
# First set of offline historical simulations of the land and ocean carbon cycle

## *Milestone 1*

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# Document Information

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| **AUTHORS** | Jens Daniel Müller & Nicolas Gruber |
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# History

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# About 4C

**Climate-Carbon Interactions in the Current Century** (4C) is an EU-funded H2020 project that addresses the crucial knowledge gap in the climate sensitivity to carbon dioxide emissions, by reducing the uncertainty in our quantitative understanding of carbon-climate interactions and feedbacks. This will be achieved through innovative integration of models and observations, providing new constraints on modelled carbon-climate interactions and climate projections, and supporting the Intergovernmental Panel on Climate Change (IPCC) assessments and policy objectives.

# Executive Summary

Overview of current availability of ocean and land carbon cycle model simulations performed with 4C.

## Keywords

Historical simulations, land, ocean, carbon cycle

# 1 Introduction

This milestone report summarises the status quo of the model runs performed within the 4C project. According to the description of relevant tasks 1.3.1 and 1.3.1 in the grant agreement, due dates for the model outputs extend until M42. Tables 1 and 2 provide an overview of currently available land and ocean model simulations. All models run to the end of 2019 and are being analysed as part of the Global Carbon Budget 2020. The model output will contribute to the RECCAP effort.

## 1.1 Simulating the global carbon cycle from 1900 to 2020 (T1.3)

According to the description of task 1.3. in the grant agreement (due in M9-M42, with contributions from ETHZ, UNEXE, UEA, ENS, CNRS, MPG, BSC, UBERN, CEA), a series of model simulations will be performed using the latest CMIP6+ model improvements and forcing on an annual basis. This includes historical simulations with the land and ocean carbon models, forced by the observed atmospheric conditions over the past 120 years. The uncertainty associated with the atmospheric forcing will be investigated by using different reconstructions of the atmospheric state. T1.3 also includes historical simulations with the 4C ESMs in emission-driven mode.

### 1.1.1 Historical simulations of the land carbon cycle (T1.3.1)

According to the description of task 1.3.1 in the grant agreement, the land carbon models will be forced over the period 1700-2020, with historical observed atmospheric $CO_2$ from a global network of monitoring stations, changing climatology (6-hourly JRA model reanalysis aligned with CRU observation-based monthly climatology from 1900), land-use and land cover changes (LUH2 as used in CMIP6), and derived nitrogen deposition, fertiliser and manure application, following the TRENDY protocol122. At least one model will explore C-cycle uncertainty associated with applying alternative historical climate forcing (e.g. using precipitations from WFDEI), and the impact of diffuse light effects (e.g. Mt Pinatubo eruption), on the unexplained carbon budget imbalance (BIM) in T1.4. The following land carbon models (with host ESM in parenthesis) will participate using their CMIP6+ configuration (see Table 1.2): JULES, ORCHIDEE (IPSL-ESM), LPX (BERN3D-LPX), LPJ-GUESS (EC-Earth ESM), JSBACH (MPI-ESM). ORCHIDEE and LPX-BERN also include the modelling of $^{13}C$ for the land atmosphere fluxes. Multiple single-forcing simulations will be made for the attribution analysis in T1.5. Single forcing variables include atmospheric $CO_2$, land-use change, nitrogen (deposition, fertiliser, manure application) and climate (trends, variability and extremes).

**Table 1: Historical simulations of the land carbon cycle, according to T1.3.1**

| Model (host ESM) | Provider | Storage location (URL) | Status |
|---|---|---|---|
| JULES-ES (IPSL-ESM) | UNEXE | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| ORCHIDEE-v3 (IPSL-ESM) | IPSL | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| ORCHIDEE-CMIP6 (IPSL-ESM) | IPSL | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| ORCHIDEE-CNP (IPSL-ESM) | IPSL | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| LPX (BERN3D-LPX) | UBERN | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| LPJ-GUESS (EC-Earth ESM) | BSC/KIT | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |
| JSBACH (MPI-ESM) | MPG | sftp trendy-v9@trendy.ex.ac.uk[1] | Data available |

[1]Access to the sftp server of the University of Exeter is password protected. Please contact S.A.Sitch@exeter.ac.uk to obtain access.

### 1.1.2 Historical simulations of the ocean carbon cycle (T1.3.2)

According to the description of task 1.3.2 in the grant agreement, the ocean models will follow the CMIP6 OMIP protocol and be forced by variable winds and buoyancy fluxes (heat and water fluxes) from reanalysis data, and with prescribed atmospheric $CO_2$. At least one ocean model will be used in a high-resolution, eddy-permitting configuration, for a shorter 30-year simulation, with a physical transport model that represents the mesoscale eddy response explicitly. The following ocean models (with host ESM in parenthesis) will participate using their CMIP6+ configuration (see Table 1.2): NEMO-PlankTOM10 at two resolutions, PISCES (IPSL ESM), HAMOCC (MPI-ESM), POP2 (NCAR-CESM), PISCES (EC-Earth). The simulations will be initialised from fully spun-up pre-industrial state, except for the high-resolution NEMO-PlankTOM10 which will be initialised from observations. Internally and externally-induced variability will be assessed by: (1) using the NEMO-PlankTOM10 (low-resolution) and POP2 (NCAR-CESM2) to test externally-forced variability using multiple forcing reanalysis products including CORE2 and JRA and sea-ice-driven freshwater forcing, and (2) using the NEMO-PlankTOM10 (low-resolution) to quantify variability triggered by internal conditions by using different initial conditions based on observations, including inorganic carbon using ocean interior carbon observations from T1.2.2. In addition to the standard historical simulations, all groups will run factorial single-forcing simulations for the attribution analysis in T1.5.

**Table 2: Historical simulations of the ocean carbon cycle, according to T1.3.2**

| Model (host ESM) | Provider | Storage location (URL) | Status |
|---|---|---|---|
| NEMO-PlankTOM5[1] | UEA | Send request to Jens Daniel Müller (jensdaniel.mueller@usys.ethz.ch) | Data available |
| PISCES (IPSL ESM) | ENS | Send request to Jens Daniel Müller (jensdaniel.mueller@usys.ethz.ch) | Data available |
| HAMOCC (MPI-ESM) | MPG | Send request to Jens Daniel Müller (jensdaniel.mueller@usys.ethz.ch) | Data available |
| POP2 (NCAR-CESMS2) | ETHZ | Send request to Jens Daniel Müller (jensdaniel.mueller@usys.ethz.ch) | Data available |
| PISCES (EC-Earth) | BSC | Send request to Jens Daniel Müller (jensdaniel.mueller@usys.ethz.ch) | Data available |

[1]NEMO-PlankTOM12 low- and high-resolution output will be provided in 2020 and 2021, respectively.