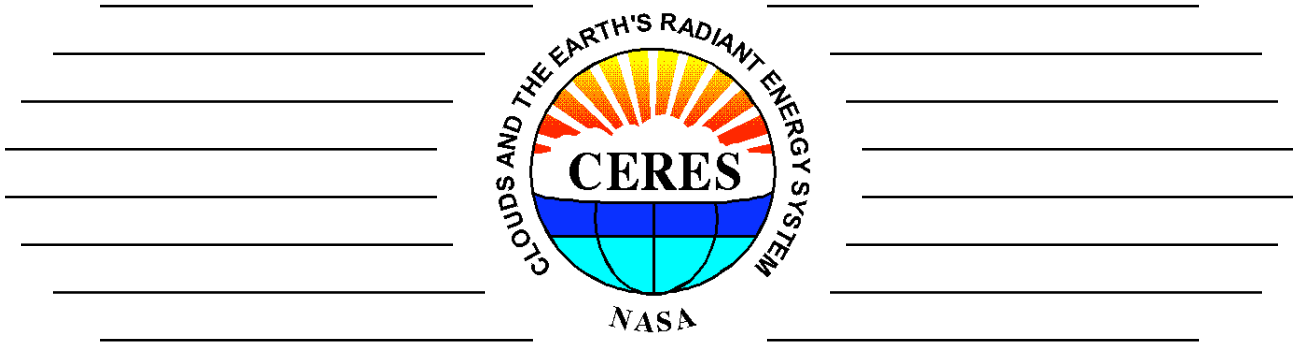
# Terra/Aqua Instrument and ERBE-Like Calibration Status Report




**Kory J. Priestley**
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**CERES Science Team Meeting**
Princeton, NJ
May 2-6, 2005

NASA Langley Research Center
Atmospheric SCIENCES

# Agenda

- CERES Project Status
  - Engineering/Housekeeping Status
  - FM-4 SW Channel Anomaly - Aqua Spacecraft
- Cal/Val Report
  - Terra/Aqua on-orbit performance
  - Possible Spectral Darkening of CERES SW channels

# CERES Terra/Aqua Health & Status

**With the exception of the SW channel on the CERES/Aqua FM-4 Instrument, the CERES Terra/Aqua instruments are functioning nominally…**

**All temperatures and voltages remain within limits**

**No discernable or alarming trends.**

| Spacecraft | Instruments | Launch | Science Initiation | Collected Data (Months) |
|---|---|---|---|---|
| TRMM | PFM | 11/97 | 1/98 | 9 |
| Terra | FM1, FM2 | 12/99 | 3/00 | 62 + |
| Aqua | FM3, FM4 | 5/02 | 6/02 | 35 + |
| ? | FM5 | ? | ? | ? |

# CERES/Aqua FM-4 SW Anomaly History

**History-**

- On March 30, 2005 at 18:42 GMT the CERES/Aqua FM-4 instrument stopped collecting valid Shortwave channel radiometric measurements.
- Anomaly was characterized by an immediate railing 'high' of the SW channel data stream, which subsequently drove the SW channel bridge balance electronics into a reset condition in an attempt to bring the SW channel output on-scale.
- The Total and Atmospheric Window radiometric channels continued to function nominally.
- All other housekeeping and science parameters remained within nominal ranges and continue to do so. No increased noise or precursor indicators prior to event.
- ~24:00 GMT March 31st, the CERES/Aqua FM-3 instrument was placed in the Cross-track scan mode to preserve the CERES Climate Data Record measurements.
- Anomaly resolution team formed on March 31st and developed a strategy to guide the investigation. NGST is included on the team.
- Complete memory dump of the FM-4 instrument was accomplished on 4/1/05. Indicated no corruption of the flight software or memory locations.

# CERES/Aqua FM-4 SW Anomaly
# Science Impacts

**Near Term**

No impact assuming the CERES/Aqua FM-3 instrument is collecting cross-track data.

*---Removes pressure from anomaly team allowing them to proceed more carefully---*

**Long Term**

If anomaly cannot be resolved, longer term science issues include (in order of priority)

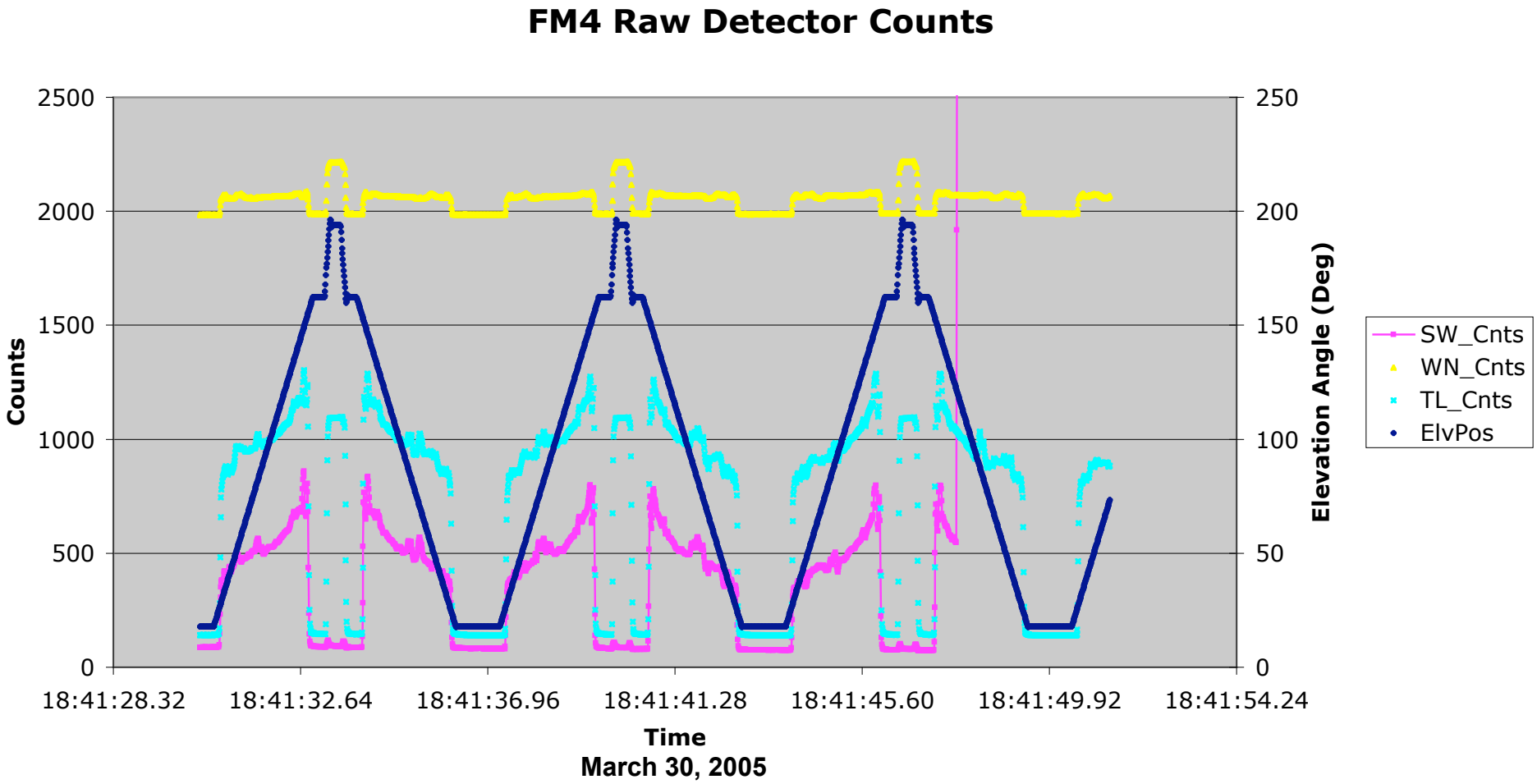
- significantly increased risk of a gap from Terra/Aqua climate record to the beginning of NPOESS using FM-5 in 2011/2012.

- the second Aqua CERES instrument for the A-train was to scan along-track for multi-angle views over the lidar/radar track to examine effects like 3-D radiative transfer

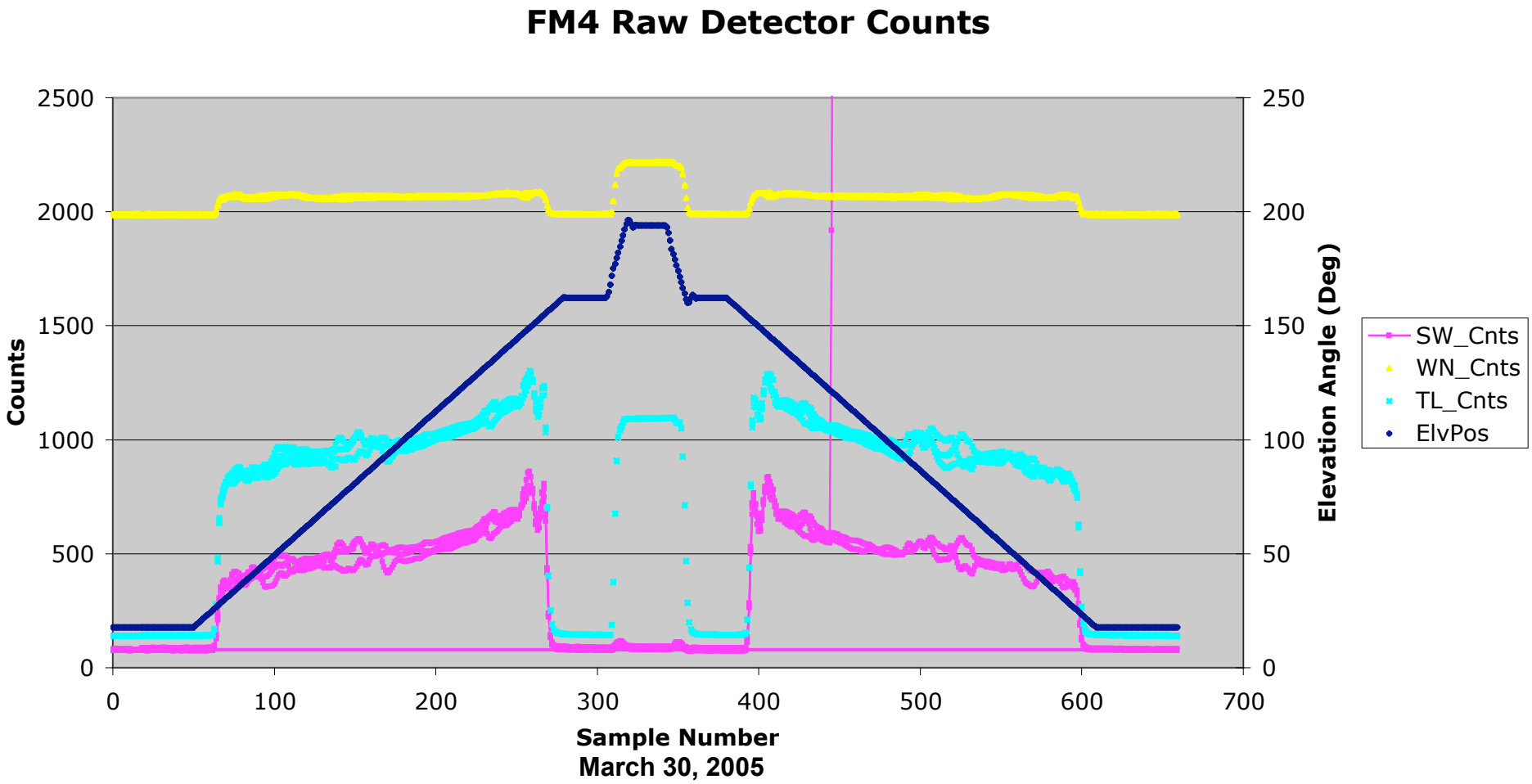
- the second Aqua CERES instrument is also used to perform intercalibrations with GERB: but these can be accomplished by the second Terra CERES as long as two CERES instruments are active on Terra

- the second Aqua CERES instrument is also used during cloud/aerosol field experiments to provide multi-angle data that tracks a pre-selected surface site (e.g. ARM site).

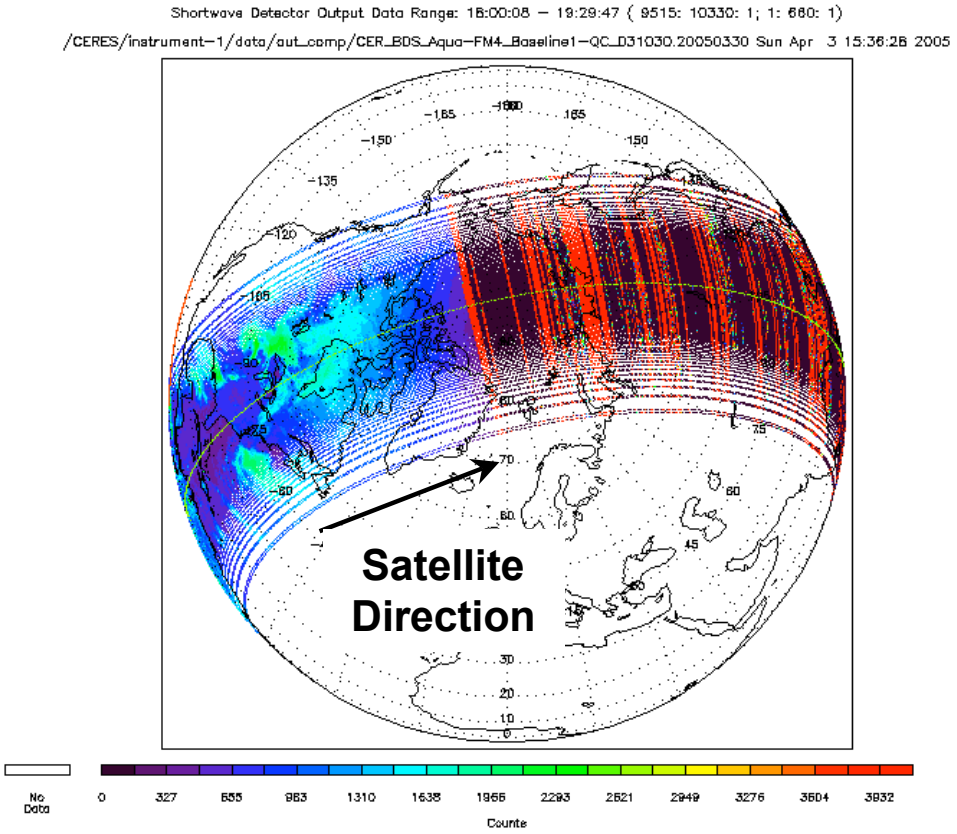
# CERES/Aqua FM-4 SW Anomaly Onset



# CERES/Aqua FM-4 SW Anomaly Onset

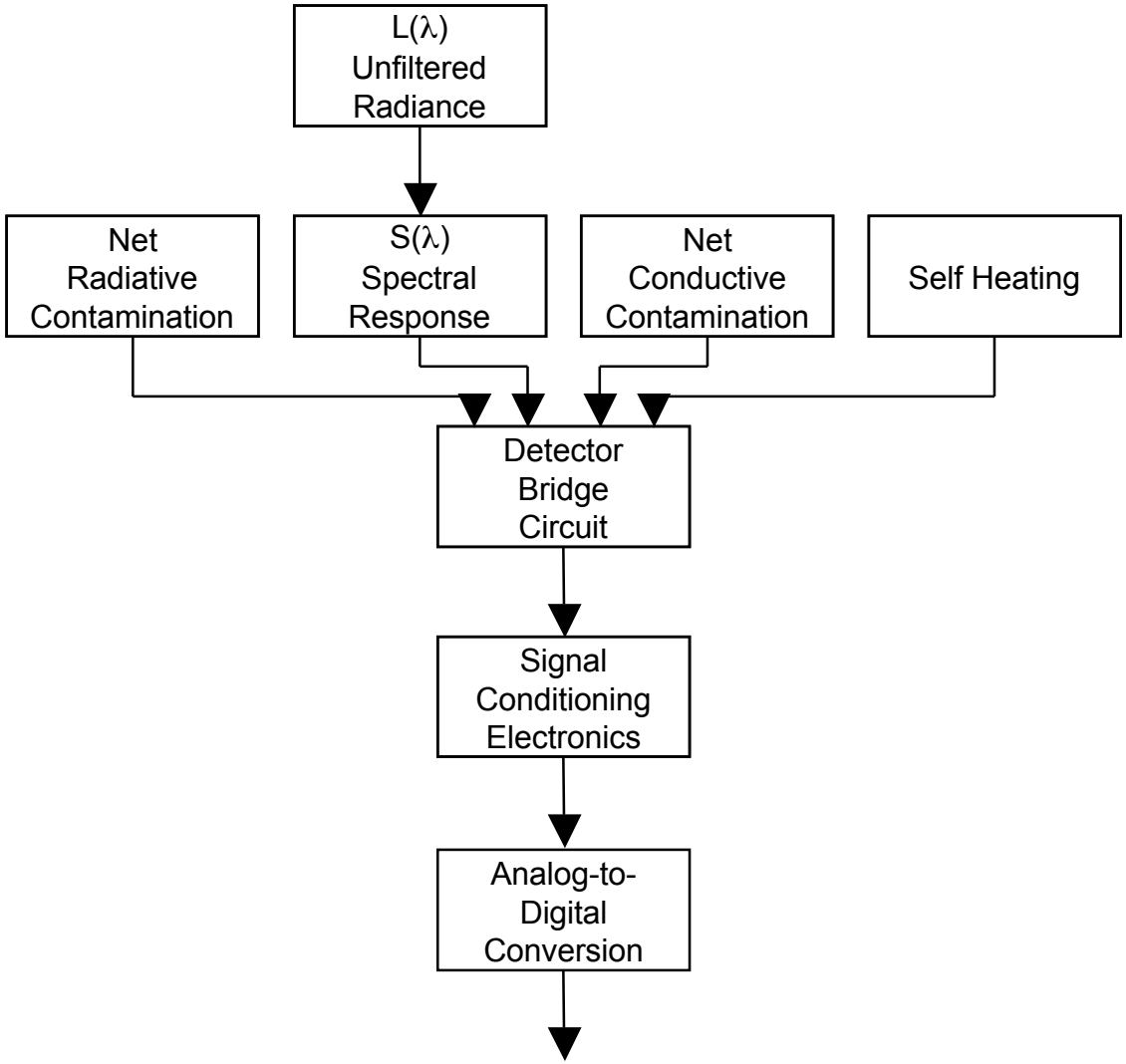


# Instrument Operations




Onset of the anomaly for the CERES FM-4 SW Channel at ~18:42 GMT 03/30/05. Plotted are the geo-located SW channel measurements. The black and red striping indicates 'railed' data at either 0 or 4095 counts.

# Information Flow: Earth Scene to Level 0 Data



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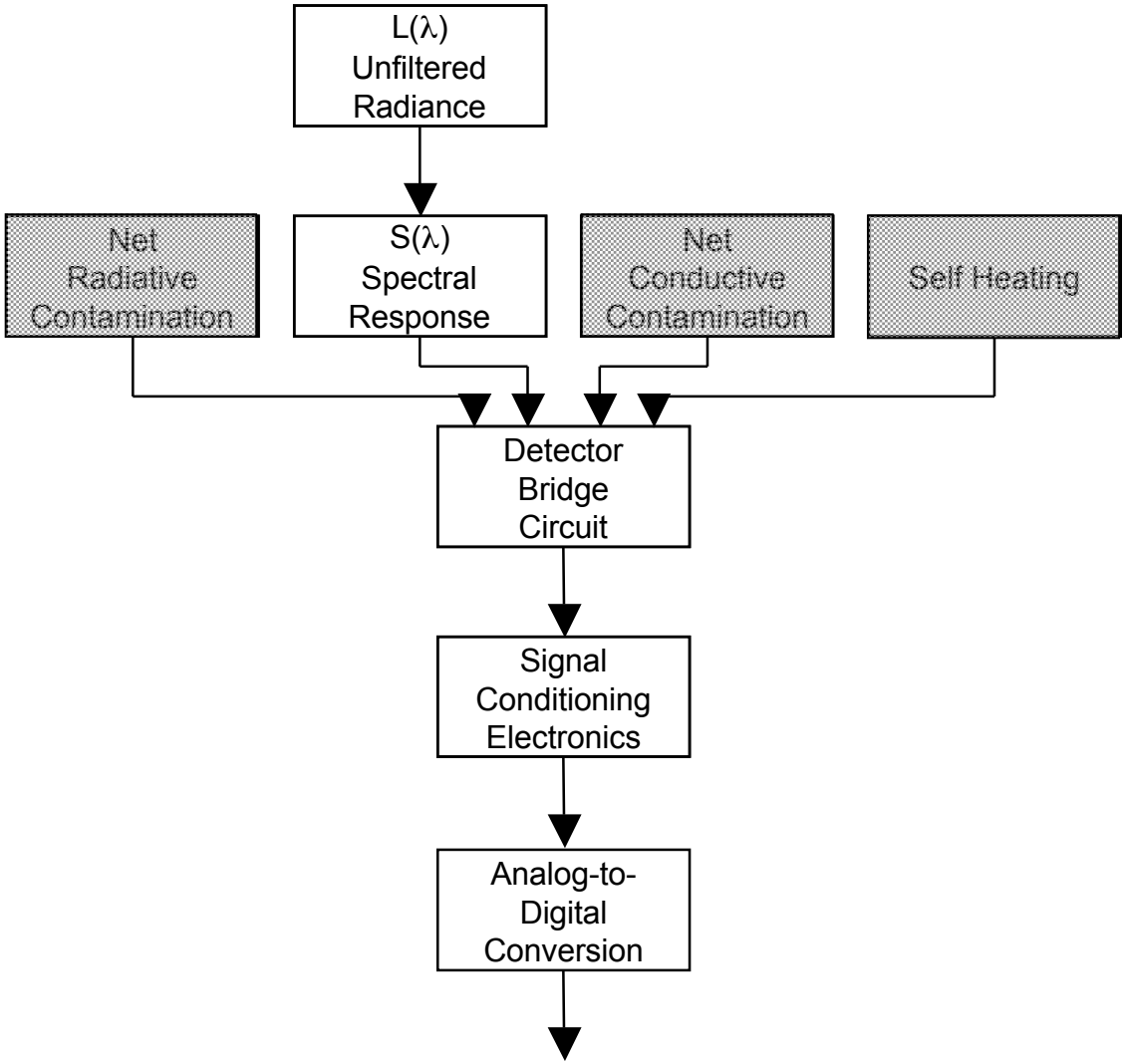
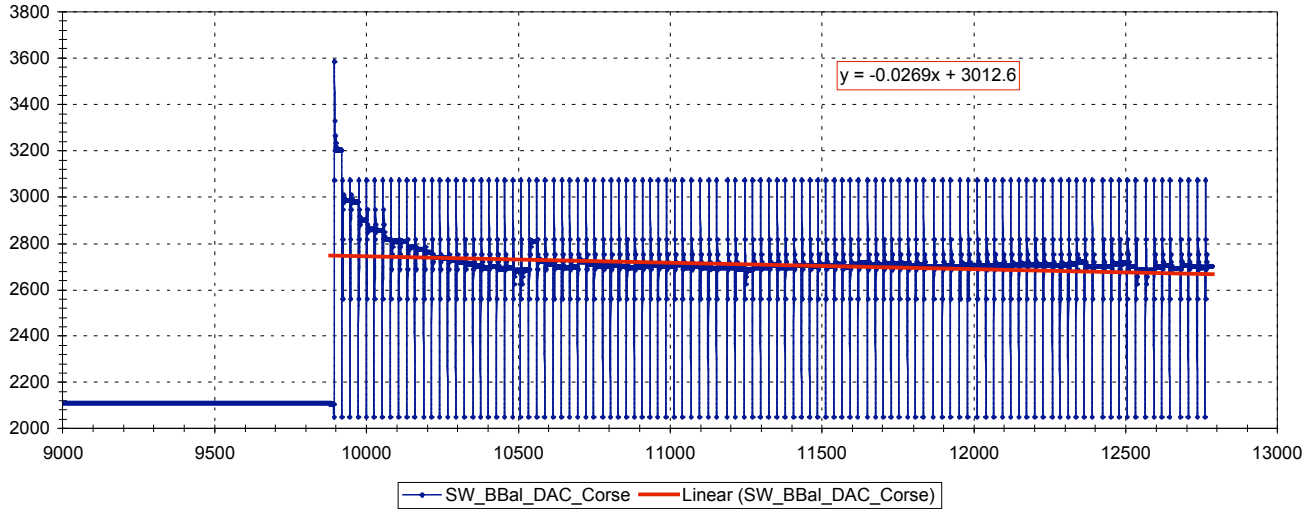
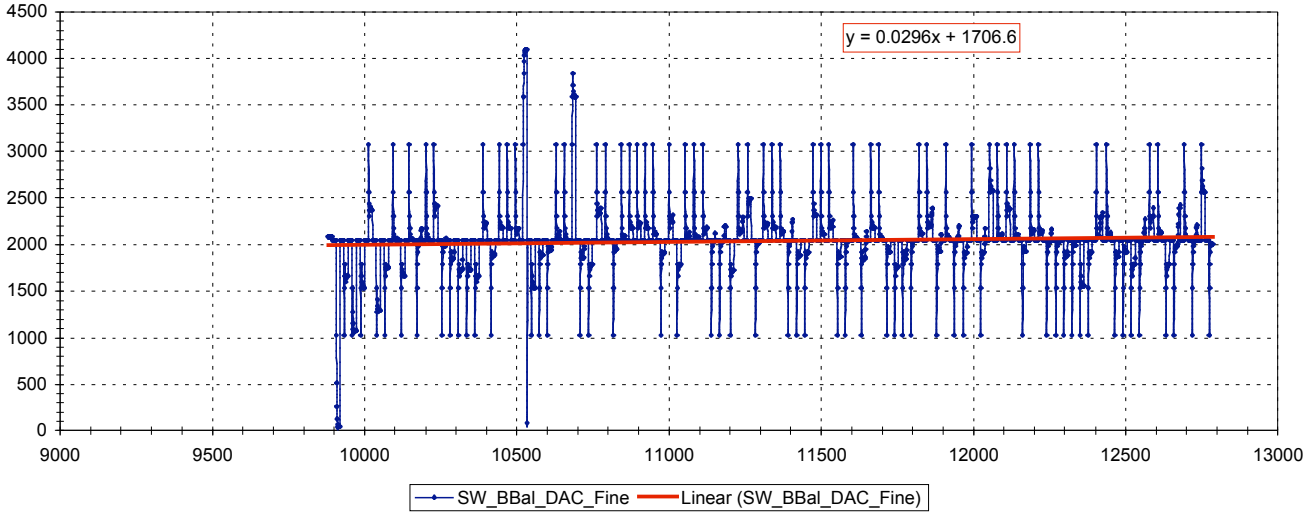
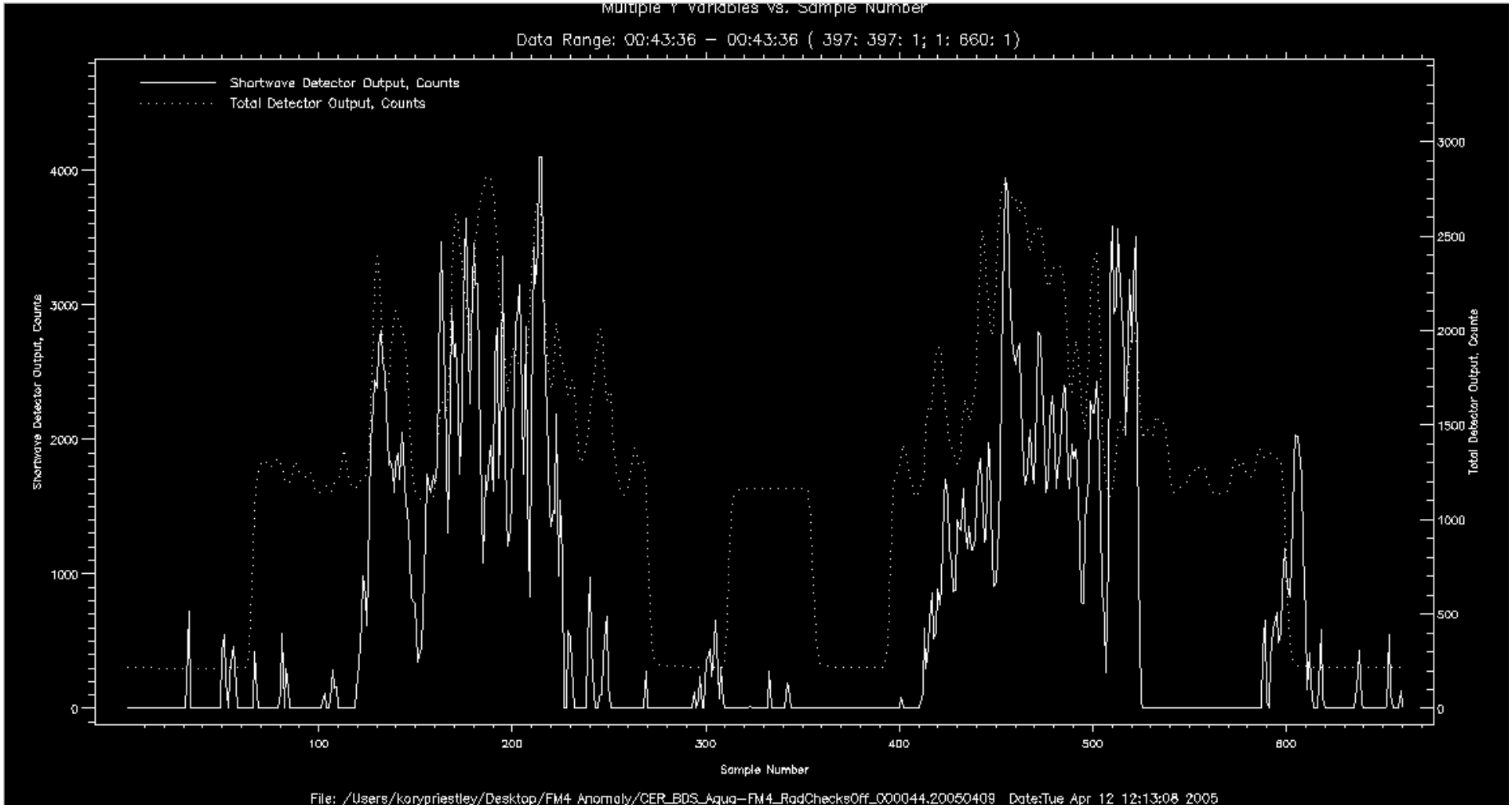


# FM4 SW Bridge Balance Coarse/Fine Values
# March 30, 2005



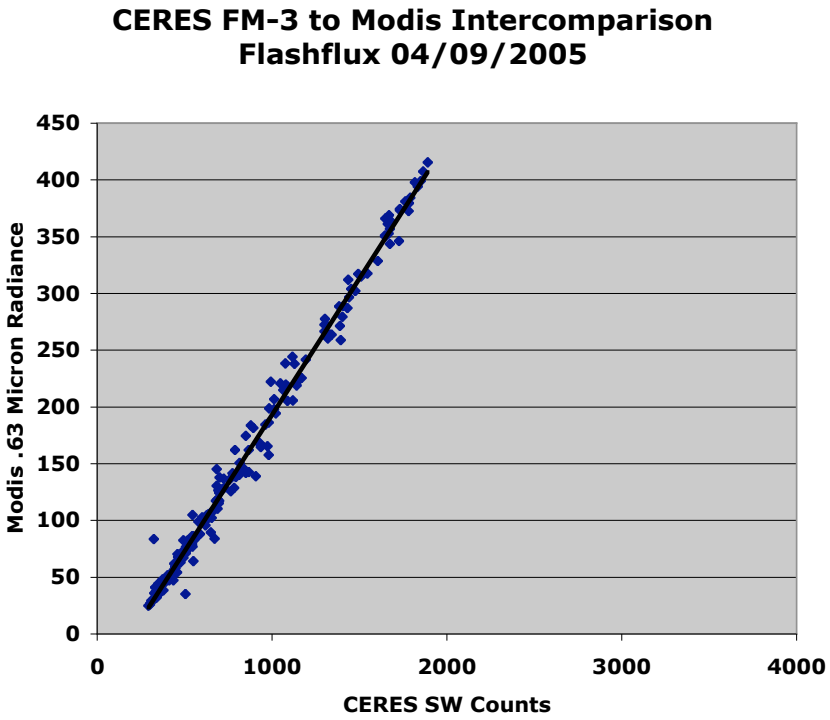



# SW and TOT Sensor Raw Counts for 04/09/05 Packet 397

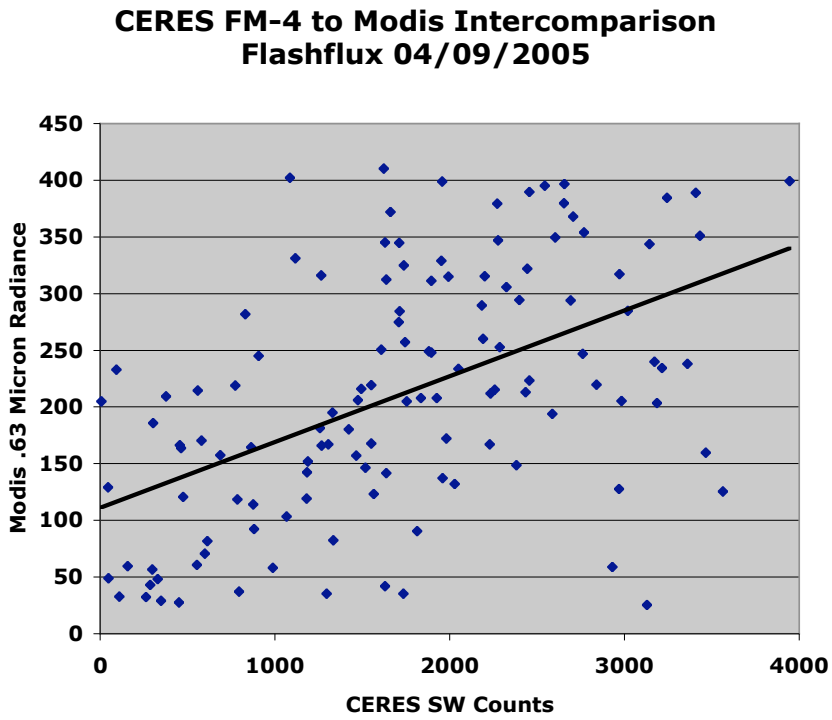


# CERES/Modis Intercomparison
# 04/09/2005, Packet 397

## FM-3




## FM-4



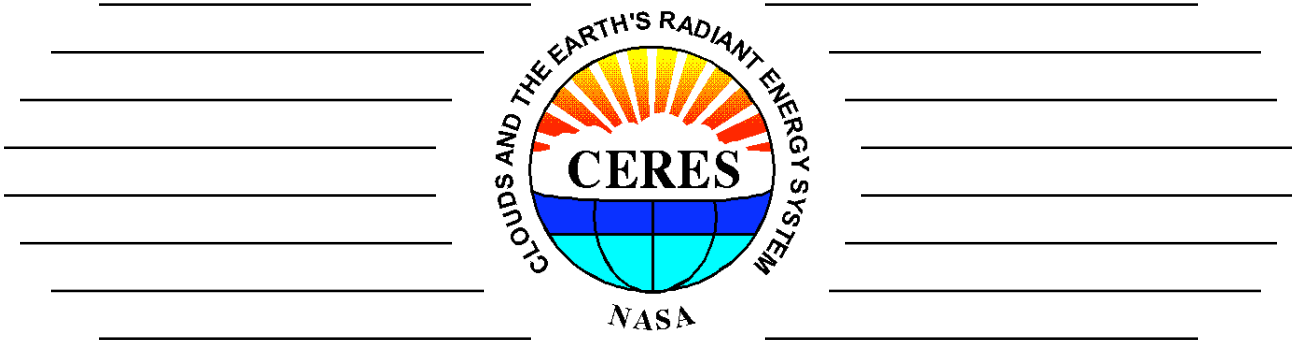

Comparison of approximately 180 CERES FOV's from a single 6.6 second packet

# CERES/Aqua FM-4 SW Anomaly
# Current Status

**Current Status-**

- Anomaly resolution team has disabled the autonomous SW channel Bridge Balance control logic and attempted to manually bring the SW channel output back on scale.
- The instrument's flight software autonomously updates the Bridge Balance control independently for each channel to correct for thermal perturbations during the orbit, as well as long term drift in the bridge offset allowing the detector output to remain on scale.
- Results have been moderately successful to date. We have seen SW channel output remain on scale for several consecutive 6.6 second data packets, however there appears to be significant 'noise' on the signal.
- On-going tasks include…
    - Incrementally improving the manual control of the bridge balance.
    - Continued analysis of the collected science/housekeeping data
    - Modeling the SW sensor electronics to probe possible failure mechanisms
    - Re-setting the Data Acquisition Processor (DAP) to clear any digital glitches

# Cal/Val Status



NASA Langley Research Center

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# Operational Coverage Request

http://asd-www.larc.nasa.gov/Instrument/operations.html

# CERES BDS and ERBE-Like Product Status

| Spacecraft | Product | Version | Available | Months Processed |
|---|---|---|---|---|
| TRMM | BDS | Edition1 | Yes | 1/98 - 8/98 , 3/00 |
| | ERBE-Like | Edition1 | Yes | 1/98 - 8/98 , 3/00 |
| | | Edition2 | Yes | 1/98 - 8/98 , 3/00 |
| Terra | BDS | Edition1 | Yes | 2/00 - present |
| | | Edition2 | Yes | 2/00 - 11/04 |
| | ERBE-like | Edition1 | Yes | 2/00 - present |
| | | Edition2 | Yes | 2/00 - 11/04 |
| Aqua | BDS | Edition1 | Yes | 6/02 - present |
| | | Edition2 | Yes | 6/02 - 7/04, 8/04 - 2/05 |
| | ERBE-like | Edition1 | Yes | 6/02 - present |
| | | Edition2 | Yes | 6/02 - 7/04, 8/04 - 2/05 |

Note: Red text indicates months are in final validation prior to public release.

# BDS and ERBE-Like Release Strategy

**Edition1 - Static Algorithms and coefficients - baseline product used in cal/val protocol**

**Edition2 - Utilizes temporally varying coefficients to correct for traceable radiometric drift**

**Edition3 - *Release date TBD*. Will incorporate temporally varying spectral artifacts in the SW measurements.**

**Revisions - Advance capabilities to the users prior to the release of the next Edition.**

**Edition2 products lag Edition1 by a minimum of 4 months, revisions may lag Edition releases.**

# Notification of Revision

## CERES BDS (BiDirectional Scan) Terra Edition2 Data Quality Summary

Investigation: **CERES**
Data Product: **Bi**Directional **S**can [BDS]
Data Set: **Terra (Instruments: FM1, FM2)**
Data Set Version: **Edition2**

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Team. This document briefly summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, algorithms, and accuracy, gives information about planned data improvements. This document also automates registration in order to keep users informed of new validation results, cautions, or improved data sets as they become available.

This document is a high-level summary and represents the minimum information needed by scientific users of this data product. It is strongly suggested that authors, researchers, and reviewers of research papers re-check this document for the latest status before publication of any scientific papers using this data product.

### Table of Contents


•Nature of the BDS Product
•Updates to Current Edition
•Validation and Quality Assurance
•Current Estimated Uncertainty of Data
•Cautions When Using Data
•Expected Revisions
•References
•Web links to Relevant information
•Referencing Data in Journal Articles
•Giving Data to Other Users

# Instrument Artifact Removal Strategy

**Remote sensing instruments generally exhibit time varying artifacts in their data products. For CERES these artifacts stem from either of 2 physical entities…..**

- **Radiometric Gain Change**
  - **Wavelength independent change in sensor responsivity**
  - **Corrections implemented in Count Conversion algorithm (SS1)**
- **Spectral Response Change**
  - **Wavelength dependent change in sensor optics**
  - **Corrections implemented in Spectral Unfiltering algorithms (SS2)**

**The current production strategy assumes that spectral response changes are 'Gray' over broad spectral regions. In other words, we assume uniform spectral response changes in these broad regions.**

| Radiometric Channel | Spectral Region | |
|---|---|---|
| | SW | LW |
| Total | <3.0 um | >3.0 um |
| SW | <5.0 um | - |
| WN | - | 8-12 um |

# CERES BDS Radiometric Inputs

| | | Radiometric Gain Values | | Radiometric Gain Temporal Variation | | WN Channel |
|---|---|---|---|---|---|---|
| Spacecraft | Version | Ground | In-Flight | Static | Varying | SW Correction |
| TRMM | Ed1 | X | | X | | |
| | Ed2 | - | - | - | - | - |
| Terra | Ed1 | X | | X | | After 3/04 |
| | Ed2 | | X | | X | After 3/04 |
| Aqua | Ed1 | | X | X | | After 3/04 |
| | Ed2 | | X | | X | X |

**CERES Science Team strongly urges data users to utilize Edition2 BDS and ERBE-Like products in their studies**

**All Editions of SSF and higher products utilize BDS Ed2 filtered radiances**

# CERES ERBE-Like Radiometric Inputs

| | | Spectral Response Values | | Spectral Response Temporal Variation | |
|---|---|---|---|---|---|
| Spacecraft | Version | Ground | In-Flight | Static | Varying |
| TRMM | Ed1 | X | | X | |
| | Ed2 | | X | X | |
| Terra | Ed1 | | X | X | |
| | Ed2 | | X | | X |
| Aqua | Ed1 | | X | X | |
| | Ed2 | | X | | X |

**CERES Science Team strongly urges data users to utilize Edition2 BDS and ERBE-Like products in their studies**

**All Editions of SSF and higher products utilize temporally varying spectral response functions**

# CERES Gain/Spectral Change Summary

## Cumulative changes incorporated in Edition 2 BDS and ERBE-Like products

| | | Channel Gain (%) | | | Channel Spectral Response (%) | | | | TOA Flux (W/m^2) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spacecraft | | TOT | WN | SW | SW | WN | SW/ TOT | LW/ TOT | SW | LWDay | LWNight |
| Terra | FM1 | .35 | - | - | - | - | .45 | - | - | 1.1 | .65 |
| | FM2 | .40 | - | - | .40 | - | 2.6 | - | .4 | 3.6 | 1.0 |
| Aqua | FM3 | .45 | - | .50 | - | - | 1.4 | - | .5 | 1.6 | 1.1 |
| | FM4 | .30 | - | .80 | - | - | 1.2 | - | .7 | 1.6 | .75 |

1. All values are maximum on-orbit changes
2. Ground to flight shifts are accounted for separately
3. SW/TOT < 3.0 microns, LW/TOT > 3.0 microns
4. TOA Flux values are all-sky global averages

# Executive Summary

- All Diagnostic/Housekeeping data is nominal…
  - Gimbal Friction measurements stable
  - Pointing stable
  - No significant voltage or temperature trends

- Cal/Val Protocol demonstrates radiometric stability of the Ed2 data products through 11/2004 of….

| | Terra | | Aqua | |
|---|---|---|---|---|
| | FM1 | FM2 | FM3 | FM4 |
| LWday | .125 | .125 | <.1 | <.1 |
| LWnight | <.1 | <.1 | <.1 | <.1 |
| SW | .2 | .3 | <.1 | <.1 |
| WN | <.1 | <.1 | .125 | .125 |

Note: Values apply to all-sky global averages
Units are in %/yr

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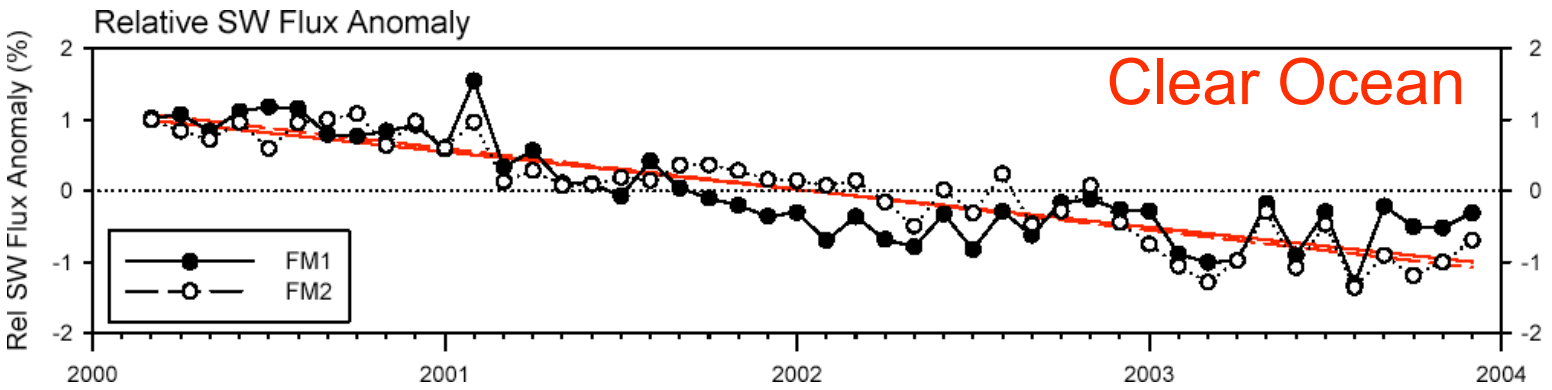
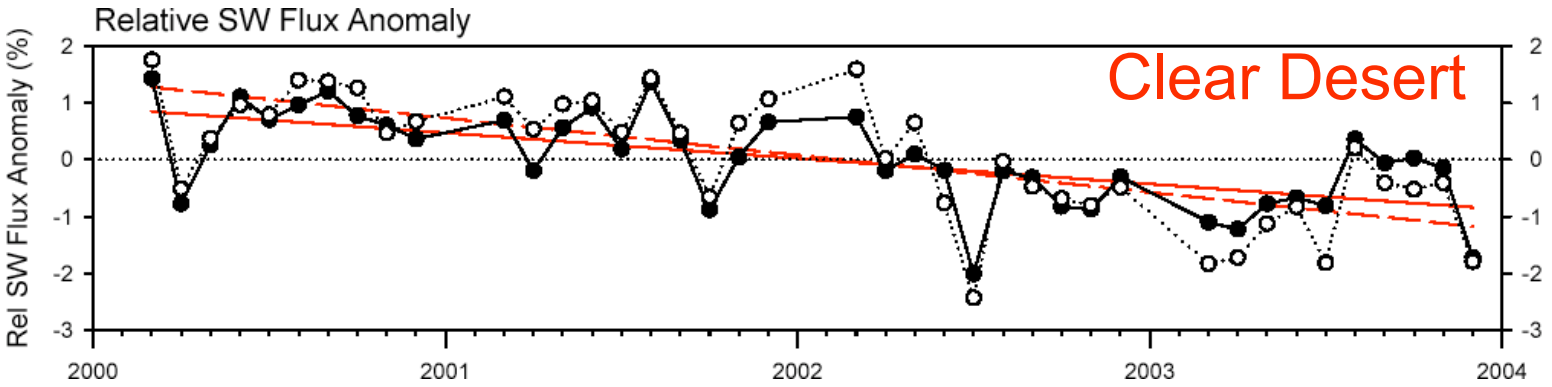
| LWnight | <.1 | <.1 | <.1 | <.1 |
| SW | .2 | .3 | .1 | .1 |
| WN | <.1 | <.1 | .125 | .125 |

Note: Values apply to all-sky global averages
Units are in %/yr

# CERES SSF Ed2B SW TOA Flux Anomaly



# Direct Comparison of Nadir Radiance Measurements

**Two CERES instruments on a common platform allows for a unique validation opportunity…..**

**Direct Comparison of simultaneous Nadir measurements**

**Each CERES/Terra instrument views nadir every 3.3 seconds**

**Thus, we obtain nearly simultaneous measurements of the same geo-location ($\Delta t < 3.3$ seconds)….**

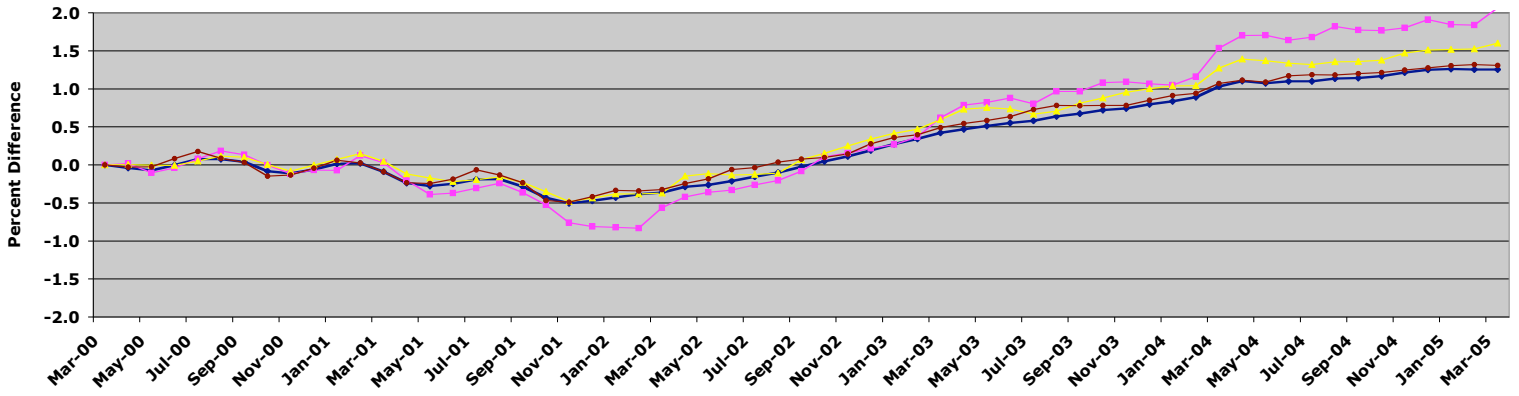
**Spatial, angular, and temporal sampling issues are virtually eliminated.**

**26,000 co-located (but not independent) measurements in a given day, provides a very rigorous statistical tool.**

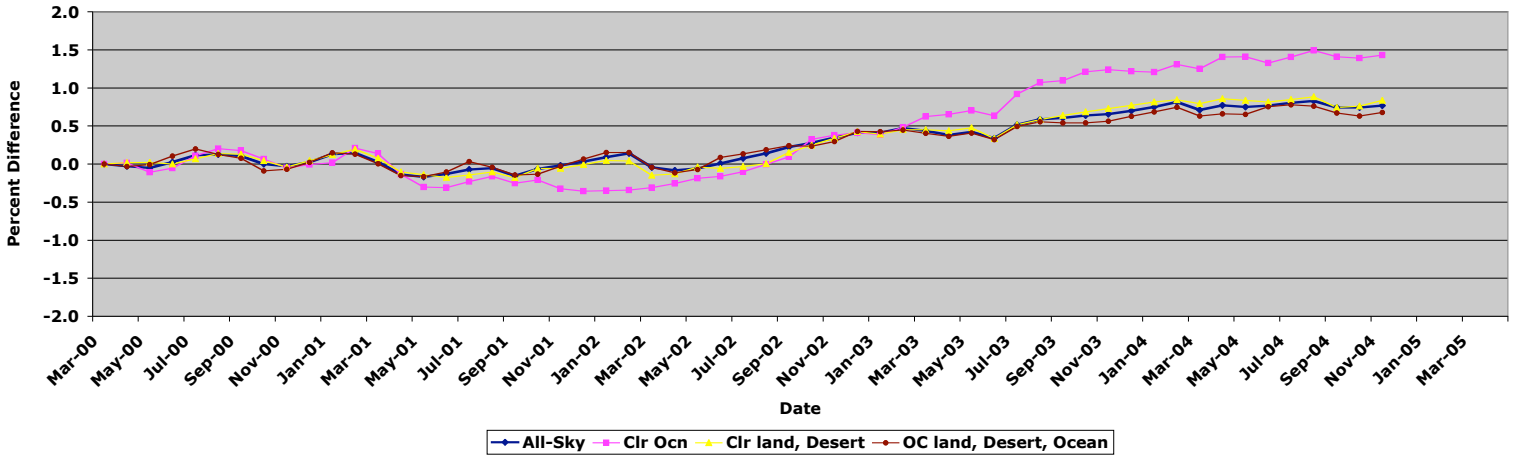
**Results can be discretized by scene type to enhance the analysis.**

# CERES SSF Ed2B SW TOA Flux Anomaly

**FM1 minus FM2**
**Edition1 ES-8 Nadir SW Fluxes**




**FM1 minus FM2**
**Edition2 ES-8 Nadir SW Fluxes**



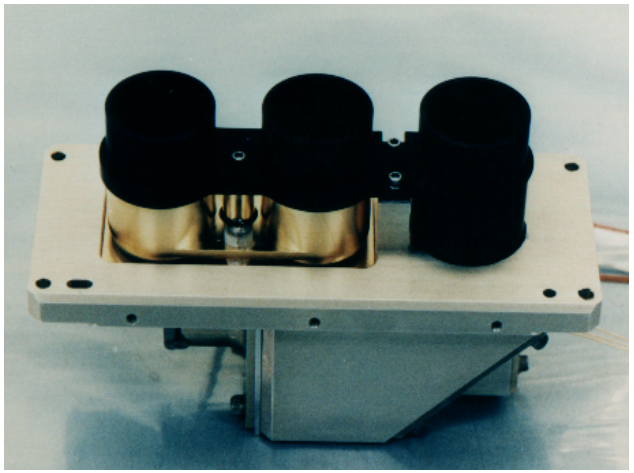
# CERES Instrument Radiometric Validation Activities

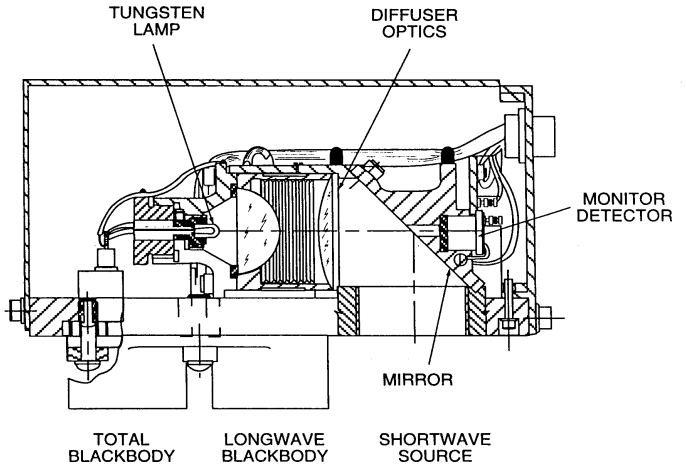
| | | Product | Spatial Scale | Temporal Scale | Metric | Spectral Band |
|---|---|---|---|---|---|---|
| On-Board | Internal BB | Filtered Radiance | N/A | N/A | Absolute Stability | TOT, WN |
| | Internal Lamp | Filtered Radiance | N/A | N/A | Absolute Stability | SW |
| | Solar | Filtered Radiance | N/A | N/A | Relative Stability | TOT, SW |
| Vicarious | Theoretical Line-by-Line | Filtered Radiance | > 20 Km | Instantaneous | Inter-Channel Theoretical Agreement | TOT, WN |
| | Unfiltering Algorithm Theoretical Validation | N/A | N/A | N/A | N/A | TOT, SW, WN |
| | Inter-satellite (Direct Comparison) | Unfiltered Radiance | 1-deg Grid | 1 per crossing | Inter-Instrument Agreement, Stability | TOT, SW, WN |
| | Globally Matched Pixels (Direct Comparison) | Unfiltered Radiance | Pixel to Pixel | Daily | Inter-Instrument Agreement | TOT, SW, WN |
| | Tropical Mean (Geographical Average) | Unfiltered Radiance | 20N – 20S | Monthly | Inter-Channel Agreement, Stability | TOT, WN |
| | DCC Albedo | Unfiltered Radiance | >40 Km | Monthly | Inter-Instrument agreement, Stability | SW |
| | DCC 3-channel | Unfiltered Radiance | >100 Km | Monthly | Inter-Channel consistency, stability | TOT, SW |
| | TIme Space Averaging | Fluxes | Global | Monthly | Inter-Instrument Agreement | LW, SW |
| | Lunar Radiance Measurements | Filtered Radiance | Sub Pixel | Quarterly | Inter-Instrument Agreement | LW, SW, WN |

# CERES Onboard Calibration Sources

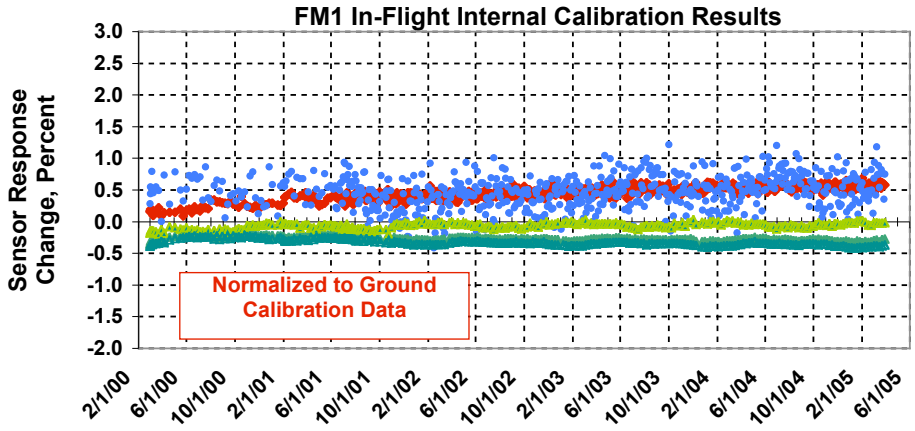
## Internal Calibration Module (ICM)

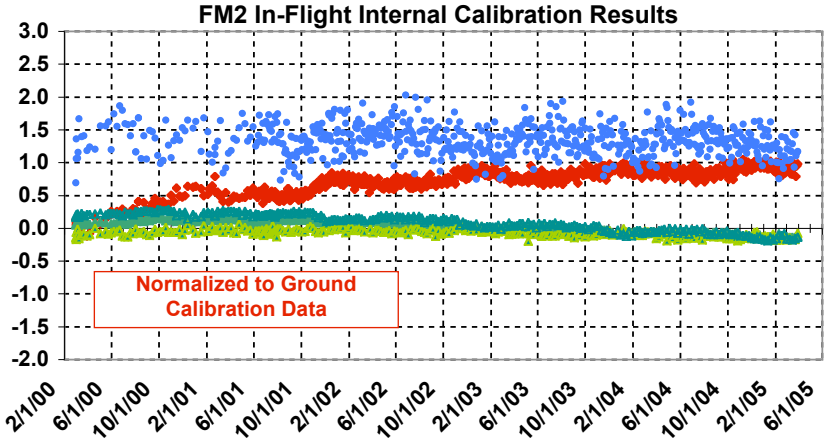
- ICM Provides 3 unique radiance levels for the SW and LW sources
- Blackbodies for the Total and Window channels
- Temperature knowledge obtained via Platinum Resistance Thermometers
- Quartz-halogen tungsten lamp for the Shortwave channel (2100, 1900, 1700 K spectrums)
- SiPd independently monitors lamp output
- Acceptance testing for lamps includes burn-in period of ~80 hours to screen for stability
- Narrow and broadband radiant intensity measurements are performed prior to acceptance
- Design specification is +-0.5% stability over 5-year mission

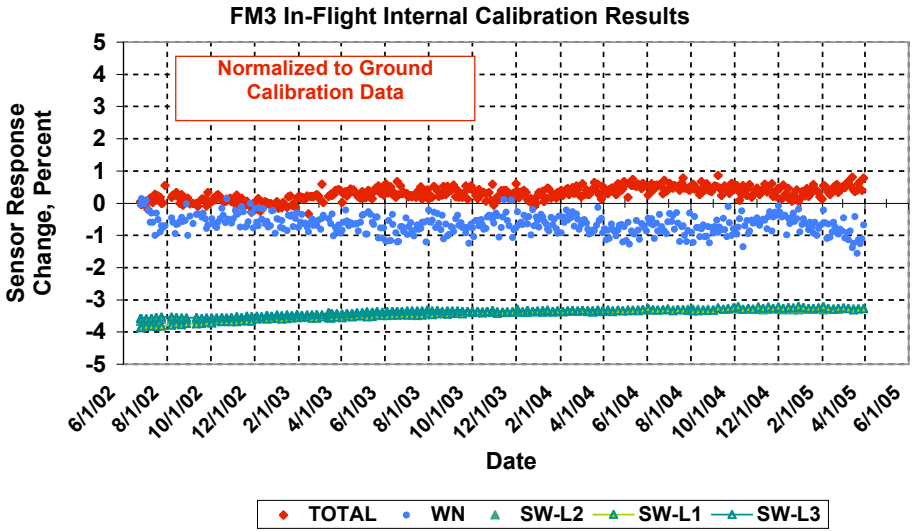


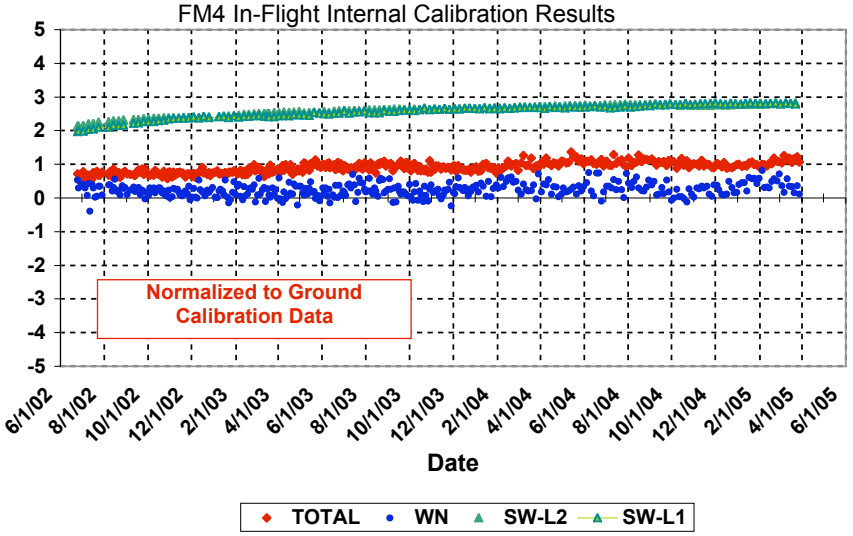


# CERES Internal Calibration Results

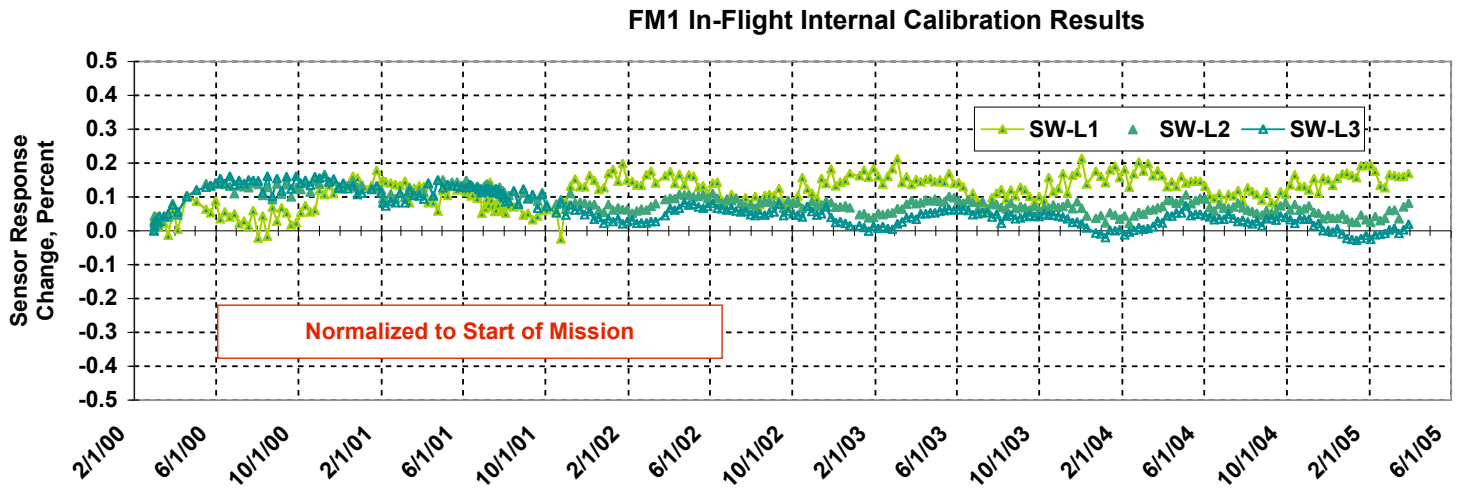


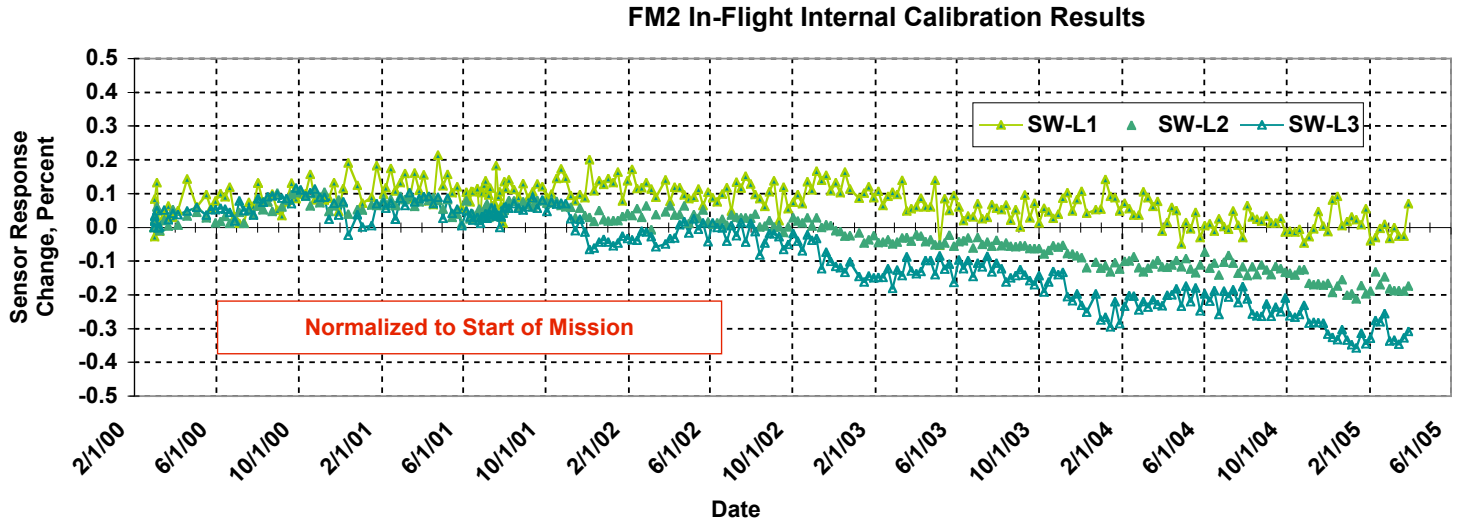



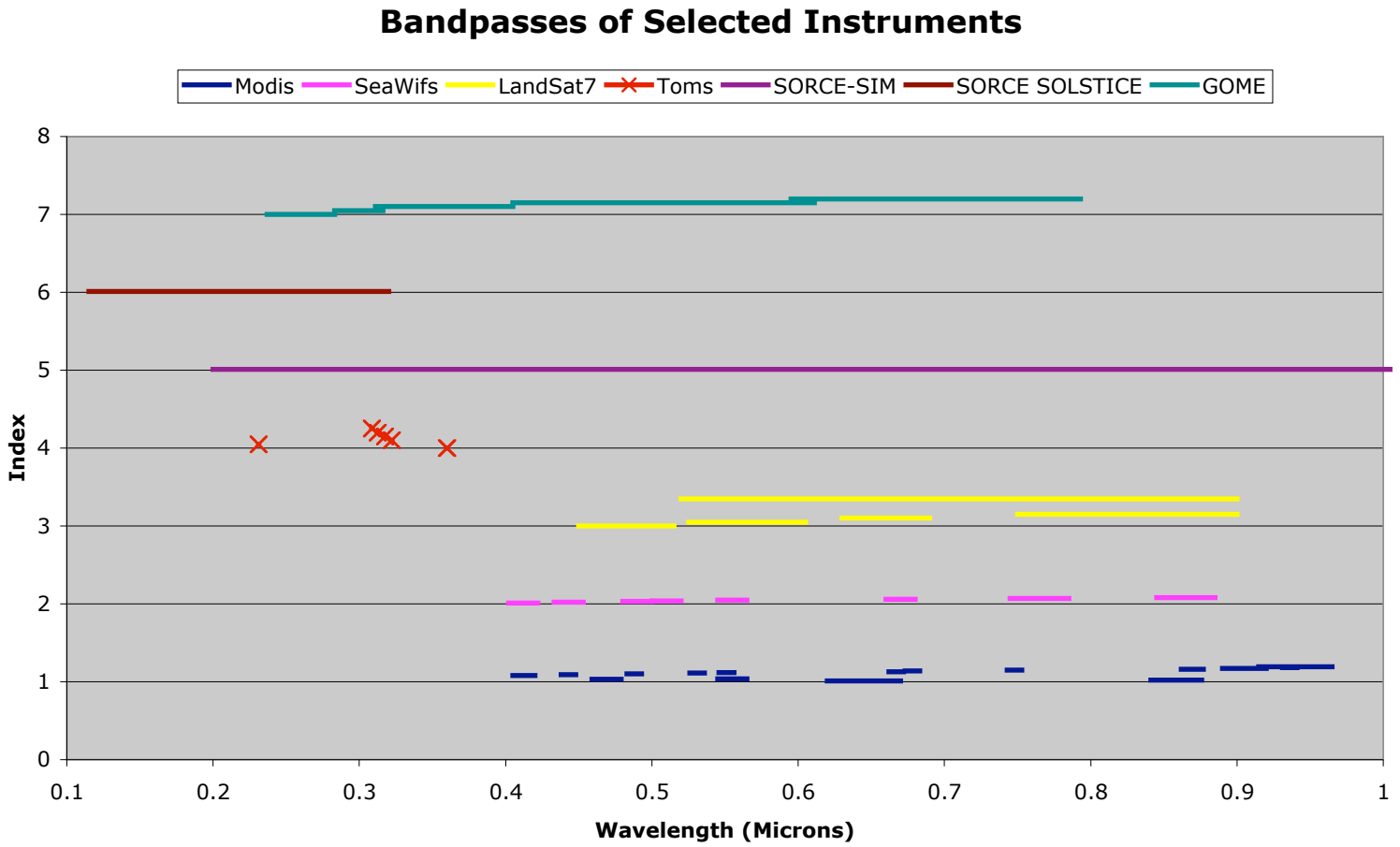



# Terra SW Internal Calibration Results

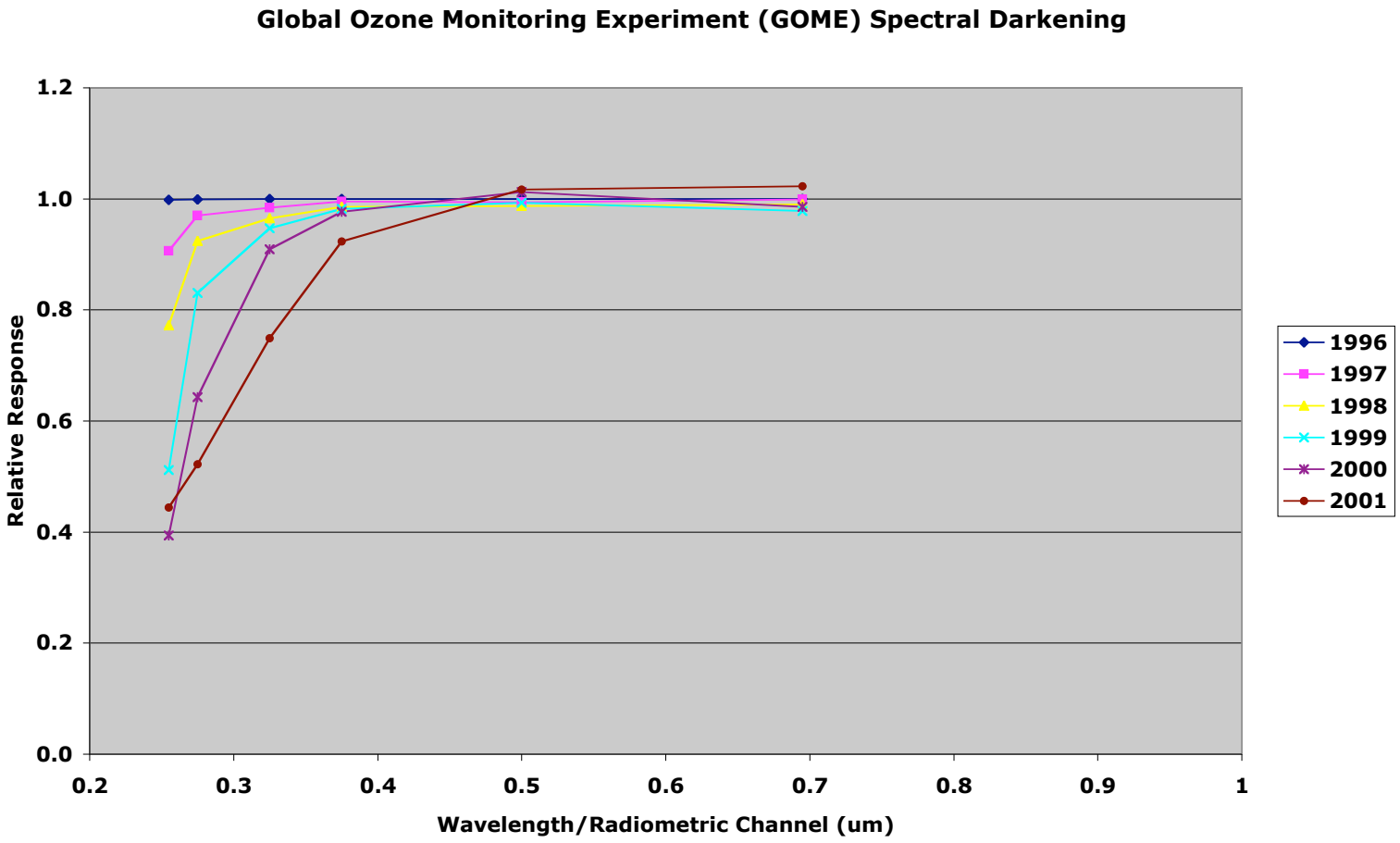


# LEO Missions Subject to Spectral Darkening

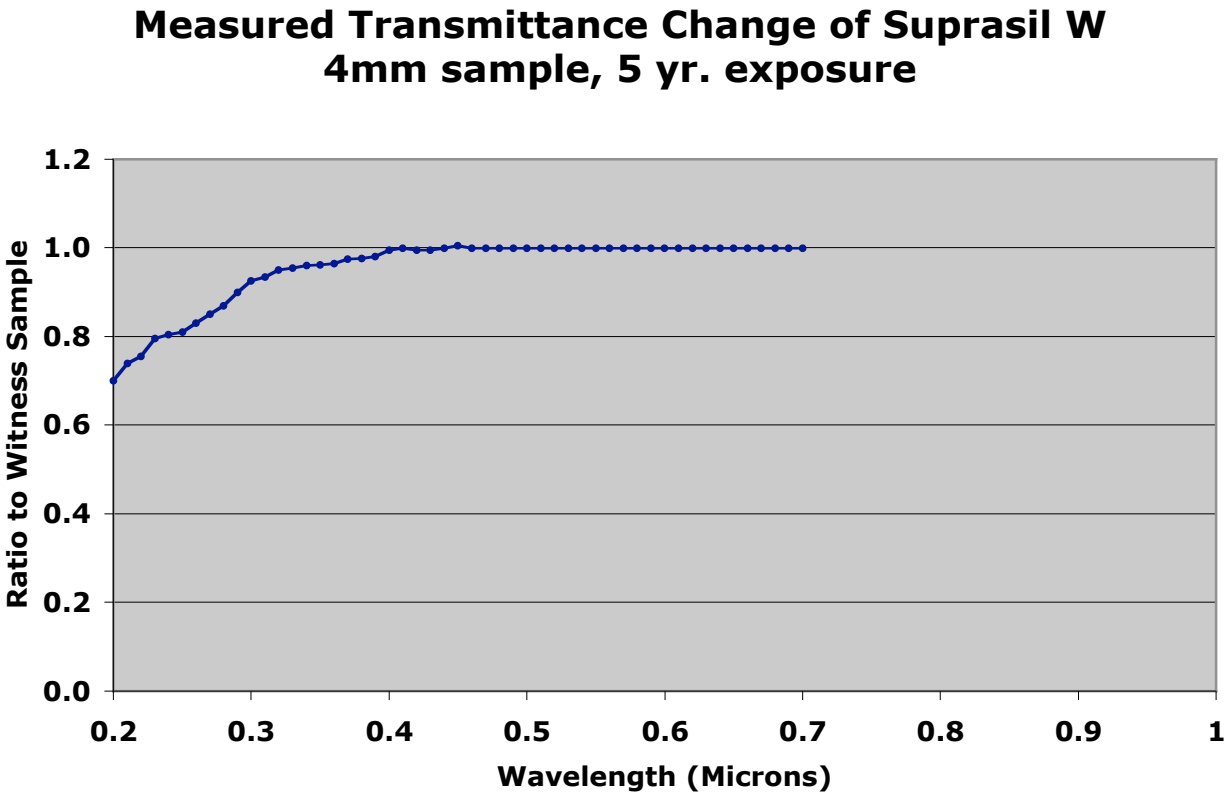


# Spectral Darkening on Similar Missions



# Spectral Darkening on Similar Missions

Spare NIMBUS ERB Radiometer flown on LDEF



# Operations to Characterize Spectral Darkening

- **FM2 Operations**

| Month | Azimuth Gimbal | Solar Exposure | RAM Direction | Darkening Rate Impact |
|---|---|---|---|---|
| February | Rotating | Nominal | Nominal | Nominal |
| March | Fixed, Xtrack | Accelerated | Eliminated | No Change |
| April | Rotating | Eliminated | Nominal | No Change |
| May | Fixed, Atrack | Eliminated | Accelerated | |

# Terra ES-8 Edition2_Rev1 Summary

•**Cal/Val Protocol demonstrates radiometric stability of the data products through 11/2004 of….**

| | Edition1 | | Edition2 | | Edition2_Rev1 | |
|---|---|---|---|---|---|---|
| | FM1 | FM2 | FM1 | FM2 | FM3 | FM4 |
| LWday | .3 | .6 | .125 | .125 | .125 | .125 |
| LWnight | .1 | .125 | <.1 | <.1 | <.1 | <.1 |
| SW | .2 | .4 | .2 | .3 | .1 | .1 |
| WN | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |

Note: Values apply to all-sky global averages
Units are in %/yr

# CERES Terra/Aqua Cal/Val Status

**Terra SW TOA fluxes decrease between March 2000 and December 2003**

- **~2% for all-sky, clear ocean and clear desert**
- **~1% for deep convective clouds.**
- **Existing Cal\Val studies suggest instrument is radiometrically stable**

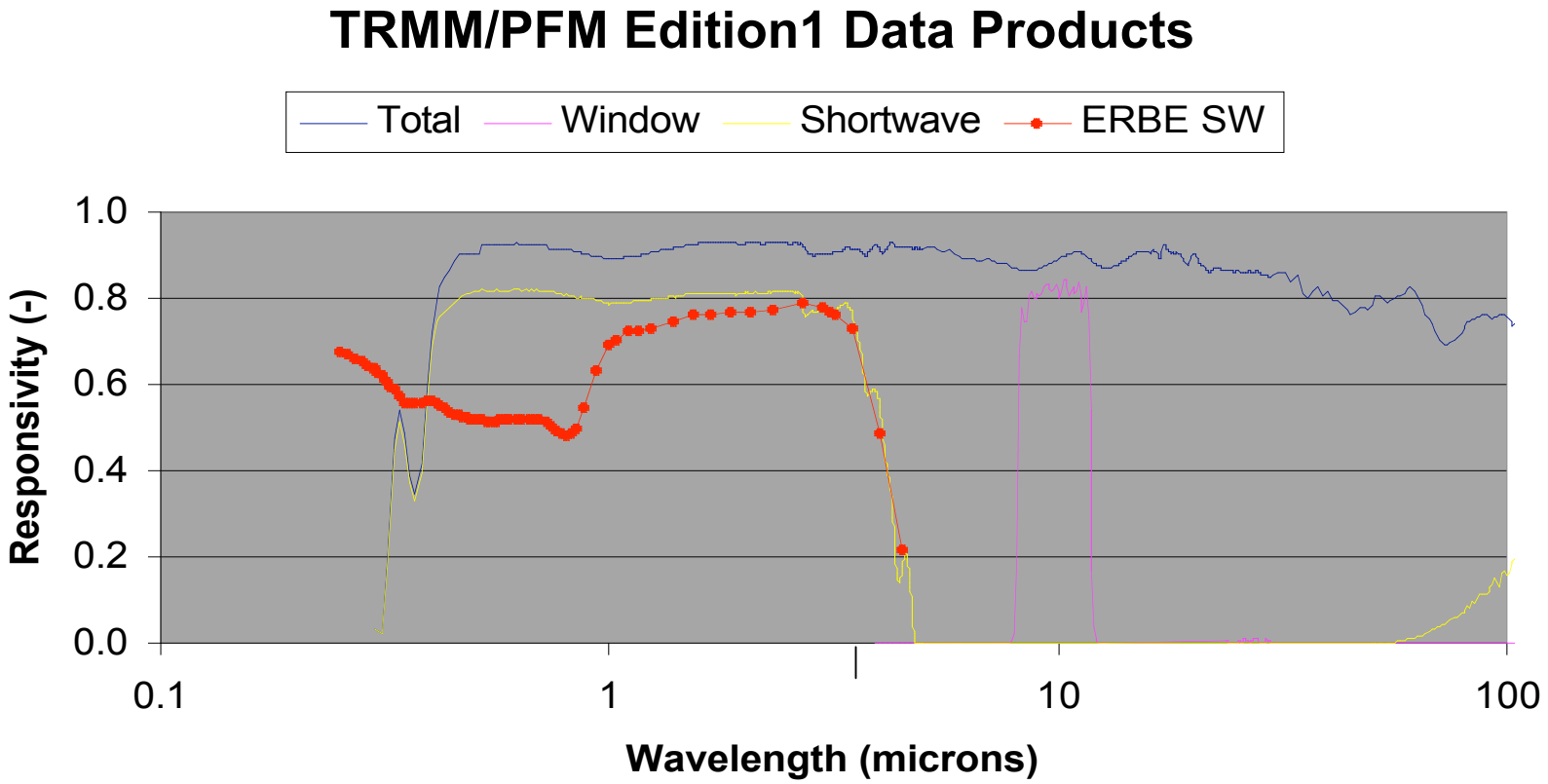
**Near Term Work:**

- **SW Calibration - FM4 Ground to Flight Shift (8%)**
- **WN correlation with SW scene brightness**

**Long Term Work:**

- **MAM Redesign**

# CERES Spectral Response Function

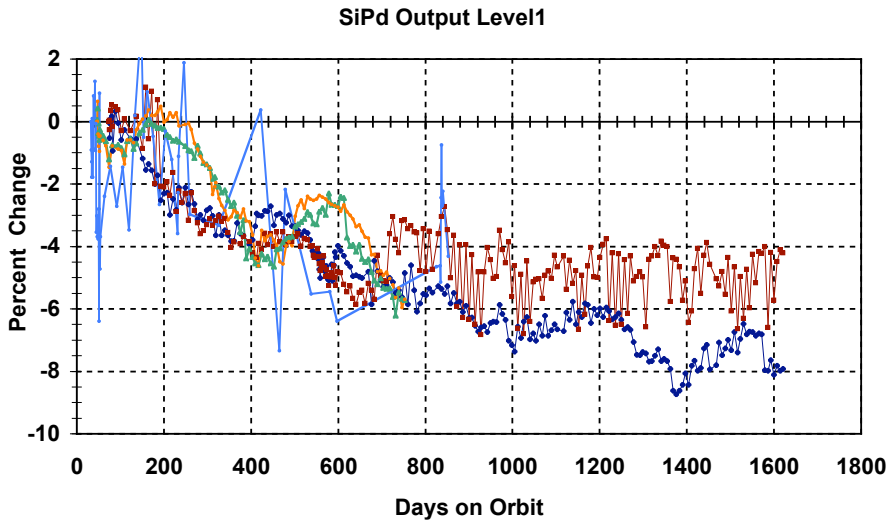
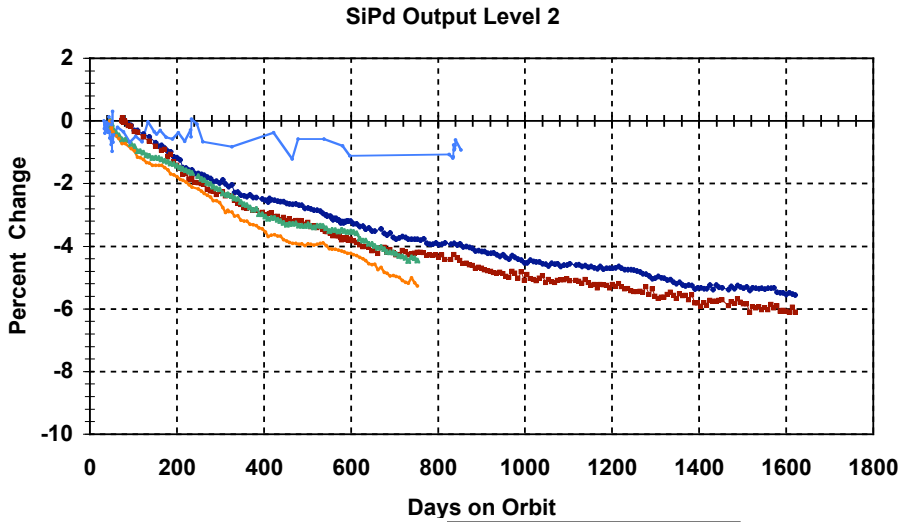
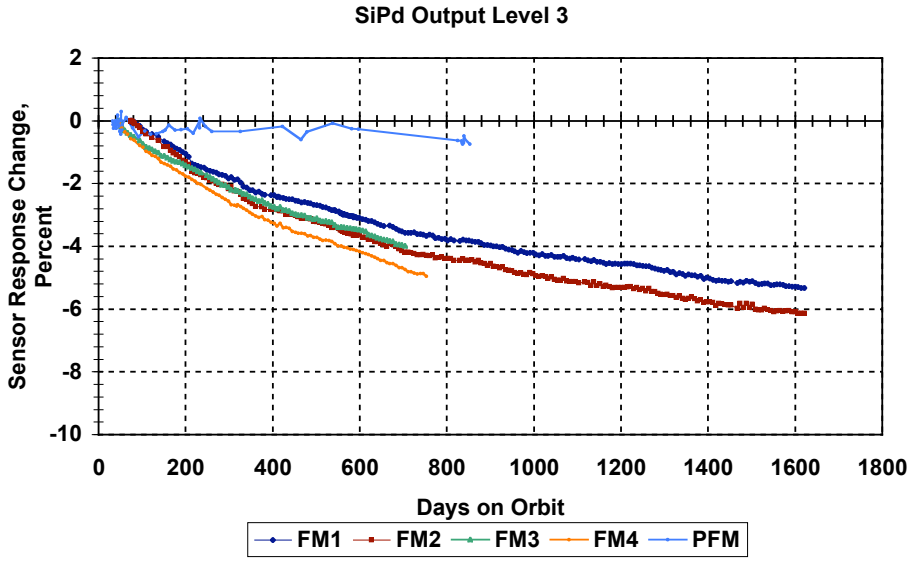



**Note: $LW_{DAY}$ = Total - Shortwave**

# Instrument Artifact Removal Strategy

| Radiometric Channel | Spectral Region | |
|---|---|---|
| | SW | LW |
| Total | <3.0 um | >3.0 um |
| SW | <5.0 um | - |
| WN | - | 8-12 um |

# CERES Instrument Radiometric Validation Activities

| | | Product | Spatial Scale | Temporal Scale | Metric | Spectral Band |
|---|---|---|---|---|---|---|
| On-Board | Internal BB | Filtered Radiance | N/A | N/A | Absolute Stability | TOT, WN |
| | Internal Lamp | Filtered Radiance | N/A | N/A | Absolute Stability | SW |
| | Solar | Filtered Radiance | N/A | N/A | Relative Stability | TOT, SW |
| Vicarious | Theoretical Line-by-Line | Filtered Radiance | > 20 Km | Instantaneous | Inter-Channel Theoretical Agreement | TOT, WN |
| | Unfiltering Algorithm Theoretical Validation | N/A | N/A | N/A | N/A | TOT, SW, WN |
| | Inter-satellite (Direct Comparison) | Unfiltered Radiance | 1-deg Grid | 1 per crossing | Inter-Instrument Agreement, Stability | TOT, SW, WN |
| | Globally Matched Pixels (Direct Comparison) | Unfiltered Radiance | Pixel to Pixel | Daily | Inter-Instrument Agreement | TOT, SW, WN |
| | Tropical Mean (Geographical Average) | Unfiltered Radiance | 20N – 20S | Monthly | Inter-Channel Agreement, Stability | TOT, WN |
| | DCC Albedo | Unfiltered Radiance | >40 Km | Monthly | Inter-Instrument agreement, Stability | SW |
| | DCC 3-channel | Unfiltered Radiance | >100 Km | Monthly | Inter-Channel consistency, stability | TOT, SW |
| | TIme Space Averaging | Fluxes | Global | Monthly | Inter-Instrument Agreement | LW, SW |
| | Lunar Radiance Measurements | Filtered Radiance | Sub Pixel | Quarterly | Inter-Instrument Agreement | LW, SW, WN |

# CERES SWICS SiPD Results