REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: The Netherlands

Principal Investigator[1]**:** Dr. Sybren Drijfhout

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Other researchers:

None

Project Title:

Implementing and testing an ocean carbon cycle in ECEARTH

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2013	
Would you accept support for 1 year only, if necessary?	YES X☐	NO ☐

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2015.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	480k	480k	600k
Data storage capacity (total archive volume) (gigabytes)	400	600	600

*An electronic copy of this form **must be sent** via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

25-4-2012

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: Dr. Sybren Drijfhout

Project Title: Implementing and testing an ocean carbon cycle in ECEARTH

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Recently, the ocean carbon cycle was evaluated in three CMIP5 Earth System Models, namely CanESM2, HadGEM2-ES and IPSL-CM5_LR (Schmittner, 2012). All three models show very different distributions of dissolved inorganic carbon and alkalinity in the interior ocean, not well reproducing the observations. This fact points to a large drift in carbon inventory during the spin-up of the ocean's carbon cycle. And indeed, most ocean models start to outgas enormous amounts of carbon dioxide when starting from observed vertical distributions (horizontal patterns are not well enough known yet), which leads to an unwanted, significant, fast increase in atmospheric CO2 concentration. This is exactly why many coupled climate models are reluctant to turn on the ocean carbon cycle interactively, like is the case with ECEARTH. Another strategy is followed by HadGEM2-ES, where the atmospheric CO2 concentration is kept fixed during the spin-up, although the ocean keeps losing large amounts of carbon dioxide to the atmosphere (Chris Jones 2012, pers. com.). As a result, such models show large biases in dissolved inorganic carbon and alkalinity distribution.

The main problem is that the equilibration time for carbon in the ocean is of the order of tens of thousands of years (Archer et al., 2009), too long for state-of-the-art coupled climate models to reach equilibrium. Here I propose a strategy to overcome this problem and to efficiently evaluate different types of carbon cycle models for use in coupled climate models.

Recently, an efficient carbon cycle model, including carbonate compensation dynamics, was proposed as a box model (Boudreau et al., 2010a, 2010b). With colleagues of the University of Utrecht I have successfully implemented and extension of this model into a coupled climate model of intermediate complexity with a full, 3D ocean component. This model, Speedo (Severijns and Hazeleger, 2010) is built on the original Speedy model developed by Molteni (2003) and made suitable for climate change experiments at KNMI. With a statistical atmosphere (SPEEDSTAT) built on observed regression relations between ocean and atmospheric variables in the fully coupled model (Cimatoribus et al., 2012), the model runs about 800 years per day on a standard workstation, making full equilibration and tuning of the ocean carbon cycle interacting with changing atmospheric concentrations feasible (Drijfhout et al., 2012).

The strategy I propose is as follows. After running SPEEDSTAT to equilibrium, the biogeochemical tracer fields in its ocean model CLIO will be interpolated on the ORCA-1 grid, which is the ocean component of ECEARTH. ORCA-1 will be forced with climatological fluxes of ECEARTH and initialized with CLIO's tracer fields. Also this configuration can be efficiently spun-up on a workstation. Thereafter the equilibrated tracer fields of ORCA-1 in stand-alone mode will be used to initialise the fully coupled model. The complete ECEARTH model will be run at ECMWF. Also, other more complex and complete ocean carbon cycle models can be tested and spun-up in the same way, for instance, the biogeochemical component of GENIE (Lenton et al., 2006) and other models, like UVIC. Note that at present the biogeochemical model PISCES is implemented in ORCA-1. However, it is bypassed in the coupled model because it would more than double the computing time of ECEARTH and increase the computing time of ORCA-1 with more than a factor of five.

The more scientific question would be which elements of the ocean carbon cycle are relevant and necessary to reproduce the present day dissolved inorganic carbon and alkalinity distribution on some specific sections for which we have observations, and which elements control the uptake and release of anthropogenic carbon.

To this end we propose to perform a historical run with ECEARTH coupled to two different carbon models; and study the transient carbon inventory when coupling the ocean-model to an atmosphere with doubled CO2 concentration. The latter run (without ocean carbon cycle) has been carried out at KNMI and initial conditions from both atmosphere and ocean can be used to study the response to a non-equilibrium situation. In particular the processes that determine lags and leads between carbon emission, carbon concentration and global warning are important to unravel (Shakun et al., 2012).

The following work schedule is proposed:

Year-1. Spinning up the carbon cycle model of Drijfhout et al. (2012) for use in ECEARTH and running ECEARTH with an online ocean carbon module. Evaluate biases between observations and model distributions of biogeochemical tracers and assess the role of carbon cycle processes in uptake of anthropogenic carbon assuming a pulse increase in atmospheric CO2 from an already existing 2xCO2 runs carried out by ECEARTH. Estimated costs in terms of sbu's: 160 years times 3k sbu/year = 480 ksbu; consisting of 30 years of spin-up and 130 years for the historical run control

Year-2. Repeat the exercise of year-1 with the Genie carbon cycle model. Evaluate the role of different carbon-cycle processes in creating/diminishing biases in observed biogeochemical distributions. (480 k sbu)

Year-3. Study with both carbon cycle models the role of various carbon cycle processes in uptake and release of anthropogenic carbon assuming a pulse increase in atmospheric CO2, starting from the already existing 2xCO2 run carried out by ECEARTH. Estimated costs in terms of sbus: 2x100 years = 600k sbu

References:

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