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Comparison of PLRM and SAR icebergs detection for Sentinel3-A and Sentinel-3B

Jean Tournadre

Ifremer, Laboratoire d'Océanographie Physique et Spatiale

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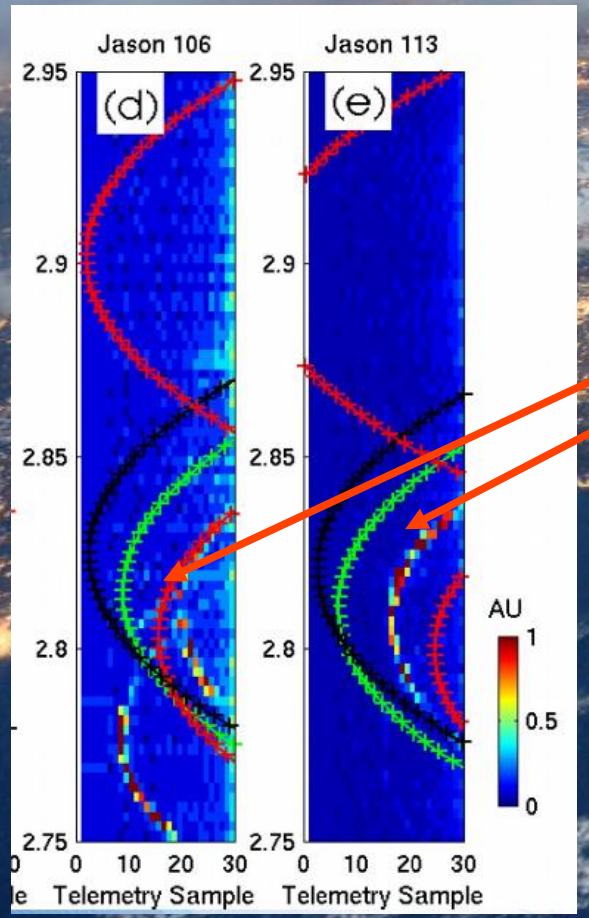
Why icebergs

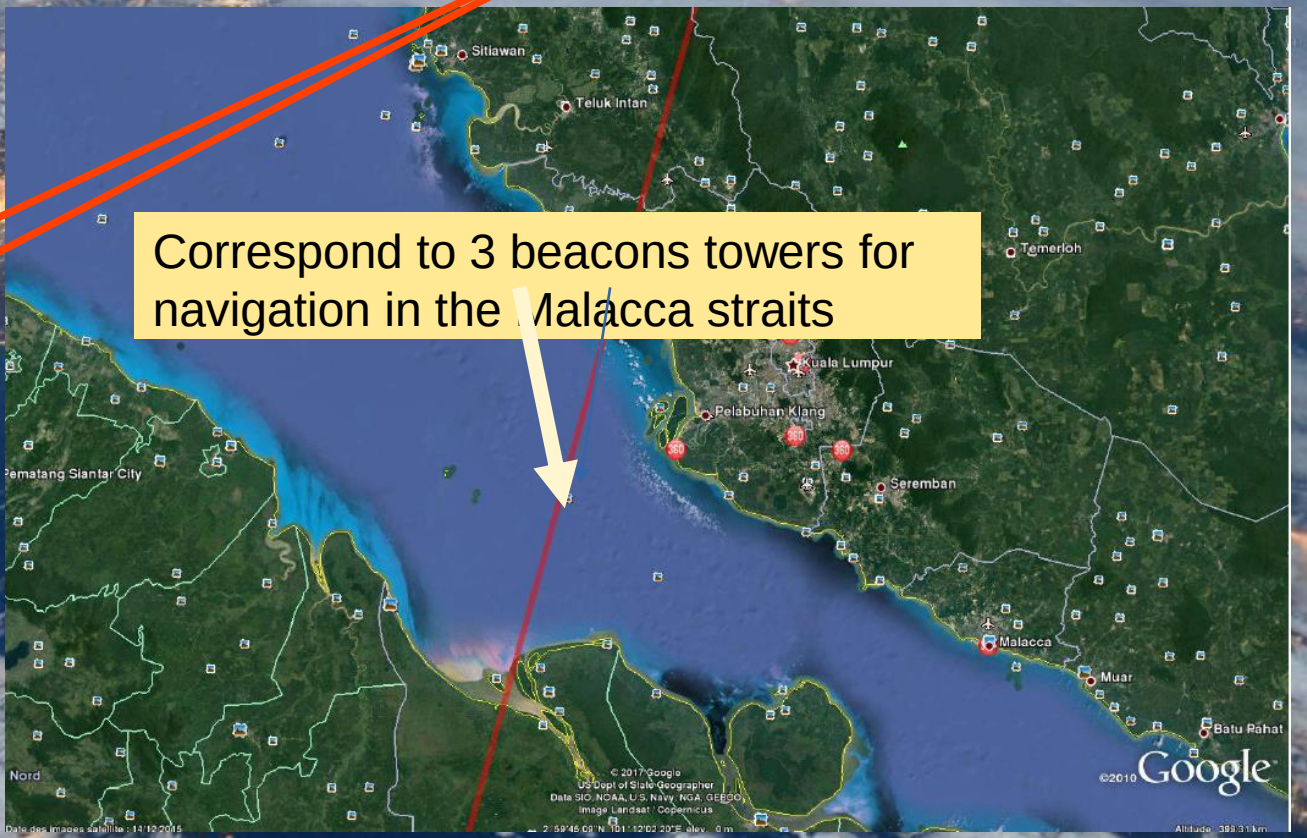
- Shipping (mainly in the northern hemisphere)
- Icebergs are a key component of the Ocean circulation at high latitude and could have a strong impact climate.
- They represent about **half of the mass loss** of the Antarctic Ice cap (Rignot et al 2015, Depoorter et al 2015) and also a significant part of the Greenland Ice cap loss.
- They transfer fresh water far away from the coast into the ocean interior
- In the Southern Ocean : Large Iceberg (>16km, 100km) transport the major part of ice while small icebergs are the main component of fresh water flux through melting
- In the northern hemisphere almost no large icebergs transport by small icebergs
- Altimeters are powerful tools to detect and characterize “small” (<3km in length) icebergs.

Origine

- For small icebergs (<3km)

Jason1 pass 1, strange parabolaes in the thermal noise part of the Jason1 waveforms



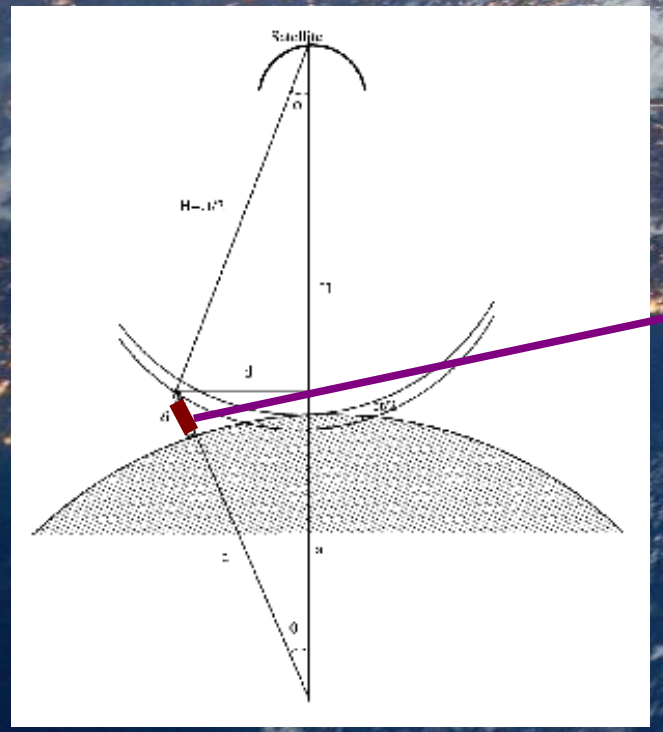


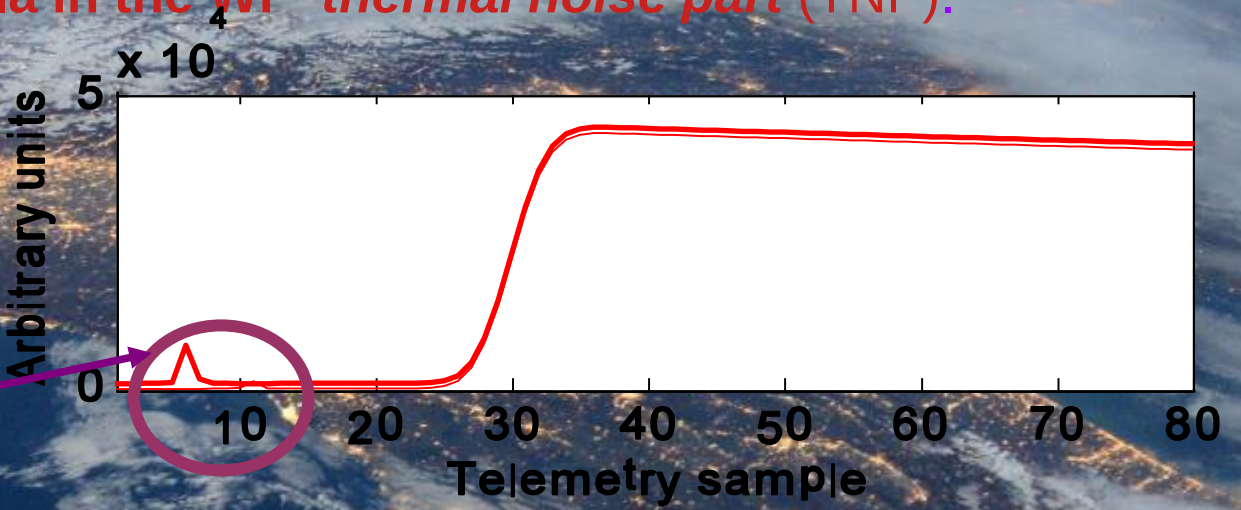
Correspond to 3 beacons towers for navigation in the Malacca straits

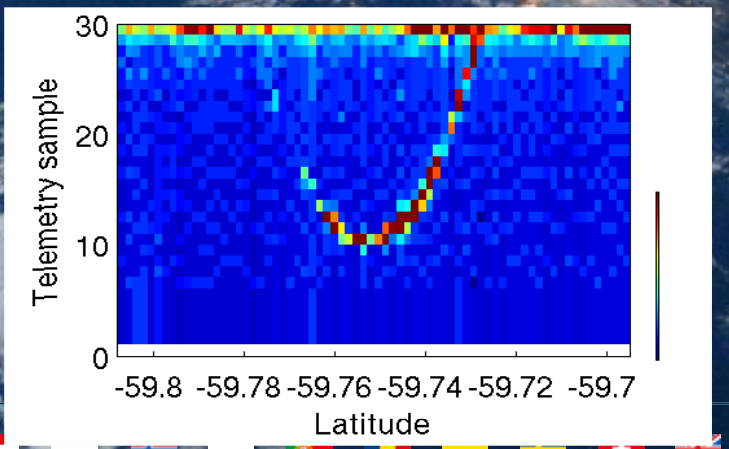
Icebergs detection using Pulse Limited Altimeter (LRM data)

- **Targets emerging from the sea** : detectable signature in the noise part of Altimeter WF [*Tournadre et al , 2008, 2012*].
- In the waveform space the signature is a parabola determined by the orbital parameters.
- **Detection algorithm: detection of parabola in the WF *thermal noise part*** (TNP).
- **Works only in open water**

Peak of σ before mean sea level

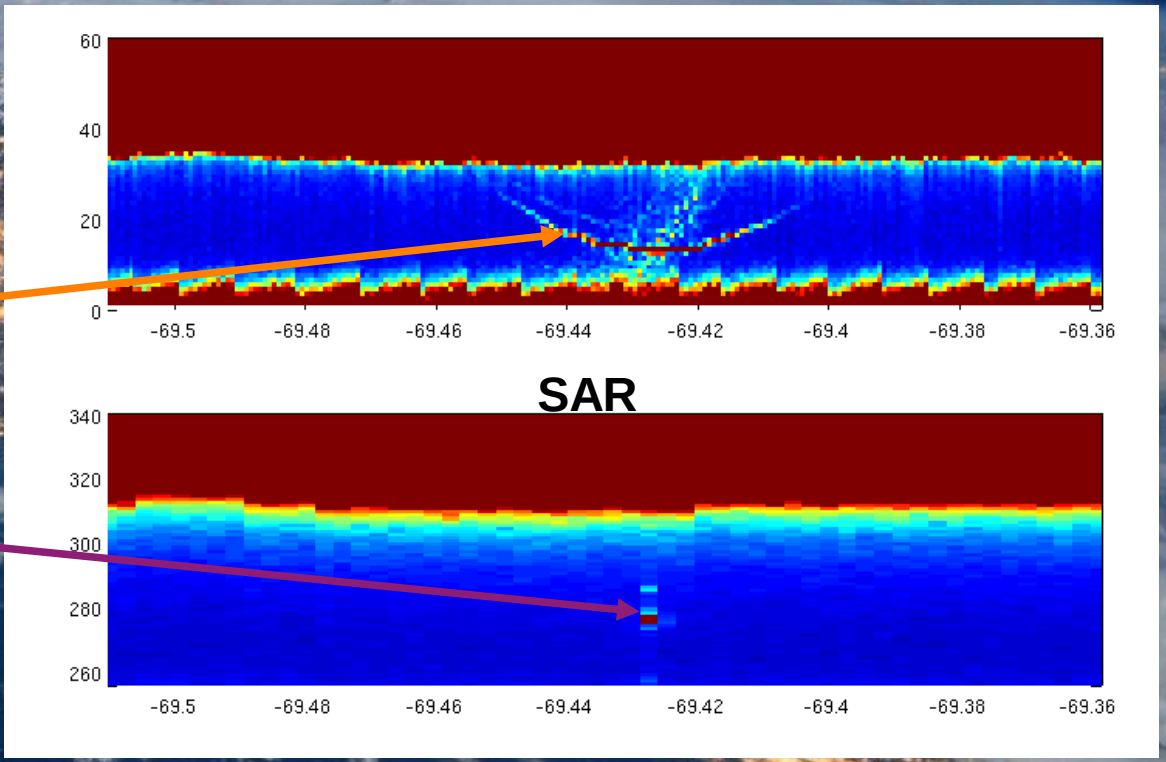






Iceberg signatures in SAR mode echoes

- range alignment including slant, tracker and Doppler range corrections , stacking and incoherent summation of stacks of co-located Doppler beams are used to produce L1B echoes and reduce the noise level.
- The parabolic signature in **LRM** reduces to a bright spot in **SAR** echoes
- Several image processing algorithms have been developed to detect bright spots in imagery (especially for medical applications)
- *Note the lighter parabolaes and spots corresponding to different parts (heights) of the iceberg*

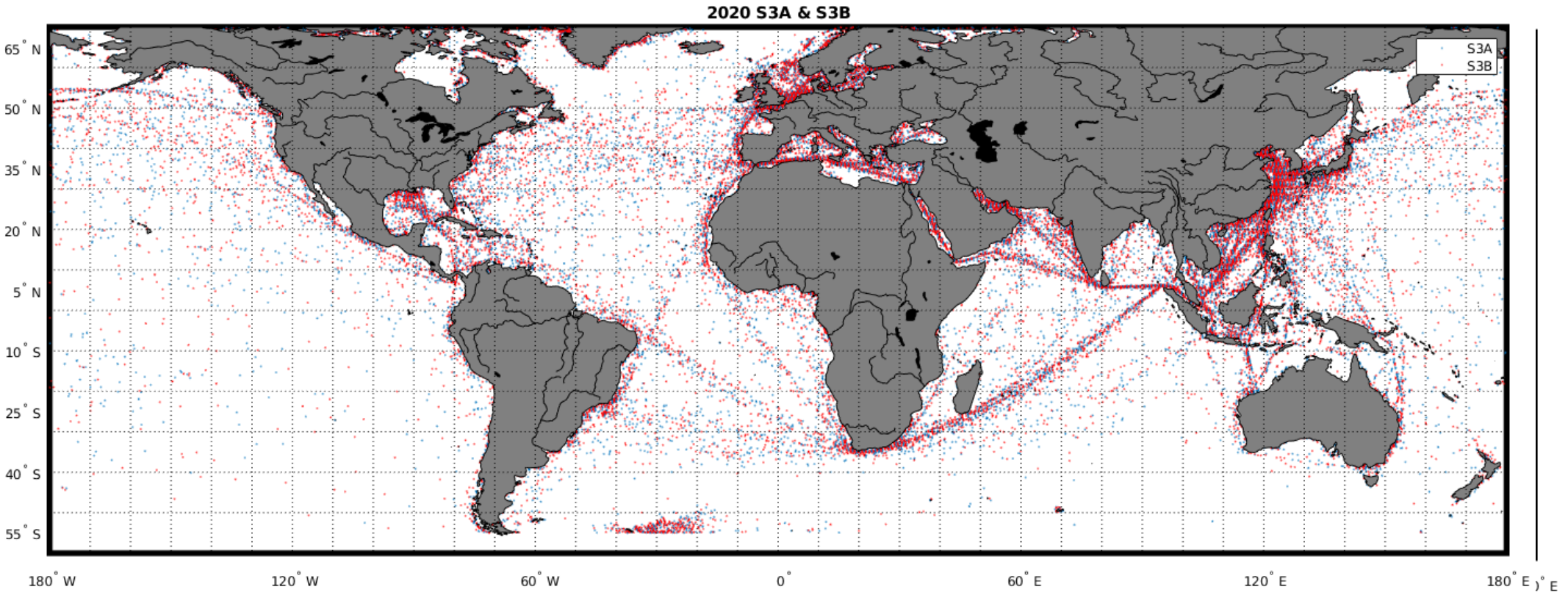


Validation

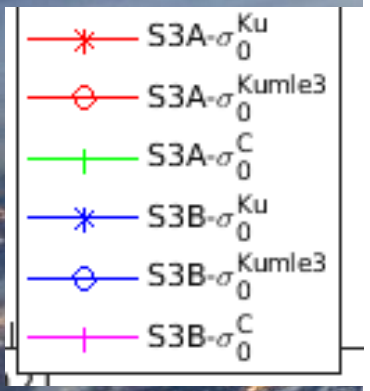
PROGRAMME OF THE EUROPEAN UNION

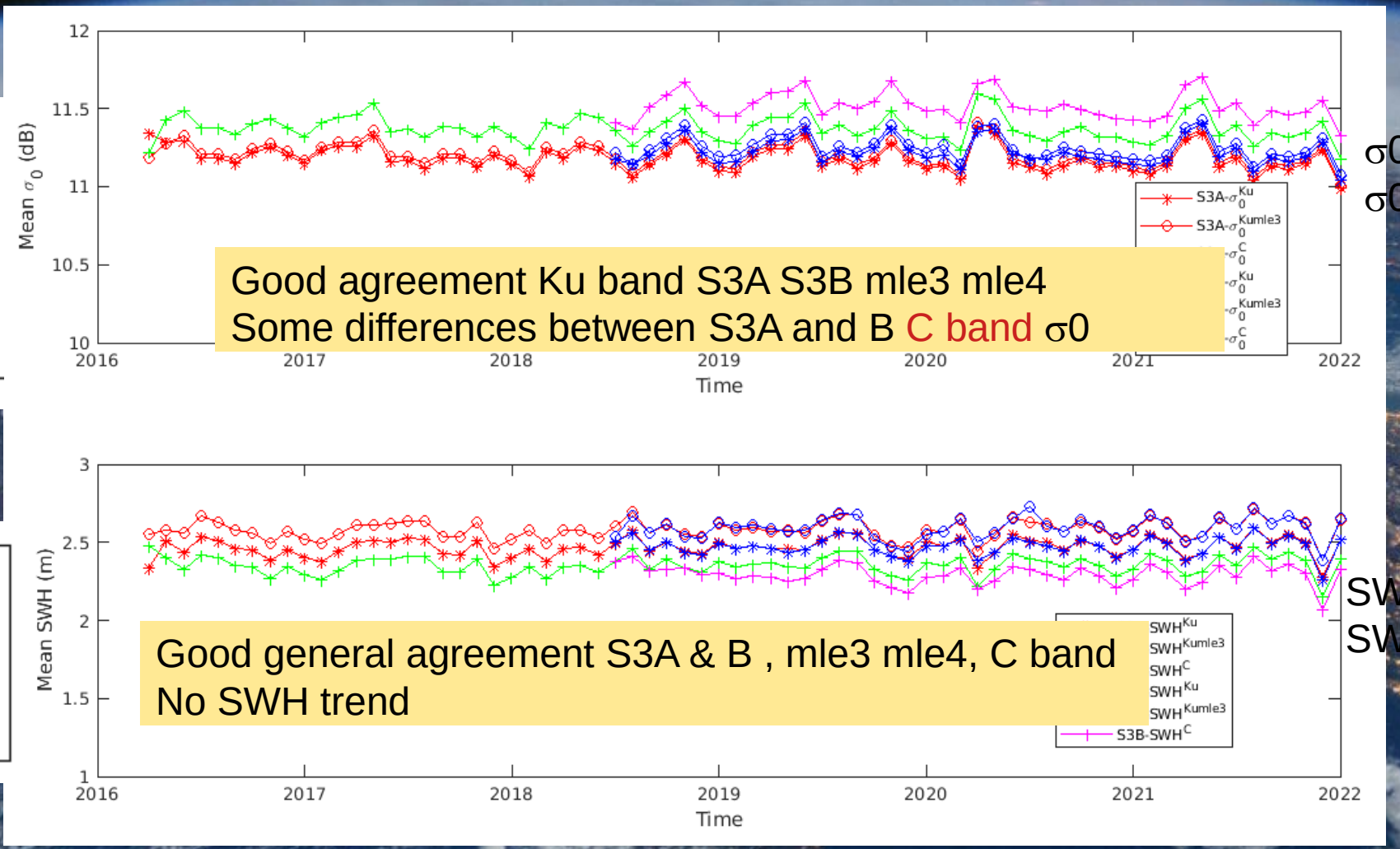
co-funded with

Very good to detect ships, oil platforms, rocks small islands ….;



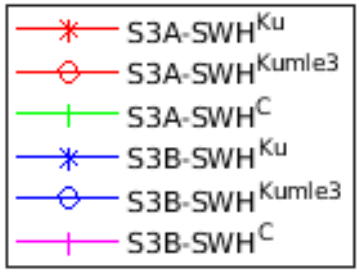
Backscatter and SWH monitoring





Good agreement Ku band S3A S3B mle3 mle4
Some differences between S3A and B C band σ0

σ0 Ku band (mle3 mle4)
σ0 C band



Good general agreement S3A & B , mle3 mle4, C band
No SWH trend

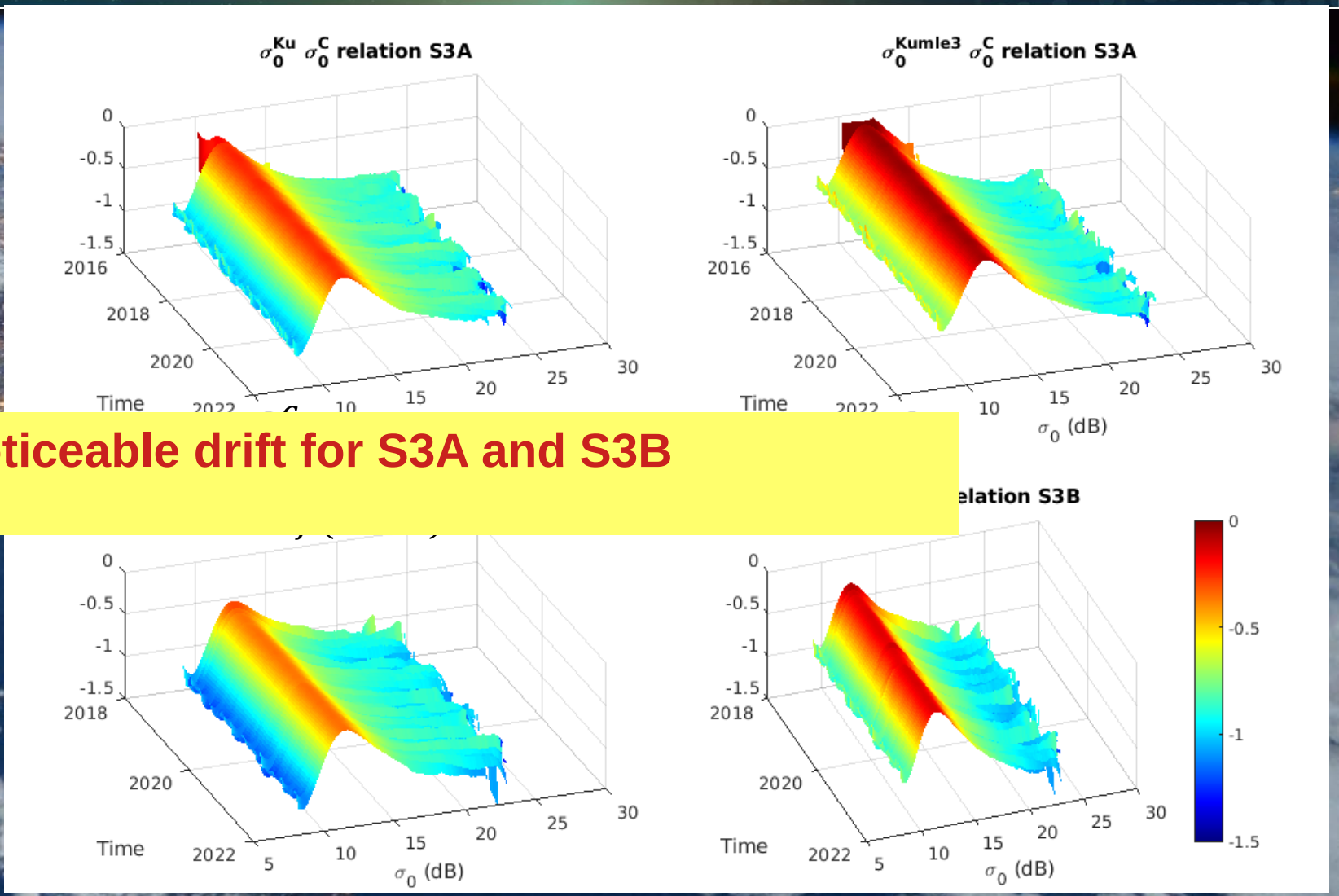
SWH Ku band (mle3 mle4)
SWH C band

Evolution of the Ku-C band relationship

The relations

$$\sigma_0^C - \sigma_0^{Ku^{mle3}} = f\left(\sigma_0^{Ku^{mle3}}\right)$$

$$\sigma_0^C - \sigma_0^{Ku}$$

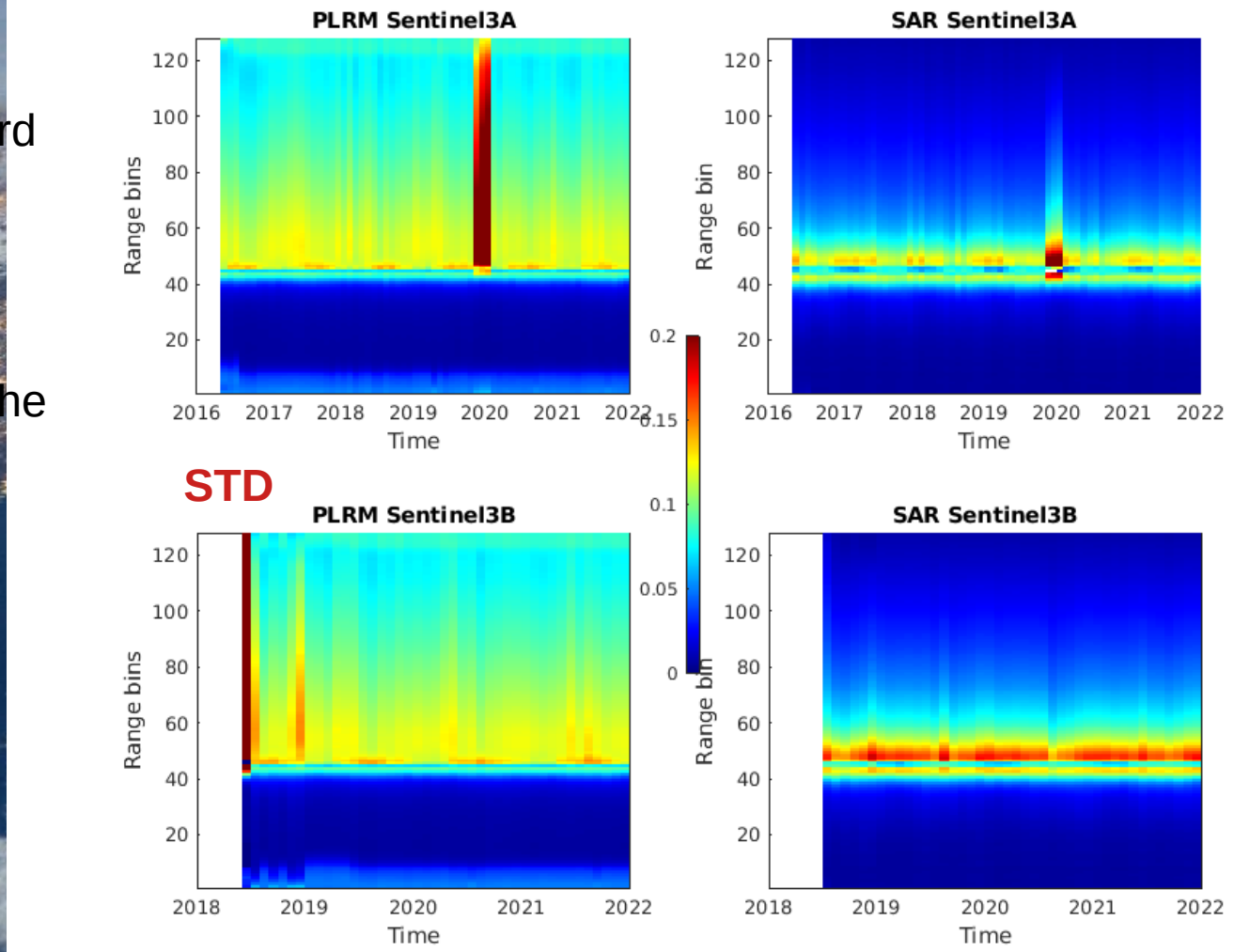


No noticeable drift for S3A and S3B

That can be used to flag for rain can also be used to monitor possible drift between the two bands

Evolution of the mean Waveforms

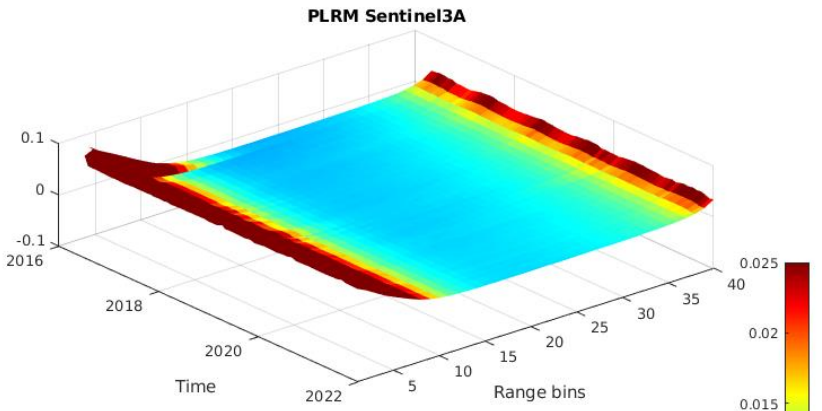
Analysis of the monthly mean and standard deviation waveform (PLRM and SAR) for S3A and S3B.
Except for the first cycles and for a short period in 2020 for S3A no significative variations of the mean waveforms and of the noise level



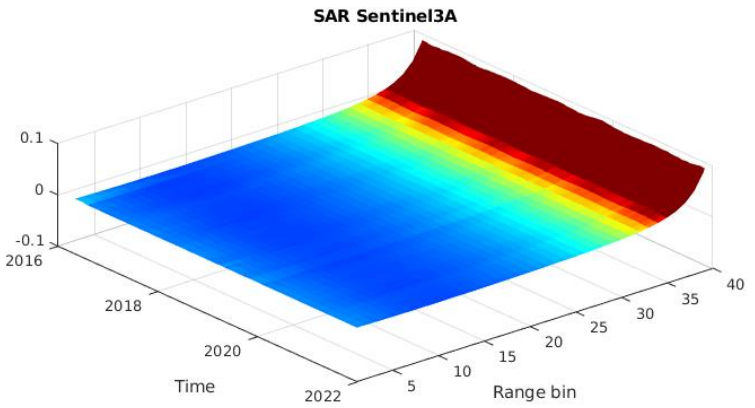
Noise level thermal noise part

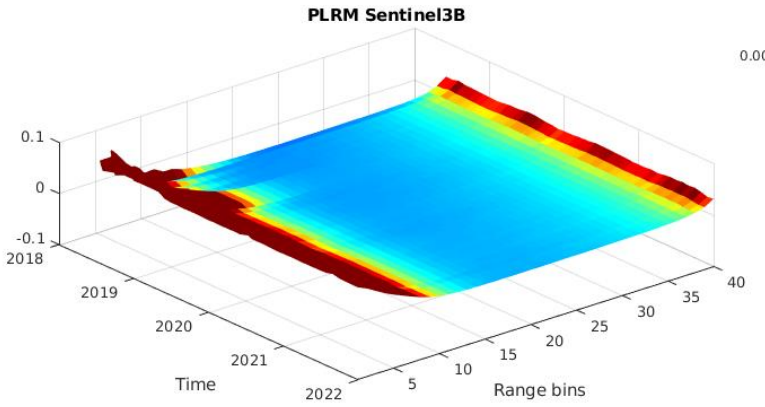
Higher noise level for PLRM than that of SAR for the thermal noise part
First bins (1 to 10) high noise in PLRM
Last bin (30-40) higher noise in SAR

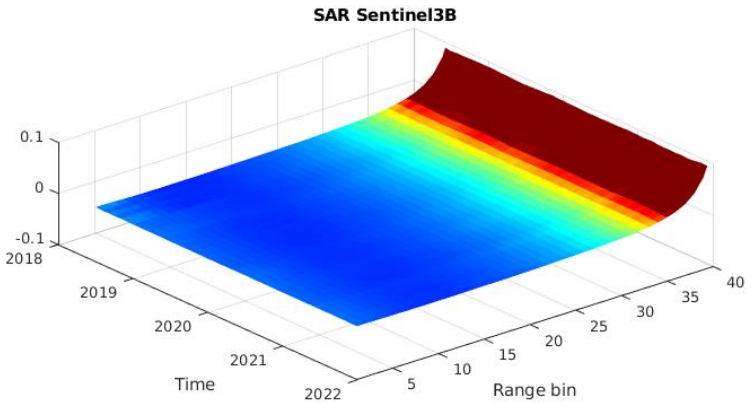
The noise level remains very stable in time for both S3A and S3B



Mean WF

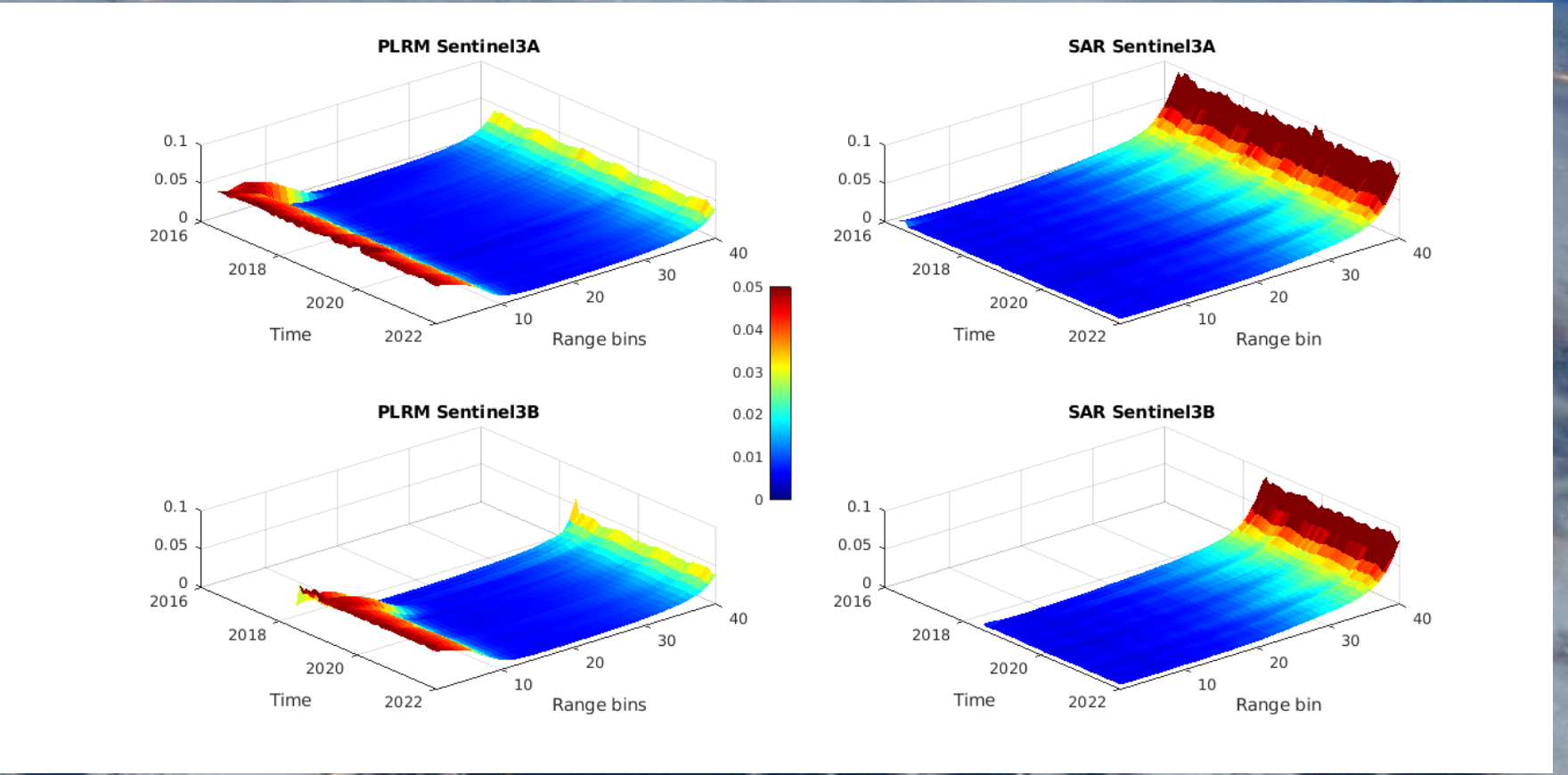




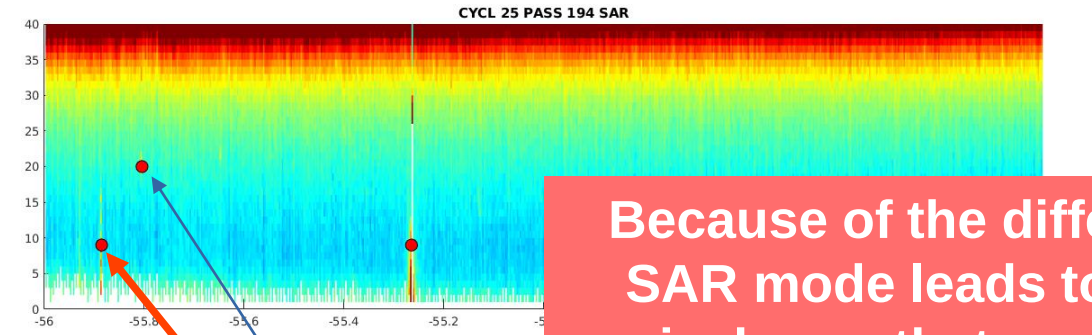


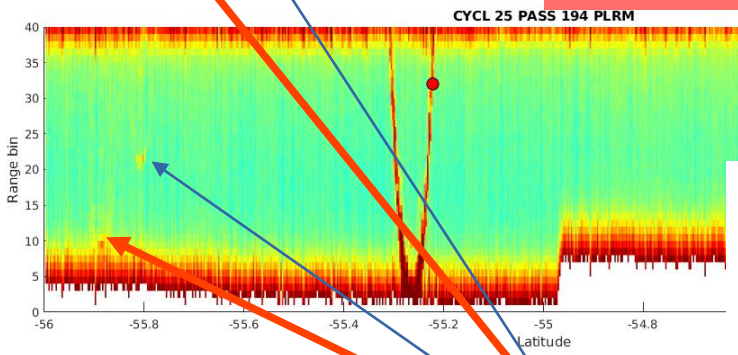
Noise level thermal noise part

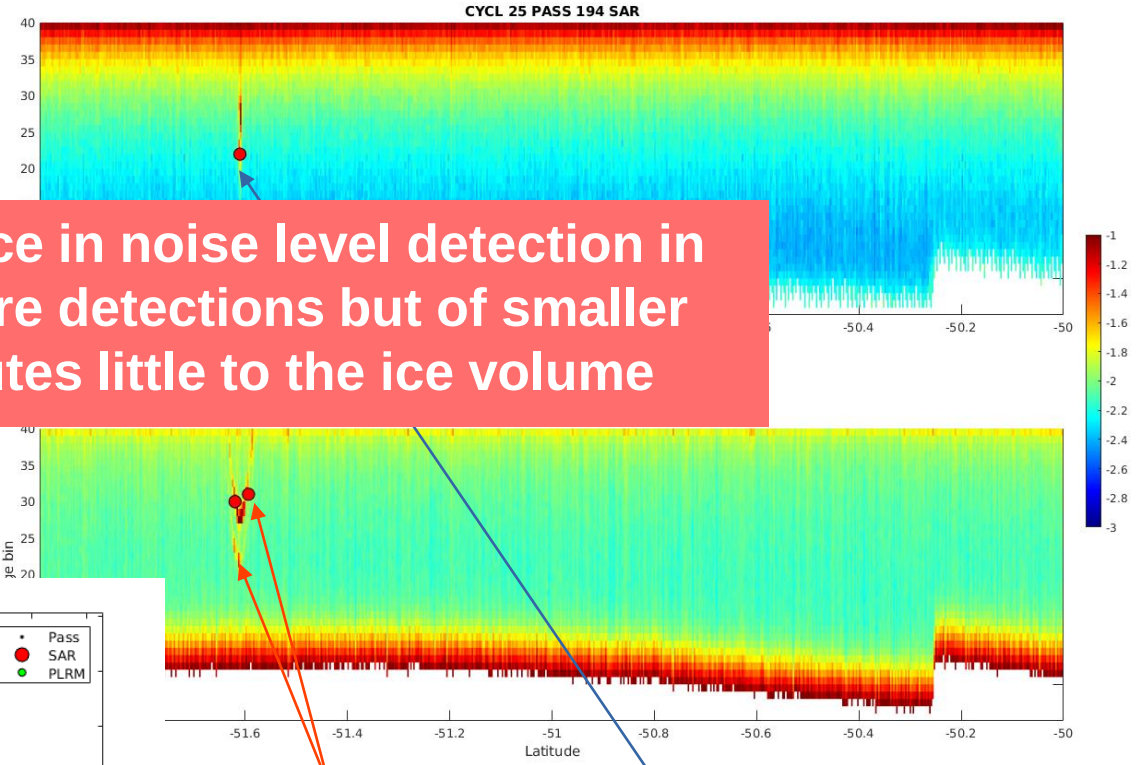
Very stable variability of the noise in the thermal noise part



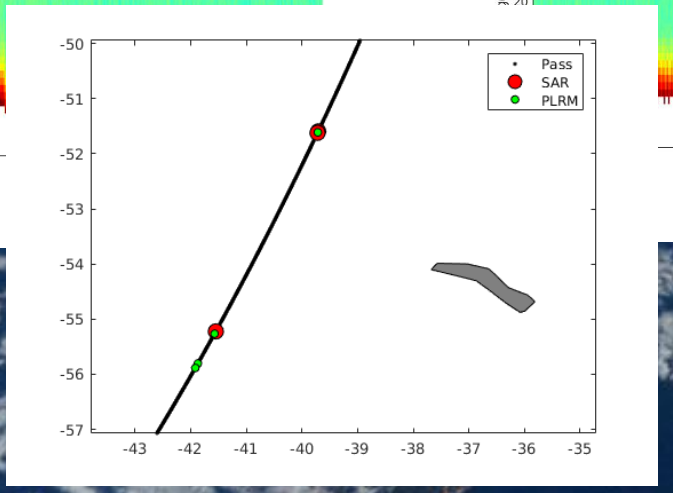
Example of SAR/PLRM detection







Because of the difference in noise level detection in SAR mode leads to more detections but of smaller icebergs that contributes little to the ice volume



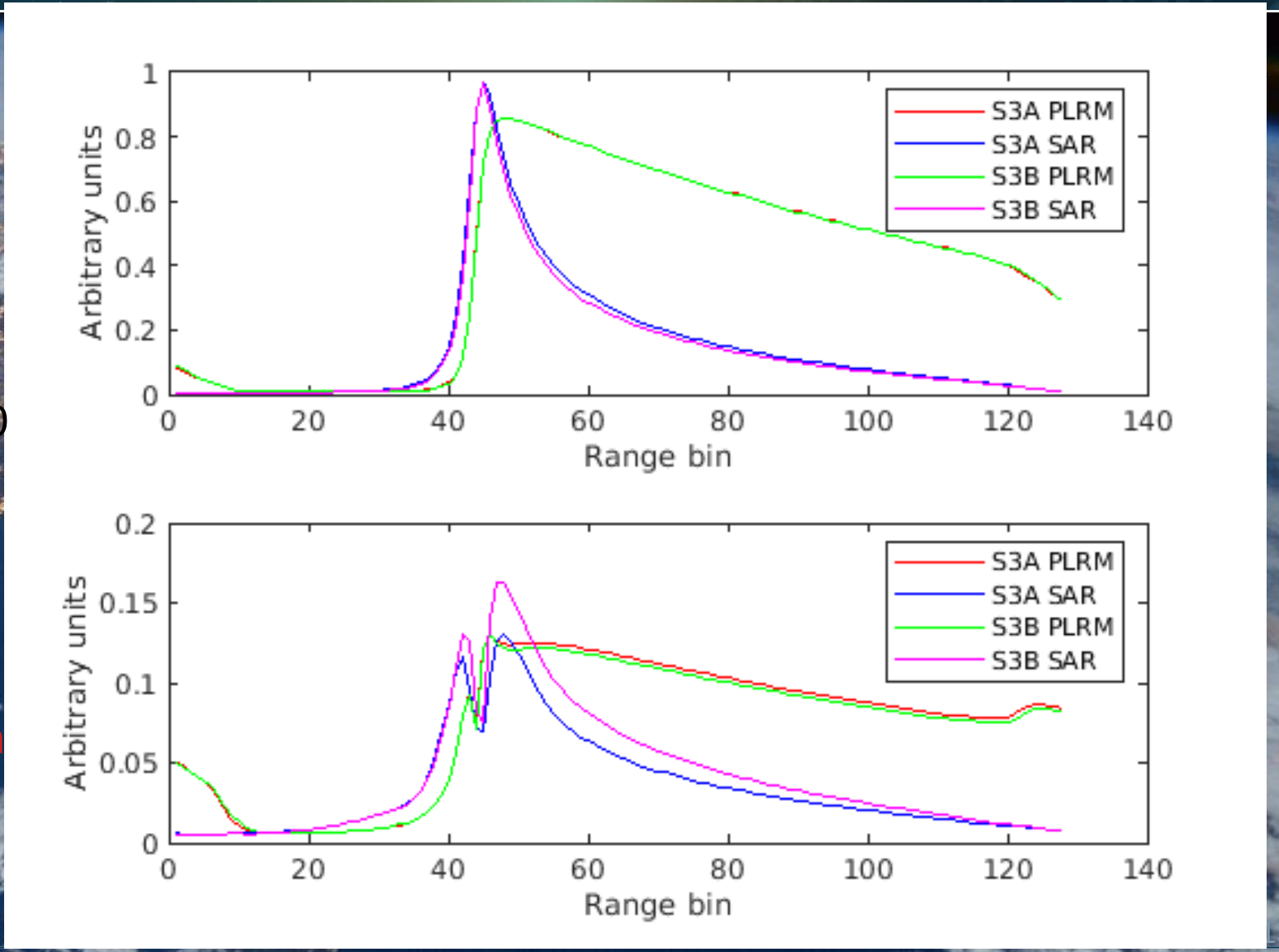
Lower noise level in SAR leads to detection of smaller bergs

Two parabolaes detectedd in PLRM but only one bright spot in SAR

Overall Mean Waveforms and std

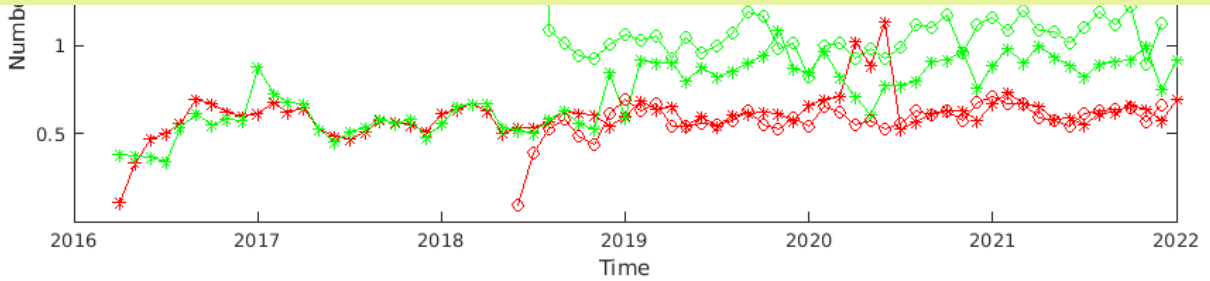
- Identical S3A and S3B mean PLRM and SAR waveforms
- Noise level also identical for S3A and S3B for SAR and PLRM
- For the thermal noise part
  - high noise and std for bin 1 to 10 in PLRM
  - high noise and std for bin 30 to 40 fror SAR mode

Detection for different bins for PLRM and SAR (i.e. distance from nadir and/or freeboard).

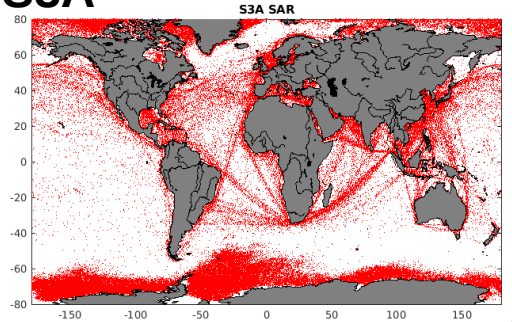


Raw detections

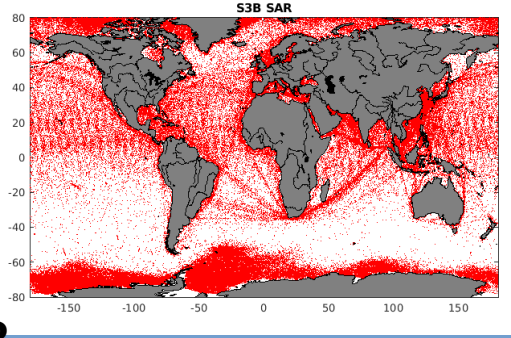
- **Very good agreement between S3A and S3B PLRM**
- **Pb with the first 3 month of S3B SAR**
- **More sensitivity to noise level for SAR**



S3A

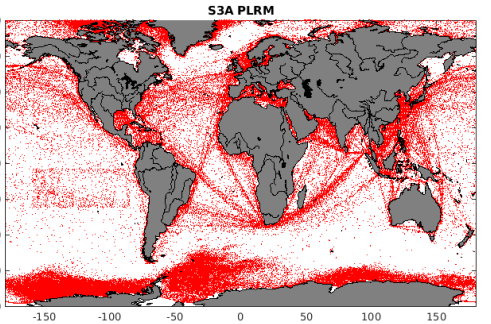


S3B

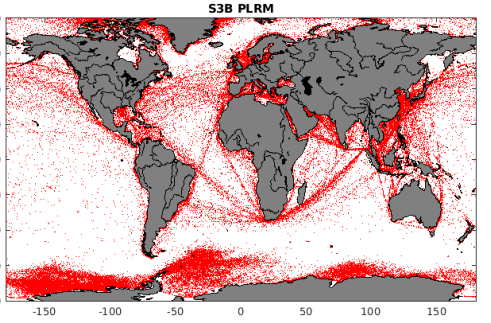


SAR

S3A



S3B

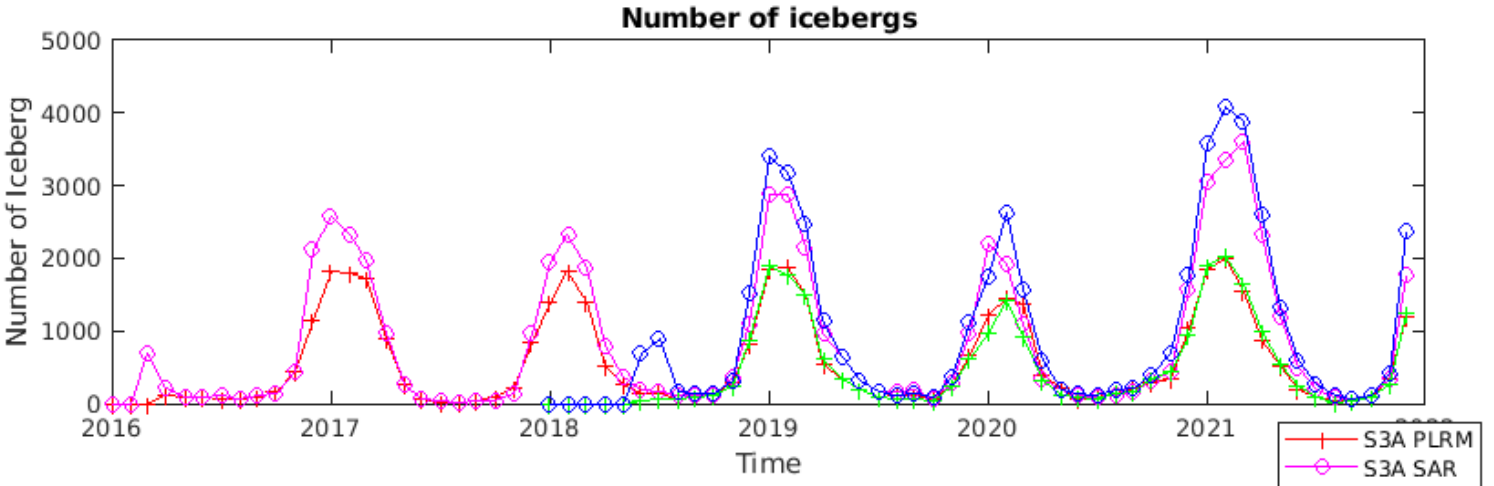


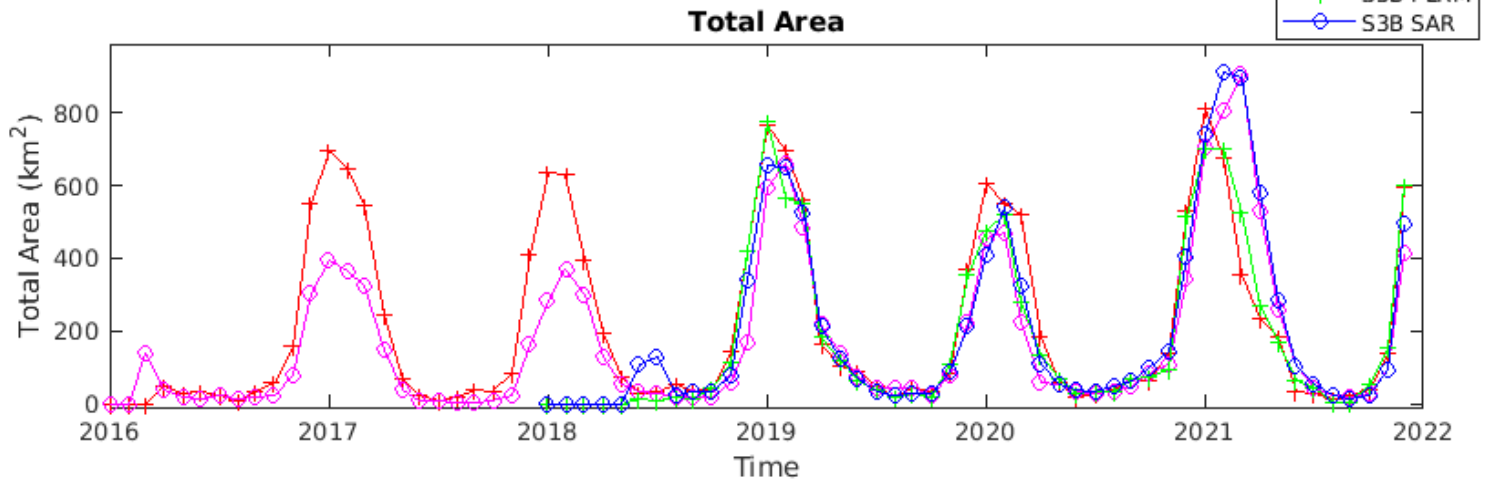
PLRM

Pb with the first 3 month of S3B

Icebergs

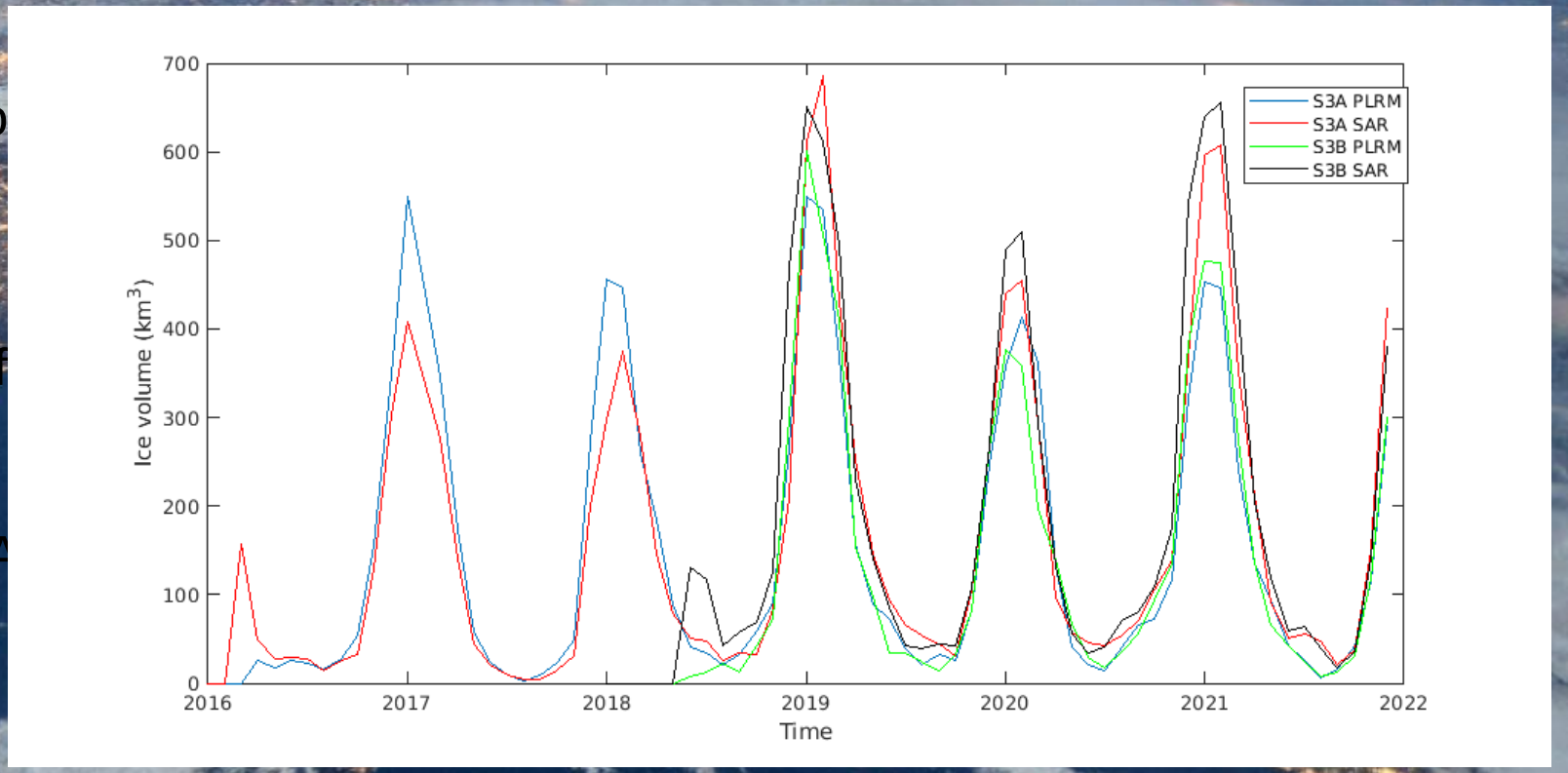
- Very good agreement between S3A and S3B for both PLRM and SAR mode. Almost same number of icebergs detected
- Problem before 2018 for S3A PLRM and SAR total area of the detected icebergs needs to be further investigated.





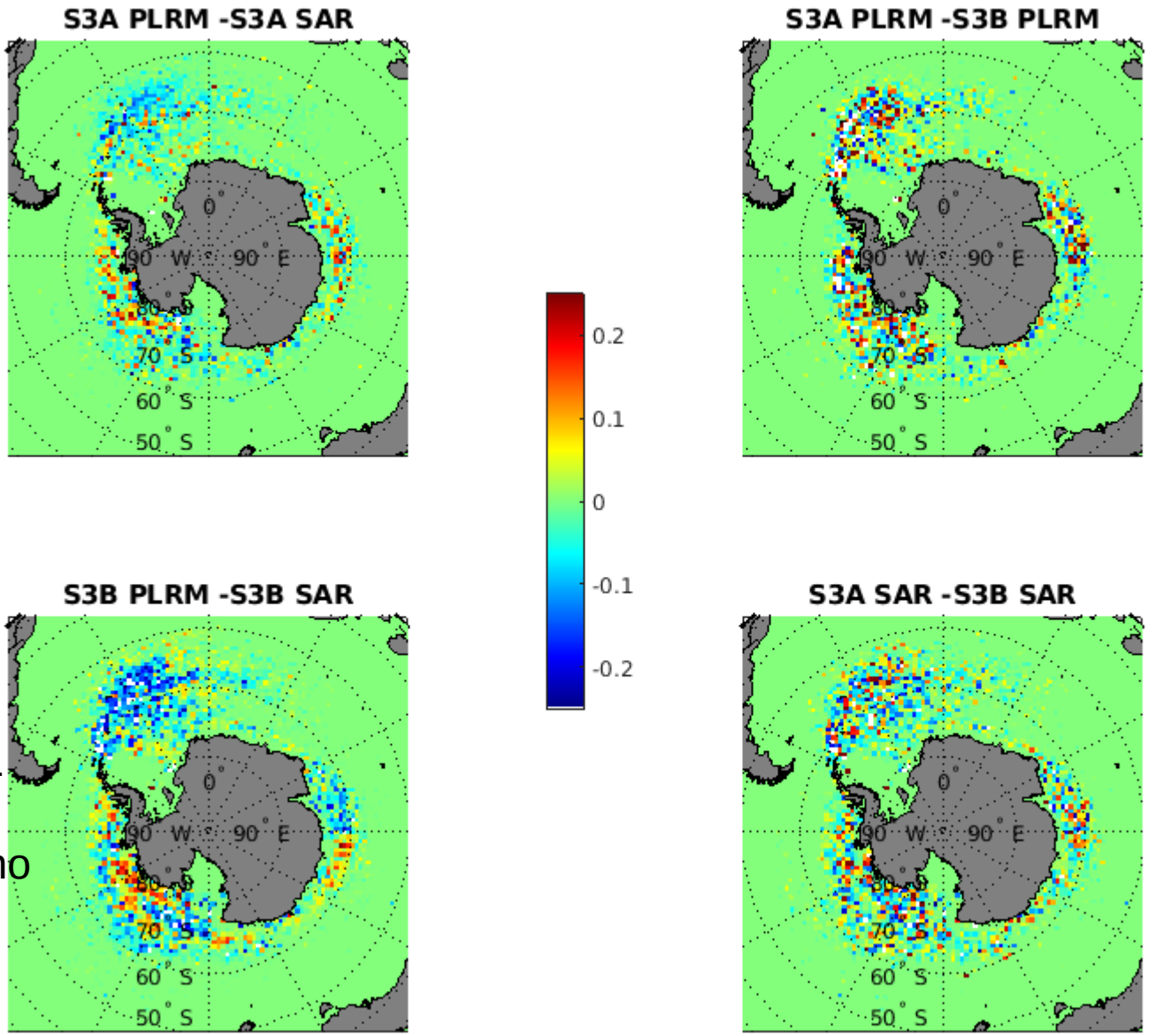
Total monthly volume of ice

- Volume of ice estimated for the mean size and the probabilty of presence of iceberg (number of iceberg/number of valid samples) o a regular grid
- SAR mode gives larger volume of ice because of a better detection of smaller icebergs
- Very good agreement between S3A and S3B for both mode



Monthly volume of ice

- Volume of ice estimated for the mean size and the probabilty of presence of iceberg (number of iceberg/number of valid samples) on a regular grid
- Very similar geographical patterns
- Less volume in the South Atlantic in PLRM and more in the Bellinghausen Sea than in SAR mode
  - Reflects may a difference in the iceberg size distribution
  - Maximum mean difference of the order of 0.1 km³
- Very good agreement between S3A and S3B, no patterns in the difference (random noise)



Conclusion

- The detection of iceberg from altimeter waveform analysis Is very sensitive to the noise level in the thermal noise part of the altimeter waveforms
- In SAR mode the noise level of the waveforms is reduced by stacking and allows a better detection of smaller icebergs
- The analysis of the detection as well as backscatter and mean WF since 2016 (2018) does not show any drift or trend
  - It also shows a very good agreement between S3A and S3B
  - Some difference exists between the PLRM and SAR detections mainly because of the noise level and detection algorithm
  - Some periods exhibit strong difference that results from a strong change of noise level (to be further analyzed)
- Very good agreement of the volume of ice (i.e. the most important parameter)
- Difference in the volume estimate in SAR and PLRM mode could be further analyzed in term of change of iceberg size distribution