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	July 2014 to June 2015
Project Title:	High Resolution Regional climate projections at 2 deg C global warming thresholds
Computer Project Account:	spsejone
Principal Investigator(s):	Colin Jones[1], Gunilla Svensson[2] David Lindstedt[1], Petter Lind[1], Patrick Samuelsson[1]
Affiliation:	[1]Swedish Meteorological and Hydrological Institute (SMHI), [2]University of Stockholm
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….…… ………………………………………………………….……
Start date of the project:	2012-12-31
Expected end date:	2015-12-29

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)	15 million	1.9 million	15 million	0
Data storage capacity	(Gbytes)	50 000	50 000	50 000	0

Summary of project objectives
(10 lines max)

The primary aim is to use a new Regional Climate Model (RCM), based on the HARMONIE NWP model and assess the ability to simulate climate processes at ~6 and 2km resolution which is a necessary step for using the model to simulate climate change.
As part of the EU FP7 project HELIX we will be downscaling an ensemble of high-resolution (T511), 30-year global climate time slices made with the global climate model EC-Earth. These time slices use bias-corrected SSTs and Sea Ice (SIC) derived from CMIP5 coupled simulations of the same model, representative of the recent past and two 30 year periods centred on 2, 4 and 6°C global warming compared to pre-industrial conditions in the RCP8.5 CMIP5 projection. Output from EC-Earth is used to force HARMONIE on a pan-European (Euro-CORDEX) domain, employing a resolution of ~6 km, to develop a set of future warming level time slices. The 6 km HARMONIE simulations will also be used to force smaller HARMONIE domains over sub-regions of Europe run at convection-resolving resolutions (~2km). A key aim is to develop a climate modelling capacity at ‘grey-zone’ resolutions ~ 3-8km and to investigate convection-resolving climate simulations.

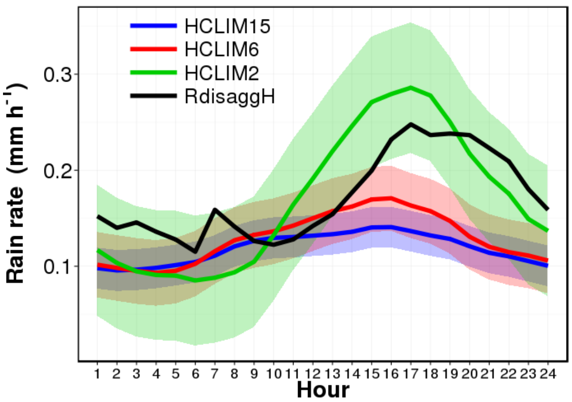
Summary of problems encountered (if any)
(20 lines max)

The technical limitations in HARMONIE for application to climate time-scales have during the past year been mostly resolved, for example the representation of sea-ice and time evolution of greenhouse gases in the model. Also, work has progressed to reduce output from the model as disk space and the volume of data needed both as boundary conditions for HARMONIE and produced as output by HARMONIE in climate mode remains a serious challenge. However, initial test runs with this to-be-operational version showed significant biases in T2m and surface short wave radiation, especially in spring and summer over southern Europe. The surface scheme (SURFEX) was not functioning properly in coupled mode and therefore the scheme was updated with code and settings from a newer development version of SURFEX. This had a major impact on the results, however there were still quite large biases in down-welling short wave radiation at the surface. We have performed tuning exercises wherein an inhomogeneity factor in the radiation scheme was adjusted down and the effect on the results was highly positive. Thus, the model version has now been released to the community as an operational version.

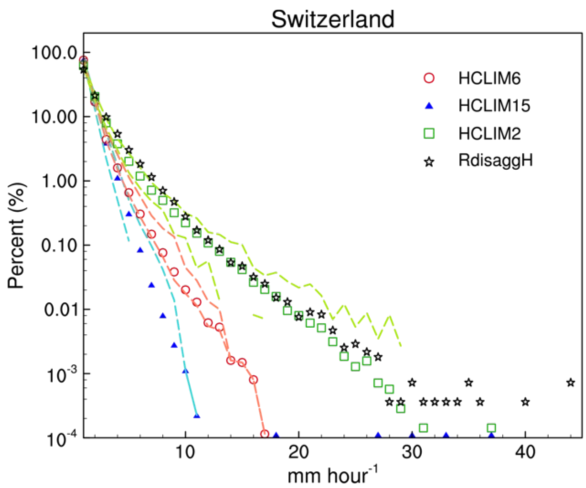
Summary of results of the current year (from July of previous year to June of current year) This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

The overall performance of HARMONIE for present climate conditions, using the Euro-CORDEX domain has been evaluated (link below to Tellus paper). HARMONIE has been run at two resolutions (15km and 6.25km) over the Euro-CORDEX domain, driven by ERA-interim lateral and surface boundary conditions, for the period 1997-2008 inclusive. The coarser resolution version allows us to compare HARMONIE performance to our present RCM (RCA4) and to other European RCMs run in Euro-CORDEX at an equivalent resolution forced by ERA-interim. The two HARMONIE resolutions allows us to assess benefits accruing from the increased resolution in a common model. After the overall performance was established we investigated to what extent the higher resolution provides an improved representation of higher order regional climate statistics such as intense precipitation events. Results from this investigation have been peer-reviewed and published in Tellus A (a link to this article is added to the List of publications section).

HARMONIE contains of a number of physics packages, specifically developed for different resolution ranges. In this project we concentrate on the ALARO physics, nominally developed for grey-zone resolutions (~3-10km) and the AROME physics, applicable to convection-permitting resolutions (~1- 3km). We have during the past year assessed the performance and added-value of going to convection-resolving resolutions, within the HARMONIE configuration, concentrating on summer season precipitation over the Alps. We chose the Alps due both to the extreme topographic forcing of precipitation and because a well-documented, high-resolution observed precipitation data set is available for model evaluation. We have run HARMONIE, on the full Euro-CORDEX domain, for 7 summer seasons (May-September inclusive) spanning a range of representative summer precipitation outcomes over the Alps. HARMONIE is run at the two resolutions; 15km and 6.25km, with the output from the 15km model used in a double-nesting step to force an inner HARMONIE domain at 2km resolution centred on the Alpine region. This interior domain is run for the same 7 summer seasons using the AROME physics. Such an experiment protocol allows us to evaluate simulated precipitation statistics in the 3 HARMONIE versions; 15km, 6.25km and 2km (the latter forced by the 15km HARMONIE) over the common Alpine region. This set of simulations has now been analysed, looking at precipitation variability and extremes, as well as the spatial and temporal aspects of precipitation events. The results show a clear improvement in several aspects when using explicit treatment of deep convection. Most notably, the spatial frequency and duration of high-intensity localized convection events are much better captured than the runs using parametrized convection when compared to high-resolution observations. A manuscript has been prepared (submitted to this report) and will be submitted by early July 2015. Planned near-future studies involves testing both ALARO and AROME at convection-permitting resolutions (< 3km), which allows an assessment of the relative benefits of both schemes at high resolution, contrasting this with the importance of physics consistency across the lateral boundaries of an interior domain such as the small Alpine domain, with ALARO physics used in a coarser resolution driving model.



Diurnal cycle of precipitation in Switzerland for HARMONIE-Climate (HCLIM) at 3 resolutions: 15 km (blue), 6km (red) and 2 km (green, AROME). Black is high-resolution gridded observations.



Empirical probability density functions of rainfall for HCLIM at 3 resolutions contrasted to observations in black. The stippled lines are the 95% confidence intervals.

List of publications/reports from the project with complete references

Lindstedt, D., Lind, P., Kjellström, E., and Jones, C.: *A new regional climate model operating at the meso-gamma scale; performance over Europe*. Tellus A 2015, **67**, 24138, http://dx.doi.org/10.3402/tellusa.v67.24138

Lind, P., Lindstedt, D., Kjellström, E., and Jones, C.: *The benefit of convection permitting horizontal resolution in a climate model for the representation of summer precipitation in the Alp region. (To be submitted to Journal of Climate)*

Oral presentations and posters

The benefit of convection permitting horizontal resolution in a climate model for the representation of summer precipitation in the Alp region.
Petter Lind, David Lindstedt, Colin Jones, and Erik Kjellström
http://meetingorganizer.copernicus.org/EGU2014/EGU2014-13319.pdf

Pan-European climate simulations using the HARMONIE limited area model - the benefit of "grey zone" horizontal resolution for precipitation and its extremes.
Petter Lind, David Lindstedt, Colin Jones, and Erik Kjellström
http://meetingorganizer.copernicus.org/EGU2014/EGU2014-13239.pdf

Very high-resolutions climate runs over Europe; an evaluation
David Lindstedt, Petter Lind, Colin Jones, and Erik Kjellström
http://cordex2013.wcrp-climate.org/posters/P1_43_Lindstedt.pdf

Summary of plans for the continuation of the project

(10 lines max)

A model version for multi-decadal simulations is now ready for use and the intended, high-resolution HARMONIE time slices for Europe, forced by EC-Earth data, will be started during summer of 2015. However, the first step is to run the model driven by ERA-interim for a 30 year period and evaluating mean climate, since so many parts of the model have been updated. Depending on progress made with these time slices we also aim to apply the same HARMONIE 6.25km configuration using both ERA-interim and EC-Earth boundary data to East Africa. Here we aim, in particular, to study potential changes in the precipitation variability, drought and flood risks, at specific warming levels.