REQUEST FOR A SPECIAL PROJECT 2023

MEMBER STATE: United Kingdom

Principal Investigator[1]**:** Dr. Kristian Strommen

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Other researchers:

Dr. Chris O'Reilly (University of Reading)
Dr. Stephanie Johnson (ECMWF)
Dr. Antje Weisheimer (ECMWF)

Project Title:

Arctic sea-ice, ENSO and seasonal prediction skill in mid-latitude winter circulation

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** GBSTRO	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2023	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2021-2023: (To make changes to an existing project please submit an amended version of the original form.)		**2023**	**2024**	**2025**
High Performance Computing Facility	(SBU)	10,000,000		
Accumulated data storage (total archive volume)[2]	(GB)	8000		

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

Principal Investigator: Dr. Kristian Strommen

Project Title: Arctic sea-ice, ENSO and seasonal prediction skill in mid-latitude winter circulation

Scientific background and motivation

The background and motivation were extensively discussed in the application for the original instance of this project. Since this request is for a very simple extension to complete the experiments proposed then, this background material has not changed. We therefore refer the reader to the original project proposal, rather than repeat verbatim the same material here.

Justification for continuation

The original project proposal was, in brief, to carry out the following two coupled seasonal hindcast experiments, with CY47R1, Tco199orca1, November 1st startdates:

1. "ArcticDenial": alter the sea ice initial conditions in the Barents-Kara region to suppress all interannual variability, and hence potential sources of hindcast skill, from this region.
2. "ENSODenial": alter the sea surface temperature initial conditions in the Nino 3.4 region to suppress all interannual variability, and hence potential sources of hindcast skill, from this region.

By removing the possible contributions of skill from both Barents-Kara sea ice and ENSO, one can assess how well the hindcast ensemble nevertheless predicts the winter North Atlantic Oscillation (NAO) over the period 1980-2015, and hence how much skill these two regions actually contribute to winter NAO forecasts. A pre-existing control hindcast run by Dr. Stephanie Johnson was to be used as a benchmark.

However, in 2021, after extensive technical discussions with Dr. Stephanie Johnson, Dr. Retish Senan, and others at ECMWF, it was determined that there were some model stability risks associated to carrying out these protocols in the coupled model. A pragmatic decision was therefore made to move to the atmosphere-only version of the model, and simply edit the sea ice and sea surface temperature boundary forcing in the equivalent manner. While this ended up working successfully, no control simulation of CY47R1 in the atmosphere-only mode existed as a benchmark. Units that were allocated towards one of the two experiments ("ArcticDenial" and "ENSODenial") therefore had to be used to generate the control hindcast instead, meaning we only had sufficient units to do one of the two Denial experiments. It was decided to do the ArcticDenial experiment, along with the control hindcast, and omit the ENSODenial. A brief progress report on the results of the ArcticDenial is included below.

The purpose of this request for the continuation of the project is simple: to obtain units necessary to run the ENSODenial experiment, as originally planned. Because the ArcticDenial experiment was successfully run, this would be a very straightforward modification of the same working methodology, and allow us to promptly finish the original project approved by ECMWF.

Please note that the technical difficulties encountered which forced the change of plan were not discovered until relatively late in 2021, due to Covid-induced delays to the project: following this, the PI went on extended paternity leave. It was not therefore possible to apply for a continuation already last year.

Technical details and unit estimation

The experiment will be run using IFS cycle 47r1 in coupled mode. The resolution to be used is **Tco199**, with the experiment covering 1980-2015 with November startdates. For each startdate, a 50-member ensemble will be run for 4 months to cover the full DJF season. Single precision mode will be used to save resources.

The SBU cost of the ArcticDenial experiment was approximately 7,000,000 SBUs on the Cray supercomputer. The ENSODenial experiment is therefore expected to cost the same amount, except it will likely run on the new Atos machine. A rough conversion factor of 1.4 from Cray SBUs to Atos SBUs produces an SBU estimate which we rounded up to 10,000,000 SBUs: the conversion factor is based on information from the following page:

https://confluence.ecmwf.int/display/UDOC/HPC+accounting

Data volume estimates are based on a pragmatic choice of output on daily and monthly frequencies, which produce 4 Tb of data for each experiment.

Short progress report

In order to suppress interannual sea-ice variability from the Barents-Kara region in a decisive and easily interpretable manner, we opted in the end to simply edit the boundary forcing files to set the sea ice concentration to 100% over this region. This amounts to permanently sealing the warm SSTs in the Barents and Kara sea with a `lid', thereby suppressing the generation of stationary heat-flux induced Rossby waves from there. Figure 1 shows that the effect of adding this `lid' to the hindcasts is to cool the atmosphere locally in the Barents and Kara region: this is physically as expected, since the SSTs are much warmer than the Arctic atmosphere during winter, so adding the `lid' is removing a big source of heating. This suggests our experimental protocol worked as expected and produced a physically sensible response.

Figure 2 shows the preliminary impact on NAO skill. The benchmark control hindcast has an ensemble mean correlation with ERA5 of 0.61, which is interestingly entirely comparable to the high skill reported by the UK Met Office, and higher than the skill typically reported using coupled version of the IFS. This suggests much of the discrepancy between the skill of ECMWF and the Met Office may have been primarily a result of biases introduced by coupling. On the other hand, the skill of the ArcticDenial experiment is 0.46, a difference of 0.15 from the control. According to the three-way-correlation test of Siegert et al. (2017), this difference is statistically significant with p=0.10, and only just fails to be significant at p=0.05. We note that the joint correlation between the two hindcasts is 0.83, and that a correlation difference of 0.17 would be classes as statistically significant at p=0.05 according to the three-way-test.

Finally, Figure 3 shows that the difference in the geopotential height fields (at 500hPa) between the two hindcasts clearly projects onto the NAO, corroborating the observed impact on skill.

Further analysis is currently in progress, but the preliminary results do suggest that sea ice in the Barents and Kara region are a source of skill for seasonal NAO forecasts in the IFS.

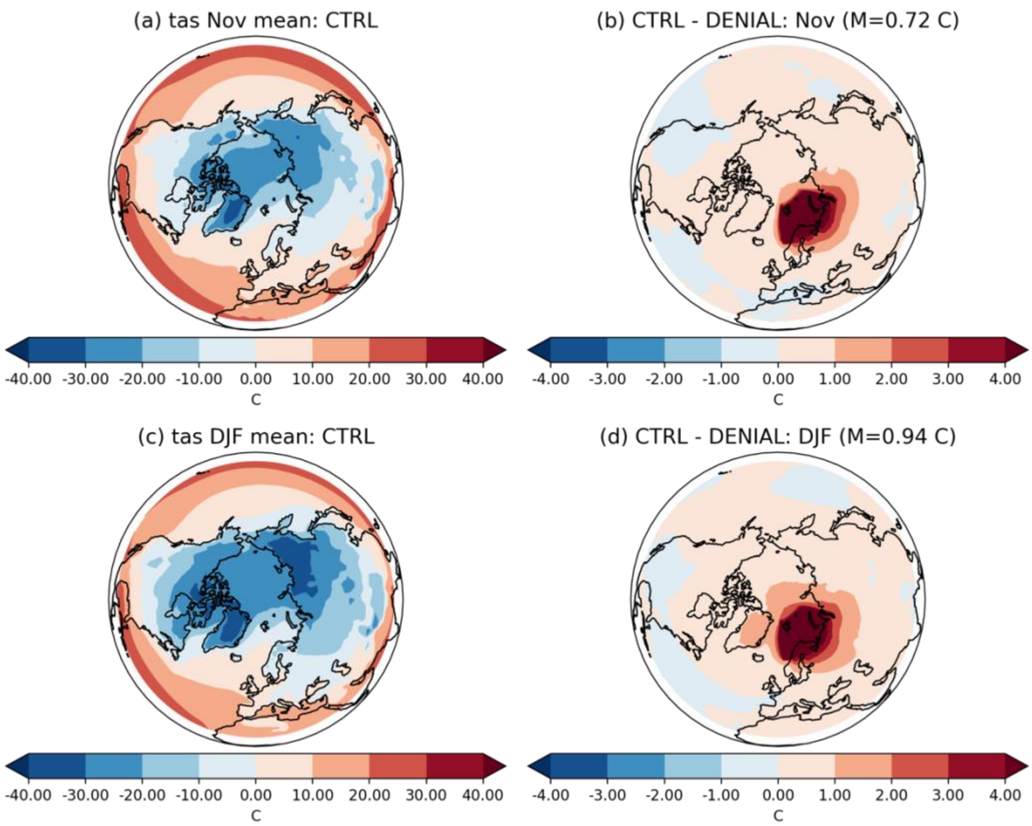

Figure 1. Composites of surface temperature (tas) for (a) Control in November, (b) Control minus ArcticDenial in November; in (c) and (d) the equivalent for DJF.

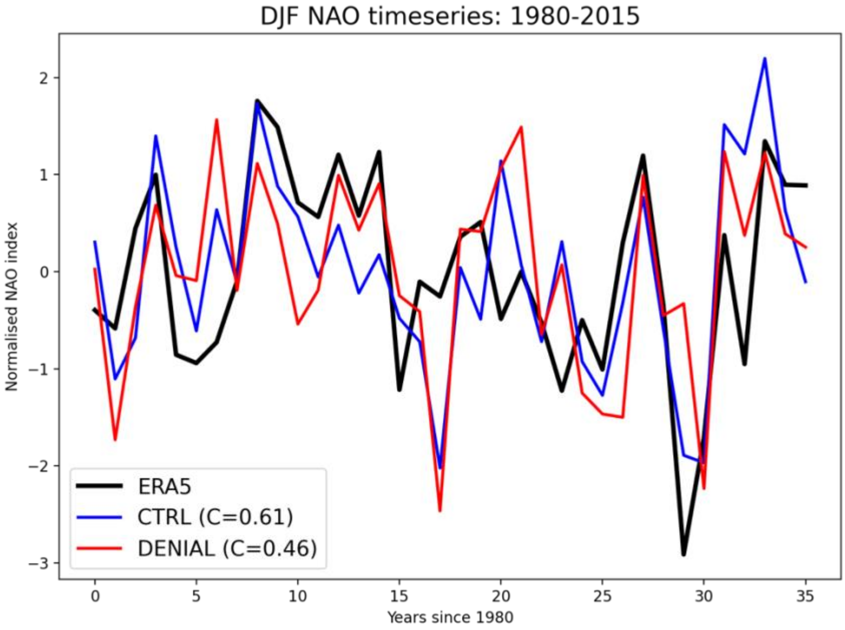

Figure 2. DJF NAO timeseries (1980-2015) for ERA5 and the ensemble means of Control and ArcticDenial. All timeseries have been normalised to have mean 0 and standard deviation 1. The values of C in the legend are the correlation with ERA5. The NAO has been computed by projecting geopotential height anomalies onto the NAO pattern of ERA5 and detrending; the NAO pattern of ERA5 is obtained using an EOF decomposition.

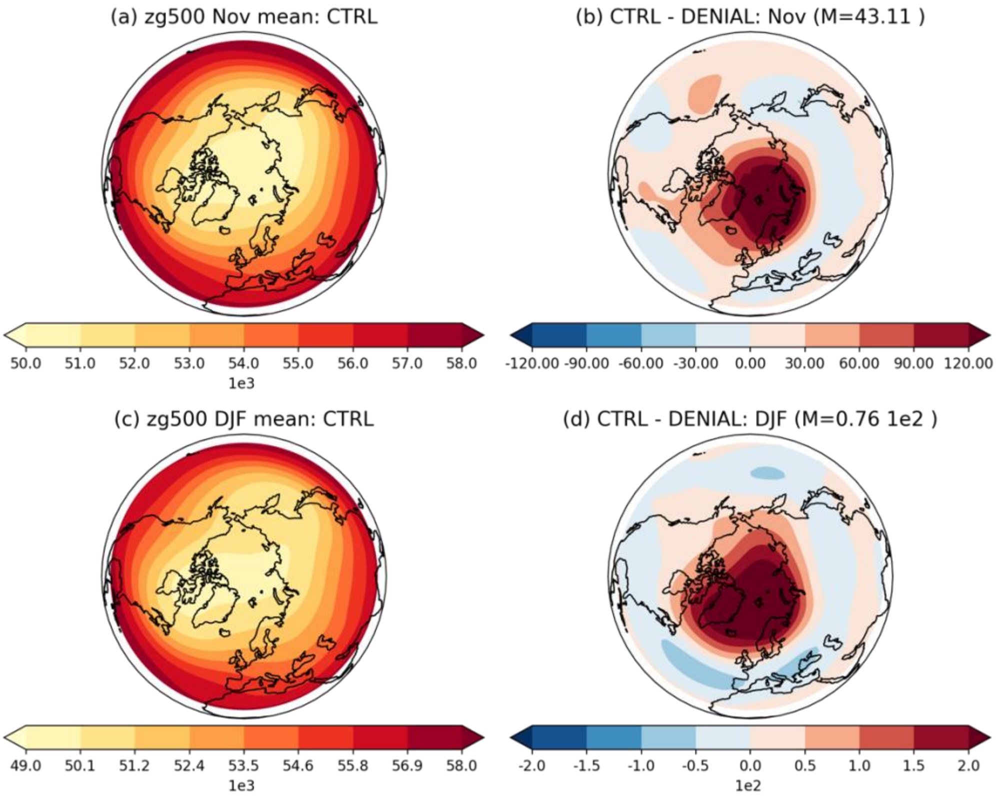

Figure 3. Composites of geopotential height at 500hPa (zg500) for (a) Control in November, (b) Control minus ArcticDenial in November; in (c) and (d) the equivalent for DJF.

REFERENCES

Siegert, S., Bellprat, O., Ménégoz, M., Stephenson, D. B., & Doblas-Reyes, F. J. (2017). Detecting Improvements in Forecast Correlation Skill: Statistical Testing and Power Analysis, *Monthly Weather Review*, *145*(2), 437-450.