

The potential of numerical models to support the design of observing systems

The Arctic as a case study

François Massonnet

with thanks to Irina Sandu, Thomas Jung and APPLICATE contributors

Second international operational satellite oceanography symposium (OSOS2)

25-27 May 2021, online



APPLICATE in a nutshell

APPLICATE.eu
Advanced prediction in
polar regions and beyond

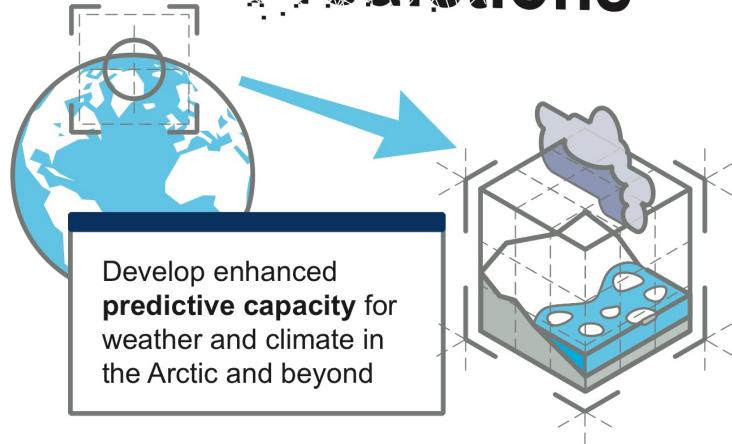
Advanced Prediction in Polar regions and beyond:
modelling, observing system design and Linkages
associated with a Changing Arctic climaTE

Horizon 2020 EU project
15 partners from 8 countries
8 million EUR
Coordinator T. Jung

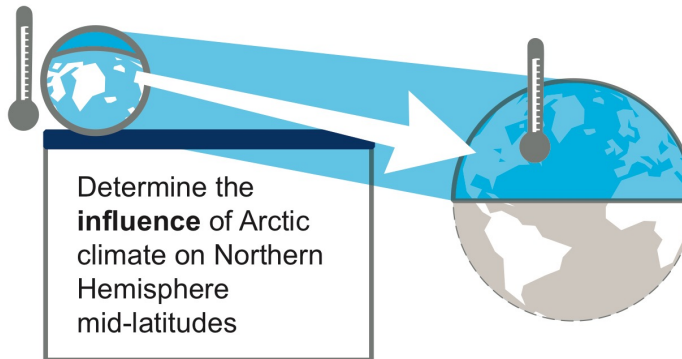
2016-2021 (finished)
www.applycate-h2020.eu

MISSION

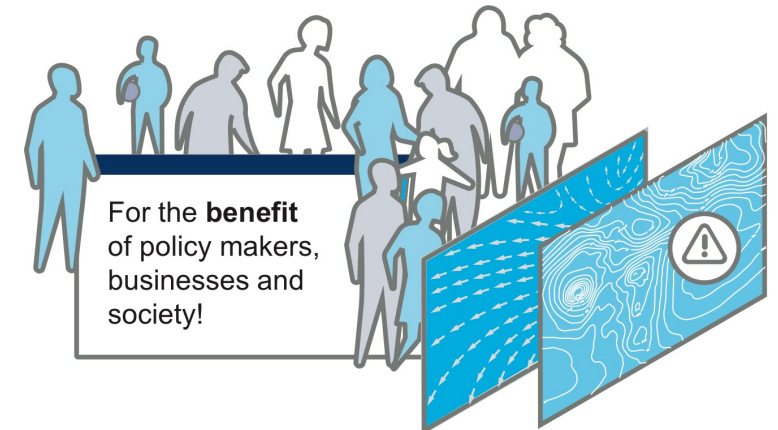
Predictions



Remote influence



Benefits



Observational challenges in the Arctic

The nature of the problem

- The Arctic is **data-sparse** in conventional observations but **data-rich** in satellite observations
- A lot of observations are either not used, underused, or misused in current numerical prediction systems (NPS; including NWP and climate models)
- Polar prediction skill is limited in NPS

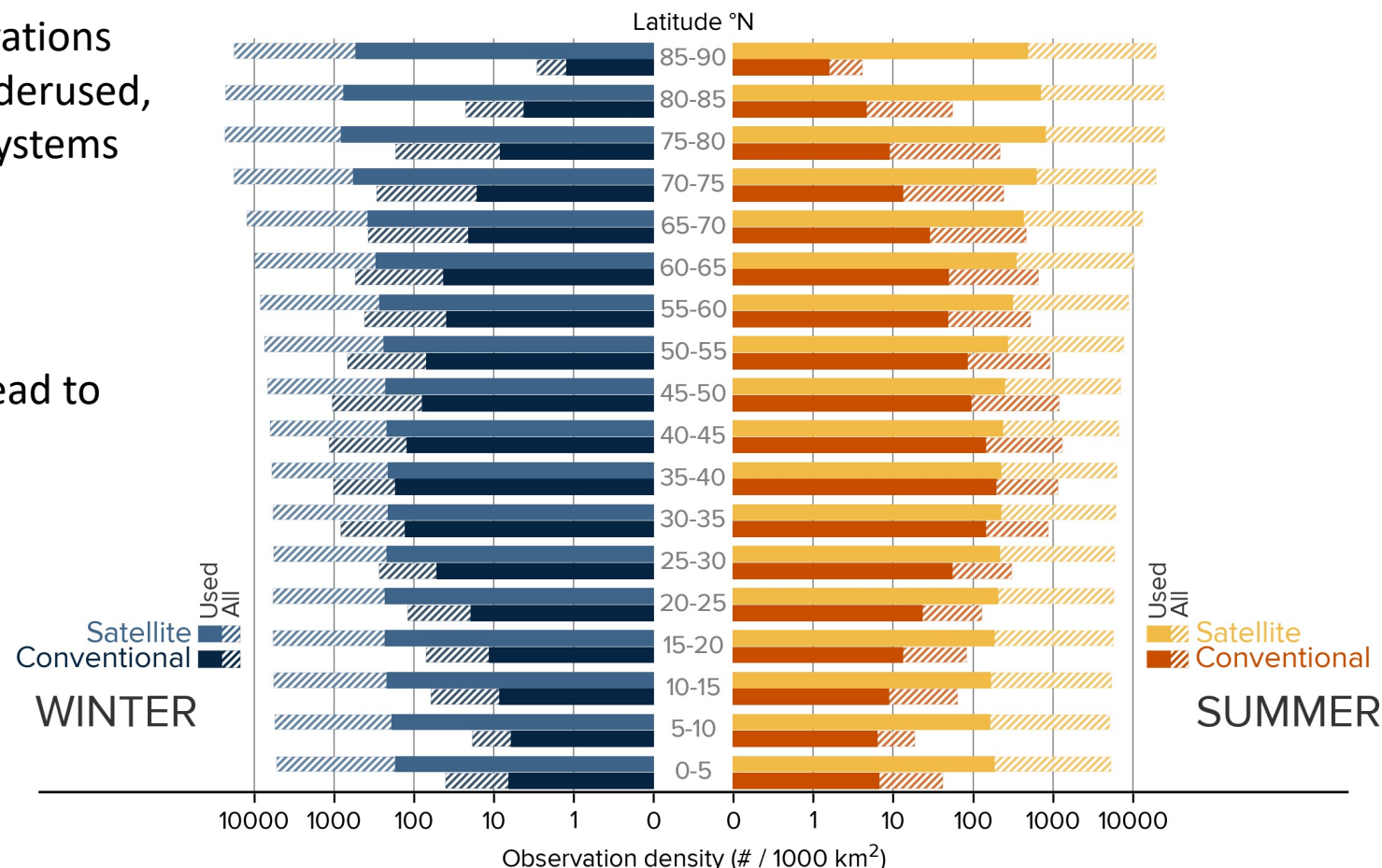
Hypotheses

- Better uptake of observations in NPS could lead to increased predictive skill
- In turn, use of NPS could inform on optimal observing system usage and design

Objectives

Derive recommendations for the design of the future observing systems in the Arctic

Number of observations available and assimilated in the ECMWF forecasting system (2019)



Progress, achievements and Key Exploitable Results

WP 4

PROSPECTS FOR IMPROVED WEATHER FORECASTS

The Arctic is sparse in terms of conventional observations but very rich in terms of satellite observations, thanks to the short return time of low Earth orbit satellites. **APPLICATE** has demonstrated that weather forecast skill in the Arctic and beyond can be further improved by **making better use of existing microwave sounding observations**, particularly over snow and sea ice, and by **maintaining existing conventional networks**.

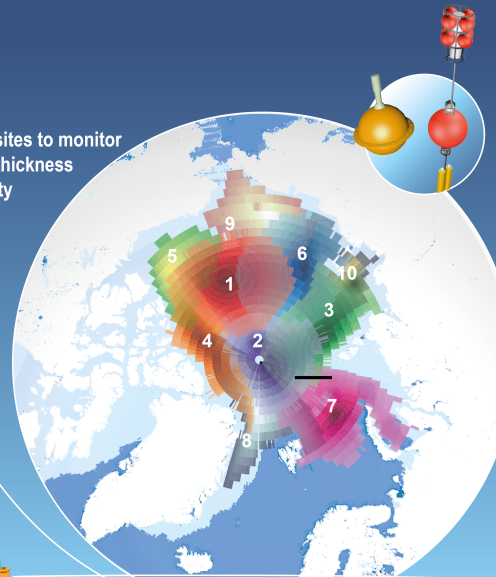
Polar flybys of
AMSU during
24 hours



IN-SITU MONITORING OF SEA ICE VOLUME CHANGES

Using state-of-the-art Earth System Models and reanalyses, **APPLICATE** has identified cost-effective **in-situ sampling strategies** based on a minimal number of sampling sites, taking advantage of the large-scale coherency of variables like sea ice thickness.

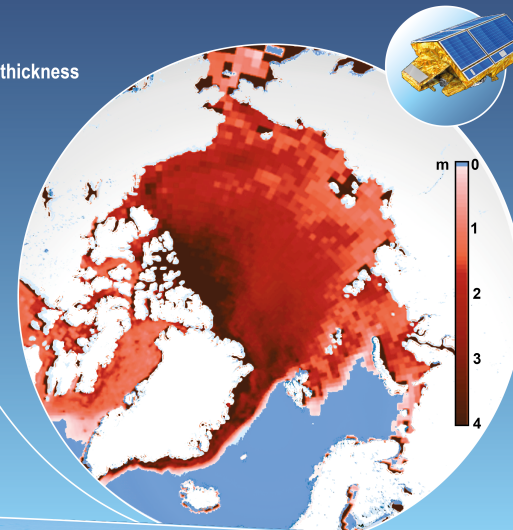
Top-10 sites to monitor
sea ice thickness
variability



PROSPECTS FOR IMPROVED SEASONAL PREDICTIONS

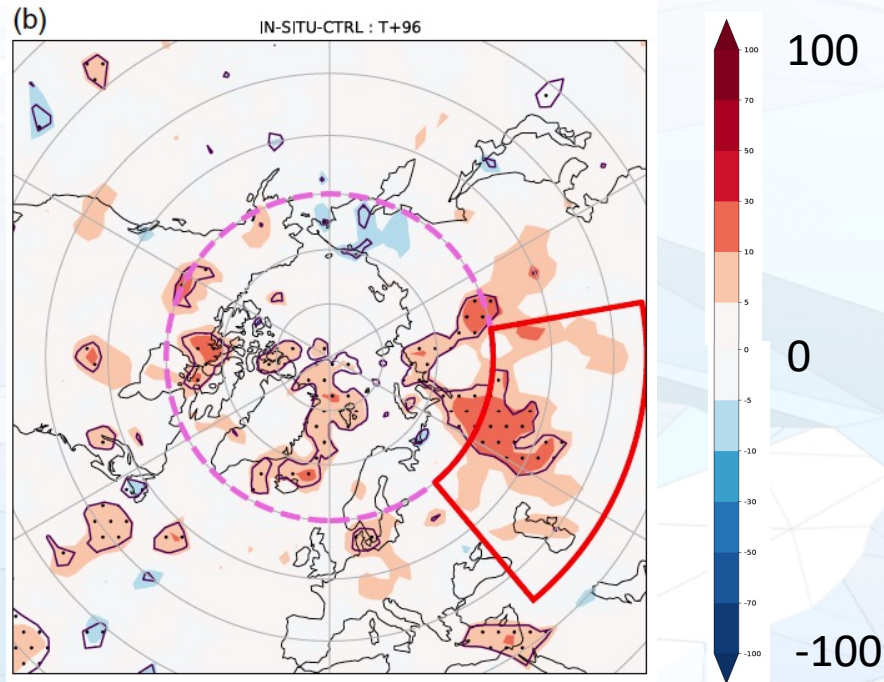
Monitoring sea ice thickness is crucial for advancing seasonal predictions and climate change projections. **APPLICATE** has reported significant improvements in seasonal sea ice prediction skill thanks to the assimilation of satellite sea ice thickness and sea ice freeboard in fully coupled prediction systems.

Sea ice thickness

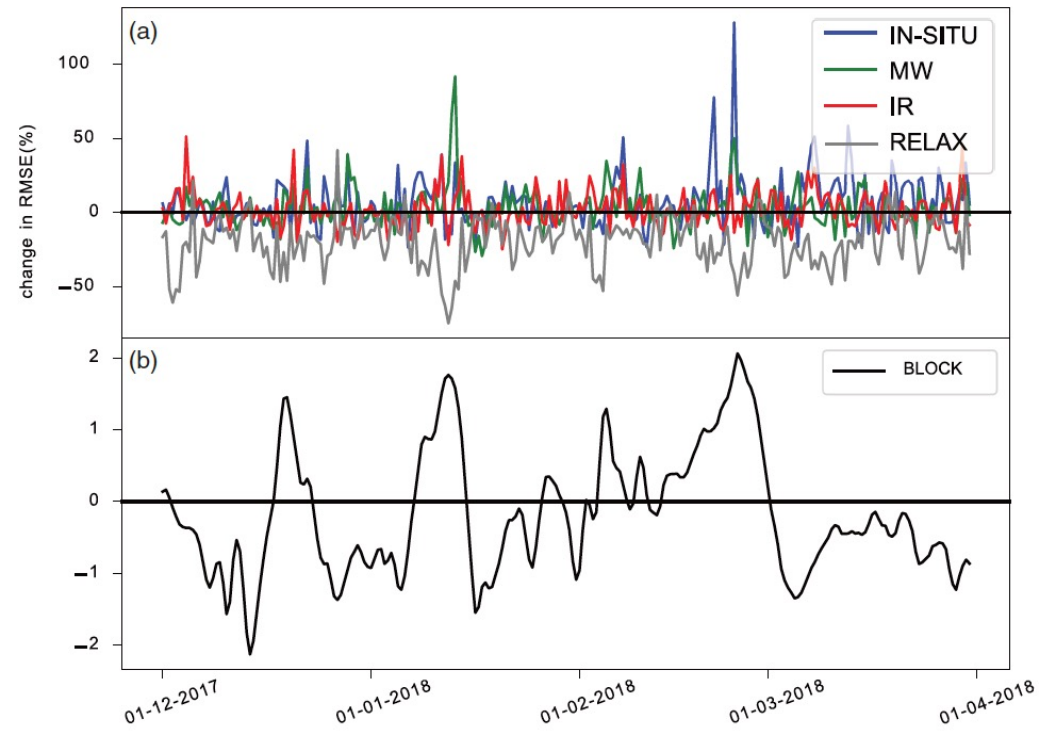


Importance of Arctic observations for mid-latitude weather prediction

Relative increase in RMSE of Z500 forecast at 96 hours,
after denying in-situ observations in the ECMWF forecast
system from the data assimilation



Dependency on the strength of the Scandinavian blocking



Day, J. J., Sandu, I., Magnusson, L., Rodwell, M. J., Lawrence, H., Bormann, N., & Jung, T. (2019). Increased Arctic influence on the midlatitude flow during Scandinavian Blocking episodes. *Quarterly Journal of the Royal Meteorological Society*, 145(725), 3846–3862.

<https://doi.org/10.1002/qj.3673>

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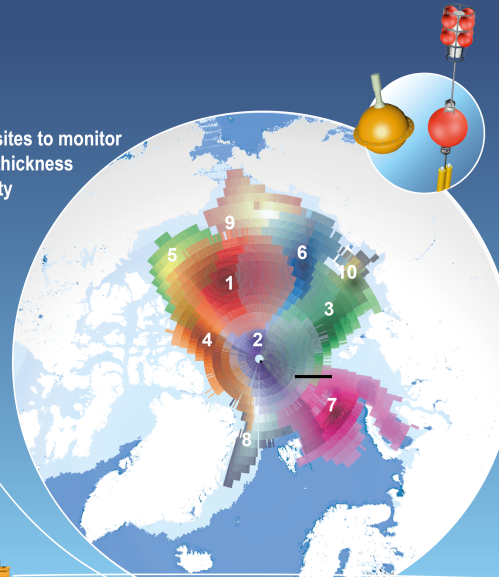


An enhanced use of microwave sounding observations would further improve weather forecasts in the Arctic, and sometimes, even beyond

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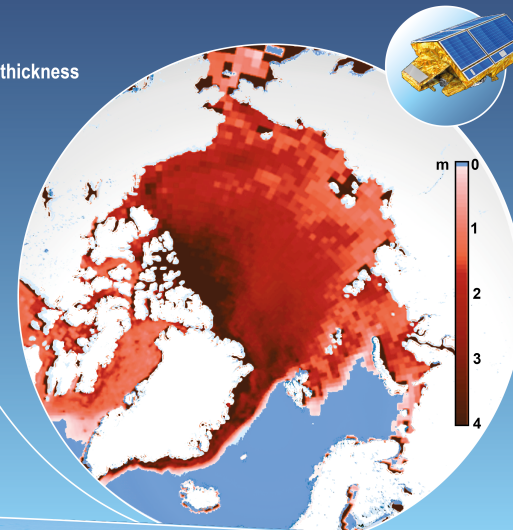
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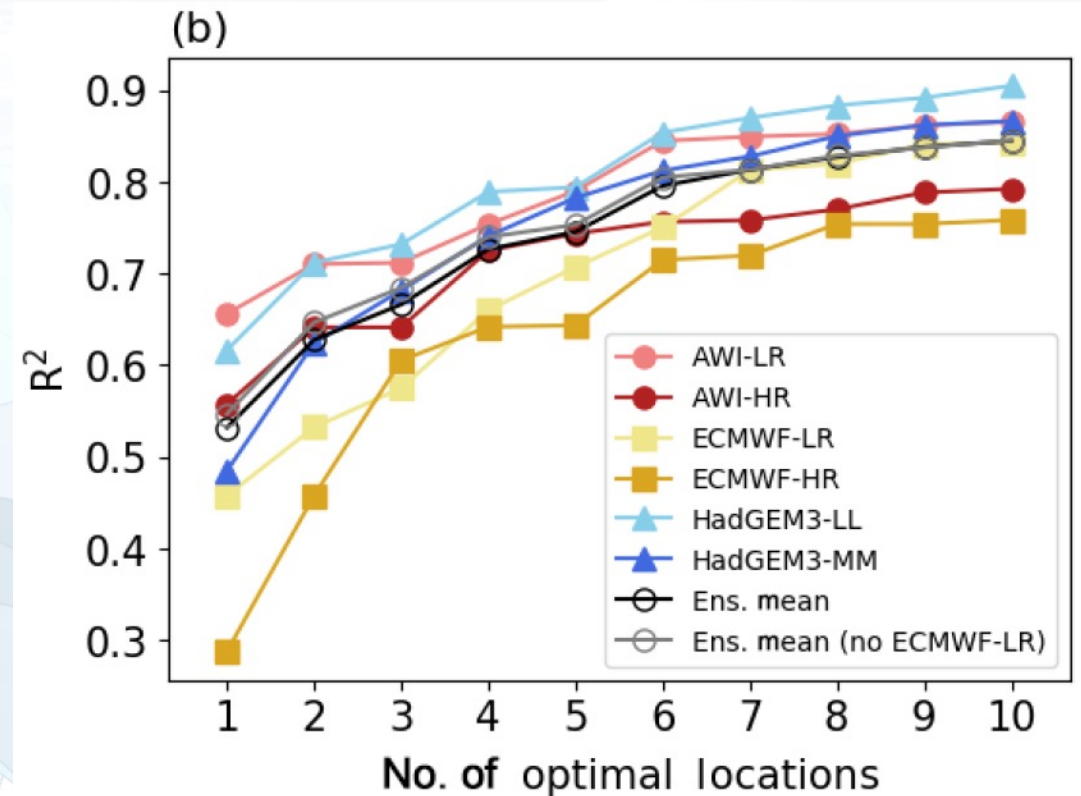
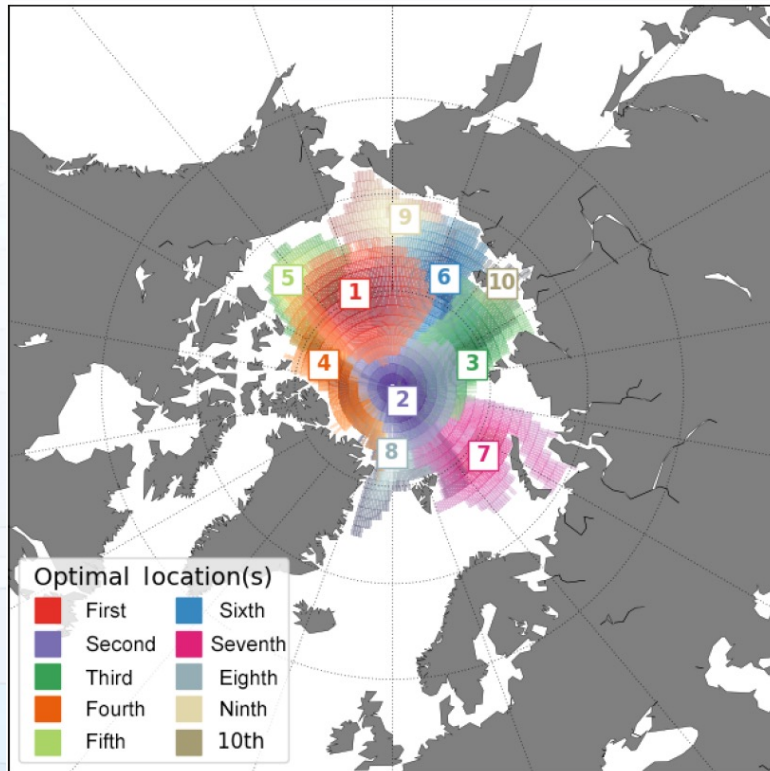
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Sea ice thickness



The knowledge of sea ice thickness at a handful of discrete locations can reconstruct sea ice volume anomalies (according to numerical models)



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Polar flybys of AMSU during 24 hours



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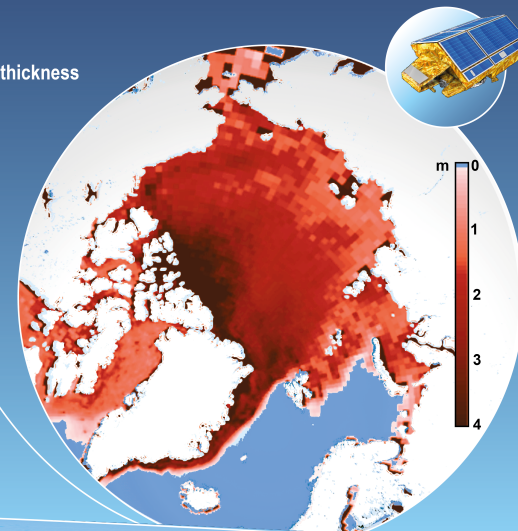
Top-10 sites to monitor sea ice thickness variability



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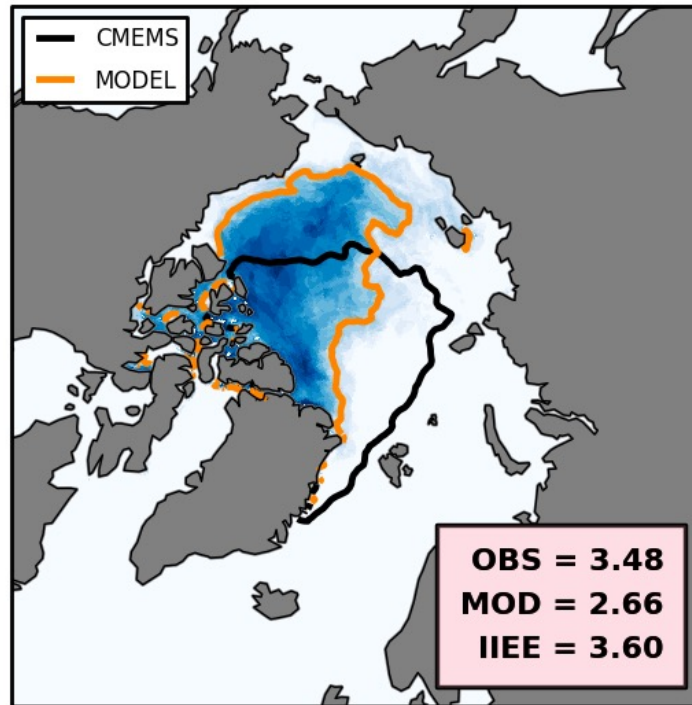
Arctic sea ice volume variability can be reconstructed and monitored from in-situ sea ice thickness measurements at strategic sampling sites



Positive impact of assimilating observed sea ice thickness on seasonal sea ice predictions

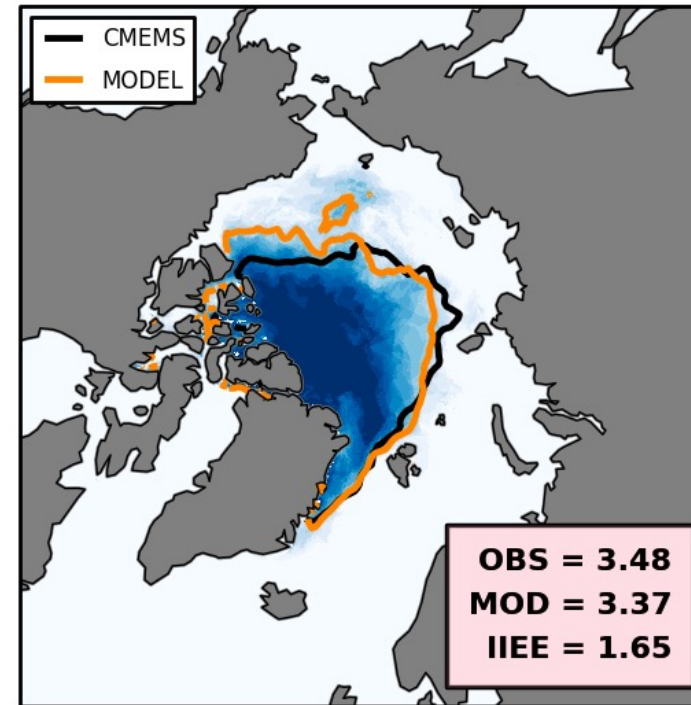
No sea ice thickness
assimilation

2012 - CTRL-HC



Sea ice thickness assimilated to
initialize seasonal predictions

2012 - ThkDA-HC



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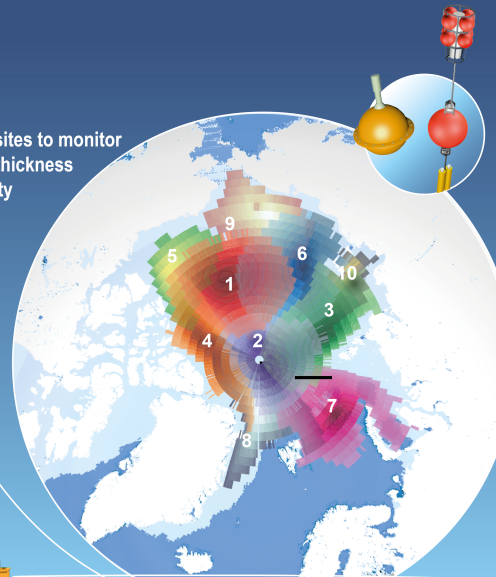
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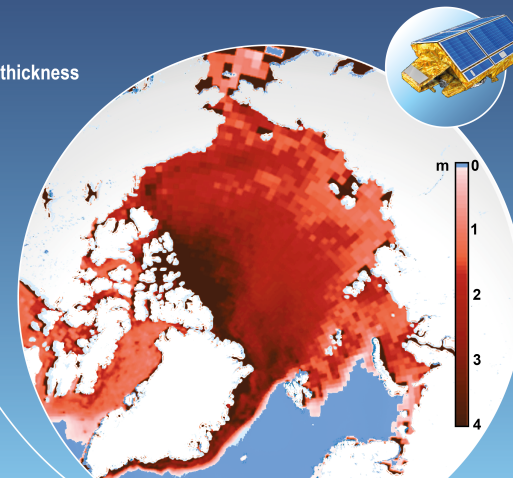
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Sea ice thickness



Assimilation of sea ice thickness
(in addition to concentration
and ocean information) leads to
significant increases in seasonal
prediction skill



Key recommendations

Concrete recommendations for the future of Arctic observing system

The potential of numerical prediction systems to support the design of observing systems: the Arctic as a case study

Abstract

Over the past decades, numerical weather prediction systems and climate models have benefited from steady advances in fundamental science and from the considerable development of supercomputing technologies. Overall, these investments have resulted in an improved predictive capacity. Here, we argue that the weather prediction systems and climate models have reached a sufficient level of maturity to examine and even question the suitability Earth's current observing system (remote and in-situ). We also propose the idea that numerical prediction systems represent one of our best chances to provide evidence-based support for the deployment of future observational networks. We illustrate our point for the Arctic – one of the world's most rapidly changing regions, which is characterised by a relatively poor coverage in terms of in-situ data but a relatively rich coverage in terms of satellite data. By reviewing recent coordinated international efforts, we demonstrate that targeted sensitivity experiments conducted with numerical models can inform on the added value of existing or even hypothetical observations, in the context of predictions from hourly to interannual time scales. These experiments can also inform on how the uptake of observations in prediction systems can be enhanced. We suggest, for instance, an increased importance of conventional in-situ observations in the Arctic for initialising numerical weather forecasts during the winter season. Moreover, we find that enhancing the uptake of observations from microwave sounders over snow and sea ice would lead to improved weather predictions in Arctic regions and beyond. Guided by the analysis of numerical climate model output, we finally suggest that deploying a small number of in-situ sea-ice thickness monitoring devices at strategic sampling sites in the Arctic could be sufficient to monitor most of the large-scale sea-ice volume variability. Adopting a model-based perspective on the design of observing systems is urgently required to ensure that the data that will be collected in future observational campaigns or through enhanced observing systems will be used optimally in future numerical prediction systems, and hence will result in maximised predictive skill.

Sandu, Massonnet et al., in prep.

Ensure continuity in sea ice thickness and concentration satellite products throughout the 2020s

Deliver satellites products at different levels of processing (L1-L4). State uncertainties.

Provide back-extensions of satellite sea ice thickness

Sample sea ice thickness at selected locations

Enhance the use of microwave sounding observations; maintain and extend the conventional network

Improve spatial coverage of snow-on-land observations



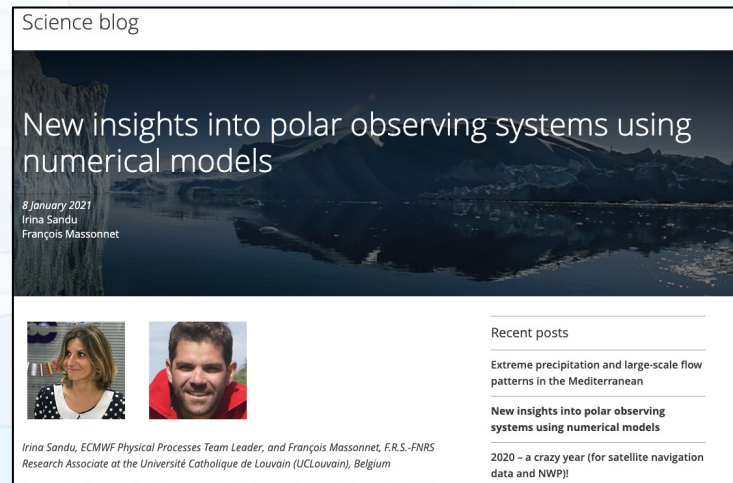
Take-home messages

- ✦ The future of the Arctic observing system is not necessarily about observing **more** facets of the Arctic, but instead:
 - (1) Making **better and smarter** use of **existing** observational resources
 - (2) Ensuring that the current network is **sustainable**, to avoid critical data gaps that would be highly detrimental to polar prediction skill
 - (3) Ensuring that available observations meet **usability and timeliness requirements** of NPS (hours for NWP, days for climate predictions)
- ✦ Investment in observing systems must be carried out **synergistically** with the investment in all components of numerical prediction systems (modelling, data assimilation, ensemble techniques and use of observations)



Thank you

<https://applicate-h2020.eu/>



<https://www.ecmwf.int/en/about/media-centre/science-blog/2021/new-insights-polar-observing-systems-using-numerical-models>



[https://rmets.onlinelibrary.wiley.com/doi/toc/10.1002/\(ISSN\)1477-870X.observing-system-experiments-in-the-arctic-region](https://rmets.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1477-870X.observing-system-experiments-in-the-arctic-region)

