

## SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

<b>Project Title:</b>	Modeling MIS3: a mild glacial climate state
<b>Computer Project Account:</b>	spdklang
<b>Start Year - End Year :</b>	2017- 2018
<b>Principal Investigator(s)</b>	Peter L. Langen
<b>Affiliation/Address:</b>	Danish Meteorological Institute Lyngbyvej 100, DK-2100 Copenhagen , Denmark
<b>Other Researchers (Name/Affiliation):</b>	Shuting Yang (miy), DMI Ida Ringgaard (nhr), DMI Qiang Li (suzk), Stockholm University

The following should cover the entire project duration.

## **Summary of project objectives**

(10 lines max)

As part of the efforts under the ERC Synergy Grant project “ice2ice”, we aimed to perform an EC-Earth simulation of climate conditions during Marine Isotope Stage 3 (MIS3), a time prior to the Last Glacial Maximum marking the period with the most pronounced climate shifts recorded in the Greenland ice core records. In light of the ongoing rapid decline of Arctic sea ice and its likely influence on the Greenland Ice Sheet, understanding of previous abrupt reorganizations in the North Atlantic/Arctic climate system is important for a clear mapping of the potential consequences of the current warming. We have devised a protocol for a coordinated set of experiments between the NorESM (run by ice2ice colleagues in Bergen), HadCM3 (by William Roberts, U Bristol) and EC-Earth models. The main experiment will consist of an equilibrium snap-shot at 38,000 years before present (38 ka). The protocol addresses the changed land-sea mask and ocean bathymetry (due to 70 m lowered sea level), ice sheet geometries for the Northern Hemisphere and settings for atmospheric composition, orbital parameters and changed/extended river routing.

## **Summary of problems encountered**

(If you encountered any problems of a more technical nature, please describe them here.)

Unfortunately, we ended up not being able to complete the experiments as we had planned. This was in no way due to technical difficulties with the ECMWF system but rather a model development issue. As a result we only used a fraction of the granted computing resources (0% in 2017 and 40% in 2018)

We made the MIS3 setup with an intermediate version of the EC-Earth code and have performed initial runs with this (see below). However, to ensure proper integration with the CMIP6 process (including the PMIP paleoclimatic runs thereunder), we needed to wait for the final, frozen version of the EC-Earth code to be used for CMIP6.

This CMIP6 version of the EC-Earth was quite delayed. The CMIP6 runs are currently being performed, but the debugging and tuning of the code was almost a year delayed compared to the expectations we had at the time we applied for this project.

However, if we did not wait, we would not have been able to compare the resulting climate to the present, pre-industrial and future climates simulated by the (eventual) CMIP6 version of the code. This would severely have limited the utility of the experiment and we would likely need to rerun it or do the full set of future experiments with the intermediate version of the code. Finally, the climate of the intermediate version suffered from the same issues that the main development were struggling with, so the lessons to be learned from running with that version would be of limited value. Towards the very end of the project (Nov 201) we ran some more tests to see if we could make a quick fix (and then perhaps ask for a small extension of the project), but this was not possible.

In the end, the process got so delayed that we were unable to perform the runs within the time frame given by the project.

## **Experience with the Special Project framework**

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The Special Project framework is a pleasure to work with. Application, mid-term reporting and final reporting smooth, easy and lightweight.

Technical support is fast, friendly and extremely competent.

## Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

With the intermediate version of the code, we have implemented the changes needed to do the MIS3 paleo-experiment:

### Orbital parameters and solar constant

- **Orbital parameters** chosen as those for 38 ka BP in the code of the models
- **Solar constant set** to same as in PI (like PMIP3)

### Greenhouse gases and aerosols

- **CO2:** 215 ppmv
- **CH4:** 550 ppbv
- **N2O:** 260 ppbv
- **CFC:** 0
- **O3:** PI
- **Aerosols:** PI

### Topo, ice sheet, and land-sea mask

- The Tarasov et al 38 ka “reconstruction” includes topo, ice mask and land sea mask

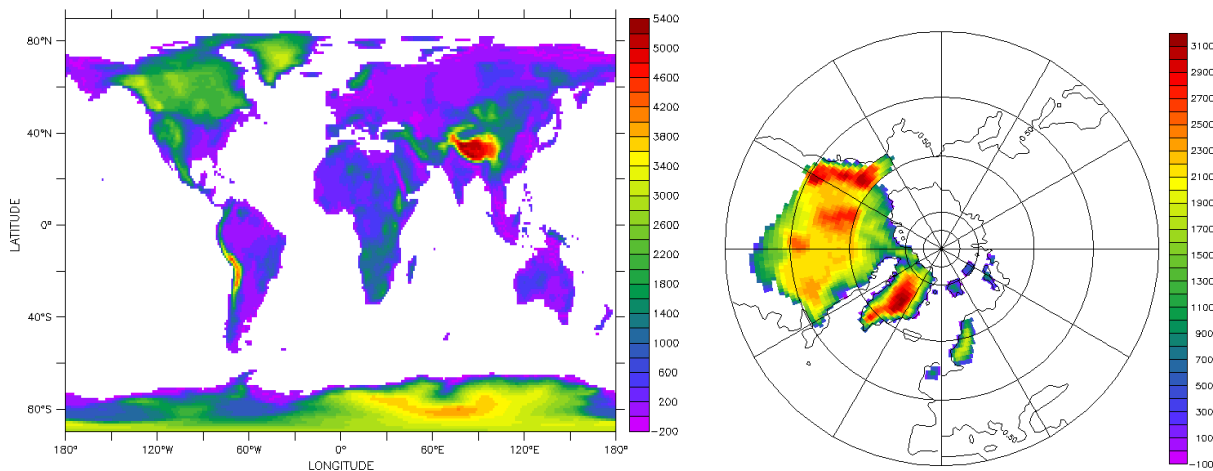
### Surface types and river routing

- In new ice points, we choose the same surface type, vegetation etc as on the current Greenland ice sheet.
- Surface type, vegetation etc in new land points: Choose typical values for tundra everywhere
- River routing: current rivers extended out to new coastline

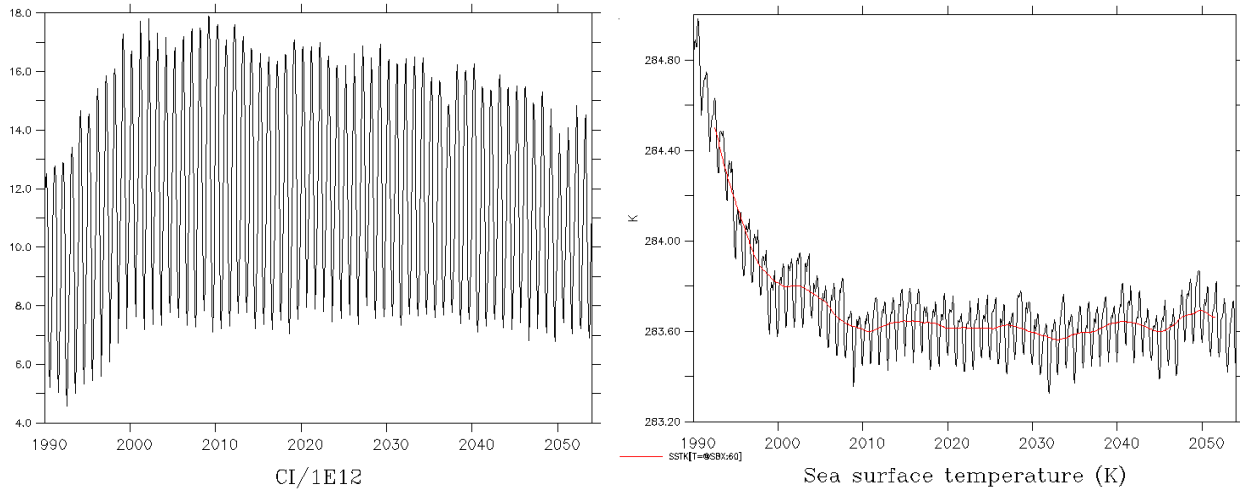
### Initialization

- Sea level is 70 m lower, so we add 0.6 psu to global ocean salinity.

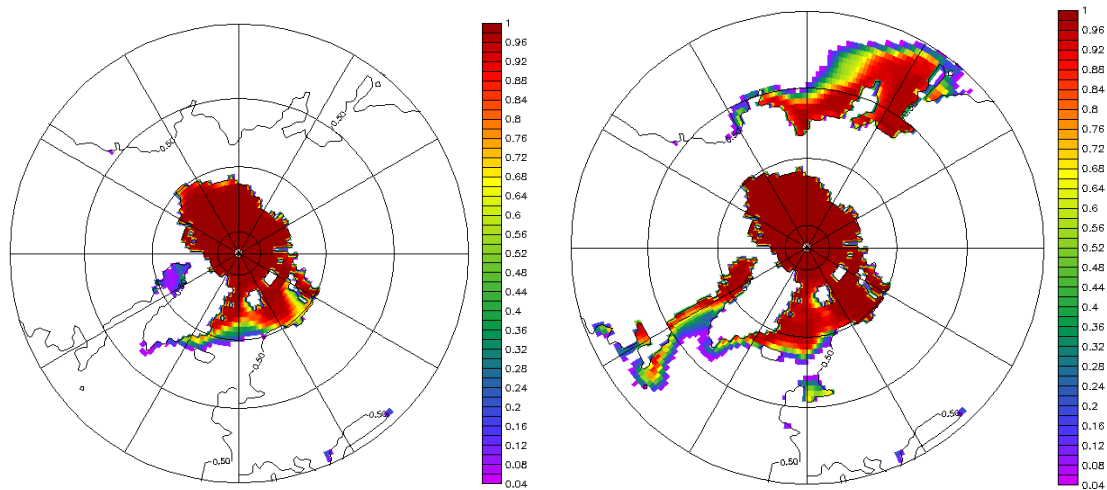
In the following figure, the resulting land sea mask is illustrated in the plot to the left, while the right hand panel illustrates the large Northern Hemisphere ice sheets of the time:



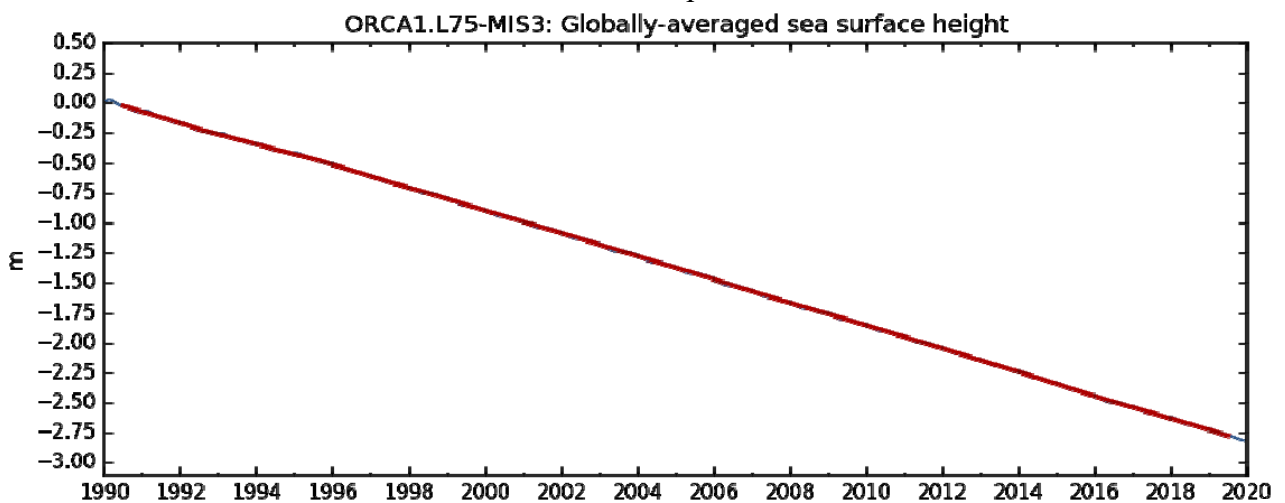
With this setup, we did an initial ~60 year test run to check the sanity. The below figure illustrates the evolution in NH sea ice area and sea surface temperature:



The final five years of the test run have been averaged to illustrate the September (left) and March (right) sea ice area. This rather modest sea ice cover (recalling that we are in a mild glacial state) is approximately as we would expect from the known paleo-records:



However, sea level is dropping in the experiment (as seen in the next figure) due to an imbalance between continental runoff in the IFS and NEMO components.



## **List of publications/reports from the project with complete references**

None to come out of the computing resources granted here – although several papers have come out of the twin experiments performed with other models in the ice2ice project.

## **Future plans**

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

Unfortunately the ice2ice project is ending this summer, so we do not expect to continue this particular experiment in the imminent future.