LATE REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: United Kingdom

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Project Title: Assessing the impact of stochastic physics (SPPT) on sub-decadal time-scales

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2019	
Would you accept support for 1 year only, if necessary?	**YES** ☒	NO ☐

Computer resources required for the years: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	N/A	9,800,000	N/A
Accumulated data storage (total archive volume)[2]	(GB)	N/A	12,000	N/A

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.
[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Principal Investigator: Daniel J. Befort

Project Title: Assessing the impact of stochastic physics (SPPT) on sub-decadal time-scales

Extended abstract

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests the evaluation will be based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

All accepted project requests will be published on the ECMWF website.

Project Description:

To obtain reliable forecasts on time-scales from days to seasons, it has been shown to be crucial to include the representation of model uncertainties (Palmer et al., 2009). Within the IFS model uncertainties are expressed by stochastic parametrisations. ECMWF's current operational forecast systems include the Stochastically Perturbed Parametrization Tendency scheme (SPPT) (e.g. Johnson et al., 2018), for which model uncertainties are assumed to be proportional to the net physics tendency.

A simple statistic for measuring reliability is by calculating the relationship of ensemble spread to ensemble mean error, which for a perfectly reliable model should be equal to 1. Using this metric, it has been shown that the reliability of Pacific sea surface temperatures (SST) improves if using SPPT compared to using no stochastic physic parametrization to represent model uncertainties on seasonal time-scales (Weisheimer et al., 2011, see Fig. 1). Besides this study, the impact of stochastic physics on seasonal time-scales have been extensively investigated using ECMWF seasonal forecasting system 4 (Subramanian et al., 2017, Weisheimer et al., 2014).

Improvements are to a large extend related to a better representation of the spread within the ensemble, but SPPT can also significantly improve model errors. These findings on seasonal time-scales are in line with those obtained on shorter time-scales, e.g. on extended-range up to 30 days for the MJO (Leutbecher et al., 2017). Here, spread error relationships are strongly improved with regards to the two leading MJO PCs (Fig. 1).

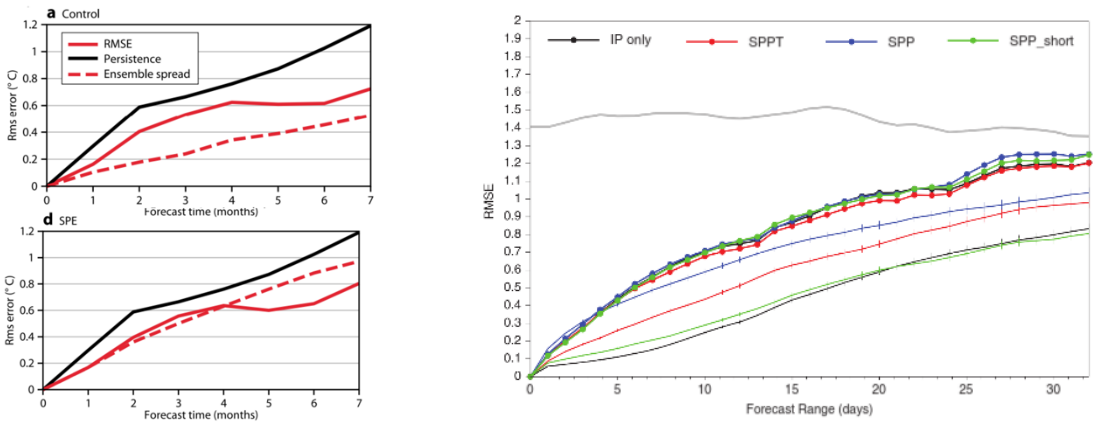

Fig. 1: ***Left:*** *"Skill comparison for predicting Niño3 SST anomalies in [...] the stochastic physics ensemble (SPE) and the control simulation for the SPE system (CTRL) showing the ensemble mean RMSE (red solid), the ensemble spread (red dashed) and the RMSE of a simple persistence reference forecast (black dash-dotted) as a function of forecast lead time" (Weisheimer et al., 2011; adapted from their Fig. 3)*
right: *"Evolution of RMS error (solid lines with dots) and ensemble spread (thin lines) for the leading two MJO PCs. Initial perturbations only (black), SPPT with global conservation fix (red), SPP (blue) and SPP with short correlation scales (green). The grey solid line represents the RMS error of the ERA-Interim climatological mean. The vertical bars represent the 90% level of confidence of the ensemble spread. 32 day reforecasts starting four times a year (1 February, May, August and November) over the period 1989–2014 (104 start dates). The ensemble size is 15 and the horizontal resolution is TCo159 with 91 vertical levels." (Leutbecher et al., 2017; their Fig. 6)*

Besides this well-known impact of stochastic physic parametrizations on shorter time-scales, studies investigated its effect on long-term climate simulations. Recently it has been shown that SPPT effects the representation of ENSO in a free running coupled climate model, by improving its main characteristics such as amplitude and periodicity (Fig. 2, Christensen et al., 2017). These improvements of SST variability over this region also have a positive effect on e.g. the Indian summer monsoon (Strømmen et al., 2017).

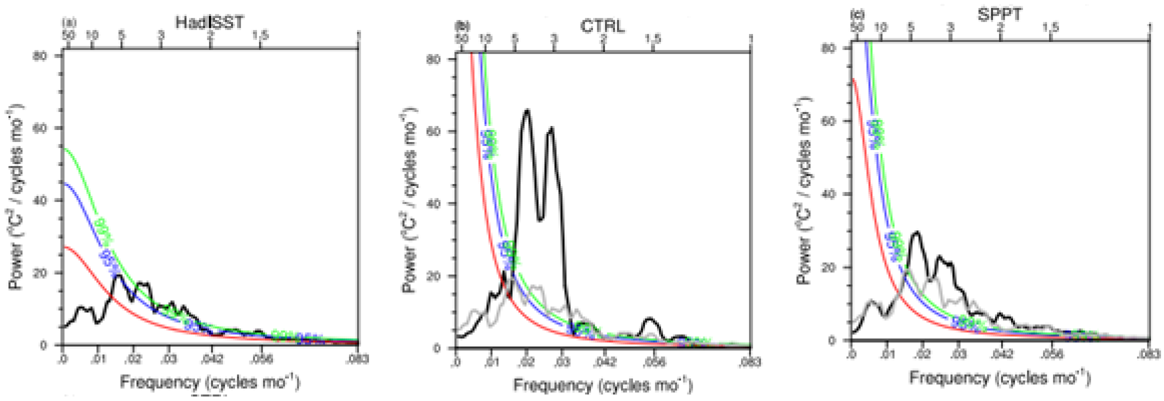

Fig. 2: *"Power spectrum of Niño-3.4 time series (black): (a) observations, (b) CTRL, and (c) SPPT. Also shown are the best-fit AR (1) spectrum (red) and its 95% and 99% confidence bounds (blue and green curves, respectively). The top x axis indicates the period in years, whereas the bottom x axis indicates the frequency in cycles per month. In (b), (c), the observational spectrum is shown in gray." (Christensen et al., 2017; adapted from their Fig. 3)*

Currently the scientific community heavily exploits the potential of decadal predictions, with some studies showing increased skill of such initialized predictions compared to non-initialized projections for certain lead times (e.g. Kruschke et al., 2014). While most studies focus on the initialization of atmospheric and oceanic states to improve these predictions, minor efforts have been made to explore the benefits of including the representation of model uncertainties in these simulations. This project aims to fill this scientific gap by conducting targeted simulations to analyse the impact of stochastic parametrizations on the reliability on sub-decadal time-scales. This will be achieved by carrying out a set of hindcast simulations both with and without SPPT using the IFS Cycle 41r1 model in a resolution of T255. For each year from 1981 until 2010 a 10-member ensemble forecast initialized in November will be carried out for the upcoming 28 months. Thus, this setup is designed to help to link scientific knowledge about stochastic parametrizations on (sub-) seasonal time-scales with those for long climate time-scales. Overall, this study will inform the scientific community about the influence of model uncertainty representations on sub-decadal time-scales and will potentially motivate the discussion about the inclusion of such stochastic schemes in current decadal prediction systems.

List of proposed experiments:

#	Model	Atm. Res.	Ocean Res.	Ini Dates	Length in month [per run]	Years	#Ens. Members	Stochastic Scheme
1	IFS 41r1	T255	1 deg	1st Nov	28	1981-2010	10	None
2	IFS 41r1	T255	1 deg	1st Nov	28	1981-2010	10	SPPT

Table 1: *List of proposed experiments*

Timeline:

Q1-Q2 2019: Experiments 1 & 2

Technical Requirements:

The proposed simulations will be conducted using the IFS Cycle 41r1 model. Coupled hindcasts with a length of 28 months initialized in November (see Table 1) with 10 ensemble members each, will be performed. Two experiment sets with SPPT (#2 in Table 1) and without stochastic physics (CTRL, #1 in Table 1) will allow to analyse the benefit of SPPT on sub-decadal time-scales. IFS Cycle 41r1 has been extensively tested and is currently used within the team at Oxford University. Therefore, no complications are expected using the proposed model setup.

Costs of proposed experiments:

The costs for one individual model run over one month using IFS Cycle 41r1 are:

- **~ 580 SBU**

Total costs for 30 years * 10 ensemble members * 28 months are:

- **~ 4,872,000 SBU**

Thus, overall costs for all experiments planned are roughly:

- **<u>~ 9,800,000 SBU</u>**

References

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