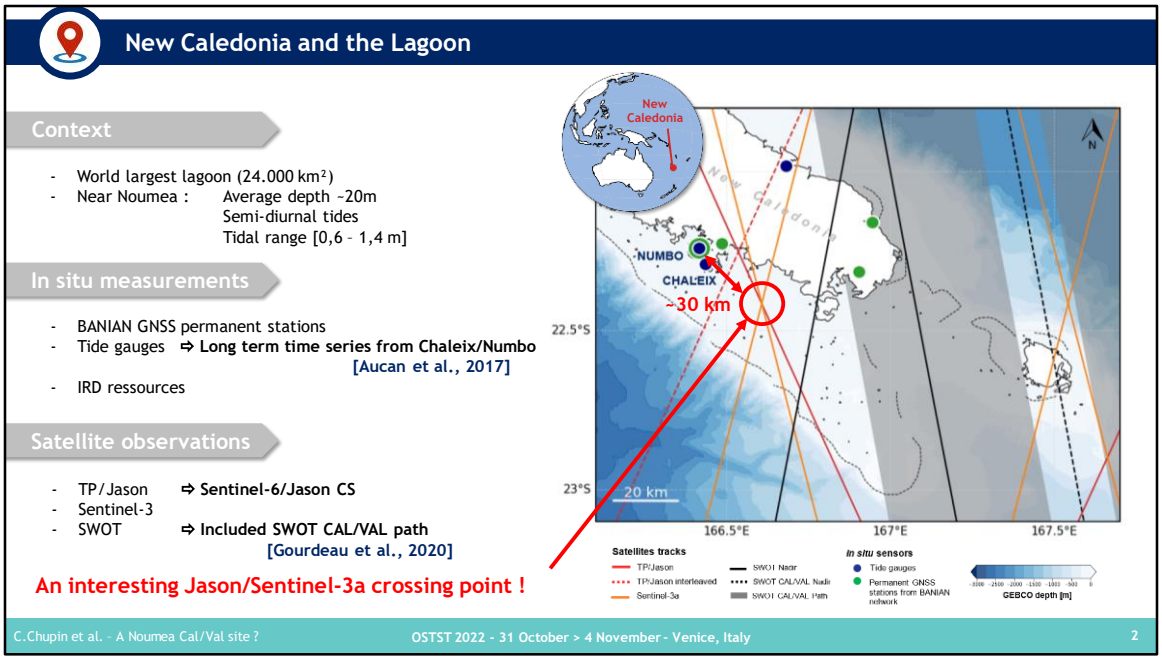
Today, I will present you some results about a field campaign held in October 2019 in the Noumea Lagoon, with the idea of using this particular site as a multi-mission cal/val site for past and future altimetry missions. With my collegues, we wrote a paper presenting theses results and if you are interested and want more informations after my presentation, the preprint is avaliable online following the QR code.



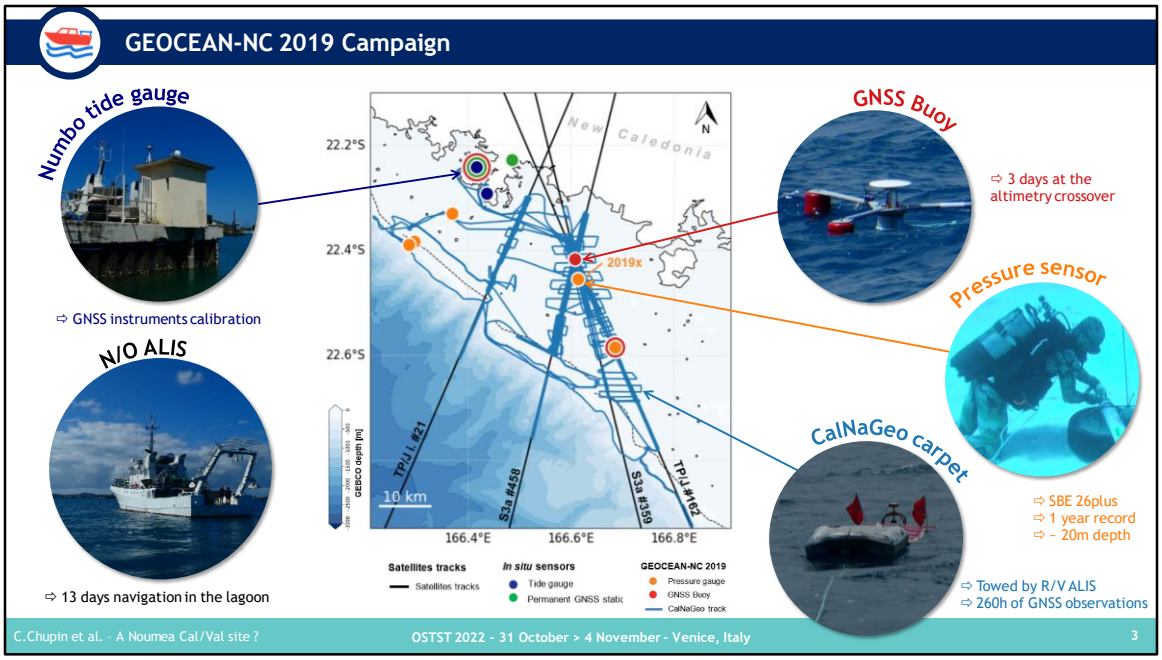
Before going further and discussing the mission and our results, I want to give you a brief overview of study area and its potential.

1. In the Southwest Pacific, the lagoon surrounding New Caledonia is the world largest lagoon with a surface of 24 thousands square km. In our study, we particularly focused on the southern part of the lagoon, near Noumea city.

2. A network of in situ measurements has been developped with permanent GNSS stations from the BANIAN network (green dots) and tide gauges (blue dots). In our study, we used the Chaleix and Numbo observations : both sites have been linked by Aucan et al. 2017 to reconstruct a unique long term time series between 1957 to present. These data are available online on the UHSLC data portal. There is also the IRD laboratory in Noumea, that offers expertise and resources to organize observation campaigns and analyses.

3. The lagoon is covered by many altimetry tracks from past and current nadir altimetry missions (TP/Jason, Sentinel-3a…). It is also the subject of dedicated Cal/Val campaigns planned during the fast-sampling phase of the future SWOT large-swath mission. And for our study, we particularly focused on the

intersection of three altimetry tracks (1 Jason and 2 Sentinel 3) at around 28km from Numbo tide gauge location.



The GEOCEAN NC campaign took place in the Noumea lagoon in October 2019, on board the oceanographic vessel ALIS during 3 weeks.

During this campaign, we deployed several instruments to measure sea level:
- CalNaGeo carpet was towed along different altimeter tracks (blue lines on the map)
- 5 pressure sensors were deployed in the lagoon (orange dots) and recovered 1 year after the mission.
- A GNSS buoy was deployed at different locations (red dots on the map).

For our study, we only consider the buoy sessions and the pressure sensor close to the altimetry crossover point.

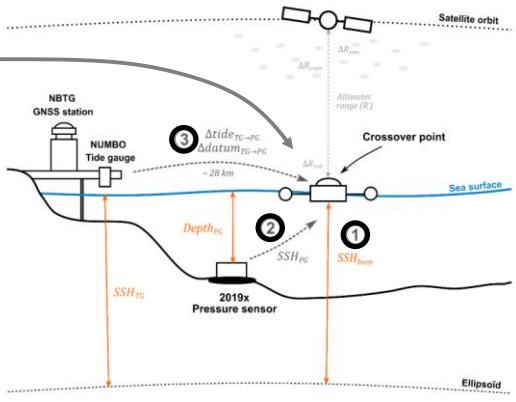
- A calibration session at the Noumea Numbo tide gauge was performed to assess the performance of all our GNSS instruments.

Data and Method

Objective Compare altimetry and *in situ* data following standards made for dedicated Cal/Val studies

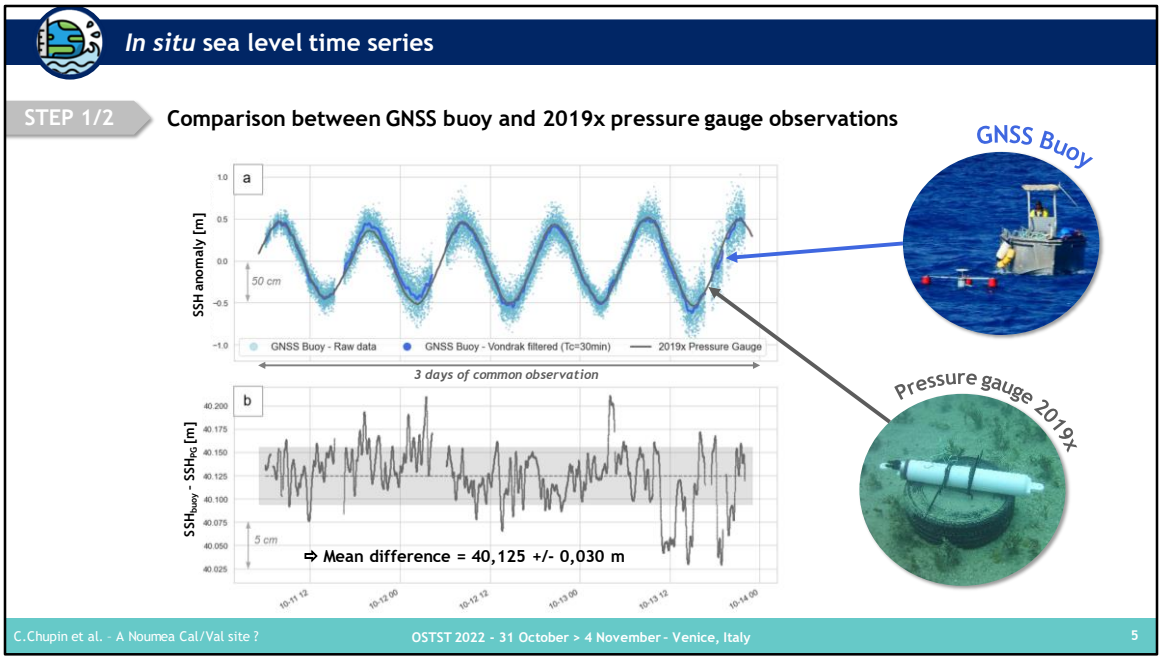
Reconstruction of a long term virtual *in situ* sea level time series under altimetry tracks

- *Direct SSH from the GNSS buoy at the crossover during 3 days*
- *Referencing pressure sensor by comparing with GNSS buoy data over the common observation period*
- *Transferred Noumea tide gauge observations by computing a tidal and datum correction using pressure gauge observations*

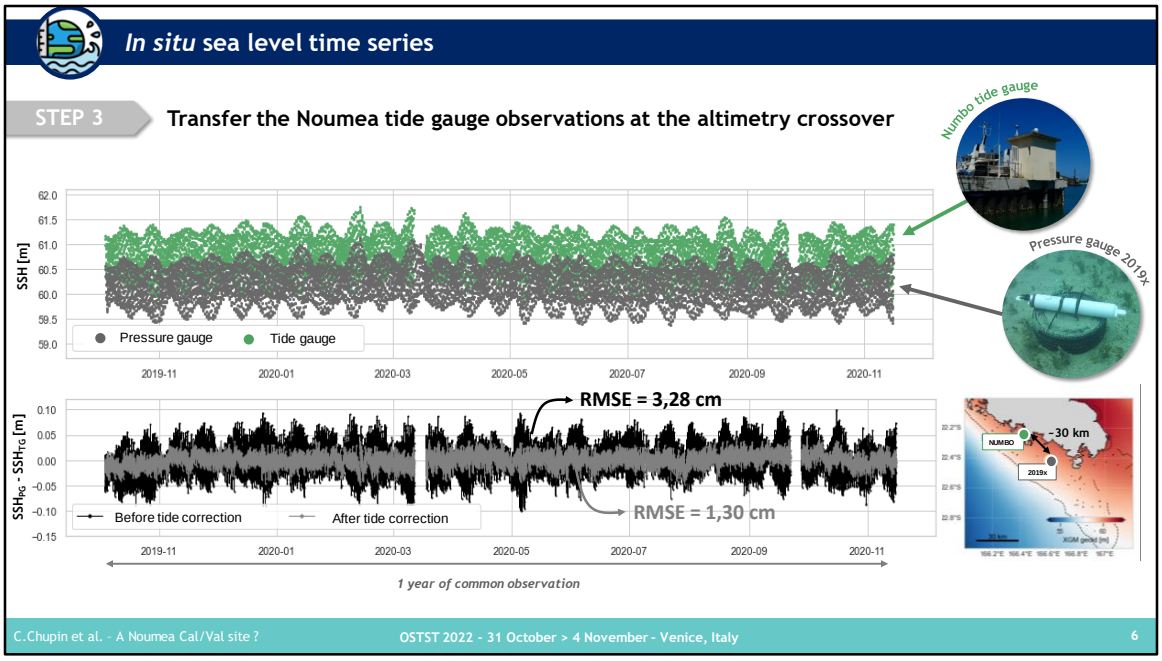


Our objective is to compare the offshore altimetry measurements at the Jason/Sentinel-3a crossover with in situ observations.

- The first step is to reconstruct a long sea level time series at the altimetry crossover : for that, we developed a mixed approach using both in situ measurements from the GEOCEAN-NC campaign and the Noumea tide gauge records.
- First, the observations of the GNSS buoy provides sea level in the same reference frame than the satellite.
- We then use the common observation period with the pressure gauge to reference its measurements in a global reference frame.
- And finnaly, we use the common year of measurements between the pressure gauge and the tide gauge to compute a tidal and datum correction : after that, the Noumea tide gauge time series is virtually transferred to the altimeter comparison point.



- In our process, the GNSS buoy observations were processed in PPP mode using the GINS software (see the blue line on the top graph).
- For the pressure gauge, we transformed the pressures into equivalent water depths. The grey line in the top figure represent the variations of the water surface seen by the pressure sensor.
- We then compute the difference between these two data sets (the bottom graph) : we obtain an average difference of 40.125m, which is the offset to be applied to reference our pressure sensor to the ellipsoid.



To extend our in situ time series, we virtually transfer the Noumea tide gauge measurements at the crossover point by using the common year of observations with our pressure gauge. The two times series are represented on the top graph : the pressure gauge is in grey, and the tide gauge in green. The difference between the two sensors, the black curve on the lower graph, has a root mean square error of 3.28 cm.

But as the two sensors are distant of about 30 km, there may be a difference in ocean dynamics. Using an harmonic analyse on the height differences, we thus compute a tidal gradient in amplitude and phase and a vertical bias between our two sensors. We then apply these tidal correction on the Noumea tide gauge time series, and after that, the root mean square error on our differences drops to 1.30 cm (grey curve on the graph).

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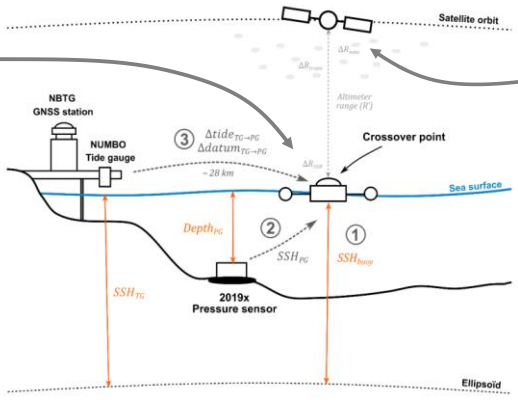


Dedicated processing of along-track altimetry data

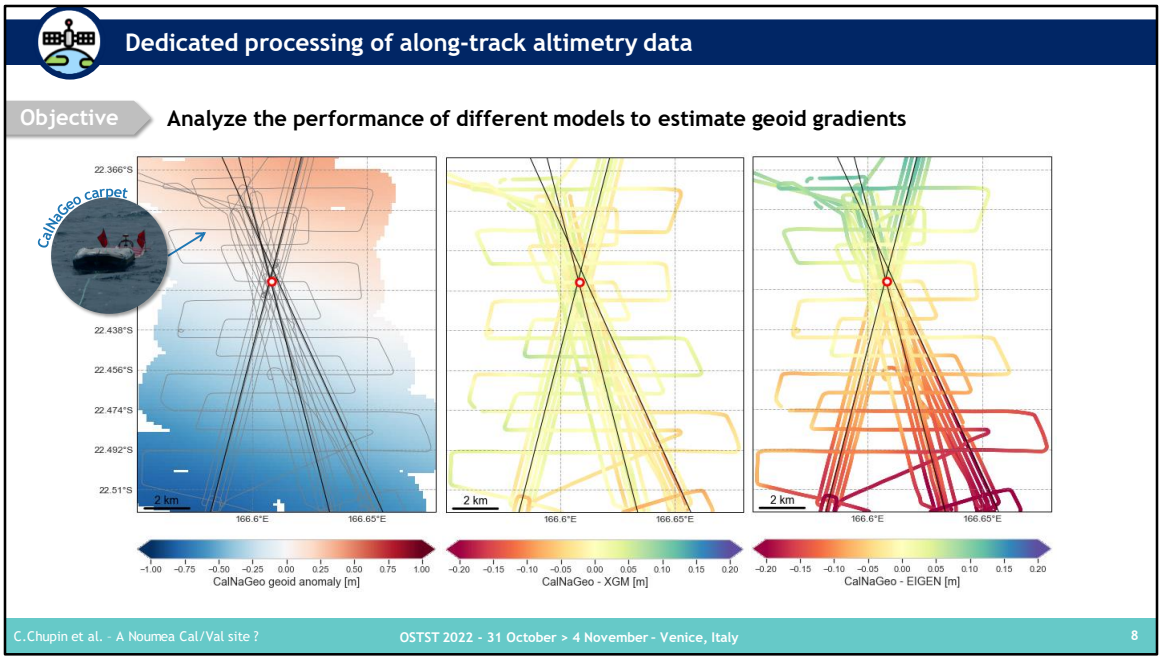
- *20Hz along-track products*
- *Cal/Val sites standards for altimetric corrections*
- *Test of several wet tropospheric delays (radiometer, GNSS, ECMWF model)*
- *Validation of XGM2019 gravity field model using CalNaGeo survey*

To have two comparable datasets, we also reprocess the along track altimetry data to derive the in-situ altimetry time series at the crossover point.

(1) As the major limitation of coastal altimetry data is the quality of the atmospheric and geophysical corrections, we consider the 20Hz data from GDR files to select the best parameters for our site.

(2) We mainly use GDR corrections, but we also test 3 different corrections for the wet tropospheric delay. Finally we find that the radiometer corrections agree with the GNSS-based corrections at the centimetric level, and we choose to keep the radiometer corrections in the following. If you want more details, you could have a look on our preprint…

(3) Regarding the geoid correction, we use the CalNaGeo survey to analyze the performance of different models to estimate geoid gradients in our study area.



Here you can see some results of this analyze : on the map on the left, we represent the mean sea surface anomalies from CalNaGeo expressed with respect to the altimeter comparison point (red dot on the map).

Along the CalNaGeo track, the comparison with the XGM2019e gravity field model shows no significant differences (on the central panel). But the comparison with the EIGEN model shows a residual southeast/northwest gradient of about 1.8 cm/km (right panel).

For our analyse, we choose the XGM model, but an interesting perspective could be to create and validate our own local mean sea surface model using CalNaGeo measurements.

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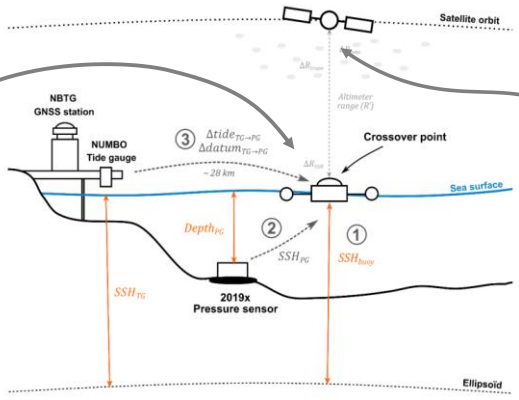


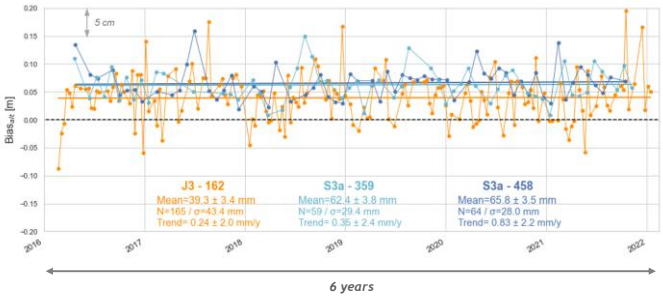
Dedicated processing of along-track altimetry data

After that, we obtain the altimetry measurements at the crossover location, and we compute the altimeter bias by substracting the in situ observations.

Results - Altimetry bias in Noumea

Objective Compare altimetry and *in situ* data following standards made for dedicated Cal/Val studies

Multi-mission comparison



Site	Sentinel 3a	Jason 3	Jason 2	Jason 1
Nouméa	+62.4 ± 3.8 mm (#359) +65.8 ± 3.5 mm (#458)	39.3 mm ± 3.4mm		
Intermission	*-24.8 mm*			
Corsica*	+17 ± 4 mm	-7 ± 3 mm		
Intermission	*-24 mm*			
Bass Strait*	+24.4 ± 2.0 mm	-6.7 ± 2.3 mm		
Intermission	*-30 mm*			
Harvest*	-	-12 mm ± 3 mm		
Intermission	-			

** Altimetric mean biases from Harvest, Corsica and Bass Strait are extracted from the 2020 OSTST sessions and will be updated with the latest results*

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We first compare altimeter biases at our crossover point for Jason 3 (in orange on the graph) and Sentinel 3a (the two blues lines for the two different tracks).

(1) Over the 6 years of our comparison, we find a Jason 3 altimeter bias of about 39 mm, and for Sentinel, we find two consistent mean biases : 62 mm for track 359 and 66 mm for track 458. Comparing to historical cal/val site as shown in the table (results of OSTST 2020), our altimetric biases are larger by about 48 mm for both missions.

(2) But regarding the inter-mission biases, we find a value of 24,8 mm which is comparable to the inter-mission biases determined at the Corsica (+24 mm) and Bass-Strait (+30 mm) sites.

(3) Consistency of these results suggests that, rather than data processing problems, there may remain errors in the absolute referencing that are still under investigation…

Results - Altimetry bias in Noumea

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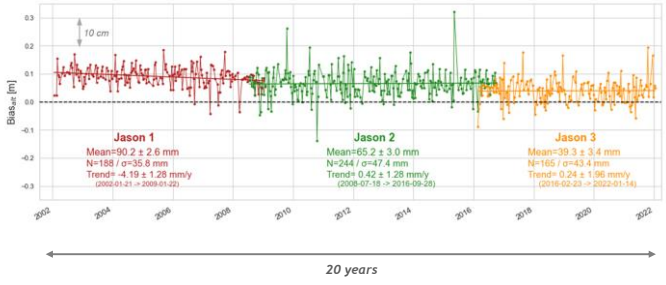
Long-term comparison



Site	Sentinel 3a	Jason 3	Jason 2	Jason 1
Nouméa	+62.4 ± 3.8 mm (#359) +65.8 ± 3.5 mm (#458)	39.3 mm ± 3.4mm	65.2 mm ± 3.0mm	90.2 mm ± 2.6mm
Intermission	*-24.8 mm*	*+25.9 mm*	*+25.0 mm*	
Corsica*	+17 ± 4 mm	-7 ± 3 mm	+16 ± 2 mm	+43 ± 3 mm
Intermission	*-24 mm*	*+ 23 mm*	*+ 27 mm*	
Bass Strait*	+24.4 ± 2.0 mm	-6.7 ± 2.3 mm	+18.8 ± 2.1 mm	+45.6 ± 2.2 mm
Intermission	*-30 mm*	*+ 25.5 mm*	*+ 26.8 mm*	
Harvest*	-	-12 mm ± 3 mm	+5 ± 3 mm	+6 ± 2 mm
Intermission	*-*	*+ 17 mm*	*+ 1 mm*	

** Altimetric mean biases from Harvest, Corsica and Bass Strait are extracted from the 2020 OSTST sessions and will be updated with the latest results*

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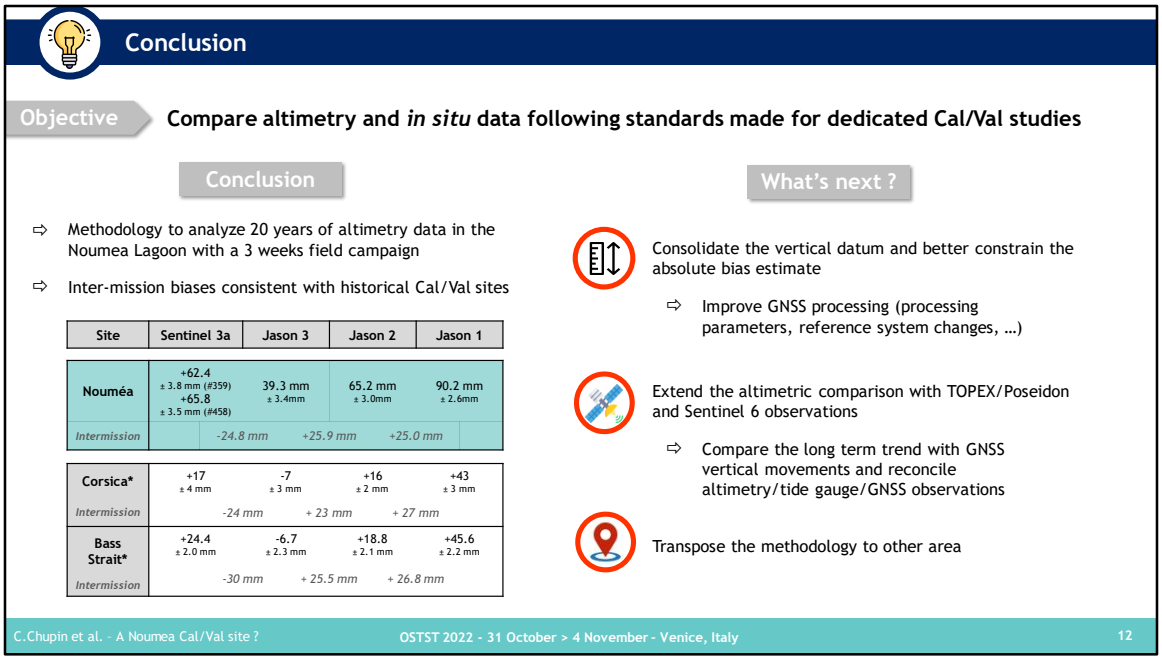
Thanks to the long sea level time series of the Noumea tide gauge, we then compute the long term altimetric bias evolution using observations of the 3 Jason missions.

We find a mean altimetric biase of 90,2mm for jason 1 (in red on the graph) and 65,2 mm for jason 2 in green. As for the multi-mission comparison, our biases are still higher than other calibration sites, but we find comparable inter-mission biases.



(1) To conclude, with our 3 weeks field campaign, we propose a methodology to analyze 20 years of altimetry data in the lagoon. We found mean absolute bias higher than historical Cal/Val sites, but the inter-mission biases are very consistent with those from Bass-Strait and Corsica sites.

(2) These results are very encouraging, and for the future, we need to consolidate the vertical datum and better constrain the absolute bias estimate. We could also extend the comparison by using data from the TOPEX/Poseidon to the recent Sentinel-6 missions. This could also help to reconcile the sea level trends seen by altimetry, tide gauges and terrestrial permanent GNSS stations, which is a real question in the area.

And finally, why not extending our method to other sites around the world ?

Thanks for your attention !

For more details about our study :

Chupin, C., Ballu, V., Testut, L., Tranchant, Y-T., Aucan, J. : Potential of the Noumea Lagoon as a multi-mission Cal/Val site for past and future altimetry missions, Ocean Science, Preprint, https://doi.org/10.5194/egusphere-2022-514 , 2022

Contact : clemence.chupin@ensta-bretagne.fr

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http://ostst-altimetry-2022.com