Corsica: a multi-mission absolute calibration site

P. Bonnefond[(1)], P. Exertier[(2)], O. Laurain[(2)], A. Guillot[(3)] , T. Guinle[(3)] , N. Picot[(3)] , P. Féménias[(4)]

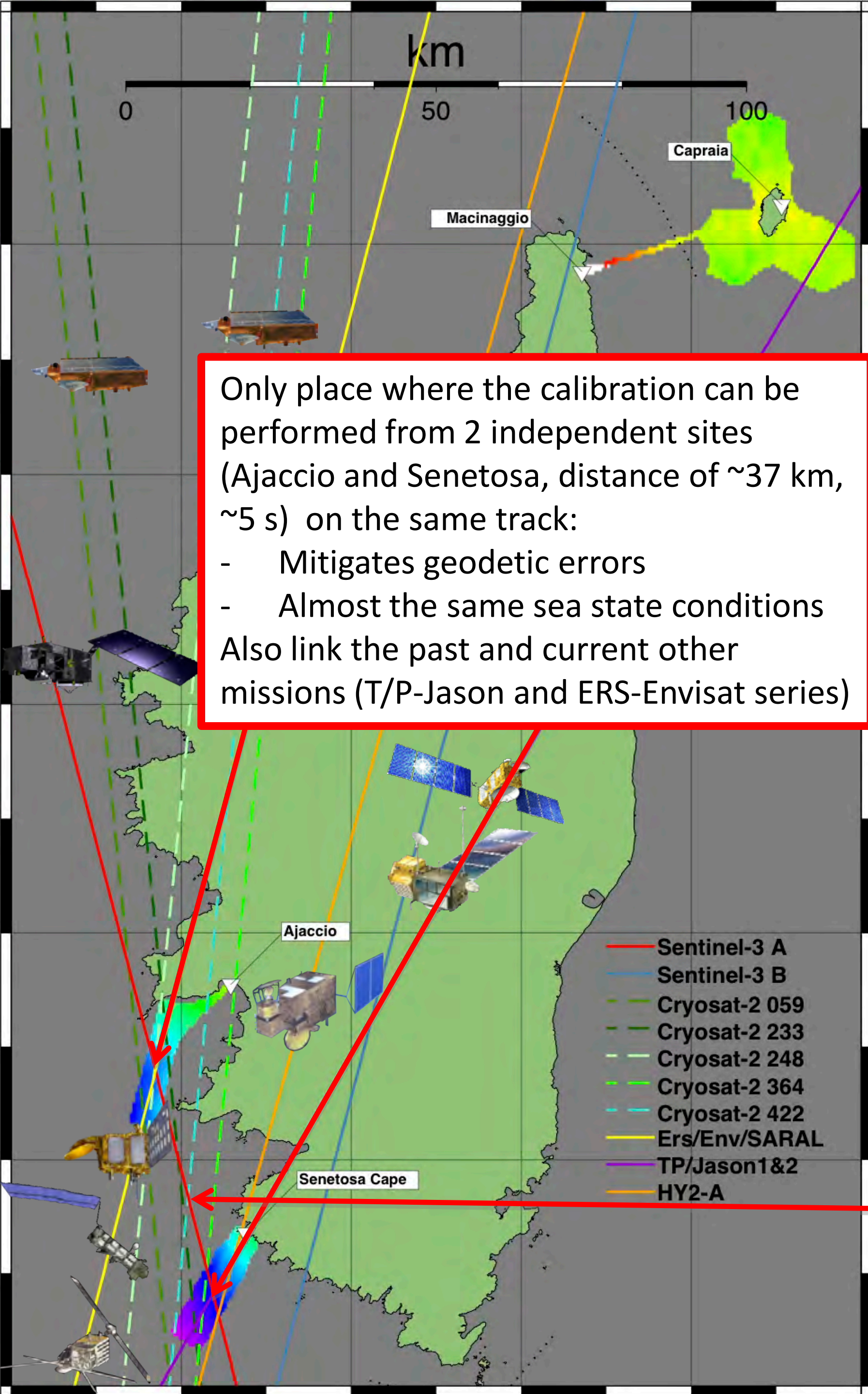
[(1)]Observatoire de Paris/SYRTE, Paris, France

[(2)]OCA/Geoazur, Sophia-Antipolis, France

[(3)]CNES, Toulouse, France

[(4)]ESA/ESRIN, Frascati, Italy

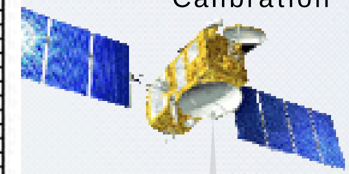
OSTST meeting – November 1-4, La Rochelle, France



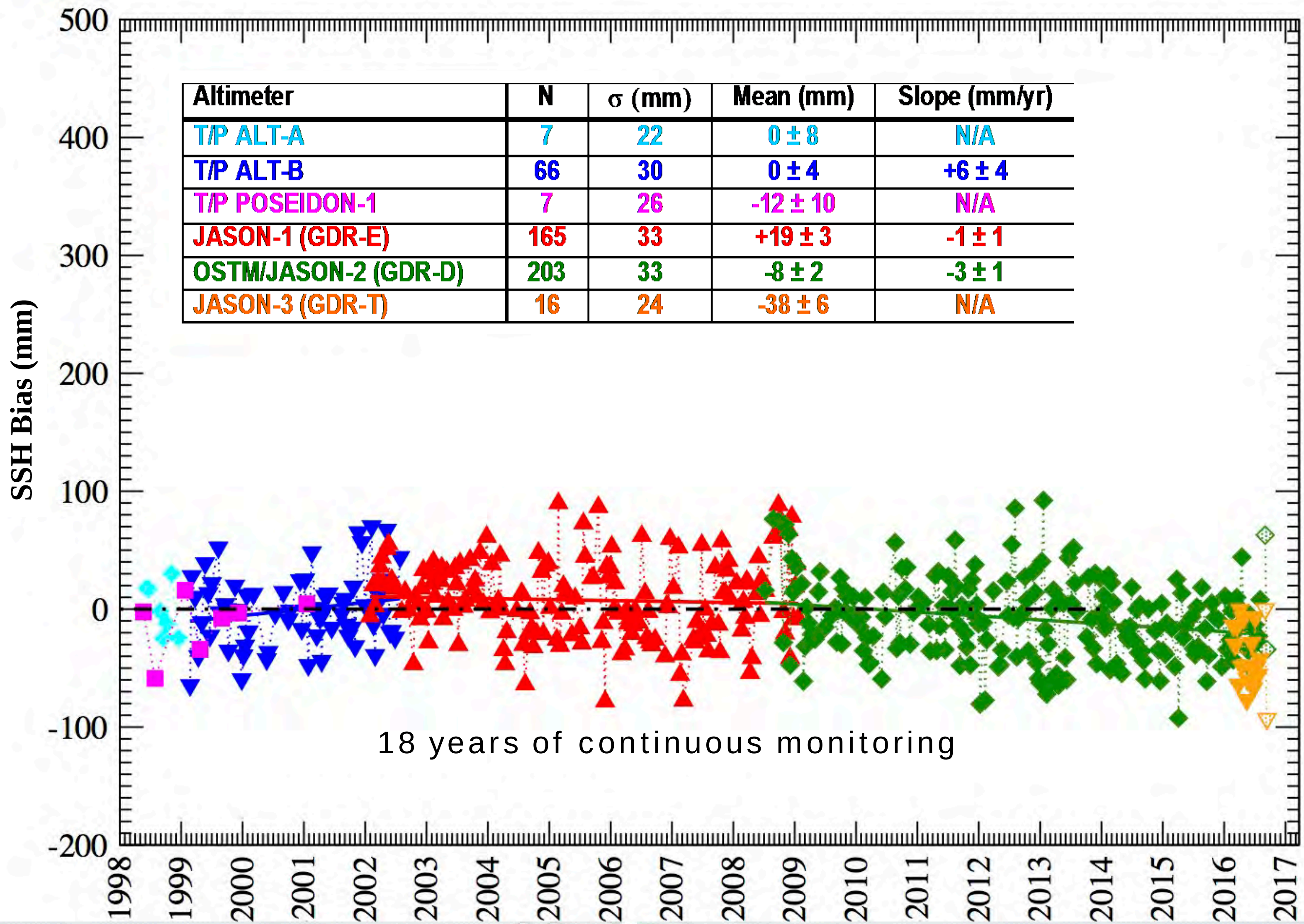
Corsica Multi-mission Calibration Site

- **Senetosa CNES calibration site** established in 1998
  - Supports continuous monitoring of Jason-2&3 (and formerly T/P and Jason-1)
  - Equipped with 4 pressure tide gauges leveled to the permanent GPS receiver
- **Ajaccio configuration** established in 2000
  - Supports continuous monitoring of SARAL/ALtiKa (and formerly ERS, Envisat)
  - Fiducial point near Ajaccio equipped with GPS/SLR(FTLRS)/DORIS.
  - Equipped with a radar tide gauge (SHOM) leveled to the permanent GPS receiver
- **Corsica multi-mission calibration site: existing facilities also used for CryoSat-2, HY-2A and Sentinel-3A**
- **Open-ocean altimeter readings** connected to tide gauges via detailed **local geoid model**
  - Derived from intensive GPS buoy and catamaran surveys along ground track (in 1999 for Senetosa). Extension to Ajaccio (2005) and Capraia (2004)
  - Open-ocean verification locations for GPS-based SSH measurement systems deployments.
  - **Planned connection of the Ajaccio and Senetosa local geoids along the Sentinel-3A track**

Corsica
Absolute
Altimeters
Calibration



BIASES TIME SERIES



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 (GDR-E)	165	33	+19 ± 3	-1 ± 1
OSTM/JASON-2 (GDR-D)	203	33	-8 ± 2	-3 ± 1
JASON-3 (GDR-T)	16	24	-38 ± 6	N/A

Products used:

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

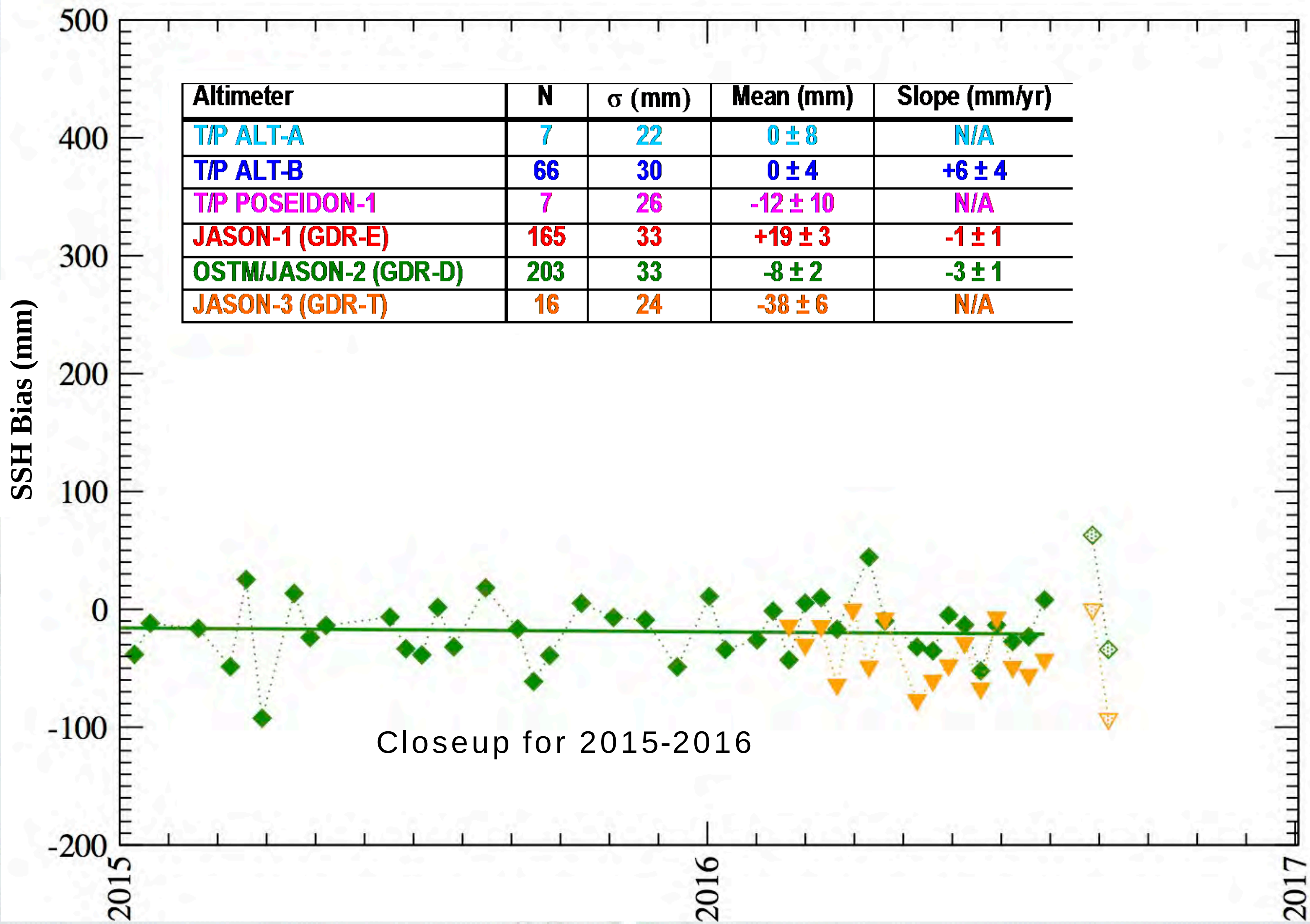
Jason-1: GDR-E (cycle 1-259)

Jason-2: GDR-D (cycle 1-298) (MLE3 = +15 ±3 mm => ≠ by -23 mm (mainly SSB))

Jason-3: GDR-T (cycle 1-19) (MLE3 = -23 ±7 mm => ≠ by -15 mm (mainly SSB))

Corsica Absolute Altimeters Calibration

BIASES TIME SERIES

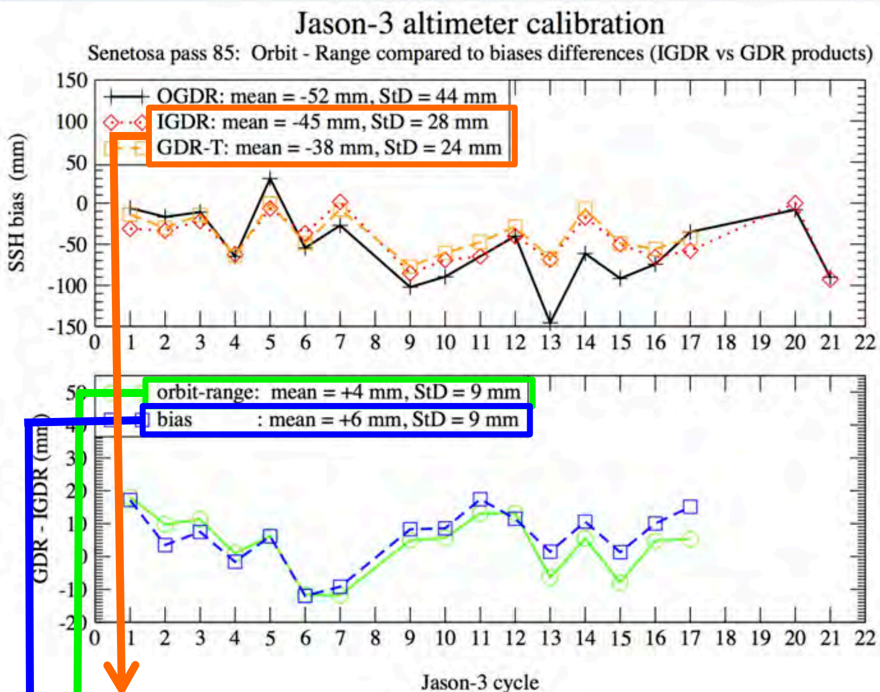


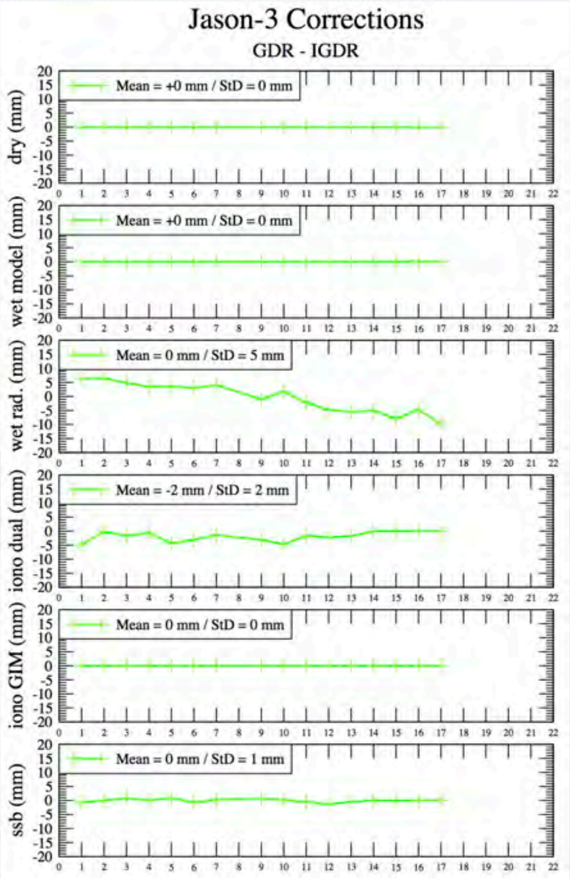
Altimeter	N	σ (mm)	Mean (mm)	Slope (mm/yr)
T/P ALT-A	7	22	0 ± 8	N/A
T/P ALT-B	66	30	0 ± 4	+6 ± 4
T/P POSEIDON-1	7	26	-12 ± 10	N/A
JASON-1 (GDR-E)	165	33	+19 ± 3	-1 ± 1
OSTM/JASON-2 (GDR-D)	203	33	-8 ± 2	-3 ± 1
JASON-3 (GDR-T)	16	24	-38 ± 6	N/A

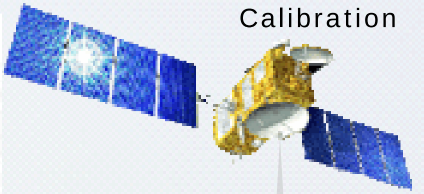
Products used:

T/P:	**MGDR + TMR replacement products + std0905 orbits (GSFC)**
Jason-1:	**GDR-E (cycle 1-259)**
Jason-2:	**GDR-D (cycle 1-298)**
Jason-3:	**GDR-T (cycle 1-19)**

Jason-3 SSH biases: OGDR, IGDR and GDR products







GDR-IGDR SSH bias differences is +7 mm
Better standard deviation for GDR
(improvement of 14 mm RSS)

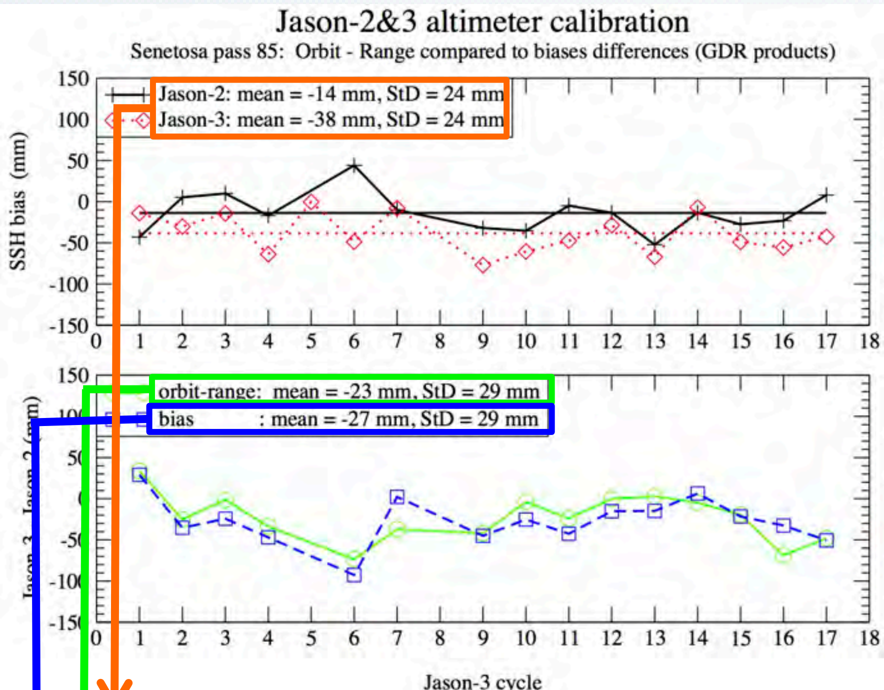
Most of the SSH bias differences come from the orbit-range (+4 mm) suggested that it comes from the orbit (range unchanged between IGDR and GDR).

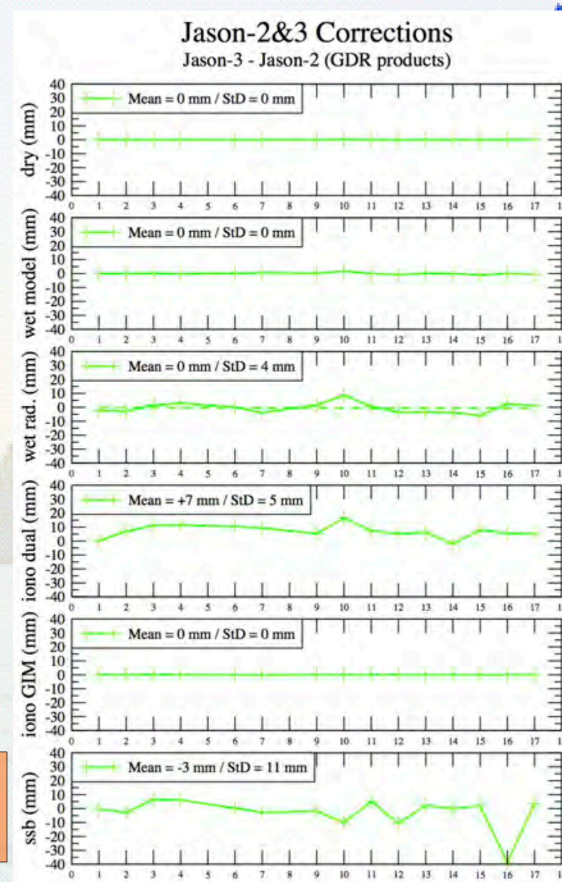
Except the orbit bias, differences between GDR and IGDR SSH bias are due to small correction contribution (-2 mm on average). Wet radiometer differences exhibits a trend (AMR calibration in GDR not applied in IGDR)

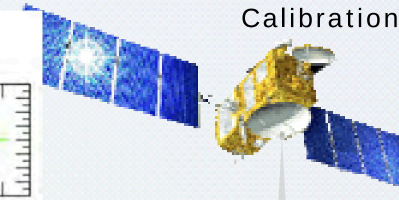
At the Corsica location the Jason-3 SSH bias is -38 mm based on 16 cycles of GDR-T product

JASON-3 SSH BIAS

Jason-3 & Jason-2 SSH biases (GDR product)







Jason-3 SSH bias lower by -24 mm (/Jason-2).
Same standard deviation for Jason-2&3

Most of the SSH bias differences come from the orbit-range (-23 mm) suggested that most of the Jason-3 and Jason-2 SSH biases difference comes from the range.

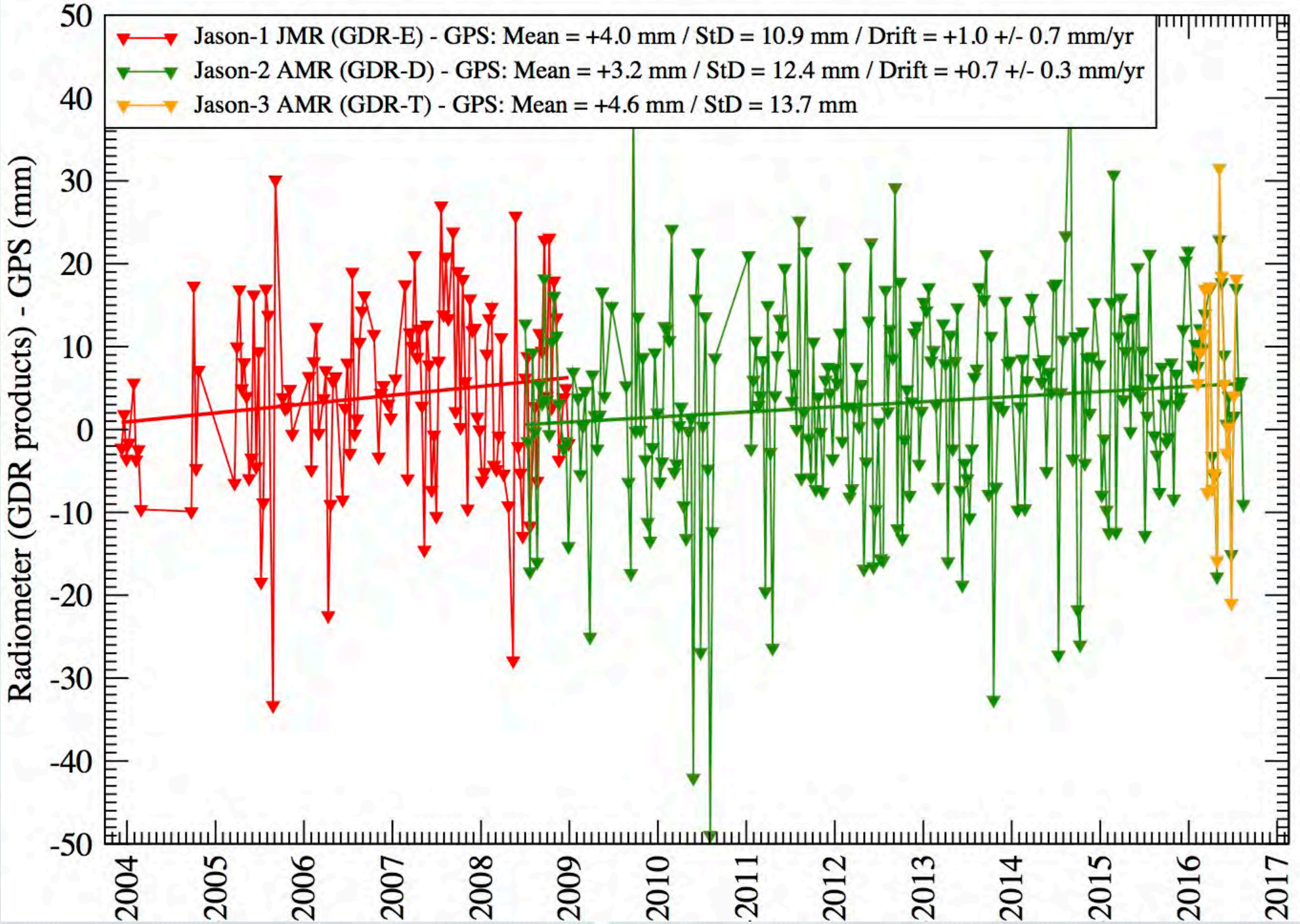
Except the range bias, differences between Jason-3 and Jason-2 SSH biases are due to dual iono (+7 mm, probably link to the Jason-3 range bias, Ku and C-band) and SSB (-3 mm).

From Corsica, Jason-3 exhibits a relative SSH bias of -27 mm compared to Jason-2 that mainly comes from a range bias of 23 mm

JASON-2&3 FFP

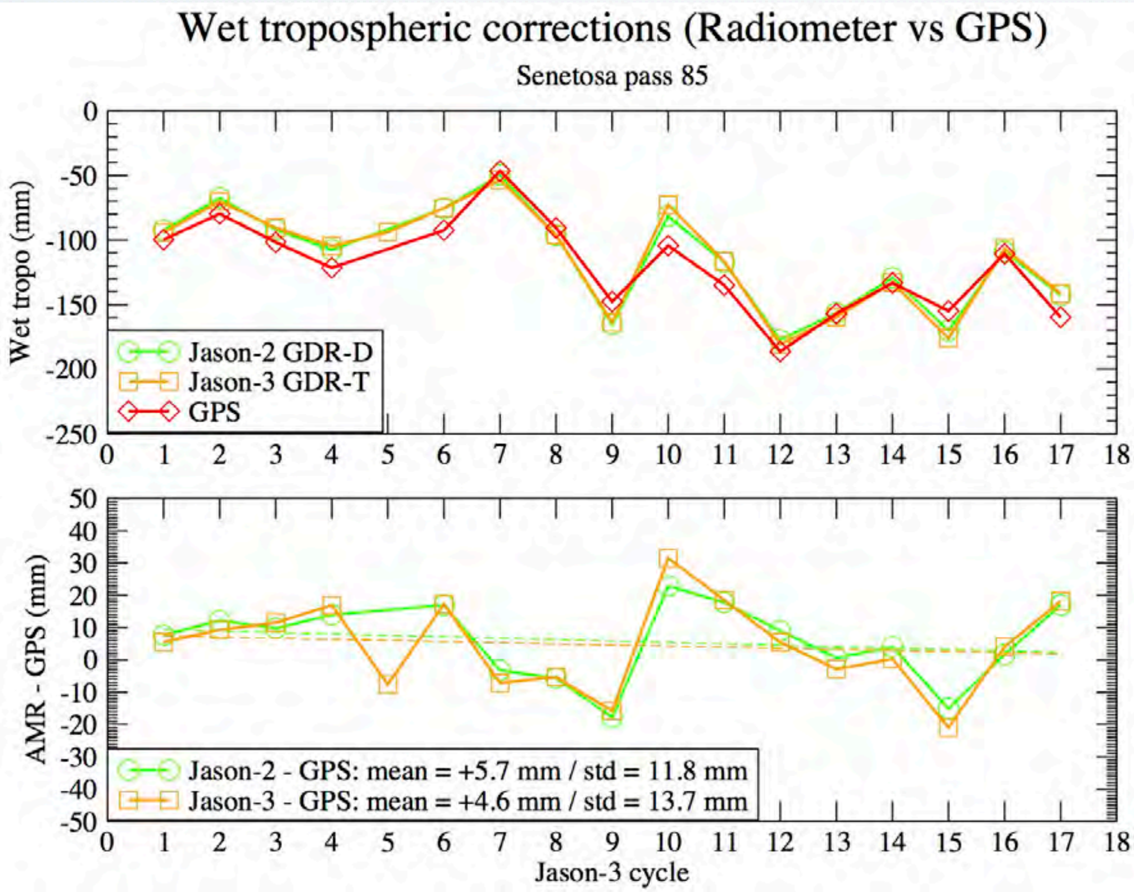
Radiometer Wet Tropospheric Correction compared to GPS

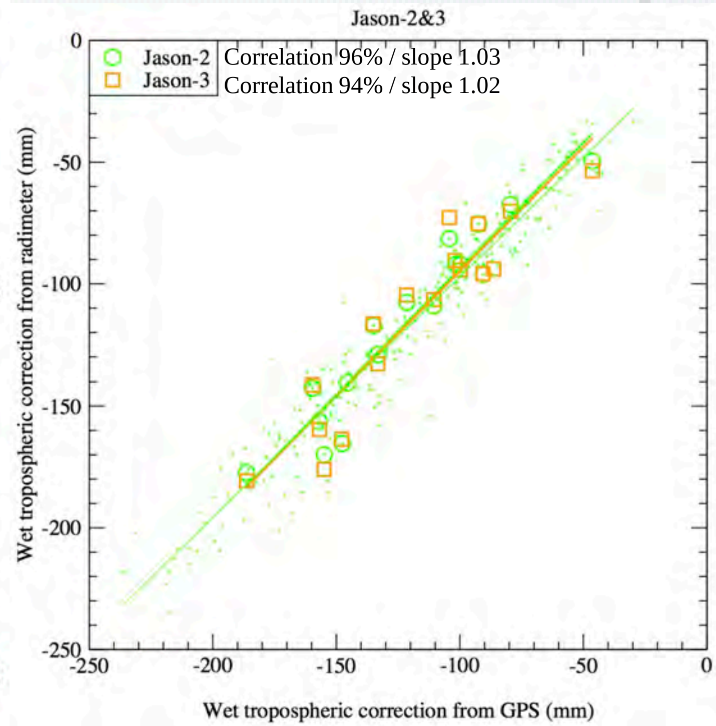
Corsica
Absolute
Altimeters
Calibration



WET TROPO JMR & AMR

Jason-3&2 wet radiometer correction vs GPS

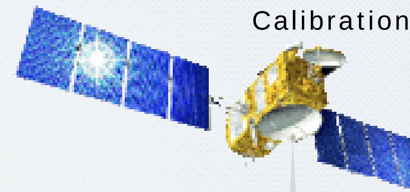


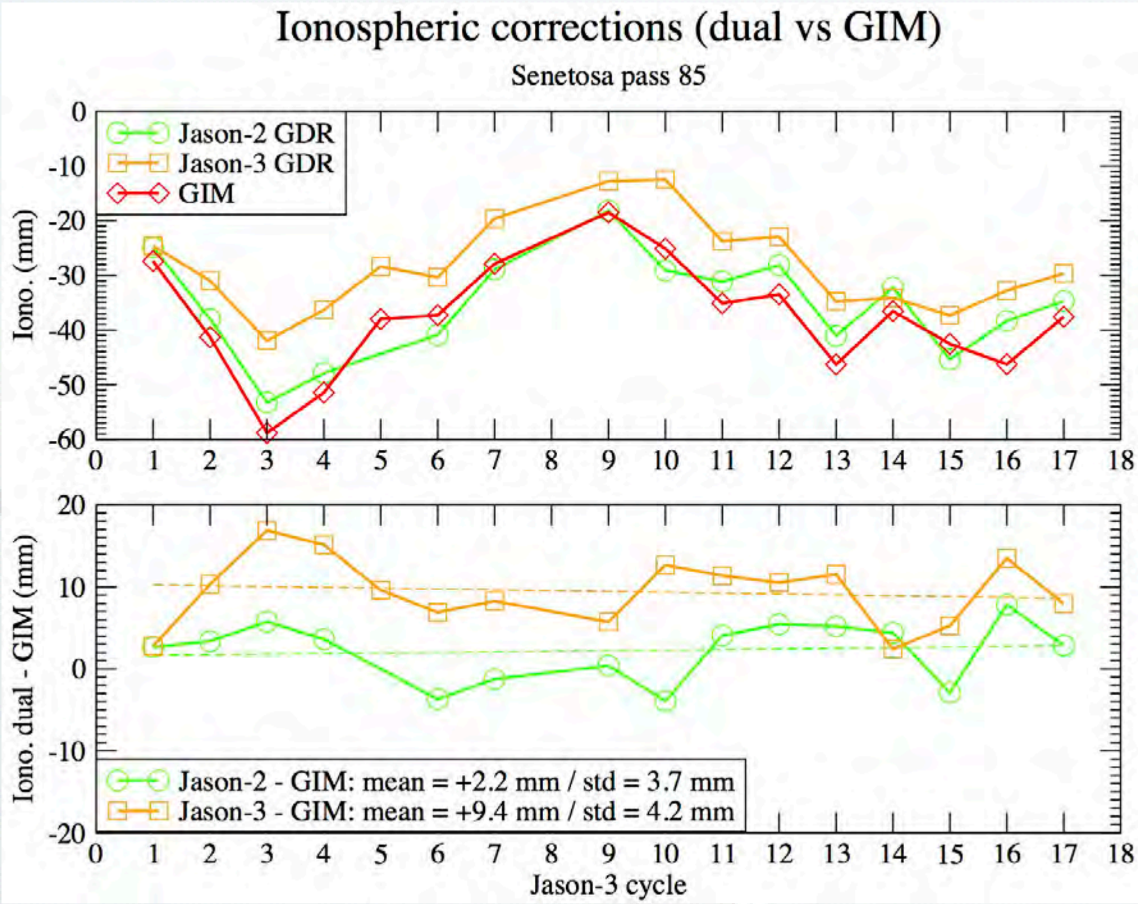


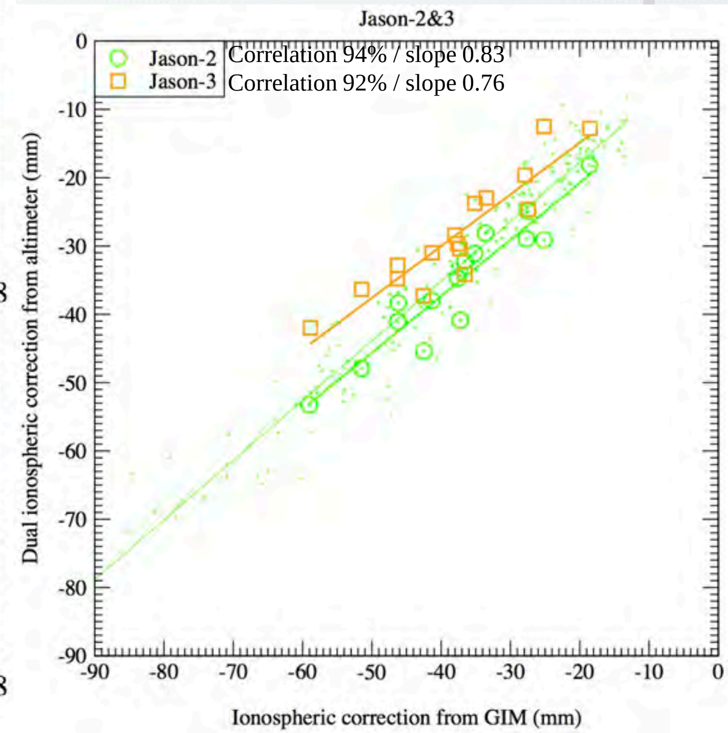
Main findings but with caution due to the small time series

- Very small differences (~+5 mm) for Jason-2&3 compared to GPS and very close to the average over the whole mission for Jason-2 (mean = +3.2 mm / std = 12.4 mm)
- A scale factor close to 1 for Jason-2&3 (0.99 with a correlation of 96% over the whole Jason-2 mission, small green crosses)

Jason-3&2 dual iono. correction vs GIM

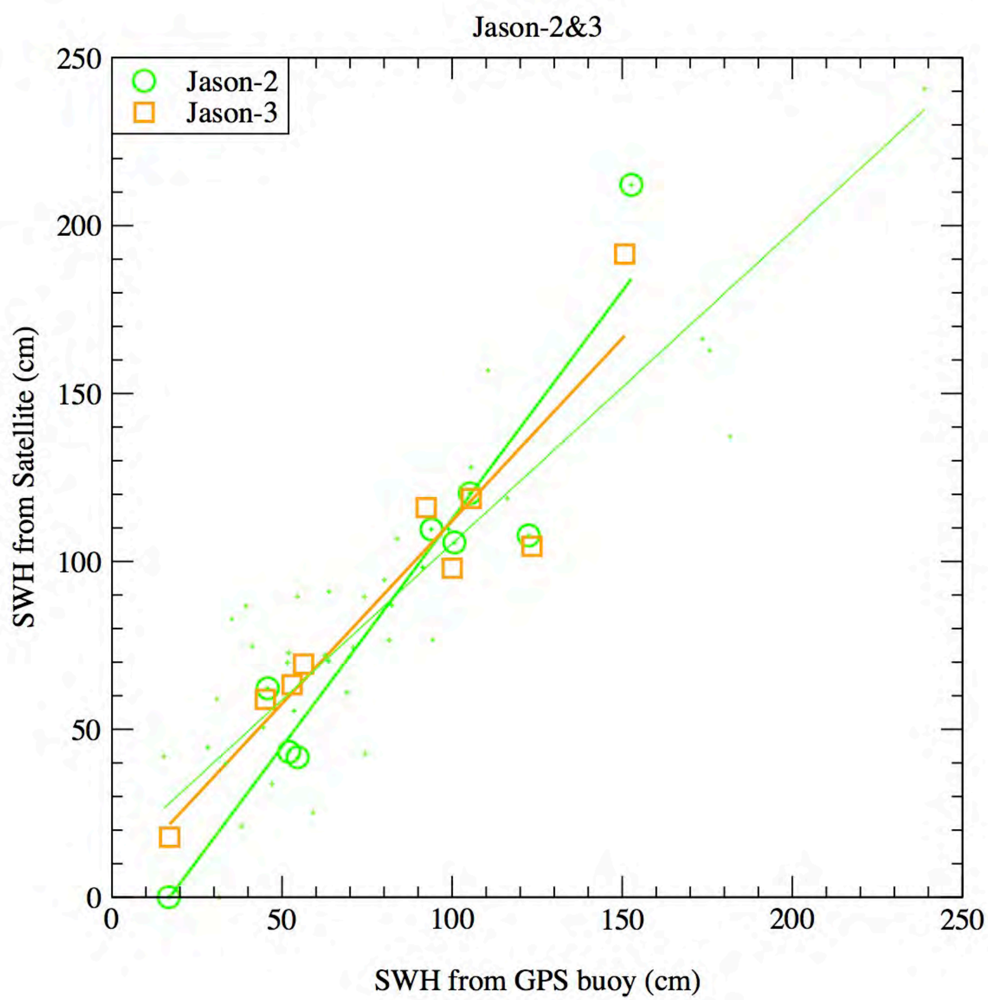




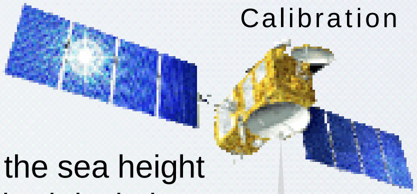


Main findings but with caution due to the small time series

- GIM very close to Jason-2 dual iono. (+2 mm)
- A larger bias for Jason-3 dual iono. compared to GIM (+9 mm)
- The scale factor is 0.76 for Jason-3 compared to 0.83 Jason-2 (0.87 with a correlation of 97% over the whole Jason-2 mission, small green crosses)



Corsica
Absolute
Altimeters
Calibration



GPS buoy measurements provide the sea height variations due to waves. The standard deviation on the GPS buoy sea height residuals (σ_{shr}) is the root square sum of σ_{gps} and σ_{wave} where σ_{wave} is the standard deviation of GPS buoy measurements due to waves and σ_{gps} the internal error of GPS buoy measurements; the GPS buoy internal error was estimated by processing kinematically a quasi-static session and is at the level of 2.6 cm (σ_{gps}).

$\boldsymbol{\sigma_{shr}^2 = \sigma_{gps}^2 + \sigma_{wave}^2}$; **so,** $\boldsymbol{\sigma_{wave} = \sqrt{(\sigma_{shr}^2 - \sigma_{gps}^2)}}$.

SWH (or H1/3) is then deduced from the formula below (Stewart, 2008):

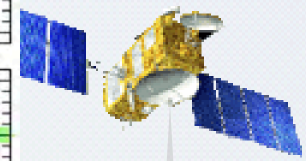
$\boldsymbol{SWH_{buoy} = 4.\sigma_{wave}}$

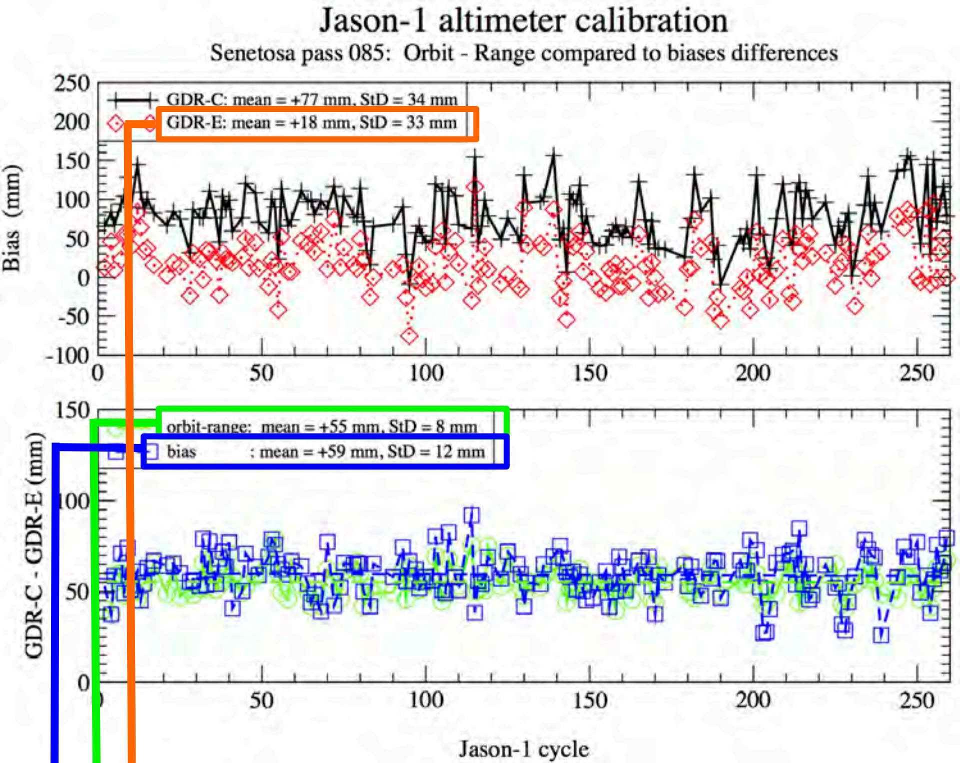
GPS BUOY FOR SWH

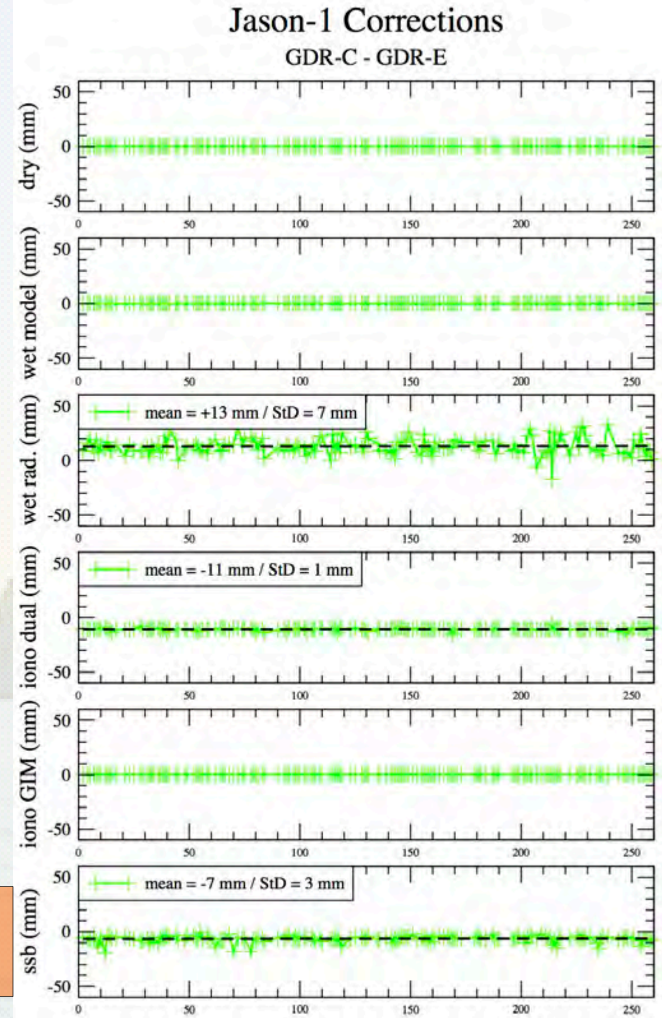
SWH monitoring using GPS (±5 min at overflight time):

	Mean (cm)	StD (cm)	Correlation (%)	Slope	Bias at origin (cm)
Jason-2 - GPS SWH	+6.4 *(+6.8)*	24.1 *(22.5)*	95 *(89)*	1.36 *(0.93)*	-23.0 *(+12.2)*
Jason-3 - GPS SWH	+10.5	16.7	94	1.09	+3.3

Values in brackets are for the whole Jason-2 mission (small green crosses on the plot)







SSH bias decreases by ~59 mm.
Standard deviations improved by 9 mm (RSS)

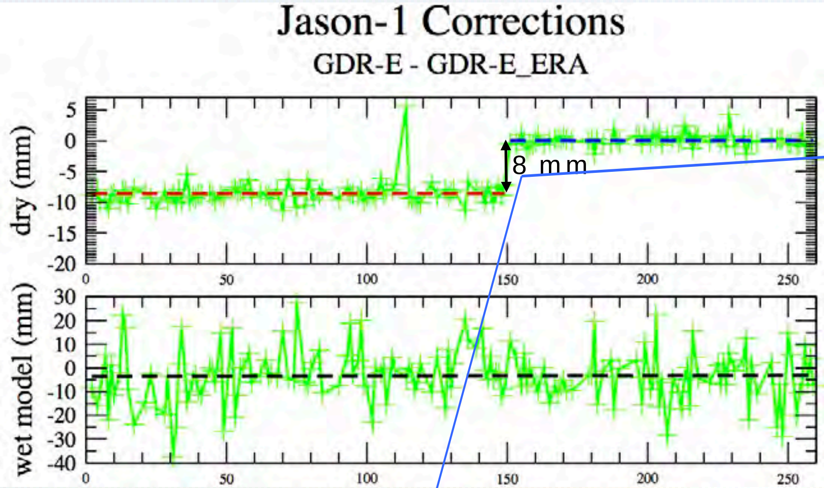
Close to the applied range correction and datation bias (~57 mm @ Corsica), so radial orbit differences between GDR-C and GDR-E are less than 2 mm in average with a standard deviation of 8 mm

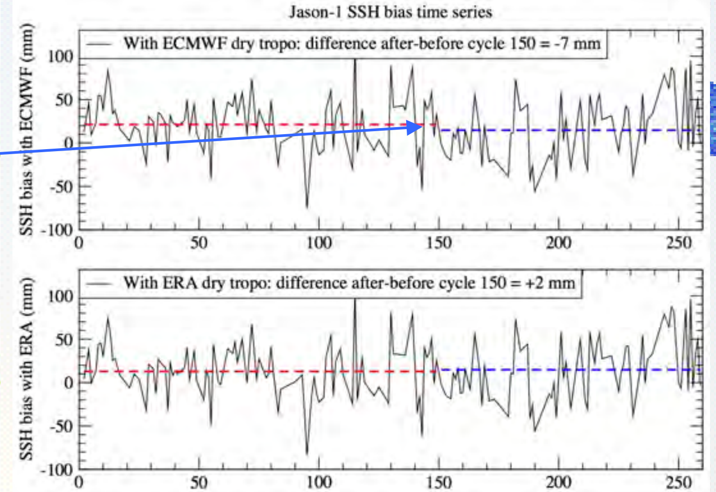
Except the range bias, differences between GDR-C and GDR-E SSH bias are due to SSB (-7 mm), iono (-11 mm) and wet tropo (+13 mm)

In GDR-E, Jason-1 SSH remains slightly biased by ~19 mm
but without significant relative trend

Comparison between ECMWF and ERA tropospheric correction

Corsica Absolute Altimeters Calibration

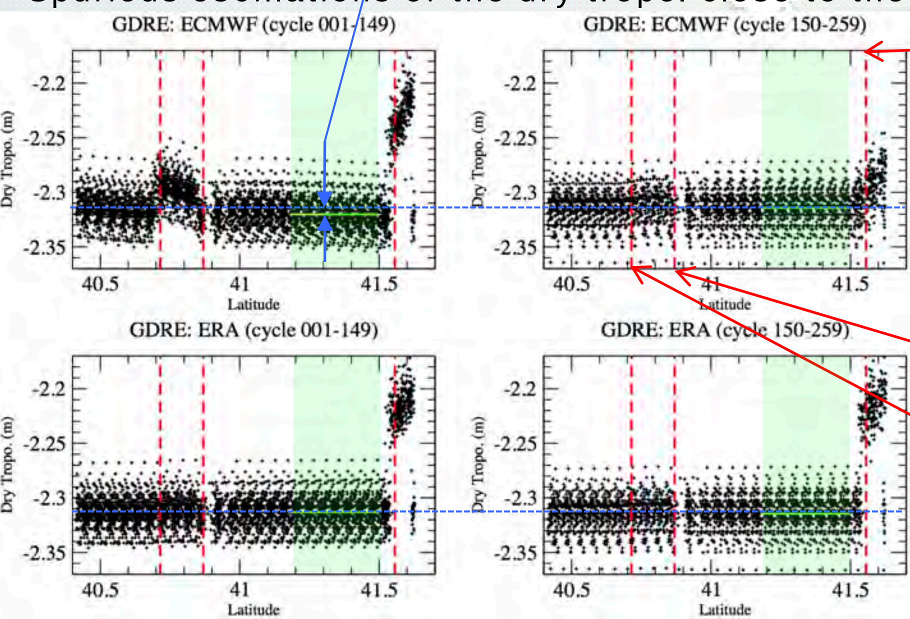


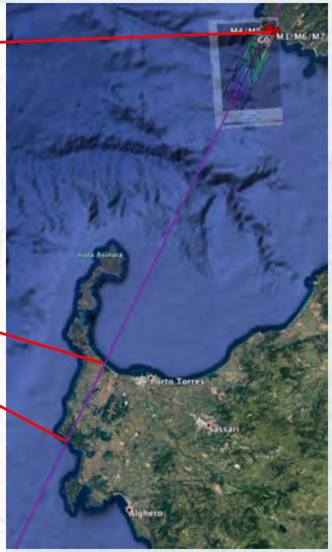


Effect on the SSH bias time series (after–before cycle 150):
- With ECMWF dry tropo.: -7 mm
=> ~1 mm/yr artificial trend
- With ERA dry tropo.: +2 mm
=> Negligible artificial trend

JASON-1 GDR-C TO GDR-E

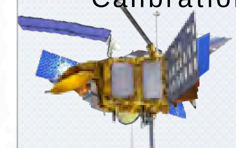
Spurious oscillations of the dry tropo. close to the coasts before cycle 150





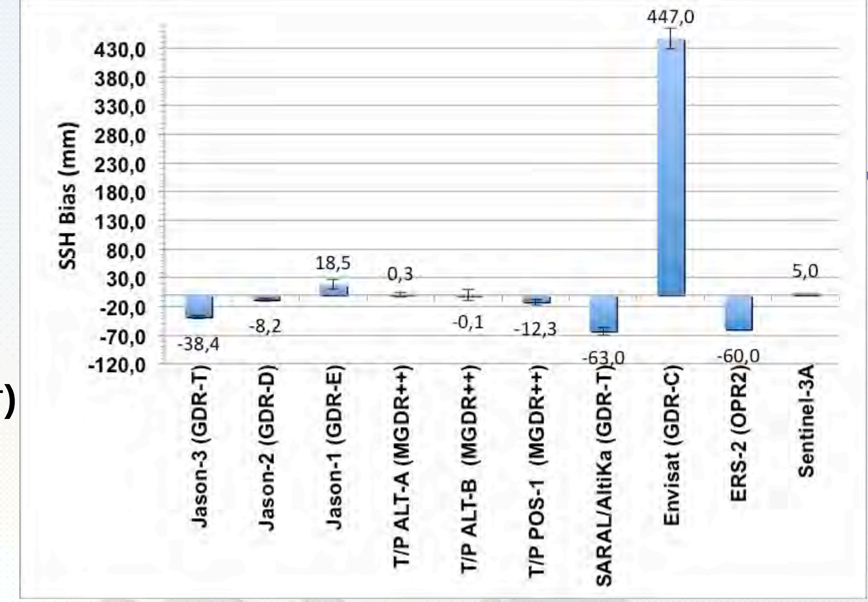
However this effects spreads far from the coast and affects the the area where the dry tropo. is interpolated (shaded green area):
The difference between before and after cycle 150 is 8 mm for ECMWF while negligible for ERA

Calibration from Corsica



Absolute biases over the whole data sets:

- **Jason-3: -38 ±6 mm (GDR-T)**
- **Jason-2: -8 ±2 mm (GDR-D)**
- **Jason-1: +19 ±3 mm (GDR-E)**
- **T/P ALT-A: 0 ±8 mm (MGDR^{++})**
- **T/P ALT-B: 0 ±4 mm (MGDR^{++})**
- **T/P POS-1: -12 ±10 mm (MGDR^{++})**
- **SARAL: -63 ±5 mm (GDR-T)***
- **Envisat: +447 ±7 mm (GDR-C)**
- **ERS-2: -60 ±18 mm (OPR-2)**
- **Sentinel-3A: +5 ±14 mm (PDGS)**



C O N C L U S I O N

Main findings for Jason-1 reprocessing (GDR-E):

- **An improvement of the standard deviation of the SSH biases mainly thanks to the orbit and the wet radiometer correction**
- **A small but significant remaining SSH bias of +18 mm (SSH too high)**
- **A wrong standard dry troposphere correction for cycle 1-150 in some coastal areas (step of 8 mm before/after cycle 150).**

Main findings for Jason-2:

- **Nothing to declare, waiting for GDR-E…**

Main findings for Jason-3:

- **All products (OGDR, IGDR and GDR-T) are of very good quality with very small differences compared to Jason-2**
- **Except a range bias of 2-3 cm that needs to be explained (SSH too low)**

Is Jason-3 GDR ready for distribution?

***SARAL AltiKa SSH bias value (since cycle 8) is from tide gauge data accounting for an instrumental bias from the tide gauge of 30 mm**