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 Total Solar Irradiance (TSI) Measurements

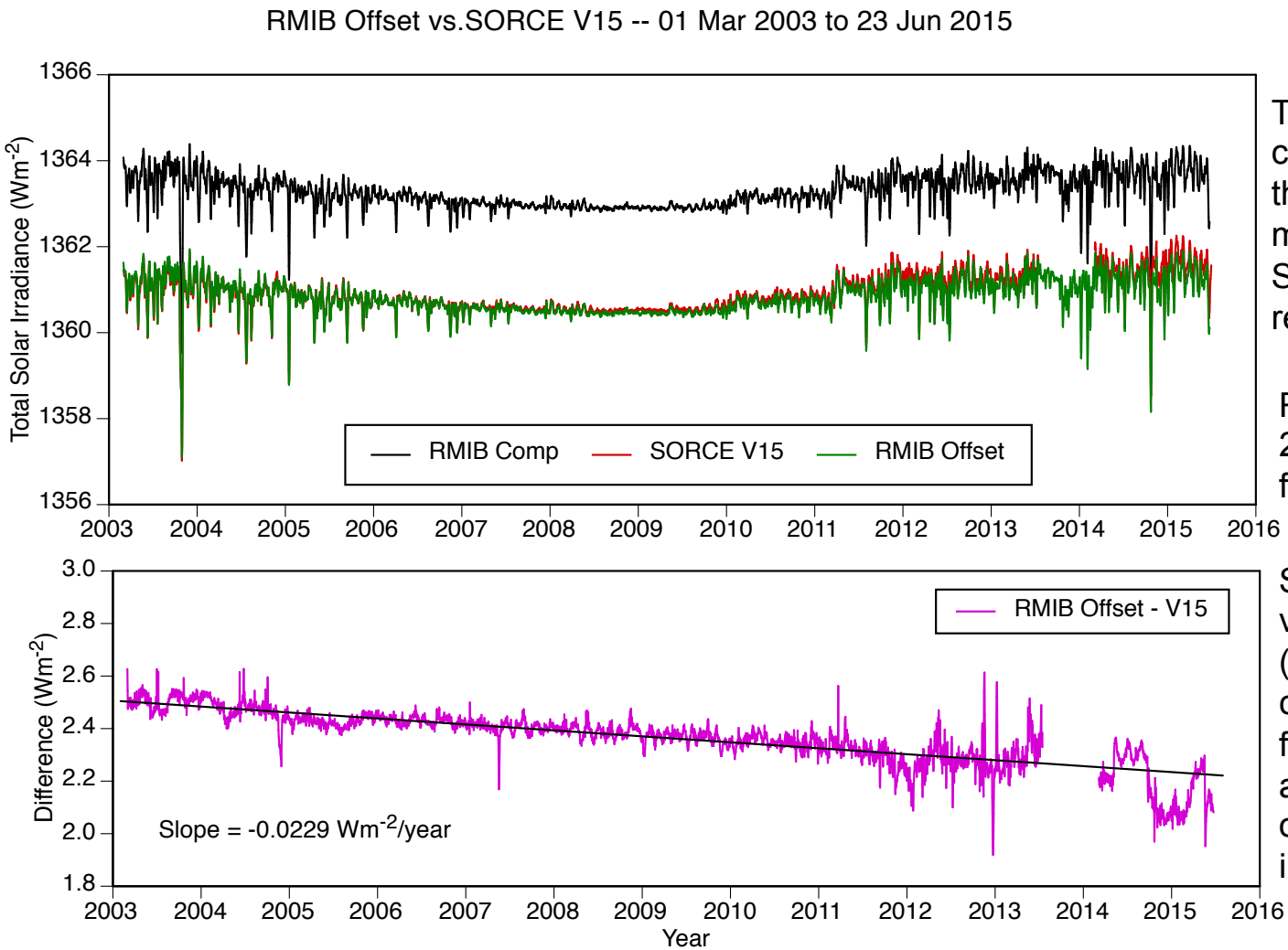
The SORCE TIM (Total Irradiance Monitor) began producing TSI data on February 25, 2003; however, a battery failure on SORCE halted regular production from July 2013 through February 2014. As a result, we began incorporating the RMIB composite TSI data from S. DeWitte.

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, 2014.

Comparison of SORCE(V15) and RMIB for the timeframe: 1-Mar-2003 to 30-Jun-2013

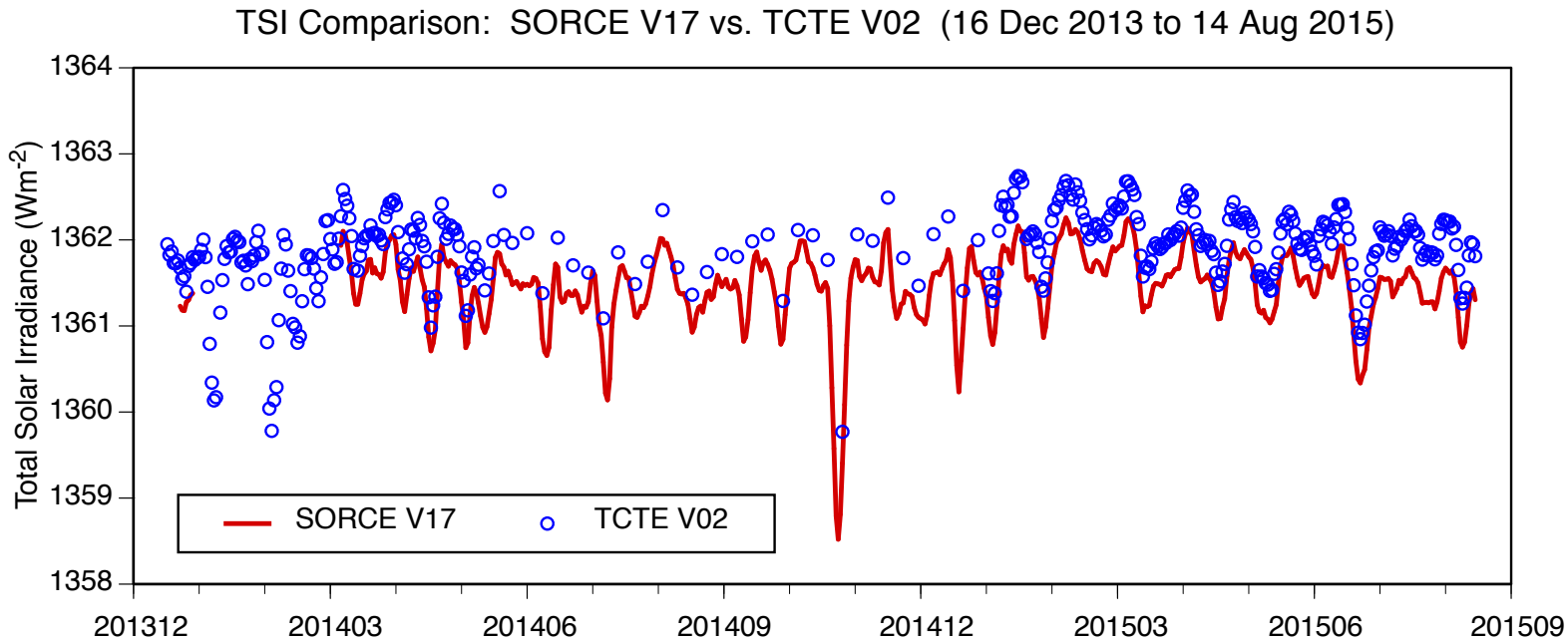


This timeframe corresponds to the first 148 months of the SORCE data record

RMIB offset by 2.4447 W/m^2 from SORCE

Slope of RMIB versus SORCE (-0.0229 W/m^2) corresponds to first 120 months and yields an offset of 1 W/m^2 in 43.67 years

Comparison of SORCE(V17) and TCTE(V02) Total Solar Irradiance Retrievals



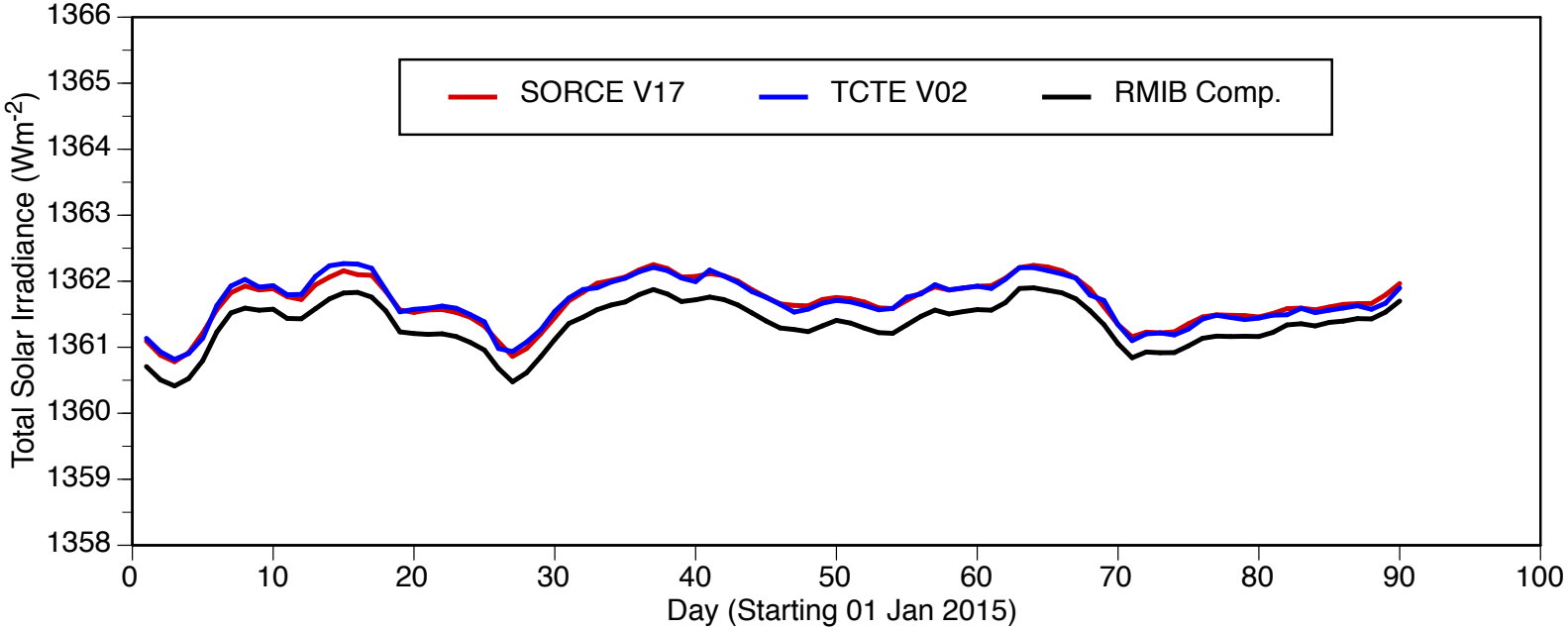
SORCE: 1 value/day, Dec 22, 2013 through Dec 28, 2013, and 1 value/day Mar 5, 2014 through Aug 31, 2014; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

TCTE: 1 value/day, Dec 16, 2013 through May 8, 2014, 1 value/week May 11, 2014 through Aug 31, 2014, 1 value/day Jan 1, 2015 through Aug 14, 2015; Absolute Accuracy: ±1.36 W/m^2 at 1361 W/m^2

Average of SORCE minus TCTE (Jan 1, 2015 to Jul 31, 2015) is -0.4713 W/m^2

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

SORCE V17, TCTE V02, and RMIB Comp. Offset to Match SORCE V15

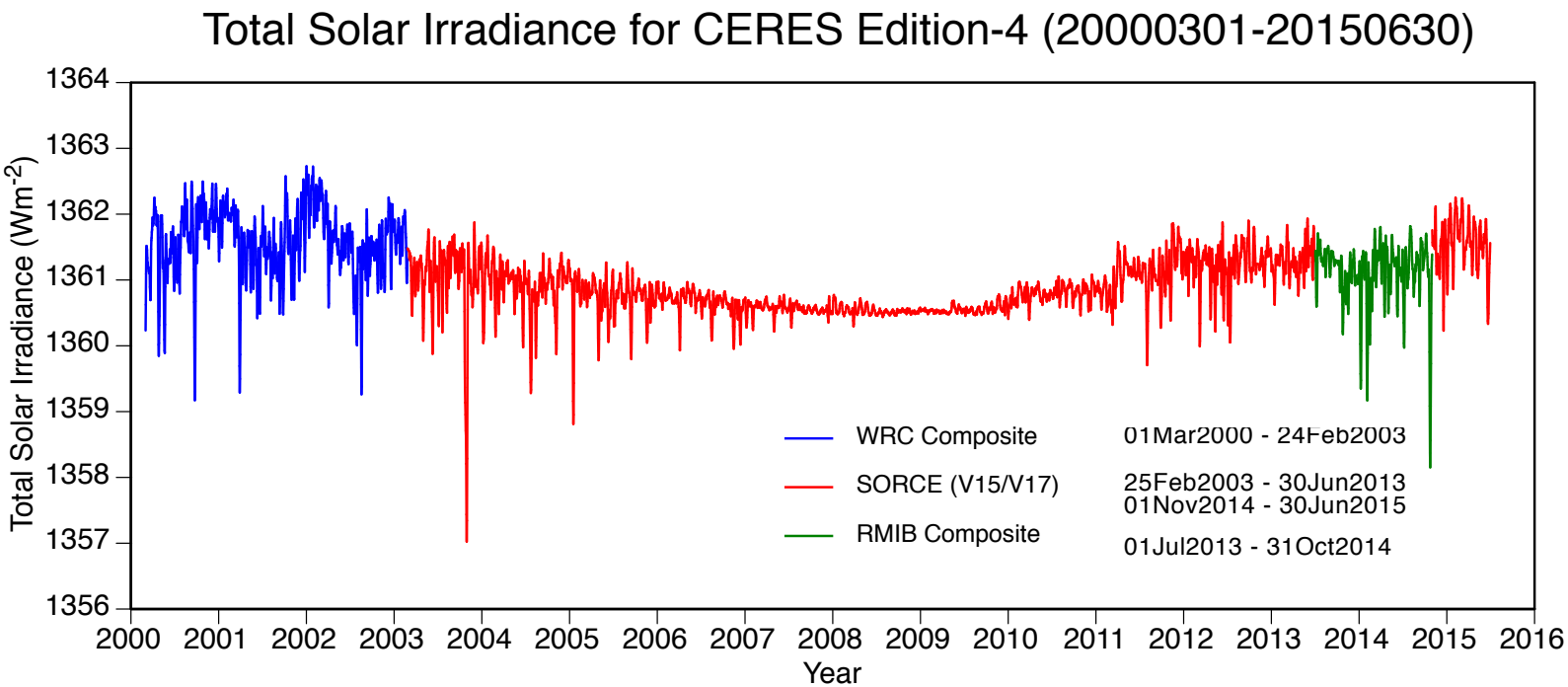


SORCE V17: 1 value/day, Jan 1, 2015 through Mar 31, 2015, Absolute Accuracy: 425 ppm or ±0.58 W/m^2 at 1361 W/m^2 (Abs. Accuracy was 350 ppm or ±0.48 W/m^2 before Oct 31, 2012) [Offset to SORCE V15 Mar 1, 2003 to Jun 30, 2013]

TCTE V02: 1 value/day, Jan 1, 2015 through Mar 31, 2015; Absolute Accuracy: 100 ppm or ±1.36 W/m^2 at 1361 W/m^2 [Offset to SORCE V15 1 Jan 2015 to Mar 31, 2015]

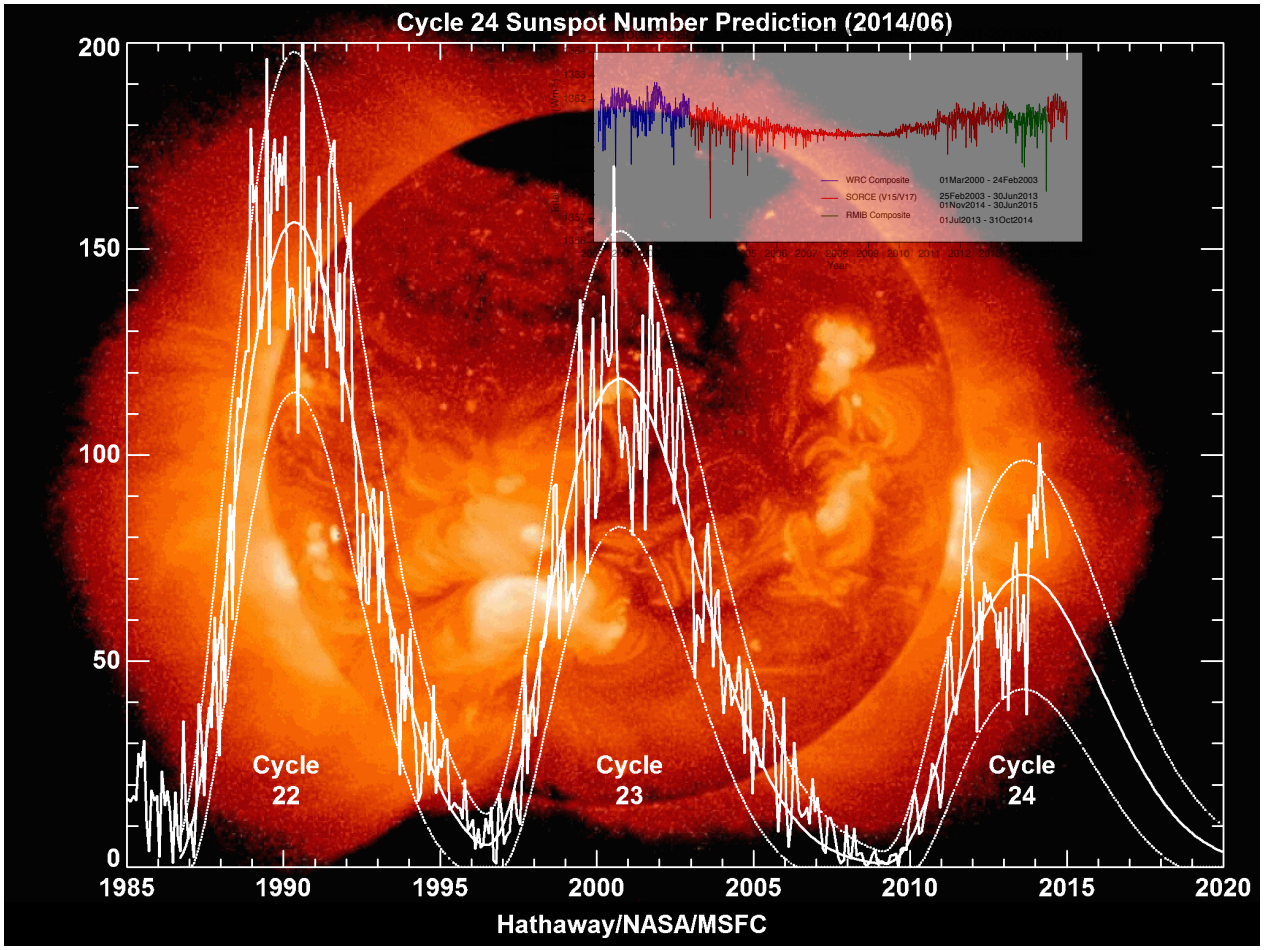
RMIB: 1 value/day, 1 Jan 2015 through 31 Mar 2015 [Offset to SORCE V15 Mar 1, 2003 to Jun 30, 2013]

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

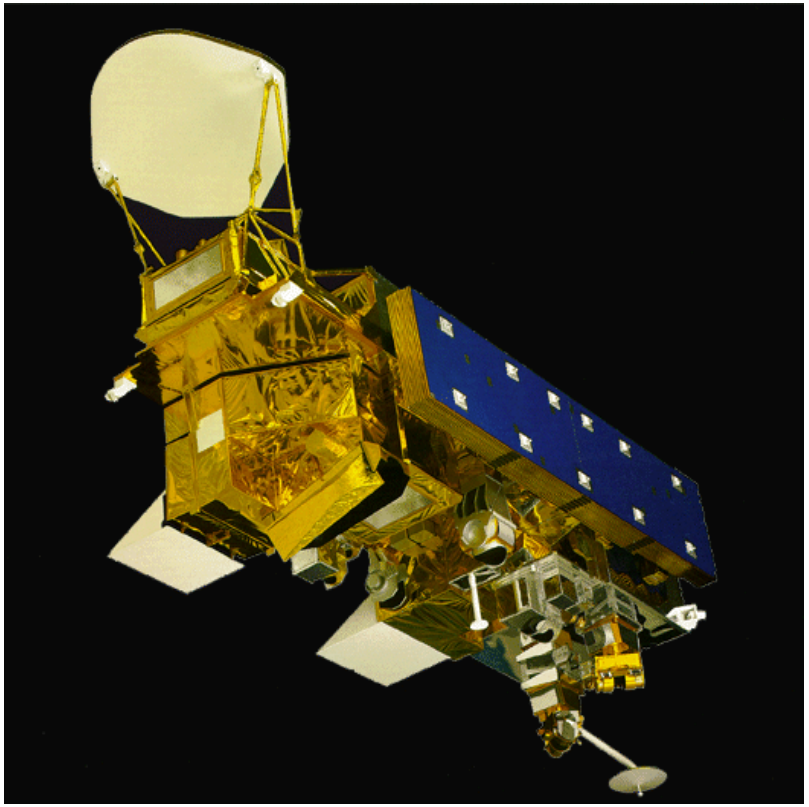


For CERES Ed4, all TSI data are offset to match SORCE TSI Version 15

Sunspot Numbers for Solar Cycles 22, 23 & 24



Comparison of Derived SW and LW Surface Fluxes
NPP versus Aqua



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

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

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

Period(NPP) – Period(Aqua) = 2.614068 minutes
Time between simultaneous nadir overpass = 63.9177 hours
Orbital Data downloaded September 24, 2014

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

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

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

Period(NPP) – Period(Aqua) = 2.612631 minutes
Time between simultaneous nadir overpass = 63.9505 hours
Orbital Data downloaded April 24, 2015

Time between simultaneous nadir overpass increased by nearly 2 minutes during this 7 month period.

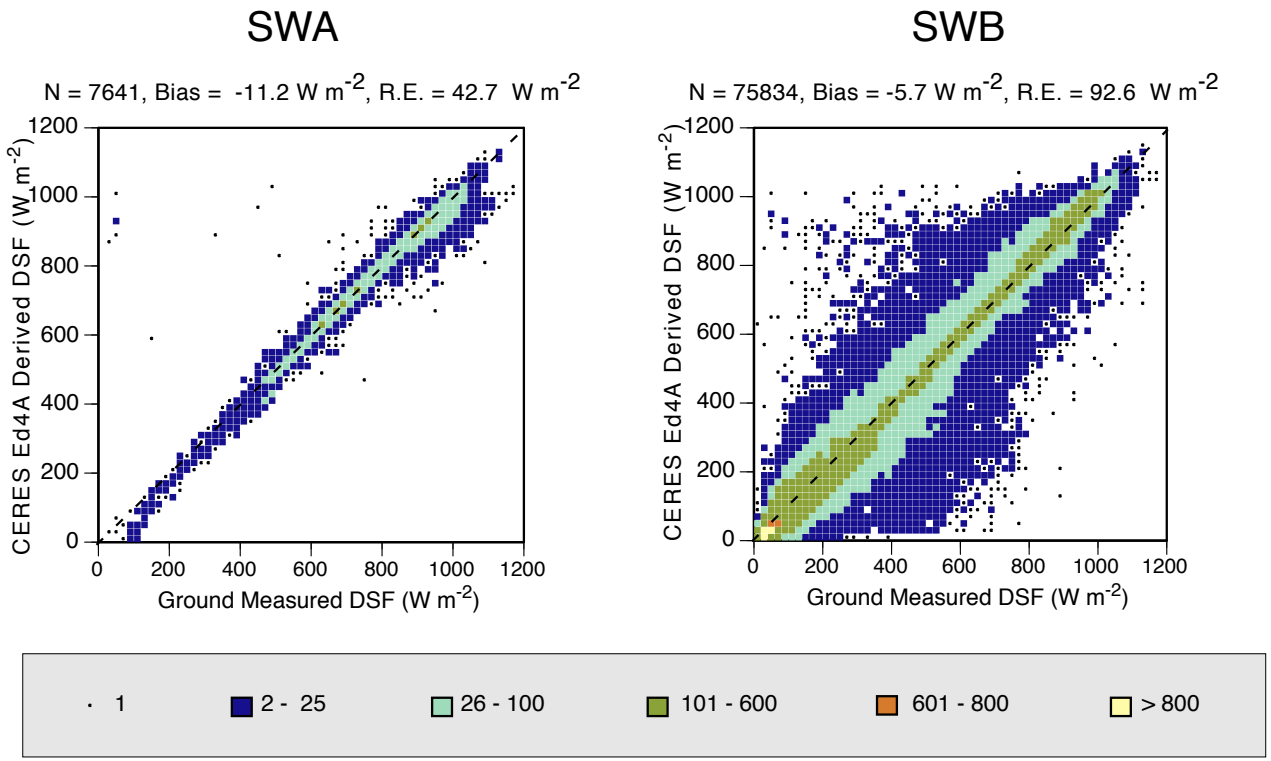
Comparisons of orbital characteristics of NPP with CERES FM5 to Aqua with CERES FM3

NPP (Launch: October 28, 2011)
COSPAR ID = 2011-061-A
826 X 827 km 98.7006° orbit
14.19567430 revolutions/day
Period = 101.439350 minutes

Aqua (Launch: May 4, 2002)
COSPAR ID = 2002-022-A
701 X 704 km 98.1981° orbit
14.57120602 revolutions/day
Period = 98.825039 minutes

Period(NPP) – Period(Aqua) = 2.614313 minutes
Time between simultaneous nadir overpass = 63.9094 hours
Orbital Data downloaded August 24, 2015
Time between simultaneous nadir overpass decreased by 2 minutes 40 seconds during this 4 month period.

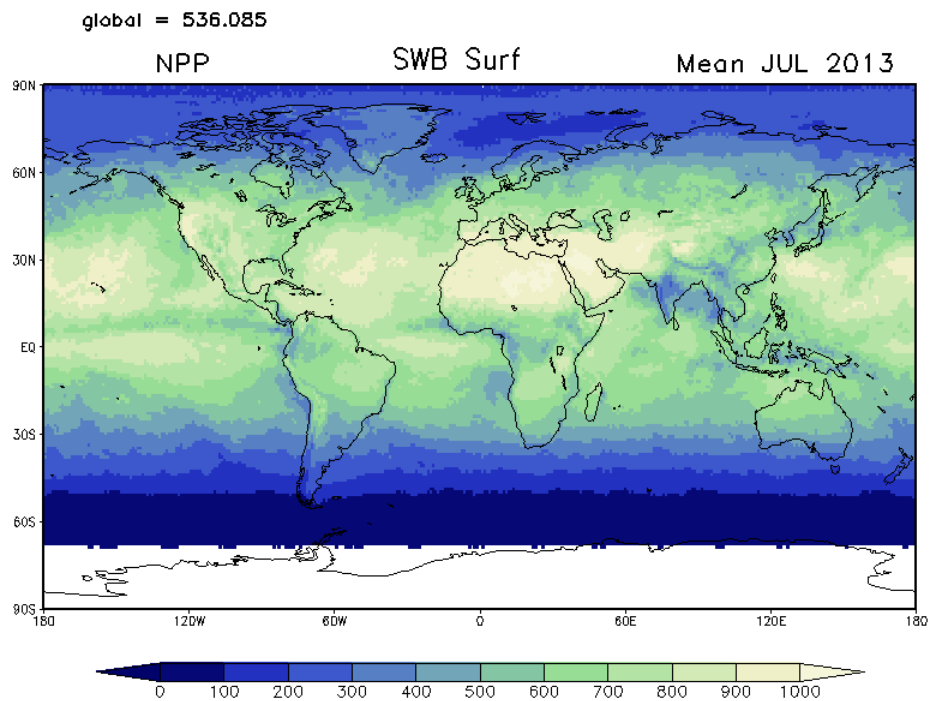
CERES Edition 4 SW Ground Validation (Global)



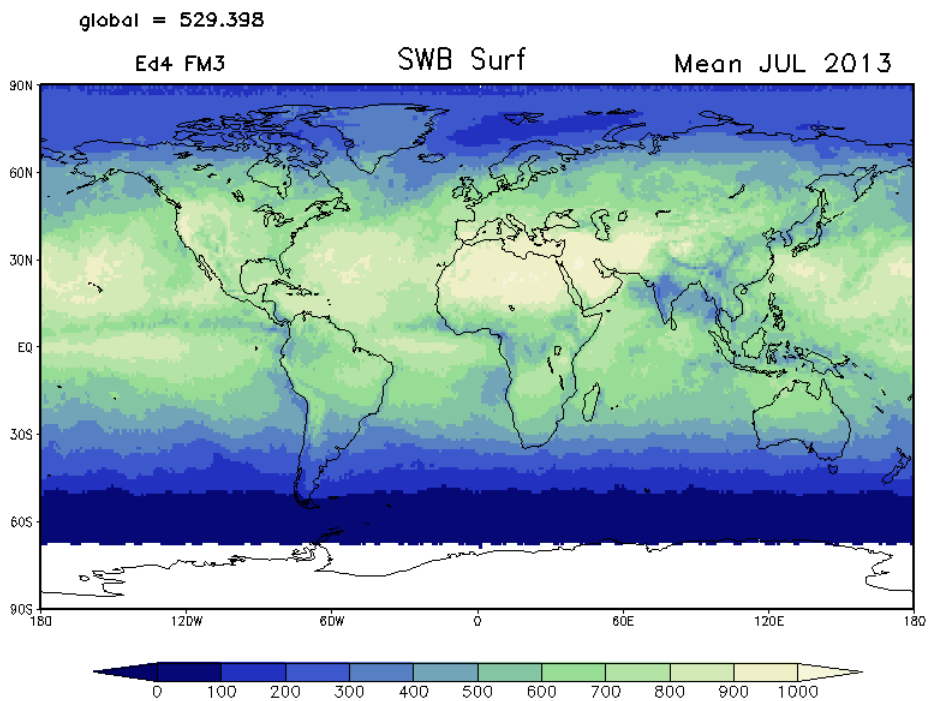
Combined SWB Ground Validation for Terra (4/2000 through 12/2011) & Aqua (7/2002 through 12/2011).

Comparison of SW Surface Fluxes from NPP and Aqua FM3 for July 2013

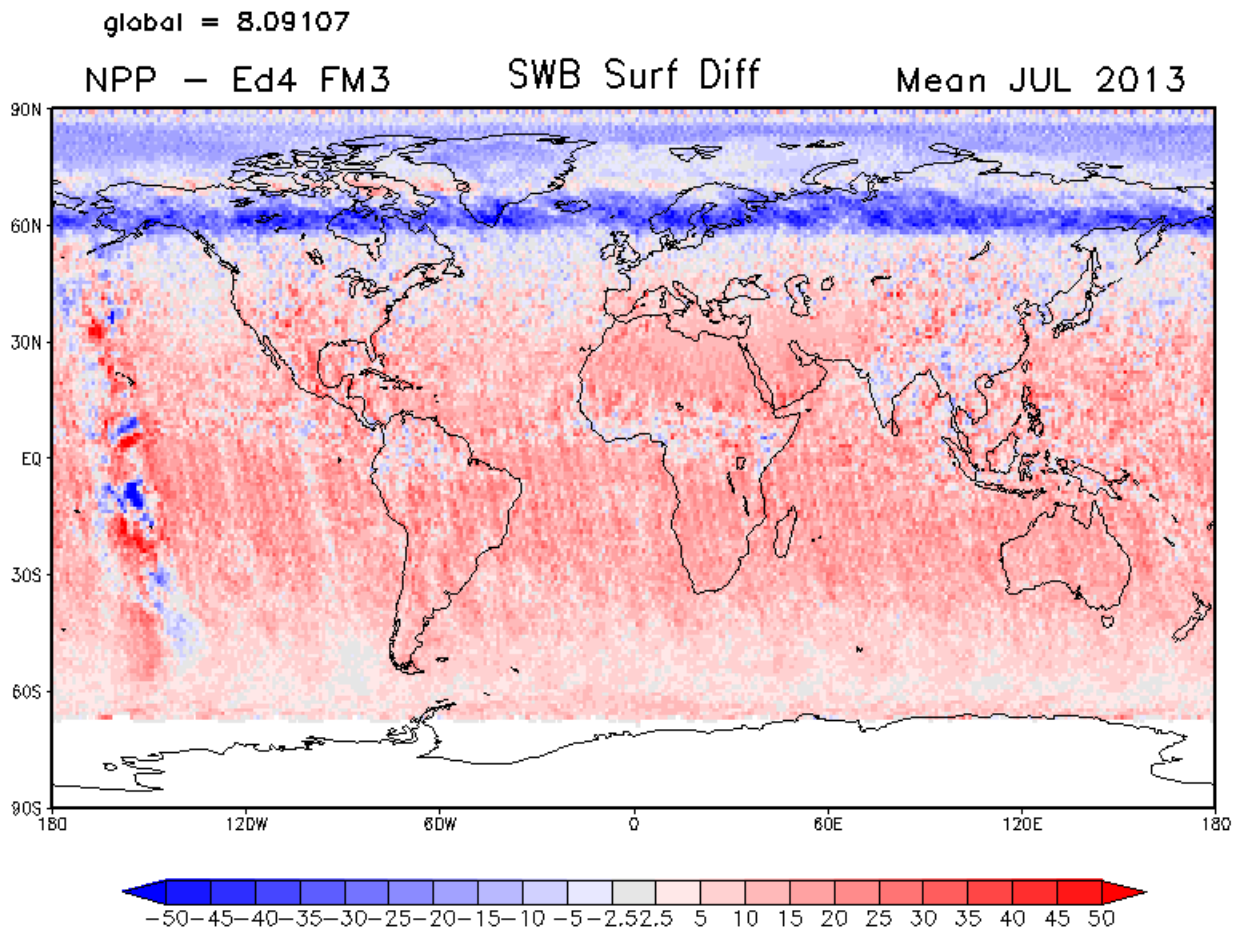
NPP SW Surface Flux W/m^2



Aqua SW Surface Flux W/m^2

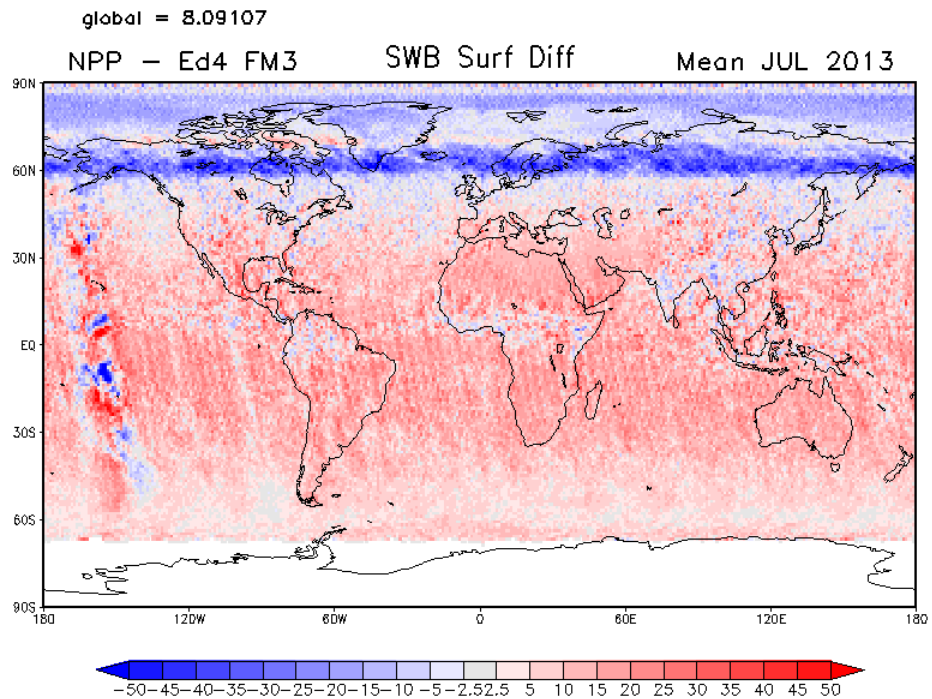


SW Surface Flux Differences between NPP and Aqua FM3 for July 2013

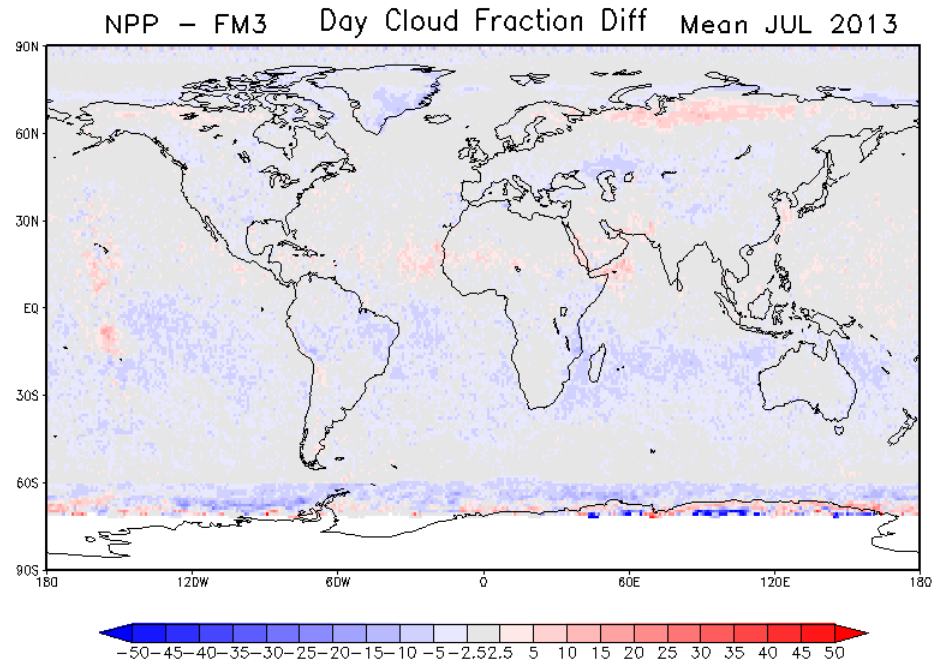


SW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for July 2013

SW Surface Difference W/m^2

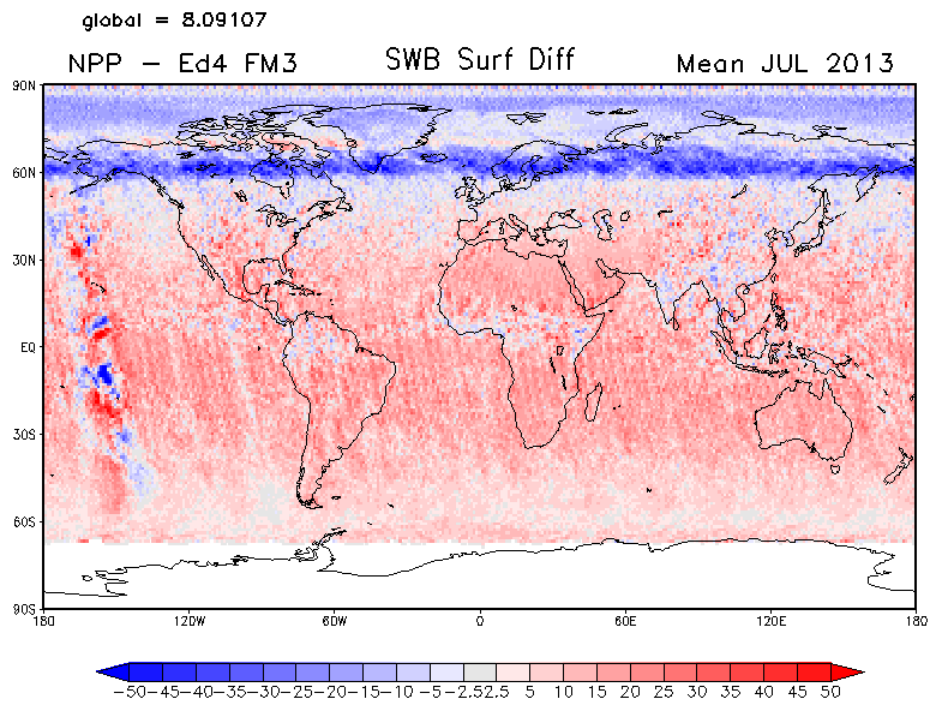


Cloud Fraction Difference

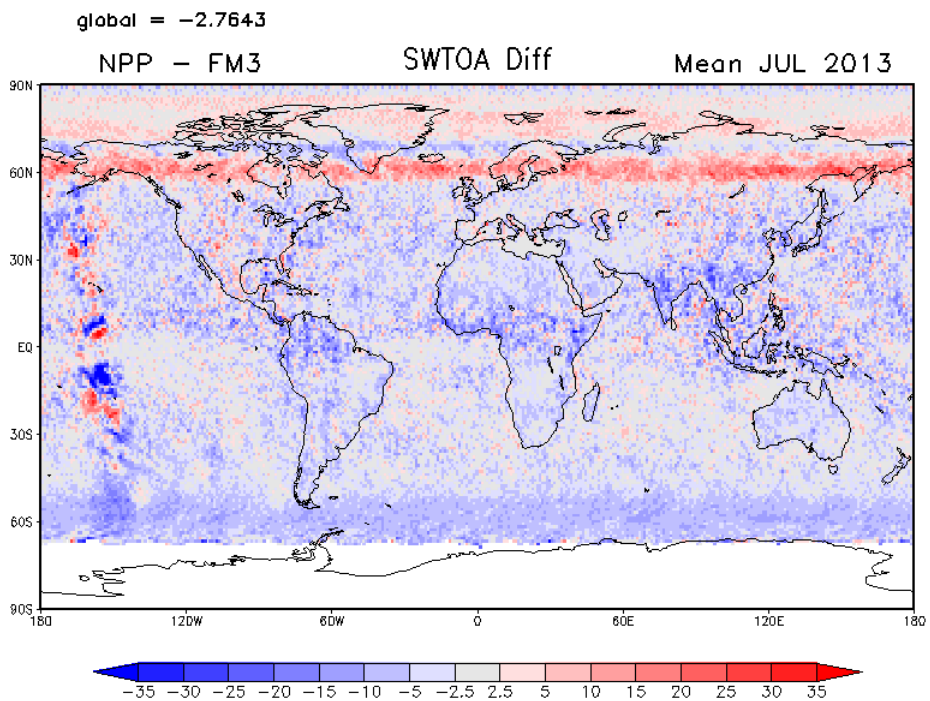


SW Surface and TOA Flux Differences between NPP and Aqua FM3 for July 2013

SW Surface Difference W/m^2

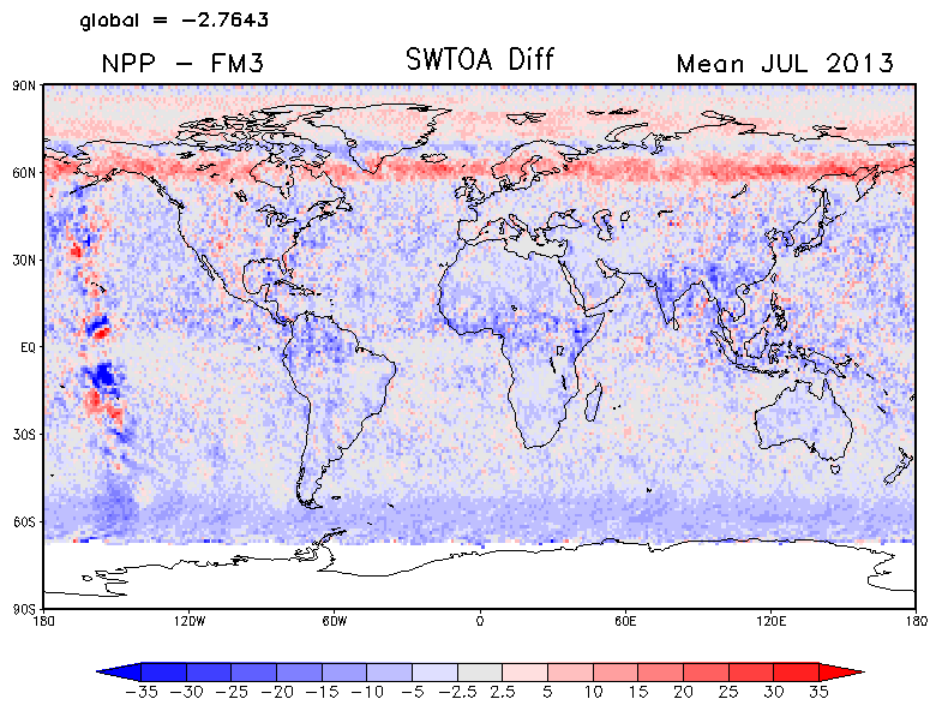


SW TOA Difference W/m^2

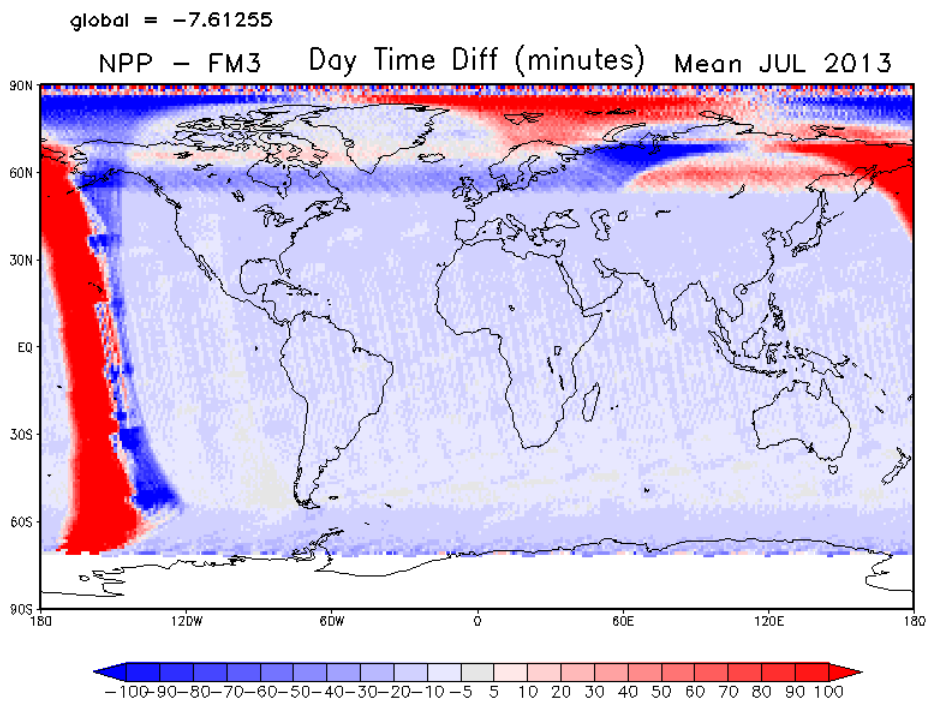


SW Surface Flux Differences between NPP and Aqua FM3 for July 2013

SW TOA Difference W/m^2

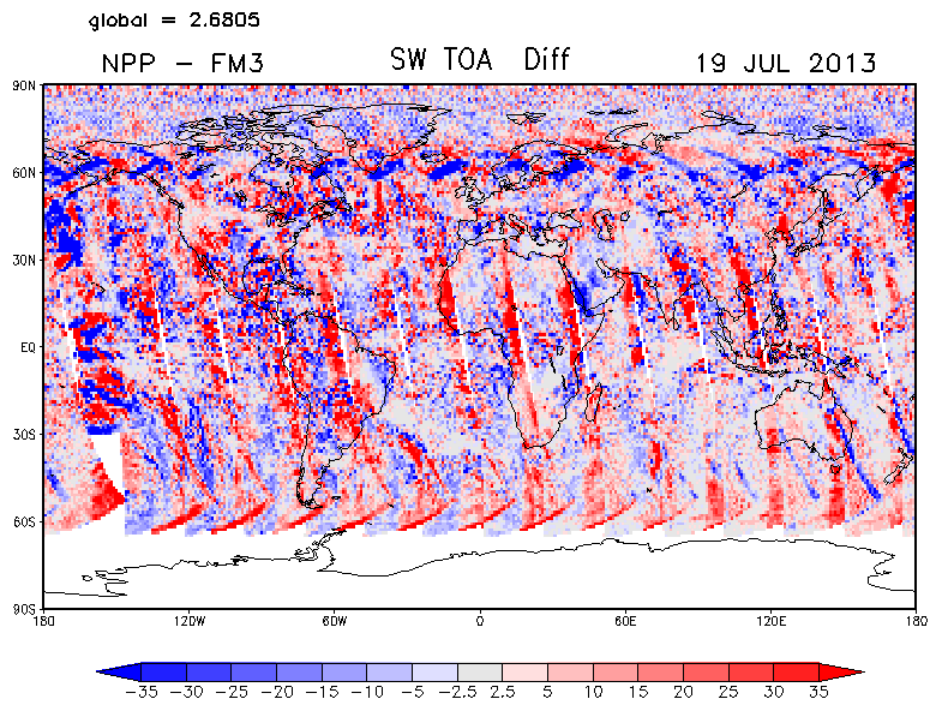


Time of Observation Difference

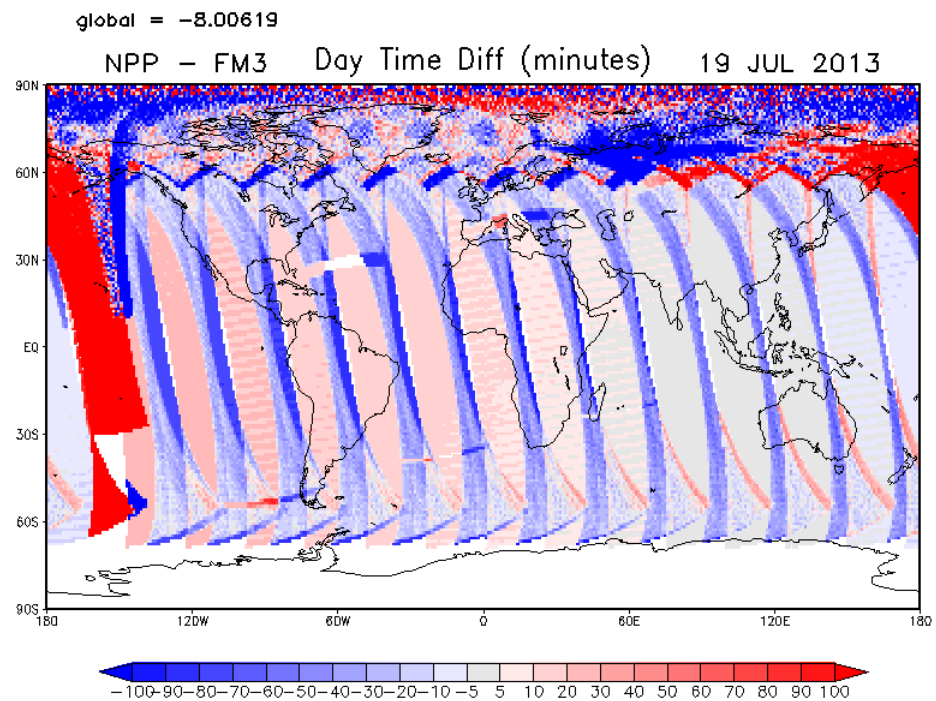


SW Surface Flux Differences between NPP and Aqua FM3 for July 19, 2013

SW TOA Difference W/m^2



Time of Observation Difference

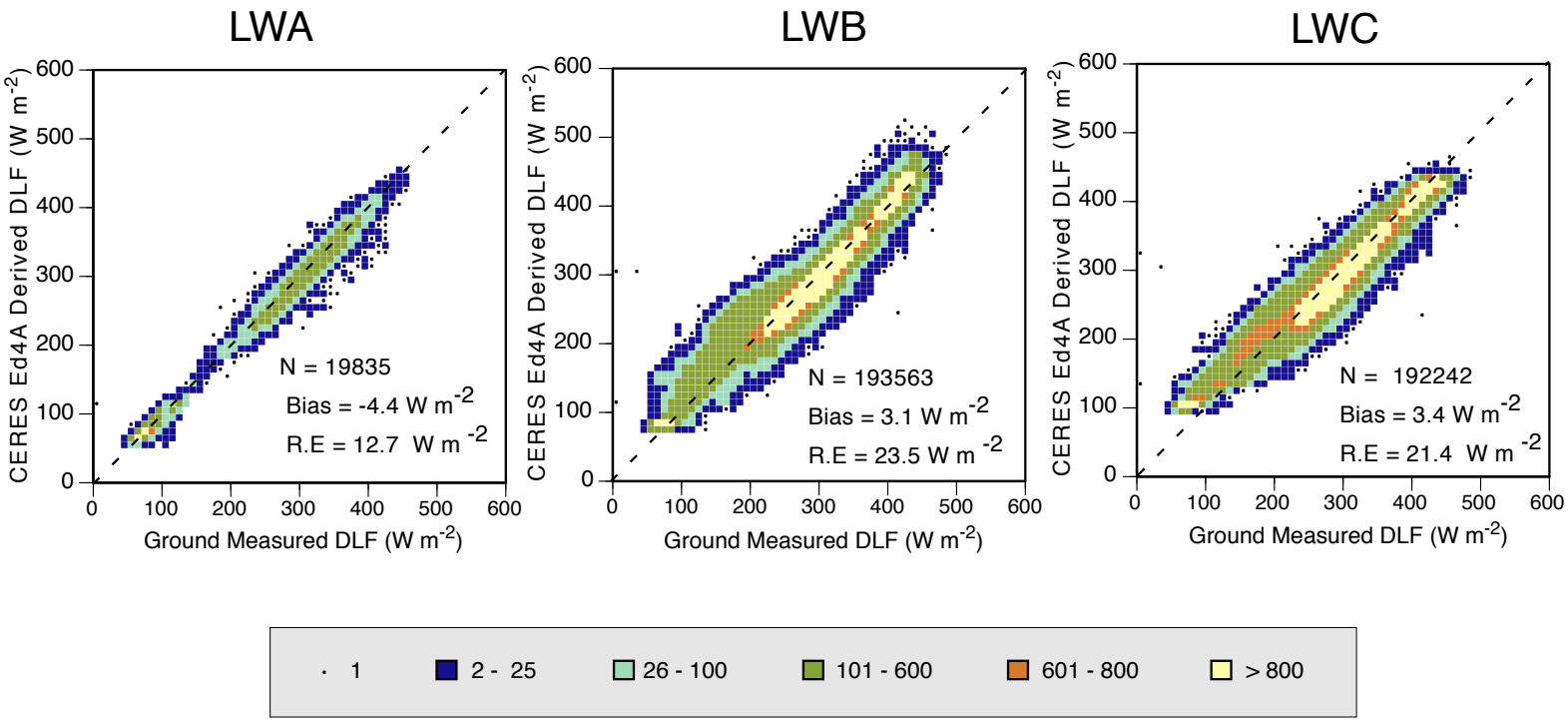


SW Surface Flux Results

The inter-comparison of the NPP and Aqua results for the SW demonstrated that the largest observed differences could be attributed to differences in the orbital parameters associated with the NPP and Aqua satellites. Differences in the orbits affect the time of observation, which affects the solar zenith angle, and consequently affects the measured value of the incoming TOA and surface SW fluxes.

Differences in the cloud effect play an important, though secondary role in producing the differences between the NPP and Aqua results.

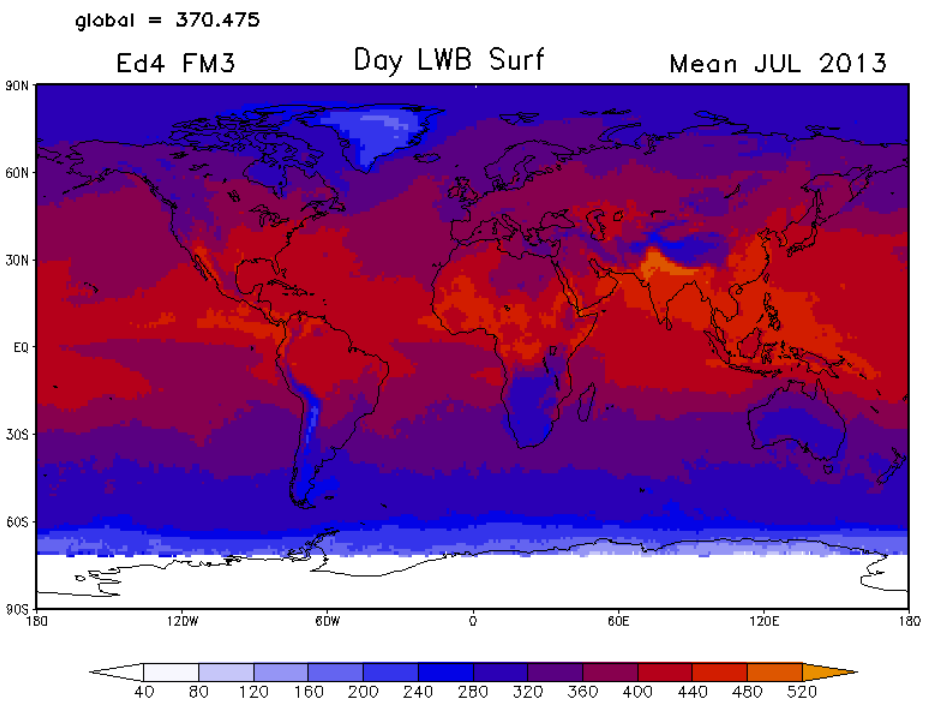
CERES Edition 4 LW Ground Validation (Global)



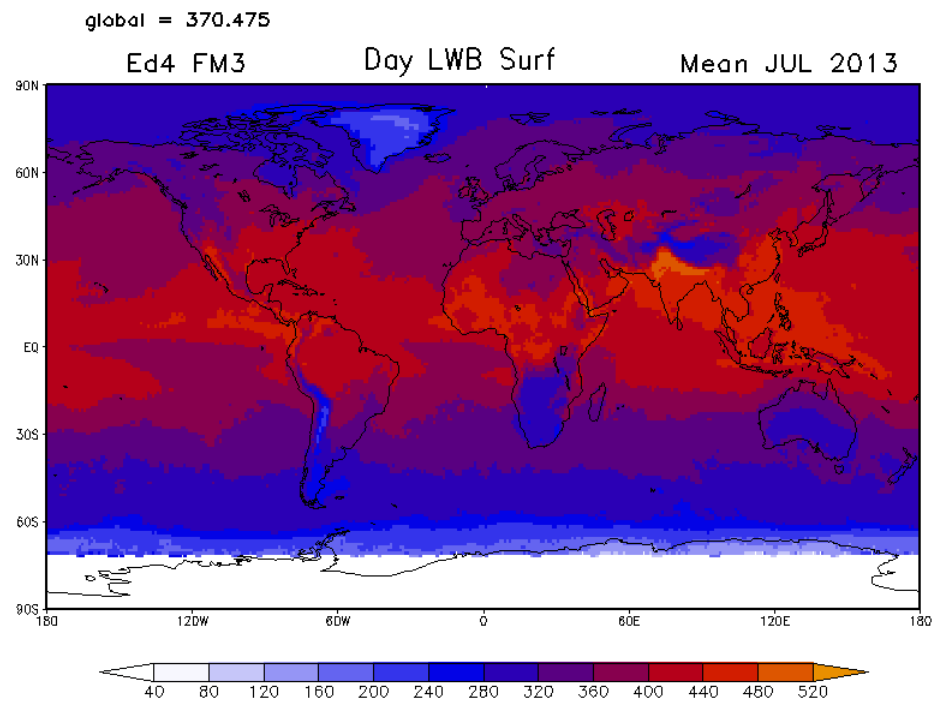
Combined LWB Ground Validation for Terra (4/2000 through 12/2011) & Aqua (7/2002 through 12/2011).

Comparison of Daytime LW Surface Fluxes from NPP and Aqua FM3 for July 2013

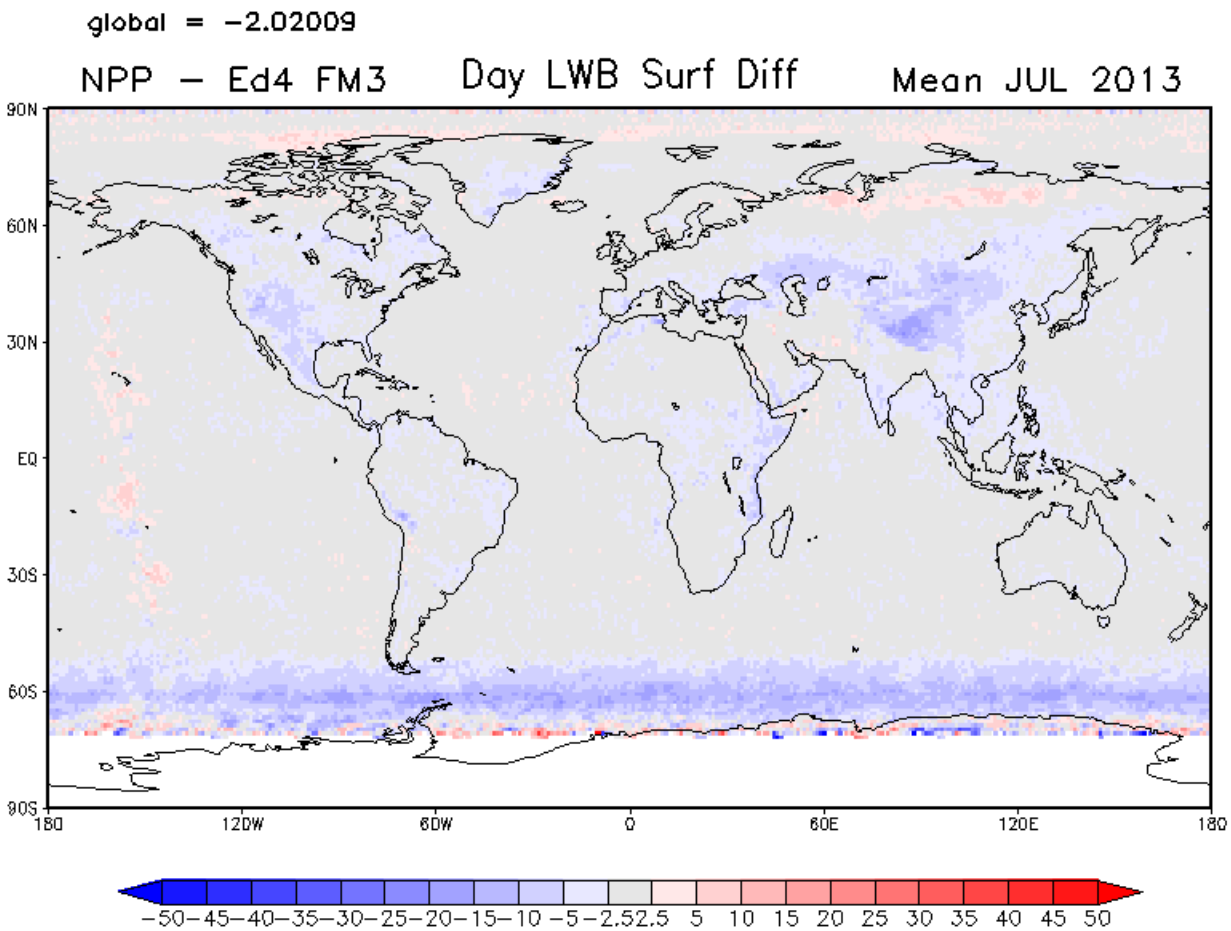
NPP LW Surface Flux W/m^2



FM3 LW Surface Flux W/m^2

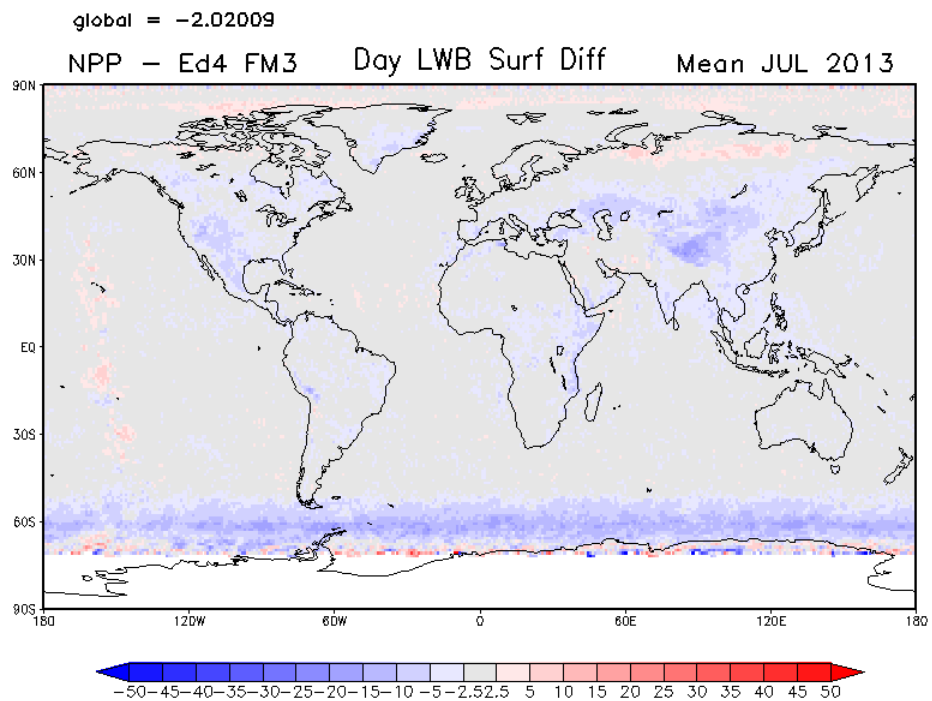


Daytime LW Surface Flux Differences between NPP and Aqua FM3 July 2013

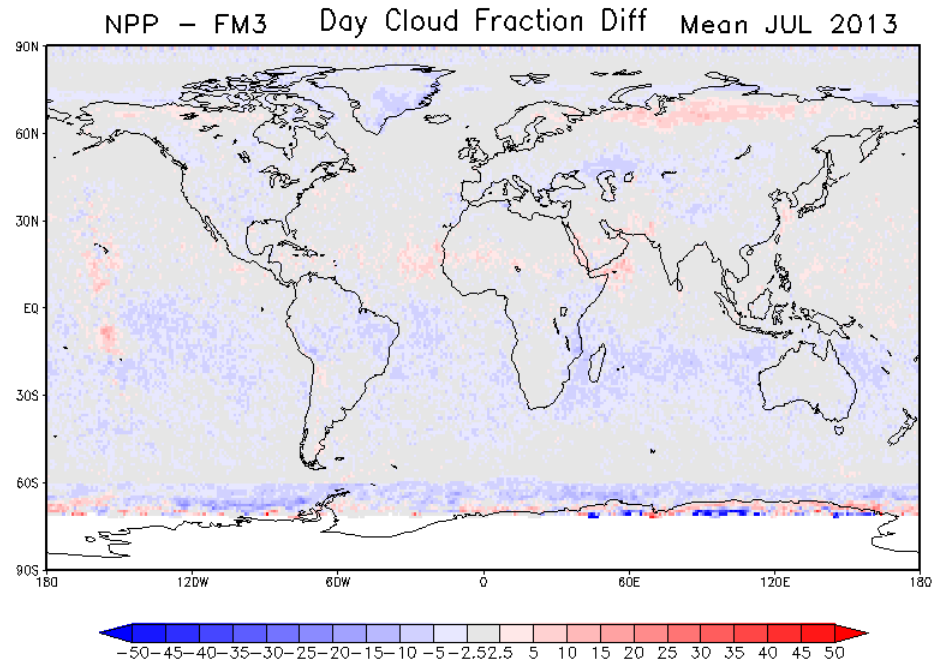


Daytime LW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for July 2013

LW Surface Difference W/m^2

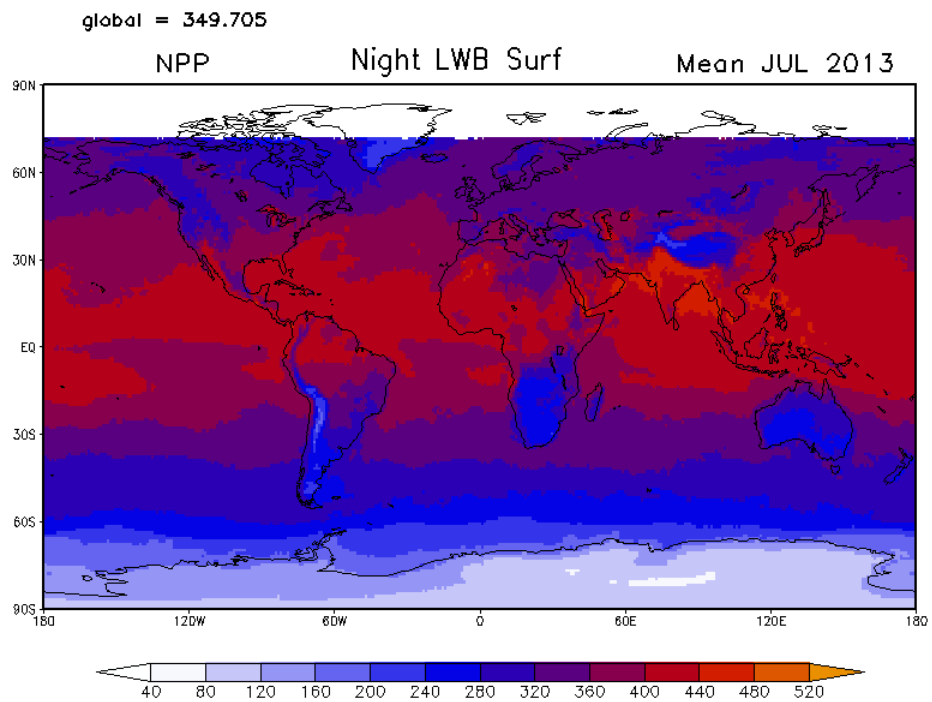


Cloud Fraction Difference

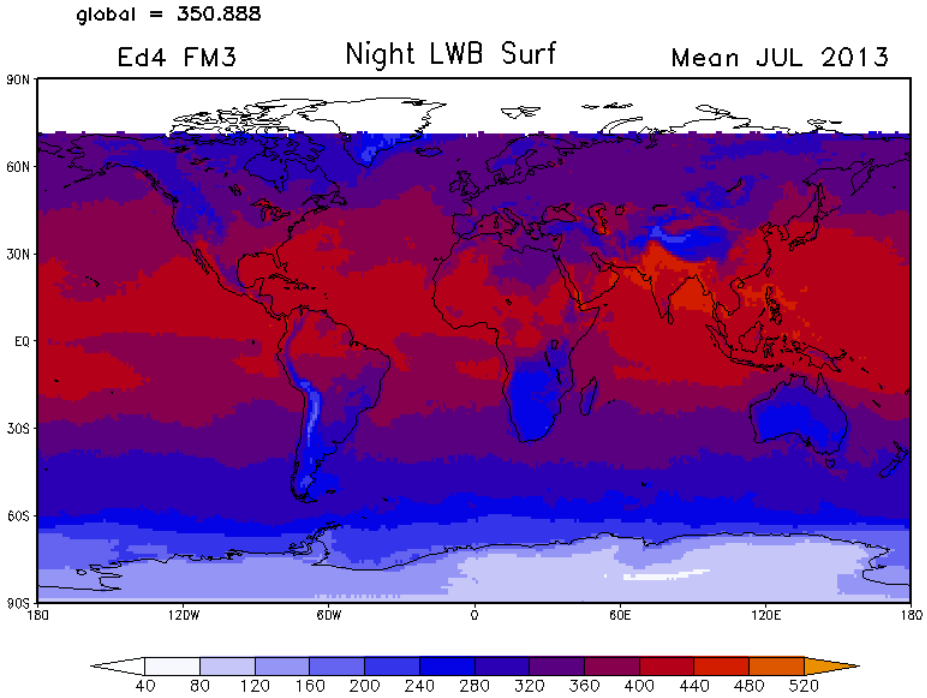


Comparison of Nighttime LW Surface Fluxes from NPP and Aqua FM3 for July 2013

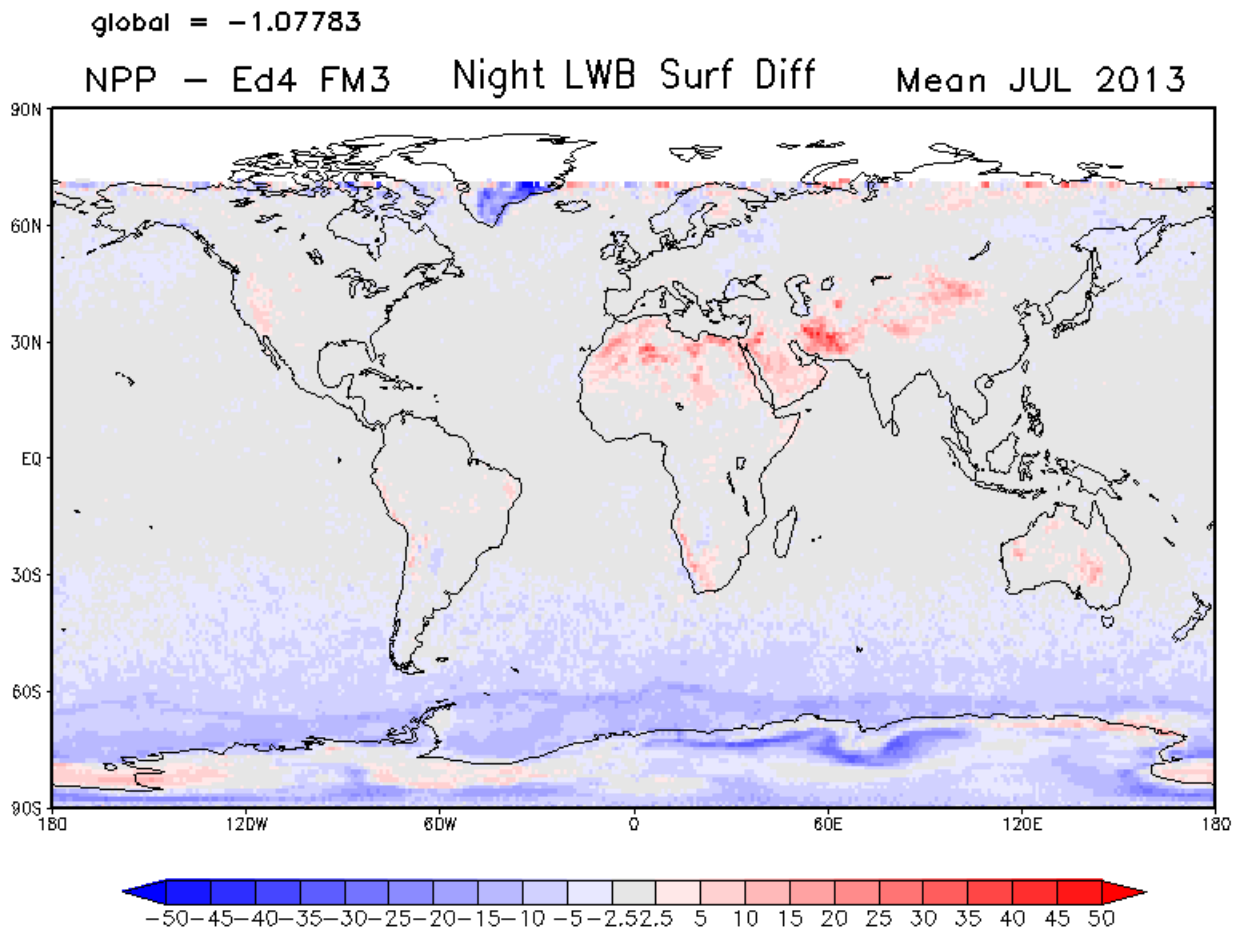
NPP LW Surface Flux W/m^2



FM3 LW Surface Flux W/m^2

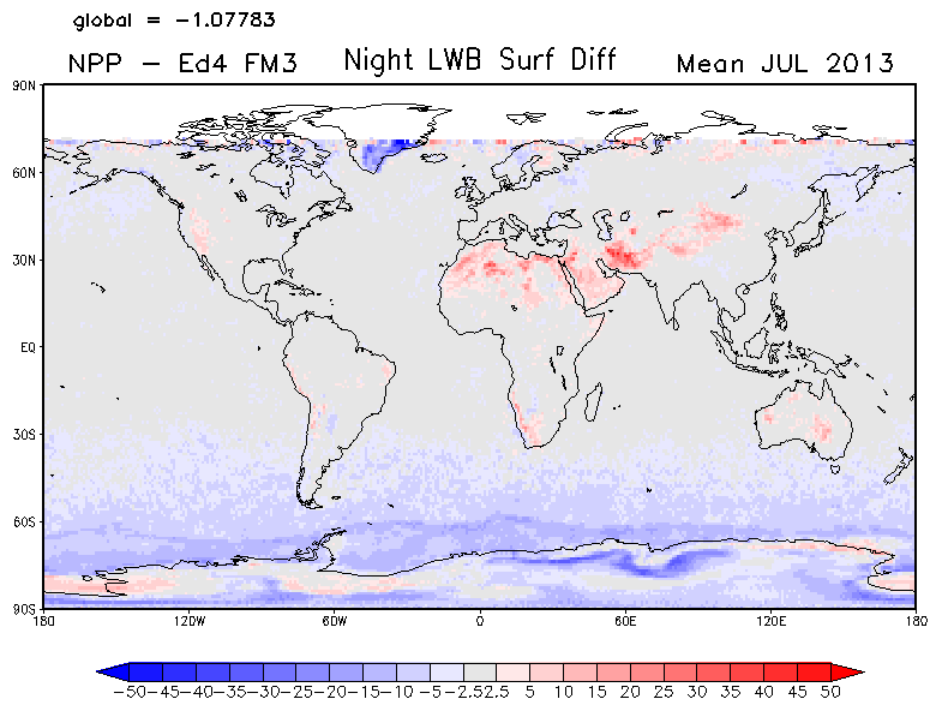


Nighttime LW Surface Flux Differences between NPP and Aqua FM3 for July 2013

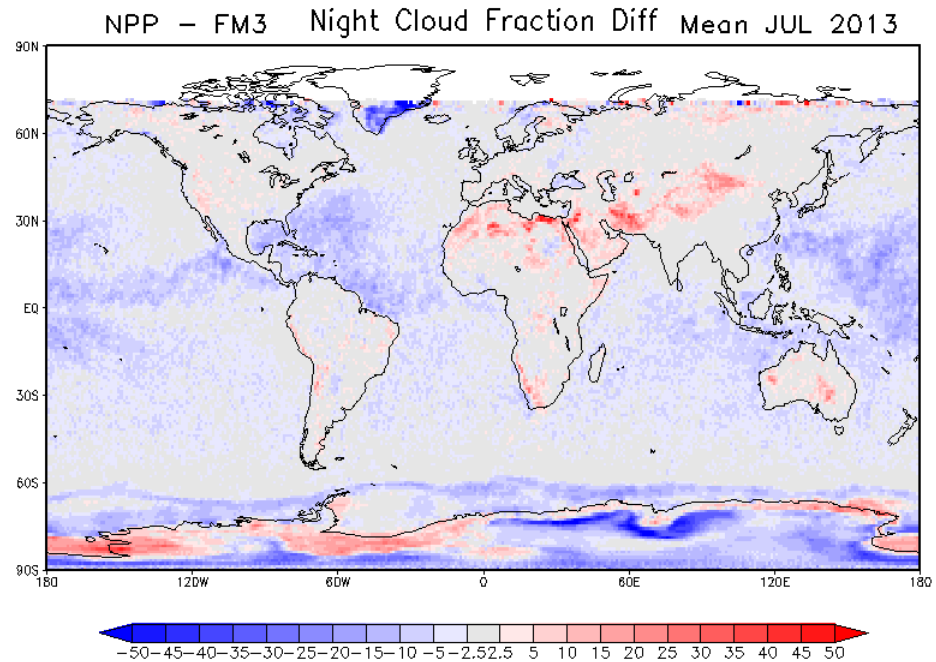


Nighttime LW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for July 2013

LW Surface Difference W/m^2



Cloud Fraction Difference



LW Surface Flux Results

Differences in the clouds appear to play the dominant role in producing the observed differences between the NPP and Aqua LW fluxes for both Day and Night.

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. Current attention is focused on deriving a regression fit to the cloud transmission data.

An analysis of the LW and SW surface only flux algorithm results using the Edition 4 inputs, especially those from the Clouds Subsystem, has indicated improved accuracies for most locations.

The comparison of the NPP and Aqua flux retrievals shows the anticipated results.