data

Calibration drift of sensors is a known error source for remote-sensing. Assessment of the calibration drift of an instrument is important for accurate analysis of the measured data.

Although the MISR cameras are calibrated every month onboard, a long-term cross-calibration of the MISR sensors with other well-calibrated instruments is also important for examination of the accuracy of the MISR data.

As an example for application of the SSFM dataset, we assess the calibration drift of the MISR instruments using the CERES and MODIS radiances over the CERES footprints.

Cross-Calibration of CERES Radiances with MODIS Data



Daily 30° N–30° S oceanic average CERES SW radiances against MODIS (a) 0.65- and (b) 0.86-mm radiance for May 2000. Lines correspond to regression fits to the data

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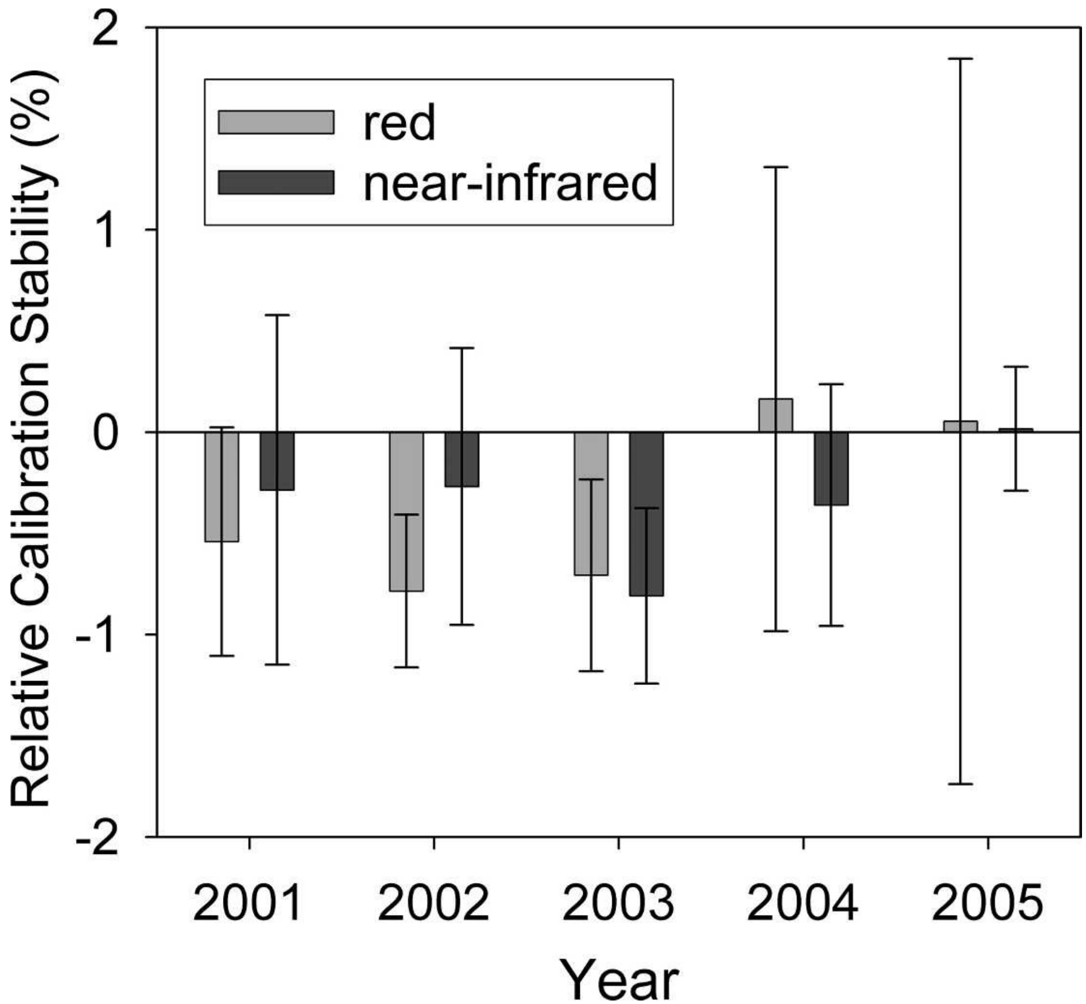

The year-to-year relative calibration stability of CERES and MODIS determined by comparing predicted mean radiances from regression relations in each year with predicted mean radiances from regression relations derived in 2000 (in CERES SW radiances)

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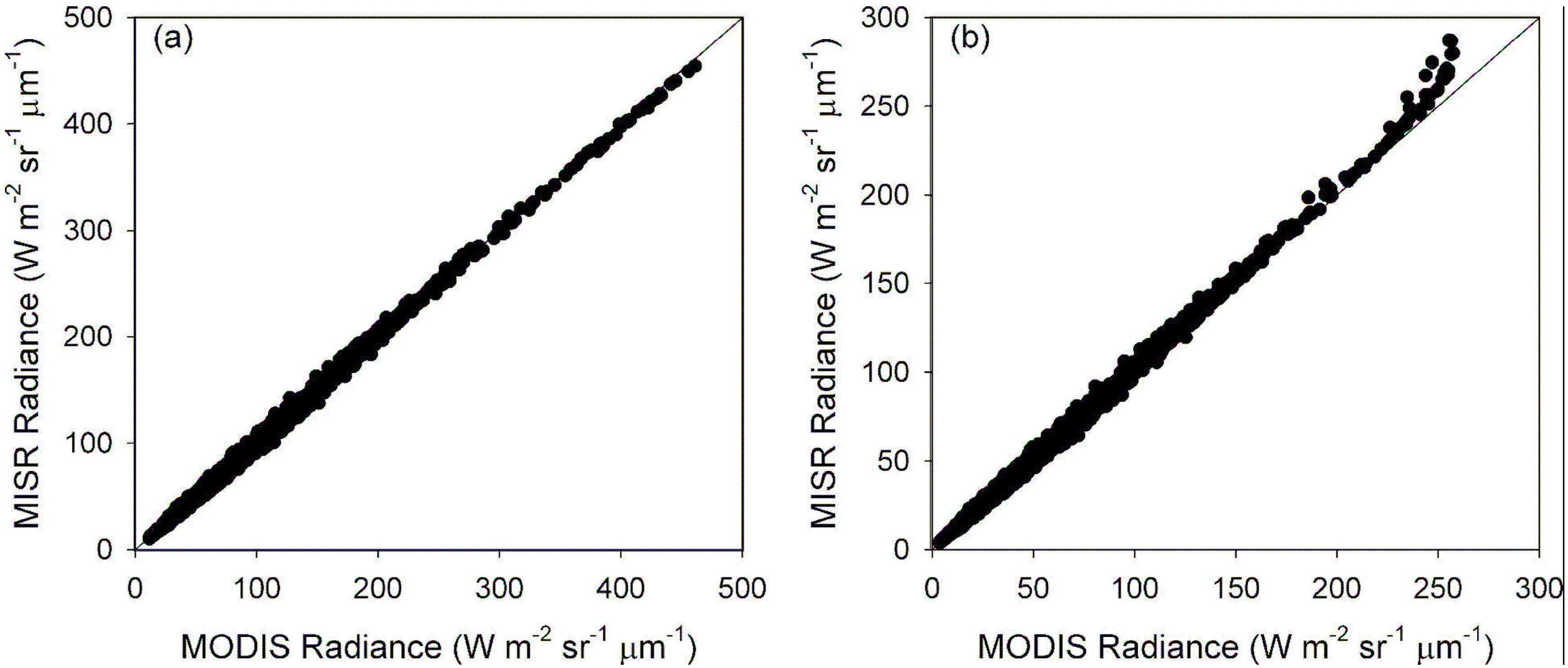
Cross-Calibration of MISR Radiances with MODIS Data



Scatter plot of footprint average MISR and MODIS (a) red and (b) near-infrared radiances for all CERES footprints over ocean between 30° S and 30° N on 12 Sep 2000. One-to-one line is indicated.

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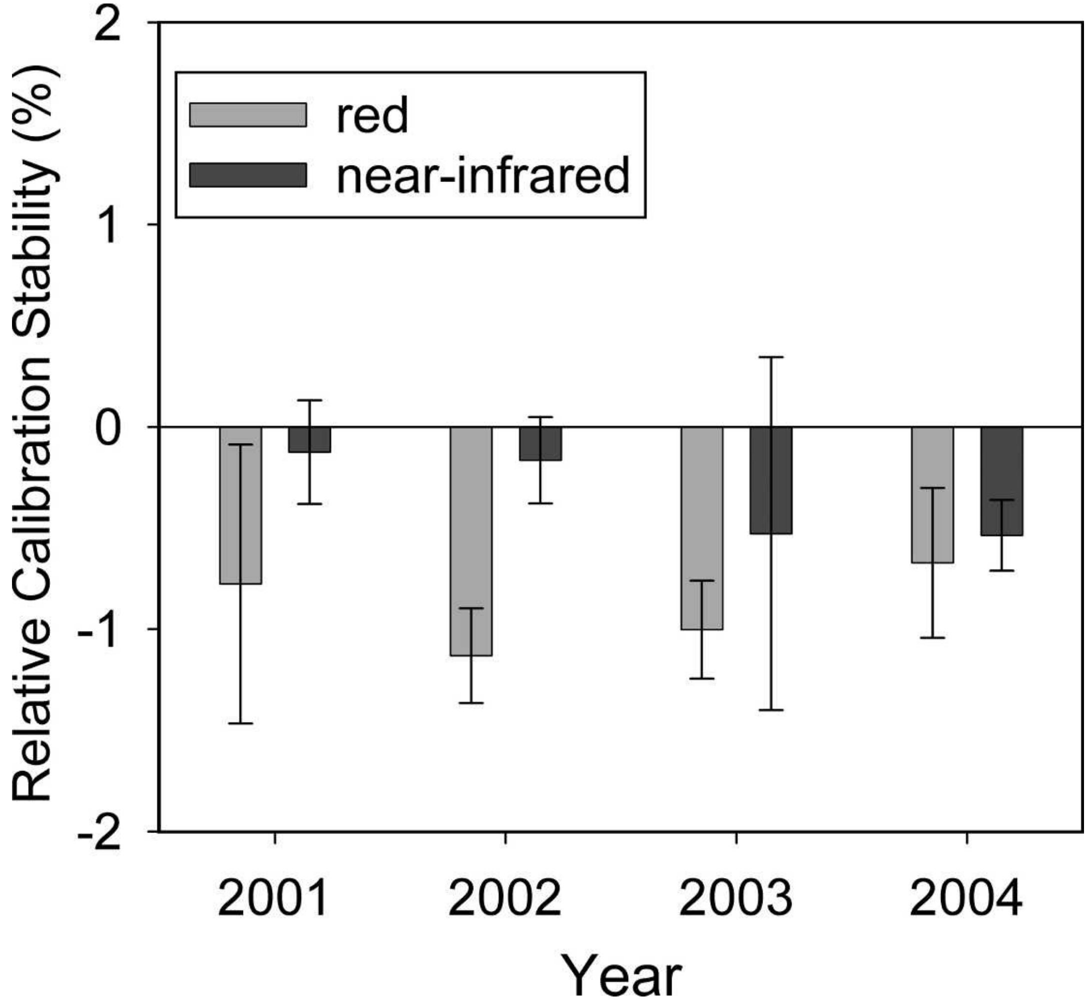

The year-to-year relative calibration stability of MISR and MODIS determined by comparing predicted mean radiances from regression relations in each year with predicted mean radiances from regression relations derived in 2000 (in CERES SW radiances)

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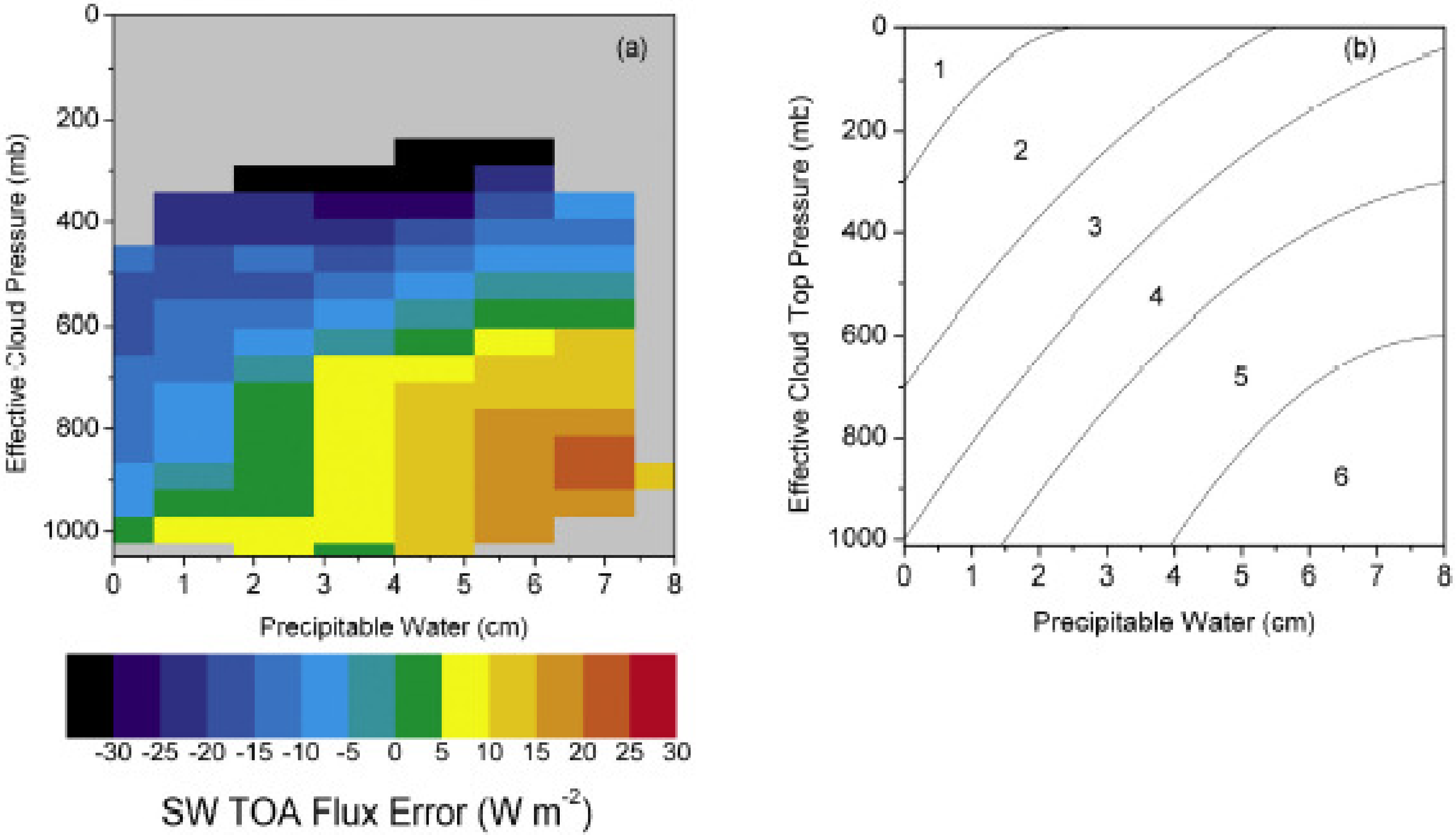
Conversion of MISR Narrowband Radiance to Broadband

Linear regression of MISR and CERES along-track data in the SSFM produces the NB to BB conversion coefficients C0, C1, and C2 as functions of sza, vza, vaz, cloud coverage, cloud pressure, precipitable water, and ground scene-type.

$$R_{sw} = c_0 + c_1 R_{red} + c_2 R_{nir}$$

Application of the NB-BB coefficient tables to MISR Red and NIR radiances converts the MISR NB radiances into CERES BB radiances.

The MISR NB-converted CERES SW radiances at 9 viewing angles for each CERES footprint will help in the CERES ADM study and will help in converting the MISR Level 2 NB albedo into BB albedo, which will be compared with the CERES BB albedo.



(a) Error in instantaneous SW TOA flux for tropical ocean overcast liquid water clouds inferred from the errors in radiances estimated from a narrow-to-broadband regression analysis that does not explicitly account for effective pressure and precipitable water variations. CERES anisotropic factors are used to convert from a radiance error to a flux error. (b) Empirically derived contours defining effective pressure and precipitable water domains

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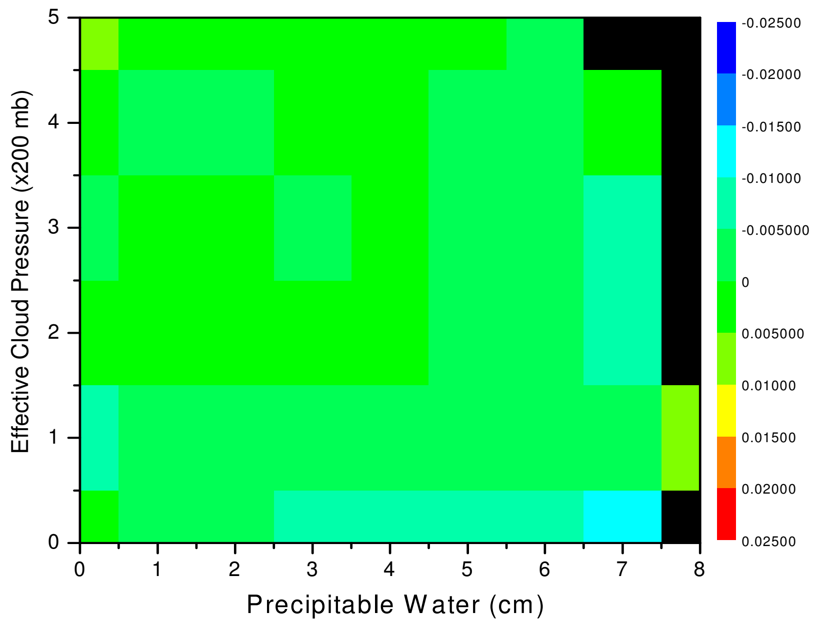
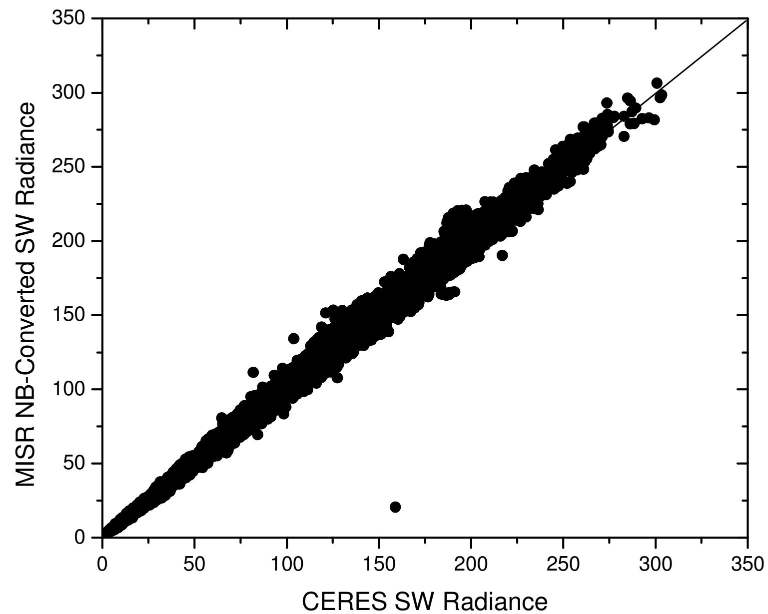




SW reflectance bias error for NB to BB algorithm with cloud pressure and precipitable water stratification.

Overcast ocean.

The comparison of the CERES SW radiance with the MISR NB-converted SW radiance from one-day SSFM data for overcast clouds over ocean. 3-4% NB-BB errors are found.

Conversion of MISR Narrowband Albedo to Broadband

MISR Level-2 spectral albedos are converted to broadband albedos by applying a narrow-to-broadband albedo regression scheme derived from the reflectance narrow-to-broadband regressions.

Since albedo is an integral of reflectance over angle, the narrow-to-broadband reflectance regression available at the nine MISR angles must be extended to other angles.

To estimate reflectances at angles that are not sampled by MISR, we use the following approximation:

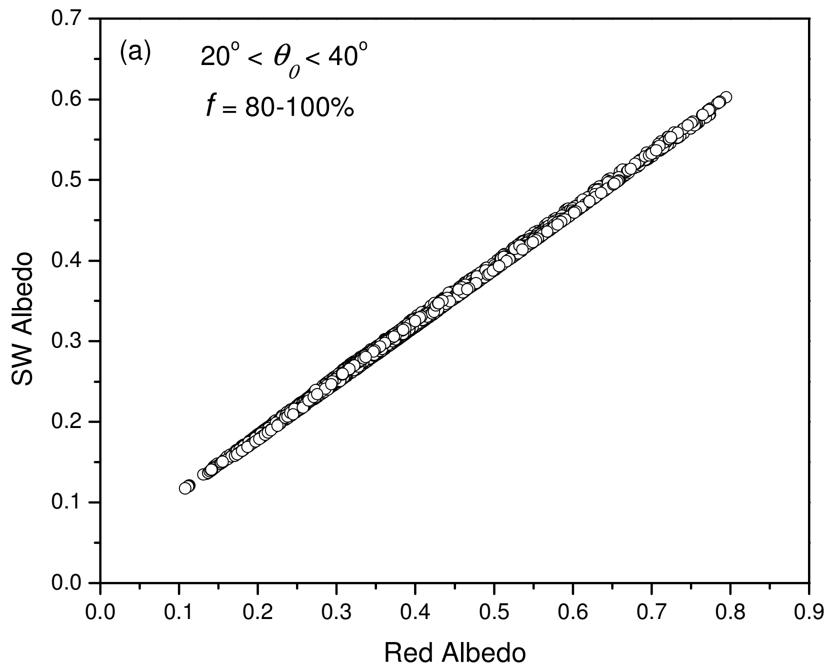
$$\hat{R}(\theta_0,\theta,\phi) = [R_t(\theta_0,\theta,\phi,\tau,f)\,/\,R_t(\theta_0,\theta_i,\phi_i,\tau,f)]\cdot R(\theta_0,\theta_i,\phi_i)$$

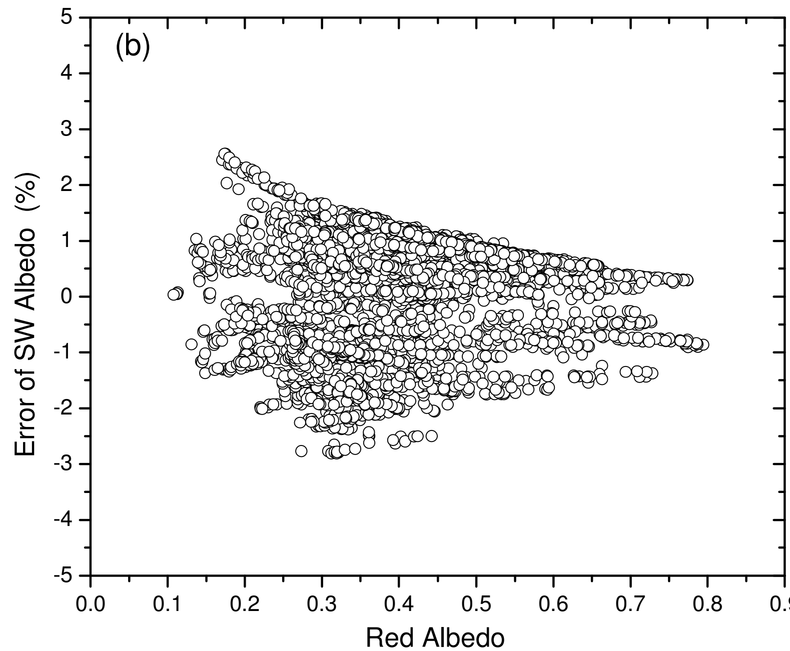
$$R_t(\theta_0,\theta,\varphi,\tau,f) = (1-f)R_d(\theta_0,\theta,\varphi,0) + fR_d(\theta_0,\theta,\varphi,\tau)$$

Tau is a free-variable, selected by minimizing

$$s^2(\theta_0,\tau,f) = \sum_{n=1}^{9}[R_m(\theta_0,\theta_n,\varphi_n) - R_t(\theta_0,\theta_n,\varphi_n,\tau,f)]^2$$

$$\alpha_{sw} = b_0 + b_1\alpha_{red} + b_2\alpha_{nir}$$





(a) The broadband albedo and (b) the error in the albedo narrow-to-broadband regression as function of the MISR red-channel albedo for a solar zenith angle range of 20 to 40 deg and a cloud fraction range of 80-100%, respectively, derived from SSFM data of November 7, 2000.

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Coefficients b_0, b_1, and b_2 for conversion of MISR Red and NIR spectral albedo to broadband albedo. Also shown are the sample number and RMS uncertainty of the conversion for each solar zenith angle bin.

θ_0	b_0	b_1	b_2	*sample no.*	*RMS (%)*
00^o-40^o	0.41833E-01	0.54756E+00	0.15144E+00	176635	1.3
40^o-50^o	0.39479E-01	0.32979E+00	0.37592E+00	429073	2.1
50^o-60^o	0.35775E-01	0.72601E+00	0.10084E-04	419692	2.3
60^o-70^o	0.31889E-01	0.63807E+00	0.10235E+00	311992	2.4
70^o-80^o	0.21622E-01	0.84271E+00	-0.71137E-01	149448	2.9
80^o-90^0	0.16645E-01	0.76100E+00	0.77291E-01	30545	6.4

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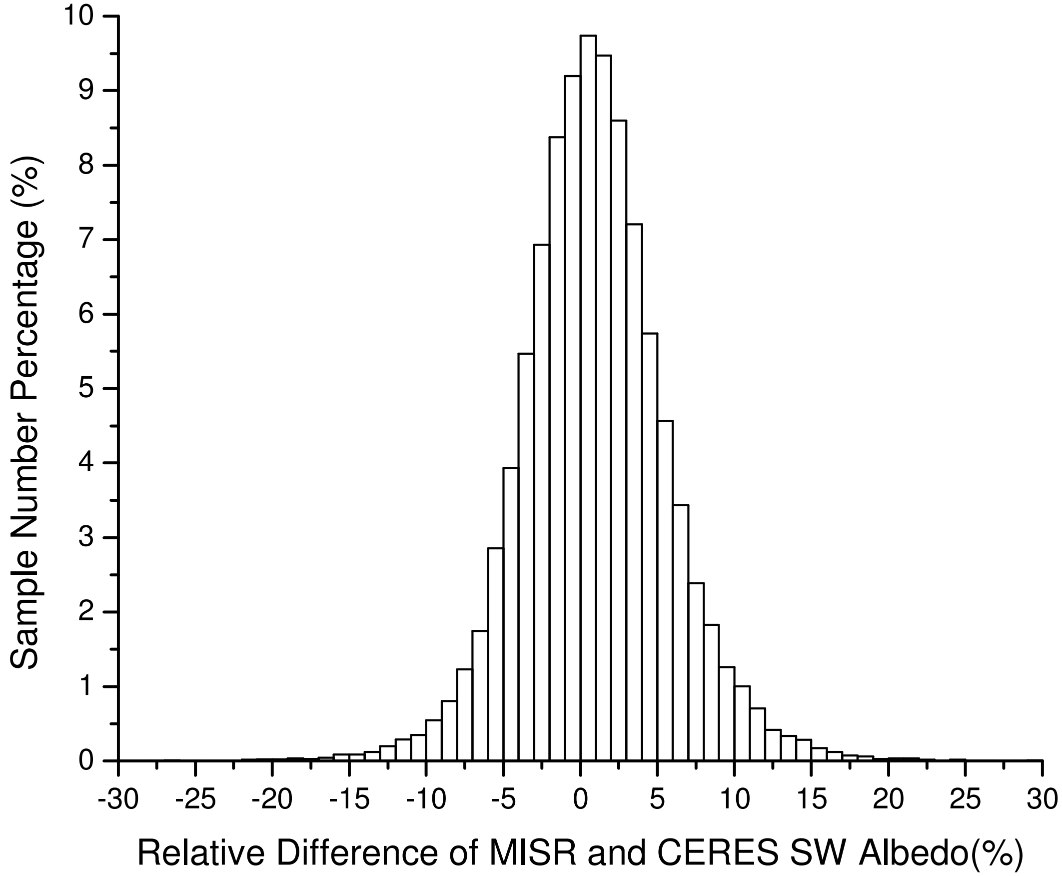

The percentage of 1° x 1° region (sample) number as a function of the relative difference between the MISR and CERES albedo for overcast ocean scenes in October 2001, for solar zenith angles ⩽ 75 deg.

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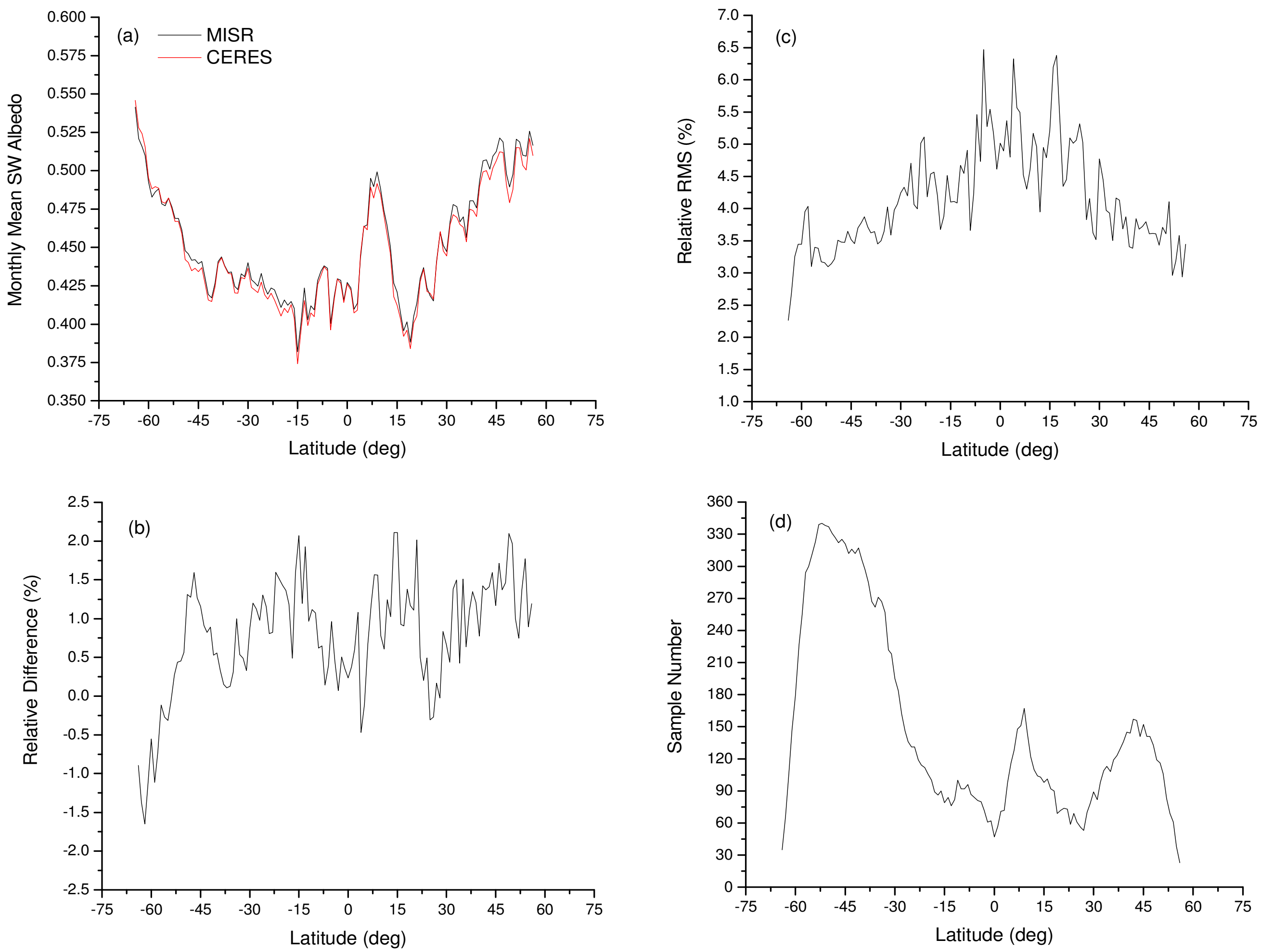

(a) The monthly zonal mean of the MISR and CERES albedos for overcast ocean scenes in October 2001, for solar zenith angles ⩽ 75deg; (b) the monthly zonal mean of the relative differences between the instantaneous 1o x 1o-region-averaged MISR and CERES albedos; (c) the monthly zonal mean of the relative RMS differences between the instantaneous 1deg x 1deg-region-averaged MISR and CERES albedos; (d) zonal 1deg x 1deg region sample numbers.

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Conclusion

1. The SSFM dataset, a fusion of CERES, MODIS, and MISR measurements on Terra, is a significant expansion to the SSF dataset.

2. The MISR spectral radiances show linear regression to CERES SW radiances. A conversion of MISR NB to CERES BB radiances is developed with an error of ~3-4%.

3. Based on the conversion of MISR NB to BB radiances, a MISR NB to BB albedo conversion algorithm is developed.

4. The MISR NB albedo is converted to BB and compared with CERES albedo. The relative root mean-square difference between MISR and CERES albedos due to angular distribution model (ADM) differences alone is estimated to be ~3.8%.

5. The remarkable consistency between CERES and MISR albedo for overcast scenes suggests that both instrument teams have derived accurate corrections for the anisotropy of cloud scenes.

References

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