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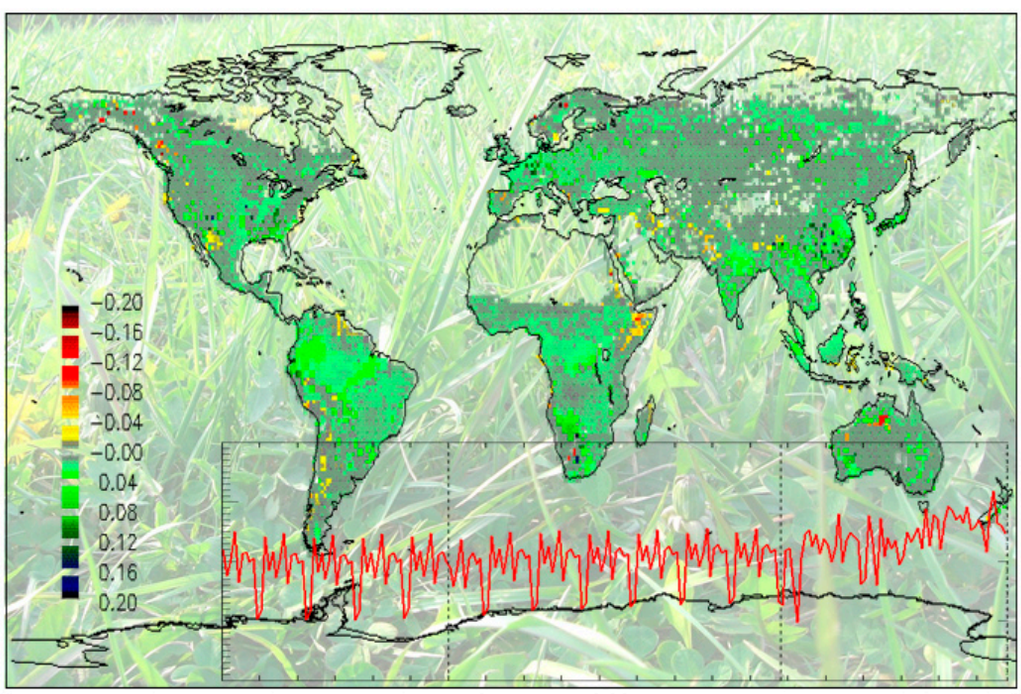

THE TERRESTRIAL ECOSYSTEM MODEL GBIOME-BGCv1

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CONTENT

GENERAL DESCRIPTION

NOTE TO GBIOME-BGCv1

GBIOME-BGCv1 is the global version of the point ecosystem model BIOME-BGC. BIOME-BGC is a numerical model that simulates the storage and fluxes of water, carbon, and nitrogen within the vegetation, litter, and soil components of a terrestrial ecosystem. The Numerical Terradynamic Simulation Group (NTSG) at the University of Montana, USA maintains benchmark code versions of BIOME-BGC for public release, and updates these benchmark versions periodically. See webpage of the BIOME-BGC model at http://www.ntsg.umt.edu/models/bgc/.

The code and executables described in this report are based on the point version 4.1.1 of the model BIOME-BGC with some modifications described below.

IMPORTANT NOTE: COPYING

The GBIOME-BGCv1 code is copyrighted. You may NOT make copies of any part of the code for distribution to any other person or group.

If you use GBIOME-BGC in your research:

- We request that you include the following acknowledgement in the relevant manuscripts:" GBIOME-BGCv1 is provided by the Max-Planck Institute for Biogeochemistry, Germany. MPI assumes no responsibility for the proper use of GBIOME-BGC by others."
- Please reference GBIOME-BGCv1: Trusilova, K. and Churkina, G., 2008. THE TERRESTRIAL ECOSYSTEM MODEL GBIOME-BGCv1. Technical Report № 14, Max-Planck-Institut für Biogeochemie, Jena, Germany.
- If you have made any significant modifications to the code, please mention them in your manuscript.

This User's Guide is the only documentation provided with this release of GBIOME-BGCv1. Various model components have been described with varying degrees of detail in the literature, and there is a list of relevant publications in this guide. The code itself contains extensive internal documentation, and users with specific questions about the algorithms used to estimate particular processes should read the comments in the appropriate source code files. The file *bgc.c* contains references to all the core science routines, and is an excellent starting point for this kind of inquiry. The file *bgc_struct.h* defines the data structures that are used to pass information between the process modules, and includes a short text description as well as units for each internal variable.

We are interested to get reports from users about new applications of GBIOME-BGC, including any problems that come up. If you have questions about the code, appropriate model applications, possible programming errors, etc., please read this entire guide first, and then feel free to contact:

Dr. Kristina Trusilova (ktrusil@bgc-jena.mpg.de) GBIOME-BGCv1

CHANGES MADE TO BIOME-BGC

Program GBIOME-BGCv1 has the core of the BIOME-BGCv4.1.1 point-based model that was expanded over the global domain. The following changes have been made:

1) daily_allocation.c
daily allocation of carbon and nitrogen, as well as the final reconciliation
of N immobilization by microbes (see decomp.c)

Modified:
by James Trembath and Galina Churkina 20/07/2001: Changes were made in the logic of the retranslocation of nitrogen, from V4.1.1 back to those of V4.1. The underlying reasons for this change are the polarised logics between the two versions. V4.1 considered a recipient based flow, the deployment of retranslocated leaf nitrogen in the spring is based on the requirements of the plant and access by the plant to this pool was ungoverned. That is to say that the plant could access all the nitrogen in one day if it so required. This often resulted in an initial modelled NEE spike in the early growing season, something that is seen in the EUROFLUX data. V4.1.1 can be considered as a donor based flow, in that the deployment of the retranslocated leaf nitrogen in the spring is a fractionation of the initial size of the translocated pool at the end of the previous growing season, not a translation in any way of plant demand. In test simulations, this induced the long-term build up of nitrogen, inaccessible to the plant, conceptually turning the retranslocated pool into a permanent nitrogen sink. The translation of this logic to the overall modelled NEE flux was to induce a mid-season crash in productivity as a result of nitrogen deficiency, something unseen in the EUROFLUX data.

2) *All input and output files 20/03/2008*
The structure of all input and output files has changed:
- meteorological data are stored in binary files
- surface data are stored in binary files
- model initializations file is restructured
- a possibility to input atmospheric nitrogen deposition from an external file instead of ramping nitrogen deposition added

CODE HISTORY

The BIOME-BGC ecosystem process model has a long heritage, and many people have contributed extensively to its development over many years. The model has undergone significant modification since its first release became available for the scientific community.

The following is a short synopsis of some of the most prominent code versions proceeding the current version 1-benchmark code for public release.

- GBIOME-BGC version 1, Kristina Trusilova, 2008 (C/C++)
- Biome-BGC Version 4.2 Final Release, Peter E. Thornton, 2003 (C/C++)
- Biome-BGC, Version 4.1.2, Peter E. Thornton, 2002 (C/C++)
- BIOME-BGC version 4.1.1, Peter E. Thornton, 2000 (C/C++)
- BIOME-BGC version 4.1, Peter E. Thornton, 2000 (C/C++)
- BIOME-BGC version 2.0 (CRB-BGC), Peter E. Thornton, 1995 (C/C++)
- BIOME-BGC version 1.37, E. Raymond Hunt, Jr., 1993 (Pascal)
- Forest-BGC, Joseph C. Coughlan, 1986 (Pascal)
- DAYTRANS-PSN, Steven W. Running, 1981
- DAYTRANS, Steven W. Running, 1975

Others who have contributed to the code in various ways and at various stages include: Galina Churkina, Tom Gower, Kathy Hibbard, Bob Keane, John Kimball, Lars Pierce, Joseph White, and Michael White.

MODEL ANALYSIS AND APPLICATIONS

Different versions of the BIOME-BGC model were used in multiple research studies ranging from the model development and validation against local-scale observations to applications on global scale for assessing global carbon budgets.

Several key scientific publications that describe development or applications of the BIOME-BGC model are listed in this section.

MODEL DEVELOPMENT

- (Running and Coughlan, 1988) – described the ecosystem process model FOREST-BGC and its application for simulations of a water, carbon, and nitrogen cycles for a hypothetical forest stand in seven contrasting environments across North America. Authors suggested and discussed ways of the model parameterisation and application at regional scales.
- (Running and Gower, 1991) – described FOREST-BGC and presented results of test simulations for several coniferous forests. A special attention was paid to the parameterisation of the nitrogen limitation effects on vegetation.
- (Running and Hunt, 1993) – described simulations of deciduous forest and grassland ecosystems with FOREST-BGC by changing only model parameters. They introduced the new model, BIOME-BGC, and showed its applications to scale biosphere processes globally from the remote sensing of absorbed photosynthetically active radiation by satellites.
- (Running, 1994) – has validated simulations of several process in the FOREST-BGC ecosystem model against measurements from the Oregon Transect Ecological Research project (OTTER). The author evaluated problems in parameterising the model from disparate data sets and made suggestions for future ecosystem modelling studies.
- (Thornton, 1998) – described 1D-BGC - the one-dimensional model of biogeochemical processes in the terrestrial biosphere. Presented the theoretical background in biophysics, physiology, and system-level ecology from which an outline of the processes controlling matter and energy dynamics in a generalized terrestrial ecosystem can be drawn. Thornton outlined a logic by which the most critical processes and states can be predicted and presented the operational detail of an implementation of this logic.

Recent MODEL APPLICATIONS at MPI-BGC

- (Churkina et al., 2003) – authors investigated the ability of the ecosystem model BIOME-BGC to estimate the daily and annual carbon dynamics as well as daily water fluxes of four European coniferous forests and shifts in these dynamics in response to changing environmental conditions. Uncertainties in the model results that arise from incomplete knowledge of site management history were estimated.
- (Vetter et al., 2005) – used the BIOME-BGC model to quantify the effects of increasing temperature, increasing atmospheric CO_2 concentration and nitrogen fertilization during 1982–2001. The study focused on coniferous forests in Europe because for them detailed forest inventories were available.
- (Jung et al., 2007a) – evaluated BIOME-BGC and two other terrestrial ecosystem models with respect to their ability to simulate large-scale climate related trends in Gross Primary Production (GPP) across European forests. It was found that the modelled with the BIOME-BGC model GPP flux is very sensitive to the meteorological fields used to drive the model.
- (Jung et al., 2007b) – analysed uncertainties in modelling Gross Primary Production (GPP) over Europe that originate from different terrestrial biosphere models, including BIOME-BGC, and their drivers. Major discrepancies in modelled GPP appear to be related to the feedback through the carbon-nitrogen interactions included in BIOME-BGC and water stress effects, besides the modelling of croplands. Authors suggest clarifying the role of nitrogen dynamics in future studies and revisiting currently applied concepts of carbon-water cycle interactions regarding the representation of canopy conductance and soil processes.
- (Churkina et al., 2007) – used the BIOME-BGC model for quantifying contributions of rising atmospheric nitrogen deposition, due to increases in fertilizer production and fossil fuel burning, on the terrestrial biosphere carbon uptake over the whole globe.
- (Vetter et al., 2008) – used the BIOME-BGC model together with other process based and diagnostic terrestrial ecosystem models to investigate spatial patterns and causes of the European carbon flux anomaly in 2003. All models agreed that plant photosynthesis was reduced in response to 2003 summer heat wave. In contrast to other models, BIOME-BGC simulated increase in ecosystem respiration in response to hot and dry summer weather in 2003.
- (Churkina et al., in review) – coupled BIOME-BGC to the climate system model CLIMBER. BIOME-BGC was coupled with CLIMBER-2 (an earth system model of intermediate complexity) to study effect of increased deposition of anthropogenic nitrogen and climate on land carbon uptake and atmospheric CO_2 concentrations.
- (Trusilova and Churkina, 2008) – used BIOME-BGC to simulate responses of carbon cycle in terrestrial ecosystems of Europe to urbanization-driven environmental disturbances: changes of land use, climate and atmospheric pollution.

TECHNICAL DESCRIPTION

WHERE TO FIND THE SOURCE CODE?

Model source files and input data can be found on the Institute's Network:
/Net/Groups/BSY/BSY_2/BIOME-BGC_PROG/
or from the CD attached to this technical report.

Alternatively you may contact Kristina Trusilova (ktrusil@bgc-jena.mpg.de) and request the latest copy of the GBIOME-BGC.

The mode source files and input data are arranged in the following subdirectories:

GRID-BGC/ - source files for GBIOME-BGCv1 and *makefile*s.

DATA/ - input data: meteorological and land surface data

co2/ - atmospheric CO_2 concentration data
- *co2_CarboeuropeIP_allyears_1800-2007.flt* – global average CO_2 [ppm]

epc/ - EcoPhysiological Constants data for eight plant functional types:
- *c3grass.epc* – C3 grass
- *c4grass.epc* – C4 grass
- *shrub.epc* – Shurb/Bush
- *dbf.epc* – Deciduous Broadleaf Forest
- *dnf.epc* – Deciduous Needleleaf Forest
- *ebf.epc* – Evergreen Broadleaf Forest
- *enf.epc* – Evergreen Needleleaf Forest

meteo_1948-precent_NCEP_1year/ - daily meteorological data
- *dswrf.<yr>_360x180.int* – downward shortwave radiation fraction [Watt m-2]
- *prate.<yr>_360x180.int* – precipitation rate [cm * 1000]
- *rhum.<yr>_360x180.int* – air relative humidity [%]
- *tmax.<yr>_360x180.int* – maximum daily temperature [°C * 100]
- *tmin.<yr>_360x180.int* – minimum daily temperature [°C * 100]

ndeposition/ - atmospheric nitrogen wet+dry deposition data
- *Ndep_Holland_2kgha-1yr-1_360x180.flt* – background nitrogen deposition to ecosystems in pre-industrial conditions [kg N m-2]
- *Ndep_Galloway_1860-2050_360x180.flt* – anthropogenic nitrogen deposition to ecosystems in industrial conditions [kg N m-2]

surface/ - land surface parameters
- *albedo_360x180.flt* – shortwave albedo data [fraction]
- *elevation_360x180.int* – digital elevation data [m]
- *landcover_360x180.int* – land cover data [type]
- *soil_depth_360x180.flt* – effective soil depth [m]
- *sand_360x180.int* – percentage of sand in soil [%]
- *clay_360x180.int* – percentage of clay in soil [%]
- *lat_360x180.flt* – percentage of clay in soil [degree]

INIFILE/ - model setup initialisation files (ASCII):
- *spinup.ini* - for spinup simulation
- *normal_1800-1860.ini* – for normal simulation
- *normal_1860-1948.ini* – for normal simulation
- *normal_1948-2007.ini* – for normal simulation

RUN/ - working directory where model output is written

INPUT and OUTPUT FILES: DESCRIPTION

GBIOME-BGCv1 uses input files each time it is executed. A brief description of all files is given first, followed by detailed discussions of each file.

Model Initializations File

**.ini* – (ASCII) contains general information necessary for model simulation: time-frame of simulation coordinates of the region for simulations, paths and names of other input and output files, lists of output variables.

There are several initialization files (called ini-files for short) in the **INIFILE/** directory of this code release:

- *spinup_1800.ini*
- *normal_1800-1859.ini*
- *normal_1860-1947.ini*
- *normal_1948-2007.ini*

These four ini-files are used in a two-step model simulation: 1) spinup simulation (*spinup_1800.ini*) and 2) transient or normal model simulation (*normal_1800-1859.ini*, *normal_1860-1947.ini*, and *normal_1948-2007.ini*). Each ini-file refers to a time interval. The simulations are performed one after another with a different set of input data in order to represent realistic dynamics of ecosystem functioning over the time of simulations. The chain of simulations and the data used for them are illustrated in Figure 1.

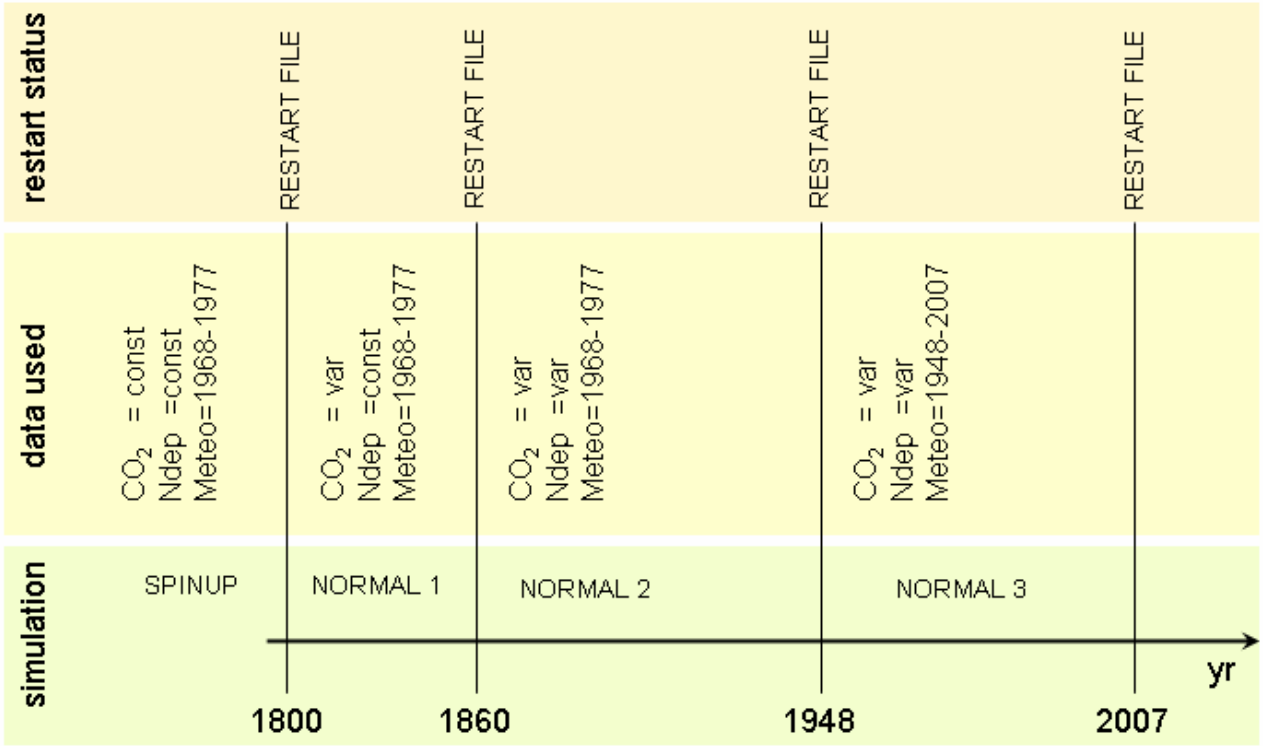

Figure 1. Example of a chain of model simulations: one spinup and one normal simulation. The normal simulation is performed in three steps (NORMAL1, NORMAL2, and NORMAL3) due to the varying data used.

The spinup simulation in this example (Figure 1) refers to 1800 because the first estimates of CO_2 global concentration for this report were available from 1800. This means that at the end of the spinup simulation the state of C/N ecosystem pools saved into a restart file characterises the state of the ecosystem in 1800. One is free to choose any reference year for the spinup simulation; however it is advisable to use reliable estimates of meteorological fields, atmospheric CO_2 concentration and nitrogen deposition data for this simulation.

The first normal simulation (NORMAL1) covers time period from 1800 to 1859. It is a transitional run between 1800, when the first CO_2 estimates were available, and 1860, when the atmospheric nitrogen deposition began to rise. During this run, the nitrogen deposition fields are set to a constant - the lowest estimated value – in order to represent preindustrial state of the atmosphere.

The second normal simulation (NORMAL2) covers time period from 1860 to 1947 and it is a transitional run between 1860 and 1947, when data for CO_2 estimate as well as for the atmospheric nitrogen were available. This simulation represents changes in dynamics of the ecosystem as it undergoes preindustrial-to-industrial rise of atmospheric CO_2 and NO_X pollution.

The third normal simulation (NORMAL3) from 1948 to 2007 represents the ecosystem's behaviour during the time of industrialisation until recent years. As the NORMAL1 and NORMAL2 simulations serve to simulate the "history" of the ecosystem's development, the NORMAL3 simulation represents the "present-day" ecosystems' dynamics. We are usually interested in analysing the model output of the NORMAL3 simulation.

Header line

<EXAMPLE>
```
GBIOME-BGCv1 : (spinup simulation, reference year 1800)
```
<END EXAMPLE>

The first line of the ini-file provides information that helps to remember which ini-file for which simulation to use. This is especially helpful when doing a sequence of simulations. This line can contain up to 100 characters of information. There is no keyword for the header line in the ini-file.

RUN_DIR block

<EXAMPLE>
```
RUN_DIR       (keyword – do not remove)
../RUN/       (path)
```
<END EXAMPLE>

The section RUN_DIR has one line that contains the path to the directory where model output and model restart files will be stored.

RUN_TIME block

<EXAMPLE>

```
RUN_TIME      (keyword – do not remove)
1800          (int) first simulation year
10            (int) tot number of sim. years (if normal sim.)
1800          (int) first year of output (if normal sim.)
1850          (int) last year of output (if normal sim.)
1             (flag)1=spinup simulation 0=normal simulation
6000          (int) max number of spinup years(if spinup sim.)
```

<END EXAMPLE>

The section RUN_TIME has the following six lines:

1. the first simulation year to run for this simulation, <*simyr1*>
2. number of years to run for this simulation, <*nsimyr*>, (valid only for a normal simulation, not for the spinup simulation)
3. first year of output <*outyr1*>
4. last year of output <*outyr2*>
5. flag (1 or 0) for spinup simulation (1) or normal simulation (0)
6. maximum number of years to run in the spinup mode, <*maxsyr*>

The first simulation year <*simyr1*> is used for

- defining the time when model output should be written out into output files. If <*simyr1*>=1800, <*outyr1*>=1800 and <*outyr2*>=1850 – the model output will be written for 1850-1800+1=51 years starting from 1800. If <*simyr1*>=1800, <*outyr1*>=1840 and <*outyr2*>=1850 – the model output will be written for 1850-1840+1=11 years starting from 1840; the first 39 years of output will not be saved. If <*outyr1*> and <*outyr2*> do not fall into the interval between <*simyr1*> *and* <*simyr2*> then no model run will be performed.
- for finding the first record in CO_2 and nitrogen deposition data if either of flags in NDEP_CONTROL or in CO2_CONTROL block is set to 1. If the flag in NDEP_CONTROL block is set to 1, the nitrogen deposition data for <*simyr1*> will be read from the file given in NDEP_FILE block. If the flag in CO2_CONTROL block is set to 1, the data on CO_2 concentration for <*simyr1*> will be read from the file given in CO2_FILE block.

It is very important to set <*simyr1*> and <*nsimyr*> correctly. The data on changing CO_2 concentrations and atmospheric nitrogen deposition, if used, will be read from input files for the time of the simulation - <*nsimyr*> years. The first year of these data is the first simulation year <*simyr1*> and the last year of these data is <*simyr1*>+<*nsimyr*>. Make sure, the input files contain data for <*nsimyr*> years of the simulation.

NOTE: The <*simyr1*> and <*nsimyr*> do not define the set of meteorological data to be used in simulations. The time of meteorological output is defined in the METEO_TIME block.

NOTE: The first and the last year of output should be within the interval <simyr1>:<simyr1>+<nsimyr>, and <*outyr2*> should be greater or equal <*outyr1*>.

NOTE: The number of simulation years, <*nsimyr*>, is used only in the normal simulation. It is ignored in the spinup simulation.

NOTE: The maximum number of years in the spinup simulation (line 6) is used limit the number of iterations in the spinup run unless the spinup run was finished with less iterations. This parameter is ignored in the normal simulation.

RESTART_CONTROL block

<EXAMPLE>
```
RESTART_CONTROL    (keyword - do not remove)
0                  (flag) 1=read  0=don't read restart file
1                  (flag) 1=write 0=don't write restart file
restart_old        (name) input restart filename
restart_new        (name) output restart filename
```
<END EXAMPLE>

The section RESTART has the following four lines:

1. flag (1 or 0) for reading (1) or not reading (0) a restart file from the end of a previous simulation
2. flag (1 or 0) for writing (1) or not writing (0) a restart file at the end of this simulation
3. input restart filename
4. output restart filename

The flags in line 1 and line 2 are used to control reading/writing of restart files. In the spinup simulation, the read-restart flag (line 1) should be set to 0 - no restart file is expected and the filename given in line 3 is ignored. In the normal simulation, the read-restart flag (line 1) should be set to 1 and the relevant name of the input restart file should be given in line 3. In the spinup simulation, the write-restart (line 2) flag should be set to 1. The restart file with the name given in line 4 will be written after the spinup simulation. In the normal simulation, the write-restart flag could be set either to 0 or 1. If the state of C/N ecosystems' pools will be analysed or this information should be re-used (by a succeeding simulation) then the restart file should be written (write-restart flag=1). Otherwise one may save disk space and write no restart file after the current normal simulation (write-restart flag=0).

NOTE: Make sure the names of input and output restart files, line 3 and 4, differ by at least one symbol.

NOTE: lines 3 and 4 contain not the absolute restart file names; a suffix will be added to the given strings in the following way:

*<restart_name>_<lc_name>_<ncol>*x*<nrow>.restart*

This suffix is generated automatically during the model run and helps to differentiate restart files. The restart file will be created and saved in the runtime directory set in the RUN_DIR block.

More on the structure of these files read in the chapter "Restart Files".

SUB_MAP block

<EXAMPLE>
```
SUB_MAP             (keyword – do not remove)
1                   (int)   first row   of the region
180                 (int)   last row of the region
1                   (int)   first column of the region
360                 (int)   last column of the region
```
<END EXAMPLE>

The section SUB_MAP has the following four lines:

1. the first row <*rowi*> of simulation over model domain
2. the last row <*rowe*> of simulation over model domain
3. the first column <*coli*> of simulation over model domain
4. the last column <*cole*> of simulation over model domain

NOTE: the *rowi*, *rowe*, *coli* and *cole* define a region for which the model is run within the global model domain (dimensions of the global domain are set in the GLOBAL_MAP block). Currently, we use the global model domain with 1 degree resolution in latitude and longitude dimensions (360 x 180 grid cells). When *rowi*=1, *rowe*=180, *coli*=1, *cole*=360 the model is run for the whole domain. When *rowi*>1, *rowe*<180, *coli*>1, *cole*<360 the model is run for the subset of model grid cells.

GLOBAL_MAP block

<EXAMPLE>
```
GLOBAL_MAP          (keyword – do not remove)
180                 (int) tot number of rows in model domain
360                 (int) tot number of columns in model domain
```
<END EXAMPLE>

The section GLOBAL_MAP has the following four lines:

1. total number of rows <*nrow*> in surface data fields
2. total number of columns <*ncol*> in surface data fields

NOTE: <*ncol*> and <*nrow*> define the number of grid cells in longitude and latitude directions of the model domain, respectively.

NOTE: In the current version of GBIOME-BGC, dimensions of meteorological input fields and the land surface data should be the same and match the grid of the model domain.

NOTE: Input files with meteorological, surface, and atmospheric nitrogen data is expected to have the suffix in the following form: "_<*ncol*>x<*nrow*>.<res>", where <res> = "flt" | "int" – suffix that corresponds to "float"|"integer" format of data in the file.

METEO_DIR block

<EXAMPLE>
```
METEO_DIR                    (keyword - do not remove)
../DATA/meteo_1948-present_NCEP_1year/         (path)
```
<END EXAMPLE>

The section METEO_DIR has one line that contains the path to the directory where the meteorological data files are stored.

METEO_TIME block

<EXAMPLE>
```
METEO_TIME          (keyword - do not remove)
1968                (int)   first year of meteo data
1977                (int)   last year of meteo data
```
<END EXAMPLE>

The section METEO_TIME has the following two lines:

1. first year of meteorological data <*metyr1*> to be used
2. last year of the meteorological data <*metyr2*> to be used

Meteorological fields from <*metyr1*> till <*metyr2*> are used to drive the model. The total number of years of meteorological data is <*nmetyr*> = <*metyr2*>-<*metyr1*>+1; data for <*metyr1*> and <*metyr2*> are used.

NOTE: For the spinup run only: as the spinup run is performed for multiple years, up to <*maxsyr*>, the meteorological data of the <*nmetyr*> years defined in this section are recycled throughout the simulation.

NOTE: For the normal run only: the number of meteorological data years, <*nmetyr*>, does not need to be equal to the number of simulation years <*nsimyr*>. If <*nmetyr*> ≥ <*nsimyr*>, then only the data of the first <*nsimyr*> years of meteorological input are used, starting at <*metyr1*>. If <*nmetyr*> ≤ <*nsimyr*> then the data of <*nmetyr*> years of meteorological data are recycled throughout the <*nsimyr*> years of simulation.

NOTE: The model expects the meteorological data to be prepared in binary format and saved in files with strictly defined names such as:

- *dswrf.*<*yr*>*_*<*ncol*>x<*nrow*>*.int*
- *prate.*<*yr*>*_*<*ncol*>x<*nrow*>*.int*
- *rhum.*<*yr*>*_*<*ncol*>x<*nrow*>*.int*
- *tmax.*<*yr*>*_*<*ncol*>x<*nrow*>*.int*
- *tmin.*<*yr*>*_*<*ncol*>x<*nrow*>*.int*

where

yr – year to which the data in the file refer.

More on the format of the meteorological data read in the chapter “Meteorological Fields Files”.

SURFACE_DIR block

<EXAMPLE>
```
SURFACE_DIR        (keyword – do not remove)
../DATA/surface/   (path)
```
<END EXAMPLE>

The section SURFACE_DIR has one line that contains the path to the directory where the surface data files are stored. There are six data files expected to be in this directory that have fixed names and cannot be renamed:

- *elevation_<ncol>x<nrow>.int*
- *soildepth_<ncol>x<nrow>.flt*
- *albedo_<ncol>x<nrow>.flt*
- *sand_<ncol>x<nrow>.int*
- *clay_<ncol>x<nrow>.int*
- *lat_<ncol>x<nrow>.flt*

More about the files read in the chapter “Land Surface Data Files”.

LANDCOVER_FILE block

<EXAMPLE>
```
LANDCOVER_FILE          (keyword – do not remove)
land_cover_map          (name) land cover file
```
<END EXAMPLE>

The section LANCOVER_FILE contains the name of the file with land cover data <*lc_name*>. There is a selection of land cover data files provided with this release of the model:

- lc1_360x180.int - all land pixels contain grass C3 vegetation type
- lc2_360x180.int - all land pixels contain grass C4 vegetation type
- lc3_360x180.int - all land pixels contain shrub/bush vegetation type
- lc4_360x180.int - all land pixels contain DBF vegetation type
- lc5_360x180.int - all land pixels contain DNF vegetation type
- lc6_360x180.int - all land pixels contain EBF vegetation type
- lc7_360x180.int - all land pixels contain ENF vegetation type
- syn_dom_360x180.int – map of dominant land cover based on SYNMAP (Jung et al., 2006)

NOTE: this block contains not the absolute name of the land cover file but the “stem” of the file’s name. There will be a suffix added to the “stem”, which identifies the spatial resolution of the data, in the following way:

<lc_name>_<ncol>x<nrow>.int

EPC_DIR block

<EXAMPLE>
```
EPC_DIR            (keyword – do not remove)
../DATA/epc/       (path)
```
<END EXAMPLE>

The section EPC_DIR has one line that contains the path to the directory where ecophysiological constants data files are stored. There are seven files in ASCII format, one for each model plant functional type represented in the model:

- *c3grass.epc* (C3 grasslands)
- *c4grass.epc* (C4 grasslands)
- *shrub.epc* (shrub/bush)
- *dbf.epc* (Deciduous Broadleaf Forest)
- *dnf.epc* (Deciduous Nedleleaf Forest)
- *ebf.epc* (Evergreen Broadleaf Forest)
- *enf.epc* (Evergreen Needleleaf Forest)

More on the structure of these files read in the chapter “EcoPhysiological Constants Files”.

NDEP_DIR block

<EXAMPLE>
```
NDEP_DIR                (keyword – do not remove)
../DATA/ndeposition/    (path)
```
<END EXAMPLE>

The section NDEP_DIR has one line that contains the path to the directory where the atmospheric nitrogen deposition data files are stored.

NDEP_CONTROL block

<EXAMPLE>
```
NDEP_CONTROL (keyword – do not remove)
0            (flag)      0=constant   1=file for Ndep
0.0004       (kgN m-2/yr) symbiotic+asymbiotic fixation of N
```
<END EXAMPLE>

The section NDEP_CONTROL has the following three lines:

1. flag (0,1) controlling atmospheric nitrogen deposition: 0=constant for all years of the simulation, 1=varying using values that will be read in from a file
2. annual rate of atmospheric nitrogen deposition (wet + dry deposition)
3. annual rate of symbiotic + asymbiotic nitrogen fixation

NOTE: If the flag is 0, a map of atmospheric nitrogen deposition data will be read from the file given in the NDEP_FILE block and held constant throughout the simulation. If the file contains data for multiple years, only the data for the first given year will be used. If the flag is 1, a series of maps of atmospheric nitrogen deposition will be read from the file given in the NDEP_FILE block. This series of maps represent a gradual change in time of nitrogen content in the atmosphere.

NOTE: The option when the flag is 1 (varying nitrogen deposition data are used) is often employed when effects of growing atmospheric nitrogen on biosphere carbon fluxes are investigated.

NDEP_FILE block

<EXAMPLE>
```
NDEP_FILE                (keyword - do not remove)
Ndep_Galloway_1860-2050  (name) atm. nitrogen deposition file
```
<END EXAMPLE>

The section NDEP_FILE has one line that contains the name of the file with atmospheric nitrogen deposition data <*ndep_name*> for one or multiple years.

NOTE: this is not the absolute name of the file, there will be a suffix added to it in the following way:
<ndep_name>_<ncol>x<nrow>.flt
More on the structure of these files read in the chapter "Atmospheric Nitrogen Deposition Data Files".

CO2_DIR block

<EXAMPLE>
```
CO2_DIR      (keyword - do not remove)
../DATA/co2/ (path)
```
<END EXAMPLE>

The section CO2_DIR has one line that contains the path to the directory where the atmospheric CO_2 concentrations data files are stored.

CO2_CONTROL block

<EXAMPLE>
```
CO2_CONTROL  (keyword - do not remove)
1            (flag) 0=constant 1=file for CO2
283.0        (ppm) constant atmospheric CO2 concentration
```
<END EXAMPLE>

The section CO2_CONTROL has the following two lines:

1. flag (0,1) controlling CO_2 concentration: 0=constant, 1=varying using values that will be read in from a file
2. the value to use for constant CO_2 concentration (ppm), if the line 1 contains 0

NOTE: When the flag is set to 0, then the value from line 2 sets the constant CO_2 level for the entire simulation. When the flag is set to 1, the value in line 2 is ignored but the file in CO2_FILE block is used for reading annual time series of CO_2 concentration.

NOTE: The flag set to 1 option is used when effects of growing atmospheric CO_2 on biosphere carbon fluxes are investigated.

CO2_FILE block

<EXAMPLE>
```
CO2_FILE                                (keyword – do not remove)
co2_CarboeuropeIP_allyears_1800-2007 (name) atm. CO2 file
```
<END EXAMPLE>

The section CO2_FILE has one line that contains the name of the file with CO_2 concentration data <*co2_name*> for multiple years.

NOTE: this is not the absolute name of the file, there will be a suffix added to it in the following way:
<co2_name>.flt
More on the structure of these files read in the chapter "Atmospheric CO2 Concentration Data Files".

OUTPUT_CONTROL block

<EXAMPLE>
```
OUTPUT_CONTROL    (keyword – do not remove)
0       (flag) 1 = write daily output   0 = no daily output
1       (flag) 1 = write monthly output 0 = no monthly output
0       (flag) 1 = write annual output  0 = no annual output
```
<END EXAMPLE>

Formats of model output files are defined in this block. There are three formats of model output available: daily, monthly, and yearly fields.
The section OUTPUT_CONTROL has the following three lines:
1. flag (1 or 0) to write (1) or not write (0) a binary output file with daily values
2. flag (1 or 0) to write (1) or not write (0) a binary output file with monthly values
3. flag (1 or 0) to write (1) or not write (0) a binary output file with annual values

NOTE: If any of the output formats is chosen (respective flag is set to 1) all model output parameters defined in OUTPUT_INDX block will be written in this format.

NOTE: There is no option of defining the output format for each model parameter individually! If several model parameters are required in different output formats, all parameters should be written out in all relevant formats and then the necessary ones could be selected.

OUTPUT_INDX block

<EXAMPLE>
```
OUTPUT_INDX  (keyword – do not remove)
3            (int) number of daily variables to output
620          (int) index number of the 1st output parameter
621          (int) index number of the 2d output parameter
627          (int) index number of the 3d output parameter
```
<END EXAMPLE>

The number of lines in the OUTPUT_INDX block can vary depending on the number of output variables requested, as follows:

1. the number of output variables requested. This value should be >0
2. the index number for the first requested output variable <*param_id*>
3. the index number for the second requested output variable <*param_id*>
4. ...

The names of the output files will be generated automatically in the following way:

- *BGCflx_<lc_name>_day_<outyr1>-<outyr2>.<param_id>.d* (daily)
- *BGCflx_<lc_name>_mon_<outyr1>-<outyr2>.<param_id>.d* (monthly)
- *BGCflx_<lc_name>_ann_<outyr1>-<outyr2>.<param_id>.d* (yearly)

The output files will be created and saved in the runtime directory defined in the RUN_DIR block.

NOTE: Index numbers of model parameters <*param_id*> can be found in Appendix "Index Numbers and Types of Temporal Aggregation for Output Variables".

NOTE: Information given in this block is only relevant for the normal run, not for the spinup run. In the spinup run no output files, except of the restart file, are created.

END_INIT block

<EXAMPLE>
```
END_INIT          (keyword – do not remove)
```
<END EXAMPLE>

This block indicates the end of the initialisations file.

Restart Files

The simplest model run is the spinup simulation that does not generate any model output file but creates the intermediate file – restart file. This file contains values of C/N pools for different parts of ecosystem from the last simulated moment for the part of the global domain defined in SUB_MAP block. This restart file is used as an input file in the following normal model simulation. Values of C/N pools are read in from the restart file and used to initialise the corresponding variables at the beginning of the normal simulation.

The parameters saved in the restart file are listed in the Appendix "Fields in Restart File".

Restart data fields are stored in a binary double precision (8 byte) file. The file contains data for all grid cell of the model domain and contains a matrix of the following structure:

C/C++: `restart_data_struct restart[<nrow>][<ncol>];`
Fortran: `restart_data_struct restart[<ncol>, <nrow>]`

The structure *restart_data_struct* is described in *bgc_struct.h* source file.

Meteorological Fields Files

The daily averaged meteorological fields from the National Center for Enviromental Prediction (NCEP) reanalysis (Kalnay et al., 1996), are used to drive the model. The original data are available on the 1.8x1.8 degree spatial resolution and are stored in NCDF-format files in the NCEP database (dataset ds090.0). The meteorological data was pre-processed and saved in binary files with the spatial resolution of 1x1 degree. In order to save disk space and operational memory meteorological data fields are stored in 2 byte integer format. However, the precipitation and temperature data are needed with a higher precision. For this purpose the precipitation (*prate)*, maximum and minimum temperature (*tmax*, *tmin*) fields were multiplied with a *Scaling Factor* and then the resulted numbers were rounded to integer values. The *Scaling Factor* for *prate* is 1000, for *tmax* and *tmin* it is 100.

The meteorological data files have following names:

- *prate.<yr>.1deg.2byteInt* – precipitation rate [cm * 1000]
- *rhum.<yr>.1deg.2byteInt* – air relative humidity [%]
- *tmax.<yr>.1deg.2byteInt* – maximum daily temperature [°C * 100]
- *tmin.<yr>.1deg.2byteInt* – minimum daily temperature [°C * 100]
- *dswrf.<yr>.1deg.2byteInt* – downward shortwave radiation fraction [Watt m-2]

where *yr* = 1948 .. 2007 – year.

These files contain daily data for one year <*yr*> each in the binary format and have the temporal resolution of 1 day and the spatial resolution of 1 degree. Each file contains a matrix of the following structure:

C/C++: `short metfield [nrow][ncol][nday];`
Fortran: `integer metfield [nday, ncol, nrow]`

where
nday = 365 – number of days,
ncol = 360 – number of columns,
nrow = 180 – number of rows.

NOTE: The structure of the meteorological data files is the same as for daily output files (Figure 2).

Land Surface Data Files

Each model simulation requires the following seven files:

- *albedo_360x180.flt* – shortwave albedo [fraction]
- *elevation_360x180.int* – digital elevation [m]
- *landcover_360x180.int* – land cover type [type]
- *soil_depth_360x180.flt* – effective soil depth [m]
- *sand_360x180.int* – percentage of sand in soil [%]
- *clay_360x180.int* – percentage of clay in soil [%]
- *lat_360x180.flt* – latitudes of grid cells [degree]

The data of surface characteristics was obtained from different sources listed in Table 1.

Table 1 . Model input data (land surface, climate data, atmospheric CO_2 concentration, atmospheric nitrogen deposition and nitrogen fertilization) used by the terrestrial ecosystem models in this study

Parameter	*Source*
Albedo	MODIS (MOD43B) (Lucht et al., 2000; Schaaf et al., 2002)
Elevation	GTOPO 30; http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html
Soil depth	TERRASTAT – Global Land Resources GIS Models and Databases, FAO Land and Water Digital Media Series # 20
Soil texture	Global Soil Data Products CD-ROM (IGBP-DIS)
Land cover	SYNMAP (Jung et al., 2006)

These files contain data fields on the spatial resolution of 1 degree in the binary format and have. Each file contains a matrix of the following structure:

C/C++: `float` or `short surfacefield [nrow][ncol];`
Fortran: `real*4` or `integer surfacefield [ncol, nrow]`

For the surface albedo, latitude, and soil depth the data are stored in floating point 4 byte format (file extension **.flt*). For the elevation, land cover, clay and sand percentage 2 byte integer format is used (file extension **.int*).

NOTE: The effective soil depth is corrected for the rock fraction. The sand and clay percentage are given by volume in rock-free soil.

NOTE: The site latitude is in scale (- for S.Hem.).

NOTE: The percent of silt in soil texture is not required as the model input. It is calculated within the model as silt [%] = 100% - sand [%] – clay [%].

EcoPhysiological Constants Files

There are eight files with ecophysiological constants for different plant functional types supplied for this release of the model. These are ASCII files and can be viewed and edited in most common text processors. Each such file defines the ecophysiological characteristics of the vegetation type being simulated. It is kept separate from the initialization file so that multiple initialization files can reference the same ecophysiological constants without cutting and pasting. Ecophysiological parameters used in the model are listed in Table 2.

Table 2. EcoPhysiological parameters and their units.

Parameter	*Units*
Flag (woody/non woody)	[logical]
Flag (evergreen/deciduous)	[logical]
Flag (C3/C4 PSN)	[logical]
Flag (model/user-specified phenology)	[logical]
Day to start new growth	[day]
Day to end litterfall	[day]
Transfer growth period as fraction of growing season	[fraction]
Litterfall period as fraction of growing season	[fraction]
Annual leaf and fine root turnover fraction	[yr-1]
Annual live wood turnover fraction	[yr-1]
Annual whole-plant mortality fraction (herbivory)	[yr-1]
Annual fire mortality fraction	[yr-1]
Allocation: new fine root C / new leaf C	Dimensionless
Allocation: new stem C / new leaf C	Dimensionless
Allocation: new live wood C / new total wood C	Dimensionless
Allocation: new coarse root C / new stem C	Dimensionless
Allocation: current growth proportion	Dimensionless
C / N of leaves	[kg C / kg N]
C / N of leaf litter, after retranslocation	[kg C / kg N]
C / N of fine roots	[kg C / kg N]
C / N of live wood	[kg C / kg N]
C / N of dead wood	[kg C / kg N]
leaf litter labile proportion	Dimensionless
leaf litter cellulose proportion	Dimensionless
leaf litter lignin proportion	Dimensionless
fine root labile proportion	Dimensionless
fine root cellulose proportion	Dimensionless
fine root lignin proportion	Dimensionless
dead wood cellulose proportion	Dimensionless
dead wood lignin proportion	Dimensionless
canopy water interception coefficient	[1 / LAI / day]
canopy light extinction coefficient	Dimensionless
all-sided to projected leaf area ratio	Dimensionless
canopy average specific leaf area (projected area basis)	[m2 / kg C]
ratio of shaded SLA / sunlit SLA	Dimensionless
fraction of leaf N in Rubisco	Dimensionless
maximum stomatal conductance (projected area basis)	[m s-1]
cuticular conductance (projected area basis)	[m s-1]
boundary layer conductance (projected area basis)	[m s-1]
leaf water potential: start of conductance reduction	[MPa]
leaf water potential: complete conductance reduction	[MPa]
vapor pressure deficit: start of conductance reduction	[Pa]
vapor pressure deficit: complete conductance reduction	[Pa]

NOTE: all *.epc files must have the same parameter lines, in the same order, but that not all lines are relevant to all vegetation types. Lines marked with (*) before the

units in the default *.epc files indicate an irrelevant parameter for that vegetation type, and any numeric value can be substituted in these places without effect.

Further information about *.eps files you can find in the “BiomeBGC User's Guide” (http://www.ntsg.umt.edu/models/bgc/, Downloads).

Atmospheric Nitrogen Deposition Data Files

These atmospheric nitrogen deposition data was taken from the work of Galloway (2004) and stored in the file *Ndep_Galloway_1860-2050_360x180.flt*

Each value represents the total wet+dry atmospheric nitrogen content [kg m-2 yr-1] for a particular location and time. This file contains data for several years <*nyear*> in the binary format and has the temporal resolution of one year and the spatial resolution of 1 degree. It contains a matrix of the following structure:

C/C++:
```
typedef struct
{
        short     year;
        float     value[nrow][ncol];
} record
record ndepfield [nyear];
```

Fortran:
```
type
        integer   ::   year
        real*4    ::   value[ncol, nrow]
end type record
record ndepfield [nyear]
```

where
nyear = 2050-1860+1 = 191 – number of years in the data file,
record – structure of two record fields <*year*> and <*value*> .

NOTE: *Ndep_Holland_2kgha-1yr-1.flt* – an additional file supplied for the current model release. This file contains preindustrial constant atmospheric nitrogen content [kg m-2 yr-1] estimated in the work of Holland et al. (1999). This data contains only one year record referenced to 1800 and can be used in the spinup simulation.

Atmospheric CO_2 Concentration Data Files

The CO_2 concentrations data was provided by the CARBOEUROPE-IP Project Database (http://www.carboeurope.org/) and is stored in the file
co2_CarboeuropeIP_1800-2007.flt

Each value represents the global average concentration [ppm] in the well mixed atmosphere of a certain year <*yr*> and is used uniformly for one simulated year <*yr*> for all grid cells of the model. The file contains an array of the following structure:

C/C++:
```
typedef struct
{
        short     year;
        float     value;
} record
record co2field [nyear];
```

Fortran:
```
type
        integer   ::   year
        real*4    ::   value
end type record
record co2field [nyear]
```

where
nyear – number of years in the data file; *nyear* = 2007-1800+1 = 208,
record – structure of two record fields <*year*> and <*value*> .

Output Files

GBIOME-BGCv1 produces only one type of output - binary output files controlled through the initialization file with information from OUTPUT_CONTROL and OUTPUT_INDX. This is the most flexible output mechanism, since the user can control exactly for which model variables to create the output files, and what time resolution to use for these variables.

File names of the output files are generated by the model code according to the following template:

- *BGCflx_<lc_name>_day_<outyr1>-<outyr2>.<param_id>.d* (daily)
- *BGCflx_<lc_name>_mon_<outyr1>-<outyr2>.<param_id>.d* (monthly)
- *BGCflx_<lc_name>_ann_<outyr1>-<outyr2>.<param_id>.d* (yearly)

where
outyr1 – first year of output,
ouyr2 – last year of output,
param_id – number of the model parameter for output

These files contain data for several years *<nyr>=<outyr2>-<outyr1>+1* in the binary format and have the temporal resolution of one day, one month, or one year and the spatial resolution of the model domain. Each file contains a matrix of data of the following structure:

C/C++:
```
float     outputfield [nrow][ncol][nout];
```
Fortran:
```
real*4    outputfield [nout, ncol, nrow]
```
where
nyear = *<yr2>-<yr1>* - number of simulated years for output,
nout = *nyear* * *nday* – number of days in the daily output file,
nout = *nyear* * 12 – number of months in the monthly output file,
nout = *nyear* – number of years in the yearly output file.

All model output data are stored in floating point 4 byte format (**.flt*).

These are not text files, and you will not be able to read them with a text editor or word processor. Instead, they are data files containing values of the output variables in

binary format. Each value is written as a single-precision IEEE floating point binary number using 4 bytes of storage per number. These values can be read directly using a simple code written in C/C++, FORTRAN, BASIC, PASCAL, and other programming languages. They can also be read by many commercially available software packages typically those that specialise in manipulating large multi-dimensional data sets (IDL, R, Mathematica, etc.). There are lots of other possibilities for reading these files, and you might want to consult with a computer programmer about the methods best suited for the kind of analysis you want to do.

NOTE: an output value of -9999.00 (or -999999.0) indicates there was no normal run performed for the corresponding model grid cell. There are two reasons for this:

1. The grid cell is in the ocean i.e. it has land cover type "water"
2. The model failed to perform a successful normal simulation due to a non-permitted combination of the input data

In order to read the binary files, you need to know how output values are ordered in the file. For a better understanding of the output file structure, study carefully the following example.

Consider a single simulation over 10 years, for which the user requested three output variables in daily, monthly and annual output format. Below is the corresponding example of relevant sections in the initialisation file:

<EXAMPLE>
```
RUN_TIME      (keyword - do not remove)
1948          (int) first simulation year
20            (int) tot number of sim years)
1850          (int) first year of output
1859          (int) last year of output
0             (flag) 1=spinup simulation   0=normal simulation
6000          (int)  max number of spinup years
```
<END EXAMPLE>

The line 2 indicates that the simulation will be performed for 20 years starting from year 1948 until year 1948+20 = 1968. The simulation starts in 1948 on January 1st at 00:00, and stops in 1968 on January 1st at 00:00. The simulation does not cover the year 1968.

The lines 3 and 4 indicate the first and the last years of model output. In the given example, the model output is written for 10 years starting in 1850 on January 1st at 00:00 and ending in 1860 on January 1st at 00:00. The last simulated year is 1959.

The line 5 indicates that the normal simulation not the spinup simulation is performed.

<EXAMPLE>
```
OUTPUT_CONTROL     (keyword - do not remove)
1        (flag) 1 = write daily output   0 = no daily output
1        (flag) 1 = write monthly output 0 = no monthly output
1        (flag) 1 = write annual output  0 = no annual output
```
<END EXAMPLE>

The lines 1, 2, and 3 indicate that the user requested daily, monthly, and yearly output, respectively.

OUTPUT_INDX block

<EXAMPLE>
```
OUTPUT_INDX  (keyword - do not remove)
3            (int) number of daily variables to output
620          (int) index number of the 1st output parameter
621          (int) index number of the 2d output parameter
627          (int) index number of the 3d output parameter
```
<END EXAMPLE>

The lines 2, 3, and 4 contain the indices of the three output parameters requested by the user.

Nine binary output files will be created for this simulation: three files for daily output, three files for monthly output, and three files for yearly output. Names of the output files are listed below:

BGCflx_lc1_day_1850-1859.620.d
BGCflx_lc1_day_1850-1859.621.d
BGCflx_lc1_day_1850-1859.627.d
BGCflx_lc1_mon_1850-1859.620.d
BGCflx_lc1_mon_1850-1859.621.d
BGCflx_lc1_mon_1850-1859.627.d
BGCflx_lc1_ann_1850-1859.620.d
BGCflx_lc1_ann_1850-1859.621.d
BGCflx_lc1_ann_1850-1859.627.d

Values of each output parameter on each chosen temporal resolution will be written into one separate file. Each file contains a three-dimensional array of values for the respective output parameter.

The first dimension is the time. There are <*nout*> values written for each <*ncol*> and <*nrow*> of the model domain. The value <*nout*> depends on the type of model output specified by user:

nout = *nyear* * *nday* – number of days in the daily output file,
nout = *nyear* * 12 – number of months in the monthly output file,
nout = *nyear* – number of years in the yearly output file.

The structure of the binary file can be represented on Figure 2.

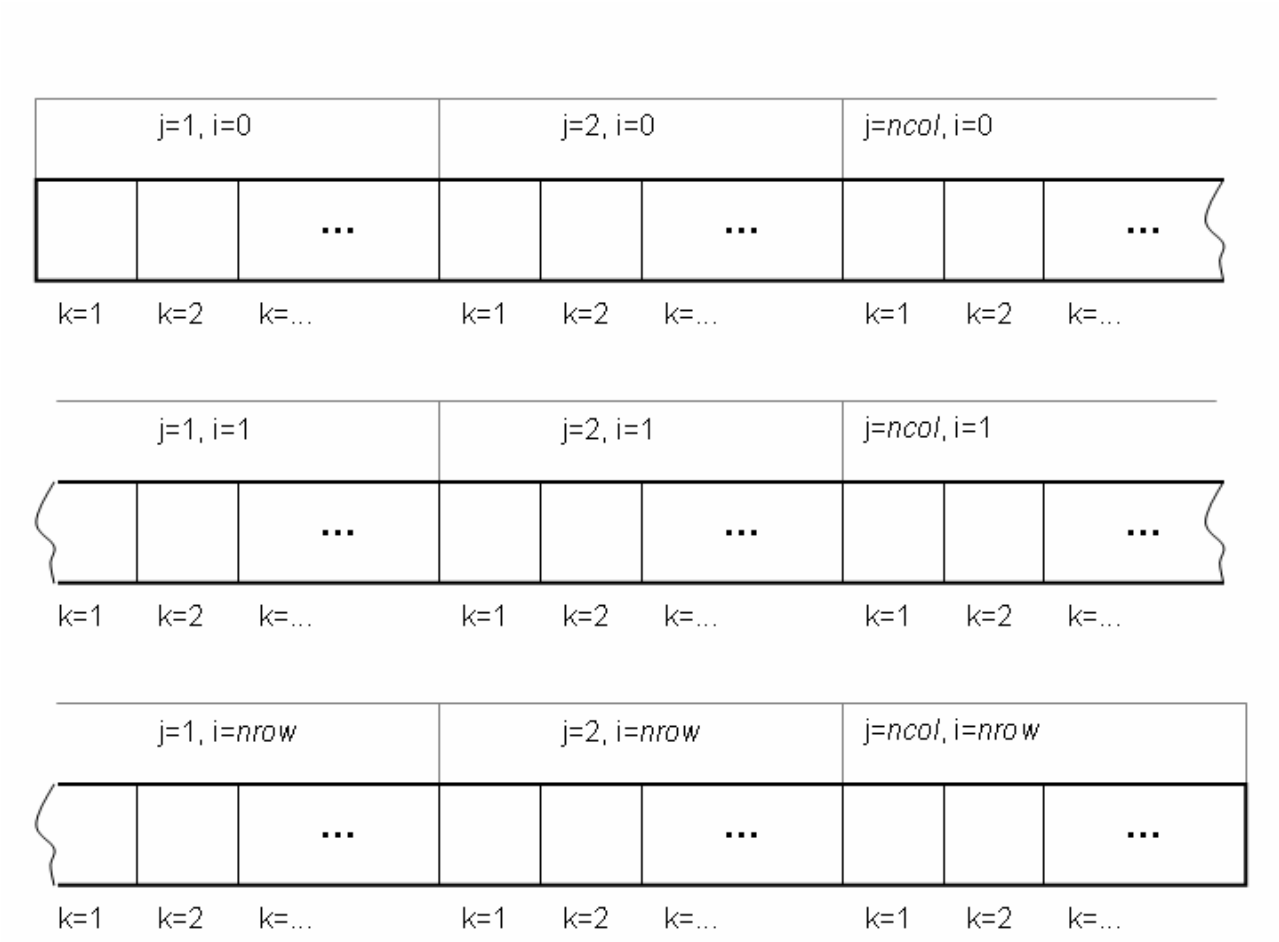

Figure 2. Schematic representation of the structure of an output file: k = 1..nout - time index (day | month | year), j = 1..ncol – column index (longitude direction), i = 1..nrow - row index (latitude direction).

Values are stored sequentially in the file as dictated by <*nout*>, <*ncol*>, <*nrow*> dimensions. As an example, for the daily output file, the first *nout* = (1859-1850+1)*365= 3650 values in the file correspond to for the model's grid cell in row 1 and column 1. The next 3650 values correspond to the grid cell in row 1 and column 2, etc. After all values for row 1 the values for the row 2 follow in the same sequence, etc.

Values of output parameters are stored in standard units as listed in *output_map_struct_init.c* source file. However, when the monthly or yearly format of the output is requested, the daily values of respective parameters are aggregated in three different ways:

- averaged daily values over each monthly | year
- total sum of daily values over each month | year
- last day value of each month | year

Depending on the type of the requested model parameters different aggregation routines are applied to them as shown in Table 3.

Table 3. Types of output aggregation for different groups of model parameters.

Type of variable	Type of aggregation
Daily meteorological variables	average
Water state variables	last day
Water flux variables	sum
Carbon state variables	last day
Carbon flux variables	sum
Nitrogen state variables	last day
Nitrogen flux variables	sum
Phenological variables	last day
Ecophysiological variables	average
Photosynthesis variables (sunlit canopy fraction)	average
Photosynthesis variables (shaded canopy fraction)	average
Carbon budget summary output variables	sum

Important Note: Leap Years

The BIOME-BGC code assumes that all years have 365 days, so meteorological data files should be edited to remove one day from leap years. Usually the 31st December is removed.

MODEL'S COORDINATE SYSTEM

As GBIOME-BGCv1 includes no horizontal exchange between grid cells of the model domain, therefore there are no restrictions on the surface projections for the model input data. The model runs pixel-by-pixel on supplied meteorological and surface input data. By default and historically the Plate Carrée projection is used. This projection was chosen because most of the required model input data are available on this projection. However, there is no restriction fro the projections choice as soon as all input data will be on the same projection.

NOTE: All model input data should contain the same region on the same projection with the same spatial resolution.

NOTE: If use another projection, make sure that relevant changes are made to the file with latitude data (*lat_360x180.flt*). This data will be used for calculating day length – an important parameter in calculations of daily carbon and water fluxes.

Model input data that are supplied for the present release of the model have the following format:

Geographical projection	Plate Carrée
Spatial resolution	1°x1° (degree)
Temporal resolution	1 day (for meteorological fields)
Coordinates of the upper left corner	180°W 90°N
Number of rows	180
Number of columns	360
Number of records for each grid cell	365 [=number of days in one year] (for meteorological fields)

The correspondence between the geographical coordinates and the model grid coordinates is illustrated with the Figure 3: the first grid cell in the upper left corner of the model domain has coordinates of the grid (1,1) and corresponds to 180°W 90°N. The lowest right corner of the model domain has coordinates (360,180) and corresponds to 180°E 90°S. For this setup the GLOBAL_MAP block looks like this:

<EXAMPLE>

```
GLOBAL_MAP    (keyword - do not remove)
180           (int) tot number of rows in the model domain
360           (int) tot number of columns in the model domain
```

<END EXAMPLE>

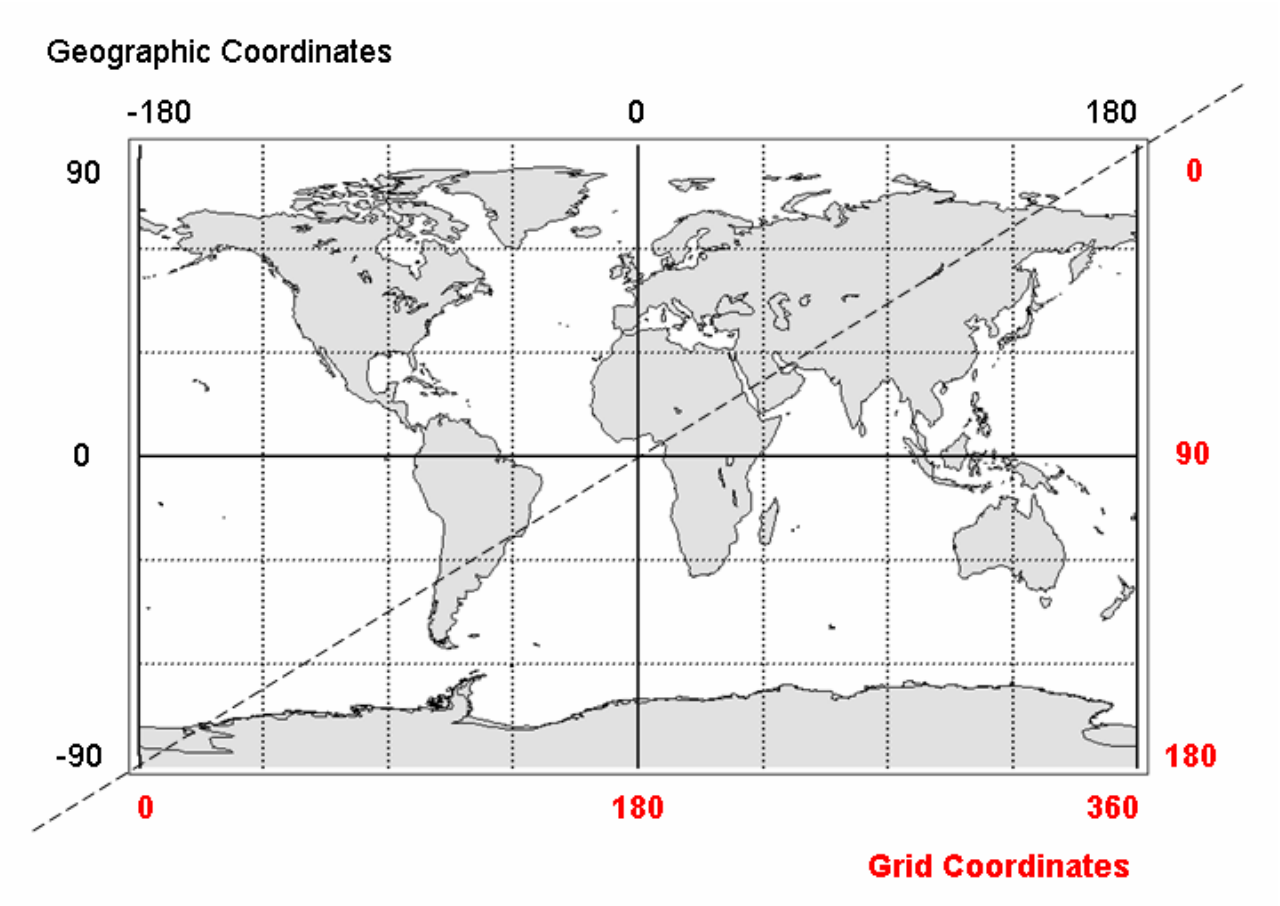

Figure 3. Correspondence between the geographical and grid coordinates of the model domain.

In order to run the model for only a part of the global domain, one has to define the coordinates (grid coordinates) of the simulated region in the SUB_MAP block. When doing a simulation for a region (<LonMin>,<LatMax>) – (<LonMax>,<LatMin>), grid coordinates for the region should be defined according to the following formula:

<*rowi*> = 90 – LatMax
<*rowe*> = 90 – LatMax
<*coli*> = 180 + LonMin
<*cole*> = 180 + LonMin

For example, the simulation will be performed for the European region (20°W, 80°N) – (40°E, 30°N), then:

<*rowi*> = 90 – (80) = 10
<*rowe*> = 90 – (30) = 50
<*coli*> = 180 + (-20) = 160
<*cole*> = 180 + (40) = 220
and the corresponding SUB_MAP block will look like:

<EXAMPLE>

```
SUB_MAP       (keyword - do not remove)
10            (int)    first row
50            (int)    last row
160           (int)    first column
220           (int)    last column
```

<END EXAMPLE>

HOW TO COMPILE GBIOME-BGCv1

The source code (Figure 4) of the model is written using standard attributes of the programming language *C* and can be compiled with any standard *C* compiler (1995 or later versions) for most available platforms.

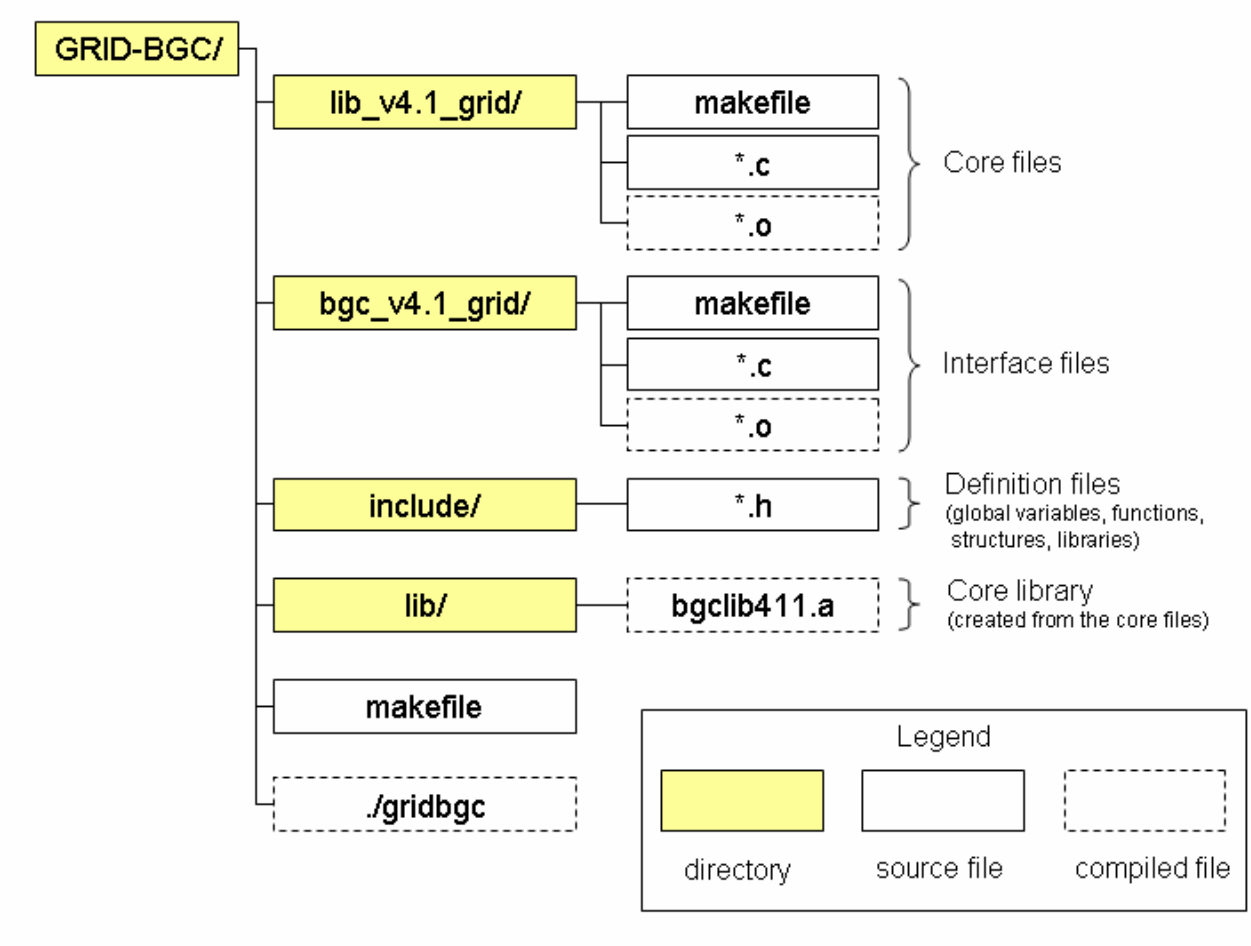

Figure 4. Hierarchy of source directories and files.

UNIX compilation

This code release comes with a set of *makefile*s that need some ajustments before you use them. The main *makefile* is in the subdirectory *GRID-BGC/*, and this does not need to be changed.

There are two other *makefile*s, one in the *GRID-BGC/lib_v4.1_grid/* subdirectory and another in the *GRID-BGC/bgc_v4.1_grid/* subdirectory that both need to be modified as follows:

1) Change the *ROOTDIR* variable so that it reflects the pathname for the *GRID-BGC/* directory. For example, if the *GRID-BGC/* directory is located inside */Net/Groups/BSY/BSY_2/BIOME-BGC_PROG/*, then you should set the *ROOTDIR* to the path */Net/Groups/BSY/BSY_2/BIOME-BGC_PROG/GRID-BGC* in both subdirectory *makefile*s.

2) Change the name of the *C* compiler to a valid name for your system. Do this by editing the line in both subdirectory *makefile*s that begins with *'CC='*, setting

this variable to the name of your *C/C++* compiler. The name of C compiler for the Galactica Linux cluster at MPI-BGC is *'pgcc'*. Possible examples for the compiler name at a workstation Linux computer would be *'cc'*, *'gcc'* or others.

3) From the *GRID-BGC/* directory, issue the command *make*. This executes the *makefile*s in both subdirectories and if successful produces a new executable called *gridbgc* in the same directory *GRID-BGC/*.

PC compilation

For the PC model release, move all of the source code in the *GRID-BGC/* directory (all **.c* and **.h* source files). Create a new project (console application) with an arbitrary name <*project name*> and open all model source file in this new project. You can generate an executable by compiling the source code with the Microsoft Visual *C/C++* compiler (version 6.0 or older). Selecting "*rebuild all*" from the "*Build*" menu will recompile the code, putting a new executable called <*project name*>*.exe* in the <*project name*>*/Release/* directory. There are many other compilers to choose from. Please contact your local PC system administrator for more information and help.

HOW TO RUN GBIOME-BGCv1

The example simulation is a chain-simulation of one spinup and three normal simulations. Instructions for UNIX users (as an example) are given below. The GBIOME-BGCv1 grid runs in two steps:

1. spinup simulation
2. normal simulation (in three steps)

Spinup Simulation

The first step is to run a spinup simulation that will start with very low initial levels of soil carbon and nitrogen and loop through the 10 years of selected[1] meteorological data many times until the total carbon levels stabilise. This simulation does not use any restart-input file, but it produces a restart-output file for use in the next step. The *spinup_opt.ini* is can be found in the *INIFILE/* directory or in the Appendix "Initialisations File ".

(Unix Workstation)

From the RUN/ directory, enter the following text at the command line and press enters:

> *./grigbgc <Enter>*
> *GBIOME-BGC version 1*
> *Copyright 2008, Kristina Trusilova, Max-Planck Institute for Biogeochemistry*
> *Enter name of initialisations file:*
> *../INIFILE/spinup_1800.ini <Enter>*

(Unix Cluster "Galactica")

From the RUN/ directory, enter the following text at the command line and press enters:

>*submit_spinup_1800.csh* <Enter>

[1] because the spinup simulation generally covers 600-6000 years the meteorological data for this simulation should be representative for the long term climate. In the present model setup we suggest using 1968-1977 of NCEP Reanalysis daily data.

The script *submit_spinup_1800.csh* contains following commands:

<EXAMPLE>
```
bsub "./gridbgc < spinup_1800.in > spinup_1800.log"
```
<END EXAMPLE>

Where the file *spinup_1800.in* contains just one line of text with the full name of the initialisations file:

<EXAMPLE>
```
/Net/Groups/BSY/BSY_2/BIOME-BGC_PROG/INIFILE/spinup_1800.ini
```
<END EXAMPLE>

The file *spinup_1800.log* will be written during the model run. It contains some diagnostics and implementation time of the run, once it will be finished. If this file does not exist it will be created, if it exists it will be rewritten.

The command "*bjobs -u <user name>*" will give you the status of the submitted job and the command "*bkill <job ID>"* will terminate the job if necessary. More about working on the Galactica MPI-BGC cluster find on the web page of the institute or ask at the IT department.

NOTE: This particular spinup run should take not more than 6000 years to reach a steady state, after which the following message will be displayed or saved into the *spinup_1800.log* file, after the simulation is completed:

> SPINUP: residual trend = 0.000212
> SPINUP: number of years = 2640

This indicates that the steady state requirement was met after 2640 years, and that there is still a slight trend in the total system carbon, in this case an increase of 0.000212 kg C m^{-2} yr^{-1}.

Normal Simulation

The second step is to run a normal simulation. This simulation uses a restart-input file from the spinup run and creates all output files. If both flags (read restart file and write restart file) are set at 1 in the RESTART_CONTROL block, a new restart-output file will be created after the normal simulation run. This file contains values of restart parameters from the last simulated moment. This file can be used as the restart-input file for the next normal simulation and so on.

NOTE: If you create a restart file during the normal simulation, please check the file paths to input and output restart files in the RESTART_CONTROL block. They must differ by at least one symbol, otherwise you will get a "Segmentation error" during the simulation, because the program will try to read from and write to the same restart file.

For launching the normal simulation you have to repeat the same procedure like for the spinup simulation. The following example illustrates how to run the chain of three normal model simulations.

(Unix Workstation)

>./grigbgc <Enter>
> GBIOME-BGC version.1
> Copyright 2008, Kristina Trusilova, Max-Planck Institute for Biogeochemistry
> Enter name of initialisations file:
> ../INIFILE/normal_1800-1859.ini <Enter>

After this simulation has been completed, start the next one and enter the name of the next initialisations file:

> ../INIFILE/normal_1860-1947.ini <Enter>

And after this one, start the last simulation with the third normal initialisations file:

> ../INIFILE/normal_1948-2007.ini <Enter>

(Unix Cluster "Galactica")

From the RUN/ directory, enter the following text at the command line and press enters:

>*submit_1800-1859.csh* <Enter>
>*submit_1860-1947.csh* <Enter>
>*submit_1948-2007.csh* <Enter>

Start each script once the previous one is completed.

EXAMPLES OF MODEL INPUT

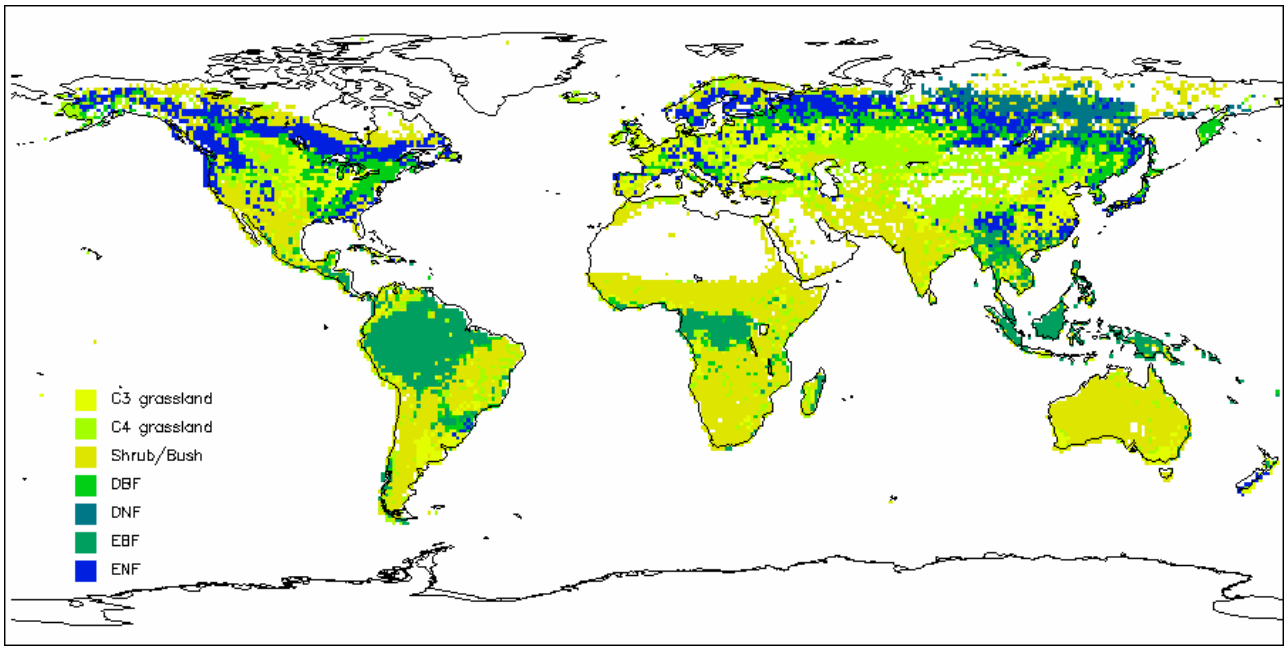

Figure 5. Land cover map used in the test model simulations (Jung et al., 2006).

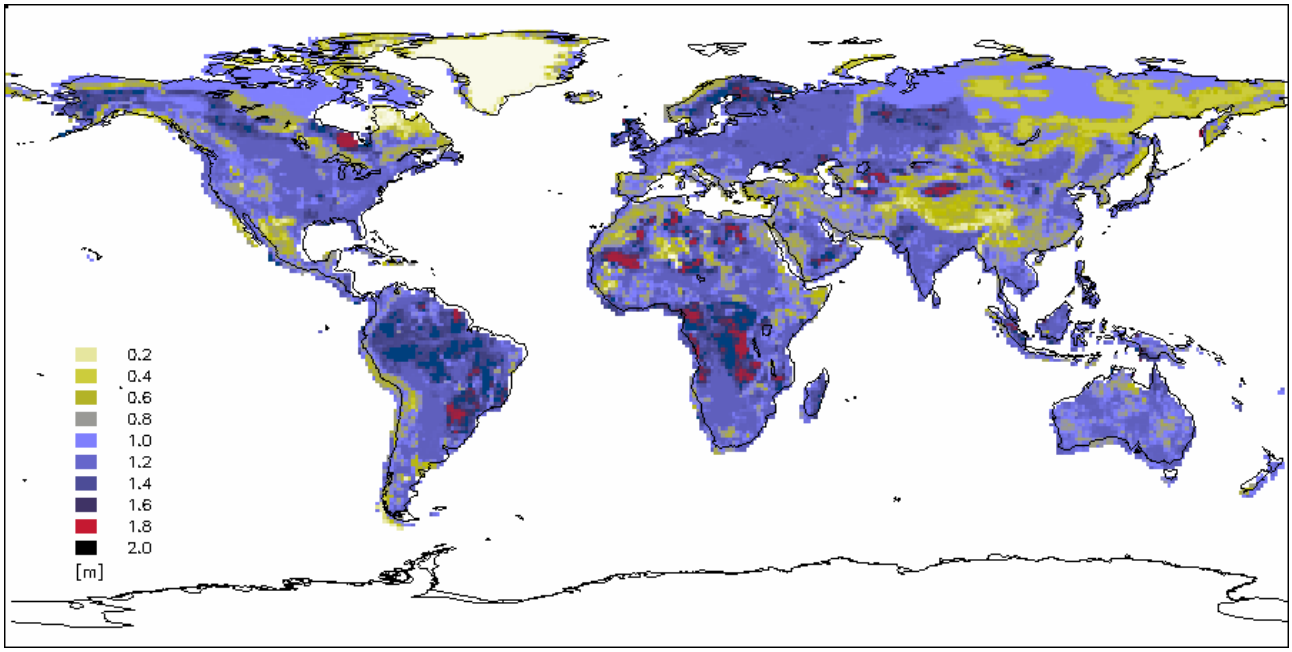

Figure 6. Effective soil depth [m] (TERRASTAT – Global Land Resources GIS Models and Databases, FAO Land and Water Digital Media Series # 20).

EXAMPLES OF MODEL OUTPUT

Global maps for GPP, NPP, RESPIRATION, and NEP as averages for last 10 years of spinup and 1990's.

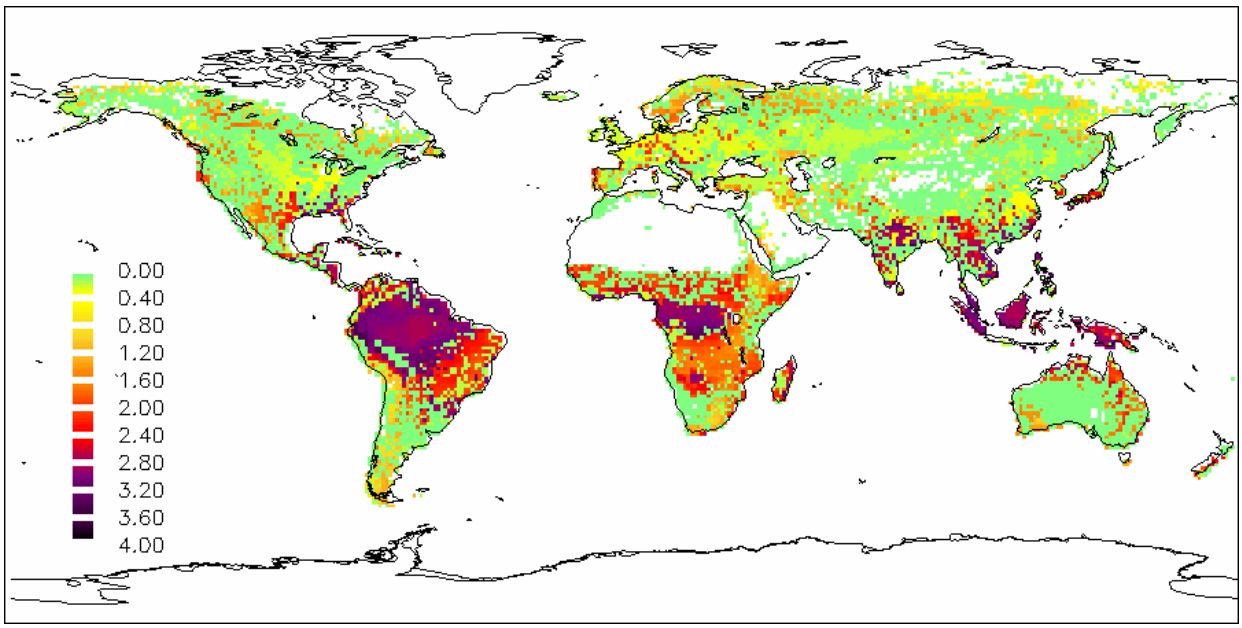

Figure 7. Annual global GPP [kg C m-2 yr-1] average over 1990-1999.

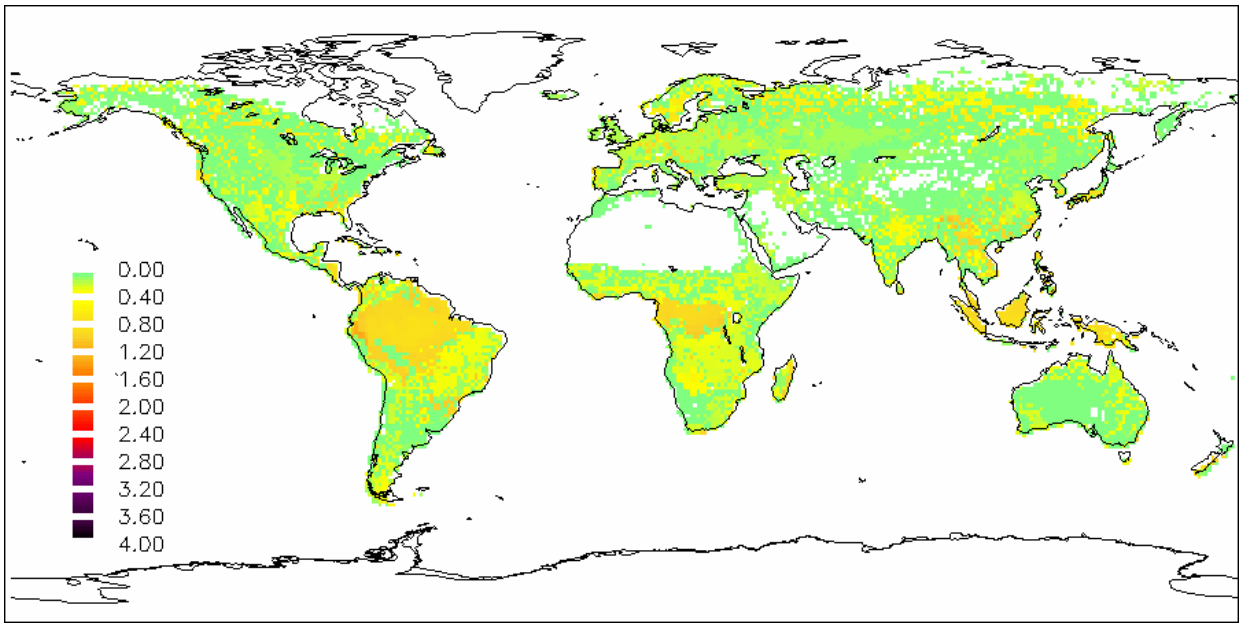

Figure 8. Annual global NPP [kg C m-2 yr-1] average over 1990-1999 calculated as NPP = GPP-MR-GR.

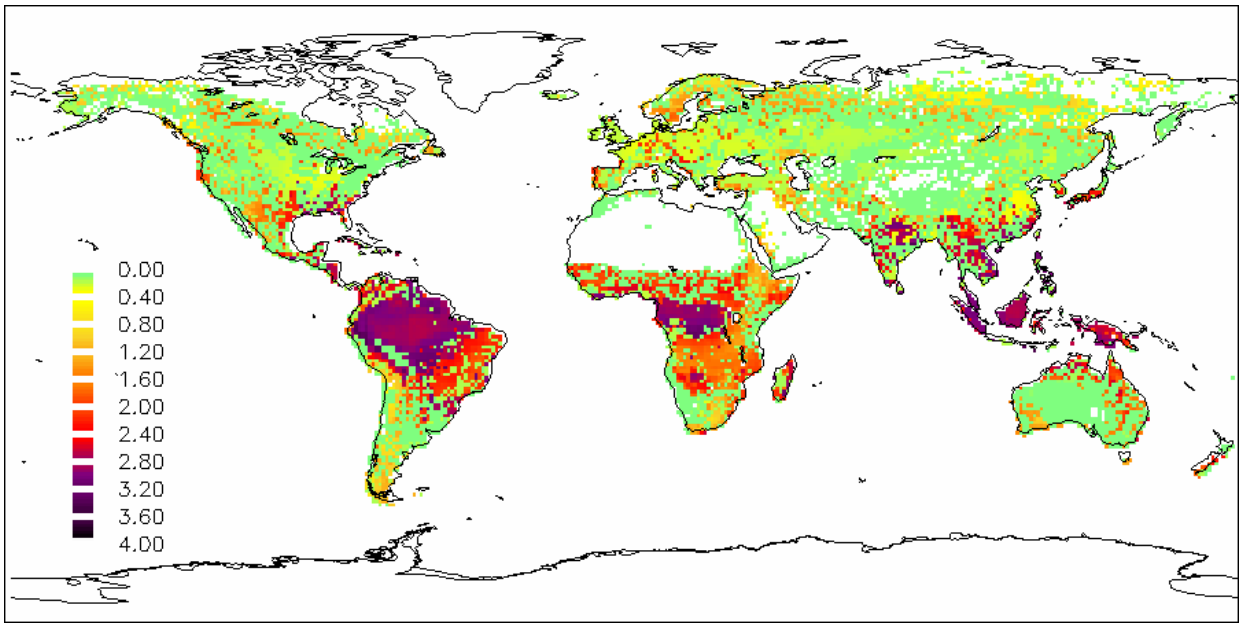

Figure 9. Annual global total ecosystem respiration [kg C m-2 yr-1] average over 1990-1999. The total ecosystem respiration includes three components: mortality respiration (MR), growth respiration (GR), and heterotrophic respiration (HR).

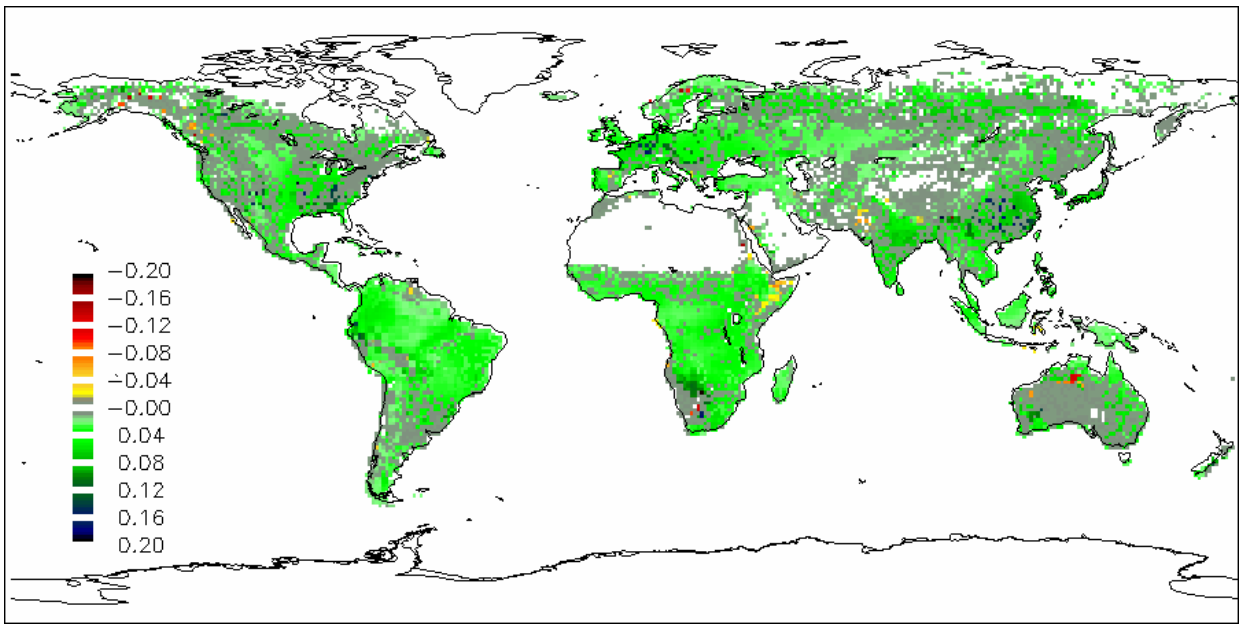

Figure 10. Annual global NEP [kg C m-2 yr-1] average over 1990-1999 calculated as NEP = GPP-MR-GR-HR.

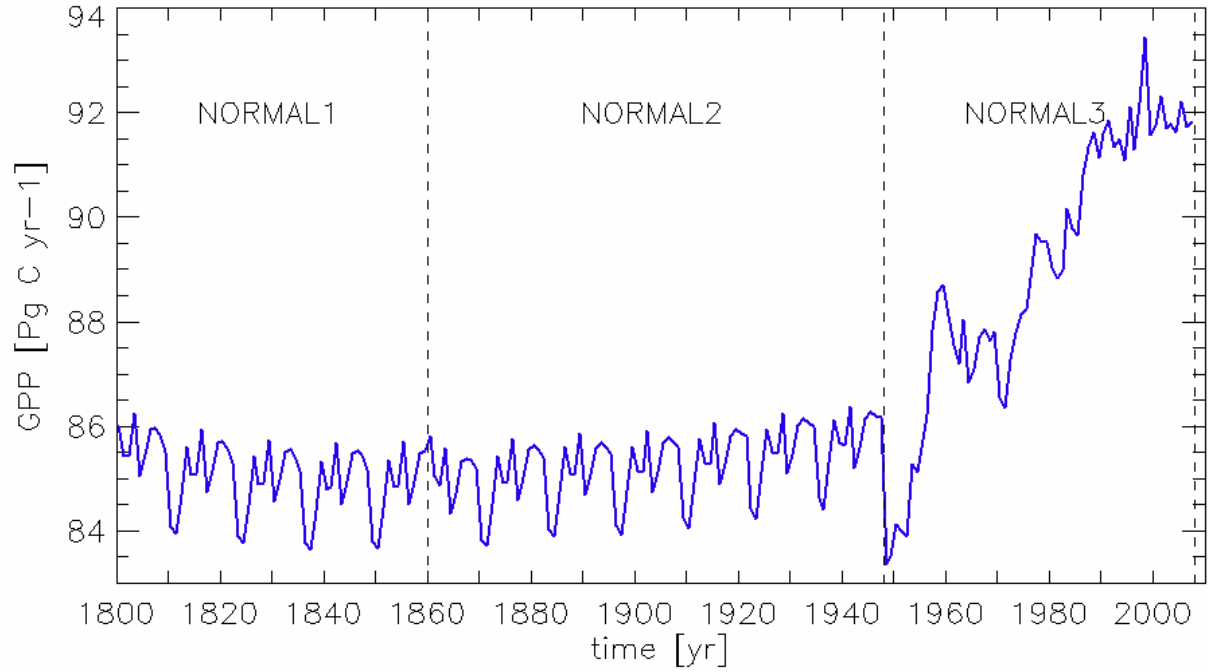

Figure 11. Total global GPP [PgC yr-1] in 1800-2007 calculated in a normal model run that was split in three steps: 1) NORMAL1 simulation for 1800-1859, 2) NORMAL2 simulation for 1860-1947, and 3) NORMAL3 simulation for 1948-2007.

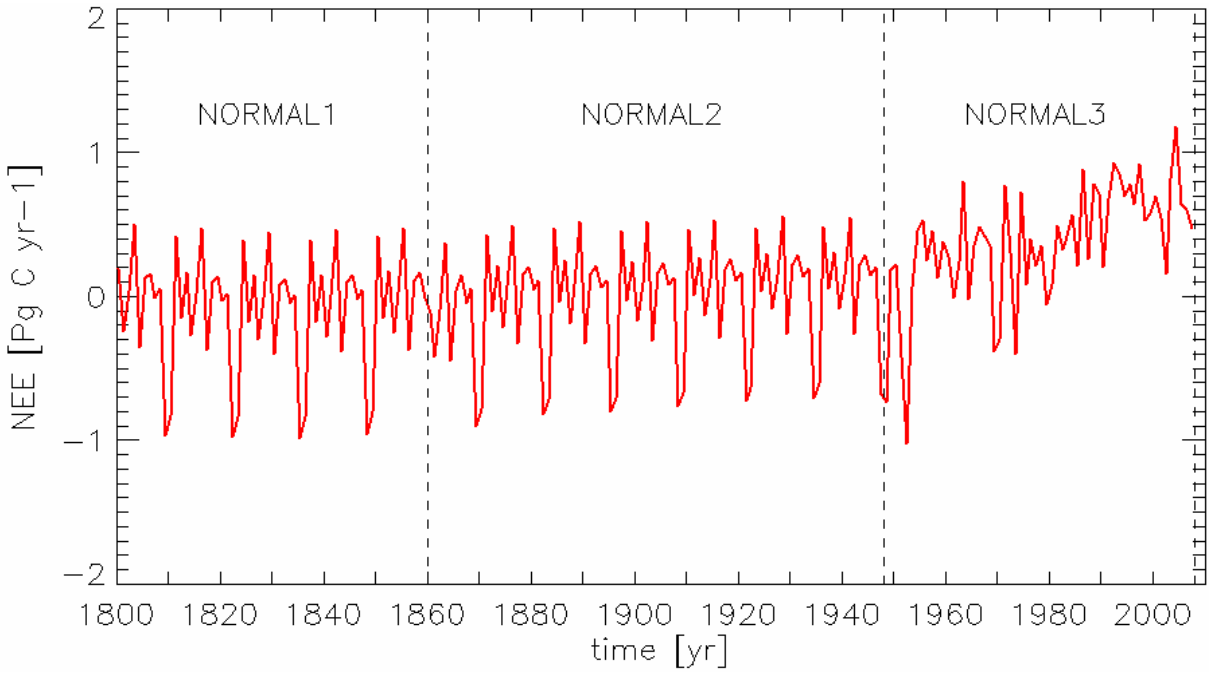

Figure 12. Total global NEP [PgC yr-1] in 1800-2007 calculated in a normal model run that was split in three steps: 1) NORMAL1 simulation for 1800-1859, 2) NORMAL2 simulation for 1860-1947, and 3) NORMAL3 simulation for 1948-2007.

HOW TO COMPILE MODEL OUTPUT USING FRACTIONAL LAND COVER MAP?

This chapter describes an alternative way of running the GBIOME-BGCv1 model for calculating model output using the fractional land cover data. The calculation is illustrated on the example for calculation GPP flux step by step:

1) You have to choose the spatial resolution on which you would like to resolve the GPP flux (final product).
2) Acquire the fractional land cover data of the required resolution for the domain of interest. Please note: classification of plant functional types within the land cover data should be consistent with the one in the model.
3) For each land cover type included into the fractional land cover dataset perform a complete series of model simulations (spinup, normal transitional and normal final runs) with same land cover time all over the domain area. For example, the files *lc<i>_360x180.int, i*=1,7 specified in the LANDCOVER_FILE block can be used. Each *lc<i>_360x180.int* file contains a map of one land cover type (*i*) spread all over the land area of the domain.
4) For each grid cell of the final product calculate the contributions of each land cover type to the total flux proportionally to their land fraction. Add together all contributing fluxes (Figure 13).

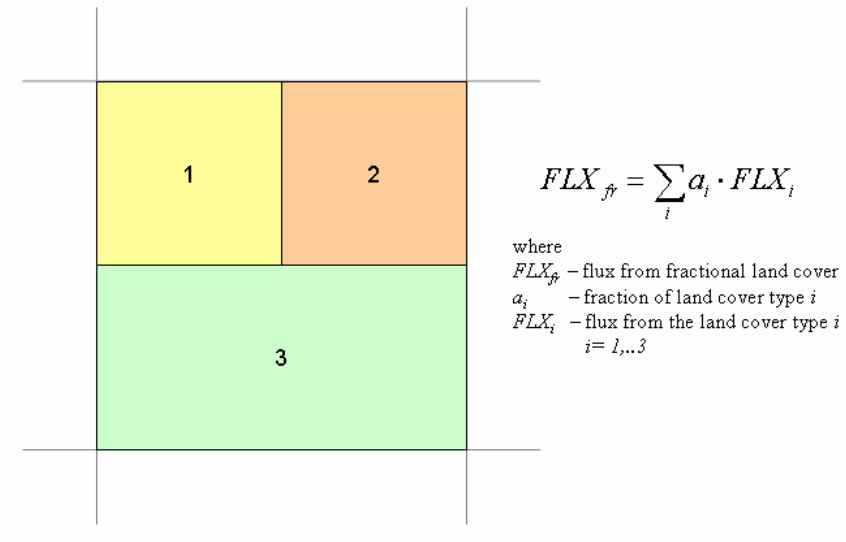

Figure 13. Contributions of different land cover types to the total flux of carbon/nitrogen/water within a grid cell of final product.

NOTE: in this chapter the principle of model output calculation based on the fractional land cover data was presented. This principle can be applied to all models state and output variables.

An IDL-script for calculating GPP, NEP, and the total ecosystem respiration fluxes on spatial resolutions of 1°, 1/4°, and 1/10° (degree) can be found in "*IDL Script for Compiling Model Output Using a Fractional Land Cover Map*".

APPENDICES

Initialisations File *spinup_1800.ini*

```
GBIOME-BGCv1 : (spinup simulation, reference year 1800)

RUN_DIR (keyword - do not remove)
../RUN/

RUN_TIME (keyword - do not remove)
1800          (int) first simulation year
60            (int) tot number of simulation years (if normal simulation)
1800          (int) first year of output           (if normal simulation)
1859          (int) last year of output            (if normal simulation)
1             (flag)1=spinup simulation   0=normal simulation
6000          (int) maximum number of spinup years (if spinup simulation)

RESTART_CONTROL (keyword - do not remove)
0               (flag) 1=read restart file   0=don't read restart file
1               (flag) 1=write restart file  0=don't write restart file
restart_xxxxxx      (name) input restart filename
restart_spinup_1800 (name) output restart filename

SUB_MAP   (keyword - do not remove)
1         (int) first row in the region
180       (int) last row in the region
1         (int) first column in the region
360       (int) last column in the region

GLOBAL_MAP (keyword - do not remove)
180         (int) number of rows in the global domain
360         (int) number of columns in the global domain

METEO_DIR (keyword - do not remove)
../DATA/meteo_1948-present_NCEP_1year/

METEO_TIME (keyword - do not remove)
1968       (int) first year of meteo data
1977       (int) last year of meteo data

SURFACE_DIR (keyword - do not remove)
../DATA/surface/

LANDCOVER_FILE (keyword - do not remove)
syn_dom    (name) land cover file

EPC_DIR (keyword - do not remove)
../DATA/epc/

NDEP_DIR (keyword - do not remove)
../DATA/ndeposition/

NDEP_CONTROL (keyword - do not remove)
0             (flag)      0=constant   1=file for Ndep
0.0004        (kgN m-2/yr) symbiotic+asymbiotic fixation of N

NDEP_FILE (keyword - do not remove)
Ndep_Holland_2kgha-1yr-1 (name) N dep file

CO2_DIR (keyword - do not remove)
```

```
../DATA/co2/

CO2_CONTROL (keyword - do not remove)
0           (flag) 0=constant 1=file for CO2
283.0       (ppm)  constant atmospheric CO2 concentration

CO2_FILE    (keyword - do not remove)
co2_CarboeuropeIP_allyears_1800-2007    (name) CO2 conc file

OUTPUT_CONTROL (keyword - do not remove)
0   (flag)  1 = write daily output   0 = no daily output
0   (flag)  1 = write monthly output 0 = no monthly output
1   (flag)  1 = write annual output  0 = no annual output

OUTPUT_INDX (keyword - do not remove)
2       (int) number of variables to output
620     (int) index of output parameter
621     (int) index of output parameter

END_INIT (keyword - do not remove)
```

Initialisations File *normal_1800-1859.ini*

```
GBIOME-BGCv1 : (normal simulation 1800-1859)

RUN_DIR (keyword - do not remove)
../RUN/

RUN_TIME (keyword - do not remove)
1800          (int) first simulation year
60            (int) tot number of simulation years (if normal simulation)
1800          (int) first year of output           (if normal simulation)
1859          (int) last year of output            (if normal simulation)
0             (flag)1=spinup simulation   0=normal simulation
6000          (int) maximum number of spinup years (if spinup simulation)

RESTART_CONTROL (keyword - do not remove)
1               (flag) 1=read restart file   0=don't read restart file
1               (flag) 1=write restart file  0=don't write restart file
restart_spinup      (name) input restart filename
restart_1800-1859   (name) output restart filename

SUB_MAP   (keyword - do not remove)
1         (int) first row in the region
180       (int) last row in the region
1         (int) first column in the region
360       (int) last column in the region

GLOBAL_MAP (keyword - do not remove)
180        (int) number of rows in the global domain
360        (int) number of columns in the global domain

METEO_DIR (keyword - do not remove)
../DATA/meteo_1948-present_NCEP_1year/

METEO_TIME (keyword - do not remove)
1968       (int) first year of meteo data
1977       (int) last year of meteo data
```

```
SURFACE_DIR (keyword - do not remove)
../DATA/surface/

LANDCOVER_FILE (keyword - do not remove)
syn_dom  (name) land cover file

EPC_DIR (keyword - do not remove)
../DATA/epc/

NDEP_DIR (keyword - do not remove)
../DATA/ndeposition/

NDEP_CONTROL (keyword - do not remove)
0            (flag)      0=constant   1=file for Ndep
0.0004       (kgN m-2/yr) symbiotic+asymbiotic fixation of N

NDEP_FILE (keyword - do not remove)
Ndep_Holland_2kgha-1yr-1 (name) N dep file

CO2_DIR (keyword - do not remove)
../DATA/co2/

CO2_CONTROL (keyword - do not remove)
1           (flag) 0=constant 1=file for CO2
283.0       (ppm)  constant atmospheric CO2 concentration

CO2_FILE (keyword - do not remove)
co2_CarboeuropeIP_allyears_1800-2007 (name) CO2 conc file

OUTPUT_CONTROL (keyword - do not remove)
0   (flag)  1 = write output   0 = no daily output
0   (flag)  1 = write monthly output 0 = no monthly output
1   (flag)  1 = write annual output  0 = no annual output

OUTPUT_INDX (keyword - do not remove)
2       (int) number of daily variables to output
620     (int) index of output parameter
621     (int) index of output parameter

END_INIT (keyword - do not remove)
```

Initialisations File *normal_1860-1947.ini*

```
GBIOME-BGCv1 : (normal simulation 1860-1947)

RUN_DIR (keyword - do not remove)
../RUN/

RUN_TIME (keyword - do not remove)
1860          (int) first simulation year
88            (int) tot number of simulation years (if normal simulation)
1860          (int) first year of output           (if normal simulation)
1947          (int) last year of output            (if normal simulation)
0             (flag)1=spinup simulation   0=normal simulation
6000          (int) maximum number of spinup years (if spinup simulation)

RESTART_CONTROL (keyword - do not remove)
1               (flag) 1=read restart file   0=don't read restart file
1               (flag) 1=write restart file  0=don't write restart file
```

```
restart_1800-1859   (name) input restart filename
restart_1860-1947   (name) output restart filename

SUB_MAP   (keyword - do not remove)
1         (int) first row in the region
180       (int) last row in the region
1         (int) first column in the region
360       (int) last column in the region

GLOBAL_MAP (keyword - do not remove)
180         (int) number of rows in the domain
360         (int) number of columns in the domain

METEO_DIR (keyword - do not remove)
../DATA/meteo_1948-present_NCEP_1year/

METEO_TIME (keyword - do not remove)
1968       (int) first year of meteo data
1977       (int) last year of meteo data

SURFACE_DIR (keyword - do not remove)
../DATA/surface/

LANDCOVER_FILE (keyword - do not remove)
syn_om  (name) land cover file

EPC_DIR (keyword - do not remove)
../DATA/epc/

NDEP_DIR (keyword - do not remove)
../DATA/ndeposition/

NDEP_CONTROL (keyword - do not remove)
1            (flag)      0=constant   1=file for Ndep
0.0004       (kgN m-2/yr) symbiotic+asymbiotic fixation of N

NDEP_FILE (keyword - do not remove)
Ndep_Holland_2kgha-1yr-1 (name) N dep file

CO2_DIR (keyword - do not remove)
../DATA/co2/

CO2_CONTROL (keyword - do not remove)
1            (flag) 0=constant 1=file for CO2
283.0        (ppm)  constant atmospheric CO2 concentration

CO2_FILE    (keyword - do not remove)
co2_CarboeuropeIP_allyears_1800-2007 (name) CO2 conc file

OUTPUT_CONTROL (keyword - do not remove)
0   (flag)  1 = write daily output   0 = no daily output
0   (flag)  1 = write monthly output 0 = no monthly output
1   (flag)  1 = write annual output  0 = no annual output

OUTPUT_INDX (keyword - do not remove)
2       (int) number of variables to output
620     (int) index of output parameter
621     (int) index of output parameter

END_INIT (keyword - do not remove)
```

Initialisations File *normal_1948-2007.ini*

```
GBIOME-BGCv1 : (normal simulation 1948-2007)

RUN_DIR (keyword - do not remove)
../RUN/

RUN_TIME (keyword - do not remove)
1948          (int) first simulation year
60            (int) tot number of simulation years (if normal simulation)
1948          (int) first year of output           (if normal simulation)
2007          (int) last year of output            (if normal simulation)
0             (flag)1=spinup simulation   0=normal simulation
6000          (int) maximum number of spinup years (if spinup simulation)

RESTART_CONTROL (keyword - do not remove)
1               (flag) 1=read restart file   0=don't read restart file
1               (flag) 1=write restart file  0=don't write restart file
restart_1860-1947   (name) input restart filename
restart_1948-2007   (name) output restart filename

SUB_MAP   (keyword - do not remove)
1         (int) first row in the region
180       (int) last row in the region
1         (int) first column in the region
360       (int) last column in the region

GLOBAL_MAP (keyword - do not remove)
180         (int) number of rows in the global domain
360         (int) number of columns in the global domain

METEO_DIR (keyword - do not remove)
../DATA/meteo_1948-present_NCEP_1year/

METEO_TIME (keyword - do not remove)
1968       (int) first year of meteo data
1977       (int) last year of meteo data

SURFACE_DIR (keyword - do not remove)
../DATA/surface/

LANDCOVER_FILE (keyword - do not remove)
syn_dom  (name) land cover file

EPC_DIR (keyword - do not remove)
../DATA/epc/

NDEP_DIR (keyword - do not remove)
../DATA/ndeposition/

NDEP_CONTROL (keyword - do not remove)
1             (flag)      0=constant   1=file for Ndep
0.0004        (kgN m-2/yr) symbiotic+asymbiotic fixation of N

NDEP_FILE (keyword - do not remove)
Ndep_Holland_2kgha-1yr-1 (name) N dep file

CO2_DIR (keyword - do not remove)
../DATA/co2/
```

```
CO2_CONTROL (keyword - do not remove)
1           (flag) 0=constant 1=file for CO2
283.0       (ppm)  constant atmospheric CO2 concentration

CO2_FILE    (keyword - do not remove)
co2_CarboeuropeIP_allyears_1800-2007 (name) CO2 conc file

OUTPUT_CONTROL (keyword - do not remove)
0   (flag)  1 = write daily output   0 = no daily output
0   (flag)  1 = write monthly output 0 = no monthly output
1   (flag)  1 = write annual output  0 = no annual output

OUTPUT_INDX (keyword - do not remove)
8       (int) number of variables to output
620     (int) index of output parameter
621     (int) index of output parameter
622     (int) index of output parameter
623     (int) index of output parameter
624     (int) index of output parameter
625     (int) index of output parameter
626     (int) index of output parameter
627     (int) index of output parameter

END_INIT (keyword - do not remove)
```

Index Numbers and Types of Temporal Aggregation for Output Variables

Type of output aggregation of daily values into monthly | yearly.

* - average value
** - total value
*** - last day value

ID	Structure	Meaning	aggregation
0-19	metv→...	daily meteorological variables	*
20-28	ws→...	water state variables	***
35-44	wf→...	water flux variables	**
50-99	Cs→...	carbon state variables	***
120-242	Cf→...	carbon flux variables	**
280-314	Ns→...	nitrogen state variables	***
340-456	Nf→...	nitrogen flux variables	**
480-484	phen→...	phenological variables	***
500-545	epv→...	ecophysiological variables	*
560-579	psn_sun→...	photosynthesis variables, sunlit canopy fraction	*
590-609	psn_shade→...	photosynthesis variables, shaded canopy fraction	*
620-640	summary→...	carbon budget summary output variables	**

Here model output variables are grouped and no indices are given for individual parameters. The indices can be found in the model source file *output_map_init.c* (parameter indecies) and file *bgc_struct.h* (parameter units).

A short list of most frequently used model output parameters is listed below.

Carbon Budget Summary Output Variables:

ID	Structure→parameter	Meaning	aggregation
		daily variables	
620	summary→daily_npp	net primary production	**
621	summary→daily_nep	net ecosystem production	**
622	summary→daily_nee	net ecosystem exchange	**
623	summary→daily_gpp	gross primary production	**
624	summary→daily_mr	mortality respiration	**
625	summary→daily_gr	growth respiration	**
626	summary→daily_hr	heterotrophic respiration	**
627	summary→daily_fire	loss through fire	**
		summed over entire simulation	
628	summary→cum_npp	net primary production	**
629	summary→cum_nep	net ecosystem production	**
630	summary→cum_nee	net ecosystem exchange	**
631	summary→cum_gpp	gross primary production	**
632	summary→cum_mr	mortality respiration	**
633	summary→cum_gr	growth respiration	**
634	summary→cum_hr	heterotrophic respiration	**
635	summary→cum_fire	loss through fire	**
		miscellaneous	
636	summary→vegc	total vegetation carbon	**
637	summary→litrc	total litter carbon	**
638	summary→soilc	total soil carbon	**
639	summary→totalc	total of vegetation, litter and soil carbon	**
640	summary→daily_litfallc	total litterfall carbon	**

Fields in Restart File

Num	Parameter name	Meaning	Units
1	soilw	water stored in soil	[kg H2O m-2]
2	snoww	water stored in snowpack	[kg H2O m-2]
3	canopyw	water stored on canopy	[kg H2O m-2]
4	leafc	leaf C	[kg C m-2]
5	leafc_storage	leaf C storage	[kg C m-2]
6	leafc_transfer	leaf C transfer	[kg C m-2]
7	frootc	fine root C	[kg C m-2]
8	frootc_storage	fine root C storage	[kg C m-2]
9	frootc_transfer	fine root C transfer	[kg C m-2]
10	livestemc	live stem C	[kg C m-2]
11	livestemc_storage	live stem C storage	[kg C m-2]
12	livestemc_transfer	live stem C transfer	[kg C m-2]
13	deadstemc	dead stem C	[kg C m-2]
14	deadstemc_storage	dead stem C storage	[kg C m-2]
15	deadstemc_transfer	dead stem C transfer	[kg C m-2]
16	livecrootc	live coarse root C	[kg C m-2]
17	livecrootc_storage	live coarse root C storage	[kg C m-2]
18	livecrootc_transfer	live coarse root C transfer	[kg C m-2]
19	deadcrootc	dead coarse root C	[kg C m-2]
20	deadcrootc_storage	dead coarse root C storage	[kg C m-2]
21	deadcrootc_transfer	dead coarse root C transfer	[kg C m-2]
22	gresp_storage	growth respiration storage	[kg C m-2]
23	gresp_transfer	growth respiration transfer	[kg C m-2]
24	cwdc	coarse woody debris C	[kg C m-2]
25	litr1c	litter labile C	[kg C m-2]
26	litr2c	litter unshielded cellulose C	[kg C m-2]
27	litr3c	litter shielded cellulose C	[kg C m-2]
28	litr4c	litter lignin C	[kg C m-2]
29	soil1c	microbial recycling pool C (fast)	[kg C m-2]
30	soil2c	microbial recycling pool C (medium)	[kg C m-2]
31	soil3c	microbial recycling pool C (slow)	[kg C m-2]
32	soil4c	recalcitrant SOM C (humus, slowest)	[kg C m-2]
33	cpool	temporary photosynthate C pool	[kg C m-2]
34	leafn	leaf N	[kg N m-2]
35	leafn_storage	leaf N	[kg N m-2]
36	leafn_transfer	leaf N	[kg N m-2]
37	frootn	fine root N	[kg N m-2]
38	frootn_storage	fine root N storage	[kg N m-2]
39	frootn_transfer	fine root N transfer	[kg N m-2]
40	livestemn	live stem N	[kg N m-2]
41	livestemn_storage	live stem N storage	[kg N m-2]
42	livestemn_transfer	live stem N transfer	[kg N m-2]
43	deadstemn	dead stem N	[kg N m-2]
44	deadstemn_storage	dead stem N storage	[kg N m-2]
45	deadstemn_transfer	dead stem N transfer	[kg N m-2]
46	livecrootn	live coarse root N	[kg N m-2]
47	livecrootn_storage	live coarse root N storage	[kg N m-2]
48	livecrootn_transfer	live coarse root N transfer	[kg N m-2]
49	deadcrootn	dead coarse root N	[kg N m-2]
50	deadcrootn_storage	dead coarse root N storage	[kg N m-2]
51	deadcrootn_transfer	dead coarse root N transfer	[kg N m-2]
52	cwdn	coarse woody debris N	[kg N m-2]
53	litr1n	litter labile N	[kg N m-2]
54	litr2n	litter unshielded cellulose N	[kg N m-2]
55	litr3n	litter shielded cellulose N	[kg N m-2]
56	litr4n	litter lignin N	[kg N m-2]

57	soil1n	microbial recycling pool N (fast)	[kg N m-2]
58	soil2n	microbial recycling pool N (medium)	[kg N m-2]
59	soil3n	microbial recycling pool N (slow)	[kg N m-2]
60	soil4n	recalcitrant SOM N (humus, slowest)	[kg N m-2]
61	sminn	soil mineral N	[kg N m-2]
62	retransn	plant pool of retranslocated N	[kg N m-2]
63	npool	temporary plant N pool	[kg N m-2]
64	day_leafc_litfall_increment	rate leaf litfall	[kg C m-2 d-1]
65	day_frootc_litfall_increment	rate froot litfall	[kg C m-2 d-1]
66	day_livestemc_turnover_increment	rate livestem turnover	[kg C m-2 d-1]
67	day_livecrootc_turnover_increment	rate livecroot turnover	[kg C m-2 d-1]
68	annmax_leafc	annual maximum daily leaf C	[kg C m-2]
69	annmax_frootc	annual maximum daily froot C	[kg C m-2]
70	annmax_livestemc	annual maximum daily livestem C	[kg C m-2]
71	annmax_livecrootc	annual maximum daily livecroot C	[kg C m-2]
72	dsr	number of days since rain, for soil evap	[days]

IDL Script for Compiling Model Output Using a Fractional Land Cover Map

```
pro compile_fractional_flux
!ORDER=1

;-- choose spatial resolution for fractional data
;-- (comment out one option)
;resolution = 0.10
 resolution = 0.25
;resolution = 1.00

;-- set time (year) for output fractional flux
yfirst = 2007
ylast  = 2007

;-- what model parameters to process?
;-- set parameter numbers from param1 to param2
param1 = 622
param2 = 627

;-- numbers of carbon budget output parameters
;620 -  daily npp
;621 -  daily nep
;622 -  daily nee
;623 -  daily gpp
;624 -  daily mr
;625 -  daily gr
;626 -  daily hr
;627 -  daily fire

;-- one fractional flux is composed from fluxes for all veg. types
;1   -  c3(grass+crop)
;2   -  c4(grass+crop)
;3   -  shrub
;4   -  dbf
;5   -  dnf
;6   -  ebf
;7   -  enf

;-- suffixes for intermediate files
suffixes = ['C3','C4','shrub','dbf','dnf','ebf','enf']

;-- processing of data is split into 4 parts due to the memory and time
requirements
PART0 = 1   ; read "raw" model output and save each year separately
PART1 = 1   ; read 1year, save monthly or 5-daily files
PART2 = 1   ; compose fractional monthly or 5-daily flux files
PART3 = 1   ; paste monthly or 5-daily files into 1-year files
;Note: monthly intermediate files are created for resolutions 1.00,0.25
;Note: 5-daily intermediate files are created for resolution 0.10

;-- set SWE (swap endian) option
;-- 'BE'- big endian 'LE'-little endian
SWE = 'BE'

;-- prefix for flux data
prefix_original= 'Y:\output\ORIGINAL\'
prefix_1yearly = 'Y:\output\PART1_ORIGINAL1YEARLY\'
```

```
prefix_1monthly= 'Y:\output\PART2_1MONTHLY\'
prefix_1monthlyfractional= 'Y:\PART3_1MONTHLY_FRACTIONAL\'
prefix_1yearlyfractional = 'Y:\PART4_1YEARLY_FRACTIONAL\'

if(resolution eq 0.10)then begin
  prefix_1monthly= 'Y:\output\PART2_5DAILY\'
  prefix_1monthlyfractional= 'Y:\output\PART3_5DAILY_FRACTIONAL\'
endif

;-- file with fractions data for different resolutions
;-- (chosen depending on the output resolution)
if(resolution eq 0.10)then begin
  file_lcfraction = 'Y:\DATA_fractional\FR_0.10deg\syn_lc_glob_6min_'
endif
if(resolution eq 0.25)then begin
  file_lcfraction = 'Y:\DATA_fractional\FR_0.25deg\syn_lc_glob_15min_'
endif
if(resolution eq 1.00)then begin
  file_lcfraction = 'Y:\DATA_fractional\FR_1.00deg\syn_lc_glob_60min_'
endif

;-- dimensions for flux data
timestep = 'day'
nday = 365
ncol = 360
nrow = 180

;-- dimensions for land use data
luncol = round(360/resolution)
lunrow = round(180/resolution)

;-- days in months
;--         jan  feb mar apr may jun jul aug sep oct nov dec
monthdays = [ 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]

;-- for 0.10 resolution blocks by 5 days
;-- days in blocks [5,5,5,..,5]
if(resolution eq 0.10)then begin
  monthdays = intarr(73)
  for i=0,72 do monthdays(i)=5
endif
nmonths = n_elements(monthdays)
print,nmonths,"  BLOCKS: ",monthdays
print," "

;-- prefix for flux files (general name)
gname = 'BGCOUT'

;***** SPLIT 1-YEAR FILES INTO 1-MONTH FILES *****

if(PART0 eq 1)then begin
 nyear = ylast-yfirst+1
 for parnum=param1,param2 do begin
   for lcidx=1,7 do begin
    str1 = gname+'_lc'+STRING(lcidx,FORMAT='(I1)')+'_'
    str2 = '_'+timestep+'_N_'+STRING(parnum,FORMAT='(I3)')+'_WHOLE'
    filein = 'NCEP'+'_lc'+STRING(lcidx,FORMAT='(I1)')+'_'+$
    STRING(yfirst,FORMAT='(I4)')+'-'+STRING(ylast,FORMAT='(I4)')+str2

    print,"Read file: ",prefix_original+filein
      close,1
```

```
      openr,1,prefix_original+filein
      for y=0,nyear-1 do begin
        filetemp = str1+STRING(yfirst+y,FORMAT='(I4)')+str2
        print,"Write file: ",2+y,"   ",prefix_1yearly+filetemp
        close,2+y
        openw,2+y,prefix_1yearly+filetemp
      end

      part = fltarr(365)
      for i=0,nrow-1 do begin
        for j=0, ncol-1 do begin
          for y=0,nyear-1 do begin
            readu,1,part
            writeu,2+y,part
          endfor
        endfor
      endfor
      part = 0

      for y=0,nyear-1 do close,2+y
      close,1
   endfor
 endfor
endif ; if PART0 =1

;***** SPLIT ORIGINAL BIOME_BGC YEARLY FILES INTO MONTHLY FILES *****

if(PART1 eq 1)then begin
  ;-- split yearly flux files on monthly
  str1 = gname+'_lc'
  for param=param1,param2 do begin
    str2 = '_day_N_'+STRING(param,format='(I3)')+'_WHOLE'
    for y=yfirst,ylast do begin
      ;-- single map for reading
      flux=fltarr(nday,ncol,nrow)
      for lc=1,7 do begin
        filein=prefix_1yearly+str1+STRING(lc,format='(I1)')+'_'+$
        STRING(y,format='(I4)')+str2
        print,'Read file: ',filein
        close,1
        openr,1,filein
        readu,1,flux
        close,1
        dayshift = 0
        for m=0,nmonths-1 do begin
          fileout=prefix_1monthly+str1+STRING(lc,format='(I1)')+'_'+$
          STRING(y,format='(I4)')+str2+'_'+STRING(m+1,FORMAT='(I2.2)')
          fluxmonth=fltarr(monthdays[m],ncol,nrow)

          fluxmonth[0:monthdays[m]-1,0:ncol-1,0:nrow-1]=$
          flux[dayshift:(dayshift+monthdays[m]-1),0:ncol-1,0:nrow-1]
          dayshift = dayshift+monthdays[m]
          print,'Write file: ',fileout
          close,1
          openw,1,fileout
          writeu,1,fluxmonth
          close,1
          fluxmonth=0
        endfor
      endfor
      flux=0
```

```
    endfor
  endfor
endif


;***** CREATE FRACTIONAL FLUX IN MONTHLY FILES *****

if(PART2 eq 1)then begin
   ;--- allocate land cover fraction map ---
   map_lcfraction    = bytarr(luncol,lunrow)
   map_waterfraction = bytarr(luncol,lunrow)

   ;-- water mask
   close,1
   print,"Read file (water mask): ",file_lcfraction+"water"
   openr,1,file_lcfraction+"water"
   readu,1,map_waterfraction
   close,1

   ;-- flag 1-when all pixels in the line are water
   ;-- flag 0-when at least one pixel is not a water pixel
   foundwater=0

   stopline = lunrow/2  ; line where flag turns to 1 or the last line
   while ((stopline lt lunrow)and(foundwater ne 1)) do begin
     res=where(map_waterfraction(*,stopline) eq 100,count)
     if(count eq 0)then foundwater=1
     stopline=stopline+1
   endwhile
   stopline=stopline-1
   print," Line after which all elements are water is ",stopline

   str1read = gname+'_lc'
   str1write= gname+'_'+string(resolution,format='(F4.2)')+'deg_lc'

   for param=param1,param2 do begin
     str2 = '_day_N_'+STRING(param,format='(I3)')+'_WHOLE'
     for y=yfirst,ylast do begin

       for m=0,nmonths-1 do begin
         totfluxmonth=fltarr(monthdays[m],luncol,lunrow)
         totfluxmonth(0:monthdays[m]-1,0:luncol-1,0:lunrow-1)=0

         for lc=1,7 do begin
           ;-- read the fraction map
           close,1
           print,"Read file: ",file_lcfraction+suffixes(lc-1)
           openr,1,file_lcfraction+suffixes(lc-1)
           readu,1,map_lcfraction
           close,1

           fileout=prefix_1monthly+str1read+STRING(lc,format='(I1)')$
           +'_'+STRING(y,format='(I4)')+$
           str2+'_'+STRING(m+1,FORMAT='(I2.2)')
           fluxmonth=fltarr(monthdays[m],ncol,nrow)
           print,'Read file: ',fileout
           close,1
           openr,1,fileout
           readu,1,fluxmonth
           close,1
        for i=0,stopline-1 do begin
```

```
         for j=0,luncol-1 do begin
          for d=0,monthdays[m]-1 do begin
           if(fluxmonth(d,j*resolution,i*resolution)gt -9999)then begin
             totfluxmonth(d,j,i)=totfluxmonth(d,j,i)+$
             fluxmonth(d,j*resolution,i*resolution)*$
             float(map_lcfraction(j,i))/100.0
           endif
          endfor
         endfor
        endfor

          fluxmonth=0
         endfor

    for i=0,stopline-1 do begin
     for j=0,luncol-1 do begin
      for d=0,monthdays[m]-1 do begin
       if(map_waterfraction(j,i)eq 100)then totfluxmonth(d,j,i)=-999999
      endfor
     endfor
    endfor

         for i=stopline,lunrow-1 do begin
           totfluxmonth(0:monthdays[m]-1,0:luncol-1,i)=-999999
         endfor
        fileout=prefix_1monthlyfractional+str1write$
        +'fractional_'+STRING(y,format='(I4)')+str2$
        +'_'+STRING(m+1,FORMAT='(I2.2)')+'.'+SWE
        print,'Write flux file ',fileout
        close,1
        if(SWE eq 'LE')then openw,1,fileout
        if(SWE eq 'BE')then openw,1,fileout,/SWAP_ENDIAN
        writeu,1,totfluxmonth
        close,1
        totfluxmonth=0
     endfor
   endfor
 endfor
   map_lcfraction=0
endif ; PART2=1...


;***** PASTE TOGETHER MONTHLY INTO YEARLY FILES *****

if(PART3 eq 1)then begin
    str1 = 'BGCOUT_'+string(resolution,format='(F4.2)')+'deg_lc'
    for param=param1,param2 do begin
      str2 = '_day_N_'+STRING(param,format='(I3)')+'_WHOLE'

      for y=yfirst,ylast do begin
        for m=0,nmonths-1 do begin
          close,m+1
          str2    = '_day_N_'+STRING(param,format='(I3)')+'_WHOLE'
          filemonth = prefix_1monthlyfractional+str1+'fractional_'+$
       STRING(y,format='(I4)')+str2+'_'+$
       STRING(m+1,FORMAT='(I2.2)')+'.'+SWE
          print,"Open input file: ",filemonth
          openr,m+1,filemonth
        endfor

        ; yearly file
```

```
        close,nmonths+2
        fileyear = prefix_1yearlyfractional+str1+'fractional_'+$
        STRING(y,format='(I4)')+str2+'.'+SWE
        print,"Open output file: ",fileyear
        openw,nmonths+2,fileyear

        for i=0,lunrow-1 do begin
          for j=0,luncol-1 do begin
            for m=0,nmonths-1 do begin
              onefluxmonth=fltarr(monthdays[m])
              readu,m+1,onefluxmonth
              writeu,nmonths+2,onefluxmonth
              onefluxmonth=0
            endfor
          endfor
        endfor

        for m=0,nmonths-1 do close,m+1
        close,nmonths+2
      endfor
    endfor

endif ; PART3=1...

end
```

Troubleshooting

Problem 1.

The modelled GPP/NPP/NEE drops in summer to low values, although the measured data show that there is no drought. This problem can occur for any vegetation type.

Solutions:

- Reduce **water canopy interception coefficient** (*.epc file, 0.041 → 0.0041). This parameter guides how much water is intercepted by the canopy and never reaches the soil. This parameter is badly defined, because it is difficult to measure it.
- Reduce **cuticular/stomatal conductance** (*.epc file) may also be reduced to avoid too high transpiration from the plant and soil.
- Increase **soil depth** (*soil_depth_360x180.flt*). The model use "effective" soil depth that may be different from the soil depth measured. Roots may be growing through cracks in rock and get water from deeper layers.

Problem 2.

The simulated growing season starts too early or finishes too late. The problem can occur in model simulations of deciduous forests, grasslands, and croplands.

Solution:

Employ "User specified phenology" in the model simulations. In the *.epc file

- set the corresponding flag to 0
- set year day to start new growth
- year-day to end litterfall

You may also adjust

- transfer growth period as fraction of growing season
- litterfall as fraction of growing season

Problem 3.

The simulated leaf area index is too high. The problem can occur in model simulations of any vegetation type.

Solution for forests:

- Check the age of simulated forest. By default the model simulates climax forest, i.e. the forest which is in equilibrium with climate. To simulate forest of certain age, edit restart file derived from spinup run, reduce vegetation carbon pools proportionally to replicate young plan.

Problem 4.

Once a map of a model parameter displayed it does not remind the contours of the simulated region. This map "shifts" may occur due to mismatches in the model input data i.e. mismatches of coastal line in land surface datasets.

Solution:

Check the input model data; make sure coastal lines and lateral boundaries of the model domain match for all input datasets.

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