A test on narrow-to-broadband radiance conversion with CERES and MODIS data

Wenbo Sun and Norman G. Loeb

Center for Atmospheric Sciences
Hampton University

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Introduction

1. Clouds and Earth's Radiant Energy System (CERES) requires the knowledge of the broadband TOA radiative flux.

2. Sensors for monitoring clouds and surface usually have narrow spectral coverage, such as MODIS, POLDER, and MISR.

3. Conversion of narrowband (NB) radiance to broadband (BB) radiance using empirical relationship from linear or higher order regressions is an important issue in Earth radiation budget study.

4. In this study, BB radiance from CERES and NB radiance from MODIS imager archived in SSF dataset are used to test the NB to BB conversion, in order to develop an algorithm using MISR NB measurements to estimate the BB albedo and the ADM for various scene-types.

SSF Data

1. The Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF) dataset is from CERES measurements and from a higher-resolution imager such as MODIS on Terra.

2. The SSF contains CERES FOV geometry and viewing angles, radiance and flux, and area statistics.

3. The SSF also contains imager viewing angles, clear and cloudy area statistics for 2 cloud height layers, cloud overlap conditions, and imager radiance at 5 channels over the CERES FOV.

3. In this study, the SSF data from the cross-track measurements are used.

Narrow-to-broadband radiance conversion

Linear regression: BB = a + b*NB

SZA and VZA bins:

0 [0-10), 1 [10-20), 2 [20-30), 3 [30-40), 4 [40-50), 5 [50-60), 6 [60-70), 7 [70-80), 8 [80-90]

AZA bins:

0 [0-20), 1 [20-40), 2 [40-60), 3 [60-80), 4 [80-100), 5 [100-120), 6 [120-140), 7 [140-160), 8 [160-180]

Cloud Fraction bins:

0 [0-20%), 1 [20-40%), 2 [40-60%), 3 [60-80%), 4 [80-100%), 5 [100%]

Cloud Altitude:

Low [0-5km), High [5km-)

Cloud Optical Thickness:

Thin [0-5), Thick [5-)

The output file format:

Clear Ocean:

Indices: SZA, VZA, AZA, Sample Count

a, b, mean BB, relative difference (%), relative rms (%)

Cloudy Ocean:

Indices: Cloud Fraction, SZA, VZA, AZA, Sample Count

a, b, mean BB, relative difference (%), relative rms (%)

Results

Cloud Fraction = 100%, SZA = 40-50, VZA = 60-70

Low Thick Clouds:

5 4 6 0 0
5 4 6 1 0
5 4 6 2 1844
0.13129E+02 0.63539E+00 0.14106E+03 0.91480E-05 0.29129E+01
5 4 6 3 19761
0.12814E+02 0.64374E+00 0.13781E+03 -0.79435E-05 0.28058E+01
5 4 6 4 0
5 4 6 5 0
5 4 6 6 4042
0.13315E+02 0.64068E+00 0.14182E+03 0.16545E-03 0.27907E+01
5 4 6 7 7669
0.13724E+02 0.64090E+00 0.14256E+03 0.11788E-03 0.32715E+01
5 4 6 8 0
5 4 6 9 0

Low Thin Clouds:

5 4 6 0 0
5 4 6 1 0
5 4 6 2 150
0.59755E+01 0.69257E+00 0.67884E+02 -0.26411E-04 0.40459E+01
5 4 6 3 1655
0.65420E+01 0.69064E+00 0.96599E+02 0.85720E-04 0.32667E+01
5 4 6 4 0
5 4 6 5 0
5 4 6 6 280
0.87962E+01 0.67588E+00 0.85152E+02 0.54462E-04 0.32496E+01
5 4 6 7 516
0.66359E+01 0.70482E+00 0.86496E+02 0.14436E-04 0.35066E+01
5 4 6 8 0
5 4 6 9 0

Cloud Fraction = 40-60%, SZA = 40-50, VZA = 60-70

Low Thick Clouds:

2	4	6	0	0
2	4	6	1	0
2	4	6	2	64
0.11286E+02	0.59455E+00	0.45457E+02	-0.22225E-04	0.61078E+01
2	4	6	3	440
0.89845E+01	0.65840E+00	0.47723E+02	0.27241E-04	0.71092E+01
2	4	6	4	0
2	4	6	5	0
2	4	6	6	243
0.13348E+02	0.62627E+00	0.56437E+02	0.26981E-05	0.55576E+01
2	4	6	7	797
0.13105E+02	0.63359E+00	0.59416E+02	0.10844E-03	0.57496E+01
2	4	6	8	0
2	4	6	9	0

Low Thin Clouds:

2	4	6	0	0
2	4	6	1	0
2	4	6	2	350
0.84096E+01	0.66905E+00	0.34173E+02	0.22565E-04	0.56118E+01
2	4	6	3	1898
0.89797E+01	0.65878E+00	0.35409E+02	0.41418E-04	0.57130E+01
2	4	6	4	0
2	4	6	5	0
2	4	6	6	1514
0.11667E+02	0.65599E+00	0.43686E+02	0.61588E-04	0.44860E+01
2	4	6	7	7091
0.12174E+02	0.65442E+00	0.45252E+02	-0.96571E-04	0.44705E+01
2	4	6	8	0
2	4	6	9	0

Cloud Fraction = 100%, SZA = 40-50, VZA = 60-70

High Thick Clouds:

5 4 6 0 0
5 4 6 1 0
5 4 6 2 1356
0.12043E+02 0.65195E+00 0.16385E+03 -0.57265E-04 0.25188E+01
5 4 6 3 15576
0.13872E+02 0.64770E+00 0.15788E+03 -0.48285E-03 0.22765E+01
5 4 6 4 0
5 4 6 5 0
5 4 6 6 4115
0.15773E+02 0.63473E+00 0.14482E+03 0.10848E-03 0.24842E+01
5 4 6 7 13000
0.15046E+02 0.64062E+00 0.14860E+03 -0.38268E-03 0.27491E+01
5 4 6 8 0
5 4 6 9 0

High Thin Clouds:

5 4 6 0 0
5 4 6 1 0
5 4 6 2 78
0.77908E+01 0.70082E+00 0.92656E+02 0.50671E-05 0.29383E+01
5 4 6 3 1056
0.11848E+02 0.66095E+00 0.10196E+03 0.50014E-04 0.29592E+01
5 4 6 4 0
5 4 6 5 0
5 4 6 6 348
0.11268E+02 0.67284E+00 0.79545E+02 0.39413E-05 0.26588E+01
5 4 6 7 2137
0.11347E+02 0.68166E+00 0.79493E+02 0.62535E-04 0.27392E+01
5 4 6 8 0
5 4 6 9 0

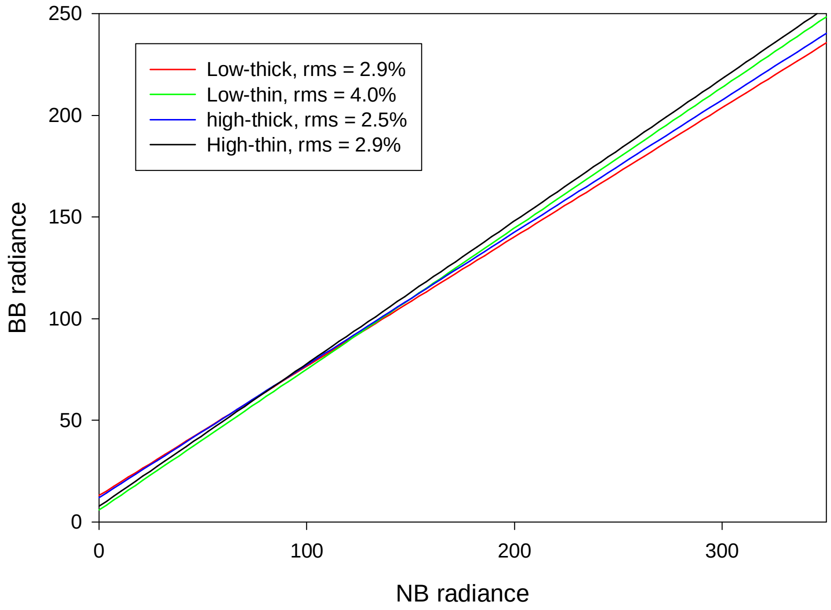
Cloud Fraction = 40-60%, SZA = 40-50, VZA = 60-70

High Thick Clouds:

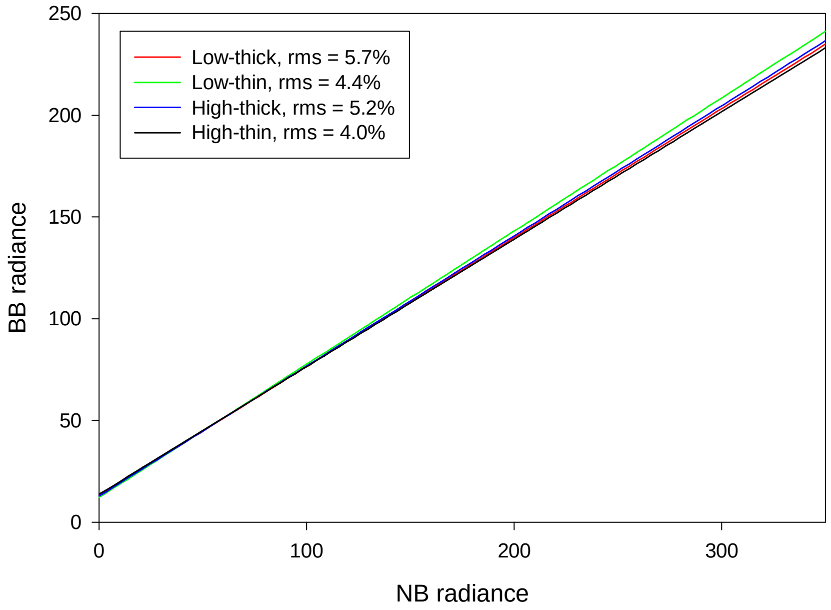
2	4	6	0	0
2	4	6	1	0
2	4	6	2	3
-0.99900E+03	-0.99900E+03	-0.99900E+03	-0.99900E+03	-0.99900E+03
2	4	6	3	18
0.11380E+02	0.64568E+00	0.56155E+02	-0.98124E-05	0.81189E+01
2	4	6	4	0
2	4	6	5	0
2	4	6	6	62
0.11467E+02	0.65293E+00	0.54149E+02	-0.23066E-04	0.51148E+01
2	4	6	7	316
0.12877E+02	0.63914E+00	0.54834E+02	0.11756E-04	0.52275E+01
2	4	6	8	0
2	4	6	9	0

High Thin Clouds:

2	4	6	0	0
2	4	6	1	0
2	4	6	2	60
0.12558E+02	0.56696E+00	0.34989E+02	0.00000E+00	0.60506E+01
2	4	6	3	315
0.85289E+01	0.67733E+00	0.34515E+02	0.22315E-04	0.61160E+01
2	4	6	4	0
2	4	6	5	0
2	4	6	6	307
0.11463E+02	0.66427E+00	0.40038E+02	-0.20049E-04	0.40220E+01
2	4	6	7	2720
0.13751E+02	0.62661E+00	0.42038E+02	0.32835E-04	0.40553E+01
2	4	6	8	0
2	4	6	9	0



NB-BB Relationship:
Cloud Fraction = 100%
SZA = 40-50
VZA = 60-70
AZA = 40-60



NB-BB Relationship:
Cloud Fraction = 40-60%
SZA = 40-50
VZA = 60-70
AZA = 140-160

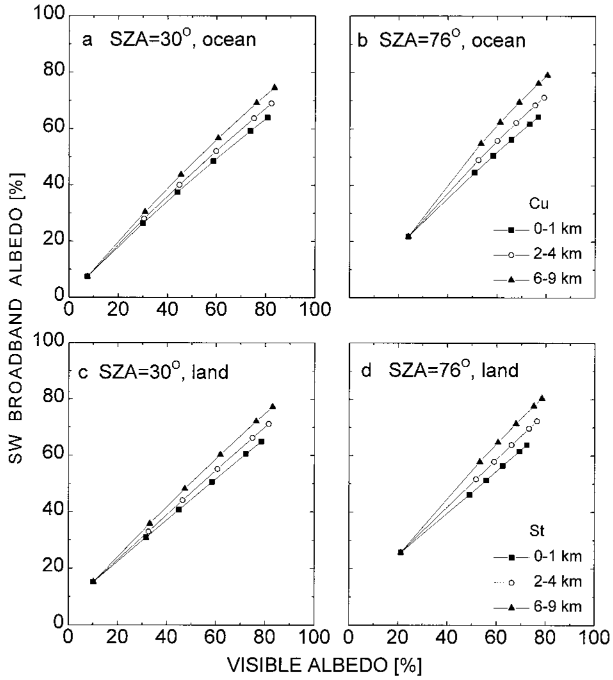


FIG. 12. Sensitivity of the modeled VIS–SW relation to cloud-top height. Cumulus (Cu) and stratus (St) model clouds are placed in different layers.

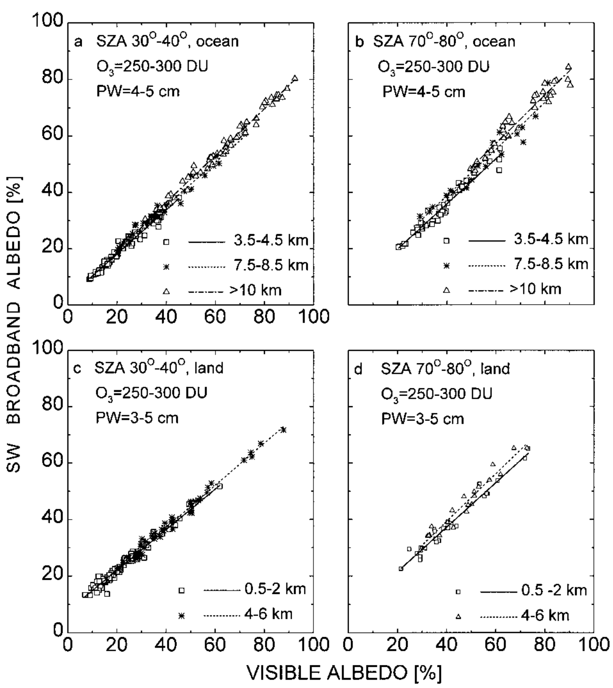


FIG. 13. Sensitivity of the observed VIS–SW relation to cloud-top height. Variations in precipitable water and ozone amount are restricted to the specified intervals. The lines are regressions of the two types of albedos for different ranges of the effective cloud-top height.

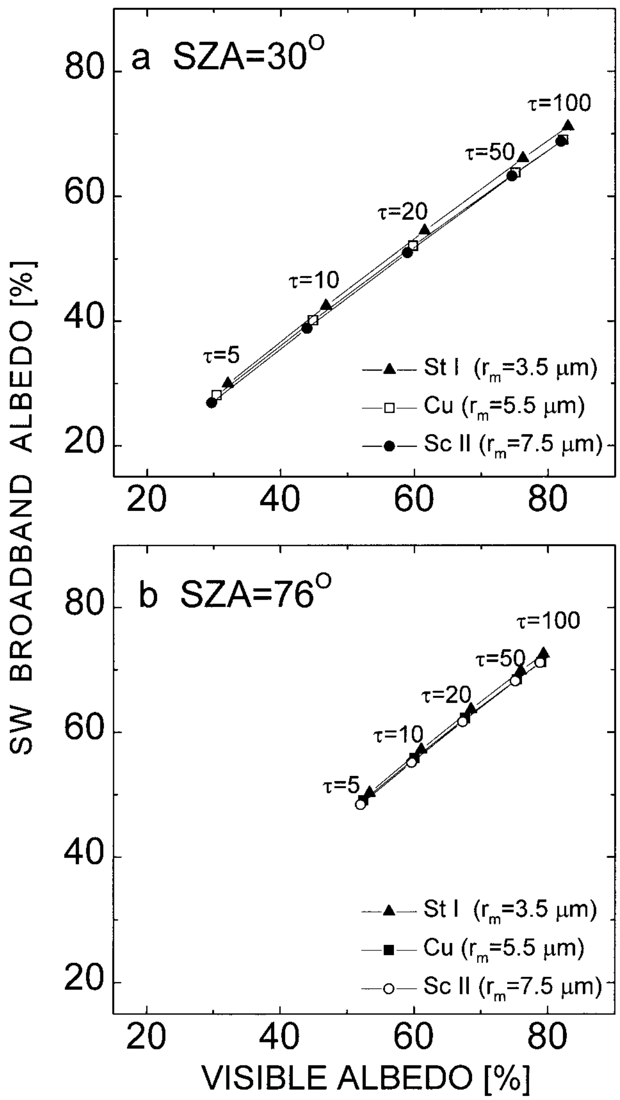


FIG. 14. Sensitivity of the modeled VIS–SW relation to cloud microphysics characterized by different values of mode droplet radius r_m (i.e., the radius corresponding to the maximum droplet concentration) for three model clouds: stratus (St), cumulus (Cu), and stratocumulus (Sc).

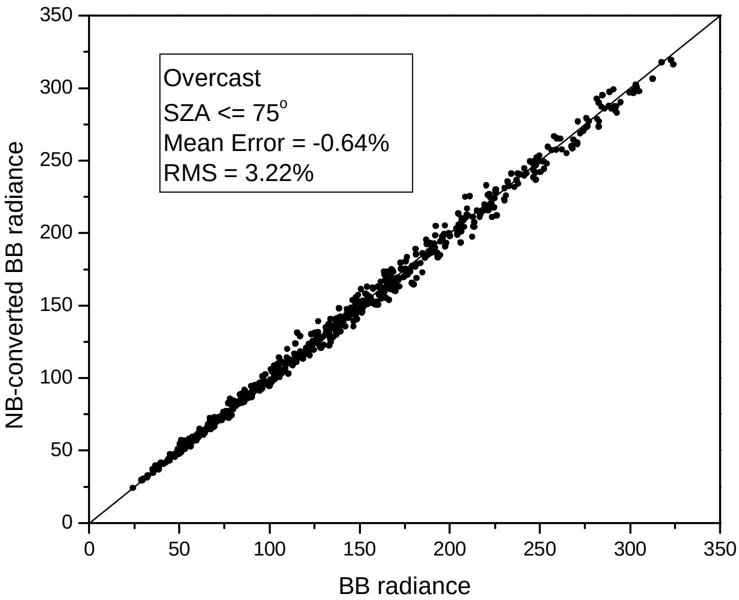
let size. It is difficult to detect such a weak dependence with any observational data of cloud microphysics. Unlike the sensitivities to other parameters, the effect of cloud droplet size remains almost invariant throughout the entire range of SZAs.

4. Development and validation of NB to BB conversion models

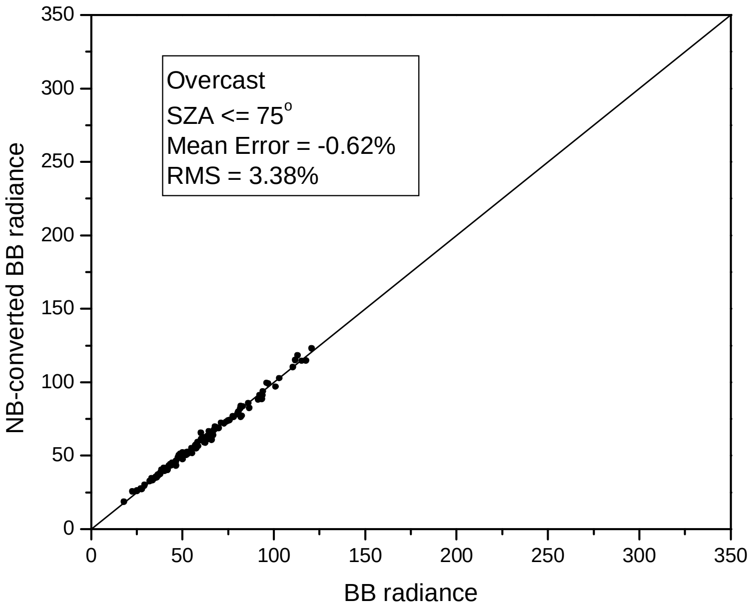
Three models with different numbers of input parameters were developed by means of conventional regression analysis using data from March, May, June, August, November, and December 1994 and February 1995.

Clear Ocean, SZA = 40-50, VZA = 40-50, 50-60, 60-70

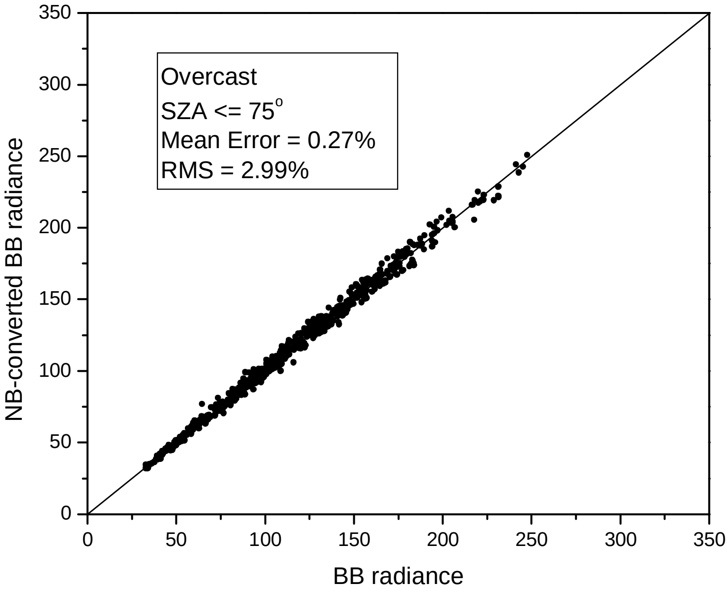
4 4 0 0
4 4 1 0
4 4 2 1221
0.94992E+01 0.45708E+00 0.16072E+02 -0.70564E-05 0.55484E+01
4 4 3 154
0.77998E+01 0.57433E+00 0.15158E+02 -0.13441E-04 0.17577E+01
4 4 4 0
4 4 5 0
4 4 6 2130
0.10818E+02 0.56698E+00 0.19451E+02 0.70998E-04 0.35040E+01
4 4 7 1510
0.12607E+02 0.51201E+00 0.21516E+02 0.28139E-04 0.25566E+01
4 4 8 0
4 4 9 0
4 5 0 0
4 5 1 0
4 5 2 450
0.96671E+01 0.51899E+00 0.17427E+02 -0.97286E-06 0.35454E+01
4 5 3 369
0.90087E+01 0.56016E+00 0.17755E+02 -0.11922E-04 0.29159E+01
4 5 4 0
4 5 5 0
4 5 6 934
0.11242E+02 0.60946E+00 0.22080E+02 -0.61994E-04 0.28953E+01
4 5 7 2293
0.12978E+02 0.56429E+00 0.24650E+02 -0.30995E-04 0.25950E+01
4 5 8 0
4 5 9 0
4 6 0 0
4 6 1 0
4 6 2 8
0.65676E+01 0.77165E+00 0.19729E+02 0.00000E+00 0.16605E+01
4 6 3 104
0.92695E+01 0.59993E+00 0.19616E+02 -0.16081E-04 0.16925E+01
4 6 4 0
4 6 5 0
4 6 6 106
0.13052E+02 0.58318E+00 0.25485E+02 0.15533E-04 0.18020E+01
4 6 7 1176
0.14702E+02 0.53551E+00 0.28202E+02 0.71606E-04 0.15861E+01
4 6 8 0
4 6 9 0



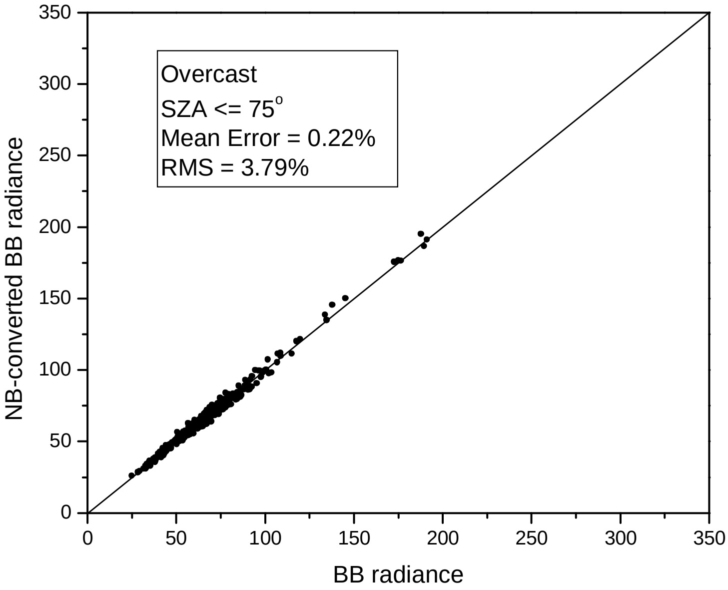
Comparison of measured broadband SW radiance with radiance converted from narrowband radiance at 0.645 micron for overcast pixels measured on July 5, 2000. Cloud heights are larger than 5 km. Cloud optical thickness is larger than 5.



Comparison of measured broadband SW radiance with radiance converted from narrowband radiance at 0.645 micron for overcast pixels measured on July 5, 2000. Cloud heights are larger than 5 km. Cloud optical thickness is smaller than 5.



Comparison of measured broadband SW radiance with radiance converted from narrowband radiance at 0.645 micron for overcast pixels measured on July 5, 2000. Cloud heights are smaller than 5 km. Cloud optical thickness is larger than 5.



Comparison of measured broadband SW radiance with radiance converted from narrowband radiance at 0.645 micron for overcast pixels measured on July 5, 2000. Cloud heights are smaller than 5 km. Cloud optical thickness is smaller than 5.

Comparing MISR with CERES in Broadband Albedos

1. MISR only has a visible albedo product. To compare MISR albedos with CERES albedos, we need do NB-BB ALBEDO conversions for MISR

2. Using MISR visible and CERES broadband radiances at MISR angles in the along-track direction, we can derive MISR-CERES radiance conversions along-track similar to the MODIS-CERES radiance conversions

3. We can use theoretical model together with MISR-CERES radiance conversions along-track to infer MISR NB and BB radiances at angles where MISR data is unavailable using

$$I(v_x)=Iobs(v)*[Ith(v_x)/Ith(v)], \qquad (1)$$

   where Iobs is data, Ith is theory, v_x is missing viewing bin, v is bin where data is available. Evaluate (1) at all available v angles and get average $\langle I(v_x) \rangle$. Repeating this over the entire range of v we can obtain MISR NB and BB radiances at each bin

4. Integrating MISR NB and BB radiances in half space we can construct MISR NB-BB ALBEDO conversion fits

5. These NB-BB ALBEDO fits can then be used to convert MISR NB albedos to MISR BB albedos. The MISR BB albedos are compared with CERES albedos

Preliminary Conclusions

The RMS for NB to BB radiance conversion is ~3% for overcast pixels, no matter thin or thick, high or low clouds.

Slopes (b) for low and thick clouds are smaller; intercepts (a) for thin and high clouds are larger.

Broken clouds show significantly larger RMS. No significant dependence on height and thickness in SSF dataset for NB-BB relationship.

When SZA > 80, RMS is significantly larger

For thin clouds, intercept decreases with the increase of VZA but slope doesn't change significantly with VZA. For thick clouds, no significant change in intercept or slope can be seen when VZA increases.

AZA dependence seems not negligible but complicated.

Higher order regression doesn't show significant effect. Linear regression is good enough.