CERES Instrument Cal/Val Report

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24th CERES Science Team Meeting
Newport News, VA

NASA Langley Research Center
Atmospheric SCIENCES

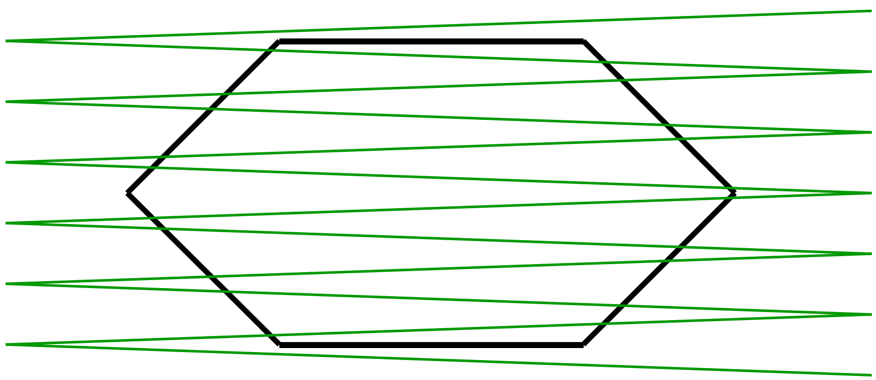
Validation of Pointing Knowledge Using Lunar Radiances

Objective: Utilize the full moon as a quasi-point source to complete a near steady-state raster scan across the CERES FOV.

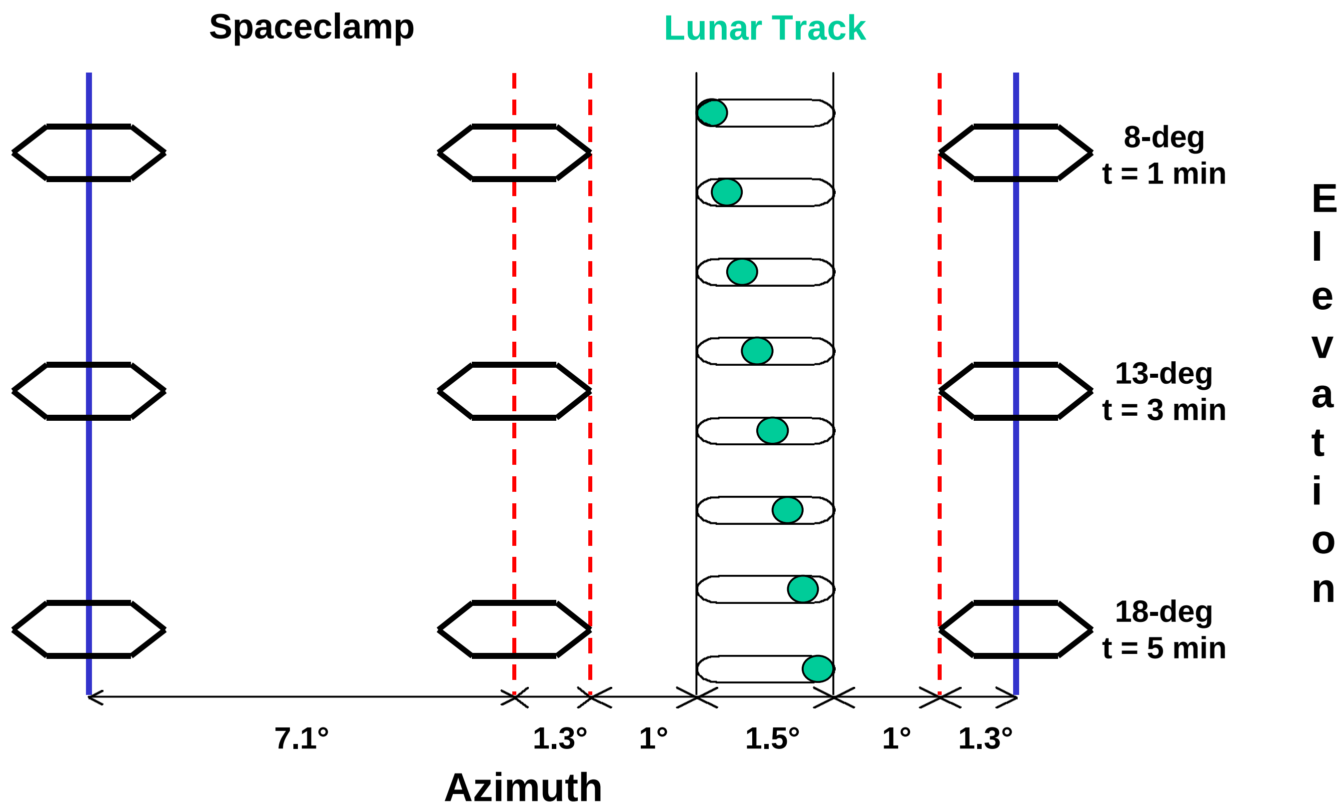
Goals

- **Validate pre-launch alignment measurements**
- **Measure inter-channel relative pointing accuracy**
- **Map out spatial non-uniformities in the CERES Optics/Detectors**
    - **This type of mapping is not performed *under vacuum* prior to launch.**

By combining knowledge of the motion of the moon relative to the spacecraft and the programmability of the the CERES Instruments we obtain……..



CERES Lunar Scanning Experimental Design



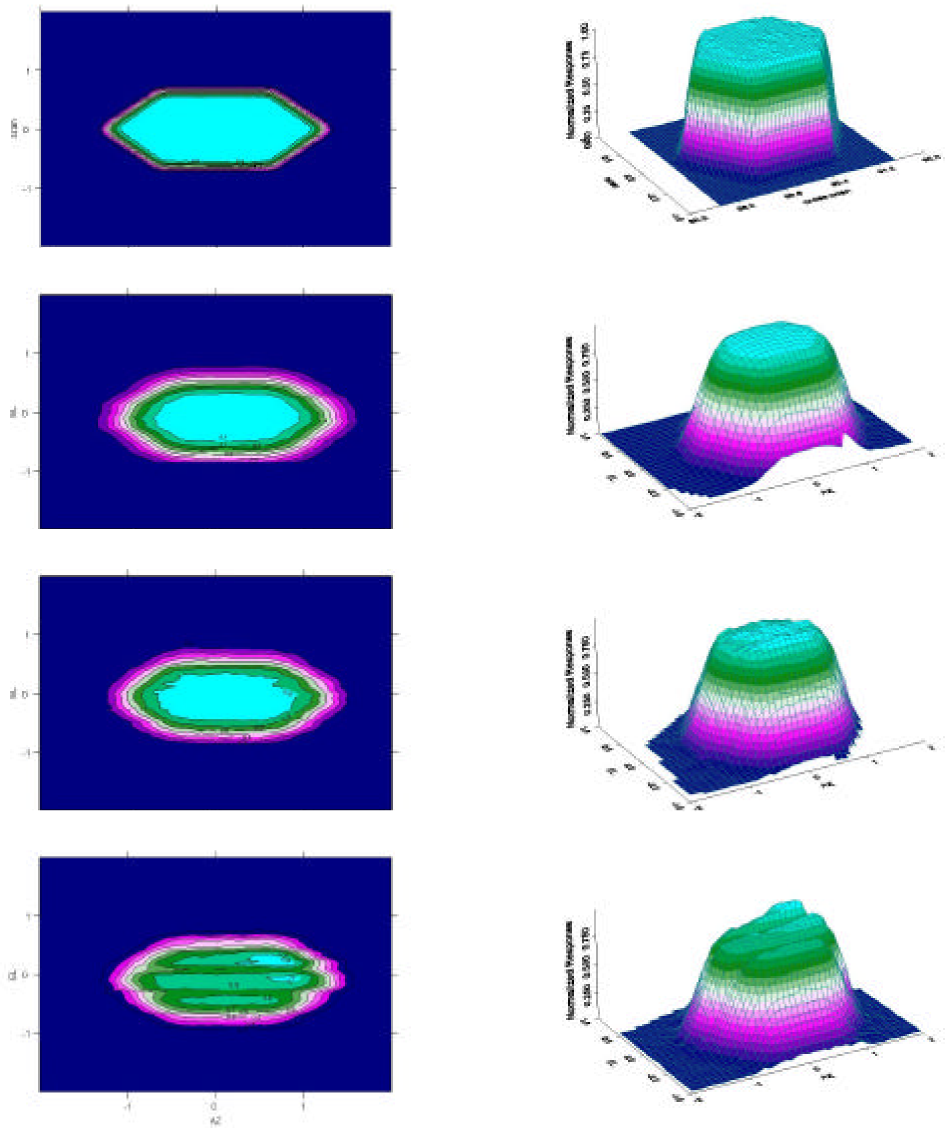
Lunar Scanning Results – CERES Optical Transfer Function

Monte-Carlo Ray Trace
(FELIX)

FM-1 Total

FM-1 Shortwave

FM-1 Window



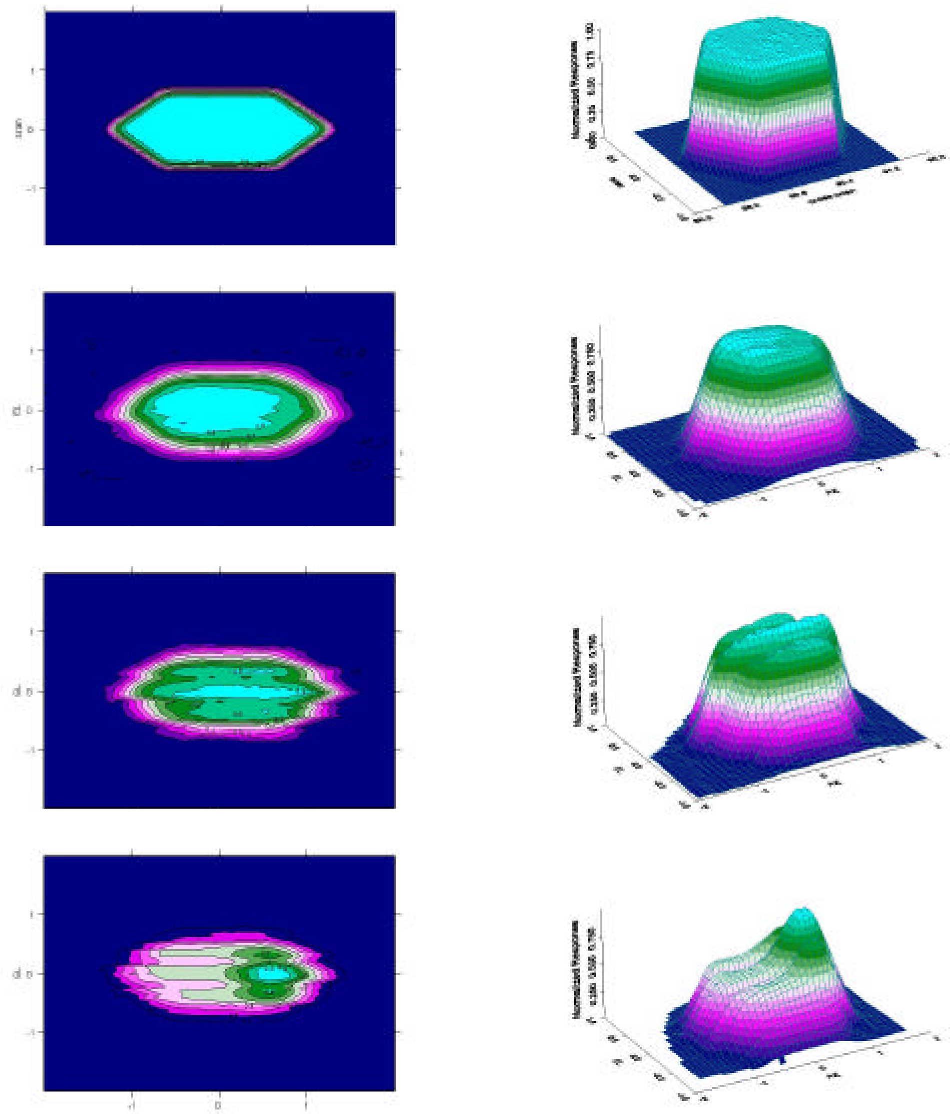
Lunar Scanning Results – CERES Optical Transfer Function

Monte-Carlo Ray Trace (FELIX)

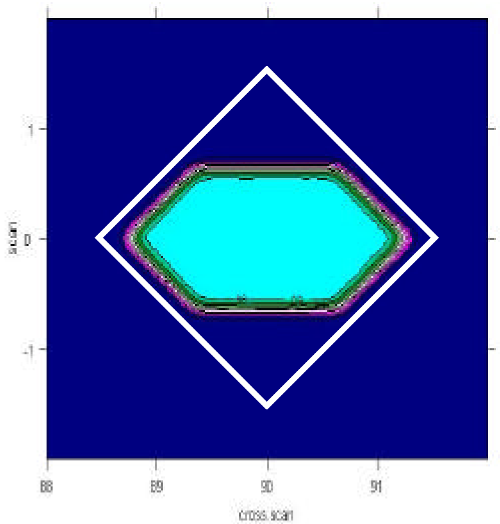
FM-2 Total

FM-2 Shortwave

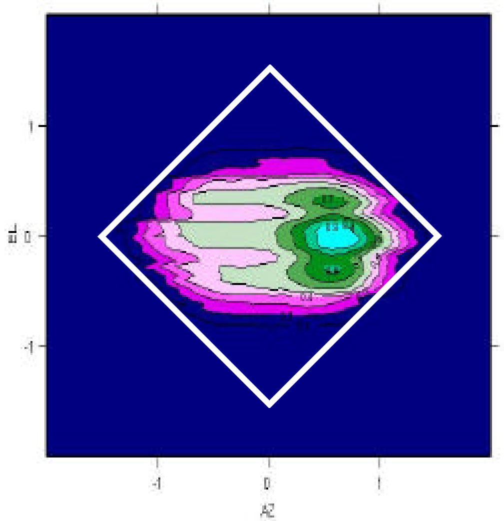
FM-2 Window



Monte-Carlo Ray Trace



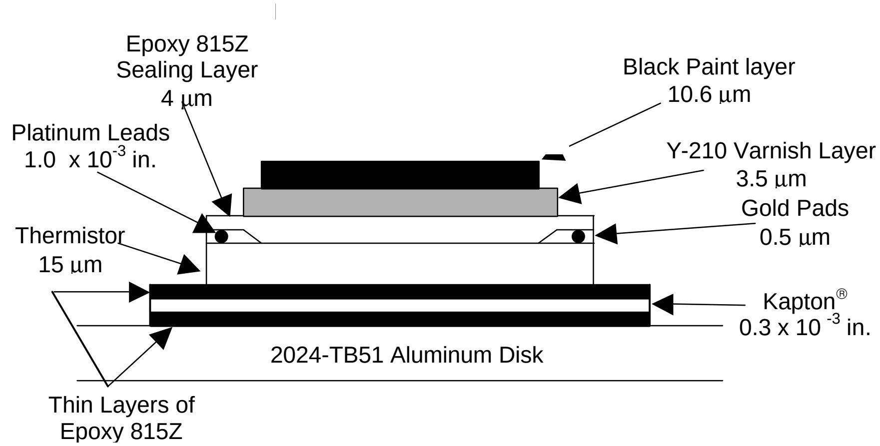
FM-2 WN Channel



FM-2 Window Channel

- **One quadrant of detector has an extremely high responivity**
- **Probably due to localized delamination of detector due to air-bubbles in the lower Epoxy layers.**
  - Consistent with known fabrication problems at the time these detectors were made.
- **The resulting void would provide a higher local thermal impedance**
  - Inducing higher temperatures in thermistor layer
  - Result in a slower time constant
  - Much longer air-to-vacuum stabilization time

Very stable radiometric performance on orbit!!!!!



CERES Detector

Lunar Scanning Summary

- **Excellent example of the close cooperation between Intrument Operations Team and the Instrument working group.**
- **Pre-flight alignment measurements are both accurate and stable**
  - No significant pointing errors (statistical accuracy ~0.1-degrees)
- **Impact of spatial non-uniformity in the FM-2 window channel still being assessed.**
  - To be modeled by Ira Sorensen as part of his dissertation
    - Point Spread Function impacts
    - Non-uniform scene impacts
    - Convolution of higher resolution imager data

CERES/TRMM Instrument Post-Mortem

Returned to service February 24th, 2000

Kory J. Priestley

22nd CERES Science Team Meeting
Newport News, VA
May 1, 2000

NASA Langley Research Center
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Data Recovery Status

- **Instrument group (I.e. Peter Szewczyk) is currently finishing the recovery of all daytime SW measurements through mid-April and after 6/1/00.**
  - Data from Mid-April to late May has unknown calibration due to large thermal transients.
  - An additional four weeks of SW data will significantly reduce any uncertainties in the comparison of TRMM/Terra SW radiance intercomparisons.
- **Details in poster session.**

Instrument Working Group
Coming Attractions

Terra Pitch-over Maneuver

Status is still somewhat uncertain. The Aster team has eased their hardline opposition tactics.

Still waiting for Terra Project to approve and execute maneuver.

Next window of opportunity begins in early August (Beta angle > 17-deg)

Bruce B. still anxiously clutching his bottles of Terra wine….

Terra Edition 2 BDS/ES-8 Data Products

Tied to execution of pitch-over maneuver to finalize scan-dependent offsets.

New Spectral Response functions will be delivered.

Drift removal based upon Internal Calibration measurements will be incorporated.

Will be a much improved data product, hopefully will enter production this Fall

New RAPS Azimuthal Scanning Rate

Requested by ADM working group, rate will change from 6.0 deg/sec to 0.5 deg/sec

Terra Validation Effort / Executive Summary

March, 2000 – April, 2000

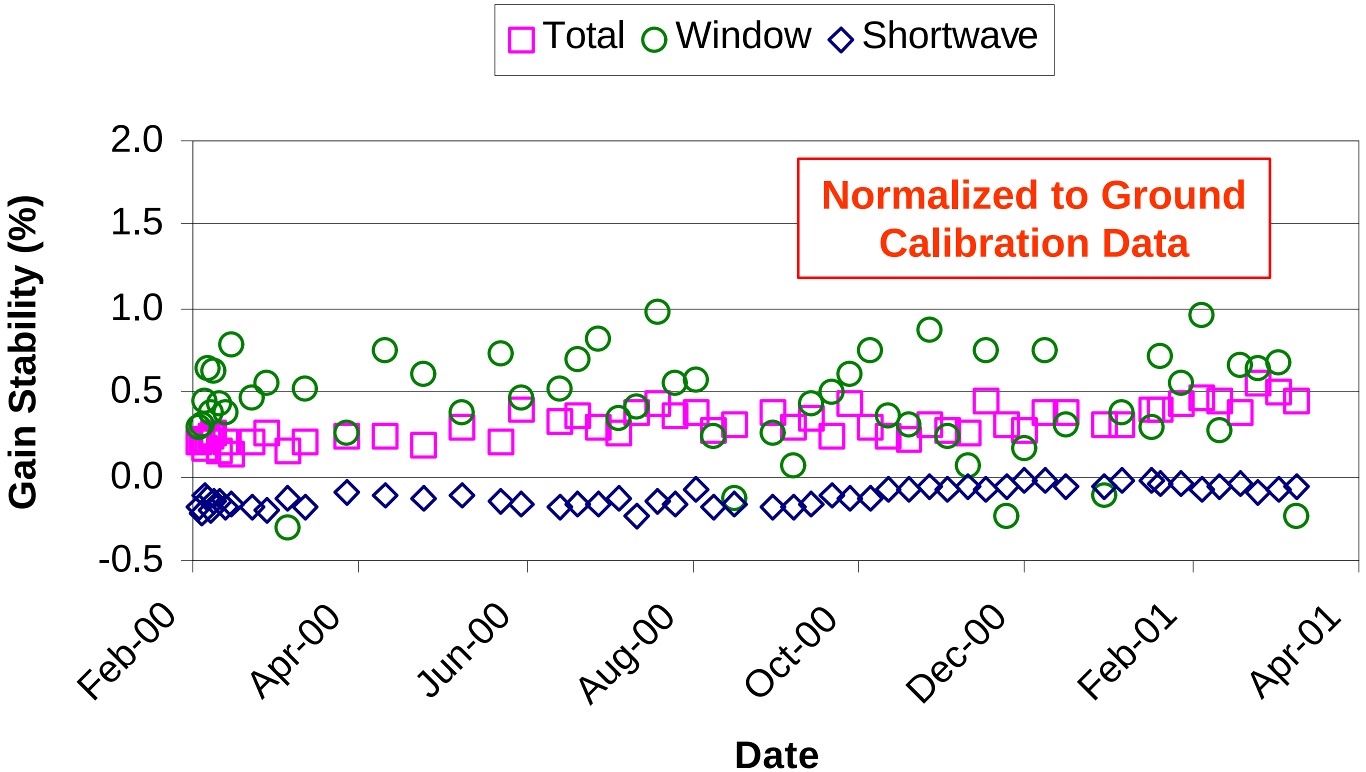
- **Ground to Flight calibration stability is better than 0.3% for TOT and SW channels**
- **WN channel calibrations shifted from ground to flight, FM-1 by 0.48%, FM-2 by 1.3%**
  - FM-2 WN radiances > FM-1 WN radiances by ~0.9%
  - Insufficient settling time allowed during ground cal's (Possible FM-2 delamination)
  - FM-1 WN channel has apparent SW leak of ~0.1%
  - No measurable drift in WN channels over mission lifetime (I.e. <0.1%)
- **SW channel radiance measurements consistent at the 0.3% level between FM-1 and FM-2 globally averaged (I.e. FM-2 > FM-1)**
  - Apparent mix of bias and gain errors (possibly spectral in nature) yields scene dependence
    - Clear Ocean FM-2 > FM-1 by ~1.9%
    - Bright Clouds FM-1 > FM-2 by ~0.7%
  - Stability better than 0.12 and 0.08 % per year based on SWICS lamps and Direct Comparison studies
- **FM-1 day and nighttime LW (I.e. total channel) radiances are stable to better than 0.25% over the first 12 months**
- **FM-2 daytime LW radiances demonstrate a slow increase of ~1%/year**
- **FM-2 nighttime radiances appear stable with no measurable drift**
  - Physics not yet completely understood

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

Terra/Flight Model 1
Lifetime Radiometric Stability

Determined with the Internal Calibration Module



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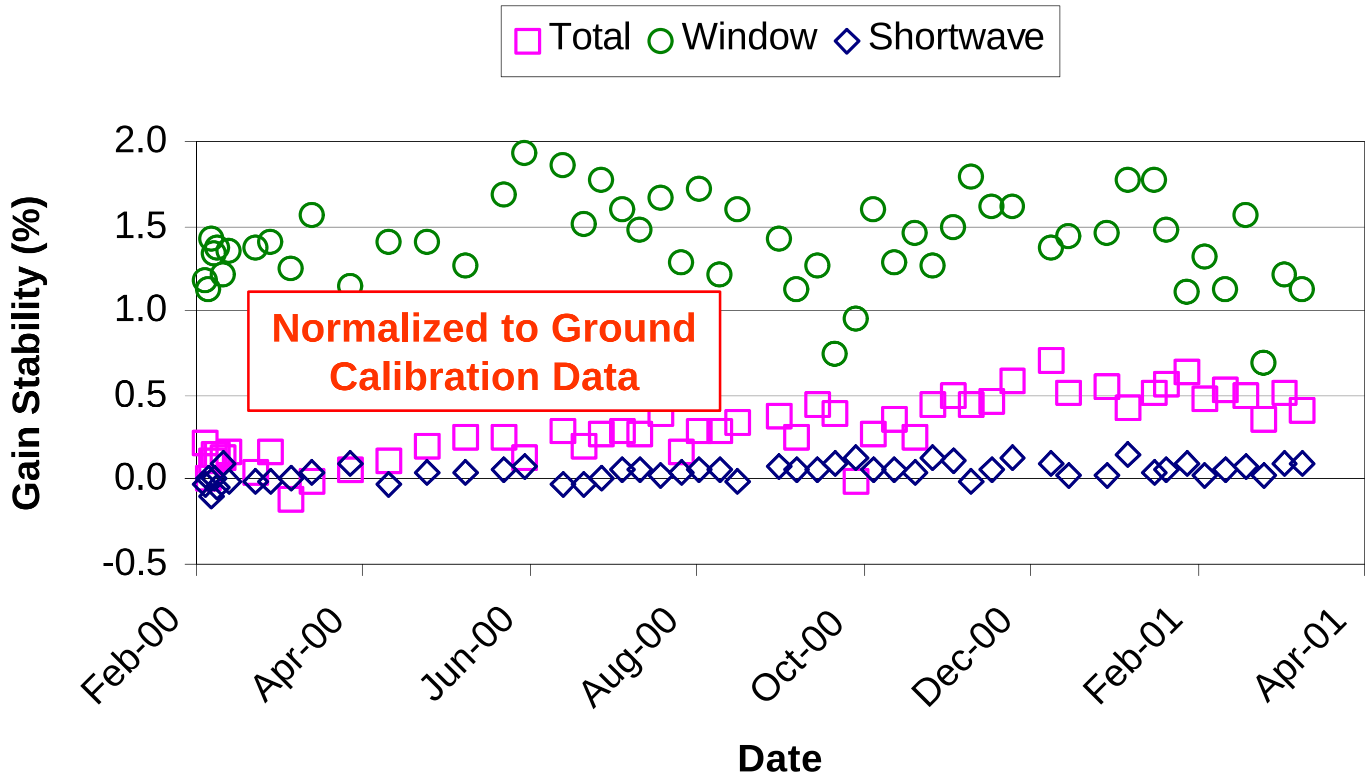
Terra/Flight Model 2
Lifetime Radiometric Stability

Determined with the Internal Calibration Module



Aiman Al-hajjah, Susan Thomas

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: 0.21* and **0.45*** %/yr for FM1 and FM2
    - WN: -0.06 and -0.02 %/yr for FM1 and FM2
    - SW: 0.12* and 0.08* %/yr for FM1 and FM2
      - * statistically significant
      - All internal calibrations have been executed in daytime portion of orbit
  - Solar Calibrations
    - Terra MAM's have continued to drift with time and results are suspect

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.

Direct Comparison of Nadir Radiance Measurements

All Scenes, Δ's = FM2 - FM1

	Day*				Night*		
	ΔSW	ΔLW	ΔWN	N, k	ΔLW	ΔWN	N
March, 2000	.239	-.190	.062	346	-.239	.064	363
April	.261	-.162	.063	331	-.239	.061	346
May	.311	-.093	.065	350	-.205	.062	361
June	.253	.019	.060	321	-.194	.055	330
July	.172	.064	.058	361	-.216	.051	360
August	.144	.074	.051	372	-.280	.045	371
September	.178	.093	.048	356	-.307	.046	355
October	.280	.136	.047	353	-.298	.048	353
November	.348	.296	.052	359	-.227	.054	356
December	.293	.491	.051	362	-.194	.054	358
January, 2001	.196	.598	.050	365	-.181	.052	364
February	.151	.593	.047	339	-.221	.048	338
All	.235	.160	.054	351	-.234	.053	355
All Percent	.33	.20	.94		-.31	1.02	
FM1 Value	72.01	78.86	5.82		74.43	5.24	

* W/m^2-sr

Shortwave channel: FM1 < FM2 by 0.33%

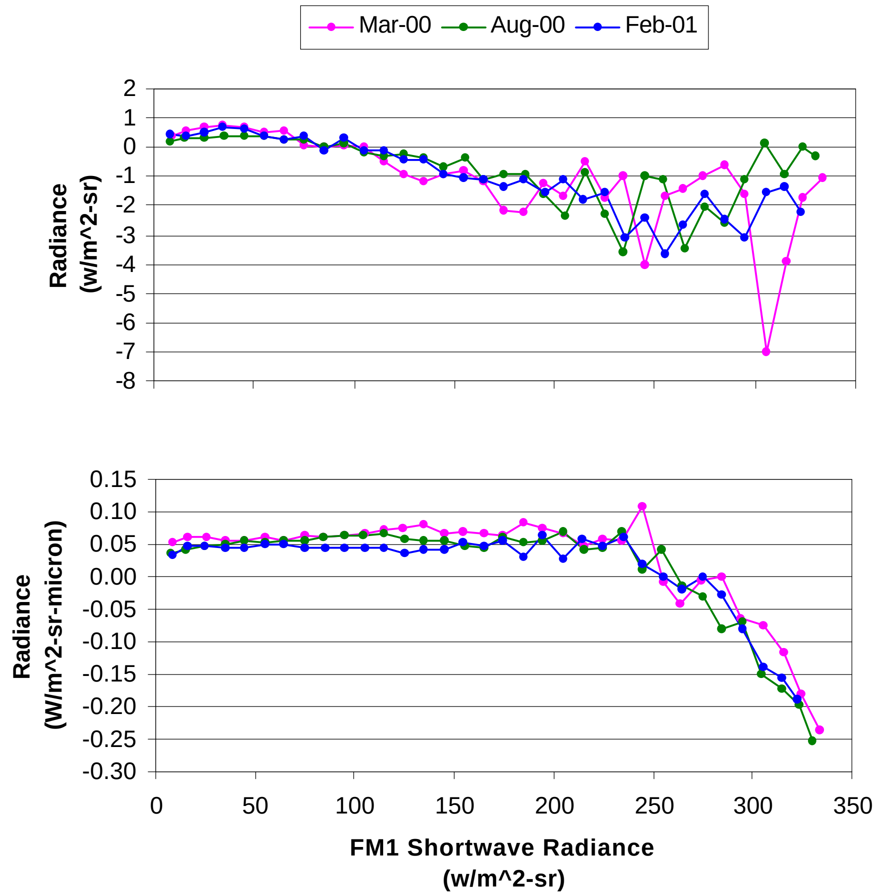
Nighttime LW: FM1 > FM2 by 0.3%

Window channel: FM1 < FM2 by 1.0%

Daytime LW: Relative Drift between FM1 and FM2

Direct Comparisons cannot isolate which instrument is drifting

SW and WN Channel Direct Comparisons
FM2 minus FM1



SW

Relative agreement is a function of SW

Invariant with time

WN

FM1 WN radiance grows with SW

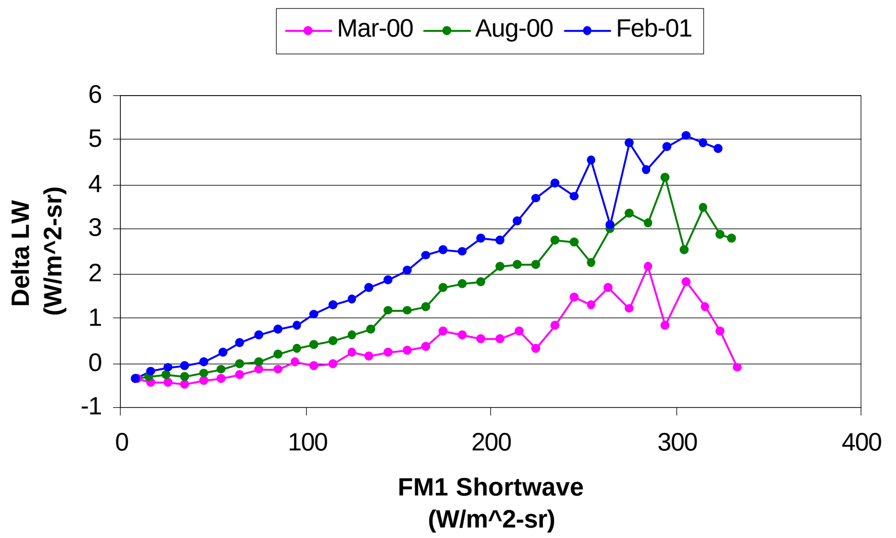
Consistent with a SW leak at the 0.1% level.

3-channel Intercomparison verifies

Invariant with time

*** Daytime Global Nadir data**

Daytime LW Direct Comparisons
FM2 minus FM1



Daytime LW

Growth in ΔLW_{day} is highly correlated to SW.

Over the first 12 months ΔLW_{day} has increased by roughly 1% of the SW signal, and is relatively independent of the LW signal.

From 3-channel intercomparison we know the changes are in FM-2.

*** Daytime Global Nadir data**

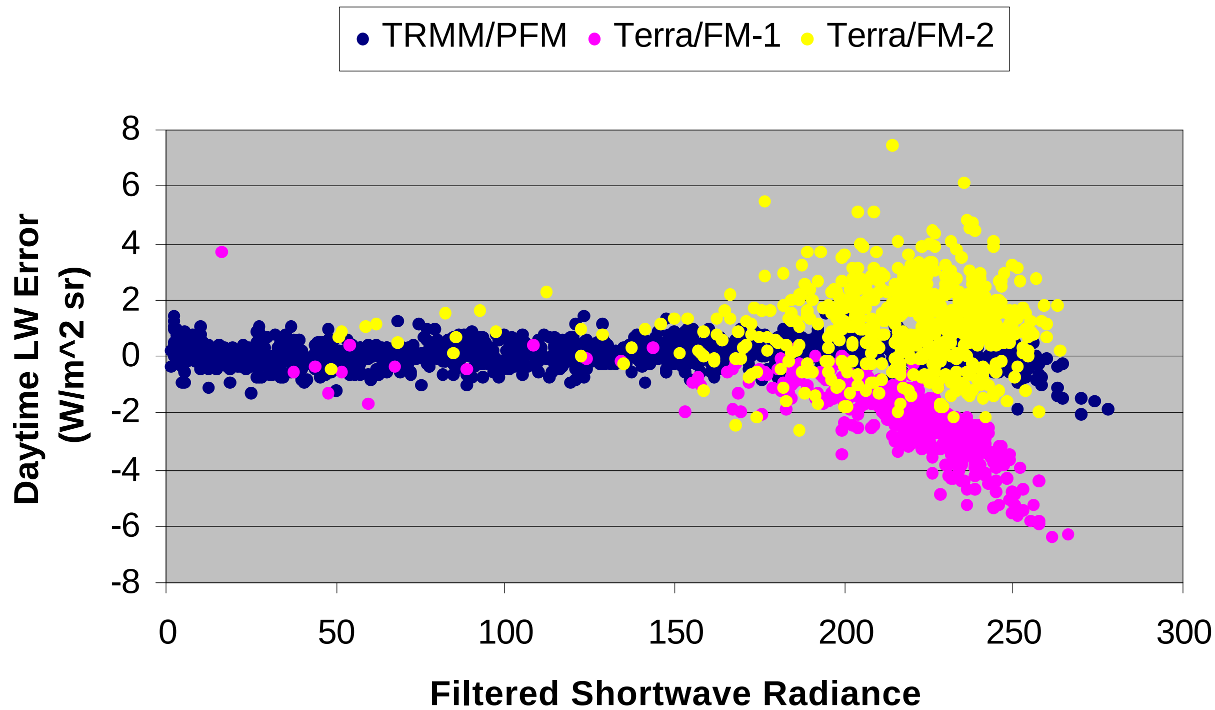
Direct Comparison / Tropical Mean Key Results

Direct Comparison

- Relative Differences
  - WN radiances: FM1 < FM2 by 1.0%, no relative drift
    - FM1 has a SW leak of ~0.1%
  - SW radiances: FM1 < FM2 by 0.33% (Globally), no relative drift
    - Clear Ocean FM-2 > FM-1 by ~1.9%
    - Bright Clouds FM-1 > FM-2 by ~0.7%
  - Nighttime LW: FM1 > FM2 by 0.3%, no relative drift
  - Daytime LW: Relative Growth of FM2 Daytime LW measurements of ~1.0% from Mar '00 to Feb '01

3-Channel Deep Convection Results

March - December 2000



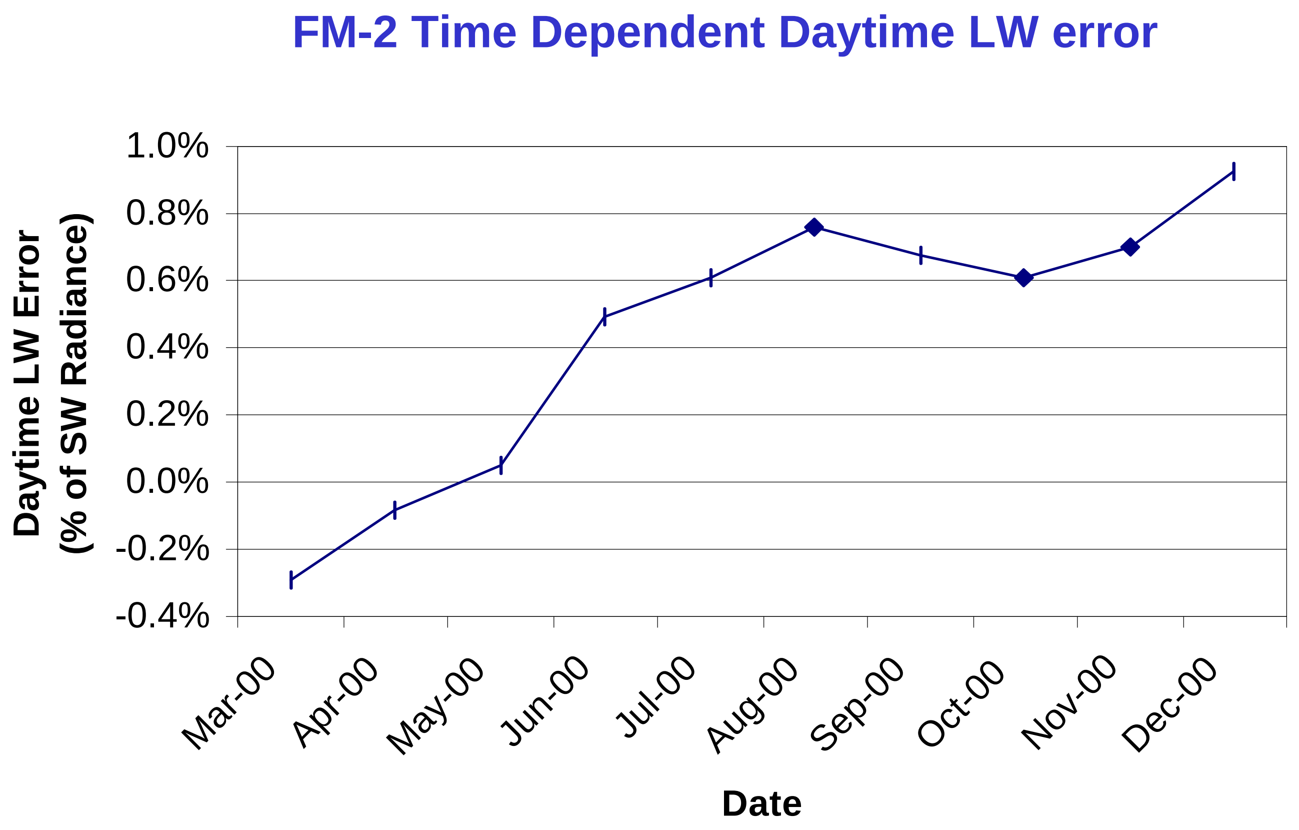
Daytime LW Error = (Total $_{day}$ – SW $_{day}$) – (C_1*WN $_{day}$ + C_2)

Where C_1 and C_2 are found by regressing the Unfiltered WN against the unfiltered Total channel at night.

Non-linearity in FM1 is due to SW leak in WN channel

3-Channel Deep Convection Results

March - December 2000



CERES Deep Convective Albedo

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 Terra FM1 and FM2**

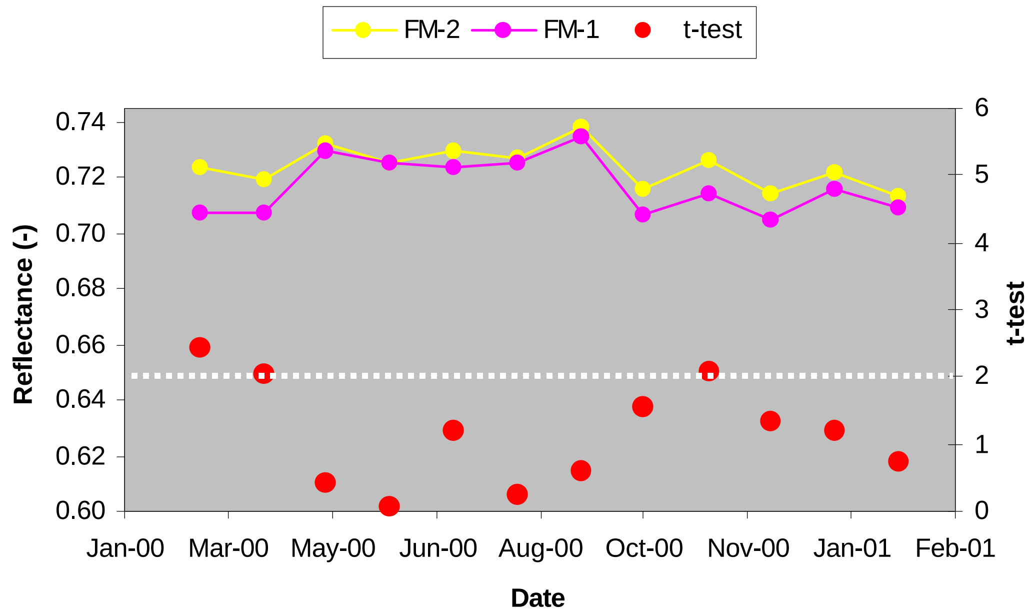
View Zenith: **Nadir footprints only**

Solar Zenith: **20 to 40-degrees (Limited by Terra Orbit)**

Latitude: **55 N to 125 S**

CERES Deep Convective Albedo

Results of estimating reflectance over the solar zenith range of 20-40 degrees.



	FM1 (M 00 - F 01)	FM2 (M 00 – F 01)	t-Test
% Reflectance (Std. dev) n	71.53 (5.70) 1090	72.24 (5.28) 1212	3.1

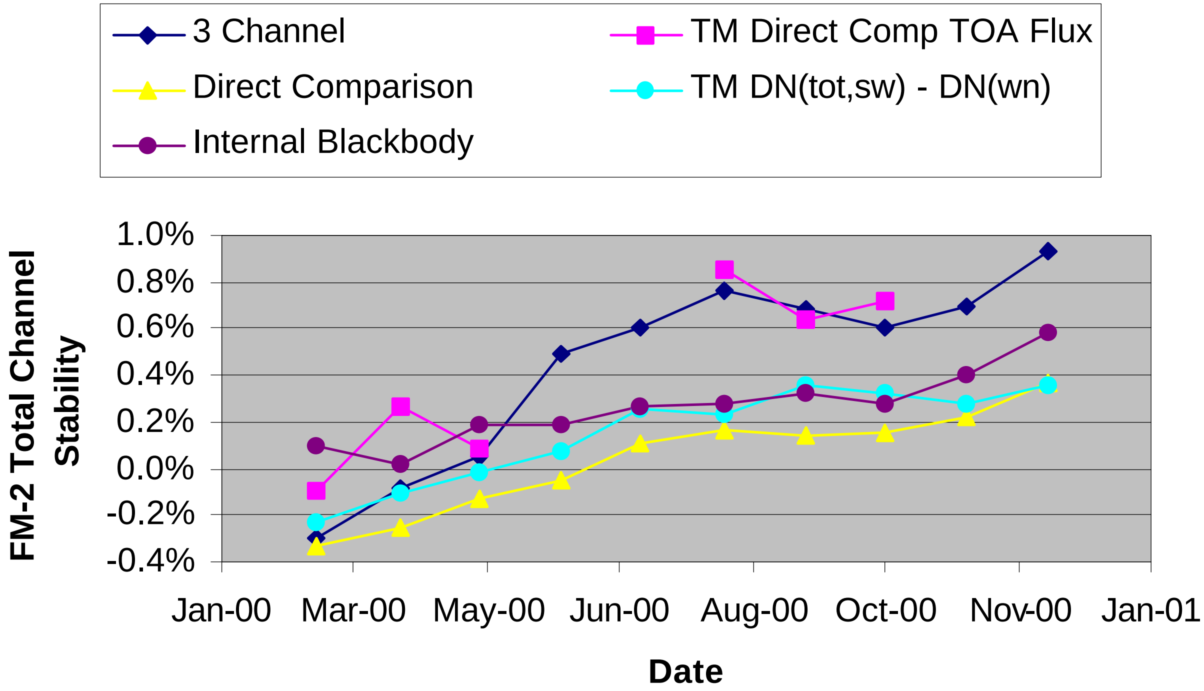
DCC Albedo / 3-Channel Intercomparison Key Results

- **DCC Albedo**
  - The SW channels from FM-1, and FM-2 demonstrate a statistically significant difference of 0.7%
    - No measurable drift from Mar-Dec ‘00

- **3-Channel Intercomparison**
  - FM-1
    - Structure in Daytime LW Error is due to WN channel SW leak
      - Intercomparison is stable over time, no detectable drift

  - FM-2
    - Time varying inconsistency in FM-2 Total channel (total change ~1.2%)
      - Direct Comparison suggests error is in the SW portion of the Total 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

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