SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2019
Project Title:	The Impact of Stochastic Parametrisations in Climate Models: EC-EARTH System Development and Application
Computer Project Account:	spgbtpsp
Principal Investigator(s):	T. N. Palmer K. J. Strommen H. M. Christensen S. Juricke D. MacLeod A. Weisheimer
Affiliation:	University of Oxford
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Antje Weisheimer
Start date of the project:	2018-01-01
Expected end date:	2020-12-31

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)	13,000,000	13,000,000	17,000,000	4,500,000
Data storage capacity	(Gbytes)	6000	6000	10,000	2000

Summary of project objectives (10 lines max)

The implementation of new stochastic schemes into EC-Earth, and diagnosing their impact on the climate of the system, including mean state, overall variability, and important circulation features such as ENSO, the Asian monsoon, North Atlantic regimes, and teleconnections between these. Ultimately, the aim is to tune the model with an optimal combination of stochastic schemes to obtain a stochastic version of EC-Earth which is a notable improvement of the deterministic version. These goals are attained through carrying out suitable climate integrations of EC-Earth using the special project units.

Summary of problems encountered (10 lines max)

Some technical problems were encountered relating to data volume. The processing of the raw model data requires software installed with Anaconda, which requires a large number of files. This was originally placed on SCRATCH for this reason, but the file deletion system eventually made this fail. After liaising with ECWMF, the number of permitted files on PERM was increased, allowing us to place the post-processing software on PERM instead.

Summary of plans for the continuation of the project (10 lines max)

A number of simulations have been carried out so far, consisting of ensembles of climate integrations of EC-Earth with different configurations of stochastic schemes. One further configuration is currently being finished. After this, we will be extending the most promising configurations out further. We are also planning on testing the impact of our stochastic ocean schemes in an integration with a high-resolution (1/4 degree) ocean component (current integrations use a 1 degree ocean).

List of publications/reports from the project with complete references

Strommen, K., H. M. Christensen, D. MacLeod, S. Juricke, T. N. Palmer (2019), Introducing the Probabilistic Earth-System Model: Examining The Impact of Stochasticity in EC-Earth v3.2, accepted with minor corrections at *Geoscientific Model Development*; https://doi.org/10.5194/gmd-2018-337

Strommen, K., P. A. G. Watson, T. N. Palmer (2019), The impact of stochastic physics on climate sensitivity in EC-Earth, under review at *Journal of Geophysial Research: Atmospheres*; preprint available at https://arxiv.org/abs/1905.06613

Summary of results

This round of the project began in January of this year, so the primary scientific results are still associated with data produced in the previous round of the project. In this reporting period, the primary achievement was to complete a set of ensemble simulations which were initiated last year. These consisted of 65 year integrations of EC-Earth in coupled mode. Four configurations of EC-

Earth were considered: deterministic control configuration (no stochasticity), SPPT only, stochastic ocean and sea-ice only, and fully stochastic (independent SPPT scheme, stochastic ocean and sea-ice, stochastic H-Tessel land scheme). These were completed, processed and fully transferred back to local storage servers by the end of March 2019.

One result which became apparent from a preliminary look at this data was that the fully stochastic configuration had an overly strong ENSO, producing El Nino events with anomalies approaching 3K regularly. This was attributed, by comparison with other experiments, to the new independent SPPT (ISPPT) scheme, which had never been tested before in long coupled simulations. As a result of this, we decided to add a 5^{th} configuration, replacing ISPPT with the regular SPPT scheme; since SPPT did not alone produce excessively large ENSO events, this was deemed likely to produce a better model climate. The first such ensemble member of this experiment has completed in the last week, confirming this. This configuration therefore represents our first stable version of a fully stochastic EC-Earth.

Initial analysis of the configurations suggests notable improvements to the mean climate of EC-Earth compared to the deterministic control version. Two examples are shown below for precipitation (Figure 1), where the classic split ITCZ bias is reduced to an extent comparable with a high-resolution (T511) version of the model, and total cloud cover (Figure 2). Analysis on the influence of stochasticity on Euro-Atlantic regimes has also been undertaken in collaboration with colleagues at ISAC-CNR; stochasticity tends to improve both the level of clustering and, for some configurations, the regime patterns: this is work in progress.

Further analysis on these aspects, as well as the other climate aspects discussed in the Project Summary (above) will begin in earnest in the next reporting period, now that all the model data is ready.

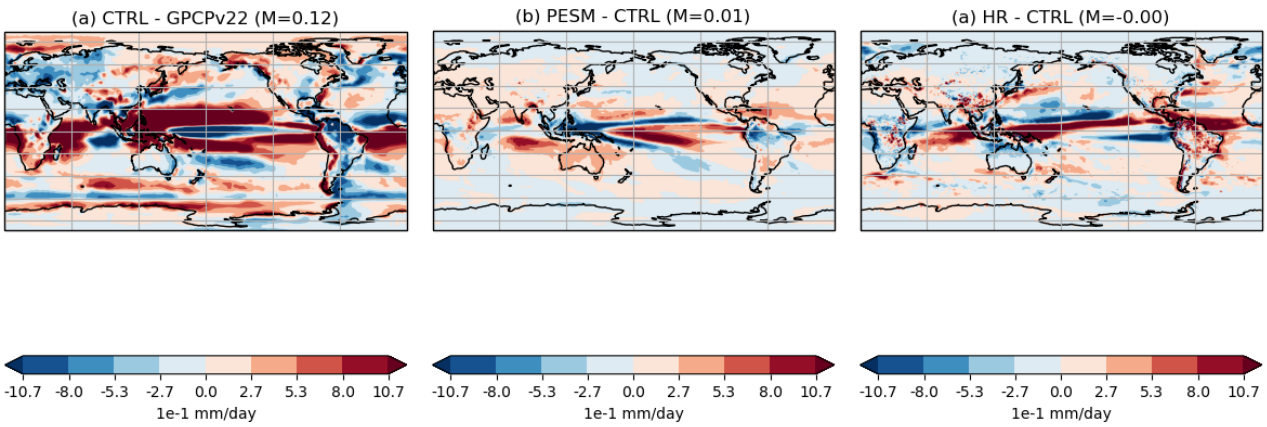

Figure 1: Impact of turning on stochasticity in all EC-Earth components (the `PESM' configuration) on monthly mean precipitation; (a) deterministic CTRL minus GPCP; (b) Fully stochastic model minus CTRL; (c) High-resolution (T511) deterministic model minus CTRL.

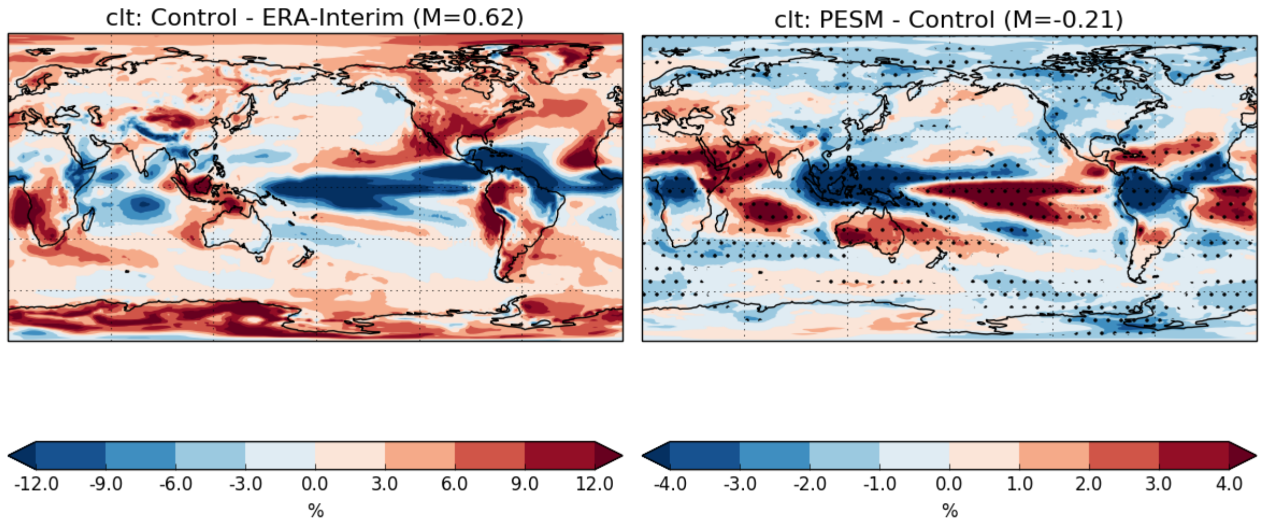

Figure 2: Impact of turning on stochasticity in all EC-Earth components (the `PESM' configuration) on monthly mean total cloud cover; (a) deterministic CTRL minus ERA-Interim; (b) fully stochastic model minus CTRL. Stipling indicates changes exceed a 95% confidence interval around the null hypothesis of no change.