AECT-2018-3-0023 Seasonal to Decadal Prediction of Fire danger using an Earth System Model

1. General Information

Activity Id
AECT-2018-3-0023

a) Activity Title
Seasonal to Decadal Prediction of Fire danger using an Earth System Model

b) Area
Astronomy, Space and Earth Sciences

2. Research Project Description

a) Is this a Test Activity?
No

b) Is this a Long Term Activity that will extend over two application periods?
Yes

c) Brief description of the Project
Wildfires are the largest source of biomass burning (approximately 70% of global annual sources) and a great source of pollutants and atmospheric CO2, with all biomass burning accounting for approximately 2GtC, equivalent to 25% of emissions from fossil fuels [1,2]. In addition to having a great impact on the environment, wildfires can also pose a threat to property and human lives and health. On the other hand, anthropogenic climate change is a strong forcing on climate and vegetation. This also has an impact on wildfire severity and occurrence, which in turn has an effect on the global carbon cycle.

Seasonal climate prediction of key variables influencing fire danger, such as precipitation and temperature, are most commonly performed, even operationally, using process-based dynamical models [3]. One such model is EC Earth [4] which couples state-of-the-art atmospheric, oceanic, sea ice and land surface models. Dynamic Global Vegetation Models (DGVMs) are based on Land Surface Models (LSMs), which simulate the interactions between the land surface and the atmosphere, and incorporate, as an improvement compared to LSMs, vegetation dynamics and the carbon cycle [5]. The LPJ-Guess model [6], a variant of the LPJ model with the addition of population dynamics, is coupled to the current version of EC-Earth (3.2.3) and an offline version has been recently developed, using output from the IFS atmospheric model or coupled to an offline version of H-TESSEL [7], the Offline Surface Model (OSM).

LPJ and LPJ-GUESS have been used for studies on wildfire using various fire models in order to study past and future fire sensitivity to climate change and its role in the carbon cycle.
The first such fire model, Glob-FIRM [8], using a moisture extinction threshold for fire occurrence, is included in EC-Earth. Several other fire models have been incorporated into the LPJ and LPJ-Guess models: Reg-FIRM [9] using the Nesterov Index; SPITFIRE [10] using the Rothermel fire behaviour equations; SIMFIRE [11] considering climate and human impacts based on population density ; BLAZE [12] is built on top of SIMFIRE and simulates monthly burned area. Many other wildfire models incorporated into ESMs have been used for long-term studies (e.g. paleoclimatology, sensitivity to climate change) [1], but their use for seasonal prediction of wildfire danger and burned area has not been attempted yet. Given that DGVMs and their wildfire models have been designed for longer timescales, using them for decadal prediction of fire danger and associated CO2 emissions shows promising potential.

The research project proposed here is to implement the EC-Earth-Fire seasonal prediction system for seasonal-to-decadal prediction of fire risk. We plan to generate the initial conditions for initializing the LPJ-GUESS model in seasonal to decadal prediction mode, and perform a series of experiments using the offline version of LPJ-GUESS, forced by the output of the decadal predictions performed by the Climate Prediction Group of the BSC in context of the Decadal Climate Prediction Project (DCPP), which is part of the CMIP6 project. This proposal is an inherent part of its principal investigator's Marie Curie Individual Fellowship "SPFireSD" - Seasonal Prediction of Fire danger using Statistical and Dynamical models (Ref SPFireSD-748750).

References:

1 Hantson, S.,et al., 2016. Biogeosciences 13, 3359–3375.
2 Knorr, W., et al., 2016. Biogeosciences 13, 267–282.
3 Doblas-Reyes, F.J., et al., 2013. WIREs Clim Change 4, 245–268.
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5 Pitman, A.J., 2003. Int. J. Climatol. 23, 479–510.
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7 Balsamo et. al, 2009. J. Hydro.Met., 10, no. 3, 623–43
8 Thonicke, K.,et al., 2001. Global Ecol. Biogeogr. 10, 661–677.
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10 Thonicke, K., et al., 2010. Biogeosciences Discuss. 7, 697–743.
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12 Rabin et. al, 2017. Geosci. Model Dev., 10, 1175-1197

d) Grants and funded projects related to this activity

Reference code
748750

Project title
Seasonal Prediction of Fire danger using Statistical and Dynamical models

Starting date
2017-09-08

Ending date
2019-09-08

Total financing (in EUR)
170.121,00

Financing source
European

e) Brief description of the Project (if this Activity takes place in the context of a Technology or Industrial Project)

f) Specific Activity proposed

The first part of this proposal is dedicated to the initialization of the EC-Earth-Fire seasonal prediction system. Implementing a seasonal prediction system requires the generation of initial conditions at each start date of prediction. While expertise is available at BSC for the generation of atmosphere, ocean and sea ice initial conditions, a methodology will be defined and tested for the generation of land and vegetation surface initial conditions. A pre-industrial spinup will be first done using ERA-20C reanalyse to initialize the model's carbon pools. The vegetation (LPJ-GUESS) and land surface (IFS/OSM) initial states used to initialize each decadal prediction with LPJ-GUESS need to be consistent with the initial states of the atmosphere (and land) and ocean components used to generate the decadal predictions with the fully coupled EC-Earth model. These will be derived from ERA-Interim (after 1979) and ERA-40 or ERA-20C (before 1979) reanalyses for the atmosphere and ORAS4 reanalysis for the ocean, respectively. We thus will run historical LPJ-GUESS/OSM simulations forced with the ERA-Interim and ERA-40 (or ERA-20C) reanalyses. The software infrastructure for these runs has been streamlined by recent developments done by the Team Leader of this proposal as well as EC-Earth partners. The Autosubmit workflow manager will be used to perform the spinup from nearly pre-industrial conditions as well as the forced historical runs. The previous methodology used by our EC-Earth partners involved a lengthy and cumbersome two-step process: first generating the daily forcings from ERA reanalyses using the OSM, which were used by LPJ-GUESS offline to compute the initial states in a manual manner. A second set of initial conditions will be generated using a more sophisticated technique, by nudging the land surface to observed precipitation and soil moisture and constraining the fire model of LPJ-GUESS to observed burned area products. This second set of initial conditions will be generated during the second application period of the project call, after running the entire DCPP hindcast, and will be used for a series of enhanced hindcasts.

The second aspect of this proposal consists in running the decadal LPJ-GUESS offline simulations initialized on Jan 1st of each year of the period 1960-2015, using the initial conditions generated previously. The daily atmospheric and land conditions (precipitation, radiation, soil temperature, near surface temperature and relative humidity and wind) forcing the LPJ-GUESS offline model will be provided by daily output from the DCPP-A hindcast conducted by members of the Climate Prediction group of the BSC. The DCPP-A hindcast consists of 55 predictions of 10 years and 10 members each, representing a total of 5500 years of simulation. We will conduct a first series of offline simulations to test the system using the Glob-FIRM fire model (already present in LPJ-GUESS) and re-do the initial conditions adjusting for any problems encountered and tuning the Glob-FIRM model for decadal predictions. We will then re-do the full hindcast for all members and start dates. As this is a long-term activity, in the second application period of the project we will conduct another series of hindcasts using the second set of improved initial conditions described above, and two more using the SIMFIRE/BLAZE model which is currently being tuned, and the SPITFIRE fire model. The delay between application periods will allow for sufficient time to develop the initialization techniques and test the required fire models.

The number of simulated years required to generate the LPJ-GUESS initial conditions are 100 for the spinup and 115 for the historical run. Restarts will be saved every 10 years to account for machine failures. This amounts to 650 years of simulation, considering that we will conduct 3 sets of initial condition creation simulations. Based on our benchmarks, coupled LPJ-GUESS/OSM simulations used to generate the initial conditions require 1 hour of computing time on 2 nodes (96 cores) on the Marenostrum4 system. We estimate the total time required to generate the initial conditions at 70,000 cpuhours, considering a 10% failure rate from machine or other errors.

The number of simulated years for the decadal hindcasts is 5,500 per set of hindcasts. LPJ-GUESS standalone simulations require 30 minutes of computing time on 1 node (48 cores) on the Marenostrum4 system. Given that we will conduct 5 sets of hindcasts, we estimate the total time required at 726,000 cpuhours (with a 10% failure rate). Given the amount of data processing involved in transforming the flat-text file output of LPJ-GUESS to netcdf format and allowing a larger buffer for errors, we estimate the total cost of the project at 900,000 cpuhours.

Disk space required for output and restarts is 50 GB/year for coupled LPJ-GUESS/OSM runs with restarts, 10 GB/year for coupled runs without restarts and 30 GB/year for LPJ-GUESS runs with restarts (mostly dominated by the LPJ-GUESS restart files) and 1GB/year for LPJ-GUESS runs without restart. The decadal predictions will be done with no restarts to save computing time and disk space, considering that each 10-year simulation requires only 5 hours (on 48 cpus) of computing time which implies a low failure rate.

g) Computational algorithms and codes outline

The EC-Earth3 GCM model has three major components: IFS (atmospheric), NEMO (ocean dynamics+PISCES for ocean biogeochemistry) and OASIS3 (coupler). It is essential to configure and build separate executable for each one of them. For IFS there is a possibility to activate an OpenMP switch but in this case the implemented MPI should be thread-safe. IFS generates output in GRIB format and NEMO in NetCDF, while OASIS3 does not generate any output. At the end of a simulation the three components always generate restarts separately (IFS in binary, and NEMO and OASIS3 in NetCDF format). In addition to the GCM EC-Earth3 model, this project utilises the LPJ-GUESS dynamic vegetation model and the OSM land surface model in offline configuration. LPJ-GUESS and OSM are also coupled via OASIS3, and are forced by output from coupled EC-Earth3 simulations or reanalysis data. LPJ-GUESS parallelization is done with MPI while OSM is built with OpenMP. For configuring and building the model executable, GNU make 3.81 or 3.81+, FORTRAN 77/90/95 complaint compiler and C++ compiler with preprocessing capabilities and NetCDF4 deployed with HDF5 and SZIP are needed. A newly designed tool for automatic build configuration called "ec-conf" can be used. This useful tool requires Python 2.4.3 or 2.4.3+ (although it does not work yet with Python 3.0+). For NEMO, FCM, bash and perl are essential, and the GRIB_API I/O 1.9.9 or 1.9.9+ and GRIBEX 370 are required for IFS. GNU date (64-bit) is also required for executing the model with the run scripts. EC-Earth3 supports several configurations which have already been tested on various supercomputing platforms, Marenostrum3 and Marenostrum4 among them. In this activity we will use the T255-ORCA1 configuration, which corresponds to a spatial resolution of 80 km in the atmosphere and 100 km in the ocean. In order to store sources and initial data, the experiments require at least ~100 GB of disk space for each release. Currently, four releases of EC-Earth3 are available, v3.0, v3.0.1, v3.1 and v3.2.3. This activity is planned to be carried out with the version v3.2.3.

3. Software and Numerical Libraries

Software components that the project team requires for the activity.

a) Applications + Libraries

BLAS, FFTW, HDF5, LAPACK, NETCDF, UDUNITS, NCO, INTELMPI

b) Compilers and Development Tools

GCC, TOTALVIEW, INTEL

c) Utilities + Parallel Debuggers and Performance Analysis Tools

CMAKE, PERL, PYTHON, NCVIEW, AUTOCONF

d) Other requested software

GRIP_API, CDO

e) Proprietary software

4. Research Team Description

a) Personal Data

Name of Team Leader	Etienne Tourigny
Gender	Male
Institution	BSC
e-mail	etienne.tourigny@bsc.es
Phone	+34 934054290
Nationality	Canada

b) The employment contract of the activity leader with the research organisation is valid at least 3 months after the end of the allocation period.

Yes

c) Curriculum Vitae of the Team Leader

Etienne Tourigny has a PhD in Meteorology from the Instituto Nacional de Pesquisas Espaciais (INPE-CPTEC, Brasil) and a M.Sc. in Atmospheric Science from the Université du Québec à Montréal (UQAM). Dr. Tourigny has a strong multi-disciplinary background, having studied physics, computer science, atmospheric science and biosphere-atmosphere interactions. He has professional experience in the Information Technology sector, before transitioning to the climate research field where he developed his expertise in the field of climate seasonal prediction, having studied the impacts of ENSO on precipitation anomalies in the tropical Americas. He contributed to the development of the Brazilian Earth System Model (BESM) at INPE – CCST acquiring in the process a very strong expertise in vegetation and fire modelling as well as in high-performance computing. Dr.

Tourigny joined the climate prediction group at BSC and obtained a Marie-Curie fellowship. He is developing a new research line on seasonal to decadal predictions of wildfires while, at the same time, actively contributing to the development of the CMIP6 version of the EC-Earth ESM.

d) Names of other researchers involved in this activity

Francisco Doblas-Reyes (francisco.doblas-reyes@bsc.es)
Pablo Ortega (pablo.ortega@bsc.es)
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Raül Marcos (raul.marcos@bsc.es)
Lars Nieradzik, Lund University (lars.nieradzik@nateko.lu.se)
All at Barcelona Supercomputing Center

e) Relevant publications

Doblas-Reyes, F. J., I. Andreu-Burillo, Y. Chikamoto, J. García-Serrano, V. Guemas, M. Kimoto, T. Mochizuki, L. R. L. Rodrigues, and G. J. van Oldenborgh. "Initialized Near-Term Regional Climate Change Prediction." Nature Communications 4 (April 16, 2013): 1715. https://doi.org/10.1038/ncomms2704.

Turco, Marco, Sonia Jerez, Francisco J. Doblas-Reyes, Amir AghaKouchak, Maria Carmen Llasat, and Antonello Provenzale. "Skilful Forecasting of Global Fire Activity Using Seasonal Climate Predictions." Nature Communications 9, no. 1 (July 13, 2018): 2718. https://doi.org/10.1038/s41467-018-05250-0.

Doblas-Reyes, Francisco J., Javier García-Serrano, Fabian Lienert, Aida Pintó Biescas, and Luis R. L. Rodrigues. "Seasonal Climate Predictability and Forecasting: Status and Prospects." Wiley Interdisciplinary Reviews: Climate Change 4, no. 4 (July 1, 2013): 245–68. https://doi.org/10.1002/wcc.217.

Marcos, Raül, Marco Turco, Joaquín Bedía, Maria Carmen Llasat, and Antonello Provenzale. "Seasonal Predictability of Summer Fires in a Mediterranean Environment." International Journal of Wildland Fire 24, no. 8 (2015): 1076–84.

Rabin, S. S., J. R. Melton, G. Lasslop, D. Bachelet, M. Forrest, S. Hantson, J. O. Kaplan, et al. "The Fire Modeling Intercomparison Project (FireMIP), Phase 1: Experimental and Analytical Protocols with Detailed Model Descriptions." Geosci. Model Dev. 10, no. 3 (March 17, 2017): 1175–97. https://doi.org/10.5194/gmd-10-1175-2017.

5. Resources

a) Estimated resources required for the Activity for the current Application Period

Requested machine	MareNostrum 4 ((Intel(R) Xeon(R) Platinum 8160, 2.10GHz with Intel(R) Omni-Path / 165888 cores)
Interprocess communication	Tightly Coupled

Typical Job Run

Number of processors needed for each job		48.00		
Estimated number of jobs to submit		2750.00		
Average job durations (hours) per job		5.00		
Total memory used by the job (GBytes)		100.00		
Largest Job Run				
Number of processors needed for each job		96.00		
Estimated number of jobs to submit		65.00		
Average job durations (hours) per job		10.00		
Total memory used by the job (GBytes)		200.00		
Total disk space (Gigabytes)	**Minimum**	500.00	**Desirable**	1000.00
Total scratch space (Gigabytes)	**Minimum**	1000.00	**Desirable**	2000.00
Total tape space (Gigabytes) (*)	**Minimum**	0.00	**Desirable**	0.00
Total Requested time (Thousands of hours)		900.00		

If this activity is asking for more than 10Million CPU hours, you need to justify the amount of resources requested for the activity. (max 1000 characters)

INFORMATION: The estimated cost of the requested hours, considering only the electricity cost, is 963 euros.

The required resources have to be executed in the selected machines, the other architectures do not fit the requirements to execute the proposal.
** this option implies that if no hours in this machine/these machines are available, the acces committee will reject the full application.

b) Estimate of the total resources that the Activity will require until it is completed (including the present and all the following Application Periods)

Number of application periods expected to complete this Activity

2

Total Requested Time (thousands of hours) expected to complete this Activity (sum of both periods)

900.00

6. Abstract for publication

Wildfires are the largest source of biomass burning and a great source of pollutants and atmospheric CO2. In addition to having a great impact on the environment, wildfires can also pose a threat to property and human lives and health. On the other hand, anthropogenic climate change is a

strong forcing on climate and vegetation. This also has an impact on wildfire severity and occurrence, which in turn has an effect on the global carbon cycle.

The research project proposed here is to implement the EC-Earth-Fire seasonal prediction system for seasonal-to-decadal prediction of fire risk, combining decadal predictions done using a state-of-the-art global climate model with an offline dynamic vegetation model and novel model initialization techniques.

7. Contact with CURES during last year

Information about the RES Users Committee (CURES).

a) User has contacted the CURES during last year

No

b) If not, indicate why you have not contacted the CURES

Because this is my first application to RES.

Usage Terms & Conditions

- The Usage Terms & Conditions have been already accepted.