Clouds and the Earth's Radiant Energy System

(CERES)

Integration and Test Status
FM3 and FM4 on EOS Aqua

CERES 23rd Science Team Meeting
January 23-25, 2001

Charles E. Jenkins (CERES I&T Manager)
Phillip L. Brown (CERES S/C Interface Manager)

CERES I&T Status Summary on EOS Aqua

Since delivery to the EOS Aqua spacecraft (TRW, Redondo Beach, CA), both CERES instruments have completed *MECHANICAL* and *ELECTRICAL CHECKOUT*, *EMI/EMC*, *DYNAMICS*, and pre- and post-dynamics *HARDWARE COMPREHENSIVE FUNCTIONAL TESTING (HCPT)*. The CERES Aqua I&T team is currently supporting dry-run test activity for Spacecraft System Level Testing (SCPT). Thermal Vacuum testing to follow.

Tests/Operations Completed Since Delivery in January 2000

CERES EOS PM IGSE Confidence Test	1/11/00 - 1/12/00
CERES EOS PM Comprehensive Functional [BAT] Test	1/12/00 - 1/13/00
FM3 and FM4 Mechanically Installed on Spacecraft	***2/01/00***
CERES EOS PM Electrical Integration and Checkout (EIC) Phase I, Phase II, [Aliveness] Test	***5/22/00 - 5/26/00***
CERES Fore & Aft EIC (in conjunction /w ISC Regression Testing), [Aliveness] Test	6/03/00 - 6/06/00
RETEST CERES Fore & Aft EIC (w/ISC Regression Testing [& Aliveness]) Test	6/06/00
Re-verification of "FMU FSW Fix Proof-of-Concept (POC) Experiment Patch"	6/14/00
2nd Re-verification of "FMU FSW Fix Proof-of-Concept (POC) Experiment Patch"	6/15/00
CERES AFT Post-1553 Connector Rework (re: DR #RR21001) Aliveness Test	6/21/00
FMU/SSR, SDDU, & IGSE Integration & Checkout [& CEA Aliveness Test]	6/24/00

CERES I&T Status on EOS Aqua

Tests/Operations Completed Since Delivery in January 2000 (cont'd)

2nd FMU/SSR, SDDU, & IGSE Integration & Checkout [& Aliveness Test]	6/28/00
3rd FMU/SSR, SDDU, & IGSE Integration & Checkout [& Aliveness Test]	6/29/00
4th FMU/SSR, SDDU, & IGSE Integration & Checkout [& Aliveness Test]	7/1/00
Spacecraft Interface (SCIF) 2A Test (SC &Instrument Configuration Operations)	7/6/00
CERES Powered Alignment Operation	7/13/00
CERES Powered Alignment Re-Measurement	7/14/00
FMU/SSR Troubleshooting	7/14/00 - 7/15/00
EM FMU Troubleshooting	7/19/00
FMU and SDDU Troubleshooting	7/26/00
CERES FORE & AFT ATS Checkout	7/31/00 - 8/01/00
FMU/SSR Troubleshooting	8/03/00
EOS PM-1 Hardware Comprehensive Performance Test - A-side (HCPT-A)	8/09/00 - 8/10/00
The FMU/SSR Troubleshooting (including CEA 'SDRI' Investigation)	8/11/00
EOS PM-1 Hardware Comprehensive Performance Test - B-side (HCPT-B)	8/13/00
CERES 3-Byte Drop Investigation (FMU/SSR Troubleshooting)	8/17/00
All Instrument Simultaneous Operation Test (**FMU/SSR Troubleshooting**)	8/24/00

CERES I&T Status on EOS Aqua

Tests/Operations Completed Since Delivery in January 2000 (cont'd)

FMU Troubleshooting (CERES '3-Byte Drop')	8/25/00 - 8/26/00
SDRI Patch Test	8/28/00
FMU Troubleshooting (CERES '3-Byte Drop')	9/13/00 - 9/15/00
EMC Conducted Emissions (CE) Dry-Run	9/24/00 - 9/25/00
EMC Radiated Emissions (RE) Dry-Run	9/29/00 - 9/30/00
EMC Qualification Test Procedure (Conducted Emissions)	***9/30/00 - 10/03/00***
EMC Qualification Test Procedure (Radiated Emissions)	***10/04/00 - 10/12/00***
SCIF 2B (Spacecraft Interface Test)	10/14/00 - 10/15/00
FMU/SSR-TIE Playback and AIRS/MODIS/AMSR Data Input Contention Retest	10/16/00 - 10/18/00
RF Compatibility Test Van Support	10/27/00 - 10/28/00
FMU/SSR TIE Playback	10/30/00 - 10/31/00
FMU/SSR 301 Regression Test	11/02/00
Aqua Dynamics Testing (Acoustics, Sine Vibe, Shock)	***11/05/00 - 11/29/00***
CERES Post-Dynamics HCPT Operations/Internal Inspection & Cleaning	12/03/00
Post-Dynamics Hardware Comprehensive performance Test (HCPT) A-Side	12/08/00 - 12/09/00
Post- Dynamics HCPT B-Side	12/12/00
SCIF 3A (Spacecraft Interface Test)	***Ongoing***
System Comprehensive Performance Test (SCPT) Dry Run Testing	***Ongoing***

CERES I&T Status on EOS Aqua

Problem/Anomaly Status

FM3 and FM4

- **To date, no problems/anomalies have been levied against either FM3 or FM4 on the instrument side of the interface.**
- In September 2000, FM3 BCU (EGSE) experienced an intermittent start-up/dropout problem that was traced to a bad SCSI cable. No BCU problem since replacing cable.

Aqua Spacecraft Problems/Issues

- **Contamination Concern - Deployment Drive Assemblies (DDAs) leaking small amounts of oil.**
  - DDAs recently removed from spacecraft for minor disassembly to drain excess oil.
  - Currently undergoing vacuum bakeout with TQCM monitoring. To be reinstalled prior to Aqua System Comprehensive Performance Test (SCPT).
- **Science Data Concern - Formatter/Multiplexer Unit (FMU) processing contention.**
  - FMU flight unit rework required due to processing contention between the 1553 data and multiple high rate data (Taxi and/or RS422) wherein 1553 processing loses.
  - Aqua I&T using EOS-Chemistry (Aura) spacecraft FMU with engineering mods as place holder.
  - Delivery, reinstallation, and regression testing of Aqua FMU required before SCPT can start.

CERES Aqua Near Term Planned Activity

EOS Aqua System Comprehensive Performance Test (SCPT)

- Expected to start by January's end. Test start dependent on receipt and installation of the flight FMU.

The System Comprehensive Performance Test (SCPT) consist of two types of testing:

•Subsystem/instrument Standalone Tests. The communication Standalone Tests are performed with most of the S/C loads off. The GN&C and EPS stand-alone tests will be performed with bus and instrument loads on.

•"Orbital Simulation" tests will attempt to simulate normal on-orbit scenarios with all instruments and bus equipment on. The orbital sim will not "simulate" a true orbit, but instead will run the typical command load mixes, science data collection, and transponder interface and transfer functions.

Bottom line:

All spacecraft subsystems and instruments have been individually tested (except for the flight FMU/SSR)but have yet to successfully operate the spacecraft system as a whole.

The current plan is not to move to thermal vacuum until TRW Aqua successfully completes the System Comprehensive Performance Test(SCPT).

CERES Aqua Near Term Planned Activity

SCPT - Aqua System level CPT will be performed in four S/C configurations: Science1, Science2, Safe1 and Safe 2. SCPT will be done before, during, and after Thermal/Vacuum.test.

SCIENCE 1 CONFIGURATION

Switch to Battery Power
Standalone Communication Tests
GN&C Power On (Electronics only)
HDE Power On
Instrument Power On
EPS Standalone Tests
GNC/Prop Standalone Tests
AMSU CPT
AIRS CPT
HSB CPT
CERES CPT
AMSR-E CPT
MODIS CPT
Orbital Simulation
Instrument Power Off

SCIENCE 2 CONFIGURATION

X-Band Power Off
USO Power Off
GNC Power Off
Thermal Power Off
S/C to Configuration 2
Communication Standalone Tests
GN&C Power On (Electronics only)
HDE Power On
Instrument Power On
GNC/Prop stand alone tests
AIRS CPT
HSB CPT
CERES CPT
AMSR-E CPT
MODIS CPT
Orbital simulation test

SAFE 1 CONFIGURATION (XSTRAP)

Instrument Science to Safe Mode
S/C Config 2 to Safe 1
Perform CDH Cmd / Tlm Check
Instrument Safe to Survival Mode
Instrument Survival to Power Off
Standalone Communication Tests

SAFE 2 CONFIGURATION (XSTRAP)

Perform CDH Cmd / Tlm Check
Standalone Communication Tests

Clouds and the Earth's Radiant Energy System
Planned Schedule

Task Name:	Duration:	Shifts:	Start:		Finish:
GSFC SCIF Test 3A	1- Day	1,2 & 3	**1/24/01**	**-**	**1/24/01**
CPT w/Ascent Timeline	11- Days	1,2 & 3	1/26/01	-	2/6/01
Pre-Thermal Fault Management Test	2-Days	1 & 2	2/7/01	-	2/8/01
Mission Test #1	1-Day	1 & 2	2/9/01	-	2/9/01
TV Test	**40 Days**	**1,2 & 3**	**3/1/01**	**-**	**4/11/01**
CERES 3 & 4 Deployment Demo.	2-Days	1 & 2	4/23/01	-	4/24/01
Fault Management Test	3-Days	1,2 & 3	5/12/01	-	5/14/01
GSFC SCIF Test #4	1-Day	1 & 2	**5/15/01**	**-**	**5/15/01**
CPT - Part 1 using Test Battery	7-Days	1,2 & 3	5/16/01	-	5/22/01
Pre-Ship Review(PSR)	1-Day	1	5/26/01	-	5/26/01
CPT - Part 2 w/SA & Flight Battery	5-Days	1,2 & 3	5/27/01	-	6/1/01
Ship SC to WTR	**1-Day**	**3**	**6/1/01**	**-**	**6/1/01**
SC CPT & Battery top off	11-Days	1 & 2	6/6/01	-	6/16/01
GSFC SCIF Test #5	1-Day	12 Hrs	**6/17/01**	**-**	**6/17/01**

Clouds and the Earth's Radiant Energy System
Planned Schedule

Task Name:	Duration:	Shifts:	Start:		Finish:
Flight Readiness Review 1 (FRR)	**1-Day**	**1**	**6/23/01**	**-**	**6/23/01**
Transport SC to Pad	1-Day	3	6/27/01	-	6/27/01
SC Mate to LV	1-Day	1	6/28/01	-	6/28/01
SC Aliveness Test	1-Day	1	6/29/01	-	6/29/01
Red Green Tag Ops.	1-Day	1	7/2/01	-	7/2/01
Final Cleaning & Red Green Tag Ops.	1-Day	1	7/3/01	-	7/3/01
Flight Readiness Review 2 (FRR)	**1-Day**	**1**	**7/6/01**	**-**	**7/6/01**
Final Launch Preparations	5-Days	1 & 2	7/6/01	-	7/11/01
Mission Management Rehearsal	1-Day	1	7/9/01	-	7/9/01
Launch Readiness Review (LRR)	**1-Day**	**1**	**7/10/01**	**-**	**7/10/01**
Launch Countdown Start	1-Day	1, 2 & 3	7/11/01	-	7/11/01
LAUNCH (1:30 AM)	**1-Day**	**-**	**7/12/01**	**-**	**7/12/01**
WTR Post Launch Support	5-Days	1	7/12/01	-	7/16/01
GSFC Mission Operations	~90-Days	1, 2 & 3	7/11/01	-	10/1/01

Status Summary
Of
TERRA Mission Operations

M. Larry Brumfield
CERES Project Office
January 23, 2001

TERRA General Mission Status

Mission operations continue with few problems in either the S/C or instrument systems

- Solar array power interface lost one shunt string; no perceptible effect on power; preliminary investigation indicates possible failure of a load resistor.
- Still experiencing radiation events in high gain antenna when passing through SAA. TMON recovery S/W works well with no significant impact to operations.
- SWIR/ASTER experiment experiencing elevated temps; Possibly due in part to additional thermal loading at higher Beta angles; investigation continuing.
- Occasional losses of data from high-rate instruments, some due to SSR configuration errors, and some due to ground receiving equipment.
- There continues to be significant delays in delivery of science data to the DAACs.

CERES Mission Operations

CERES instruments continue trouble-free ops; with no identified problems

- **Will switch RAPS/FAPS operational modes Feb 1 (3-month cycle)**
  - activity developed to automatically acquire azimuth gimbal and baseline radiometric noise data completed
- **Executed lunar-eclipse observation activity (1/9/01)**
  - Sun avoidance constraints at totality meant only one of two possible measurement opportunities was successful.
- **Developing sequence to utilize the moon to evaluate pointing knowledge**
  - Will prove useful on Aqua with deployment mechanisms
- **The instrument design/programming flexibility has repeatedly allowed new observation ideas to be successfully implemented while maintaining a very robust self-protection capability.**
- **IOT members have become very experienced at adapting the instrument operations to accommodate science team needs.**

TERRA Deep Space Cals Are Coming !!
(MAYBE)

- Next major activity is the deep space calibration pitch-over maneuvers – expected sometime mid-February.
- GSFC FOT has done all the simulation studies required, and have a preliminary maneuver timeline developed.
- Final planning only requires HQ approval, and an actual date established so FDF products can be generated.
- LaRC IOT and science reps are developing a final set of scan sequences that the instruments will run in in tight time synchronization with the S/C timeline.
- These final sequences will be loaded to the instruments and given a test run prior to the actual pitch maneuvers.
- Expect completion of CERES preparations by end of January.

CERES Instrument Cal/Val Report

Kory J. Priestley
Robert Lee, Richard Green, Dave Young, Susan Thomas,
Aiman Al-Hajjah, Robert Wilson, Pete Spence, Ed Kizer

23rd CERES Science Team Meeting
Williamsburg, VA
January 23, 2001

NASA Langley Research Center
Atmospheric
SCIENCES

CERES/TRMM Instrument Post-Mortem

Returned to service February 24th, 2000

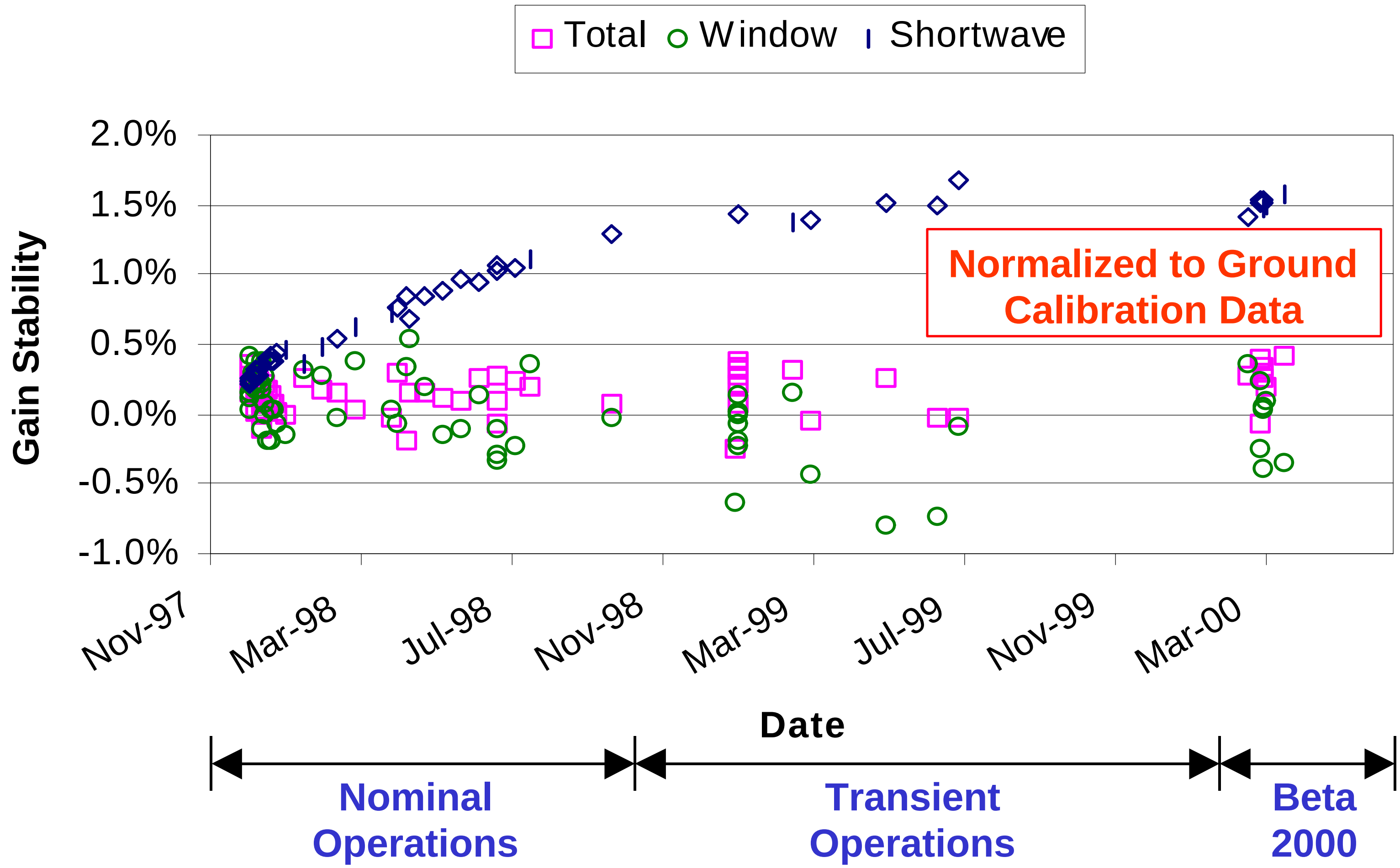
Kory J. Priestley

22nd CERES Science Team Meeting
Huntsville, AL
September 20, 2000

NASA Langley Research Center
Atmospheric SCIENCES

TRMM/Proto Flight Model Lifetime Radiometric Stability

Determined with the Internal Calibration Module



CERES/TRMM Instrument Post-Mortem

- Loss of all science and DAA Housekeeping parameters
  - Began suddenly on 6/14/00
  - Science data has never returned
  - Housekeeping data returns at low orbital temperatures (I.e. Minimum Beta angles)
  - Numerous software diagnostic patches have been developed by Jim Donaldson to develop a work-around, but the patient remains comatose.
- On 9/17/00 the TRMM spacecraft Flight Software autonomously removed powered from all science instruments
- Operational power restored on 12/14/00
  - Instrument powered up successfully
  - Still no science data….Patient Remains Comatose….

Shuttle to the rescue?

Data Recovery Possibilities

- **Instrument group is currently working on recovering all data through mid-April and after 6/1/00.**
  - Data from Mid-April to late May has unknown calibration due to large thermal transients.

- **Priority has been to recover SW data.**
  - An additional four weeks of SW data will significantly reduce any uncertainties in the comparison of TRMM/Terra SW radiance intercomparisons.
  - Efforts to recover SW are ongoing
  - It's a very slow (somewhat manual) process

CERES/TRMM Recent Publications

'Inter-calibration of CERES and ScaRaB Earth radiation budget datasets using temporally and spatially collocated measurements'

Haeffelin et al.

Geophysical Research Letters, January 2001.

'Postlaunch Radiometric Validation of the Clouds and the Earth's Radiant Energy System (CERES) Proto-Flight Model on the Tropical Rainfall Measuring Mission (TRMM) Spacecraft through 1999'

Priestley et al.

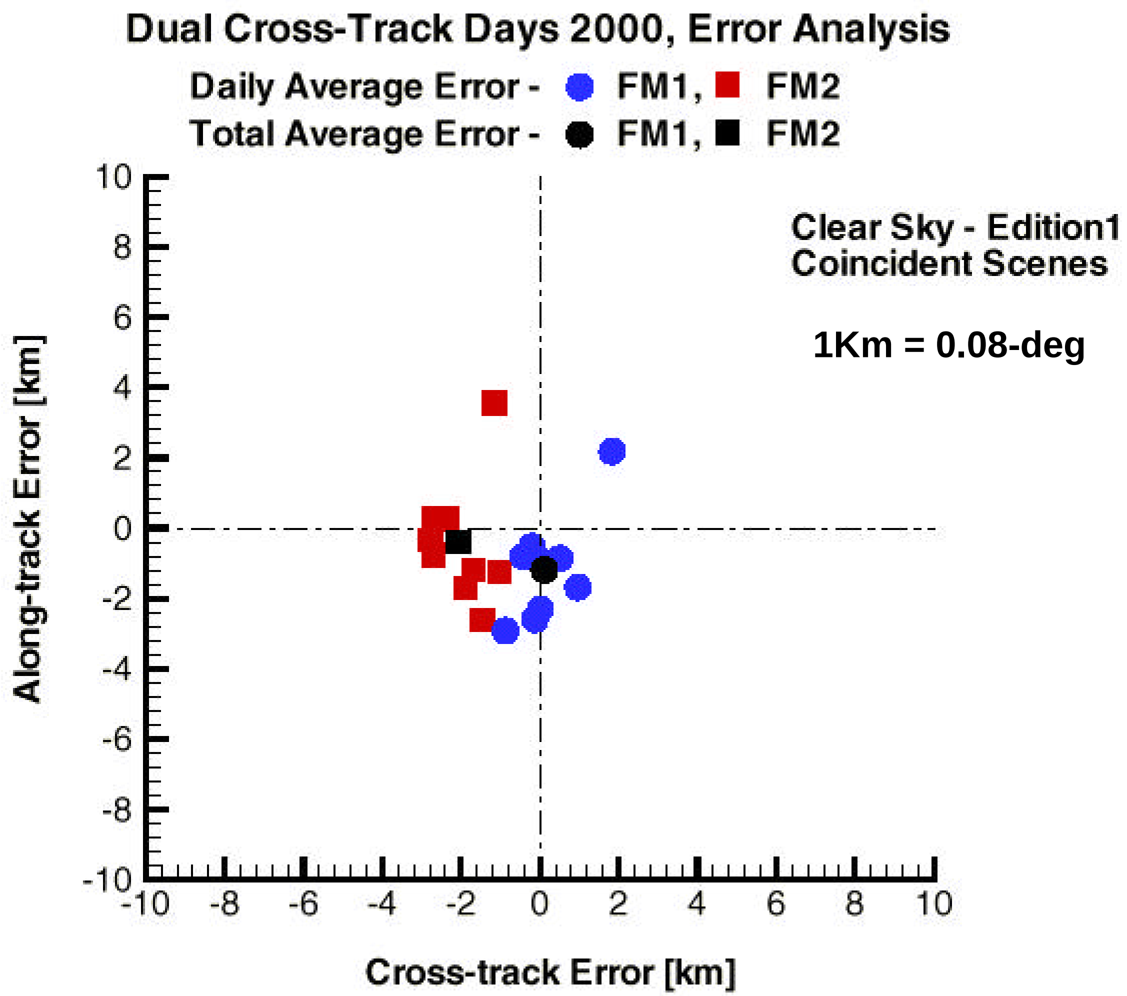
Journal of Applied Meteorology, December 2000.

Terra Validation Effort / Executive Summary

March – December, 2000

- **Ground to Flight calibration stability is better than 0.3% for TOT and SW channels**
- **WN channel calibrations shifted from ground to flight, FM-1 by 0.48%, FM-2 by 1.3%**
  - FM-2 WN radiances > FM-1 WN radiances by ~0.9%
  - Insufficient settling time allowed during ground cal's
- **SW radiances measurements are consistent at the 0.2% level between FM-1 and FM-2**
- **FM-1 day and nighttime LW radiances are stable, but high by ~0.6%**
  - Caused by LW/TOT spectral response being too low
- **FM-1 daytime LW radiances are stable, but low by ~1.0%**
  - Caused by the SW/TOT spectral response being too high
  - Net effect is FM-1 daytime LW radiances are low by ~0.4%
- **FM-2 daytime LW radiances demonstrate a slow increase of ~0.5%/year**
  - Probable culprit is thermal control on the FM-2 total channel heatsink.
- **FM-2 nighttime radiances are stable with no measurable drift**

CERES Terra Navigation Accuracy
Coastline Detection



Pete Spence

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
	Tropical 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

CERES Instrument Radiometric Validation Activities

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On-Board	Internal BB	Filtered Radiance	N/A	N/A	Absolute Stability	TOT, WN
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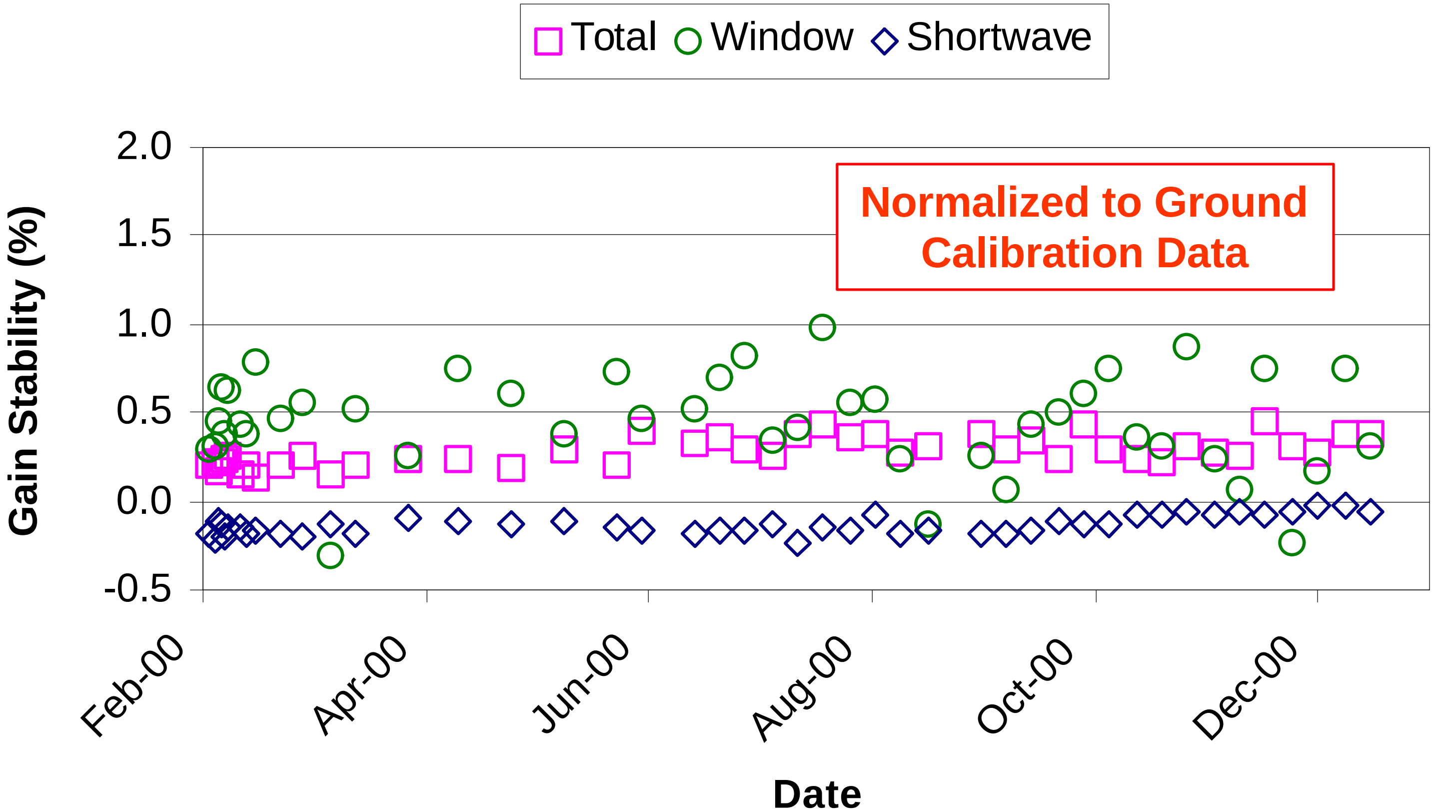
	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	TOT, SW, WN
	Inter-satellite (Direct Comparison)	Unfiltered Radiance	1-deg Grid	1 per crossing	Inter-Instrument Agreement, Stability	TOT, SW, WN
	Tropical Matched Pixels (Direct Comparison)	Unfiltered Radiance	Pixel to Pixel	Daily	Inter-Instrument 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

Terra/Flight Model 1
Lifetime Radiometric Stability

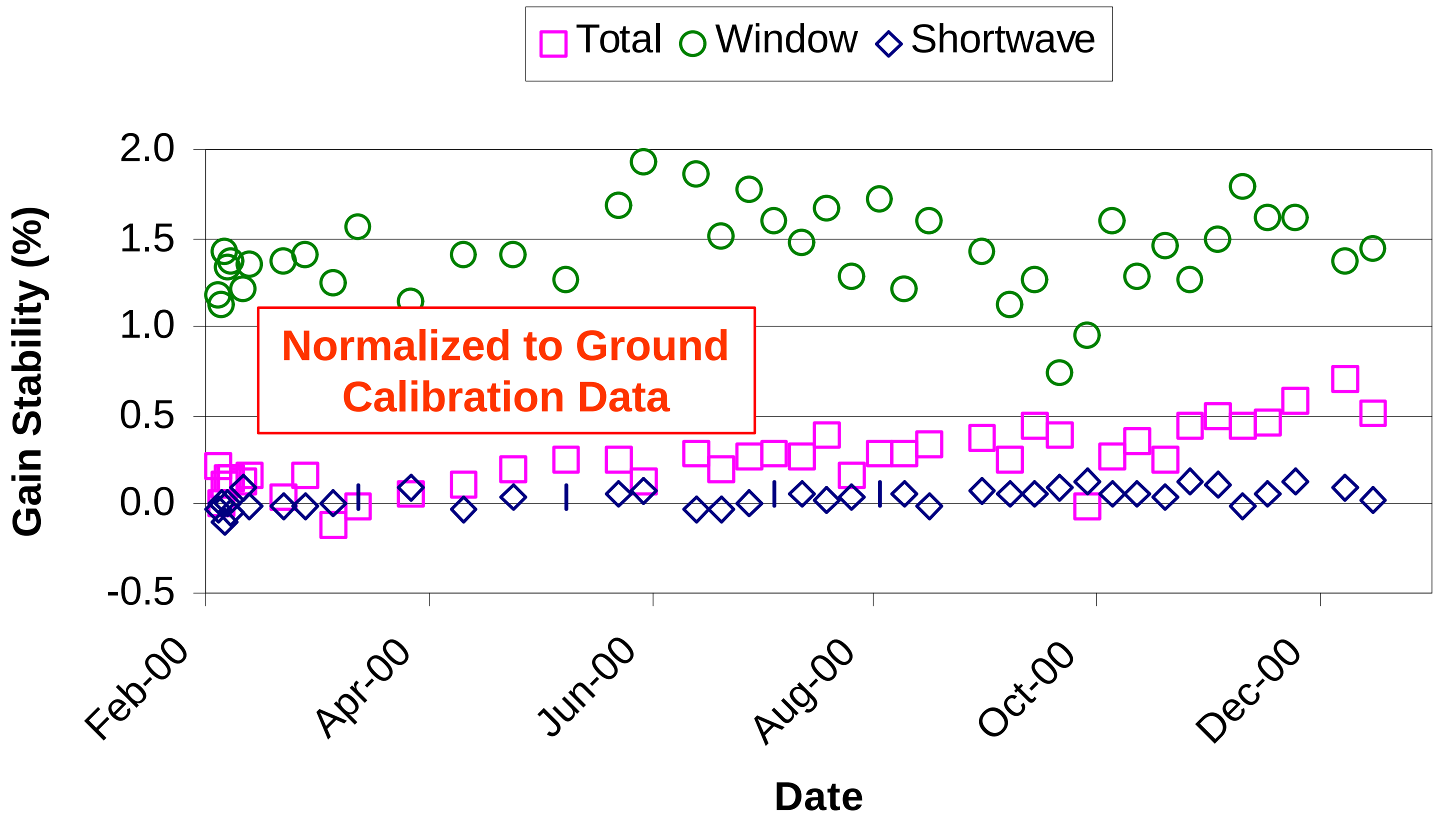
Determined with the Internal Calibration Module



Aiman Al-hajjah, Susan Thomas

Terra/Flight Model 2
Lifetime Radiometric Stability

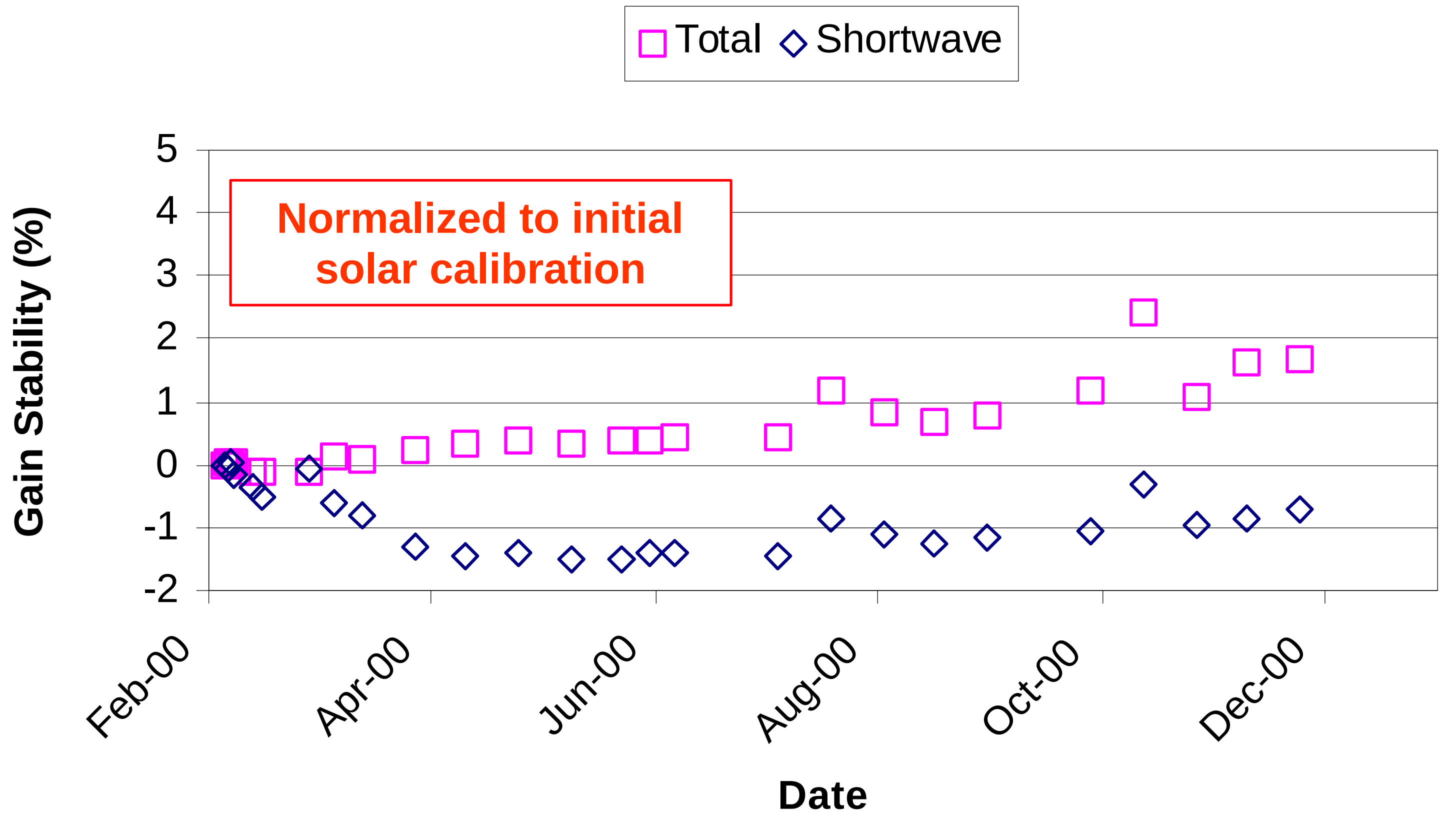
Determined with the Internal Calibration Module



Aiman Al-hajjah, Susan Thomas

Terra/Flight Model 1
On-orbit Shortwave Radiometric Stability

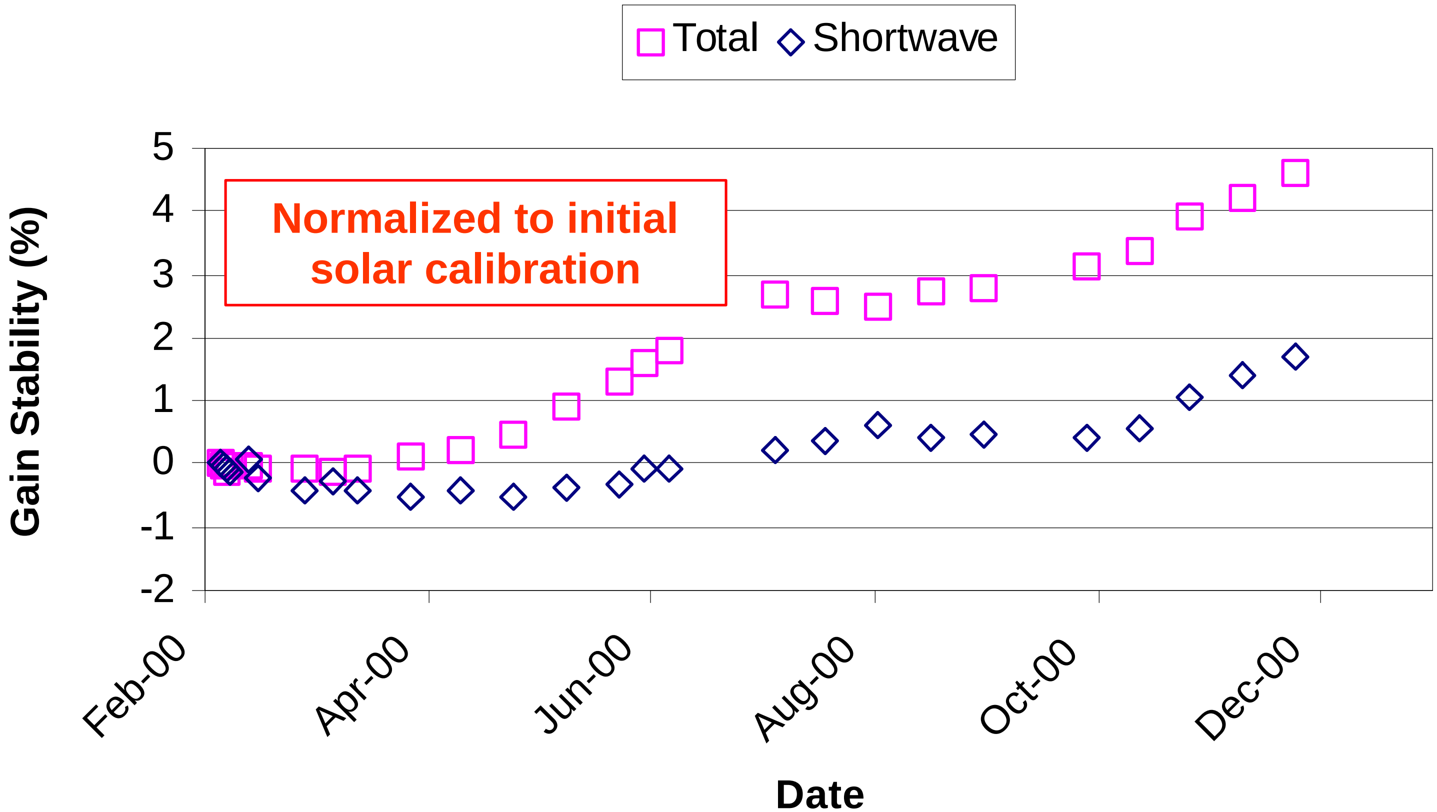
Solar Calibrations Performed with the Mirror Attenuator Mosaic



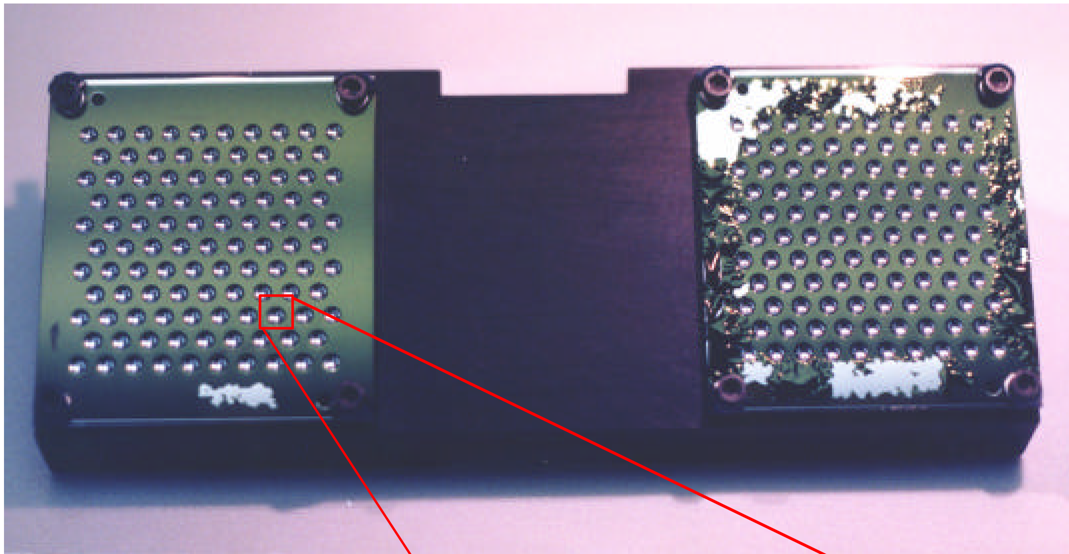
Robert Wilson

Terra/Flight Model 2
On-orbit Shortwave Radiometric Stability

Solar Calibrations Performed with the Mirror Attenuator Mosaic



Robert Wilson



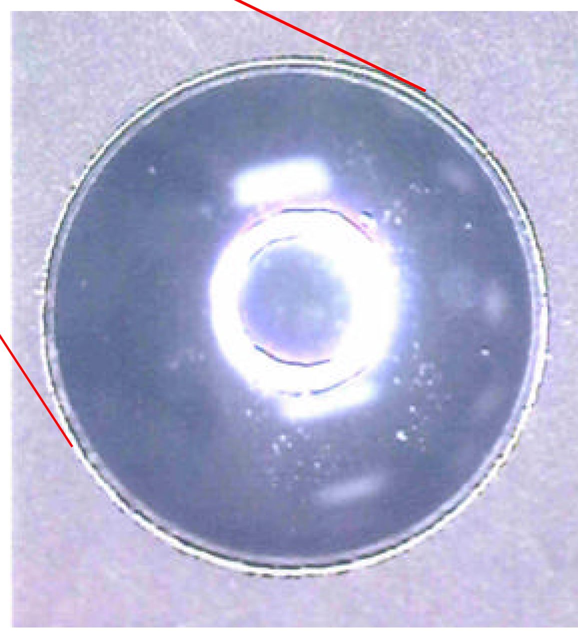
FM-1 MAM's had a 'dull matte finish with varying degrees of blistering'.

Deemed acceptable after passing accelerated life-test.

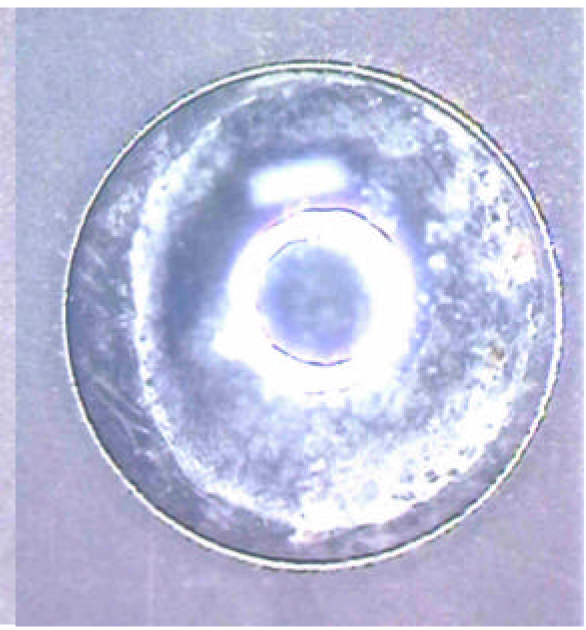
FM-2 MAM's from later production run.

CERES

Mirror
Attenuator
Mosaic



Acceptable Coating



Blistered/Crazed Coating

Internal/Solar Calibrations Key Results

- **Ground to Flight Calibration Stability**
  - Determined with Internal Calibration Module
    - TOT: 0.20 and 0.12% for FM1 and FM2
    - WN: 0.48 and 1.3% for FM1 and FM2
    - SW: -0.16 and <0.1% for FM1 and FM2

- **On-Orbit Calibration Stability (%/year)**
  - Internal Calibration Module
    - TOT: 0.18* and 0.49* %/yr for FM1 and FM2
    - WN: -0.11 and 0.01 %/yr for FM1 and FM2
    - SW: 0.11* and 0.11* %/yr for FM1 and FM2
      - * statistically significant
      - All internal calibrations have been executed in daytime portion of orbit
  - Solar Calibrations
    - suggests large drift in 3 of the four channels
    - **But**, <u>questionable build history on the FM-1 MAM's</u>

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
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	Intra-satellite (Direct Comparison)	Unfiltered Radiance	Pixel to Pixel	Daily	Inter-Instrument Agreement	TOT, SW, WN
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	TIme Space Averaging	Fluxes	Global	Monthly	Inter-Instrument Agreement	LW, SW

Direct Comparison to Measure Relative Drift

Δ's = FM2 - FM1

	Day				Night		
	ΔSW	ΔLW	ΔWN	N	ΔLW	ΔWN	N
March, 2000	0.12	-0.29	0.075	3	-0.45	0.084	7
April	0.08	-0.22	0.080	3	-0.48	0.084	14
May	0.17	-0.11	0.081	5	-0.45	0.085	13
June	0.24	-0.04	0.068	5	-0.46	0.078	10
July	0.08	0.10	0.064	7	-0.48	0.072	13
August	0.10	0.15	0.058	19	-0.52	0.064	23
September	0.16	0.13	0.058	13	-0.52	0.065	20
October	0.21	0.14	0.061	13	-0.49	0.070	10
November	0.16	0.20	0.069	11	-0.42	0.075	17
December	0.17	0.33	0.071	6	-0.41	0.080	5
All	0.15	0.05	0.068	85	-0.47	0.076	132
All Percent	0.2	0.1	0.9		-0.5	1.1	
FM1 Value	64.84	88.39	7.22		88.32	7.15	

Window channel: FM1 < FM2 by 1.0%

* Nadir data

Shortwave channel: FM1 < FM2 by 0.2%

Nighttime LW: FM1 > FM2 by 0.5%

Daytime LW: Relative Drift between FM1 and FM2

Direct Comparisons cannot isolate which instrument is drifting

Richard Green

Tropical Mean

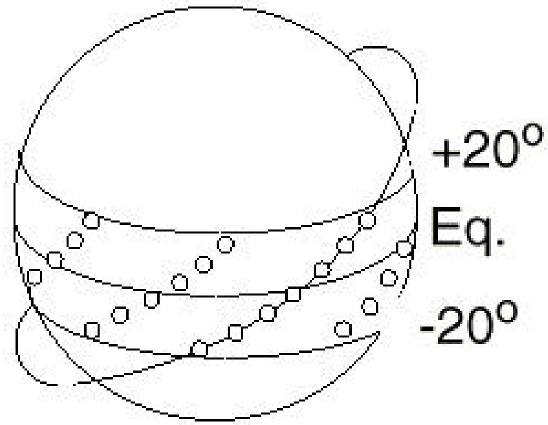
Tropical Ocean, All Sky, Noon Adjustment

Monthly Mean Nadir Radiance at Night for ERBS

	1985	1986	1987	1988	1989	Mean	Std
Mar	87.61	86.63	88.60	88.51	88.42	87.95	0.84
Apr	87.14	87.20	87.38	88.02	86.79	87.31	0.45
May	87.52	87.29	87.44	87.27	87.16	87.34	0.14
Jun	87.83	86.13	87.46	87.64	87.10	87.23	0.67
Jul	87.10	87.18	87.50	86.79	87.35	87.18	0.27
Aug	86.43	86.16	87.11	86.92	87.17	86.76	0.44
Sep	86.60	86.68	87.38	87.37	87.45	87.10	0.42
Oct	87.58	87.88	87.55	86.90	87.09	87.40	0.40
Now	87.20	86.20	87.00	86.54	86.49	86.69	0.41
Dec	87.06	85.74	87.38	86.36	87.08	86.72	0.67
Jan	86.77	86.73	86.84	86.81	86.00	86.65	0.36
Feb	87.56	87.21	87.86	86.29	87.17	87.22	0.59
Mean	87.20	86.76	87.45	87.12	87.11	**87.13**	
Std	0.44	0.62	0.45	0.67	0.57		**0.58**

$$\sigma_{\bar{x}} = \sigma_x / \sqrt{n^k}$$

$$\sigma_{\overline{TM}} = 0.58 / \sqrt{60^{0.62}} = 0.16\ Wm^{-2}sr^{-1}$$



Longwave Radiance

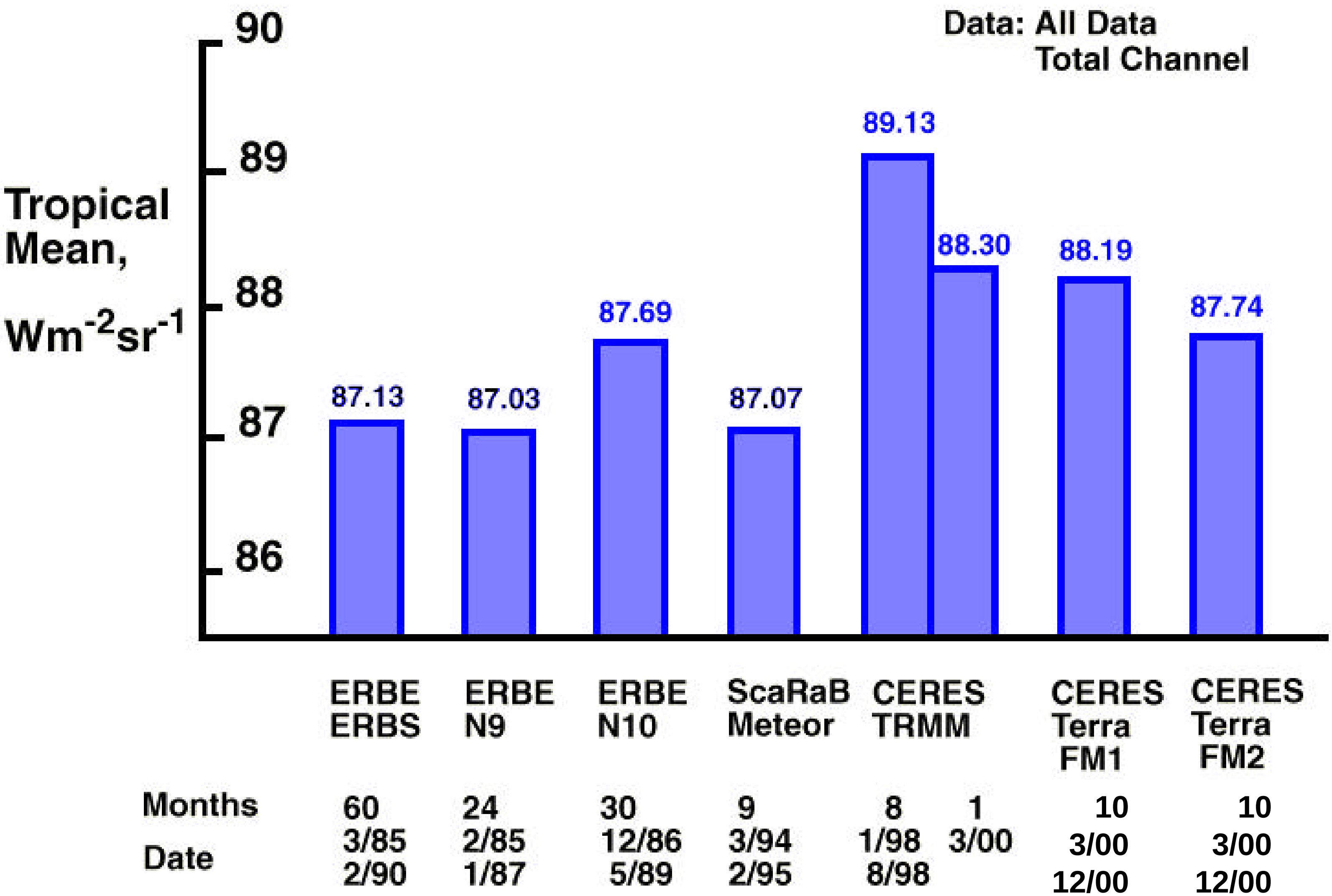
1 measurement: Std = 15 %

1 day (3200 meas): Std = 1.2 %

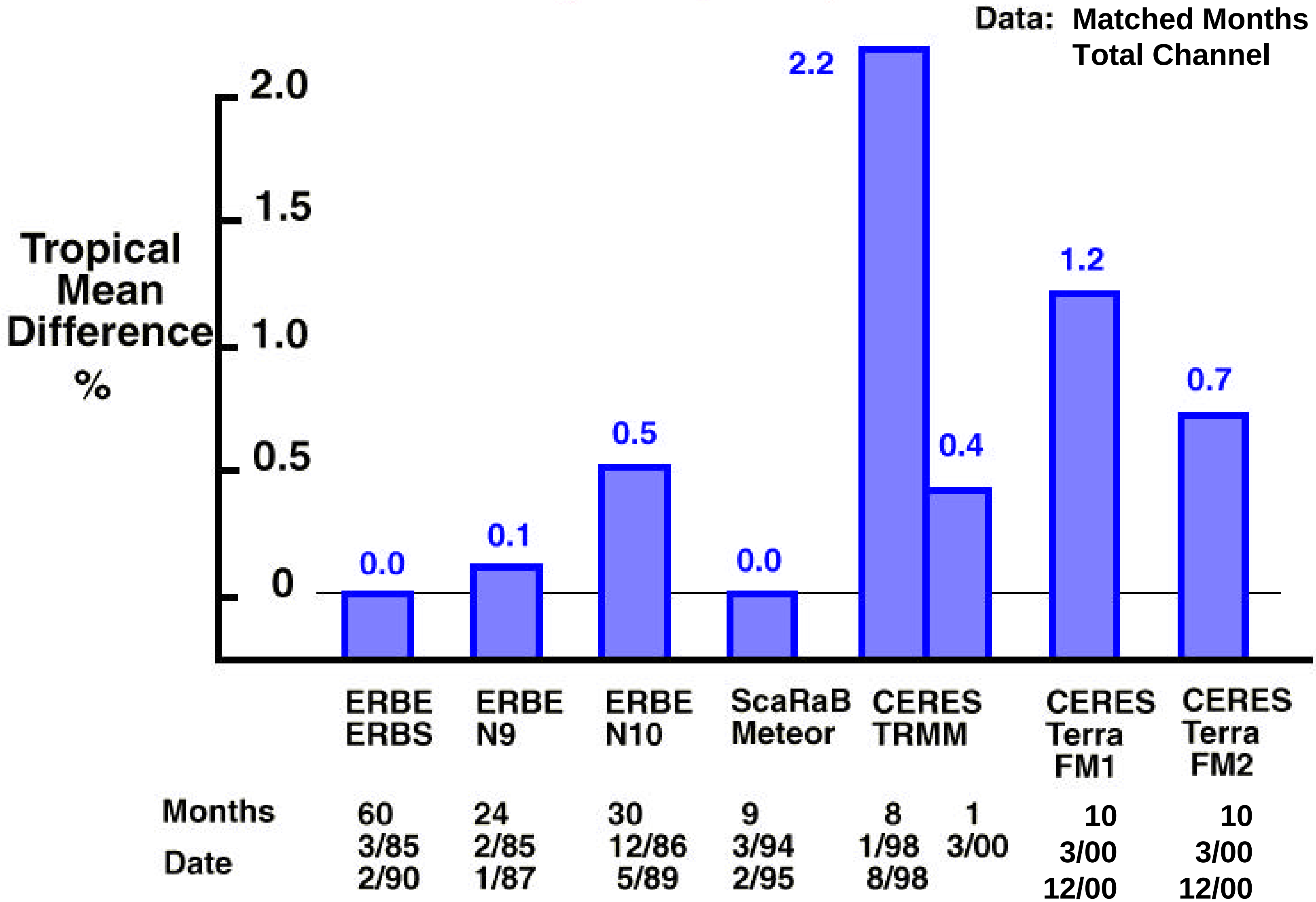
1 month (20 days): Std = 0.6 %

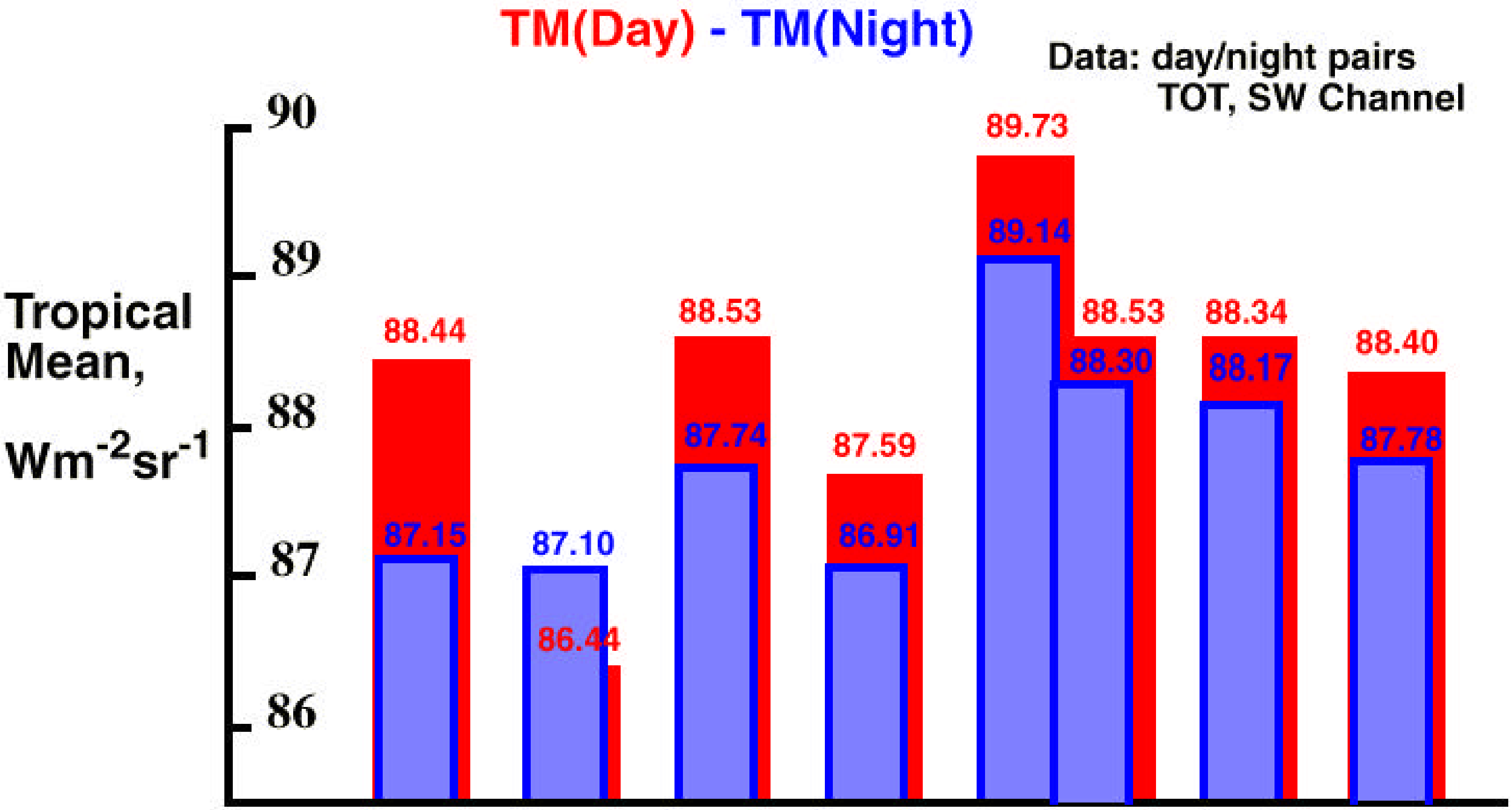
1 year (12 months): Std = 0.2 %

Tropical Mean at Night



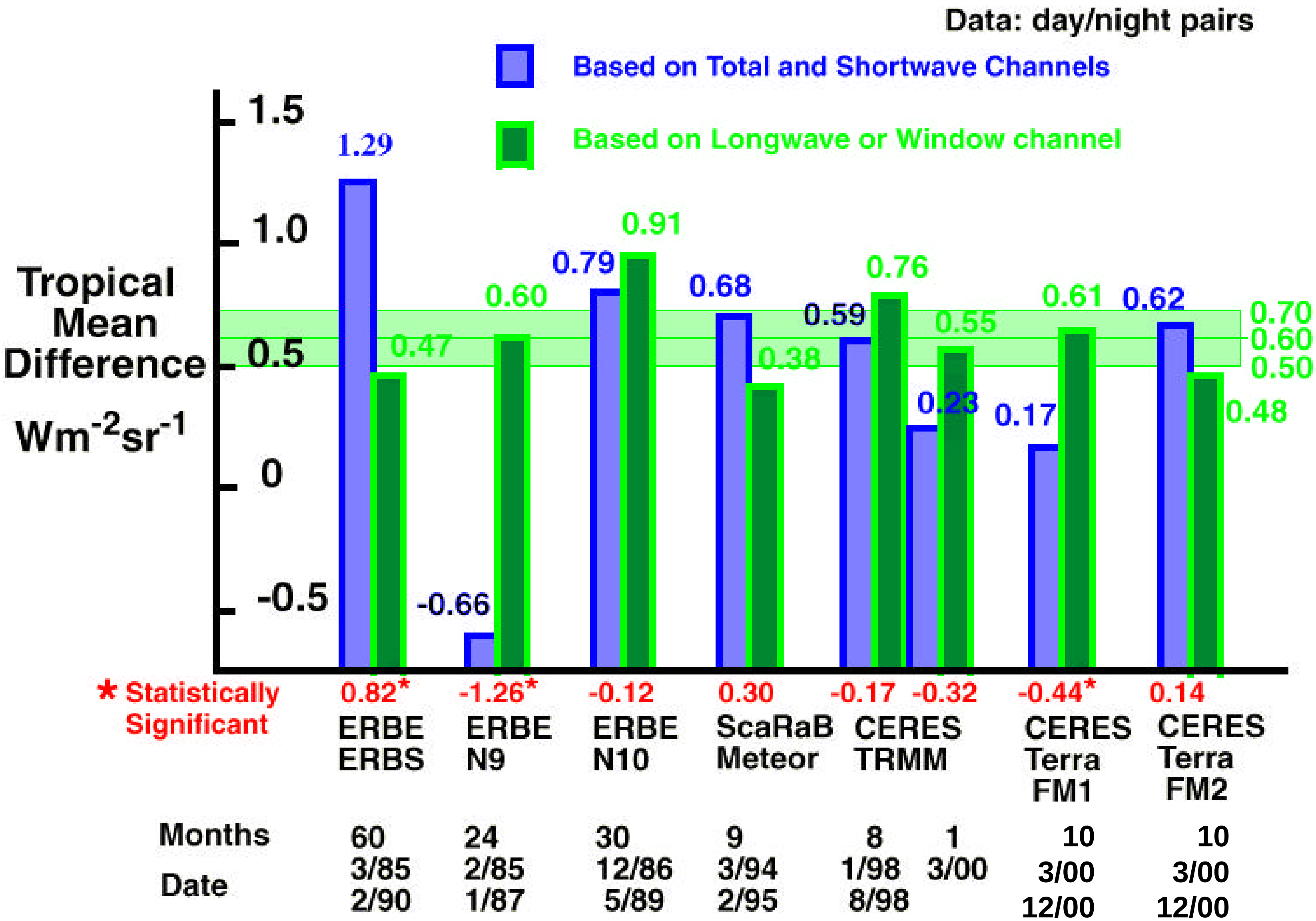
Tropical Mean at Night
TM - TM(ERBS equivalent)





	ERBE ERBS	ERBE N9	ERBE N10	ScaRaB Meteor	CERES TRMM		CERES Terra FM1	CERES Terra FM2
Months	60	24	30	9	8	1	10	10
Date	3/85 2/90	2/85 1/87	12/86 5/89	3/94 2/95	1/98 8/98	3/00	3/00 12/00	3/00 12/00

Comparison of Day/Night Differences



Direct Comparison

Tropical Mean for Collocated Footprints

	DN(tot,sw) - DN(wn)	
	FM1	FM2
March, 2000	-0.49	-0.20
April	-0.46	-0.09
May	-0.43	-0.01
June	-0.42	0.07
July	-0.42	0.23
August	-0.54	0.21
September	-0.39	0.32
October	-0.38	0.29
November	-0.48	0.25
December	-0.44	0.32

This Table shows that FM2 is the instrument that is drifting and not FM1. In this Table each instrument is treated separately.

Direct Comparison / Tropical Mean Key Results

Direct Comparison

- Relative Differences
  - WN radiances: FM1 < FM2 by 1.0%, no relative drift
  - SW radiances: FM1 < FM2 by 0.2%, no relative drift
  - Nighttime LW: FM1 > FM2 by 0.5%, no relative drift
  - Daytime LW: Relative Drift between FM1 and FM2 of 0.70% from Mar to Dec '00

Tropical Mean

- Nighttime
  - Nighttime LW: FM1 > FM2 by 0.5%
- Day Night Difference: DN(tot,sw) – DN(wn)
  - DN(wn) or DN(lw) should be highly correlated with DN(sw,tot)
  - Direct Comparison and Internal calibrations rule out drift in WN and SW channels
  - DN(tot,sw) – DN (wn) isolates drift to the FM-2 Total channel

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
	Tropical 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

CERES Deep Convective Albedo, March 2000

We have calculated the isotropic albedo, or reflectance, R, for Tropical Deep Convective Clouds as defined by

$$R = \frac{\pi I}{E_o d^{-2} \cos\theta_o}$$

The goal is to intercompare the three CERES instruments.

DATASET

Scene Type: Independent Deep Convective Cloud systems

Cloud Size: Greater than 10 Km in ground track direction

Cloud Temperature: Less than 215 K (Dispersion <0.1)

Data Product: CERES PFM, FM1 and FM2

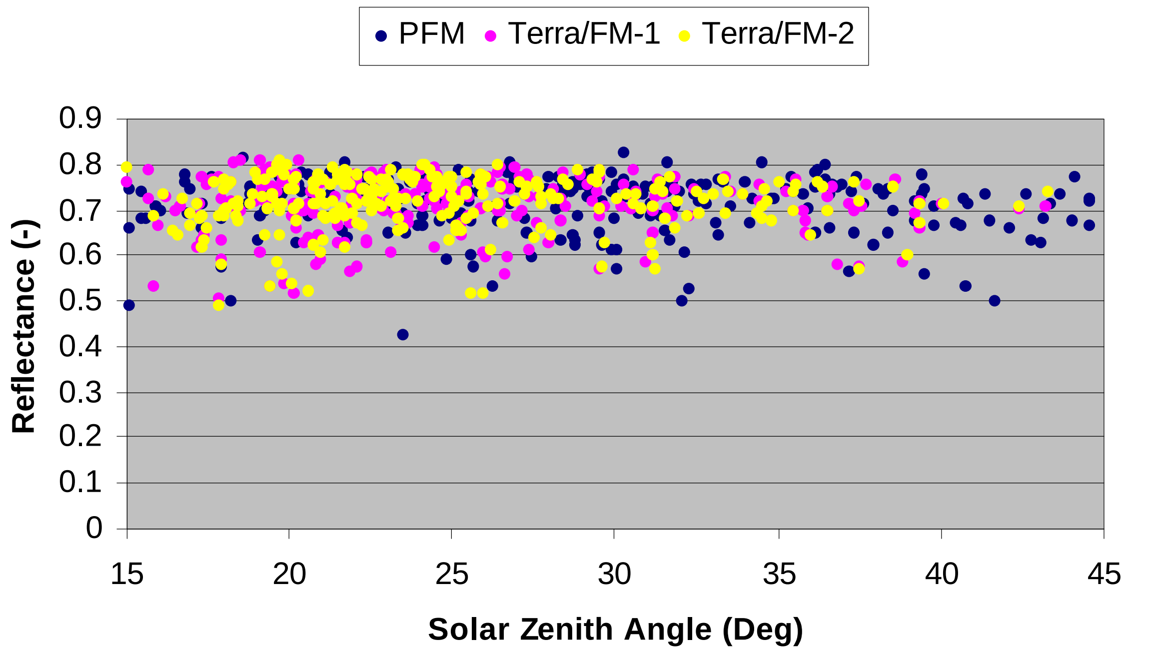
View Zenith: Nadir footprints only

Solar Zenith: 15 to 45-degrees (Limited by Terra Orbit)

Latitude: 40 N to 140 S

CERES Deep Convective Albedo

Results of estimating reflectance over the solar zenith range of ~15-45 degrees.



	PFM (M-A-M-J)	FM1 (M-D)	FM2 (M-D)
% Reflectance (Std. Error)	71.16 (.41)	71.66 (.32)	71.46 (.33)

Mean Values agree to within 0.5%

3-Channel Deep Convection Results

Assess the agreement between our best estimates of the unfiltering of the SW channel and the SW portion of the Total Channel.

With this method we cannot distinguish between errors in the spectral response function and relative errors in the spectral unfiltering method.

DATASET

Scene Type: **Deep convective clouds**

Cloud Size: **Greater than 80 Km in ground track direction**

Cloud Temperature: **Less than 210K**

Data Product: **Terra FM-1 and FM-2 'Edition 1' ES-8 files**

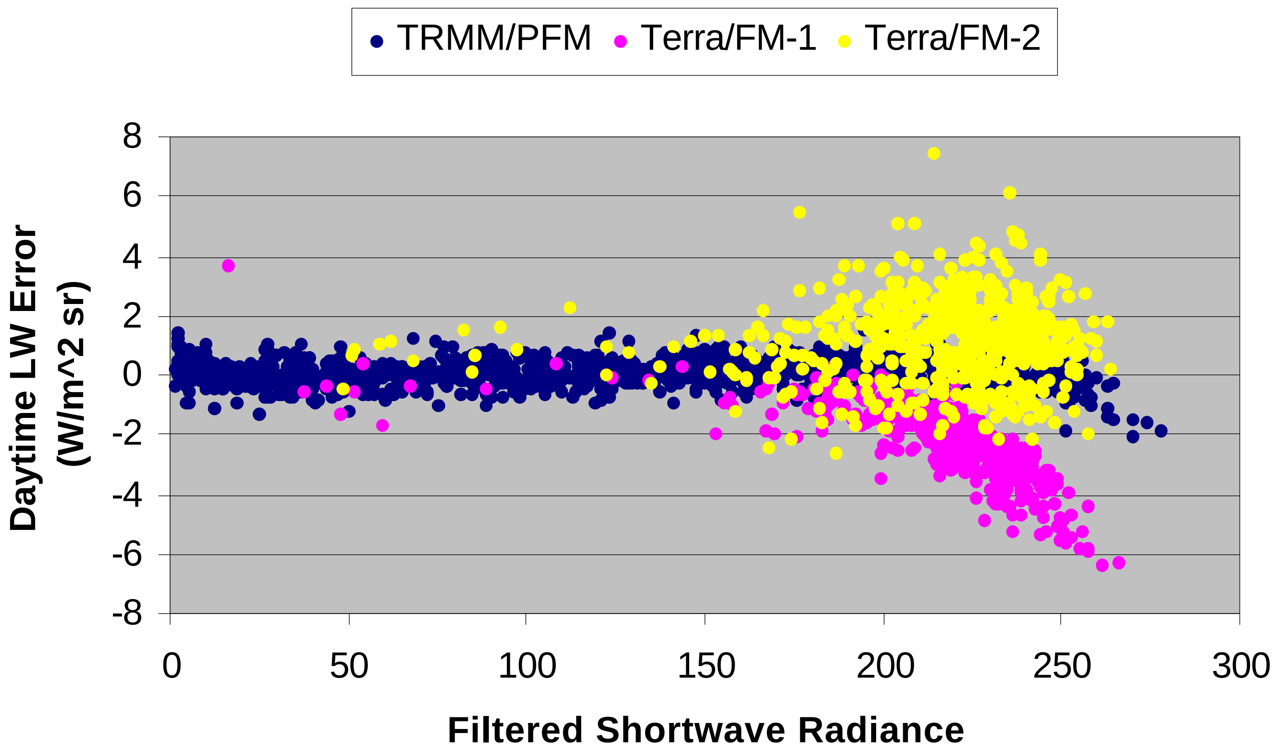
View Zenith: **Nadir footprints only**

Solar Zenith: **Less than 80-degrees**

Latitude: **40 N to 140 S**

3-Channel Deep Convection Results

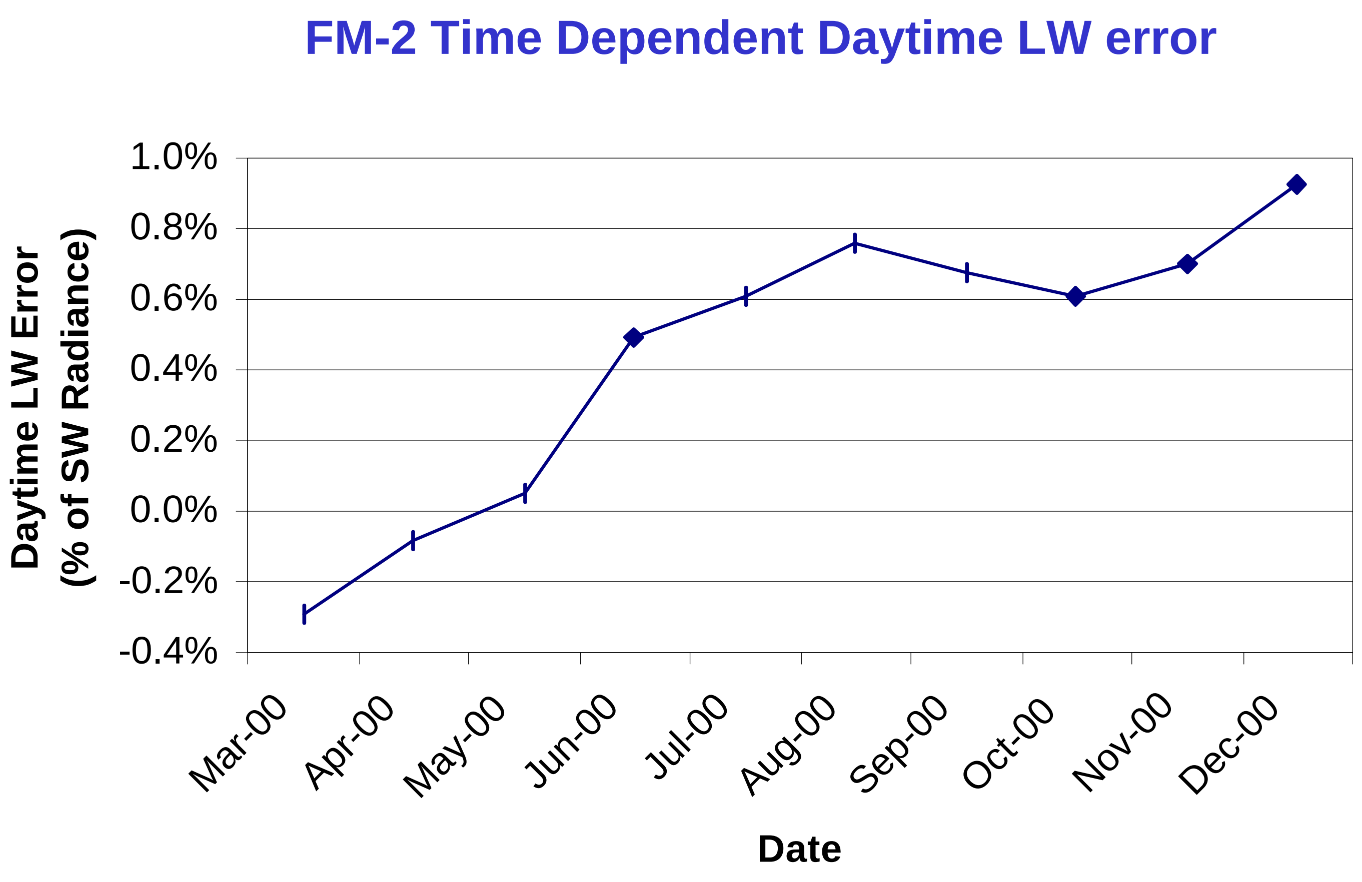
March - December 2000



TRMM/PFM : no significant errors (March – August, 1998)
Terra/FM-1 : Daytime LW too low by up to 6 w/m^2/sr for bright DCC
Terra/FM-2 : Daytime LW error varies with time

3-Channel Deep Convection Results

March - December 2000



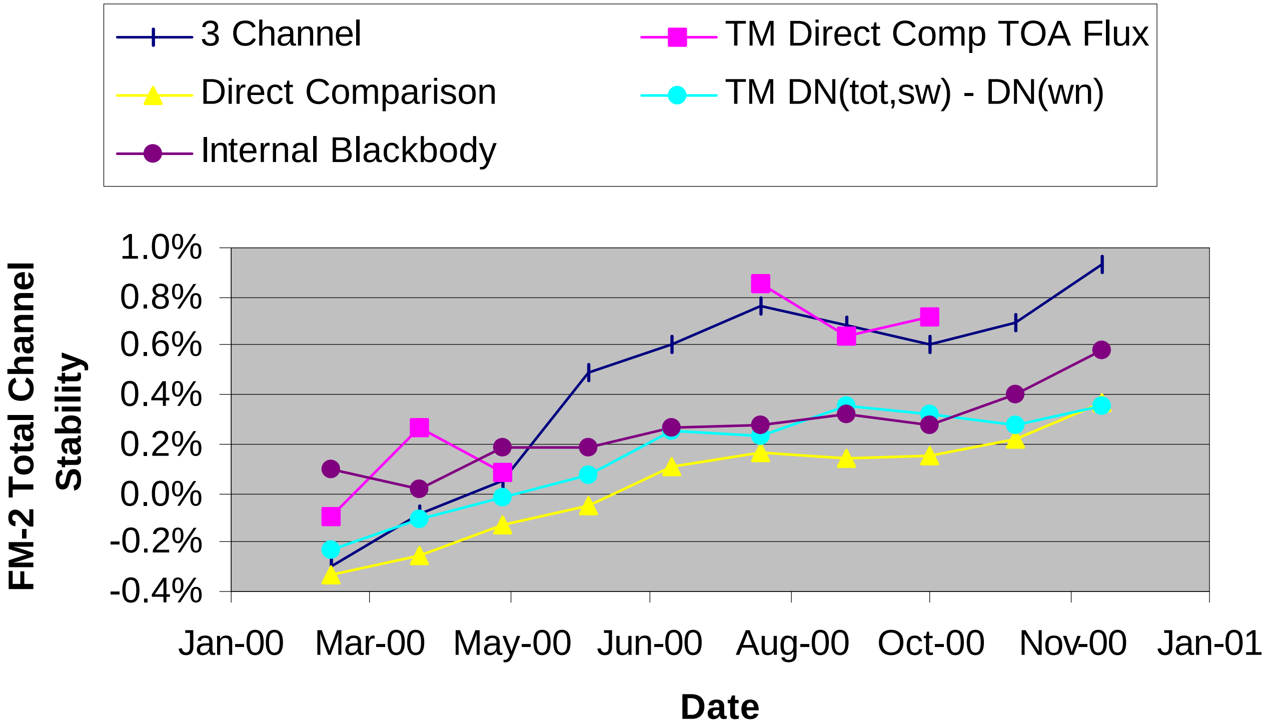
DCC Albedo / 3-Channel Intercomparison Key Results

- **DCC Albedo**
  - The SW channels from PFM, FM-1, and FM-2 agree to within 0.5%
    - No measurable drift from Mar-Dec '00

- **3-Channel Intercomparison**
  - FM-1
    - SW and SW/TOT channel inconsistency at the 1% level
      - Inconsistency is stable over time
      - DCC Albedo results suggest the error is in the TOT channel

  - FM-2
    - Time varying inconsistency in FM-2 Total channel (total change ~1.2%)
      - DCC Albedo results suggest the error is in the TOT channel

FM-2 TOT Channel Drift Summary



Several distinct validation efforts which cover several data product levels, temporal, spectral and spatial domains all arrive at the same result: a sensitivity to changes at the sub 0.5-percent level.

That is a success from a validation point of view.

Terra Validation Effort / Executive Summary

March – December, 2000

- **Ground to Flight calibration stability is better than 0.3% for TOT and SW channels**
- **WN channel calibrations shifted from ground to flight, FM-1 by 0.48%, FM-2 by 1.3%**
  - FM-2 WN radiances > FM-1 WN radiances by ~0.9%
  - Insufficient settling time allowed during ground cal's
- **SW radiances measurements are consistent at the 0.2% level between FM-1 and FM-2**
- **FM-1 day and nighttime LW radiances are stable, but high by ~0.6%**
  - Caused by LW/TOT spectral response being too low
- **FM-1 daytime LW radiances are stable, but low by ~1.0%**
  - Caused by the SW/TOT spectral response being too high
  - Net effect is FM-1 daytime LW radiances are low by ~0.4%
- **FM-2 daytime LW radiances demonstrate a slow increase of ~0.5%/year**
  - Probable culprit is thermal control on the FM-2 total channel heatsink.
- **FM-2 nighttime radiances are stable with no measurable drift**