# CERES FM1 – FM5 Instrument Status

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**CERES Instrument Working Group Team**

**CERES Science Team Meeting**
**NASA Langley Research Center**
**Hampton, Virginia**
**May 16, 2017**

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# CERES Instrument Operations: FM1 - 5

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

**Upcoming campaigns for Summer 2017**

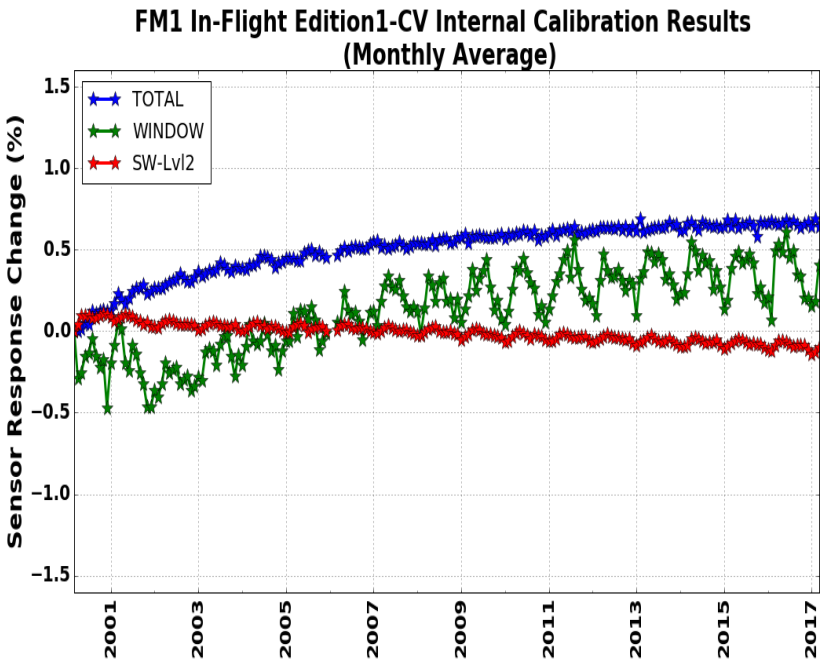
- **Terra Deep Space Calibration – August 5, 2017**
- **CERES Terra/FM1 – S-NPP/FM5: May 1 – July 31, 2017.**
- **CERES Terra/FM1 – Aqua/FM3: June 1 – 30, 2017**
- **CERES Terra/FM2 - CLARIFY-2017 (Cloud-Aerosol-Radiation interactions and Forcing: 2017) – August 15 – Sept 8 2017**

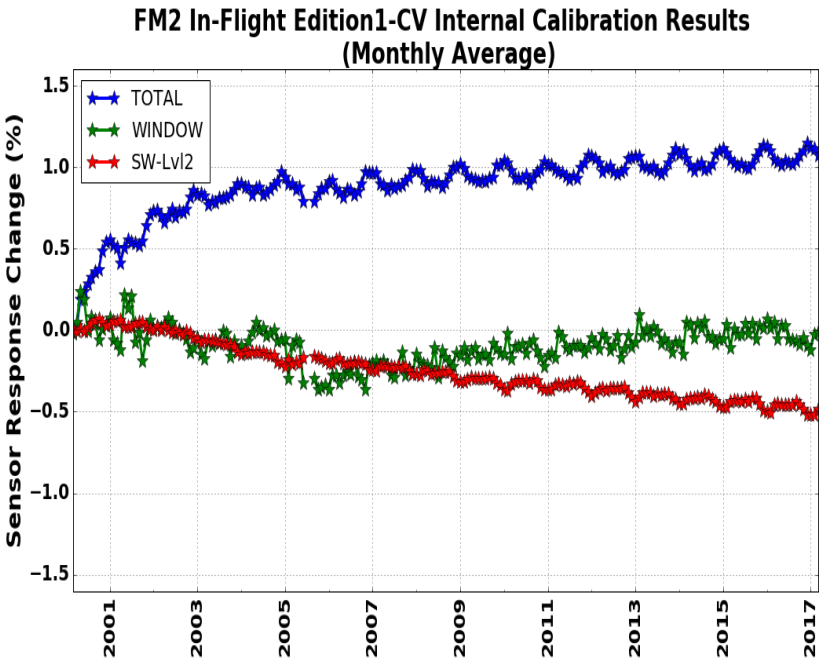
# TERRA & AQUA INSTRUMENT STATUS

# [CERES FM1 – FM4]

# Terra CERES FM1 & FM2 Instrument Calibration

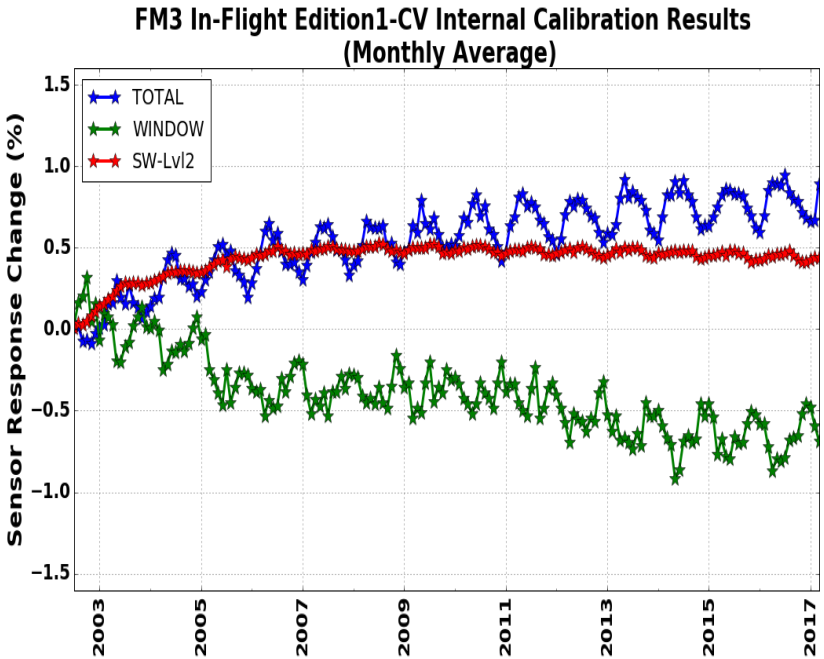
**Flight Models 1 and 2 (FM1 & FM2) instruments showed increase in response for Total and Window sensors and a decrease in SW sensor responses.**

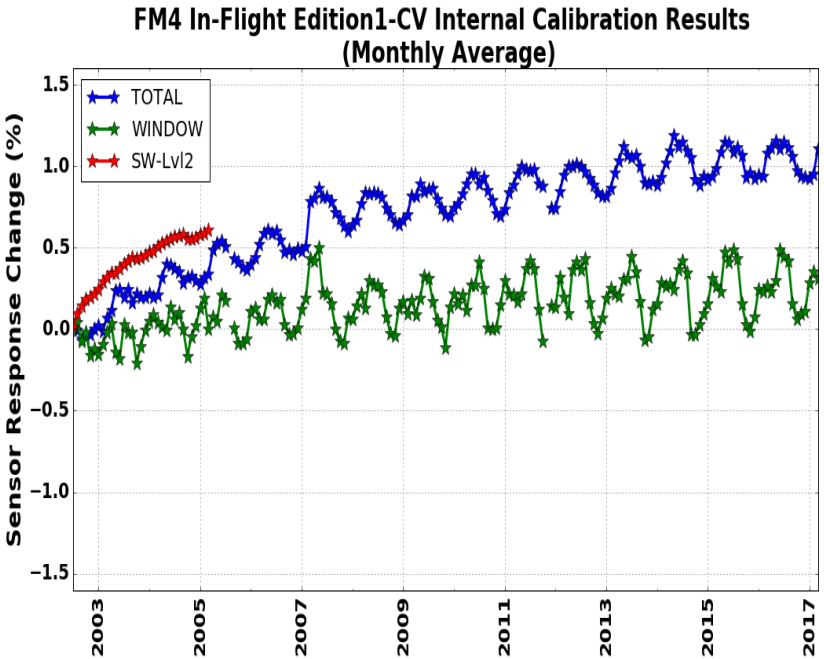


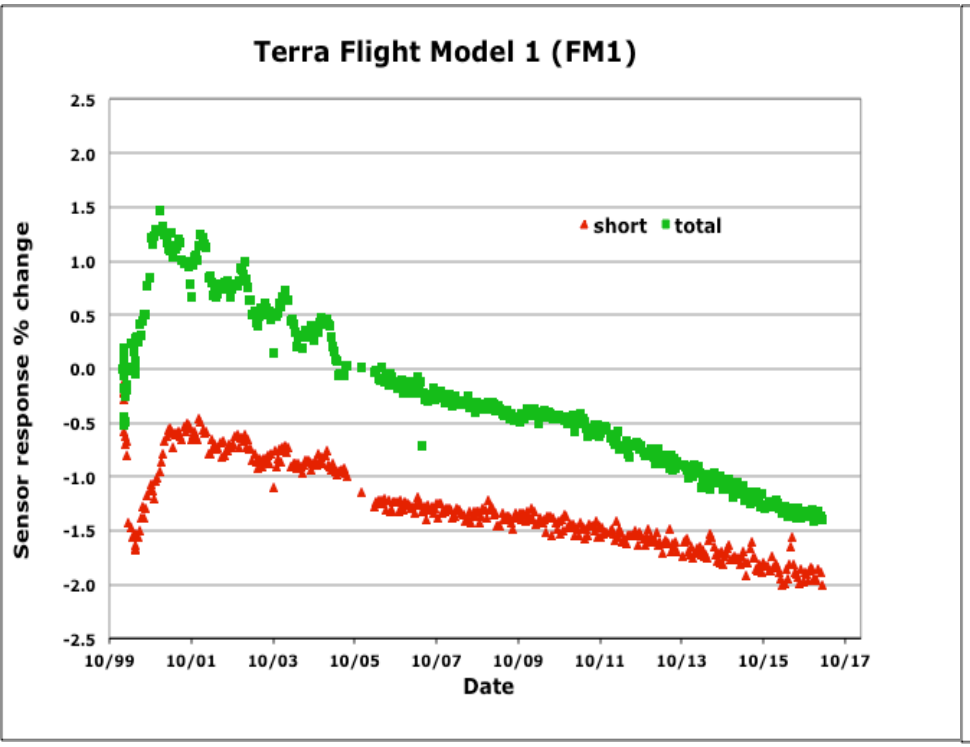
# Aqua CERES FM3 & FM4 Instrument Calibration

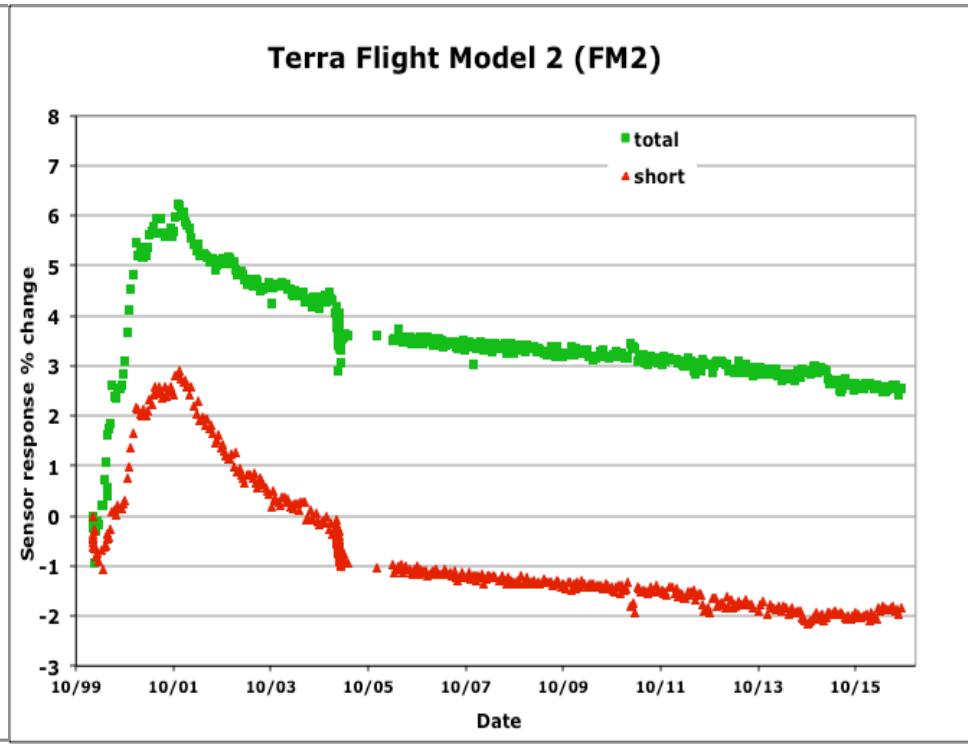
**Flight Models 3 and 4 (FM3 & FM4) instruments showed increase in response for Total and SW sensors. Window sensor on FM3 instrument showed a drop where as FM4 instrument showed an increase in the response.**



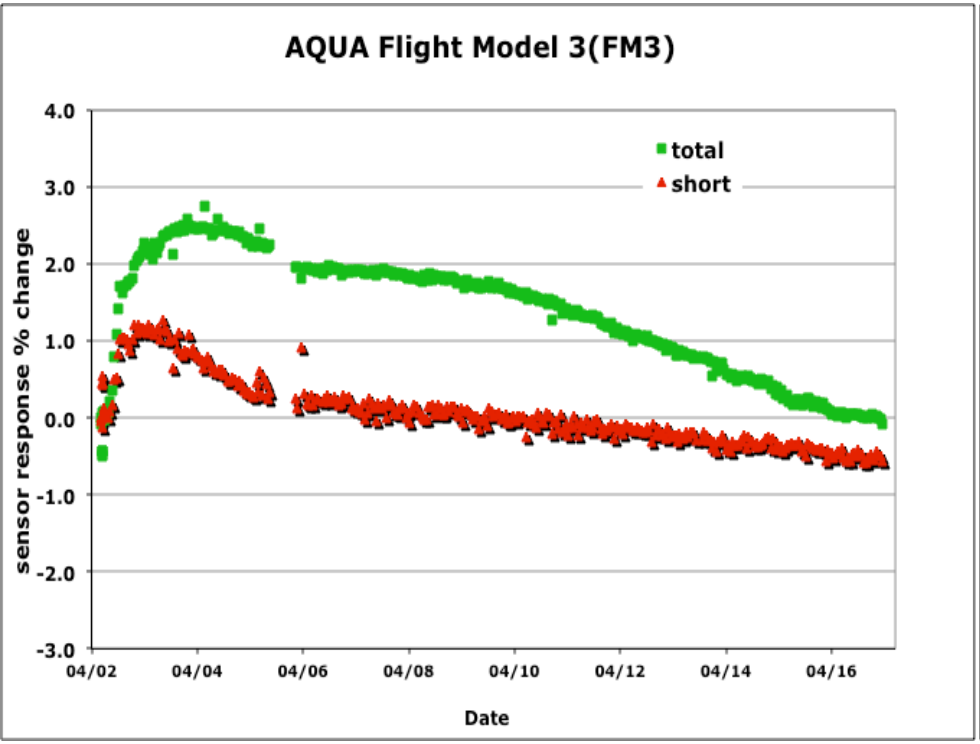



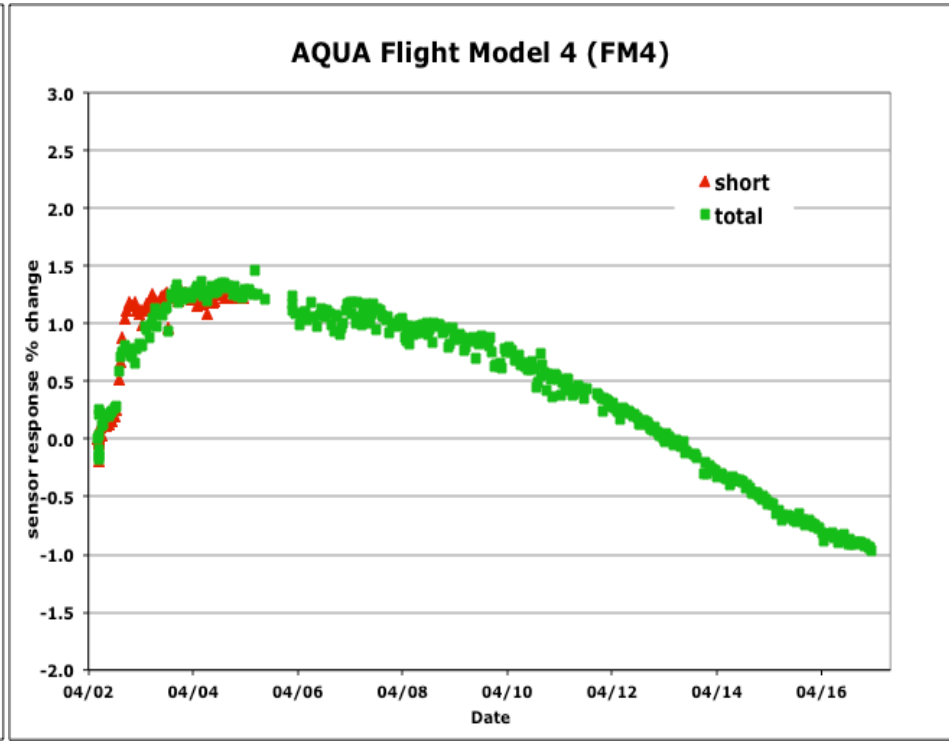
# Terra FM1 & FM2 Solar Calibration Results



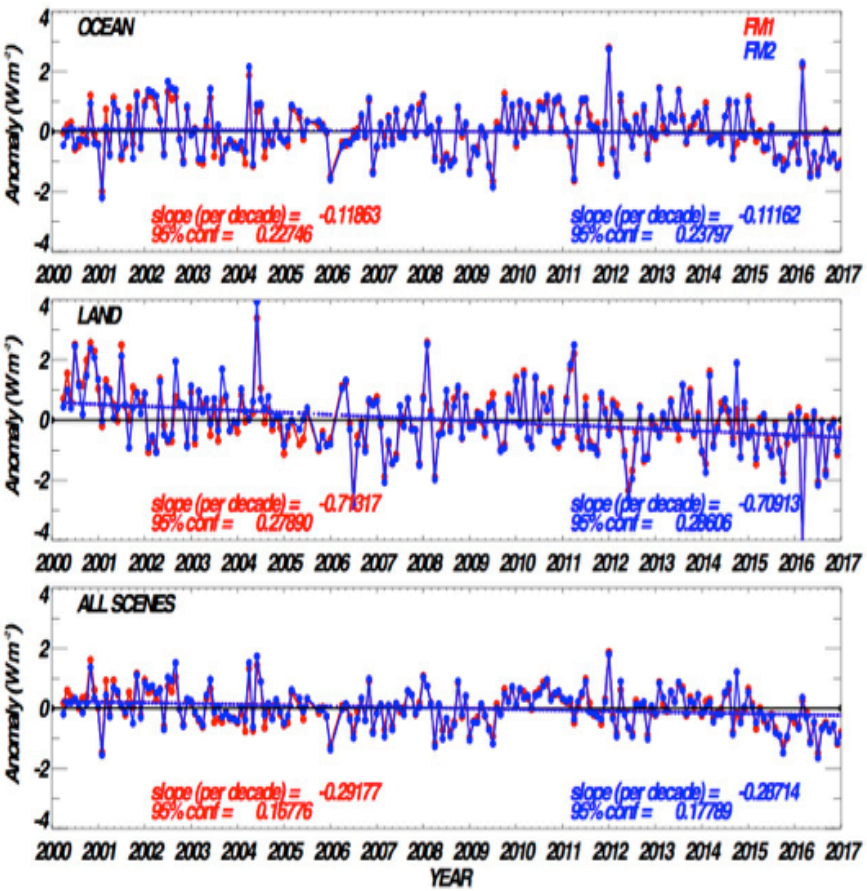
# Aqua FM3 & FM4 Solar Calibration Results



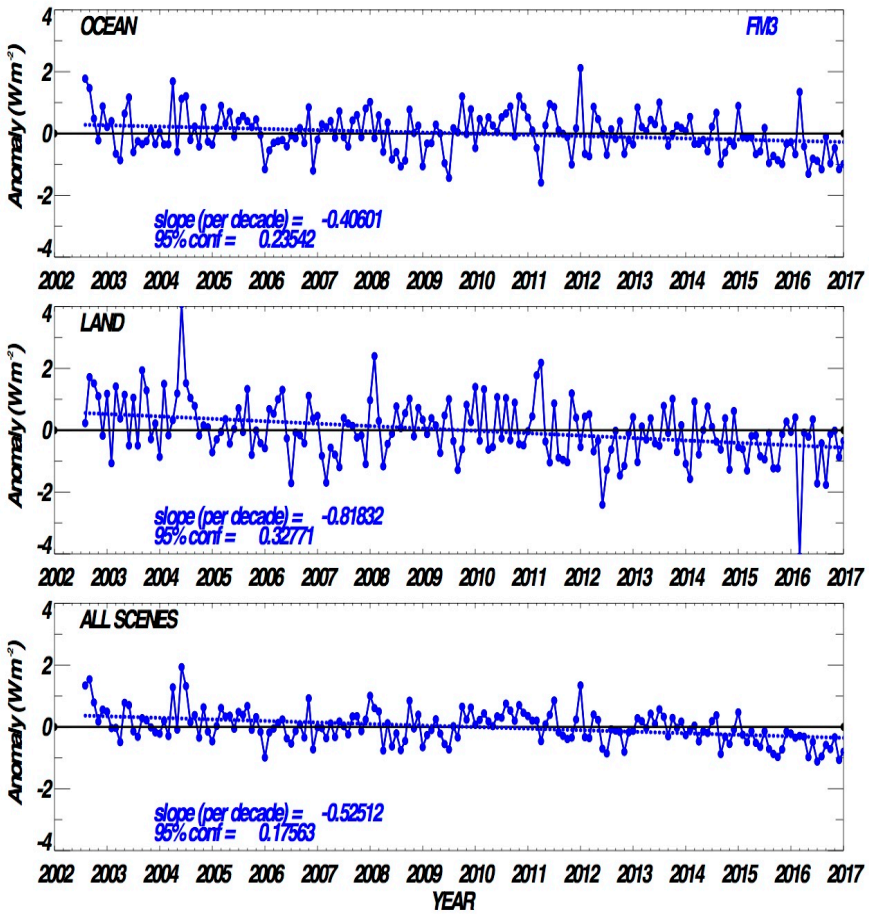



# EDITION-4 RESULTS: TERRA & AQUA SW SENSORS

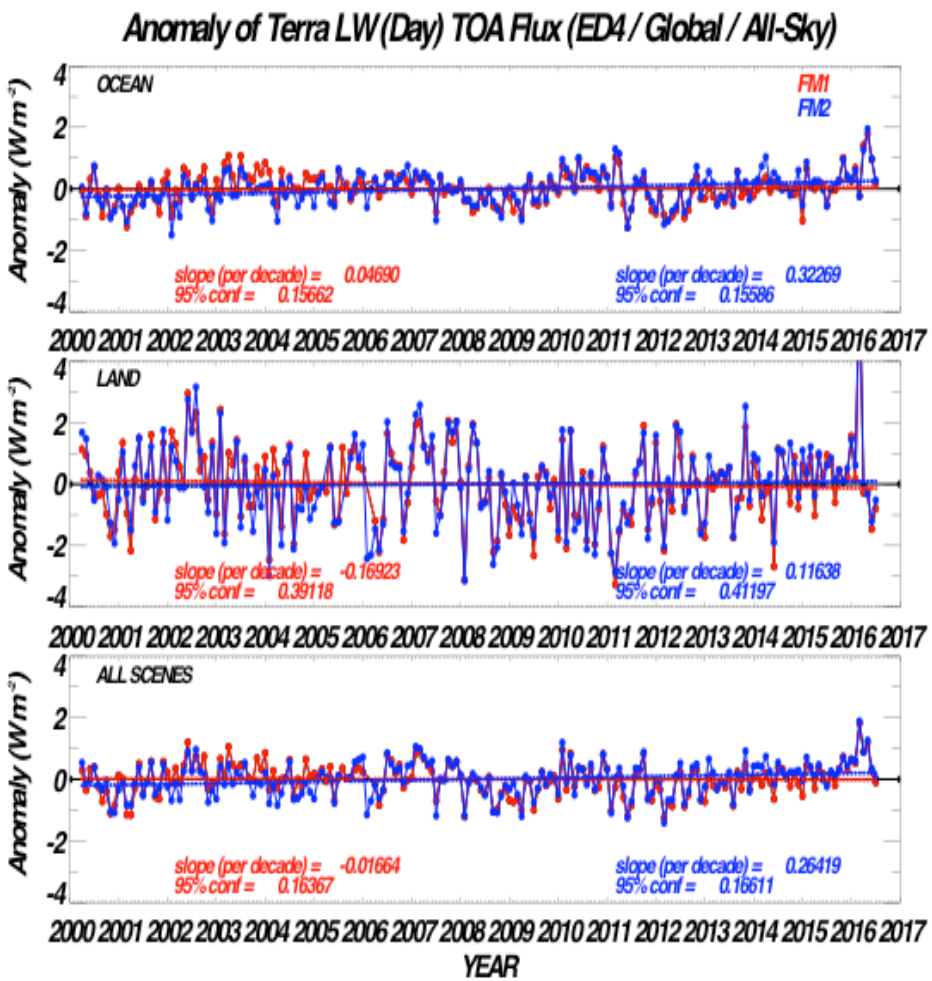
**Anomaly of Terra SW Flux (24h) (ED4 / Global / All Sky)**

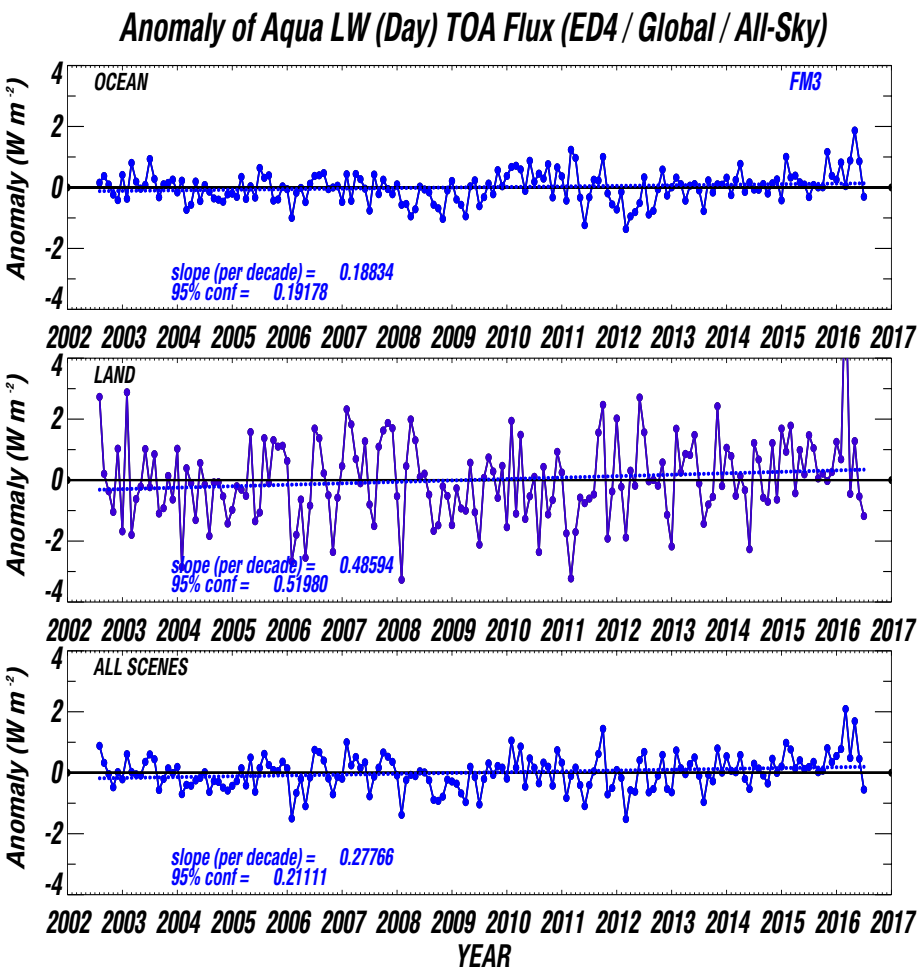



**Anomaly of Aqua SW Flux (24h) (ED4 / Global / All Sky)**

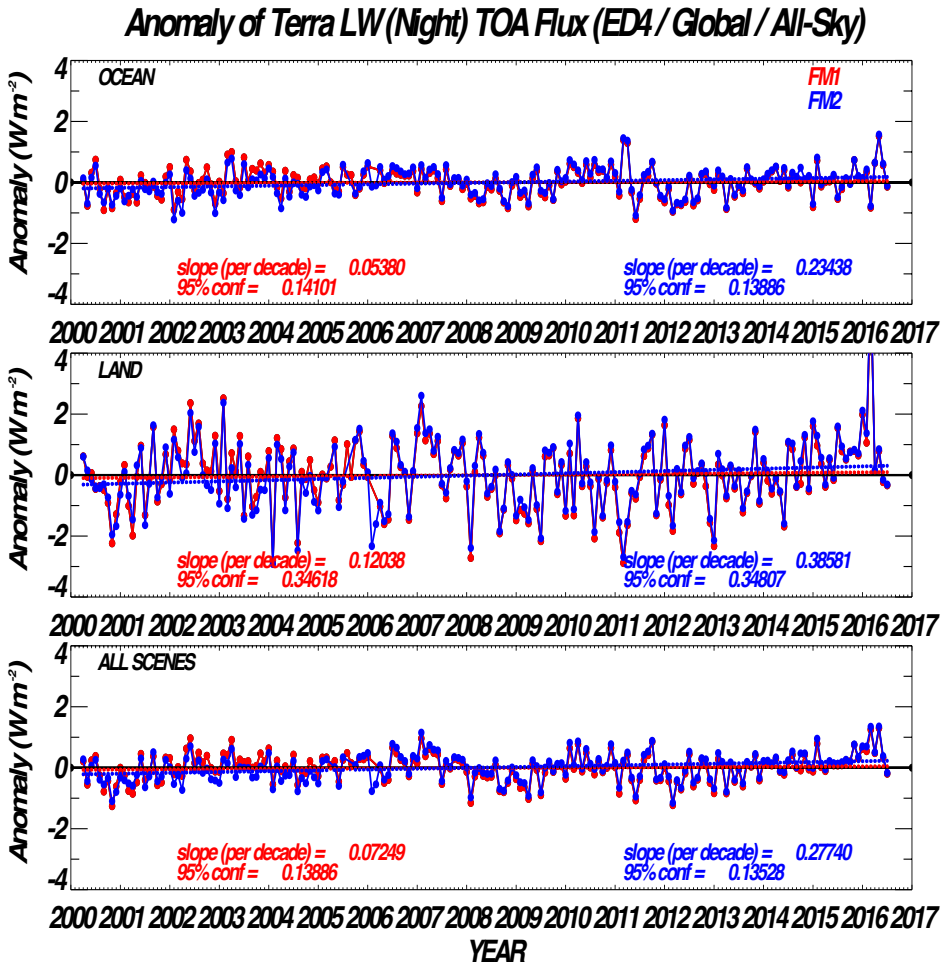


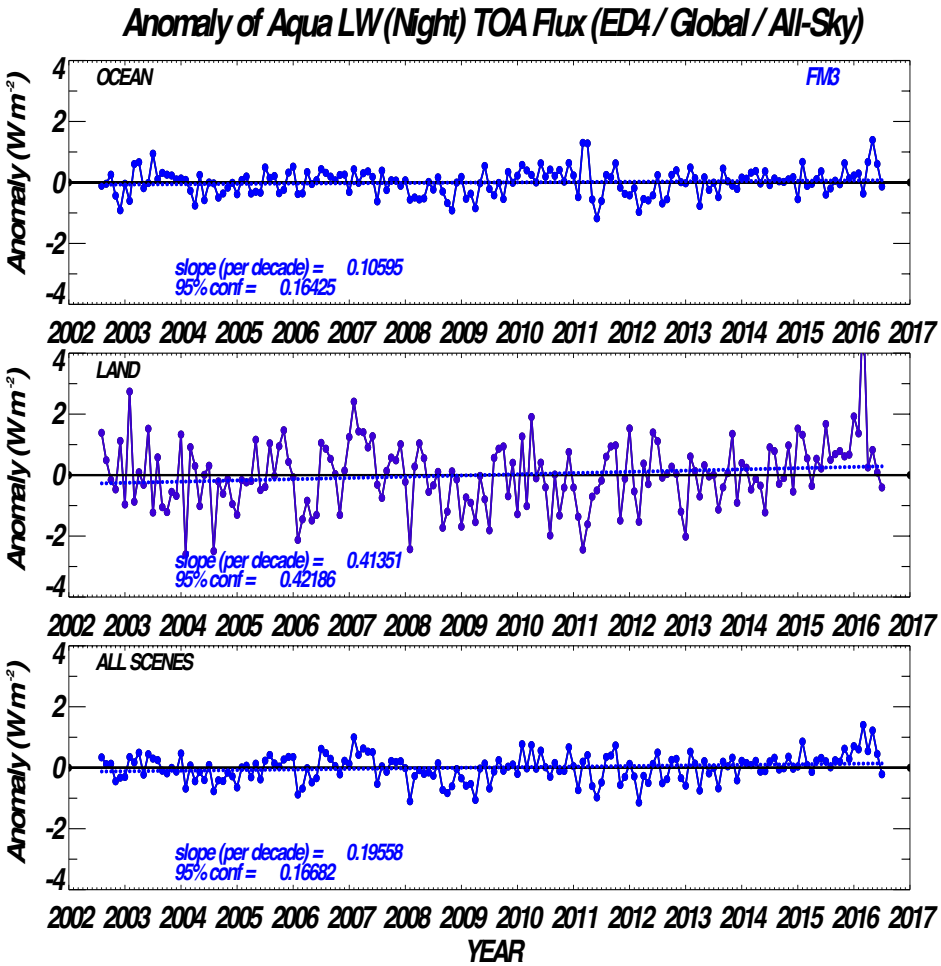
# EDITION-4 Results: TERRA & AQUA LW_Day Flux



# EDITION-4 Results: TERRA & AQUA LW_Night Flux

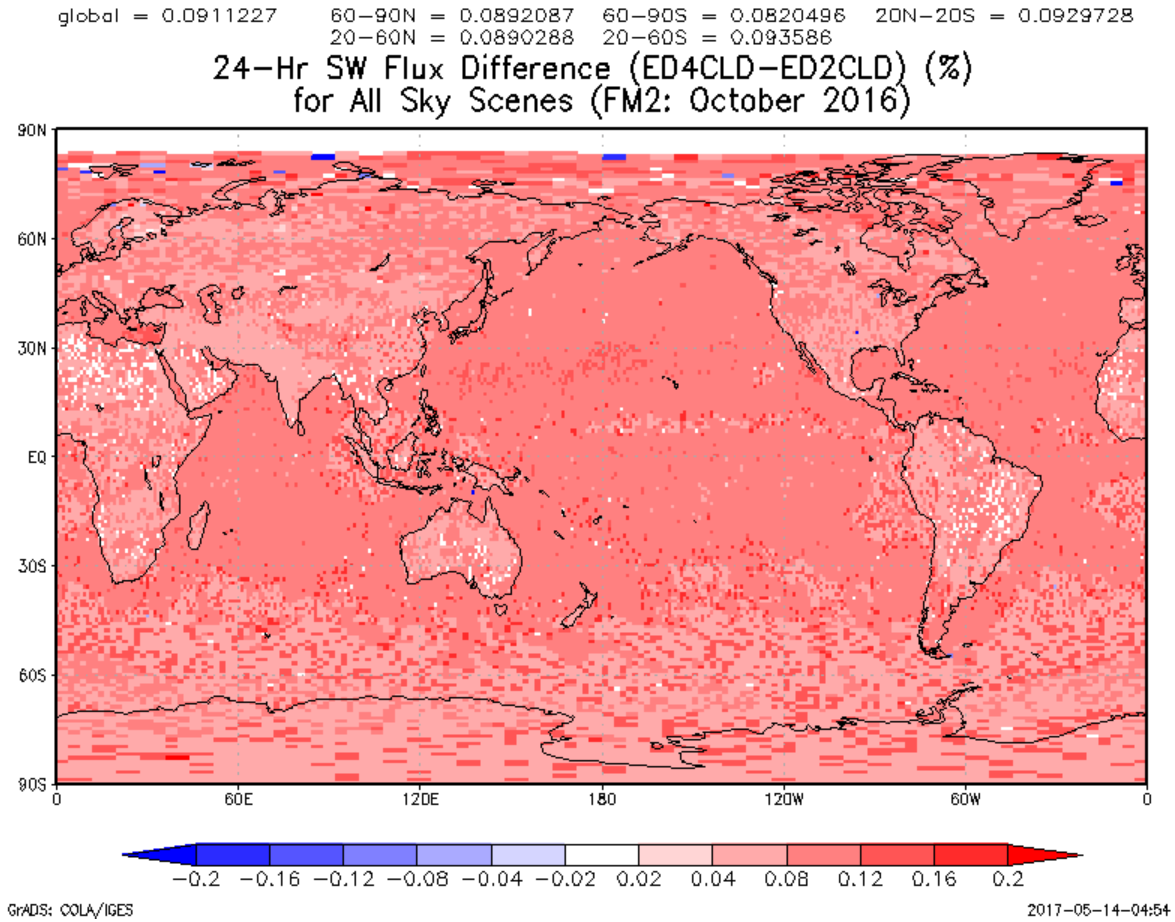


# FM2 SW Flux Difference: SRF with Ed4 and Ed2 Clouds

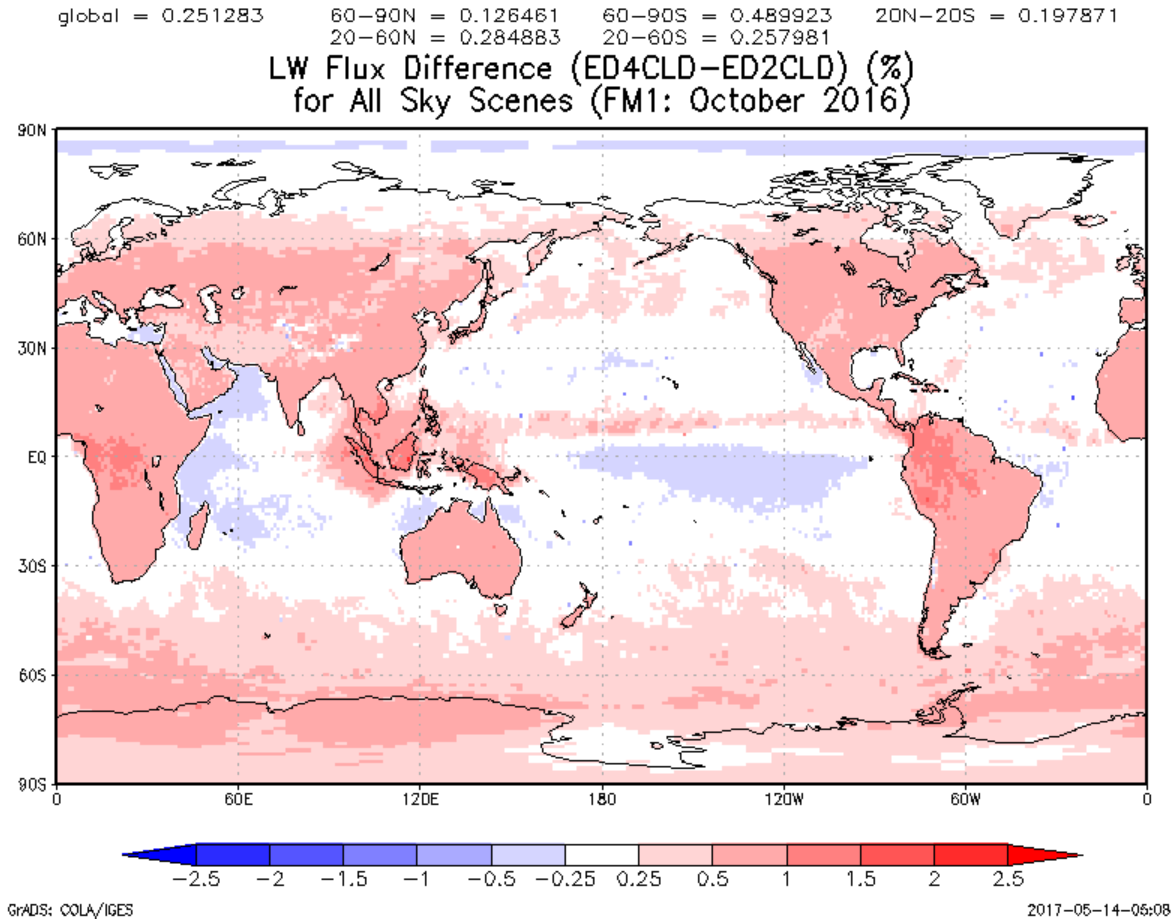
Edition-4 FM2 SW Spectral Response Function (SRF) was derived with Edition2 and Edition4 Clouds Algorithm.

Global Flux Difference (Ed4 CLD – Ed2 CLD)
0.091 W/m2



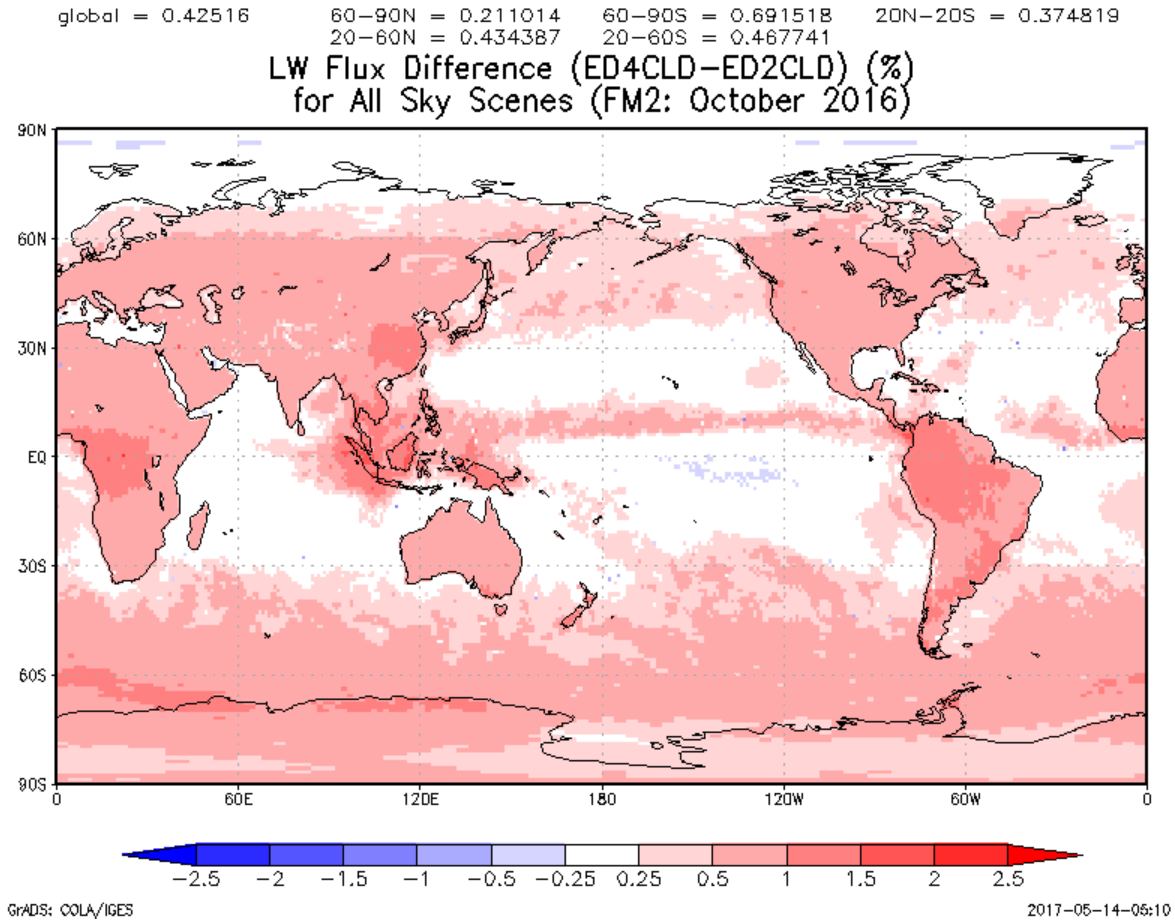
# FM1 LW Flux Difference: SRF with Ed4 and Ed2 Clouds

Edition4 Terra/FM1 LW October 2016 Spectral Response Function (SRF) derived with Edition2 and Edition4 Clouds Algorithms showed Global Flux Difference (Ed4 CLD – Ed2 CLD) of 0.251 W/m2



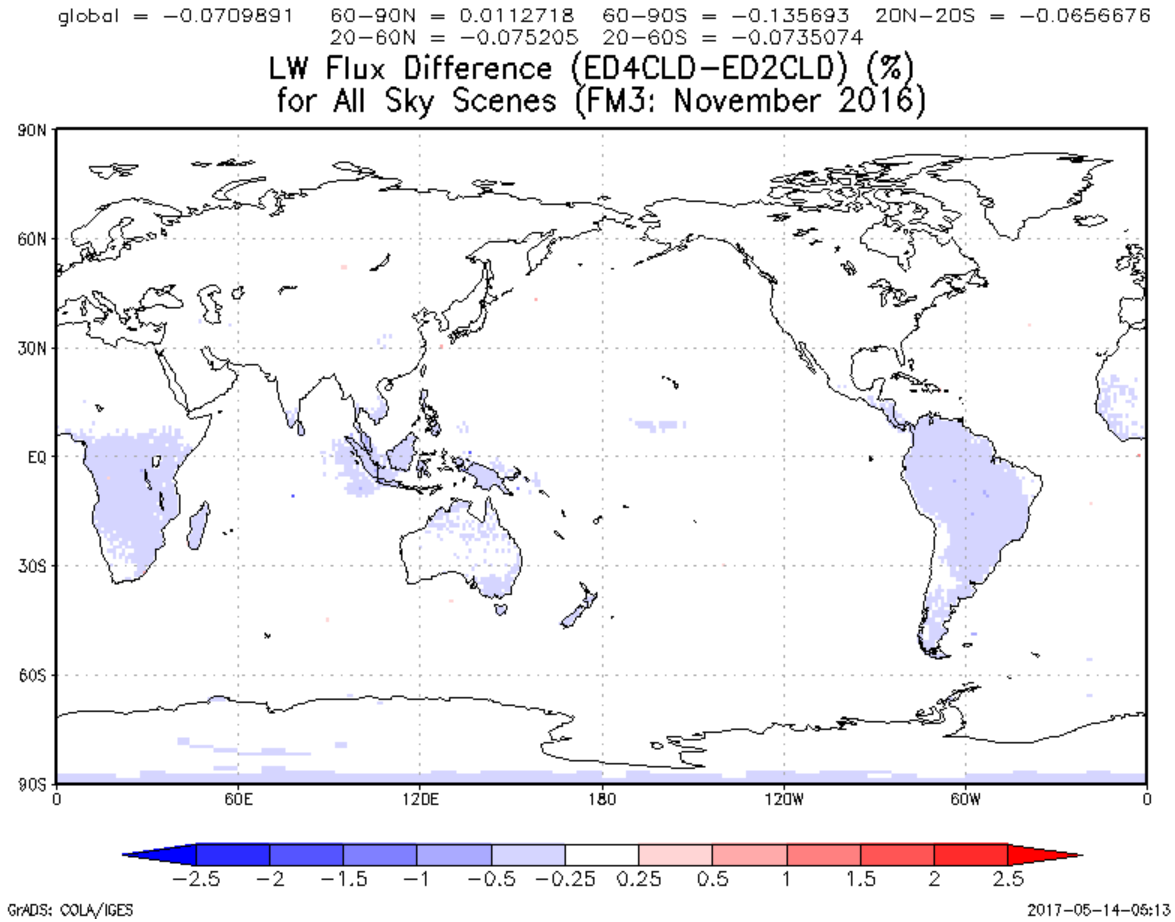
# FM2 LW Flux Difference: SRF with Ed4 and Ed2 Clouds

Edition4 Terra/FM2 LW October 2016 Spectral Response Function (SRF) derived with Edition2 and Edition4 Clouds Algorithms showed Global Flux Difference (Ed4 CLD – Ed2 CLD) of 0.425 W/m2



# FM3 LW Flux Difference: SRF with Ed4 and Ed2 Clouds

Edition4 Aqua/FM3 LW November 2016 Spectral Response Function (SRF) derived with Edition2 and Edition4 Clouds Algorithms showed Minimal change.
Global Flux Difference (Ed4 CLD – Ed2 CLD) of -0.071 W/m2

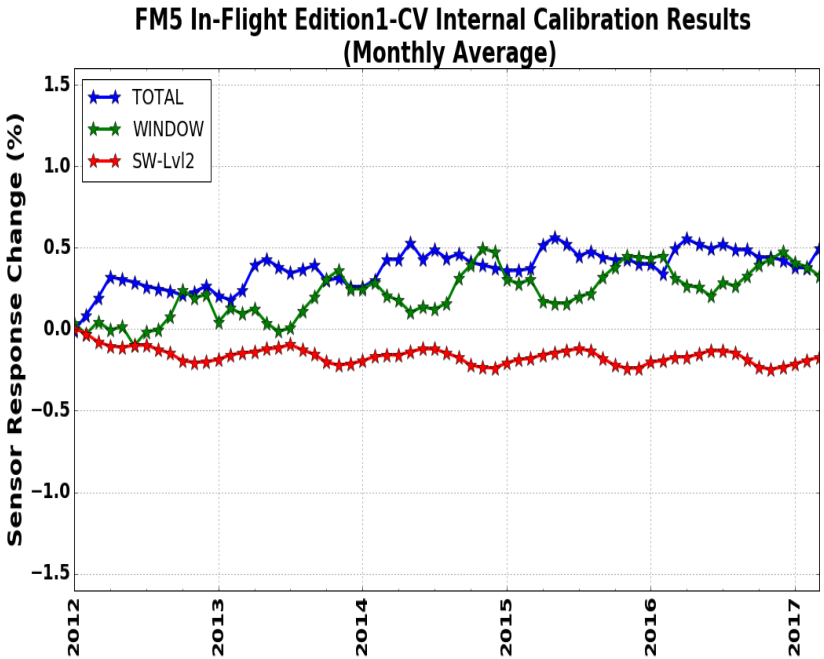


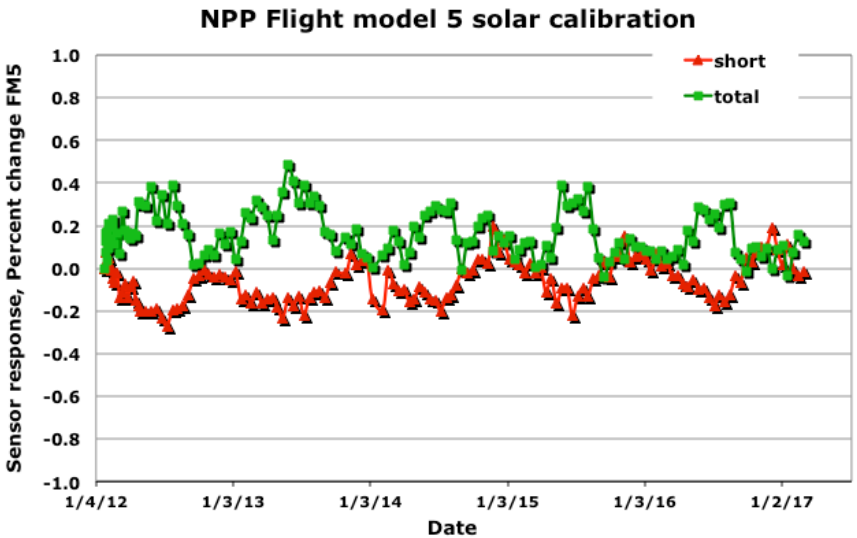
# S-NPP/ CERES FM5 INSTRUMENT STATUS

# S-NPP CERES FM5 Instrument Calibration

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

**Sensor response trends from solar calibrations vary between -0.2 to +0.4 percent.**

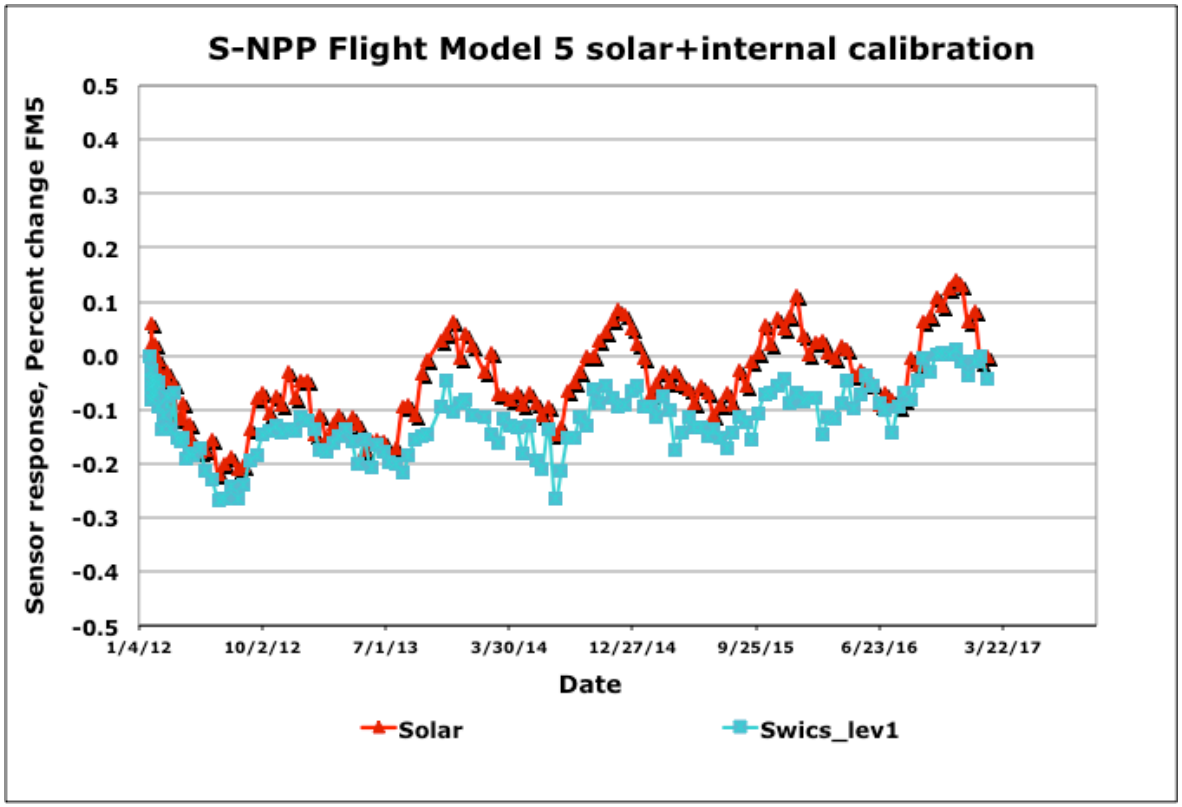



**Sensor gain corrections based on ICM calibrations are applied to Edition1 data products.**

# S-NPP/CERES FM5 Instrument Calibration

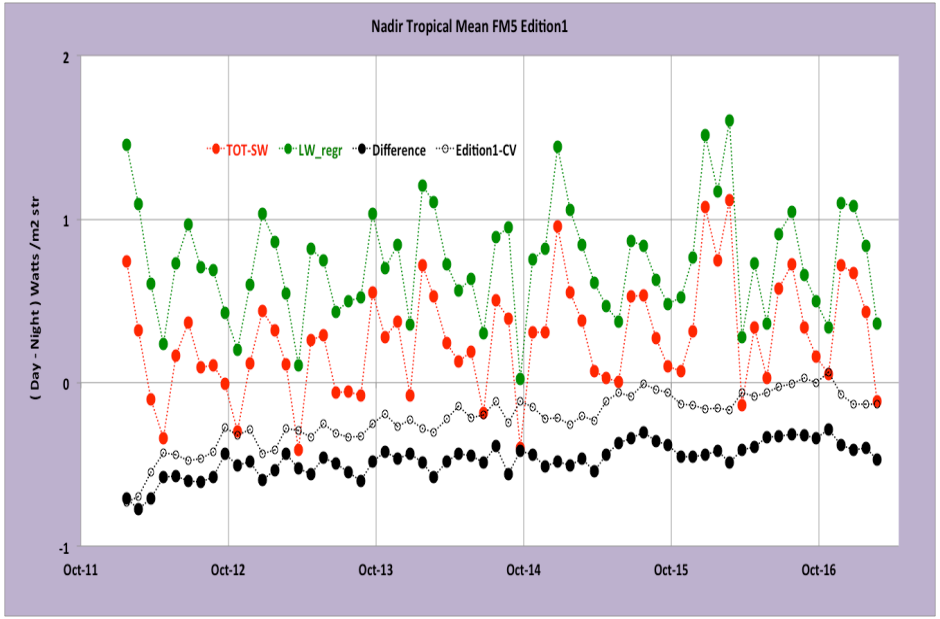
**Calibration results from SWICS (Level1) and MAM showed similar trends in the SW sensor. The rate change in the trend is higher for solar calibration results.**

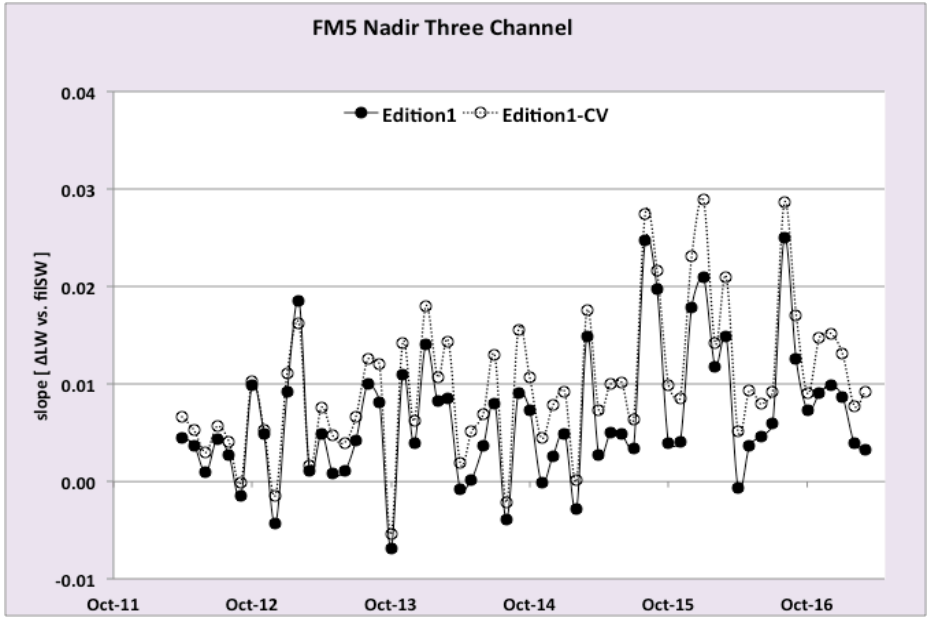


# Suomi NPP/CERES FM5 Validation Results

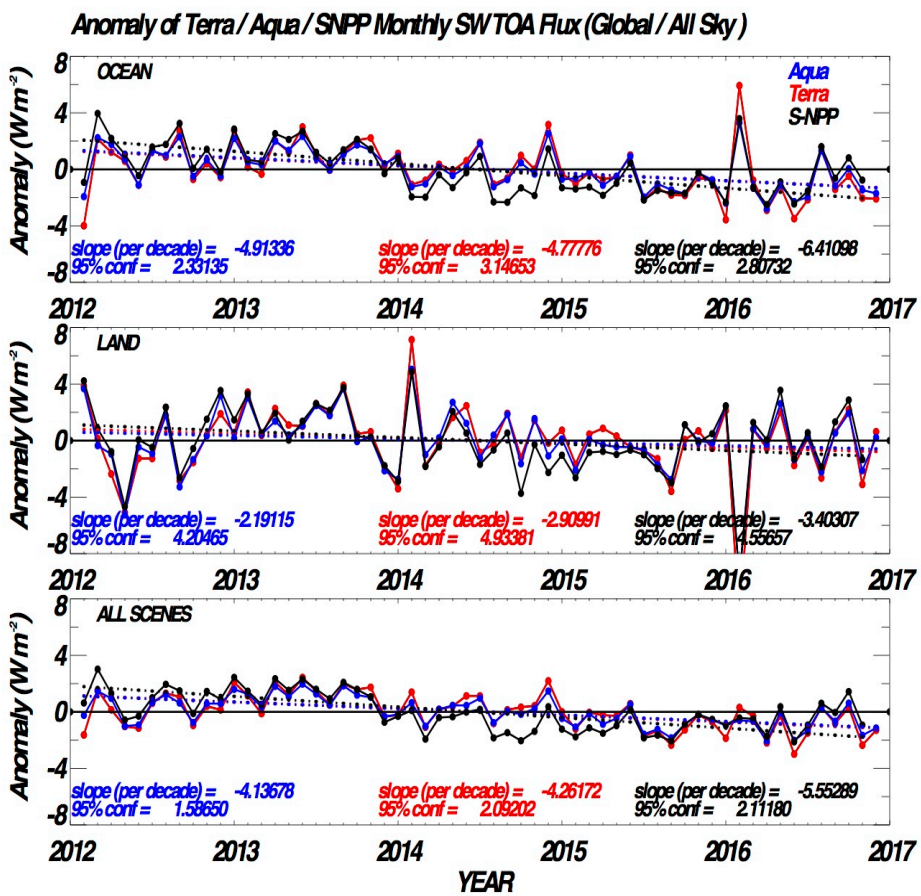
**Tropical Mean (TM): Nadir LW radiance for All-sky Ocean in ± 20 deg Latitude. Changes in SW/TOT channel is monitored through Day-Night Difference comparison between LW and Window measurements.**

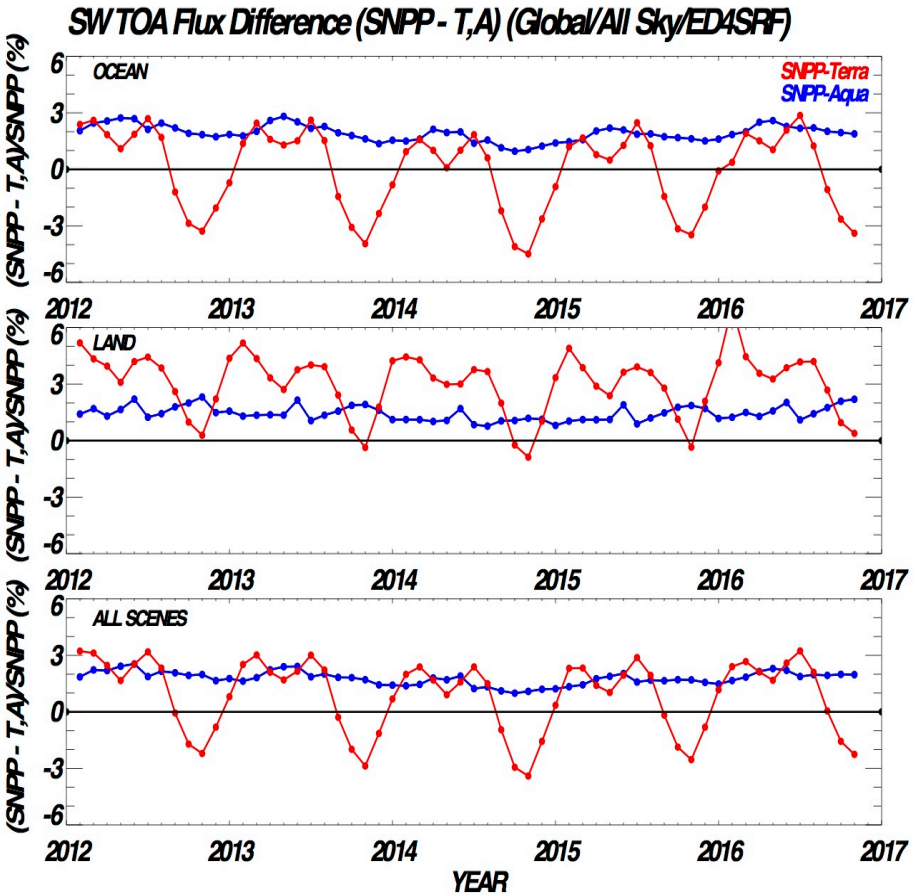
**Three Channel comparison use Deep Convective Cloud (DCC) as target. Trend in monthly slope between delta LW and SW measurements is monitored.**



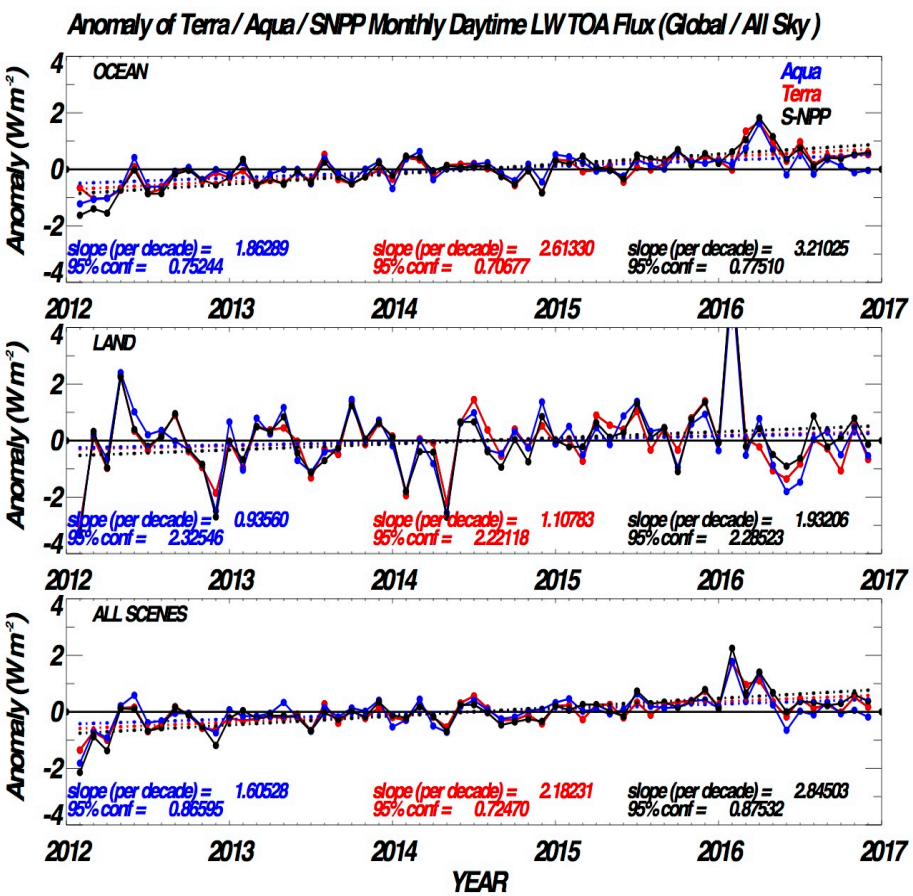
# S-NPP/FM5, TERRA & AQUA COMPARE: SW

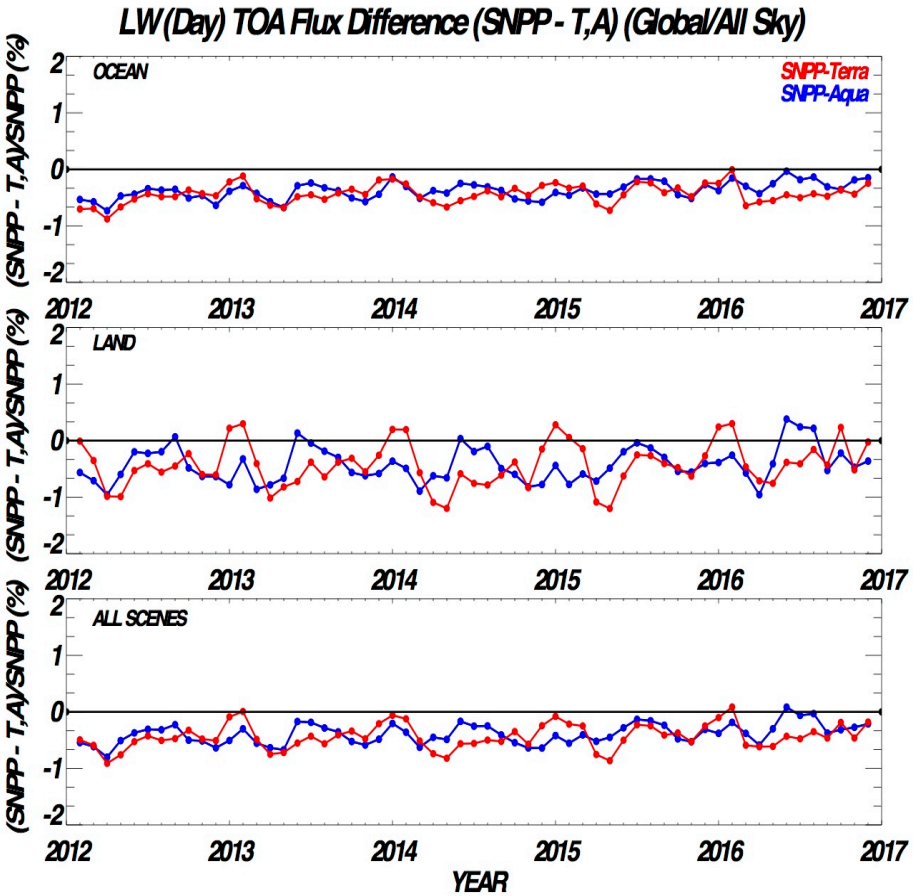



SW Flux anomaly from the 3 instruments show a downward trend. Results from S-NPP/FM5 show higher trend than FM1 and FM3 instruments.

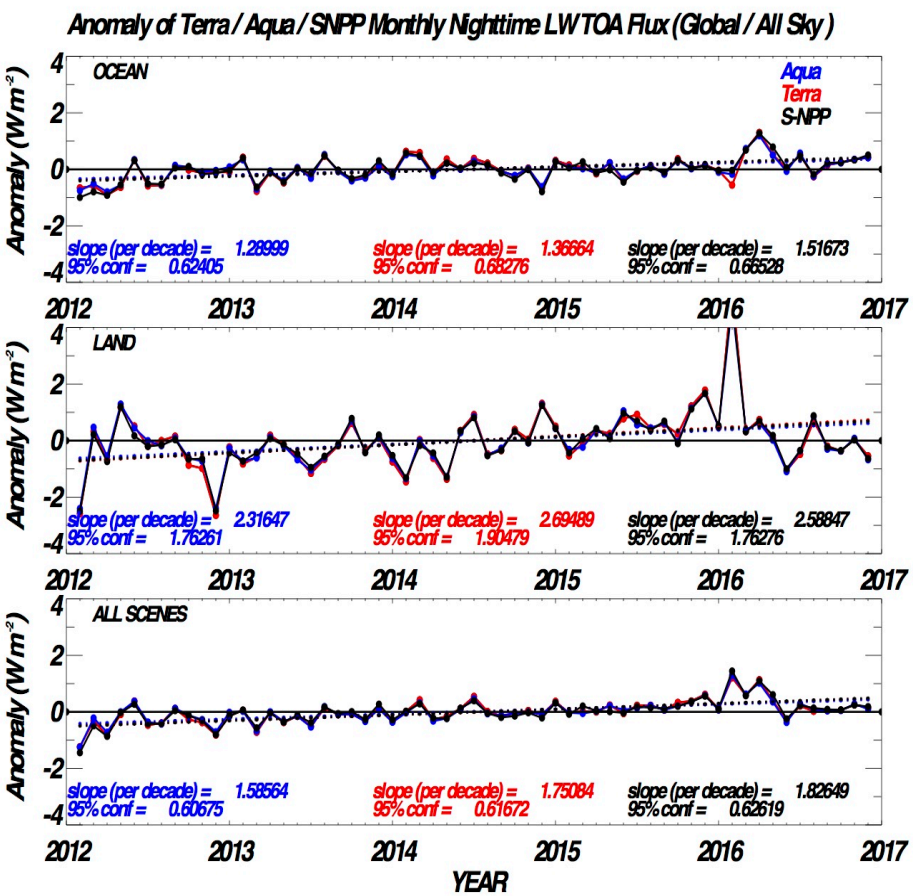
# S-NPP/FM5, TERRA & AQUA COMPARE: LW Day

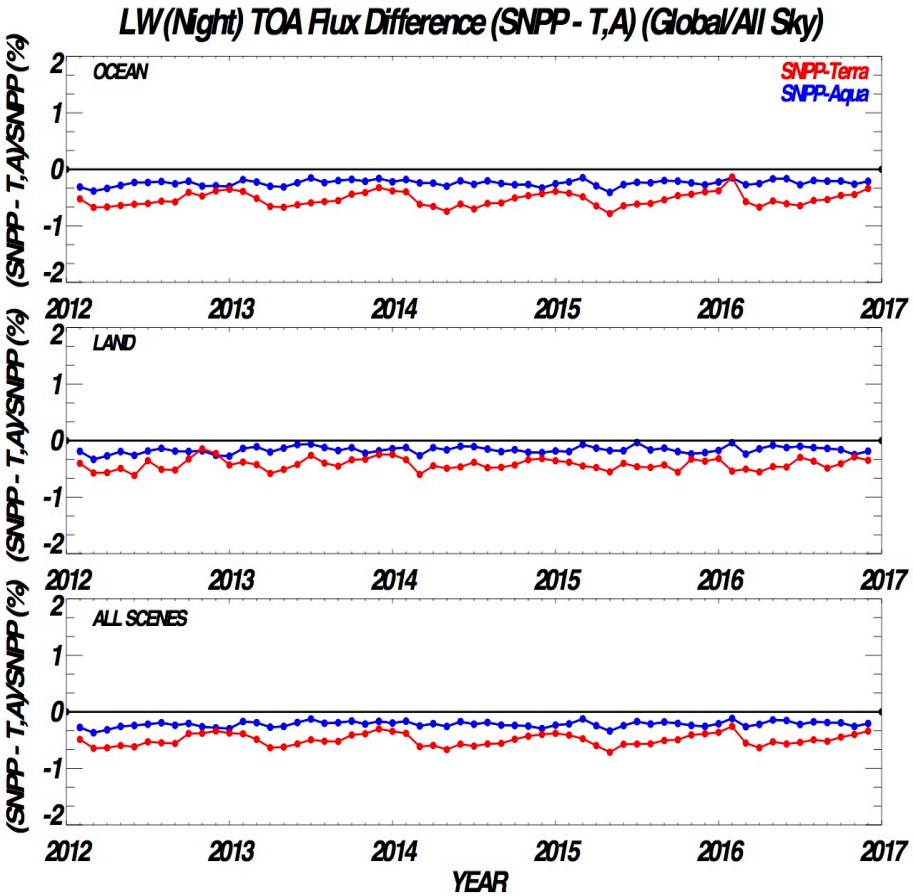



LW-Day Flux anomalies from the 3 instruments show positive trend. Results from S-NPP/FM5 show higher trend than FM1 and FM3 instruments.

# 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.

# Inter-comparison: FM5/ FM3/ FM1 instruments

- Annual campaign around summer solstice (Minor plane)
  - FM1 and FM5 May-July each year since 2012
    - In 2016, there are 91 comparison regions.
  - FM3 and FM5 in June of each year since 2012
    - In 2016, there are 50 comparison regions.
  - Each data collection at 70$^{o}$ N, which lasts 90 sec
  - Scan orientation is perpendicular to the solar plane
- FM5–FM3 "simultaneous Earth" observation(tandem data)
  - In 2016, 224 day and night comparison regions occurring every 64 hours
- Edition1 FM5 and Edition4 FM3/FM1 ES8 data used.

# Minor Plane Inter-Compare: FM5 and FM1

2012/2013/2014/2015/2016
$\Delta$Time < 5min

All-sky

Shown differences are statistically significant

| (FM5-FM1)/ FM5 | FM5 radiance [W $m^{-2}$ $sr^{-1}$] | Relative Error [%] | α-confidence [95%] | N of smpls |
|---|---|---|---|---|
| SWR | 87/102/111/109/104 | .8 /.9 /.9 /1.0 /1.0 | .3 /.2 /.1 /.2 /.1 | > 120 |
| LWR - day | 79/76/75/75/75 | -.5 /-.2 /-.8 /-.7 /-.6 | .1 /.1 /.1 /.1 /.1 | > 130 |

- 2012 campaign lasted only 6 weeks
  - June 16 – July 31
- 2013/2014/2015/2016 campaigns lasted 3 months
  - May 1 – July 31

# Minor Plane Inter-Compare: FM5 and FM3

2012/2013/2014/2015/2016

11 min < ΔTime < 21min

All-sky

Shown differences are statistically significant

| (FM5-FM1)/ FM5 | FM5 radiance [W $m^{-2}$ $sr^{-1}$] | Relative Error [%] | α-confidence [95%] |
|---|---|---|---|
| SWR | 79/84/77/81/101 | 3.3 /2.7 /1.0 /1.7 /0.9 | .4 /.3 /.4 /.4 /.3 |
| LWR - day | 76/74/77/77/78 | -1.1 /-1.3 /-.6 /-.9 /.4 | .1 /.1 /.1 /.1 /.2 |

- 2012/2013/2014/2015/2016 campaigns lasted 1 month
  - June 1 – June 30

# Direct compare of FM5 and FM3

2012/2013/2014/2015/2016
(Rev. 05/11/17)
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 |

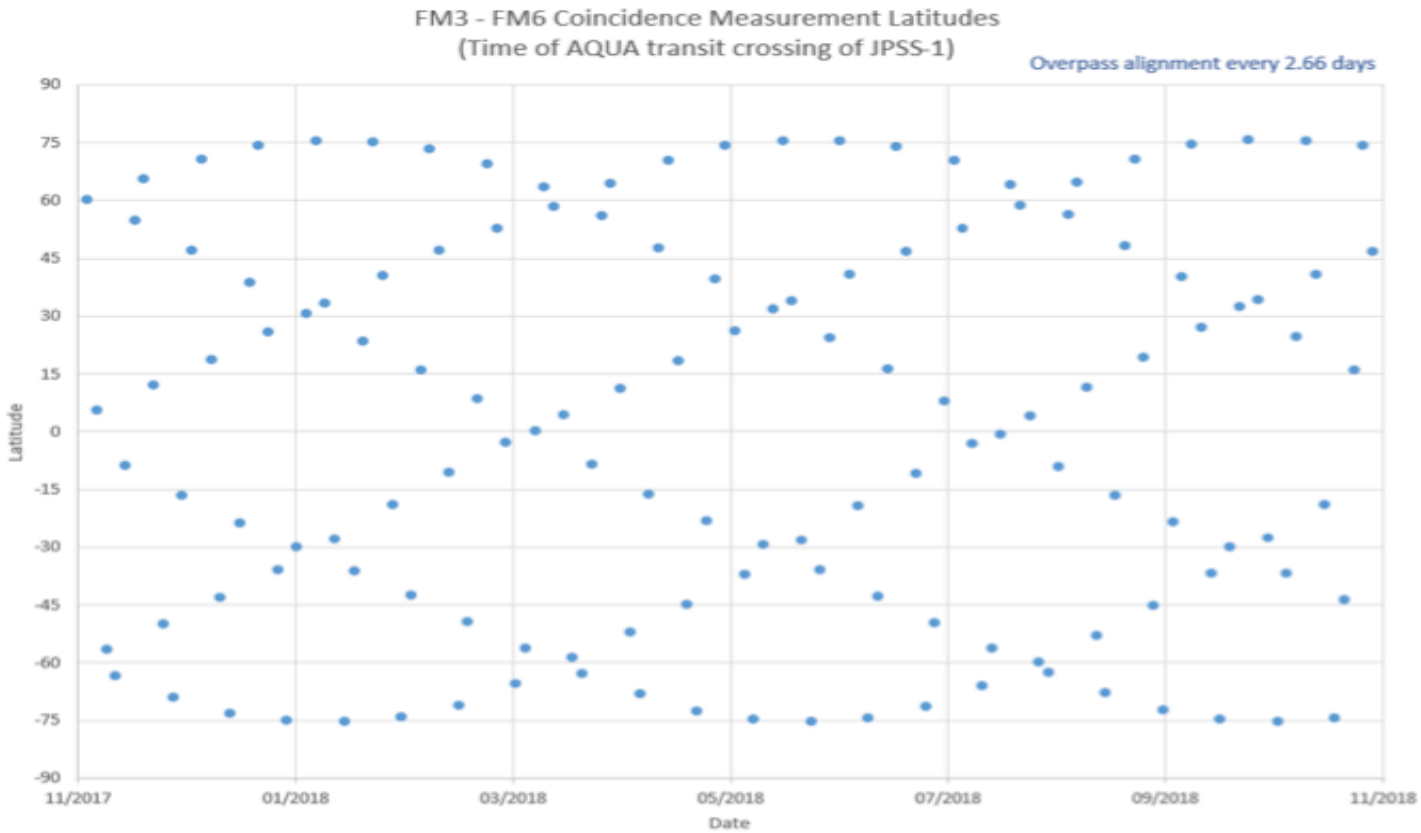
- Shown differences are computed as "average of differences" to avoid error cancellation

# 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.

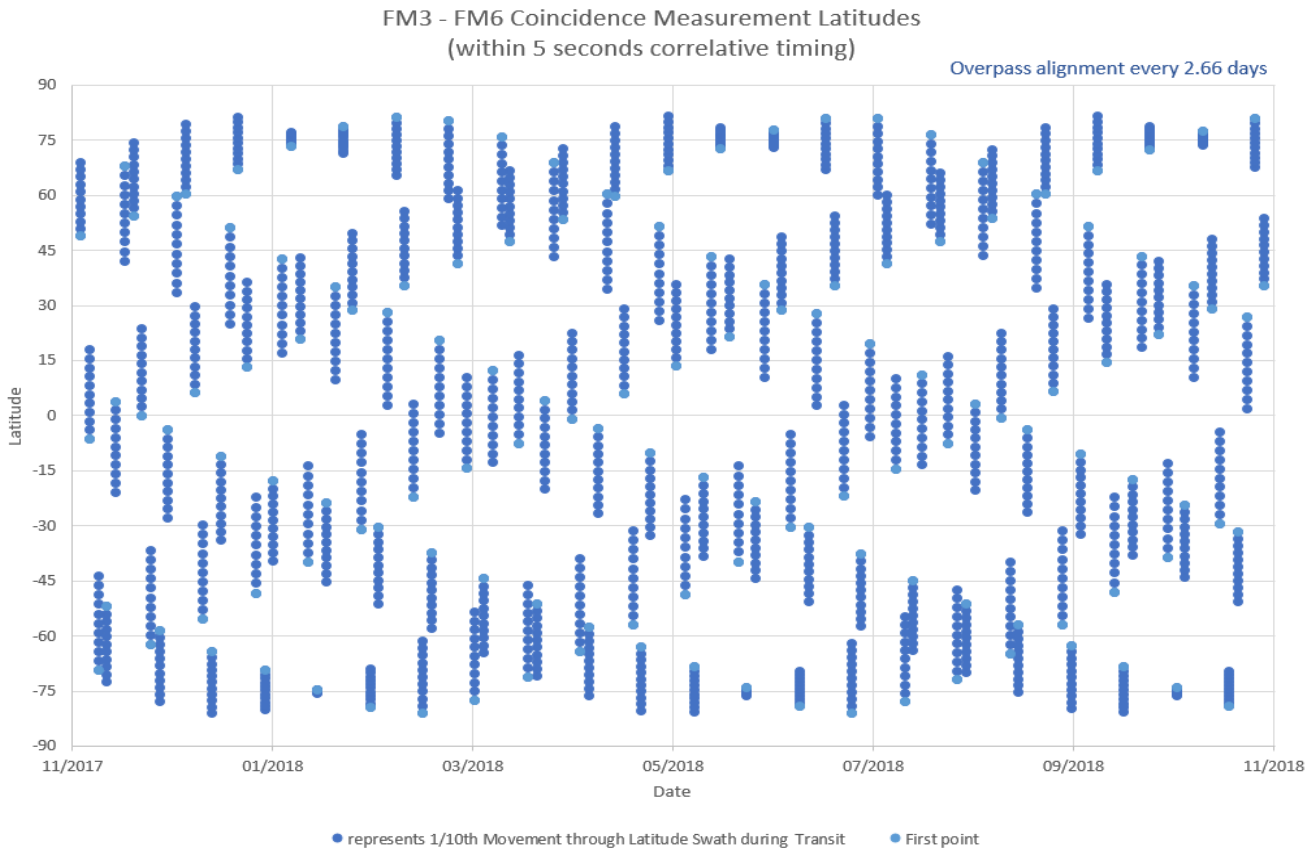
# Aqua – JPSS-1 Orbital Overlap Study

**Aqua – JPSS-1 Orbit alignment occurs about 2.66 days apart that provides coincident measurements opportunity.**



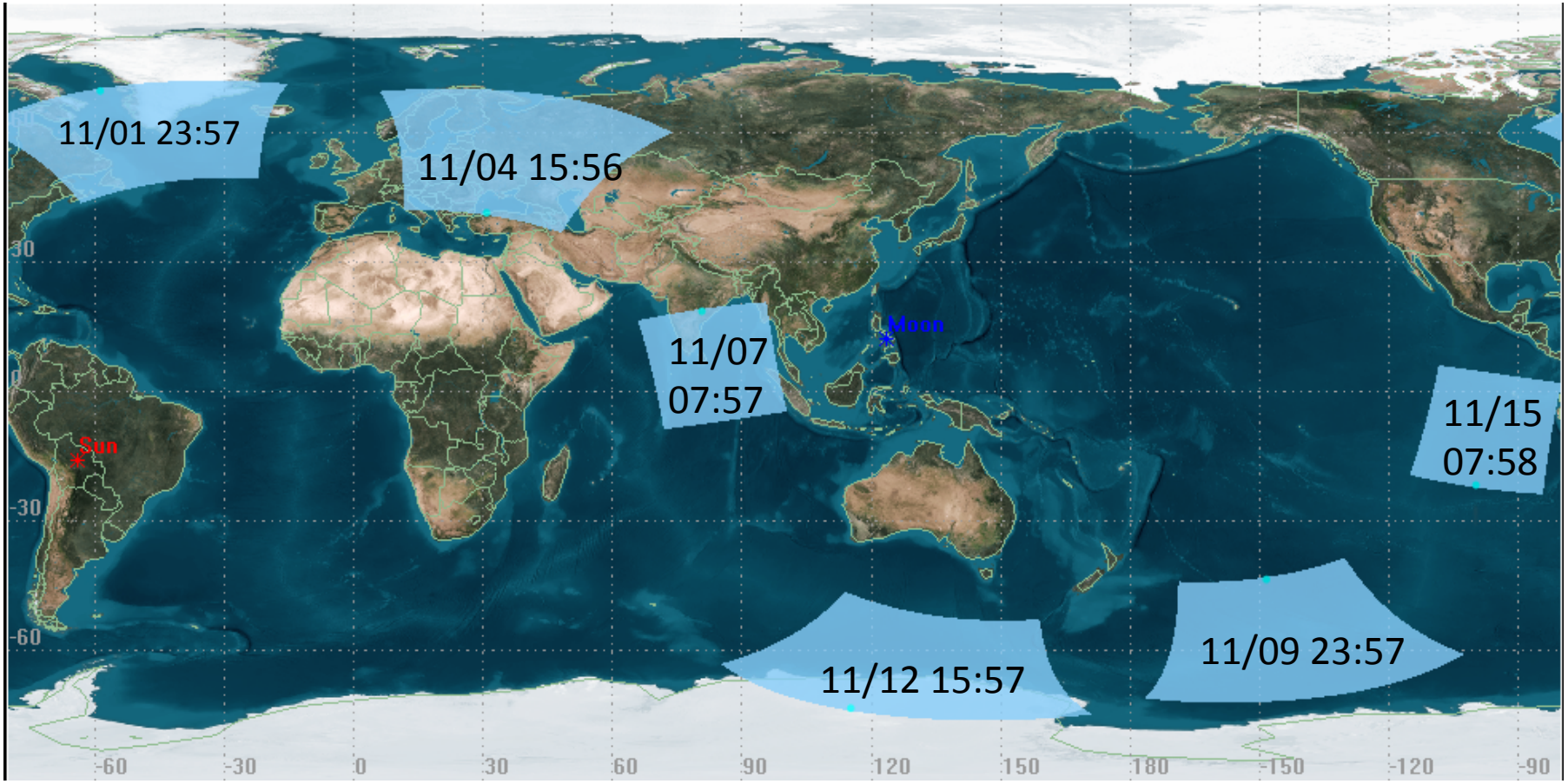
# Aqua – JPSS-1 Overlap Region Study

**Aqua – JPSS-1 coincident measurement opportunities for a year within 5 second timing is shown. Each opportunity provide 7 min of data on the average.**



# Aqua – JPSS-1 Overlap Region Study

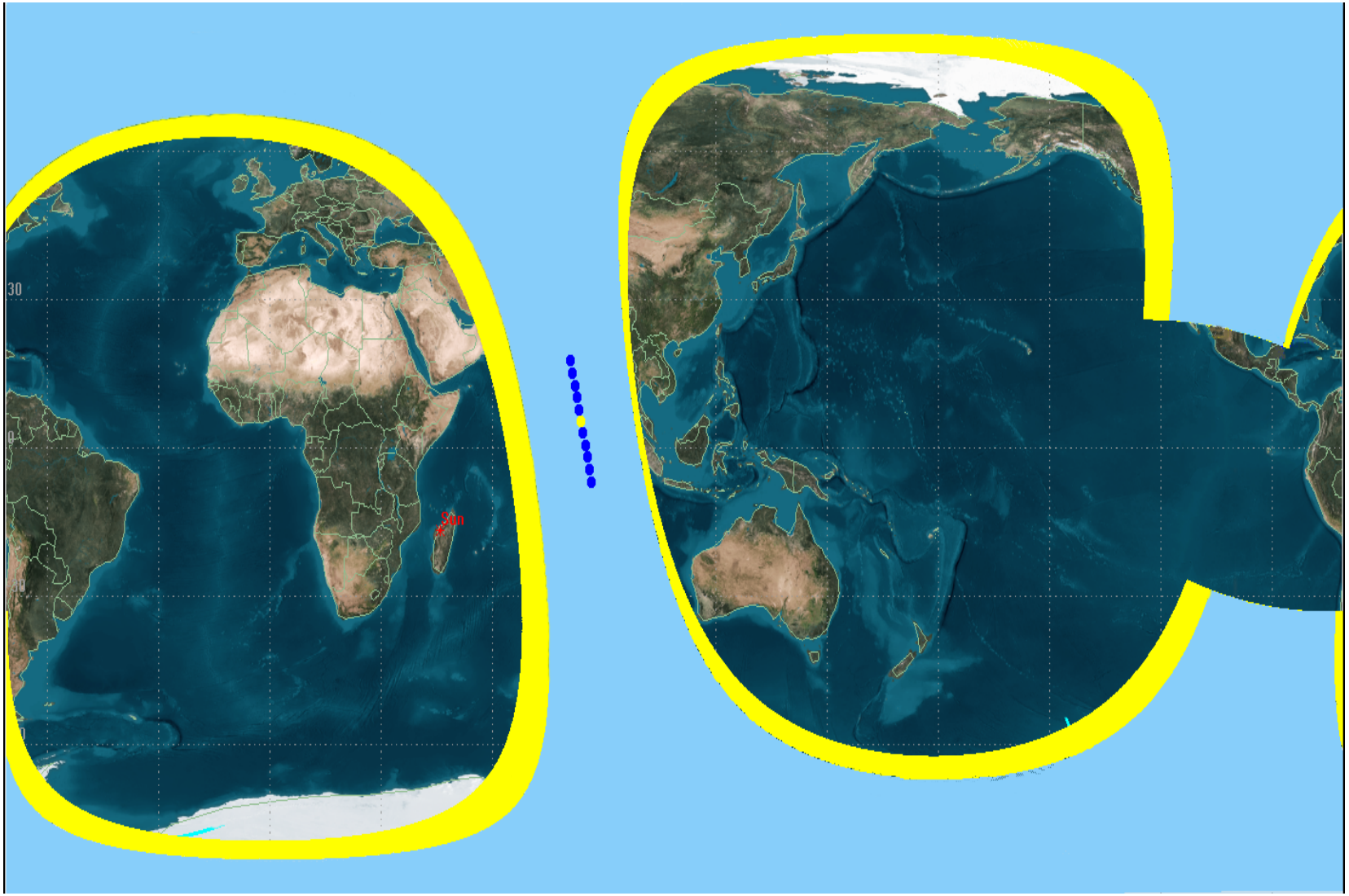
2 Weeks of coincidence measurements between FM3 and FM6 with AQUA under-flight crossing time of JPSS-1 and all points with coincident timing within 5 seconds.



# SUMMARY

- Validation results from Edition-4 datasets continue to show slight negative trend in SW Flux anomaly and positive trends in FM2 and FM3 LW_Day Flux anomaly. FM1 instrument show no trend in LW-Day Flux .
- Change in SSF Ed1-CV dataset used for Ed4 SRF calculation showed no significant impact on calculated SW Flux and LW Flux for FM3. Terra instruments showed an increase in LW Flux values.
- S-NPP/FM5 SW sensor results showed similar trends for SWICS and MAM calibrations with the rate of change higher in solar calibrations.
- Anomaly trends for S-NPP/FM5, Terra/FM1 and Aqua/FM3 showed positive trends for LW day and night Flux values. A negative trend was observed in SW Flux for all 3 instruments.
- 2016 S-NPP/FM5 minor plane intercomparison with Terra/FM1 and Aqua/FM3 showed similar results in both SW and LW measurements. As previous years.
- Aqua/FM3 and JPSS-1/FM6 Overlap region simulation showed coincident measurement opportunity occur in ~2.66 days.

# BACK UP SLIDES




AQUA under-flight crossing time of JPSS-1 on November 7 and all points within 1 minute.
Blue is 60 degree swath of FM3. Yellow is the 60 degree swath of JPSS-1.
The points in the center of the swath represent the points on the +/- 5 second Latitude plot.

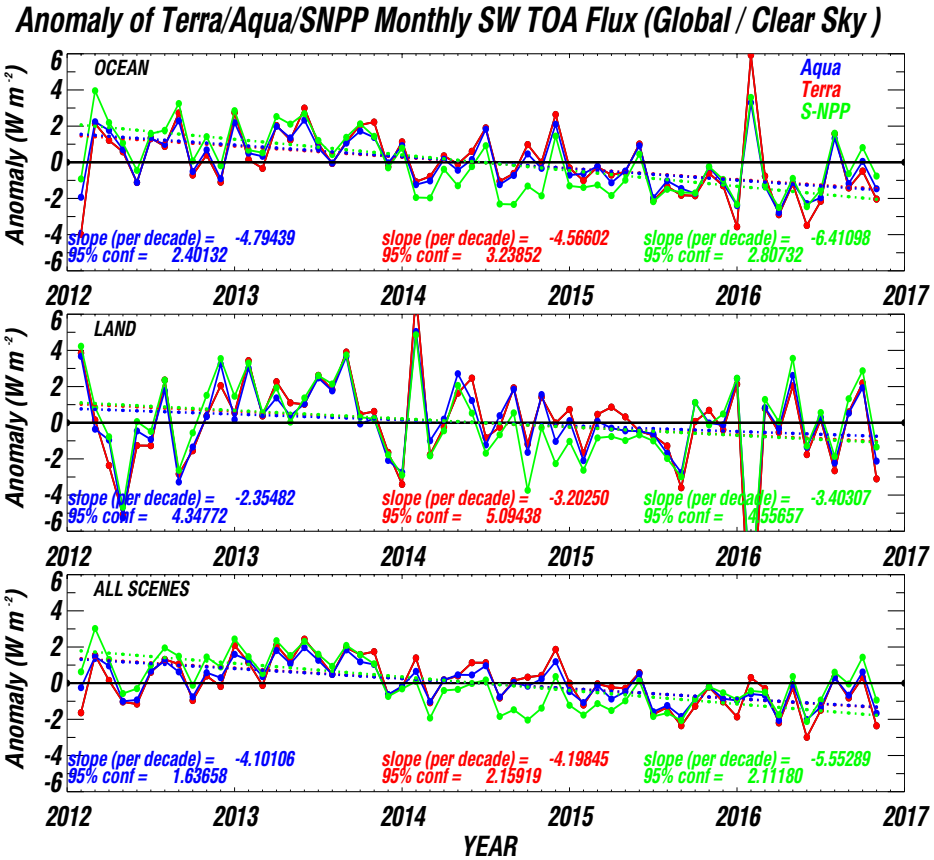
# TERRA/AQUA GAIN and SRF Delivery

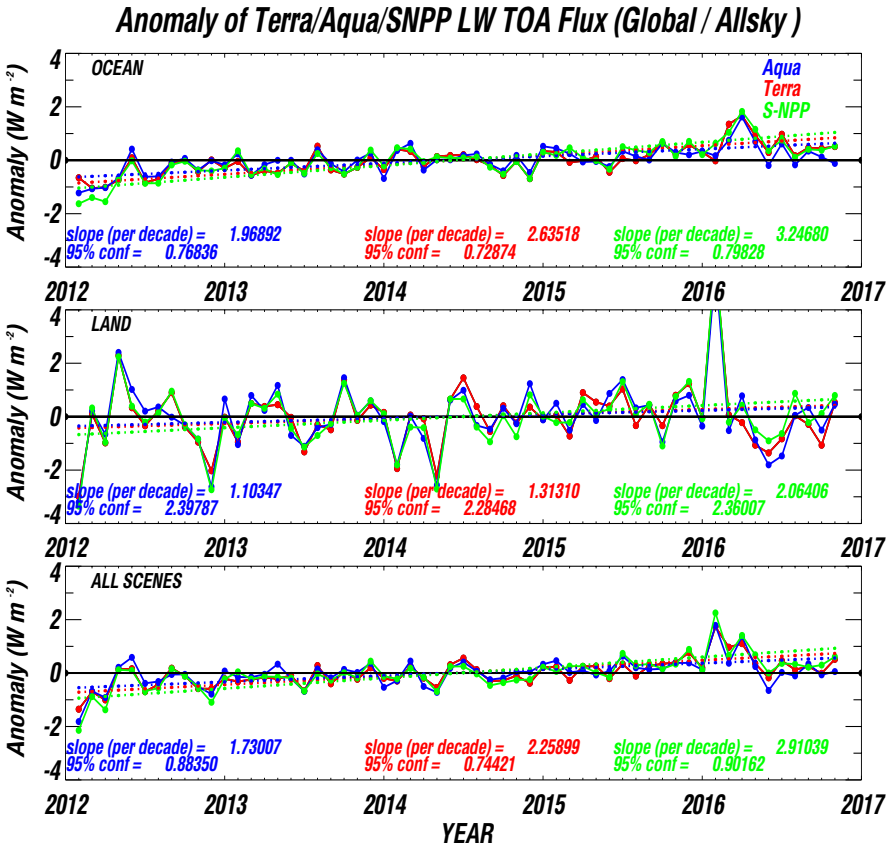
**Edition3 Gains and Spectral Response Functions (SRF) :**
**Start of Mission – January 2017**

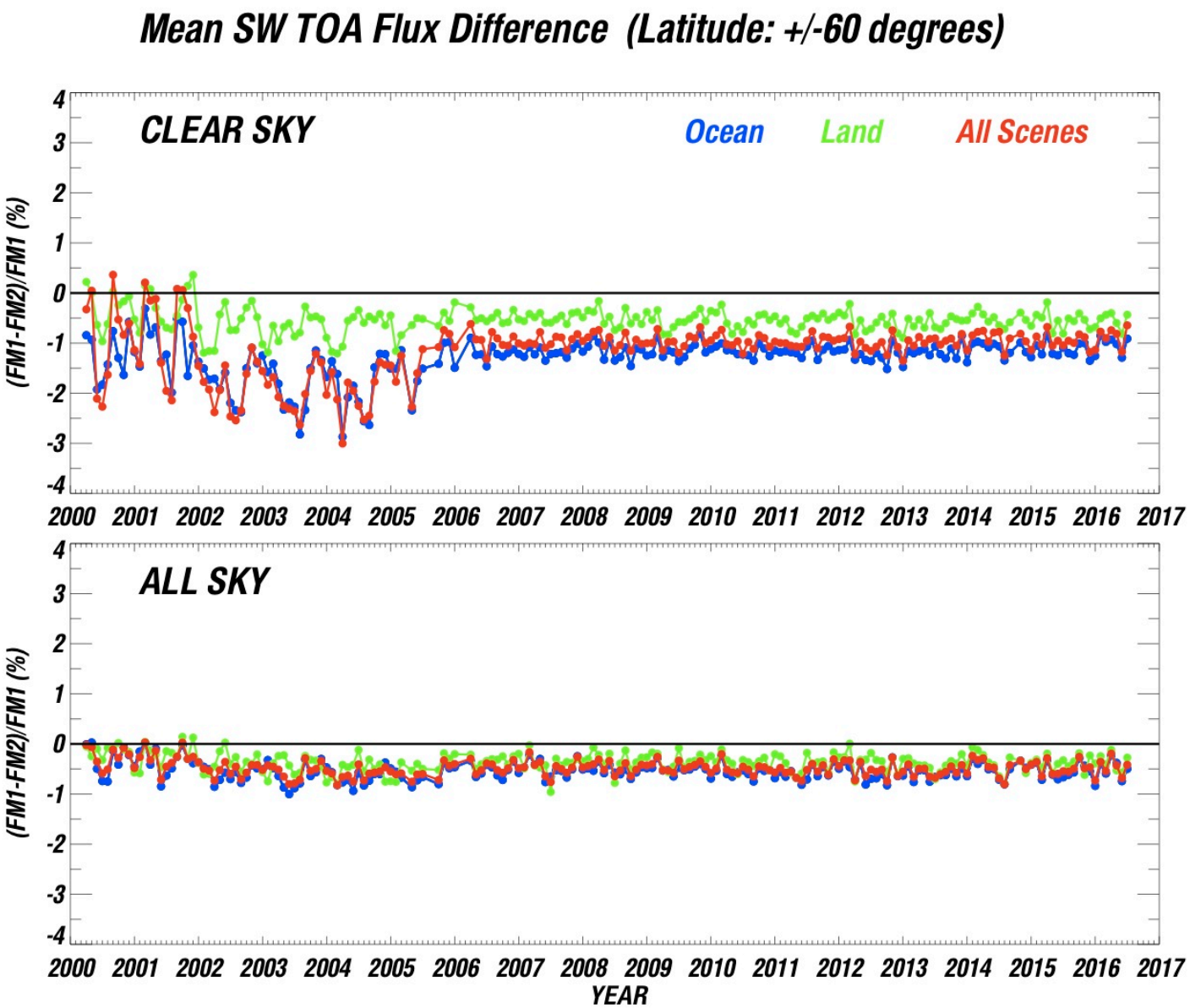
**Edition4 Gains and Spectral Response Functions (SRF) :**

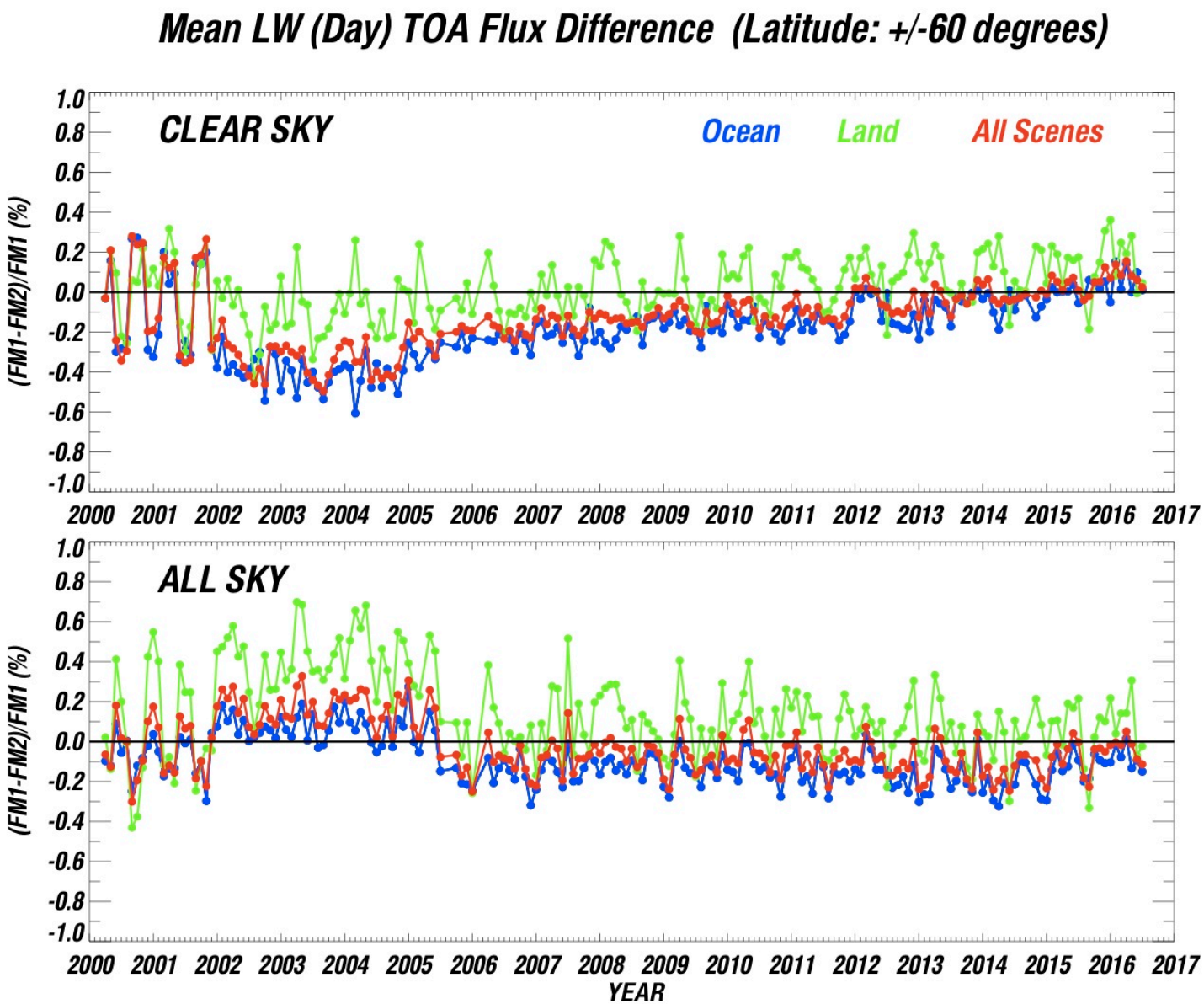
**Terra and Aqua - Start of Mission to January 2017**

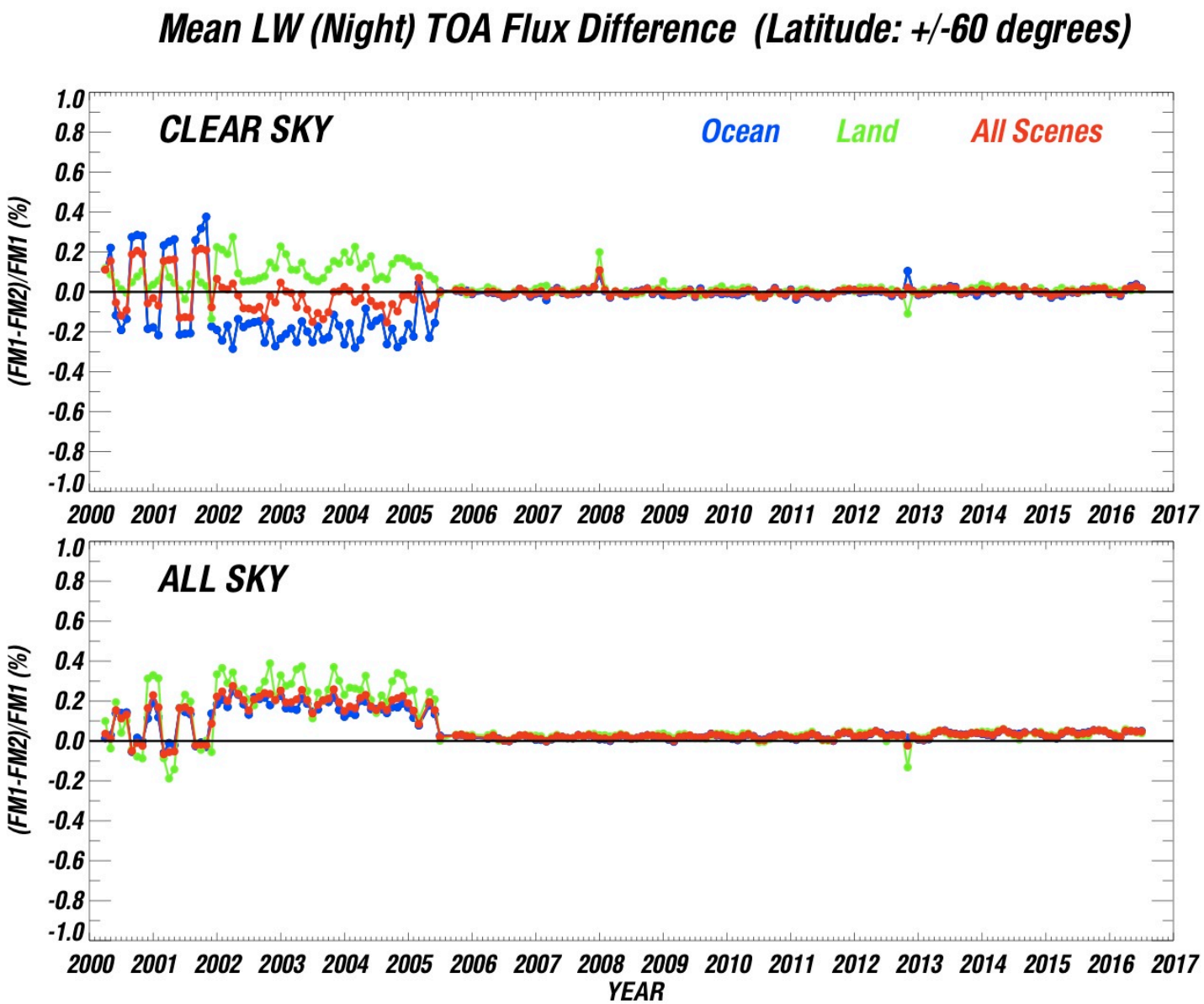
# S-NPP/FM5, TERRA & AQUA COMPARISON




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

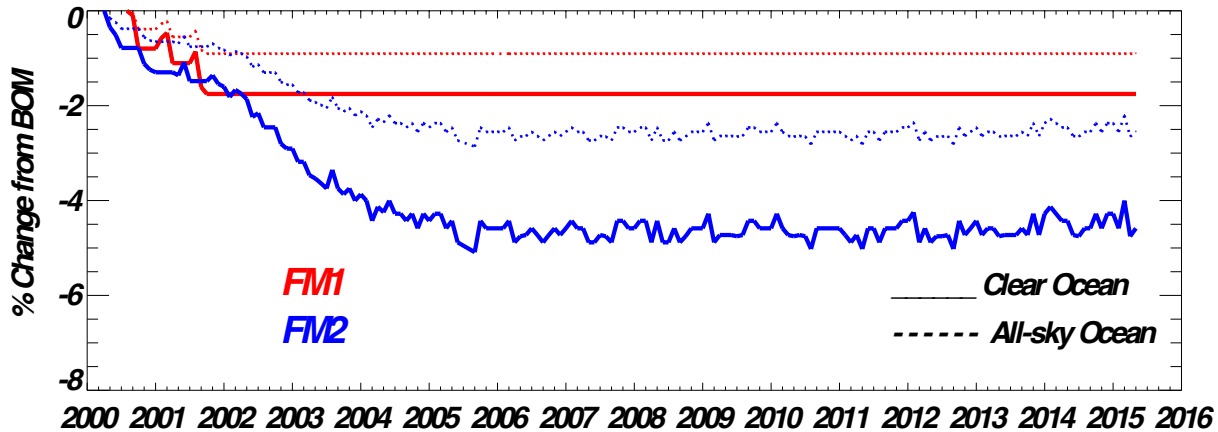

Mean LW (Night) TOA Flux Difference (Latitude: +/-60 degrees)
CLEAR SKY
Ocean
Land
All Scenes
ALL SKY
(FM1-FM2)/FM1 (%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
YEAR

# TERRA/AQUA EDITION-4: SW SENSOR

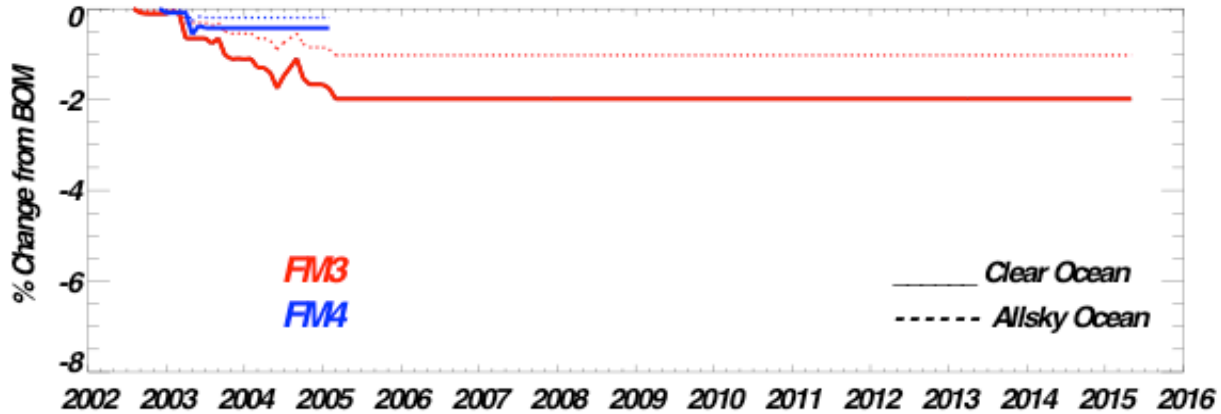
**The SW sensor Spectral Response Function (SRF) correction is applied based on the Nadir comparison of Clear Ocean SW measurement from two instruments on same spacecraft. The correction is applied to SRF for the instrument operating in RAPS mode.**

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

TERRA




AQUA

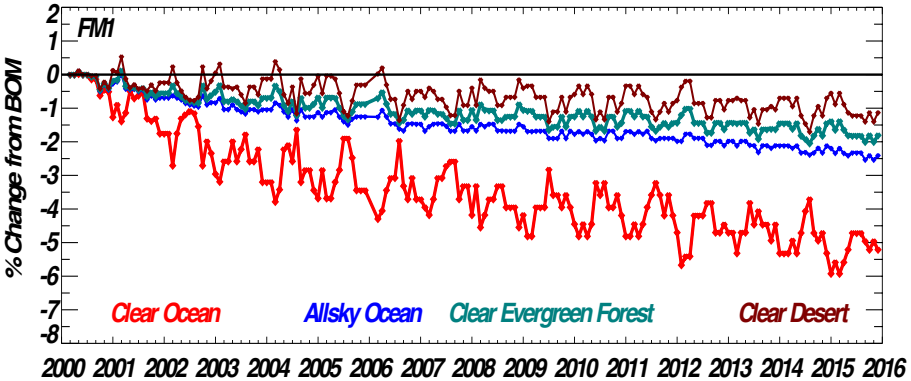



**CERES Instrument Working Group**

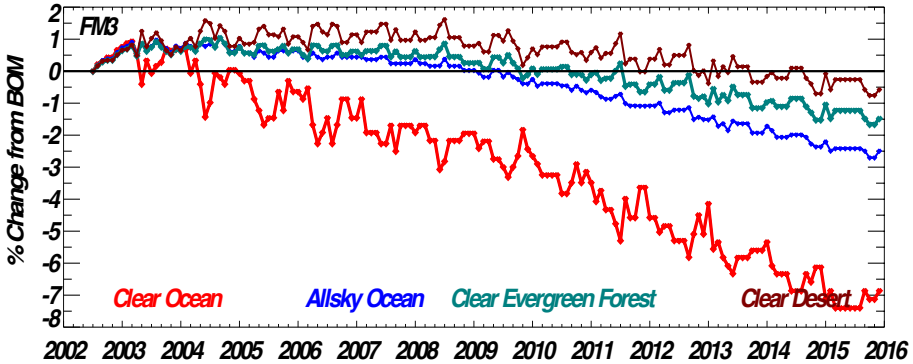
# EDITION-4 TERRA/AQUA: SW/TOT SENSOR

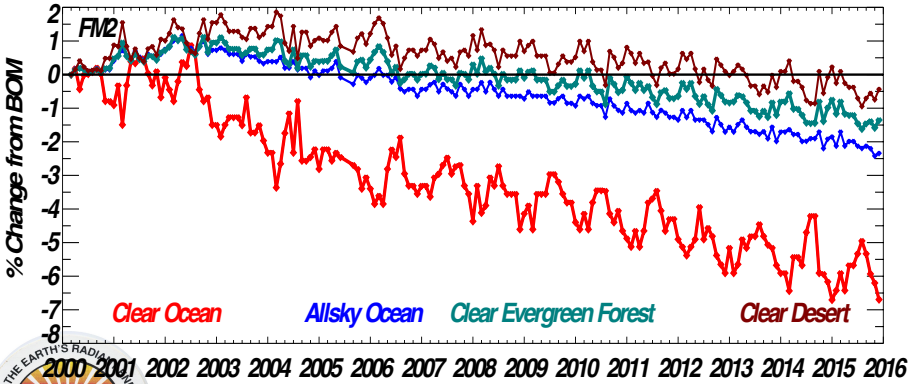
- **Correction to SW/TOT sensor of each instrument is based on the regression between LW(Day-Night) and WN (Day-Night) using Tropical Ocean and Land scenes.**

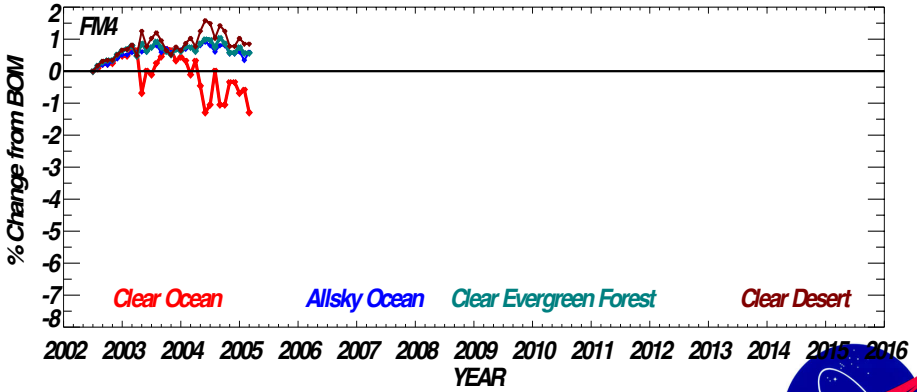
**SW/TOT 'Optimal' Throughput Change for Terra (Terra SRF with SCIAMACHY Scene Spectra)**




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

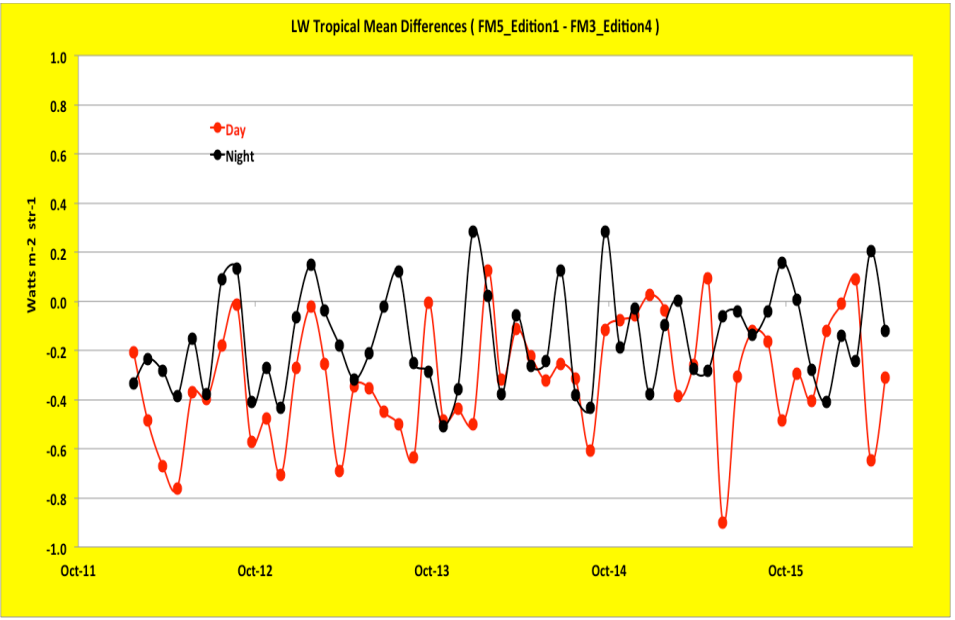


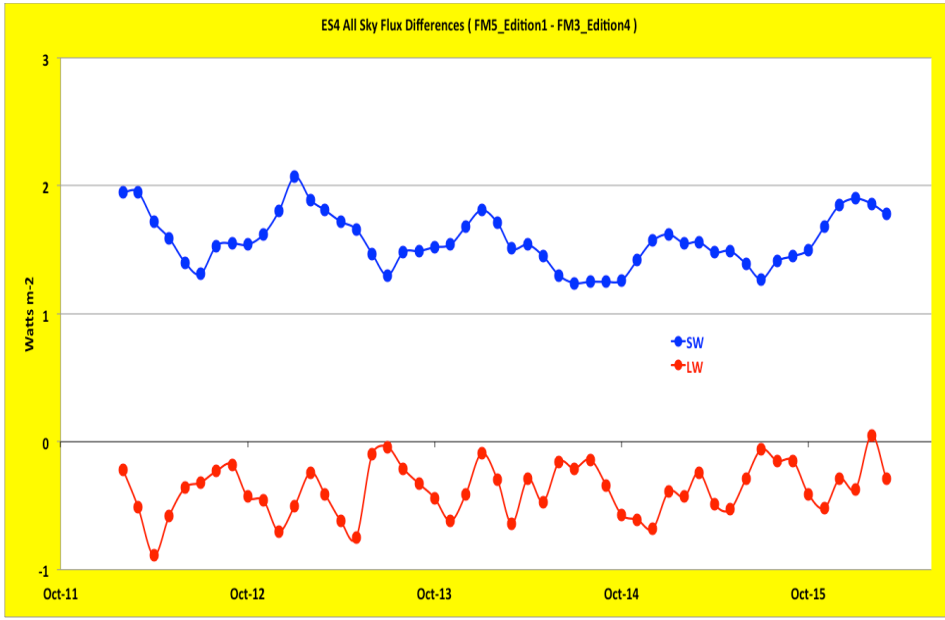



# CERES S-NPP/FM5 – Aqua/FM3 Comparison

**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.**



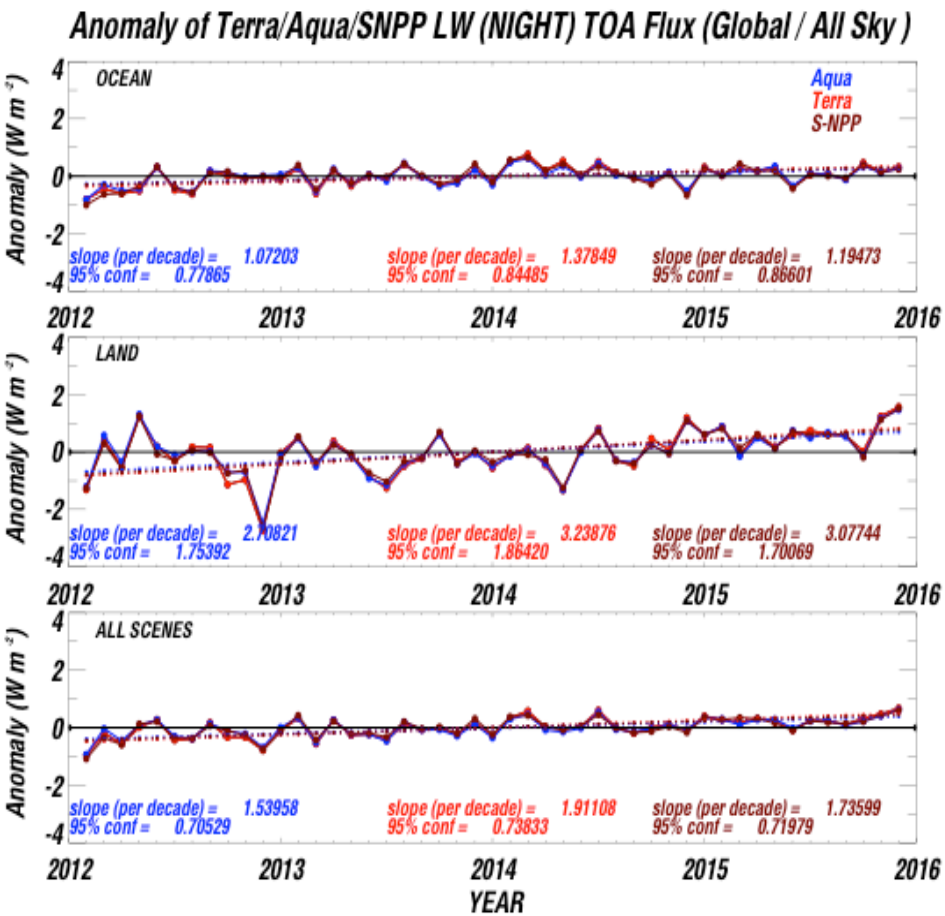
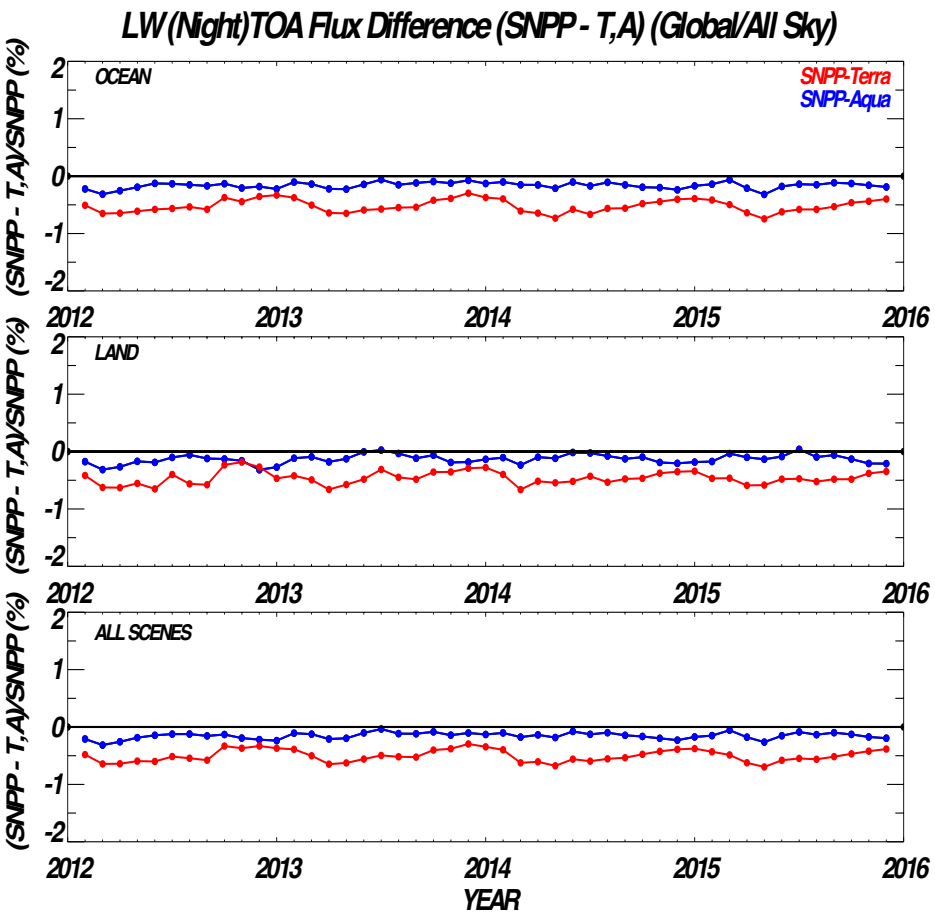



# CERES FM5 - FM3 Matched Footprint Comparisons

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

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