End-to-end forecast of the Arctic sea ice initialized directly from observations

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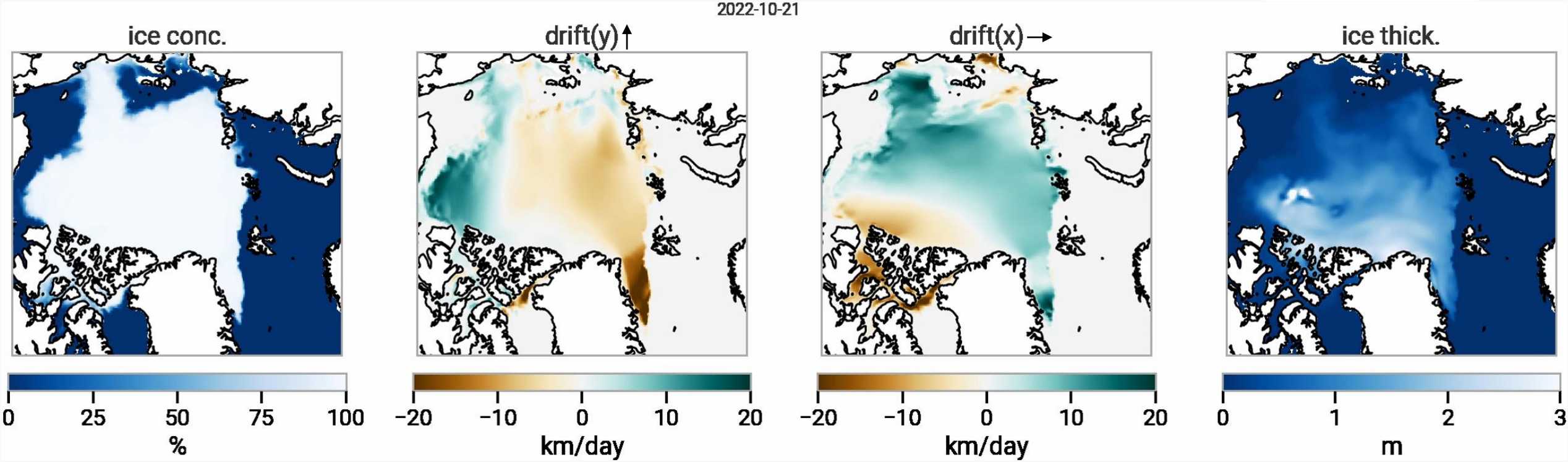
This work has been carried out as part of the Copernicus Marine Service **IceCastNet** project. Copernicus Marine Service is implemented by Mercator Ocean in the framework of a delegation agreement with the European Union.

Current sea ice forecast

Sea ice forecast are produced operationally by **physical-based models.**
Ex: the **TOPAZ system** (available on Copernicus marine) delivers every day forecast **up to 10 days**



Instrumental for navigation in the Arctic, search-and-rescue, oil spill contingency planning: **~5000 Monthly downloads…**

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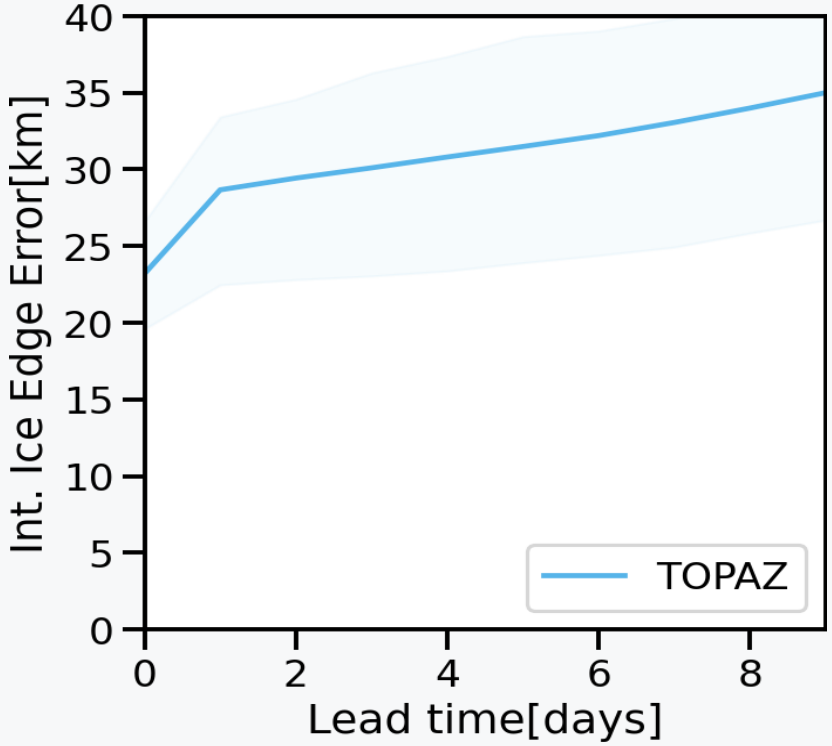
Limitations of current physical-based sea ice forecast

1 Biased forecast

Error in positioning the ice edge



Comparison versus observations
(average 2022-2023)

2 Computational efficiency

Computation time:

12 h over 100 GPU (ocean + sea ice)

~1h30 for the sea ice only

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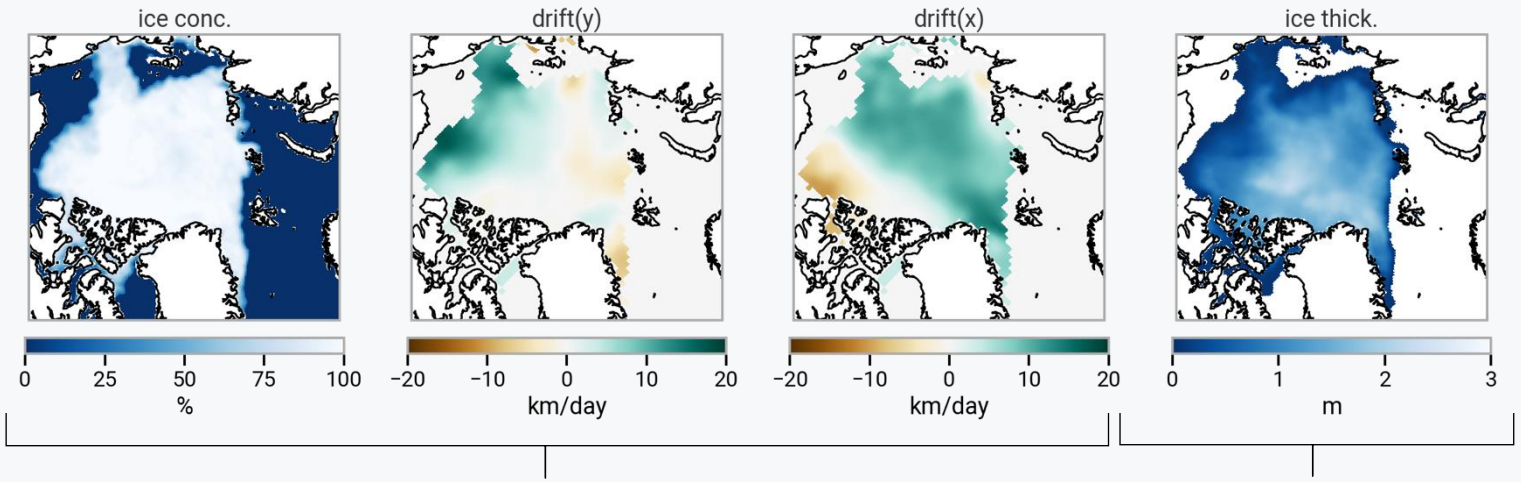
Explore the use of machine learning: IceCastNet

1 ~~Biased forecast~~

Unbiased forecast

Training based on satellite observations



From Passive Microwave satellites

From
Cryosat 2+SMOS in winter
TOPAZ Reanalysis in summer

Example from October 20, 2022

2 ~~Computational efficiency~~

~1h30 on multiple GPU

Efficient Model
Graph Transformer
~10 sec on one GPU

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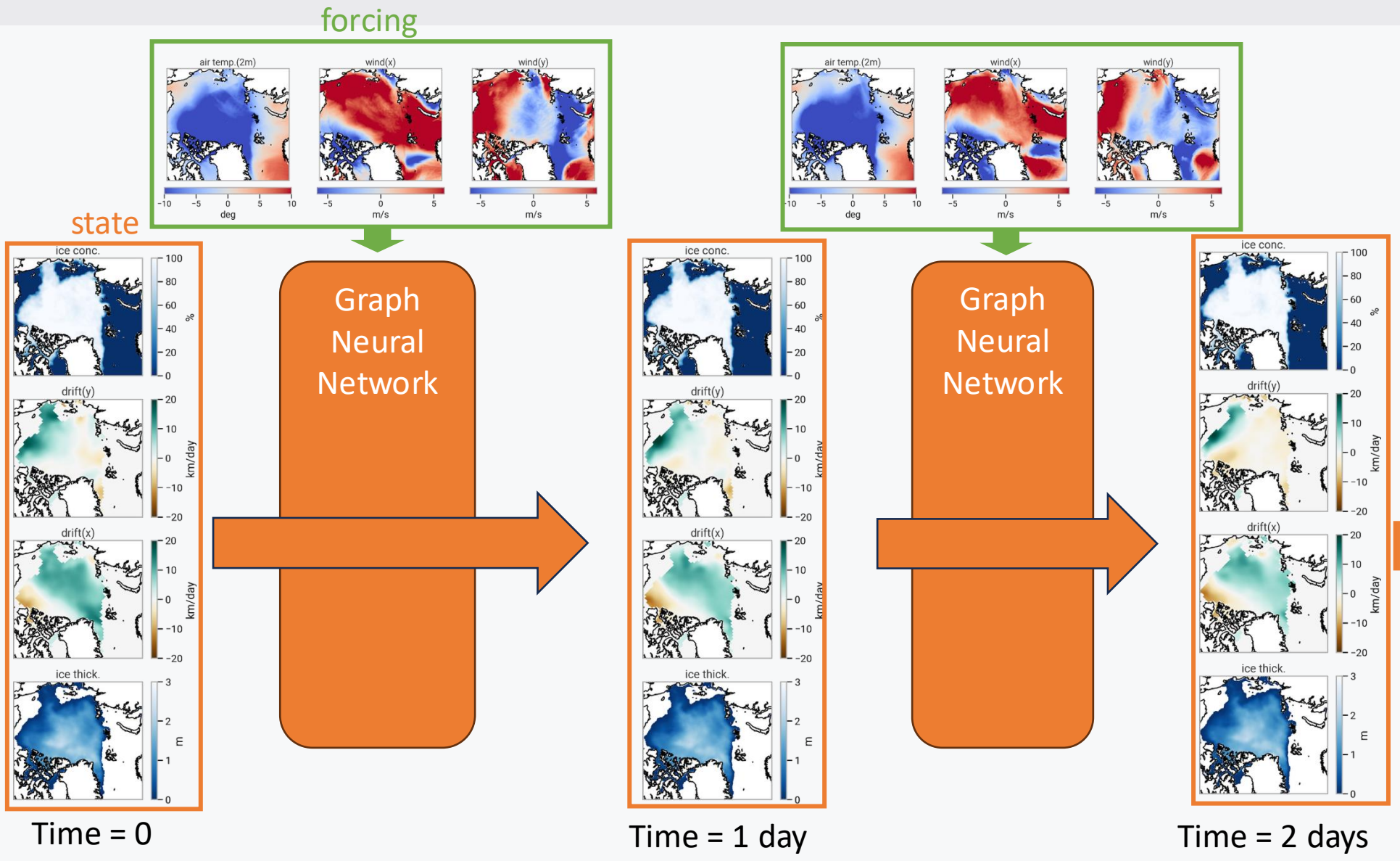
Scheme of the method



Training: **2018-2022**
Evaluation: **2022-2023**

Size of the model:
~87.5 millions parameters

Framework used:
anemoi

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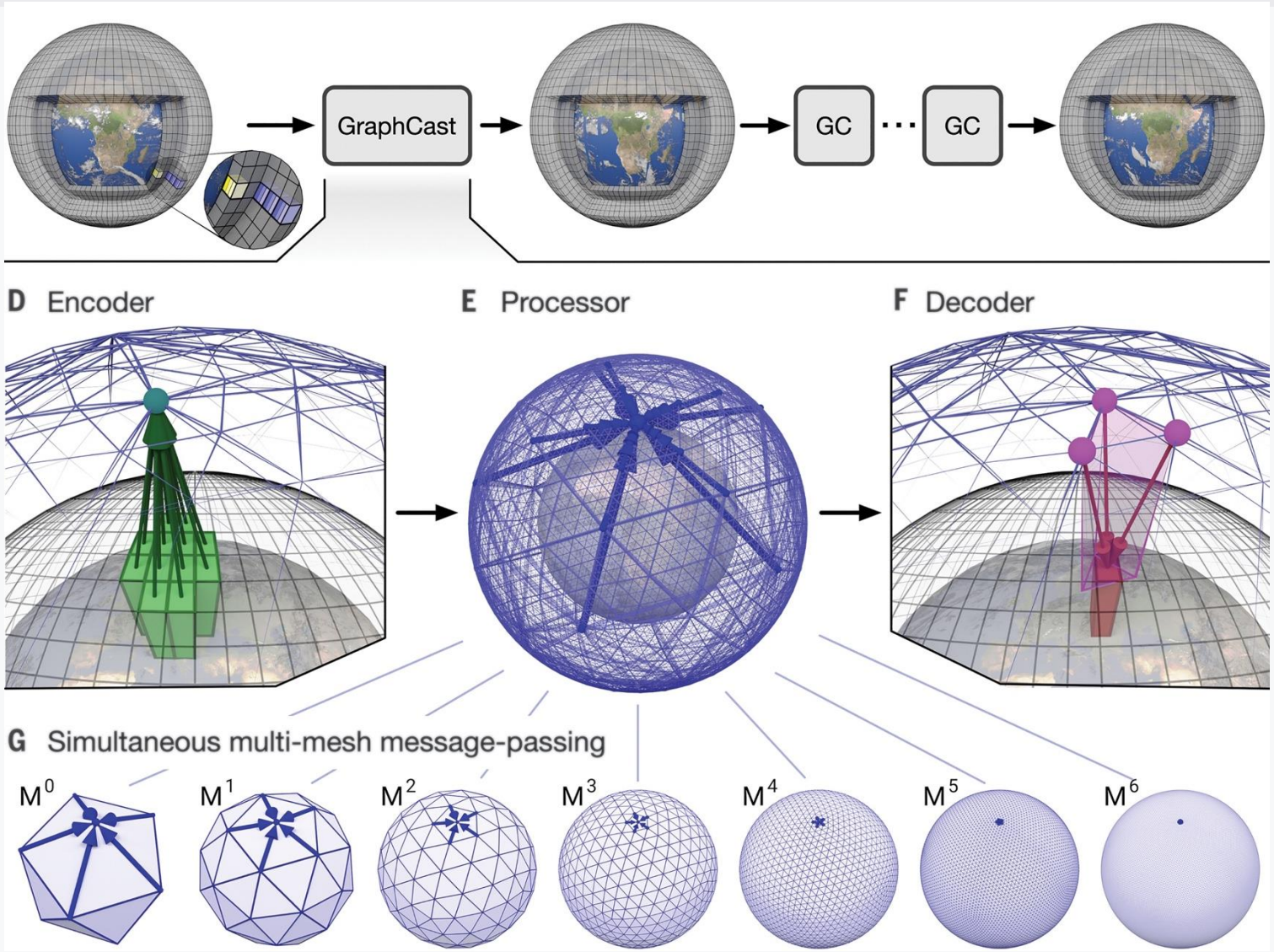
Model architecture

From Lam et al. 2023



Similar approach as Graphcast:
Restricted to the Arctic region
Encoder: 0.6 cutoff
Processor: M7 multimesh
Decoder: 3 Nearest neighbours

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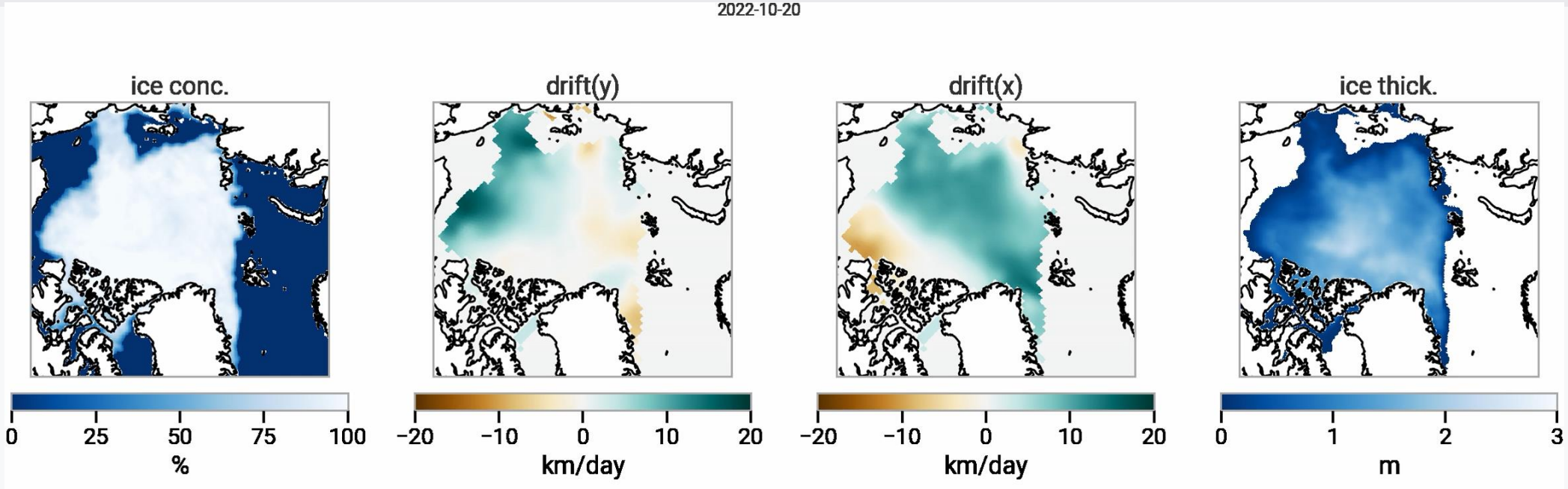
One result

IceCastNet forecast



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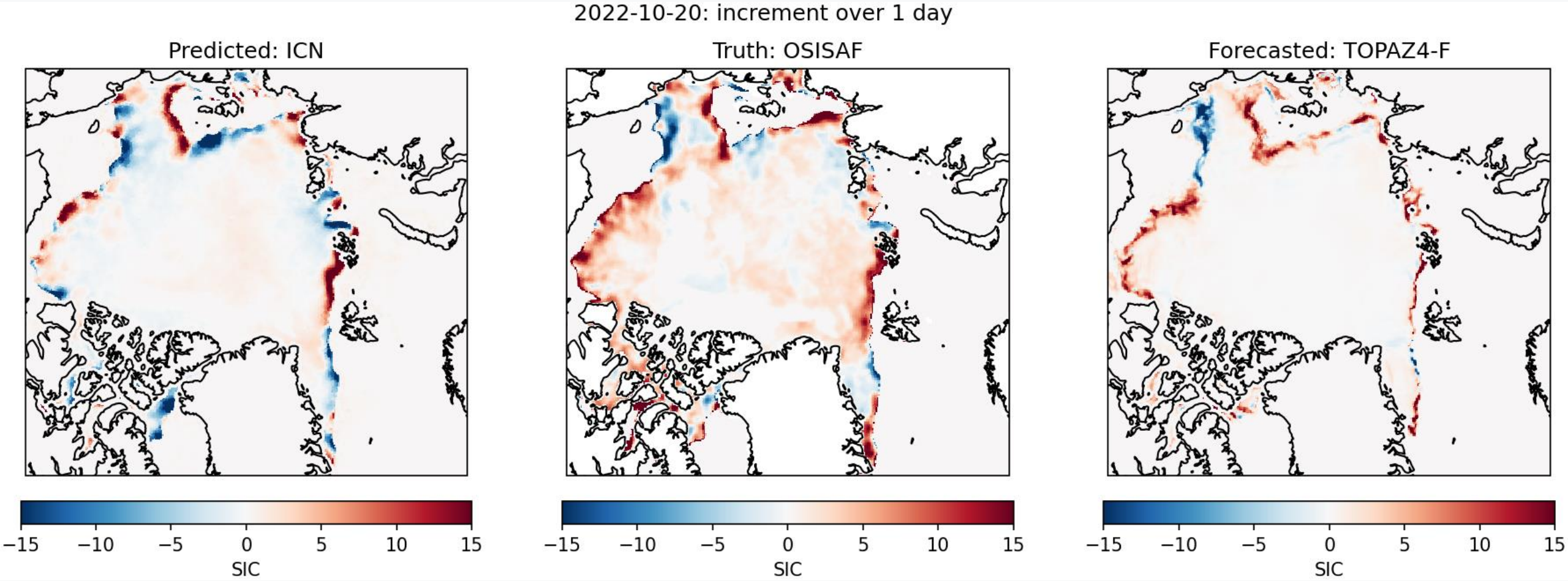
Comparison with TOPAZ (Sea Ice concentration)



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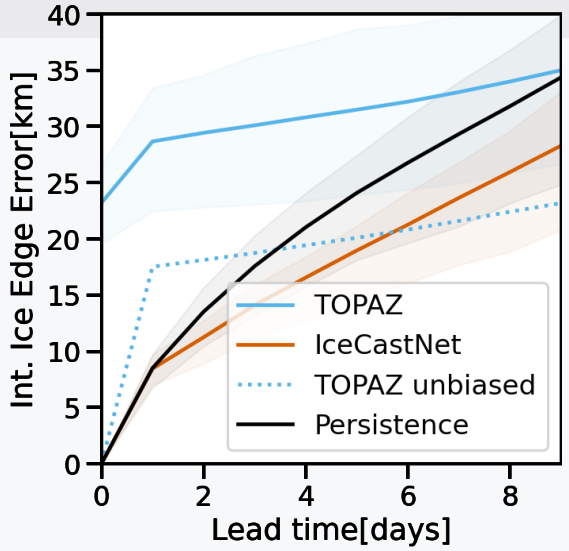
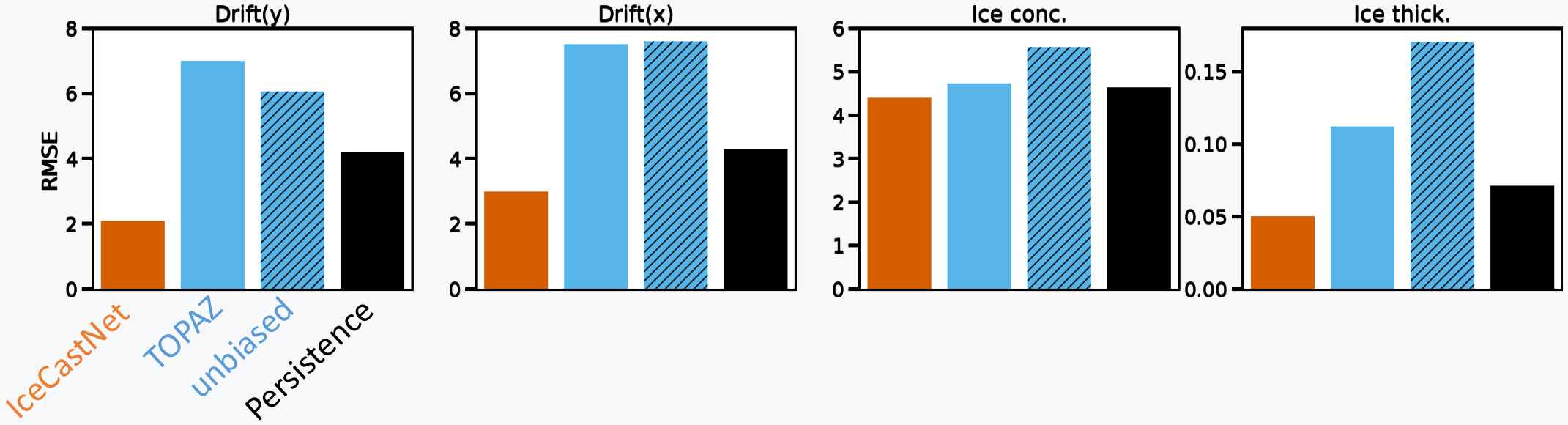
Validation with observational product (average over 2022-2023)

Error in positioning the ice edge



Error at Lead time: 9 days



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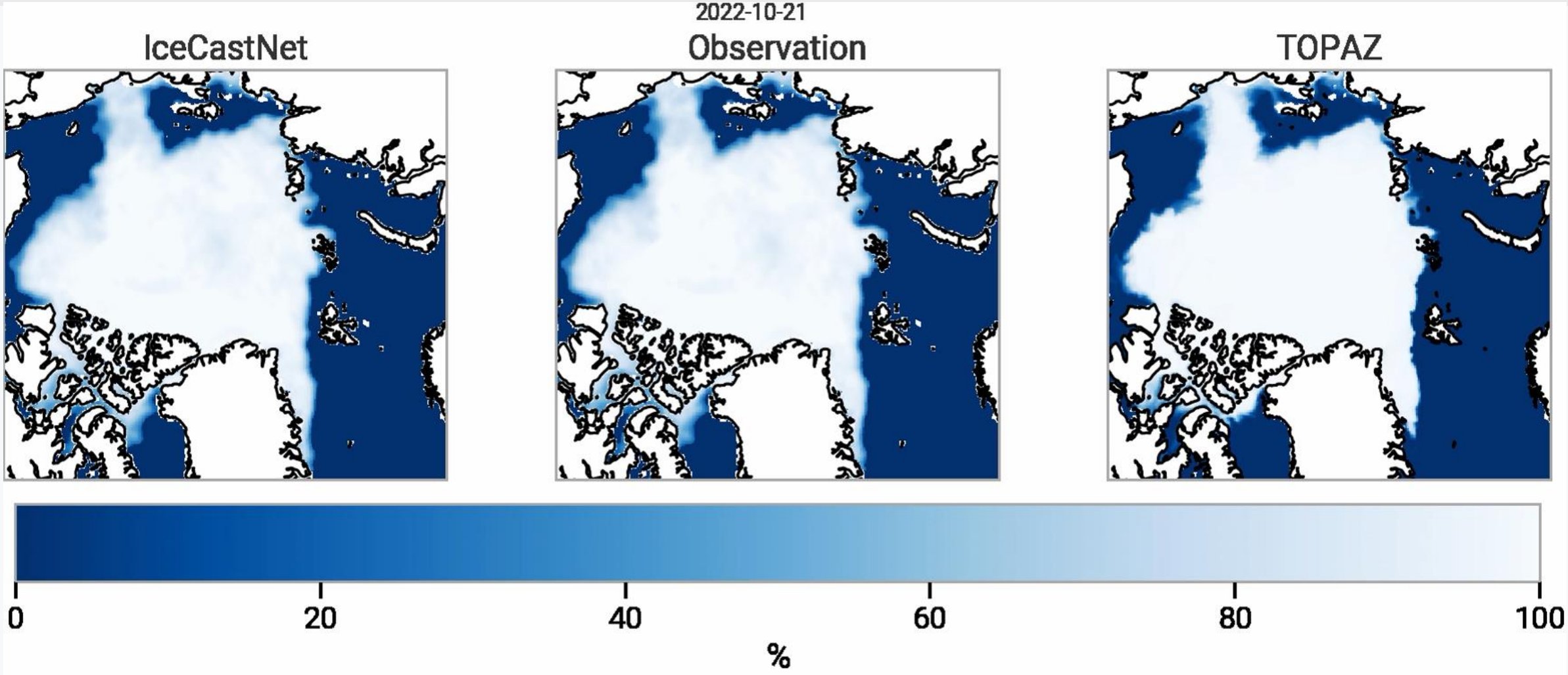
Comparison of sea ice concentration prediction



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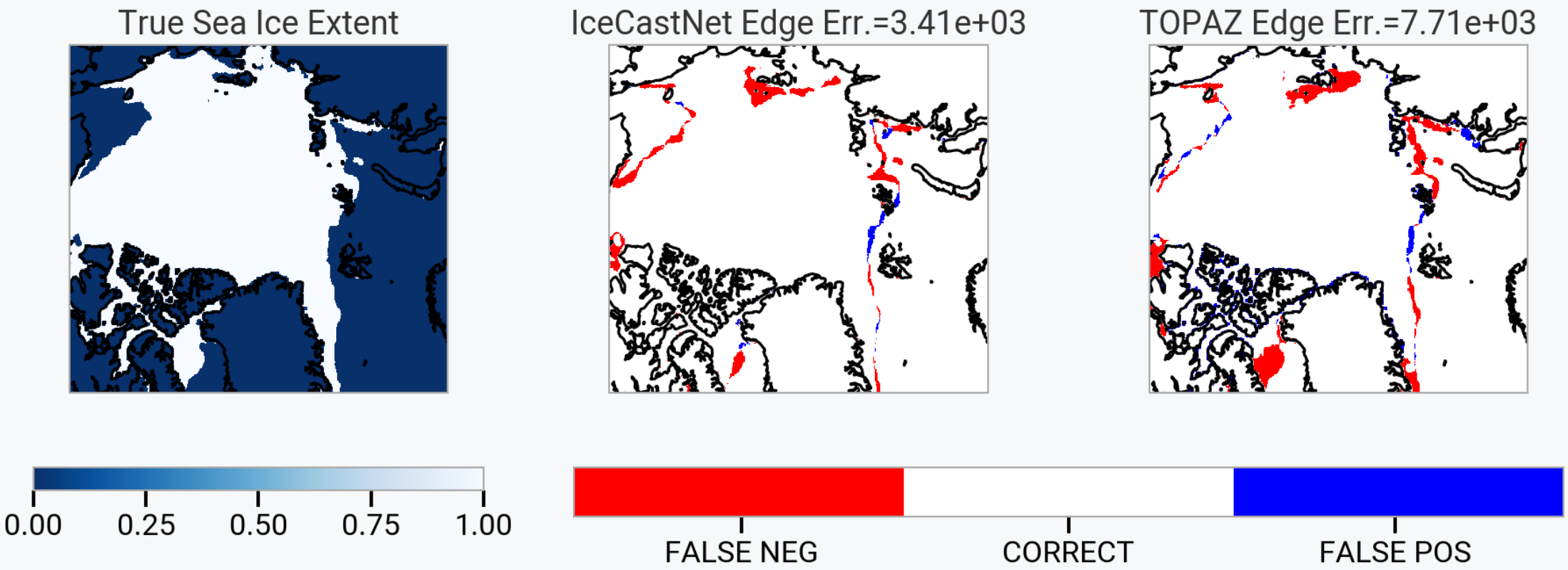
Sea Ice Extent



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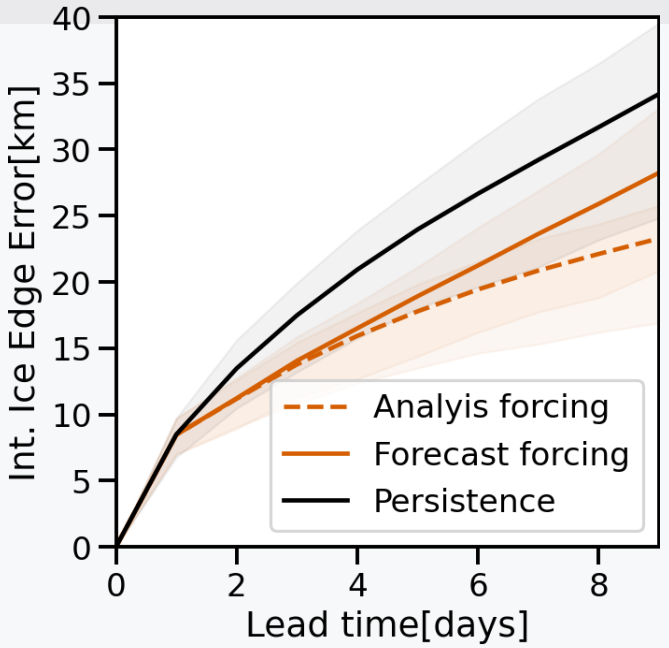
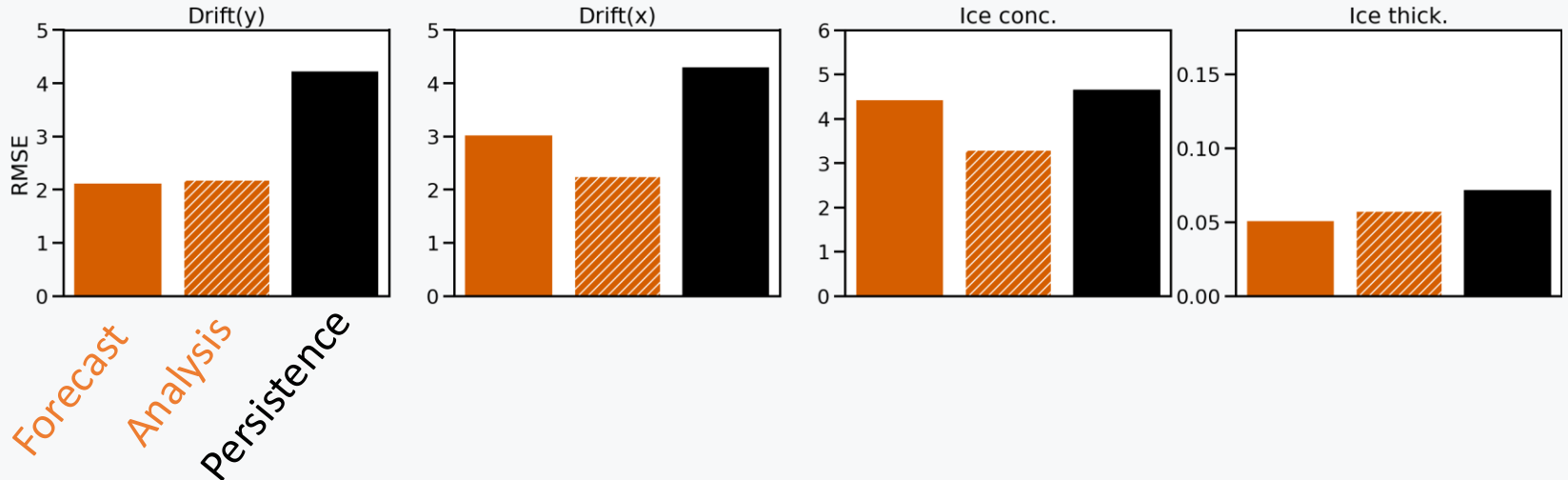
Meterological forecast Vs Meteorological analysis





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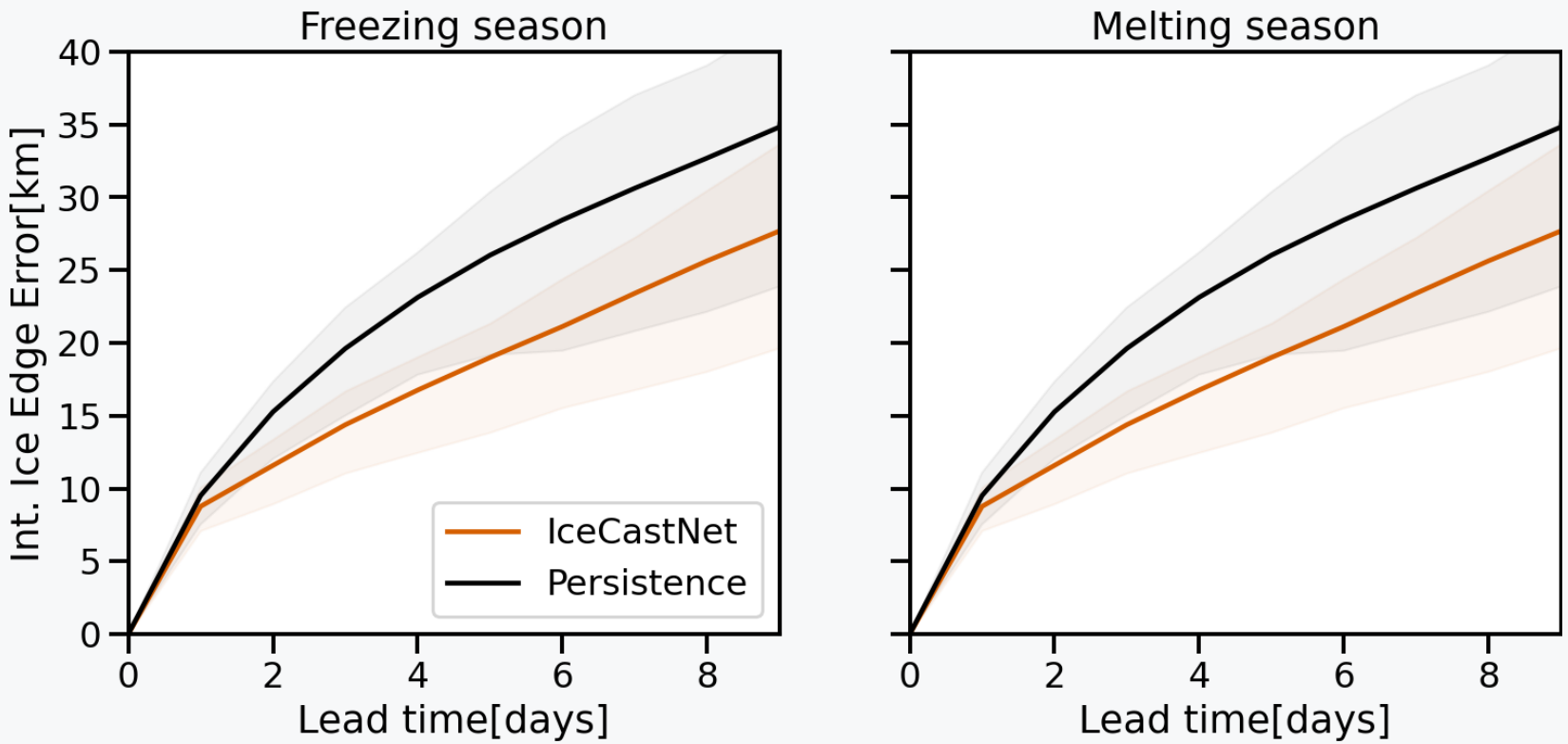
Different seasons?



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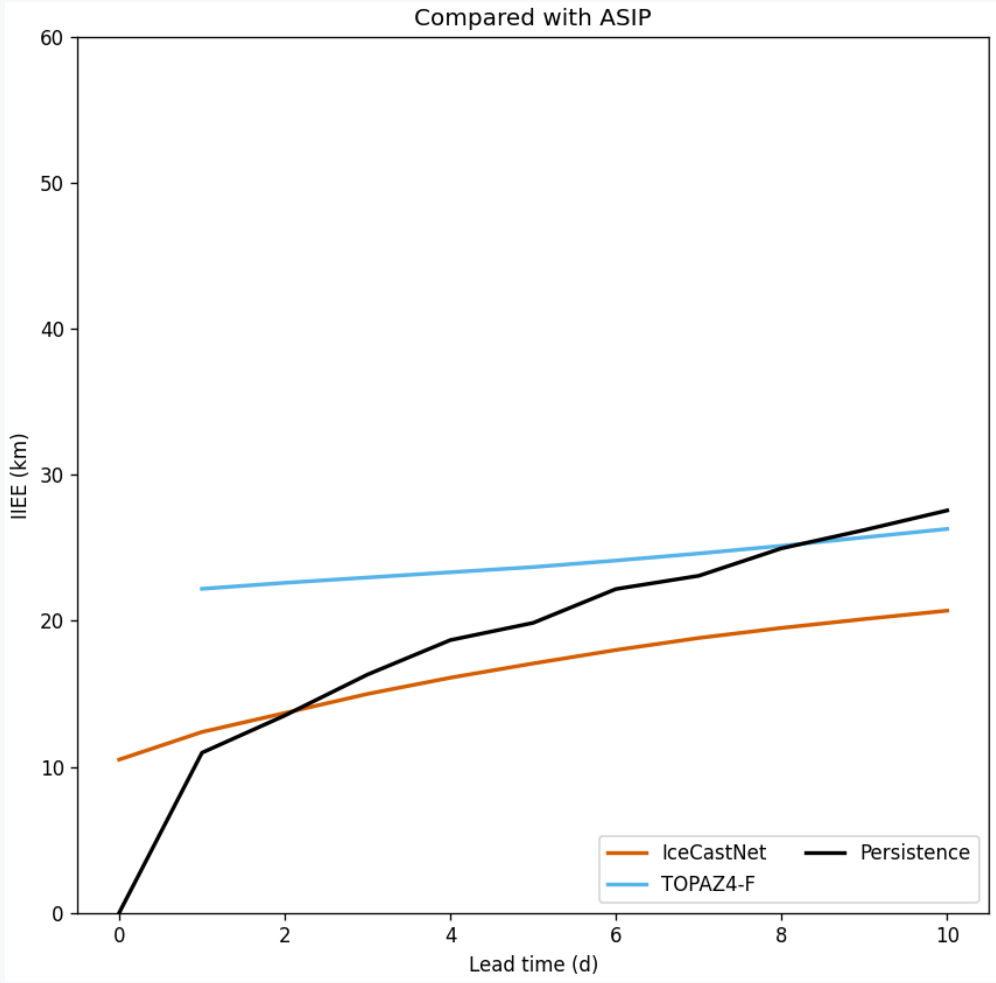
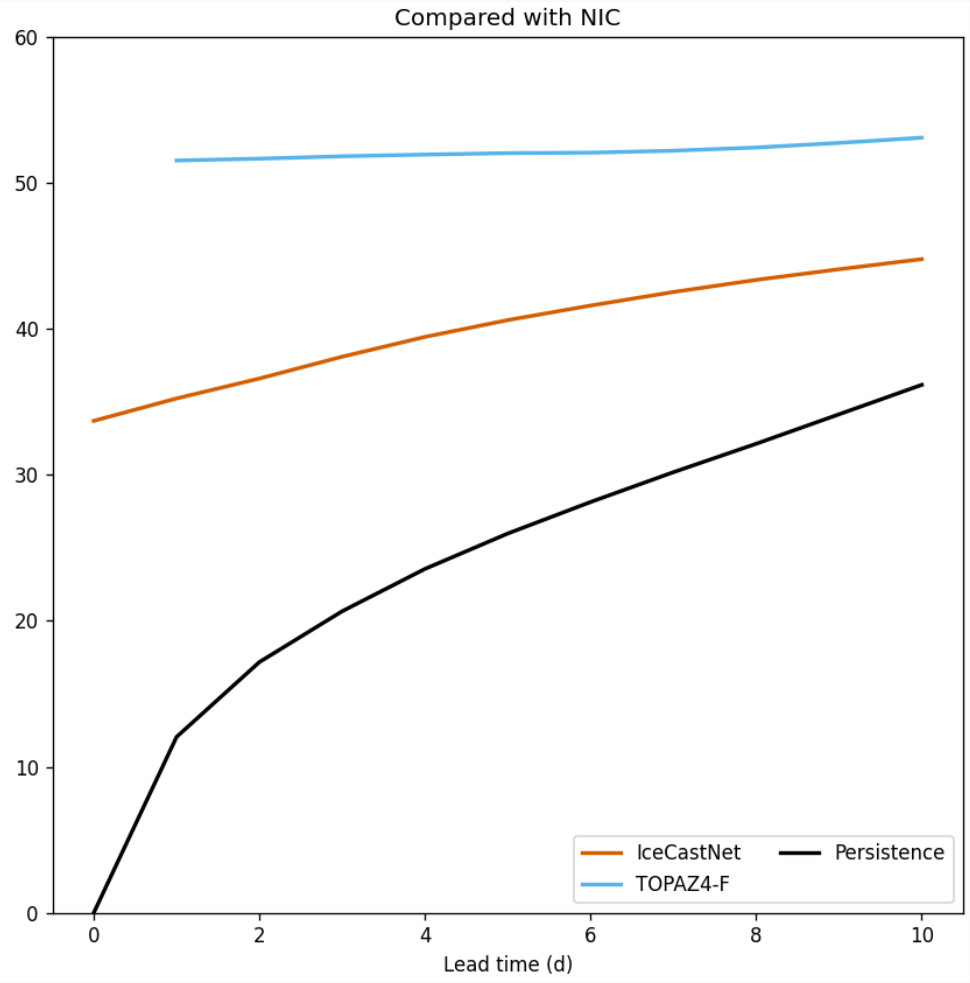
Validation using other products (ASIP+NIC)

ASIP (SAR)



US ice charts



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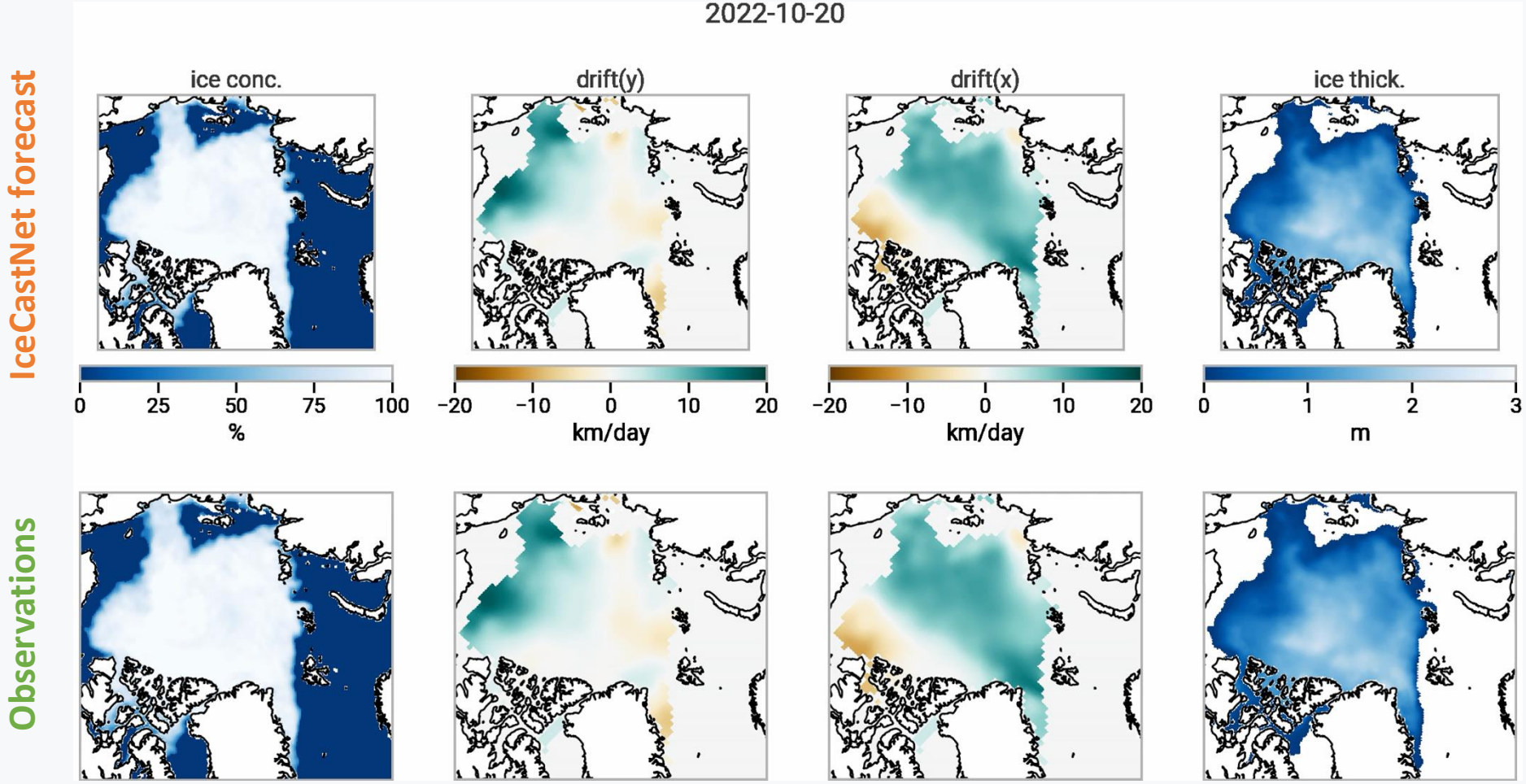
Push the limits?

Run over **3 months**, forced by meteorological analysis.
Running time (on 1 GPU): **1m15s**



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Conclusion

- ✓ IceCastNet is a data-driven model simulating **sea ice concentration, thickness and drift**
- ✓ IceCastNet is trained (almost) exclusively from **observational dataset** and is forced by atmospheric forecast
- ✓ Over a lead time of 10 days, IceCastNet is **faster** (**10 sec** Vs **1h30**) and **less biased** than the the operational physics-based model (compared with observations)
- ✓ IceCastNet is stable over long runs

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