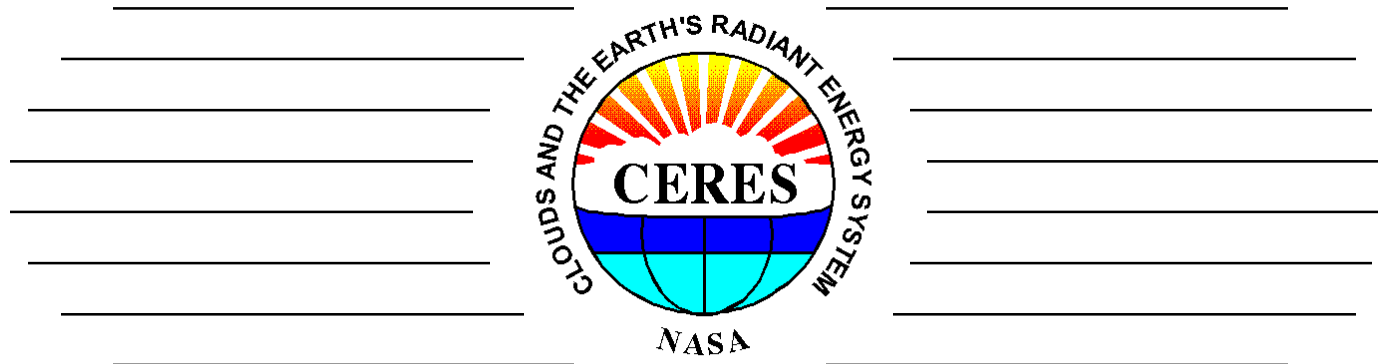


# CERES Scan Dependent Offset Studies

## CAM Justification



**Kory J. Priestley**  
**Robert B. Lee III, Bruce R. Barkstrom, Bruce A. Wielicki**

SWAMP Meeting  
NASA Goddard Space Flight Center  
16 March, 2000

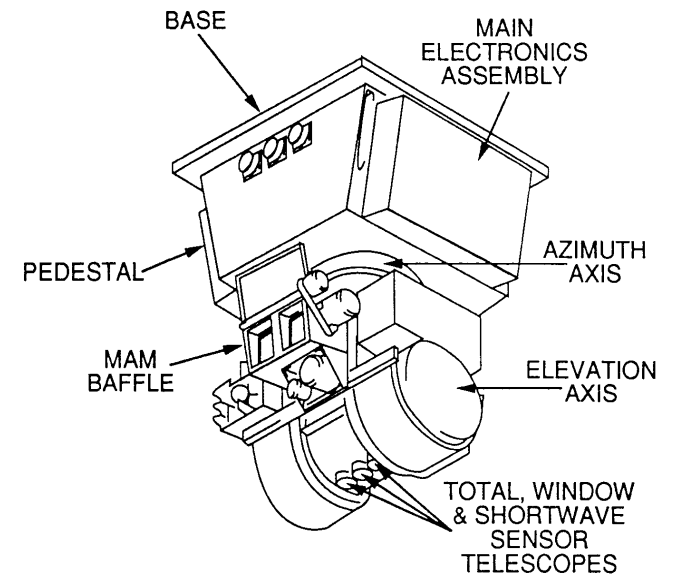


NASA Langley Research Center

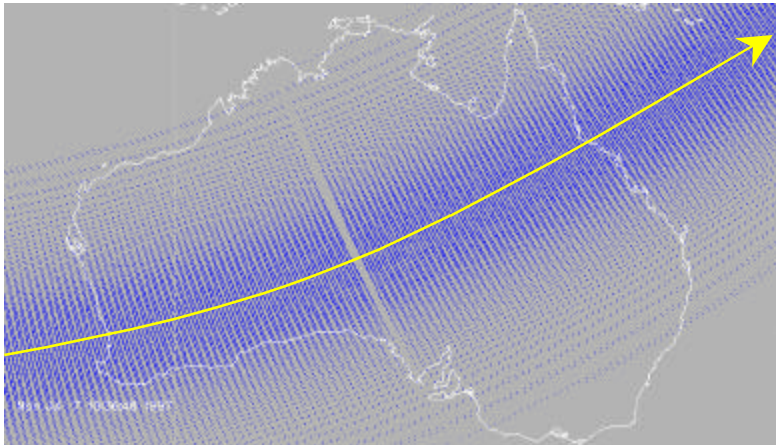
**Atm**  **spheric**  
SCIENCES

# CERES Instrument

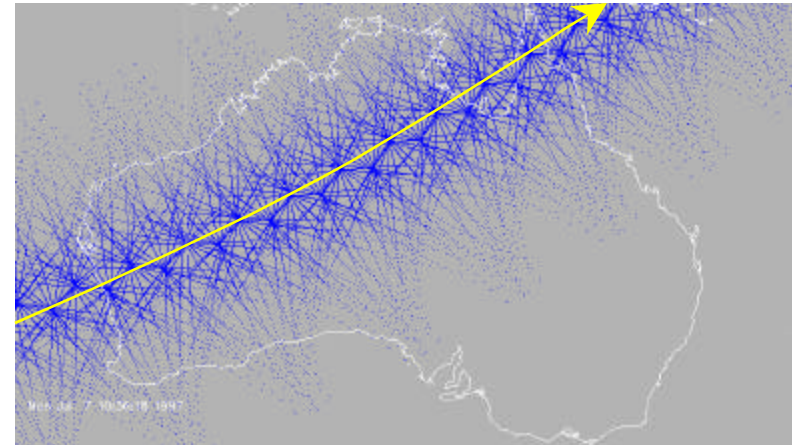
- Sensors measure thermal radiation in the near-visible through far-infrared spectral region
- Design is based upon the Earth Radiation Budget Experiment (ERBE) philosophy
- Careful redesign and partitioning of the electronics intended to reduce extraneous emf fields
- Cantilevered Beryllium sensor elevation mounting plate reduces micro-physical strains on detectors while scanning
- Hemispherical sampling obtained with an azimuthal axis drive system
- For nominal operations there are 11 combinations of azimuthal and elevation scan modes.
- Scan dependent offsets must be characterized for each of these modes.



# Surface Scan Patterns



**Fixed Azimuth Plane Scanning  
(FAPS)**



**Rotating Azimuth Plane Scanning  
(RAPS)**



# Scan Dependent Offsets, What are they and what is their origin?

Scan dependent offsets,  $o$ , are extraneous instrument artifacts which impart sample dependent biases on the radiometric measurements.

Typically arise from one of two sources:

1. Electromagnetic signals

These signals are picked up as the sensor rotates through dynamic emf fields which surround the high voltage electronic circuitry

2. Micro-strains

Thermistor bolometers act as strain gauges and rotating the sensor modules can impart micro-strains on the detectors.

Magnitude is typically a function of 6 parameters, the angular position, scan rate, and acceleration rate of the sensor about both the elevation ( $\epsilon$ ) and azimuthal ( $\alpha$ ) axes,

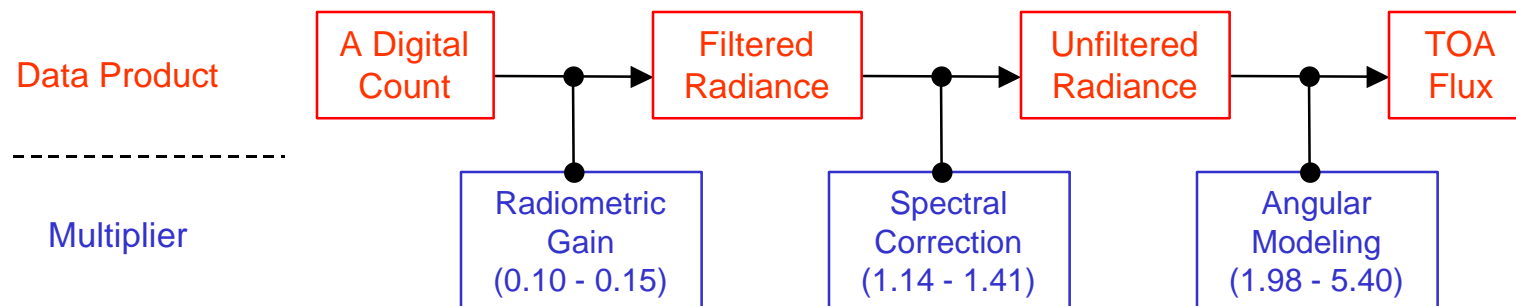
$$o = F(\epsilon, \dot{\epsilon}, \ddot{\epsilon}, \alpha, \dot{\alpha}, \ddot{\alpha})$$



# How significant are they?

Mission accuracy requirements are 0.5% for Longwave 1.0% for Shortwave, or  
1.2 W/m<sup>2</sup> TOA LW Flux  
2.0 W/m<sup>2</sup> TOA SW Flux

Accurate knowledge of scan dependent offsets at the sub 1-count level is necessary to meet this objective. The relationship between a digital count and TOA Flux is.....



SW : 1 count ~0.50 W/m<sup>2</sup> TOA Flux

LW<sub>NIGHT</sub> : 1 count ~0.55 W/m<sup>2</sup> TOA Flux

→ LW<sub>DAY</sub> : 1 count ~1.05 W/m<sup>2</sup> TOA Flux ←

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

Therefore, the Total and Shortwave offsets are roughly additive in the worst case.



# TRMM Lessons Learned

- **Ground to on-orbit shifts of approximately 1 count peak-to-peak occurred in all three channels of the CERES PFM instrument.**
  - Shifts were not systematic among the channels
  - Total and Shortwave channels shifted in opposite directions
- **Analyses of the collected data indicates that 30-50 repetitions of each combination of elevation and azimuthal angle are necessary.**
- **CERES/TRMM scan dependent offsets have been reduced an order of magnitude from ERBE.**

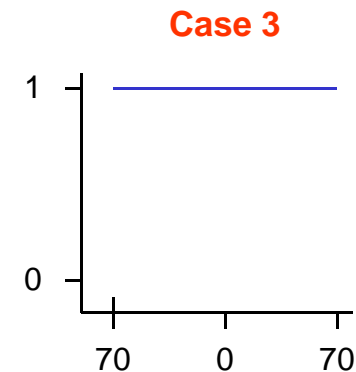
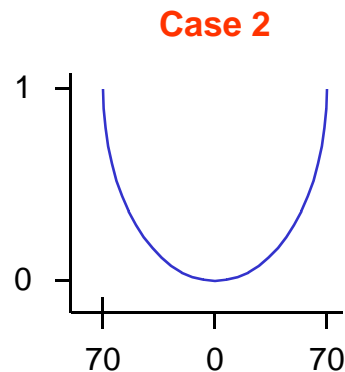
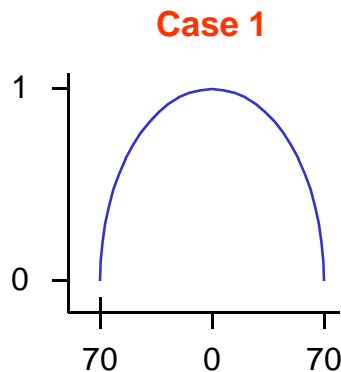
## Bottom Line

- **A significant improvement made over ERBE**
- **CERES Accuracy requirements are a factor of 2 more stringent than ERBE**
- **Offsets are still significant as potential error sources for CERES**
- **TRMM should only be viewed as a 'best case' until the design is validated over several flight models**




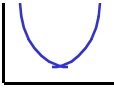

# TOA Flux Bias Studies

- **Characterize the spatial and temporal propagation of errors in the CERES/Terra data products resulting from modest uncertainties in the scan dependent offsets**
- **Three separate simulations:**
  - Case 1
    - Uncertainty modeled as a half-sine wave across viewing zenith angles of 0 - 70 deg.
    - Max uncertainty of 1-count at nadir, Min uncertainty of 0-counts at 70 deg
    - Representative of what we saw on TRMM
  - Case 2
    - Uncertainty Modeled as a half-sine wave across viewing zenith angles of 0 - 70 deg
    - Max uncertainty of 1-count at 70 deg, Min uncertainty of 0-counts at nadir
  - Case 3
    - Uncertainty Modeled as flat 1-count bias across all viewing zeniths



# Potential TOA Flux Bias Errors Across Data Products

All values have units of  $W/m^2$

		Instantaneous (Footprint)		Daily (Regional)		Monthly (Regional)	
		Average	Max	Global Avg	+ - 30 Avg	Global Avg	+ - 30 Avg
	Case 1 LW/Day	.83	1.37	.69	.60	.80	.83
	LW/Night	.35	.52	.30	.26	.34	.35
	SW/Clr-Ocn	.48	.85	.39	.34	.46	.48
	Case 2 LW/Day	.38	.92	.40	.43	.38	.38
	LW/Night	.20	.61	.23	.28	.20	.20
	SW/Clr-Ocn	.18	.35	.21	.23	.18	.18
	Case 3 LW/Day	1.22	1.37	1.13	1.11	1.18	1.21
	LW/Night	.55	.61	.53	.54	.53	.55
	SW/Clr-Ocn	.67	.85	.60	.57	.65	.67

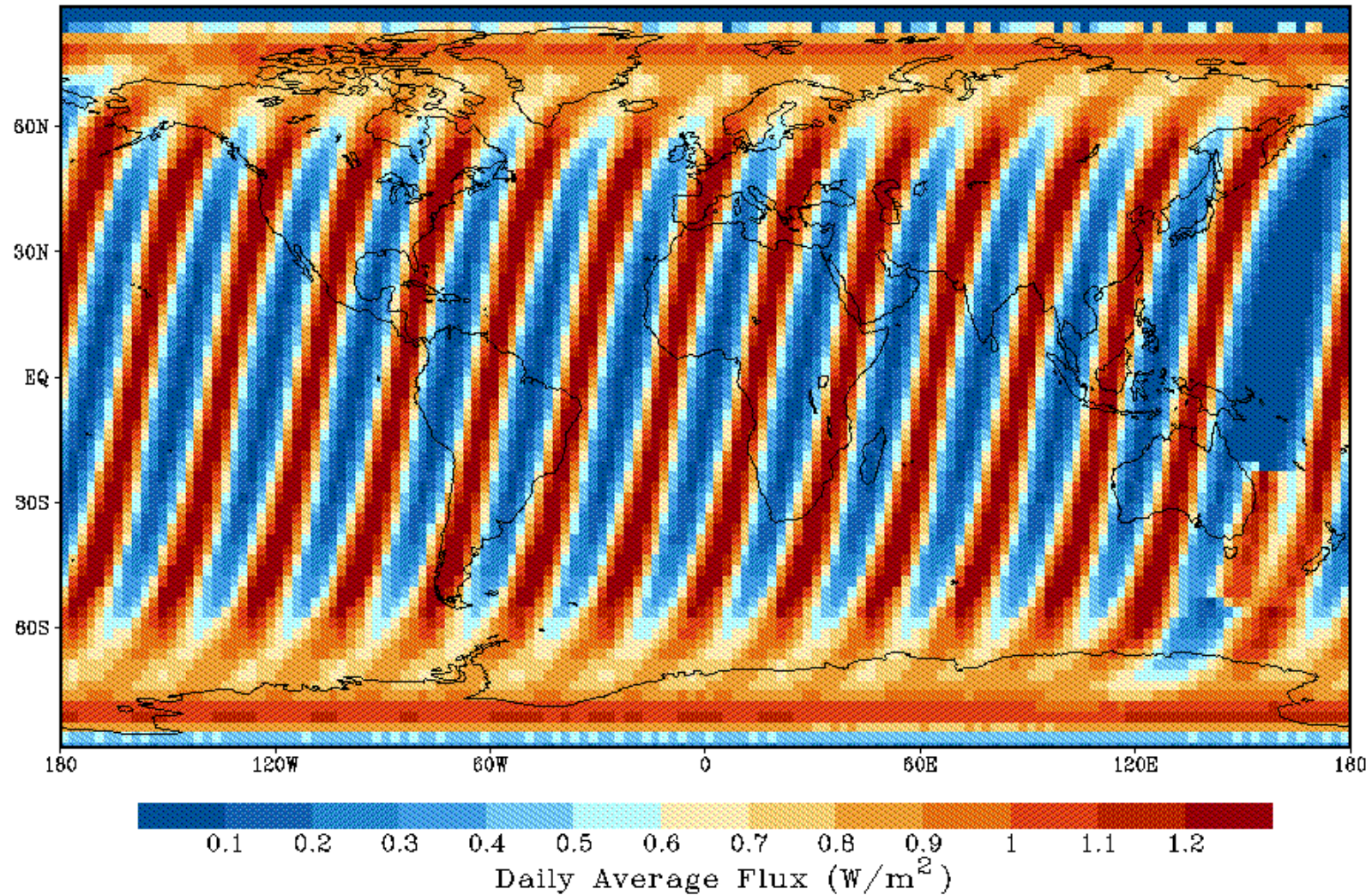
**Relatively modest uncertainties in scan dependent offsets  
will dominate/exceed the entire error budget**

**1.2  $W/m^2$  TOA LW Flux  
2.0  $W/m^2$  TOA SW Flux**





# Impact of 1 Count Offset Uncertainty on LW Daytime TOA Flux (Case 1)

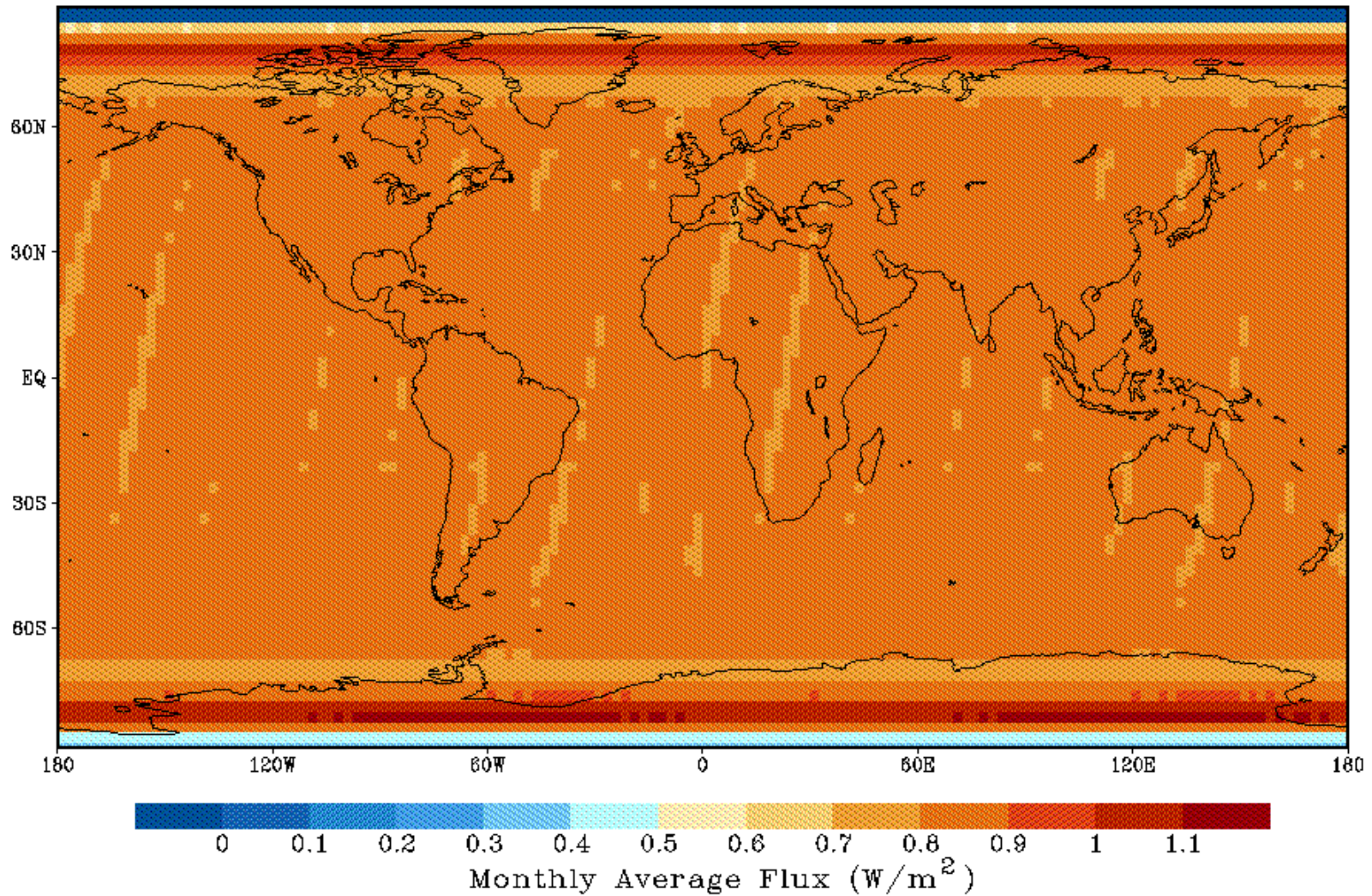


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# Impact of 1 Count Offset Uncertainty on LW Daytime TOA Flux (Case 1)



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# Impact of Terra Omitting/Delaying CAM's

## Immediate

- Traceability to ground calibration radiometric scale less certain
- Significant impact on validation timeline for the Level-1 data
  - this would then impact all downstream data products ERBE-like, TISA, SSF etc.
- Could force unnecessary reprocessing
- Intercalibration with other Earth Radiation Budget instruments less certain

## Long Term

Accurate and useful monitoring of the Global climate requires instruments that very accurately measure small perturbations about a relatively large mean value.

- Ability to detect climate change would be limited. An instantaneous doubling of atmospheric CO<sub>2</sub> would produce a temporary change in TOA flux of ~4 W/m<sup>2</sup>.
- Apparent change in OLR from ERBE to CERES of ~4W/m<sup>2</sup> on decadal scale.
- TRMM radiometric stability - no detectable change at 0.25% (95% confidence)
- Voltage converters replaced - need to verify no impact on offsets
- Detectable change in baseline electronic noise on FM-1. First noticed subsequent to spacecraft level environmental testing.



# What conditions are necessary to make measurements?

- **Must be measured in a vacuum while scanning a stable and well characterized radiometric source**
  - eliminates the ability to use the inside of the contamination covers on-orbit
- **Must be free from all gravitational effects**
  - eliminates the possibility of measuring RAPS mode during ground testing
- **Instrument must be in a nominal mission mode both operationally and thermally**
  - Electromagnetic fields may be affected with the main contamination covers being closed vs. open during initial on-orbit checkout.
  - Micro-strains may be increased during cold operations due to increased bearing drag and stiffening of electrical wires.



# CERES CAM Preferences

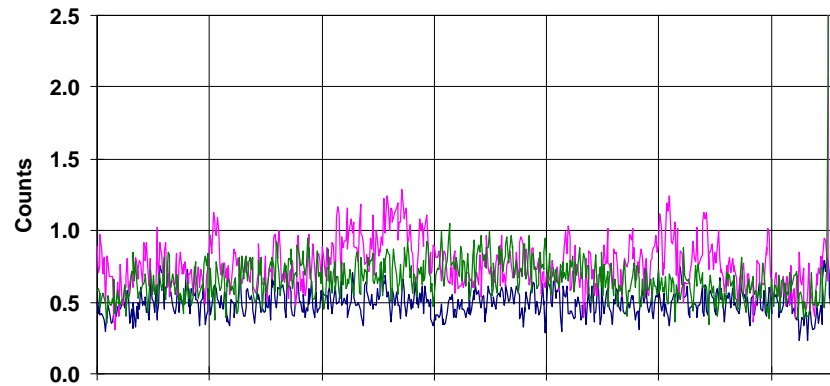
- **Baseline instrument noise varies between 0.5 and 2.0 counts 1-sigma. Obtaining knowledge of the mean offset values at the 0.25 count level requires 16 to 64 repetitions of each operational profile.**
  - Ground calibration/characterization results for all 6 CERES instruments support this finding.
- **Deep-space viewing time is the constraint, not the number or type of maneuvers.**
- **No requirements on how closely spaced the maneuvers are to each other.**
- **Accurate knowledge of the location of the moon relative to the spacecraft during the maneuvers is absolutely necessary to aid in planning.**
- **For the proposed constant pitch maneuver a minimum of 3 are required to meet the minimum validation requirements, more preferable.**
- **For a TRMM type inertial hold maneuver 2 would be acceptable.**
- **A third option would be a single constant pitch maneuver and a single inertial hold maneuver**



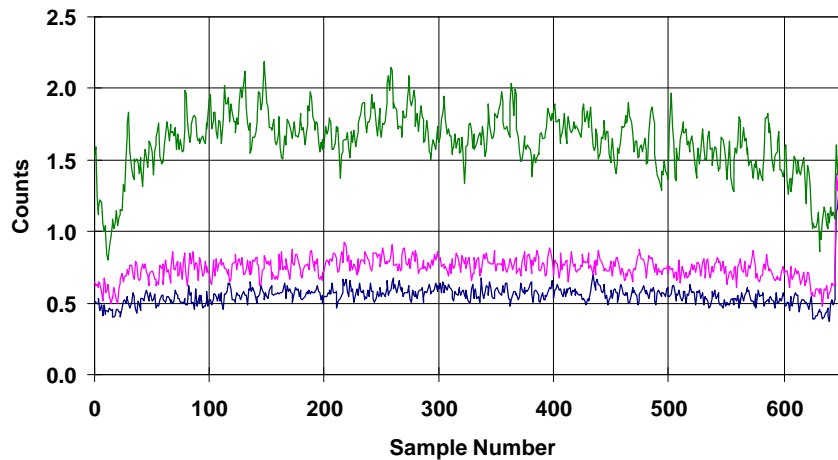
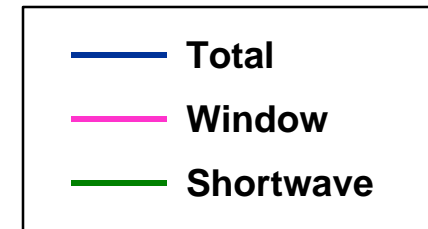
# CERES FM1 and FM2

## Sample Dependent 1-sigma noise

Results are for a single 6.6 second data packet



**FM-1**



**FM-2**



# CERES Desired Pitch-Over Data Collect

Azimuth Mode	Elevation Mode	Time (minutes)	Repetitions	
Rotating	Normal	22	20	66-second repeating cycle
	Short	22	20	
	Truncated Normal	22	20	
	Long Dwell Normal	22	20	
Fixed (X-track)	Normal	2.2	20	6.6-second repeating cycle
	Truncated Normal	2.2	20	
	Long Dwell Normal	2.2	20	
Fixed (Along-Track)	Short	2.2	20	6.6-second repeating cycle
	Normal	2.2	20	
	Truncated Normal	2.2	20	
	Long Dwell Normal	2.2	20	
		<b>104</b>		



# CERES Terra Pitch-Over Agreement (3 Maneuvers)

Azimuth Mode	Elevation Mode	Time (minutes)	Repetitions
Rotating	Normal	0	0
	Short	3 or 9	3 or 9
	Truncated Normal	6 or 12	6 or 12
	Long Dwell Normal	0	0
Fixed (X-track)	Normal	12	108
	Truncated Normal	18	162
	Long Dwell Normal	6	54
Fixed (Along-Track)	Short	0	0
	Normal	0	0
	Truncated Normal	3	27
	Long Dwell Normal	0	0
		54	





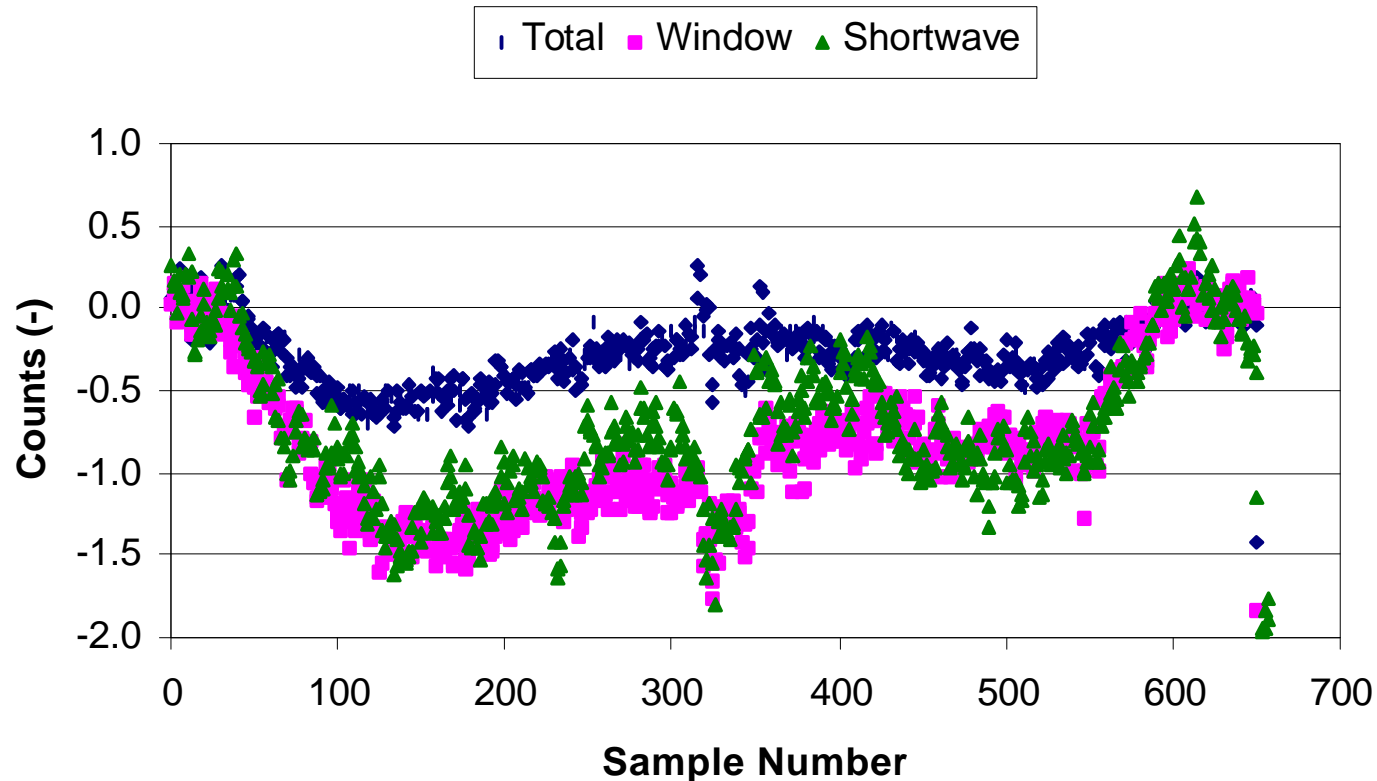
# Summary

- **It is imperative that CERES accurately characterizes their scan dependent offsets in order to achieve their scientific goals and continue the long term dataset.**
- **Failure to do so would mean...**
  - high probability we will not meet our performance goals
  - significant impact to the data validation timeline
  - delay in the release of validated data products
  - more frequent reprocessing
  - less certain intercalibration with similar type instruments
  - degraded ability to monitor long-term climate change
- **Significant rework to instruments subsequent to ground measurement of the offsets increases risk of significant change**
- **Detectable systematic change in FM-1 instrument noise ‘signature’**



# CERES PFM Scan Dependent Offsets

Instrument Mode is Normal Cross-Track  
Results are for a single 6.6 second data packet



## CERES count-to-TOA Flux Conversions

Total: 1 count  $\sim 0.55 \text{ W/m}^2$

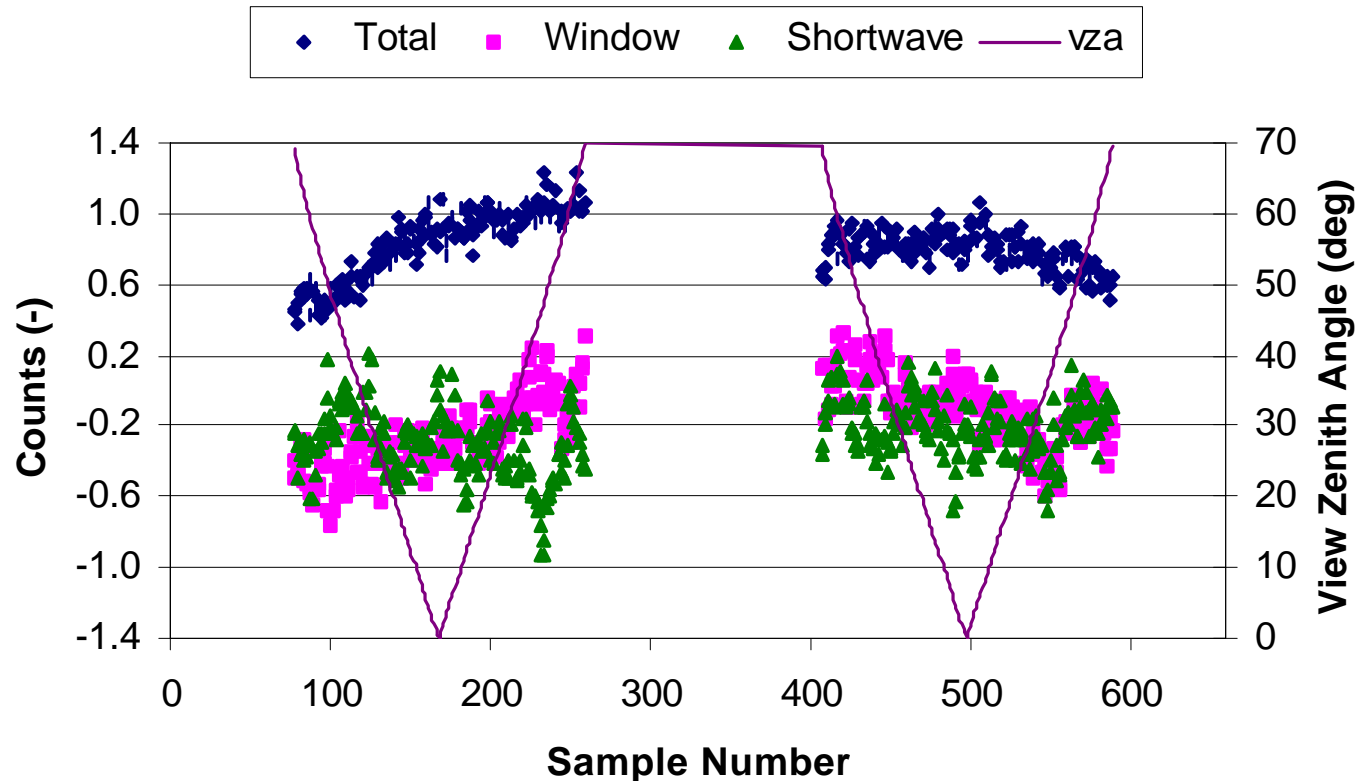
Window: 1 count  $\sim 0.40 \text{ W/m}^2$

Shortwave: 1 count  $\sim 0.50 \text{ W/m}^2$



# Change in Scan Dependent Offsets

CERES/TRMM (orbit - ground)  
Instrument Mode is Normal Cross-Track



## CERES count-to-TOA Flux Conversions

Total: 1 count  $\sim 0.55 \text{ W/m}^2$

Window: 1 count  $\sim 0.40 \text{ W/m}^2$

Shortwave: 1 count  $\sim 0.50 \text{ W/m}^2$



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