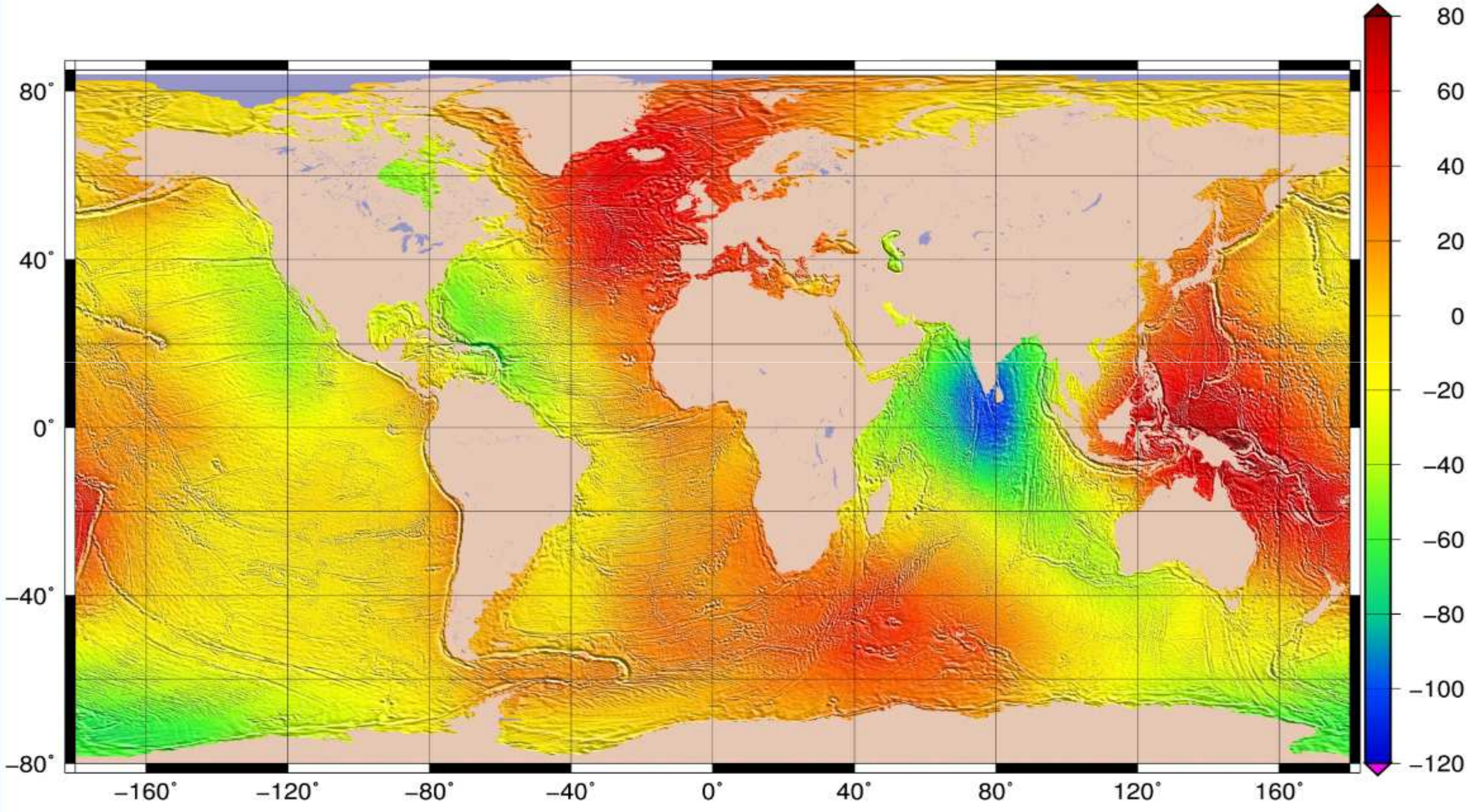
P. Schaeffer, I. Pujol, Y. Faugere(CLS),
A. Guillot, N. Picot (CNES).

# The CNES CLS 2015 Global Mean Sea surface




OST-ST, La Rochelle, October 2016.

CLS
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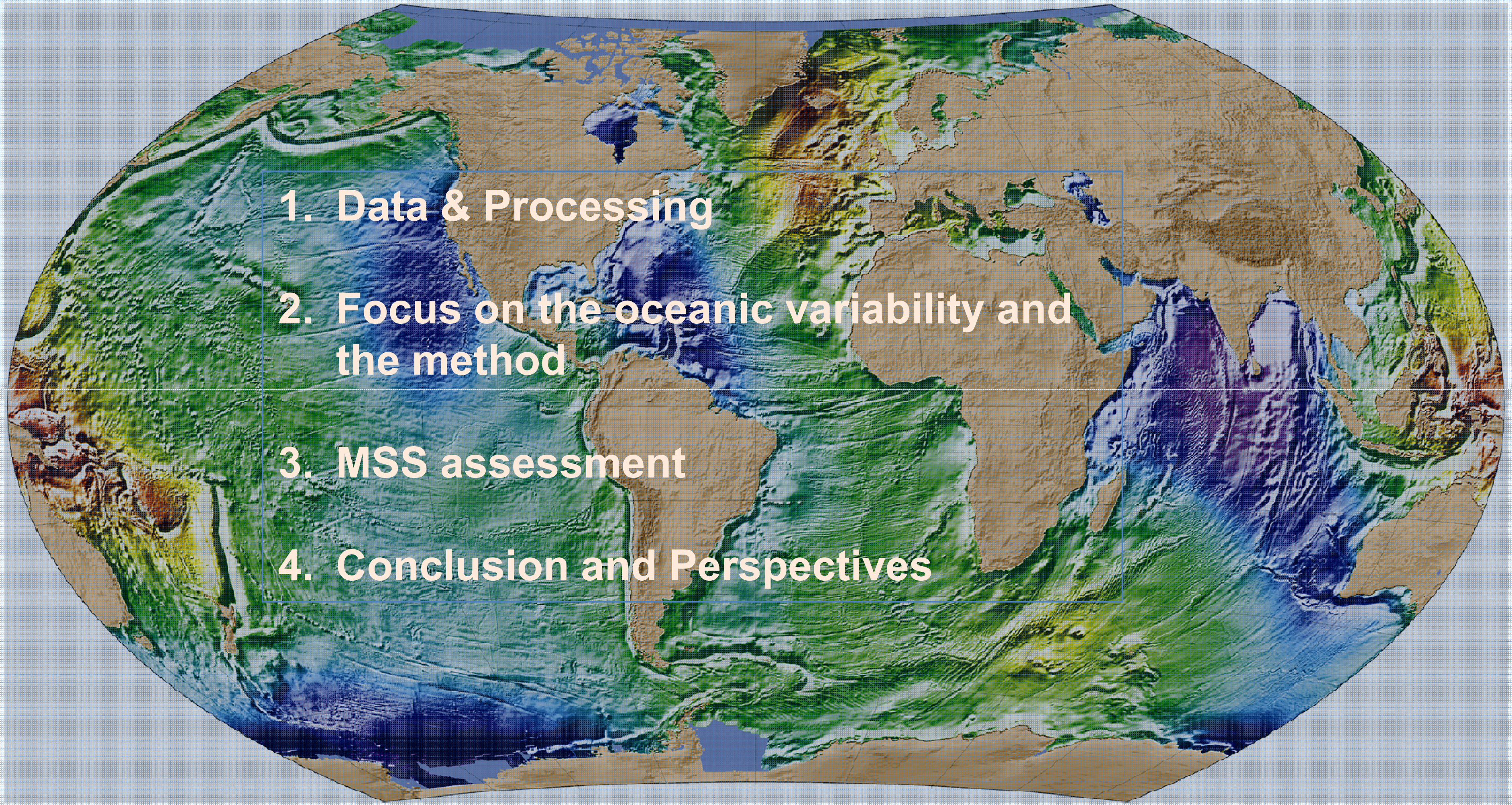
# Plan



1. Data & Processing

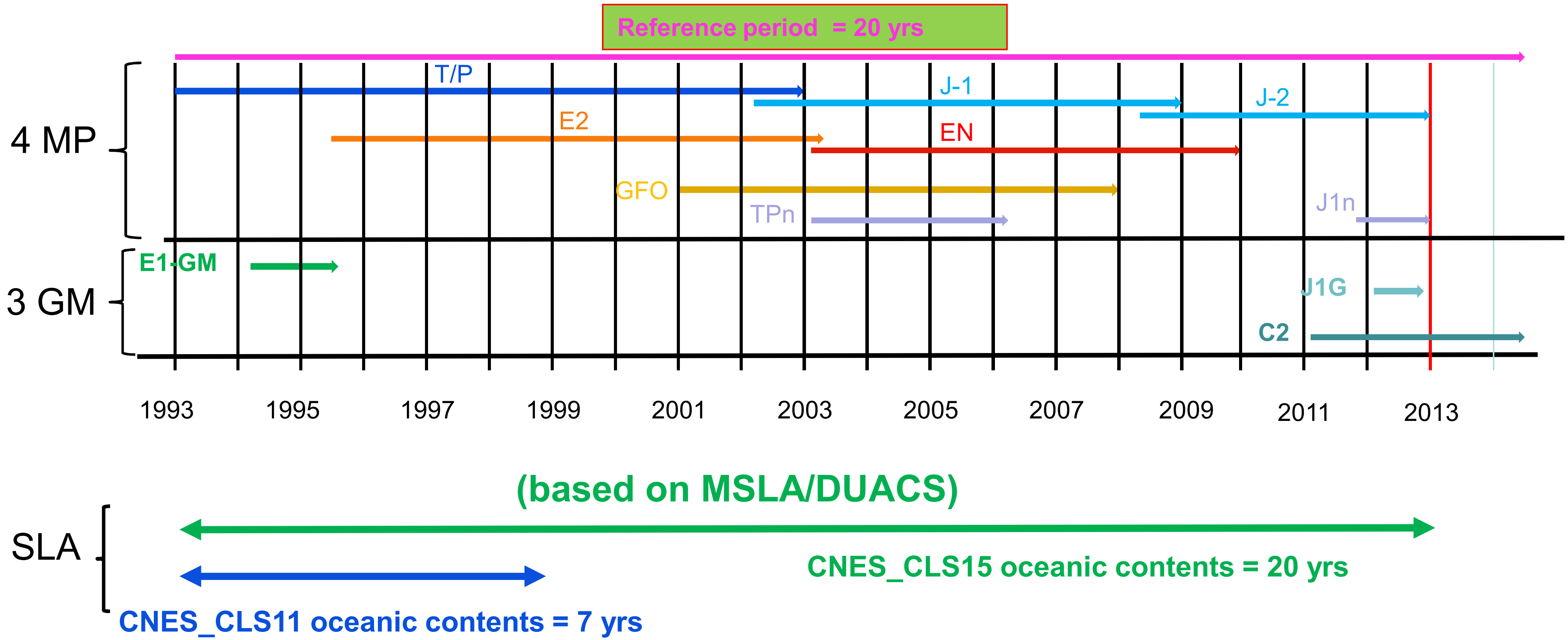
2. Focus on the oceanic variability and the method

3. MSS assessment

4. Conclusion and Perspectives

# Data & *Processing*

**Dataset :** **using a total of 20 years of altimetric data (Mean Profiles, Geodetic Mission, and SLA)**

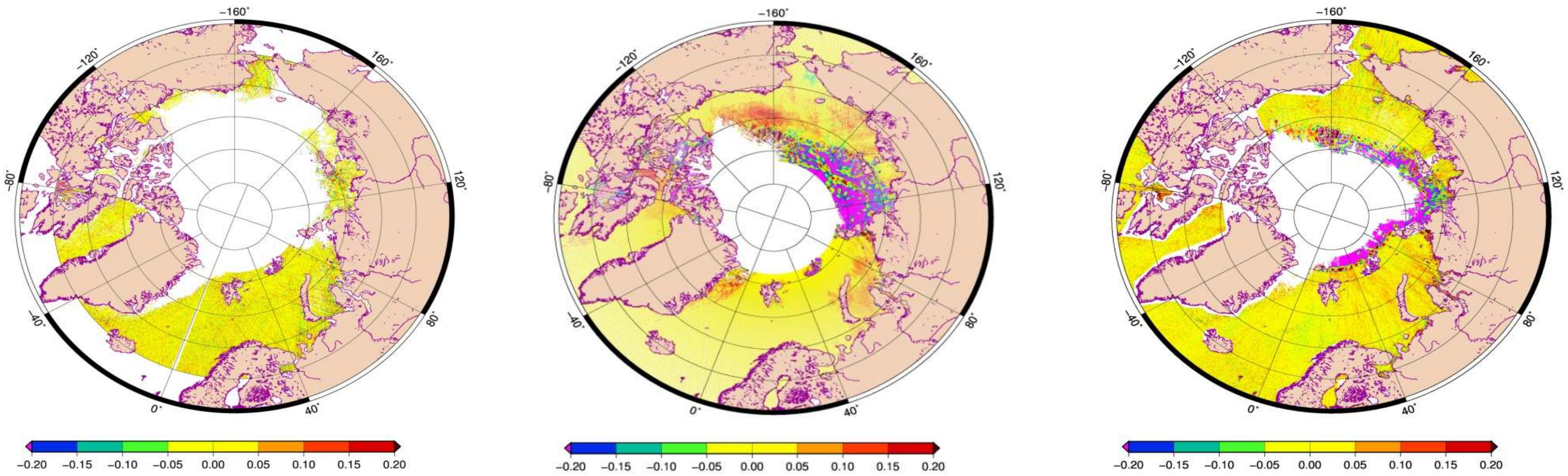



MP+GM represent more than 100 million observations !

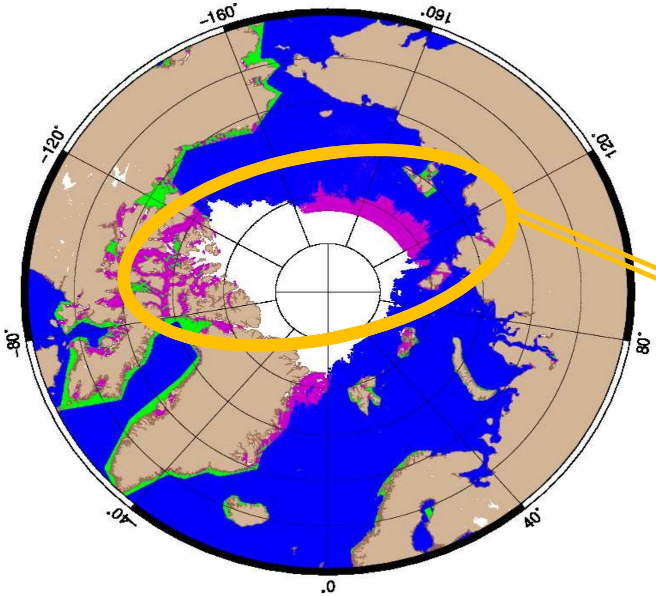
# Data & *Processing*

## Coverage in Arctic: significant improvement !

E1-GM(1994-1995) MP E2EN (1995-2010) C2 (2012-mid2014)




Differences between $SSH_{cor}$(2015) and MSS 2011 (meter)




Data coverage for MSS 2015: : E1GM, E2EN, and C2 **are complementary** !

**New area (2015 vs 2011) !**

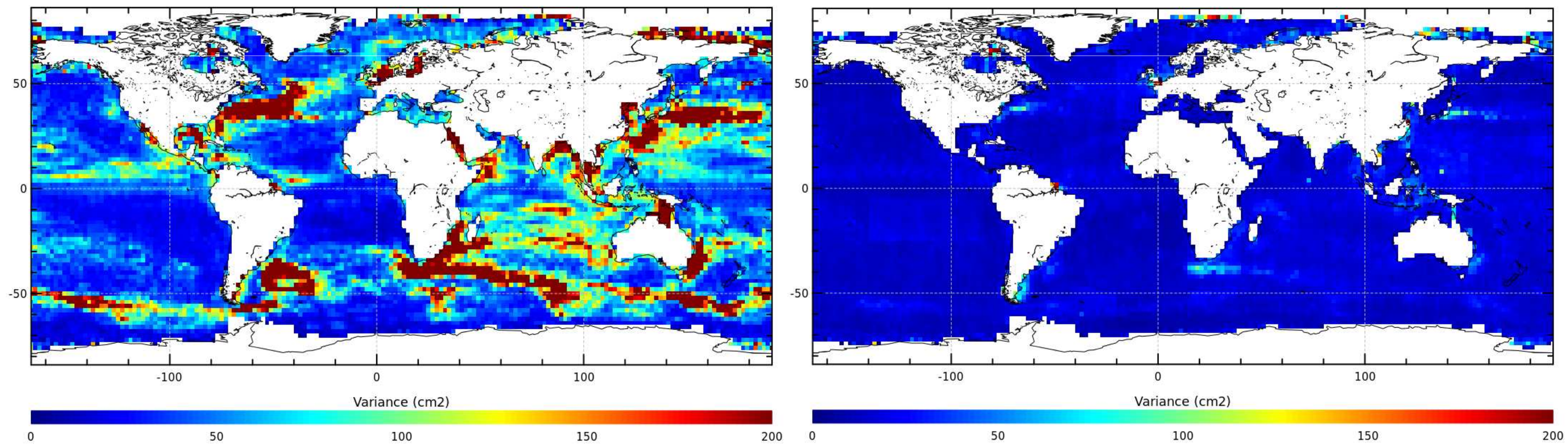
# Removing Oceanic Variability
## Objective Analysis of SLA

- **Computation of Mean Profiles & Geodetic Missions:**
  - ➢ interannual & seasonal oceanic variability corrected from Optimal Analysis of SLA (Le Traon et al, 1998) >>> $\mathbf{SSH_{cor}(t,\lambda,\varphi) = SSH(t,\lambda,\varphi) - OA[SLA^{i}_{(t,\lambda,\varphi)}]}$
  i=(1,N) defines a set of SLA surrounding the SSH in a space-time bubble.

- A particular attention is necessary concerning Geodetic Missions for which time averaging is not possible.

Variance of Cryosat-2 SLA before and after dynamical SLA variability correction.

**Before SLA variability correction** **After SLA variability correction**




- The method developed allows us to reduce drastically the effect of the oceanic variability.
- It also give us the possibility to homogenize the mean oceanic content which is different for certain missions (GFO, 2001-2008) with an arbitrary period (1993-2013).

Le Traon, P.-Y, et al (1998). An improved mapping method of multisatellite altimeter data. J. Atmos. and Oceanic Tech., 15, 522-534.

# Data & Processing

- **Computation of the MSS**:

  ❑Optimal Interpolation (details are given in Schaeffer et al, 2012)

- **specific characteristics:**

➢ Anisotropic covariance model.
➢ Noise budget (3 components: instrumental, residual effect of the oceanic variability, long wavelengths bias)

➢ new covariance matrix each 5 km (3 minutes) which implies local adjustment of covariance function
➢ inversion of this MSS represent more than 16 million matrix (of 2500 elements)

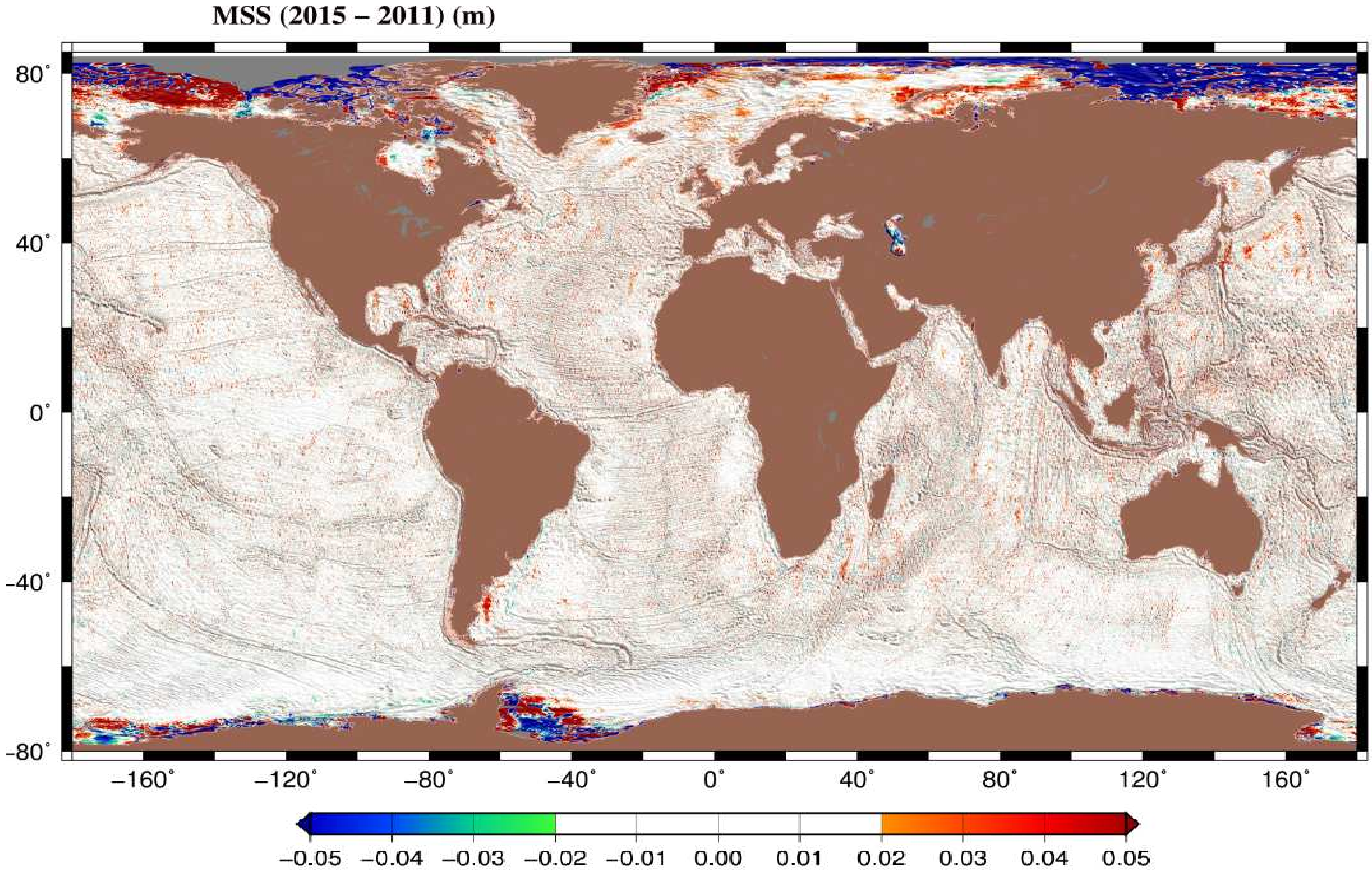
➢ Spatial coverage 80°S / 84°N
➢ Cartesian grid with a step of 1 minutes (1.8 km/eq)
➢ Calibrated error (Xover).

Schaeffer P., et al (2012). The CNES CLS11 Global Mean Sea Surface Computed from 16 Years of Satellite Altimeter Data. *Marine Geodesy*, 2012, Special Issue, *Jason*-2, Vol.35.

# MSS_CNES_CLS_2015 improving the shortest wavelengths

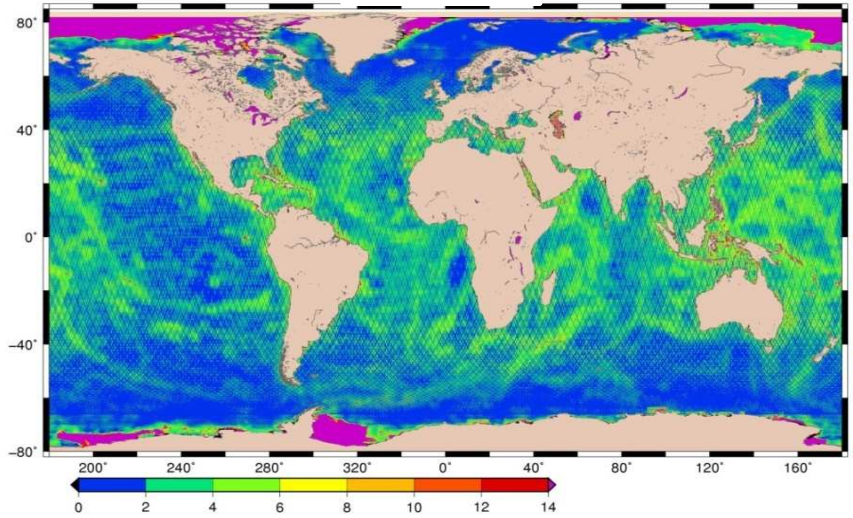


➢ Globally, differences between 2015 and former 2011 MSS are dominated by topographic structures at the shortest wavelengths !

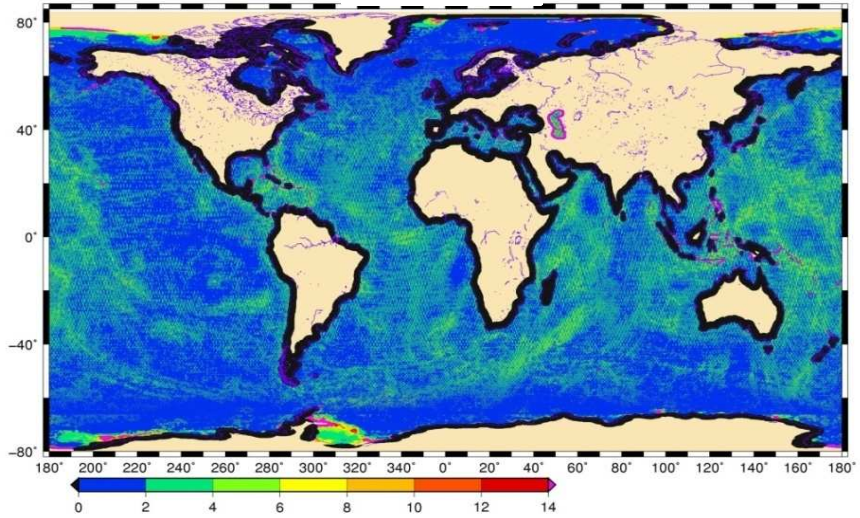


# Improving the accuracies (since 2001)

CLS2001

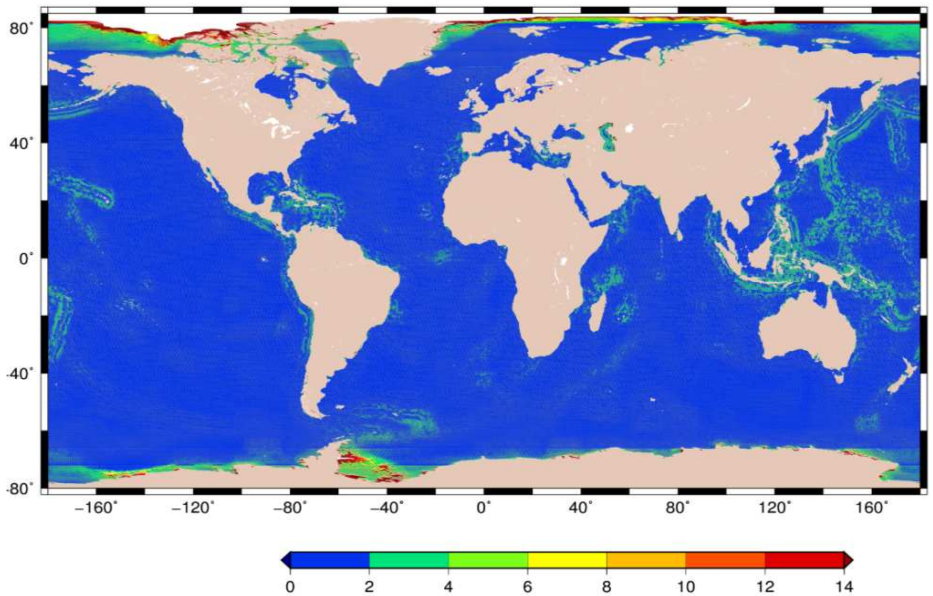



CNES_CLS2011




**Error (cm)**

CNES_CLS2015




Remember that error is adjusted on crossover statistics

| Error (cm) | average | std |
|---|---|---|
| CLS01 | 2.9 | 3.7 |
| CNES_CLS11 | 1.9 | 2.1 |
| CNES_CLS15 | 1.4 | 1.3 |

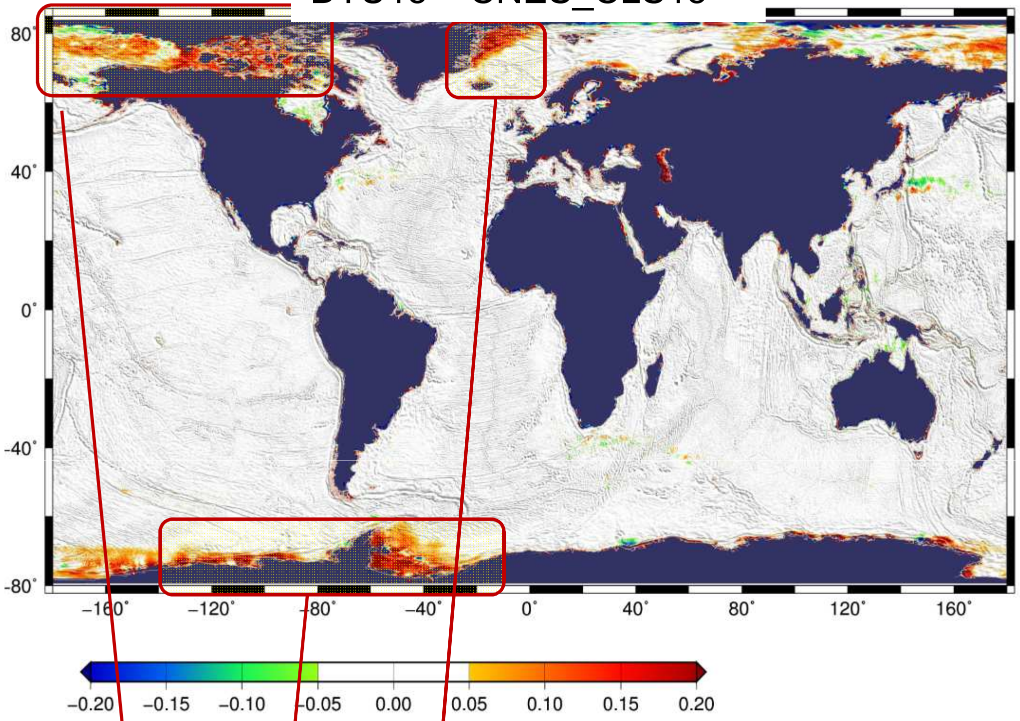
- The reduction of the average is greater than 100 %, and close to 200 % for the std !
- Improvement of the error uniformity suggest better homogeneity concerning the accuracy of the new MSS !

## Difference with DTU15

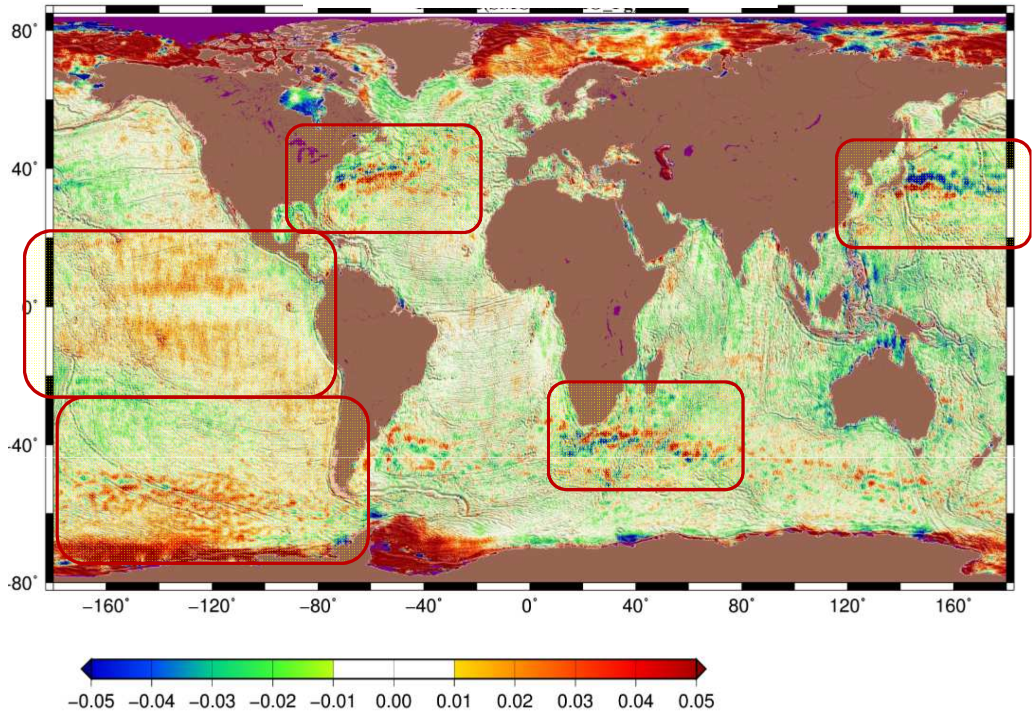
Two complementary differences: from the point of view of the amplitude

over 5 cm versus lower 5 cm

DTU15 – CNES_CLS15




DTU15 – CNES_CLS15




Shading = wavelengths of MSS < 150 km

C2 different period !

Globaly, the 2 MSS are closed,
no significant geophysical structure appears !
(confirmation in the next slide)

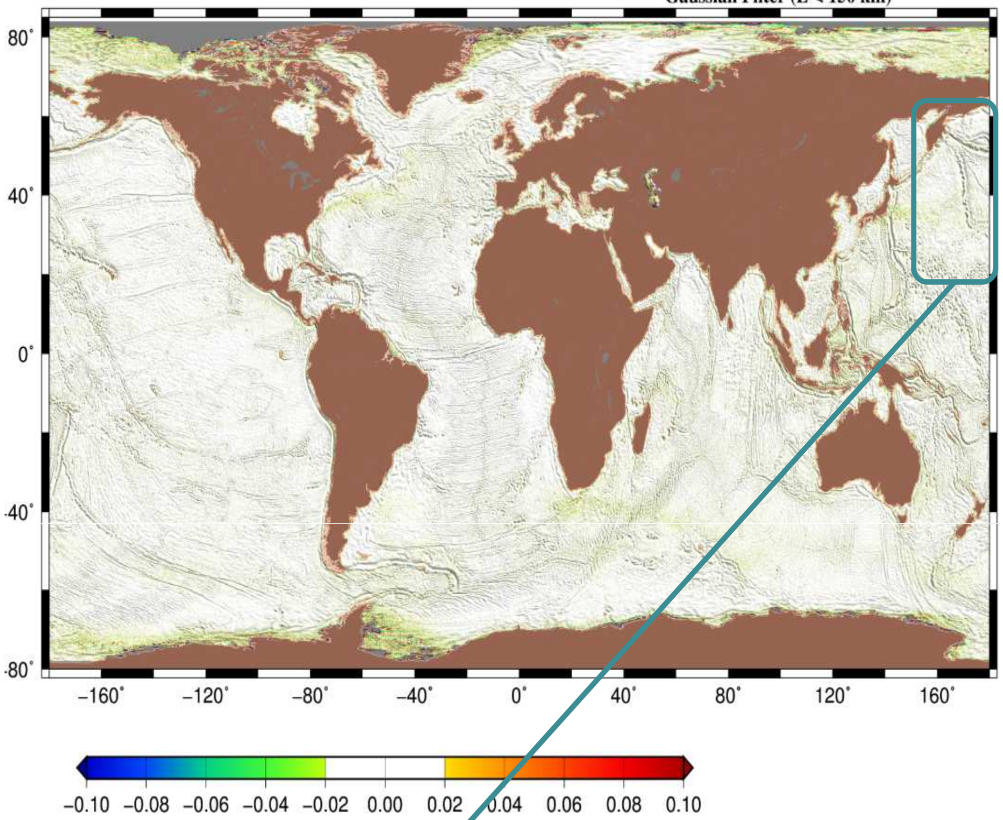
On a scale of few cm: differences are dominated by residual effect of the oceanic variability ! (*despite the 2 MSS are referenced to a similar period of 20 y).*

# In the same order of ideas, comparison to DTU15 at different wavelengths



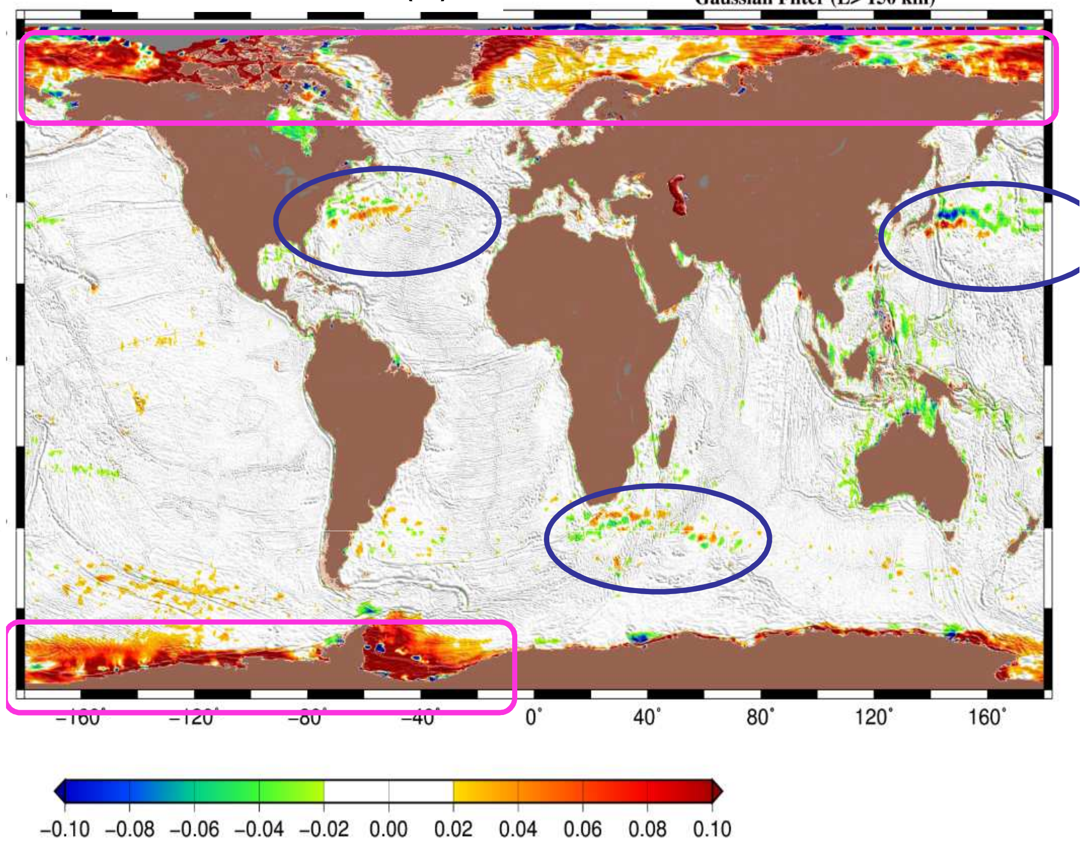
Short wavelengths λ < 150 km

**Dif DTU15 – CLS15 (m)**




Long wavelengths λ > 150 km

**Dif DTU15 – CLS15 (m)**




*Zoom on the Hawaiian-Emperor seamount chain*

- No significant difference at short wavelengths.

- The difference between the two MSS at long wavelengths still contains residue of ocean variability and also shows differences concerning the data processing or the time coverage of C2 at high latitude.

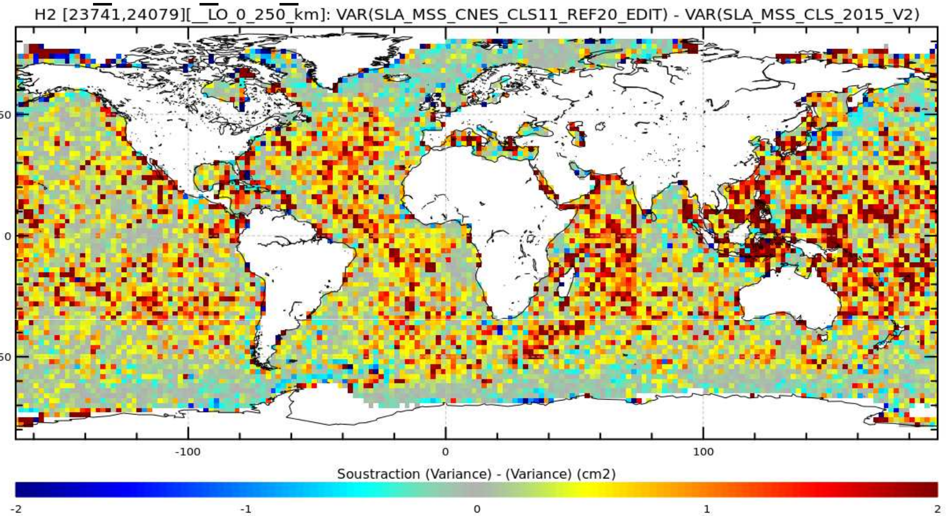
# MSS_CNES_CLS_2015 assessment using the variance of the SLA



= = = = > assessment with HY-2A (not used for these MSS)

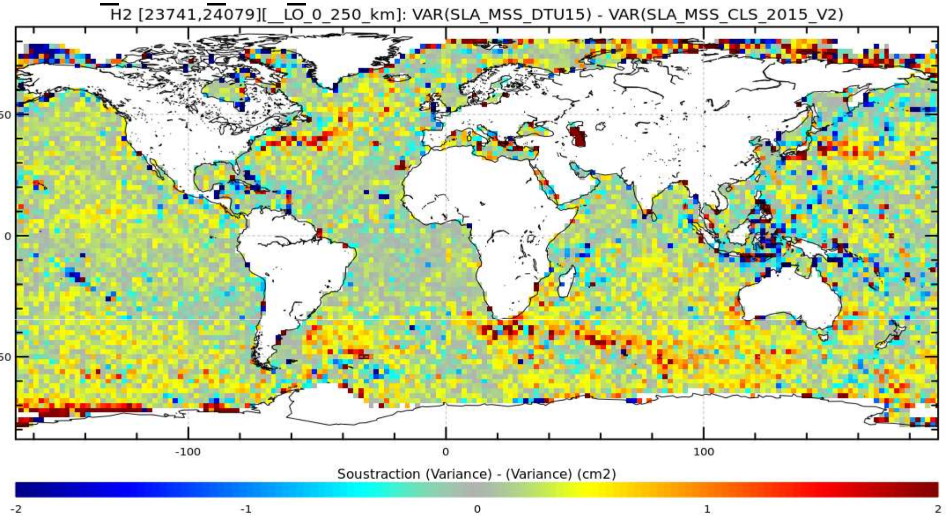
- Difference of the variance of the SLA selected for wavelengths < 250km
- Statistics computed over year 2015

Dif of SLA variance using MSS_CNES_CNES_CLS_2011 and MSS_CNES_CLS_2015.




VAR(SLA MSS CNES_CLS_2011) – VAR(SLAMSS CNES_CLS_2015)
(Wavelengths [0, 250 km])

Dif of SLA variance using MSS_DTU15 and MSS_CNES_CLS_2015.




VAR(SLA MSS_DTU15) – VAR(SLA MSS_CNES_CLS_2015)
(Wavelengths [0, 250 km])

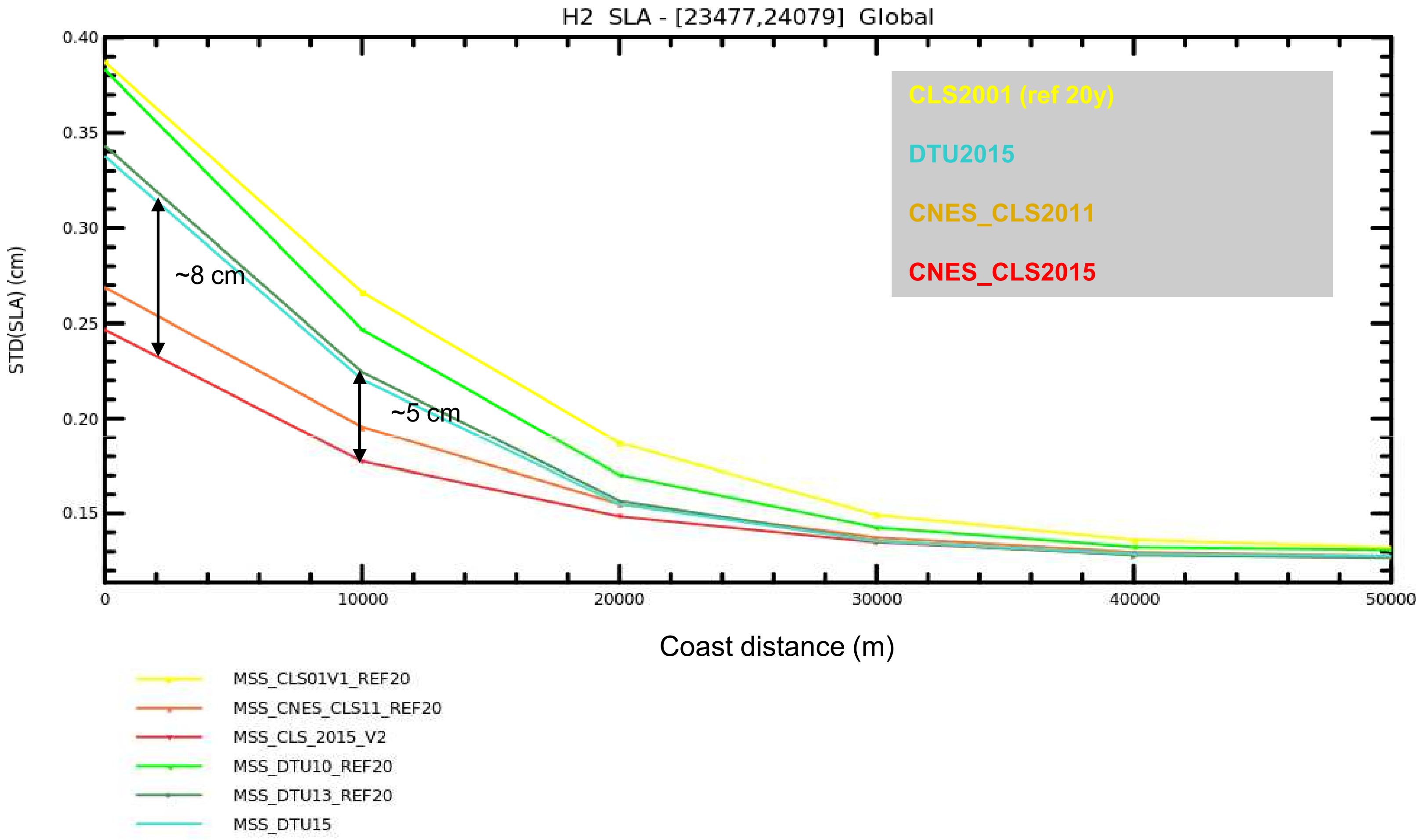
High differences in red color are strongly correlated with topographical structures. This mean that the former 2011 MSS is smoother than the new CNES_CLS  2015 MSS

In this case, we remark that the differences are correlated with areas of strong currents which suggest that CNES_CLS15 is probably better corrected from the oceanic variability than DTU15. Note that here is no correlation with topographical structure. This indicates that these 2 MSS have similar contents at the shortest wavelengths.

# MSS_CNES_CLS_2015 assessment near the coasts



➢ STD of the SLA along HY-2A tracks as a function of the distance to the coast, and using different MSS solution. (Latitudes > 60° are excluded).

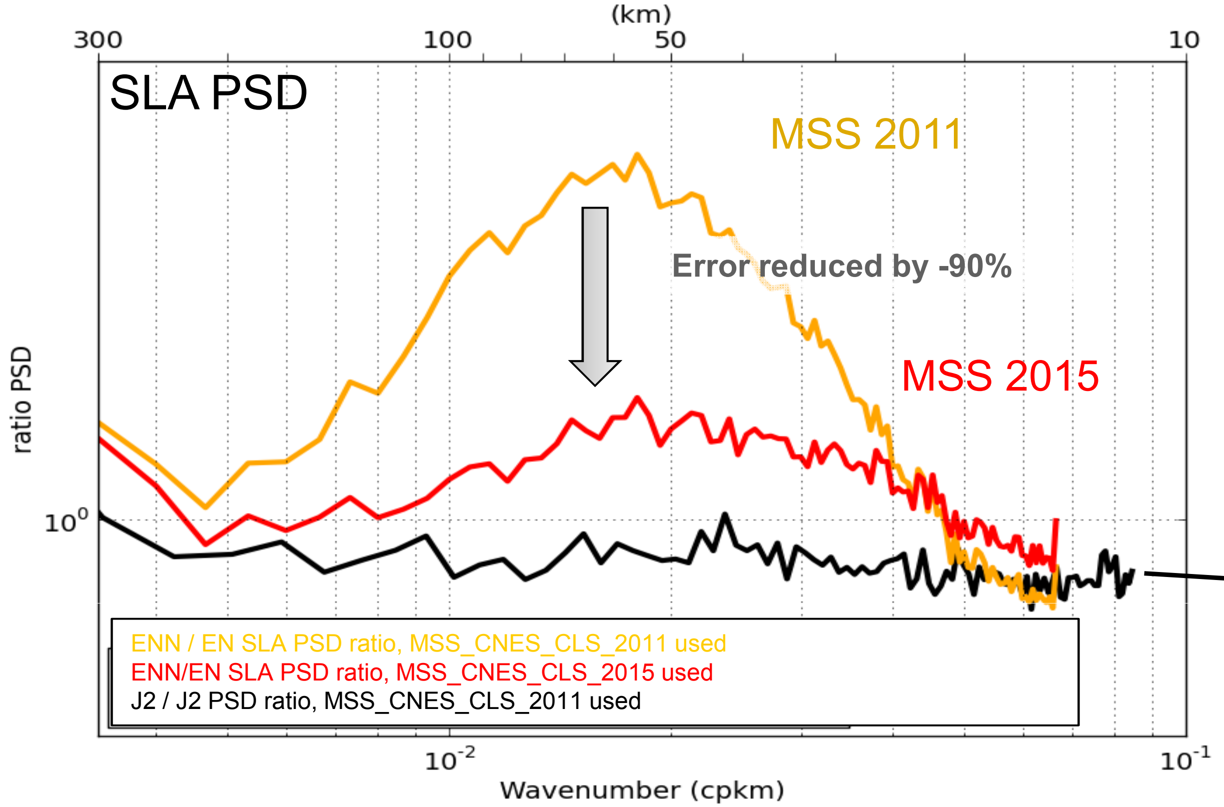



• The main differences can be observed in the [0, 30km] band approaching the coast.

• Costal areas are better retrieved with CNES_CLS_2015 MSS.

# MSS_CNES_CLS_2015 assessment using ENN SLA PSD






More details will be presented tomorrow by I Pujol in the session dedicated to the errors

**Reference is the J2 ratio during ENN period.**

- Comparison of SLA PSD along repetitive tracks and drifting tracks reveal **omission errors on MSS_CNES_CLS_2011 for wavelength < ~200km.**

- **Reduction of the MSS error along Envisat drifting tracks**
  - Maximal error reduction near wavelength of 60km.
  - MSS Error reduction on the [0, 200km] wavelength range : -90% (-0.8 cm rms)

- **Results also confirmed along independent HY-2A tracks**

- **Note that ENN is also not used for MSS_CNES_CLS computation.**

# Conclusion

The key points of this new CNES_CLS 2015 MSS

✓ *a drastic improvement of the shortest wavelengths,*

✓*a better correction of the oceanic variability,*

✓ *a reduced degradation of SLA near the coast.*

✓ *globaly, strong reduction of errors when computing SLA*

✓ *more homogeneity of accuracy compared to the former versions*

# Perspective

Key issues for the next MSS generation:

✓ Improve resolution with data sampled at frequencies greater than 1 Hz
✓Continue to improve correction of the ocean surface variability,
in particular for wavelengths < ~200km.
✓MSS estimation strongly benefits from geodetic missions. Reduction of the ocean variability along theses tracks is however primordial.
✓Continue improvement in Coastal areas

- This new MSS will be soon available to user:
http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/mss/index.html