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 (January-June)
Project Title:	Impact of atmospheric stochastic physics in high-resolution climate simulations with EC-Earth
Computer Project Account:	SPITVONH
Principal Investigator(s):	Jost von Hardenberg
Affiliation:	Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR), Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Antje Weisheimer
Start date of the project:	1/1/2016
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)	/	/	25000000	615800 (January-June 2016)
Data storage capacity	(Gbytes)	/	/	50000	-

Summary of project objectives

(10 lines max)

In this special project we plan to explore the impact of Stochastic Physics (in the atmosphere) in long climate integrations as a function both of model resolution and in coupled and uncoupled configurations. Hindcast simulations will allow us to evaluate if there is sensible improvement in the model climate due to stochastic parameterizations. Future scenarios which will allow us to answer another question: what is the expected impact of stochastic parameterizations on future scenarios, under a different anthropogenic forcing? Atmospheric stochastic parameterizations have not been tested extensively, up to now, for long climate runs. Particular attention will be placed to the tuning of the model using the SPPT atmospheric stochastic parameterization for climatic applications, with the goal of reaching a realistic representation of the main radiative fluxes and conservation of energy and humidity in the atmosphere.

Summary of problems encountered (if any)

(20 lines max)

No specific problem. Some resources will be dedicated to perform scaling tests and find model configurations optimal for the new Broadwell architecture on cca.

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

As planned in the project proposal, activities in the first 6 months have been dedicated mainly to tuning of the atmospheric model, particularly of the version with stochastic physics.

Model tuning

Energy and mass conservation in stochastic physics

Part of the preliminary tuning activities have focused on the specific case of stochastic physics: the standard SPPT and SKEB schemes were designed for use at NWP timescales. When implemented in a climate model, the SPPT scheme in particular showed a strong imbalance which involves the water cycle, with a negative P-E that was ten times larger than in the deterministic model, associated with an anomalous latent heat flux and a negative net surface flux of about $2W/m^2$. This was mainly because the SPPT scheme was not designed specifically to conserve water vapour, leading to a water vapour sink in the atmosphere. We developed a fix, requiring that the global average of the tendencies (i.e. winds, temperature and more importantly specific humidity) before and after the SPPT perturbation is conserved. The new scheme removes the imbalance in P-E, which is now equal to that in the run where the SPPT scheme is disabled. Fig. 1 reports shows the improvement in the P-E imbalance in a 10-year long run.

However, we notice that the SPPT scheme still leads to a negative bias in the surface heat fluxes of about 0.8 W/ m^2, likely caused by a different distribution of the cloud cover, which will be further investigated..

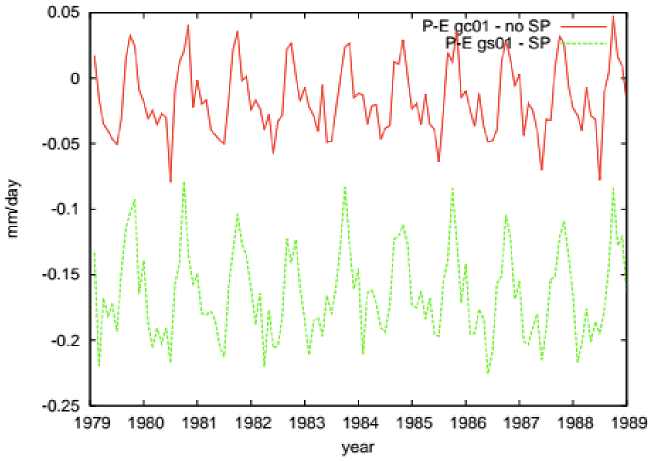

Figure 1: Precipitation-Evaporation imbalance in SPPT runs with (red) and without the fix discussed above.

This activity has led to further work (in collaboration with Antje Weisheimer, Simon Lang, Linus Magnusson and Massimo Bonavita at ECMWF) to implement the same SPPT fix also in a recent cycle of IFS.

The enclosed Research Department Memorandum describes more in detail the fix and presents the results of forecast experiments.

Model radiative imbalance

With respect to the previous version (v3.0.1), EC-Earth 3.1 and EC-Earth 3.2 show a reduced radiative imbalance and an improved hydrological cycle. However they still exhibit a cold bias in both its atmosphere-only and coupled configuration and a small imbalance in precipitation minus evaporation (P-E). In a “present day” AMIP configuration, the model is too cold, extracting heat from the underlying sea surface temperatures (SST) by about $1.5W/m^2$ and showing unrealistically high values for net SW and LW fluxes at TOA (around 243-244 W/m^2). Thus the first goal of the tuning was to provide reasonable radiative fluxes at TOA and at the surface for the standard deterministic version of the model (T255, see next paragraph for further description on the configurations adopted).

To improve the radiation budget, some of the convection and microphysical parameters from a more recent version of IFS (cy40r1) were retrieved. In addition to this, two standard tuning parameters have been modified (see Mauritsen et al., 2012): the entrainment rate for organised convection (ENTRORG) was reduced from $1.75\cdot10^4$ to $1.5\cdot10^4$, and the rate of conversion of liquid water to rain (RPRCON) was reduced from $1.4\ 10^3$ to $1.2\ 10^3$.

The optimal choice of tuning parameters provides reasonable fluxes at the TOA (around 240 W/m^2) and a positive flux at surface of about $0.6W/m^2$, in accordance with the best estimates from observations (e.g. Wild et al., 2013). Up to now the tuning of the radiative fluxes has been carried out only for the T255 deterministic model version.

The main radiative fluxes resulting after the complete tuning procedure are reported in Table 1 for a series of experiments at variable resolutions. As shown in this table, the radiative balance of the model at higher resolution (and with stochastic physics) shows larger TOA SW and LW fluxes with increasing resolution. Net surface fluxes are highly variable, with higher values for coarser resolutions.

Simulation	Net Sfc	Net TOA	TOA SW	TOA LW
T159D	1.57	1.22	239.93	238.71
T159S	0.75	0.33	239.32	238.99
T255D	0.67	0.41	240.23	239.82
T255S	-0.16	-0.49	239.65	240.14
T511D	0.16	1.05	241.50	240.44
T511S	-0.75	0.19	241.07	240.88
T799D	-0.12	1.16	242.10	240.94
T799S	-0.82	0.47	241.78	241.31
T1279D	-0.09	1.44	242.58	241.14
T1279S	-1.09	0.41	242.16	241.74

Table 1. Radiative fluxes expressed in W/m^2 for experiments at different resolutions. D stands for deterministic simulation, S for stochastic. Fluxes have been tuned for T255D.

Non-orographic gravity wave drag

Further tuning has been performed, as planned, in order to produce a realistic Quasi-Biennial Oscillation (QBO) also at higher resolutions. The EC-Earth 3 non-orographic gravity waves scheme is characterised by a momentum flux that is continuously launched at in the mid-troposphere to simulate the effect of gravity waves. The latitudinal profile of this momentum flux governs the correct parameterisation of gravity waves: a too high amplitude of the momentum flux will disturb the QBO in equatorial zones, particularly at high resolutions, while a too low value will lead to unrealistic eddy-driven jets, especially in the southern hemisphere, where orographically induced wave drag is low. With the current latitudinal profile, the QBO was simulated only at standard resolution (T255 with 91 vertical levels). Following advice from ECMWF staff, a resolution-dependent parameterisation of non-orographic gravity wave drag replaced the version-dependent parameterisation present in EC-Earth 3. Namely, instead of using a low momentum flux average value (GFLUXLAUN=0.02) with a positive Gaussian peak at 50°S, we use a higher value (GFLUXLAUN=0.0375) which is reduced with a Gaussian shape at the equator. This negative peak is slightly deeper for stochastic runs than for deterministic simulations to compensate the effect of the stochastic noise. The average value of the momentum flux was further reduced with increasing resolution (starting from T799) according to the ECMWF specification for IFS cy40r1. The new non-orographic gravity wave scheme allows now the simulation of the QBO also at higher resolutions, without deteriorating the jet streams (see Fig. 3).

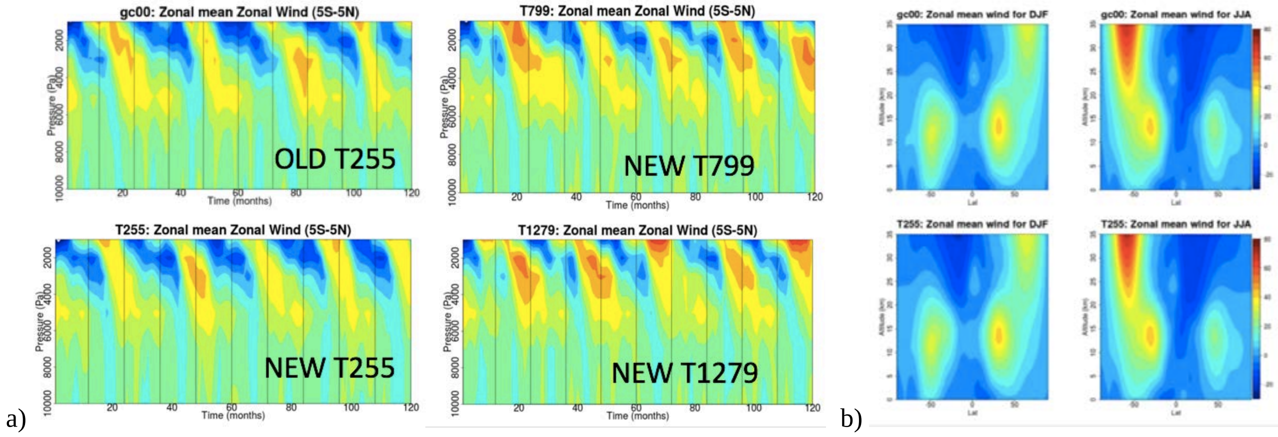

Figure 3: Improved representation of the QBO in the model at different resolutions. Panel a) shows equatorial mean zonal wind profiles at different model resolutions. Panel b) shows that the changes do not affect significantly the model zonal mean winds.

List of publications/reports from the project with complete references

- S. Lang, A. Weisheimer, J. von Hardenberg, L. Magnusson, M. Bonavita. Modification of SPPT to improve global conservation properties of momentum, energy and moisture. ECMWF Research Department Memorandum, May 2016.

- Davini, P., von Hardenberg, J., Corti, S., Christensen, H. M., Juricke, S., Subramanian, A., Watson, P. A. G., Weisheimer, A., and Palmer, T. N.: Climate SPHINX: evaluating the impact of resolution and stochastic physics parameterisations in climate simulations, Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-115, in review, 2016.

Summary of plans for the continuation of the project

(10 lines max)

In the next months we will continue a series of of AMIP and coupled model runs over short periods (typically 5, up to 10 years) aimed at tuning the model in climate mode. In particular we will focus attention on achieving realistic radiative fluxes in the CMIP6 version of the model, including recent changes in the forcing fields (CMIP6 versions of solar forcing, Greenhous gases and aerosols), applied also to the case of stochastic physics. We will also start tuning of the coupled high-resolution (T511L91) version of the model.
Attention will also be devoted to obtaining a better mass (freshwater) conservation in the coupled atmosphere-ocean system.
Further we will complete and start analysing a set of coupled model runs at standard resolution, with and without stochastic physics, using CMIP5 forcing, in the historical and in the RCP8.5 scenarios.