SPECIAL PROJECT FINAL REPORT

Project Title:	OpenIFS Modeling of the Atmospheric Carbon Cycle
Computer Project Account:	spnlpete
Start Year - End Year :	2022-2022
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Summary of project objectives

The main objective of this Special Project is to build the foundations of a strong community focused on GHG modelling with OpenIFS including land-atmosphere feedbacks in the terrestrial biosphere, land-use change (LUC) scenarios that include short-(aerosol) and long-term (CO_2) climate impacts, and coupled carbon-water exchange for climate modelling, multi-tracer simulations, fast chemistry-schemes, ensemble predictions, and data assimilation (outside the scope of ECMWF's NWP setting). 3 sub-projects have been designed in order to achieve these goals: (1) CO2 transport in coupled climate model with OpenIFS (BSC) ; (2) CO2 transport in long-window data assimilation with OpenIFS (WUR) ; (3) Decadal multi-flux evaluations for CO2 with OpenIFS (MPI). We have set up a CONFLUENCE space for the OpenIFS/CC project to track developments and document our meetings, which is available at https://confluence.ecmwf.int/pages/viewpage.action?pageId=226496552..

Summary of problems encountered

Our project has suffered from delays in the first release of EC-Earth 4 and its availability on the ECMWF HPC2020 supercomputer, as well as delays in the official availability of the said supercomputer, which we had planned to run the OpenIFS model on. A number of issues encountered when conducting the IFS 43R3 reference runs with CO2 tracer on CCA described below (access to some GEMS files, issues with old code or deleted experiments, model stability) have been found and have been corrected, except for a segmentation fault in the trans functions when running fullpos (ifs/fullpos/transdir_fp.F90, trans/module/dir_trans_ctl_mod.F90), for which ECMWF support was not able to provide a solution. Thus we were not able to obtain output of 10-day runs for our benchmark simulations. As the SBU billing on HPC2020 was only implemented in July of 2022, we have consumed few resources (442 SBU) during the remaining months.

Experience with the Special Project framework

Our experience with the Special Project framework is overall positive and stimulates collaboration between ECMWF and other research institutions. The frequency of reporting, with interim reporting every half-year, is not ideal as some projects might not have progressed significantly during the first 6 months. From the point of view of users, it would be preferable to submit progress reports later in the year (e.g. in September).

Summary of results

Anne-Wil van den Berg (WUR) and Alexander Winkler (MPI) attended the "A hands-on introduction to numerical weather prediction models: understanding and experimenting" workshop organized by ECMWF and gained experience in building and running OpenIFS 43R3v2.

With the help of Anna Agusti-Panareda from ECMWF, we were able to perform with prepIFS on CCA the reference runs using IFS cycle 43R3 with CO2 tracers, GEMS CO2 fluxes and BC (Bermo & Conde) mass fixer on the CCA machine, in order to generate initial data (initial CO2 model-level data and surface CO2 fluxes) and proper namelist settings. However, due to an issue explained above, we were not able to obtain output of 10-day runs for our benchmark simulations to compare OpenIFS runs to. From these runs we were able to extract the relevant IFS namelist parameters to activate the CO2 tracer, appropriate mass fixers as well as grib output of pressure-level CO2 using grib code 210061. We were also able to obtain a number of initial data, including CO2 on model levels and CO2 surface flux forcings. Available CO2 flux forcings are biomass burning

(210080/co2fire grib code) from a CAMS experiment, ocean flux (210067/co2of) from Takahashi et al. 2009, land fluxes (210068/co2nbf) in principle from CASA or other model but in practice they are usually a copy of the anthropogenic fluxes and anthropogenic fluxes (210069/co2apf). This is described in the CONFLUENCE page https://confluence.ecmwf.int/pages/viewpage.action?pageId=283545358. These settings and data were used to initialise and run OpenIFS 43r3v2 on both Marenostrum and ECMWF HPC2020 for short periods.

We were also able to identify the important routines which initialise, update and query the CO2 flux tendencies. These routines will be modified to update the CO2 flux tendencies from those sent from the CO2 Flux Data Coupler to OpenIFS through the pyOasis interface.

src/ifs/phys_ec/gems_init.F90
src/ifs/module/surface_fields_mix.F90
src/ifs/climate/updclie_co2.F90
src/ifs/phys_ec/vdfmain.F90
src/ifs/adiab/postphy.F9
src/ifs/setup/su_surf_flds.F90
src/ifs/module/yomgrib.F90
src/ifs/setup/suafn1.F90
src/ifs/module/yomcompo.F90

Moreover, BSC has successfully built and run the EC-Earth4 4.0 release on the BSC's Marenostrum4 HPC, as well as the trunk version on both Marenostrum4 and ECMWF's ATOS HPC, which includes an update to OpenIFS 43r3v2 (with improved mass fixers), NEMO 4.2 and oasis3-mct-5.0 (with python api required for the python/oasis forcing reader).

Based on this experience at BSC, it was decided during the final meeting of the OpenIFS/CC project year 2022 to collectively use the EC-Earth4 framework to conduct our follow-up experiments. This recognizes that also our other plans would benefit from EC-Earth4 specific features such the access to AMIP SST/SIC forcings, CMIP6 forcings, a flexible python/oasis-based forcing reader adaptable to various forcing sources, e.g. input4MIPS (for CMIP6), GridFED emissions and biogenic CO2 fluxes from CarbonTracer Europe, replacing the reading of grib files in OpenIFS. The components together comprise the EC-Earth4-CC-lite configuration in which the CO2 fluxes from the land vegetation (LPJ-GUESS) and ocean (NEMO/PISCES) biogenic components in the full EC-Earth4-CC configuration are replaced with fluxes from from CarbonTracer Europe (see Figure 1).

Finally, we have made some progress in the implementation of the flexible python/oasis-based forcing reader from EC-Earth4 adaptable to various forcing sources, e.g. input4MIPS (for CMIP6),GridFED emissions and biogenic CO2 fluxes from CarbonTracer Europe, replacing the reading of grib files in OpenIFS. The tool has been named “CO2 Flux Data Coupler” (see Figure 2 for a schematic of the final implementation), an instance of the Data Coupler, which is a flexible interface to manage netcdf input files and send a number of output fields to the OpenIFS model using pyOasis. The latest commit on December 27 2022 implements reading of the CEDS CO2 emissions used in CMIP6 and sending them to a dummy “IFS toy model” and can be found on the BSC gitlab server : https://earth.bsc.es/gitlab/es/python-amip-reader/-/commit/a22ac87b5c98e845a2829a768c0e53584a31a7d7 .

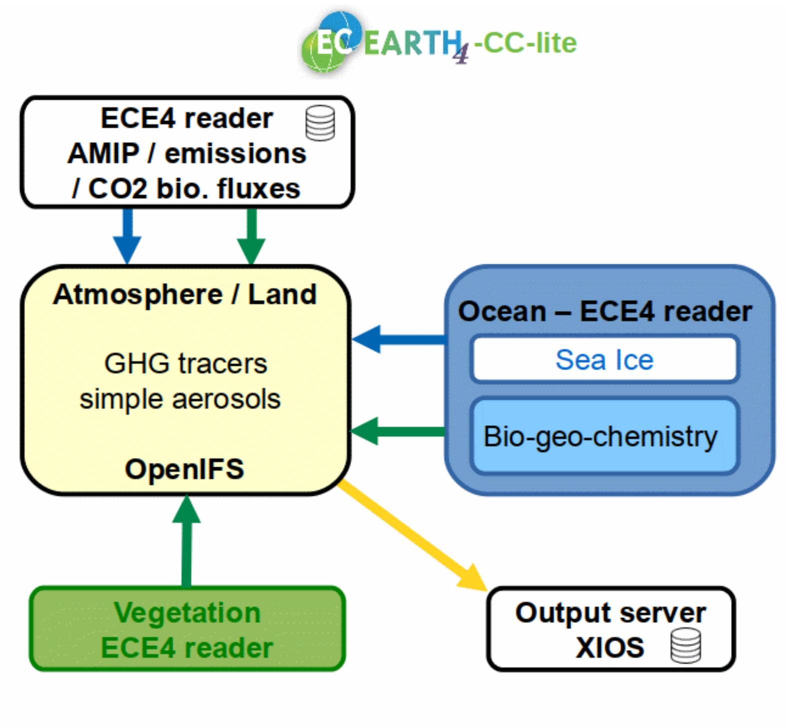

Figure 1 - Diagram of the EC-Earth4-CC-lite configuration.

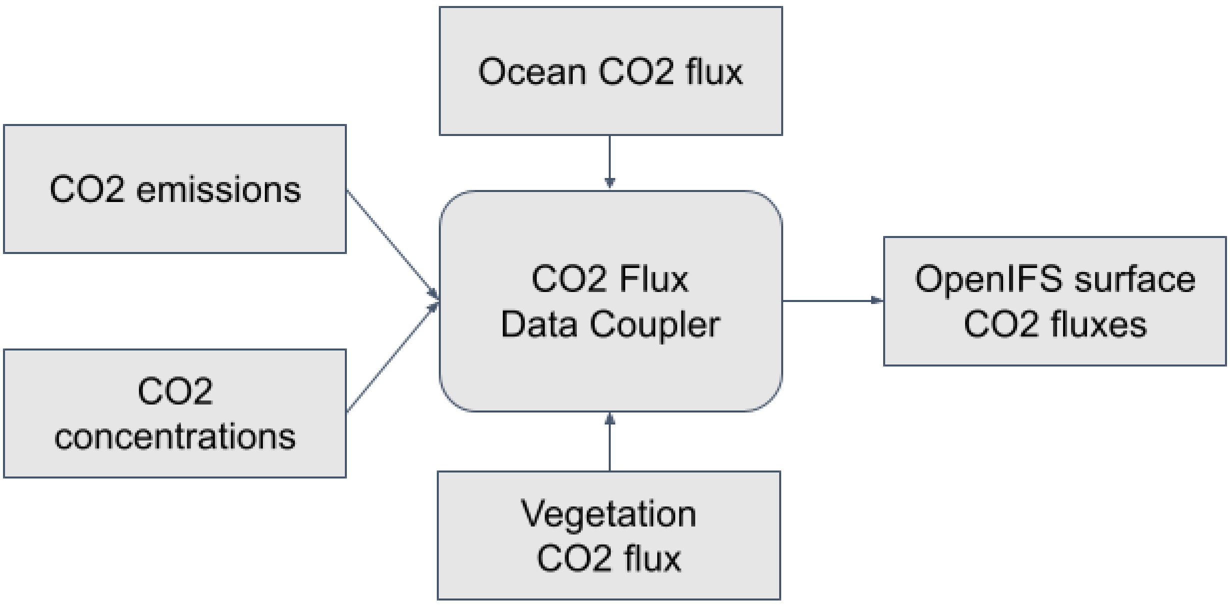

Figure 2 - Schematic of the CO2 Flux Data Coupler under development.

List of publications/reports from the project with complete references

The CONFLUENCE page https://confluence.ecmwf.int/pages/viewpage.action?pageId=283545358 documents the knowledge gained on running OpenIFS 43r3v2 with CO2 tracer and mass fixer.

The latest commit on December 27 2022 implements reading of the CEDS CO2 emissions used in CMIP6 and sending them to a dummy "IFS toy model" and can be found on the BSC gitlab server : https://earth.bsc.es/gitlab/es/python-amip-reader/-/commit/a22ac87b5c98e845a2829a768c0e53584a31a7d7 .

Future plans

We will carry out the work planned in this special project and new related activities in the ongoing continuation of this Special Project spnlpete_2023. Please see the Special Project request for further details : https://www.ecmwf.int/sites/default/files/special_projects/2023/spnlpete-2023-request.pdf