Sentinel-3 Land STM MPC: Status and evolutions of the Sea-Ice product

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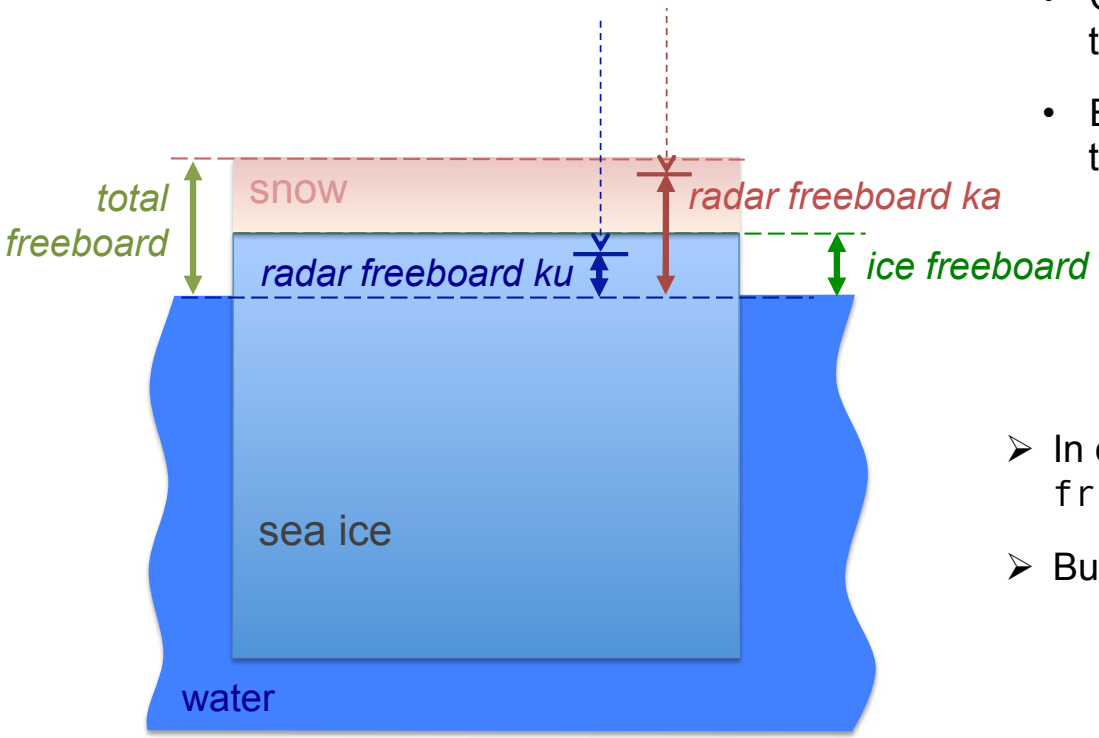
Sea Ice Thematic: versions

Baseline Collection	Processing Baseline (PB)	When	from cy/orb	Main changes for Sea Ice
005	3.20	Sept 2023	S3A: 001 S3B: 001	**0-padding**, **hamming**, **sea ice concentration OSI-430,** MWR ice type, DTU21, FES14, GOT4.10
005	3.29	Sept 2024	S3A: 115 S3B: 096	Add sea ice type (FYI/MYI) from OSI-403d
005	Trump PB (between 3.32 3.34)	July 2025	S3A: 126/341 S3B: 107/288	No more SSMI data, switch to AMSR Sea ice concentration: OSI-430 -> OSI-438
006	3.35	Feb 2026	S3A: 135/385 S3B: 116/001	• `freeboard` **renamed** `radar_freeboard` • hf componant of the DAC added in sea level corrections • Add NN waveforms classifier • Add a filter radar freeboard • Add snow depth ADF • Add snow and ice densities • Add sea ice freeboard and sea ice thickness

freeboard -> radar_freeboard



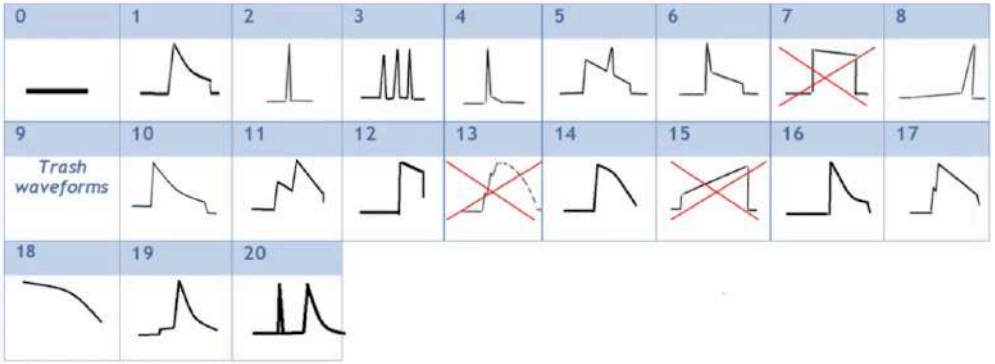
- Over sea ice, the 'freeboard' refers to height of the ice above the water.
- But the radar altimeters do not measure directly the ice freeboard because of the snow layer

➢ In order to avoid ambiguities the variable `freeboard` has been rename `radar_freeboard`

➢ But the values are the same

NN waveforms classification

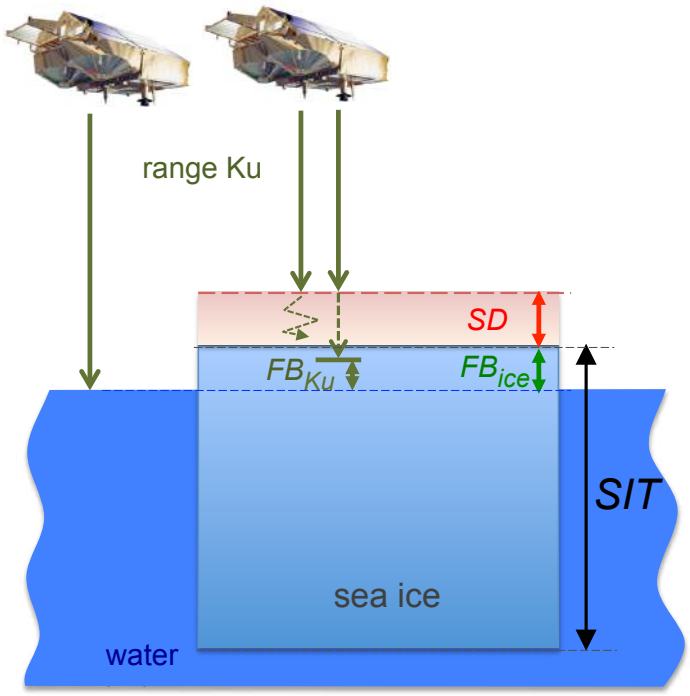
From CLS [Poisson et al 2018]



- 4 new variables
  - `waveform_class_rank1_20_ku`
  - `waveform_class_prob_rank1_20_ku`
  - `waveform_class_rank2_20_ku`
  - `waveform_class_prob_rank2_20_ku`

- Not used for now on the sea ice processing
- The lead/floe classification still based on the Pulse Peakiness (PP) criteria

Sea Ice Thickness ?



$$SIT = \frac{\rho_w}{\rho_w - \rho_i} FB_{Ku} + \frac{\rho_w (1 + T\rho_s)^{1.5} - \rho_w + \rho_s}{\rho_w - \rho_i} SD$$

The Sea Ice Thickness (SIT) was one of the main objective of this new Baseline Collection

But it is not straight forward…

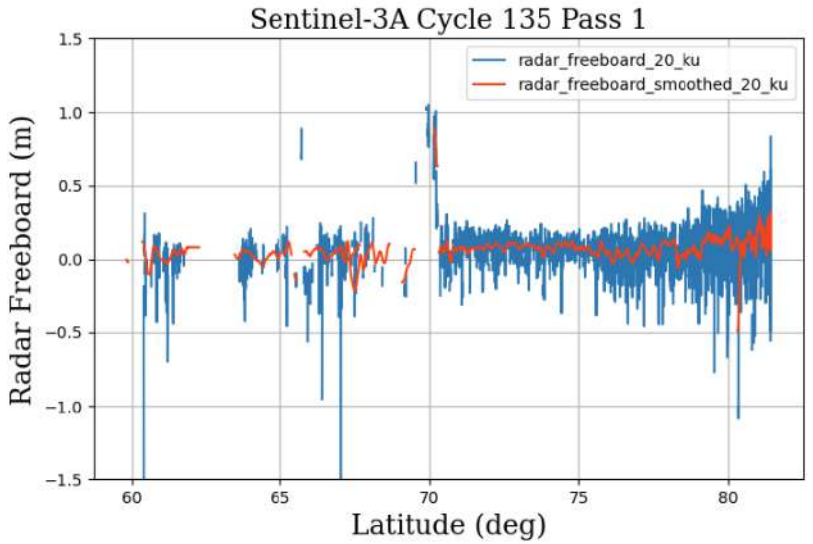
Need for 4 more parameters:

- the snow depth SD
- the densities of the water ρ_w, the ice ρ_i and the snow ρ_s

The smoothed radar freeboard

Motivations:

- Raw measurements of radar-freeboard over sea ice are intrinsically very noisy.
- Many measurements are discarded, either deliberately, to avoid any confusion between leads and floes, or because the waveforms are not usable



➢ Difficult to make local analyses from along-track data.

➢ It has motivated us to compute a smoothed and interpolated radar-freeboard before computing the sea ice thickness.

The smoothed radar freeboard

The new variable is also interpolated/extrapolated:

- It doubles the number of values and divides by 2 the STD

The new PB includes 2 radar freeboard variables:

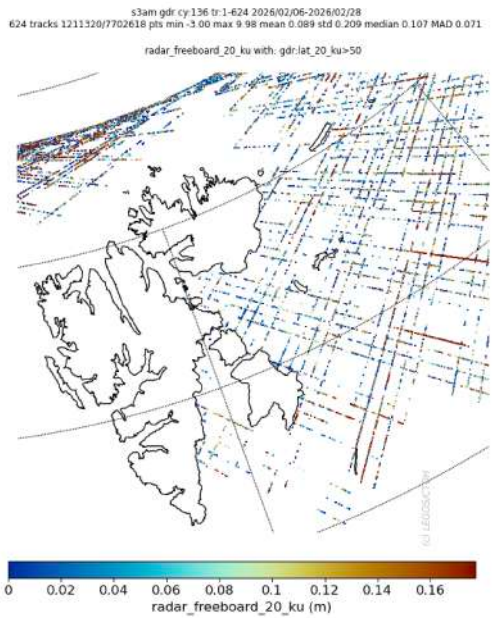
- `radar_freeboard`
- `radar_freeboard_smoothed`

Warning !!

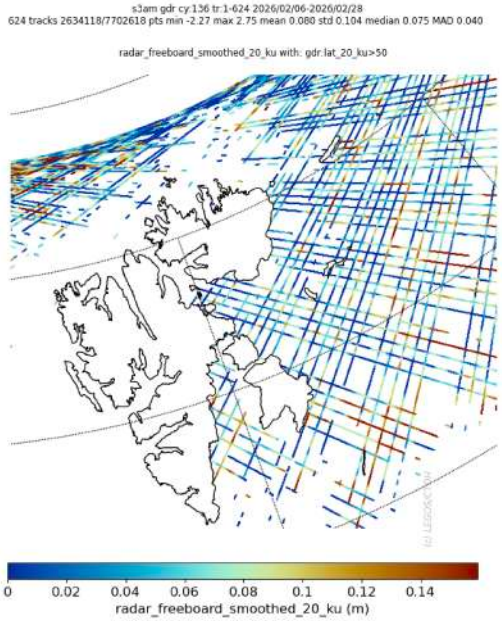
`radar_freeboard_smoothed` values are not any more independent measurements !

➢ for statistic analyses or assimilation in models the raw `radar_freeboard` should be used.

`radar_freeboard`



`radar_freeboard_smoothed`



Snow Depth

- PB < 3.35
  - Arctic: old Warren99 `snow_depth`
  - Antarctic: None

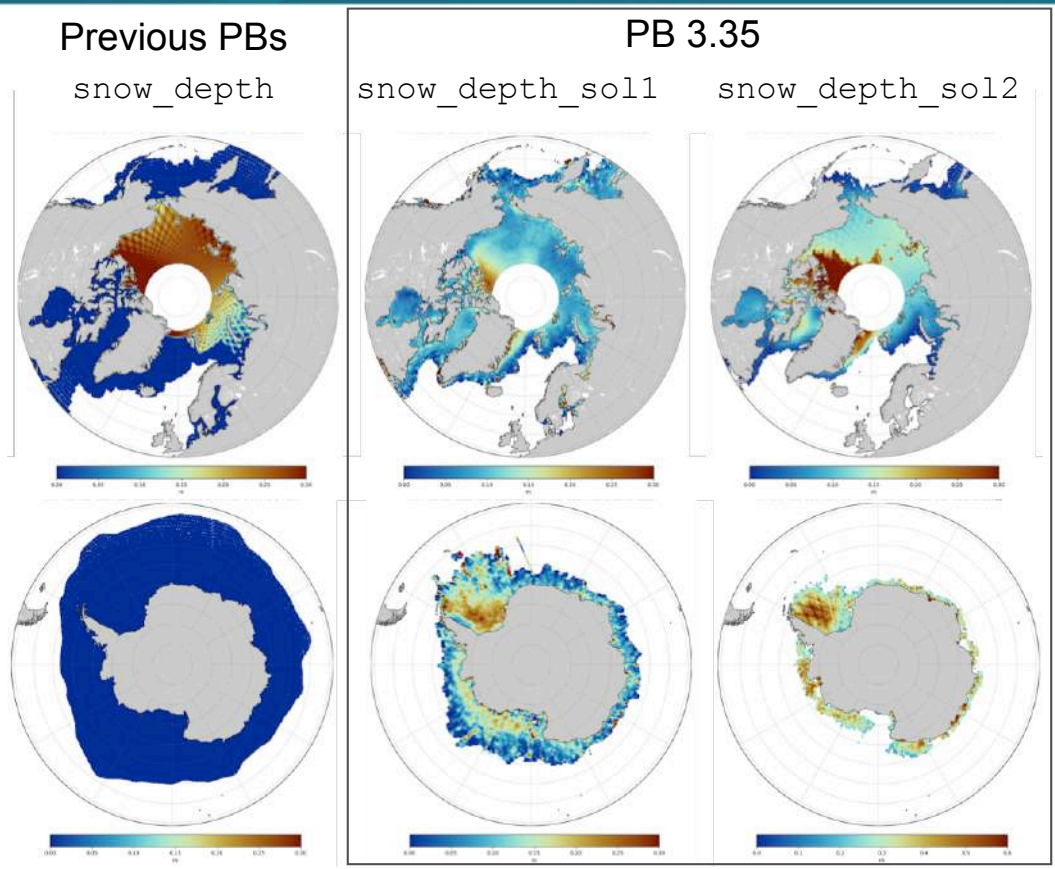
- PB 3.35
  - `snow_depth_sol1`

    Altimetric KaKu solution from Saral x CryoSat-2 pLRM computed by LEGOS
  - `snow_depth_sol2`

    SI-CCI solution computed by AWI based on AMSR (combined with Warren in Arctic)

<u>Warning</u>

For all these snow_depth we have to use monthly climatology versions because they cannot be computed within less than a month.



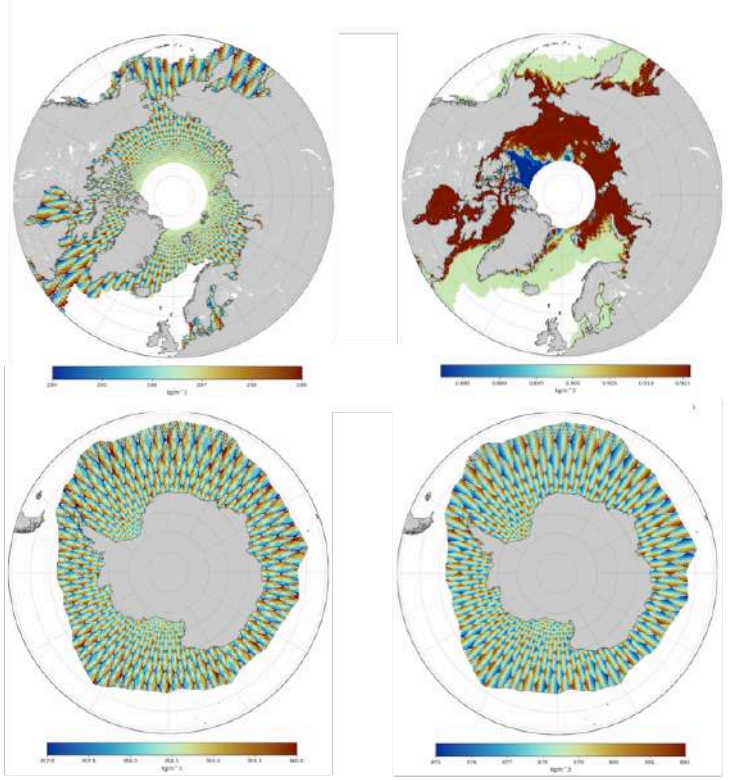
Snow and Ice Densities

Solutions from the literature:

`snow_density`:
- Depends on month of the year, linearly interpolated
- Arctic: from Mallett et al. (2020)
- Antarctic: from Fons et al. (2023)

`sea_ice_density`:
- Arctic: depends on ice type [Alexandrov et al. 2010]
- Antarctic: depends on month of the year [Fons et al. 2023]

`snow_density` `sea_ice_density`



Sea Ice Freeboard and Thickness !

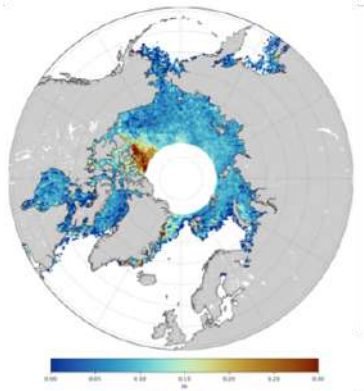
- sea_ice_freeboard
- sea_ice_freeboard_smoothed

$$FB_{ice} = FB_{Ku} + ((1 + T\rho_s)^{1.5} - 1)\, SD$$

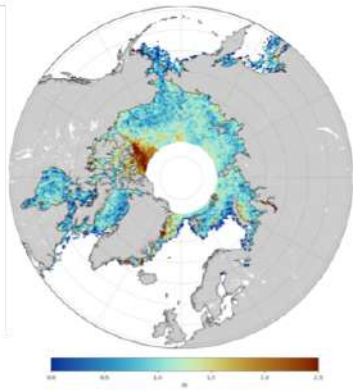
- sea_ice_thickness
- sea_ice_thickness_smoothed

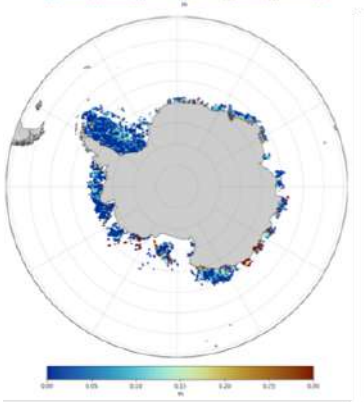
$$SIT = \frac{\rho_w}{\rho_w - \rho_i} FB_{Ku} + \frac{\rho_w (1 + T\rho_s)^{1.5} - \rho_w + \rho_s}{\rho_w - \rho_i} SD$$

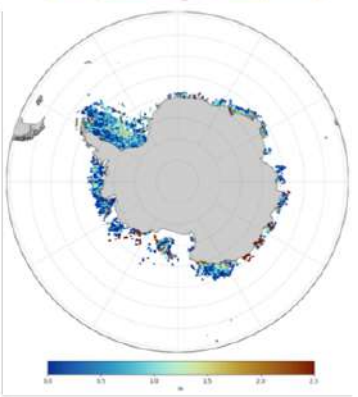
sea_ice_freeboard_smoothed



sea_ice_thickness_smoothed

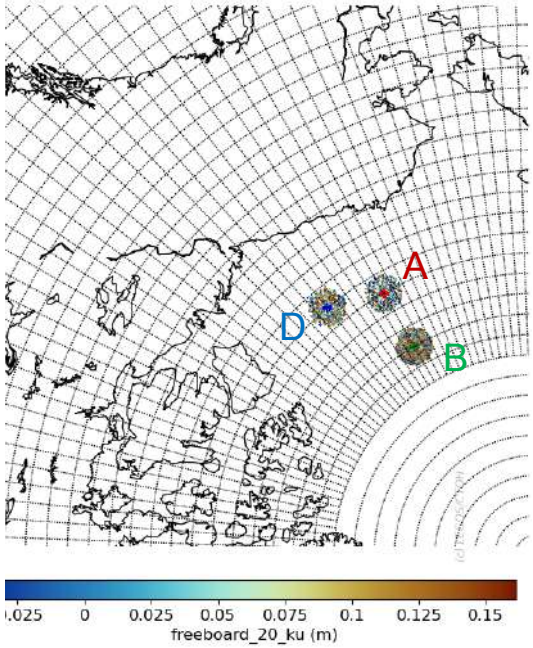


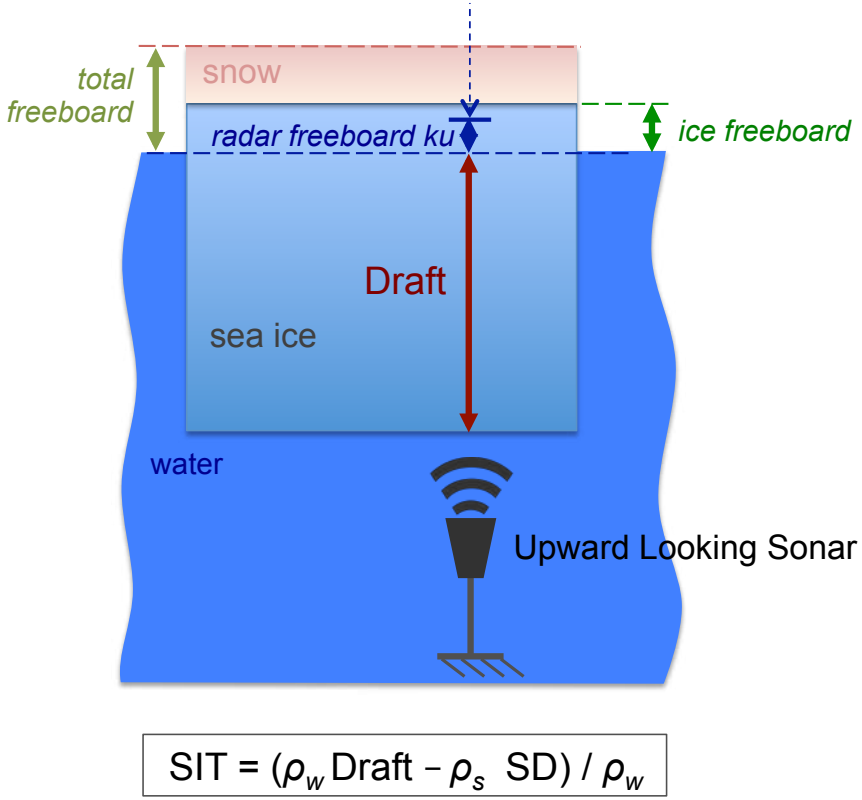




Evaluation of the SIT against BGEP moorings

3 BGEP moorings in Beaufort Gyre

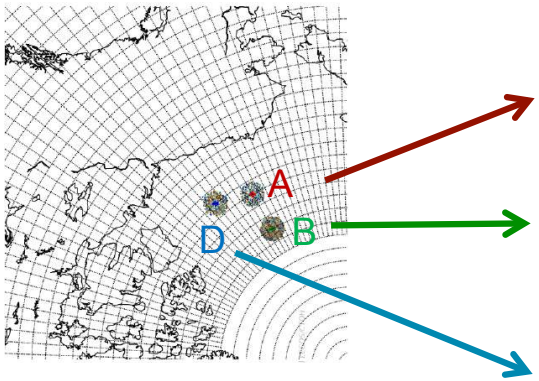


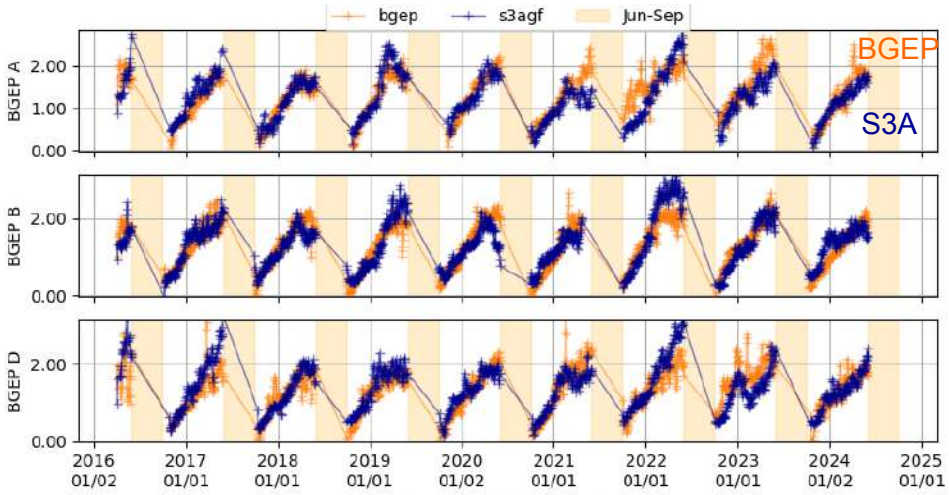


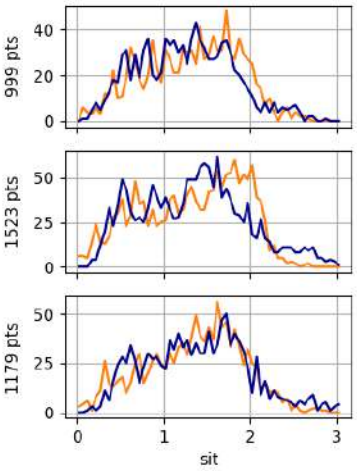
$$SIT = (\rho_w \, Draft - \rho_s \, SD) / \rho_w$$

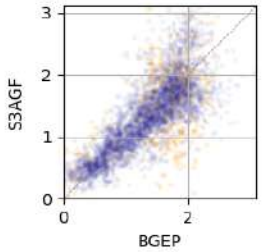
Evaluation of the S3A SIT against BGEP moorings

`sea_ice_thickness` using: `radar_freeboard` `snow_depth_sol_1`





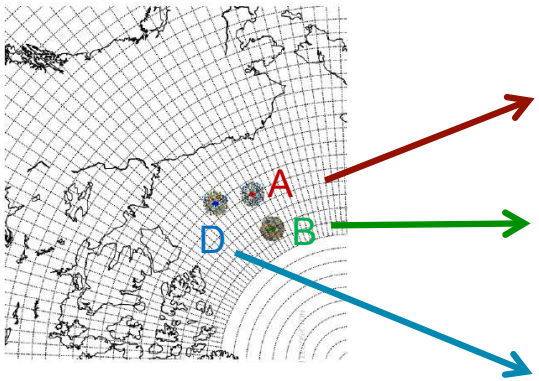


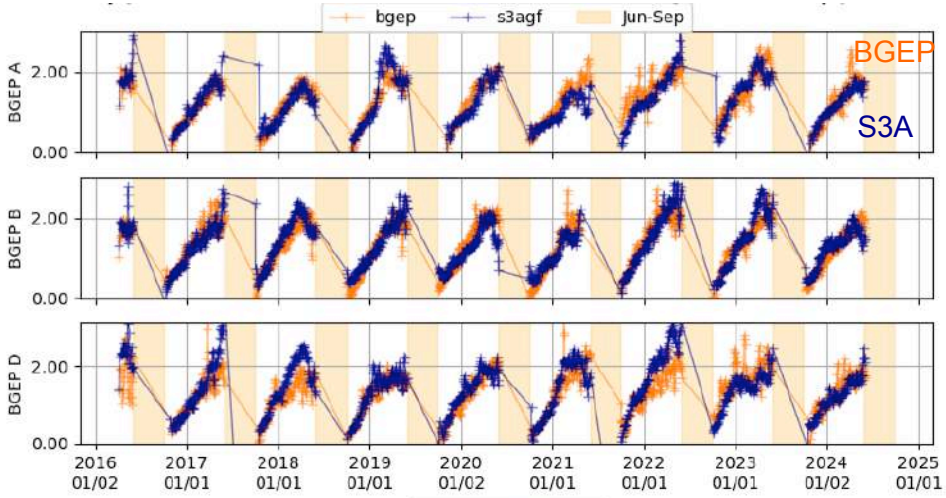


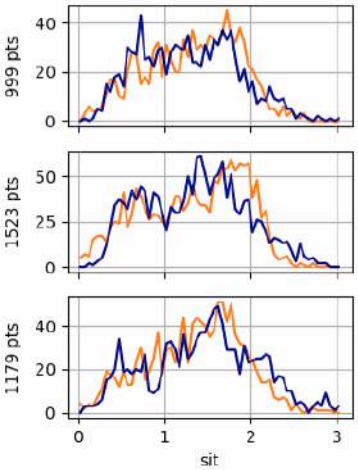
R	bias	RMSE	STD	slope
0.80	0.005	0.37	0.01	0.84

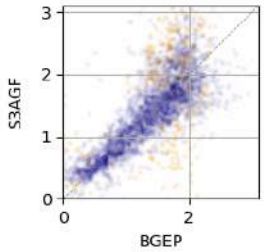
Evaluation of the S3A SIT against BGEP moorings

`sea_ice_thickness` using: `radar_freeboard` `snow_depth_sol_2`





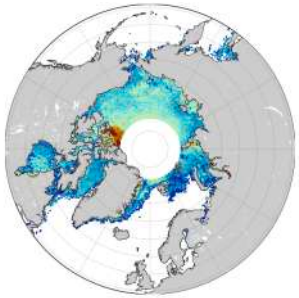


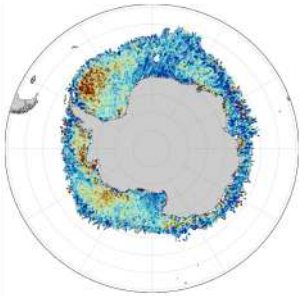


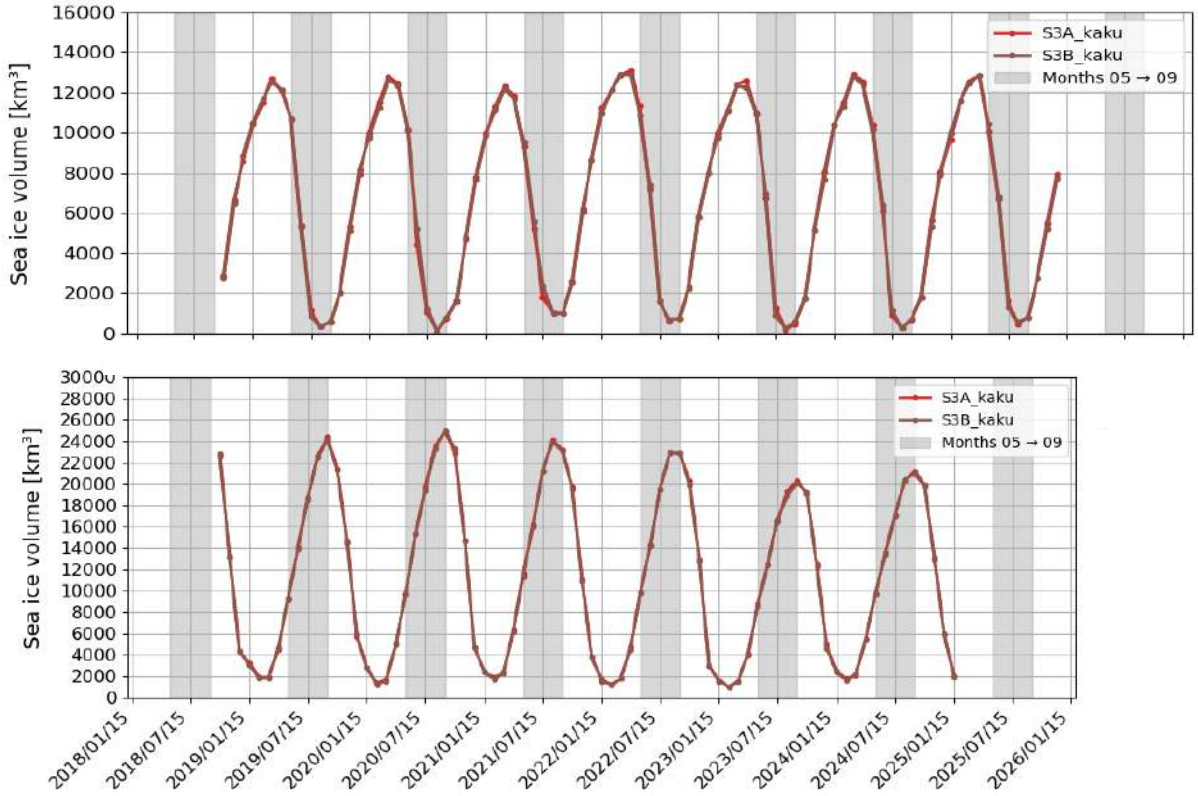
R	bias	RMSE	STD	slope
0.77	0.002	0.42	0.01	0.90

Sea Ice Volume Variations S3A & B

Sea Ice Volume (SIV) from S3A & S3B `radar_freeboard` and `snow_depth_sol_1`



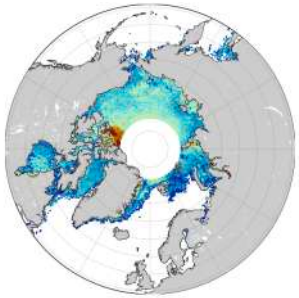


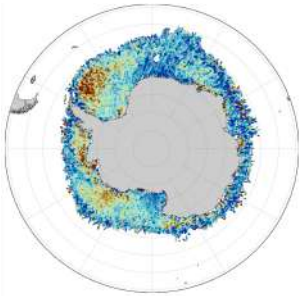


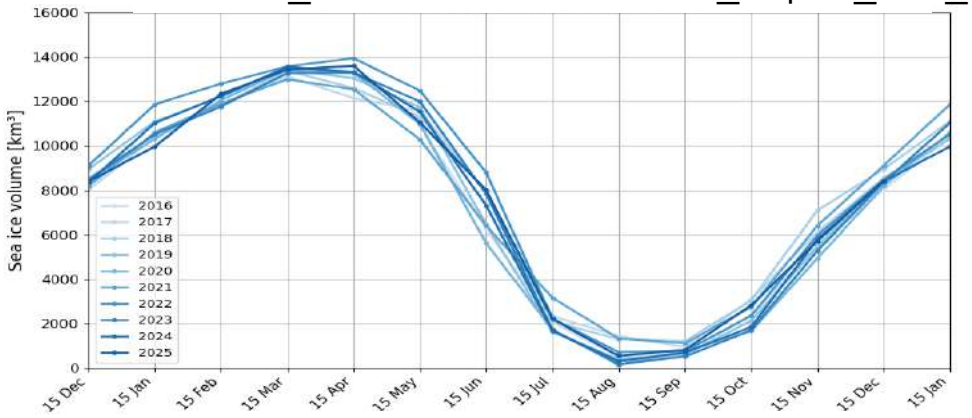
[Tom Megain]

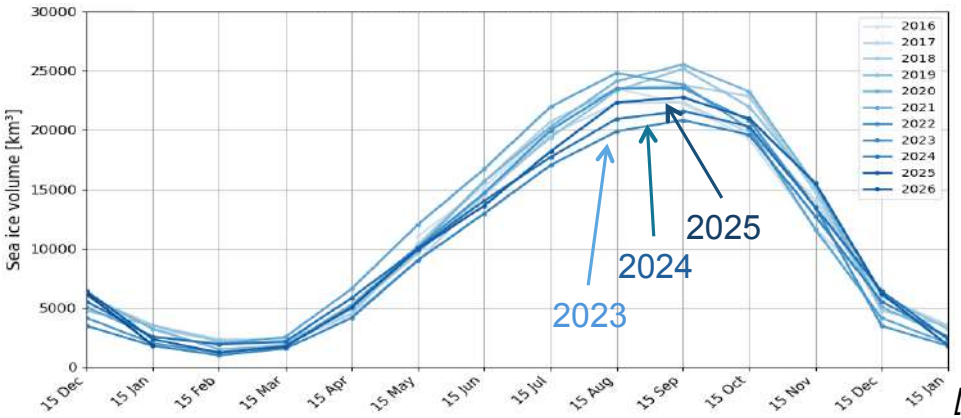
Sea Ice Volume Variations per month of the year

Sea Ice Volume (SIV) from S3A `radar_freeboard` and `snow_depth_sol_1`





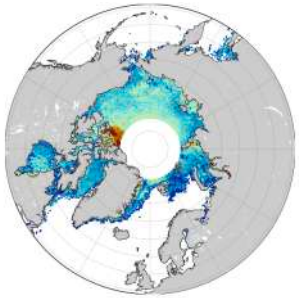


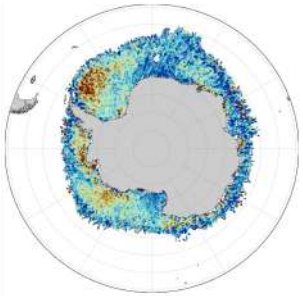


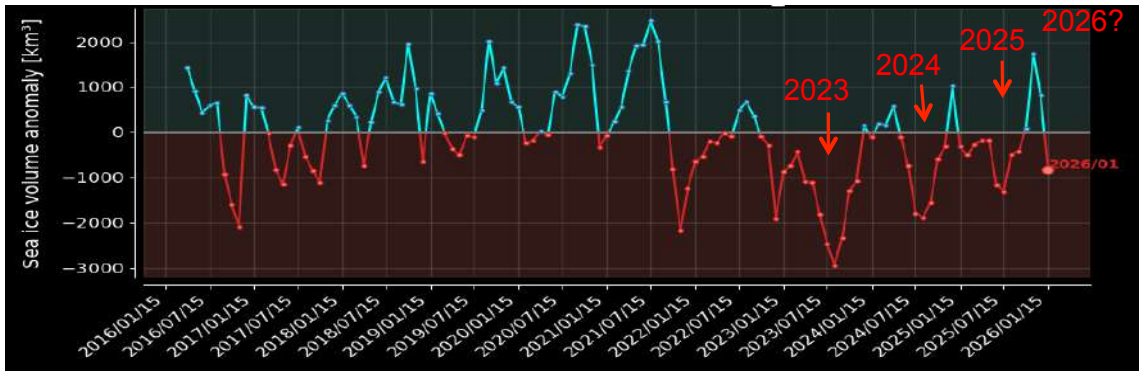
[Tom Megain]

Sea Ice Volume Variations Anomalies

Sea Ice Volume Anomalies from S3A `radar_freeboard` and `snow_depth_sol_1`



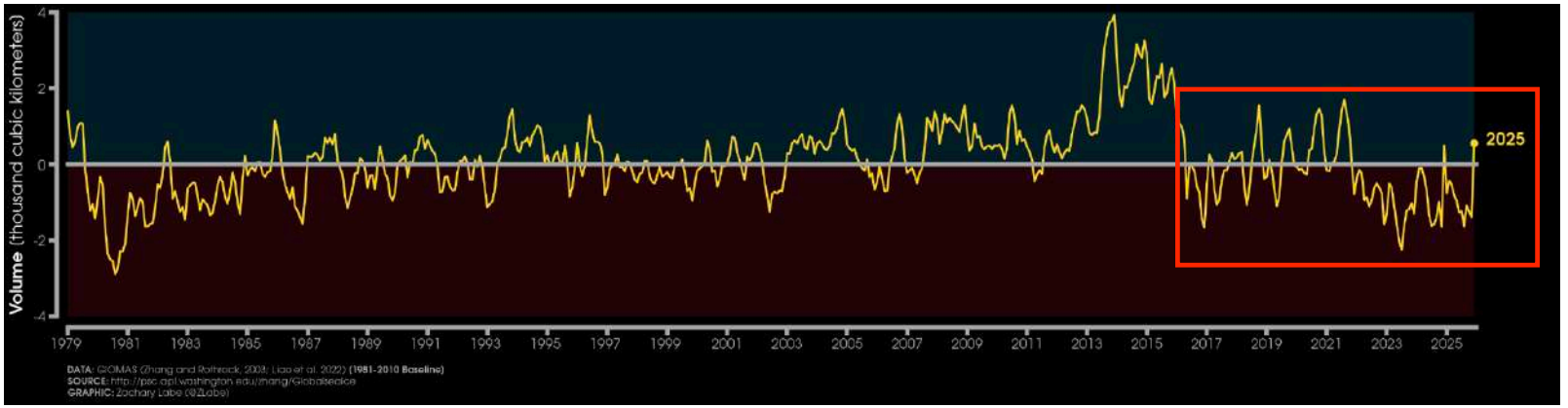




[Tom Megain]

Sea Ice Volume Variations Anomalies in Antarctic

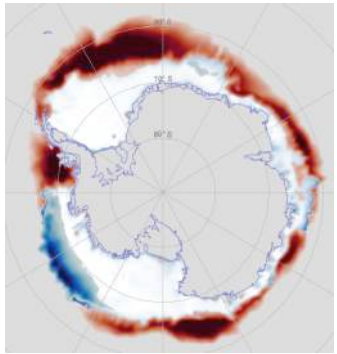
Antarctic Sea Ice Volume Anomalies from model GIOMAS (https://zacklabe.com)



GIOMAS

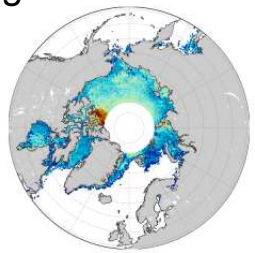
from S3A

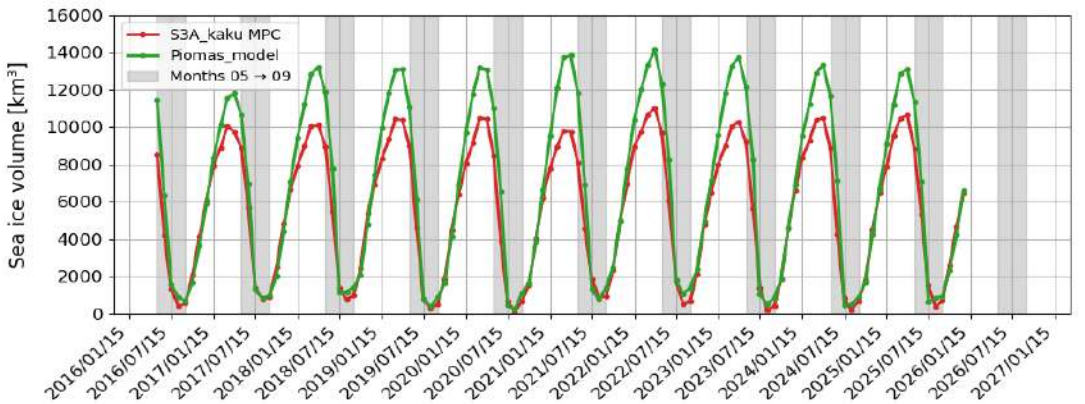
Extension Anomaly June 2023



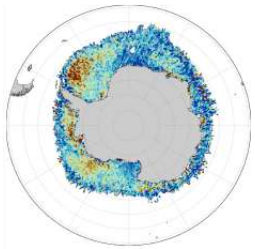
Sea Ice Volume Variations S3A versus PIOMAS/GIOMAS

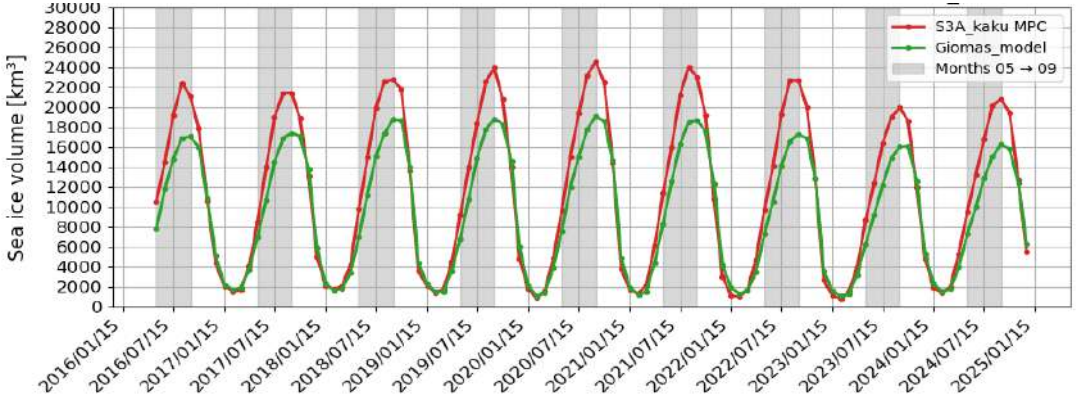
Important negative bias versus PIOMAS





Important positive bias versus GIOMAS





Who is right ? To be investigate !
⇒ **need for in-situ reference measurements (SIT + SD)**

Conclusions

New Baseline Collection 006 (PB 3.35)

- 20 new parameters, including smoothed radar-freeboard, snow depth and sea ice thickness
- Processing has started from cycle 136 for S3A and from cycle 116 for S3B
- Full reprocessing for Q3 2026

Identified priorities for next versions:

- Using physical retracker instead of heuristic one (see Cryo-TEMPO and S3 WAT)
- Add the uncertainties on `radar_freeboard, sea_ice_freboard and sea_ice_thickness`
- New snow depth solutions:
  - LaKu Altimetric Snow Depth deduced from IceSat-2 x CryoSat-2 (to replace KaKu)
  - Using S3 radiometers (see the 2 next presentations)
- New sea ice concentration and sea ice type using S3 radiometer

New progresses need for reference local measurements (Cal/Val) !

- Sea ice thickness and volume from altimetry are making great progresses.
- SIV variations are coherent with PIOMAS/GIOMAS models … **but strong bias**
- To demonstrate the value of these unique measurements (navigation, models, climate) need for CalVal !

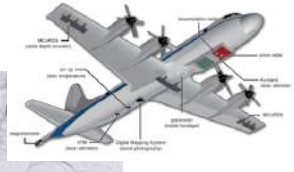
  => SIT + SD

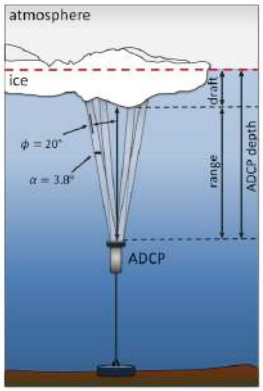
To make new progresses, need for local References !

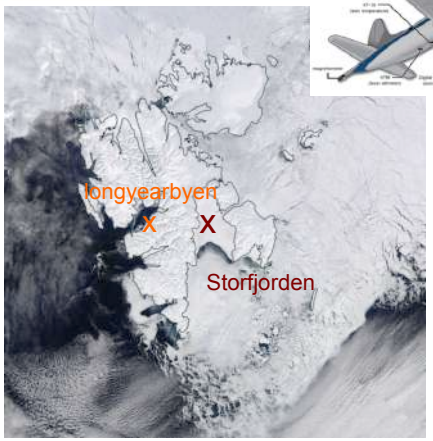
ESA project **St3TART-FO**
2026-2028 in Svalbard

... and after ?

… **toward a European CalVal site in Svalbard ?!**







InSync in Antarctic

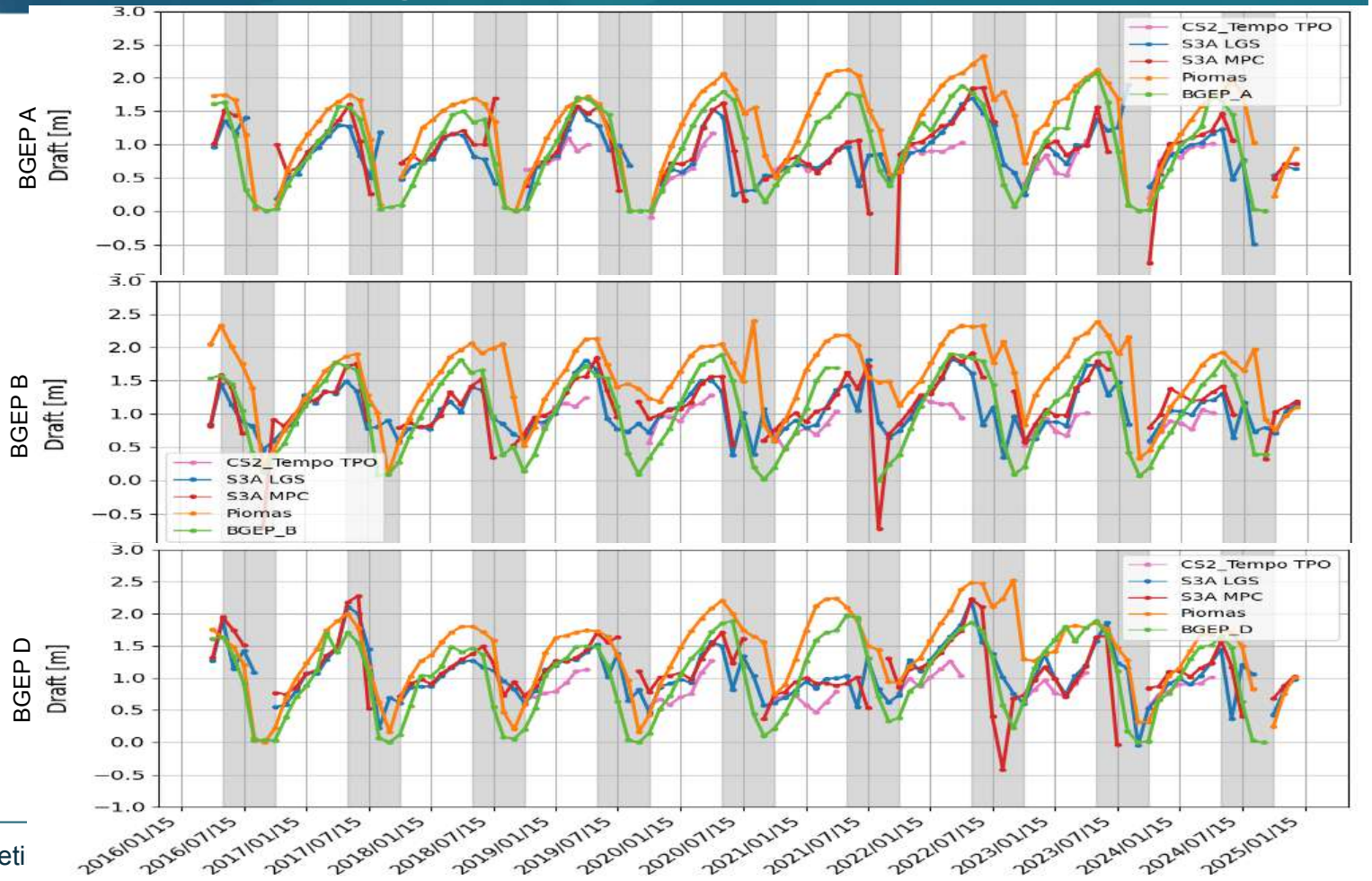
Annexe

Added AFTER after the S3VT workshop …

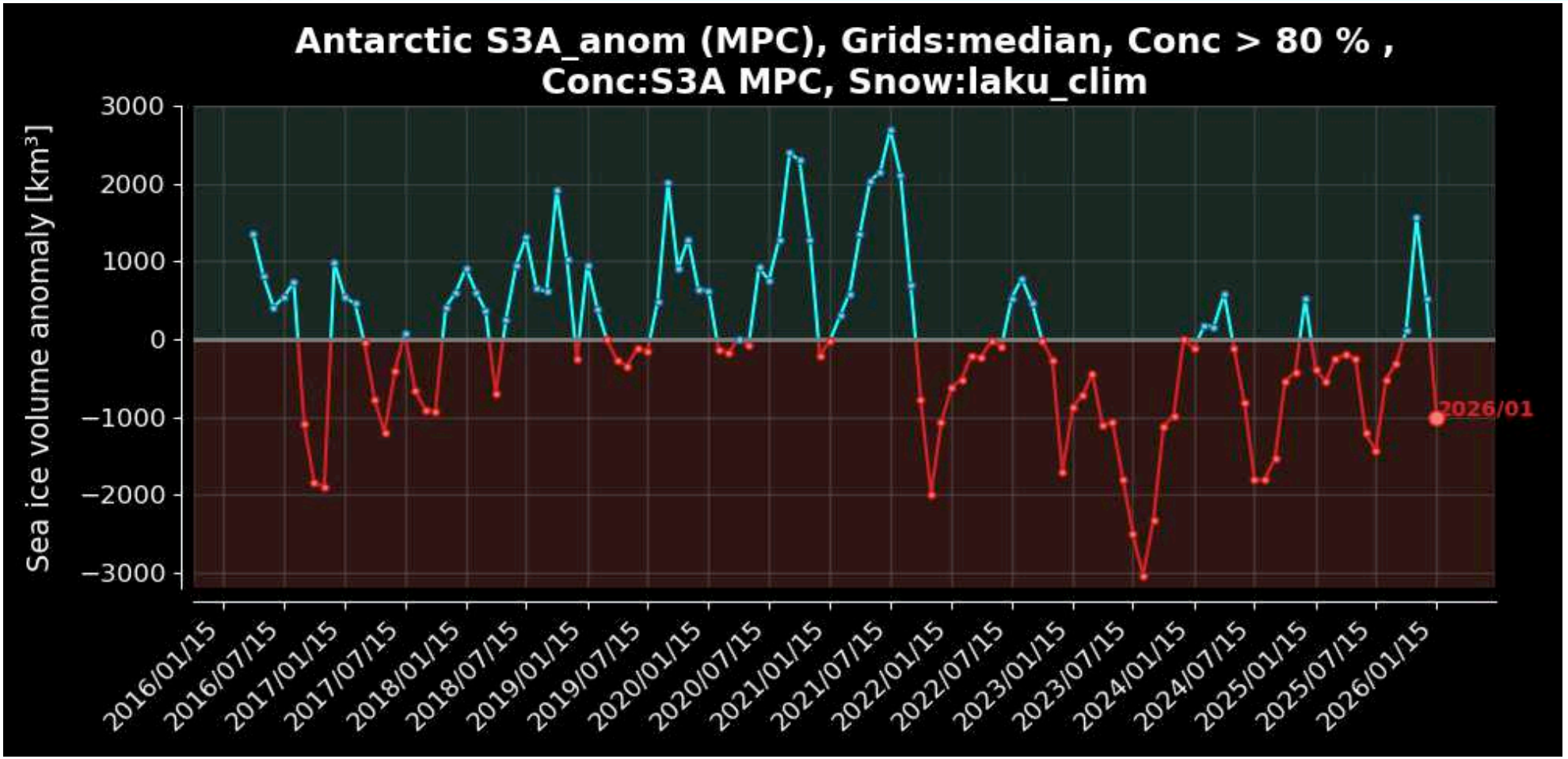
Arctic – KaKu - Median grids / Mean draft BGEP

Relatively to BGEP moorings:

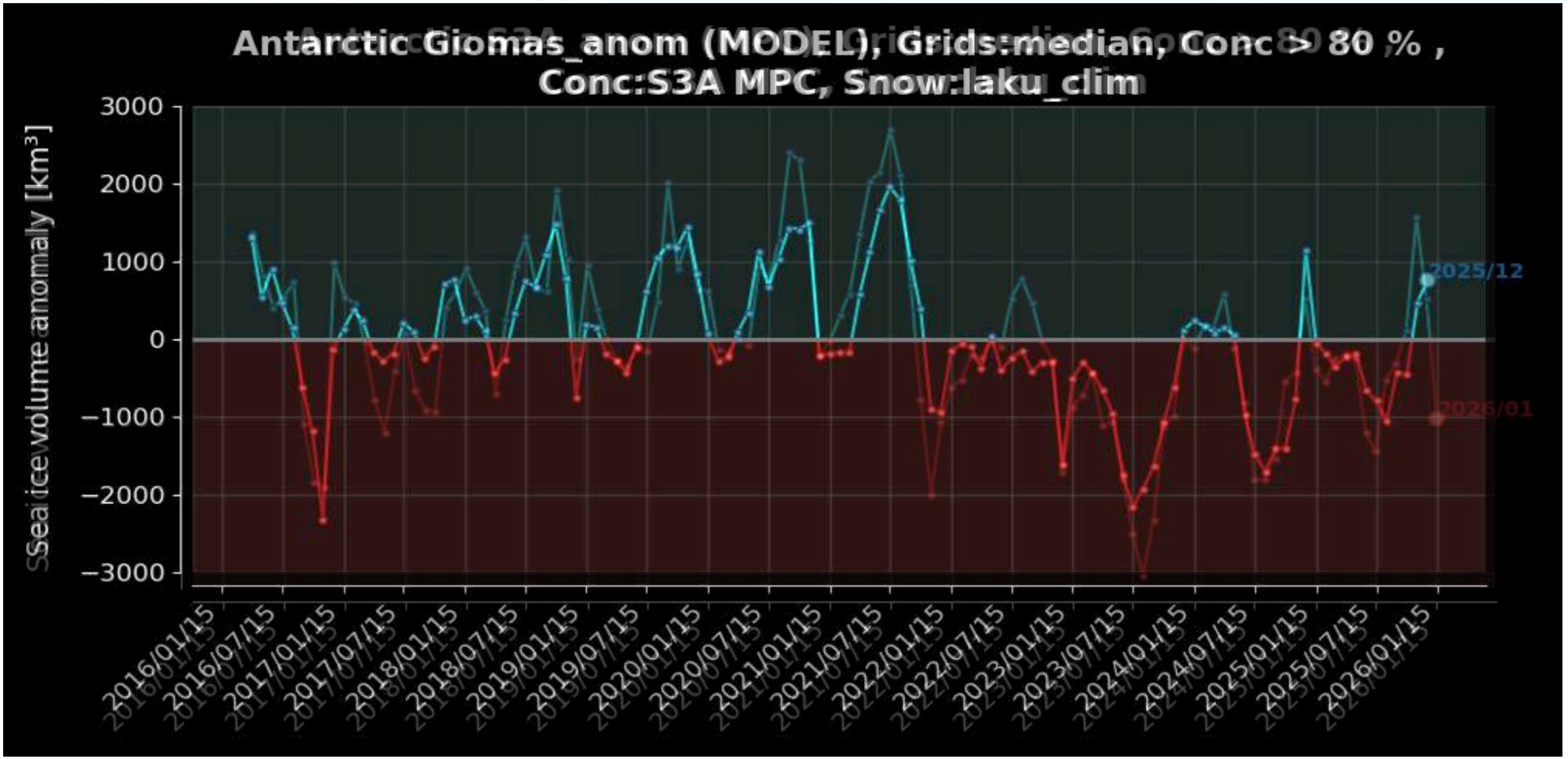
- PIOMAS draft is way too high
- S3A-MPC and S3A-LGS are often but not systematically low
- CS2-Tempo is very significantly too low.



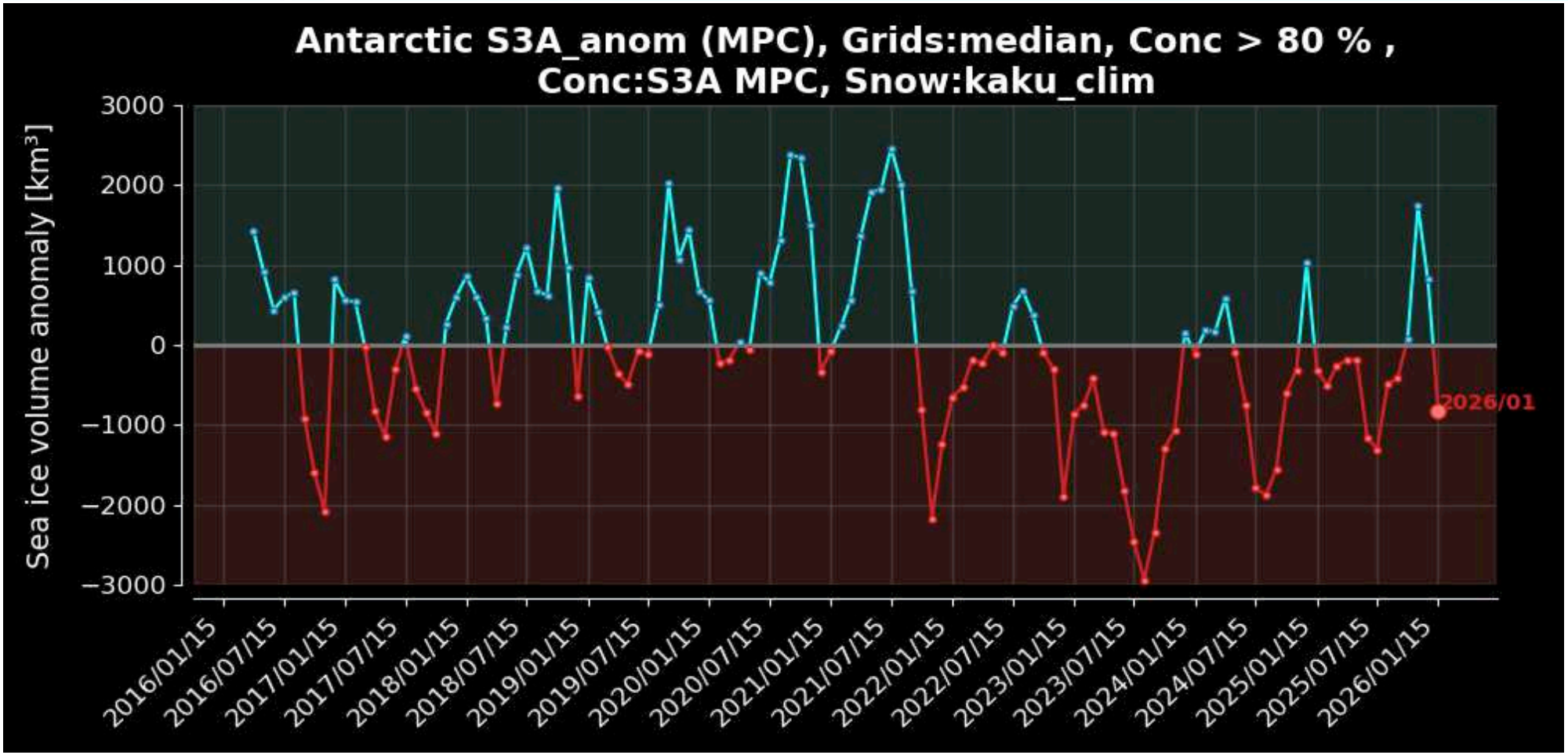
S3A SIV Anomalies **LaKu**



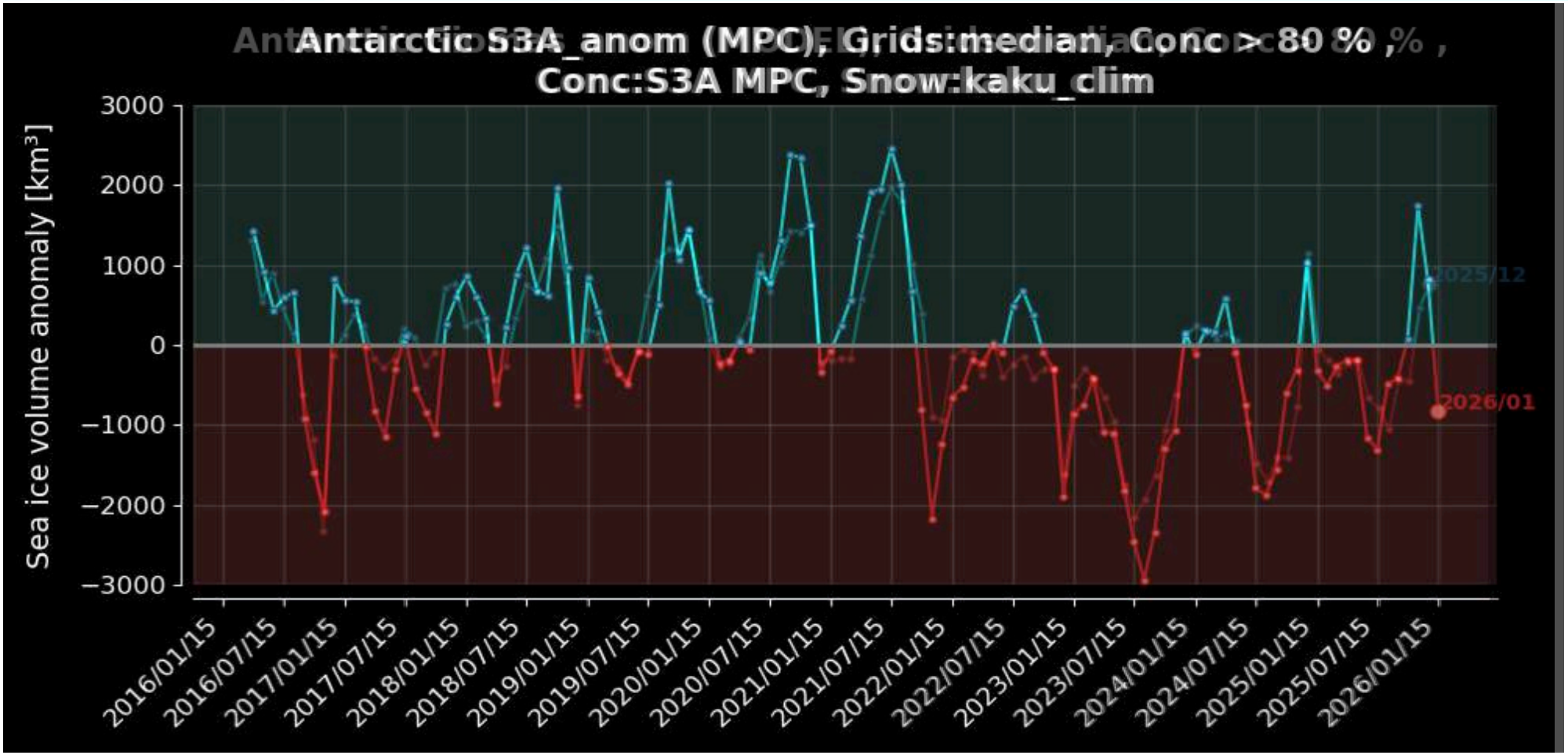
S3A vs Giomas SIV Anomalies **LaKu**

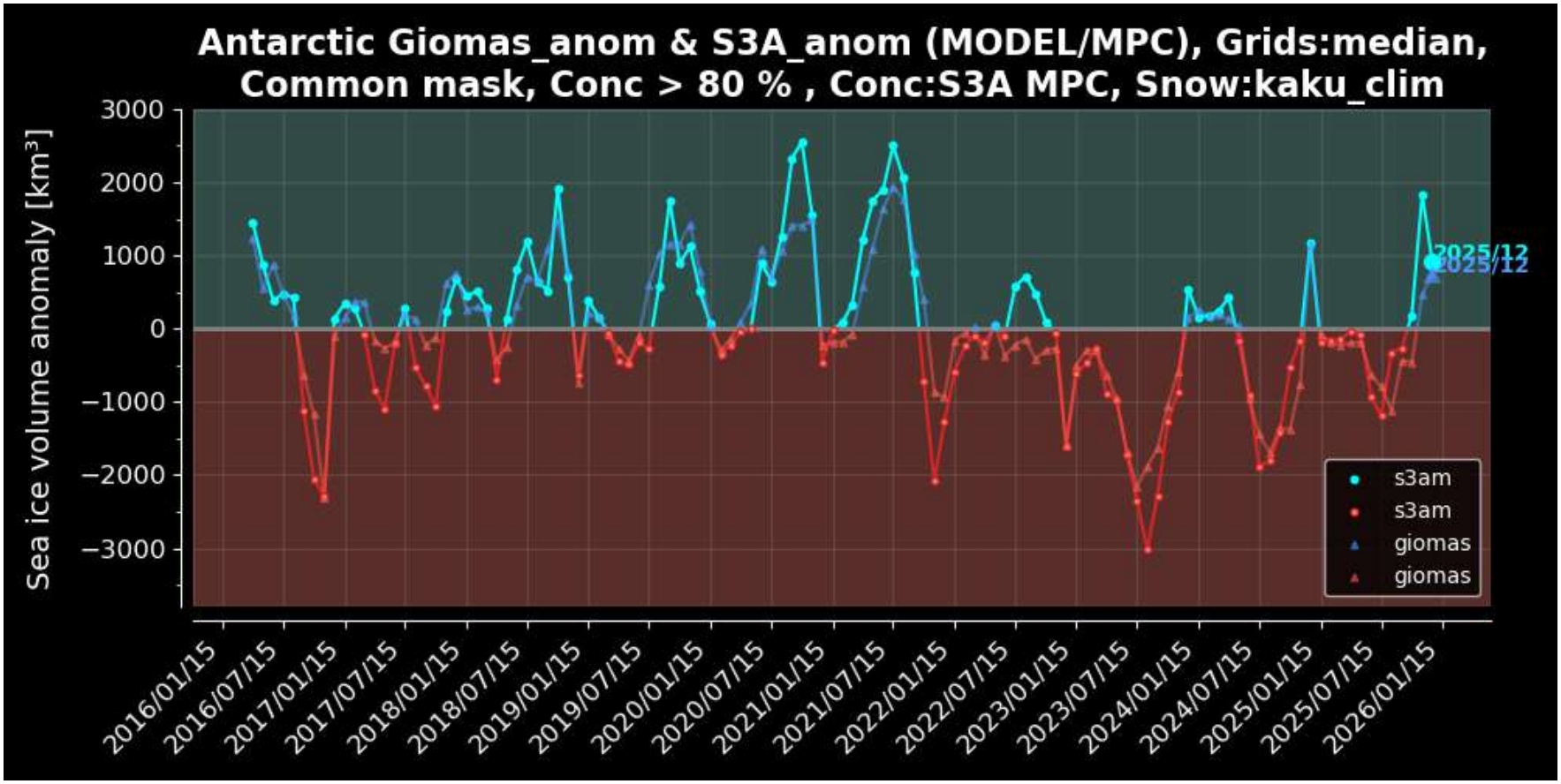


S3A SIV Anomalies **KaKu**

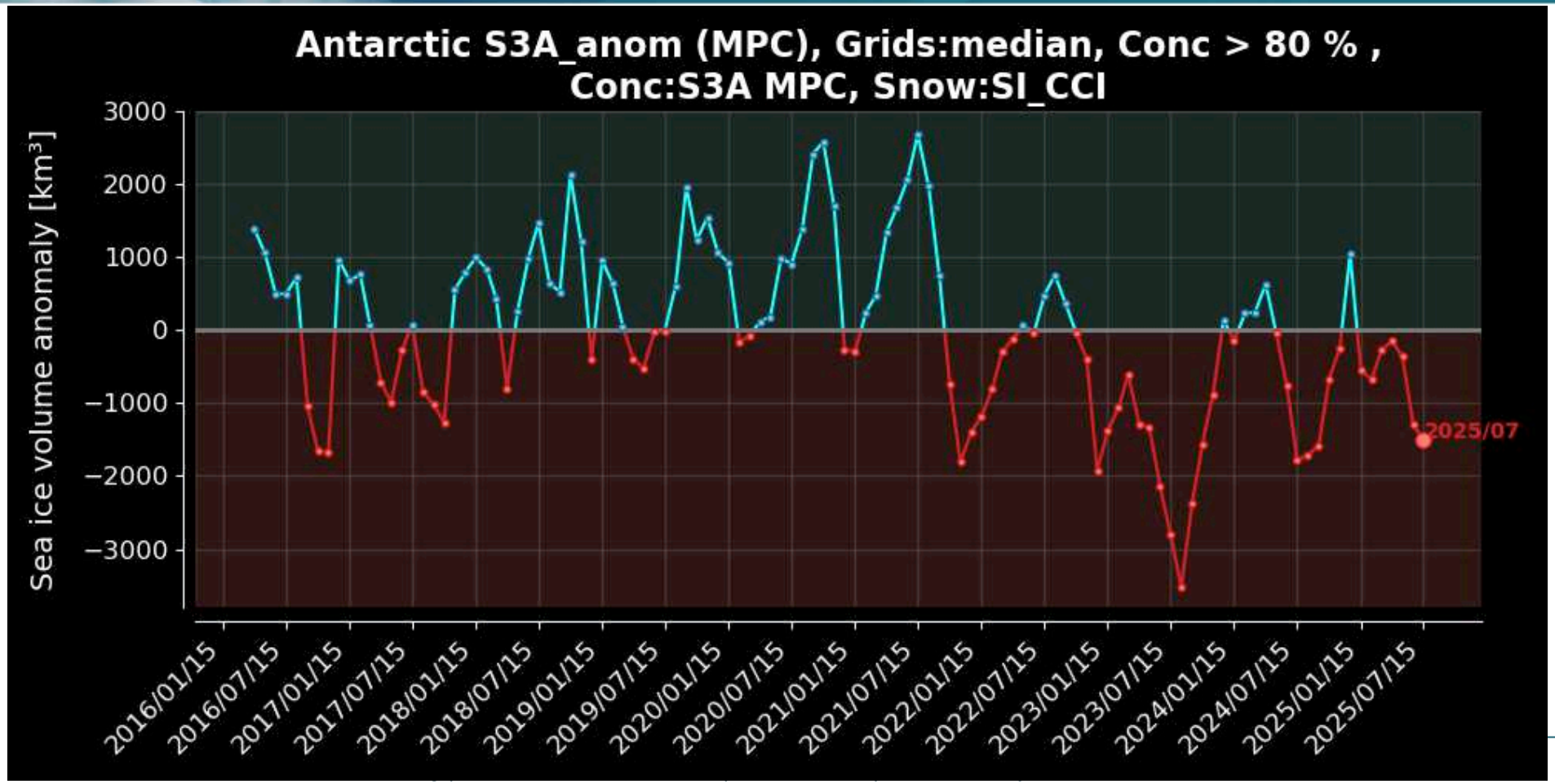


S3A vs Giomas SIV Anomalies **KaKu**




Antarctic Giomas_anom & S3A_anom (MODEL/MPC), Grids:median,
Common mask, Conc > 80 % , Conc:S3A MPC, Snow:kaku_clim
Sea ice volume anomaly [km³]
3000
2000
1000
0
−1000
−2000
−3000
2025/12
2025/12
s3am
s3am
giomas
giomas
2016/01/15
2016/07/15
2017/01/15
2017/07/15
2018/01/15
2018/07/15
2019/01/15
2019/07/15
2020/01/15
2020/07/15
2021/01/15
2021/07/15
2022/01/15
2022/07/15
2023/01/15
2023/07/15
2024/01/15
2024/07/15
2025/01/15
2025/07/15
2026/01/15

S3A SIV Anomalies **CCI**



S3A vs Giomas SIV Anomalies **CCI**