REQUEST FOR A SPECIAL PROJECT 2016–2018

MEMBER STATE: ……ITALY……...…

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Project Title: Go Beyond Current Limitations of Climate Simulation and Projection over Land
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If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**_____	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2016	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2016-2018: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2018.)		**2016**	**2017**	**2018**
High Performance Computing Facility	(units)	4 million	5 million	5 million
Data storage capacity (total archive volume)	(gigabytes)	50000	50000	50000

*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):
……24/06/15……

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.

Principal Investigator: …… Andrea Alessandri……

Project Title: … Go Beyond Current Limitations of Climate Simulation and Projection over Land ……

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 H2020 project, Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach (CRESCENDO). CRESCENDO aims at improving the process realism and simulation quality of European ESMs and will deliver an ensemble of novel and advanced Earth system projections sampling a range of plausible future socio-economic pathways. The ENEA efforts in CRESCENDO are expected to significantly contribute to the overarching activities in the context of the WCRP's Coupled Model Intercomparison Project (CMIP6), the Global Energy and Water Exchanges (GEWEX; http://www.gewex.com) and the Climate and Cryosphere project (CliC; http://www.climate-cryosphere.org).

One of the main objectives of CRESCENDO is to go beyond current limitations of climate simulation and projection over land areas by improving representation of the land surface processes that are still poorly represented in Earth System Models (ESMs). Particular emphasis in CRESCENDO will be posed on transitional climate areas over land (Koster et al., 2004, 2010) that are expected to be especially sensitive to global change (Alessandri et al., 2014).
State-of-the-Art ESMs, such as EC-Earth (Hazeleger et al., 2012), still lack a treatment of surface albedo able to properly discern the different land cover/land use types (van den Hurk et al., 2000; 2003; Weiss et al., 2012). For instance, for each grid point EC-Earth prescribes the same time-invariant blended albedo value for both bare soil and vegetated fractions. This could greatly limit the sensitivity of modeled climate in transitional areas due to the lack of albedo response to the changes of water availability (soil moisture and snow) as well as changes in land cover/land use types (Pitman et al., 2009; De Noblet et al., 2012; Brovkin et al., 2014).
The objectives of this special projects are (i) develop a process-based albedo parameterization in EC-Earth, (ii) validate and assess the effects of the new albedo scheme on the simulated climate during the last Century historical period and (iii) evaluate the interactions and feedbacks of the interactive albedo in the future climate projections (CMIP6). The couplings and feedbacks of the newly introduced interactive albedo will be assessed together with the interactions with the changes of water availability (soil moisture and snow) as well as changes in land cover/land use types (Pitman et al., 2009; De Noblet et al., 2012; Brovkin et al., 2014).

The New interactive Albedo Scheme

A new interactive albedo scheme will be specifically designed and implemented in order to be included into HTESSEL (Balsamo et al., 2009), i.e. the land surface scheme included in

EC-Earth (Hazeleger et al., 2012). The bare soil albedo for both extremely dry and extremely wet conditions will be derived from the available global datasets of soil textures and colours. A parameterization of the bare soil albedo is then deduced as a function of soil water content in the land surface model included in EC-Earth. For albedo of vegetated fraction, both strategies of (i) obtaining albedo from the dynamically coupled vegetation model and (ii) obtaining albedo from available atlas for each vegetation type considered in EC-Earth could be addressed. For soil exposed under vegetation, albedo is also a function of litter mass and wetness. Feasibility to obtain litter information from dynamically coupled vegetation model will be evaluated.

Validation and assessment of the albedo effects during last Century

In order to validate and assess the effects of the new albedo scheme on the simulated climate during the last Century historical period, we'll perform a set of historical simulations covering the last Century (1900-2014). The sensitivity of the simulated climate change during the last century to the better representation of the albedo will be assessed by comparing the simulations performed with and without the new albedo scheme.
The above set of simulations is performed including land use variations during the past century as reconstructed from available historical data. In case additional resources will become available, a further simulation will be performed with land use fixed to the beginning of 20th Century. The comparison of the two sets of simulations for the past Century may delineate the couplings and feedbacks of the newly introduced interactive albedo scheme with the changes in land cover/land use types.

Interactive albedo feedbacks in climate projections

The EC-Earth ESM with the improved albedo representation will be used to perform at least one scenario experiment that will be selected in a later stage from the sampling in the CMIP6 ScenarioMIP (http://www.wcrp-climate.org/). The same scenario simulation will be performed with and without the new albedo scheme to assess the feedbacks of the interactive albedo on climate change. The above projections include land use variations consistent with selected scenario from ScenarioMIP.

As a further step, the GLACE-CMIP5 protocol (Seneviratne et al., 2013) will be adapted to evaluate the mechanisms of interaction of the newly introduced interactive albedo in the selected future climate ScenarioMIP projection. To this aim the effect of the future albedo changes will be assessed together with the interactions with the changes of water availability (soil moisture and snow) as well as changes in land cover/land use types (Pitman et al., 2009; De Noblet et al., 2012; Brovkin et al., 2014). Following Seneviratne et al. (2013), a set of forced experiments is carried out, where land surface states are prescribed from an a priori defined database. Two configurations will be considered: one in which the prescribed climatology is derived from "present climate conditions" (1980-2014; hereinafter GLACE-A), aiming at diagnosing the role of land-atmosphere feedback at the climate time scales. The second set of projections will prescribe climatology using a transient 30-yr running mean (GLACE-B; see also summary of experiments in Table 1), where a comparison to the standard CMIP6 runs allows diagnosing shifts in the regions of strong land-atmosphere coupling. Two member ensembles will be performed for both GLACE-A and GLACE-B, one member with land use variations from projected future scenario from ScenarioMIP and one member prescribing fixed land-use conditions of the end of 20th Century.
This effort will possibly contribute to the proposed activities in the framework of the Land Surface, Snow, and Soil moisture MIP (LS3MIP; http://www.climate-cryosphere.org/activities/targeted/ls3mip) in the framework of the WCPR's CMIP6, GEWEX and the CliC project.

Summary of experiments and resources

The summary of experiments planned in this project is reported in Table 1.

Experiment name	Description	Start	End	Ens	Total years	Schedule
Test-ALB	Testing albedo parameterization (ALB)				50	2016
Hist-CTL	Historical run without ALB	1900	2014	1	115	2016
Hist-ALB	Historical run with ALB	1900	2014	1	115	2016
Proj-CTL	CMIP6 projection without ALB	1980	2100	1	120	2017
Proj-ALB	CMIP6 with ALB	1980	2100	1	120	2017
GLACE-A	GLACE-CMIP6 run with prescribed 1980-2010 climatological land surface from Hist-ALB	1980	2100	2	120	2017
					120	2018
GLACE-B	GLACE-CMIP6 run with prescribed 30-yrs projected running mean from GLACE-A	1980	2100	2	240	2018

Table 1: Summary of the Experiments planned in this project, total years of simulation and indicative schedule.

Overall, we plan to perform a total of 950 years of simulations at T255 horizontal resolution (corresponding to approximately 80 km lat x lon) and 91 vertical levels in the atmosphere, and ORCA1 grid in the ocean (irregular grid corresponding to nominally an average of 1 deg lat x lon) with 46 vertical levels. Additionally, using the same configuration, we will need about 50 years of simulations to perform preliminary tests aimed at verifying technical aspects of the new albedo parameterization.

The scheduling of the simulations is as follows:
-2016: implementation, preliminary test and validation of the new albedo parameterization Test-ALB (50 years) + historical runs Hist-CTL and Hist-ALB (2*115 years); TOT = 280 years

-2017: CMIP6 projections Proj-CTL (120 years), Proj-ALB (120 years) and GLACE-A (one member=120 years); TOT = 360 years

-2018: GLACE-CMIP6 runs GLACE-A (one member 120 years) and GLACE-B (240 years); TOT = 360 years

Configuration and justification of resources

We will use EC-Earth3.2 in the standard model configuration: IFS cycle 36r4, NEMO 3.3.1 and OASIS3. The default resolution is T255 with 91 vertical levels in the atmosphere, and ORCA1 with 46 vertical levels in the ocean. The EC-Earth version 3.2 is still under testing on the cca platform and the porting procedure is expected to complete in a few weeks (at the date of writing). Based on the extensive evaluation performed in the framework of EC-Earth consortium using EC-Earth 3.1, the optimal configuration on cca is obtained by using 15 nodes, i.e. 360 total cores. The processors are allocated such that 288 are for IFS, 48 for NEMO and 16 for OASIS. With this optimal configuration, it is estimated that the model requires about 13500 SBUs per year. Therefore, the total resources estimated for the project in three years is rounded to 14000000 SBUs (See Table 1 for distribution of activities per year).

The storage (atmosphere+ocean) required is about 50 GB per year of simulation assuming 6-hourly output storage for the atmosphere and monthly means for the ocean. Therefore, the total storage required for the project is: 50000 GB

For comparison, the computing resources allocated (2nd column) and used (percent with respect to allocated; 3rd column) for the previous special project (SPITALES; http://old.ecmwf.int/about/special_projects/Requests_2013/Italy_Alessandri_new.pdf) in 2013 and 2014 are reported in Table 2.

Table 2. Use of SPITALES resources during the previous years of the project.

Year	Allocated budget	Percent used (with respect to request)
2013	1.6 million	70
2014	2.2 million	100
	+ 1082440 (additional)	89

It is noted that by passing from low resolution in EC-Earth2.4 (T159L62; released resolution) to higher resolution in EC-Earth3.2 (T255L91), together with the transition from previous IBM Power7 c2a system to the new CRAY cca platform, is leading to almost a quadrupling of resources per year that are required to run the EC-Earth ESM.

In case additional resources will become available through applications to PRACE and analogous programmes, further simulations will be performed with fixed land use change (as mentioned for the historical simulations) and to possibly enlarge the sampling for the experiments described in Table 1, i.e. increase the number of ensemble members.

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