<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: ITALY

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Project Title: Go Beyond Current Limitations of Climate Predictions over Land

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

Computer resources required for 2013-2015: (The project duration is limited to a maximum of 3 years, agreed at the beginning of the project. For late requests the project will start in the current year.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	1.6 million	2.2 million	0.85 million
Data storage capacity (total archive volume) (gigabytes)	11000	25000	30000

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): 16 January, 2013

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[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.

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

The Italian National agency for new technologies, Energy and sustainable economic development (ENEA) is partner in a new European Union FP7 project, Seasonal-to-decadal climate Prediction for the improvement of European Climate Services (SPECS, http://specs-fp7.eu/). SPECS aims to identify the main problems in climate prediction and investigate a battery of solutions from a seamless perspective. SPECS will deliver a new generation of European climate forecast systems, based on Coupled General Circulation Models (CGCMs), with improved forecast quality and a focus on extreme climate events, in order to provide enhanced services to satisfy the climate information needs of a wide range of public and private stakeholders. This grand challenge is at the centre of SPECS' overarching objectives that will push the boundaries of the current capability in climate forecasting.

One of the main objectives of SPECS is to go beyond current limitations of climate predictions over land areas. Predictability of climate at seasonal and longer time scales stems from the interaction of the atmosphere with slowly varying components of the climate system such as the ocean and the land surface (e.g: Shukla and Kinter, 2006). However, much of the improvement so far has been obtained over ocean, where extensive availability of observations allowed models progresses and reliable application of assimilation techniques (e.g: Rosati et al. 1997; Alessandri et al. 2010). In contrast, forecasts performance over land is substantially weaker compared to the ocean (Wang et al., 2009; Alessandri et al., 2011a). Since most of the applications of climate predictions would serve economic interests that are land-based, there is an urgent need to improve probabilistic forecasts over land. As shown by several modeling studies, land surface memory can contribute to subseasonal and longer climate predictions (e.g: Koster et al, 2004; Ferranti and Viterbo, 2006) and in particular it is over transition zones between wet and dry climates that a strong coupling between land surface and precipitation can be clearly identified (Koster et al., 2004, 2010, 2011). In this regard, the observational study by Alessandri and Navarra (2008) clearly identified a link between rainfall and land surface-vegetation variability indicating an important delayed feedback of the land surface to the precipitation pattern on seasonal and longer time scales.

In order to better understand predictability and to put the base for improved climate forecasts over land it is very important to assess whether the improved representation of the land-surface and of climate-vegetation processes in dynamical models can play an important role in enhancing and sustaining variability and extreme events, in particular for near-surface temperature and precipitation. To this aim we'll perform sensitivity experiments by using retrospective forecast framework and by focusing on 3 key aspects of the land surface-vegetation potential contribution on predictability: (i) sensitivity to initialized vegetation for seasonal predictions, (ii) handling unconstrained parameters: perturbation of soil field capacity and/or surface resistance to evapotranspiration, and (iii) exploratory effort on the sensitivity of the decadal forecasts to vegetation initialization.

The EC-Earth (Hazeleger et al. 2011; version 2.3 and/or higher) CGCM is the modeling tool that we are planning to use in its default resolution configuration, i.e: T159 for the atmosphere (~125km) and one degree of horizontal resolution for the ocean component (See http://ecearth.knmi.nl/ for further details).

(i) For a focus on phenology and a more realistic prediction context, seasonal predictions with initialized vegetation states will be compared to uninitialized predictions. Two model configurations will be compared: one in which phenology is fixed, and one with a prognostic evolution of LAI (Leaf Area Index). We will evaluate a fully interactive LAI modeling approach against a strategy of "damped persistence" of initial LAI anomalies, which will be less responsive than a fully active scheme but may be more stable against systematic biases. An initial phase will be used to preliminary evaluate the modeling approach taken and eventually make adjustments for the larger set of integrations in order to maximize the convenience of the experimental design used. A standard seasonal experimental set up will consist of ten-member ensembles, with at least one start date per year (first of May) over the 1981-2012 period and seven-month forecast length. A total simulation estimate of 370 years is obtained [10(ensemble members) x7(months) x32(years) x2(experiments)].

In order to accurately estimate the computational requirements, a set of experiments has been specifically designed and performed on the ECMWF IBM Power 7 (c2a) system using the same codes that will be used in the production phase. The aim is to verify the performance of the codes and determine the better processors configuration. Large scalability is not an issue in our case, since we plan to run different experiments at the same time. Therefore, we limited our tests to a maximum of 384 parallel tasks. The tests also analysed the opportunity to use two threads per physical core. All the tests run for 1 hour wall clock time with the model in coupled (ocean-atmosphere) configuration. Based on the results of the tests on the c2a system, we found that the best configuration for version 2.3 is 189 tasks (on 3 nodes) distributed on: 1proc OASIS3 (coupler) + 32procs NEMO (Ocean model)+ 156 procs IFS (Atmospheric model), which uses about 3550 SBU per simulation year. Based on the above estimation, the retrospective forecasts to assess sensitivity to initialized vegetation for seasonal predictions will require 1.35*10^6 SBU.

(ii) Forecasts performance over land is weaker compared to ocean at least in part because of the lack of observations, which has hampered the development of well-constrained land models. Due to the lack of observations, modeling the soil water cycle appears to be unconstrained problem, i.e. model results have no reference soil moisture content and water fluxes. As a result of this, different land surface models have very different operating ranges for soil wetness (Koster and Milly, 1997), thus producing very different surface evapotranspiration. The simplest bucket treatments of surface hydrology have assumed a universal 150 mm of soil-water capacity. This value is probably reasonable within a factor of two over any given continental scale region in comparison with reality (Trenberth, 2010). However, it is difficult, at present, to obtain higher accuracy over local regions of soil information. Such a high level of uncertainty in the water holding capacity over a large region can potentially have significant implications for the overall climate of the region. To quantify how this uncertainty can affect predictability, we will perform perturbations of land parameters that are currently poorly constrained and that are critically important in determining land hydrology and vegetation sensitivity. In particular, the sensitivity of seasonal predictions to perturbations of soil field capacity and/or surface resistance to evapotranspiration will be assessed. Standard seasonal prediction experiments will be performed, although with a primary focus on the boreal summer. It will consist of ten-member ensembles, with at least one start date per year (first of May) over the 1981-2012 period and seven-month forecast length. A total simulation estimate of 370 years is obtained [10(ensemble members) x7(months) x32(years) x2(experiments)], thus requiring 1.35*10^6 SBU of computing resources in the ECMWF IBM Power 7 (c2a) system.

(iii) An exploratory effort will be performed to assess the sensitivity of decadal forecasts to the vegetation initialization. This experiment will include a phase 1 in which the feasibility of vegetation initialization for decadal predictions will be evaluated. This will include a full vegetation development (including dynamics and type distribution) and will need several hundreds of years of simulations to properly initialize the vegetation. Through phase 1 we'll evaluate whether the more appropriate way to address the scientific problem is through real retrospective forecasting exercise (i.e: by initializing the vegetation towards observations) or through potential predictability exercise. Initial vegetation build-up will be accomplished through a spin up using pre-industrial conditions. To evaluate the feasibility of a realistic initialization of vegetation we'll perform an offline simulation of the land surface-vegetation model driven by fluxes from the available 20th Century reanalysis (e.g. ERA-CLIM, NOAA-20C) and ERA-INTERIM since 1979. In the satellite era (from 1980 onwards) vegetation will be conceivably nudged to available remote sensing data using the European Space Agency (ESA) land-surface essential climate variables (ECVs).
Results of exploratory phase will drive decisions of the design of the unprecedented decadal prediction sensitivity experiments to be subsequently planned and subject to the availability of sufficient computing resources. The experimental design will possibly cover the Fifth Coupled Model Intercomparison Project (CMIP5) decadal prediction experiment period. The planned decadal experimental set up consists in five-member ensembles, starting on the first of November (or some time close to that date) of the years 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010 with a five-year forecast length. A total simulation estimate of 550 years is obtained [5(ensemble members) x5(years) x11(start dates) x2(experiments)], thus requiring 1.95*10^6 SBU of computing resources in the ECMWF IBM Power 7 (c2a) system.

In summary, this project will be composed of three parts, each of them with its set of experiments: (i) the sensitivity to initialized vegetation for seasonal predictions [computer resources required 1.35*10^6 SBUs], (ii) the sensitivity to perturbation of unconstrained parameters [resources required 1.35*10^6 SBUs] and (iii) the exploratory effort on the sensitivity of the decadal forecasts to vegetation initialization [resources required 1.95*10^6 SBUs]. The overall computational requirement amounts to 4.65 SBUs, of which 1.6 SBUs are allocated for 2013, 2.2 SBUs for 2014 and 0.85 for 2015.
All data for the project will be stored on the original grid and in NetCDF4 format (CF compliant) following the recommendations and common strategy adopted in the SPECS project. A total of 5 3-Dymensional (3D) and 24 2-Dymensional (2D) variables will be saved for the atmosphere. For the ocean, 5 3D and 15 2D variables will be saved. The time frequency of the outputs spans from 6-hourly data to daily and monthly averages, depending on the variable considered. A realistic estimate of the storage for one year of simulation gives a total of 23 GB of data to be stored. Therefore, the overall data storage capacity required for the project amounts to 30TB.

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