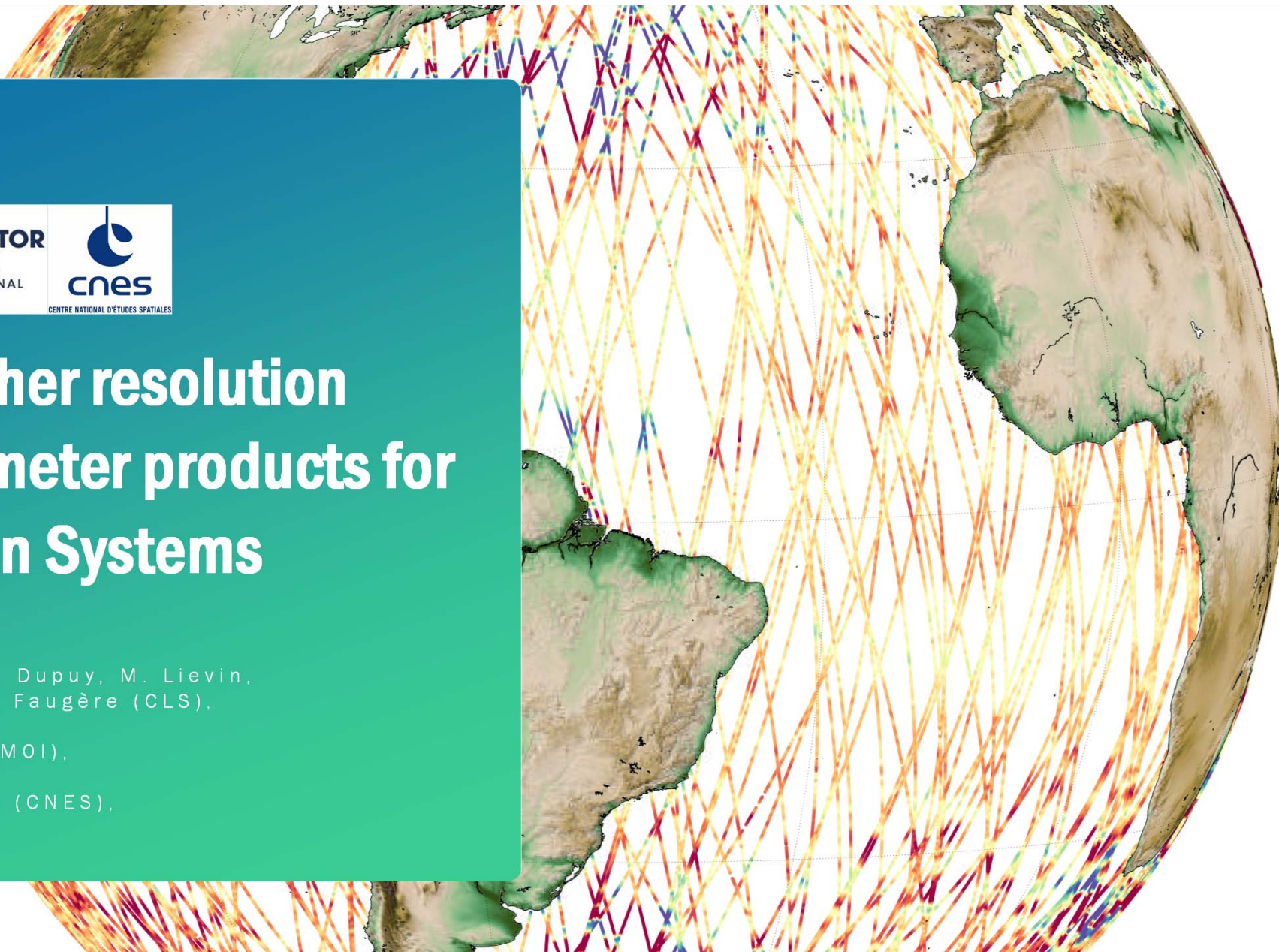# Toward Higher resolution Level3 altimeter products for Assimilation Systems

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Overview

- Why working on L3 products with higher resolution

- First version of along-track L3 products delivered with 5Hz resolution
  - overview of the products
  - example of application

- New V2 samples in preparation
  - overview of the products

Introduction

Why develop a along-track L3 altimeter product with higher resolution than the current 1Hz products ?
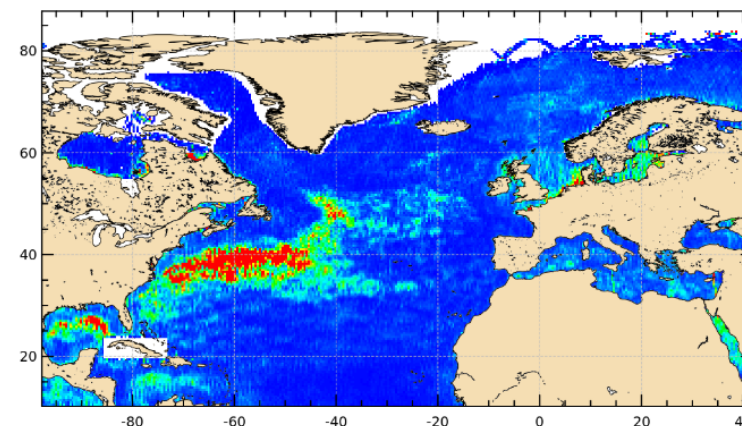
- Answer the users need & Copernicus Marine Service (CMEMS) requirement:
  - Toward higher resolution model in open ocean and coastal areas: model resolution increased by a factor 3 or more in the post 2025 period.

    → need higher resolution altimeter products to constraint them (P-Y Le Traon, OceanPredict 2019)

  - Downstream applications:
    - marine safety: search & rescue; marine transport, pollution monitoring, offshore operations
    - biogeochemical activity : fish egg and larvae drift
    - Research activities: access the finer scales to better understand the ocean dynamic

L3 5Hz samples v1

Mission		Start date L3	End date L3
Jason-2	J2	2015-01-01	2016-02-29
Cryosat 2	C2	2015-01-01	2015-12-31
Altika	AL	2015-01-01	2017-02-03
Jason-3	J3	2016-03-28	2017-03-29
Sentinel-3A	S3A	2016-04-06	2017-04-17

- Delayed Time L3 along-track products

- Defined over the North Atlantic Area, including Med and Black Sea

- 5 Hz sampling: good compromise between observing capabilities and sampling needs

- Altimeter standards and corrections homogeneous with contemporaneous 1Hz products + noise reduction processing (derived from Zaron et DeCarvalho. [2016] methodology) applied on LRM measurements

- Different physical variables available:
  - Access to essential geophysical corrections currently removed from altimeter measurement and that can be used to change the physical content of the SLA
  - Estimation of across-track geostrophic currents

North Atlantic:
Latitudes (min/max) -> 10° North / 88° North
Longitudes (min/max) -> 98° West / 42° East

L3 5Hz samples v1

SLA low pass filtered in order to reduce noise measurement:

- Methodology based on the SLA spectral content analysis over the Europe area
- 20Hz noise used for SAR measurement and reduced 1Hz bump measurement
- Different cut-off wavelength applied according to the altimeter considered

	North Atlantic Area
AL	30 km
S3	30 km
J3	35 km
C2	35 km
J2	35 km

Cut-off wavelengths used for 5Hz V1 processing

➔ Cut-off wavelength defined for Sentiel-3A consistent with independent study (Heslop et al, 2017):

> 30 km low-pass filter for the Sentinel-3A data was sufficient to remove the high-frequency noise while still providing a more accurate view of the mesoscale features in the WMED than previously possible

**Across-track absolute Geostrophic Velocity along S3 track**
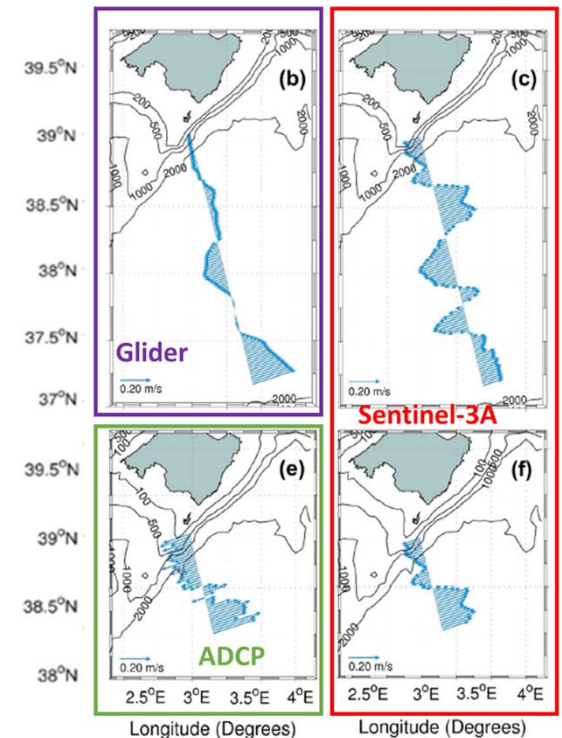
Example of application

Test impact of the 5Hz altimeter products 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: 20% gain

- Positive impact on other variables ➔ modelized SST better in accordant with observations when assimilation 5Hz altimeter products rater than 1Hz

- Better consistency between model output and independent measurement
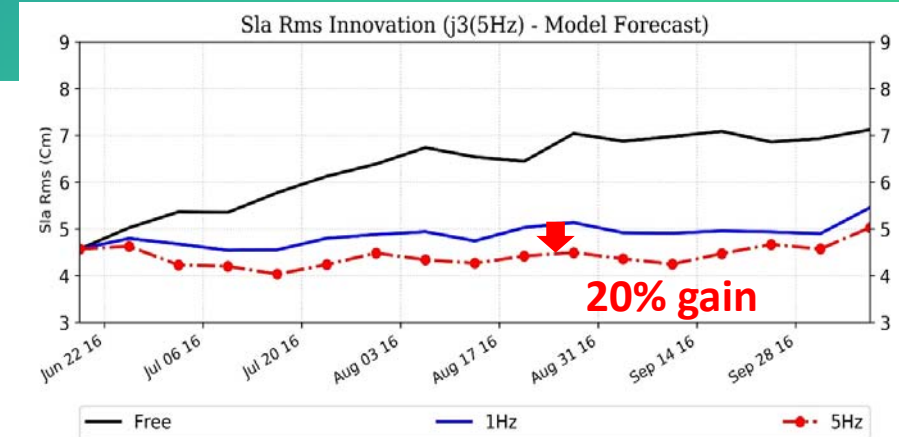
SLA innovation temporal evolution (difference between observation and model forecast) for model free run (black) and model assimilated with 1Hz (blue) or 5Hz (red) altimeter measurement
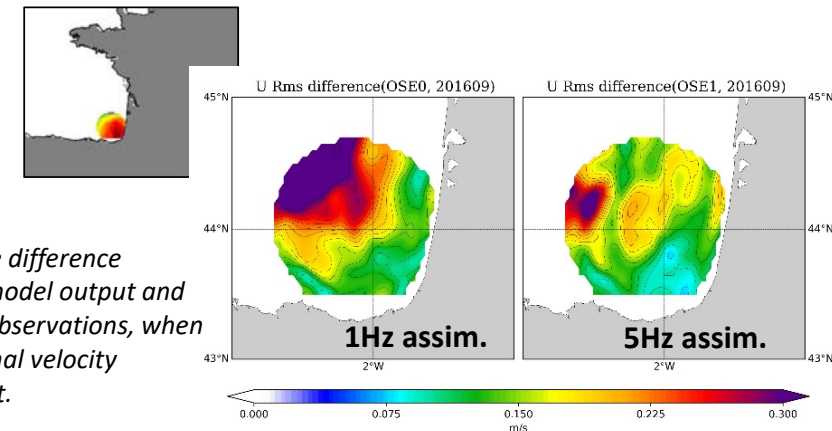
RMS of the difference between model output and HF radar observations, when model. Zonal velocity component.

L3 5Hz samples v2

Objectives:

- Better resolve the small mesoscale structures:

    → use up-to-date geophysical corrections and innovative altimeter processing

- Fix some anomalies detected in the v1 samples, improve the processing:

    → mainly editing anomalies (no tuned editing for ice areas; over editing near the coasts for LRM; …)

- Consolidate the design of the processing for a future operational production.

L3 5Hz samples v2

Use resent progress done in altimeter processing:

- LR-RMC processing (Boy, 2017) that contributes to reduce the swell impact compared to the SAR processing

- Adaptive processing (Thibaut et al, OSTST 2017) that reduces the noise and bump on LRM measurements

- HFA empirical correction (Zaron et DeCarvalho, 2016; Tran, 2019): reduction of the noise measurement signature

- HMP estimation along uncharted tracks (Dibarboure & Pujol, 2019): reduction of the MSS errors at short wavelengths

L3 5Hz samples v2

Up-to-date geophysical corrections:

- 2D SSB [Tran et al, 2019] for Jason

- FES2014b ocean tide solution

- Internal Tide signal [Zaron, 2018] included in geophysical corrections

Altimeter standards used for L3 5Hz samples V2 production.
Differences with V1 samples

|	Sentinel-3A	OSTM/Jason-2	Jason-3	SARAL/AltiKa	Cryosat-2
Orbit	GDR-E				
retracking	LR-RMC (with LUT correction)	Adaptive [Thibaut et al, 2017]	Adaptive [Thibaut et al, 2017]	LRM	SAR & LRM
Noise reduction	-	HFA adaptive [Tran 2019]	HFA adaptive [Tran 2019]	HFA [Tran 2018]	HFA [Tran 2018] (LRM)
Sea State Bias	Non parametric SSB [Tran 2015]	2D SSB [Tran 2019]	2D SSB [Tran 2019]	Non parametric SSB	Non parametric SSB
Ionosphere	Dual-frequency altimeter range measurement	Dual-frequency altimeter range measurement	Dual-frequency altimeter range measurement	GIM [Ijima et al., 1999]	
Wet troposphere	From AMR radiometer	From J3-AMR radiometer Neural Network correction (3 entries), [Fréry et al. in prep]	From J3-AMR radiometer Neural Network correction (3 entries), [Fréry et al. in prep]	Neural Network correction (5 entries) [Picard et al., in prep]	From ECMWF model
Dry troposphere	Model based on ECMWF Gaussian grids				
Combined atmospheric correction	MOG2D High frequencies forced with analysed ECMWF pressure and wind field [Carrere and Lyard, 2003; operational version used, current version is 3.2.0] + inverse barometer Low frequencies				
Ocean tide	FES2014b [Carrère et al., 2015]				
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]				
Pole tide	[DESAI, 2017]				
MSS	HMP_2019	CNES-CLS-2015			
MDT	CNES_CLS18 (including SOCIB Med)				
IW	Zaron 2018 (M2,K1,O1,S2)				

L3 5Hz samples v2

## Refined estimation of the MSS solution along Sentinel-3A tracks (HMP):

– Benefit of the LR-RMC processing to reduce the noise → we expect to better resolve small scales

– Benefit of extended temporal period vs the first version of the HMP

→ HPM errors at WL [100, 15km] : 0,09 cm² (7,5% of the estimated noise free SLA variance)

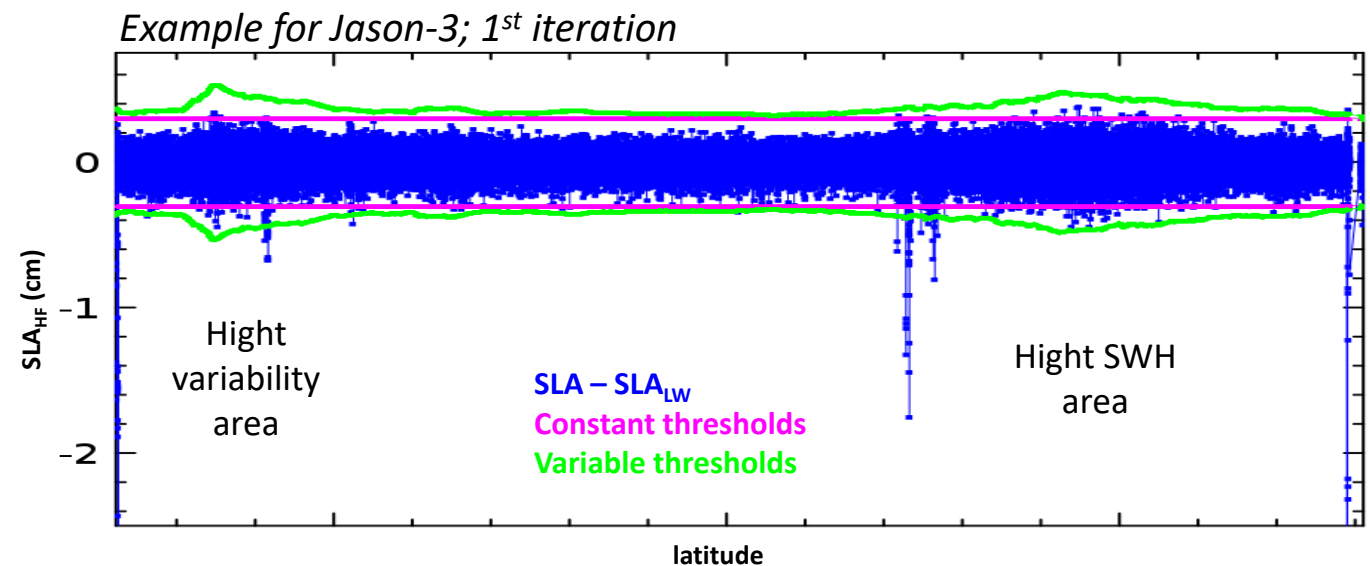Preliminary results → to be consolidated

S3A HPM error at [100, 15km]
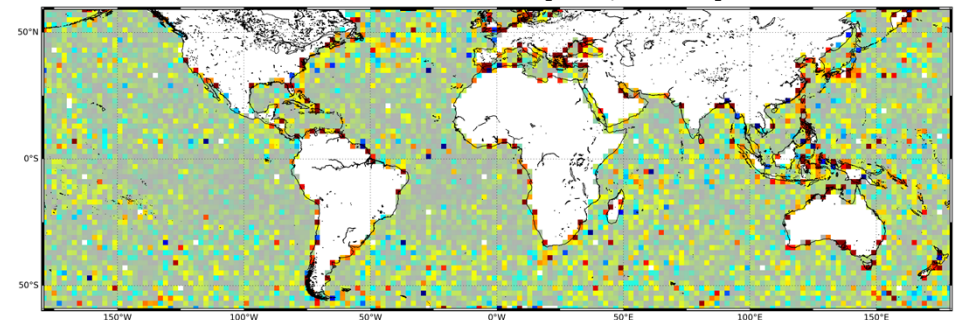
Error reduction vs MSS CNES_CLS15

cm²

−2.0 −1.6 −1.2 −0.8 −0.4 0.0 0.4 0.8 1.2 1.6 2.0
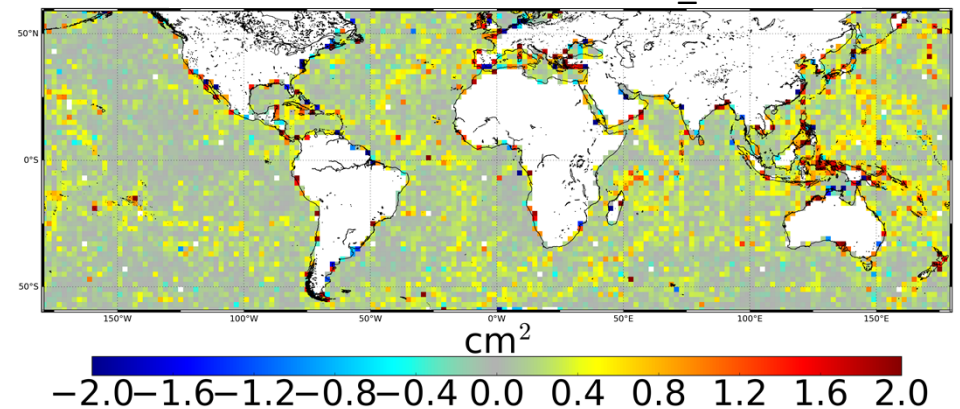
L3 5Hz samples v2

Improved valid data selection:

- Specific selection over ice areas using wave-from classification (Sentinel-3, Jason-3) and OSISAF

- Iterative editing taking into account modulation by high SWH and high ocean variability in thresholds definition
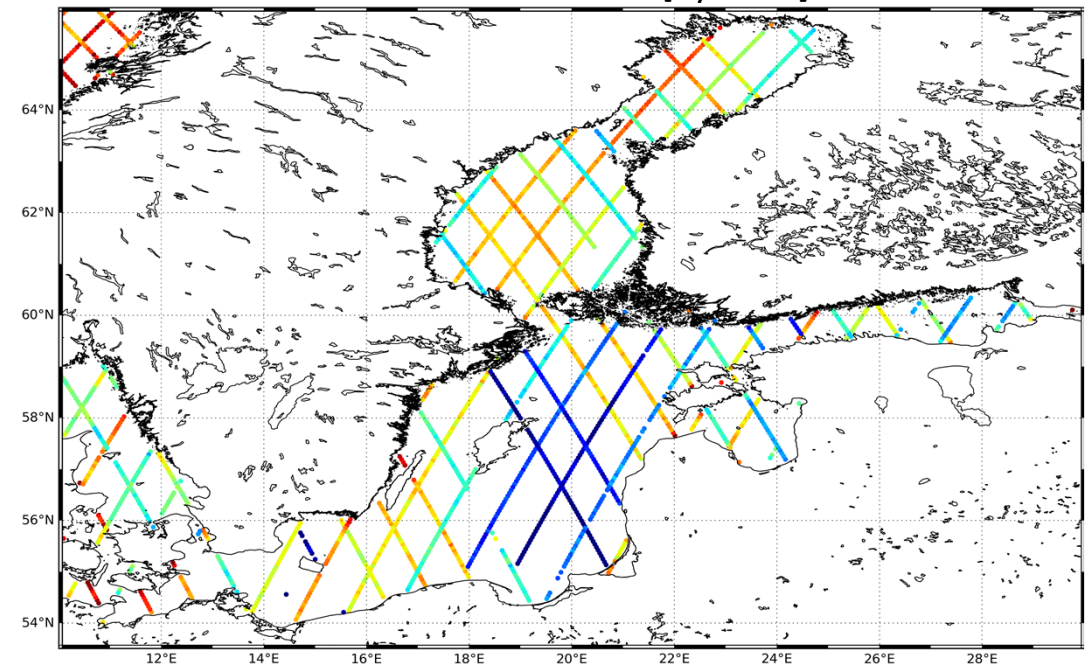

Example for Jason-3; 1st iteration

Hight variability area

Hight SWH area

SLA – SLA_{LW}
Constant thresholds
Variable thresholds

SLA_{HF} (cm)

latitude

L3 5Hz samples v2

Example of 20Hz data selection with Sentinel-3A: Globally better spatial coverage with 20Hz than with 1Hz valid measurements

20Hz valid measurements [Cycle 38]
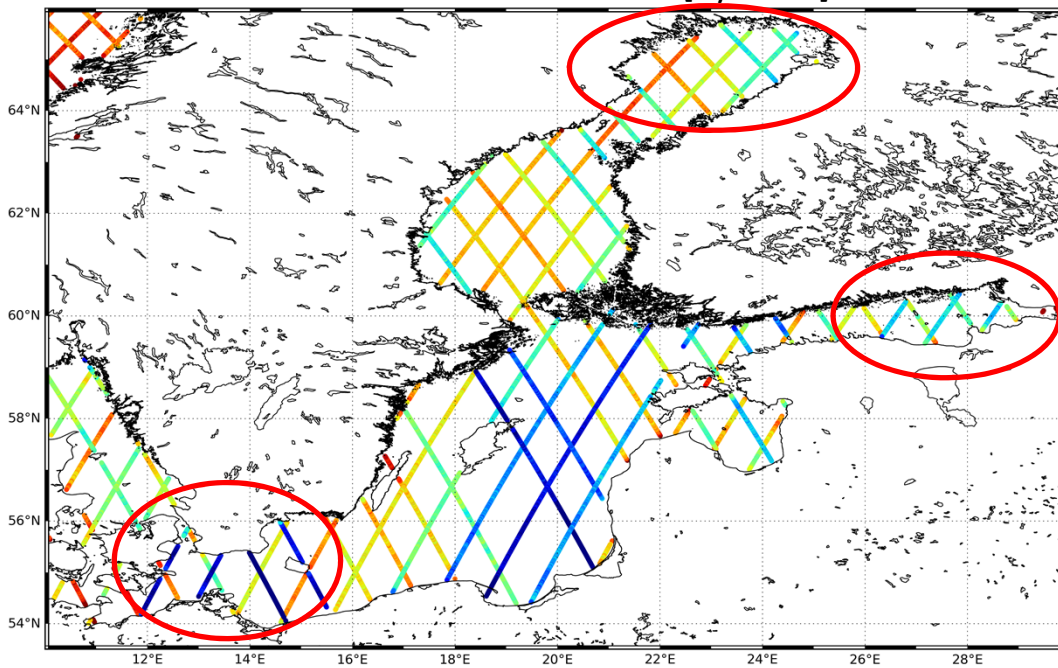
1Hz valid measurements [Cycle 38]
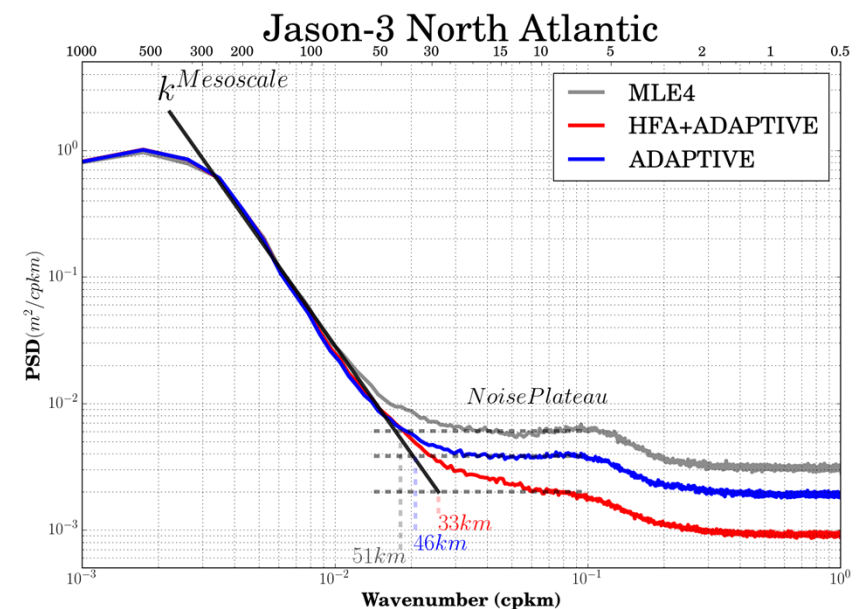
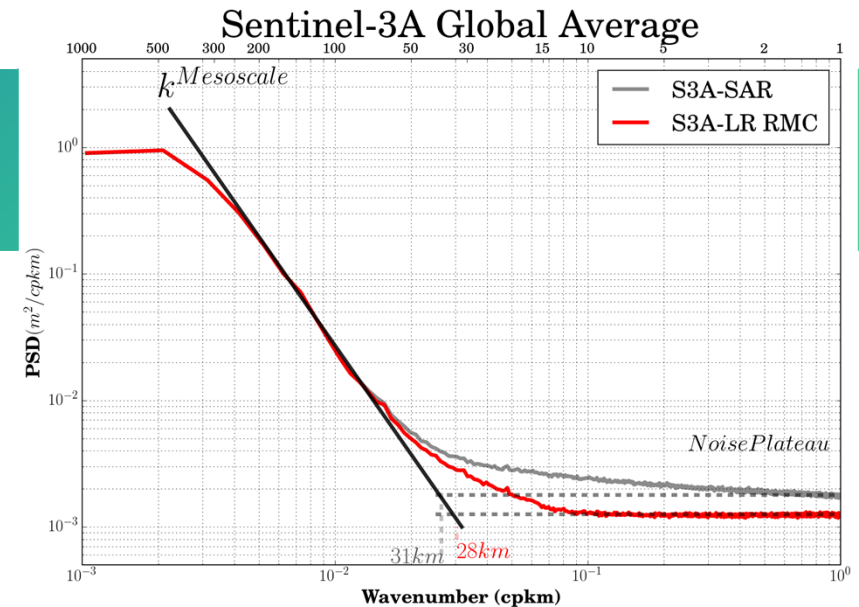# L3 5Hz samples v2

Sentinel-3A LR-RMC benefits:

- Reduced noise measurement
- Reduced swell impact (→ red noise)
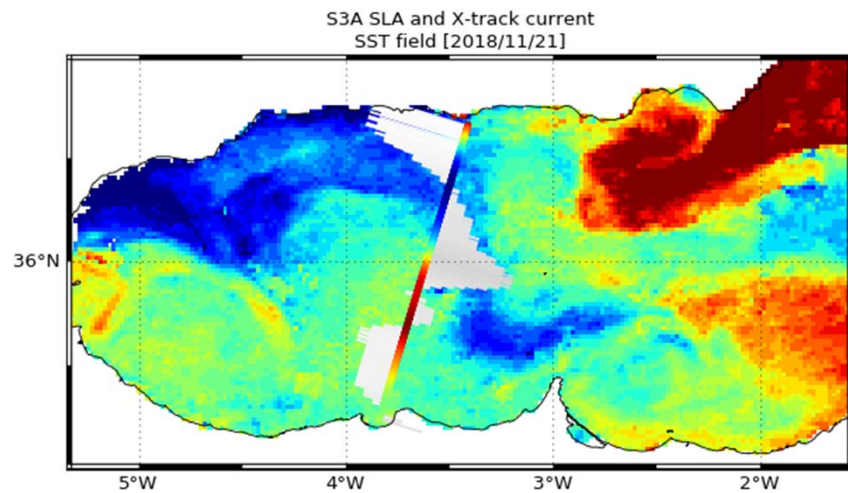
Jason Adaptive + HFA benefits:

- Reduced noise measurement
- Reduced spectral hump

→ we expect to better resolve the smallest scales compared to conventional SAR and LME4 processing: up to ~30km expected
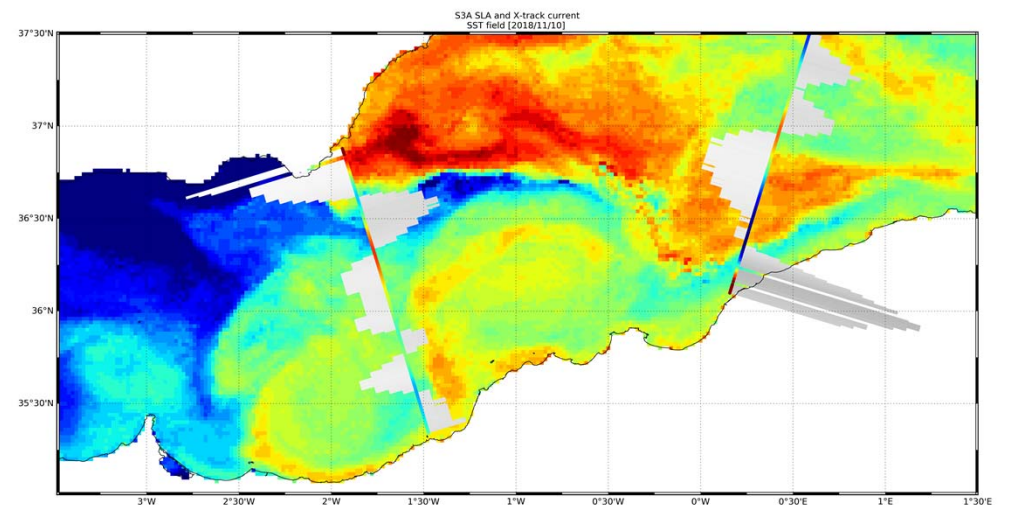
Preliminary results → to be consolidated

L3 5Hz samples v2

S3A SLA and X-track current
SST field [2018/11/21]

Examples of consistency between altimetry
and SST field in November 2018

S3A SLA and X-track current
SST field [2018/11/10]

Preliminary results → to be consolidated

L3 5Hz samples v2

- **Missions**: Jason-3; OSTM/Jason-2, Sentinel-3A, SARAL-DP/AltiKa, Cryosat-2

- **Period** : [Jul. 2016, Dec. 2018]

- **Area:** North Atlantic + Arctic Area (lat > 50°N)

- **Content:** SLA low-pass filtered, essential geophysical corrections (ocean tide, IW, DAC, LWE), across-track geostrophic currents, MDT
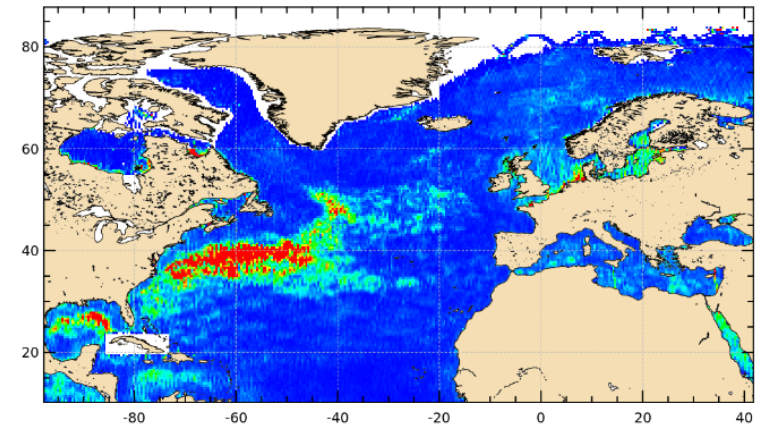
Production Still ongoing
Will be available on AVISO+ hopefully early 2020

conclusions

The need of higher resolution altimeter products goes increasing

- Need to access the finer scales
- Need for assimilation in high resolution models
- Impact for various applications

We are working on the development of a L3 along-track product with 5Hz (~1,3km) sampling:

- first version of samples already available on AVISO+
- second version including improved processing soon available

➔ The transition toward an operational production is foreseen in the coming years

Thanks for your attention