Toward Higher resolution Level-3 altimeter Sea Level products

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Since few years, efforts are done in order to improve the altimeter measurement in open ocean and coastal area. A new generation of along-track products is under development with support from CNES (DUACS-RD project) and ESA (EO4SIBS project). They consist in along-track sea level products delivered with a 5Hz (~1km) sampling.

Processing overview

Nearly same processing than conventional L3 1Hz with few differences:

- **Use upstream 20Hz** (~350m) instead of 1Hz (~7km) → the 5Hz subsampling is done as last step of the processing
- **merge recent developments** that enable to optimize the Sentinel3 SAR altimeter processing (i.e. LR-RMC processing; and the Jason-3 noise level (i.e. Adaptive processing and High Frequency Adjustment correction; Thibaut 2021, Tran 2021)
  - S3A: LR-RMC CNES experimental processing (Boy 2017, Moreau,2018) : reduce red noise usually observed on conventional SAR processing (induced by effects of the sea-surface state) (Fig 1, left)
  - J3 : Adaptive processing (Thibaut 2021) coupled with coherent SSB and High Frequency Adjustment correction (Tran, 2019) : significantly reduce the measurement noise and spectral hump. (Fig 1, right)
- Use **valid/invalid data selection** consistent with the 20Hz upstream sampling
- Includes **estimation of the geostrophic currents** in the across-track direction
- Low pass filter the SLA before subsampling at 5Hz: Cut-off frequency variable from an altimeter to the other

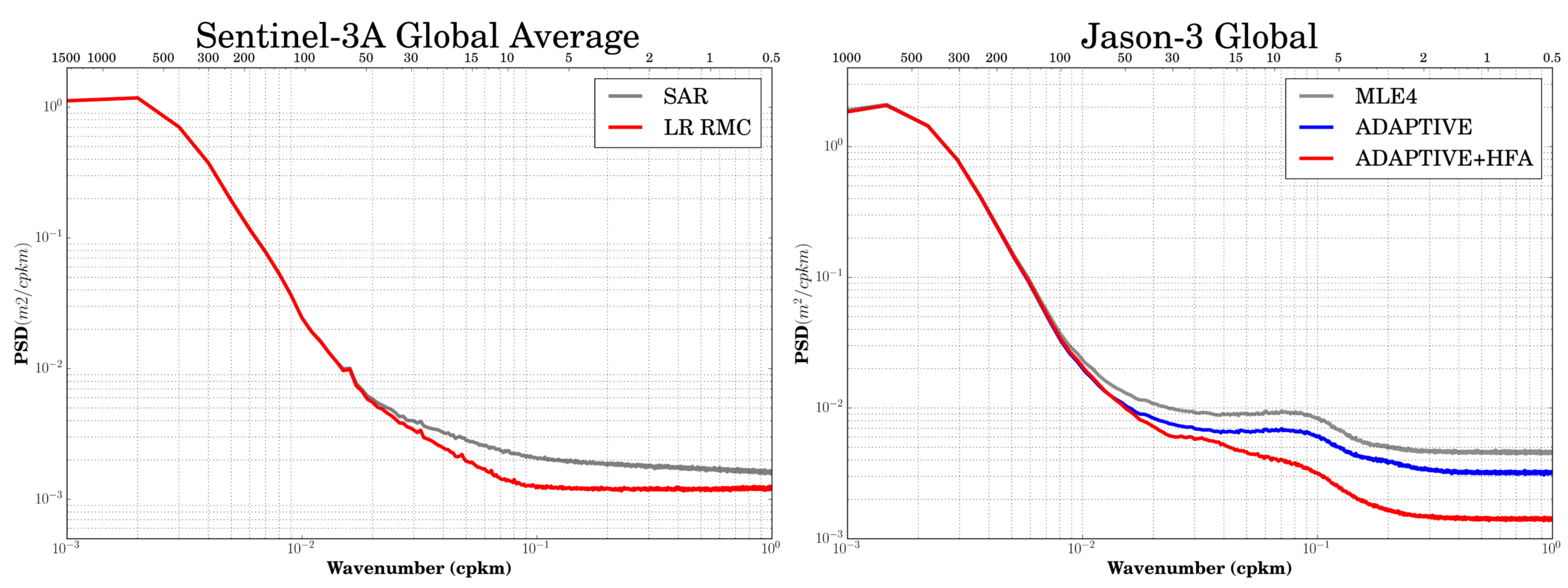

Fig 1 : Power spectral density of the SLA along S3A (left) and J3 (right) tracks estimated using different processes. For S3A, conventional SAR (grey) and new LR-RMC (red) processors are presented. For J3, conventional MLE4 (grey), new adaptive (including revised SSB; blue) and new adaptive combined with HFA correction (red) processors

L3 5Hz quality overview

Validation results show that the L3 5Hz product allows:

- **A better sampling the coastal areas**, without significant degradation of the signal : it is defined up to ~5 km against ~10 km for the 1Hz version (Fig1).
- **An improved consistency with Tide Gauges**:
  - Higher number (~+45%) of TGs selected for comparison with L3 5Hz compared with L3 1Hz (selection criteria based on max correlation threshold and temporal length of the comparable series)
  - Reduction of the variance of the differences with TGs when using L3 5Hz rather than L3 1Hz : -5% reduction for S3A, -17% for J3. (Fig 2)
- **An enhanced observability at mesoscale**
  - observable wavelengths up to ~35 km with S3A and ~55 km with Jason-3 in the North Atlantic area i.e. reduced by up to one third, or up to half compared to the conventional L3 1Hz.
  - observable wavelengths up to ~25 km with S3A and 30km with Cryosat-2 in the Black Sea i.e. 15 to 20 km better than the conventional L3 1Hz product
- **A refined sea level spectral content**: S3A 20Hz upstream signal underscores a small-mesoscale slope consistent with the unbalanced motion theory, in terms of slope, transition scale with mesoscale signal, spatial and seasonal variability. The content of the measurement at such wavelengths however remains to be better characterized. (Fig. 3, Tab1)

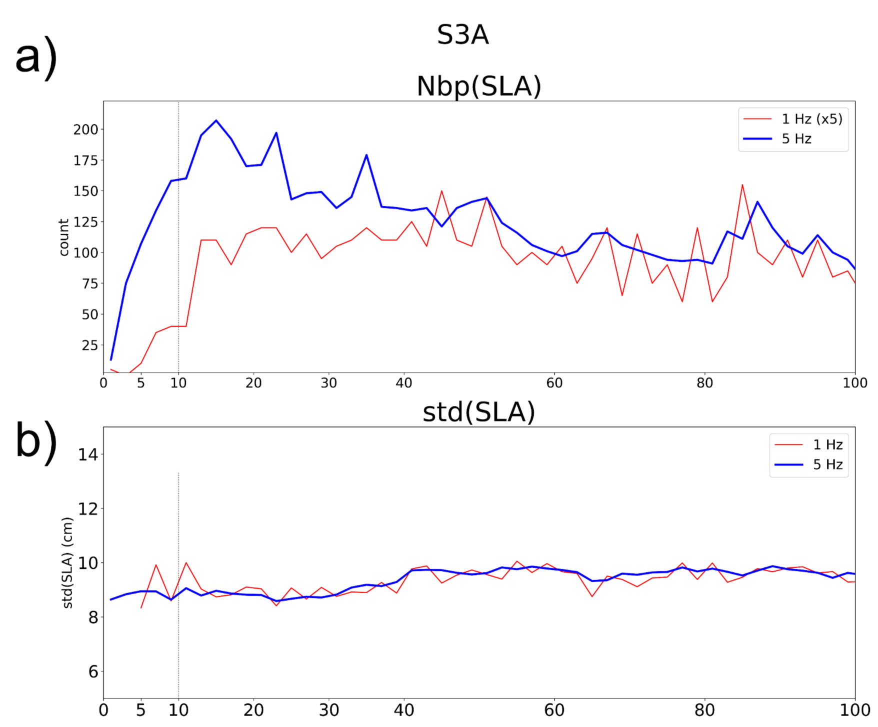

Fig 1 : Number of valid measurements (a) and mean SLA variance (b) as a function of the distance to the coast. Statistics computed on S3A measurements from 1Hz (red line) and 5Hz (blue line) products over the Black Sea area. Only measurement points with a minimal sampling rate of 80% compared to the maximal number of expected cycles are considered. (From Grégoire et al, 2022)

→ The rate of available measurements is significantly higher with the L3 5Hz product when approaching the coast (~twice higher at 15km from the coast).
With L3 5Hz product, the SLA variability remains consistent when approaching the coast.

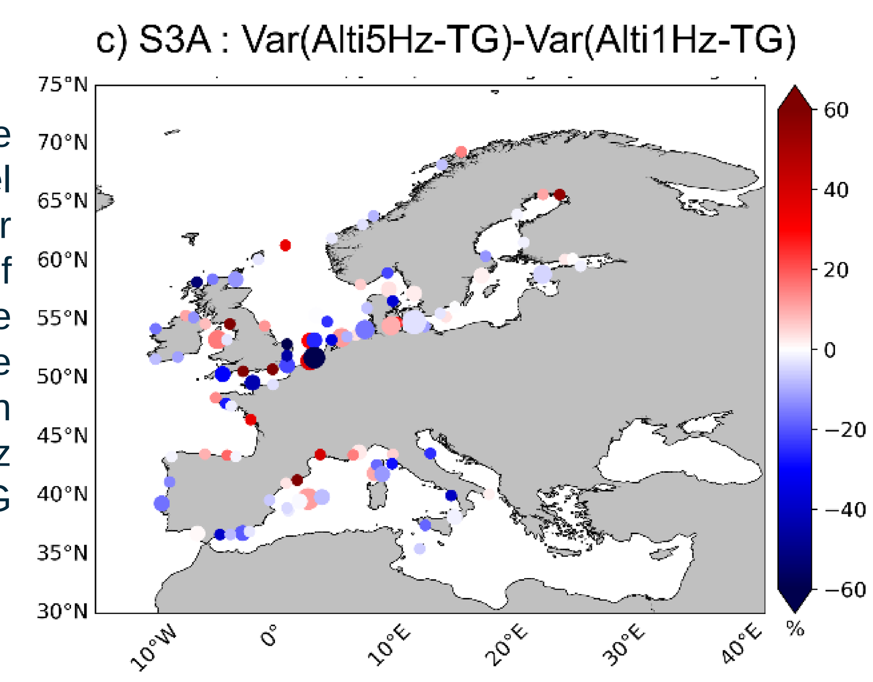

Fig 2: Differences of the Variance of the differences between S3A and TGs sea level signal, when using L3 5Hz and L3 1Hz altimeter measurements. Large dots indicate clusters of neighboring TGs that have been weighted for the computation of global mean statistics. Negative values mean that the SLA differences between altimetry and TGs are lower for the 5Hz products. (Unit: % of the variance of the TG signal). (From Pujol et al, 2022)

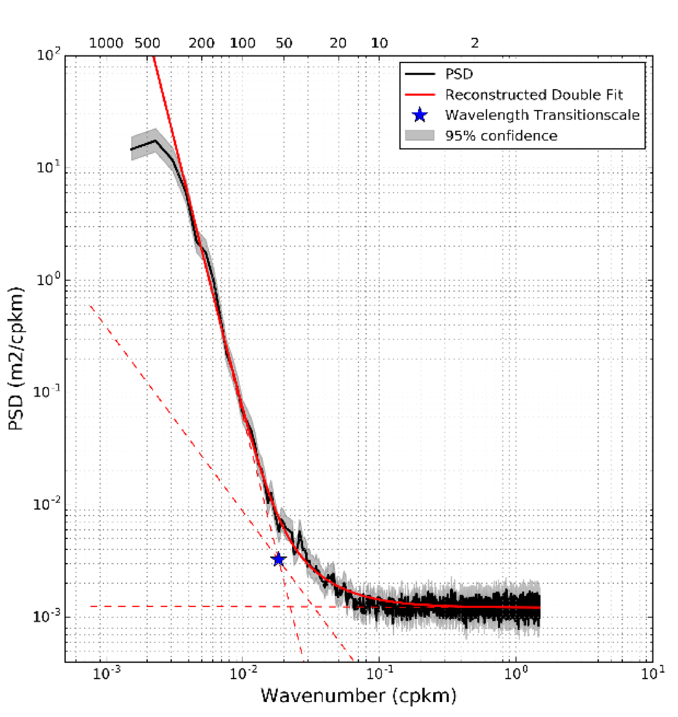

Fig 3: Example of decomposition of the power spectral density of the SLA . The black line shows the true PSD deduced from the signal. The 95% confidence interval is represented by the light grey band centered on the true PSD. The dashed red lines show the 3-slope spectral decomposition. The thick red line shows the theoretical spectrum deduced from the sum of the 3 different slopes. The blue star shows the transition scale (Lt) dividing mesoscale from small-mesoscale motions. (From Pujol et al, 2022)

→ A spectral slope close to the QG (GS) and SQG (NEA) theory; A sub-mesoscale signal consistent with the unbalanced motion theory (spectral slope and amplitude of the signal), with transition scale between mesoscale and sub-mesoscales signal consistent with model observations (e.g. Qui et al, 2018) and showing expected seasonal variability.

Tab 1: spectral decomposition parameters obtained with S3A (20Hz) over the Gulf Stream and North-East Atlantic areas. Annual and seasonal (FMA, ASO) values are given (From Pujol et al, 2022)

	Gulf Steam [42, 66° W] [33, 45° N]			North East Atlantic [10, 34° W] [35, 47° N]		
	Full year	FMA	ASO	Full year	FMA	ASO
Mesoscale slope	-4.93 +/- 0.08	-4.89 +/- 0.23	-5.03 +/- 0.13	-4.3 +/- 0.19	-3.83 +/- 0.45	-4.74 +/- 0.37
Sub-mesoscale slope	-1.41 +/- 0.17	-1.64 +/- 0.46	-1.32 +/- 0.22	-1.42 +/- 0.12	-1.37 +/- 0.48	-1.49 +/- 0.14
Lt (km)	53.61 +/- 7.36	54.76 +/- 23.29	59.07 +/- 11.19	98.16 +/- 21.24	74.06 +/- 55.94	121.35 +/- 38.38

Example of application : coastal current observation

Western Mediterranean Northern current

The 5Hz product's enhanced ability in resolving narrow current veins located close to the coast (eg Fig 4). The seasonal variability corresponds quite well to the mean tendency, with an intense stream during the winter months (up to 0.8 m/s in OND) and less intense during the spring and summer, (r ~0.5 m/s in AMJ). Additionally, the current is shifted slightly further from the coast during this last season.

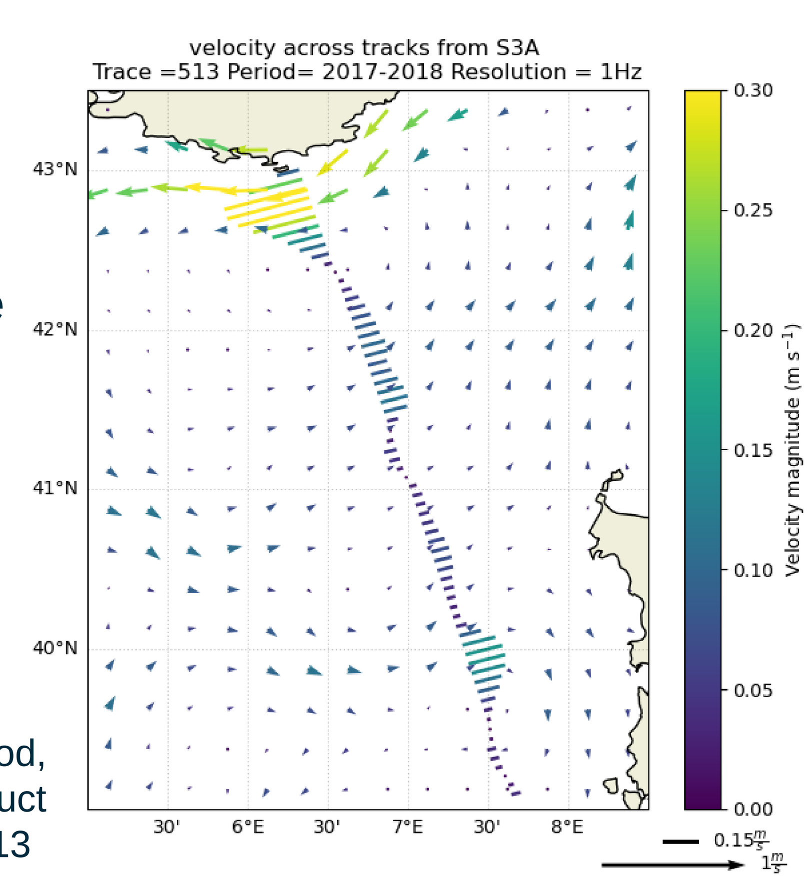

Fig 4: Mean geostrophic currents over the [2017, 2018] period, deduced from DUACS gridded (L4) altimeter product (background) and L3 5Hz product along Sentinel-3A track #513

Perspectives

- **Products samples already available :**
  - DUACS-RD V1 & V2 (North Atlantic area) on https://www.aviso.altimetry.fr/duacs & https://marine.copernicus.eu/
  - EO4SIBS (Black Sea) on http://www.eo4sibs.uliege.be/
- **Future samples expected in 2023**
  - DUACS-RD V3 (Global Ocean): baseline for future recommendation for operational production
- **Operational production expected end 2022 in Copernicus Marine Service:**
  - based on conventional SAR and LRM processing, with specific HFA correction for measurement noise reduction; use up-to date altimeter standards available and part of the processing from R&D outcome.
  - Future evolutions expected (2023 e/o 2024) to use recommended processing & corrections aiming to reduce errors at short wavelengths.

References:

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