Corsica:
A 20-Yr Multi-Mission Absolute Altimeter Calibration Site

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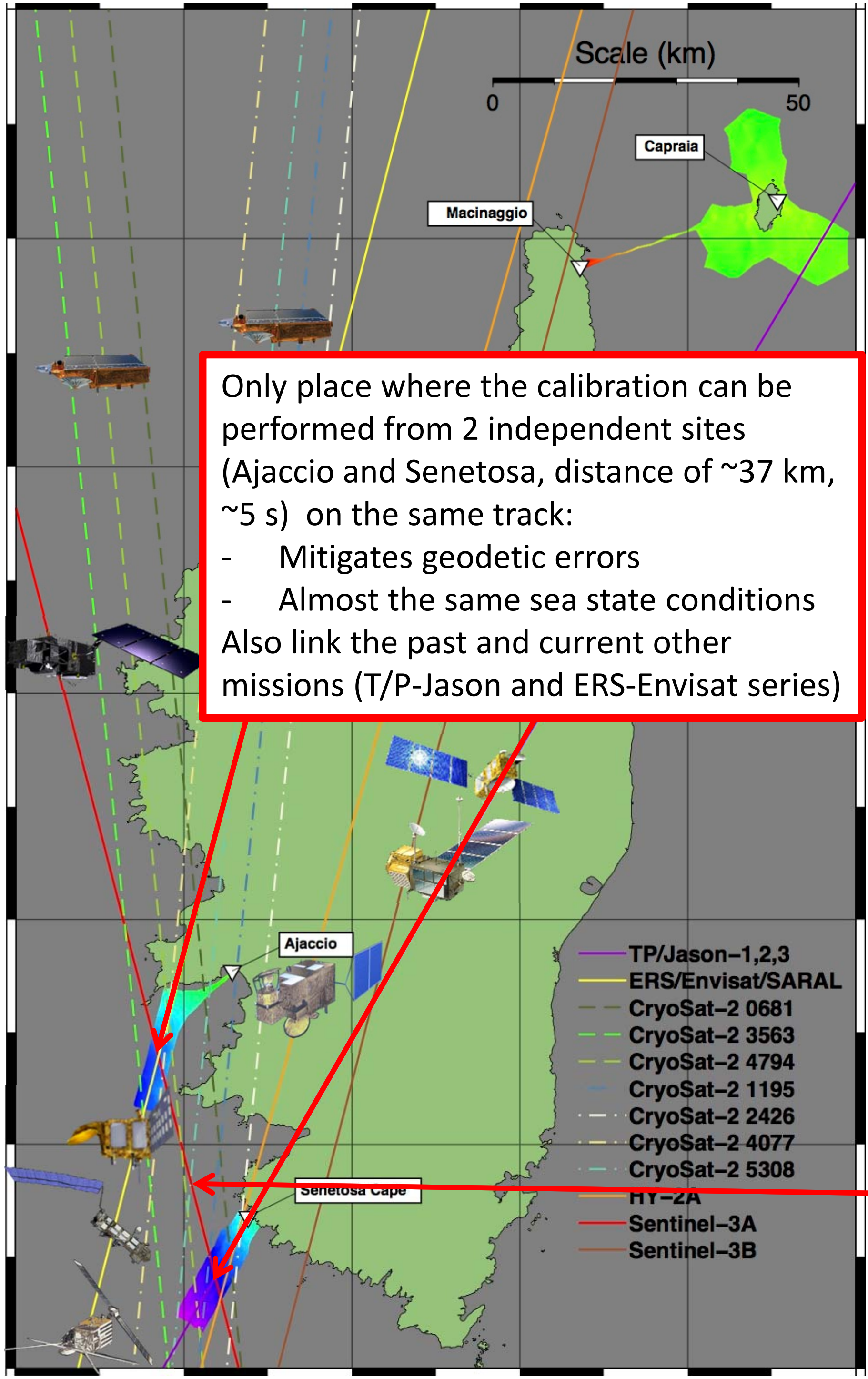
l'Observatoire de Paris | SYRTE

Systèmes de Référence Temps-Espace

GeoAzur
TERRE - OCÉAN - ESPACE



Corsica Multi-mission Calibration Site

- **Senetosa CNES calibration site** established in 1998
  - Supports continuous monitoring of Jason-3 (and formerly T/P and Jason-1&2)
  - Equipped with 4 pressure tide gauges leveled to the permanent GPS receiver

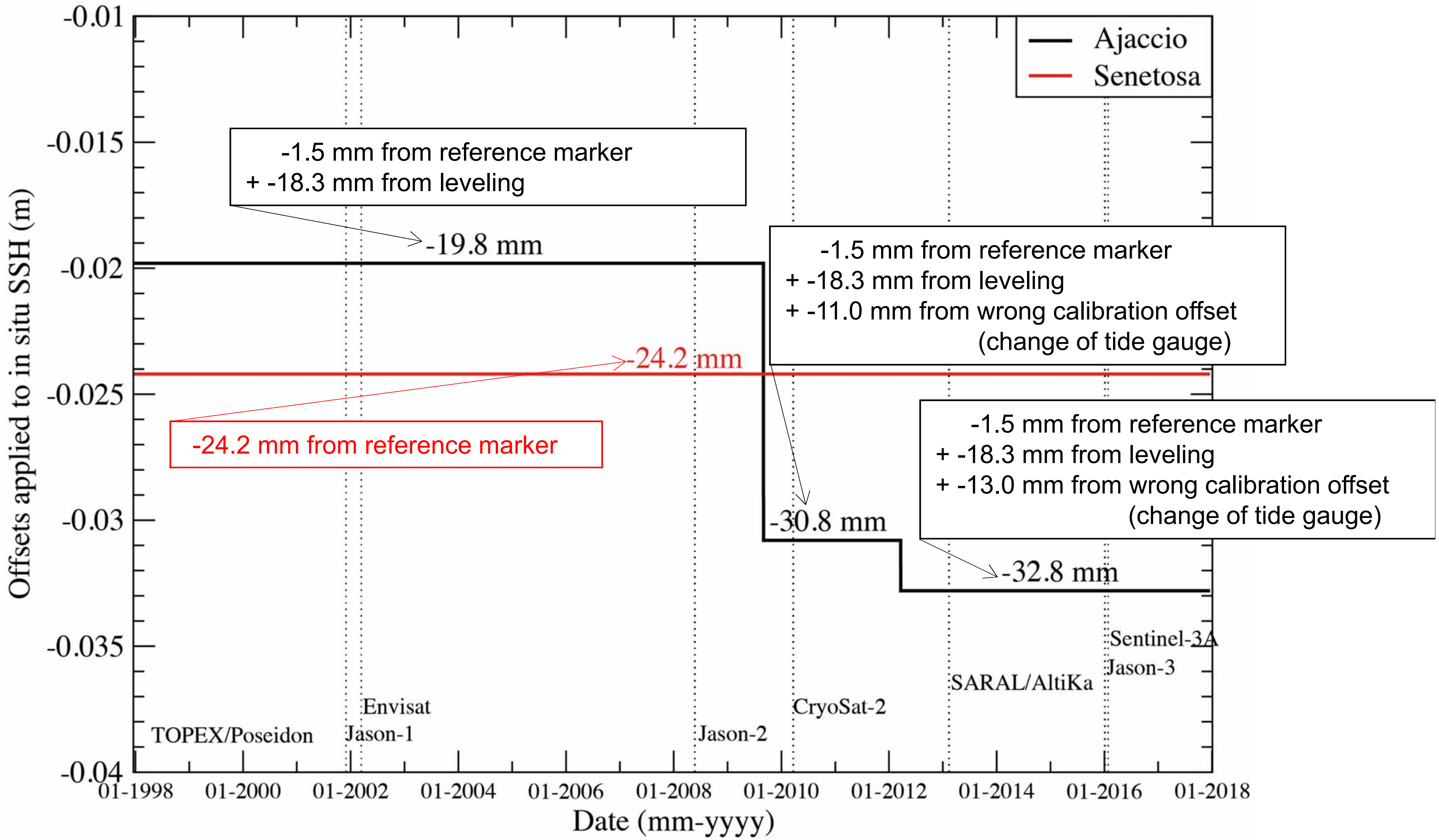
- **Ajaccio configuration** established in 2000
  - Supports continuous monitoring of SARAL/AltiKa (and formerly ERS, Envisat)
  - Fiducial point near Ajaccio equipped with GPS/SLR(FTLRS)/DORIS.
  - Equipped with a radar tide gauge (SHOM) leveled to the permanent GPS receiver

- **Corsica multi-mission calibration site: existing facilities also used for CryoSat-2, HY-2A and Sentinel-3A&B**

- **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**

Update of the geodetic datum

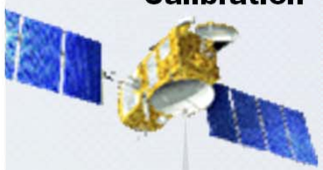
It sometimes takes time to clean out our closet…

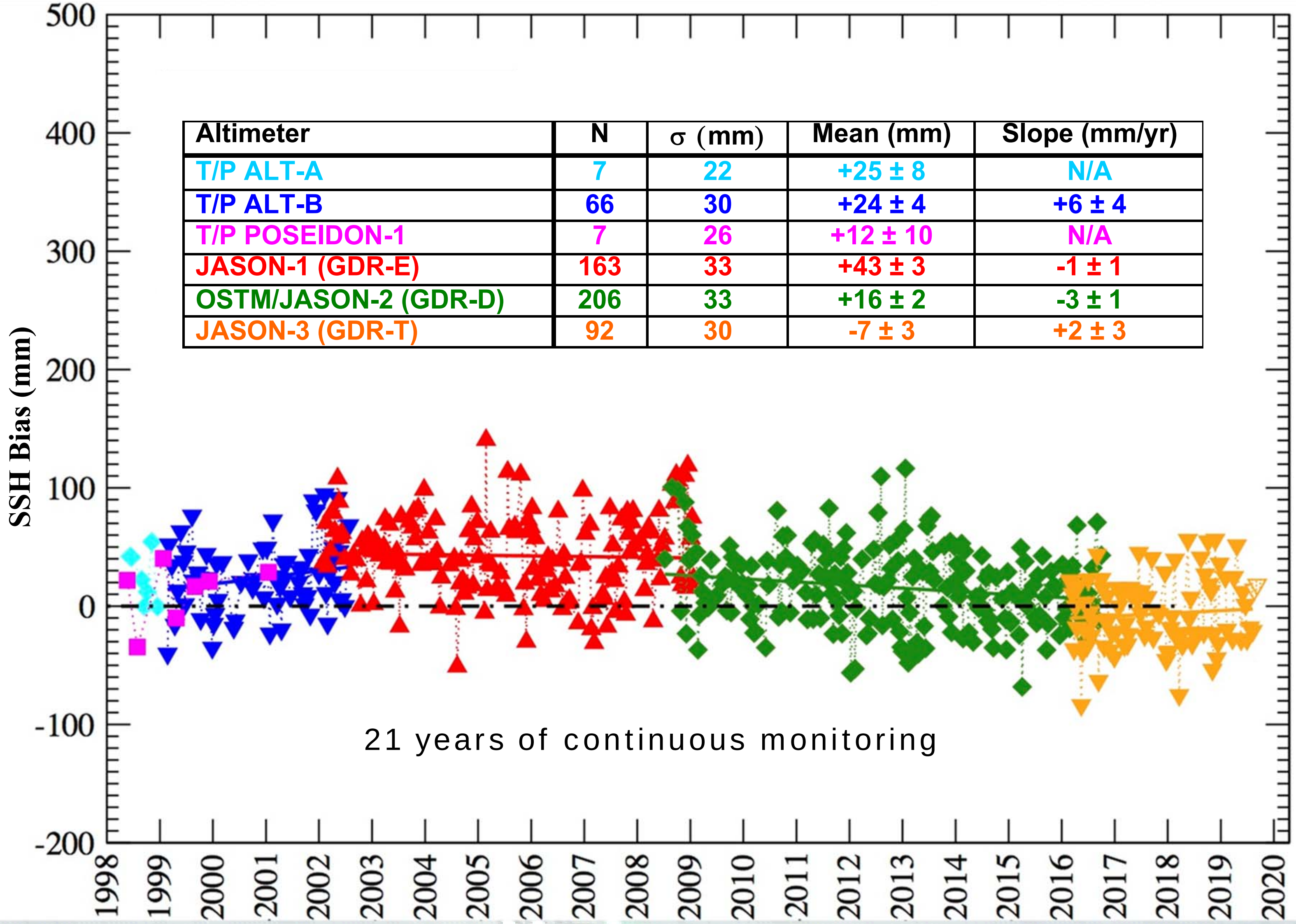


The SSH biases for all the missions have been recomputed based on these geodetic datum changes.

(see Bonnefond et al. 2019 (https://doi.org/10.1016/j.asr.2019.09.049) in 25YPRA ASR Special issue)

Corsica
Absolute
Altimeters
Calibration





Altimeter	N	σ (mm)	Mean (mm)	Slope (mm/yr)
T/P ALT-A	7	22	+25 ± 8	N/A
T/P ALT-B	66	30	+24 ± 4	+6 ± 4
T/P POSEIDON-1	7	26	+12 ± 10	N/A
JASON-1 (GDR-E)	163	33	+43 ± 3	-1 ± 1
OSTM/JASON-2 (GDR-D)	206	33	+16 ± 2	-3 ± 1
JASON-3 (GDR-T)	92	30	-7 ± 3	+2 ± 3

T / P & JASON

Products used:

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

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

Jason-2: GDR-D (cycle 1-305) (MLE3 = +40 ±3 mm => ≠ by -24 mm (mainly SSB))

Jason-3: GDR-T (cycle 1-128) (MLE3 = +13 ±4 mm => ≠ by -20 mm (mainly SSB))

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

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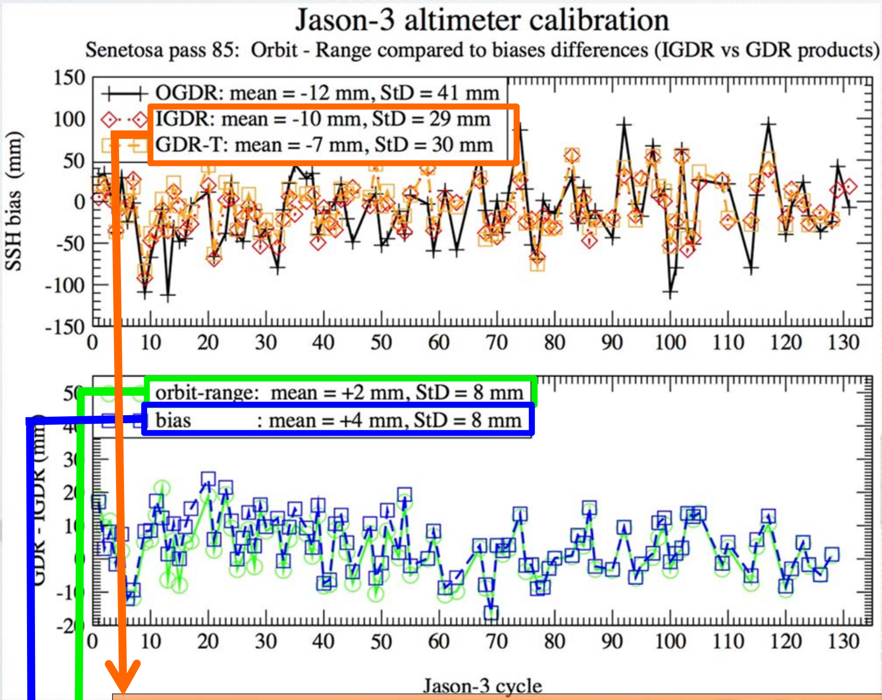

GDR-IGDR SSH bias difference is only +3 mm
With equivalent standard deviation

SSH bias differences coming from the orbit-range (+2 mm) is small showing that MOE and POE orbits are very close.

Except the orbit bias, differences between GDR and IGDR SSH bias are due to small correction contribution (+2 mm on average).

At the Corsica location the Jason-3 SSH bias is -7 ± 3 mm (GDR-T)

JASON-3 SSHBIAS

Absolute SSH biases (PDGS: SARM & PLRM)

Corsica
Absolute
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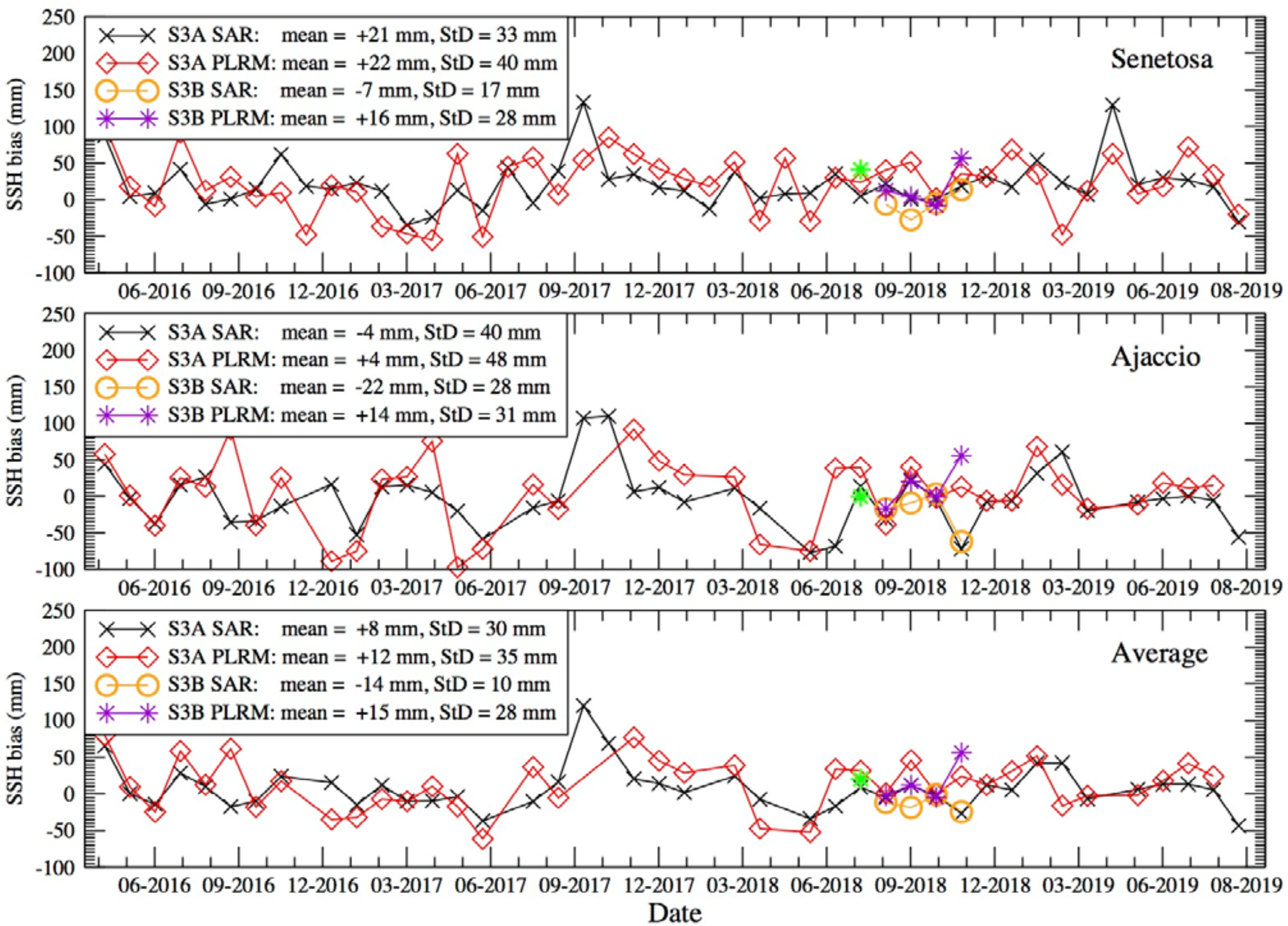
Calibration



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The averaged Sentinel-3A SSH bias (NTC products) for both locations is:

- SAR: +8 ± 5 mm

- PLRM: +12 ± 6 mm

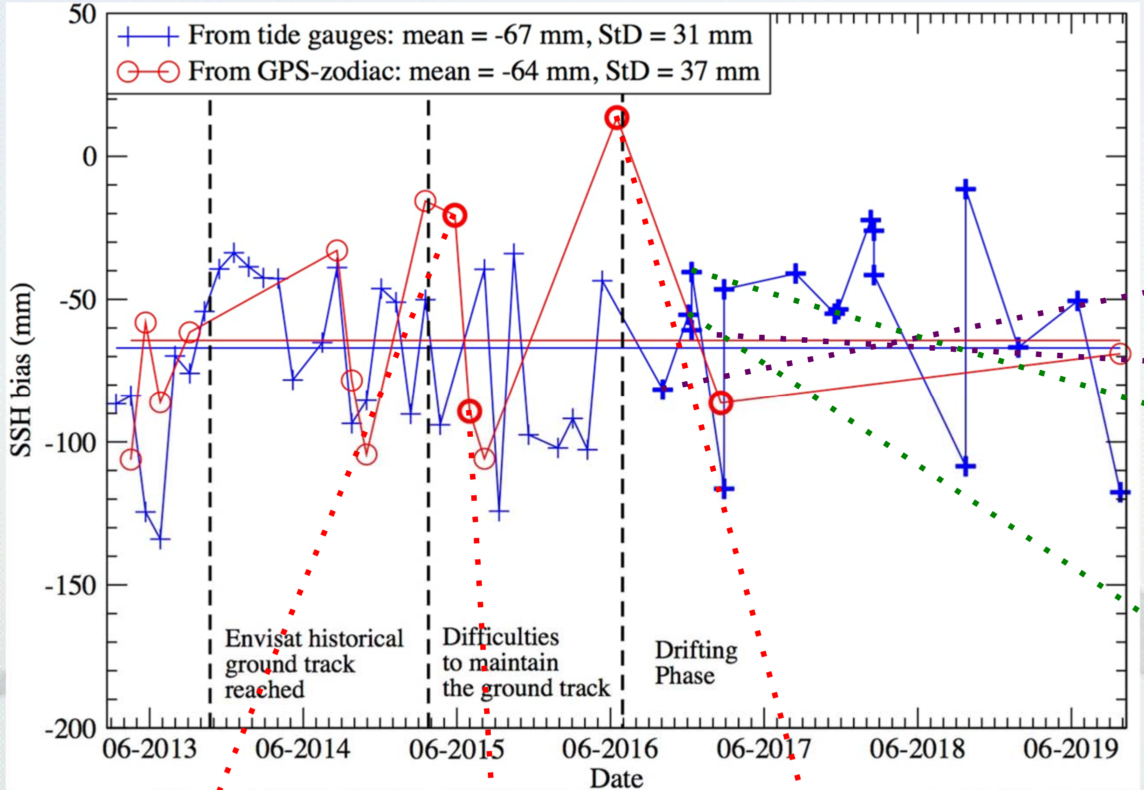
Recent studies using the transponder installed in Crete show that the SAR range bias converted in SSH bias (inverse sign) is -6 mm (Mertikas et al., 2018) and -8 mm (Garcia-Mondejar et al., 2017), so our results are very good agreement.

For Sentinel-3B, the SSH bias (NTC products) in tandem with Sentinel-3A is:

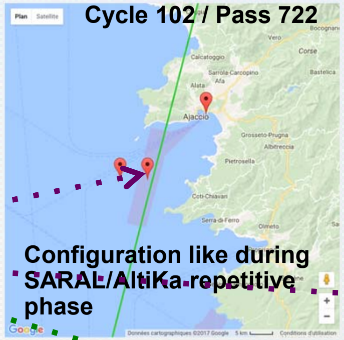
- LRM: +20 mm (first cycle)

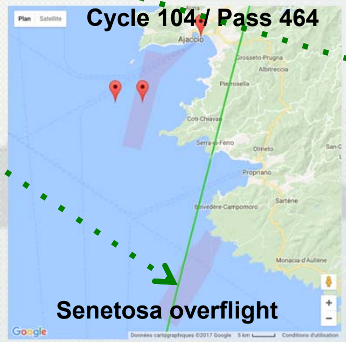
- SAR: -14 ± 5 mm (4 cycles)

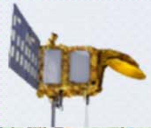
- PLRM: +15 ± 14 mm (4 cycles)

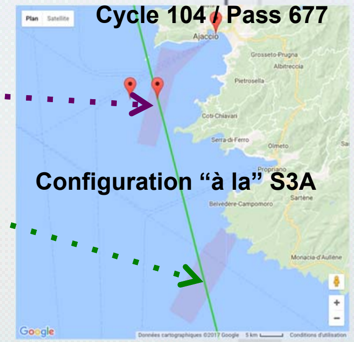


Standard tide gauge calibration

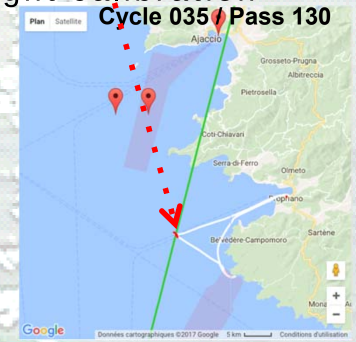








GPS-zodiac device for direct overflight calibration



S A R A L / A L T I K A

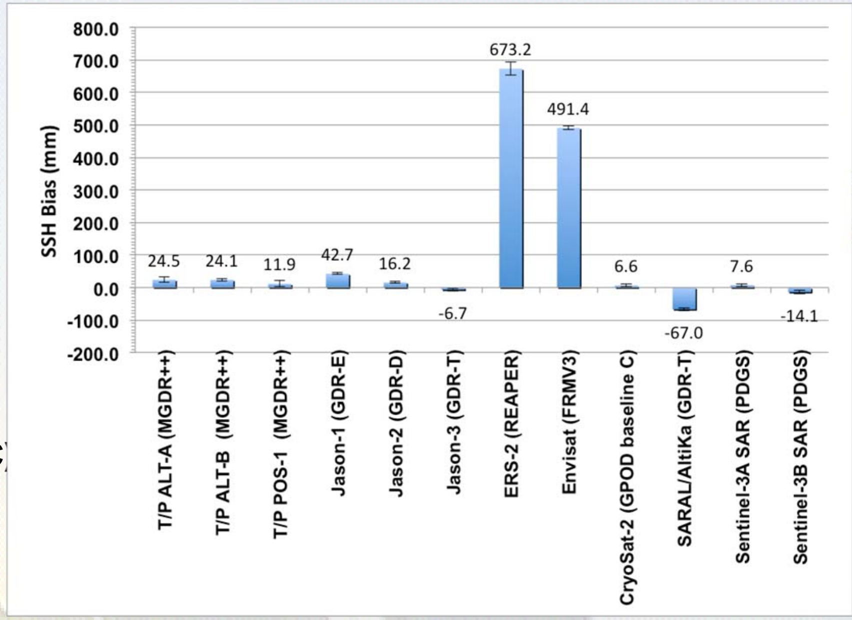
Using **either indirect (tide gauges) or direct (GPS-zodiac) calibration/validation approach gives similar SSH bias, respectively −67 ± 5 mm and −64 ± 10 mm.** Even during the Drifting Phase, we can continue to monitor the SSH bias using both approaches with a good agreement compared to the whole time series and a period close to the initial one: 36 days in average compared to the 35-day repeat period during the nominal phase, but not evenly distributed in time and location.

Calibration from Corsica

Corsica
Absolute
Altimeters
Calibration

Absolute SSH biases over the whole data sets:

T/P ALT-A: +25 ±8 mm (MGDR++)
T/P ALT-B: +24 ±4 mm (MGDR++)
T/P POS-1: +12 ±10 mm (MGDR++)
Jason-1: +43 ±3 mm (GDR-E)
Jason-2: +16 ±2 mm (GDR-D)
Jason-3: -7 ±3 mm (GDR-T)
ERS-2: +673 ±19 mm (REAPER)
Envisat: +491 ±6 mm (FRMV3)
CryoSat-2: +7 ±4 mm (GPOD baseline C)
SARAL: -67 ±5 mm (GDR-T)
S3A SAR: +8 ±5 mm (PDGS, NTC)
S3B SAR: -14 ±5 mm (PDGS, NTC)



These new SSH biases are based on a complete update of Ajaccio and Senetosa geodetic datum and the most recent reprocessed data sets

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Main findings:

Jason-1 reprocessing (GDR-E):
- Message from last years: a wrong standard dry troposphere correction for cycle 1-150 in some coastal areas (step of 8 mm before/after cycle 150). Will be corrected in GDR-F ?

Jason-2 (GDR-D):
- Nothing to declare, waiting for GDR-F

Jason-3 (GDR-T):
- A very stable SSH bias close to zero, waiting for GDR-F before Jason-CS launch
- IGDR and GDR are very close in terms of quality

Sentinel-3A&B (PDGS):
- Sentinel-3A (NTC): a very stable SSH bias close to zero for SAR
- Sentinel-3B (NTC): first 4 cycles shows a SSH bias statistically close to Sentinel-3A time series

CryoSat-2 (GPOD):
- Re-processing of the whole CryoSat-2 data (SAR, baseline C) gives a very stable SSH bias of +7 mm

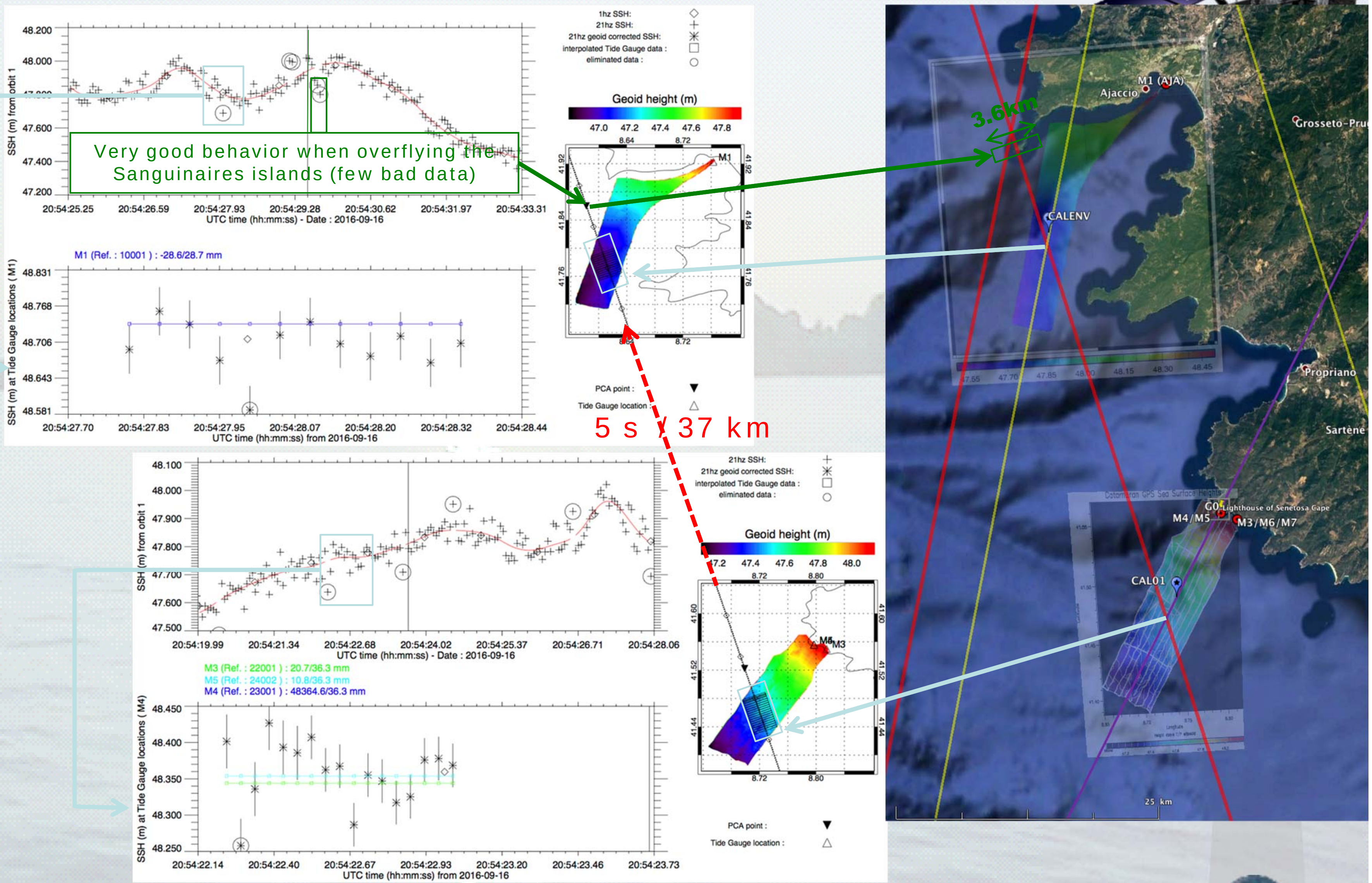
SARAL/AltiKa (GDR-T):
- SSH bias monitoring also during the drifting phase and is stable (-66 mm), waiting for GDR-F

Wet tropospheric correction from radiometers compared to GPS:
- no clear offsets for Jason series as well as for Sentinel-3A&B and SARAL/AltiKa

Backup slides

Processing

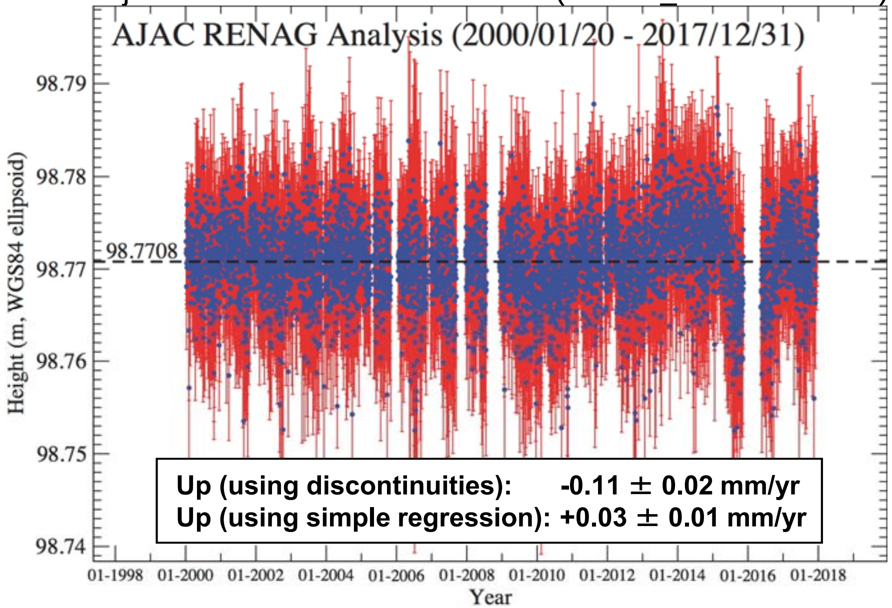
Sentinel-3A, SAR mode
Pass 741, Cycle 8, 2016-09-16 20:54



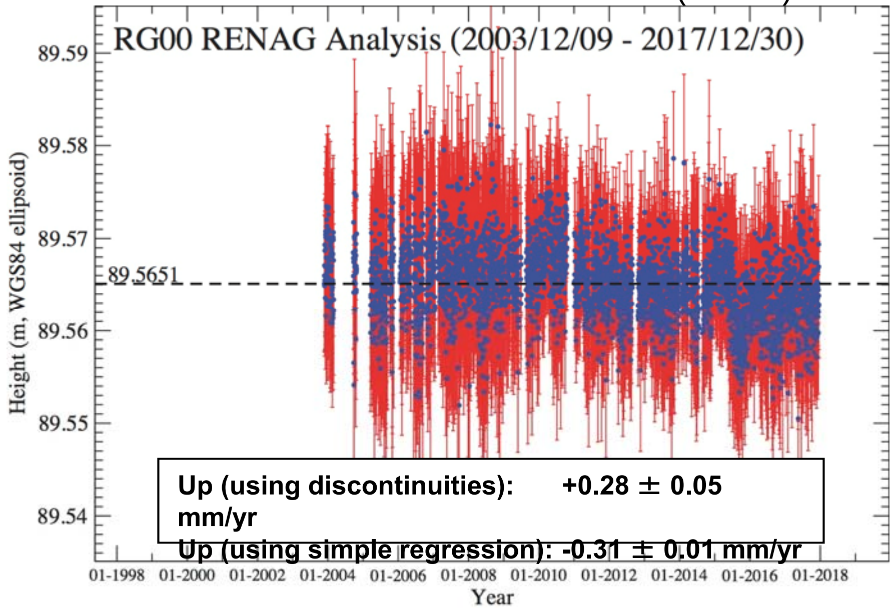
Update of the geodetic datum (1/2)

It sometimes takes time to clean out our closet…

Ajaccio reference marker (AJAC_10077M005)



Senetosa reference marker (RG00)



In the frame of the RENAG project (http://renag.resif.fr) a **complete reanalysis of the GPS coordinates has been performed** for the Ajaccio (AJAC) and Senetosa (RG00) reference markers **in the ITRF2014 reference frame**.

In terms of absolute vertical coordinates these new solutions have changed our historical references:

- 98.7708 m for **Ajaccio** (AJAC) => **-1.5 mm when compared to our historical reference** (and -0.7 mm compared to official ITRF2014)
- 89.5651 m for **Senetosa** (RG00) => **-24.2 mm when compared to our historical reference** (and -4.5 mm compared to a solution computed recently with GIPSY/JPL over the same period)

The small values of the velocities and the opposite signs within a very short distance (~37 km) suggest that there is **no vertical geophysical motion over this area**. We then considered in this study a zero velocity for both sites. Over the whole studied periods, 1998-present for Senetosa and 2000-present for Ajaccio, it will lead to a possible error of respectively ~6 mm and ~2 mm.

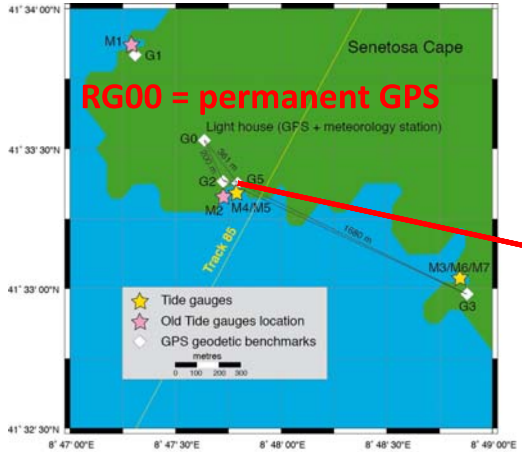
Impact of the geodetic datum update

Change of
up coordinate (-24.2 mm)
for the Senetosa
reference marker (RG00)

The update of the up coordinate (-24.2 mm) for the Senetosa reference marker (RG00) improves the consistency with Harvest and Bass Strait for all the altimeters (T/P-A&B, Jason-1,2,3). Comparisons are based on OSTST 2018 results for both Harvest and Bass Strait.

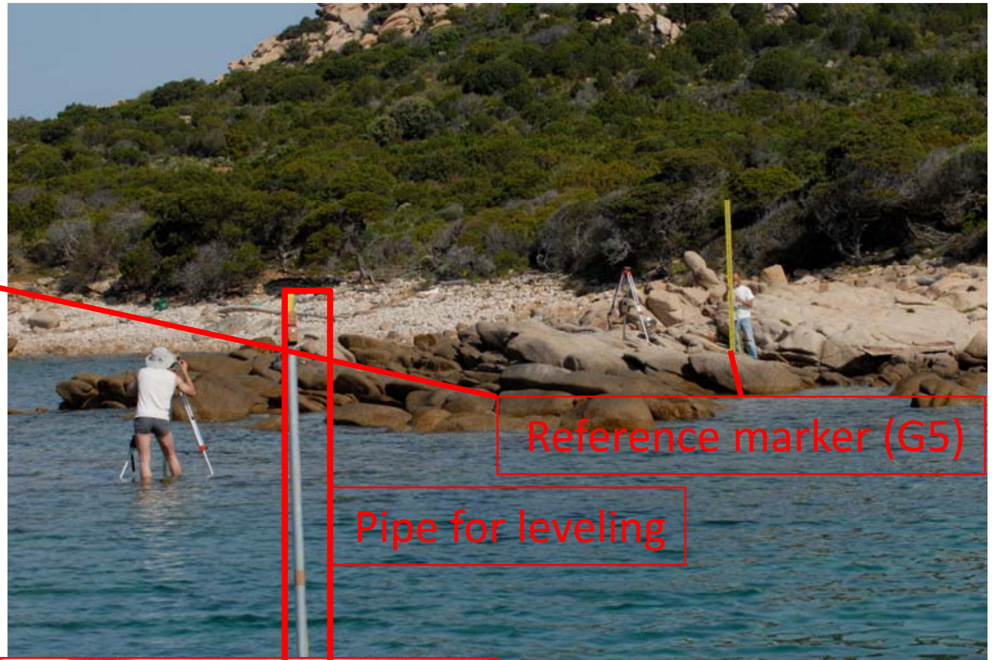
Absolute calibration accuracy at the cm level is still a challenge...

Stability of the geodetic reference
Leveling of the in situ instruments

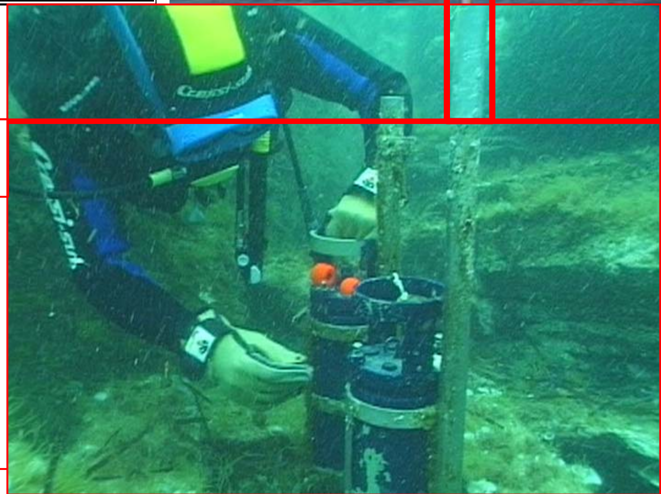


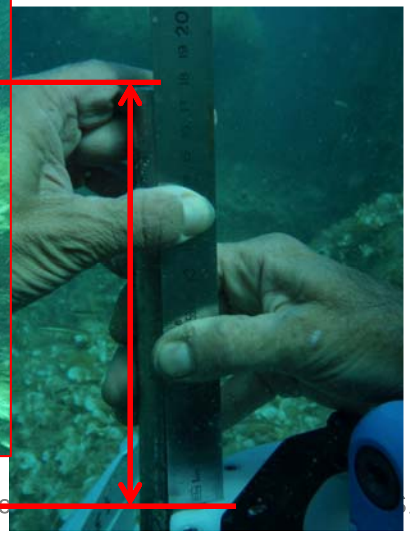
	Leveling 2009 (m)	Leveling 1998 (m) / Leveling 2001 (m)	Differences (mm)
G5 --> M4	-4.5166	-4.5169	0.3
G5 --> M5	-4.4986	-4.4990	0.4
G3 --> M3	-5.5583	-5.5585	0.2
G2 --> G5	-3.0531	-3.0535	0.4
G0 --> G2	-38.7550	-38.7560	1.0

Less than 1 mm differences even after 10 years



Reference of the tide gauge mount

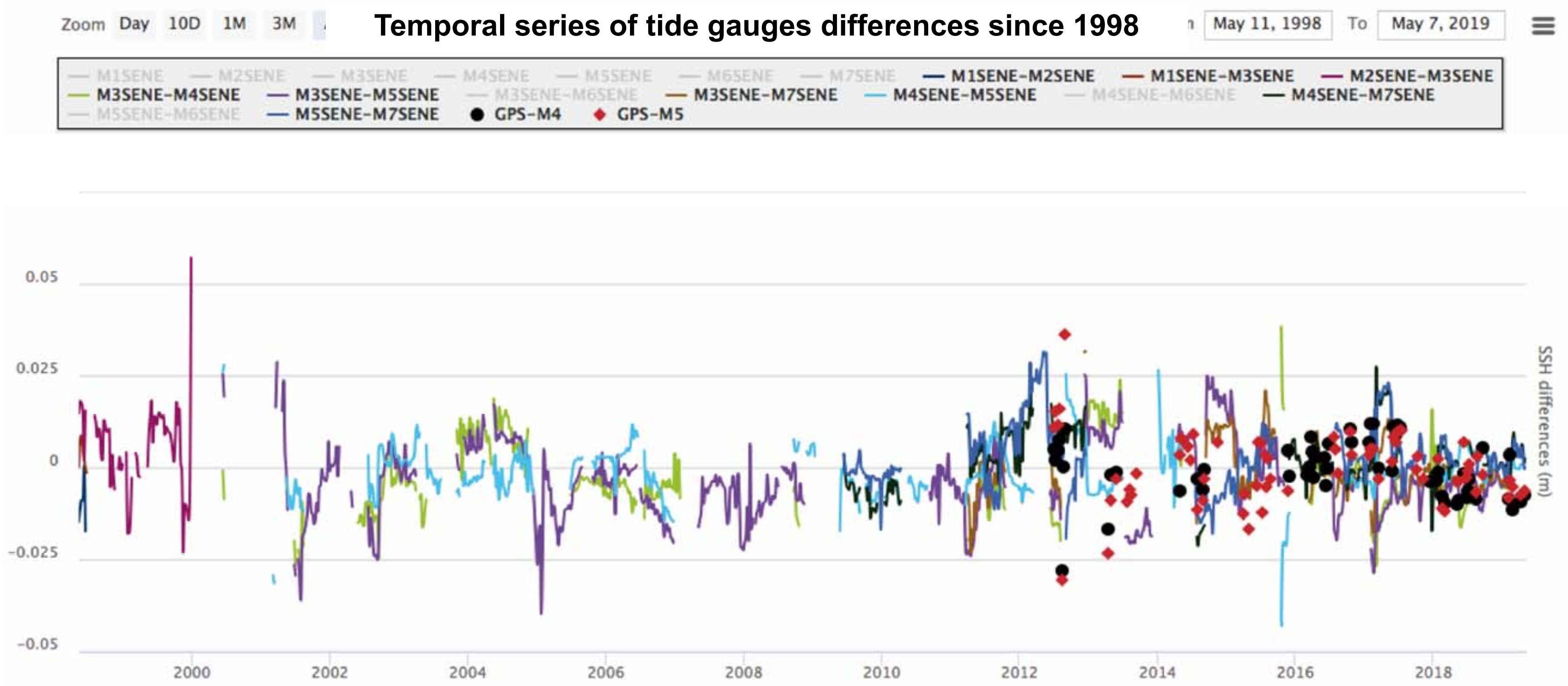




Reference of the tide gauge pressure

Tide gauges are installed by pair:
M4/M5 (photo) on one side of the bay
M3/M7 on the other side

Stability of in situ measurement system
Comparisons with independent measurements



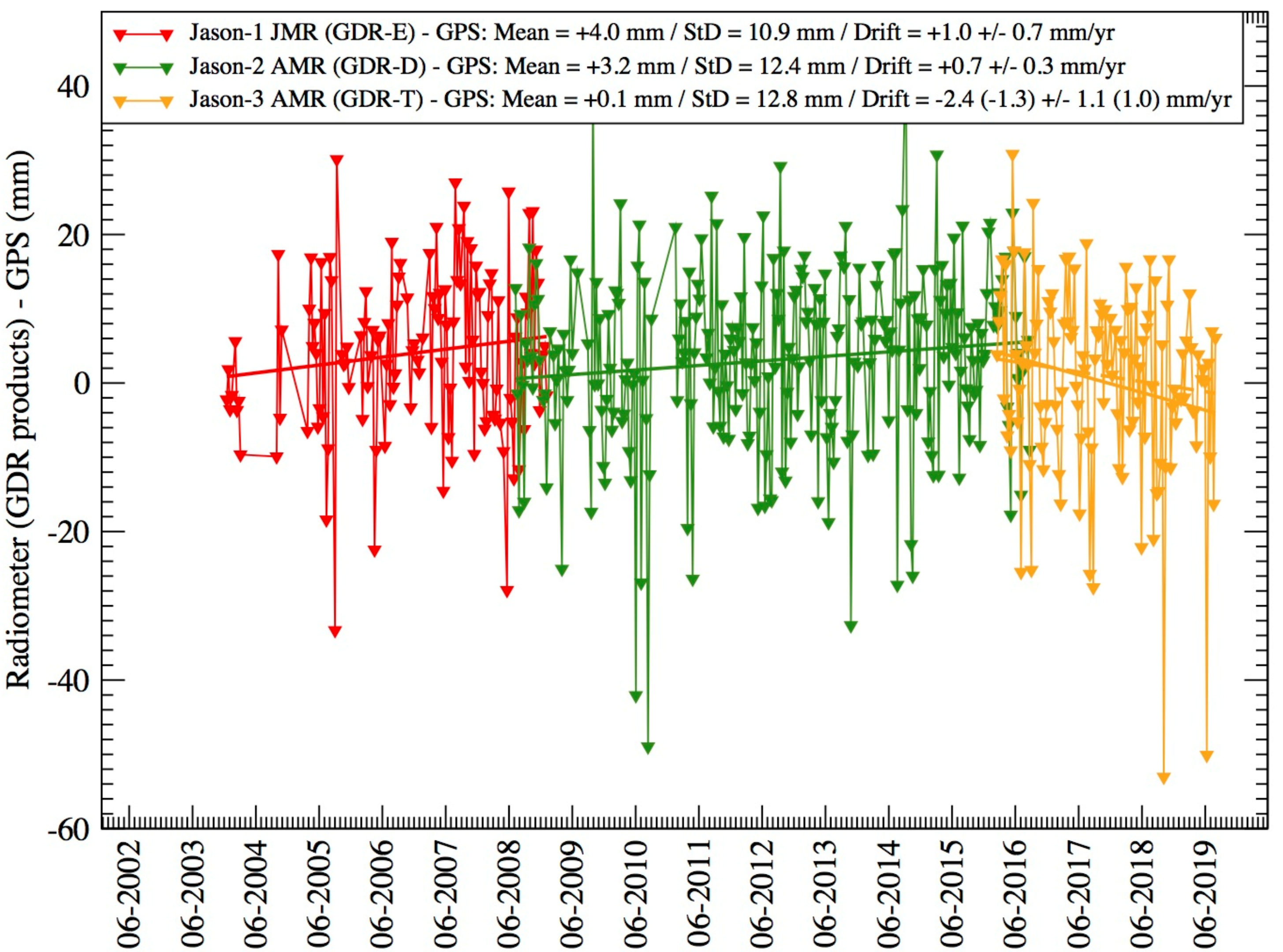
Average differences at the few millimeters level with ~1 cm standard deviation

Stability of the differences better than ~0.1 mm/yr

GNSS system for measuring SSH

Type of comparaison	Mean (mm)	σ (mm)	Drift (mm/yr)	Number
between tide gauges since (1998)				
M3SENE-M4SENE	-2.3	10.9	-0.07 ± 0.02	10184
M3SENE-M5SENE	-3.6	12.0	+0.07 ± 0.02	16357
M4SENE-M5SENE	-0.9	7.71	+0.05 ± 0.01	13026
between GNSS et tide gauges (since 2012)				
GPS-M4SENE	-0.6	7.7	-0.28 ± 0.47	64
GPS-M5SENE	-0.5	9.4	-0.28 ± 0.52	83

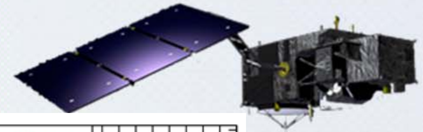
Radiometer Wet Tropospheric Correction compared to GPS



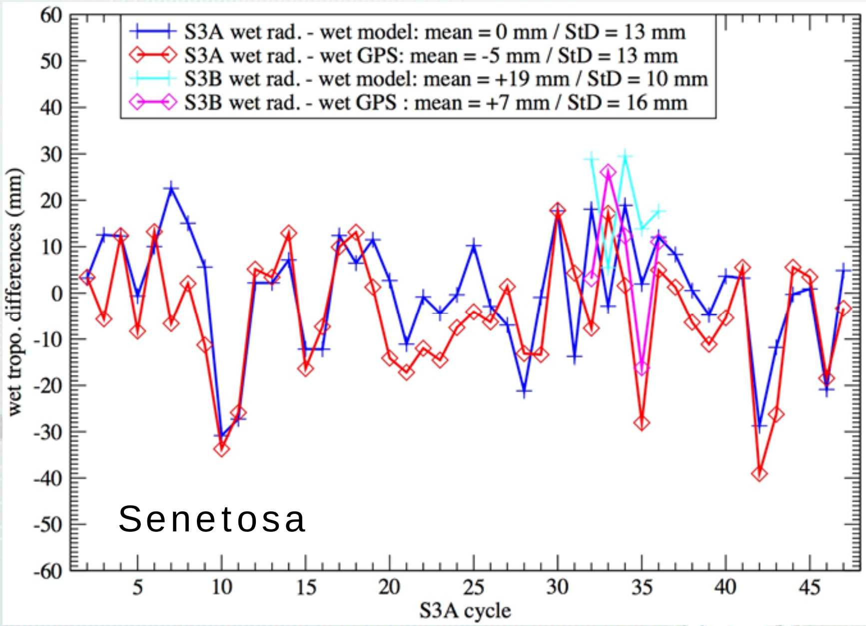
WET TROPO JMR & AMR

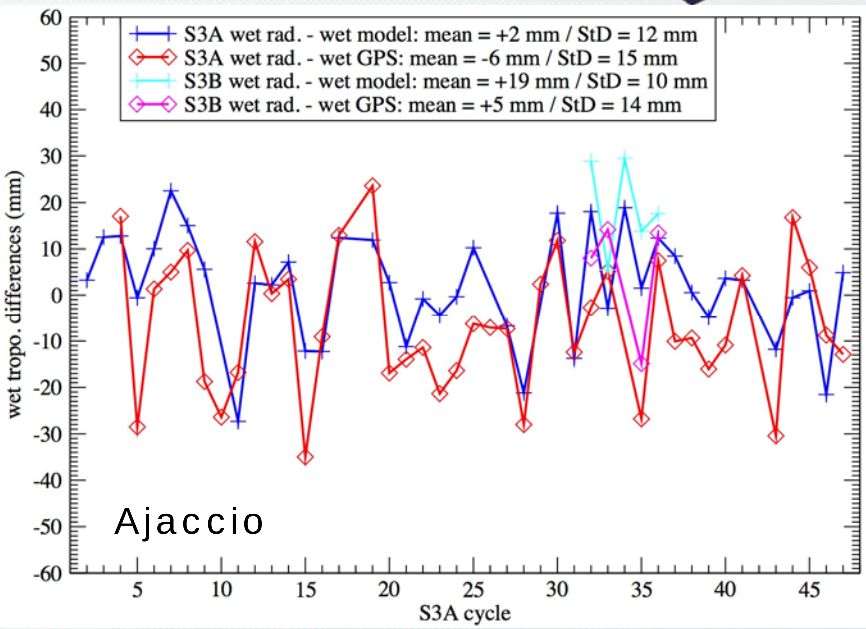
The permanent GPS receiver installed at Senetosa since 2004 also provide monitoring of the wet tropospheric correction:

- No significant offsets observed
- Drifts are below 1 mm/yr (for long series)



Radiometer Wet Tropospheric Correction compared to GPS

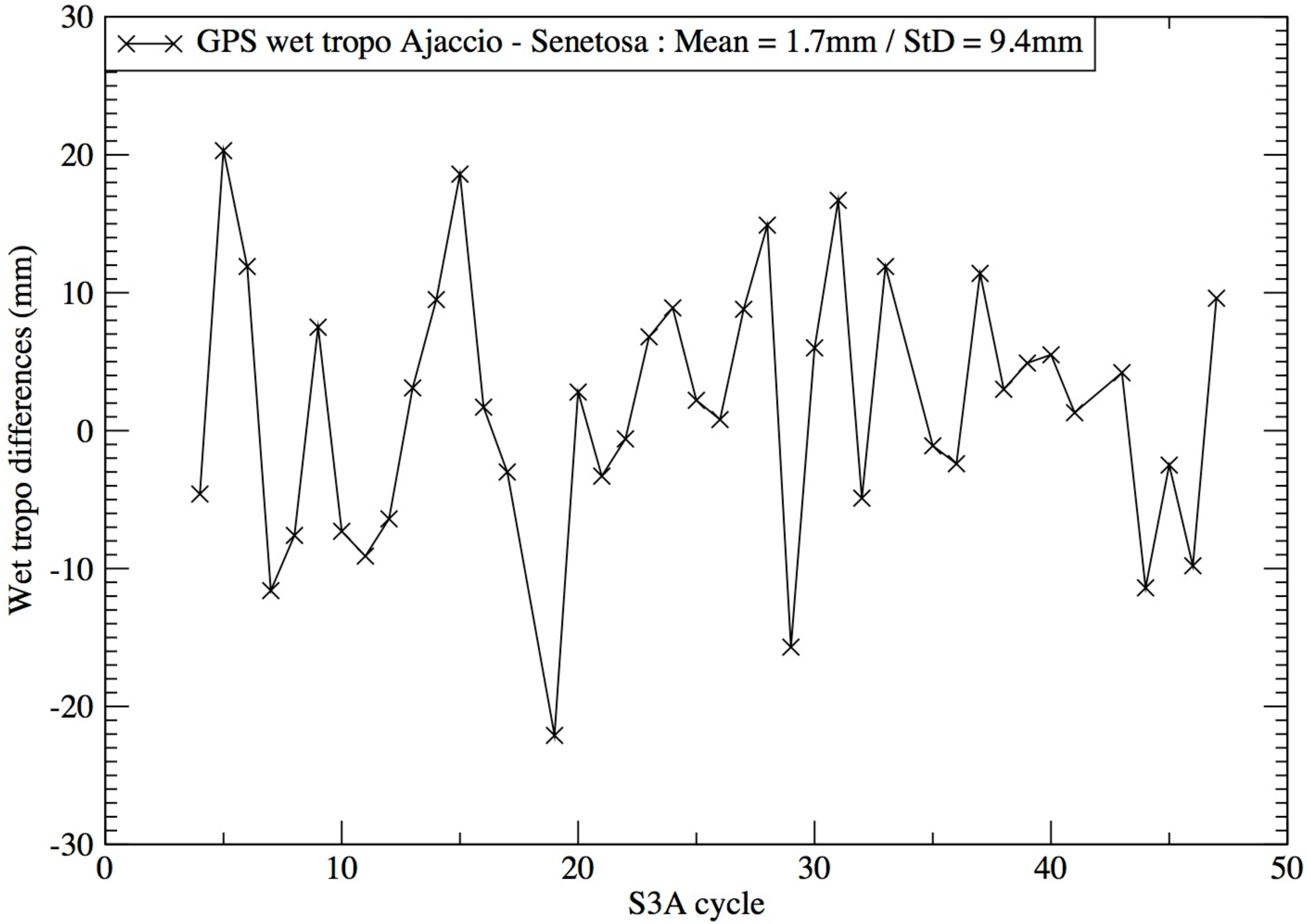


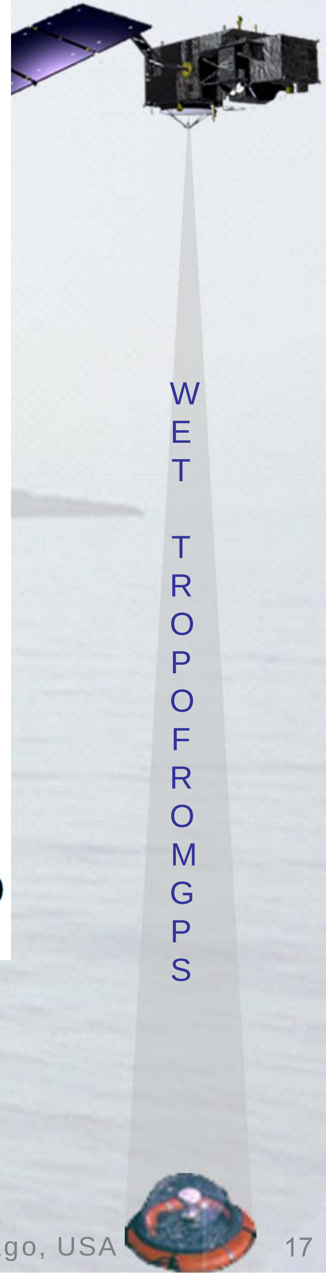


The permanent Ajaccio and Senetosa GPS receivers provide monitoring of the wet tropospheric correction:

- No significant offsets observed for Sentinel-3A and Sentinel-3B

WET TROPO SENTINEL-3





The wet tropospheric corrections from Ajaccio and Senetosa GPS receivers distant by 40km are coherent reflecting small differences (<1cm rms) due to local weather differences

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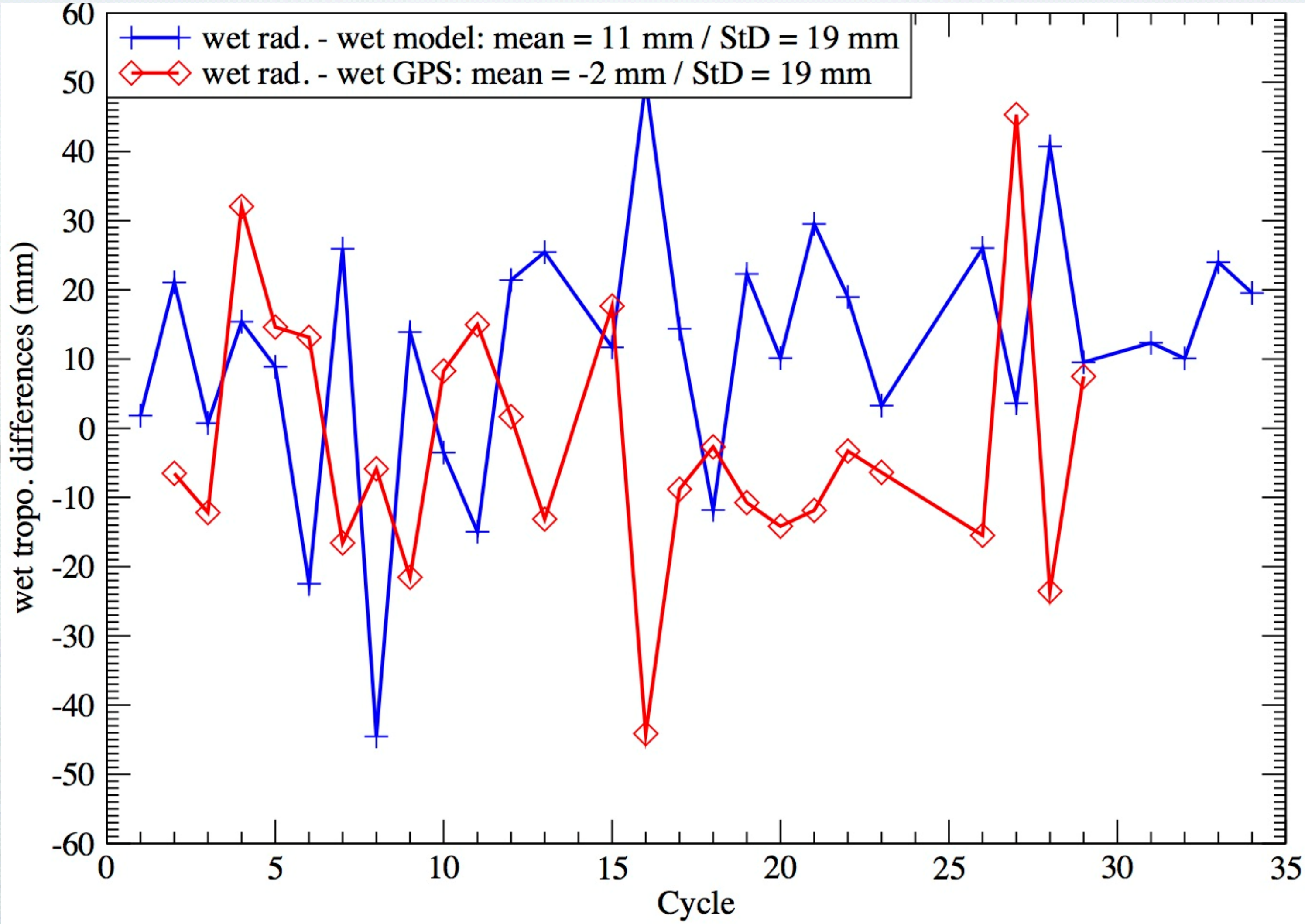
Radiometer Wet Tropospheric Correction compared to GPS



WET TROPOSARAL/ALTIKA

The permanent Ajaccio GPS receiver provide monitoring of the wet tropospheric correction:

- No significant offset observed for SARAL/AltiKa