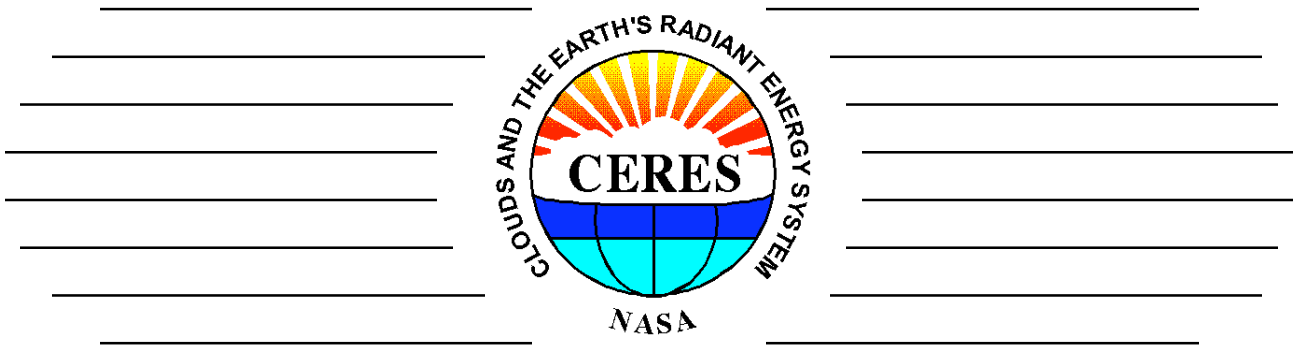
Terra/Aqua Instrument Calibration: SW Revision 1



Kory J. Priestley
Susan Thomas, Denise Cooper,
Phil Hess, Grant Matthews, Peter Szewczyk,
Dale Walikainen, Robert Wilson

CERES Science Team Meeting
Williamsburg, VA
May 2-4, 2006

NASA Langley Research Center
Atmospheric SCIENCES

CERES Instrument Working Group Homepage

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

Agenda

Today's talks are going to be primarily concerned with SW Calibration issues… whether they impact the SW or SW/TOT channels.

- **Provide a status of the BDS and ERBE Like Data Products**
    - **Edition 3 vs. Edition2_Rev1**
- **Potential modifications of the Cal/Val protocol.**
    - **Use Deep Convective Clouds vs. SWICS Lamps**
- **New operational constraints,**
    - **impacts to special operations**
- **Detailed discussion of Edition3 algorithm modifications.**

Questions and Comments for thought

1. In Edition3 does the Science Team want all of the CERES instruments placed on the same radiometric scale?
2. Is the Science Team comfortable with using Deep Convective Clouds as a relative calibration target?
3. New operational constraints require additional justifications for field campaign/intercalibration coverage requests.

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…

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	76 +
Aqua	FM3, FM4	5/02	6/02	46 +
?	FM5	?	?	?

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TRMM	PFM	11/97	1/98	9
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Aqua	FM3, FM4	5/02	6/02	46 +
?	FM5	?	?	?

20.3 Instrument Years of Data

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. All spectral changes are broadband and 'gray'.

Edition3 - *Release date Fall 2006*. Will incorporate temporally varying spectral artifacts in the SW measurements. A complete re-analysis of Ground Calibration with additional component characterization 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 4 months

Notification of Revision

ATMOSPHERIC SCIENCES DATA CENTER

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**

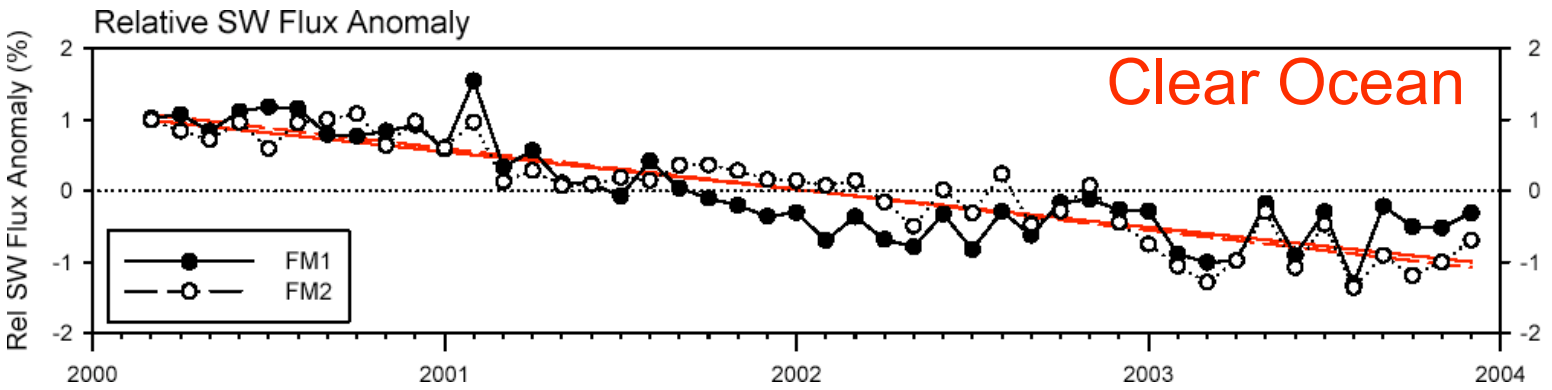
The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Team. This document briefly summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, 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.

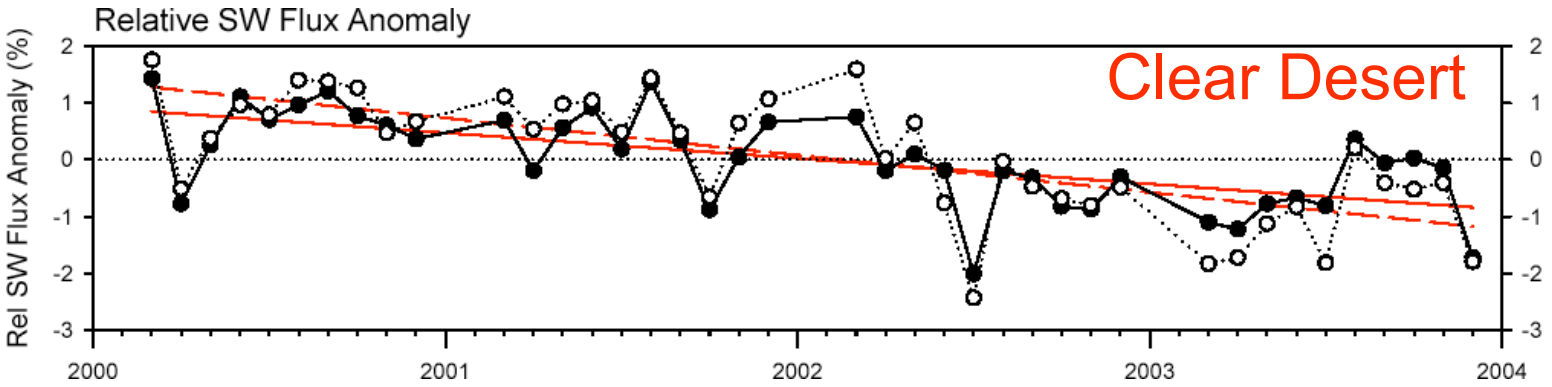
This document is a high-level summary and represents the minimum information needed by scientific users of this data product. It is strongly suggested that authors, researchers, and reviewers of research papers re-check this document for the latest status before publication of any scientific papers using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

Table of Contents

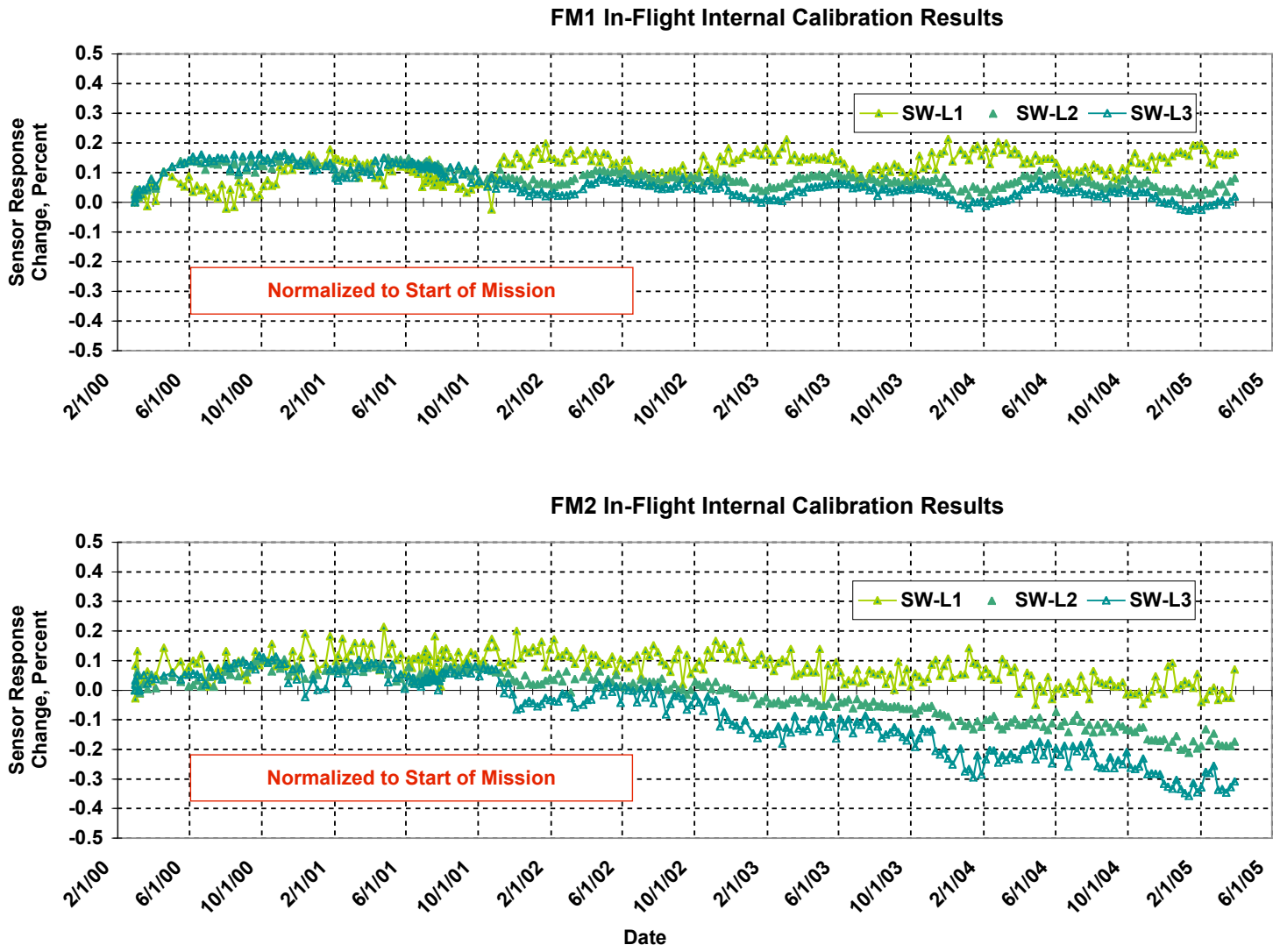
- Nature of the BDS Product
- Updates to Current Edition
- **User Applied Revisions**
- Validation and Quality Assurance
- Current Estimated Uncertainty of Data
- Cautions When Using Data
- Expected Reprocesings
- References
- Web links to Relevant information
- Referencing Data in Journal Articles
-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

CERES SSF Ed2B SW TOA Flux Anomaly

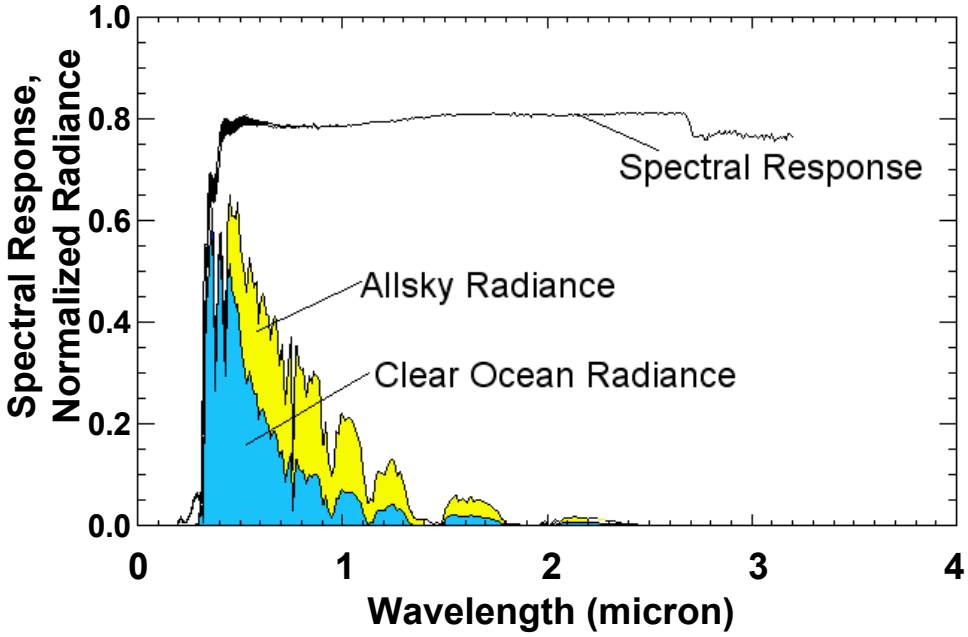


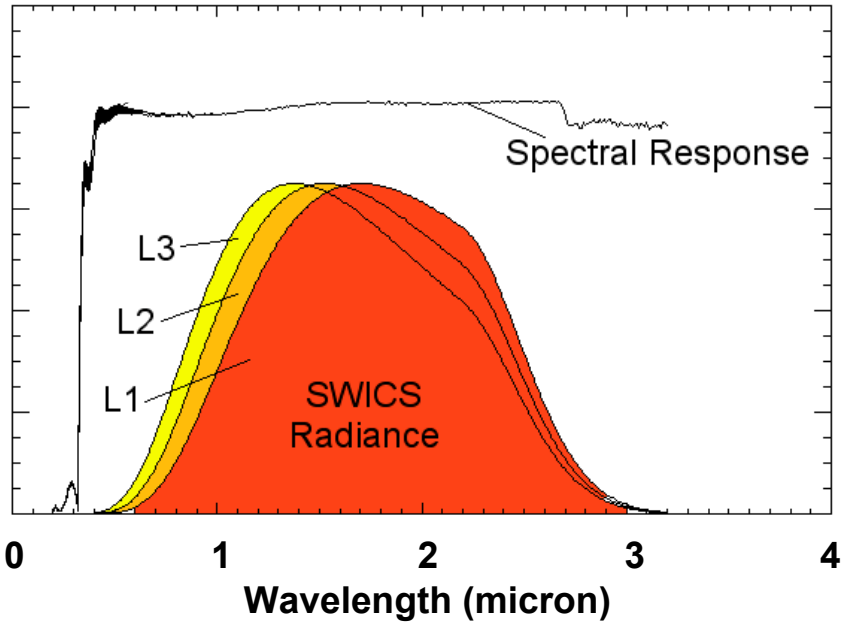


Terra SW Internal Calibration Results



Spectral Degradation : SWICS vs. Earth Spectra

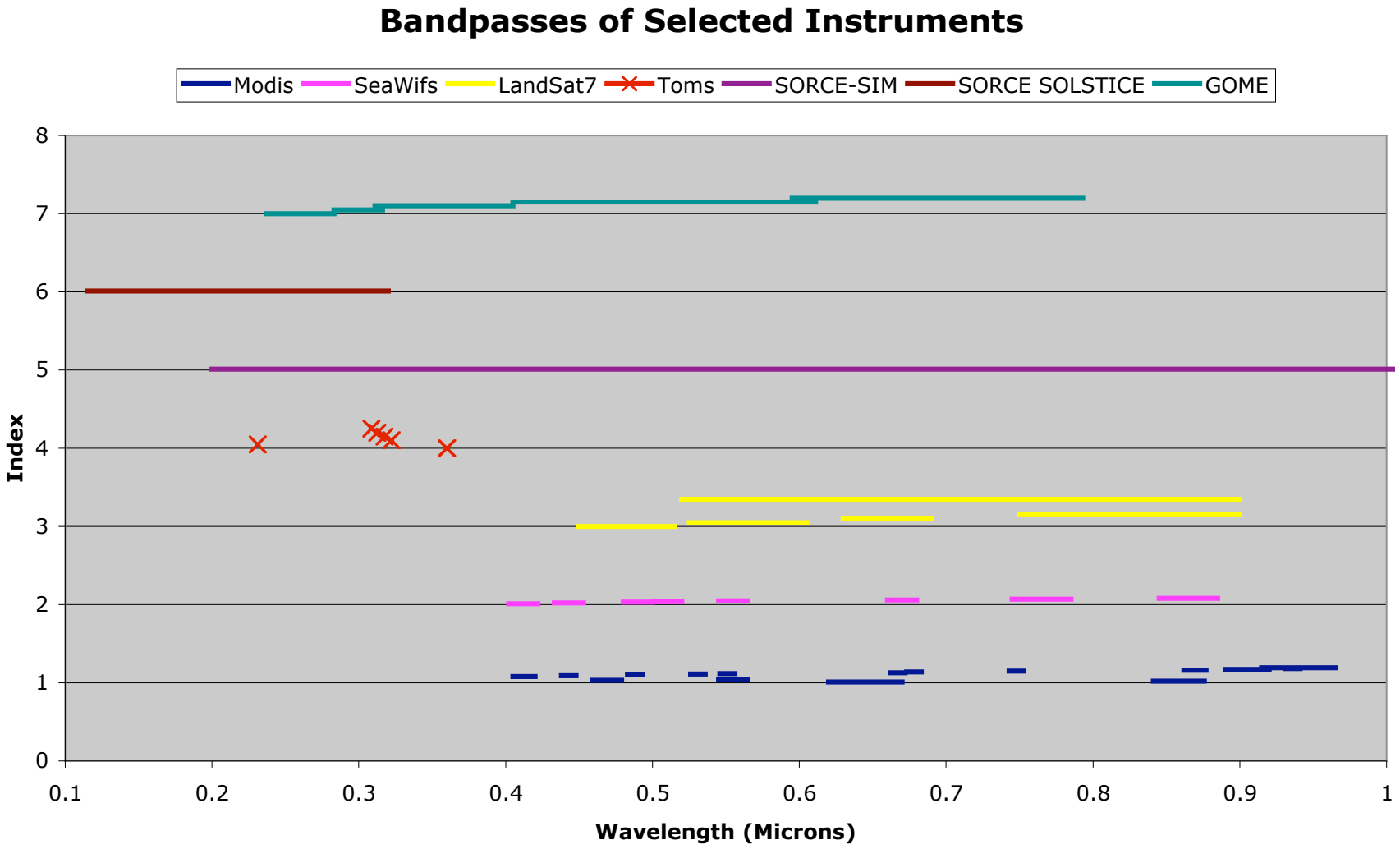




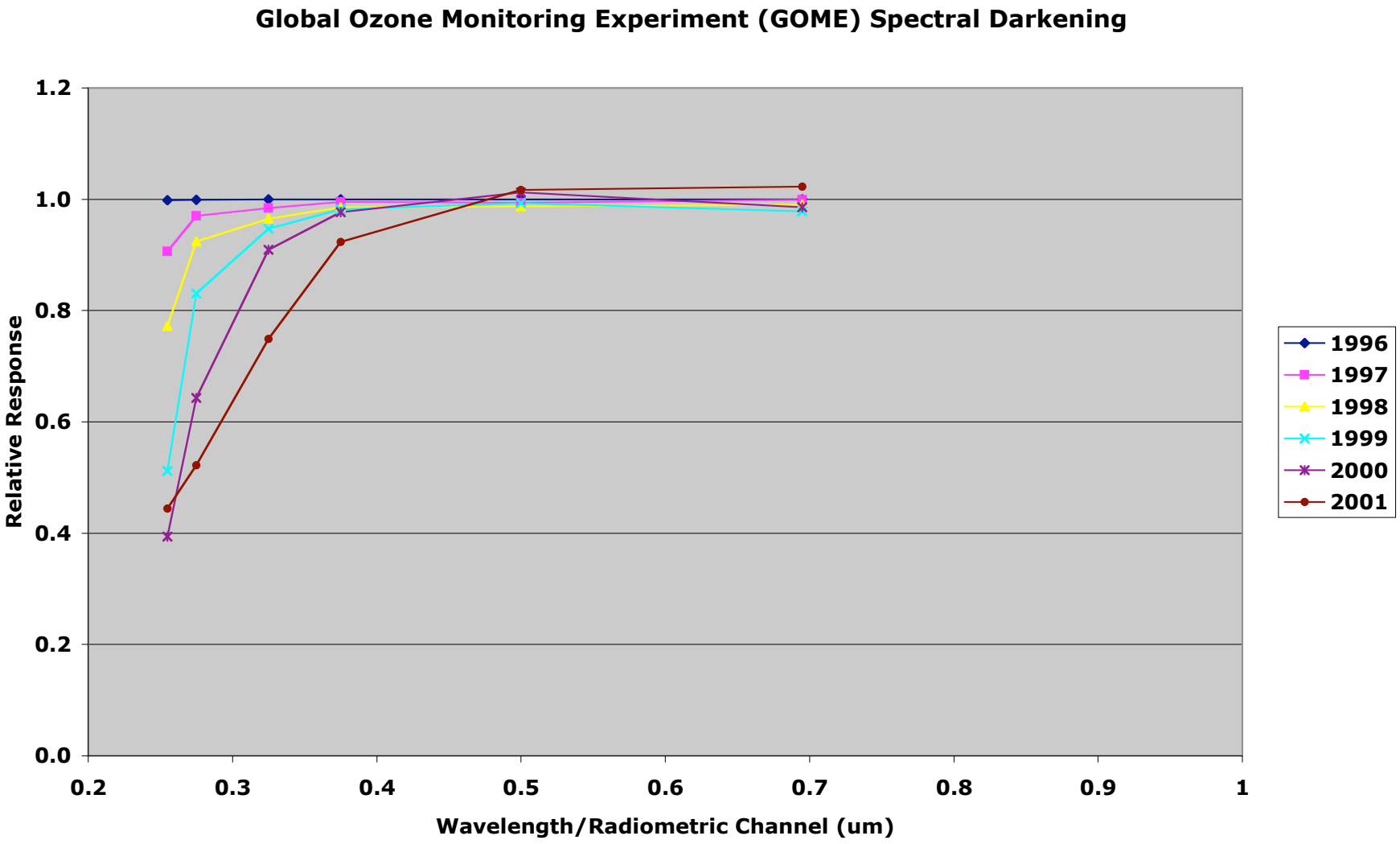
$$f^{sw}_{allsky} \text{ change} \approx -2\%$$

$$f^{sw}_{swics} \text{ change} \approx -0.1\%$$

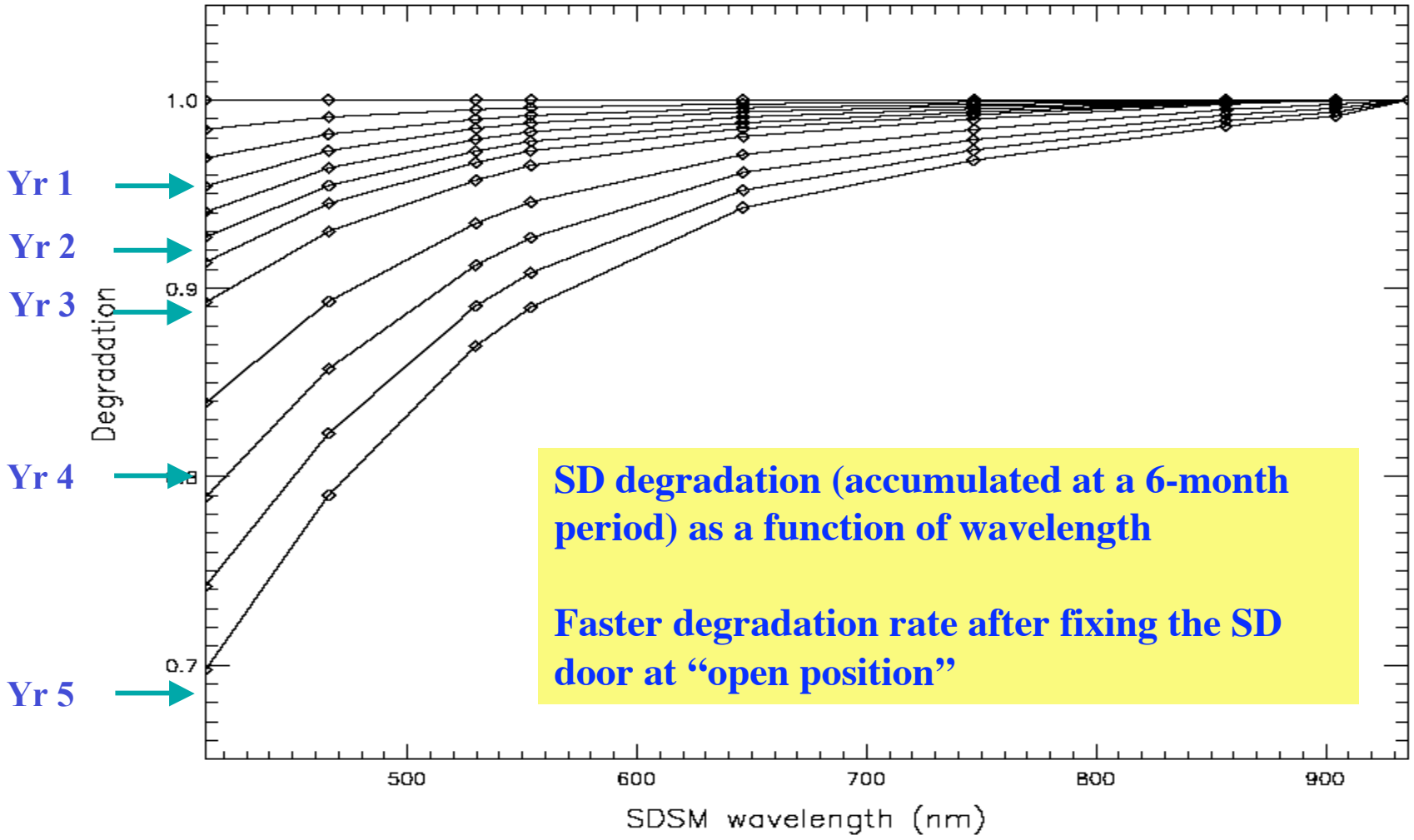
LEO Missions Subject to Spectral Darkening



Spectral Darkening on Similar Missions



Modis Solar Diffuser Spectral Degradation



SD degradation (accumulated at a 6-month period) as a function of wavelength

Faster degradation rate after fixing the SD door at "open position"

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.

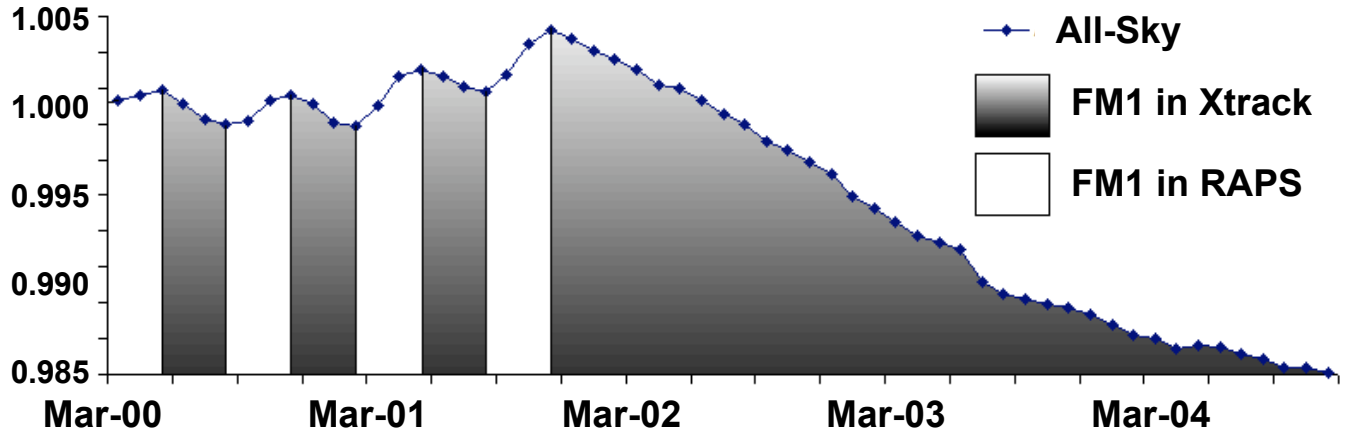
26,000 co-located (but not independent) measurements in a given day, provides a very rigorous statistical tool.

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

Terra Edition2 Nadir Direct Comparison

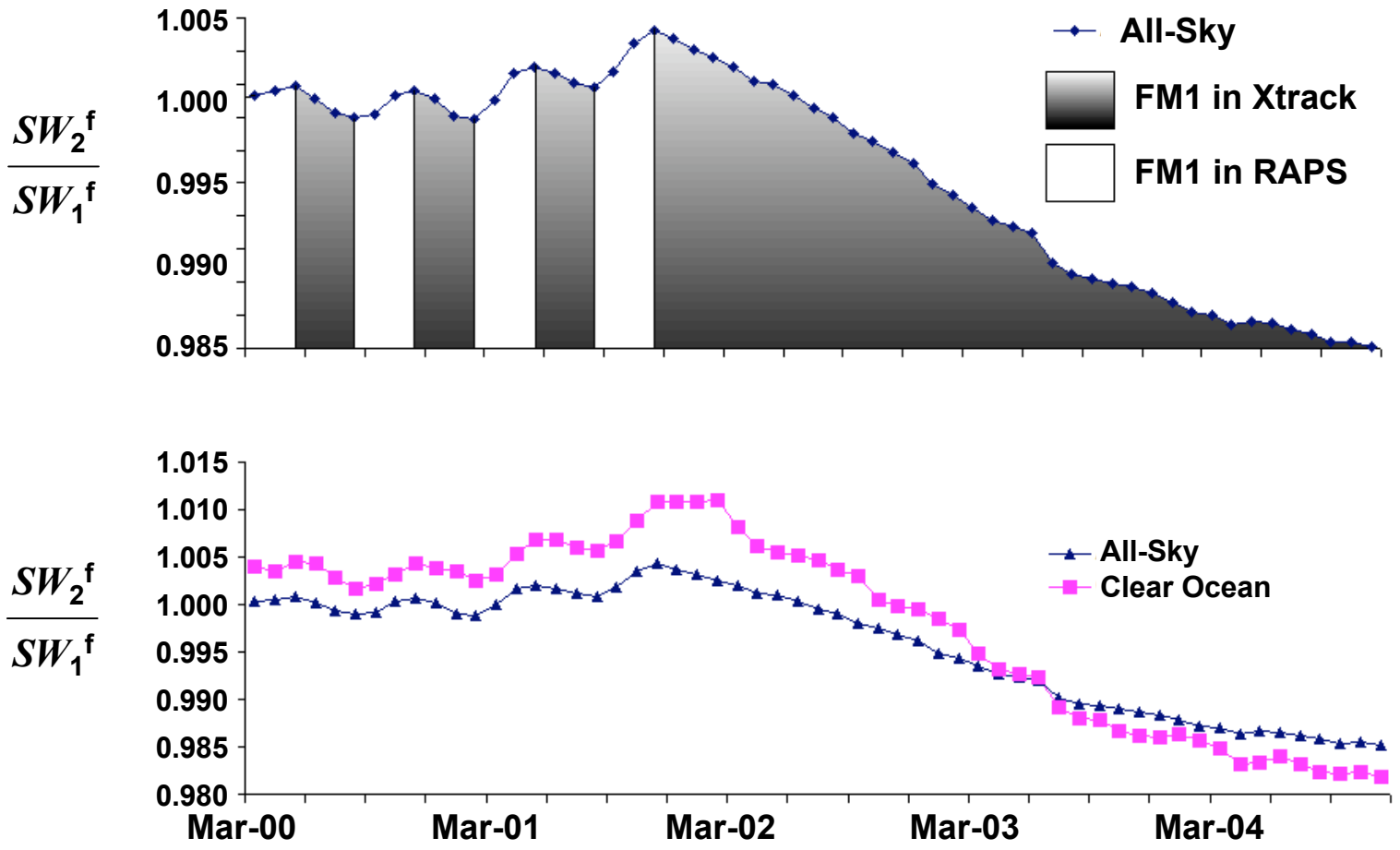
SW Nadir Radiances

$$\frac{SW_2^f}{SW_1^f}$$

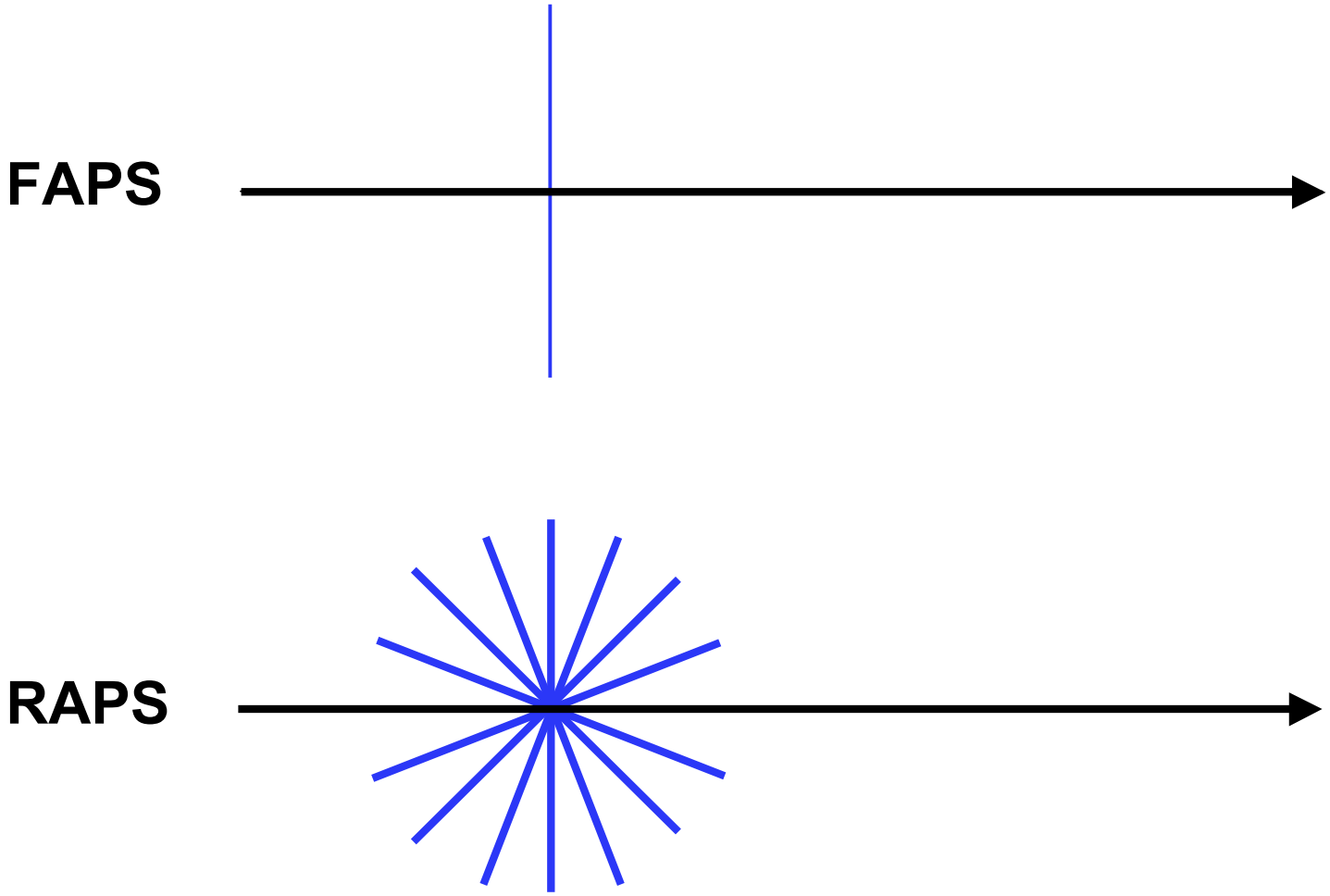


Terra Edition2 Nadir Direct Comparison

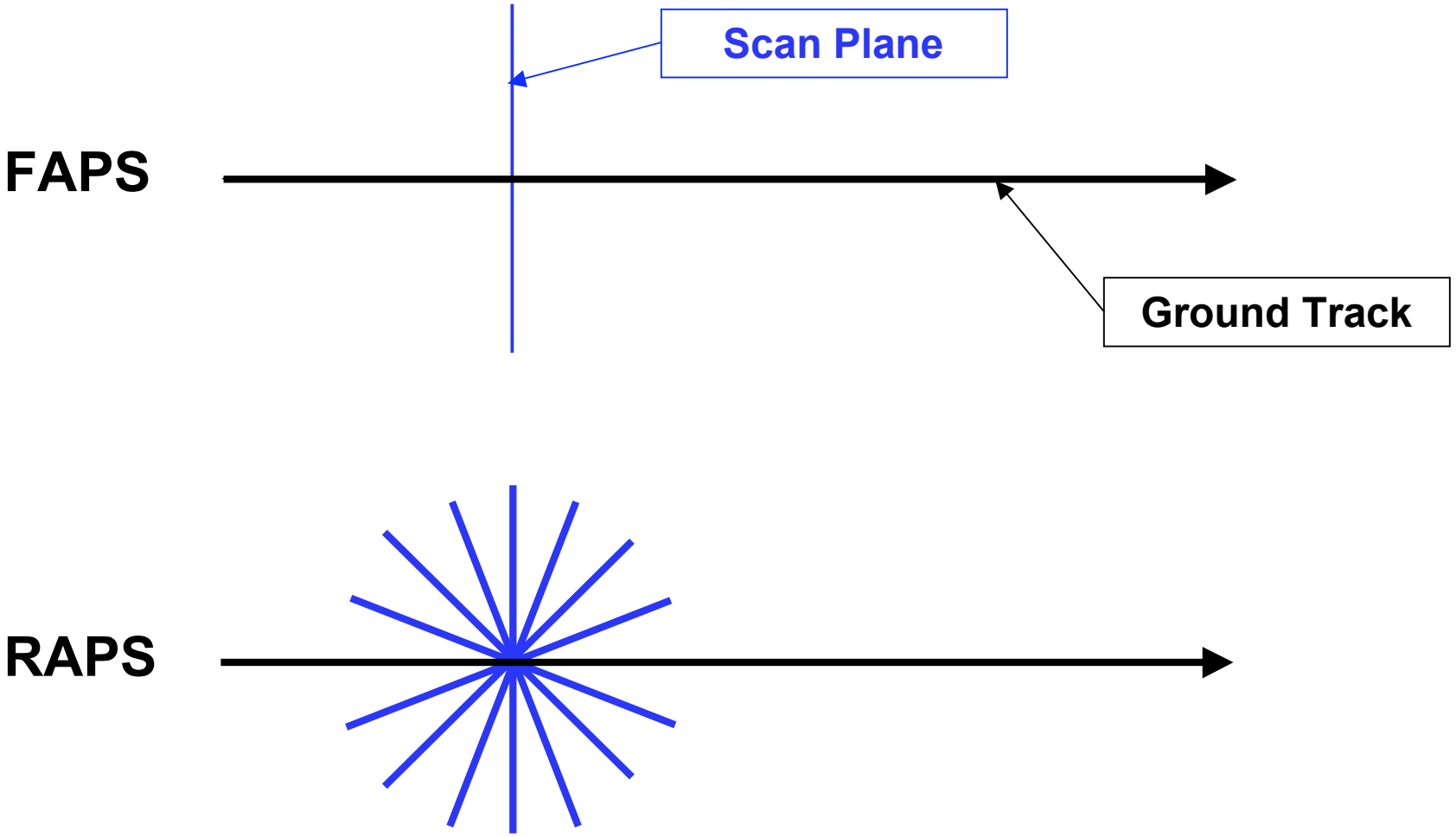
SW Nadir Radiances



Whats the difference between RAPS and FAPS?



Whats the difference between RAPS and FAPS?



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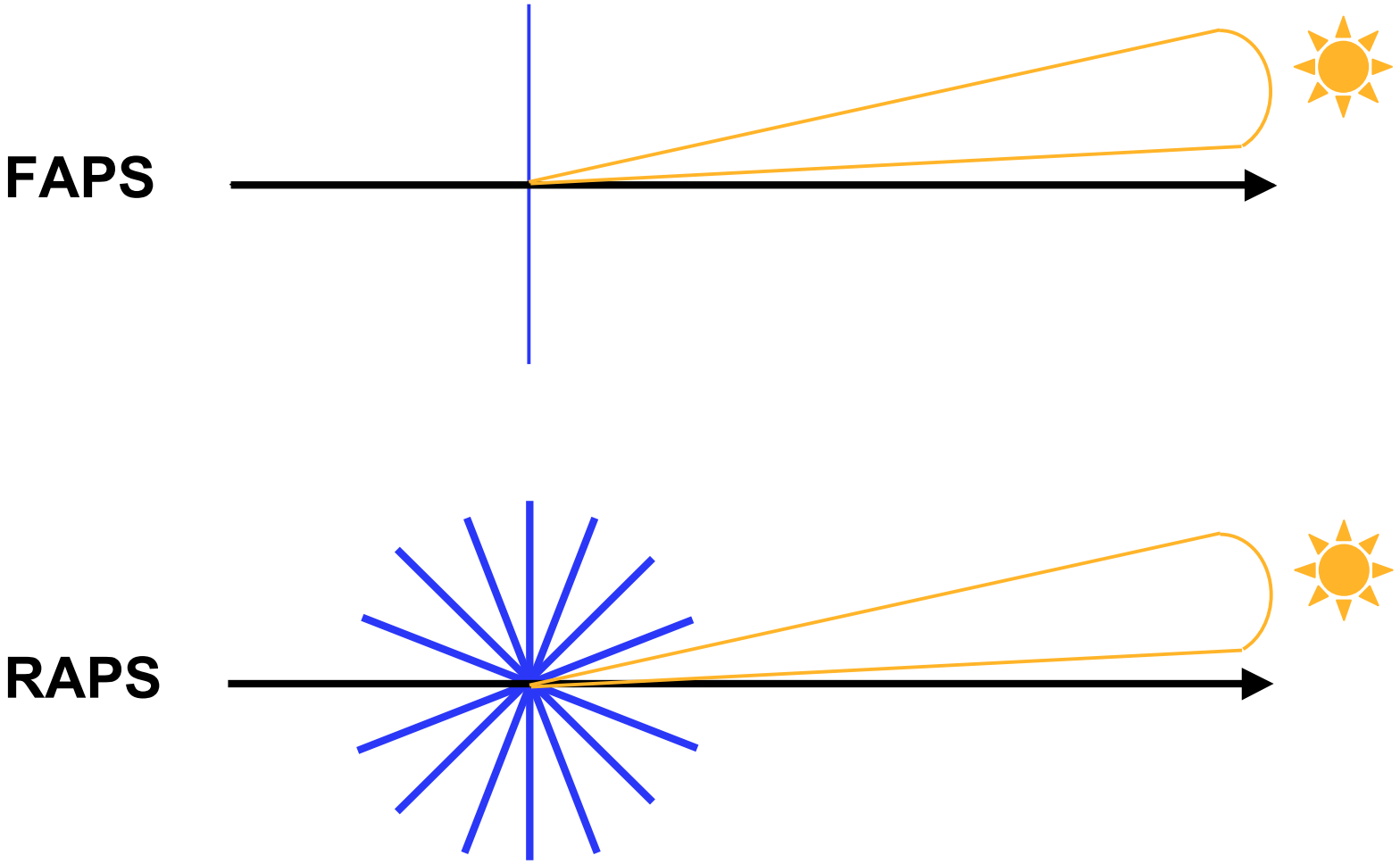

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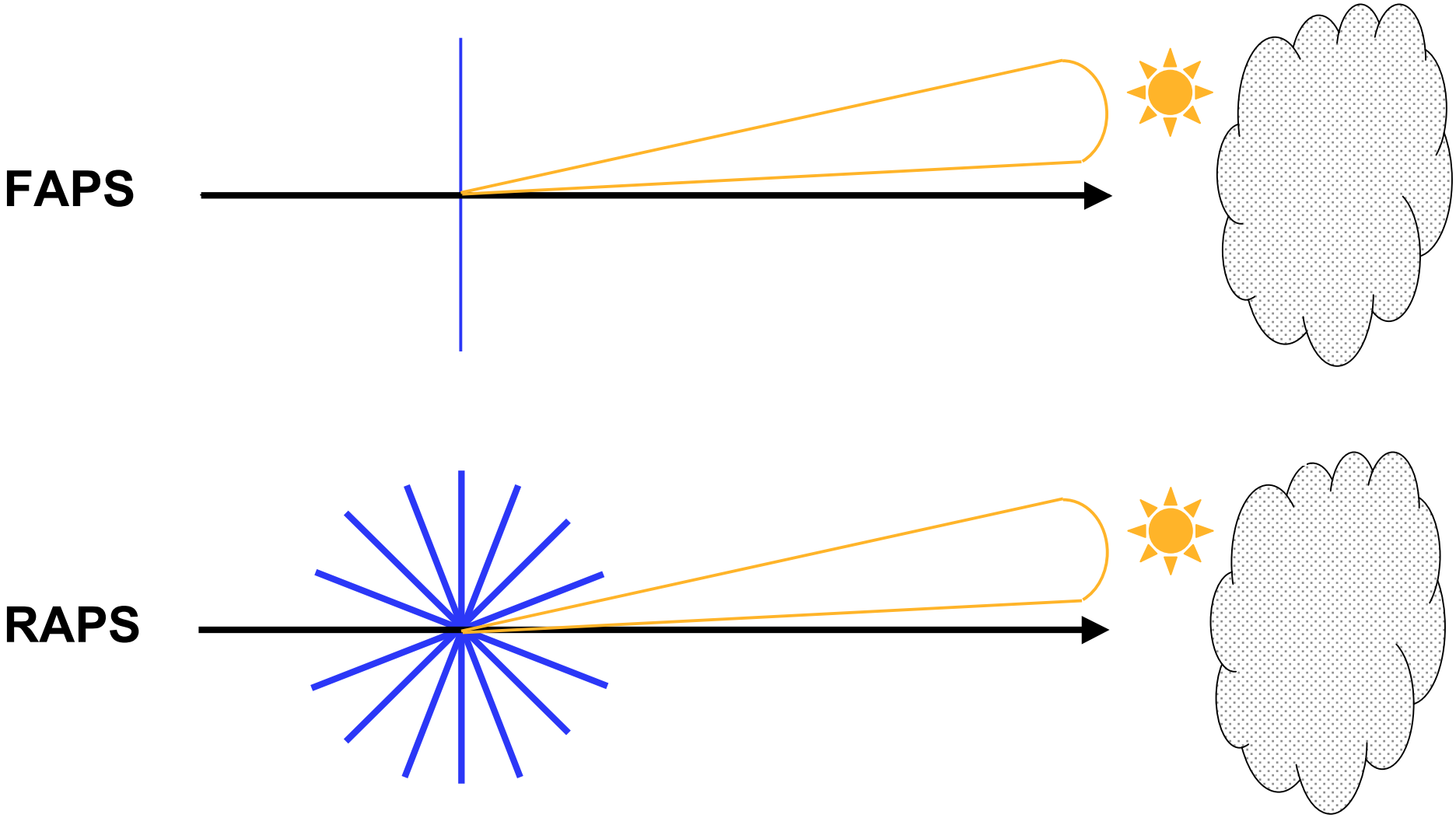
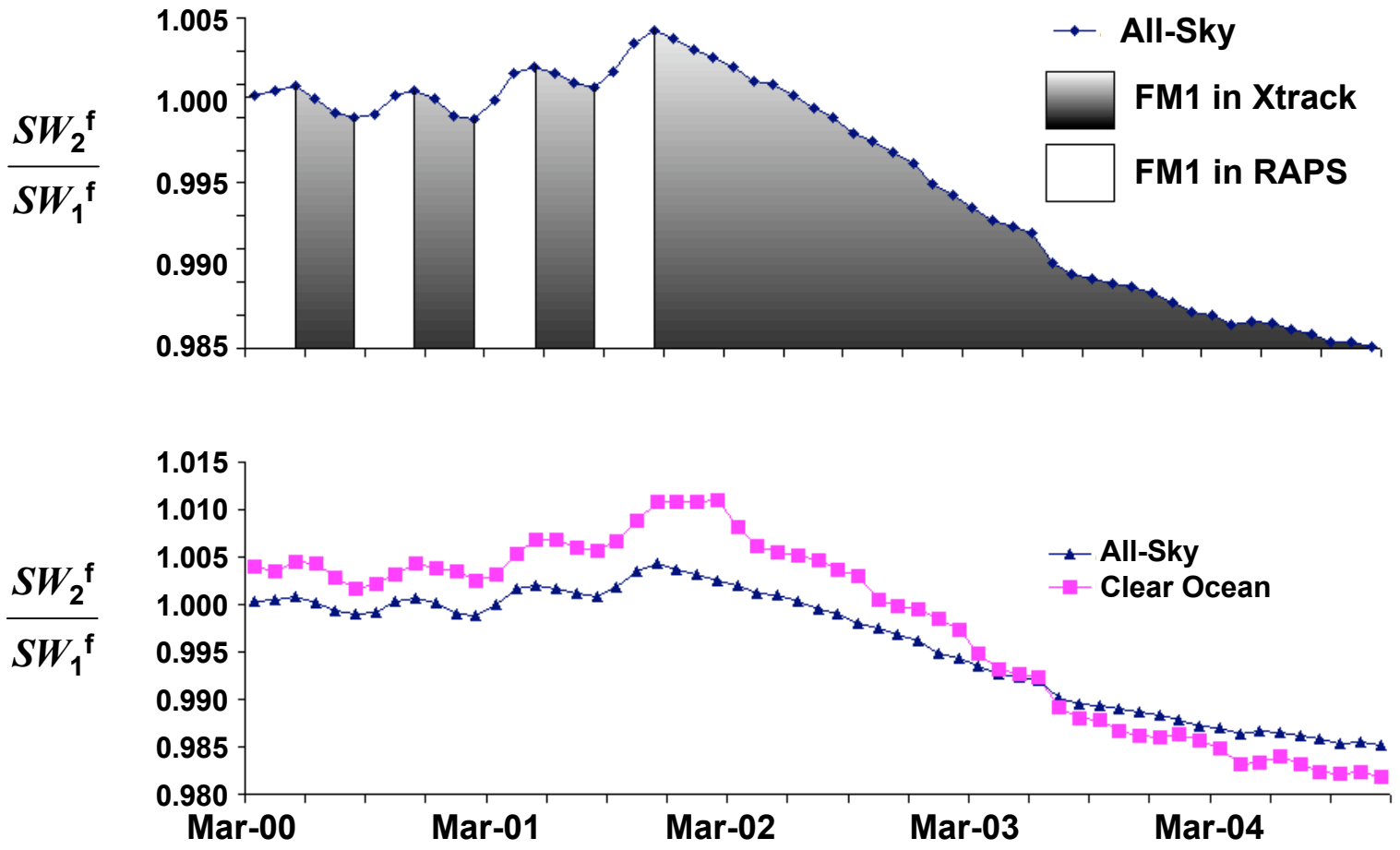
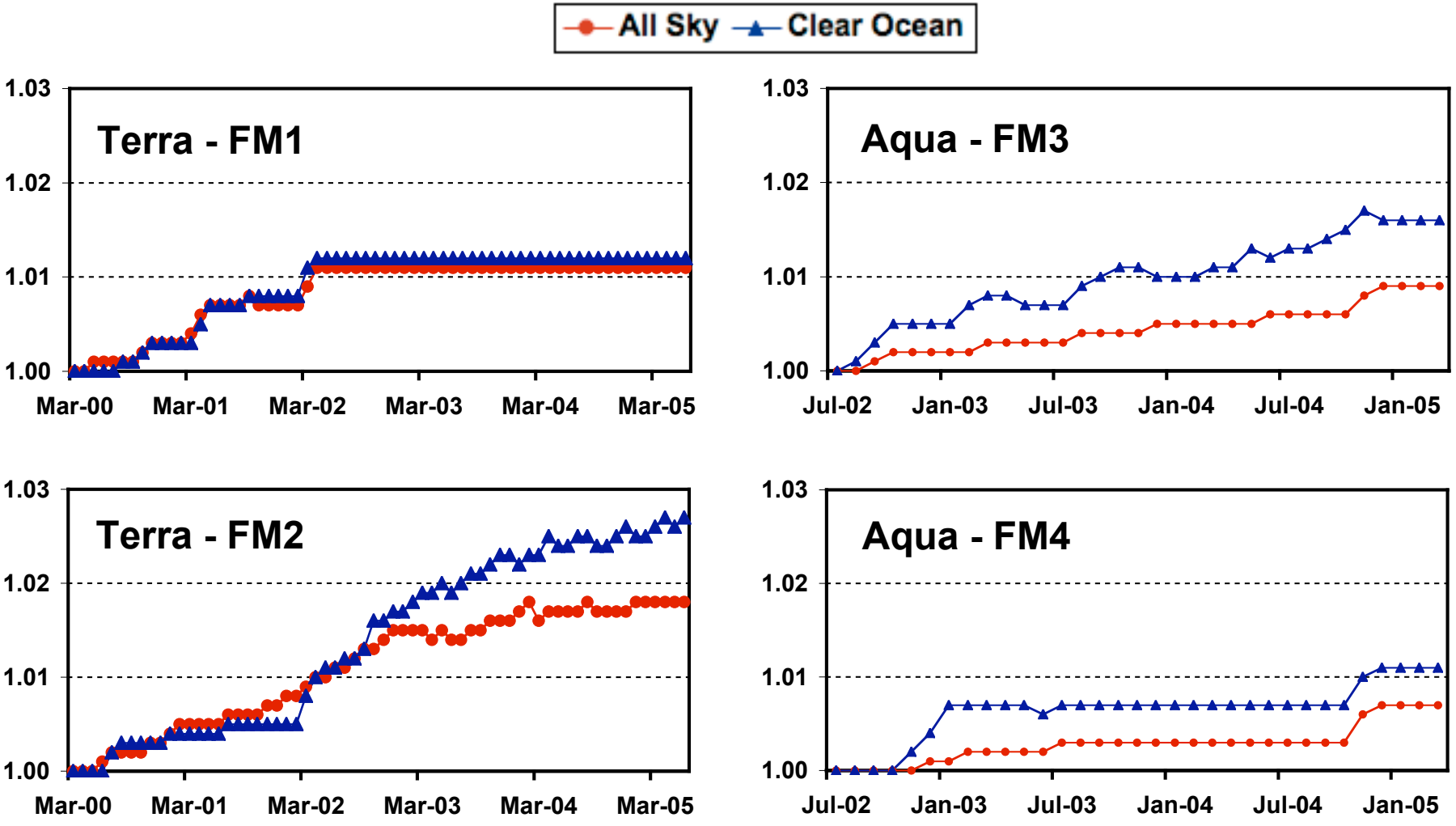


Terra Edition2 Nadir Direct Comparison

SW Nadir Radiances



Edition2_Rev1 Scaling Factors



Edition2_Rev1 SW Scaling Factors

A table of Edition2_Rev1 monthly scaling factors is provided via the CERES Data Quality Summaries…

ATMOSPHERIC SCIENCES DATA CENTER

CERES Terra Revision Table

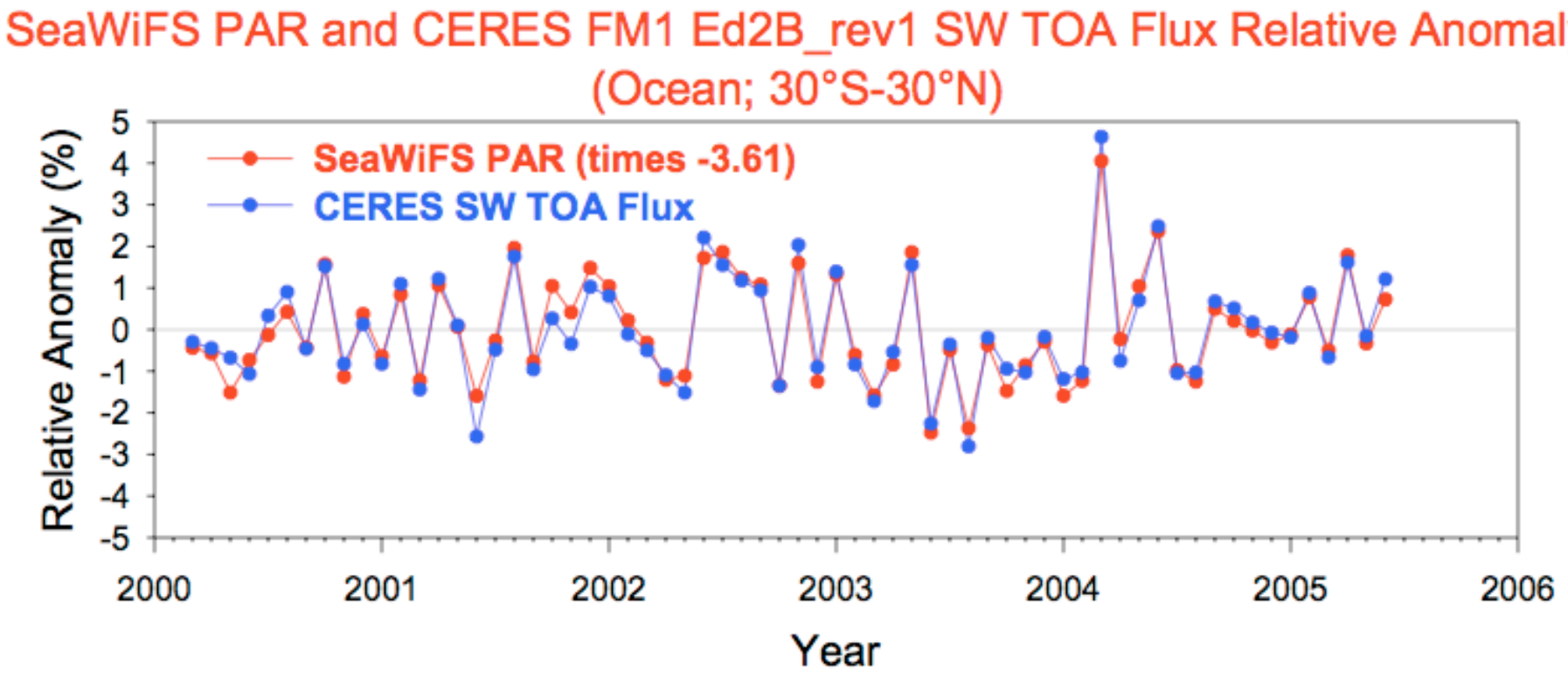
2000 | 2001 | 2002 | 2003 | 2004 | Tab-delimited file

		All Sky		Clear Ocean	
Year	Month	FM1	FM2	FM1	FM2
2003	Jan	1.011	1.015	1.012	1.017
	Feb	1.011	1.015	1.012	1.018
	Mar	1.011	1.015	1.012	1.019
	Apr	1.011	1.014	1.012	1.019
	May	1.011	1.015	1.012	1.020

Multiply your May 03 Terra allsky SW fluxes by these values

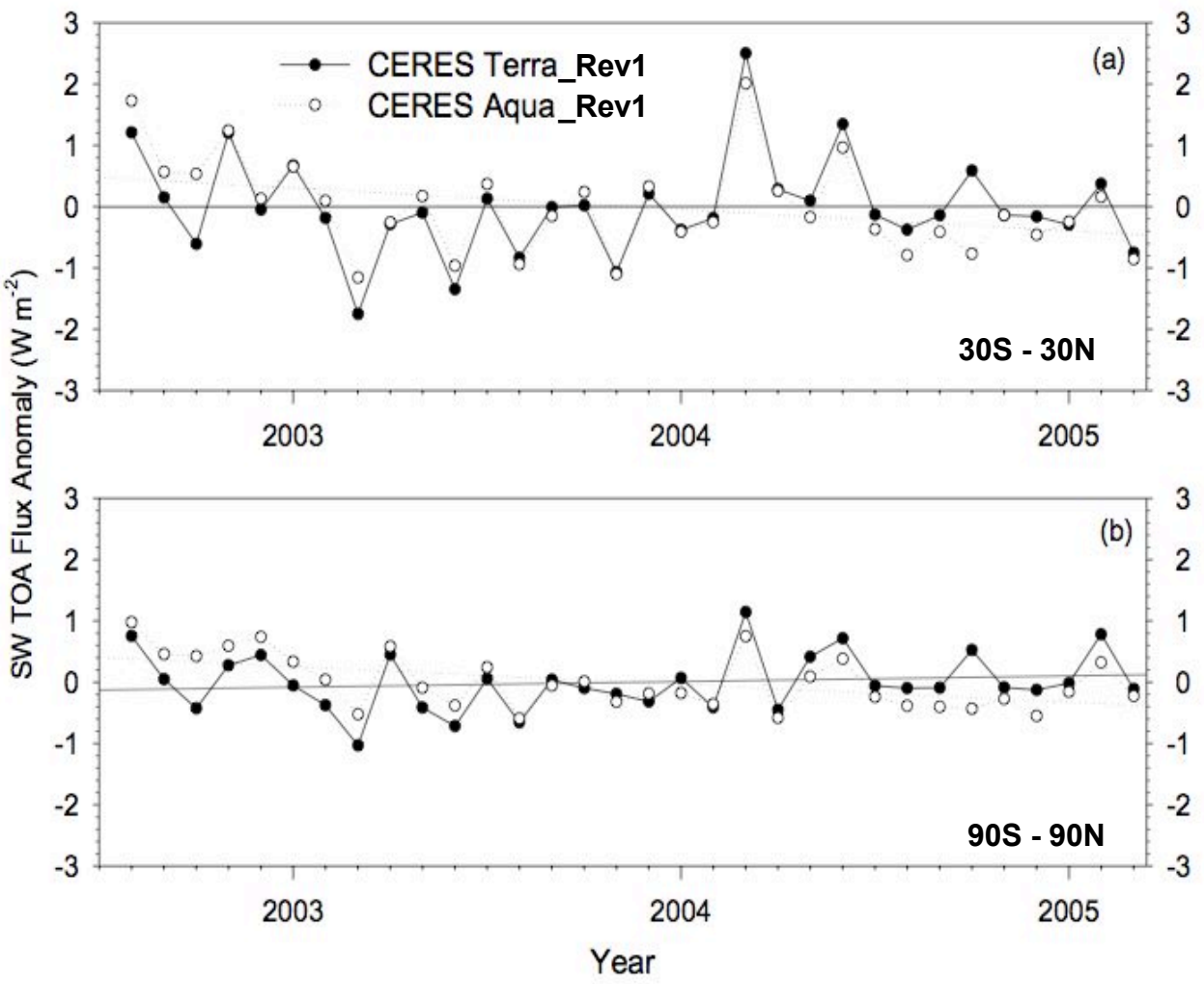
Multiply your May 03 Terra clear ocean SW fluxes by these values

Application of Edition2_Rev1 Scaling Factors



Application of Edition2_Rev1 Scaling Factors

Deseasonalized monthly anomalies in Terra FM1 and Aqua FM4 all-sky SW TOA Flux



Edition2_Rev1 Key Assumptions

The Rev1 algorithm requires two key assumptions:

1. That the Xtrack instrument is radiometrically stable
2. The SWICS lamps provide a radiometrically stable calibration source.

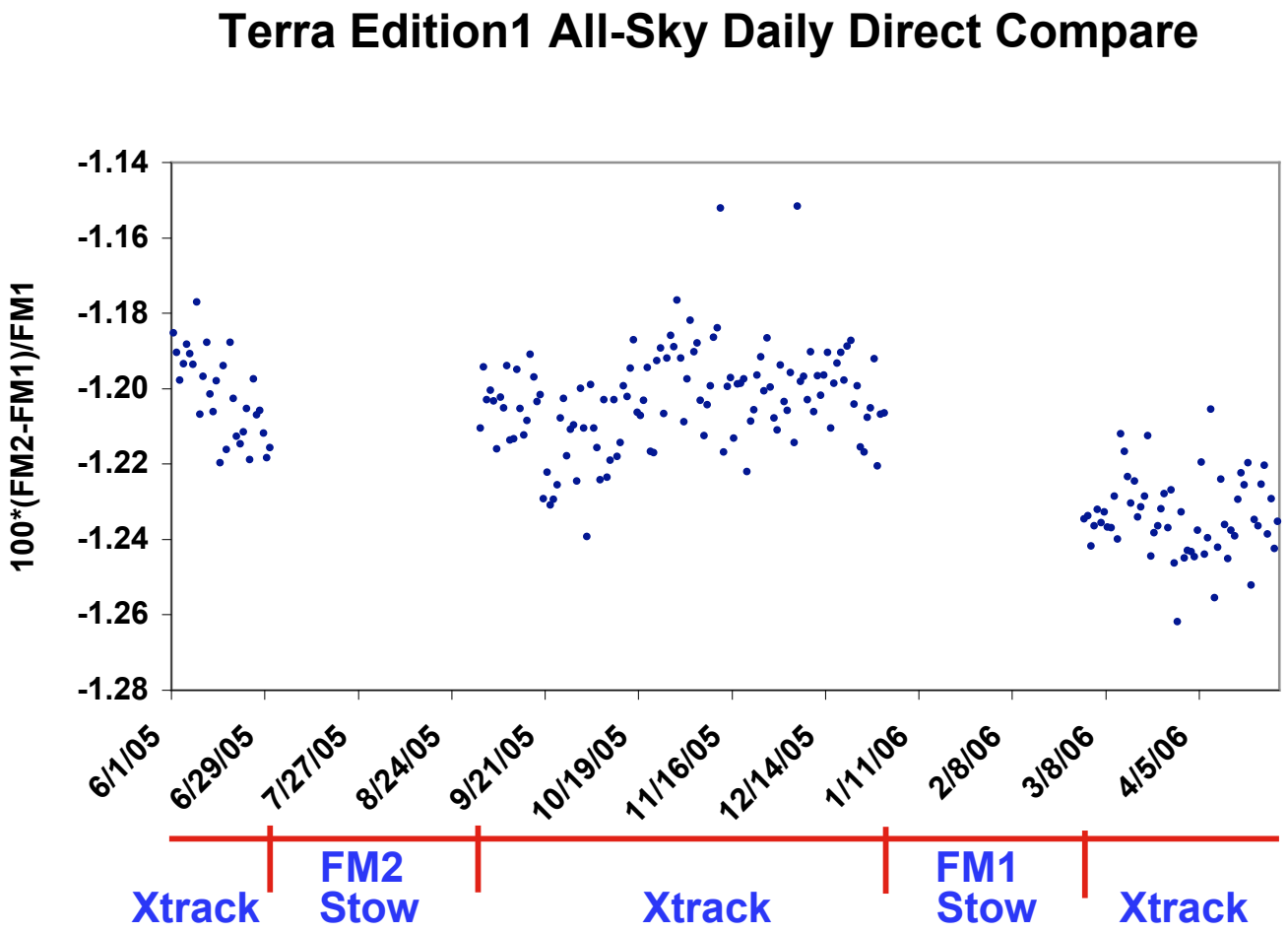
Operations to Characterize Spectral Darkening

Month (2005)	FM1 Azimuth Gimbal	FM1 Solar Calibrations	FM2 Azimuth Gimbal	FM2 Solar Calibrations	FM2 Solar Exposure	FM2 RAM Direction	Darkening Rate Impact
February	Xtrack	Yes	Xtrack, Atrack	Yes	Nominal	Nominal	Nominal
March	Xtrack	Yes	Xtrack	Daily	Accelerated	Accelerated	No Change
April	Xtrack	Yes	Rotating	Yes	Reduced[1]	Nominal	No Change
May	Xtrack	Yes	Rotating, Atrack	Yes	Eliminated[2]	Reduced[2]	
June	Xtrack[3]	Yes	Xtrack[4]	No	Eliminated	Eliminated	
July	Xtrack[3,5]	Yes	Stowed	No	-	-	
August	Xtrack	Yes	Stowed	No	-	-	
September	Xtrack	Yes	Xtrack[6]	No	Eliminated	Eliminated	
October	Xtrack	No	Xtrack	No	Eliminated	Eliminated	
November	Xtrack	No	Xtrack	No	Eliminated	Eliminated	
December	Xtrack	No	Xtrack	No	Eliminated	Eliminated	
January	Stowed	No	Xtrack	No	Eliminated	Eliminated	
February	Stowed	No	Xtrack	No	Eliminated	Eliminated	
March	Xtrack	No	Xtrack	No	Eliminated	Eliminated	
April	Xtrack	No	Xtrack	No	Eliminated	Eliminated	

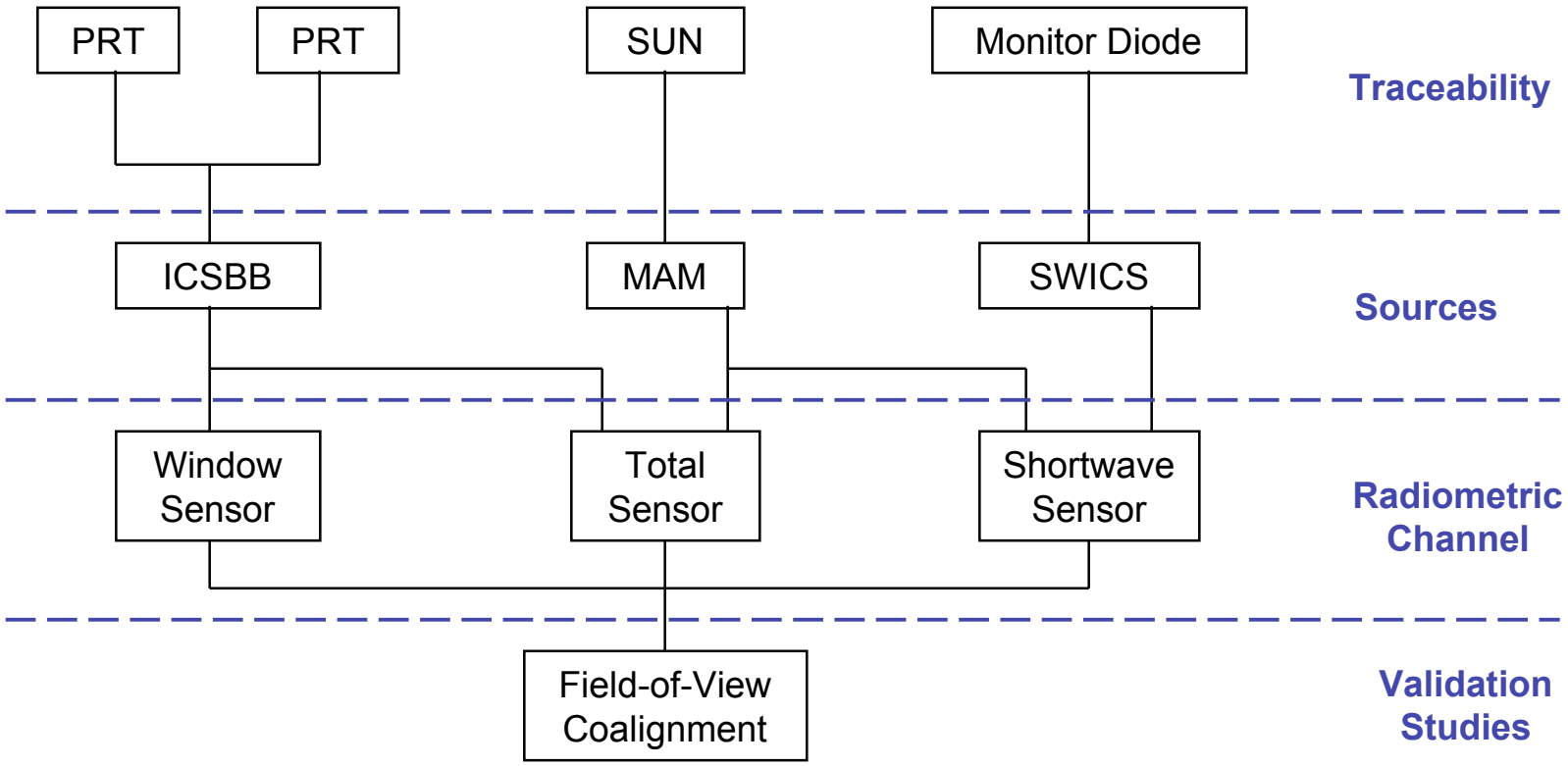
Notes:

1. Short-Earth scan profile turn-around reduced 8 degrees on March 31, 2005 to both FM1 and FM2.
2. Expanded solar-avoidance region criteria May 13, 2005.
3. Greenland Summer Solstice Terra-Aqua Inter-Calibration, June 6- July 6, 2005
4. GERB Operations, June 9-30, 2005.
5. Nighttime internal calibrations, July 1-7, 2005.
6. Valencia Over-Flights, September 12-17, 2005.

Terra Pre and Post Stow SW Direct Compare



CERES Onboard SW Calibration Philosophy

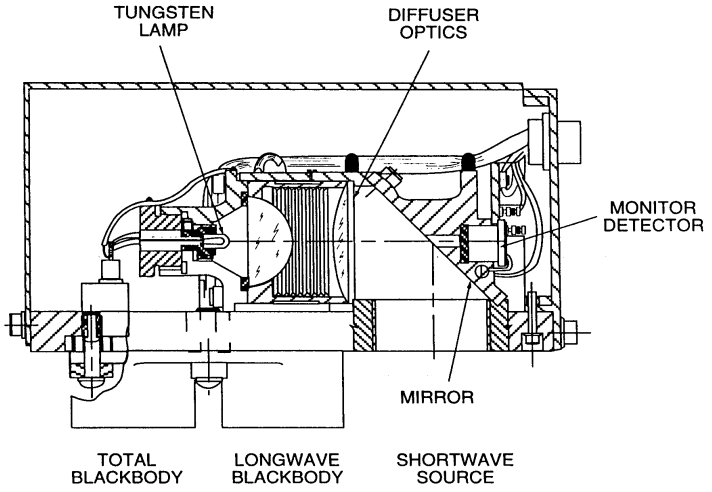


MAM's, SWICS, and DCC's

CERES Onboard SW Calibration Equipment

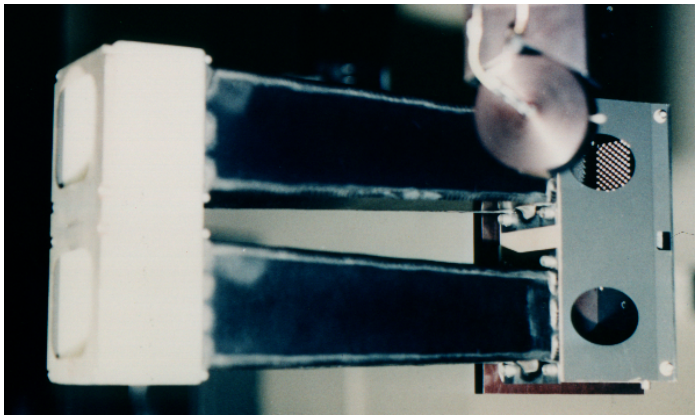
Shortwave Internal Calibration Source (SWICS)

- Quartz-halogen tungsten lamp (2100, 1900, 1700 K spectrums)
- SiPd independently monitors lamp output
- Design specification is +-0.5% stability over 5-year mission
- Designed primarily to transfer Ground Calibration measurements into orbit

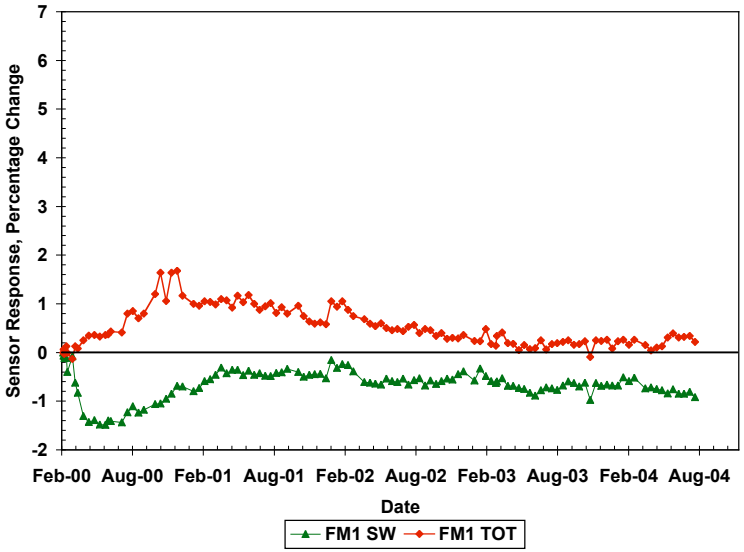


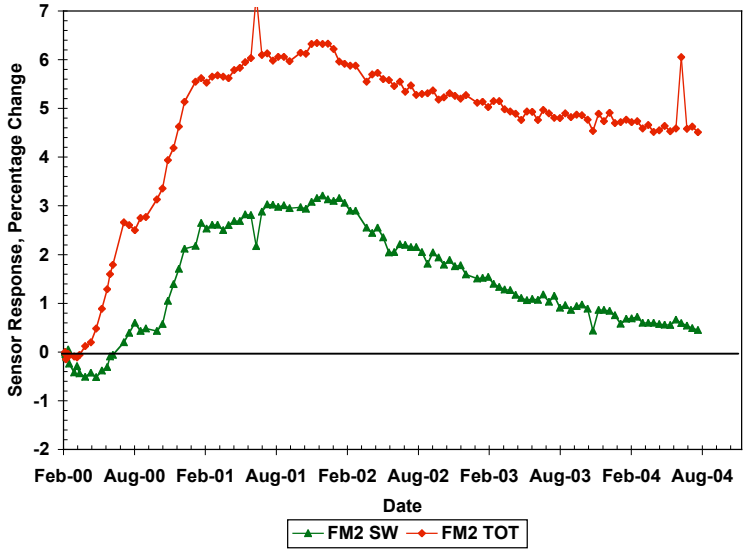
Mirror Attenuator Mosaic (MAM)

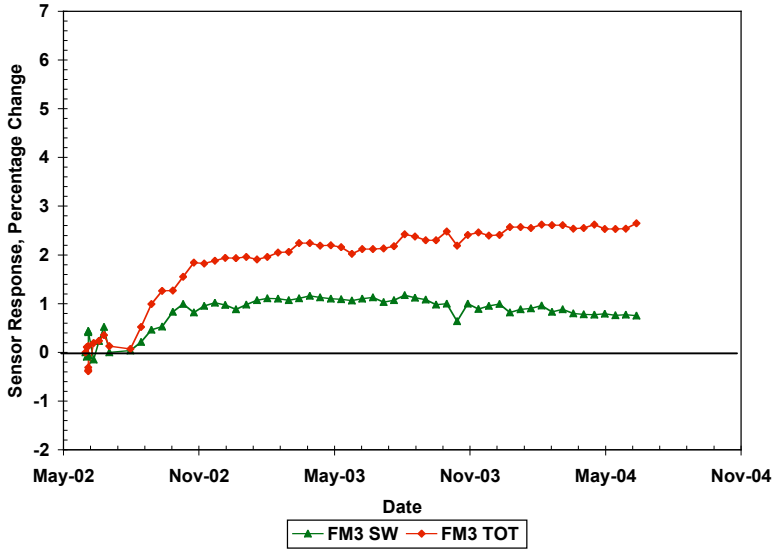
- Solar Diffuser plate attenuates direct solar view (~5800K Spectrum)
- MAM is a Nickel substrate with Aluminum coated spherical cavities or divots
- Provides a Relative calibration of the Shortwave channel and the SW portion of the Total channel
- Designed to provide a long-term on-orbit SW calibration source.
- Solar Cal results to date are suspect due to large initial drift in MAM surface reflectances…

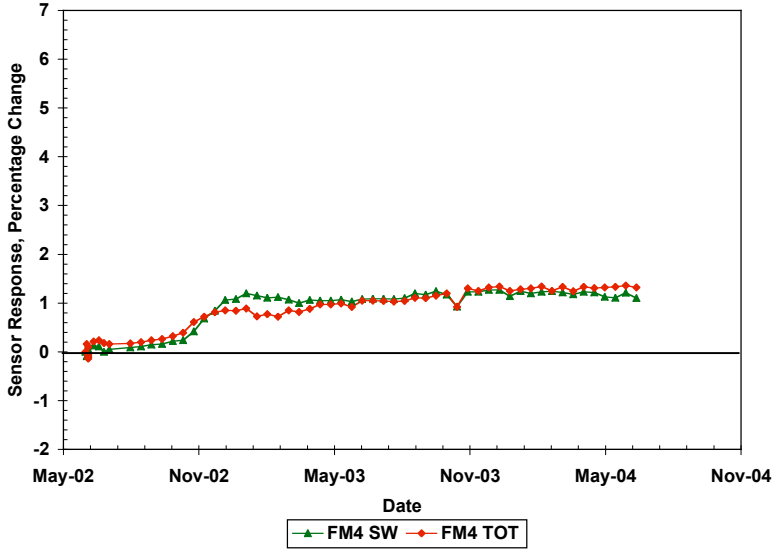


CERES Solar Calibration Results





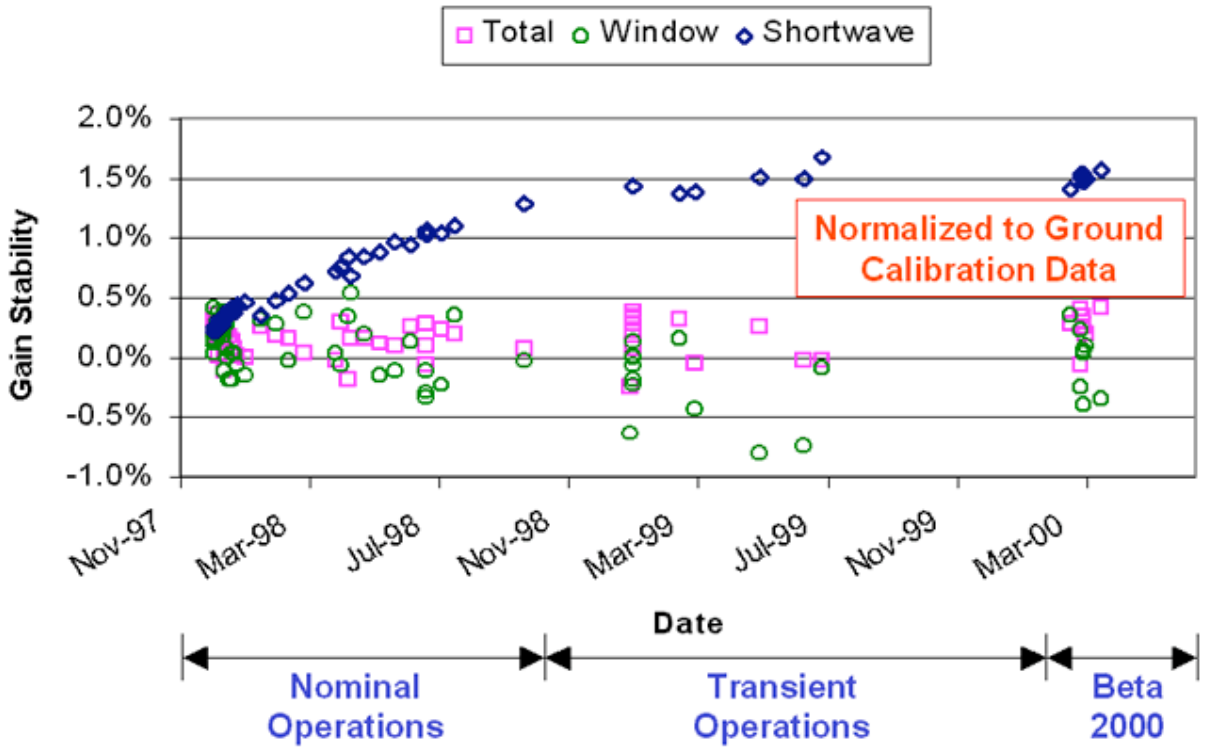




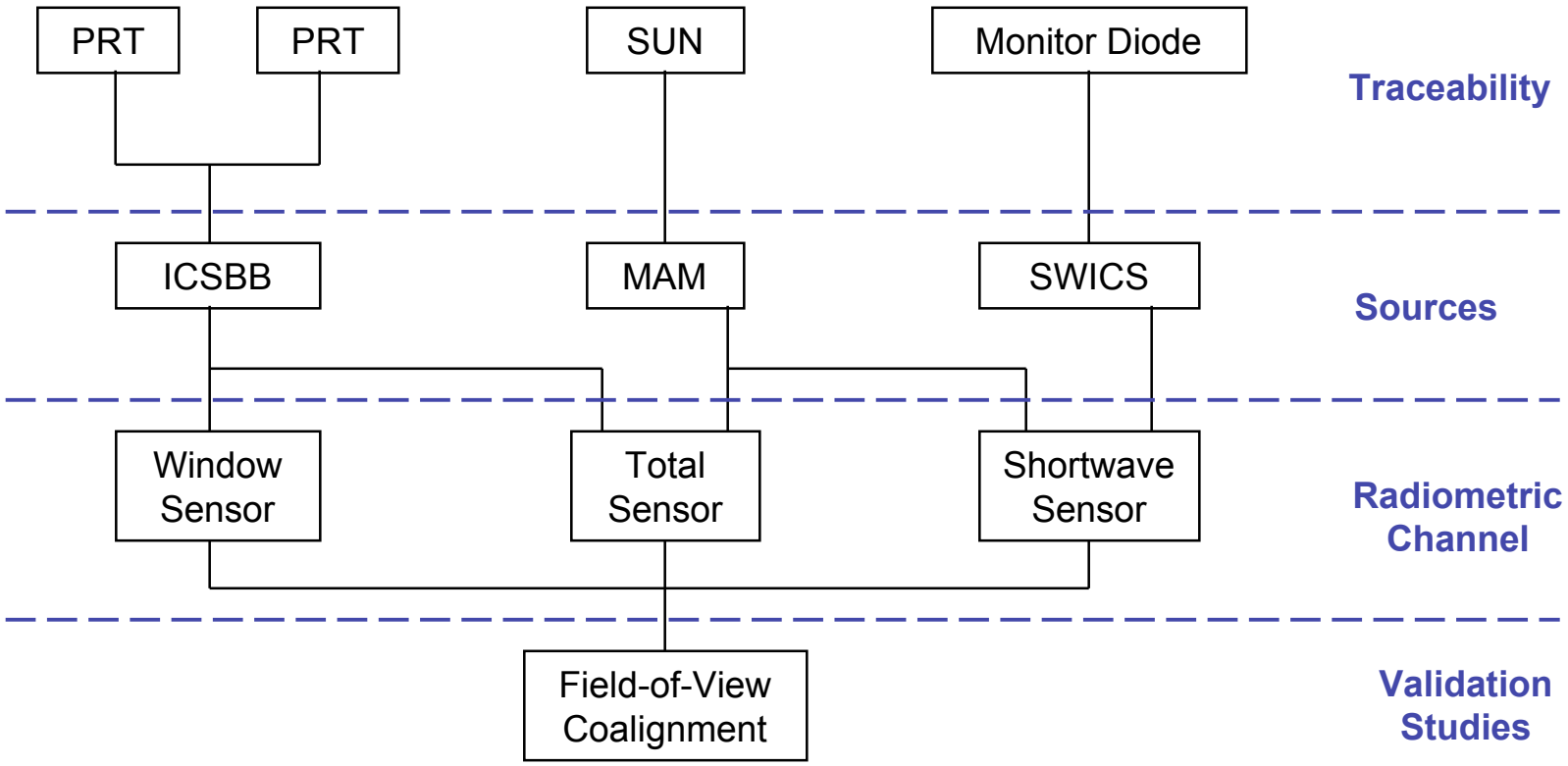
CERES TRMM/PFM Internal Calibration Results

TRMM/Proto Flight Model
Lifetime Radiometric Stability

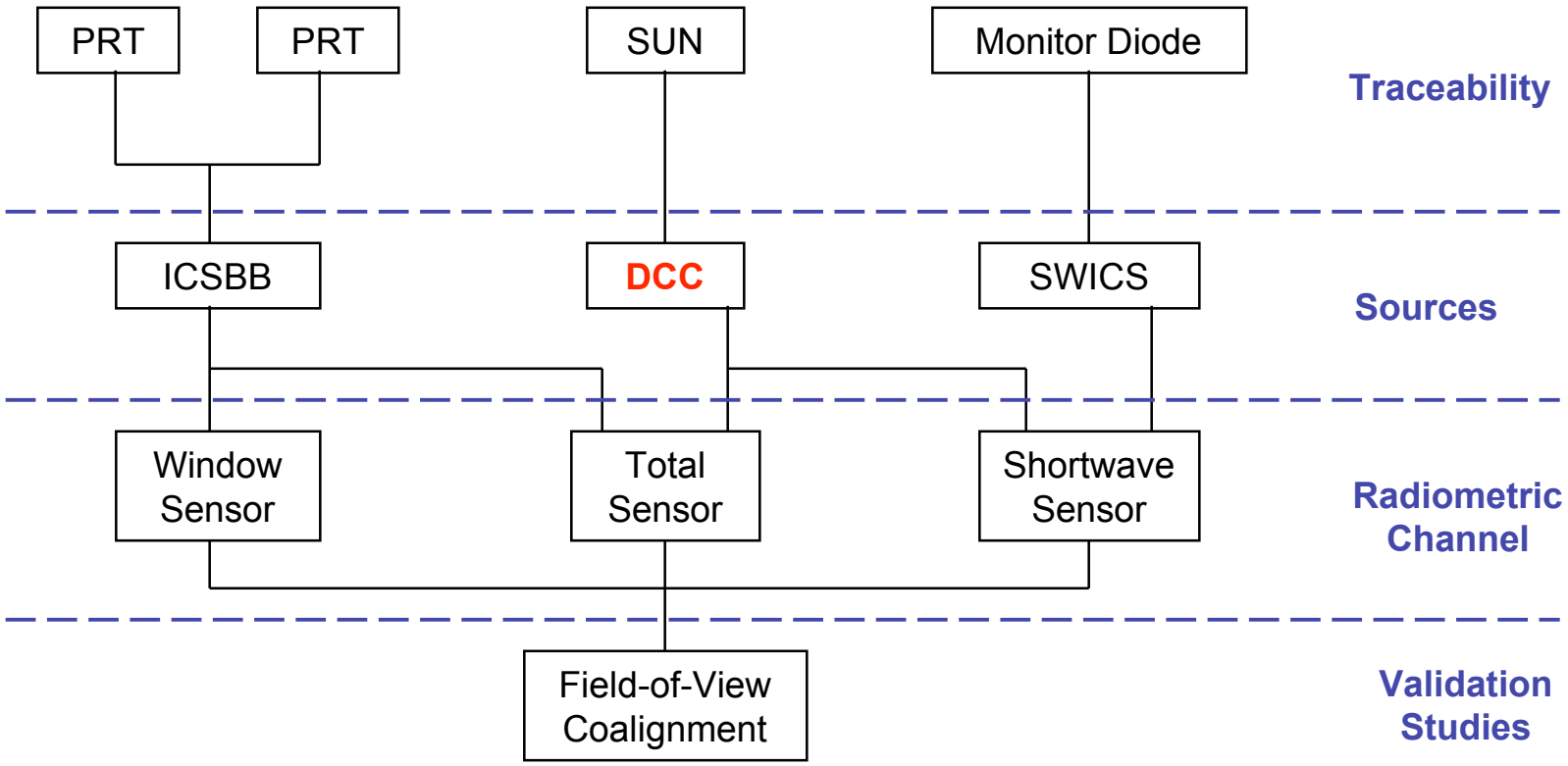
Determined with the Internal Calibration Module



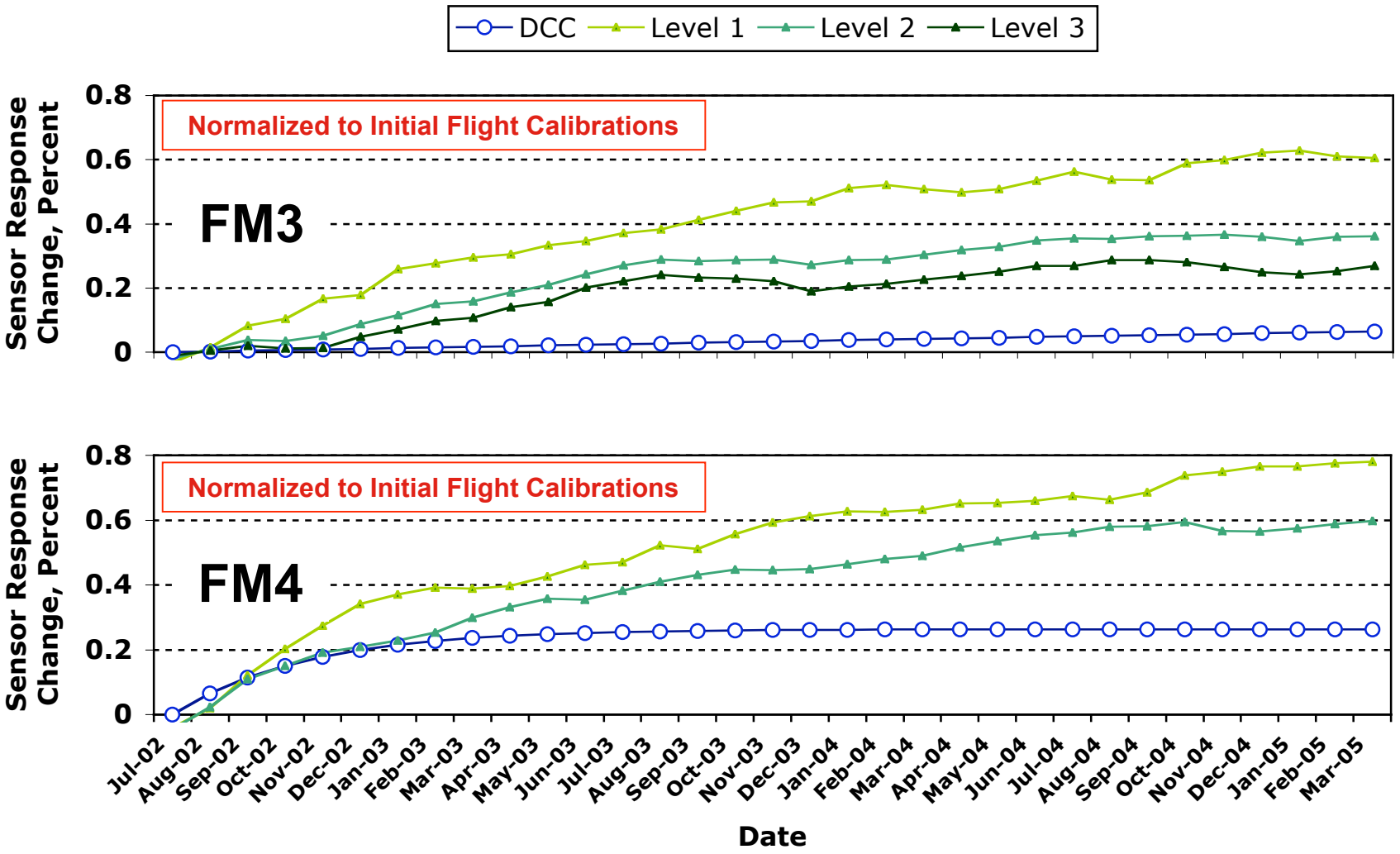
CERES Onboard SW Calibration Philosophy



CERES Onboard SW Calibration Philosophy



Aqua SW Internal and DCC Calibration Results



Back-Up Material

New Operational Constraints

CERES ES-8 Edition2_Rev1 Summary

•Cal/Val Protocol demonstrates radiometric stability of the data products through 12/2005 of….

	Edition1				Edition2				Edition2_Rev1			
	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4
LWday	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15
LWnight	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25
WN	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	.1	.1

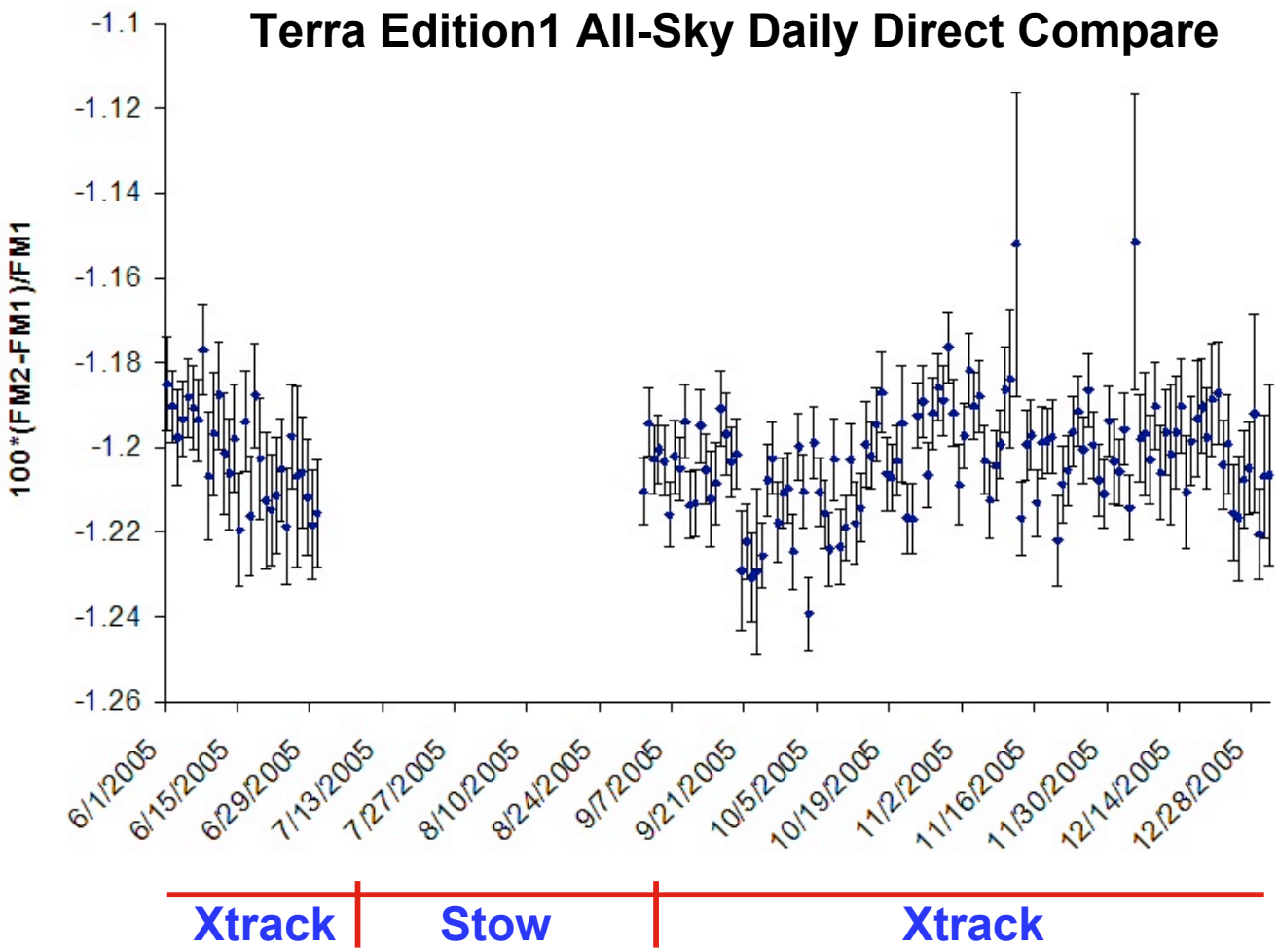
Note: **Values apply to all-sky global averages**
Units are in %/yr

CERES 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 - 12/05
	ERBE-like	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 12/05
Aqua	BDS	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/05
	ERBE-like	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 12/05

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

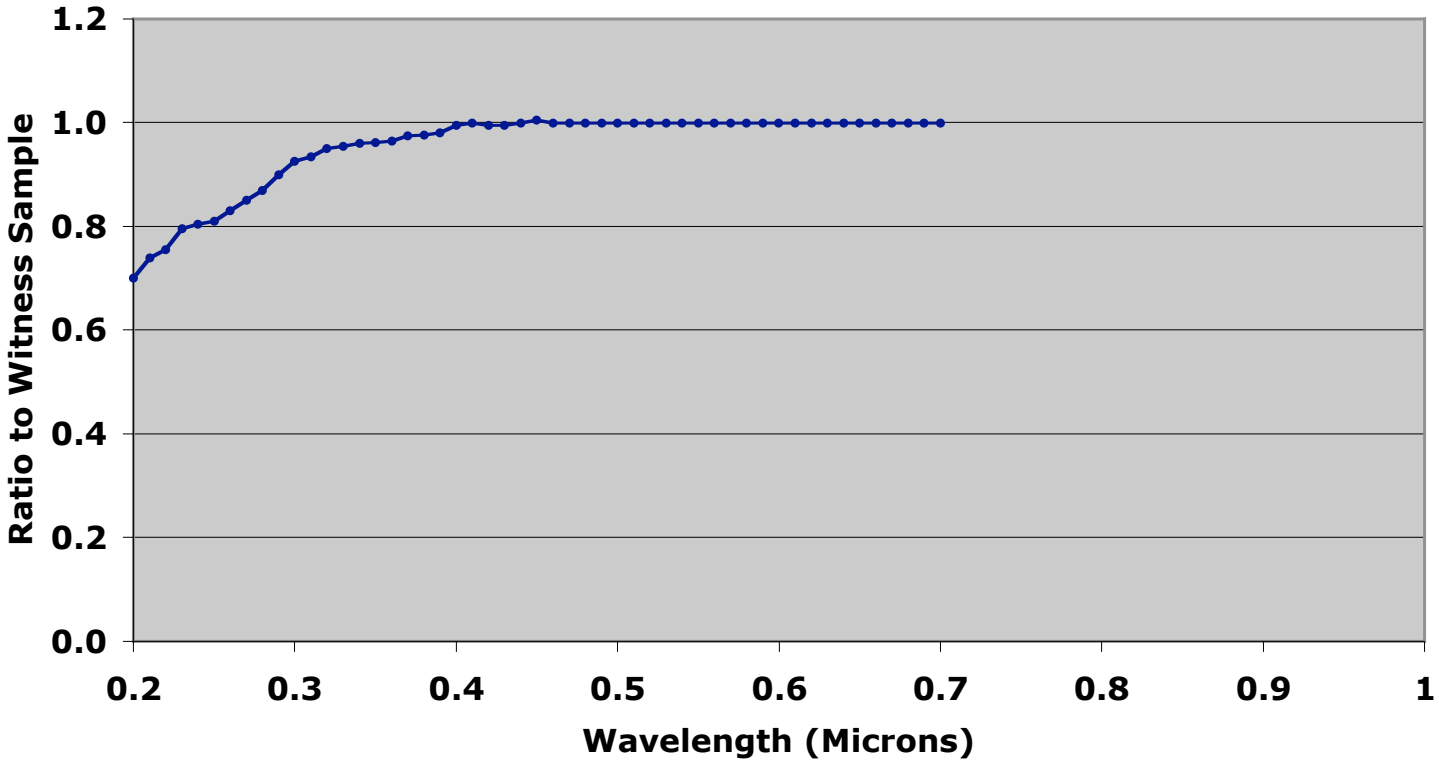
Pre and Post FM2 Stow SW Direct Compare



Spectral Darkening on Similar Missions

Spare NIMBUS ERB Radiometer flown on LDEF

Measured Transmittance Change of Suprasil W
4mm sample, 5 yr. exposure



Instrument Artifact Removal Strategy

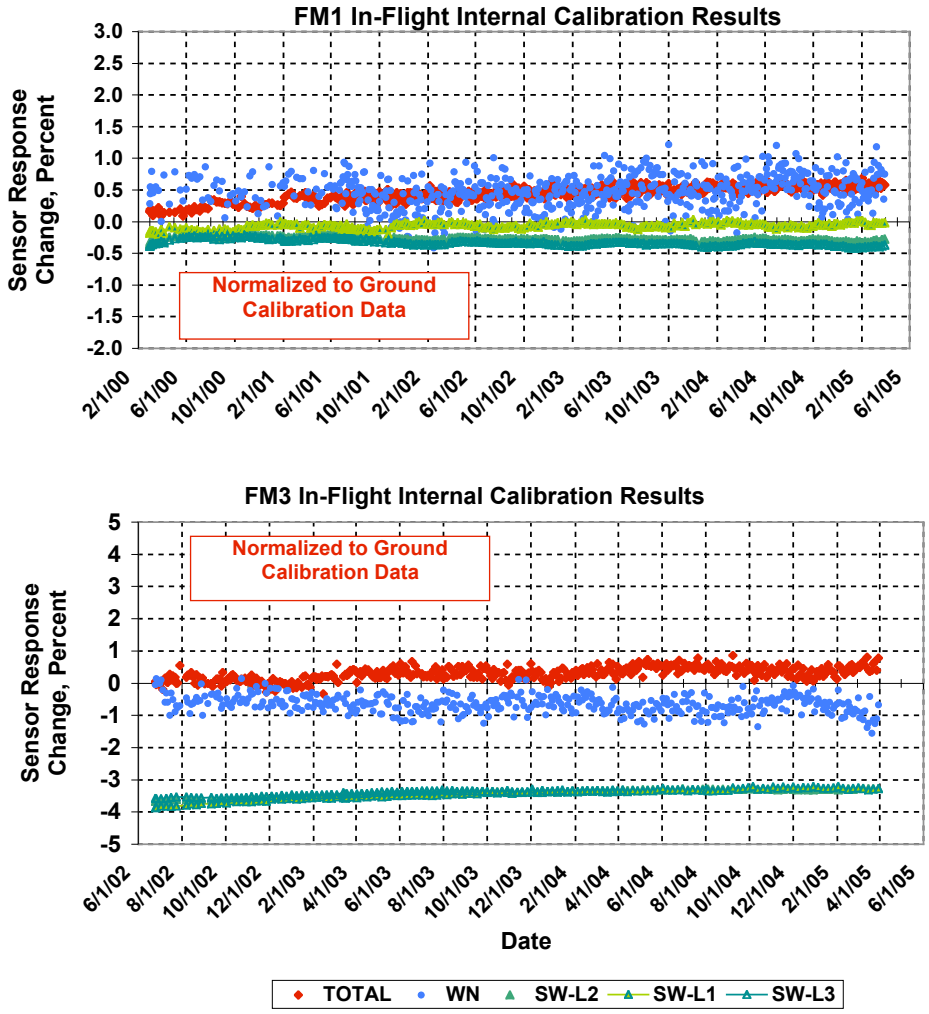
Remote sensing instruments generally exhibit time varying artifacts in their data products. For CERES these artifacts stem from either of 2 physical entities…..

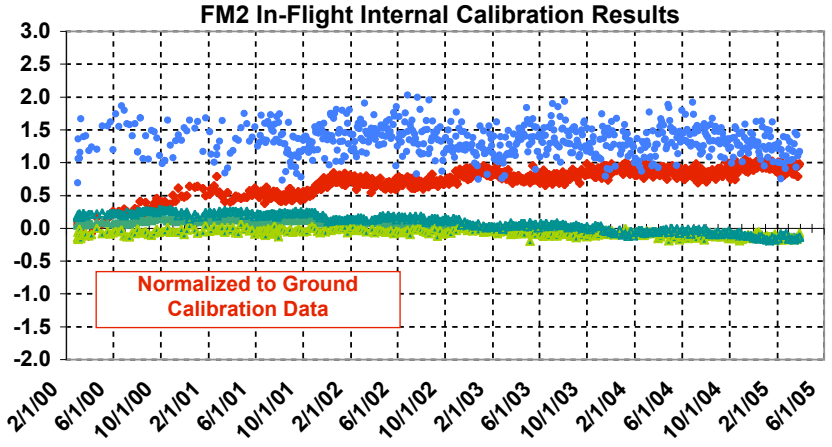
- **Radiometric Gain Change**
  - **Wavelength independent change in sensor responsivity**
  - **Corrections implemented in Count Conversion algorithm (SS1)**
- **Spectral Response Change**
  - **Wavelength dependent change in sensor optics**
  - **Corrections implemented in Spectral Unfiltering algorithms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

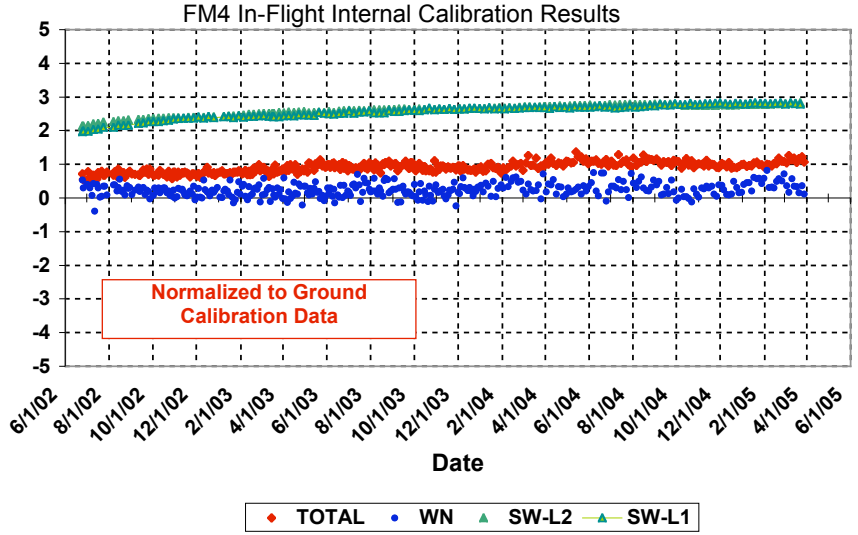
The Edition2 production strategy assumes that spectral response changes are 'Gray' over broad spectral regions. In other words, we assume uniform spectral response changes in these broad regions.

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

CERES Internal Calibration Results







CERES Gain/Spectral Change Summary

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

		Channel Gain (%)			Channel Spectral Response (%)				TOA Flux All-Sky (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

CERES ES-8 Edition2_Rev1 Summary

•Cal/Val Protocol demonstrates radiometric stability of the data products through 12/2005 of….

	Edition1				Edition2				Edition2_Rev1			
	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4
LWday	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15
LWnight	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25
WN	<.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 ES-8 Edition2_Rev1 Summary

•Cal/Val Protocol demonstrates radiometric stability of the data products through 12/2005 of….

	Edition1				Edition2				Edition2_Rev1			
	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4	FM1	FM2	FM3	FM4
LWday	.3	.6	.4	.4	.125	.125	.3	.3	.125	.125	.15	.15
LWnight	.1	.125	.125	.125	<.1	<.1	.1	.1	<.1	<.1	.1	.1
SW	.2	.4	.4	.5	.2	.3	.3	.4	<.1	<.1	.25	.25
WN	<.1	<.1	.1	.1	<.1	<.1	.1	.1	<.1	<.1	.1	.1

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