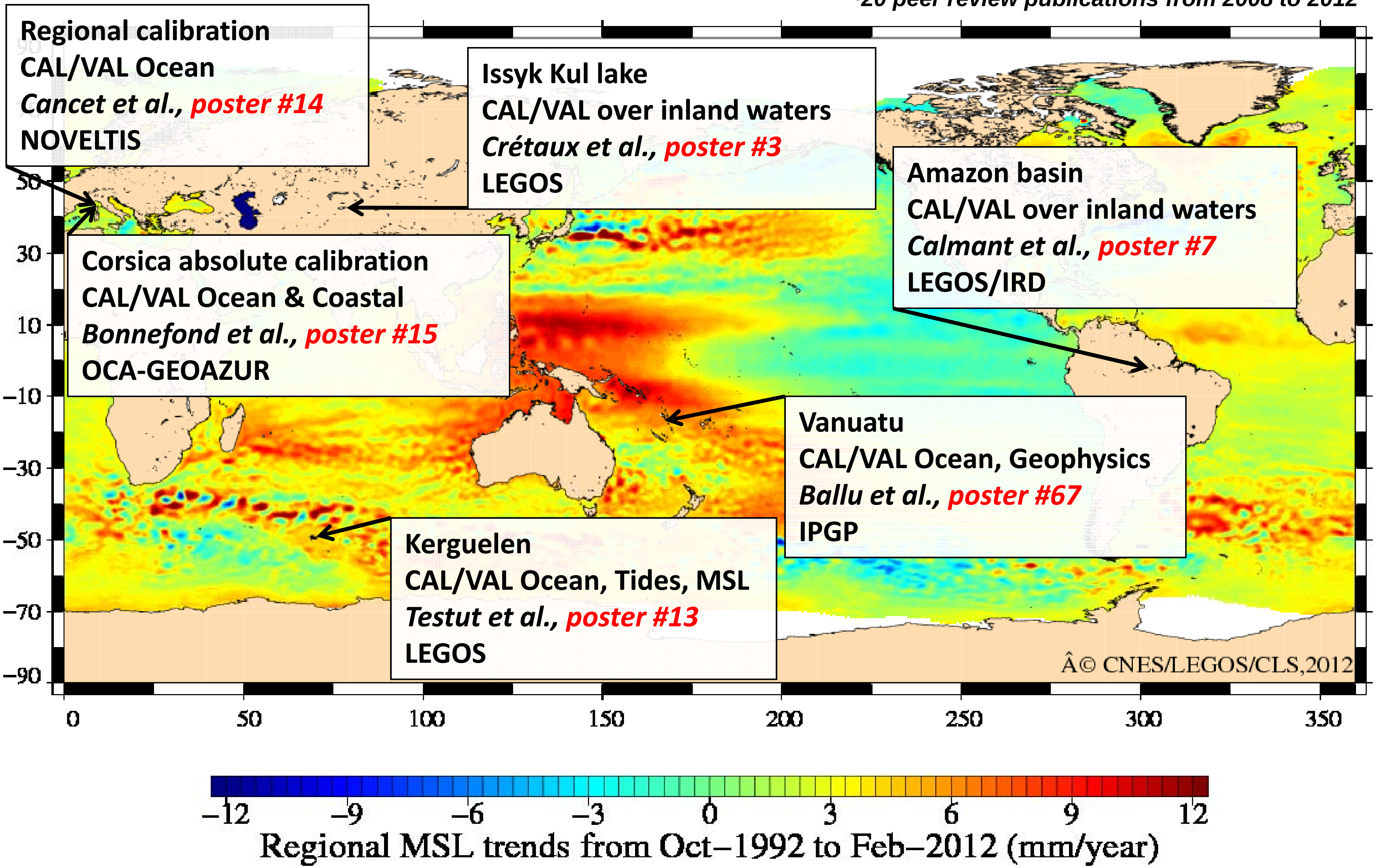
FOAM: From Ocean to inland waters Altimetry Monitoring

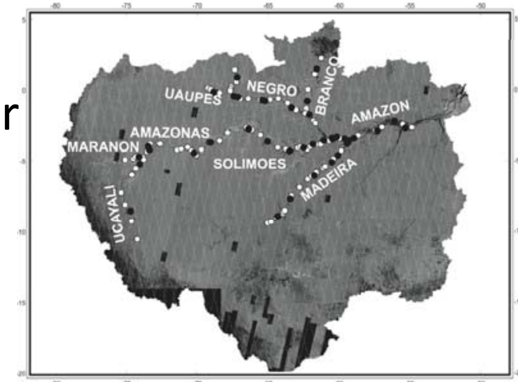
Goal: aggregate the past effort of several groups, in order to notably establish a homogeneous network of calibration sites geographically distributed for more robust characterization of the existing and future radar altimeter system instrument biases and their drifts.

~20 peer review publications from 2008 to 2012



Altimetry Biases over Rivers (Amazon basin)

S. CALMANT, D. MOREIRA, J. SANTOS DA SILVA, F. SEYLER, F. PEROSANZ, CK SHUM

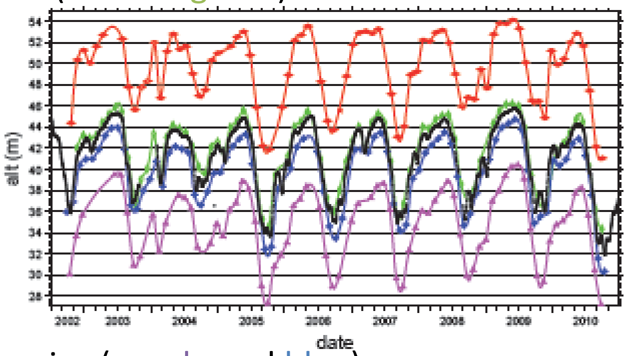


Motivation: put together series from different missions and/or different retracking algorithm of radar pulses

Instrumentation: about ~30 gauges leveled by GPS

Upstream Envisat series (red and green)

Gauge series (black)



Downstream Envisat series (purple and blue)

Results :

	ICE-1 (m)	ICE-3 (m)
Envisat	1.04 ± 0.21 Corsica: 0.77 ± 0.11 (std)	/
Jason-2	0.64 ± 0.33 Corsica: 0.58 ± 0.17 (std)	0.58 ± 0.34

Method: transfer upstream and downstream series to the gauge location using a linear or quadratic model and compare to the gauges series => Biases

Conclusion: over rivers, altimetry biases vary

- with mission/altimeter (ENV-RA2+*ICE-1* ≠ J2-Pos3 + *ICE-1*)
- with algorithm (J2+*ICE1* ≠ J2+*ICE3*, and ≠ from J2+*ocean/MLE4*)

and probably with location (as suggested by the large σ)

Poster
7

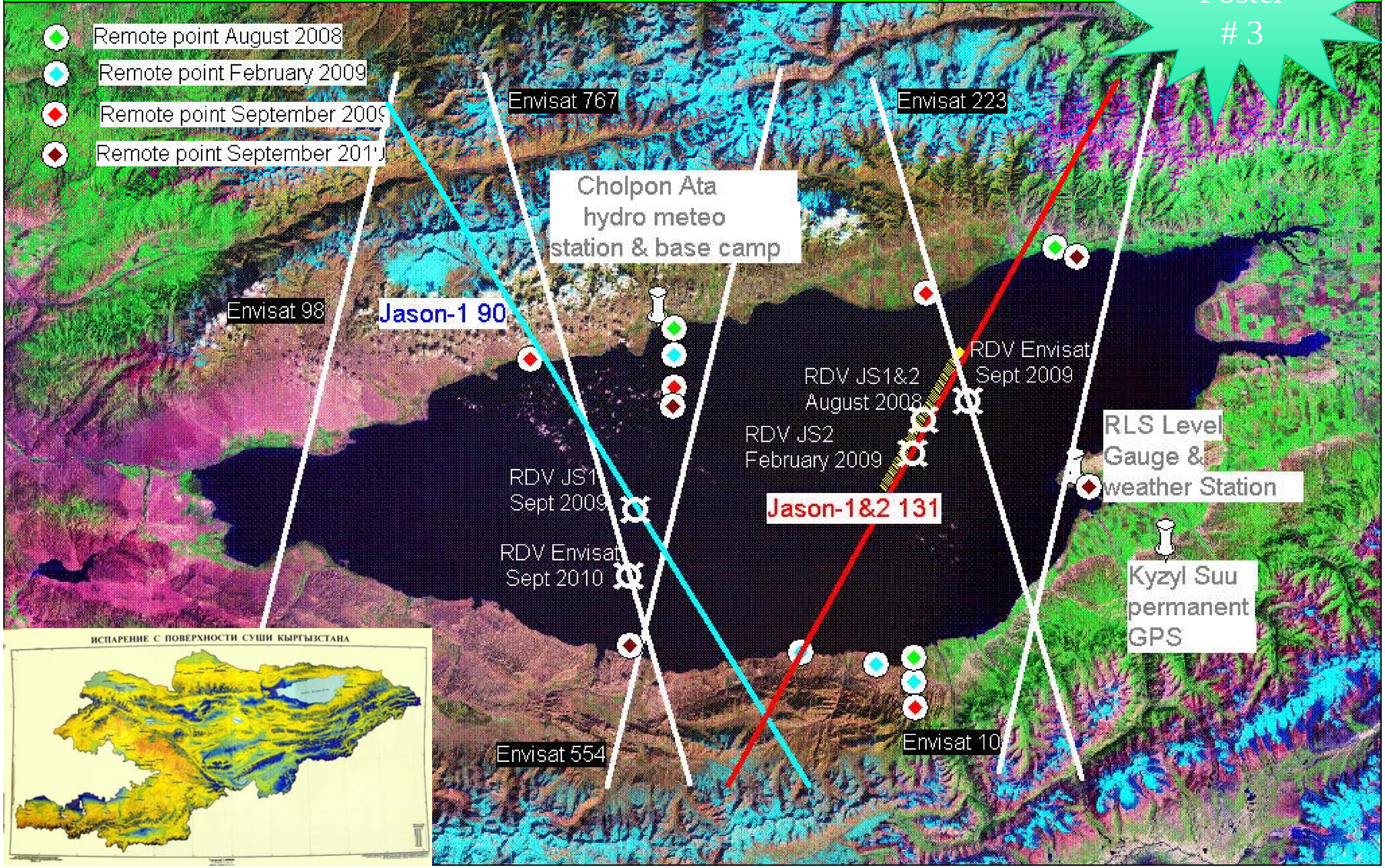
Absolute calibration of altimeters over the Lake Issykkul

8 field campaigns between 2004 and 2012 for multi satellite Cal/Val

Results for Jason-1 and Jason-2 over 2 campaigns in 2009

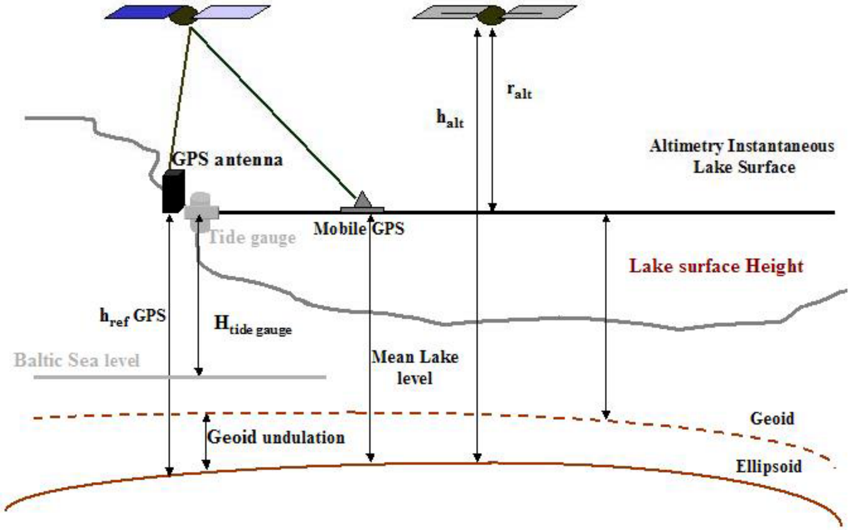
In the frame of the FOAM project funded by CNES

Poster # 3



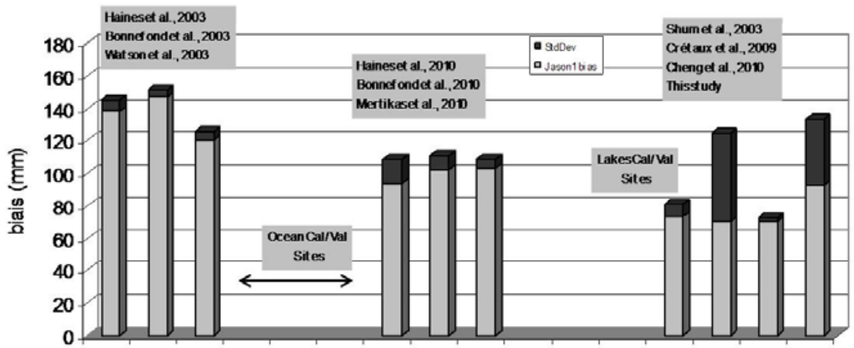
Absolute calibration of altimeters over the Lake Issykkul

J.-F. CRETAUX, M. BERGÉ-NGUYEN, S. CALMANT, V. ROMANOVSKI, B. MEYSSIGNAC, F. PEROSANZ, S. TASHBAEVA, A. ARSEN, F. FUND, N. MARTIGNANO, P. BONNEFOND, O. LAURAIN, R. MORROW, P. MAISONGRANDE

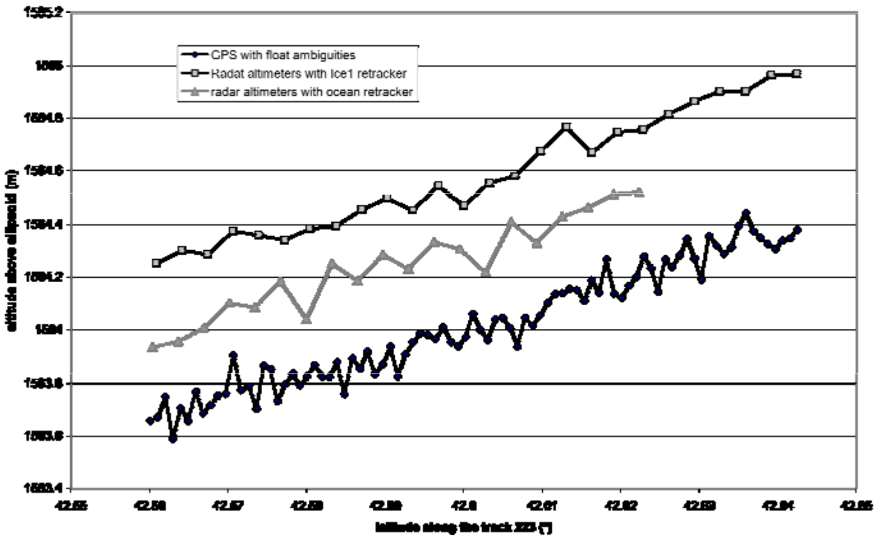


altimetry Calibration principle from GPS
On lake surface

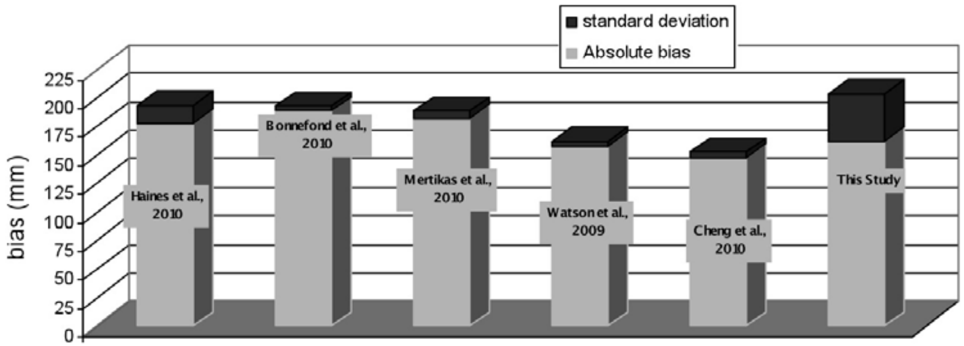
Absolute bias of Jason-1



Absolute bias of Envisat



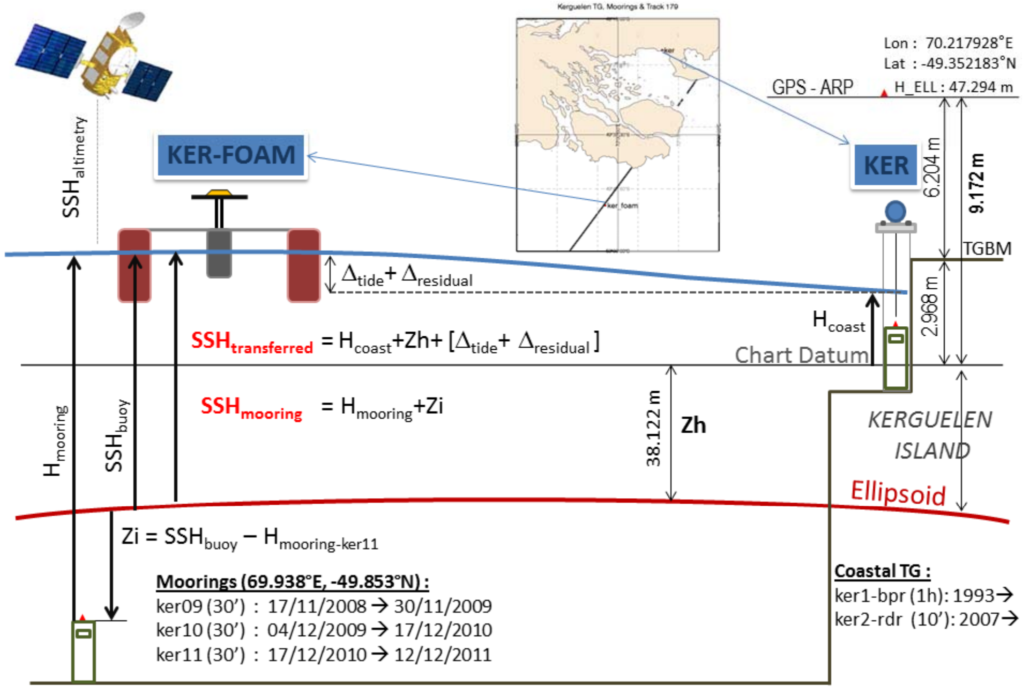
Absolute bias of Jason-2



Kerguelen Islands CAL/VAL activities

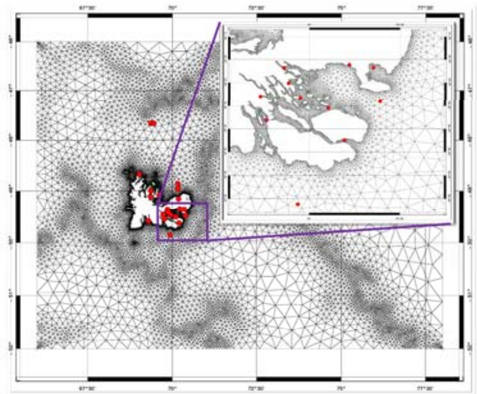
Poster # 13

L. Testut (LEGOS), P. Bonnefond, O. Laurain (OCA), M. Calzas, A. Guillot, C. Drezen (DT/INSU)



- **Permanent TG since 1993 at 20 Km from cal/val site**
- **Deployment of 3 moorings since 2009 under track #179**
- **GPS buoy session at cal/val site**
- **Instrumental developpement of a GPS buoy with DT/INSU**
- **Development of HR barotropic model for dealiasing**

	Jason-1 GDR-C	Jason-2 GDR-T	Jason-2 GDR-D
KER-FOAM (M1)	+47 mm (std=35)	+116 mm (std=41)	-71 mm (std=43)
KER1-BPR (M2)	-6 mm (std=55)	+96 mm (std=44)	-89 mm (std=48)
KER2-RDR (M3)	+46 mm (std=49)	+114 mm (std=48)	-70 mm (std=52)
Mean	+29 mm (std=46)	+109 mm (std=44)	-77 mm (std=48)
CORSICA	*+77 mm (std=35)*	*+155 mm (std=35)*	*-1 mm (std=37)*



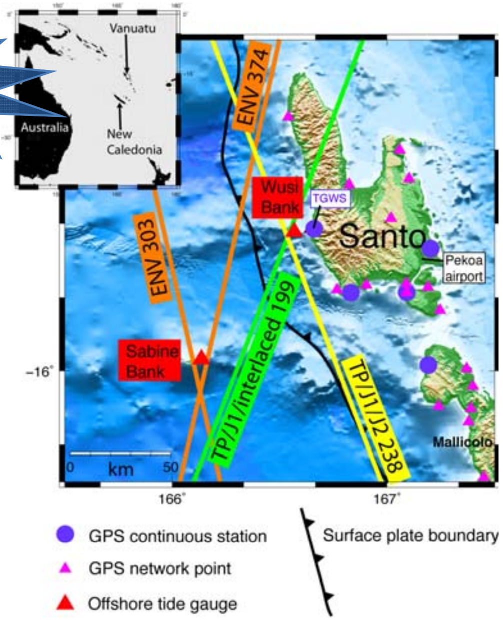
The absolute differences in the biases are due to the uncertainty of the link (mainly geoid) between the offshore (KER-FOAM) and the coastal (KER) in situ data: realized with only a 3-hour session of the GPS buoy. This will be updated in a near future

Vanuatu:

Poster # 67

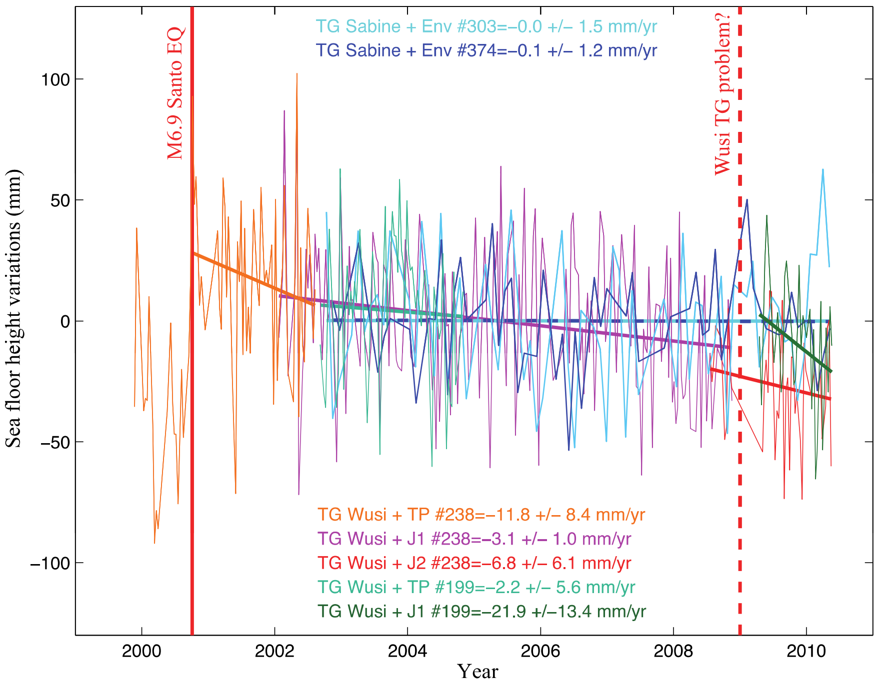
Using radar altimetry, combined with bottom pressure data, to measure underwater vertical movements

V. BALLU, P. BONNEFOND, S. CALMANT, M.-N. BOUIN, B. PELLETIER, W. CRAWFORD, C. BAILLARD, O. LAURAIN, O. DE VIRON



Comparing altimetry and seafloor pressure data in non-dedicated sites can bring new insights on:

- Calibration aspects that need specific configuration (ex. problem of coastal land contamination)
- Development of new geodetic methods (here the measurement of seafloor vertical motion, due to geodynamics).



Combining altimetry and seafloor pressure, we have demonstrated **subsidence of the over-ridding plate close to the plate limit**.

Evidence for locking of the subduction (earthquake risk).

=> This was made possible thanks to recent reprocessing of Envisat that reconciles the SSH series with those of T/P and Jason-1&2

Developing new applications of altimetry, for measuring ground deformation: towards a better assessment of seismic risk in subduction zones.

NOVELTIS

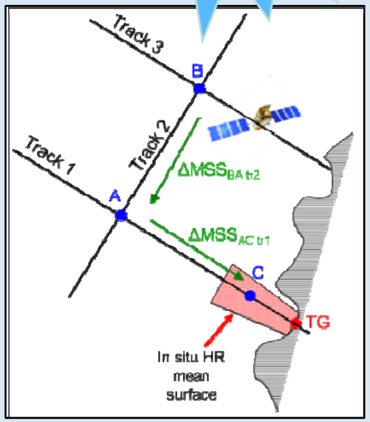
Regional CALVAL method in Corsica: Validation of the Jason-1, Jason-2 and Envisat missions at non-dedicated sites

Poster # 14

M. Cancet, E. Jeansou, P. Bonnefond, O. Laurain, F. Lyard, P. Femenias, E. Bronner

Generic regional CALVAL method:

✓for any satellite altimetry mission, even without any dedicated calibration site
✓for any types of orbits including non-repetitive ones
✓to multiply the estimates to reduce the noise in the mission bias quantification
✓to monitor the missions at non-dedicated sites

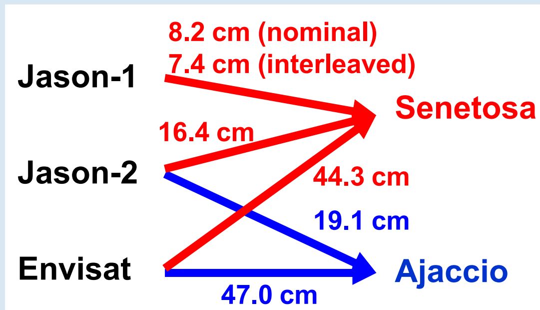


… developed for the Senetosa calibration site and TP/Jason nominal orbit

→Need for an evaluation of the method robustness

- at other sites than Senetosa → Ajaccio
- for other orbits → Envisat nominal orbit, J1 interleaved mission

➔ Cross-calibration experiment for Jason-2 and Envisat in Corsica



Main results:

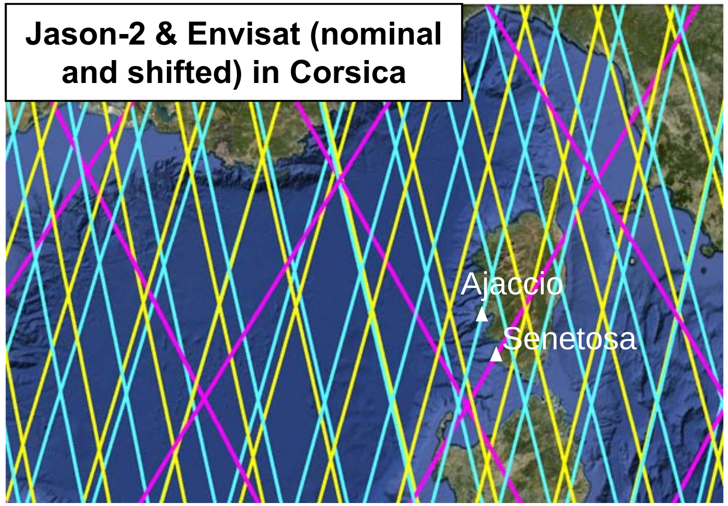
✓In Senetosa, for the three missions:

→Very coherent results, in agreement with the estimates of the other groups
Jason-1/2 in Senetosa, Harvest, Gavdos and Bass Strait, Envisat in Ajaccio

✓In Ajaccio for Envisat and Jason-2:

→Differences up to ~2.5cm in some cases, probably linked to dubious in situ measurements in the tide gauge time series ➔ Still under investigation

Cancet et al., 2012, ASR, special issue on Altimetry Calibration



Jason-2 & Envisat (nominal and shifted) in Corsica

Jason-2 & Envisat (nominal and shifted) in Harvest

Future work

Calibration of Envisat shifted orbit in Corsica

→First experiment of local/regional in situ calibration

Calibration of Envisat nominal and shifted orbits in Harvest

→First local in situ calibration of Envisat in Harvest

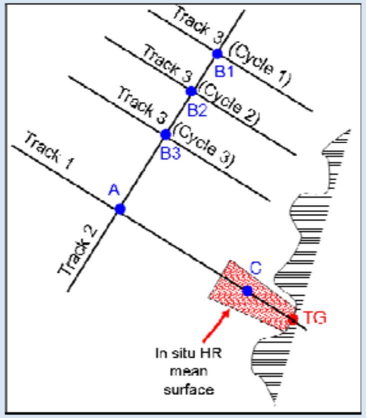
→Different ocean dynamics conditions / Corsica

→More local points for comparison with the global CALVAL

Perspectives

Calibration of non-repetitive orbits

→Estimation of the bias for missions on non-repetitive orbits, at various calibration sites (ex: Cryosat-2)



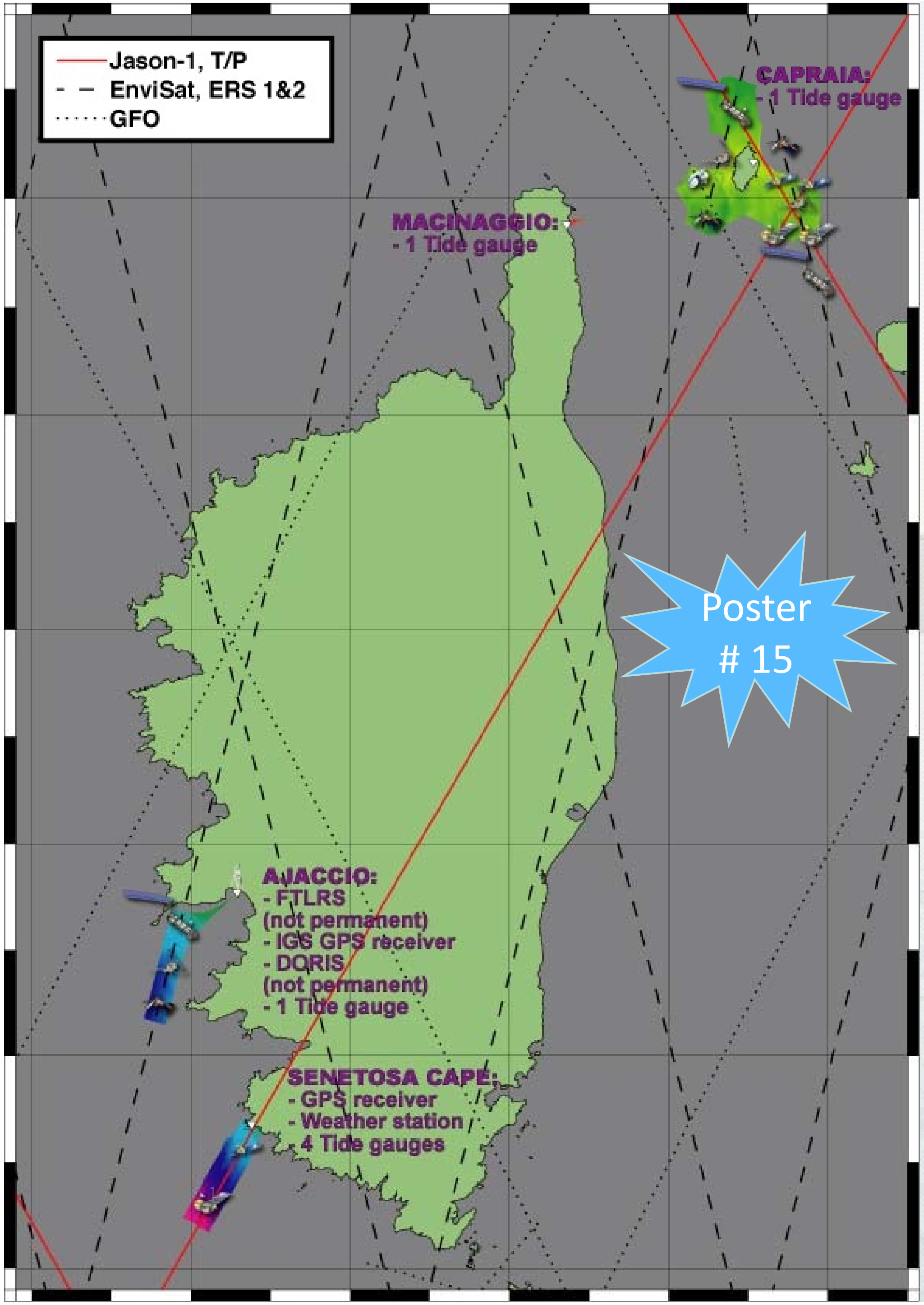
Regional method for non-repetitive orbits

Calibration of missions on new orbits

→Estimation of the bias for missions without any dedicated calibration site (ex: Sentinel-3)

Future missions: AltiKa, Sentinel-3, Jason-3, Jason-CS…

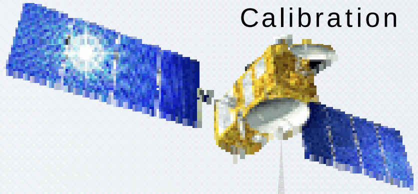
Other sites: Harvest, Gavdos, Bass Strait…



Corsica Calibration Site

Corsica
Absolute
Altimeters
Calibration

P. BONNEFOND,
P. EXERTIER,
O. LAURAIN,
T. GUINLE,
P. FÉMÉNIAS

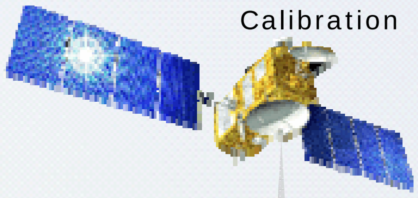


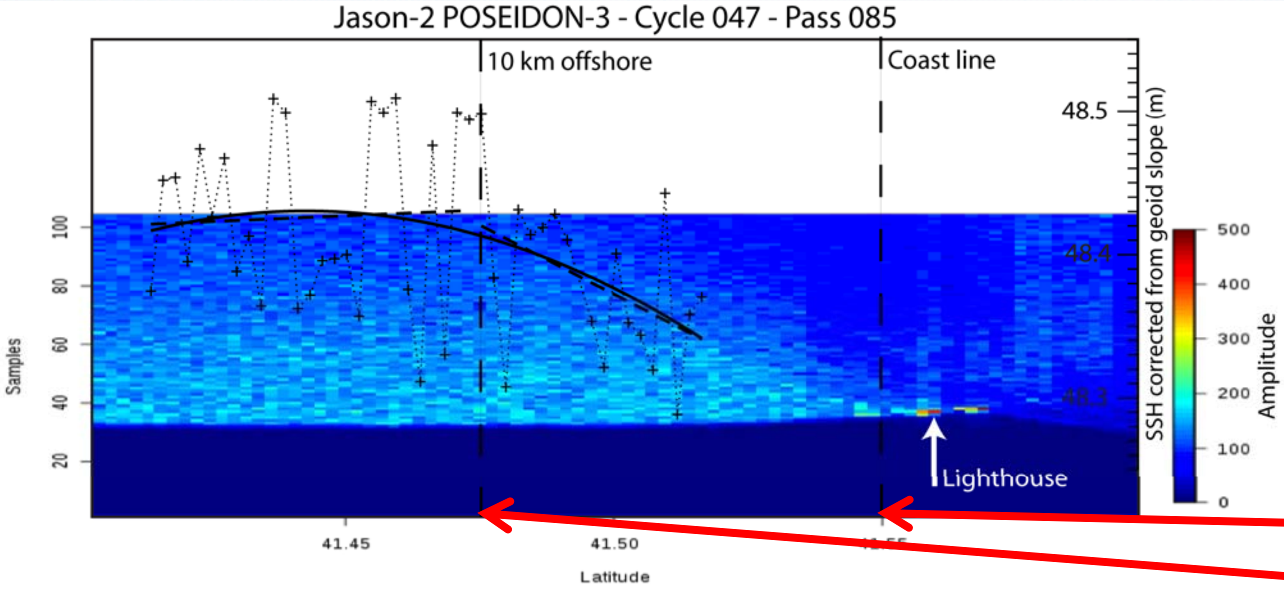
- **OCA/CNES calibration site established in 1998**
- Supports continuous monitoring of Jason-1&2 (and formerly T/P)
- **Employs distributed configuration**
  - Fiducial point near **Ajaccio** equipped with a **tide gauge** and **GPS/FTLRS/DORIS**.
  - **Senetosa** coastal site (along ground track) equipped with **tide gauges and GPS**.
  - Open-ocean verification points for **GPS buoy deployments**.
- Open-ocean altimeter readings connected to tide gauges via **detailed local geoid model**
  - Derived from intensive GPS buoy and catamaran surveys along ground track.
- **Extension to Ajaccio (2005) and Capraia (2004)**
  - EnviSat, ERS, GFO, Jason-1&2 and **soon SARAL/AltiKa**.

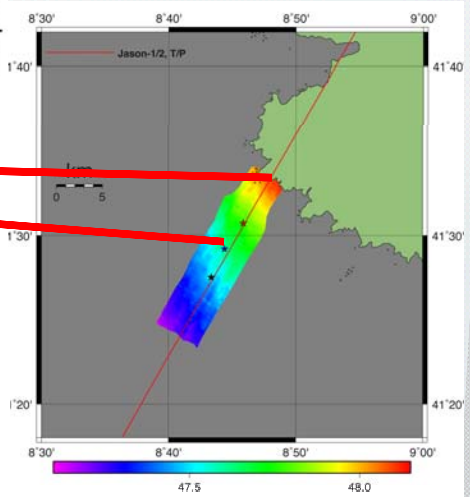
SITE DESCRIPTION

Land contamination

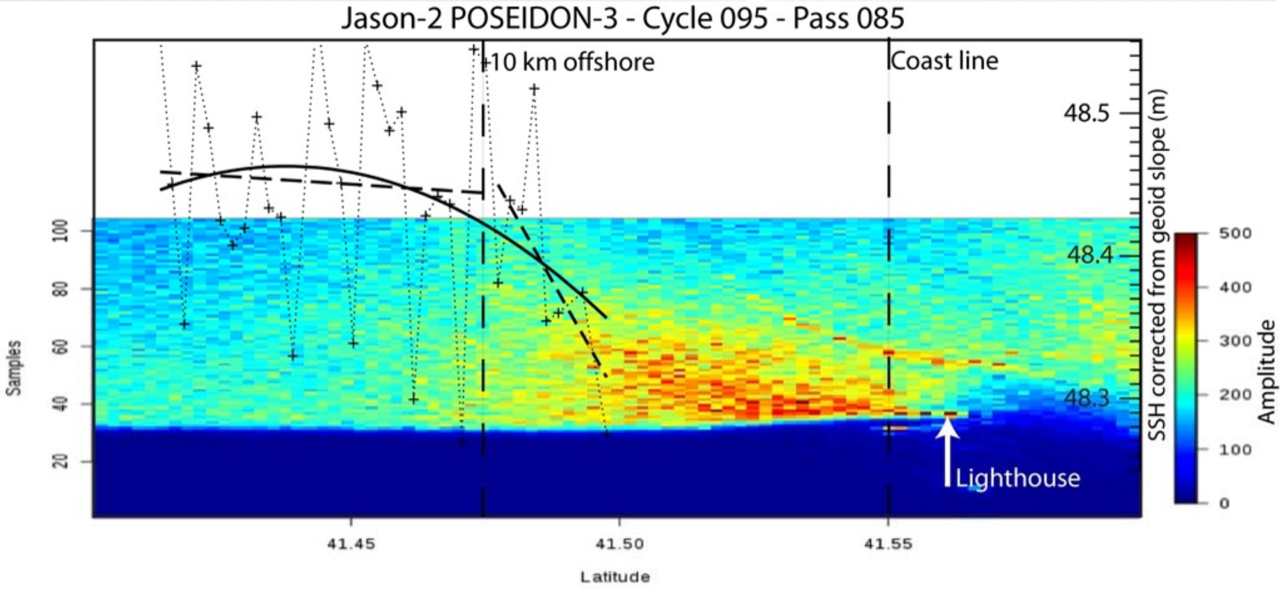
Corsica Absolute Altimeters Calibration



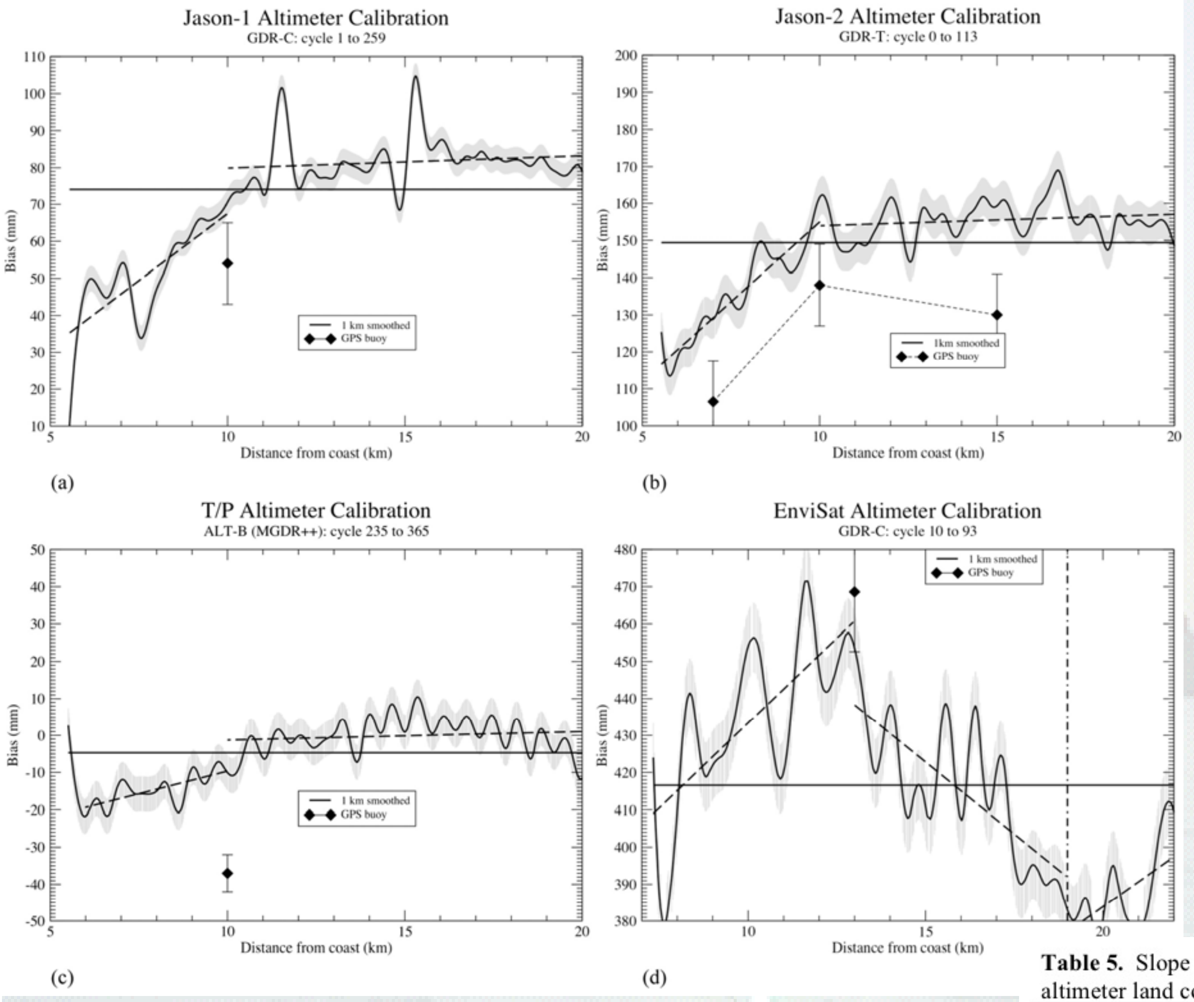




Land contamination + Sea State effects



ALTIMETER CONTAMINATION



Corsica
Absolute
Altimeters
Calibration

Bonnefond et al., **GPS-based sea level measurements to help the characterization of land contamination in coastal areas**, ***Advances in Space Research***, Available online 14 July 2012, ISSN 0273-1177, 10.1016/j.asr.2012.07.007.

See also poster # 15

ALTIMETER CONTAMINATION

Integrated effect of the land contamination over the full set of data available

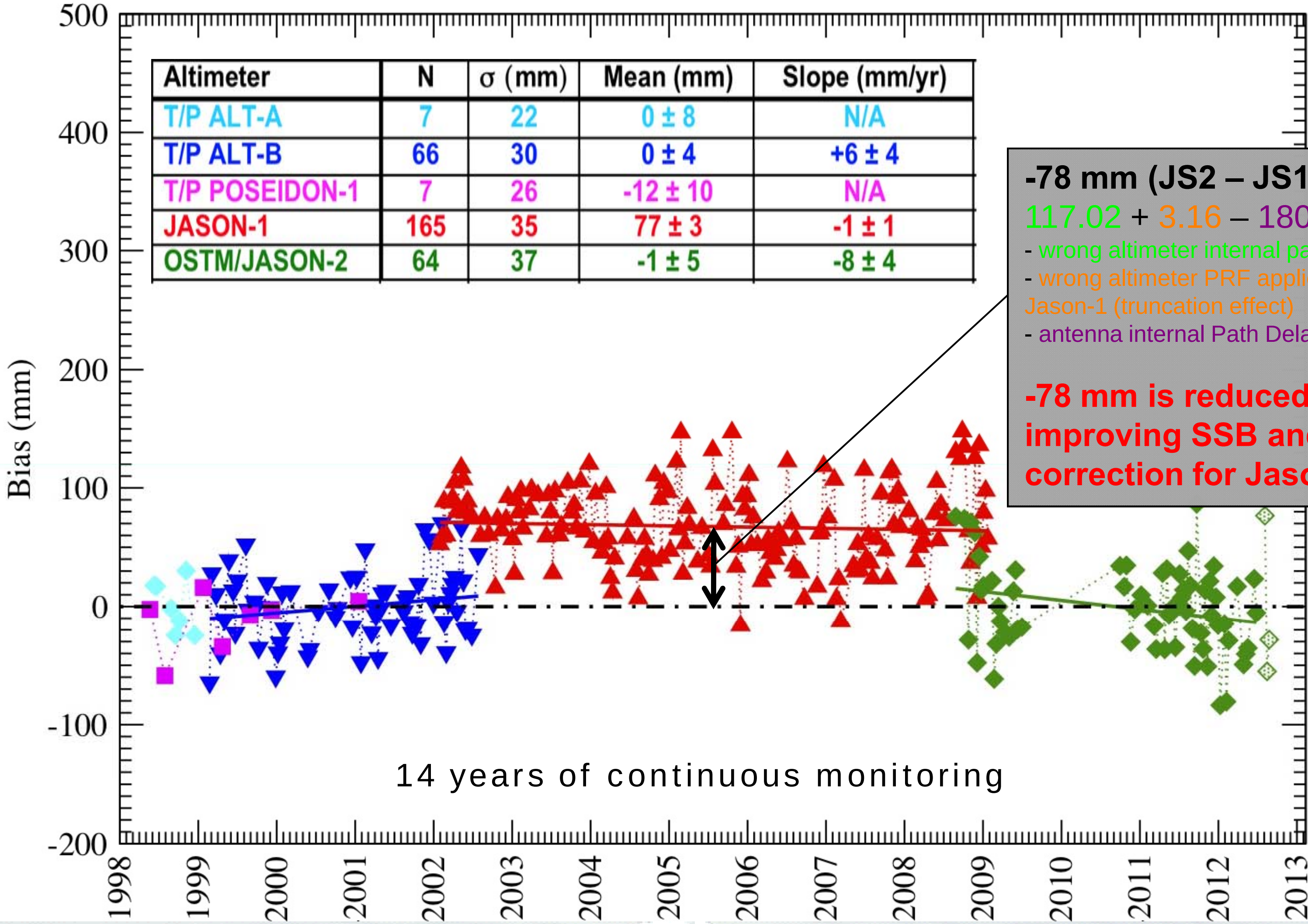
For each cycle, the SSH bias (altimeter - tide gauge) is the result of the mean of all the SSH biases evaluated at each 20-Hz (or 10-Hz for T/P) point on approach to the coast and entering the surfaces mapped with the Catamaran-GPS. These individual "high-rate biases" are saved and can be stacked over a long period to be able to extract any persistent behavior as a function of distance to the coast.

Table 5. Slope in the SSH and bias differences due to the altimeter land contamination (derived from Figure 7)

Site / Instrument	Slope (mm/km)	Bias differences* (mm)
Senetosa (5 km to 10 km)		
ALT-B (TOPEX/Poseidon)	+2.4	+4.6
POSEIDON-2 (Jason-1)	+7.2	+7.6
POSEIDON-3 (Jason-2	+8.6	+6.1
Ajaccio (RA-2, Envisat)		~+30
7 km to 13 km	+9.1	
13 km to 19 km	-7.7	
19 km to 22 km	+6.8	

*estimated from the area where altimeter should not be contaminated: 10 km to 20 km at Senetosa and only at 13 km for Ajaccio (see text in the beginning of section 3.1.1 for details).

Corsica
Absolute
Altimeters
Calibration



Altimeter	N	σ (mm)	Mean (mm)	Slope (mm/yr)
T/P ALT-A	7	22	0 ± 8	N/A
T/P ALT-B	66	30	0 ± 4	+6 ± 4
T/P POSEIDON-1	7	26	-12 ± 10	N/A
JASON-1	165	35	77 ± 3	-1 ± 1
OSTM/JASON-2	64	37	-1 ± 5	-8 ± 4

-78 mm (JS2 – JS1) to be compared to:

117.02 + 3.16 – 180.92 = **-60.74 mm**

- wrong altimeter internal path delay value used on Jason-1
- wrong altimeter PRF applied in the ground segment on Jason-1 (truncation effect)
- antenna internal Path Delay reference error

-78 mm is reduced to -68 mm when improving SSB and wet radiometer correction for Jason-1

IASES TIME SERIES

Products used (processed with NO altimeter land contamination effect):

T/P: **MGDR + TMR replacement products + std0905 orbits (GSFC)**

Jason-1: **GDR-C (cycle 1 to 259)**

Jason-2: **GDR-D (cycle 1-36 / 82-146) MLE4 = -1 ±5 mm**

Jason-2: **GDR-D (cycle 1-36 / 82-146) MLE3 = +22 ±5 mm => ≠ by 23 mm (mainly SSB)**

From GDR-T to GDR-D: mainly SSB but also iono and wet corrections differences

Differences (mm) in the measurement system between T/P, Jason-1 and Jason-2 during the Formation Flight Phases on common cycles

	Absolute biases	Orbit - Range	Corrections	Expected from remaining instrumental errors*
T/P ALT-B (MGDR) – Jason-1 POS-2 (GDR-C)	83	79	-4	*-61*
T/P ALT-B (improved MGDR**) – Jason-1 POS-2 (improved GDR-C***)	81	84	+3	*-61*
Jason-2 POS-3 (GDR-D) – Jason-1 POS-2 (GDR-C)	-74	-58	+16	-61
Jason-2 POS-3 (GDR-D) – Jason-1 POS-2 (improved GDR-C***)	-61	-58	+3	-61

* 117.02 + 3.16 – 180.92 = **-60.74 mm (Jason-2 – Jason-1)**

- wrong altimeter internal path delay value used on Jason-1
- wrong altimeter PRF applied in the ground segment on Jason-1 (truncation effect)
- antenna internal Path Delay reference error

** TMR replacement products + std0905 orbits (GSFC)

*** new MLE4 SSB (Tran et al., 2010) and Enhanced Path Delay (Brown, 2010)

Dry = -9 mm
Wet = +19 mm
Iono dual = +3 mm
SSB = -17 mm

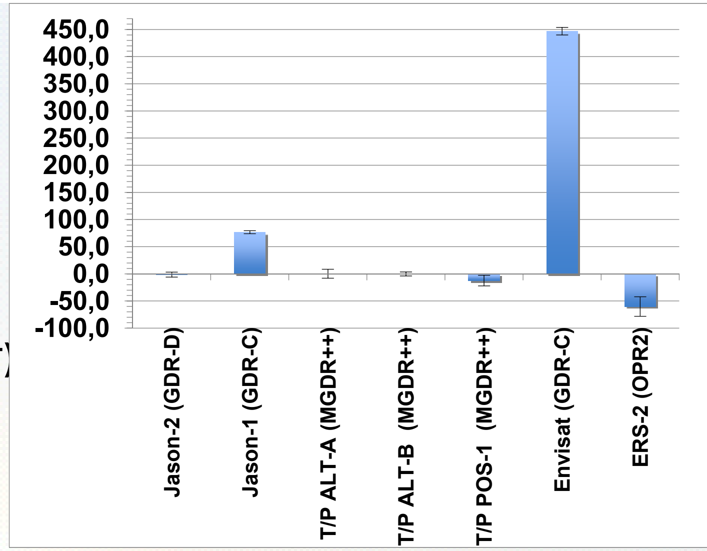
Dry = -9 mm
Wet = 0 mm
Iono dual = +3 mm
SSB = +9 mm

Wet = -15 mm
Iono dual = +7 mm
SSB = +24 mm

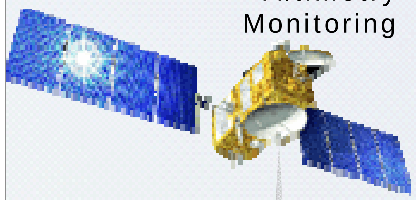
Very close to what is expected from remaining instrumental errors

Iono dual = +7 mm
SSB = -4 mm

Calibration from Corsica



From Ocean
to inland waters
Altimetry
Monitoring



<u>Absolute biases over the whole data sets:</u>

Jason-2: -1 ±5 mm (GDR-D)
Jason-1: +77 ±3 mm (GDR-C)
T/P ALT-A: 0 ±8 mm (MGDR++)
T/P ALT-B: 0 ±4 mm (MGDR++)
T/P POS-1: -12 ±10 mm (MGDR++)
EnviSat: +447 ±7 mm (GDR-C)
ERS-2: -60 ±18 mm (OPR-2)

<u>Jason-1&2 main results:</u>

Better agreement between Jason-1&2 during FFP when upgrading Jason-1 (wet/EPD+SSB)

=> differences very close to expected remaining instrumental errors

Jason-2 with GDR-D => no more significant SSH bias

Jason-2 retracking => SSH relative bias (MLE4-MLE3) = -23 mm (mainly SSB) and ranges have different behavior when approaching the coast (<10 km)

FOAM major issues

Inland waters:

Amazon basin: **Jason-2 and Envisat biases (ICE1) close to Corsica study**

Issyk Kul lake: **very coherent results with those from the different calibration sites (as noticed during OSTST 2011)**

Ocean

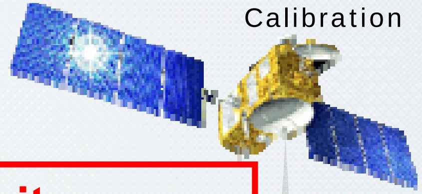
Regional calibration: **coherent results with absolute calibration in Corsica**

Kerguelen: **first results very encouraging, need to better tie offshore /**

FOAM Follow-on is on going with focus on new missions (SARAL/Altika, ...), new retrackings and new technologies (GPS-reflectometry), ...

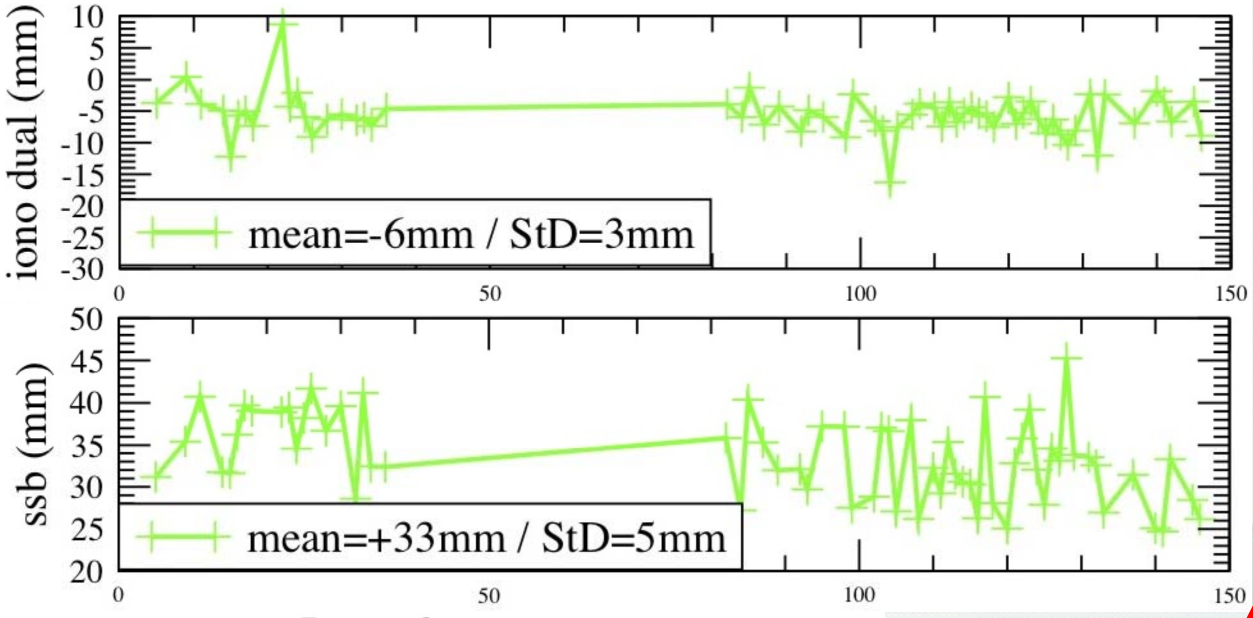
CONCLUSION

Corsica
Absolute
Altimeters
Calibration

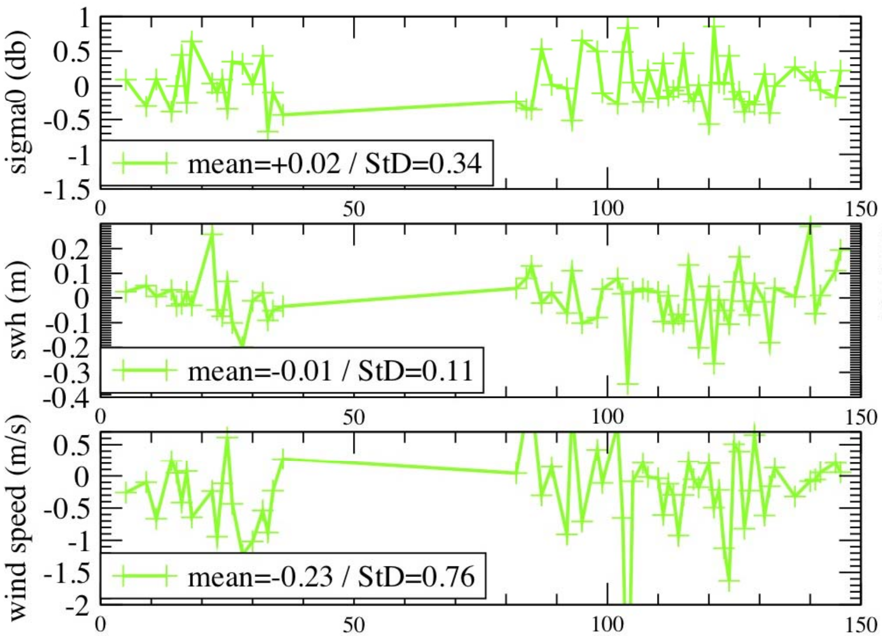


GDR-D MLE4 vs MLE3

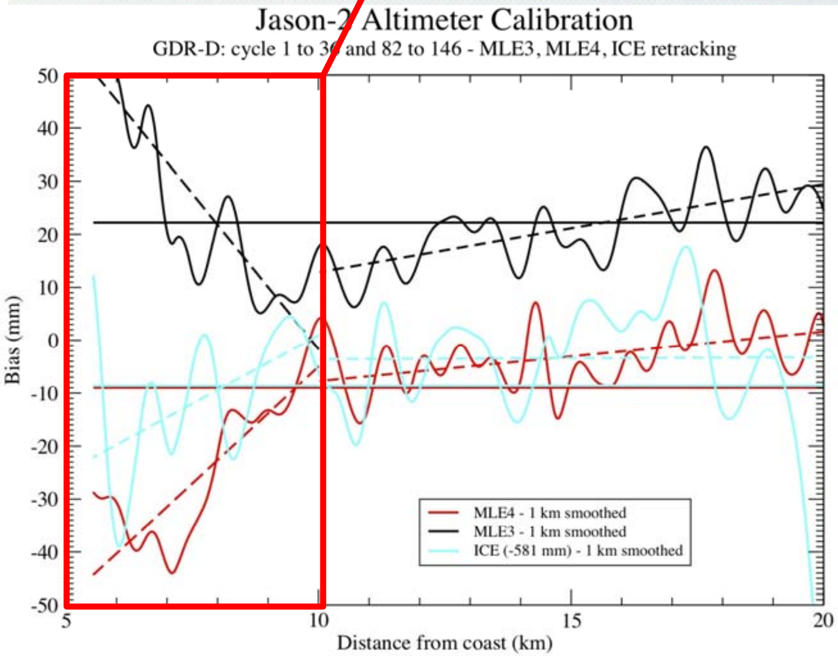
Jason-2 Corrections
GDRD (MLE4 - MLE3)



Jason-2 parameters
GDRD (MLE4 - MLE3)

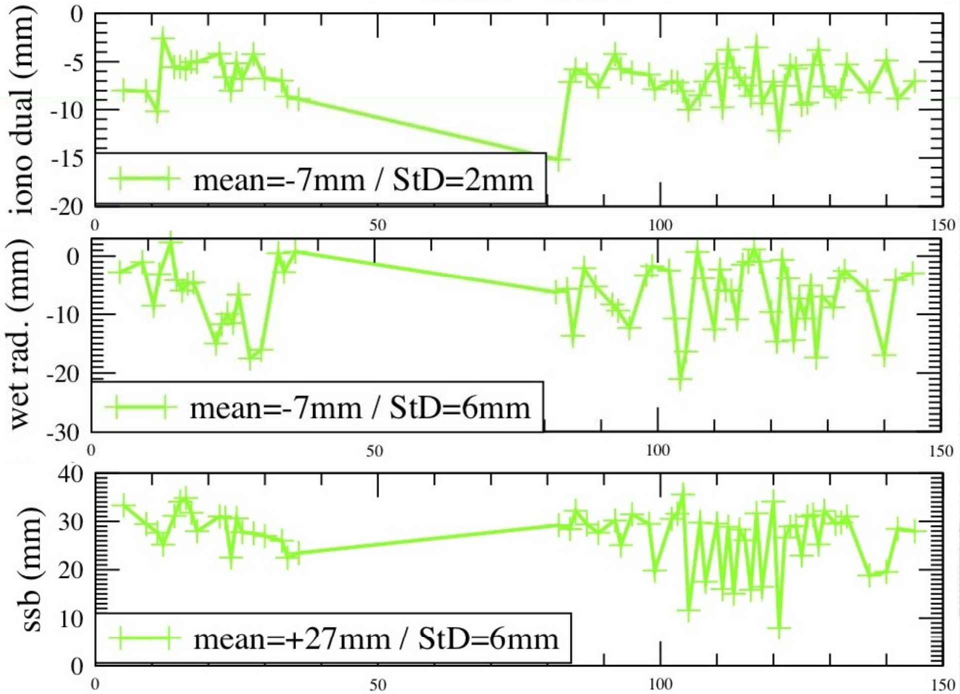


Opposite behavior from 10 km up to the coast



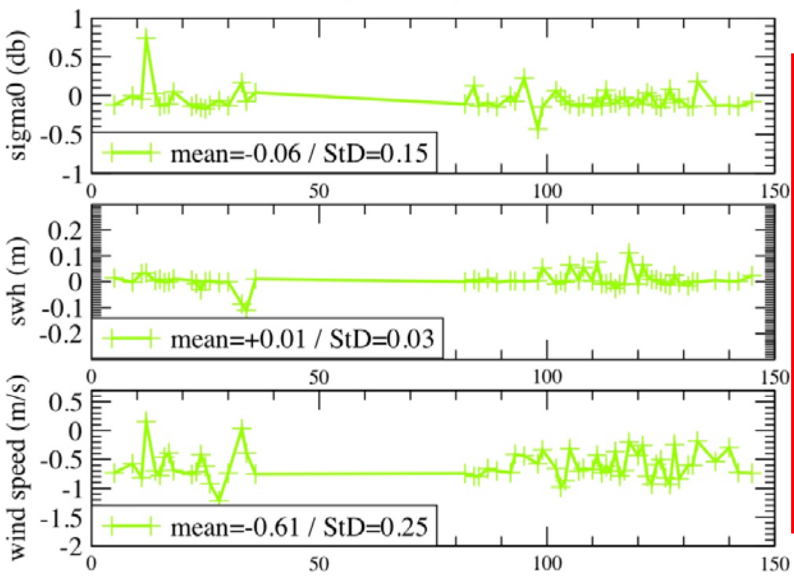
Jason-2 Corrections

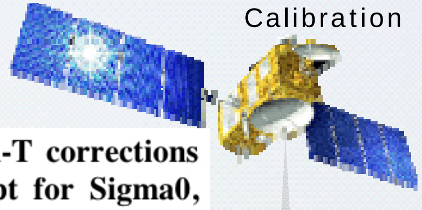
GDR-D - GDR-T



Jason-2 parameters

GDR-D - GDR-T





Jason-2 GDR-D minus Jason-2 GDR-T corrections and biases differences in mm (except for Sigma0, Significant Wave Height and wind speed)

	Mean	σ
Corrections		
Wet troposphere (AMR)	-7	6
Ionosphere (dual frq.)	-7	2
Sea State Bias	+27	6
Total	**+13**	
Environmental parameters		
Sigma0 (dB)	-0.06	0.15
SWH (m)	+0.01	0.03
Wind speed (m/s)	-0.61	0.25
Biases		
Absolute biases	-155	16
Orbit - range	-142	10

~-156 expected from instrumental errors:

24.71 – 180.92 = **-156.21 mm**

- wrong altimeter PRF applied in the ground segment on Jason-2 (truncation effect)
- antenna internal Path Delay reference error

Differences comes mainly from:

- MQE fit regional differences: ~4 mm
- GDR-D – GDR-T orbit differences: ~3 mm
- pseudo datation bias: ~4 mm

=> ~3 mm remains unexplained, waiting for the complete set for better averaging

GDR-D vs GDR-T