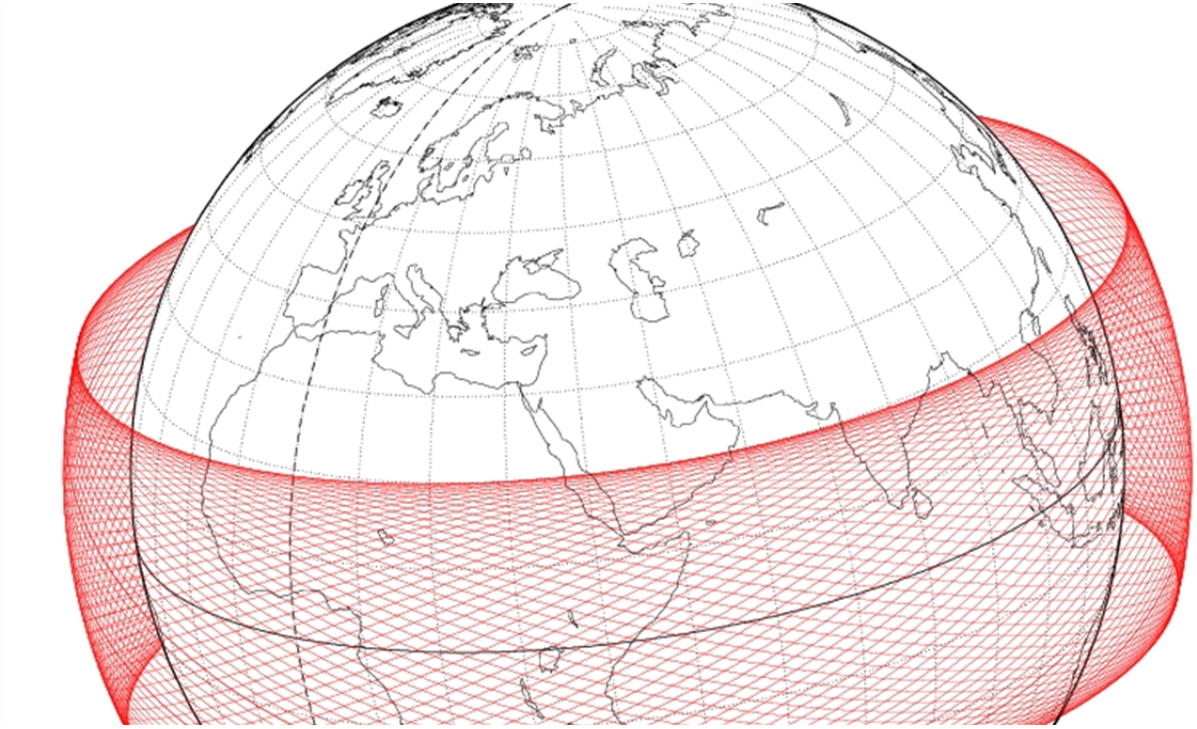
CERES and ScaRaB comparison campaigns, method, schedule for rendez-vous and results



O. Chomette, M. Capderou, R. Roca & N. Loeb

Outline

-CERES & ScaRaB comparisons

- The PAPS campaigns (2012, 2015, 2016)

- Schedule for rendez-vous

- Colocation method

- Comparison results

CERES & ScaRaB comparisons

Objective : To compare CERES & ScaRaB SW and LW radiances in order to
- validate the ScaRaB measurements
- confirm the CERES measurements
- analyse the possible drifts between these instruments

NB : No in-situ measurements

ScaRaB-SW error budget @ 1σ ≈ 1,6%

Items	Value	Type	
Short wave calibration (sphere)	3% @2σ	Biais	1.5%
Error on spectral response		Biais	0.4%
Thermal gain correction	0.08%/° dT= 0.04° @1σ	Random	0.03%
Thermal leak correction	20% of the thermal leak@1σ	Random	0.04%
Location	0.06°@1σ	Random	0.4%
Budget at 1 sigma			1.6%

Rosak et al., 2012

CERES-FM2-SW error budget @ 1σ ≈ 1%

	Bias errors of unknown sign (W m^{-2})				
Source	Incoming solar	Outgoing SW	Outgoing LW	Net incoming	Comment
Total solar irradiance	±0.2	0	0	±0.2	Absolute calibration (95% confidence)
Filtered radiance	0	±2.0	±2.4 (N) ±5.0 (D)	±4.2	Absolute calibration (95% confidence)
Unfiltered radiance	0	±0.5	±0.25 (N) ±0.45 (D)	±1.0	- Instrument spectral response function - Unfiltering algorithm

Loeb et al., 2009 [CERES-FM2 error budget @2σ]
They showed that their error budget was consistent with the climate monitoring.

+ errors due to the collocation

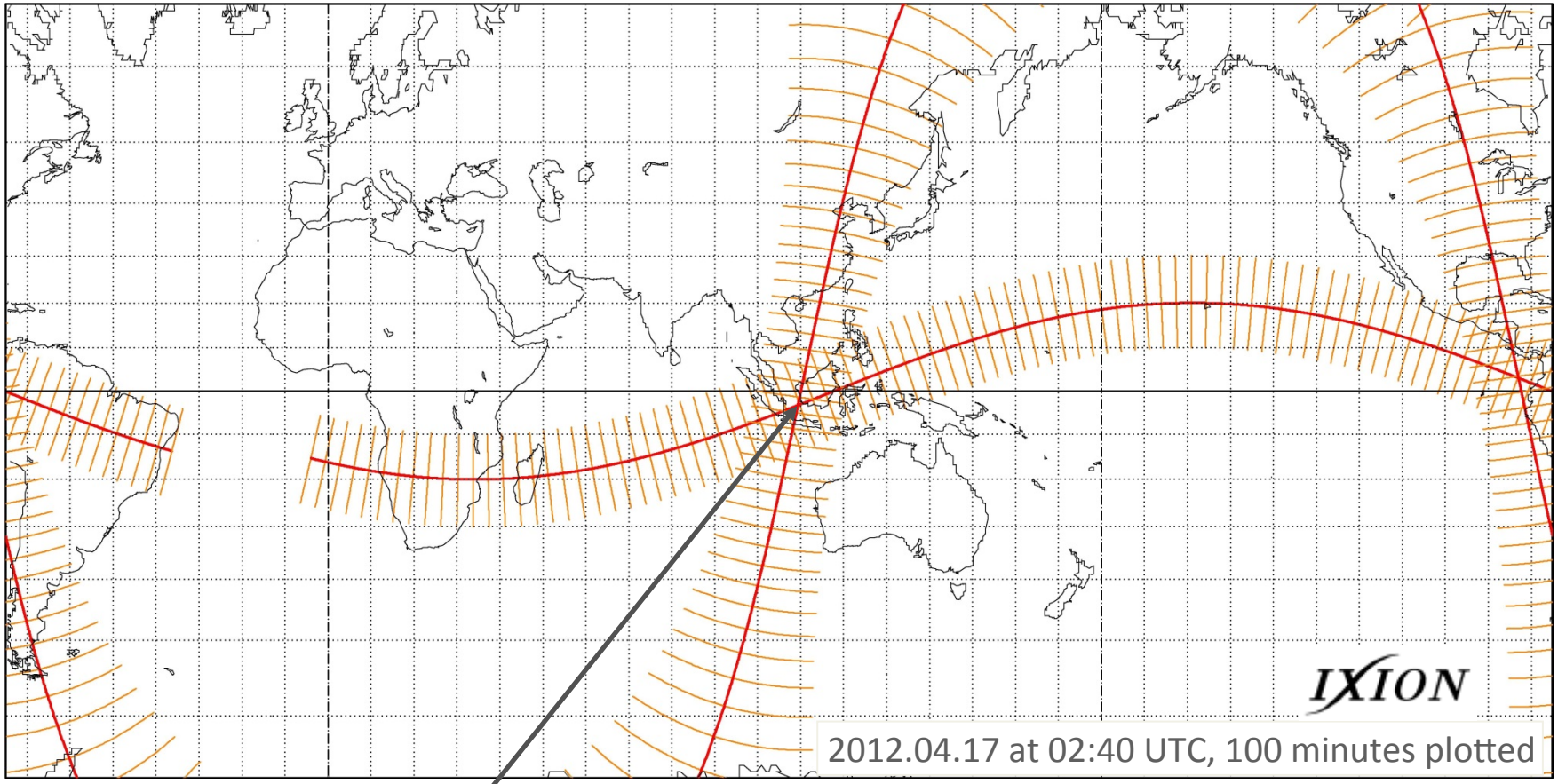
- Not the same instrument technologies
- independent measurements

→ Comparisons between ScaRaB & CERES (instantaneous comparisons i.e. pixel by pixel).

CERES & ScaRaB comparisons

→ Intersections + same angular conditions

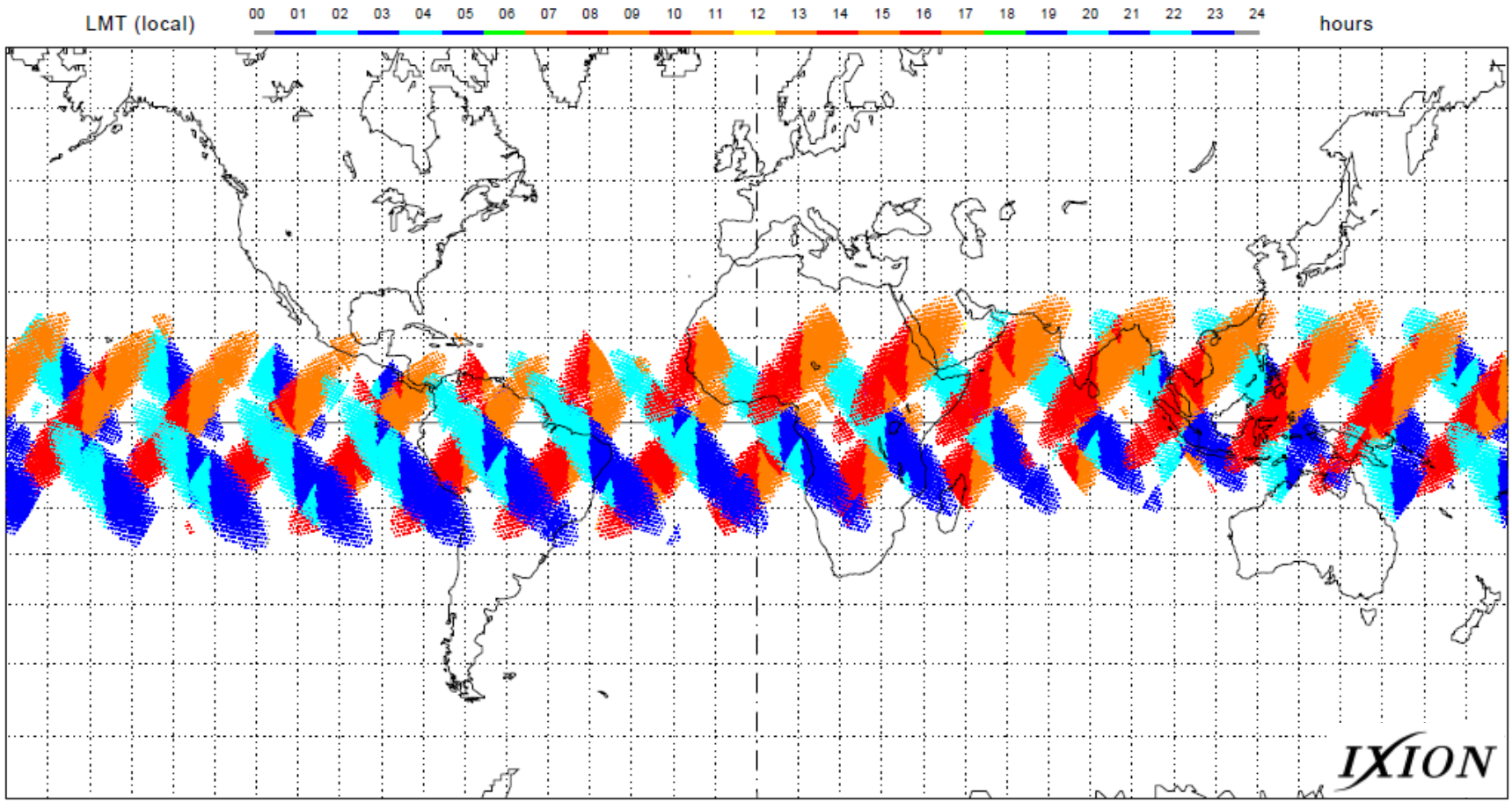
ScaRaB on MT ➔ 20° inclination, half-swath: 48.9° - XT mode
CERES on TERRA ➔ 98.2° inclination, half-swath: 55.2° - XT mode



CERES & ScaRaB crossing ; same angular conditions only near nadir.

CERES & ScaRaB comparisons

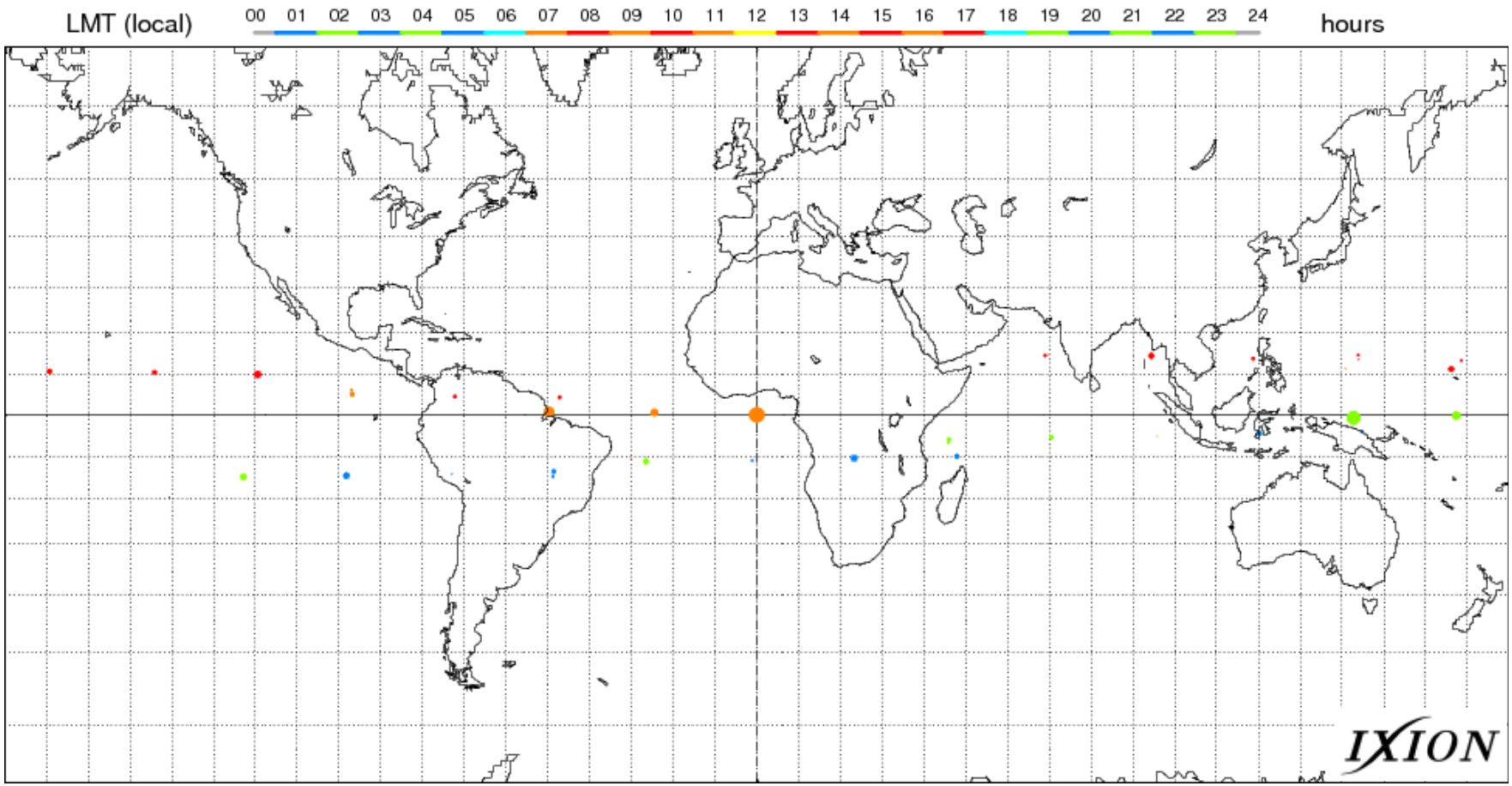
CERES/TERRA & ScaRaB/MT
Represented period : 16 days
Temporal colocation : 5’



No co-angular restriction here !

CERES & ScaRaB comparisons

CERES/TERRA & ScaRaB/MT
Represented period : 16 days
Temporal colocation : 5'
Conical aperture = **5°** ← **Angular constraint**



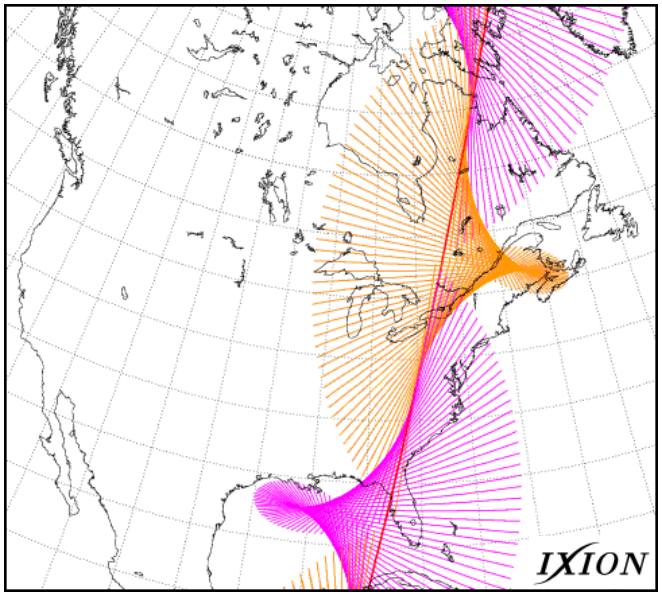
The PAPS campaigns

It is required to have measured radiances under the same angular conditions to improve radiances matching for highly anisotropic scenes ➔ inconvenient poorer statistics in XT mode

To optimize the frequency of co-angular observations: use the CERES others scanning modes

CERES can change the angle of his axis scan.

PAPS mode: rotating angle is fixed for a required period ⟶ Possibility to align CERES and ScaRaB swaths.



CERES in RAPS mode
(Scan angle modified over time)

The PAPS campaigns

Alignment of the CERES scan axis with the ScaRaB Scan axis :

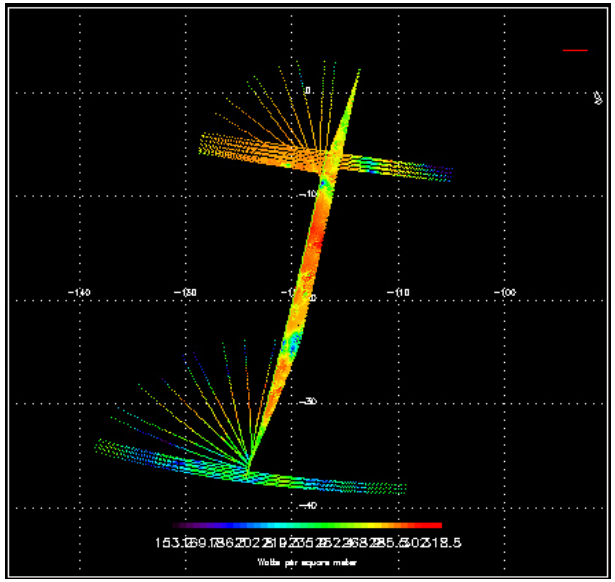
The 3 PAPS campaign

1 – **April/May 2012, 2015 & 2016**

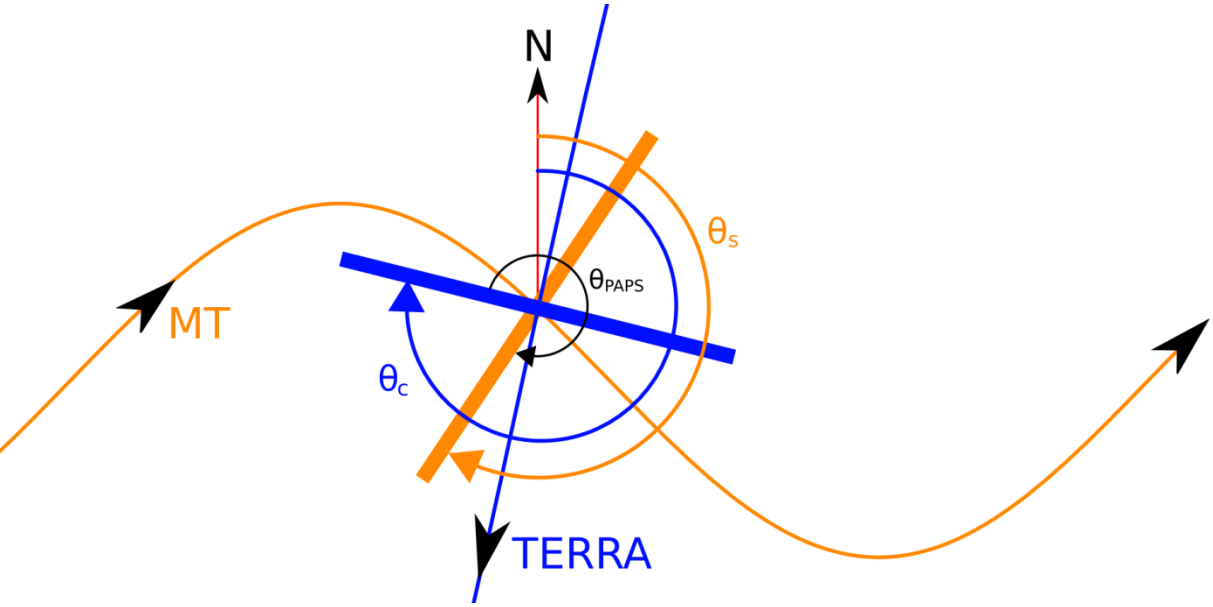
2 – Only during daytime (for SW).

3 – Crossing forecasts (computed with IXION and NORAD data) with durations & PAPS angles sent to NASA.

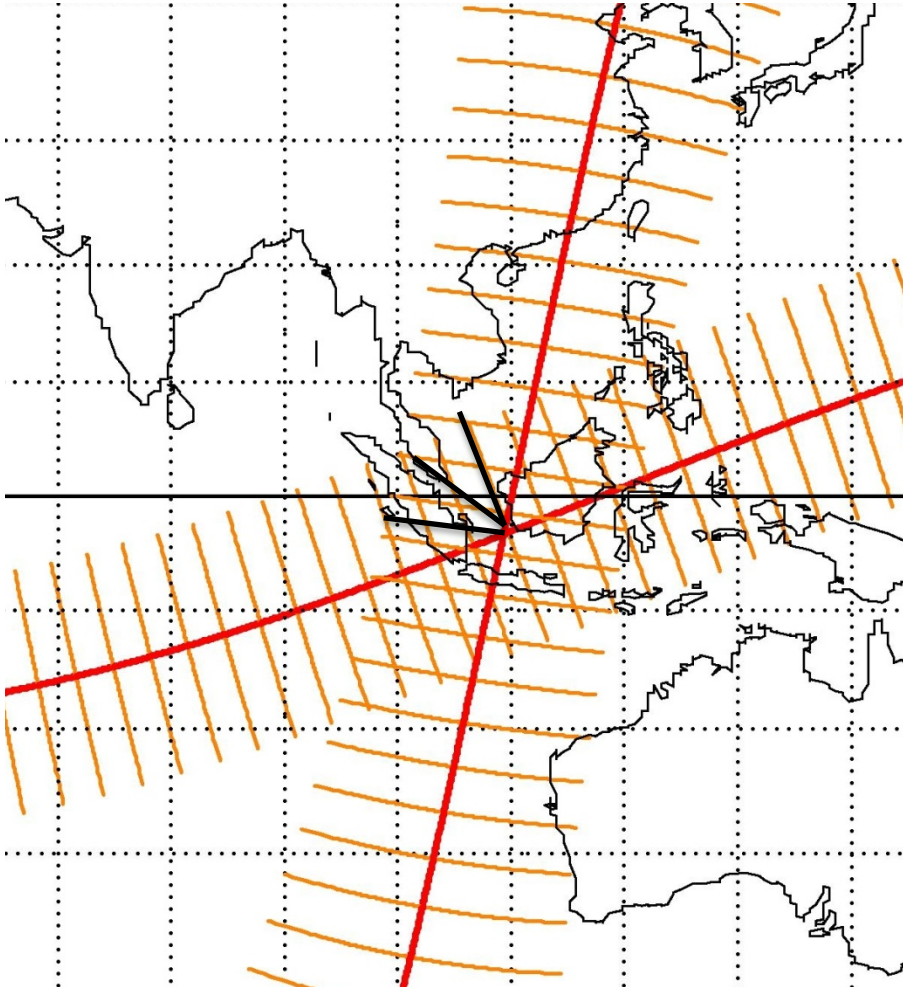
4 – Advantages: Increase the collocated pixels between the 2 instruments + all swath pixels has been collocated.



CERES-FM2 on PAPS mode
(backward scan only)



The rendez-vous



CERES goes to PAPS mode when crossing ScaRaB.

The rendez-vous

Megha-Tropiques
Orbit - Ground track

Recurrence = [14; -1; 7] 97

>>>> Time span shown: 102.0 min = 0.07 day

Across track swath (XT mode)

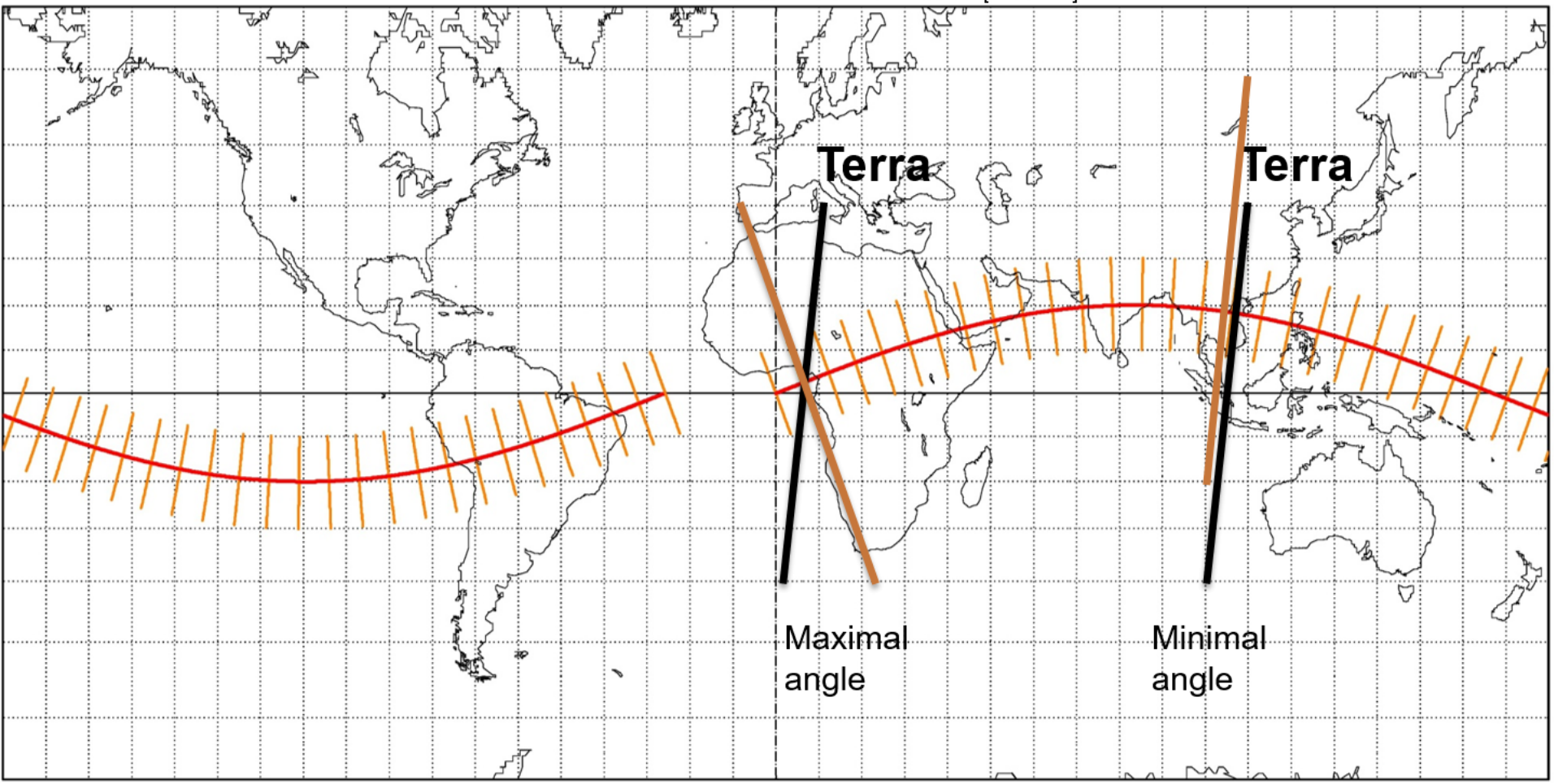
Altitude = 865.5 km a = 7243.677 km

Inclination = 20.00 °

Period = 101.93 min * Rev/sid.d= 14.09

Equat. orbital shift = 2892.0 km (26.0 °)

** Half-swath: 48.9° => 1108 km [2.00 min]



Projection: Mercator
Property: Conformal
⊕ T.:Cylindrical - Graticule: 10°

Project. center: 0.0 ° ; 0.0 °
Aspect: Direct
{4.2}[+0.0/ +0.0/ +0.0] [-] EGM2008

Asc. Node: 0.00 ° [00:00 LMT]
Max. attained latit. = 30.0 °

Ξιων
MC ★ LMD
Ατλας

The rendez-vous

ISRO-CNES
megha-tropiques

Megha-Tropiques
Orbit - Ground track

Recurrence = [14; -1; 7] 97

2015 03 30 16:00:00 UTC >>> 60.0 min = 0.04 day

Across track swath (XT mode)

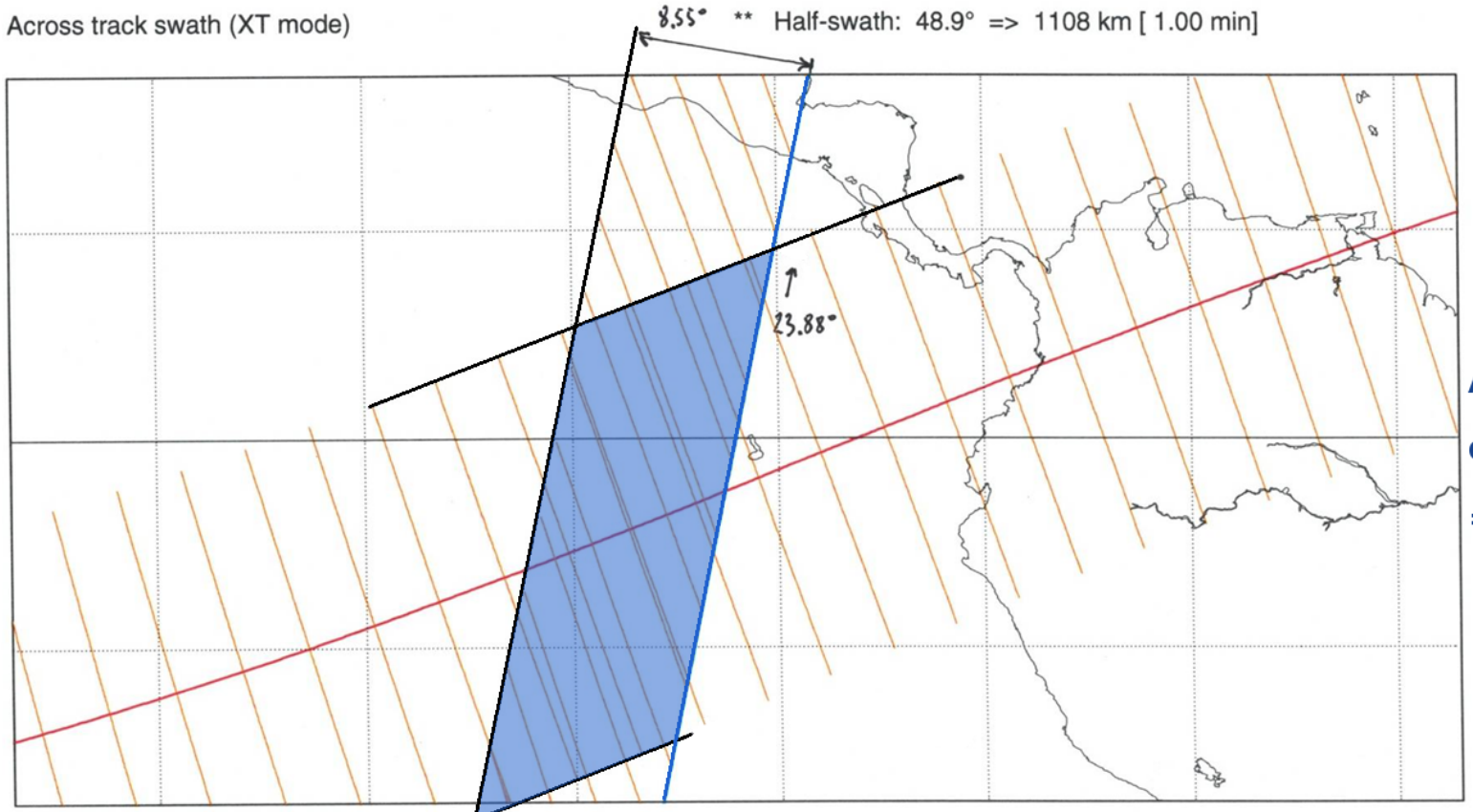
Altitude = 865.4 km a = 7243.570 km

Inclination = 19.98 ° e = 0.000997

Period = 101.93 min * Rev/sid.d=14.09

Equat. orbital shift = 2892.0 km (26.0 °)

** Half-swath: 48.9° => 1108 km [1.00 min]



A=61.9

Q=32

=> P=100%

Projection: Mercator
Property: Conformal
⊕ T.:Cylindrical - Graticule: 10°

PC: 0.0° ; 0.0 ° /ZC: 0.0 ° ; 92.0 ° W
Aspect: Direct **> zoom : 5.14**
{5.3} [+90.0/ +0.0/ -90.0] [-] EGM2008

Asc. Node: 147.38 ° [00:01 LMT]
[NORAD] Revolution: 17477
[NORAD] 2015 03 02 14:11:37 UTC

Ιξιων
MC ★ LMD
Ατλας

The rendez-vous

ISRO-CNES
megha-tropiques

Megha-Tropiques
Orbit - Ground track

Recurrence = [14; -1; 7] 97

2015 03 30 16:00:00 UTC >>> 60.0 min = 0.04 day

Across track swath (XT mode)

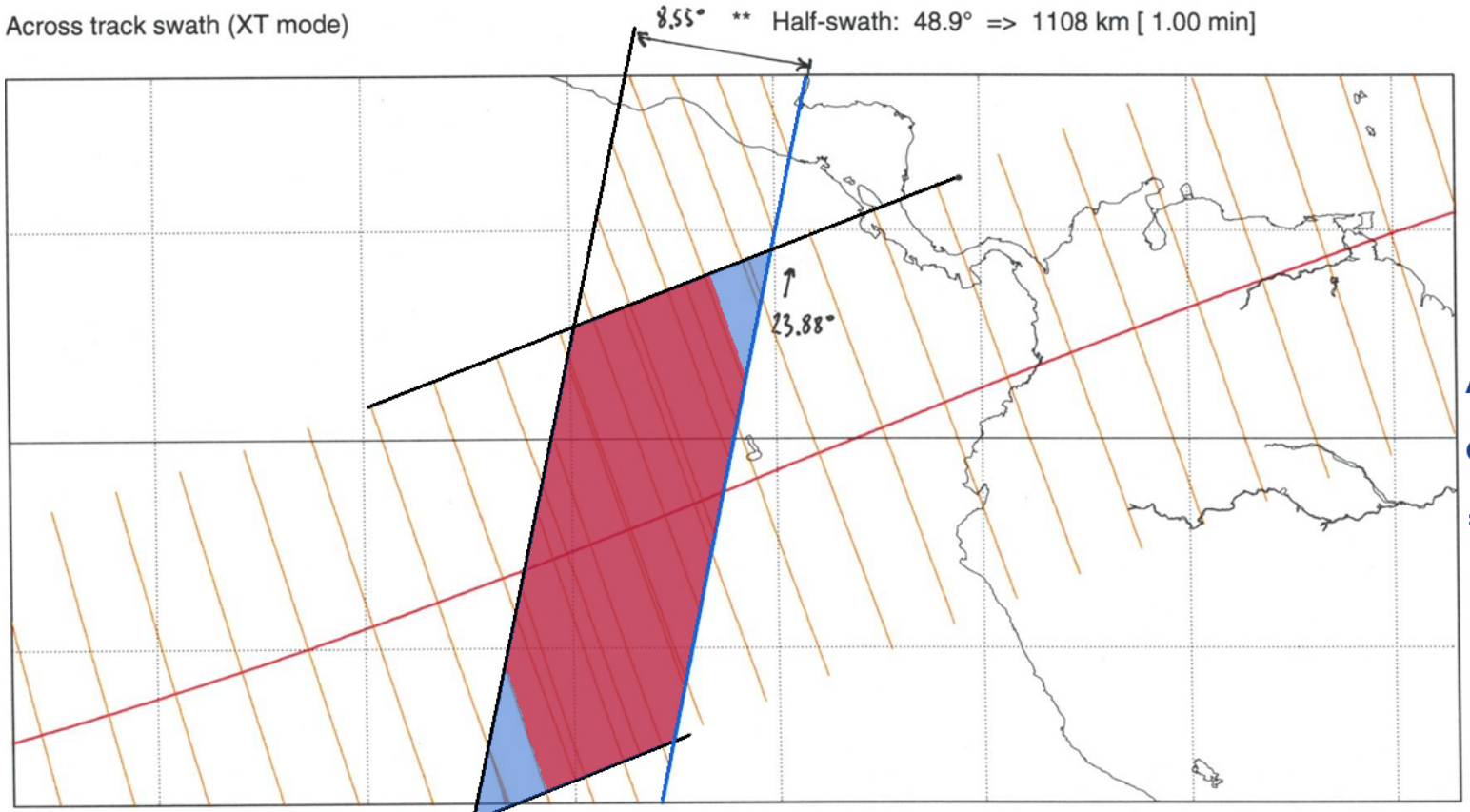
Altitude = 865.4 km a = 7243.570 km

Inclination = 19.98 ° e = 0.000997

Period = 101.93 min * Rev/sid.d=14.09

Equat. orbital shift = 2892.0 km (26.0 °)

** Half-swath: 48.9° => 1108 km [1.00 min]



A=61.9

Q=32

=> P=100%

Projection: Mercator
Property: Conformal
⊕ T.:Cylindrical - Graticule: 10°

PC: 0.0° ; 0.0° /ZC: 0.0° ; 92.0° W
Aspect: Direct > **zoom : 5.14**
{5.3} [+90.0/ +0.0/ -90.0] [-] EGM2008

Asc. Node: 147.38 ° [00:01 LMT]
[NORAD] Revolution: 17477
[NORAD] 2015 03 02 14:11:37 UTC

Ιξιων
MC ★ LMD
Ατλας

The rendez-vous

ISRO-CNES
megha-tropiques

Megha-Tropiques
Orbit - Ground track

Recurrence = [14; -1; 7] 97

2015 04 17 04:00:00 UTC >>> 60.0 min = 0.04 day

Across track swath (XT mode) ** Terra: -91.0 °

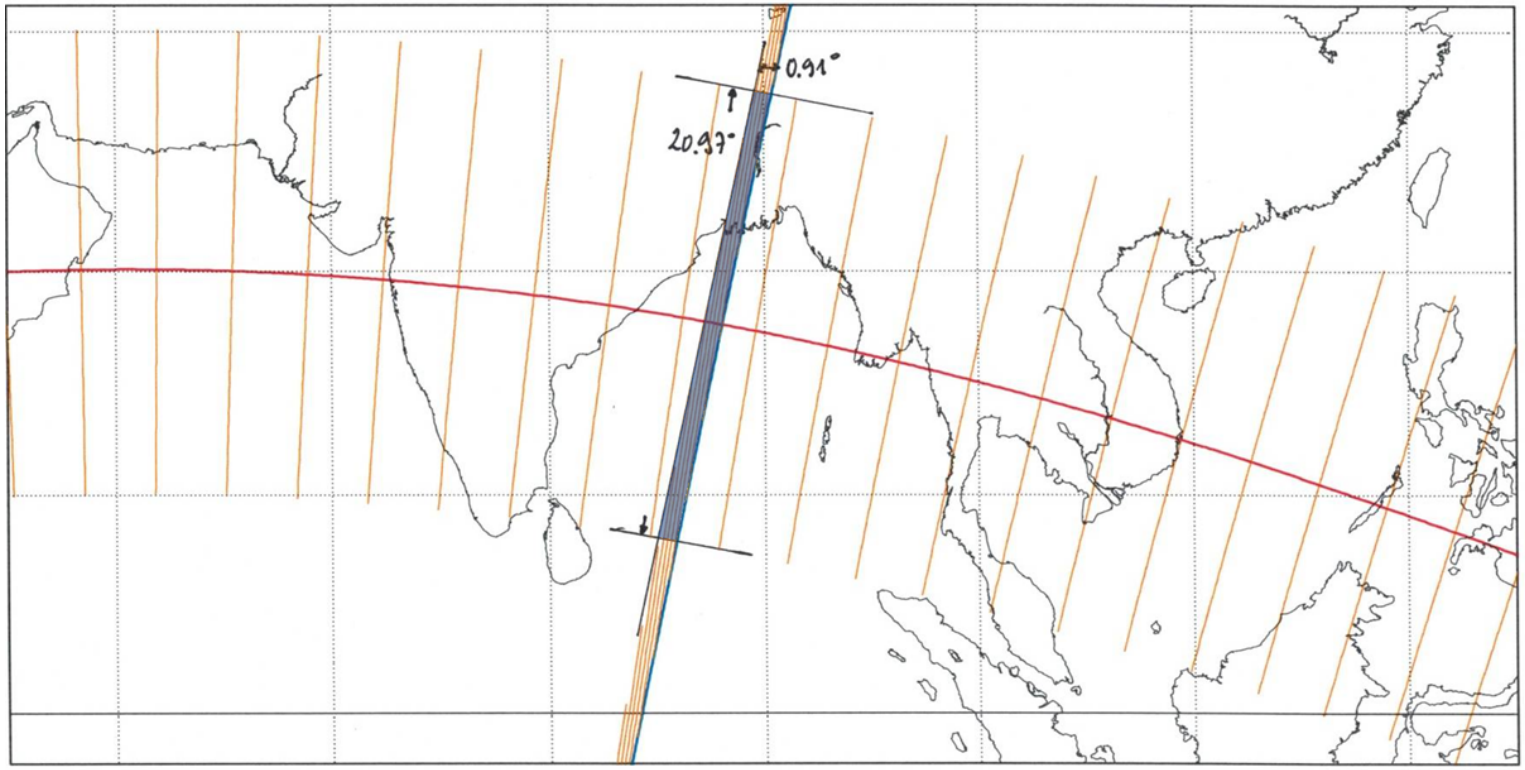
Altitude = 865.4 km a = 7243.570 km

Inclination = 19.98 ° e = 0.000997

Period = 101.93 min * Rev/sid.d=14.09

Equat. orbital shift = 2892.0 km (26.0 °)

** Half-swath: 48.9° => 1108 km [1.00 min]



A=91.0

Q=3

=> P=8%

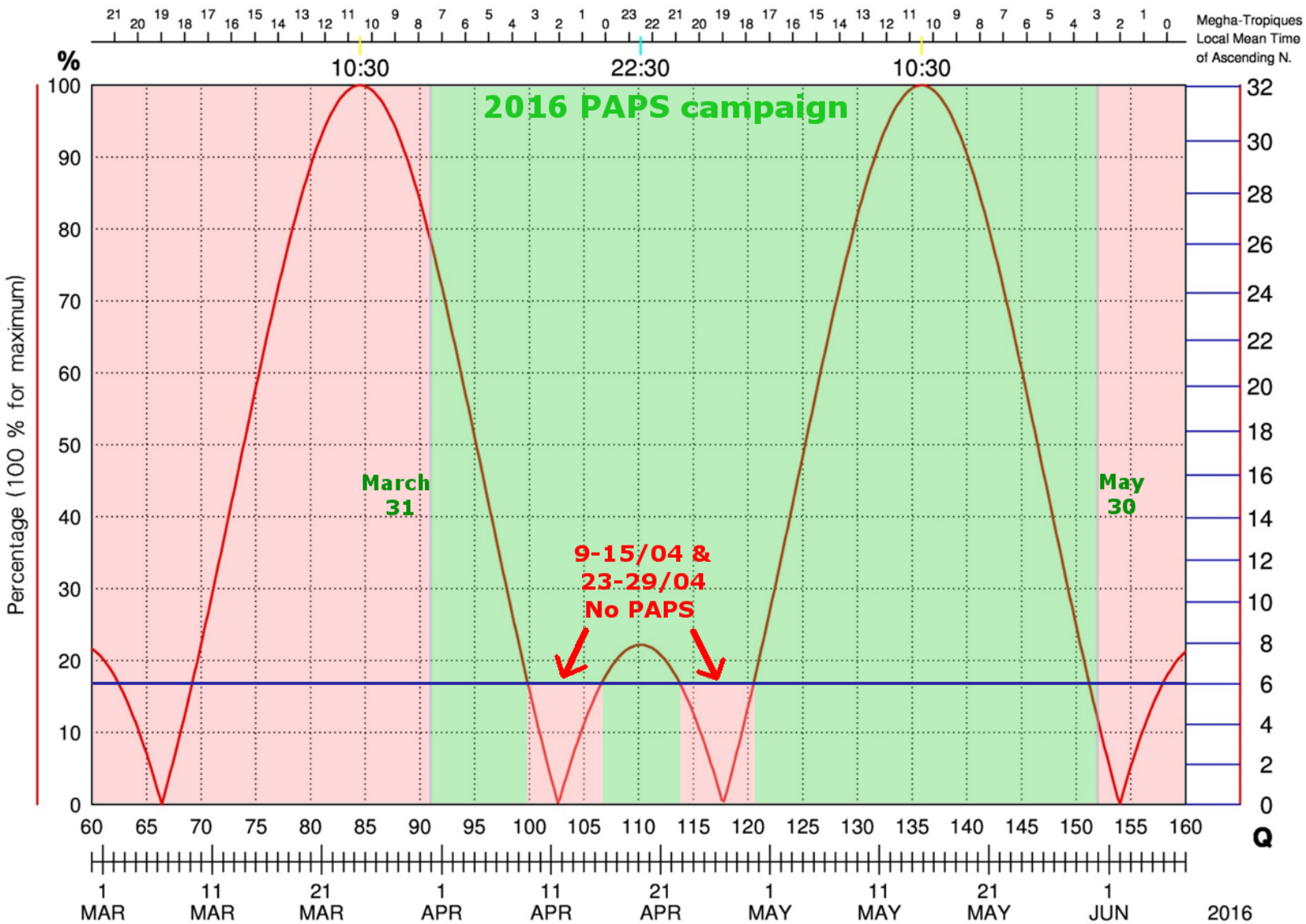
Projection: Mercator
Property: Conformal
⊕ T.:Cylindrical - Graticule: 10°

PC: 0.0 ° ; 0.0 ° /ZC: 15.0 ° N; 90.0 ° E
Aspect: Direct > **zoom : 5.14**
{5.3} [+90.0/ +0.0/ -90.0] [-] EGM2008

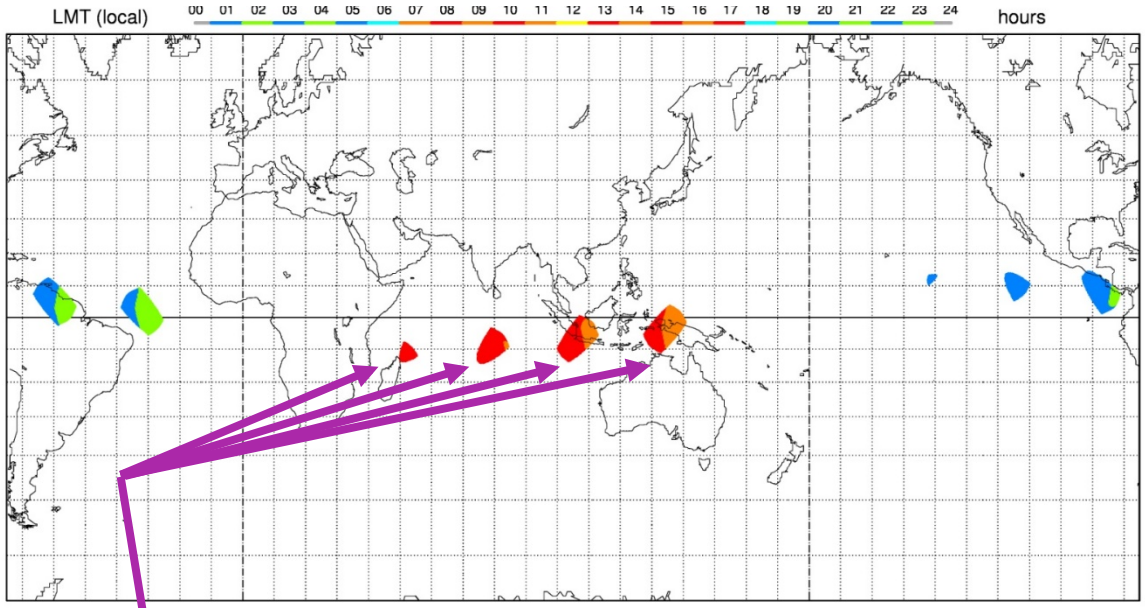
Asc. Node: 147.38 ° [00:01 LMT]
[NORAD] Revolution: 17477
[NORAD] 2015 03 02 14:11:37 UTC

Ιξιων
MC ★ LMD
Ατλας

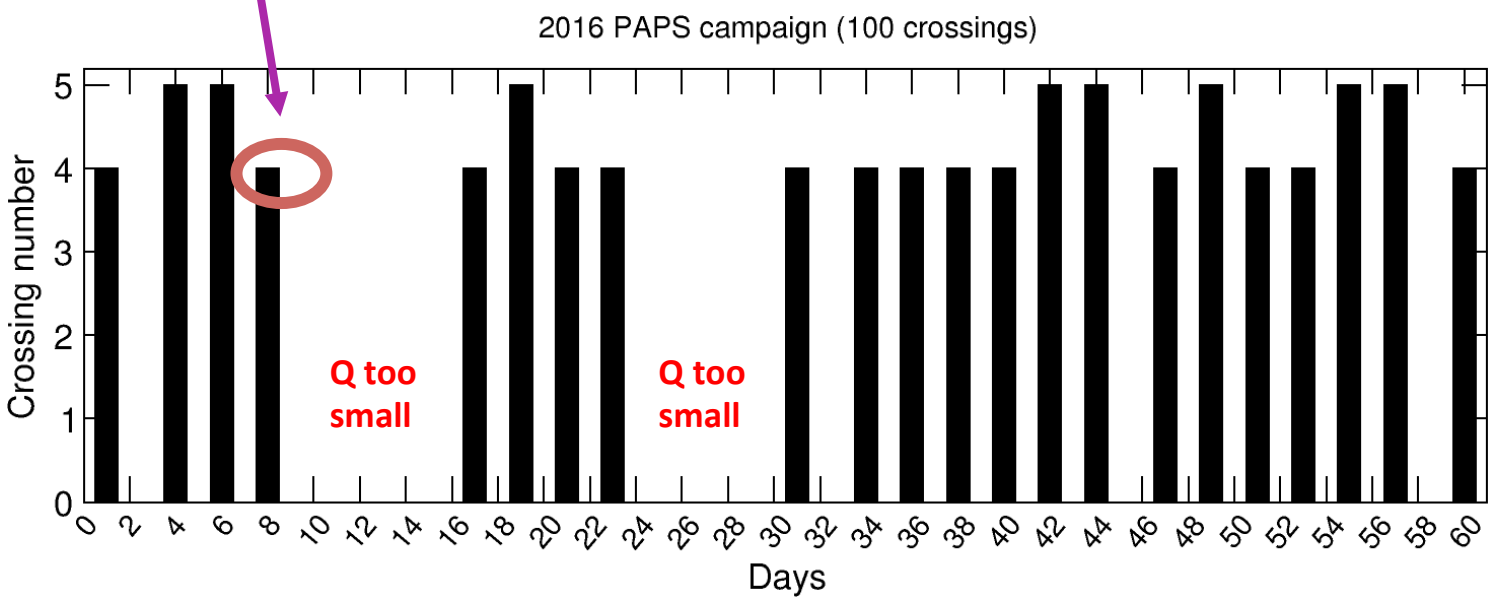
The rendez-vous



The PAPS campaigns



Ex :
2016 PAPS campaign



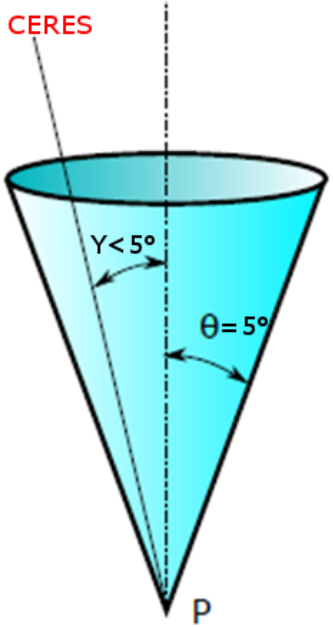
Colocation method

- Comparisons with another ERB instruments

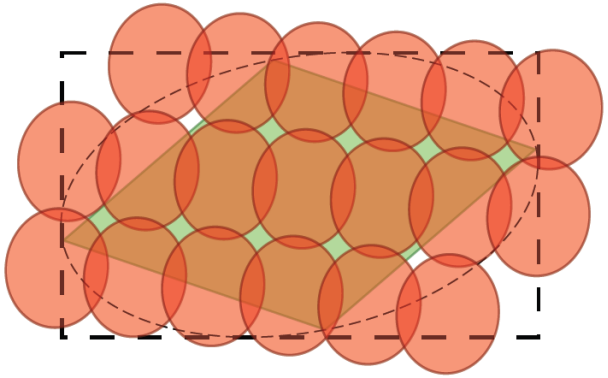
  Geographical colocation

  Temporal colocation ➔ **ΔT = 5'**

  Angular colocation (because of the anisotropy of the observed scenes). ➔ **$\theta_{cône}$ = 5°**



Spatial colocation



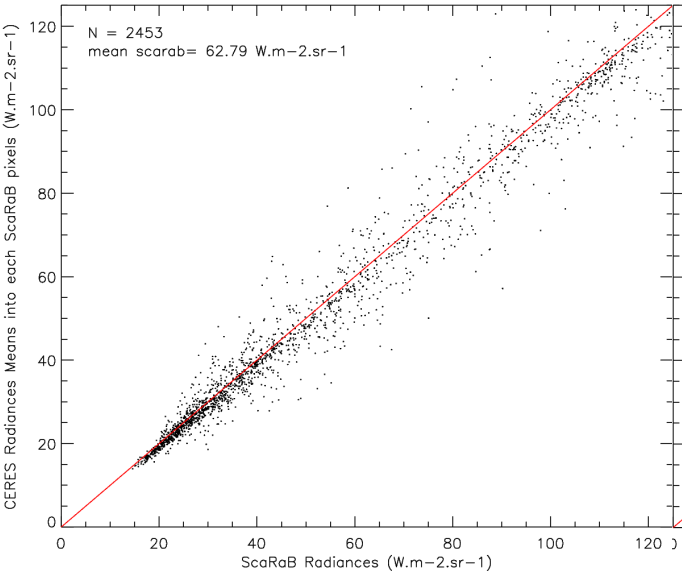
CERES pixels **(red)** are projected into a ScaRaB pixel **(green)**

Comparisons between an **CERES** averaged value and the **ScaRaB** measurement.

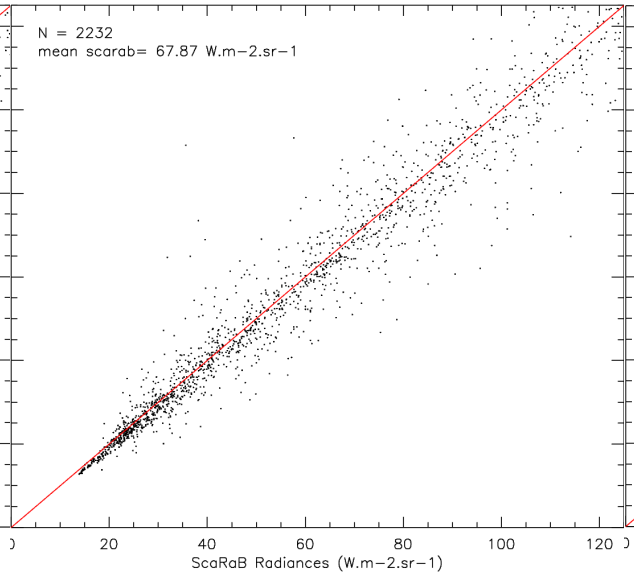
Results

Unfiltered ScaRaB **SW Radiances** vs. Unfiltered CERES-FM2-PAPS SW Radiances with 5', 5° & coverage of at least 80% (surface) of the ScaRaB pixel.
Daytime data only.

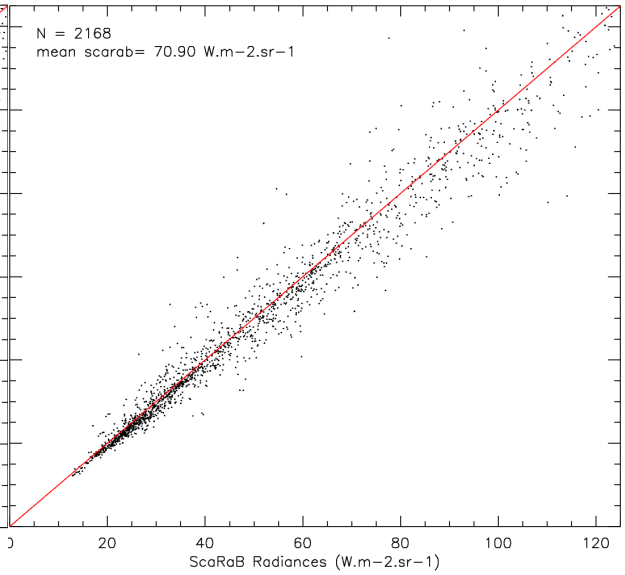
PAPS 2016



PAPS 2015



PAPS 2012



SW Radiances
5° 5' 80%
All pixels.

ALL PIXELS		surface > 80% 5' – 5°
PAPS Years	**N**	**SW Radiances** $\frac{(ScaRaB-CERES)}{mean(CERES)}$
2016	2453	2.54 ± 10.48 %
2015	2232	2.13 ± 10.96 %
2012	2168	1.86 ± 9.89 %

Results

To compare CERES & ScaRaB it's better to compare homogeneous pixels between them (to be sure that bias & std are not due to the scene heterogeneity)

➔ Statistics over homogeneity index : $\dfrac{\sigma_{CERES(in\ each\ ScaraB\ pixel)}}{mean(CERES)_{in\ each\ ScaraB\ pixel}}$

$\dfrac{\sigma_{CERES(in\ each\ ScaraB\ pixel)}}{mean(CERES)_{in\ each\ ScaraB\ pixel}}$	N	mean	std
0 – 5 %	576	2.09	2.92
5 – 10 %	539	2.72	7.32
10 – 15 %	395	1.81	9.12
15 – 20 %	286	3.23	12.51
20 – 50 %	630	3.29	16.19
50 –100 %	27	-4.54	15.12
TOTAL (0 – 100 %)	2453	2.54	10.48
0 – 10%	1115	2.38	5.27
0 – 20%	1796	2.39	7.83

PAPS 2016 SW Radiances – surface > 0.8 – 5 min – 5°

Results

To compare CERES & ScaRaB it's better to compare homogeneous pixels between them (to be sure that bias & std are not due to the scene heterogeneity)

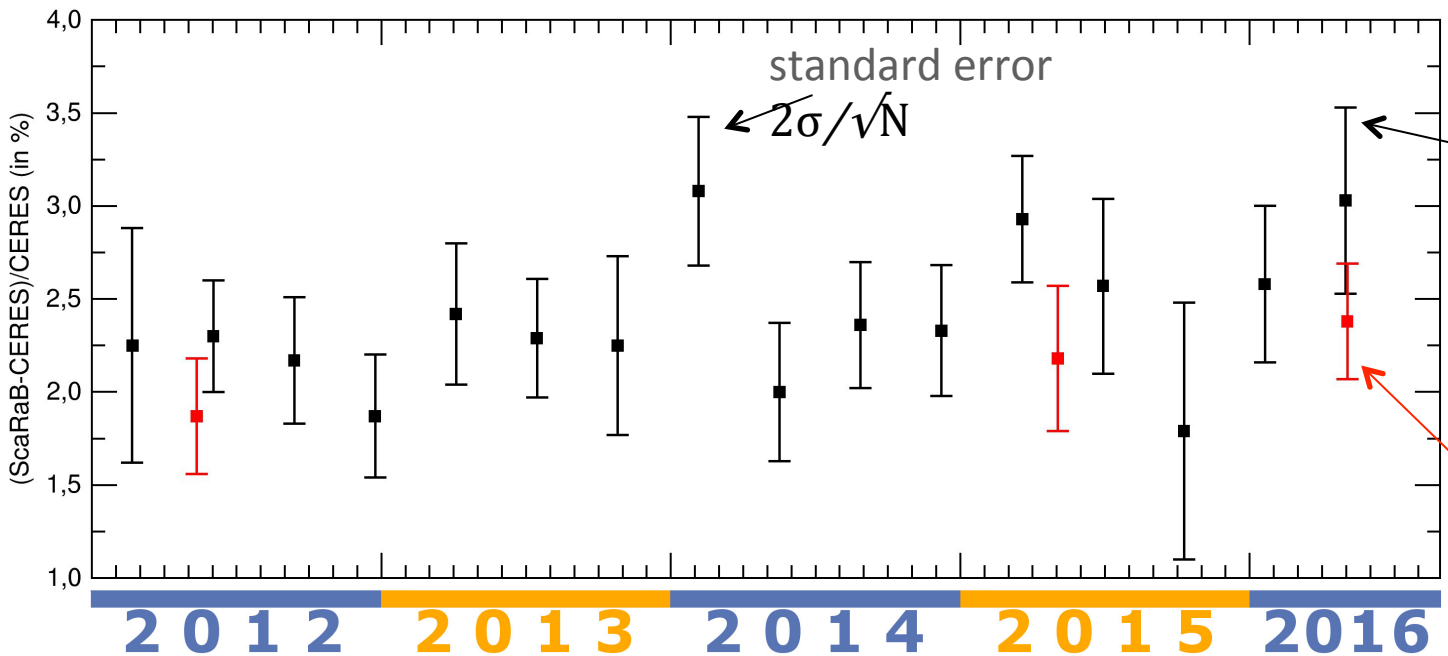
➔ Statistics over the values of $\dfrac{\sigma_{CERES(in\ each\ ScaraB\ pixel)}}{mean(CERES)_{in\ each\ ScaraB\ pixel}}$

SW Radiances ($\frac{\text{ScaRaB}-\text{CERES}}{\text{mean(CERES)}}$)	surface > 80% 5′ – 5°		
$\frac{\sigma_{CERES}}{mean(CERES)}$ ➔ PAPS Years	0-5%	0-10%	0-20%
2016	2.09 ± 2.92 %	2.38 ± 5.27 %	2.39 ± 7.83 %
2015	2.35 ± 3.80 %	2.18 ± 5.76 %	2.41 ± 8.41 %
2012	1.49 ± 3.74 %	1.87 ± 5.23 %	2.12 ± 7.82 %

Results

CERES & ScaRaB are in good agreement.

➔ biais ≈2.5% in SW, with
error budget ScaRaB≈1.6%, CERES≈1% (at 1 σ)
+ errors brought by the colocation method > 1,5%



Comparisons in XT mode in **black**
102 days each
550 px on average

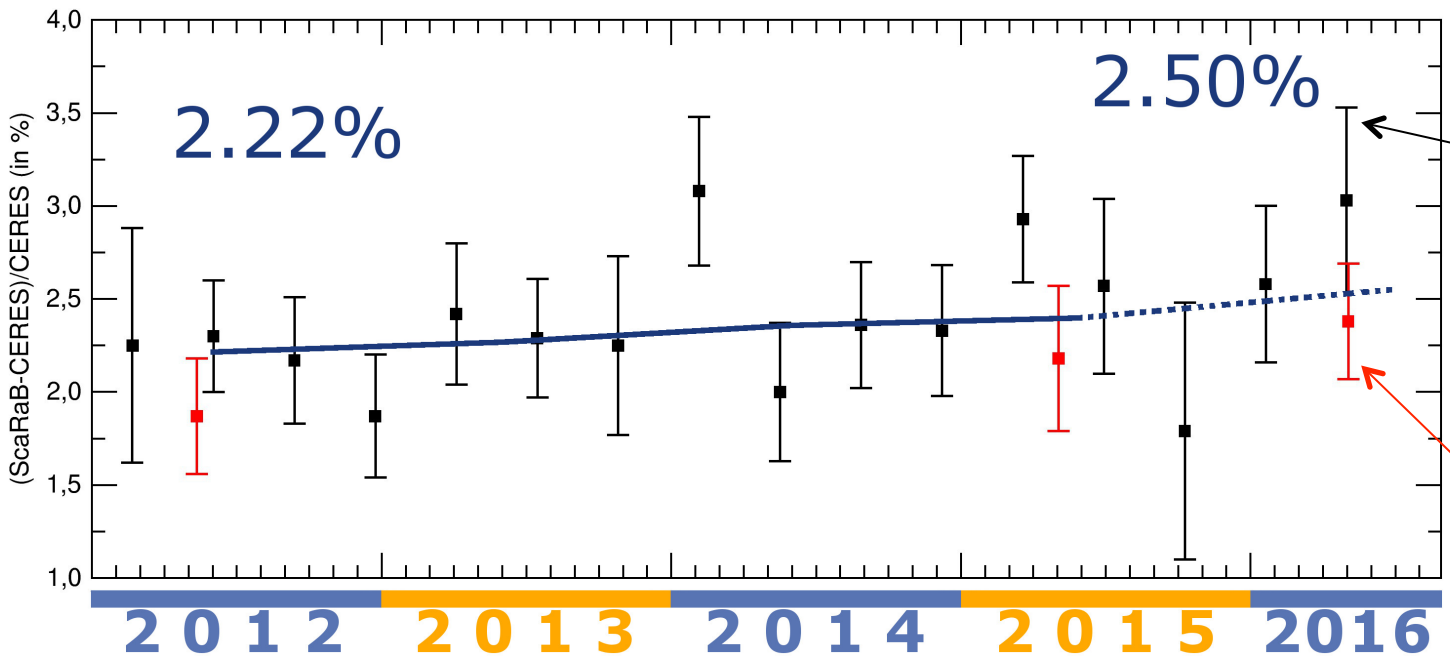
PAPS campaigns in **red**
≈ 60 days each
1000 px on average

Unfiltered SW radiances : 5’ 5° 80% $\frac{\sigma_{CERES(in\ each\ ScaraB\ pixel)}}{mean(CERES)_{in\ each\ ScaraB\ pixel}}$ ➔0-10%

Results

CERES & ScaRaB are in good agreement.

➔ biais ≈2.5% in SW, with
error budget ScaRaB≈1.6%, CERES≈1% (at 1 σ)
+ errors brought by the colocation method > 1,5%

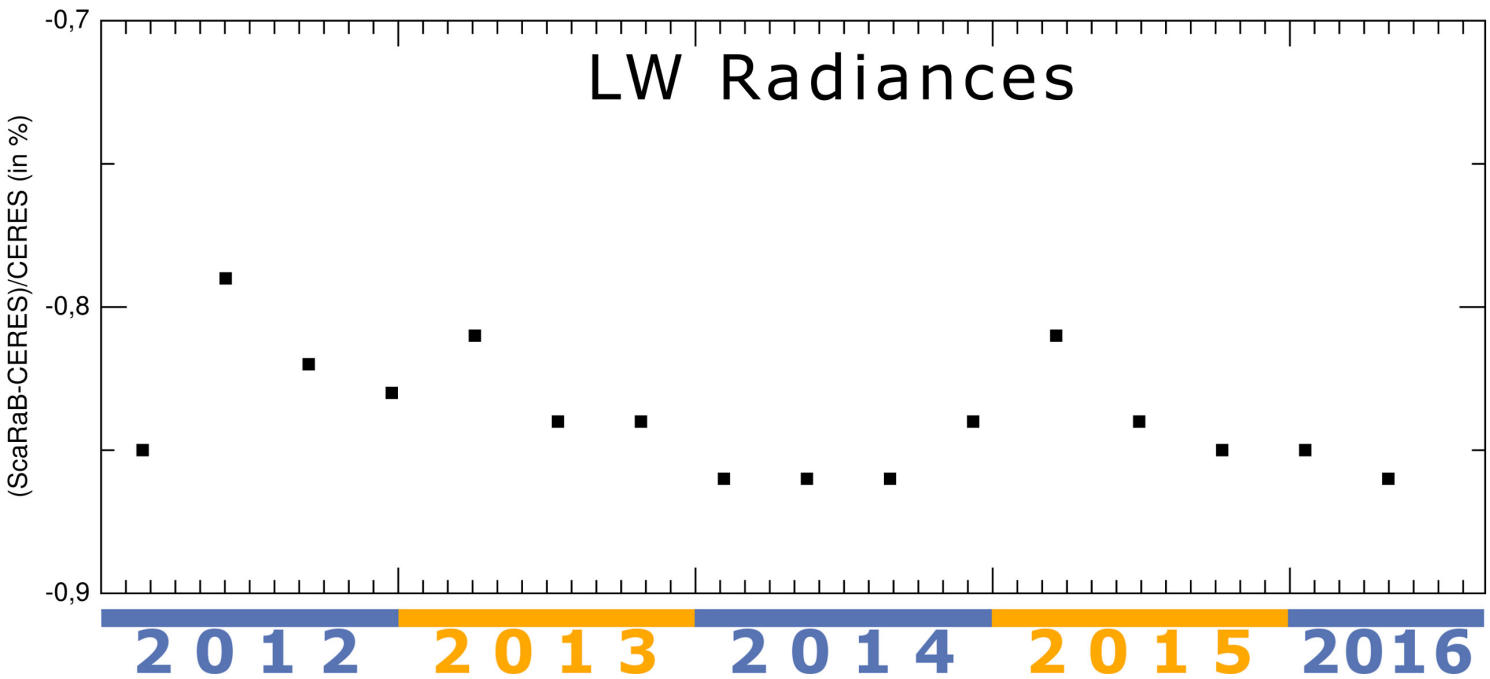


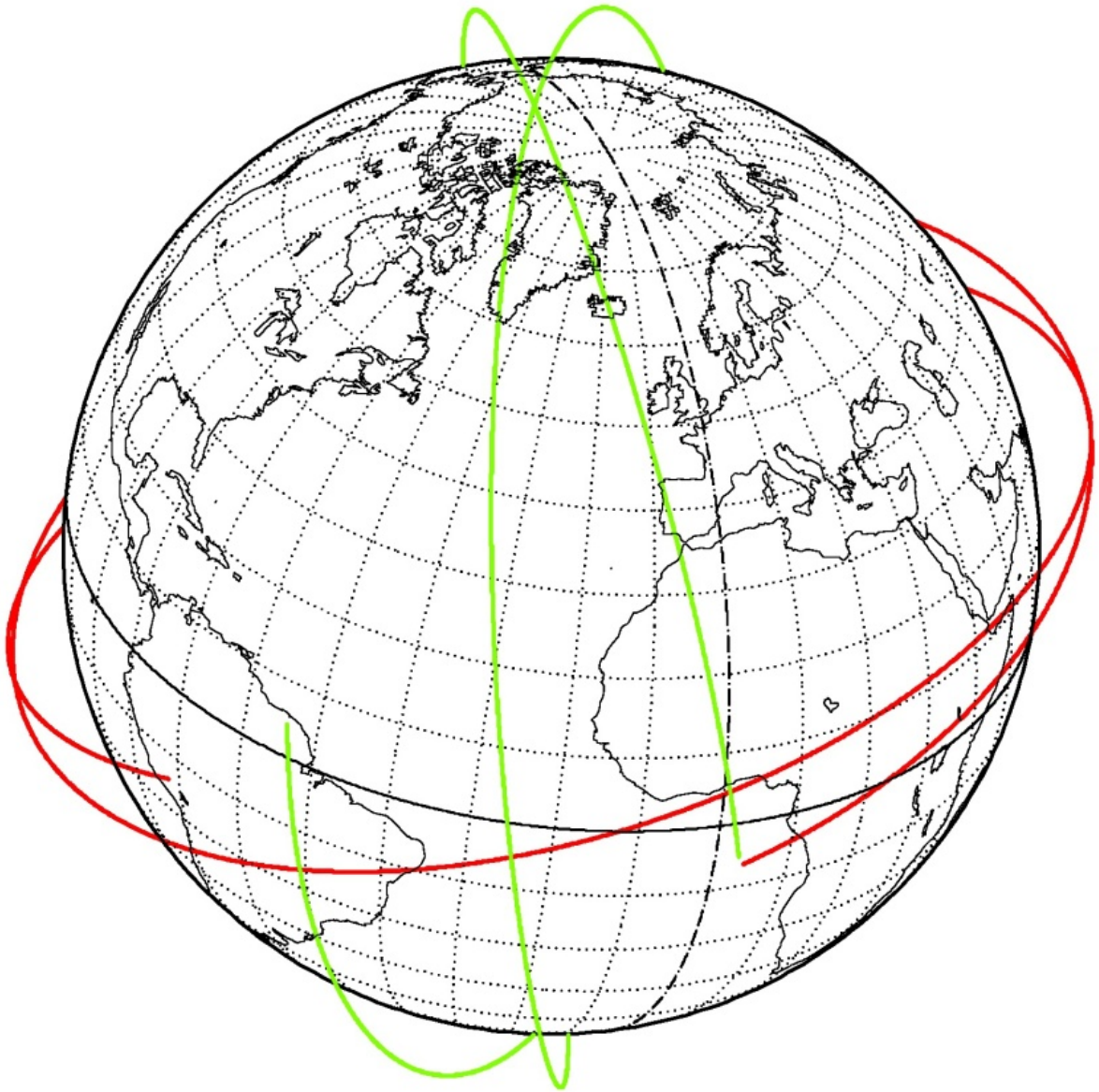
Comparisons in XT mode in **black**
102 days each
550 px on average

PAPS campaigns in **red**
≈ 60 days each
1000 px on average

Unfiltered SW radiances : 5’ 5° 80% $\frac{\sigma_{CERES(in\ each\ ScaraB\ pixel)}}{mean(CERES)_{in\ each\ ScaraB\ pixel}}$ ➔0-10%

Thank you!


LW Radiances
(ScaRaB-CERES)/CERES (in %)
-0,7
-0,8
-0,9
2012
2013
2014
2015
2016



Colocation method

ALL PIXELS	surface > 80% 2012 PAPS campaign	
Criteria	**N**	**SW Radiances**
5° - 5min	2168	1.86 ± 9.89 %
5° - 2min	606	0.95 ± 9.99 %

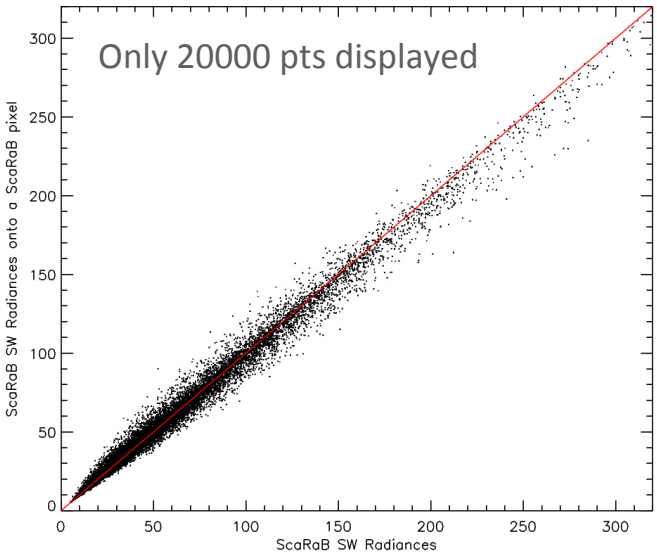
Restrict the criteria (angular, temporal, « surface », scene homogeneity)

↓

Improve the statistics

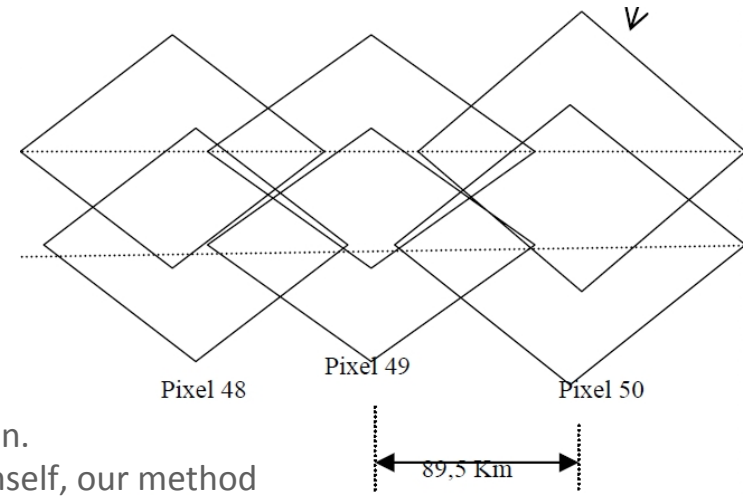
↓

But also reduce N



ScaRaB L1A2, XT mode, MT
vs.
ScaRaB L1A2, XT mode, MT

SW Radiances
(**2545273** colocated pixels)
-0.02 ± 9.38 % (RMS : 9.4%)



Same colocation criteria, same algorithm ➔ No biais but large dispersion.

⚠ When comparing same instrument with overlaping pixels with himself, our method brings std.

Colocation method

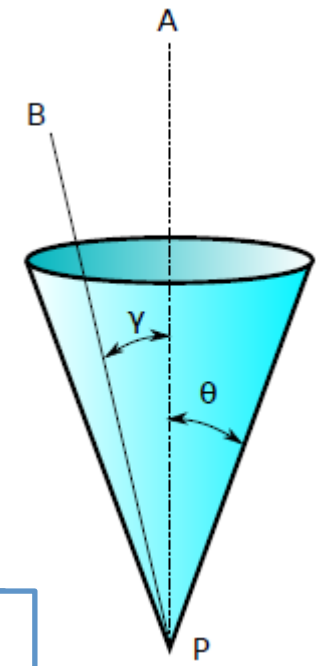
- Comparisons with another ERB instruments

  Pixels colocation: geographical, temporal and angular
  (because of the anisotropy of the observed scenes).

SW radiances

Co-angular ($\theta_{zenith} \pm x°$ & $\theta_{azimuth} \pm x°$ or conical aperture with an aperture of x°)

Simultaneous ($\Delta T \pm x$ mn)



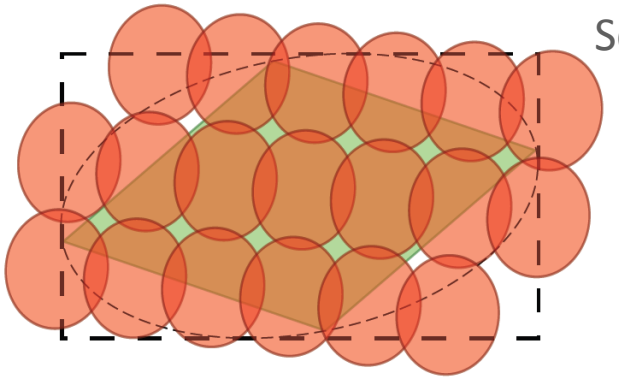
LW radiances

Same as SW without the $\theta_{azimuth}$ constraint

$\theta_{cône}$ = 5° et ΔT = 5'

Colocation method

- Spatial colocation

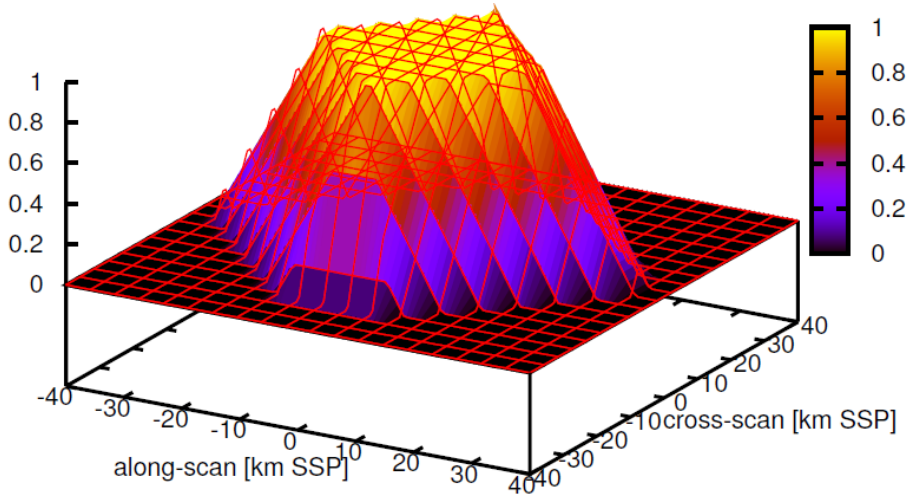


ScaRaB **(green)** = master pixel ; CERES **(red)** = slave pixel

Pixels with different sizes, shapes and weighting functions

The deformation of the pixels are taken into account

The PSF-weighted co-location estimates the contribution of each slave **(red)** pixel inside the master **(green)** one



Exemple of ScaRaB PSF

Comparisons between an averaged value (CERES pixels into a ScaRaB pixel) and the ScaRaB measurement.