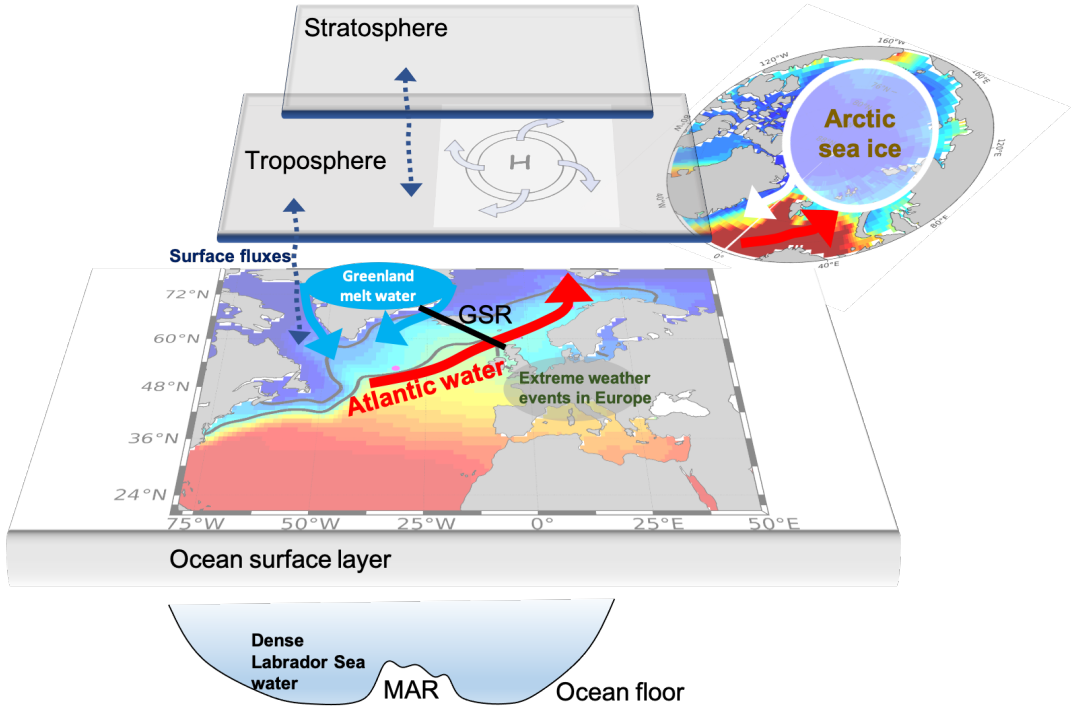
Advancing climate predictions from mid-latitude North Atlantic to the Arctic

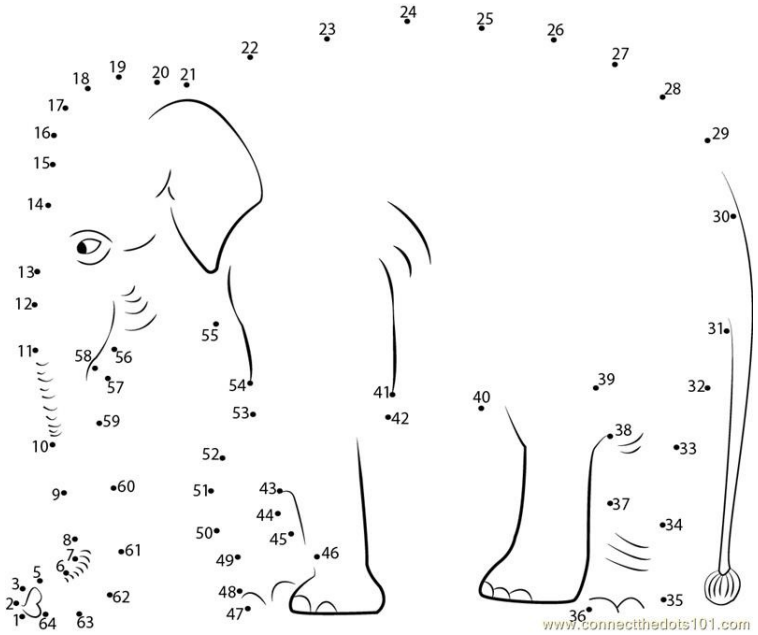
H. R. Langehaug, D. Matei, N. Keenlyside, M. Årthun, P. Athanasiadis, S. Barthélémy, A. Bellucci, I. Bethke, L. Borchert, F. Counillon, G. Danabasoglu, M. Devilliers, S. Drijfhout, Y. Gao, K. Lohmann, E. Maroon, J. Mecking, J. Mignot, S. M. Olsen, M. Payne, T. Schmith, D. Swingedouw, T. Tian, Y. Wang, S. Yang, S. Yeager

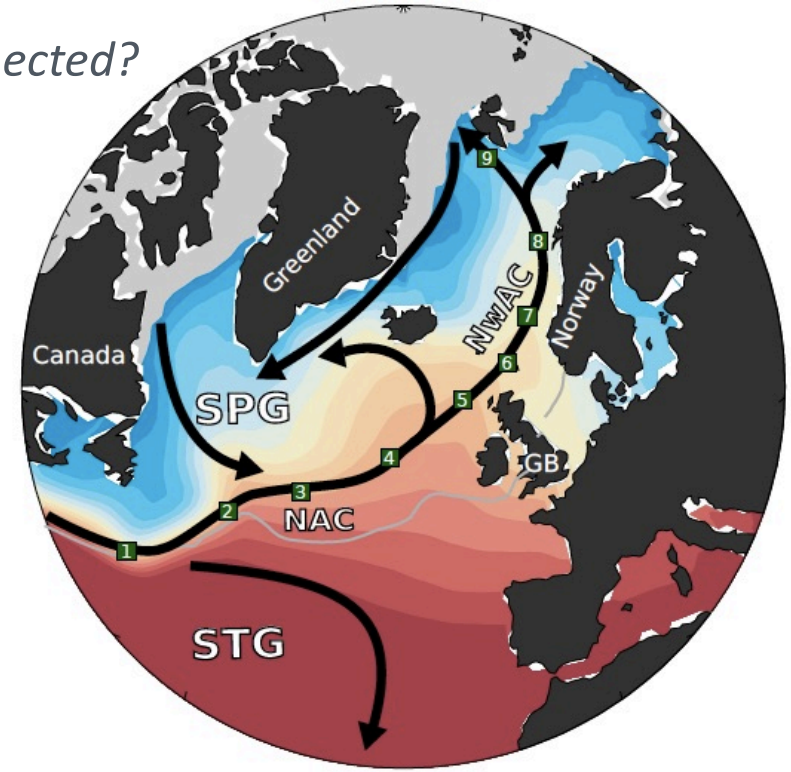


Dynamical understanding of North Atlantic and Arctic climate predictability: **the role of the ocean**

Upper ocean

How are the stations connected?





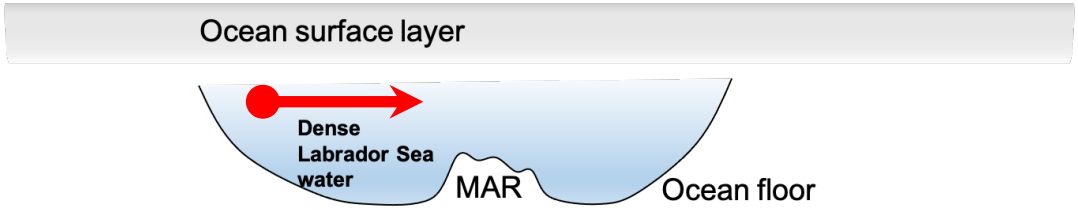
Key message: Ocean plays a key role in the poleward circulation of **Atlantic Water**

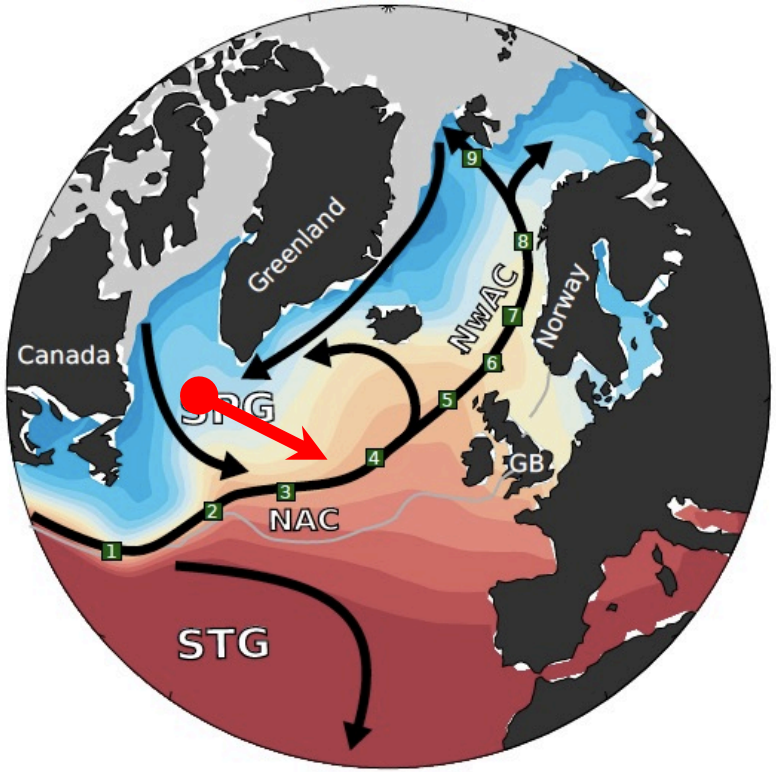
Papers related to Blue-Action: Årthun et al. (2017, 2018, 2019, 2021), Asbjørnsen et al. (2019), Athanasiadis et al. (2020), Dai et al. (2020), Langehaug et al. (2019), Lohmann et al. (2020), Bethke et al. (in revision), Omrani et al. (submitted), Yeager (2020)

Dynamical understanding of North Atlantic and Arctic climate predictability: **the role of the ocean**

Deep ocean

"The decadal ocean memory stems from the slow, interior propagation of **Labrador Sea Water** thickness anomalies towards the mid-Atlantic ridge (MAR)."





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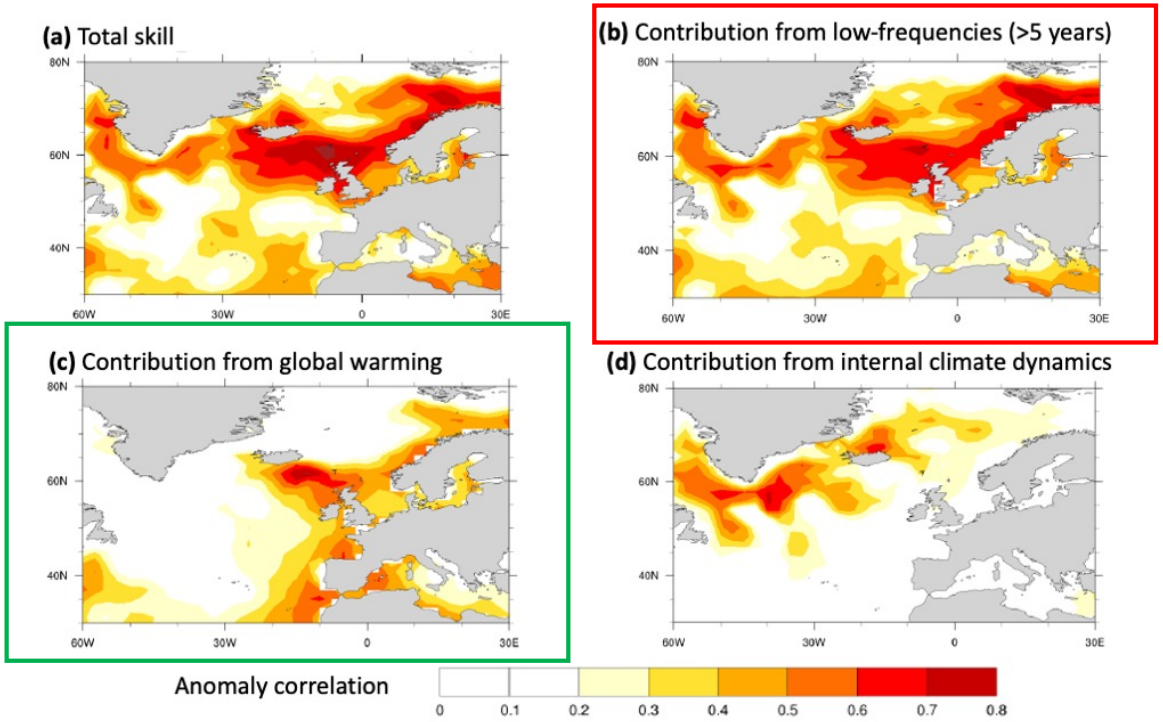
Dynamical understanding: **the role of** Arctic freshwater budget and **external forcing**

Correlation skill at 12 months lead

Components of seasonal prediction skill in surface temperature of the Norwegian Seas

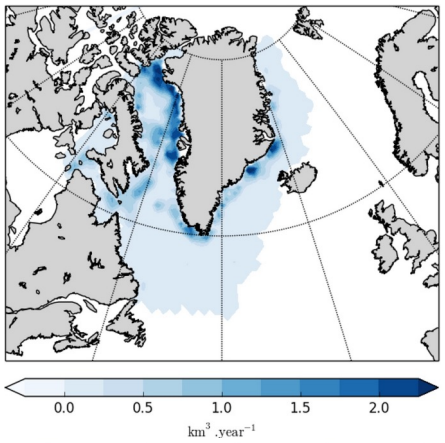


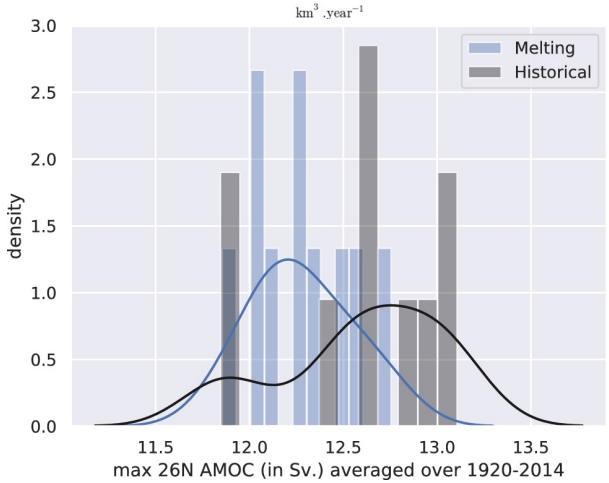
Key message: Melting from Greenland Ice sheet impacts variability downstream in the North Atlantic as well as the external forcing and notably the volcanic eruptions

Papers related to Blue-Action: Borchert et al. (2021), Devilliers et al. (2021), Langehaug et al. (in revision), Pariyar et al. (in prep), Schmith et al. (2018)

Dynamical understanding: **the role of Arctic freshwater budget** and external forcing

Runoff and solid ice discharge





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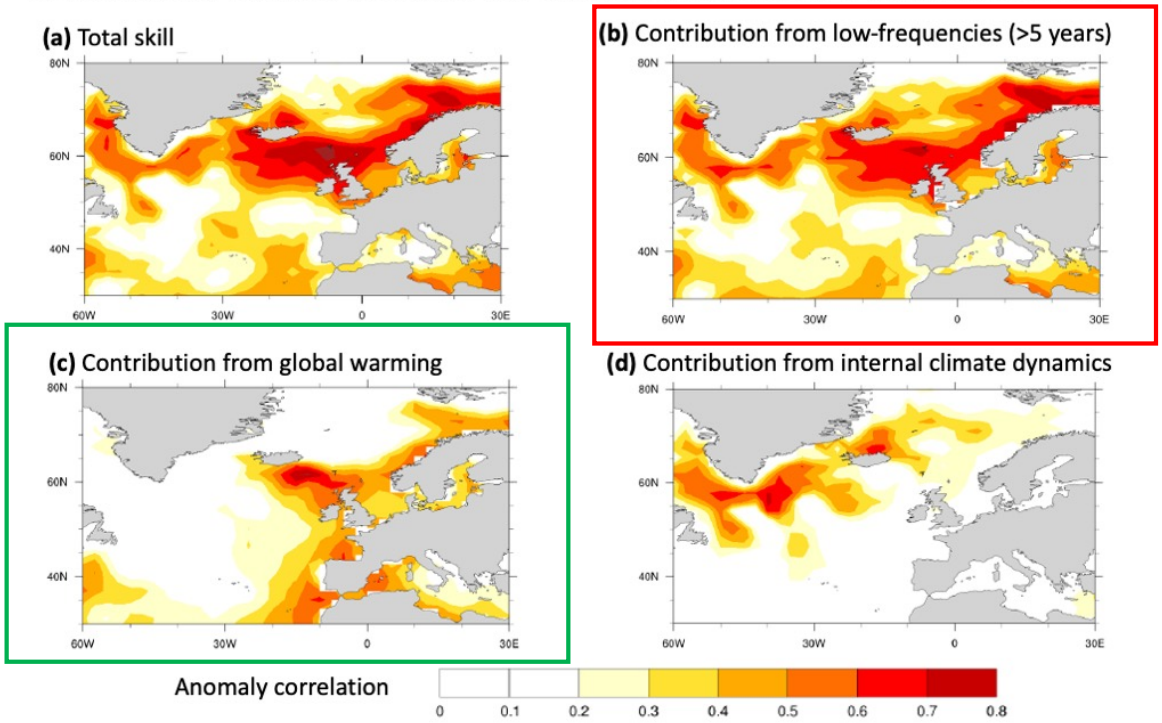

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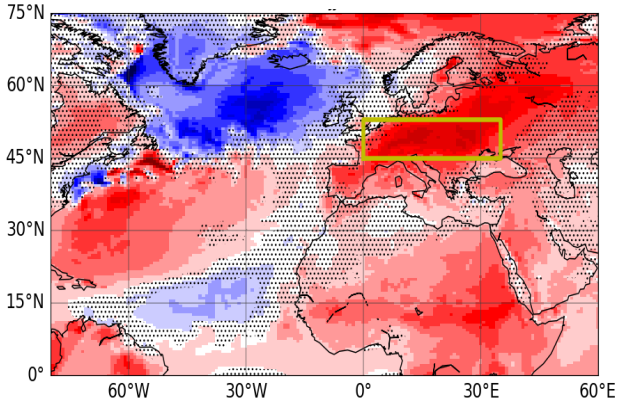
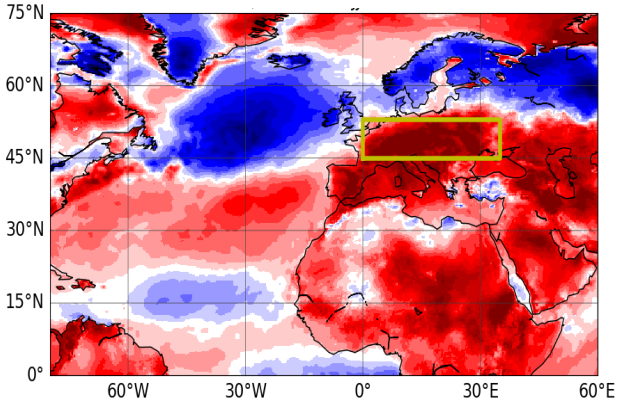
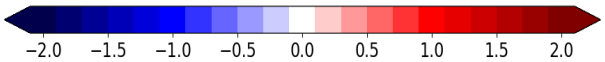
Dynamical prediction of climate extremes over the North Atlantic/European region: **what did we learn?**

2015: Summer SAT, HadGEM3



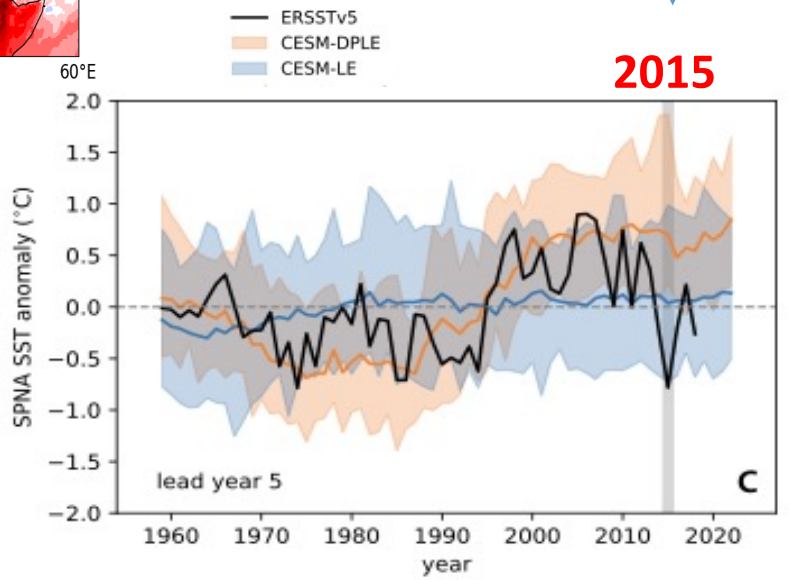
2015: Summer SAT, ERA5





Temperature difference from the long-term mean

Yesterday's talk by Elizabeth Maroon

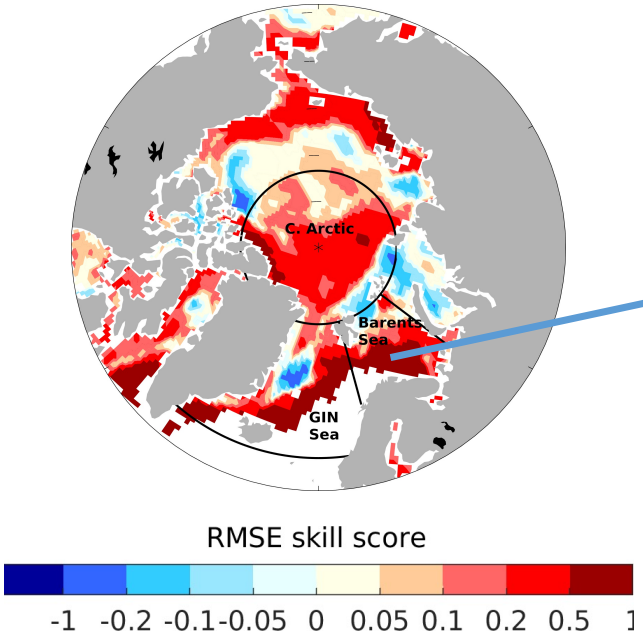


Key message: The ocean might have played an essential role in predicting climate extremes over Europe, such as the European heatwave in 2015.

Papers related to Blue-Action: Maroon et al. (2021), Mecking et al. (2019)

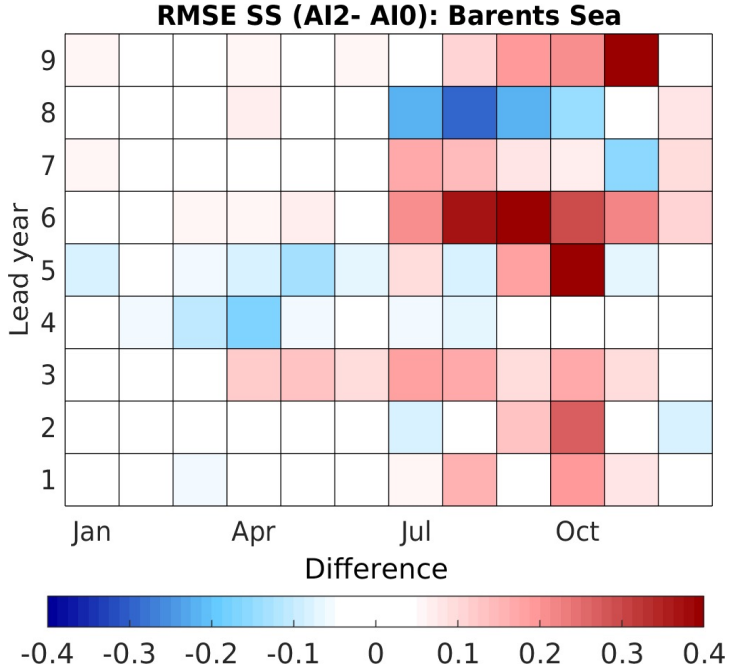
Recent advancements in dynamical climate predictions over the North Atlantic and Arctic

Sea ice concentration
(forecast time 2-9 yrs)



Scores above 0 denote more accurate prediction than FREE run

Sea ice concentration



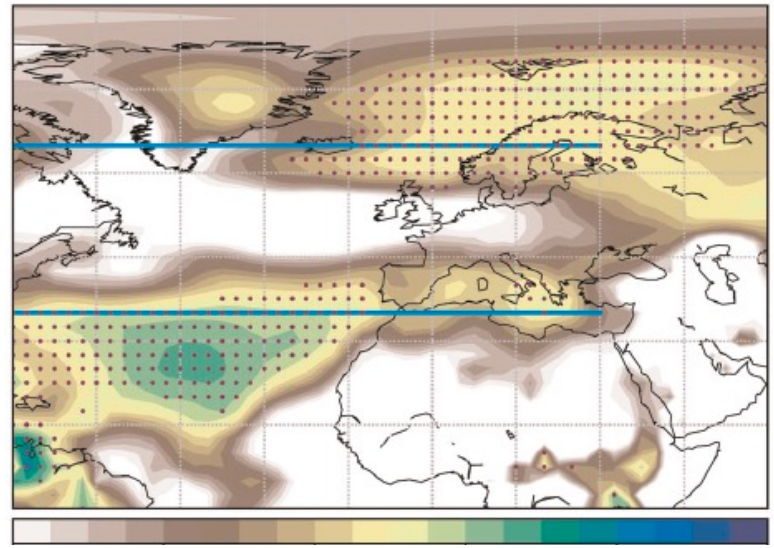
The difference of RMSE skill score is added skill from sea ice initialization

Key message: Sea ice initialization in addition to ocean initialization enhances overall Arctic skill

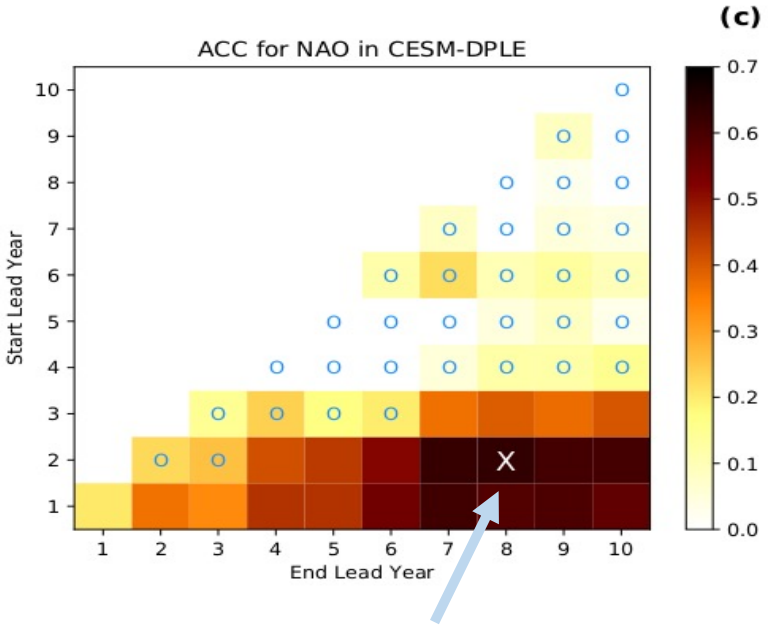
Papers related to Blue-Action: Kimmritz et al. (2019), Tian et al. (2021)

Recent advancements in dynamical climate predictions over the North Atlantic and Arctic

Prediction of winter atmospheric sea level pressure several years ahead



Correlation skill



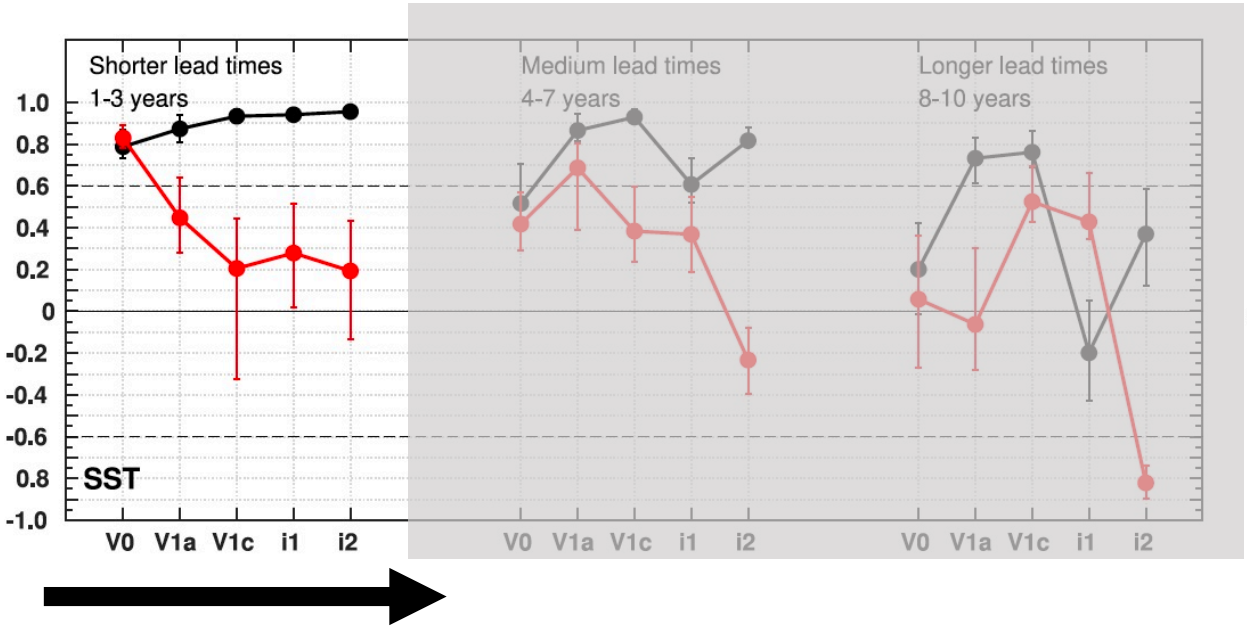
ACC = 0.63 for lead year range 2-8 yrs

Key message: Decadal predictability of key atmospheric processes (NAO, blocking) in large ensembles of decadal predictions

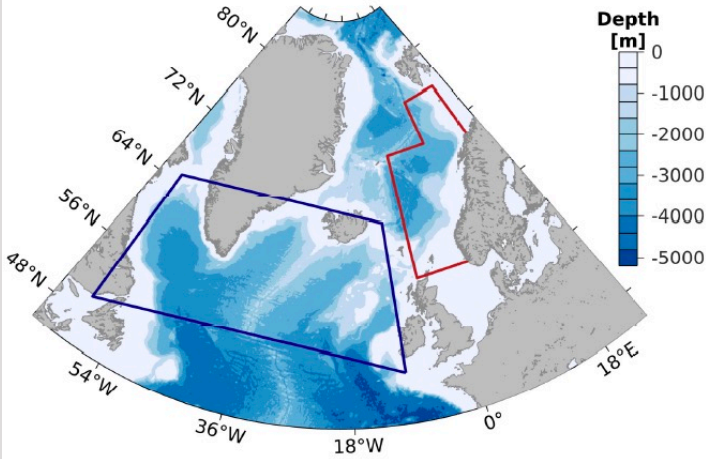
Papers related to Blue-Action: Athanasiadis et al. (2020), Smith et al. (2020)

Current challenges in dynamical climate predictions over the Arctic and Northern Hemisphere

Large difference in predictive skill north and **south** of the Greenland-Scotland Ridge



Different ways of initializing predictions

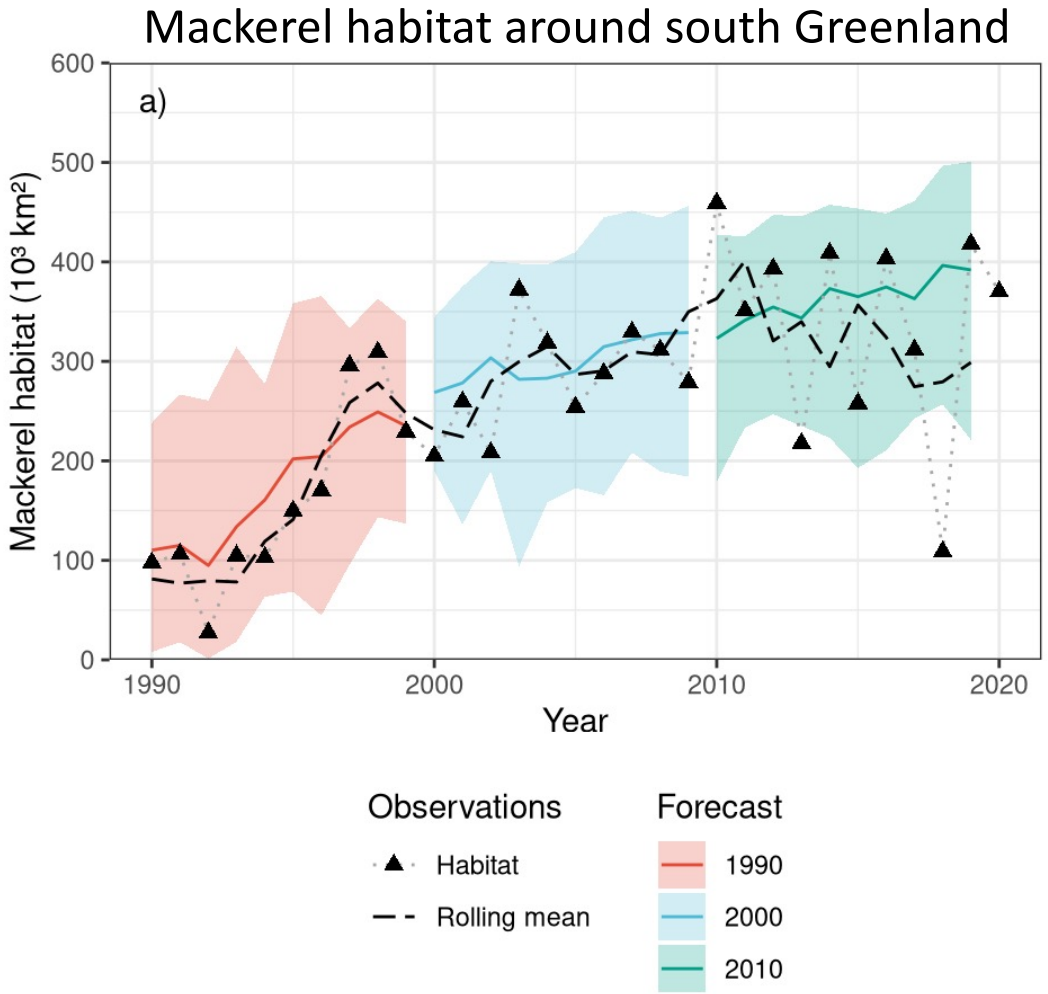


More to come in tomorrow's talk by Sébastien Barthélémy and Julien Brajard

Key message: Great potential to enhance skill, but requires **new cost-efficient ways** of producing large ensemble with high resolution models

Papers related to Blue-Action: Barthélémy and Counillon (in review), Langehaug et al. (in revision), Passos et al. (in review)

End-users applications of current decadal predictions



- Habitat forecasts from the best performing individual model system started at select times

→ **Key fish habitat can be forecasted**

More to come in tomorrow's talk by Mark Payne

Key message: Ocean climate impacts predictability of marine ecosystem and predictability over Europe

Papers related to Blue-Action: Payne et al. (2017), Årthun et al. (2018), Borchert et al. (in prep), Miesner and Payne (2018), Sgubin et al. (in revision), Payne et al. 2021 (submitted)

Protocol to enhance predictive skill

- what did we learn during Blue-Action?

1) **Multi-model approaches:** multi-model generally outperforming any single prediction system.

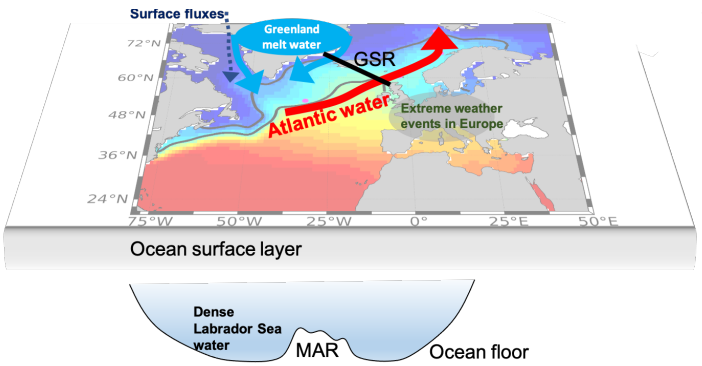
2) **Subsurface temperature and salinity and sea ice** data should be included in the initialization. In particular, improved initialization of **abyssal ocean density.**

3) **Properly represent the influences of external forcing:** this includes the meltwater from the Greenland Ice Sheet and the impact of volcanic eruptions.

4) **Application of higher resolution** (<0.25º): to better represent ocean-atmosphere interaction and connectivity with higher latitudes.

We note that settings that increase skill in the subpolar region are not necessarily the same for the Nordic Seas.

OCEAN



Protocol to enhance predictive skill

- what did we learn during Blue-Action?

1) **Predictions with a high ensemble size** are needed: to isolate the predictable signal.

2) **Advanced post-processing of predictions** is required: to maximize signal to noise and thereby enhance predictive skill.

3) **Models must realistically represent ocean** dynamics and ocean-atmosphere interaction, because predictability in the ocean transfers to the atmosphere.

4) **Models should properly represent stratosphere-troposphere interaction**, as stratospheric circulation anomalies are shown to play a role in tropospheric changes.