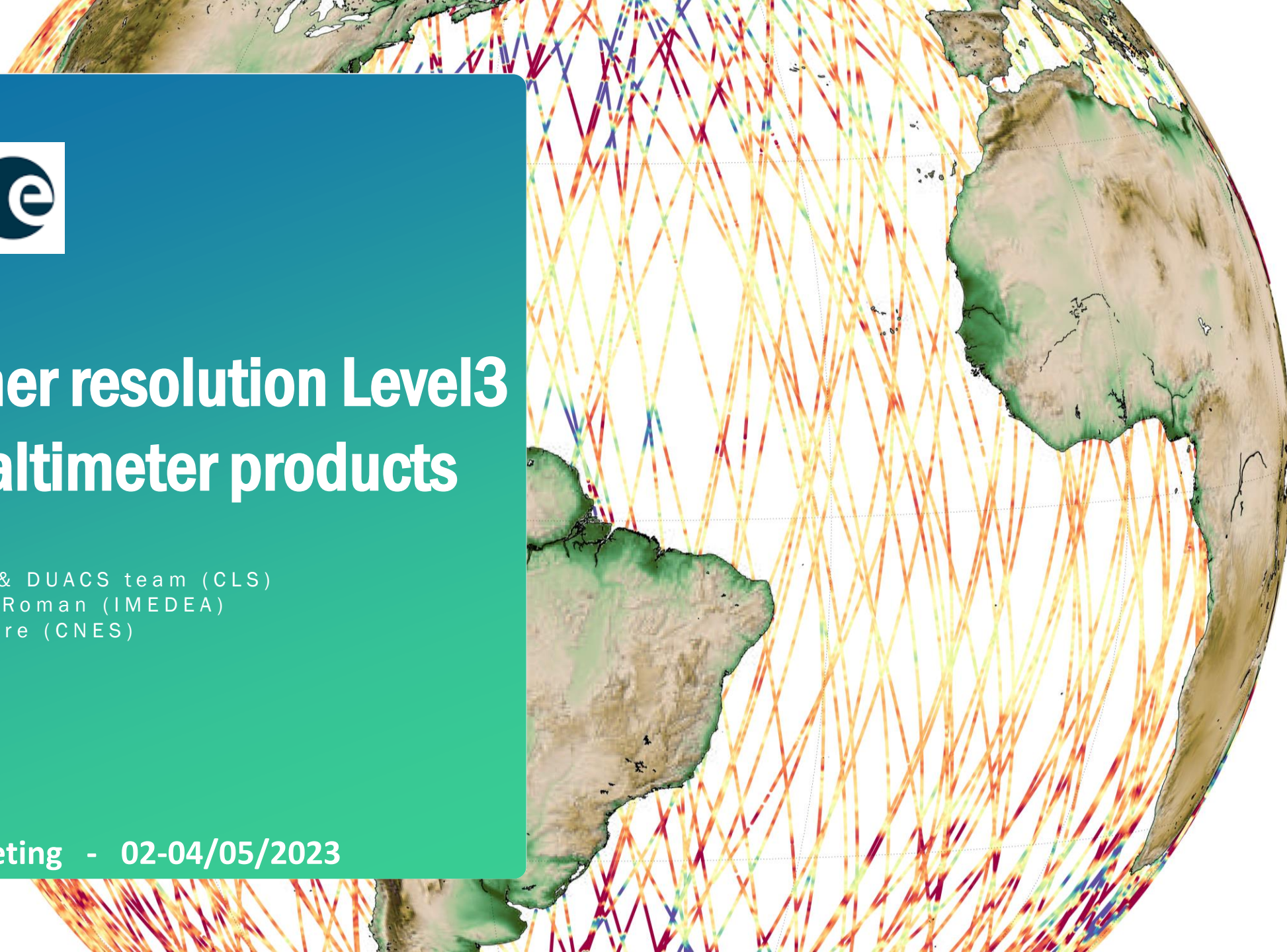




Toward Higher resolution Level3 sea level altimeter products

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Motivations

Why a L3 altimeter product with a 5Hz (~1km) sampling ?

→ To answer the users' need :

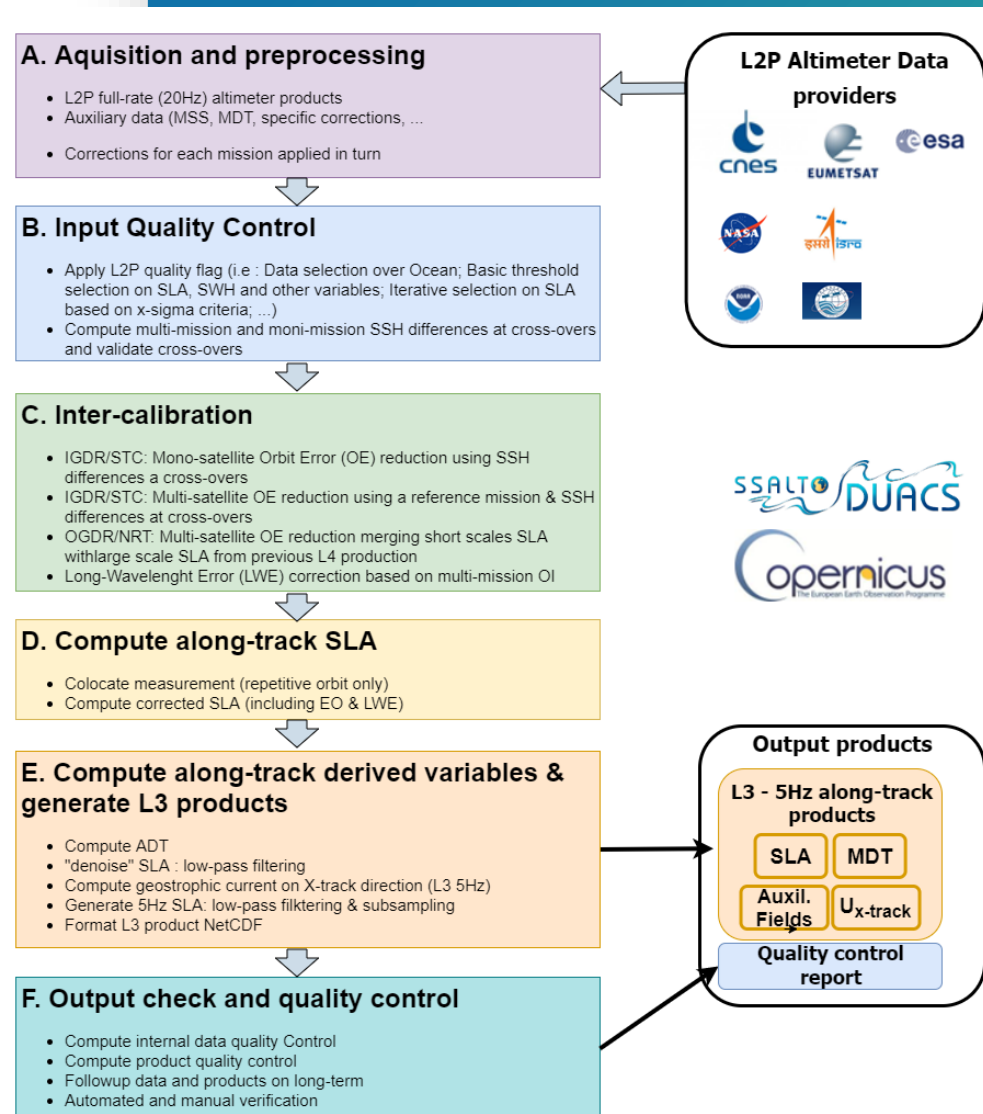
- Observe small-scale signal
- Improve data availability in coastal areas
- Prepare the SWOT era
- Better serve downstream applications :
 - Research activities
 - Regional applications / HR models
 - marine safety
 - biogeochemical activity
 - ...

→ Various nadir altimeter L3 5Hz/20Hz products are available (OP and R&D) and expected in a near future

L3 high resolution (20Hz; 5Hz) products

| Product type | Product Name | Area | Time period | Altimeter missions | Access | Comments |
|---------------|---------------------------|----------------------------------|-----------------------|------------------------|--|--|
| Open Ocean | DUACS-RD V1 | North Atlantic | [2015/01, 2017/04]* | S3A, J3, J2G, C2* | AVISO : DOI 10.24400/527896/a01-2021.003 | 5Hz Obsolete : V2 & V3 versions available |
| | DUACS-RD V2 | North Atlantic | [2016/07, 2018/12]* | S3A, J3, J2G, ALG, C2* | CMEMS : SEALEVEL_ATL_PHY_HR_L3_MY_008_064 AVISO : DOI 10.24400/527896/a01-2021.003 | 5Hz Focus on S3A & J3 recommended: innovative retrackings/corrections used |
| | DUACS-RD V3 | Global | [2016/07, 2021/12]* | S3A, J3, H2B* | AVISO : Expected Q3 2023 CMEMS : TBC | 5Hz Focus on S3A & J3 recommended |
| | CMEMS | Europe | [2022/11, now] | S6A, S3A, S3B, J3* | CMEMS : SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_08_059 (*PT0.2S datasets) | 5Hz based on conventional retracking available in L2 operational products |
| | CMEMS | Global | [2023/11, now] | S6A, S3A, S3B, J3* | CMEMS : Expected Q4 2023 | 5Hz based on conventional retracking available in L2 operational products |
| Sea-Ice leads | DUACS-RD sea-ice leads V1 | Arctic & Antarctic | [2016/06, 2020/07] * | S3A, C2, AL* | AVISO : DOI 10.24400/527896/a01-2020.001 & 10.24400/527896/a01-2022.010 | 5Hz Bias to be corrected for merging with open ocean DUACS production : 9.6cm |
| | DUACS-RD sea-ice leads V2 | Arctic | [mid 2011, mid2021] * | S3A, C2, AL* | AVISO : Expected Q2 2023 CMEMS : TBC | 5Hz |
| Coastal | Coastal V1 | Global (coastal band [0, 500km]) | [2016/03, 2021/08] | J3 | AVISO : Expected Q2 2023 | 20Hz |

L3 5Hz processing overview



Nearly the same processing steps than for conventional L3 1Hz production with some adjustments:

- **Upstream used with 20Hz posting rate** → Sea level measurement processed in 20Hz up to the end of the processing.
- Use up-to-date altimeter **standards and corrections able to reduce the measurement noise** (quite high on raw 20Hz measurements !)

Copernicus Marine Service prod :

- High Frequency Adjustment (Zaron et al, 2016; Tran et al, 2020)

R&D prod :

- SAR : LR-RMC processing (Moreau et al, 2020)
- LRM : Adaptive processing (Thibaut et al, 2017)
- All: up-to-date SSB (3D version when available ; Tran 2020); High Frequency Adjustment (Zaron et al, 2016; Tran et al, 2020)

Some **key parameters updated specifically on the 20Hz posting rate** when possible (MSS (or Mean profile if available), SSB, ...)

- Quality control criteria fitted on the 20Hz posting rate. Still under progress.
- Colocation strategy : **process data on its true location**; collocated positions (using nearest theoretical position) provided.
- **Low-pass SLA filtering** to remove short wavelength dominated by noises.
 - cut-off variable from one altimeter to the other to fit the different observing capabilities
- Geostrophic current estimation (on X-track direction) using "sla_filtered" variable as upstream
- **5Hz subsampling applied at final processing step**

Some validation results

L3 5Hz are compared with L3 1Hz altimeter products :

- Higher data availability in coastal areas with L3 5Hz data compared to L3 1Hz : 80% data availability up to ~5km from the coast (~10km for L3 1Hz) and no significant degradation of the SLA variance when approaching the coast compared to L3 1Hz except in some areas (see next slide).

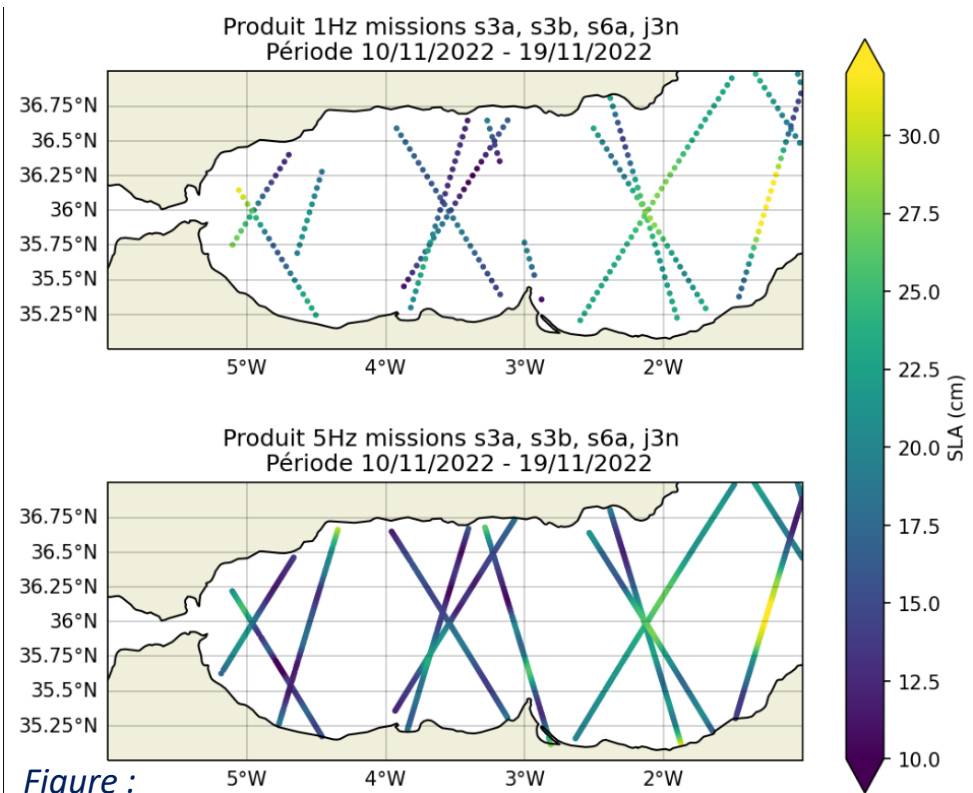


Figure : Example of L3 1Hz and 5Hz altimeter measurement in Alboran Sea

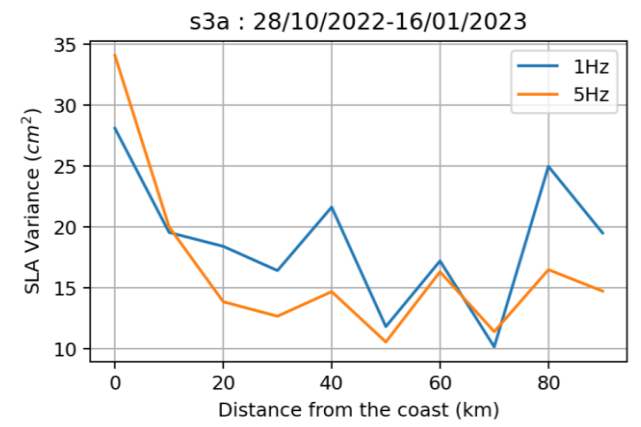
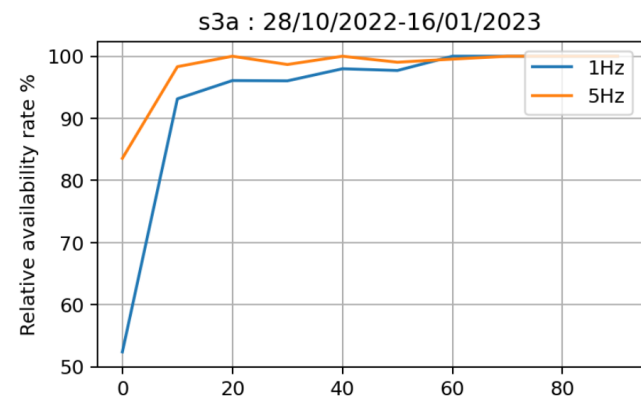
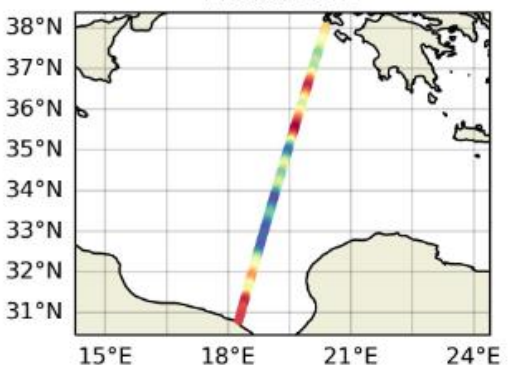


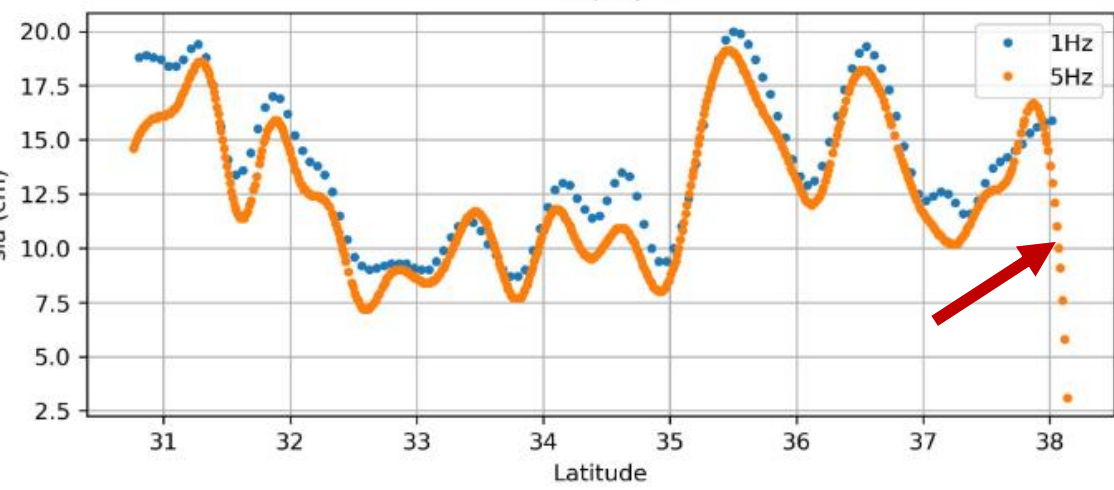
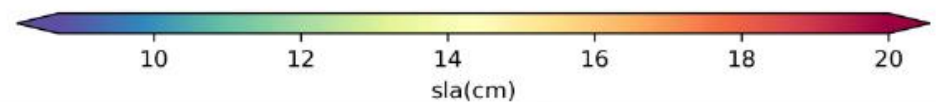
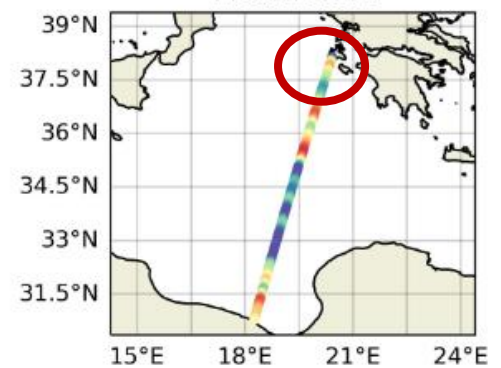
Figure : Data availability rate and SLA variance near the northern Spanish coast (Unit: % of theoretical expected measurements; cm²)

Coastal anomalies

S3A 1Hz



S3A 5Hz



L3 5Hz are compared with L3 1Hz altimeter products :

- Some anomalies observed near the coast :
 - Mainly explained by the reduced quality of the gridded MSS near the coast (CNES-CLS-2015 model used in L3 5Hz production; specific Men Profile used in L3 1Hz)
 - Visible in specific locations/tracks
- ➔ Will be improved with the next generation of MSS (CNES-CLS-2022) : change expected early 2024 for CMEMS NRT production

Some validation results

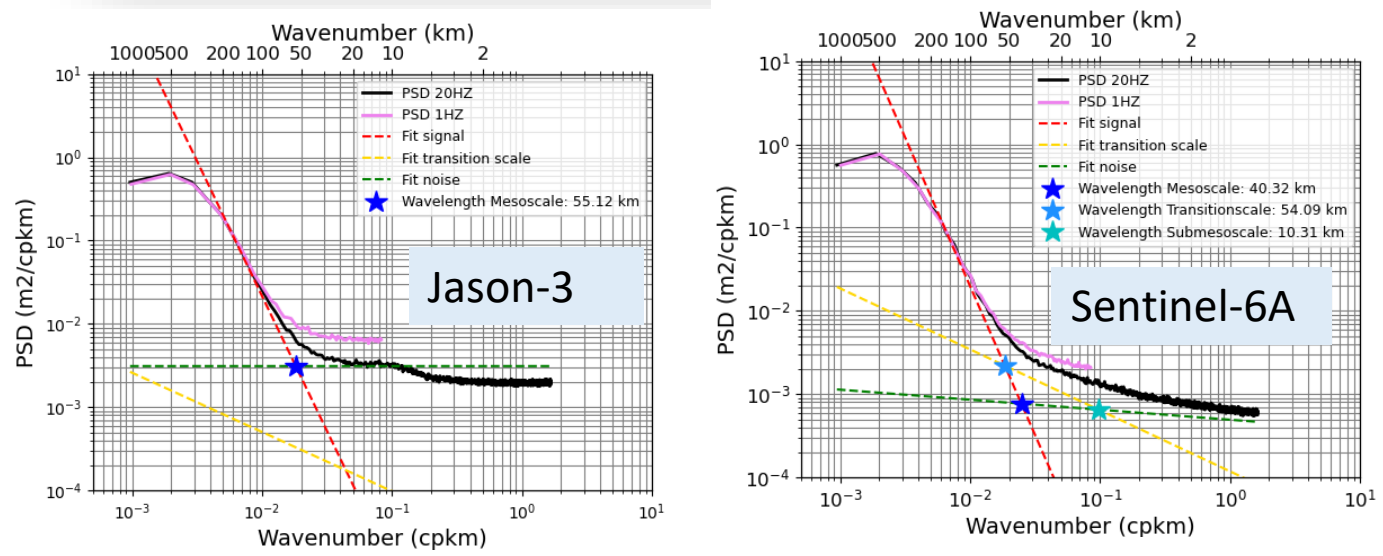


Fig: PSD of the SLA observed with the upstream L2P 1 Hz conventional altimeter measurement (pink) and with the full-rate (20 Hz) measurement (black) over the North-East Atlantic area, over the [April, June 2022] period.

Mesoscale observing capability (OWL) extracted from spectral component using Vergara (2022) methodology:

- Mesoscale signal (balanced motion)
- Small-mesoscale signal (mix bwn balanced/unbalanced motion & measurement errors)
- Noise : white for LRM (J3) & or red colored for SAR (S3 & S6)

OWL : WL where Mesoscale signal = Noise signal

SLA 20Hz PSD presents lower energy than 1Hz PSD at small wavelenghts :

→ improved precision of the 20Hz measurement with proportionally reduced noise vs 1Hz. (Rq: 20Hz(5Hz) noise expected 20x(5x) the 1Hz noise without specific processing = same spectral amplitude)

→ Part of the small-mesoscale signal is now accessible with conventional SAR measurement (e.g. S6A); it remains masked by residual spectral hump in LRM (e.g. J3). Content of this small-wavelength signal still under investigation (physical signal ; errors)

| | Sentinel-6A HR | Sentinel-3A/B | Jason-3 |
|--|----------------|---------------|---------|
| OWL in the North-Eastern Atlantic Area (km) with 20Hz or 5Hz products. ([Apr., Jun. 2022]) | 40 | 48 | 55 |
| Improvement vs OWL deduced from 1Hz LRM (65km; Vergara et al, 2019) | -38% | -26% | -15% |

Example of application

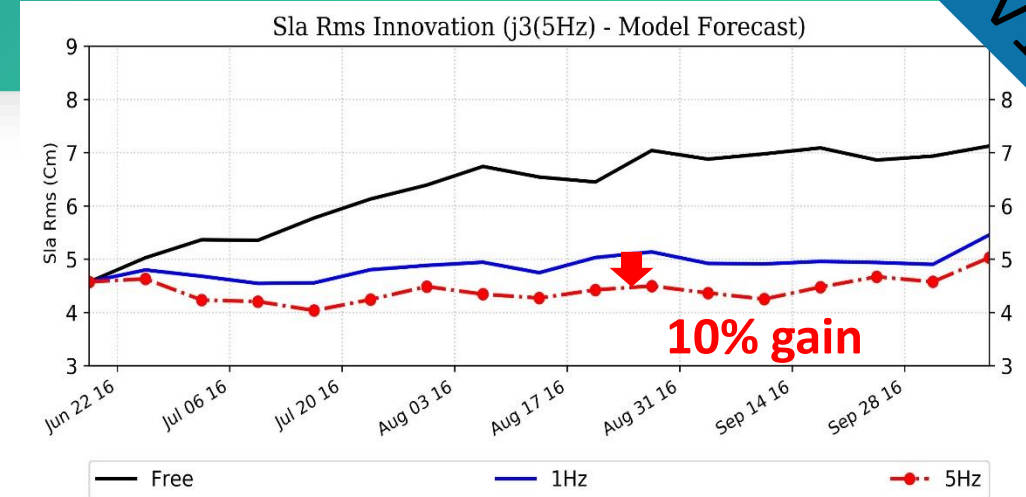
Samples V1

Courtesy of Mounir Benkiram (MOi)

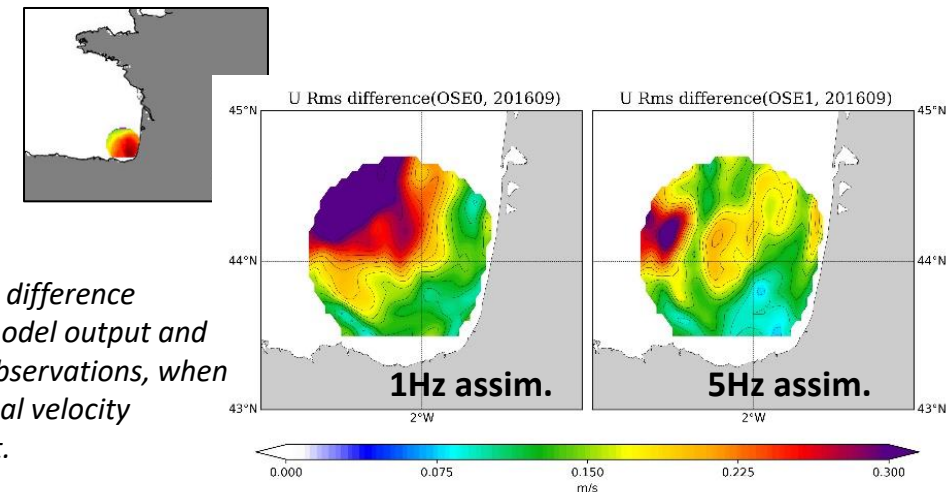
Test impact of the 5Hz altimeter products (V1 samples) assimilation into the CMEMS IBI model with 1/36° spatial resolution :

➔ the high-resolution products significantly improve the model performances:

- Higher resolution SLA assimilation impact at mesoscales ➔ visible on SLA increments
- Model SSH forecast improved ➔ better consistency between model forecast and observations: 10% gain
- Positive impact on other variables ➔ modeled SST better in accordant with observations when assimilation 5Hz altimeter products rather than 1Hz
- Better consistency between model output and independent measurement



SLA innovation temporal evolution (difference between observation and model forecast) for model free run (black) and model assimilated with 1Hz (blue) or 5Hz (red) altimeter measurement



RMS of the difference between model output and HF radar observations, when model. Zonal velocity component.

Some validation results

L3 5Hz are compared with L3 1Hz altimeter products :

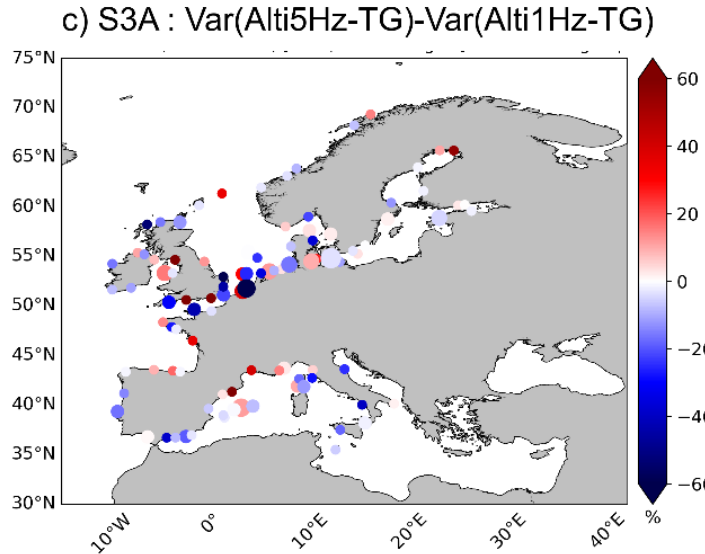
L3 5hz Product defined close to the coasts

| | L3 1Hz | L3 5Hz |
|-----|--------|--------|
| S3A | 10 km | 5 km |
| J3 | 11 km | 6 km |

Mean distance of the nearest point to the coast for which the sampling rate reaches at least 80% of the maximum number of cycles defined for the period between mid-2016 to the end of 2018. Results obtained with L3 1Hz & 5Hz products, for S3A and J3.

*Pujol et al, Remote Sensing 2023.
<https://www.mdpi.com/2072-4292/15/3/793>*

Improved consistency with TG measurements



- Higher Alti-TG data pair to compare when L3 5Hz altimeter product is used : ~9% with S3A; ~6% with J3
- Reduction of the variance of the differences between altimetry and TG when L3 5Hz altimeter product is used : -5% with S3A; -17% with J3

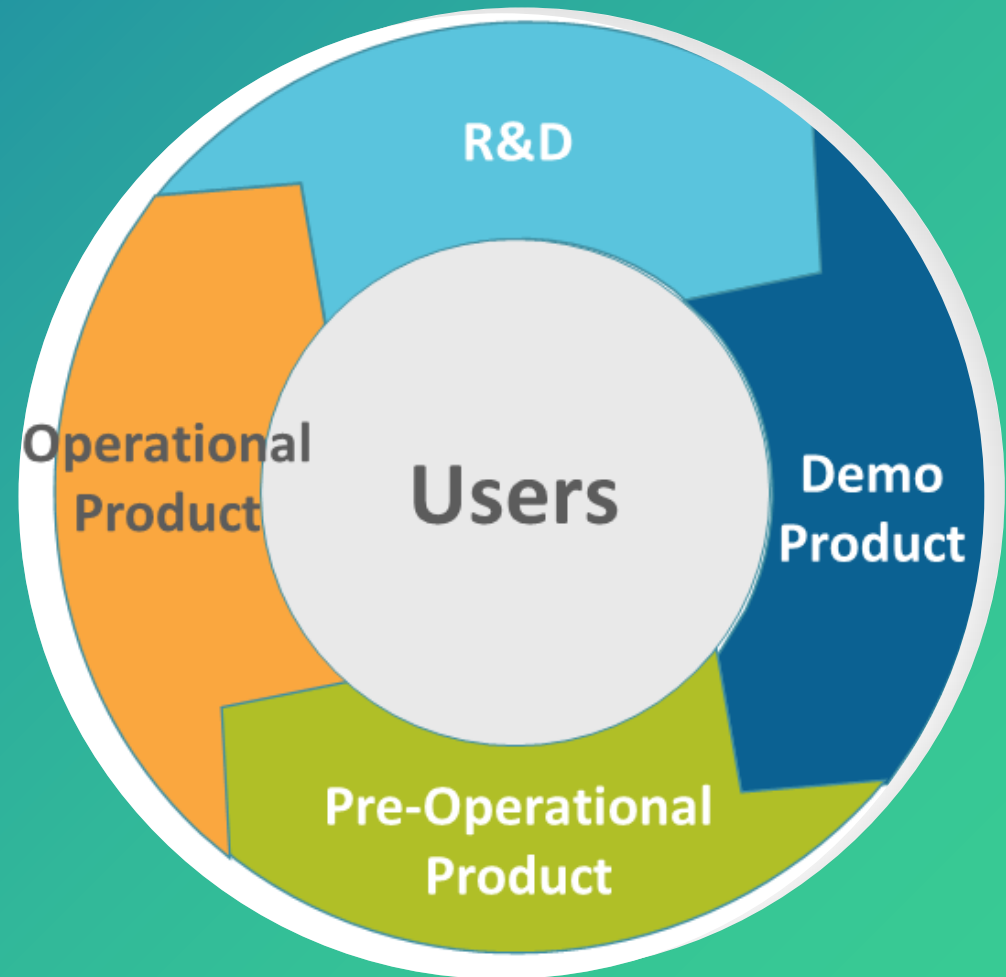
Figure : Reduction of the variance of the differences between S3A altimeter measurements and TG SLA signal when the L3 5Hz altimeter product is used rather than the L3 1Hz. (Unit: % of the variance of the TG signal).

Conclusions

Various operational and R&D new “high resolution” nadir L3 sea level altimetry products exist.

Do not hesitate to test these products and give your feedback !

- Necessary to ensure possible transfer from R&D to operational production
- Useful to improve the product quality and content for your applications
 - Open Ocean DUACS-RD : specific google form <https://forms.gle/rJoxGHbENR8NEMzM9>
 - Other products : contact mpujol@groupcls.com



Thanks for your attention