Linking Conventional and SAR Altimetry with Cryosat-2: An assessment over the whole mission

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1: CLS 2: CNES

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Outline

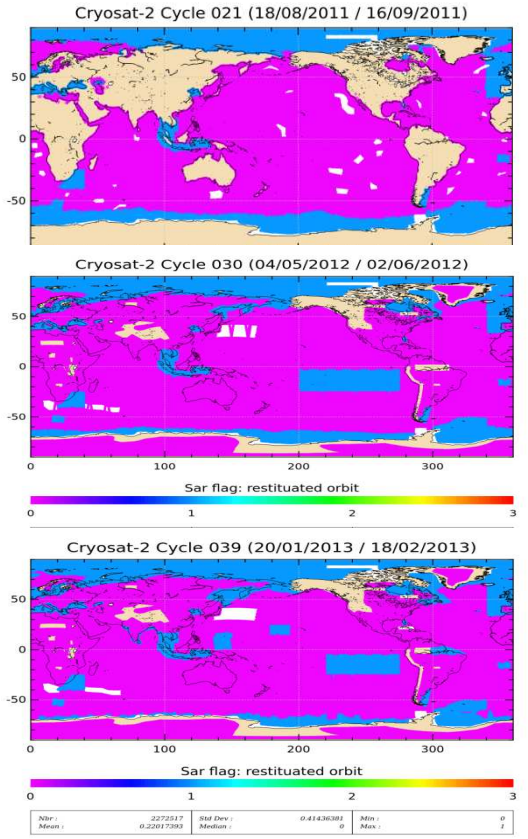
- Talk objective is twofold:
  - Focus on **Cryosat-2 data quality** for the Mean Sea Surface calculation
  - Some illustrations on the **potential of Cryosat-2 data in SAR mode for detecting unrevealed MSS features**
- Why improving MSS?
  - HY2A already flying on a new track and next year Sentinel-3 => better exploitation of these 2 data sets both for operational and scientific use.
  - SWOT in a near future

The SAR Data Set

- The specificities of Cryosat-2 of importance for the Mean Sea Surface:
  - SAR and LRM modes over different geographic areas
  - Need of **a seamless transition below the cm level** between LRM and SAR SSH.

- SAR Level-2 products generated by CNES and CLS teams (Boy et al OSTST 2012)
  - SAR Ocean processing devoted to SAR echoes with Delay Doppler processing inherited from Sentinel-3 Processing Baseline + numerical retracking
  - Whole time serie May 2012 till May 2014.
  - Compared to the other teams that used Cryosat-2 data for MSS (Andersen, Sandwell), the CPP processing starts from FBR (Level 0 data)

The SAR zone mask for Cryosat-2 varies in time



2011

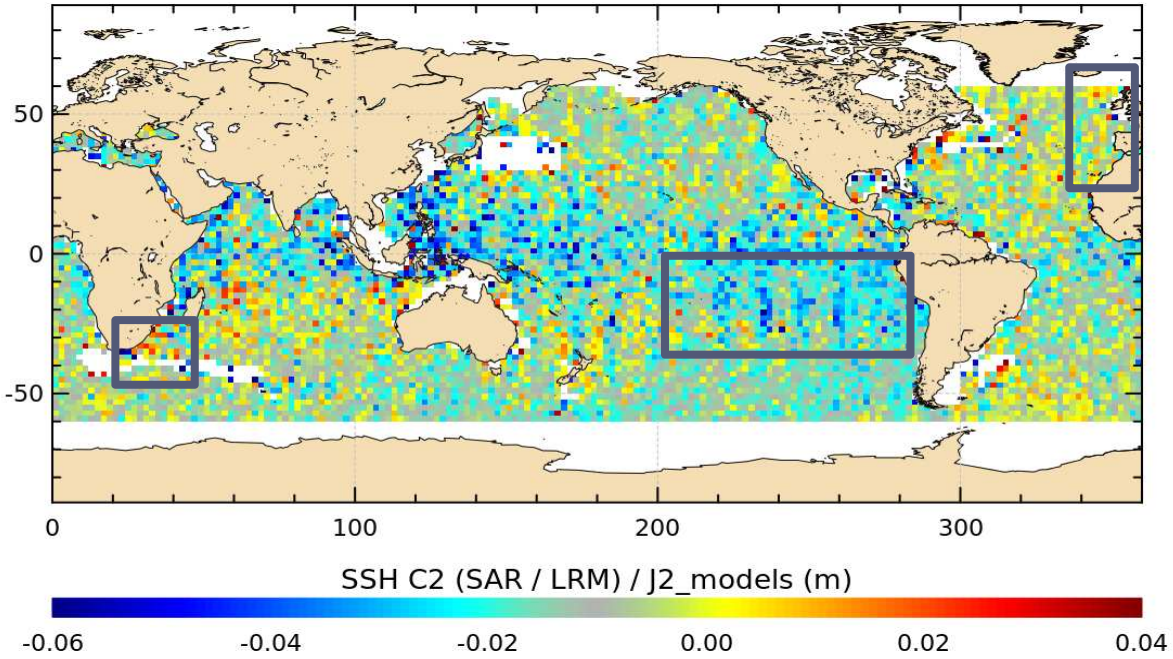
2012

2013

You can download the CPP level 2 products at :
ftp.cy2_sar_l2.oceanobs.com

SAR-LRM Continuity

Crossovers between C2 and J2 over 1 full year. Jason-2 SSH is computed with the same geophysical corrections to cancel ionosphere and troposhere errors



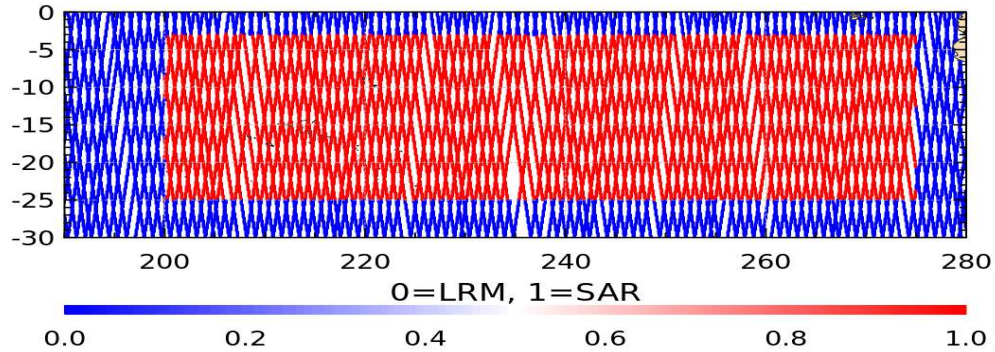
Very good agreement between C2 and J2 SLA

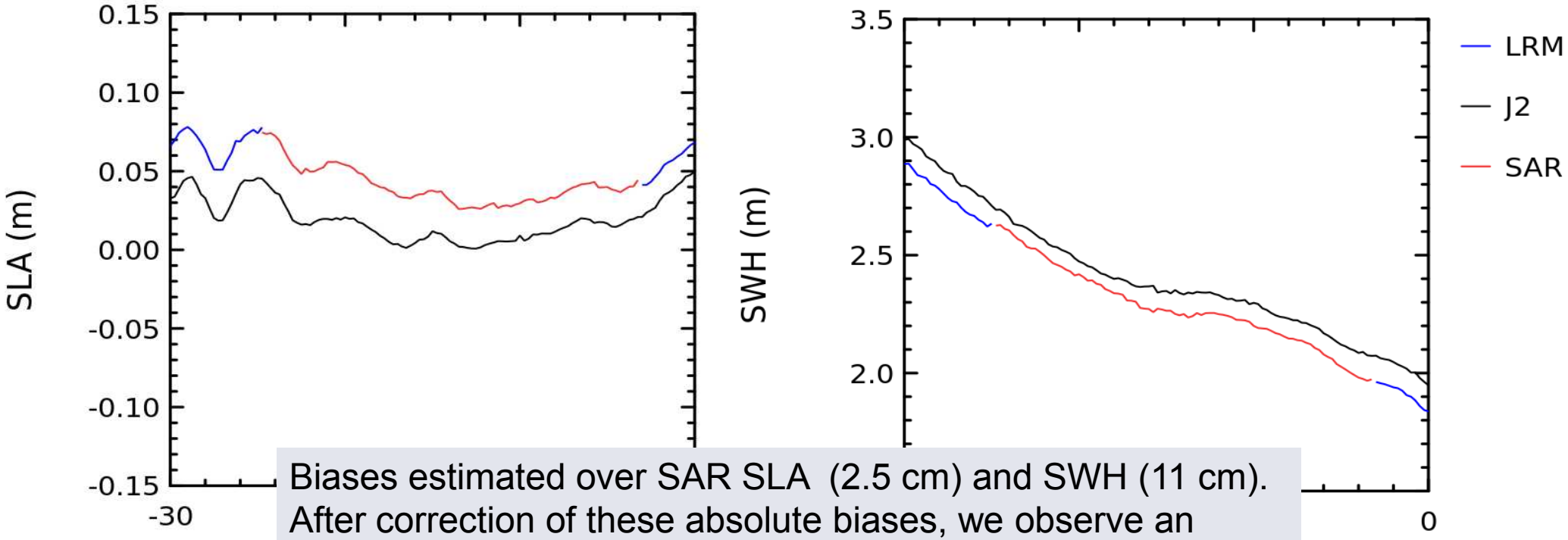
Geographical patterns of +/- 2cm linked to residual orbit error and possibly to residual ionospheric errors (difference in local time between J2 and C2).

Seamless transition between LRM and SAR modes over the 3 largest SAR boxes.

SAR-LRM Continuity

Data are averaged over all longitudes to focus on the transition between LRM and SAR zones.





Biases estimated over SAR SLA (2.5 cm) and SWH (11 cm). After correction of these absolute biases, we observe an excellent agreement with Jason-2 and a seamless transition between LRM and SAR profiles.

Cryosat-2 Assets

- What brings Cryosat-2 for Mean Sea Surface? Several assets…

- **Geodetic orbit** with 4 years available now => helps to fill the gaps between the repeat track historical orbits

Data used in existing Mean Sea Surface

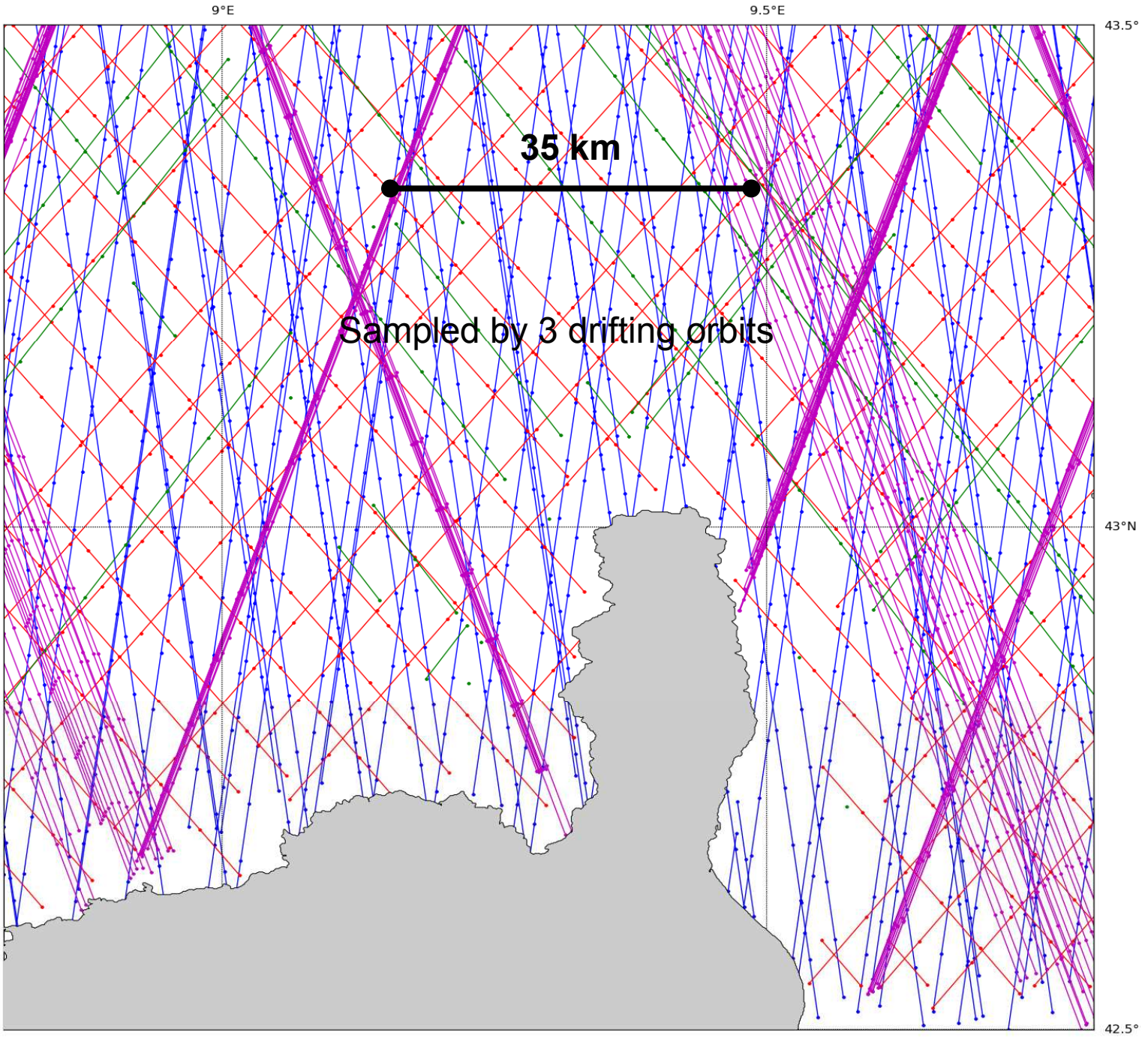
Data used for next Mean Sea Surface

Mainly repeat track missions

T/P/ JA1/JA2
TP/JA1 inter
ERS-1/2/EN
GFO
ERS-1 Geo

Geodetic:

C2
EN Geo
JA1 Geo



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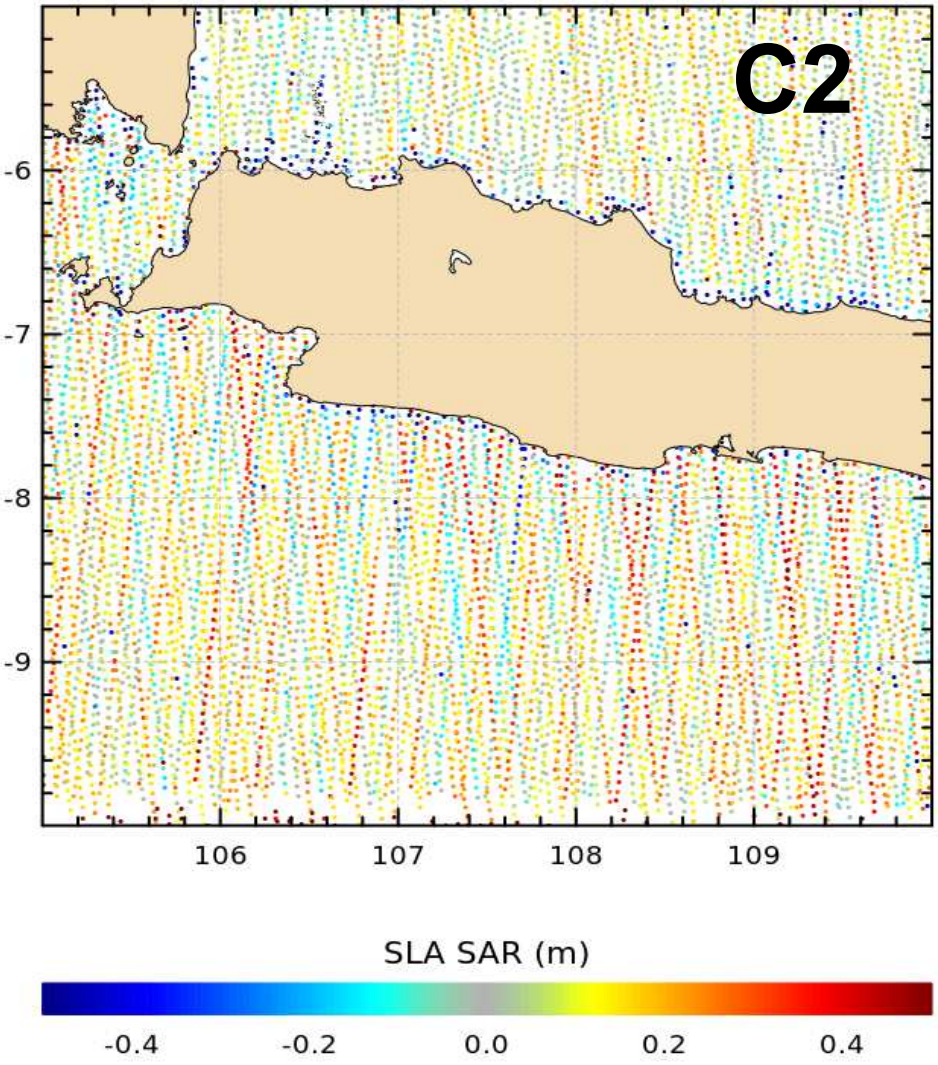
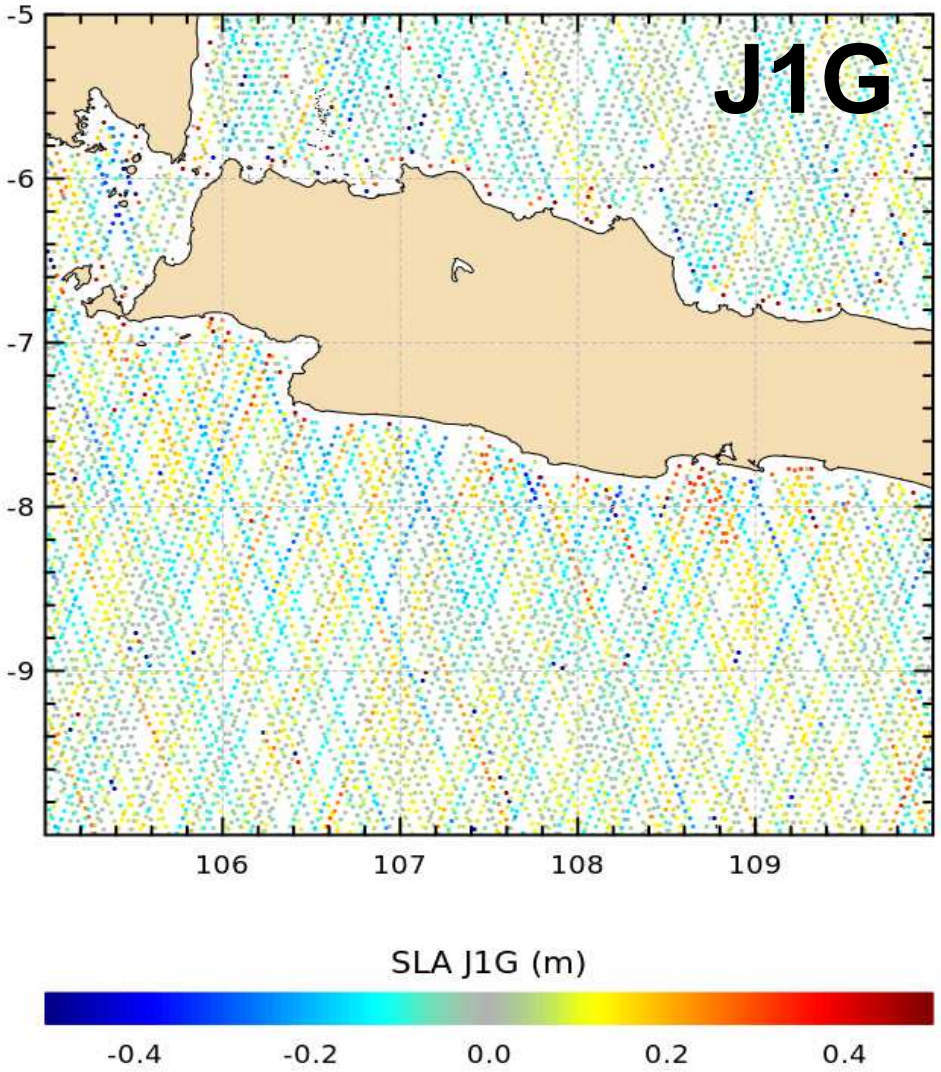
- **New Sensor** with better coverage near coasts due to the reduced footprint in SAR mode

Cryosat-2 Assets

Zoom over the Indenosian Coast (Java Island)





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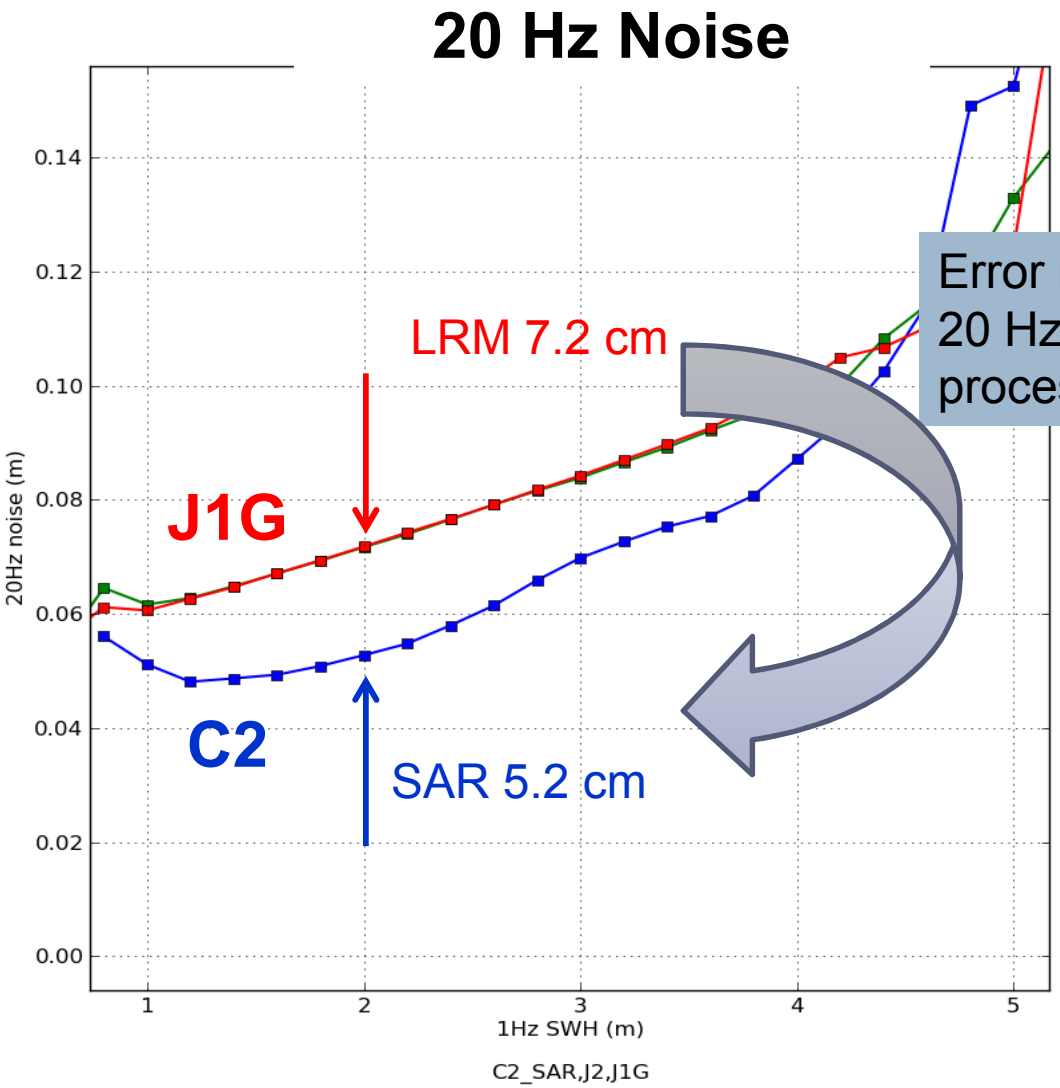
- **New Sensor** with better coverage near coasts due to the reduced footprint in SAR mode
- **New Sensor** with reduced noise in SAR mode

Cryosat-2 Assets



Error reduction of 48% at 20 Hz due to SAR processing

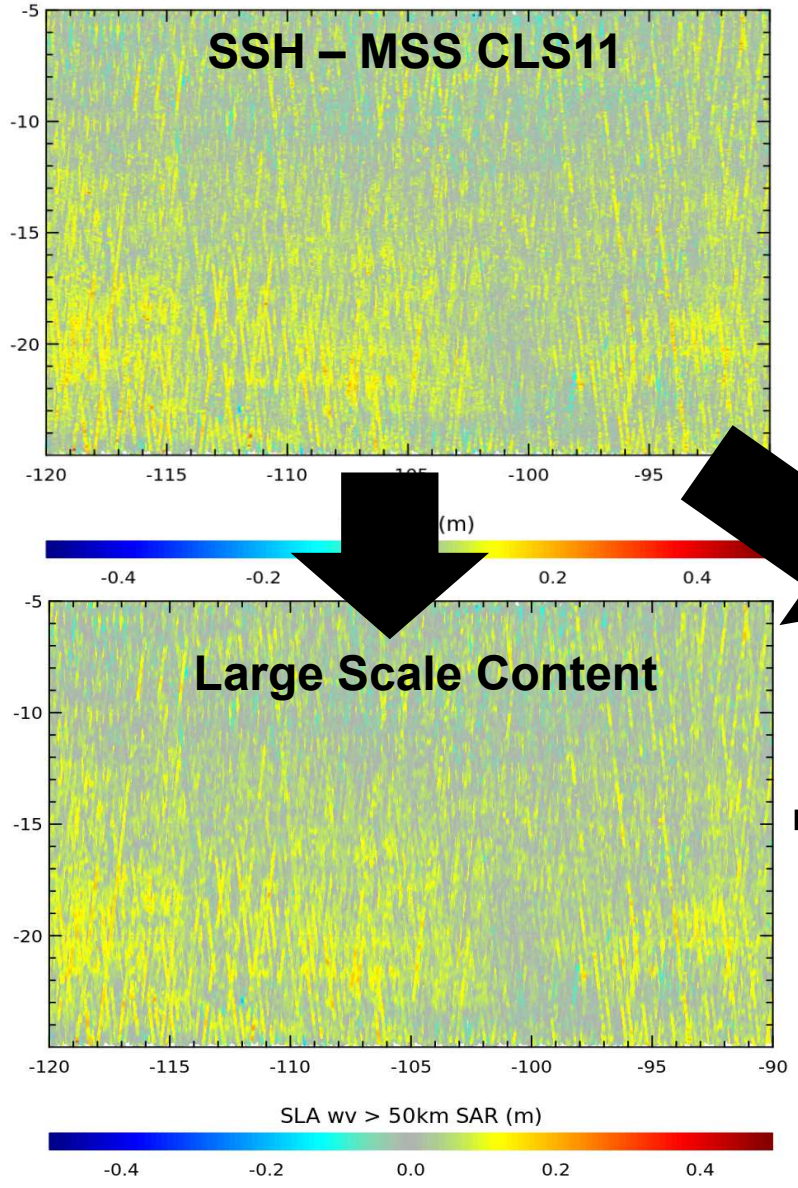
What happens at 1 Hz ?

In theory precision @ 2 m:

LRM 7.2 cm / sqrt(20) = 1.6 cm
SAR 5.2 cm / sqrt(20) = 1.1 cm

Cryosat-2 Assets

Zoom over the Equatorial Pacific



What happens at 1 Hz ?

Pacific zone well suited for noise assessment (stable wave conditions close to 2 m + low oceanic varibility)

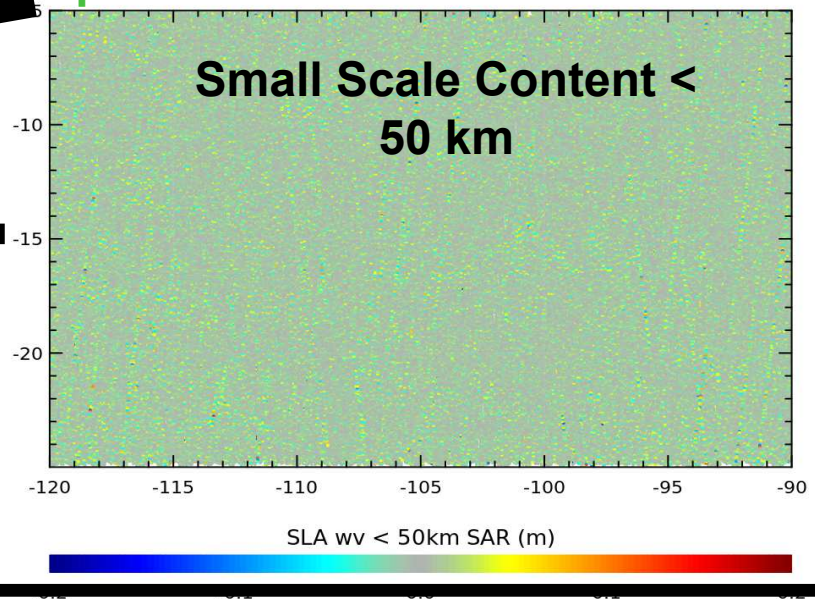
High frequency content (below 50 km) of SSH – MSS CLS11 which contains:

1 Hz « instrumental noise »

+ « bump errors » at 1 Hz for LRM altimetry

+ Ocean structures < 50 km

+ Sea floor content never sampled or under represented in the MSS CLS 2011



Cryosat-2 Assets

What happens at 1 Hz ?

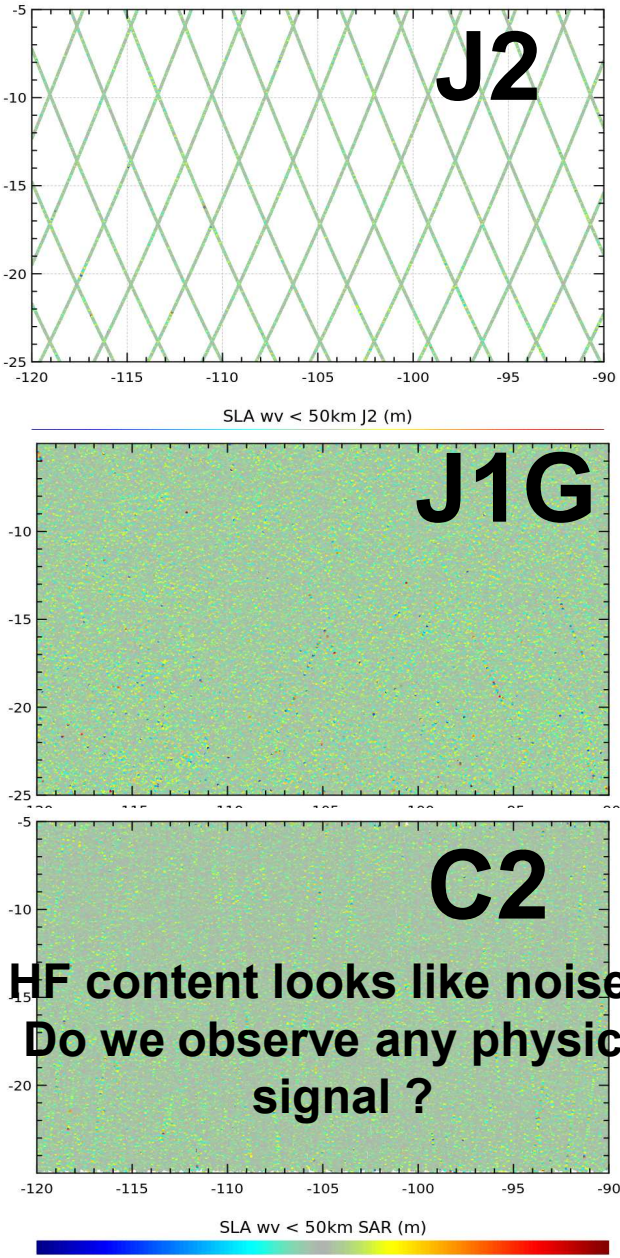
1 Hz HF content observed over the Equatorial Pacific

LRM J2	2.0 cm
Instr. Noise	1.6 cm
LRM J1G	2.3 cm
Instr Noise	1.6 cm
SAR C2	1.7 cm
Instr Noise	1.1 cm

Same sensor => more small scale structures observed by J1G

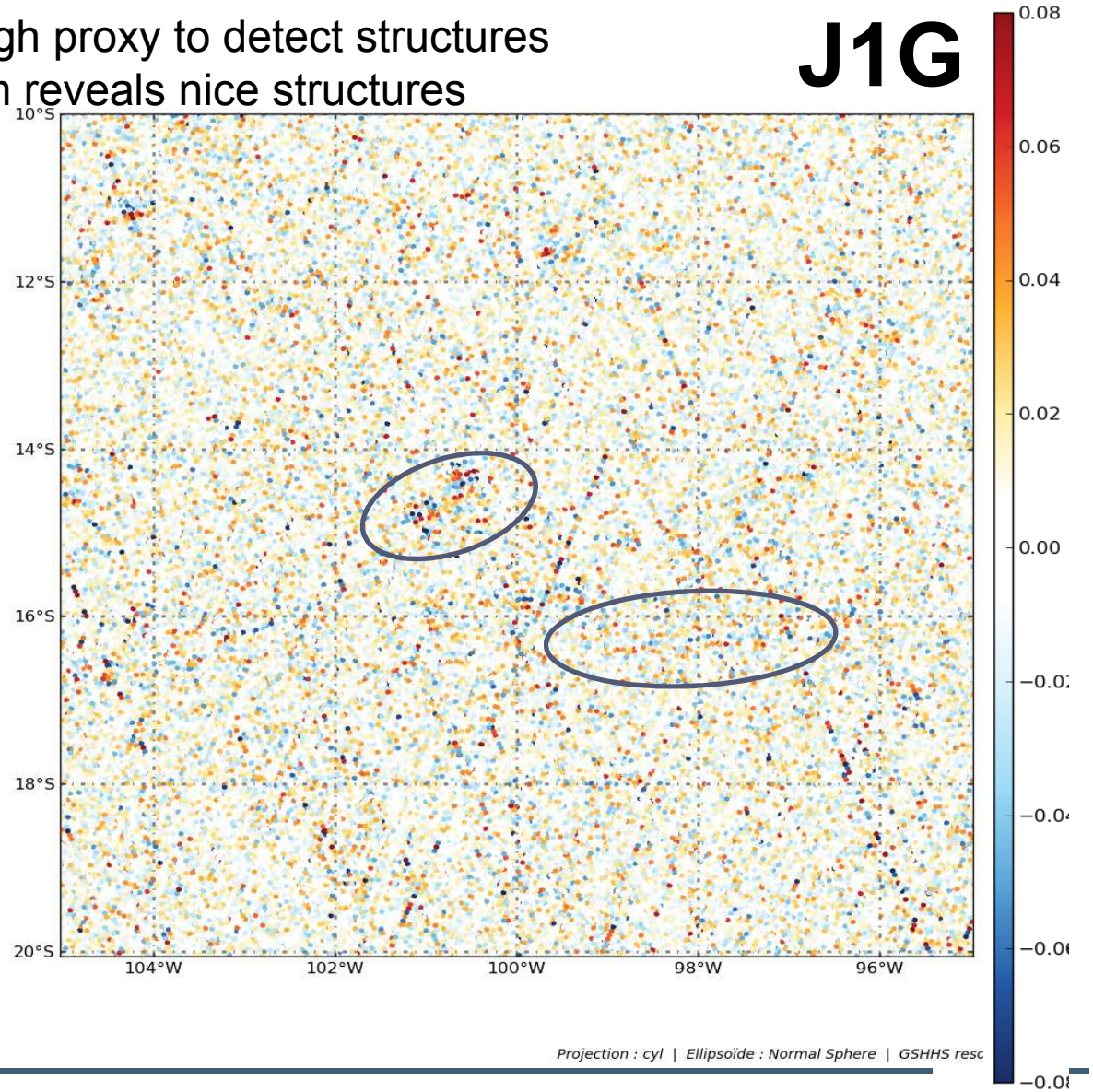
Same small structures but different altimeter => Error reduction due to SAR processing

Lowest 1 Hz error Difference wrt instrumental noise due to geoid structures



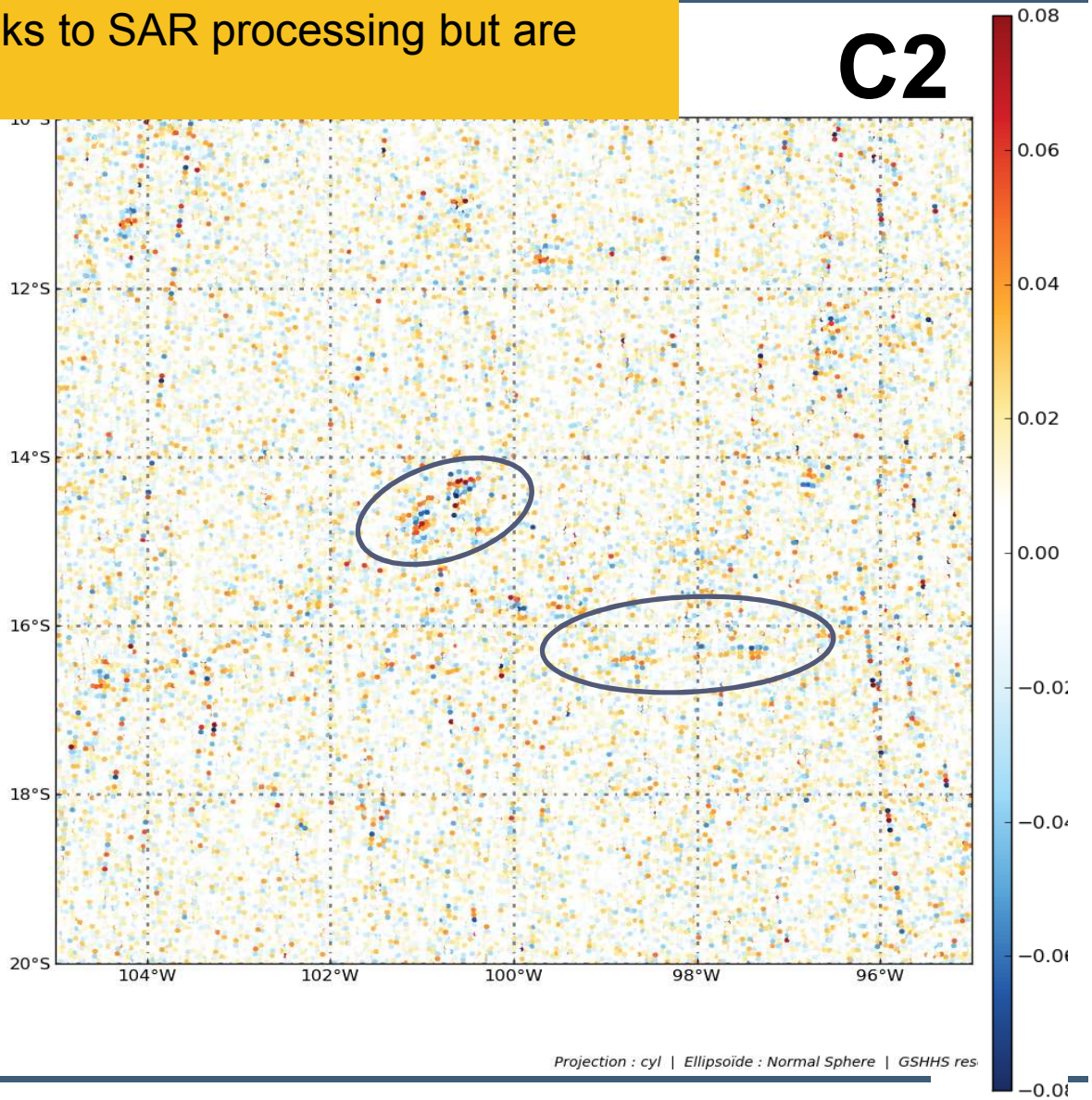
Improving MSS with Cryosat-2 SAR data

The same HF content is used as a rough proxy to detect structures observed by Cryosat and J1G => zoom reveals nice structures



Improving MSS with Cryosat-2 SAR data

Cleaner signal oberved on Cryosat-2 thanks to SAR processing but are they true structures?

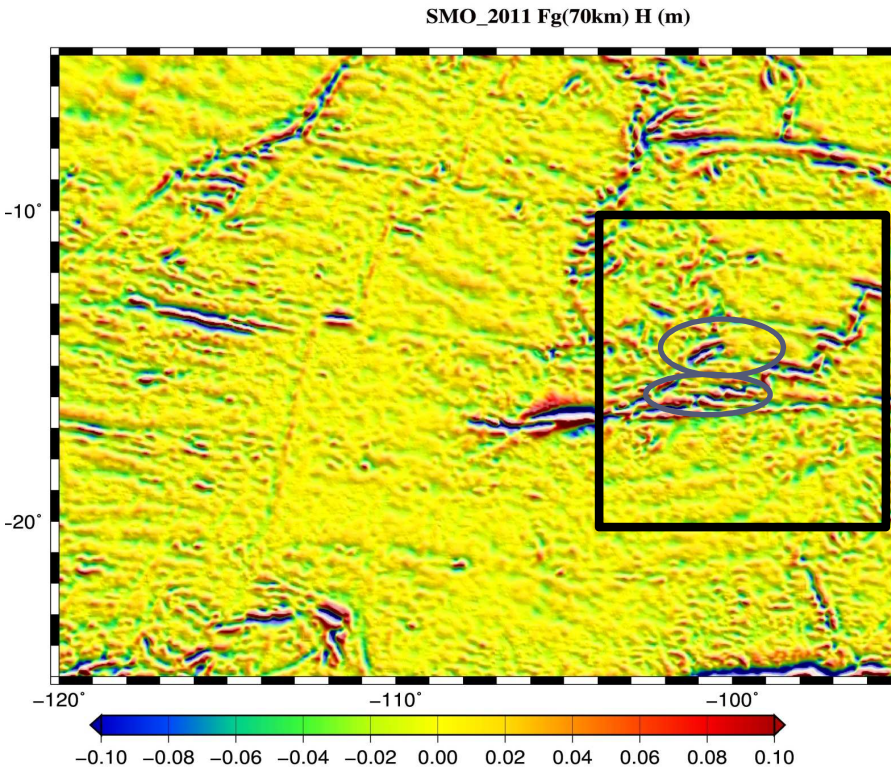


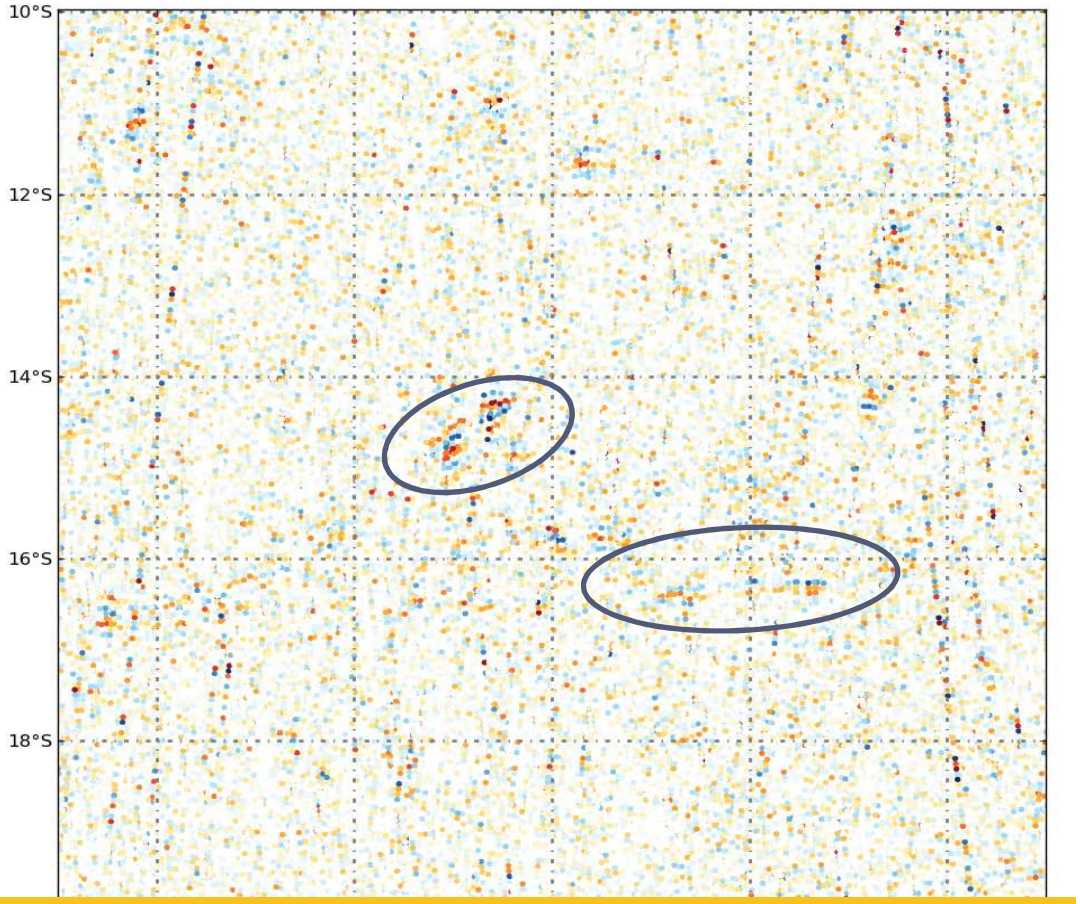
Improving MSS with Cryosat-2 SAR data

The HF content of SSH-MSS CLS11 is compared with HF content of MSS CLS11

=> These are true structures!

C2

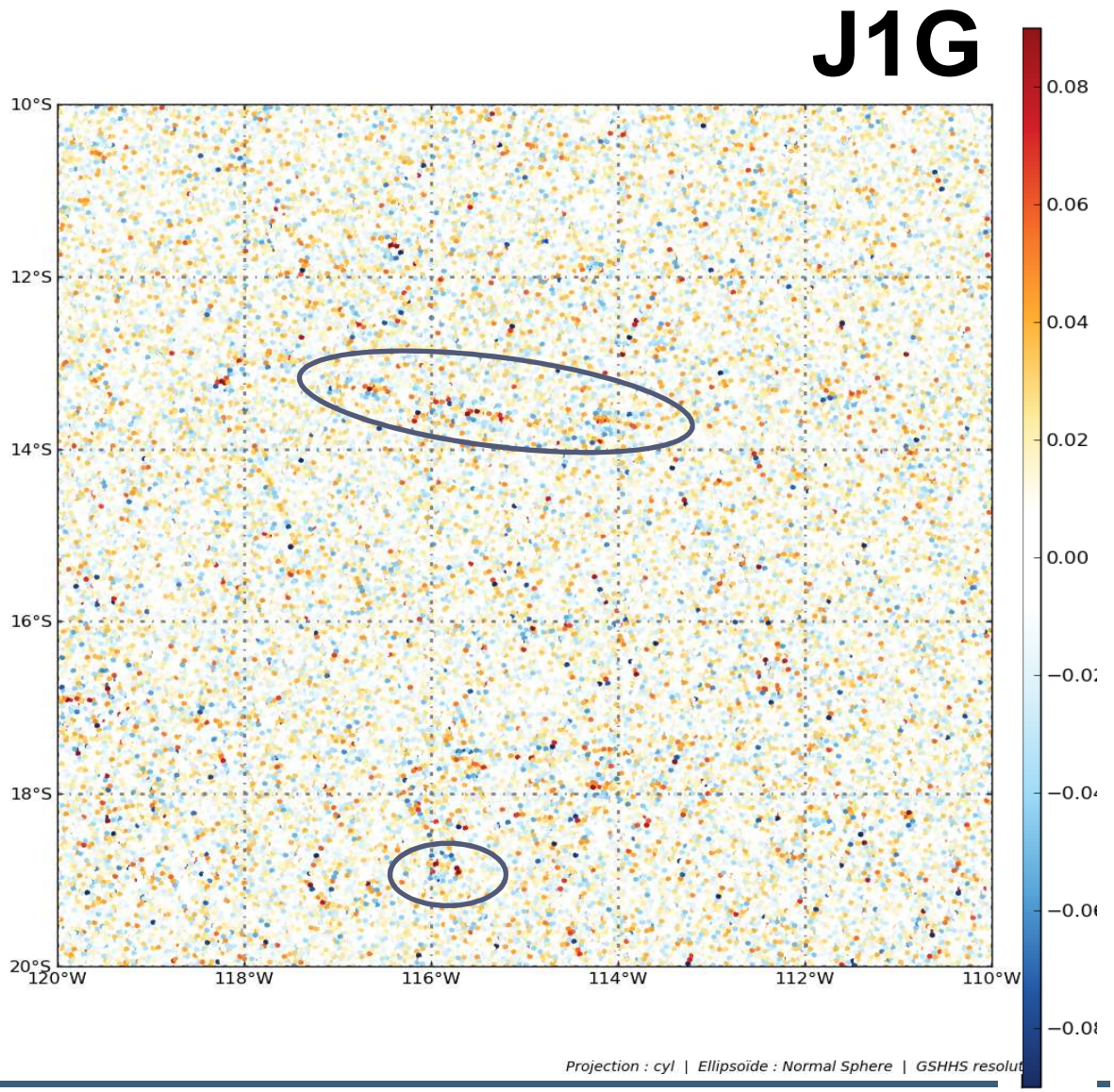




Improved signal to noise ratio confirmed on Cryosat-2 compared to J1 altimeter

=> Small sea mounts details are better delineated with Cryosat-2 data

Improving MSS with Cryosat-2 SAR data



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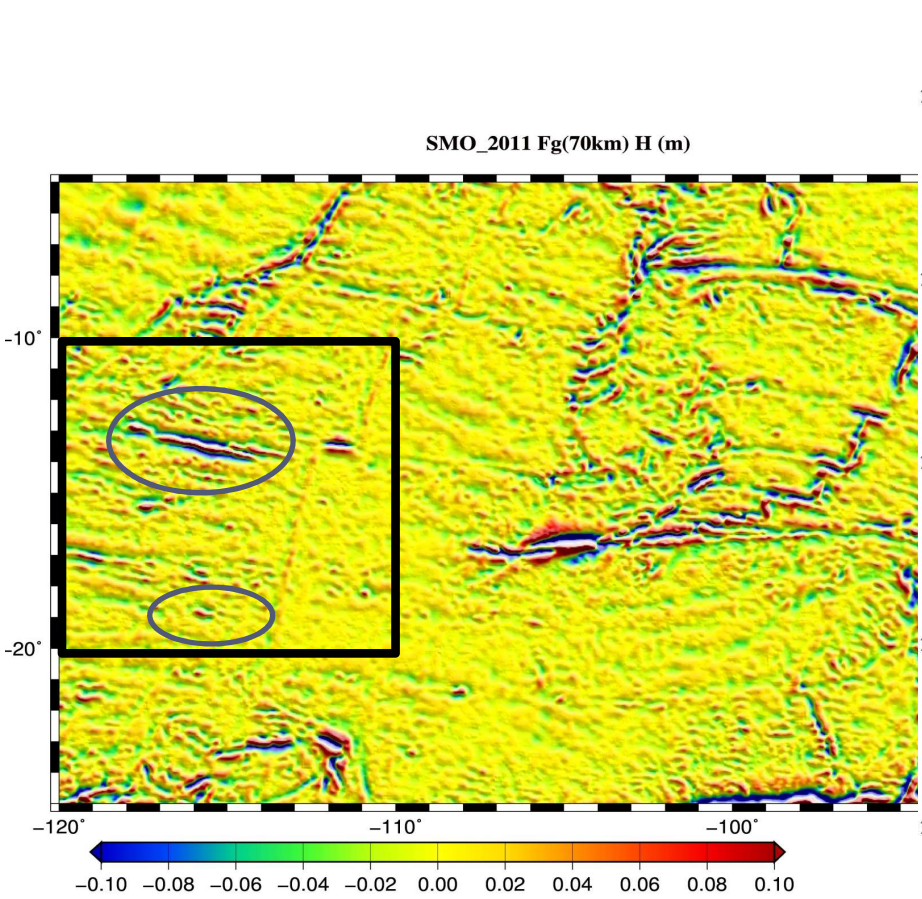

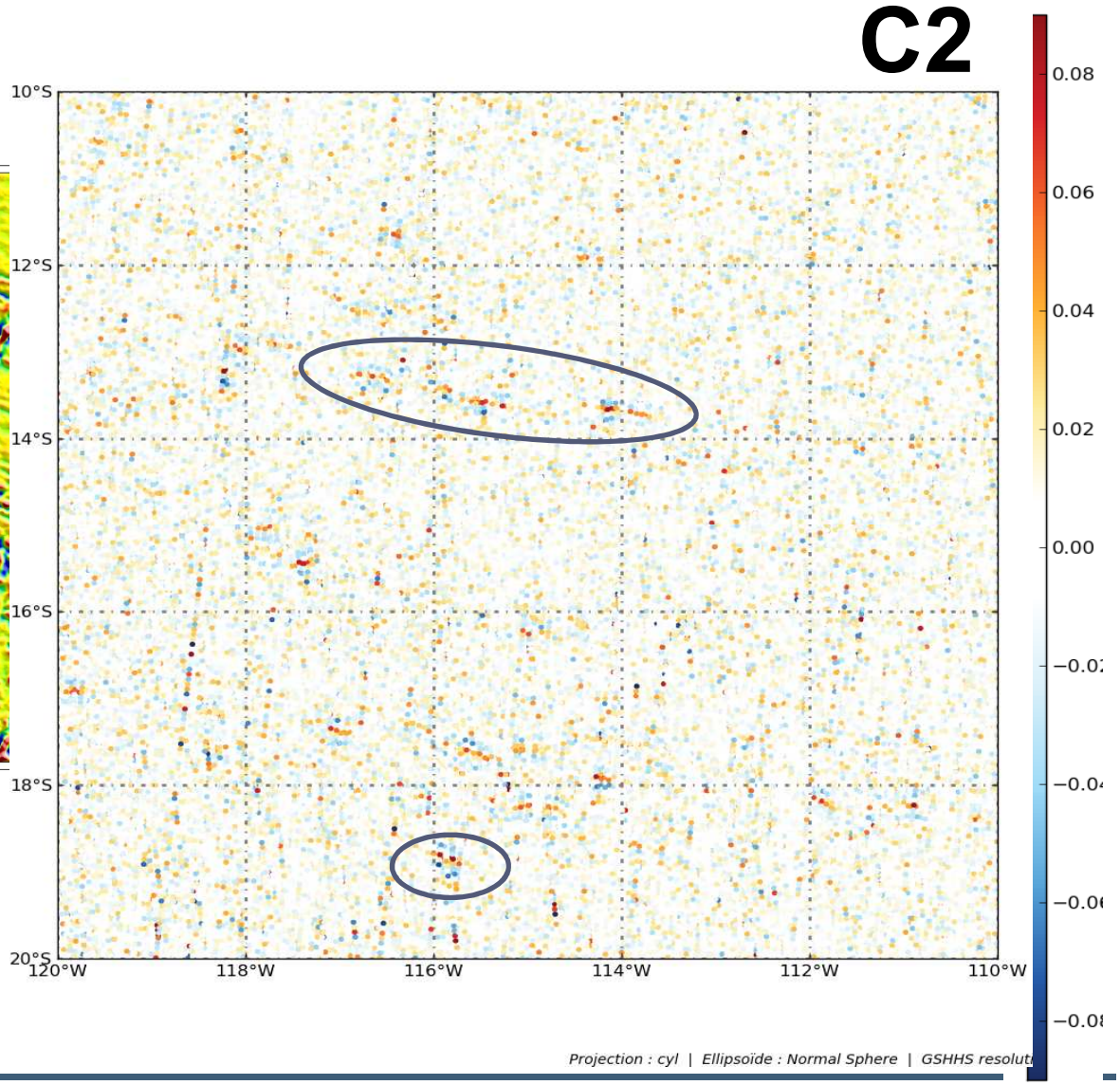

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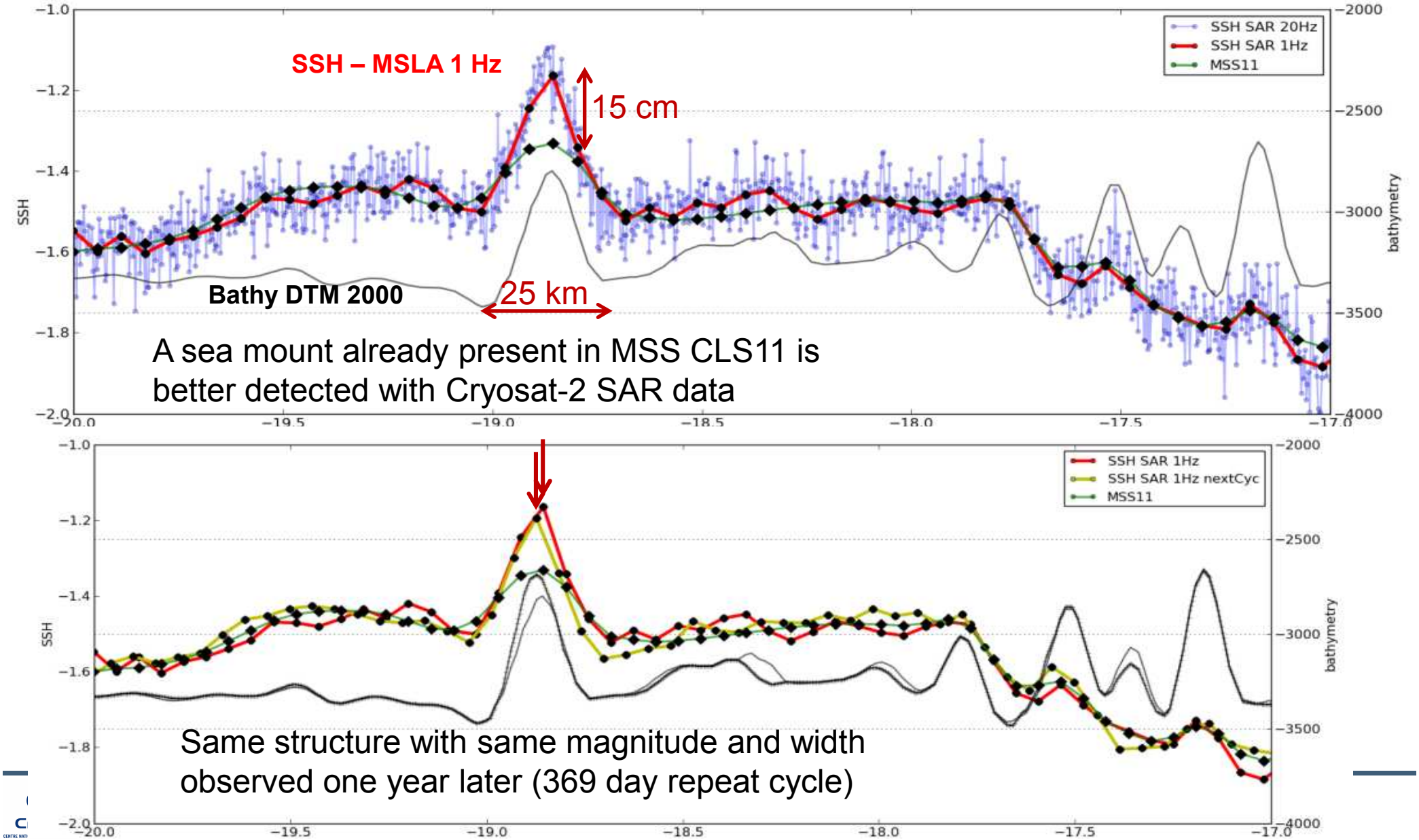
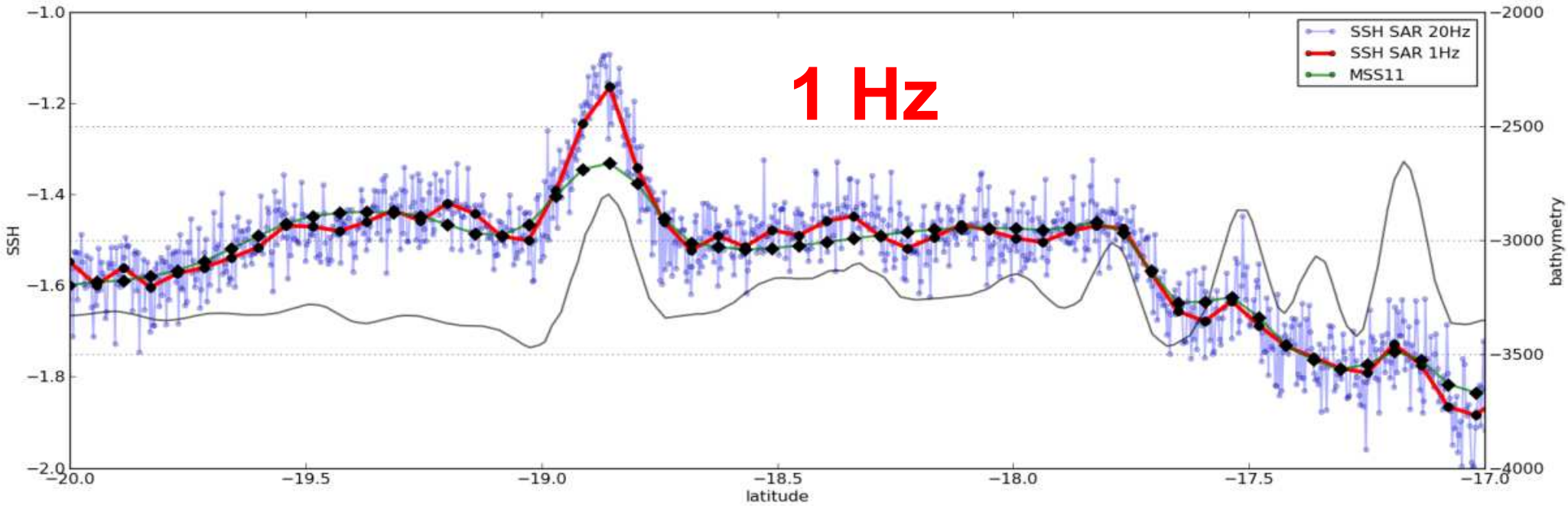
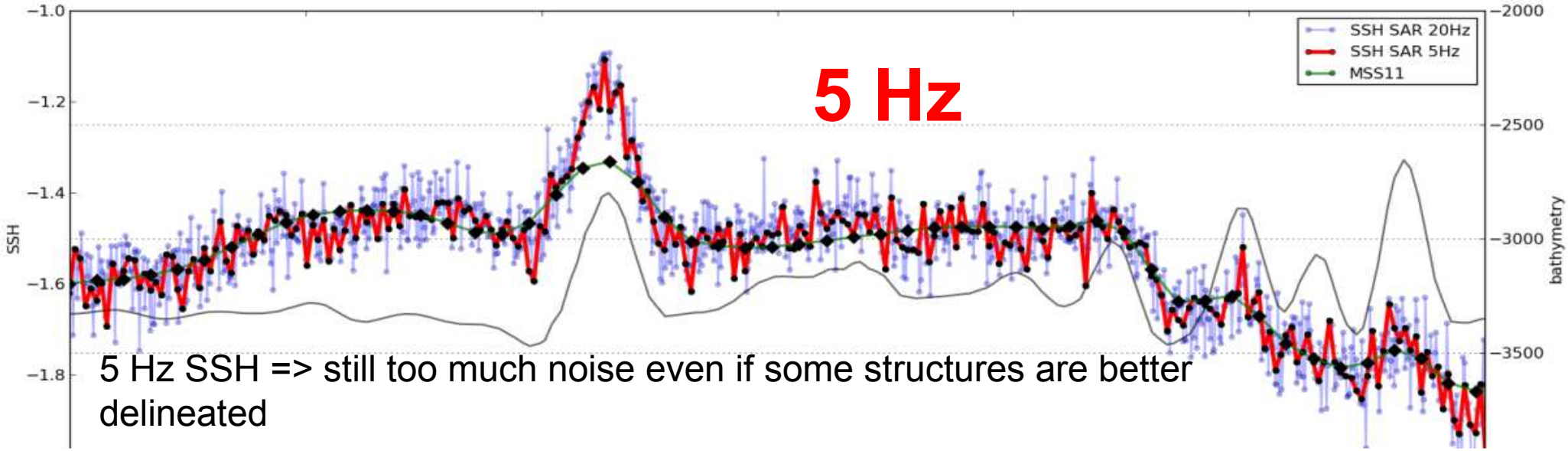


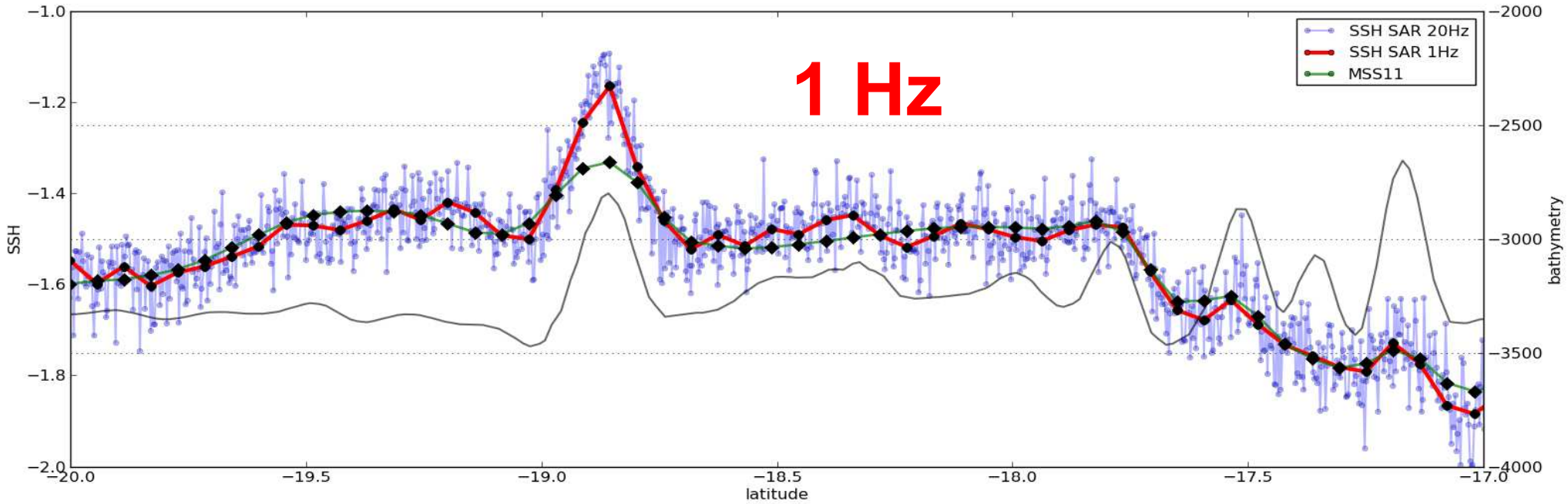
Improving MSS with Cryosat-2 SAR data

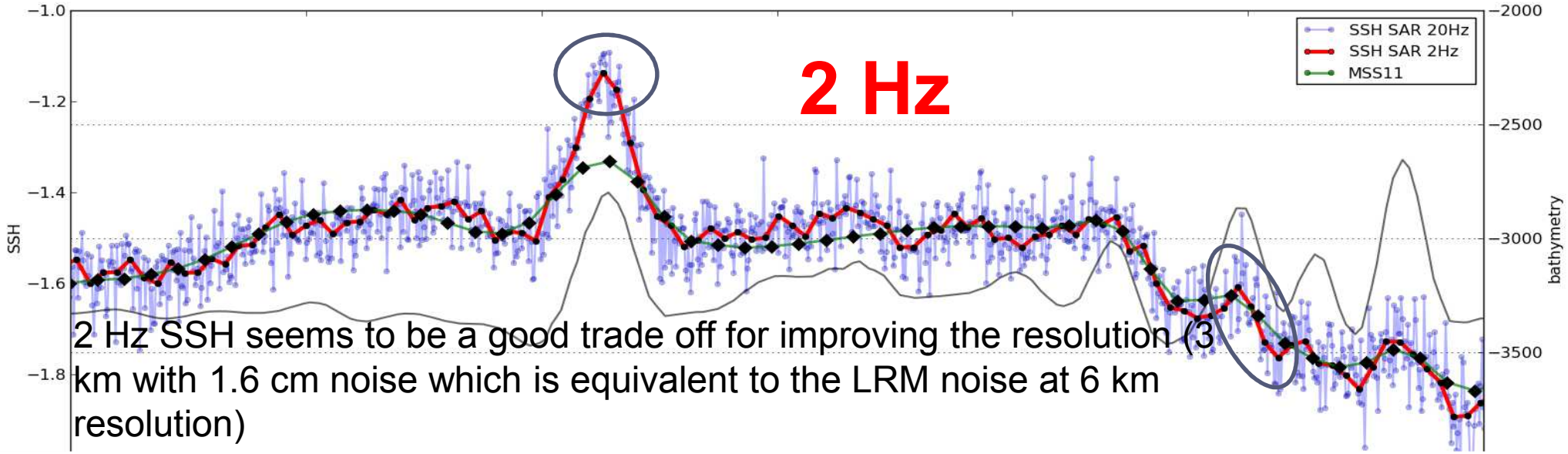




5 Hz SSH => still too much noise even if some structures are better delineated

Improving MSS with Cryosat-2 SAR data





2 Hz SSH seems to be a good trade off for improving the resolution (3 km with 1.6 cm noise which is equivalent to the LRM noise at 6 km resolution)

Conclusions

- Cryosat-2 data processed in SAR mode provides a precious data set for Mean Sea Surface improvement
  - **Geodetic orbit** will provide an excellent coverage
  - **Reduced Noise at 20 Hz and 1 Hz**
- Excellent data quality both for LRM and SAR mode
  - Excellent agreement with Jason-2 mission at basin scale (+/- 2cm)
  - The **LRM and SARM data show a seamless transition at the centimeter level** which is critical for the MSS not to introduce irrealistic gradients!

- **Capability of resolving small sea mounts** of 20 km length previously badly represented in MSS CLS11 (due to under weighting of ERS1 Geodetic phase)

  => the confidence that we have in C2 SAR data associated to other geodetic missions (ERS1GM, EN GM and J1 GM) will greatly benefit to the sea floor mapping in-between the historical tracks (better estimation of magnitude and location of the structures)
- A first attempt for finding a finer resolution has been tested : 2 Hz appears an appealing solution while 5 Hz is still too noisy…