APPLICATION FORM
DECI 7 call

General Information

Type of proposal	DECI PROJECT
Start date	1st Nov 2011

Project acronym:	SPIESM
Research field	Earth Sciences and Environment

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Amount of computing time requested in core-hours	5,000,000

Class of machine	
IBM BlueGene/P	☐
IBM Power 6	☐
Cray XT4/5/6, XE6	√
Cluster (Xeon/Nehalem+GPU/SGI/PowerPC/Westmere+GPU/Bullx+GPU)	☐

Summary of the project: (Maximum 500 words):

SPIESM : Seasonal prediction improvement with an Earth System Model

This project contributes to the "Reducing Uncertainty in global Climate Simulations using a Seamless climate prediction system (RUCSS)" project funded by the Spanish Science and Investigation Ministry. In RUCSS we aim at testing the seamless approach (Palmer et al., 2008) for climate modelling with the EC-Earth Earth System Model (ESM) to constrain the sources of uncertainty in both short-term climate prediction and climate-change projections by increasing the understanding of the climate system. In this project, detailed analysis of climate simulations with different time horizons will be carried out using similar metrics to better understand the development of the systematic errors in EC-Earth with the hope of reducing the risk of overconfidence in both climate predictions and long-term projections. Among the processes that will be investigated are the water vapour feedback in the extratropics, the climate variability at the surface of the tropical Pacific and the extraordinary summer warming and drying observed and foreseen over Southern Europe.

The basic premise of the seamless approach is that there are fundamental physical processes in common to both seasonal and decadal forecast, as well as climate-change time scales. If essentially the same ESM using a similar ensemble system can be validated both probabilistically and from a physical point of view on time scales where validation data exist, that is, on daily, seasonal and decadal time scales, then users will have the possibility of a) modifying the probabilistic estimates of regional climate-change, b) gaining insight into the ESM limitations to reduce the systematic error and c) improve the realism of the unavoidable physical parameterizations used in dynamical models. The seamless approach makes no distinctions about the relevance of particular processes in an ESM as a function of the time scale of the target problem, the correct representation of all physical processes affecting all types of climate simulations.

This initiative is both innovative and ambitious. A limited number of seasonal forecasting research and operational groups already exists in Europe (EUROSIP, an operational system to which the UK Met Office, Météo-France and the European Centre for Medium-Range Weather Forecasts contribute; Stockdale et al., 2009), Canada (with the multi-model operational system run by Environment Canada; Derome et al., 2001), USA (the National Centers of Environmental Prediction, NCEP, with their Climate Forecast System; Saha et al., 2006), Australia (the Australian Bureau of Meteorology runs the POAMA system; Wang et al., 2008), and Korea (the Asia-Pacific Climate Community, APCC gathers quasi-operational multi-model seasonal forecast information; Wang et al., 2008). At the same time, a great interest in climate modelling has risen in Europe and some skill in seasonal predictions of summer temperature has been found over Southern Europe, as well as for other regions where there are European interests (e.g. South America and areas of Africa).

Recent bibliographic references that are relevant to the project:

Derome J., G. Brunet, A. Plante, N. Gagnon, G. J. Boer, F. W. Zwiers, S. J. Lambert, J. Sheng and H. Ritchie, 2001. Seasonal predictions based on two dynamical models. Atmos. Ocean., 39, 485-501.

Doblas-Reyes, F.J., A. Weisheimer, M. Déqué, N. Keenlyside, M. McVean, J.M. Murphy, P. Rogel, D. Smith and T.N. Palmer (2009). Addressing model uncertainty in seasonal and annual dynamical seasonal forecasts. Quarterly Journal of the Royal Meteorological Society, 1538-1559, doi: 10.1002/qj.464

Doblas-Reyes, F.J., M.A. Balmaseda, A. Weisheimer and T.N. Palmer (2011). Decadal climate prediction with the ECMWF coupled forecast system: Impact of ocean observations. Journal Geophysical Research A, in press.

Doblas-Reyes, F.J., R. Hagedorn, T.N. Palmer and J.-J. Morcrette (2006). Impact of increasing greenhouse gas concentrations in seasonal ensemble forecasts. Geophysical Research Letters, 33, L07708, doi:10.1029/2005GL025061.

Doblas-Reyes, F.J., R. Hagedorn and T.N. Palmer (2006). Developments in dynamical seasonal forecasting relevant to agricultural management. Climate Research, 33, 19-26.

Palmer, T.N., F.J. Doblas-Reyes, A. Weisheimer and M. Rodwell, 2008. Towards "seamless" prediction: Calibration of climate-change projections using seasonal forecasts. Bulletin of the American Meteorological Society, 89, 459-470.

Saha, S., S. Nadiga, C. Thiaw, J. Wang, W. Wang, Q. Zhang, H. M. van den Dool, H.-L. Pan, S. Moorthi, D. Behringer, D. Stokes, M. Pena, S. Lord, G. White, W. Ebisuzaki, P. Peng and P. Xie , 2006. The NCEP Climate Forecast System. J. Climate, 19, 3483.3517.

Stockdale, T., F.J. Doblas-Reyes and L. Ferranti, 2009. EUROSIP: multi-model seasonal forecasting. ECMWF Newsletter, 118, 10-16.

Wang, B., J. -Y. Lee, I.-S. Kang, J. Shukla, C.-K. Park, A. Kumar, J. Schemm, S. Cocke, J.-S. Kug, J.-J. Luo, T. Zhou, B. Wang, X. Fu, W.-T. Yun, O. Alves, E. K. Jin, J. Kinter, B. Kirtman, T. Krishnamurti, N. C. Lau, W. Lau, P. Liu, P. Pegion, T. Rosati, S. Schubert, W. Stern, M. Suarez and T. Yamagata, 2008. Advance and prospectus of seasonal prediction: assessment of the APCC/CliPAS 14-model ensemble retrospective seasonal prediction (1980–2004). Climate Dynamics, 33, DOI:10.1007/s00382-008-0460-0.

Weisheimer, A., F.J. Doblas-Reyes, T. Jung and T.N. Palmer (2011). On the predictability of the extreme summer 2003 over Europe. Geophysical Research Letters, 38, L05704, doi:10.1029/2010GL046455.

Computer resources requested:

Total storage required (Gbyte) (only available during the duration of the project)	5000
Maximum number of files to be stored during the granting period	10000
Amount of data to be transferred to/from the production system (total amount Gbyte)	5000

Describe your strategy concerning the handling of data (pre-/post-processing, transfer of data to/from the production system, retrieving of relevant data for long-time storage after the end of the project to the applicant's local system (data storage is only possible during the duration of the project). Please also include any middleware requirements (UNICORE, DESHL, GridFTP, etc.):

Our intention is to use an automatic job launching and monitoring tool via SSH. IC3 has developed such a tool which is called Autosubmit. It is designed by using Python suite of scripts. It can manage number of experiments with arbitrary number of jobs on any HPC platform remotely. Autosubmit acts as a wrapper over the queue system and HPC scheduler. It defines the experiment as a sequence of jobs (list of jobs) and after resolving dependencies among different types of jobs, it submits the jobs one by one on queue system. Thereafter it keeps on monitoring the queue system after some defined time interval and perform further necessary actions accordingly.

We do not need any pre-processing ot the data but the post-processing of the outputs will include an interpolation toward a coarser grid to reduce the cost of storage. The transfer of files from our local machines to the production system will be minimal as the initial conditions (atmosphere, ocean and sea-ice) are relatively small, but we will have to transfer all the outputs files from the production system to our local machines, after interpolation, to perform the analyses locally.

Wall clock time of a typical run	4.5-8.5 h
Numbers of jobs that can run simultaneously i.e do not depend on each other	10
Expected number of cores	2000-4000
Memory necessary per run	50 Gb

I/O intensive ? **Yes**

If the answer is Yes, please describe your strategy concerning I/O (for example usage of I/O libraries, MPI I/O, netcdf, HDF5 or other approaches):

Our simulations will require MPI libraries and runtime facilities (MPICH2, MPICH-MX, OpenMPI), optimization and data handling tools, such as BLAS LAPACK NETCDF PARMETIS SCALAPACK P-NETCDF UDUNITS GRIB_API, and general configurations tools, such as PERL PYTHON AUTOCONF AUTOMAKE.

Describe what work has already been done to develop the codes

This should include the following: describing the main algorithms, how they have been implemented and parallelized, and their main performance bottlenecks and the solutions to the performance issues you have considered. Please provide the name and version of all codes to be used in the project. For each code that needs to be optimized, please provide the details listed below.

1. **Name and version.**
2. **Webpage and other references.**
3. **Licensing model.**
4. **Contact information of the code developers.**
5. **Your relationship to the code (developer, collaborator to main developers, end user, etc.).**

The EC-EARTH earth-system model (http://ecearth.knmi.nl) is the tool selected to perform the investigation, of which we are end users, as part of the EC-EARTH consortium. The development of EC-Earth started with ECMWF's Integrated Forecast System (IFS) as a well-tested atmospheric module, with different components being added over time. The oceanic (NEMO), sea ice (LIM) and land surface (HTESSEL) components have been coupled to the IFS through the OASIS3 coupler. The first scientific papers (e.g. Hazleger et al., 2010) that use EC-Earth have already been published. Additionally, EC-Earth will contribute to the next Coupled Model Intercomparison Project (CMIP5), distributing different members of the various ensemble experiments among the consortium institutes, thus using different hardware platforms:

- SGI Altix 3500, Intel Itanium 2 processors by the KNMI
- NEC-SX6 by the DMI
- Linux cluster, 129 CPU nodes, each with 64-bit dual Intel Xeon EM64T CPU @ 3.40GHz by the SMHI
- Dell PowerEdge 2900 (18 nodes) by the CGUL
- IBM pSeries 575, Power6 processors by the KNMI
- 64 IBM p575+ 16-way nodes, 1.9GHz dual-core cpus, 2080 GB memory by the KNMI
- IBM Power PC 970MP processors at 2.3 GHz by the IC3

In this project, we are planning to run the most recent EC-Earth version (version 3) at very high horizontal resolution, that is :

- T511 for the atmospheric and soil components or T799 if Lindgren is more efficient than expected
- ORCA1 resolution for the ocean and sea ice components or ORCA0.5°/ORCA0.25° resolution if ocean and sea ice conditions become available at this resolution before the end of the allocated period.

Hazeleger W., Severijns C., Semmler T, Ştefănescu S, Yang S, Wang W, Wyser K, Dutra E, Baldasano J. M, Bintanja R, Bougeault P, Caballero R, Ekman A M L, Christensen J H, van den Hurk B, Jimenez P, Jones C, Kållberg P, Koenigk T, McGrath R, Miranda P, Van Noije T, Palmer T, Parodi J A., Schmith T, Selten F, Storelvmo T, Sterl A, Tapamo H, Vancoppenolle M, Viterbo P, Willén U. (2010) EC-Earth: A Seamless Earth-System Prediction Approach in Action. Bull. Amer. Meteor. Soc. 91:10, 1357-1363. doi: 10.1175/2010BAMS2877.1

Klaus Wyser (Klaus.Wyser@smhi.se) and Wilco Hazelger (hazelege@knmi.nl) and Richard Bintaja (Richard.Bintanja@knmi.nl) are the main coordinators of the code development.

Describe what enabling work will need to be completed before production runs can begin. Please make it clear what work will need to be done by your own group and what you are requesting to be done by PRACE staff. Please also make it clear if any enabling work can be done in parallel with production runs:

Through a recent national Swedish allocation, our co-applicants (Stockholm University and SMHI) will have access to the Lindgren system from summer 2011. Within this national project they will install the latest version 3 of EC-Earth and apply the system to the problem of decadal climate prediction. This work will begin in late August. We are therefore confident the model system will be fully installed by the time Lindgren would be available to us through this application. Furthermore, SMHI scientists lead the development of a very high resolution version (~0.25°) of EC-Earth, with PRACE support, through the is-ENES project. Testing of this system is planned on Lindgren under their national allocation, this will also facilitate a rapid application of the system within this application. Cerfacs is mainly involved in OASIS coupling performance measurement, in the context of scalability and performance on PRACE machines, and this builds on collaborative work between SMHI and Cerfacs through the is-ENES funded OASIS dedicated support facility and through the is-ENES/PRACE collaborative work on climate high resolution models.

If we are able to run on Lindgren, the enabling work will therefore be significantly reduced compared to any other platform.

As part of the enabling work however, it will be necessary to test the automatic submitting tool called Autosubmit which has been developed at IC3. Autosubmit chains the jobs but also allows some monitoring and handling of the multiple dependencies between jobs. It runs locally and logs to the platform regularly to check the status of the running jobs, submit the following if necessary, re-submit the failed ones in some special cases. For the testing and adaptation of this tool, we will need some advices from the PRACE staff.

Finally, enabling work will include some testing of the data transfer from the computing nodes to the HPC storage and from there to our local machines.

The access to a common platform for scientists from IC3, SMHI, MISU and CERFACS thanks to the PRACE support stands as an opportunity to enhance collaborative work on the seamless approach and on the further development of the EC-Earth model in terms of scalability, performance of very high resolution jobs and multiple ensemble simulations. This will also be a preparatory step for an application to PRACE Tier 0 systems in 2012.

Discuss the routes that you will use for dissemination of the project and for any appropriate knowledge transfer. This should include any resources that you will be using to support this. (Maximum 500 words) :

The dissemination of the project will be done through the submission of at least two manuscripts to international journals on the following topics:

- Forecast quality assessment of the EC-Earth seasonal hindcasts and its comparison with other systems, such as EUROSIP and NCEP's Climate Forecast System.
- Analysis of the systematic error of the EC-Earth seasonal hindcasts over Africa. In particular, East and West tropical Africa as well as Southern Africa will be considered as part of an additional contribution to the European-Union funded project QWeCI, wherein IC3 takes part.

The knowledge gained on the issues of scalability and performances through the development of EC-Earth will be communicated to is-ENES and PRACE scientists. The testing of Autosubmit tool on a new platform will help its further development. ECMWF seasonal prediction group will also be informed via the scientific performance of EC-Earth in seasonal prediction mode at high resolution. The use and investigation on scaling and performance of both OASIS and NEMO will carry potential benefits for other European ESM groups working with these tools.

<u>Confidentiality</u>

Is any part of the project covered by confidentiality? No

If YES, please give the reasons for confidentiality:

Do you have any other support for this application e.g. from your national funding council, the EC or international collaborations? Please give details of this below :

These analyses will contribute to the scientific project recently funded by the Spanish Science and Investigation Ministry "Reducing Uncertainty in global Climate Simulations using a Seamless climate prediction system (RUCSS)". The RUCSS project started on January 2010 and will last until December 2014. The Spanish Ministry has provided funding for one PhD student, travel to conferences and article fees.

Please use the remainder of this form to give a detailed description of the project and its relevance for PRACE.

Please provide 3-4 pages, including:
1. scientific objectives
2. scientific and technical innovation potential
3. current profile and performance of code(s), including scalability, requirements on interconnect, I/O, architecture, clarification of how requested core-hours was calculated, are jobs independent, chained and/or workflows, etc.
4. computational objectives
5. specific benefits expected from PRACE
6. summary

1. Scientific objectives

The seamless approach, which promotes the use of the same dynamical climate model across different time scales, going from seasonal to climate-change time scales, as the most adequate way to develop better models and increase the much-required confidence on future climate-change projections, has been recently defined by the World Climate Research Programme (WCRP). EC-Earth, a new Earth System Model (ESM) for climate research, is based on the operational seasonal forecasting system from the European Centre for Medium-Range Weather Forecasts (ECMWF), which has proved to the best of its kind in the world. The EC-Earth consortium within which different groups focus on the preformance of the EC-Earth model on different timescales represents a first oportunity to address the seamless paradigm with a high-quality modelling system. Dynamical seasonal forecasting, an aspect still not explored with EC-Earth, is an additional entry gate into the seamless framework that offers access to many more validation cases (compared to decadal predictions and climate-change projections). This increased number of cases should help identify the processes at the origin of climate-change projection confidence. In addition, the use of EC-Earth for seasonal forecasting will allow a forecast system to benefit for the first time from developments in climate-change modelling (e.g. direct and indirect aerosol effects, dynamic vegetation and water table, etc). Forecast quality assessment will be carried out in a probabilistic framework. The assessment will focus on seasonal means of temperature and precipitation over the European and extended Mediterranean area, the tropical oceans, the Northern Hemisphere continental areas, as well as on the major teleconnection modes.

2. Scientific and technical innovation potential

One of the main scientific contributions of the “Seasonal prediction improvement with an Earth System Model” proposal will be the submission of at least two manuscripts to international journals. The knowledge gained on the issues of scalability and performances through the development of EC-Earth will be communicated to is-ENES and PRACE scientists. The use and investigation on scaling and performance of both OASIS and NEMO will carry potential benefits for other European ESM groups working with these tools.

Other benefits in terms of knowledge and technological advances turn around the progress of the cutting-edge concept of seamless climate prediction. This concept is likely to be the backbone of a significant portion of the research to be carried out for the next IPCC assessment report. To our knowlegde, only the UK Met Office, the National Center for Atmospheric Research and the Japan Meteorological Institute have undertaken this highly demanding task as the amount of simulations required exceeds the computing resources of most institutions. EC-Earth offers a unique oportunity to contribute to this effort by doing frontier research. The results of the project will be of the research type and, hence, will not be the subject of commercial use. Instead, the results will be widely presented in scientific conferences and courses, which includes a plan to accept a reduced number of master students at the CFU to acquire the experience of using a global dynamical model. Furthermore, the results of the project will feature at the meetings of CLIVAR’s Working Group on Seasonal-to-Interannual Prediction, of which the team leader is a panel member. Finally, an important objective consists in the planned public data dissemination system that will increase the outreach of the project results by allowing international scientists to freely access a significant subset of the model output.

The applicant research team (CFU) is part of the EC-Earth consortium. As such, it is collaborating closely with teams at KNMI, ECMWF, MISU, the Danish Meteorological Institute (DMI) and the Swedish Meteorological and Hydrological Institute (SMHI), all members of the EC-Earth consortium. This feature rightly emphasizes the potential benefits derived from the proposal, which could be associated not only with important technical issues, such as implementing and deploying the EC-Earth model itself, but also with relevant scientific questions like exploring different methodologies to initialize and assess seamless predictions. Due to the absolute novelty of the seamless approach, this proposal will guarantee the international presence of the project in scientific conferences and courses.

On the other hand, the project leader has a long experience in seasonal forecasting that started the late 1990s. This includes the technical implementation of seasonal forecast systems, the performance of seasonal forecasts for research and the detailed evaluation of these forecasts. This experience has been the source of a vast range of scientific papers, and been the origin of a large network of collaborations in the field and beyond. In particular, in the framework of the ENSEMBLES FP6-European project, in which the leader of the current proposal was one of the principal investigators, dynamical seasonal forecasting and climate-change scientists found an excellent ground for collaboration. The current proposal, thus, will also take advantage of this important factor to ensure the quality of its attempts in this field.

Finally, the project leader team has received external funding from the European Commission Seventh Framework, FP7, with two distinct contracts: QWeCI, Quantifying weather and climate impacts on health in developing countries; and CLIM-RUN, Climate local information in the Mediterranean region: responding to user needs. This scenario ensures an encouraging window at European level to promote preliminary results and discuss them, and to provide direct benefit of climate information derived from the proposal to applications on health, renewable energies and/or tourism.

3. current profile and performance of code(s), including scalability, requirements on interconnect, I/O, architecture, clarification of how requested core-hours was calculated, are jobs independent, chained and/or workflows, etc.

The EC-EARTH model uses korn shell (ksh93) and perl in a generic Makefile to build the source libraries. MPI1 is required for the parallel execution. The code is written in Fortran 95, so that a compiler that supports an auto-double (or -r8) capability is needed. Some routines are coded in C, so that a standard compiler is necessary. The OASIS3 coupler requires Cray pointers. OpenMP could also be used with the atmosphere component. This requires the MPI implementation to be thread-safe. The output is in GRIB format for the soil and atmosphere and in NetCDF for the ocean component, henceforth the corresponding set of libraries are also required. OASIS3 and NEMO make use of NetCDF libraries. The number of processors used to run the system can be adjusted for each platform.

Numbers for this system running on Lindgren were not available at the time of writing. To obtain an estimate of the required computer resources, simulations performed on an IBM power PC platform platform at BSC was used. An IFS-only simulation with T159L62 resolution used 96 MPI tasks and employed ~200 CPU hours per year of simulation. Due to the increase in horizontal (*10.5), vertical (*1.5), and temporal resolution (*4), the cost of one year of simulation with T511L91 IFS resolution would be 12600 CPU hours. To run 350 years of simulations (details are given in the following section), this leads to a total of 4.500.000 CPU hours, neglecting the cost of the ocean model and the coupler. Adding a small allowance for unavoidable mistakes in the setup of the experiments, we reach a total of 5.000.000 CPU hours. It is likely that an improved scaling on Lindgren reduces substantially this amount, in which case we would be able to run EC-Earth with a T799L91 atmospheric and soil resolution or an ORCA0.5° or ORCA0.25° ocean and sea ice resolution.

As an IFS-only simulation with T159L62 resolution run 1 year in 2h using 96 MPI task on an IBM power PC platform, which gives a typical wall clock of 3h-6h to run one EC-Earth year with a T511L91/ORCA1 resolution with 2000-4000 cores in case of a perfect scaling. Assuming a scaling factor of 0.7 leads to a typical wall clock of 4.5h-8.5h. However, Lindgren being a newer machine set up with 24 cores per node, we could expect a increase in speed by a factor 1.5-2. All the jobs will be independent and can be run in parallel. We plan to run roughly 10 at the same time. Thus, our 350 years of simulations could be run in about one month.

Finally, a large amount of scratch space would be required to perform several runs (there is no dependency between the members of an ensemble or the re-forecasts for each start date) at the same time : 5Tb of storage.

4. Computational objectives

The experiments will be run in high resolution, i.e. :

- T511 resolution for the atmospheric (IFS) and soil (HTESSEL) components, or even T799 if the efficiency of Lindgren allows it.
- ORCA1 resolution for the ocean (NEMO) and sea ice (LIM) components with version 3 of the EC-Earth model which has been recently released. If ocean and sea ice initial conditions become available at ORCA0.25° resolution before the end of the computing period, we also plan to use this higher resolution for ocean and sea ice components.

The length of our sample of hindcasts (or re-forecasts) is limited by the quality of the data used to provide the initial conditions and to verify the predictions. As a consequence, the experiments will be carried out first for the period posterior to 1980, when the observational network has reasonable quality and coverage. We will this conduct an ensemble experiment with two start dates per year (first of May and November) over the period 1981 to 2010 using initial conditions from ERA-40 and ERA-Interim and the ECMWF System 4 ocean reanalysis, where the hindcasts are run for a forecast period of seven months into the future.

The comparison of the forecast quality with a companion set of experiments run at lower resolution at BSC (T159/ORCA1) will allow an assessment of the impact of increasing the horizontal resolution.

The experiment makes a total of at least 60 start dates (2 start dates per year over a 30 year period). This makes a total of 350 years of simulation when using ten-member ensembles. All the start dates and all the members being independent, the 600 jobs of seven months will all be independent.

5. specific benefits expected from PRACE

This project is particularly innovative and demanding in computational resources. Recognizing that forecast skill is likely to be dependent on specific atmosphere-ocean-ice initial conditions and that quality assessment requires large enough samples, we consider the construction of a hindcast dataset as long as possible rather than the analysis of a few case studies. PRACE would offer the opportunity to run at very high horizontal resolution and assess the potential benefits of such an increase in resolution which has never been assessed in hindcast mode up to now.

6. summary

The goal of this “Seasonal prediction improvement with an Earth System Model” proposal is to investigate the evidence that seasonal climate variables such as regional temperature, precipitation and atmospheric and ocean circulation are predictable with a few months of lead time, within the limit of the predictability induced by ocean surface tropical heat sources. It is expected that understanding the mechanisms that propagate in time the initial-condition information in the climate system will allow the implementation of a long-range seasonal climate forecast capability in our country. The EC-Earth Earth System Model will be used in a set of ensemble seasonal forecast experiments initialized with the best analyses of the climate system available. The focus will be on the European and Mediterranean area, and on the impact of running at very high atmospheric resolution.