CERES Instrument Status
Flight Models 1 -6 (FM1 – FM6)

Susan Thomas
CERES Instrument Working Group Team

CERES Science Team Meeting
NASA Goddard Space Flight Center
Greenbelt, Maryland
September 26, 2017

Instrument Working Group

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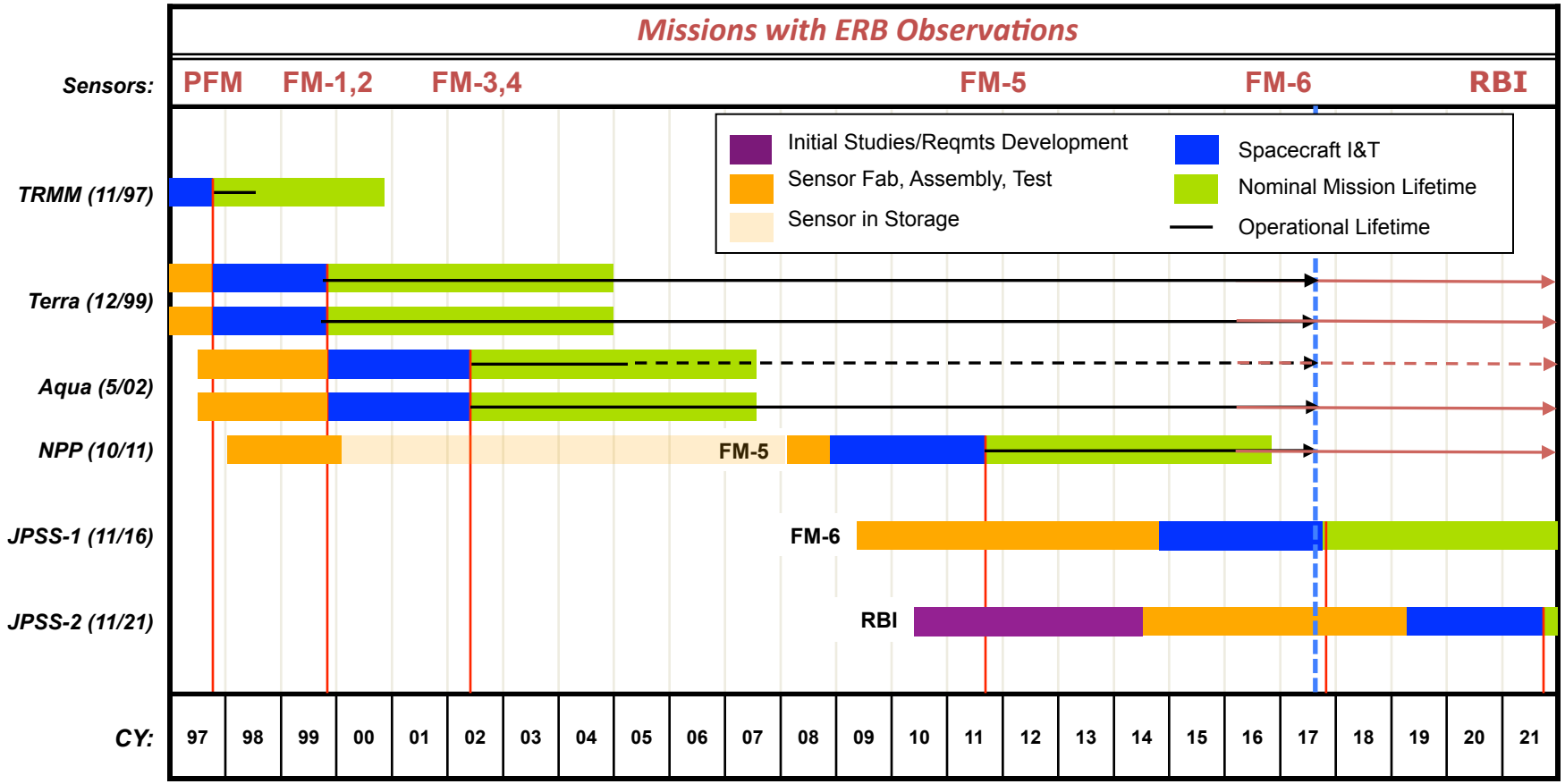
Mohan Shankar
G. Lou Smith
Nathaniel Smith
Nitchie Smith
Z. Peter Szewczyk
Robert Wilson

Climate Data Record Continuity

CERES/RBI Flight Schedule



We now have over 69 years of flight experience with the CERES instruments

CERES Instrument Operations: FM1 - 5

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

Special Operations for Summer 2017

Terra Deep Space Calibration – August 5, 2017

Full Pitch of the spacecraft that lasted ~36 minutes (23:15:45z to 23:51:39z.)

CERES Terra/FM2 - CLARIFY-2017 (Cloud-Aerosol-Radiation interactions and Forcing: 2017) – August 12 – Sept 9 2017

Data collect over Ascension Island – one orbit/day for 3-5 minutes

CERES Terra/FM1 – S-NPP/FM5: May 1 – July 31, 2017.

CERES Terra/FM1 – Aqua/FM3: June 10 – July 31, 2017

TERRA & AQUA INSTRUMENT STATUS

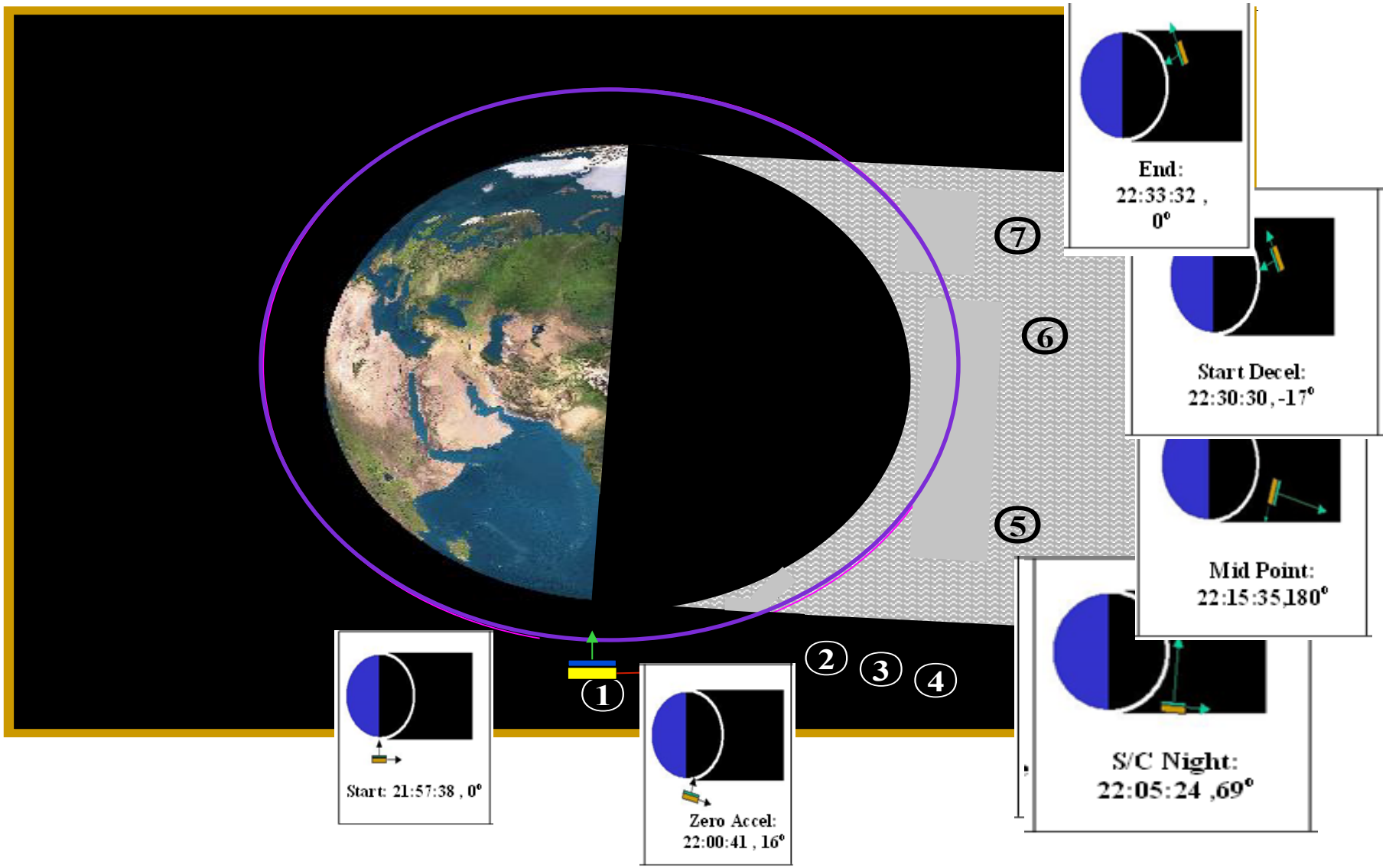
[CERES FM1 – FM4]

Terra Lunar Deep Space Calibration Maneuver

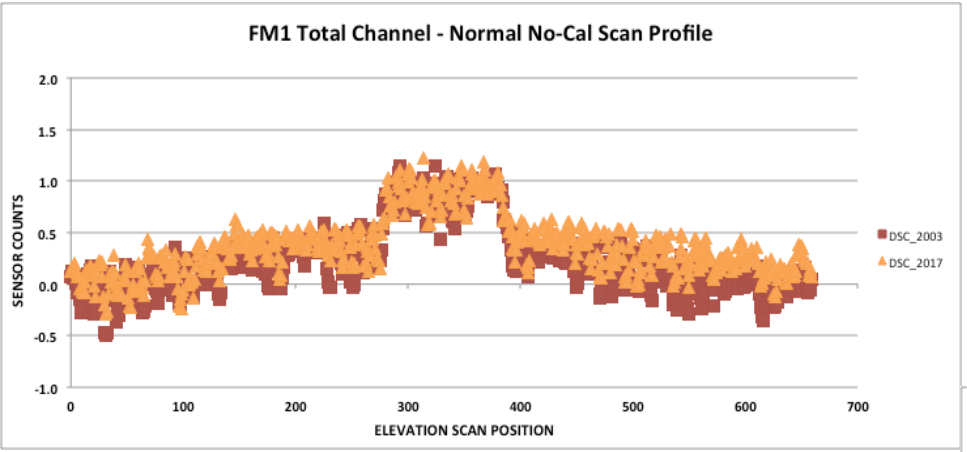
- Lunar Deep Space Calibration (LDSC) maneuver provides the instruments an opportunity to view the cold background of deep space and an option for a lunar viewing through an accelerated pitch-over during Spacecraft night.
- On August 5, 2017 Terra spacecraft successfully performed a LDSC maneuver.
- Terra spacecraft had performed two Deep Space Calibrations in 2003 – a DSC on March 26 and a LDSC on April 14.
- CERES instruments Flight Models 1 and 2 performed special scanning to quantify scan angle dependent offsets for all Earth viewing Elevation angles.
- The offsets are a significant source of uncertainty in the instantaneous sensor measurements.
- The instruments collected measurements in 5 Elevation scan profiles that are normally used in Earth observations.
- The sensor offset counts are showing similar trends as the ones measured in April 2003.

DSC Concept Diagram Animation

Note: The Blue block on S/C is the Instrument Deck.

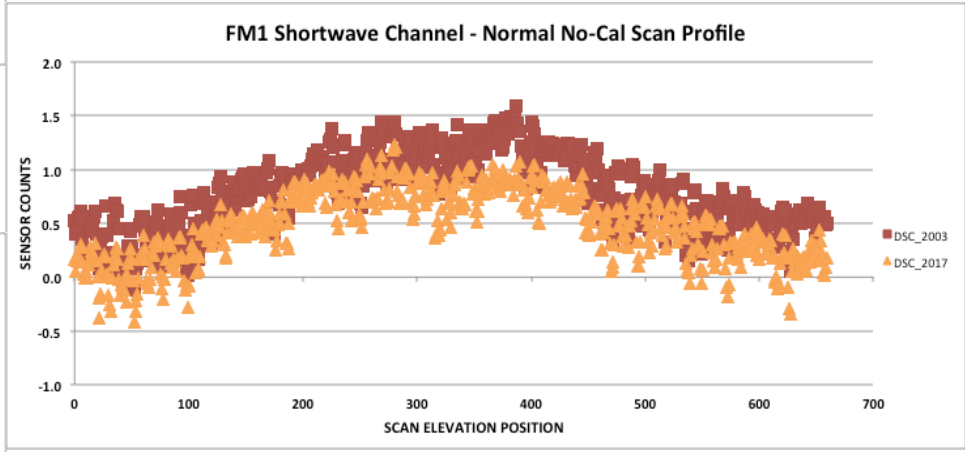


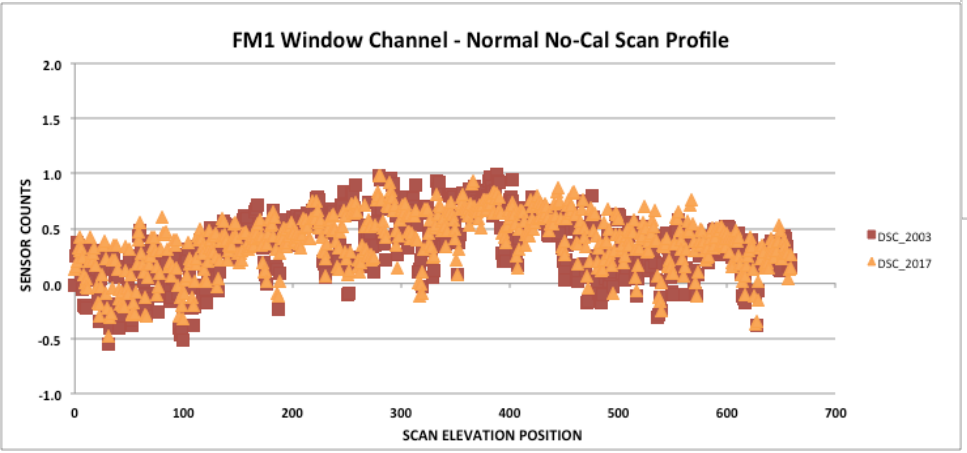
Terra Lunar Deep Space Calibration: FM1 RESULTS



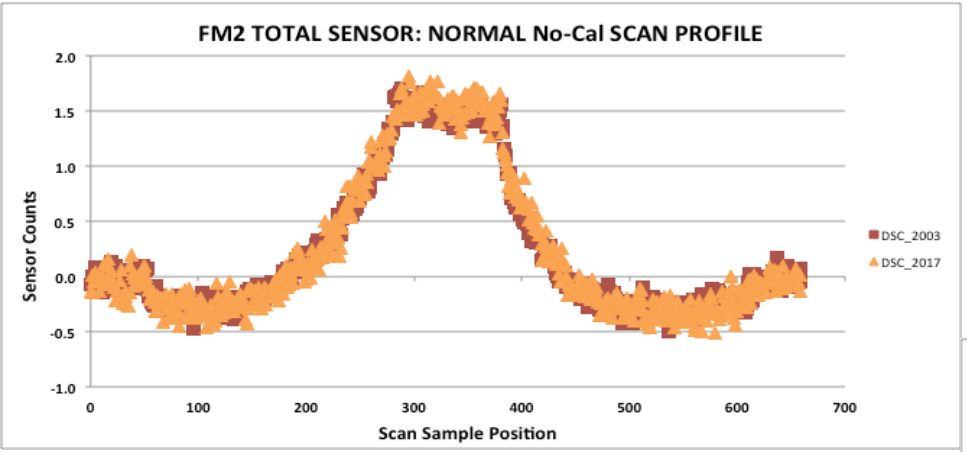
The measurements are collected for Earth-viewing positions in Crosstrack Normal Elevation Scan Profile

View of calibration sources is eliminated in this special scan profile.

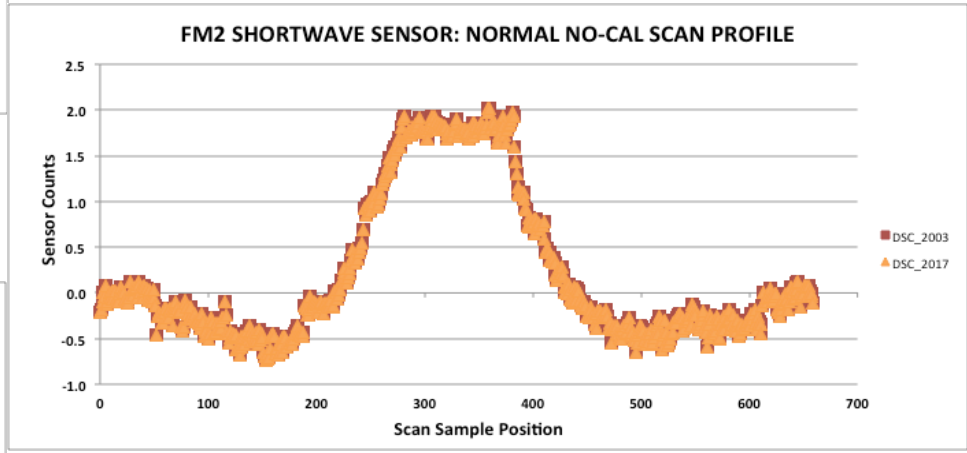


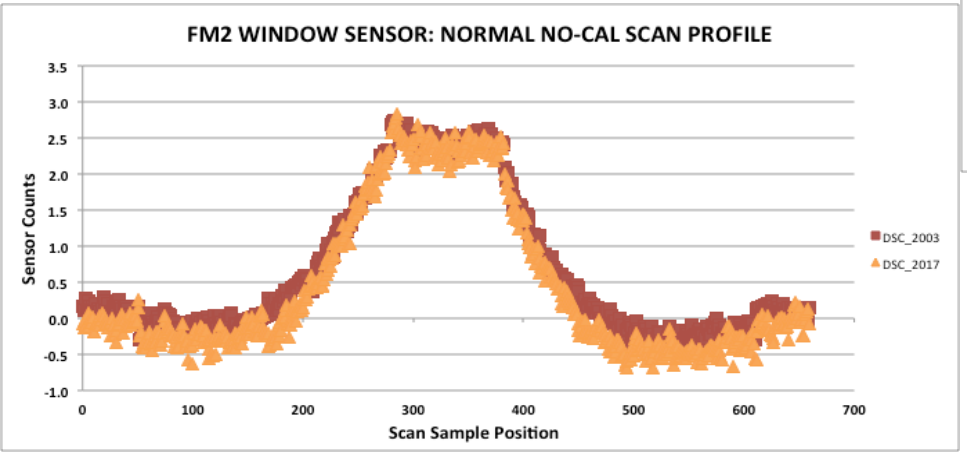


Terra Lunar Deep Space Calibration: FM2 RESULTS



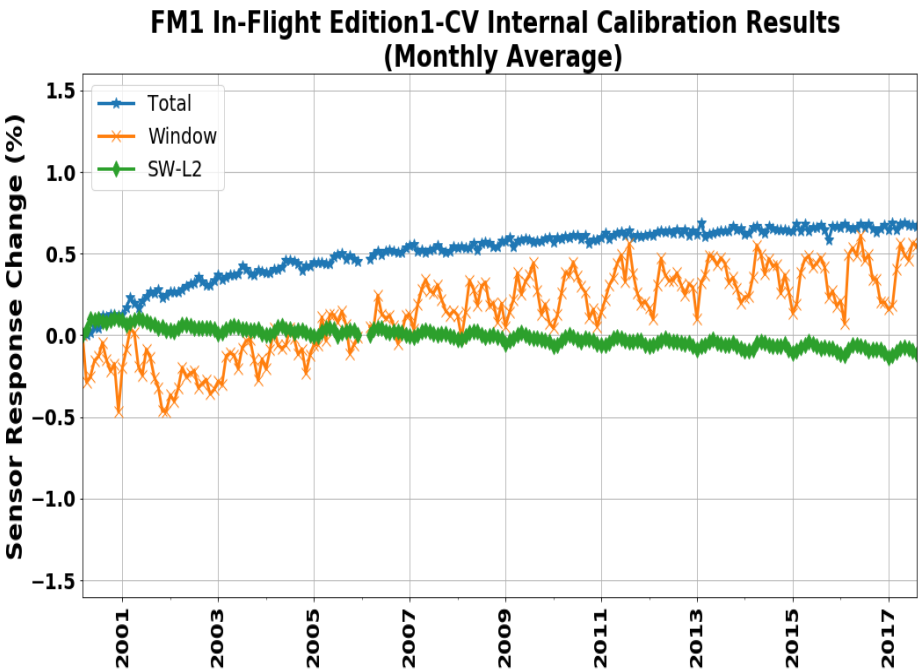
The results for the 2017 LDSC are in good agreement with 2003 LDSC measurements.

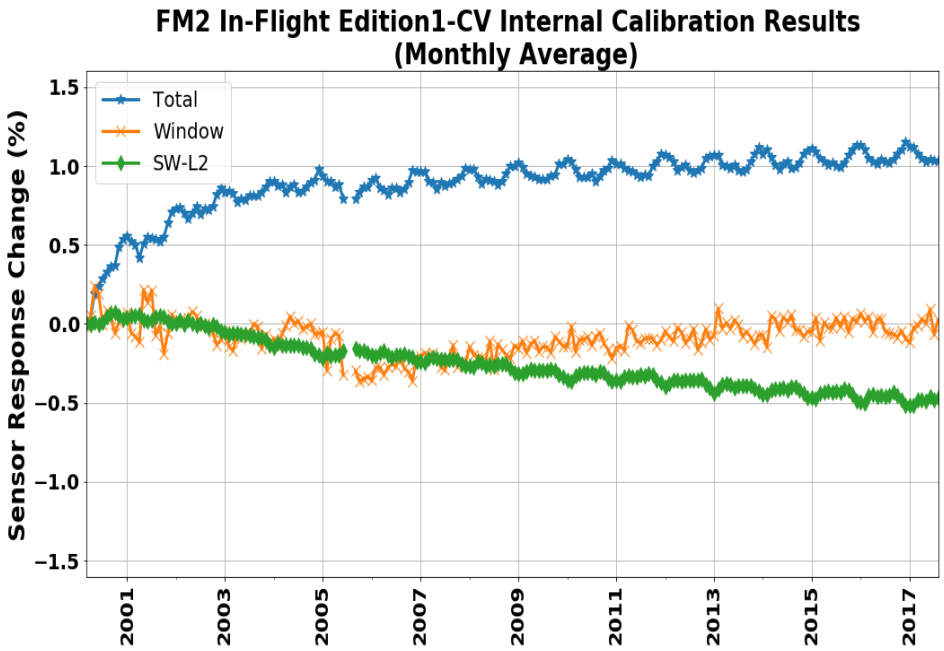




Terra CERES FM1 & FM2 Instrument Calibration

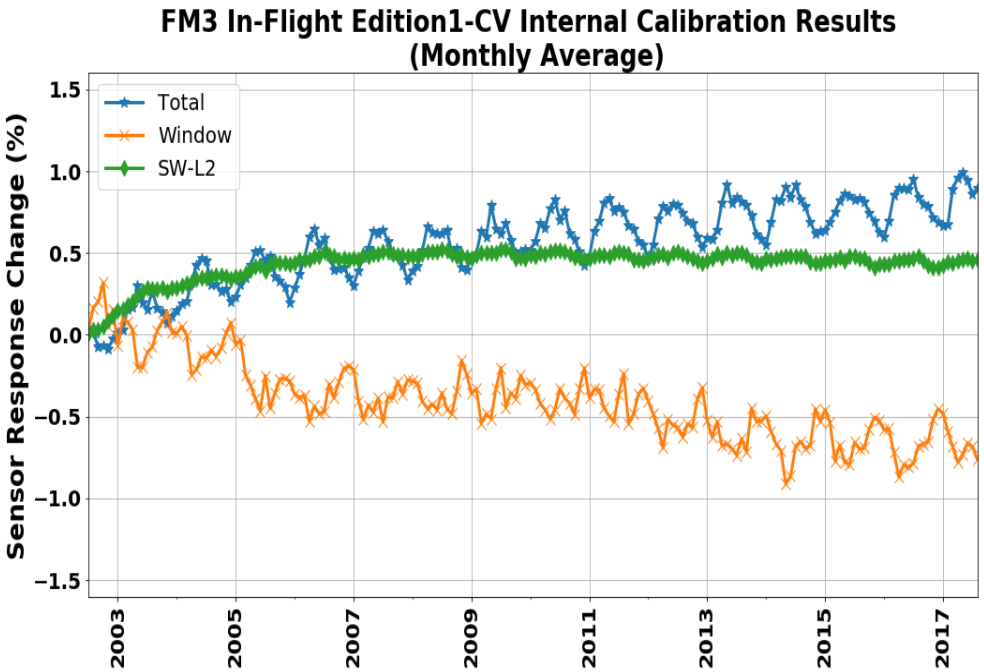
Flight Models 1 and 2 (FM1 & FM2) instruments continued to show slight increase in response for Total and Window sensors and a decrease in SW sensor responses.

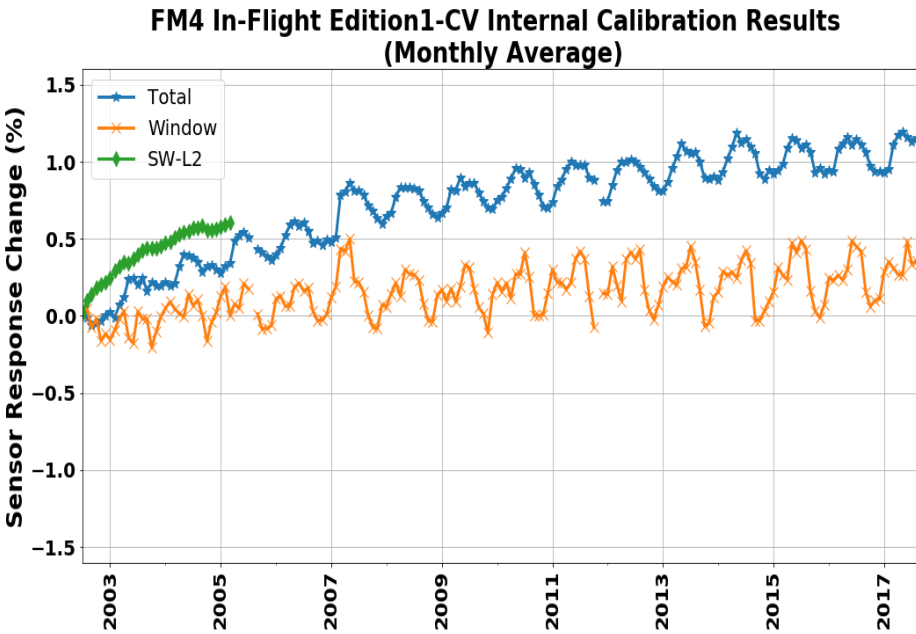




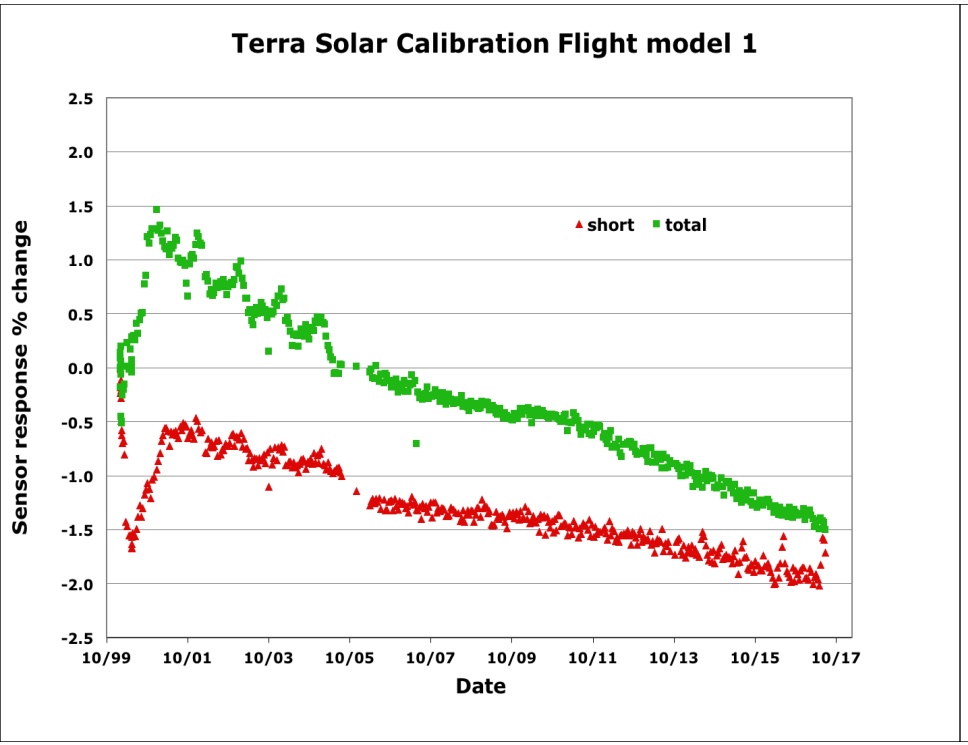
Aqua CERES FM3 & FM4 Instrument Calibration

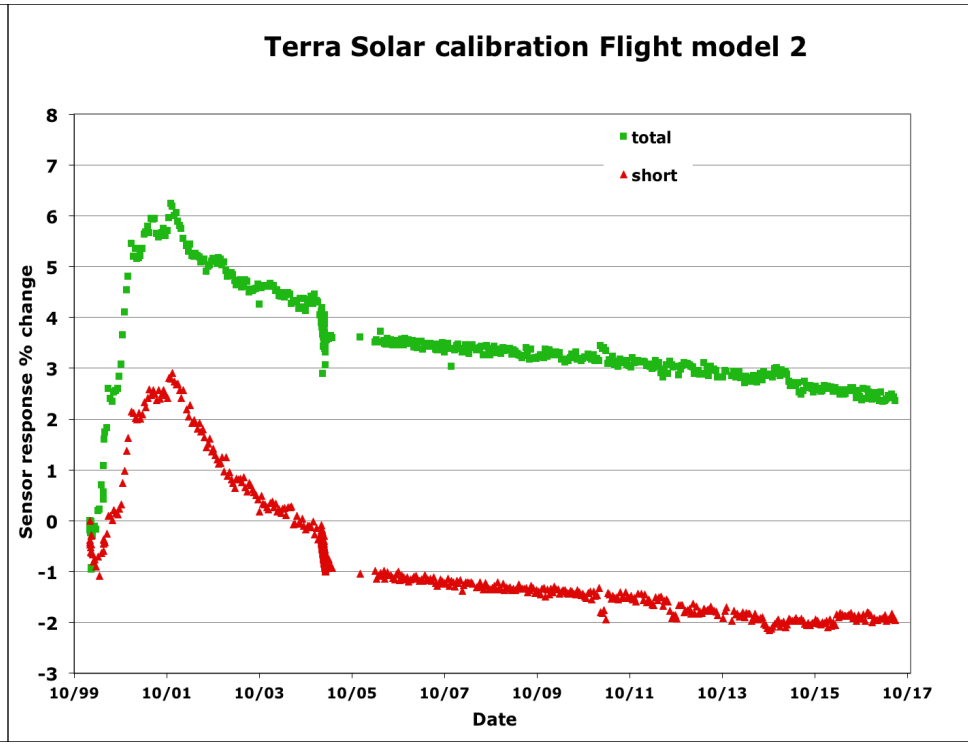
Flight Models 3 and 4 (FM3 & FM4) instruments showed increase in response for Total and SW sensors. Window sensor on FM3 showed a drop where as FM4 instrument response has an upward trend, similar to FM1 and FM2 instruments.



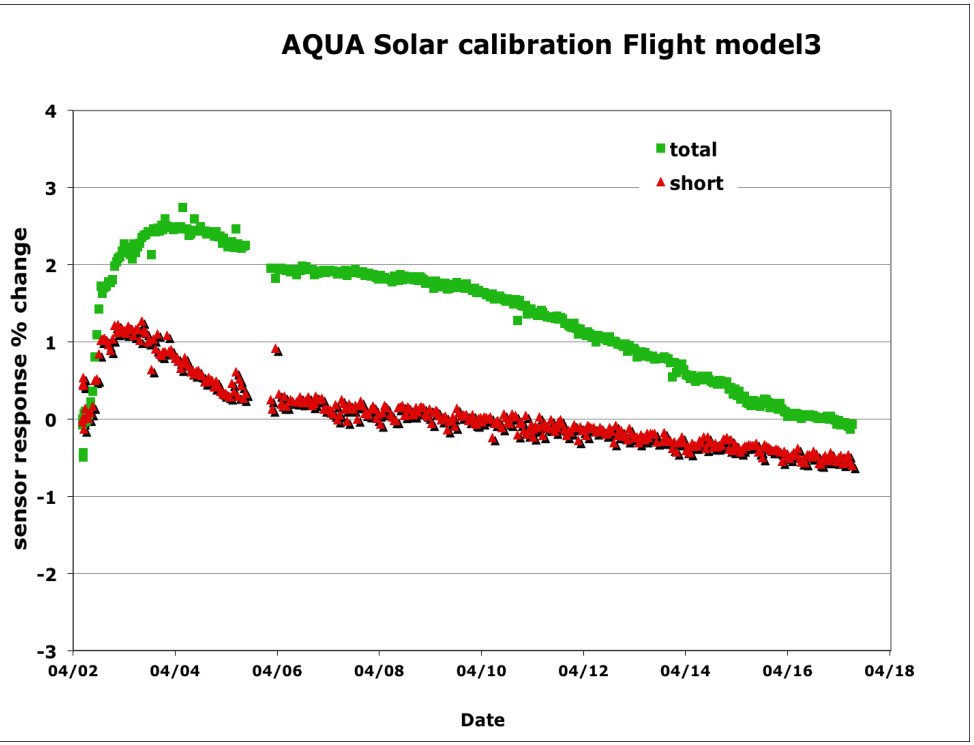


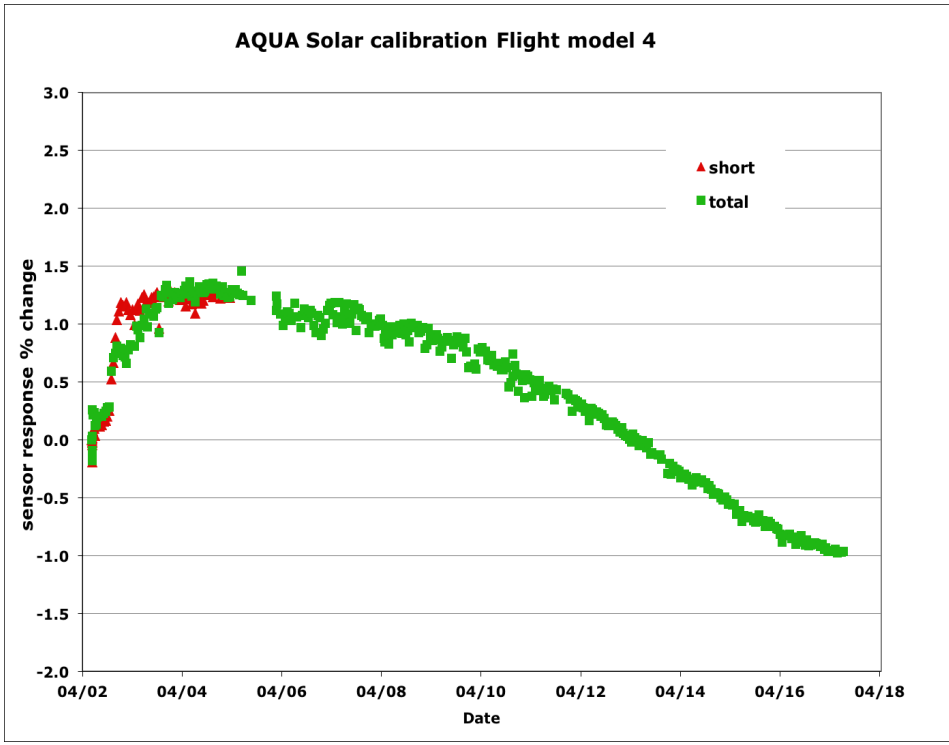
Terra FM1 & FM2 Solar Calibration Results



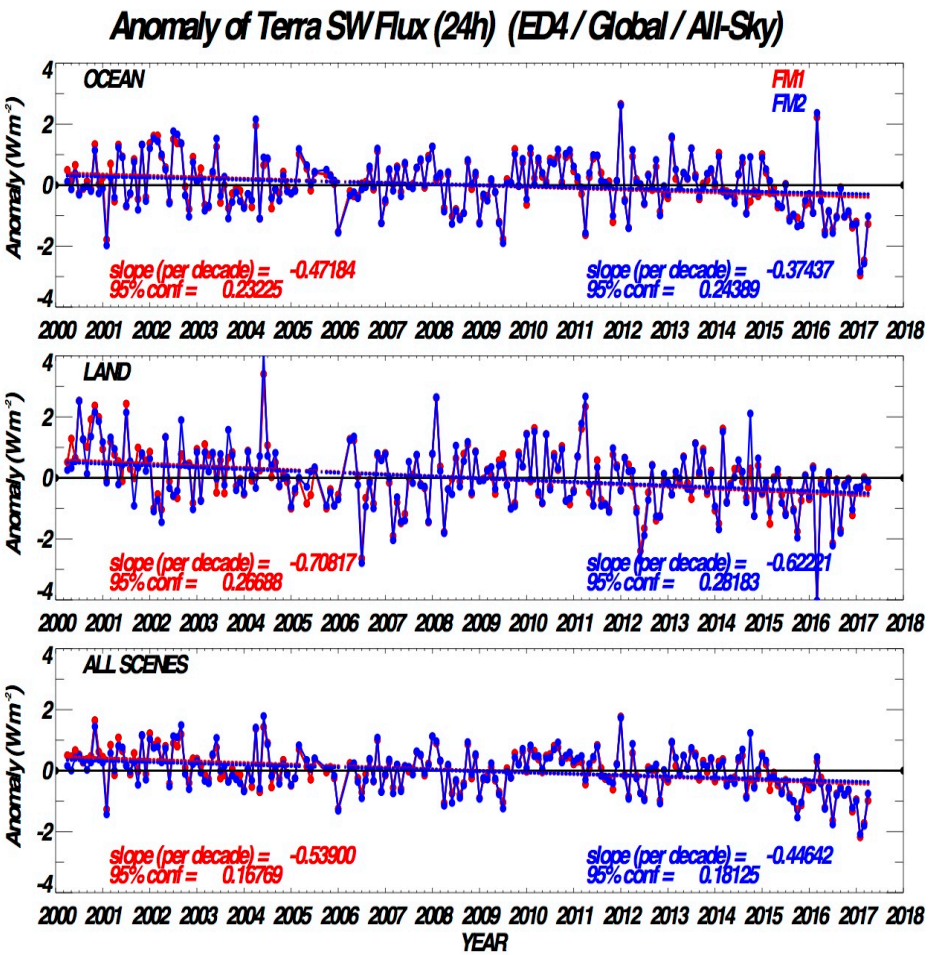


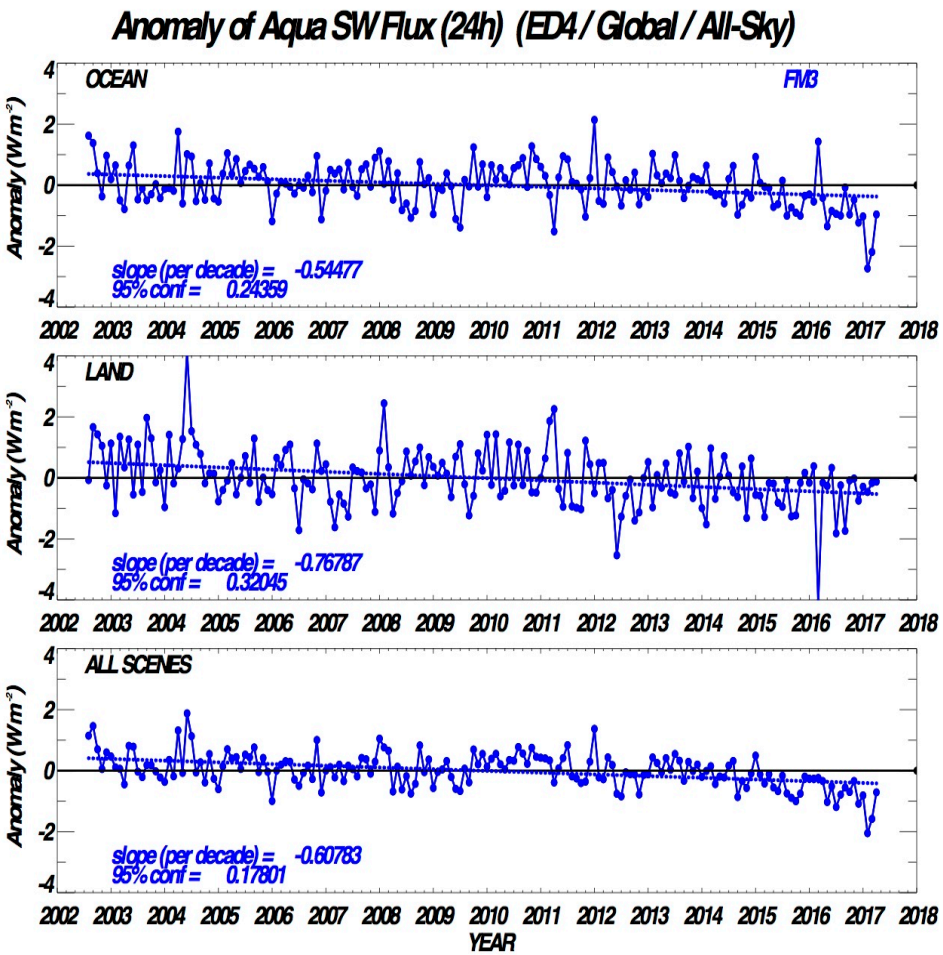
Aqua FM3 & FM4 Solar Calibration Results



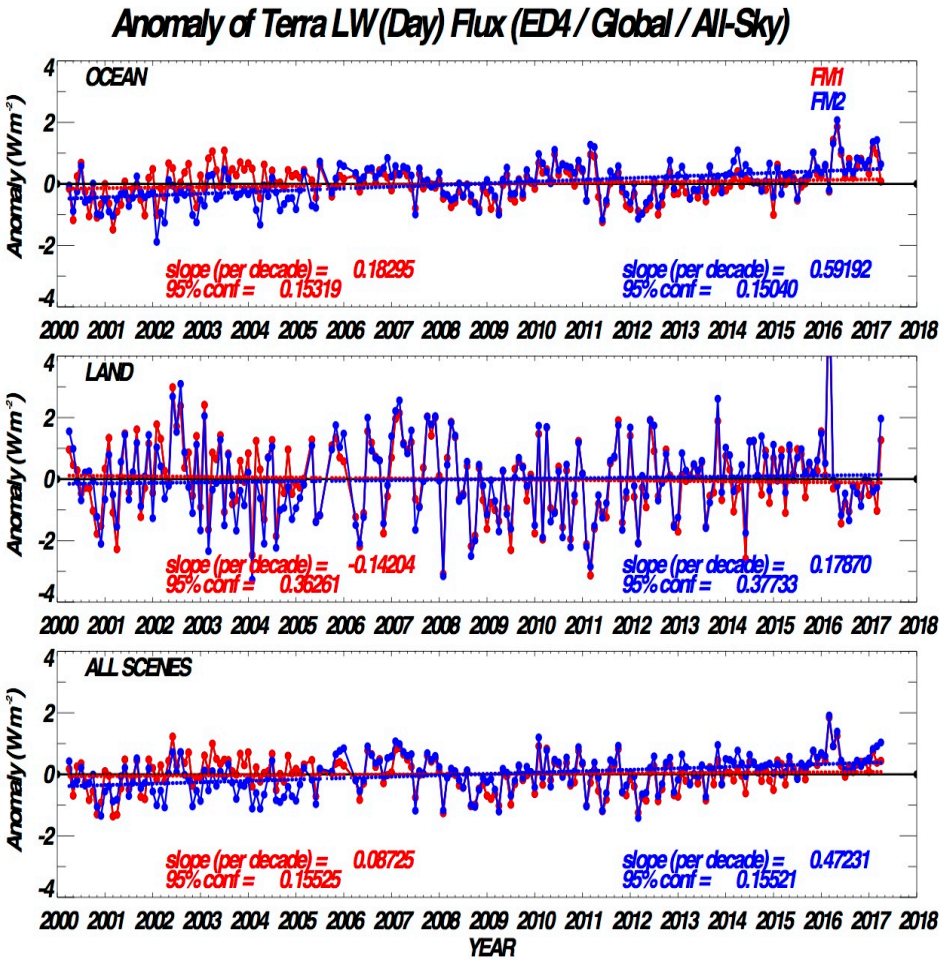


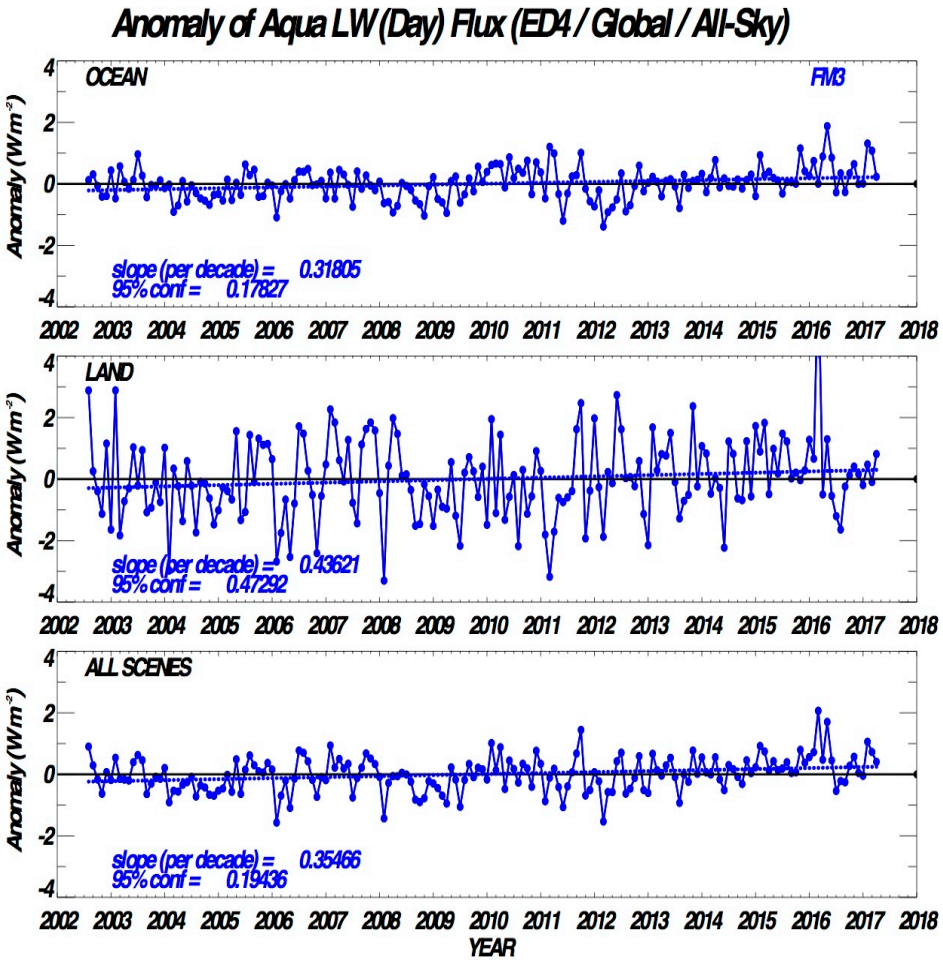
EDITION-4 RESULTS: TERRA & AQUA SW SENSORS



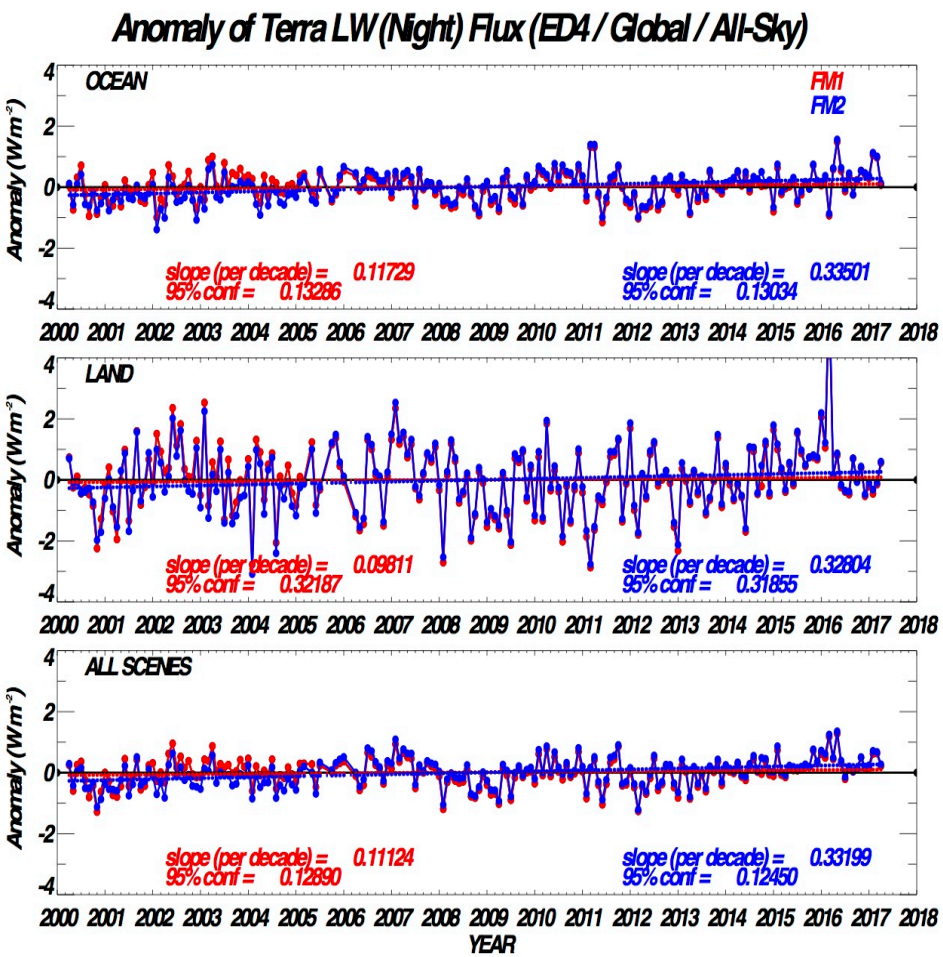


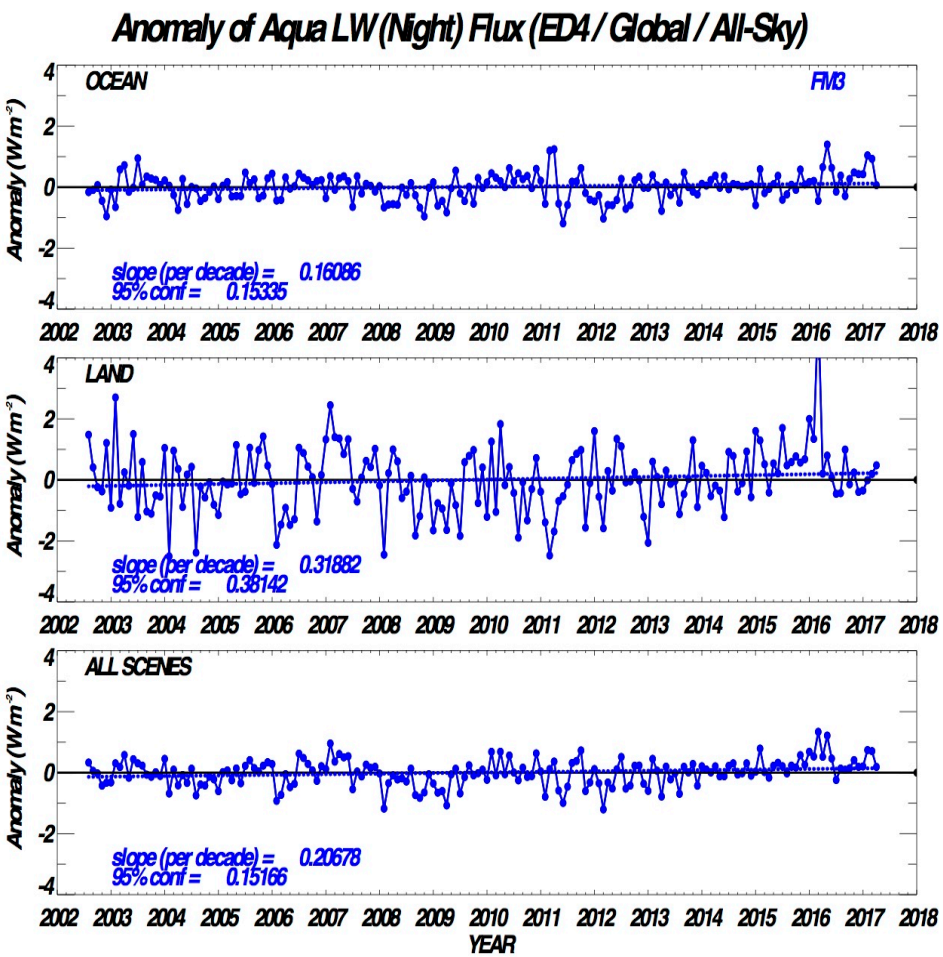
EDITION-4 Results: TERRA & AQUA LW_Day Flux





EDITION-4 Results: TERRA & AQUA LW_Night Flux



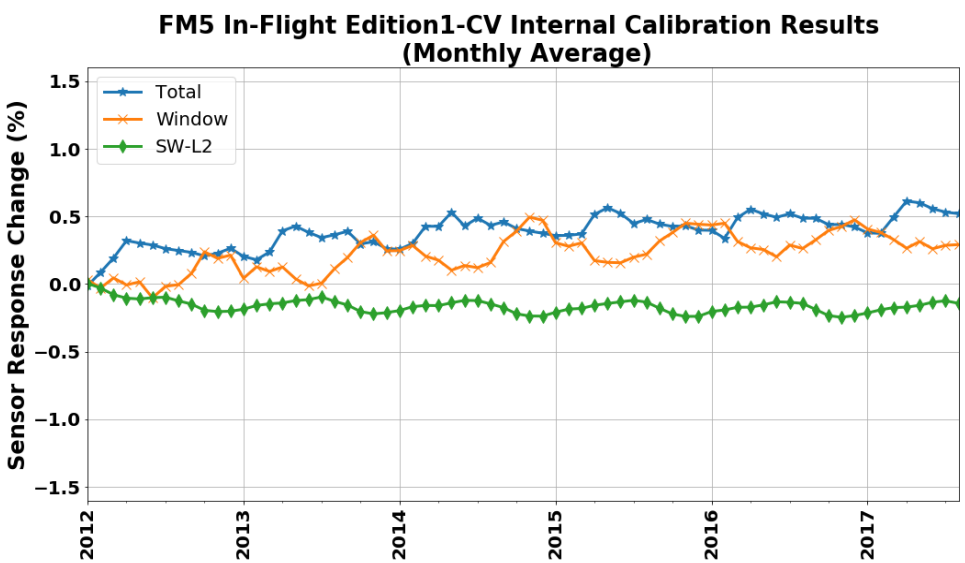


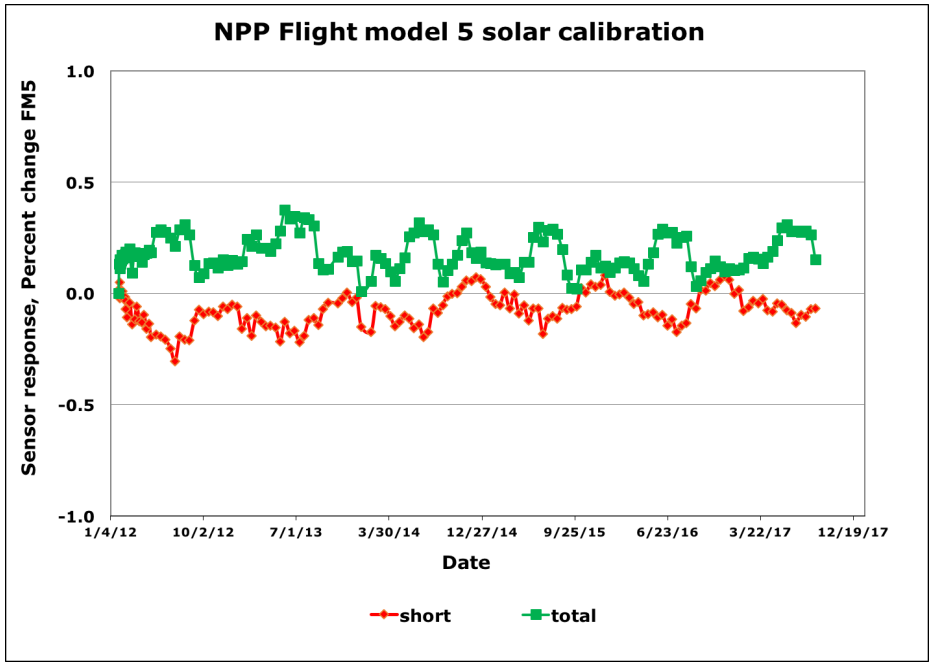
S-NPP/ CERES FM5 INSTRUMENT STATUS

S-NPP CERES FM5 Instrument Calibration

ICM calibrations show a response increase of 0.5% for Total and Window sensors. SW sensor shows an initial drop of 0.2%

Sensor response trends from solar calibrations vary between -0.3 to +0.4 percent.

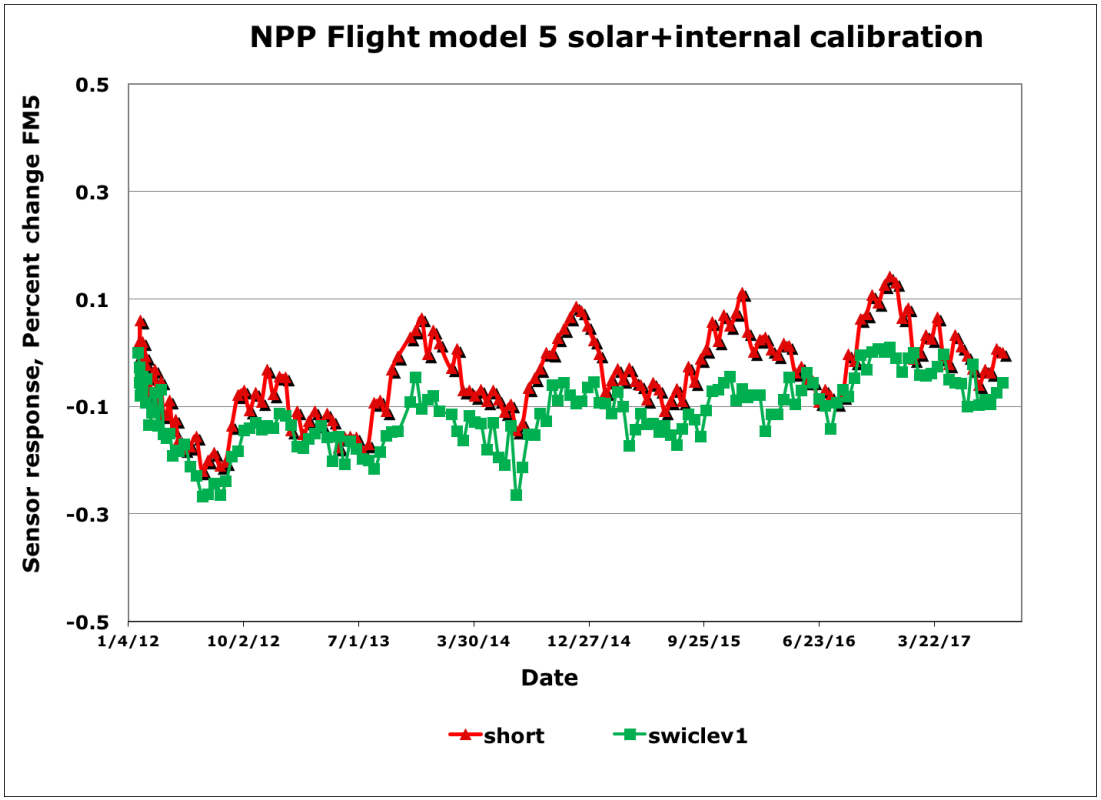




Sensor gain corrections based on ICM calibrations are applied to Edition1 data products.

S-NPP/CERES FM5 Instrument Calibration

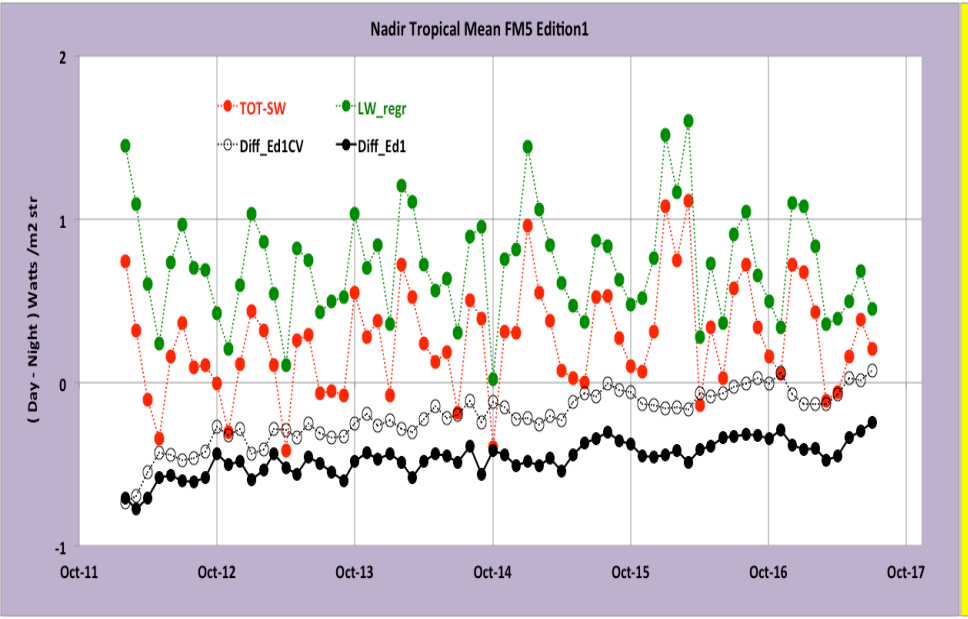
Calibration results from SWICS (Level1) and MAM showed similar trends in the SW sensor. The rate change in the trend is higher for solar calibration results.

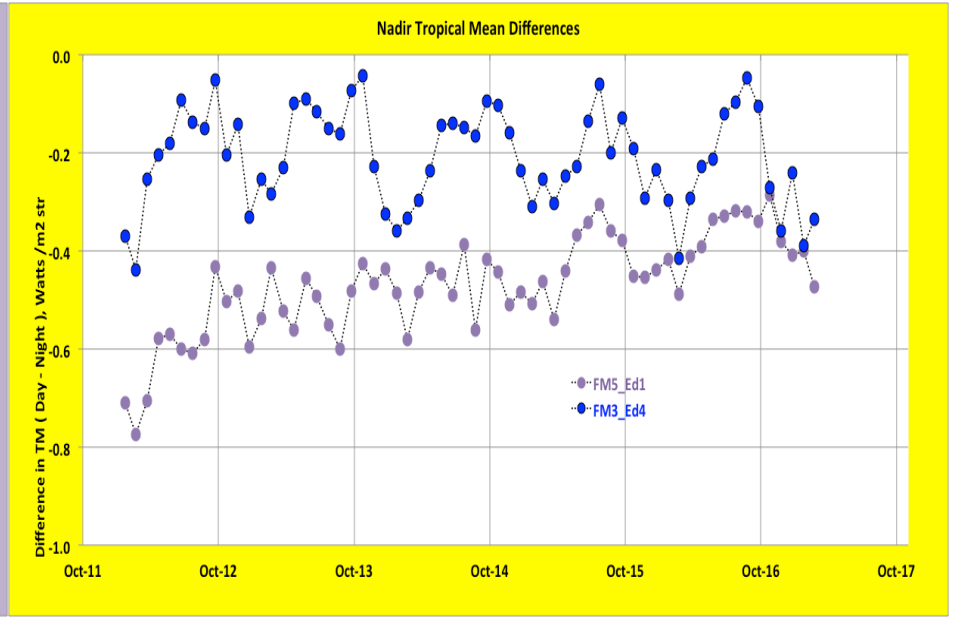


Suomi NPP/CERES FM5 Validation Results

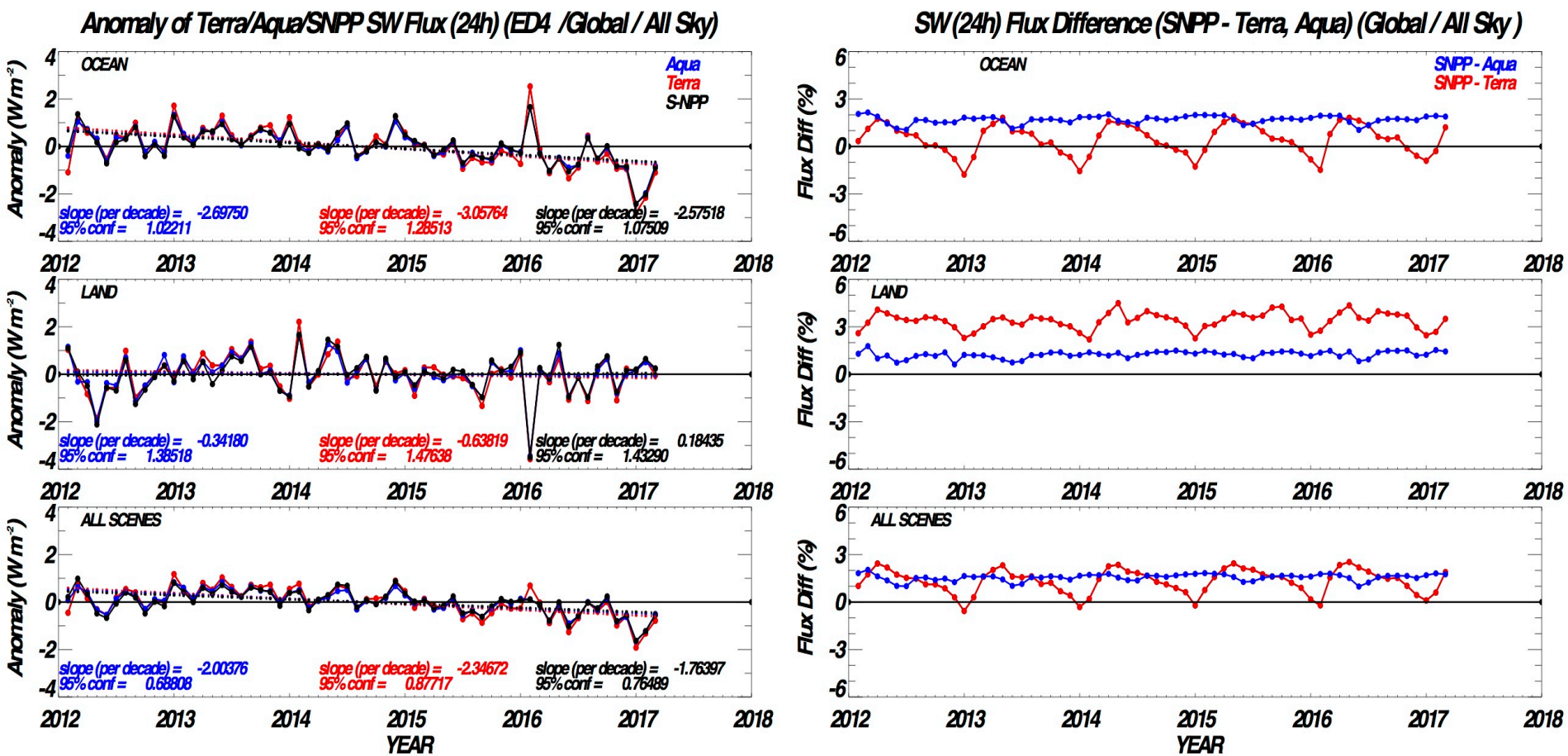
Tropical Mean (TM): Nadir LW radiance for All-sky Ocean in ± 20 deg Latitude. Changes in SW/TOT channel is monitored through Day-Night (DN) Difference comparison between LW and Simulated LW from Window measurements.

Comparison of DN Difference of FM5 Edition1 and FM3 Edition4 results highlight a trend in the SW/TOT of FM5 results.



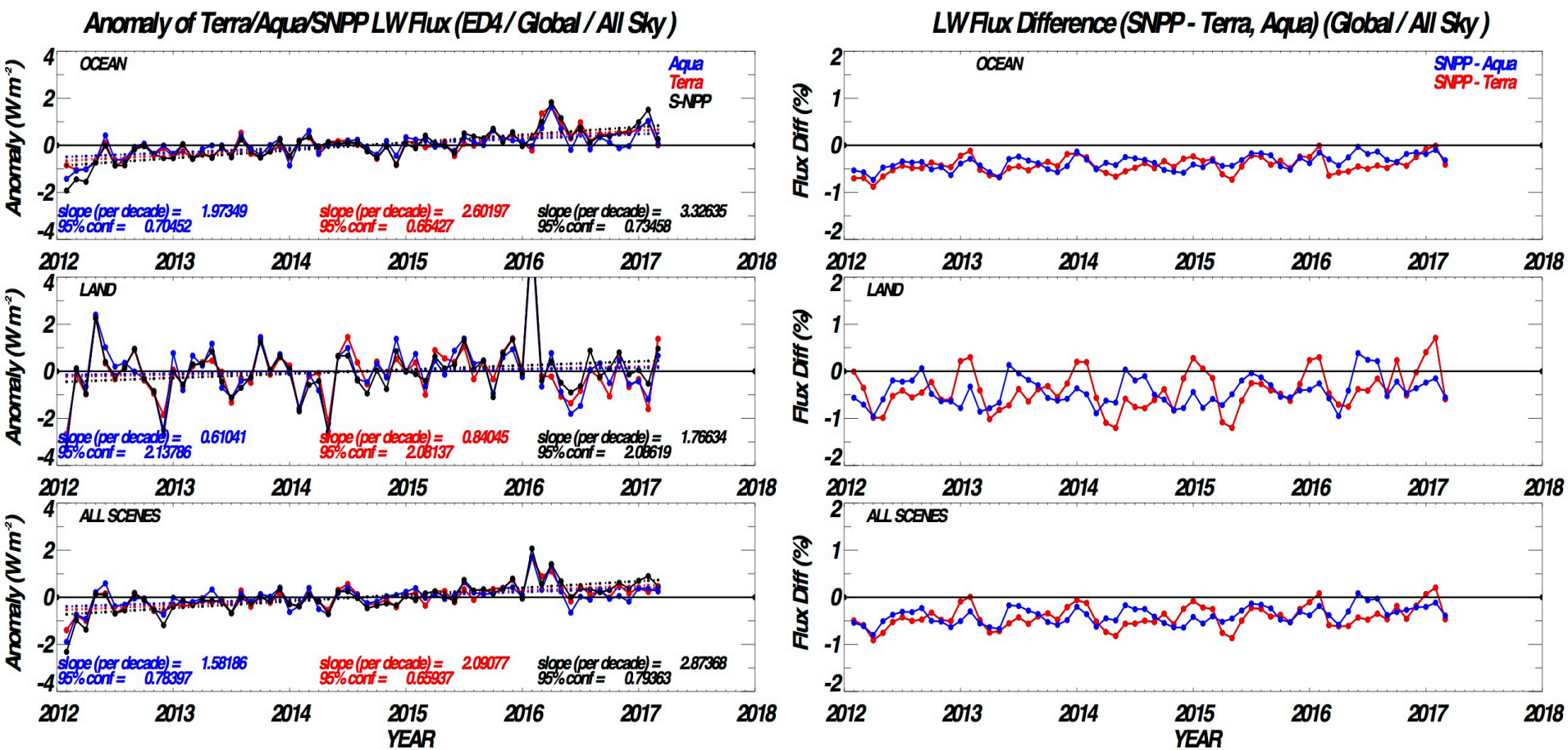


S-NPP/FM5, TERRA & AQUA COMPARE: SW



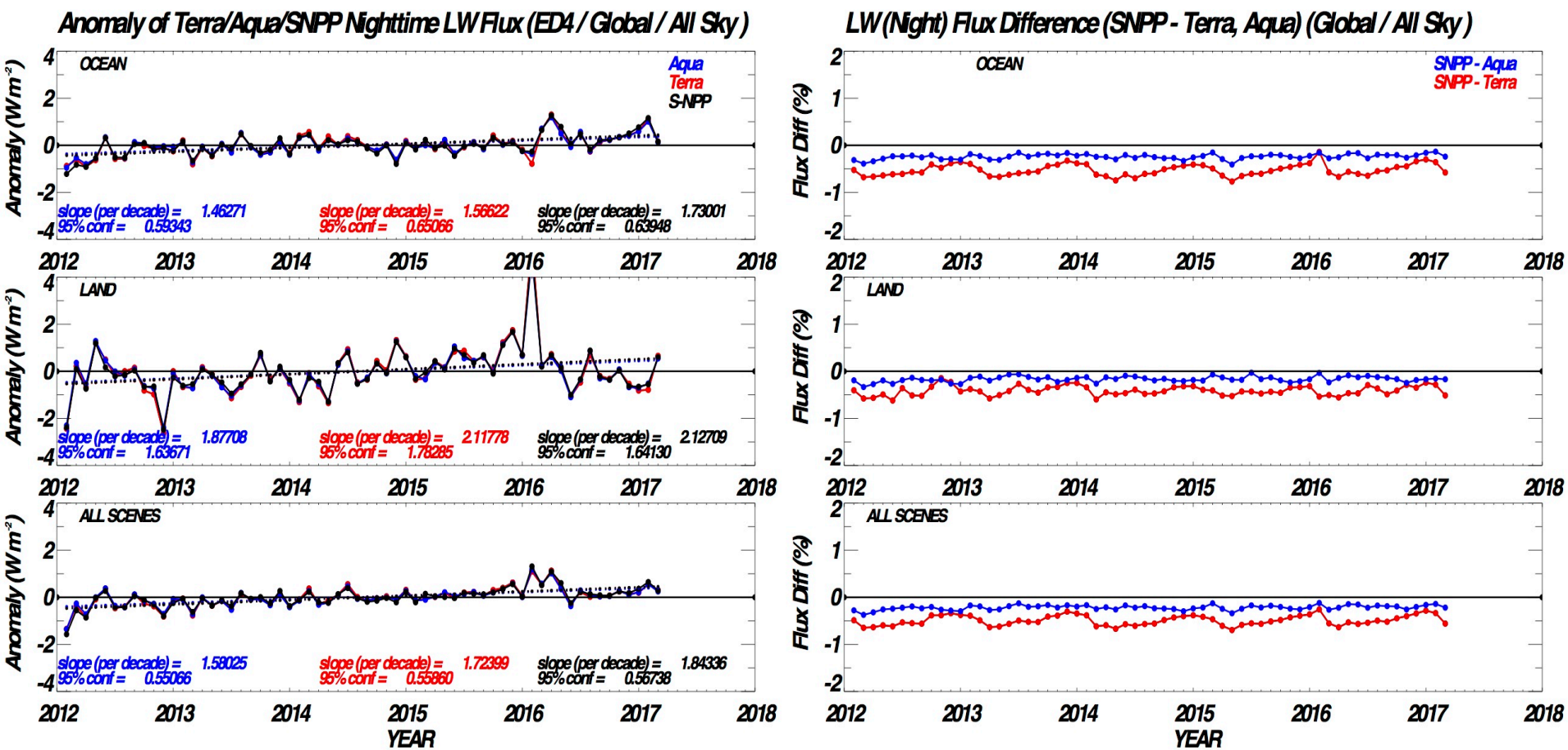
SW Flux anomaly from the 3 instruments show a downward trend. Results from S-NPP/FM5 show slight smaller trend than FM1 and FM3 instruments.

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



LW-Day Flux anomalies from the 3 instruments show positive trend. Results from S-NPP/FM5 show higher trend than FM1 and FM3 instruments.

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



LW-Night Flux anomalies show similar positive trend on all 3 instruments. Results from S-NPP/ FM5 show slightly higher trend than FM1 and FM3 instruments.

Direct compare of FM5 and FM3

FM5–FM3 "simultaneous Earth" observation

2012/2013/2014/2015/2016

ΔTime < 1min; ΔRAZ < 10°; ΔVZA <10°

All-sky

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 /85 /77 /81 /80	**3.3 / 2.7 / 1.0/ 1.7 /2.6**	.4 /.3 /.4 /.4 /.3	65/86/91/85/91
LW daytime	76 /74 /77 /77 /76	**-1.1 /-1.3 /-0.6 /-0.9 /-1.0**	.1 /.1 /.1 /.1 /.1	69/89/91/85/91
LW nighttime	66 /65 /68 /66 /66	**-0.3 /-0.3 /0.0 /-0.2 /-0.3**	.1 /.1 /.1 /.1 /.1	87/105/106/105/111

- Shown differences are computed as "average of differences" to avoid error cancellation

JPSS-1/ CERES FM6

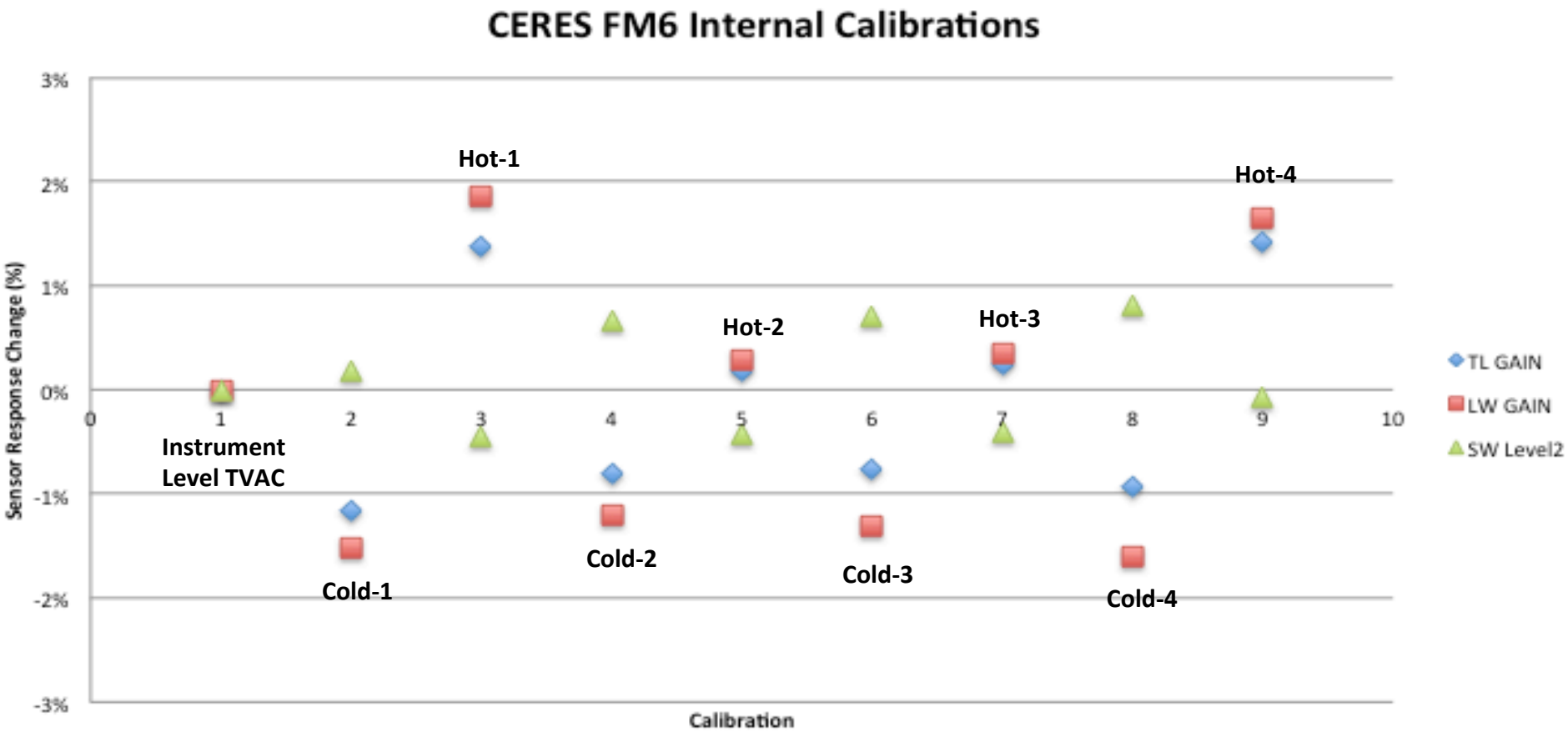
JPSS-1 Satellite I&T Overview

- JPSS-1/CERES FM6 is preparing for launch operations
  - Launch will be from Vandenberg AFB, CA
  - Current Launch Date: November 10, 2017
  - Launch Vehicle provider: Boeing Delta-2 (same as S-NPP)
- Ball Aerospace & Technologies Corporation (BATC) in Boulder, CO is the JPSS-1 spacecraft provider and satellite integrator.
- JPSS-1 Pre-Ship Review completed at BATC: August 22-24,2017
- NASA LaRC personnel supported the spacecraft Environmental tests at BATC.
- LaRC personnel will perform CERES FM6 Launch Site test activities.

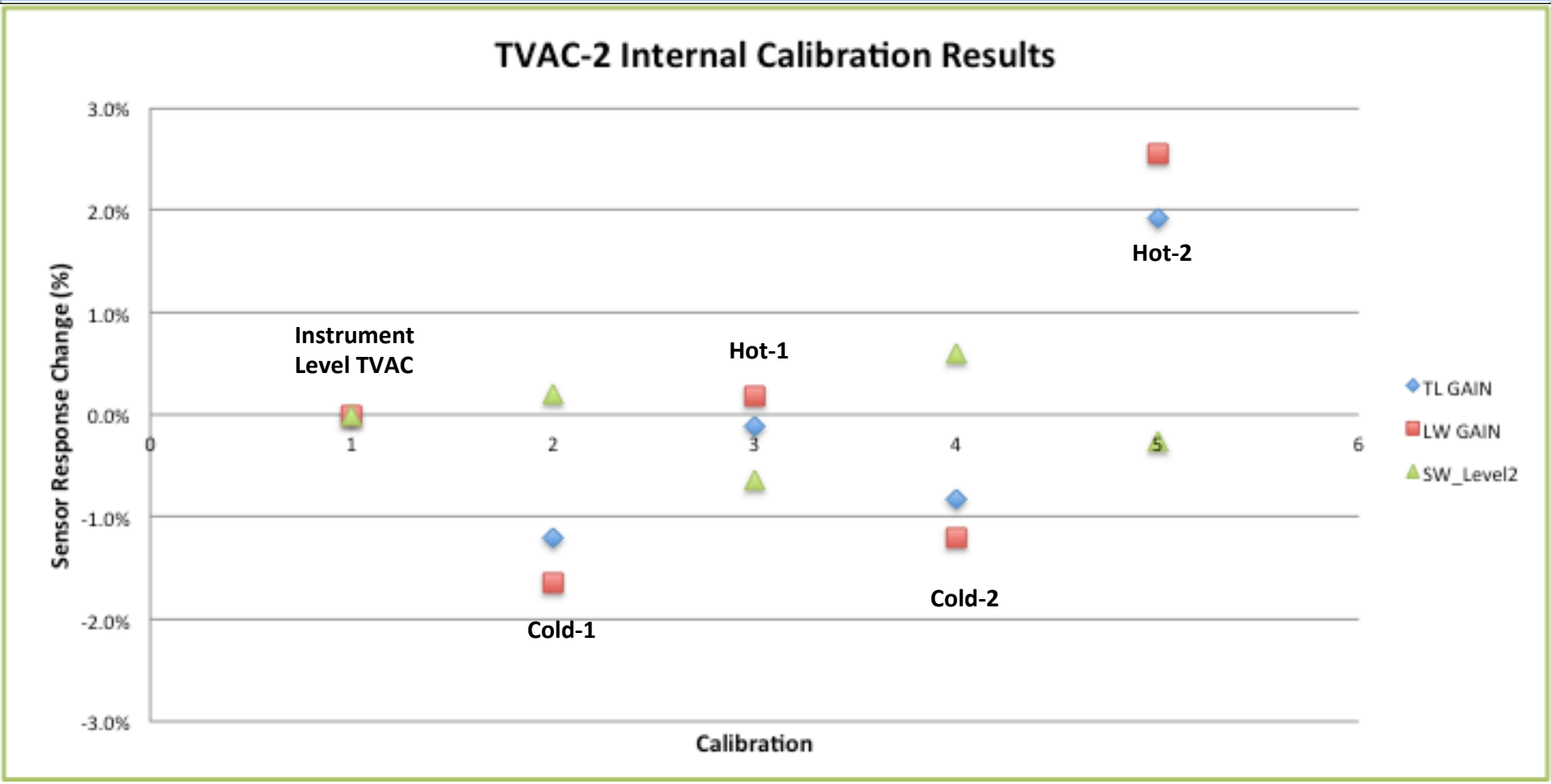
CERES FM-6 Summary

- CERES FM6 is actively marching towards Launch.
- CERES FM6 Operational Readiness Review (ORR): Oct 4, 2017
- Operations Team supported Mission Rehearsals and Integrated Mission Timeline (IMT) Reviews.
- Ground Systems Data Processing Team along with ASDC has supported the 8- day End to End Data Flow Test that verified the CERES Level0 and ancillary data flow from EDOS to LaRC DAAC and processing of the data.
- Sensor Performance results from the two Spacecraft Level Thermal Vacuum tests showed the responses are well within expected range.

JPSS-1/CERES FM6 TVAC1 RESULTS



JPSS-1/CERES FM6 TVAC-2 RESULTS



SUMMARY

- Validation results of Terra/Aqua Edition-4 datasets continue to show slight negative trend in SW Flux anomaly and positive trends in LW_Day Flux anomaly. LW-Day Flux trends show minimal change in FM1 instrument.
- S-NPP/FM5 SW sensor results showed similar trends for SWICS and MAM calibrations. The trend rate is slightly higher in solar calibration results.
- Anomaly trends for S-NPP/FM5, Terra/FM1 and Aqua/FM3 show negative trend in SW Flux, and positive trends for LW day and night Flux. The trend in LW-Day Flux is higher for S-NPP in comparison with Terra and Aqua results.
- S-NPP/FM5 inter-comparison with Aqua/FM3 showed SW measurements are running higher and LW measurements are lower for FM5 instrument in comparison with FM3.
- S-NPP/FM5 Edition2 will address the radiometric scale difference with Aqua and the trend in LW_Day Flux.
- CERES FM6 Instrument has completed all Pre-launch tests and will be ready for Launch and Early Orbit Checkout activities.

BACK UP SLIDES

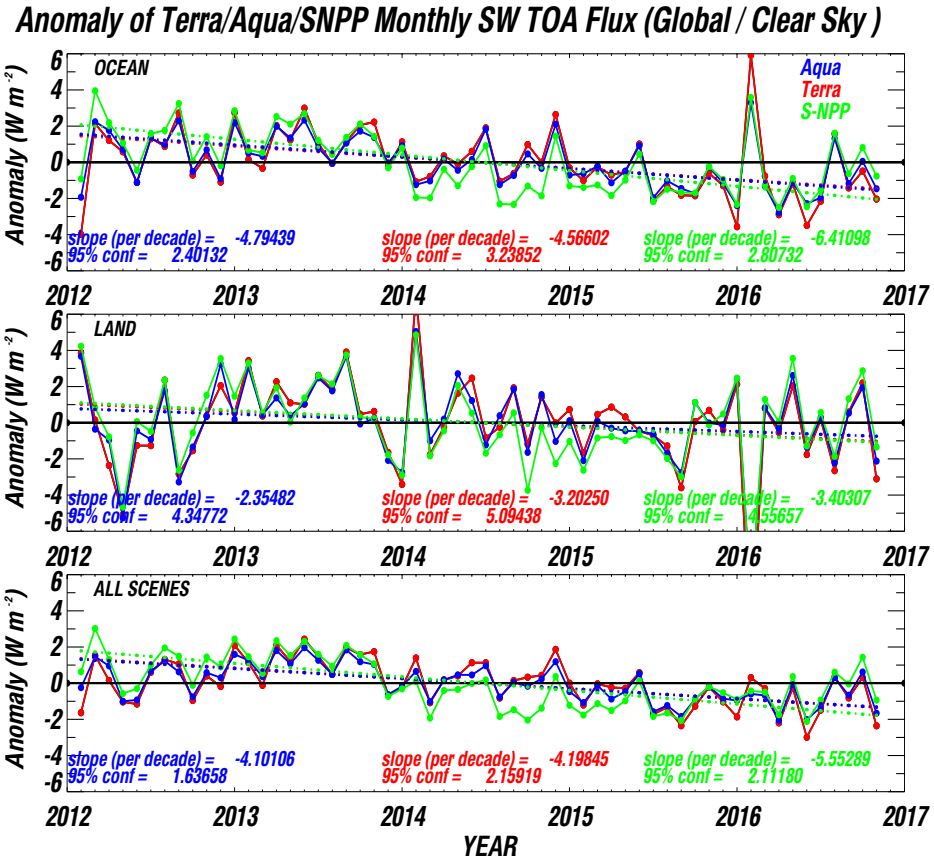
TERRA/AQUA GAIN and SRF Delivery

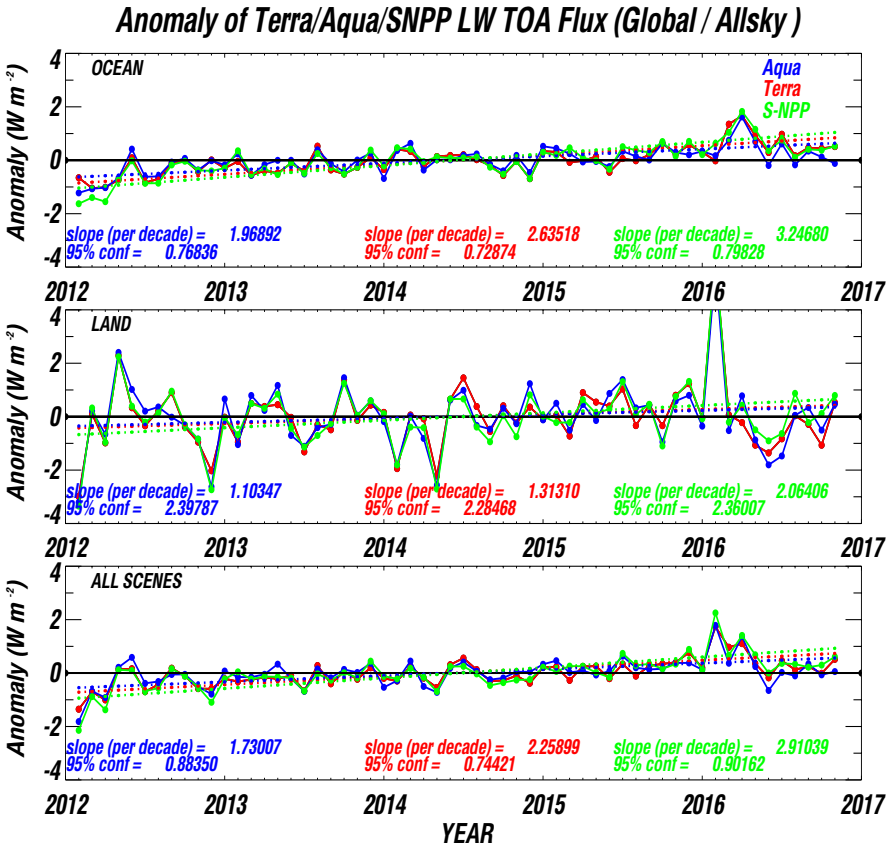
Edition3 Gains and Spectral Response Functions (SRF) :
Start of Mission – February 2017

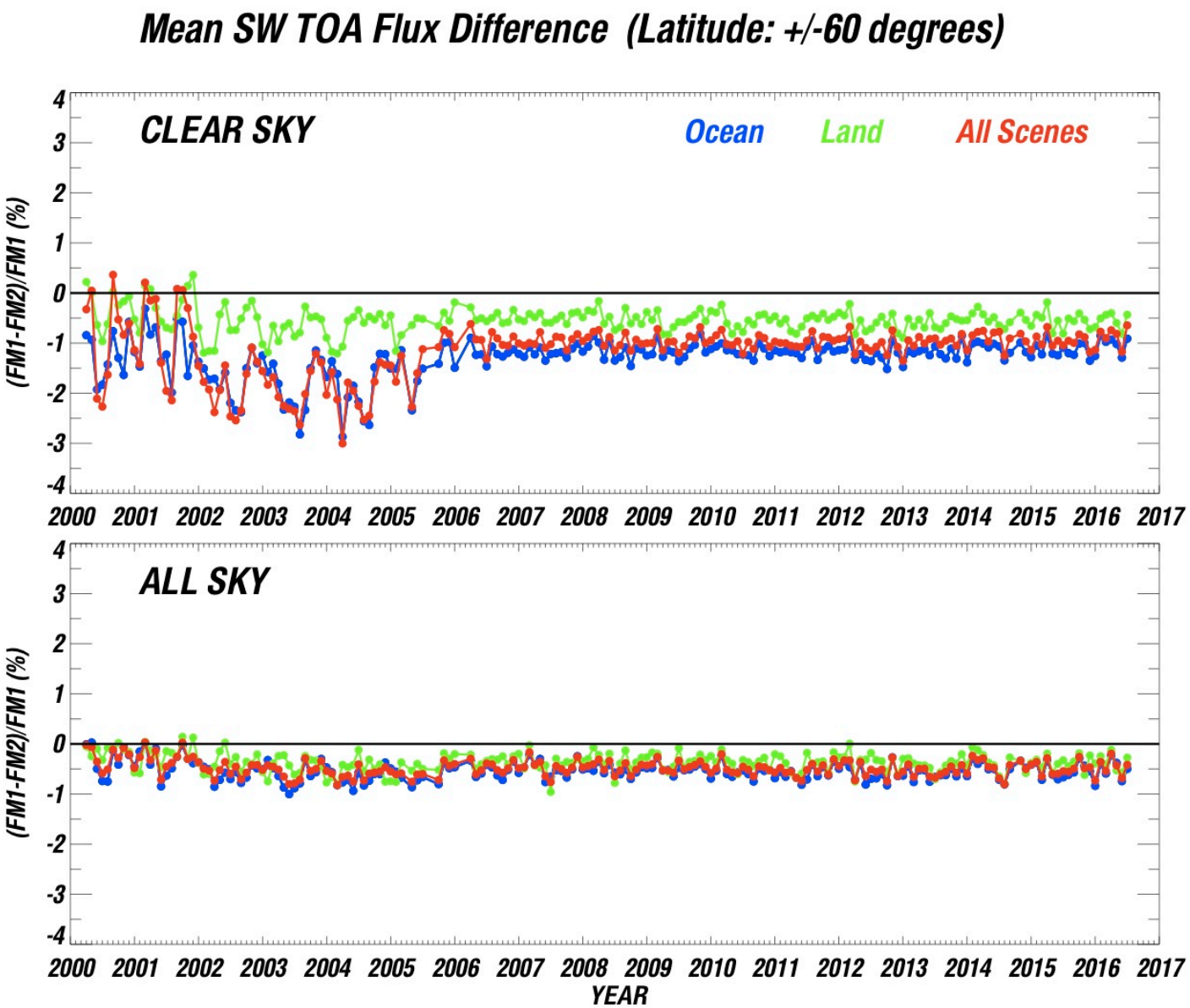
Edition4 Gains and Spectral Response Functions (SRF) :

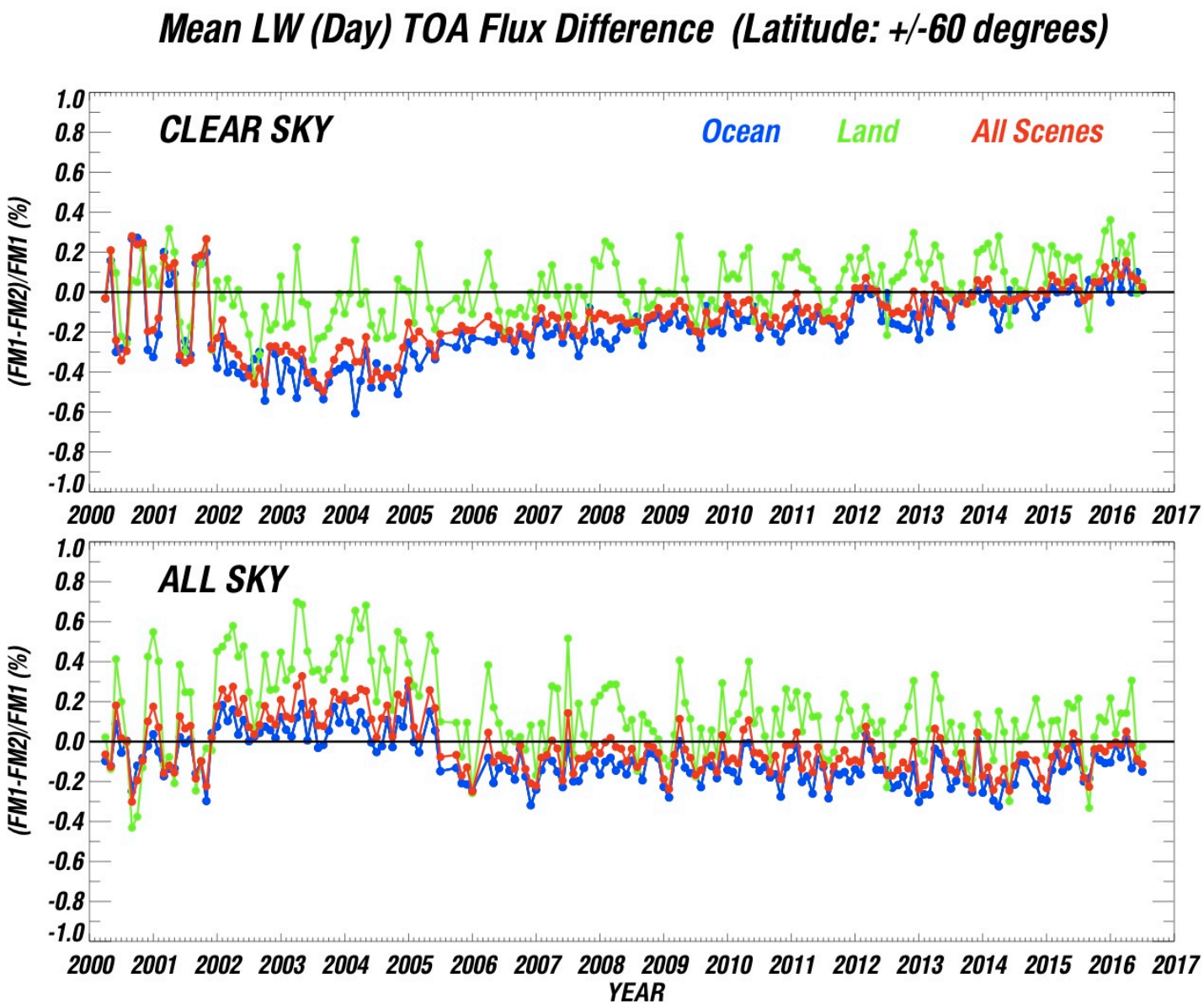
Terra and Aqua - Start of Mission to March 2017

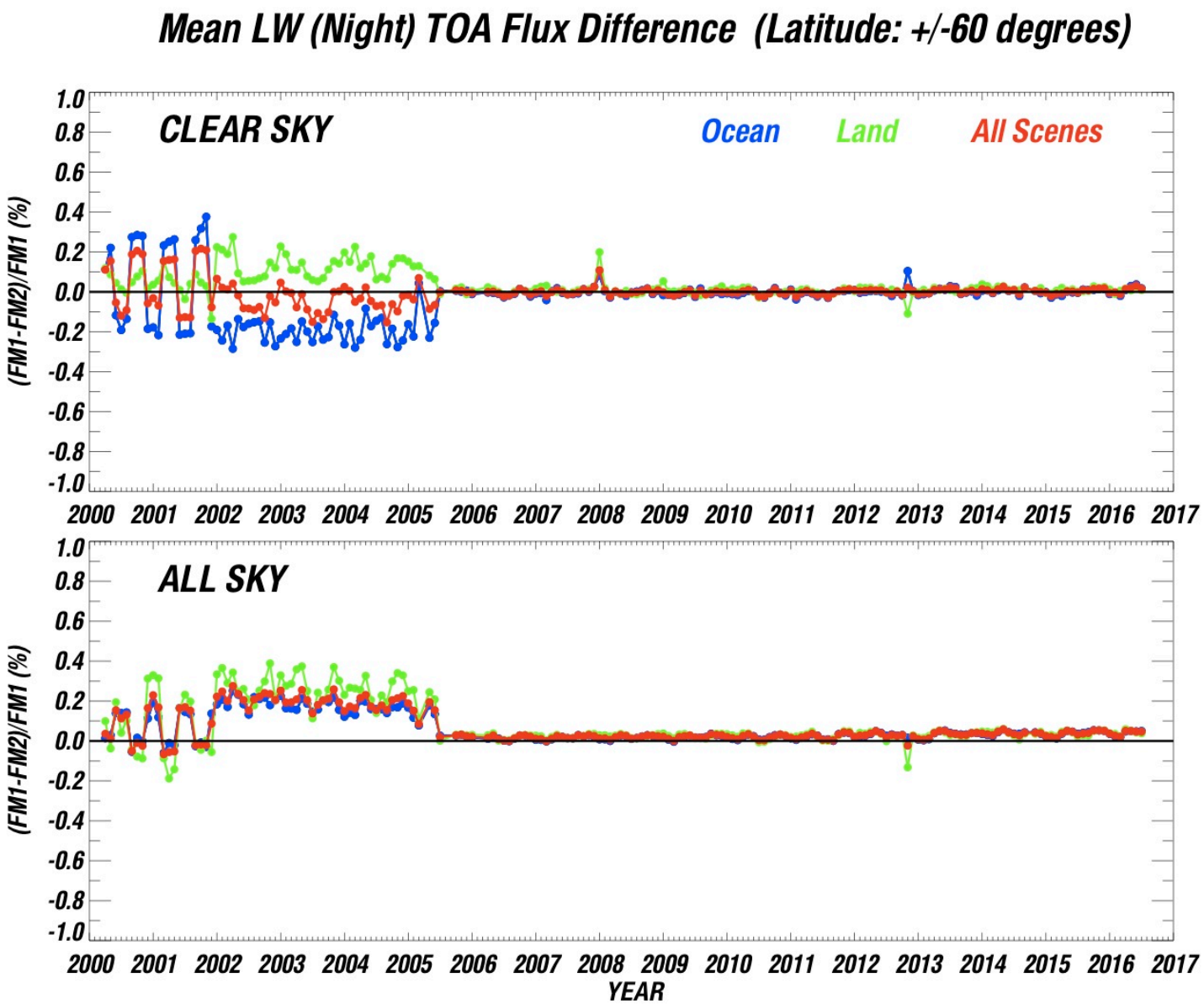
S-NPP/FM5, TERRA & AQUA COMPARISON






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

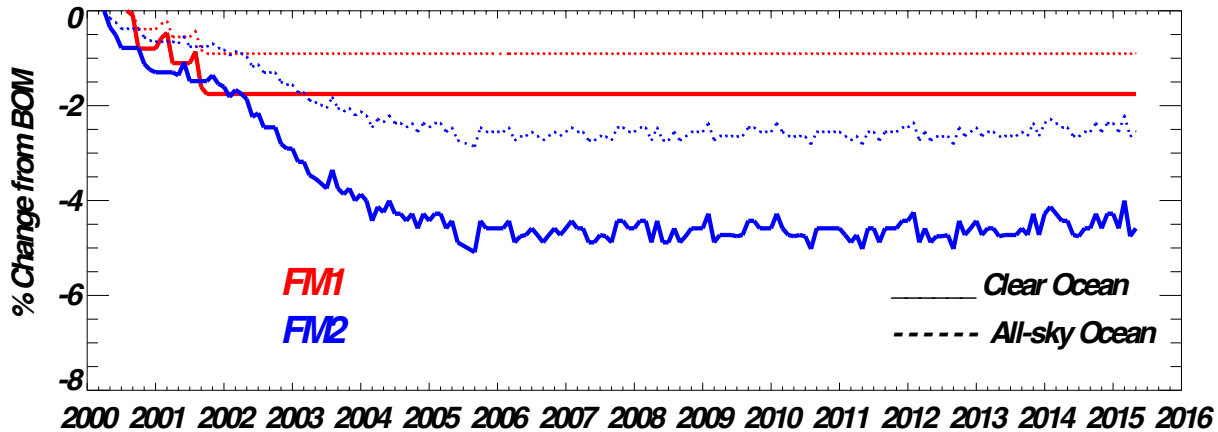

Mean LW (Night) TOA Flux Difference (Latitude: +/-60 degrees)
CLEAR SKY
Ocean
Land
All Scenes
ALL SKY
(FM1-FM2)/FM1 (%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
YEAR

TERRA/AQUA EDITION-4: SW SENSOR

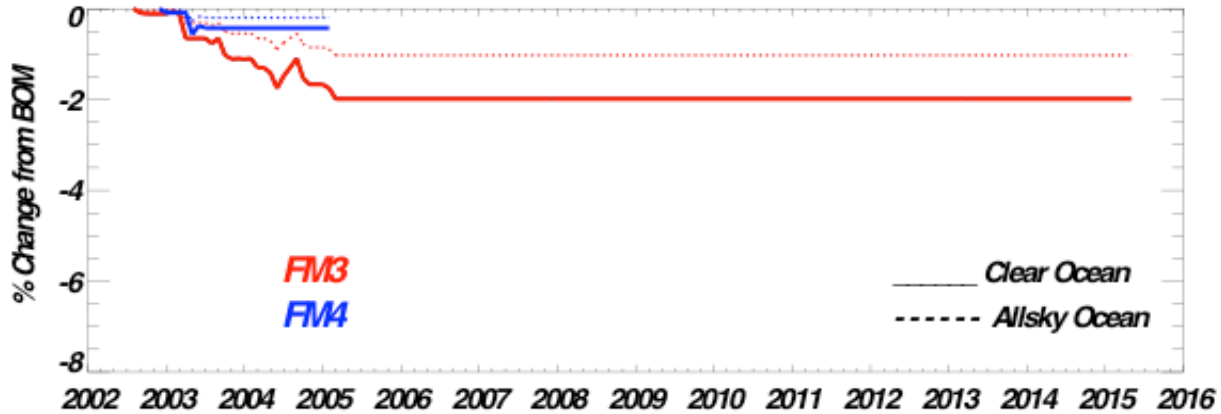
The SW sensor Spectral Response Function (SRF) correction is applied based on the Nadir comparison of Clear Ocean SW measurement from two instruments on same spacecraft. The correction is applied to SRF for the instrument operating in RAPS mode.

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

TERRA



AQUA



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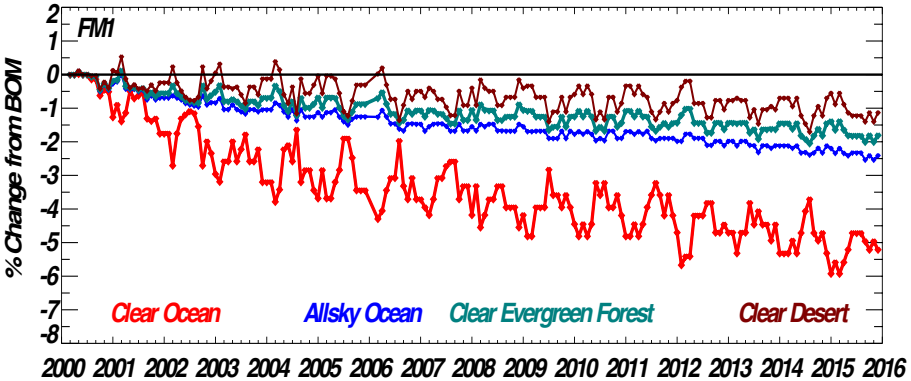
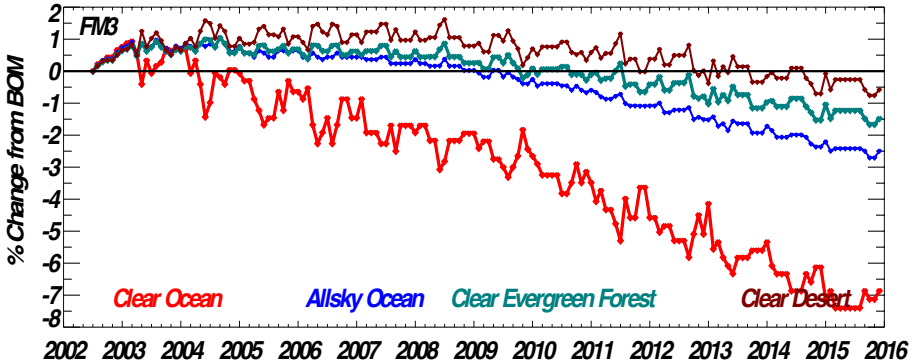
EDITION-4 TERRA/AQUA: SW/TOT SENSOR

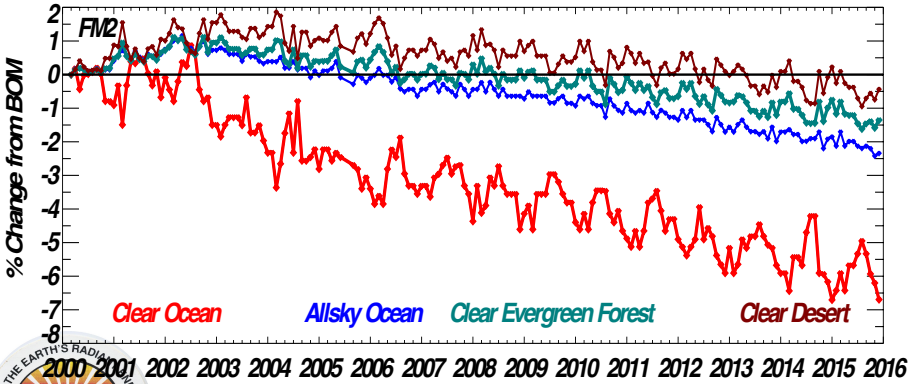
- **Correction to SW/TOT sensor of each instrument is based on the regression between LW(Day-Night) and WN (Day-Night) using Tropical Ocean and Land scenes.**

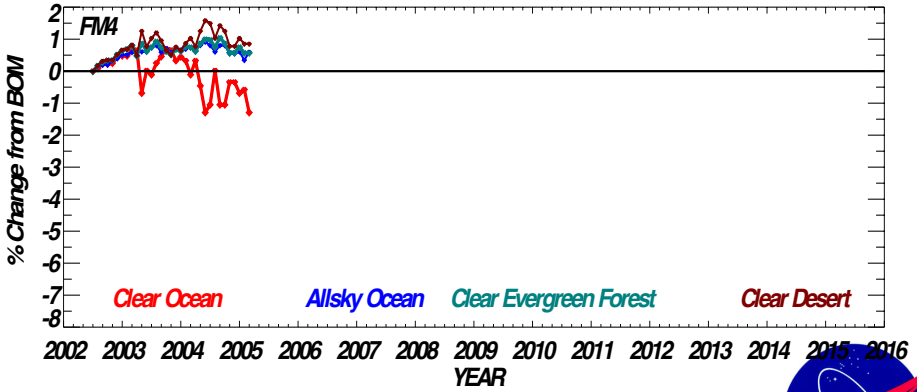
SW/TOT 'Optimal' Throughput Change for Terra (Terra SRF with SCIAMACHY Scene Spectra)



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







2016 Inter-comparison: FM5/ FM3/ FM1

- SW all-sky differences
  - (FM5-FM1)/FM5 shows 1.0%; consistent with previous years (minor-plane data)
  - (FM5-FM3)/FM5 shows 0.9%; ranging from 1.0% to 3.3% before (minor-plane data)
  - (FM5-FM3)/FM5 shows 2.6%; ranging from 1.0% to 3.3% before (tandem data)
- LW day all-sky differences
  - (FM5-FM1)/FM5 shows -0.6%; consistent with previous years (minor-plane data)
  - (FM5-FM3)/FM5 shows 0.4%; about -1% before (minor-plane data)
  - (FM5-FM3)/FM5 shows -1.0%; the same as average from before (tandem data)
- LW night all-sky differences
  - (FM5-FM3)/FM5 shows -0.3%; about the same as before (tandem data)
- All shown differences are statistically significant
  - All-sky composition of data is different each year for "tandem FM5/FM3 data"
  - Unlike FM5/FM1 (5 min.), time difference for FM5/FM3 is from 11 min. to 21 min.