# RECCAP2: Ocean Modeling Protocol



## Overview

**Version:** 2021-01-14

Deadline for submission of simulations: Feb, 2021

**Goal:** To provide model output to the Regional Carbon Cycle Assessment and Processes (RECCAP2) global and regional papers.

The protocol defined here follows, in spirit, that of the Global Carbon Budget, in that the modeling groups are free to use their own forcing and parameterizations, as well as their own initialization and spinup procedures. This contrasts with the specificity of OMIP (Orr et al., 2017), where many of these elements are specified. We do, however, request substantially more information and data than GCB, and also encourage the modelers to perform and analyze more simulations. The protocol is written for both global and regional models.

**Analysis period:** The analysis period is 1980 through 2018.

## Simulations

We encourage, particularly the global modelers, to conduct a total of 4 simulations, i.e. A through D (Table 2). These four simulations vary in terms of their atmospheric $CO_2$ (increasing vs preindustrial), and in terms of their atmospheric forcing (time varying versus climatological). Simulation A is mandatory for all participating groups, and simulation B is mandatory for all global modelling groups, whereas C and D are encouraged. Models that include a separate tracer for anthropogenic $CO_2$ can skip simulations B and D.

Simulation B is necessary to judge model drift. Simulation D is required to compute the fluxes and change in storage of anthropogenic $CO_2$.

Regional modelers need to conduct and report at least A, although a run that permits to decipher the drift in the model, i.e., some form of a modified run B is encouraged.

(Note: In RECCAPv1, A corresponds to ANTH, D to PIND, and C to ACO2; compare also to the nomenclature of the Trendy project, S0 ≈ B, S1 ≈ C, S2 ≈ A)

***Table 2:*** *Summary of simulations*

| | Simulation A | Simulation B 'ctrl' | Simulation C | Simulation D |
|---|---|---|---|---|
| Request level | Mandatory, Tier 1 | Mandatory for global models, Tier 1 | Tier 2 | Tier 2 |
| Atmospheric $CO_2$ | Increasing | Constant, preindustrial | Increasing | Constant preindustrial |
| Atmospheric forcing (wind, fluxes of heat and freshwater) | Variable, reanalysis | climatological | climatological | Variable, reanalysis |
| Considered components(1) | $Flux_{ant}^{ss}$ + $Flux_{ant}^{ns}$+ $Flux_{nat}^{ss}$ + $Flux_{nat}^{ns}$ | $Flux_{nat}^{ss}$ | $Flux_{ant}^{ss}$ + $Flux_{nat}^{ss}$ | $Flux_{nat}^{ss}$ + $Flux_{nat}^{ns}$ |

(1) Total Flux = $Flux_{ant}^{ss}$ + $Flux_{ant}^{ns}$+ $Flux_{nat}^{ss}$ + $Flux_{nat}^{ns}$, where $Flux_{ant}$ is the air-sea flux of anthropogenic $CO_2$, and $Flux_{nat}$ that of natural $CO_2$. "ss" refers to steady-state and "ns" to non-steady state, i.e., the variability component imposed on natural and anthropogenic $CO_2$ by all non-seasonal variability. The same differentiation applies also to the change in ocean interior DIC, i.e., $\Delta DIC = \Delta DIC_{ant}^{ss} + \Delta DIC_{ant}^{ns} + \Delta DIC_{nat}^{ss} + \Delta DIC_{nat}^{n}$

The simulation A should reproduce the interannual variability and trend in the ocean carbon uptake in response to changes in both atmospheric $CO_2$ and climate. Thus models should be forced by observed climate (e.g. from reanalysis products) and observed atmospheric $CO_2$ throughout the entire time period. While there are no specified products recommended, we require continuity in forcing, i.e. only one forcing data should be used for the full time-series of the analysis period, i.e., 1980 through 2018. Available forcing data sets for the full time-series are for example NCEP/NCAR R1 and JRA55 (link to JRA55 data) or JRA55-do (link to JRA55-do data).

The simulations with constant atmospheric forcing (B) should *be consistent* with the variable climate simulations (A), for example by using a climatology calculated from the variable forcing or looping over a certain year.

You can use your own atmospheric $CO_2$ time-series, but you are encouraged to use a common time-series provided under this [link] to facilitate model simulations. The data represents the average atmospheric $CO_2$ (dry mixing ratio) (ppm) and thus will have to be converted to partial pressure (including total pressure and air humidity) according to each model's protocol. In the simulations with constant atmospheric $CO_2$, i.e., B and D, atmospheric $CO_2$ should be kept constant at preindustrial levels (recommendation: 278 ppm) and it should be started from the spin-up or from another simulation with constant $CO_2$ (at 278 ppm) and not from a simulation with increasing atmospheric $CO_2$. Using a constant $CO_2$ value other than 278 ppm is accepted if well documented (roughly plus/minus 10 ppm).

## Initialization and Spinup

Two strategies can be pursued for the initialization and the spinup.

**Strategy 1 (Regional models)**: Initialization from observations for the 1960s, followed by a short spinup. This strategy will be used primarily by the regional models. This strategy will typically involve an initialization of the ocean interior distributions for the late 1960s or early 1970s, followed by spinup phase for the 1970s, during which atmospheric $CO_2$ rises according to the observations. From 1980 onward, the simulation is then continued until 2018, providing the basis for the analyses. Only simulation A can be provided if this strategy is selected, although a modified version of simulation B is encouraged in order to determine the drift of the model.

**Strategy 2 (Global models):** Initialization from preindustrial conditions, followed by a long spinup. This strategy will be used primarily by the global models. Here, the ocean is initialized from (reconstructed) preindustrial conditions and then spun up for several decades to centuries in order to ensure minimal drift in the surface fluxes. The models are then brought forward in time to the analysis period using either constant atmospheric forcing until the reanalysis period begins or by cycling through the atmospheric forcing time-series (the latter strategy is the one recommended by OMIP, see Orr et al., 2017)).

We will assume that no drift correction and other post-processing (e.g. correction for riverine outgassing) has been applied unless you let us know otherwise.

# Output

## Variable descriptions

In addition to providing the globally-integrated air-sea $CO_2$ flux time-series calculated on the native model grid, we request that the raw output of the models is regridded by each group to a standard 1x1 latitude longitude grid (see below for grid convention), and that the resulting regridded data are provided at the indicated frequency for the following fields:

Naming conventions and units should follow largely Orr et al. (2017)

***Table 3**: List of requested output, for the period 1980-2018*

| Variable Name | Units | Output frequency | Shape | Priority | Long name |
|---|---|---|---|---|---|
| | | ***Surface ocean or 2D properties*** | | | |
| fgco2_glob | Pg C $yr^{-1}$ | monthly | T | 1 | Globally integrated air-sea $CO_2$ flux (positive upward) |
| fgco2_reg | Pg C $yr^{-1}$ | monthly | iT | 1 | Regionally integrated air-sea $CO_2$ flux (positive upward) (using regional bounds), i: number of regions |
| fgco2 | mol $m^{-2}$ $s^{-1}$ | monthly | XYT | 1 | Flux density of the total air-sea CO2 exchange (positive upward) |
| spco2 | µatm | monthly | XYT | 1 | Surface ocean pCO2 |
| fice | - | monthly | XYT | 1 | fractional ice-cover (=sea-ice concentration) used for the computation of the air-sea exchange flux [0-1] |
| intpp | mol $m^{-2}$ $s^{-1}$ | monthly | XYT | 1 | vertically-integrated net primary production |
| epc100 | mol m-2 s-1 | monthly | XYT | 1 | Particle flux of POC at 100 m |
| epc1000 | mol m-2 s-1 | monthly | XYT | 2 | Particle flux POC at 1000 m |
| epc100*type* / epc1000*type* | mol m-2 s-1 | monthly | XYT | 2 | particle fluxes at 100 and 1000 m for different particle types (e.g. slow, fast or small, large) |
| epcalc100 | mol m-2 s-1 | monthly | XYT | 1 | Export flux of CaCO3 at 100 m |
| Kw | m $s^{-1}$ | monthly | XYT | 2 | Air-sea piston velocity |
| pco2atm | µatm | monthly | XYT | 2 | Atmospheric pCO2 ('pco2atm' [uatm] will vary spatially, as opposed to the spatially uniform 'xco2atm' [ppm] atm CO2 forcing due to corrections for atm pressure and vapor pressure) |
| alpha | mol $kg^{-1}$ $atm^{-1}$ | monthly | XYT | 3 | CO2 solubility |
| tos | degC | monthly | XYT | 1 | sea-surface temp |
| sos | - | monthly | XYT | 1 | sea-surface salinity (PSS-78) |
| dissicos | mol $m^{-3}$ | monthly | XYT | 1 | sea-surface DIC |
| talkos | mol $m^{-3}$ | monthly | XYT | 1 | sea-surface Alkalinity |
| no3os | mol $m^{-3}$ | monthly | XYT | 2 | Surface Dissolved Nitrate Concentration |

| | | | | | |
|---|---|---|---|---|---|
| po4os | mol $m^{-3}$ | monthly | XYT | 2 | Surface Total Dissolved Inorganic Phosphorus Concentration |
| sios | mol $m^{-3}$ | monthly | XYT | 2 | Surface Total Dissolved Inorganic Silicic acid Concentration |
| dfeos | mol m-3 | monthly | XYT | 2 | Surface Dissolved Iron Concentration |
| o2os | mol $m^{-3}$ | monthly | XYT | 2 | Surface Dissolved Oxygen Concentration |
| intphyc | mol C m-2 | monthly | XYT | 1 | Vertically-integrated Concentration of total phytoplankton expressed in carbon units |
| intphynd | mol C m-2 | monthly | XYT | 2 | Vertically-integrated Concentration of non-diatom phytoplankton expressed in carbon units (if available) |
| intdiac | mol C m-2 | monthly | XYT | 2 | Vertically-integrated Concentration of diatom Phytoplankton expressed in carbon units (if available) |
| intzooc | mol C m-2 | monthly | XYT | 1 | Vertically-integrated concentration of total zooplankton expressed in carbon units |
| chlos | kg m-3 | monthly | XYT | 1 | Surface Mass Concentration of Total Phytoplankton expressed as Chlorophyll in Sea Water |
| mld | m | monthly | XYT | 1 | user-defined mixed layer depth |
| zeu | m | monthly | XYT | 1 | user-defined euphotic zone depth |
| | | | | | |
| **Interior ocean or 3D properties** | | | | | |
| dissic | mol $m^{-3}$ | annual | XYZT | 1 | Dissolved inorganic carbon |
| talk | mol $m^{-3}$ | annual | XYZT | 1 | Total Alkalinity |
| thetao | degC | annual | XYZT | 1 | seawater potential temperature |
| so | - | annual | XYZT | 1 | Salinity (PSS-78) |
| epc | mol m-2 s-1 | annual | XYZT | 1 | 3D field of particle flux of POC |
| no3 | mol $m^{-3}$ | annual | XYZT | 2 | Dissolved Nitrate Concentration |
| po4 | mol $m^{-3}$ | annual | XYZT | 2 | Total Dissolved Inorganic Phosphorus Concentration |
| si | mol $m^{-3}$ | annual | XYZT | 2 | Total Dissolved Inorganic Silicic Concentration |
| o2 | mol $m^{-3}$ | annual | XYZT | 2 | Dissolved Oxygen Concentration |

In order to optimally work with the submitted data, we require each group to submit also the following ancillary information:

***Table 4**: List of requested ancillary data.*

| Variable Name | Units | Shape | Priority | Long name |
|---|---|---|---|---|
| area | $m^2$ | XY | 1 | Total surface area of each grid cell |
| volume | $m^3$ | XYZ | 1 | Total volume of each grid cell |
| mask_sfc | - | XY | 1 | Field indicating the fraction of presence of ocean in a grid cell [0-1]; fraction of surface area |
| mask_vol | - | XYZ | 1 | Field indicating the fraction of presence of ocean in a grid cell [0-1] fraction of volume |

| | | | | |
|---|---|---|---|---|
| Area_tot_native | M2 | | 1 | Total surface ocean area covered by native grid |
| Vol_tot_native | M3 | | 1 | Total ocean volume covered by native grid |
| Atm_CO2 | ppm | T | 1 | Time-series of atmospheric CO2 used to drive the model. |

## Output format

Please prepare your output as follows:

### Coordinate system

Lat, Lon: 1x1 degree grid (0.5 to 359.5°E longitude, -89.5 to 89.5°N latitude)

Vertical: z-coordinate system (vertical depth axis). Model groups that do NOT use z-coordinates will need to interpolate their results to standard z depth levels. Depth: positive downwards

Time: seconds since Jan 1, 1980.

### Individual file format

We request the data in netcdf format (preferably following the CF convention as currently adopted for CMIP, http://cfconventions.org/ ).

Please generate one file per variable (do not merge different variables into one file). This file should contain full time-series for 2-D-variable. For 3-D variables, split in chunks as need be.

File names: Groups are encouraged to follow the CMIP naming convention for file names (see this link), the file name can be constructed consistent with the following template

file name =
<variable_id>_<model_id>_<experiment_id>_<member_id>_<grid_label>_<time_range>.nc

Example file name =
fgco2_CESM-ETHZ_A_1_gr_1980-2018.nc

## File tarring

To facilitate easy handling and further use of your data, please tar individual files together into following four groups, referred to as <tar_id>, before submission (see instructions below):

**2D_CO2**: Files containing following of the 2D variables listed in Table 3:
"fgco2", "fgco2_glob", "fgco2_reg", "spco2", "fice", "Kw", "pco2atm", "alpha", "mld", "tos", "sos", "dissicos", "talkos", "no3os", "po4os", "sios"

**2D_BIO**: All files containing 2D variables listed in Table 3, that are not included in 2D_CO2

**3D_ALL:** All files containing 4D variables listed in Table 3

**Ancillary_data:** All files containing ancillary data listed in Table 4

Please name the created tar files according to following template:
Tar file name =
<model_id>_<tar_id>.tar

# Data on the MPI-BGC FTP-server

## Uploading data

For RECCAP2-ocean data products, it is recommended to upload zipped or tar files using the FTP:

ftp://ftp.bgc-jena.mpg.de/pub/incoming

For FTP upload, please add a readme file with the file information: owner, version, description that should go in the file metadata.

Please notify abastos@bgc-jena.mpg.de and jensdaniel.mueller@usys.ethz.ch when uploading files.

For additional information regarding data upload, please refer to this document [link] provided by Ana Bastos.

## Data access

Data uploaded by various data providers through the MPI-BGC FTP-server, will be further compiled into single files per <tar_id>. The compiled files will be made available through the following data portal:

https://www.bgc-jena.mpg.de/geodb/projects/Home.php

The download required authorization and registration. RECCAP2-ocean partners should already be authorized through their email, but still need to register upon first access. For additional information regarding registration, please refer to this document [link] provided by Ana Bastos.

## Data policy

We will use the Fair Use Policy of RECCAPv2-ceans (see here)

# Open Issues to be further discussed.

Some of the analysts are interested in the following additional data: (Priority 3)

**Monthly (***annual or decadal***) mean transports (volume and natural and anthropogenic carbon) at the OVIDE-A25 (See map) section (***Mean Jun-Jul of 2002, 2004, 2006, 2008, 2010, 2012, 2014 and 2016***), 24N (See map) (***Mean Jul-Aug of* **1992,** *Mean Jan-Feb of* **1998,** *Mean Apr-May of* **2004,** *Mean Jan-Feb of* **2010,** *Mean Feb-Mar of* **2011,** *Mean Dec* ***2015*** *with Jan of* **2016), 7.5ºN (See map)(***Mean Feb-Mar of* **1993,** *Mean Apr-May of* **2010), 24S (See map) (***Mean Mar-Apr of* **2009 and 2018), 35S (See map) (***Mean Jan* **1993,** *Mean Nov of* **2003,** *Mean Oct of* **2011 and** *Mean Jan of* **2017 ), Pacific: 64N, 18 S/N, 44S and Indonesian Throughflow.**