# SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

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|---|---|
| **Reporting year** | 2022 |
| **Project Title:** | OpenIFS Modeling of the Atmospheric Carbon Cycle |
| **Computer Project Account:** | spnlpete |
| **Principal Investigator(s):** | Wouter Peters, Etienne Tourigny |
| **Affiliation:** | KNMI |
| **Name of ECMWF scientist(s) collaborating to the project** (if applicable) | Marcus Koehler, Anna Agusti-Panareda, Gianpaolo Balsamo |
| **Start date of the project:** | 01/01/2022 |
| **Expected end date:** | 12/31/2022 |

**Computer resources allocated/used for the current year and the previous one**
(if applicable)
Please answer for all project resources

| | | **Previous year** | | **Current year** | |
|---|---|---|---|---|---|
| | | Allocated | Used | Allocated | Used |
| **High Performance Computing Facility** | (units) | | | 6M | 0M |
| **Data storage capacity** | (Gbytes) | | | ??? | 0M |

## 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 (CO2) 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 of 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 ATOS supercomputer, as well as delays in the official availability of the ATOS supercomputer which is the HPC we had planned to run the OpenIFS model on. A number of issues (access to some GEMS files, issues with old code or deleted experiments, model stability) have been found and most have been corrected, except for the segmentation fault error in the trans functions when running fullpos (ifs/fullpos/transdir_fp.F90, trans/module/dir_trans_ctl_mod.F90) which is currently being investigated with help from IFS support. As we have been running our initial tests on TEMS and ATOS there are no computing hours which have been billed on our special project yet.

## Summary of plans for the continuation of the project

Our first objective is for BSC to complete the IFS 43R3 reference runs on CCA using prepIFS with $CO_2$ tracers, GEMS $CO_2$ fluxes and mass fixer. In parallel BSC with EC-Earth partners will finalise developments required to run the AMIP configuration with $CO_2$ tracer and mass fixer on the ATOS supercomputer and perform a 10-year integration. In parallel Anne-Wil van den Berg (WUR) will continue her work with OpenIFS 43R3v2 on the WUR computer (Snellius) also with $CO_2$ tracer and mass fixer. Once working, she will focus on setting up nudged runs (with assistance from Marylou Athanase from AWI) to reproduce observed as well as TM5-CarbonTracker simulated $CO_2$ mixing ratios. We also aim to assess mass-conservation in longer run windows typically used in GHG data assimilation. Next we will implement the flexible python/oasis-based forcing reader from EC-Earth4 adaptable to various forcing sources, e.g. input4MIPS (for CMIP6),GridFED emissions and biogenic $CO_2$ fluxes from CarbonTracer Europe, replacing the reading of grib files in OpenIFS. Alexander Winkler (MPI) will lead this effort based on his python knowledge and experience with different $CO_2$ flux products.

## List of publications/reports from the project with complete references

OpenIFS/CC Meetings https://confluence.ecmwf.int/pages/viewpage.action?pageId=226496645

## Summary of results

Etienne Tourigny (BSC) has performed basic tests of standalone OpenIFS 43r3v1 using $CO_2$ and CH4 tracers initialised from synthetic values (using the O3 tracer concentrations from initial data obtained with prepIFS) and activating the Bermejo-Conde (BC) mass fixer following instruction from Michail Diamantakis' CONFLUENCE page provided by Markus Koehler, using the following namelist parameters:

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|---|---|
| &NAMCOMPO<br>/<br>&NAMGFL<br>YQ_NL%LGP=true,<br>YQ_NL%LSP=false,<br>YL_NL%LGP=true,<br>YI_NL%LGP=true,<br>YA_NL%LGP=true,<br>YO3_NL%LGP=true,<br>LTRCMFBC=true,<br>NOPTMFBC=1,<br>LTRCMFIX_PS=true,<br>NOPTVFE=1,<br>NMFDIAGLEV=2, | NGHG=2,<br>YGHG_NL(1)%LGP=true,<br>YGHG_NL(1)%CNAME="CO2",<br>YGHG_NL(1)%IGRBCODE=210061,<br>YGHG_NL(1)%LMASSFIX=true,<br>YGHG_NL(1)%BETAMFBC=2,<br>YGHG_NL(2)%LGP=true,<br>YGHG_NL(2)%CNAME="CH4",<br>YGHG_NL(2)%IGRBCODE=210062,<br>YGHG_NL(2)%LMASSFIX=true,<br>YGHG_NL(2)%BETAMFBC=2,<br>/ |

Whereas the following namelist is setup when configuring a IFS 43R3 experiment with prepIFS:

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|---|---|
| &NAMGFL<br>NGHG=1,<br>YGHG_NL(1)%CNAME='CO2',<br>YGHG_NL(1)%IGRBCODE=210061,<br>YGHG_NL(1)%LADV5=true,<br>YGHG_NL(1)%LMASSFIX=true,<br>YGHG_NL(1)%LNEGFIX=.FALSE.,<br>YGHG_NL(1)%LQM=false,<br>YGHG_NL(1)%LQM3D=true,<br>YGHG_NL(1)%BETAMFBC=2, | NOPTVFE=0,<br>YQ_NL%LGP=true,<br>YQ_NL%LSP=false,<br>YL_NL%LGP=true,<br>YI_NL%LGP=true,<br>YA_NL%LGP=true,<br>YO3_NL%LGP=true, |

Some investigation is required to make the choice of right parameters to use.

During the OpenIFS/CC project meetings we decided to use the EC-Earth4 framework (based on OpenIFS 43r3 and NEMO 4) to conduct our experiments, as this would allow to benefit from the EC-Earth4 modelling framework (AMIP SST/SIC forcings, CMIP6 forcings, etc.) useful for the multi-decadal experiments planned. In line with this decision, we initiated the process for the MPI-BGC to join the EC-Earth consortium.

The BSC team has been busy setting up reference IFS 43R1 and 43R3 experiments with CO2 tracers, anthropogenic emissions, CTESSEL fluxes, ocean fluxes and biomass burning fluxes using the prepIFS infrastructure, with the help of Anna Agusti-Panareda. These reference runs are done in order to identify the proper namelist configuration and initial and forcing files required to run OpenIFS with $CO_2$ tracers enabled. We are confident the segmentation fault issue will be resolved soon.

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 BullSequana XH2000 (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).

Anne-Wil van den Berg (WUR) attended the "A hands-on introduction to numerical weather prediction models: understanding and experimenting" workshop organized by ECMWF and has been able to build and run OpenIFS 43R3v2 on the WUR computer (Snellius). She also took first steps to compile on Atos, but seized her attempts to wait for EC-Earth4.

Alexander Winkler (MPI) also attended the "A hands-on introduction to numerical weather prediction models: understanding and experimenting" workshop, compiled the OpenIFS 43r3 model, modified the source code, and conducted various simulations. He prepared various datasets of terrestrial biogenic $CO_2$ fluxes to be tested in the OpenIFS $CO_2$ tracer setup. He waits to get access to EC-Earth4 to start implementing the EC-Earth forcing file reader functionality (access licence to be issued soon).