REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE: ………Germany.………………………………………………...…

This form needs to be submitted via the relevant National Meteorological Service.

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Other researchers: …Prof. Dr. Mojib Latif……………………………………..……

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Project Title: …Response of midlatitude weather extremes and mean circulation to surface warming in the OpenIFS model………………………….……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _DEKJEL__________	
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 **X**	NO ☐

Computer resources required for 2019-2021: (To make changes to an existing project please submit an amended version of the original form.)		**2019**	**2020**	**2021**
High Performance Computing Facility	(SBU)	8 million	8 million	
Accumulated data storage (total archive volume)[2]	(GB)	22500	22500	

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

……29 June 2018………

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: ……Dr. Joakim Kjellsson …………………………

Project Title: … Response of midlatitude weather extremes and mean circulation to surface warming in the OpenIFS model …

Extended abstract

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 will be evaluated by ECMWF as well as the Scientific and Technical Advisory Committees. The evaluation of the requests is 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.

Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.

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

See attached file.

Response of midlatitude weather extremes and mean circulation to surface warming in the OpenIFS model

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GEOMAR Helmholtz Centre for Ocean Research

June 29, 2018

Short summary

- Extend current project, "Extreme Weather and the Midlatitude Response to Recent Decadal Warming in OpenIFS" (SPDEKJEL) to also study the summer season, JJAS, where Arctic warming is strongest, Atlantic hurricanes are most frequent, and Southern Hemisphere jet is strongest.
- Study variability of midlatitude jet stream, and model biases due to insufficient resolution.
- Results will feed back to current development of a coupled modelling system based on OpenIFS and NEMO at GEOMAR.

Motivation

Studies using climate-model simulations have found that surface warming can lead to increased precipitation, increased wind speeds, and increase the frequency of some extreme weather events, e.g. heat waves and wind storms (*Frei et al.*, 2006; *Meehl*, 2004). It has also been proposed that the Arctic surface warming and sea-ice loss reduces the mean meridional temperature gradient which can slow down Rossby-wave propagation and make weather events more persistent. However, very few studies have simulated the atmospheric response to surface warming at horizontal resolutions finer than $\Delta x \sim 25$km. We propose to study how the atmosphere in midlatitudes responds to surface warming using the OpenIFS global atmospheric model. This project focuses on simulating the response of the midlatitude atmosphere to surface warming, and builds upon achievements from the previous special project "Extreme Weather and the Midlatitude Response to Recent Decadal Warming in OpenIFS" (SPDEKJEL) in 2018.

Understanding and predicting climate change and climate variability requires realistic simulations of the current climate using numerical models, but many climate models suffer from biases in e.g. SST, precipitation or jet stream position due to insufficient horizontal and/or vertical resolution of the atmosphere model (*Harlaß et al.*, 2017; *Volosciuk et al.*, 2015; *Hertwig et al.*, 2015). Simulating extreme weather events, e.g. heavy precipitation events and intense wind storms, requires a very high resolution, e.g. $\Delta x \sim 10$ km (*Jung et al.*, 2012) or finer. Thus, we will run simulations with OpenIFS at a very high horizontal and vertical resolution, T_L1279L137. We will use observed surface conditions from two different time periods, 1983-1987 and 2013-2017, as well as results from climate-model simulations in the RCP8.5 scenario to understand how surface warming and sea-ice loss impacts the midlatitude atmosphere. In particular we will focus on wind storms and heavy precipitation events, and variability of the midlatitude jet stream.

In our current project (SPDEKJEL) we have already set up OpenIFS in a T_L1279L137 configuration. Initial results using T_L159L91, T_L255L60 and T_L511L91 configurations, which are run at the HLRN HPC in Germany, have shown that the response of precipitation extremes to surface warming varies significantly with horizontal resolution. We have also begun studying in the mean strength and position of the NH midlatitude jet. While the current project (SPDEKJEL) only studies the boreal winter season (DJF), this project will extend to simulate the summer season (JJAS) when the Arctic sea-ice loss is the most pronounced, the Atlantic hurricanes are the most frequent, and the Southern Hemisphere (SH) jet is at its strongest. Furthermore, while the previous project only covered the time periods 1982-1987/2012-2017 using observed sea-surface temperature (SST) and sea-ice concentration (SIC) data, this new project will study the relative impacts of surface warming and sea-ice changes as well as using global warming scenarios (see Fig. 2). Just as in our previous project, we will run this special project in tandem with another compute project at HLRN in Germany where we conduct simulations at lower resolution, namely T_L159L91, T_L255L60, and T_L511L91.

It has been suggested that the NH midlatitude jet stream has an intrinsic mode of variability where it shifts between a more "wavy" jet and a more "coherent" jet (*Woollings et al.*, 2018). In addition to examining the mean state and variability of the midlatitude weather, we will also study the kinetic energy balance of the NH midlatitude jet stream by employing an analysis technique in spectral space, as done for oceanic currents by *Kjellsson and Zanna* (2017) and similarly to *Augier and Lindborg* (2013). This will give insight into how the strength and position of the jet stream is maintained by e.g. conversion of potential energy to kinetic energy, dissipation, surface drag or eddy-eddy interactions as well as how variations are excited. The results are likely sensitive to the horizontal and vertical resolution of the model, since only very-high-resolution simulations can resolve the mesoscale $k^{-5/3}$ spectrum (*Wedi et al.*, 2012). We also propose to run a trial simulation using the newer version of OpenIFS, CY43R3, which in-

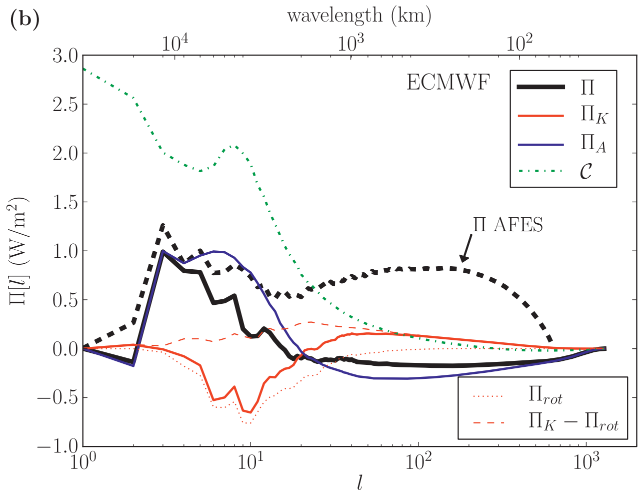

Figure 1: Total (black solid line), available potential energy (APE, blue line) and kinetic energy (KE, red) spectral fluxes in simulations with IFS at T1279. Also shown is conversion from APE to KE (green dashed line) and total spectral flux in the AFES model at T639. Figure is taken from *Augier and Lindborg* (2013).

cludes a stochastic backscatter parameterisation that may have a strong impact on the kinetic energy balance.

Technical aspects

All our proposed simulations are listed in Table 1. The current model version we have set up at ECMWF (CCA) is OpenIFS CY40R1 with the WAM wave model activated, and run using SST and SIC from the daily 1/4° NOAA OI data set. We store zonal and meridional wind, temperature and specific humidity on model levels, as well as heat and water fluxes at the surface at a 6-hourly frequency. As this project is a continuation of a previous project also using OpenIFS and at the same horizontal and vertical resolutions, we expect very few technical obstacles. We already have OpenIFS successfully installed and tested on the ECMWF CCA cluster, and have done evaluations of the performance using various code compilers and install methods. Some of the results from the evaluation are to be presented in the coming paper "Carver et al., The ECMWF OpenIFS numerical weather prediction model release cycle 40r1: description and use cases". One month of simulation with OpenIFS T_L1279L137 costs ≈ 100000 SBU and requires 0.3 Tb of storage. As we propose to run several simulations of several summer seasons, we estimate the total cost of this project to 16 million SBU and 45 Tb, distributed over a 2-year period. Final storage will be at the GEOMAR data cluster, and all configuration files

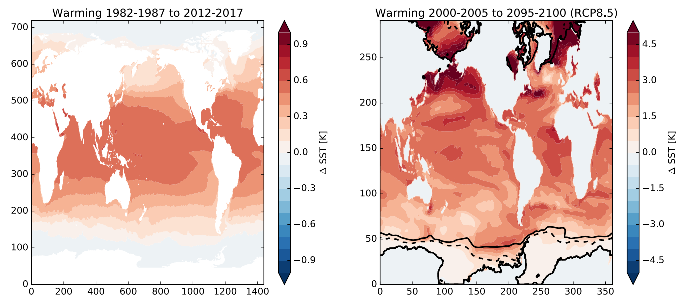

Figure 2: Changes in boreal summer (JJA) surface temperature between 1982-1987 and 2012-2017 in observations (left) and between 2000-2005 and 2095-2100 in one simulation with the EC-Earth climate model with RCP8.5 forcing. Note the difference in colour scales. For EC-Earth, the 15% sea ice concentration contour line shown for 2000-2005 (solid line) and 2095-2100 (dashed line).

(namelists, run scripts, etc.) as well as input and output files will be made available upon request.

We aim to perform most of the proposed simulations using OpenIFS CY40R1, as was used in our previous project, although we will make some trial simulations with the newer version OpenIFS CY43R3, to be released late 2018. The new cloud physics scheme in CY43R3 may result in some differences compared to CY40R1, and the new stochastic backscatter parameterisation will likely give interesting contributions to the spectral kinetic energy budget. Furthermore, an additional experiment will be run with 30 min output frequency of surface fluxes to investigate fast fluxes that are not captured at 6-hourly frequency, which can be of vital importance in a coupled climate model (**?**).

Outcomes

Our high-resolution experiments, as well as companion experiments at lower resolution performed elsewhere, will help us understand how wind storms and heavy precipitation events as well as the maintenance of the midlatitude jet stream are impacted by surface warming and sea-ice loss. Another outcome of this project is to further evaluate OpenIFS CY40R1 at high resolution, and also do some test simulations with OpenIFS CY43R3, which are vital for another ongoing project at GEOMAR to couple the OpenIFS model to our configurations of NEMO ocean model with 2-way nesting capabilities. Some initial test simulations using OpenIFS CY40R1 at T159L91 and NEMO ORCA05 have already been performed. Understanding how higher horizontal resolution impacts the simulation climate in atmosphere-only simulations with OpenIFS will guide the future development of our coupled system. The results may also be of interest for other institutes using coupled model with OpenIFS atmosphere, e.g. the EC-Earth community.

Surface conditions and heat/water fluxes as well as three-dimensional wind, temperature and humidity will be stored at 6-hourly frequency, transfered to the GEOMAR data cluster and made available upon request. All configuration files, e.g. namelists, scripts etc., will also be made available. As our simulations will be done using a global model, there is a wide range of phenomena that may be studied using the data. Future work could include studying storm tracks, intensity of Atlantic hurricanes, or recent changes to the stratospheric circulation.

Table 1: Proposed simulations with OpenIFS. Each simulation will include an extra month to allow the model to drift away from the initial conditions. * indicates a simulation using OpenIFS CY43R3, and ** indicates a simulation with 30 min output frequency (surface fluxes only).

Configuration	SST	SIC	Est. cost (SBU)	Est. storage (Tb)
T_L1279L137	JJAS 1983	JJAS 1983	500 000	1.4
T_L1279L137	JJAS 1984	JJAS 1984	500 000	1.4
T_L1279L137	JJAS 1985	JJAS 1985	500 000	1.4
T_L1279L137	JJAS 1986	JJAS 1986	500 000	1.4
T_L1279L137	JJAS 1987	JJAS 1987	500 000	1.4
T_L1279L137	JJAS 2013	JJAS 2013	500 000	1.4
T_L1279L137	JJAS 2014	JJAS 2014	500 000	1.4
T_L1279L137	JJAS 2015	JJAS 2015	500 000	1.4
T_L1279L137	JJAS 2016	JJAS 2016	500 000	1.4
T_L1279L137	JJAS 2017	JJAS 2017	500 000	1.4
T_L1279L137*	JJAS 2013	JJAS 2013	500 000	1.4
T_L1279L137*	JJAS 2014	JJAS 2014	500 000	1.4
T_L1279L137*	JJAS 2015	JJAS 2015	500 000	1.4
T_L1279L137*	JJAS 2016	JJAS 2016	500 000	1.4
T_L1279L137*	JJAS 2017	JJAS 2017	500 000	1.4
T_L1279L137**	JJAS 2013	JJAS 2013	500 000	0.5
T_L1279L137	JJAS 2013	JJAS 1983	500 000	1.4
T_L1279L137	JJAS 2014	JJAS 1984	500 000	1.4
T_L1279L137	JJAS 2015	JJAS 1985	500 000	1.4
T_L1279L137	JJAS 2016	JJAS 1986	500 000	1.4
T_L1279L137	JJAS 2017	JJAS 1987	500 000	1.4
T_L1279L137	JJAS 2095 (RCP8.5)	JJAS 2095 (RCP8.5)	500 000	1.4
T_L1279L137	JJAS 2096 (RCP8.5)	JJAS 2096 (RCP8.5)	500 000	1.4
T_L1279L137	JJAS 2097 (RCP8.5)	JJAS 2097 (RCP8.5)	500 000	1.4
T_L1279L137	JJAS 2098 (RCP8.5)	JJAS 2098 (RCP8.5)	500 000	1.4
T_L1279L137	JJAS 2099 (RCP8.5)	JJAS 2099 (RCP8.5)	500 000	1.4
T_L1279L137	JJAS 2095 (RCP8.5)	JJAS 1983	500 000	1.4
T_L1279L137	JJAS 2096 (RCP8.5)	JJAS 1984	500 000	1.4
T_L1279L137	JJAS 2097 (RCP8.5)	JJAS 1985	500 000	1.4
T_L1279L137	JJAS 2098 (RCP8.5)	JJAS 1986	500 000	1.4
T_L1279L137	JJAS 2099 (RCP8.5)	JJAS 1987	500 000	1.4
Total			16 million SBU	45 Tb

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