Improving the CERES Surface-Only Flux Algorithms for Edition 3 and beyond

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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 et al. (2007): *J. Geophys. Res*., **112**, D15102.
SOFA: Kratz et al. (2010): *J. Appl. Meteor. Climatol*., **49**, 164-180.
SOFA: Gupta et al. (2010): *J. Appl. Meteor. Climatol.* 10.1175/2010JAMC2463.1

Background (contd.)

- The SOFA SW & LW Models use rapid parameterizations to calculate the transfer of energy from TOA to surface.
- 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.
- The Edition 2B SW & LW surface flux results have undergone extensive validation (See: Kratz et al. 2010), and provide independent verification of the SARB results.
- LW Model C will be introduced in Edition 3 processing to maintain two independent LW algorithms after the CERES Window Channel is replaced in future versions of the CERES instrument.

Status of LW & SW Models as of April 2010

- 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.

- LW Models A, B & C tend to overestimate downward surface fluxes for conditions where the surface temperatures significantly exceed the lowest layer air temperature, and underestimate downward surface fluxes for conditions where inversions exist.

- SW Model A provides satisfactory global flux retrievals, though there remain problems with cloud contamination and significant flux underestimations for conditions with low water vapor amounts.

- SW Model B has been improved significantly, though additional improvements are still required in several areas.

- Validation of LW & SW Models A & B reported by Kratz et al. (2010).

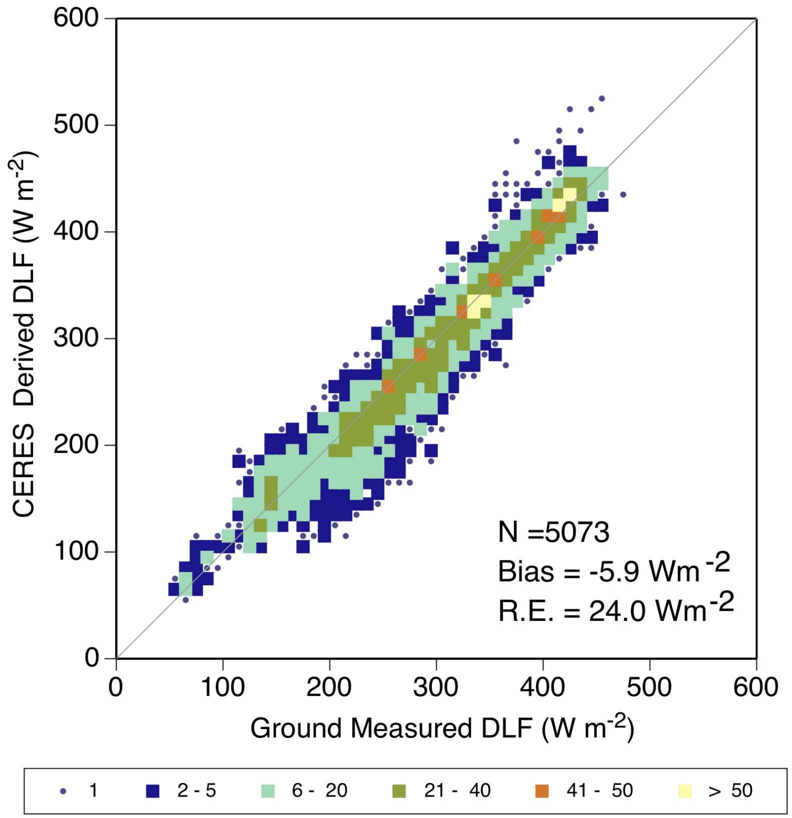
LW Algorithm Improvements for Edition 3

- LW Model C: Reformulated to handle cases involving cirrus and low water vapor amounts [See: Zhou et al. (2007)].
- LW Model C: Algorithm modifications completed to incorporate code into CERES processing [See: Zhou et al. (2007)].
- LW Models A, B & C: Implement near-surface air-temperature constraint to manage conditions where the surface temperature greatly exceeds the overlying air temperatures, [See: Gupta et al. (2010)].
- LW Models A, B & C: Implement near-surface air-temperature constraint to manage conditions where the surface temperature falls greatly below (inversion) the overlying air temperatures. Most prevalent for high altitude & low water vapor amount cases such as the Antarctic Plateau.

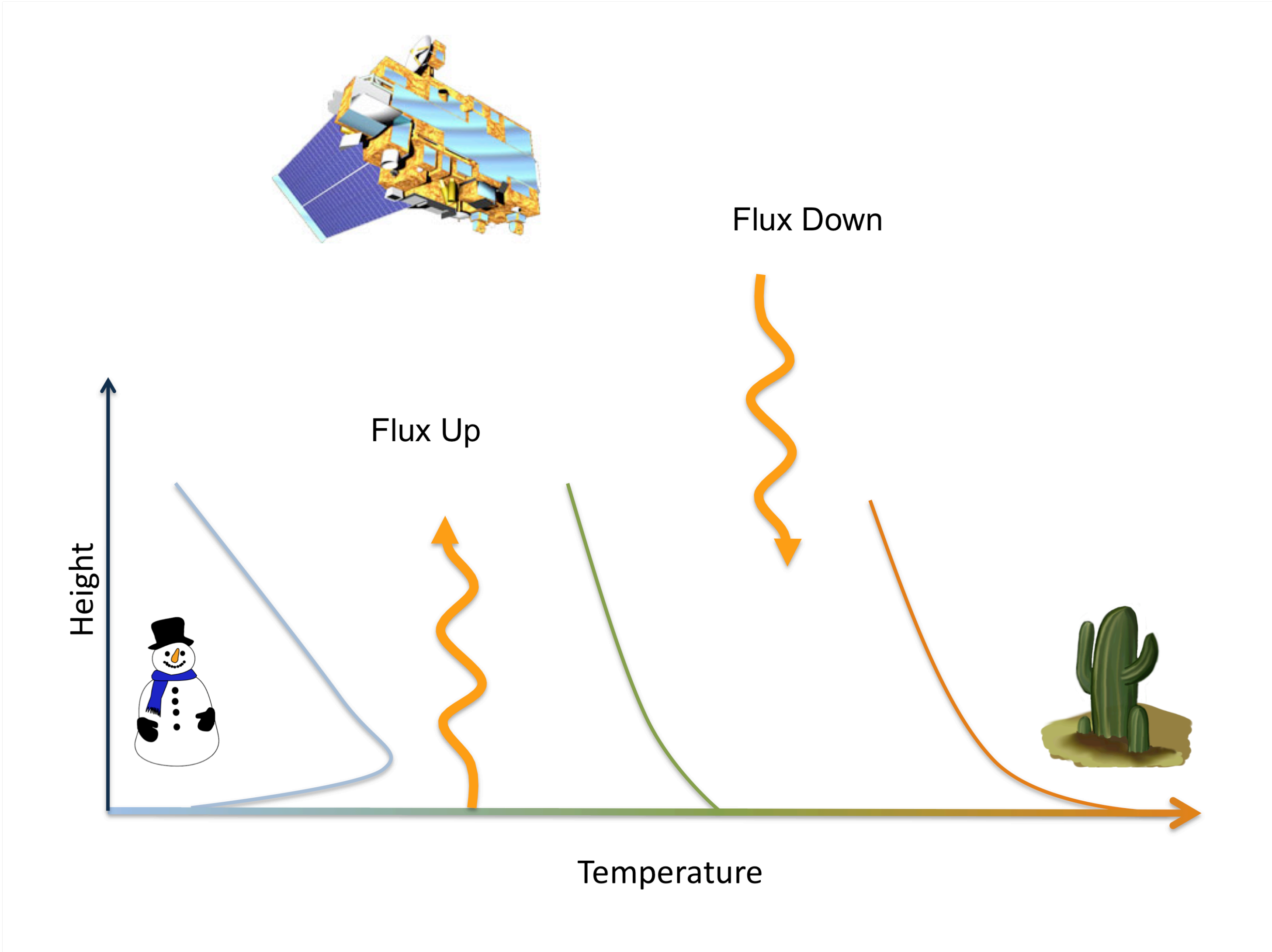
LW Model B

A test case for the near-surface air temperature constraint

Results showing global validation before the application of any of the temperature constraints. The model shows overestimations near the high range of fluxes and shows underestimations near the low to middle range of fluxes. The blue dots represent individual points, while the various squares follow the pattern: blue (2-5), turquoise (6-10), olive (21-40), orange (41-50) & yellow (>50). Data is from January & July 2004.

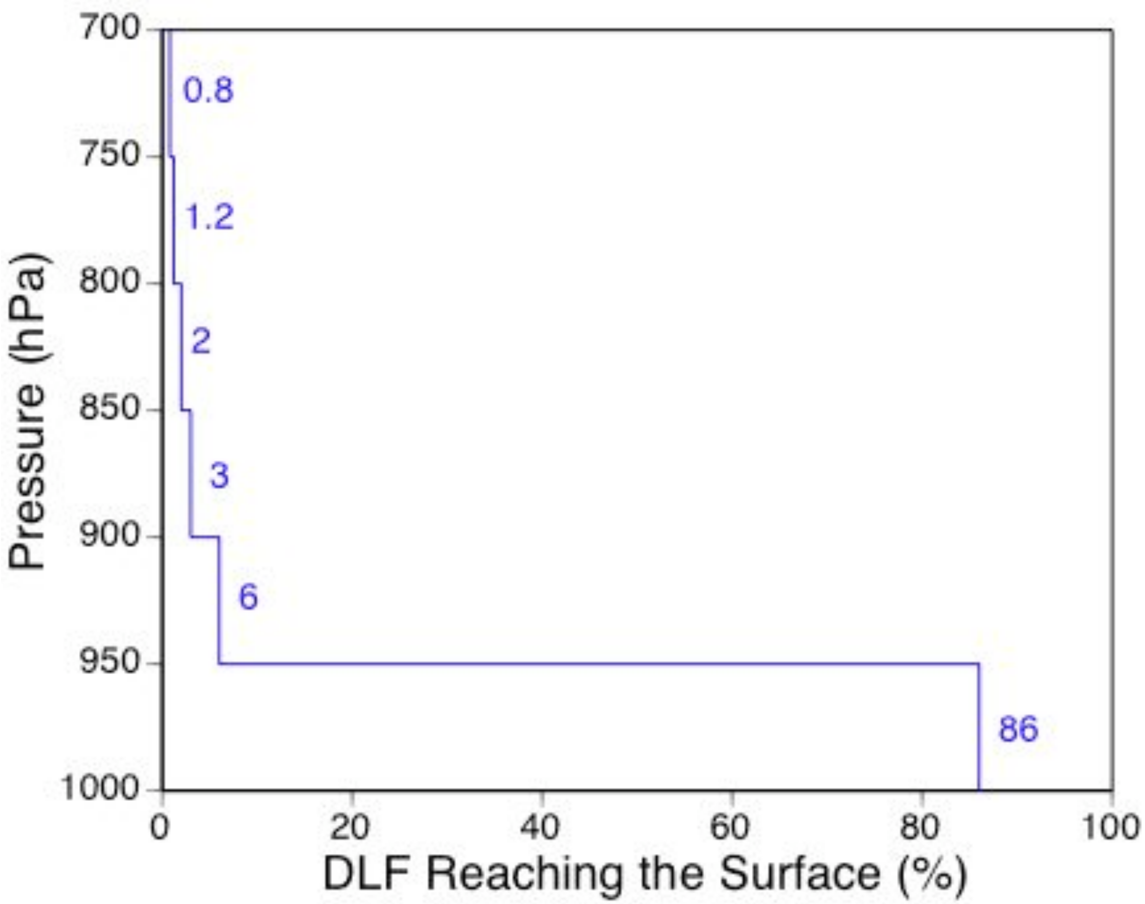


Temperature Profiles for Various Conditions



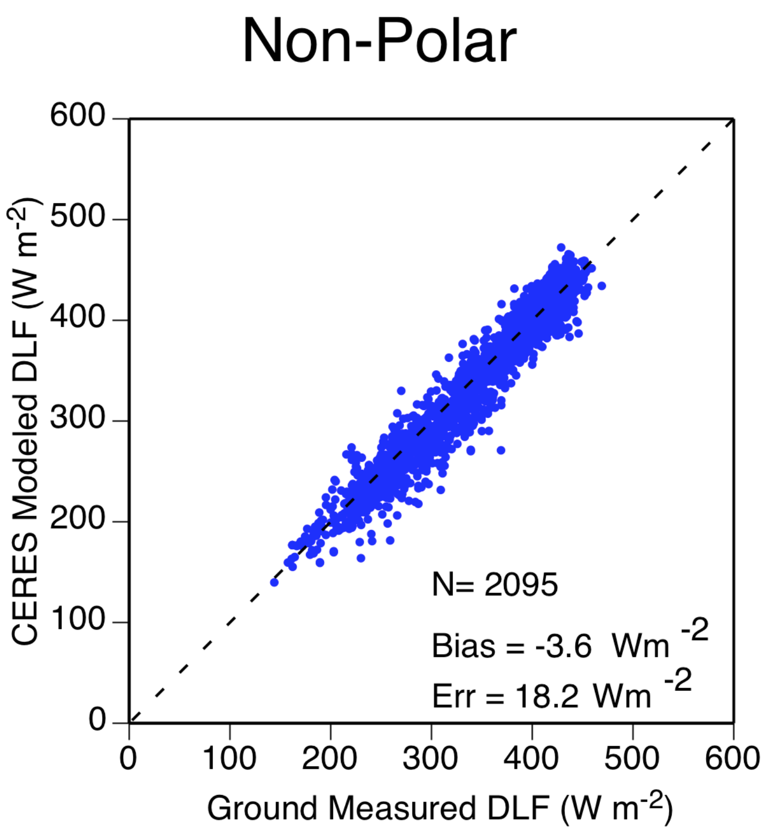
Weighting Function for DLF Reaching the Surface

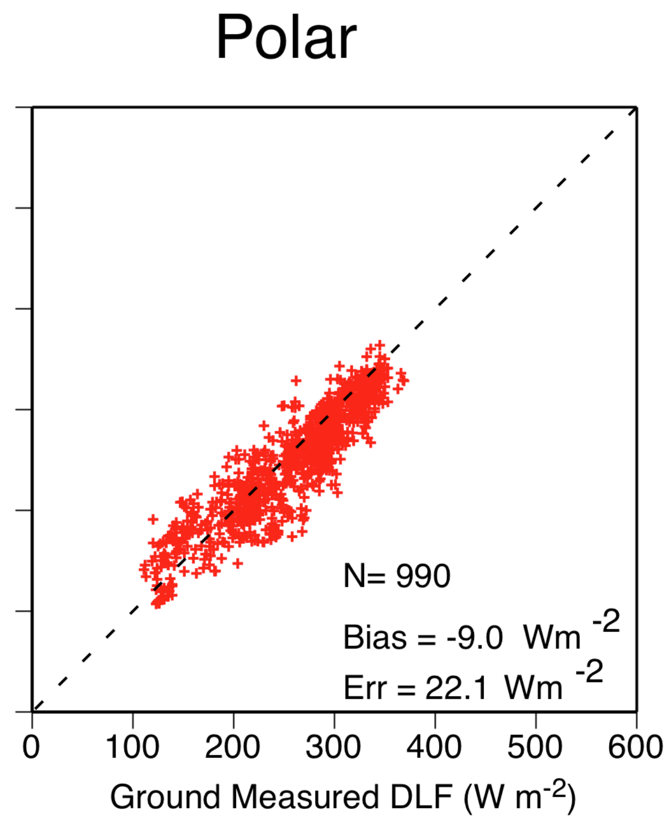
(Mid-Latitude Atmosphere – 50 hPa Layers)



LW Model B

Cases that required no temperature constraint



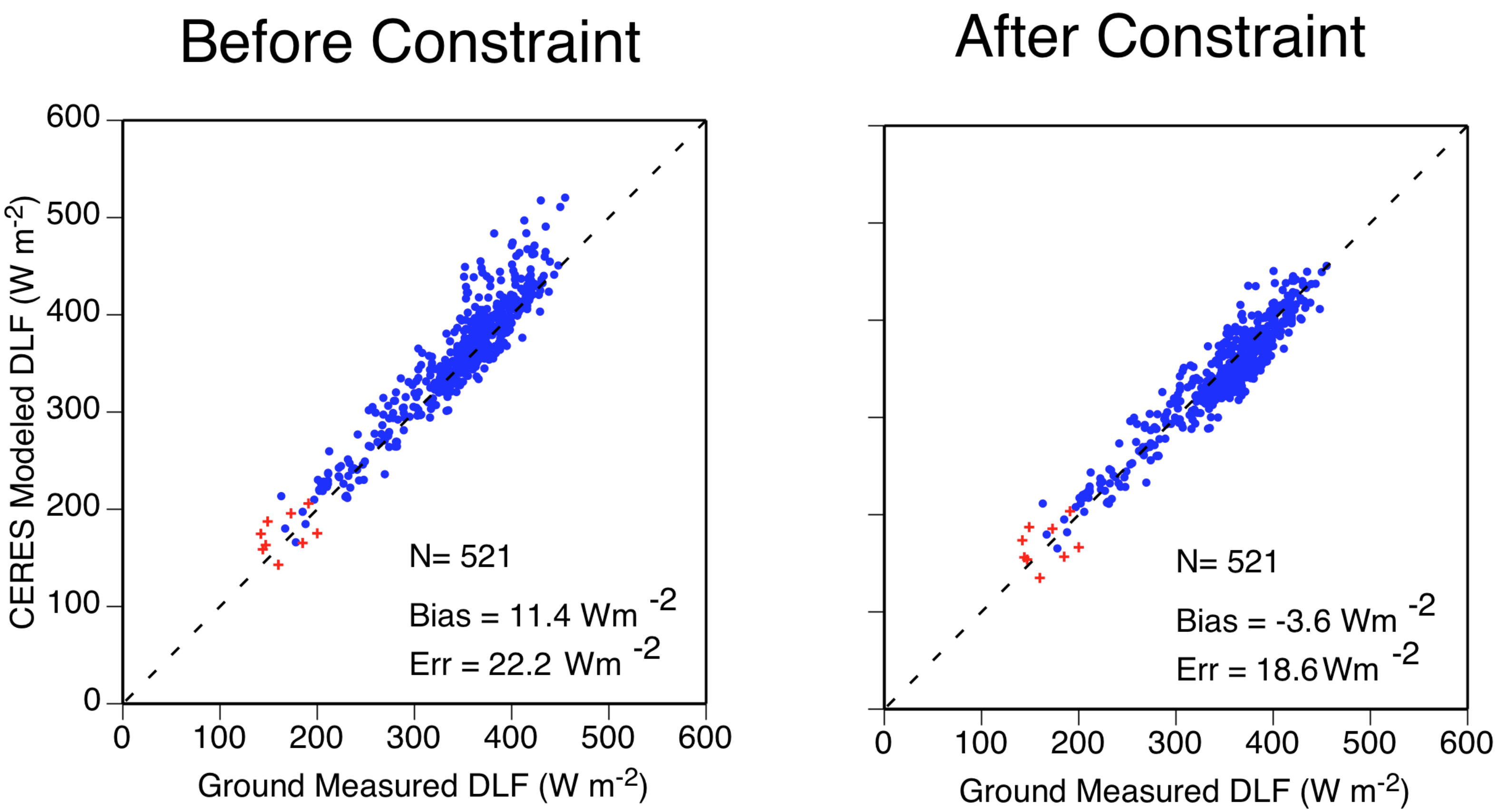


LW Model B

Cases where the high T_s constraint was applied

[Lapse rate in the P_s to (P_s-200hPa) range > 10K/100hPa]

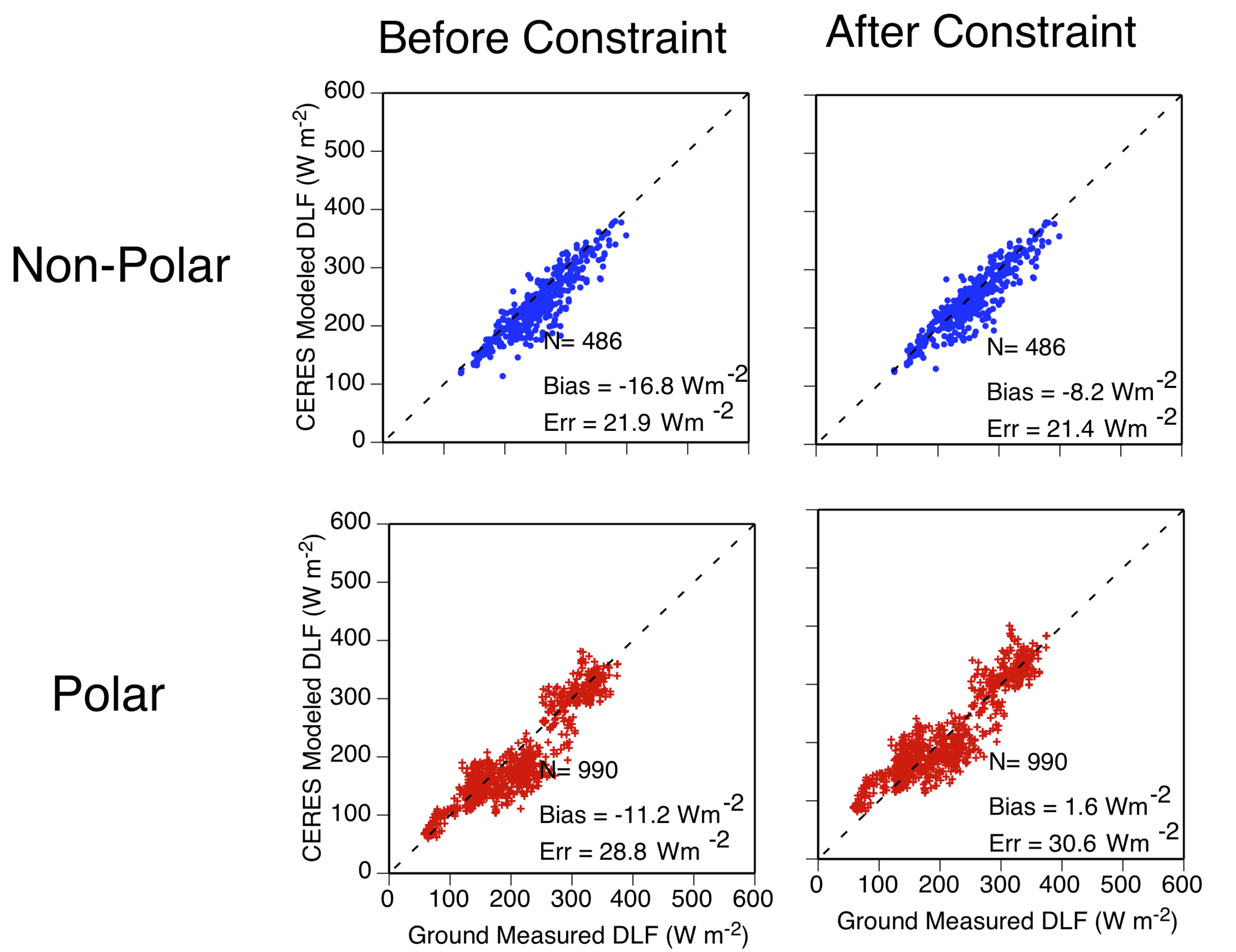
Detailed results presented in Gupta et al (2010)



LW Model B

Cases where the inversion constraint was applied

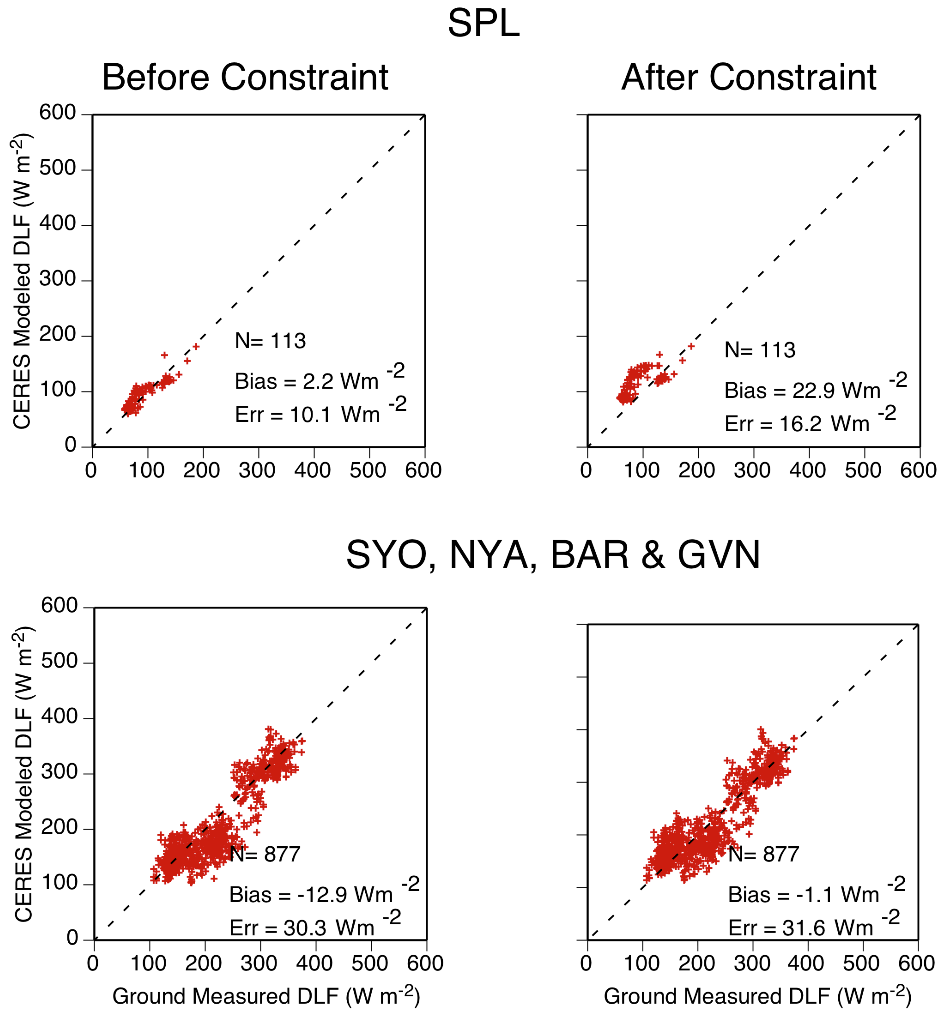
[Lapse rate in the P_s to (P_s-200hPa) range < 0K/100hPa]



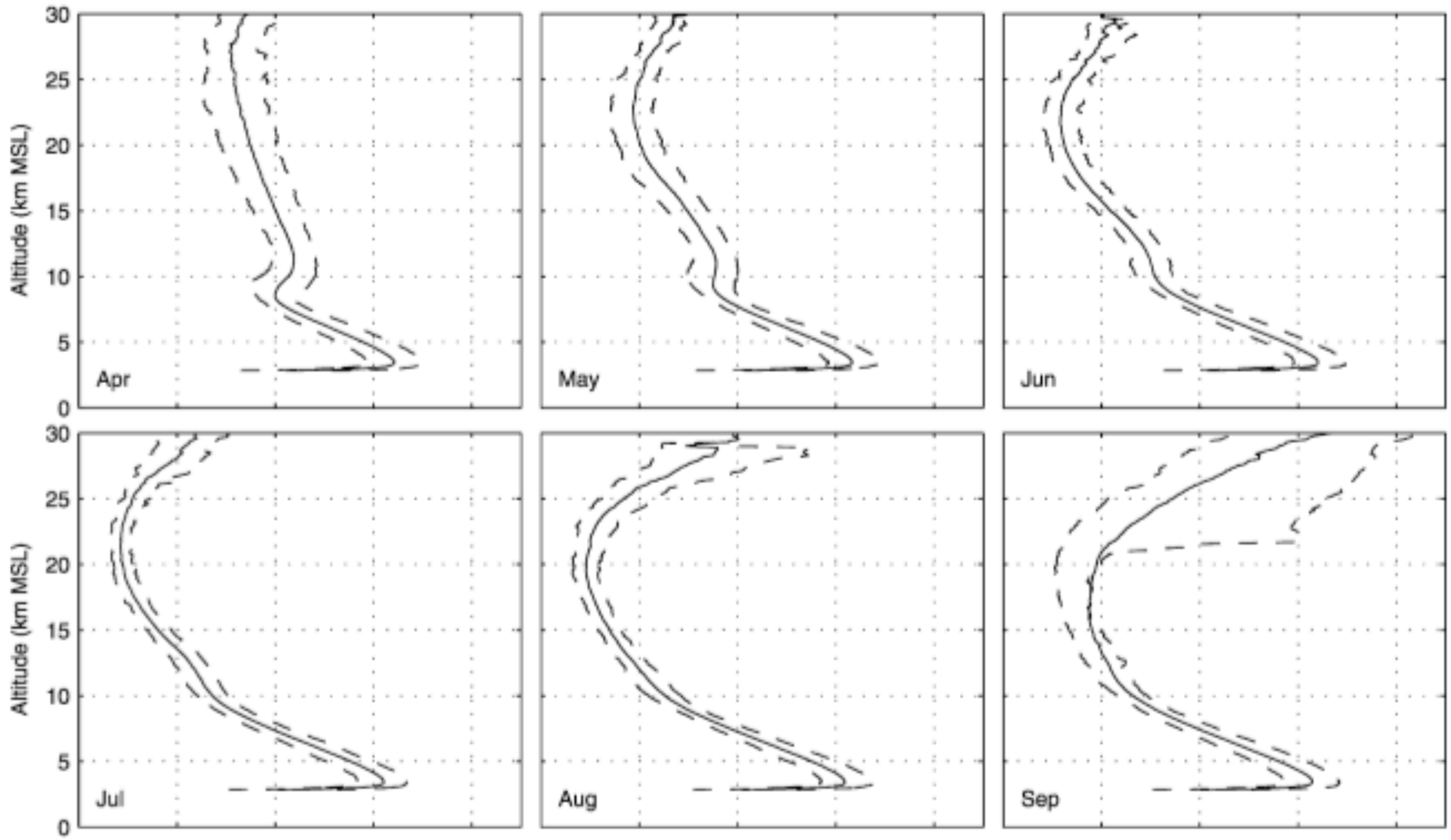
LW Model B

Cases where the inversion constraint was applied

[Lapse rate in the P_s to (P_s-200hPa) range < 0K/100hPa]



Monthly mean (solid line) atmospheric temperature profiles from 2 m to 30 km MSL over the South Pole (The dashed lines show the 10th and 90th percentiles of temperature at each height). Figure adopted from Hudson and Brandt (2005), *JC*, **18**, 1673-1696.



Results of Recent LW Model Improvements

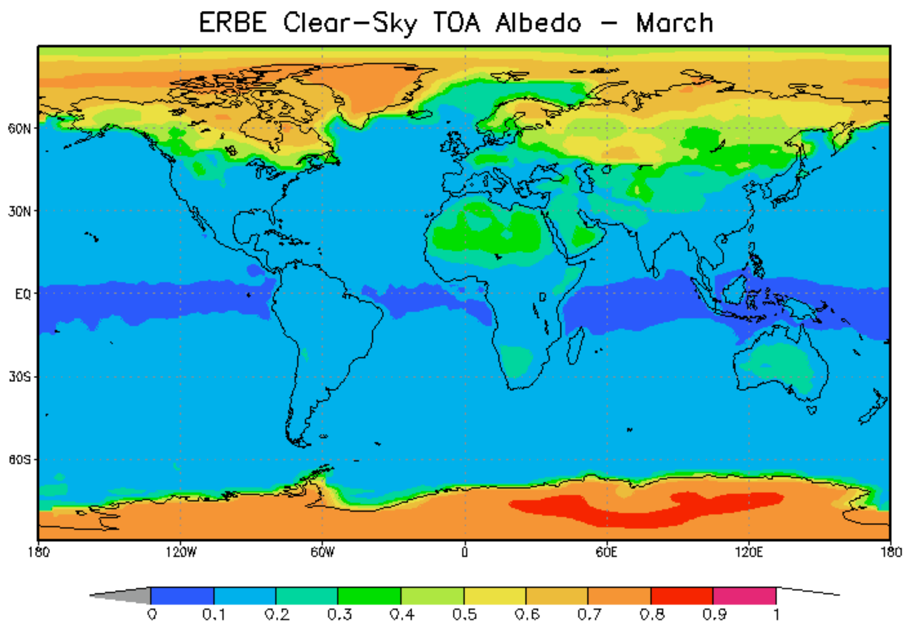
- To improve upon the accuracy of the LW Models, methods have been formulated to constrain the near-surface air temperature for the downward flux calculations to allow for the effective management of two extreme conditions:
- 1) For the condition involving surface temperatures that greatly exceed the overlying air temperatures, constraining the lapse rate by the dry adiabatic lapse rate has significantly improved the results, see Gupta et al. (2010).
- 2) For conditions involving surface temperatures that are much below the overlying air temperatures (inversions), removing the inversion from the downward calculations works well except for conditions involving high altitudes & low water vapor amounts, such as the Antarctic Plateau, which require special attention since the air temperatures immediately above the inversion are not representative of the atmospheric emission to the surface.

SW Model B Algorithm Improvements for Edition 3 (Page I)

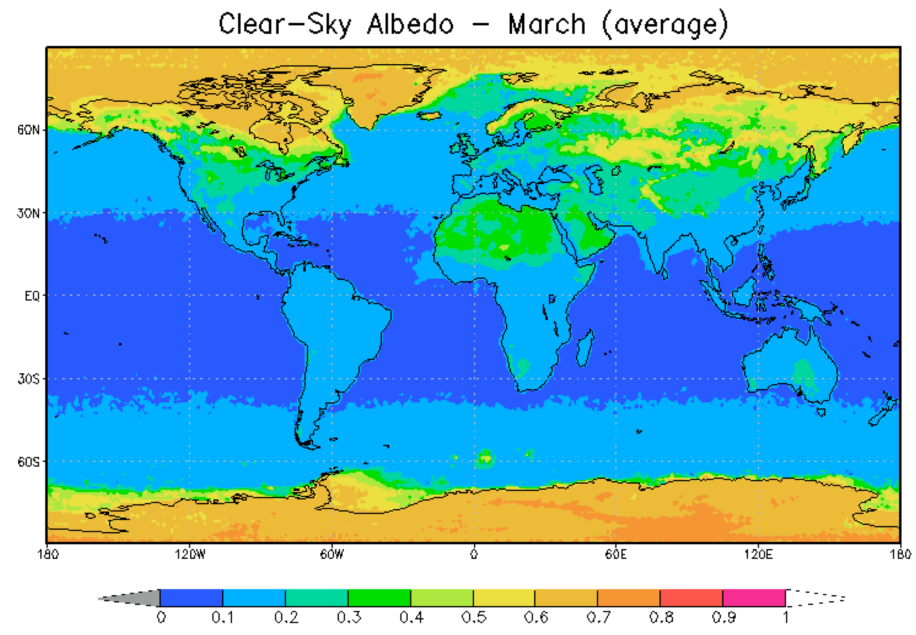
- Correct code limitation that prevents flux calculation for O_3 column abundances exceeding 500 Dobson units.
- Modify formulation to provide a more realistic dependence of instantaneous surface albedo on cosine of the solar zenith angle.
- For Terra processing, replace monthly climatology clear-sky 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.

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

Clear-Sky TOA Albedo from 48 Months of ERBE Data



Clear-sky TOA Albedo from 70 Months of Terra Data

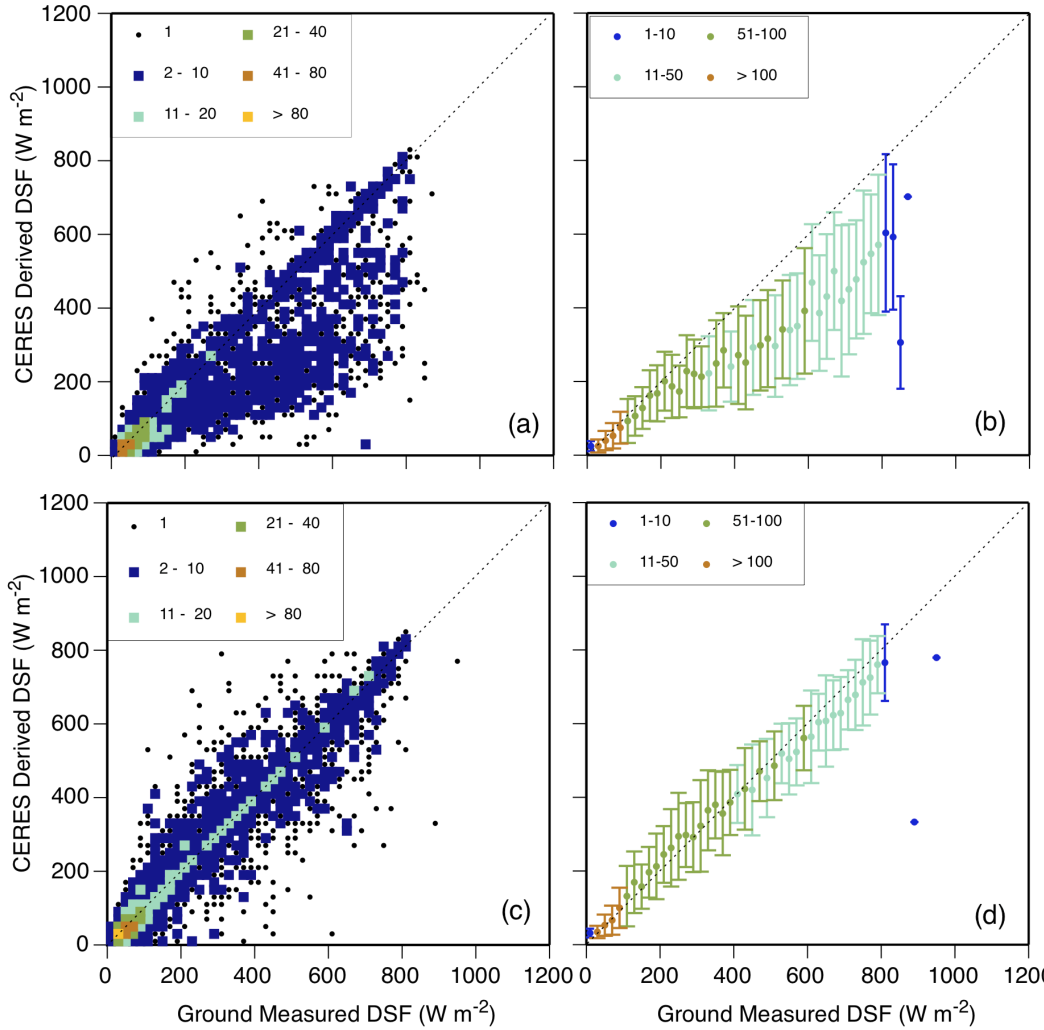


Comparison between surface-measured and CERES-derived fluxes

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.

Results adopted from Figure 3 of Kratz et al. 2010.

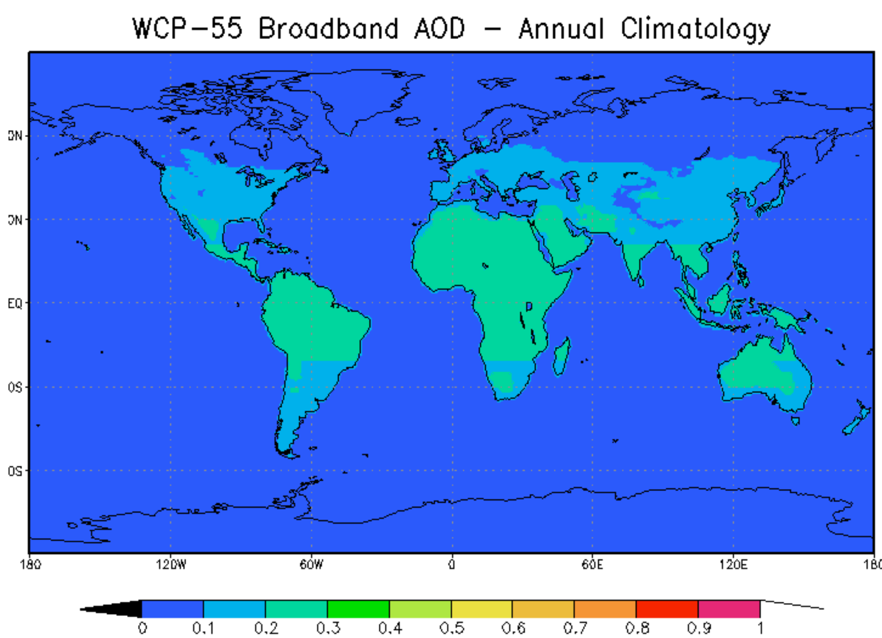


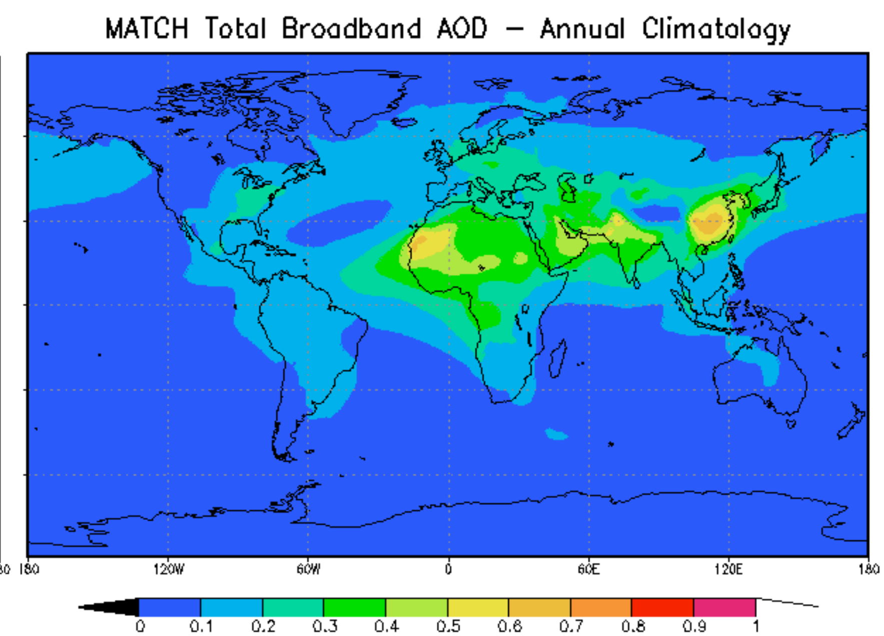
SW Model B Algorithm Improvements for Edition 3 and beyond (Page II)

- 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.
- Revise the Rayleigh scattering formulation in SW Model B (See Bodhaine et al. (1999): *J. Atmos. Oceanic Tech*., **16**, 1854-1861).
- Examine the relationship between clear and cloudy-sky results.
- Revise the molecular absorption parameterizations in SW Model B using the latest HITRAN database.

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





Flux Comparisons for SGP Surface Site

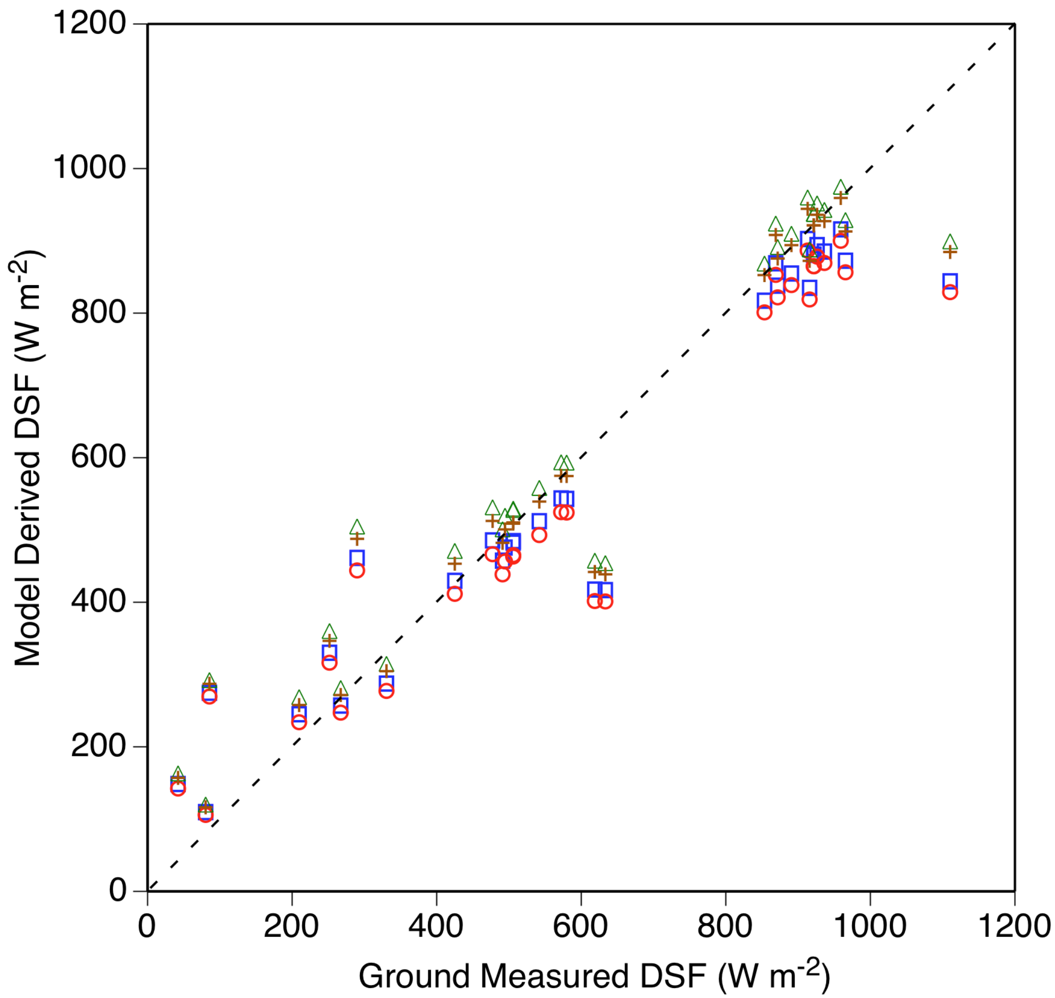
(Mostly Clear-Sky Conditions)

□ Old Rayleigh, WCP-55 Aerosols
Bias = -25.2 Wm^{-2} (Aqua 1B/2B)

Δ Old Rayleigh, MATCH Aerosols
Bias = 18.7 Wm^{-2} (Aqua 2A)

O New Rayleigh, WCP-55 Aerosols
Bias = -40.4 Wm^{-2}

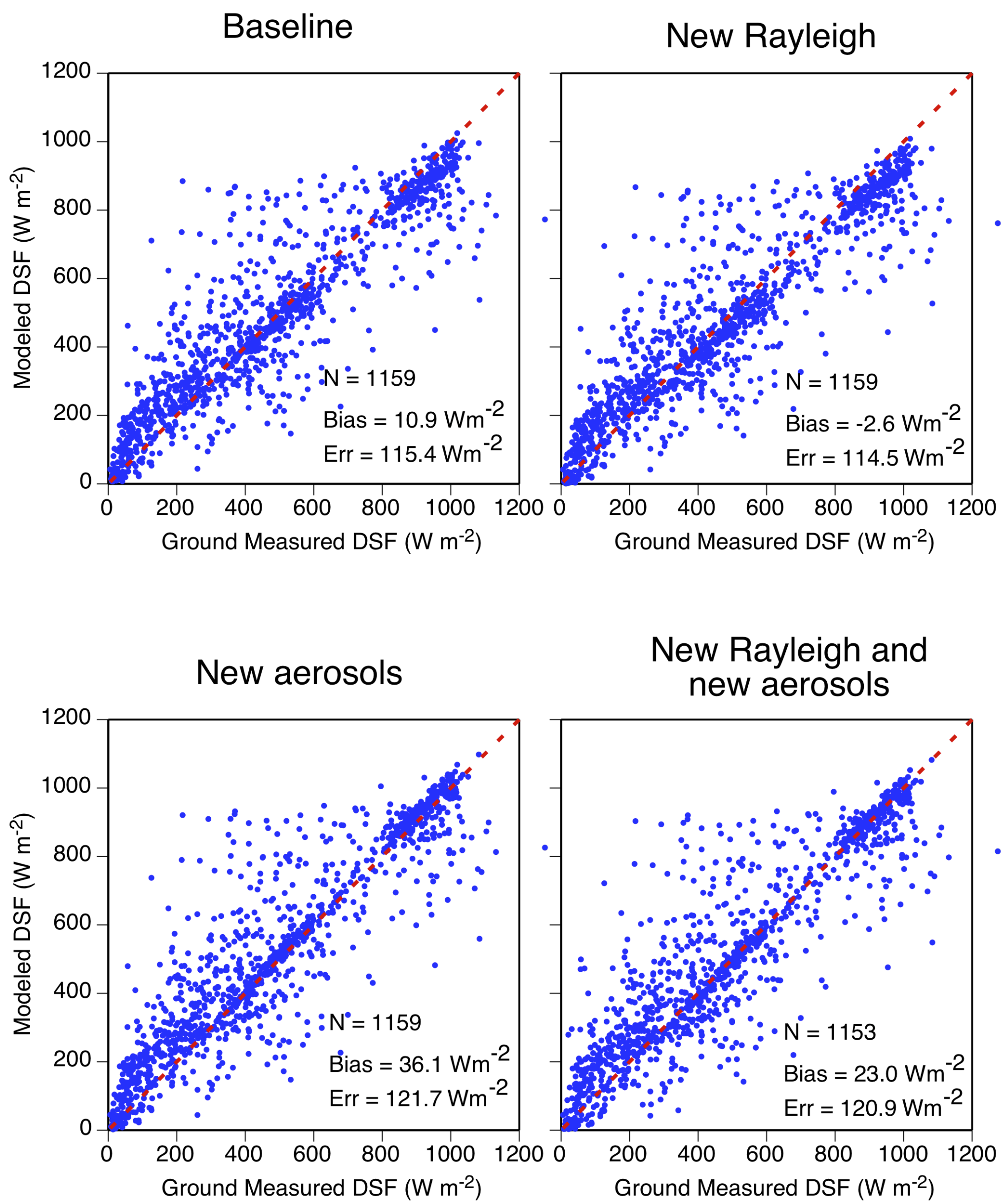
+ New Rayleigh, MATCH Aerosols
Bias = 3.7 Wm^{-2} (Aqua 3)



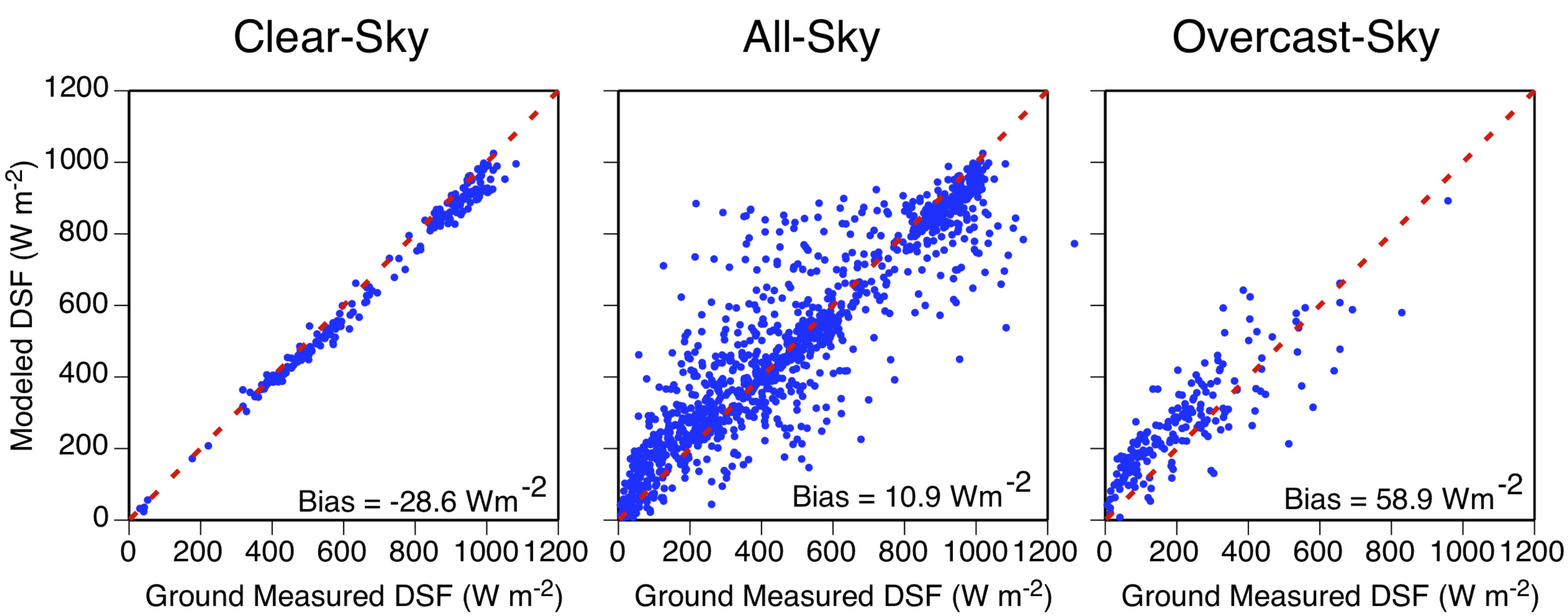
Comparison between surface-measured and CERES-derived fluxes: All-Sky

All-sky results for comparisons among the results for a) WCP-55 aerosols & old Rayleigh algorithm, b) WCP-55 aerosols & new Rayleigh algorithm, c) MATCH aerosols & old Rayleigh algorithm, and d) MATCH aerosols & new Rayleigh algorithm.

For the all sky case, the new formulation with the MATCH aerosols & the new Rayleigh algorithm shows a modest degradation in the results mostly due to the removal of compensating errors in the old formulations.



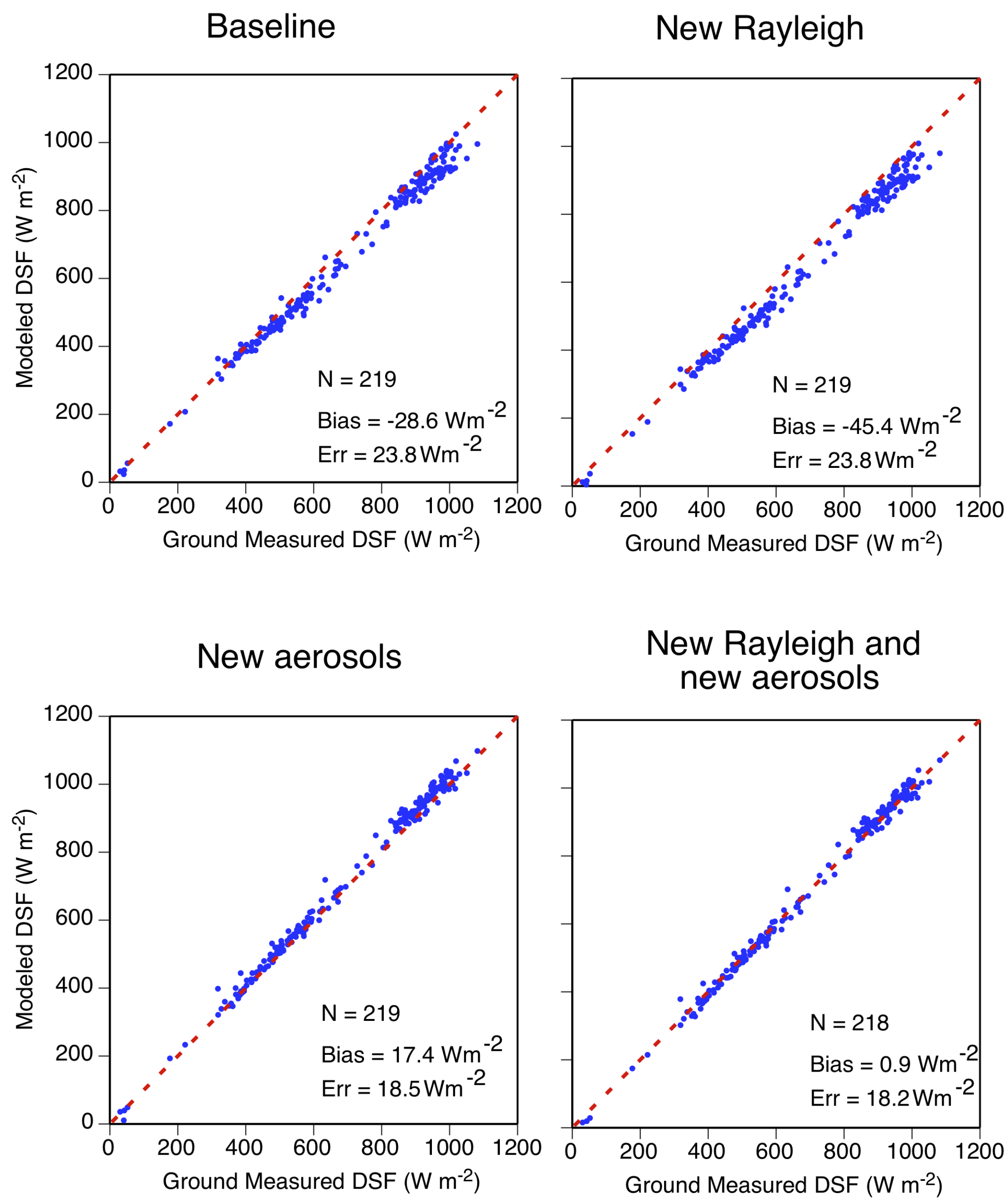
Comparison between surface-measured and CERES-derived fluxes for clear-sky, all-sky and overcast



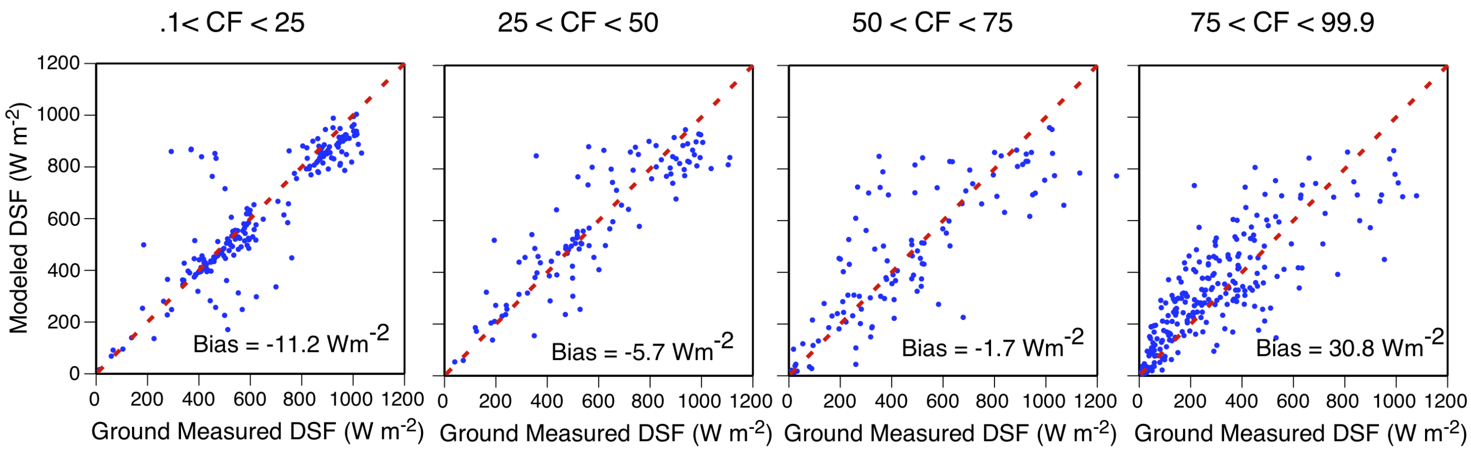
Comparison between surface-measured and CERES-derived fluxes: Clear-Sky

Clear-sky results for comparisons among the results for a) WCP-55 aerosols & old Rayleigh algorithm, b) WCP-55 aerosols & new Rayleigh algorithm, c) MATCH aerosols & old Rayleigh algorithm, and d) MATCH aerosols & new Rayleigh algorithm.

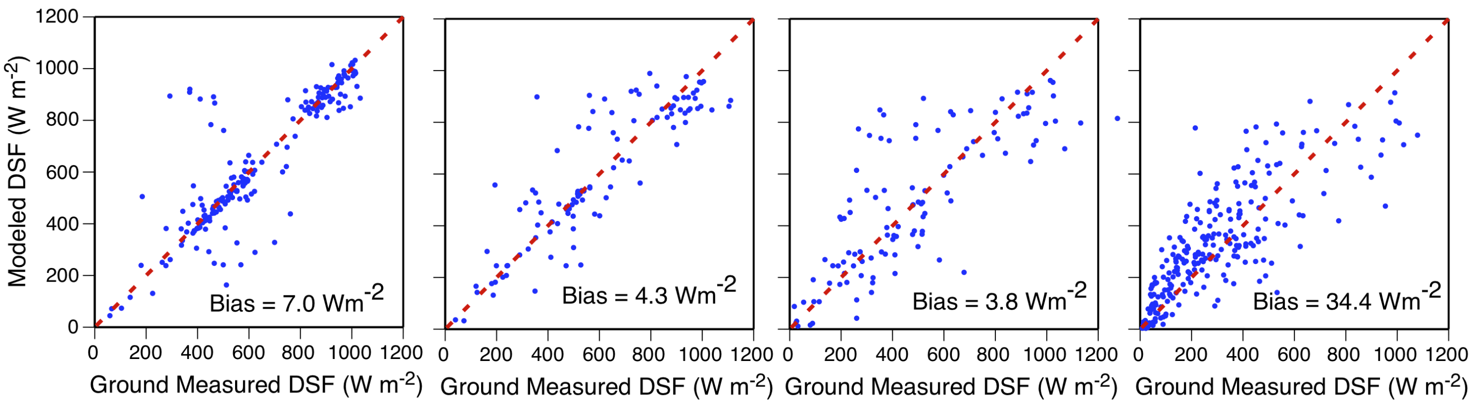
For the clear-sky case, the new formulation with the MATCH aerosols & the new Rayleigh algorithm shows a remarkable improvement.



Baseline



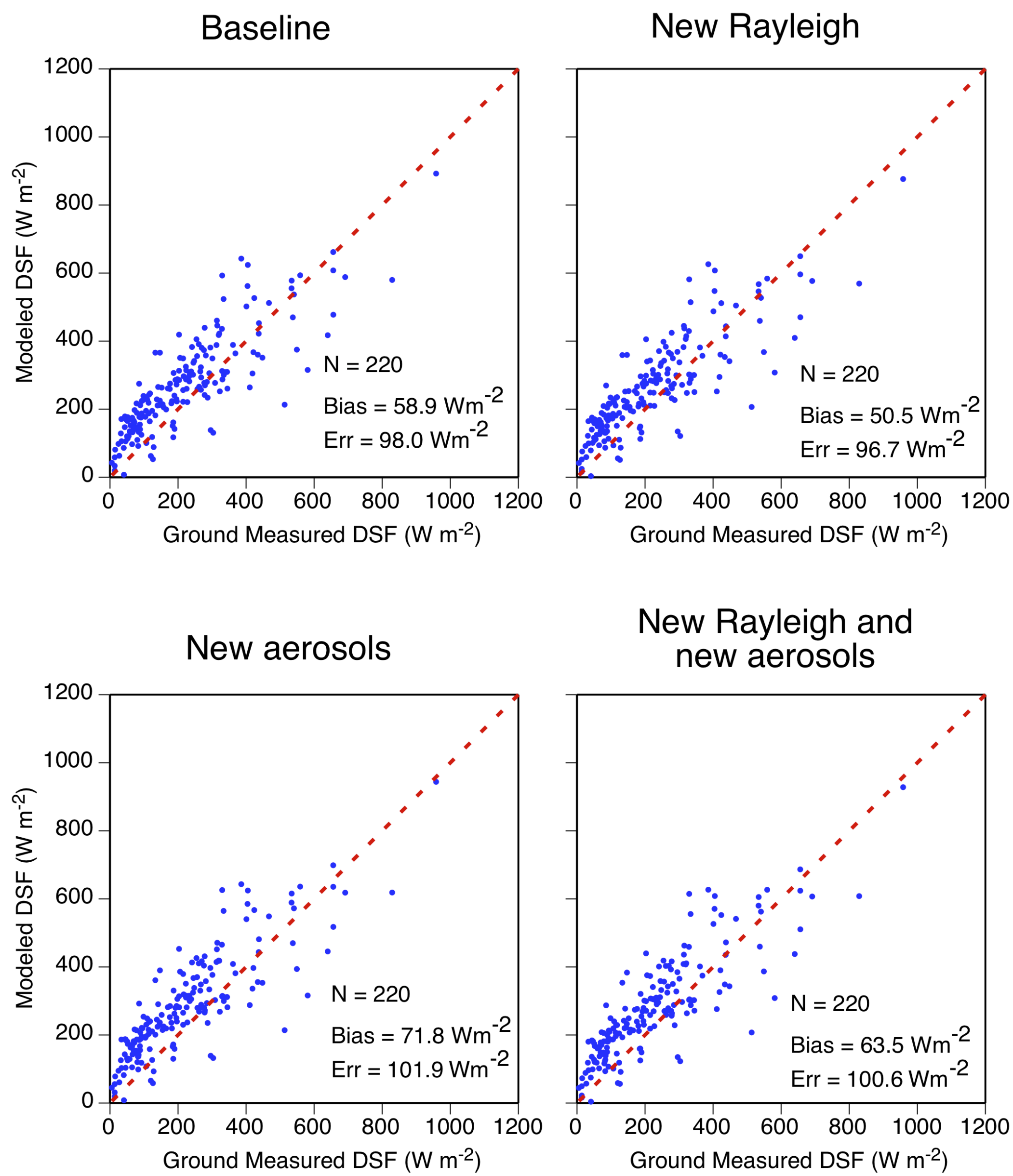
New Rayleigh and New Aerosols



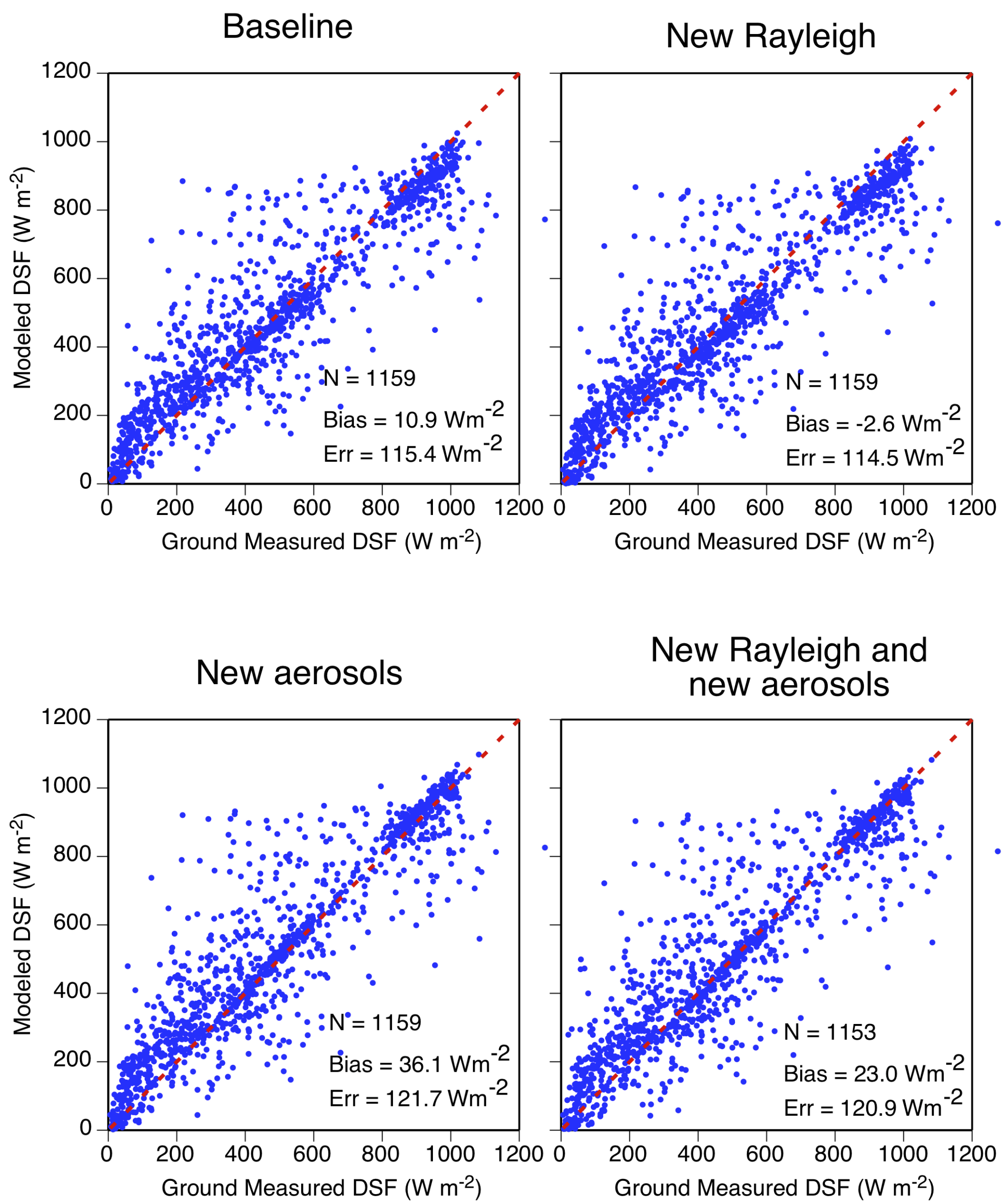
Comparison between surface-measured and CERES-derived fluxes: Overcast

Overcast (> 99.9% cloudy) sky results for comparisons among the results for a) WCP-55 aerosols & old Rayleigh algorithm, b) WCP-55 aerosols & new Rayleigh algorithm, c) MATCH aerosols & old Rayleigh algorithm, and d) MATCH aerosols & new Rayleigh algorithm.

For the overcast (> 99.9% cloudy) sky case, the new formulation with the MATCH aerosols & the new Rayleigh algorithm shows no improvement.



Comparison between surface-measured and CERES-derived fluxes: All-Sky



All-sky results for comparisons among the results for a) WCP-55 aerosols & old Rayleigh algorithm, b) WCP-55 aerosols & new Rayleigh algorithm, c) MATCH aerosols & old Rayleigh algorithm, and d) MATCH aerosols & new Rayleigh algorithm.

For the all sky case, the new formulation with the MATCH aerosols & the new Rayleigh algorithm shows a modest degradation in the results mostly due to the removal of compensating errors in the old formulations.

Results of Recent SW Model Improvements and Course of Action for the Future

- Simultaneously replacing the original WCP-55 aerosols with the MATCH aerosols, and the original Rayleigh molecular scattering formulation with an improved Rayleigh molecular scattering formulation has significantly improved the surface SW flux calculations for clear to variably cloudy sky conditions.

- Results for the mostly cloudy to overcast conditions strongly suggest that further work on the cloud transmittance calculation is necessary. Our attention is currently focused on the formulae used for the cloud transmittance and the overcast albedo.