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	2016
Project Title:	The Impact of Stochastic Parametrisations in Climate Models: EC-EARTH System Development and Application
Computer Project Account:	spgbtpsp
Principal Investigator(s):	Prof Tim Palmer Dr Hannah Christensen Dr Andrew Dawson Dr Stephan Juricke Dr Dave MacLeod Dr Aneesh Subramanian Dr Peter Watson
Affiliation:	University of Oxford
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Antje Weisheimer
Start date of the project:	Jan 2015
Expected end date:	Dec 2017

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)			9,600,000	497,945
Data storage capacity	(Gbytes)			7,000	

Summary of project objectives

The central aim of the project is to implement stochastic parametrisation schemes in multi-year integrations of the EC-Earth climate model and investigate their impacts on the modelled climate. Oxford University recently joined the EC-Earth Consortium. Because the EC-Earth model is based on System 4, all development done so far at Oxford for System 4 will be tested and implemented within the EC-Earth system. Once the stochastic parametrisations have been implemented in the EC-Earth system, the impact of stochastic parametrisations on the coupled model mean state and variability can be investigated.

Summary of problems encountered (if any)

N/A

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

From November 2015, the University of Oxford has been collaborating on the H2020 project PRIMAVERA (PRocess based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment). Within this project, we are considering the impact of stochastic parametrisation schemes in the atmosphere, ocean, land surface, and sea ice models on the simulated climate of EC-Earth. We are using our special project spgbtpsp to support our contribution to PRIMAVERA.

In PRIMAVERA there are several EC-Earth partners. While other partners will be running the deterministic EC-Earth model at different horizontal resolutions, our unique contribution is to perform EC-Earth integrations including stochastic parametrisation schemes. The decision was made to use the CMIP6 release of EC-Earth for all PRIMAVERA integrations: EC-Earth 3.2 (beta). This decision has caused us some delays, as the CMIP6 version was not ready at the start of PRIMAVERA, and was only available for use in Spring 2016.

EC-Earth configuration changes

In order to prepare for experiments using EC-Earth 3.2 at ECMWF it was necessary to make some changes to the EC-Earth configuration. Modifications were made to the EC-Earth run-time configuration system that ensure users of EC-Earth 3.2 at ECMWF could use the model without having to modify their default user environment. The resulting configuration changes have been integrated back into the main EC-Earth 3.2 release, and as a result the stock EC-Earth 3.2 version can be compiled and run on ECMWF machines (using Intel compilers) without any changes to the build/run configurations outside of those normally required to control the model behaviour. Assistance from ECMWF staff members Souhail Boussetta and Dominique Lucas was helpful while working on this task.

Development and porting of stochastic parametrisation schemes

The decision to use EC-Earth 3.2 necessitated the porting of our stochastic parametrisation schemes to the new model version. Three stochastic schemes required porting: stochastic perturbation of parameters in the land surface scheme HTESSEL (MacLeod et al 2015); stochastic parametrisation of sub-grid mixing in the NEMO ocean model (Juricke et al, in prep); a generalisation to the Stochastically Perturbed Parametrisation Tendencies (SPPT) scheme, ‘independent SPPT’ (Christensen et al, in prep). This work has now largely been completed. Testing of these three schemes has been carried out separately in medium range and seasonal forecasts in the IFS and NEMO (detailed below). However, we have not yet started testing these schemes in EC-Earth. Over the coming month we will start testing these schemes. Once tested in EC-Earth, we will start our climate integrations. We anticipate that we will rapidly use the units assigned to us for this project.

Stochastic land surface scheme

Hydrological parameters in the land surface model HTESSEL have a large uncertainty, despite being represented deterministically in the model (MacLeod et al 2015, MacLeod et al 2016). Previous work done as part of the 2014-2016 special project spgbweis: "Incorporating land-surface model uncertainty into the IFS" has investigated the impact of explicitly representing the uncertainty in two key parameters: the van-Genuchten alpha and saturated soil conductivity, focusing on seasonal scales (see previous progress reports for details). This work focused on the seasonal timescale using IFS and demonstrated that improved representation of hydrological parameter uncertainties led to improved seasonal forecasts, including representation of the 2003 European heatwave (MacLeod et al 2015). It also showed that the uncertainty in hydrological parameters has a significant but variable impact on soil moisture memory (MacLeod et al 2016). In the coming months we propose to investigate the impact of perturbation of the same parameters in EC-EARTH on climate timescales.

Stochastic ocean mixing

We have investigated the impact of introducing stochastic perturbations to different parametrisations of sub-grid scale mixing in the ocean model component of EC-Earth. The perturbations represent unresolved sub-grid scale variability not captured by commonly used deterministic parametrisations. Even though the perturbations act on sub-seasonal to seasonal timescales, low frequency variability is affected on inter-annual and longer timescales. In uncoupled ocean-only simulations these perturbations improved the representation of low frequency variability in the ocean for state variables such as sea surface height when compared to observations. Additionally, we have tested these stochastic schemes in a coupled setup of the ECMWF seasonal forecasting System 4 with the help of Antje Weisheimer. The aim was to show that these schemes can also be used as a measure of ocean model uncertainty. Inclusion of the stochastic parametrisations has increased model spread in 10 month forecasts by up to 30 percent, depending on the variable that is diagnosed. Since the configuration of System 4 is relatively close to the configuration of EC-Earth 3.1, these findings help to improve our understanding of the impact of the stochastic schemes in coupled climate simulations.

Independent SPPT

We have investigated a generalisation to the Stochastically Perturbed Parametrisation Tendencies (SPPT) scheme in collaboration with Sarah-Jane Lock. The “independent SPPT” (iSPPT) scheme uses independent spectral patterns to perturb each of the physics tendencies, instead of perturbing the sum of the tendencies with a single pattern as in SPPT. The scheme has been tested in medium-range weather forecasts in the IFS where it has been shown to have a beneficial impact on the spread of the forecasts. In some cases, the iSPPT scheme lead to over-dispersive ensembles. However, the scheme is very flexible with many tuneable parameters which allow the characteristics of the random pattern (magnitude, correlations etc) to be specified separately for each process. Little tuning has been performed so far, though one alternative that has been considered is perturbing all the moist processes with one pattern, while the dry processes are perturbed with a separate pattern. This partially independent SPPT improves scores for most variables in both the tropics and extra tropics. The iSPPT scheme has been ported to EC-Earth. Testing is underway to establish if the scheme is as beneficial in longer climate integrations as it is in medium range forecasts.

Preliminary Results for Climate SPHINX

In parallel to this project, we have been collaborating on the Climate SPHINX (Stochastic Physics HIgh resolutioN eXperiments) PRACE (Partnership for Advanced Computing in Europe) project. This is a comprehensive set of ensemble simulations that have been completed over the past year. The main goal of the project is to evaluate the sensitivity of present and future climate to model resolution and stochastic physics. The simulations are performed with the EC-Earth Earth-System Model, so the experience gained from these simulations will be invaluable for our special project. Ensemble runs over a 30-year climate integration period is performed at five different resolutions (from coarse 125 km up to 16 km high resolution). All model runs were performed with and without stochastic physics active. The model runs produced about 140 TBytes of post-processed data and are stored on a remote server for access from CINECA supercomputing centre.

We have evaluated these model runs for the impact of stochastic physics on tropical climate variability. In a recent publication under review, we show that including stochastic physics parameterization helps improve propagation of tropical intra-seasonal oscillations such as the Madden Julian Oscillation and also the amplitude distribution of rainfall in the Tropics especially at the low resolution. Some of this analysis was done with the help of the computing resources provided on the ECMWF supercomputing facilities under this special project.

We are further analysing these runs to understand the mechanisms by which stochastic physics helps improve the representation of the tropical variability in climate models. This work is in progress and will be written up as a manuscript for peer review in the coming year.

Results dissemination and impact

We have presented our results at a number of national and international meetings including:

EC-Earth meeting, Rome, 2nd-3rd February 2016
ECMWF Model Uncertainty Workshop, 11th-15th April 2016

List of publications/reports from the project with complete references

MacLeod, D. A., Cloke, H. L., Pappenberger, F. and **Weisheimer, A.** (2015), Improved seasonal prediction of the hot summer of 2003 over Europe through better representation of uncertainty in the land surface. Q.J.R. Meteorol. Soc., 142: 79–90. doi: 10.1002/qj.2631

MacLeod D. A., Cloke H. L., Pappenberger F and **Weisheimer A,** (2016) Evaluating uncertainty in estimates of soil moisture memory with a reverse ensemble approach, HESS (accepted, see http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-28/ for discussion paper).

Davini, P., J. von Hardenberg, S. Corti, **H. M. Christensen, S. Juricke, A. Subramanian, P. A. G. Watson, A. Weisheimer,** and **T. N. Palmer**, 2016: Climate SPHINX: evaluating the impact of resolution and stochastic physics parameterisations in climate simulations. Geoscientific Model Development, In review.

Subramanian, A. C., A. Weisheimer, T. N. Palmer, P. Bechtold, F. Vitart, 2016: Impact of stochastic physics on tropical precipitation and climate variability in the ECMWF IFS. Quarterly Journal of the Royal Meteorological Society, In review.

Juricke, S., T. N. Palmer, and L. Zanna, in preparation for Journal of Climate: Stochastic parametrizations of sub-grid scale ocean variability: Impacts on low frequency variability.

Christensen, H. M., Lock, S.-J., Moroz, I. M. and **Palmer, T. N.**, in prep. Targeting uncertainty in individual parametrisation schemes: the Independent Stochastically Perturbed Parametrisation Tendencies approach

SAC Topic Paper on Model Uncertainty: authors include **Christensen, Subramanian, Weisheimer**

Summary of plans for the continuation of the project

(10 lines max)

Having ported our code changes to EC-Earth, and successfully set up the PRIMAVERA version of the model to run on the CRAY, we are now able to evaluate the impact of our schemes in EC-Earth. We anticipate rapid progress will be made over the coming months.