ABSOLUTE CALIBRATION OF THE SARAL/ALTIKA MEASUREMENT SYSTEM AT CORSICA AND HARVEST

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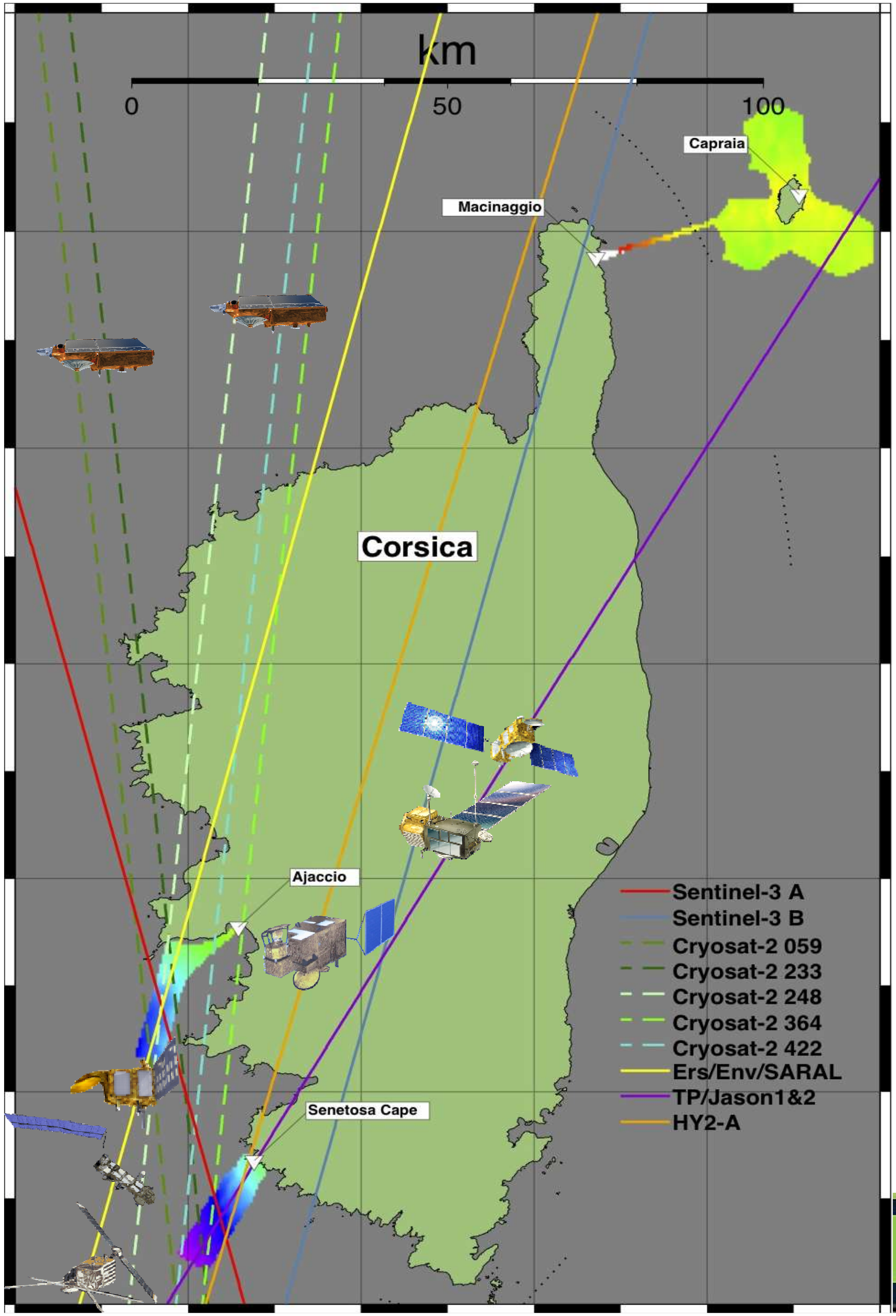
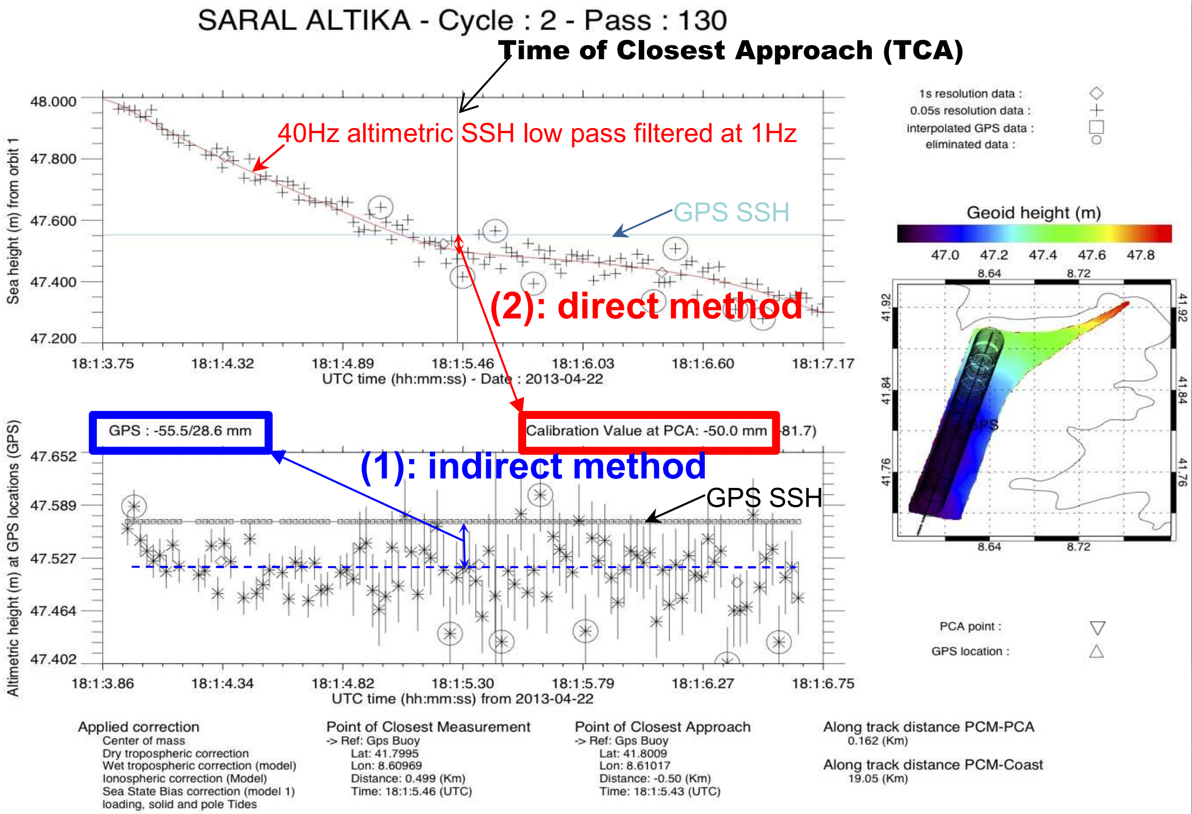
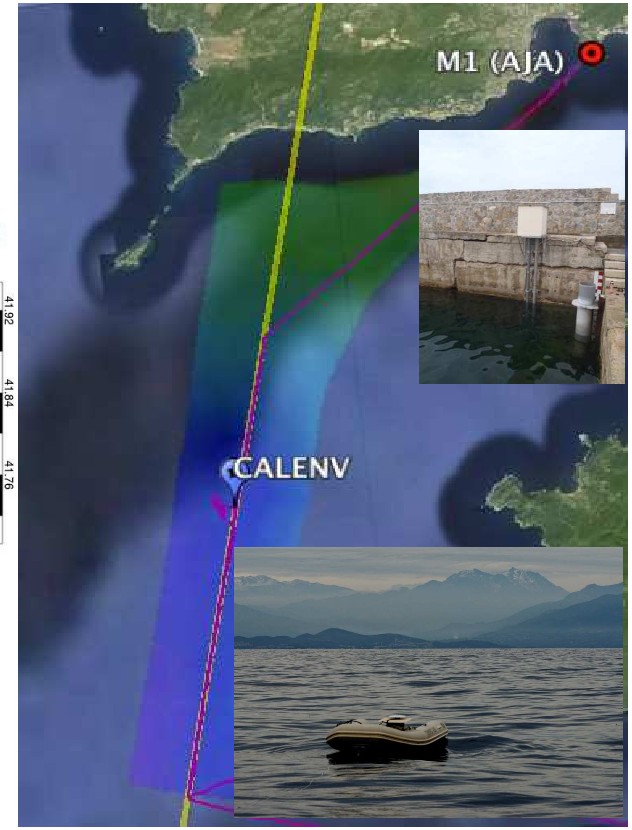


Corsica Calibration Site

- **Senetosa CNES calibration site established in 1998 (equipped with 4 pressure tide gauges.)**
  - **Supports continuous monitoring of Jason-2 (and formerly T/P and Jason-1)**
- **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)**
  - **Open-ocean verification location for GPS zodiac deployments.**
- **Ajaccio configuration**
  - **Supports continuous monitoring of SARAL/ALtiKa (and formerly ERS-2, Envisat)**
  - **Fiducial point near Ajaccio equipped with GPS/FTLRS/DORIS.**
  - **Ajaccio radar tide gauge (SHOM)** ***New one since 2009/09/16 (moved on 2012/04/03)***

Some tracks of CryoSat-2 and HY2-A cross the geoids allowing absolute calibration





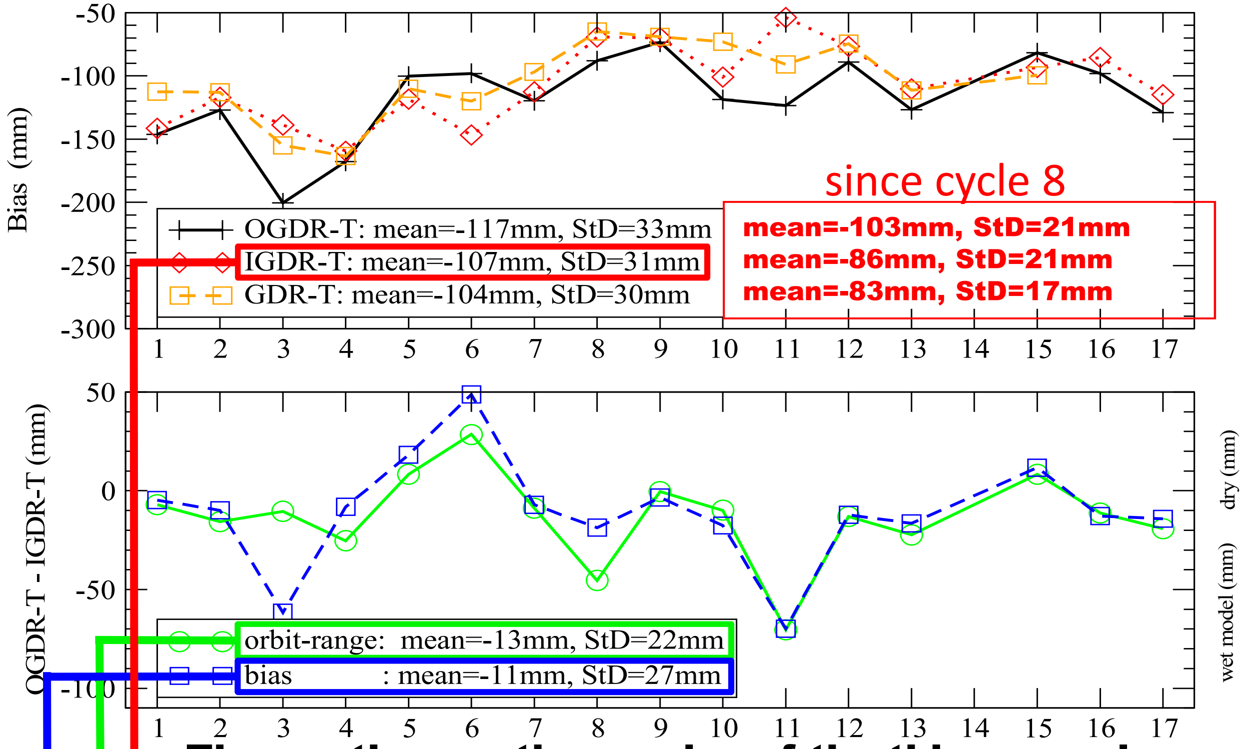
METHODS & INSTRUMENTS

2 Methods to compute SSH bias:

- **Indirect: need to correct from geoid slope** and potential ocean dynamics effects between in situ and altimetric measurements
- **Direct:** in situ **instrument** needs to be as **close as possible from altimetric measurement** to avoid any geoid slope and potential ocean dynamics effects

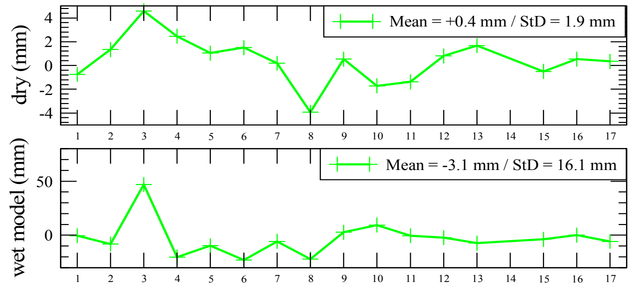
2 independent instruments to compute SSH bias:

- From **tide gauge**:
  - **(0) SSH from altimetry needs to be corrected from geoid**
- From **GPS measurement** (GPS aboard a zodiac located under the track, CALENV):
  - **(1) Using geoid correction to average all the altimetric SSH** (noted GPS-mean)
  - **(2) Computation at the Point of Closest Approach = no need to correct from geoid** (noted GPS-PCA)



I/OGDR-T: in patch P2 since cycle 11
GDR-T: whole set in patch P2

Corrections used:
- GIM for ionosphere
- Wet troposphere model
- Product SSB



OGDRT / IGDRT / GDRT

The continuous time series of the tide gauge is very useful to study the stability of the SSH bias as well as to cross-compare the different products

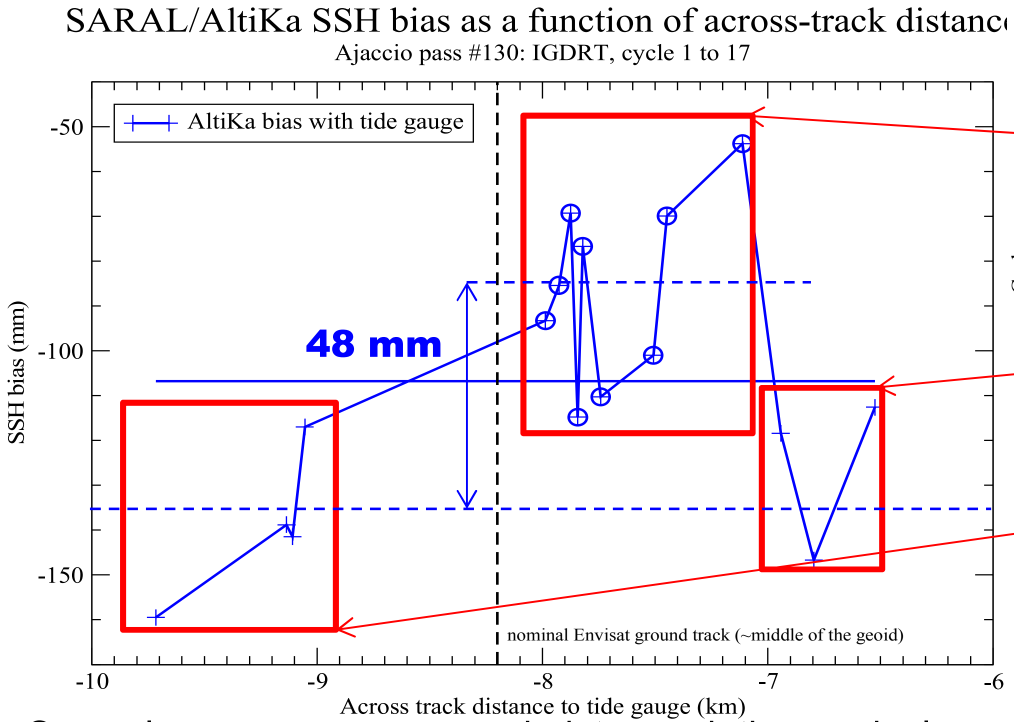
Standard deviation (31 mm) compararable to typical Jason-2 one (~35 mm)

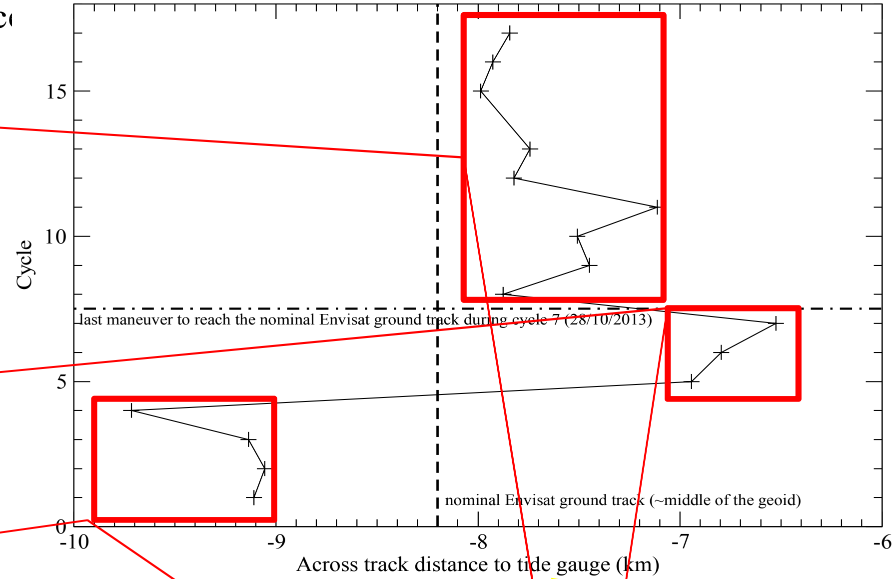
Mean radial orbit differences between DIODE and MOE (-13 mm): comparable to orbit errors analyzed over Europe using short-arc orbit technique (-20 mm)

Differences between OGDR-T and IGDR-T SSH bias are due to dry and wet tropo and linked to differences between predicted and computed ECMWF model

A SSH bias difference of only 3 mm between IGDR-T and GDR-T

ACROSS TRACK IMPACT

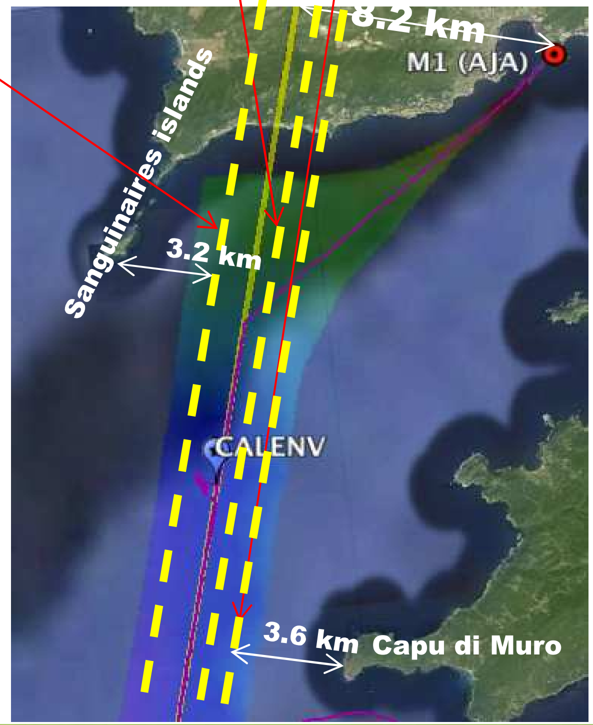




Several maneuvers were needed to reach the nominal ground track, it can be divided into 3 parts:

1- cycle 1 to 4: ground track located in the western part
=> contamination from “Sanguinaires islands”
2- cycle 5 to 7: ground track located in the eastern part
=> contamination from “Capu di muro”
3- from cycle 8: ground track located in the center part
=> no a priori contamination except very close to the coast in the northern part

Impact on the averaged SSH bias: 48 mm
(SSH bias cycles 1-7 compared to cycles 8-17)
Better stability since cycle 8: 20 mm rms
(31 mm rms on the whole set)



Absolute SSH biases from tide gauge since cycle 8:

OGDR-T: -103 ±7 mm (9 cycles)
IGDR-T: -86 ±7 mm (9 cycles)
GDR-T: -83 ±6 mm (7 cycles)

Comparison between tide gauges and GPS-zodiac (IGDR-T):

Tide gauge: -86 ±7 mm (indirect method)
GPS (mean): -53 ±12 mm (semi-indirect method)
GPS (PCA): -60 ±9 mm (direct method)

⇒ 26 mm difference between tide gauge and GPS (PCA) methods/instruments

- ✓ 30 mm comes from instrumental differences (comparisons @ tide gauge location): this remains unsolved
- ✓ Other effects: ocean dynamics? A high resolution model is in development to estimate the impact but it should be small

Estimated land contamination for the altimeter:

- ✓ first 8 cycles affected because too close to coastal features
- ✓ However, clearly reduced in comparison to Envisat

SWH monitoring using GPS:

- ✓ Altimeter SWH higher by ~7 cm

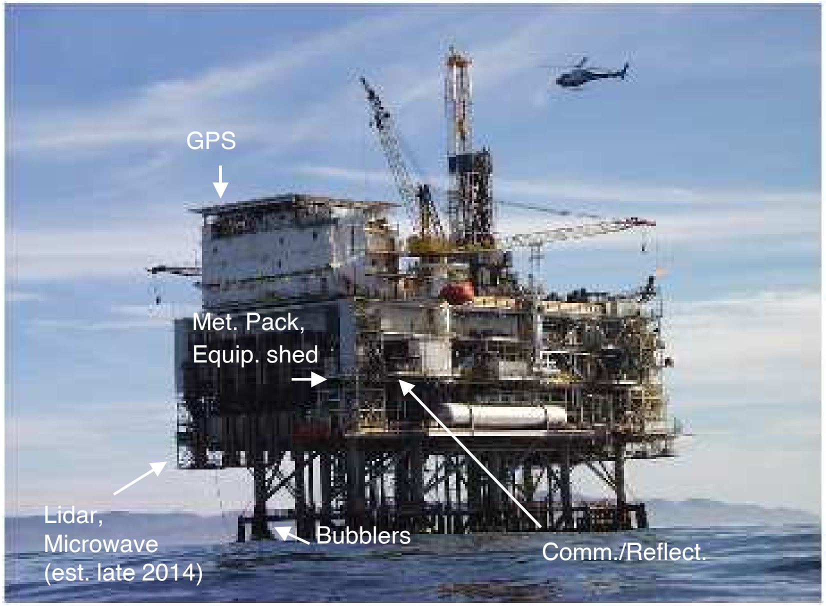
Radiometer monitoring using GPS:

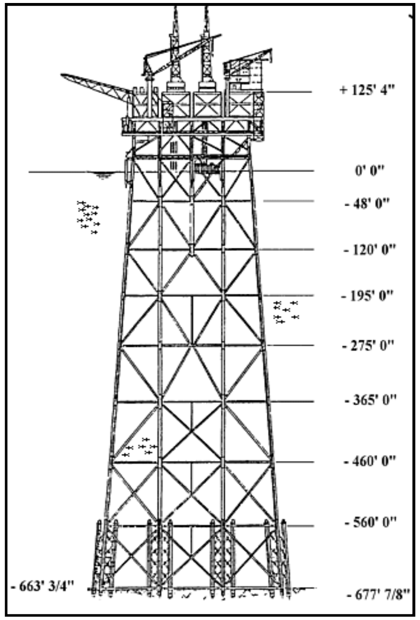
- ✓ Radiometer dryer by ~10mm

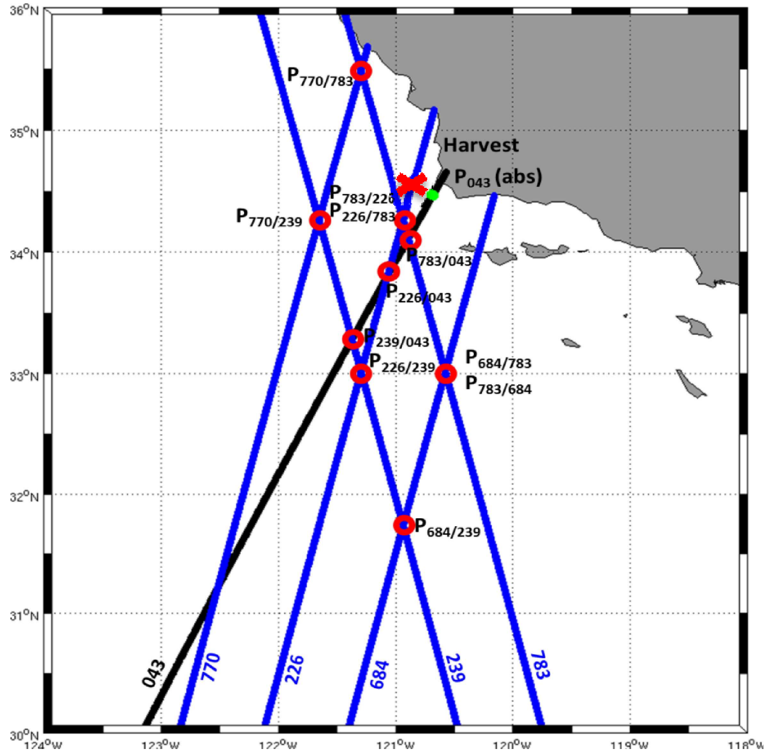
Rain impact:

- ✓ No major impact on the SSH bias even during the Cleopatra storm (2013/11/18) but radiometer is wetter by ~50 mm

Harvest Experiment







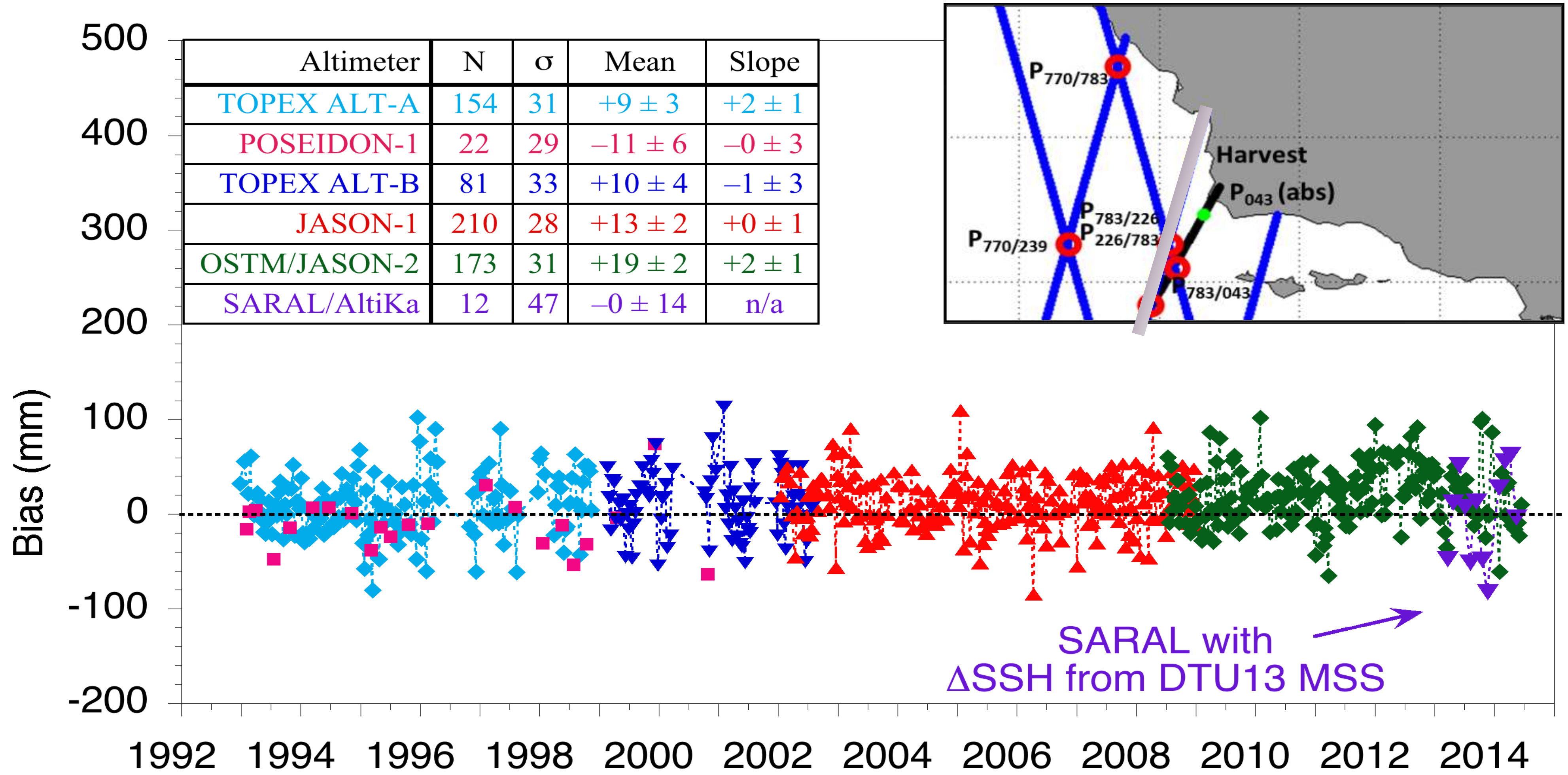
- **NASA Prime Verification Site for High-Accuracy (Jason-class) Altimetry**
  - Open-ocean location along 10-d repeat track (by design)
  - 10-km off coast of central California near Jason launch site (Vandenberg Air Force Base).
  - Continuous monitoring for over two decades (established 1992 prior to TOPEX/Poseidon launch).
- **Regional techniques used to extend calibration footprint in support of other missions.**
- **First absolute calibration of ENVISAT yields SSH bias of +48 to 50 cm** (*Cancet et al.*, 2013).
  - Uses multiple crossover traverses with underpinning from mean track profiles (100+ repeat cycles).
- **First absolute calibration of SARAL/AltiKa.**
  - Uses traditional "nearest-approach" technique for descending pass 226 of 35-d repeat orbit.
  - Contemporary MSS models used to connect open ocean PCA to Harvest (~45 cm rise over 18 km).

Harvest Long-Term Calibration Record

Include SARAL SSH Bias Estimates

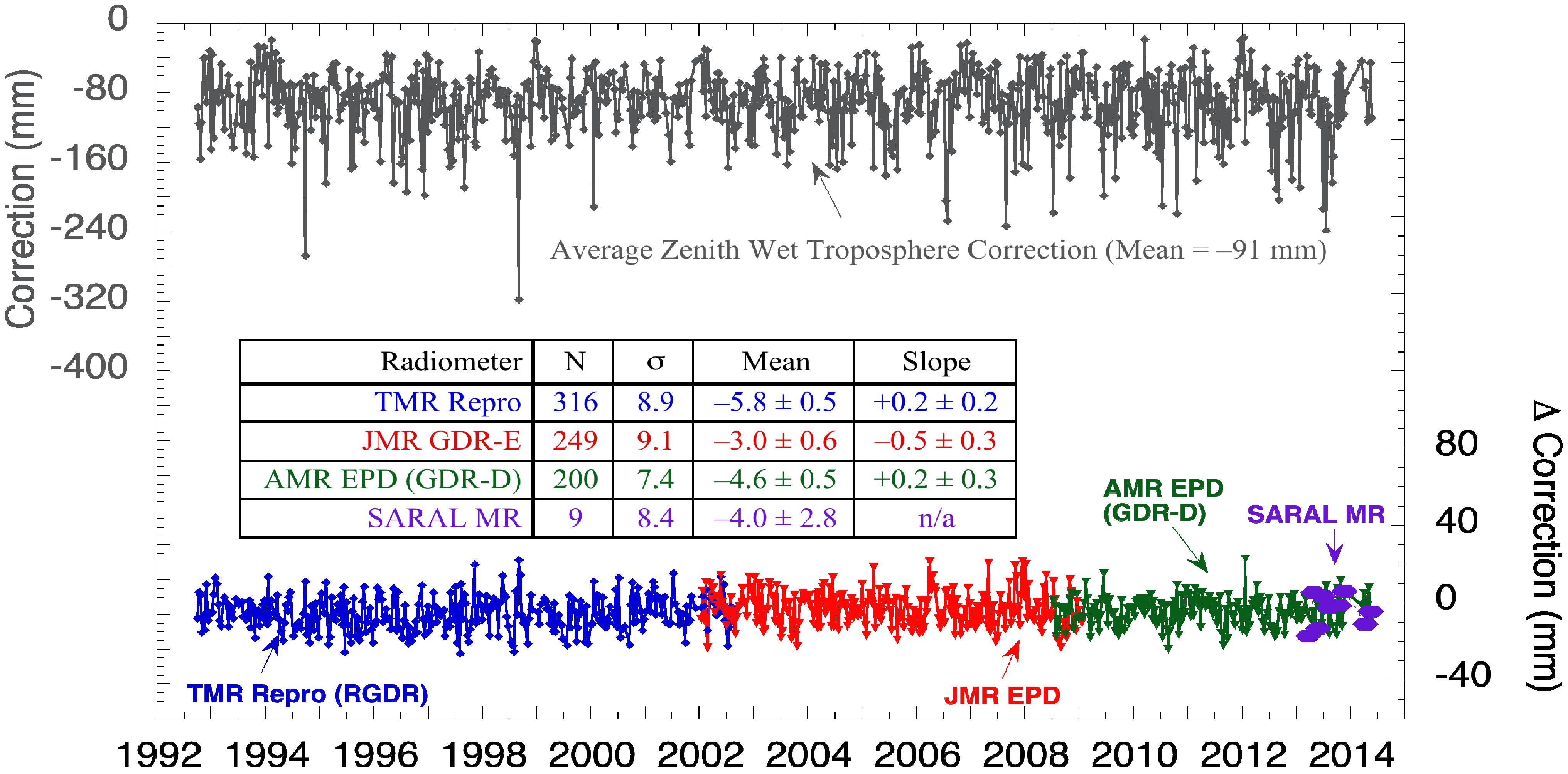
Using DTU 2013 Global Mean Sea Surface (Andersen et al., 2013) to Correct for Gradient Over 18 km

Altimeter	N	σ	Mean	Slope
TOPEX ALT-A	154	31	+9 ± 3	+2 ± 1
POSEIDON-1	22	29	−11 ± 6	−0 ± 3
TOPEX ALT-B	81	33	+10 ± 4	−1 ± 3
JASON-1	210	28	+13 ± 2	+0 ± 1
OSTM/JASON-2	173	31	+19 ± 2	+2 ± 1
SARAL/AltiKa	12	47	−0 ± 14	n/a



Wet Path Delay: Radiometer vs. GPS

Retrievals from SARAL Radiometer Show Good Agreement with GPS



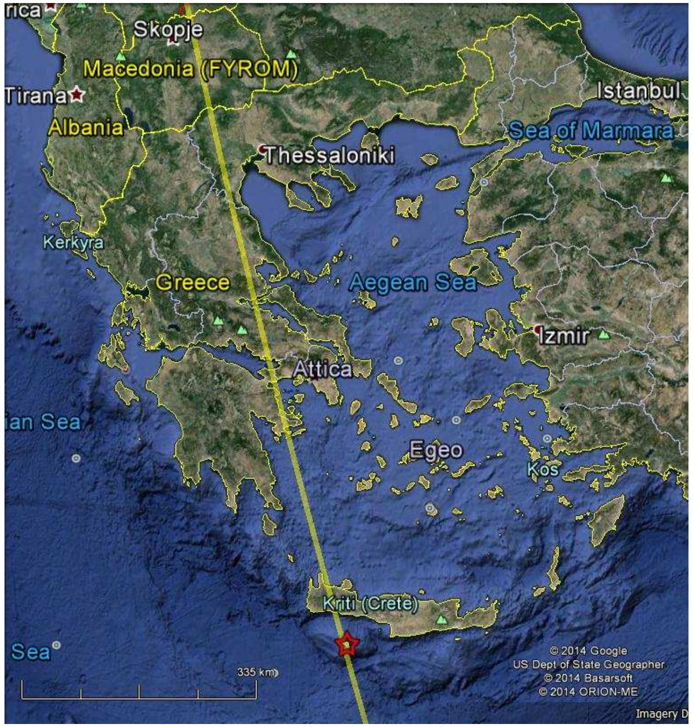
Radiometer	N	σ	Mean	Slope
TMR Repro	316	8.9	–5.8 ± 0.5	+0.2 ± 0.2
JMR GDR-E	249	9.1	–3.0 ± 0.6	–0.5 ± 0.3
AMR EPD (GDR-D)	200	7.4	–4.6 ± 0.5	+0.2 ± 0.3
SARAL MR	9	8.4	–4.0 ± 2.8	n/a

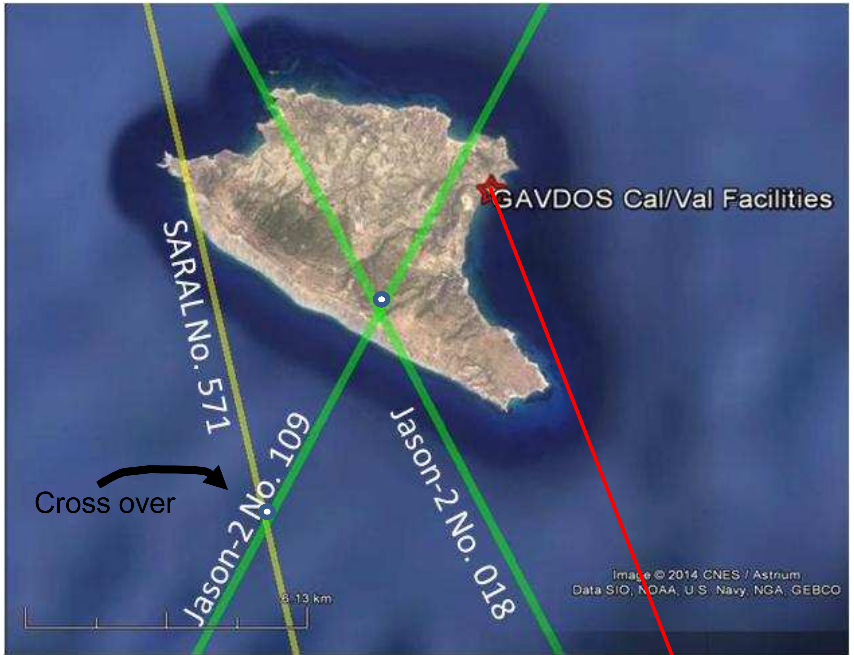
Harvest Summary

- SARAL/AltiKa absolute SSH bias of –39 mm ± 14 mm (one standard error with σ = 5 cm and N = 12)
  - Uses data from pass 226 only (18 km open-ocean approach to Harvest).
  - Based on gradient correction from average of CLS11 and DTU13 MSS
  - Limiting error source is MSS correction (no pelagic survey).
- Retrievals from SARAL microwave radiometer show excellent agreement with GPS.
  - Bias and scatter of 4 and 8 mm respectively.
- Additional regional calibrations planned (e.g., Cancet et al., 2014).
  - Use ground-track traverses to regional crossover locations.
  - Average down MSS errors and “oceanographic noise”

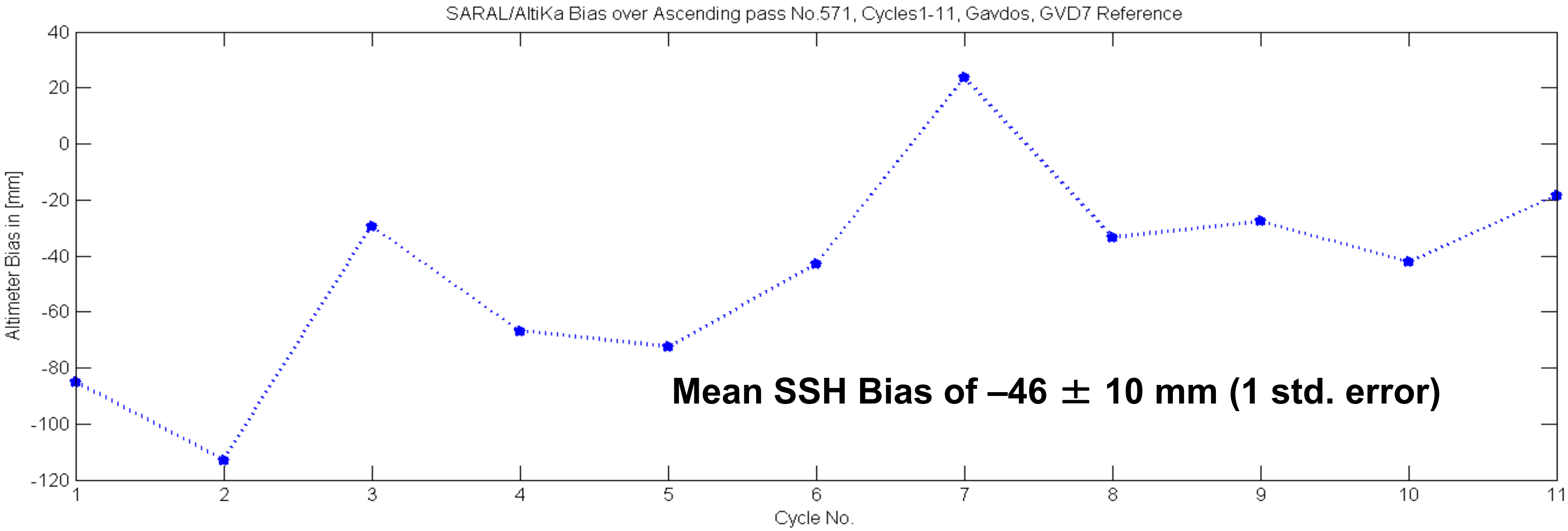
Gavdos, Crete

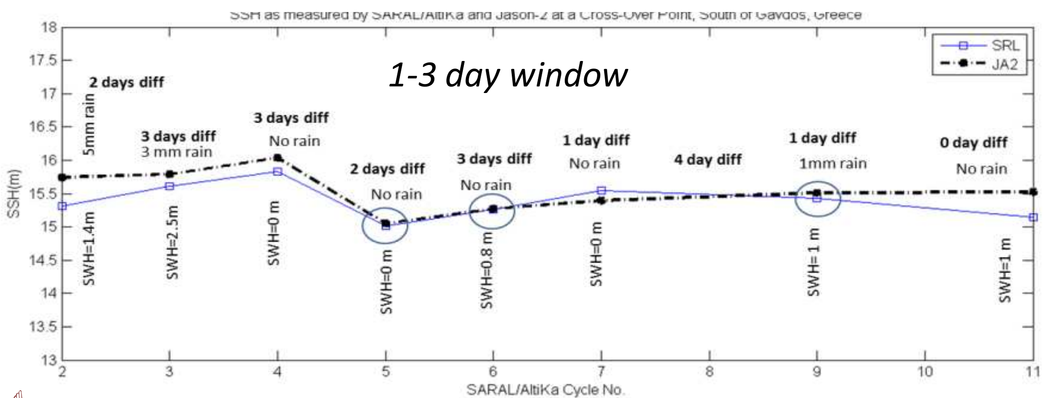
Absolute Calibration of SARAL/AltiKa

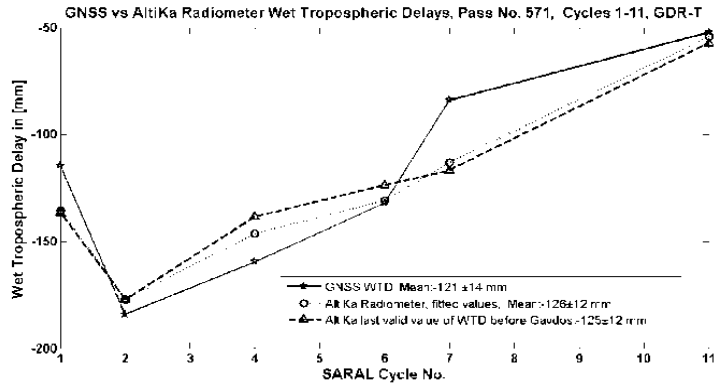




Calibration Results for SARAL/AltiKa at Gavdos *Ascending Pass No. 571, GDR-T, Patch 2, First 11 35-d Repeat Cycles*



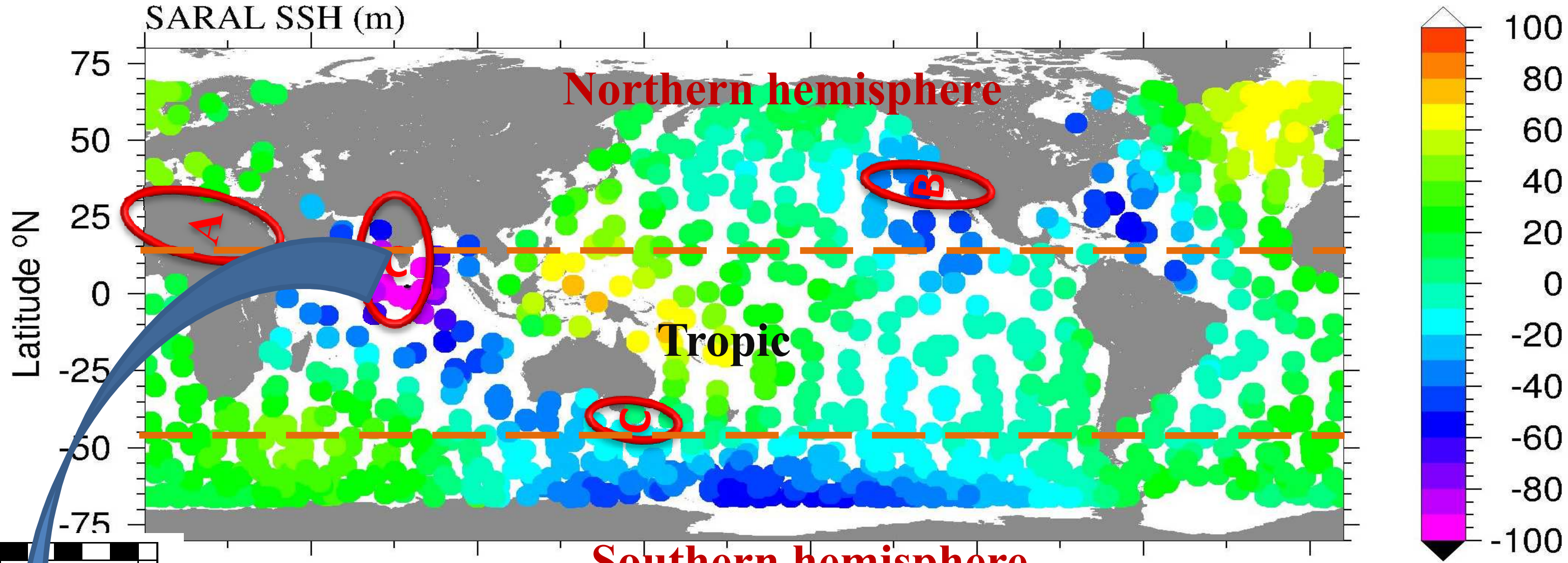


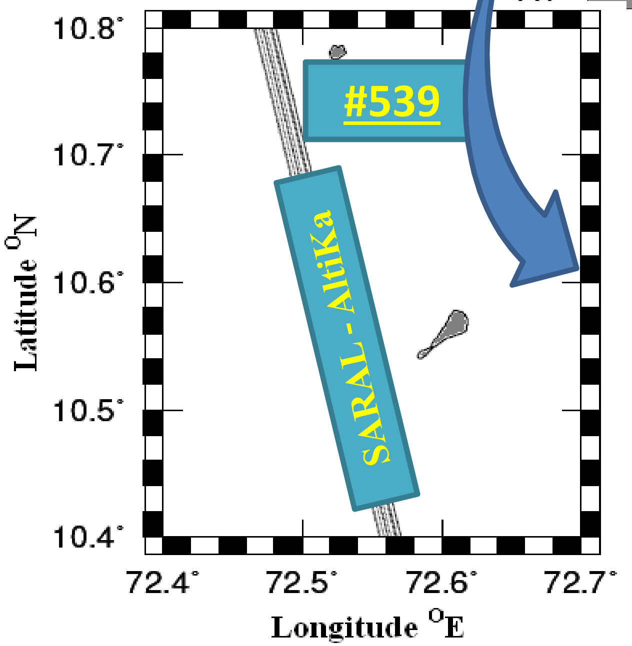


Nearby crossover indicates SARAL SSH lower than Jason-2 SSH by 4.6 cm

SARAL wet troposphere delay wetter than GPS by 4-5 mm.

Global sea surface height - AltiKa





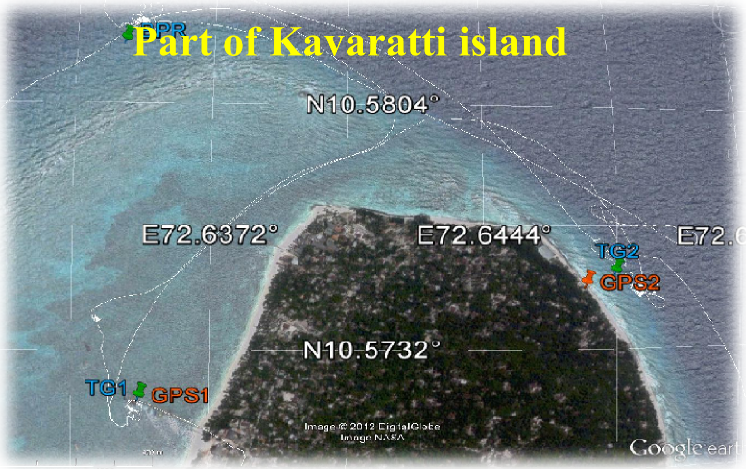
Permanent altimeter calibration sites

A – Corsica, Ibiza, Gavdos (Northern hemisphere)
B – Harvest (Northern hemisphere)
* C – Kavaratti (Equatorial zone)
D – Bass strait (Southern hemisphere)

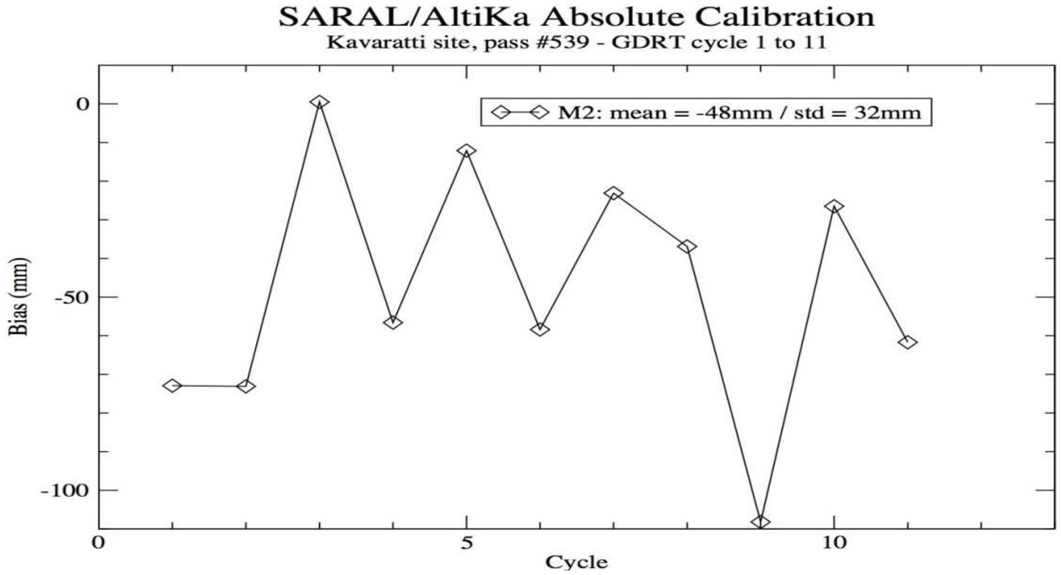
At Kavaratti site:

Pass #539 passes over west of Kavaratti site. The 11 cycles of AltiKa have spread over ~2Km along the altimeter track, and hence its absolute bias with respect to the in-situ observations.

Kavaratti calibration site

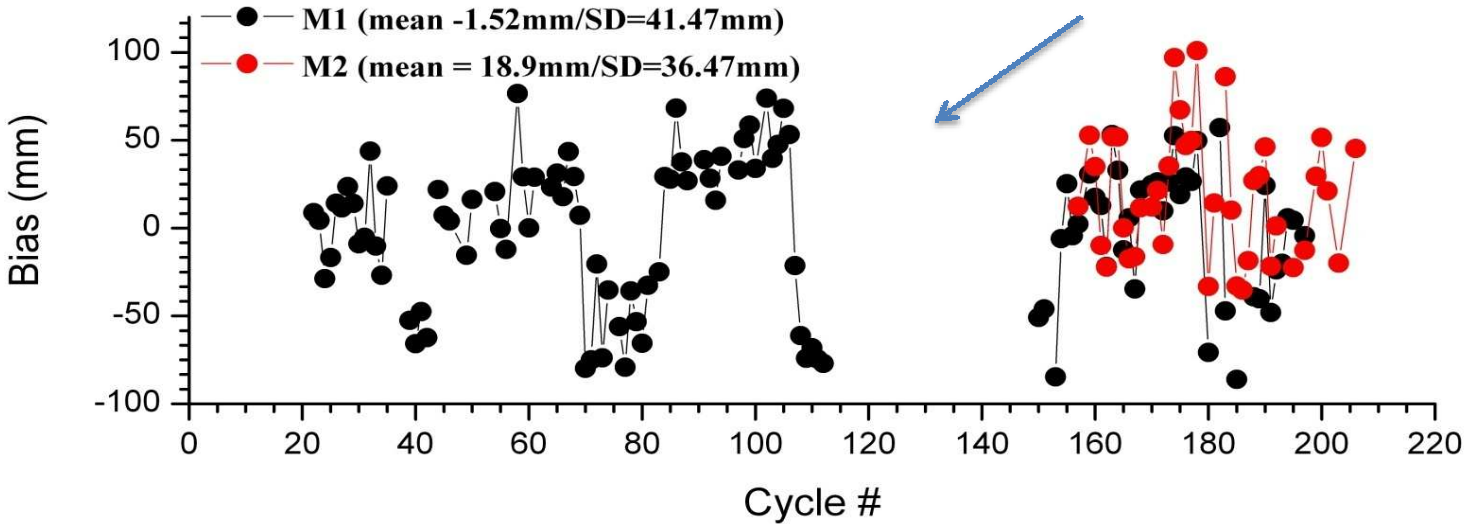


Absolute calibration bias results for SARAL/AltiKa and Jason-2



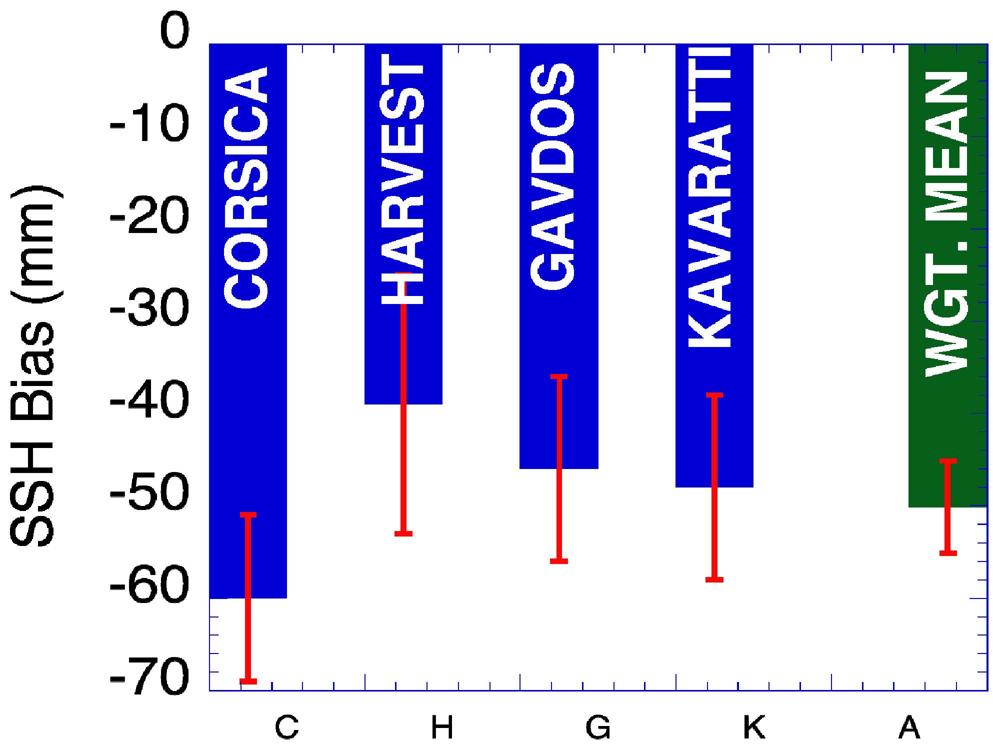
SARAL/AltiKa Bias = –48 mm (σ = 32 mm, N= 11)

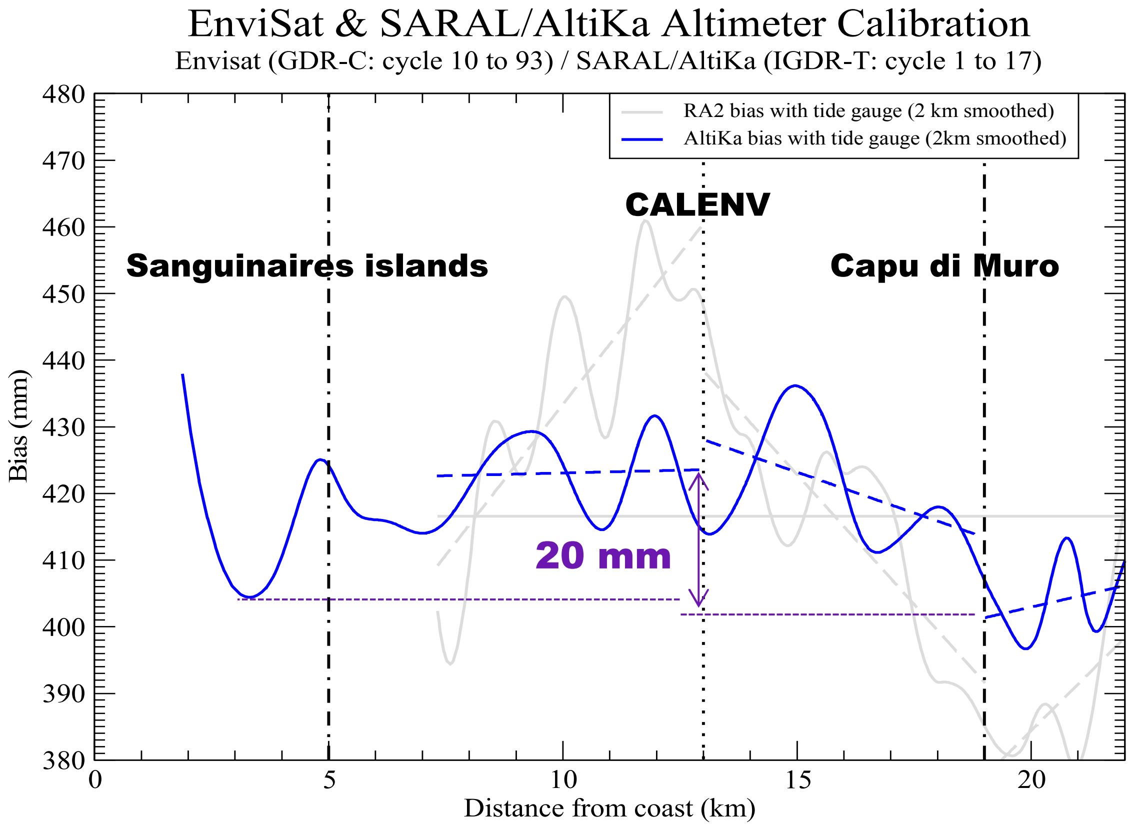
Jason-2 Absolute calibration



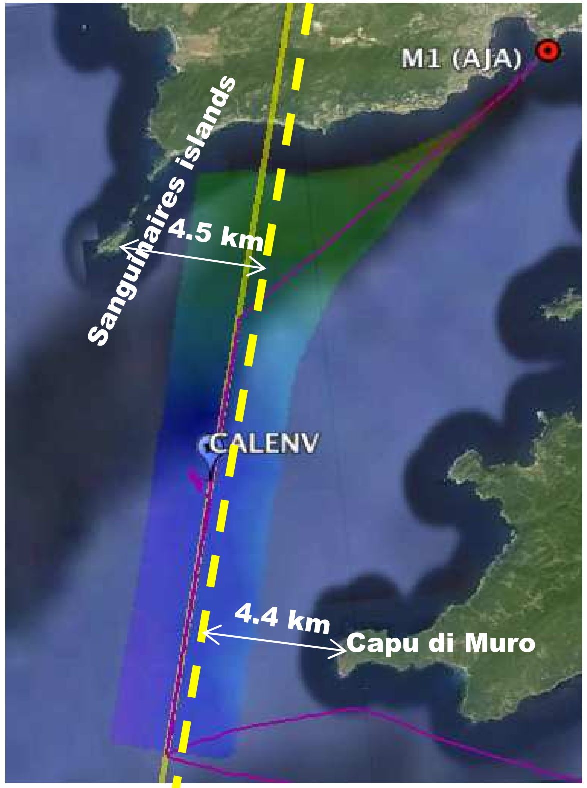
Summary

- Consensus estimate for absolute bias: –50 ± 5 mm
  - Based on I/GDR-T
  - Weighted average from four calibration sites.
- Absolute bias consistent with global observations.
  - SARAL SSH 4–6 cm lower than Jason-2 (e.g. Desai et al., this meeting).





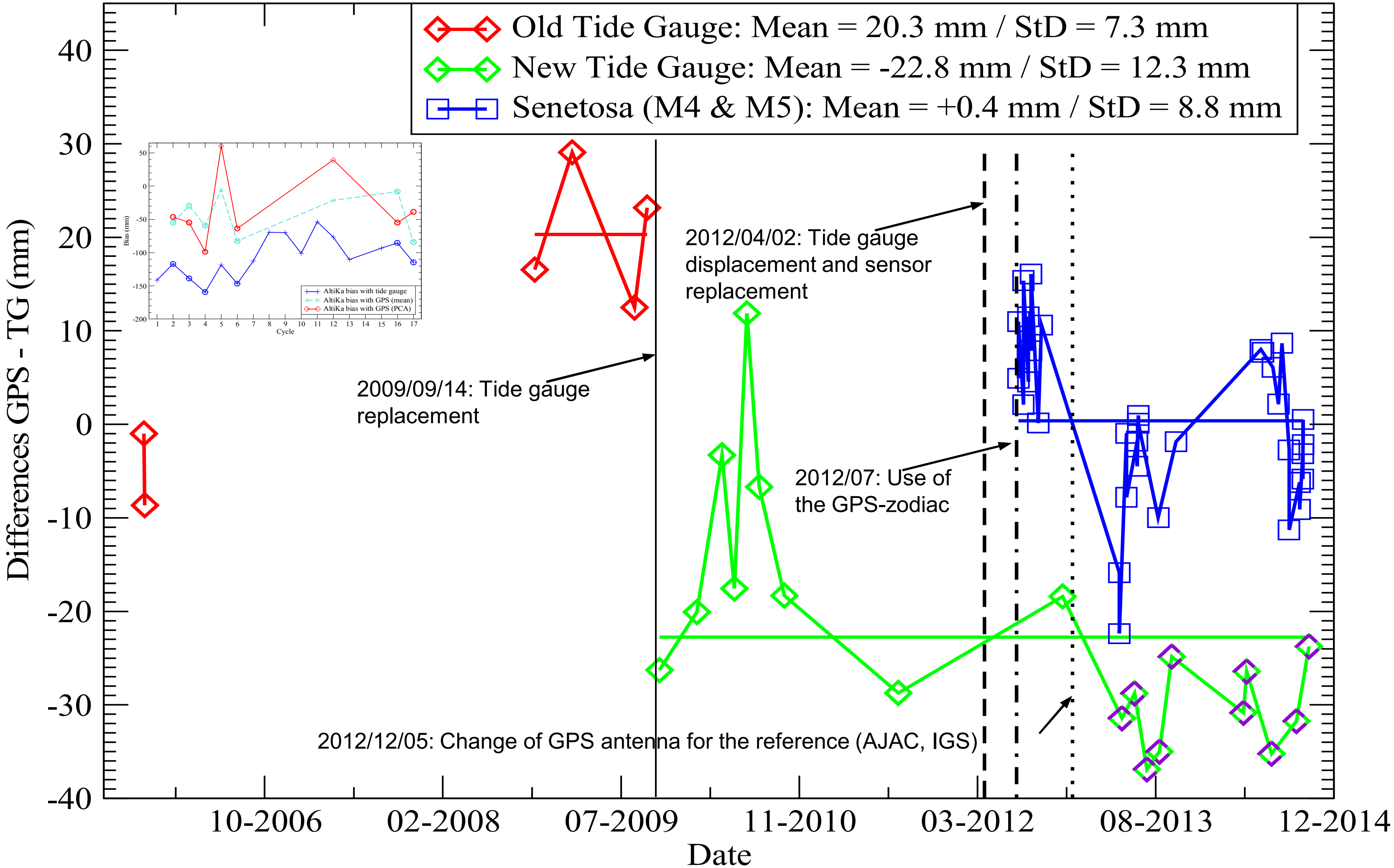
To make the comparison easier the AltiKa SSH bias has been shifted to the RA2 SSH bias by the difference of their SSH biases (523 mm).



Averaged ground track since cycle 8 (~500m eastward from Envisat nominal track)

ALONG TRACK IMPACT

This plot shows the average SSH bias in function of the distance to the coast:
Even if the **land contamination is much smaller than for the Envisat** (RA2) altimeter, it is estimated to be **at the level of 20 mm** in vicinity of the "Sanguinaires islands" and "Capu di Muro": the theoretical AltiKa footprint radius is 4 km, so AltiKa should not been theoretically impacted…
However, **even by selected data from cycle 8, the structures identified in the above figure remain**.



GPS / TIDE GAUGE

@ Tide gauge location, a clear instrumental bias has been identified from the 2 instruments

- ✓**-23 mm (**after tide gauge replacement in september 2009**).**
- ✓**-30 mm since the SARAL/AltiKa launch (very stable, only 5 mm rms)**.

⇒ **This bias remains unsolved:**

✓ **AJAC antenna change should not have impact (taken into consideration in the processing)**

✓ **Comparisons with the same GPS-zodiac @ Senetosa site do not exhibit any bias**