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	2018
Project Title:	High Resolution EC-Earth Simulations
Computer Project Account:	spienola
Principal Investigator(s):	Dr Paul Nolan Dr Sarah Gallagher
Affiliation:	Climate Research Department, Met Éireann
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	01/01/2016
Expected end date:	31/12/2018

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)	16 million	~16 million	16 million	~8 million
Data storage capacity	(Gbytes)	22,000	22,000	22,000	12,000

Summary of project objectives

The goal of the research project is to simulate the effects of climate change at the global scale. The first component of the research involved tuning and testing the new version (3.2.3) of the EC-Earth Earth System Model (ESM) in preparation for the upcoming Coupled Model Intercomparison Project Phase 6 (CMIP6) contributions. Once the testing phase was complete, it was planned to run a number of EC-Earth production runs. However, the EC-Earth community have delayed the start of the CMIP6 simulations due to problems with the newest version of the model. Because of these delays, the PI used the resources of the Special Project (spienola) for long-term (~100s years) tuning experiments, validation/test simulations and model development. The bugs are nearly completely fixed and the CMIP6 production simulations will start in the summer of 2018.

Summary of problems encountered (if any)

The EC-Earth community have delayed the start of the CMIP6 simulations due to problems with the newest version of the model. The PI has assisted with the community effort of model development and bug fixing, and to this end, has run and analysed a number of century-long test/tuning simulations (see below section). The problems with the EC-Earth model have been identified and are expected to be completely fixed during the summer of 2018.

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

1. Scale-Testing of latest version of EC-Earth

The EC-Earth model (v3.2.2/3) was implemented on the ECMWF (cca), PRACE (Beskow) and local ICHEC machines. The Intel compilers with the standard EC-Earth compile flags were used on each machine.

The following strategies were tested:

- number of IFS cores = number of Nemo cores. One node each for xios and runoff.
- number of IFS cores = 2 x Nemo cores. One node each for xios and runoff.

Scaling results for a one-month simulation (T255T91, ORCA1L75) on the ECMWF and Beskow (PRACE) machines are presented in Figure 1. In each case, one node (32 & 36 cores for Beskow and ECMWF cca, respectively) was used for both xios and rnfmapper. The scaling results demonstrate the feasibility of running a large ensemble of CMIP6 production runs. Furthermore, the analysis establishes the optimal number of CPUs to request per run, while striking a balance between run-time and use of computational resources. The T511-ORCA025L75 EC-Earth configuration was also scale-tested and was found to be approximately 12 times more computationally expensive compared to T255-ORCA1L46. The scaling results have been shared with the EC-Earth community.

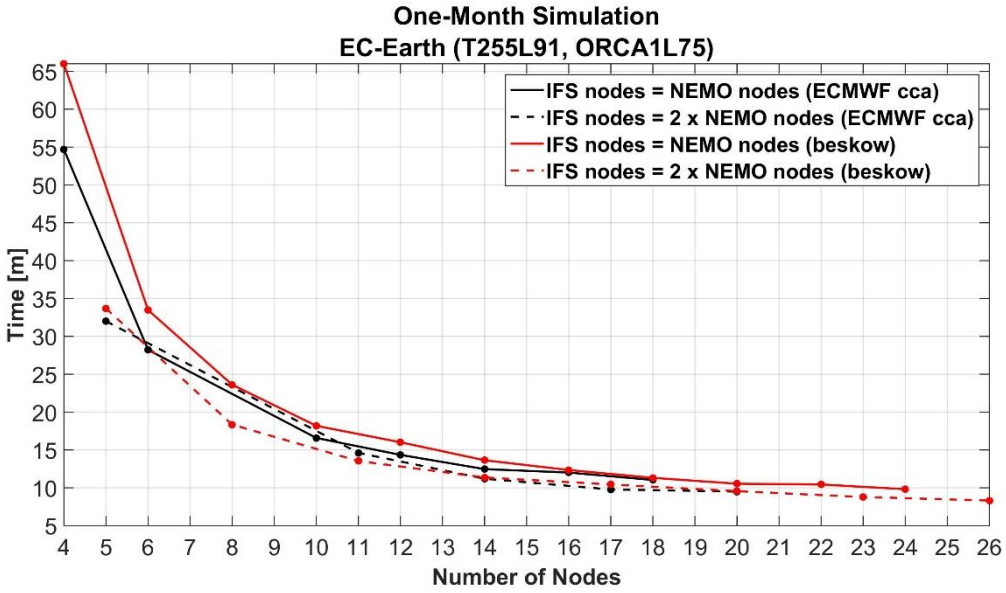

Figure 1. *EC-Earth (T255L91, ORCA1L75) scaling results on ECMWF (cca) and Beskow for a one-month simulation.*

2. Model Testing and Tuning

During the period under review, the PI was actively involved with the EC-Earth tuning group. A number of long-term simulations (~6x100 years) were carried on the ECMWF systems with the aim to determine the source of the remaining EC-Earth bugs and assist with the tuning effort. In particular, the PI worked closely with the EC-Earth community to investigate two issues; the under-estimation of the global overturning circulation and unrealistic Sea Surface Temperatures (SSTs). The results and output of these long-term tuning/test simulations were shared with the EC-Earth community via the development portal.

In order to locate the source of EC-Earth SST bias, the PI completed two 100-year EC-Earth coupled experiments:

i. Control simulation using zero SSH restart conditions (named f1E3)
ii. Langmuir sensitivity experiment: As above but setting rn_lc=0.30 in namelist.nemo-ORCA1L75-coupled.cfg.sh (named f2E3)

The experiments were run using the most up-to-date EC-Earth version (svn info: "Revision: 5569, Last Changed Rev: 5564, Last Changed Date: 2018-05-23 10:36:33 +0000 (Wed, 23 May 2018)")

The results of the Langmuir sensitivity experiments (f2E3) showed:

- a reduction in the SST warm bias almost everywhere (e.g., see Figure 2), which implies improved North Pacific SSTs but higher biases in the North Atlantic. Antarctic SST bias remains high (see Figure 3).
- a general cooling in the upper ocean (see Figure 4).
- a general warming in the deep ocean (see Figure 4).
- a slightly reduced Atlantic Meridional Overturning Circulation (see Figure 5).

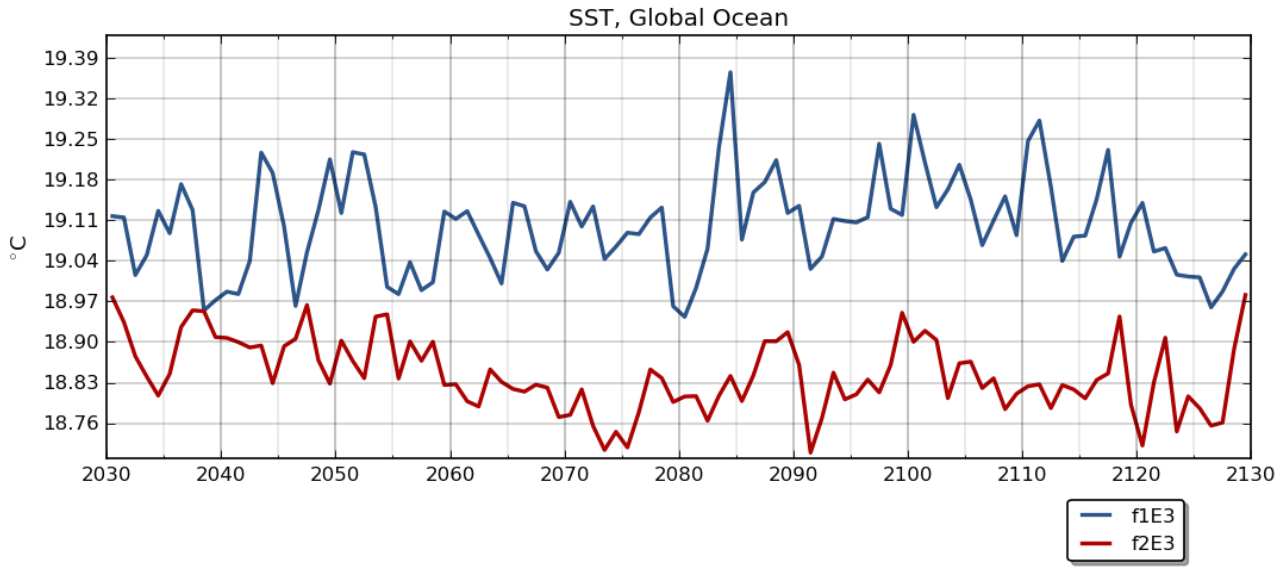

Figure 2. *Global SST as simulated by EC-Earth for experiment 'f1E2' and 'f2E2'*

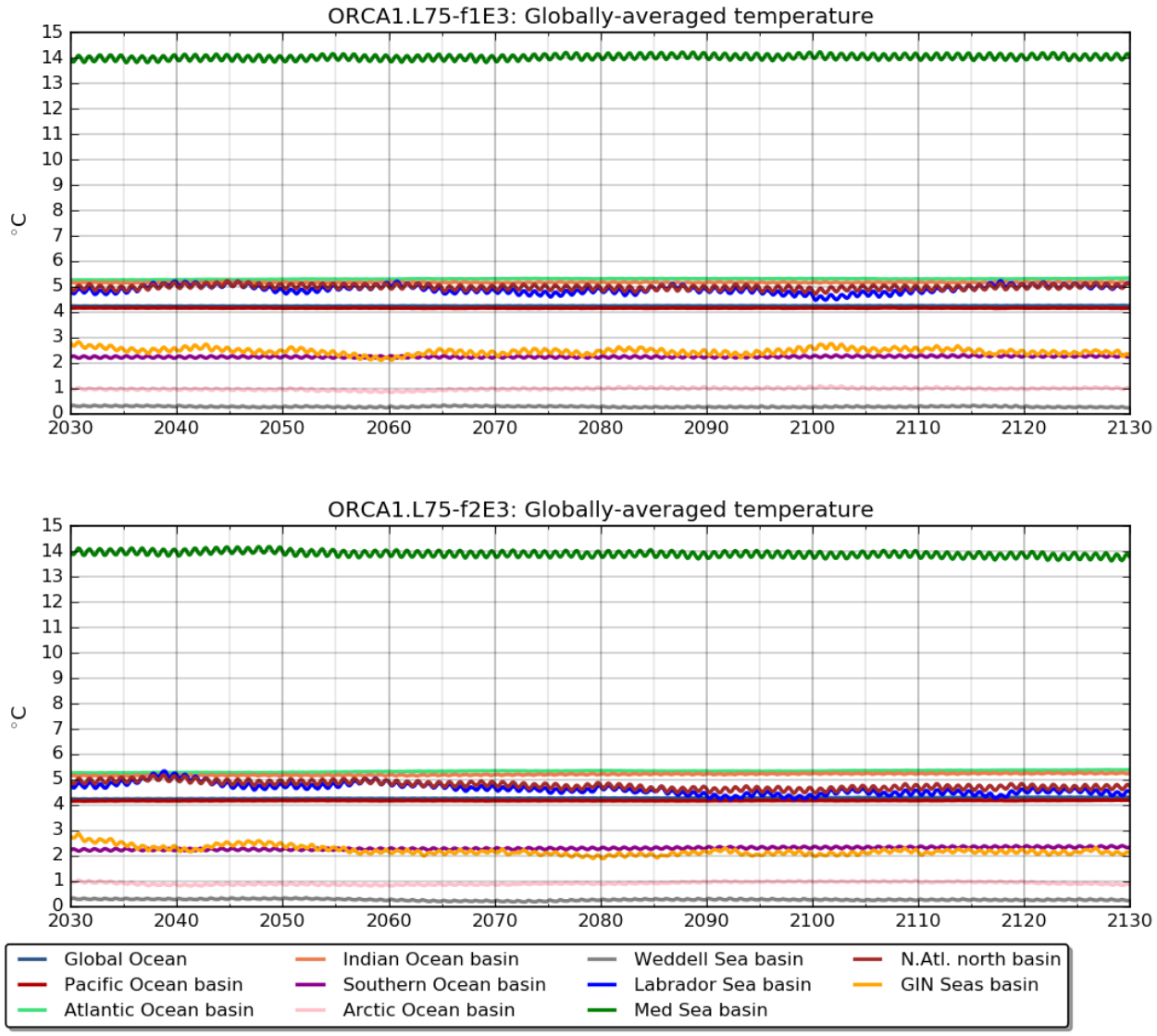

Figure 3. *Global Averaged Surface Temperature as simulated by EC-Earth for experiment 'f1E2' and 'f2E2'*

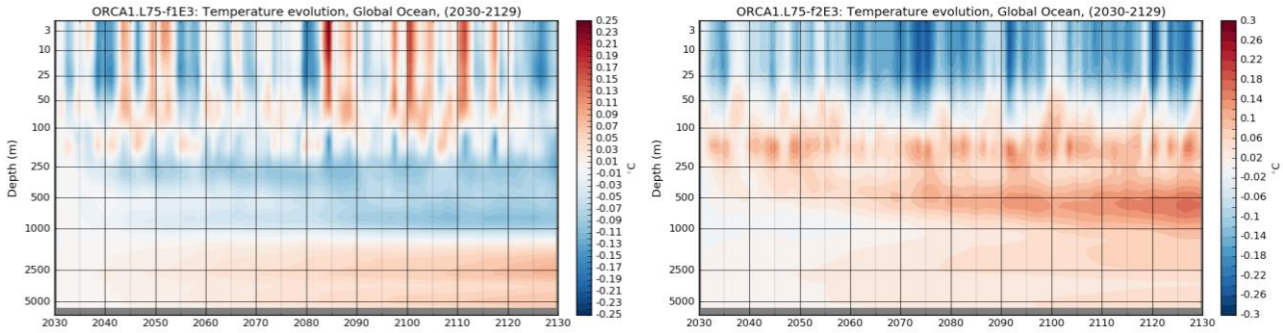

Figure 4. *Evolution of Global Sea Temperature (by depth) as Simulated by EC-Earth for Experiment 'f1E2' and 'f2E2'*

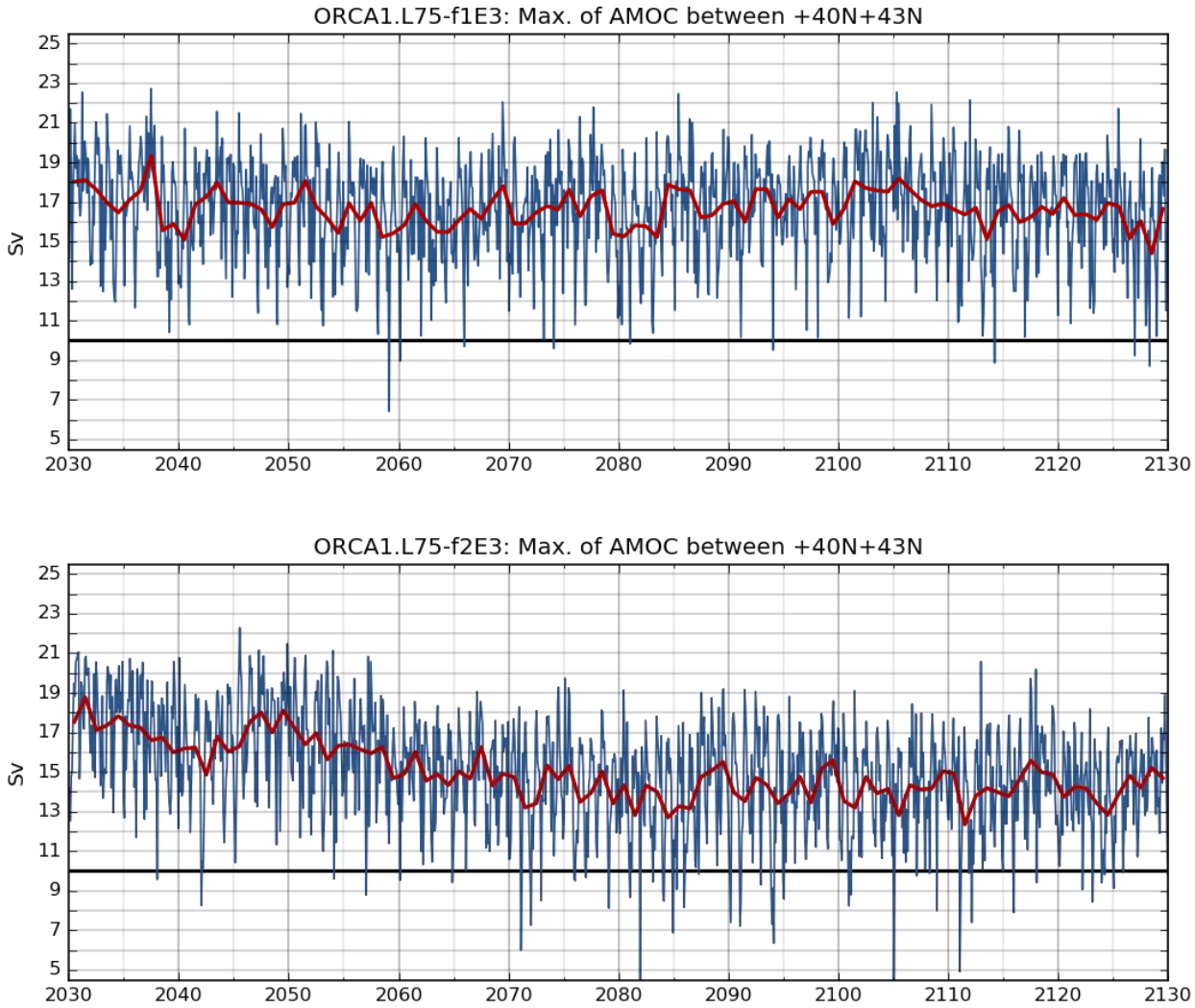

Figure 5. *Atlantic Meridional Overturning Circulation as simulated by EC-Earth for experiment f1E2 and f2E2*

Full analysis, validation and diagnostics plots can be found at:

- https://barakuda.ichec.ie/~pnolan/f1E3/
- https://barakuda.ichec.ie/~pnolan/f2E3/
- https://barakuda.ichec.ie/~pnolan/comp_f1E3_f2E3/

Table 1 presents an overview of "EC-Mean" diagnostics.

EC-Mean diagnostic	Experiment f1E3(2030-2129)	Experiment f2E3(2030-2129)
TOAnet SW	242.2470	241.5981
TOAnet LW	-242.2458	-241.4046
Net TOA	0.0013	0.1935
Sfc Net SW	166.7834	166.4546
Sfc Net LW	-62.1871	-62.3812
SH Fl.	-18.3226	-18.3796
LH Fl.	-85.2733	-84.4898
SWCF	-44.0266	-44.0345
LWCF	26.2815	26.2580
NetSfc	0.2781	0.4645
TOA-SFC	-0.2768	-0.2710
t2m	287.759	287.167
TCC	0.639235	0.640543
LCC	0.346047	0.347772
MCC	0.258621	0.259986
HCC	0.398751	0.399436
TP	2.9271	2.89996
P-E	-0.017651	-0.0176356

Table 1. *Overview of EC-Mean Diagnostics for EC-Earth experiments f1E3 and f2E3.*

The results have been shared with the EC-Earth community and will inform strategies to reduce the EC-Earth SST warm bias.

A second set of simulations were carried out to investigate the issues of the under-estimation of the global overturning circulation as simulated by EC-Earth. A similar analysis was carried out as above and results were shared with the EC-Earth community via the development portal.

We have prepared pre-processing scripts to downscale the CMIP6 EC-Earth data, using the WRF3.9 and COSMO-CLM5 RCMs. These simulations will provide high-resolution regional projections for Europe (Euro-CORDEX) and Ireland using resources from a separate ICHEC HPC project.

We have implemented an experiment to assess the impacts of Methane on global warming. The experiment involves running two long-term (~100 years) EC-Earth simulations; one with actual and one with 2 x Methane concentrations in the atmosphere. These simulations are currently running and results will be submitted for publication in the coming months.

List of publications/reports from the project with complete references
N/A

Summary of plans for the continuation of the project

The EC-Earth tuning work will complete and the CMIP6 productions runs will commence in the coming months. The PI will mostly focus on this research during this period. Specifically, ICHEC/ Met Éireann are committed to running the following EC-Earth CMIP6 contributions:

- 3 x T255-ORCA1L75 AOGCM CMIP6 Historical Simulations, 1850-2014
- 3 x T255-ORCA1L75 for each of the IPCC RCP scenarios (2.6, 4.5, 6.0 & 8.5) 2015-2100 (12 86-year simulations in total)
- 2 x T511L91-ORCA025L75 CMIP6 HighResMIP-2 1951-2050 Simulations (200 years).
- To evaluate the impact of increased resolution, the high resolution experiments will be repeated with the standard CMIP6 T255-ORCA1L75 resolution.

The PI submitted a “Special Project” in June 2018 so as to allow the continuation of these simulation into 2019.