RECCAP2-ocean: Protocol for modelling products

Overview

Version: 2021-02-01

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 downward**)
fgco2_reg	Pg C yr^{-1}	monthly	iT	1	Regionally integrated air-sea CO_2 flux (**positive downward**) (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 downward**)
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	m^2		1	Total surface ocean area covered by native grid
Vol_tot_native	m^3		1	Total ocean volume covered by native grid
Atm_CO2	ppm	T	1	Time-series of atmospheric CO2 used to drive the model.

Any additional information that is useful to interpret the outcome of a specific model is of course welcome, and should be declared in the readme file (see template in Appendix 1). This could for example refer to detailed information about the native model grid (eg “thkcello”) that should be considered for budget calculations.

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. It is up to each provider to decide upon suitable standard depth levels and document them in the 3D variable files. Depth: positive downwards

Time: days 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 consider to compress your output using the netCDF4 format, which is recommended but not mandatory.

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>_<version_id>.nc

Example file name =
fgco2_CESM-ETHZ_A_1_gr_1980-2018_v20200101.nc

version _id: We suggest to use version numbering of your files, indicating the date of creation as vYYYYMMDD. Please keep track of the submitted versions in your readme file, briefly explaining the differences between versions.

member _id: Will be “1” in most of the cases, but can be used to distinguish variants of the same model, such as runs with different forcings. Variant 1 should be considered the standard case used in the analysis.

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

Please notify abastos@bgc-jena.mpg.de and jensdaniel.mueller@usys.ethz.ch before starting your upload, indicating names and sizes of your files.

Note that ftp folder "incoming" is hidden to the exterior for security, so you cannot see your files after upload. A confirmation of your successful upload will be sent by mail.

Useful commands for two approaches that we previously tested, are:

Upload via FileZilla

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

Leave all other fields blank

Click “Quickconnect”.

Upload via console

Use command: ftp ftp.bgc-jena.mpg.de

Name: anonymous

Password: none, leave blank

Upload your files to folder /pub/incoming

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)

Appendix 1: Readme template for Model description

Information request for Ocean-General Circulation models (O-GCMs):

In order to gain a better understanding of the sea-air CO2 fluxes and inventory changes in the O-GCMs, and the possible interdependency of model results we'd appreciate some specific details on the model runs provided for RECCAPv2:

A. Model designation: Please indicate <model_id> and <version_id> as used in the file naming

B. Primary reference for model in general and for the supplied simulation results in particular.

C. Model dimensions

a) Original horizontal and vertical resolution. If applicable, please provide also information on the regridding procedure applied to derive the 1x1 degree horizontal grid as well as regular z depth levels.
b) Surface area and volume of ocean in original ocean.
c) Average areas of ice: Please provide annual min and annual max separately for the northern and southern hemisphere, derived from the averaged seasonal cycle over the full period 1980-2018.

E. Model initialization:

a) Was the model "spun-up" to a preindustrial steady-state (strategy 2) or initialized with observations for a particular year (strategy 1)?
b) What atm. CO2 was used for this preindustrial steady-state?
c) Which data set was used for initial conditions?
d) Please specify the spin-up procedure in detail.

F. Model simulation:

a) Global integral of the pre-anthropogenic sea-air CO2 flux
b) Please provide reference to the physical forcing used (surface forcing type and frequency, including winds)
c) Atmospheric CO_2 concentrations used (including spatial and temporal resolution)
d) How did you deal with sea-ice with respect to air-sea gas exchange?
e) Which gas transfer velocity parameterization was used. What is the global mean gas transfer velocity?
f) Please report which CO2 system constants, if any, deviate from those recommended for best practices by Dickson et al. (2007). Following best practices, it is recommended to use K1 and K2 from Lueker et al. (2000) and the boron-to-salinity ratio Bt from Uppstrom (1974). Groups should also report which pH scale (total or seawater) is used in their model. The total scale is recommended for best practices and adopted for OMIP and CMIP6.
g) Specify which CO2 calculation routine / software was used.
h) Specify whether model's equation for total alkalinity includes the phosphoric and silicic acid systems

i) Please specify the model's calendar (e.g., 'noleap', '360_day', '365_day', or 'gregorian', or 'proleptic_gregorian')

G. Model specifics

a) Describe the key characteristics of your ecosystem model (e.g. how many/which phytoplankton & zooplankton terms). Provide the key reference(s).
b) Treatment of lateral inputs (riverine inputs) and burial.
c) Is the model tuned to recreate a best estimate for a certain time period, and if so how is this done?
d) Are there any other specifics, such as temporally changing atmospheric deposition fluxes?
e) How do you specify atmospheric pCO2? Do you account for variations in atmospheric pressure and varying water vapor pressure?
f) Specify the half-saturation constants for nutrients used
g) Specify the temperature-growth relationship used
h) Indicate how particle sinking and remineralisation is parameterised (e.g. T-dependency, or not, of remineralisation)

H. Results:

a) Is the anthropogenic CO_2 flux and inventory in the ocean determined from the difference between a steady atm CO_2 level (if so what level, 278 ppm?) and a run with increasing atm CO_2 levels? If not, how is anthropogenic CO2 flux determined?
b) What is the total anthropogenic CO2 inventory in the ocean for the model for the year 2000?
c) Water mass transport: Please calculate mean annual transport rates for : Drake Passage Transport, Bering Straight through flow; Indonesian through flow, AMOC as max streamfunction at 26N

I. Others

a) Are there any specific model idiosyncrasies that might impact intercomparison of results between the models and observations on global or basin scales? (Such as representation of sea-ice in the Arctic)
b) Did your model run differ from the recommendations given in this protocol, i.e., was “numerical drift” corrected?

Appendix 2: Open Issues to be further discussed.

Fiz Perez declared an 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.**

Please get in touch with Fiz for additional information if you think you can provide those estimates.