Sea ice volume changes from 1993 using altimetry

RÉPUBLIQUE FRANÇAISE
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Introduction

Sea ice is a key witness and driver of climate change. Sea ice extent evolution is widely studied and well identified contrary to its thickness, nevertheless sea ice volume that is computed from the thickness is a mandatory variable to understand the full evolution of sea ice. Thin ice would be more sensitive to storms and will melt faster during spring time than thick ice. Sea ice area or extent products start in the 70's for both polar oceans, whereas no product has been published before winter 2002/2003 [1,2,3] for the Arctic and 2010 for the Antarctic. The first objective of this thesis has been to retrieve sea ice thickness from the very beginning of the altimetry era : 1991 for both hemisphere and reach a 30 years record of sea ice volume.

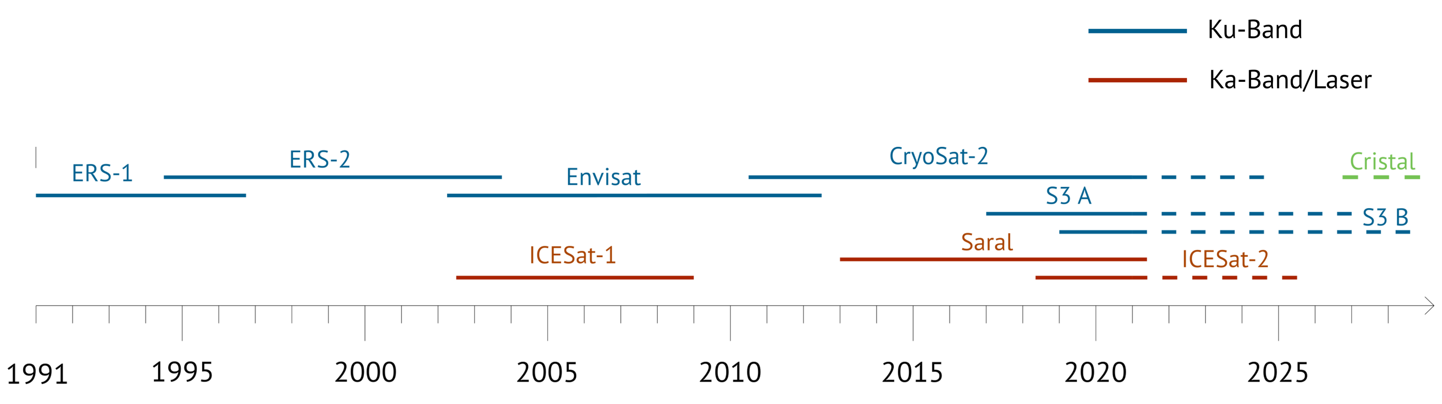

Figure 1 : Overview of Altimetry missions for sea ice observation

Methods

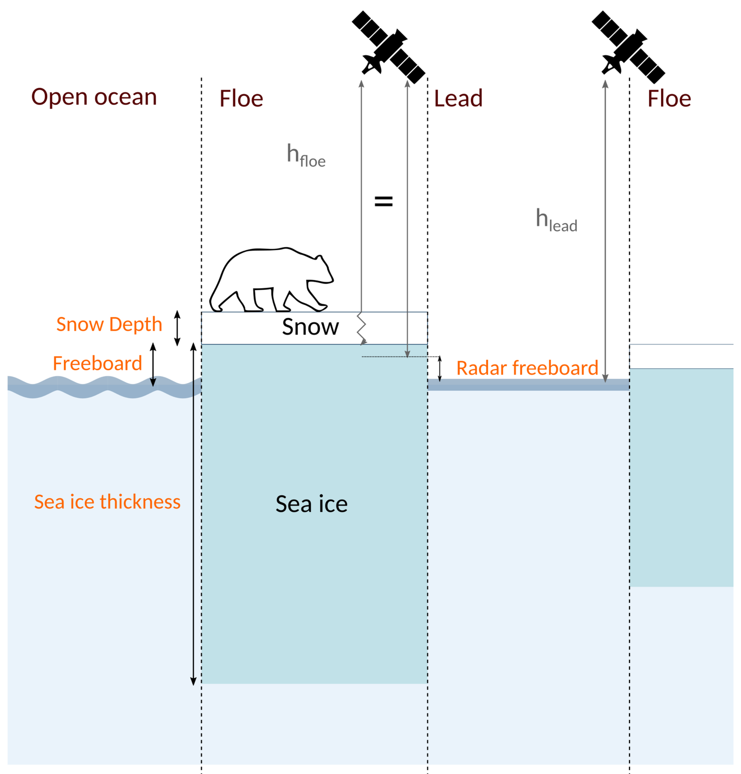

Figure 2 : Sea ice thickness retrieval from altimetry, freeboard methodologyn

Sea ice thickness (SIT) can be retreived using altimetry by comparing the height measured over the floes and over the leads : the radar freeboard. The sea ice thickness can be deduced assuming hydrostatic equilibrium and by correcting the radar freeboard of the signal propagation slowdown within the snow pack.

$$FB_{radar} = h_{floe} - h_{lead}$$

Hydrostatic balance

Sea ice thickness

$$\frac{\rho_w}{\rho_w - \rho_i} FB_{radar} + \frac{(c/c_s - 1)\rho_w + \rho_s}{\rho_w - \rho_i} SD$$

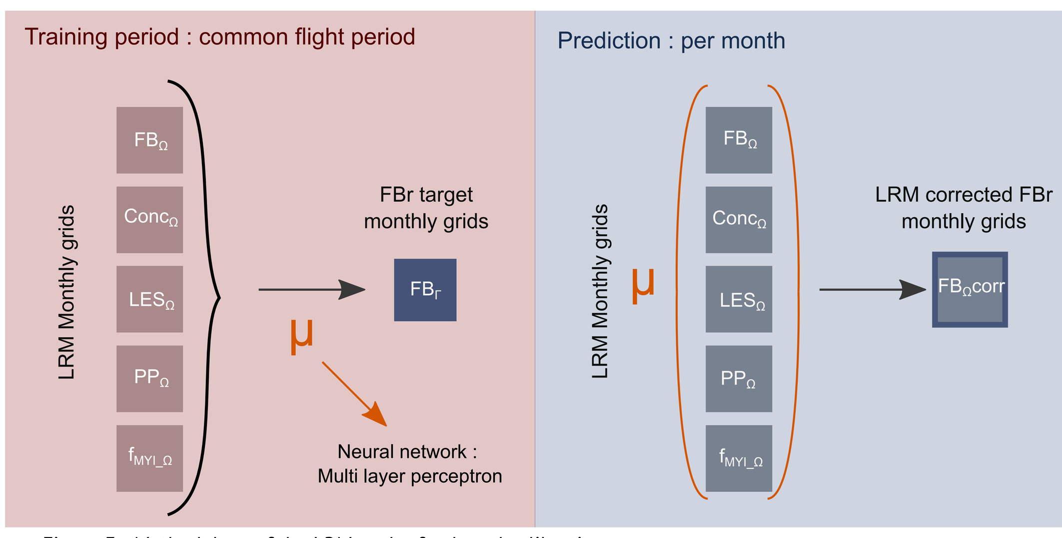

Figure 3 : Methodology of the LRM radar freeboard calibration

Sea ice thickness estimations became meaningfull thanks to CryoSat-2 and ICESats missions and their reduced footprint size. Former altimeters with large footprint size are more impacted by the surface roughness and measurments need to be corrected. The correction developed take advantage of the mission-overlap period between missions to calibrate past missions over recent ones using a neural network.

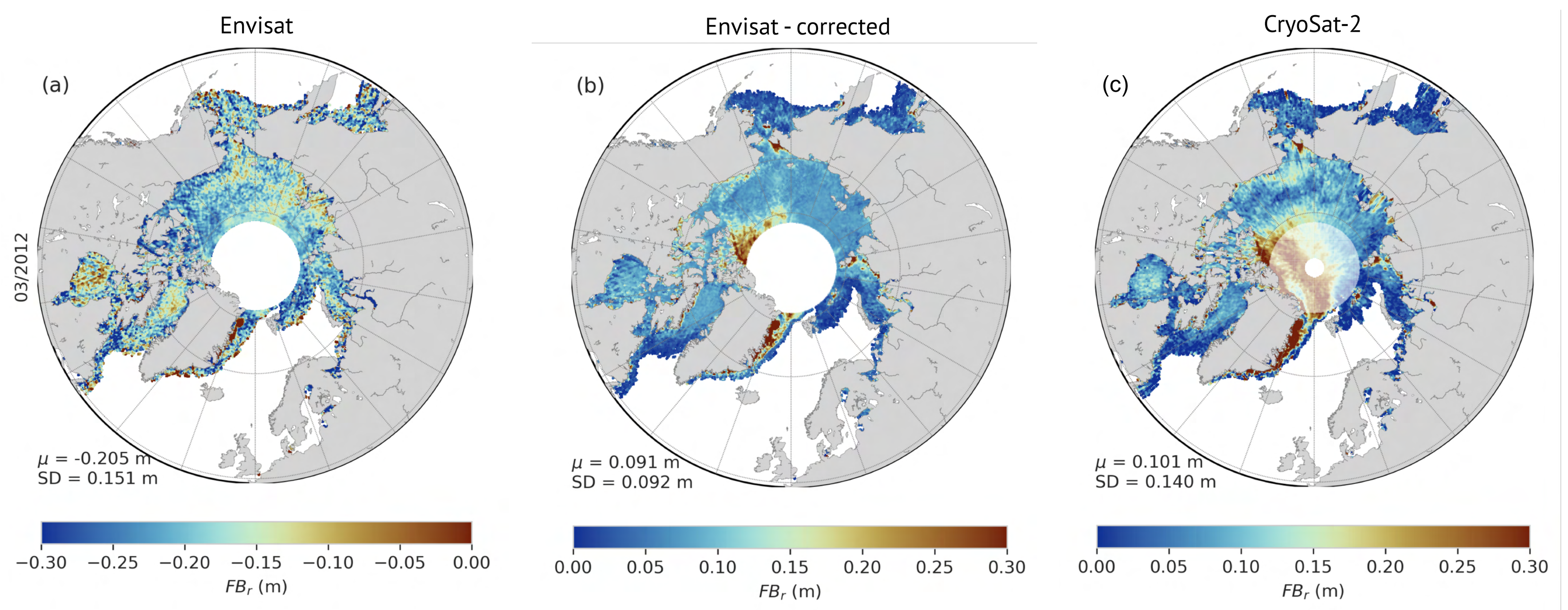

Figure 4 : Radar freeboard from (a) Envisat, (b) Envisat corrected and (c) CryoSat-2 for April 2012

Results

Global Analysis

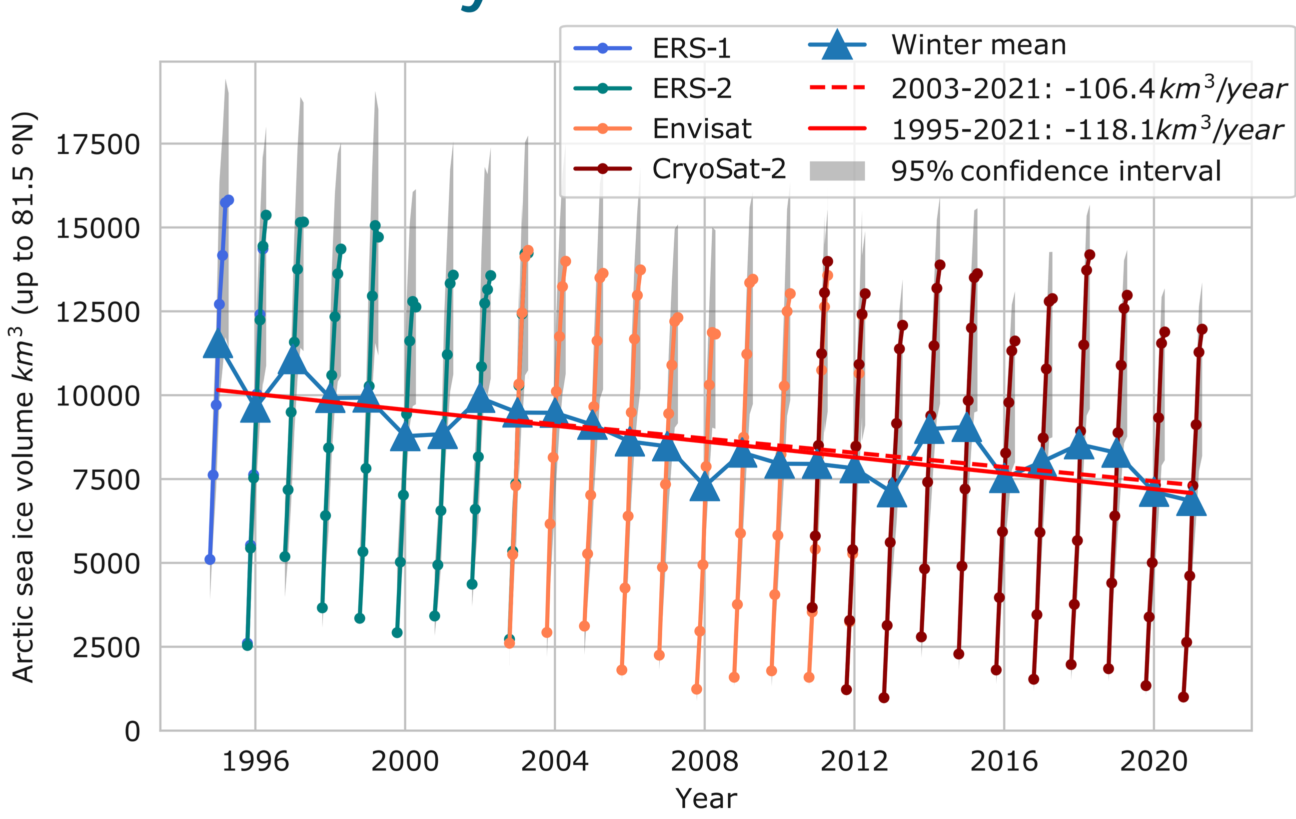

Figure 5 : Arctic sea ice volume between 1994 and 2021 during winter time

Monthly radar freeboard from ERS-1, ERS-2 and Envisat have been corrected between 1993 and 2012 New arctic radar freeboards were validated using a dozens of independant datasets (Airborne data, ULS, Satellites, ...). Methodologies and validation are presented in [4]. To convert this monthly radar freeboard into a volume time series, the radar freeboard has been converted to sea ice thickness using snow depth from [5] for NH and [6] for SH. Monthly total volume are obtained by multiplying the thickness by the sea ice area into each grid cells and sum up over the whole grid for each month.

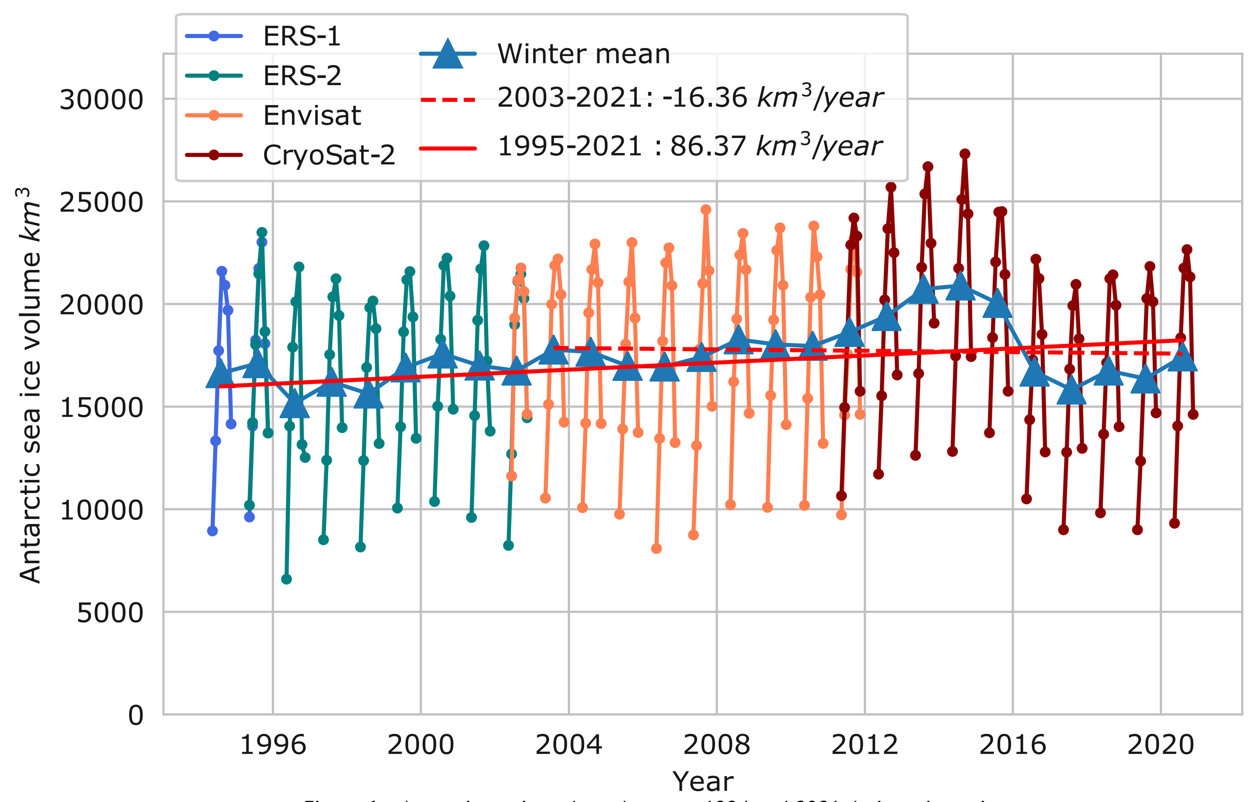

Figure 6 : Antarctic sea ice volume between 1994 and 2021 during winter time

Arctic Sea Ice Analysis

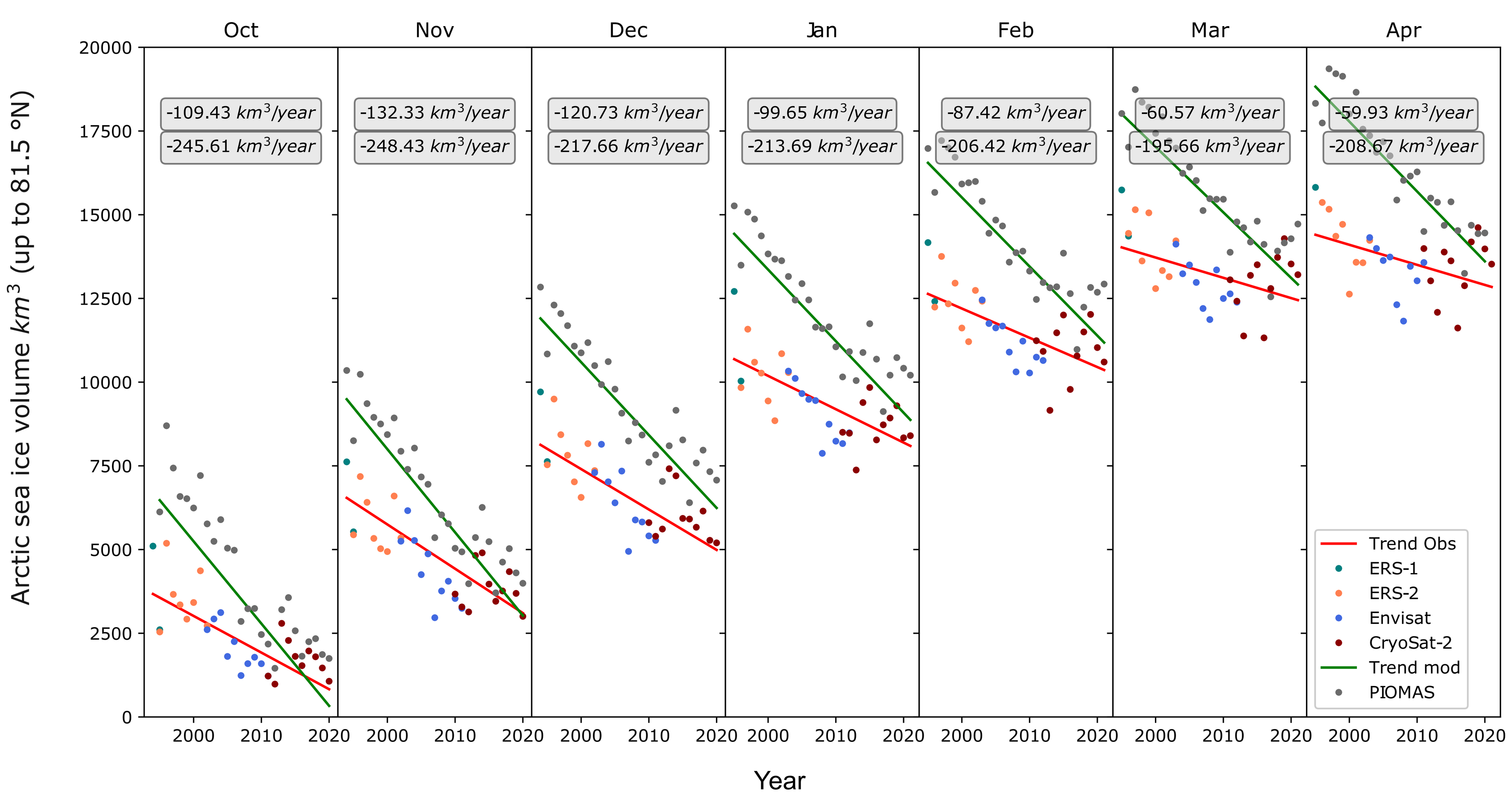

Figure 7 : Arctic sea ice volume between 1994 and 2021 during winter time for each winter month, in red volume from Altimetry and in green volume from PIOMAS model

Uncertainties were computed using Monte carlo methodology from the very begining of the processing chain until the bassin-scale volume computation.

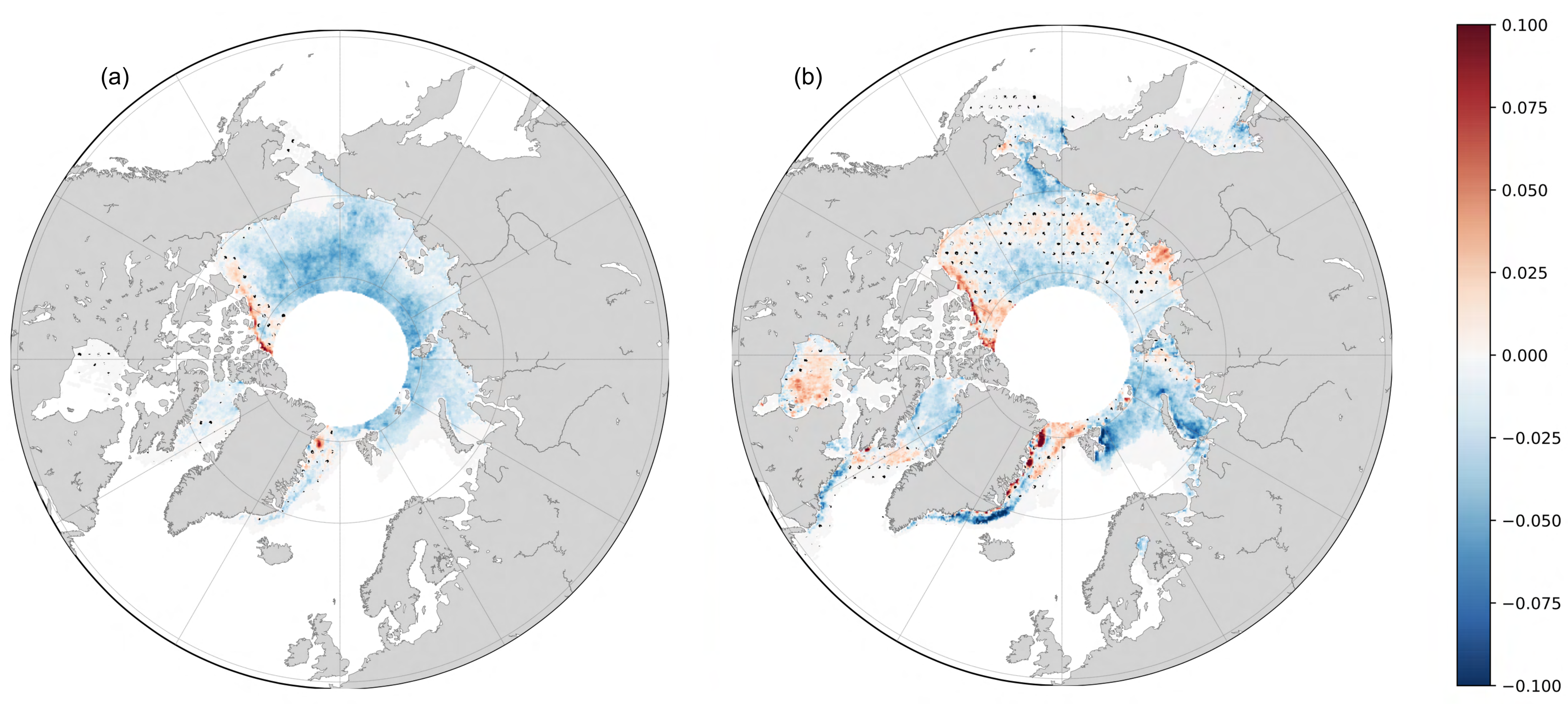

Figure 8 : Arctic sea ice thickness trends between 1994 and 2021 during winter time for (a) November and (b) April, black dots represent trends that are statistically significant at 75%

Conclusion

This work provides the very first long time series of sea ice thickness and volume for both polar oceans. Measurements are provided with their uncertainties estimates following a Monte Carlo methodology. Uncertainty quantifications are quiet new for this kind of measurements. Future work will consist in studying sea ice changes of the past 30 years

References

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