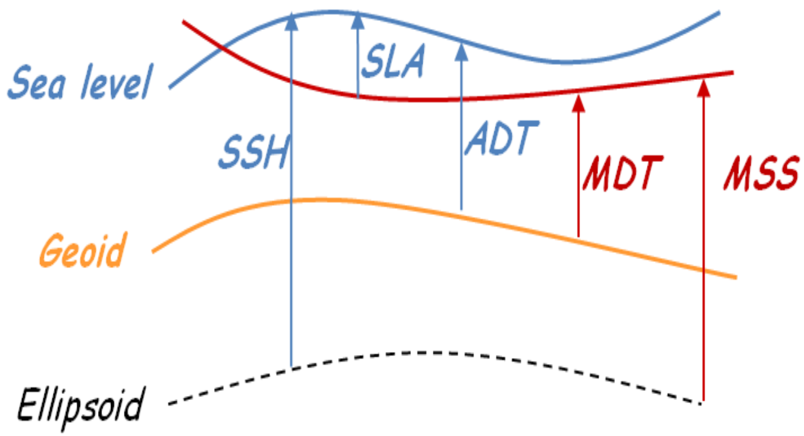
Improvements and limitations of recent mean sea surface models: importance for Sentinel-3 and SWOT.

M.-I. Pujol, P. Schaeffer, Y. Faugère, F.-X. Davanne, D. Sandwell,
G. Dibarboure, N. Picot

Introduction



$$SLA = SSH - MSS$$

SLA: Sea Surface dynamic

SSH: Measured by of the altimeter

MSS: Mean Sea Surface

➔The quality of the MSS field has a direct impact on the quality of the SLA field

Toward a new era of altimetry :

- New technologies (SAR, wide-swath)
- Improved data processing (retracking, noise reduction, improved environmental/geophysical corrections, …)

➔ It will be possible to observe small/sub-mesoscales in a near future

What are the MSS errors at small/sub mesoscale ?
How can we reduce them ?

Recent MSS errors characterization

MSS are characterized by :

- **Omission errors** : part of the MSS signal is missing (cf cross-track altimeter resolution, smoothing induced by the mapping methodology, …)

Main source of error in previous MSS models (e.g. CNES_CLS11), they have been strongly reduced in up to date models (e.g. CNES_CLS15, DTU15) thanks to the use of geodetic altimeter measurements

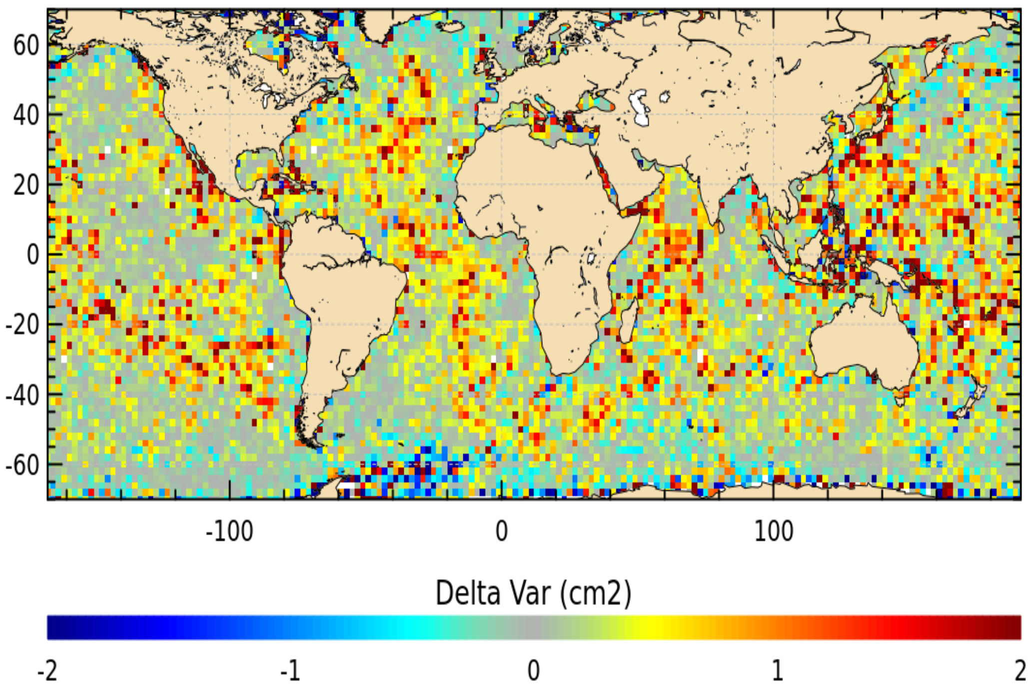


Fig: Differences between CNES_CLS11 errors and CNES_CLS15 errors estimated at wavelengths ranging 10-100km along Sentinel-3 A track

CNES_CLS15 vs CNES_CLS11:

Errors reduced by a factor 2.3 for wavelengths ranging 30-100km

22% reduction of the SLA variance in coastal areas

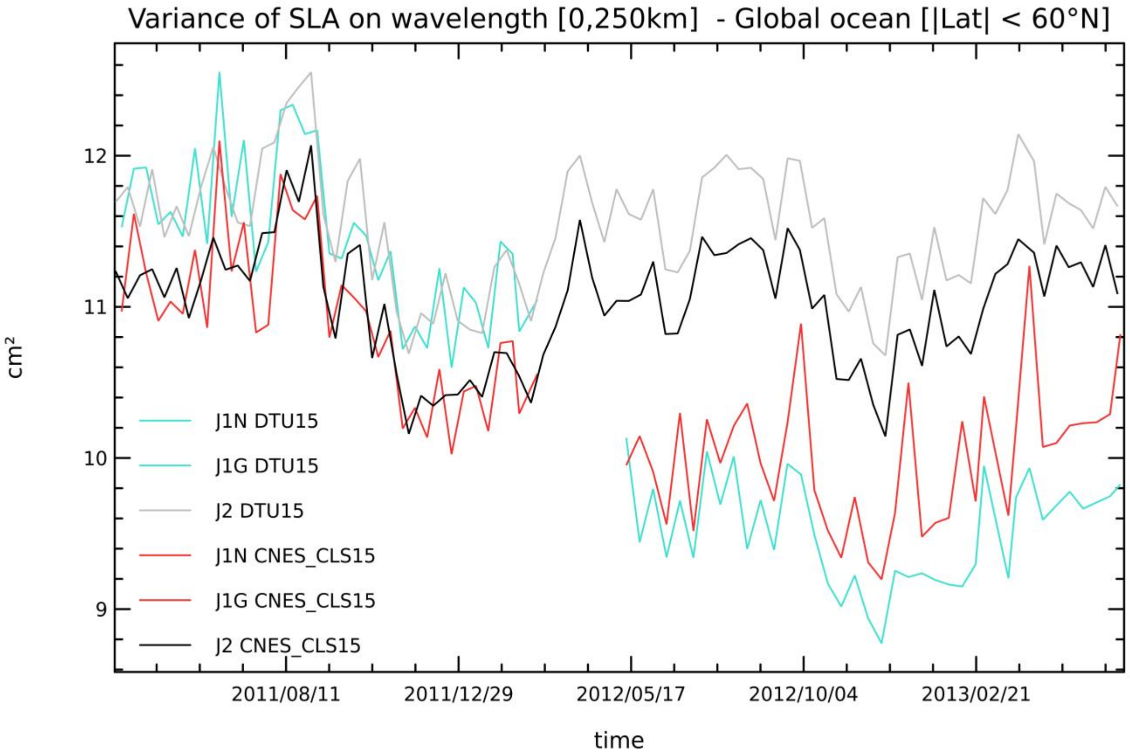
Pujol et al, 2017 (in revision)

Recent MSS errors characterization

MSS are characterized by :

- **Commission errors**: part of non-MSS signal is introduced (e.g. ocean variability, HF errors, …).

The commission error is higher along track of geodetic measurements : difficulty to mitigate the ocean variability at wavelengths < ~200km



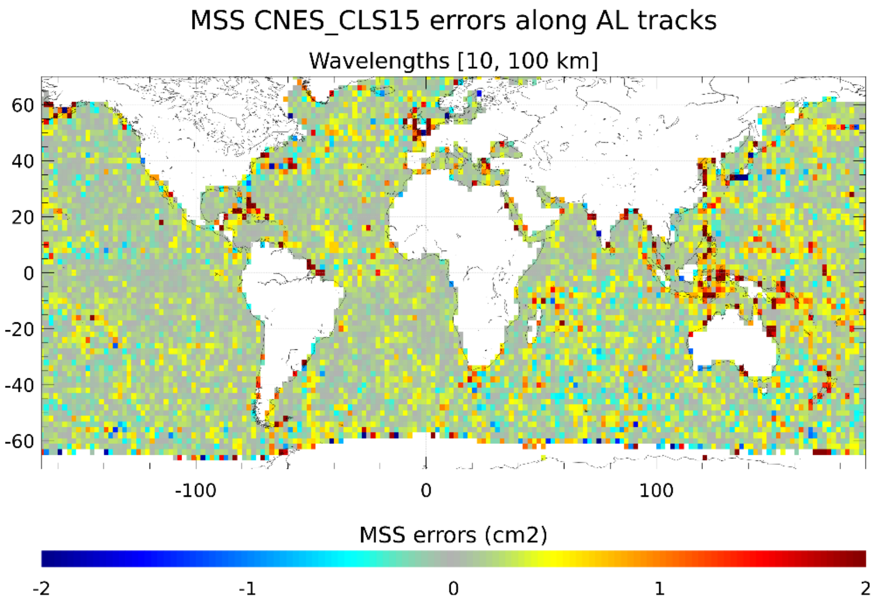
CNES_CLS15 (DTU15): commission errors represent ~1cm² (1.7 cm²) i.e. 9.3% (17%) of the SLA variance along Jason-1 geodetic tracks

Fig: Temporal evolution of the SLA variance along the tracks of Jason-2 (J2) and Jason-1 interleaved (J1N) and geodetic (J1G) phases. The SLA was high-pass filtered (250km) and estimated using MSS CNES_CLS15 (black and red lines) and DTU15 (grey and cyan lines)

Pujol et al, 2017 (in revision)

Recent MSS errors characterization

MSS are errors at short wavelengths (<100km) are estimated using the “delta-cycle” methodology (Pujol, 2017)

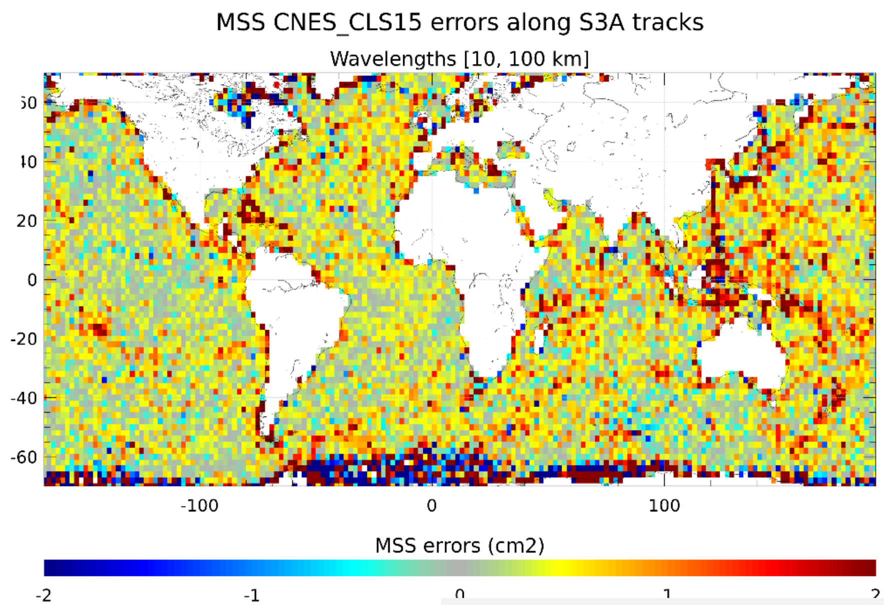


CNES_CLS15 (DTU15):

- 12% (30%) of the SLA variance along repetitive tracks (AL): mainly omission
- 30% (30%) of the SLA variance along uncharted ground tracks (S3A): omission+commission

They locally reach more than 2 cm².

Fig: Variance of the absolute MSS errors estimated for MSS CNES_CLS15 for wavelengths ranging from 10 to 100 km along AltiKa (top) and Sentinel-3A (bottom) tracks.



Pujol et al, 2017 (in revision)

Potential improvements with alternative processing

A collaboration with **D Sandwell** (SIO) for preparing MSS for CAL/VAL SWOT.

Approach:

- Use CNES_CLS15 MSS model to constrain large scales (> 30 km).
- Use in addition slope profiles from 20Hz J1G and Cryosat-2 to constrain small scales

✓ no impact on large scale
✓ improvement of finest topographic structures

✓ grid differences are globally lower than 3 cm
✓ the mean difference is ~2 mm and std ~9 mm !

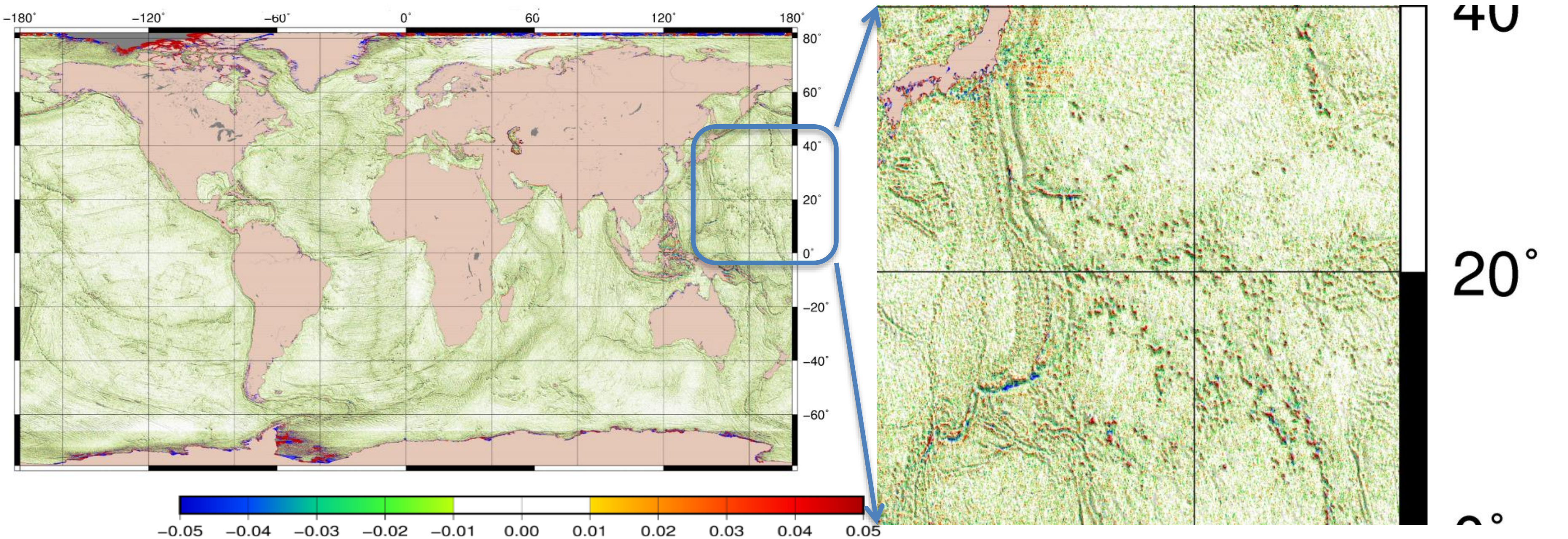
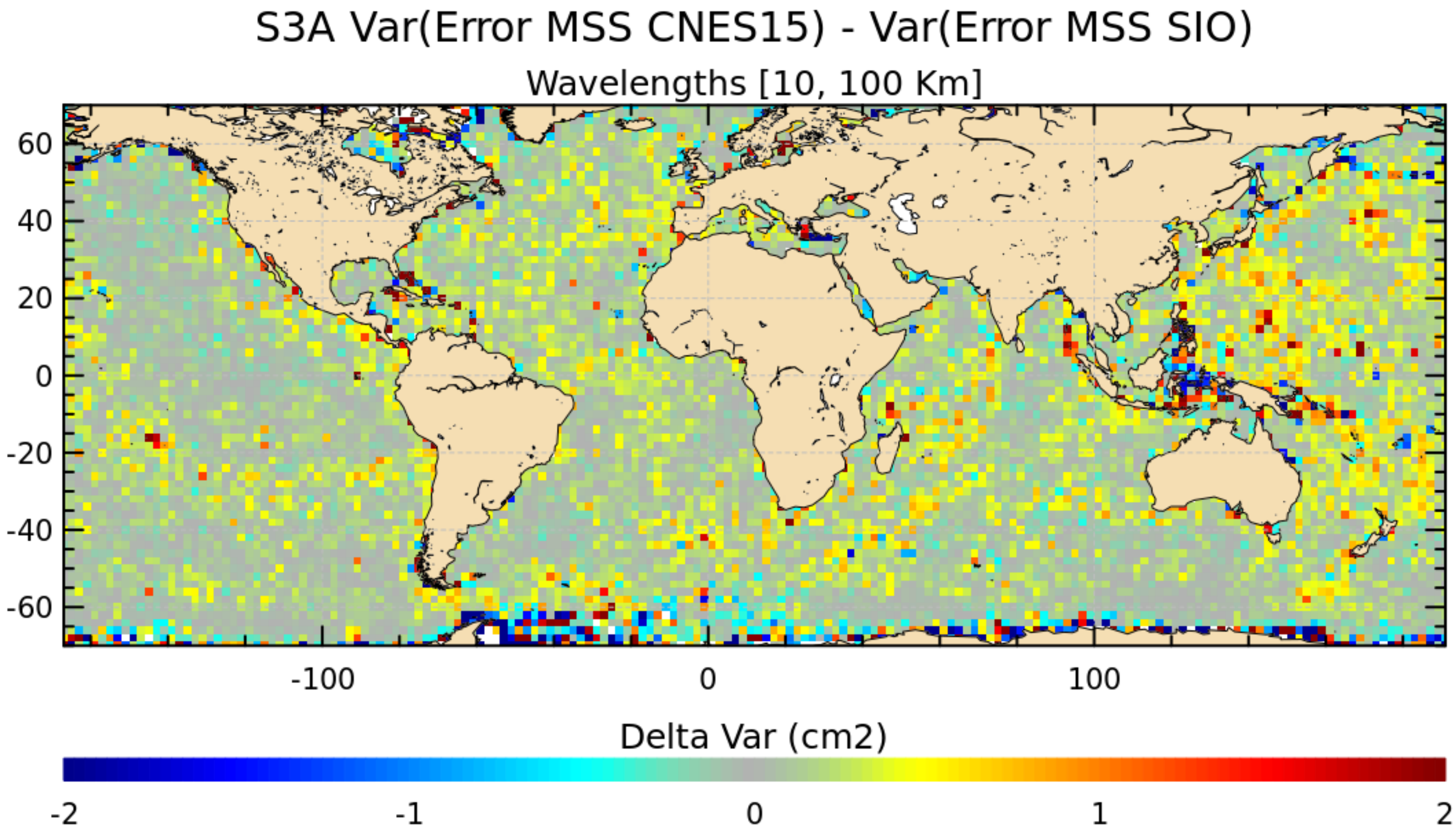


Fig: Differences between SIO & CNES-CLS 2015 MSS (cm)

Potential improvements with alternative processing

MSS_SIO: omission errors reduction wavelengths < 100km by a factor ~1/3 compared to the CNES_CLS15 model. Locally up to 2 cm² reduction.



Differences between CNES_CLS11 errors and CNES_CLS15 errors estimated at wavelengths ranging 10-100km

Potential improvements with Sentinel-3A

On going work: A precise MSS can be estimated along the Sentinel -3A tracks. It consist in a hybrid precise Mean Profile (HMP).

First estimation done with nearly 1 year (cycles 3-10 +12) of Sentinel-3A measurements at 20Hz resolution. 1 cycle kept independent (Cycle 11)

The methodology consists in:

1) colocation of the measurement at theoretical positions

2) correction of the ocean surface variability thanks to the DUACS merged products → limitation at wavelengths < 200km

3) Correction of the MSS gradients between observed and theoretical position

4) temporal mean of the collocated measurements

5) Merging the temporal mean and the MSS CNES_CLS15

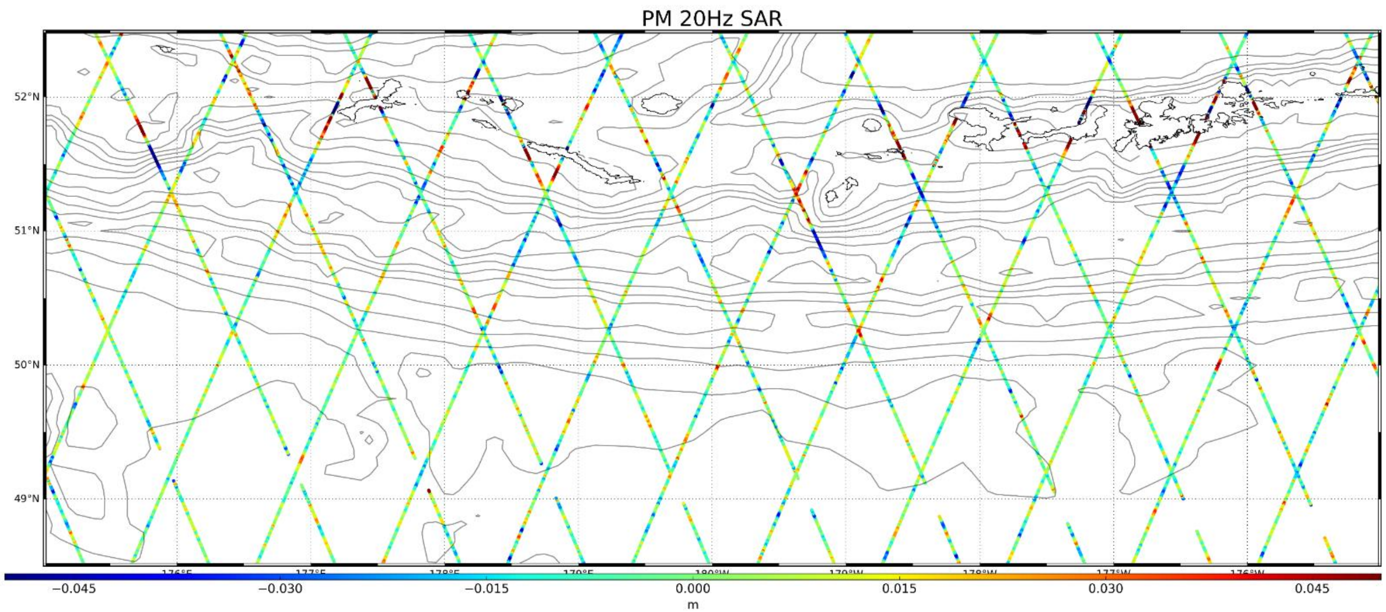
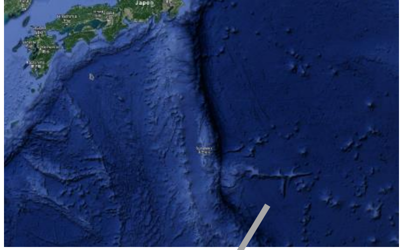
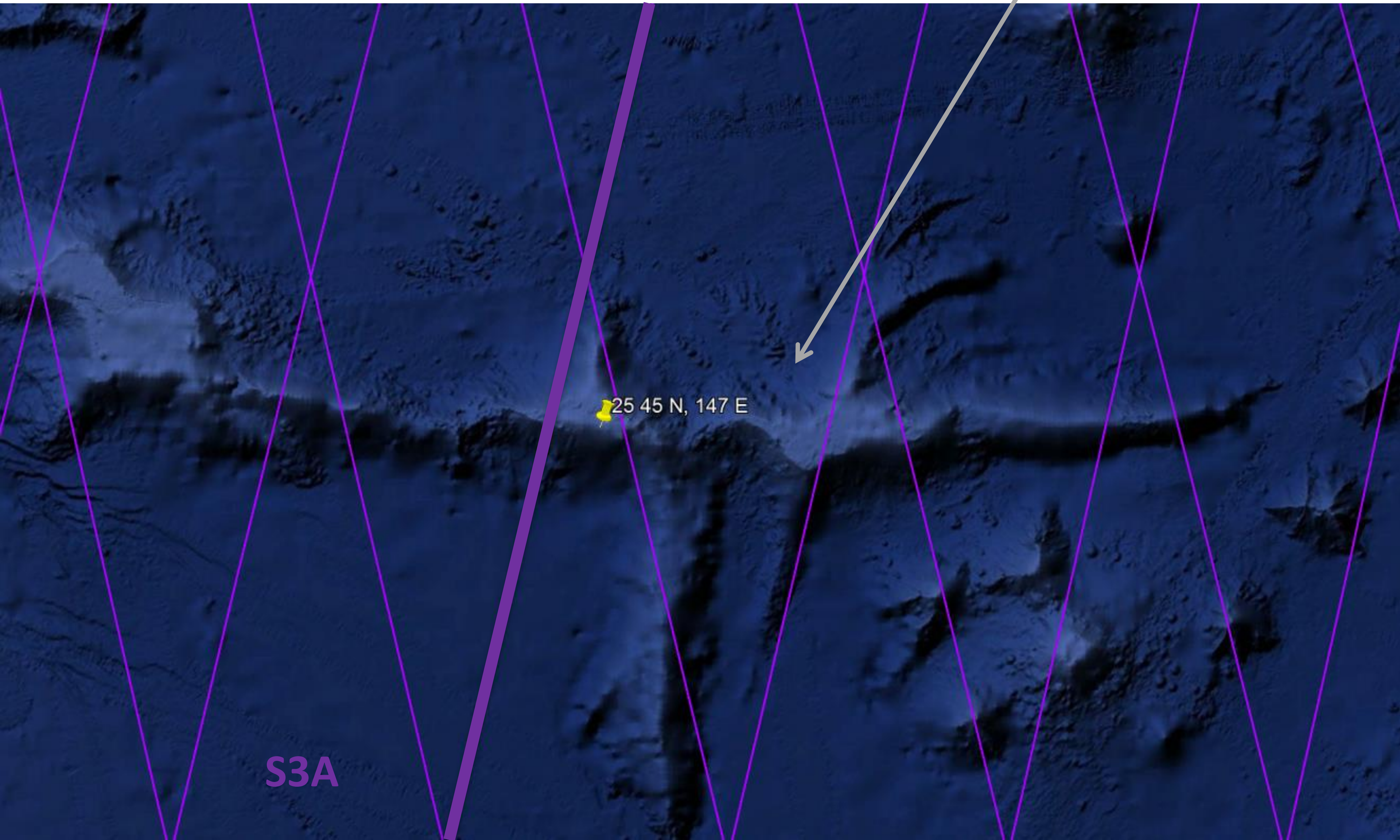


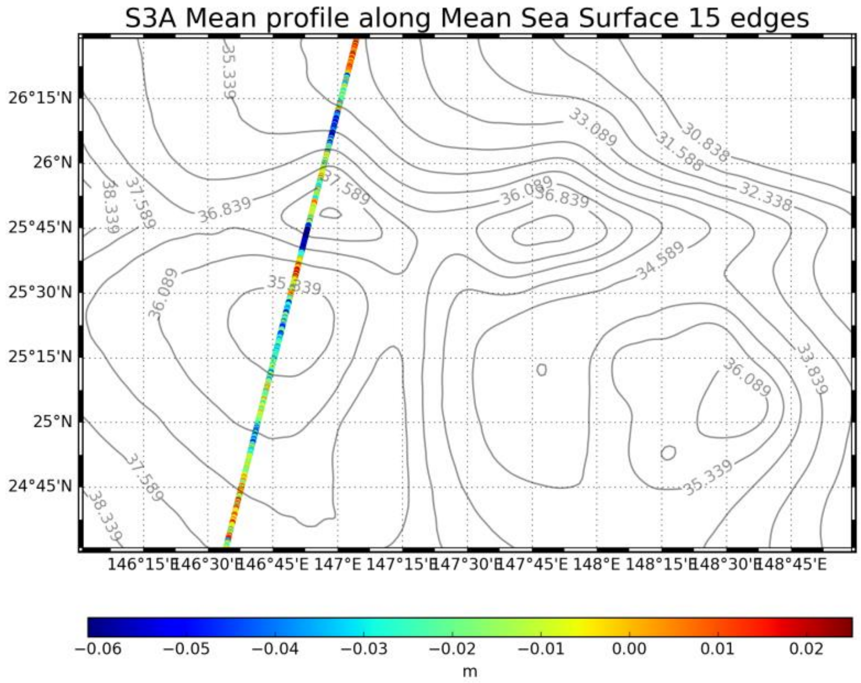
Fig: Differences between MSS CNES_CLS15 and HMP estimated along Sentinel-3A tracks *bathymetric structure south of Japan sampled by Sentinel-3A*



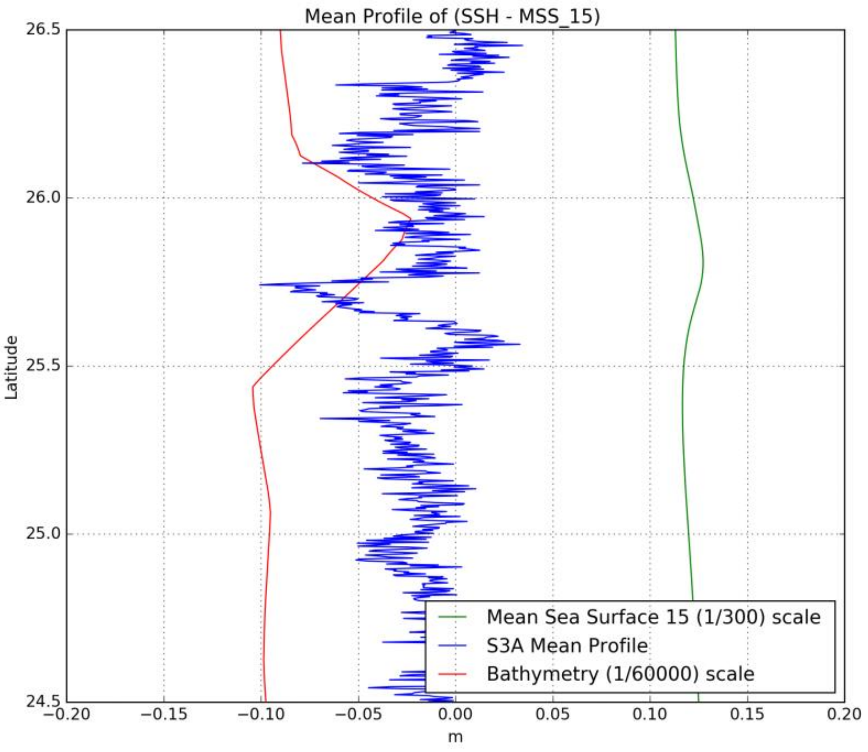


Potential improvements with Sentinel-3A

<u>On going work:</u> Preliminary results shows that the HMP estimated along the tracks of Sentinel-3A seems to resolve more accurately some MSS gradients: continental slopes, seamounts.



MSS contours and differences of Sentinel-3A HMP and MSS



Evolution of the bathymetry (red line), MSS_CNES_CLS15 (green) and Sentinel-3A HMP(blue) along the Sentinel-3A track

Potential improvements with Sentinel-3A

<u>On going work:</u> First analyses suggest a reduction of the MSS errors along the tracks of Sentinel-3A when using the HMP estimated along the tracks.
However, 1 year of Sentinel-3A does not allow to accurately reduce part of the ocean variability.

Using cycle 11
=>independant

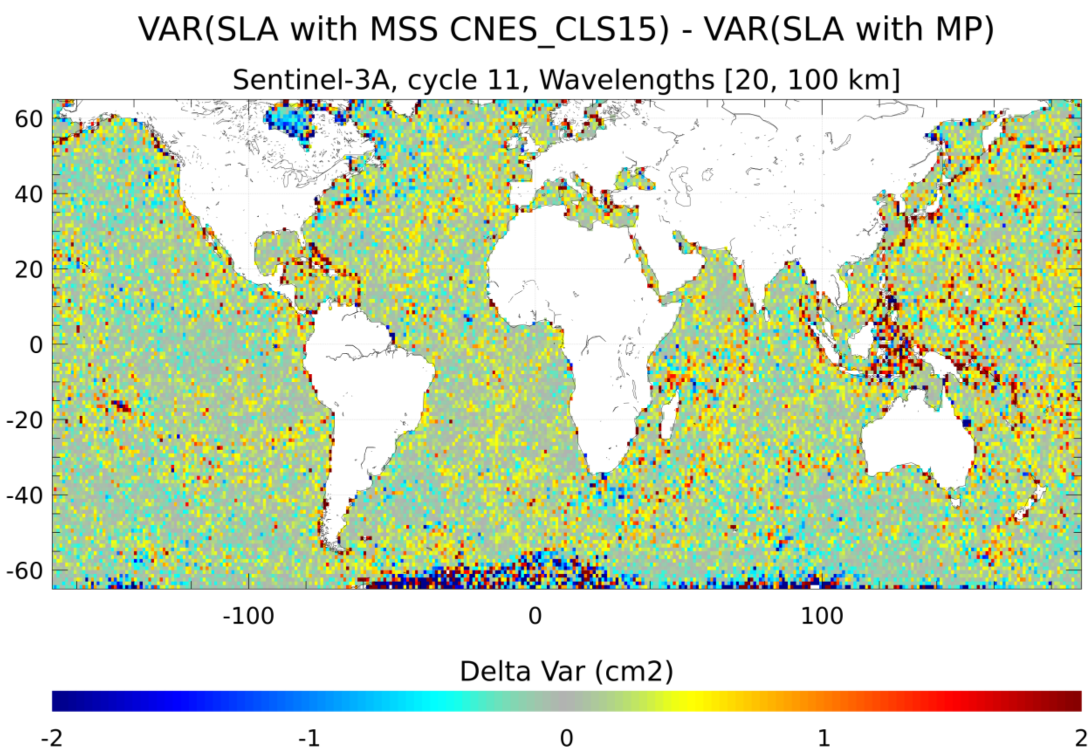


Fig: Differences between SLA variance estimated using the MSS CNES_CLS15 and using the Sentinel-3A along-track MP. Estimation done on cycle 11 kept independant for HMP estimation

Using a HMP along the Sentinel-3A track contributes to reduce the MSS errors along specific geodetic structures. → up to 2cm² reduction.

However, part of the SLA variance reduction underline significant commission errors : only few month of Sentinel-3A measurements available

Potential improvements with Sentinel-3A

<u>On going work:</u> First analyses suggest a reduction of the MSS errors along the tracks of Sentinel-3A when using the HMP estimated along the tracks.
However, 1 year of Sentinel-3A does not allow to accurately reduce part of the ocean variability.

Using cycle 12 =>not independant

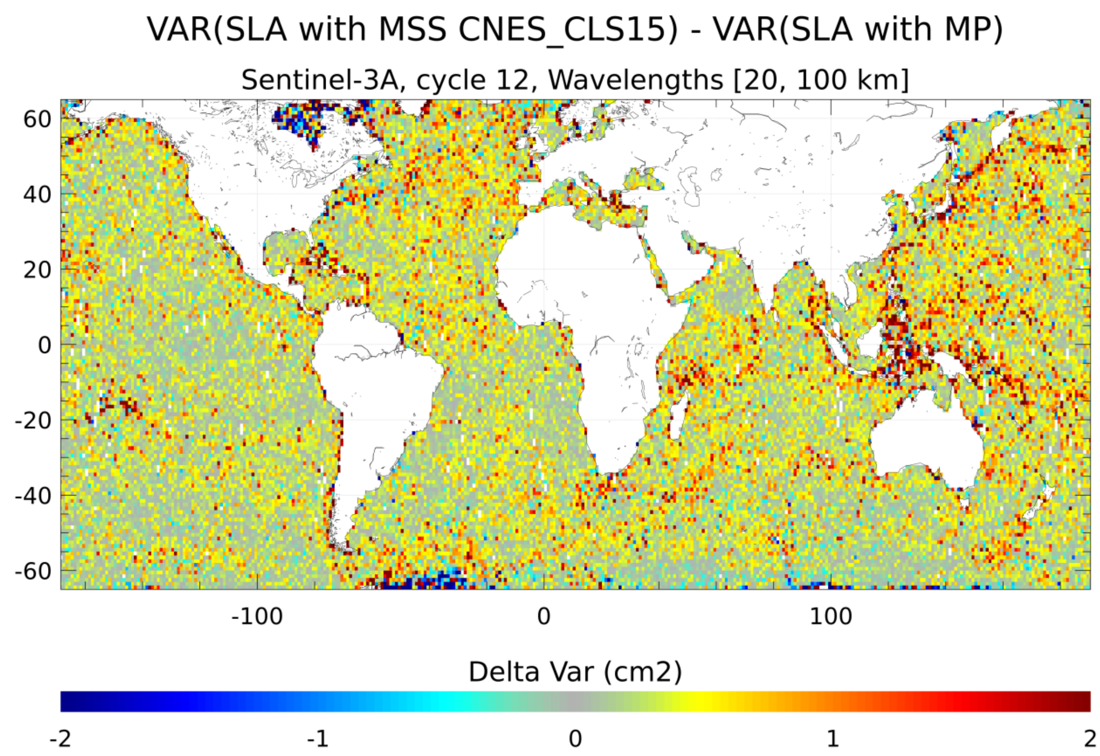


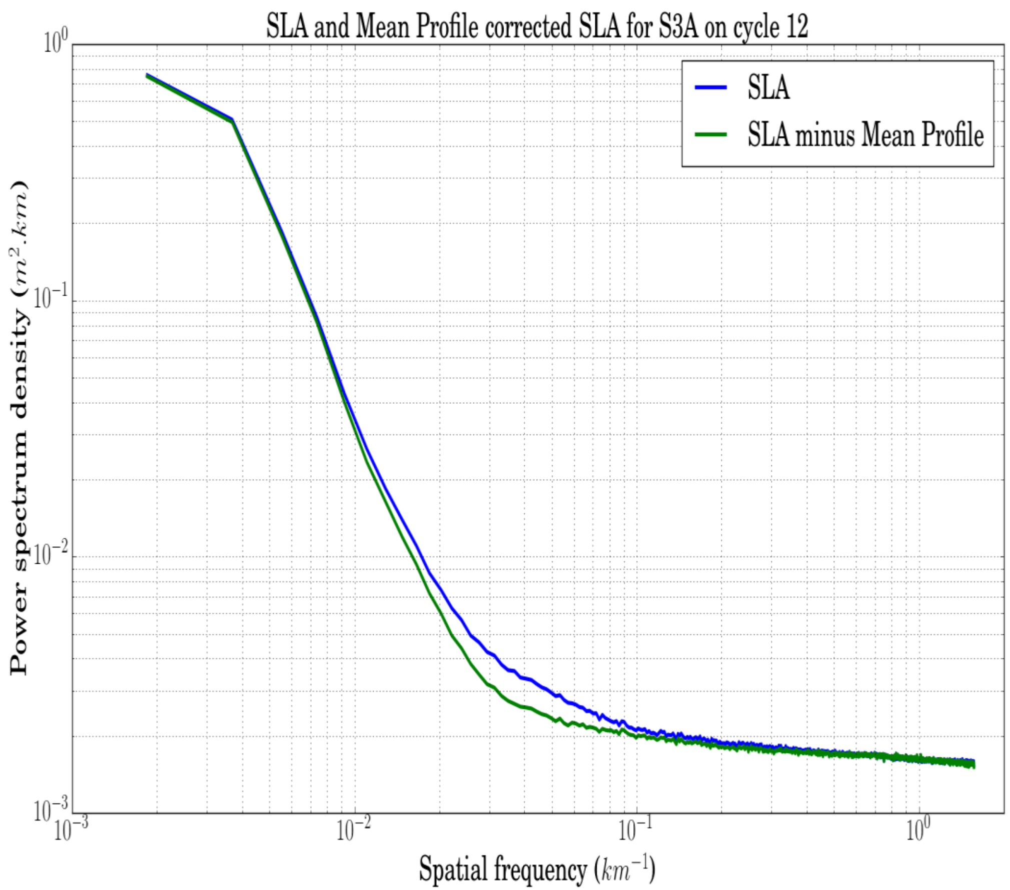
Fig: Differences between SLA variance estimated using the MSS CNES_CLS15 and using the Sentinel-3A along-track HMP. Estimation done on cycle 12 used for MP estimation

Residual commission errors observed on HMP induce a reduction of the SLA variance when considering a period used for MP estimation

➔ On going work to be consolidated

Potential improvements with Sentinel-3A

On going work: First analyses suggest a reduction of the MSS errors along the tracks of Sentinel-3A when using the HMP estimated along the tracks.



SLA variance reduction observed at wavelengths ~10-150km when using the HMP estimated along Sentinel-3A tracks.

➔ On going work to be consolidated

Fig: Sentinel-3A SLA PSD (cycle 12). SLA computed using MSS_CNES_CLS15 (blue) or HMP estimated along Sentinel-3A tracks (green)

Conclusions

MSS errors have been significantly reduced in the latest versions (CNESCLS15, DTU15)
→Important contribution of geodetic measurements

However, MSS errors remain significant along uncharted tracks:
➔ omission errors: **we need additional measurements (HR) on uncharted tracks**
➔ commission errors : **we need additional measurements to better average out the ocean variability**

The up-to-date MSS models do not allow us to access the smallest wavelengths (< ~30km) → **we need to improve the MSS estimation at small wavelengths** to benefit fully from new upcoming altimeter technologies. **Work is on going to improve the MSS estimation methodology** :

- Improved altimeter processing methodology → reduction of the noise measurement; better restitution of the MSS gradients
- Sub-optimal algorithm used to merge the gridded MSS and S3 HMP → Great potential of the SAR sentinel-3A measurement with reduction of the omission errors

Thank You !

Contact: mpujol@cls.fr