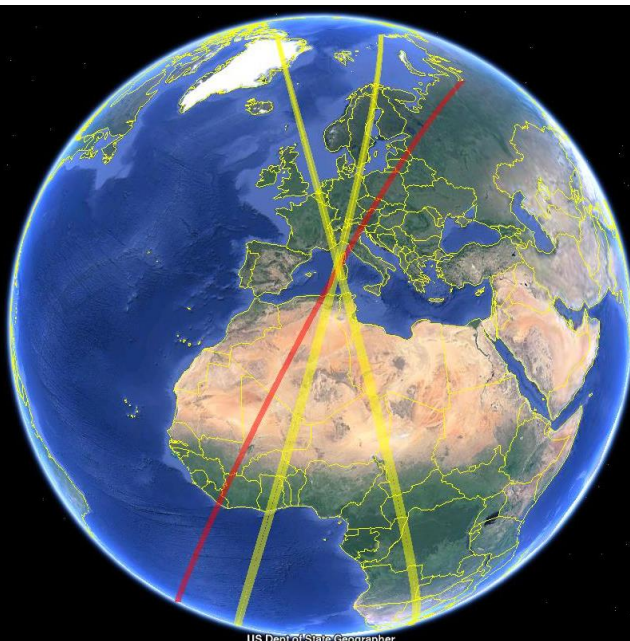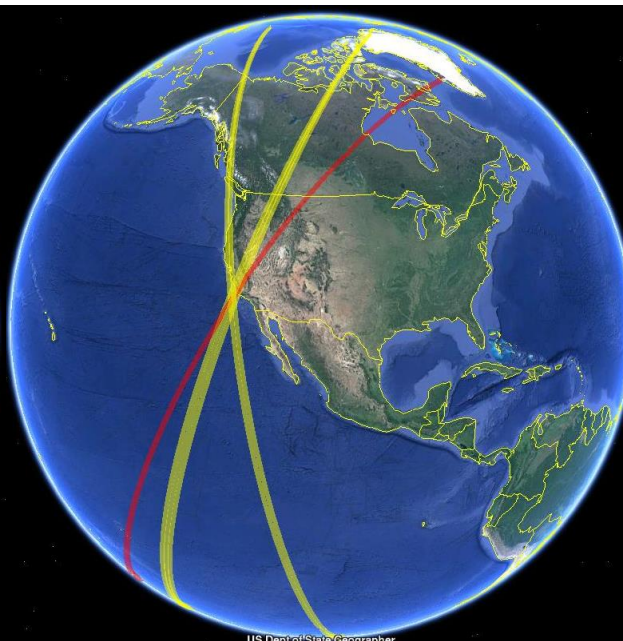# Regional in situ CALVAL of Sentinel-3 altimeter range at non-dedicated sites
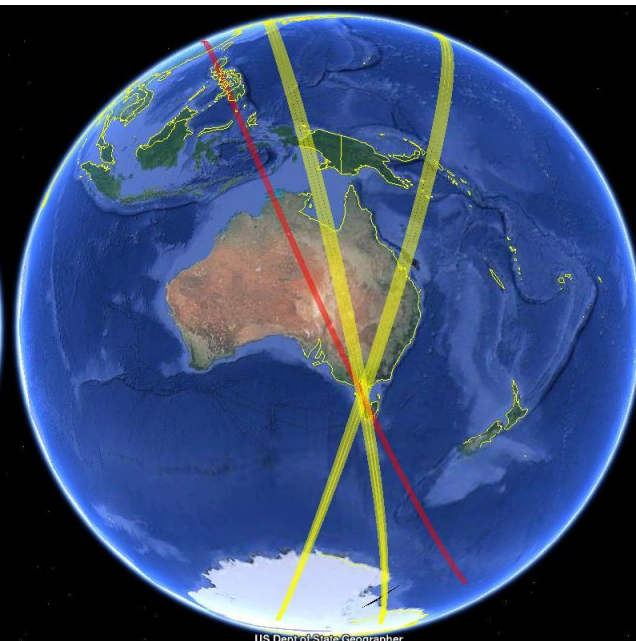
M. Cancet *(NOVELTIS)*, P. Bonnefond *(OBSPM)*, C. Watson *(Univ. Tasmania)*, B. Haines *(JPL)*, F. Lyard *(LEGOS)*, O. Laurain *(OCA)*, P. Féménias *(ESRIN)*

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- **Main objectives**
  - › **Altimeter performance:** SSH stability (drifts), SSH bias between the altimetry missions
  - › **Products improvement:** Evaluation of new corrections and parameters (orbit,…)

- **Global CALVAL**
  - › **Intra/intermission comparisons:**
    - ▪ At crossover points and along the tracks (in boxes)
    - ▪ Large patterns, geographically correlated errors, open ocean performance
  - › **Comparisons to tide gauge global networks:** altimeter drifts, global coastal performance
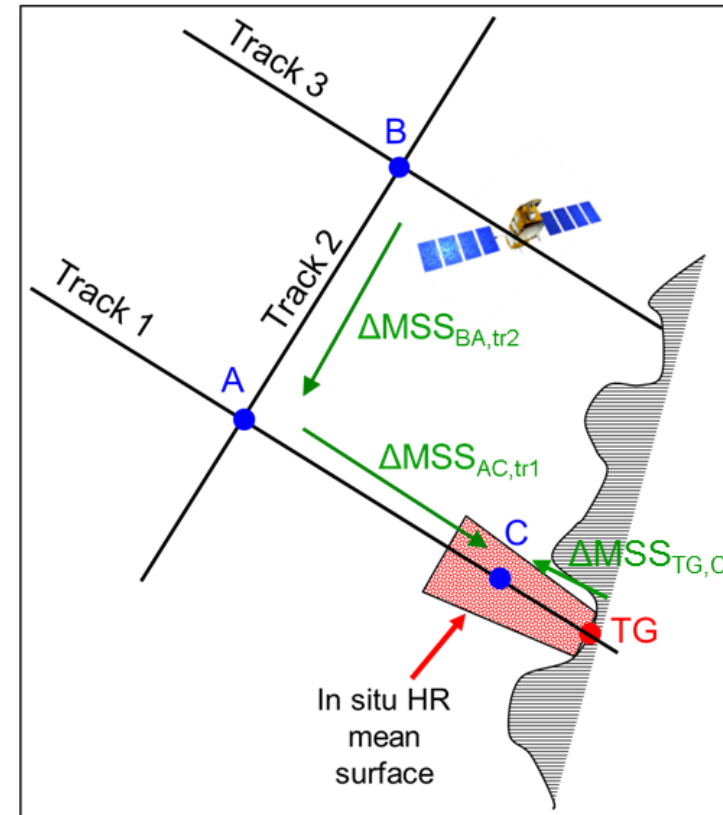
- **Local CALVAL**
  - › **Comparisons to georeferenced tide gauges at a few calibration sites:**
    - ▪ Altimeter absolute bias, drifts, geographically correlated errors, local coastal performance
    - ▪ Limitation: only for the altimeters that fly over the calibration sites (mainly Jason suite)

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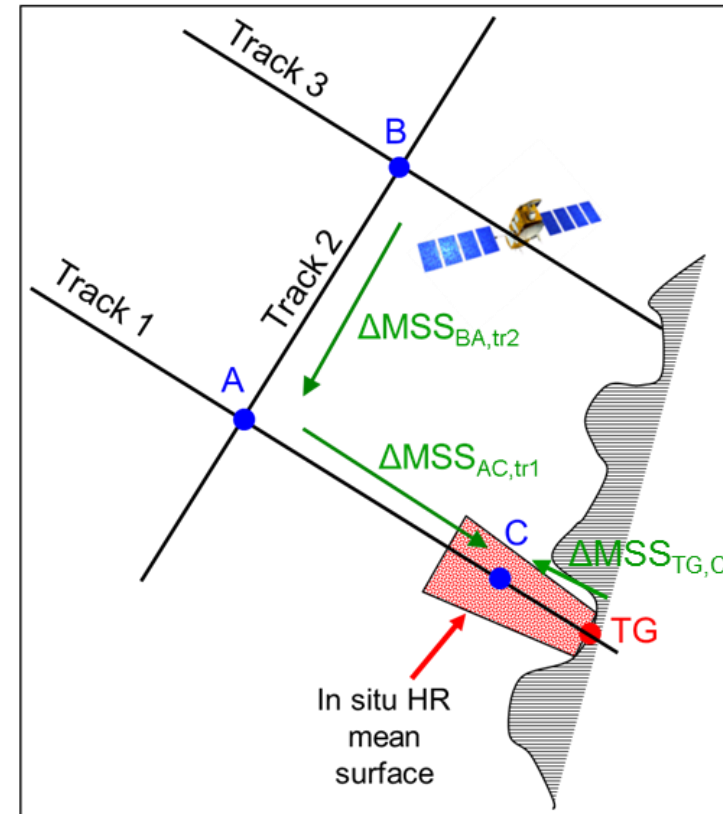- **NOVELTIS regional absolute CALVAL method**

Combination of:

  › **Local CALVAL: Direct comparison** between altimeter and tide gauge SSH (point C).

  ▪ Only for satellites directly flying over or very close to the calibration sites.

  ▪ Comparable to the absolute bias estimates computed by the local in situ Calval groups (Corsica, Harvest, Bass Strait, Gavdos…)

  › **Offshore CALVAL:** Computation of the bias on **offshore passes** (points A & B)

  ▪ Following a succession of accurate mean sea surface profiles, combining several missions

  ▪ Using a high resolution mean sea surface to link the in situ and altimetry SSH, when available (MSS otherwise)

  ▪ Taking into account the ocean dynamics (ocean tide and atmospheric effects) between the offshore tracks and the tide gauge location

3

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- **NOVELTIS regional absolute CALVAL method**

  Generic method:

  › **Calibration of missions on new orbits**

    ▪ After an **orbit change** (ex: interleaved TP, Jason-1 & Jason-2, Envisat after October 2010)

    ▪ For **orbits without dedicated calibration sites**

  › **Calibration of non-repetitive orbits**

    ▪ Missions on **non-repetitive or drifting orbits** (ex: CryoSat-2, SARAL, Jason-1 end-of-life).

  › **Applicable to any calibration site:** Corsica, Harvest Platform, Bass Strait, Gavdos…

  › **Already implemented:**

    ▪ in Corsica, at Harvest and Bass Strait

    ▪ for Topex, Jason-1, Jason-2, Envisat, SARAL and Sentinel-3A&B

  → Jan et al, 2003; Cancet et al, 2012; Bonnefond et al, 2017; Quartly et al, 2020

Sentinel-3 CALVAL results
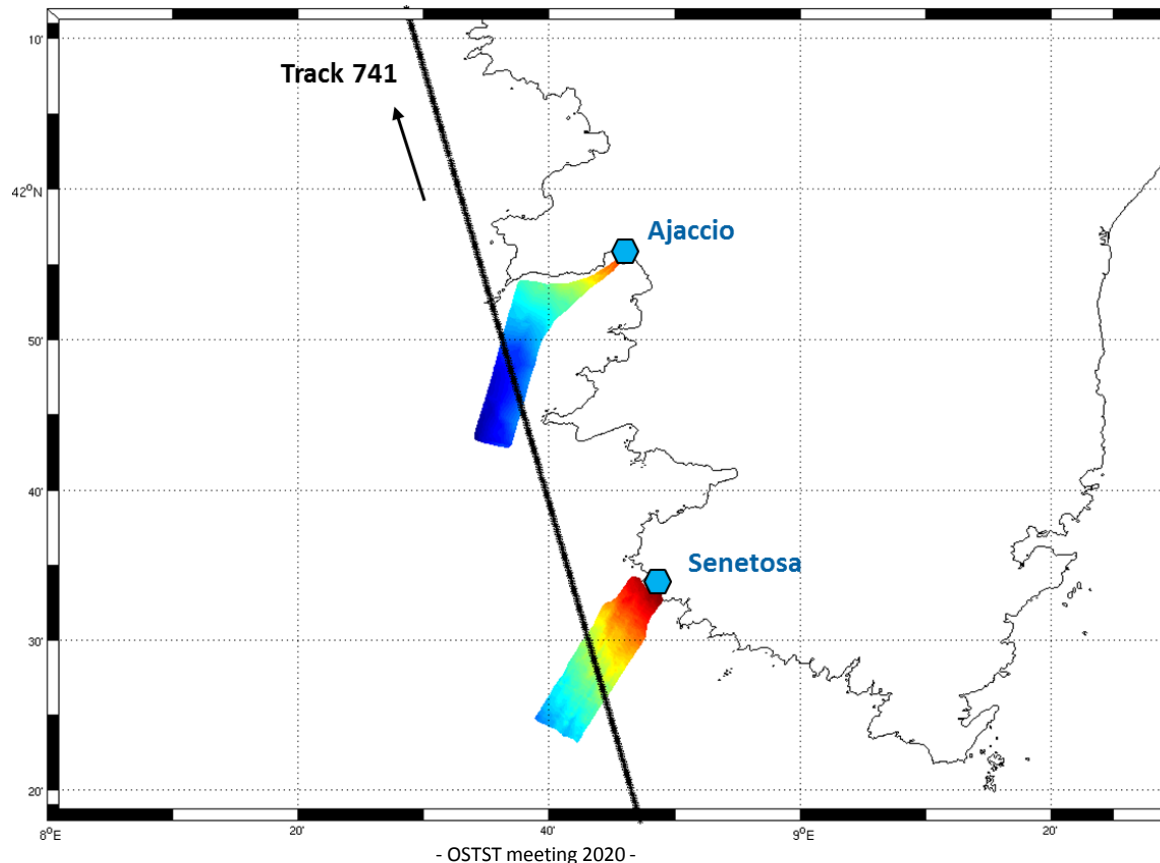
- **Sentinel-3 altimetry data**
  - › **ESA Non-Time-Critical (NTC) Land products**
    - ▪ **Sentinel-3A:** PB 2.33 – 2.45
    - ▪ **Sentinel-3B:** PB 1.0 – PB 1.17 (tandem phase)
  - › **Range:** analyses for SAR and PLRM data
  - › **Wet troposphere:**
    - ▪ **Corsica:** ECMWF model (due to land contamination)
    - ▪ **Harvest / Bass Strait:** radiometer correction
  - › **Ionosphere:** GIM correction at all sites

- **Tide gauge data**
  - › **Corsica:** The Ajaccio tide gauge dataset was provided by REFMAR. The Senetosa site is maintained by CNES and OCA.
  - › **Harvest:** Tide gauge data provided by JPL.
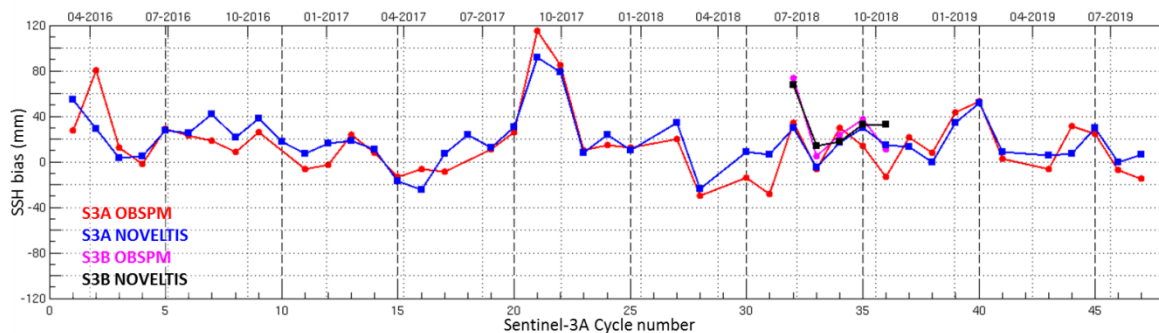 - › **Bass Strait:** Mooring SSH data provided by the University of Tasmania.

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- **Sentinel-3A and Sentinel-3B (tandem phase) local configuration in Corsica**

The Sentinel-3A orbit provides a unique opportunity to compute direct absolute calibration estimates on track 741 at the two sites in Corsica, a few seconds apart.
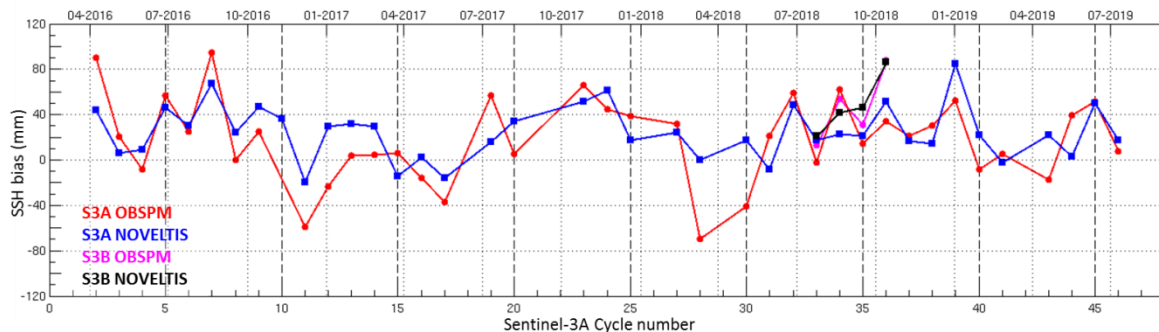
- ## Local absolute bias estimates and comparison with OBSPM results in Corsica

Sentinel-3A & B SSH absolute bias estimates averaged over Senetosa and Ajaccio – SAR mode

S3A OBSPM
S3A NOVELTIS
S3B OBSPM
S3B NOVELTIS

Sentinel-3A & B SSH absolute bias estimates averaged over Senetosa and Ajaccio – PLRM mode

S3A OBSPM
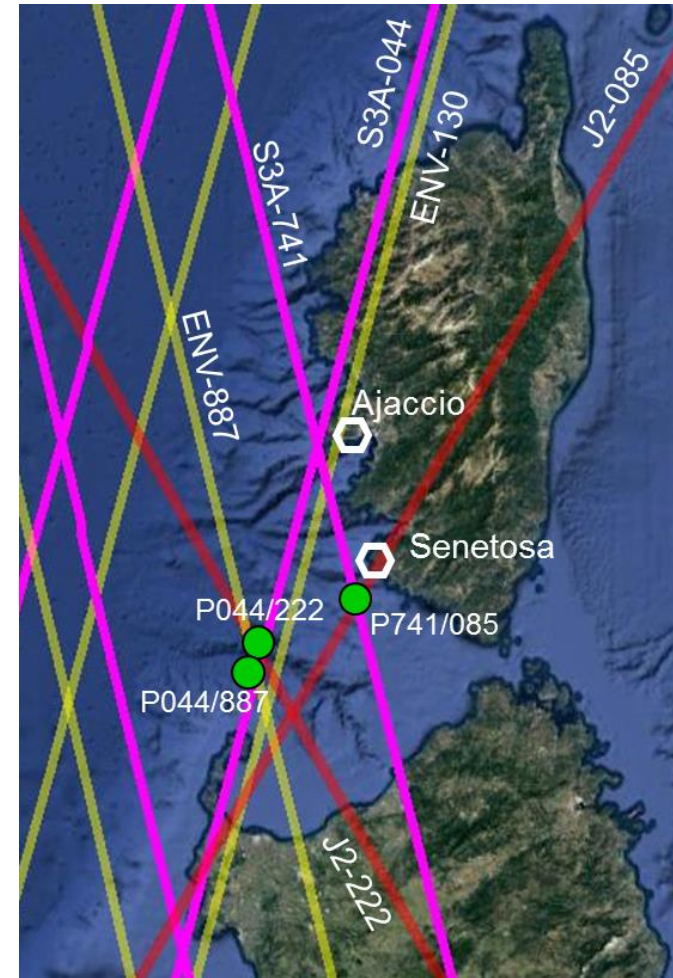S3A NOVELTIS
S3B OBSPM
S3B NOVELTIS

Comments on results:

- Very good agreement between both processing centres (OBSPM and Noveltis), slight differences due to the specific selection of data in each processing technique.

- S3-A and S3-B bias estimates for SAR mode are consistent for both sites in Corsica (more noise in PLRM)

- S3-B bias estimates are locally slightly higher than S3-A bias due to the use of model wet tropo correction for the SSH computation (2-cm bias between the S3-B radiometer and model wet tropo corrections in Corsica in this version of the products).

- In general, the largest bias values are linked with large SWH, as the SSB correction available in the products is not optimal, neither for SAR or PLRM data.

Satellite	Processing center	SAR		PLRM	
		SSH bias (mm)	# cycles	SSH bias (mm)	# cycles
Mean (Senetosa/Ajaccio)					
S3A	OBSPM	+16 ± 4	42	+18 ± 6	38
S3A	NOVELTIS	+19 ± 3	44	+24 ± 4	39
S3B	OBSPM	+19 ± 7	4	+46 ± 16	4
S3B	NOVELTIS	+24 ± 5	4	+49 ± 14	4

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- **Sentinel-3A regional configuration in Senetosa**

  › **Sentinel-3A offshore crossover points** (tracks 741 and 044) with Jason-2 and Envisat tracks (green dots)

  › **MSS profiles along Jason-2 and Envisat tracks** to link the offshore Sentinel-3A SSH and the Senetosa tide gauge SSH

  › **Ocean dynamics:**

    ▪ High-resolution regional ocean tide model from NOVELTIS

    ▪ TUGO-m global simulation from LEGOS to remove the atmospheric effects (inverse barometer and high-frequency signals – available only until December 2017, ie cycle 25)

NOVELTIS

- **Sentinel-3A regional bias estimates in Senetosa**

Comments on results:

- Very stable results from one crossover point to the other, generally within less than 1 cm.

- Larger variability of the SSH bias estimates at the crossover point with the Envisat track 887, mainly explained by strong SSH bias values for a few cycles in the SAR product, and by the strong SSH bias value on cycle 13 in the PLRM product.

- The Sentinel-3A regional SSH bias in Senetosa is quite consistent with the local estimates, both in terms of mean and variability.
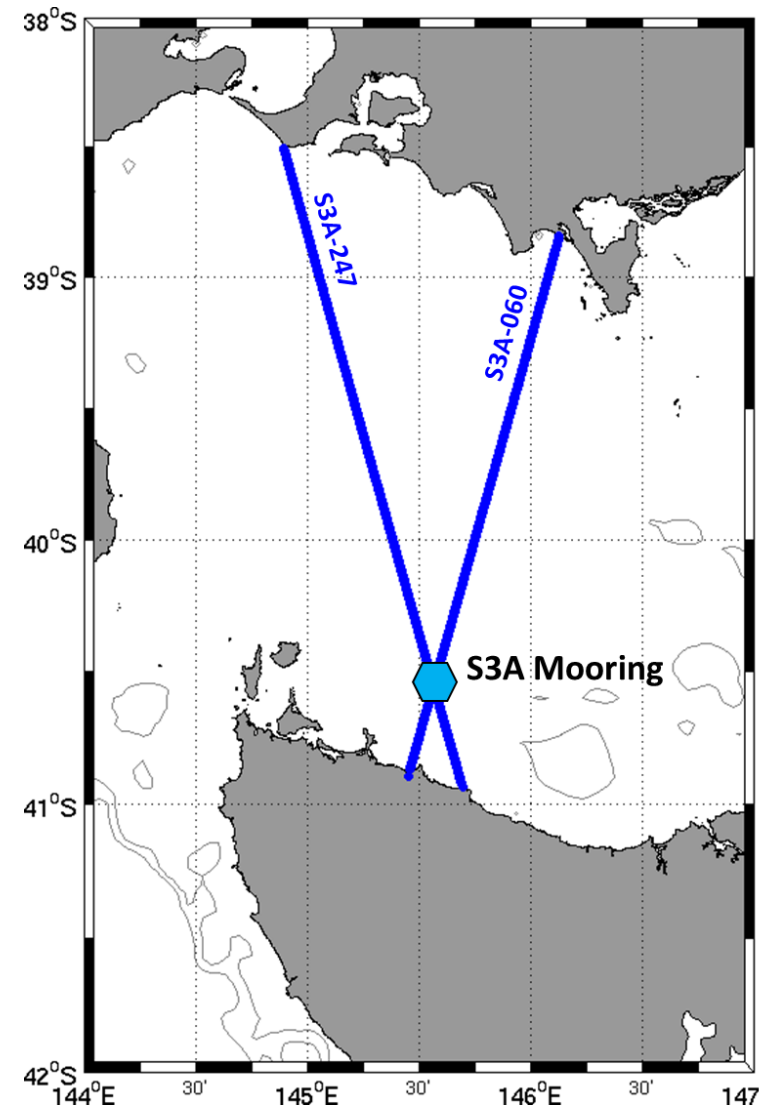

Senetosa PB 2.33 (MPC S3) cycles 1 – 26	SAR			PLRM		
	Mean (mm)	Standard deviation (mm)	Number of cycles	Mean (mm)	Standard deviation (mm)	Number of cycles
Track 741 (local) *no ocean dyn. corr.*	23 ± 5	24	24	24 ± 6	28	23
Track 741 (local)	22 ± 5	26	24	22 ± 6	30	23
Track 741 X J2 085	10 ± 6	31	24	11 ± 8	36	23
Track 044 X Env 887	20 ± 7	33	25	21 ± 10	47	23
Track 044 X J2 222	16 ± 5	27	25	22 ± 8	40	23
Regional mean	**17 ± 6**	**29**	**25**	**19 ± 8**	**38**	**23**

10

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- **Sentinel-3A and Sentinel-3B (tandem phase) configuration in Bass Strait**

Mooring data are available at the crossover point between Sentinel-3A tracks 060 and 247.

This configuration enables to estimate the range bias for these two tracks (ascending and descending) 6 days apart.

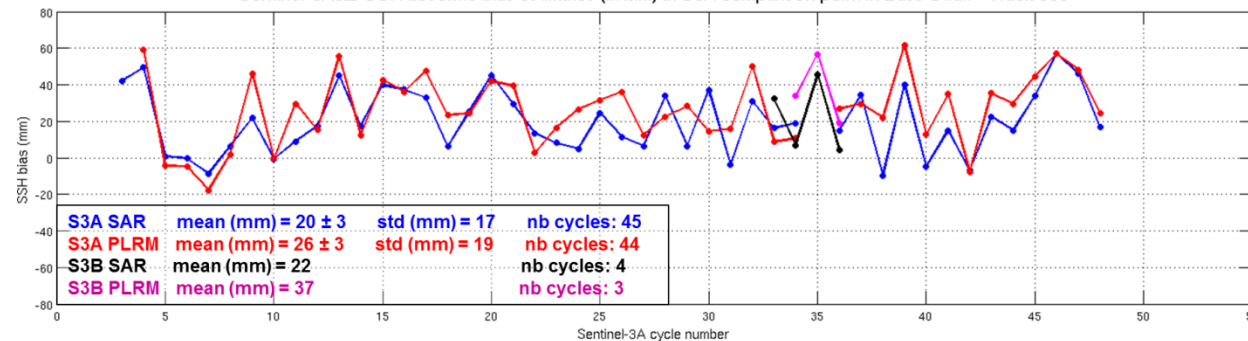S3A mooring data available until 31/08/2019 for this work.

- OSTST meeting 2020 -

- **Sentinel-3A and Sentinel-3B (tandem phase) local bias estimates in Bass Strait**

Sentinel-3A&B SSH absolute bias estimates (in mm) at S3A comparison point in Bass Strait - Track 060

S3A SAR	mean (mm) = 20 ± 3	std (mm) = 17	nb cycles: 45
S3A PLRM	mean (mm) = 26 ± 3	std (mm) = 19	nb cycles: 44
S3B SAR	mean (mm) = 22		nb cycles: 4
S3B PLRM	mean (mm) = 37		nb cycles: 3

Sentinel-3A&B SSH absolute bias estimates (in mm) at S3A comparison point in Bass Strait - Track 247

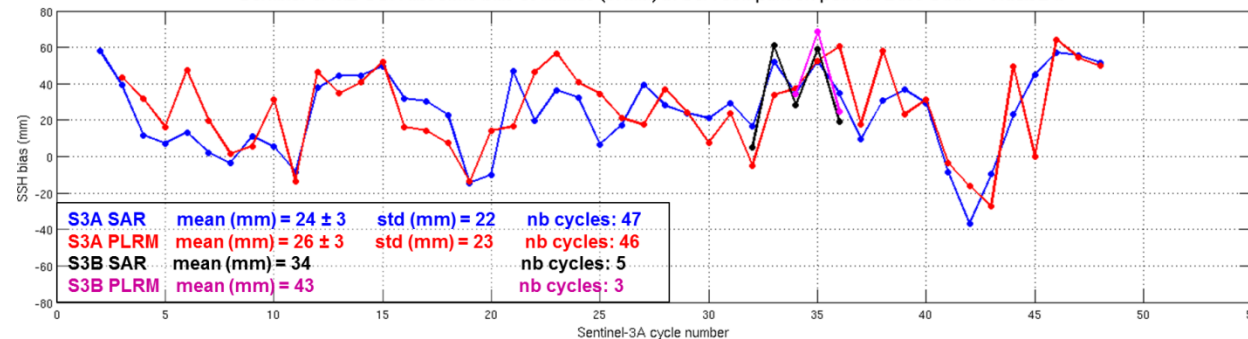|			
S3A SAR	mean (mm) = 24 ± 3	std (mm) = 22	nb cycles: 47
S3A PLRM	mean (mm) = 26 ± 3	std (mm) = 23	nb cycles: 46
S3B SAR	mean (mm) = 34		nb cycles: 5
S3B PLRM	mean (mm) = 43		nb cycles: 3

Comments on results:

- Consistent bias estimates for both tracks, in terms of mean and variability, for SAR and PLRM data.

- Good agreement with the bias estimates obtained by C. Watson, from the University of Tasmania, using his own method.

- Very good agreement between Corsica and Bass Strait, with bias estimates of about 2 cm for Sentinel-3A and Sentinel-3B (tandem phase).

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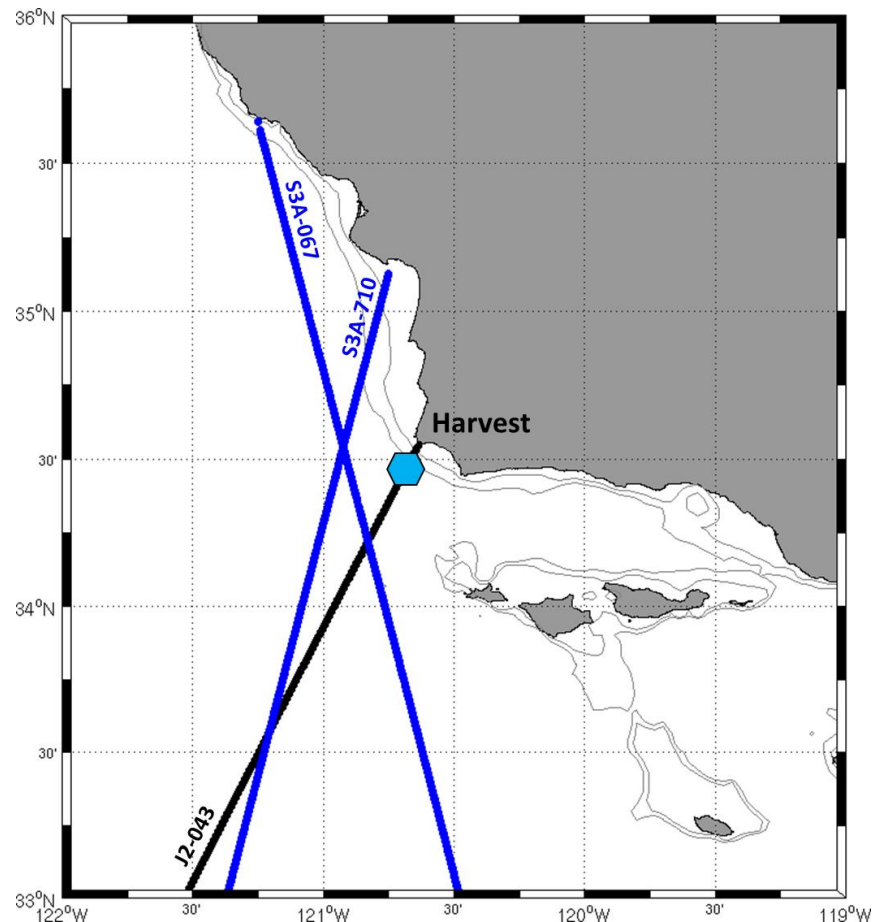- ## Sentinel-3A and Sentinel-3B (tandem phase) configuration in Harvest

The Harvest calibration site is located under the Jason-2 track 043. Two Sentinel-3A tracks (067 and 710) cross nearby, at about 18 km from the Harvest platform.

As a first step, the S3A biases were estimated directly from the S3A tracks. In future work, the crossover points with the Jason-2 track 043 will be considered for regional estimates.
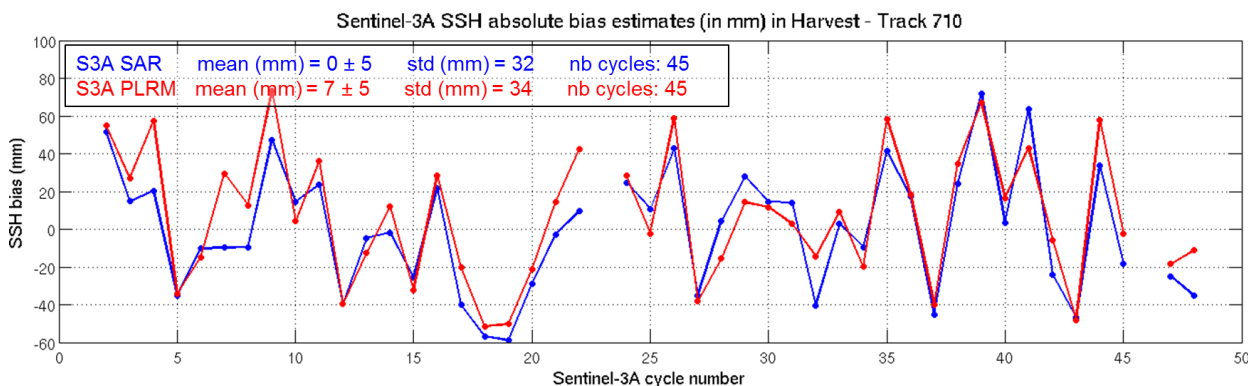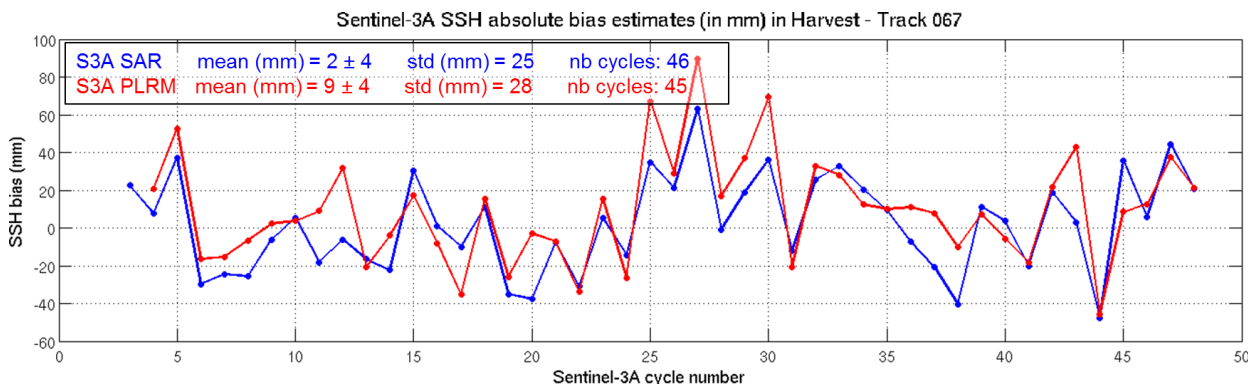
No ocean dynamics correction was applied to the altimeter and tide gauge SSH data, but this will be considered in future work.

Harvest in situ data available until 31/08/2019 for this work.

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- **Sentinel-3A and Sentinel-3B (tandem phase) bias estimates in Harvest**

Sentinel-3A SSH absolute bias estimates (in mm) in Harvest - Track 067

S3A SAR mean (mm) = 2 ± 4 std (mm) = 25 nb cycles: 46
S3A PLRM mean (mm) = 9 ± 4 std (mm) = 28 nb cycles: 45

Sentinel-3A SSH absolute bias estimates (in mm) in Harvest - Track 710

S3A SAR mean (mm) = 0 ± 5 std (mm) = 32 nb cycles: 45
S3A PLRM mean (mm) = 7 ± 5 std (mm) = 34 nb cycles: 45

Comments on results:

- Consistent bias estimates for both tracks, in terms of mean and variability, for SAR and PLRM data.

- More variability in the bias estimates (in particular on track 710) than at Bass Strait and in Corsica.

- For both missions, lower bias estimates (close to 0) than in Bass Strait and in Corsica (about 2 cm) but some further computations are needed, in particular with the ocean dynamics corrections (ocean tides and atmospheric effects).

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- **Conclusions**

  › Very consistent results in Corsica and Bass Strait for Sentinel-3A and Sentinel-3B (tandem phase)

  › 2-cm lower bias in Harvest but further computations needed (ocean dynamics)

  › In Corsica, very good agreement between local and offshore S-3A bias estimates

  › Clear dependency of the SSH bias with the SWH

  ➔ **Need for a SAR-dedicated SSB correction in the products**

- **Next steps**

  › Number of crossover points to be extended in Corsica for the whole time series (with tide and atmospheric corrections)

  › Implementation of the regional method at Harvest and Bass Strait

  › Monitoring of the Sentinel-3B mission on its nominal orbit at the 3 sites

  › Update of the time series depending on in situ data availability