AECT-2017-3-0010 Improving seasonal forcast capacity by including sea ice data assimilation

1. General Information

Activity Id
AECT-2017-3-0010

a) Activity Title
Improving seasonal forcast capacity by including sea ice data assimilation

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
This activity is part of the APPLICATE project funded by the European Commission under the Horizon 2020 program. The overarching goal of APPLICATE is "To develop enhanced predictive capacity for weather and climate in the Arctic and beyond, and to determine the influence of Arctic climate change on Northern Hemisphere mid-latitudes, for the benefit of policy makers, businesses and society."

The Arctic region is experiencing faster climatic changes than any other region in the planet. Sea ice concentration and volume have decreased significantly in the last decades, the mean surface temperature has risen by about 2 degrees in the last decades (IPCC, 2013). Even if the Paris agreement of limiting global mean surface temperatures below two degrees since pre-industrial times is achieved, Arctic temperatures would increase by more than five degrees according to state of the art climate models (IPCC, 2013). Thus, the climatic shift in the Arctic will very likely have consequences in mid-latitude weather (Handorf, et al., 2015; Cohen et al., 2014). Numerical models still struggle to capture many aspects of mid-latitude climate on seasonal timescales (Guemas et al. 2014). It is imperative to improve and evaluate forecasting systems that capture the interaction of Arctic sea ice changes and northern hemisphere mid-latitude climate on seasonal timescales.

The Climate Prediction group at the Earth Sciences Department of the Barcelona Supercomputing Center (BSC) has long experience in numerical climate forecast in the seasonal to decadal scales. Based on this and within the APPLICATE framework we plan to evaluate the added value of using more realistic sea ice conditions to initialize seasonal climate prediction by comparing against observations in the period 1979-2015 (satellite era). Realistic sea ice initialization of seasonal forecast has proven to be a key aspect to improve the quality of the forecasts (Guemas et al. 2016).

References:

Cohen, Judah, et al. "Recent Arctic amplification and extreme mid-latitude weather." Nature geoscience 7.9 (2014): 627-637.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Guemas, V. et al. "A review on Arctic sea-ice predictability and prediction on seasonal to decadal time-scales." Quarterly Journal of the Royal Meteorological Society 142.695 (2016): 546-561.

Guemas, V., et al. "Impact of sea ice initialization on sea ice and atmosphere prediction skill on seasonal timescales." Geophysical Research Letters 43.8 (2016): 3889-3896.

Handorf, Dörthe, et al. "Impacts of Arctic sea ice and continental snow cover changes on atmospheric winter teleconnections." Geophysical Research Letters 42.7 (2015): 2367-2377.

d) Grant References

APPLICATE (GA 727862)

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

f) Specific Activity proposed

Recently, the Climate Prediction group at BSC has implemented an advanced method to generate initial conditions of sea ice. The method relies on assimilating observations using Bayesian statistics in an algorithm called Ensemble Kalman Filter (EnKF). The EnKF is an advanced data assimilation method which propagates the model updates from observed variables to non-observed variables through the error covariance matrix which appears in the gain matrix formulation, the latter being used to update the model. When assimilating observational data through the EnKF, partial observations can therefore have a global impact. For example, the observation of sea ice concentration alone can lead to a substantial correction of sea ice thickness but also sea surface temperature, salinity or even currents. The other strength of the EnKF is the fact that this filter accounts for both model and observational uncertainties. In regions where the model is relatively confident (e.g., the interior of the Arctic sea ice pack in winter), updates will be minor; while they will be larger in the marginal ice zone where the position of modelled ice edge is usually uncertain. At the same time, updates will be large where observations are relatively confident. By doing so, more realistic initial conditions can be achieved and the added value of forecasts can be compared against standard initialization methods. The standard sea ice model initialization approach uses ocean model simulations nudged to reanalysis products to generate the sea ice starting conditions, but no sea ice observations are assimilated in this method.

Our aim is to compare the traditional sea ice initialization method with the more advanced EnKF one by evaluating the model improvement in accuracy of simulating basic climatic variables in retrospective seasonal climate forecasts initialized every 1st of May and every 1st of November for the period 1979 to 2015 seven months into the future. To have robust results each starting date will have 25 ensemble members initialized through perturbed conditions. This means that every 1st of May and every 1st of November for the period 1979-2015, 50 seven-month simulations will be initialized (25 for the standard initialization + 25 for EnKF initialization). We will use the standard configuration of EC-Earth 3.2 (T255-ORCA1). The atmospheric component is IFS, it has a horizontal resolution of about 0.7 degrees and 91 vertical levels. The ocean component is NEMO, running with ORCA1 configuration consisting of a tripolar grid at a resolution of approximately 1 degree. The sea ice model is LIM3 which is integrated in the NEMO architecture. The atmosphere and ocean sea-ice components of EC-Earth are coupled every three hours with the Ocean Atmosphere Sea Ice Soil coupler version 3 (OASIS3).

g) Computational algorithms and codes outline

EC-Earth3 comprises three major components: IFS (atmospheric component), NEMO (oceanic component) and OASIS3 (coupler). It is essential to configure and build separate executable 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.

EC-Earth3 supports several configurations which have already been tested on various supercomputing platforms, Marenostrum3 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 version v3.2.

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, PERL, PYTHON, VALGRIND, NCVIEW, NCL, AUTOCONF

d) Other requested software

GRIB_API, CDO.

e) Proprietary software

4. Research Team Description

a) Personal Data

Name of Team Leader	Juan Camilo Acosta Navarro
Institution	Barcelona Supercomputing Center
e-mail	jacosta@bsc.es
Phone	654 499 846
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. Juan Camilo Acosta Navarro is currently a scientific researcher in the Climate Prediction group within the Earth Sciences department at the Barcelona Supercomputing Center (BSC). His work is focused on sea ice process and how sea ice may affect climate remotely via atmospheric and oceanic linkages. Dr. Acosta obtained his PhD at Stockholm University in 2016 on earth system modelling and climate sciences, and has extensive experience with the Norwegian Earth System model and

EC-Earth, both models being part of the Coupled Model Intercomparison Project (Phases 5 and 6). He has published ten scientific peer reviewed articles, being first in three of them. He has been adviser to two MSc students and is currently advising one PhD student.

d) Names of other researchers involved in this activity

Virginie Guemas (virginie.guemas@bsc.es)
Francisco Doblas-Reyes (francisco.doblas-reyes@bsc.es)
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Pablo Ortega (pablo.ortega@bsc.es)

e) Relevant publications

Acosta Navarro, JC & Varma, V et al. "Amplification of Arctic warming by past air pollution reductions in Europe." Nature Geoscience 9.4 (2016): 277-281.

Acosta Navarro, JC., et al. "Future response of temperature and precipitation to reduced aerosol emissions as compared with increased greenhouse gas concentrations." Journal of Climate 30.3 (2017): 939-954.

Guemas, V., et al. "Impact of sea ice initialization on sea ice and atmosphere prediction skill on seasonal timescales." Geophysical Research Letters 43.8 (2016): 3889-3896.

Guemas, V. et al. "A review on Arctic sea-ice predictability and prediction on seasonal to decadal time-scales." Quarterly Journal of the Royal Meteorological Society 142.695 (2016): 546-561.

Fučkar, NS., et al. "The Role of Arctic Sea Ice and Sea Surface Temperatures on the Cold 2015 February Over North America." Bulletin of the American Meteorological Society 97.12 (2016): S36-S41.

5. Resources

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

Requested machine	MareNostrum 4 ((Technical description to be confirmed)

Interprocess communication	Tightly Coupled

Typical Job Run

Number of processors needed for each job	648.00		
Estimated number of jobs to submit	3700.00		
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**	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)		2400.00		

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 2568 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

Arctic sea ice cover interannual variability and long-term decreasing trends has an effect on wintertime weather patterns in continental mid-latitude locations in North America and Eurasia. Seasonal forecast systems need realistic sea ice conditions to successfully predict climatic conditions in the months following the initialization.
The accuracy in mid-latitude climate of the model EC-Earth 3.2 will be tested in retrospective seasonal forecast mode to quantify the added value of using realistic sea ice initial conditions generated by Ensemble Kalman Filter methods. The method assimilates sea ice concentrations from satellite observations to correct model biases and enhance climate predictability, which is very relevant from a societal perspective.

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.