An inter-comparison between the reprocessed Sentinel-3 sea-ice products, Cryosat-2 and IceSat-2 over sea-ice

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The MPC team

- ✓ The **MPC** is the ESA project in charge of the Sentinel-3 operational products for Hydro, Land-Ice and Sea-Ice.
- ✓ The **ESL (Expert Support Laboratories)** team is in charge of the content and validation

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Mission Performance Cluster
of Surface Topography Mission

+ Jérémie Aublanc
CLS
ESLs coordinator

- ✓ A full mission reprocessing of Sentinel-3A/B was performed in 2023 to generate the **Sea-Ice Thematic Products,** showing **great improvements with respect to the former baseline (LAND)**
- ✓ This talk aims at comparing these new products to the reference missions for polar applications, i.e. **CryoSat-2** and **IceSat-2**

1. Improvements brought by the Sea-Ice Thematic Products
2. Comparison Cryosat-2/Sentinel-3 : radar freeboard
3. Comparison Cryosat-2/Sentinel-3 : time series of freeboard volume
4. Comparison IceSat-2/Sentinel-3 : total freeboard
5. Conclusions

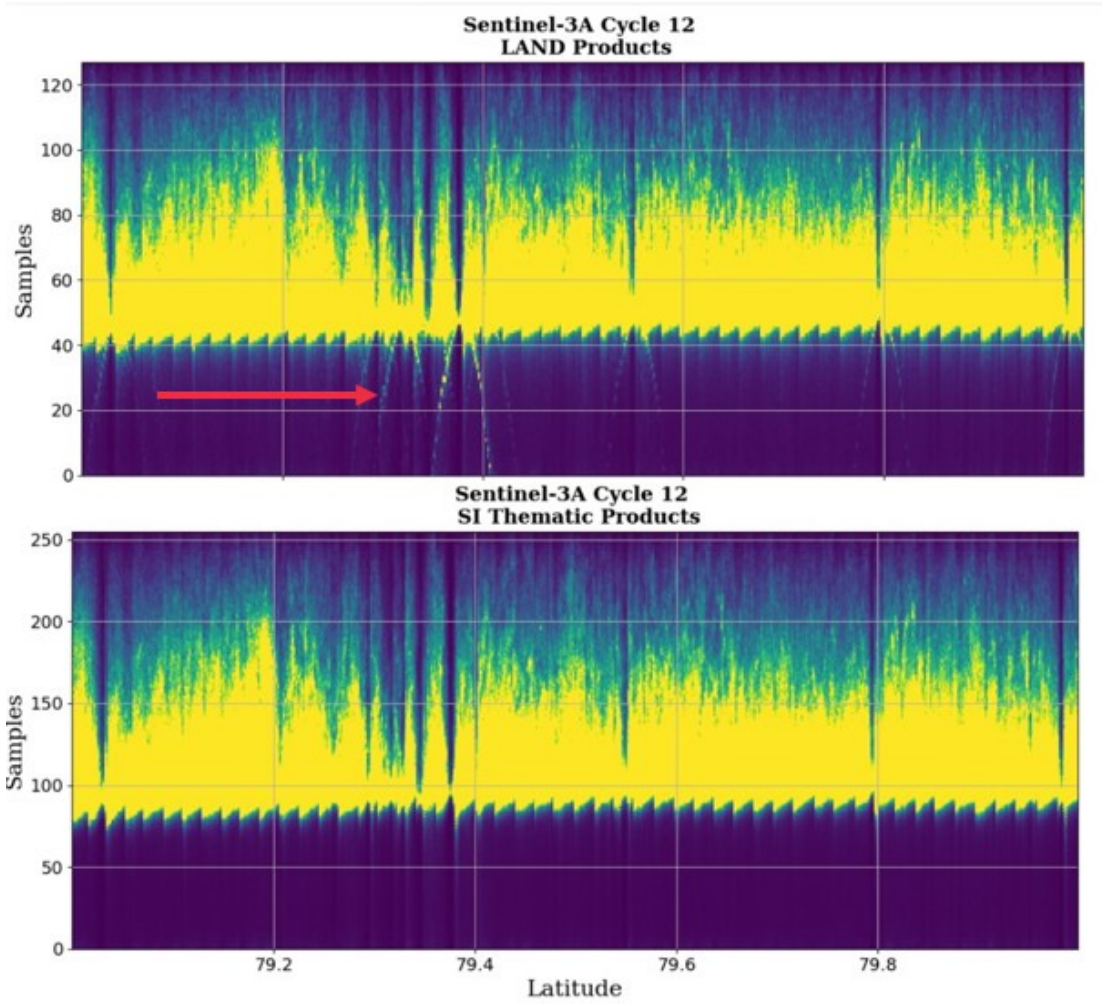
Download the products (“LAN_SI”)

https://

The S3 Thematic products : Main evolutions

Hamming Weighting Window

Significant reduction of the perturbations on the leading edge of the waveforms due to the secondary lobes of the azimuth PTR on specular echoes



Example of the impact of the Hamming weighting for specular echoes

The S3 Thematic products : Main evolutions

Hamming Weighting Window

Significant reduction of the perturbations on the leading edge of the waveforms due to the secondary lobes of the azimuth PTR on specular echoes

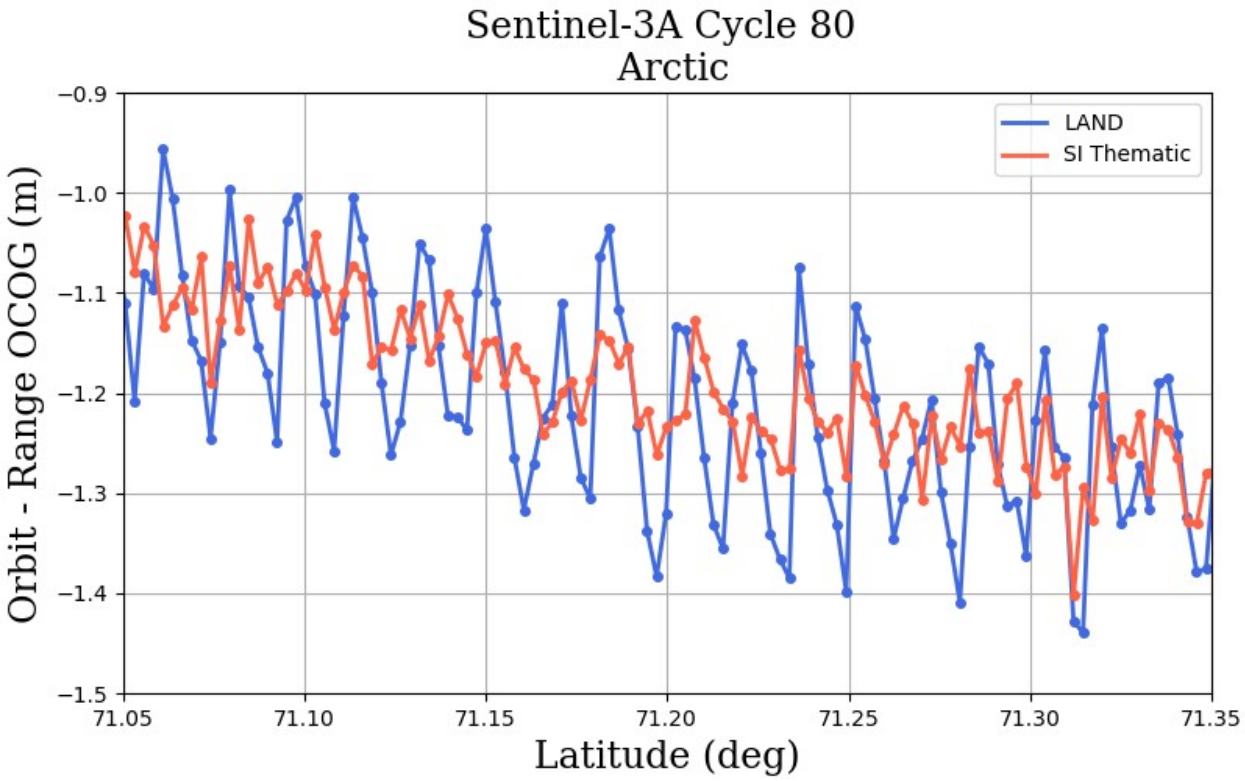
+

Zero-Padding

Allows to smooth the oscillations (“jitter noise”) observed with empirical retrackers due to the sampling of specular echoes → improves accuracy of the waveform

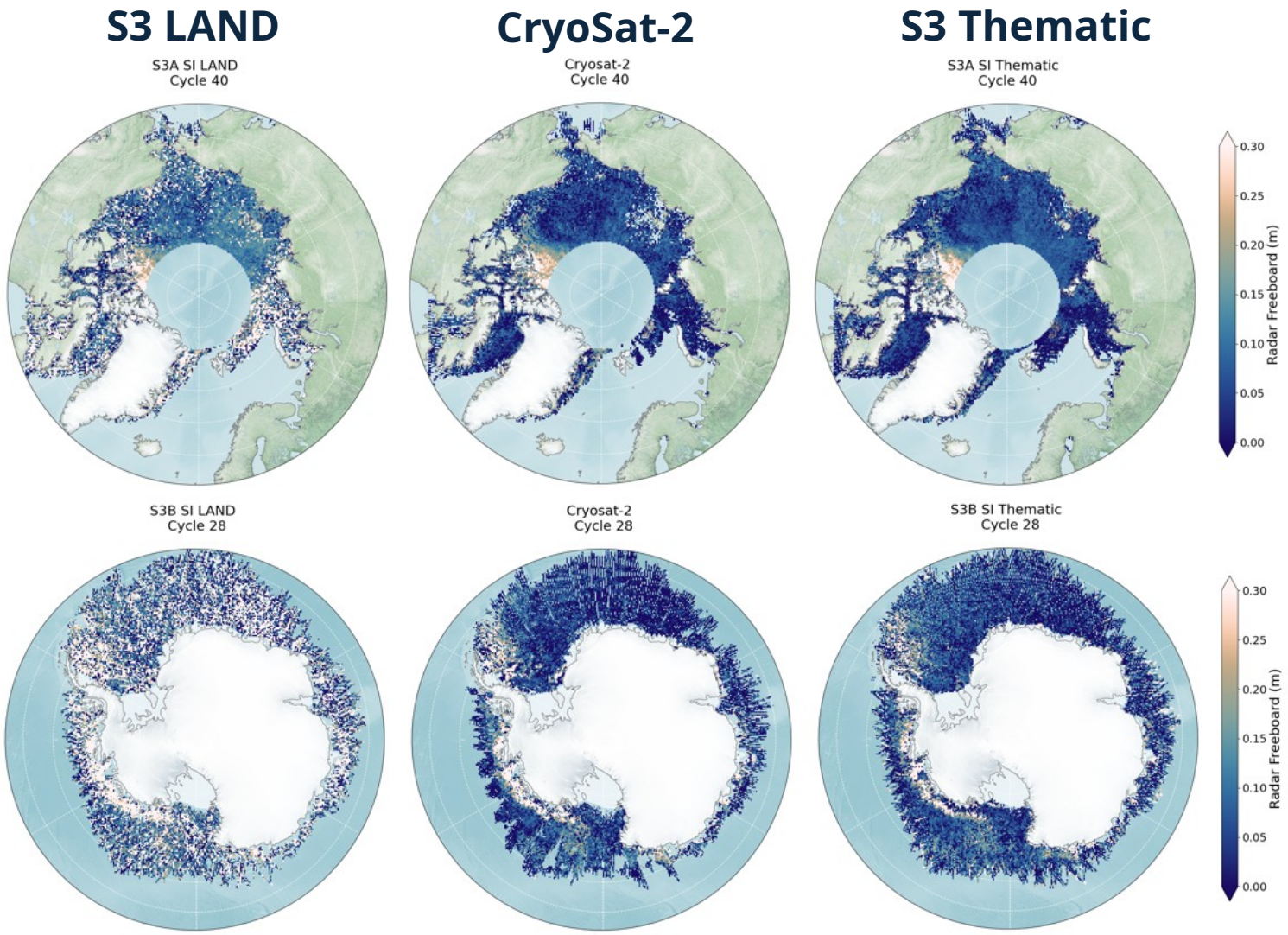
[see J.Aublanc, ESL council meeting #7 2020]

- ✓ Already implemented in Cryosat-2 Baseline-E
- ✓ Absolutely essential for Sea-Ice



Reduction of the jitter noise on S3 thanks to the zero-padding,

Sentinel-3 VS CryoSat-2 : radar freeboard



Gridded maps of Radar

Comparison to Cryosat-2 Baseline-E

(one cycle of data, similar masking)

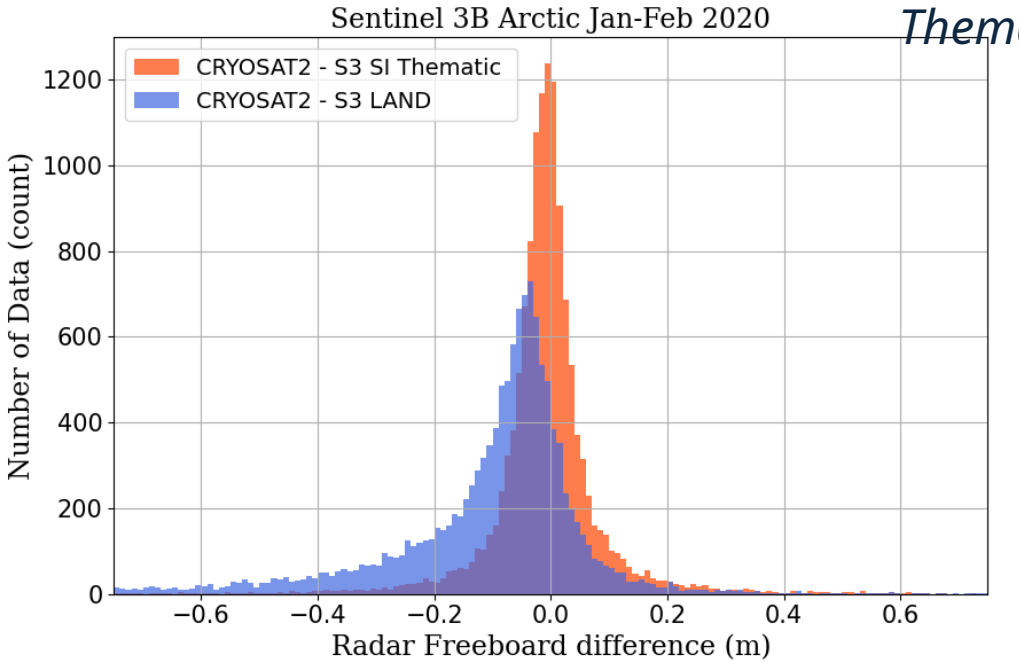
- ✓ S3 Thematic patterns close to CS2
- ✓ Noise significantly reduced

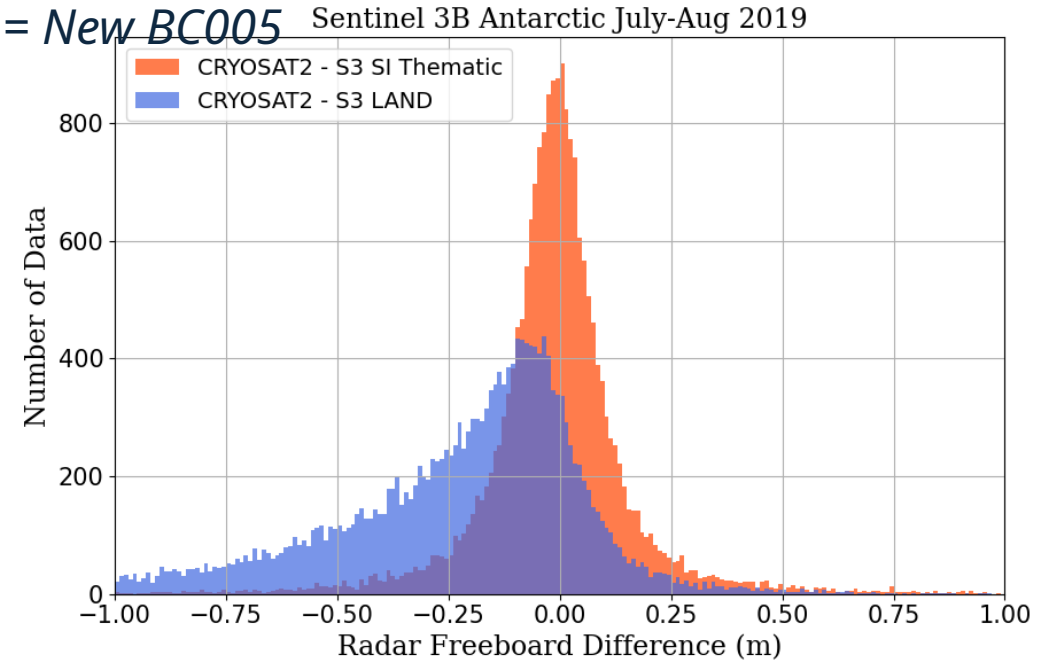
LAND = Previous BC004
Thematic = New BC005

Sentinel-3 VS CryoSat-2 : radar freeboard

LAND = Previous BC004

Thematic = New BC005





Arctic	LAND	Thematic
[CS2-S3] Median	-6.7 cm	-0.8 cm
[CS2-S3] STD	31.5 cm	19 cm

Antarctic	LAND	Thematic
[CS2-S3] Median	-17.6 cm	-0.9 cm
[CS2-S3] STD	43.2 cm	20.4 cm

Performances of the S3 thematic products

- ✓ Performances of the Sea-Ice Thematic Products have been detailed in a **peer-reviewed publication** dedicated to the 3 surfaces (Land-Ice, Hydro, Sea-Ice) → Submitted during the summer [J.Aublanc et al.]

- ✓ Take away message regarding the Sea-Ice thematic Products performance :

The former version of the Sentinel-3 products (LAND) was not performing well enough to be exploited by sea ice users

→

The **Thematic Product** now provides radar freeboard measurements closely aligned to those available from CryoSat-2 ICE, that can be exploited by sea-ice users

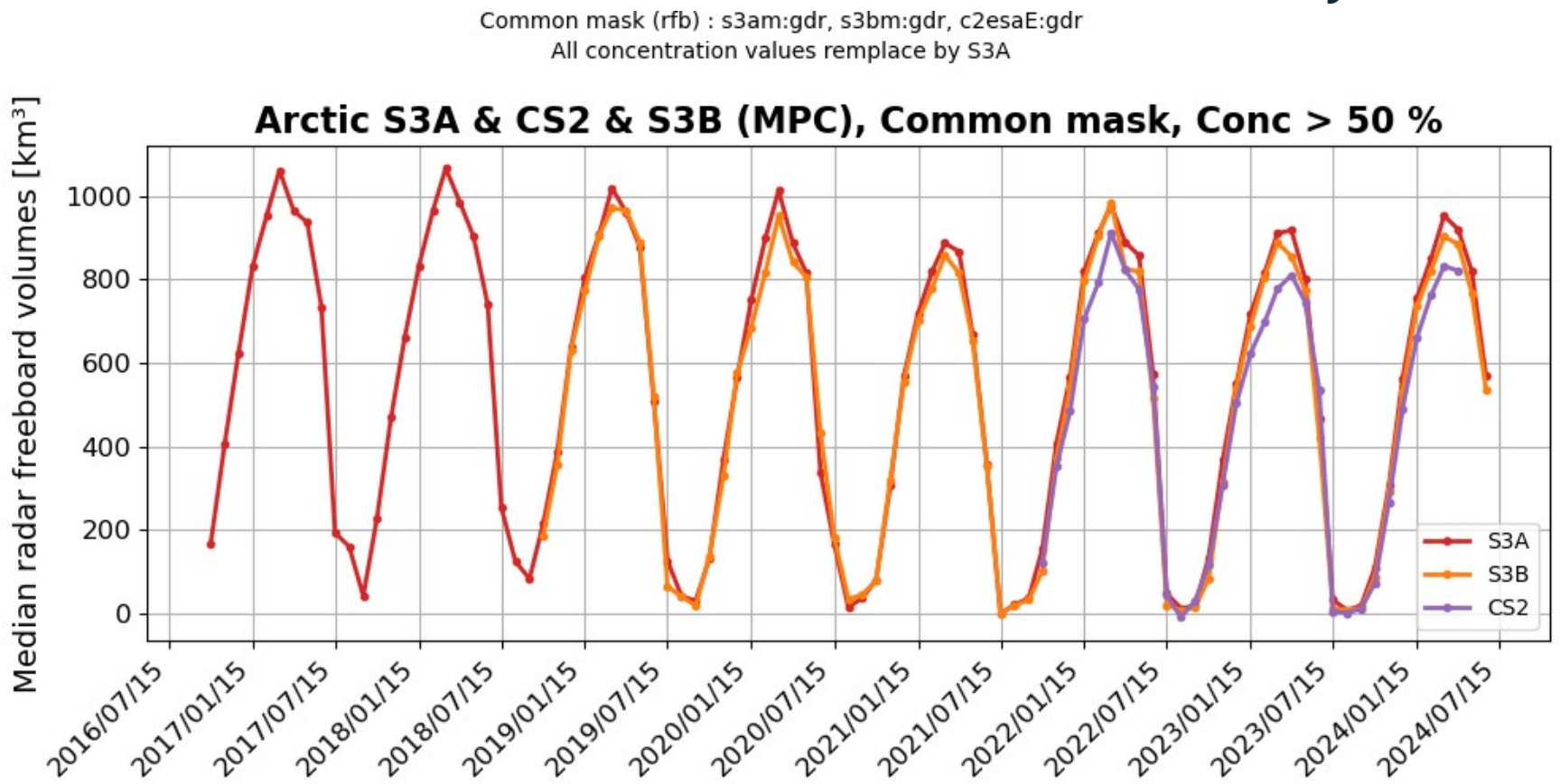
↳ The priority for future Processing Baseline is to compute and deliver the **Sea Ice Thickness** to the users (sea-ice type from OSISAF is now available in the products !)

↳ **Sentinel-3 can now be used to monitor sea-ice indicators, such as sea-ice volume, sea-ice thickness …**

Sentinel-3 VS CryoSat-2 : radar freeboard volume

Radar Freeboard Volume [km³]

Sentinel-3A/B Thematic Products
CryoSat-2 Baseline-E

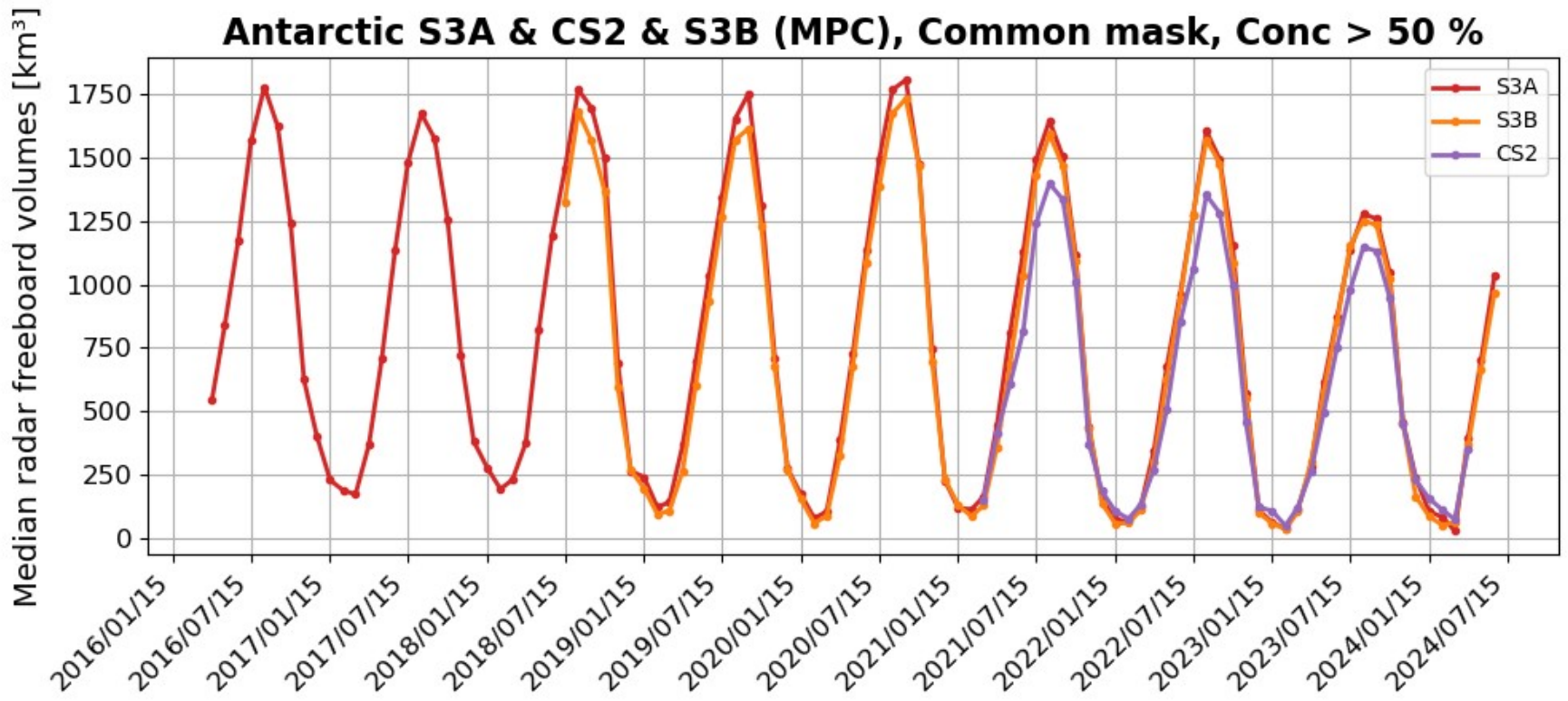


Courtesy of S.Fleury

Sentinel-3 VS CryoSat-2 : radar freeboard volume

Radar Freeboard Volume [km³]

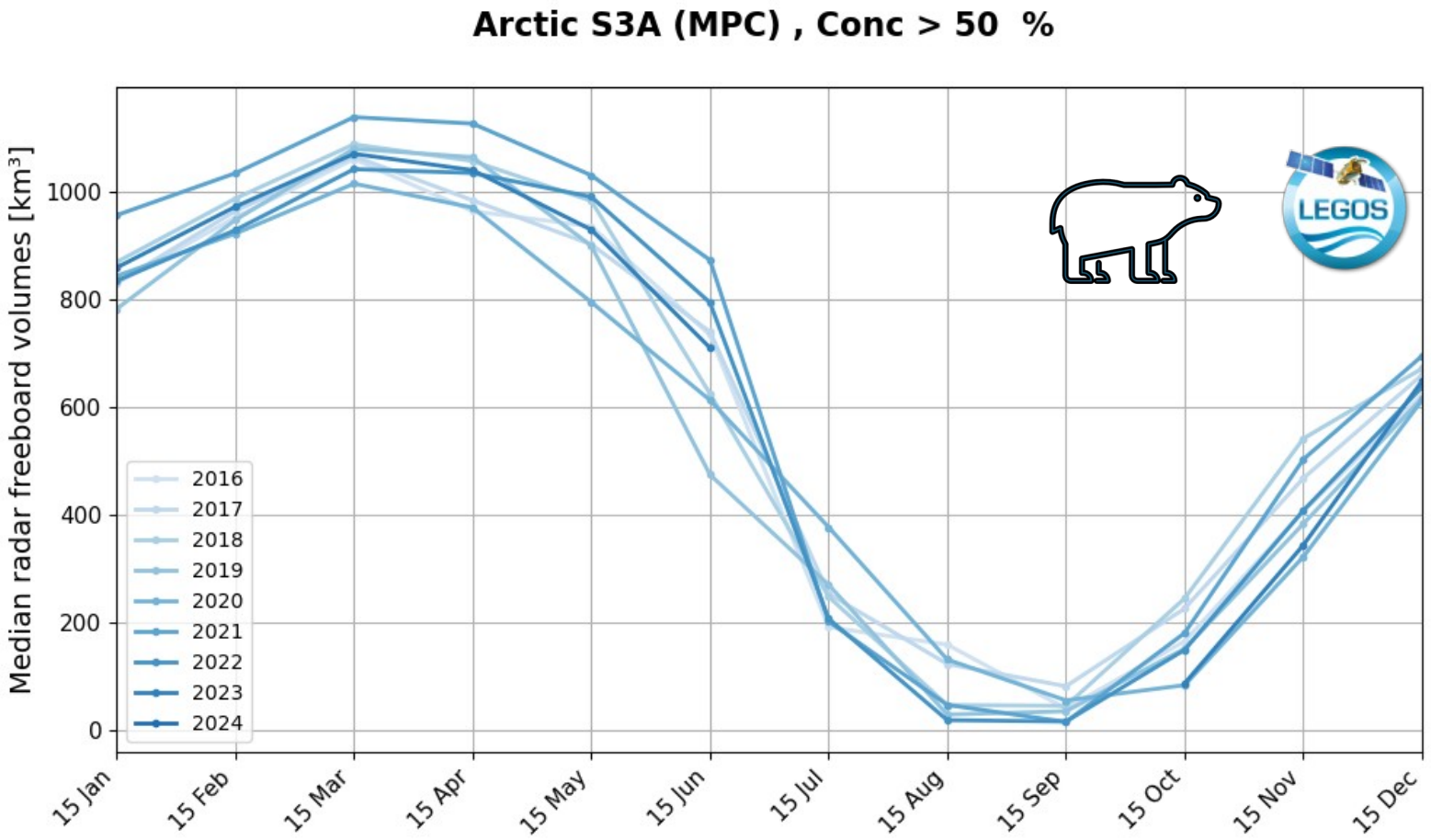
Sentinel-3A/B Thematic Products
CryoSat-2 Baseline-E



Courtesy of S.Fleury

Sentinel-3 : Arctic seasonal variations

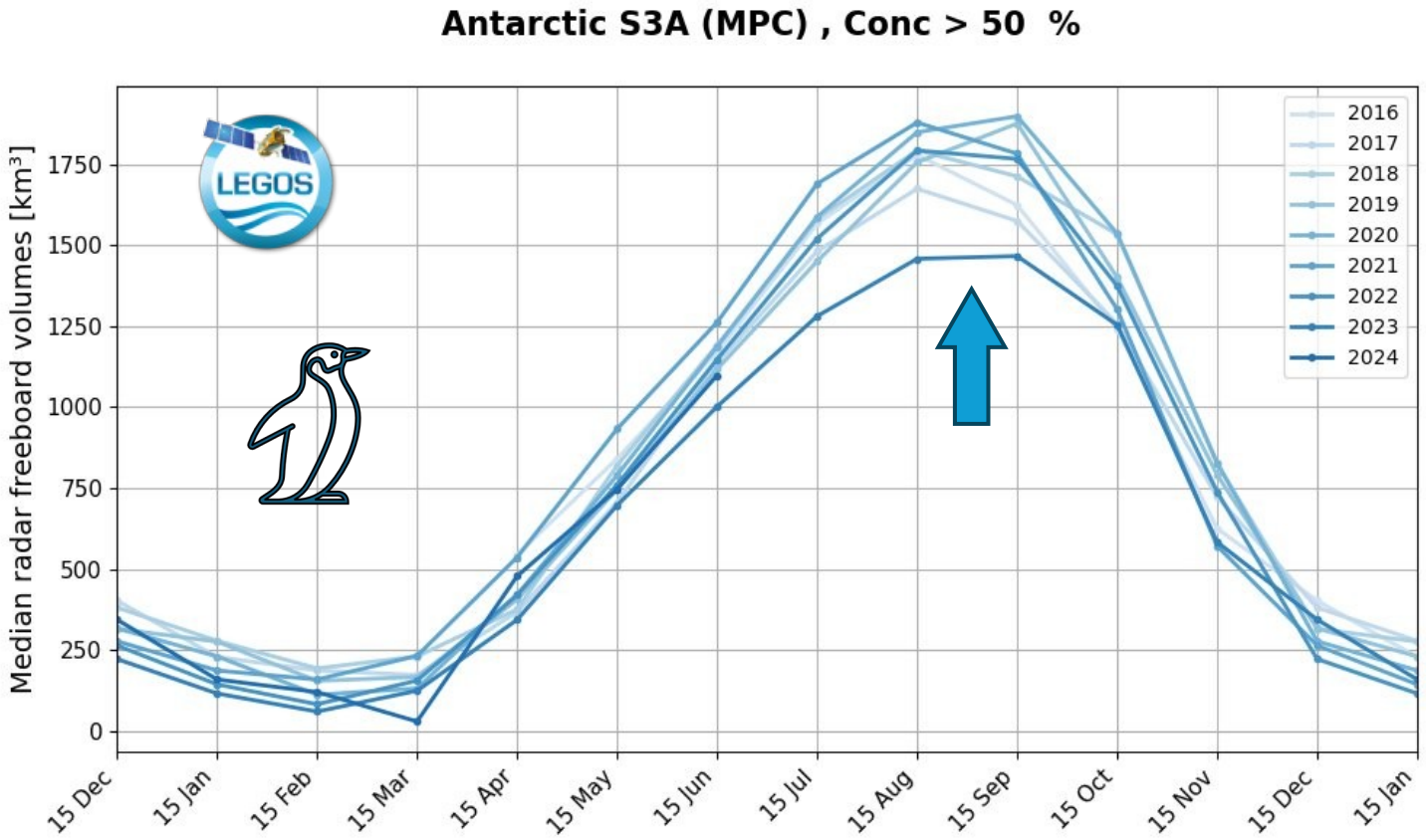
Sentinel-3A Thematic Products

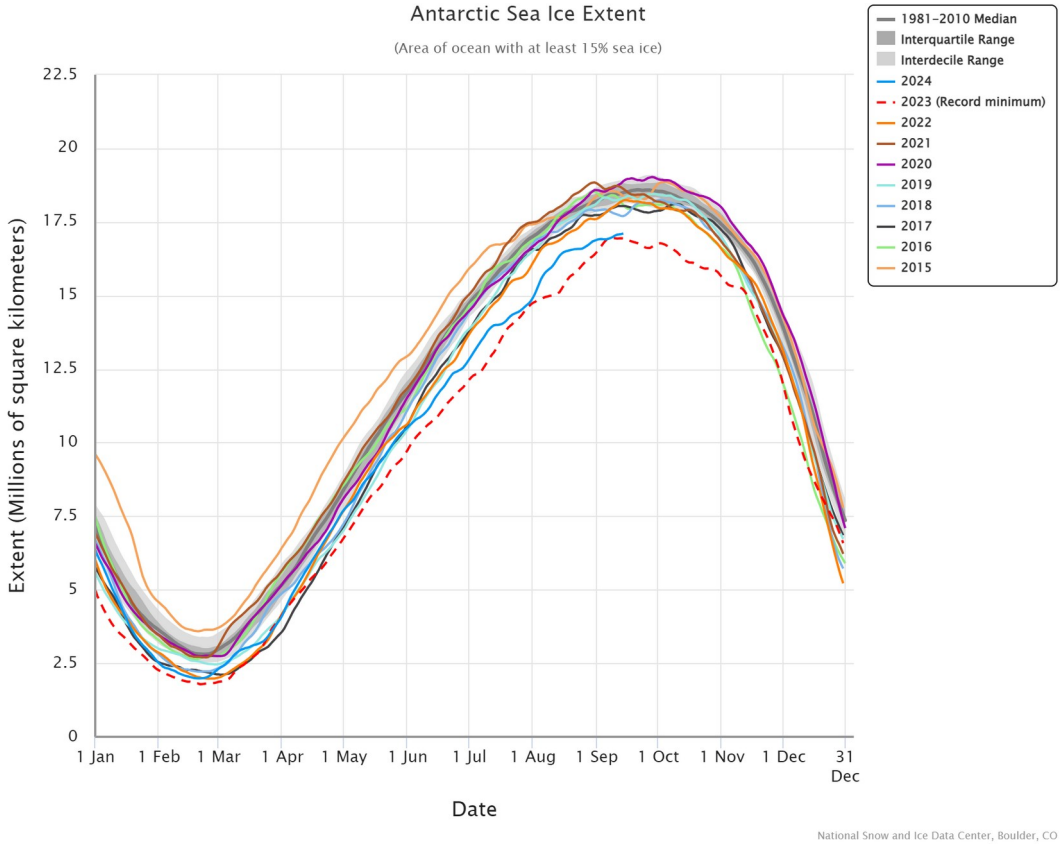


Courtesy of S.Fleury

Sentinel-3 : Antarctic seasonal variations

Sentinel-3A Thematic Products





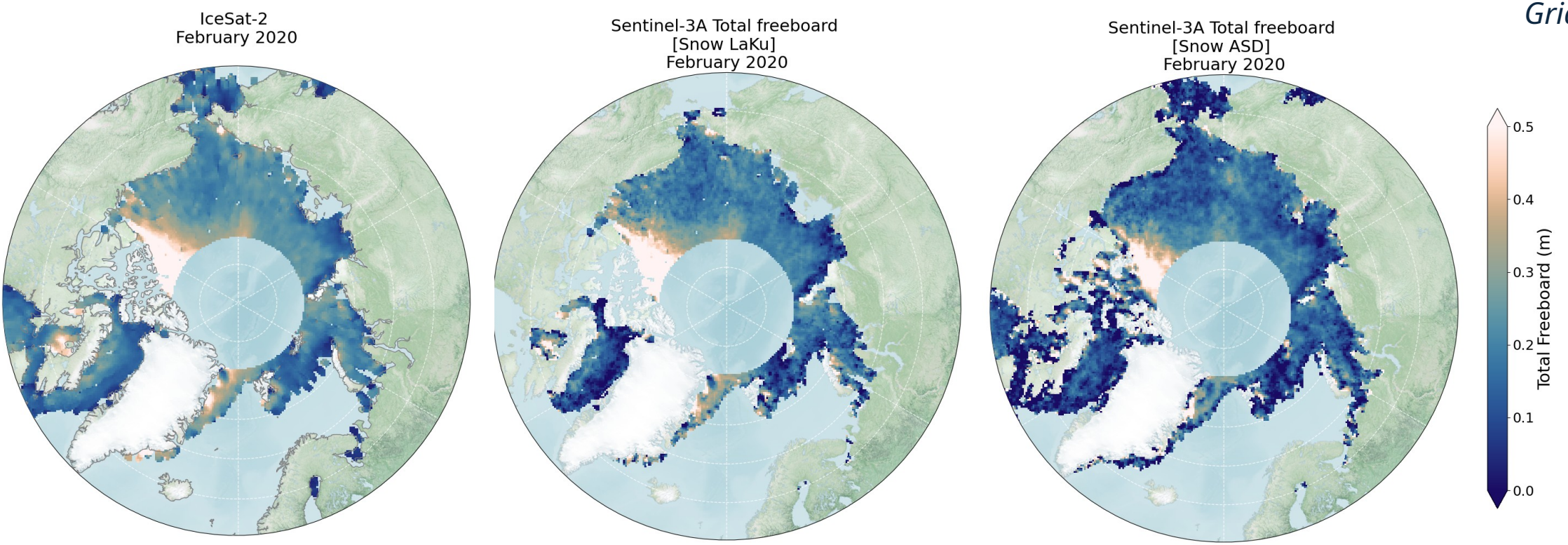
Sea-Ice extent from NSIDC

→ Anomaly of Antarctic winter 2023 clearly visible using S3 data !

Courtesy of S.Fleury

Sentinel-3 VS IceSat-2 : Total freeboard

Grids of 25x25km



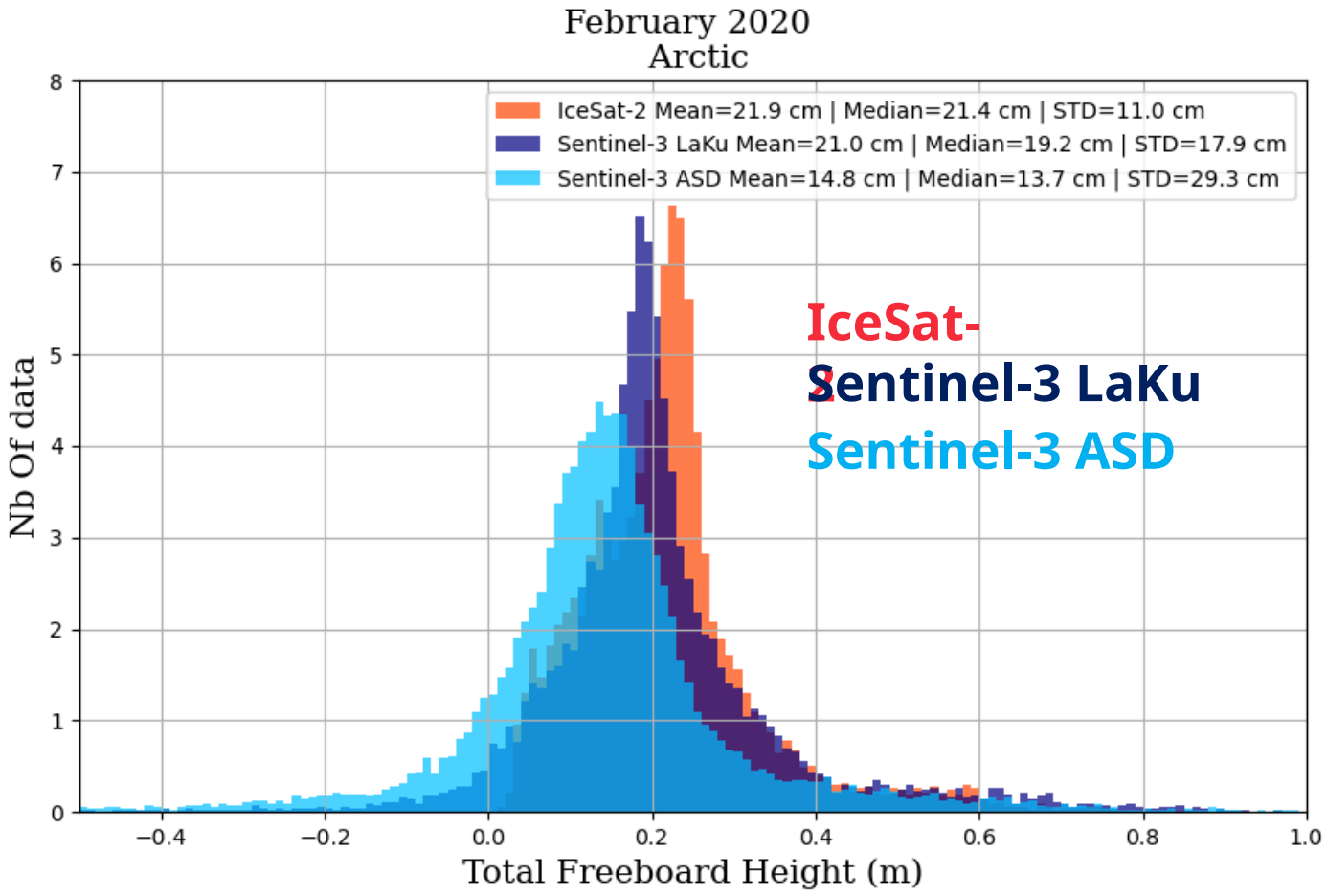
IceSat-2 ATL10
Strong beam 3
Latitude limited to 81.5°

S3 total freeboard
computed with LEGOS **LaKu snow depth**
→ IceSat-2/CryoSat-2 snow

S3 total freeboard
computed with LEGOS **ASD snow depth**
→ SARAL/CryoSat-2 snow

Dataset independent of IceSat-2/S3

Sentinel-3 VS IceSat-2 : Total freeboard



1cm mean bias with snow LaKu
7cm mean bias with snow ASD

Several differences between IceSat-2 ATL10 and S3 processing :
→ **For instance : IceSat-2 freeboards < 0 are edited**

To go further : recompute IceSat-2 freeboard from ATL07

Take away messages

The Full Mission Reprocessing of Sentinel-3A and 3B was performed in 2023 → Available online

- ✓ Excellent performances observed, fully compatible with CryoSat-2 → detailed in peer-reviewed publication (submitted)
- ✓ Generation of time series of freeboard volume showing consistent variations
- ✓ S3A and S3B will allow a drastic increase of the density of sea-ice measurements close to the Arctic and Antarctic coasts relatively to CS2 alone (about x7 more data!).
- ✓ First comparisons with IceSat-2 show compatible S3/IS2 total freeboards, especially using the "**LaKu" snow depth** that uses IceSat-2 data, but also using an independent snow (**ASD**) → To be continued !
- ✓ Open question : If unfortunately, CryoSat-2 does not last until CRISTAL, could Sentinel-3 bridge the gap between the 2 missions despite its poorer coverage of the Arctic (81.5N) ?

What's next for S3 products on sea-ice ?

Sentinel-3 Sea-Ice Thematic Products Roadmap

Short-term

- ✓ Add SI-CCI and LEGOS-ASD **snow depth** (SD) along track → on-going
- ✓ Towards an along-track **filtering of the freeboard** to reduce the Signal to Noise Ratio

Mid-term

- ✓ Add a first along-track **sea ice thickness (SIT)** estimation
- ✓ Evaluation of the performances of the sea ice type deduced from **S3 radiometer** (Tran et al. 2009) to be compared with OSI-SAF 403d.
- ✓ Build a dedicated snow depth for S3 using Saral Ka (or IceSat-2) and S3 pLRM Ku (instead of CS2)

If you have any suggestions concerning this S3 Sea Ice Thematic Product → Contact us!

Thank you ! ☺

Any questions ?

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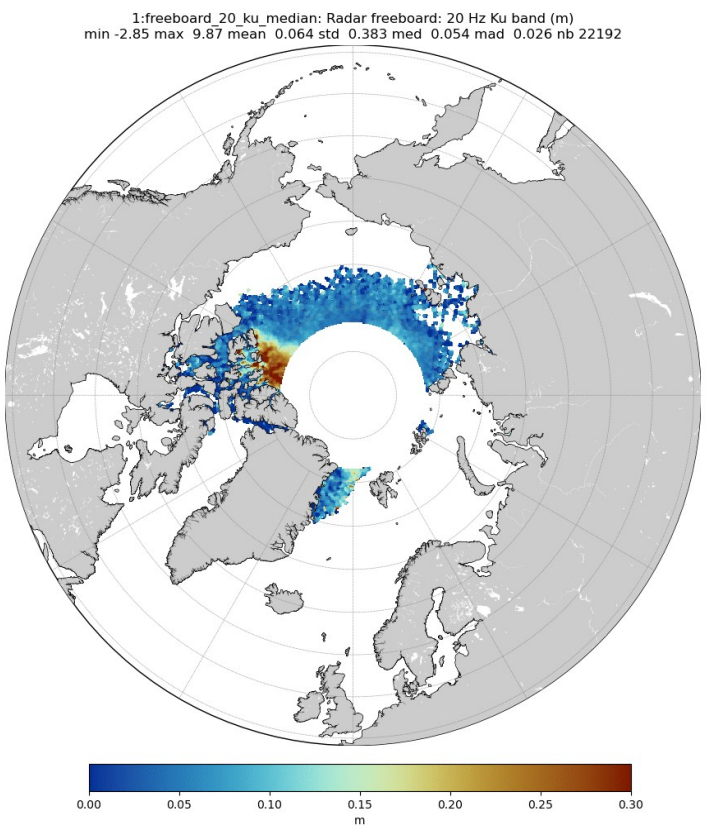

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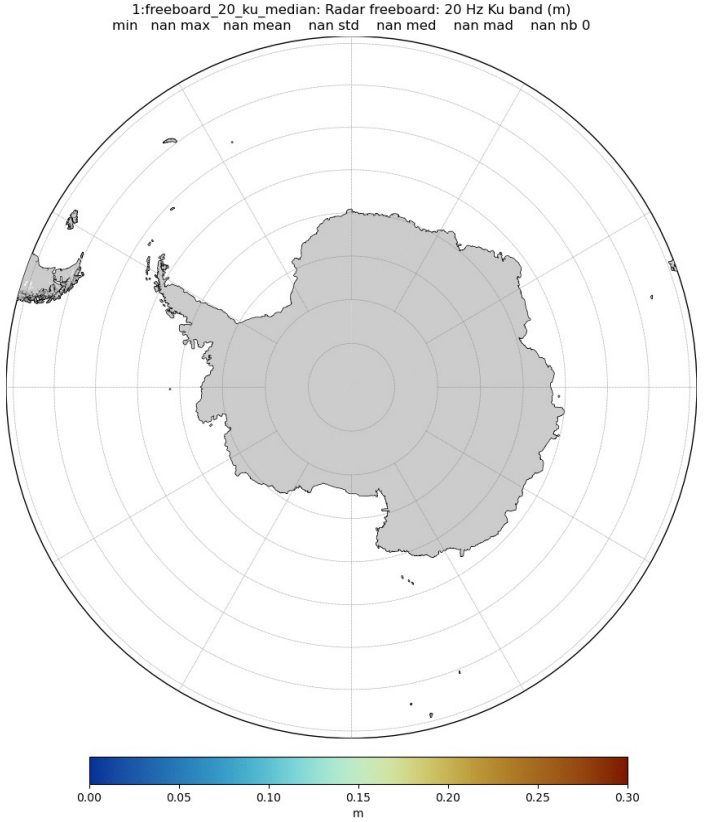


fpiras@groupcls.com

What's next ?

Sentinel-3 Sea-Ice Thematic Products Roadmap

Short-term

- ✓ Add SI-CCI and LEGOS-AltiSD **snow depth** (SD) along track (new ADF) → on-going
- ✓ Towards an along-track **filtering of the freeboard** to reduce the Signal to Noise Ratio

Mid-term

- ✓ Add a first along-track **sea ice thickness (SIT)** estimation
- ✓ Evaluation of the performances of the sea ice type deduced from **S3 radiometer** (Tran et al. 2009) to be compared with OSI-SAF 403d.
- ✓ Build a dedicated snow depth for S3 using Saral Ka (or IceSat-2) and S3 pLRM Ku (instead of CS2)

If you have any suggestions concerning this S3 Sea Ice Thematic Product → Contact us!

But also (not in the frame of the MPC)

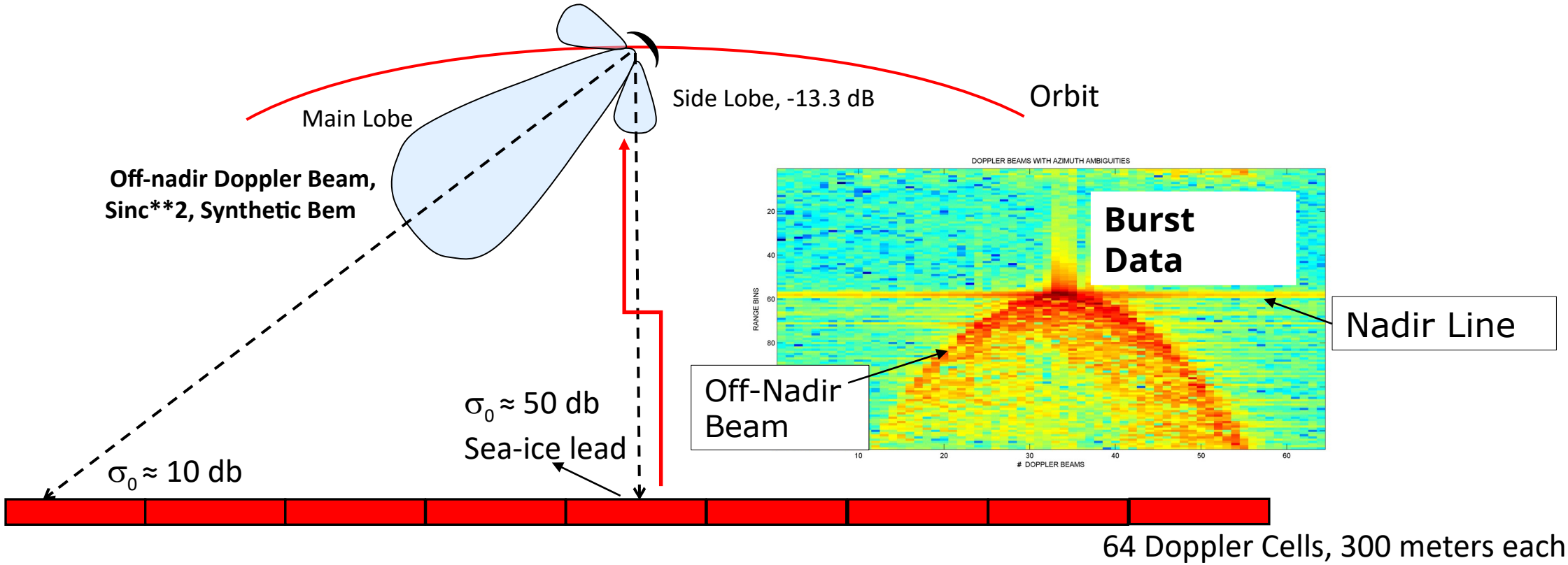
- ✓ Exploitation of **S̈ẄOT** over sea-ice and comparison with IceSat-2/KaRin in the frame of CROPS (CNES, funded by ESA)

→ See G.Jestin talk at 30YPRA (Montpellier) regarding the computation of freeboard using Karin

- ✓ Computation of IceSat-2 freeboard from the ATL07 data (range), using the LEGOS processing chain

Azimuth ambiguities (ghosts) over sea-ice lead → spurious signal enters from nadir direction through an off-nadir Doppler beam side-lobe

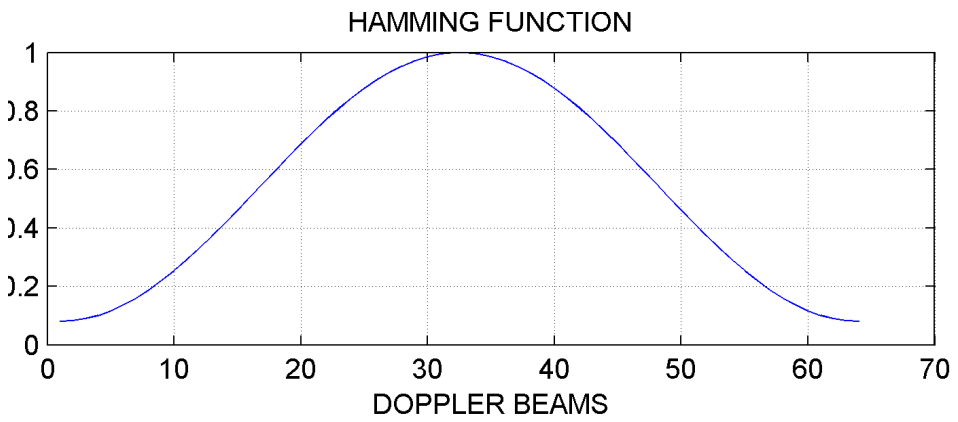
"Ghost" Spurious Leakage through a side-lobe directed to nadir direction:

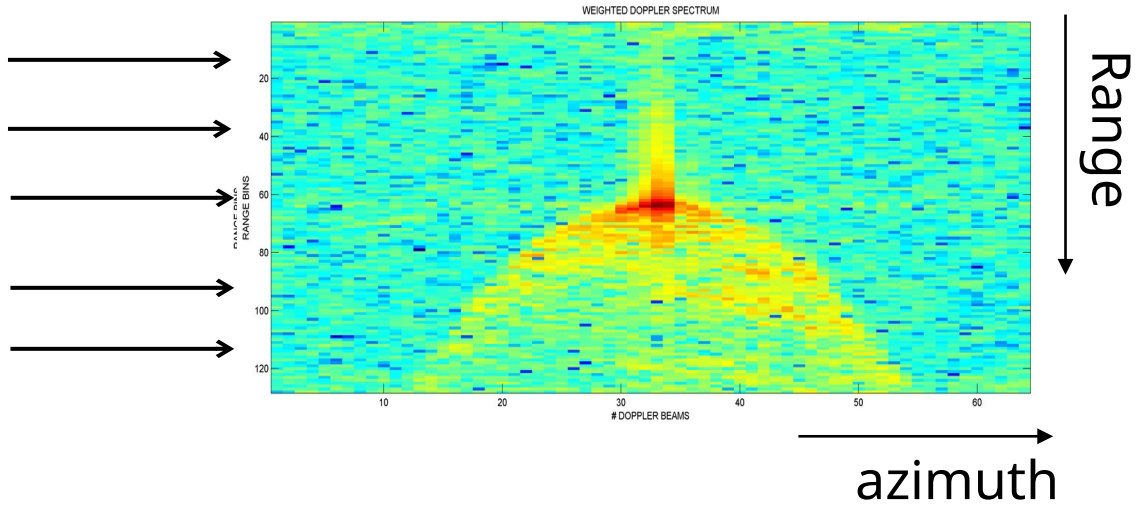


At burst Level, spurious returns show up as "straight line" .
At stack level (i.e. after the range migration), the straight-line artifact will become "parabolic arch"

Azimuth Spectral Weighting Window:

To suppress parabolic arches on the waveforms => application of a weighting window to the burst data in azimuth dimension before the Beam-Forming. In this slide, weighting window is Hamming window





Hamming window will change the first sidelobe level from -13.3 to something around to -40 dB

Freeboard from IceSat-2 ATL10