Description of the PILPSC-1 experiment

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1 Introduction

1.1 objective of PILPSC-1

The PILPS experiments which have been conduced up to now (Pitman *et al.* 1993, Henderson-Sellers *et al.* 1993, Henderson-Sellers *et al.* 1995) have clearly improved our knowledge of evaporation driving the exchanges between atmosphere and land surface. This has lead to many improvements in land surface schemes and has emphasized the importance of model parameterization of soil moisture and soil water stress for instance.

In parallel but with no link to PILPS several intercomparison project have also been accomplished in the framework of the IGBP program to compare the simulation of biogeochemical processes taking place at the terrestrial surface (mainly the carbon cycle).

But it is now established that biogeochemical and biophysical processes are highly coupled at the land surface from the scale of seconds to centurys. For instance it as been demonstrated that the feedback of atmospheric CO_2concentration on stomatal conductance induces change in the hydrologic cycle with important consequence on the climate and vice-versa (Sellers *et al.* 1996, Betts *et al.* 1997)

The recent evolution of land surface representation both for the study of carbon cycle or climate have lead to an improvement of the coupling between biophysical and biogeochemical processes. At the same time, since the middle of the 1990's several sites have been instrumented to continuously measuring both net CO_2 flux and energy fluxes (latent and sensible).

Thus we are able now to go further in our understanding of coupling between CO_2 and the water cycle by comparing simulated CO_2 and energy fluxes with in situ data.

The PILPSC-1 experiment proposed here is an initiative within the GEWEX/GLASS (Global Land-Atmosphere System Study) panel. The objective of this project is the comparison of models that simulate water cycle and model that simulate both CO_2 and water cycles with continuous "in situ" observations for 2 years.

Among the sciences questions to be addressed by PILPS-C1 are:

- What is the ability of the models to correctly reproduce both biophysical and biogeochemical process ?
- Taking into account the long term history of the site, are the models able to reproduce the observed sink of carbon ?
- Do models which include the carbon cycle out-perform those which do not for the simulation of the energy and water budgets ?

Today, different types of models that are able to simulate the water and CO_2 fluxes. On the one hand we have SVATs that simulate only the water and energy cycles and which in some cases have introduced a parameterization for the CO_2 cycle mainly to improve the simulation of physical processes. On the other hand we have biogeochemical models which are oriented towards the carbon cycle (BGC and DGVM). More recently there has been a move towards "complete" models that couple SVAT, BGC and DGVM modules. Likewise there are 2D models for large scale applications and local models specific to one ecosystems.

All these kinds of models have not been compared to evaluate the relative advantage of each one. Hence, one objective of this project, and one of its originality, is to compare very differents kinds of surface models that have been designed for differents purposes For this reason we encourage the participation of a large scientific community coming from traditional land surface scheme but also from more carbon oriented models. In particular we would like to attract the participation of global scale 2D models as well as 0D models. Likewise, because available measurements include not only net CO_2 fluxes but also latent and sensible heat fluxes, we encourage participation of model that only simulate latent and heat fluxes.

1.2 Description of the site and instrumentation

The experiment will be carried out on the site of Loobos. This experiment site belongs to the "Euroflux" program network. The vegetation cover is a scots pine (Pinus sylvestris) forest located in the center Netherlands (see figure 1 for a map of situation of Loobos and 2 for a view of the site). The soil is sandy and the climate is cool with a mean annual temperature of 10 C and an annual precipitation around 800mm. The forest was planted on sand dunes in the beginning of the 20th century and is now almost 100 years of age. Existing soil organic matter was largely removed at this time. There is an understory of *Deschampsia flexuosa*, a grass that can reach a height of 50cm. The soil is sandy (humuspodzol) with a 10cm layer of organic matter.

The net CO_2 fluxes, latent and sensible heat fluxes have been measured by eddy correlation method from January 1997 to December 1998 on a flux tower at a height of 27 meters with a 30 minutes time step. The fetch is at least 1.5 kilometres in all directions and consists of similar forests with the same species of similar age and height. For this site Elbers et al. calculated that most of the flux originates from 500m around the tower, with maximum flux contribution at 120m for neutral atmosperic conditions. An automated weather station was put on the site and measured incoming and reflected shortwave and longwave radiation, soil heat flux, windspeed, temperature and relative humidity. Rainfall was also measured above the canopy and in the open field with automated tipping bucked rain gauges

Several ancillary data like leaf area index, albedo, surface roughness or soil characteristics have also been measured. Main features of the site with regards to vegetation and soil characteristics are summarized in table 1.2 The period considered for the experiment will begin in January 1997 and finish in December 1998.

It should be noted that a meteorologic station which has measured major meteorological parameters since the beginning of the 20th century exists near the Loobos site. This information combined with the fact that the forest was planted on a soil with almost no carbon, gives us the unique oportunity to simulate the entire history of carbon in the soil and vegetation at this location.

Site description	
Latitude	52 10'00" N
Longitude	05 44'38" E
Elevation [m a.s.l.]	52 m
Topology	Flat
Vegetation and stand characteristics	
Dominant species	Pinus Sylvestris
Understorey	Deschampsia flexuosa
Stand age (years)	80
Canopy height(m)	14
Stem density (ind/ha)	620
Climate	
Annual precipitation (mm)	786
Annual mean temperature (C)	9.8
Nitrogen deposition (Kg N /ha/ y)	40
soil	
Parent material	sand dune
Soil texture	sandy
Soil depth (cm)	50
measurement conditions	
Tower Height (m)	24
Measurements Height (m)	27

Table 1: Main characteristics of Loobos site

Figure 1: Situation of the Loobos site

Figure 2: A photograph view of the Loobos site

2 Experimental set-up

2.1 General

The model forcing consist of 2 years starting from January 1, 1997 and ending December 31, 1998. The atmospheric forcing has a 30' time step giving a total of 35040 values for each forcing variable.

The atmospheric forcing data are to be linearly interpolated from the 30' to the model time step if it is need at a higher time resolution. On the contrary fields must be averaged or summed (depending on the variables) for models working with longuer time step.

2.2 Proposed model Intercomparison runs

A set of simulations will be proposed in the frame of this project, some more oriented of coupling between biophysical and biogeochemical process and some more oriented on the carbon cycle. Because the models expected to participate to the project will be very differents and because the objectives of the project are multiple, it is not expected that all participants do all the simulations. Participants are invitated to choose the simulations that they will do. The minimum requirements is the first simulation described below.

2.2.1 short term simulations, free run

For this first simulation we propose that models simulate CO_2 net fluxes, latent and sensible heat fluxes with the half hourly time step for the years 1997 and 1998. For spin-up it is asked that participants run their models with the first year of data in loop until equilibrium of all the differents pools has been reached. Equilibrium mean that all state variables of the model must changes of less than few percent from one year to another. From this equilibrium state, we ask that the modelers simulate 2 more years and only report results for these last two years. For this simulation called "free models", we propose to use a minimum of input parameters to the model (i.e climate, and soil forcing). The objective of this simulation is to evaluate models ability to reproduce in situ data where they are driven only by the parameters that could be provided over large region (i.e they are run the same conditions as in a GCM for instance). For models that compute vegetation distribution (e.g DGVM) it is asked to do one simulation with prescribed vegetation (if possible) and one simulation with calculated vegetation.

2.2.2 short term simulations, constrained run

For the second simulation called "constrained models" we propose a protocol similar to the previous one except that the models are forced by the available ancillary data (mainly the Leaf Area index, the albedo, the roughness and soil carbon) that will be provided for the site. The objective of this simulation is to separate the contribution of various processes in the discrepancies between models and observations found in the previous experiment. Obviously this simulation will be only possible for models that can prescibe these ancillary paremeters to their models. Participants are requested to report the parameters which have been forced and those which remained simulated.

2.2.3 long term simulation

The spin-up problem of models when considering carbon pools is complex. The time for equilibrium between vegetation and soil carbon can take hundreds of years. In fact for most of the sites where net CO_2 flux have been measured, a net carbon sink is observed (i.e the annual net ecosystem exchange is negative) and no equilibrium has been reached. This is the case for the Loobos site where a net carbon sink is observed for both 1997 and 1998. An important question then, is to know if models that simulate the full carbon cycle (i.e in vegetation and soil) are able to reproduce the observed sink at the site when the simulation is not done using historical forcing data.

To reproduce what has been observed one needs in theory to know the history of the site for several hundred of years. Fortunately in the Loobos case, the forest was planted eighty years ago on a soil with almost no carbon. Moreover a long time series of meteorological data is available from a station not too far away from the site. Thus a good approximation of real site conditions can be simulated by models which explicitly simulate the soil decomposition. In this simulation it is asked to run the models for 100 years (the age of the forest) beginning with a zero biomass and no soil carbon content (The real initial soil carbon content was less than 0.4 % of soil weight). For living biomass a inital non zero value is allowed if needed to permit the start of the first vegetative cycle. For this simulation we will provided a hundred year time series of climate. A synthetic 30' time step data (constructed from the initial daily measurements) will be provided to the participants. For this simulation we will also provide the annual mean atmospheric CO_2 concentration.

2.2.4 Summary of Experiments

In Summary, three runs are proposed in the frame of the PILPS-C1:

1. The "free with equilibrium spin-up" run (named F-E). This is the base simulation for all participants with climate and soil data provided with an equilibrium spin-up. It will be compared to observed latent and sensible heat fluxes and unbiased net CO_2 fluxes.

2. The "Constrained with equilibrium spin-up" run (named C-E). Simulation with ancillary forcing (LAI, z0 etc...) and equilibrium spin-up. For model that can prescribed these parameters.

   For these two first simulations, because spin-up will be done until equilibrium of all reservoirs is reached, the annual net coarbon exchange will be zero by definition. Thus, to be comparable to observation, the mean net CO_2 flux observed at Loobos will be subtracted from the halfhourly net CO_2 flux prior to comparison with simulations.

3. The "100 years simulation" run (named F-100). This simulation will be done only with climate and soil data and is limited to models that explicitly calculate all the

respiration terms. In this case, the simulations will be directly compared to observed net CO_2 flux.

3 Model forcings

All the data are provided using the NetCDF format and the ALMA conventions. Additional information on the ALMA conventions and links for information on the netCDF format can be found at : *http://www.lmd.jussieu.fr/ALMA/*

3.1 Surface forcings

The surface forcings will be provided at an half-hour time step for the period 1997-1998. The forcings are summarized in table 2. The variables are :

1. the wind speed (only the module of the wind is available)
2. Rainfall and snowfall. In the initial file only water precipitation was provided, the estimation of snowfall was done assuming snowfall when temperature is below 273.3 K.
3. air temperature
4. Specific humidity. In the original data, only the relative humidity of the air was given. the specific humidity was estimated by the following formula:

$$\mathrm{Qair} = \frac{0.622 h_r * S_v}{P - h_r * S_v * 0.378}$$

   H_r is relative humidity, P the Pression (in hPa) and S_v the saturation vapor pressure:

$$S_v = 611.0 \exp^{17.269(T-273.16)/(T-35.86)}$$

   where T is the air temperature at 2m (K)

5. Incident shortwave radiation
6. Incident long wave radiation
7. Surface pressure. This measurement was not available at the site. A constant standard value of 1.01310^5 Pa was assumed.

3.2 Soil characteristics

The table 3 and 4 gives respectively the texture and hydraulic characteristics of the soil

Variable name	description	Units	Time step
Wind	surface module of wind	$m.s^{-1}$	1800s
Rainf	Rainfall rate	$kg.m{-}2.s{-}1$	1800s
Snowf	Snowfall rate	$kg.m{-}2.s{-}1$	1800s
Tair	Near surface air temperature	K	1800s
Qair	Near surface specific humidity	$Kg.Kg^{-1}$	1800s
Psurf	Surface pressure	Pa	1800s
SWdown	Surface incident shortwave radiation	$W.m^{-2}$	1800s
LWdown	Surface incident longwave radiation	$W.m^{-2}$	1800s

Table 2: Atmospheric forcing for models forcing

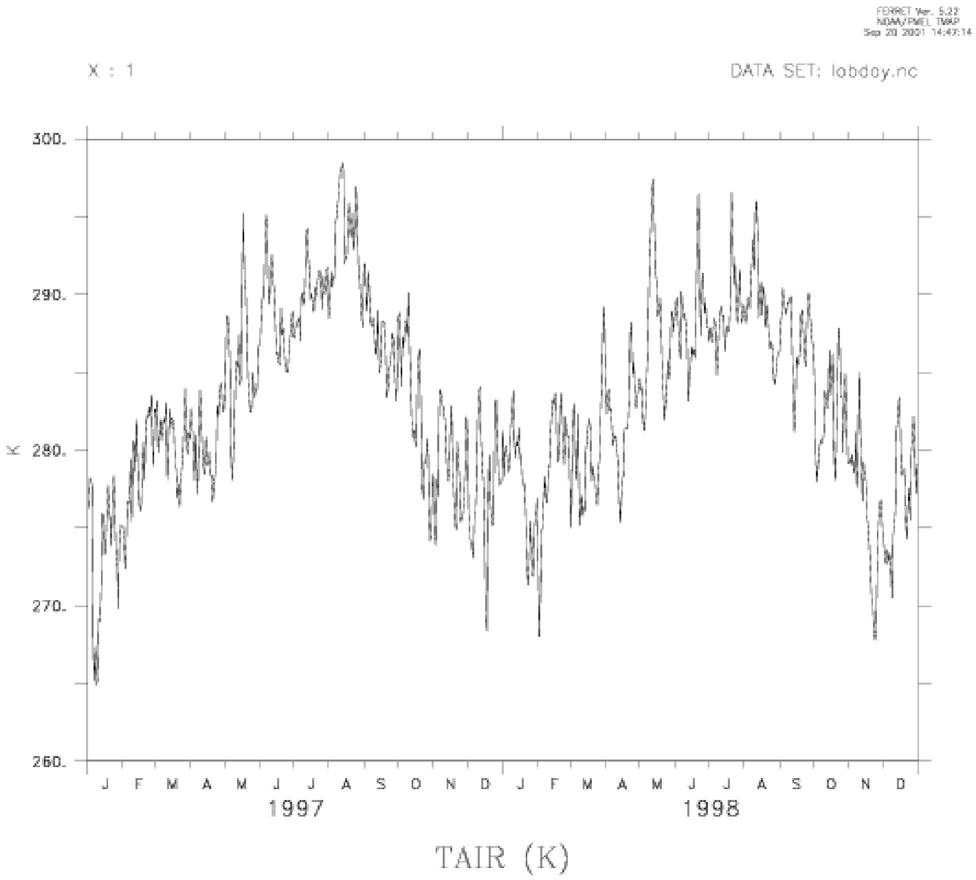

Figure 3: daily mean air temperature at Loobos for 1997-1998 (K)

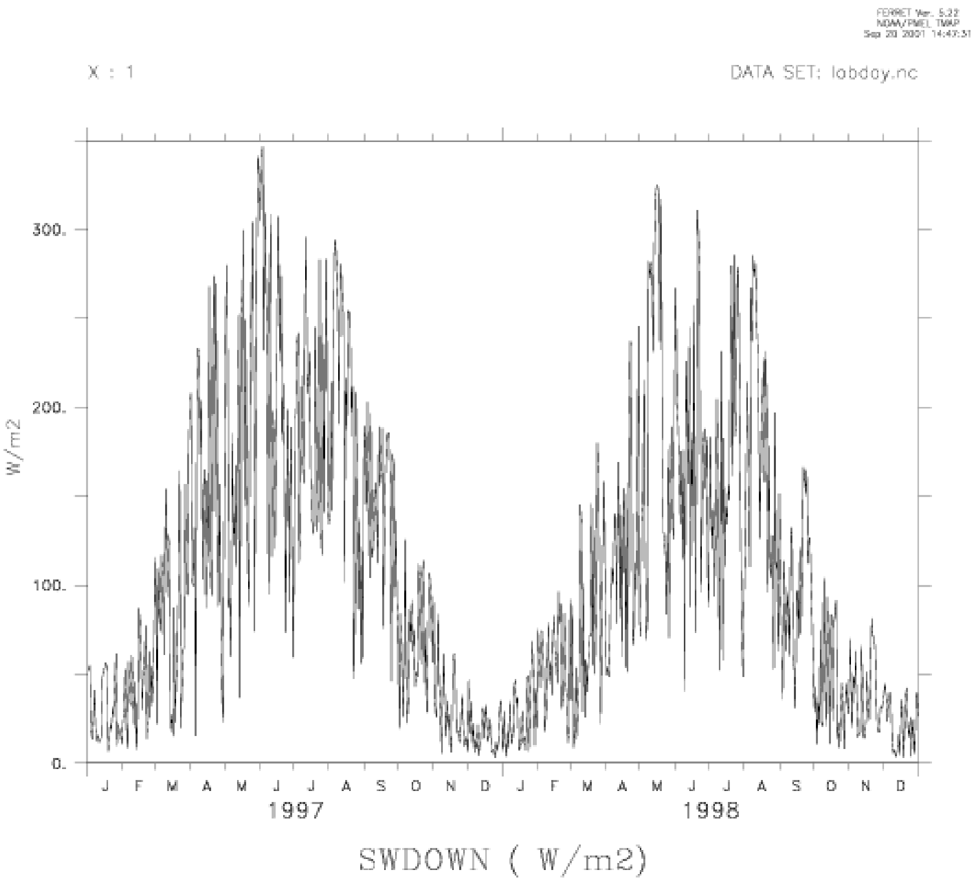

Figure 4: daily mean shortwave radiation at Loobos for 1997-1998 ($W.m^{-2}$)

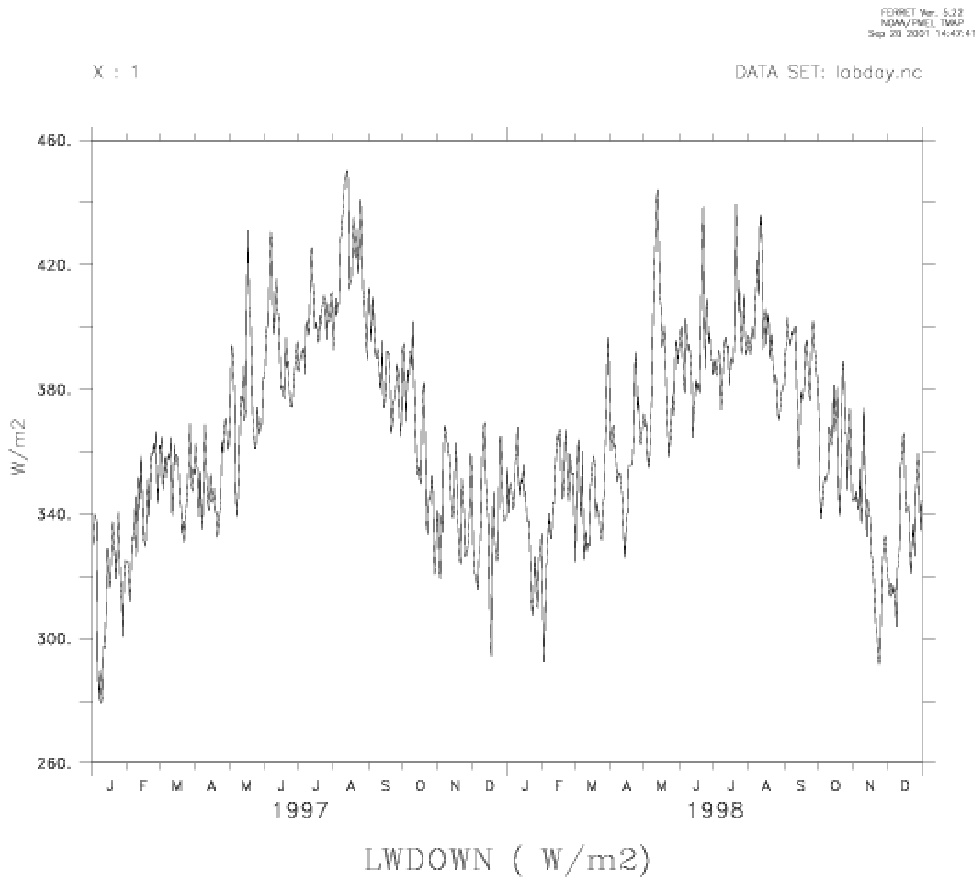

Figure 5: daily mean longwave radiation at Loobos for 1997-1998 ($W.m^{-2}$)

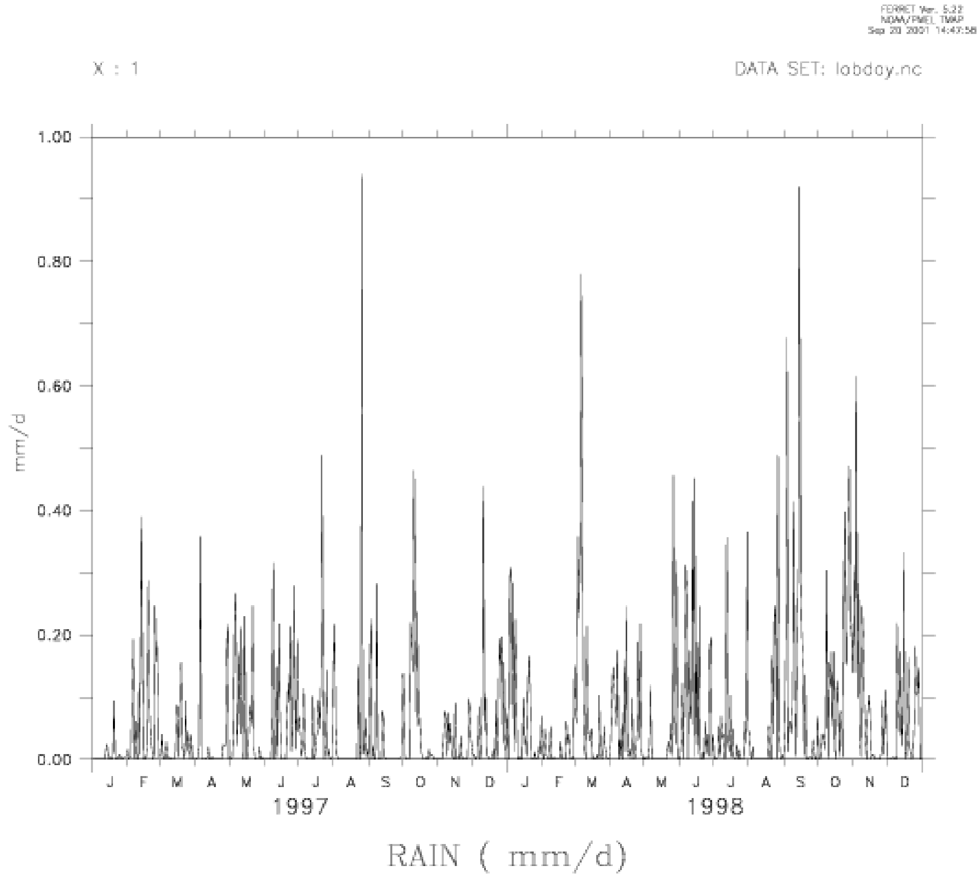

Figure 6: daily total precipitation at Loobos for 1997-1998(mm/day))

Loobos				
depth (m)	x_{sand} ($m^3\ m^{-3}$)	x_{clay} ($m^3\ m^{-3}$)	x_{org} ($m^3\ m^{-3}$)	ρ_{sample} ($m^3\ m^{-3}$)
0-0.20	0.53	0.01	0.02	1.56
0.40-0.60	0.60	0.01	0.00	1.63

Table 3: Volume fractions of sand, clay and organic matter and the density.

Loobos								
depth (m)	θ_r (-)	θ_s (-)	α (cm^{-1})	N (-)	m (-)	l (-)	k_s (cm d^{-1})	k_s^* (cm d^{-1})
0.10-0.18	0.01	0.44	0.0239	3.429	0.708	0.5	19.717	268.0
0.50-0.58	0.01	0.38	0.0198	5.410	0.815	-0.9	9.334	178.0

*) saturated hydraulic conductivity determined seperatedly on a suturated sample.

Table 4: The fitting parameters of the soil hydraulic characteristics as defined by van Genuchten (1980). The last column shows the saturated hydraulic conductivity as determined seperatedly for a saturated sample.

3.3 additional forcing data for "constrained model" simulation

In addition to data provided in the previous section (3.1) the ancillary data provided for the "constrained" simulation will be the leaf area index, the roughness length, the displacement height, the Vmax at leaf level and rooting depth.

This data will be provided after the results of the first simulation.

4 Model output data

The information to return for each participant are summarized in table 5. For the F-100 simulation we ask to report only the last two years of the run except for Total living biomass, Total soil carbon, NPP and NEE that must be provided for the 100 years but with an annual time step.

5 Proposed Analyses

As described above, the experiment will consist of two kind of simulations (with and without constraint) with two different spin-up ("equilibrium" and "stand age run"). This section summarizes the expected analyses to be made. This list may change and expand with time.

The analysis will be done on the parameters directly measured at the site. The primary parameters that will be compared will be Latent Heat flux (Qle), Sensible heat flux (Qh), Net shortwave radiation (SWnet), Net longwave radiation (LWnet) and Net ecosystem production (NEE). For the carbon cycle, an estimation of partition of the NEE measured at

Variable name	**description**	**Units**	**Time step**
0.1 Energy balance components			
SWnet	Net shortwave radiation	$W.m^{-2}$	3 hours
LWnet	Net longwave radiation	$W.m{-}2$	3 hours
Qle	Latent heat flux	$W.m{-}2$	3 hours
Qh	Sensible heat flux	$W.m{-}2$	3 hours
0.2 General water balance components			
Rainf	Rainfall rate	$Kg.m^{-2}.s^{-1}$	3 hours
Evap	Total Evapotranspiration	$Kg.m^{-2}.s^{-1}$	3 hours
0.4 Subsurface State Variables			
SoilMoist	Average layer soil moisture	$kg.m^{-2}$	3 hours
SoilTemp	Average layer soil temperature	K	3 hours
SoilWet	Total soil wetness	-	3 hours
0.5 Evaporation components			
PotEvap	Potential Evapotranspiration	$Kg.m^{-2}.s^{-1}$	3 hours
Ecanop	Interception evaporation	$Kg.m^{-2}.s^{-1}$	3 hours
Tveg	vegetation transpiration	$Kg.m^{-2}.s^{-1}$	3 hours
ESoil	Bare soil evaporation	$Kg.m^{-2}.s^{-1}$	3 hours
Ewater	evaporation from surface water storage	$Kg.m^{-2}.s^{-1}$	3 hours
ACond	Aerodynamic conductance	$m.s^{-1}$	3 hours
0.9 Carbon budget components			
GPP	Gross Primary Production	$Kg.m^{-2}.s^{-1}$	3 hours
NPP	Net Primary Production	$Kg.m^{-2}.s^{-1}$	3 hours
NEE	Net Ecosystem Exchange	$Kg.m^{-2}.s^{-1}$	3 hours
AutoResp	Autotrophic Respiration	$Kg.m^{-2}.s^{-1}$	3 hours
HeteroResp	Heterotrophic Respiration	$Kg.m^{-2}.s^{-1}$	3 hours
TotSoilCarb	Total soil carbon	$Kg.m^{-2}$	daily
TotLivBiom	Total living Biomass	$Kg.m^{-2}$	daily

Table 5: Subset of ALMA output variables to be returned in the runs

Loobos between gross ecosystem production and total respiration will be done to also compared components of the net flux. A first analysis will be done both on daily mean and diurnal cycles:

For each of these parameters we will do the following comparison with data at the Loobos site:

- Comparison between simulated and observed monthly mean
- Comparison between simulated and observed daily mean
- Comparison between simulated and observed daily amplitude of the diurnal cycle
- Comparison between simulated and observed daily phase of the diurnal cycle
- Comparison between simulated and observed min and max of the diurnal cycle

This first analysis will allow to determine the ability of models to correctly reproduce the observed variability of the differents parameters at differents time scale

Then a set of more complex statistical analysis will be done:

- Analysis by type of weather: Several classes of weather will be determined from meteorological parameters. The mean differences between simulation and observation for each weather class and each model will be determined. This will allow to find systematic errors of models for particular weather conditions.
- Analysis of coefficient of correlation on time windows. This analysis will allowto determine at which period the variation of both simulated and observed signal are correlated.
- Analysis of the coefficient of determination. This coefficient R_{XY} is defined as

$$R_{XY} = 1 - \frac{\sum_{j=i-\lambda/2}^{j=i+\lambda/2} (Y_i - X_i)^2}{\sum_{j=i-\lambda/2}^{j=i+\lambda/2} (X_i - \bar{X})^2}$$

  where X is the observations and Y the simulation. This coefficient of determiniation, in complement of the coefficient of correlation take also into account for the absolute value of the signal weighted by the inverse of variance of the signal.

Complementary analysis can be done after the first analysis

6 Data protocols

All data handling and format requirements will follow the guidelines of ALMA, as described on the ALMA web page (see *http://www.lmd.jussieu.fr/p̃olcher/ALMA/dataex_main.html.*

Meteorological forcing data will be distributed and returned in netCDF format with the GDT convention following the ALMA guidelines. Guidelines for utilizing netCDF directly, or for transferring to and from ASCII files, can also be found on the ALMA web page.

6.1 Data distribution and Return

The forcing data and models output will be provided via FTP. Output variables that a given model cannot provide or does not produce, should simply be omitted in the generated netCDF file. the adresses where data should be taken and return as well as instructions about these data (e.g naming convention) will be provided be E-Mail to each participant when the data will be available.

6.2 Quality Control

ALMA has made available a screening program to check the correctness of the output netCDF files prior to return. This program based on those define for PILPS 2e Experiment will apply the annual water, energy and carbon balance criteria, as well as ensuring that all variables are within reasonable ranges. The range requirements are not meant to comment on the appropriness of model output, merely to verify unit correctness and sign. A number of utilities are freely available for plotting netCDF files, as listed on the ALMA web site, and we encourage you to use these as well. The screening program will be run after submission prior to any analysis. Any data that fail the screening will not be considered. So we encourage participants to run the program prior to submitting results.

6.3 Results Documentation

In addition to results of runs some informations will be asked to participants:

- Short description of model and model structure ,(especially for model that have not participated to previous PILPS experiments)
- General impressions and comments on the results obtained based on experiences with one's own model
- Specific problems or concerns which were experienced
- If a interpolation/average method have been use for application of forcing data, detail the methodology used.
- For the "constrained run" Detail on the parameters that have been forced to the model

7 Proposed Time line

The anticipated timeline for the experiments is as follows:

- **February 2001: Submission of experimental protocol**
- **May 2001: Distribution of forcing data to the participant**
- **August 2002: Deadline for submission of results.**
- **November 2002: workshop for analysis of preliminary results.**

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