SYMPOSIUM OP'24 — ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Assimilation of freeboard and snow altimetry in an Arctic and Antarctic ocean and sea ice modelling system

Introduction & objectives

MONITORING SEA ICE

Sea ice volume is a key variable in sea ice evolution, and it is important for sea ice memory/prediction.

The monovariate/monodata sea ice concentration assimilation systems still struggle to correctly represent sea ice volume.

Multivariate/multidata ice assimilation to control sea ice volume in both the Arctic and Antarctic.

DIRECT RADAR FREEBOARD ASSIMILATION

There are significant uncertainties in sea ice volume observations:

- Radar freeboard measurements uncertainties;
- Uncertainties in the freeboard - ice thickness conversion variables (snow thickness, ice and snow densities).

To control better all sources of uncertainty, assimilation of along-tracks RFB directly.

SNOW OBSERVATIONS ASSIMILATION

Needed especially in Antarctica because the model has significant biases.
Allows to control the conversion RFB-SIT.

Assimilation of altimetric KaKu snow thickness.

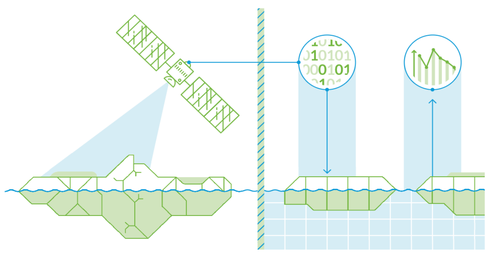
Questions

→ Does the **multivariate/multidata approach** provides added value over the widespread **univariate/unidata method** ? What are the impacts of using altimetric radar freeboard and altimetric snow observations in addition to the SSMIS SIC data?

→ What challenges arise when applying the **same sea ice assimilation scheme to both the Arctic and Antarctic**, given their different physical environments and ice dynamics?

Abbreviations

RFB – Radar freeboard
SIC – Sea ice concentration
SIV – Sea ice volume
SNV – Snow volume
SIT – Sea ice thickness
SNT – Snow thickness



Model configuration

MODEL

- **NEMO4.2/SI3**
- Atm forcing: **ERA5** (1h)
- **Global ¼°** iORCA grid
- 11 ice categories – EVP – Landfast – no melt ponds
- Fixed ice and snow densities (917 kg/m³ ; 330 kg/m³)

ASSIMILATION SYSTEM

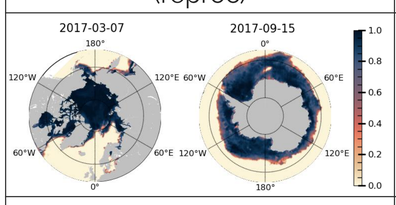
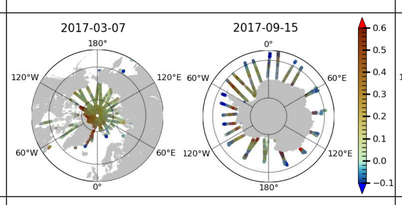
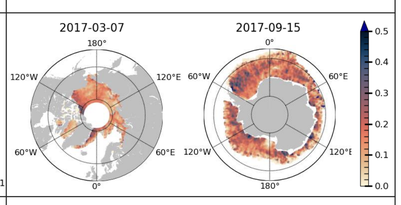
Analysis based on a 2D local multivariate SEEK/LETKF filter. 7-days cycle, 4D increment, IAU (Incremental Analysis Update).
2 separate analyses :

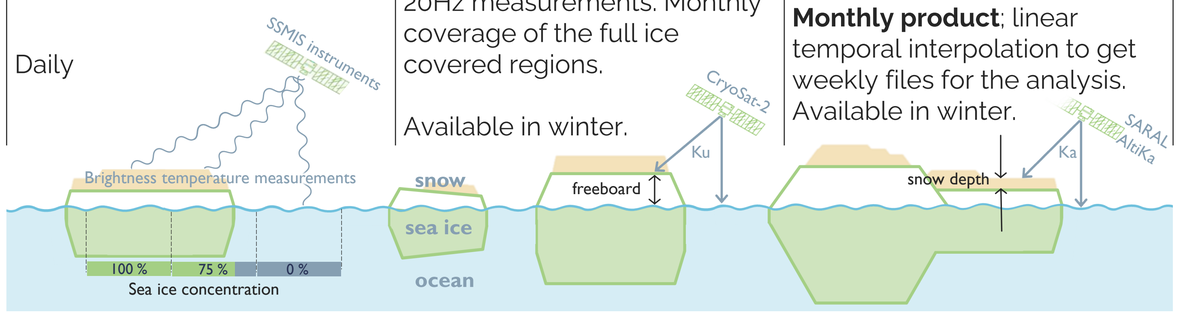
- Ocean Analysis (SLA, InSitu T/S vertical profiles, SST), IAU on (h,T,S,U,V);
- Ice Analysis: **univariate/monodata vs multivariate /multidata.**

Forecast error covariances are built from a prior ensemble of Sea Ice Model anomalies. Anomalies are computed from a 2010-2020 free experiment.

EXPERIMENTS 2 full seasonal cycles 2017-2018.	**FREE** no assimilation	**UNIVAR** univariate/monodata	**MULTIVAR** multivariate/multidata
Observed variable	**assimilated observations**		
SIC	None	SSMIS	SSMIS
RFB	None	None	Altimetric
SNT	None	None	Altimetric
Updated variable	**ICE model update**		
SIC	No update	Increment	Increment
SIV	No update	$SIV_{inc} = h^* \times SIC_{inc}$	Increment
SNV	No update	No update	Increment

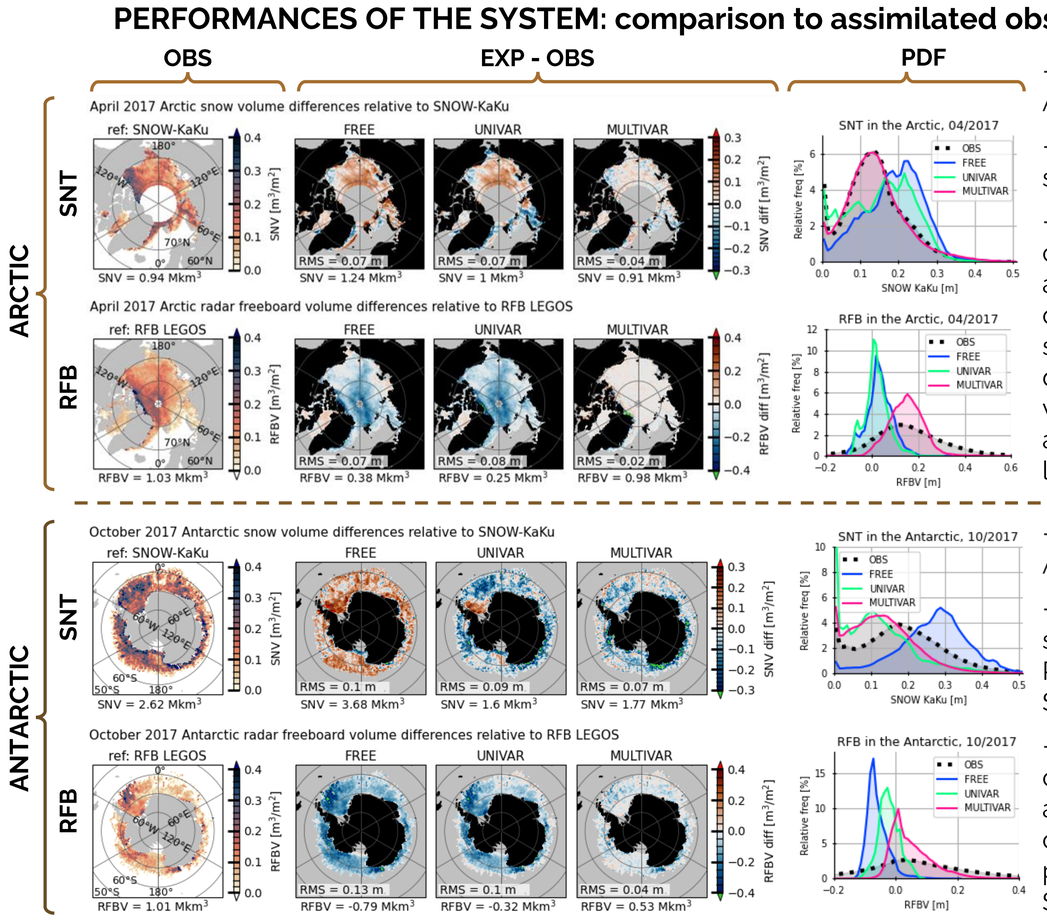
Assimilated observations

SIC EUMETSAT OSISAF OSI-450 (reproc)	**RFB** RFB LEGOS	**SNT** SNOW KaKu LEGOS
		
L4 gridded	Along-tracks	Gridded
SSMIS passive microwave radiometers.	CryoSat-2 satellite, Ku band radar altimetry.	CryoSat-2 & SARAL/AltiKa satellites. **Difference between Ku and Ka** band radar altimetry.
Error: from the product, inflated for a maximum of 25% (40%) in the Arctic (Antarctic).	Error : from the product.	Error : from the product.
Daily	20Hz measurements. Monthly coverage of the full ice covered regions. Available in winter.	**Monthly product**; linear temporal interpolation to get weekly files for the analysis. Available in winter.



Results

PERFORMANCES OF THE SYSTEM: comparison to assimilated observations.



→ End of winter in the Arctic.

→ FREE and UNIVAR : similar biases.

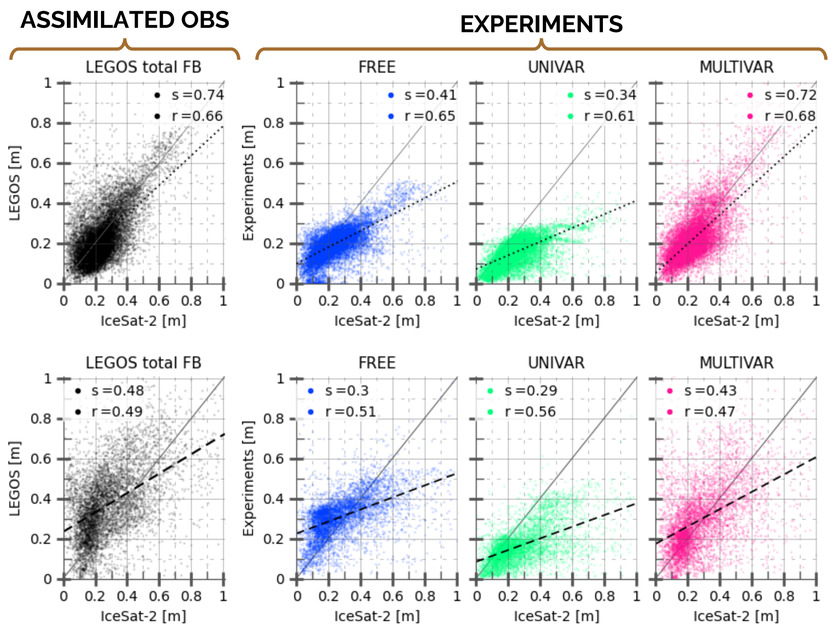
→ MULTIVAR : the closest to the assimilated obs ; orbital hole of the snow obs and RFB data tracks are not visible thanks to the assimilation localization algorithm.

→ End of winter in the Antarctic.

→ FREE and UNIVAR : similar biases for the RFB but not for the SNT.

→ MULTIVAR : the closest to the assimilated obs ; change the spatial pattern of both the SNT and the RFB.

COMPARISON WITH INDEPENDENT DATA: ICESAT2 Total freeboard.



IceSat-2 laser altimetry measurements on the x-axis, and their equivalent for the assimilated obs (LEGOS) and the 3 experiments on the y-axis.

→ Better agreement with all the experiments in the Arctic than in the Antarctic.

→ MULTIVAR : better slopes (s) than FREE and UNIVAR in both hemispheres and higher total freeboard values.
→ MULTIVAR : higher r-value (r) than the other experiments in the Arctic.
→ MULTIVAR : points more dispersed → lower r-value in the Antarctic, in accordance with the shape of the assimilated LEGOS data.

Conclusions

The multivariate/multidata sea ice assimilation system :
✓ performs well
✓ brings the modelled ice cover, its volume and the snow distribution **towards the assimilated observations**.

The RFB and snow assimilation :
✓ increases the ice volume and reduces the presence of snow **in the Arctic and Antarctic**.
✓ enables the system to approach the Icesat-2 total freeboard estimation.

✗ However, the multivariate systems is **less performant in the Antarctic** than in the Arctic.

Perspectives

→ Implementing **varying densities for the ice and snow** in the model.
→ CIMR & CRISTAL Copernicus Sentinel missions satellites.

Authors: Aliette Chenal [1,2], Gilles Garric [1], Charles-Emmanuel Testut [1], Mathieu Hamon [1], Giovanni Ruggiero [1], Pierre-Yves Le Traon [1,3].

Correspondance to: achenal@mercator-ocean.fr

[1] Mercator Ocean International, Toulouse, France ; [2] CNES, Toulouse, France ; [3] Ifremer, Plouzané, France.

Ocean Predict — In partnership with unesco Intergovernmental Oceanographic Commission — 2021 2030 United Nations Decade of Ocean Science for Sustainable Development — MERCATOR OCEAN INTERNATIONAL — cnes CENTRE NATIONAL D'ÉTUDES SPATIALES