Status of the SOFA Validation and TSI Data

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Background (Part 1)

CERES uses several Surface-Only Flux Algorithms (SOFA) to compute SW and LW surface fluxes as well as the more precise model used by SARB. The SOFA 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

SOFA References:

SW A: Li et al. (1993): *J. Climate*, **6**, 1764-1772.
SW B: Darnell et al. (1992): *J. Geophys. Res.*, **97**, 15741-15760.
SW B: 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.,* **49**, 1579-1589.
FLASH: Kratz et al. (2014): *J. Appl. Meteor. Climatol.*, **53**, 1059-1079.

Background (Part 2)

- The SOFA LW and SW Models are based on rapid, highly parameterized TOA-to-surface transfer algorithms to derive the surface fluxes.
- LW Models A and B and SW Model A 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 the CERES instrument on the TRMM satellite.
- The Edition 2B LW and SW surface flux results underwent extensive validation (Kratz et al. 2010).
- The ongoing validation process has already led to improvements to the LW models (Gupta et al., 2010).
- LW Model C (Zhou et al., 2007) was introduced into the Edition 4 processing to maintain two independent LW algorithms after a broadband LW Channel was chosen to replace the CERES Window Channel for the CERES FM-6 and the follow-on Radiation Budget Instrument (RBI).
- LW and SW Models B were incorporated into the FLASHFlux effort to produce a rapidly available Environmental Data Record (Kratz et al., 2014)

Recent and Future Improvements to the Surface-Only Flux Algorithms

SW Model Improvements: 1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al. (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4. 4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for the new Edition 4 clouds.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

SW and LW Model Improvements: 1) The availability of ocean buoy measurements is expected to allow for improved surface flux retrievals by providing validation over ocean regions.

Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 2B	CERES 4
Clear-Sky TOA albedo Terra	48 month ERBE	70 month Terra
Clear-Sky TOA albedo Aqua	46 month Terra	70 month Terra
Clear-Sky Surf. albedo	46 month Terra	70 month Terra
TOA to Surface albedo transfer	Instantaneous	Monthly average
Spec. Corr. Coef.	CERES 2B	CERES 4A
Cos (sza) dependence of Surface Flux	LPSA	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 500 DU	0 to 800 DU
Twilight cutoff		New
Cloud transmission empirical coefficient	0.80	0.75
LW high temperature surface correction	No	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	No	Maximum Inversion Strength -10K/100hPa

Status of SW Model Improvements

Incorporating the MATCH aerosols along with an improved Rayleigh molecular scattering formulation has significantly improved the surface SW flux calculations for clear through partly cloudy sky conditions.

To account for the short term variability of aerosol properties, we have incorporated the daily aerosol properties into SW Model B.

The ADMs and MATCH aerosols have been revised for Ed4.

SORCE & RMIB have been used to produce Total Solar Irradiance. TCTE is now available and can be used when the need arises.

Results for the mostly cloudy to overcast conditions were improved by revising the a_0 coefficient but results suggest that further work on the cloud transmittance calculation is necessary. Recent efforts have been focused on formulating an improved method to estimate all-sky cloud transmittance (results pending).

Status of Total Solar Irradiance (TSI) Measurements

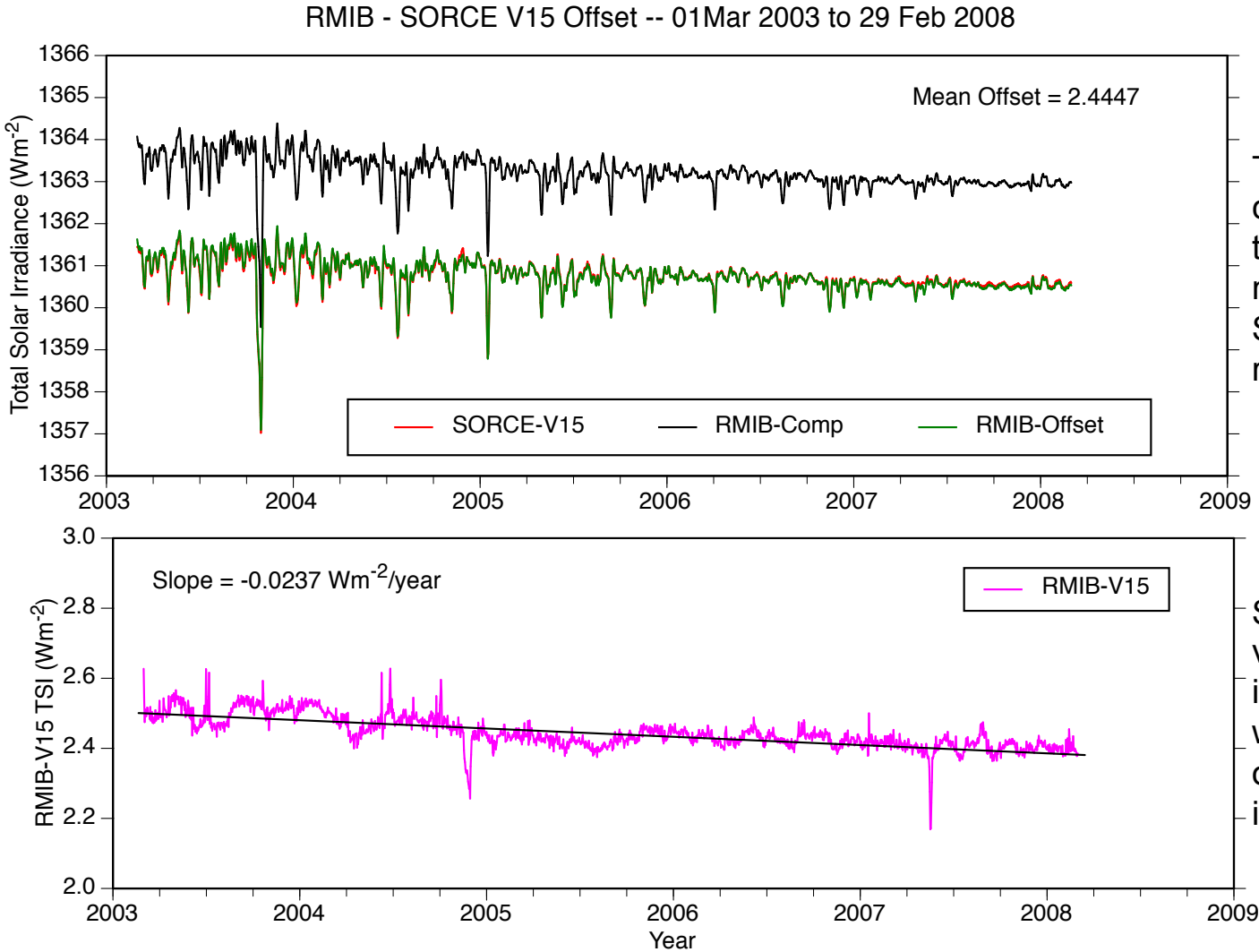
The SORCE TIM (Total Irradiance Monitor) began producing TSI data on February 25, 2003; however, a battery failure on SORCE halted regular production from July 2013 through February 2014. As a result, we began incorporating the RMIB composite TSI data from S. DeWitte.

The RMIB data, however, requires an offset from the DIARAD VIRGO solar minimum value of ~1363 W/m^2 to match the SORCE solar minimum of ~1361 W/m^2. Note, for CERES Ed4 processing, all TSI data are offset to match the SORCE TSI Version 15.

In the meantime, the TSI Calibration Transfer Experiment (TCTE) was launched into orbit on November 19, 2013 and began producing TSI data on an irregular basis on December 16, 2013, and more recently, on a regular daily basis on January 1, 2015.

The SORCE instrument resumed data production on a daily basis on March 5, 2014. CERES subsequently resumed merging the SORCE TSI data into the CERES processing beginning on November 1, 2015.

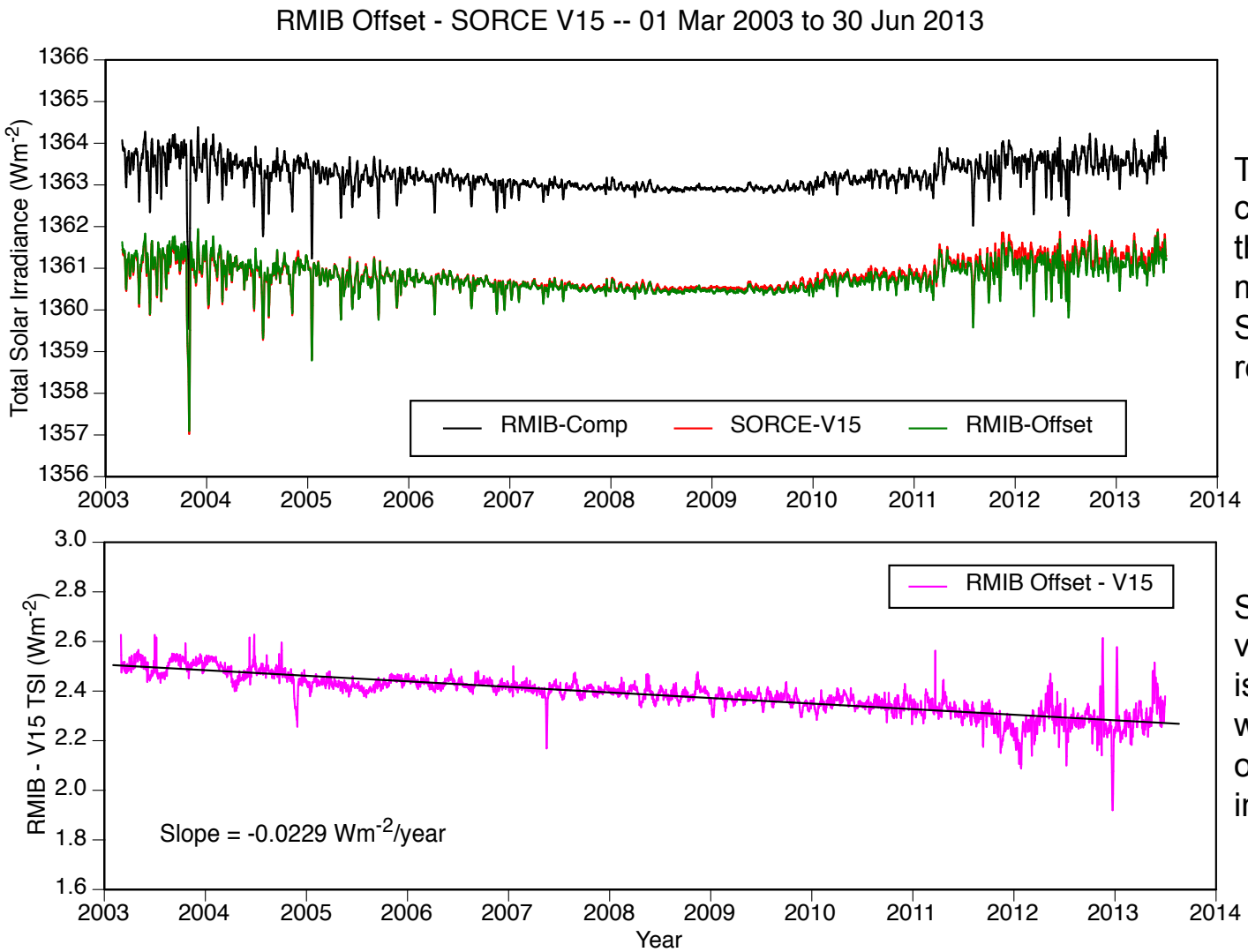
Comparison of TSI data [SORCE(V15) versus RMIB] for the 5-year overlap period 1-Mar-2003 to 29-Feb-2008



This timeframe corresponds to the first 60 months of the SORCE data record

Slope of RMIB versus SORCE is -0.0237 W/m^2 which yields an offset of 1 W/m^2 in 42.19 years

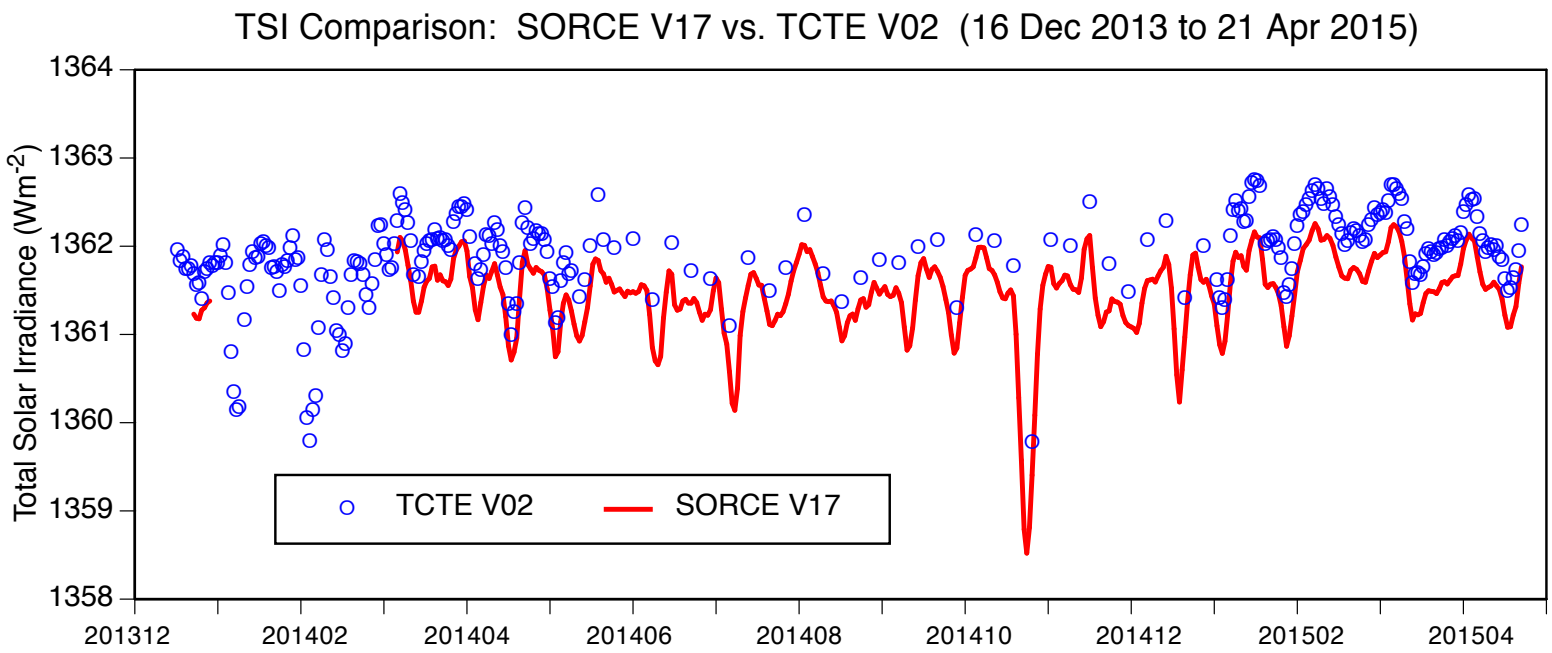
Comparison of TSI data [SORCE(V15) versus RMIB] for the entire SORCE period: 1-Mar-2003 to 30-Jun-2013



This timeframe corresponds to the first 124 months of the SORCE data record

Slope of RMIB versus SORCE is -0.0229 W/m^2 which yields an offset of 1 W/m^2 in 43.67 years

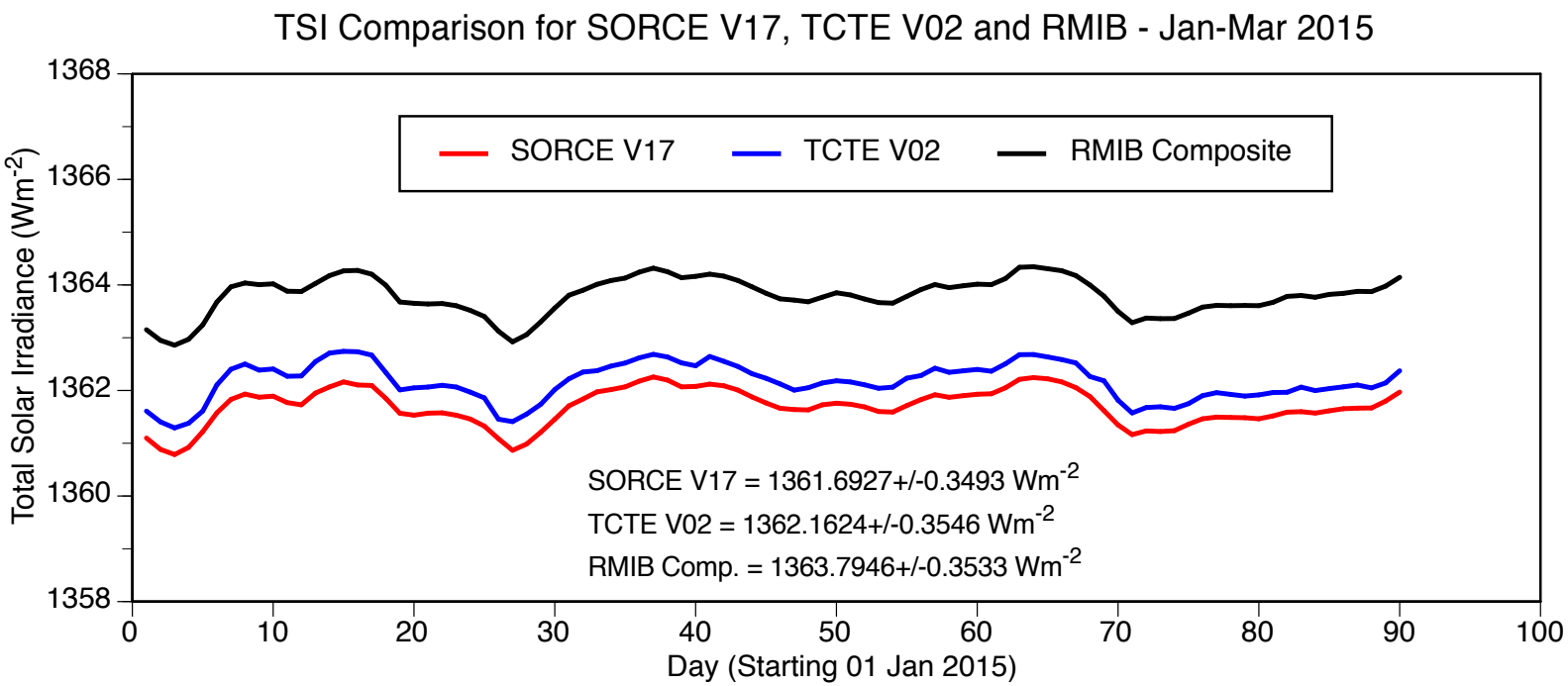
Inter-comparison of SORCE(V16) and TCTE Total Solar Irradiance Retrievals



SORCE: 1 value/day, 22 DEC 2013 through 28 DEC 2013, and 1 value/day 5 MAR 2014 through 31 AUG 2014; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

TCTE: 1 value/day, 16 DEC 2013 through 8 May 2014, and 1 value/week 11 MAY 2014 through 31 AUG 2014; Absolute Accuracy: ±1.36 W/m^2 at 1361 W/m^2

Inter-comparison of SORCE(V17), TCTE (V02) & RMIB Total Solar Irradiance Retrievals for 2015

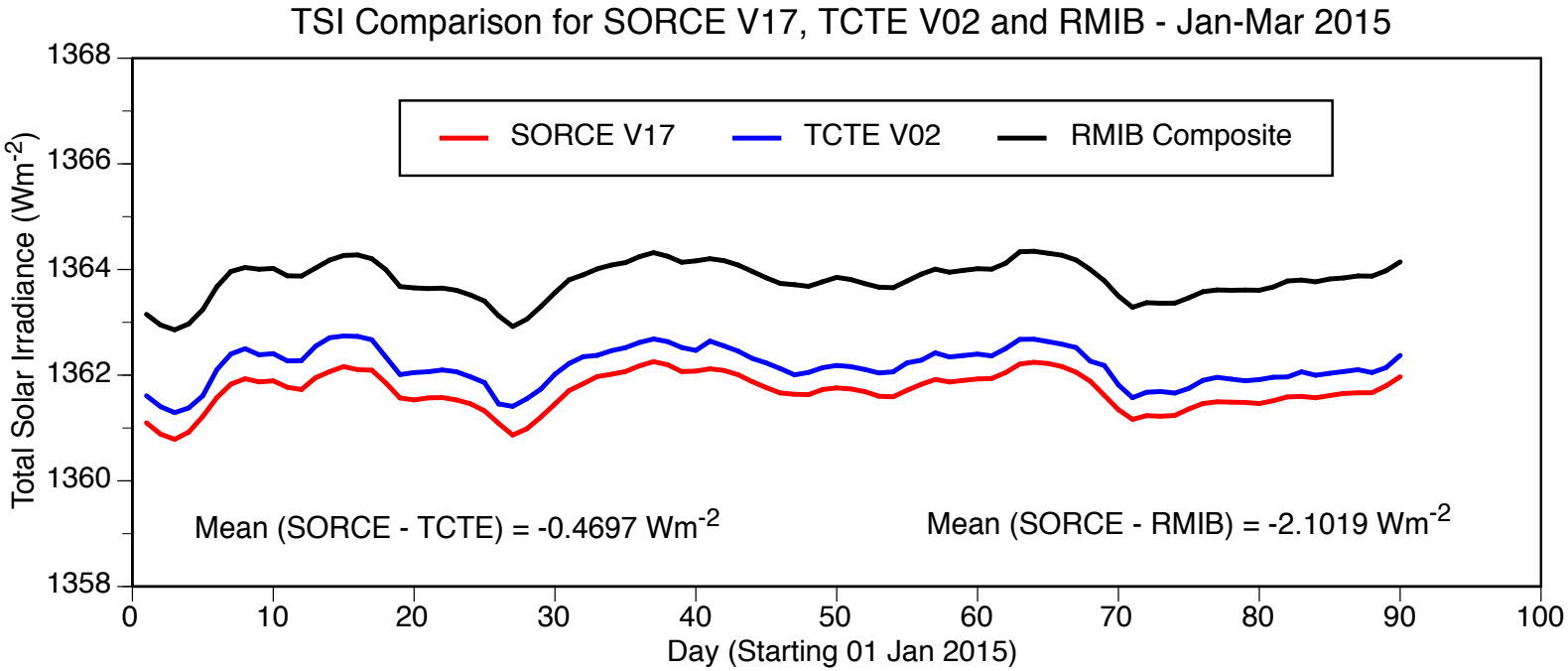


SORCE V17: 1 value/day, 1 JAN 2015 through 31 MAR 2013, Absolute Accuracy: ±0.58 W/m^2 at 1361 W/m^2 (was ±0.48 W/m^2 before 31 Oct 2012)

TCTE V02: 1 value/day, 1 JAN 2015 through 31 Mar 2015; Absolute Accuracy: ±1.36 W/m^2 at 1361 W/m^2

RMIB: 1 value/day, 1 JAN 2015 through 31 Mar 2015

Inter-comparison of SORCE(V17), TCTE (V02) & RMIB Total Solar Irradiance Retrievals for 2015

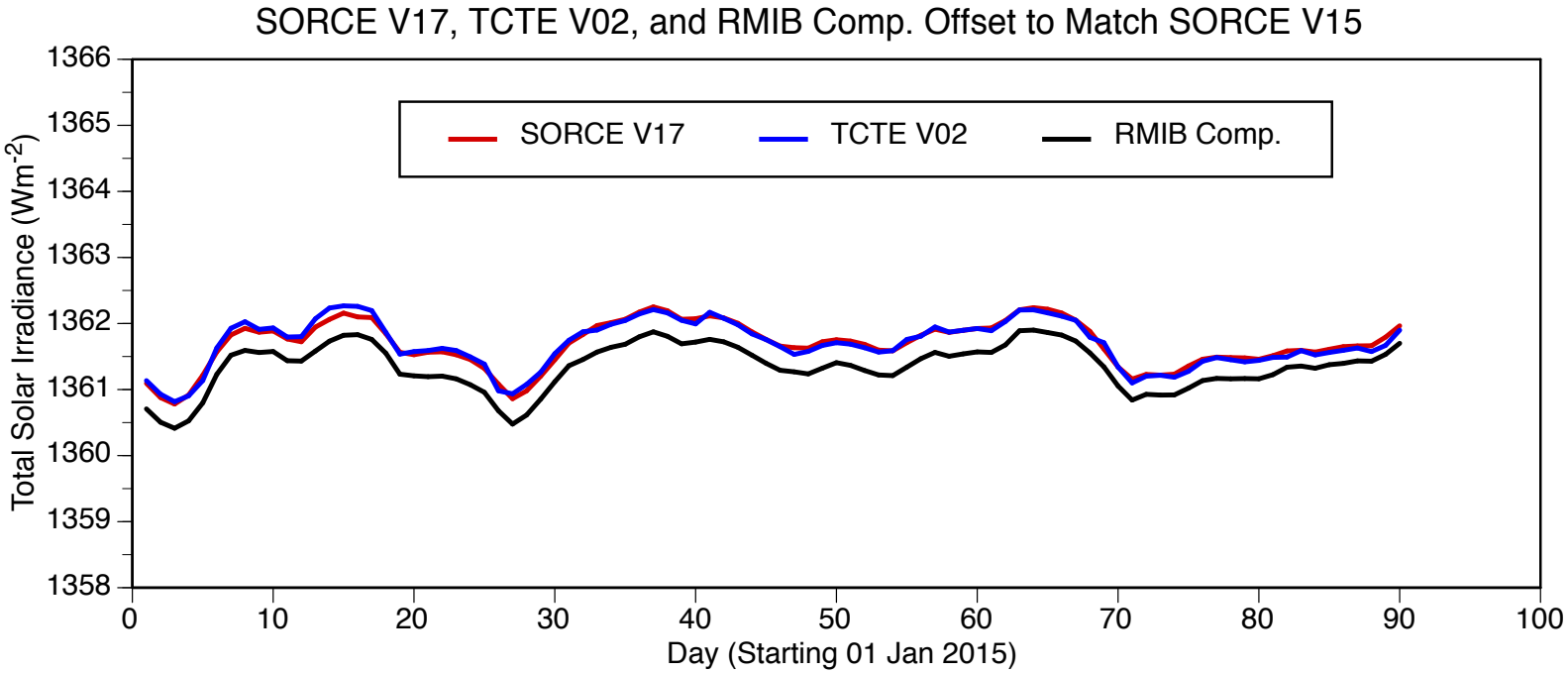


SORCE V17: 1 value/day, 1 JAN 2015 through 31 MAR 2013, Absolute Accuracy: ±0.58 W/m^2 at 1361 W/m^2 (was ±0.48 W/m^2 before 31 Oct 2012)

TCTE V02: 1 value/day, 1 JAN 2015 through 31 Mar 2015; Absolute Accuracy: ±1.36 W/m^2 at 1361 W/m^2

RMIB: 1 value/day, 1 JAN 2015 through 31 Mar 2015

Inter-comparison of SORCE(V17), TCTE (V02) & RMIB Total Solar Irradiance Retrievals

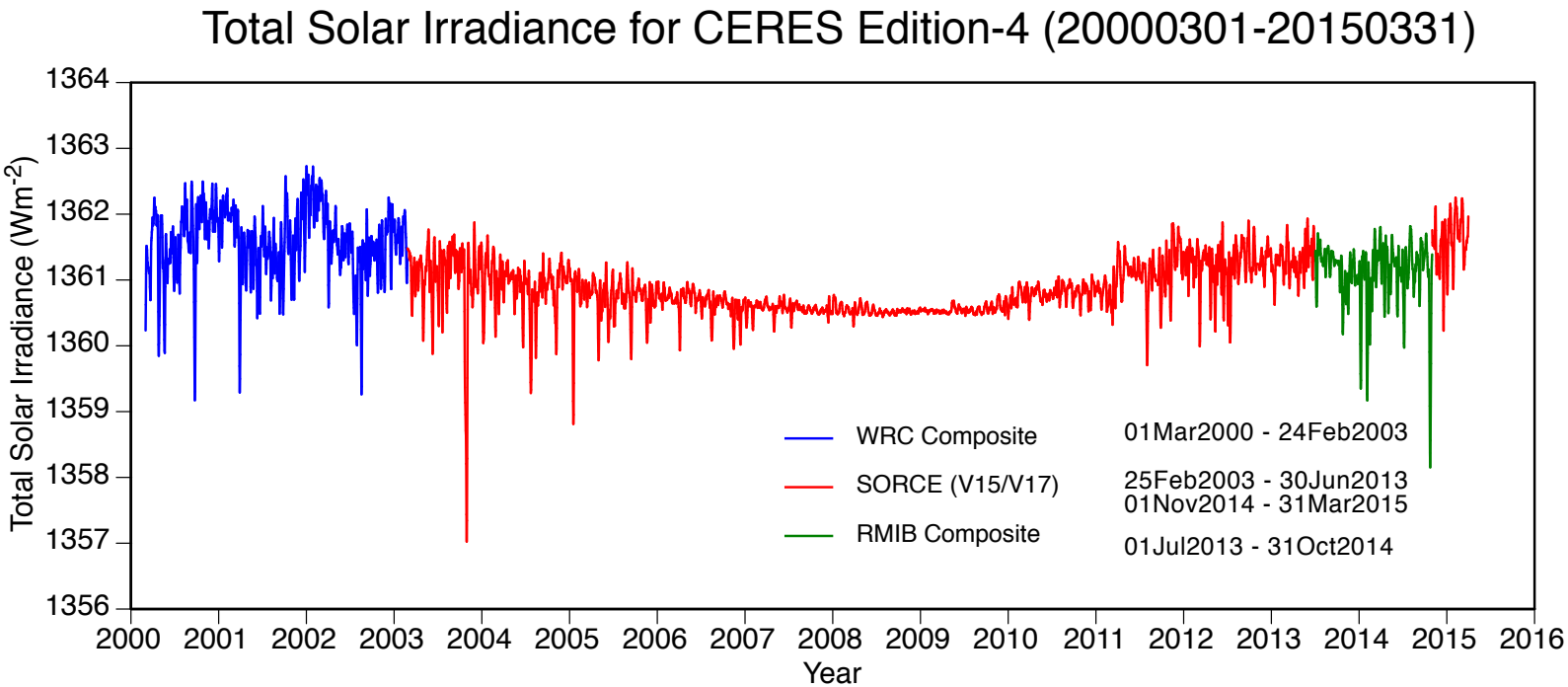


SORCE V17: 1 value/day, 1 JAN 2015 through 31 MAR 2013, Absolute Accuracy: 425 ppm or ±0.58 W/m^2 at 1361 W/m^2 (Abs. Accuracy was 350 ppm or ±0.48 W/m^2 before 31 Oct 2012)

TCTE V02: 1 value/day, 1 JAN 2015 through 31 Mar 2015; Absolute Accuracy: 100 ppm or ±1.36 W/m^2 at 1361 W/m^2

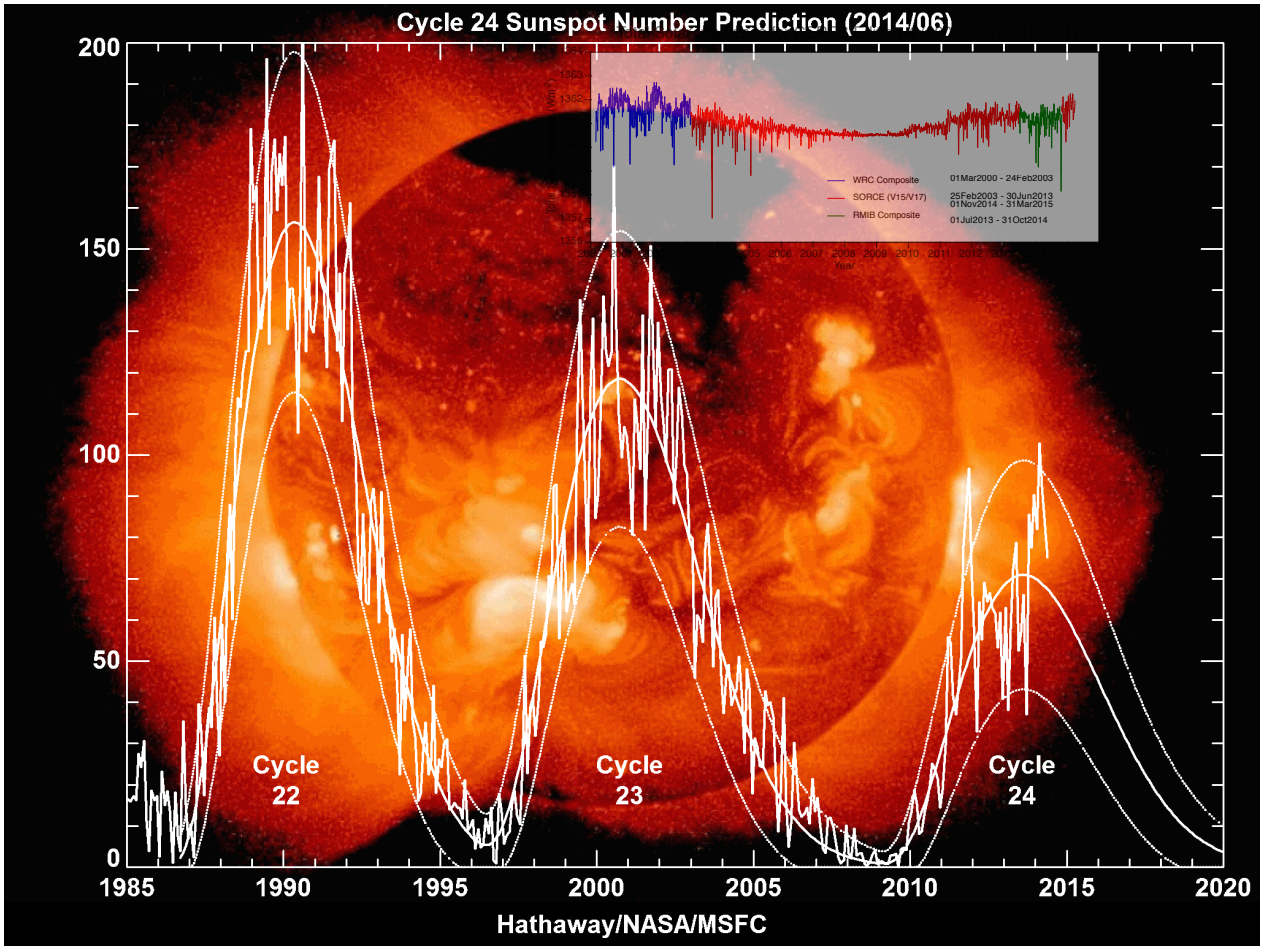
RMIB: 1 value/day, 1 JAN 2015 through 31 Mar 2015

TSI composite data from WRC, SORCE(V15) and RMIB for the Timeframe of CERES Terra, Aqua & NPP

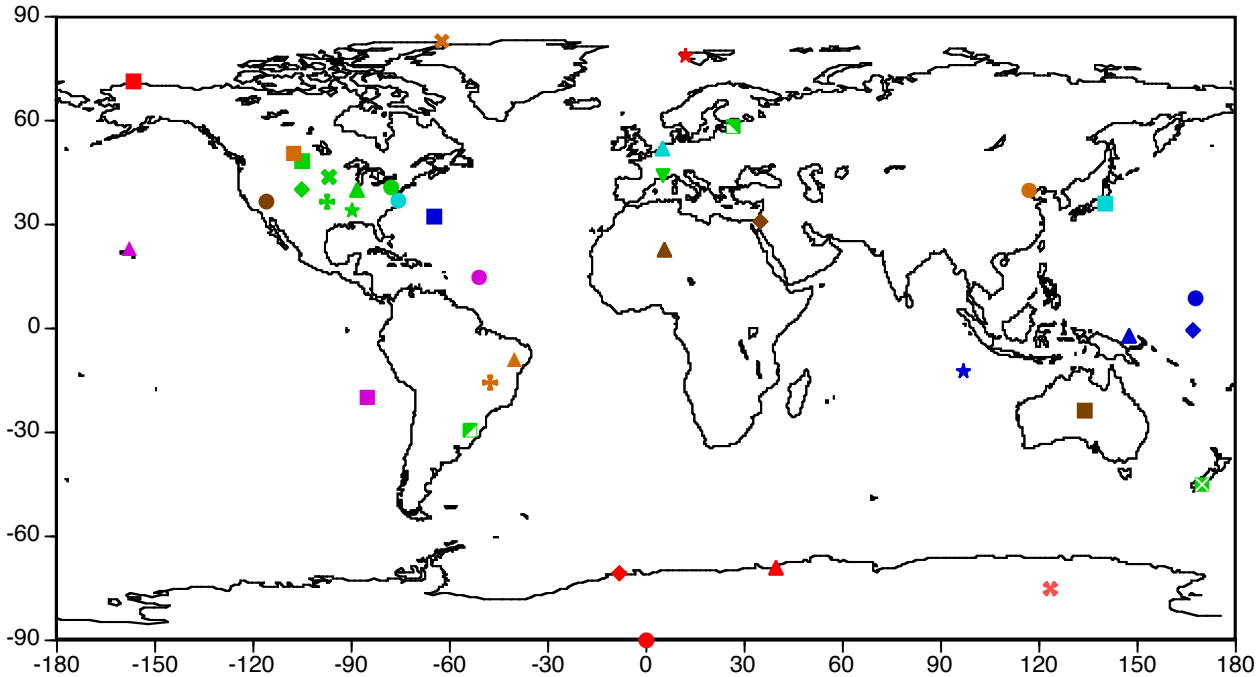


For CERES Ed4, all TSI data are offset to match SORCE TSI Version 15

Sunspot Numbers for Solar Cycles 22, 23 & 24

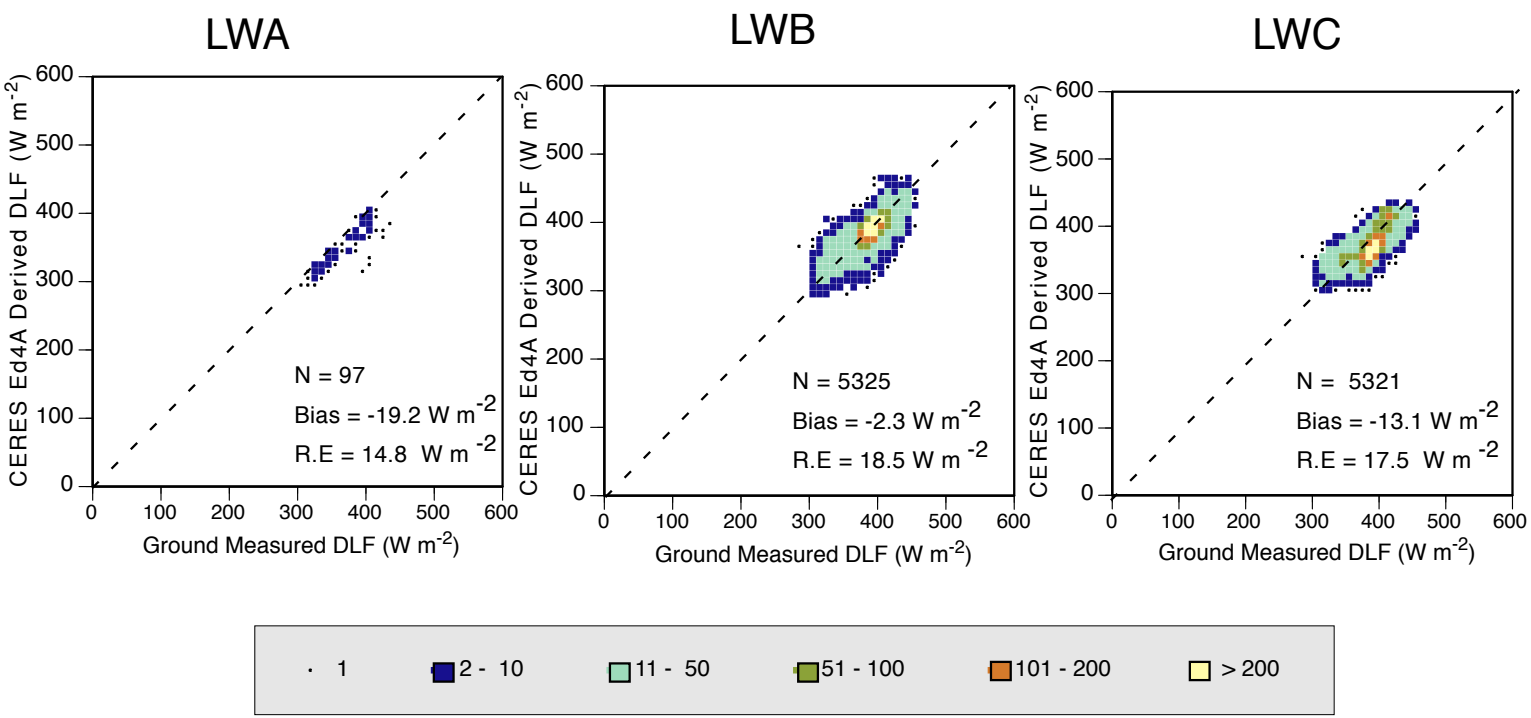


Surface Sites Available for Validation of Ed 4



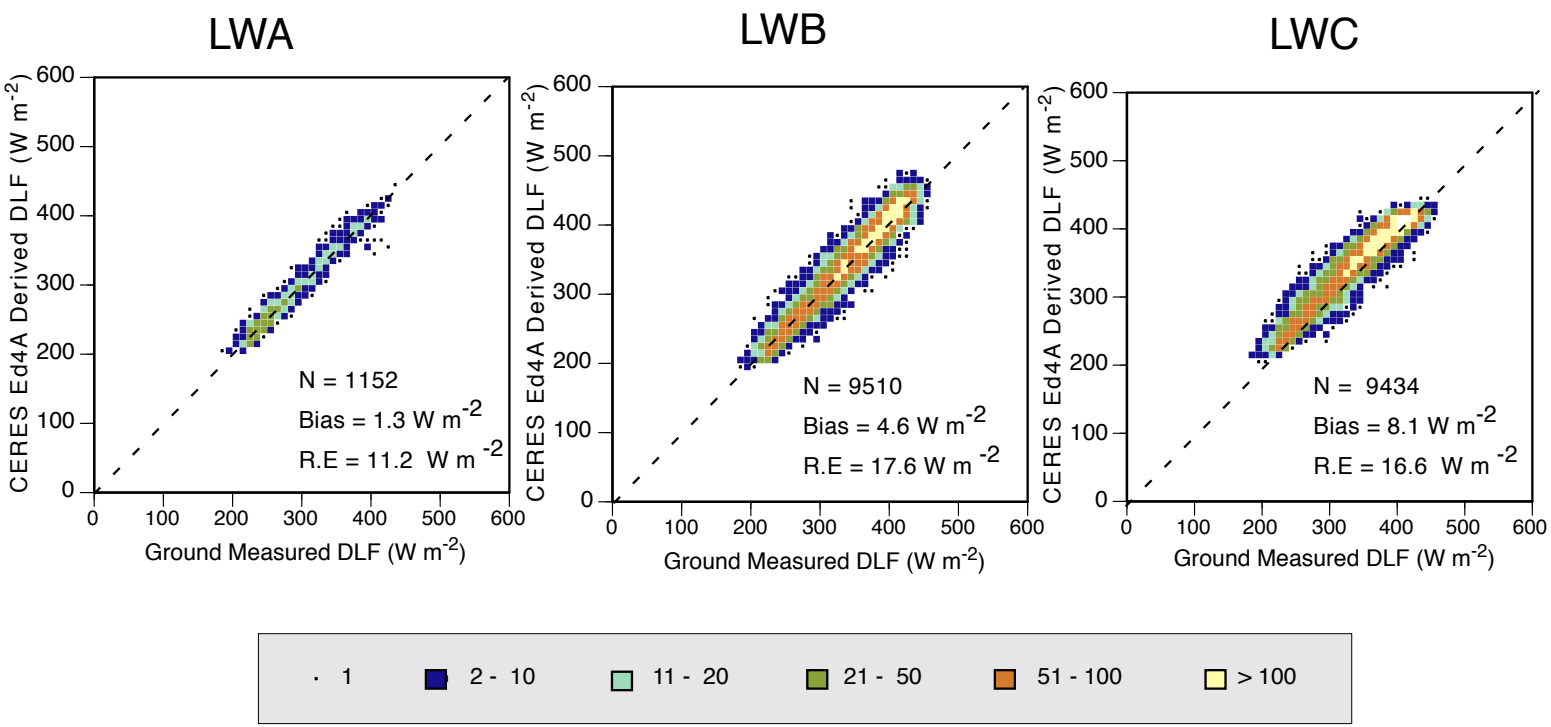
- 48.31N, 105.10W Fort Peck, MT
- 40.72N, 77.93W Penn State, PA
- 40.05N, 88.37W Bondville, IL
- 40.13N, 105.24W Boulder, CO
- 34.25N, 89.87W Goodwin Creek, MS
- 43.73N, 96.92W Sioux Falls, SD
- 36.60N, 97.48W SGP ARM
- 45.03S, 169.7E New Zealand
- 44 N, 5.1E Carpentras, FR
- 29.4S, 53.8W Brazil
- 58.3N, 26.5E Toravere, Estonia
- 32.30N, 64.77W Bermuda
- 8.72N, 167.72E Kwajalein
- 2.06S, 147.42 E Manus
- 0.52S, 166.9 E, Nauru
- 12S 97E Cocos Isl
- 36.05N, 140.13E Tatano
- 36.9N, 75.71W Ches Light
- 51.97N, 4.9E Cabauw, Netherlands
- 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
- 75S 123E Dome Station
- 23.70S, 133.87E Alice Springs
- 36.63N, 116.02W Desert Rock, NV
- 22.78N, 5.52E Algeria
- 30.9N , 34.8E Sede Boger, Israel
- 20.2S, 85.2W WHOI Stratus
- 14.5N, 51W WHOI NTAS
- 22.8N, 157.9W WHOI Hawaii
- 50.2 N, 107.7 W Regina, Canada
- 9.07 S, 40.3 W Petrolina, Brazil
- 39.8N, 116.9E Xianghe, China
- 82.5N. 6.4W Alert, Canada
- 15.6S, 47.7W Brasilia, Brazil

CERES Edition 4 LW Ground Validation (Buoy)



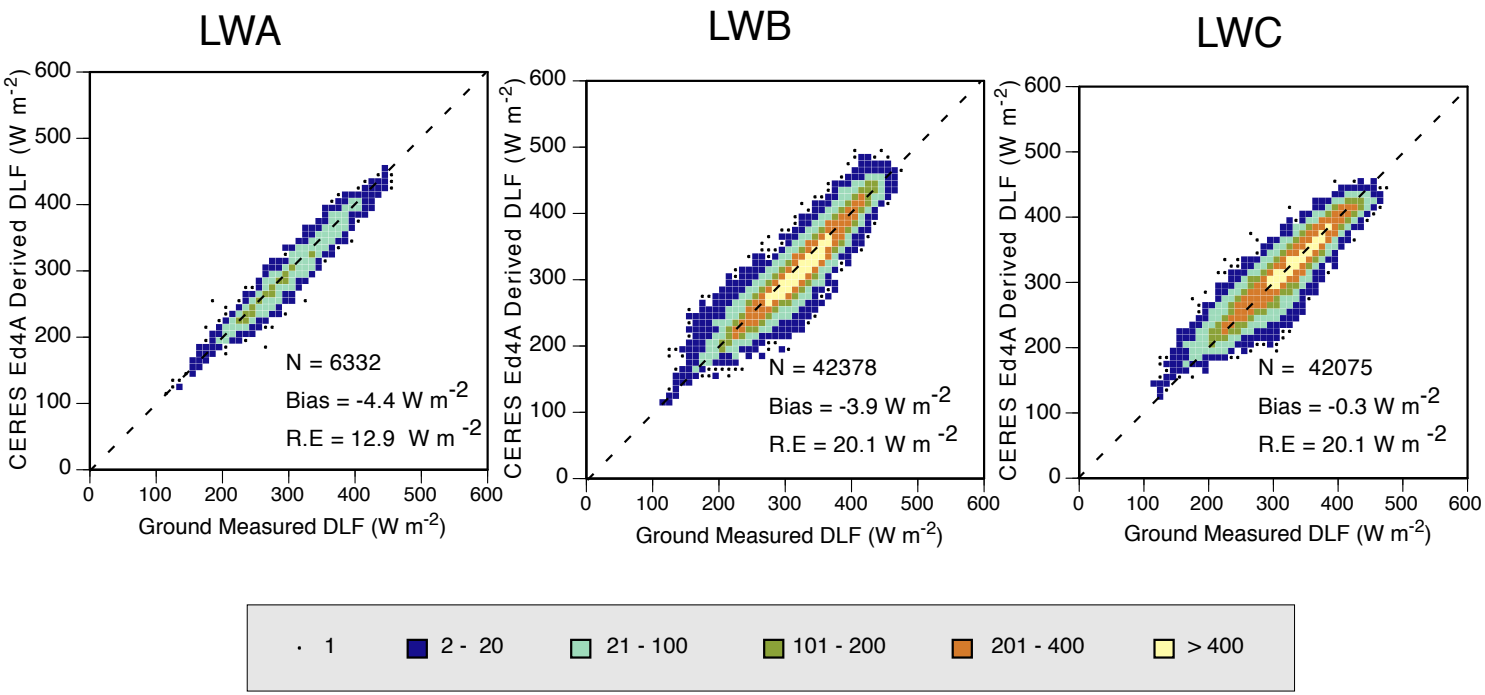
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Coastal)



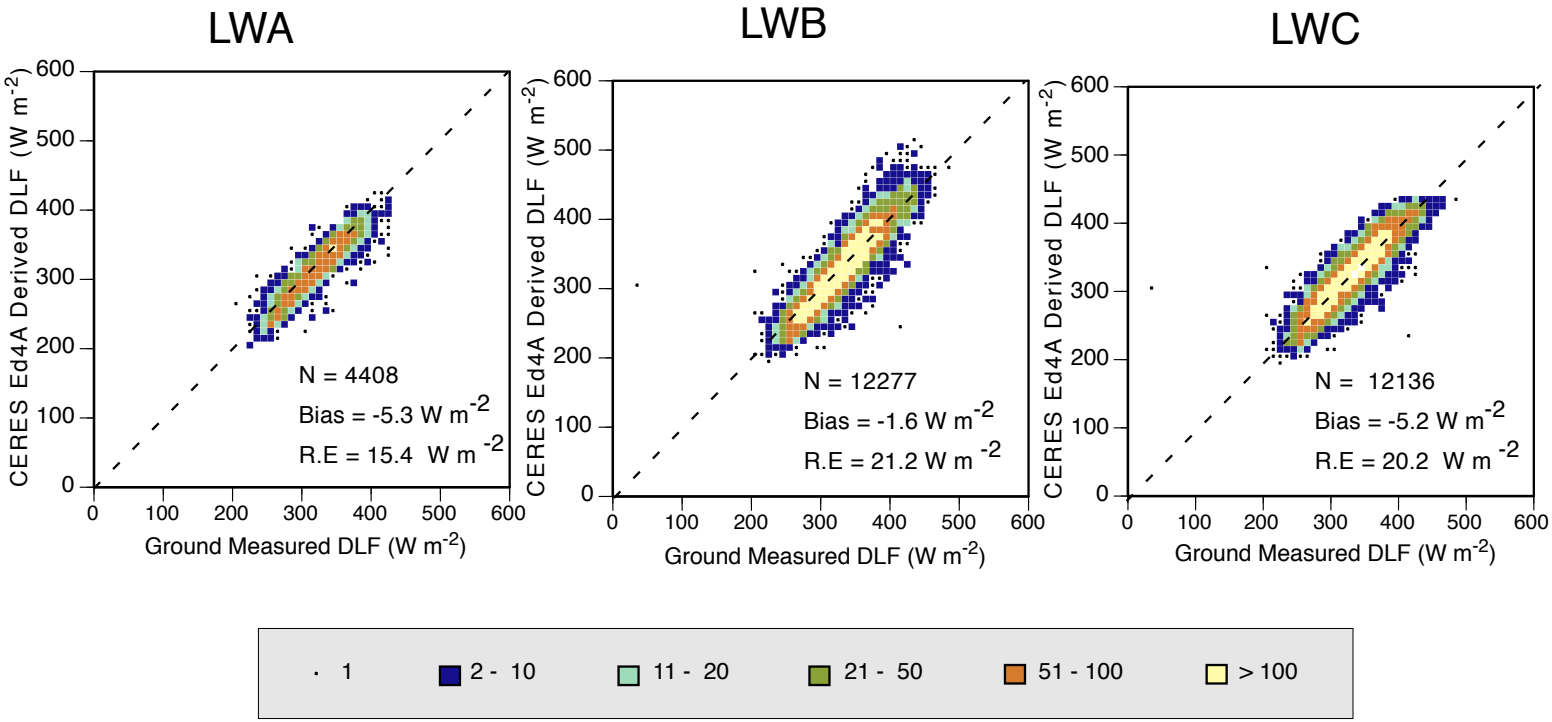
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Continental)



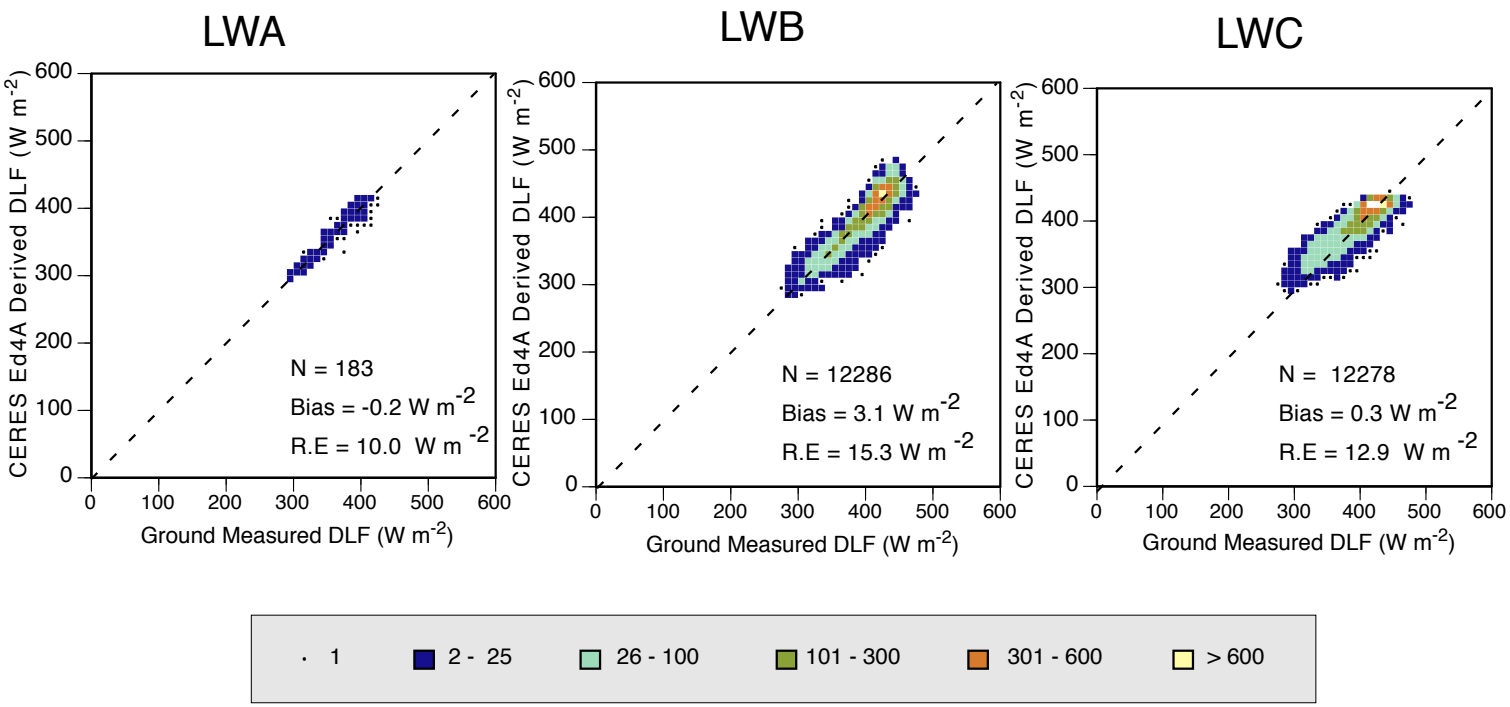
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Desert)



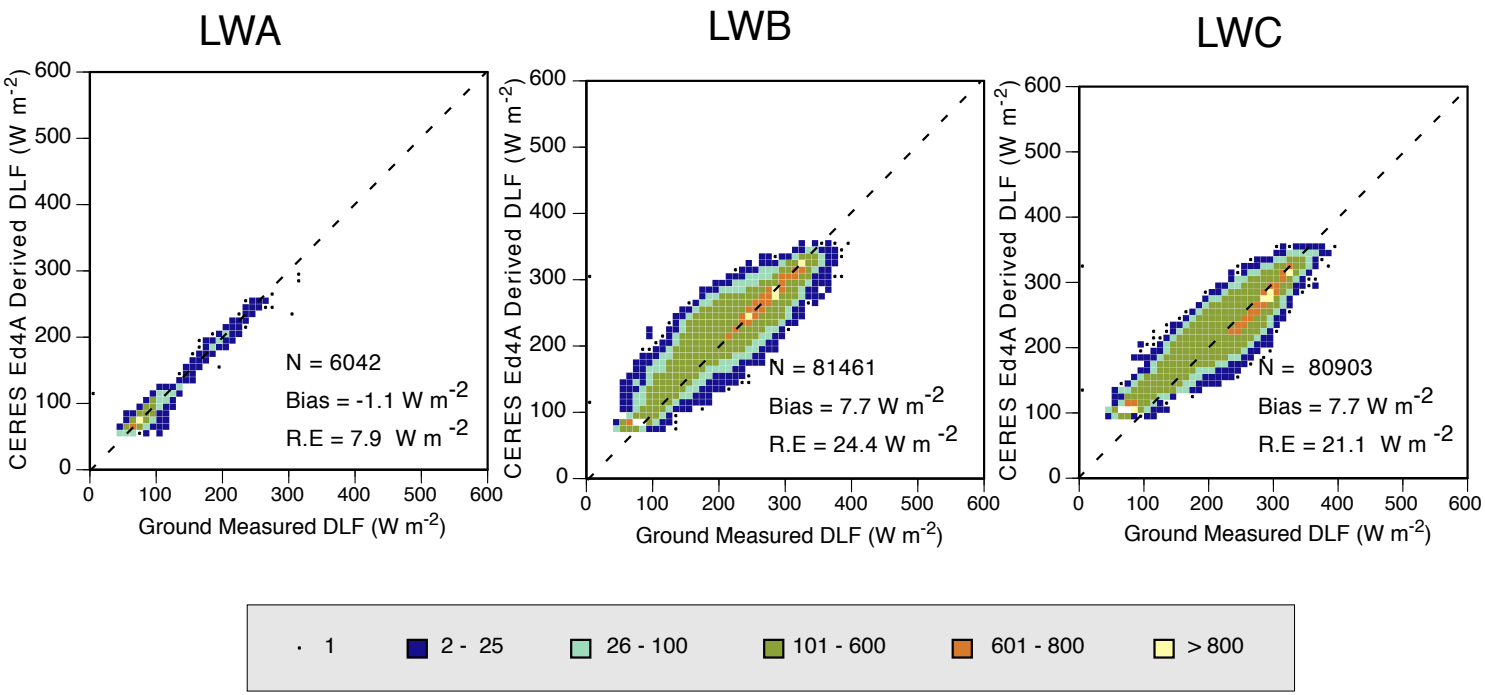
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Island)



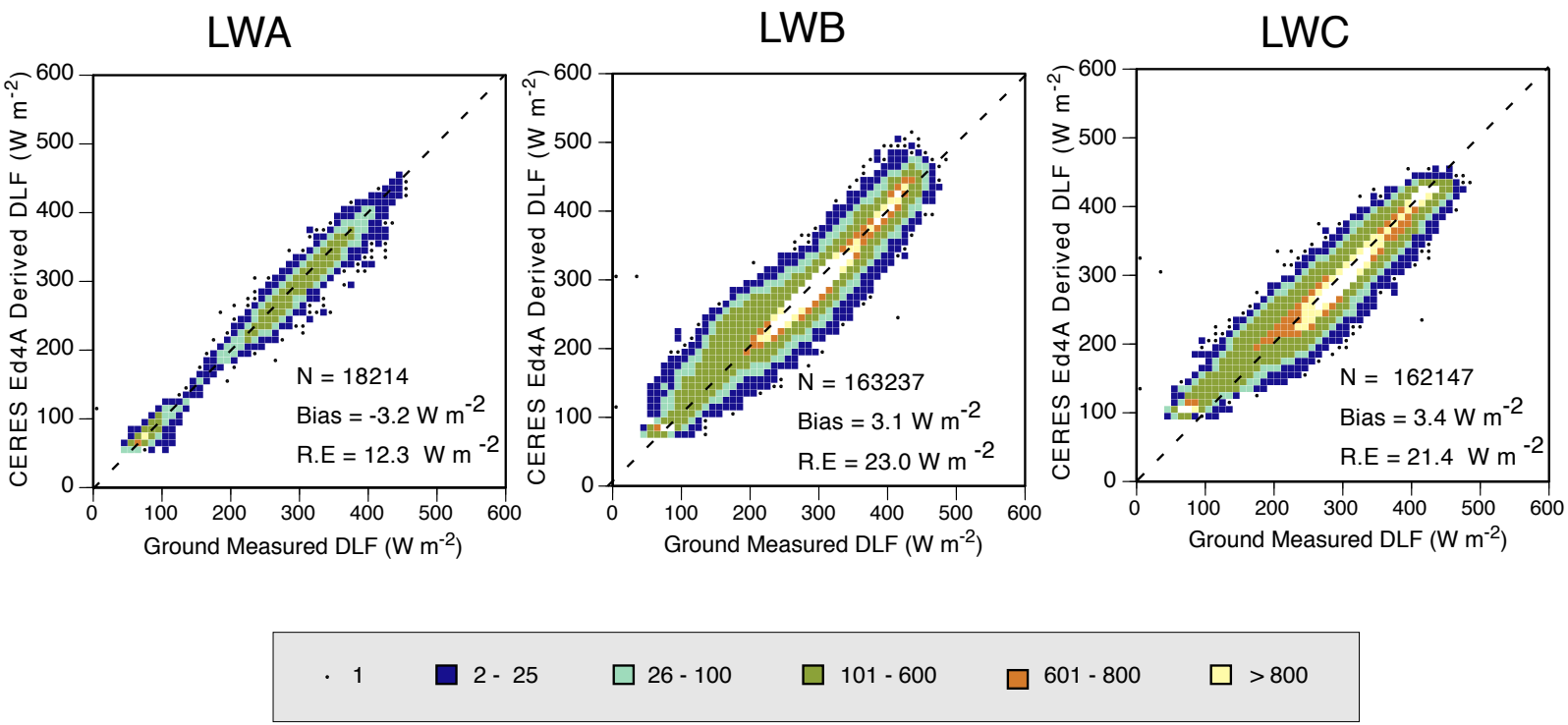
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Polar)



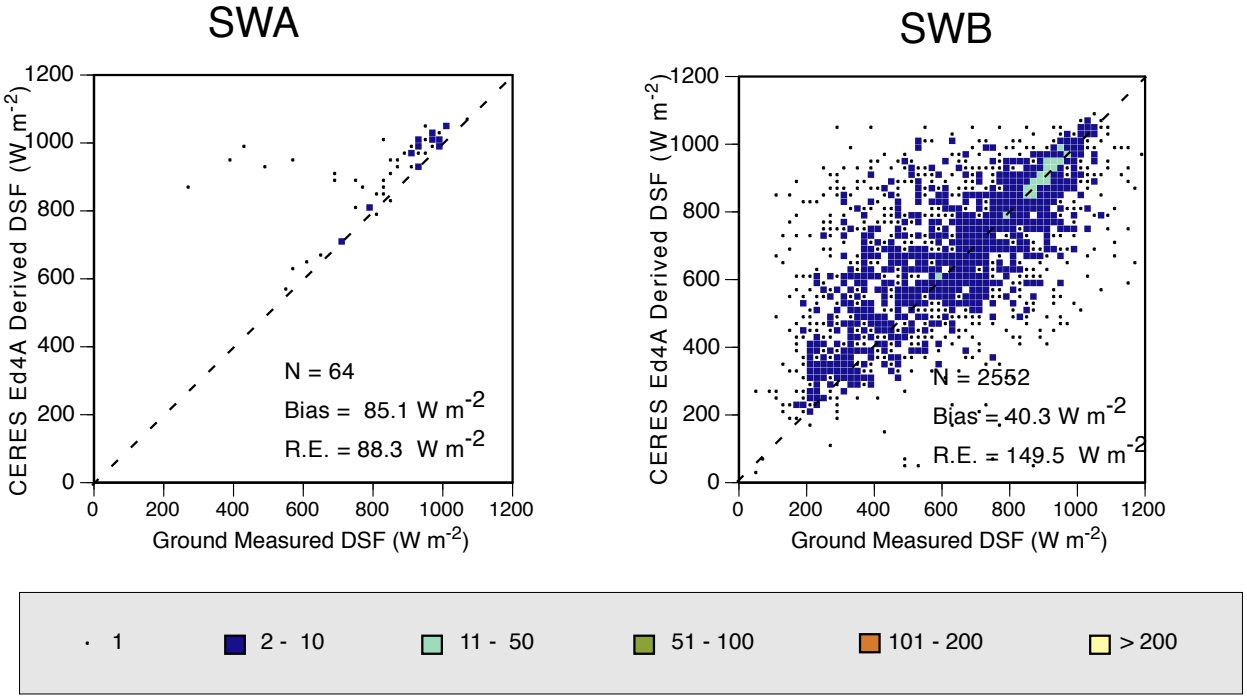
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 LW Ground Validation (Global)



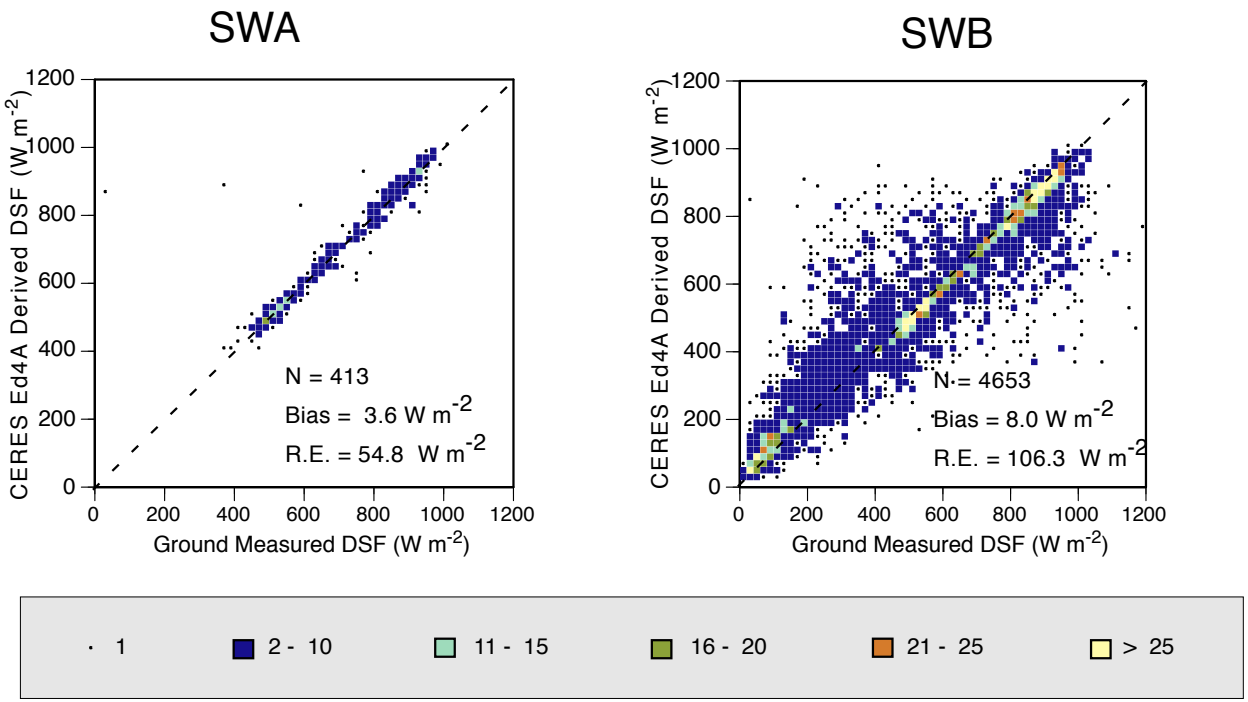
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Buoy)



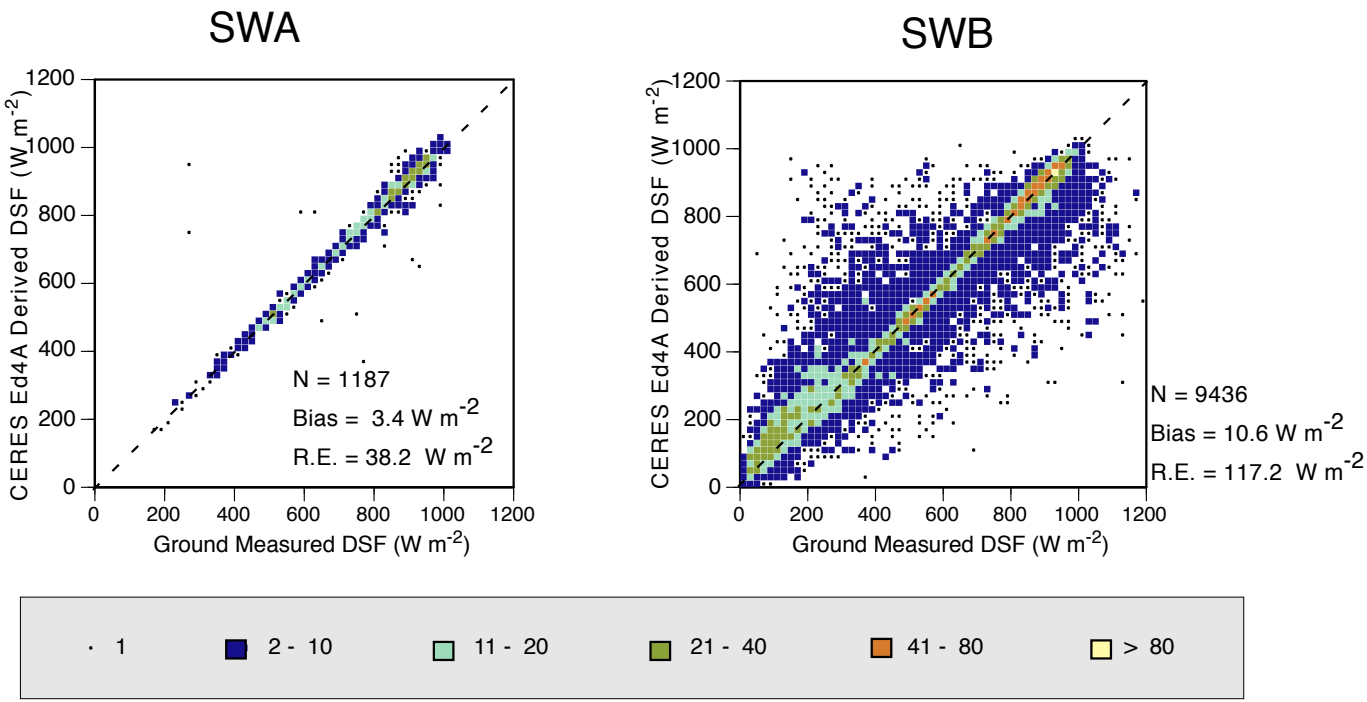
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Coastal)



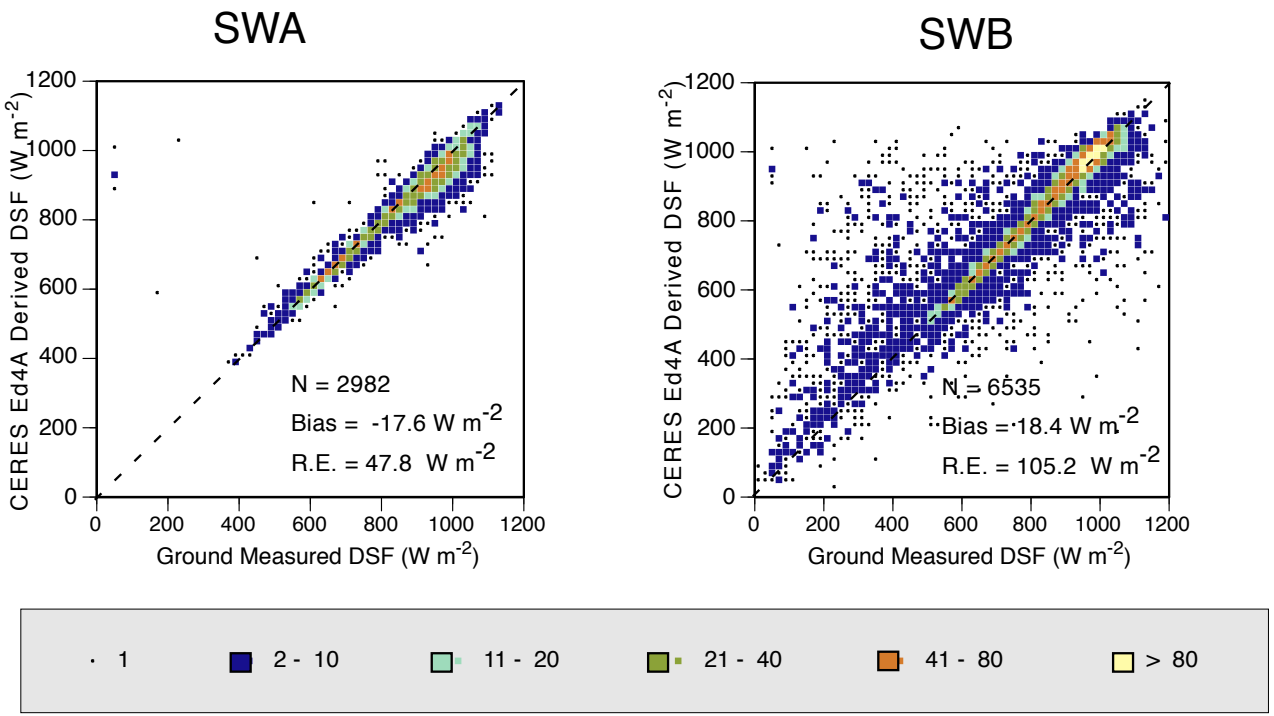
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Continental)



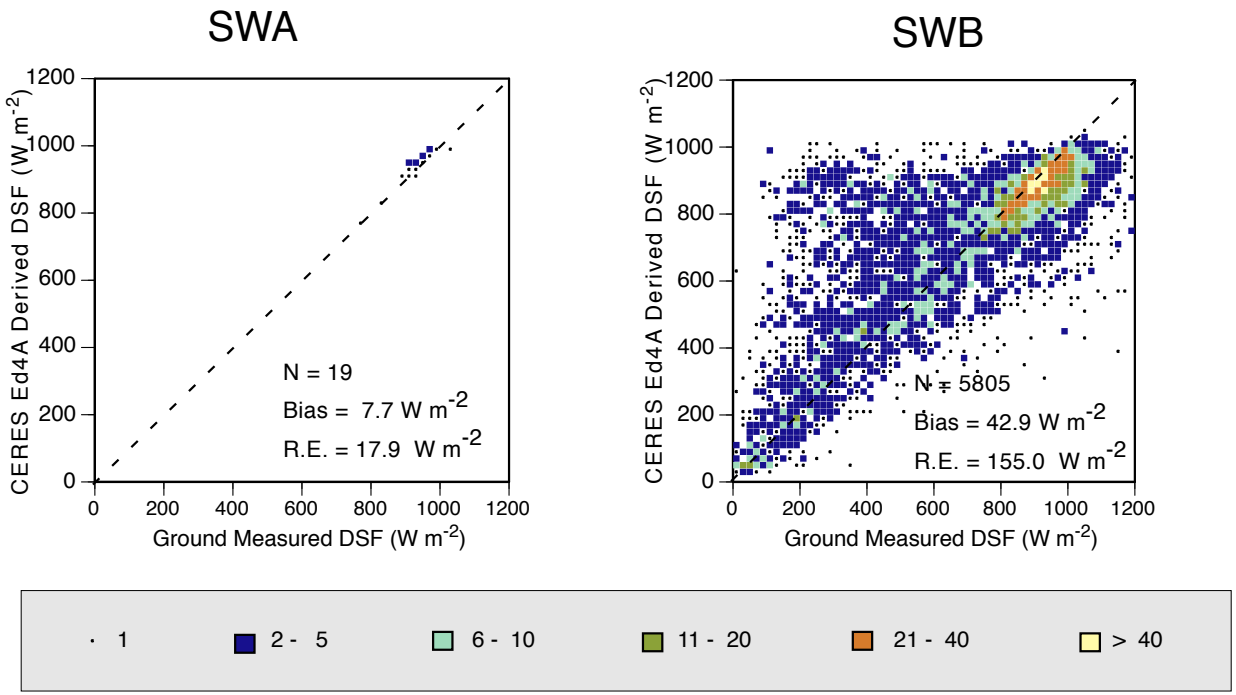
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Desert)



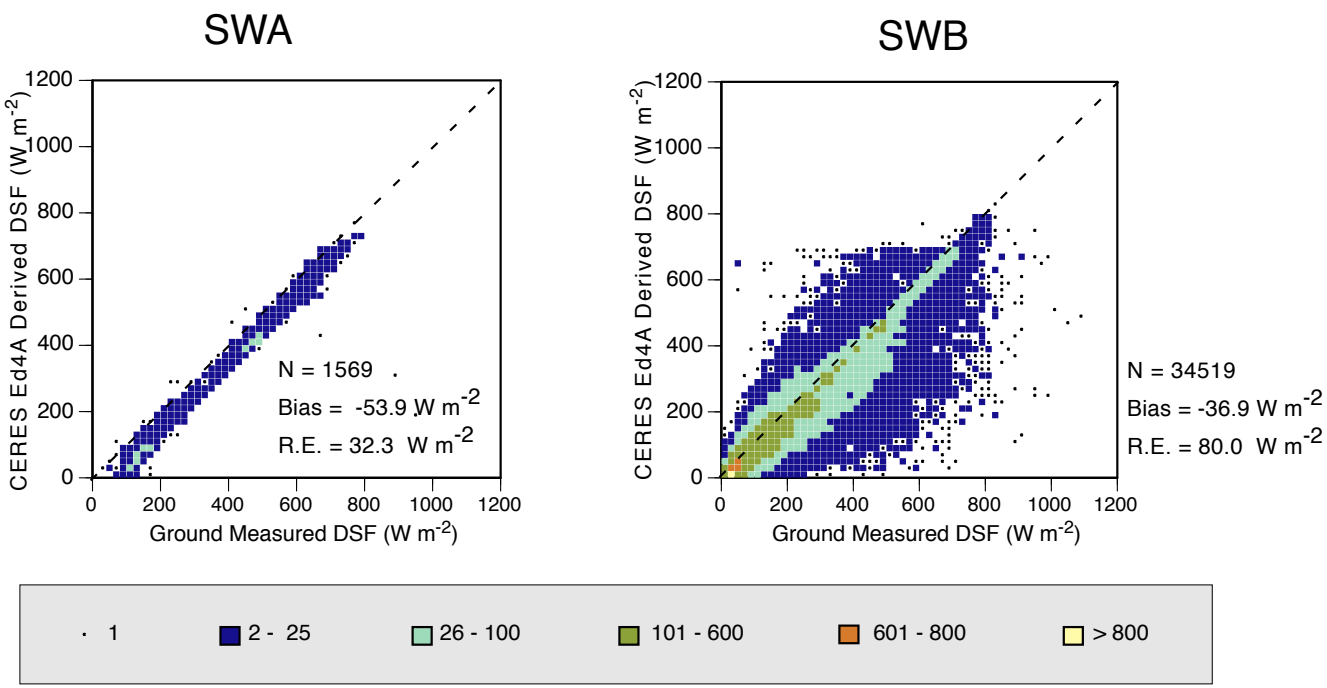
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Island)



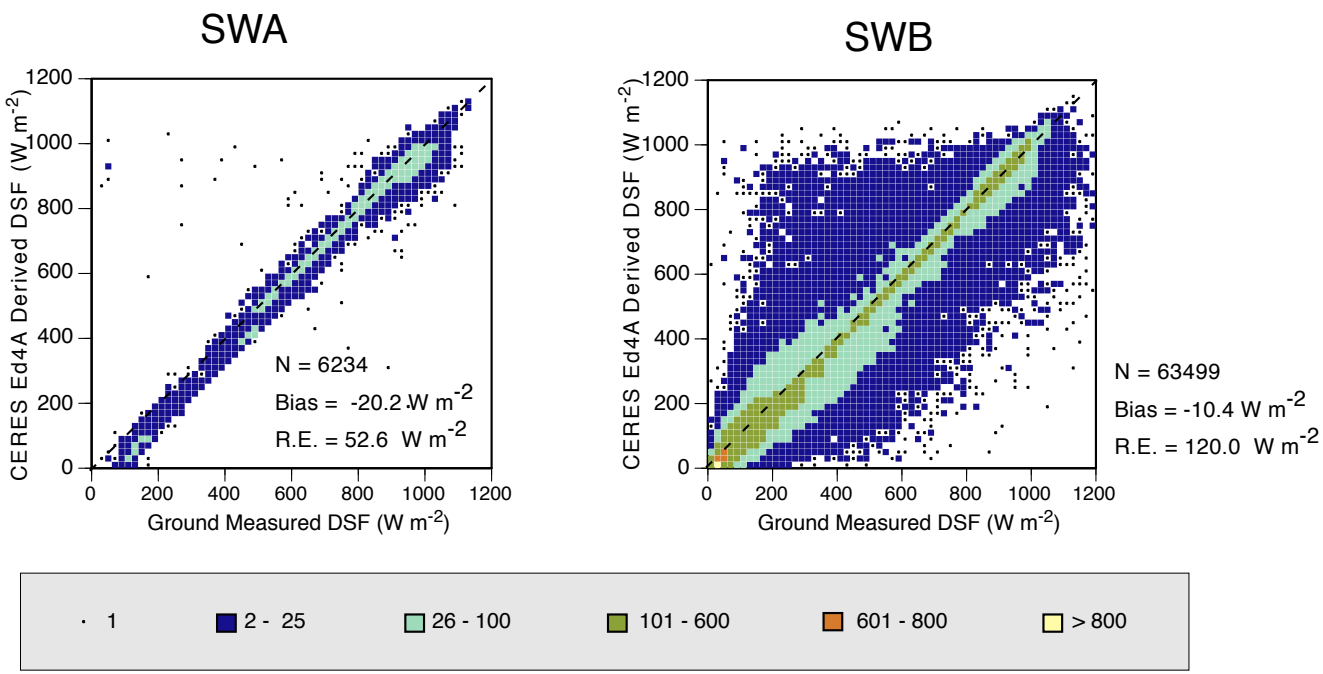
Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Polar)



Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

CERES Edition 4 SW Ground Validation (Global)



Combined LWB Ground Validation for Terra (4/2000 through 7/2008) & Aqua (7/2002 through 7/2008).

Conclusions for SOFA Ed4 algorithms

Previous validation studies have demonstrated that revisions to both the LW algorithms and the SW algorithms (for clear to partly cloudy conditions) appear to be working well, though further revisions to the cloud transmission method and/or overcast albedo method are needed for SW Model B. Our attention for future improvements is focused on deriving a regression fit to the cloud transmission data.

A preliminary analysis of the LW and SW surface only flux algorithm results using the Edition 4 inputs, especially those from the Clouds Subsystem (See results from the 22nd CERES Science Team Meeting), indicated improved accuracies for most locations.

Comparisons of orbital characteristics of NPP with CERES FM5 to Aqua with CERES FM3

Aqua (Launch 4-May-2002)
COSPAR ID = 2002-022-A
701 X 703 km 98.2087° orbit
14.57091655 revolutions/day
Period = 98.827002 minutes

NPP (Launch: 28-October-2011)
COSPAR ID = 2011-061-A
825 X 828 km 98.7483° orbit
14.19543342 revolutions/day
Period = 101.441070 minutes

Period(NPP) – Period(Aqua) = 2.614068 minutes
Time to realign orbits = 63.9177 hours
Orbital Data as of 24-Sep-2014

Comparisons of orbital characteristics of NPP with CERES FM5 to Aqua with CERES FM3

Aqua (Launch 4-May-2002)
COSPAR ID = 2002-022-A
701 X 704 km 98.2002° orbit
14.57108656 revolutions/day
Period = 98.825849 minutes

NPP (Launch: 28-October-2011)
COSPAR ID = 2011-061-A
826 X 827 km 98.6944° orbit
14.19579617 revolutions/day
Period = 101.438480 minutes

Period(NPP) – Period(Aqua) = 2.612631 minutes
Time to realign orbits = 63.9505 hours
Orbital Data as of 24-Apr-2015
Time to realign orbits has increased by nearly 2 minutes over the past 7 months