

living planet symposium

BONN
23–27 May
2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE



Sentinel-6 PDAP products assessment over ocean

CNES⁽¹⁾ on behalf of MPWG members (EUMETSAT⁽²⁾, ESA⁽³⁾, NOAA⁽⁴⁾, NASA⁽⁵⁾, CNES)
With the support from CLS⁽⁶⁾

Claire Maraldi⁽¹⁾, Emeline Cadier⁽⁶⁾, Adrien Guerou⁽⁶⁾, Salvatore Dinardo⁽⁶⁾, Thomas Moreau⁽⁶⁾, François Boy⁽¹⁾, Nicolas Picot⁽¹⁾, Gilles Tavernier⁽¹⁾,
Cristina Martin-Puig⁽²⁾, Marco Meloni⁽²⁾, Remko Scharroo⁽²⁾, Carolina Nogueira Loddo⁽²⁾, Craig James Donlon⁽³⁾, Marco Fornari⁽³⁾, Robert Cullen⁽³⁾,
Luisella Giulicchi⁽³⁾, Walter H. F. Smith⁽⁴⁾, Alejandro Egido⁽⁴⁾, Eric Leuliette⁽⁴⁾, Jean-Damien Desjonqueres⁽⁵⁾, Shailen Desai⁽⁵⁾

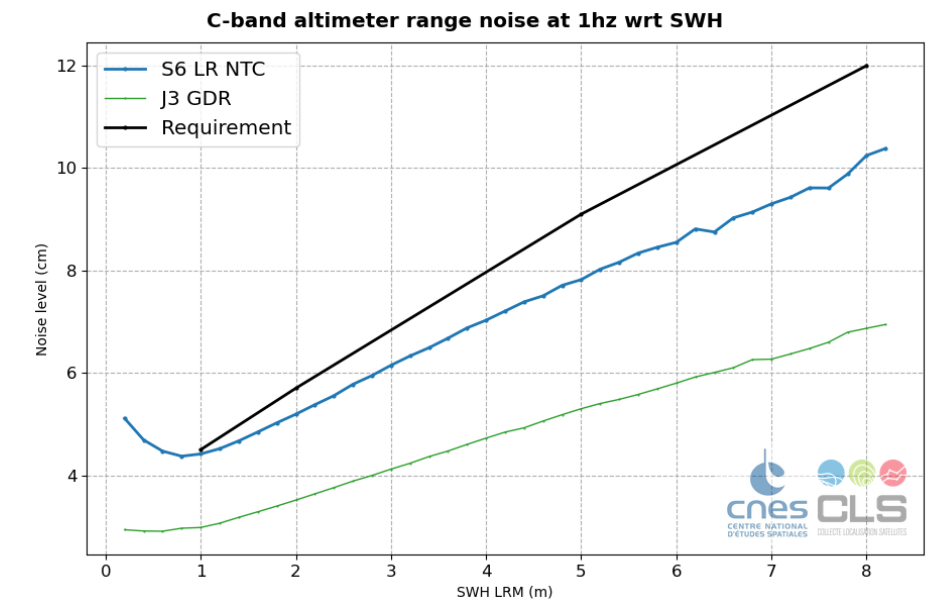
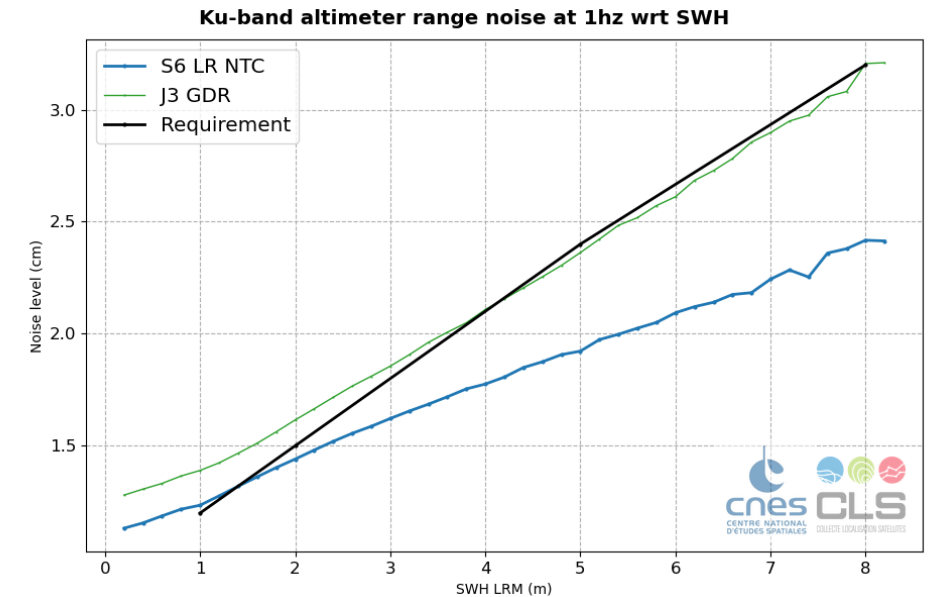
LR NTC altimeter range noise

Ku Band

- ❖ **Lower noise on S6 with lower Significant Wave Height (SWH) dependency**
 - Due to better sampling and higher PRF

C band

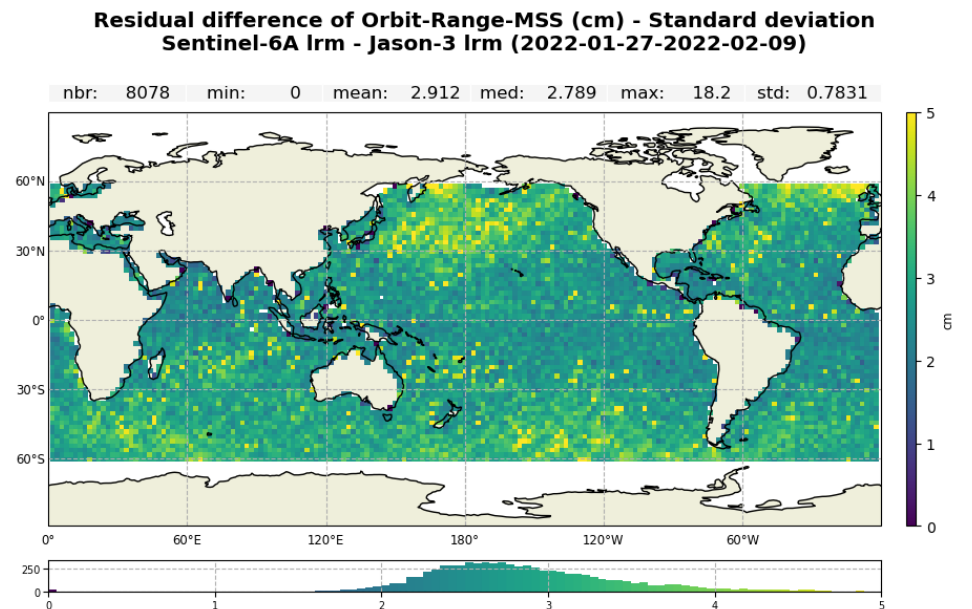
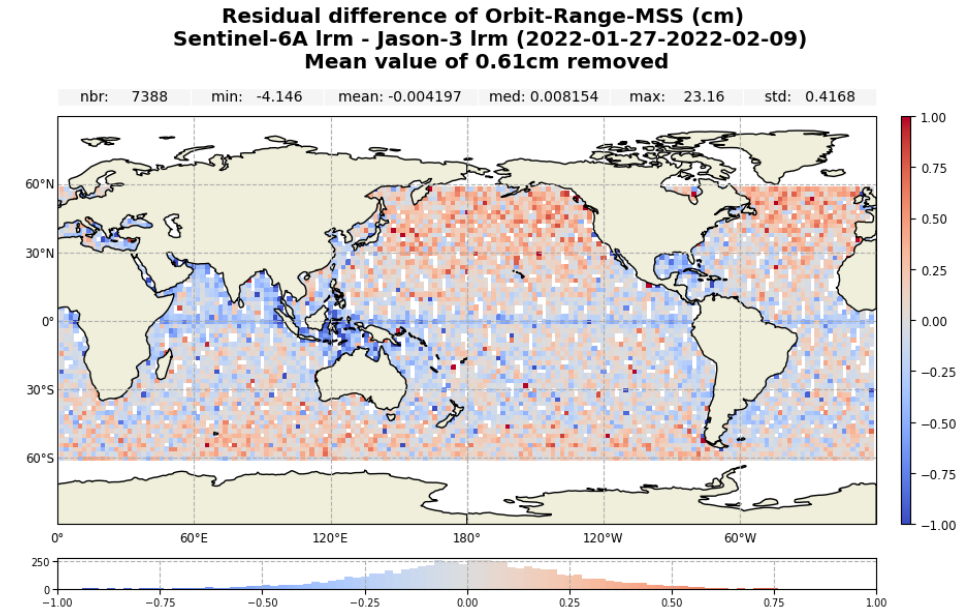
- ❖ **Higher noise on S6 than J3**
 - Expected (less pulses in radar cycle)
- ❖ **Within specification**



LR NTC altimeter range

Ku Band

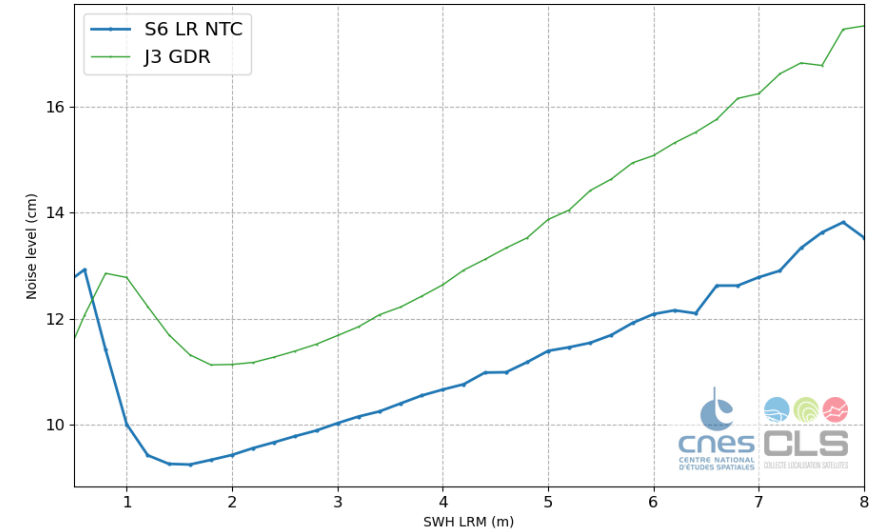
- ❖ **Very good consistency with J3**
 - Bias < cm
 - Very low standard deviation
 - No hemispheric bias → validation of orbit quality
- ❖ **Open issues**
 - Equatorial signature
 - Also seen with JPL orbits (Shailen Desai, S6VT)
 - Small SWH dependency
 - On-going investigation, only observed on range retracking estimates



LR NTC SWH

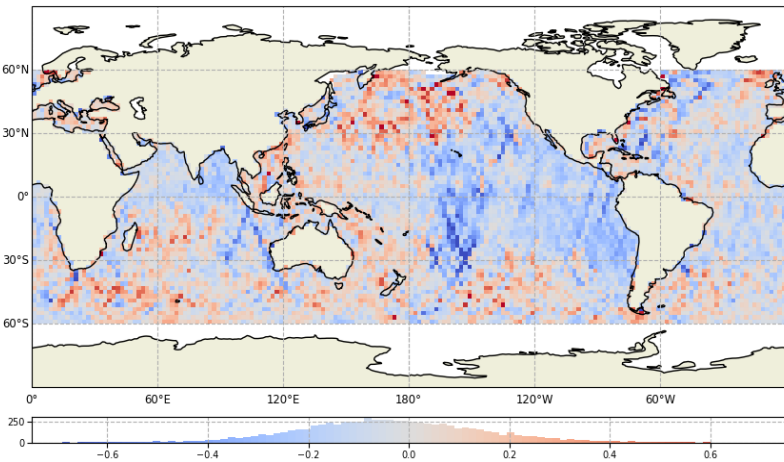
- ❖ **Lower noise on S6**
 - Differences at low SWH linked to different negative SWH value management
 - Small dependency wrt SWH
- ❖ **Excellent agreement with J3**
 - Mean difference centered around -1.7 cm only
 - No geographical pattern
- ❖ **Good match with models**

Ku-band altimeter SWH noise at 1hz wrt SWH

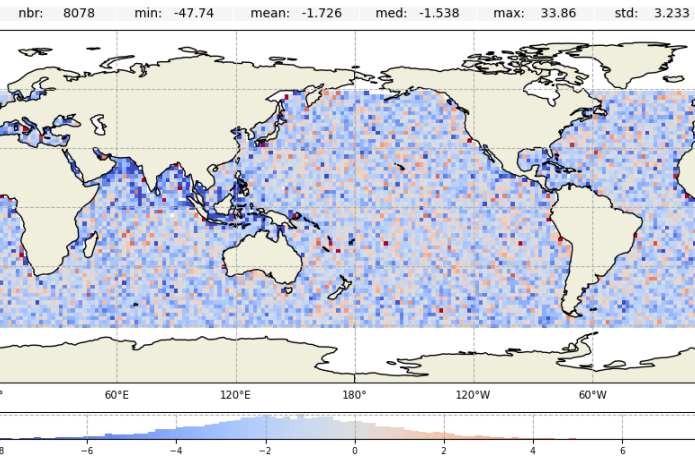


Sentinel-6 SWH bias : Altimeter LRM NTC - ERA5 Model (m)

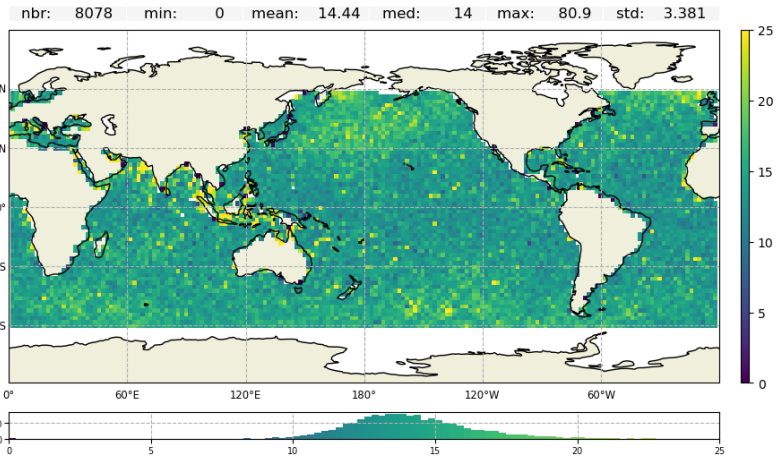
nbr: 8168 min: -1.506 mean: -0.03416 med: -0.03917 max: 1.596 std: 0.2135



Residual difference of Significant Wave Height (cm)
Sentinel-6A lrm - Jason-3 lrm (2022-01-27-2022-02-09)

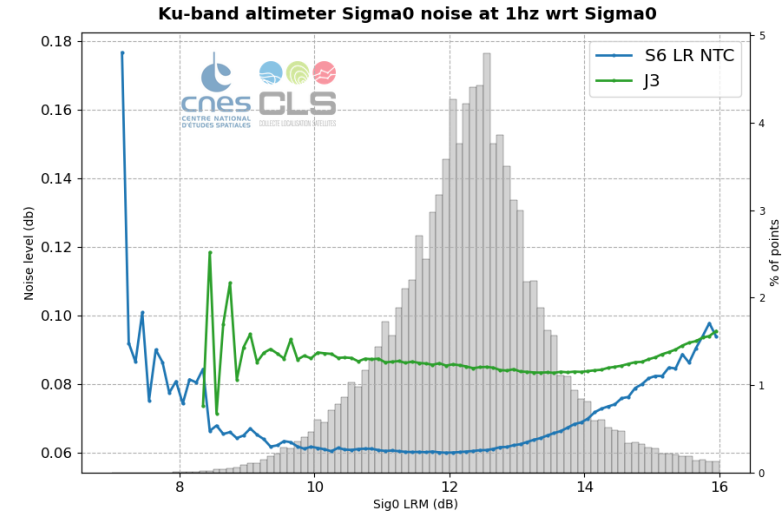


Residual difference of SWH (cm) - Standard deviation
Sentinel-6A lrm - Jason-3 lrm (2022-01-27-2022-02-09)

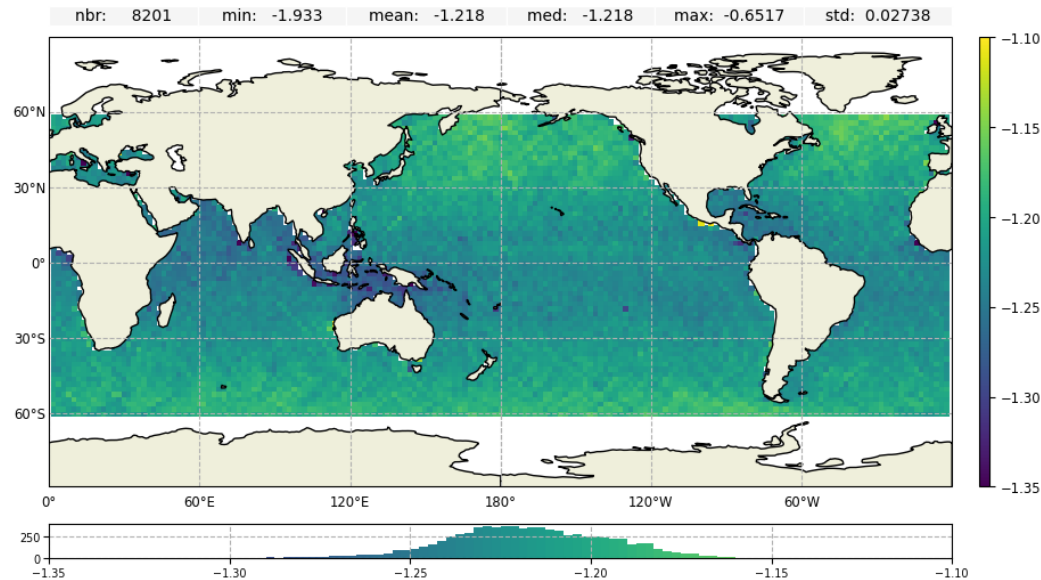


LR NTC sigma0

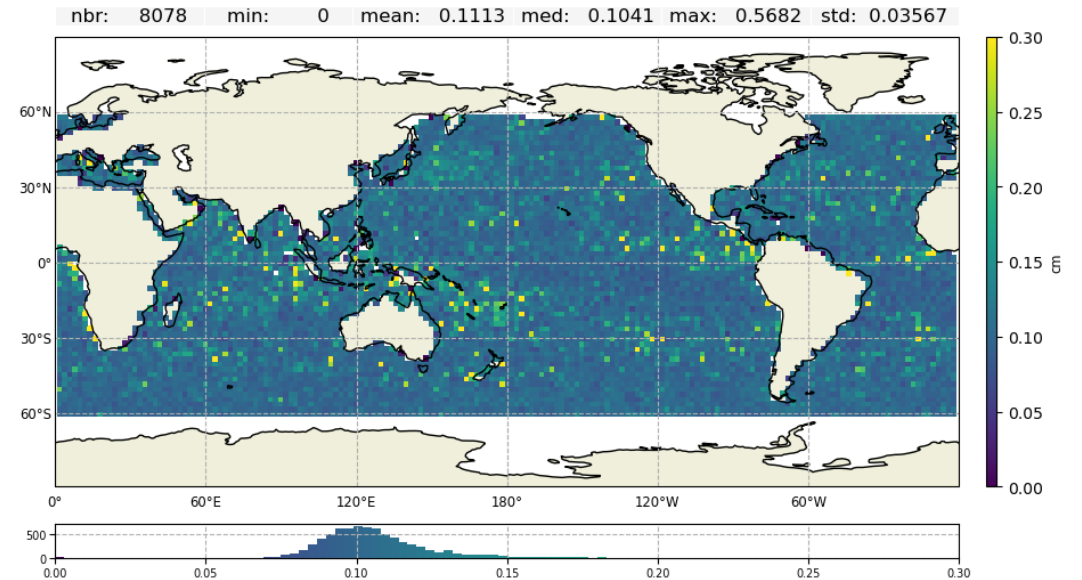
- ❖ **Lower noise on S6, largely improved**
 - Due to better radiometric resolution
- ❖ **Bias of -1.22 dB on side B**
 - Note: bias taken into account before wind computation
- ❖ **Excellent agreement with J3**



**Residual difference of Altimeter Sigma0 (dB)
Sentinel-6A lrm - Jason-3 lrm (2022-01-27-2022-02-09)**

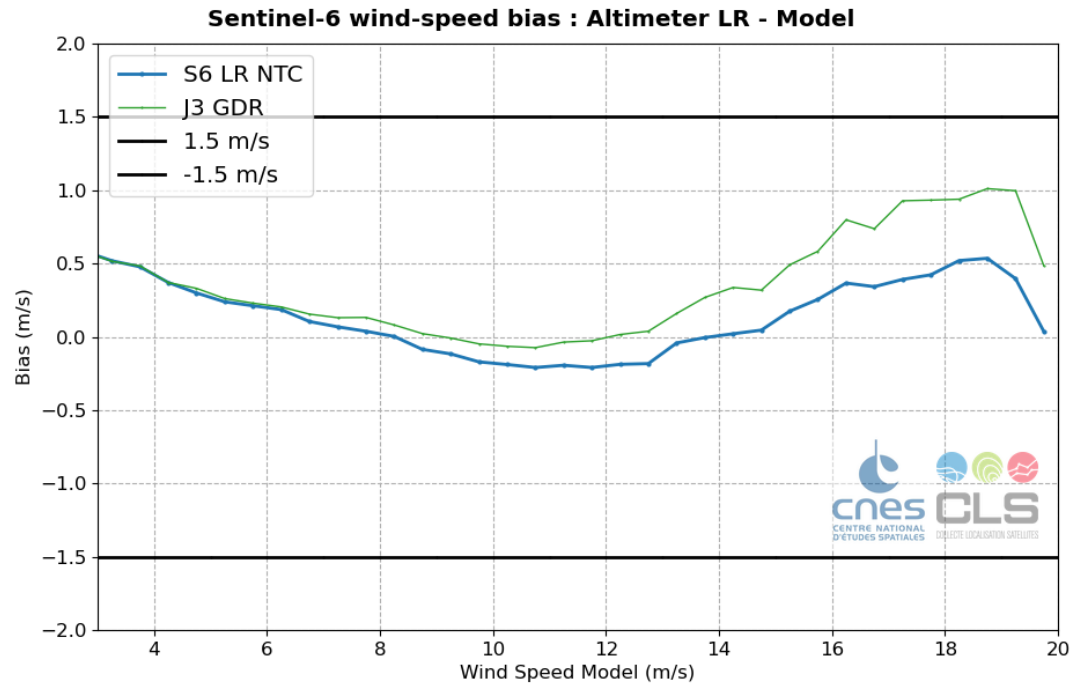


**Residual difference of Sigma0 (db) - Standard deviation
Sentinel-6A lrm - Jason-3 lrm (2022-01-27-2022-02-09)**

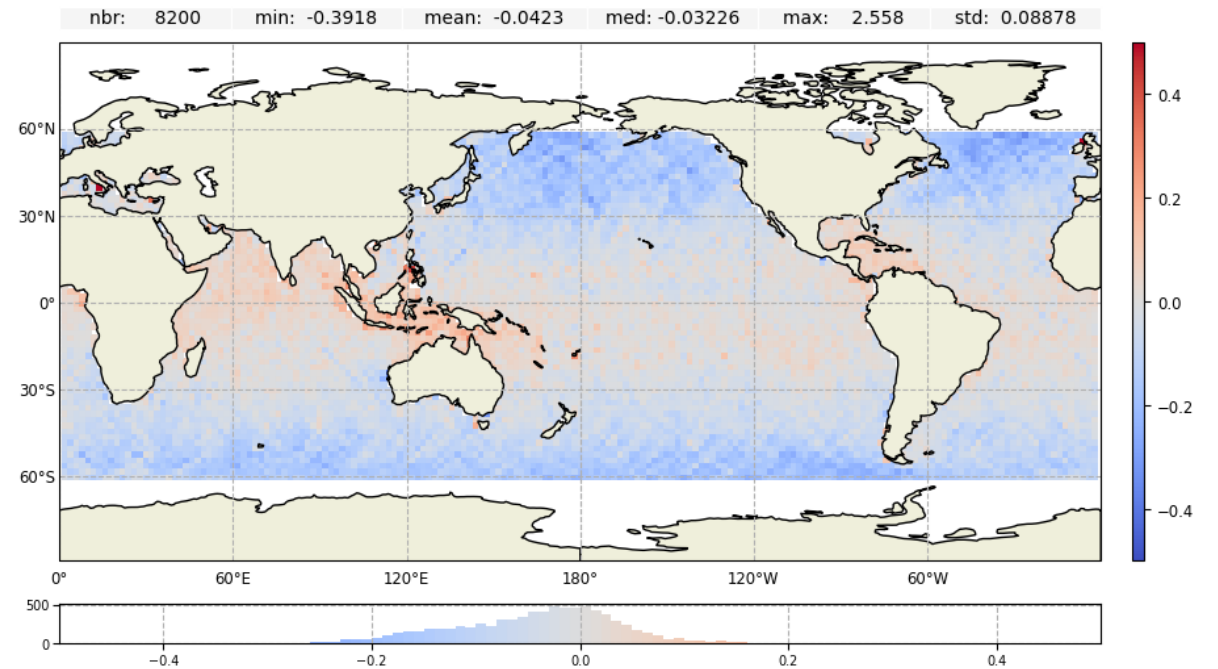


Wind speed

- ❖ Collard wind model for both S6 and J3
- ❖ S6 in line with J3 (bias < 5 cm/s)



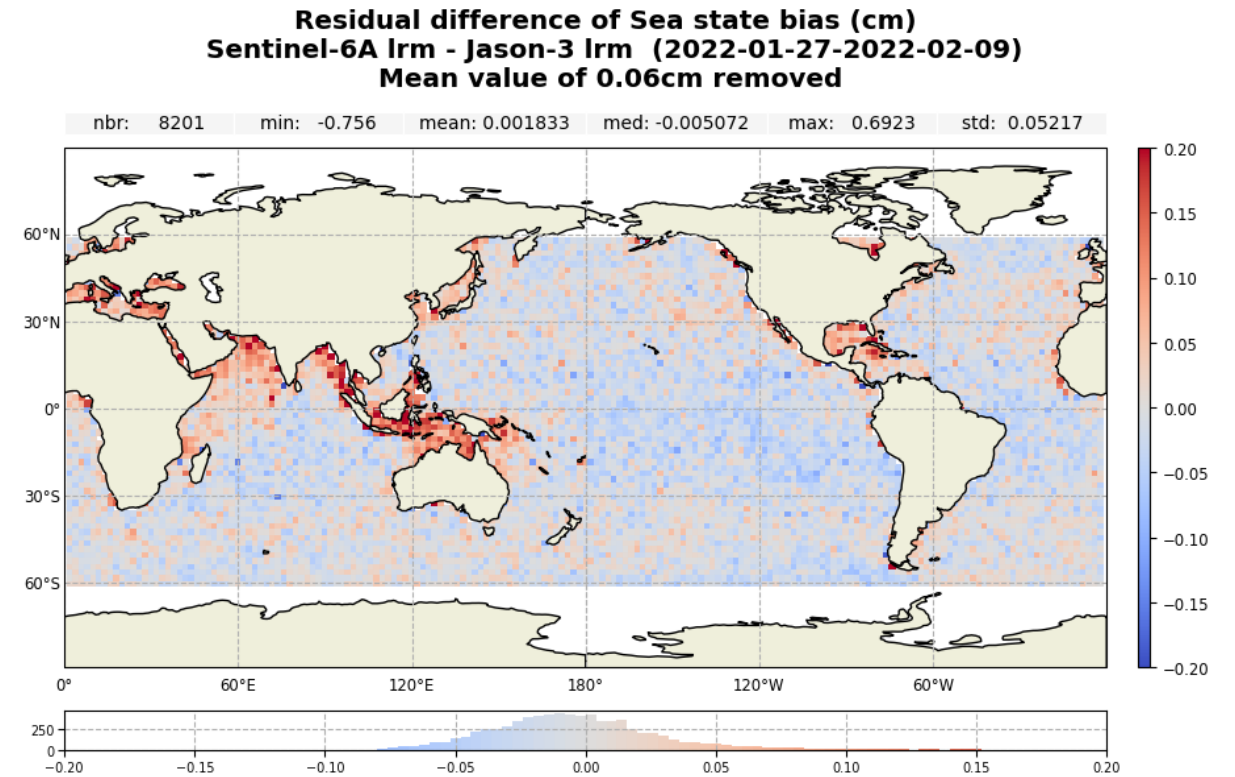
**Residual difference of Altimeter wind speed (m/s)
Sentinel-6A Irm - Jason-3 Irm (2022-01-27-2022-02-09)**



LR NTC Sea State Bias (SSB)

❖ S6 and J3 share the same J3 GRD-F SSB

- <cm bias
- Small discrepancies in bloom regions
- J3 SSB very consistent elsewhere



LR & HR NTC geophysical corrections

❖ Ionospheric correction

- In line with J3
- <cm bias

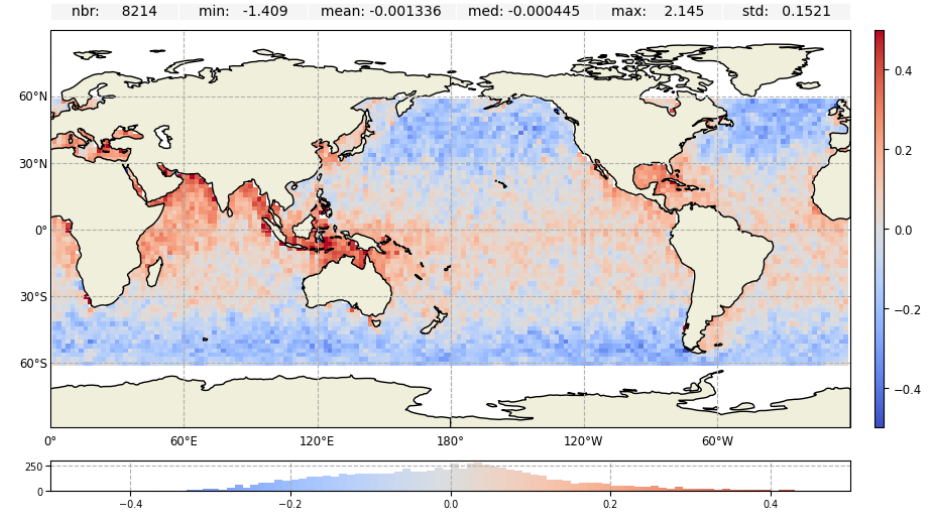
❖ Dry troposphere

- Not shown. In line with J3

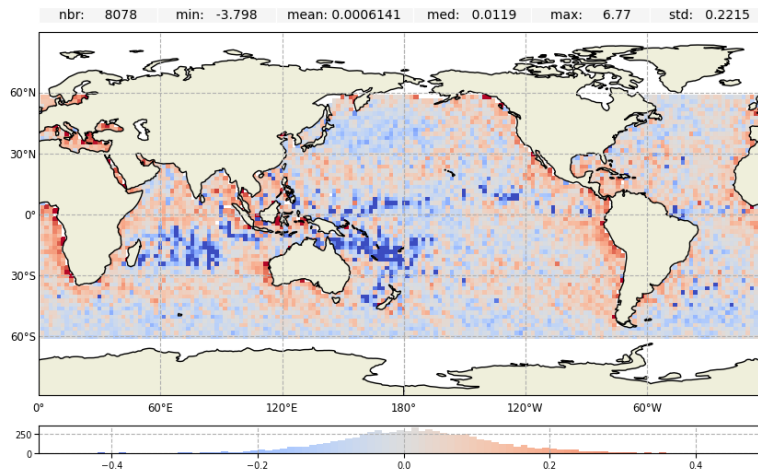
❖ Wet troposphere from radiometer

- In line with J3
- Negligible bias wrt ECMWF model

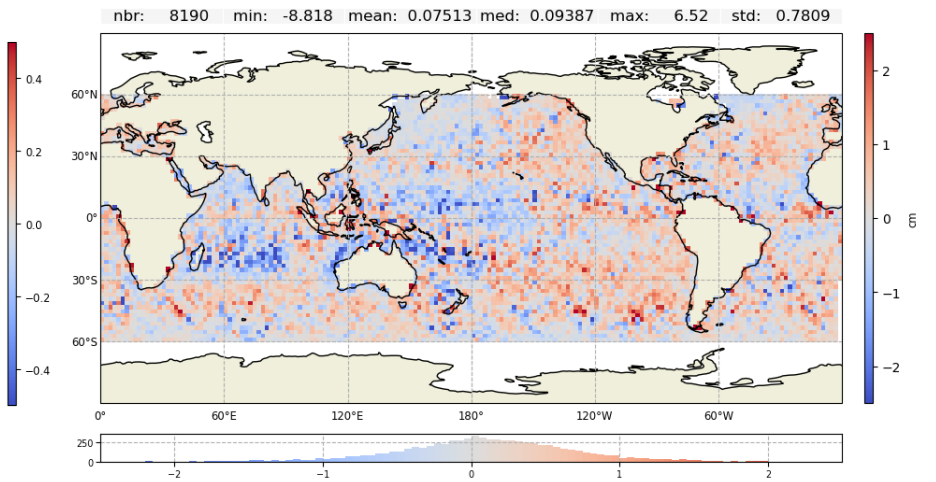
**Residual difference of Filtered ionospheric correction (cm)
Sentinel-6A Irm - Jason-3 Irm (2022-01-27-2022-02-09)
Mean value of -0.36cm removed**



**Residual difference of Radiometer wet tropospheric correction (cm)
Sentinel-6A Irm - Jason-3 Irm (2022-01-27-2022-02-09)
Mean value of -0.05cm removed**



**Wet tropospheric correction difference :
Radiometer - ECMWF model (cm)**



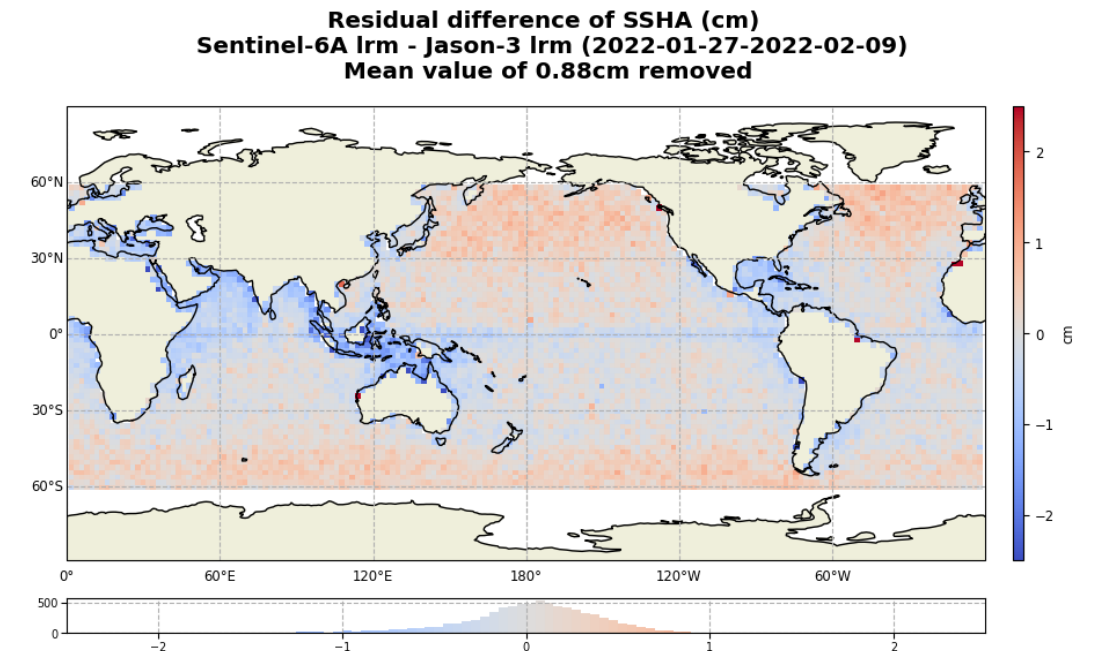
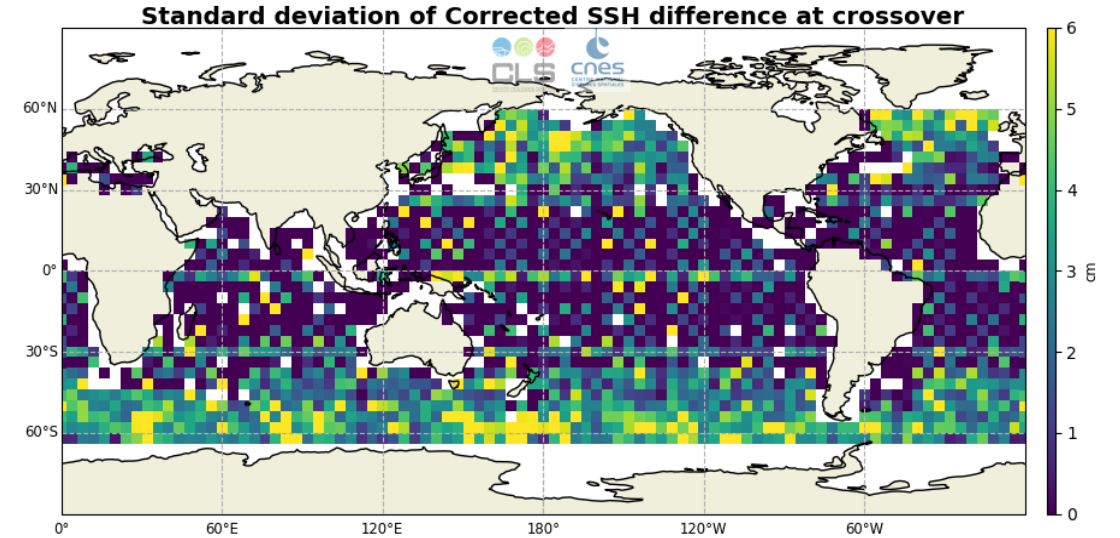
LR NTC corrected Sea Surface Height

❖ Corrected SSH error at Xovers

- Within specification
 - Global = 3.57 cm
 - Over Pacific ocean = 2.68 cm
- Low values in area with small waves
- Metric impacted by geophysical effects in high SWH regions

❖ Very consistent with Ja3

- SSHA geographical differences of the order of +/-1 cm



LR NTC – stability and drift

❖ Inter-mission bias (side-B)

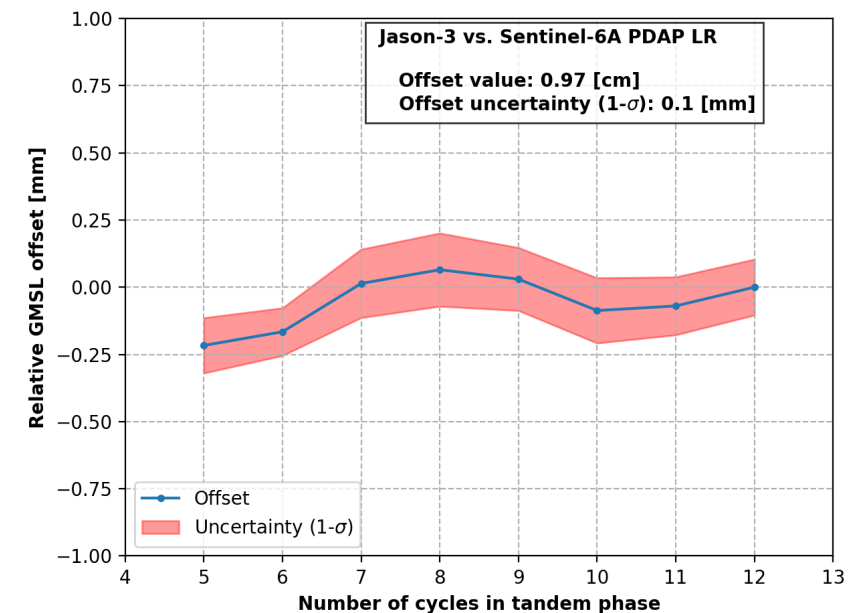
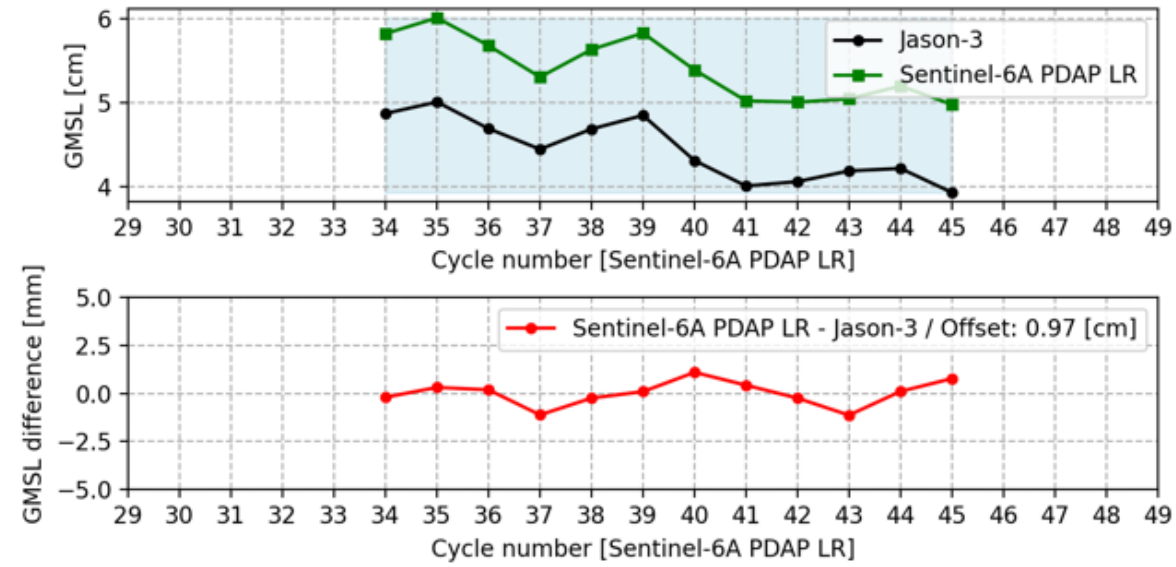
- Stable with max oscillation amplitude around +/-2 mm
- Offset of 0.97 cm
- Benefits from
 - PDAP evolutions during the first phase of CalVal
 - PDAP stable version over the side-B period
 - POE-F over the period

❖ Uncertainty on the GMSL bias (side-B)

- Can be a large contributor to the total GMSL trend uncertainty between two consecutive missions
- Key result of the tandem phase
- Very stable bias and uncertainty about 0.1 mm (1- σ)
- NB same order of magnitude that for Jason-1/-2/-3 missions (~0.2 mm)

❖ Impact of instrumental drift on GMSL

- Impact on long term times series
- Numerical retracking needed



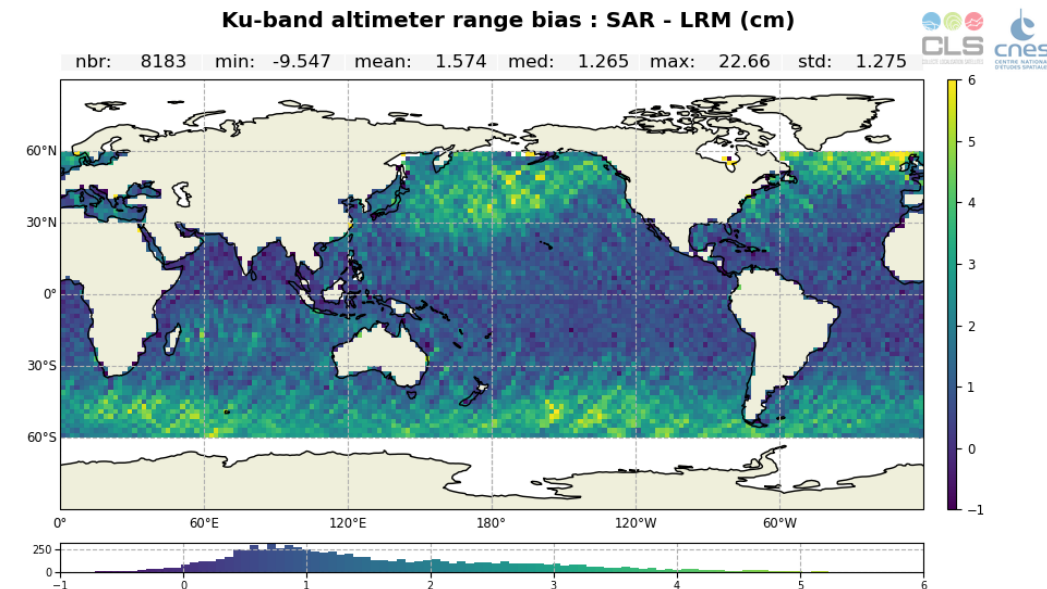
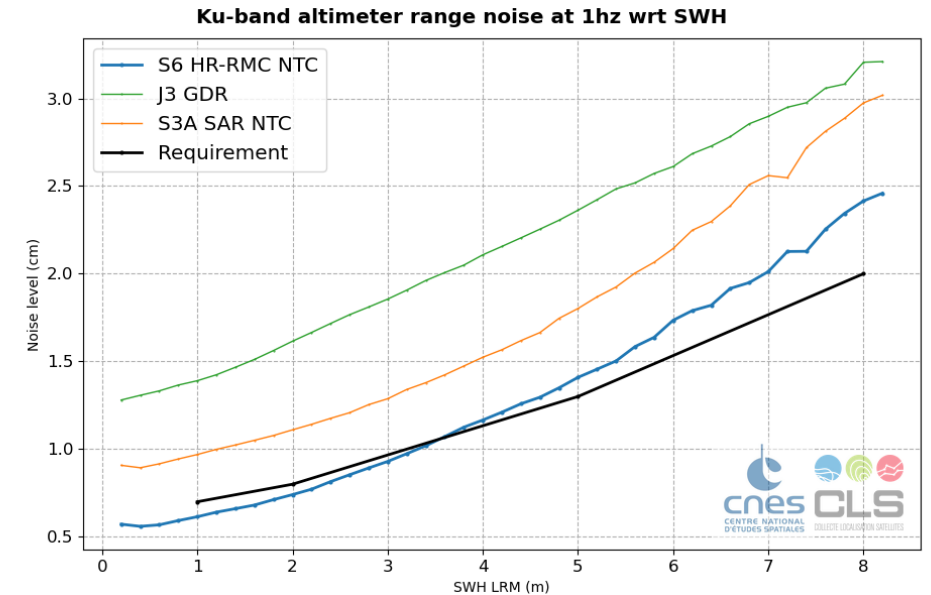
HR altimeter range – Ku band - noise

❖ Noise

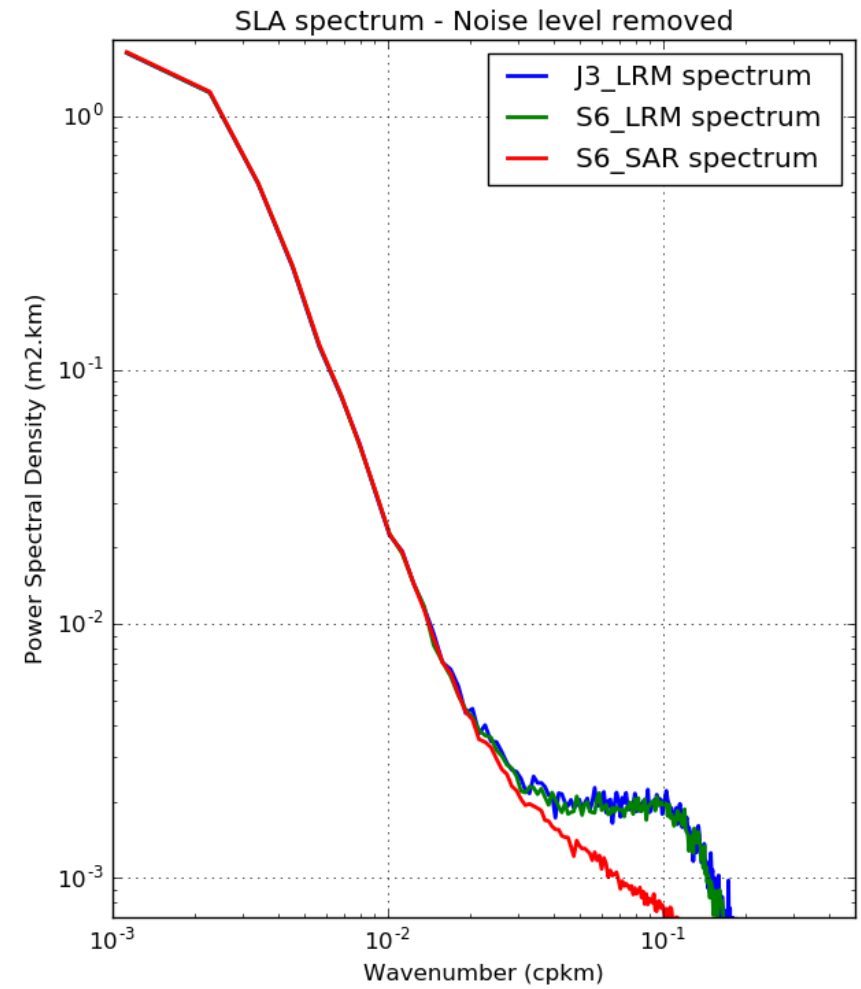
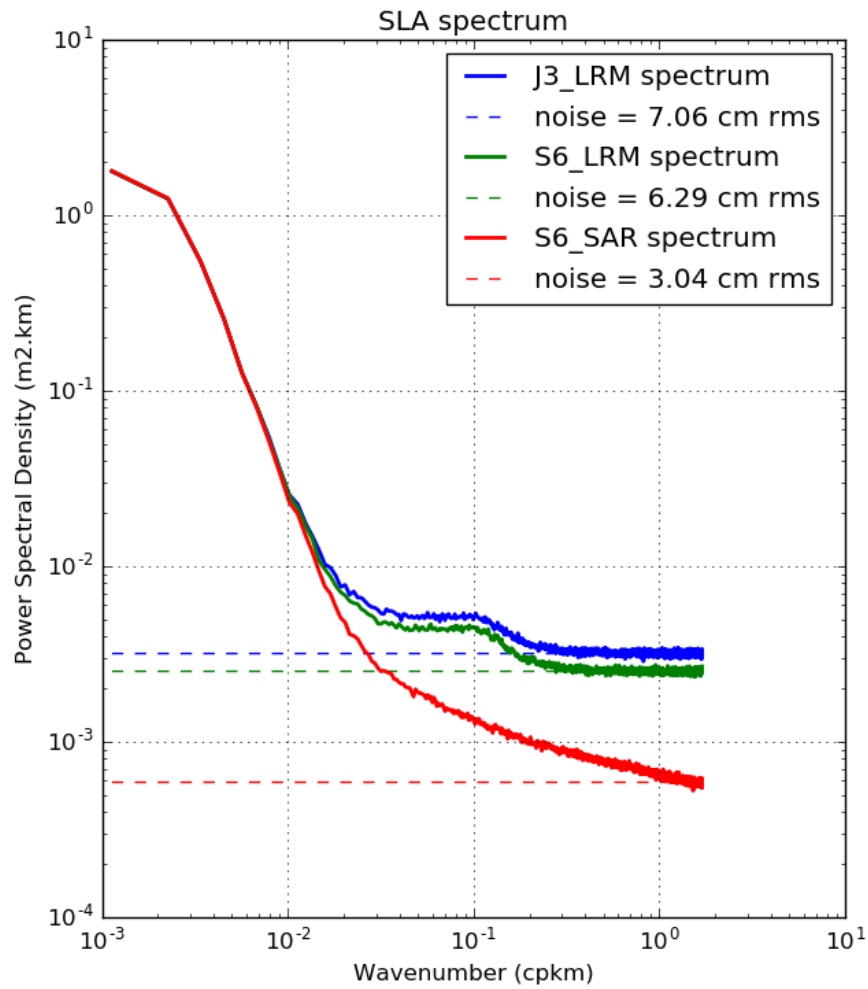
- Excellent performances for noise (well below S3)
 - Higher number of looks
 - Slight deviation for highest swh (swell sensitivity)
- RMC noise equivalent to RAW noise

❖ J3/S6 residuals

- Up to 6 cm bias between HR-LR
 - Skewness to be aligned with LR
 - Impact of Doppler ambiguities management to be assessed
 - processing optimizations required (skewness, SWH, SSB) before full use of S6 HR promising capabilities



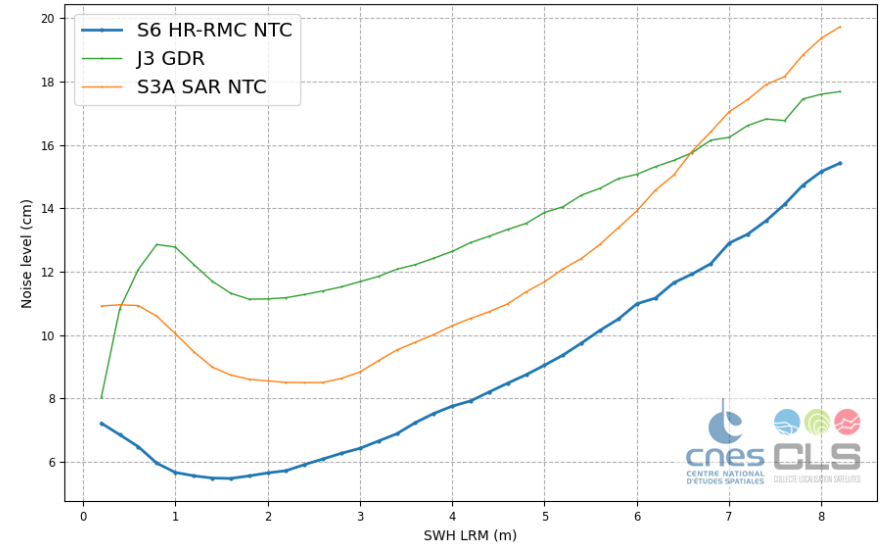
Corrected SSH spectra



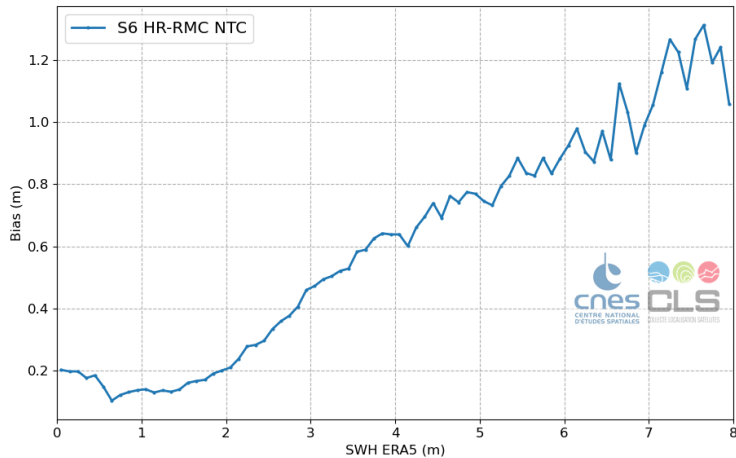
HR SWH

- ❖ **Excellent performances for noise (well below S3)**
 - Differences at low SWH linked to different negative SWH value management
- ❖ **Up to 80cm bias between HR-LR**
 - Vertical waves motion impact (known issue observed on S3 too)
 - Impact on SSHA via SSB
- ❖ **LR-HR Ascending/Descending tracks bias link to meridional wind component (known issue observed on Sentinel-3 too)**

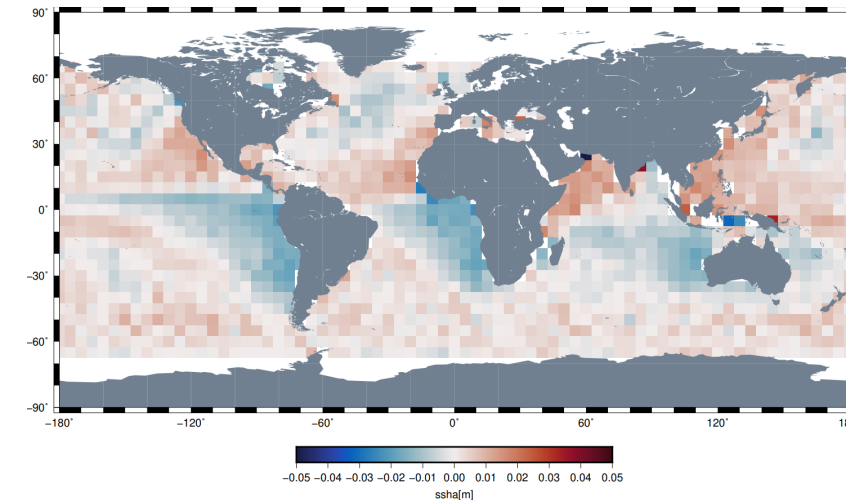
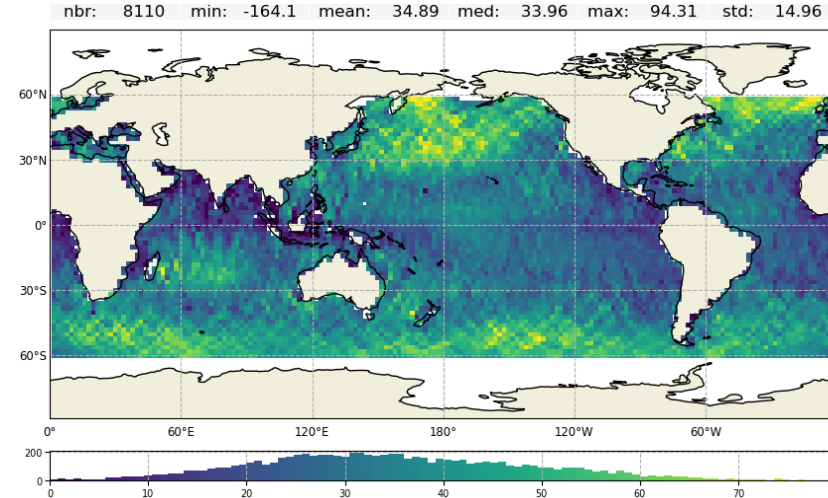
Altimeter SAR swh noise at 1hz wrt SWH



Sentinel-6 SWH bias : Altimeter - ERA5 Model (m)



Residual difference of SWH (cm)
Sentinel-6A sar - Jason-3 lrm (2022-01-27-2022-02-09)



HR – Range Migration Correction (RMC) mode validation over ocean

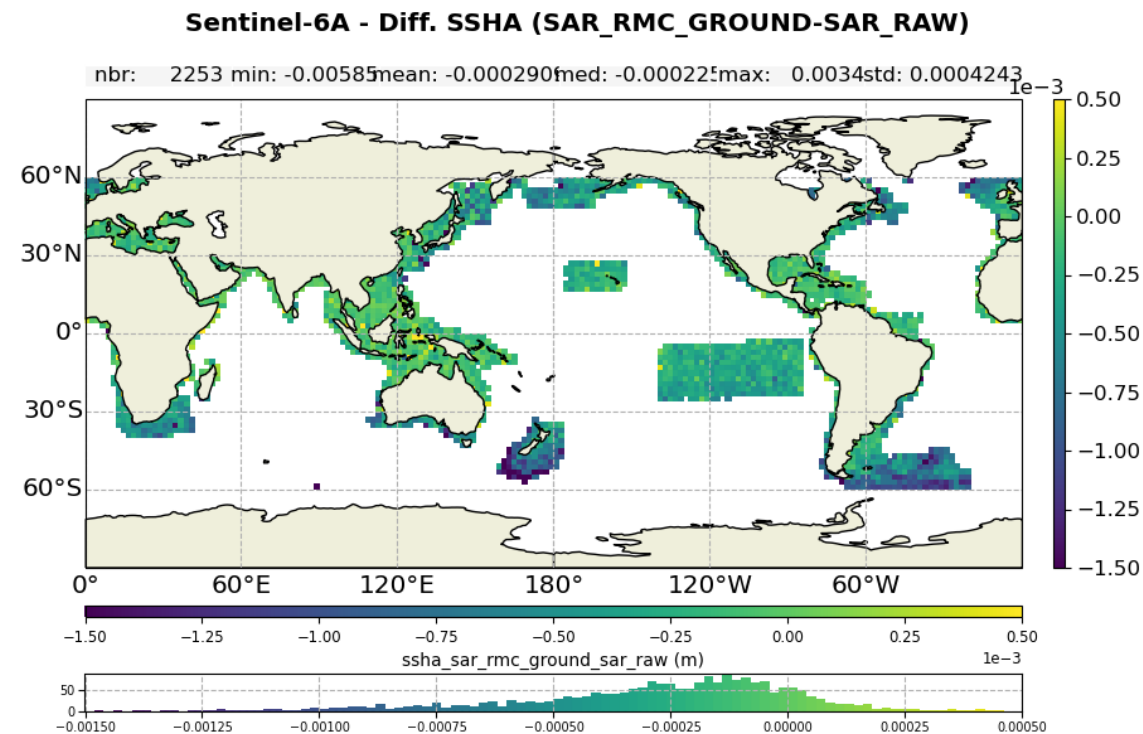
❖ No sensitivity observed wrt the mean sea surface slopes & the distance to the coast

- Range differences have a slight SWH dependency (from 0 to 2.5mm) but it will be absorbed with SSB

❖ Negligible RAW-RMC differences

- Retracked parameters
 - <2mm on range
 - <1cm on SWH
 - <0.02dB on sigma0
- Negligible differences over open ocean and coastal areas
- Negligible differences for inland waters
 - E.g. Over Amazon basin: 95% of measurements with range discrepancies <2cm.

❖ → RMC everywhere as operational mode



Conclusion

- ❖ **S6-MF data of very high quality**
- ❖ **Very good inter-mission bias between JA3 data and S6-MF Altimeter SideB data**
 - Very stable bias and uncertainty about 0.1 mm ($1-\sigma$)
 - Numerical retracking needed for long term trends
 - Future PDAP evolutions will ensure GMSL trend continuity with JA3
- ❖ **RMC and RAW data inline**
- ❖ **Some remaining processing improvements required**
 - LR data
 - Remaining differences with JA3 as a function of SWH and other features
 - Application of small Look up Tables at higher level to merge S6-MF with other data is still required
 - HR data: skewness, vertical waves motion, wind effects, range walk correction
- ❖ **S6PP CNES/CLS prototype was used for investigations during CalVal and will still be used for R&D and future PDAP evolutions**

Full mission reprocessing

❖ HR new configuration with substack

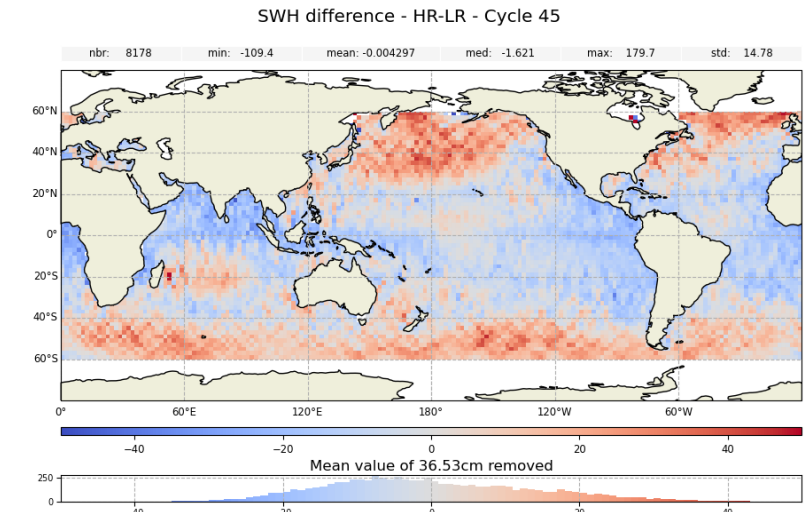
- 322 looks: compromise between HR bias reduction and noise
- Removes outer beams affected by
 - Vertical wave velocity effects
 - Range Walk effect
 - Doppler ambiguities

❖ Main impact on SWH

- HR-LR bias: ~14cm reduction
- HR-LR SWH dependency reduced

❖ Full mission reprocessing on-going

PDAP : operational



PDAP : 322 looks

