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 2014 ……..……

Project Title: Permafrost in a changing climate: Formulating the proper lower boundary condition in EC-Earth ……..……

Computer Project Account: SPDKHESS ……..……

Principal Investigator(s): Jens Hesselberg Christensen ……..……

Affiliation: Danish Meteorological Institute ……..……

Name of ECMWF scientist(s) collaborating to the project (if applicable) ……..……

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Start date of the project: Jan. 1, 2014 ……..……

Expected end date: Dec. 31, 2014 ……..……

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)	N/A		450,000	398,800
Data storage capacity	(Gbytes)	N/A		500	300

Summary of project objectives
(10 lines max)

In climate models a fundamental assumption is often made in the formulation that the lower boundary underlying land surfaces is characterized by a zero flux formulation. As the lowest model level in the soil is often located less than 5 meters below the surface and thus the atmosphere, this is clearly not deep enough to reflect the penetration of transient temperature signals into the deeper layers for cold regions underlain by permafrost (Nicolsky et al. 2007; Christensen et al. 2008). The aim of this project is to investigate the sensitivity of climate response to the zero flux formulation at the lower boundary in the permafrost regions in EC-EARTH.

Summary of problems encountered (if any)
(20 lines max)

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

In the standard EC-EARTH, there is no exchange of geothermal heat (i.e., zero flux) at the lowest boundary everywhere in the model land soil. A study by Lee and Uyeda (1965) had indicated the ground heat flow beneath the land permafrost may be between 40 mW/m^2 for continental shield (i.e., land permafrost) to 60 mW/m^2 for the offshore canyons (i.e., subsea permafrost). We thus replace the zero flux lower boundary condition with a relaxation value of 40 mW/m^2. A new set of climate change experiments following the CMIP5 protocol, starting from the pre-industrial control state of the coupled EC-EARTH and consisting of the historical and future RCP4.5 as well as RCP8.5 scenario, have been carried out using this new setup (hereafter referred to as experiment pmFrost). The experiments are then compared with the CMIP5 experiments using the standard EC-EARTH (hereafter referred to as Ctrl).

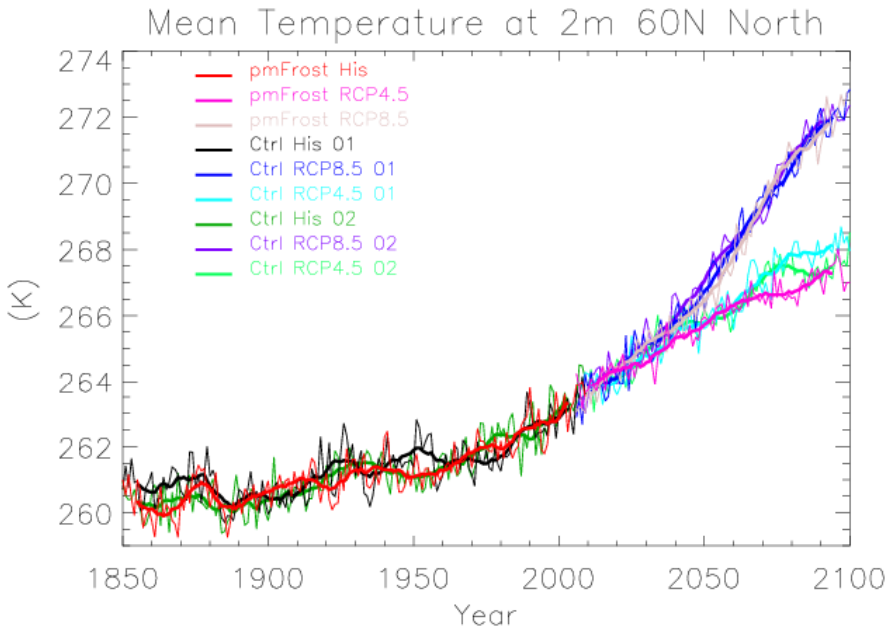

Figure 1. Annual mean (thin lines) near surface temperature averaged over north of 60°N simulated in the climate change (CMIP5) experiments suing the permafrost-sensible version of the EC-EARTH (pmFrost) and the standard EC-EARTH (Ctrl). The CMIP5 experiments evolve the historical period from 1850 to 2005 and following with the future RCP4.5 and RCP8.5 scenarios until year 2100. Two Ctrl CMIP5 experiments (labelled as 01 and 02) are shown in the figure. The thick lines indicate the 11-year running mean. Unit: K.

Figure 1 shows the annual mean near surface air temperature (SAT) averaged over north of 60°N as simulated by pmFrost and two Ctrl (labelled as 01 and 02 in the figure). The simulated SAT evolutions of all three experiment sets are similar in general. However, a close look reveals that the regional averaged temperature in pmFrost is more than a half degree lower than that in the Ctrl-RCP4.5 scenario. The geographic distribution of the SAT differences can be seen in Figure 2. It is evident that the Arctic area is generally about 0.5 – 2.0 K colder in the pmFrost experiment than that in the two Ctrl experiments.

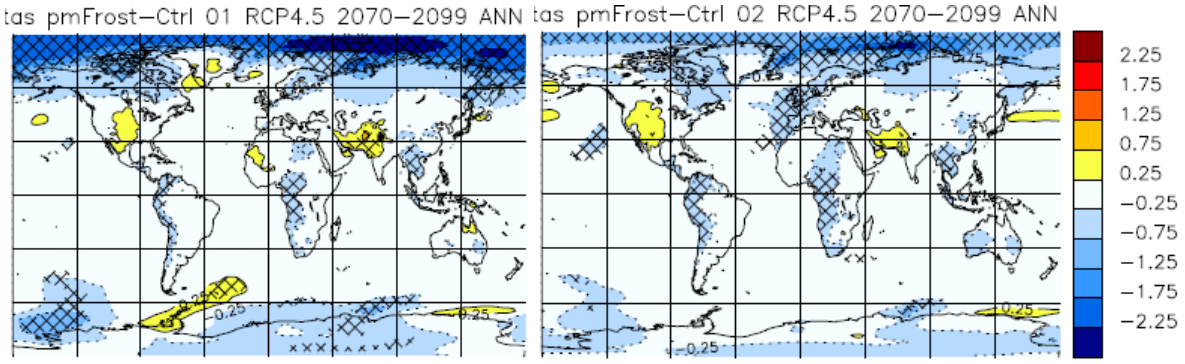

Figure 2. Averaged differences of the annual mean surface temperatures in the period 2070-2099 as simulated in the pmFrost RCP4.5 with respect to the two Ctrl experiments (i.e., Ctrl RCP4.5 01 and Ctrl RCP4.5 02, respectively). The hatched area indicates the significance level exceeding 95%. Unit: K.

It is also interesting to observe in Figure 1 that, in the RCP8.5, the SAT in pmFrost is also somewhat below that in the Ctrl during the large transition period around 2040 to 2060 in the RCP8.5 scenario, even though the SAT in pmFrost follows closely that the Ctrl experiments in general. All these differences may imply that the non-zero flux formulation for the lower boundary can lead to a delay of the warming, in comparison with the traditional zero flux formulation.

List of publications/reports from the project with complete references

Summary of plans for the continuation of the project

In the next stage we will further explore the climate sensitivities due to the different formulation of the lower boundary in the above EC-EARTH simulations. To what extent the difference induced is significant will also be investigated.