CERES FM1-FM4 Edition3 Calibration Update

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Instrument Edition-3 Evaluations

1. Re-evaluation of ground calibration data

Determine the Start of Mission Spectral Response Functions and Radiometric Gains for the CERES sensors.

2. Establish a common Radiometric Scale for all CERES instruments

With Flight Model 1 (FM1) chosen as the standard, derive the correction factors to place all CERES instruments on the same radiometric scale.

3. In-Flight Radiometric gain changes

Incorporate the correction for the derived changes in Radiometric Gain based on the on-board calibration sources.

4. Determine corrections for the Spectral Response Function to account for the on-orbit darkening in Short wavelength region

Nadir Radiance comparisons for instruments on the same spacecraft is used to correct for the change in the SW sensors.

Regression on the Day-Night differences of Longwave and Window measurements on each instrument is used to correct for the degradation in the shortwave region of total sensor.

Spectral Response Function Evaluation

Measurements from the pre-launch calibration test data were re-examined to determine the optimal Spectral Response Function (SRF) for CERES sensors.

Reflected Solar Region:

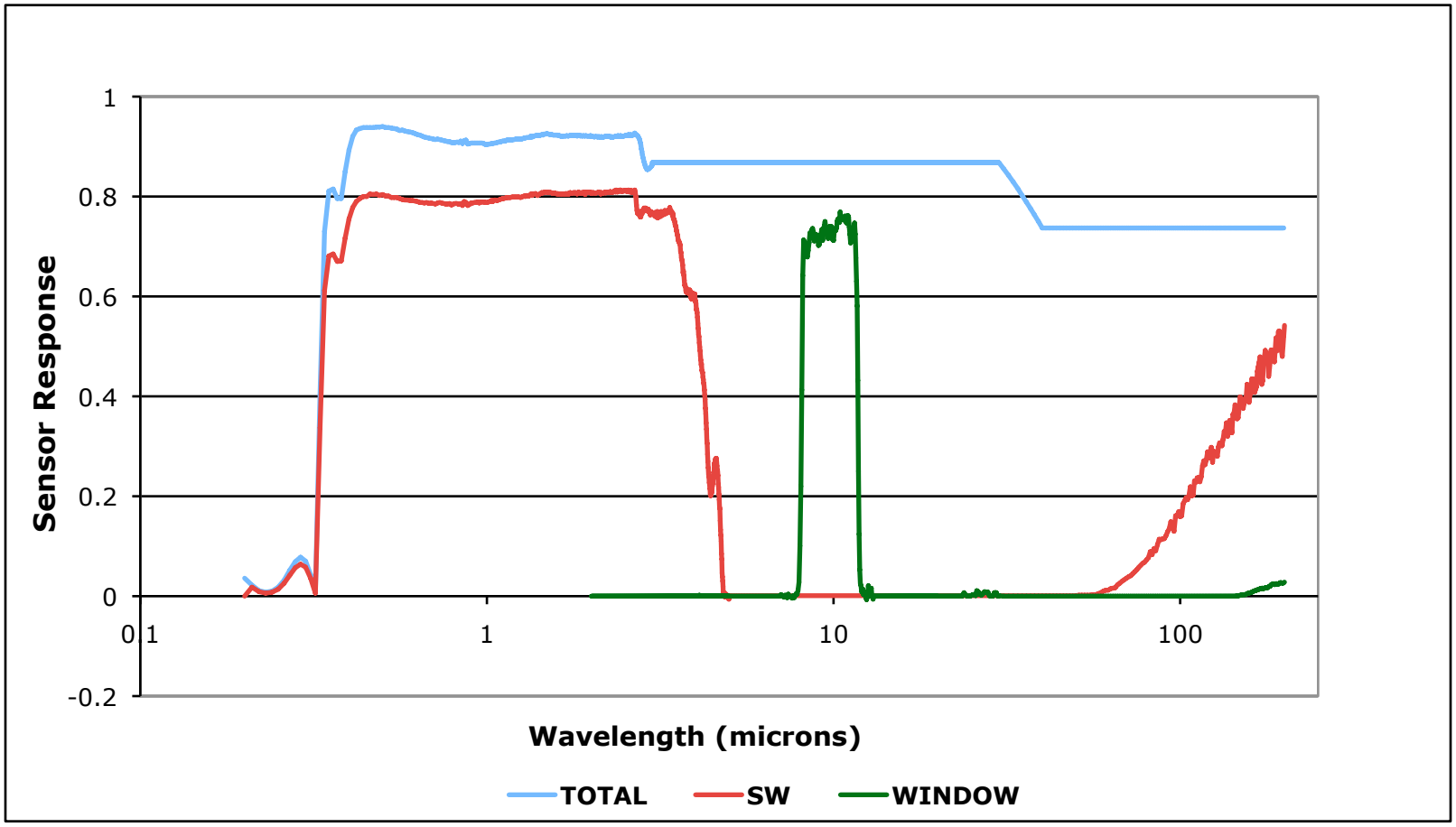
Re-evaluation of component Silver measurements from different coating runs.

Impact of shortwave reference source (SWRS) spectral throughput on band-pass filters used in the determination of Gain/SRF.

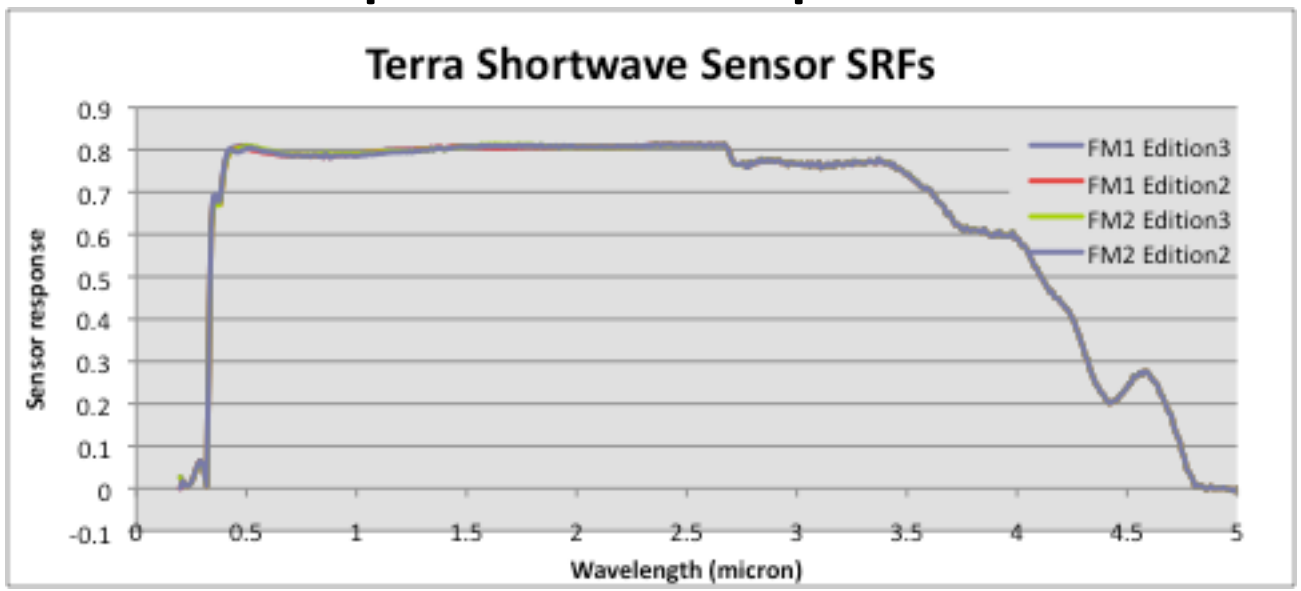
Emitted Thermal Region:

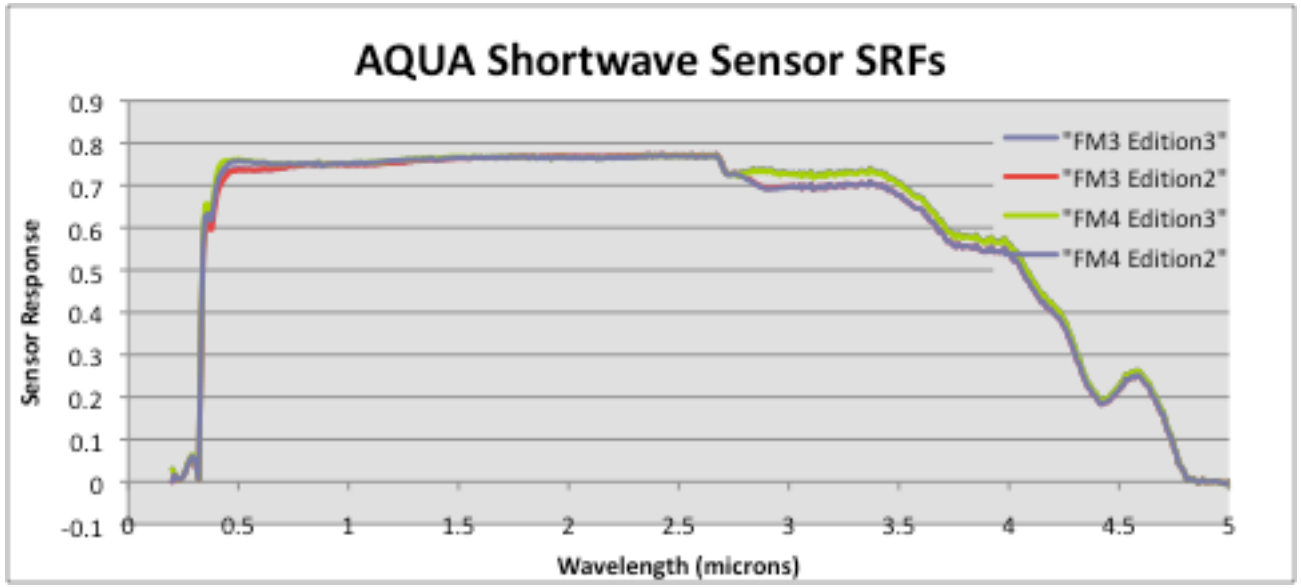
Analysis of Total sensor measurements with the Fourier Transform Spectrometer (FTS) to determine the SRF in Longwave region.

CERES Spectral Response Function
FM1 Edition2 - Start of Mission

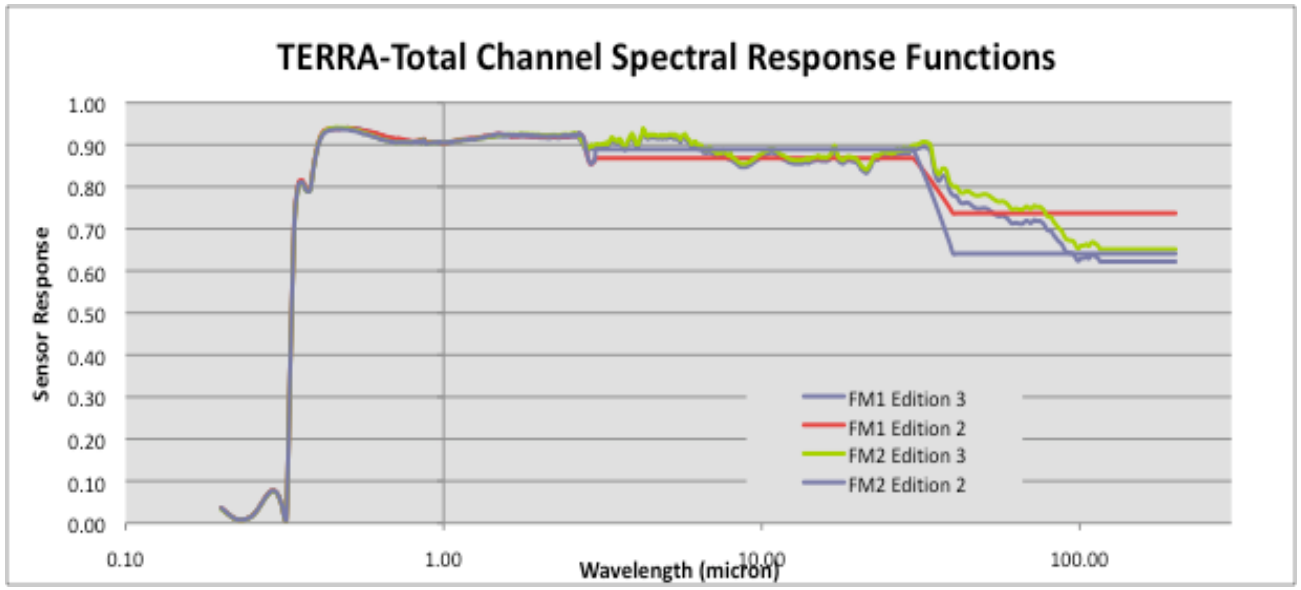


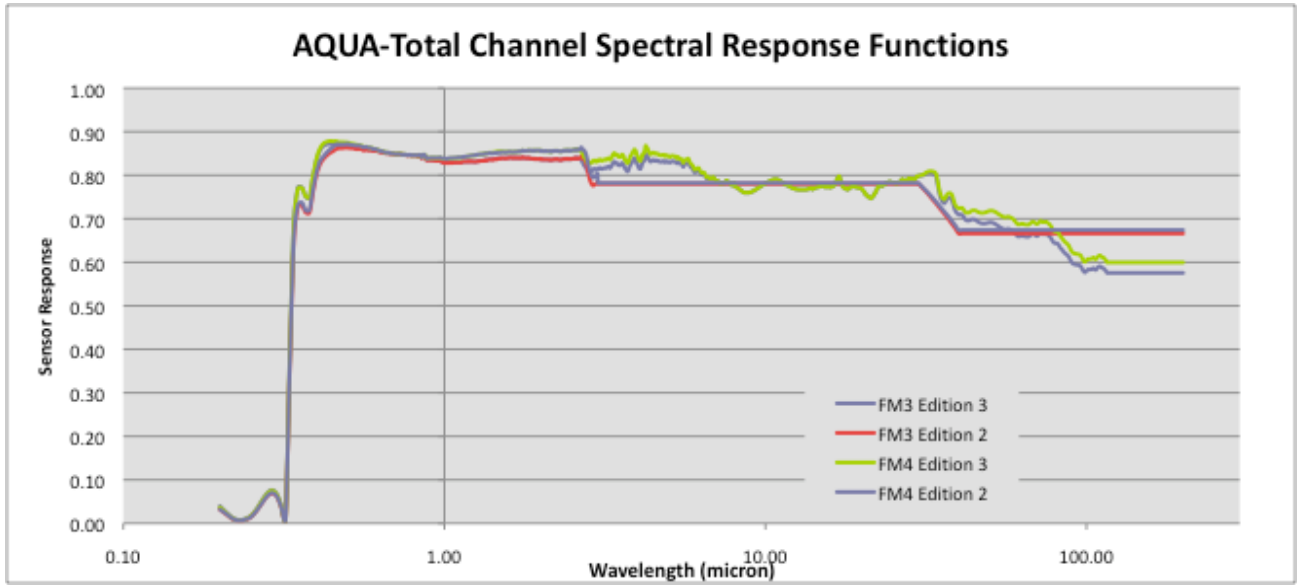
SW Sensor Spectral Response Functions





Total Sensor Spectral Response Functions





Start of Mission Radiometric Gains

Sensor performance was evaluated using on-board calibration sources during pre-launch calibration tests. The response changes between ground and start-of-mission calibrations were used as Ground to Flight corrections for radiometric gains.

Ground to Flight Sensor Response Changes:

	Total	Window	Shortwave
FM1	-0.13%	0.4%	-0.5%
FM2	-0.21%	1.61%	-0.01%
FM3	0.08%	-0.06%	-8.00%
FM4	1.05%	0.96%	1.96%

Common Radiometric Scale for CERES measurements

- CERES Flight Model 1 (FM1) selected as standard
- The radiometric scale determined independently at the Beginning of Mission for each platform.

  March 2000 for Terra and July 2002 for Aqua

- Terra – Aqua Comparisons: FM1 and FM4

  Targeted scanning at Orbital Nodes – July 2002

- Comparison factors applied to Aqua sensors (FM3 & FM4) to bring them on FM1 scale.

Common Radiometric Scale for CERES Measurements

Comparison of unfiltered All-Sky radiance with matched geometry of measurement for VZA < 60^0

Averaging over 1x1 degree grid

Radiometric Scaling factors for CERES sensors:

	Shortwave	Window	Total	Total (<3μm)
FM2	0.08%	0.2%	0.28%	-0.5%
FM3	0.27%	-	0.16%	2.5%
FM4	0.57%	0.4%	1.8%	2.5%

Note: positive factor – drop in SRF yielding rise in radiance
negative factor - rise in SRF yielding drop in radiance

TERRA Radiance Comparison

Edition2 and Edition3 At Launch Values

ALL SKY Global Flux Results for March 2000
based on ERBE-Like ES-8 product Nadir data

	FM1			FM2		
	Edition3 Wm-2	Edition2 Wm-2	Ed3-Ed2	Edition3 Wm-2	Edition2 Wm-2	Ed3–Ed2
LWday	230.62	228.72	0.8%	230.44	229.8	0.28%
LWnite	224.7	223.86	0.38%	224.6	223.52	0.49%
SW	256.36	256.24	0.05%	256.6	256.09	0.2%

Post-Launch Radiometric Gains

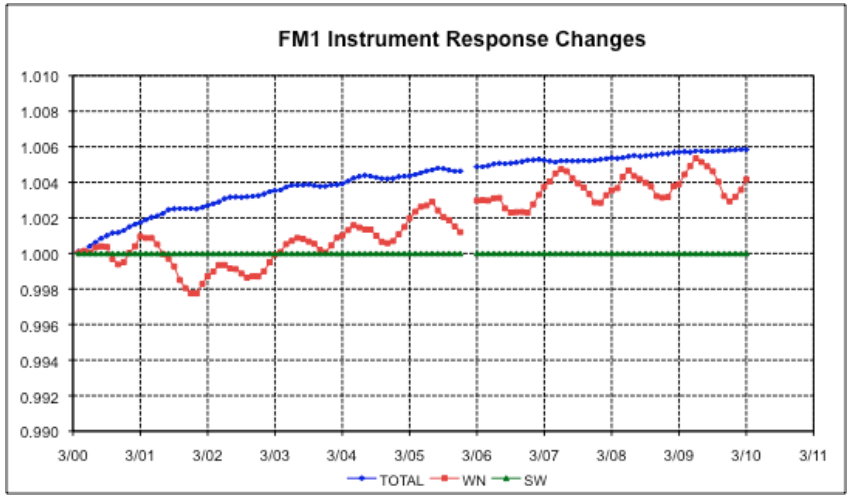
The in-flight gain changes were determined using the on-board Internal Calibration Module (ICM).

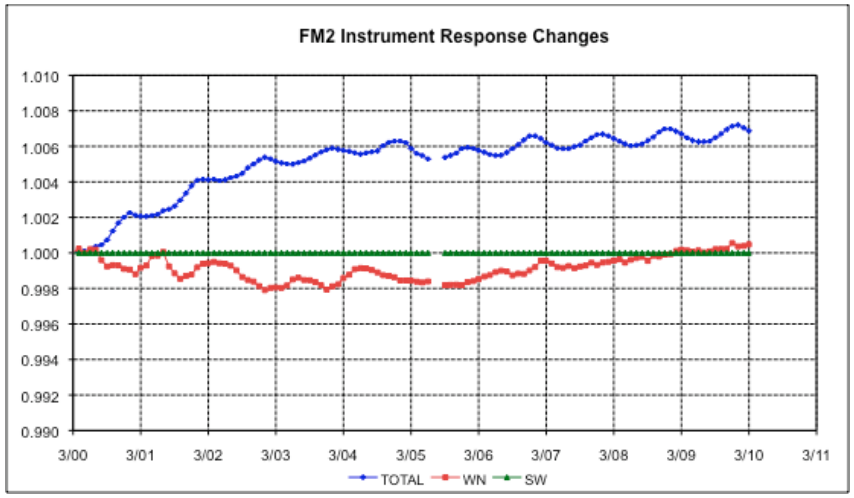
Blackbody sources: Total, Window

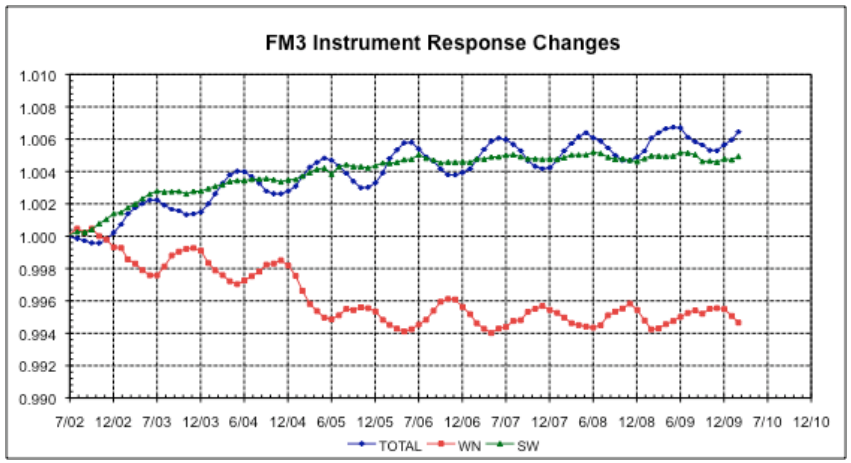
Shortwave Internal Calibration Source (SWICS): SW

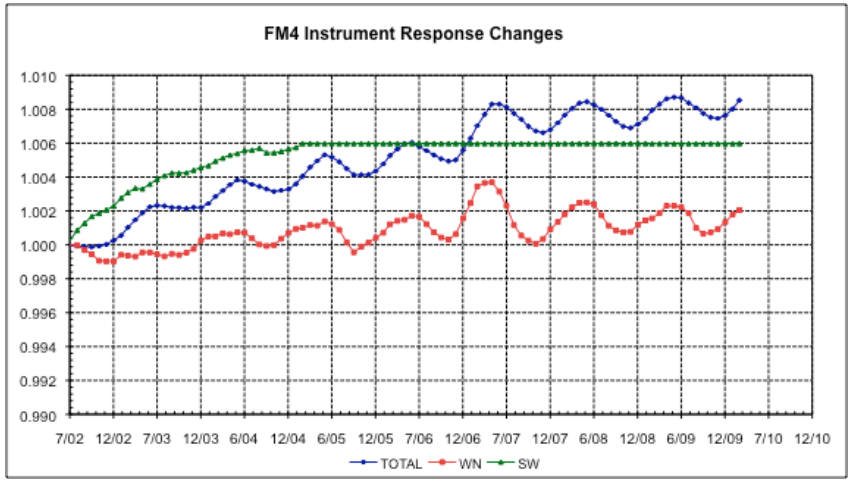
The monthly variation in the total and window sensor gains were reduced with five month averaging approach.

Post-Launch Radiometric Gain Change





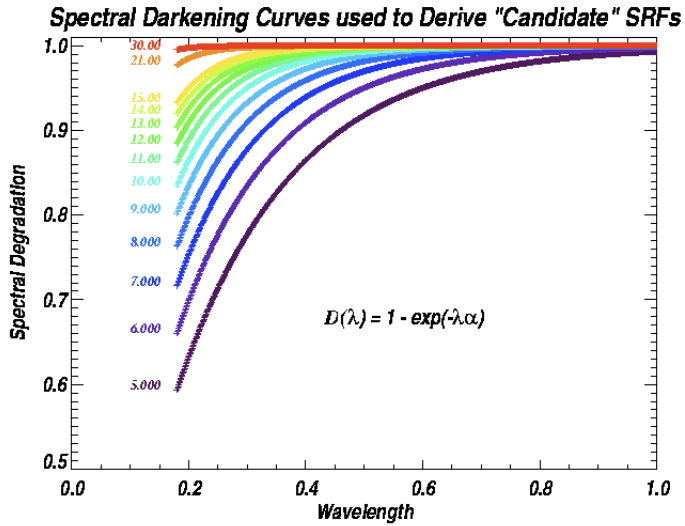




In-flight Spectral Darkening Correction

Degradation was observed in the reflected solar spectral band regions of SW and TOTAL sensors.

Spectral Darkening increases for shorter wavelengths.

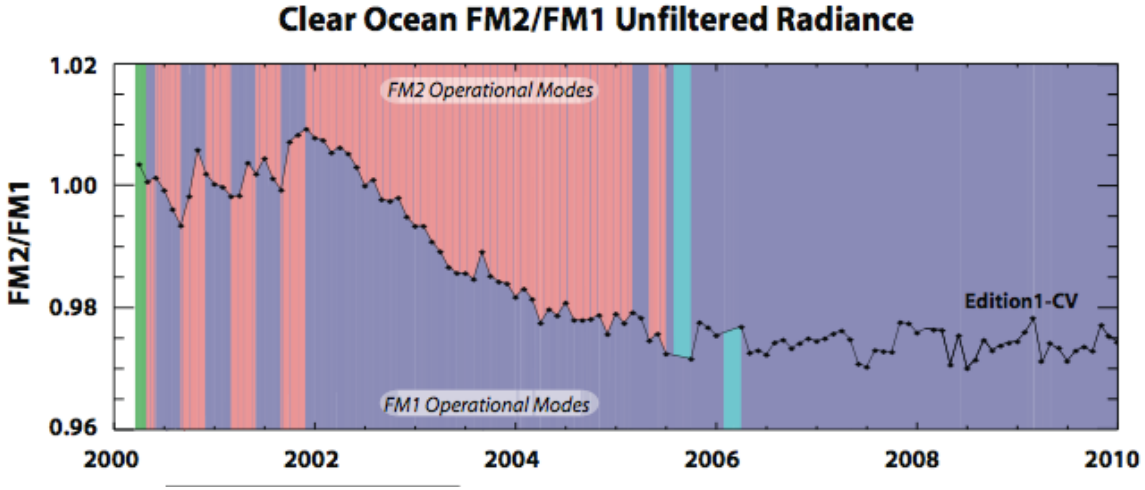


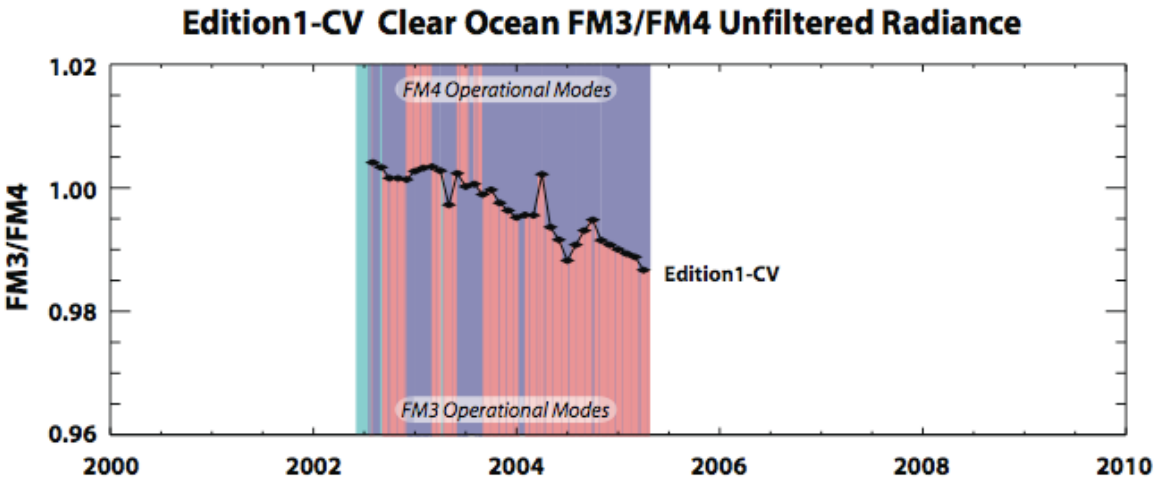
Strategy for characterizing SW spectral degradation

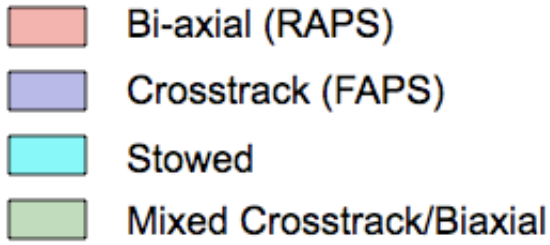
Direct Nadir Radiance Comparison

- **Assumptions**
  - **Temporal variation in the SW unfiltered radiance ratio is due to spectral degradation**
  - **Spectral degradation occurs only on RAPS instrument**
- **Compare monthly averaged spatially/temporally matched nadir observations for specific scene types**
  - **Clear ocean shows largest sensitivity to RAPS spectral darkening**
- **Xtrack mode sensor - unfilter with previous month's SRF.**
- **RAPs mode sensor - Retrieve optimal SRF from a set of candidate SRFs with varying degrees of spectral darkening**
  - **Optimal RAP SRFs ensure constant SW unfiltered radiance ratio throughout the mission.**

Operational Mode and Radiance Comparison

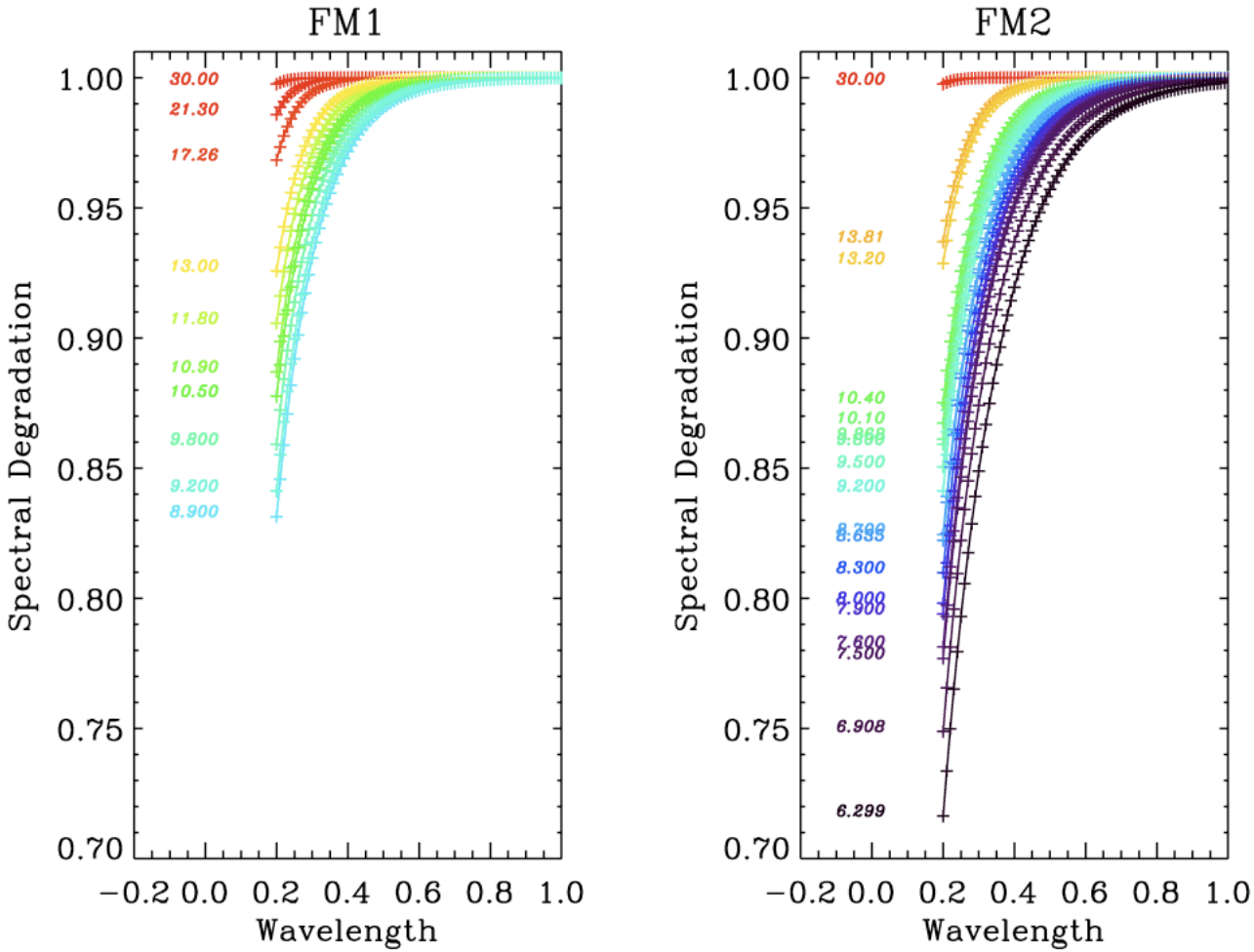




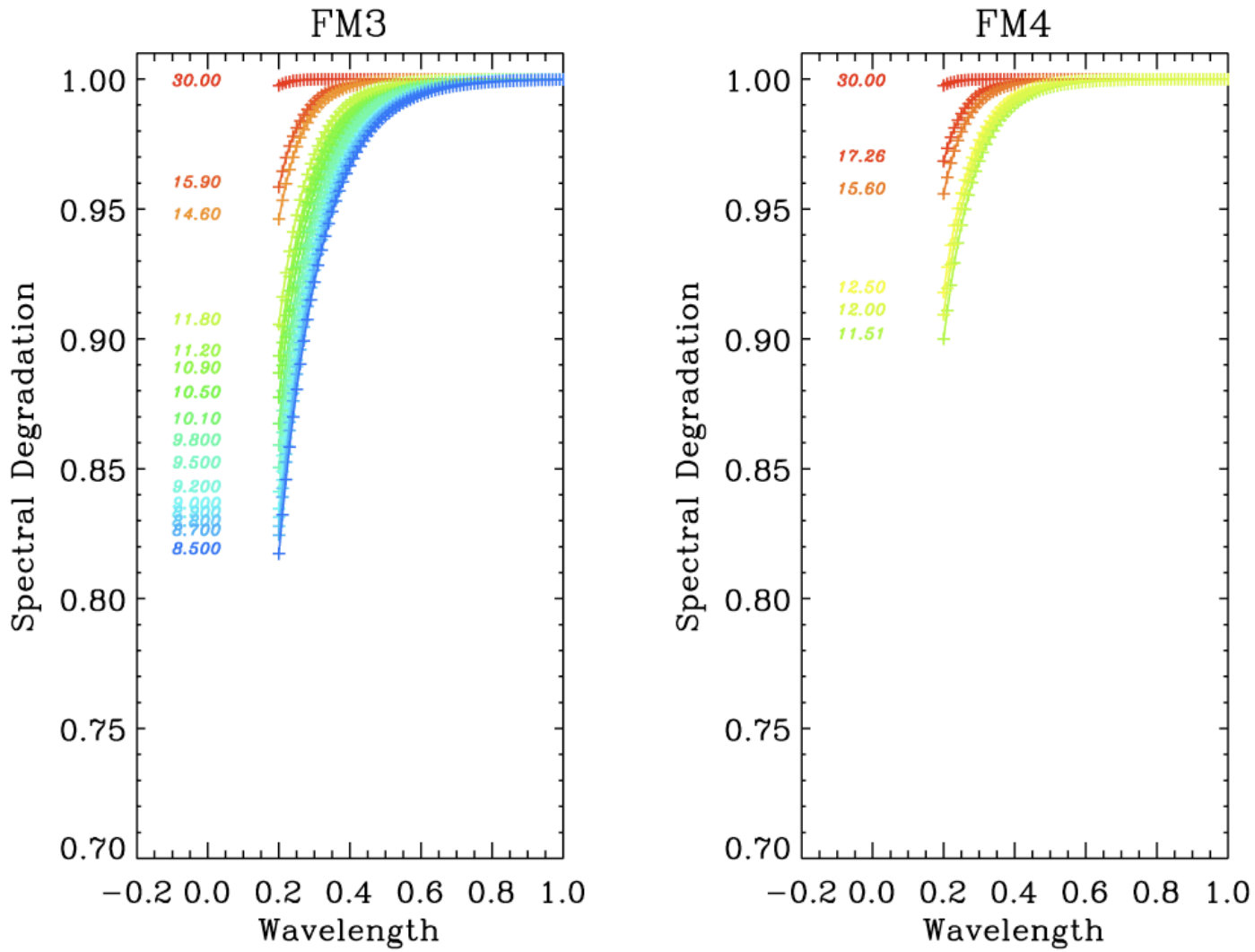


The ratio displays the radiance drop in the instrument operating in RAPS mode

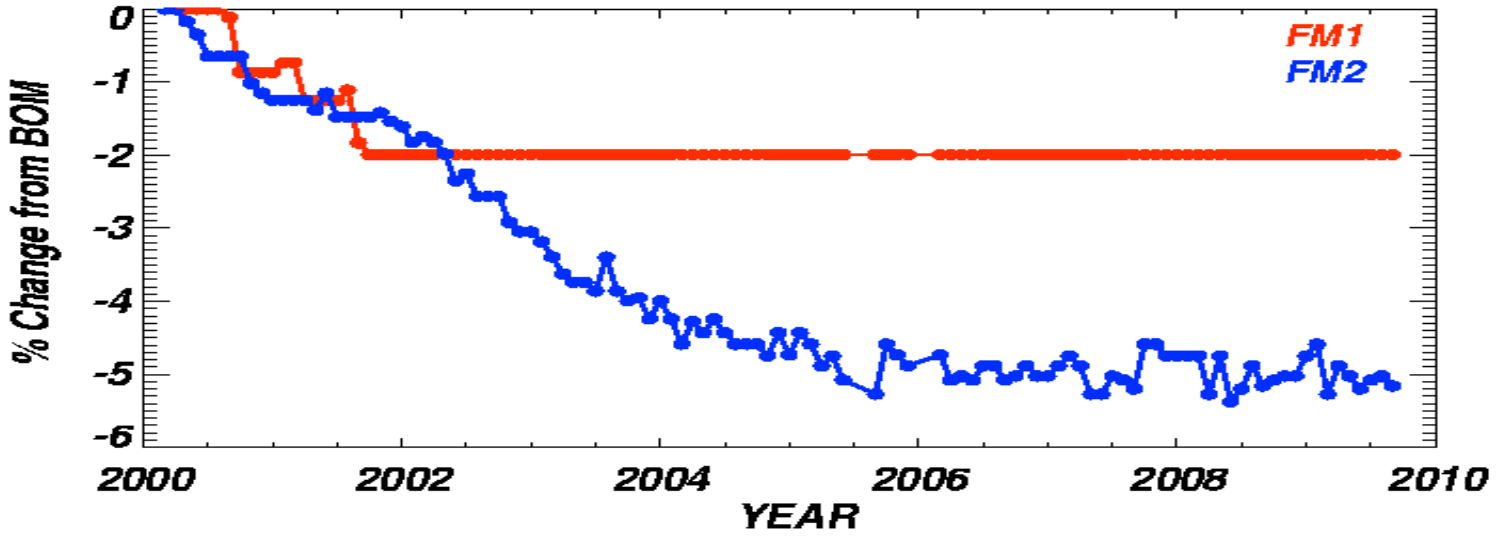
Alpha Retrievals for FM1 and FM2 SW Sensors

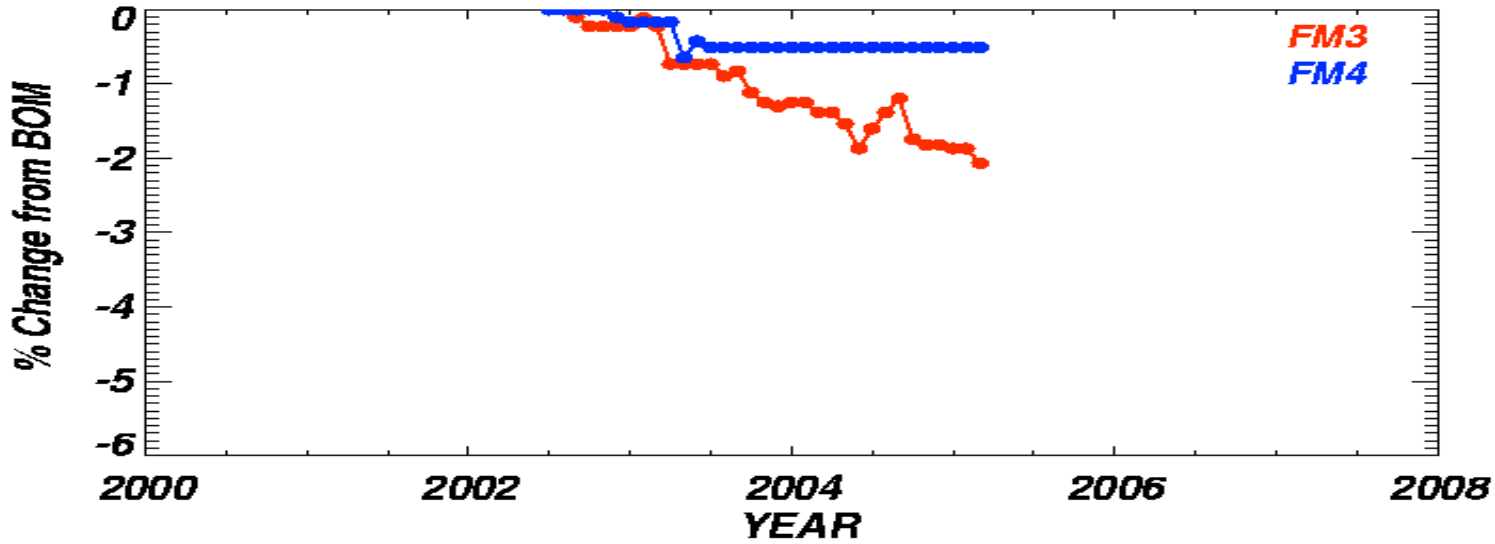


Alpha Retrievals for FM3 and FM4 SW Sensors

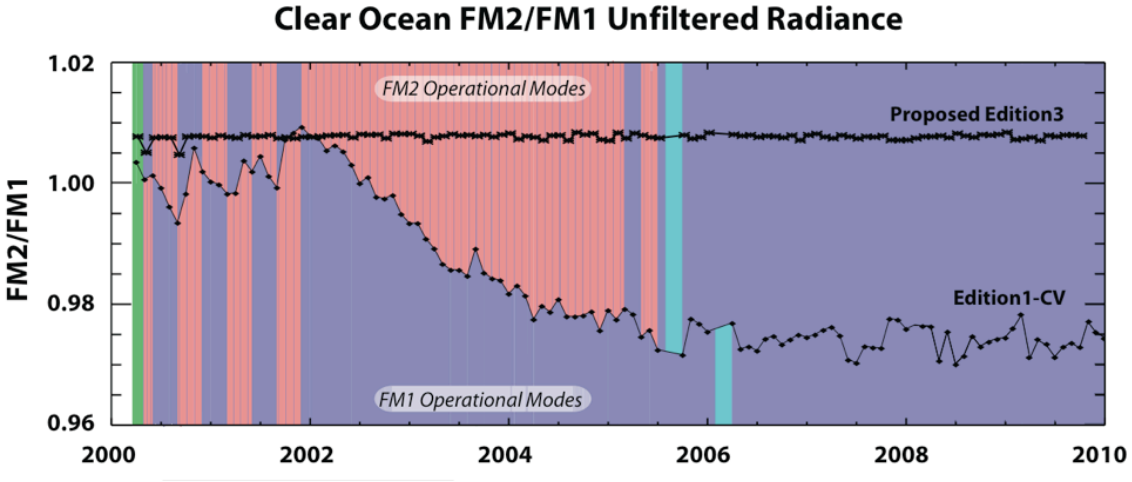


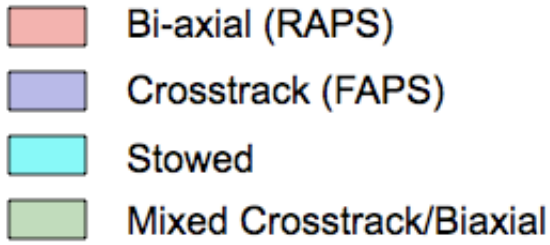
SW Sensor Change of Response

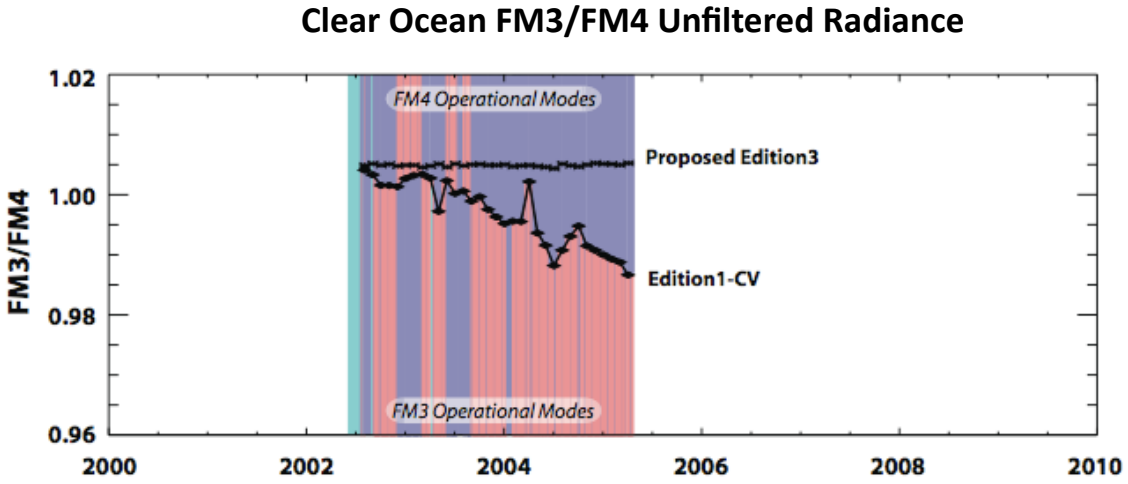




Operational Mode and Radiance Comparison

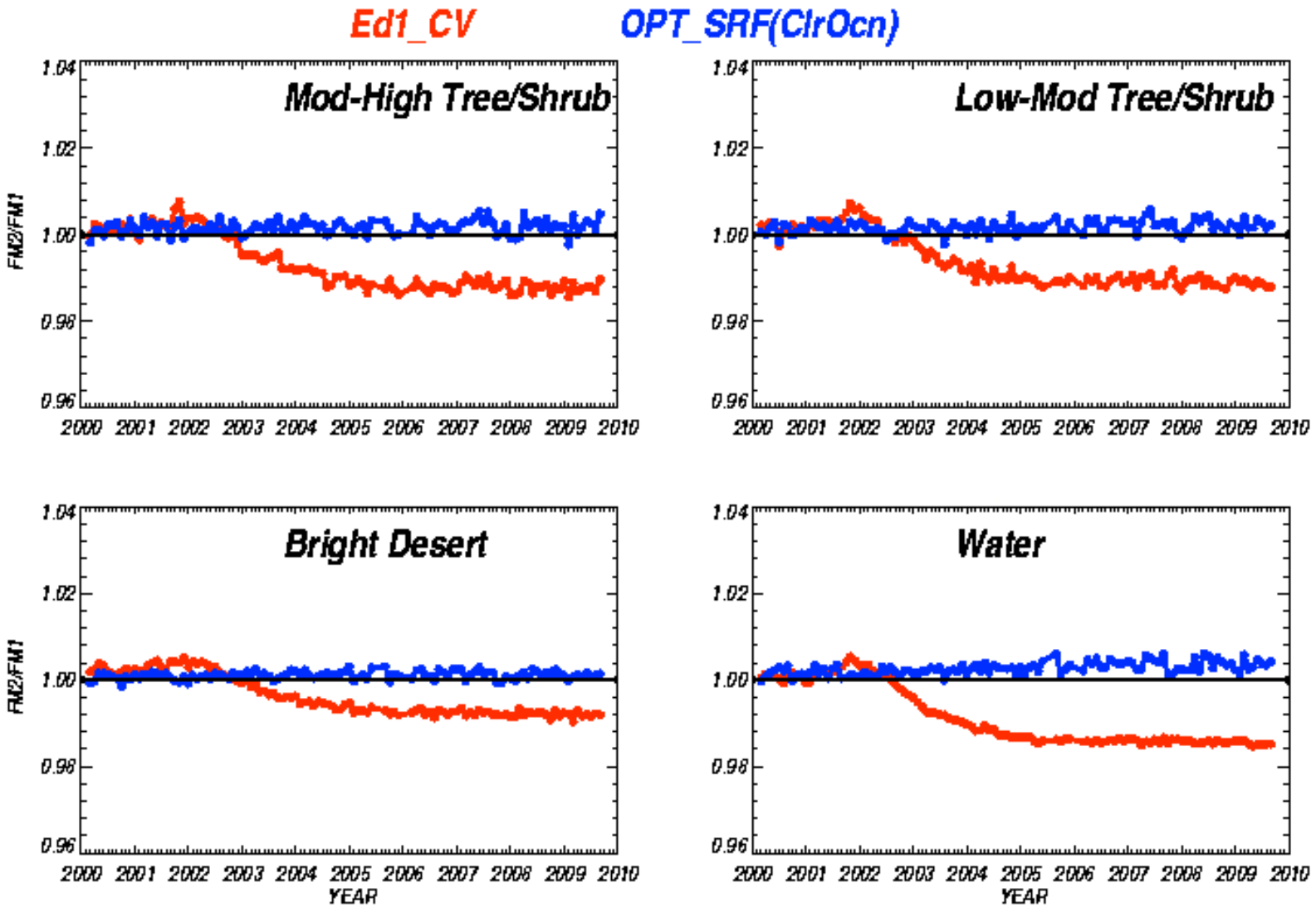




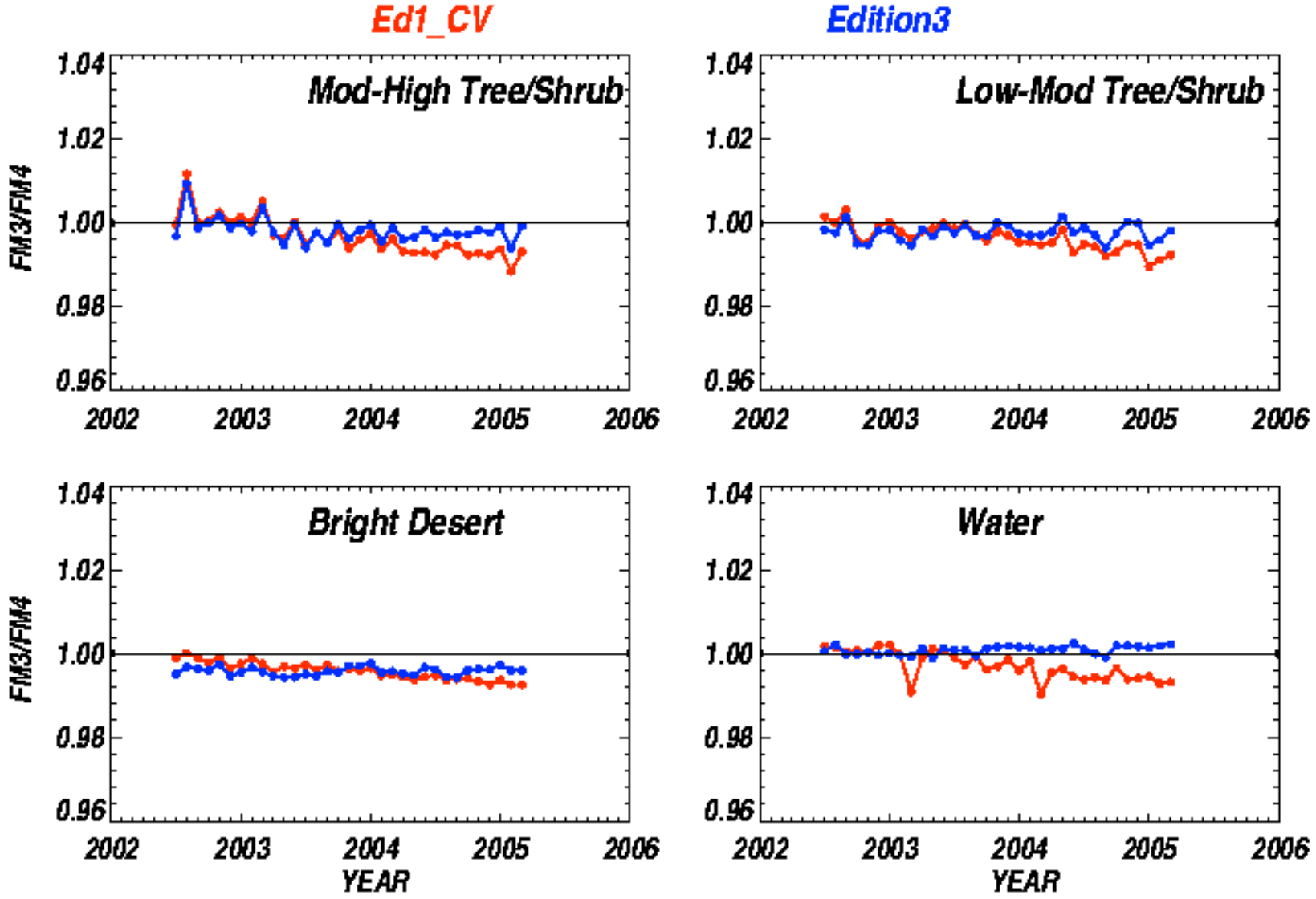


The SRF correction factors applied to Edition3 show a constant ratio between the instruments.

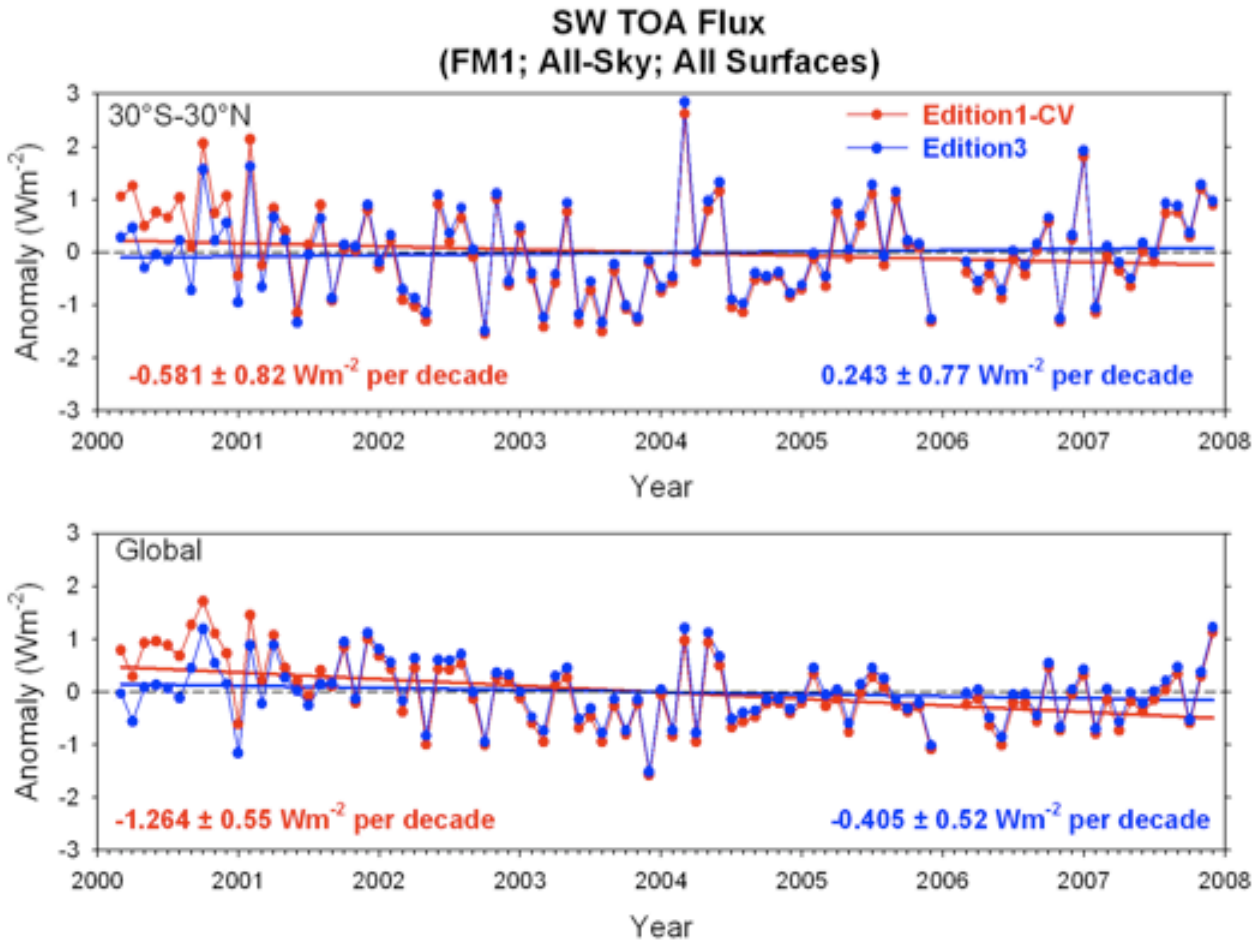
Terra Unfiltered SWR Ratio For Allsky Scenes



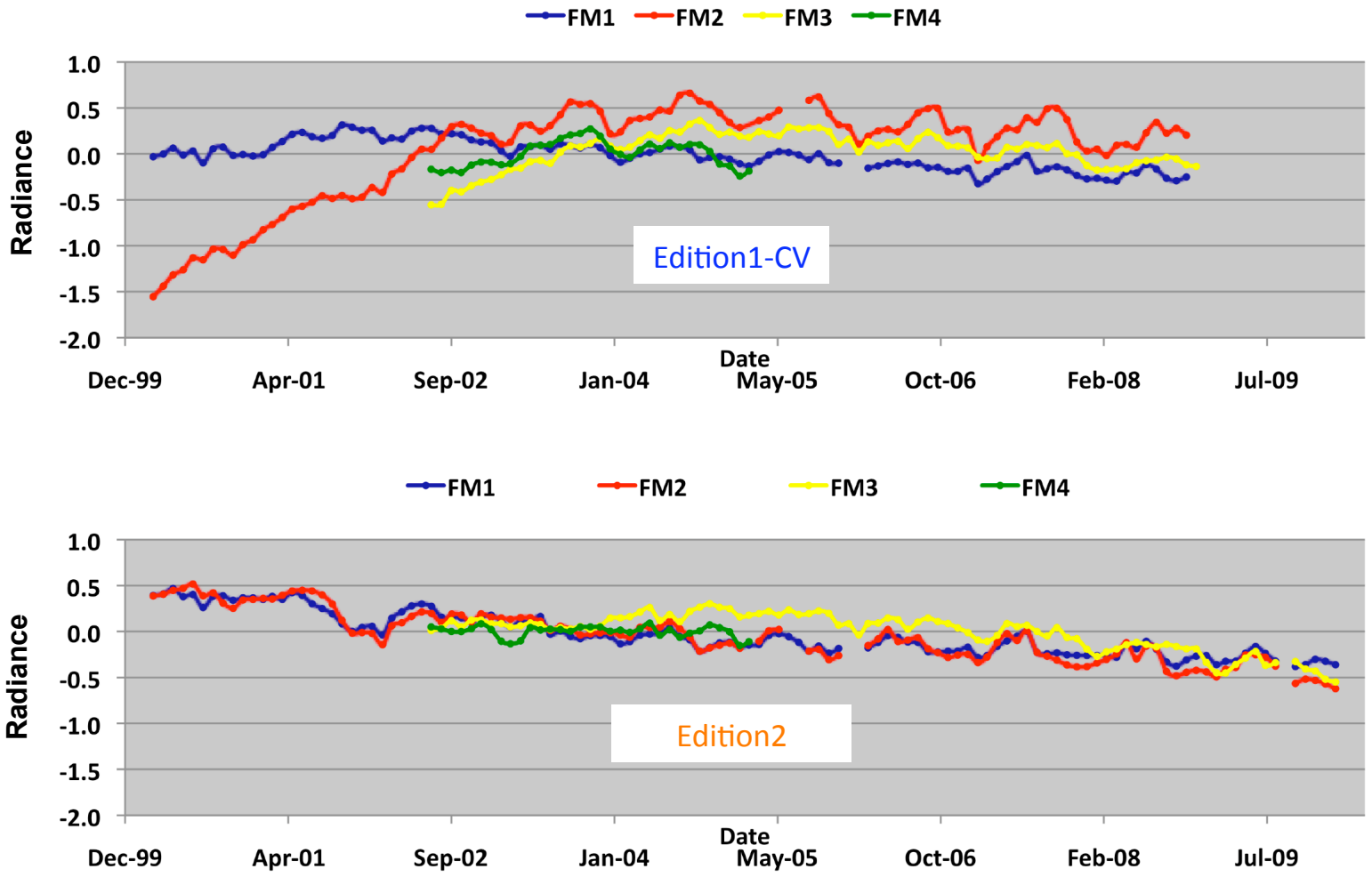
FM3/FM4 SW Unfiltered Radiance Ratio For All Sky Scenes



Edition3 Validation: SW TOA Flux



OLR Day-Night Difference Trends: Tropical Mean

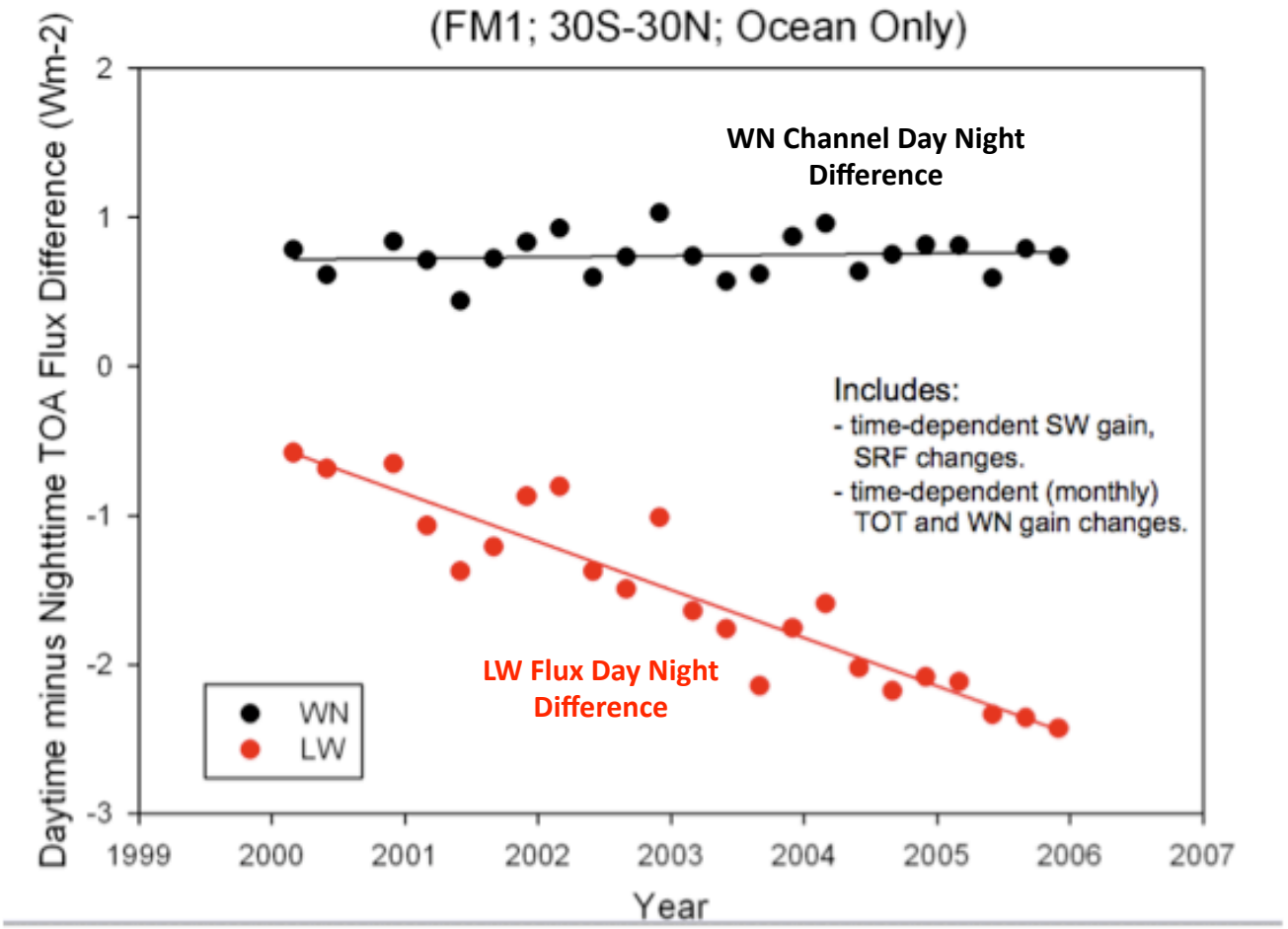


Data Set

- LW Unfiltered Radiance
- Nadir
- 20N - 20S
- Tropical Ocean
- All-Sky

LW Day (SW/TOT) Correction

Tropical Mean Day- Night Difference



Strategy for LW Day (SW/TOT) Correction

$$LW_{day} = Total - Shortwave$$

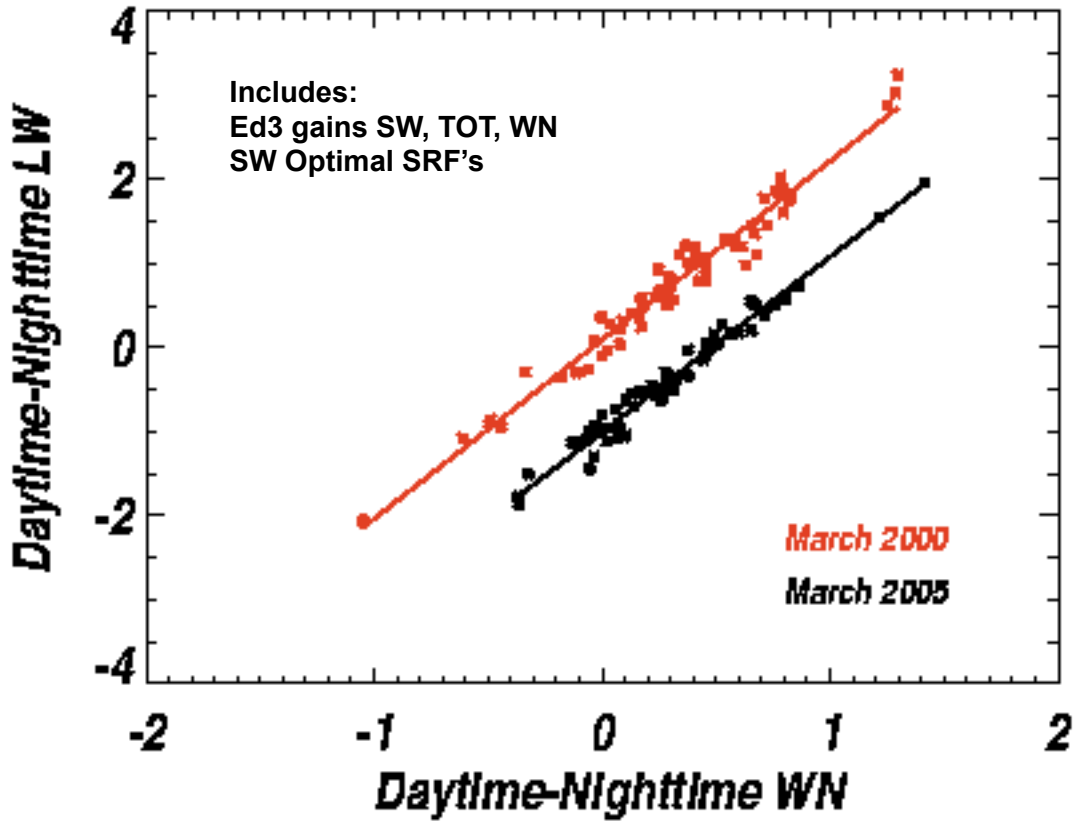
$$LW_{day} = LW/TOT + SW/TOT - Shortwave$$

$$LW_{night} = LW/Total$$

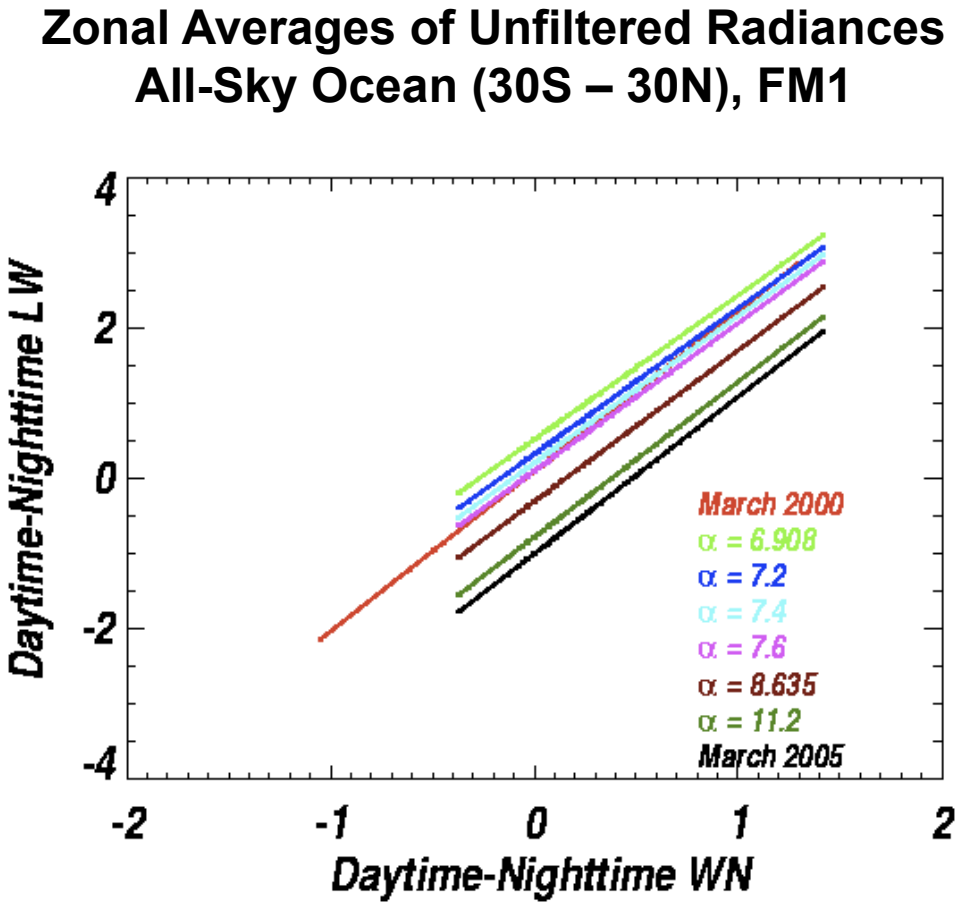
- Apply Total, WN and SW gains.
- Apply Optimal SW channel SRF's
- Select Total SRF from a "candidate" set of SRFs such that trend between the OLR Daytime minus Nighttime difference and the WN channel Daytime minus Nighttime observations held constant over time.

Comparison of LW and WN Day-Night Differences

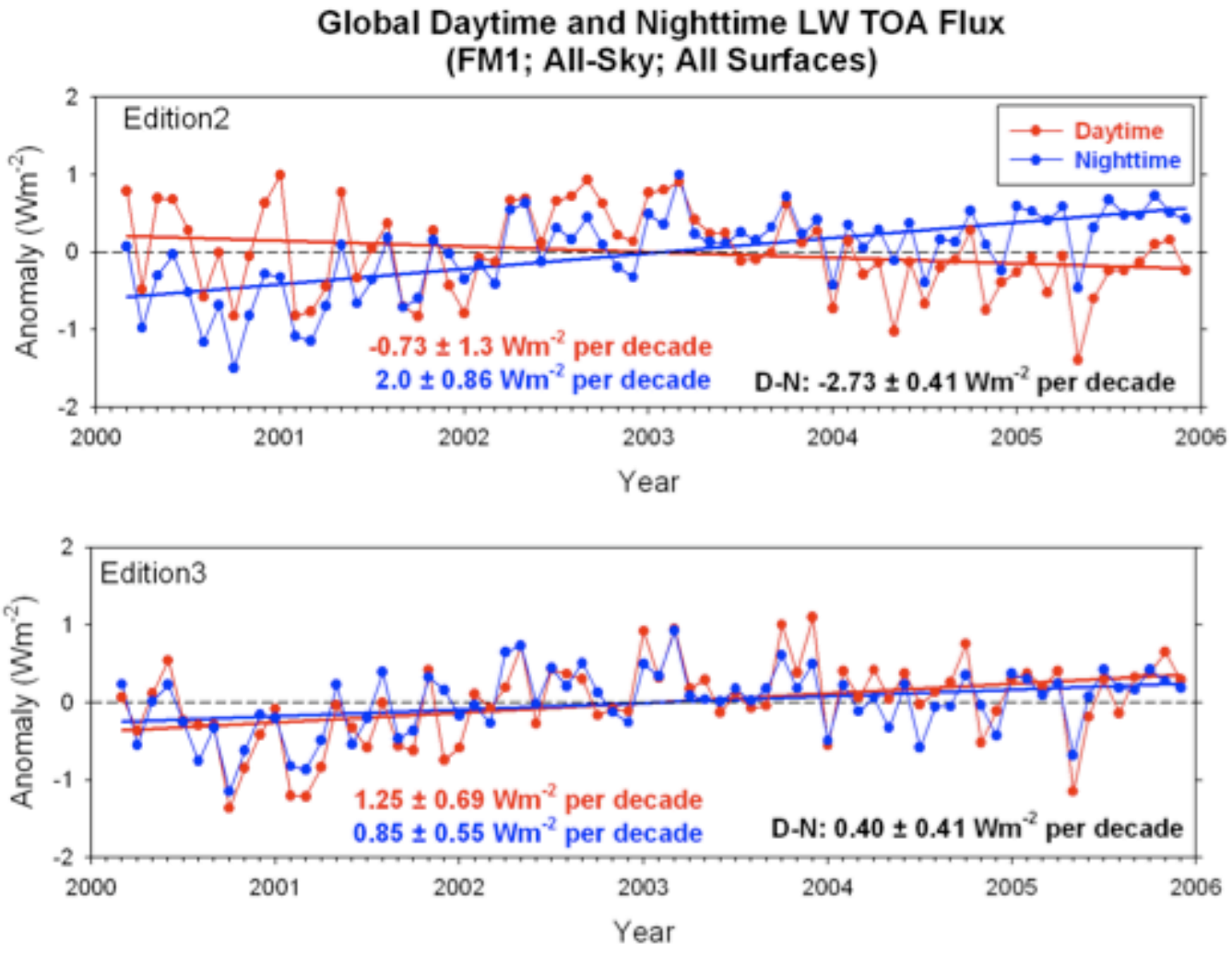
Zonal Averages of Unfiltered Radiances
All-Sky Ocean (30S – 30N), FM1

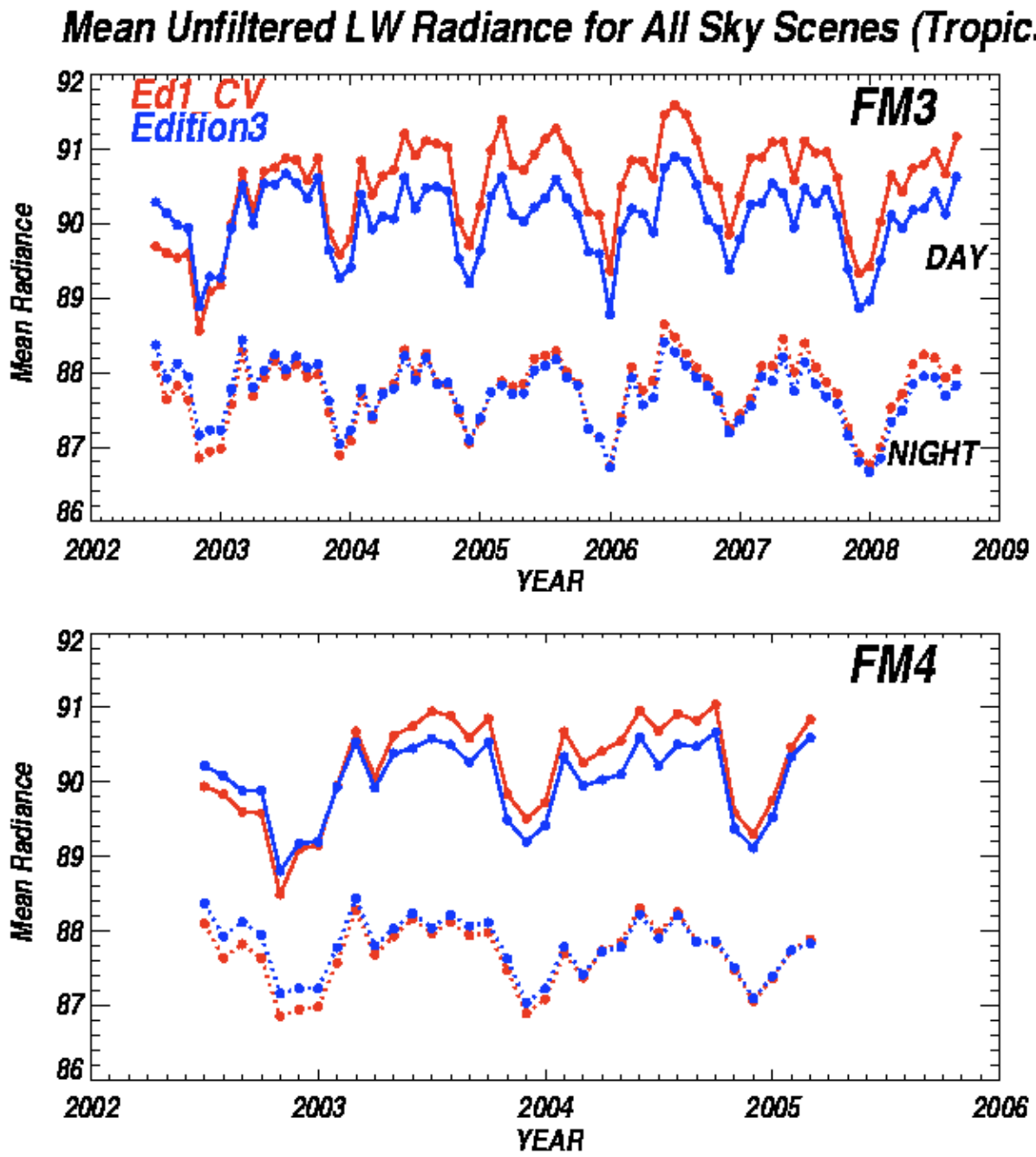


Selection of Optimal SRF for SW/TOT

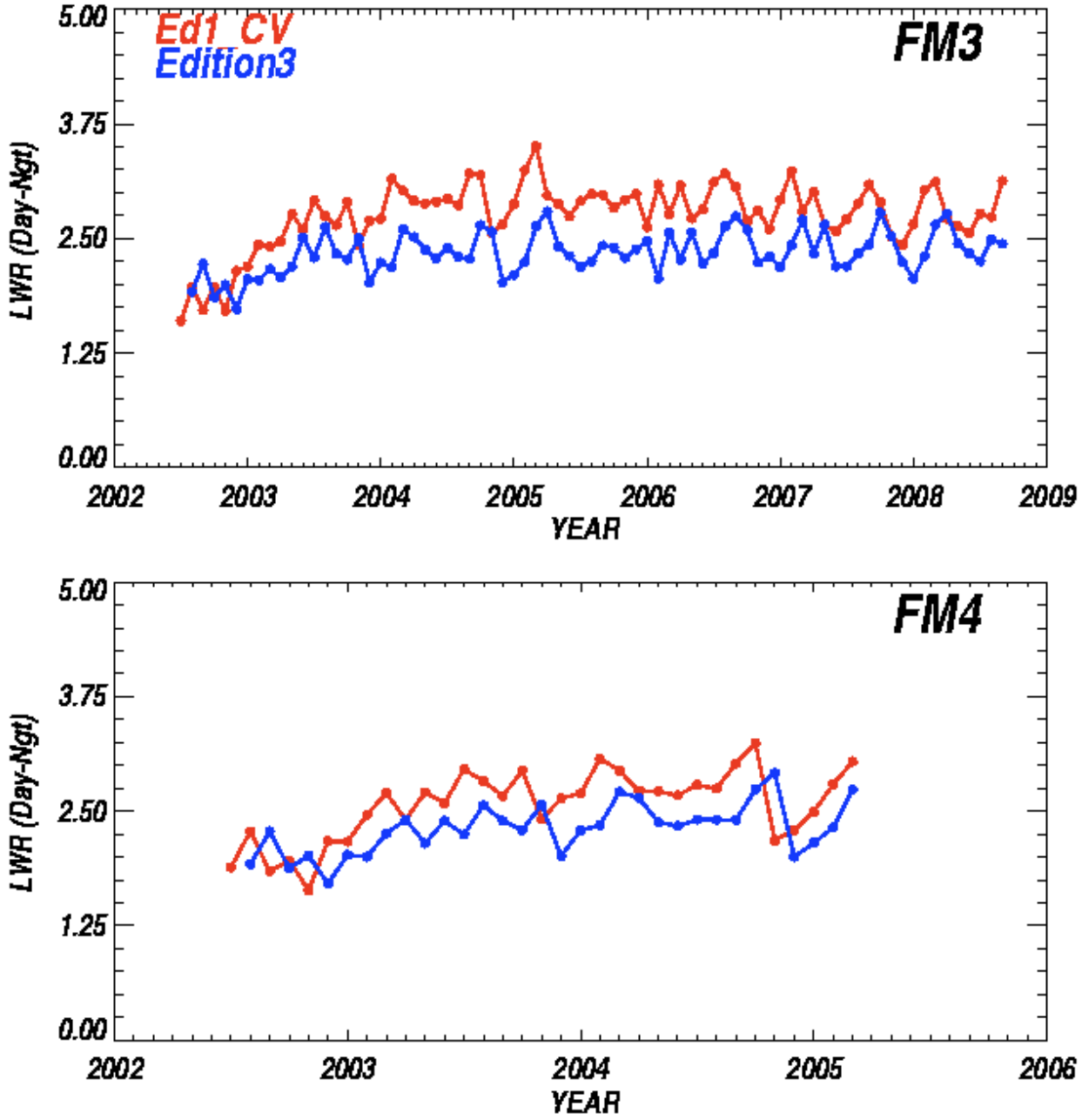


LW TOA Flux: Edition2 and Edition3 Comparison

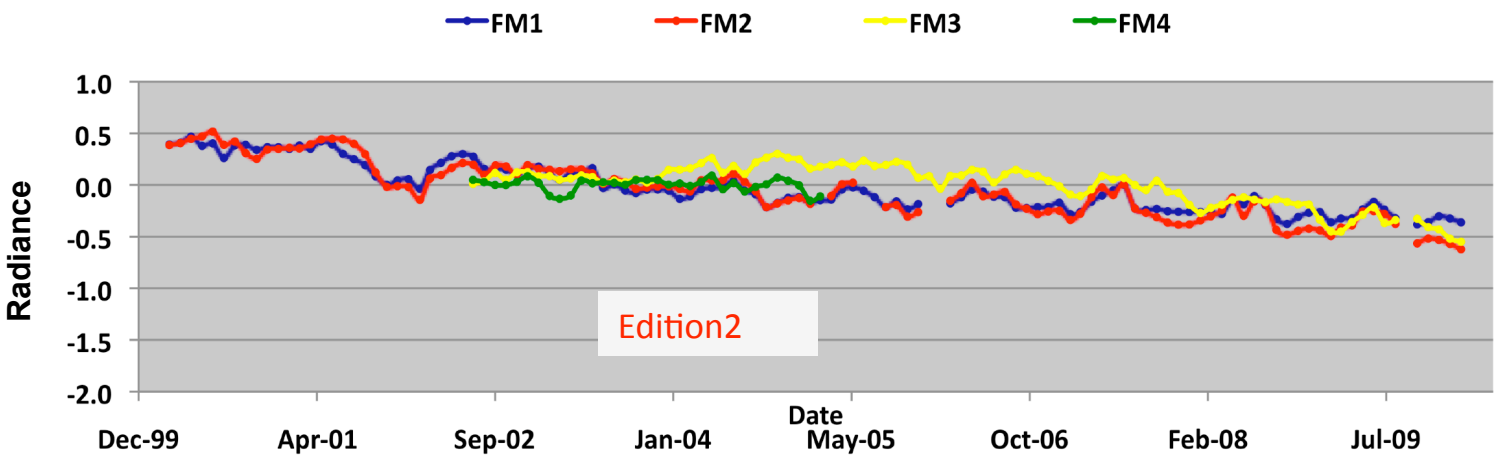


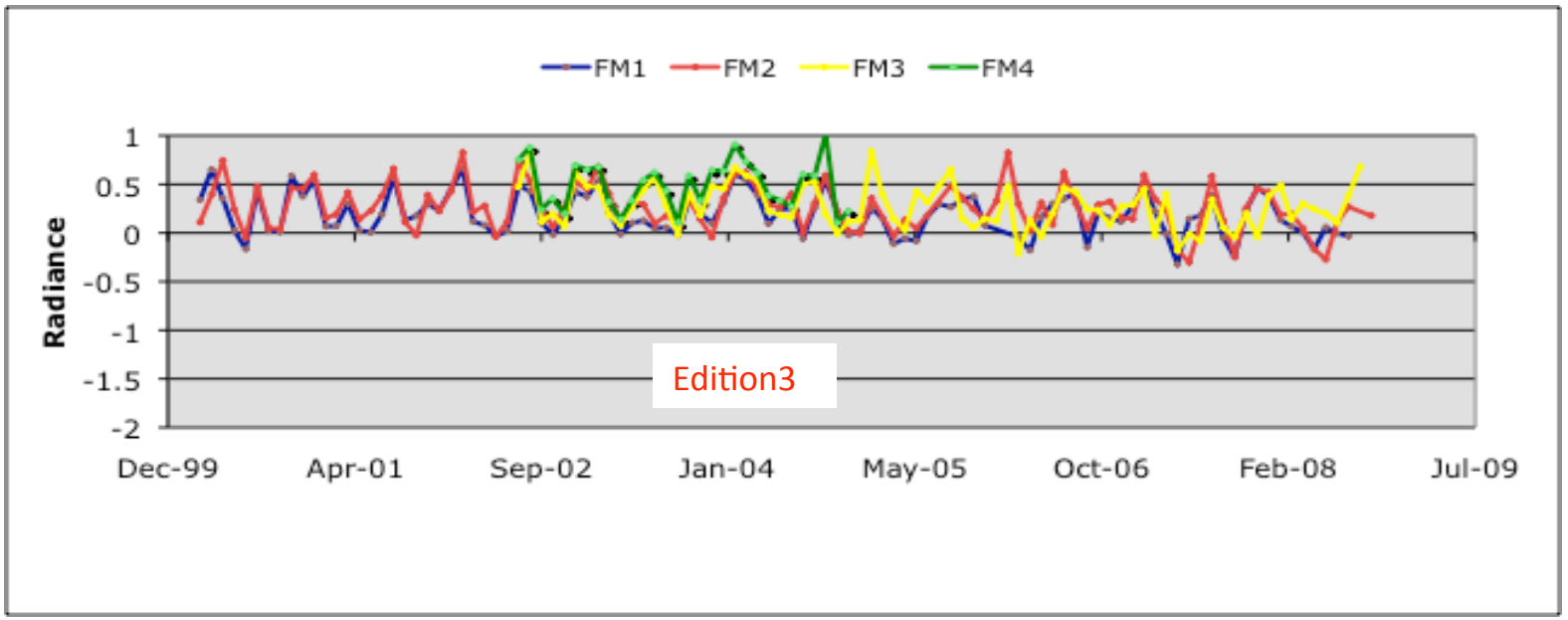

Mean Unfiltered LW Radiance for All Sky Scenes (Tropics)
Ed1_CV
Edition3
FM3
DAY
NIGHT
Mean Radiance
92
91
90
89
88
87
86
2002
2003
2004
2005
2006
2007
2008
2009
YEAR
FM4
Mean Radiance
92
91
90
89
88
87
86
2002
2003
2004
2005
2006
YEAR

Mean Unfiltered (Day - Night) LW Radiance for All Sky Scenes (Tropics)



OLR Day-Night Difference Trends: Tropical Mean

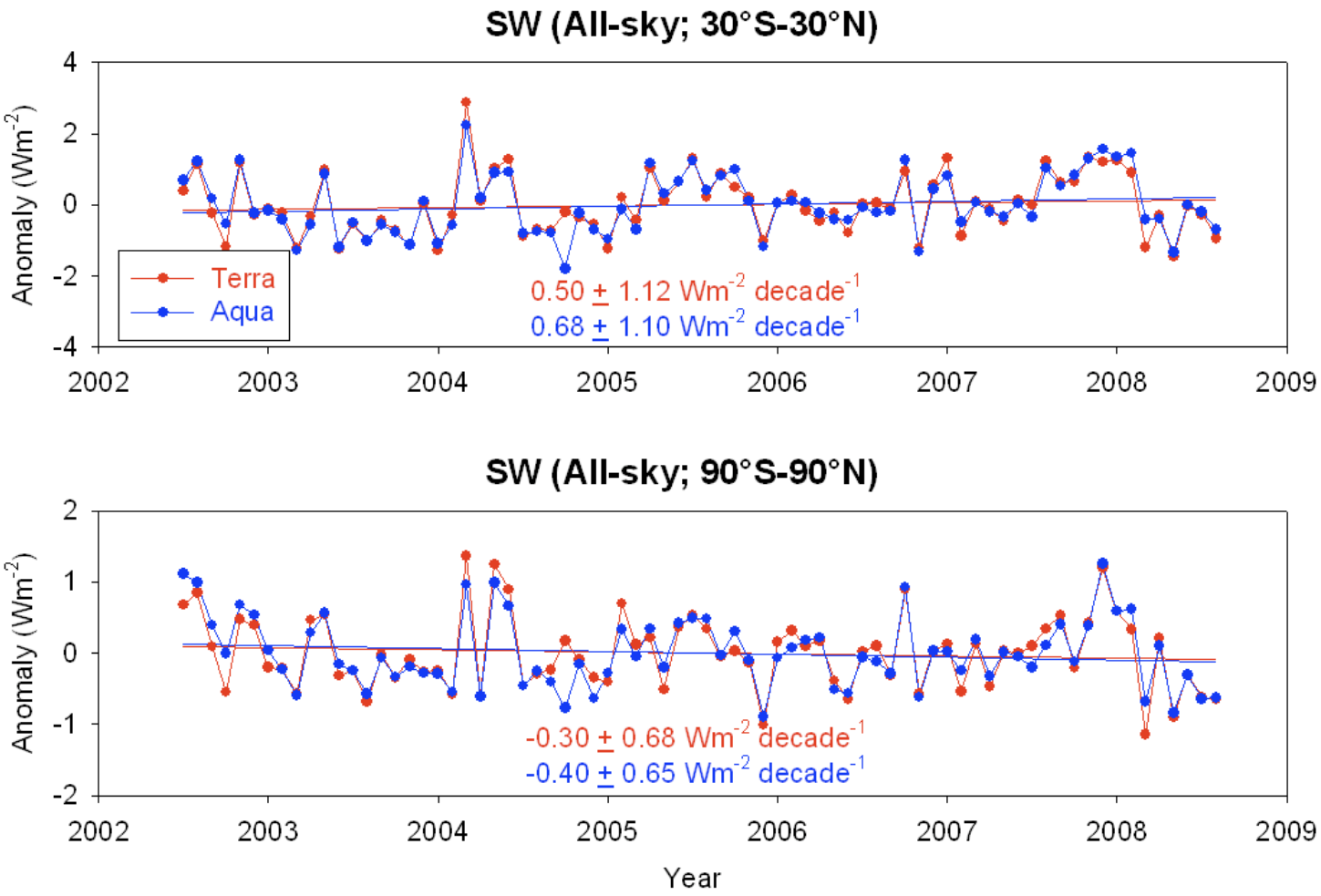




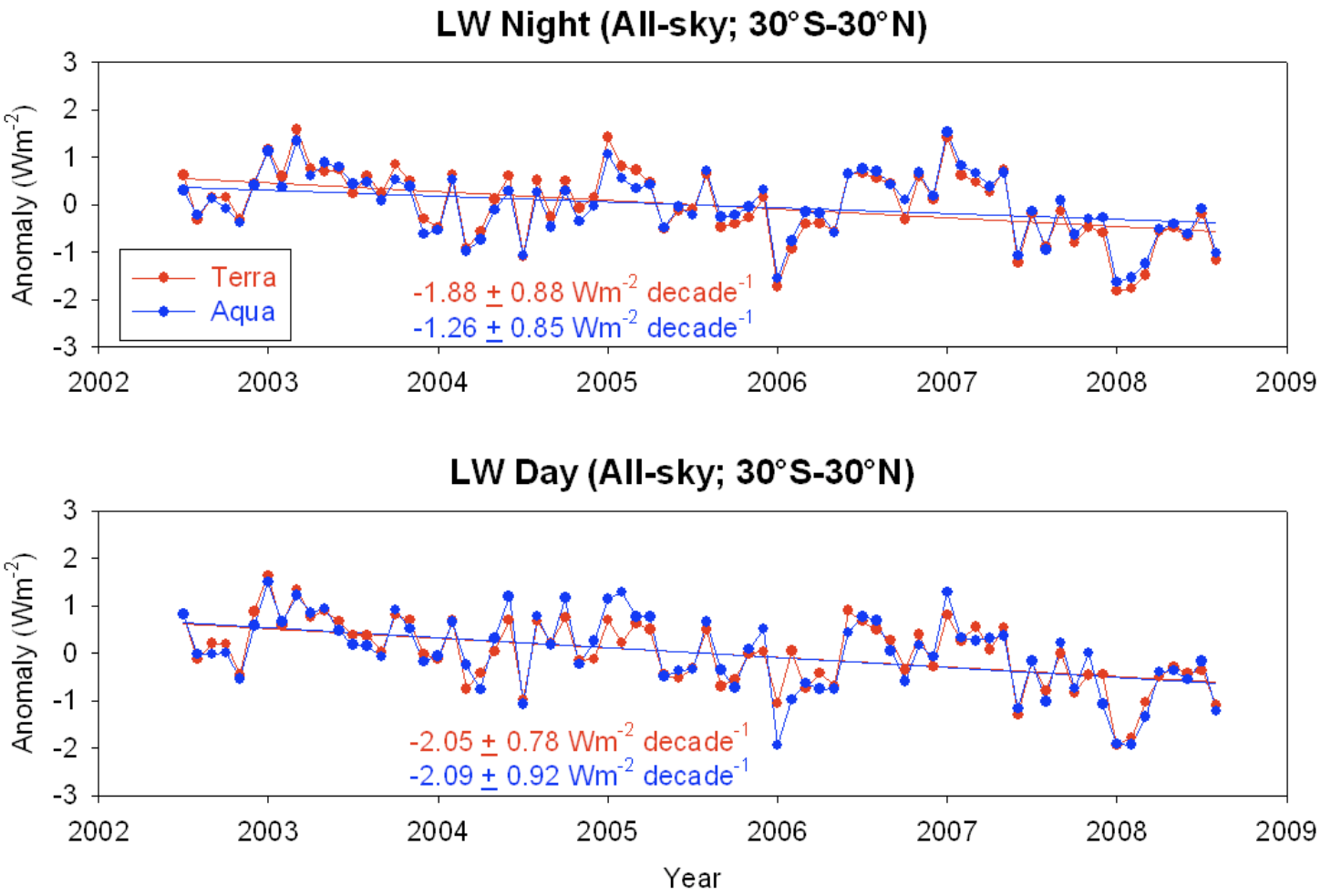
Data Set

- LW Unfiltered Radiance
- Nadir
- 20N - 20S
- Tropical Ocean
- All-Sky

Edition3 Validation: Terra – Aqua Comparison



Edition3 Validation: Terra – Aqua Comparison



Edition 3 Calibration Summary

The in-flight Radiometric Sensor Response Changes for the CERES FM1 – FM4 Instruments were determined and delivered for processing.

Terra (FM1, FM2): March 2000 – February 2010

Aqua (FM3, FM4): July 2002 – February 2010

The corrections for spectral response functions to account for the spectral darkening in the reflected solar band regions were derived.

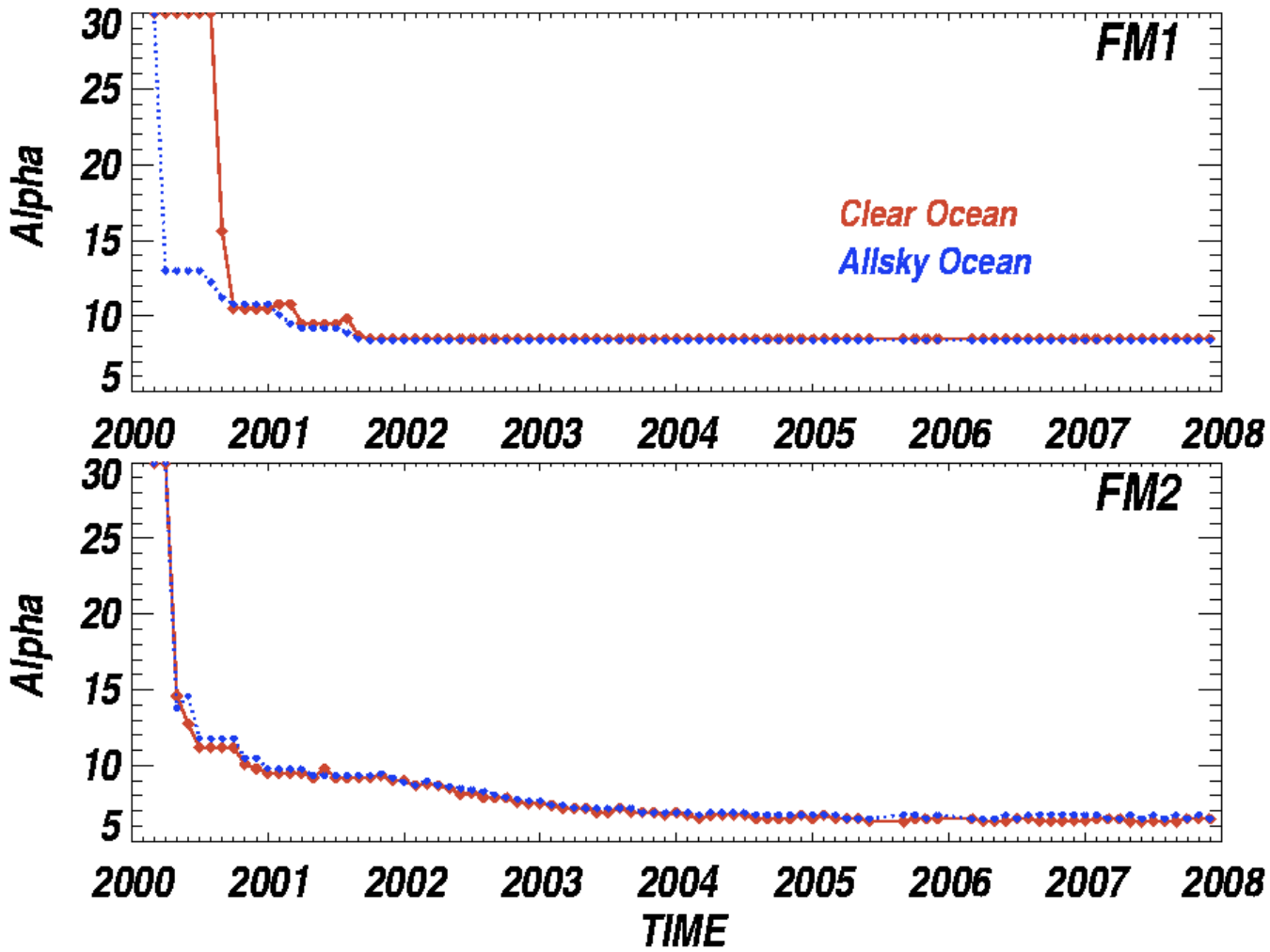
Terra (FM1, FM2): March 2000 – February 2010

Aqua (FM3, FM4): July 2002 – September 2008

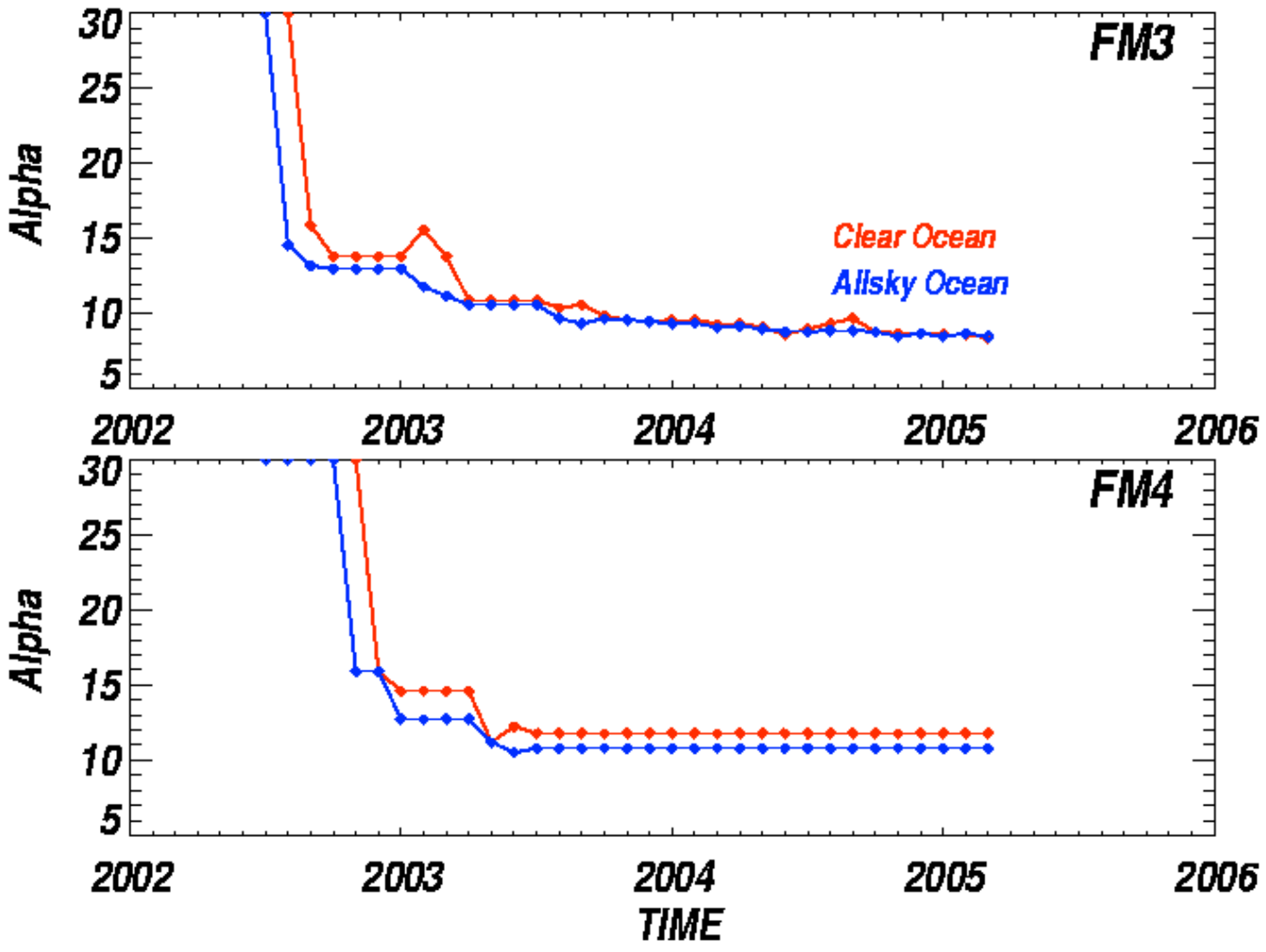
All CERES Instruments were placed on a common radiometric scale with Flight Model 1 (FM1) as the standard instrument.

BACK UP SLIDES

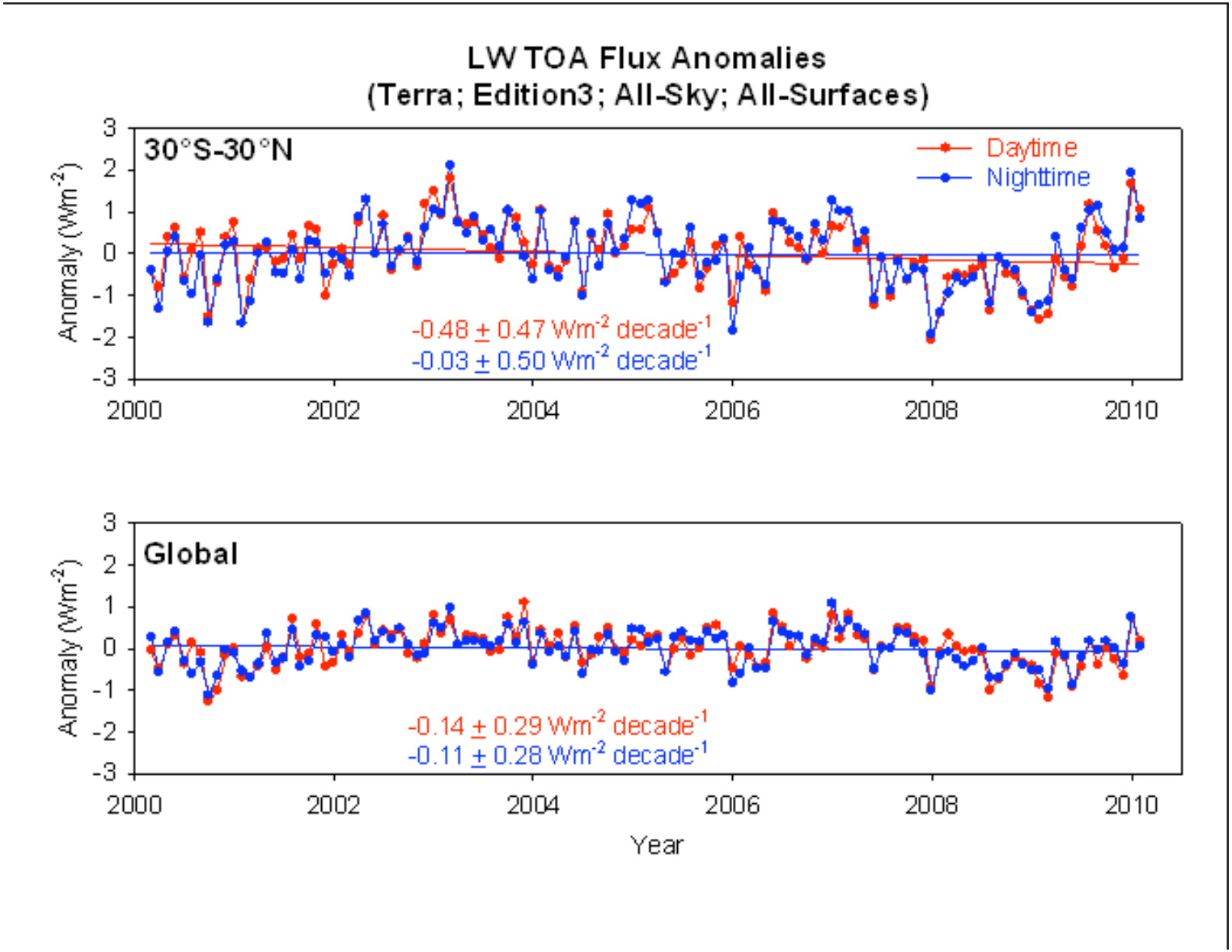
Alpha Retrievals for FM1 and FM2 SW Sensors



Alpha Retrievals for FM3 and FM4 SW Sensors



Edition3 Validation: Terra LW TOA Flux



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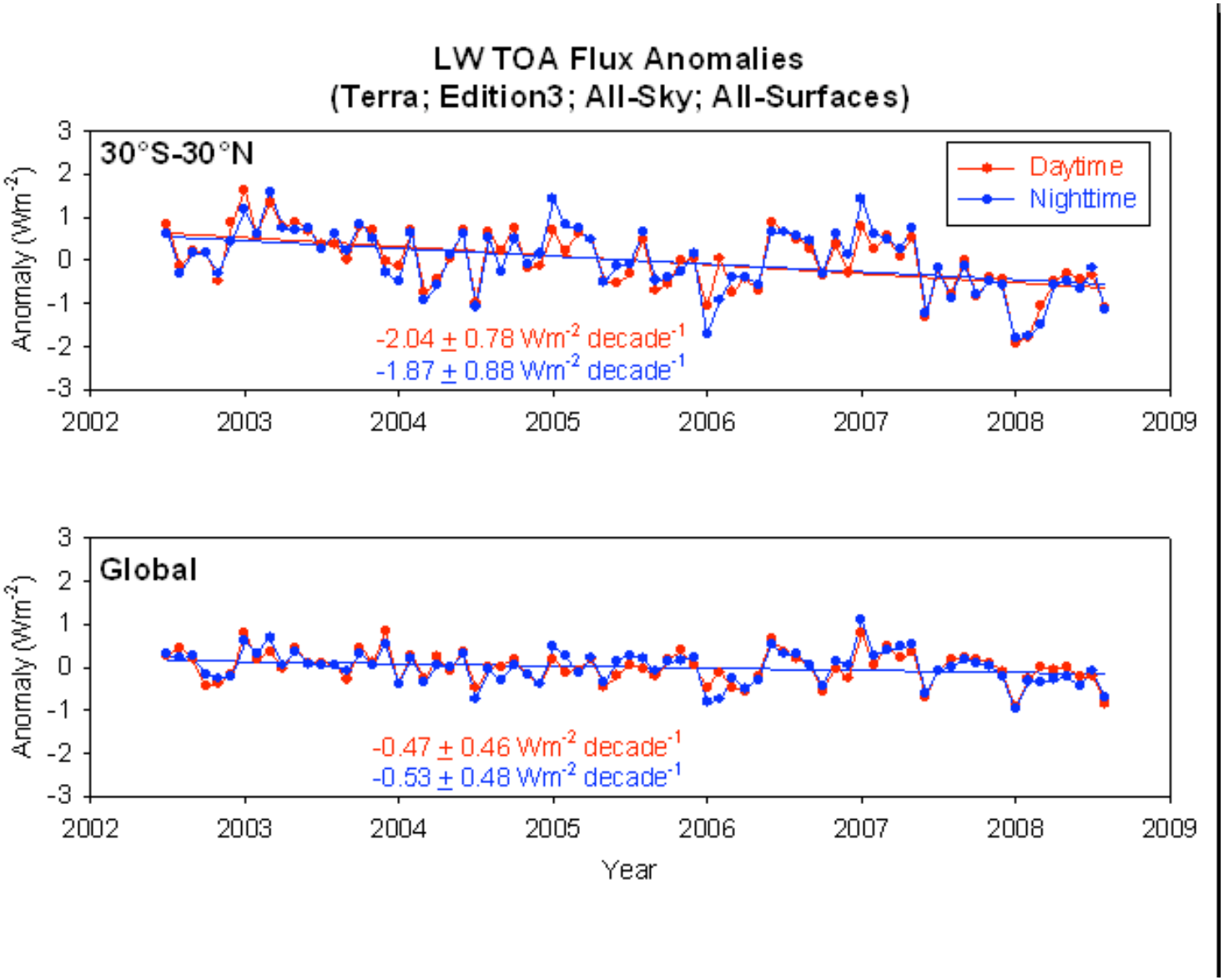

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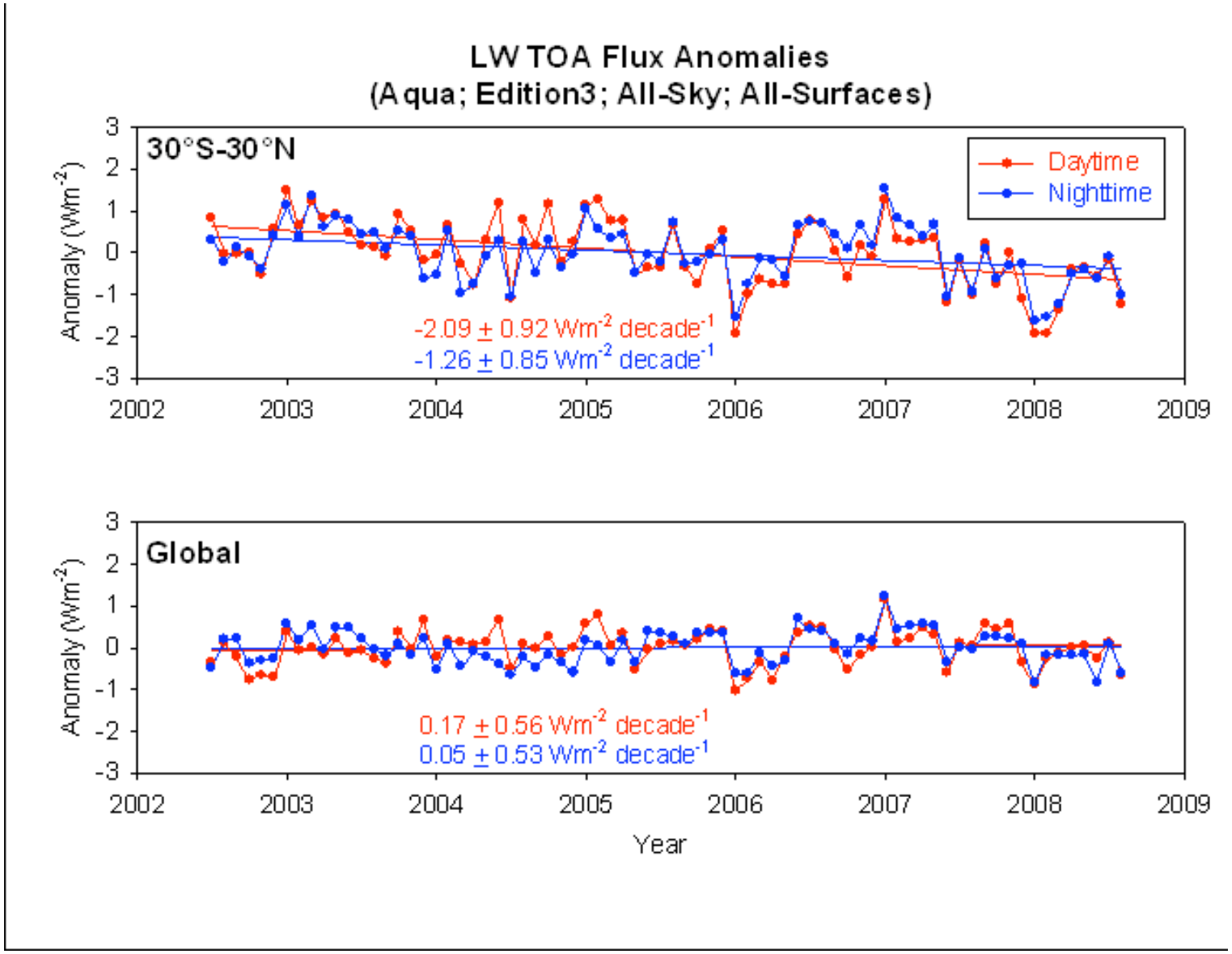
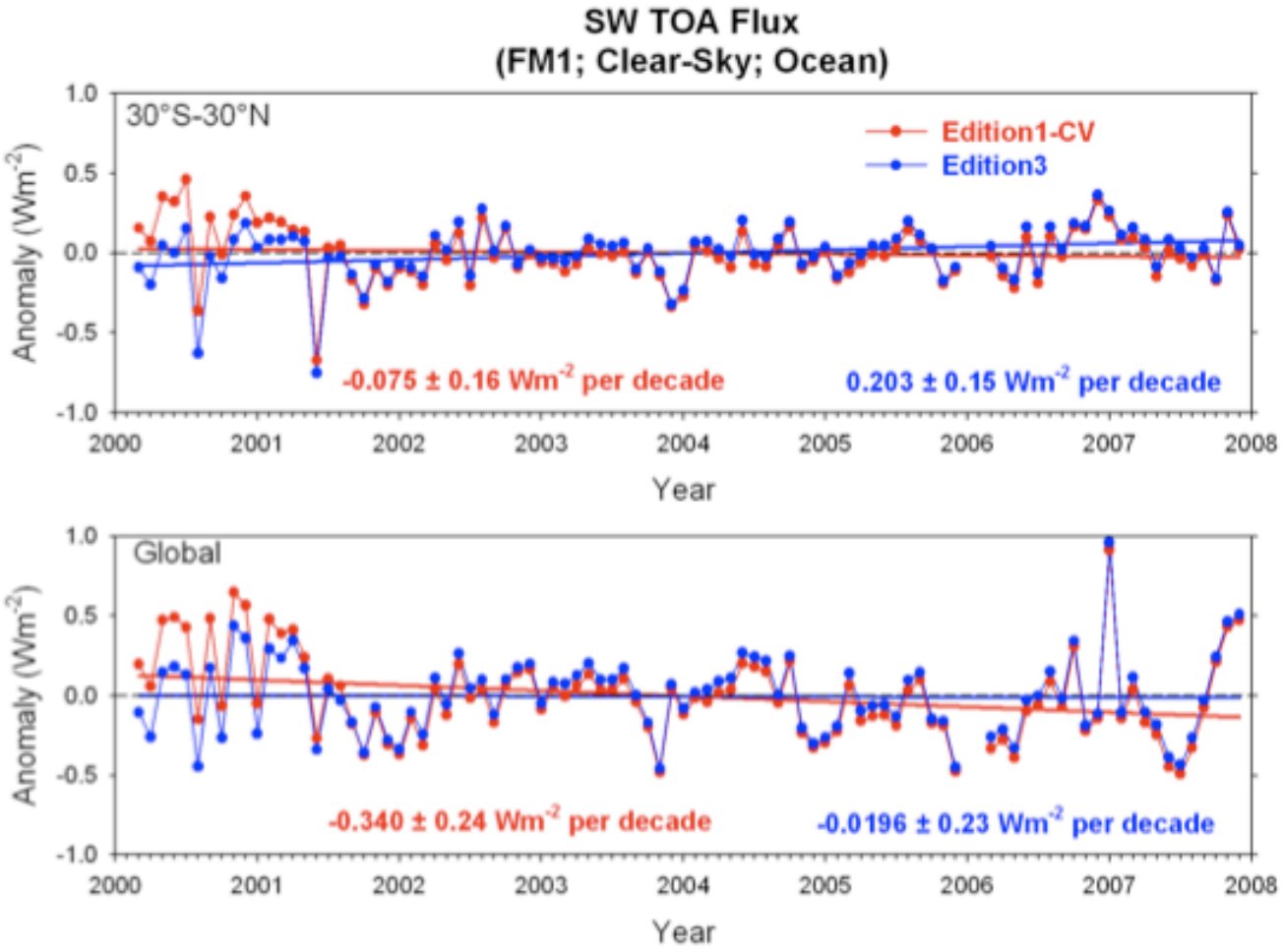


Edition3 Validation: SW TOA Flux



Test to set CERES FM1 as reference

- Direct compare of CERES FM1 and FM2 based on ERBE-Like ES-8 product
  - Proposed Edition 3 data for March 2000
  - Comparison at the unfiltered radiance level
    - matched geometry of measurements for VZA $< 60°$
  - 1500 comparison regions for day or night in one month
  - Averaging over $1° \times 1°$ grid
  - For all three channels and all scene types