

esa



Assessment of Ka-Ku Altimetric Snow Depth on Sea Ice during Arctic and Austral Winters

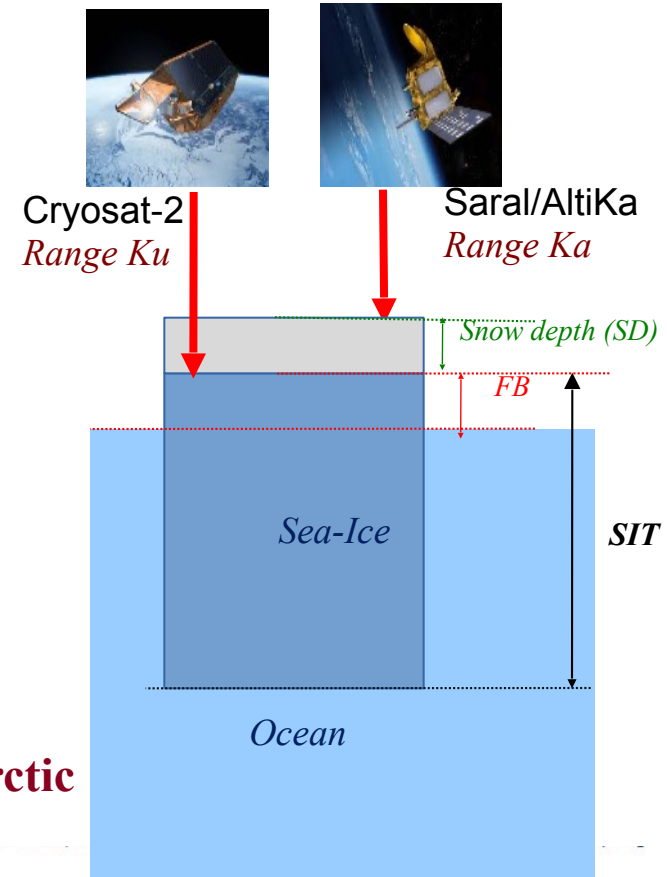
Florent Garnier, Sara Fleury, Gilles Garric, Jérôme Bouffard, Michel Tsamados
Antoine Laforge, Marion Bocquet, Frédérique Rémy
and Rénée Mie Fredensborg Hansen



Bi-frequency altimetric Snow depth measurement

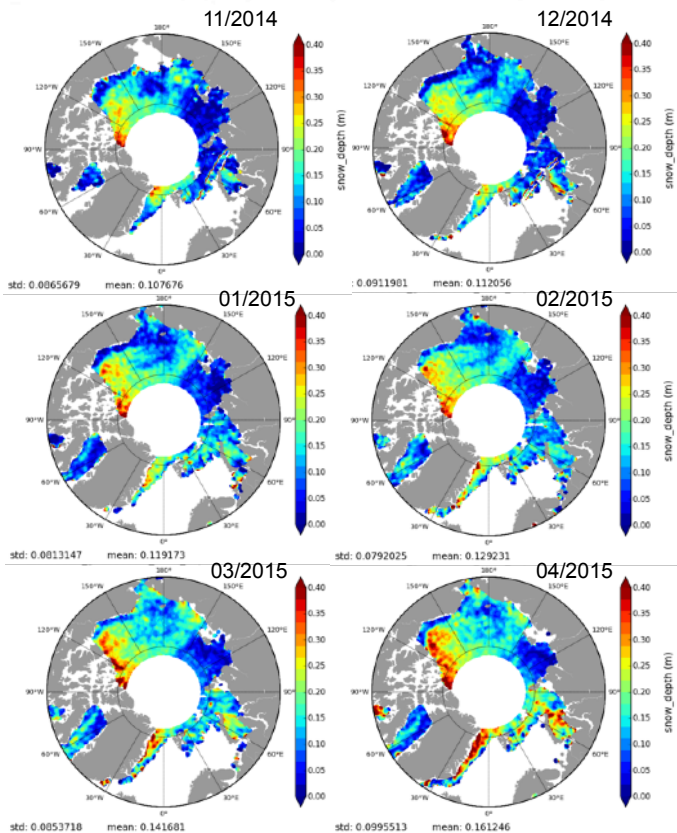
Based on the difference of penetration between
Ka (35.7 Ghz) and **Ku (13.5 Ghz)** frequencies
(Guerreiro et al 2016, Armitage et al, 2015)

$$\rightarrow \text{SD} = \text{FB}_{\text{Saral/altika}} - \text{FB}_{\text{Cryosat-2}}$$



!!! Saral orbit limits the ASD coverage to 81.5° in the Arctic

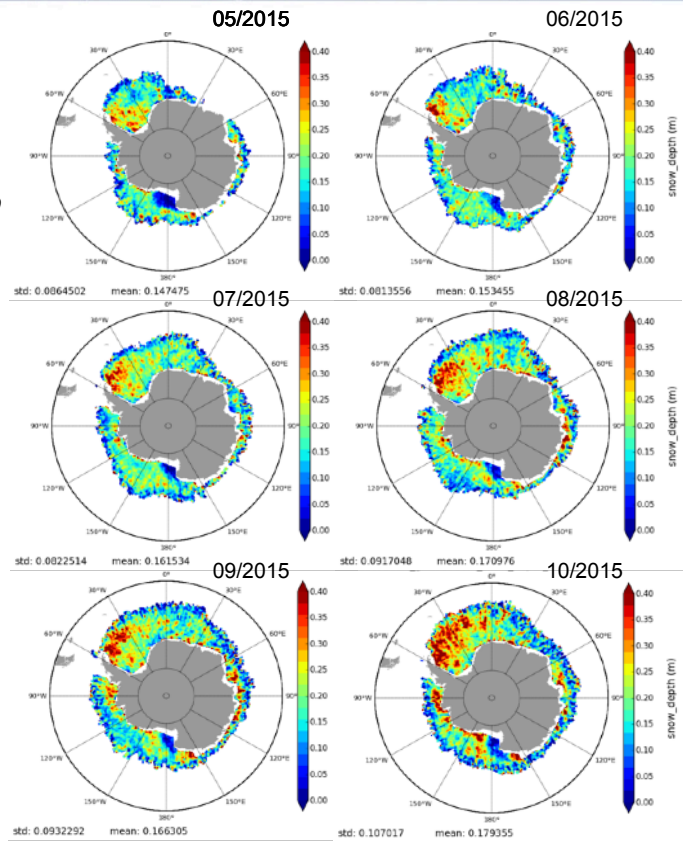
The Altimetric Snow Depth (ASD) product



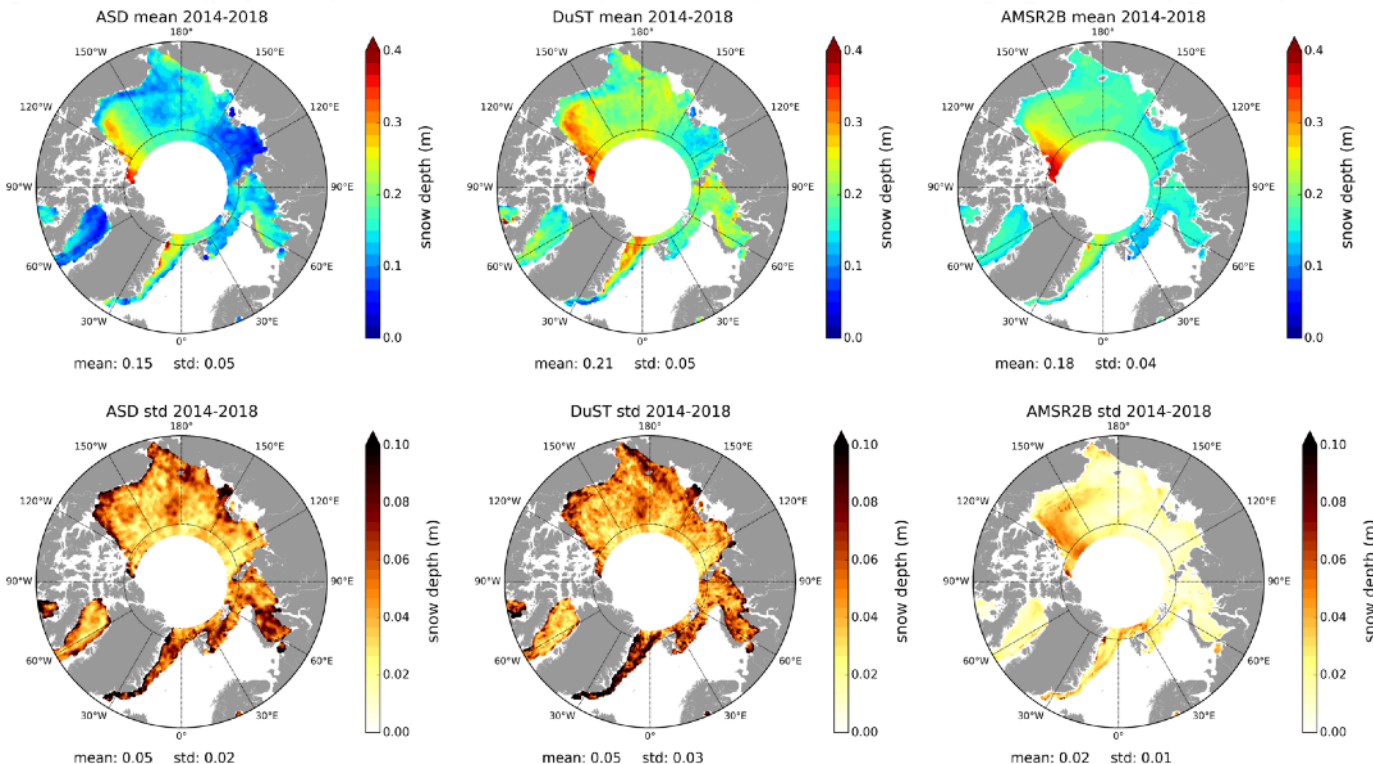
*Saral/Altika :
SGDR AVISO L2
Cryosat-2 :
ESA (B-C)GOP PLRM L1b*

**The ASD Snow Depth data is
available at AVISO+/ODATIS
(in the 2013-2019 time period)**
<http://ctoh.legos.obs-mip.fr>

*Data for 2020 are also available.
Please contact Florent Garnier to
have access to these data.*



Comparison with AMSR-2 and DuST in the Arctic



DuST : Dual-Altimeter Snow Thickness Ka-Ku product from UCL (*Lawrence et al, 2018*)

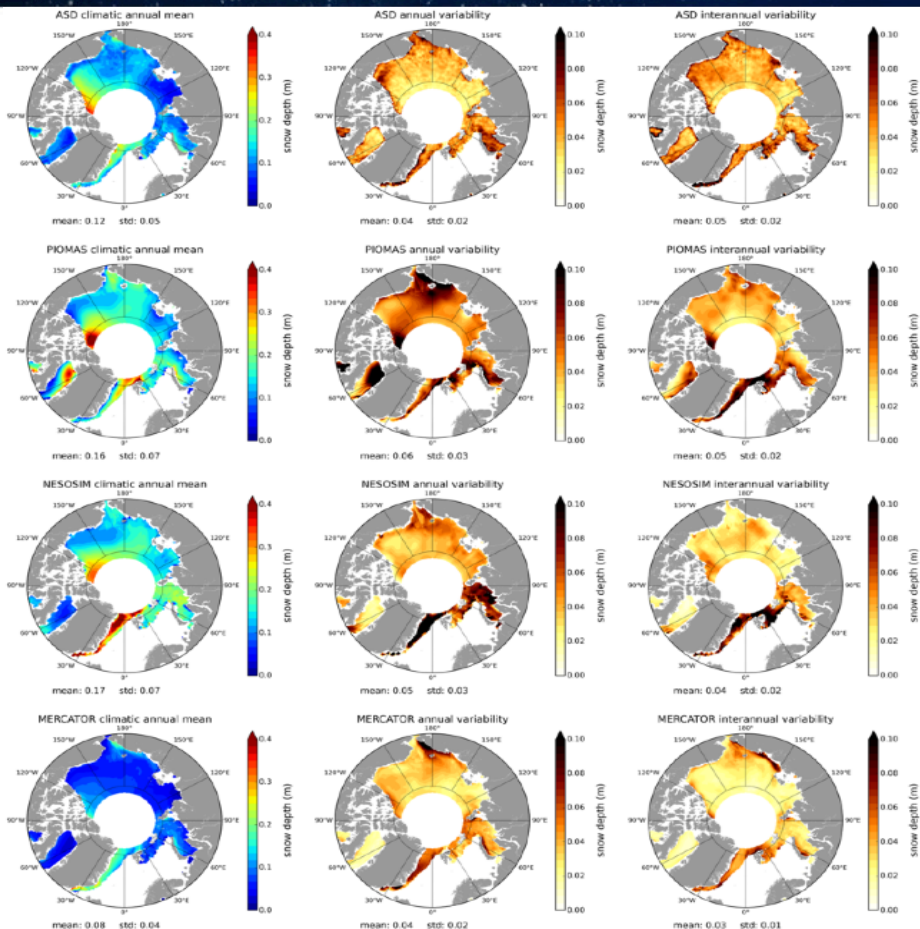
AMSR-2B Advance Microwave Scanning Radiometer 2 (*Bremen version, Rostosky et al, 2018*)

ASD: Ka-Ku snow depth product developed at the LEGOS (*Garnier et al, 2021*)

Comparisons of bi-monthly (March and April) “climatological” snow depth mean maps calculated over the period 2014-2018. The standard deviation between all the data used to calculate the mean snow depth maps is presented in the second line.

Note that references are explicated in the last slide

Comparison with models in the Arctic

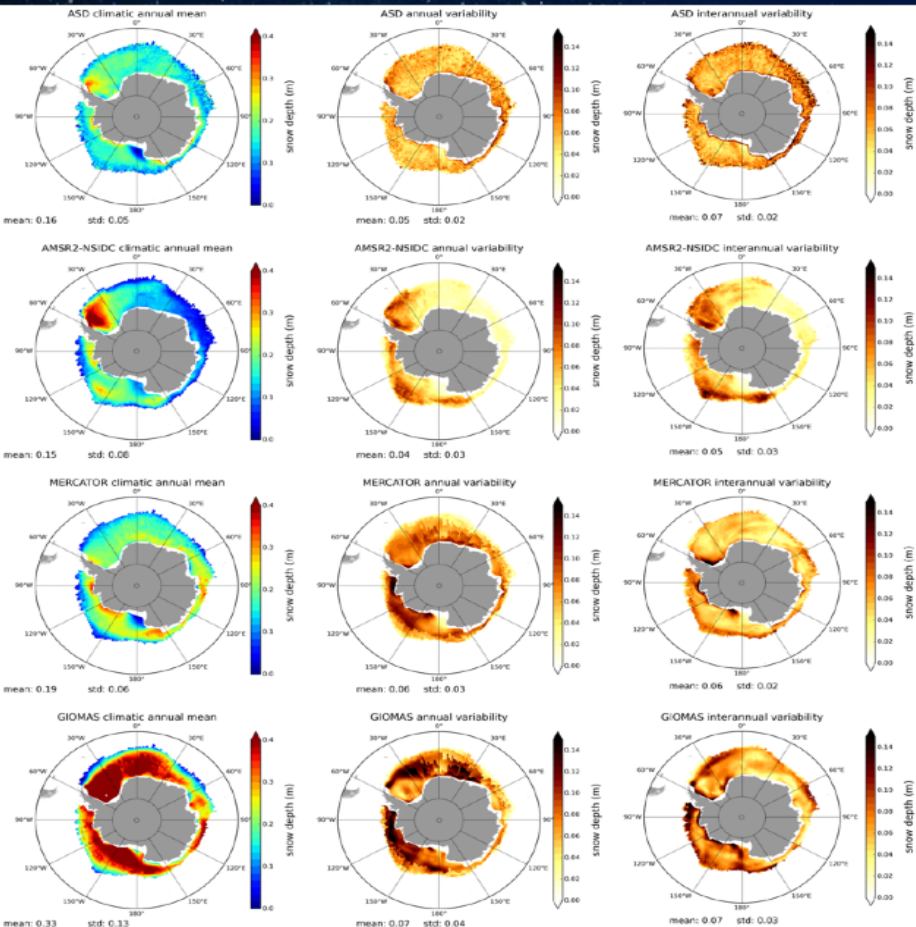


Comparisons between the ASD data and model snow depth products (PIOMAS, NESOSIM, MERCATOR) in the Arctic.

The first column presents the "climatic mean" snow depth maps, the second column the "annual variability" and the third column the "interannual variability".

These diagnosis are calculated from March 2013 to April 2019 for ASD (first row), PIOMAS (second row) and MERCATOR (fourth row) and from March 2013 to April 2017 for NESOSIM (third row).

Comparison in Antarctica

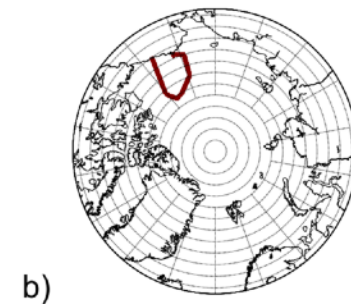
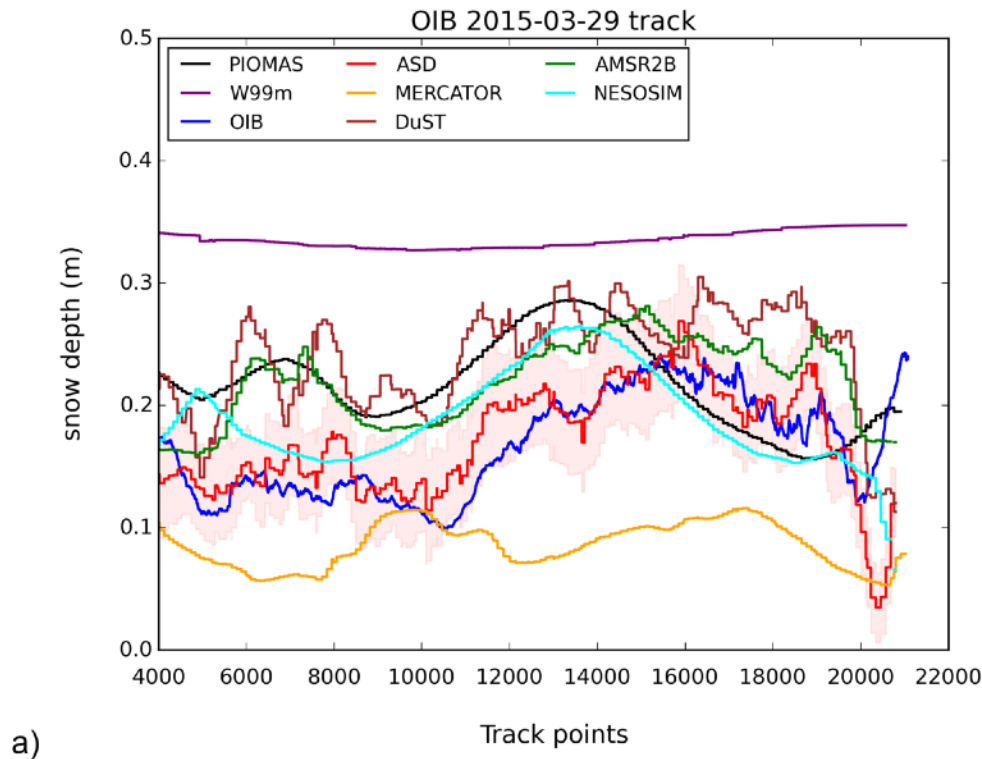


Comparisons between ASD data and other snow depth estimations in Antarctica (AMSR-2-data from the NSIDC, MERCATOR, GIOMAS).

The first column presents the "climatic mean" snow depth maps, the second column the "annual variability" and the third column the "interannual variability".

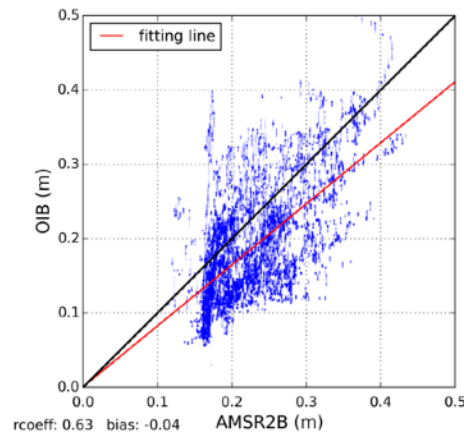
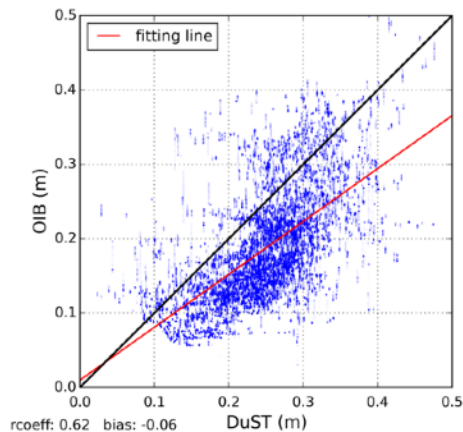
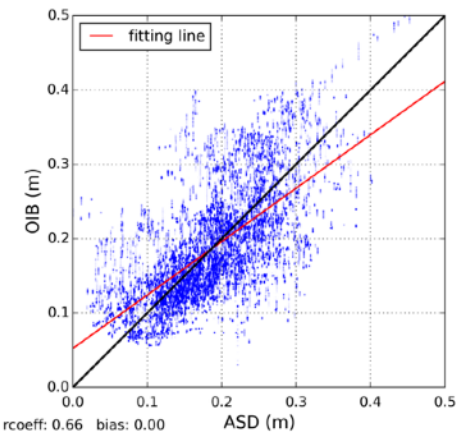
These diagnosis are calculated from May 2013 to October 2019 for the ASD data (first row), the AMSR-2 NSIDC (second row) and the MERCATOR model (third row) and from May 2013 to October 2016 for the GIOMAS model data (fourth row).

Comparison with OIB in the Arctic



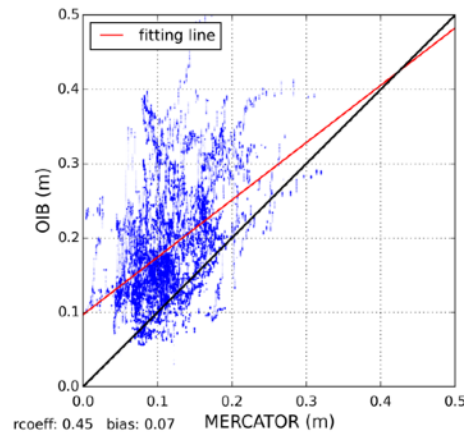
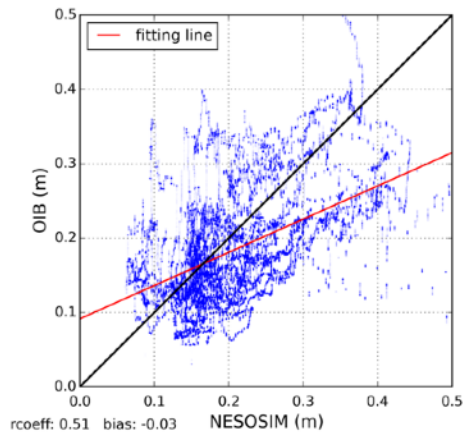
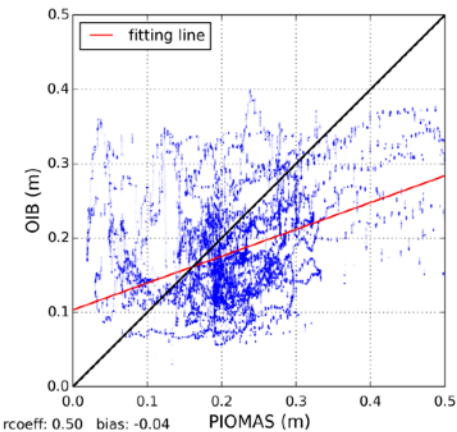
a) Along-track comparison between snow depth products and the OIB snow radar data during 29th March 2015 2015 spring campaign in the Arctic. The red envelope refers to the ASD uncertainties. b) The geographical map specifies the geographical location of this particular one-day OIB track.

Comparison with OIB in the Arctic

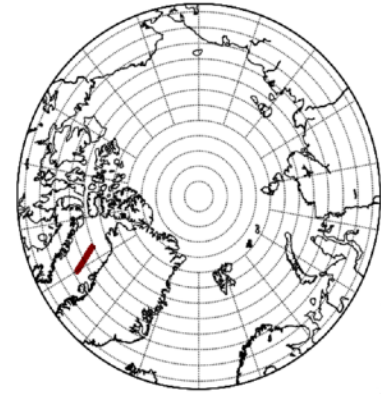
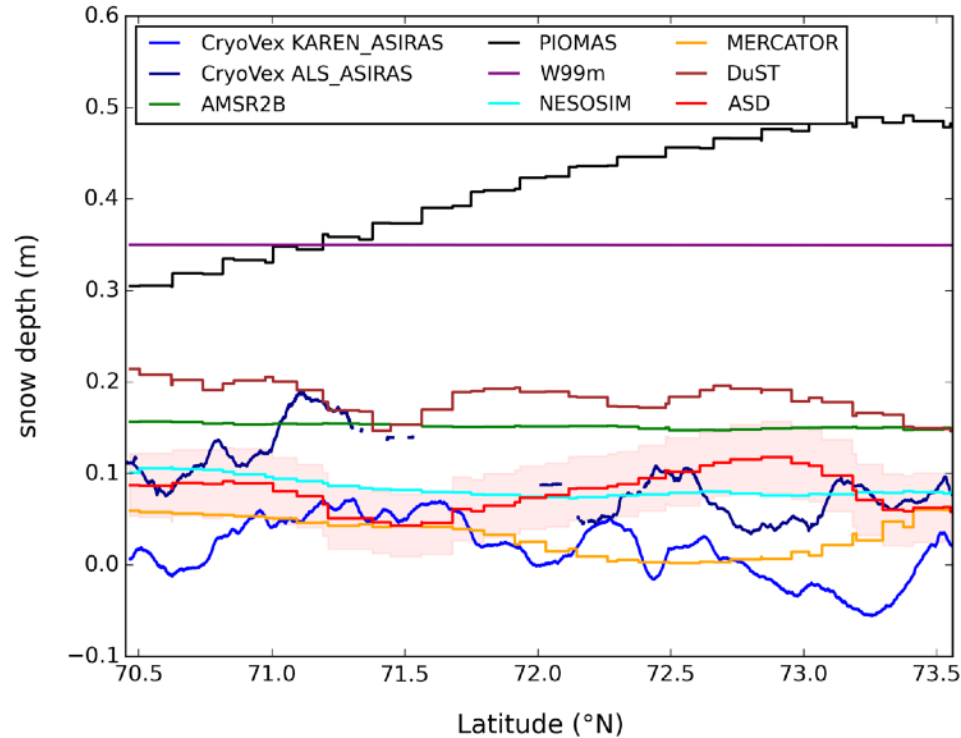


Scatter plots comparing OIB snow radar data (considering the 2014 to 2018 missions) with ASD and other snow depth products (shown in the previous slides) in the Arctic

Note that for NESOSIM, 2018 is not considered.

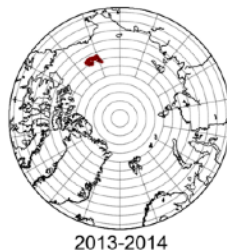
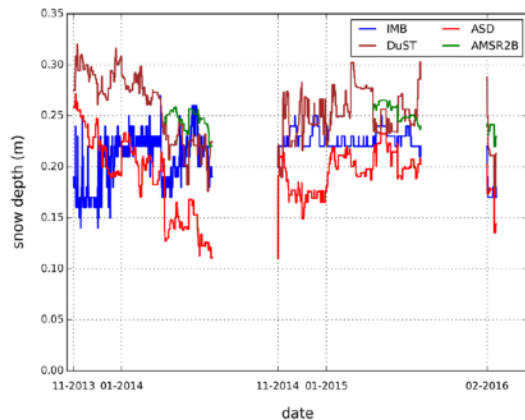


Comparison with the 2017 CryoVEx campaign



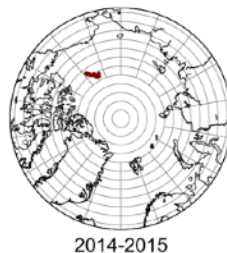
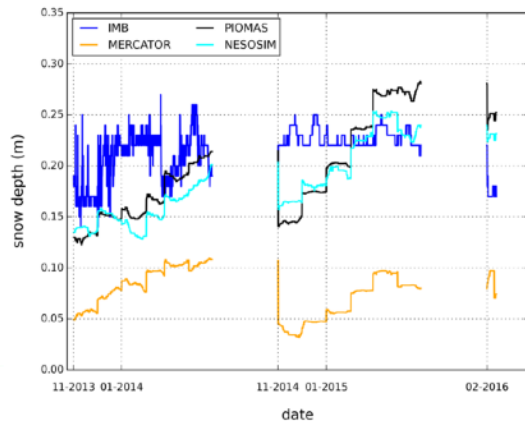
Along-track comparison, in the Arctic, between ASD and other snow depth products (models and satellites) and the CryoVEx snow depth data calculated from the KAREN Ka band radar (blue) and the ALS laser (dark blue) with the ASIRAS Ku-band radar during the 31st March 2017 campaign. The red envelope refers to the ASD uncertainties. The map specifies the geographical location of the CryoVEx track.

Comparison with the IMB snow buoys

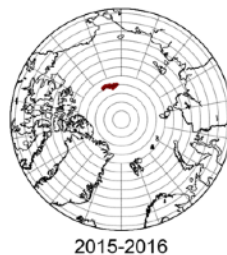


Along-track comparison between the snow depth products and the IMB in-situ data.

(Top left) IMB buoys compared with satellite data; both passive and active, (bottom left) IMB buoys compared with model data.

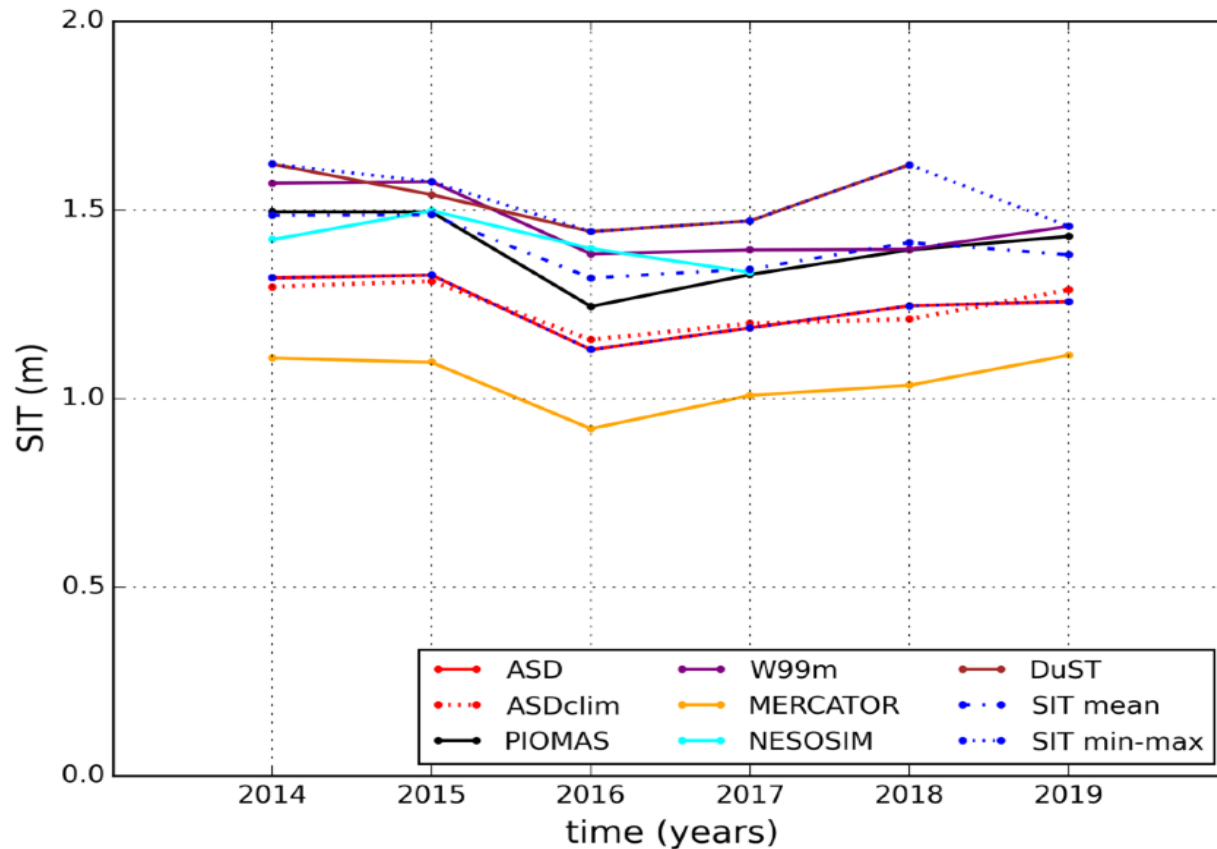


Right column shows geographical maps from data for all three periods (2013–2014, 2014–2015, 2015–2016). The maps presents the geographical location of the three IMB buoys.



Uncertainty on SIT due to snow depth

Arctic ($< 81.5^\circ$) annual mean



Arctic annual mean time series (2014-2019) of the averaged SIT solutions computed using various snow depth products (models, and active/passive satellite-based).

The dotted blue lines define the annual mean, minimum and maximum values between all solutions (except for MERCATOR).

The AMSR-2 data are not represented since they are not available over the entire Arctic area.

Armitage, T. W. K. and Ridout, A. L.: Arctic sea ice freeboard from AltiKa and comparison with CryoSat2 and Operation IceBridge, *Geophysical Research Letters*, 42, 6724–6731, <https://doi.org/10.1002/2015GL064823>, <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015GL064823>, 2015.

F.Garnier, S. Fleury, G.Garric, J.Bouffard, M.Tsamados, A.Laforge, M.Bocquet, R M.Fredensborg Hansen and F. Rémy, (2021). *Advances in altimetric snow depth estimates using bi-frequency Saral/Cryosat-2 Ka/Ku measurements. Submitted in The Cryosphere.*

Guerreiro, K., Fleury, S., Zakharova, E., Rémy, F., and Kouraev, A.: Potential for estimation of snow depth on Arctic sea ice from CryoSat-2 and SARAL/AltiKa missions, *Remote Sensing of Environment*, 186, 339–349, 2016.

Lawrence, I. R., Tsamados, M. C., Stroeve, J. C., Armitage, T. W., and Ridout, A. L.: Estimating snow depth over Arctic sea ice from calibrated dual-frequency radar freeboards, *The Cryosphere*, 12, 3551–3564, 2018.

Rostosky, P., Spreen, G., Farrell, S. L., Frost, T., Heygster, G., and Melsheimer, C.: Snow Depth Retrieval on Arctic Sea Ice From Passive Microwave Radiometers — Improvements and Extensions to Multiyear Ice Using Lower Frequencies, *Journal of Geophysical Research: Oceans*, 123, 7120–7138, 2018.