CERES FM1 – FM6 Instrument Status

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Instrument Working Group

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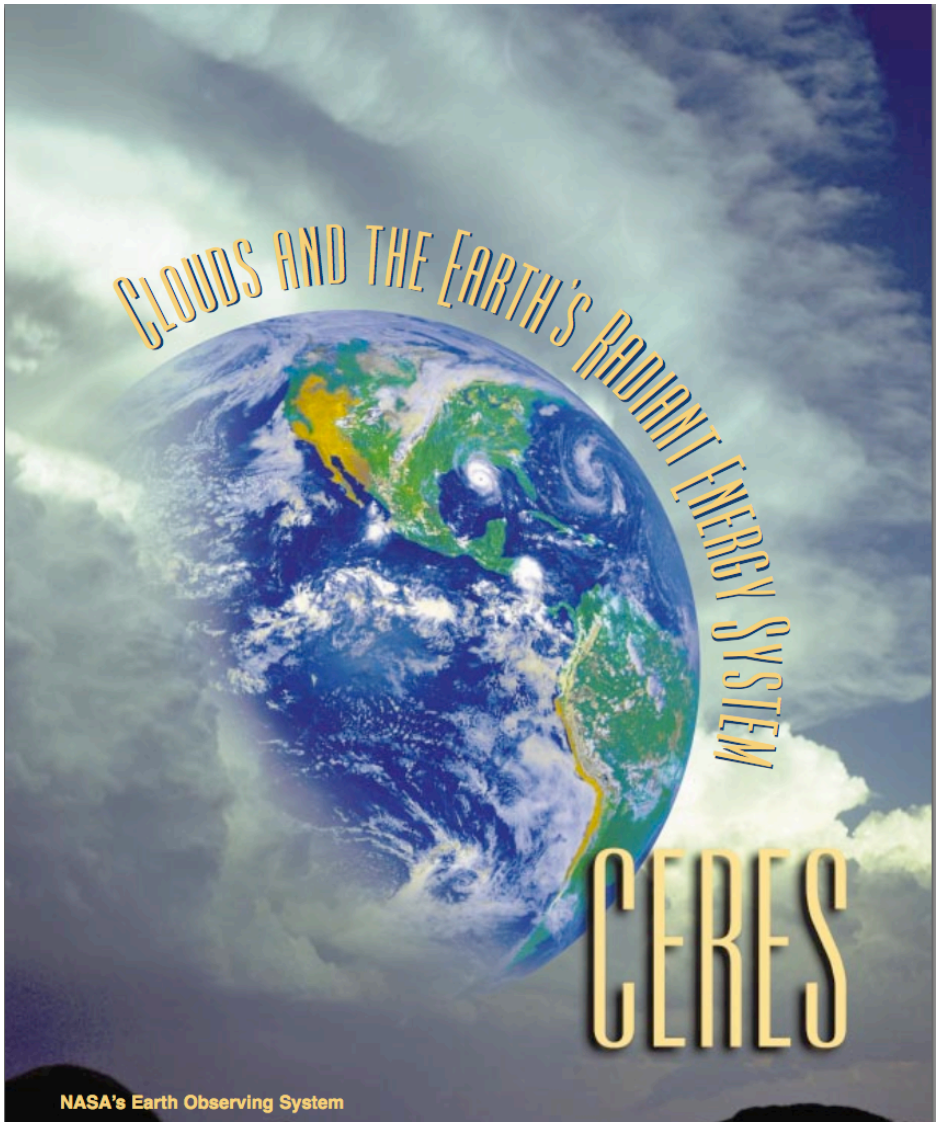
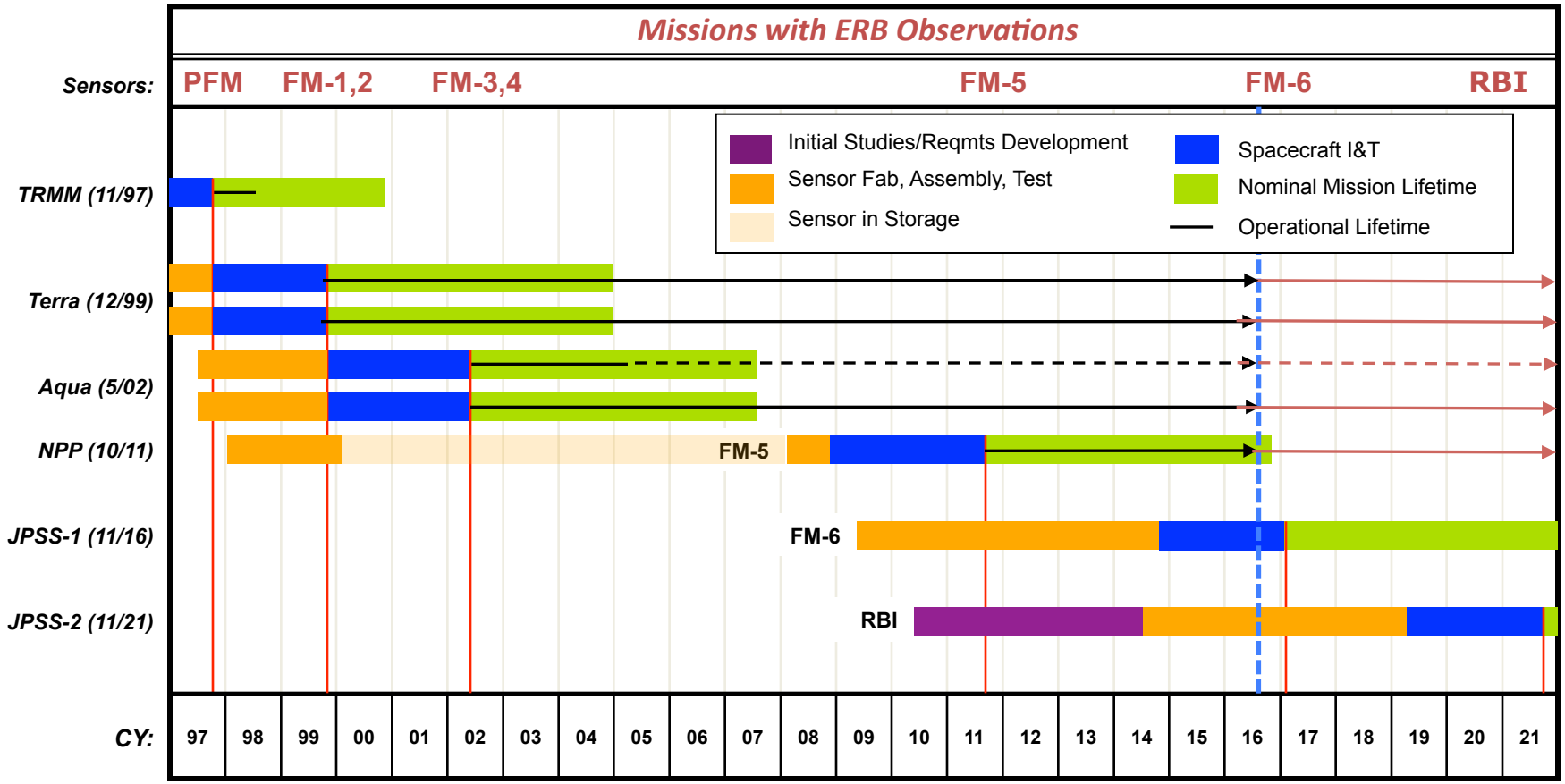
Discussion Topics



- ERB missions Overview
  - Flight history/future
- Operations
- Instrument Status
  - FM1–4 on Terra/Aqua
  - FM-5 on S-NPP
  - FM-6 on JPSS-1
- Summary

Climate Data Record Continuity

CERES/RBI Flight Schedule



CERES Instrument Operations: FM1 - 5

CERES Instruments, Flight Models 1- 5 (FM1 – FM5) are primarily in Cross-Track mode of operation.

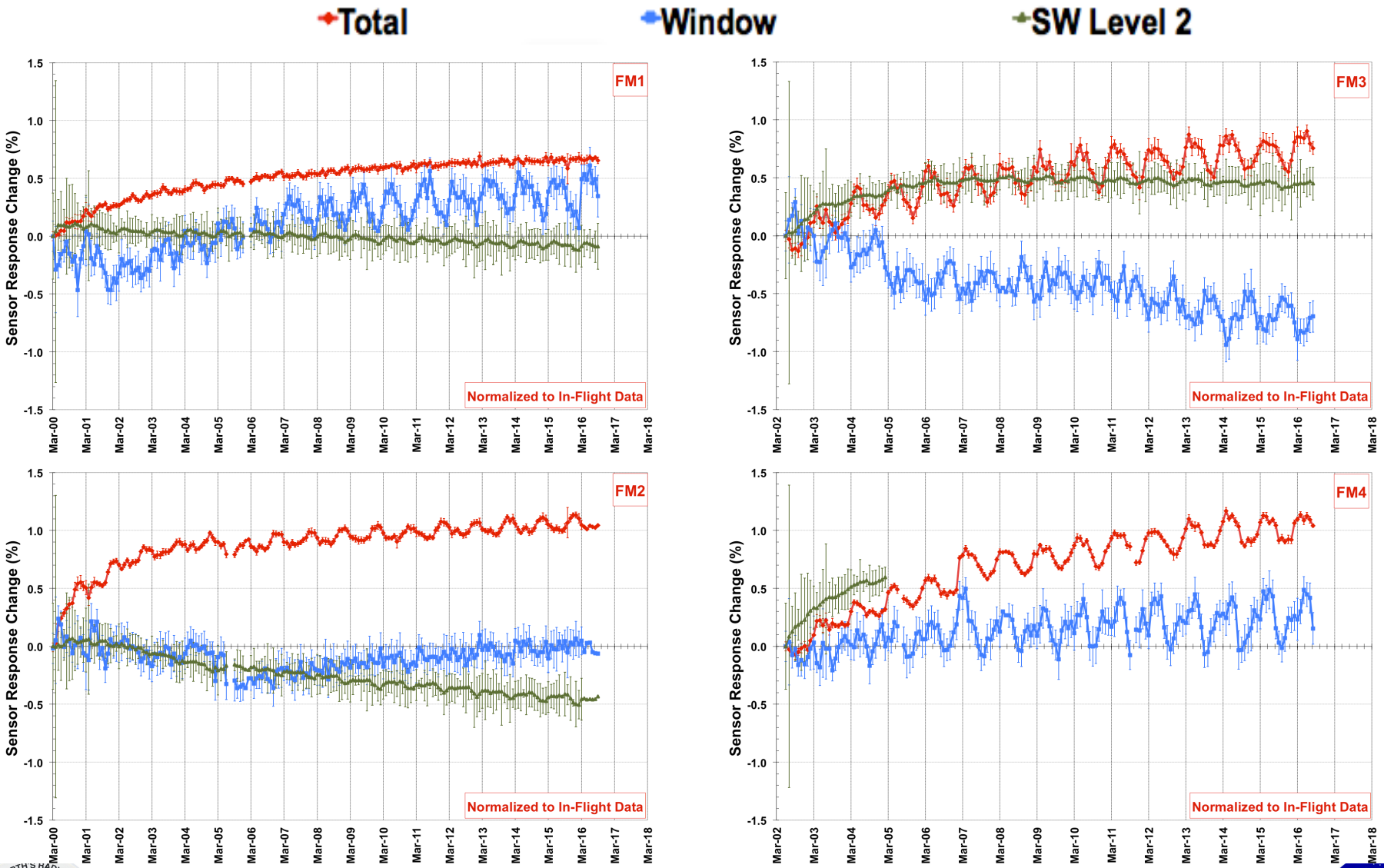
Inter-comparison campaigns in 2016

- **CERES Terra/FM2 – ScaRAB: April 1 – May 31, 2016**
- **CERES Terra/FM2 – GERB: June 1 – June 30, 2016**
- **CERES Terra/FM1 – S-NPP/FM5: May 1 – July 31, 2016.**
- **CERES Terra/FM1 – Aqua/FM3: June 1 – 30, 2016**

TERRA & AQUA INSTRUMENT STATUS

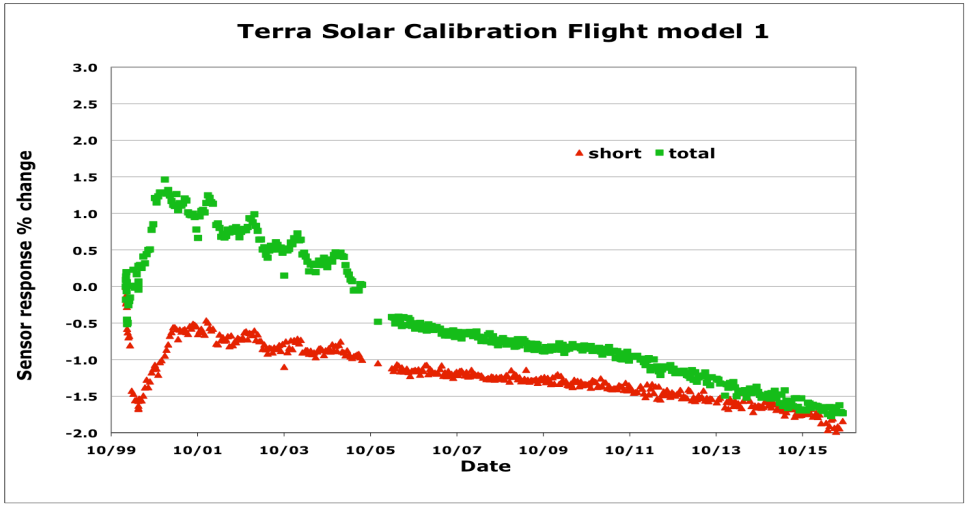
[CERES FM1 – FM4]

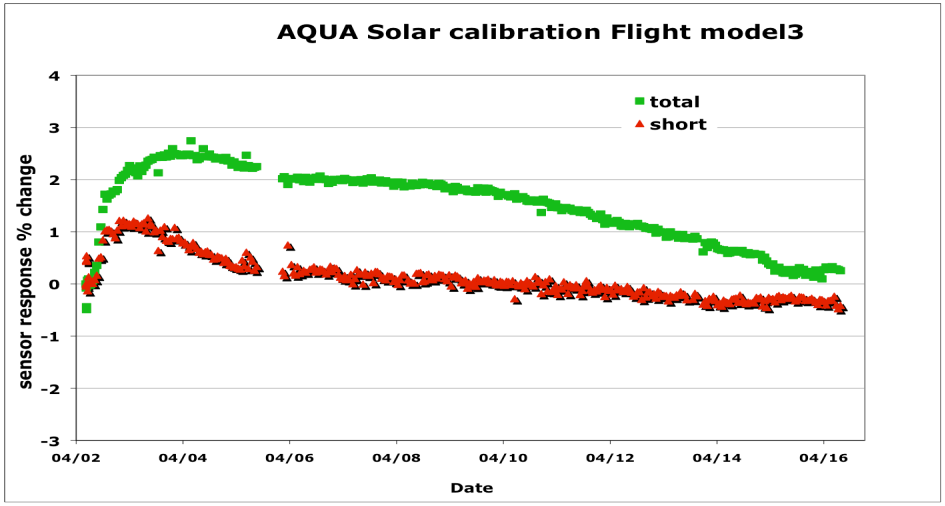
Terra – Aqua Sensor Performance

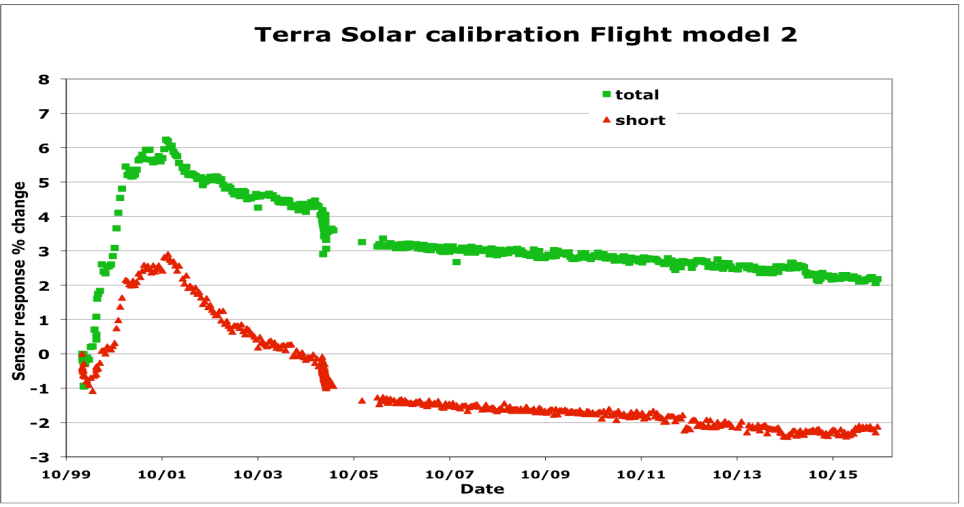


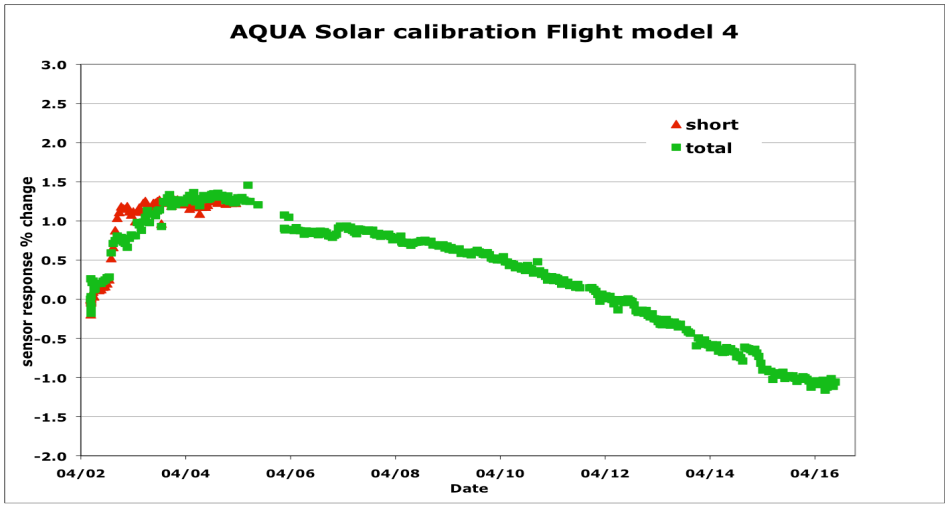
CERES Instrument Working Group

Terra – Aqua Solar Calibration Results

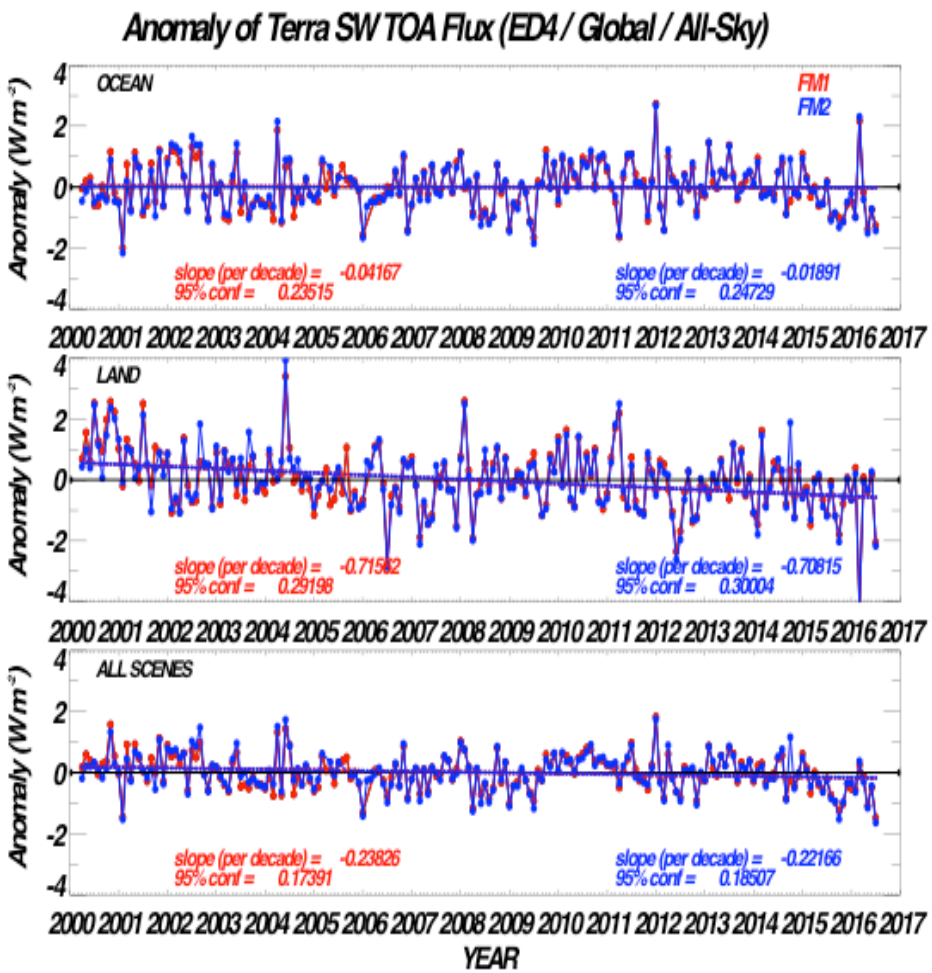


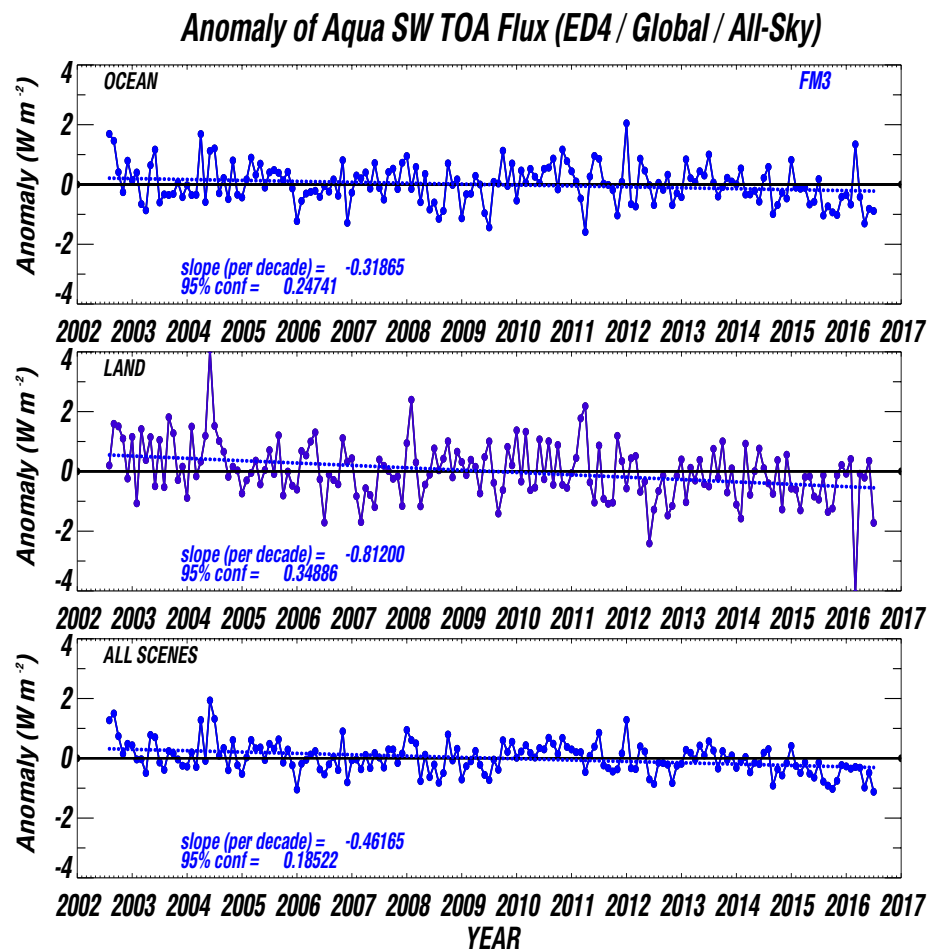




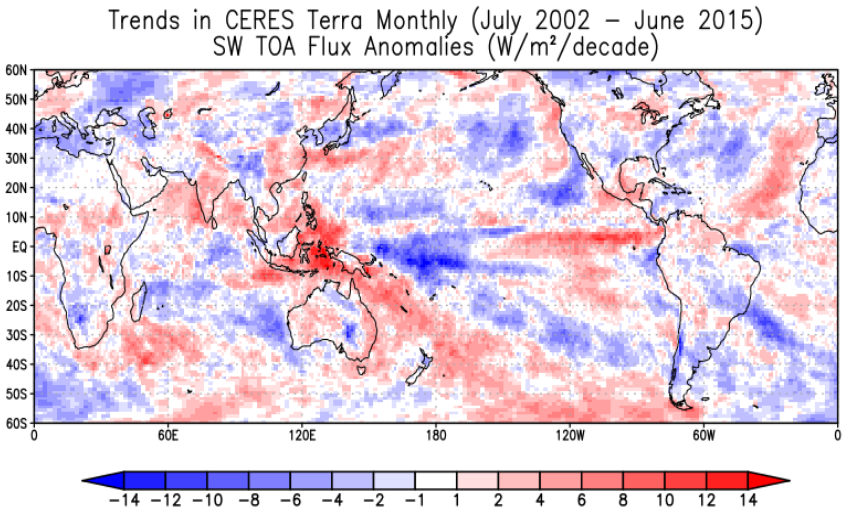


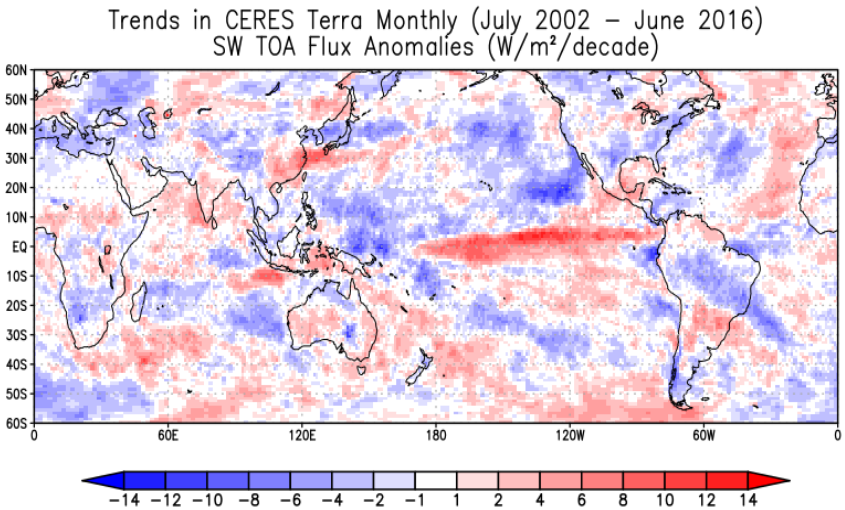
EDITION-4 RESULTS: TERRA & AQUA SW SENSORS

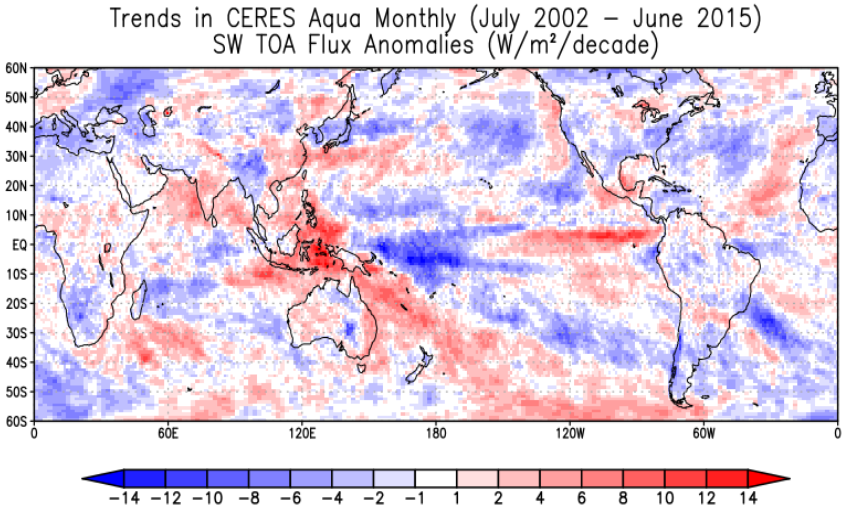


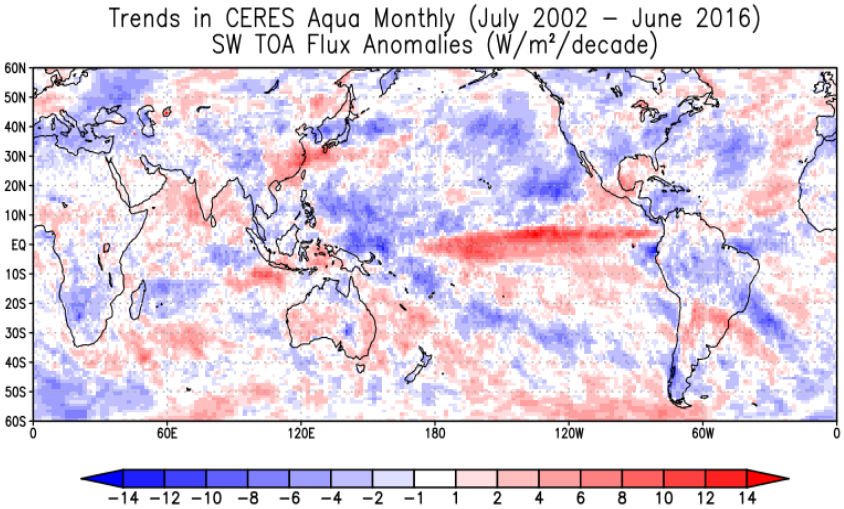


Terra – Aqua SW Anomaly Trends

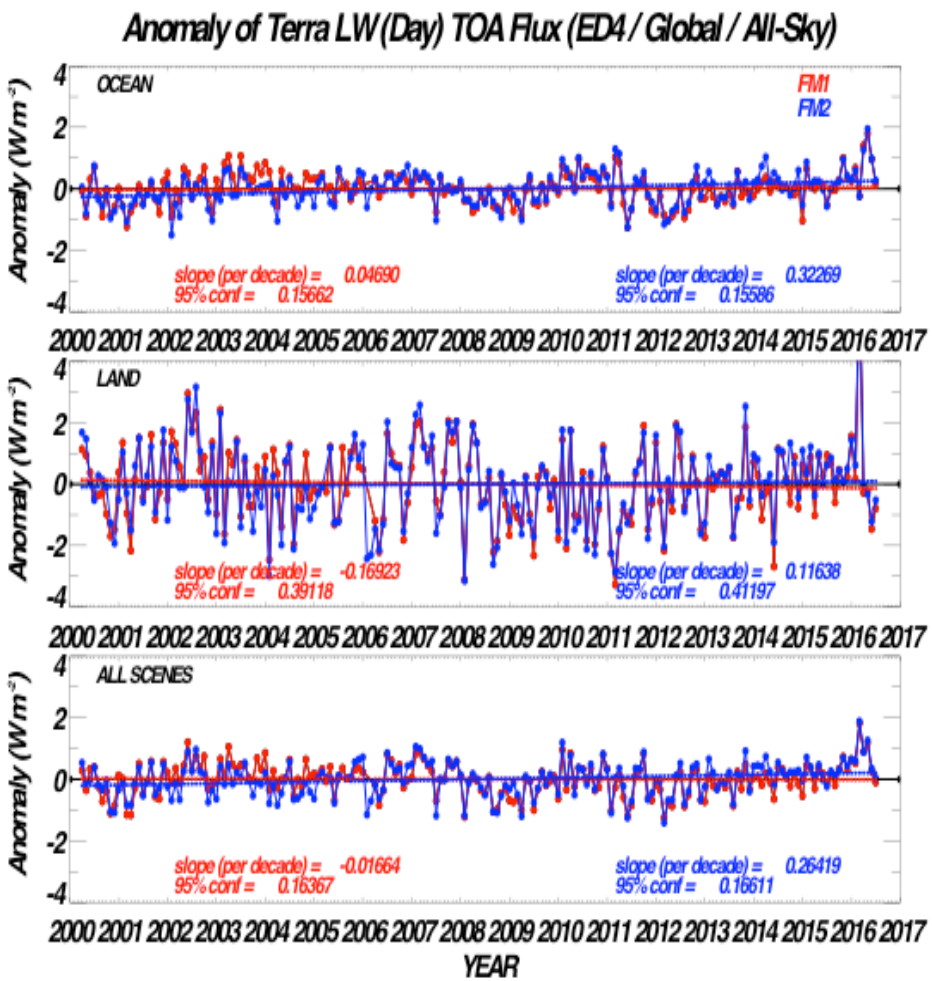


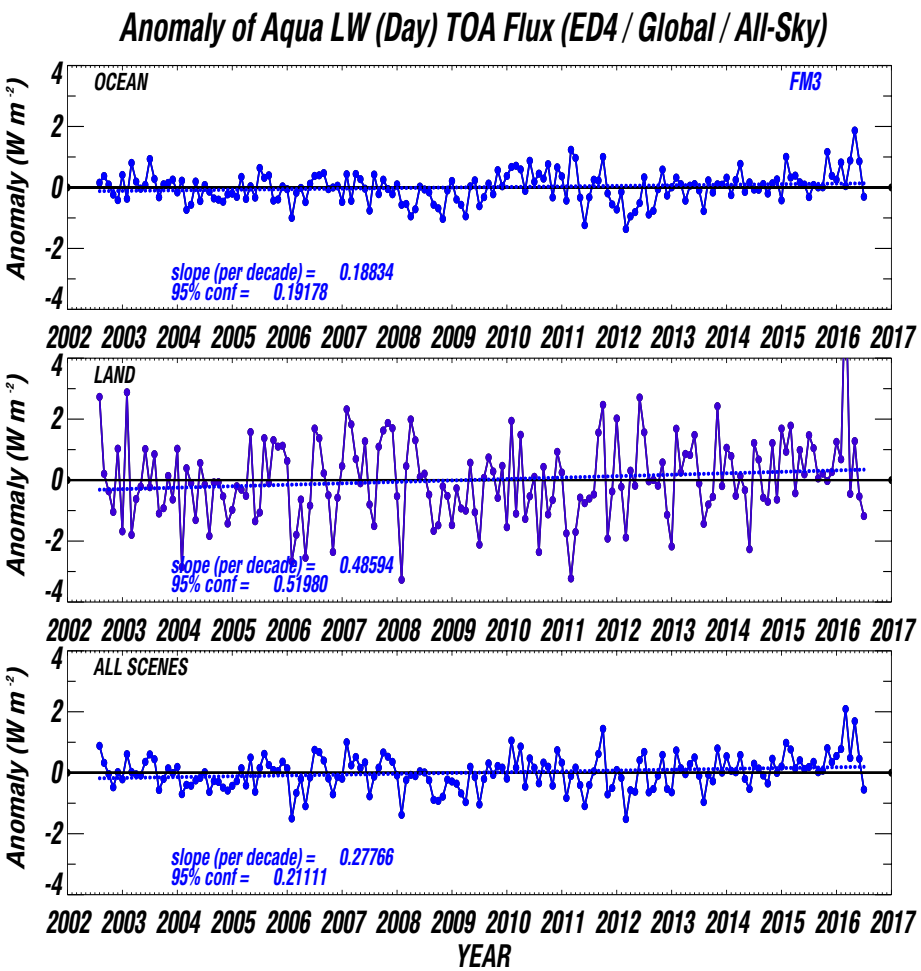






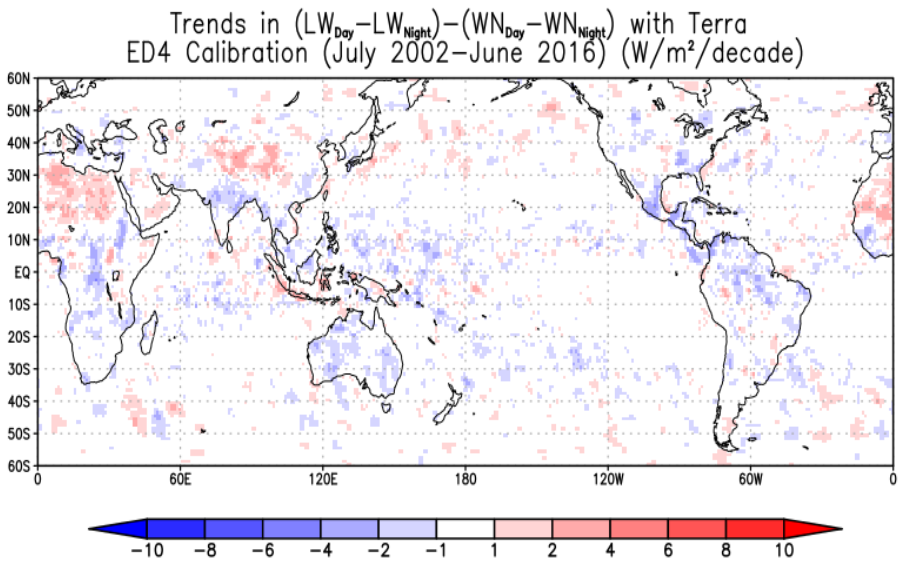
EDITION-4 Results: TERRA & AQUA LW_Day Flux

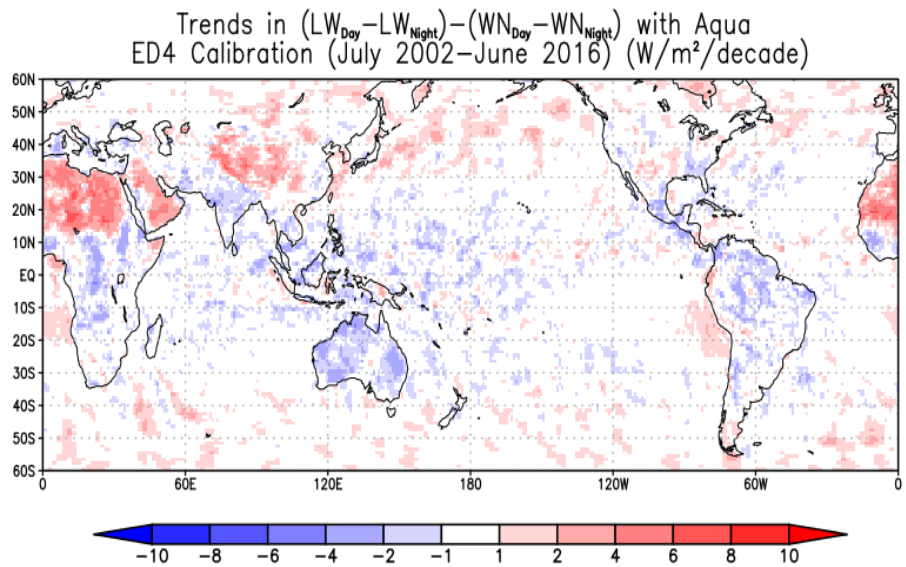




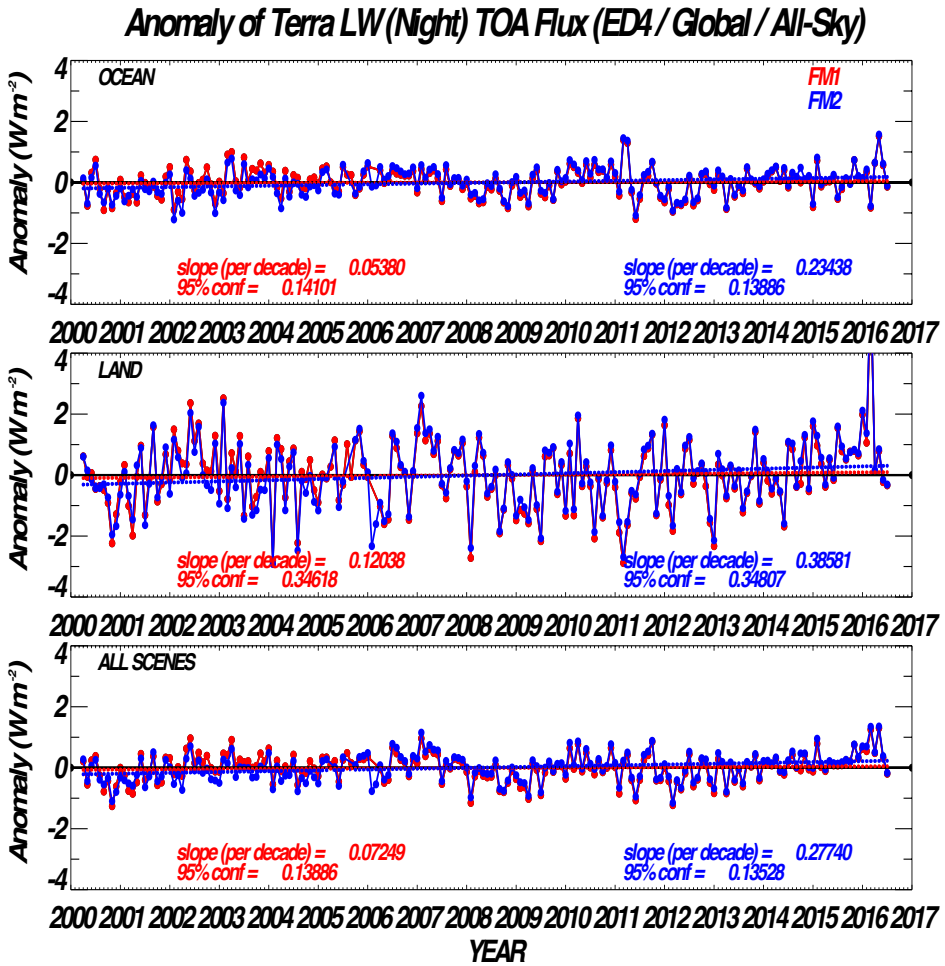
EDITION-4: TERRA & AQUA LW_Day Validation

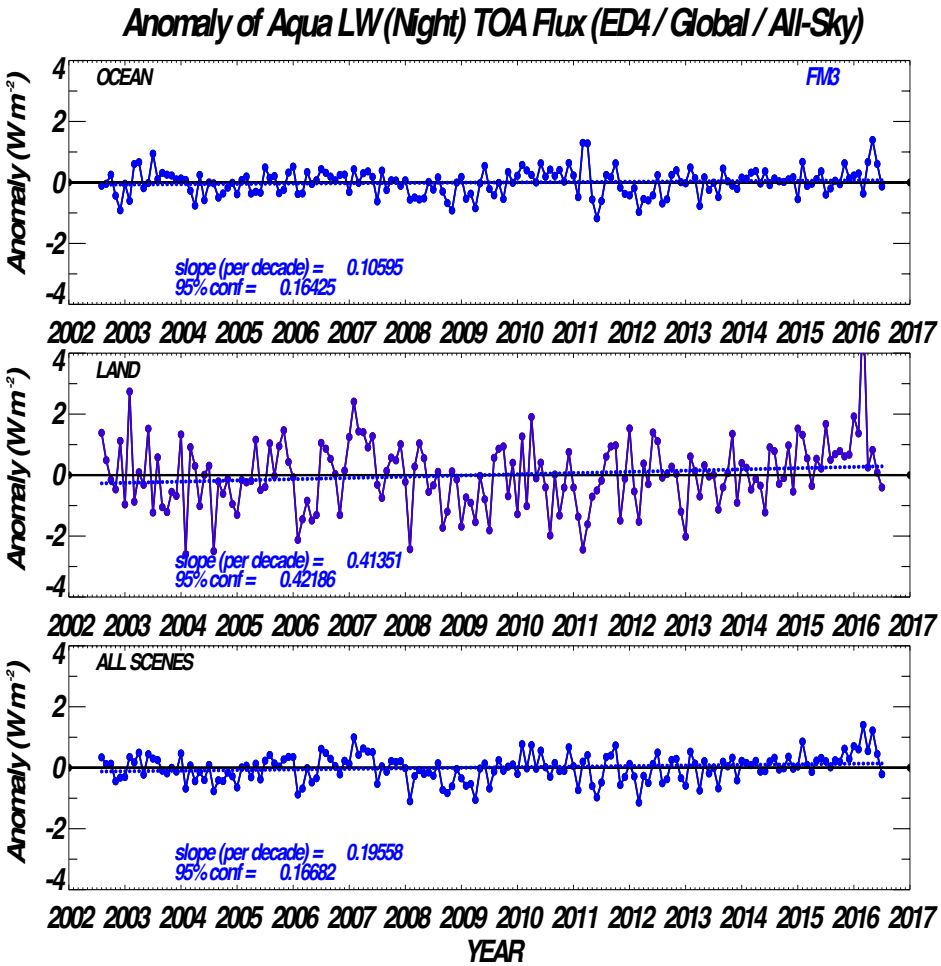
- **Anomaly Trends of the difference between Day-Night difference of Longwave and Window measurements for 1x1 degree region was performed.**
- **The results show the trends are more pronounced in certain Land scenes of Aqua measurements.**





EDITION-4 Results: TERRA & AQUA LW_Night Flux



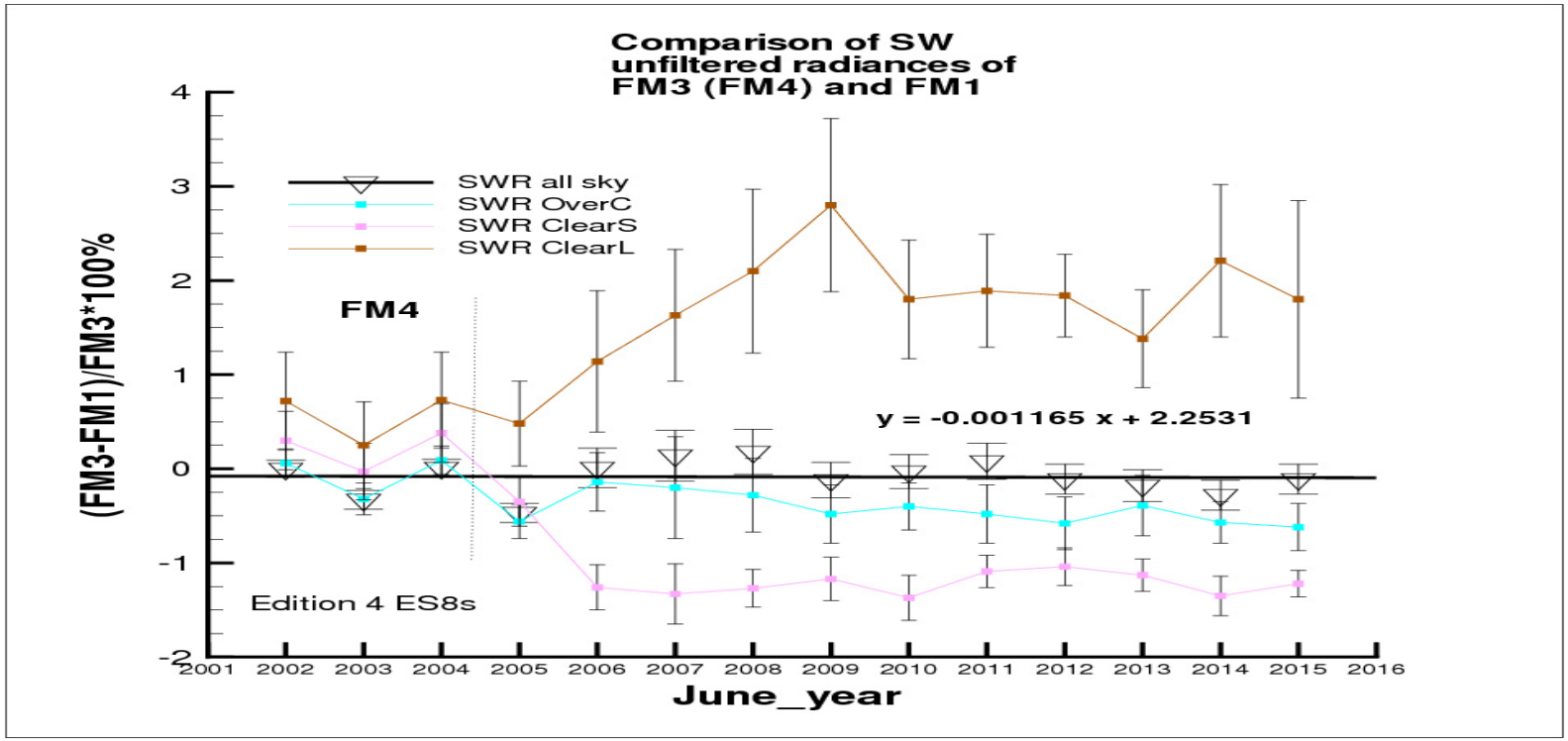


Minor plane radiation measurements

- Annual campaign around summer solstice
  - FM1 and FM3 in June of each year since 2002
    - On all orbits with time differential < 18 minutes
  - FM1 and FM5 May-July each year since 2012
    - A few orbits every 64 hours; $\Delta T < 5$ minutes
  - Each data collection lasts 90 sec
- FM1/FM3/FM5 scan in the minor plane
  - Scan orientation is perpendicular to the solar plane
  - Double nadir scan profile to avoid ram directions
- Data collection region is about 70°N
  - Various scene types including Greenland (ice/snow)

Shortwave results for FM3/FM1

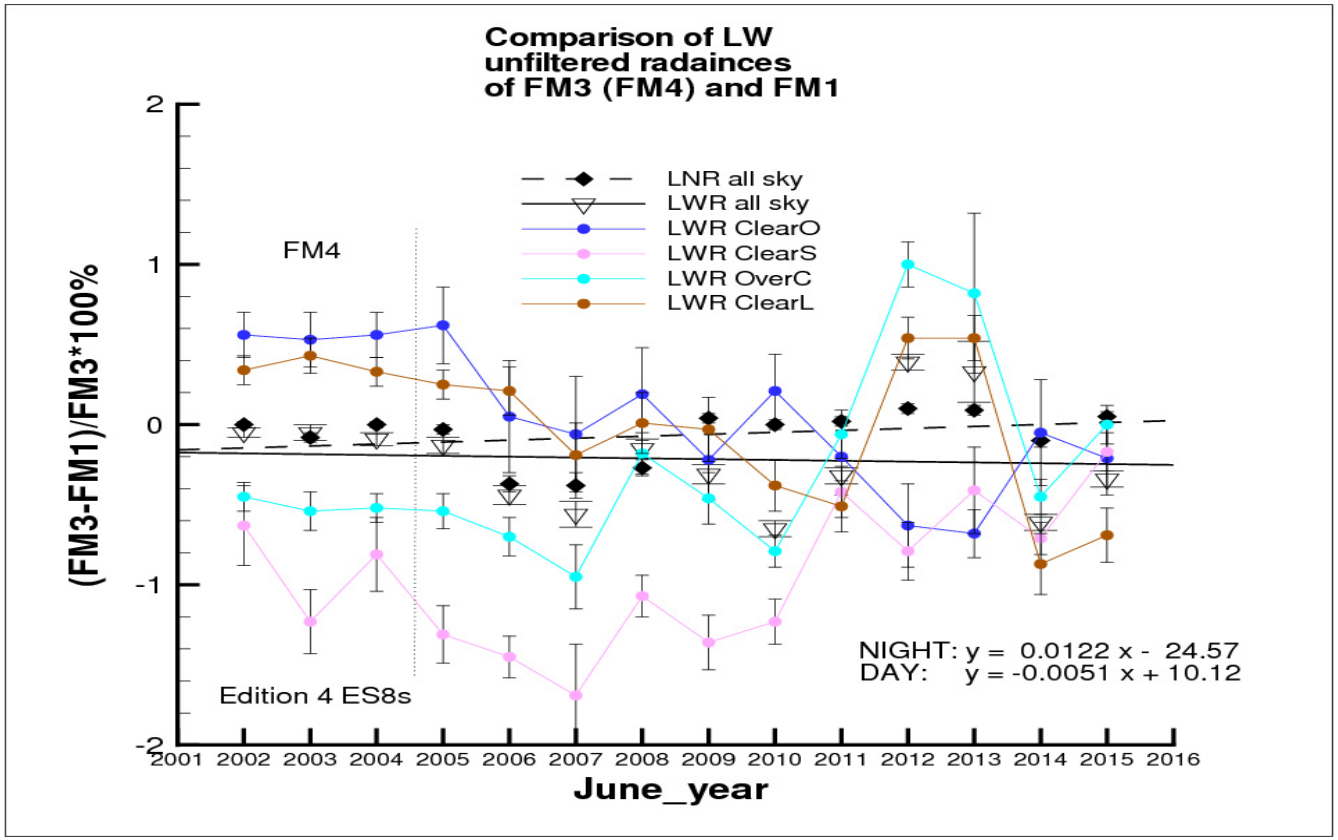
Shortwave measurements are directly measured by a detector



Excellent consistency for "all-sky"; $-0.5\% < \Delta SW < 0.2\%$

Longwave results for FM3/FM1

LWN measured; LWD derived: TOT - SW



Good consistency for "all-sky"; - 0.5% < ΔLWday < 0.4%

Better consistency; - 0.25% < ΔLWnight < 0.1%; small upward trend

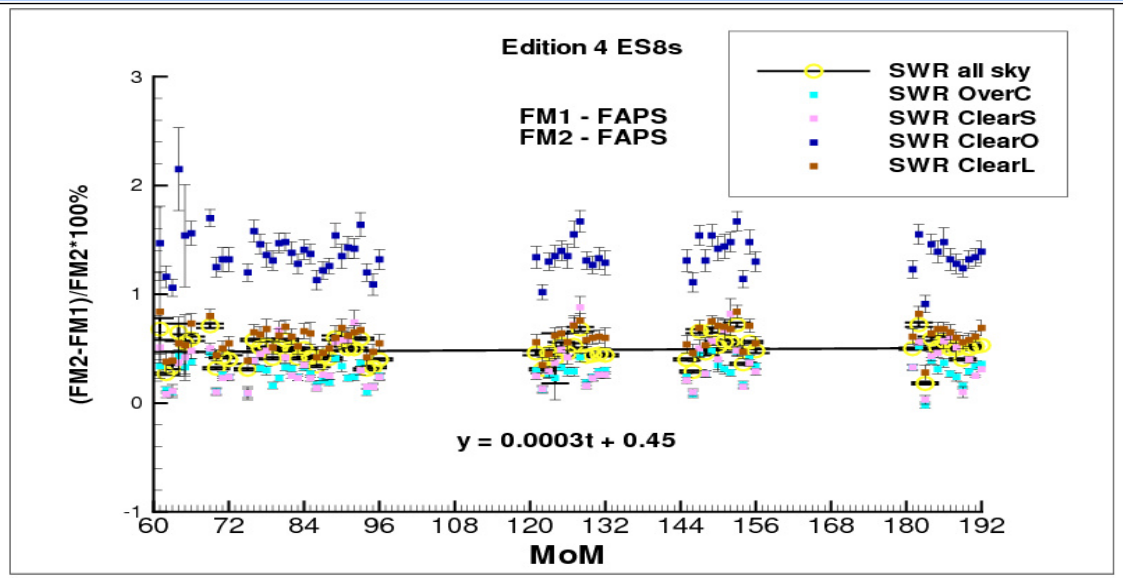
Direct compare FM2/FM1 (unfiltered radiance)

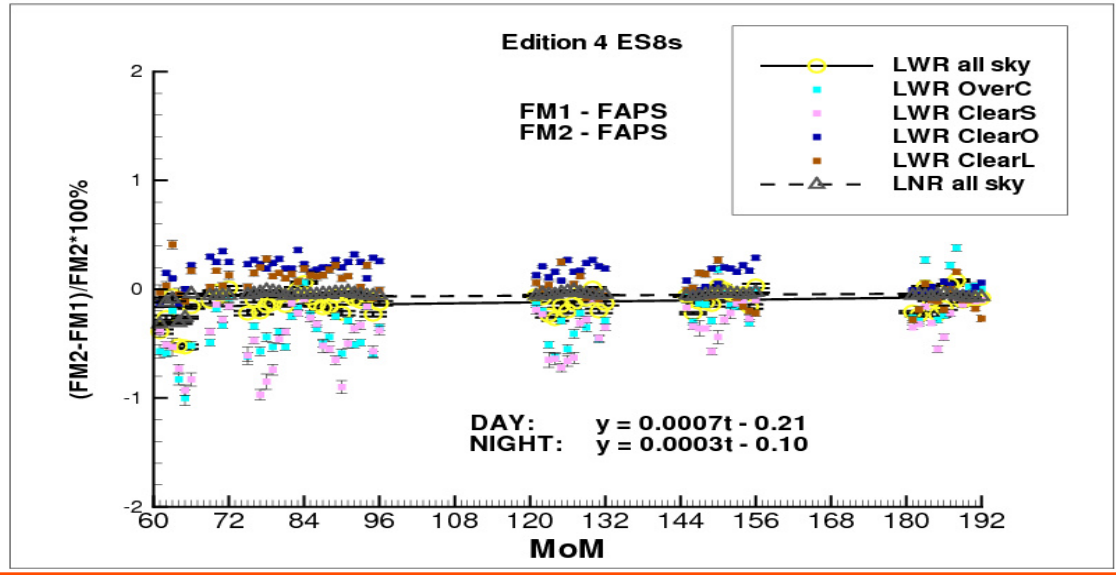
- Terra CERES in XT since 2005
- Very stable & consistent
- Δ's plotted for selected years

- SW: FM2 > FM1 by 0.5%
- LW Day: FM2 ≅ FM1
- LW Night: FM2 ≅ FM1

- ✓ SW:
- ✓ CLRO FM2 > FM1 by 1.5%
- ✓ Other scene types < within 1%

- ✓ LW Day:
- ✓ All scene types within 1%





TERRA/AQUA DATA AVAILABILITY

Edition3 Gains and Spectral Response Functions (SRF) :
Start of Mission – May 2016

Edition4 Gains and Spectral Response Functions (SRF) :

Terra and Aqua - Start of Mission to May 2016

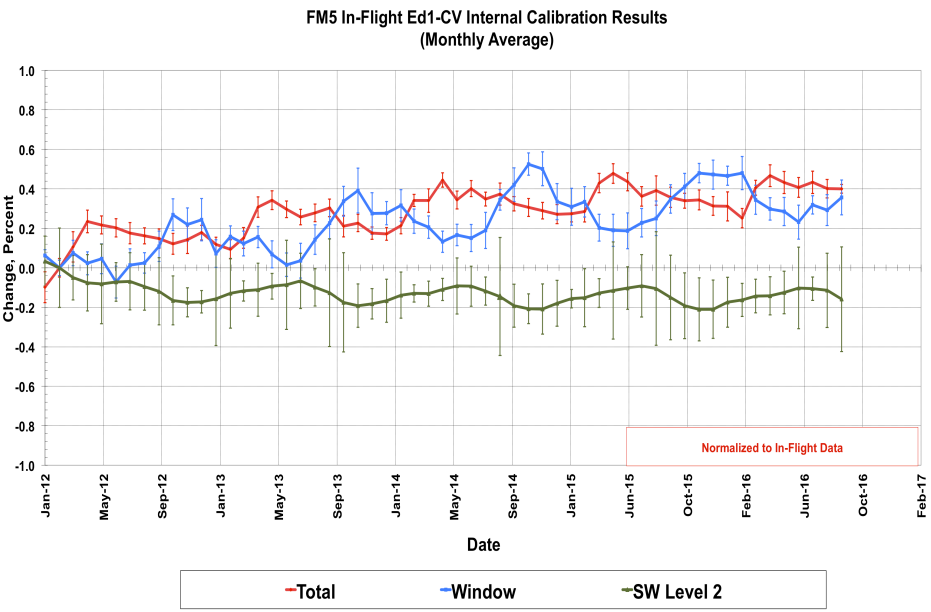
Edition1-CV Data Products (Instrument & ERBE-like):
Start of Mission – September 2016

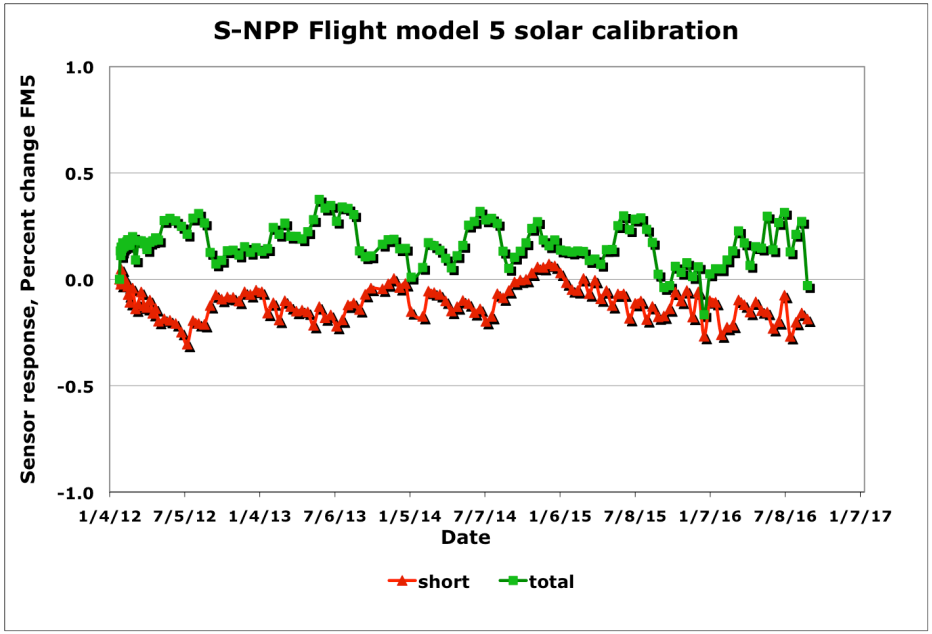
S-NPP/ CERES FM5 INSTRUMENT STATUS

S-NPP/CERES FM5 Instrument Calibration

ICM calibrations show a response increase of 0.4% for Total, 0.5% for Window sensor and a drop of 0.2% in SW sensor.

Sensor response trends from solar calibrations remain within ± 0.5%.

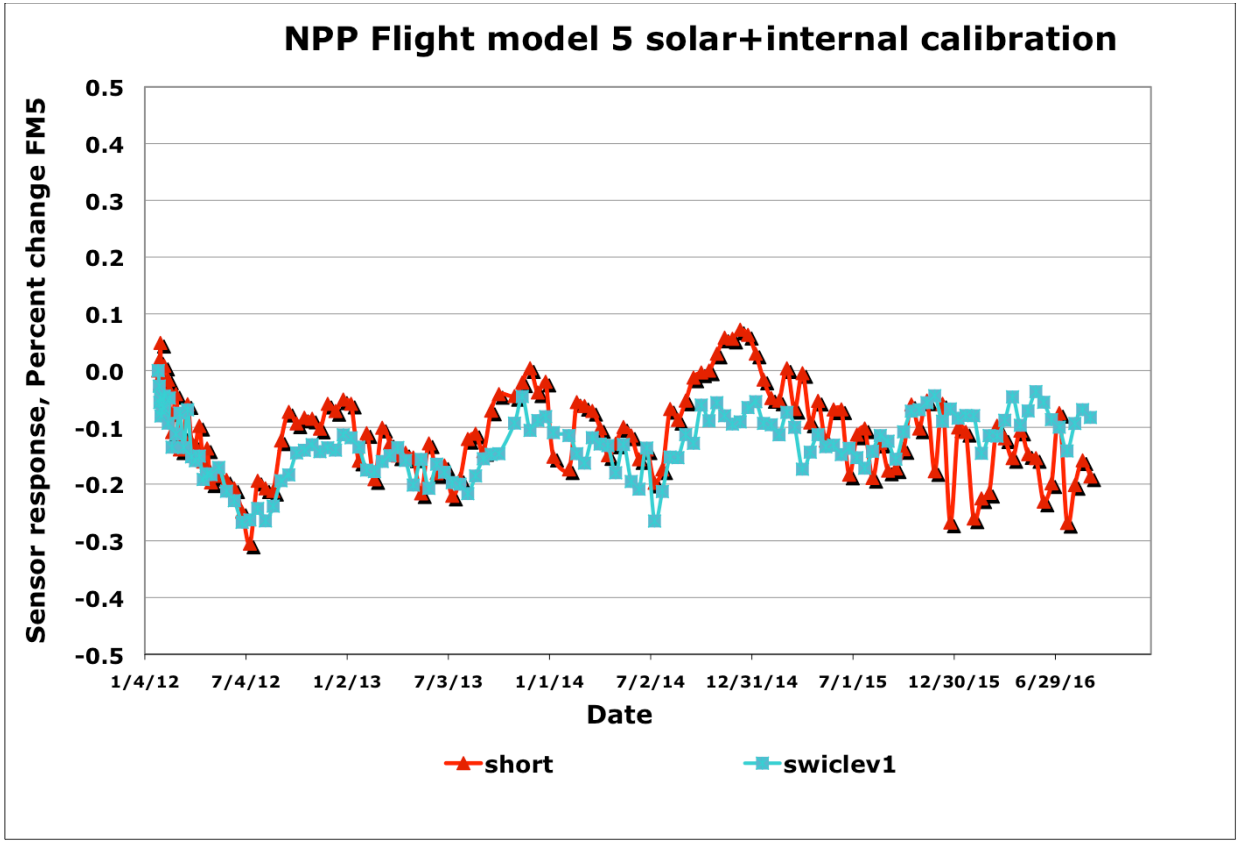




Sensor gain corrections based on ICM calibrations are applied to Edition1 data products.

S-NPP/CERES FM5 Instrument Calibration

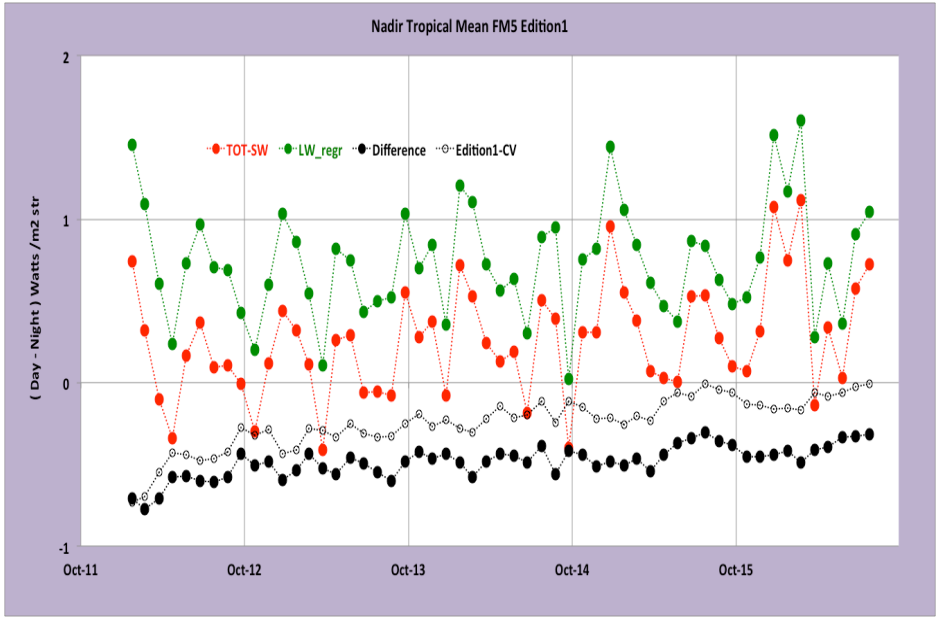
Calibration results from SWICS (Level1) and MAM showed consistent trends in the SW sensor.

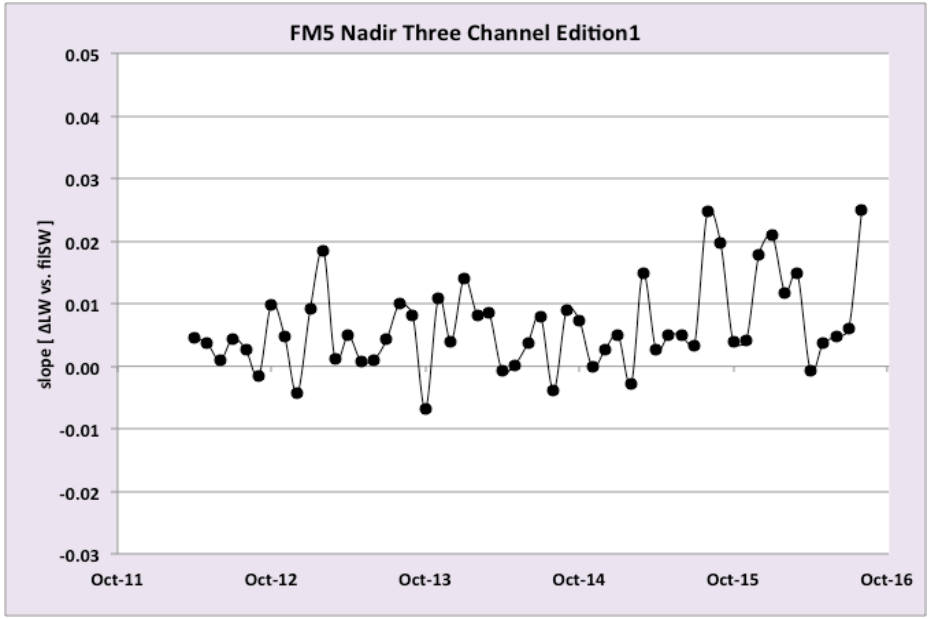


Suomi NPP/CERES FM5 Validation Results

Tropical Mean (TM): Nadir LW radiance for All-sky Ocean in ± 20 deg Latitude. Changes in SW/TOT channel is monitored through Day-Night Difference comparison between LW and Window measurements.

Three Channel comparison use Deep Convective Cloud (DCC) as target. Trend in monthly slope between delta LW and SW measurements is monitored.



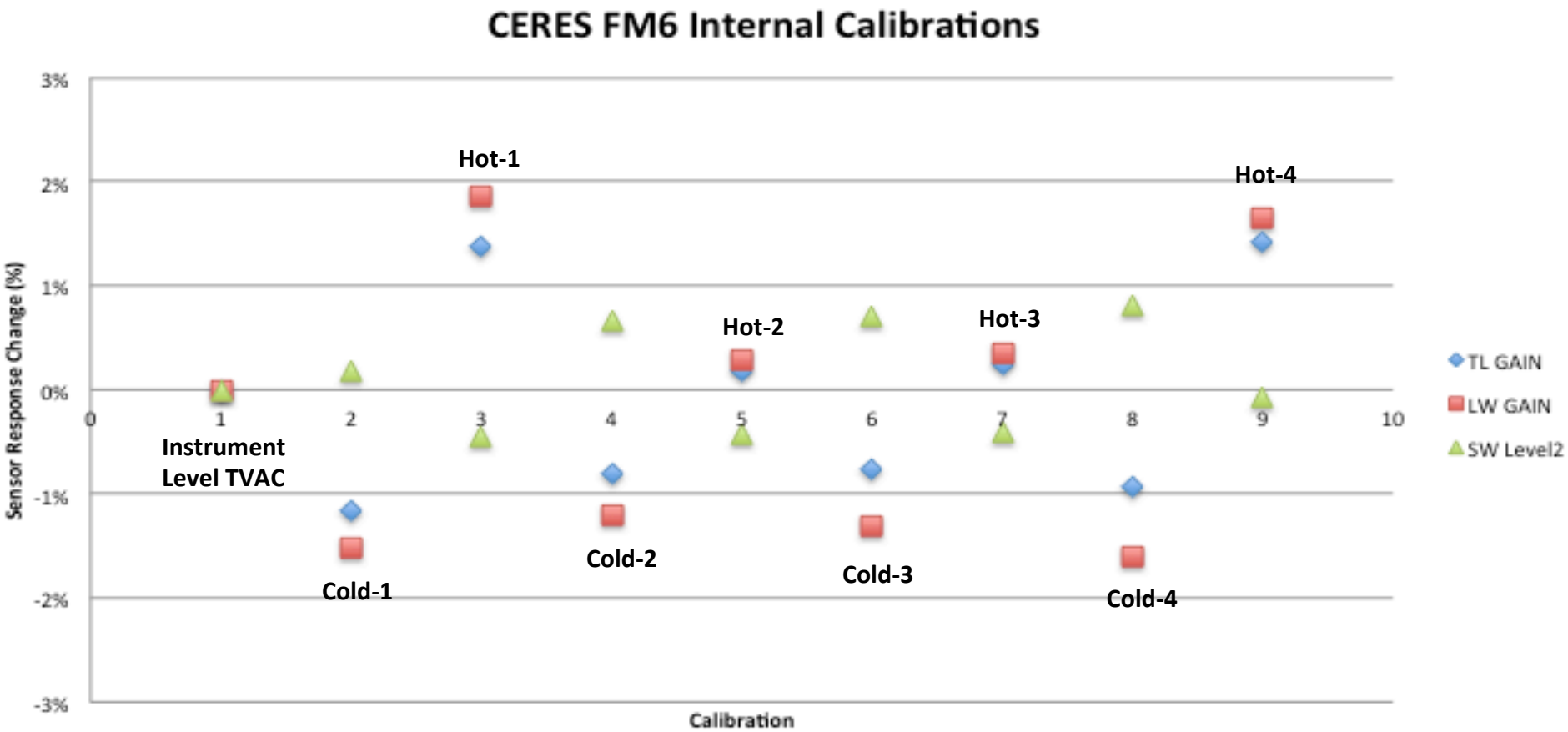


CERES FM-6

JPSS-1 Satellite I&T Overview

- Ball Aerospace & Technologies Corporation (BATC) in Boulder, CO is the JPSS-1 spacecraft provider and satellite integrator.
- JPSS-1/CERES FM6 completed the Environmental Campaign.
  - Vibration: May 2016
  - EMI/EMC: June-July 2016
  - Thermal Vacuum (TVAC): August – October 2016
- JPSS Compatibility Tests and Mission Rehearsals were conducted to evaluate the Instrument post-launch operation capabilities.
- JPSS coordinate launch operations through NASA KSC
  - Launch will be from Vandenberg AFB, CA – NET March 2017

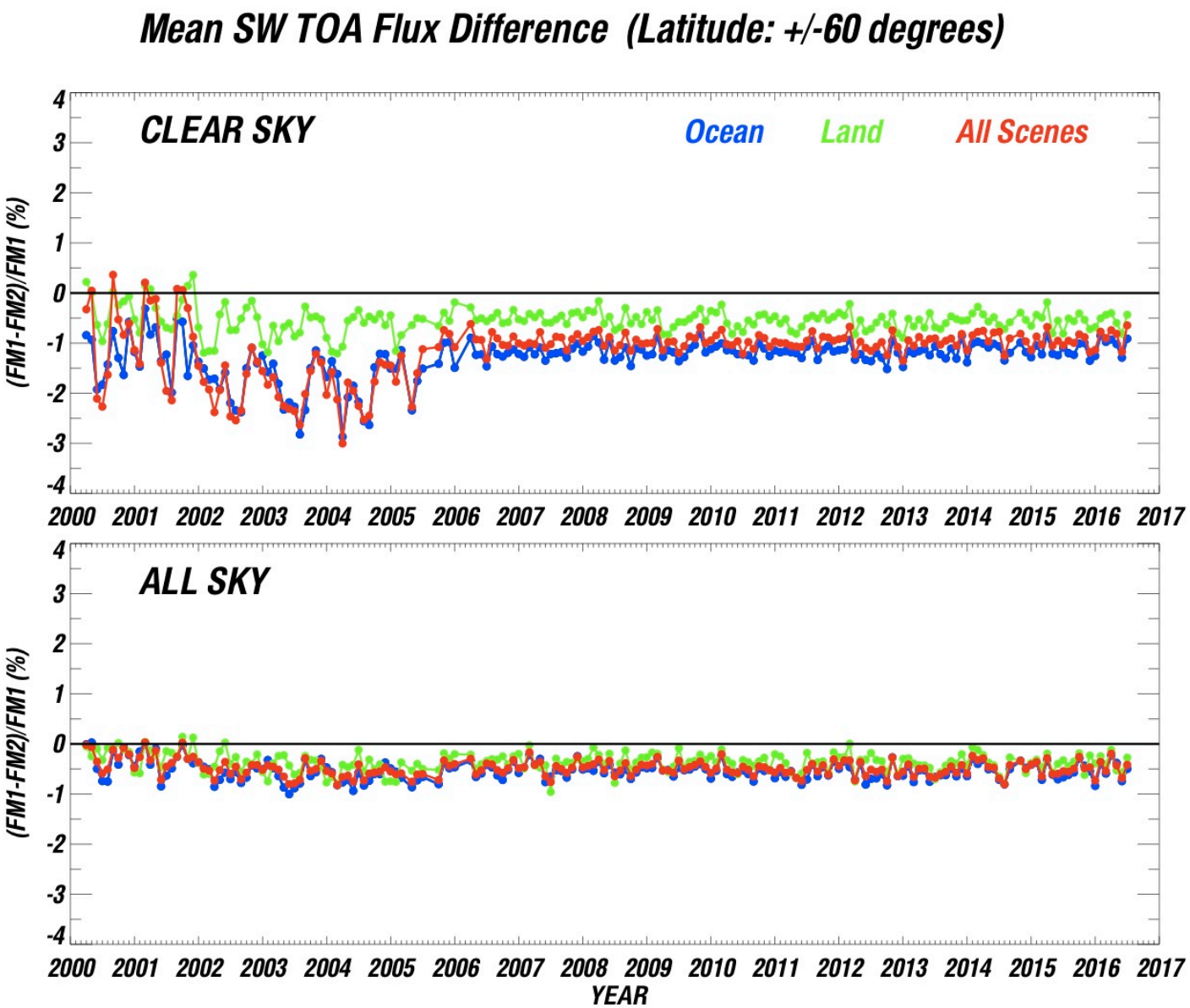
JPSS-1/CERES FM6 TVAC RESULTS

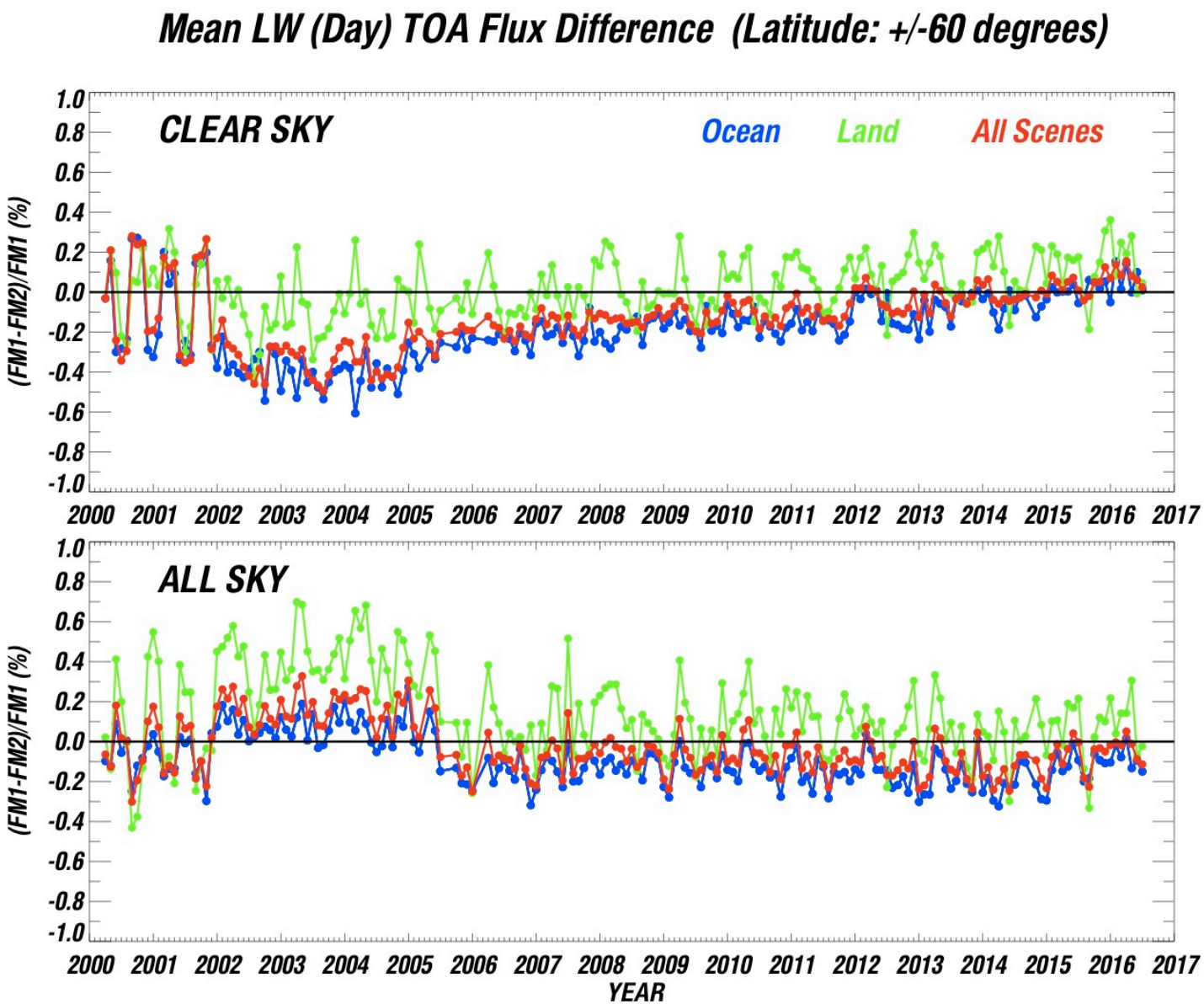


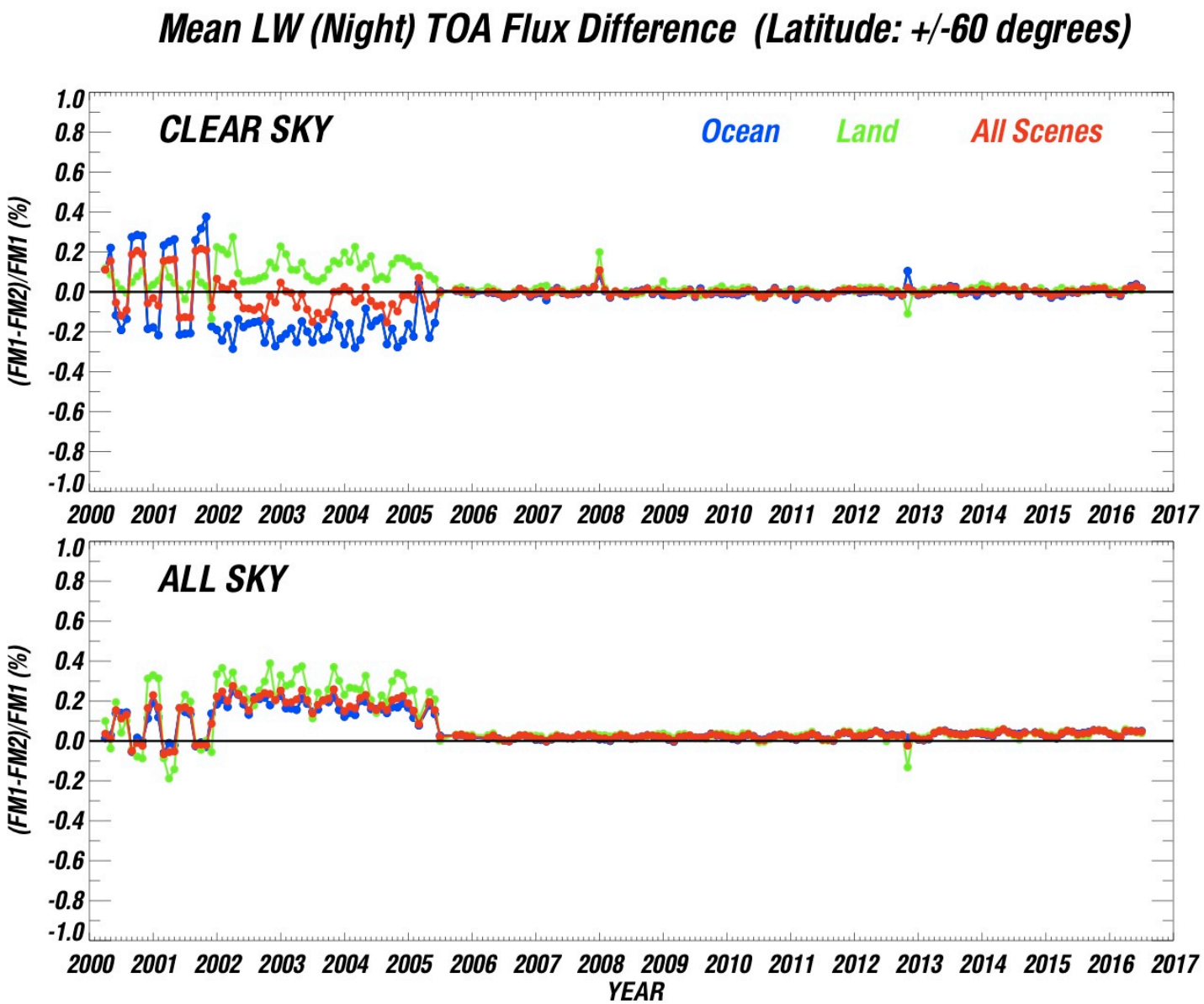
SUMMARY

- Validation results from the Edition-4 datasets show slight negative trend in SW (FM1: -0.24, FM2: -0.22 and FM3: -0.46 W/m2/decade).
- LW-Day anomaly results show positive trends in FM2 (0.26 W/m2/dec) and FM3 (0.28 W/m2/dec) and no trend in FM1 instrument.
- Terra and Aqua Inter-comparison campaign results show good consistency in both SW and LW measurements.
- CERES FM5 calibration results show the performance trends are within expected range.
- CERES FM6 instrument has successfully completed all Spacecraft Level Test Campaign.

BACK UP SLIDES


Mean SW TOA Flux Difference (Latitude: +/-60 degrees)
CLEAR SKY
Ocean
Land
All Scenes
(FM1-FM2)/FM1 (%)
4
3
2
1
0
-1
-2
-3
-4
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
ALL SKY
(FM1-FM2)/FM1 (%)
YEAR


Mean LW (Day) TOA Flux Difference (Latitude: +/-60 degrees)
CLEAR SKY
Ocean
Land
All Scenes
ALL SKY
(FM1-FM2)/FM1 (%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
YEAR

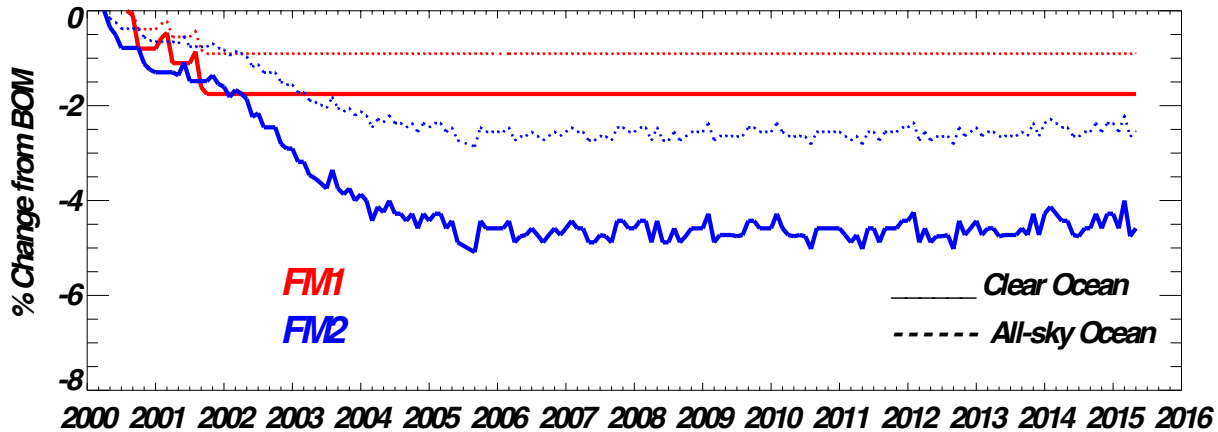

Mean LW (Night) TOA Flux Difference (Latitude: +/-60 degrees)
CLEAR SKY
Ocean
Land
All Scenes
ALL SKY
(FM1-FM2)/FM1 (%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
YEAR

TERRA/AQUA EDITION-4: SW SENSOR

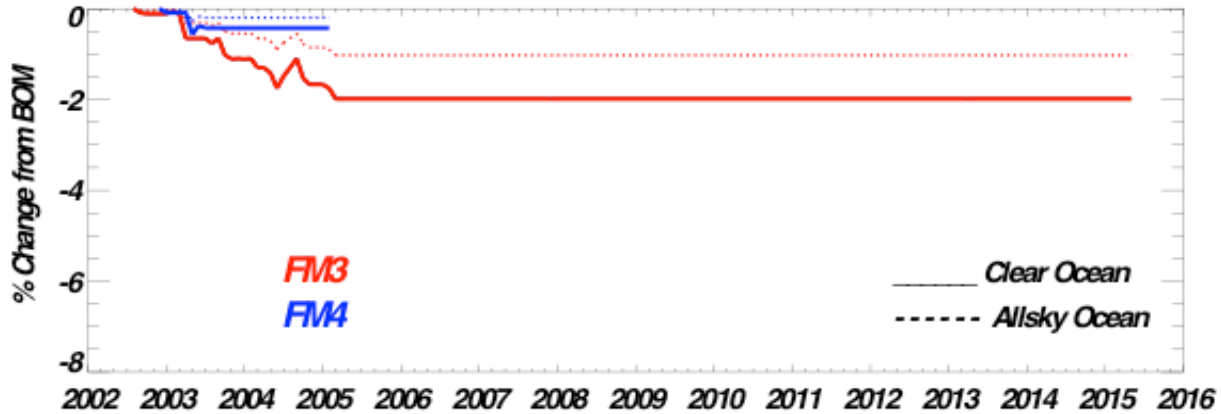
The SW sensor Spectral Response Function (SRF) correction is applied based on the Nadir comparison of Clear Ocean SW measurement from two instruments on same spacecraft. The correction is applied to SRF for the instrument operating in RAPS mode.

SW 'Optimal' Throughput Change calculated with SCIAMACHY Clear/All Ocean Spectra

TERRA



AQUA

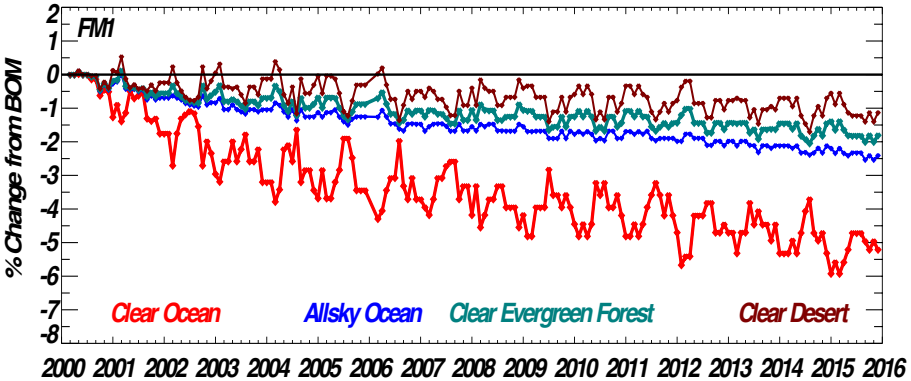


CERES Instrument Working Group

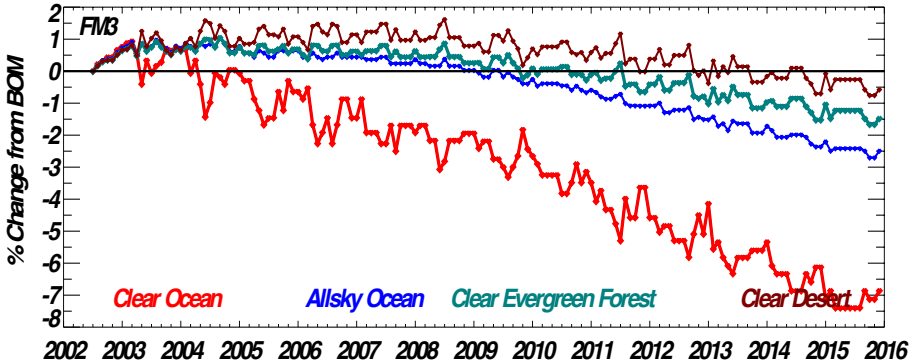
EDITION-4 TERRA/AQUA: SW/TOT SENSOR

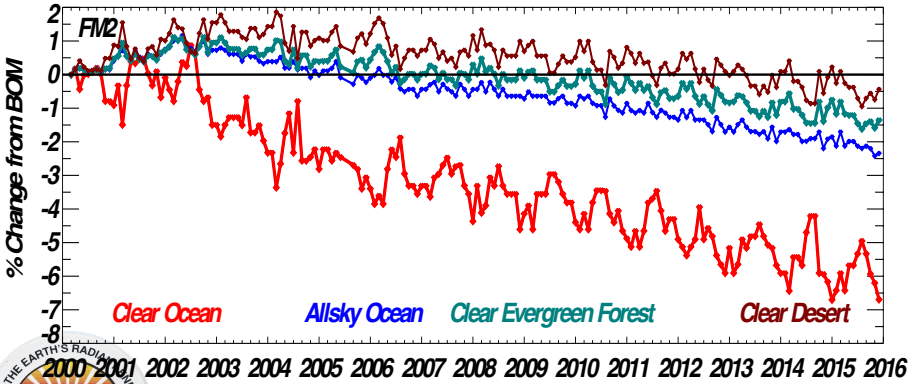
- **Correction to SW/TOT sensor of each instrument is based on the regression between LW(Day-Night) and WN (Day-Night) using Tropical Ocean and Land scenes.**

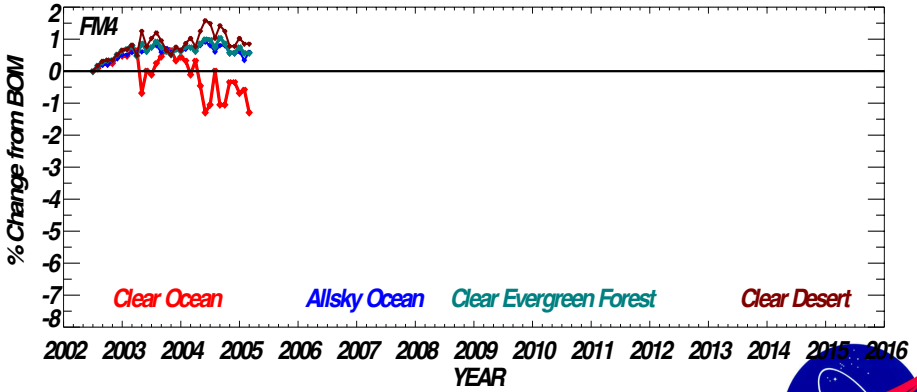
SW/TOT 'Optimal' Throughput Change for Terra (Terra SRF with SCIAMACHY Scene Spectra)



SW/TOT 'Optimal' Throughput Change for Aqua (Aqua SRF with SCIAMACHY Scene Spectra)

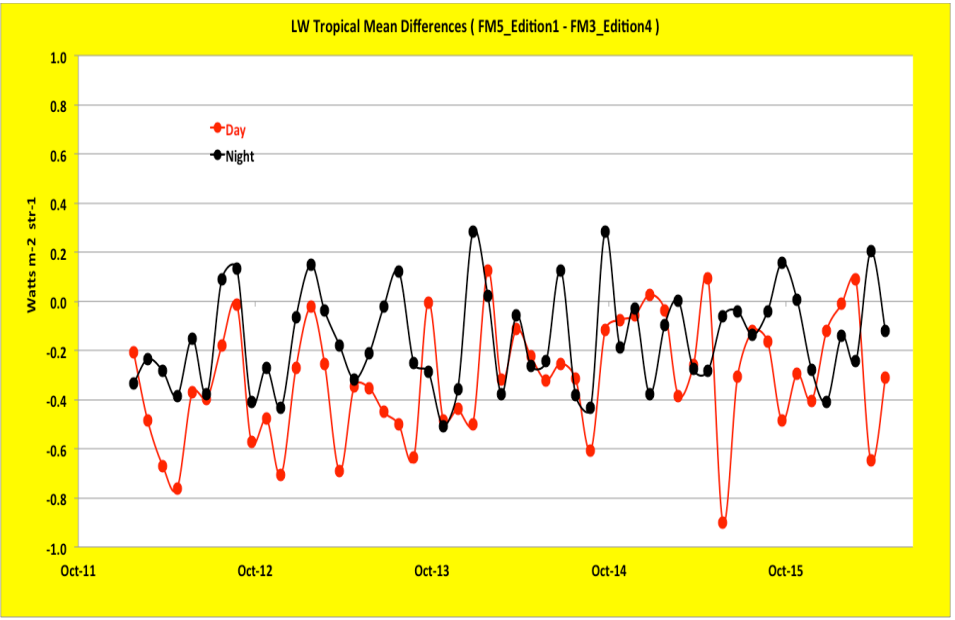


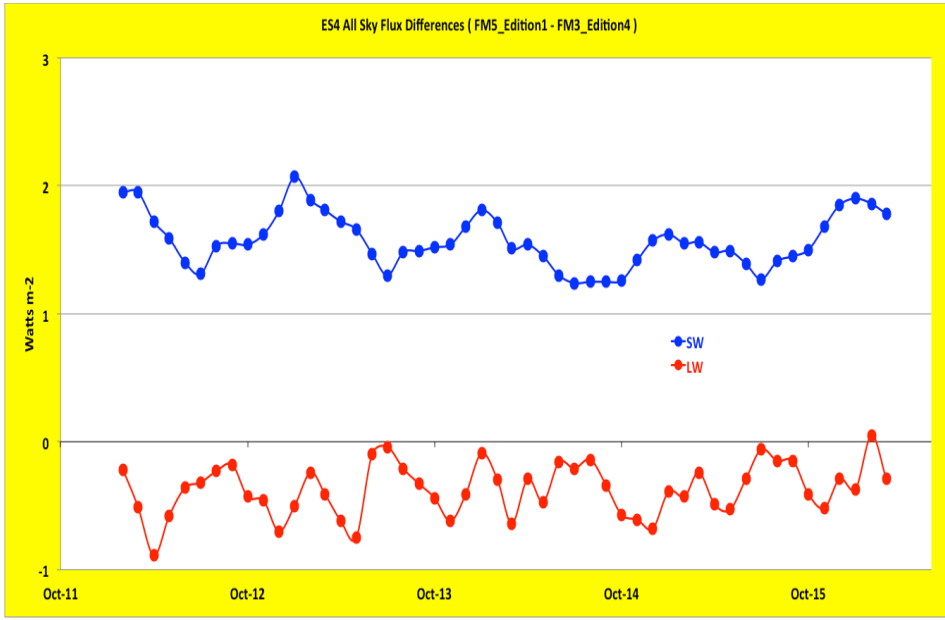




CERES S-NPP/FM5 – Aqua/FM3 Comparison

Tropical Mean LW comparisons show stable results.
Global Flux Differences show that CERES FM5 SW measurements are higher and LW measurements lower than FM3 measurements.





CERES FM5 - FM3 Matched Footprint Comparisons

All-sky 2012/2013/2014/2015
(Rev. 04/19/16)
ΔTime < 1min; ΔRAZ < 10°; ΔVZA <10°

Shown differences are statistically significant

(FM5-FM3)/ FM5	FM5 Radiance [W m^{-2} sr^{-1}]	Relative Error [%]	α-confidence [95%]	Number of samples
Shortwave	79.1/84.5/77.2/80.6	**3.29 / 2.68 / 1.02/ 1.71**	.40/.31/.35/.35	65/86/91/85
LW daytime	75.7/74.0/76.9/76.6	**-1.13/-1.25/-0.57/-0.87**	.09/.10/.13/.10	69/89/91/85
LW nighttime	66.2/64.9/67.5/65.5	**-0.31/-0.27/0.01/-0.15**	.07/.08/.06/.07	87/105/106/105

- Edition 1 for FM5 and Edition 4 for FM1/FM3 are used
- Shown differences are computed as "average of differences" to avoid error cancellation

Direct compare of FM5 and FM3

Minor Plane Scanning

All-sky 2013/2014/2015

13min < ΔTime < 23min

Differences are not statistically significant

(FM5-FM3)/ FM5	FM5 Radiance [W m^{-2} sr^{-1}]	Relative Error [%]	α-confidence [95%]	Number of samples
Shortwave	97.7/108.7/105.7	**0.86 / 0.96 / 0.88**	0.93/0.90/0.87	39/30/30
LW daytime	77.8/76.4/75.7	**0.15 / -0.03 / -0.14**	0.39/0.46/0.38	39/30/30

- Edition 1 for FM5 and Edition 4 for FM3 are used
- The differences are similar to those of FM5/FM1
- Larger uncertainties make differences statistically non-significant

Direct compare of FM5 and FM1

Minor Plane Scanning

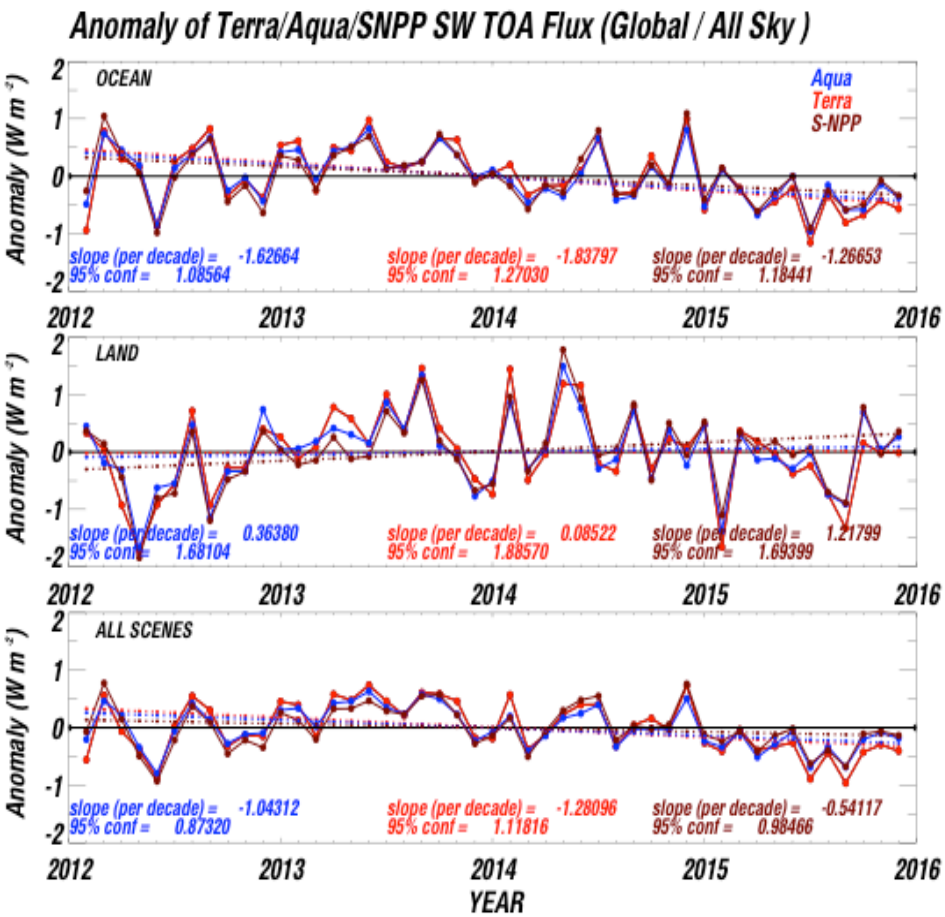
All-sky 2012/2013/2014/2015
ΔTime < 5min

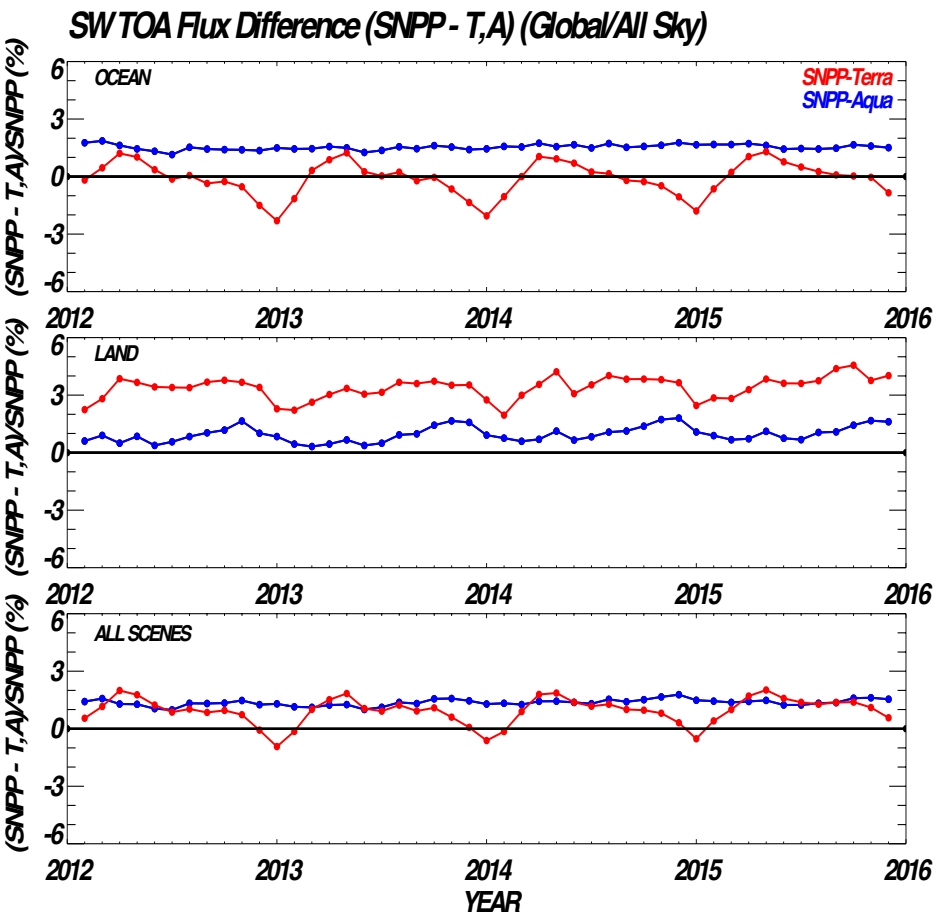
Shown differences are statistically significant

(FM5-FM1)/ FM5	FM5 radiance [W m^{-2} sr^{-1}]	Relative Error [%]	α-confidence [95%]	Number of samples
Shortwave	87.0/101.6/111.1/108.6	.81/.93/.86/1.00	.26/.17/.14/.17	64/108/123/139
LW daytime	78.6/76.1/74.8/74.8	-.46 /-.16 /-.81/-.71	.13/.09/.12/.12	68/112/130/141

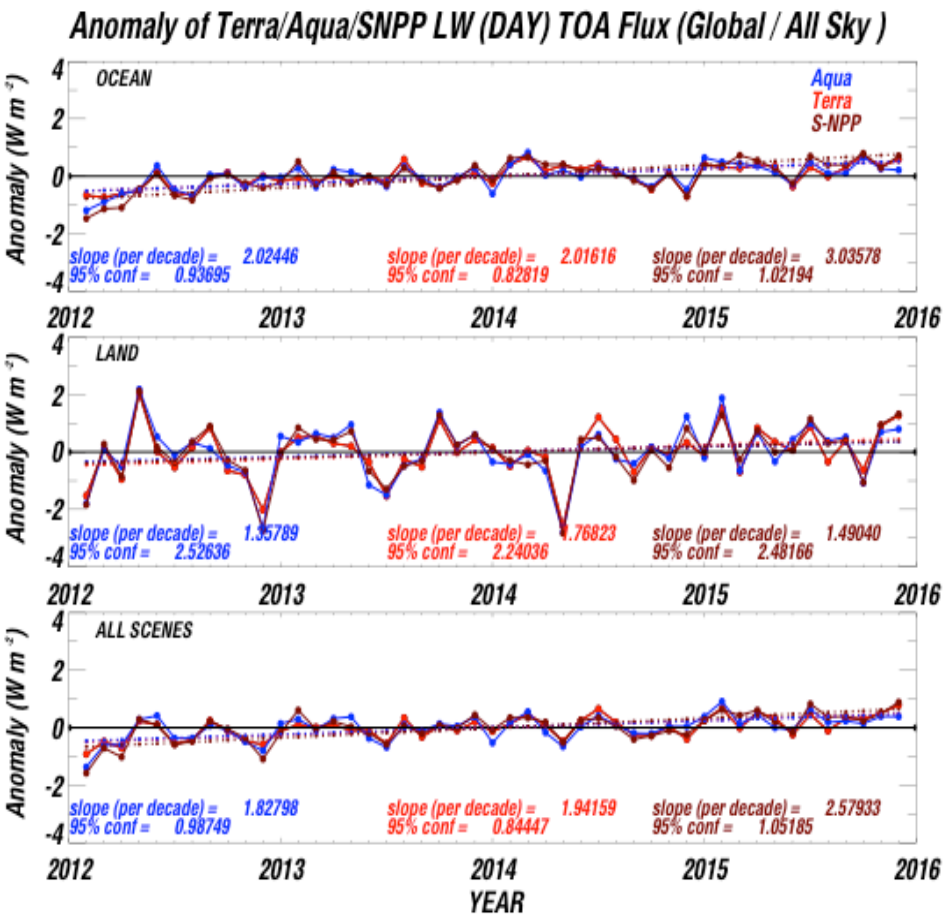
- 2012 campaign lasted only 6 weeks
  - June 16 – July 31
- 2013/2014/2015 campaigns lasted 3 months
  - May 1 – July 31

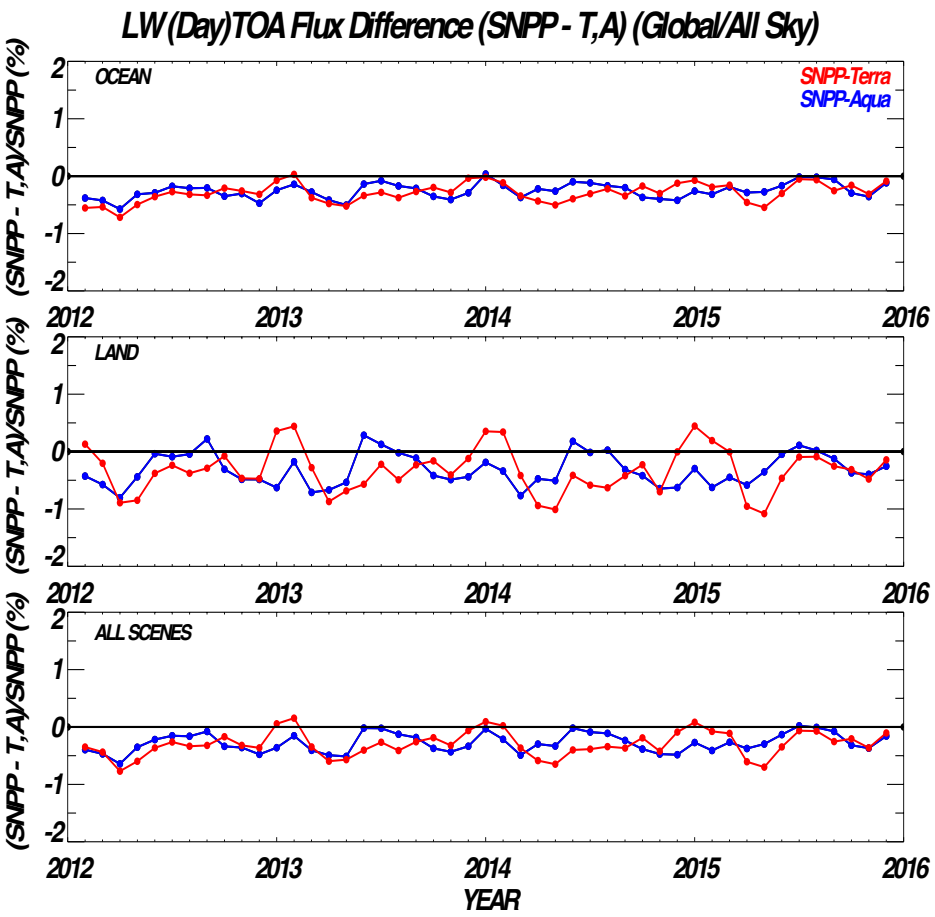
S-NPP/FM5, TERRA & AQUA COMPARE: SW FLUX



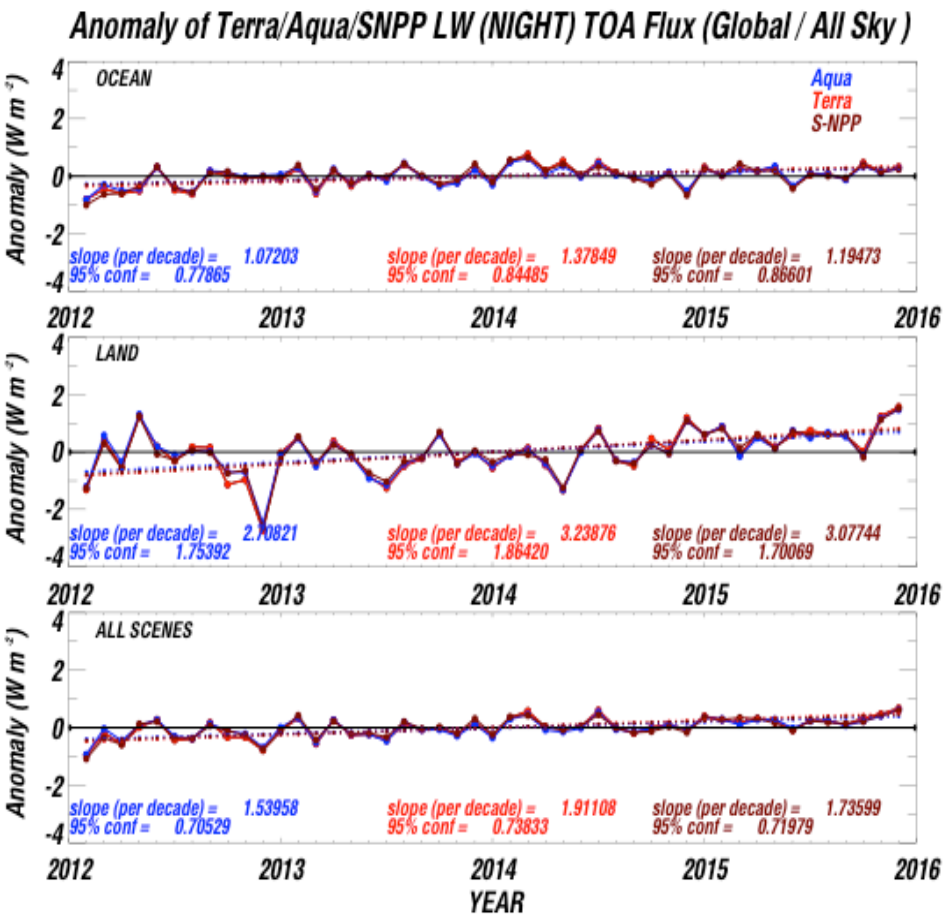


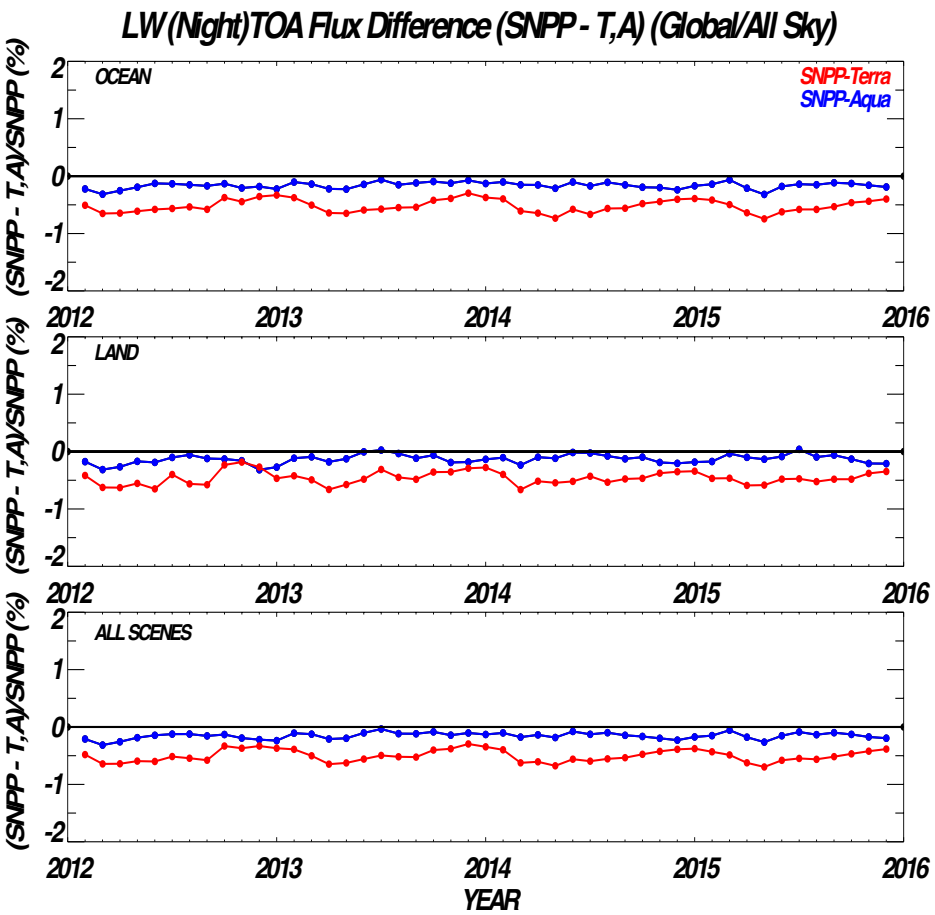
S-NPP/FM5, TERRA & AQUA COMPARE: LW Day





S-NPP/FM5, TERRA & AQUA COMPARE: LW Night





CERES FM6 TVAC OPERATIONS

- CERES Instrument conducted 4 Comprehensive Function Tests (CPT) at COLD-1, HOT-1, COLD-4 and HOT-4 Plateaus.
- CERES operates primarily in Cross-Track mode (default on-orbit mode) during TVAC.
- Calibration using the on-board sources are conducted at each Thermal plateau.
- Total and Longwave sensor stability is evaluated using on-board Blackbody sources at each Thermal plateau.