

ERB instruments comparison using CERES special operations

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Opening Remarks

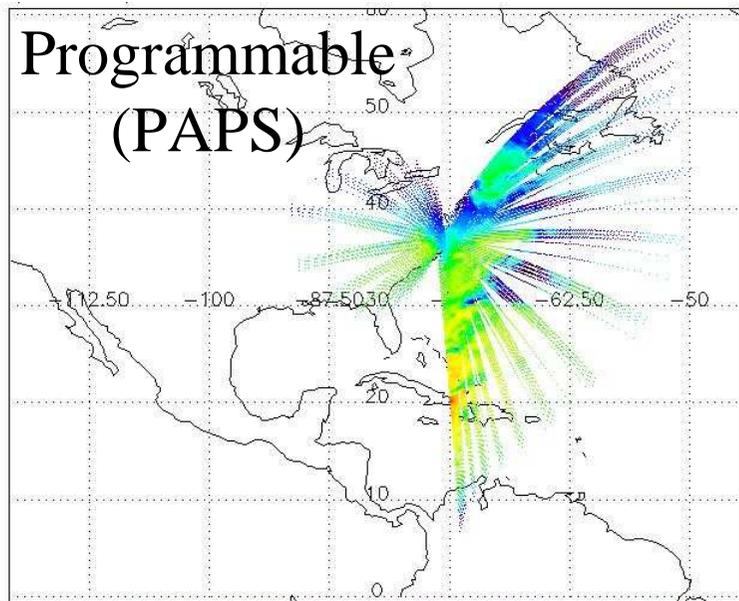
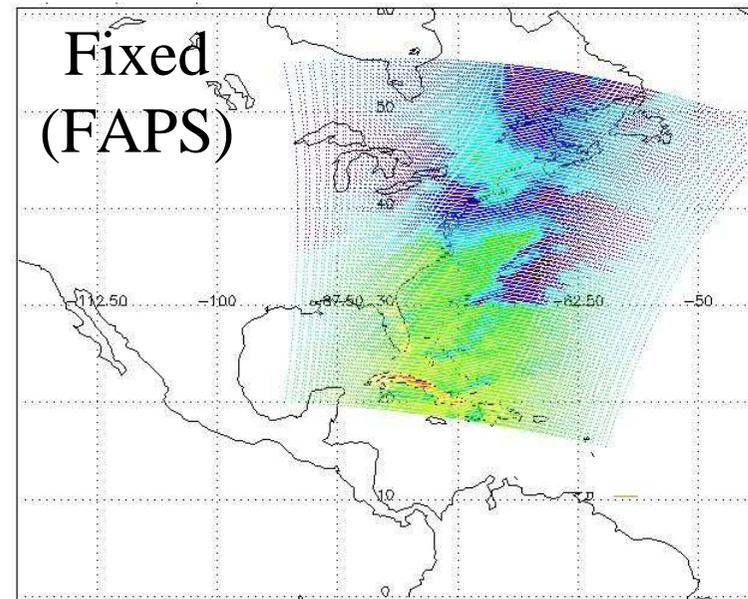
- Four CERES scanners
 - Terra has orbited the Earth 57,000 times (10+ years)
 - Aqua has orbited the Earth 43,000 times (8+ years)
- CERES/FM2 on Terra is the only scanner for special operations
- [Brief report](#) on the CERES use in various field campaigns for ERB instruments comparison
 - PFM/ScaRaB-2 in January and March of 1999
 - PFM/FM1 & FM2 in March of 2000
 - FM2/ GERB-1 & GERB-2 since 2003
 - FM2/ScaRaB-3 in 2011



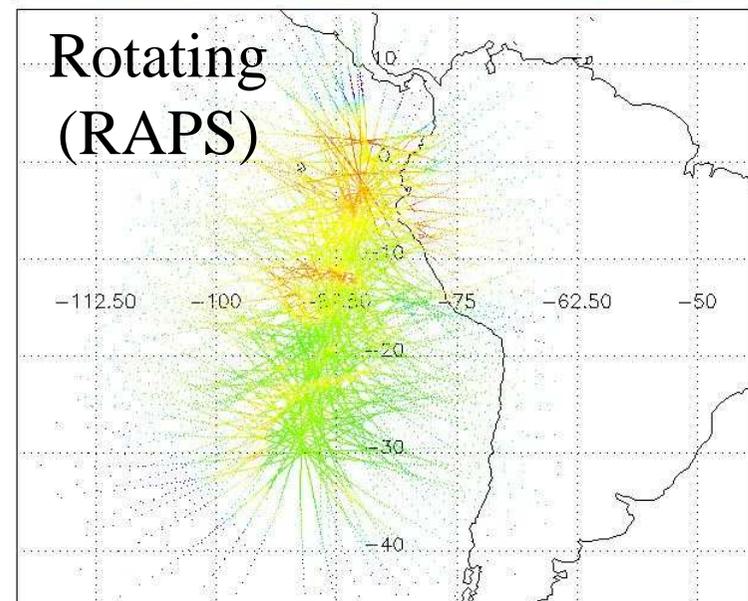
CERES

Azimuth Plane

Scan Modes



1.90 2.67 3.44 4.21 4.98 5.75 6.52 7.29 8.06 8.83 9.60
Watts per square meter per steradian per micron



0.60 1.15 1.70 2.25 2.80 3.35 3.90 4.45 5.00 5.55 6.10
Watts per square meter per steradian per micron



PAPS for comparing ERB instruments

CERES scanning plane is programmed to match the viewing geometry of other instruments:

- Direct comparisons of measured radiances
- Comparison uncertainty dominated by spatial noise

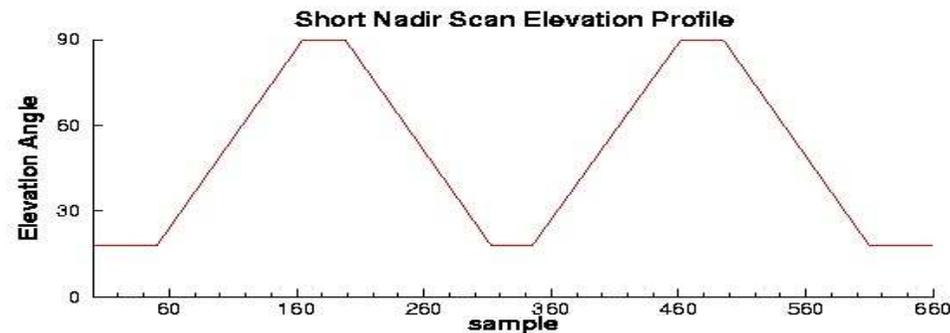
Examples:

- CERES/PFM vs. ScaRaB-2 & FM2 vs. ScaRaB-3 (1999&2011)
- Terra/CERES vs. PFM (2000)
- CERES/FM2 vs. GERB-2 & GERB-1 (since 2003)
- CERES/FM1 vs. Aqua/CERES (since 2002)



PAPS features

- In Programmable Azimuth Plane Scan (PAPS) mode, scanning plane orientation follows a prescribed schedule
 - ✓ Step-wise changes of the azimuth (RAZ) angle
 - ✓ Time and RAZ changes depend on satellite position in an orbit
 - ✓ No ram directions since 2005
- New and more effective elevation profile since 2006
 - Increases sampling by factor of two



PAPS implementation

- Relative azimuth (RAZ) predictions
 - Obtain 7-day satellite ground track file from Goddard
 - Compute scanner orientation for each scan (every 6.6s) or any multiple of that
 - Generate daily RAZ prediction files for commanding
- Automated Command uploads
 - One-day sequences (ODS) formatted for a direct upload
 - All commands needed for execution
- Ops group needs just a 48-hour lead time



LEO satellite comparison

- Orbital periods may be the same (sun-sync) or not (with precessing)
- Scan planes aligned at orbital crossing to match azimuth angle

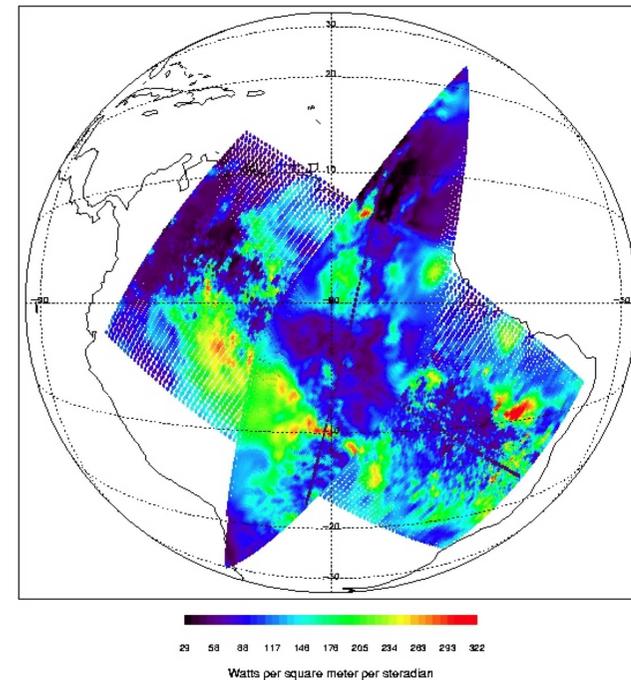
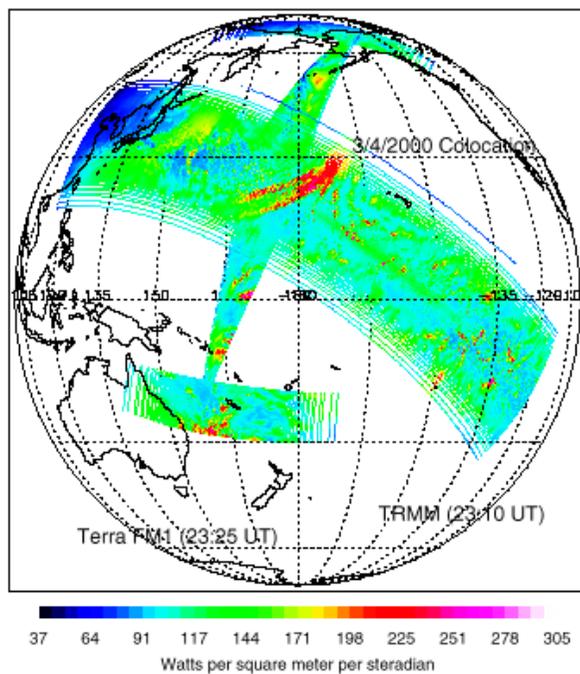


Figure 6. PFM and FMI1 scanning patterns during an orbital crossing, their relative azimuth angles coincide.

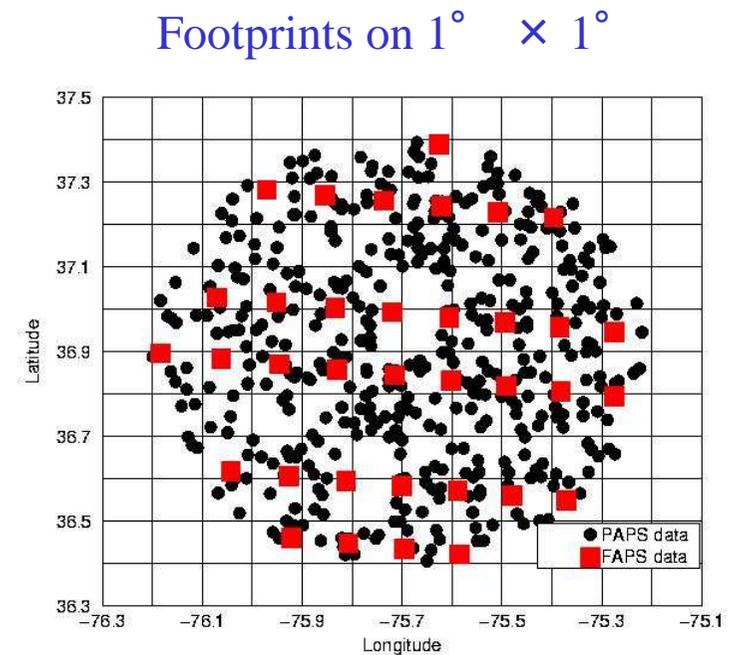
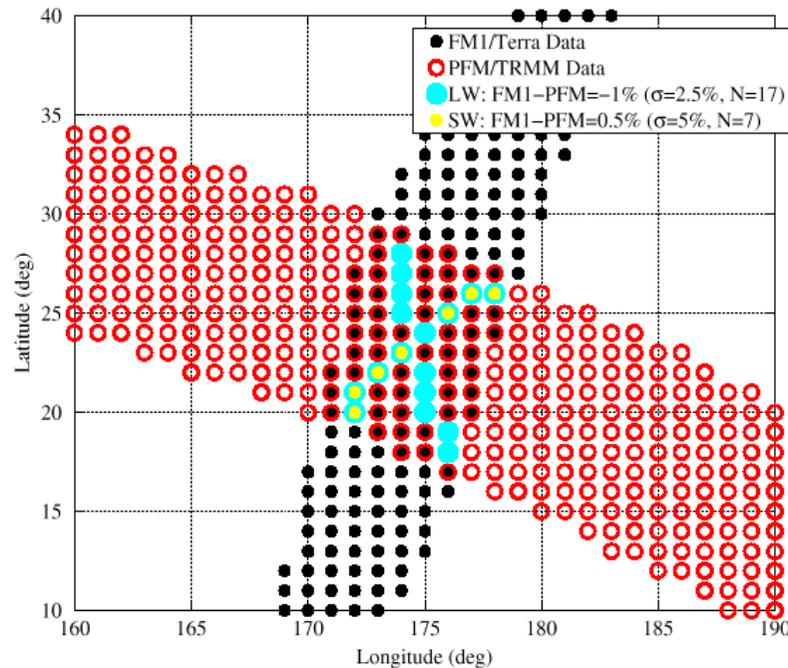


Processing features

Collocated data with matched viewing zenith angle

Main source of uncertainty is spatial noise

Comparison on $1^\circ \times 1^\circ$ grid; average of each OBX is independent



PFM/ScaRaB-2 comparison

- Work by Martial Haeffelin
- Each orbital crossing is an independent sample
- Uncertainty $\varepsilon = \frac{t_{\alpha/2}\sigma}{\sqrt{N}}$
- Spatial noise dominates

(Wm ⁻² sr ⁻¹)		Δ	σ	N	ε
CERES- ScaRaB	SW	1.1	2.2	26	0.9
	LW	-0.5	0.5	50	0.2



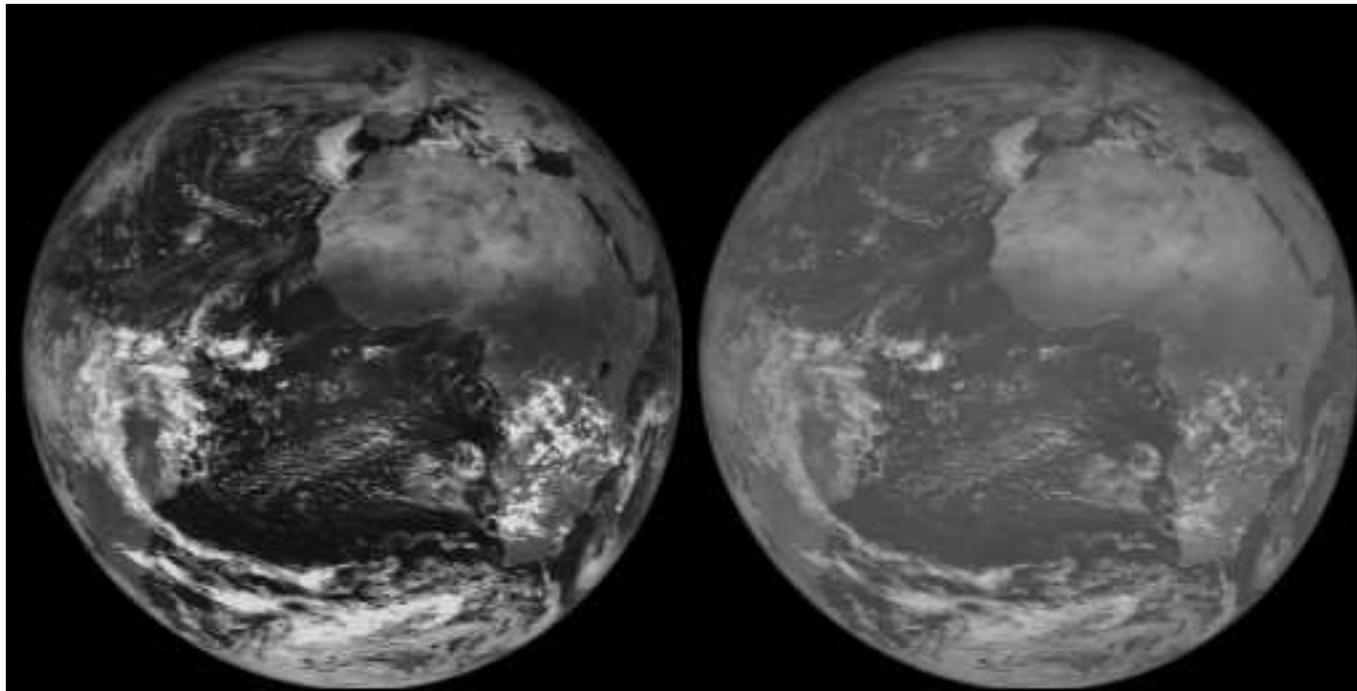
Comparison of GERB and CERES

GERB:

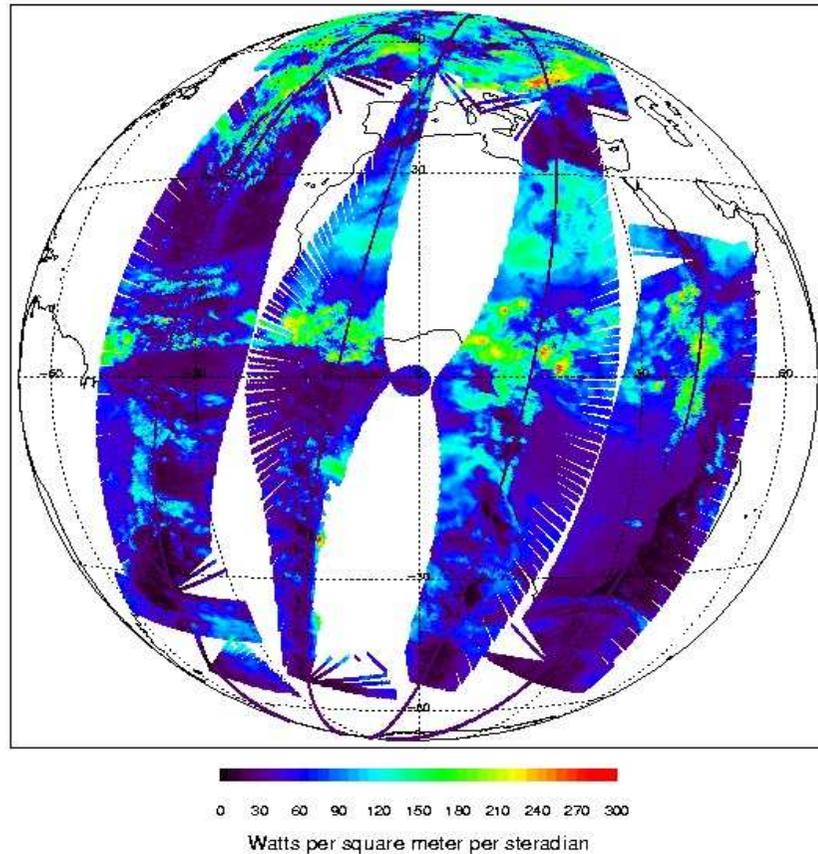
- 50-km resolution
- 256 detectors
- 15-min images

CERES:

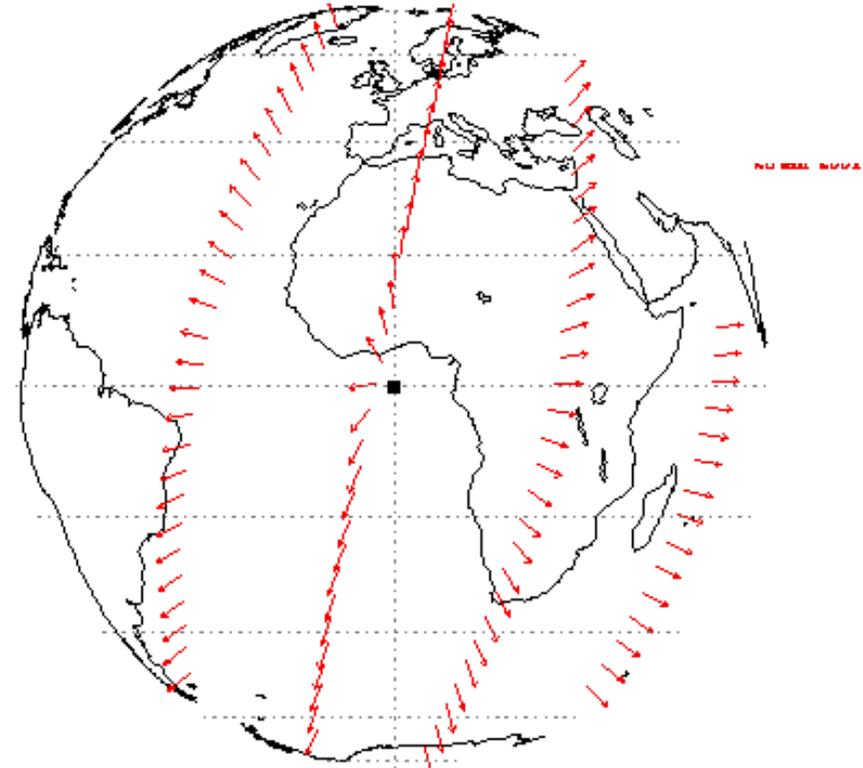
- 20-km at nadir
- 1 scanning detector
- Continuous coverage



GERB-2/ FM2 comparison



CERES/GERB Relative Azimuth

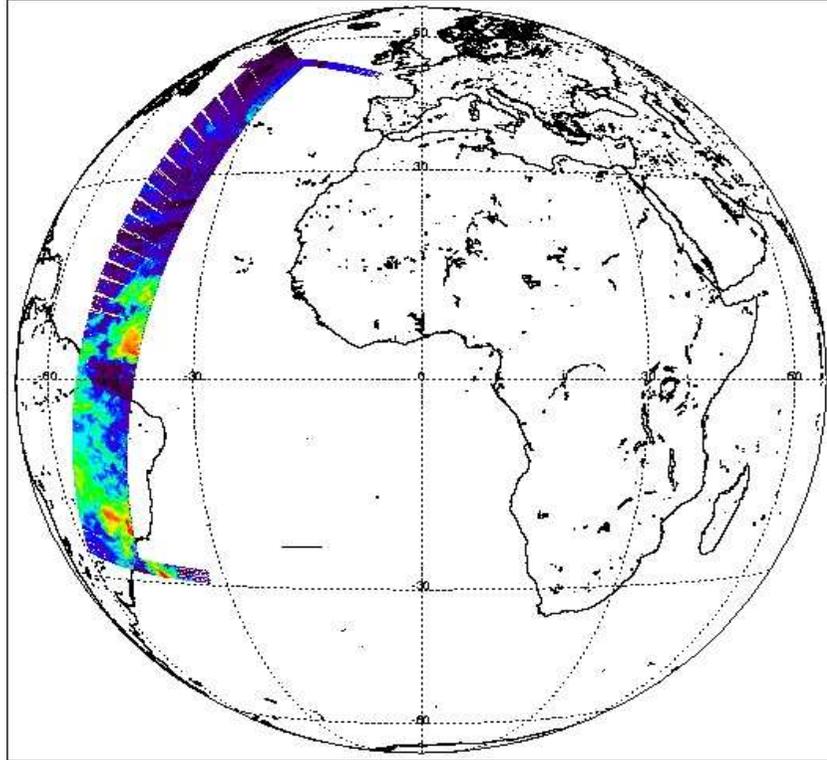


Data collection campaigns are run during summer and winter solstices



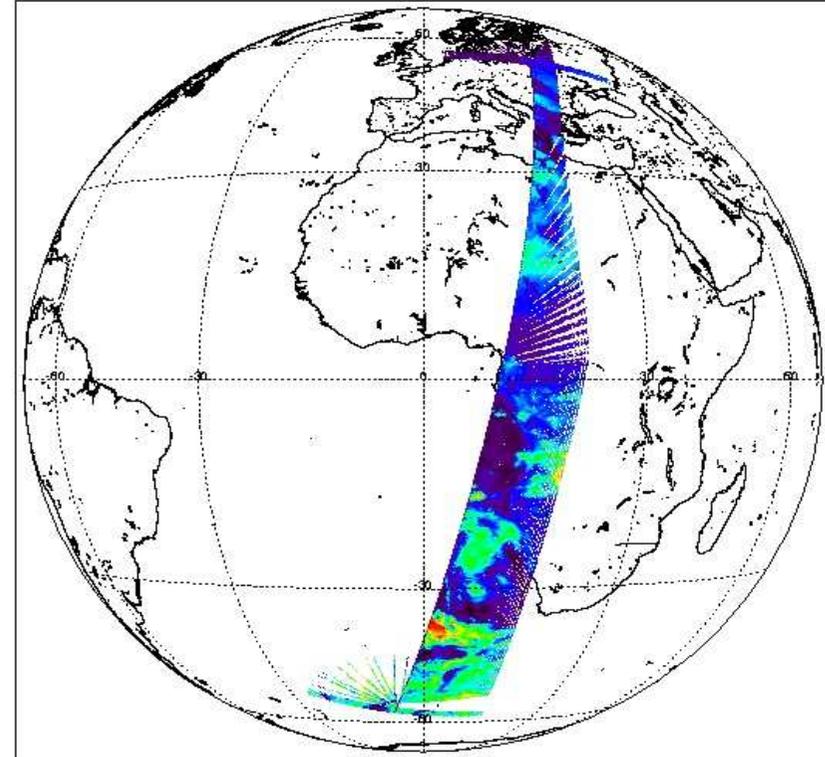
GERB-1 / FM2 comparison

CERES SW flux at TOA Data Range: 12:55:07 - 13:17:46 (7047: 7253: 1, 1: 660: 1)
/nfs/xsan/CERES/verbelike/dir_ES8s/CER_ES8_Terra-FM2_Edition2_026031.20081225 Mon Aug 24 15:53:32 2009



40 133 226 319 412 505 598 691 784 877 971
Watts per square meter

CERES SW flux at TOA Data Range: 09:37:07 - 10:07:55 (5247: 5527: 1, 1: 660: 1)
/nfs/xsan/CERES/verbelike/dir_ES8s/CER_ES8_Terra-FM2_Edition2_026031.20081225 Mon Aug 24 15:47:10 2009



31 115 200 284 369 454 538 623 707 792 877
Watts per square meter

2 out of 4 daily passes are shown in the summer 2008



ERB Workshop, Paris 09/13-16/2010



Comparison of GERB and CERES

- In RAPS mode the azimuth of CERES and GERB are matched 11% of the time (± 10 deg tolerance: 20/180 deg)
- In PAPS mode the azimuth of CERES and GERB are matched continuously (100%)
- Spatial noise due to FOV size differences can be reduced by averaging data over 1-deg regions
- In PAPS mode each FM2 daytime pass provides 1 independent sample
- Since 2006 data are collected only in the Northern Hemisphere

95% confidence interval in the comparison (using 1-deg spatial average)

	1° × 1° grid/orbit	30 days	
		SW	LW
PAPS	55/110	0.5	0.1
RAPS	0/13	1.5	0.3



Campaigns FM2/GERBx

Campaign	Duration	Orbits	Amount of data
FM2/GERB1	06 & 12/2008	112	1344 min
FM2/GERB2	12/24 – 28/2008	20	220 min
FM2/GERB1	06 & 12 / 2009	165	1990 min
FM2/GERB1	June/2010	86	1030 min

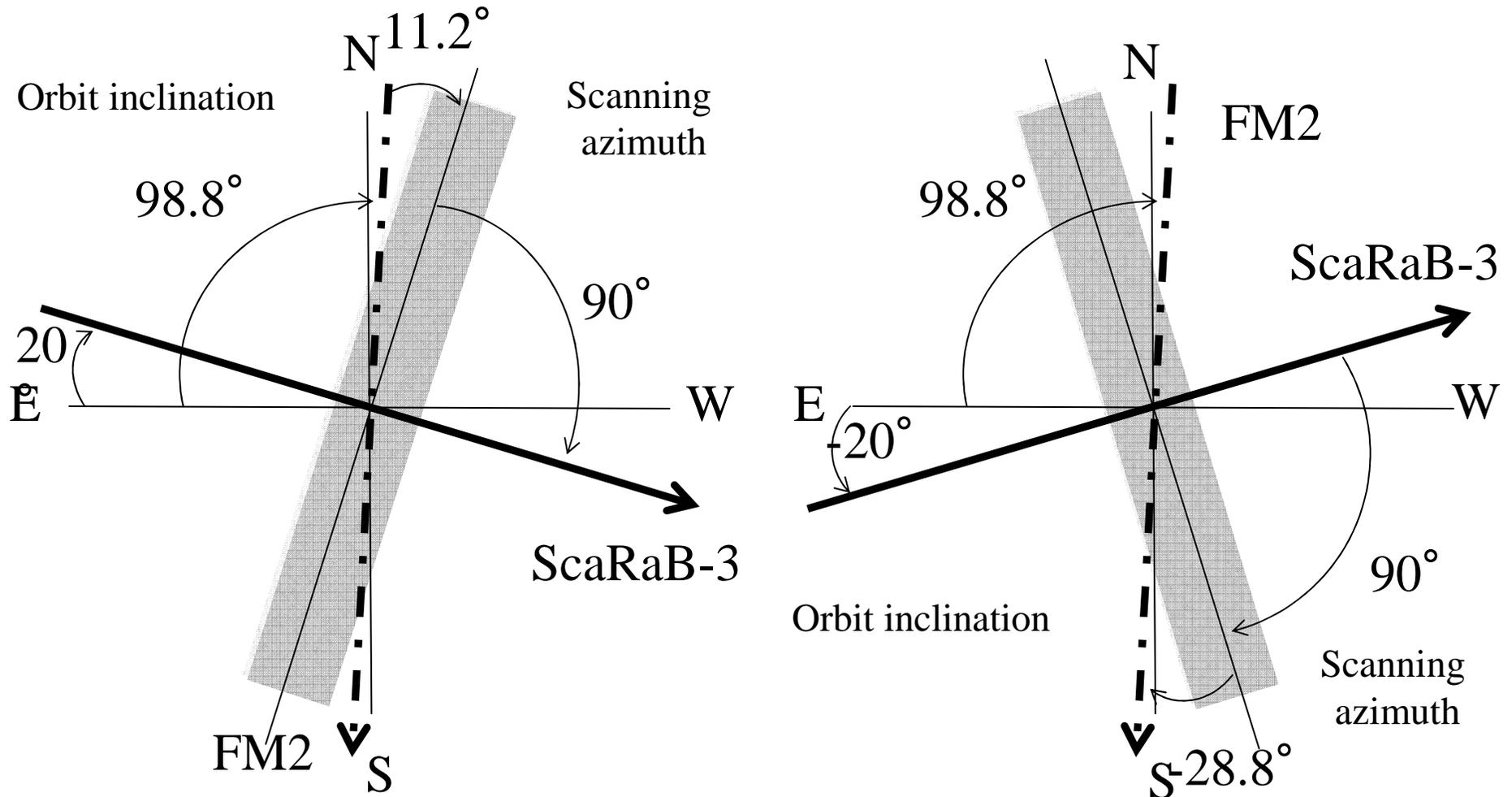


FM2/ScaRaB-3 comparison

- Orbits:
 - Terra in 98.8° sun-sync, T=98.52sec, H = 707km
 - M-T in 20° precessing, T=101.93sec, H = 866km
- Scanners:
 - FM2 pixel size 32 × 16 km at nadir
 - ScaRaB pixel size 40 × 40 km at nadir
- Compare matched radiances over 1° × 1° grid:
 - Temporally within 15 min
 - Angularly for RAZ (< 5°) and VZA (< 10°)



FM2/ScaRaB-3 comparison



Concluding Remarks

- CERES/FM2 on Terra is the only scanner for special operations
 - PAPS mode enables comparison of radiances
- **Edition3** of CERES data adds new level of accuracy to ERB instruments comparison
 - FM2/ GERB-1 & GERB-2
 - Hours of data still to be processed
 - FM2/ScaRaB-3 in 2011
 - Lifting ram direction restrictions?

