Danmarks Meteorologiske Institut

DMI Report 22-30
Oceanic Drivers of Arctic Change

Final scientific report of the 2021 National Centre for Climate Research Work Package WP 4.3, Oceanic drivers of Arctic Change

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1. Scientific summary

Short description
We seek to assess the ability of current climate models to predict Northern Hemisphere extra-tropical climate on decadal time-scales and also to identify regions, variables, and time-scales where such skill exists. The perspective is to apply new constraints to reduce model uncertainty. Climate models have difficulties in simulating fundamental aspects of the Arctic Ocean stratification such as the cold Arctic halocline. This affects both predictions and projections of arctic changes. The objective of this WP is to assess the ability of current climate models to represent processes specific to the transition of the Arctic Ocean such as Atlantification (Borealization), Pacification and sea ice retreat.

Overall results
We started a set of new experiments to complement the ensemble of historical EC-Earth simulations. This includes a set of 1920 to 2020 simulations which incorporates a realistic amount of freshwater forcing of the North Atlantic Ocean, as runoff and calving from the Greenland Ice Sheet and surrounding glaciers, and from ice caps melting. Previous experiments with other models led to an increase of the Arctic surface salinity and to a modification of the convection sites which slightly slowed the Atlantic meridional overturning circulation (AMOC).

There has been progress towards screening across CMIP6 models for skill in representing the trends in the Arctic region and its ocean properties including setting up the computational environment and building an extensive internal data archive for efficient computations. First, the very large ensemble of EC-Earth3 (25 members) has been downloaded to our servers.

Finally, we present in a paper (Christensen et al., submitted) a critical look at the recent idea that a weak realistic North Atlantic oscillation (NAO) signal can be extracted from very large ensembles of initialized and non-initialized climate model experiments.

Next steps
The ambition is to analyze existing climate models to identify variables and regions with decadal predictive skill, superior model systems and the “responsible” processes. Different options exist for efficient analysis (e.g. CLIMAF, ESMvalTool) but available online screening options are presently not considered adequate (e.g. C3S). We will keep updating the internal archive with full resolution ocean data from CMIP6 model members with priority on systems with documented performance. The robustness of classical in-situ based diagnostic metrics will then be tested against the diversity of models in this archive including diagnostic metrics for the rate and extend of Atlantification. This will form a basis for a new design of new targeted diagnostics. Collaboration with Nansen Environmental and Remote Sensing Center(NERSC) initiated in 2021 will be continued. A particular focus here will be on best practices and use of in-situ data from the Arctic region.

The historical ensemble experiment using realistic runoff into the North Atlantic will be completed, making use of historical simulations available from EC-Earth3 CMIP6 contribution. This will allow us to assess if the sensitivity to freshwater runoff depends on how the ocean is preconditioned. Our experiment will simultaneously be done at KMNI (Utrecht) with a ¼ degree resolution in the ocean to try to discover the role that resolution plays in these regions.

2. Scientific publication

Climate models usually do not diagnose well the amount of freshwater release in the North Atlantic and the Arctic Ocean. This is because they cannot afford a complete interactive ice sheet model for Greenland (too computationally expensive). The solution we propose here is to externally force the model with observed freshwater fluxes (FWF). The freshwater experiment consists of an ensemble of historical runs from 1920 to 2014 using the dataset of freshwater fluxes and their temporal variability from *Bamber, et al (2018)*, extended in the past using results from the *Box and Colgan (2013)* study. The full description of the methodology can be found in the study of *Devilliers et al. (2021), which* reports on a similar experiment made on collaboration with the IPSL model system (LOCEAN laboratory, Paris). We choose to start the simulations with EC-Earth3 (1 degree ocean resolution) in 1920 to account for the large melting of the 1920-1930s.

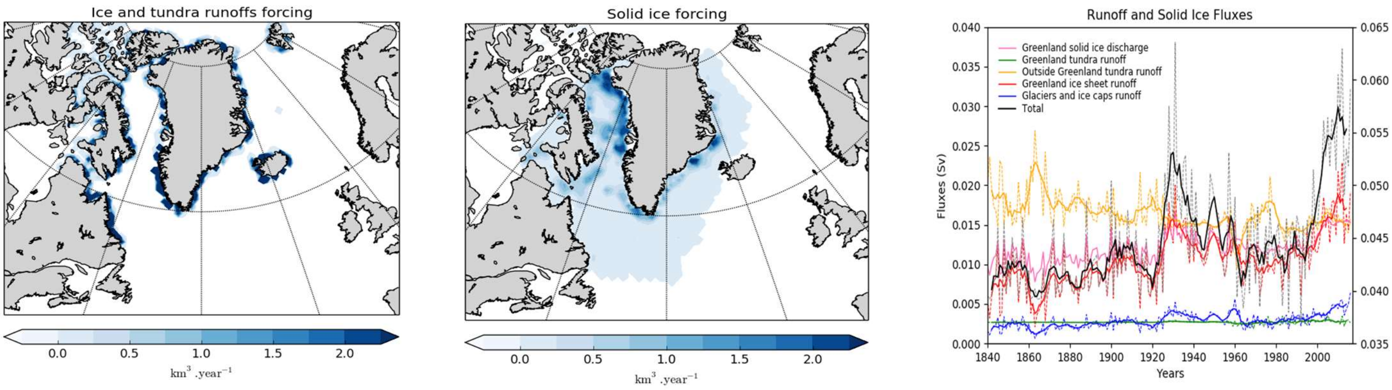

Figure 1. Spatial distribution (left, and middle) and time series (right) of the runoff and solid ice discharge fluxes used in the freshwater experiment.

To facilitate and streamline analysis also across CMIP6 historical simulations from the model ensemble, different tools have been investigated. This includes the Climate Model Assessment Framework (CliMAF) and ESMValTool. The first diagnostics chosen will be the volume of water above 5 degrees crossing several transects (Fram strait, Greenland Scotland Ridge) and the depth of the halocline in the Arctic.

Papers submitted:

Bo Christiansen, Shuting Yang & Dominic Matte: On the forced response and the predictability of the North Atlantic1Oscillation (J. Climate, Submitted), https://www.researchgate.net/publication/356042196_On_the_forced_response_and_the_predictability_of_the_North_Atlantic_Oscillation