Ocean Surface Topography Science Team Meeting (OSTST)

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

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l'Observatoire de Paris — SYRTE
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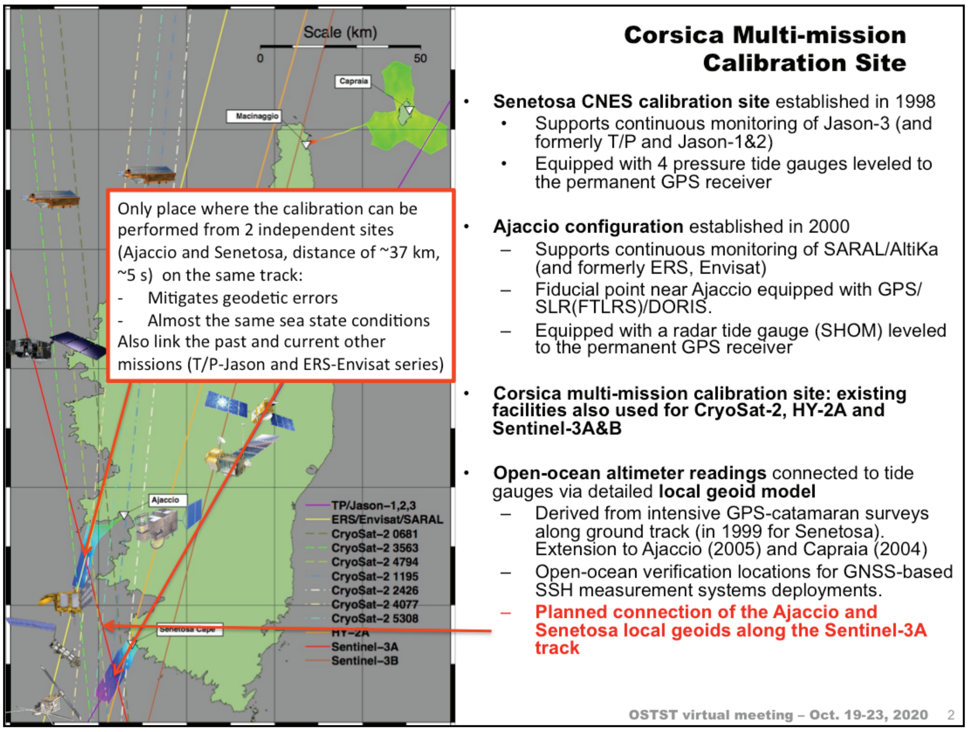
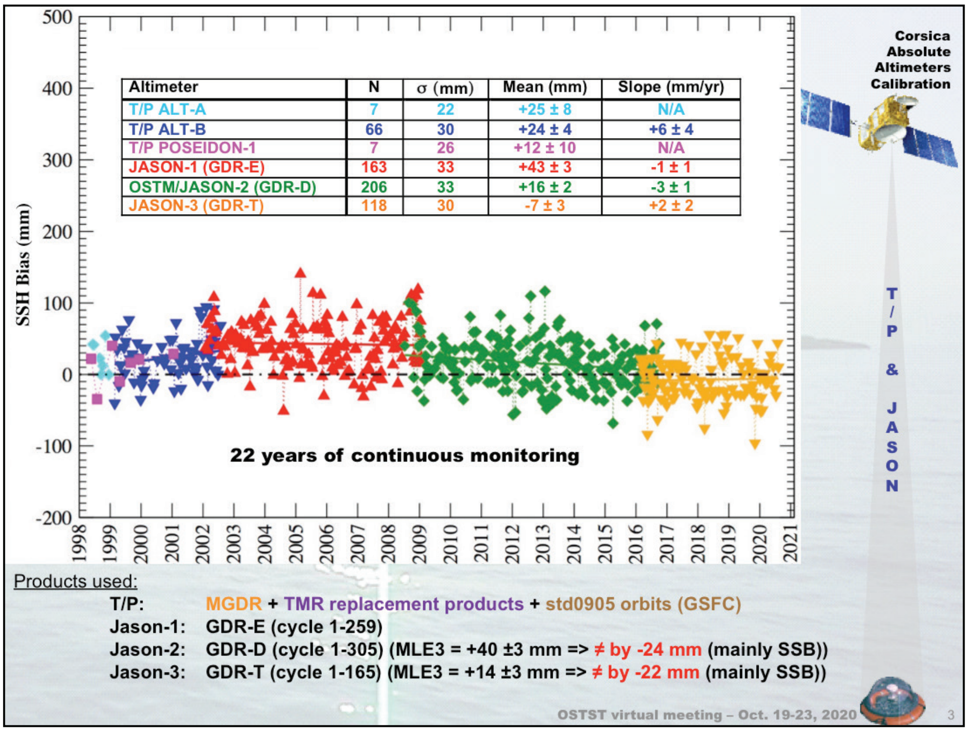



**Corsica Multi-mission Calibration Site**

The Corsica experiment which makes a collective reference to the instrumentation and facilities located in the western part of the Mediterranean at Ajaccio-Aspretto, Senetosa, and on the island of Capraia (Italy), is used to maximize the capability of performing the absolute calibration of a range of altimeters (see Figure left for the respective sites and the satellites ground tracks). On the other hand, it implies preserving the coherence of the overall Corsica experiment in terms of geodesy despite the diversity of instruments, approaches and geophysical conditions in addition to the range of distances between the sites.

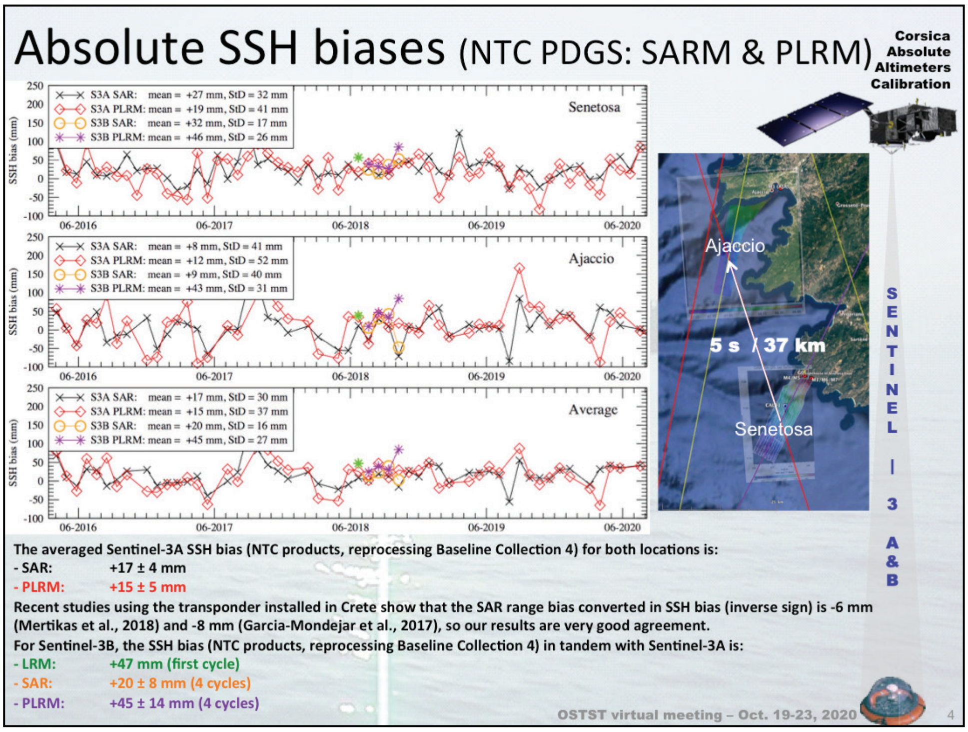
Since the development of the Ajaccio and Senetosa sites, absolute calibration were performed independently at each site depending of the overflying mission without any means of verifying the reliability of their respective geodetic datum (absolute sense). However, thanks to the configuration of Sentinel-3A repeat ground track and some CryoSat-2 passes, it has been possible to determine two distinct SSH biases at each site for each altimeter overflying both Senetosa and Ajaccio with a time delay of about five seconds (about 37 km). As a consequence, it allowed us to compare these biases and thus interconnect both datum. Moreover, because the SARAL/AltiKa mission was placed on a drifting orbit phase since July 2016, a similar interconnection between both Ajaccio and Senetosa datum has been achieved. All recent results and history of the Corsica calibration site are available in this paper:

Bonnefond, P., Exertier, P., Laurain, O., Guinle, T., Féménias, P. (2019) Corsica: A 20-Yr Multi-Mission Absolute Altimeter Calibration Site, Advances in Space Research, Special Issue « 25 Years of Progress in Radar Altimetry », doi : https://doi.org/10.1016/j.asr.2019.09.049




**Reference missions (TOPEX/Poseidon, Jason-1, Jason-2, Jason-3)**

The Senetosa calibration facilities have been initially developed to monitor the performance of TOPEX/Poseidon and to follow the Jason legacy satellite altimeters. This site provides more than 20 years of SSH observations for these missions. As discussed in Bonnefond et al. (2019), a particular care has been taken to insure the stability of the geodetic datum and the instruments' measurements. Because the time series are composed of only one determination every ten days, it is however difficult to derive any drift of the altimeters' SSH biases, even over several years. The linear trend values the Figure are thus given only for information and are not statistically significant. On the other hand, the mean values of the SSH biases are determined with a high level of confidence with a standard error of few millimeters (2 mm for the longer time series of Jason-2). The mean SSH biases range from -11 (Jason–3) to +43 mm (Jason-1) with a standard deviation of 18 mm: this shows that inter-mission biases still exist at the level of several centimeters and this reinforces the need of tandem verification phase between consecutive missions to insure the consistency of the climate record of these reference missions.

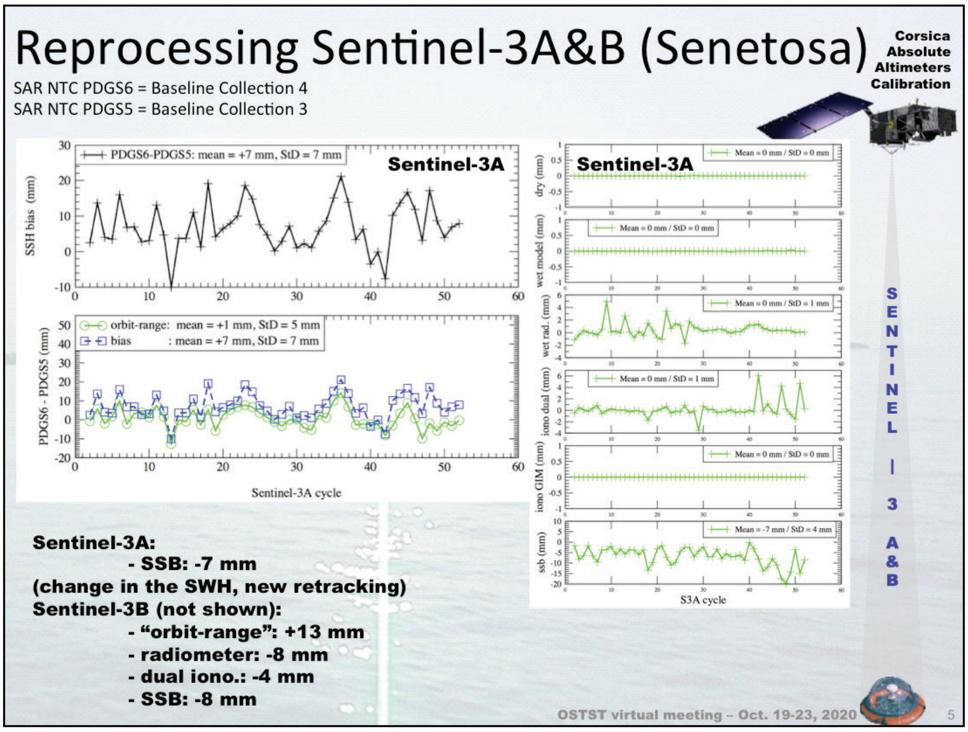



**Sentinel-3A and Sentinel-3B**

The Sentinel-3A ascending pass #741 overflies the Senetosa site and the Ajaccio one ~5 s later. This allows us to compare the SSH biases, which can be independently determined at both locations, and then to assess geodetic references together with in-situ measurements. The Figure shows the time series of Sentinel-3A and Sentinel-3B for Senetosa (top), Ajaccio (middle) and the average of both sites (bottom). The times series are given for the two modes that are used to derive the sea surface height from the radar measurements: (i) the SAR (Synthetic Aperture Radar) mode and (ii) the PLRM (pseudo LRM) mode that mimics the classic LRM.

In summary, for Sentinel-3A, the averaged SSH bias for both locations is +17 ± 4 mm in SAR mode and +15 ± 5 mm for PLRM mode. For Sentinel-3B, the averaged SSH bias (based only on 4 cycles) for both locations is +20 ± 8 mm in SAR mode and +45 ± 14 mm for PLRM mode. On cycle 9, Sentinel-3B was in LRM mode so this SSH bias of +47 mm (green star on the Figure) has been excluded from the statistics. However, this value is within the error bar of the PLRM time series, and so is not statistically different considering the small number of cycles.

Recent studies using the transponder installed in Crete show that the SAR range bias (inverse sign for SSH bias) for Sentinel-3A is +6 mm (standard deviation of 12 mm) (Mertikas et al., 2018) and +8 mm (standard deviation of 12 mm) (Garcia-Mondejar et al., 2017). For Sentinel-3B, preliminary result shows a range bias of -3 mm (standard deviation of 18 mm) (Garcia-Mondejar, personal communication). So our results are in very good agreement with transponder ones (differences within 15-17 mm) considering that difference between these two determinations can be due to the geophysical corrections (notably the SSB) as already mentioned for CryoSat-2 (section 4.4).



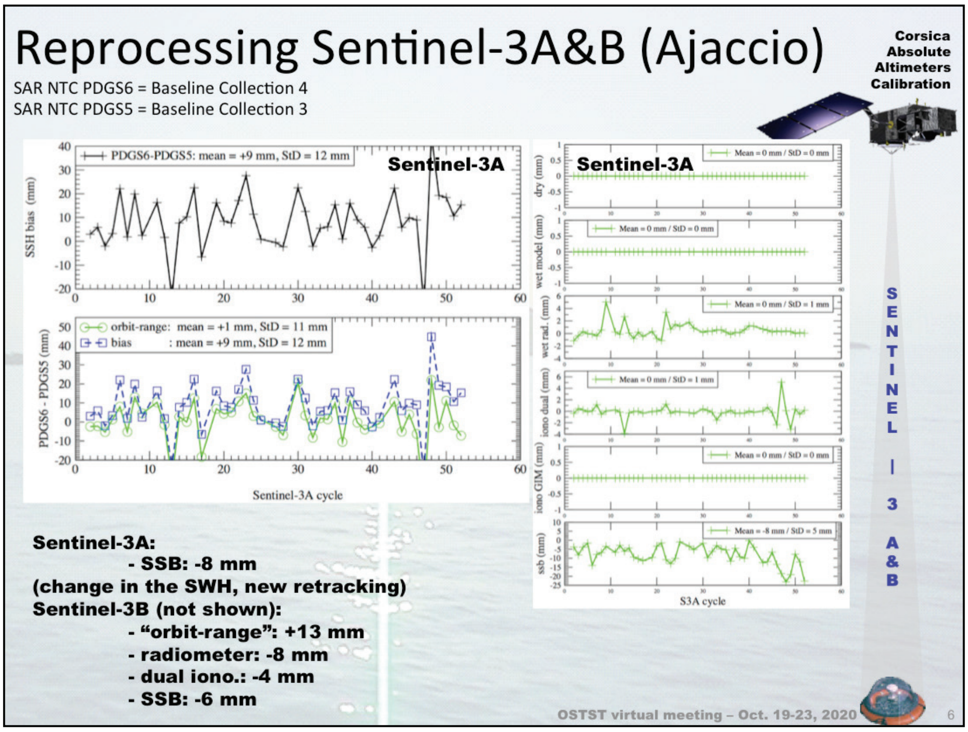

**Reprocessing of Sentinel-3A and Sentinel-3B (analyses at Senetosa)**

The full reprocessing of Sentinel-3 SRAL/MWR data to the latest standards (Baseline Collection 004) has been delivered in May 2020.

We have compared it to the previous Processing Baseline at both Senetosa (this slide) and Ajaccio (next slide) calibration sites.

Results show a very small change in term of absolute SSH bias for Sentinel-3A . The main difference comes from SSB (-7 mm) due to an evolution of the SAMOSA retracker that changes the SWH. The range is also changed by ~1 mm (see "orbit-range" on the left plot).

The difference is larger for Sentinel-3B due to additional differences of the radiometer (-8 mm) and the dual ionospheric (-4 mm) corrections. SSB impact is at the same level than for Sentinel-3A (-8 mm). The range is also changed by ~13 mm. In total the Sentinel-3B SSH bias is increased by 34 mm.




**Reprocessing of Sentinel-3A and Sentinel-3B (analyses at Ajaccio)**

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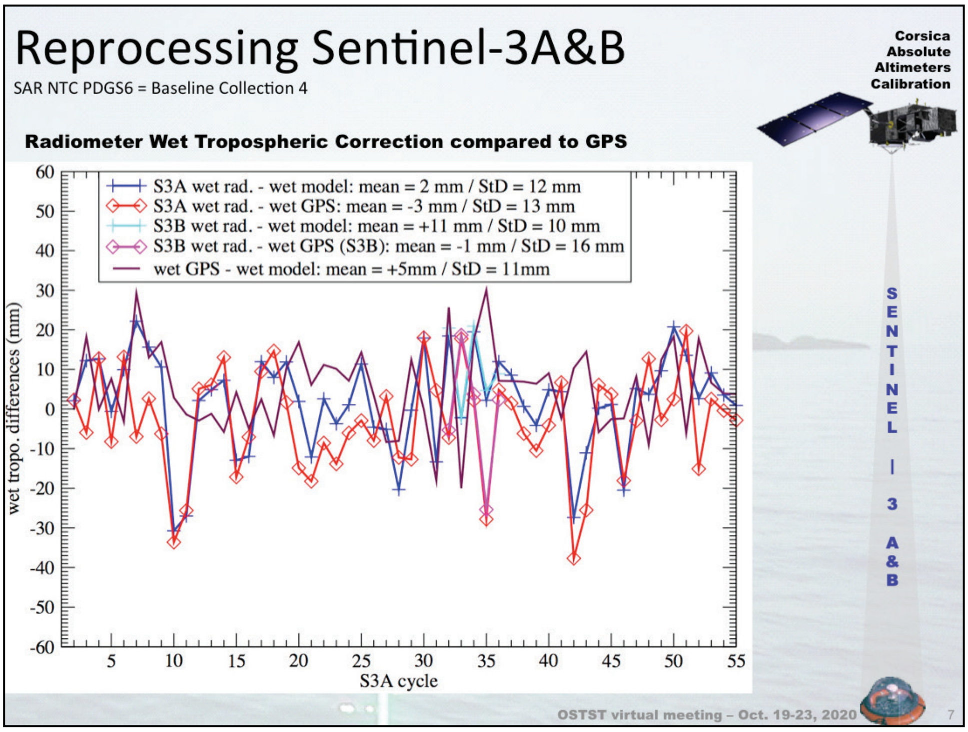
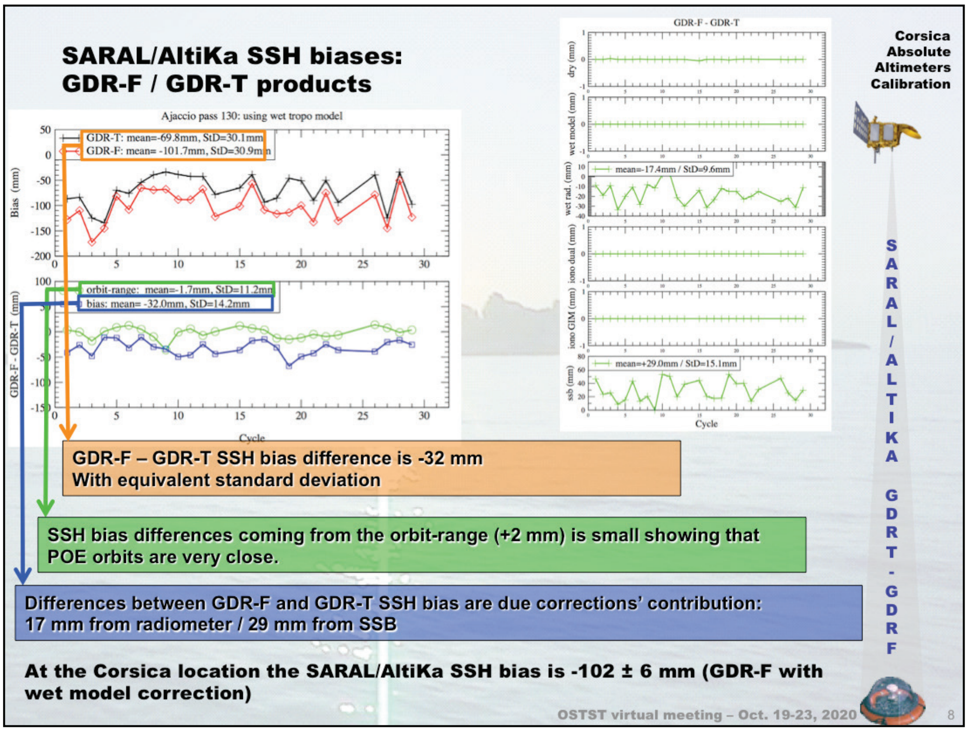
The difference is larger for Sentinel-3B due to additional differences of the radiometer (-8 mm) and the dual ionospheric (-4 mm) corrections. SSB impact is at the same level than for Sentinel-3A (-6 mm). The range is also changed by ~13 mm. In total the Sentinel-3B SSH bias is increased by 32 mm.




**Sentinel-3A and Sentinel-3B wet radiometer correction for the new Processing Baseline (4)**

The reprocessing has clearly improved the Sentinel-3B radiometer wet tropospheric correction and the comparison with the one derived from GNSS is now at the mm level for both Sentinel-3A and Sentinel-3B.

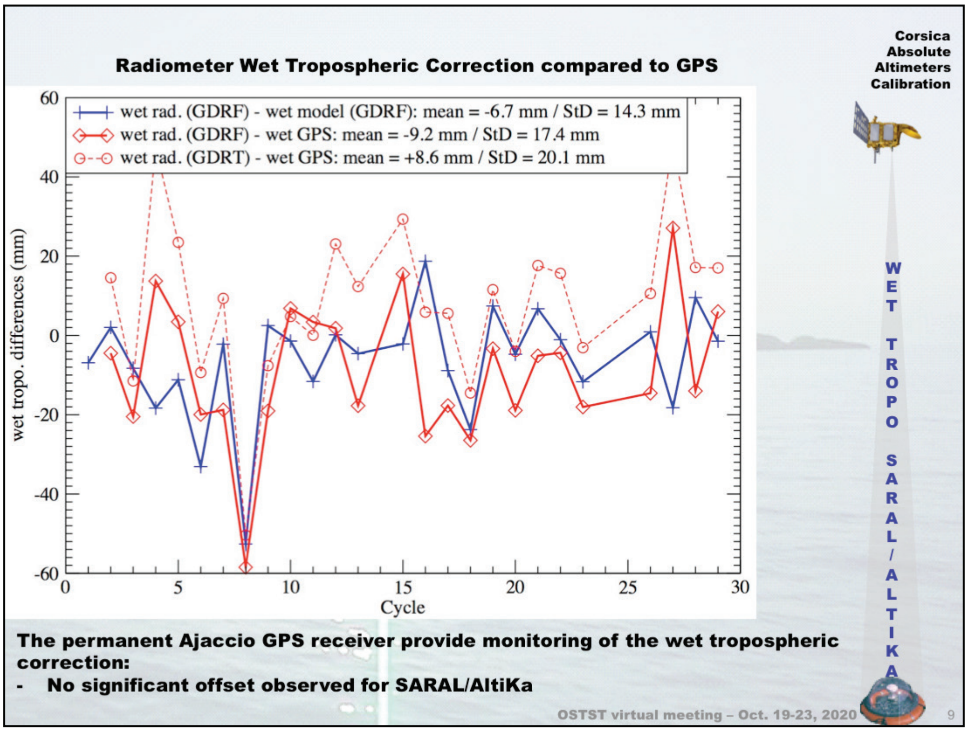



**SARAL/AltiKa**

The GDR-F products were analyzed and compared to the GDR-T using the Ajaccio calibration site for the subset of reprocessed data (year 2013 and 2014). At the end of the chosen period the ground trace was poorly maintained which explains the absence of some cycles (24 and 25). The SSH bias presented was calculated using the wet tropospheric correction from the model. The model/radiometer difference is: +10.8 mm and -6.6 mm for the GDR T and GDR F respectively.

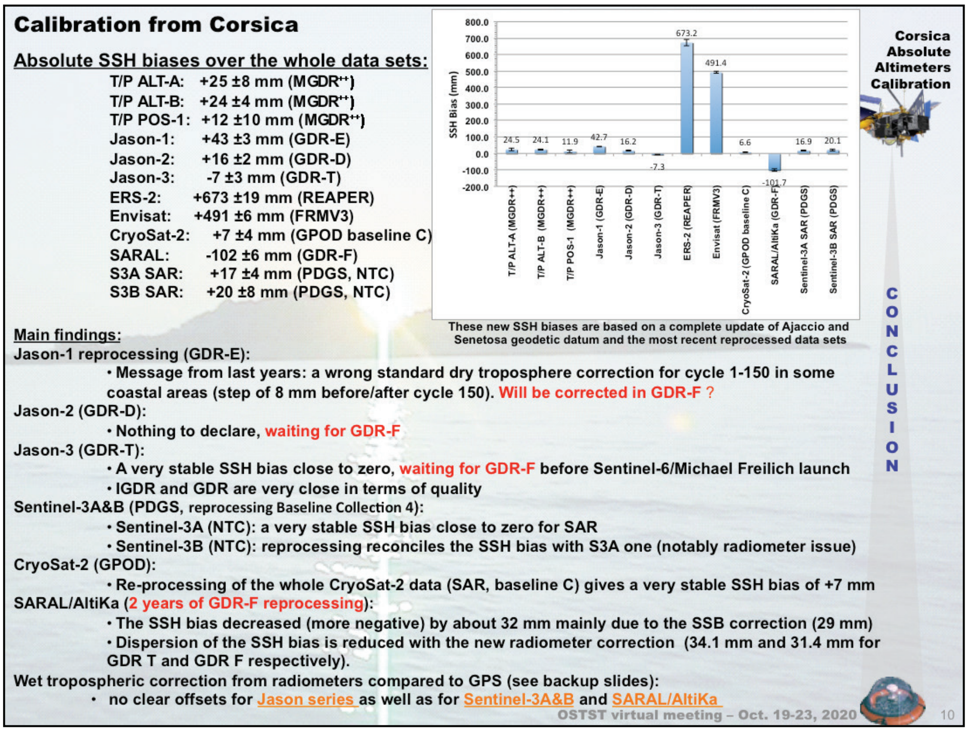
In summary :

- The SSH bias decreased (more negative) by about 32 mm mainly due to the SSB correction (29 mm). We have not used the new 3D SSB field for the moment. The bias, which was already quite important and still unexplained, is therefore worsening and reaches ~ 10 cm.
- The "orbit-range" differences reveal a small difference of -1.7 mm that comes from the difference in orbit and range.




**SARAL/AltiKa (Wet tropospheric correction)**

The wet tropospheric correction of the radiometer shows a difference of -17.4 mm compared to the GDR-T. Our comparisons with the wet tropospheric correction determined with the Ajaccio GPS show that, on average, the radiometer correction is on either side of that of the GPS (+8.6 mm and -9.2 mm for GDR-T and GDR-F respectively). On the other hand, the dispersion of the differences is reduced for GDR-F (20.1 mm and 17.4 mm for GDR-T and GDR-F respectively). Similarly, the dispersion of the SSH bias is reduced (34.1 mm and 31.4 mm for GDR T and GDR F respectively).

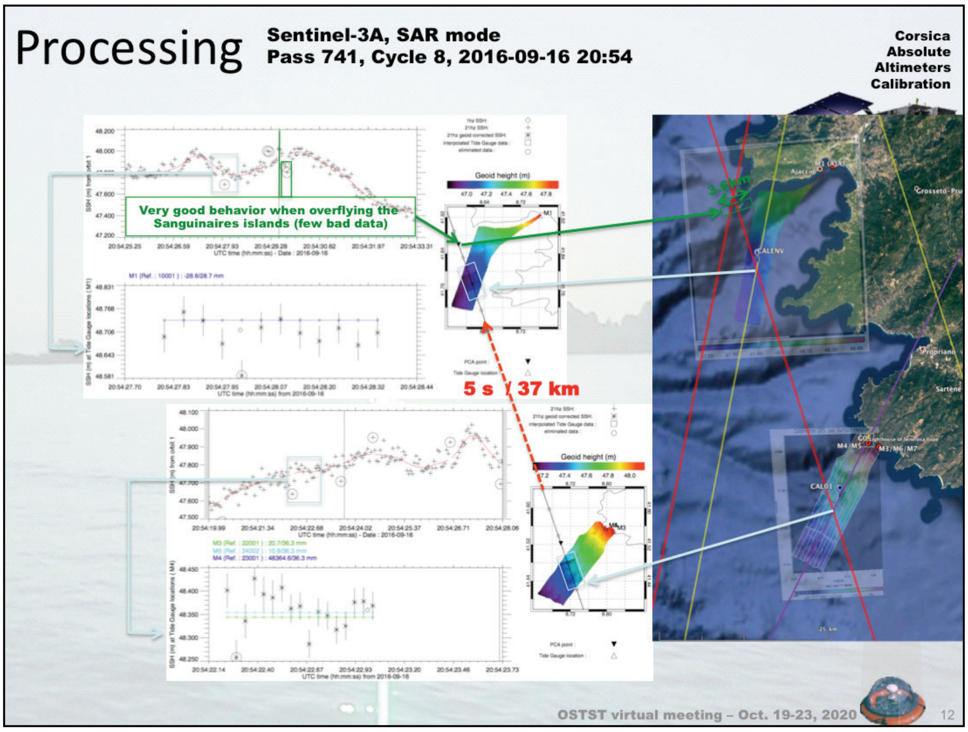



## Conclusion

Since the start of the Calibration/Validation activities in Corsica, 1998, the geodetic datum and instruments as well as the methodologies have been continuously upgraded in view of determining (in absolute sense) and monitoring the SSH bias of many altimetric space missions on the long term. Bonnefond et al. (2019) describes the different aspects (events, campaigns and regular controls) of the work that have been carried out in both the Senetosa and Ajaccio sites, and it presents the most recent results that have been achieved in terms of geodesy: leveling, GNSS positioning, in situ calibrations, and above all absolute SSH biases. A long process of "data archeology" has permitted to improve the consistency of the data series that enter in the overall monitoring and, more particularly, to understand the origin of the offsets that were identified before either at Ajaccio or Senetosa. We showed that the long-term stability of any ground motion can be achieved at a precision better than few tenths of millimeters per year and that the regular leveling of in situ instruments (tide gauges) ensure a repeatability of the geodetic links to the reference markers of no more that 1 mm over several years.

Based on several updates of the geodetic datum established on both Corsica sites and using the 20-yr series of sea level measurements, we have computed a new series of absolute SSH biases for a number of altimetric missions, using the most recent reprocessing of their data. The results are synthetized in the Table and show that the absolute SSH biases are at the level of few millimeters to few centimeters for most of the missions except for ERS-2 and Envisat suggesting that a constant error (e.g. internal path delay) still remains, despite the recent reprocessing. For the longest time series the standard error is at the level of few millimetres giving a high level of confidence in our results. Moreover, independent approach based on transponders can help to discriminate sea side effects from range bias; in that case, the comparisons made for either CryoSat-2 or Sentinel-3A&B show consistent results with the SSH biases determined in this study.

# Backup slides

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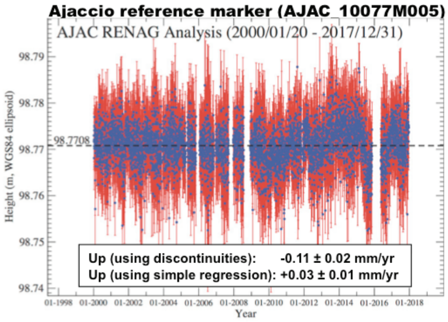
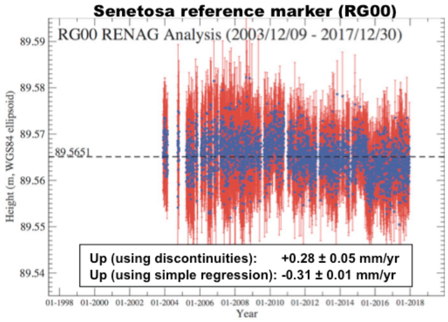
# Update of the geodetic datum (1/2)

***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.



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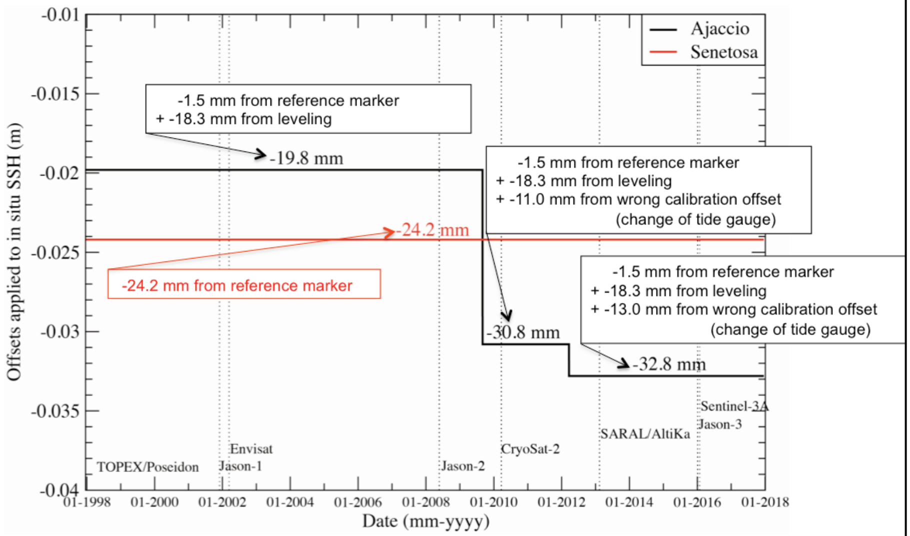
# Update of the geodetic datum

***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)**

OSTST virtual meeting – Oct. 19-23, 2020 14

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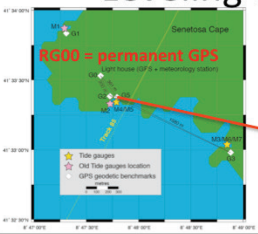
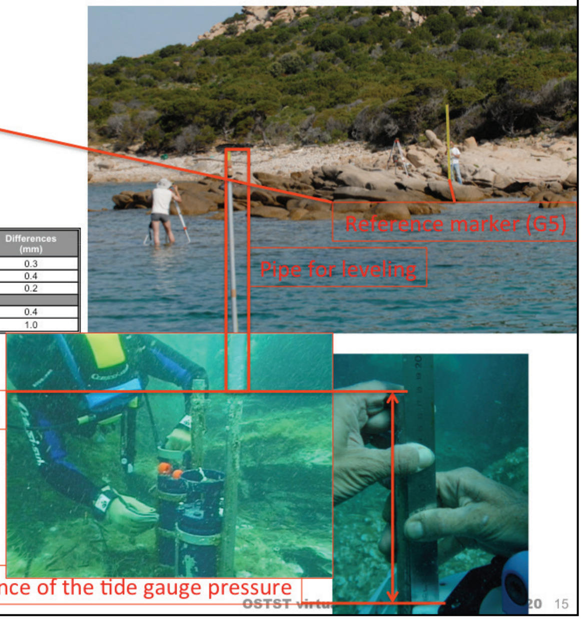
# Stability of the geodetic reference
# Leveling of the in situ instruments




| | 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**




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

15

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# 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…**



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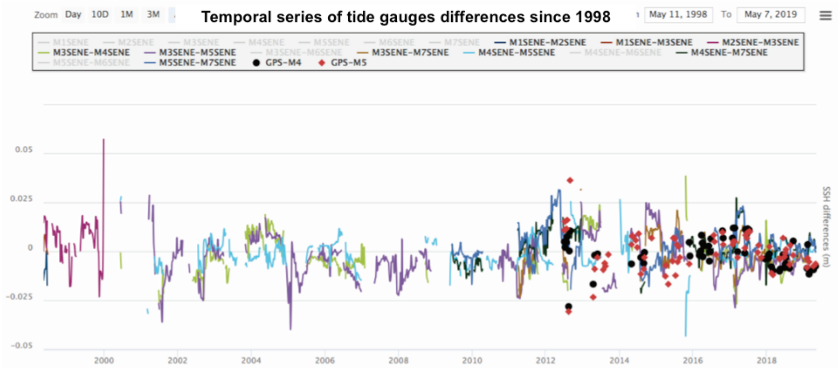
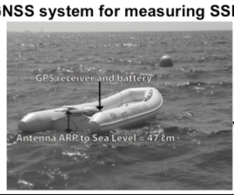
# Stability of in situ measurement system
# Comparisons with independent measurements




**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 |

OSTST virtual meeting – Oct. 19-23, 2020 17

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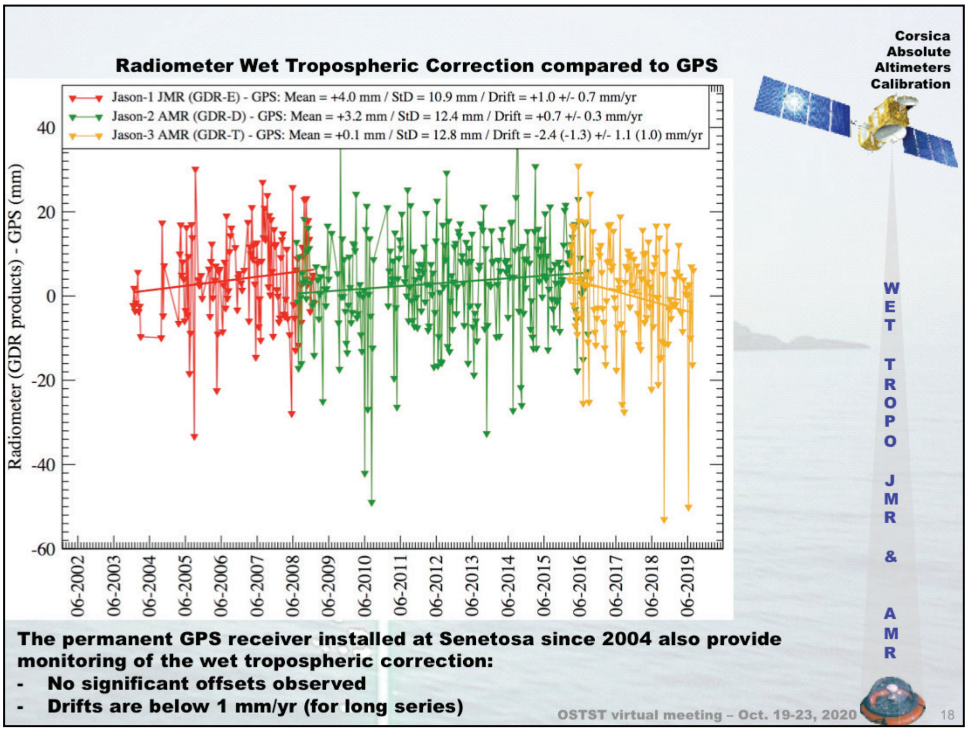


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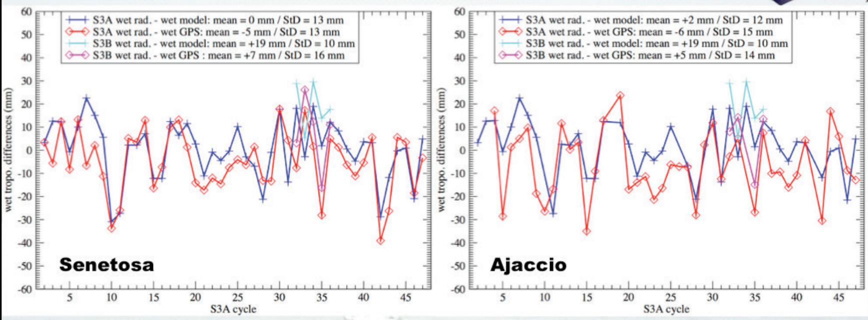
**Radiometer Wet Tropospheric Correction compared to GPS (processing Baseline Collection 3)**

**Corsica Absolute Altimeters Calibration**




**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**

OSTST virtual meeting – Oct. 19-23, 2020 19

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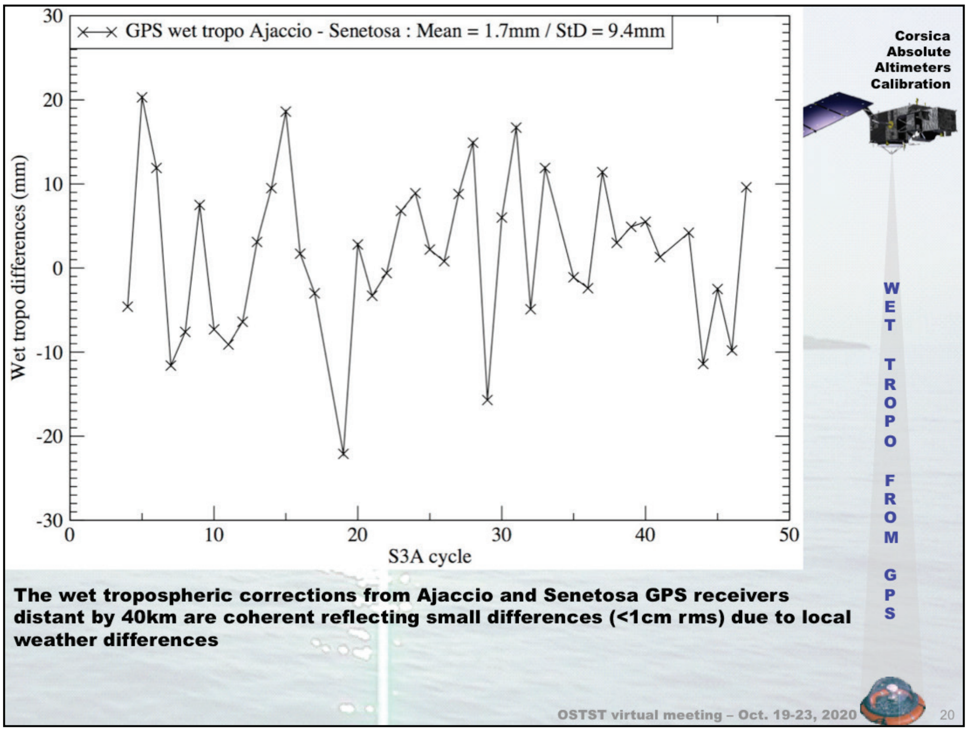


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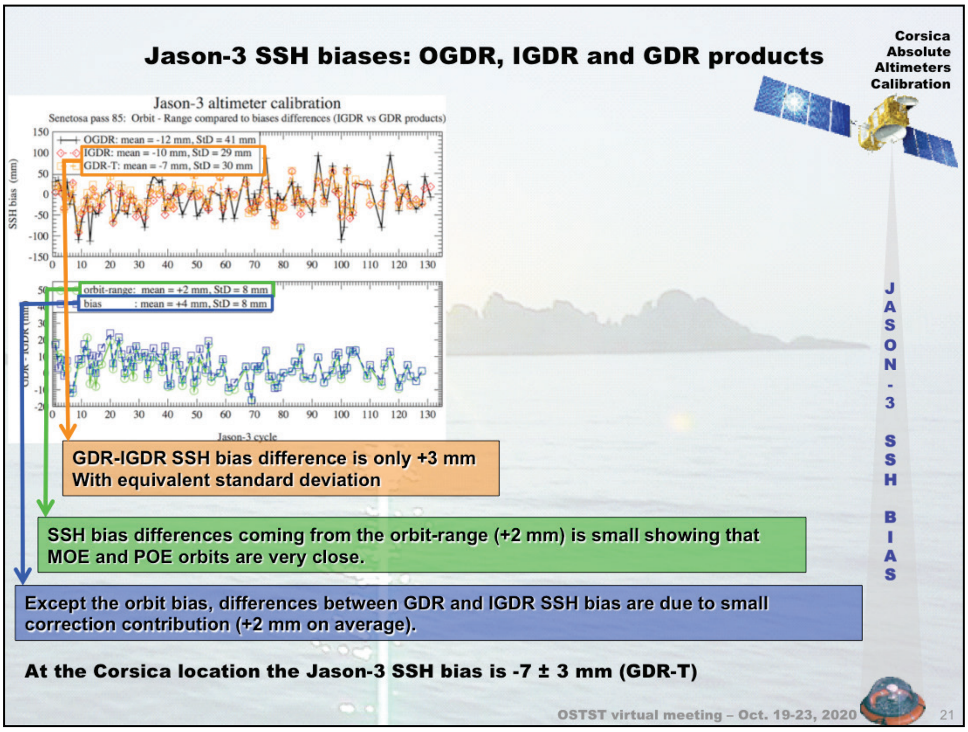


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