The 2023 Hybrid Mean Sea Surface.

CLS: P. Schaeffer, M-I. Pujol, P. Veillard, A. Laloue, Y. Faugere, Q. Dagneau
CNES: G. Dibarboure, N. Picot
SIO: D. Sandwell, Y. Yu, H. Harper
DTU: O. Andersen, A. Abulaitijiang, S. Zhang, S-K. Rose

Overview

This new MSS has been determined using a combination of recent models considered as the most precise which are the SCRIPP_CLS22, CNES_CLS22, and DTU21 MSS's.

The aim was to generate a new MSS by taking advantage of the best properties of each model based on various validations of these 3 MSS (1).

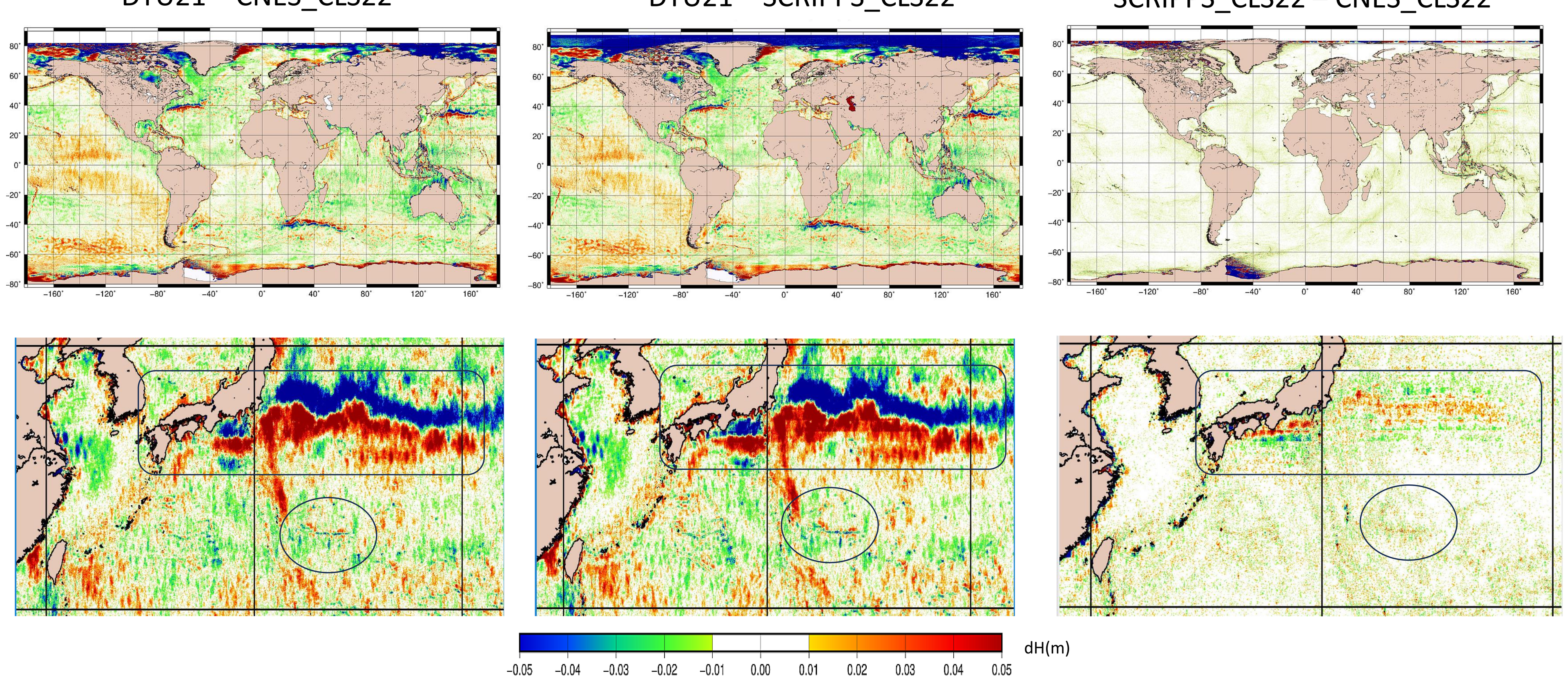
- This work focused on the following points:
- achieving a centimetric accuracy considering the SWOT specification of 1cm/2km,
- while minimizing residual ocean variability,
- and obtaining the most accurate mapping of the finest topographic structures down to wavelengths of less than 10 km.
- Particular attention has also been paid to the Arctic and Antarctic areas.

3 different MSSs used

	CNES_CLS22	SCRIPPS_CLS22	DTU21
Data used	Mean profiles from LRM 1Hz : TP/J1/J2/J3 (& interleave), E2/EN/AL, GFO HR measurements with **one pass RTK + 5Hz** **filtering:** C2, AL	Background : Based on CNES_CLS MSS for λ > 100 Km HR measurements with **two-pass RTK + 5Hz** **filtering:** Geosat, J1/J2, EN, C2, AL, S3	Mean profiles from LRM 1Hz : TP/J1/J2/J3 (& interleave), E2/EN/AL, GFO HR measurements with **two-pass RTK + 2Hz** **filtering:** C2, AL, J1/J2
Observations	SSH corrected from oceanic variability (mesoscales & large scales)	**SLOPE** combined with **HEIGTH**	**SSH (4 parameter estimation of SL variability)**
Mapping method	Optimal interpolation + noises budget (white & correlated) + optimal filtering	Biharmonic splines in tension	Optimal interpolation + noises budget

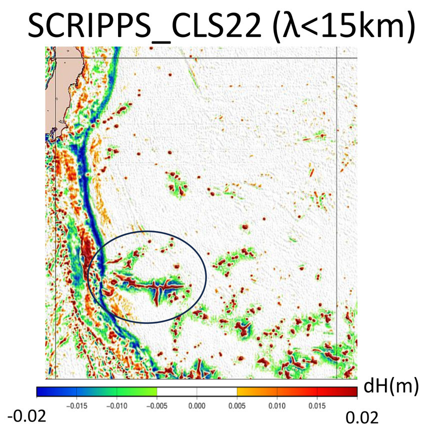
Differences between CNES_CLS22, SCRIPPS_CLS22, DTU21 MSS

DTU21 – CNES_CLS22 | DTU21 – SCRIPPS_CLS22 | SCRIPPS_CLS22 – CNES_CLS22



- The low values of the averages imply that these MSSs are "centered" and therefore consistent in term of Sea Level Rise.
- The standard deviation values show that these MSSs are close in terms of high-resolution content.
- Differences between DTU21 and two other MSSs (SCRIPPS_CLS22, CNES_CLS22) show ocean variability greater than 4/5 cm in area of strong currents.
- The standard deviation of differences between SCRIPPS_CLS22 and CNES_CLS 22 is less than 1 cm (cf. specifications for SWOT 1cm/2km).

Short wavelengths of SCRIPPS_CLS22 (λ<15km)



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

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

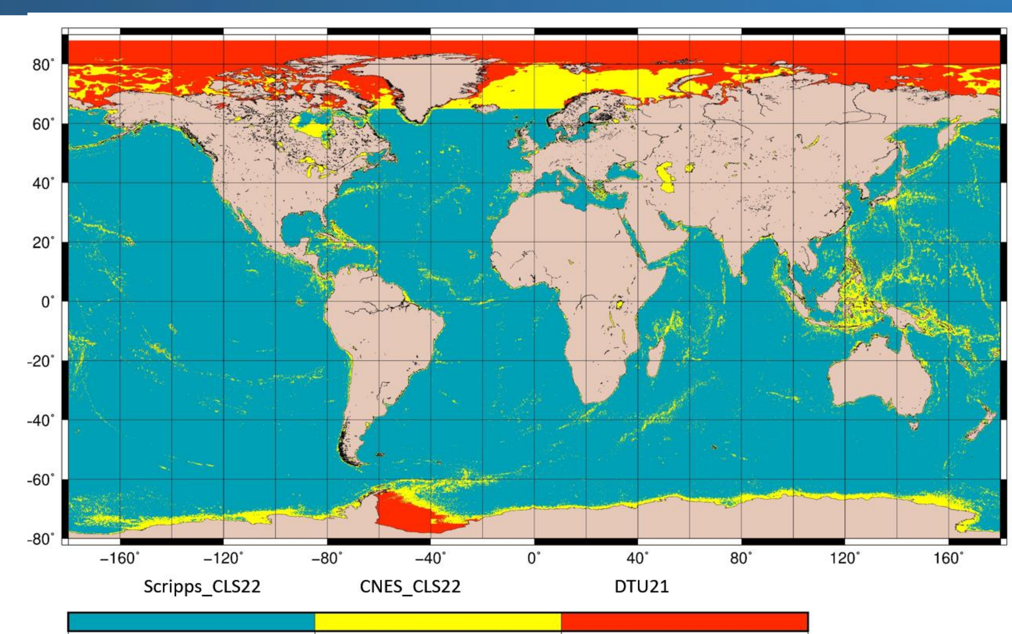
- DTU21 has slightly lower amplitudes on certain structures (probably due to the 2 Hz filtering applied to data compared to the 5 Hz used by SCRIPPS & CLS).
- SCRIPPS_CLS22 shows a residual effect of ocean variability in areas of strong ocean currents.

Hybridation method

The method is based on the calculation of the RMS of the difference between two MSS which is calculated every 1 minutes in ~10 km boxes of influence (5*5 pixels=25 pixels). And this is only done if the difference between the 2 MSS is greater than 1 cm. Then the algorithm searches for the boundaries of all zones corresponding to these criteria.

More in detail:

- Step 1: Calculation of statistics of the difference between two MSS (Avg,Std,RMS)
  - this is only done if the difference between 2 MSS is greater than 1 cm
  - statistics are calculated if there are at least 9 pixels out of the total of 25.
  - The rms of the corresponding pixel is saved if -and only if- it is greater than 1.5 cm.
- Step 2: Determining the boundary corresponding to pixels with RMS greater than 1.5 cm.
- Step 3: Filtering the boundary area with size lower than 50 Km (in open ocean)
- Step 4: Remove the first MSS and replace it by the second one



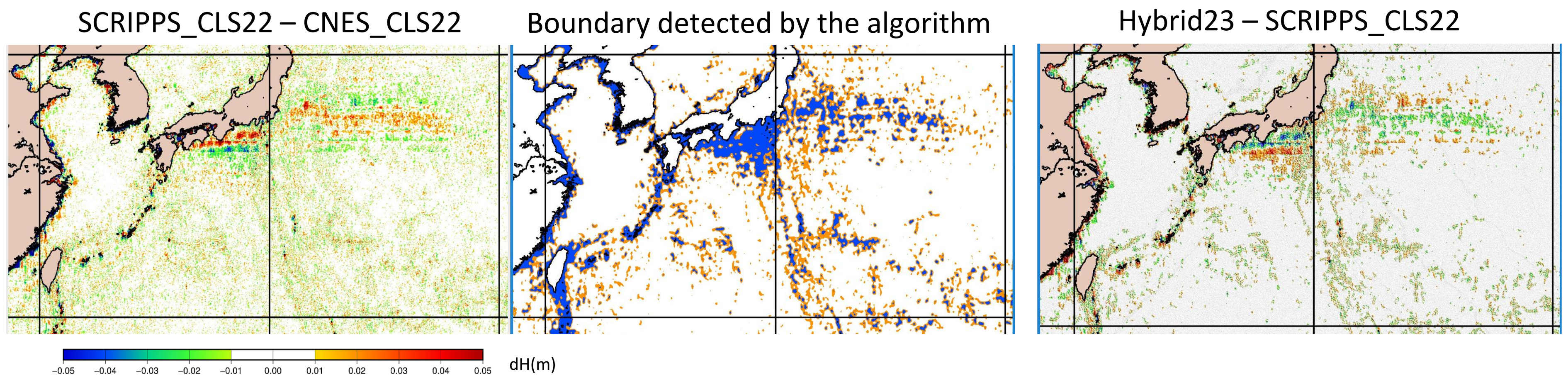
Contribution of the different MSSs

- The Hybrid23 MSS is the result of the combination of SCRIPPS_CLS22 in the open ocean, supplemented by CNES_CLS22 in regions of strong ocean currents and near the coast, and complemented by DTU21 in polar regions.

Validation results

In high variability areas

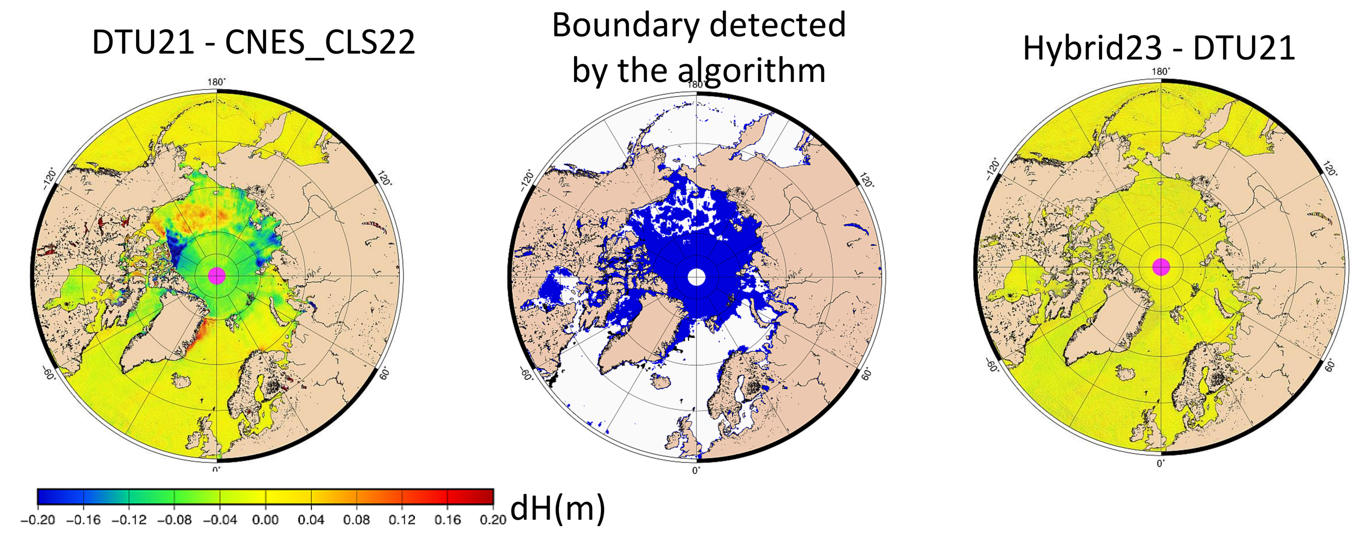
SCRIPPS_CLS22 – CNES_CLS22 | Boundary detected by the algorithm | Hybrid23 – SCRIPPS_CLS22



- The "blue" part is the part removed from one MSS to be replaced by the other (middle map).
- The difference related to residual variability between SCRIPPS_CLS22 and CNES_CLS22 (left map) is the opposite of the difference between Hybrid23 and SCRIPPS_CLS22 (right map), indicating that most of the residual variability has been effectively removed.

In the Arctic

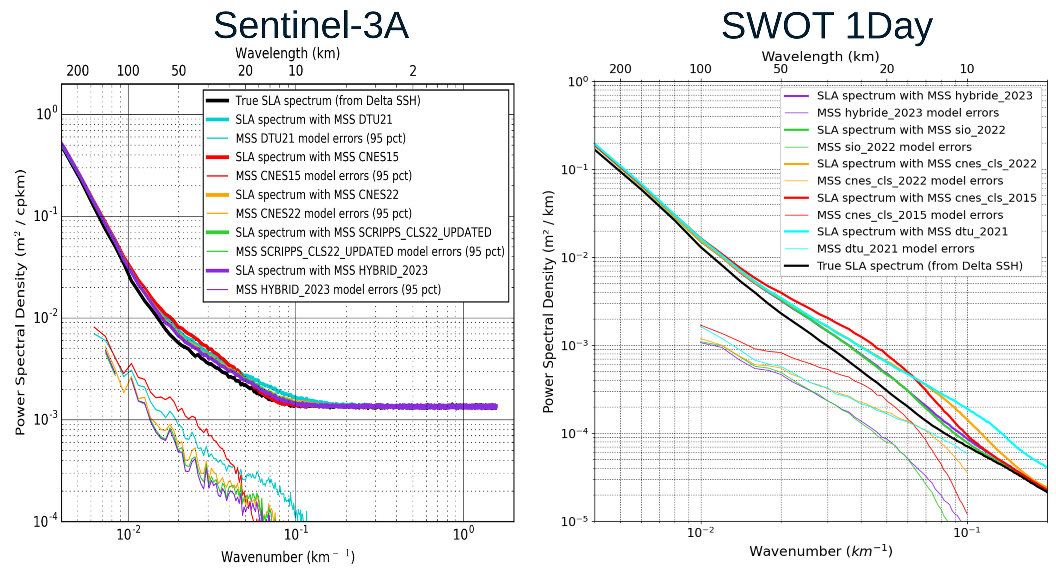
DTU21 - CNES_CLS22 | Boundary detected by the algorithm | Hybrid23 - DTU21



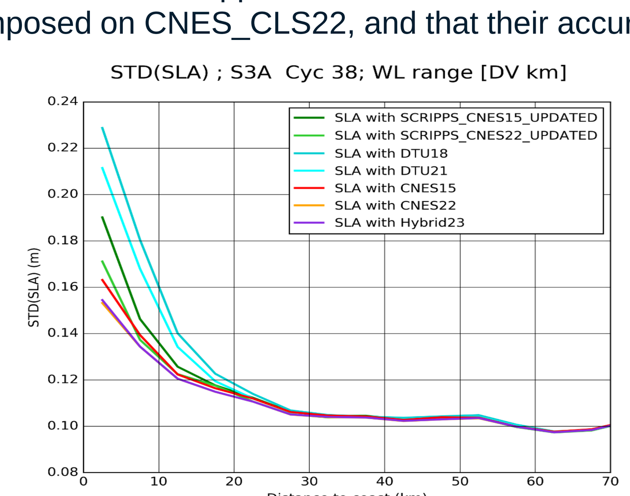
- The long wavelength differences between DTU21 and CNES_CLS22 (left) are removed after hybridization (right).

Over the global ocean

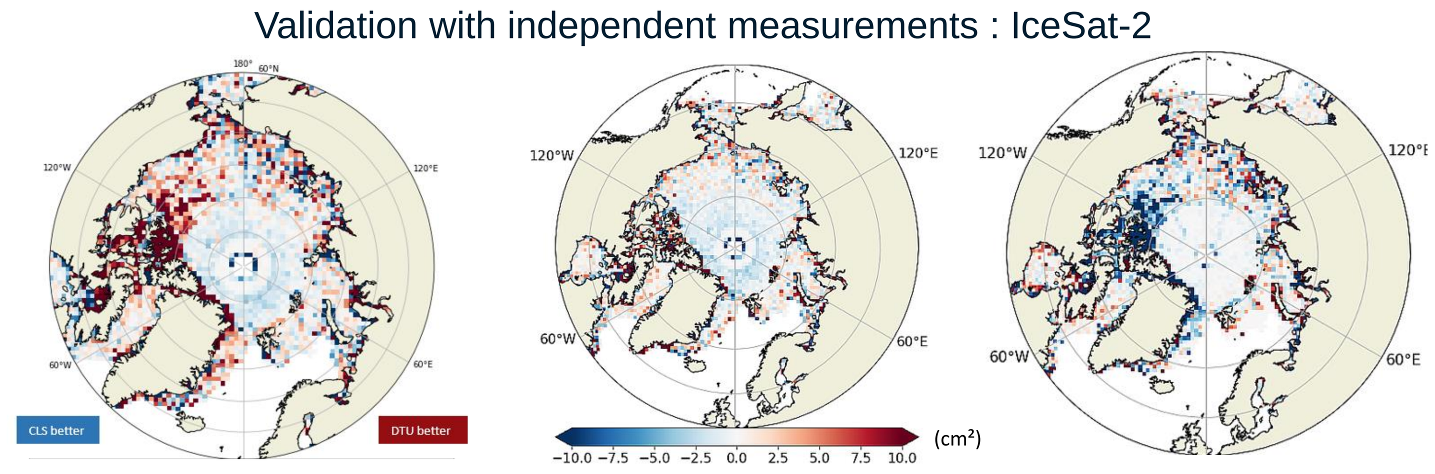
Sentinel-3A | SWOT 1Day



- Seen by Sentinel 3 & SWOT-1D: the Hybrid23 MSS is more accurate than the three previous models.
- The drop in the CNES_CLS15 spectrum after 20 km can be explained by the fact that it was built from 1 Hz data.
- Analysis of the std on approach to the coast shows that Hybrid23 is superimposed on CNES_CLS22, and that their accuracy is equivalent.



Validation with independent measurements : IceSat-2



Var(Sla[CNES_CLS22]) – Var(SLA[DTU21]) | Var(Sla[Hybrid23]) – Var(SLA[DTU21]) | Var(Sla[Hybrid23]) – Var(SLA[CNES_CLS22])

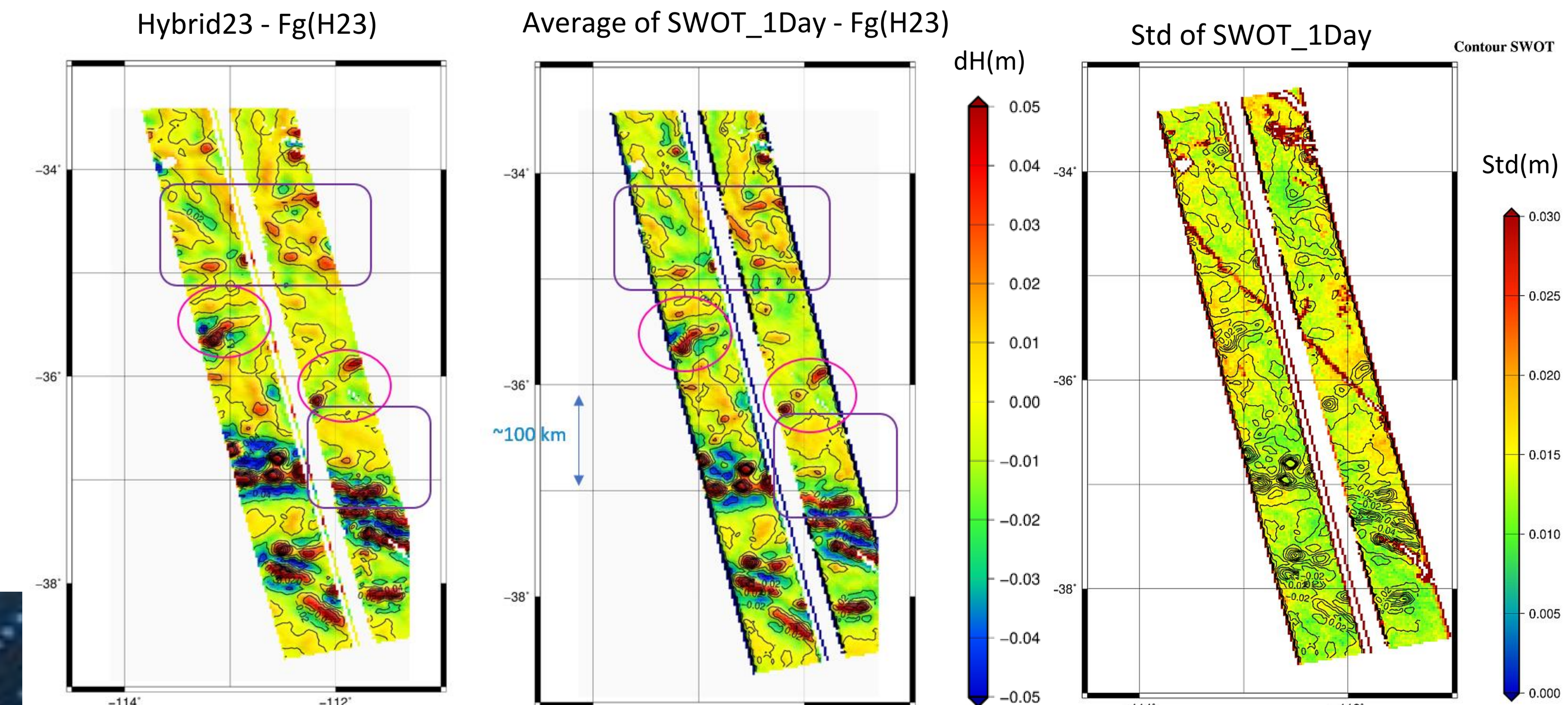
- These validations show that Hybrid 23 is globally more accurate than CNES_CLS22 and DTU21.

Conclusion and perspectives

- The method used to create the hybrid MSS allowed us to achieve a level of accuracy that is globally better than the three reference solutions.
- First comparisons with SWOT swaths show a good consistency of certain topographic structures up to sizes of the order of 10 km.
- At the same time, these initial results show that SWOT will enable us to access even smaller structures with a centimeter-level of precision.

Preliminary result using 90 cycles of SWOT 1-Day phase (Pass 26)

Hybrid23 - Fg(H23) | Average of SWOT_1Day - Fg(H23) | Std of SWOT_1Day



- The average of SWOT 1 Day is calculated with 90 cycles (In this case, Flag/Val was not used which explains some erroneous values at the swath border).
- The two maps on the right represent the difference relative to the Hybrid23 MSS filtered for wavelengths below 30 km (FgH23).
- This first preliminary result already shows that SWOT enables us to map new seamounts (magenta circles) of the order of 10 km in size (or even less).
- We can see in the purple rectangles that there is still some differences at medium-wavelength (L>30 km), the cause of which has yet to be analyzed.

More details:
(1) Comparisons between MSS : *Schaeffer et al., 2022: New CNES CLS 2022 mean sea surface. Presentation, OSTST 2022.*