REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: Italy……………………………………………………………………...…
This form needs to be submitted via the relevant National Meteorological Service.

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Project Title: WeatHer rEgimes' REpresentation (WHERE)…………………..……

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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.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	8,000,000	8,000,000	
Accumulated data storage (total archive volume)[2]	(GB)	32,000	64,000	

***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): 29/06/2017……………………………

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.

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Extended abstract

PROJECT DESCRIPTION

The WHERE special project intends to carry out a set of atmosphere-only (AMIP) ensemble historical (1950-2014) and future scenario (2015-2050) simulations with the EC-Earth global climate model in order to study the ability of the model to represent the Euro-Atlantic and Pacific North American atmospheric weather regimes (e.g. [Cassou 2010], [Straus et al. 2007]) and the related prevailing teleconnection patterns. Several ensemble members are necessary to assess the relative contribution of the forced and the unforced variability to the frequency of weather regimes. Since all the ensemble members will be run using the same Sea Surface Temperatures (SSTs), the inter-ensemble variability provides an estimate of the internal variability, whereas the forced variability is represented by the variability of the ensemble mean. The activation of a stochastic physics parameterization scheme [Palmer et al. 2009] to represent subgrid-scale processes will be investigated by comparing with the baseline simulations.

SCIENTIFIC PLAN

The large-scale circulation of the extratropical atmosphere can be described by the alternation of different circulation regimes (or weather regimes), in which anomalies in the amplitude and phase of planetary waves are dynamically equilibrated by variations in diabatic energy sources and non-linear interactions with synoptic-scale eddies. Weather regimes are preferred recurrent circulation patterns of the midlatitude low-frequency atmospheric variability (e.g. [Molteni et al. 2006]). The meteorological fluctuations can be described in terms of temporal transition among regimes. The year-to-year (or longer timescale) climate fluctuations can be interpreted as changes in their frequency of occurrence [Cassou 2010]. In a dynamical system with regime structure, the time-mean response of the system to some imposed forcing is in part determined by the change in frequency of occurrence of the naturally occurring regimes [Corti et al. 1999]. Therefore, evaluating the ability of a model in representing weather regimes is crucial because a model that fails to simulate well the observed regime structures, could possibly fail to simulate the correct response to imposed forcings (e.g. the changes in greenhouse gases concentration forcing).

In particular we will investigate the following specific topics:

- To what extent are the properties of model-simulated regimes over the Euro-Atlantic and Pacific North American region consistent with those of regimes obtained from re-analysis data?
- Are the differences between observed regime properties in different periods within the range of internal atmospheric variability for the same external forcing?
- Are interannual variations in regime frequencies (at least partially) reproducible as a function of SST anomalies?

For these purposes, AMIP integrations will be realized with the last version of the EC-Earth global climate model [Hazeleger et al. 2010] which is developed by a large consortium of European Institutions and that participates in the Coupled Model Intercomparison Project (CMIP) effort.

A balance between number of ensemble members and resolution is needed to tackle computational constraints. A total of 20 ensemble integrations at horizontal resolution of about 80km (T255L91) will be carried out: 10 members (without stochastic physics) during the first project year and 10 members (with stochastic physics) during the second project year. Stochastic physics parametrizations have been shown to have a positive impact on weather regimes simulations (e.g. [Weisheimer et al. 2004], [Dawson and Palmer 2015]). If the improvement in regime representation due to the introduction of a stochastic physics scheme is confirmed, this will allow to run climate models at a relatively low resolution saving the computational resources that higher resolution experiments would require.

EXPERIMENTAL SET UP

The EC-Earth Earth-System Model version 3.2.2 will be used to perform 20 AMIP simulations at T255 horizontal resolution (about 80km), over the 2 years of the project.

For the first project year, 10 ensemble members for 65-year-long historical simulations of the recent past (1950-2014) and 10 ensemble members for 36-year-long future scenario simulations (2015-2050) will be carried out.

During the second year, the same experimental set up is repeated with the implementation of stochastic physics.

Here, the CMIP6 High-resolution Model Intercomparison project (HighResMIP) protocol [Haarsma et al. 2016] is adopted:

- Historical simulations for the period 1950–2014
  - forced by daily ¼º HadISST2-based dataset [Rayner et al. 2016] of SST and Sea Ice Concentration (SIC).
  - To the model aerosol concentration background climatology, an anthropogenic time-varying forcing provided via the MACv2-SP method [Stevens et al. 2016] will be added.
  - Initial atmosphere and land states come from ERA-20C reanalysis [Poli et al. 2013].
- Scenario simulations for the period 2015–2050
  - forced by daily ¼º HadISST2-based dataset [Rayner et al. 2016] of SST and SIC for interannual variability, while the projected future trend is derived from an ensemble mean of CMIP5 Representative Concentration Pathway 8.5 (RCP8.5) simulations.
  - For the future time period, GHG and aerosol concentrations come from a high-end emission scenario of the Shared Socioeconomic Pathways (SSPs) [Riahi et al. 2016] will be prescribed.
  - Initial atmosphere and land states come from historical simulations.

The historical simulations will be used to evaluate if there is a sensible improvement in the model climate due to stochastic parameterizations; whereas the future scenario simulations will be used to study the expected impact of stochastic parameterizations on weather regimes' frequency and structure, under a different anthropogenic forcing.

The initialisation of each ensemble member is carried out from identical initial conditions in the ocean, land and sea-ice components, and slightly different initial conditions in the atmospheric model (taken from different days from the same historical simulation).

Since they share the same model version and the same protocol, the ensemble simulations proposed here will integrate and complement those produced in the framework of the Special Project led by

Jost von Hardenberg "Impact of atmospheric stochastic physics in high-resolution climate simulations with EC-Earth". This will allow a better assessment of the internal climate variability.

METHODS

First, Empirical Orthogonal Function (EOF) analysis will be applied to the daily winter geopotential height field at 500 hPa and a relatively small number M (typically 4 to 20) Principal Component (PC) time series will be retained to define a low-dimensional space.

Cluster analysis will be applied to those PCs to identify the weather regimes: it categorizes an entire set of maps into groups with similar characteristics so that these groups are more similar to the others of the same group than to the maps in the other groups. Cluster analysis is a general methodology and can be accomplished using different methods. The k-means [Michelangeli et al., 1995] method seeks to partition all states into a fixed, pre-chosen number k of clusters, aiming at maximizing the ratio R of variance among the k cluster centroid coordinates (weighted by the population of the cluster) to the average intra-cluster variance. The centroid coordinates are defined as the average coordinates of all members of the cluster. The cluster partition is achieved iteratively: the algorithm starts out with k seed points and assigns each state to the seed point to which it is closest (according to a measure of distance). Given this initial partition, the algorithm re-computes the cluster centroid coordinates, adjusts the partitioning of states into clusters based on the new centroids, and iterates until R does not change. Repeating this procedure many times assures that the partition with the highest R is obtained [Hannachi et al., 2017].

The representation of weather regimes will be assessed comparing it with the observed one (i.e. from Reanalysis dataset), by means of the following metrics:

- Significance of cluster partition
- Frequency of weather regime occurrence
- Pattern correlation relative to observations

Uncertainty in the metrics refers to the difference in the metrics between ERA-Interim [Dee et al. 2011] and NCEP/NCAR [Kalnay et al. 1996] reanalysis.

The relationship between weather regimes and precipitation, SST, land surface conditions, etc. will be inspected via teleconnection maps, in order to improve our comprehension of the mechanisms driving the climate variability in different regions.

JUSTIFICATION OF THE COMPUTER RESOURCES REQUESTED

This project requires an ensemble of AMIP simulations at standard T255 resolution with the EC-Earth model.

Previous tests performed on ECMWF cca (in the framework of the SPNLTUNE project) have determined that in its current configuration EC-Earth is consuming 10,500 SBU/year in AMIP mode.

The planned AMIP simulations at T255 horizontal resolution are:

FIRST YEAR (605 simulated years)

- tuning runs: 1,050,000 SBU for 100 years
- baseline experiments: 3,412,500 SBU for 65 years (1950-2014) for 5 members
- baseline scenario experiments: 1,890,000 SBU for 36 years (2015-2050) for 5 members

The sum for the first year is 6,352,500 SBUs

SECOND YEAR (605 simulated years)

- tuning runs: 1,050,000 SBU for 100 years
- stochastic physics experiments: 3,412,500 SBU for 65 years (1950-2014) for 5 members
- stochastic physics scenario exp.: 1,890,000 SBU for 36 years (2015-2050) for 5 members

The sum for the second year is 6,352,500 SBUs.

We ask for 5% more computing time to make sure we can safely complete the whole integrations and for post processing analysis, so the total number of required SBU for the 2-year project is 16,000,000 SBUs.

Storage requirements are around 50 GB/model-year, assuming 3-hourly output storage. So the total storage will be about 64,000 GB over the two years.

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