Abiotic-HOWTO

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This document provides step-by-step guidelines to make the so-called solubility pump runs for CO2 and C-14 according to the standard OCMIP-2 protocols. No biological effects are included. The ocean model carries only DIC and DIC14. We describe five types of abiotic simulations: (1) **Equilibrium** run, (2) **Historical** run for 1765-2000, (3) **Future** runs (IPCC S650 and CIS92A) for DIC only, (4) a 1000-yr **Pulse** Input run for DIC only, and (5) three **Control** runs needed for drift correction for the Abiotic transient runs (i.e., the **Historical**, **Future**, and **Pulse** simulations).

Contents

1 Recuperation of OCMIP-2 files by ftp:

To comply with OCMIP-2 guidelines, all modelers must make simulations according to OCMIP-2 standard boundary conditions. To do so, one must first recuperate the following files via this Web page. (you can save a file to disk by clicking on its link while holding down the Shift key)

- Files concerning gas exchange (same for all OCMIP-2 runs)
  - rgasx_ocmip2.f
  - gasx_ocmip2.nc.gz
  - vgasx_ocmip2.jnl
- Files concerning atmospheric CO2 and C-14, for transient simulations
  - splco2.dat
  - stab.dat
  - cis92a.dat
  - c14nth.dat
  - c14equ.dat
  - c14sth.dat
  - read_co2atm.f
  - read_c14atm.f
  - c_interp.f
  - try_c_interp.f
  - locate.f
- Files concerning abiotic model
  - scco2.f
  - co2flux.f
- Files concerning standard carbonate chemistry (same for all OCMIP-2 carbon runs)
  - README.Cchem
  - Makefile
  - co2calc.f
  - drtsafe.f
  - ta_iter_1.f
  - test.r
  - test.out.gz

After transferring these files (in binary mode), modelers must then uncompress (gunzip) the file containing the gas exchange boundary conditions (gasx_ocmip2.nc.gz):

```
gunzip gasx_ocmip2.nc
```

Other files are text and need no special treatment after transfer. Use of these files is described below.

2 Model runs

2.1 Conservation equations

For the inorganic carbon and radiocarbon, both passive tracers, the conservation equations carried in the model are

(1a) **d[DIC]/dt = L([DIC]) + Jv + J**

and

(1b) **d[DIC14]/dt = L([DIC14]) - Lambda * [DIC14] + Jv14 + J14**

where

- **[DIC]** is the model's concentration (moles/mˆ3) of total dissolved inorganic carbon;
- **[DIC14]** is the model's DIC-normalized concentration (also in moles/mˆ3) of total dissolved inorganic C-14 (see below);
- **L** is the 3-D transport operator, which represents effects due to advection, diffusion, and convection;
- **Lambda** is the radioactive decay constant for C-14 (ln(2) / 5730 year = 1.2097e-04 yearˆ-1), converted to sˆ-1 using the number of seconds/year in your particular model;
- **Jv** is the "virtual" source-sink term representing the changes in surface **[DIC]** due to evaporation and precipitation, which must be accounted for because of the relatively high background concentration of **[DIC]**;
- **Jv14** is the "virtual" source-sink term for changes in surface **[DIC14]**due to evaporation and precipitation (E-P changes in background concentrations are of the same order as observed variability);
- **J** is the the source-sink term due to air-sea exchange of CO2; and
- **J14** is the source-sink term due to air-sea exchange of 14CO2.

The source-sink terms **Jv**, **Jv14**, **J**, and **J14** are added only as surface boundary conditions. That is they are equal to zero in all subsurface layers. These source-sink terms are equivalent to the fluxes, described below, divided by the surface layer thickness **dz1**.

Jv = Fv/dz1

Jv14 = Fv14/dz1

J = F/dz1

J14 = F14/dz1

2.2 Virtual flux (Fv)

In models where surface salinity is restored to observed values, this results in a surface flux of salt, not a surface flux of water as in the real world. Such surface salt fluxes are typically found in models with a rigid lid, and even in some models with a free surface (e.g., the OGCM from Louvain-la-Neuve). For simplicity, we categorize both classes of models as ”rigid-lid-like”. Conversely, non-rigid-lid-like models have a free surface and restore surface salinity by an equivalent flux of water leading to dilution or concentration (e.g., the MPI LSG model). Salinity in the latter type of free-surface model is conserved; E-P fluxes are taken into account by the velocity fields and thus do not need to be explicitly formulated in the transport model.

Yet for all rigid-lid-like models, we must explicitly take into account the concentration-dilution effect of E-P (Evaporation minus Precipitation), which changes surface **[DIC]** and **[Alk]**. Thus we add the virtual flux to the surface layer, each time step according to

(2a) **Fv = DICg * (E-P)**

(2b) **Fv14 = DIC14g * (E-P)**

where DICg and DIC14g are the model’s globally averaged surface concentrations of DIC and DIC14, respectively. Both global averages must be computed at least once per year. For rigid-lid-like models with only salinity restoring, we suggest that (P - E) be computed as

(3) **P - E =** $(S - S')/Sg$ *** dz1 /Tau**

where **S’** is the observed local salinity to which modeled local salinity **S** is being restored, **Sg** is the model’s globally averaged surface salinity, **dz1** is the top layer thickness, and **Tau** is the restoring time scale for salinity. For rigid-lid-like models which in addition include explicit P - E water fluxes, that term must of course also be added to eq (3).

2.3 Air-sea gas exchange fluxes (F and F14)

For simulations of DIC and DIC14, OCMIP-2 simulations will directly model the finite air-sea fluxes **F** and **F14**, respectively. Modelers must use the formulation for the standard OCMIP-2 air-to-sea flux,

(4a) **F = Kw (Csat - Csurf)**

(4b) **F14 = Kw (14Csat - 14Csurf)**

with

(5a) **Csat = alphaC * pCO2atm * P/Po**

(5b) **14Csat = Csat * Ratm**

where

- **Kw** is the CO2 gas transfer (piston) velocity [m/s] ;
- **Csurf** is the surface aqueous [CO2] concentration [mol/mˆ3], which is computed from the model’s surface [DIC], T, S, and [Alk] (see section 2.5);
- **14Csurf** is the surface ocean [14CO2] (see section 2.5);

- **alphaC** is the C solubility for water-vapor saturated air [mol/(mˆ3 * uatm)];
- **pCO2atm** is the partial pressure of CO2 in dry air at one atmosphere total pressure [in microatm], which is the same as the dry air mixing ratio of CO2 multiplied by 10ˆ6 ;
- **P** is the total air pressure at sea level [atm], locally;
- **Po** is 1 atm; and
- **Ratm** is the normalized atmospheric ratio of C-14/C-12, which for our purposes we divide by the analogous ratio for the standard **Rstd**

(6) **Ratm = (1 + D14Catm/1000)**

where **D14Catm** is the atmospheric Delta C-14, the fractionation corrected ratio of C-14/C-12, given in permil (see below).

Those familiar with C-14, may be surprised that in equation (6) we define **Ratm**, without multiplying the right hand term by **Rstd** (1.176e-12). Instead, we prefer to be able to compare **[DIC14]** to **[DIC]**, directly, in order to simplify early interpretation and code verification. With the above formulation for the OCMIP equilibrium runs (where pCO2atm=278 ppm and D14Catm=0‰), if both tracers are initialized identically, the only difference between units for the **[DIC]** and **[DIC14]** tracers will be due to radioactive decay. For the anthropogenic runs, there will also be contributions due to differences between atmospheric records for **pCO2atm** and **D14Catm**.

2.4 The Piston Velocity Kw

For simulations of DIC and DIC14, modelers must use the standard OCMIP-2 formulation for the piston velocity **Kw** for CO2. The monthly climatology of **Kw**, to be interpolated linearly in time by each modeling group, is computed with the following equation adapted from Wanninkhof (1992, eq. 3):

(7) **Kw = (1 - Fice) [Xconv * a *(u2 + v)] (Sc/660)**-1/2**

where

- **Fice** is the fraction of the sea surface covered with ice, which varies from 0.0 to 1.0, and is given as monthly averages from the Walsh (1978) and Zwally et al. (1983) climatology (OCMIP-2 modelers must reset **Fice** values less than 0.2 to zero, after interpolation to their model grid)
- **u2** is the instantaneous SSMI wind speed, averaged for each month, then squared, and subsequently averaged over th e same month of all years to give the monthly climatology. (see the OCMIP-1 README.satdat for further details);
- **v** is the variance of the instantaneous SSMI wind speed computed over one month temporal resolution And 2.5 degree spatial resolution, and subsequently averaged over the same month of all years to give the monthly climatology. Again, see the OCMIP-1 README.satdat for further details.
- **a** is the coefficient of 0.337, consistent with a piston velocity in cm/hr. We adjusted the coefficient **a** for OCMIP-2, in order to obtain Broecker et al.'s (1986) radiocarbon-calibrated, global CO2 gas exchange of 0.061 mol CO2 /(mˆ2 * yr * uatm), when using the satellite SSMI wind information (**u2 + v**) from Boutin and

Etcheto (pers. comm.). Our computed value for **a** is similar to that determined by Wanninkhof (**a** = 0.31), who used a different wind speed data set and assumptions about wind speed variance; we use the observed variance.

- **Xconv** = 1/3.6e+05, is a constant factor to convert the piston velocity from [cm/hr] to [m/s]. This conversion factor is already included in the forcing field **xKw,** provided below.
- **Sc** is the Schmidt number which is to be computed using modeled SST, using the formulation from Wanninkhof (1992). The function scco2.f computes the Sc (unit-less) for CO2.

Practically speaking, to use equation (2) each group will interpolate the OCMIP-2 standard information to their own model grid. The standard information is provided by IPSL/LSCE as a monthly climatology on the 1 x 1 degree grid of Levitus (1982) in netCDF format (in file gasx_ocmip2.nc). Gridded variables in that file include

- the variable **Fice**,
- the second term, **[Xconv * a * (u2 + v)]**, denoted as **xKw** [m/s]
- the mask **Tmask** (1 if ocean; 0 if land),
- the total atmospheric pressure at sea level **P** [atm]
- the longitude **Lon** at the center of each 1 x 1 degree grid box,
- the latitude **Lat** at the center of each 1 x 1 degree grid box.

For the variables **Fice** and **xKw**, continents on the 1 x 1 degree standard grid have been flooded with adjacent ocean values. Such an approach avoids discontinuities at land-sea boundaries during interpolation. See the Fortran program rgasx_ocmip2.f for an example of how to read the information in gasx_ocmip2.nc.gz into your interpolation routines. After compilation, to link and use rgasx_ocmip2.f, one must have already installed netCDF.

`<http://www.unidata.ucar.edu/packages/netcdf/>`

The file `gasx_ocmip2.nc` may also be inspected with software that uses netCDF format, such as ncdump or Ferret. Ferret will be used for some of the analysis during OCMIP-2. We encourage participants to become familiar with Ferret now

`<http://ferret.wrc.noaa.gov/Ferret/>`

After installation, one can visualize maps of the standard information in gasx_ocmip2.nc, by using the Ferret script vgasx_ocmip2.jnl.

After launching Ferret, simply issue the following command (at Ferret's "yes?" prompt)

```
yes? go vgasx_ocmip2.jnl
```

2.5 Oceanic and Atmospheric Components

Apart from Kw, there are a total of four other terms in equation (4a) and (4b) which require further development.

2.5.1 Ocean

The oceanic terms **Csurf** and **14Csurf** [in mol/mˆ3] are not carried as tracers, so they must be computed each timestep to determine gas exchange

Csurf is the surface [CO2] concentration [mol/mˆ3], which is computed from the model's surface **[DIC]**, **T**, **S**, and **[Alk]** through the equations and constants found in the subroutine co2calc.f. As input, we must provide alkalinity, which we determine as a normalized linear function of salinity.

(8) **[Alk] = Alkbar * S/Sbar**

where **[Alkbar]** is 2310 microeq/kg and **Sbar** is the model's annual mean surface salinity, integrated globally (horizontally). Two other input arguments, both nutrient concentrations, are needed as input. Although accounting for both of their equilibria makes a difference, neither nutrient is included in the solubility pump run. Hence we take concentrations of both as being constant, equal to the global mean of surface observations: 0.5 micromol/kg for phosphate and 7.5 micromol/kg for silicate. Note that for the later OCMIP-2 run which includes the biological pump, we will use observed seasonal distributions of surface phosphate.

IMPORTANT: The carbonate chemistry subroutine co2calc.f was originally designed to require tracer input (**[DIC]**, **[Alk]**, **[PO4]**, and **[SiO2]**) on a per mass basis (umol/kg); however, for OCMIP-2 co2calc.f has been modified to pass tracer concentrations on a per volume basis (mol/mˆ3), as carried in ocean models. To do so, we use the mean surface density of the ocean (1024.5 kg/mˆ3) as a constant conversion factor; we do NOT use model-predicted densities. For example, OCMIP-2 modelers should used SiO2 = 7.7e-03 mol/mˆ3 and PO4 = 5.1e-04 mol/mˆ3 as input arguments; again both are constant for the abiotic simulation. The output arguments *co2star* (**Csurf**) and *dco2star* (**Csat - Csurf**) are also returned in mol/mˆ3.

14Csurf is the surface ocean [14CO2], defined as

(9) **14Csurf = Csurf * Rocn**,

where

(10) **Rocn = [DIC14]/[DIC]**.

Furthermore, for comparison to ocean measurements, we compute

(11) **D14Cocn = 1000*(Rocn - 1)**.

Following equation (4), we do not include **Rstd** when calculating **D14Cocn** in the model.

2.5.2 Atmosphere

The atmospheric components **Csat** and **14Csat** in equations (4a) and (4b) are specified *a priori* via four remaining terms:

1. **alphaC**: The CO2 solubility **alphaC** is to be computed using modeled SST and SSS, both of which vary in time at each grid point. For OCMIP-2 we use the solubility formulation of Weiss (1974), corrected for the contribution of water vapor to the total pressure (Weiss and Price, 1980, Table IV for solubility in [mol/(l * atm)]). The solubility **alphaC** is calculated within the routine co2calc.f.
2. **pCO2atm**: For the *Equilibrium run*, pCO2atm is held constant at 278 ppm. For the anthropogenic perturbation, we define the equilibrium state as year 1765.0. Then for the *Historical run*, the model must be

integrated until the end of 1999, following the observed record until 1990.5 (splco2.dat) and IPCC scenario S650 (stab.dat) until 2000.0 (Enting, 1994). That same scenario, *Future run S650*, will be continued from 2000.0 to 2300.0. Similarly, a second *Future run CIS92A* (see also cis92a.dat) will be run from 1990.0 to 2100.0, after initializing with model output from the *Historical run* in 1990.0. Additionally a *Pulse run* will be made, where preindustrial atmospheric CO2 is doubled and allowed to decline for 1000 years. Finally to eliminate effects due to model drift, we will make essentially two *Control runs*: (1) the first will be held to the same atmospheric boundary conditions as the *Equilibrium* run , carrying both DIC and DIC14 during 1765-2000 but only DIC from 2000-2300; (2) the second will be analogous to the Pulse run, made in forward mode for 1000 years, except that atmospheric CO2 will not be doubled on the first time step.

3. **D14Catm**: is atmospheric Delta C-14 [in permil]. For the *Equilibrium run*, D14Catm is held constant at 0‰. For the *Historical run*, we define the equilibrium state as year 1765.0. Then the model must be integrated until the end of year 1999 following the observed record (Enting, 1994). The observed atmospheric C-14 record is given for three latitudinal bands:

   - 90S-20S
   - 20S-20N
   - 20N-90N

   There will be NO future or pulse simulations for C-14.

4. **P**: Is the total atmospheric pressure [atm] from the monthly mean climatology of Esbensen and Kushnir (1981). The latter, given originally on a 4 x 5 degree grid (latitude x longitude) in bars, is converted to atm by multiplying by (1/1.101325). Land and sea ice values in the original data set were filled with average values from adjacent ocean points. These monthly mean arrays were then linearly interpolated to the 1 x 1 degree grid of Levitus (see netCDF file gasx_ocmip2.nc).

Technical notes:

1. The ASCII file splco2.dat provides values of atmospheric pCO2 [in microatm], every half year, for the period from 1765.0 to 1990.5. Thereafter, there are two files used for future scenarios: for *scenario S650*, the ASCII file stab.dat provides half-year values of atmospheric pCO2 [in microatm] for the period from 1990.5 to 2300.5; for *scenario CIS92A*, the ASCII file cis92a.dat provides yearly values of atmospheric pCO2 for the period from 1990.5 to 2100.5. The subroutine read_co2atm.f reads atmospheric CO2 information from all three files.
2. The ASCII files c14nth.dat, c14equ.dat, and c14sth.dat provide mid-year values of atmospheric D14Catm [in permil] for the period from 1764.5 to 2000.0. See the subroutine read_c14atm.f
3. The Fortran subroutine c_interp.f temporally interpolates (linearly) both **pCO2atm** and **D14Catm** at a given timestep. That routine is called by the demonstration program try_c_interp.f, which spatially assigns **D14Catm** to the three latitudinal bands for C-14 (see above). Thus both routines together effect (1) temporal interpolation for both **pCO2atm** and **D14Catm** and (2) spatial ”interpolation” for **D14Catm** as a function of latitude.

3 Initialization and duration of simulations

1. **Equilibrium run**:

- *Initial Conditions*: These don't really matter for the Abiotic Equilibrium run. That is, the final steady-state distributions for DIC and DIC14 do not depend on the initial conditions because exchange with the atmosphere will ultimately determine their final steady-state inventories. However, a judicious choice of initial conditions can reduce the integration time required to reach steady-state. Unfortunately, initial conditions must be quite close indeed to the steady-state solution if there is to be a significant reduction in computing time. The choice of initial conditions is left to the discretion of each of the modeling groups. For initial debugging, groups may prefer to initialize DIC14 to the same 3-D field as used for DIC. That way the only difference between the two tracers is driven by radioactive decay.
- *Duration*: The Equilibrium run for abiotic DIC and DIC14 should be continued until at least both the following criteria are reached:
  - For DIC, we recommend that the globally integrated air-sea flux should be less than 0.01 Pg C/yr
  - For C-14, we recommend that 98% of the ocean volume should have a drift of less than 0.001‰/year (Aumont et al., 1998, p. 105). In terms of C-14 age, this drift is equivalent to a change of 8.27 yr per 1000 years of simulation.

  For most models, these criteria can be reached only after integrations of at least few thousand model years.

2. **Historical run**:

- *Initial Conditions*: The historical abiotic simulation for both DIC and DIC14 will be initialized with final output (on Dec. 31) from the **Equilibrium run** or "steady-state" simulation.
- *Duration*: The historical simulation will begin at the beginning of 1765 (Jan 1, i.e., 1765.0). The anthropogenic simulation will be continued until the year 2000.0.
  - CO2: Until 1990.5, **pCO2atm** will follow the splco2.dat; then from 1990.5 to 2000.0, the atmosphere will follow IPCC scenario S650 in stab.dat.
  - C-14: Atmospheric **D14Catm** will follow values in c14nth.dat, c14equ.dat, and c14sth.dat (for 90S-20S, 20S-20N, and 20N-90N, respectively) until 2000.0. For lack of data, atmospheric C-14 between 1995.5 and 2000.0 is held constant at 107‰.

3. **Future runs (DIC only)**:

- *Future run CIS92A*:
  - *Initial Conditions*: 3-D DIC field, 2-D Cumulative Fluxes and 2-D Cumulative Virtual Flux fields to be initialized with output from the Historical run at 1990.0
  - *Duration*: to be continued using atmospheric CO2 from IPCC Scenario CIS92A until the year 2100.0
- *Future run S650*:
  - *Initial Conditions*: 3-D DIC field, 2-D Cumulative Fluxes and 2-D Cumulative Virtual Flux fields to be initialized with output from the Historical run at 1990.0
  - *Duration*: to be continued using atmospheric CO2 from IPCC Scenario S650 until the year 2300.0

4. **Pulse input response function (DIC only)**:

- *Initial Conditions*: Ocean DIC is to be initialized with final output from the Equilibrium run; Atmospheric CO2 is to be doubled (556 ppm, where 1 ppm = 2.123 Pg C) at t=0, and then be controlled only via air-sea fluxes. Thus the model is then to be run in forward mode (atmospheric CO2 is calculated). The Injection HOWTO describes other forward simulations in more detail.

- *Duration*: The total integration will be for 1000 years (1765.0 - 2765.0).

5. **Control Runs**

- *Historical Control* (DIC and DIC14); and *Future Control* (DIC only)/:
  - *Initial Conditions*: Ocean DIC is to be initialized with final output from the Equilibrium run; Atmospheric CO2 and C-14 are to be held at preindustrial conditions (278 ppm, 0‰) throughout the duration of the simulation.
  - *Duration*: The total integration for DIC will be for 535 years (1765.0 - 2300.0). However the integration including DIC14 is only necessary for the first 235 years (*Historical Control* run 1765.0 - 2000.0).
  - *Historical-Future transistion*: If run separately, the *Future Control* run should be initialized with the 3-D DIC fields AND the 2-D Cumulative Fluxes (i.e., both air-sea gas cumulative flux and virtual cumulative flux) from the last time step of 1999 (end of *Historical Control* run).
- *Pulse Control* (DIC only):
  - *Initial Conditions*: Ocean DIC is to be initialized with final output from the Equilibrium run; Atmospheric CO2 is to be initialized with the quantity of CO2 equivalent to 278 ppm (1 ppm = 2.123 Pg C) at t=0, and then be controlled only via air-sea fluxes. Thus the model is to be run in forward mode (atmospheric CO2 is calculated). The Injection HOWTO describes other forward simulations in more detail.
  - *Duration*: The total integration will be for 1000 years (the equivalent of 1765.0 - 2765.0).

There are no *Future* or *Pulse* simulations for DIC14.

4 Output type and frequency

1. **Equilibrium Output**: steady-state ”natural” simulation

- *Type*: (N.B. Below, the terms 3-D, 2-D, and 0-D refer to spatial dimensions; another dimension must be added for time).

  3-D fields:
  (a) Concentrations for both passive tracers **[DIC]** and **[DIC14]** (both in mol/mˆ3); and
  (b) Alk (in eq/mˆ3), as determined from equation (8);

  2-D fields
  (a) **pCO2surf = Csurf/alphaC** (uatm);
  (b) **dpCO2 = (Csurf - Csat*P/Po)** (uatm);
  (c) Air-sea DIC gas exchange flux **F** (mol/(mˆ2 * s));
  (d) Air-sea DIC14 flux **F14** (mol/(mˆ2 * s));
  (e) Virtual DIC flux **Fv** (mol/(mˆ2 * s));
  (f) Virtual DIC14 flux **Fv14** (mol/(mˆ2 * s));
- *Frequency*: Monthly means and annual mean for the final year of equilibrium simulation.

2. **Historical Output**: for anthropogenic run for CO2 and C-14 (1765.0-2000.0)

   - *Type*: Same as for the Equilibrium run (except Alk, which is the same), plus

     2-D fields

     (a) Surface **DIC** concentration (mol/mˆ3);
     (b) Surface **DC14ocn** (permil), see equation (11);
     (c) Vertical Inventory of DIC (mol/mˆ2), i.e., the vertical integral of its concentration with depth, throughout the water column.
     (d) Vertical Inventory of **DC14ocn** (permil * m), i.e., the vertical integral of its level with depth, throughout the water column (permil*m are strange but useful units).
     (e) End-of-the-year cumulative air-sea gas exchange fluxes **F** and **F14**, accumulated every time step since year=1765.0 (mol/mˆ2).
     (f) End-of-the-year cumulative virtual fluxes **Fv** and **Fv14**, accumulated every time step since year=1765.0 (mol/mˆ2).

     0-D fields

     (a) Globally averaged atmospheric **pCO2atm** (uatm) and **DC14atm** (permil);
     (b) Globally averaged air-sea fluxes **F** and **F14** (mol/(mˆ2 * s)
     (c) Globally averaged virtual fluxes **Fv** and **Fv14** (mol/(mˆ2 * s)
     (d) Globally averaged **DIC** and **DIC14** (mol/mˆ3), i.e., a *Volume integral*
     (e) Globally averaged surface **DIC** and **DIC14** (mol/mˆ3), i.e., a *Surface integral*
     (f) Globally averaged **pCO2surf** (uatm)
     (g) Globally averaged **dpCO2** (uatm)
     (h) Globally averaged surface **DC14ocn** (permil), see equation (11);
     (i) Globally averaged **DC14ocn** (permil), see equation (11);
     (j) Globally averaged cumulative air-sea fluxes (end-of-month) for F and F14 (mol/mˆ2);
     (k) Globally averaged cumulative virtual fluxes (end-of-month) for Fv and Fv14 (mol/mˆ2)

   - *Frequency*:

     0-D fields:

     (a) Monthly means during every year (1765-1999, inclusive)

     2-D fields:

     (a) Monthly means for 1838, 1839, 1900, and every year from 1948-1999 (inclusive).

     3-D fields:

     (a) Monthly means for 1838, 1953, 1954, 1957, 1965, 1972, 1973, 1974, 1977, 1978, 1981, 1982, 1983, 1985, 1986, 1987, 1988, 1989, 1991, 1993, 1995, 1997, 1999.
     (b) Annual means for 1838, 1839, 1900, and every year from 1953-1999 (inclusive).

3. **Future Output**: for future runs CIS92A and S650

   - *Type*: Same as the Historical run, but only for the DIC component, not DIC14
   - *Frequency*:

     0-D fields:

(a) **CIS92A**: Monthly means during every year (1990-2099, inclusive)

(b) **S650**: Monthly means during every year (1990-2299, inclusive)

2-D and [3-D] fields:

* **CIS92A**

(a) Monthly means for 2000 and 2099.

(b) Annual means for 2000, 2010, every 20 years for 2020-2080, and 2099.

* **S650**

(a) Monthly means for 2000, 2100, 2200, and 2299.

(b) Annual means for 2000, 2010, every 20 years for 2020-2280, and 2299.

4. **Pulse Output**: for OCMIP models to be included in next IPCC analysis

- *Type*: Same as the Future run for 0-D and 2-D fields; **No** 3-D fields!
- *Frequency*:

0-D fields

* 0.0-10.0 years: monthly means (12 x 10 = 120 records)
* 10.0-100.0 years: annual means (i.e., 90 records)
* 100.0-1000.0 years: annual means every 10 years (i.e., 90 records)
* Final year (999.0-1000.0): annual mean (i.e., 1 record)

2-D fields

* 0.0-10.0 years: annual means each year (11 records)
* 10.0-100.0 years: annual means every 10 years (90 records)
* 100.0-1000.0 years: annual means every 100 years (90 records)
* Final year (999.0-1000.0): annual mean (1 record)

5. **Control Output**:

- *Type*:
  - *Historical Control* (1765.0 - 2000.0) -¿ Just like Historical run
  - *Future Control* (2000.0 - 2300.0) -¿ Just like Future run–only DIC component, not DIC14.
  - *Pulse Control* (0.0 - 1000.0) -¿ Just like Pulse run–only DIC component.
- *Frequency*:

0-D fields:

(a) *Historical Control:* Monthly means during every year (1765-1999, inclusive)

(b) *Future Control:* Monthly means during every year (2000-2300, inclusive)

(c) *Pulse Control:* just like Pulse run

* 0.0-10.0 years: monthly means (12 x 10 = 120 records)
* 10.0-100.0 years: annual means (i.e., 90 records)
* 100.0-1000.0 years: annual means every 10 years (i.e., 90 records)
* Final year (999.0-1000.0): annual mean (i.e., 1 record)

2-D fields:

(a) *Historical Control:* Annual means for 1838, 1839, 1900, and every year from 1948-1999 (inclusive).

(b) *Future Control:* Annual means for 2000, 2010, every 20 years for 2020-2080, 2099, every 20 years for 2100-2280, and 2299.

(c) *Pulse Control:* just like Pulse run

- 0.0-10.0 years: annual means each year (11 records)
- 10.0-100.0 years: annual means every 10 years (90 records)
- 100.0-1000.0 years: annual means every 100 years (90 records)
- Final year (999.0-1000.0): annual mean (1 record)

3-D fields:

(a) *Historical Control:* Annual means for 1838, 1839, and every year from 1953-1999 (inclusive)

(b) *Future Control:* Annual means for 2000, 2010, every 20 years for 2020-2080, 2099, every 20 years for 2100-2280, and 2299.

(c) *Pulse Control:* None!

5 Output Format

Each modeling group must provide their output in the standard OCMIP-2 format. Model output that does not follow these formatting conventions cannot be included for analysis during OCMIP-2. Model groups must use the standard routines that we have developed specifically for writing output in standard form for OCMIP-2.

If this is the first OCMIP-2 simulation you have made, you will need to recuperate the routine write_nc_MaskAreaBathy.f to write out characteristics of your model grid, mask, and bathymetry using the standard OCMIP-2 format. Use of this routine is detailed in the CFC HOWTO (section 5.1).

Otherwise if you have submitted OCMIP-2 model output previously, you will only need to resubmit the output file produced by write_nc_MaskAreaBathy.f under two conditions:

1. either your model's grid, mask, or bathymetry have changed; or
2. you have been notified by the OCMIP-2 analysis center at IPSL that your output file from this subroutine did not pass the routine integrity tests.

5.1 Output routines

Each modeling group must use the routines listed in the following table to store results in standard OCMIP-2 format for the Equilibrium Output, Historical Output, Future Output, Pulse Output, and Control Output.

Input to these routines consists of your model's output and characteristics. The first routine `write_nc_Abiotic_equil.f` must be called ONLY once, at the end of model spin-up. We define the final output of that run to be the initial conditions (at 1765.0) for the transient runs. The Historical routines (`write_nc_Abiotic_hist_year_3D.f` `write_nc_Abiotic_hist_year_2D.f`) must be called for the appropriate *output years* of the Historical run (see previous section Output type and frequency); conversely the

Historical routine (`write_nc_Abiotic_hist_year_0D.f` is called only once, after builiding a 1-D time series of global mean information. The same strategy holds for the output routines for the other Abiotic transient runs:

- Future runs (`write_nc_Abiotic_futr_year_3D.f`, `write_nc_Abiotic_futr_year_2D.f`, and `write_nc_Abiotic_futr_year_0D.f`);
- Pulse run (`write_nc_Abiotic_puls_year_2D.f`, and `write_nc_Abiotic_puls_year_0D.f`); and
- Control runs
  - *Historical Control*: `write_nc_Abiotic_ctrlH_year_3D.f`, `write_nc_Abiotic_ctrlH_year_2D.f`, and `write_nc_Abiotic_ctrlH_year_0D.f`;
  - *Future Control*: `write_nc_Abiotic_ctrlF_year_3D.f`, `write_nc_Abiotic_ctrlF_year_2D.f`, and `write_nc_Abiotic_ctrlF_year_0D.f`; and
  - *Pulse Control*: `write_nc_Abiotic_ctrlP_year_2D.f`, and `write_nc_Abiotic_ctrlP_year_0D.f`).

The routine `write_nc_Abiotic_TS_year.f` should be called only once for offline models; for online models, it should also be called a second time, in the year 1990.

```
-------------------------------------------------------------------------------
Routine                          Input                        Units    Comments
-------------------------------------------------------------------------------

write_nc_Abiotic_equil.f        1) Conc. of DIC               mol/m^3       (*)
                                2) Conc. of DIC14             mol/m^3
                                3) Alk from eq. (8)            eq/m^3
                                4) Surf. ocean pCO2             uatm
                                5) Delta pCO2 (dpCO2)           uatm
                                6) Gas Exch. Flux of DIC      mol/(m^2*s)
                                7) Gas Exch. Flux of DIC14    mol/(m^2*s)
                                8) Virtual   Flux of DIC      mol/(m^2*s)
                                9) Virtual   Flux of DIC14    mol/(m^2*s)

write_nc_Abiotic_hist_year_3D.f 1) Conc. of DIC               mol/m^3
                                2) Conc. of DIC14             mol/m^3

write_nc_Abiotic_hist_year_2D.f 1) Surf. ocean pCO2            uatm
                                2) Delta pCO2 (dpCO2)          uatm
                                3) Gas Exch.  Flux of DIC     mol/(m^2*s)
                                4) Gas Exch.  Flux of DIC14   mol/(m^2*s)
                                5) Virtual    Flux of DIC     mol/(m^2*s)
                                6) Virtual    Flux of DIC14   mol/(m^2*s)
                                7) Surface DIC                  mol/m^3
                                8) Surface Delta C-14          permil
```

```
                                  9) Vert. Integral of DIC      mol/m^2
                                 10) Vert. Integral of DC-14ocn  permil*m
                                 11) Cum. Gas   Flux of DIC    mol/m^2    1765->
                                 12) Cum. Gas   Flux of DIC14  mol/m^2    1765->
                                 13) Cum. Virt. Flux of DIC    mol/m^2    1765->
                                 14) Cum. Virt. Flux of DIC14  mol/m^2    1765->

write_nc_Abiotic_hist_year_0D.f  1) Glob_mean (Gm) pCO2atm     uatm
                                 2) Gm Delta C-14 atm         permil
                                 3) Gm Gas Ex. Flux of DIC    mol/(m^2*s)
                                 4) Gm Gas Ex. Flux of DIC14  mol/(m^2*s)
                                 5) Gm Virtual Flux of DIC    mol/(m^2*s)
                                 6) Gm Virtual Flux of DIC14  mol/(m^2*s)
                                 7) Gm DIC                    mol/m^3
                                 8) Gm DIC14                  mol/m^3
                                 9) Gm Surface DIC            mol/m^3
                                10) Gm Surface DIC-14         mol/m^3
                                11) Gm pCO2surf                uatm
                                12) Gm Delta pCO2 (dpCO2)      uatm
                                13) Gm Surface Delta C-14      permil
                                14) Gm Delta C-14              permil
                                15) Gm Cum. Gas Flux of DIC    mol/m^2   1765->
                                16) Gm Cum. Gas Flux of DIC14  mol/m^2   1765->
                                17) Gm Cum. Virt. Flux of DIC  mol/m^2   1765->
                                18) Gm Cum. Virt. Flux of DIC14 mol/m^2  1765->

write_nc_Abiotic_futr_year_3D.f  1) Conc. of DIC              mol/m^3

write_nc_Abiotic_futr_year_2D.f  1) Surf. ocean pCO2           uatm
                                 2) Delta pCO2 (dpCO2)         uatm
                                 3) Gas Exch.  Flux of DIC    mol/(m^2*s)
                                 4) Virtual    Flux of DIC    mol/(m^2*s)
                                 5) Surface DIC                mol/m^3
                                 6) Vert. Integral of DIC      mol/m^2
                                 7) Cum. Gas   Flux of DIC     mol/m^2   1765->
                                 8) Cum. Virt. Flux of DIC     mol/m^2   1765->

write_nc_Abiotic_futr_year_0D.f  1) Glob_mean (Gm) pCO2atm     uatm
                                 2) Gm Gas Ex. Flux of DIC    mol/(m^2*s)
                                 3) Gm Virtual Flux of DIC    mol/(m^2*s)
                                 4) Gm DIC                    mol/m^3
                                 5) Gm Surface DIC            mol/m^3
                                 6) Gm pCO2surf                uatm
                                 7) Gm Delta pCO2 (dpCO2)      uatm
```

```
                                 8) Gm Cum. Gas Flux of DIC    mol/m^2   1765->
                                 9) Gm Cum. Virt. Flux of DIC  mol/m^2   1765->

write_nc_Abiotic_puls_year_2D.f  1) Surf. ocean pCO2           uatm
                                 2) Delta pCO2 (dpCO2)         uatm
                                 3) Gas Exch.  Flux of DIC    mol/(m^2*s)
                                 4) Virtual    Flux of DIC    mol/(m^2*s)
                                 5) Surface DIC                mol/m^3
                                 6) Vert. Integral of DIC      mol/m^2
                                 7) Cum. Gas   Flux of DIC     mol/m^2   1765->
                                 8) Cum. Virt. Flux of DIC     mol/m^2   1765->

write_nc_Abiotic_puls_year_0D.f  1) Glob_mean (Gm) pCO2atm     uatm
                                 2) Gm Gas Ex. Flux of DIC    mol/(m^2*s)
                                 3) Gm Virtual Flux of DIC    mol/(m^2*s)
                                 4) Gm DIC                    mol/m^3
                                 5) Gm Surface DIC            mol/m^3
                                 6) Gm pCO2surf                uatm
                                 7) Gm Delta pCO2 (dpCO2)      uatm
                                 8) Gm Cum. Gas Flux of DIC    mol/m^2   1765->
                                 9) Gm Cum. Virt. Flux of DIC  mol/m^2   1765->

write_nc_Abiotic_TS_year.f       1) Potential temperature     degrees C   (*)
                                 2) Salinity                    psu

write_nc_Abiotic_ctrlE_year_3D.f -> Same args as  "write_nc_Abiotic_hist_year_3D.f"
write_nc_Abiotic_ctrlE_year_2D.f -> Same args as  "write_nc_Abiotic_hist_year_2D.f"
write_nc_Abiotic_ctrlE_year_0D.f -> Same args as  "write_nc_Abiotic_hist_year_0D.f"

write_nc_Abiotic_ctrlL_year_3D.f -> Same args as  "write_nc_Abiotic_futr_year_3D.f"
write_nc_Abiotic_ctrlL_year_2D.f -> Same args as  "write_nc_Abiotic_futr_year_2D.f"
write_nc_Abiotic_ctrlL_year_0D.f -> Same args as  "write_nc_Abiotic_futr_year_0D.f"

write_nc_Abiotic_ctrlP_year_2D.f -> Same args as  "write_nc_Abiotic_puls_year_2D.f"
write_nc_Abiotic_ctrlP_year_0D.f -> Same args as  "write_nc_Abiotic_puls_year_0D.f"

--------------------------------------------------------------------------------
(*) For the equilibrium run: for online models, all 2- and 3-D fields
    should be averaged for each month over the last year of the
    simulation.
```

5.2 Downloading the output routines

The output routines can be transferred to your machine by clicking on the links below, while holding down the Shift key.

- write_nc_MaskAreaBathy.f (This routine is the same as linked to the CFC HOWTO; thus, there is no need to recuperate it if you have already contributed OCMIP-2 CFC results).
- write_nc_Abiotic_equil.f
- write_nc_Abiotic_hist_year_3D.f
- write_nc_Abiotic_hist_year_2D.f
- write_nc_Abiotic_hist_year_0D.f
- write_nc_Abiotic_futr_year_3D.f
- write_nc_Abiotic_futr_year_2D.f
- write_nc_Abiotic_futr_year_0D.f
- write_nc_Abiotic_puls_year_2D.f
- write_nc_Abiotic_puls_year_0D.f
- write_nc_Abiotic_TS_year.f
- write_nc_Abiotic_ctrlH_year_3D.f
- write_nc_Abiotic_ctrlH_year_2D.f
- write_nc_Abiotic_ctrlH_year_0D.f
- write_nc_Abiotic_ctrlF_year_3D.f
- write_nc_Abiotic_ctrlF_year_2D.f
- write_nc_Abiotic_ctrlF_year_0D.f
- write_nc_Abiotic_ctrlP_year_2D.f
- write_nc_Abiotic_ctrlP_year_0D.f

You will also need to transfer the subroutine handle_errors.f to properly deal with possible errors while you are writing your netCDF files.

5.3 Compiling the output routines

Here is a an example of how you would compile one of the output routines:

```
f77 -c -O -L/usr/local/lib -lnetcdf -I/usr/local/include \
     write_nc_Abiotic_equil.f
```

Because we have made these routines F77 compatible, you may need a function len_trim.f (from F90), which we also provide and which returns the length of a character string (after neglecting trailing blanks).

5.4 Using the output routines

5.4.1 Equilibrium Output

The Abiotic-run output routines store your model results following the naming and output conventions (netCDF, GDT version 1.2) chosen for OCMIP-2. The output filename is constructed automatically within each routine from three of the arguments: the tracer name, the year, and the *standard model code* `<http://www.ipsl.jussieu.fr/OCMIP/phase2/#modgroups>` used during OCMIP-2 to identify your group.

For example, after compiling and linking the OCMIP-2 output routines, we add the following code to the IPSL routines to store output in standard OCMIP-2 form

```
        call write_nc_Abiotic_equil("IPSL","NGL46_SI",
     &  imt, jmt, kmt,
     &  60*60*24*365, 1200,
     &  MDIC, MDIC14, Alk,
     &  MpCO2surf, MdpCO2,
     &  MF, MF14,
     &  MFv, MFv14)
```

By line, the arguments include

1. the OCMIP-2 *model code* AND your own *model version* indicator (in GDT 1.2 terminology, these 2 variables refer to the *institution* and *production*, respectively);
2. dimensions;
3. the number of seconds per year (in your model), and the number of timesteps per year;
4. the 12 monthly means for the 3-D tracer arrays for DIC (mol/mˆ3) and DIC14 (mol/mˆ3) and for the Alk computed from eq. (8) (eq/mˆ3).
5. the 12 monthly means for the 2-D arrays for surface ocean pCO2 (pCO2surf, in uatm) and the sea-air pCO2 difference (dpCO2, in uatm).
6. the 12 monthly means for the 2-D air-sea flux for F and F14 (both in mol/(mˆ2*s)); and

7. the 12 monthly means for the 2-D arrays for the surface ”virtual” fluxes Fv and Fv14 (both in mol/(mˆ2*s));

When do I call the above Equilibrium output routine? It should be called only once, at the end of the simulation after building monthly arrays (12 members) for each of the 2-D and 3-D spatial fields given as arguments.

5.4.2 Historical Output

We need to use a slightly different routines for saving transient results from the Historical run. Unlike the equilibrium run, we separately store 3-D, 2-D, and 0-D data. The reason is that we store the higher dimensional data less often, to save space.

For your 3-D model output for the Abiotic Historical run, use

```
      call write_nc_Abiotic_hist_year_3D("IPSL","NL46_SI",
     &  imt, jmt, kmt, nt,
     &  1985, 60*60*24*365, 1200,
     &  MDIC, MDIC14)
```

Note that we have also added the dimension *nt* on line 2. You must use nt to signal if you are passing annual means (nt=1) or monthly means (nt=12). The argument *nt* is used in the same fashion for routines that follow. The 3-D input arrays MDIC and MDIC14 are as described for the Equilibrium run.

When do I call the above 3-D Historical output routine? It should be called for each of the following times:

- with *nt=12* (monthly means, 12 records per year) for each of the years 1838, 1953, 1954, 1957, 1965, 1972, 1973, 1974, 1977, 1978, 1981, 1982, 1983, 1985, 1986, 1987, 1988, 1989, 1991, 1993, 1995, 1997, 1999.
- with *nt=1* (annual means, 1 record per year) for each of the years 1838, 1839, 1900, and every year for 1953-1999 (inclusive).

For your 2-D Historical output, use

```
      call write_nc_Abiotic_hist_year_2D("IPSL","NL46_SI",
     &  imt, jmt, nt,
     &  1985, 60*60*24*365, 1200,
     &  MpCO2surf, MdpCO2,
     &  MF, MF14,
     &  MFv, MFv14,
     &  Ms_DIC, Ms_DC14ocn,
     &  Mi_DIC, Mi_DC14ocn,
     &  CF_F, CF_F14,
     &  CF_Fv, CF_Fv14)
```

For 2-D output, we no longer need the dimension *kmt*, formerly in line 2. Conversely, we need supplemental 2-D model output for the Historical run which was not included in the equilibrium output. This supplemental 2-D output is needed to due to the Historical run’s transient nature and our asynchronous saving of its 2-D and 3-D output. Supplemental 2-D Historical output includes

- line 7: the mean surface DIC (mol/mˆ3) and DC14ocn (permil), see eq. (11);
- line 8: the mean vertical inventory of DIC (mol/mˆ2) and DC14ocn (permil * m);
- line 9: the end-of-year 2-D cumulative flux for F (mol/mˆ2) and F14 (mol/mˆ2);
- line 10: the end-of-year 2-D cumulative flux for Fv and Fv14 (both in mol/mˆ2)

Cumulative fluxes (lines 9 and 10 above) must be initialized to zero and integrated with respect to time (i.e., each time step) from year=1765.0. Note that these values should be output only at the end of each year, regardless of whether nt=12 or nt=1.

When do I call the above 2-D Historical output routine? It should be called with *nt=12* for each of the following years: 1838, 1839, 1900, and every year for 1948-1999 (inclusive).

For 0-D (1-D with time) Historical output, use

```
      call write_nc_Abiotic_hist_year_0D("IPSL","NL46_SI",
   &  nrec, times,
   &  G_pCO2atm, G_DC14atm
   &  G_F,  G_F14,
   &  G_Fv, G_Fv14,
   &  Gv_DIC, Gv_DIC14,
   &  G_DIC, G_DIC14,
   &  G_pCO2surf, G_dpCO2,
   &  G_DC14ocn, Gv_DC14ocn,
   &  G_CF_F, G_CF_F14,
   &  G_CF_Fv, G_CF_Fv14)
```

By line, the arguments include

1. the OCMIP-2 *model code* AND your own *model version* indicator (in GDT 1.2 terminology, these 2 variables refer to the *institution* and *production*, respectively);
2. the number of records saved and the array of the times (in decimal years) at which they were saved–for monthly means, *times* should be set to the corresponding time at mid-month (see below for exact values).
3. the corresponding arrays of the history of the global mean atmospheric CO2 (model input, in uatm) and global mean atmospheric C-14 (in permil, calculated from model input as an area weighted mean of your ocean grid boxes that you have identified as being in the 90S-20S, 20S-20N, and 20N-90N latitudinal bands);
4. the corresponding array of the history of the global mean air-sea flux F (mol/mˆ2*s) and F14 (mol/mˆ2*s);
5. the history of the global mean virtual fluxes Fv (mol/mˆ2*s) and Fv14 (mol/mˆ2*s);
6. the history of the global mean concentrations of DIC (mol/mˆ3) and DIC14 (mol/mˆ3);
7. the history of the global mean surface concentrations of DIC (mol/mˆ3) and DIC14 (mol/mˆ3);

8. the history of global mean surface ocean pCO2 (pCO2surf, in uatm), and the global mean sea-air pCO2 difference (dpCO2, in uatm);
9. the history of global mean surface ocean DC14ocn (in permil), and the whole-ocean global mean DC14ocn (in permil);
10. the history of the global mean cumulative fluxes F and F14 (in mol/mˆ2, integrated since 1765.0) at the end of each month, with each month indicated by its mid-month time given in line 2; and
11. the history of the global mean cumulative fluxes Fv and Fv14 (in mol/mˆ2, integrated since 1765.0) at the end of each month, with each month indicated by its mid-month time given in line 2.

When do I call the above 0-D Historical output routine? It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency is regular: every month throughout the entire run (i.e., all years 1765-1999, inclusive). Thus modelers must use *nrec* = 2820, and fill the 1-D temporal array *times* with the appropriate values (i.e., 1765.04167, 1765.125, 1765.2083, 1765.29167, 1765.375, ... 1999.875, 1999.9583).

5.4.3 Future Output

Another similar set of 3 routines is needed for storing results from the Future runs CIS92A and S650. Here we have removed arguments related to C-14 and added an argument for indicating which future run (CIS92A or S650) is appropriate (see line 2). Note that this argument must be given in UPPER case. These 3 routines are given below (details of other arguments are the same as given above):

```
      call write_nc_Abiotic_futr_year_3D("IPSL","NL46_SI",
     &  "S650",
     &  imt, jmt, kmt, nt,
     &  2000, 60*60*24*365, 1200,
     &  MDIC)
```

```
      call write_nc_Abiotic_futr_year_2D("IPSL","NL46_SI",
     &  "S650",
     &  imt, jmt, nt,
     &  2000, 60*60*24*365, 1200,
     &  MpCO2surf, MdpCO2,
     &  MF,
     &  MFv,
     &  Ms_DIC,
     &  Mi_DIC,
     &  CF_F,
     &  CF_Fv)
```

When do I call the above 2-D and 3-D Future output routines? They should both be called for each of the following times:

- For **CIS92A**
  - with *nt=12* for both of the following years: 2000 and 2099
  - with *nt=1* for each of the following years: 2000, 2010, 2020, 2040, 2060, 2080, and 2099.
- For **S650**
  - with *nt=12* for each of the following years: 2000, 2100, 2200, 2299
  - with *nt=1* for each of the following years: 2000, 2010, 2020, 2040, 2060, 2080, 2100, 2120, 2140, 2160, 2180, 2200, 2220, 2240, 2260, 2280, 2299.

```
      call write_nc_Abiotic_futr_year_0D("IPSL","NL46_SI",
   &  "S650",
   &  nrec, times,
   &  G_pCO2atm,
   &  G_F,
   &  G_Fv,
   &  Gv_DIC,
   &  G_DIC,
   &  G_pCO2surf, G_dpCO2,
   &  G_CF_F,
   &  G_CF_Fv)
```

When do I call the above 0-D Future output routine? It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency is regular: every month throughout the entire run (i.e., all years 1990-2299, inclusive). Thus modelers must use *nrec* = 3720, and they must fill the 1-D temporal array *times*) with appropriate corresponding values (i.e., 1990.04167, 1990.125, 1990.2083, 1990.29167, 1990.375, ..., 2299.875, 2299.9583).

5.4.4 Pulse Output

Another set of 2 routines is needed for storing the 2-D and 0-D results from the Pulse run; for that run there is **NO** 3-D output. Differences relative to the Pulse output routines are

- the scenario specification has been removed (only 1 pulse run is to be made); and
- the *nt* term has been removed from the 2-D routine since 2-D output is to be saved only for annual means, not monthly means.

```
      call write_nc_Abiotic_puls_year_2D("IPSL","NL46_SI",
   &  imt, jmt,
   &  1, 60*60*24*365, 1200,
   &  MpCO2surf, MdpCO2,
   &  MF,
   &  MFv,
```

```
&  Ms_DIC,
&  Mi_DIC,
&  CF_F,
&  CF_Fv)
```

When do I call the above 2-D Pulse output routine? It should be called using annual means, for each of the following years: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 999. These details are given in a structured way in the previous section (Output type and Frequency).

```
   call write_nc_Abiotic_puls_year_0D("IPSL","NL46_SI",
&  nrec, times,
&  G_pCO2atm,
&  G_F,
&  G_Fv,
&  Gv_DIC,
&  G_DIC,
&  G_pCO2surf, G_dpCO2,
&  G_CF_F,
&  G_CF_Fv)
```

When do I call the above 0-D Pulse output routine? It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency (spacing between individual members of the array *times*) is NOT regularly spaced in time. For the 0-D *Pulse* run, output as specified by *times* must be given for

- every month from years 0.0 to 10.0 (i.e., 12 x 10 = 120 records), with corresponding monthly means provided at mid-month (i.e., for *times* = 0.04167, 0.1250, 0.2083, 0.29167, 0.3750, ... 9.875, 9.9583);
- every year from years 10.0 to 100.0 (i.e., 90 records), with corresponding annual means provided at mid-year (i.e., for *times* = 10.5, 11.5, 12.5, ... 99.5);
- every 10 years from years 100.0-991.0 (i.e., 90 records), with corresponding annual means provided at mid-year (i.e., for *times* = 100.5, 110.5, 120.5, 130.5, ... 990.5); and
- the final year (i.e., 1 record), with its corresponding annual means provided at mid-year (i.e., for *times* = 999.5).

Thus with this irregular spacing, models must use *nrec* = 301 (i.e., 120 + 90 + 90 + 1).

5.4.5 Control Output

Finally we need to store output for the control run. The control run is necessary because 3-D tracer fields and associated fluxes in our **Equilibrium** run never reach perfect equilibrium. The associated drift affects results for the transient runs. Correcting for drift may be important when comparing model differences, particularly integrated quantities, over long time periods. The control run is needed to drift-correct models, before comparison. It is desirable that all groups make all three control runs, but this may not be possible for some, due to CPU requirements. Below are a few guidelines to help you decide when the Control runs are necessary and what shortcuts can be taken:

1. If you will make the *Pulse* run, you MUST also make the equivalent *Pulse Control* run.
2. If you have NOT respected the Equilibrium drift criteria you MUST make the *Historical Control* and *Future Control* runs.
3. If you have respected the recommended Equilibrium drift criteria, you may skip making the *Historical Control* and *Future Control* runs. However, we do HIGHLY RECOMMEND that you make these simulations, if you can afford them, i.e., if they do not represent a large proportion of your annual CPU budget. Having this output will simplify analysis and eliminate guess work.
4. If you have respected the Equilibrium drift criteria and choose not to submit *Historical Control* and *Future Control* output, you MUST still provide an indication of the drift of your model. In other words, you must use the three *ctrlH* routines (see below) to provide your output for another year. For instance, you could provide output from the 0-D, 2-D, and 3-D *ctrlH* routines for the year 1775. We would then compute your model drift and treat it as constant.

Those who will be making all the CO2 Injection simulations can economize a little. That is, with those runs, one automatically makes make both the *Late Control* and the *Pulse Control* runs, simultaneoulsy. The first of the ten Injection tracers is the control tracer. Unfortunately, the *Injection* runs do NOT offer an opportunity to skip the *Historical Control* run. For more details, see the final version of the Injection HOWTO.

Arguments of the **Control** output routines are the same as those used in the *Historical*, *Future*, and *Pulse* output routines, as described below.

1. *Historical* **Control** output (for 1765-1999, inclusive): We save both the DIC and DIC14 related components. We use 3 routines, with the same arguments as the 0-D, 2-D, and 3-D *Historical output routines*.
   - **When do I call the above 3-D** *Historical* **Control output routine (write_nc_Abiotic_ctrlH_3D.f)?** It should be called with *Annual means* (*nt=1*) for 1765, 1838, 1839, 1900, and every year from 1953-1999 (inclusive).
   - **When do I call the above 2-D** *Historical* **Control output routine (write_nc_Abiotic_ctrlH_2D.f)?** It should be called with *Annual means* (*nt=1*) for 1765, 1838, 1839, 1900, and every year from 1948-1999 (inclusive).
   - **When do I call the above 0-D** *Historical* **Control output routine (write_nc_Abiotic_ctrlH_0D.f)?** It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency is regular: every month throughout the entire run (i.e., all years 1765-1999, inclusive). Thus modelers must use *nrec* = 2820, and fill the the 1-D temporal array *times* with the appropriate values (i.e., 1765.04167, 1765.125, 1765.2083, 1765.29167, 1765.375, ... 1999.875, 1999.9583). The *Historical Control* Run uses the same *nrec* and *times* array as does the *Historical* run.
2. *Future* **Control** output (for 2000-2764, inclusive): We save only the DIC-related component. We use 3 routines with the same arguments as the 0-D, 2-D, and 3-D *Future output routines*.
   - **When do I call the above 3-D** *Future* **Control output routine (write_nc_Abiotic_ctrlF_3D.f)?** It should be called with *Annual means* (*nt=1*) for years 2000, 2010, 2020, 2040, 2060, 2080, 2099, 2100, 2120, 2140, 2160, 2180, 2200, 2220, 2240, 2260, 2280, 2299.

- **When do I call the above 2-D *Future* Control output routine (write_nc_Abiotic_ctrlF_2D.f)?** It should be called with *Annual means* (*nt=1*) for years 2000, 2010, 2020, 2040, 2060, 2065, 2080, 2099, 2100, 2120, 2140, 2160, 2165, 2180, 2200, 2220, 2240, 2260, 2265, 2280, 2299.
- **When do I call the above 0-D *Future* Control output routine (write_nc_Abiotic_ctrlF_0D.f)?** It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency is regular: every month throughout the entire run (i.e., all years 2000-2300, inclusive). Thus modelers must use *nrec* = 3600, and they must fill the 1-D temporal array *times*) with appropriate corresponding mid-month values (i.e., 2000.04167, 2000.125, 2000.2083, 2000.29167, 2000.375, ..., 2299.875, 2299.9583). Note that *nrec* and *times* are NOT identical to those used when calling the analogous 0-D routine to save Future output (i.e., *nrec* is smaller; *times* starts 10 years later).

3. *Pulse* **Control** output (for 2000-2764, inclusive): We save only the DIC-related component. We use 2 routines with the same arguments as the 0-D and 2-D *Pulse output routines*.

- **When do I call the above 2-D *Pulse* Control output routine (write_nc_Abiotic_ctrlP_2D.f)?** It should be called with *Annual means* (*nt=1*) for years 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 999.
- **When do I call the above 0-D *Pulse* Control output routine (write_nc_Abiotic_ctrlP_0D.f)?** It should be called only once, after constructing 1-D (in time) arrays from all of your model output. The time storage frequency is NOT regularly spaced in time. For the 0-D *Pulse Control* run, output as specified by *times* must be given for
  - every month from years 0.0 to 10.0 (i.e., 12 x 10 = 120 records), with corresponding monthly means provided at mid-month (i.e., for *times* = 0.04167, 0.1250, 0.2083, 0.29167, 0.3750, ... 9.875, 9.9583);
  - every year from years 10.0 to 100.0 (i.e., 90 records), with corresponding annual means provided at mid-year (i.e., for *times* = 10.5, 11.5, 12.5, ... 99.5);
  - every 10 years from years 100.0-991.0 (i.e., 90 records), with corresponding annual means provided at mid-year (i.e., for *times* = 100.5, 110.5, 120.5, 130.5, ... 990.5); and
  - the final year (i.e., 1 record), with its corresponding annual means provided at mid-year (i.e., for *times* = 999.5).

  Thus with this irregular spacing, models must use *nrec* = 301 (i.e., 120 + 90 + 90 + 1).

5.4.6 Names of Output files

All arguments of the Abiotic routines are input; none are output. With the arguments as listed in the nine routines above, The corresponding output netCDF files are

- `"IPSL_Abiotic_equil.nc"`;
- `"IPSL_Abiotic_hist_1985_3D.nc"`, `"IPSL_Abiotic_hist_1985_2D.nc"`, `"IPSL_Abiotic_hist_global_0D.nc"`;
- `"IPSL_Abiotic_S650_2000_3D.nc"`, `"IPSL_Abiotic_S650_2000_2D.nc"`, `"IPSL_Abiotic_S650_global_0D.nc"`;
- `"IPSL_Abiotic_puls_0001_2D.nc"`, `"IPSL_Abiotic_puls_global_0D.nc"`.

- "IPSL_Abiotic_ctrlH_1985_3D.nc", "IPSL_Abiotic_ctrlH_1985_2D.nc", "IPSL_Abiotic_ctrlH_global_0D.nc";
- "IPSL_Abiotic_ctrlF_2000_3D.nc", "IPSL_Abiotic_ctrlF_2000_2D.nc", "IPSL_Abiotic_ctrlF_global_0D.nc";
- "IPSL_Abiotic_ctrlP_0001_2D.nc", "IPSL_Abiotic_ctrlP_global_0D.nc".

These files along with all others produced by the Abiotic routines should be trasferred to IPSL (see section Transfer of output). Filenames should NOT be changed. Subsequently, at IPSL, files will be (1) tested for consistency, (2) included in the OCMIP-2 data base, and (3) processed for base analysis.

5.5 Need more details?

See <http://www.ipsl.jussieu.fr/OCMIP/tech>. for additional information about the format netCDF and other conventions (COARDS, GDT) chosen for storing OCMIP-2 model output.

If you have other questions, please contact orr@cea.fr or Patrick.Brockmann@ipsl.jussieu.fr.

6 Transfer of output

We provide details only for transferring Equilibrium Output. Output from the other Abiotic simulations (Historical Output, Future Output, Pulse Output, and Control Output) should be transferred in an analogous fashion.

The Equilibrium Output files `IPSL_Abiotic_equil.nc` and `IPSL_Abiotic_TS_year.nc` should first be compressed.

```
gzip IPSL_Abiotic_equil.nc IPSL_Abiotic_TS_year.nc
```

If gzip is not available on your machine, the alternative is to use `compress`. After compression, you should ftp your files to LSCE for processing and analysis. Your model output could be quite large depending upon model resolution. Fear not though, because we have the disk space to accommodate output from all OCMIP models. Contact us if the ftp transfer rate is inadequate. In that case, you'll need to write your output to tape (DDS, DDS2, Exabyte, or DLT) and mail it to

```
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Bat. 709, L'Orme des Merisiers
F-91191 Gif-sur-Yvette CEDEX
FRANCE
```

Here are the commands to transfer your output by ftp:

```
ftp: ftp.cea.fr
user: anonymous
passwd: your full email
cd incoming2/y2k01/OCMIP
mkdir <your group name>
mkdir <your group name>/Abiotic
cd <your group name>/Abiotic
binary
prompt
mput <your group name>*nc*
```

Then e-mail us (orr@cea.fr and Patrick.Brockmann@ipsl.jussieu.fr) that your transfer is complete.

To avoid confusion, you can create further subdirectories (Abiotic/equil, Abiotic/hist, Abiotic/futr, Abiotic/puls, and Abiotic/ctrl) to distinguish the five different types of runs. The ftp archive is erased automatically every 8 days, so be sure to contact us as soon as you have completed transfer, and save your output files at least until we have notified you that they have been transferred to the OCMIP-2 model output archive.

7 References

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8 Contacts

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9 Same document, another format?

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