Homogeneous multi-mission along-track Sea Level Anomalies, Wave and Wind (Level-2P) : implementation of Sentinel 6-MF/Jason-CS

Cecile Kocha (CLS), Alexandre Philip (CLS), Marine Lievin (CLS), Sabine Philipps (CLS),
Christophe Ferrier (cnes), Isabelino Denis (Cnes), Thierry Guinle (cnes), Carolina Nogueira Loddo (eumetsat)

Contact: aviso@altimetry.fr

Context

Since the launch of TOPEX/Poseidon and ERS-1 in the early 90's more than 15 other Altimetry missions were launched and operated by different agencies.

The level 2 data (destinated to expert users) are distributed using different file formats (binary, netcdf) and contain different geophysical standards used to compute the sea level anomaly. Some dataset evolve rapidly and are regularly reprocessed, whereas other datasets, especially from finished missions are seldom reprocessed or not at all (and therefore do not profit from new standards).

L2P/L3 is a homogeneous product thanks to the joined effort from :

L2P-SALP (Service d'Altimétrie et de Localisation Précise) project supported by CNES (Centre National d'Etudes Spatiales)
Sentinel-3 Marine Altimetry L2P-L3 Service (operated under an EUMETSAT contract in the frame of the COPERNICUS Programme funded by the European Union)
L3-CMEMS and C3S service implemented by MERCATOR Ocean International

L2P = INTER MISSION CALIBRATION

- **L2** • Spurious measurements and biases between missions are detected
- **L2P** • Spurious measurements and global biases are removed, SLA is more homogenous
- **L3** • sea-level is filtered and subsampled and discrepancies between missions adjusted

Climate scales relies on **reference altimeters** series (TP, J1/2/3, S6A)
Coverage altimeters (E1/2, EN, S3A/B, J3N)
collaborative missions (AL, HY2A/B) and **opportunity missions** (GFO, C2), are needed to retrieve the **mesoscale signals**.

Reprocessed – every 3 yrs → Delayed Time – 4-6 month delay → NRT(RT) – 6h delay

Ocean Reanalyses and Climate studies

Ocean Reanalyses Climate, non RT applications and ocean studies

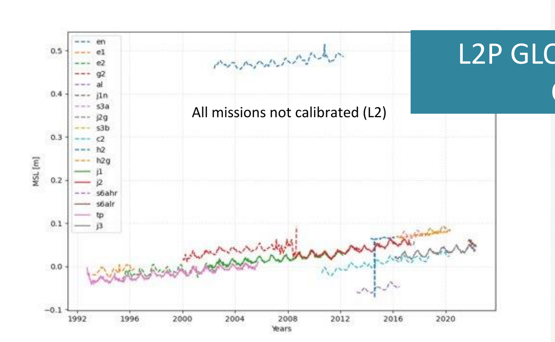
Ocean analyses and Forecasts RT applications

NTC L2P	Poseidon Topex	Jason 1	Jason 2	Jason 3	ERS-1	ERS-2	ENVISAT	SARAL	Sentinel 3A	Sentinel 3B	Geosat FO	Cryosat 2	HY 2A	HY 2B	S6A SAR/LRM
ORBIT	GSFC STD18	POE-E	POE-F	POE-F	Reaper		POE-E	POE-F	POE-F		GSFC	POE-F	POE-D	POE-F	POE-F
IONOSPHERIC CORRECTION	Filtered dual-frequency altimeter range measurements [Guibbaud et al. 2015] ; DORIS on Poseidon		Filtered dual-frequency altimeter range [Guibbaud et al. 2015] (from SSB C-band)	Filtered dual-frequency altimeter from [Guibbaud et al. 2015] & c>170 from L2 GDRF	Reaper NIC09 model [Scharroo and Smith, 2010]	GIM [Ijima et al., 1999]	Filtered from L2 ; c>65 GIM [Ijima et al., 1999] corrected for 8mm bias	GIM [Ijima et al., 1999]	Filtered from L2		GIM [Ijima et al., 1999]				Filtered dual-frequency altimeter range from L2 LR
SEA STATE BIAS	Non parametric [N. Tran et al. 2010] ; BM4 on Poseidon	Non parametric [N. Tran 2015]	Non parametric [N. Tran 2012]	Non parametric from J2 [N. Tran 2012] & c>170 from [N. Tran 2020 report] J3 GDRF	BM3 [Gaspar and Ogor, 1994]	Non parametric [Mertz et al., 2005]	Non parametric [N. Tran 2017]	Non parametric [N. Tran 2018]	Non parametric [N. Tran 2012]		Non parametric [Tran and Labroue, 2010]	Non parametric [N. Tran 2018] Baseline C	Non Parametric [N. Tran 2012 Vent S. Labroue]	L2 product	Non parametric from [N. Tran 2020] J3 GDRF
WET TROPOSPHERE	GPD+ [Fernandes and Lazaro, 2016]	JMR (GDRE) radiometer	AMR radiometer	AMR radiometer (c>170 from L2 GDRF)	GPD+ [Fernandes and Lazaro, 2016]		MWR radiometer reprocessed	Neuronal Network (5 entries) V4	MWR 3 radiometer		GFO Radiometer and ECMWF model	GPD+ [Fernandes and Lazaro, 2016]	ECMWF model		Radiometer HR/LR
DRY TROPOSPHERE	ERA5 (1-hour) model based														
DYNAMICAL ATMOSPHERIC CORRECTION	TUGO High frequencies forced with analysed ERA 5 pressure and wind field + inverse barometer Low frequences		TUGO HF forced with analysed ERA 5 pressure and wind field; and after 02/2016 MOG2D HF forced with analysed ECMWF pressure and wind field + inverse barometer LF	MOG2D HF forced with analysed ECMWF pressure and wind [Carrere and Lyard, 2003; operational version 3.2.0] + inverse barometer LF	TUGO High frequencies forced with analysed ERA 5 pressure and wind field + inverse barometer Low frequences			TUGO HF forced with analysed ERA 5 pressure and wind field; and after 02/2016 MOG2D HF forced with analysed ECMWF pressure and wind field + inverse barometer LF	MOG2D High frequencies forced with analysed ECMWF pressure and wind field [Carrere and Lyard, 2003; operational version 3.2.0] + inverse barometer Low frequencies		TUGO High frequencies forced with analysed ERA 5 pressure and wind field + inverse barometer Low frequences	TUGO High frequencies forced with analysed ERA 5 pressure and wind field ; and after 02/2016 MOG2D High frequencies forced with analysed ECMWF pressure and wind field + inverse barometer Low frequences		MOG2D High frequencies forced with analysed ECMWF pressure and wind field [Carrere and Lyard, 2003; operational version 3.2.0] + inverse barometer Low frequencies	
OCEAN TIDE	FES 2014 B [Carrère et al. 2016]														
INTERNAL TIDE	ZARON 2019 (HRETv8.1 tidal frequencies: M2, K1, S2, O1)														
POLE TIDE	DESAI et al.2015 ; Mean Pole Location 2017														
SOLID TIDE	Elastic response to tidal potential [Cartwright and Tayler, 1971 ; Cartwright and Edden, 1973]														
MEAN SEA SURFACE	Composite (SCRIPPS,CNES/CLS15,DTU15)														

+ L2P correction based on Numerical retracking And NOAA's correction for SAR vertical velocities

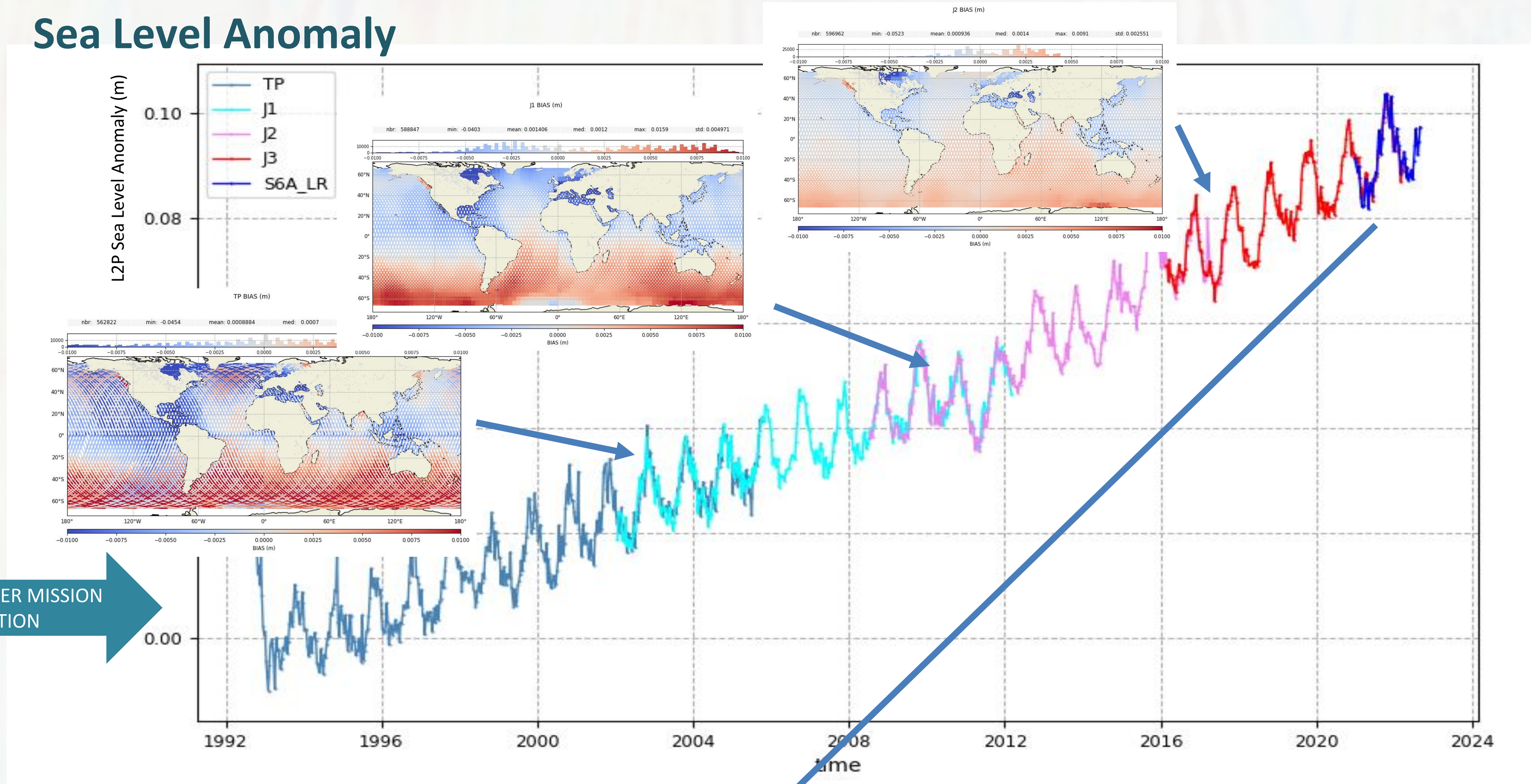
Global Mean Sea Level Calibration

Different satellite altimetry missions have been monitoring the GMSL successively and continuously since 1993 on a well-determined reference orbit: TOPEX/Poseidon, Jason-1, Jason-2, Jason-3 and soon, Sentinel-6 MF. Dedicated calibration phases between the successive missions, during which the satellites fly a few second apart, help to ensure the long-term stability and precise monitoring of the sea level. In addition, a permanent control of the data quality and instrumental performances, in combination with the homogenization of the data processing and geophysical corrections, are key to produce homogeneous data that well capture the long-term evolution of the sea level.



L2P GLOBAL INTER MISSION CALIBRATION

Sea Level Anomaly



Regional Sea Level Calibration

Reference altimeters need accurate global & regional calibration to ensure a seamless transition to build the time series suitable for climate studies.
These biases can depend on :
- ascending/descending passes,
- latitude,
- waves,
- …

For in-flight missions, L2P can anticipate future developments through corrections based on validated prototypes. **S6-MF is the first mission to benefit from it !**

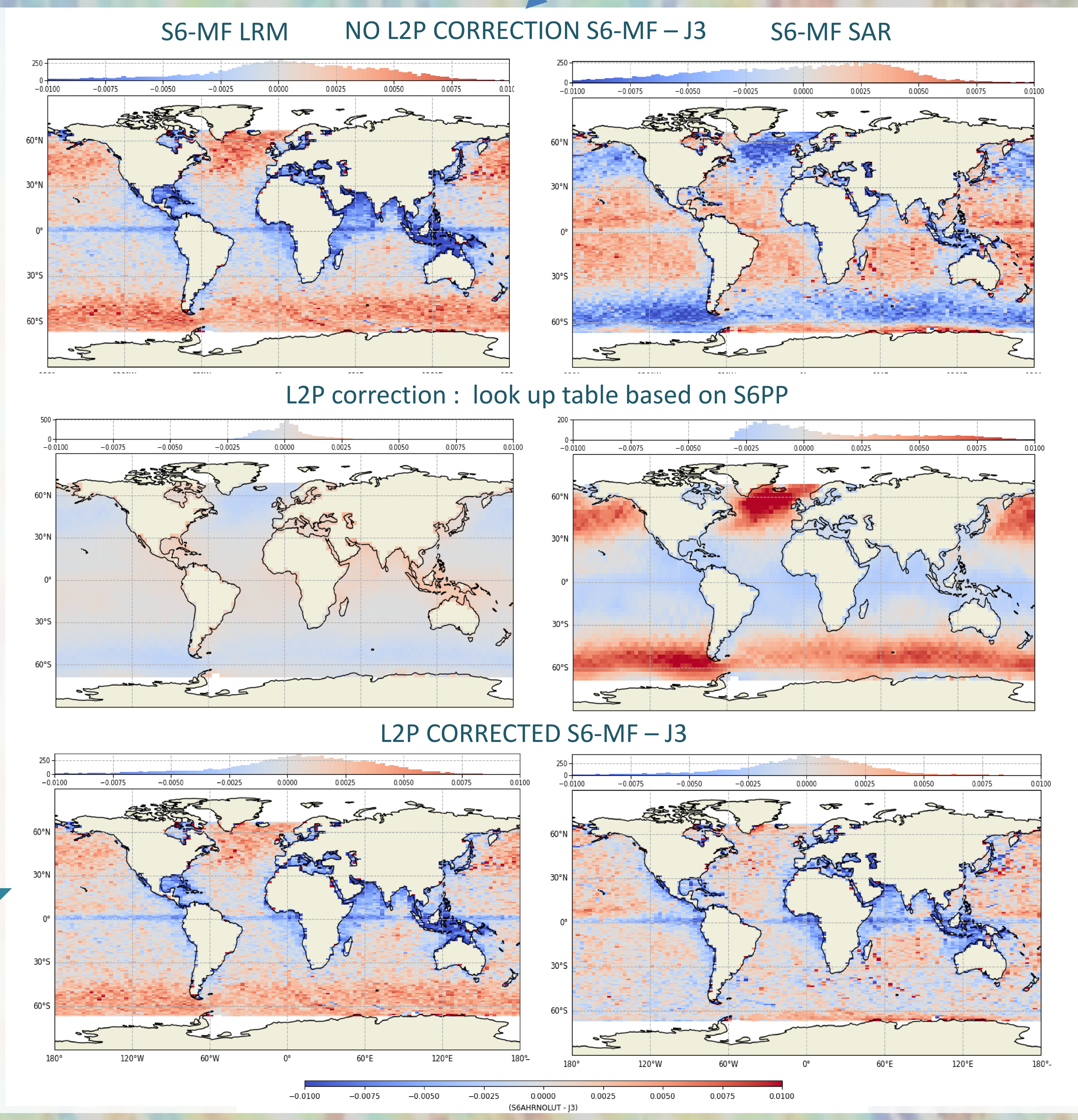
Regional Sea Level Calibration for S6-MF

S6-MF/J3 tandem phase revealed sea level bias depending on waves for both SAR and LRM modes with opposite sign! Such correlation is problematic for climate users as they are not constant in space and time. Investigations shown that such behavior is mainly due to S6-MF processing. Solutions have been found (such as numerical retracker, addition of a skewness parameter in SAR or correction of ocean vertical velocity effect in SAR) and will be implemented in the future PDAP Processing Baselines.

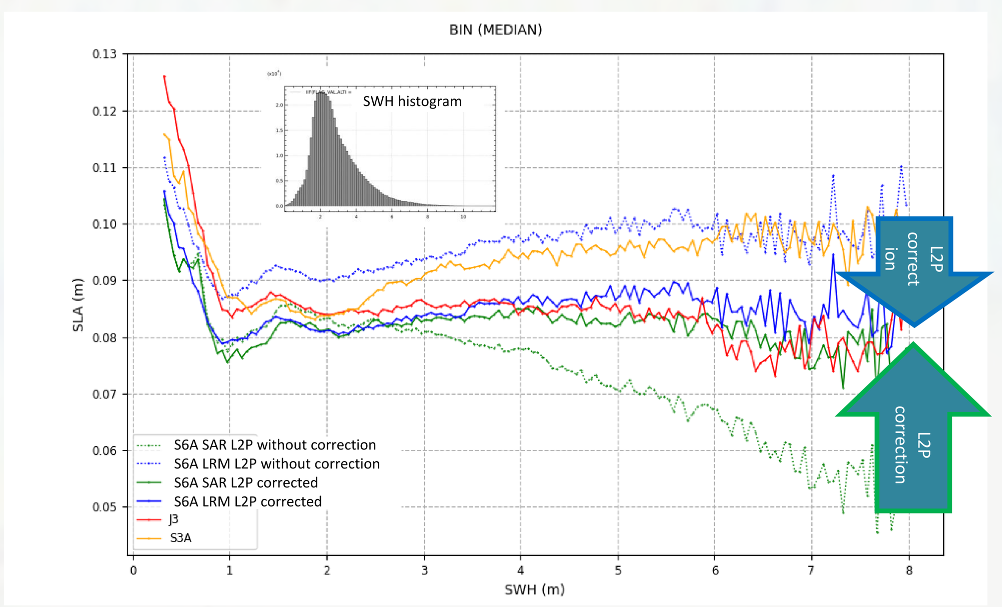
In the meantime, **L2P processing aims to correct the explained bias using CNES/CLS S6PP which already include the forthcoming PDAP evolutions** *(see Dinardo S. et al, Sentinel-6 MF Poseidon-4 Radar Altimeter: Main Scientific Results from S6PP LRM and UF-SAR chains in the first year of the mission, submited) and NOAA's LUT for OVV effect (see Egido A. et al presentation, A Significant Wave Height Correction to Account for Vertical Wave Motion Effects in SAR Altimeter Measurements, OSTST 2022).*

A look up table S6-MF minus S6PP function of SWH was implemented into L2P S6-MF products :
- Correct most of the wave dependencies observed in L2
- Ensure the continuity with next L2 evolutions
- Ensure S6A as reference mission into L3 products without impacting other missions

L2P REGIONAL INTER MISSION CALIBRATION



Sea Level Anomaly function of waves



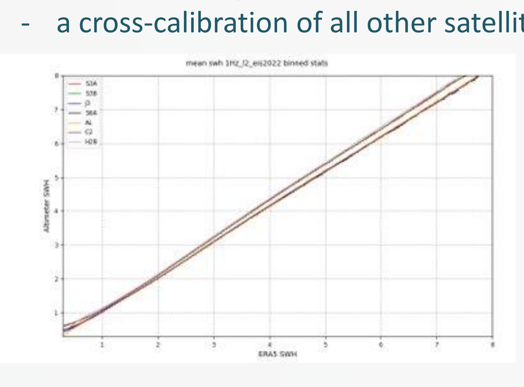
L2P S6A correct the Sea level anomaly wave dependance at high waves.
For S6A SAR further investigations see : Cadier E. et al, Leveraging S6A interleaved mode to characterize Sentinel-6A High Resolution error budget over ocean, OSTST 2022, presentation.

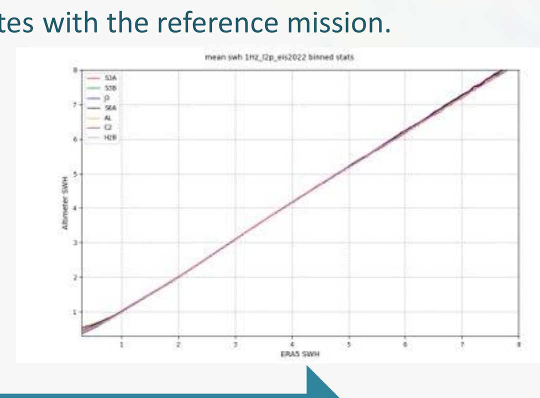
Residual biases need to be further investigated to correctly address them :
•**Ionospheric correction** differences between S6A and J3. Some of these are dependent on waves.
•**Equatorial band** is still under investigation and is less than 5mm.
•**Small waves** : study ongoing

See Bignalet-Cazalet F., Sentinel-6 PDAP products assessment over ocean, OSTST 2022, presentation for further investigations

Wind and wave Calibration

Calibration is divided in two main steps :
- for waves only, absolute calibration of a long reference mission against in-situ data (buoys).
- a cross-calibration of all other satellites with the reference mission.





L2P INTER MISSION CALIBRATION

Conclusion

L2P learn from each mission with different instruments, orbit and treatments to calibrate each other to insure a more reliable earth observation.

Long term continuity on the reference orbit will be ensured thanks to L2P S6-MF for a 4th decade.

Mesoscale & small mesoscale retrieval is improved thanks to S6-MF low noise. Thus, CMEMS observation and modelling products are (positively) impacted by S6A in real time. Still, S6A needs to be complemented by other altimeters to describe and forecast ocean currents at fine scale.

DOWNLOAD DATA :

•**AVISO+ website** https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/along-track-sea-level-anomalies-l2p.html
•**EUMETSAT website** EUMETCAST
•**Copernicus website** https://resources.marine.copernicus.eu/product-detail/SEALEVEL_GLO_PHY_L3_NRT_OBSERVATIONS_008_044/INFORMATION

COMING SOON :

- **L2P NTC S6A LRM & SAR data (side B) : 1/11/2022**
- **L3 NTC S6A LRM & SAR data : 15/12/2022**
- **L2P NRT/STC 20Hz S6A SAR : end 2022** *(See Phillips et al. APO 005)*
- **Reprocessed data L2P NTC V4.0 : Summer 2023**

OSTST meeting 2022