Barcelona Supercomputing Center
Centro Nacional de Supercomputación

RES
RED ESPAÑOLA DE SUPERCOMPUTACIÓN

AECT-2018-1-0006 Volcanic activity in seasonal to decadal climate forecasts

1. General Information

Activity Id

AECT-2018-1-0006

Previous Activity Id

AECT-2017-2-0009

a) Activity Title

Volcanic activity in seasonal to decadal climate forecasts

b) Area

Astronomy, Space and Earth Sciences

2. Results of this activity from the previous application periods

a) Description of the results obtained during the previous periods

Part 1: Forecasting the climate response to volcanic eruptions (completed)

Under the CMIP5 exercise (Taylor et al., 2005), the climate prediction team of the BSC took part in the Decadal Climate Prediction Project (DCCP, Boer et al., GMD, 2016), by running 5-member decadal hindcasts, initialised in November of each year from 1960 to 2015. Here, we have run again these hindcasts for the periods covering the last large volcanic eruptions, but with a model configuration that excludes the volcanic forcing. This was consisting in simulations initialised the years surrounding the 1963 Agung, the 1982 el Chichón and the 1991 Pinatubo eruptions, i.e. fifteen 10-year and 5-member experiments, reaching a total of 750 years of simulation. This set of experiments allowed to investigate the atmospheric and oceanic responses to the last eruptions in decadal hindcasts with the final goal to diagnose the forecast system skill that is related to the volcanic forcing. A second set of experiments has been conducted following a similar protocol, but with hindcasts using an idealized volcanic forcing that could be used for real-time forecast. This idealized forcing is based on an estimation of the observed volcanic forcing that decreases with an exponential decay during the forecast. It is representative as the protocol of a real-time forecast, since it does not use any information of the future (as retrospective hindcasts typically include observed forcings and cannot be considered as real forecasts). This second set consists in a total of 750 years of simulation.

We also run a third set of simulation that was based two 10-year and 20 member hindcasts initialised in 2014, one excluding and another one including a Pinatubo-like eruption (a total of 400 years). This last set was a common experiment required for the VolMIP and DCPP initiatives. It aims at comparing CMIP-model forecasts considering a potential new eruption that would have occurred recently. This set of experiment is currently analysis in collaboration with European colleagues.

The first part of this RES application allowed to produce experiments that have been used to evaluate the ability of the EC-Earth forecast system to predict the climate response to volcanic eruptions. It was based on a total of 1900 years of simulation requiring a total of ~570000 hours CPU (~300*1900). We used only 50% of the amount of hours asked in this RES application, because half of the simulations have been run under other account one month before the beginning of this RES project, to fit the calendar of the scientific project VOLCADEC (funded by the MINECO).

The full set of simulations run under this project have been used for investigations described in a publication that is currently under revision for Environmental Research Letters (see the list below). The investigations performed trough this RES project ave been also useful for the finalisation of another publication devoted to the climate response to volcanic eruptions (Ménégoz et al., 2017, see the title in the list below).

b) List of publications, communications in conferences, presentations, patents, etc, resulted in previous periods of this Activity

Publications:

* Ménégoz, M., Bilbao, R., Bellprat, O., Guemas, V., Doblas-Reyes, F.J., Forecasting the climate response to volcanic eruptions, in revision for Environmental Research Letters.

* Ménégoz, M., Cassou, C., Swingedouw, D., Bretonnière, P.-A., Doblas-Reyes, F., 2017: Role of the Atlantic Multidecadal Variability in modulating the climate response to a Pinatubo-like volcanic eruption, Climate Dynamics, 1-21, doi 10.1007/s00382-017-3986-1.

Communications:

* Ménégoz, M.,, Cassou, C., Swingedouw, D., Bilbao R., Bellprat, O., Doblas-Reyes F.J., Understanding, modelling and forecasting the climate response to volcanic eruptions, IGE internal seminar, Grenoble, France, 2017.

* Ménégoz, M., Bilbao, R., Bellprat, O., Guemas, V., Doblas-Reyes, F.J., Forecasting the climate response to volcanic eruptions, abstract submitted for a presentation during the next EGU General Assembly 2018, April, Vienna, Austria.

3. Research Project Description

a) Specific Activity proposed

Introduction

Apart from human factors impacting the climate with a response time of several decades, natural variability induces a strong inter-annual to decadal climate variability that is challenging to forecast (Hawkins et al., 2009). There is a strong need for a better understanding of the natural variability to design models able to provide forecasts for the next years to decades. Climate models still need significant progress for successful operational applications at seasonal to decadal scales. Initialisation of climate models is fundamental to forecast temperature and precipitation at these time scale (Doblas-Reyes et al., 2013), but external radiative forcings play also a significant role: variations of greenhouse gases, human-made aerosols, volcanic particles, solar irradiance and land use changes are the main forcings which impact climate decadal variability (e.g. Hansen et al., 2011). Among these factors, volcanic aerosols - the main source of stratospheric aerosols - have inter-annual variations whose impact is challenging to estimate because their representation in climate models is generally basic. As a consequence, it is difficult to estimate the predictability associated to stratospheric aerosols in seasonal to decadal forecasts. In addition, when the next large volcanic eruption will occur, the uncertainties on aerosols emissions added to the low skill of current climate models will strongly limit our possibility to forecast its seasonal to decadal climatic impacts.
Agung (1963), El Chichón (1982) and Pinatubo (1991) are the last three major eruptions with significant climatic impact. By injecting a large amount of sulphate aerosols into the stratosphere, such eruptions partly blocked the downward solar radiation, inducing a cooling of the troposphere ranging between 0.1°C and 0.5°C. However, it is challenging to understand the regional climate response to these eruptions that is often driven by complex dynamical processes involving both the ocean and the atmosphere (Swingedouw et al, 2017). Due to the low number of observations of both the eruptions and their climate impacts, it is difficult to isolate its signal from the high natural variability of the climate system, and in particular its interactions with the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO), the latter strongly driving temperature and precipitation rates in the Mediterranean area (Bladé et al., 2011). Furthermore, recent investigations showed that small eruptions also affect the stratospheric aerosol burden and could have explained part of the current slowdown of the global warming (Solomon et al., 2011). In a general manner, there is a strong need to design climate models able to forecast the climate response to stratospheric aerosols changes at seasonal to decadal timescales. This is the aim of the VOLCADEC project for which we apply for computation hours to the Red Española de Supercomputación (RES).

People involved in the project

The VOLCADEC project is carried out within the Climate Prediction team (https://www.bsc.es

/discover-bsc/organisation/scientific-structure/climate-prediction) of the Barcelona Supercomputing Center (BSC), involving Martin Ménégoz (PI of the project, with 19 publications focusing on climate variability and aerosols), Roberto Bilbao (expert in oceanography), Omar Bellprat (expert in statistical analysis of climate data), Pablo Ortega (head of the climate prediction group) and Francisco Doblas-Reyes (head of the Earth Department at BSC). The VOLCADEC research is also supported by the overall climate prediction team that develops statistical tools and invests heavily in the development of the EC-Earth climate model (Hazeleger et al., 2010). The VOLCADEC team includes also two internationally recognized French researchers: Christophe Cassou (CNRS, France, expert in decadal climate variability) and Didier Swingedouw (CNRS, France, expert in climate response to volcanoes). The VOLCADEC activities are also related to several European projects, in particular the Seasonal to Decadal climate Predictions for the improvement of the European Climate Services (http://www.specs-fp7.eu/), recently leaded by BSC and bringing together the 20 main European institutes investigating the climate predictability at seasonal to decadal timescales. At the Spanish level, BSC stands as the national reference in this research field. The VOLCADEC project benefits from the strong experience of all the groups involved in SPECS, in particular KNMI (Netherlands), ECMWF and MetOffice (UK), Météo-France and CERFACS (France) and SMHI (Sweden). As stated in the previous summary, the experiments launched under the VOLCADEC project will serve as a base to involve the climate prediction team in DCPP and VOLMIP, two model intercomparison projects planned under CMIP6 that will reinforce our position at the international level.

Sets of experiments

The VOLCADEC project focuses on two major issues: (1) Verifying the ability of current climate models to forecast the climate response to volcanic eruptions and setting up new protocols to take into account stratospheric volcanic aerosols in climate forecast systems; (2) Using an original approach to investigate the regional climate impacts of volcanic aerosols. The first issue has been approached with a first set of experiments run with the version 2.3 of EC-Earth (Part 1, completed), and the second one will be based on the analysis of a second set run with the version 3.2 of this model. Note that a one-year EC-Earth v3.2 simulation need approximately 600 CPU hours on the Marenostrum4 BSC supercomputer.

Part 1: Forecasting the climate response to volcanic eruptions. This part has been completed (see previous Section)

Part 2: Investigating the regional climate impacts of a volcanic eruption. (to be done within the second part of this activity)

Under the CMIP6 initiative, our team is currently contributing to the development of the last version of EC-Earth, by implementing in particular the forcing recommended under CMIP6. Our team is developing a new scheme for the stratospheric aerosols that includes a vertical resolution and a waveband dimension that was not included in the previous versions of this model. We expect this new parameterisation to allow a better representation of the particle interactions with the solar radiation. This new configuration will be used here to run a 1000-year control simulation including the pre-industrial forcing levels. Following the VolMIP protocol, we will then simulate a Pinatubo eruption initialised from climate conditions extracted from the control simulation and describing extreme states of the natural modes of variability (ENSO, NAO, Atlantic and Pacific Multidecadal Variability, etc.). This experiment consists in a 10-year and 100-member simulation, reaching a total of 1000 years of simulation, which will be used to investigate how the climate conditions affect the climate response itself to a volcanic eruption. This approach has already been partly investigated by our team, questioning how the Atlantic Variability modulates the climate response to volcanic eruptions in the middle latitudes (Ménégoz et al., in rev). The second part of this RES project requires a total of 2000 years simulated with the version 3 of EC-Earth, reaching a cost of ~1 200 000 hours (~600*2000).

References:
Bladé, I. et al., 2011, Clim. Dyn., 39, 3-4.
Doblas-Reyes, F., et al., 2013, Wiley Interdisc. Rev.: Clim. Change, 4(4), 245-268.
Hansen, J. et al., 2011, Atm. Chem and Phys, 11(24), 13421-13449.
Hawkins E., et al., 2009, Bull. Amer. Meteor. Soc, 90(8), 1095-1107.
Hazeleger, W. et al., 2010, Bull. Amer. Meteor. Soc., 91, 1357–1363.
Ménégoz, M. et al., 2017, Clim. Dyn, 1-21, doi 10.1007/s00382-017-3986-1.
Solomon, S. et al., 2011, Science, 333(6044), 866–870.
Swingedouw, [...], Ménégoz, M et al., Glob. and Planet. Change, Vol. 150, P. 24–45.
Taylor, K. E. et al., 2012, Bull. Amer. Meteor. Soc., 93, 485–498.

b) Computational algorithms and codes outline

EC-Earth is a European model (http://www.ec-earth.org/) that comprises three major components: IFS (atmospheric component), NEMO (oceanic component) and OASIS3 (coupler). It is essential to configure and build separate executables for each one of them. IFS and NEMO fully support a parallel environment, while OASIS3 supports a pseudo-parallel environment. OASIS3 requires Cray pointers. For IFS there is a possibility to activate an OpenMP switch but in this case the implemented MPI should be thread-safe. IFS generates the 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).

For configuring and building the model executable, GNU make 3.81 or 3.81+, FORTRAN 77/90/95 complaint 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.
Currently, several releases of EC-Earth are available, v2.3, and several versions of v3. This second part of the activity will be carried out with the version v3.2. EC-Earth supports several configurations that have already been tested on various supercomputing platforms, Marenostrum3 and Marenostrum4 among them. The experiments using the v3.2 in this activity 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.

In the context of the experiments planned with EC-Earth v3.2, a benchmarking performed previously suggests that, taking into account the average load of the Marenostrum queues, optimum performance is obtained when using 1248 cores. This is a configuration which runs faster than previous experiments at Marenostrum but still remains scalable for this resolution. This configuration generates 2 GB of output per month of simulation.

4. Software and Numerical Libraries

Software components that the project team requires for the activity.

a) Applications + Libraries

BLAS, HDF5, LAPACK, SCALAPACK, UDUNITS

b) Compilers and Development Tools

GCC, INTEL, MVAPICH2

c) Utilities + Parallel Debuggers and Performance Analysis Tools

CMAKE, PERL, PYTHON, VALGRIND, NCVIEW, AUTOCONF

d) Other requested software

GRIB_API, GRIBEX, CDO, NCO and CDFTOOLS

e) Proprietary software

5. Research Team Description

a) Personal Data

Name of Team Leader	Martin Ménégoz
Gender	Male
Institution	Barcelona Supercomputing Center
e-mail	martin.menegoz@bsc.es
Phone	+33 614310391
Nationality	France

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

Dr Martin Ménégoz is the Principal Investigator (PI) of this proposal. He is a research associate at the Earth Science department led by Prof. Doblas-Reyes of the BSC. Dr Ménégoz received his PhD at Météo France (Toulouse) in 2009, where he studied the interactions between the atmosphere and natural and anthropogenic aerosols. After investigating the sinks and sources of dust, sulphate and black carbon, to evaluate the particle pollution rates at the global scale and more regionally in the Arctic and in Europe, he focused on their impacts on the climate system. He highlighted the links between aerosols and weather regimes in Europe.

Located in French CNRS institutes from 2010 to 2014, Dr Ménégoz investigated the sensitivity of glaciers and snow cover to greenhouse gases and aerosol pollution, by using and developing both global and regional climate models. He modelled in particular how the aerosol deposition affects the snow cover during the last century and in different climate scenarios over the XXIth century. He has been involved in the evaluation of the CMIP5 models to simulate snow cover and its sensitivity to global warming. He also supervised field campaigns in various mountainous areas around the world to measure glaciers mass balance.

Now at BSC, Dr Ménégoz leads the research line devoted to stratosphere-troposphere coupling processes in the Earth Sciences Department. He is largely involved in the development of the EC-Earth European model. He is applying this model in initialised simulations to make quasi-operational forecasts at seasonal-to-decadal timescales. He investigates the possibility to predict the climate response to large volcanic eruptions. He also takes part in a collaborative development of a statistical tool to assess the performance of forecast systems. He developed collaborations with 13 research institutes, organizing its research through several European and national projects, including one MINECO project that he is coordinating (VOLCADEC, 168Keuros). He has an H-index of 11 (Google Scholar), with 17 articles in peer-review journals (7 as first author), 2 articles in revision and 644 citations. He presented his results trough 40 conferences and international project meetings. His scientific background and his skill in modelling coupled to his large international network of collaborations consist in solid basis to develop climate models and forecast systems. His full CV is available at http://martinmenegoz.neowordpress.fr/.

d) Names of other researchers involved in this activity

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e) Relevant publications

Ménégoz, M., Cassou, C., Swingedouw, D., Doblas-Reyes, F., Bretonnière, P.A., 2017, Modulation of the climate response to a Pinatubo eruption by the Atlantic Multi-decadal Variability, Climate Dynamics, 1-21, doi 10.1007/s00382-017-3986-1.

Siegert, S., Stephenson, D. B., Bellprat, O., Ménégoz, M., & Doblas-Reyes, F. J., 2016: Detecting improvements in forecast correlation skill: Statistical testing and power analysis. Monthly Weather Review, doi: http://dx.doi.org/10.1175/MWR-D-16-0037.1

Guemas V., F.J. Doblas-Reyes, I. Andreu-Burillo and M. Asif (2013). Retrospective prediction of the global warming slowdown in the past decade. Natuer Climate Change, 3, 649-653, doi:10.1038/nclimate1863.

Doblas-Reyes, F. J., Andreu-Burillo, I., Chikamoto, Y., García-Serrano, J., Guemas, V., Kimoto, M., ... & Van Oldenborgh, G. J. (2013). Initialized near-term regional climate change prediction. Nature communications, 4, 1715.

Ménégoz, M., Guemas, V., Salas y Melia, D. and Voldoire, A, 2010: Winter interactions between aerosols and weather regimes in the North-Atlantic European region, J. Geophys. Res., 115, D09201, doi:10.1029/2009JD012480, http://onlinelibrary.wiley.com/doi/10.1029/2009JD012480/abstract

6. 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	Null

Typical Job Run

Number of processors needed for each job	1248.00
Estimated number of jobs to submit	1000.00
Average job durations (hours) per job	1.00
Total memory used by the job (GBytes)	100.00

Largest Job Run

Number of processors needed for each job	0.00
Estimated number of jobs to submit	0.00

Average job durations (hours) per job		0.00		
Total memory used by the job (GBytes)		0.00		
Total disk space (Gigabytes)	**Minimum**	8000.00	**Desirable**	10000.00
Total scratch space (Gigabytes)	**Minimum**	15000.00	**Desirable**	15000.00
Total tape space (Gigabytes)	**Minimum**	0.00	**Desirable**	0.00
Total Requested time (Thousands of hours)		1200.00		

If this activity is asking for more than 5Million 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 1284 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.

7. Abstract for publication

Martin Ménégoz is coordinating at BSC the "Volcanic activity in seasonal to decadal climate forecasts" project, (VOLCADEC) with the aim to answer how forecast systems should take into account stratospheric particles. It focuses on two main challenges: (1) how can the climate response to a large volcanic eruption and to stratospheric aerosols changes be predicted? (2) How climate conditions modulate the climate response to large volcanic eruptions? The final goal of VOLCADEC is to design the optimal strategy to take into account stratospheric aerosols in climate forecast systems. Optimized systems will be very helpful to provide climate information, in particular in the Mediterranean region, where the climate variability is largely dependent on the stratospheric aerosols load.

8. 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 I have not needed it.