Update : CERES FM-5, 6 & CERES follow-on Terra/Aqua Edition3 Study Results

Kory Priestley
~ The entire Instrument Working Group Team ~

CERES Science Team Meeting
Marriott at City Center
Newport News, VA
April 27, 2009

NASA Langley Research Center
Atmospheric SCIENCES

Instrument Working Group Personnel

Science

- Susan Thomas -
Melody Avery
Phil Hess
Costy Lukashin
Suzanne Maddock
Mohan Shankar
Nitchie Smith
Peter Szewczyk
Robert Wilson

Data Management

- Denise Cooper -
- Dale Walikainen -
Lisa Coleman
Ashley Alford
Dianne Snyder
Mark Timcoe
Thomas Grepiotis
Mark Bowser

Mission Operations

- Bill Vogler -
James Bailey
Janet Daniels
Jim Donaldson
John Butler
William Edmonds

S/C Integration & Test

- Roy Zalameda -
Mike Tafazoli
Eugene Sutton
Gene Andrews

Significant increases have been necessary to implement new FM5 and FM6 work

Tom Evert receives NASA Honor Award

Tom Evert, NGST CERES Chief Engineer, was awarded NASA's Medal for Distinguished Public Service.

The Distinguished Public Service Award is the highest honor bestowed by NASA on an individual who was not a government employee when the service was performed.

CERES Flight Schedule

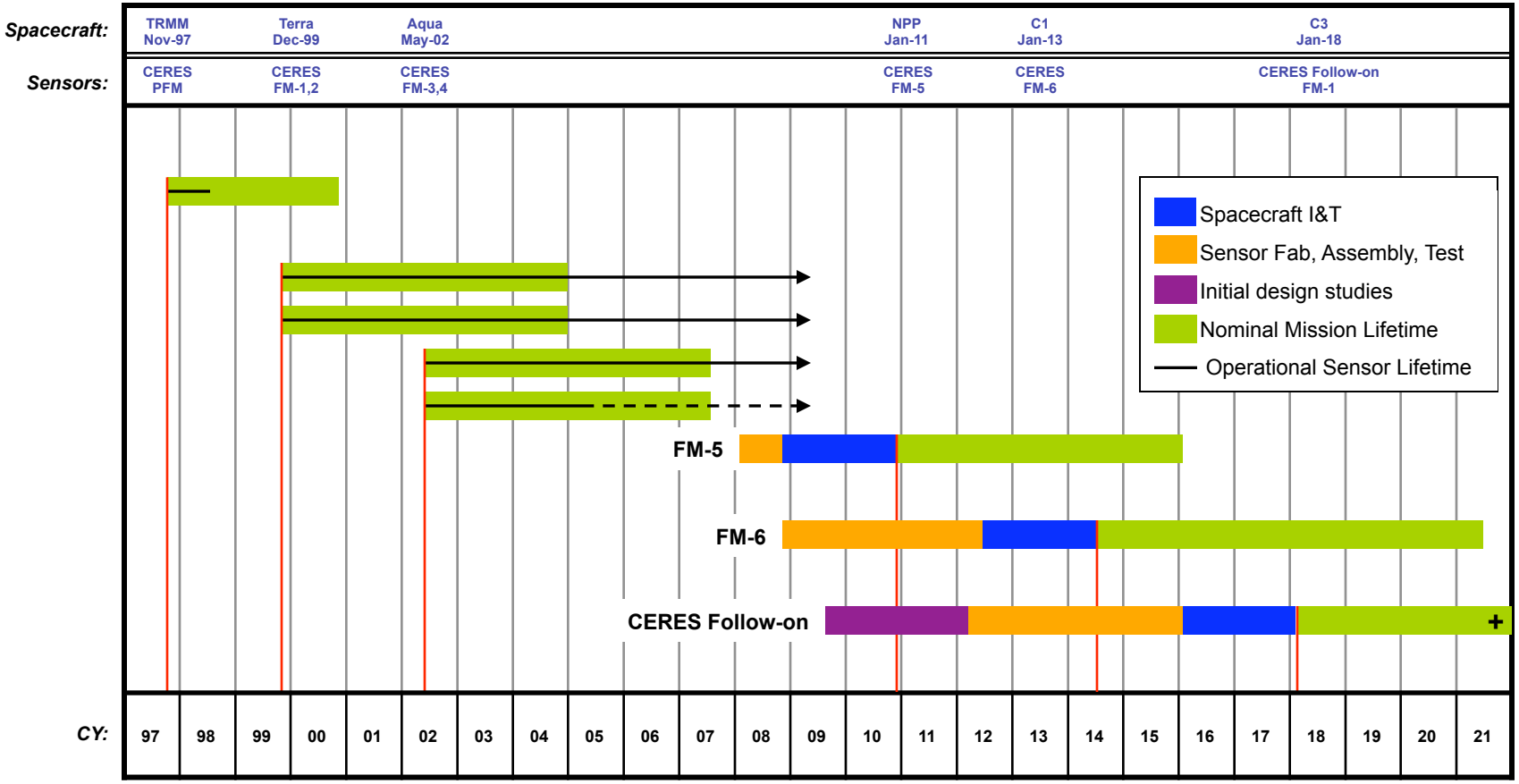
Enabling Climate Data Record Continuity

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	111 +
Aqua	FM3, FM4	5/02	6/02	82 +
NPP	FM5	June 2010	-	-
NPOESS C1	***FM6***	***January 2013***	-	-
NPOESS C3	***CERES follow-on***	***January 2018***	-	-

33 Instrument Years of Data

CERES Flight Schedule

Enabling Climate Data Record Continuity



Radiometric Performance Requirements

CERES is defined as a class 'B' Mission

5-year design Lifetime

Spectral Regions	Solar		Terrestrial		Atmospheric Window
Wavelengths	0.3 - 5.0 μm		5.0 - 200 μm		8 - 12 μm
Scene levels	<100 w/m^2-sr	>100 w/m^2-sr	<100 w/m^2-sr	>100 w/m^2-sr	All Levels
Accuracy Requirements	0.8 w/m^2-sr	1.0 %	0.8 w/m^2-sr	0.5 %	0.3 w/m^2-sr
SOW Stability Requirements		< 0.14%/yr		< 0.1%/yr	
Climate Stability Goals		< 0.6 w/m^2/dec < 0.03 %/yr		< 0.2 w/m^2/dec < 0.02%/yr	

- **Requirements for CERES are more stringent than ERBE's by a factor of 2**
- **Requirements per Ohring et. al. are more stringent than CERES by a factor of 3-5**

Calibrate, Calibrate, Calibrate….

Cal-Val Approach

Pre-Launch

- Implement a rigorous & thorough ground calibration/characterization program
- Responsible for Spacecraft Level I&T activities
- Cal/Val role must be prominent in original proposal and SOW
- System level characterization is typically last test performed prior to delivery of the instrument
- Cost and schedule constraints typically drive programs at that point

Post-Launch

- Implement a protocol of independent studies to characterize on-orbit performance
- Studies should cover all spectral, spatial and temporal scales as well as data product levels
- Continuous development of new validation studies

Data Product Release Strategy

- Develop a logical and well understood approach to data release.
- Minimize the number of Editions/Versions of Data
- Utilize Data Quality Summaries for the community

BDS and ERBE-Like Data Product Release Strategy

Edition1_CV - Static Algorithms and coefficients - baseline product used in cal/val protocol

Edition2 - Utilizes temporally varying coefficients to correct for traceable radiometric drift. All spectral changes are broadband and 'gray'.

Edition3 - Incorporates temporally varying spectral artifacts in the SW and LW measurements.

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

Edition2 products lag Edition1 by a minimum of 6-12 months

Lessons Learned / Future Direction

In the future CERES will fly in a single orbit with one instrument per spacecraft, eliminating key Direct Comparison validation capabilities…

Programmatic Implementation

- Increase weighting/influence of Radiometric Performance in cost/schedule trades
- Maintain positive/open relationship with hardware provider. Avoid 'Us' vs. 'Them' mentality.
  - *LaRC/NGST Team has proven track-record and experience*

Ground Characterization Procedures

- Re-verify traceability of calibration targets
- Establish collaborations with NIST, other international agencies
- Implement automated Data Acquisition System on Calibration Chamber

Operational Mode

- Do not point optics in 'forward' looking direction
  - *Strong Correlation to spectral darkening of SW channel optics*

Onboard Calibration Hardware

- Provide additional SW spectral characterization capability
  - *Stringent measurement requirements demand SW spectral capabilities*

Handling Procedures

- Minimize possibility of contamination
- Develop Inspection and cleaning procedures

Path to ERB CDR Continuity

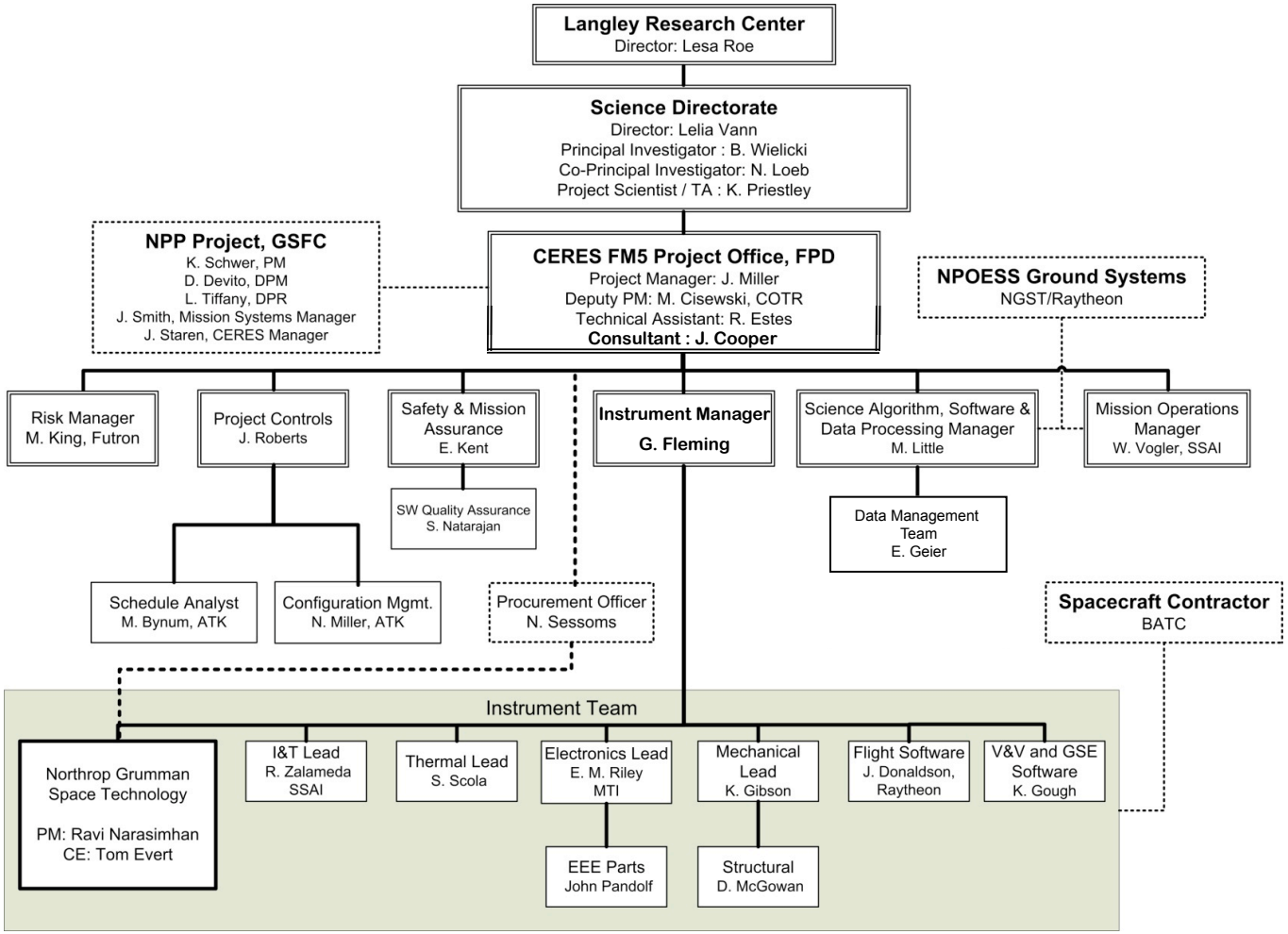
Capability	FM-5	FM-6	CERES Follow-on
Lineage	As-Built	Build to Print, with modest upgrades, Technology Bridge	New Design
Flight Software	Bug fixes, minimal functionality improvements	Bug fixes, minimal functionality improvements	Bug fixes, Full functionality improvements
New Solar Calibration MAM		Yes + enhanced screening	Yes + enhanced screening
Shortwave Internal Cal Source Upgrade*		Minimal Spectral Capability	Multi-spectral Capability
Replace 8-12 μm Channel		5 - 100 Micron	5 - 100 Micron
New Detectors			Yes
"10 km" FOV**			Yes
Ground Calibration	Re-verify sources, revisit procedure	Re-verify sources, update procedures, upgrade data acquisition equipment, enhanced emphasis in SOW	Re-verify sources, update procedures, upgrade data acquisition equipment, enhanced emphasis in SOW

* Updated shortwave requirements based on improved understanding of reflected spectrum from CERES experience

** Nominal improved FOV, final requirement set as part of CERES follow-on instrument study

FM-5 Status

CERES Project Organization



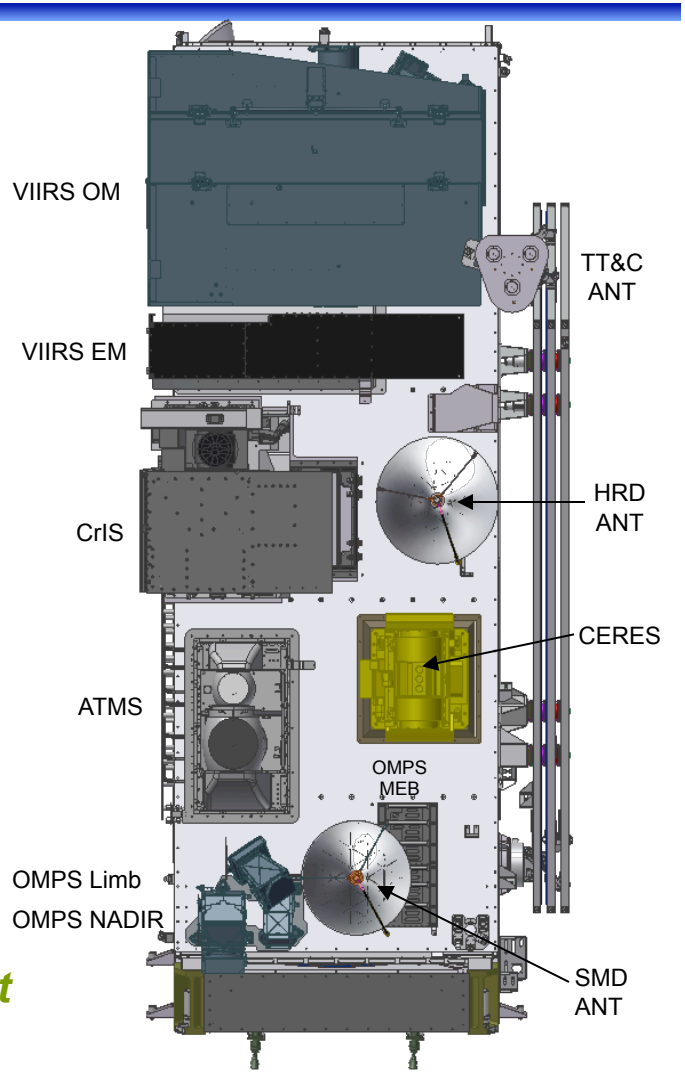
CERES FM5 Hardware Status & Near-Term Activities

- **Fabrication, Assembly and Test Program is complete**
- **Ground Calibration was most extensive to date in the CERES Program**
  - 33 days under continuous vacuum
  - 6 supplemental tests beyond legacy procedure
  - NGST Test Team did an outstanding job…
- **System Acceptance Review 10/30 at NGST**
- **Shipped to BATC on 11/2/09**
- **Mechanical/Electrical Integration to NPP spacecraft completed 11/11/08**
  - **P12 Connector Replacement completed 1/27/09**
- **System End-to-End Test completed 2/12-26/09**
- **Ground Calibration TIM at NGST 3/26/09**
- **Spacecraft Environmental Campaign 1-6/10**
- **NPP Launch Readiness Date is currently NST June 2, 2010**
  - Initial NPP launch date was mid-2006
  - Earliest 'feasible' launch date is Jan. 2011
  - Realistic launch date is late 2011

CERES Authorized for Flight on NPP

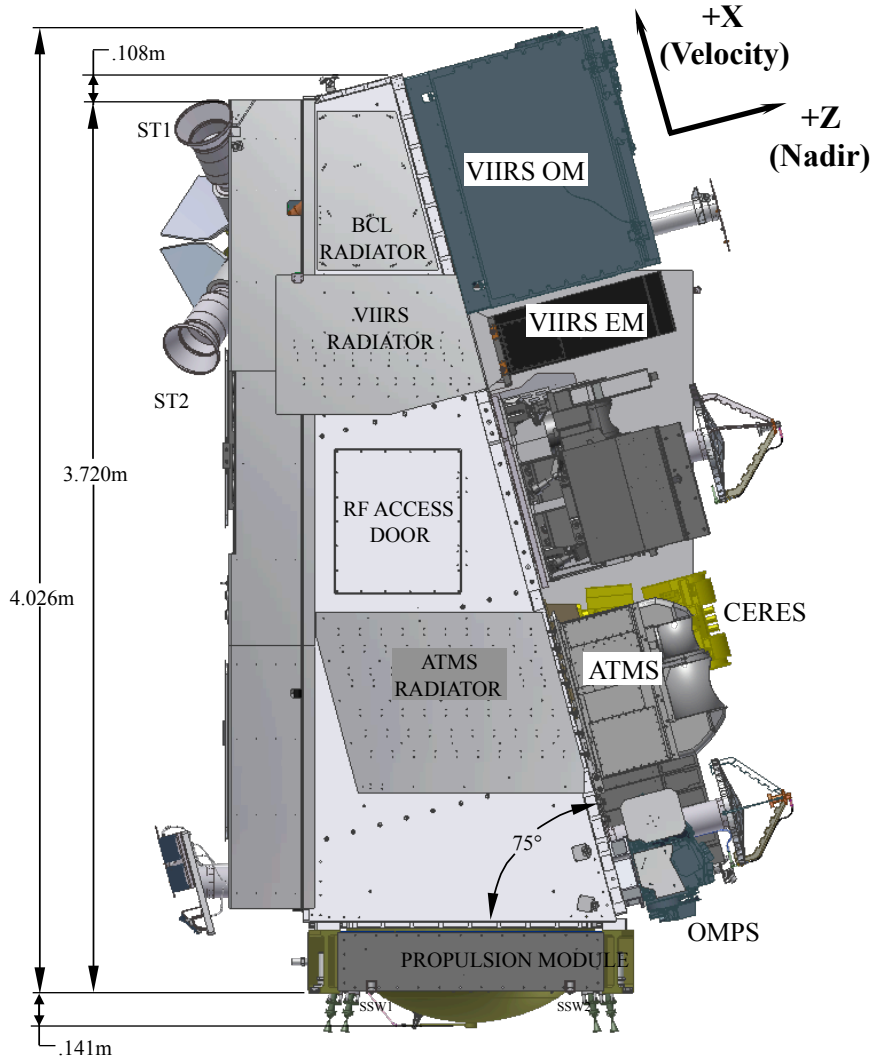
NASA HQ authorized multi-phase study in 2007 to assess feasibility of adding CERES back on NPP

- **Phase 1: Initial Feasibility Study (February – May 2007)**
  - Passed the sanity test
  - Recommended progression to Phase 2
- **Phase 2: Detailed Analysis and Engineering design (June 1, 2007 – September 14, 2007)**
  - Identified instrument, spacecraft & ground system modifications
  - No technical or schedule barriers identified
  - Results indicated CERES could be accommodated without impacting Sept. 2009 (now 6/10) Launch Readiness Date
- **Phase 3: Implement CERES Accommodation on NPP (October 15, 2007 – July 2008)**
  - Sensor ATP granted 1/23/08



CERES originally carried as part of NPP mission but not approved at Mission Confirmation Review in Nov 03.

CERES Compatibility with NPP Spacecraft

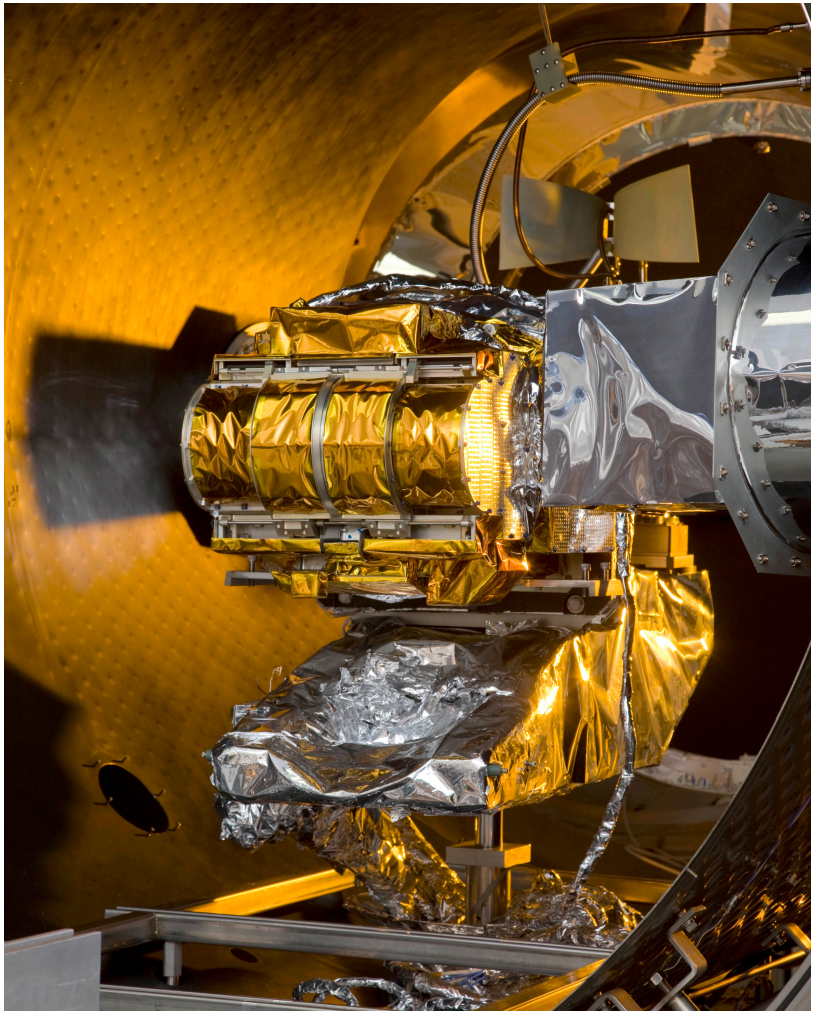


Observatory Information

- Launch Readiness - June, 2010
- Location - Vandenberg AFB
- Launch Vehicle - Delta II
- Altitude - 824 Km
  - CERES FOV increases to ~ 24Km
- Inclination - Sun-Synch, 98.7-deg
- Crossing Time - 1:30pm, Ascending
- Payload -
  - CERES
  - VIIRS
  - OMPS
  - CRIS
  - ATMS

Radiometric Calibration Complete

Radiometric Calibration Facility



NPP Program Status

- **All of the NASA elements (i.e. launch vehicle, spacecraft, CERES, ATMS) of the program are on schedule…**
- **Due to significant delays with the NGST/NPOESS led procurement of the VIIRS sensor, and it's resulting impact on the NPOESS program, everything with regard to NPP is now on the table…**
- **Scenarios being re-considered include, but are not limited to :**
  - Wait for VIIRS (fly as-is, less than fully functional)
    - Unknown schedule/cost impact
  - *Replace VIIRS with AVHRR*
    - *Estimated 2-year schedule delay*
  - *Replace VIIRS with a cloud 'camera'*
    - *Unknown delay*
  - *Fly with no imager*
    - *No schedule delay*
  - *Cancel NPP*

FM-6 Status

CERES FM6 Status & Near-Term Activities

- Project received ~$5M for FM6 in FY09
- Allowed for enhanced study phase only, start 11/08
  - review of legacy processes and procedures
  - Initial Spacecraft/sensor ICD development
  - Upgraded internal calibration equipment design studies
- Long Lead item procurements authorized 3/09
- Contract negotiations completed 4/23/09
- Key Milestone Dates (Preliminary)
  - Authority To Proceed – 5/1/09
  - Systems Readiness Review – June 2009
  - Delta Preliminary Design Review – January 2010
  - Delta Critical Design Review – July 2010
  - Delivery – July 2012
  - Launch Readiness Date of May 2014

Path to ERB CDR Continuity

Capability	FM-5	FM-6	CERES Follow-on
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Flight Software	Bug fixes, minimal functionality improvements	Bug fixes, minimal functionality improvements	Bug fixes, Full functionality improvements
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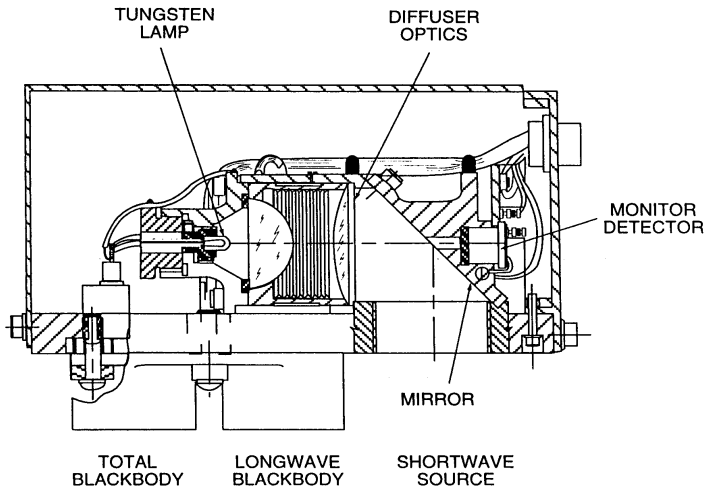
** Nominal improved FOV, final requirement set as part of CERES follow-on instrument study

CERES FM6 Onboard SW Calibration Equipment

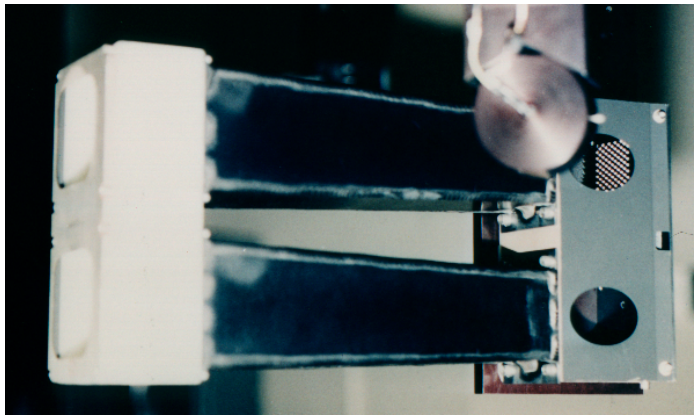
Shortwave Spectral Internal Module (SSWIM)

- Legacy Evacuated Tungsten lamp with supplemental 'blue' LED
- Ability to vary strength of legacy lamp preserved (2 vs. 3 levels)
- New Photodiode monitor(s) for independent monitoring of source outputs
- Design goal is 0.1% stability over 5-year mission
- Designed primarily to spectrally resolve changes in optical transmission

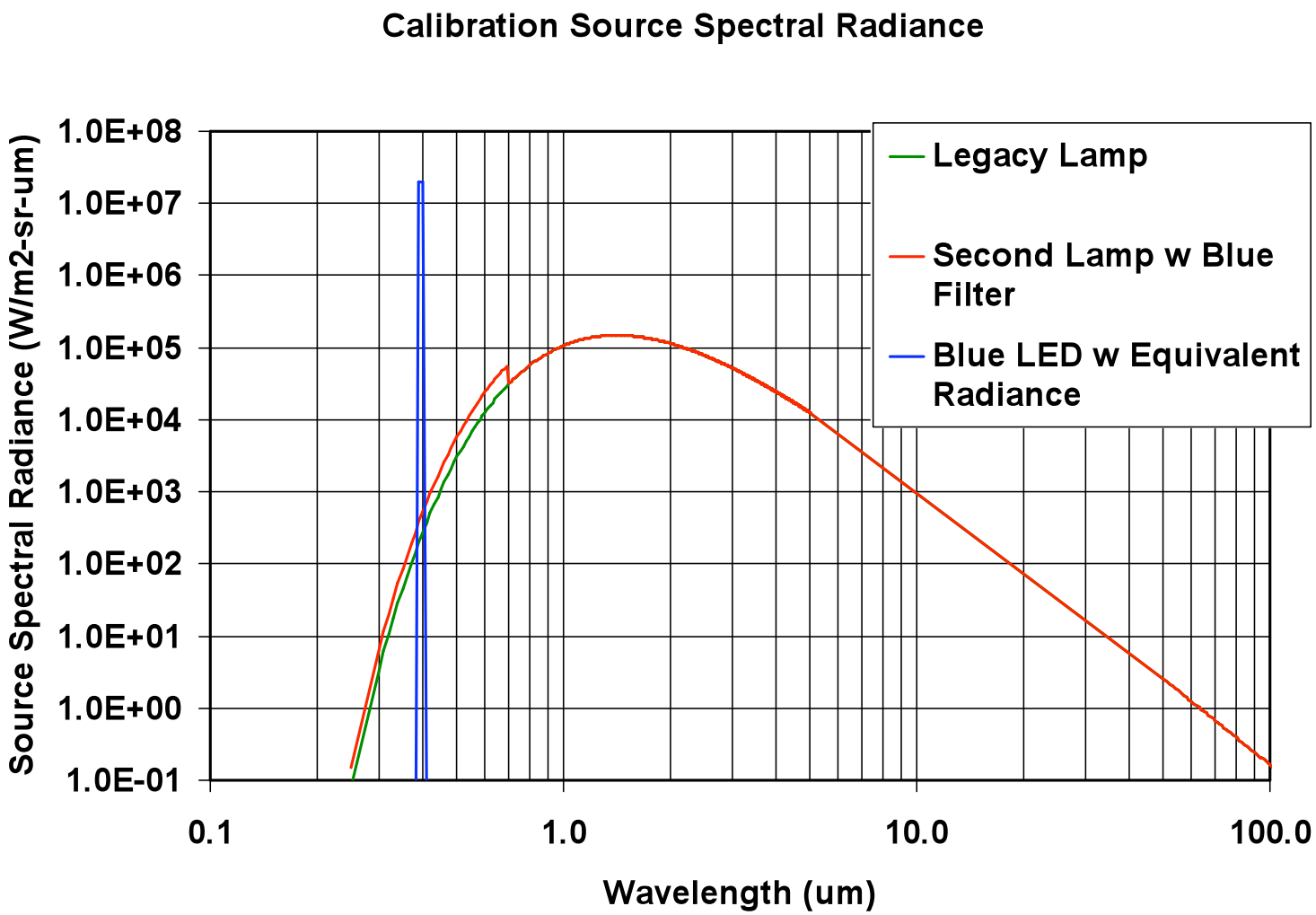


Mirror Attenuator Mosaic (MAM) Solar Diffuser

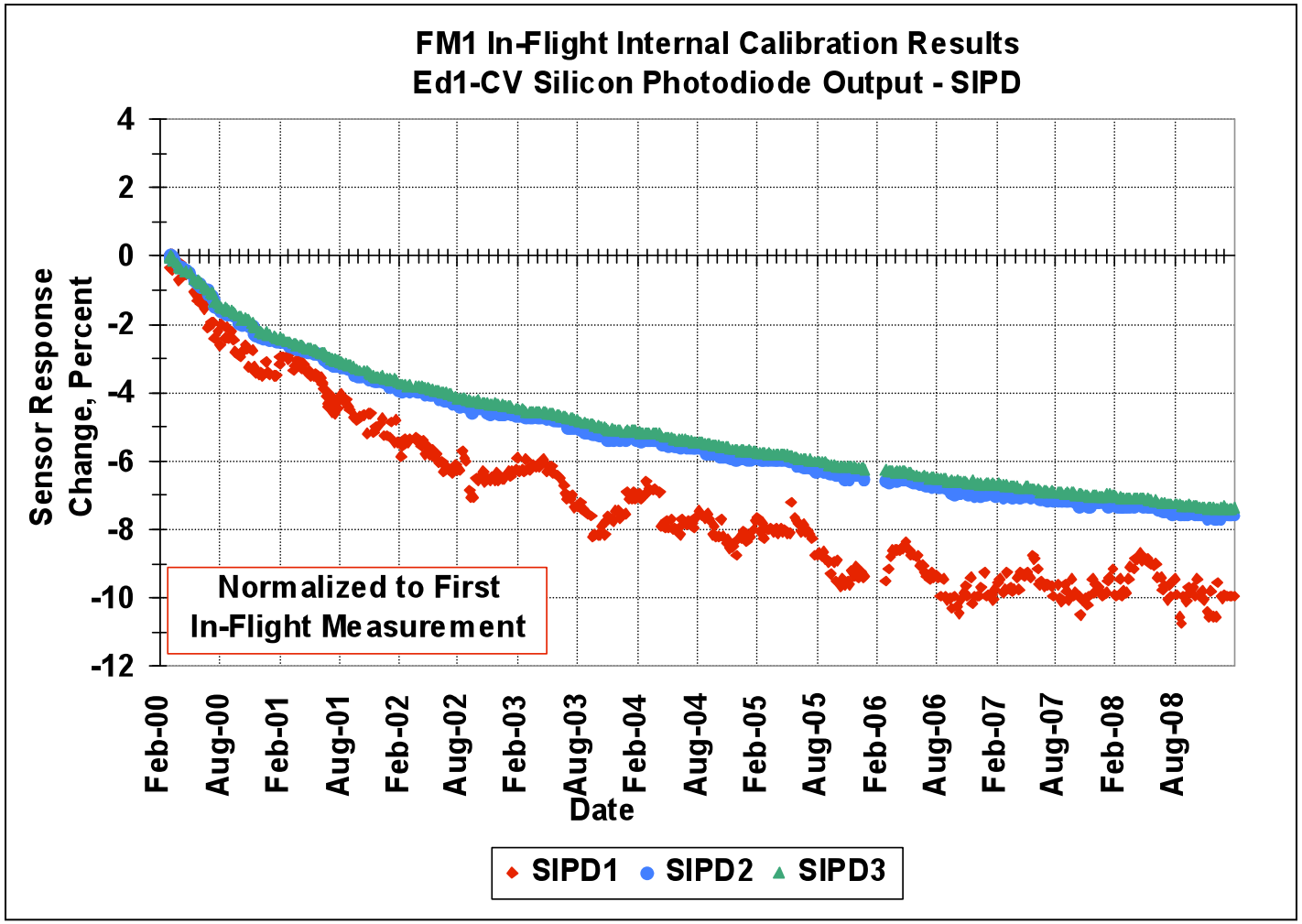
- Solar Diffuser plate attenuates direct solar view (~5800K Spectrum)
- MAM is currently a Nickel substrate with Aluminum coated spherical cavities or divots
- Provides a Relative calibration of the Shortwave channel and the SW portion of the Total channel
- Designed to provide a long-term on-orbit SW calibration source.



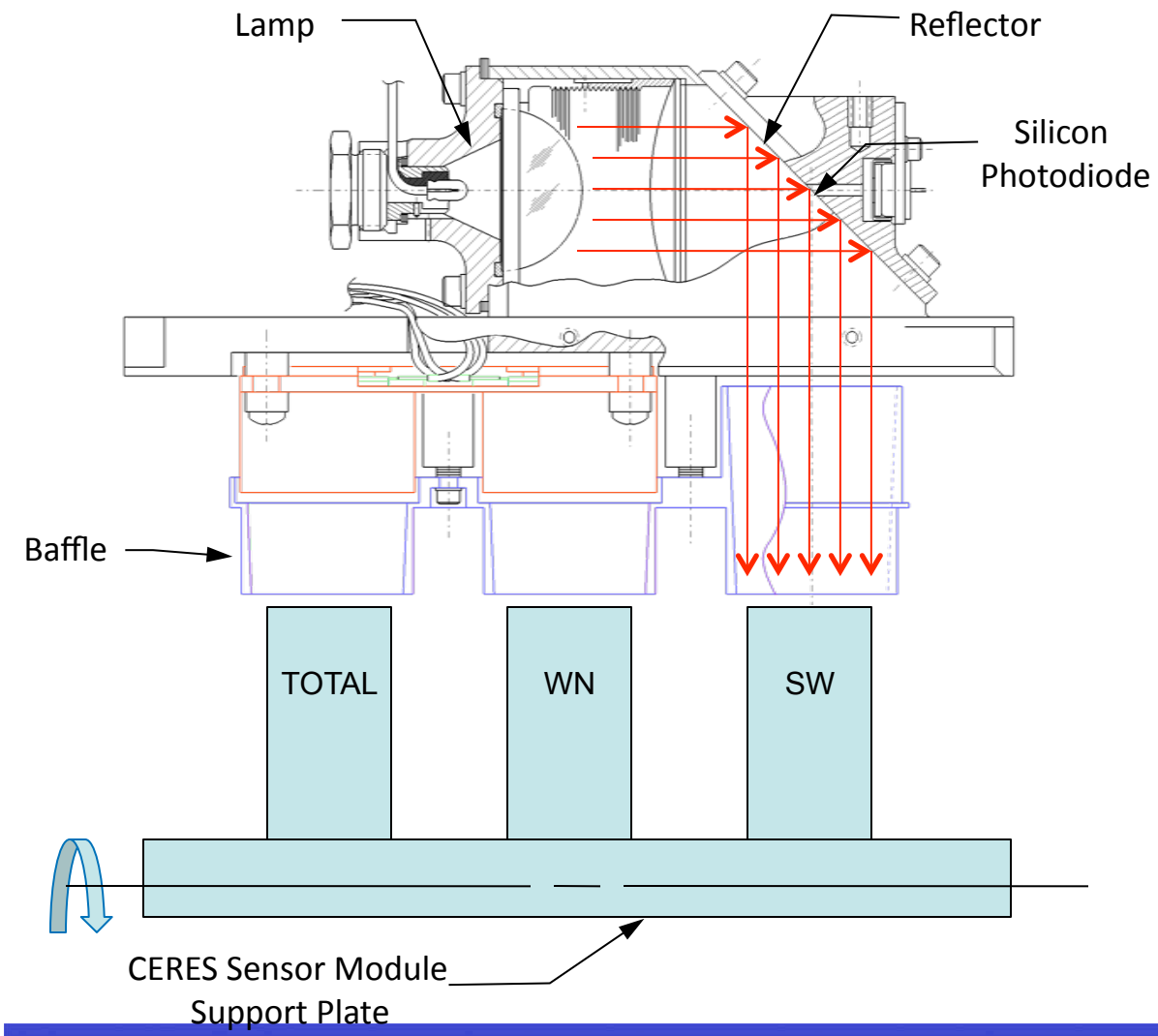
LED vs. Heritage Lamps

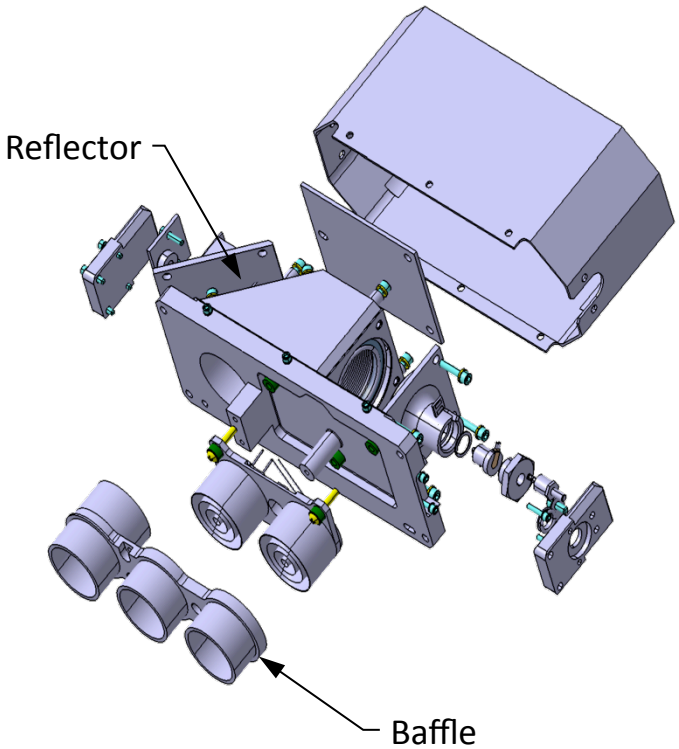


SWICS Photodiode Degradation

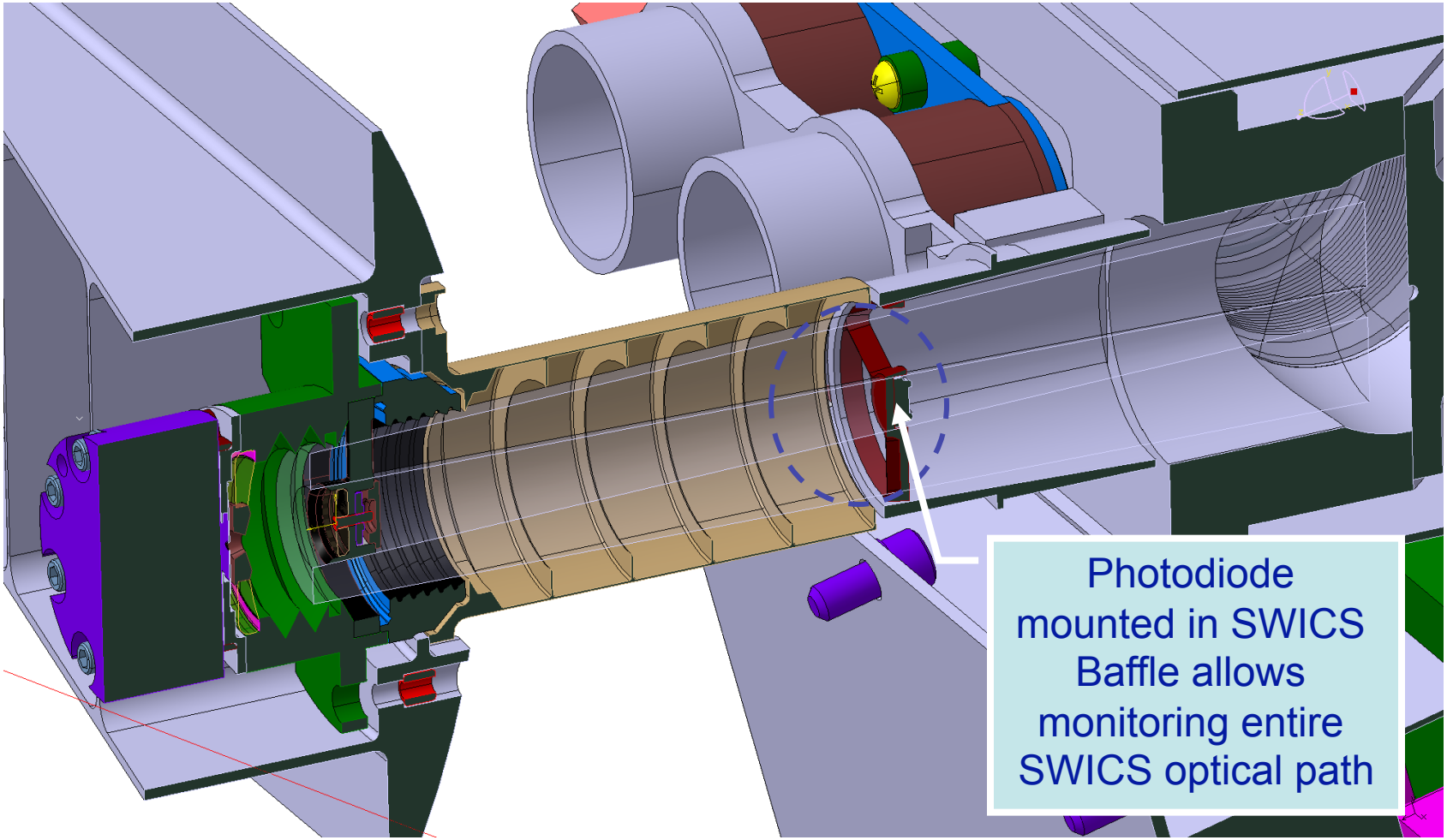


CERES SWICS/IBB Assembly

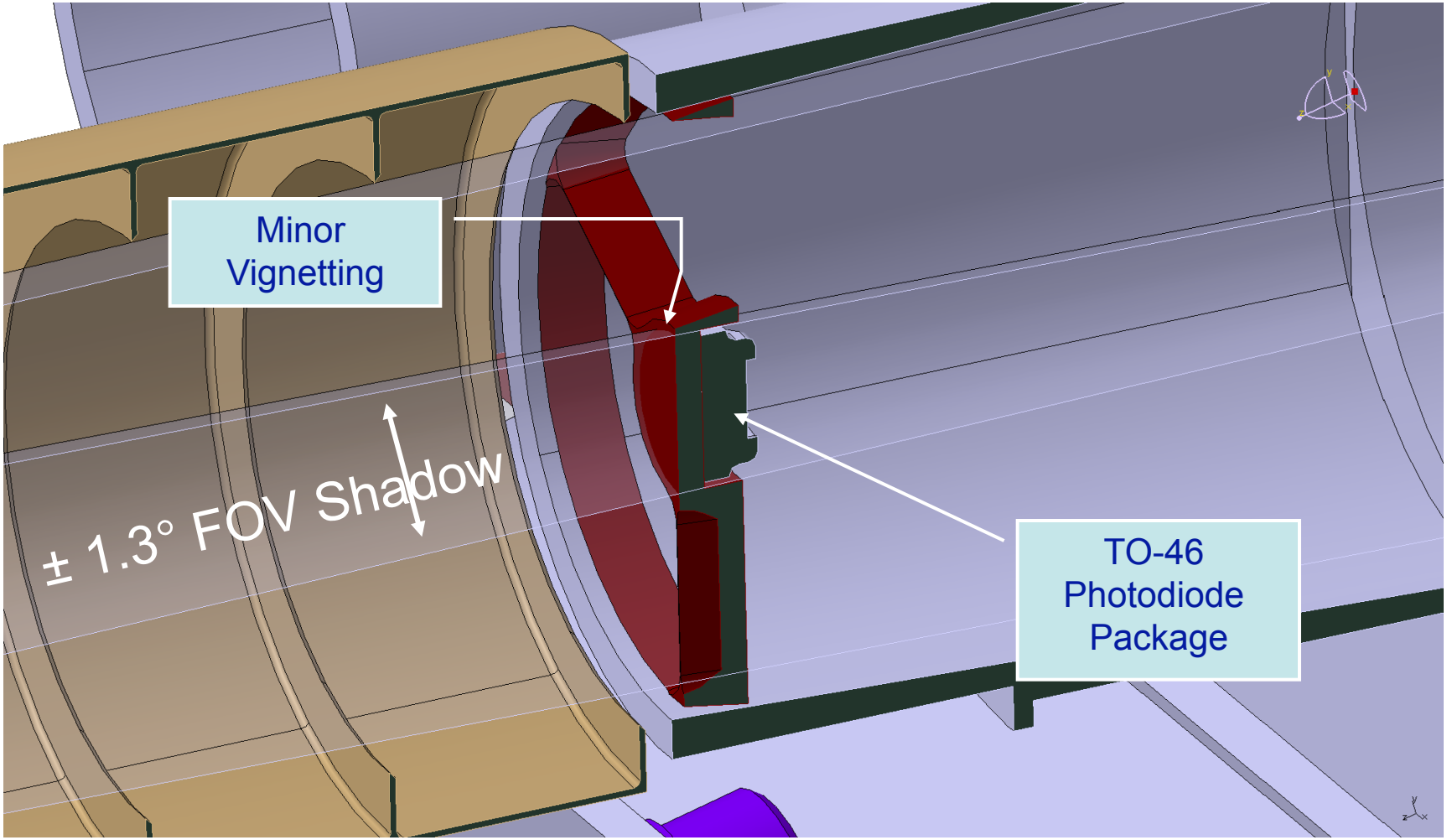




Photodiode Relocation Concept (1 of 2)



Photodiode Relocation Concept (1 of 2)



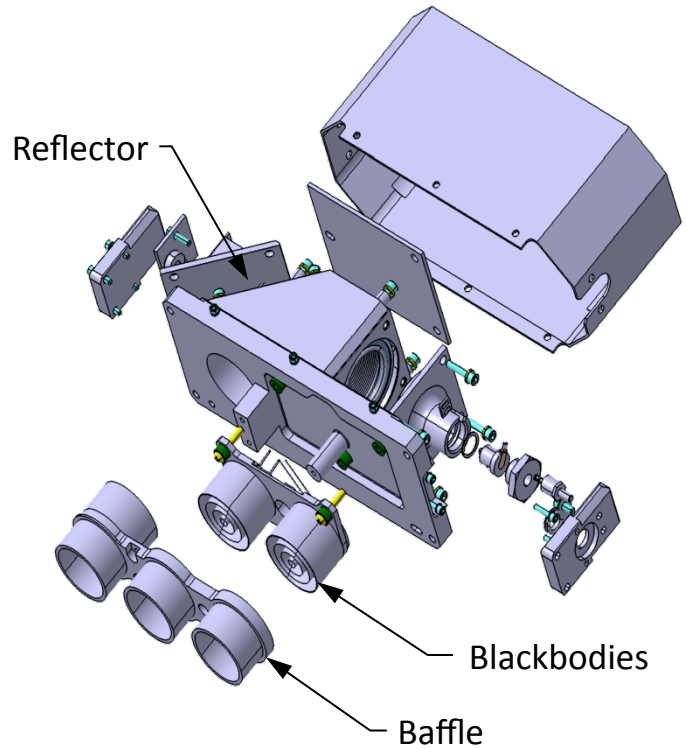
SWICS Electronics Approach

- **Lamp voltage measurement**
  - Differential measurement- no new circuitry
  - Connect Lamp high/low sides to spare analog telemetry channels
  - Voltage may be calculated in post-processing
  - Add select switch if more than 1 lamp
- **Accommodate 2nd Lamp or LED**
  - Use existing lamp drive circuitry
  - Lamp and LED drives have similar requirements
    - <5v, <500mA
    - Drive current stability of ± 0.1%
  - Upgrade components as necessary (power transistor, etc.)
    - Additional 5-10W DAA power needs to be dissipated
  - Add select switch
  - Utilize spare telemetry output channels

CERES FM6 Onboard LW Calibration Equipment

Internal Flight Calibration BlackBody (IFCC)

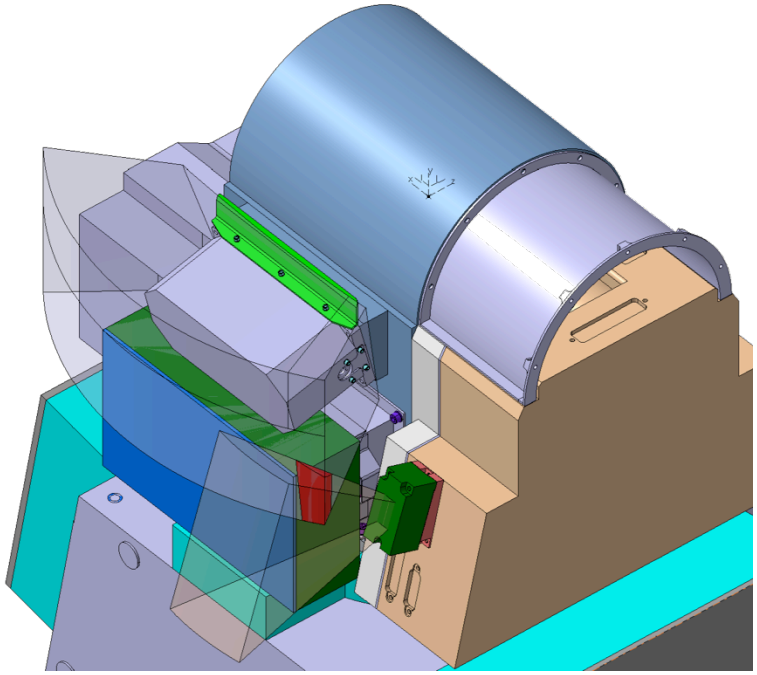
- Legacy IBB was designed for an operational temperature range of 10 to 25 deg C.
- New threshold range of 0 to +60 deg. C
- Objective threshold range of -20 to +60 deg. C
- Baseline Concept
  - Couple an thermally isolated passive heat sink to ICS blackbodies for sub-zero °C cooling
  - Use legacy BB heaters and control loop to regulate BB's at calibration

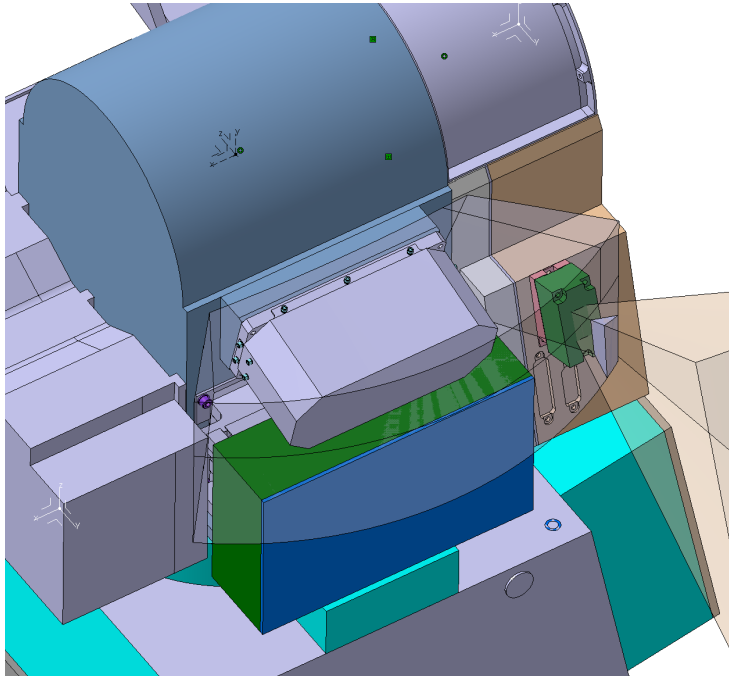


Maximum Allowable SWICS/ICSBB Volume

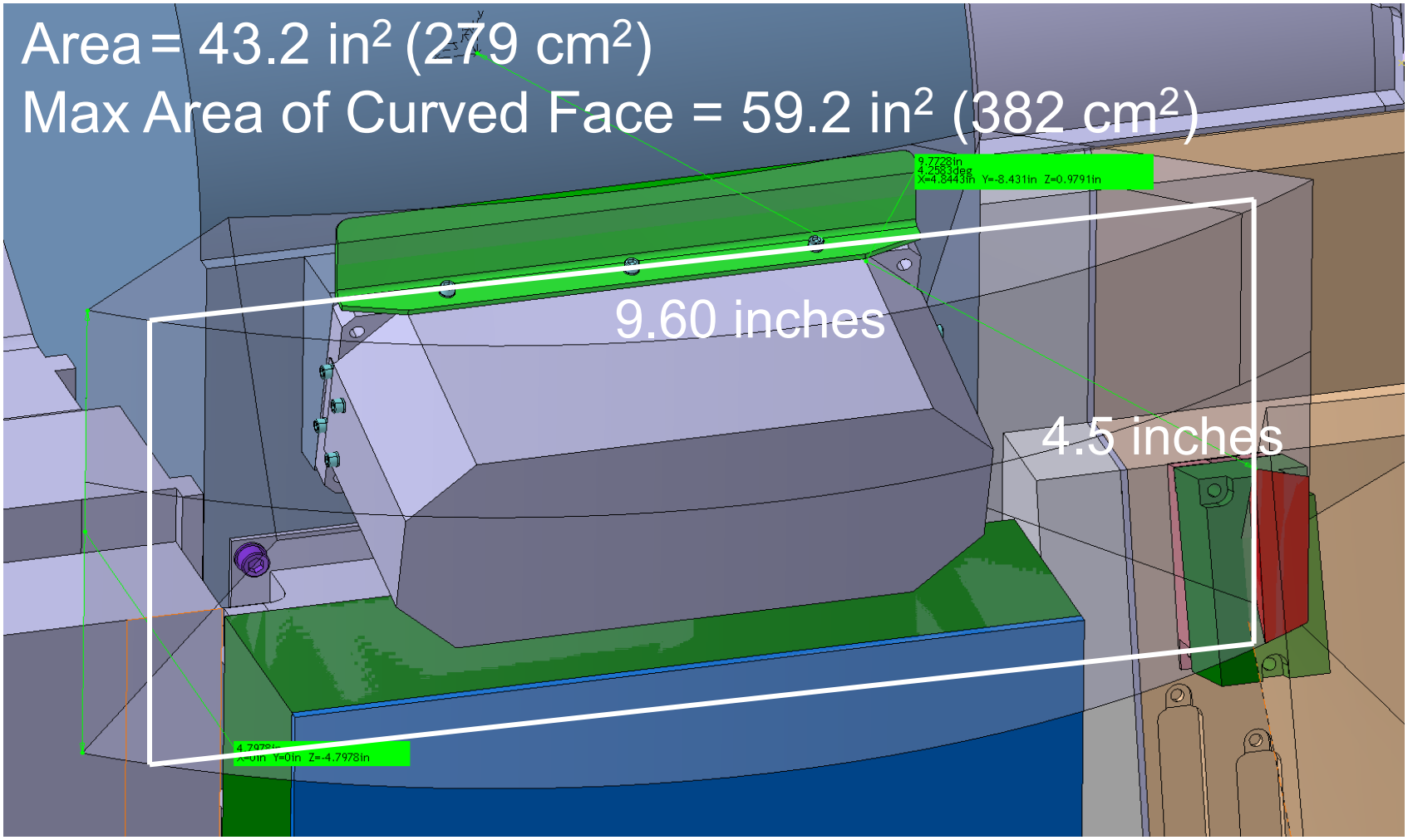
Constrains radiator area and overall design growth

- Volume accounts for extending max radial swept extent of CERES
- Is flush to top of DCA, tangent to ECA and DAA
- Small interception of SPS FOR (±12°, ±22° about normal at center of aperture)
- Is height limited by calibration scan baffle to prevent sensor from viewing glint

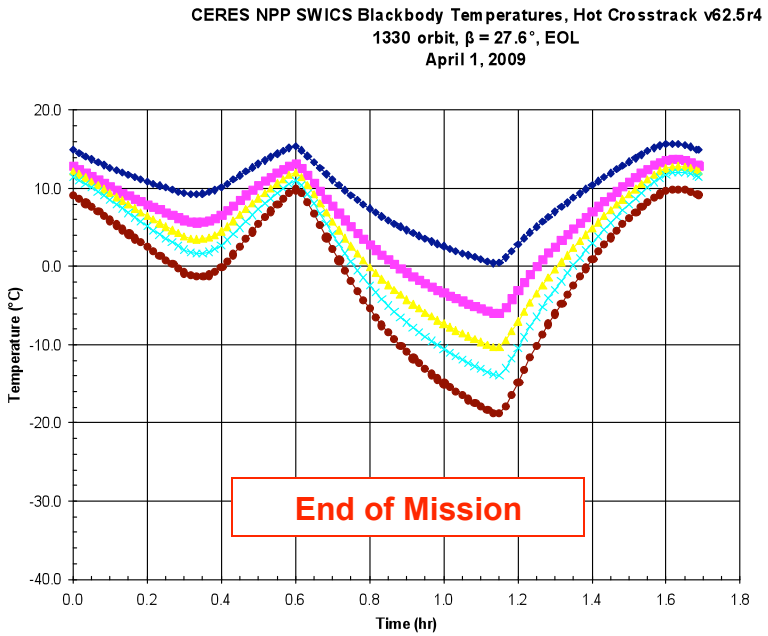


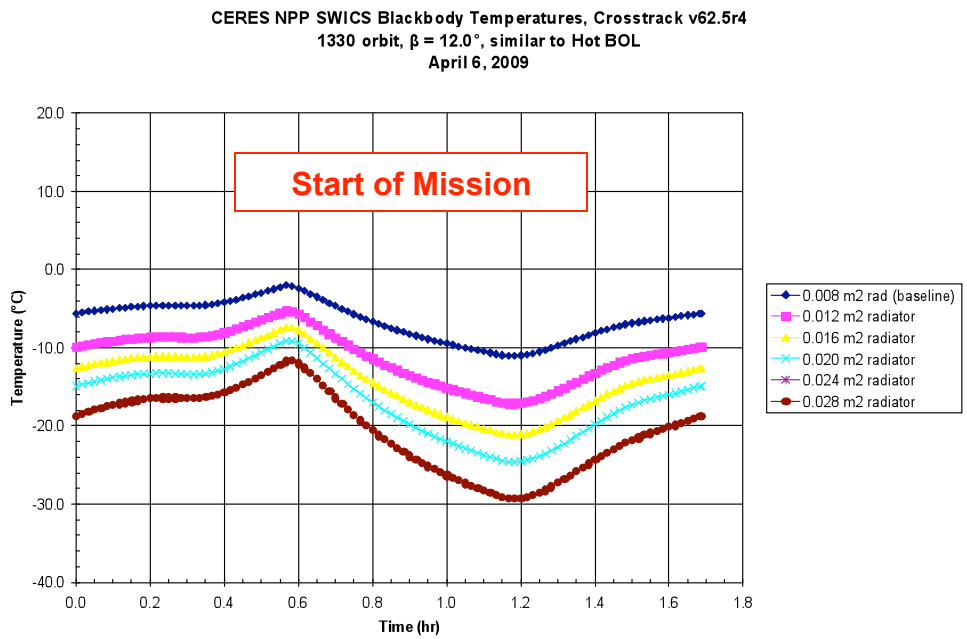


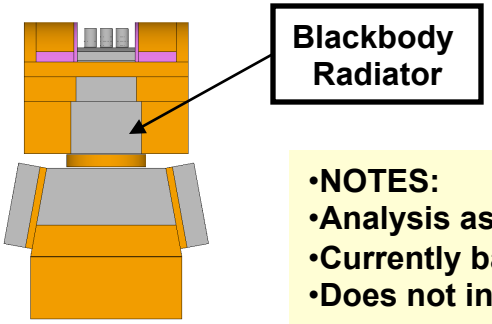
ICSBB Preliminary Maximum Radiator Area



Preliminary FM6 IBB Thermal Analysis







- **NOTES:**
- **Analysis assumes floating IBB temperature with no heater power applied**
- **Currently based on NPP configuration, not NPOESS 1330 configuration**
- **Does not include extra thermal masses, heaters, or other thermal control hardware**

Edition 2 Status

Why is Edition2 Calibration so difficult?

A question of time scales, experience and balancing accuracy with providing data products to the community.

- Edition2 Radiances have been released on ~6 month centers
- 6 months is just a blink of an eye when analyzing long term trends…

Same time scale as phenomena which influence instrument response
- Beta Angle
- Earth Sun Distance
- Orbital shifts
- Instrument Operational modes (I.e RAPS vs. Xtrack)

Complicates separation of instrument 'artifacts' from natural variability.

Edition3 reprocessing of the first 5 years of CERES radiances allows a much more rigorous identification and separation of instrument artifacts and true climate signals.

Terra/Aqua Edition2 Availability

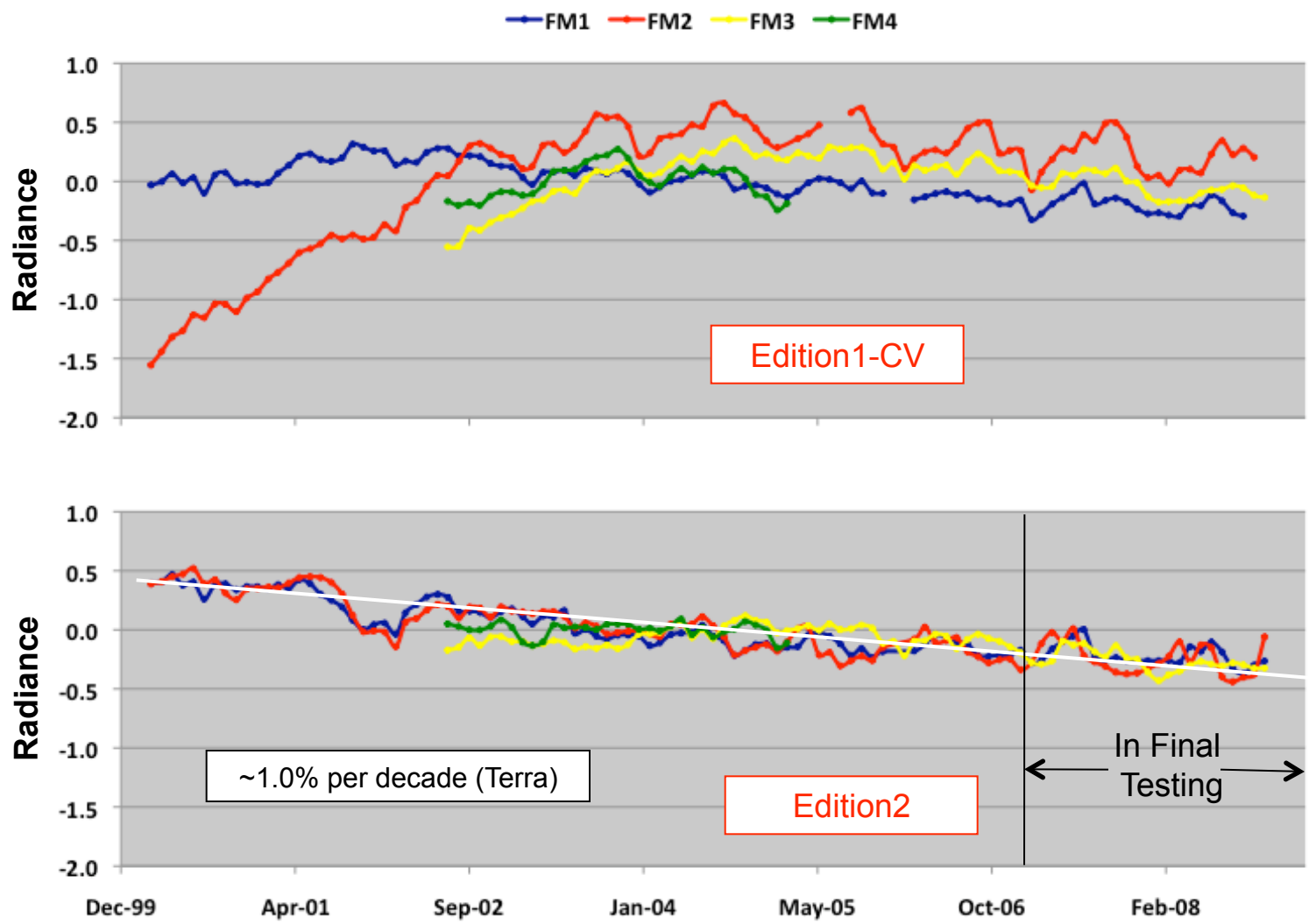
Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98 , 3/00
	ERBE-Like	Edition1	Yes	1/98 - 8/98 , 3/00
		Edition2	Yes	1/98 - 8/98 , 3/00
Terra	BDS	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 12/08
	ERBE-like	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 12/08
Aqua	BDS	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/08
	ERBE-like	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/08

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

CERES/EOS Edition2 Cal-Val Protocol

		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

Tropical Mean : LW Day Night Difference Trends



Data Set

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

CERES Unfiltered Radiance Summary

•Cal/Val Protocol demonstrates radiometric stability of the data products through 12/2006 of….

	Edition1_CV				Edition2				Edition2_Rev1				Edition 3 (Anticipated)			
	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4
LW_{day}	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15	<.1	<.1	<.1	<.1
LW_{night}	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25	<.1	<.1	<.1	<.1
WN	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	<.1	<.1

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

CERES Edition2 Calibration Summary

Residual calibration errors in CERES Edition2 data products are dominated by spectral degradation of sensor optics in the reflected solar bands. (SW and SW/TOT)

This results in

- **Artificial decreasing trend in the reflected solar measurements**
- **Divergence between daytime and nighttime OLR records with time.**
  - **LW_{day} = Total - Shortwave**
  - **LW_{night} = Total**

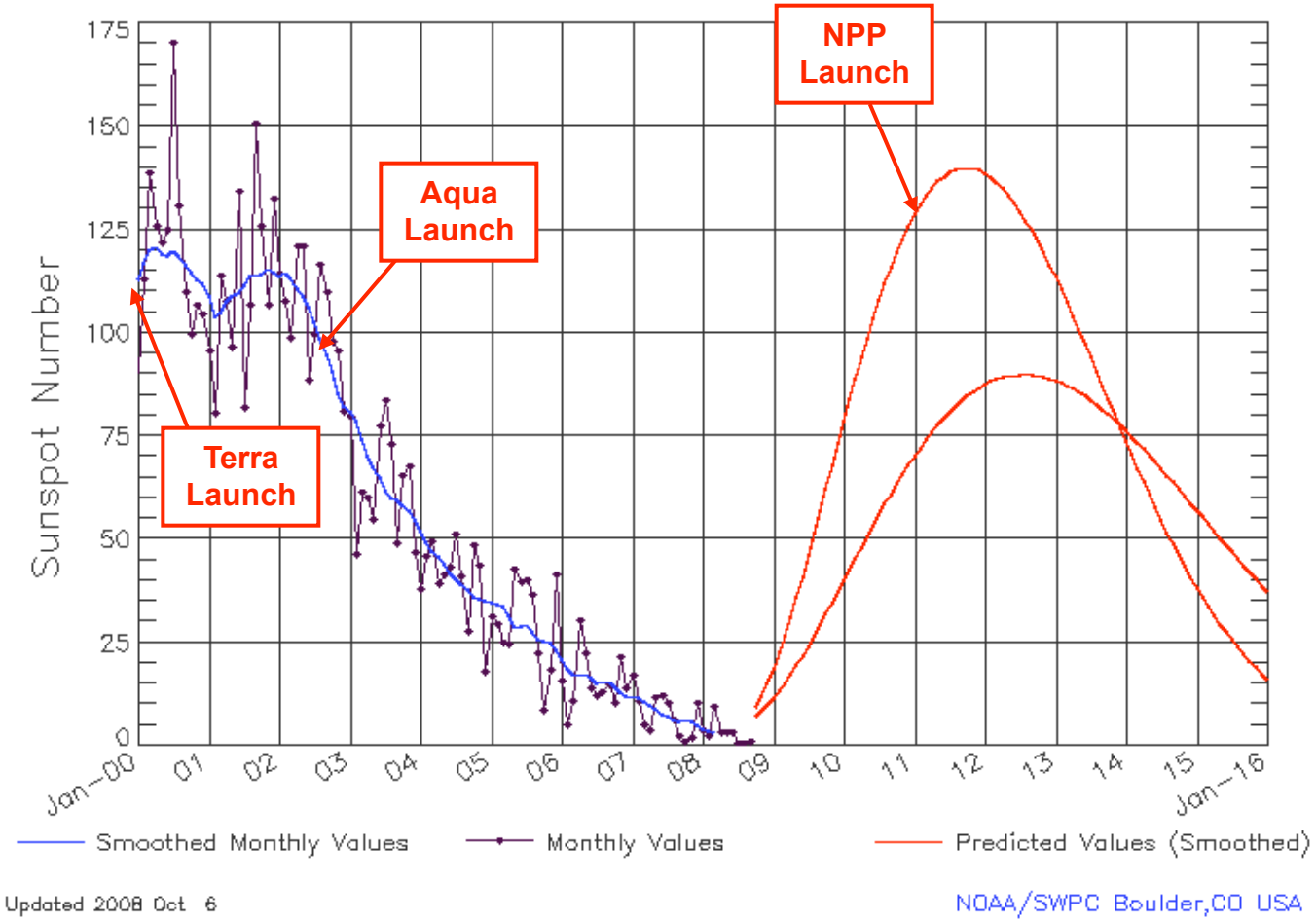
Occurs on all four CERES EOS sensors to varying degrees

Highly correlated to several factors

- **Operational Mode**
- **Solar Cycle**
- **Atomic Oxygen fluence levels**

Instability of the Solar Diffusers (MAM's) and lack of adequate Spectral knowledge in the onboard SW sources greatly complicates the characterization and removal of this phenomena

Solar Cycle Sunspot Number



Edition3 Studies
&
Omega-1 Results

Edition3 Studies : Path Forward

The plan moving forward consist of 3 separate efforts

Effort 1 - Gain Adjustments

Instrument Group will incorporate all known, physically based changes in gain and other calibration coefficients for each instrument,

- Use internal cals
- Thermal Environment impacts
- Incorporate Scan Dependent offset measurements determined on-orbit
- Apply Edition 2 Cal/Val protocol to the full 6-year dataset as opposed to 6 month intervals

Develop and implement a method of placing all CERES instruments on the same radiometric scale at mission start.

- Reanalysis of Ground calibration data will yield new at launch gains and Spectral Response function.
- Utilize satellite intercomparisons

Edition3 Studies : Path Forward

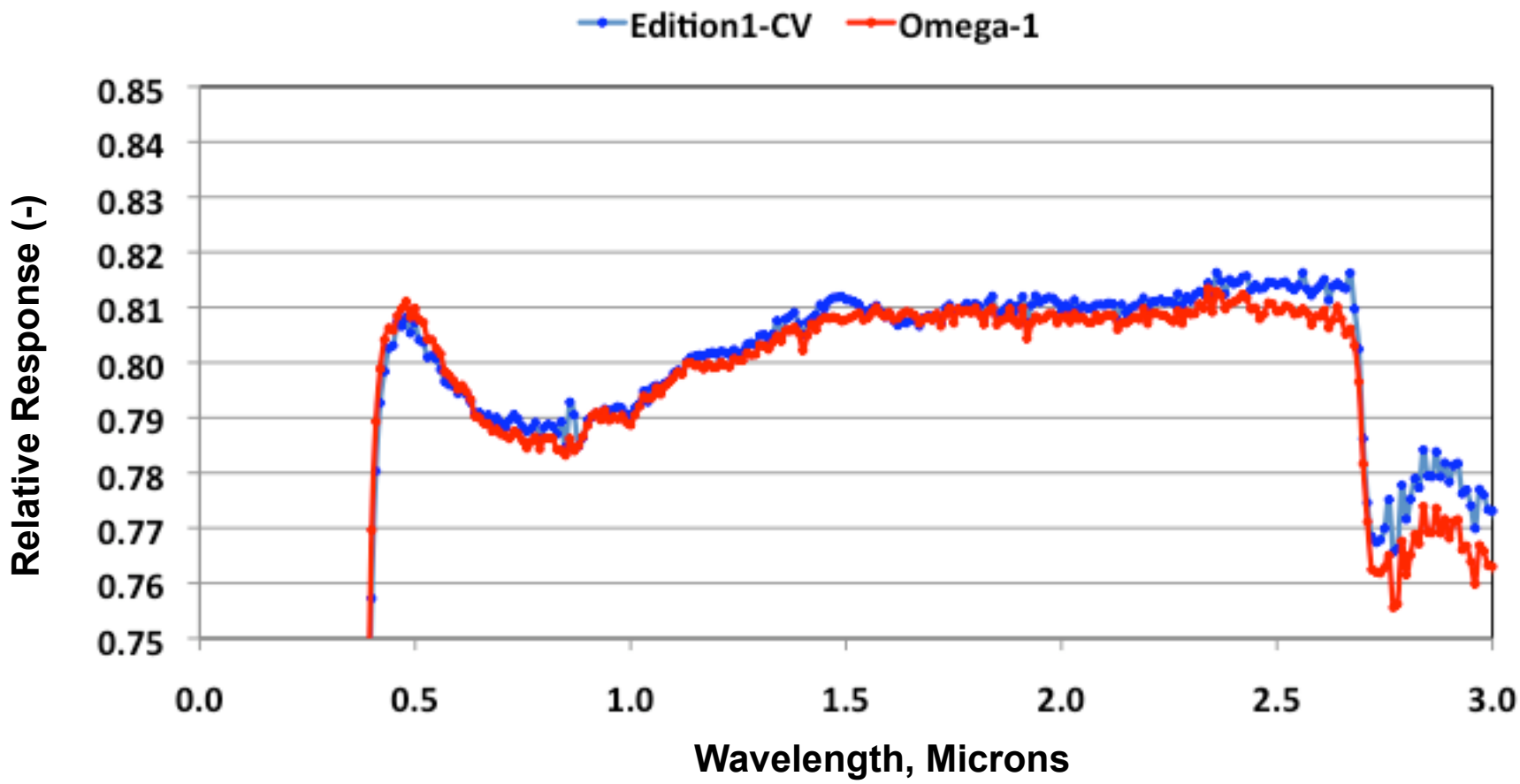
Effort 2 – Determine Beginning of Mission Spectral Response Functions

- Reassess beginning of mission spectral response functions derived from the ground calibration program.
- Incorporate knowledge gains made in the ground calibration protocol to reduce uncertainties

Effort 3 - Determine "Optimal" SRFs from Direct Compare approach.

- The concept is to "retrieve" RAP instrument SW SRFs each month from a pre-populated set of candidate SRF's with varying degrees of spectral degradation.
- Nadir Direct comparisons are completed for each of the SW channels for Clear Ocean.
- "Optimal" SRF retrieval yields the smallest XTRACK-RAP "direct compare" nadir radiance difference in a given month.

FM1 SW Spectral Response Function



SW Spectral Response Change

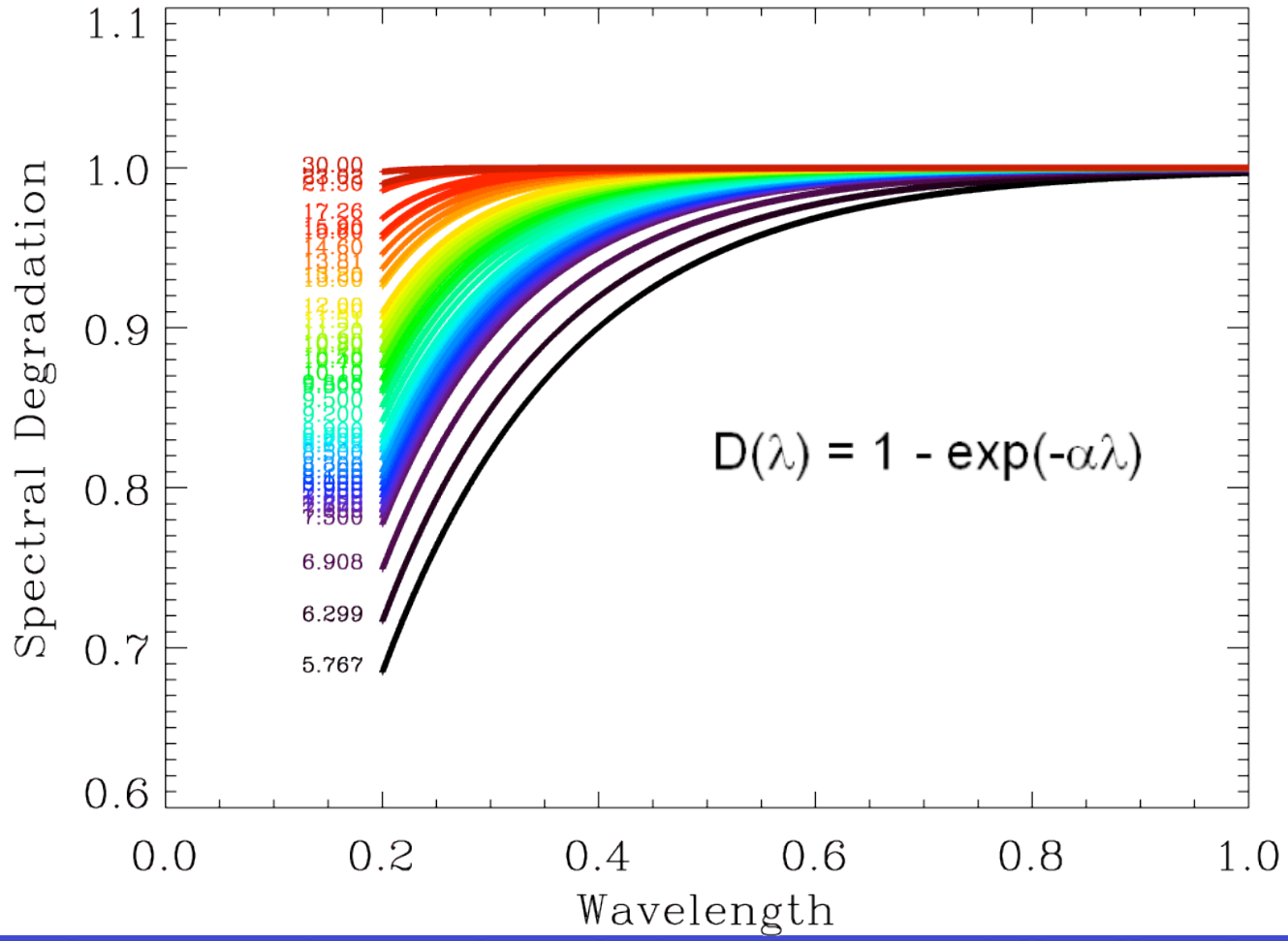
Using Direct Nadir Radiance Comparisons - FM1 and FM2

Method 1:

- Determine time-varying gains from onboard internal calibration.
- Assume any temporal variation in FM2/FM1 SW unfiltered radiance ratio is caused by changes in spectral response function (SRF) only.
- Infer SRF for each month that ensures constant unfiltered FM2/FM1 SW radiance ratio throughout mission.
  - ⇒ Compare spatially/temporally matched nadir FM1 & FM2 footprint radiance pairs.
  - ⇒ Assume SRF changes only occur for instrument in RAP mode.
  - ⇒ Select SRF from a set of “candidate” SRFs with varying degrees of spectral darkening that ensures constant unfiltered FM2/FM1 SW radiance ratio.
  - ⇒ Apply to different scene types (clear ocean, all-sky, forest, desert, etc.)

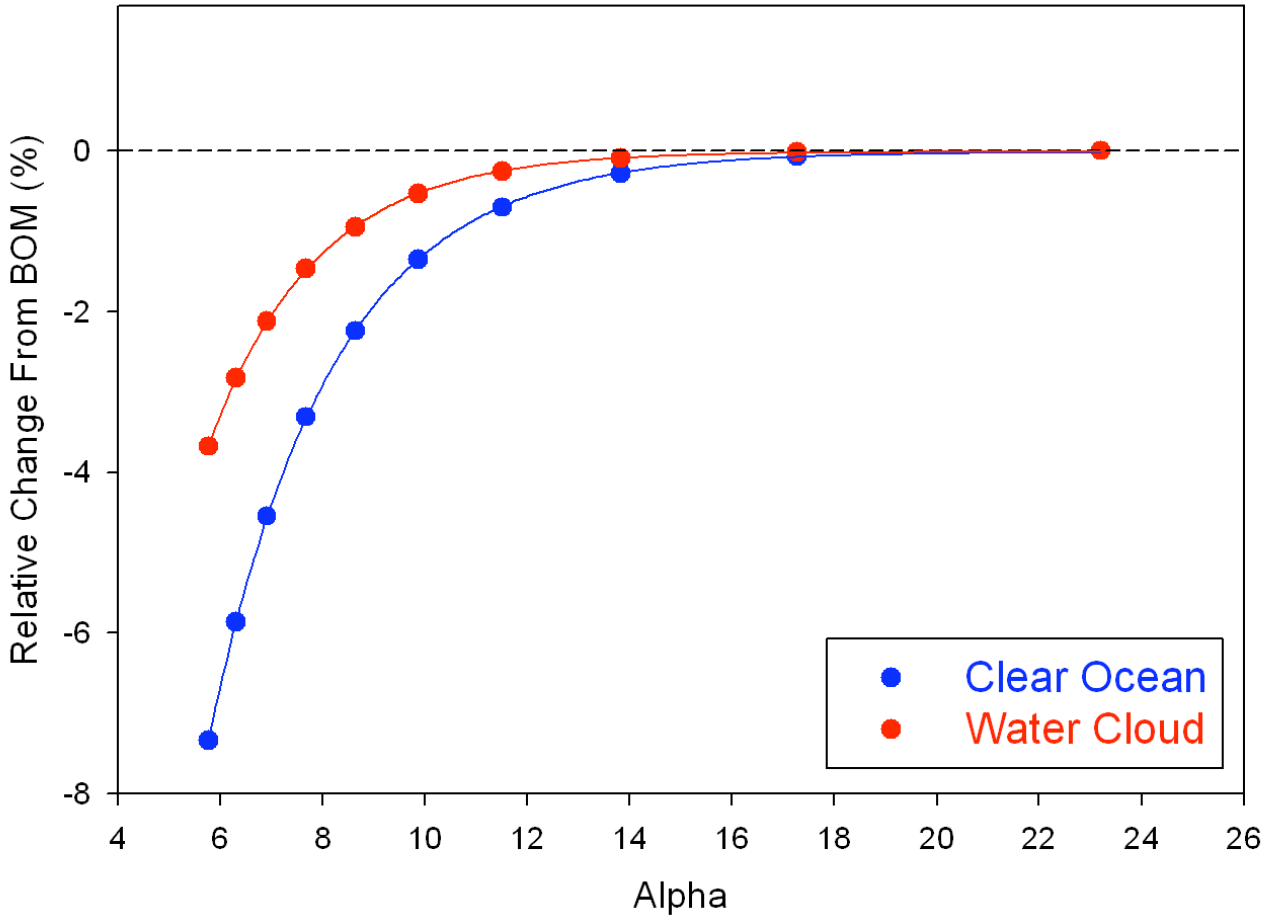
SW Spectral Response Function Changes

(Spectral Darkening Curves used to Derive “Candidate” SRFs)



Sensitivity of SW Filtered Radiance to Alpha

Approximate Relationship Between Spectral Darkening Parameter Alpha and SW Radiance Change Since Beginning of Mission (BOM)



SW Spectral Response Change

Using Direct Nadir Radiance Comparisons - FM1 and FM2

Method 2:

- Determine time-varying gains from onboard internal calibration.
- Assume a radiance spectrum from MODTRAN to simulate the time dependence in FM2/FM1 filtered radiance ratio.
- Assume SRF changes only occur for instrument in RAP mode.

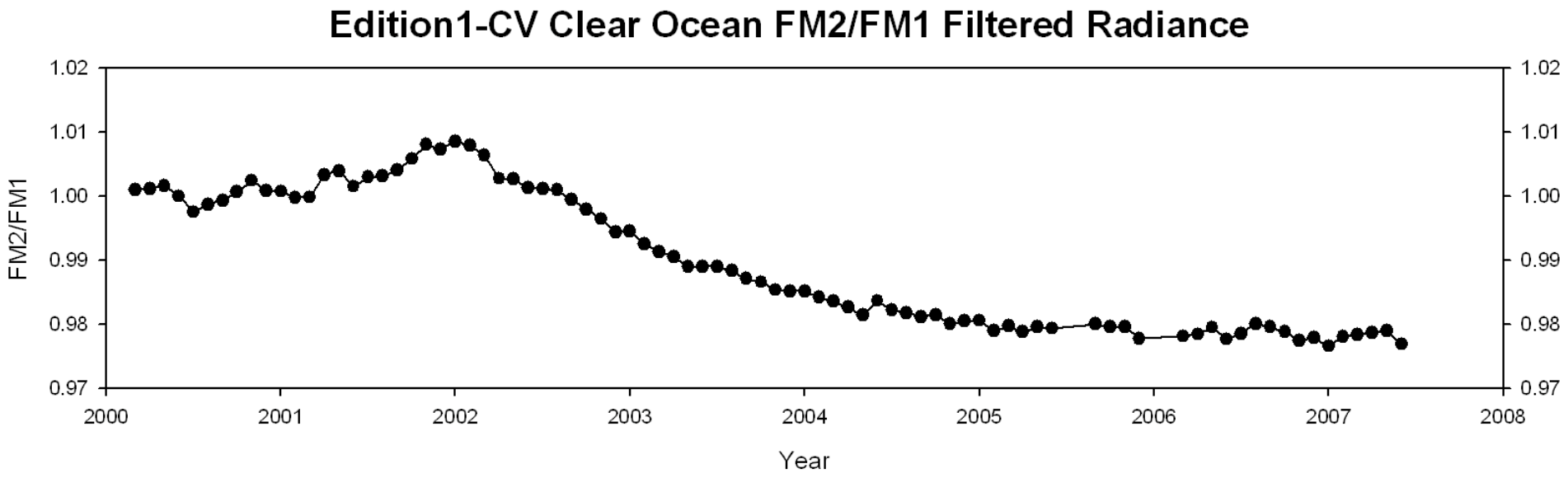
$$\frac{f_2}{f_1} = \frac{\int_0^\infty I_\lambda R_{2,\lambda} d\lambda}{\int_0^\infty I_\lambda R_{1,\lambda} d\lambda}$$

I_λ = Spectral Radiance (MODTRAN)

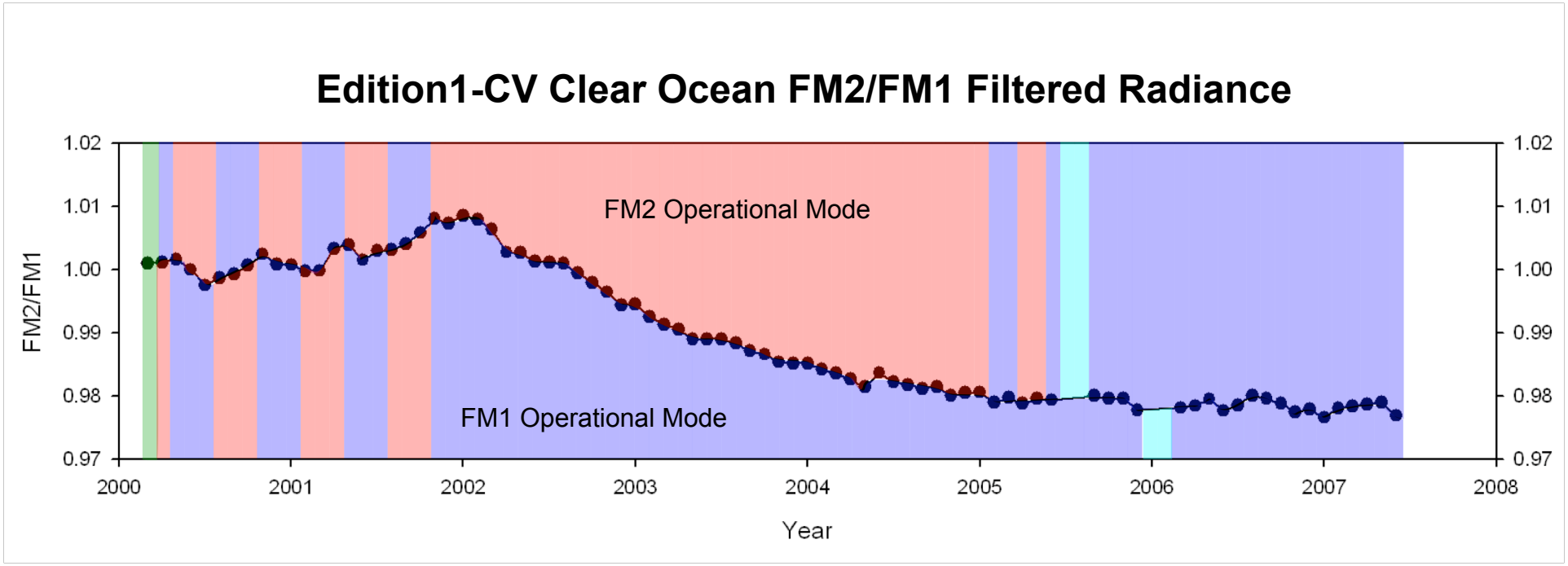
R_λ = Spectral Response Function

f = filtered SW radiance

Nadir Direct Compare



Operational Mode and Direct Compare



Bi-axial (RAPS)

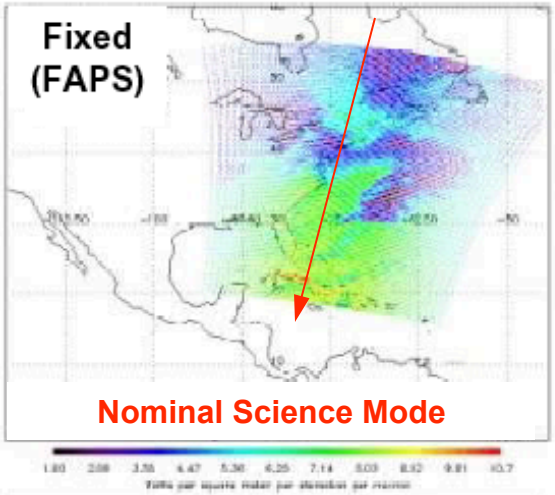
Crosstrack (FAPS)

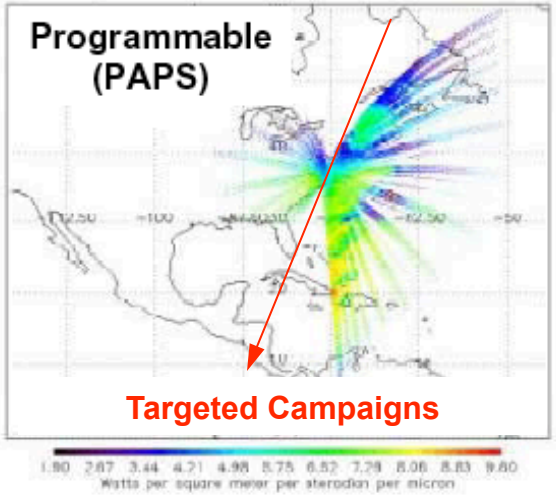
Stowed

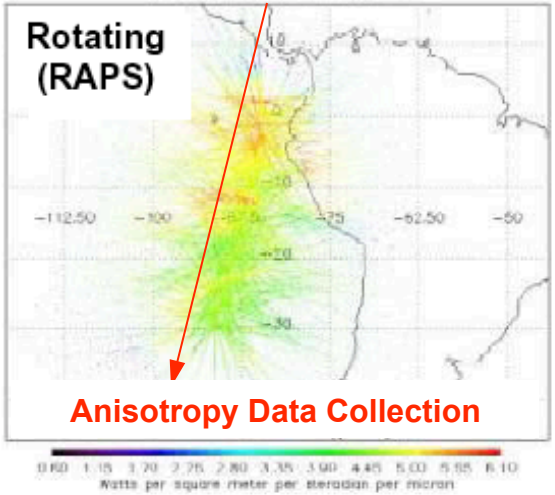
Mixed Crosstrack/Biaxial

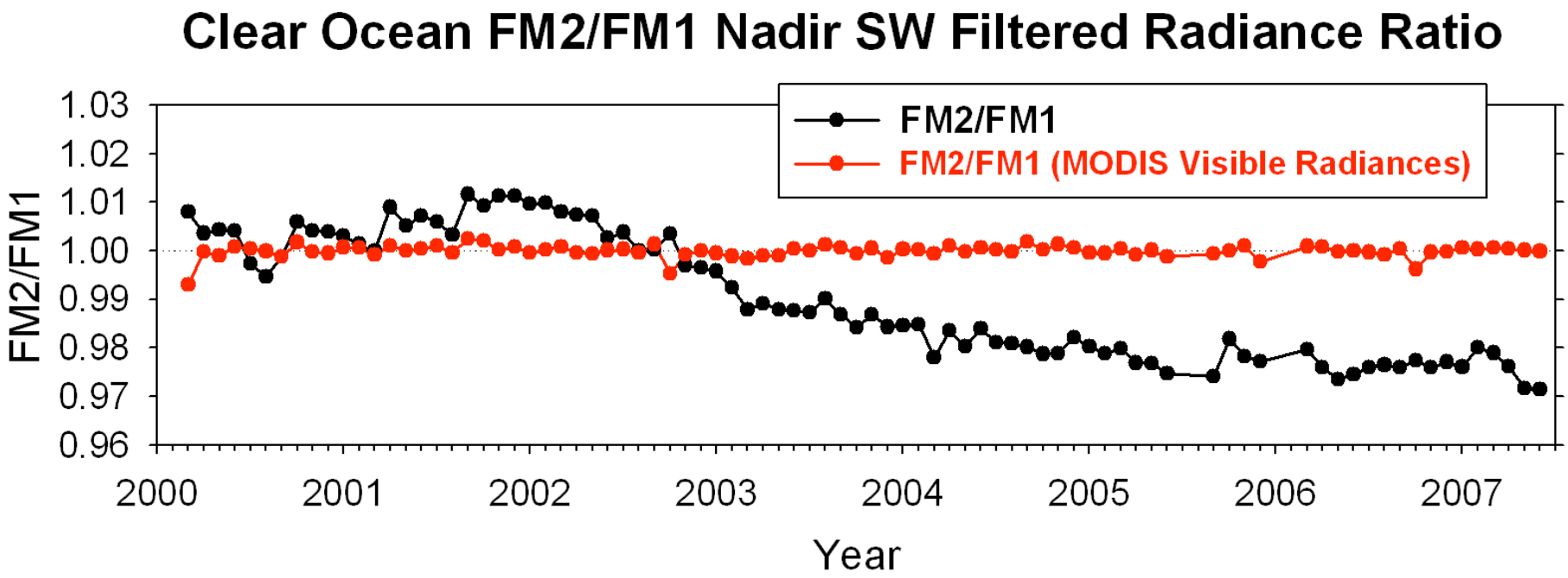
Operational Scanning Capabilities

CERES Azimuth Plane Scan Modes



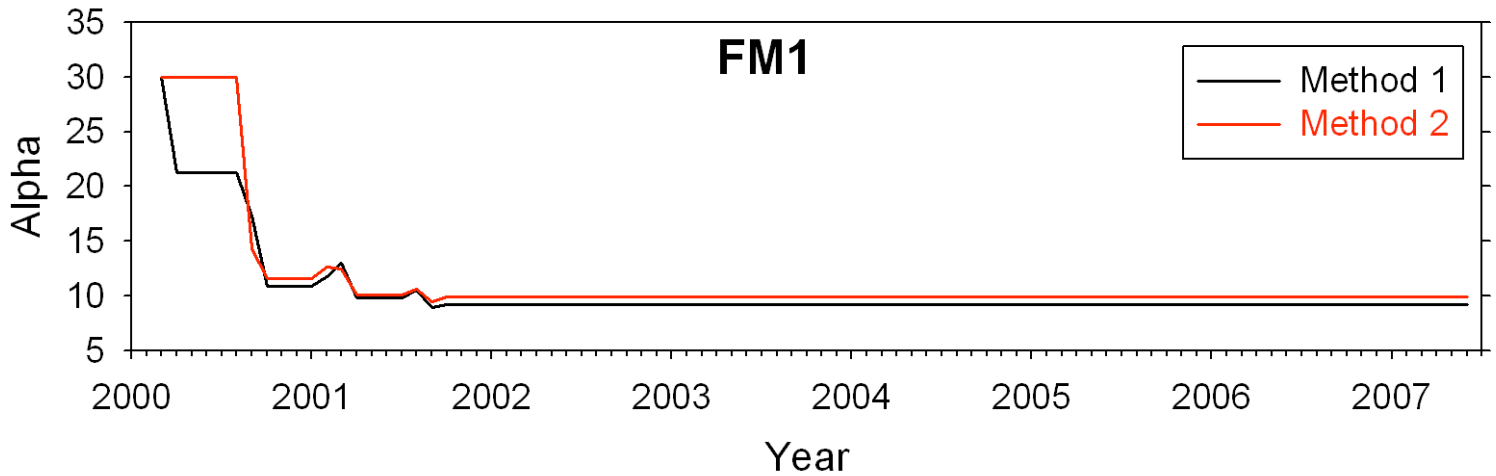


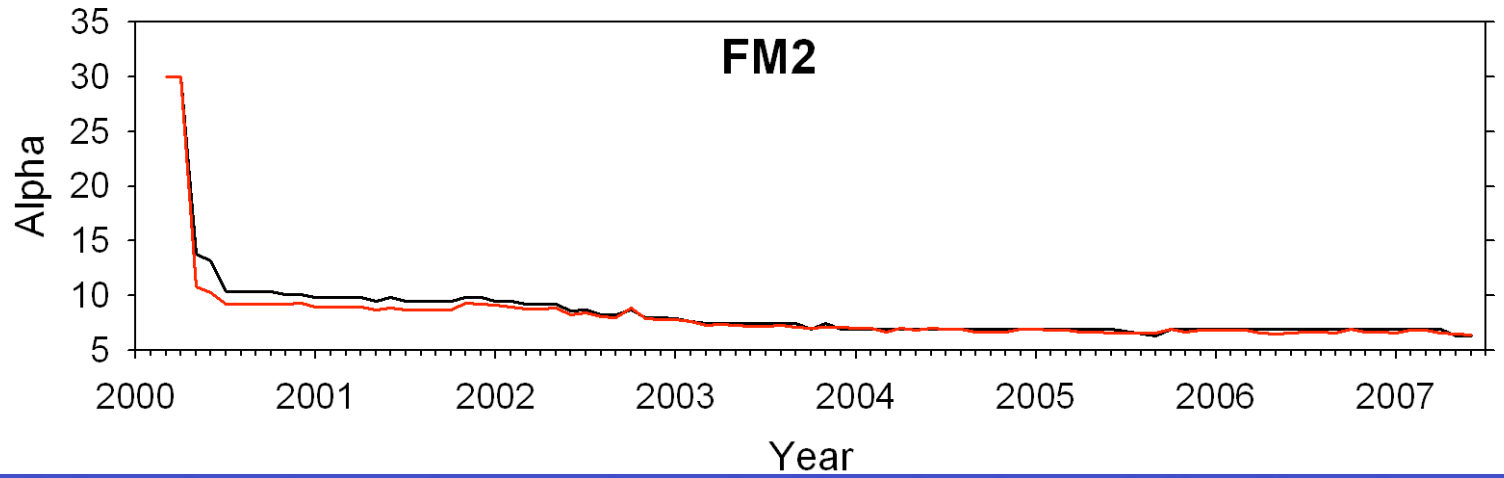



Clear Ocean FM2/FM1 Nadir SW Filtered Radiance Ratio
FM2/FM1
FM2/FM1 (MODIS Visible Radiances)
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
FM2/FM1
2000
2001
2002
2003
2004
2005
2006
2007
Year

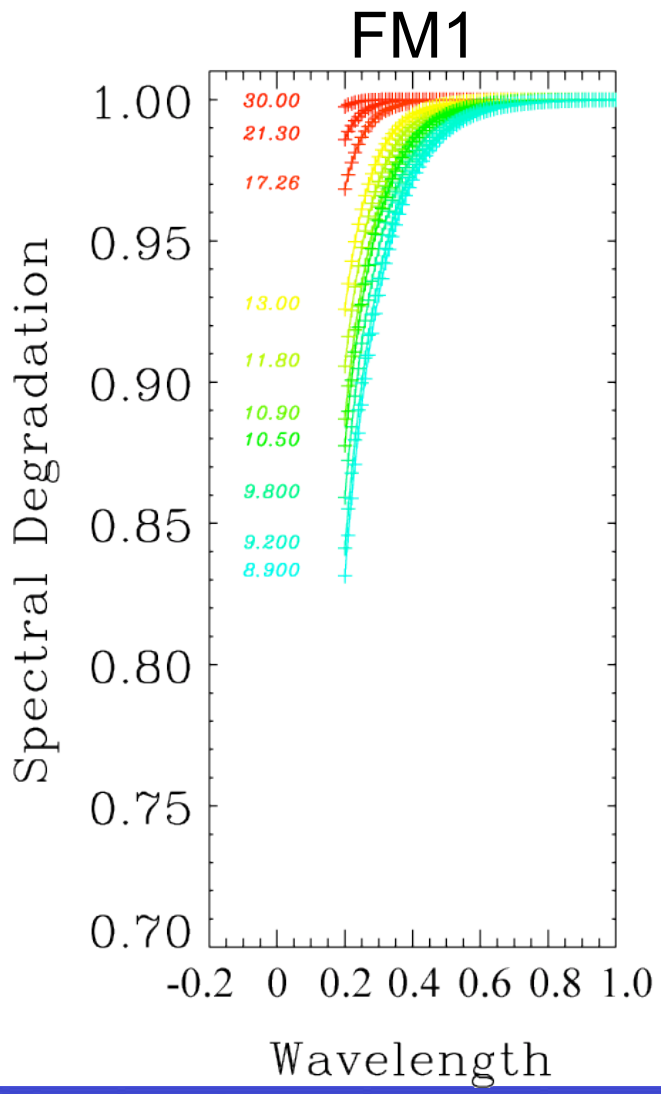
Preliminary Alpha 'Retrieval' Results

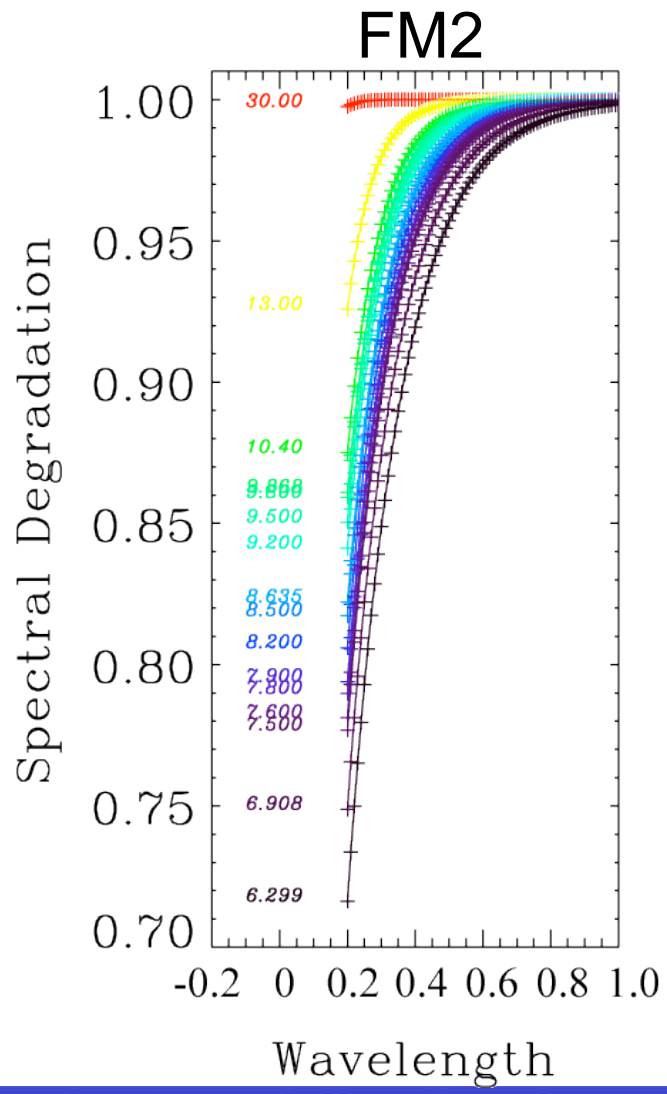
SW Degradation Factor (Alpha) Derived from Clear Ocean FM2/FM1 Ratio





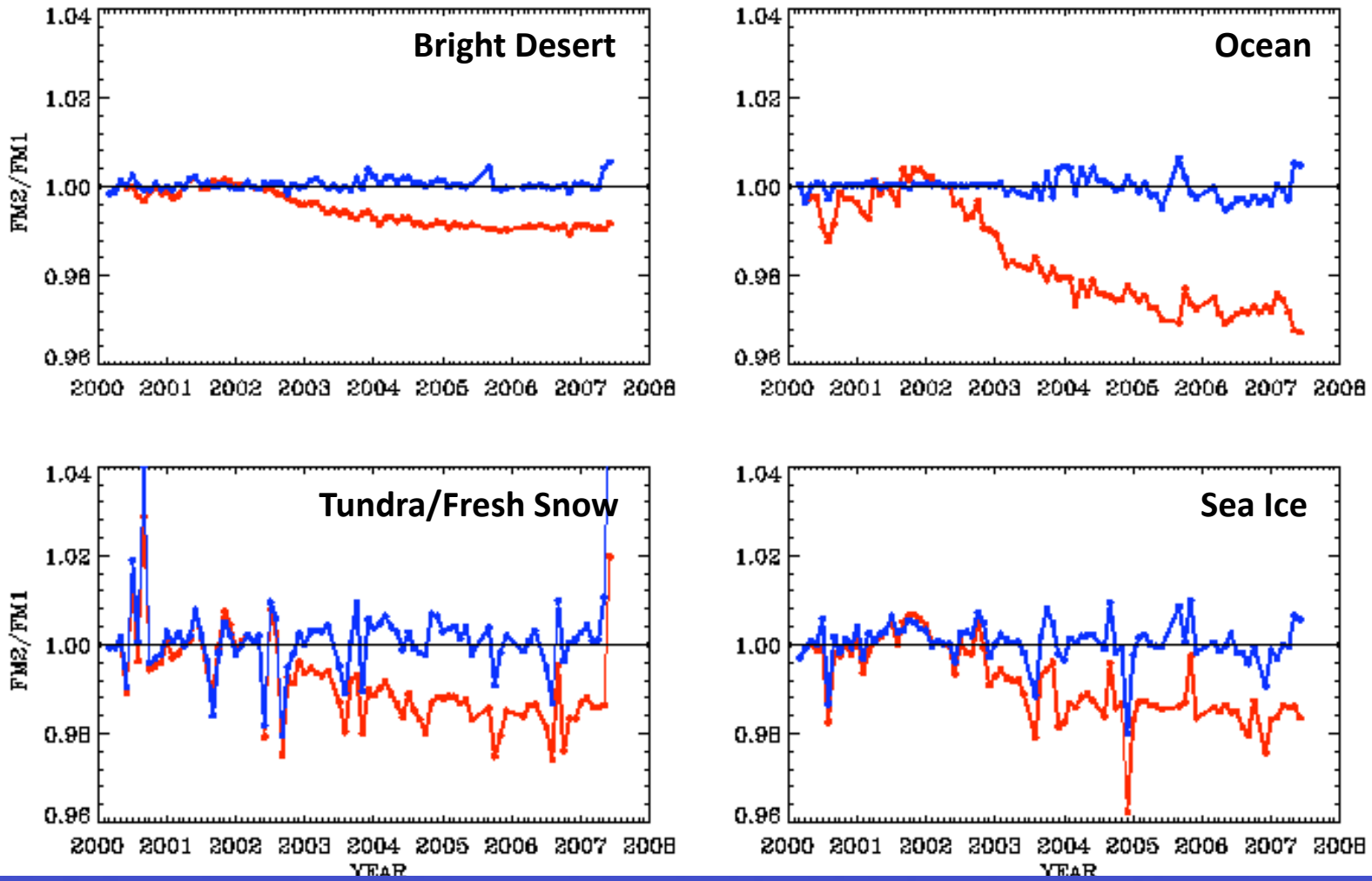
Omega-1 Alpha 'Retrieval' Results



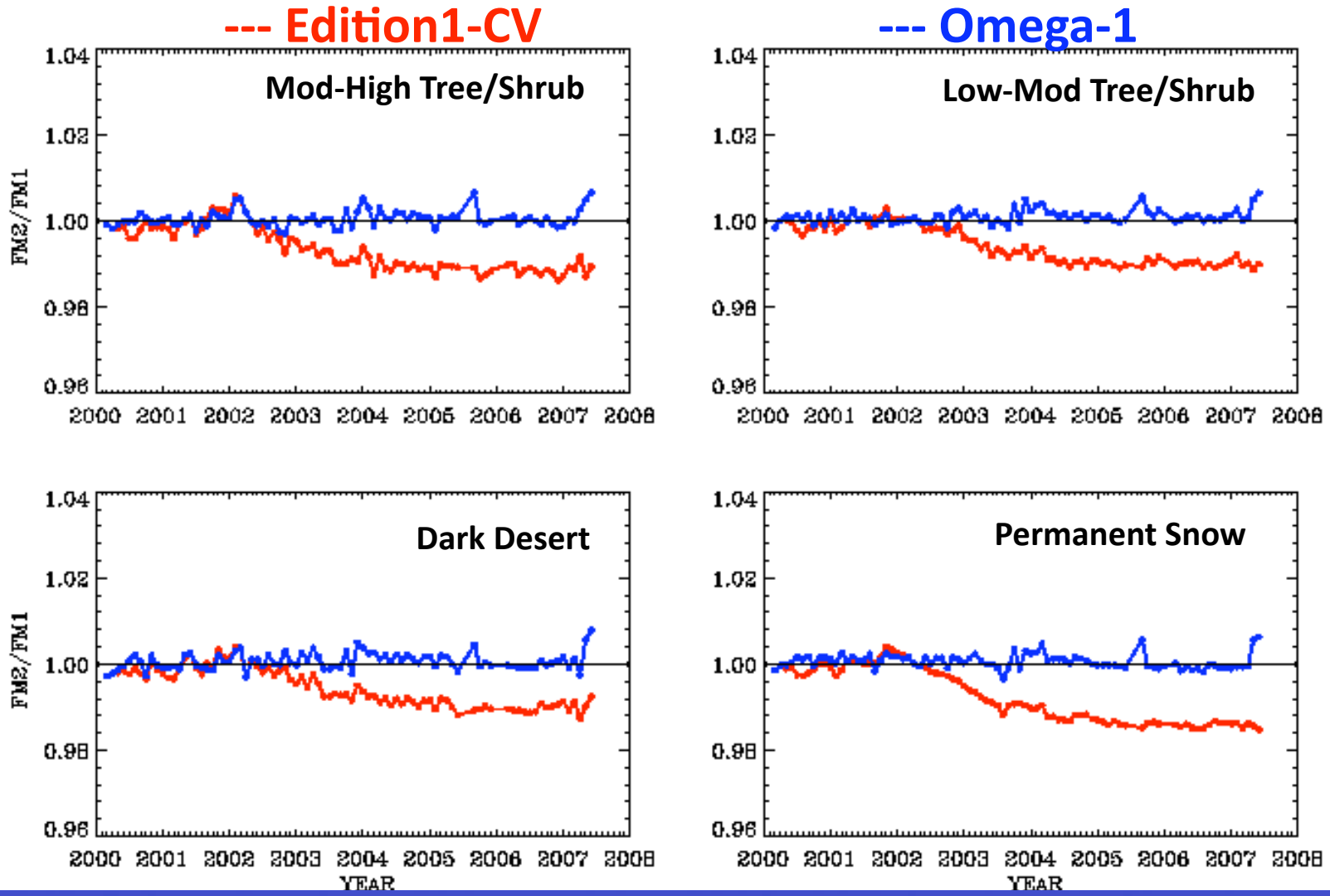


FM2/FM1 SW Unfiltered Radiance Ratio for Clear Sky Scenes

--- Edition1-CV --- Omega-1

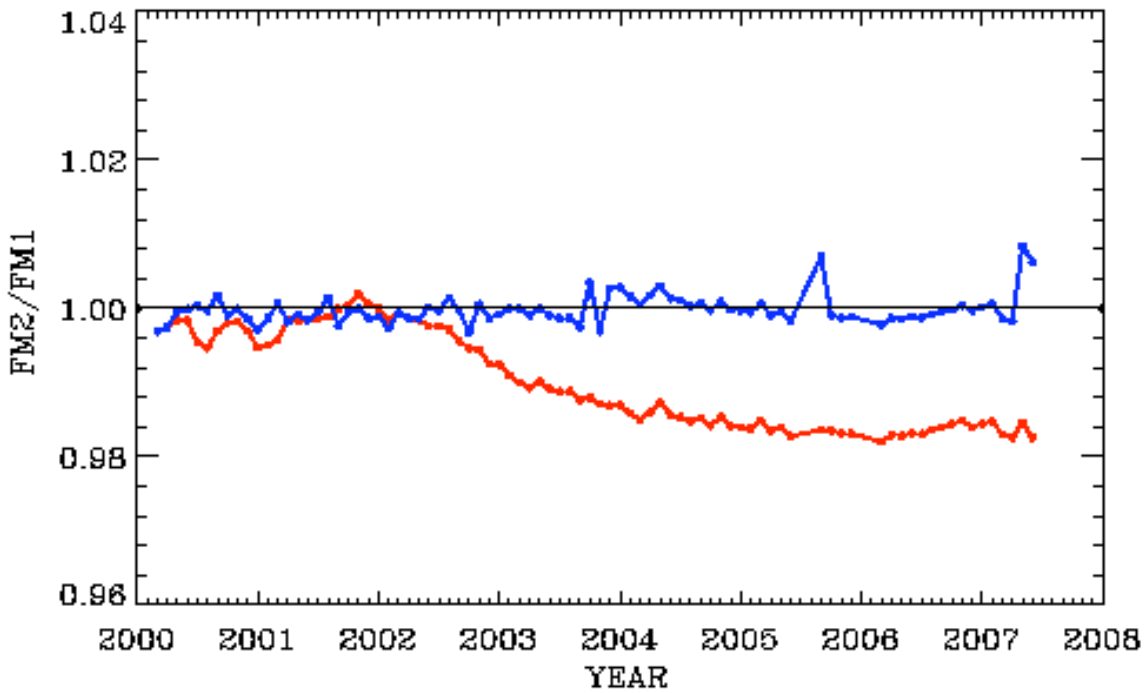


FM2/FM1 SW Unfiltered Radiance Ratio for Clear Sky Scenes

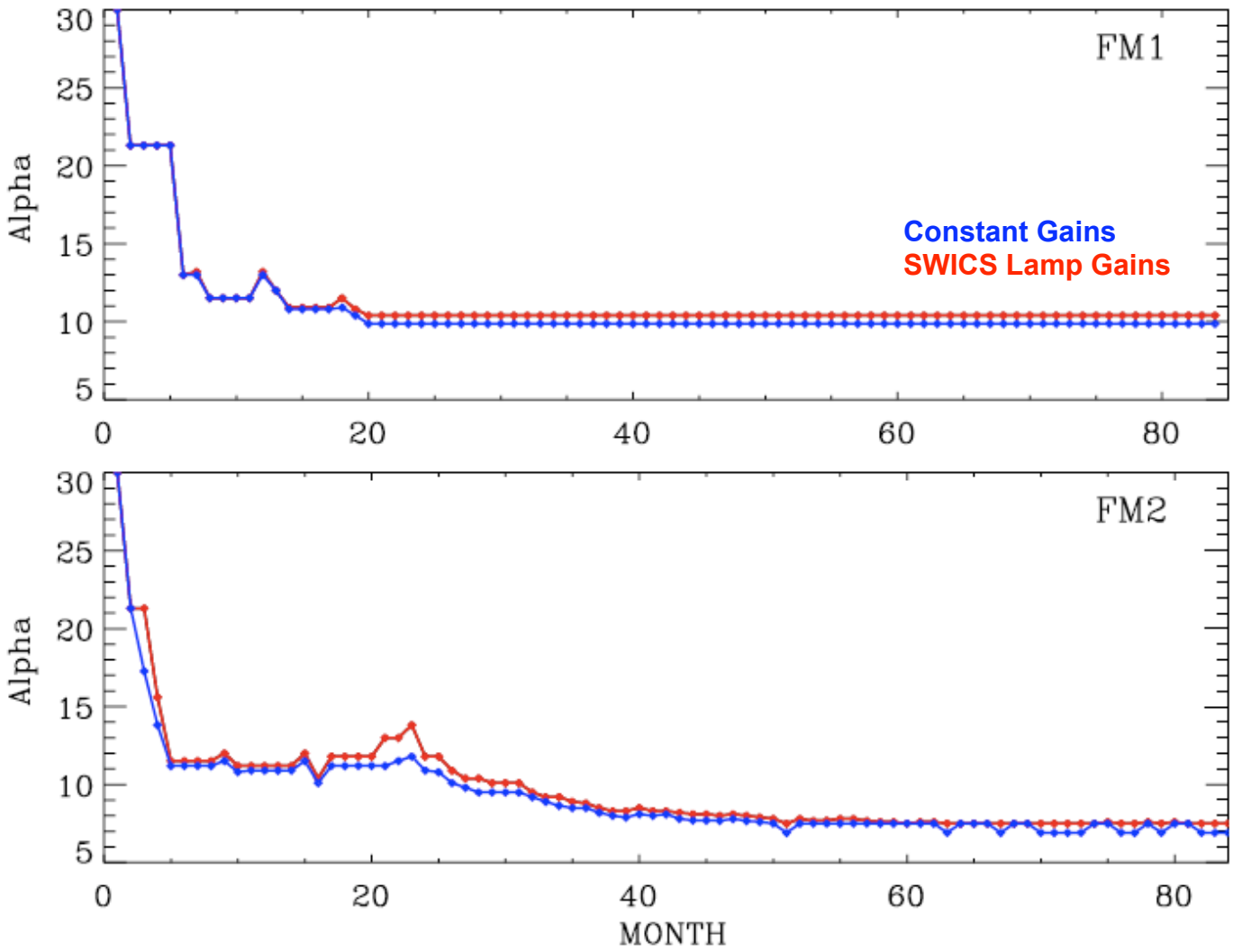


FM2/FM1 SW Unfiltered Radiance Ratio for All Sky Ocean

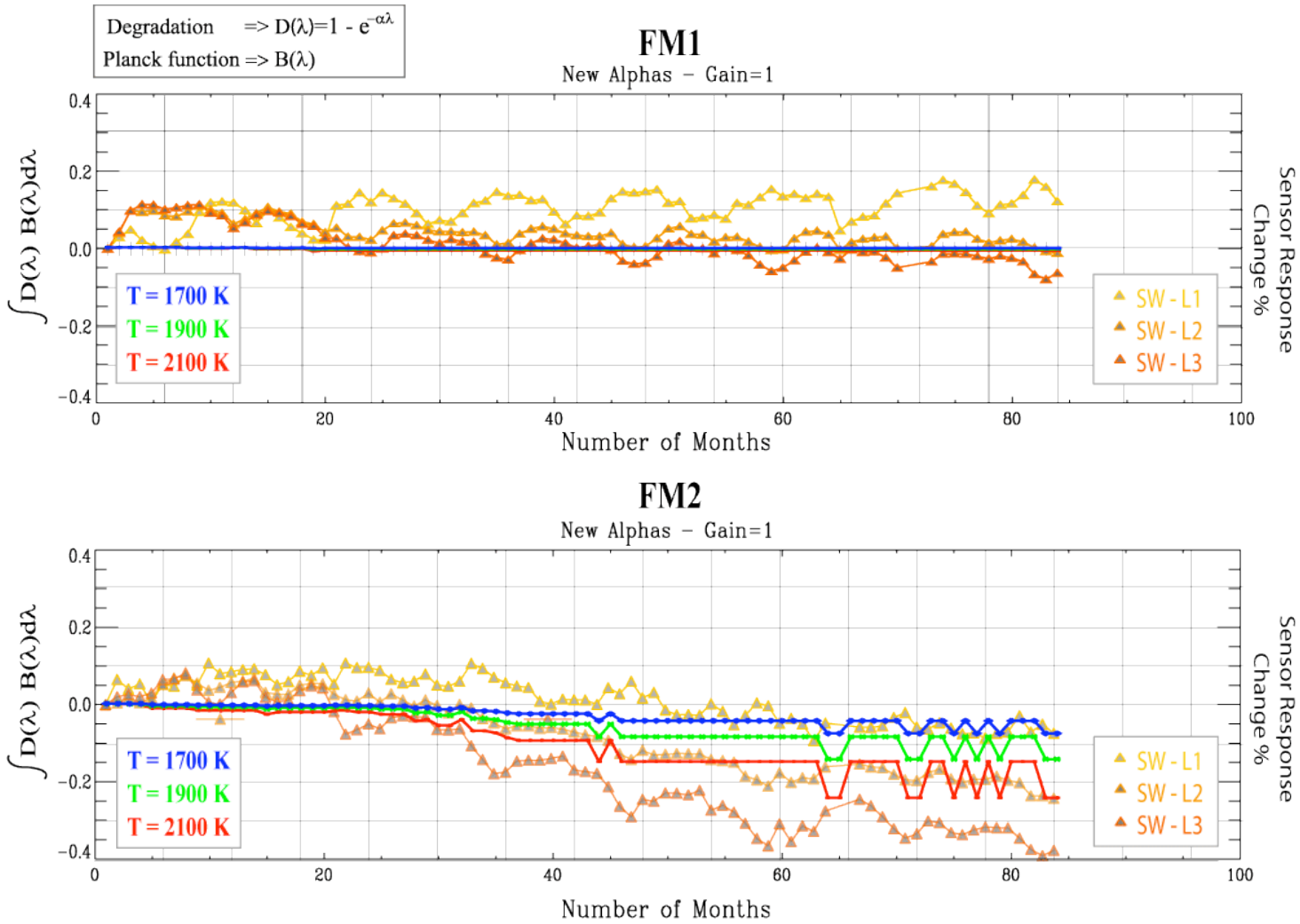
--- Edition1-CV --- Omega-1



Sensitivity of SRF "Retrieval" to SW Channel Gain



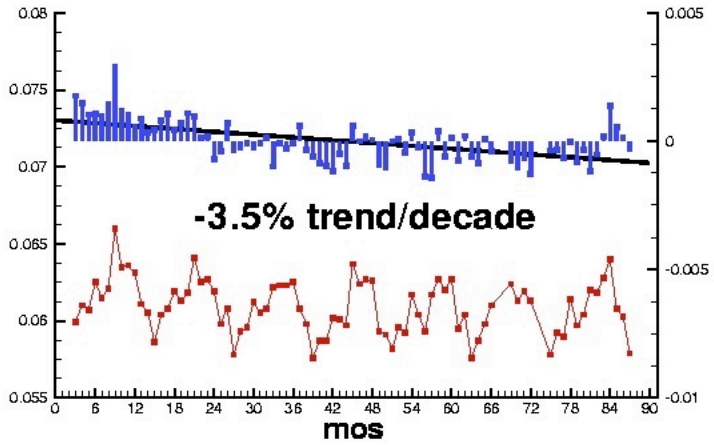
Separation of Gain and Spectral Effects

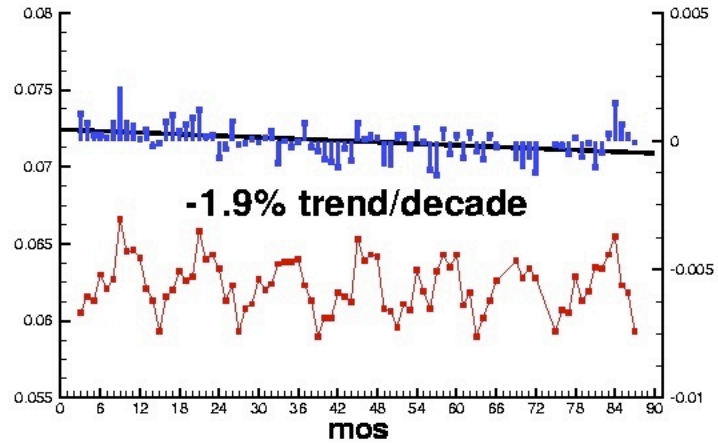


Clear Ocean Albedo Results

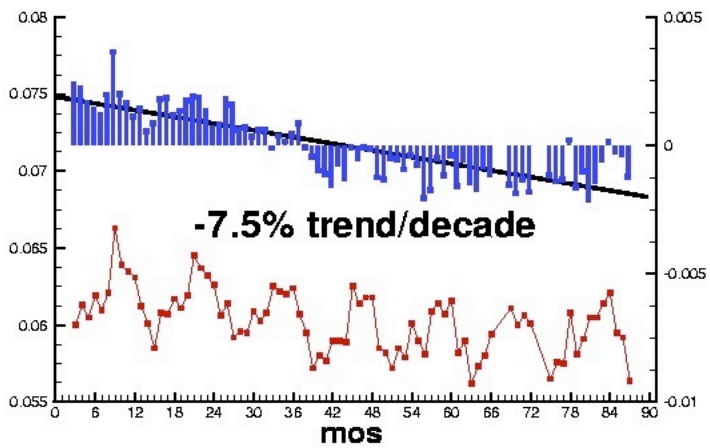
Edition1-CV | **Omega-1**

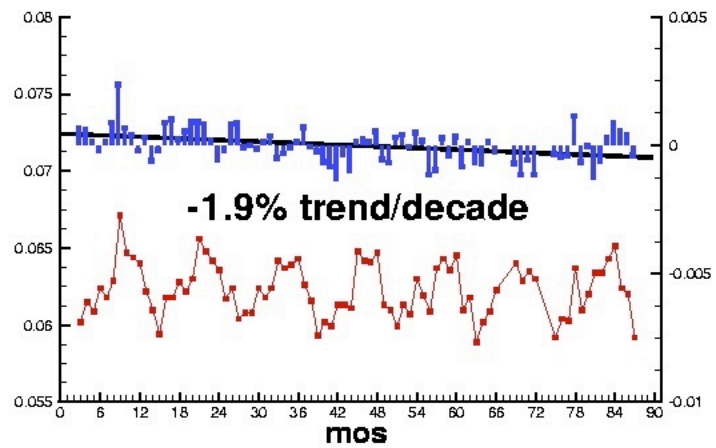
FM1





FM2

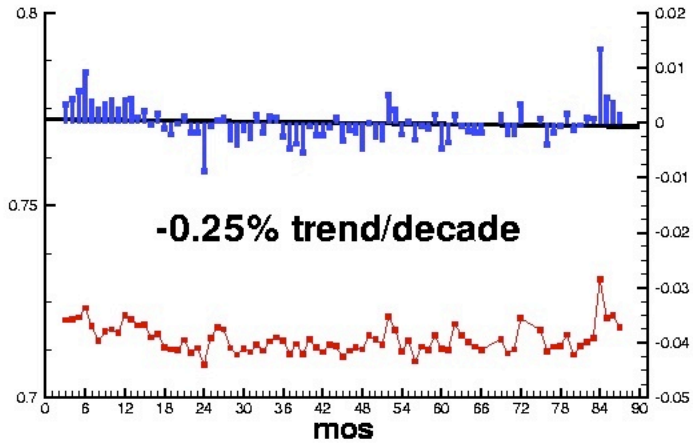


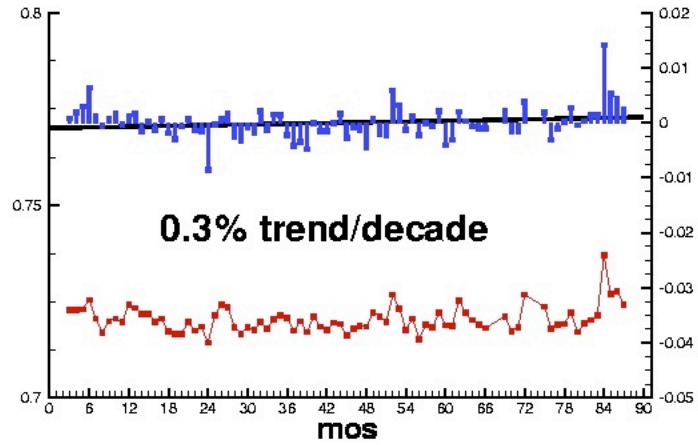


Deep Convective Cloud Albedo Results

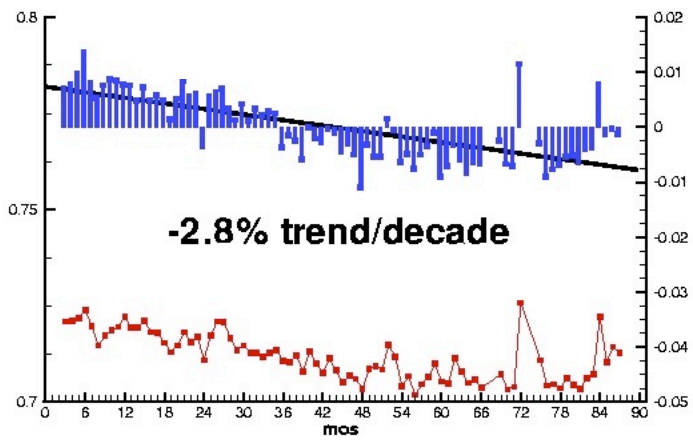
Edition1-CV | **Omega-1**

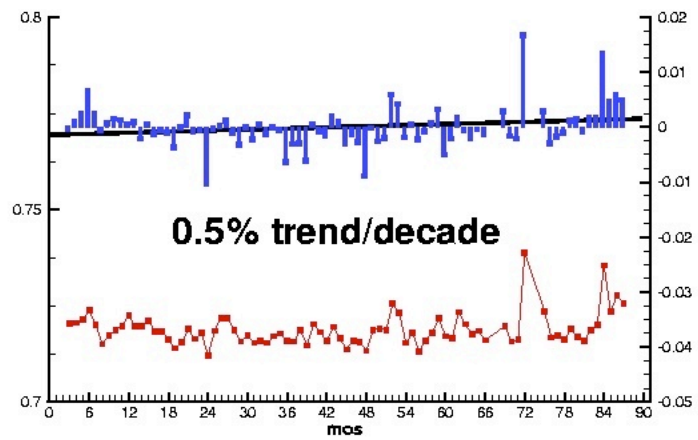
FM1



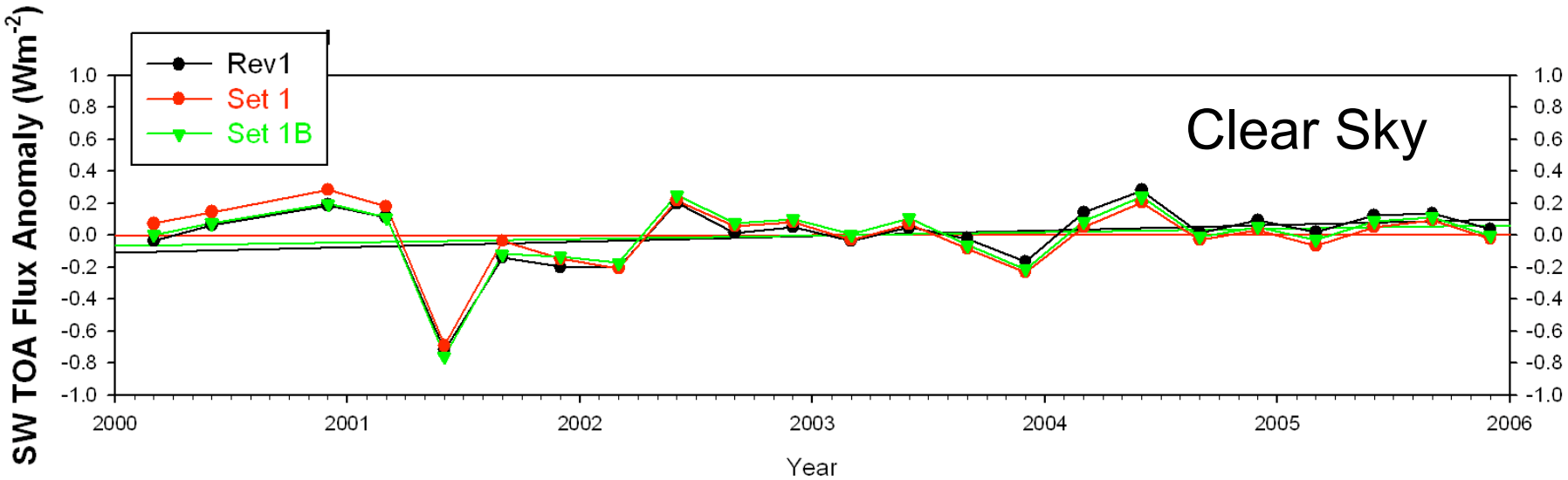


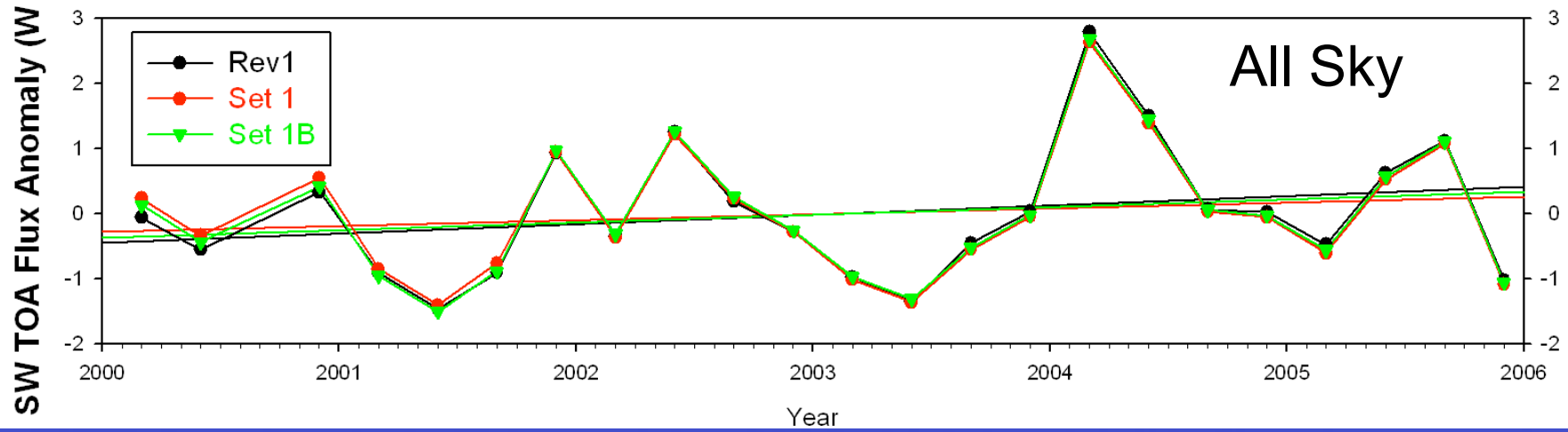
FM2





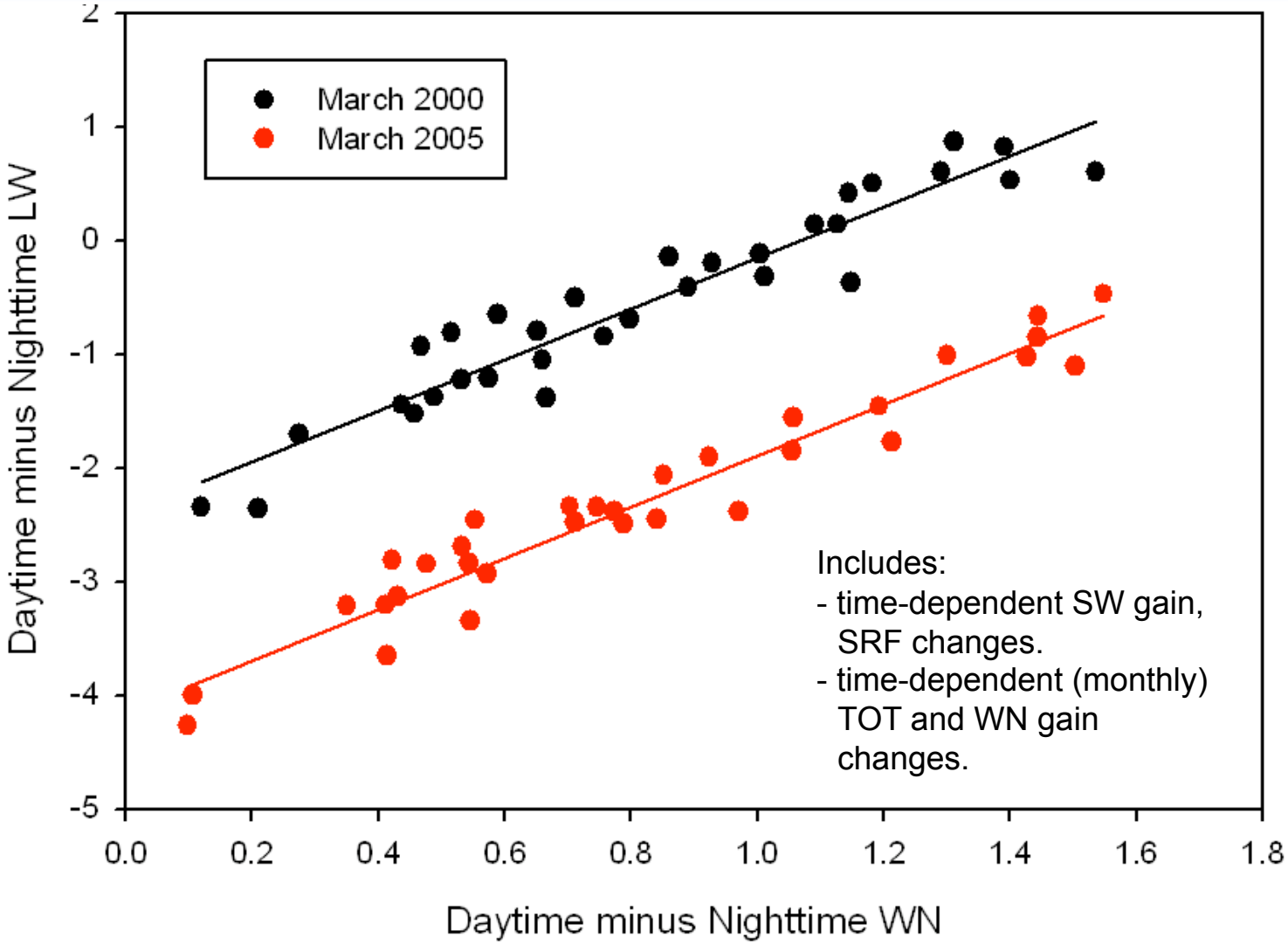
Tropical Ocean SW TOA Flux Anomaly – FM1



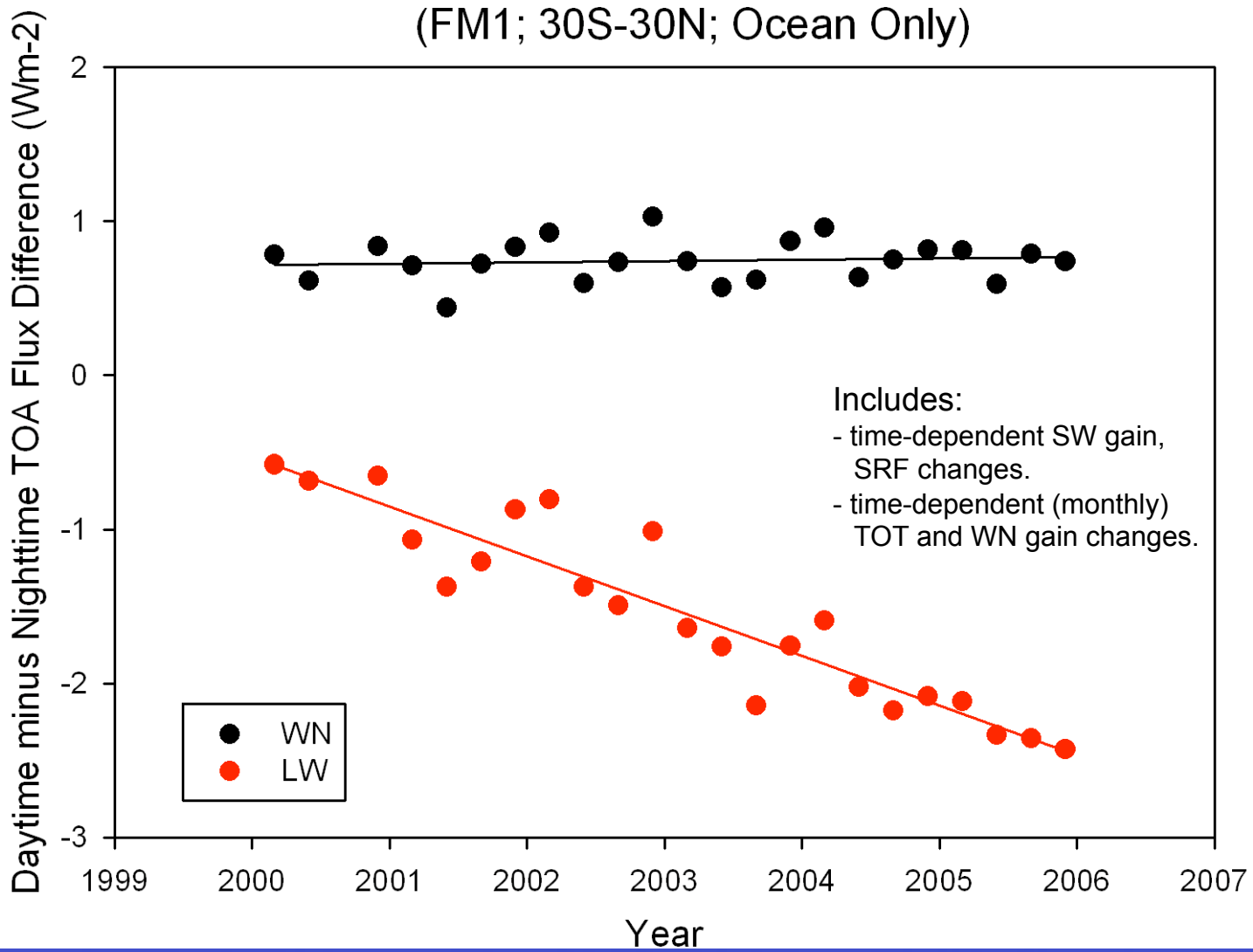


DAYTIME/NIGHTTIME LW

FM1 Zonal Averages; Ocean Only; 16S – 16N

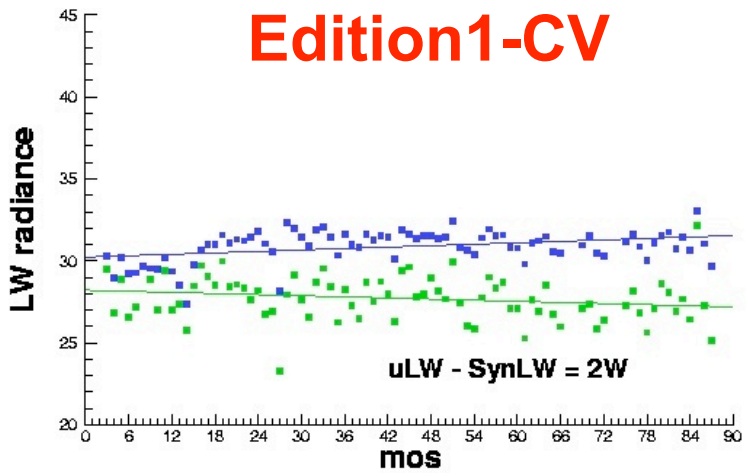


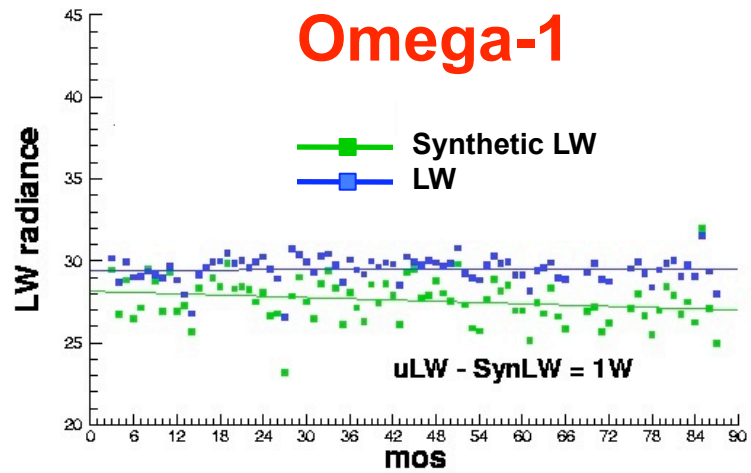
Tropical Mean TOA Day – Night Flux Difference



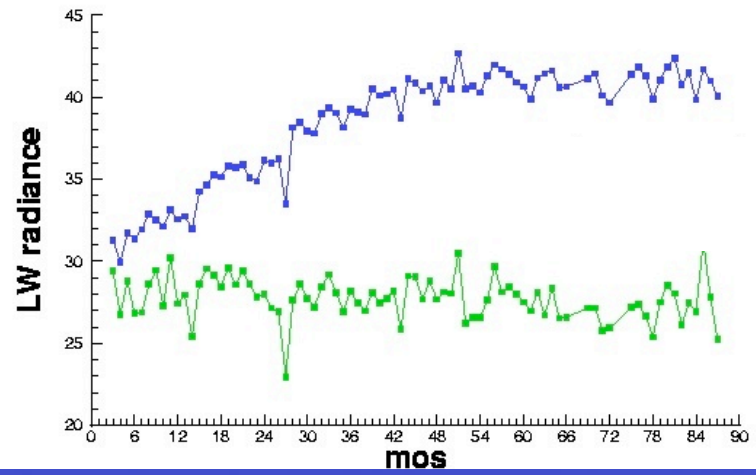
Deep Convective Cloud Daytime LW Radiance

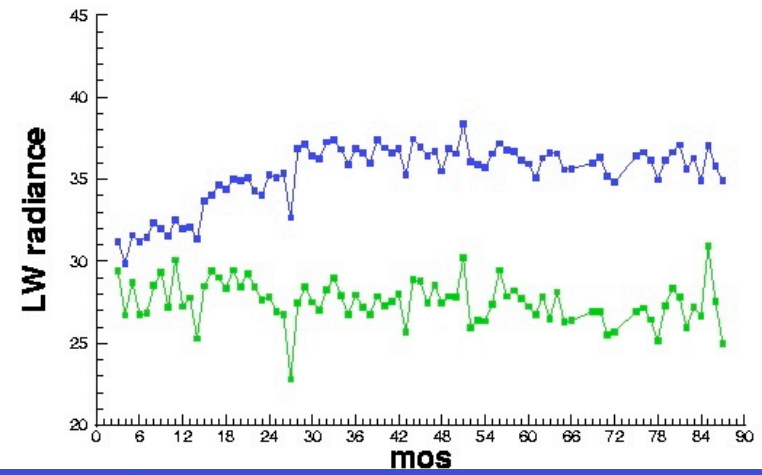
FM1





FM2





CERES Edition3 Calibration Summary

Residual calibration errors in the Omega-1 studies are dominated by spectral degradation of sensor optics in the reflected solar bands. (SW and SW/TOT)

This results in

- **Artificial decreasing trend in the reflected solar measurements**
- **Divergence between daytime and nighttime OLR records with time.**
  - **LW_{day} = Total - Shortwave**
  - **LW_{night} = Total**

Occurs on all four CERES EOS sensors to varying degrees

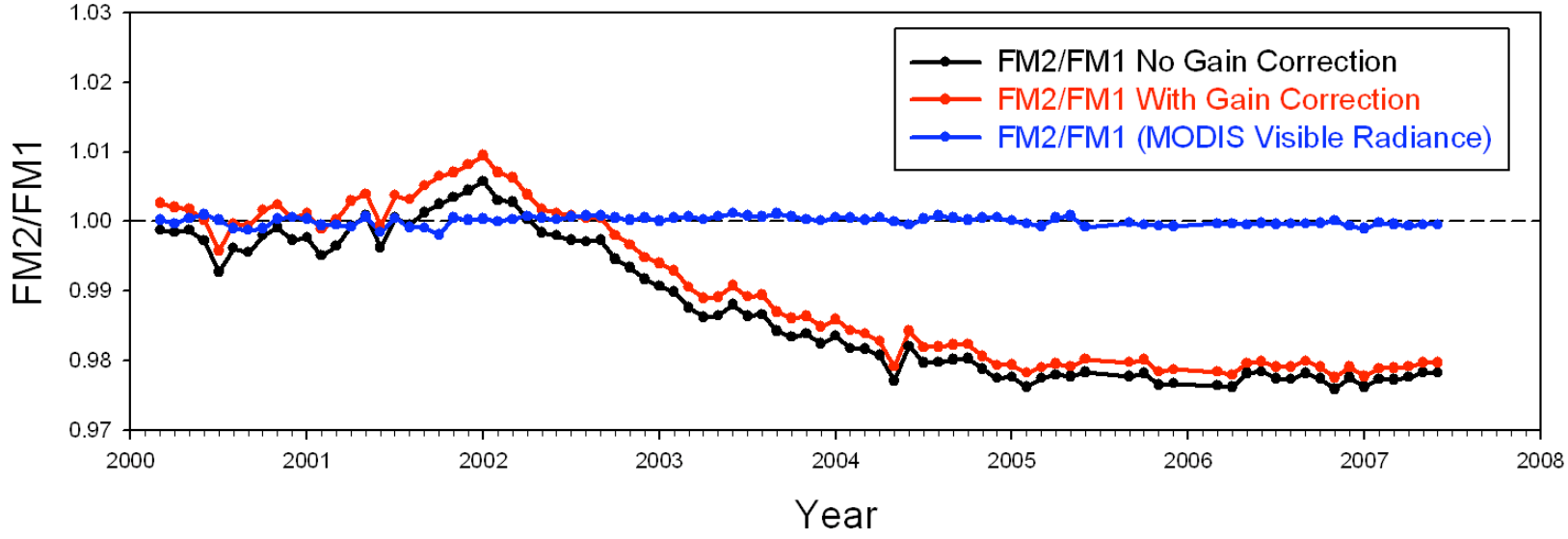
Highly correlated to several factors

- **Operational Mode**
- **Solar Cycle**
- **Atomic Oxygen fluence levels**

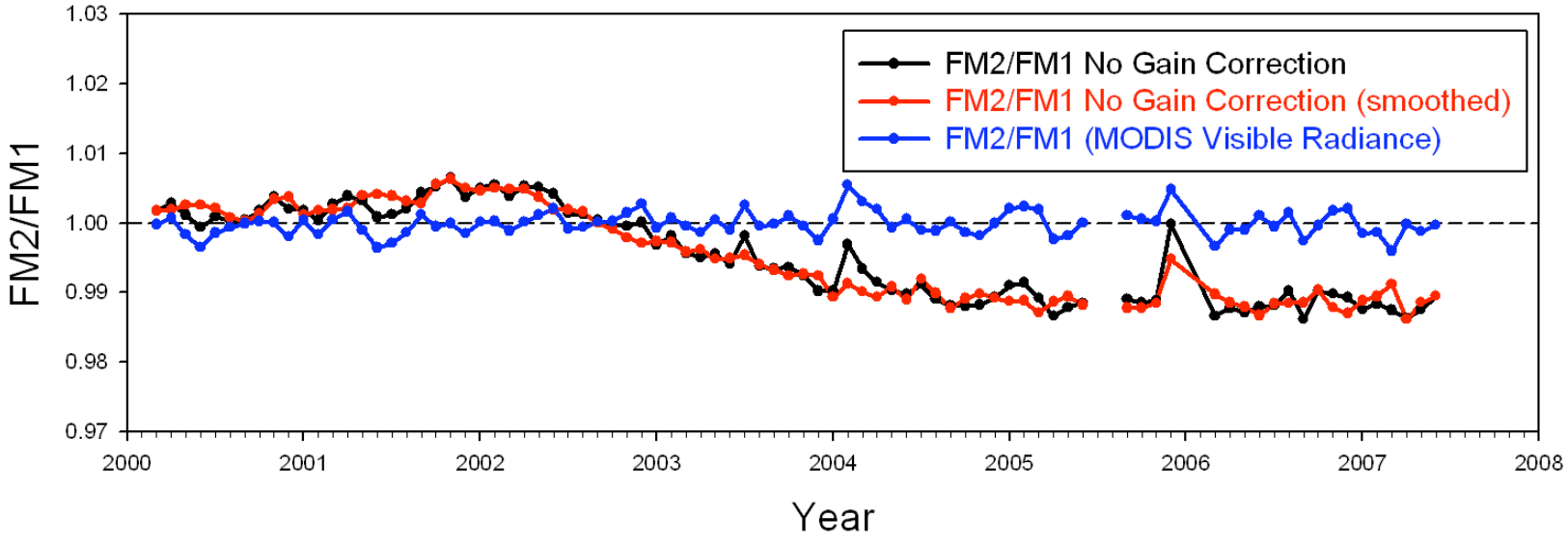
Instability of the Solar Diffusers (MAM's) and lack of adequate Spectral knowledge in the onboard SW sources greatly complicates the characterization and removal of this phenomena

Back-up Slides

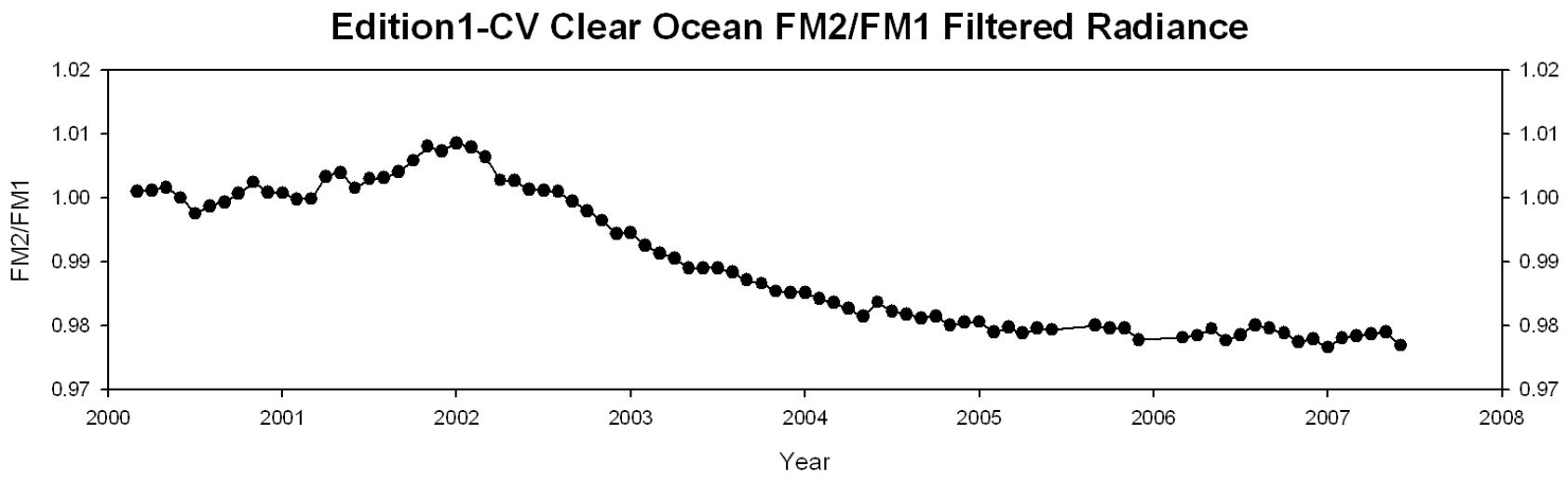
Clear Ocean FM2/FM1 Nadir SW Filtered Radiance Ratio

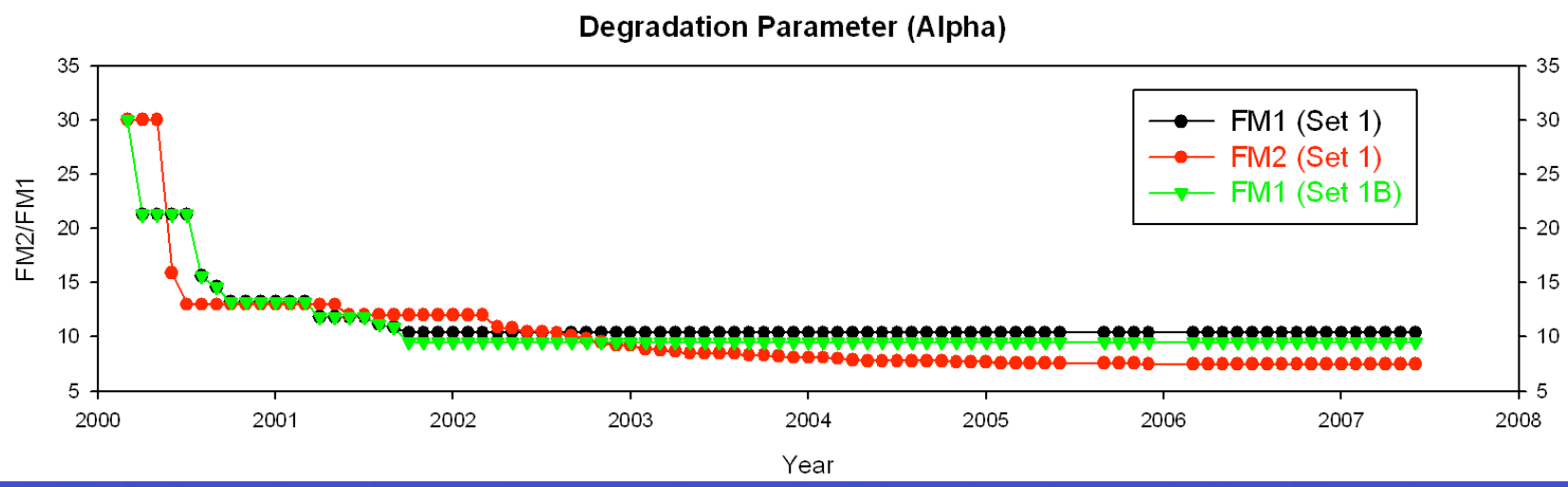


Deep Convective Cloud FM2/FM1 Nadir SW Filtered Radiance Ratio

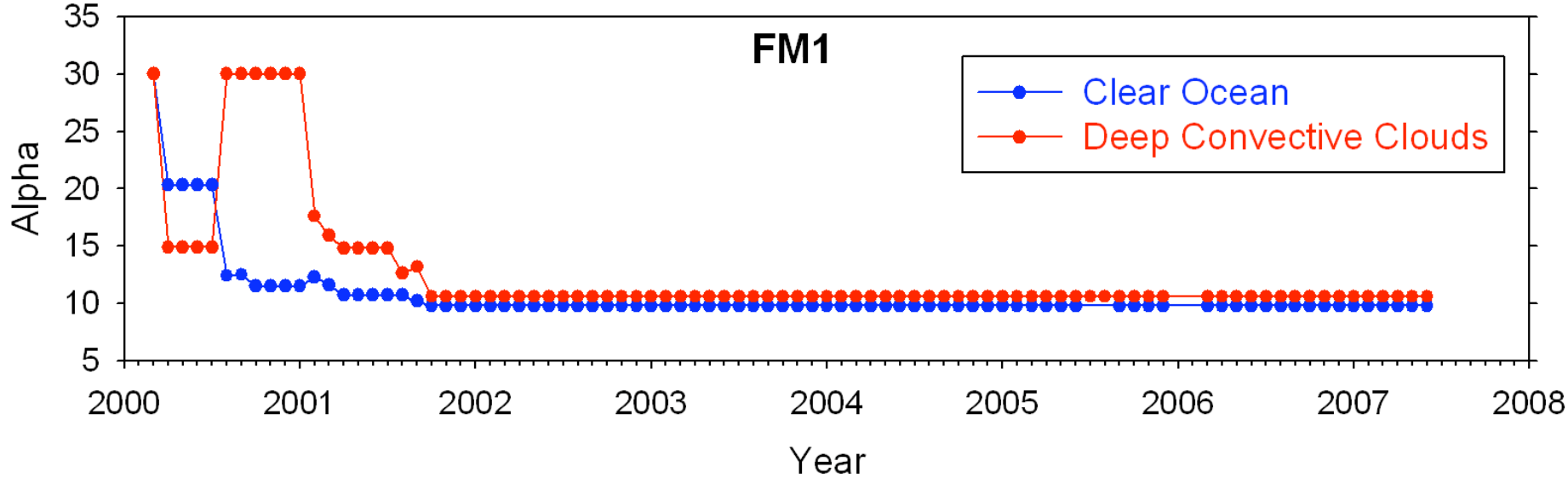


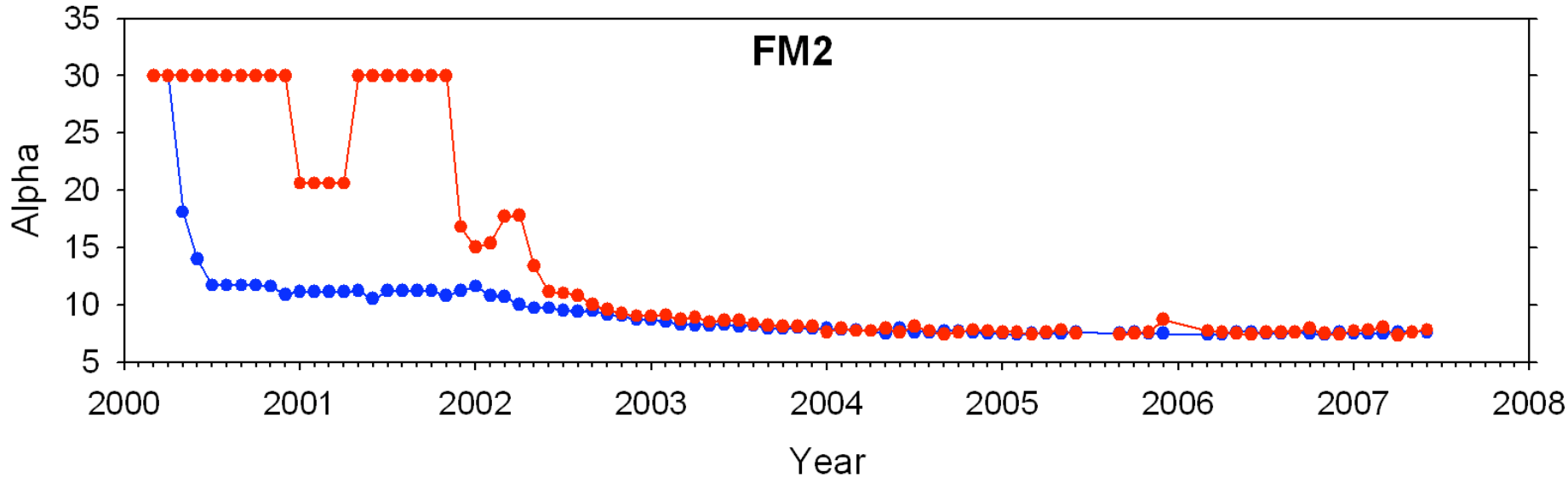
Deep Convective Cloud Albedo Results



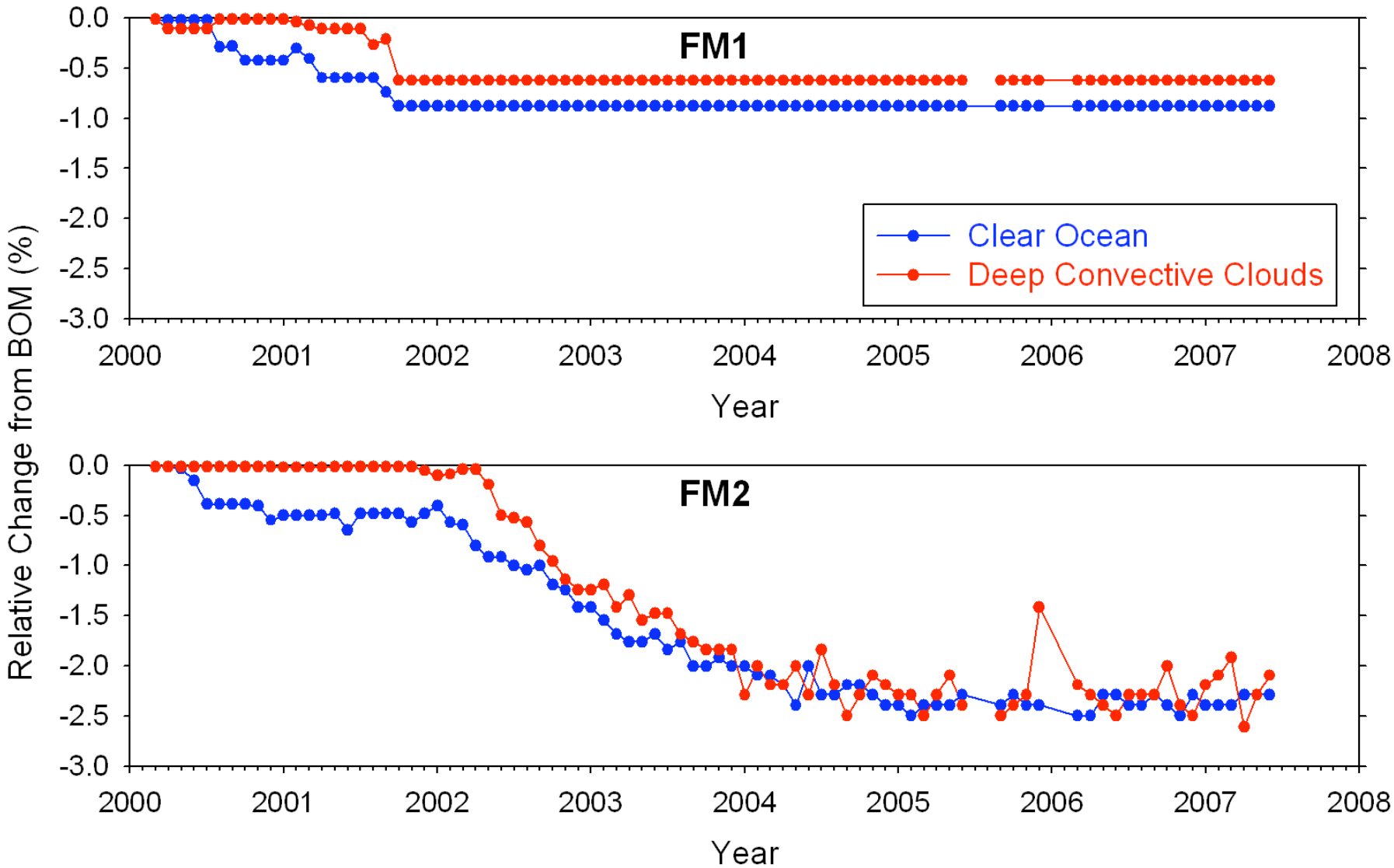


Spectral Degradation Factor (Allpha) From Theory (Method 2)

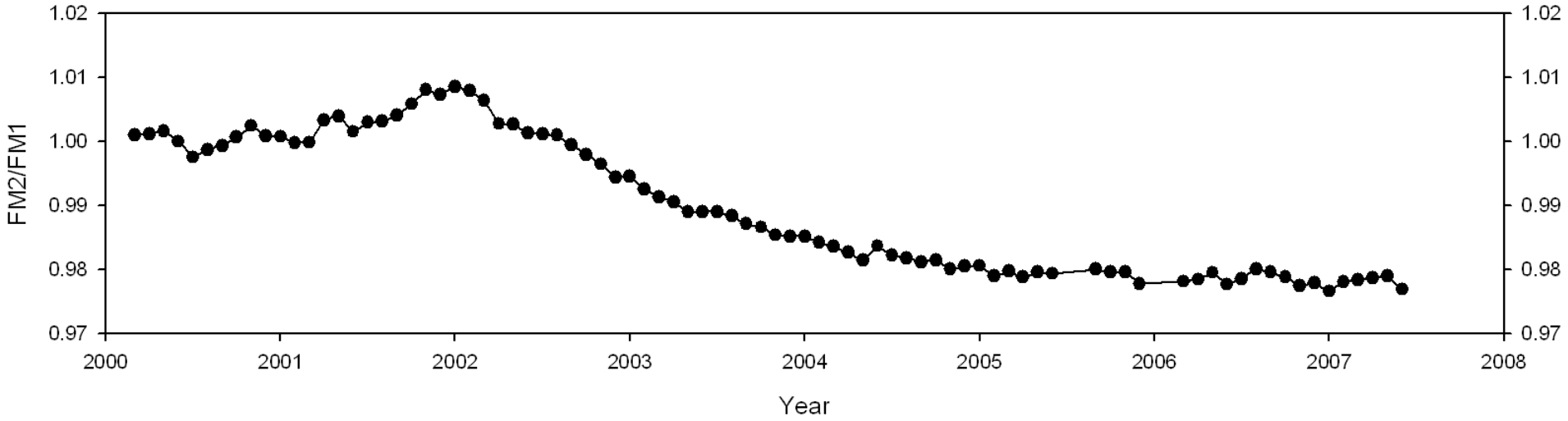




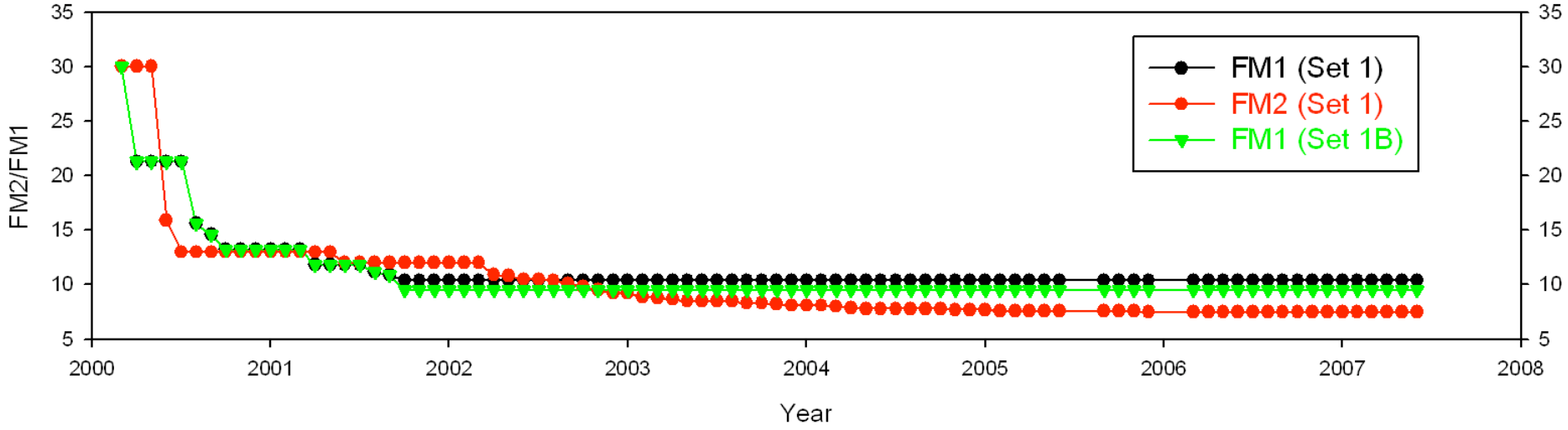
Estimated Change in All-Sky SW Radiance Since Beginning of Mission

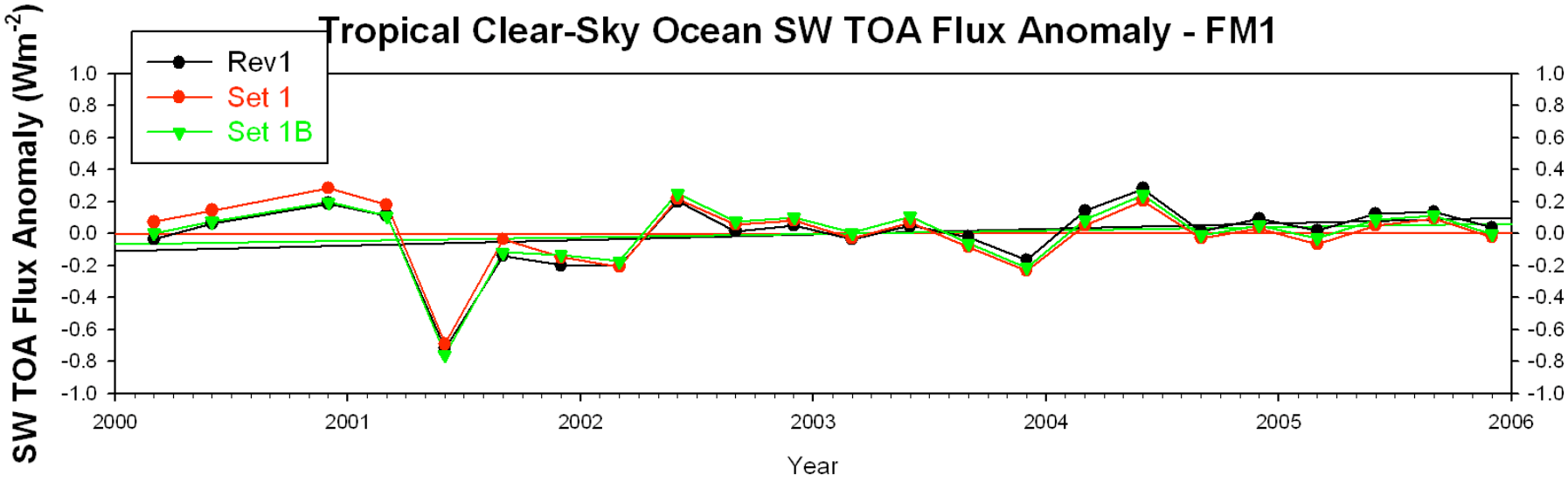


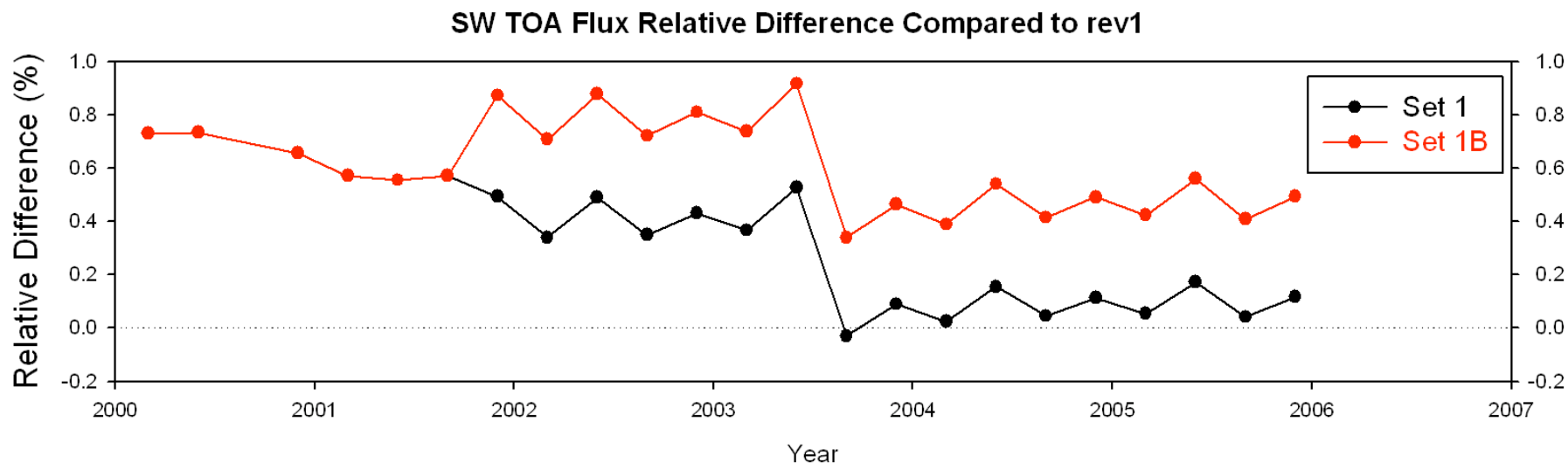
Edition1-CV Clear Ocean FM2/FM1 Filtered Radiance

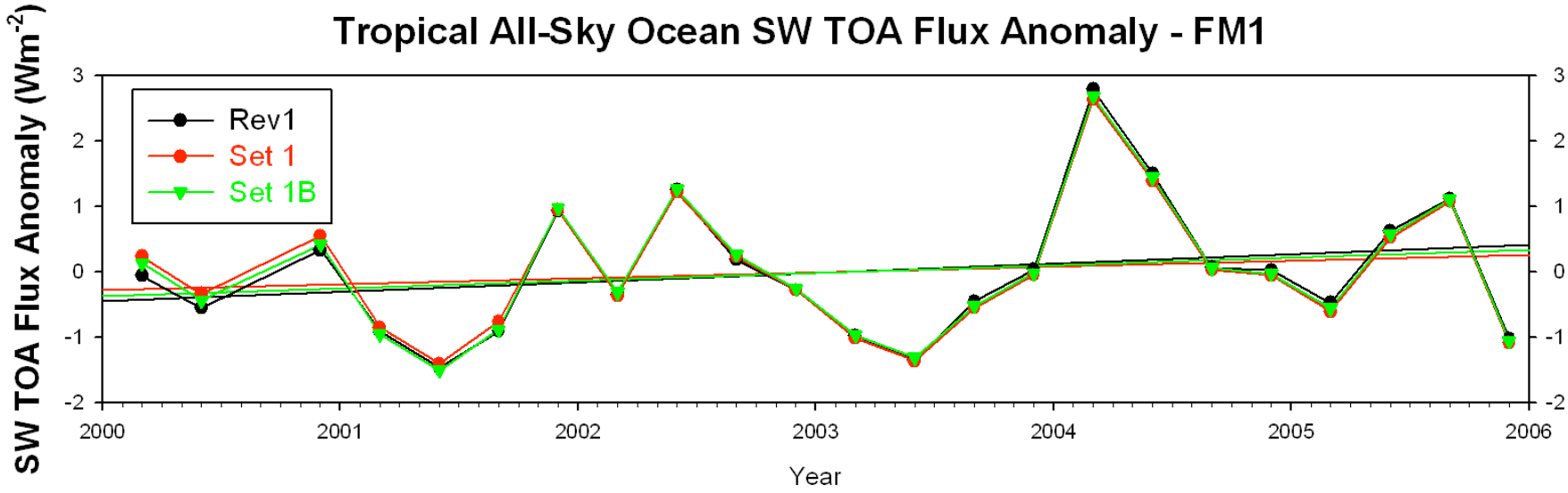


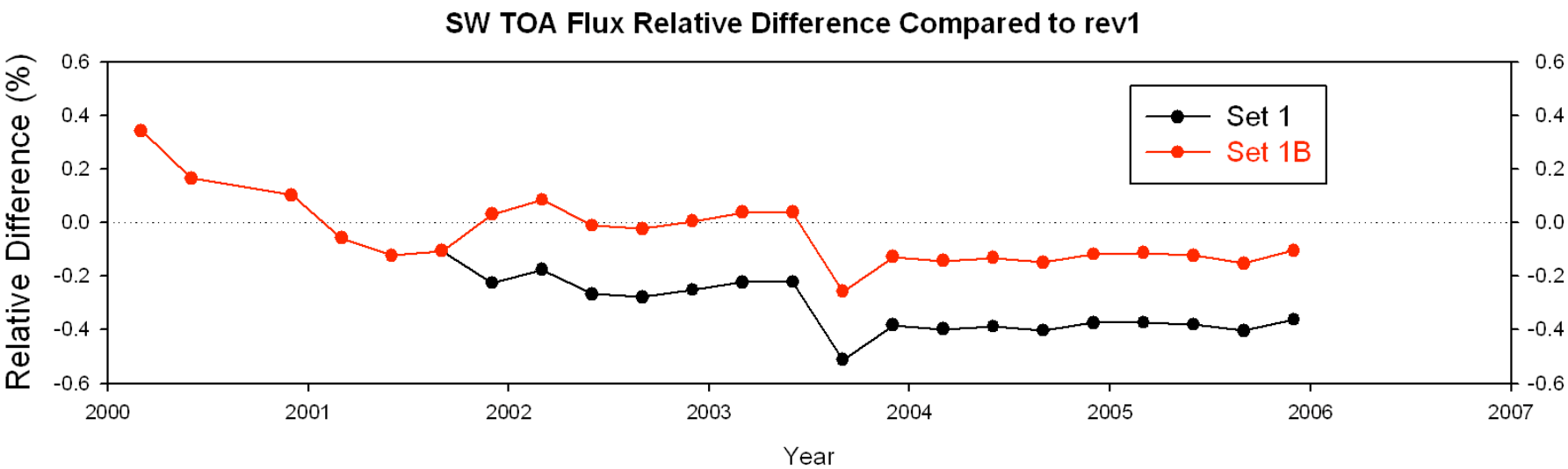
Degradation Parameter (Alpha)



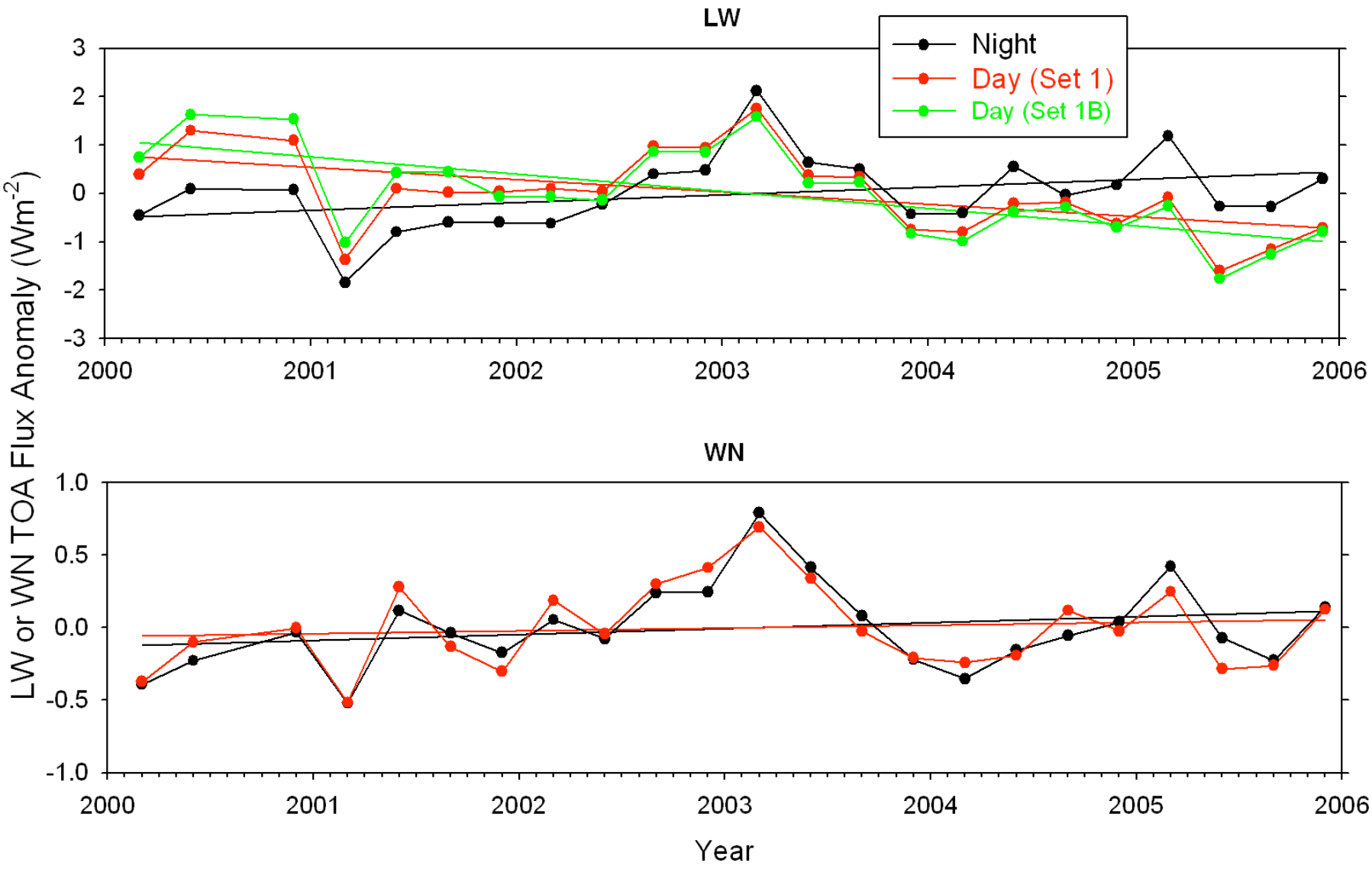

Tropical Clear-Sky Ocean SW TOA Flux Anomaly - FM1
SW TOA Flux Anomaly (Wm-2)
Rev1
Set 1
Set 1B
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2000
2001
2002
2003
2004
2005
2006
Year


SW TOA Flux Relative Difference Compared to rev1
Relative Difference (%)
Set 1
Set 1B
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2000
2001
2002
2003
2004
2005
2006
2007
Year

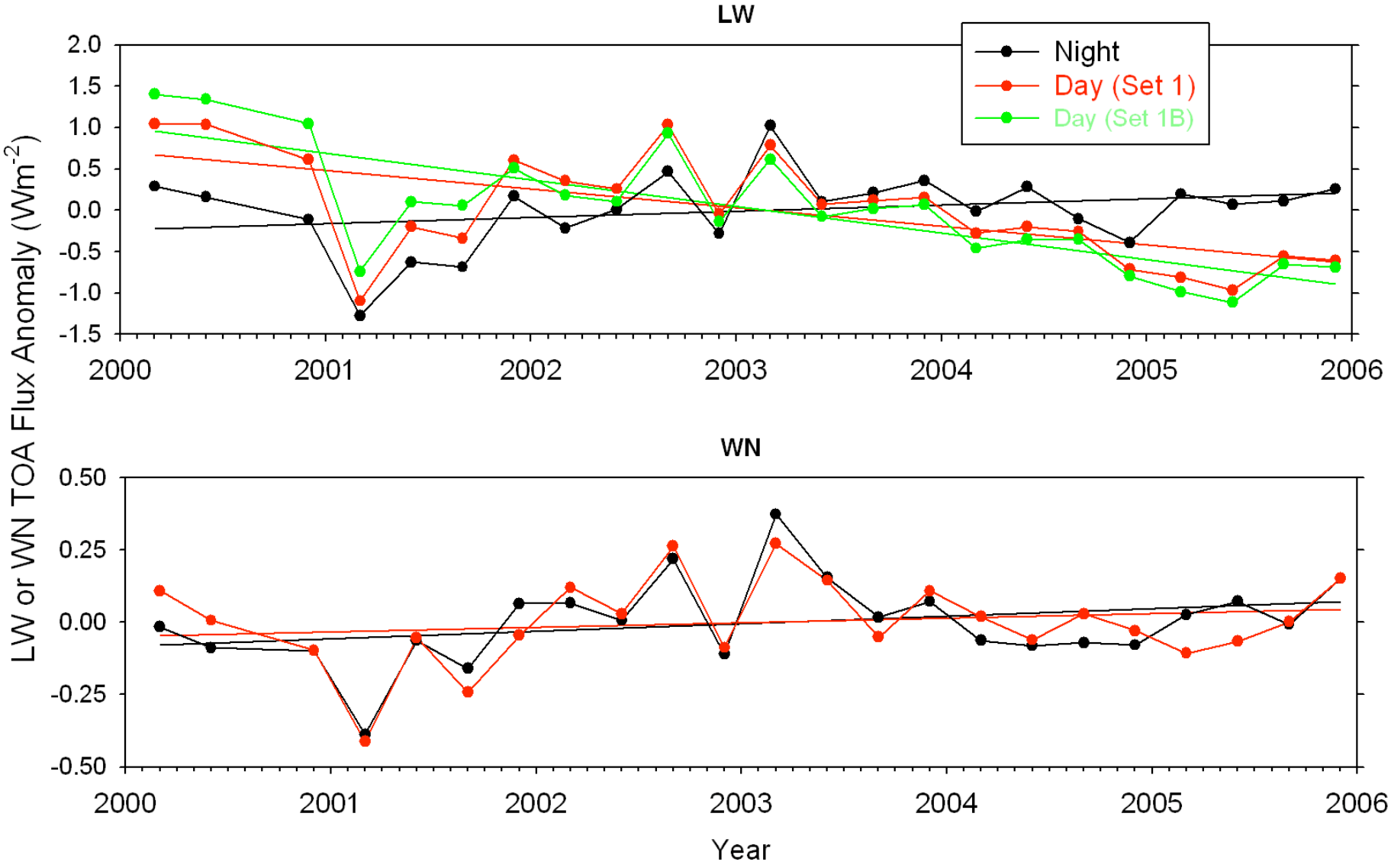

Tropical All-Sky Ocean SW TOA Flux Anomaly - FM1
SW TOA Flux Anomaly (Wm-2)
Rev1
Set 1
Set 1B
3
2
1
0
-1
-2
2000
2001
2002
2003
2004
2005
2006
Year


SW TOA Flux Relative Difference Compared to rev1
Relative Difference (%)
Set 1
Set 1B
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
2000
2001
2002
2003
2004
2005
2006
2007
Year

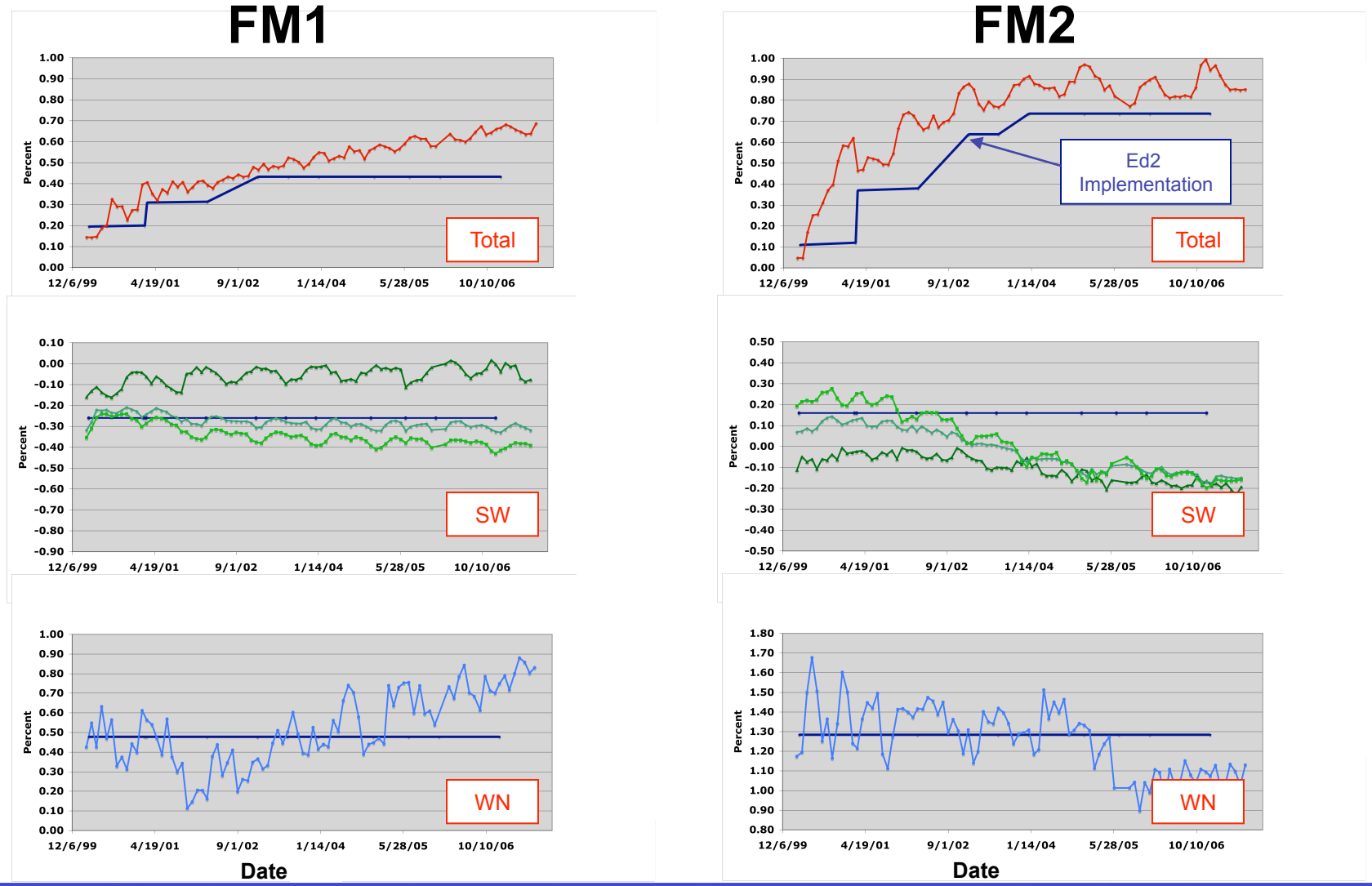
FM1 LW and WN TOA Flux Anomalies: Tropics



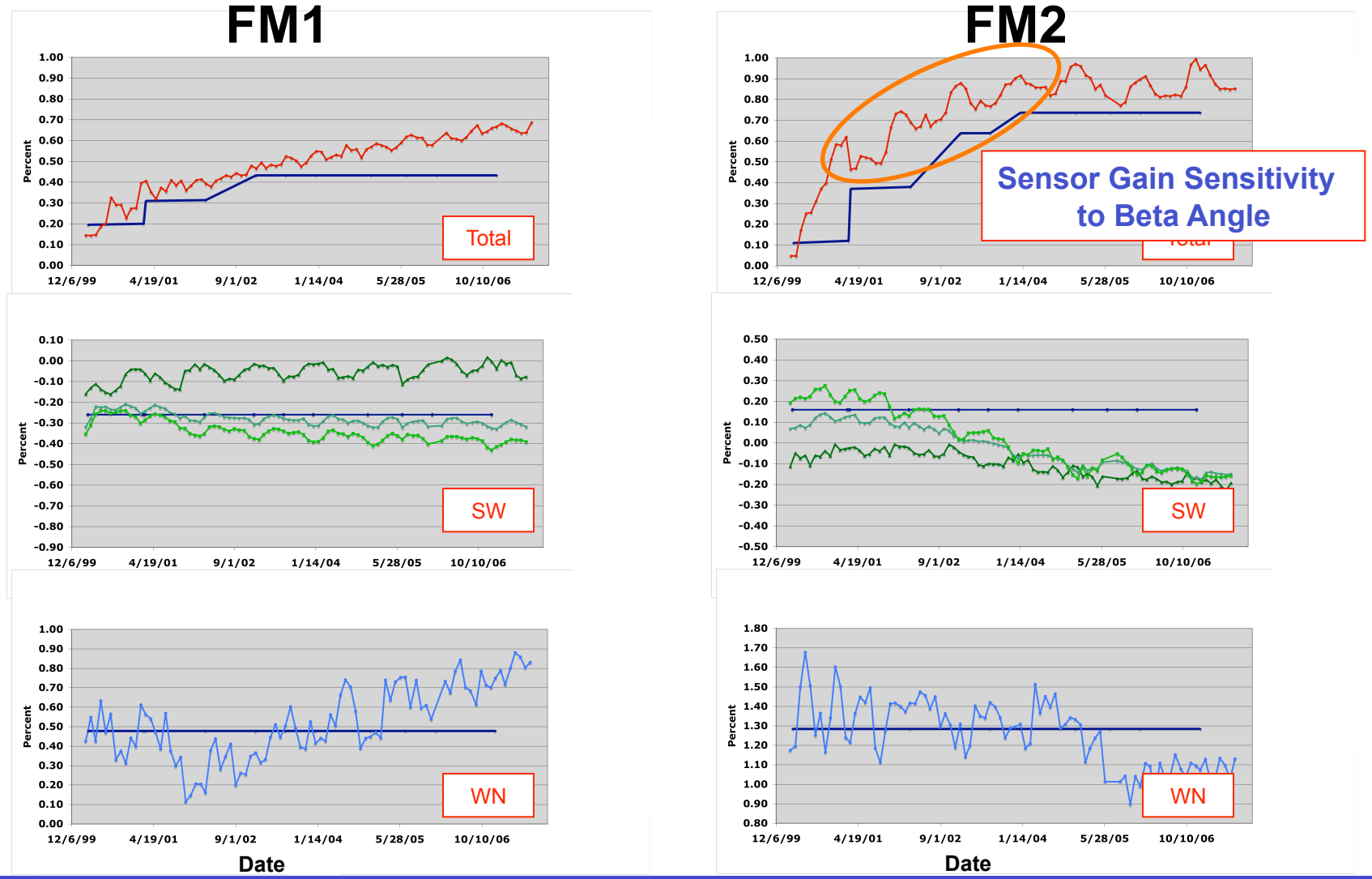
FM1 LW and WN TOA Flux Anomalies: Global



Terra Monthly Average ICM Results

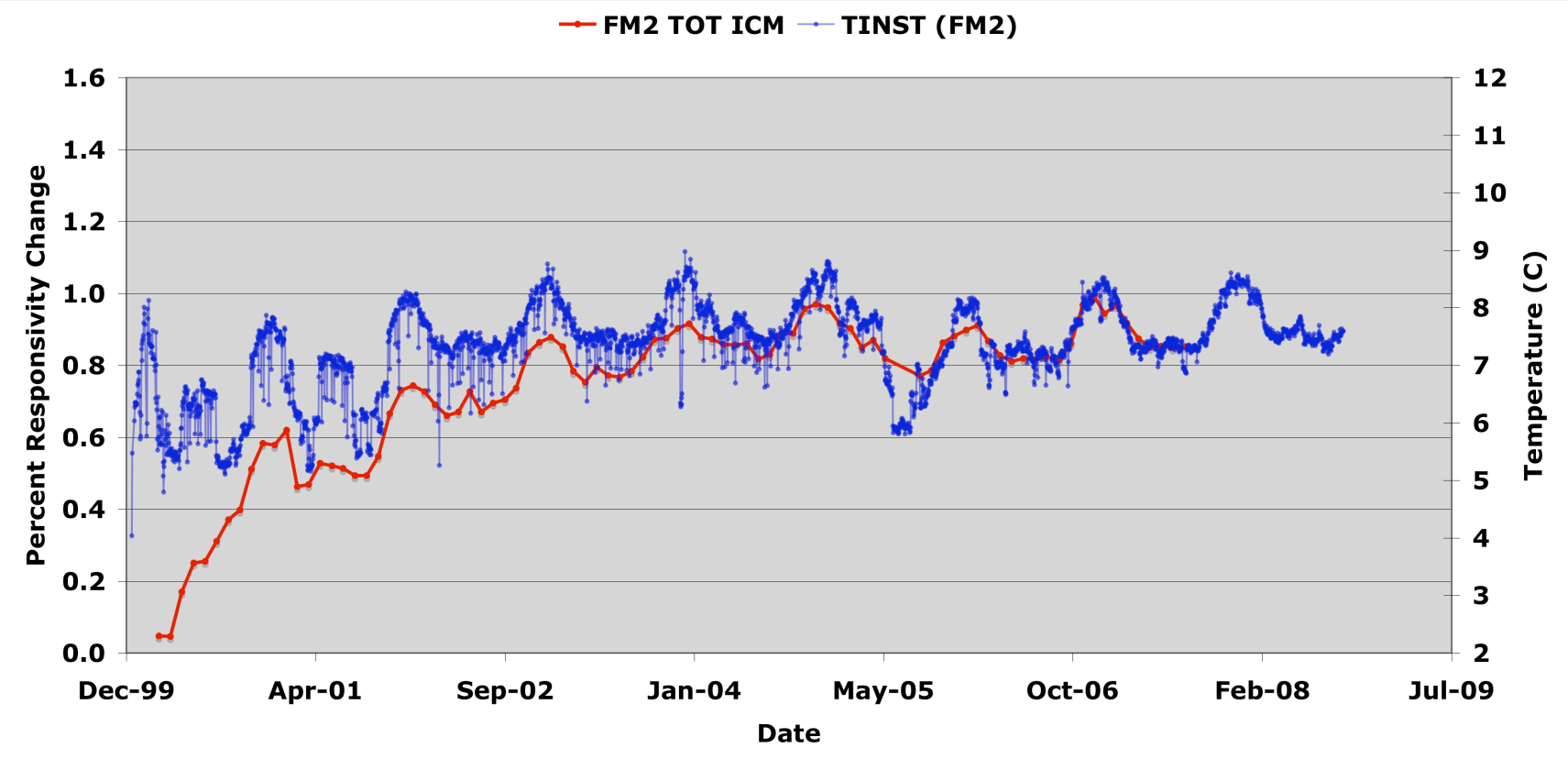


Terra Monthly Average ICM Results



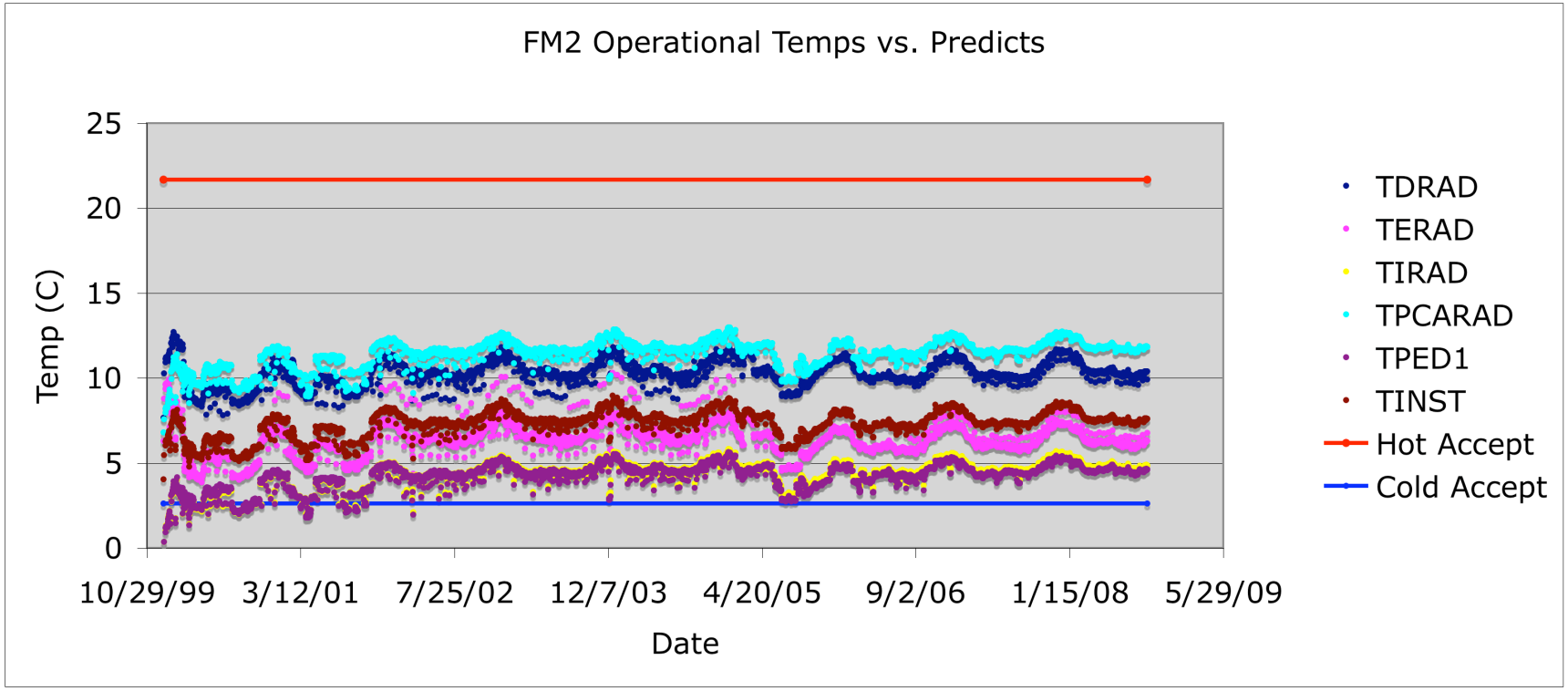
FM2 Total Channel Monthly Average ICM Results

Sensor Responsivity is highly correlated with instrument operating temperature



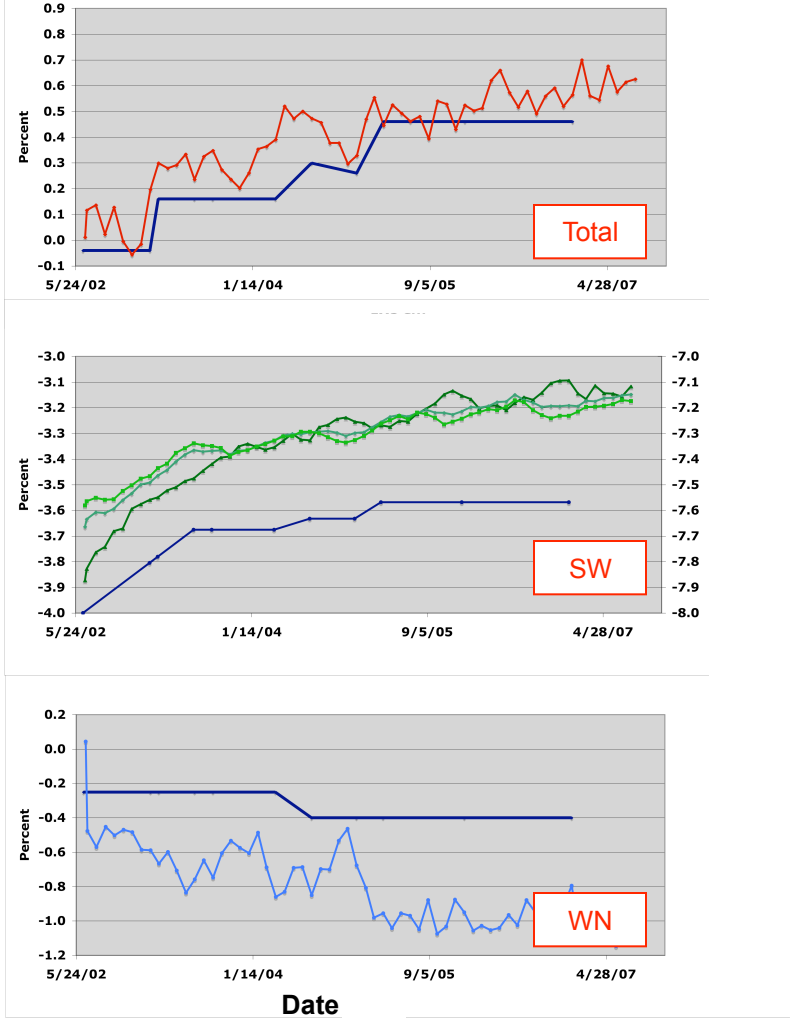
FM2 Operational Temperatures vs. Predicts

Ground Calibration typically conducted at Hot Acceptance Temperatures

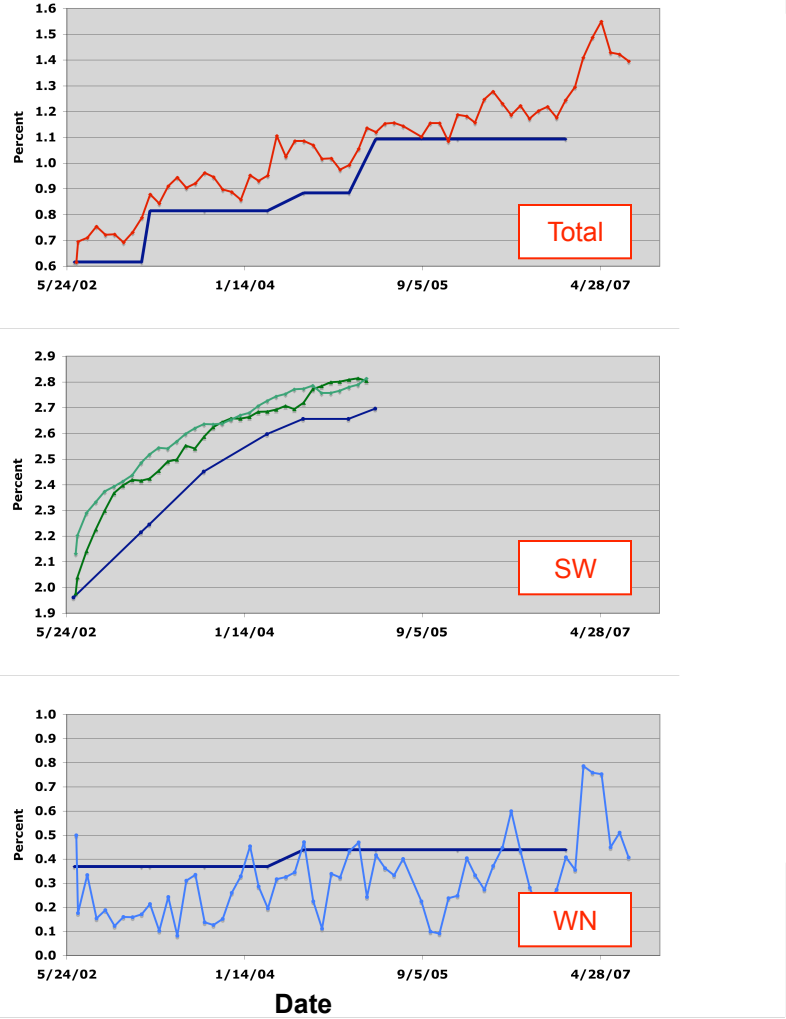


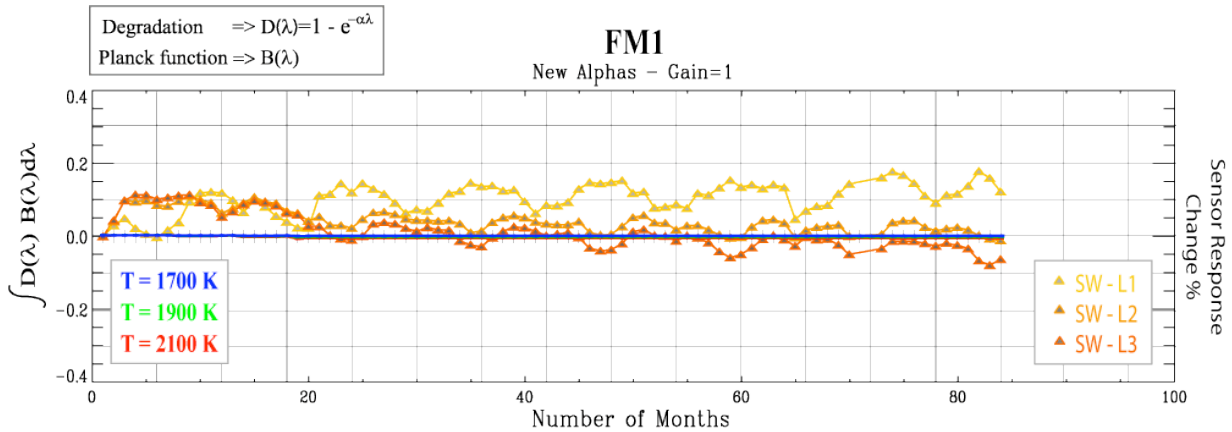
Aqua Monthly Average ICM Results

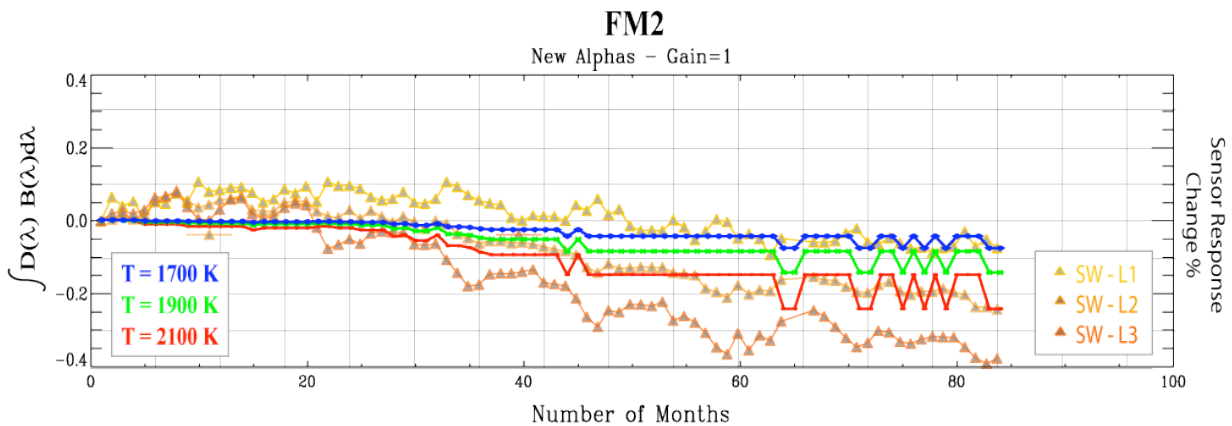
FM3

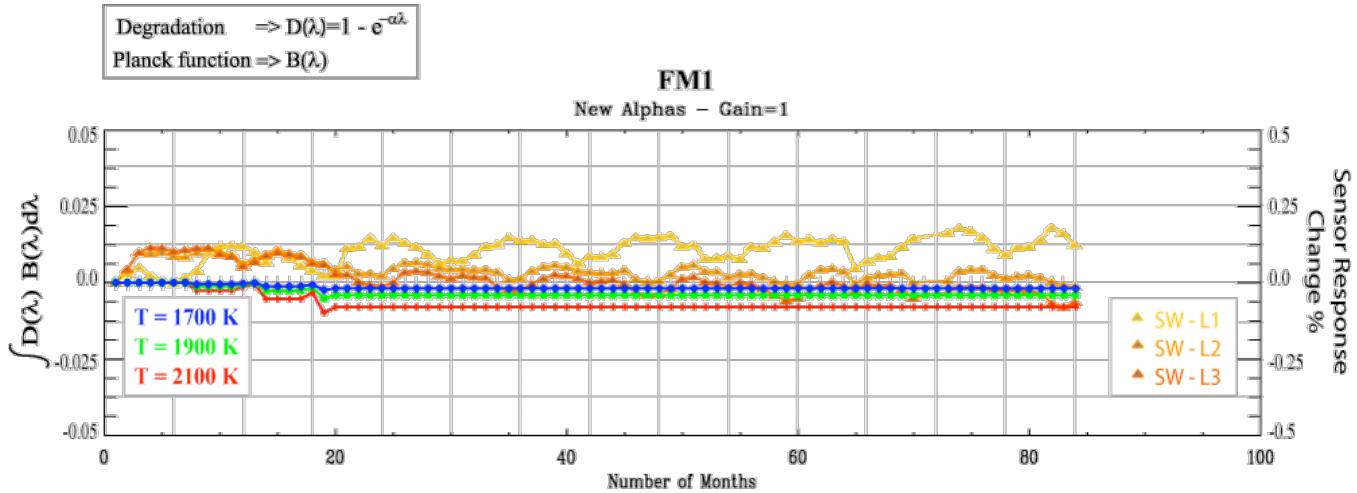


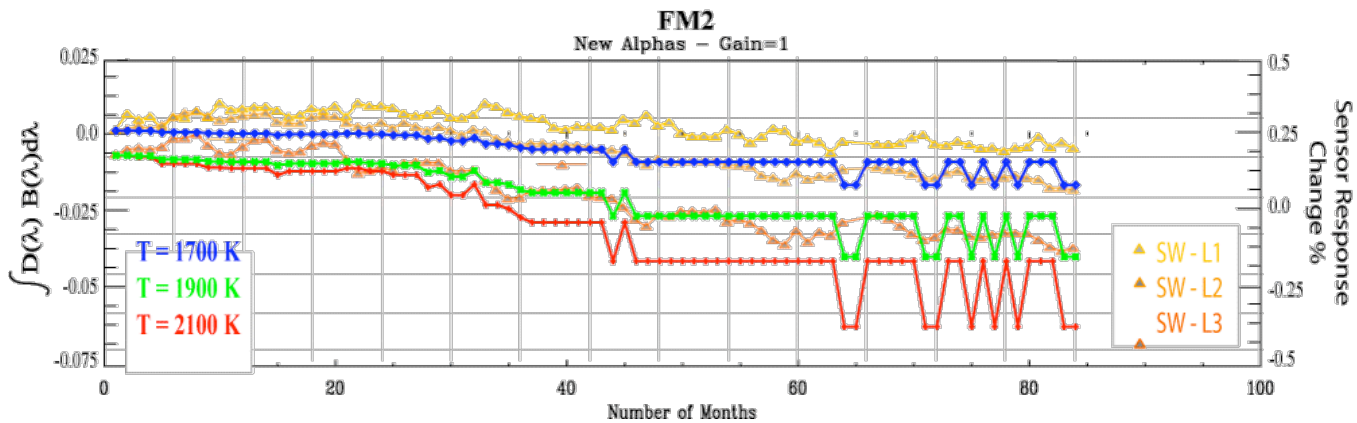
FM4




Degradation => D(λ)=1 - e^-αλ
Planck function => B(λ)
FM1
New Alphas – Gain=1
∫D(λ) B(λ)dλ
Sensor Response Change %
T = 1700 K
T = 1900 K
T = 2100 K
SW - L1
SW - L2
SW - L3
Number of Months


FM2
New Alphas – Gain=1
∫D(λ) B(λ)dλ
Sensor Response Change %
T = 1700 K
T = 1900 K
T = 2100 K
SW - L1
SW - L2
SW - L3
Number of Months


Degradation => D(λ)=1 - e^-αλ
Planck function => B(λ)
FM1
New Alphas – Gain=1
∫D(λ) B(λ)dλ
Sensor Response Change %
T = 1700 K
T = 1900 K
T = 2100 K
SW - L1
SW - L2
SW - L3
Number of Months


FM2
New Alphas – Gain=1
∫D(λ) B(λ)dλ
Sensor Response Change %
T = 1700 K
T = 1900 K
T = 2100 K
SW - L1
SW - L2
SW - L3
Number of Months

Deseasonalized SW Anomalies : Terra

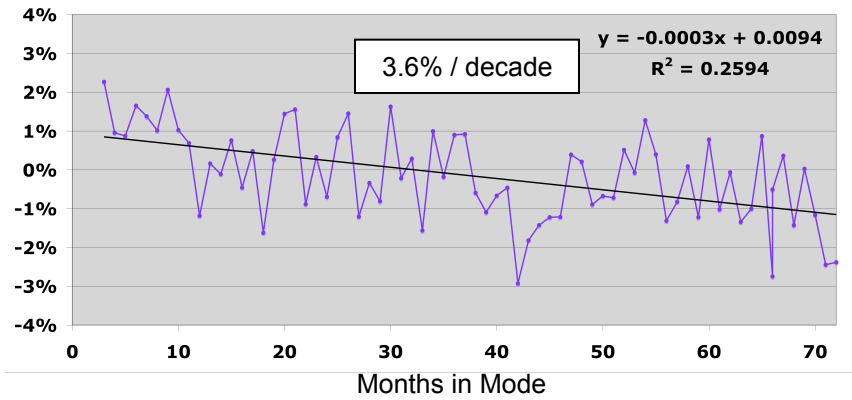
Scene Type

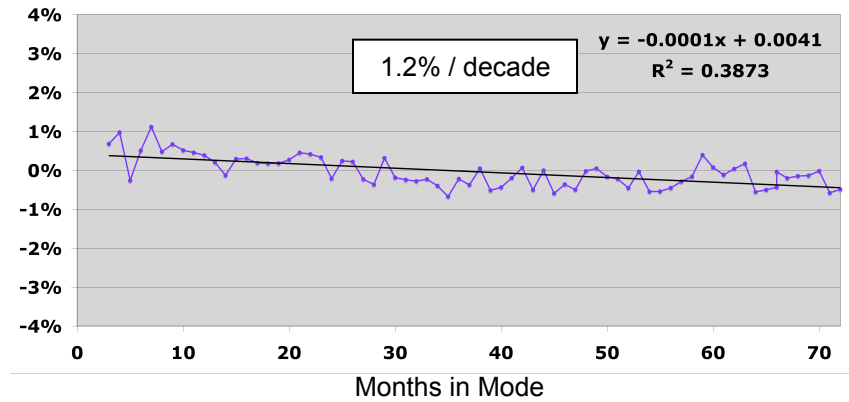
Operational Mode

ClrOcn

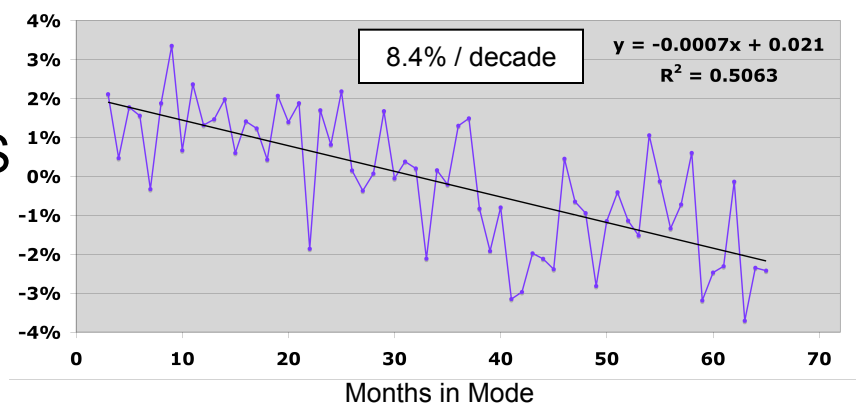
DCC

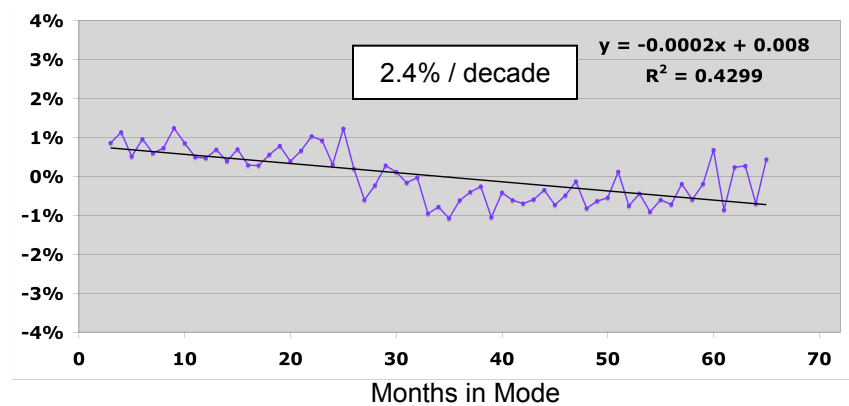
Xtrack





RAPS





Note: Unfiltered SW radiance measurements sorted into Angular bins (I.e. VZA and RAZ) and averaged on a monthly basis

Edition3 Studies : Status

Instrument has pursued two independent paths to characterize spectral degradation

Path A: led by Peter Szewczyk (Presented at May, 2008 STM)

Premise : Trends explained solely by operational mode, not by sensor

- Sort Clear Ocean (ClrOcn) and Deep Convective Cloud (DCC) unfiltered SW radiance measurements into Angular bins (I.e. VZA and RAZ)
- Determine monthly mean SW measurements for each bin
- Calculate deseasonalized anomalies for Xtrack and RAPS time series
- Trends in ClrOCn and DCC deseasonalized anomalies define drops in spectral thoughput at 0.4 and 0.65 microns respectively
  - DCC directly
  - ClrOCn, relative trend of RAPS to Xtrack measurements

Pros: simple, results appear robust for SW channel

Cons: Assumes DCC is absolutely stable, not applicable to SW/TOT

Edition3 Studies : Status

Instrument has pursued two independent paths to characterize spectral degradation

Path B: led by Grant Matthews (Presented at May & Nov 2007 STM's, latest results presented today by SARB, TISA)

Premise : Optics contaminated on-orbit due to transfer of contaminants by Atomic Oxygen

- Spectral degradation is characterized by an 8 parameter exponential fit
- Deep Convective Cloud Albedo used as an absolute stability metric
- All sensor channels normalized to DCC Albedo on a monthly basis

Pros: Results appear consistent
Passes all sanity checks
Provides good engineering insight to possible physical processes

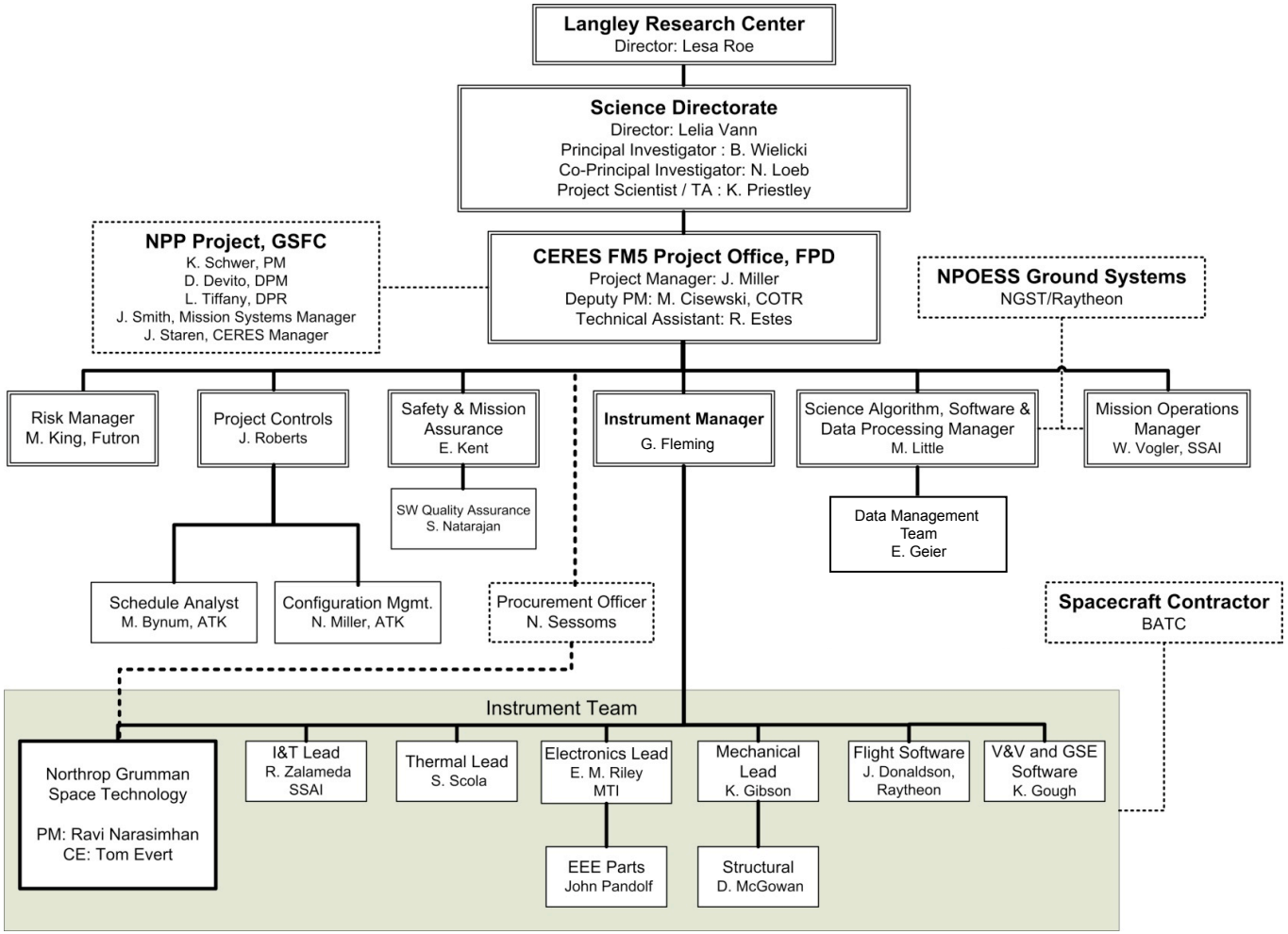
Cons: Too complicated with too many inter-dependencies
Assumes DCC is absolutely stable
Requires non-physically based changes to spectral response function to resolve divergence in Day/Night OLR
Assumes complete failure of the onboard SW calibration equipment

What is the impact of 8-years of storage?

Key Concerns are being addressed :

- **Review of Electronic parts for age and radiation environment**
  - NPP Orbit provides different radiation environment
  - Parts Review underway
  - No significant concerns identified
- **Limited Life articles**
  - Bearing lubrication
    - N_2 purged storage environment was optimal
    - No concern for limiting lifetime
  - Onboard Calibration lamps
    - No known mechanisms to reduce life expectancy
- **Address on-orbit anomalies from Terra/Aqua**
  - FM4 SW channel Sensor Electronics Assembly failure
    - Tiger Team reconstituted
    - 90 years of operational lifetime on circuit with one failure
    - Awaiting Recommendation

CERES Project Organization



NPP S/C Layout - 1