The Large Scale Biosphere-Atmosphere Experiment in Amazônia, Model Intercomparison Project (LBA-MIP) protocol

Updates to this **LBA-MIP protocol** throughout are in blue and summarized here**:**

1. The datasets are distributed in UTC 00:00 time, the exact time coverage being determined by site-specific data availability.

2. The drivers will be distributed with leap day (Feb 29).

3. Table 1B (this protocol) was updated to include numerical percentages for each soil texture class based on a recent synthesis of the literature. The USDA texture classes table was removed since numerical values for texture classes are provided for each site in Table 1B.

4. Table 2: Period for K77 is now listed as 2001-2005.

5. We encourage folks to follow the topic "2.3(a) Phenological information" in this protocol. Please run your models with the different LAI sources: MODIS-derived (Table 3a), Reto Stockli's Phenology model-derived (Table 3b), and prognostic (if your model is capable of doing so).

6. In an effort to bring together NACP Synthesis and LBA-MIP participants into a common framework, additions and changes were made to tables 4A – F, and Tables 4G and 4H. Please take note of these changes and additions (all are listed in blue).

7. It is not necessary to report the entire time series from 1999 – 2006 for each site. Only those years for which driver data were given for any given site are required to be included in submission files

The Large Scale Biosphere-Atmosphere Experiment in Amazônia, Model Intercomparison Project (LBA-MIP) protocol

LBA-MIP website: http://www.climatemodeling.org/lba-mip/

Luis Gustavo de Goncalves (primary contact: Luis.G.DeGoncalves@nasa.gov)
Ian Baker (baker@atmos.colostate.edu)
Bradley Christoffersen (bchristo@email.arizona.edu)
Marcos Costa (mhcosta@ufv.br)
Natalia Restrepo-Coupe (ncoupe@email.arizona.edu)
Humberto da Rocha (humberto@model.iag.usp.br)
Scott Saleska (saleska@email.arizona.edu)
Michel Nobre Muza (michel.n.muza@nasa.gov)

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(variations from previous version highlighted in blue)

1. Summary

A. Motivation

The importance of the land-surface dynamics of the Amazon region to the global and regional climates, including water, heat and carbon exchanges between land and atmosphere, has motivated an evaluation of the performance of the land surface models by the LBA community. During the workshop *Integrating eddy flux tower sites, remote sensing, and models to understand Amazonian carbon dynamics*, which was held in Brasilia, Brazil in October 2006 in parallel with the 10th LBA-ECO Science Meeting, a working group was established to plan an LBA Model Intercomparison Project (LBA-MIP). The working group recognizes that by comparing the ecosystem models that simulate terrestrial energy, water and CO_2 fluxes with the continuous observations of these quantities over the LBA area will provide understanding on how well the models quantify the land surface process and define any deficiencies in the models and how they can be improved. As such, LBA-MIP will further the goals of the phase III of LBA which is focused on synthesis and analysis.

Similar studies have been conducted in the past. The well-known Project for Intercomparison of Land-surface Schemes (PILPS; Pitman et al. 1993, Henderson-Sellers et al. 1993, Henderson-Sellers et al. 1995) led to a distinct improvement in the understanding of the exchanges of water and energy between land surface and atmosphere. More recently, model intercomparison projects with specific objectives have focused on particular climatic conditions (e.g. SNOWMIP-2, PILPS-urban, PILPS semi arid and PILPS C-1). LBA now provides a unique data source for extending process-based understanding of the coupled terrestrial carbon and water cycle in the

Amazon. The LBA-MIP initiative has the potential to lead to an improved representation of seasonal-decadal land-atmosphere interactions in tropical climates of global climate simulations.

B. Objectives.

The goal is to gain comparative understanding of ecosystem models that simulate energy, water and CO_2 fluxes over the LBA area. **The task** is to subject all the models to the same forcing and experimental protocol, and compare the output. **The protocol** presented below proposes the model intercomparison to be executed in two major steps. The first step is to run models at eight individual LBA tower sites using the most up-to-date available atmospheric forcing and validation data. The second step is will then be to make gridded simulations with the models using the South American LDAS (SALDAS) atmospheric forcing dataset, which is based on the new CPTEC regional reanalysis and surface observations within the LBA region. Initial results from the first phase, generated in advance of LBA-MIP workshops on 24-25 September, 2007 and 2-3 May, 2008, lay ground for more detailed subsequent analysis and simulations suitable for comparison with field data.

In earlier 2010, in an effort to bring together NACP Synthesis and LBA-MIP participants into a common framework, some changes were made to this protocol. These adaptations are necessary to ensure NACP participants can also contribute to the LBA-MIP activities and vice-versa. Some of these changes, compared to previous versions of this protocol, include introducing more model output variables and adapting analysis strategy.

2. Data protocols

2.1 Sites description and driver data availability

Available sites range across a variety of land classes and soil types as documented in Tables 1A, 1B and 1C. Each group may prescribe additional soil characteristics (rooting depth, depth-to-bedrock, among others) that better suits its model requirements. Therefore, the parameters table used for each site and run as well as any other model assumptions should be reported in a separate README file. Therefore, it is required to report the parameters table used for each site and run, as well, as other model assumptions. Crop growth history for the two converted sites (Santarém K77 and FNS) and flooding history at Bananal Island (BAN), are expanded at Tables 1D, 1E and 1F, respectively:

Table 1A. Eddy covariance tower sites providing driver data for LBA-MIP Table 1B. Site characterization

ID	Short Code	Site Name	Longitude [deg]	Latitude [deg]	Elev. [m]	Tower Height [m]	Biome Type	IGBP Link
1	BAN	Javaes River - Bananal Island	-50.159111	-09.824417	120	40	Forest-Savanna	4
2	K34	Manaus Km34	-60.209297	-02.609097	130	50	Tropical rainforest	2
3	K67	Santarém Km67	-54.958889	-02.856667	130	63	Tropical rainforest	2
4	K77	Santarém Km77	-54.894357	-03.019833	130	18	Pasture-Agriculture	12
5	K83	Santarém Km83	-54.971435	-03.018029	130	64	Selectively logged tropical rainforest	2
6	RJA	Reserva Jarú	-61.930903	-10.083194	191	60	Tropical rainforest	2
7	FNS	Fazenda Nossa Senhora	-62.357222	-10.761806	306	8.5	Pasture	12
8	PDG	Reserva Pe-de-Gigante	-47.649889	-21.619472	690	21	Savanna	9

Principle Investigators and data references for these tower sites are as follows. Please see "Important Note on Data-Use policy," at the end of this section:

K34: Manzi, A., Nobre, A. (INPA, Brazil) (Araujo et al., 2002)
K67: Wofsy, S. (Harvard University, USA), Saleska, S. (UofA, USA), Camargo, A. CENA/USP, Brazil). (Hutyra et al., 2007; Saleska et al., 2003)
K83: Goulden M. (UC Irvine, USA), Miller, S. (SUNY, Albany, USA), da Rocha, H. (USP, Brazil). (da Rocha et al., 2004; Goulden et al., 2004; Miller et al., 2004)
K77: Fitzjarrald, D. (SUNY, Albany , USA) (Sakai et al., 2003)
RJA: Manzi, A. (INPA, Brasil), Cardoso, F. (UFR, Brazil.) (Kruijt et al., 2004; von Randow, 2004).
FNS: Waterloo, M.(Vrije Universiteit Amsterdam, The Netherlands), Manzi, A. (INPA, Brazil) (von Randow, 2004)
BAN: da Rocha, H. (USP, Brazil) (Borma et al., submitted)
PEG: da Rocha, H. (USP, Brazil) (da Rocha et al., 2002)

Table 1B. Site characterization

ID	Short	% Sand	% Silt	% Clay	Vegetation cover fraction	Canopy height [m]
1	BAN	24	39	37	0.98	16
2	K34	20	12	68	0.98	35
3	K67	2	8	90	0.98	35
4	K77	18	2	80	0 to 0.8	0 to 0.6
5	K83	18	2	80	0.98	35
6	RJA	80	10	10	0.98	30
7	FNS	80	10	10	0.85	0.2 to 0.5
8	PDG	85	12	3	0.80	12

Soil Texture references:

BAN: da Rocha, H. personal comunication (email Feb 4, 2009)
K34: Chambers, J.Q., J. dos Santos, R.J. Ribeiro, and N. Higuchi, Tree damage, allometric relationships, and aboveground net primary production in a central Amazon forest, Forest Ecology and Management, 152, 73–84, 2001.
K67: Williams, M., Y.E. Shimabukuro, D.A. Herbert, S.P. Lacruz, C. Renno, and E.B. Rastetter, Heterogeneity of soils and vegetation in an eastern Amazonian rain forest: Implications for scaling up biomass and production, Ecosystems, 5 (7), 692-704, 2002. (Average of sites 1, 3, 4)
K77: Same as K83
K83: Keller, M., R. Varner, J. Dias, and H. Silva, Soil-atmosphere exchange of nitrous oxide, methane, and carbon dioxide in logged and undisturbed forest in the Tapajós National Forest, Brazil, Earth Interactions, 9 (23), 1-28, 2005.
RJA: Andreae, M.O., P. Artaxo, C. Brandao, F.E. Carswell, P. Ciccioli, A.L. da Costa, A.D. Culf, J.L. Esteves, J.H.C. Gash, J. Grace, P. Kabat, J. Lelieveld, Y. Malhi, A.O. Manzi, F.X. Meixner, A.D. Nobre, C. Nobre, M.D.L.P. Ruivo, M.A. Silva-Dias, P. Stefani, R. Valentini, J. von Jouanne, and M.J. Waterloo, Biogeochemical cycling of carbon, water, energy, trace gases, and aerosols in Amazonia: the LBA-EUSTACH experiments, Journal of Geophysical Research, 107 (D20), Art. No. 8066, 2002.
FNS: same as RJA
PDG: da Rocha, H. personal comunication (email Feb 4, 2009)

Table 1C. IGBP biome classification

No.	Class name
0	Water
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needleleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forests
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands
13	Urban and Built-Up
14	Cropland/Natural Vegetation Mosaic
15	Snow and Ice
16	Barren or Sparsely Vegetated

Table 1D. K77 Crop growth history

Date	Cover Type K77 (Sakai et al., 2003)
Before ~Nov 1990	Moist tropical forest
Jan 2000 Sep 2000 (start EC) - Nov 14,2001	Grassland (pasture)
Nov 14, 2001–Feb 24, 2002	Barren (pasture was burned and plowed)
Feb 24, 2002–Jun 13–14, 2002	Cropland (non-irrigated rice)
Jun 13–14, 2002–Jan, 2003	Barren (after harvest spontaneous re-growth of rice)

Table 1E. FNS Crop growth history

Date	Cover Type FNS (von Randow, 2004)
Before ~1977	Tropical dry forest
1977	Deforested by fire
Since 1991	Pasture (cattle ranch)

Table 1F. BAN flooding schedule*

Year	Flooding starts	Flooding ends
2004	02-Feb-2004 **	10-Jun-2004
2005	12-Feb-2005	06-Jun-2005
2006	12-Dec-2005	17-Jun-2006

*: Based on soil moisture reaching saturation, approximated dates
**: Missing data

Site-specific driver data are available in ALMA-compliant NetCDF and ASCII formats at the LBA-MIP website: http://www.climatemodeling.org/lba-mip/.

Available data includes:

general site-specific information (see Table 1, above), in ASCII format only from the LBA-MIP website: ftp://ftp.climatemodeling.org/pub/lbamip/data/vegsoil.lbamip.txt

Atmospheric forcing data (see Section 2.2, below)

MODIS-derived vegetation phenological data (LAI, NDVI, EVI and FPAR), available for those models which cannot simulate fully dynamic vegetation prognostically (see Section 2.3, below).

Important Note on Data-Use policy

In accordance with LBA data sharing policy this data is freely available to all LBA researchers (http://www.lbaeco.org/lbaeco/data/data_poldoc.htm; see policy #2). Note, in particular, that policy #7 states that:

> *7. Where data are used for modeling or integrating studies, the scientist collecting the data will be credited appropriately, either by co-authorship or by citation. The data collectors should be informed of publication plans well in advance of submission of a paper, given an opportunity to read the manuscript, and be offered co-authorship. In cases where data from other investigators are a minor contribution to a paper, the data should be referenced by a citation. Users of the data will always have to state the source of the data*

Please note that, notwithstanding the availability of this common driver dataset, the LBA data sharing policy still requires any author or presenter of this data to contact and appropriately credit PIs from individual projects that generated the data used. The necessary contact information is given in the Table 1.

2.2 Atmospheric Forcing Datasets

The forcing data are ALMA-compliant, multi-year consistently-filled meteorological observations from selected LBA flux towers (Brasil flux network), including boundary conditions (site location, biome type, soil type and initial data). The data are for periods between 1999 and 2006 *in* UTC 00:00 time, the exact time coverage being determined by site-specific data availability (see table below). Forcing datasets include:

a. air temperature
b. specific humidity
c. module of wind speed
d. downward long wave radiation at the surface
e. surface pressure
f. precipitation
g. shortwave downward radiation at the surface
h. CO_2 will be set to 375 ppm.

These atmospheric drivers are provided at 1-hour time-step as ALMA-compliant ASCII and NetCDF format files (see http://www.lmd.jussieu.fr/~polcher/ALMA/). Models should use linear interpolation (except for solar radiation, where zenithal angle would be more appropriate) if they are run at shorter than a 1 hour time step. These data are available from the LBA-MIP website http://www.climatemodeling.org/lba-mip/

Table 2. Site-specific Availability of continuously filled driver data

	1999	2000	2001	2002	2003	2004	2005	2006
1. BAN								
2. K34								
3. K67								
4. K77								
5. K83								
6. RJA								
7. FNS								
8. PDG								

2.3 (a) Phenological information

Models with dynamic vegetation (DVMs) should be run in the mode in which they generate their own phenology (e.g., Leaf Area Index, LAI), and the value of LAI should be reported in the outputs (see Table 4F). To facilitate inclusion of those models which cannot prognostically simulate dynamic vegetation structure and phenology, a standard set of monthly LAI values derived by a phenology model (Stöckli et al., 2008) or MODIS-derived phenological information are provided (Tables 3a-c). It should be recognized that known remote sensing technical and physical uncertainties mean these data may be unreliable. However, to minimize these defects, aggregations of the best quality filtered satellite phenological information were derived for each tower site.

To facilitate comparison between models and to explore the effect of differences between dynamic vegetation model-derived and MODIS-derived vegetation phenologies, DVM's should be run in two modes if possible: i.e. in prognostic mode (in which leaf phenology is simulated) and in forced mode (in which model phenology is forced by the MODIS or phenology-model (Stöckli et al., 2008) derived). As not all sites allow for constant LAI values (e.g.: PDG or FNS), participants are encouraged to use LAI values in the following priority: modeled LAI (Table 3a), MODIS-derived monthly LAI (Table 3b) then MODIS-derived constant LAI (Table 3c). Please report both the source of the selected LAI, and the actual LAI values used.

Table 3a. Modeled monthly LAI (Stöckli et al., 2008)

ID	Short	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	BAN	5.27	5.05	4.99	4.99	5.00	5.14	5.24	5.26	5.26	5.27	5.31	5.32
2	K34	6.03	5.96	5.91	5.88	5.81	5.8	5.88	5.98	6.01	6.04	6.07	6.07
3	K67	5.77	5.71	5.67	5.62	5.63	5.63	5.70	5.80	5.82	5.82	5.82	5.81
4	K771	2.04	1.28	0.72	0.81	0.91	1.24	2.59	2.85	2.76	2.32	2.10	2.54
5	K83	5.59	5.39	5.36	5.41	5.48	5.53	5.67	5.76	5.75	5.75	5.76	5.76
6	RJA	5.64	5.64	5.64	5.65	5.63	5.63	5.63	5.63	5.63	5.64	5.64	5.64
7	FNS	5.56	5.60	5.63	5.61	5.46	4.74	3.77	3.15	3.34	4.13	4.95	5.43
8	PDG	3.41	3.56	3.54	3.5	3.21	2.90	2.49	2.21	2.13	2.29	2.48	2.98

Table 3b. MODIS-derived monthly LAI

ID	Short	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	BAN	5.35	4.58	4.63	4.71	4.77	4.51	4.88	4.86	4.81	4.9	4.24	5.6
2	K34	5.6	4.97	5.37	4.94	4.78	4.94	5.37	5.96	6.05	5.91	5.81	5.75
3	K67	5.08	5.43	5.58	5.19	4.93	5.33	5.22	5.56	5.15	5.55	5.5	5.73
4	K771	2.04	1.28	0.72	0.81	0.91	1.24	2.59	2.85	2.76	2.32	2.10	2.54
5	K83	5.13	4.10	5.24	4.89	4.66	4.96	5.00	4.90	4.86	4.93	5.42	5.01
6	RJA	5.09	5.20	4.38	5.18	4.79	4.85	4.97	5.31	5.50	5.56	5.18	5.44
7	FNS	4.81	5.70	5.23	4.64	5.15	4.62	3.38	3.27	2.10	3.82	3.98	4.82
8	PDG	2.03	2.67	3.06	3.49	3.26	2.92	2.22	1.74	1.28	1.49	1.89	2.32

Table 3c. MODIS-derived average LAI

ID	1	2	3	4	5	6	7	8
Short	BAN	K34	K67	K771	K83	RJA	FNS	PDG
LAI	4.82	5.45	5.35	1.85	4.93	5.12	4.29	2.36

Site history combined to LAI-2000 in-situ measurements at a similar site Santarém Km69 (18 July 2002) (Huete et al., 2007)

2.3 (b) Vegetation structure

A few of the eddy flux sites also have data on vegetation structure, for example: above-ground live biomass and biomass increment, litterfall rates, stocks of coarse wood debris, and soil respiration. We will endeavor to assemble this information for comparison to models in a timely manner.

2.4 Initialization and spin-up

Model physics and biophysics should be initialized as follows:

a) Soil moisture in all layers set to 0.95 of saturation (porosity)
b) Soil temperature in all layers set to the mean of the yearly air temperature
c) Because reliable carbon and nitrogen pools observations are not available, soil carbon, living biomass, etc should be spun up according to the best practices for each model, but the spin up procedure used should be documented.
d) Initial CO_2 values will also be assumed as steady-state solution

Spin-up for model physics and biogeochemistry should use one of the following procedures:

a) Replicate the driving dataset to achieve a 10-15 year simulation run
b) Replicating the driver dataset until the mean monthly soil moisture does not deviate by more than 0.1% from the previous year.

2.5 Model output

Model outputs should be uploaded at the LBA-MIP website:
http://www.climatemodeling.org/lba-mip/

The first phase of the LBA-MIP will focus on model simulations at eight individual towers using the meteorological forcing data from the LBA project. Participating models should be able to provide the defined set of variables in the ALMA-compliant format (please see ALMA website http://www.lmd.jussieu.fr/~polcher/ALMA/convention_3.html for units and details). This will allow compatibility among all the models and simplify comparisons. Output should be provided at 1-hour time-step, *in* UTC time in NetCDF for the variables listed below (see appendix for more information on NetCDF data format). The values of state variables should be given at the end of each time-step, fluxes should be averaged values over a time-step, and storage change variables should be accumulated over each time-step.

a. Model states and outputs
   i. Carbon fluxes: GPP, NPP, and Re.
   ii. Energy balance and hydrology: sensible and latent heat flux, net radiation for short and long wave, and runoff
   iii. Surface soil temperature and soil temperature by layer,
   iv. Soil moisture at the surface and soil moisture by layer
   v. Soil carbon (total, and by pools if possible, including separate litter pool)
   vi. Input parameters, re-output at the time resolution to simplify analysis
   vii. Parameters table used for soil description at each site and run, as well as other model assumptions should be reported (e.g. rooting depth).

b. Vegetation dynamics (if applicable);
   i. vegetation carbon (total, leaves, roots, woods etc. if possible)
   ii. Tree mortality, recruitment, and growth (in carbon flux and as annual rates) (broken down by components if possible: total, leaves, roots, and wood)

Table 4 shows the list of ALMA variables that each modeling group should return. If a variable is not deliverable, it should be replaced by the value of -999.99 that will represent either undefined or missing value. Please note the desired sign convention for flux directionality is specified in column five of the table. Because it may vary from model to model, reporting by model preference the analysis would complicate the future comparative model analysis.

Model diagnostic variables should comply with the following radiation energy and water conservation equations. Participants are advised to check against these before submitting their results. This will ensure that diagnostics, units and timings of the submitted results are appropriate for the analysis:

$$SWnet + LWnet - Qh - Qle - Qg = DelCanh /dt$$

Water balance (residual at all times should be smaller than $1x10^{-6}$ kg/m^2/s):

Rainf + Snowf - Evap - Qs - Qsb + Qrec = (DelIntercept + DelSrfStor + DelSoilMoist) /dt

For the LBA towers neither snow nor ice is separately diagnosed since these states are not likely to occur. If this is a problem for closing the energy and water balance above, please add snow states and fluxes to respective water state and flux variables. If the model needs additional diagnostic radiation, heat and water storage terms (e.g. canopy air space water and heat storage) on the right hand side of the above equations, please add those to the diagnostic output and let us know.

Some important notes on Table 4:

NetCDF dimensions: In addition to including variable names, descriptions, definitions, units, the expected sign convention, and priority, Table 4 now also specifies the expected NetCDF dimension of each variable in the NetCDF submission files. All NetCDF submission files should specify at least the following dimensions, and utilize them for each variable as specified in Table 4:

nsoil
npool
time

Nearly all variables have only one dimension: time. Some of the variables have a second dimension: nsoil (number soil layers), or npool (number carbon pools). Some variables are constants, and thus have "NA" for their NetCDF dimension.

Forcing variables: Note that in addition to the model simulations, the forcing variables are required as part of the output. This additional step is necessary to ensure proper synchronization between input and output. These variables are now listed in **Table 4G**.

NACP Participants only: Table 4 also has 2 additional columns, NACP code and NACP category, to help you match variables required by the NACP Site Synthesis Protocol with those required by the LBA-MIP protocol. **Table 4H** shows NACP variables **not** required for the LBA-MIP. However, we do not foresee any problems if the submission files include these variables.

Table 4A. General energy balance components:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
SWnet	Net shortwave radiation	Incoming solar radiation less the simulated outgoing shortwave radiation, averaged over a grid cell	W/m^2	Downward	Mandatory	time	E6**	Energy Flux
LWnet	Net long wave radiation	Incoming longwave radiation less the simulated outgoing longwave radiation averaged over grid cell	W/m^2	Downward	Mandatory	time	E2**	Energy Flux
Qle	Latent heat flux	Energy of evaporation, averaged over a grid cell	W/m^2	Upward	Mandatory	time	E5**	Energy Flux
Qh	Sensible heat flux	Sensible energy, averaged over a grid cell	W/m^2	Upward	Mandatory	time	E4**	Energy Flux
Qg	Ground heat flux	Heat flux into the ground, averaged over a grid cell	W/m^2	Downward	Mandatory	time	E3**	Energy Flux
DelCanHeat	Change in canopy heat storage	Change in canopy heat storage	J/m^2	Increase	Mandatory	time	*	*
DelSurfHeat	Change in surface heat storage	Change in heat storage over the soil layer and the vegetation for which the energy balance is calculated, accumulated over the sampling time interval.	J/m^2	Increase	Recommended	time	*	*

Note: These outputs are intended to capture energy budget components sufficient to ensure that the energy balance is satisfied: SWnet + LWnet - Qh - Qle - Qg = DelCanh /dt

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

Table 4B. General water balance components:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
Rainf	See Table 4G							
Evap	Total evapo-transpiration	Sum of all evaporation sources, averaged over a grid cell	$kg/m^2/s$	Upward	Mandatory	time	E1**	Energy Flux
Qs	Surface runoff	Runoff from the land surface and/or subsurface storm flow	$kg/m^2/s$	Out of gridcell	Mandatory	time	SM1**	Soil Moisture
Qrec	Recharge	Recharge from river to the flood plain	$kg/m^2/s$	Into gridcell	Optional	time	*	*
Qsb	Subsurface runoff	Gravity drainage and/or slow response lateral flow. Ground water recharge will have the opposite sign.	$kg/m^2/s$	Out of gridcell	Mandatory	time	SM2**	Soil Moisture
Qt	Total runoff	Qsb + Qs (allows water-budget closure for models that don't separate into Qs & Qsb)	$kg/m^2/s$	Out of gridcell	Mandatory	time	*	*
DelSoilMoist	Change in soil moisture	Change in the simulated vertically integrated soil water volume, averaged over a grid cell, accumulated over the sampling time interval.	kg/m^2	Increase	Mandatory	time	*	*
DelSurfStor	Change in surface water storage	Change in vertically integrated liquid water storage, other than soil, snow or interception (lake, depression and river channel etc.), accumulated over the sampling time interval.	kg/m^2	Increase	Recommended	time	*	*
DelIntercept	Change in interception storage	Change in the total liquid water storage in the canopy accumulated over the sampling time interval.	kg/m^2	Increase	Recommended	time	*	*
WaterTableD	Water table depth	Depth of the water table if it is considered by the land surface scheme	m	-	Mandatory (if modeled)	time	SM9**	Soil Moisture

Note: These outputs are intended to capture water budget components sufficient to ensure that the water balance is satisfied: Rainf - Evap - Qs - Qsb + Qrec = (DelIntercept + DelSrfStor + DelSoilMoist) /dt

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

Table 4C. Surface state variables:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
VegT	Vegetation canopy temperature	Vegetation temperature, averaged over all vegetation types	K	-	Mandatory	time	T2**	Temperature
BaresoilT	Temperature of bare soil	Surface bare soil temperature	K	-	Mandatory	time	*	*
AvgSurfT	Average surface temperature	Average of all vegetation, bare soil and snow skin temperatures	K	-	Mandatory	time	*	*
Albedo	Surface Albedo	Grid cell average albedo for all wavelengths.	-	-	Mandatory	time	*	*
SurfStor	Surface water storage	Total liquid water storage, other than soil, snow or interception storage (i.e. lakes, river channel or depression storage).	kg/m2	-	Mandatory	time	*	*
fPAR	Absorbed fraction of PAR	Absorbed fraction of incident photosynthetically active radiation	-	-	Recomended	time	P1**	Phenology

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

Table 4D. Subsurface State Variables

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
nsoil	number of soil layers	number of soil layers	NA	-	Mandatory	NA	M1	
z_top	Top of the soil layer	Upper boundary of the soil layer	m	-	Mandatory	nsoil	M2	*
z_bottom	Bottom of the soil layer	Lower boundary of the soil layer	m	-	Mandatory	nsoil	M3	*
z_node	Layer node depth	Layer node depth	m	-	Mandatory	nsoil	M4	*
SoilMoist	Layer soil moisture	Soil water content in each soil layer; includes the liquid, vapor and solid phases of water	kg/m2	-	Mandatory	nsoil, time	SM6**	Soil Moisture
SoilTemp	Average layer soil temperature	Soil temperature in each soil layer	K	-	Recommended	nsoil, time	ST2**	Soil Temperature
SoilWet	Total Soil Wetness	Vertically integrated soil moisture divided by maximum allowable soil moisture above wilting point.	-	-	Mandatory	time	SM8**	Soil Moisture

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

4E. Evaporation components:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
ECanop	Interception evaporation	Evaporation from canopy interception, averaged over all vegetation types within a grid cell.	kg/m2/s	Upward	Recommended	time	*	*
TVeg	Vegetation transpiration	Transpiration from canopy, averaged over all vegetation types within a grid cell.	kg/m2/s	Upward	Mandatory	time	E7**	Energy Flux
ESoil	Bare soil evaporation	Evaporation from bare soil.	kg/m2/s	Upward	Mandatory	time	*	*
EWater	Open water evaporation	Evaporation from surface water storage.	kg/m2/s	Upward	Recommended	time	*	*
RootMoist	Root zone soil moisture	Total simulated soil moisture available for evapotranspiration.	kg/m2	-	Mandatory	time	SM3**	Soil Moisture
CanopInt	Total canopy water storage	Total canopy interception, averaged over all vegetation types within a grid cell.	kg/m2	-	Recommended	time	*	*

* Exclusive components LBA-MIP
** Common components for LBA-MIP and NACP

4F. Carbon Budget:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
GPP	Gross Primary Production	Net assimilation of carbon by the vegetation	kg/m2/s	Downward (production is positive)	Mandatory	time	C2**	Carbon Flux
NPP	Net Primary Production	Carbon assimilation by photosynthesis	kg/m2/s	Downward	Mandatory	time	C5**	Carbon Flux
NEE	Net Ecosystem Exchange	Total ecosystem respiration minus Gross Primary Productivity (TotalResp-GPP) or Heterotrophic Respiration minus Net Primary Productivity (HeteroResp-NPP)	kg/m2/s	Upward	Mandatory	time	C4**	Carbon Flux
AutoResp	Autotrophic Respiration	Total respiration due to plant maintenance and growth	kg/m2/s	Upward	Recommended	time	C1**	Carbon Flux
HeteroResp	Heterotrophic Respiration	Total flux from decomposition of organic matter	kg/m2/s	Upward	Recommended	time	C3**	Carbon Flux
ANPP	Above-ground Net Primary Production	Component comparable to measurements	kg/m2/s	Downward (production is positive)	Recommended	time	*	*
BgResp	Belowground Respiration	Auto- and heterotrophic respiration belowground	kg/m2/s	Upward	Recommended	time	*	*
LitterFall	Leaf litterfall	Not including reproductive or fine wood litter	kg/m2/s	Downward (production is positive)	Recommended	time	*	*
npool	Number of carbon pools	Number of carbon pools	--	--	Mandatory	NA	M5**	Biomass
pool_name	Name of carbon pools	Name of carbon pools	--	--	Mandatory	n_pool	M6**	Biomass
CarbPools	Size of each carbon pool	Carbon mass of each carbon pool	kg/m2	--	Mandatory	npool, time	B2**	Biomass
TotLivBiom	Total Living Biomass	Total carbon content of the living biomass (leaves+roots +wood+seeds)	kg/m2	-	Recommended	time	B5**	Biomass
AbvGrndWood	Above ground woody biomass	Total carbon content of the aboveground live wood biomass	kg/m2	Downward (production is positive)	Recommended	time	B1**	Biomass
LAI	Leaf Area Index	Leaf Área index	m2 m-2		Mandatory	time	P2**	Phenology

Note: Either re-report LAI used from this protocol, or report prognostic LAI if your model was run in that mode.

Note: units should be in mass (kg) of carbon, not mass of CO_2 or organic matter (biomass).

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

4G. Driver Variables:

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	NetCDF Dimensions	NACP code	NACP Category
Tair	Near surface air temperature	Driver	K	-	Mandatory	time	D7**	Driver
Qair	Near surface specific humidity	Driver	kg/kg	-	Mandatory	time	D4**	Driver
Wind	Near surface module of the wind	Driver	m/s	-	Mandatory	time	D8**	Driver
Rainf	Rainfall rate	Average of the total rainfall over a time step and grid cell.	kg/m2/s	Downward	Mandatory	time	D5**	Driver
Psurf	Surface atmospheric pressure	Driver	Pa	-	Mandatory	time	D3**	Driver
SWdown	Surface incident shortwave radiation	Driver	W/m2	Downward	Mandatory	time	D6**	Driver
LWdown	Surface incident longwave radiation	Driver	W/m2	Downward	Mandatory	time	D2**	Driver
CO2air	Near surface CO2 concentration	The partial pressure of CO2 concentration at the atmospheric reference level (3D variable).	ppmv	-	Mandatory	time	D1**	Driver

* Exclusive components LBA-MIP

** Common components for LBA-MIP and NACP

Table 4H: Exclusive components to NACP

Variable	Description	Definition	Units	Positive Dir. (Traditional)	Priority	Code	Category
CASCO2	Canopy air space CO_2 concentration	Canopy air space CO_2 concentration	ppmv	NA	Not request	B3	Biomass
CropYeild	Annual crop yield	Annual yield of perennial crops	Kg/m2	NA	Not request	B4	Biomass
TotSoilCarb	Total soil carbon	Total soil and litter carbon content integrated over the entire soil profile	Kg/m2	NA	Not request	B6	Biomass
TotalResp	Total ecosystem respiration	Total ecosystem respiration (AutoResp+ HeteroResp)	Kg/m2/s	Into Atm.	Not request	C6	Carbon Flux
del13CPools	Delta 13C values of carbon pools	Delta 13C values of carbon pools relative to pbp standard	per mil	NA	Not request	I1	Isotope
del13CCASCO2	Delta 13Cvalue of canopy airspace CO_2	Delta 13C value of canopy air space CO_2 relative to pbp standard	per mil	NA	Not request	I2	Isotope
del13CtotalResp	Delta 13C value of respired CO_2	Delta 13C value of respired CO2 relative to pbp standard	per mil	NA	Not request	I3	Isotope
del18OTotalResp	Delta 18Ovalue ofrespiredCO_2	Delta 18O value of respired CO_2 relative to pdb standard	per mil	NA	Not request	I4	Isotope
del18OLeafMoist	Delta 18O value of leaf H2O	Delta 18Ovalue of leaf H_2O relative to smow standard	per mil	NA	Not request	I5	Isotope
del180SoilMoist	Delta 18O value of soil H_2O	Delta 18O value of soilH_2O relative to smow standard	per mil	NA	Not request	I6	Isotope
nsnow	Number snow layers	Total number of snow layers as a function of time; zero for no snow conditions	-	Up	Not request	S1	Snow
SnowDepth	Total snow depth	Total snow depth from soil surface to top of snow pack	m	NA	Not request	S2	Snow
Snowdz	Thickness of each snow layer	Thickness of each snow layer; bottom layer is layer	m	NA	Not request	S3	Snow
SnowFrac	Snowcoveredf raction	Grid cell snow covered fraction.	-	NA	Not request	S4	Snow
SnowT	Snow surface temperature	Temperature of the snow surface as it interacts with the atmosphere, averaged over a grid cell.	K	NA	Not request	S5	Snow
SnowTdz	Temperature of each snow layer	Temperature of each snow layer; bottom layer is layer 1	K	NA	Not request	S6	Snow
SWE	Snow water equivalent	Total water mass of snow pack (liquid plus frozen)	kg/m2	NA	Not request	S7	Snow
SWEdz	Snow water equivalent of	Total water mass of each snow layer	kg/m2	NA	Not request	S8	Snow

	each snow layer	(liquid plus frozen); bottom layer is layer 1					
SMFrozFrac	Layer fraction of frozen moisture	Fraction of soil moisture mass in the solid phase in each soil layer	-	NA	Not request	SM4	Soil Moisture
SMLiqFrac	Layer fraction of liquid moisture	Fraction of soil moisture mass in the liquid phase in each soil layer	-	NA	Not request	SM5	Soil Moisture
SoilMoistFrac	Layer fraction of saturation	Fraction of saturation in each soil layer (fraction of filled pore space) includes the liquid, vapor and solid phases of water	-	NA	Not request	SM7	Soil Moisture
Fdepth	Frozen soil depth	Depth from surface to the first zero deg C isotherm. Above this isotherm T<0 deg C, and below this line T>0 degC	m	Downward	Not request		Soil Temperat ure
Tdepth	Active layer depth	Depth from surface to first zero degC isotherm. Above this isotherm Tair>0 degC, and below this isotherm Tair<0 degC.	m	Downward	Not request	ST1	Soil Temperat ure
CAST	Canopy air space temperature	Canopy air space temperature	K	NA	Not request	T1	Temperat ure
dom	Day-of-month, start of time period	Day-of-month, start of time per.	day	NA	Not request	Ti1	Time
month	Month, start of time period	Month, start of time period	month	NA	Not request	Ti2	Time
start_doy	Day-of-year, start of time per.	Day-of-year at start of time averaging period	day	NA	Not request	Ti3	Time
start_hr	Hour of day, start of time per.	Hour of day at start of time averaging period	hour	NA	Not request	Ti4	Time
start_sec	Second since Jan 1,start per.	Seconds since Jan 1of year at the start of the time averaging period	sec	NA	Not request	Ti5	Time
stop_doy	Day-of-year, stop of time per.	Day-of-year at stop of time averaging period	day	NA	Not request	Ti6	Time
stop_hr	Hour of day, stop of time per.	hour of day at stop of time averaging period	hour	NA	Not request	Ti7	Time
stop_sec	Second since Jan 1, stop per.	Seconds since Jan 1of year at the stop of the time averaging period	sec	NA	Not request	Ti8	Time
year	Year, start of time period	Year, start of time period	year	NA	Not request	Ti9	Time

2.6. Checklist and diagnostics for submission

A diagnostic tool is available online (http://www.climatemodeling.org/lba-mip/tools) so that each modeling group can systematically check the simulations, as represented in NetCDF format, for correct format and internal consistency. In particular, the diagnostic tool will ensure that the checklist (**Table 5**, below) applies.

Table 5. Checklist and Diagnostic Procedures

Issue	Desired Procedure
Timestamp correct	Driver data are in UTC 00:00 time consequently output should also be in UTC. Note that this procedure differs from previous version of this protocol.
Leap days excluded	Drivers will be distributed WITH leap year. However, the leap day (Feb. 29) should be excluded in the model outputs.
Variable Names correct	Make sure column names of output variables are compliant with the protocol
Variable sign conventions correct	The output specification table (Table 4) indicates the sign conventions for each variable.
Additional variables added	Incorporate additional carbon-cycle variables (if relevant to model) into output (Table 4F).
Convert to NetCDF	To ensure consistency and uniformity of access to simulation data, all output in NetCDF format is strongly recommended (see appendix A of this protocol.
Run output diagnostic tool	Provided, with instructions, on the LBA-MIP website (http://www.climatemodeling.org/lba-mip/)
Upload runs	Upload runs to the LBA-MIP website (http://www.climatemodeling.org/lbamip/ upload_instructions.html)

3. Intercomparison Methods and Analysis

The models compared will be divided in two categories, i.e. models that simulate carbon (C) and models that do not simulate carbon (NC). Models that simulate carbon may also participate in the simulations for group NC with their carbon component disabled. Models that simulate carbon will further be divided into fully dynamic vegetation models (which prognostically simulate vegetation phenology) and those that require phenological driving data.

The evaluation will include comparison between the model output and measured fluxes and state variables, at the different sites, namely:

a. Latent heat flux
b. Sensible heat flux
c. Ground heat flux
d. Carbon flux (NEE – Net Ecosystem Exchange)
e. Soil moisture
f. Soil temperature
g. Net short wave radiation
h. Net long wave radiation

The proposed evaluation will also be performed at different time-scales:

a. Daily mean
b. Monthly mean
c. Annual mean
d. Seasonal (dry and wet seasons analyzed separately)
e. Hourly
f. Diurnal cycle (amplitude and phase)
g. Daytime and nighttime carbon

3.1. Sensitivity analysis

A minimal standard set of sensitivity analyses are recommended for all model participants, with focus on sensitivity to precipitation and to vegetation phenology: In the case of *phenology*, in addition to runs in which MODIS phenology is used, a sensitivity run in which models use their own default phenology prescription (i.e.: model calculated or from lookup tables). The following relevant driving data are available:

Vegetation and Soil Characteristics
ALMA NetCDF forcing data
ASCII forcing data
Plots of driver variables
Annual and monthly mean LAI fields

4. Files and datasets name conventions

The file naming will follow the PILPS convention:

[modelname].[simulationcode].[sitename].lbamip.nc

where:

[modelname] is the name of the model used;
[simulationcode] is the convention used to identify the experiment: “c” or “nc” for carbon or non carbon, respectively, followed by the experiment number;
[sitename] is the name of the site, for example, “ban” or “fns” or “k83” or “k77” or etc.
file extension ‘.nc’ indicates the NetCDF format.

For example, the file “sib.nc1.k83.lbamip.nc” includes all the output for the first experiment using the sib model, without carbon at the K83 site. Files with additional information such as set of parameters used at a specific experiment or initial states should follow similar convention, respectively, e.g.:

[modelname].[simulationcode].[sitename].lbamip.par
[modelname].[simulationcode].[sitename].lbamip.ini

5. Participant Models Registration

A list of participating modeling groups is being maintained Groups that have not yet registered their model should provide the following information:

a. Complete a questionnaire available at http://www.climatemodeling.og/lba-mip

b. A short description of model structure and how the land surface can be represented (topography? Land cover (plant functional types? Or biomes?, rooting depth, soil texture etc.) Although some parameters will be provided (i.e. vegetation cover, LAI, height of canopy, etc.) for LBA-MIP, the default set of parameters for the given soil and vegetation types for each site should be reported.

c. A description of the external forcing required (not calculated by the model) such as time variant and time invariant parameters, atmospheric forcing, etc.

d. Description of the “default” parameters used based on the different sites characteristics and, if any calibration is used, description of the calibration procedure and parameters affected.

e. Groups may upload models source code if desired.

6. LBA- MIP Timeframe and Deadlines

Mar 1, 2010:	Driver datasets at individual tower sites made available (downloadable at: http://www.climatemodeling.org/lba-mip/
Mar 1–Apr 25, 2010:	Initial simulation runs conducted
Apr. 30, 2010:	Target for preliminary model outputs made available by participants
Apr 30 – Jun 1, 2010:	Analysis and intercomparison of initial model outputs
Jun XX-XX, 2010:	Workshop meeting to present/discuss the LBA/MIP preliminary results (TBD)
Aug, 8-13 2010	2010 The Meeting of the Americas Foz do Iguaçu, PR, Brazil Special session B15: Processes of carbon and water cycles in Brazilian ecosystems

Appendix A. Notes on using NetCDF file formatting convention for model runs

Please note the following requirements for NetCDF files:

1 Dimension names: nsoil, npool, time
2 Time series length must equal the length of input driver data, minus leap day where it exists (note change from last protocol: it is not necessary to report the entire time series from 1999 – 2006)
3 Spelling – it is crucial you spell variable names properly to streamline analysis

Please supply additional variables as needed. Re-reporting of model variables that correspond to driver data variables also helps us verify that you used the correct driver data.

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