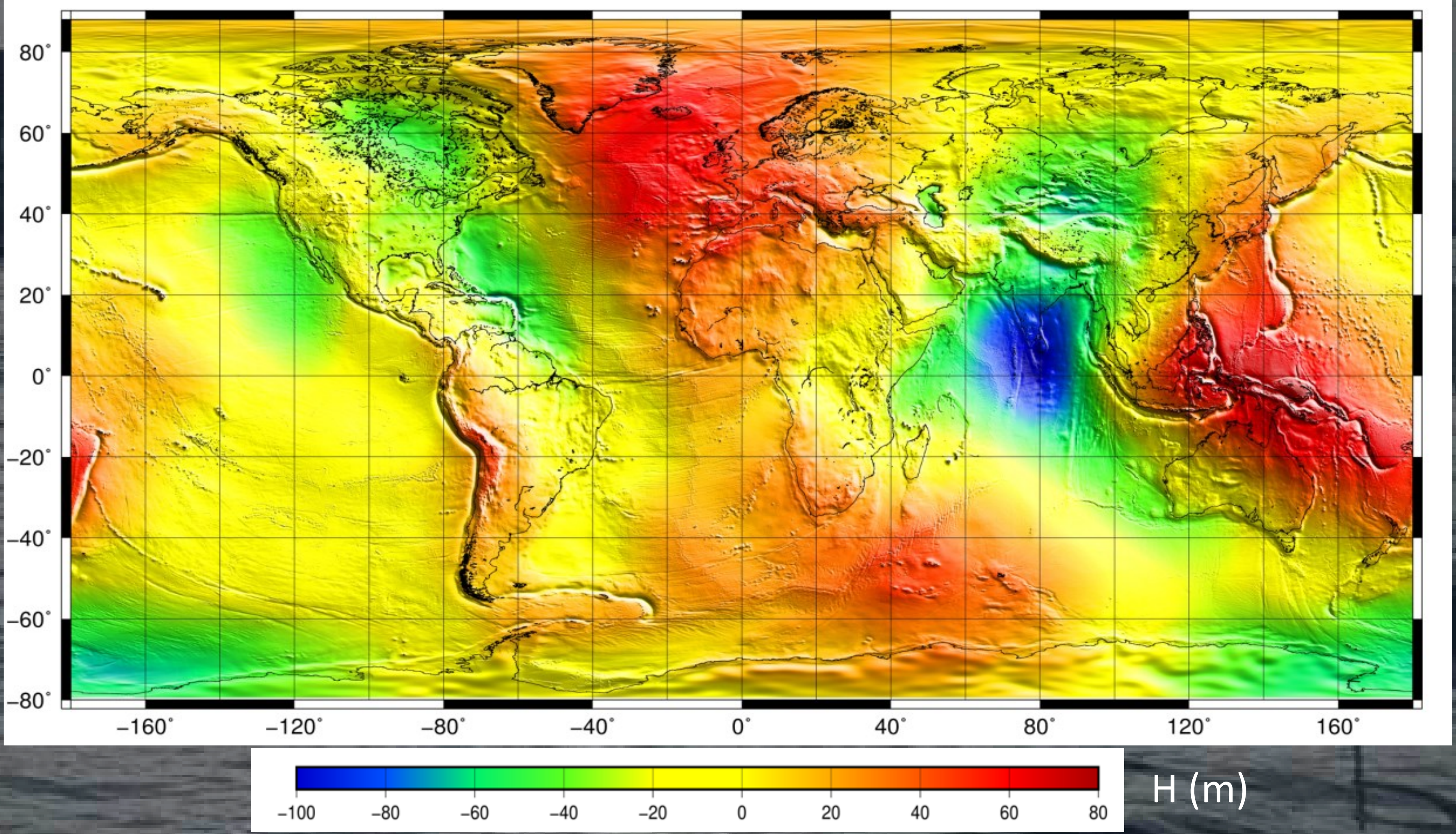
MSS CNES_CLS 2022

CLS : P Schaeffer, M Pujol, Y Faugere, P Veillard
CELAD : Q Dagneaux
CNES: G Dibarboure, N Picot



- Completed with EIGEN 6C4 over continent

- Removing the oceanic variability
- Improving the shortest wavelengths
- Comparisons / Validation

MSS CNES CLS 2022 characteristics

Mean Profiles => ERM Missions (1 Hz)
(TP/J1/J2/J3 (& interleave), E2/En/Aka, GFO)

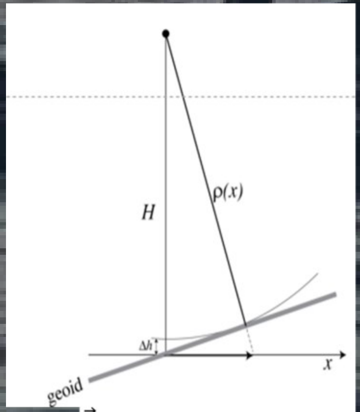
HR Data
Integration of: C2(20Hz) + AltiKa(40Hz): **one pass RTK + 5Hz filtering (~6 Billion of data)**
S3(20Hz)+ C2(20Hz)+AltiKa(40Hz) => LEADS for Arctic area

Observation
SSH – MSLA DUACS (Oceanic Variability)

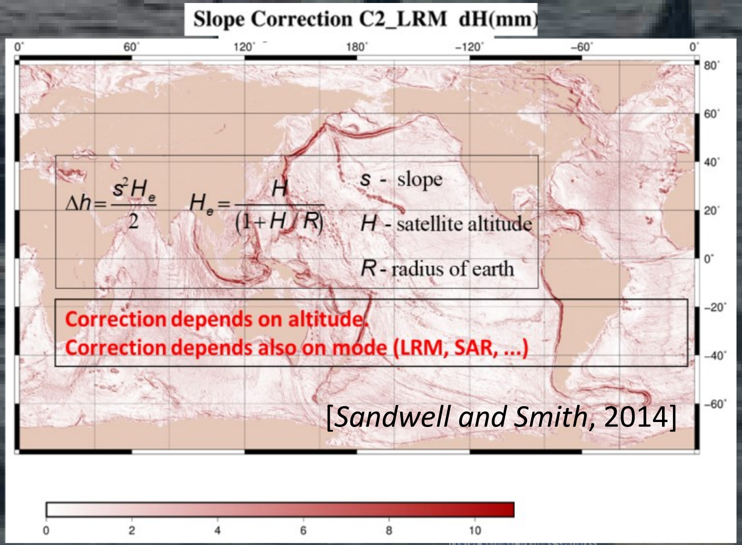
Mapping (1 min grid)
Optimal interpolation + noises budget (white & correlated) + optimal filtering

➢ **MSS must be corrected for the slope effect**

- New MSS will result from a combination of **various altimeter (LRM, SAR, KaRIn)** that are not affected in the same way by the slope of the sea surface.



$\vec{x}$: in direction of the maximum slope (from nadir)



SSH – MSLA DUACS : the treatment of the oceanic variability

- **Correct each observation for oceanic variability by space-time interpolation of SLA (Map of SLA DUACS = 1 map /day)**

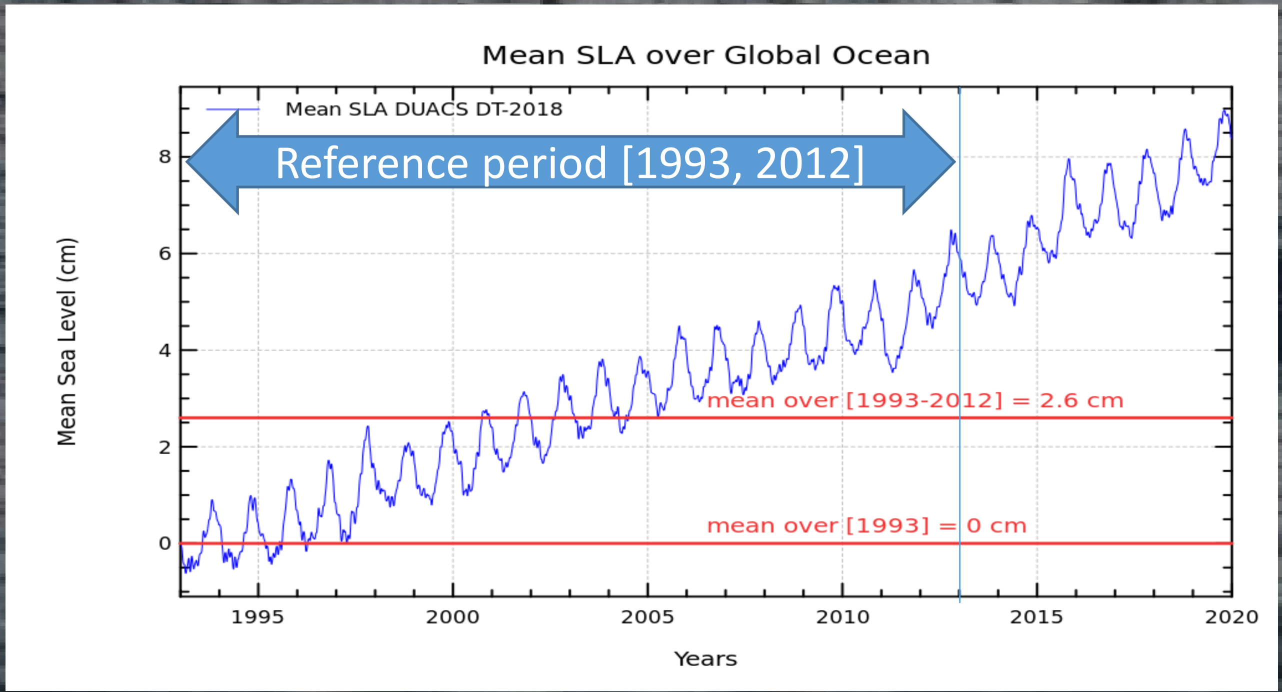
  1. Remove (large and meso-scale) seasonal and interannual oceanic variability
  2. Remove Sea Level Trend (referenced at an arbitrary time / **mid-1993**)

  3. Obtain an optimal compromise between mean oceanic content and high-resolution topographic structures

- ***goal is to tend to the "steady state" of the ocean***

Accurate with Mean Profiles (1Hz)

HR Provided by C2 & AltiKa



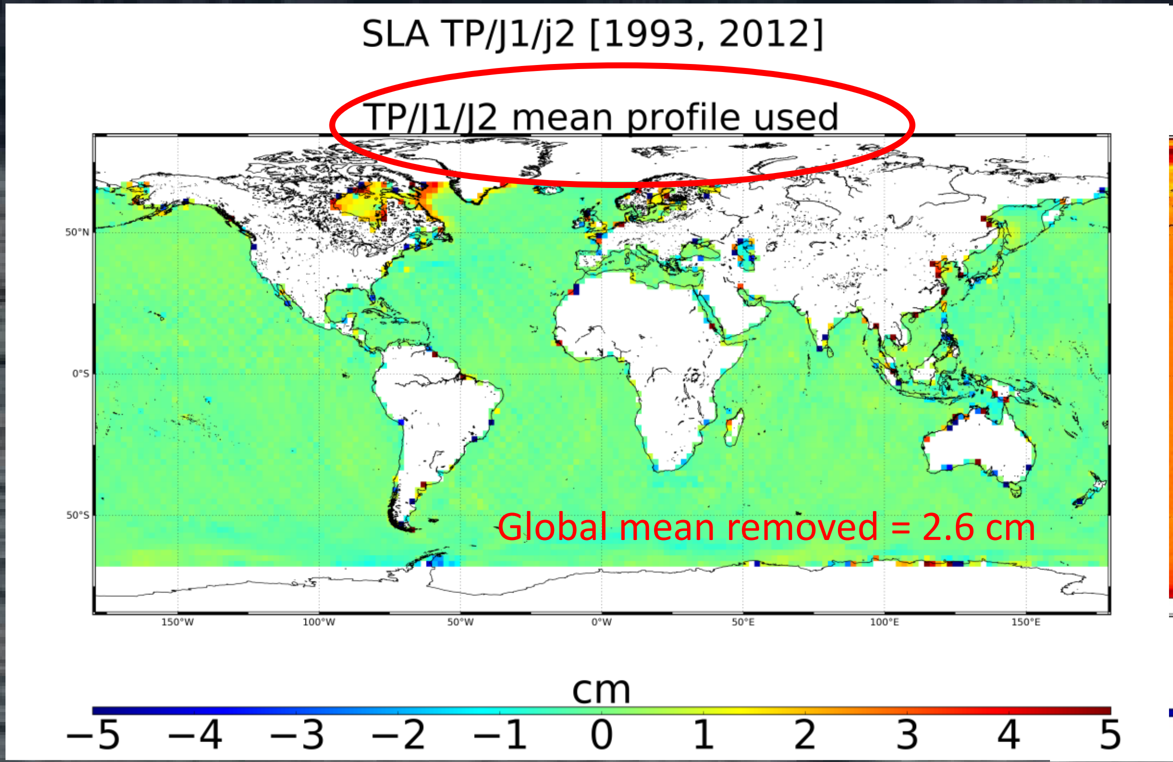
- **DUACS** uses the **20y reference period** [1993, 2012]
- **DUACS convention : $< SLA_{20y} >_{1993} = 0$**

Implies that 1993 is the reference date

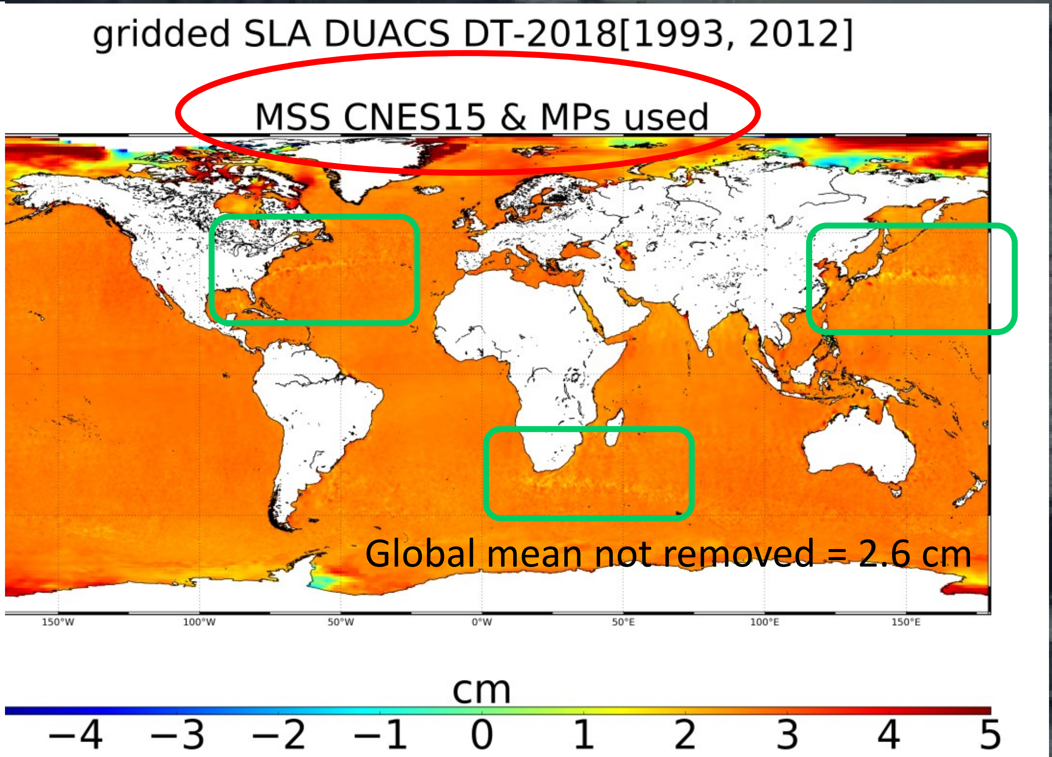
SSH – MSLA DUACS : the treatment of the oceanic variability

➢ **Mean SLA over the reference period should be close to 0 (or constant value for DUACS convention)**

Boxed mean SLA TP/J1/J2 over the MSS reference period [1993, 2012]



Mean of multi-mission DUACS gridded products over the MSS reference period [1993, 2012]



➢ **nearly cst map as expected => This means that an average calculated over 20 years brings us closer to the steady state !**

Taking account of the imperfection of the oceanic variability correction

Mapping method is based on objective analysis: $\theta_{est}(\vec{\mathbf{r}}_0) = \sum_{i=1}^{N}\sum_{j=1}^{N} A_{ij}^{-1}\, C_{xj}\, \Phi_{obs,i}$ (Bretherton et al., 1976):

$$A_{ij} = \langle \Phi_{obs,i} \cdot \Phi_{obs,j} \rangle = \langle \theta\,(\vec{\mathbf{r}}_i) \cdot \theta\,(\vec{\mathbf{r}}_j) \rangle + \langle E\,(\vec{\mathbf{r}}_i) \cdot E\,(\vec{\mathbf{r}}_j) \rangle$$

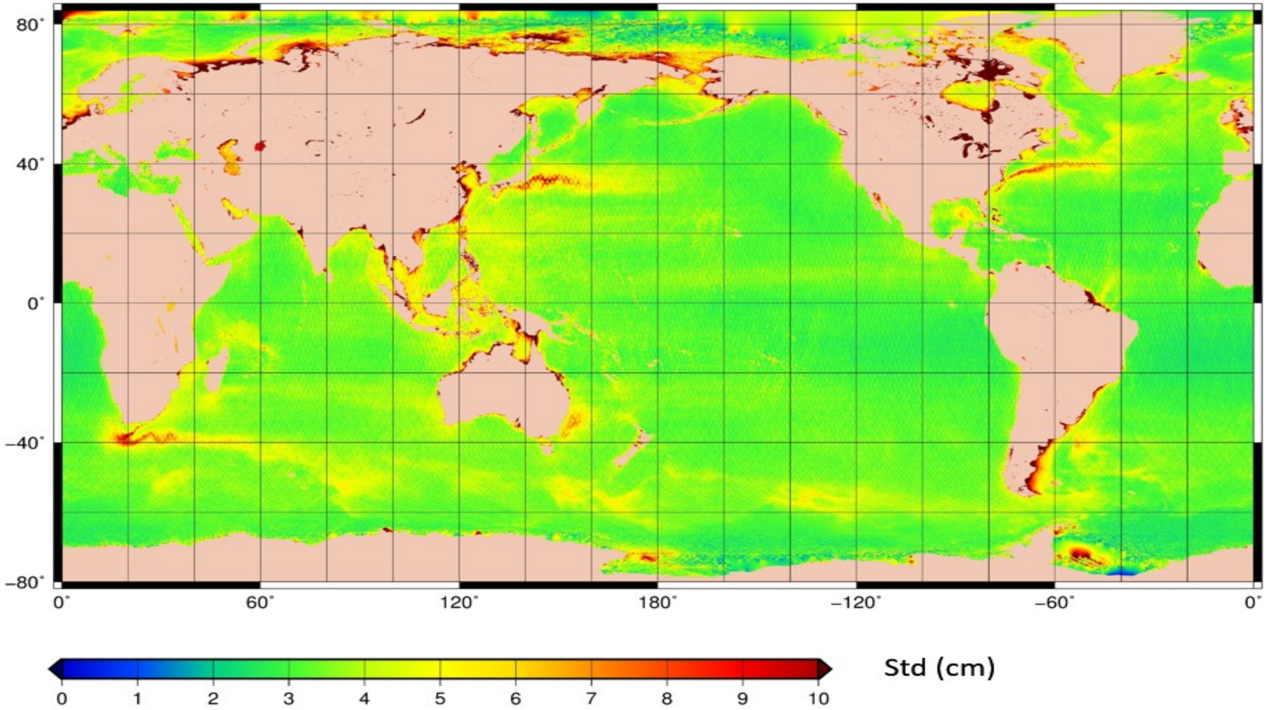
=> covariances of Obs + Errors

$$\langle E\,(\vec{r}_i) \cdot E\,(\vec{r}_j) \rangle = \underbrace{\delta_{ij}\,\langle \varepsilon^2 \rangle}_{\text{Withe noise}} + \underbrace{\zeta_{ij} \langle B^2 \rangle}_{\text{LWE}} + \underbrace{\zeta_{ij} \sqrt{\langle {V_i}^2 \rangle \cdot \langle {V_j}^2 \rangle}\; exp\left(\frac{(\vec{r}_j - \vec{r}_i)^2}{L_{Var}}\right)}_{\text{Oceanic residual variabilty}} + \underbrace{\zeta_{ij} A.\, exp\left(\frac{(\vec{r}_j - \vec{r}_i)^2}{C^{te}}\right)}_{\text{Optimal filter}}$$

ζ_{ij} $\Rightarrow$ same track, same satellite

Withe noise — LWE — Oceanic residual variabilty — Optimal filter

V_i= interpolation of the maximum of the std of MP in 5km boxes



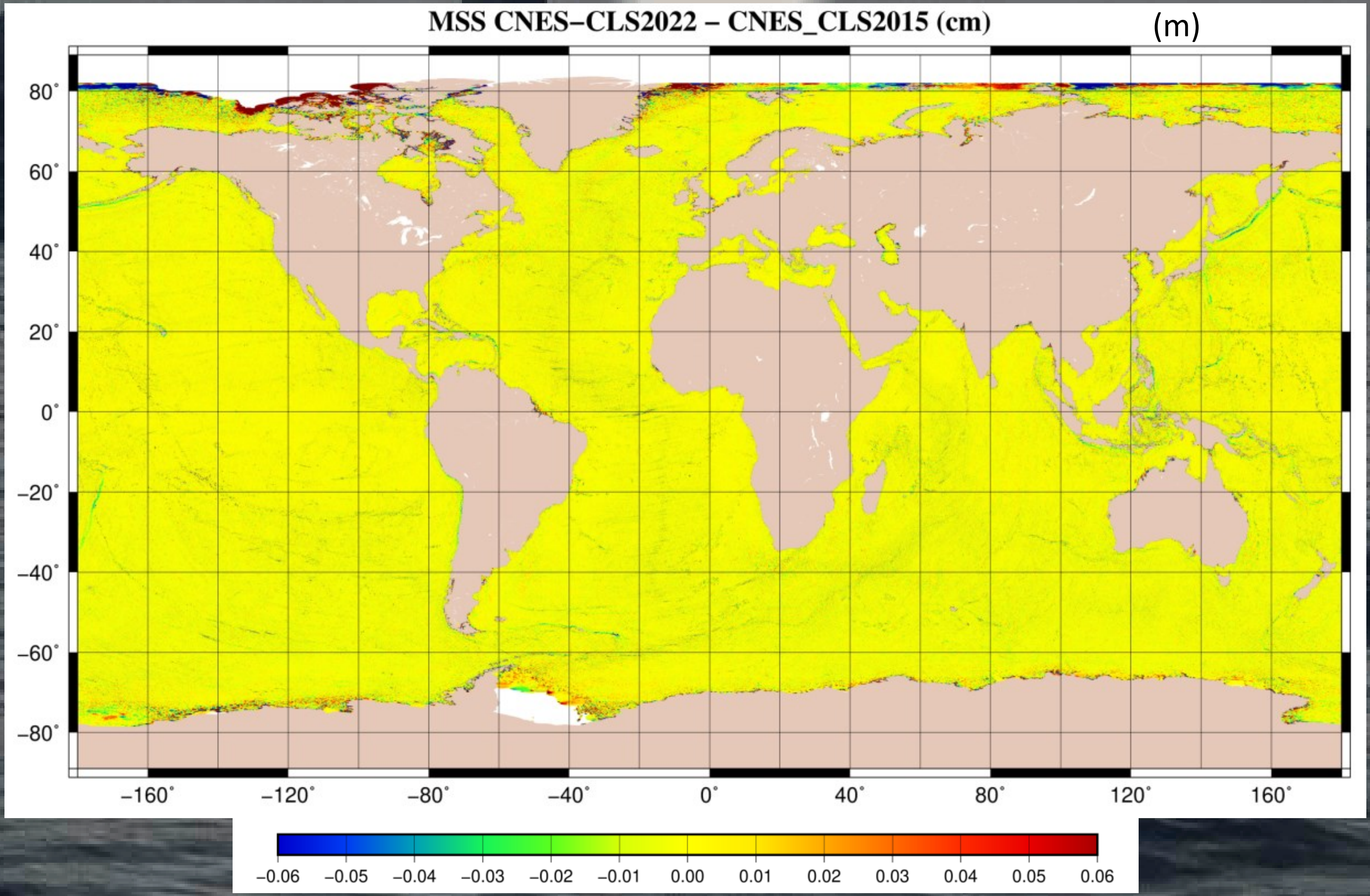
Can also be considered as an omission error !

Differences between CNES_CLS 2022 & 2015 MSS

MSLA DUACS = Reference period [1993, 2012] = 20 yrs

Data used for CNES_CLS 2022 [1993, 2021] = 29 yrs

Data used for CNES_CLS 2015 [1993, 2014] = 22 yrs



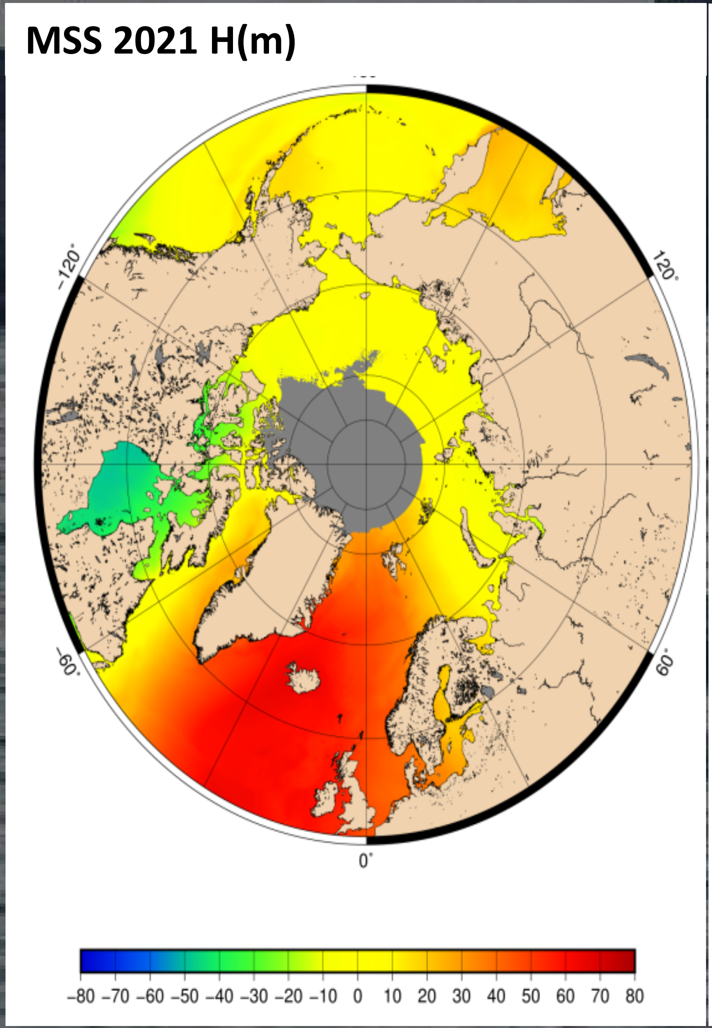
Different temporal coverage

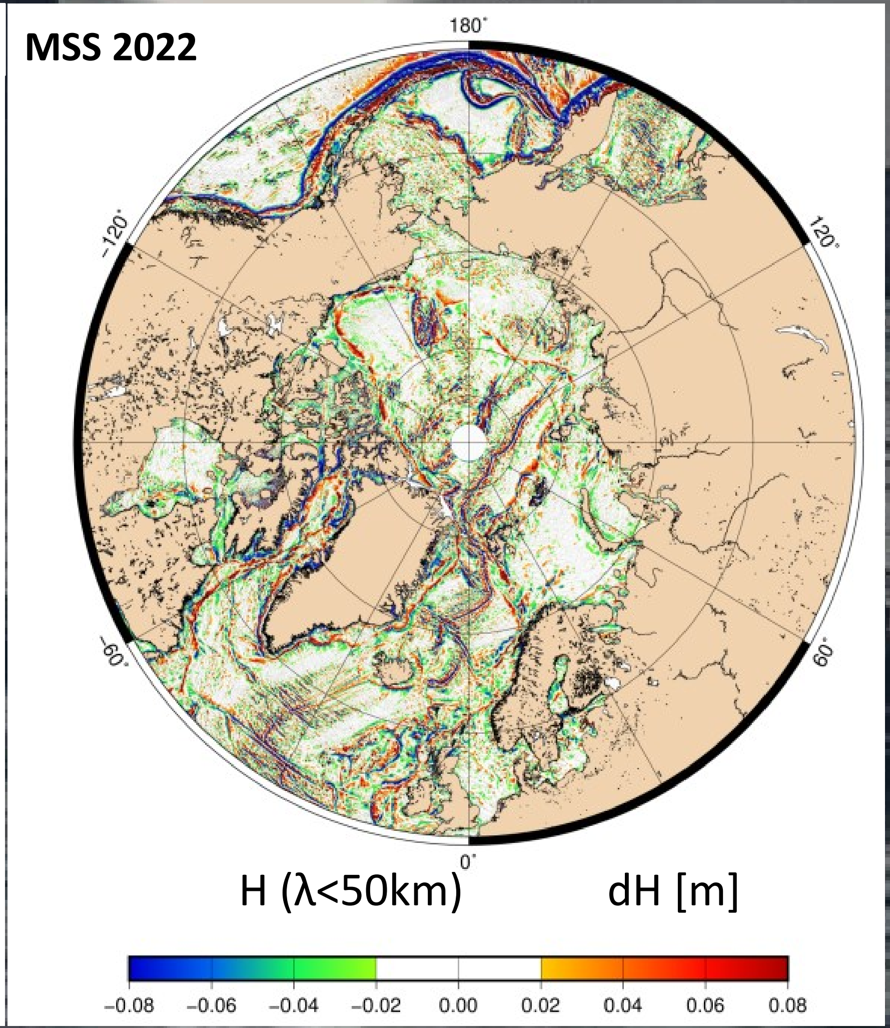
But …

⇒ No effect of oceanic variability !

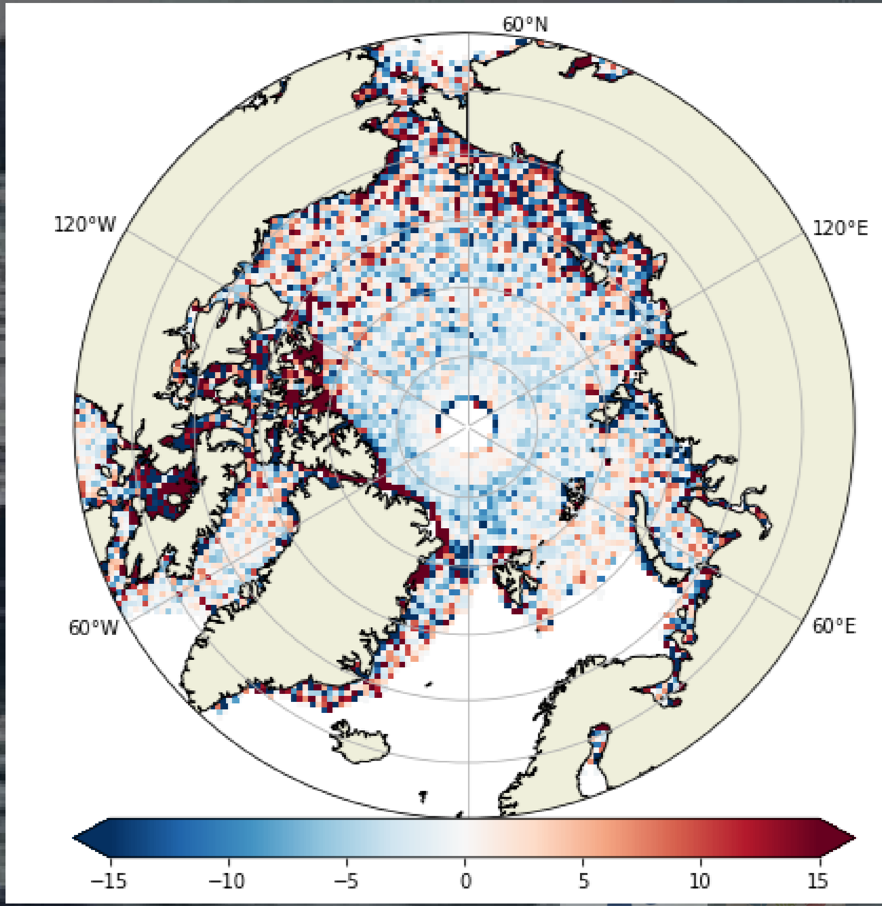
➢MSS CNES_CLS 2022 = update of 2021 version using LEADS in Arctic

- Data set = Leads of S3A (20 Hz), Cryosat-2 (20 Hz), and AltiKa (40 Hz) over 2016/07 – 2020/07 period





Var(SLA icesat-2 w/ MSS CNES/CLS22) - var(SLA icesat-2 w/ MSS DTU15) [cm²]



➢ DTU more precise near the coast !

Collaboration between Scripps (D. Sandwell) & CLS

➢ Improving the short wavelengths for SWOT Cal/Val

HR MSS determination => 2 ways : 2 different dataset and 2 mapping methods are used !

CLS (first step)
Removing oceanic variability

→

Scripps(second step)
Improving Short wavelengths

Mean Profiles = all ERM Missions (1Hz)
(TP/J1/J2/J3 (& interleave), E2/En/Aka, GFO)

HR Data

Integration of: C2 + AltiKa:
one pass RTK + 5Hz filtering
S3 => for validation

Observation

SSH – MSLA DUACS

Mapping

Optimal interpolation + noises budget (white & correlated) + optimal filtering

Based on CNES_CLS MSS for λ > 100 Km

HR Data

Integration of: Geosat/J1/J2/En + C2 + AltiKa + S3 :
two-pass RTK + 5 Hz filtering

Observation

SLOPE combined with **HEIGTH**

Mapping

Biharmonic splines in tension

Differences between CLS22, Scripps22, DTU21 MSS

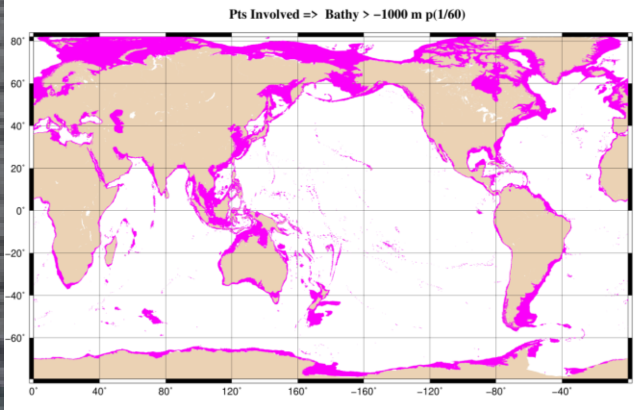
- Differences are calculated on grids at 1 min resolution (~1,8 km/eq).

Bathy > 1000 m

Diff	Nb Points	Mean (cm)	Std (cm) [3σ]
Scripps – CLS	119 439 521	0,06	0,80
CLS - DTU	118 365 843	0,09	1,38
Scripps – DTU	118 861 025	0,02	1,46

Bathy < 1000 m

Diff	Nb Points	Mean (cm)	Std (cm) [3σ]
Scripps – CLS	12 542 354	0,63	3,38
CLS - DTU	12 599 451	0,40	4,99
Scripps – DTU	12 535 188	-0,25	5,22

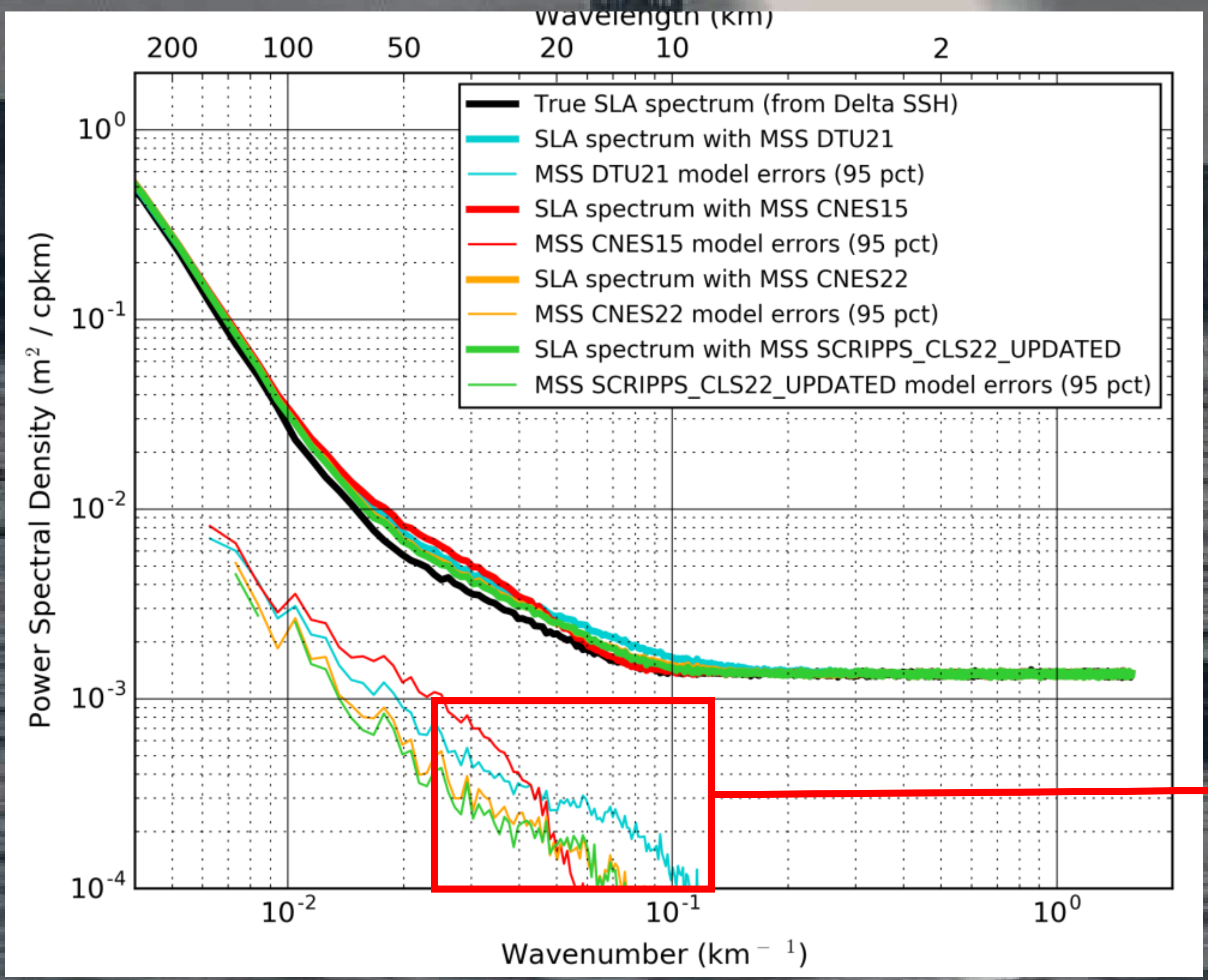


- The low values of the averages imply that these MSS are "centered" and therefore consistent in term of Sea Level Rise.
- The standard deviation values show that these MSS are close in terms of high-resolution content and also consistent with the expected accuracy of SWOT.
- We note a relative degradation of the consistency near the coasts which remains one of the major difficulties concerning the processing of altimetric data.

- excluding latitudes higher than 60 degrees gives the same results

Spectral analysis (global)

Gridded MSSs errors at short WL – S3A LR-RMC reference



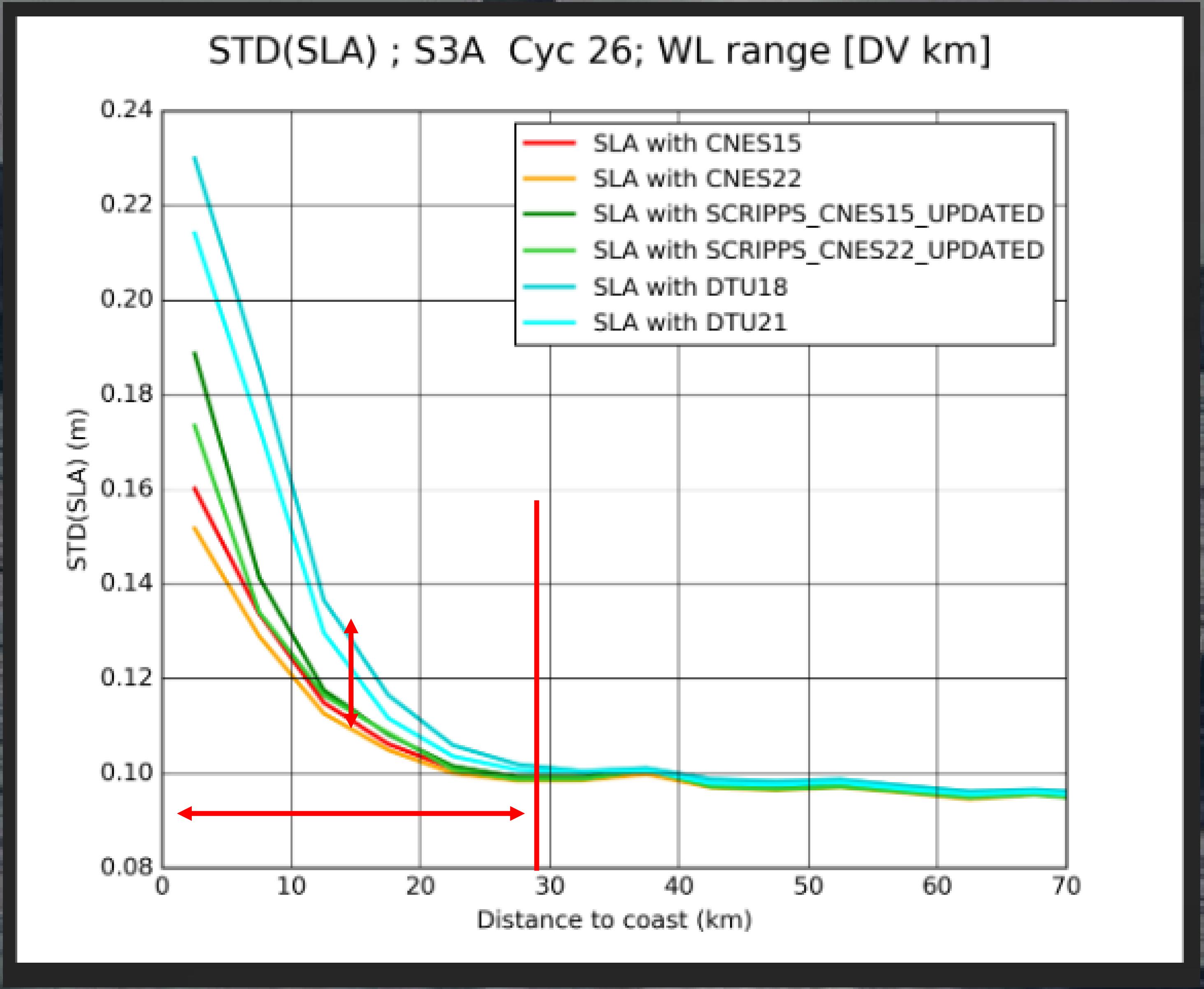
Pujol et al (JGR 2018; https://doi.org/10.1029/2017JC013503)

MSS	Error [15, 100 km]		
	cm²	% for SLA (noise free) variance*	% improvement /CLS15
SCRIPPS CLS 22	**0.21**	**18**	**51**
CNES_CLS 22	0,23	20	46
DTU 21	0,34	29	21
CNES_CLS 15	0,43	37	0

- SCRIPPS CLS 22 & CNES_CLS 22 : Closest results
- SCRIPPS CLS 22 : the smallest error from the point of view of S3A => improvement of short wavelengths

If we look at the wavelengths between 50 and 10 km: the integral of the differences between the curves is less than 5 mm in std ! *(CLS 15 is not considered here)*

Validation depending on the distance to the coast



- validation based on the variance of the difference between S3A and MSS.

- ➢ differences become significant from 15 km of the coast

- ➢ CLS solutions remain the most accurate

Conclusion

- These 3 MSS are "centered in time" and therefore consistent in term of Sea Level Rise.
- In open ocean: MSS are close in terms of high-resolution content and consistent with the expected precision for SWOT.
- 3 key points:
  - DTU: the most accurate along the Greenland coast.
  - Scripps: improvement of the shortest wavelengths in open ocean.
  - CLS: globally the most accurate near the coast.

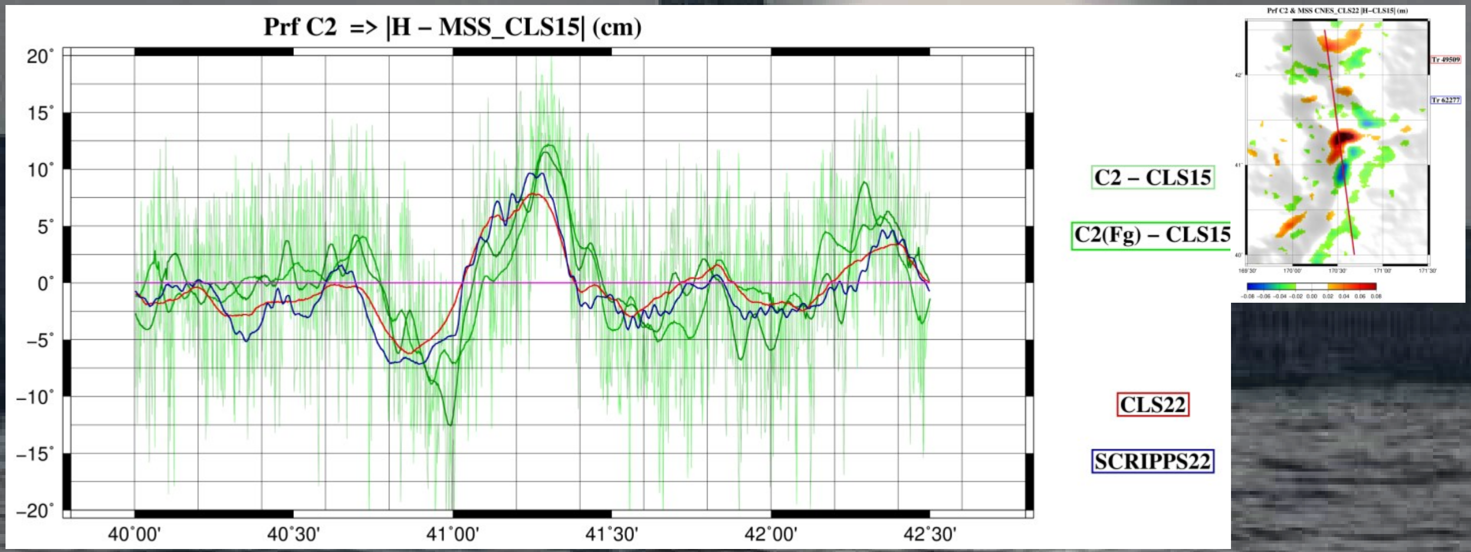
Perspective

- Creation of a new hybrid version for SWOT Cal/Val with the best of SCRIPPS, DTU, and CLS MSS (planned for the first quarter of 2023)

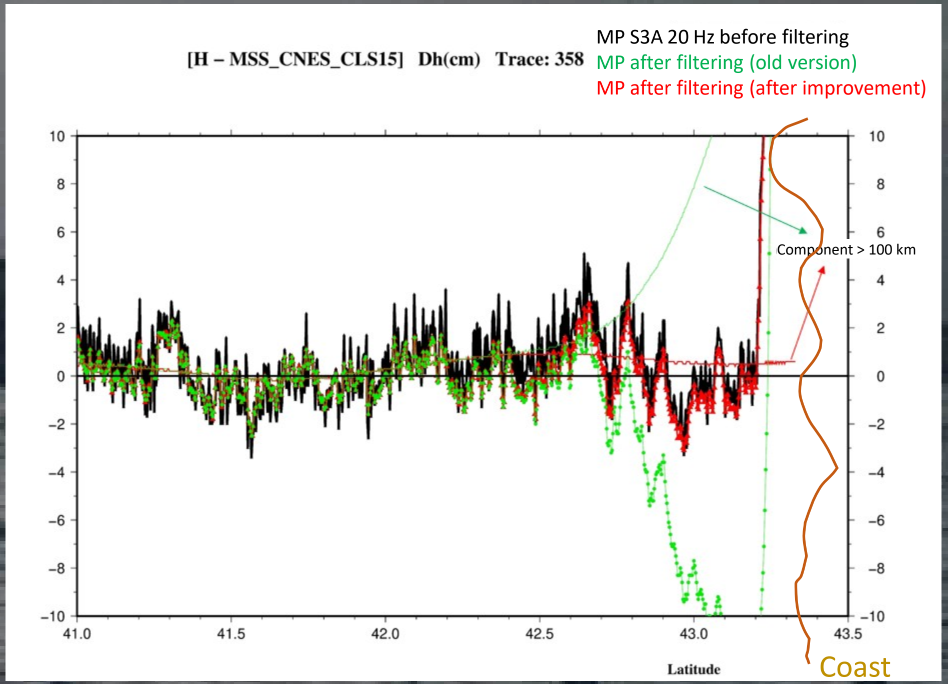
BACK SLIDES

Improvement of the filter method

HR data must be filtered to make the noise acceptable



Improving behavior near the coast

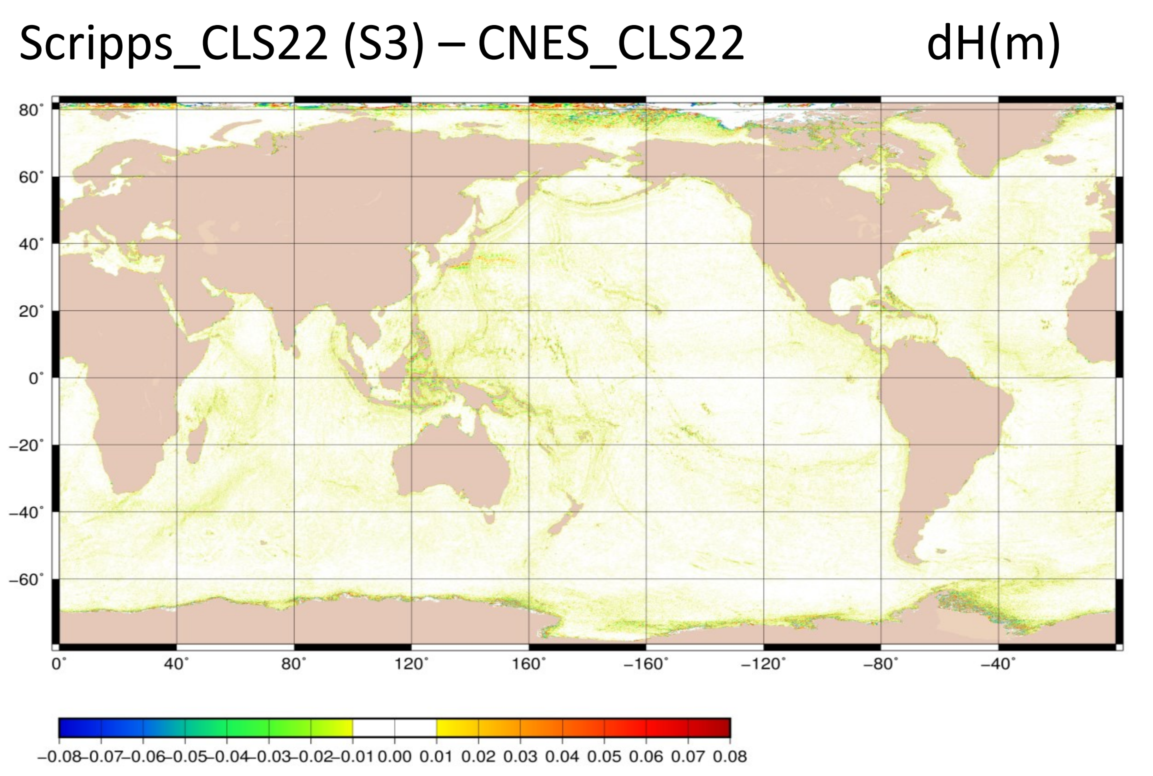


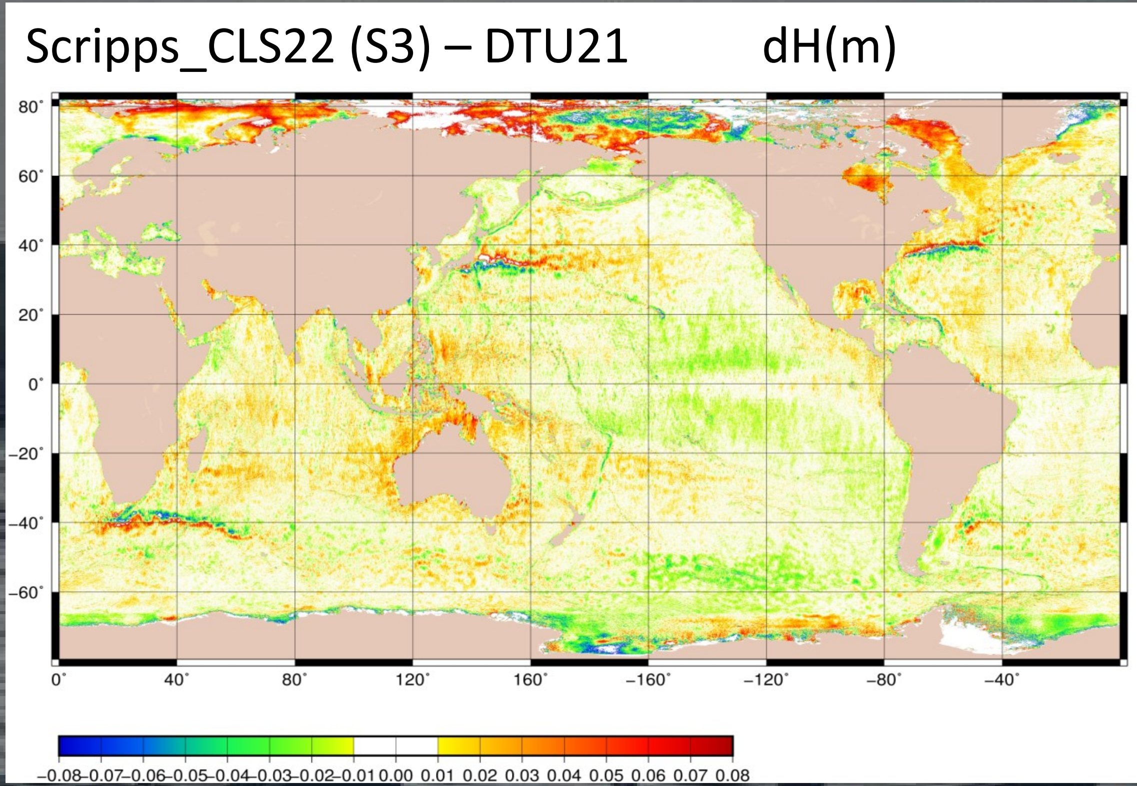
- Results of gaussian filter : C2 & AltiKa (North Pacific)

Nbr Obs	Average	Std	RMS	dH(m)
C2 PDGS(20Hz) cycles 17-34				
122 716 126	-0.056	0.039	0.068	H-CLS15
122 716 122	0.000	0.020	0.020	H_Fg-CLS15
C2 PDGS(20Hz) cycles 117-126				
54 177 688	-0.028	0.074	0.079	H-CLS15
54 177 688	0.000	0.022	0.022	H_Fg-CLSO15
AltiKa (40Hz)				
371 560 919	-0.007	0.041	0.042	H-CLS15
371 560 632	0.000	0.019	0.019	H_Fg-CLS15

- Homogeneity of the Observations after filtering

Differences between CLS22, Scripps22, DTU21





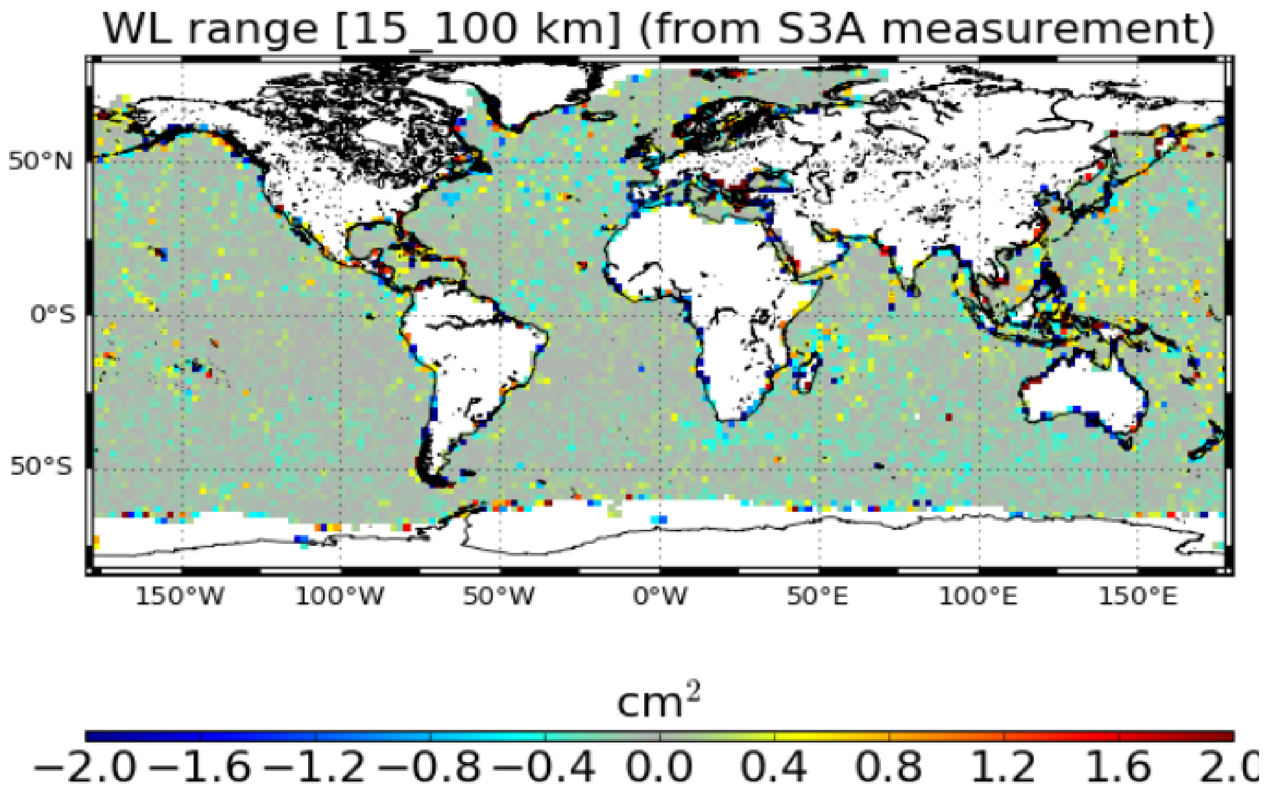
- Scripps & CLS are very close

- Small residual effect of ocean variability
- Scripps => Improvement of several HR structures at level of 1 to 2 cm

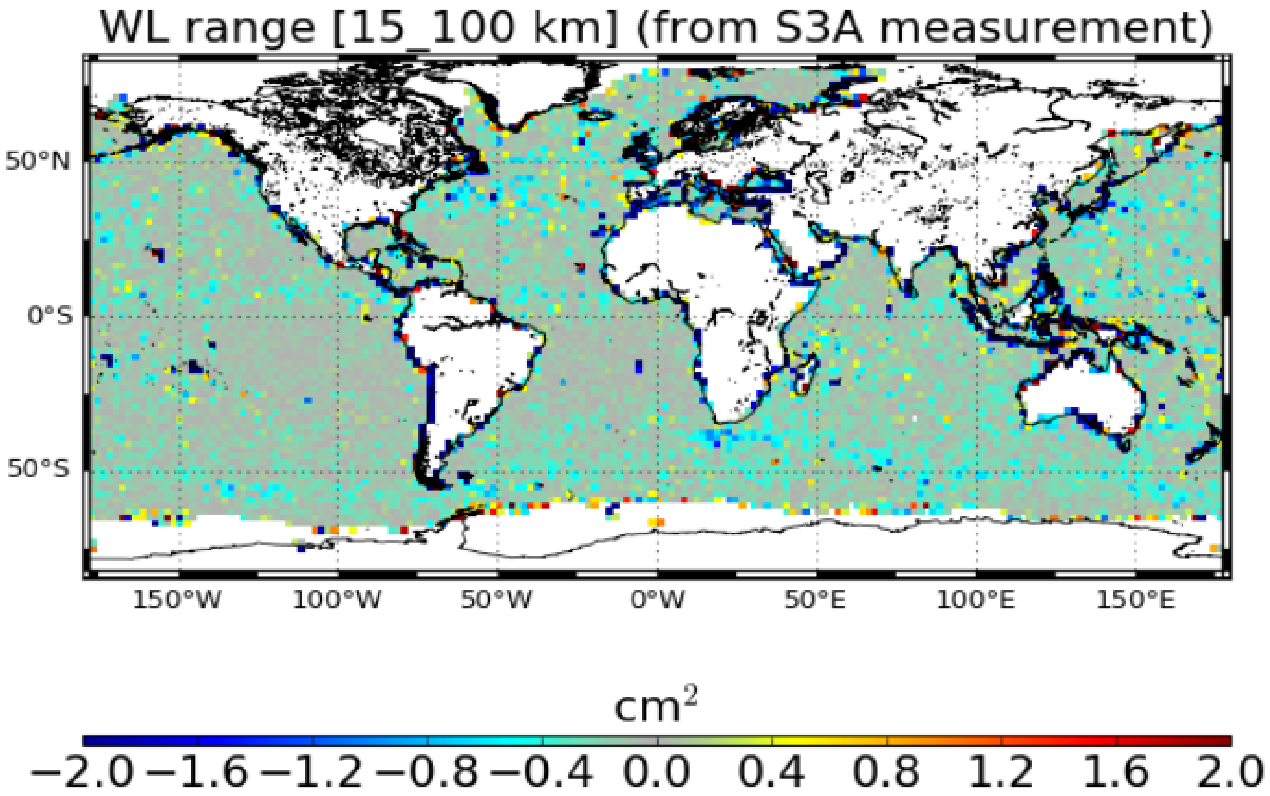
Difference in ocean variability content (interannual) for DTU

Gridded MSSs errors at short WL – S3A LR-RMC reference

Difference: Error Scripps_CLS22 – Error CNES_CLS21



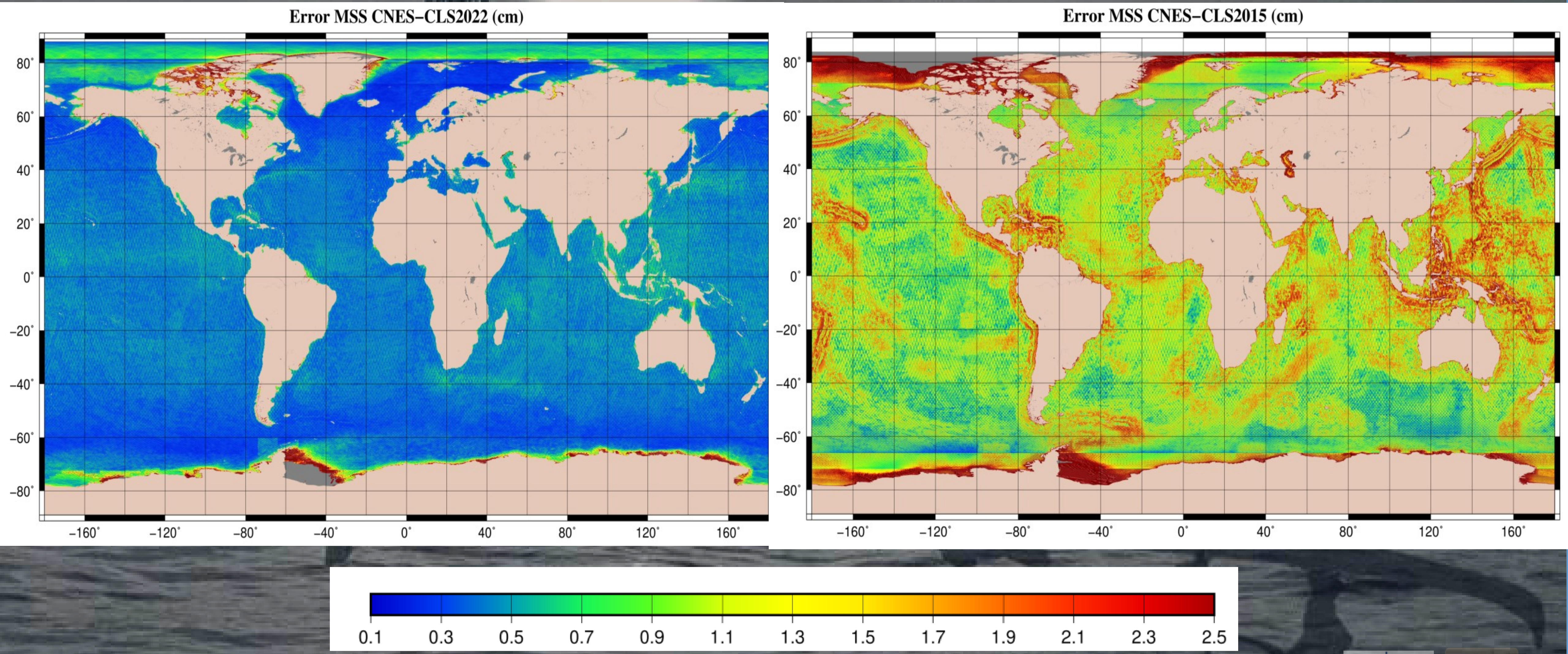
Difference: Error Scripps_CLS22 – Error DTU21



- Very close results in open ocean
- Differences in blue suggest that DTU contains more oceanic variability

MSS Error

=> Mainly the impact of the number of data: 6 Billion vs 200 Million !



Short wavelengths of CNES CLS 22 MSS