The Global Land Surface Model
ORCHIDEE

(ORganizing Carbon and Hydrology In Dynamic Ecosystems Environment)

Plan

- A brief history of ORCHIDEE & motivations
- Formalism
- Main processes
- Configurations & Inputs requirements

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A brief history

Model

Carbon Cycle
(STOMATE)

SECHIBA → ORCHIDEE

Dynamic Veg. (LPJ)

+ new hydrology

+ river routing

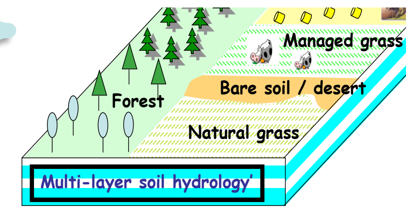
+ Forest management

+ Crops module

+ Permafrost

+ Nitrogen Cycle

Toward a single community tool



(Laval et al., 1981) *(Ducoudré et al., 1993)* *(Viovy et al., 1997)* *(Polcher et al., 1998)* *(Krinner et al., 2005)*

80s — 90s — 2000 — 2009

Project / Users

Few Scientists at LMD (3-4) — **Small group btw LMD/LSCE (5-10)** → **Increasing number of developers & users (15-25)**

LMD — **organization LMD/LSCE** → **Specific “Project Group” across IPSL & few other labs.**

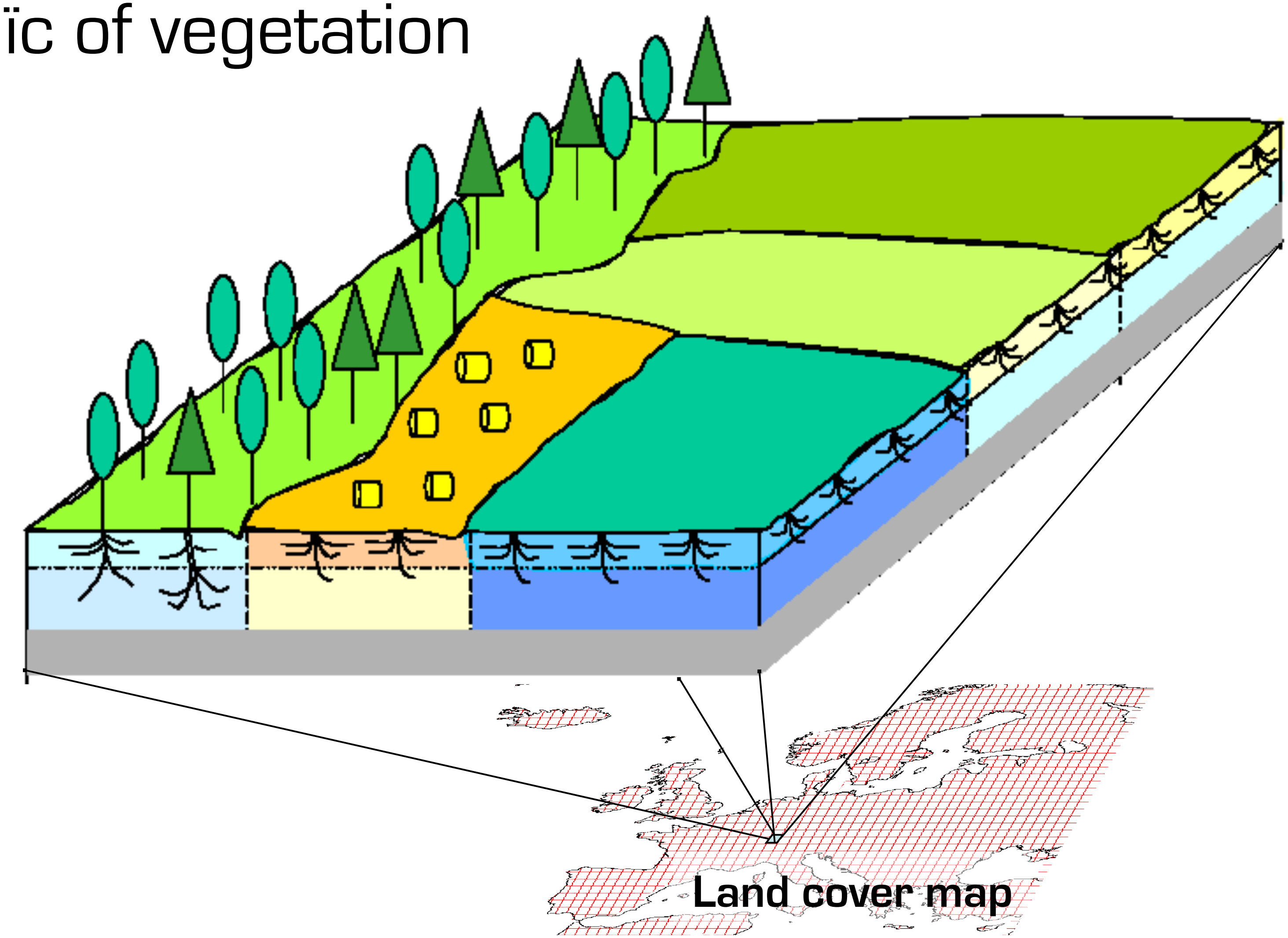
Objective

⌘ Simulate Energy, Water and Carbon fluxes at the land surface/atmosphere interface.

- To be used for being the ‘land surface’ component of a Earth system model (IPSL-CM5).
  - Global => to represent the main vegetation cover.
- For past, present and future climates
  - Module of vegetation dynamic
  - Process-based modeling

How the surface is represented ?

⌘ A mosaïc of vegetation



How the surface is represented ?

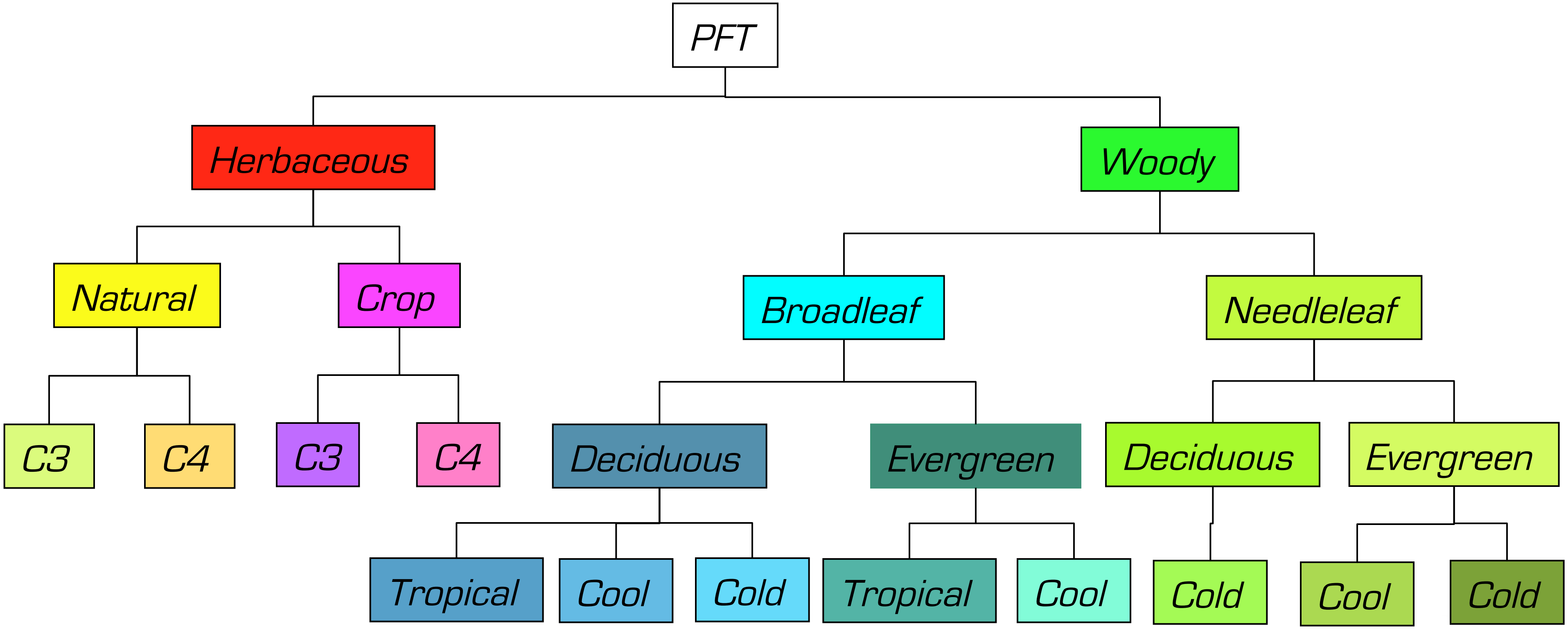
- In each grid cell, we account for:
  - Bare soil
    - *veget_max[1]*
  - Vegetated lands
    - *veget_max[2:nvm]*
  - Other lands (so far, only the continental ice)
    - *frac_nobio*

$$\sum_{i=1}^{nvm}\left(veget\_\max_i\right) + frac\_nobio = 1$$

- One soil type per grid cell (eg. one set of soil properties grid cell)

Vegetated lands

- Concept of 'Plant Functional Types' (PFT)
- Defined according to systematic, physiological, phenological, climatic conditions



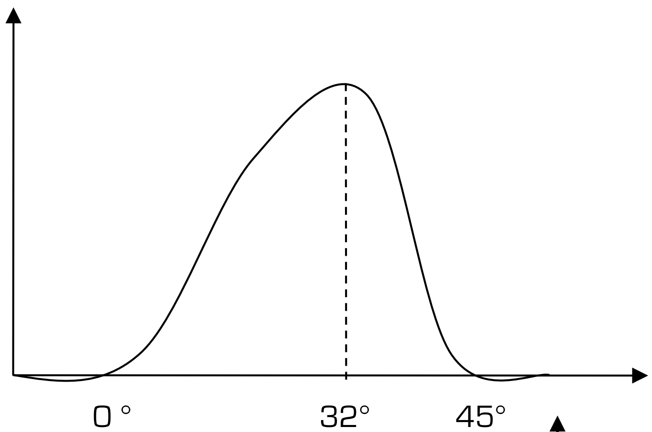
Plant Functional Types

- A same set of equations governs PFT
- But parameter values differ among PFT's

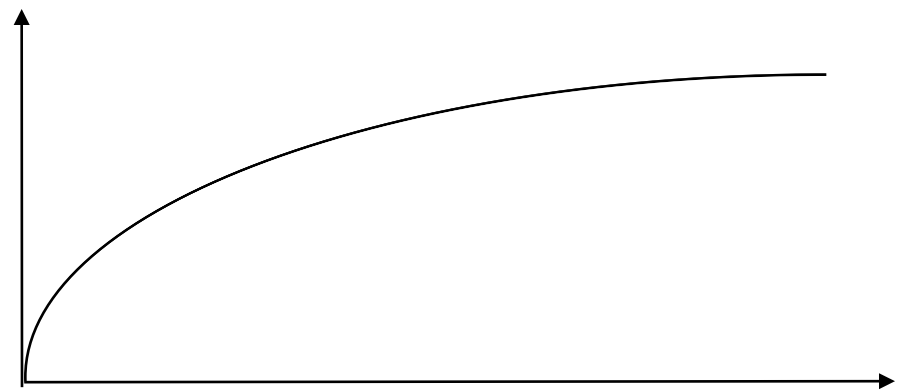
PFT	$V_{cmax,opt}$	T_{opt}	λ_{max}	z_{root}	α_{leaf}	h	A_c	T_s	H_s
TrBE	50	37	10	1.25	0.12	25	910	-	0.3
TrBR	60	37	10	1.25	0.14	25	180	-	0.3
TeNE	37.5	27	5	1.	0.14	15	910	-	-
TeBE	37.5	32	5	1.25	0.14	15	730	-	-
TeBS	37.5	28	5	1.25	0.14	15	180	12.5	-
BoNE	37.5	25	4.5	1.	0.14	10	910	-	-
BoBS	37.5	25	4.5	1.	0.14	10	180	5	-
BoNS	35	25	4	1.25	0.14	10	180	7	-
NC3	70	$27.5 + 0.25T_l$	2.5	0.25	0.20	0.2	120	4	0.2
NC4	70	36	2.5	0.25	0.20	0.2	120	5	0.2
AC3	90	$27.5 + 0.25T_l$	6	0.25	0.18	0.4	150	10	0.2
AC4	90	36	3	0.25	0.18	0.4	120	10	0.2

Response to environmental conditions

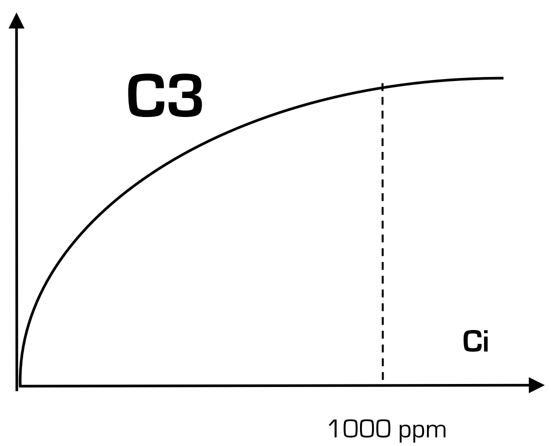
Temperature

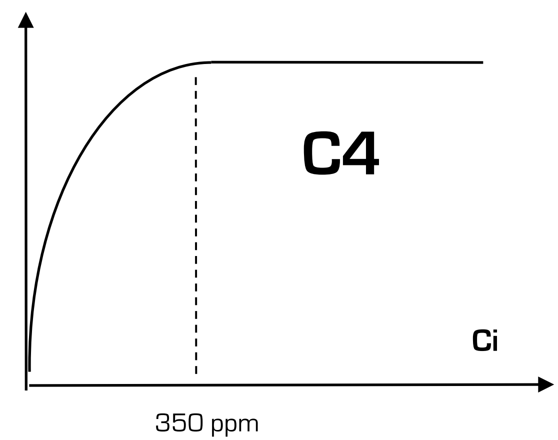


Light



[CO2]





Concept of externalization

- By default 13 PFT's (named Metaclass) with pre-defined parameters setting
- Most of the parameters can be modified by the user (see http://forge.ipsl.jussieu.fr/orchidee/wiki/Documentation/OrchideeParameters or orchidee.default file in the config/PARAM directory)
- The number of PFT's can be extended
  - By setting the NVM parameter and PFT_TO_MTC (correspondance array linking a PFT to MTC)

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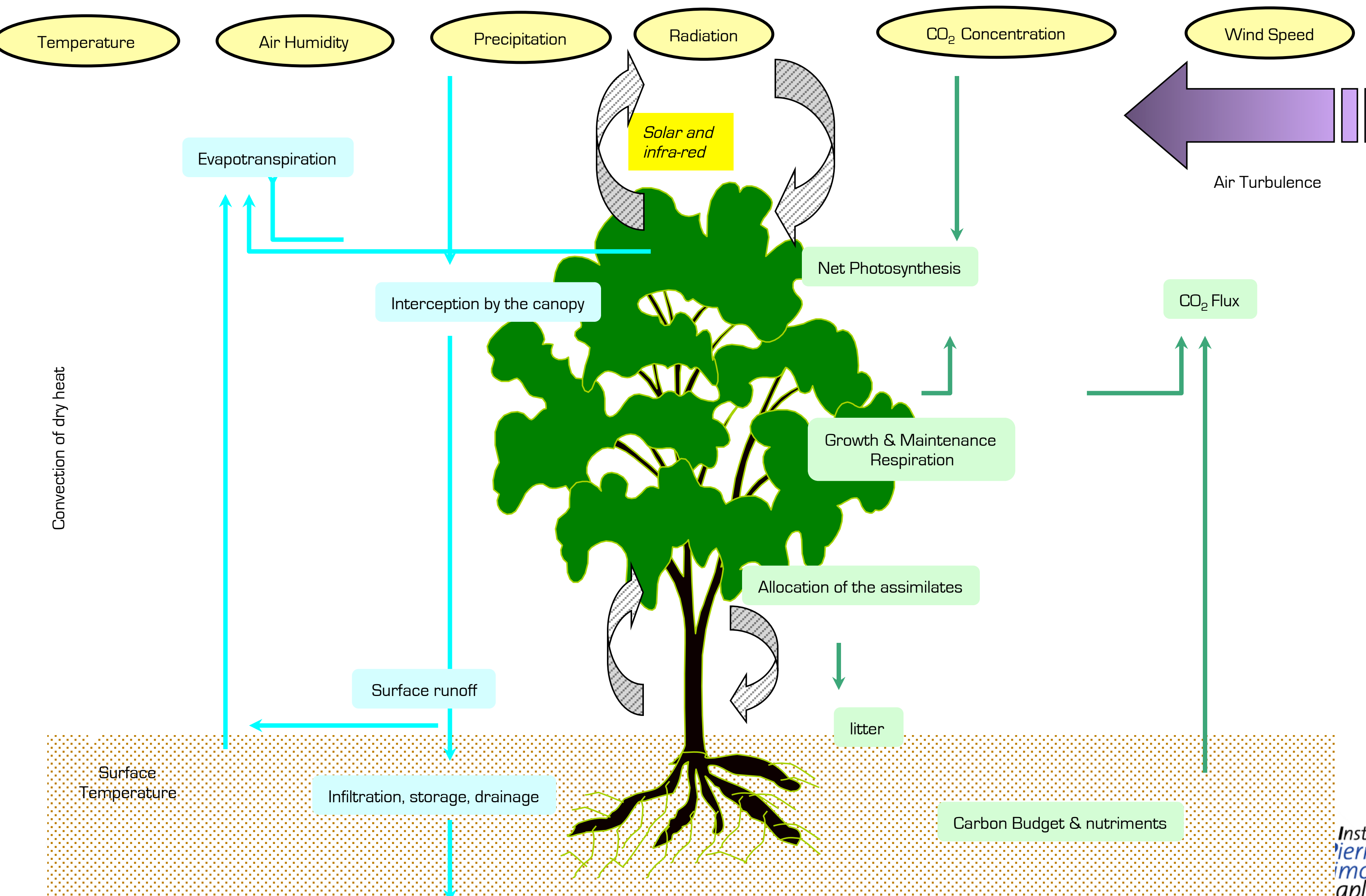
Concept of externalization (2)

- In the run.def

```
NVM=14
PFT_TO_MTC=1,2,3,4,5,6,7,8,9,10,11,12,13,13
VCMAX25_14=100
```

=> The 14th PFT will inherit of all the parameter values of the 13th PFT, except for VCMAX25 that is set to 100.

Main processes



Energy budget

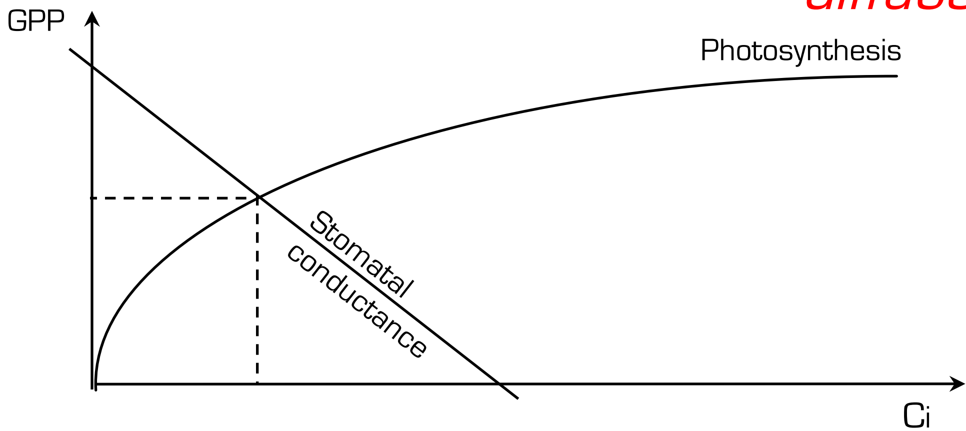
enerbil module

- Calculation of the
  - Sensible heat flux
  - Latent heat flux
    - Transpiration
    - Evaporation of bare soil and leaf water
    - Sublimation
  - Net radiation
  - Soil and surface temperature
  - GPP calculation
- *One calculation per grid cell*
- *No vertical discretization*

Photosynthesis / stomatal conductance

diffuco module

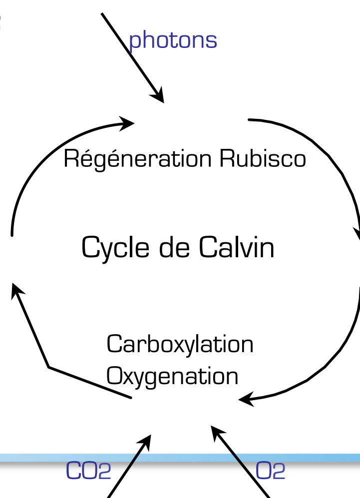
diffuco_trans_co2 routine



Photosynthesis

(Farqhuar et al., Collatz et al.)

$A_n = f(V_{carbox}, V_{régéner}) - R$

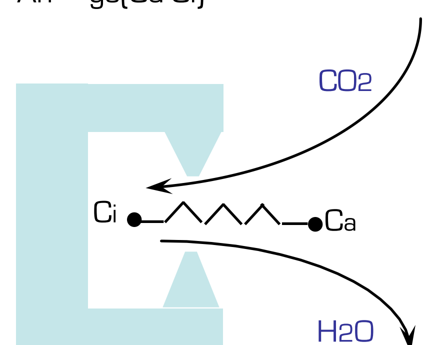


Stomatal conductance

(Ball et al.)

$G_s = m\, A_n * H_r / C_a$

$A_n = g_s(C_a - C_i)$



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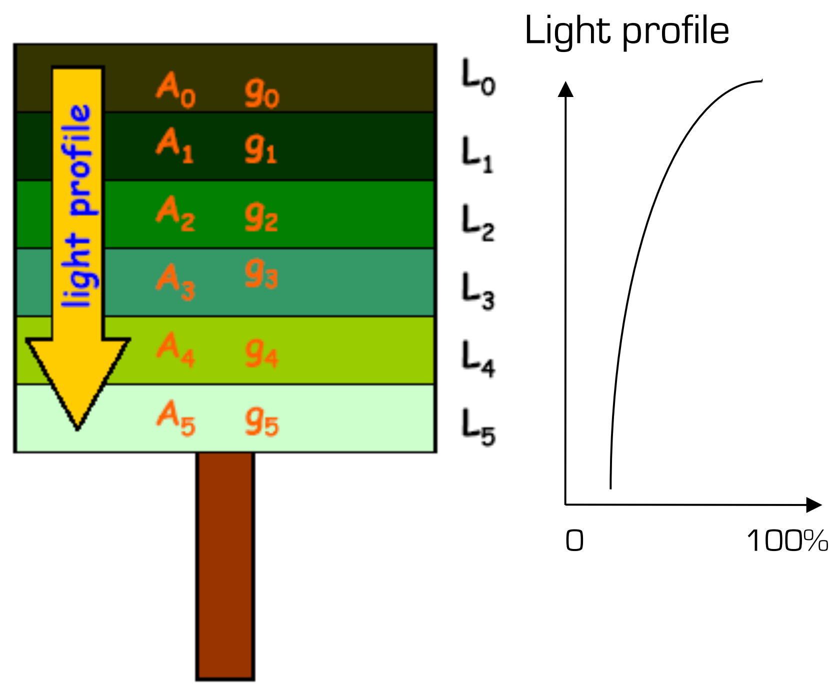
From the leaf to the canopy

- PS and Gs are calculated at each LAI level:
- Beer-Lambert decrease of light in the canopy
- Exponential decrease of Vmax (but limited to 30%) to mimic nitrogen decrease
- The others parameters (e.g CO_2, rel hum..) are held constants.



Soil temperatures

thermosoil module

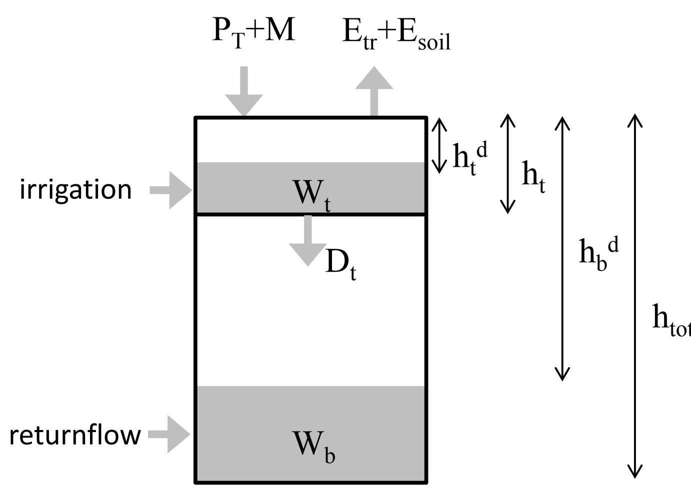
- Calculates the soil temperatures by solving the heat diffusion equation within the soil
  - the soil is divided into 7 layers, reaching to as deep as 5.5m down within the soil, with thiscknesses following a geometric series of ratio 2.

Soil water balance

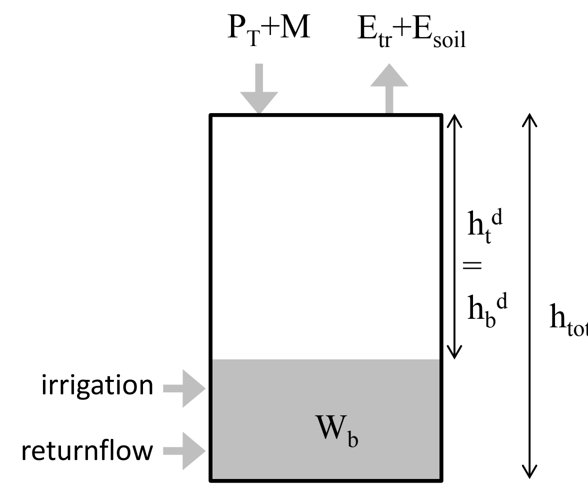
- Current standard version : a 2-layer bucket model
- One balance per PFT

hydrolc module

2 soil layers



1 soil layer

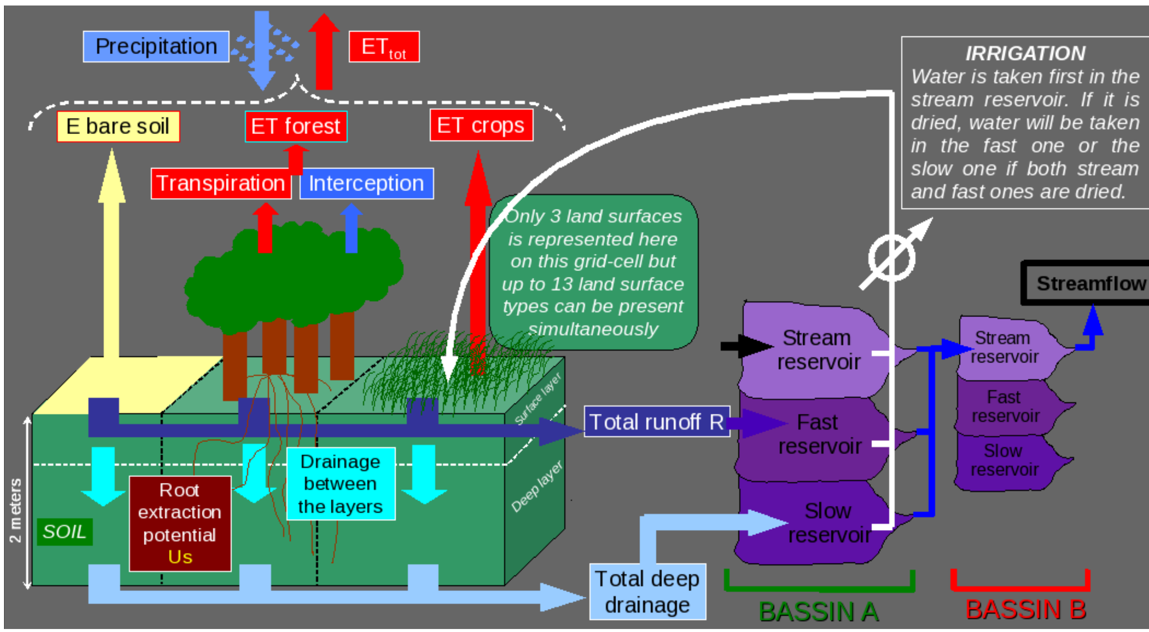


Symbol	Name in ORC	Units	Symbol	Name in ORC	Units
h_{tot}	dpu_cste	m	W_t	gqsb	$kg.m^2$
h_t^d	dss	m	W_b	bqsb	$kg.m^2$
h_t	dsg	m	D_t	gdrainage	$kg.m^2.s^{-1}$
h_b^d	dsp	m			

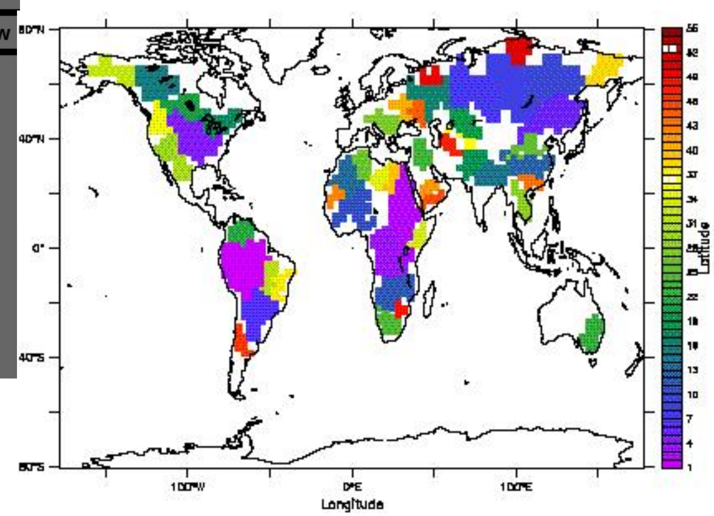
Routing / Irrigation

routing module

- Routing parametrization to calculate water discharge to river



From Guimberteau (thesis, 2010)



The 50 major river basins on the LMD-GCM grid

Biomass and soil pools

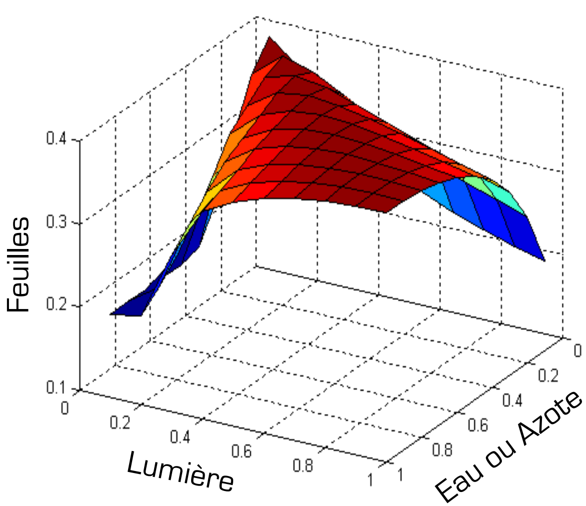
- 8 pools of living biomass
  - Leaves, fine roots, above and below sapwood, above and below heartwood, 'fruits' and 'reserves'
- 4 pools of litter
  - Above/below, Structural & Metabolic
- 3 pools of soil
  - Active, Slow and Passive

Allocation of assimilates

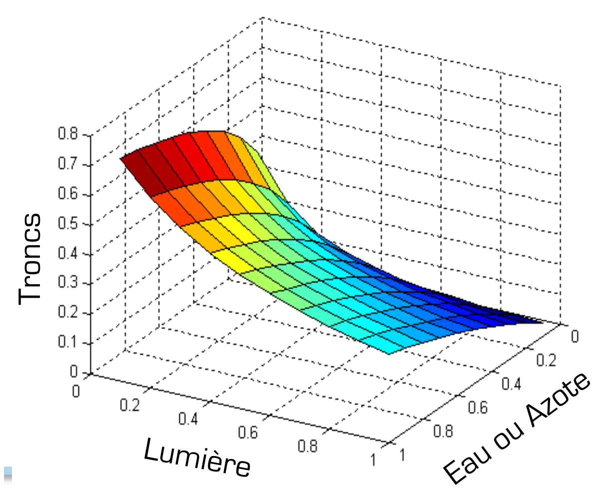
stomate_alloc module

- Principle of ressource optimisation
- Allocation to leaves, branchs, roots as a function of ressources : water (H), nitrogen (N) and light (L)

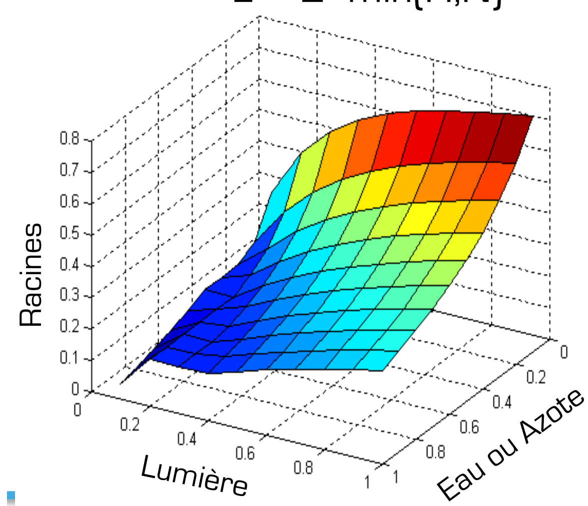
$$Leaf = 1 - Branch - Root$$



$$Branch = \frac{3\,T_0\,\min(H,N)}{2\,L + \min(H,N)}$$



$$Root = \frac{3\,R_0\,L}{L + 2\,\min(H,N)}$$



Friedlingstein et al., 1998

Phenology

- Budburst model (Botta el al. 2000)

  stomate_phenology module

  - Defined for each PFT based on Growing degree days, Number of chilling days, soil water, …
  - Calibrated at global scale from budburst estimated by satellite

- Senescence

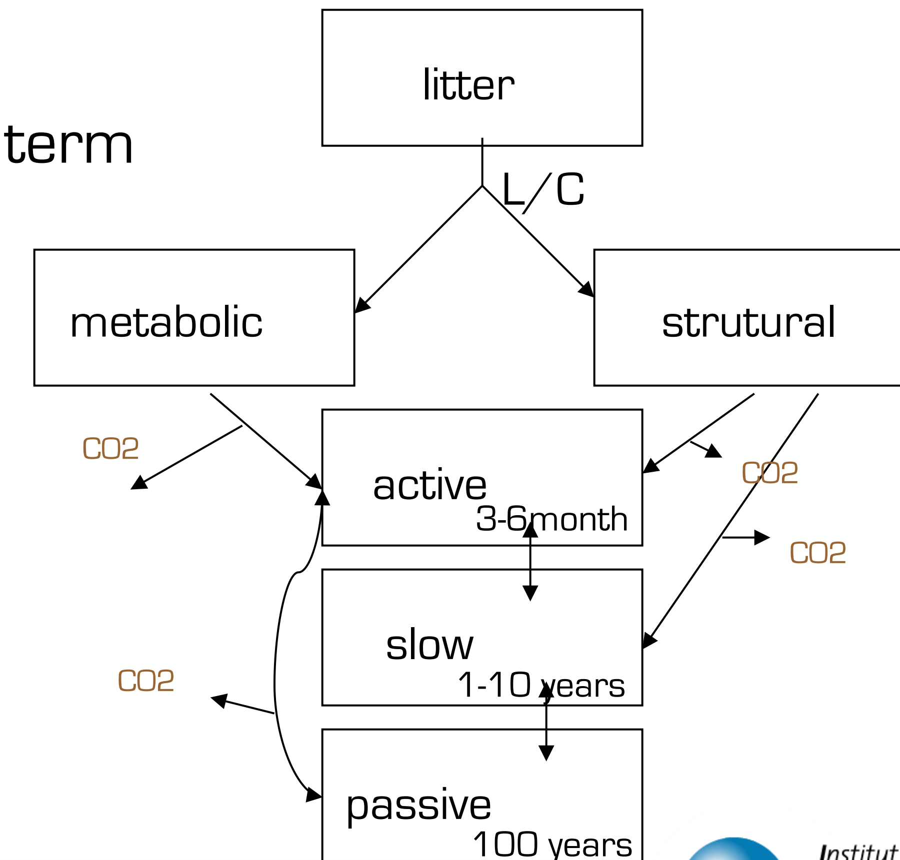
  stomate_turnover module

  - Function of leaf age and environmental conditions
  - For trees, a senescence stage is considered after what all leaves fall (while for grass senescence it is a continuous process)

Respirations

- Autotrophic respiration
  - Maintenance *stomate_resp module*
    - linear response to temperature (Ruimy et al.)
    - potential adaptation to long term temperature
  - Growth *stomate_npp module*
    - a fixed part of assimilates
- Heterotrophic respiration
  - Century-like model

stomate_litter & stomate_soilcarbon modules



Land cover change

stomate_lcchange module

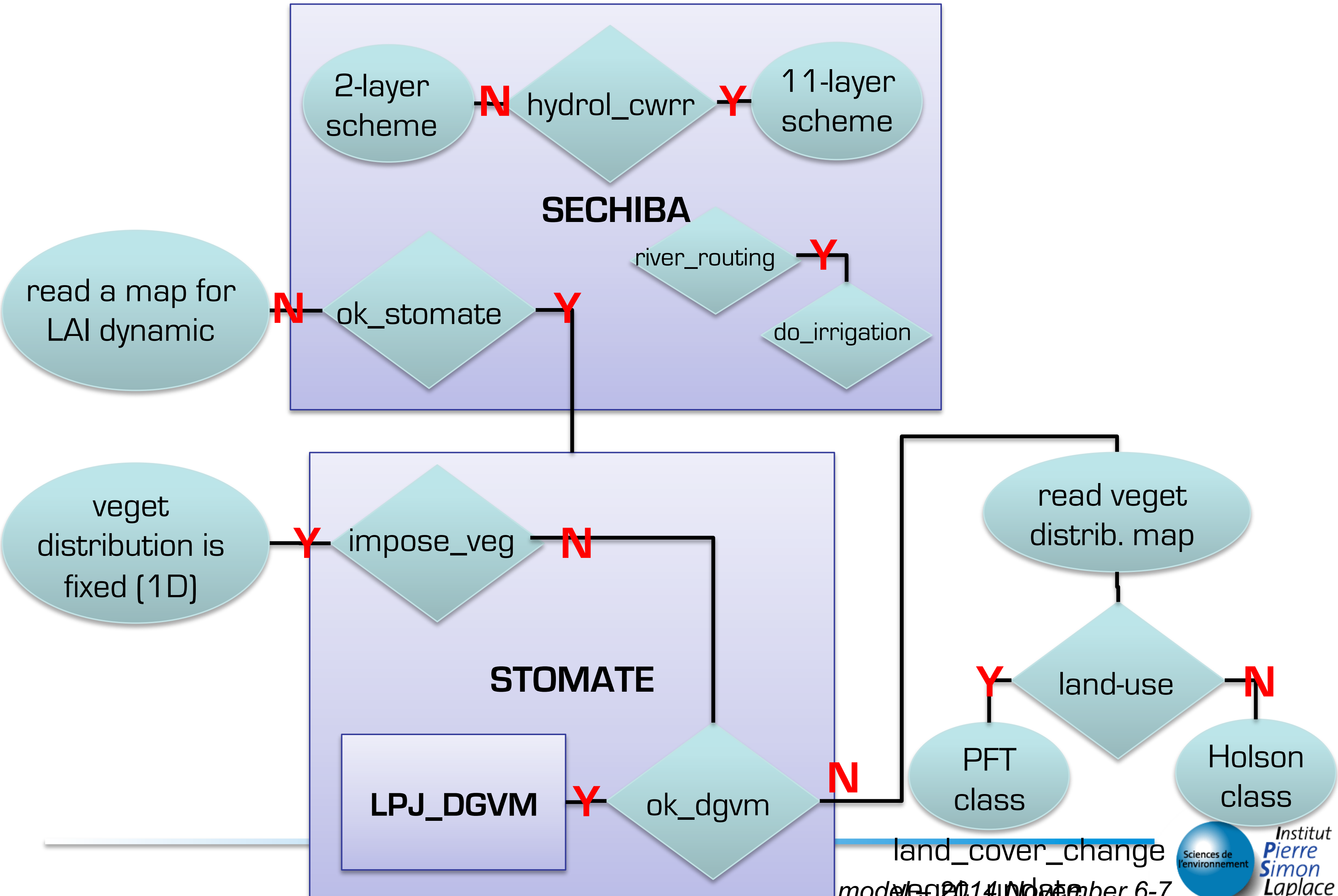
- Vegetation map can vary from one year to another
  - For decreasing PFT
    - A part of biomass is exported and goes to 3 decomposition pools (1 year, 10 year 100 years), the rest goes to litter of increasing PFTs.
    - Soil carbon of decreasing PFT is diluted to soil carbon of increasing PFT's
  - When a PFT disappears => reset to its inital state
  - When a PFT appears => growth from seed

Vegetation dynamic

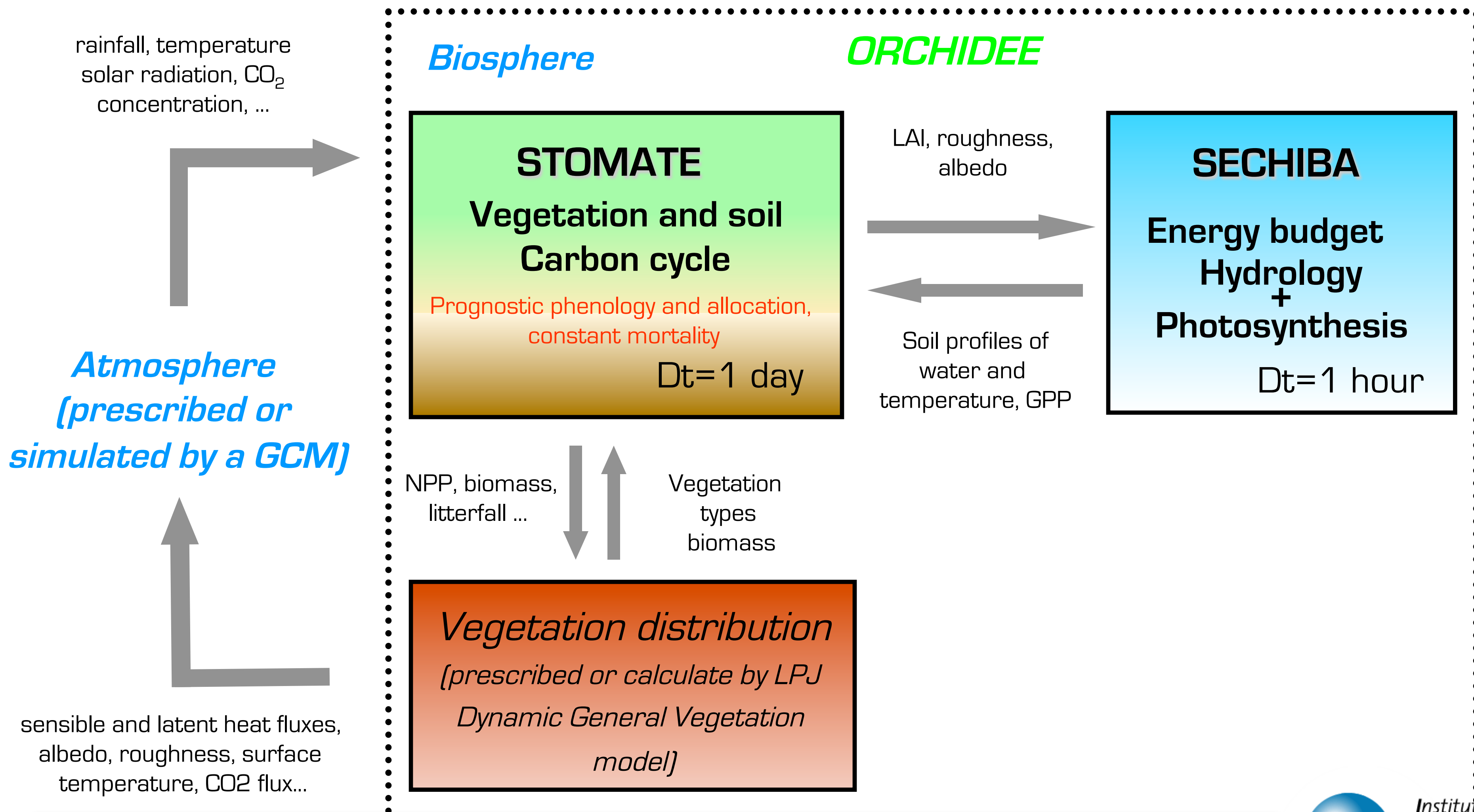
lpj_kill, lpj_pftinout, lpj_constraints modules

- Taken from LPJ model
- All PFT's are able to growth in each grid cell
  - Climate constraints define regeneration and adaptation of PFT's
  - Ligth competition when canopy closure (PFT with NPPmax dominate)
  - Trees ever dominate the grass

Configurations



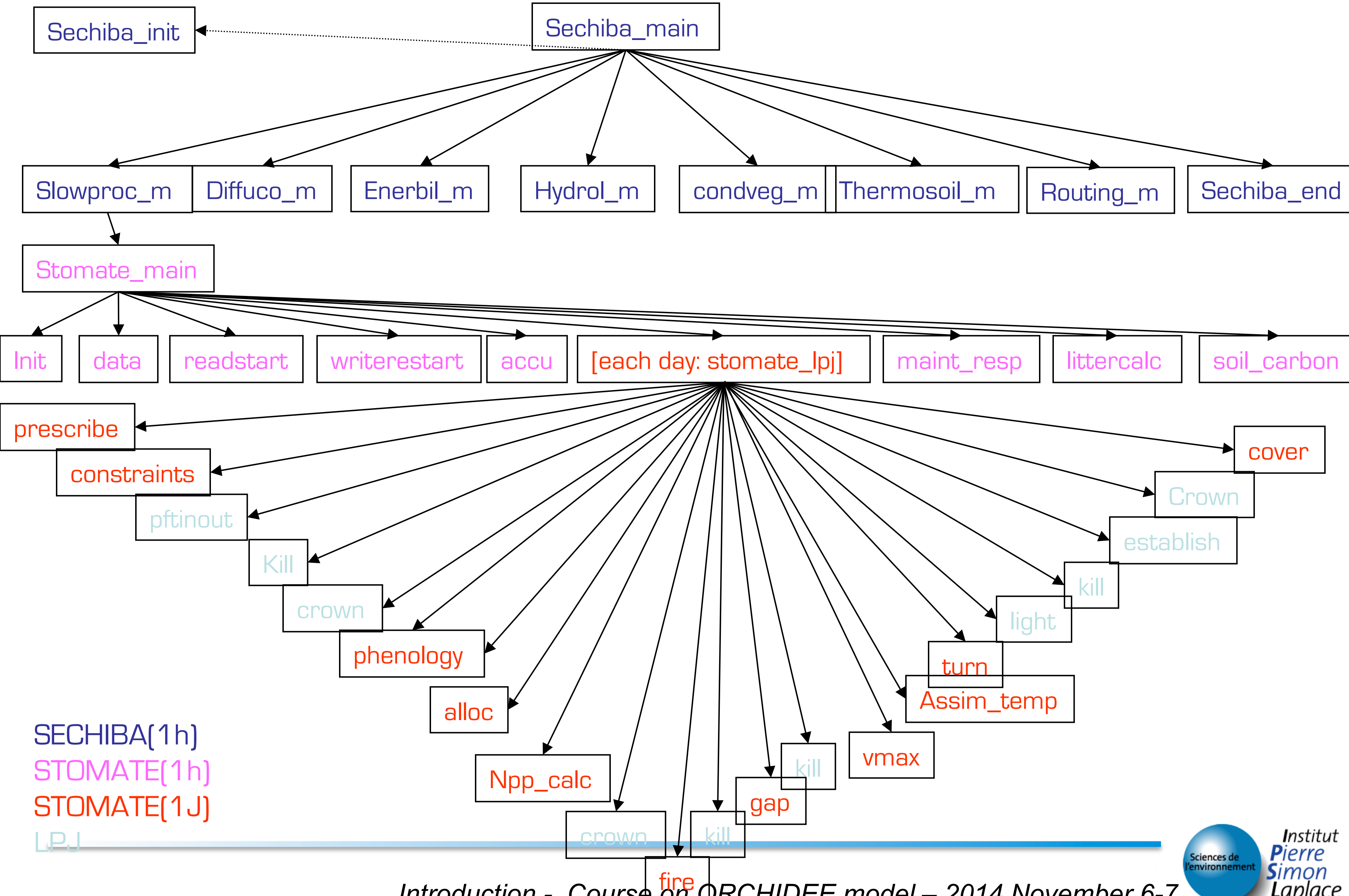
ORCHIDEE, standard version



Structure of the code

- Use of a modular structure
  - All the variables are dynamics (allocatable)
  - For each module:
    - A « main point » <module>_main
    - An initialisation procedure (l_first_<module> (including reading of initial state)
    - an optional end procedure
    - a call to write of restart
  - All the variables are transmitted by subroutine parameters

Subroutine Call graph



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Module description (1)

- SECHIBA
  - Diffuco: diffusion coefficients (+photosynthesis)
  - Enerbil: energy budget
  - Hydrolc,Hydrol: soil water budget (2 levels bucket, 11 levels complex)
  - Condveg: toolbox for vegetation
  - Thermosoil: Soil temperature
  - Routing: routing of water
  - Slowproc: link to STOMATE + simplified parametrisation of LAI

Module description (2)

⌘ STOMATE

- Stomate: main point of stomate: accu of variables+ writing of forcing…
- Stomate_lpj: interface to 1 day processes
- Main_resp: maintenance respiration
- Littercalc: litter respiration and pools
- Soil_carbon: soil respiration and pools
- Prescribe: prescribe some parameters where no DGVM

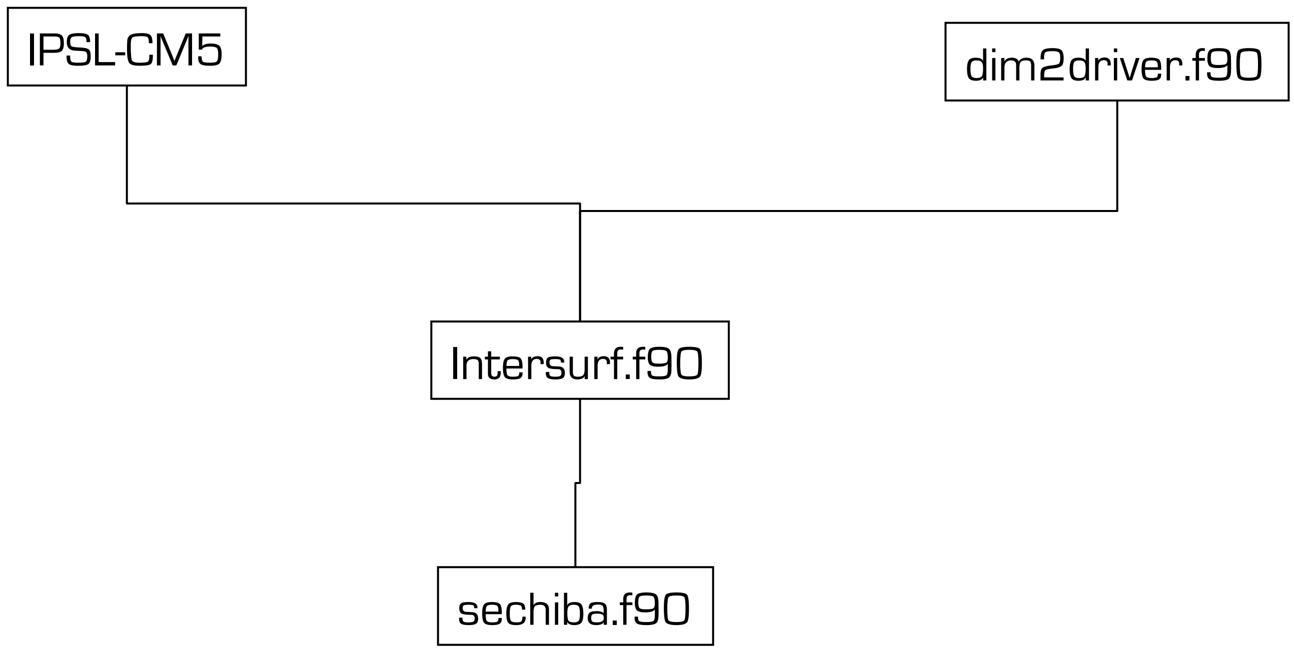
Module description (3)

- STOMATE_LPJ
  - Crown: crown area of trees
  - Phenology: determination of beginning of leaves
  - Alloc: allocation of NPP
  - NPP_calc: update of carbon pools
  - Fire: fire probability
  - Gap: tree motality
  - Vmax: estimation of Vmax as a function of leaf age
  - Assim_temp: estimation of PS temperature response
  - Turn: leaf turnover
  - Light: estimation of light competition
  - Establish: rate of PFT expension
  - Cover: estimation of veget_max (max fractionnal coverage)

Module description (4)

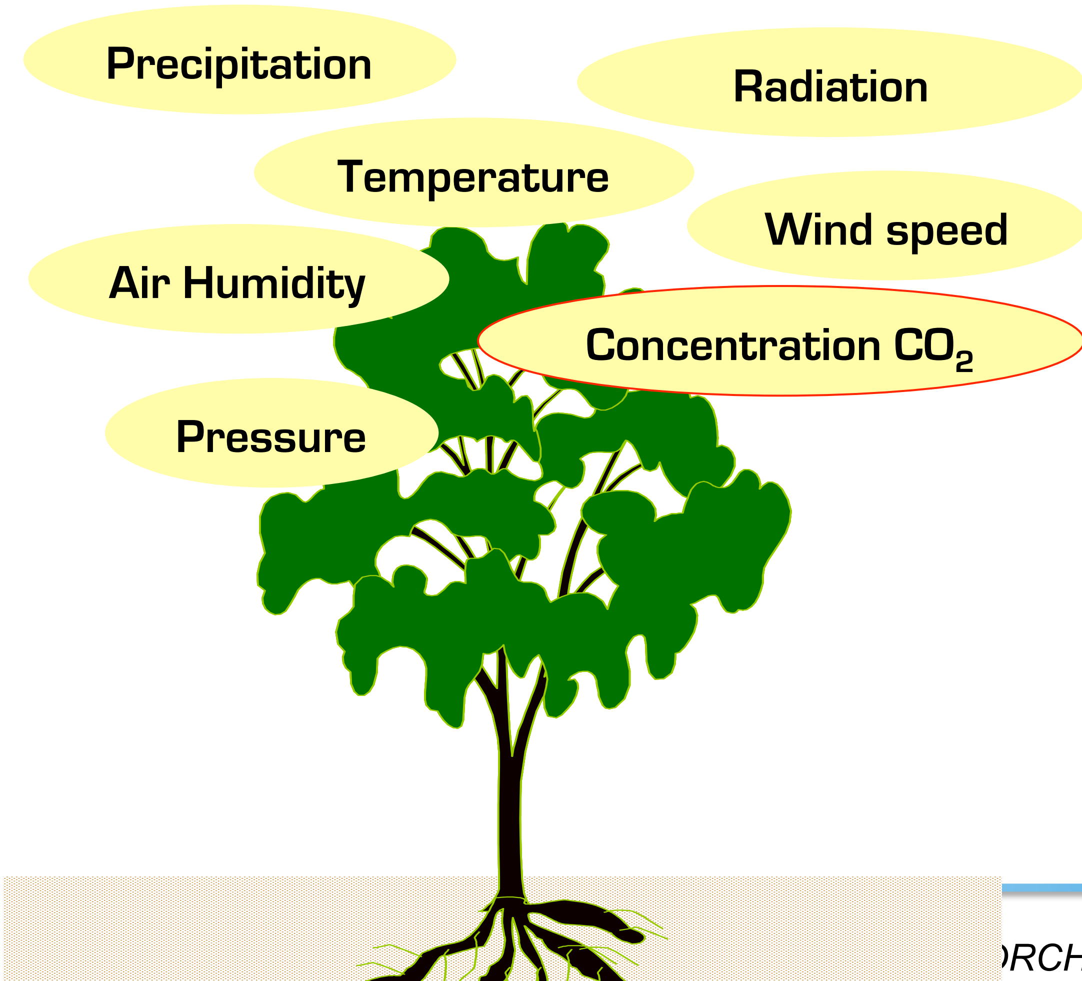
- LPJ
  - Constraints(DGVM): constrain for PFT survival
  - Pftinout: estimation of PFT that appear/disappear
  - Kill: killing of a PFT

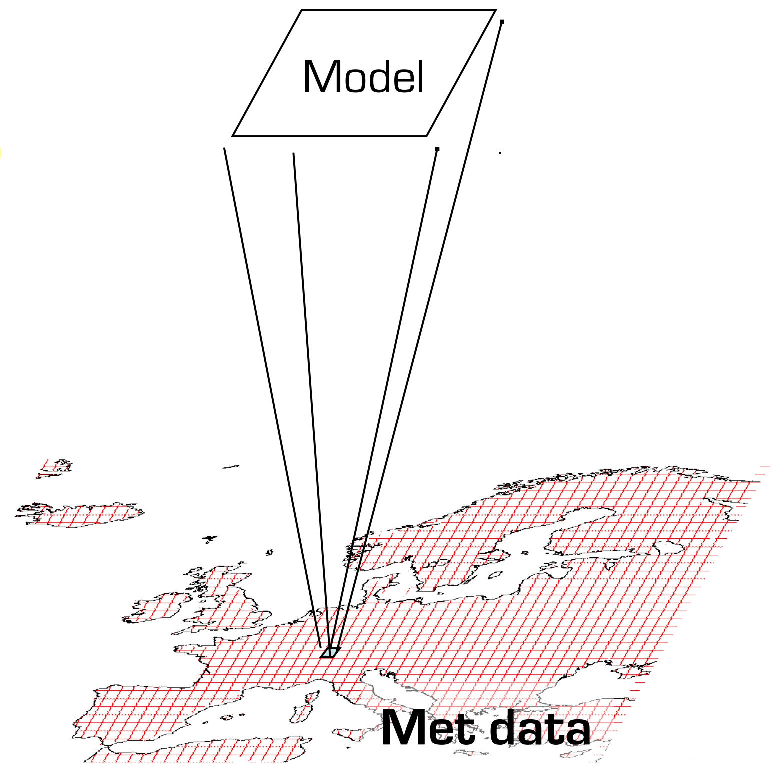
Top structure



Model Interface

- Meteorological forcings (from monthly to half-hourly)
  - split_dt parameter





Meteorological forcings

- One often uses reanalysis or in-situ data with different time resolution (3h, 6h, ½ hour, …)
- The time step of a simulation is defined by the time resolution of the forcing and the value of the SPLIT_DT parameter
- SPLIT_DT is the number of model iterations done per forcing time period.
- Default value of SPLIT_DT is 12 (one assumes a 6-hourly forcings)

Other forcings

- Soil data (class, texture)
- Long-term mean temperature map
- Optional (=f^n of the configuration)
  - LAI map (SECHIBA alone)
  - Vegetation map (ORCHIDEE without vegetation dynamic)
  - Routing/irrigation maps
  - Restart files (initial conditions)

+ Parameter file (run.def)

=> All the files are in NetCdf,

  - except the run.def : ASCII file <parameter=value>

Outputs

- 'history' files
  - One/two for SECHIBA component
  - One/two for STOMATE component
- Restart files for next simulations (driver, sechiba, stomate components)