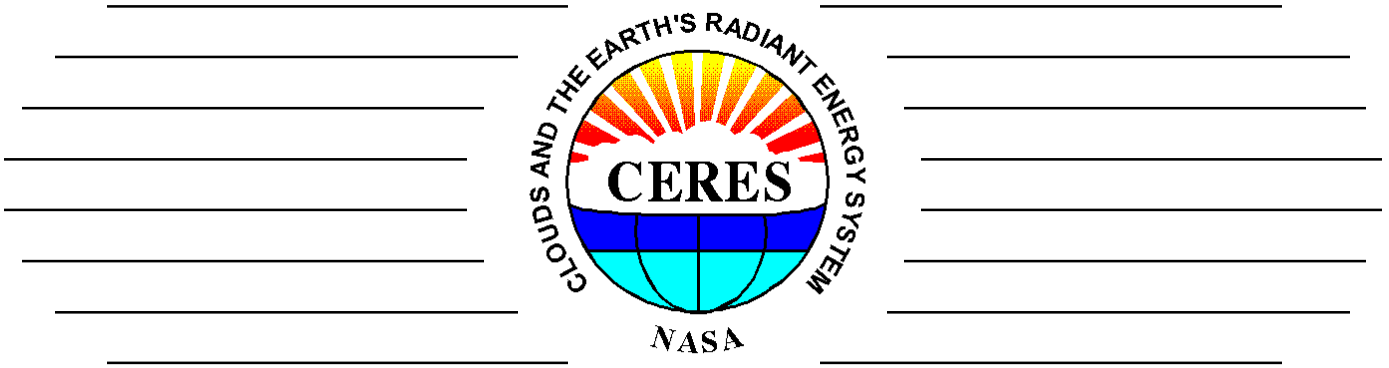
CERES Scan Dependent Offset Studies
CAM Justification



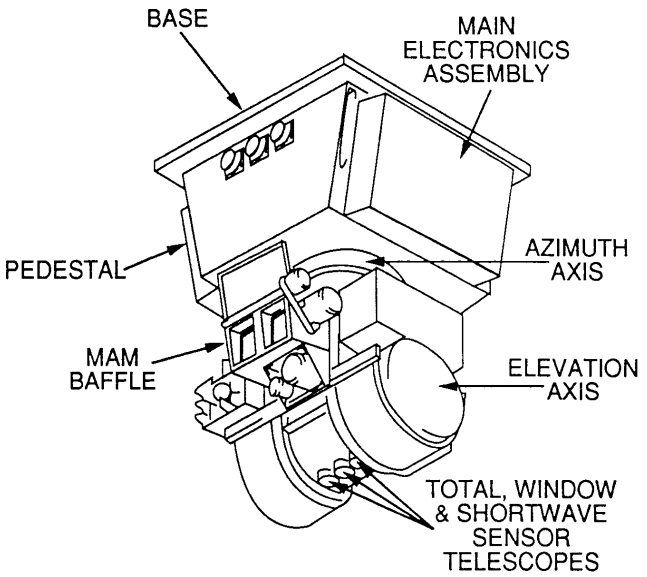
Kory J. Priestley
Robert B. Lee III, Bruce R. Barkstrom, Bruce A. Wielicki

SWAMP Meeting
NASA Goddard Space Flight Center
16 March, 2000

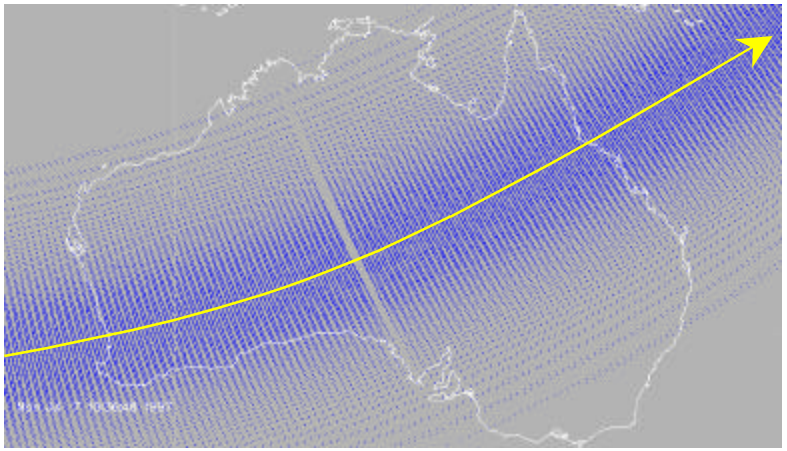
NASA Langley Research Center
Atmospheric SCIENCES

CERES Instrument

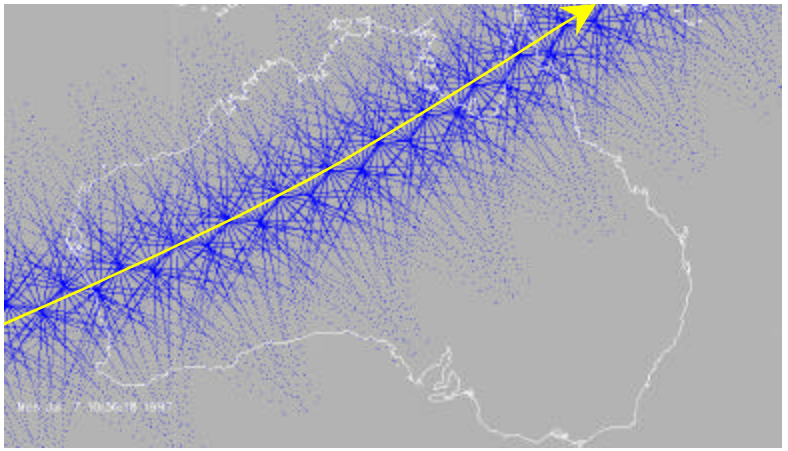
- Sensors measure thermal radiation in the near-visible through far-infrared spectral region
- Design is based upon the Earth Radiation Budget Experiment (ERBE) philosophy
- Careful redesign and partitioning of the electronics intended to reduce extraneous emf fields
- Cantilevered Beryllium sensor elevation 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 (ε) and azimuthal (α) axes,

$$o = F\left(\varepsilon, \dot{\varepsilon}, \ddot{\varepsilon}, \alpha, \dot{\alpha}, \ddot{\alpha}\right)$$

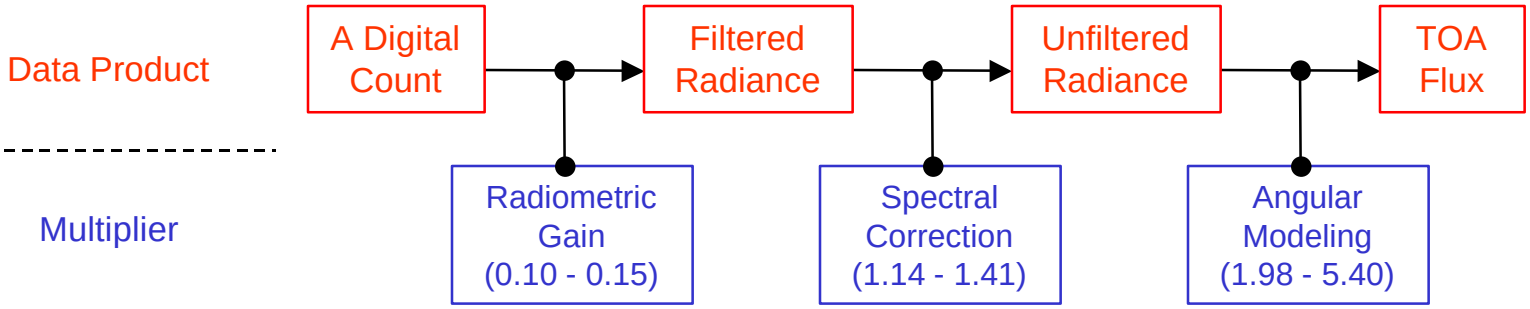
How significant are they?

Mission accuracy requirements are 0.5% for Longwave 1.0% for Shortwave, or

1.2 W/m^2 TOA LW Flux

2.0 W/m^2 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^2 TOA Flux

LW $_{NIGHT}$: 1 count ~0.55 W/m^2 TOA Flux

LW $_{DAY}$: 1 count ~1.05 W/m^2 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 necesary.**
- **CERES/TRMM scan dependent offsets have been reduced an order of magnitude from ERBE.**

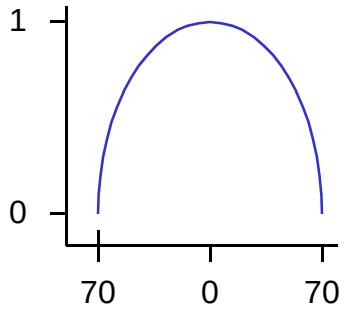
Bottom Line

- **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**

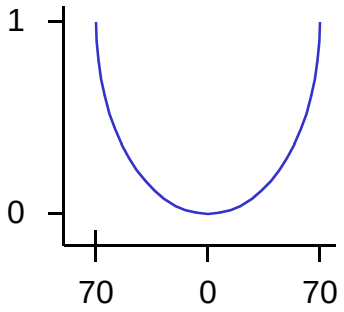
TOA Flux Bias Studies

- **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 uncetainty of 0-counts at nadir
  - Case 3
    - Uncertainty Modeled as flat 1-count bias across all viewing zeniths

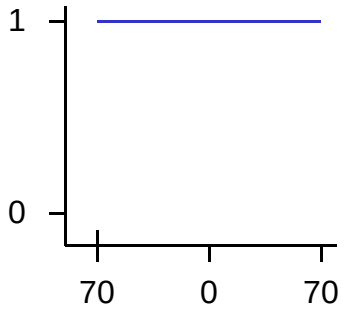
Case 1



Case 2

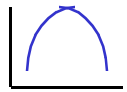
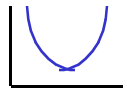
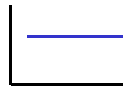


Case 3



Potential TOA Flux Bias Errors Across Data Products

All values have units of W/m^2

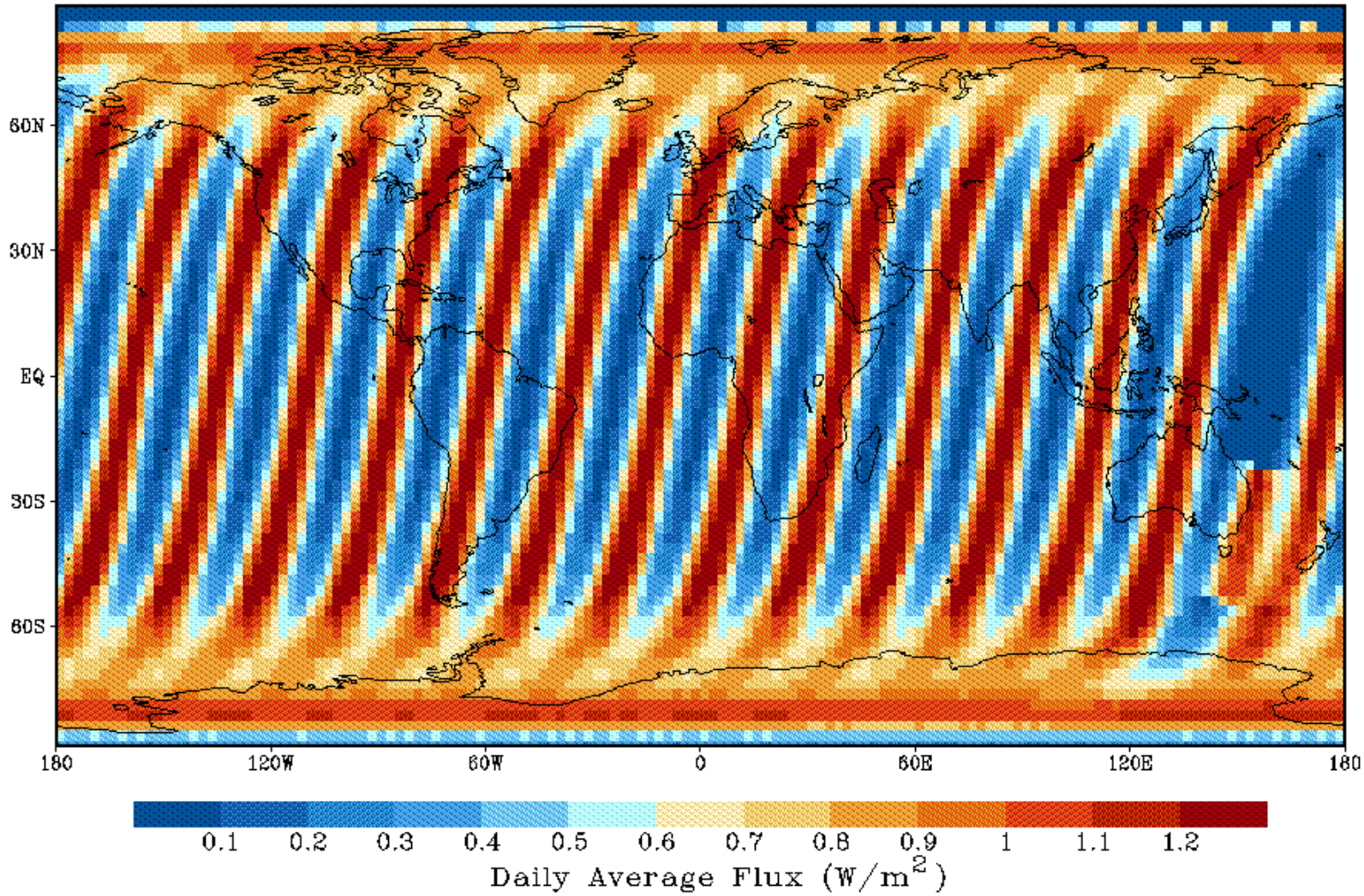
		Instantaneous (Footprint)		Daily (Regional)		Monthly (Regional)	
		Average	Max	Global Avg	+- 30 Avg	Global Avg	+- 30 Avg
Case 1	LW/Day	.83	1.37	.69	.60	.80	.83
	LW/Night	.35	.52	.30	.26	.34	.35
	SW/Clr-Ocn	.48	.85	.39	.34	.46	.48
Case 2	LW/Day	.38	.92	.40	.43	.38	.38
	LW/Night	.20	.61	.23	.28	.20	.20
	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

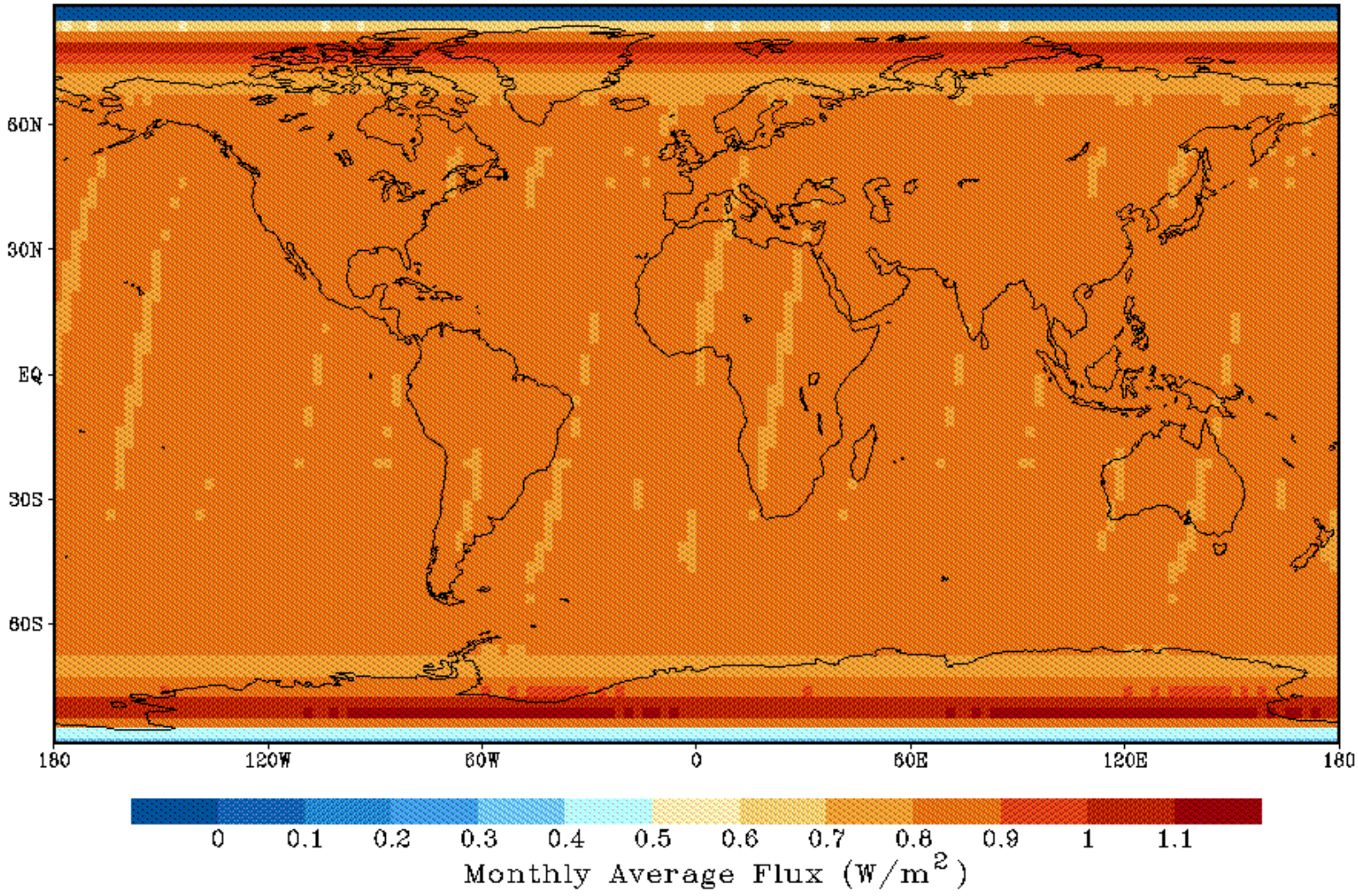
1.2 W/m^2 TOA LW Flux

2.0 W/m^2 TOA SW Flux

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



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



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_2 would produce a temporary change in TOA flux of ~4 W/m^2.**
- **Apparent change in OLR from ERBE to CERES of ~4W/m^2 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?

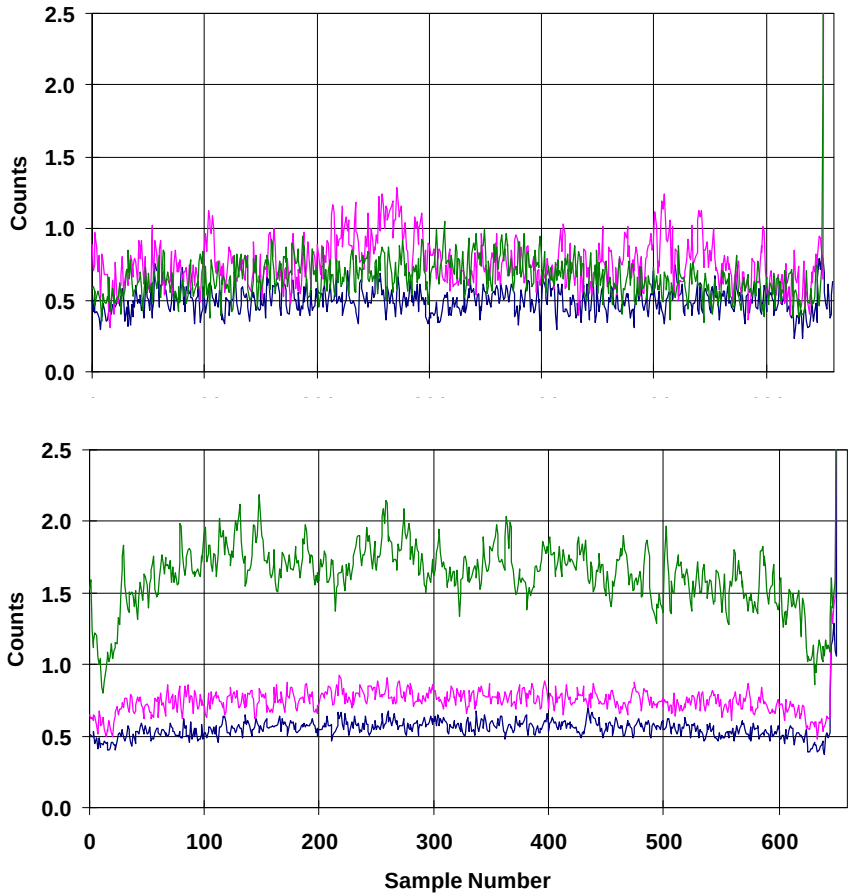
- **Must be measured in a vacuum while scanning a stable and well characterized radiometric source**
  - eliminates the ability to use the inside of the contamination covers on-orbit
- **Must be free from all gravitational effects**
  - eliminates the possibility of measuring RAPS mode during ground 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

Total
Window
Shortwave

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	
		104		

CERES Terra Pitch-Over Agreement

(3 Maneuvers)

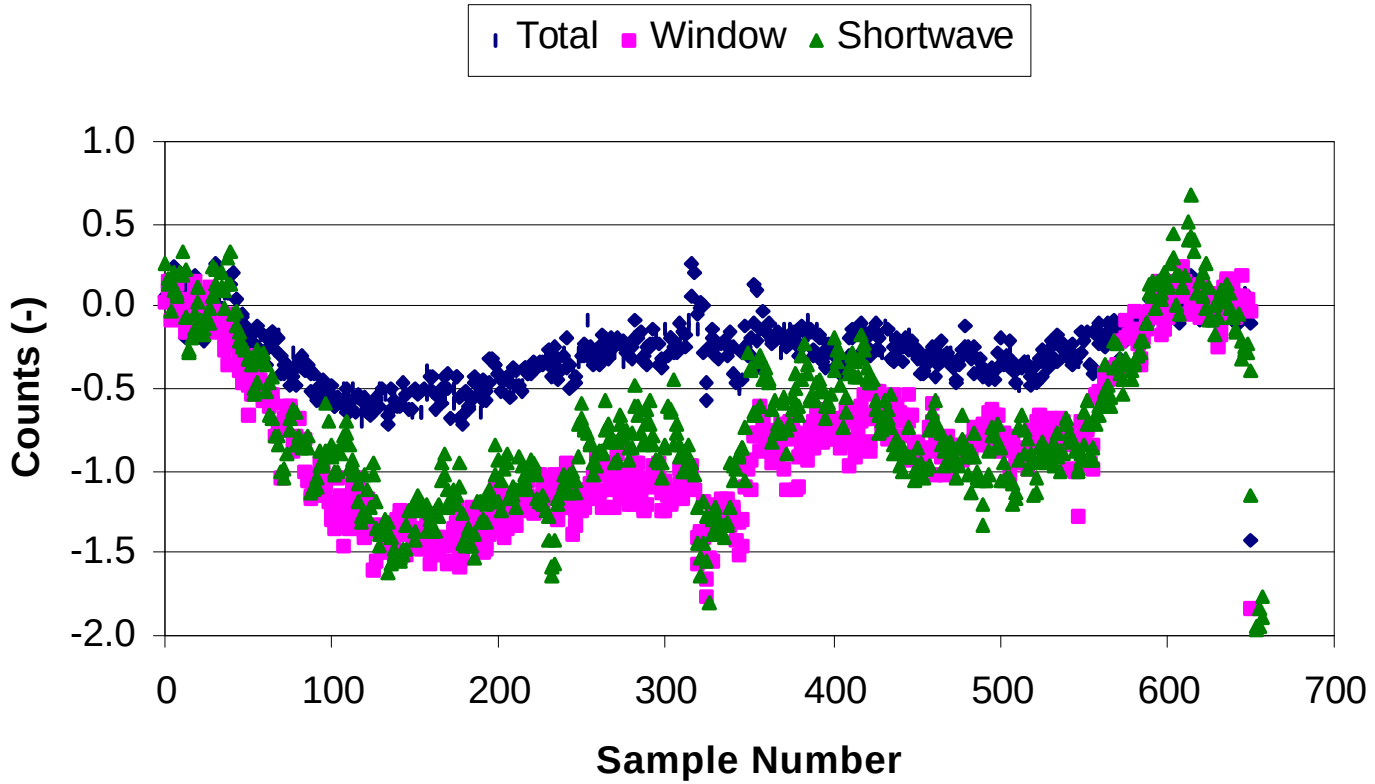
Azimuth Mode	Elevation Mode	Time (minutes)	Repetitions
Rotating	Normal	0	0
	Short	3 or 9	3 or 9
	Truncated Normal	6 or 12	6 or 12
	Long Dwell Normal	0	0
Fixed (X-track)	Normal	12	108
	Truncated Normal	18	162
	Long Dwell Normal	6	54
Fixed (Along-Track)	Short	0	0
	Normal	0	0
	Truncated Normal	3	27
	Long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

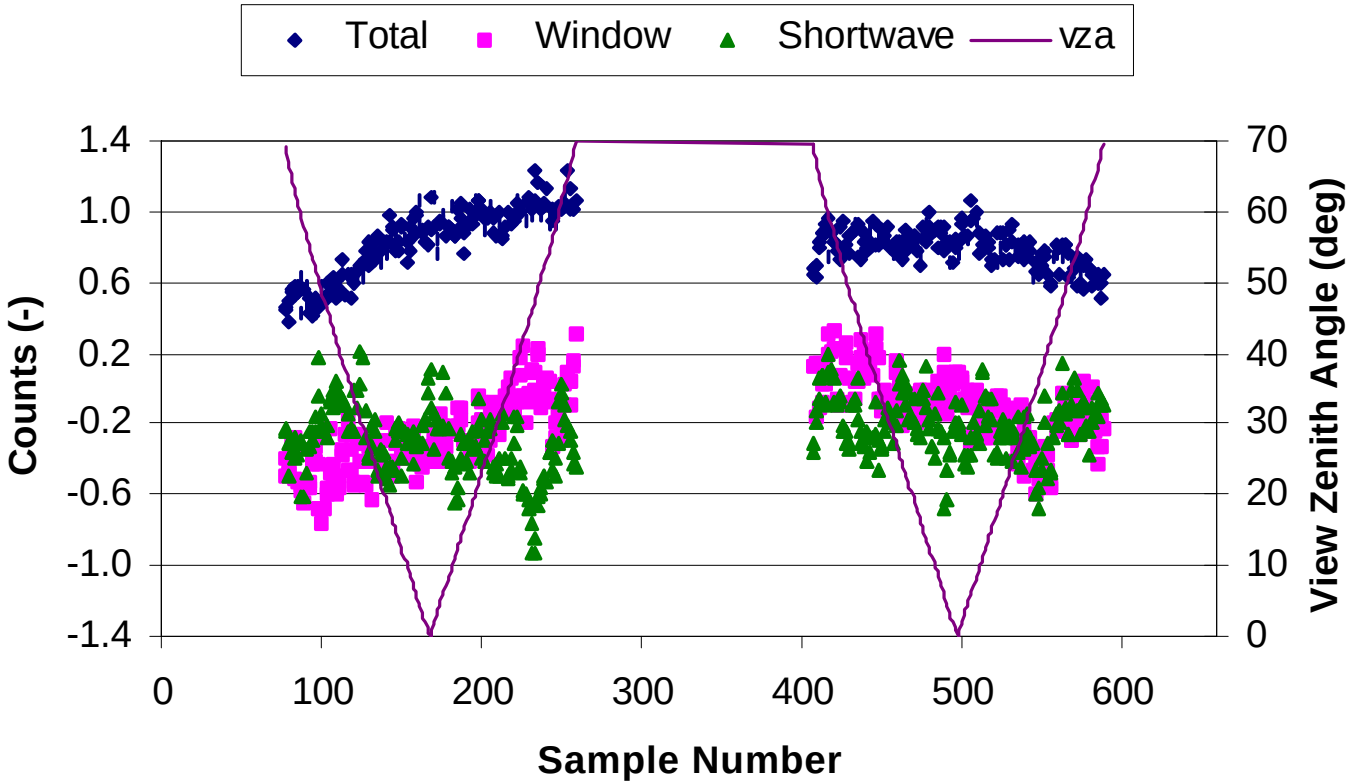
Total: 1 count ~ 0.55 W/m^2

Window: 1 count ~ 0.40 W/m^2

Shortwave: 1 count ~ 0.50 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 ~ 0.55 W/m^2

Window: 1 count ~ 0.40 W/m^2

Shortwave: 1 count ~ 0.50 W/m^2