Climber3α+C simulations for marine biogeochemistry and primary production

(https://doi.org/10.5880/pik.2023.003)

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1. Licence

2. Citation

When using the data please cite:

Hofmann, Matthias; Liebermann, Ralf (2023): Climber3α+C simulations for marine biogeochemistry and primary production. V.1.1. GFZ Data Services. https://doi.org/10.5880/pik.2023.003

The data are supplementary material to:
Liebermann, Ralf; Hofmann, Matthias; Feulner, Georg (2024)"Shutdown of Atlantic overturning circulation could cause persistent increase of primary production in the Pacific", Environmental Research Letters, Vol. 19, No.2, https://doi.org/10.1088/1748-9326/ad178b

3. Version history

- 30 August 2023: release of version 1.0
- 11 December 2023: release of version 1.1: changes are described in the updated version of the data description. The data description of version 1.0 and two updated scripts have been moved to the “previous/” folder

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4. Data Description

The data comprise Climber3alpha+C simulations created by Matthias Hofmann (PIK) as part of the Work Package 2.1 of the EU-Horizon2020 COMFORT project as well as model input data and PyFerret scripts (written by Ralf Liebermann and Matthias Hofmann) used for their evaluation. The purpose was to analyze the simulations regarding climate change-induced changes in marine biogeochemistry and primary production, which will be published under the title "Shutdown of Atlantic overturning circulation could cause persistent increase of primary production in the Pacific" (Liebermann et al., 2024).

The simulation data consist of netCDF files (snap_*.nc and history.nc) for ocean, atmosphere and mixed layer depth (hmxl) performed for different idealized scenarios summarized in the table below (note: here, we name the scenarios are named according to their corresponding files and directories; in the publication, they are named CONTROL, 2xCO2, 4xCO2, 2xCO2HOSING, 4xCO2HOSING and HOSING):

- CONTROL, which represents the baseline equilibrium with preindustrial CO2 concentrations (280ppm)
- CO2X2 and CO2X4, which represent transient double (X2) and fourfold (X4) atmospheric CO2 concentrations after an increase of 1%/year, followed by a similar decrease
- CO2X2_HOSING and CO2X4_HOSING, which represent transient double and fourfold atmospheric CO2 concentrations plus a forcing of North Atlantic freshwater addition (hosing)
- HOSING, which represents preindustrial CO2 concentrations plus the hosing applied for CO2X4_HOSING

Furthermore, tracer simulations for CONTROL, CO2X4, CO2X4_HOSING and HOSING as well as simulations with constant scavenging (i.e. without CO2 impact on scavenging) for CO2X4 are included. Input data are monthly values of sea surface wind stress data (in dyn/cm²): taux.mom for zonal values, tauy.mom for meridional values.

4.1. Data processing

Climate Data Operators (CDO) was used to aggregate monthly simulation data into annual data contained in the snap_*.nc files.

5. File description

5.1. File inventory

The directory is named COMFORT WP 2.1 simulations, according to the research project and the working group. The subdirectory names correspond to the names of the scenarios (CONTROL, CO2X2, CO2X2_HOSING, CO2X4, CO2X4_HOSING, HOSING) under which the associated simulation files were created. Wind stress data for model input are filed under “Input Data”, PyFerret scripts are in the eponymous directory.

5.2. File naming convention

history.nc files (included in CONTROL, CO2X2, CO2X4, CO2X2_HOSING, CO2X4_HOSING, CO2X4_FROZ_SCAV, HOSING) represent overview files with annual values. Snap_*.nc files are named after their respective Earth subsystem i.e. ocean, atmos for atmosphere, or the model with which they have been produced (potsdam2 = atmospheric module in Climber3). File names including “1000” contain continuous values for at least 1000 simulation years, file names including “hosing” stem from scenarios with freshwater addition (freshwater fording). Files stemming from tracer simulations named with “ink”, files containing ocean mixed layer depths are named with “hmxl”.

5.3.Folder and file content

The data are organized in seven folders with the following contents:

Folder name	File names	content
CO2X2/	history.nc	overview file with annual simulation values for scenario of transient doublin (X2) of atmospheric CO2
	snap_hmxl.nc	ocean mixed layer depths for scenario of transient doubling (X2) of atmospheric CO2
	snap_ocean.nc	simulation data from the ocean module for scenario of transient doubling (X2) of atmospheric CO2
CO2X2_ HOSING/	history.nc	overview file with annual simulation values for scenario of transient doublin (X2) of atmospheric CO2 and North Atlantic freshwater addition (HOSING)
	snap_hmxl_hosing.nc	ocean mixed layer depths for scenario of transient doubling (X2) of atmospheric CO2 and North Atlantic freshwater addition (HOSING)
	snap_ocean_hosing.nc	diverse simulation data from the ocean module for scenario of transient do bling (X2) of atmospheric CO2 and North Atlantic freshwater addition (HOSING)
CO2X4/	history.nc	overview file with annual simulation values for scenario of transient quadru pling (X4) of atmospheric CO2
	snap_atmos_1000.nc	diverse simulation data from the atmosphere module for scenario of transient quadrupling (X4) of atmospheric CO2; min. 1000 simulation years
	snap_hmxl_1000.nc	ocean mixed layer depths for scenario of transient quadrupling (X4) of atmospheric CO2; min. 1000 simulation years
	snap_ocean_1000.nc	diverse simulation data from the ocean module for scenario of transient quadrupling (X4) of atmospheric CO2; min. 1000 simulation years
	snap_ocean_ink.nc	tracer simulation data from the ocean module for scenario of transient qua rupling (X4) of atmospheric CO2; shows only tracer (ink) dispersion with injection at Westafrican Coast
CO2X4_FROZ_ SCAV/	history.nc	overview file with annual simulation values for scenario of transient quadru pling (X4) of atmospheric CO2, but with constant scavenging at baseline lev (FROZ_SCAV)
	snap_ocean_ froz_scav.nc	diverse simulation data from the ocean module for scenario of transient quadrupling (X4) of atmospheric CO2, but with constant scavenging at base line level (FROZ_SCAV)
CO2X4_ HOSING/	history.nc	overview file with annual simulation values for scenario of transient quadru pling (X4) of atmospheric CO2 and North Atlantic freshwater addition (HOSING)
	snap_hmxl_ hosing_1000.nc	ocean mixed layer depths for scenario of transient quadrupling (X4) of atmospheric CO2 and North Atlantic freshwater addition (HOSING); min. 1000 simulation years
	snap_ocean_ hosing_1000.nc	diverse simulation data from the ocean module for scenario of transient quadrupling (X4) of atmospheric CO2 and North Atlantic freshwater additio (HOSING); min. 1000 simulation years
	snap_ocean_ ink.nc	tracer simulation data from the ocean module for scenario of transient qua rupling (X4) of atmospheric CO2 and North Atlantic freshwater addition (HOSING); shows only tracer (ink) dispersion with injection at Westafrican Coast
	snap_potsdam2_ hosing_1000.nc	diverse simulation data from the atmosphere module (Potsdam2) for scenario of transient quadrupling (X4) of atmospheric CO2 and North Atlantic freshwater addition (HOSING); min. 1000 simulation years
CONTROL/	history.nc	overview file with annual simulation values for scenario of constant atmospheric CO2 (at 280ppm)
	snap_hmxl_1000.nc	ocean mixed layer depths for scenario of constant atmospheric CO2 (at 280ppm); min. 1000 simulation years
	snap_ink_indian.nc	tracer simulation data from the ocean module for scenario of constant atmospheric CO2 (at 280ppm); shows only tracer (ink) dispersion with injectio at Arabian Sea (Indian ocean)

	snap_ocean_1000.nc	diverse simulation data from the ocean module for scenario of constant atmospheric CO2 (at 280ppm) min. 1000 simulation years
	snap_ocean_ink.nc	tracer simulation data from the ocean module for scenario of constant atmospheric CO2 (at 280ppm); shows only tracer (ink) dispersion with injectio at Westafrican Coast
	snap_potsdam2_ 1000.nc	diverse simulation data from the atmosphere module for scenario of constant atmospheric CO2 (at 280ppm); min. 1000 simulation years
HOSING	history_1000.nc	overview file with annual simulation values for scenario of constant atmospheric CO2 (at 280ppm) and North Atlantic freshwater addition
	snap_hmxl_hosing_alone.nc	ocean mixed layer depths for scenario of constant atmospheric CO2 (at 280ppm) and North Atlantic freshwater addition
	snap_ocean_hosing_ink_1000.nc	diverse simulation data from the ocean module for scenario of constant atmospheric CO2 (at 280ppm) and North Atlantic freshwater addition ca. 1000 simulation years
InputData/	taux.mom	zonal, monthly values of sea surface wind stress data (in dyn/cm²) for mode input
	tauy.mom	meridional, monthly values of sea surface wind stress data (in dyn/cm²) for model input
PyFerretScript	COMFORT_ froz_scav.j	plots scavenging rates under 4xCO2: compares normal 4xCO2-scavenging a scavenging without 4xCO2 impact (scavenging rate frozen at baseline)
	COMFORT_ ink-tracer.j	shows global maps of marine tracer dispersion
	COMFORT_map-projections.jnl	global maps of net primary production (NPP) and limitation factors of PO4 and Fe: NPP maps showing difference between all forcing scenarios (2xCO2 4xCO2, 2xCO2hosing, 4xCO2hosing) and CONTROL scenario after 500 years; limitation factor maps (L_{PO4}, L_{Fe}) showing difference between strong forcing scenarios (4xCO2, 4xCO2hosing) and CONTROL scenario after 500 years
	COMFORT_nutrient-map-projections.jnl	global maps of PO4 and Fe showing difference between strong forcing scenarios (4xCO2, 4xCO2hosing) and CONTROL scenario after 500 years
	COMFORT_paper_rev.j	revised plots of mixed layer height and net primary production comparing 6 scenarios (CONTROL, CO2X2, CO2X2_HOSING, CO2X4, CO2X4_HOSING, HOS ING) and 3 regions (East equatorial Pacific, Southern Ocean and Indian Ocean)
	COMFORT_plots-with-legend_rev.jnl	revised plots for comparing 6 scenarios (CONTROL, CO2X2, CO2X2_HOSING CO2X4, CO2X4_HOSING, HOSING) and 8 variables: atmospheric CO2, freshwater forcing, global net primary production (NPP), Atlantic meridional ove turning circulation, NPP in the East equatorial Pacific and Southern Ocean, and limitation factors for PO4 and Fe
Animated_ figures	4xCO2HOSING-400years.gif	animated geographic maps of NPP, Fe concentrations and ink tracer spread ing at 100m depth for the first 400 years in the CO2X4_HOSING scenario; al includes a vertical cut through the Atlantic (30°W) showing tracer spreading over contours of the stream function
	HOSING-400years.gif	animated geographic maps of NPP, Fe concentrations and ink tracer spread ing at 100m depth for the first 400 years in the HOSING scenario; also includes a vertical cut through the Atlantic (30°W) showing tracer spreading over contours of the stream function

The following two scripts have been moved to the “previous/” folder:

- PyFerretScripts/COMFORT_paper.jnl
- PyFerretScripts/COMFORT_plots-with-legend.jnl

6. Changelog version 1.1

Due to revision of the paper "Shutdown of Atlantic overturning circulation could cause persistent increase of primary production in the Pacific", the following data had been added:

New simulations (folder: HOSING) with: history_1000.nc, **snap_hmxl_hosing_alone**, **snap_ocean_hosing_ink_1000**

- These three files contain the simulations for an additional scenario, "HOSING", which is based on freshwater addition identical to that in 4xCO2HOSING, but without CO2 increase (i.e. the CO2 level is identical to CONTROL).

New animated-figures folder: 4xCO2HOSING-400years.gif, HOSING-400years

- Short animations to show the temporal progression in the HOSING and 4xCO2HOSING scenarios. Shown are the geographic distribution of a tracer designed to mimic iron-rich Saharan dust along the West African coast, both horizontally in 100m water depth and vertically along the Atlantic Ocean (at longitude 30°W, including contour plot for the Atlantic overturning circulation stream function). In addition, the changes in iron concentration (Fe) and net primary production (NPP) relative to CONTROL (also in 100m water depth).

Scripts: COMFORT_plots-with-legend_rev.jnl, COMFORT_paper_rev.jnl

- Revised versions of the scripts COMFORT_plots-with-legend.jnl and COMFORT_paper.jnl, which were used to generate the plot diagrams in Fig. 1 and Fig. S2 in the paper. Now also including curves for the HOSING scenario and, in the case of COMFORT_plots-with-legend_rev.jnl (Fig. 1 in the paper), two additional diagrams for visualising the NPP in the Southern Ocean and in the Eastern Equatorial Pacific.

7. References

Liebermann, Ralf; Hofmann, Matthias; Feulner, Georg (2024)"Shutdown of Atlantic overturning circulation could cause persistent increase of primary production in the Pacific", Environmental Research Letters, Vol. 19, No.2, https://doi.org/10.1088/1748-9326/ad178b