AECT-2019-1-0011 The Coupled Climate-Carbon Cycle Model Intercomparison Project (C4MIP). BSC contribution with the Earth System Model EC-Earth.

1. General Information

Activity Id

AECT-2019-1-0011

a) Activity Title

The Coupled Climate-Carbon Cycle Model Intercomparison Project (C4MIP). BSC contribution with the Earth System Model EC-Earth.

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?

No

c) Brief description of the Project

Based on recent advances in Earth system modelling, the Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC-AR5) concluded that “Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond”, unambiguously identifying the causal link between anthropogenic emissions of carbon dioxide (CO_2) and global warming (1). The IPCC-AR5 further summarized that "Cumulative total emissions of CO_2 and global mean surface temperature response are approximately linearly related. Any given level of warming is associated with a range of cumulative CO_2 emissions, and therefore, e.g. higher emissions in earlier decades imply lower emissions later." The IPCC-AR5 also assessed the positive feedback between climate change and the carbon cycle stating: "there is high confidence that the feedback between climate and the carbon cycle is positive in the 21st century. As a result more of the emitted anthropogenic CO_2 will remain in the atmosphere" (1). These findings highlight the central role of the carbon cycle in the global climate system.

The recent COP21 Paris agreement on climate ties the participating countries (Spain and the whole EU among them) to take actions to reduce anthropogenic carbon emissions in order to contain global warming within 2oC by the end of this century. This translates into the necessity to precisely estimate the compatible CO_2 emissions well ahead of time to make sure targets are met. However, precision in the estimate of compatible CO_2 emissions can be achieved only if all sources and sinks of atmospheric carbon are known with the highest possible accuracy.

Future projections of the evolution of atmospheric CO_2 can be performed using state-of-the-art Earth System Models (EMSs) that include a full description of the global carbon cycle, including ocean biogeochemistry and land vegetation components. However, ESMs differ widely in their formulation providing a significant degree of uncertainty in their end-of-century projections of the coupled carbon-climate system. To correctly interpret such uncertainty the international climate modeling community developed since the 90s' common frameworks to be adopted by all modeling groups in order to facilitate the inter comparison of results from different models. Coordinated experimental design and implementation have originated a series of periodic activities named Model Intercomparison Projects (MIPs). Of these, the Coupled Climate-Carbon Cycle Model Intercomparison Project (C4MIP) is focused on the interactions and feedbacks between the climate and the global carbon cycle (2).

The participation to MIPs is on a voluntary basis and modeling groups need to find the resources to do it on their own. The Climate Prediction Group at the Earth Science department of BSC is strategically expanding its activities towards the near-term prediction of global carbon cycle and related biogeochemical variables. The PI on this proposal is leading such effort and has already obtained funding for three projects related to this subject (running until mid 2023). The continuity of the european and national support depends on the maintenance of the high-standard of the group's scientific activity. One fundamental milestone to achieve this is the participation to C4MIP.

We plan to perform the set of experiments with the EC-Earth ESM that are required to officially participate to the C4MIP exercise. These activities will be carried out at BSC within the context of three projects in which the principal researcher of this proposal is also the PI: "Near-term predictability of net primary production in the Atlantic Ocean", a Marie-Curie Individual Fellowship (Ref.: NeTNPPAO-708063); "Decadal predictions of Carbon Uptake in the Southern Ocean and impact of the biological carbon pump uncertainty" (Ref.: DeCUSO-CGL2017-84493-R) and “Climate-Carbon Interactions in the Coming Century” (Ref.: CCiCC-821003).

References:

1 - IPCC. in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers. (ed T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley) 1-29 (Cambridge University Press, 2013).
2- Jones, C. D., Arora, V., Friedlingstein, P., Bopp, L., Brovkin, V., Dunne, J., Graven, H., Hoffman, F., Ilyina, T., John, J. G., Jung, M., Kawamiya, M., Koven, C., Pongratz, J., Raddatz, T., Randerson, J. T., and Zaehle, S.: C4MIP – The Coupled Climate–Carbon Cycle Model Intercomparison Project: experimental protocol for CMIP6, Geosci. Model Dev., 9, 2853-2880, https://doi.org/10.5194/gmd-9-2853-2016, 2016.

d) Grants and funded projects related to this activity

Reference code	Project title
CGL2017-84493-R	Decadal predictions of Carbon Uptake in the Southern Ocean and impact of the biological carbon pump uncertainty (DeCUSO)

Starting date	Ending date	Total financing (in EUR)	Financing source
2018-01-01	2020-12-31	114.103,00	National

Reference code	Project title
708063	Near-term predictability of net primary production in the Atlantic Ocean (NeTNPPAO)

Starting date	Ending date	Total financing (in EUR)	Financing source
2017-02-01	2019-05-31	170.121,60	European

Reference code	Project title		
821003	Climate-Carbon Interactions in the Coming Century (CCiCC)		
Starting date	Ending date	Total financing (in EUR)	Financing source
2019-04-01	2023-03-31	795.000,00	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 set of simulations proposed strictly follows the protocol described for C4MIP (2). The overall objective of C4MIP is to evaluate the response of the global carbon cycle to the present and future physical climate and its feedback into the climate system. In order to do so, modeling groups need to be able to run their Earth System Models in two configurations:

a) driven by atmospheric CO2 concentrations (concentration-driven)
b) driven by CO2 emissions (emission-driven)

In the first case, the global carbon cycle components are responding passively to the physical climate while the atmospheric CO2 concentration is prescribed from either historical observations or future scenarios derived from socio-economic models. In this configuration the ESM is not able to modify the atmospheric CO2 concentration so there is no feedback of the carbon cycle onto the climate.

In the second case, the global carbon cycle is fully coupled to the climate system and the atmospheric CO2 concentration is updated continuously by the land and ocean components in response to the CO2 emissions prescribed coherently to their concentration-driven counterpart (i.e. from either observations or socio-economic scenarios) . In this case, there is a feedback from the carbon cycle onto the climate system.

The two configurations differ in performance as the emission-driven configuration needs an extra model component to simulate the transport of CO2 within the atmosphere.

The list of simulations to complete Tier-1, and a brief description of each follows:

Concentration-driven (total of 1047 years):

-online adjustment (100 years) - this is required before starting the piControl in order to minimize the drift.

-piControl (500 years) – Atmospheric CO2 and all other radiatively active gases and aerosols are kept constant at preindustrial levels, representative of year 1850.
-historical (165 years, 1850 – 2014) – Atmospheric CO2 and all other radiatively active gases and aerosols are prescribed according to observed values until the end of year 2014.
-1pctCO2 (141 years) – Atmospheric CO2 is increased by 1% annually until doubling.
-1pctCO2-bgc (141 years) – Atmospheric CO2 is increased by 1% annually until doubling. However, the increase in atmspheric CO2 is seen only by the land and ocean carbon components (not by the atmospheric radiation code).

Emission-driven (total of 851 years):

-online adjustment (100 years) - this is required before starting the piControl in order to minimize the drift.
-esm-piControl (500 years) – Like piControl but with interactive carbon cycle and zero-emission of CO2.
-ems-hist (165 years, 1850-2014) – Like historical but with historical emission of CO2 rather than historical atmospheric CO2 concentrations.
-esm-ssp585 (86 years, 2015-2100) – Future scenario with CO2 emissions following the socio-economic scenario associated with RCP8.5.

g) Computational algorithms and codes outline

EC-Earth3 comprises three major components: IFS (atmospheric component), NEMO (oceanic component) and OASIS3 (coupler). To run simulations in the emission-driven configuration a fourth component is needed: TM5 (atmospheric tracers transport). It is essential to configure and build separate executable for each one of them. For IFS and TM5 there is a possibility to activate an OpenMPI 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 four components always generate restarts separately (IFS and TM5 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. 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. This activity is planned to be carried out with the upcoming version v3.3.

3. Software and Numerical Libraries

Software components that the project team requires for the activity.

a) Applications + Libraries

BLAS, FFTW, HDF5, LAPACK, NETCDF, R, OPENMPI, UDUNITS, NCO

b) Compilers and Development Tools

GCC, TOTALVIEW, INTEL

c) Utilities + Parallel Debuggers and Performance Analysis Tools

CMAKE, OCTAVE, PERL, PYTHON, VALGRIND, NCVIEW, NCL, AUTOCONF

d) Other requested software

GRIP_API, CDO

e) Proprietary software

4. Research Team Description

a) Personal Data

Name of Team Leader	Raffaele Bernardello
Gender	Male
Institution	Barcelona Supercomputing Center
e-mail	raffaele.bernardello@bsc.es
Phone	934137678
Nationality	Italy

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. Raffaele Bernardello (Team leader on this project) has a wide experience in the use and development of Earth System Models, particularly on the ocean biogeochemical aspect. During his PhD (Universitat Politecnica de Catalunya, Spain) he implemented a coupled physical-biogeochemical model configuration for the Western Mediterranean Sea to study the interannual variability of phytoplankton blooms and their relation to the export of organic matter (3) . After the completion of his PhD he joined the Ocean and Climate Dynamics group at the University of Pennsylvania as a postdoctoral researcher under the supervision of Dr. I. Marinov. At the same time Bernardello has strictly collaborated with the Atmospheric and Oceanic Sciences department at Princeton University, led by Prof. J. Sarmiento. During this time he has directed his research at unveiling the complex mechanisms regulating the response of ocean carbon uptake to projected physical perturbations driven by future climate change using a climate model, with particular attention to Southern Ocean's dynamics (4,5). Bernardello then moved to the UK where he accepted a position as a research scientist within the Ocean Biogeochemistry and Ecosystem Department at the National Oceanography Centre (NOC), Southampton. At NOC Bernardello collaborated, among others, with Dr. A. Martin and Prof. S. Khatiwala to investigate the impact on global nutrient distributions of different parameterizations commonly used in ESMs for export and remineralization of organic matter (6). Finally, in 2017 Bernardello joined BSC as a Marie-Curie fellow. At BSC, Bernardello is leading the effort in extending the department's experience in near-term predictions to ocean biogeochemical conditions and the global carbon cycle. Bernardello has been recently granted a national project (DeCUSO Ref:CGL2017-84493-R) and acts as a WP leader on an european H2020 project (Ref.: CCiCC-821003). Both projects investigate the predictability of decadal variability of global carbon uptake. He is currently supervising one postdoctoral researcher and will start supervising one PhD student and a second postdoctoral researcher later this year.

References

3 Bernardello, R. et al. Biogeosc. 9, 4233–4245 (2012).
4 Bernardello, R. et al. J. Clim. 27, 2033–2053 (2014).
5 Bernardello, R. et al. Geophys. Res. Lett. 41, (2014).
6 Bernardello, R. et al. Submitted to Glob. Biogeochem. Cycles.

d) Names of other researchers involved in this activity

Francisco Doblas-Reyes (francisco.doblas-reyes@bsc.es)
Etienne Tourigny (etienne.tourigny@bsc.es)
Pablo Ortega (pablo.ortega@bsc.es)
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Marcus Falls (marcus.falls@bsc.es)
All at Barcelona Supercomputing Center

e) Relevant publications

Bernardello, R. et al. (2014) Response of the Ocean Natural Carbon Storage to Projected Twenty-First- Century Climate Change. Journal of Climate 27: 2033-2053.

Bernardello, R. et al. (2014) Impact of Weddell Sea deep convection on natural and anthropogenic carbon in a climate model. Geophysical Research Letters 41: 7262–7269.

Doblas-Reyes, F. J. et al. Initialized near-term regional climate change prediction. Nat Comm. 4, 1715 (2013).

Guemas, V. et al. A review on Arctic sea-ice predictability and prediction on seasonal to decadal time- scales. Q. J. R. Meteorol. Soc. 142, 546-561 (2014).

Guemas, V., Doblas-Reyes, F. J., Andreu-Burillo, I. & Asif, M. Retrospective prediction of the global warming slowdown in the past decade. Nat. Clim. Chang. 3, 1–5 (2013).

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	432.00
Estimated number of jobs to submit	1097.00
Average job durations (hours) per job	2.80
Total memory used by the job (GBytes)	100.00
Largest Job Run	
Number of processors needed for each job	576.00

Estimated number of jobs to submit		901.00		
Average job durations (hours) per job		6.00		
Total memory used by the job (GBytes)		100.00		
Total disk space (Gigabytes)	**Minimum**	1500.00	**Desirable**	2000.00
Total scratch space (Gigabytes)	**Minimum**	10000.00	**Desirable**	10000.00
Total tape space (Gigabytes) (*)	**Minimum**	0.00	**Desirable**	0.00
Total Requested time (Thousands of hours)		4800.00		

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 5136 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.

6. Abstract for publication

The Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC-AR5) highlighted the central role of the carbon cycle in the global climate system. Earth System Models (ESMs) can provide comprehensive projections of the future evolution of the climate and its inter-dependency on the response of the global carbon cycle. The international climate modeling community developed since the 90s' common frameworks to facilitate the inter comparison of results from different models. These are known as Model Intercomparison Projects (MIPs). Of these, the Coupled Climate-Carbon Cycle MIP (C4MIP) is focused on the interactions and feedbacks between the climate and the global carbon cycle and the Climate Prediction group at the Earth Science department of the BSC has taken the strategic decision to participate to it with the ESM EC-Earth.

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 I contacted other RES representatives (e.g. Access Committee or User Support).

Usage Terms & Conditions

- The Usage Terms & Conditions have been already accepted.

Barcelona Supercomputing Center, 2016