SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	…2015……………………………………………………..……
Project Title:	…Modelling interglacial climate..……………………..……
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Computer Project Account:	…SPDKLANG…………………………………….……
Principal Investigator(s):	…Peter L. Langen………………………………..……
	…Rasmus Anker Pedersen…………………….……
Affiliation:	…DMI, Copenhagen, Denmark…………………..……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………………………..……
	……………………………………………………………..……
Start date of the project:	…January 1st 2014……………………………….……
Expected end date:	…Dec 31 2015...…………………………………..……

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	1,100,000	~1,100,000	1,100,000 +4,500,000	2,001,749
Data storage capacity	(Gbytes)	3,500	~3,000	3,500 +3,500	~6,000

Summary of project objectives

(10 lines max)

The project is a part of the Ph.D. project by Rasmus Anker Pedersen, which aims to investigate the last interglacial climate state using GCM simulations with EC-Earth. The original version of the model has been expanded with a module that allows for orbital changes, and the model can now be used for paleoclimate simulations. The main experiment is a simulation of the last interglacial climate (the Eemian, 125,000 years ago), and a pre-industrial climate simulation (year 1850) is used as control climate. Additionally specific sensitivity studies might reveal how the properties of the Eemian climate have changed. Sensitivity studies will be based on the main experiment, and start from the obtained equilibrium climate state, where the response to a perturbation in a climatic parameter is simulated – the focus here will be on changes in sea ice cover, ice sheet configuration, and CO_2 level (i.e. comparison to potential future climate states).

Summary of problems encountered (if any)

(20 lines max)

Since the last progress report, we have successfully set up the latest version of EC-Earth (v.3.1) and have been running simulations over the last year. Simulation with the new model version on CCA has proven to be more computationally expensive than running the old version on C2A. Thus, we have (successfully) applied for additional resources in February 2015 (marked with plusses in the "Computer resources" table above). The additional resources mean that we can still achieve the project objectives, even with the increased computational cost of the simulations.

The new version of the model is suffering from occasional numerical problems in the ocean component. We have found an acceptable solution to this, but it has required some effort and computational time to test potential ways to overcome these issues. The same problem is occurring on other systems too and is not related to our setup or CCA specifically.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

The main simulation has been running for 500 model years. Currently, the simulation is paused as most parameters indicate stable climate conditions. We still plan to extend the simulation further, but want to make sure to have enough computational units to complete the planned sensitivity experiments and the control climate.

The last 300 years of the simulation reveals no clear long-term trends, but considerable decadal and multi-decadal scale variability. This behaviour is seen in a wide range of parameters; as an example Figure 1 presents the surface air temperature averaged globally and over the Arctic region.

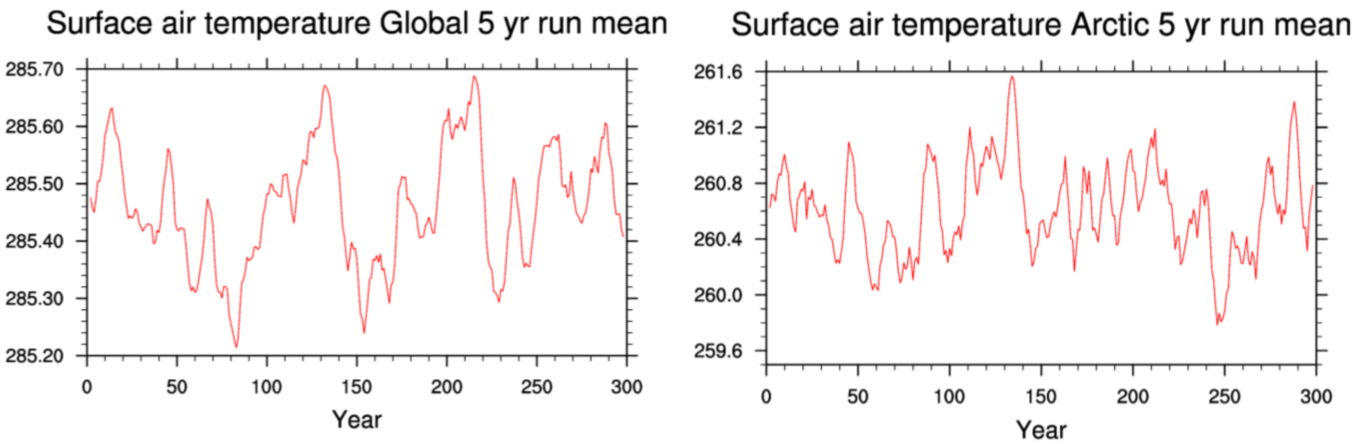

Figure 1 Surface air temperature [K] for the last 300 years of the Last Interglacial simulation. Left: Global, Right: Arctic mean

The new module for orbital forcing is working as desired. The simulated Eemian time slice (125,000 years ago) is characterised by the insolation changes shown in Figure 2. The high northern latitudes receive more insolation during summer, while the insolation is slightly reduced in the fall, whereas the high southern latitudes have a decrease during summer countered by an increase during winter. In the annual mean high latitudes receive an increased insolation compared to the tropics, where the insolation is reduced.

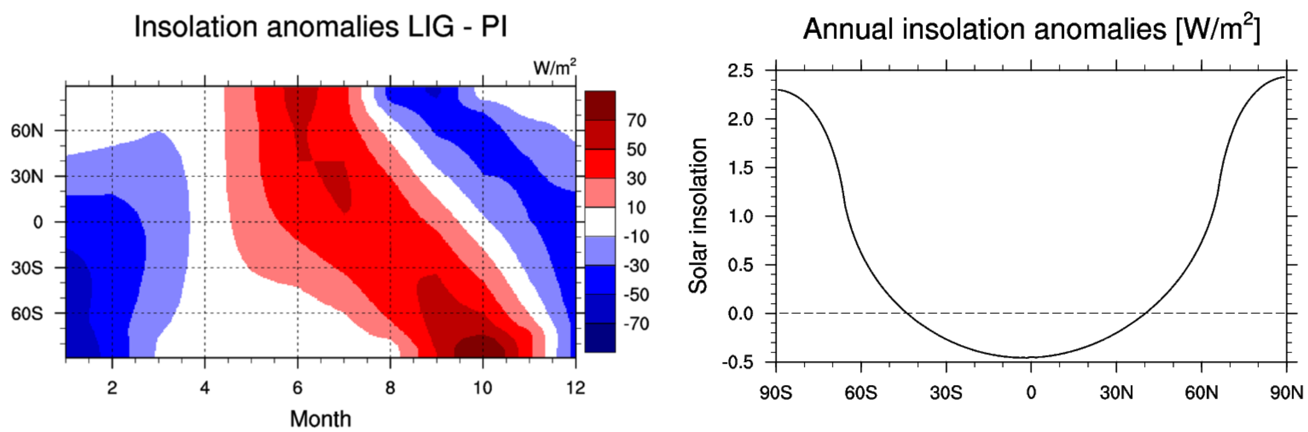

Figure 2 Insolation changes in the Last Interglacial (Eemian, 125,000 years ago) compared to the pre-industrial (1850). Left: Annual cycle of insolation anomalies by latitudes. Right: Annual mean insolation change by latitude.

We are conducting a detailed analysis of the climatic changes in response to the solar forcing. The analysis is based on a climatology of monthly mean data based on the last 100 years of the simulation. We will present a few results in terms of seasonal means.

The high northern latitudes show a pronounced warming, which is clearly evident in all seasons (presented in Figure 3). Although the insolation increase is limited to summer, the warming signal is evident throughout the year. This is, at least in part, related to snow and ice feedbacks, which make the warming anomaly persist throughout the year. A spatial resemblance of the annual mean warming pattern and the pattern of seasonal sea ice loss (Figure 4) suggests such a link (especially in the North Atlantic region).

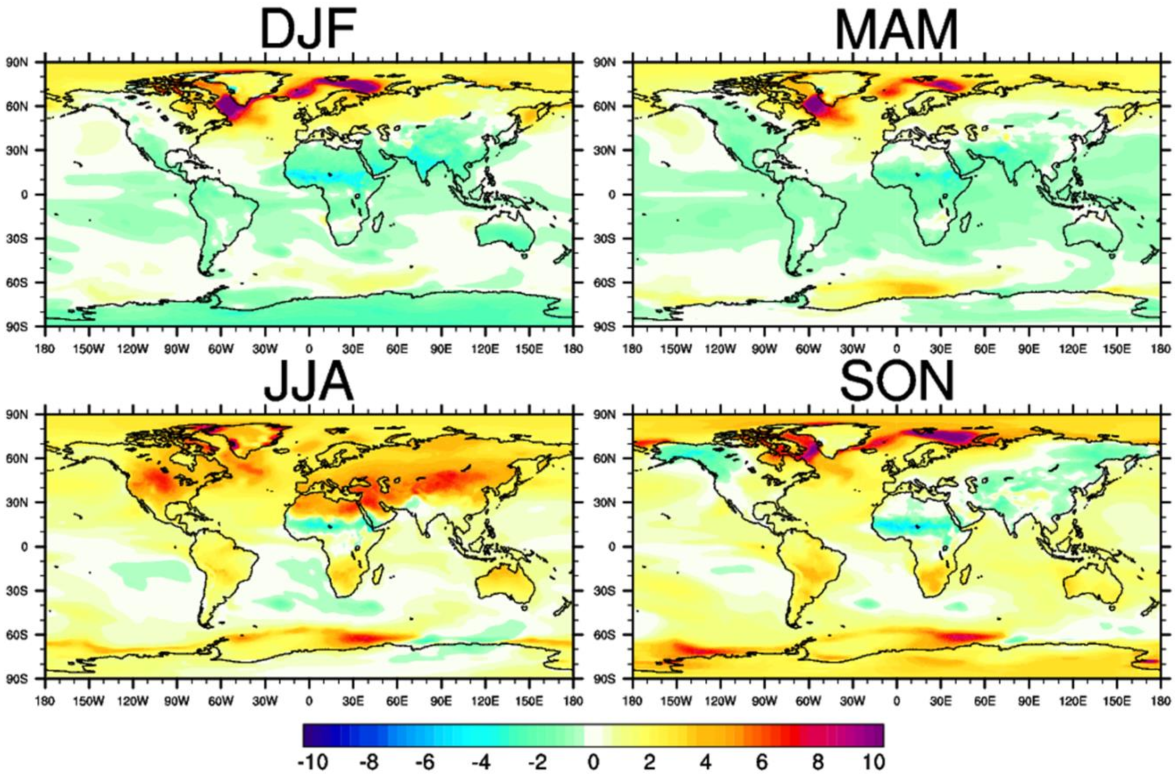

Figure 3 Seasonal mean warming [K]: Last Interglacial compared to pre-industrial.

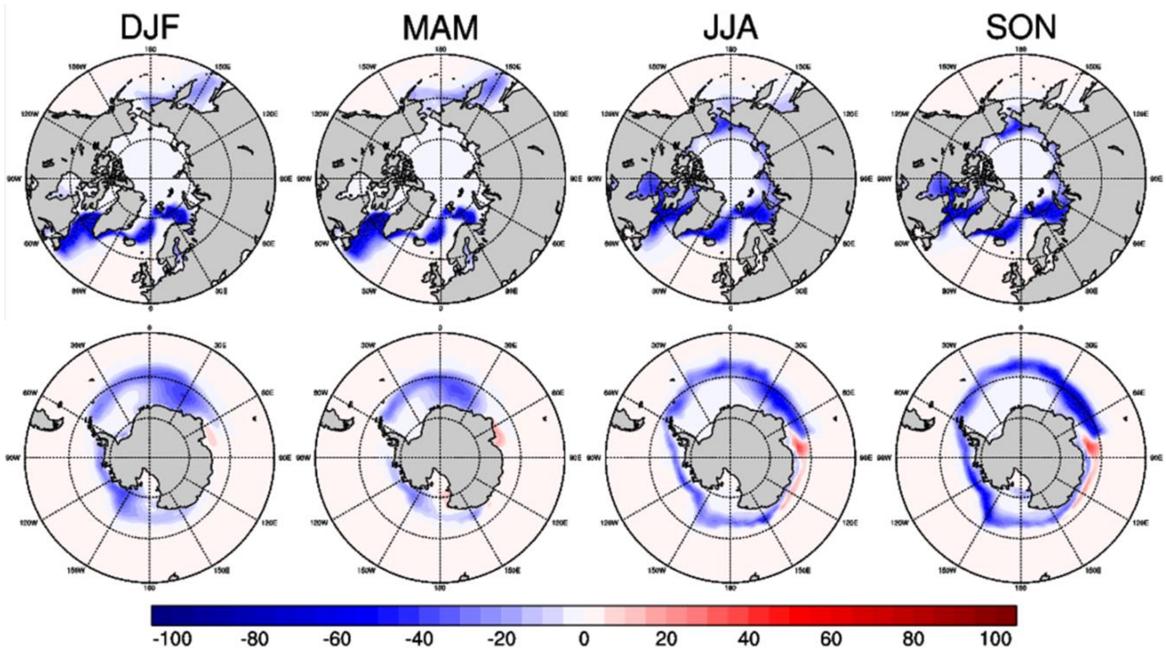

Figure 4 Sea ice cover anomalies [%]: Last Interglacial - pre-industrial

The increased insolation during summer enhances the melt of snow and sea ice. The loss of sea ice means that more heat can be absorbed in the ocean (albedo effect), which further increases the Arctic warming. The smaller sea ice extent at the end of summer combined with the warmer surface ocean causes a delayed and limited sea ice growth in the fall; despite the fact that the insolation is reduced. Hence, the increased summer melt creates a year-round reduction of the sea ice extent. The sea ice cover acts as an insulator between ocean and atmosphere, and the loss of the insulator sets up a strong heat flux from the ocean surface to the atmosphere. The heat flux in the newly ice free areas arises from a big temperature gradient between the ocean and the much colder overlying air. This mechanism explains the strong warming signal in the North Atlantic evident through the colder seasons.

The analysis will have a special focus on the Arctic region and Greenland. We will investigate the mechanisms of the climate change, and “decompose” the warming signal to assess the contribution directly from the insolation change and the contribution from the subsequent climatic feedbacks. One part of this analysis is the planned sea ice sensitivity experiments. We will assess the relative contributions by constructing two simulations based on the fully coupled simulations of the Last Interglacial (LIG) and the pre-industrial (PI): (1) Sea ice cover from LIG and insolation from PI and (2) sea ice cover from PI and the insolation from LIG.

List of publications/reports from the project with complete references

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Summary of plans for the continuation of the project

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We are currently running the control climate simulation, which should be done within a few weeks. Awaiting the progress of model development in our department, we will then initiate the sea ice experiments either in a full coupled setup with a sea ice nudging option, or alternatively in an atmosphere stand-alone setup with prescribed sea ice conditions. These simulations will be used to assess the relative contributions of the insolation changes and the subsequent sea ice changes to the climatic changes. Depending on the remaining resources at this point we will then initiate the ice sheet sensitivity and/or CO_2 sensitivity experiment(s).