Improvements in the Surface-Only Flux Algorithms (SOFA) Beyond CERES Edition 2B

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Background

- CERES uses several surface-only flux algorithms to compute SW and LW surface fluxes in conjunction with the detailed model used by SARB. These algorithms include:

LPSA/LPLA:
Langley Parameterized SW/LW Algorithm

		Model A	Model B	Model C
SW	Clear	Li et al.	LPSA	--
	All-Sky	--	LPSA	--
LW	Clear	Inamdar and Ramanathan	LPLA	Zhou-Cess
	All-Sky	--	LPLA	Zhou-Cess

References:

SW A: Li et al. (1993): *J. Climate*, **6**, 1764-1772.
SW B: Darnell et al. (1992): *J Geophys. Res.*, **97**, 15741-15760.
Gupta et al. (2001): *NASA/TP-2001-211272*, 31 pp.
LW A: Inamdar and Ramanathan (1997): *Tellus,* **49B**, 216-230.
LW B: Gupta et al. (1992): *J. Appl. Meteor.,* **31**, 1361-1367.
LW C: Zhou and Cess (2001): *J. Geophys. Res.,* **106**, 12477-12488.
Zhou et al. (2007): *J. Geophys. Res.*, **112**, D15102.

Background (contd.)

- The SOFA SW & LW Models use rapid parameterizations to calculate the transfer of energy from TOA to surface.
- The SOFA calculated surface fluxes have undergone extensive validation and provide an independent verification of the SARB results.
- SW Model A and LW Models A & B were incorporated at the start of the CERES project.
- SW Model B was adapted for use in the CERES processing shortly before the launch of TRMM.
- LW Model C to be introduced in Edition-3 processing to maintain two independent LW algorithms when the CERES Window Channel is replaced in future versions of the CERES instrument.

Recent SW Algorithm Improvements

- SW Model A: Replaced GFDL aerosol optical depths with 550nm MATCH aerosol optical depths (Aqua Edition 2A).
- SW Model B: Replaced the monthly clear-sky TOA albedo maps based on 48 months of ERBE data with corresponding albedo maps based on 46 months of Terra data (Aqua Edition 2A).
- SW Model B: Corrected a code limitation that prevented flux calculation for O_3 column abundances exceeding 500 Dobson units (Edition 3).
- SW Model B: Modified formulation to provide a more realistic dependence of instantaneous surface albedo on cosine of the solar zenith angle (Edition 3).

Recent LW Algorithm Improvements

- LW Model B: Modified code to calculate cloud effects for high altitude regions, such as Tibet, where cloud base heights were often not available from the SSF (Aqua Edition 2A).

- LW Model C: Reformulated to handle cases involving cirrus and low water vapor amounts (Edition 3).

- LW Model C: Preliminary work completed to incorporate code into CERES processing (Edition 3).

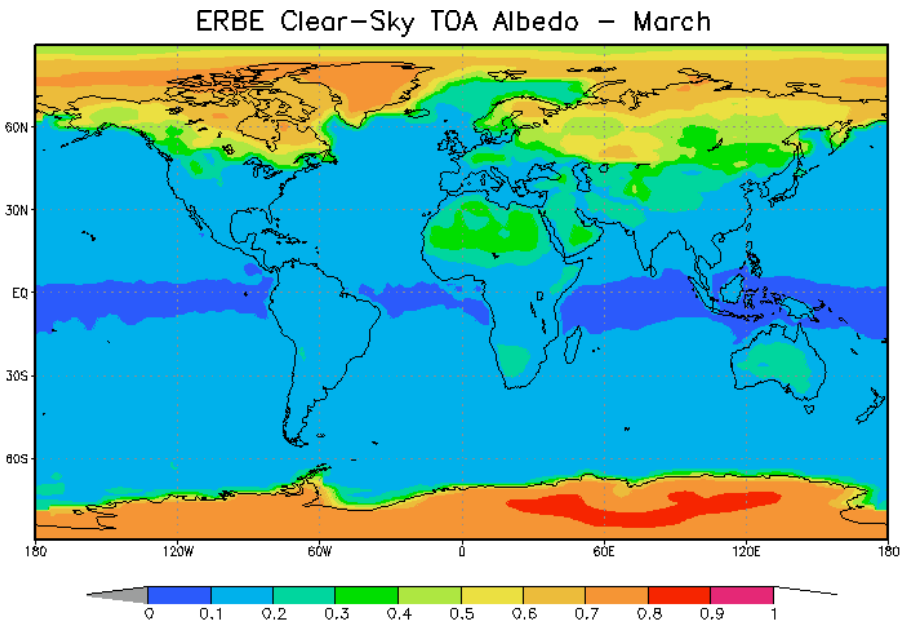
- LW Models A, B & C: Implemented near-surface air-temperature constraint to handle cases where the skin surface temperature greatly exceeds the overlying air temperatures, e.g., daytime deserts and cold continental outbreak events over oceans (Edition 3).

Status of SW & LW Models as of May 2008

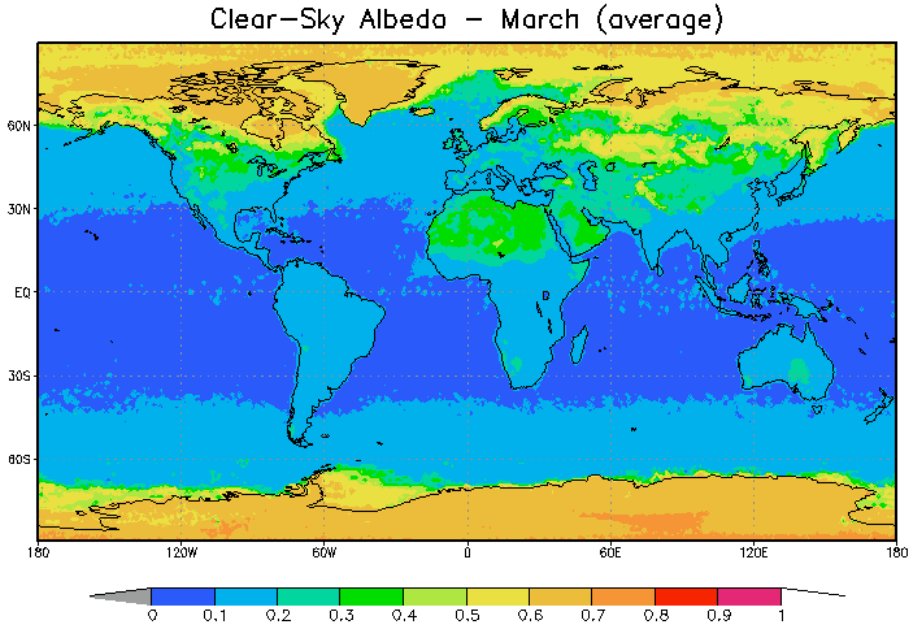
- SW Model A provides satisfactory global flux retrievals, though there remain problems with cloud contamination and significant flux underestimations for cases with low water vapor amounts.
- SW Model B has been improved significantly, though additional improvements are still required.
- LW Models A provides very good clear-sky results for most validation sites; however, the polar sites yield a modest negative bias due to a known discrepancy at low water vapor amounts.
- LW Models B & C provide very good clear-sky and all-sky results for all of the validation sites that were considered.

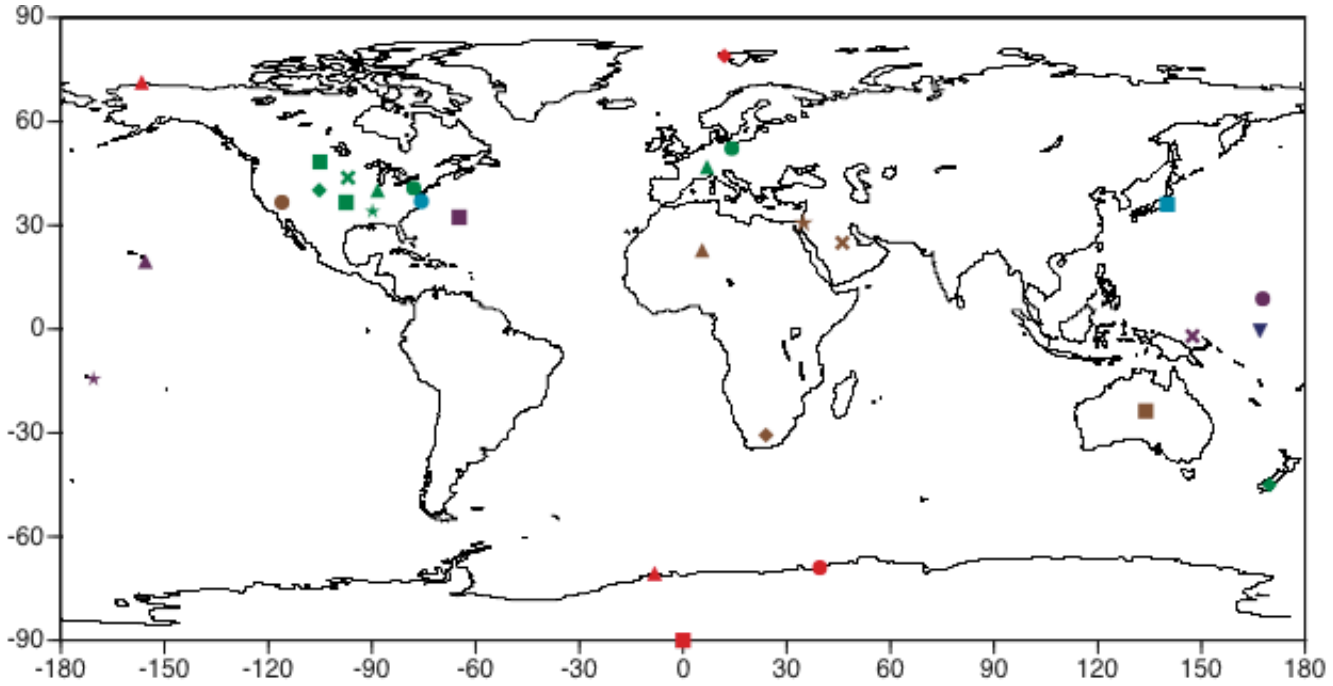
Comparison of Clear-sky TOA Albedo derived from ERBE and Terra Data

Clear-Sky TOA Albedo from 48 Months of ERBE Data



Clear-sky TOA Albedo from 46 Months of Terra Data





- 48.31N, 105.10W Fort Peck, MT
- 40.72N, 77.93W Penn State, PA
- 40.05N, 88.37W Bondville, IL
- 40.13N, 105.24W Boulder, CO
- 34.25N, 89.87W Goodwin Creek, MS
- 43.73N, 96.92W Sioux Falls, SD
- 36.60N, 97.48W SGP ARM
- 52.22N, 14.12E Lindenberg
- 46.82N, 6.95E Payerne
- 45.03S, 169.7E New Zealand
- 32.30N, 64.77W Bermuda
- 8.72N, 167.72E Kwajalein
- 19.54N, 155.58W Mauna Loa, HI
- 14.23S, 170.56W American Samoa
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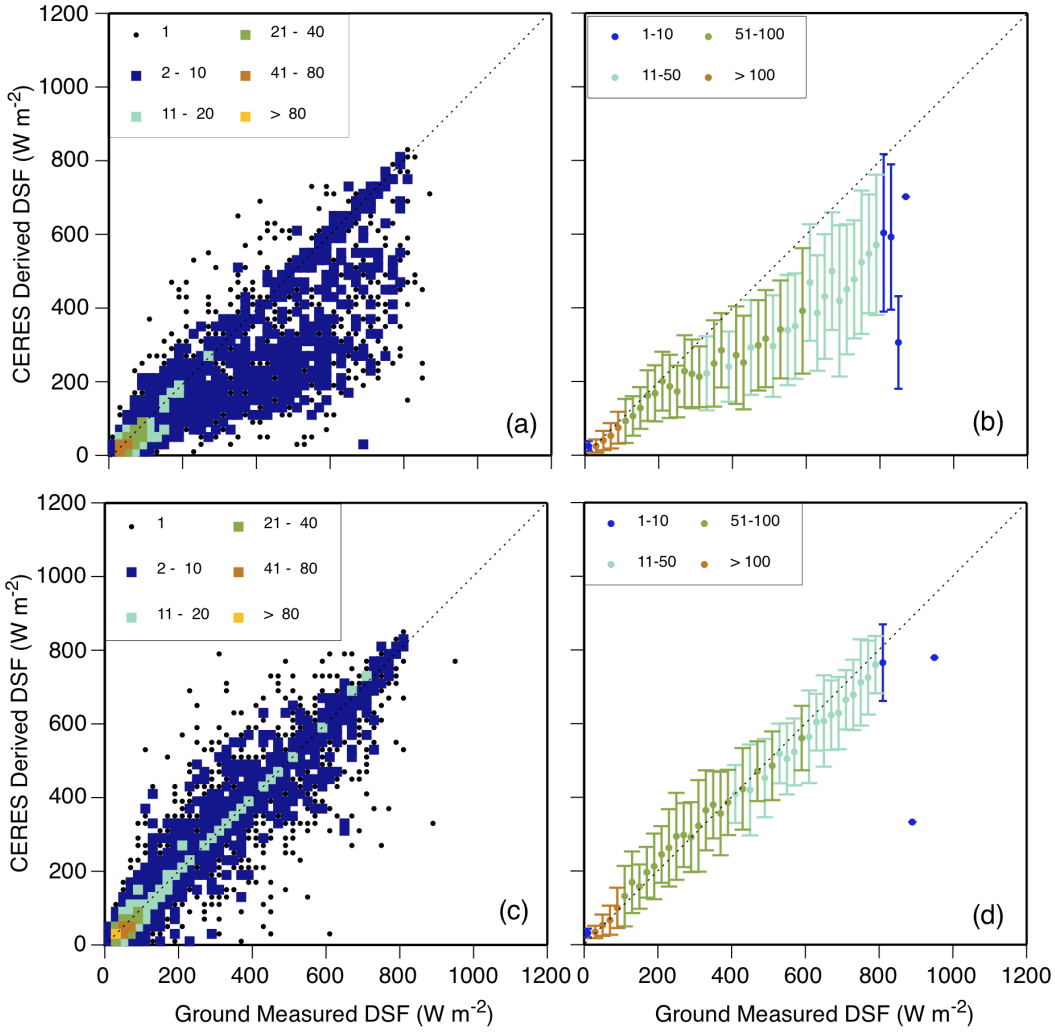
- 36.9N, 75.71W COVE
- 71.32N, 156.61W Barrow, AK
- 90.00S, 0.00 South Pole
- 69.00S, 39.58E Syowa
- 70.65S, 8.25W Georg von Neumayer
- 78.9N, 11.95E Ny Alesund
- 24.91N, 46.41E Saudi Solar Village
- 23.70S, 133.87E Alice Springs
- 36.63N, 116.02W Desert Rock, NV
- 22.78N, 5.52E Algeria
- 30.67S, 24.0E De Aar
- 30.9N , 34.8E, Sede Boger, Israel

Comparison between surface-measured and CERES-derived fluxes

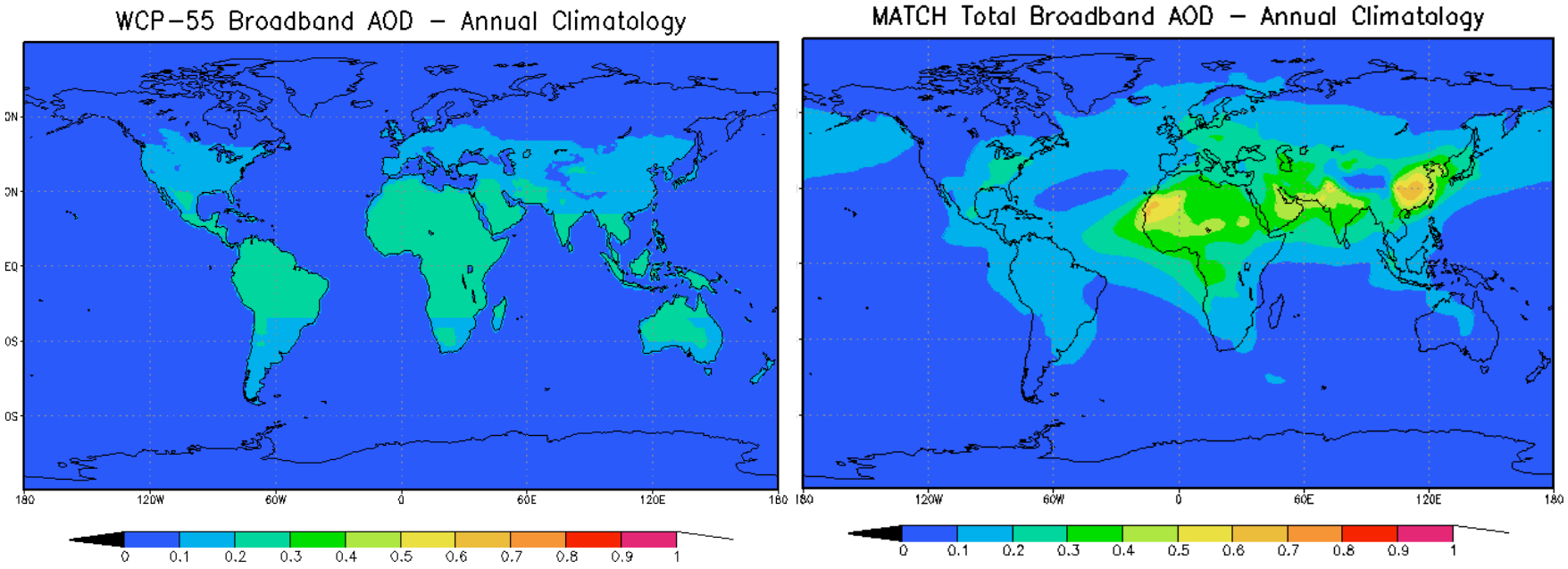
Comparisons of SW Model B under cloudy-sky conditions for the polar sites Georg von Neumayer and Syowa showing the improvement between the Terra results using the ERBE TOA clear-sky albedo (a & b) and the Aqua results using the Terra clear-sky albedo (c & d).

Plots b & d represent bin-averaged equivalence of the scatter plots a & c.



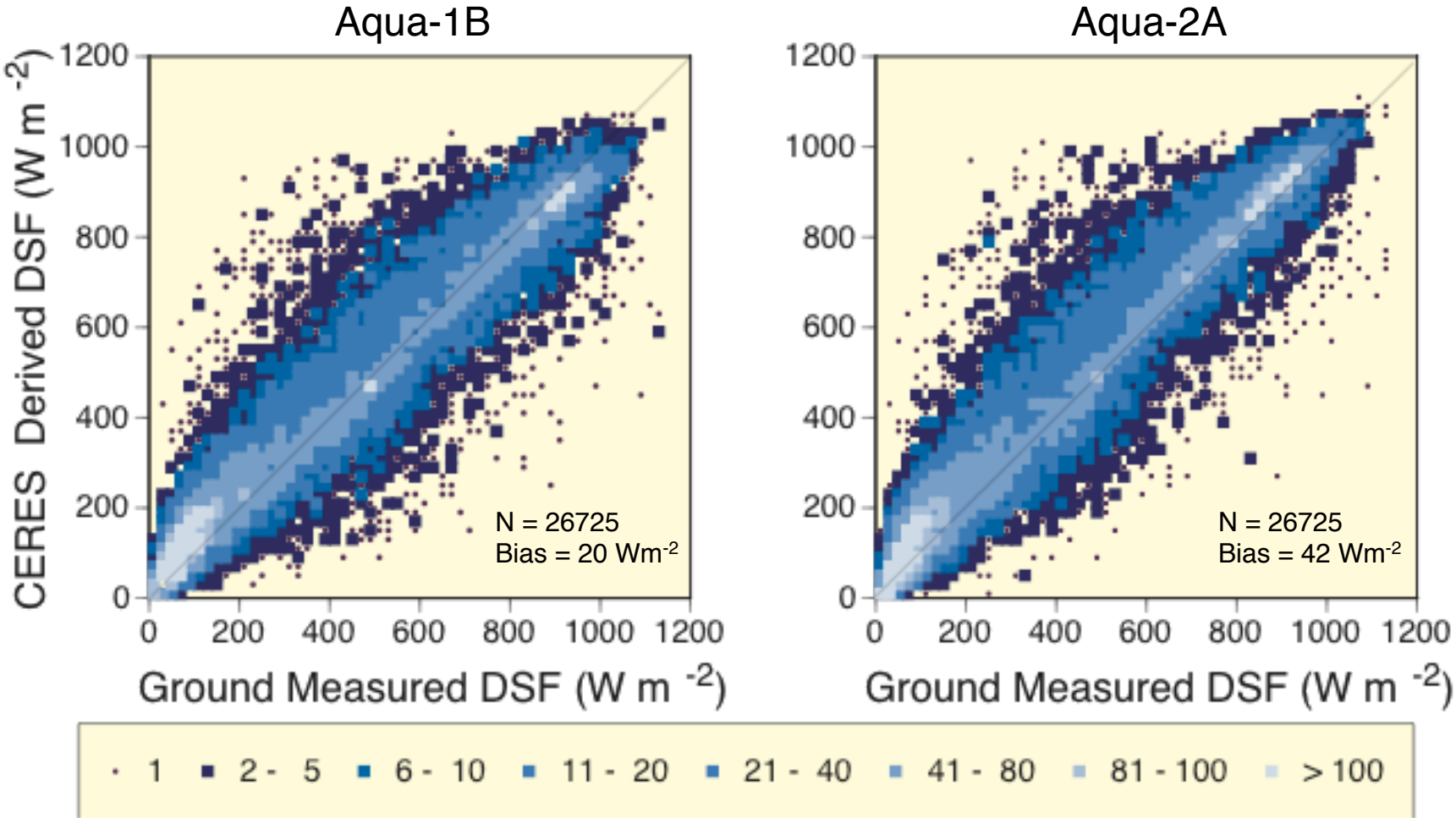
Comparison of WCP-55 and MATCH Aerosol Optical Depths

The MATCH aerosols provide a more realistic distribution of aerosol optical depths than the WCP-55 aerosols



SW Model B Cloudy-Sky Surface Insolation

(July 2002 - March 2005)[Image from 24-26 April 2007 CSTM]



Validation of SW Model B SSF

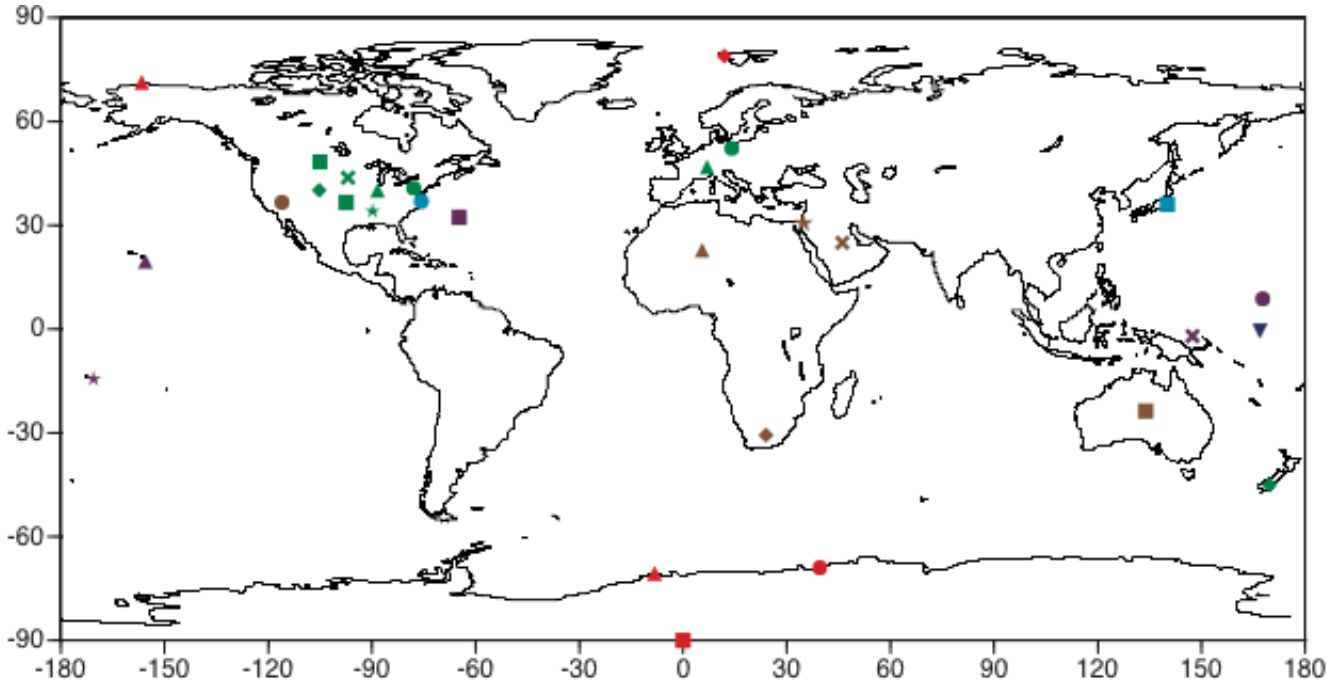
Aqua-1B, 2A & 2B Comparison – July 2002 – June 2003

Sites # of Points	Edition Aerosol TOA Albedo	Aqua-1B WCP-55 ERBE	Aqua-2A MATCH Terra	Aqua-2B WCP-55 Terra
Continental 2291	Bias Wm^{-2} (%)	14.27 (2.87)	47.17 (9.48)	17.82 (3.58)
Desert 631	Bias Wm^{-2} (%)	7.46 (0.99)	44.61 (5.90)	2.38 (0.31)
Coastal 360	Bias Wm^{-2} (%)	32.14 (6.40)	47.49 (9.50)	33.02 (6.60)
Island 597	Bias Wm^{-2} (%)	69.61 (11.60)	82.00 (13.67)	59.61 (9.94)
Polar* 1689	Bias Wm^{-2} (%)	10.15 (4.04)	9.95 (3.96)	10.28 (4.10)
Global 5568	Bias Wm^{-2} (%)	19.34 (4.17)	39.36 (8.49)	19.23 (4.15)

*Polar sites do not include Syowa & Georg von Neumayer

Status of SW & LW Models as of April 2009

- SW Model A provides satisfactory global flux retrievals, though there remain problems with cloud contamination and significant flux underestimations for cases with low water vapor amounts.
- SW Model B is undergoing testing to determine if simultaneous improvements to the Rayleigh Scattering formulation and the Aerosol parameters can improve model results.
- LW Models A provides very good clear-sky results for most validation sites; however, the polar sites yield a modest negative bias due to a known discrepancy at low water vapor amounts.
- LW Models B & C provide very good clear-sky and all-sky results for all of the validation sites that were considered.



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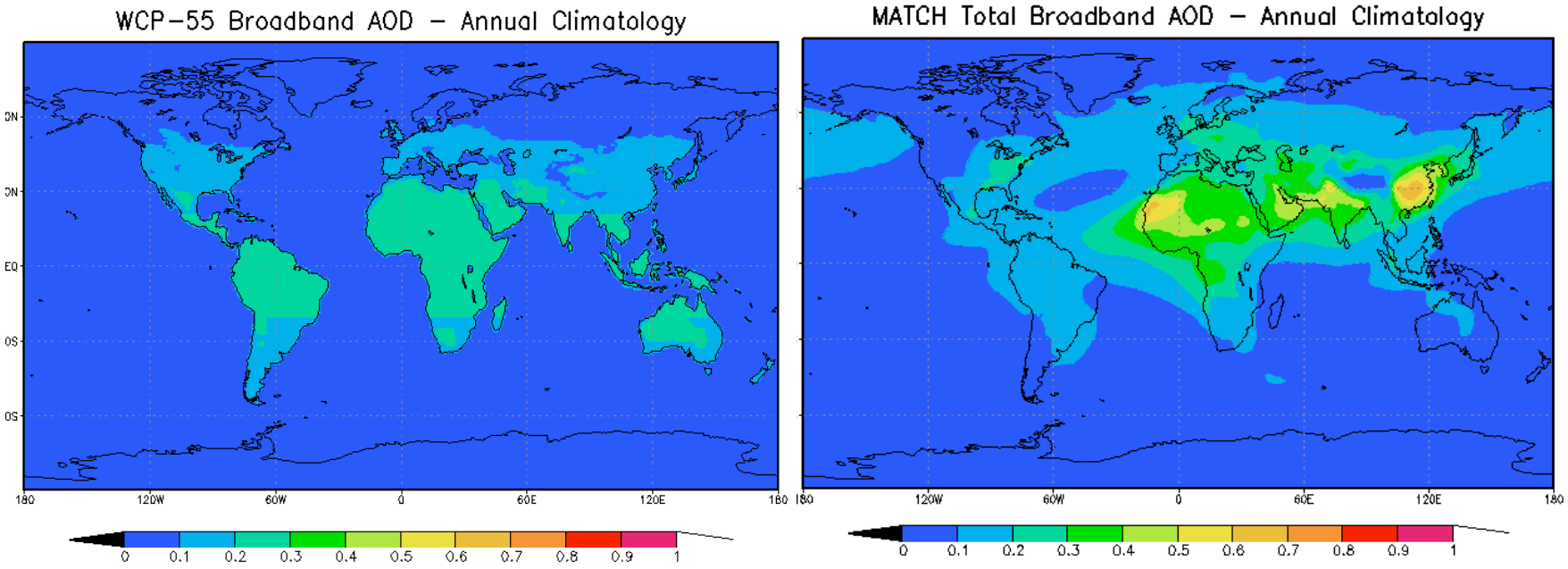


Comparison of WCP-55 and MATCH/OPAC aerosol properties

Aerosol Optical Depth (MATCH)

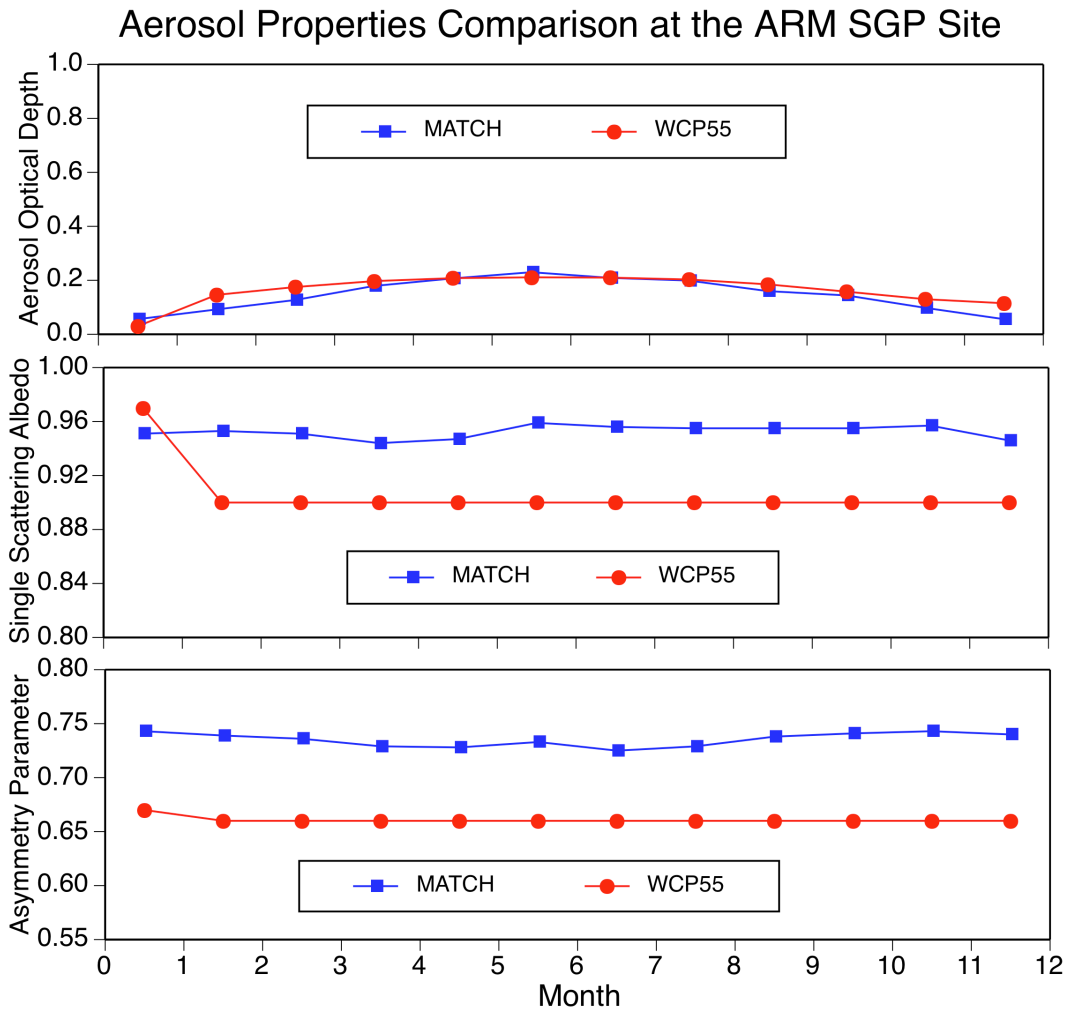
Single Scattering Albedo (OPAC)

Asymmetry Parameter (OPAC)

Aerosol Optical Depth (WCP-55)

Single Scattering Albedo (WCP-55)

Asymmetry Parameter (WCP-55)

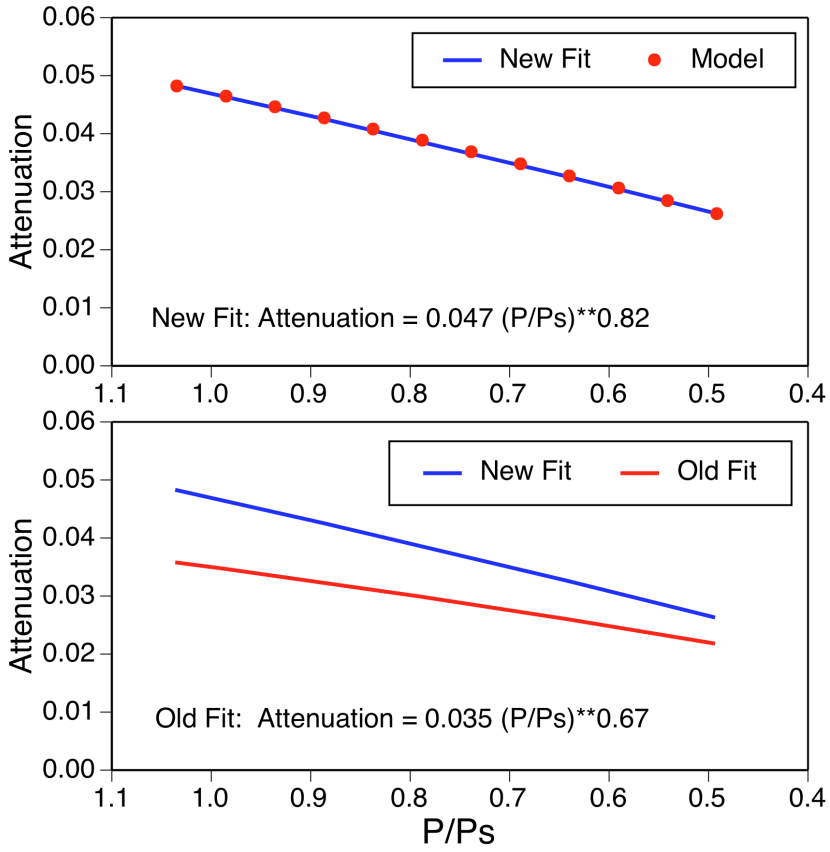


Revised Rayleigh Formulation for SOFA SW Model B

Model: On Rayleigh Optical Depth Calculations. Bodhaine, Wood, Dutton, and Slusser(1999): J. Atmos. Oceanic Tech.

Attenuation: For the forward beam

Ps = 1013.25 hPa



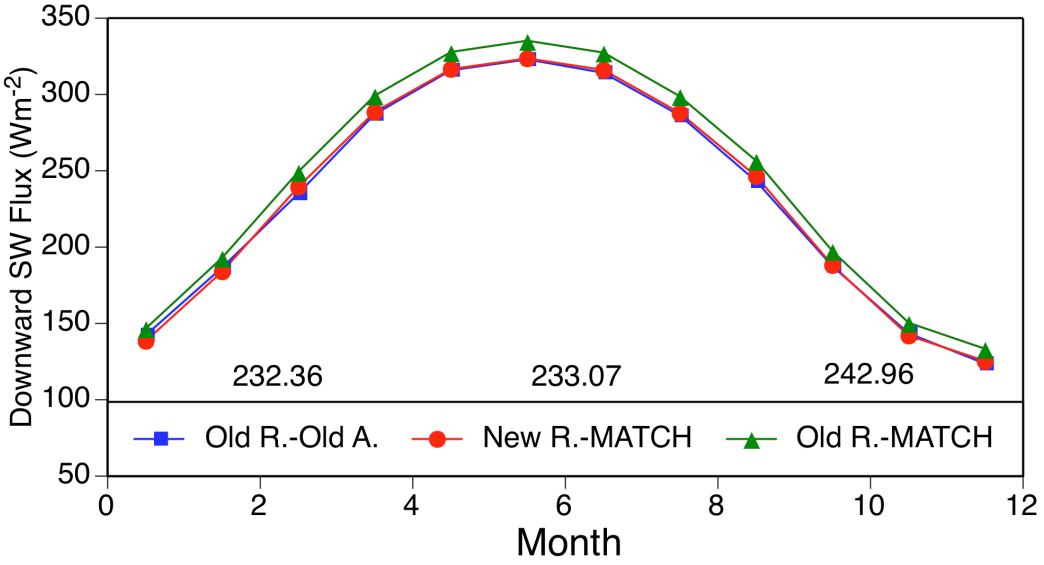
Comparison of Downward SW Model B fluxes at the surface using:

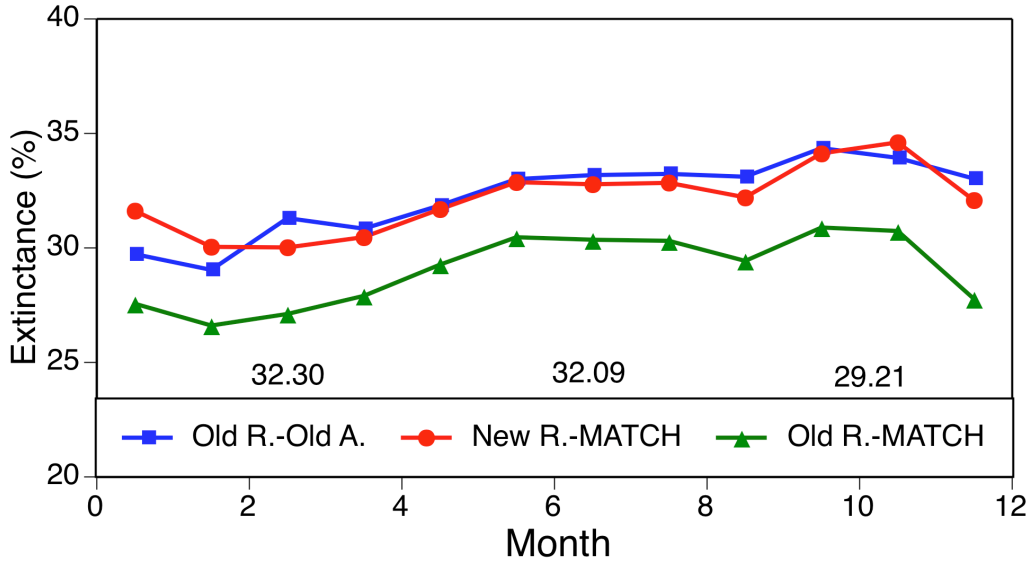
1) The old Rayleigh formula: alpha = 0.035 $(P/P_s)^{0.67}$ and the WCP-55 aerosols,

2) The old Rayleigh formula: alpha = 0.035 $(P/P_s)^{0.67}$ and the MATCH aerosols,

3) The revised Rayleigh formula: alpha = 0.047 $(P/P_s)^{0.82}$ and the MATCH aerosols.

Comparison of Rayleigh-Aerosol Combinations





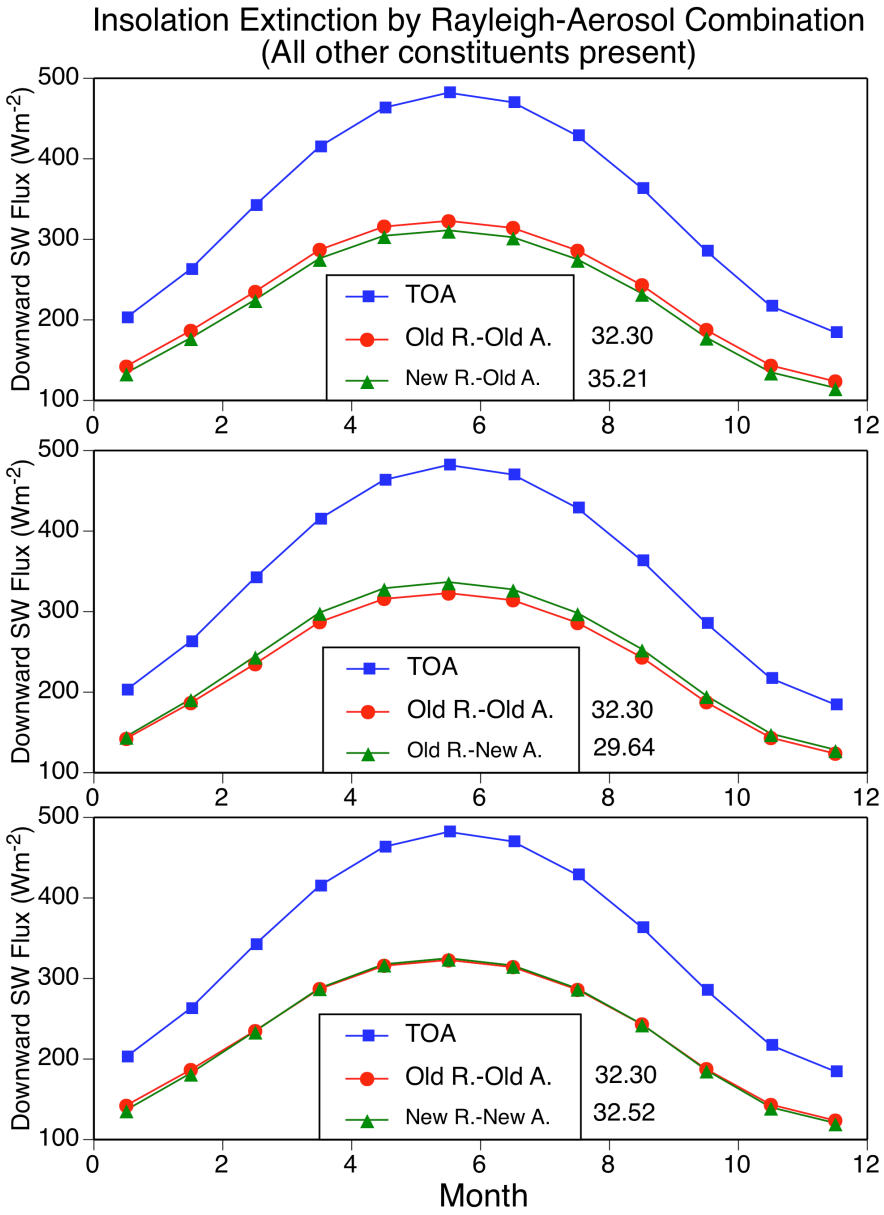
Insolation Extinction dependent on Rayleigh-Aerosol Combination

TOA Insolation

Downward SW Flux at the surface using old Rayleigh formula and the WCP-55 aerosols.

Downward SW Flux at the surface using:

1) The revised Rayleigh formula and the WCP-55 aerosols,
2) The old Rayleigh formula and the MATCH aerosols, and
3) The revised Rayleigh formula and the MATCH aerosols.



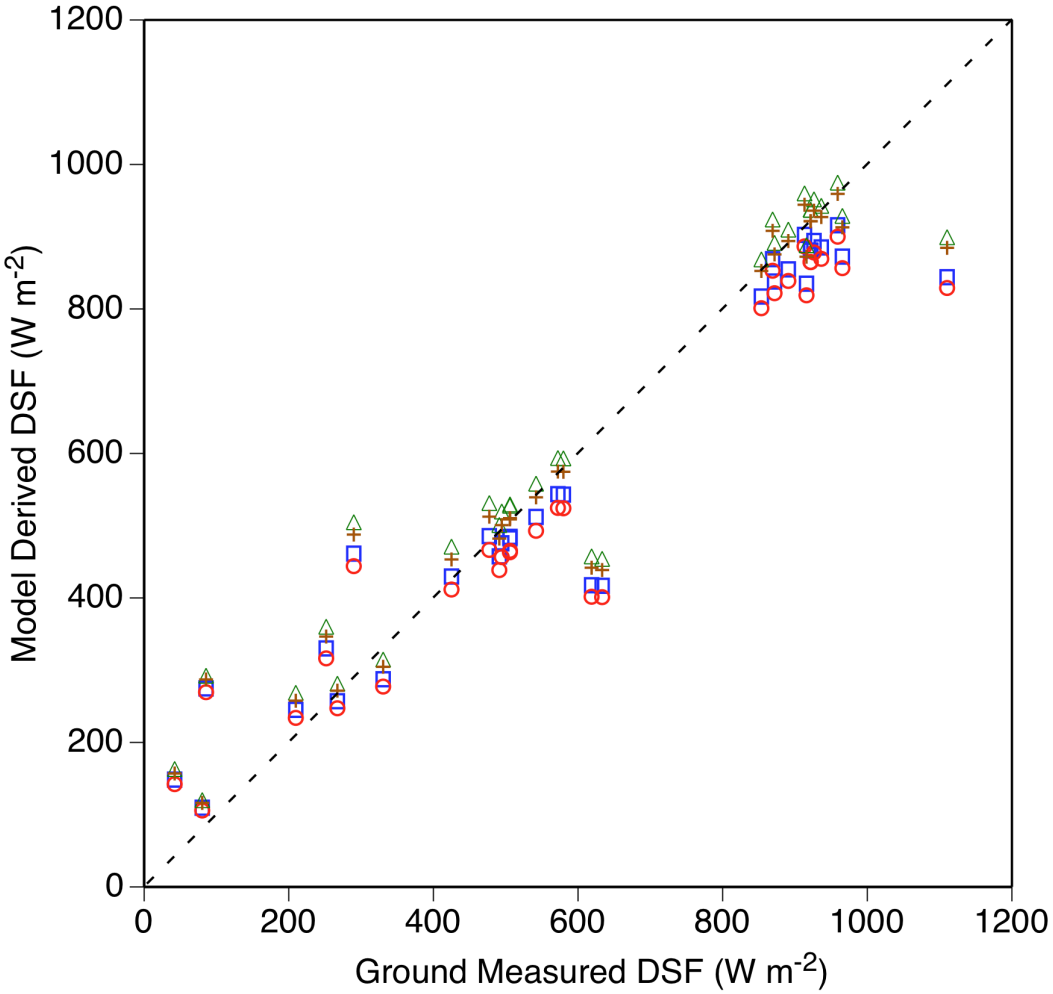
Flux Comparisons for SGP Surface Site

Old Rayleigh, WCP-55 Aerosols

New Rayleigh, WCP-55 Aerosols

Old Rayleigh, MATCH Aerosols

New Rayleigh, MATCH Aerosols



Planned Improvements in SW Model B

- Revise the Rayleigh scattering formulation in SW Model B
- Replace the WCP-55 aerosol properties in SW Model B with the MATCH aerosol optical depths and the OPAC single scattering albedos and asymmetry parameters.
- If necessary, revise the molecular absorption parameterizations in SW Model B using the latest HITRAN database.
- For Terra processing, replace monthly climatology clear-sky TOA albedos based on 48 months of ERBE data with TOA albedos based on 70 months of Terra data.
- For Aqua processing, upgrade clear-sky TOA albedos by using 70 months of Terra data rather than 46 months of Terra data.
- Improve surface albedo formulation.
- Examine the relationship between clear and cloudy-sky results.

Documentation
(Papers currently in production)

- Validation of the CERES Edition 2B Surface-Only Flux Algorithms by Kratz et al, submitted to JAMC, April 6, 2009.
- Improvement of Surface Longwave Flux Algorithms Used in CERES Processing by Gupta et al, to be submitted to JAMC, May, 2009.
- The Fast Longwave and Shortwave Flux Project, I: Processing from the Input Meteorological Data to the Single Scanner Footprint Fluxes by Kratz et al, to be submitted in Spring 2010.