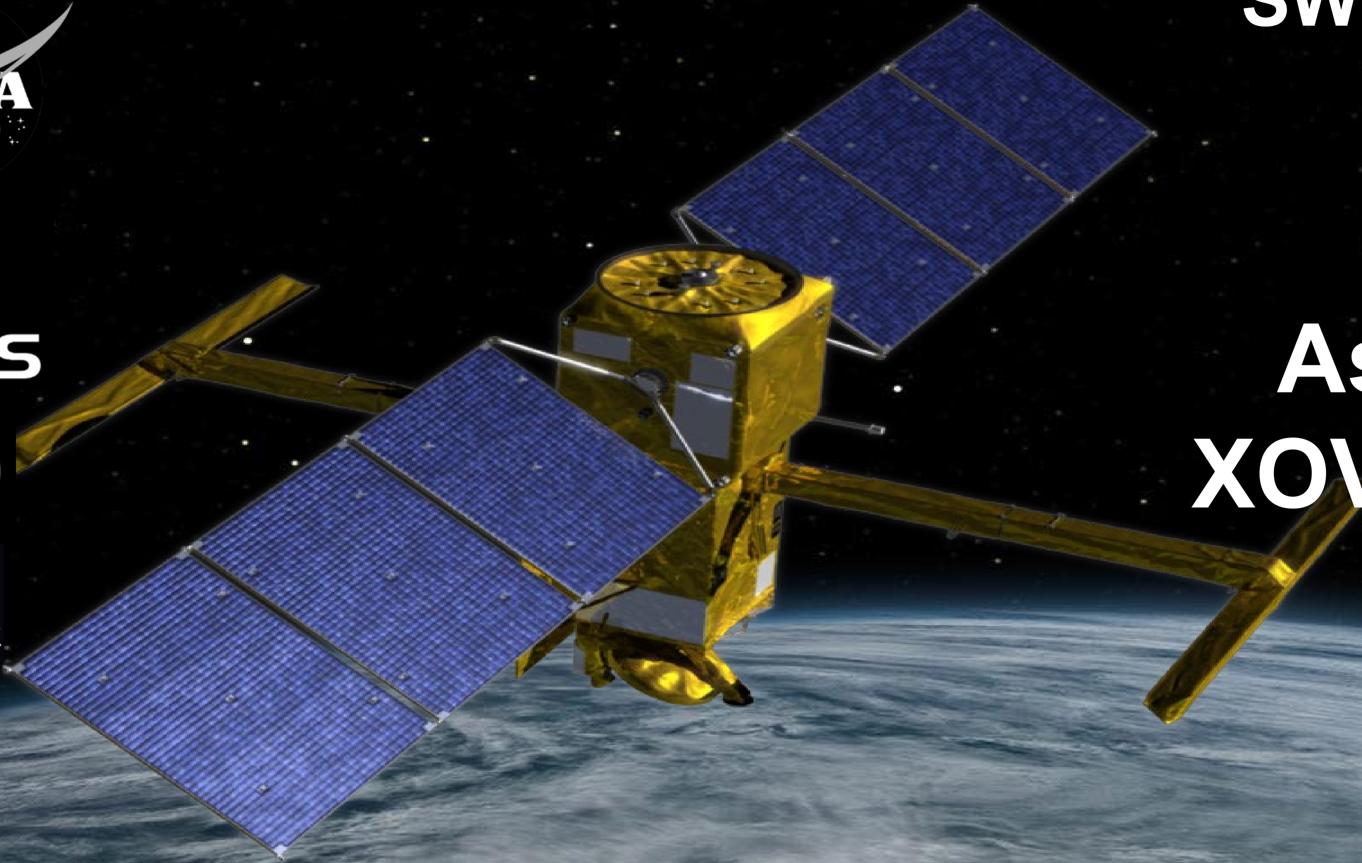
SWOT validation meeting

17-21 June 2024



Assessment of the XOVER performances

CNES and CLS Calval Team

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CLS : Benjamin Flamant, **Maxime Vayre,** Pierre Prandi, Emeline Cadier

DATLAS: Clément Ubelmann

OUTLINE

- **Quick reminder on what systematic errors look like**

- **XCAL performances analysis**
  - **Ocean**
  - **Land**
  - **Over Land using a Virtual continent definition**

- **XCAL quality flag : is adressed in next presentation**_"Crossover Calibration Plans for Future"_

Context

- KaRIn SSHA is impacted by systematic errors at scales above 1000 km (negligeable impact below)
- The L2 Xover calibration aims at estimating these systematic errors
- There is no requirement on the quality of the Xover correction over Ocean. The correction is not necessary to measure ocean topography features below 1000km.
- The correction is however particularly important for Hydro applications. The requirement specifies that the residual error after correction of the systematic errors should be lower than 7.4 cm .

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3 components of systematic errors

Antenna roll angle is not perfect?
Phase error in processing?

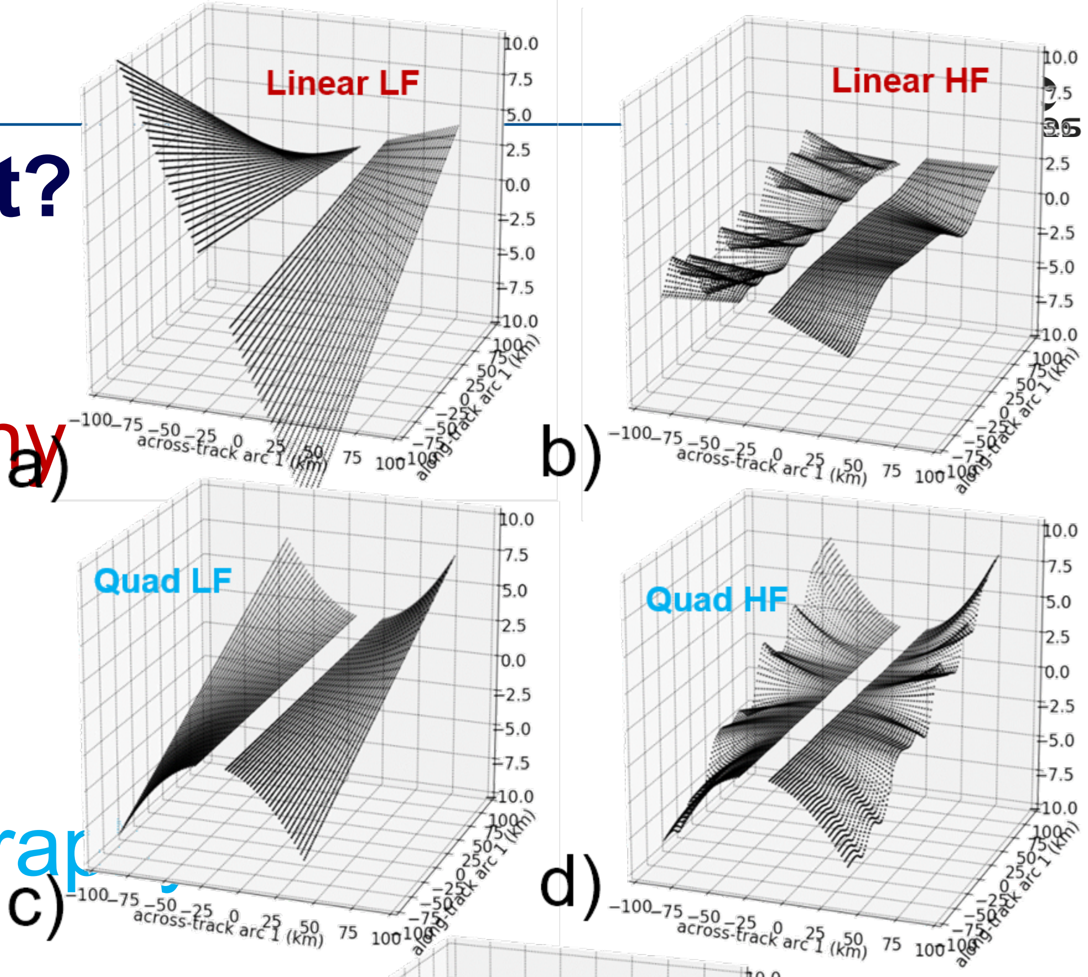
- Linear cross-track topography

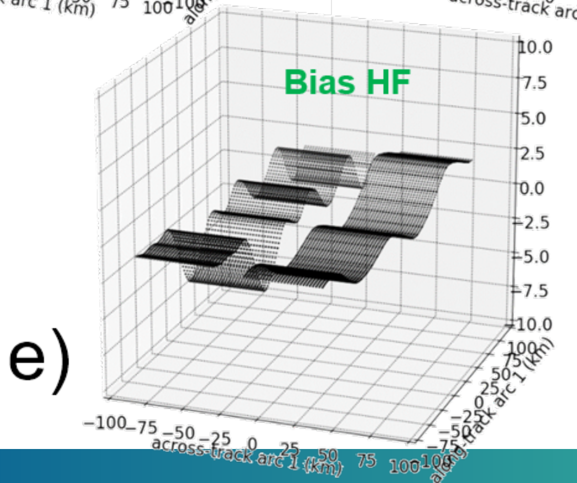
Baseline length is not perfect?

- Quadratic cross-track topograp

Range timing bias in KaRIN?

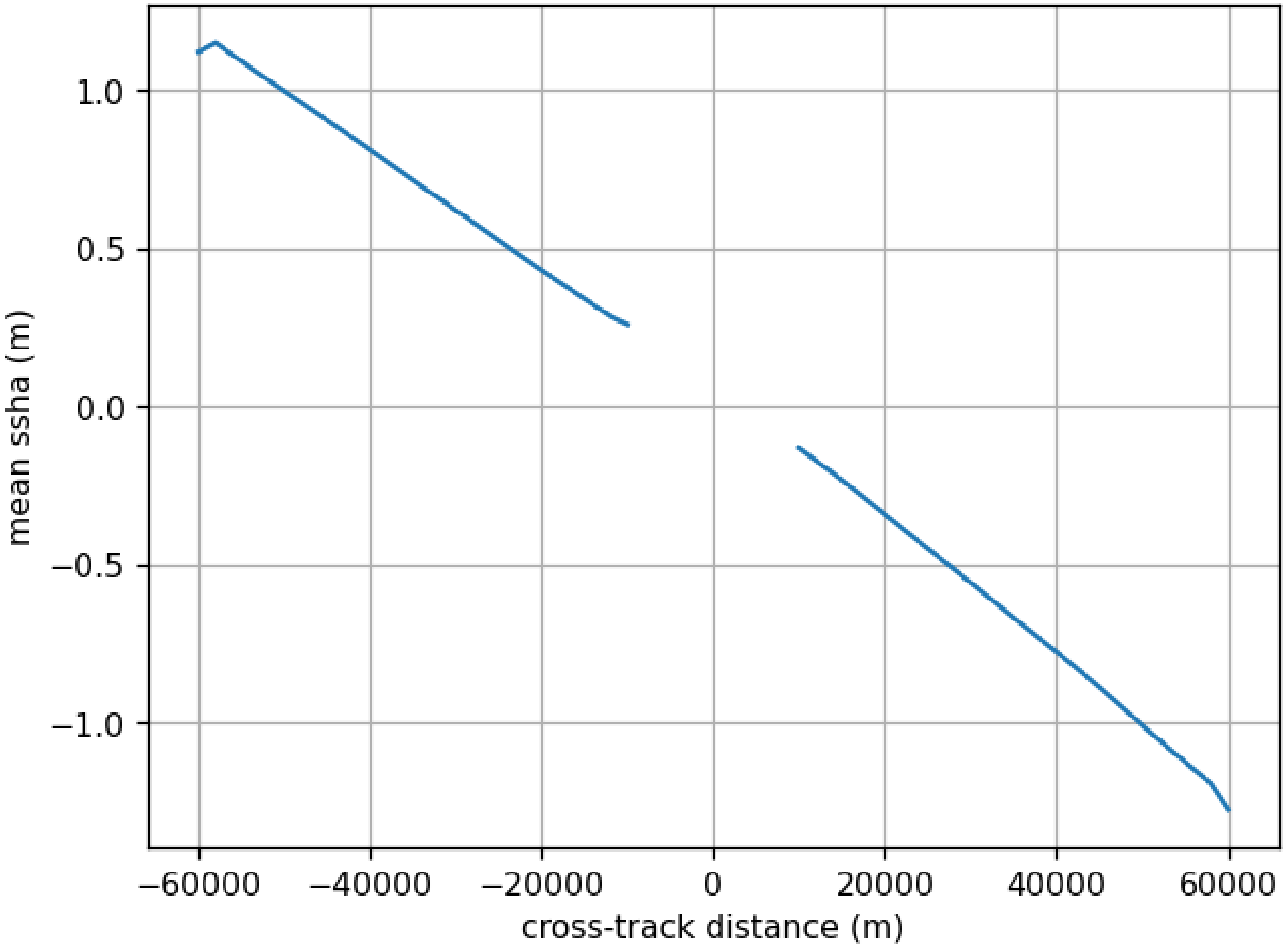
- Time-varying offset topography





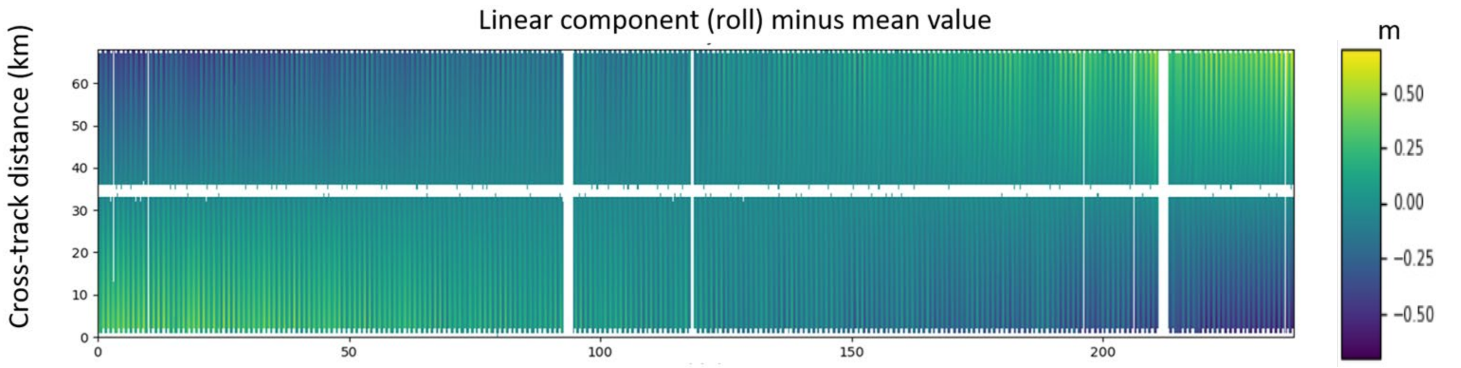
Note : actual Z scales range from millimeter-level to meter-level (see next slides)

First order (o 1m)

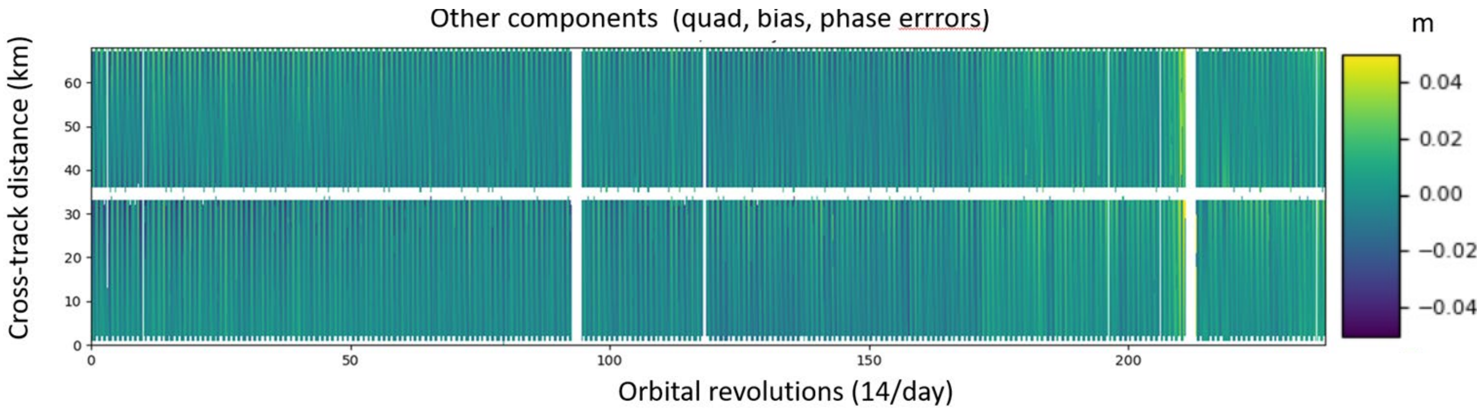


2nd order

Linear (o tens of cm)



Alinear, Quad, Bias (o cm)



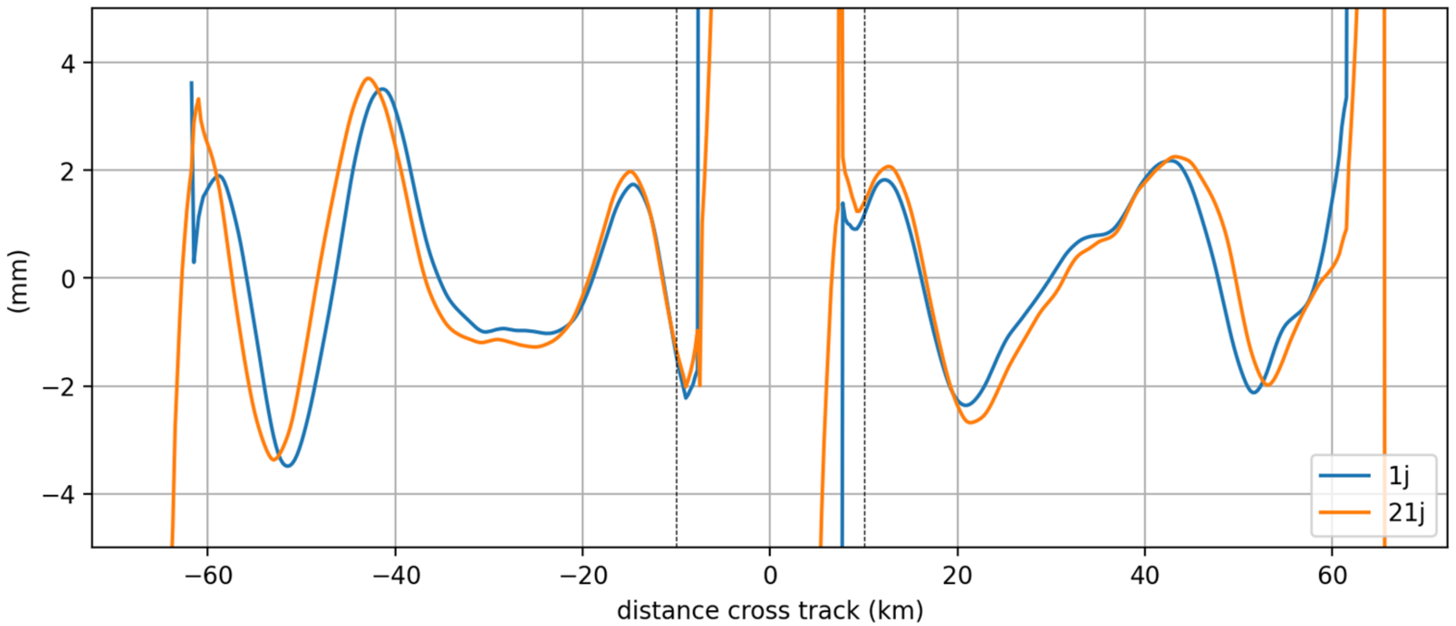
- **Summary of the error term estimations at different scales**
  - **From C. Ubelmann (paper submitted)**

	120 days	4 first harmonics	Below orbital frequency
Geometrical terms	**Beta scale**	**Orbital scale**	**Broadband**
Bias (B)	1 cm	3 cm	~4cm
differential Bias (aB)	0.8cm	1cm	Undetectable
Linear (L)	60 cm	15 cm	~3cm
a-Linear (aL)	6cm	2cm	Undetectable
Quadratic (Q)	1 cm	2 cm	Undetectable
a-Quadratic (aQ)	3cm	2cm	Undetectable

After XCAL correction

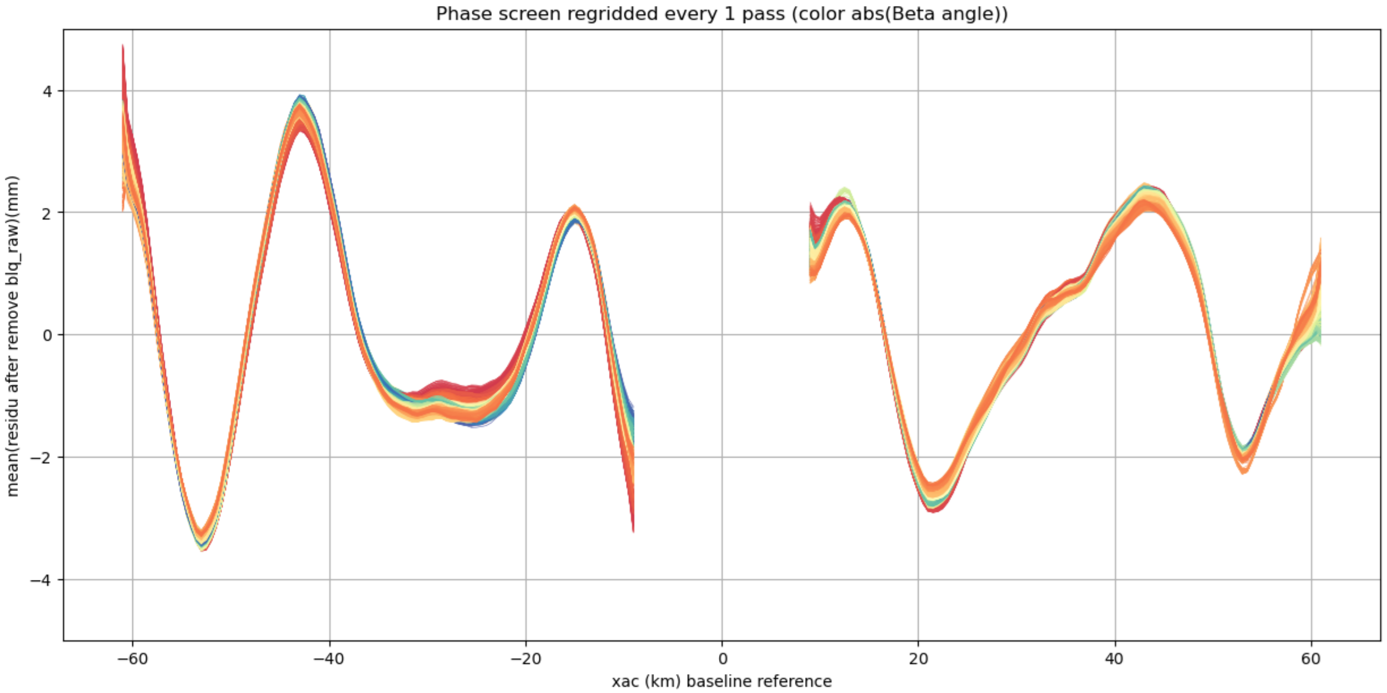
- 3rd order (o few mm)

static « residual phase screen »

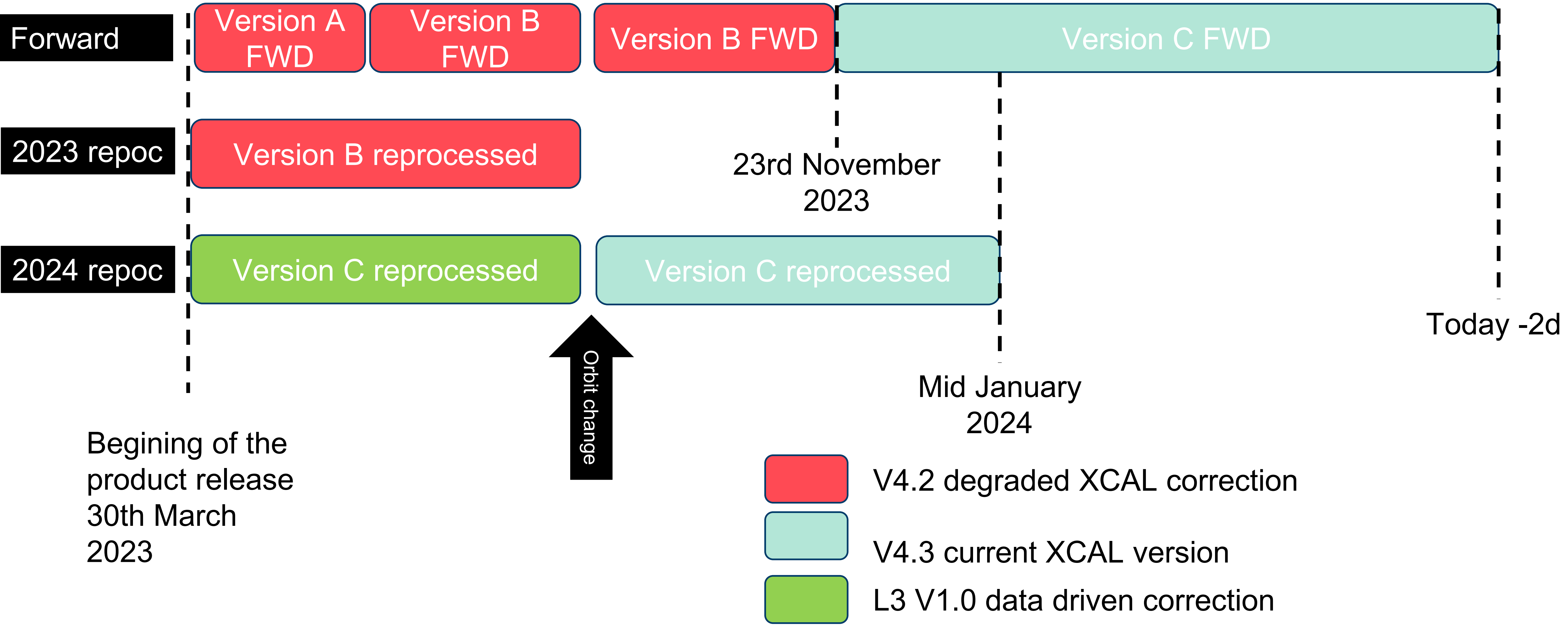


- 4th order (o < mm)

Dynamic « residual phase screen »



Timeline XCAL versions on the different products



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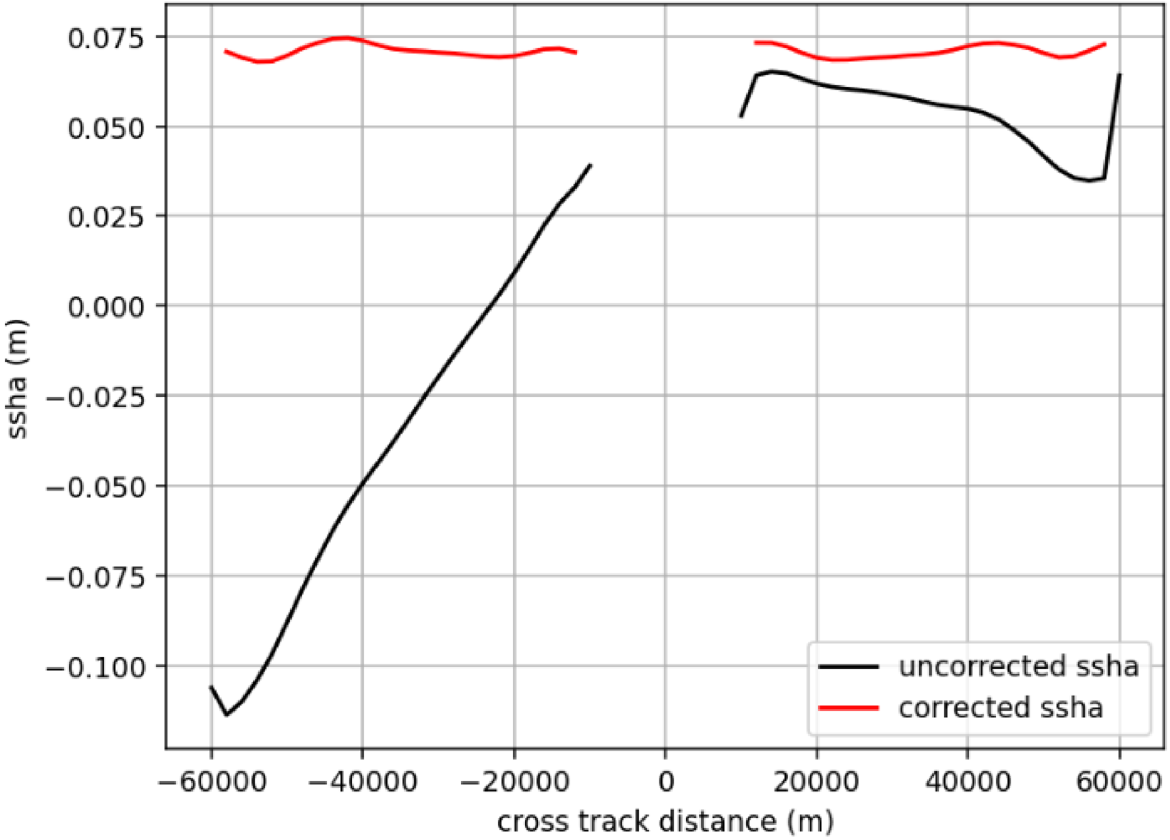
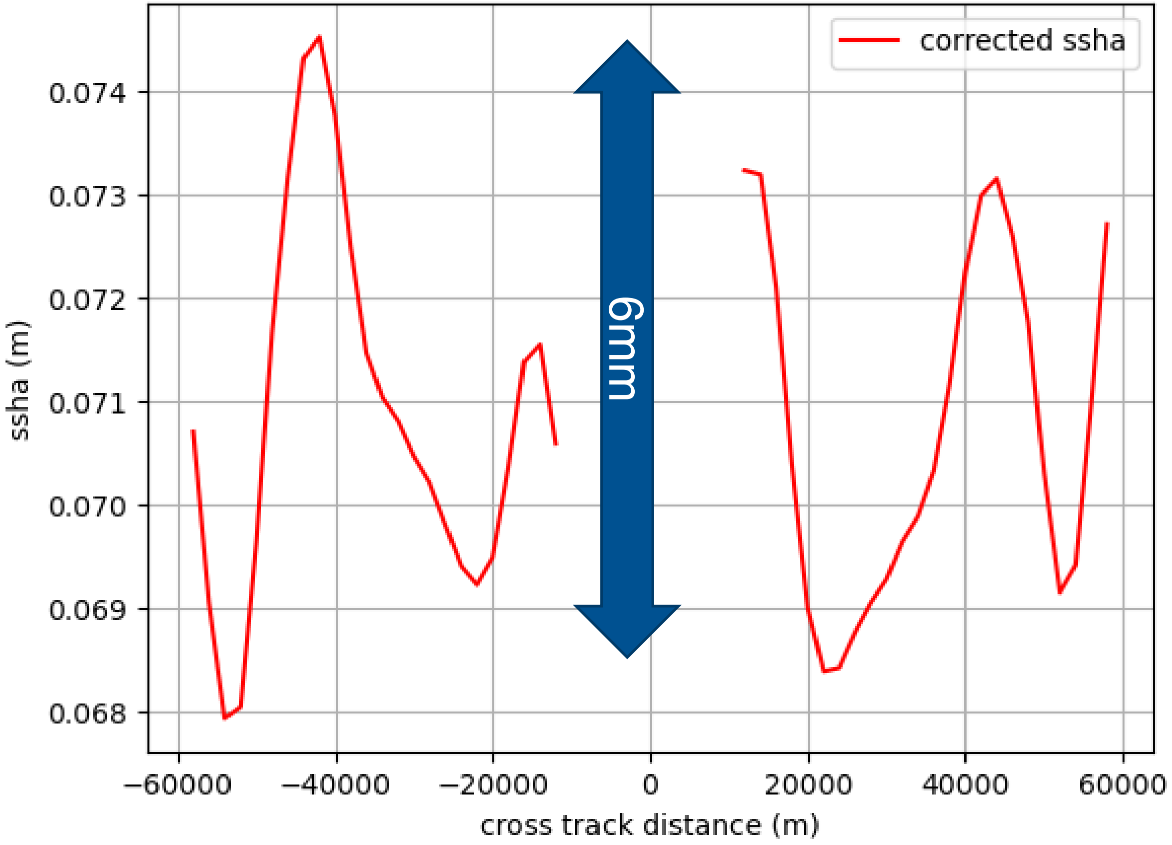
L2 XCAL validation over Ocean

- **Analysis of the residual cross-track bias after Xover correction**

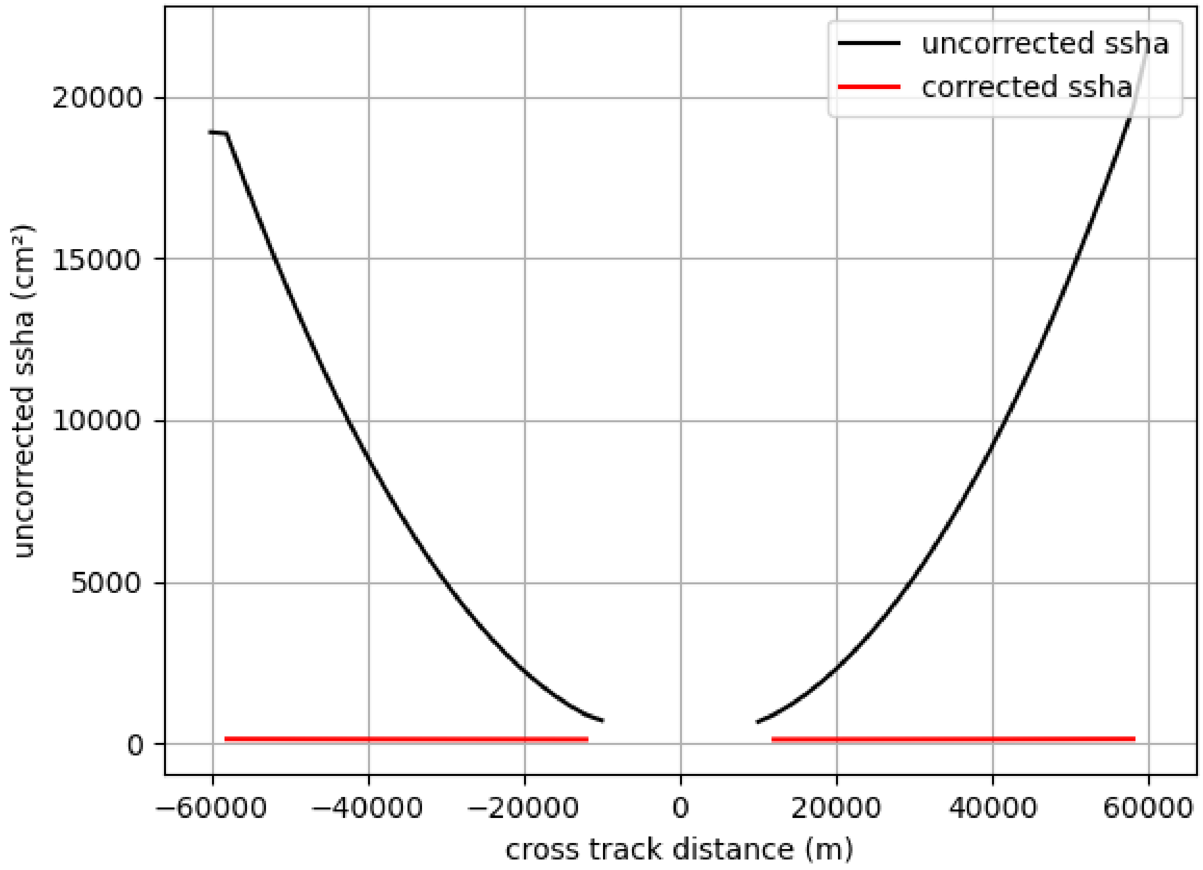
- No bias between left/right swath
- No BLQ residual
- Residual phase screen signature of few mm expected





L2 XCAL validation over Ocean

- **The correction significantly reduce the SSHA variance**
  - **Higher errors at far range positions**
  - **Above SSHA expected variance by a factor of ~1500**

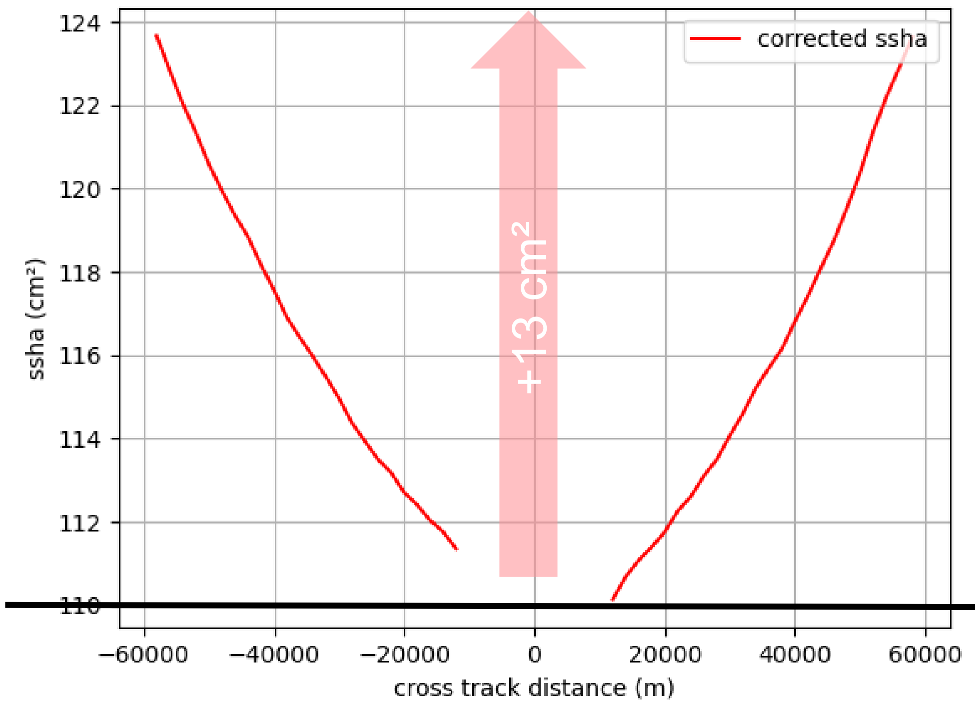


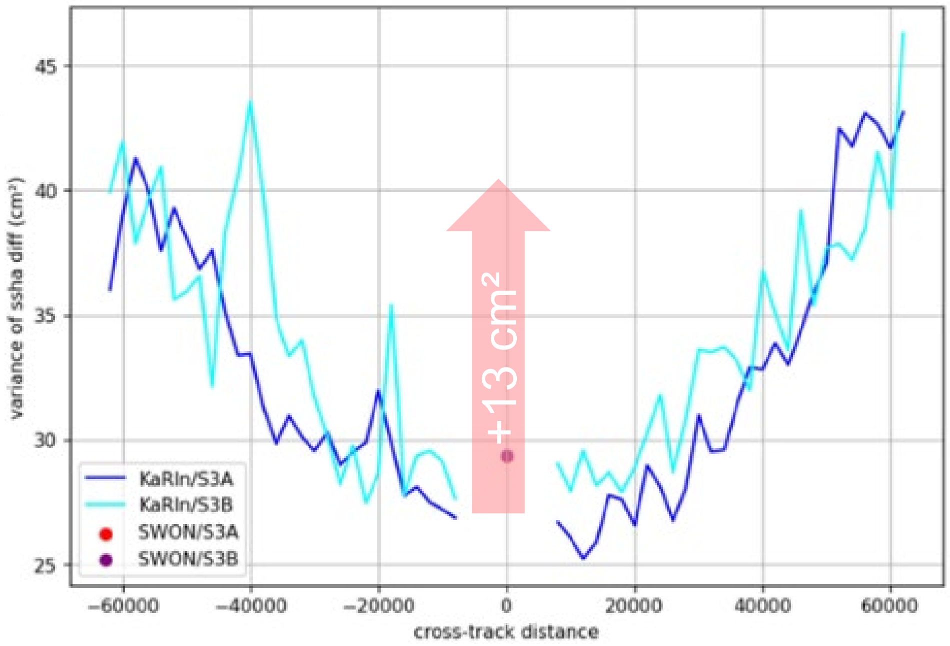
L2 XCAL validation over Ocean

- V-shape mostly induced by residual sys errors not captured by the XCAL
  - ~+ 13 cm² from near to far range
  - **+5cm²** in average over the swath

- Note that:
  - Model WTC is used to avoid specific cross-track error signature (AMR beams centred on the middle of the swaths)
  - SWH model (instead of nadir) is used to avoid specific SSB error cross-track signature (spatial variability of the SWH in the cross-track direction)
  - Some residual SSB errors could have a cross-track signature because of the current SSB model used
- Two different methods provides similar results
- **WARNING : This estimation does not include the XCAL error at near range location**

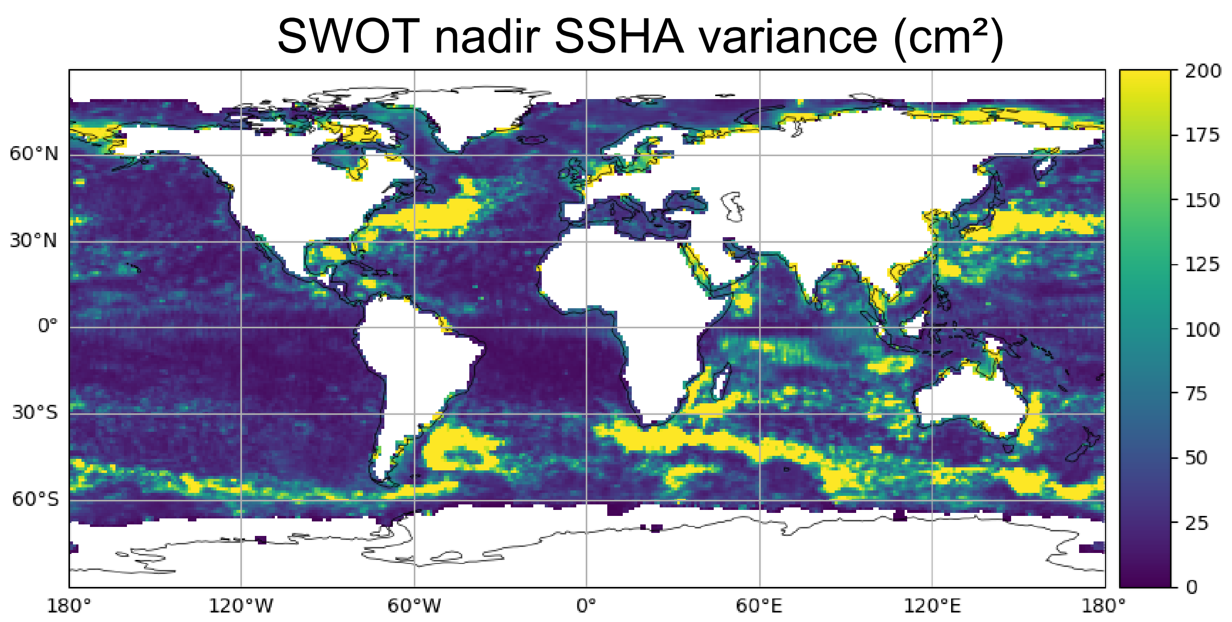
Ocean variability + near range residual sys error

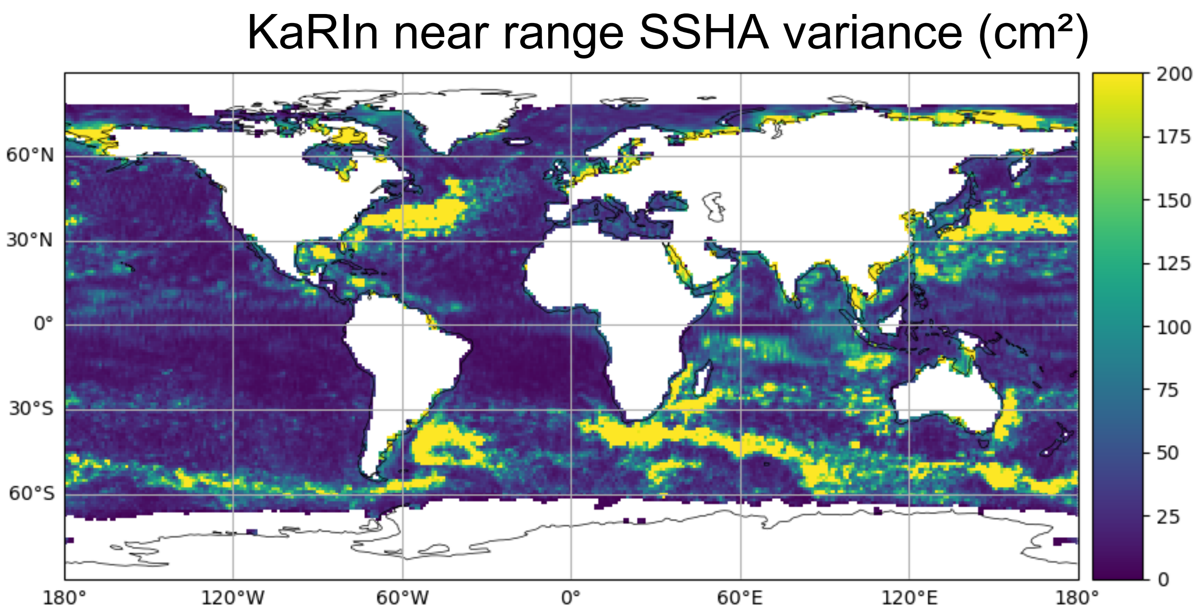




L2 XCAL validation over Ocean

- Estimation of the XCAL residual errors at near range





This map contains:

- True oceanic variability
- Nadir errors +
- Geophysical errors

This map contains:

- True oceanic variability
- KaRIn systematic erros (near range
- Geophysical errors
- Other KaRIn errors

L2 XCAL validation over Ocean

The difference of the 2 previous maps contains:

- KaRIn systematic erros (near range)
- Other KaRIn errors
- The nadir errors

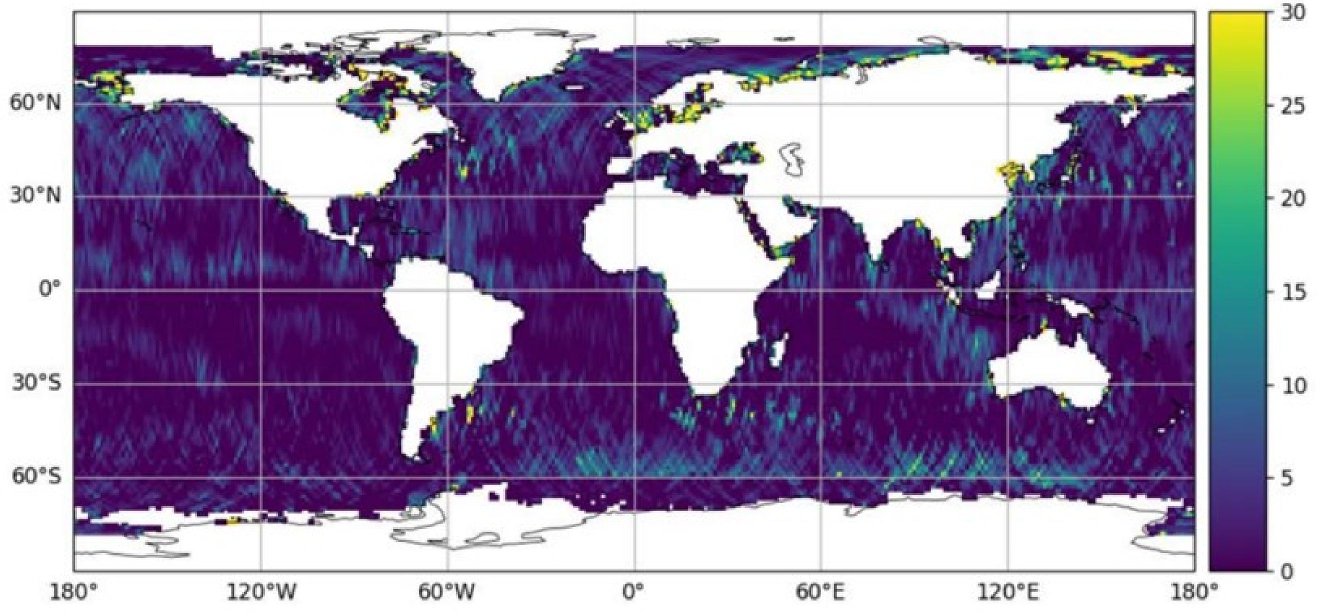
- Other components are cancelled out in the difference
  - True oceanic variability
  - Common geophysical errors

- To remove the nadir & KaRIn uncorrelated high frequency errors (random errors and other HF errors not related to the systematic errors) the corrected ssha is low pass filtered with cut off frequency of 1000 km

- The additional variance measured in KaRIn is of **1.67 cm²**. It is an estimation of the residual systematic errors at the near range location (10-12km)

□ The sum of the two terms (increase of variance wrt near range + near range error) gives an upper bound of the KaRIn systematic errors of 2.58 cm (sqrt(1.67 + 5))

VAR (ssha_karin_bf[12km]) – VAR(SWOT_nadir_bf) (cm²)

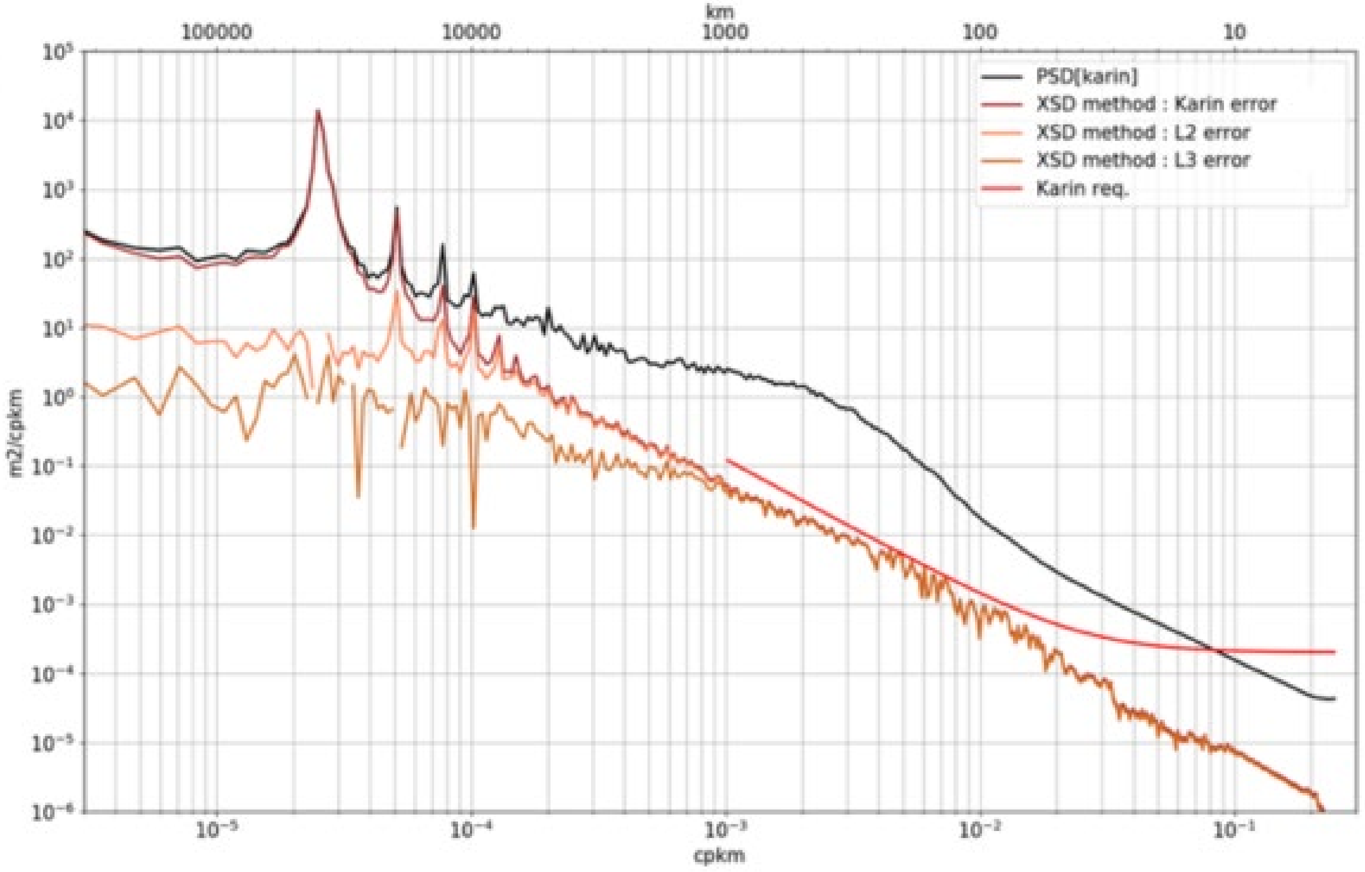


- **Some small residual signature of the oceanic variability are observed**

- **Residual variance in KaRIn ssha also observed in high SWH areas**
  - **Consistent with L2 LR CalVal metrics that shows a small SSB residual error in KaRIn ssha**

L2 XCAL validation over Ocean

- The XSD method (Ubelmann et al, 2018) is applied to the KaRIn corrected SSHA to estimate the residual signature of systematic errors
- L2 XCAL reduces the systematic errors from 5000 km up to a factor 10 at largest scales
- The integral of the L2 residual systematic errors spectrum is of **2.5 cm RMS (consistent with previous estimation)**



OUTLINE

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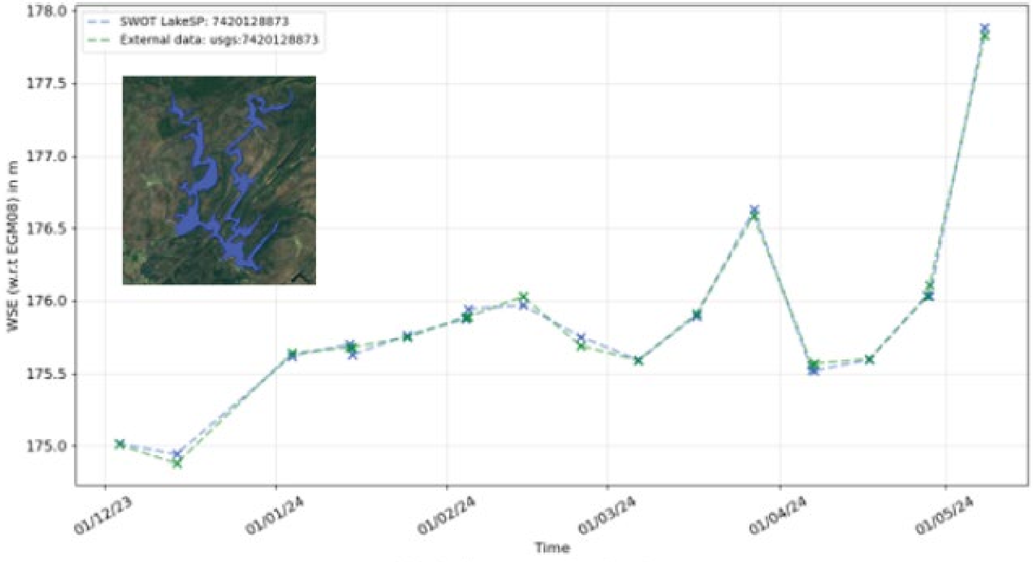
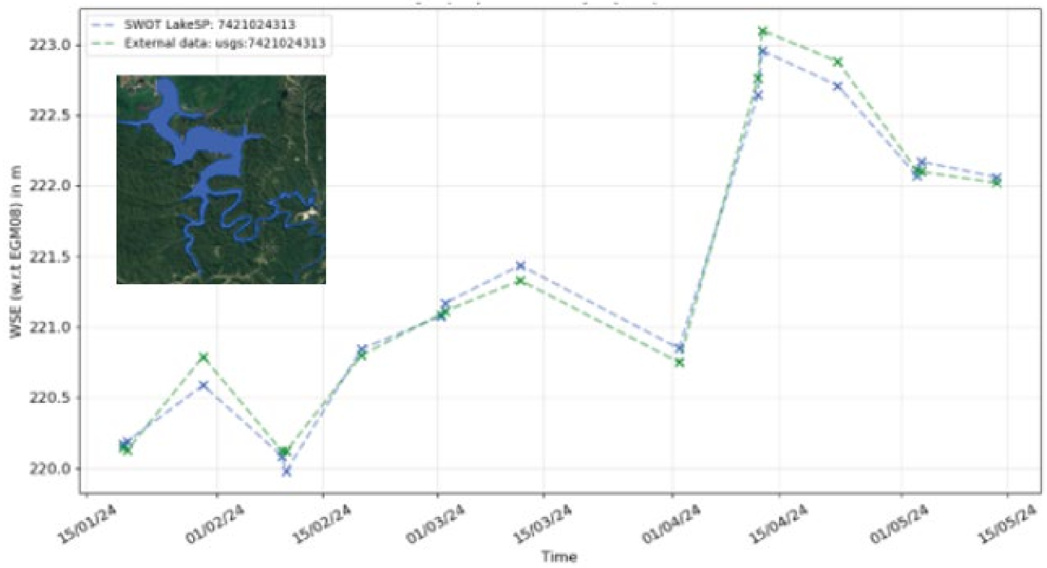
Verification of the mean bias correction with respect to insitu measurements

- Use of BAFU (swiss) & USGS (US) in situ networks (leveled wrt EMG08 geoid)
- Comparison over 141 lakes
- 2464 comparisons performed

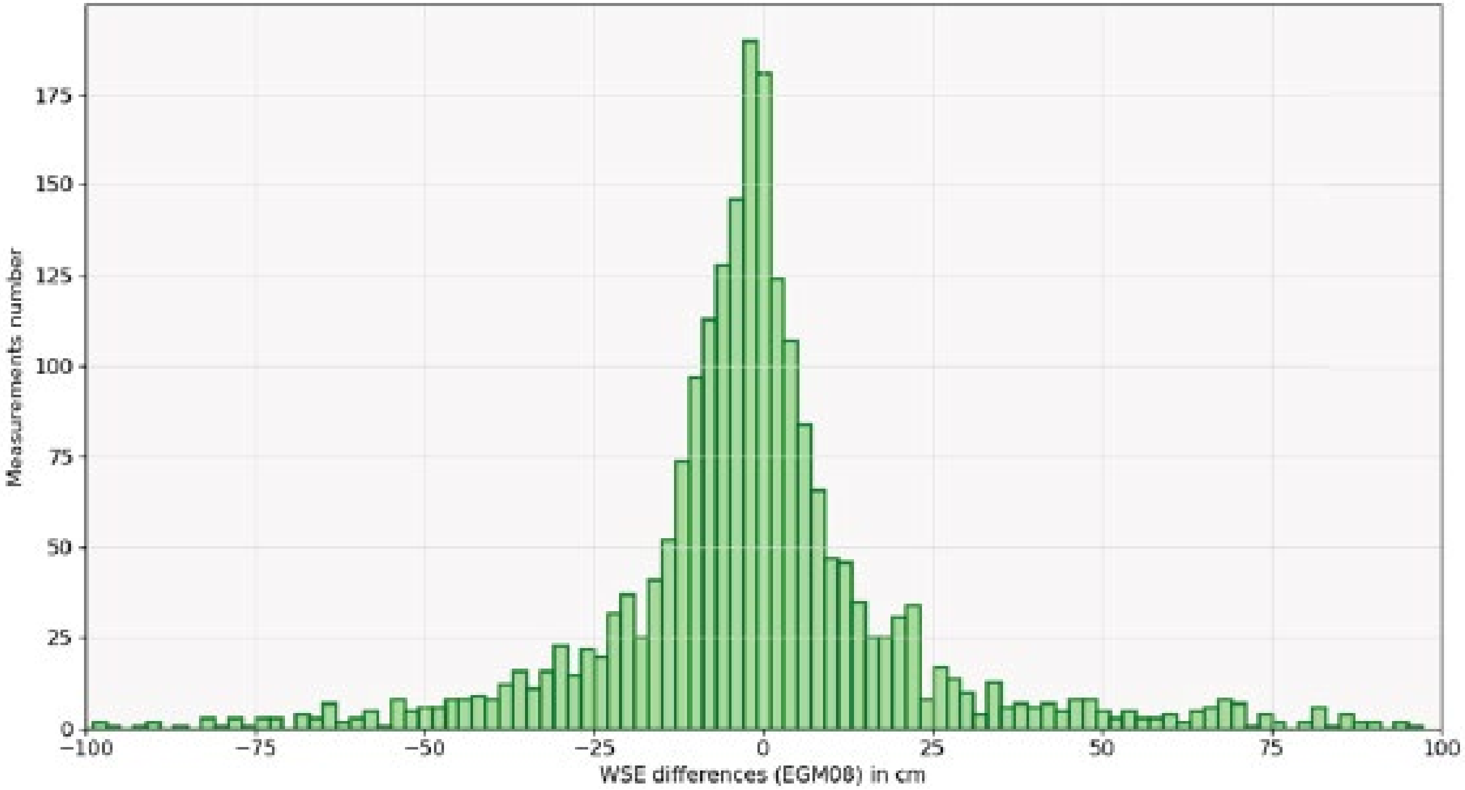




XCAL Validation over LAND

Verification of the mean bias correction with respect to insitu measurements

- Median value of 0,3 cm
- MAD of 9.9 cm



No important bias for more than 50% of the data analyzed.

Quite important dispersion:

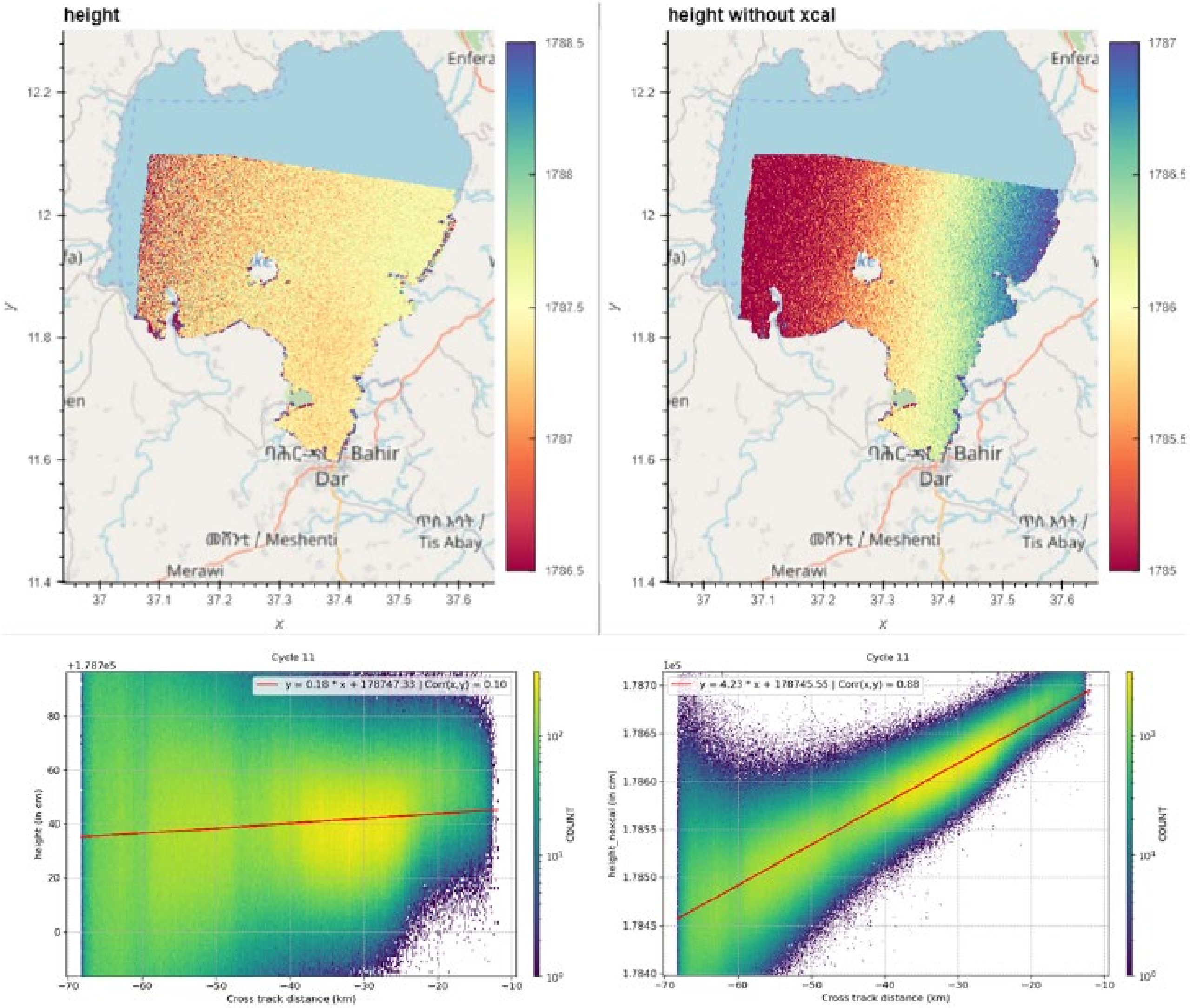
- From XCAL punctual errors
- From insitu errors
- From geoid errors (location of the station wrt KaRIn measurements)

- Need further investigations

XCAL Validation over LAND

Estimation of the cross-track slope over lakes

- Estimation over 200 large lakes using PIXC products
- From November 23rd to April 4th (version C products)
- 2400 tiles analyzed
- Lakes are supposed flat (0 cm/km)
- Important contribution from geoid errors expected



Tana Lake (ethiopia)

Validation

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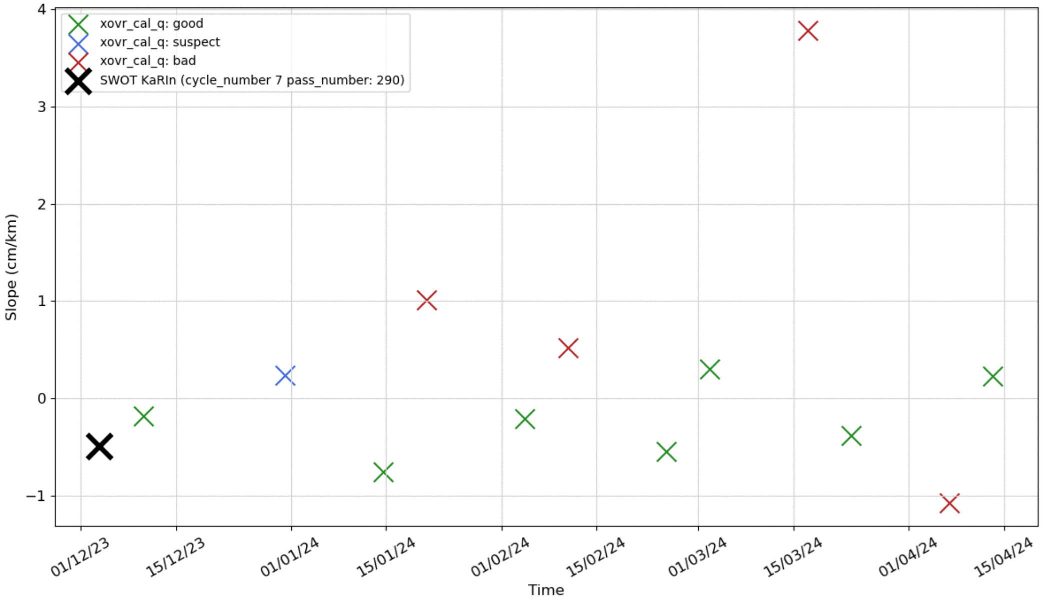

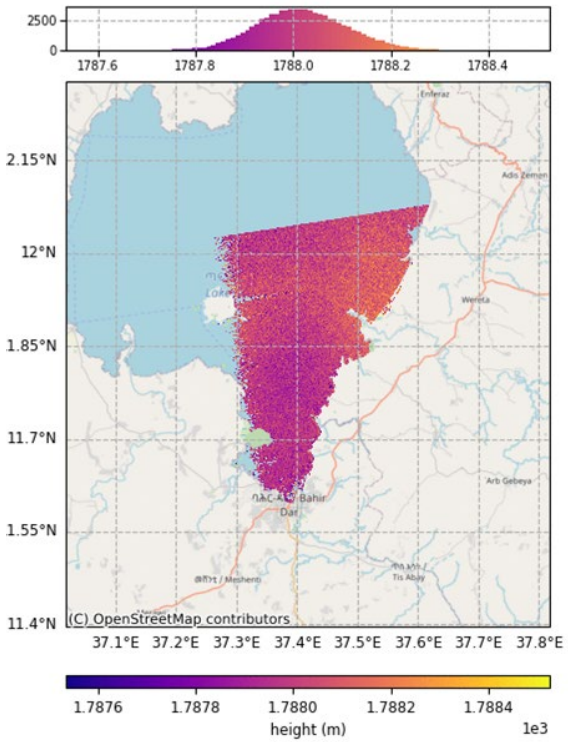

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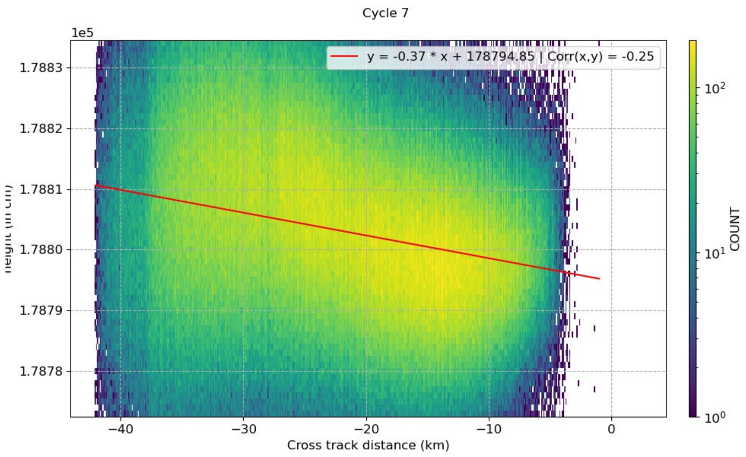
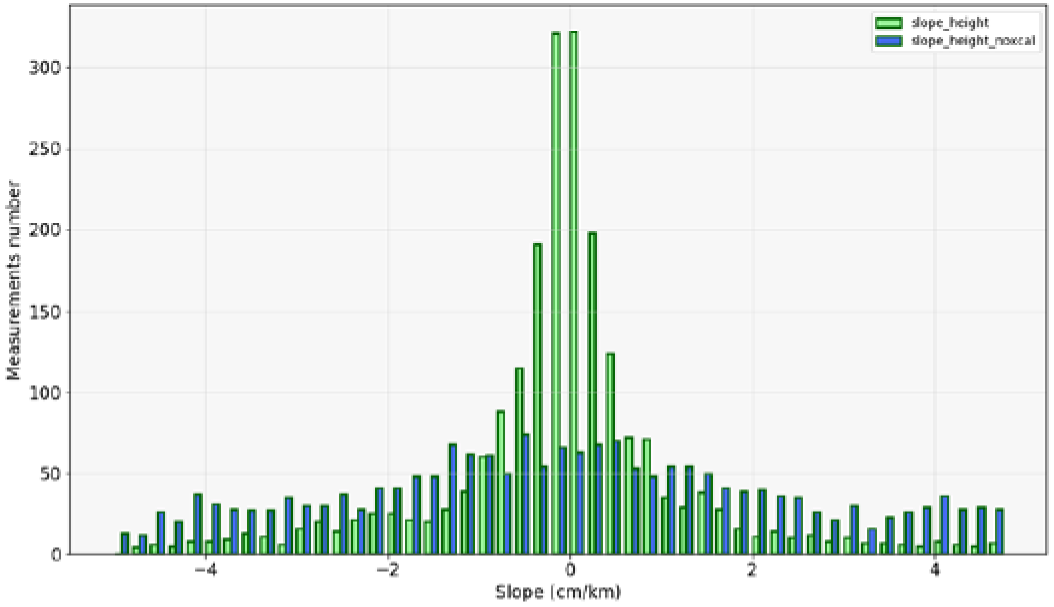


XCAL Validation over LAND

- **Clear reduction of the cross-track slope with the L2 XCAL**
  - **Distribution centred on 0 cm/km**
  - **68% of the cases present a cross-track slope lower than 1.3 cm/km (more than 3cm/km before calibration)**

- **Ongoing work to estimate the contributions from geoid errors**



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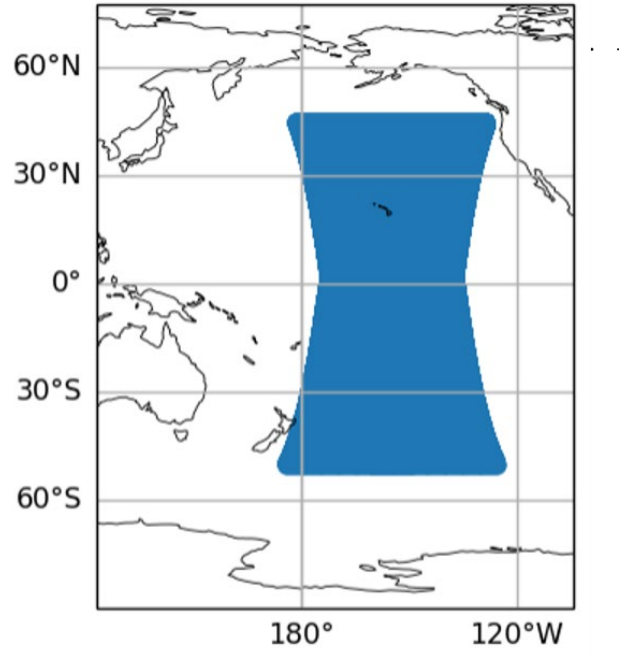
XCAL Validation over a « simulated continent »

- Definition of a virtual continent in Pacific Ocean
  - 58 passes flagged between [-50°, 45°] of latitude (need to let some crossovers apart from the region) overe cycle 3.
  - Segment length of ~11000 km

- Run of a degraded XCAL (V4.3 same as in operation) after flagging these data no crossovers to estimate the correction in this region

- Analysis of the increase of variance as a function of the distance to previous/next crossover



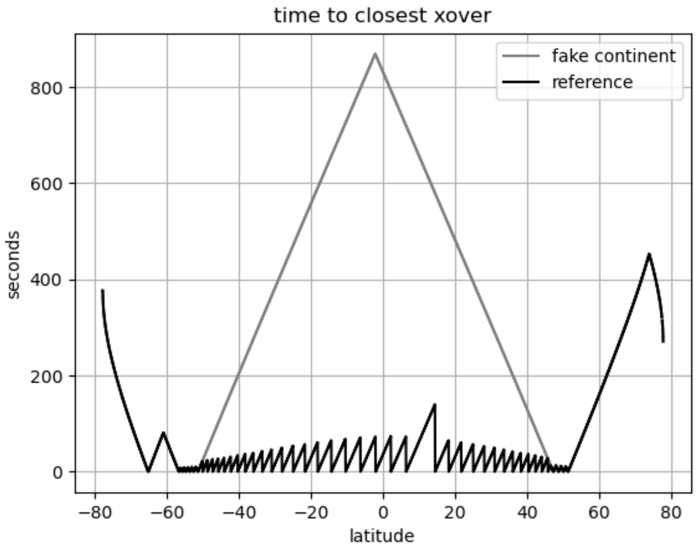
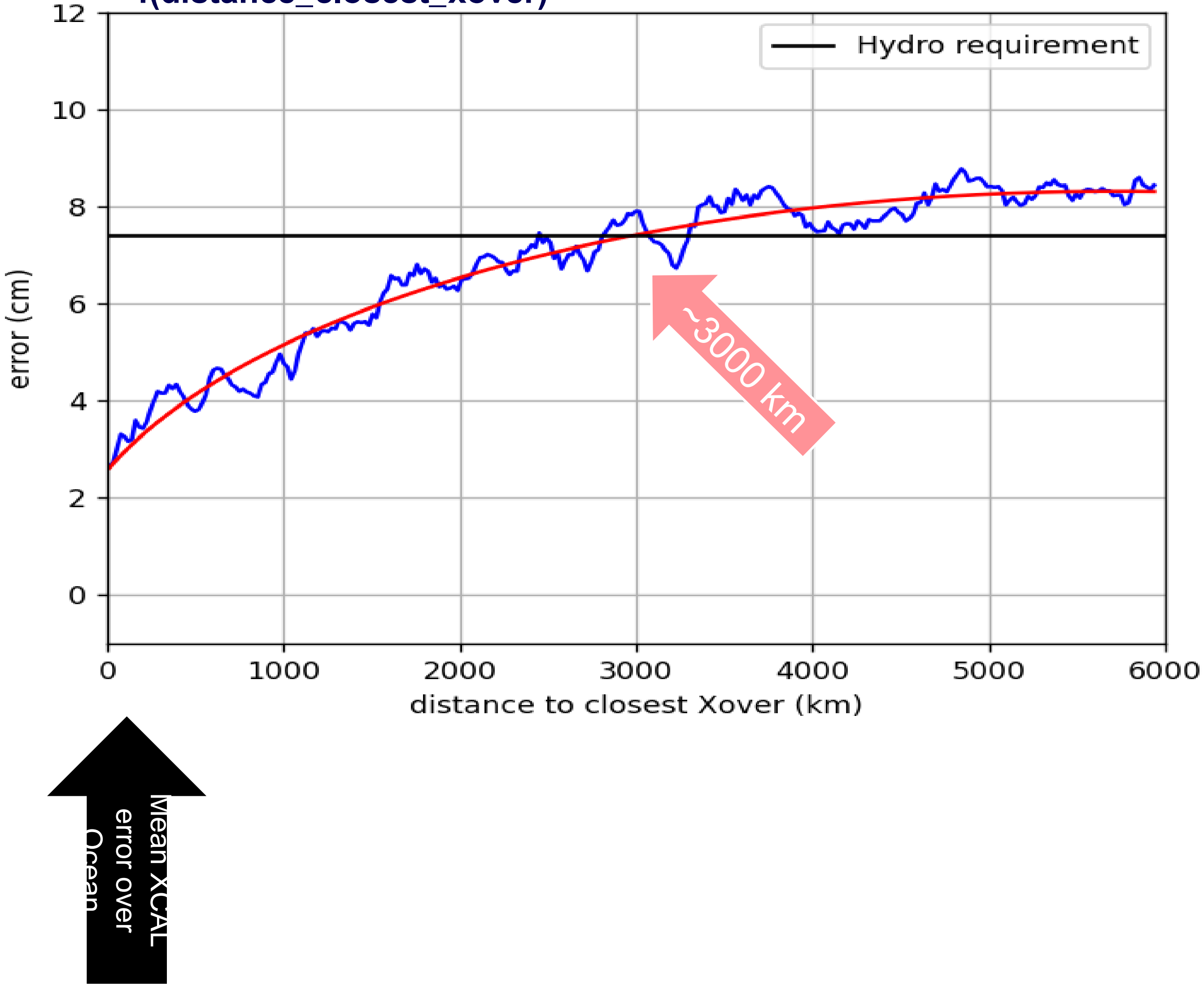


Illustration for one of the passes crossing this virtual continent

XCAL Validation over a « simulated continent »

- At d = 0 both SSHA variables have the same variance (not shown)
- A constant error of 2,5 cm (from Ocean error estimation) have been « added » (in variance) to the curve to simulate the total XCAL error.
- The error increase with the distance from the nearest crossover and reach the Hydro requirement of 7.4 cm rms
  - At ~ 2300 km (upper bound method)
  - At 2700 km (from XSD method)
- These estimations are an upper bound because the XCAL error estimated over Ocean includes distances to nearest xovers > 0.
- The results (shape of the curve and error level) are consistent with preflight simulation (Dibarboure et al., 2022)
- Need to extend this analysis over a longer time series (to cover entire beta angle cycle)

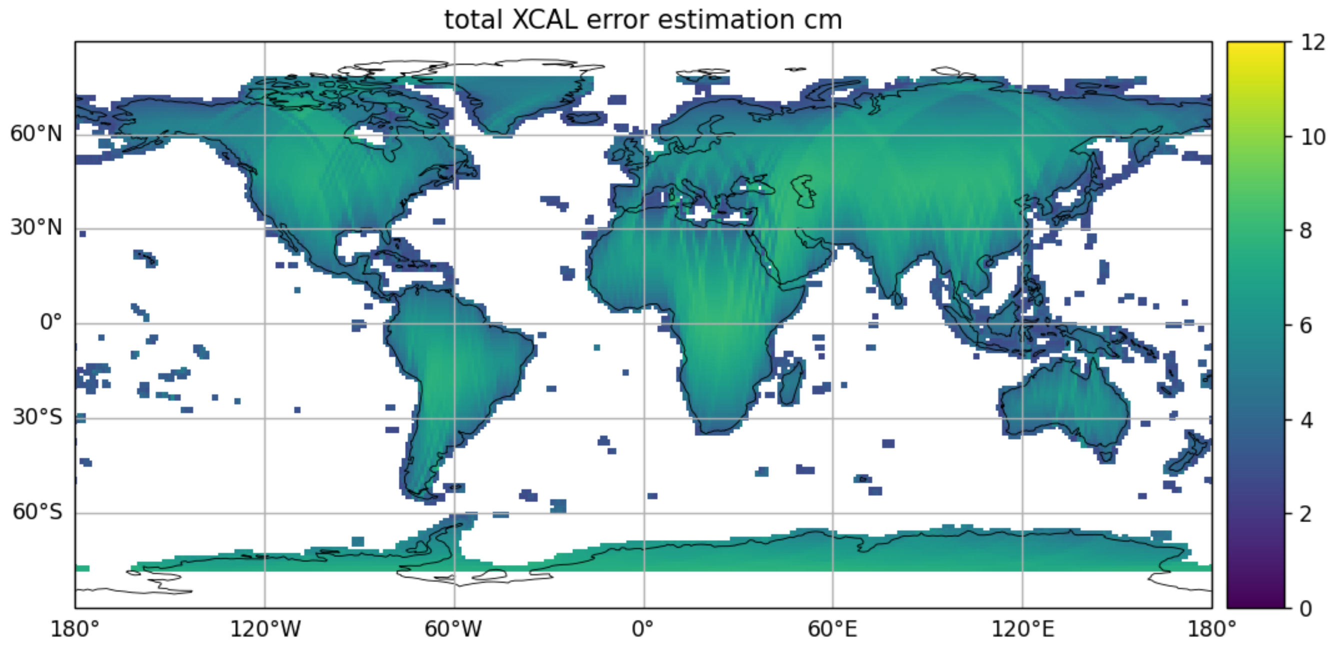
VAR[ssha_degraded_corr] – VAR[ssha_ref_corr] = f(distance_closest_xover)



XCAL Validation over a « simulated continent »

- **Estimation of the XCAL L2 error over land from the distance to nearest xover**

- **The mean error over LAND is of 5.7 cm (optimal configuration as computed at the end of summer)**



Conclusions

- L2 XCAL errors over open Ocean have been estimated from 2 different methods and provides very similar metrics of about 2.5 cm.
- Estimation of the L2 XCAL errors over LAND is much more complex (strong residual geoid errors) □ ongoing activities dedicated to improve this estimation
- The definition of a virtual continent provides complementary alternative to try to estimate the residual over Land.
    - The study performed shows that averaged error estimated is of about 5.7 cm (~in September)
    - Need to extend this study over a longer time period to cover a whole beta angle cycle and other seasons (Xovers availability at high latitudes)