The Global Land Surface Model
ORCHIDEE
(ORganizing Carbon and Hydrology In Dynamic Ecosystems Environment)

Outline

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

A brief history

Model

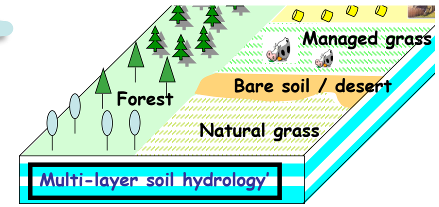
Carbon Cycle (STOMATE)

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

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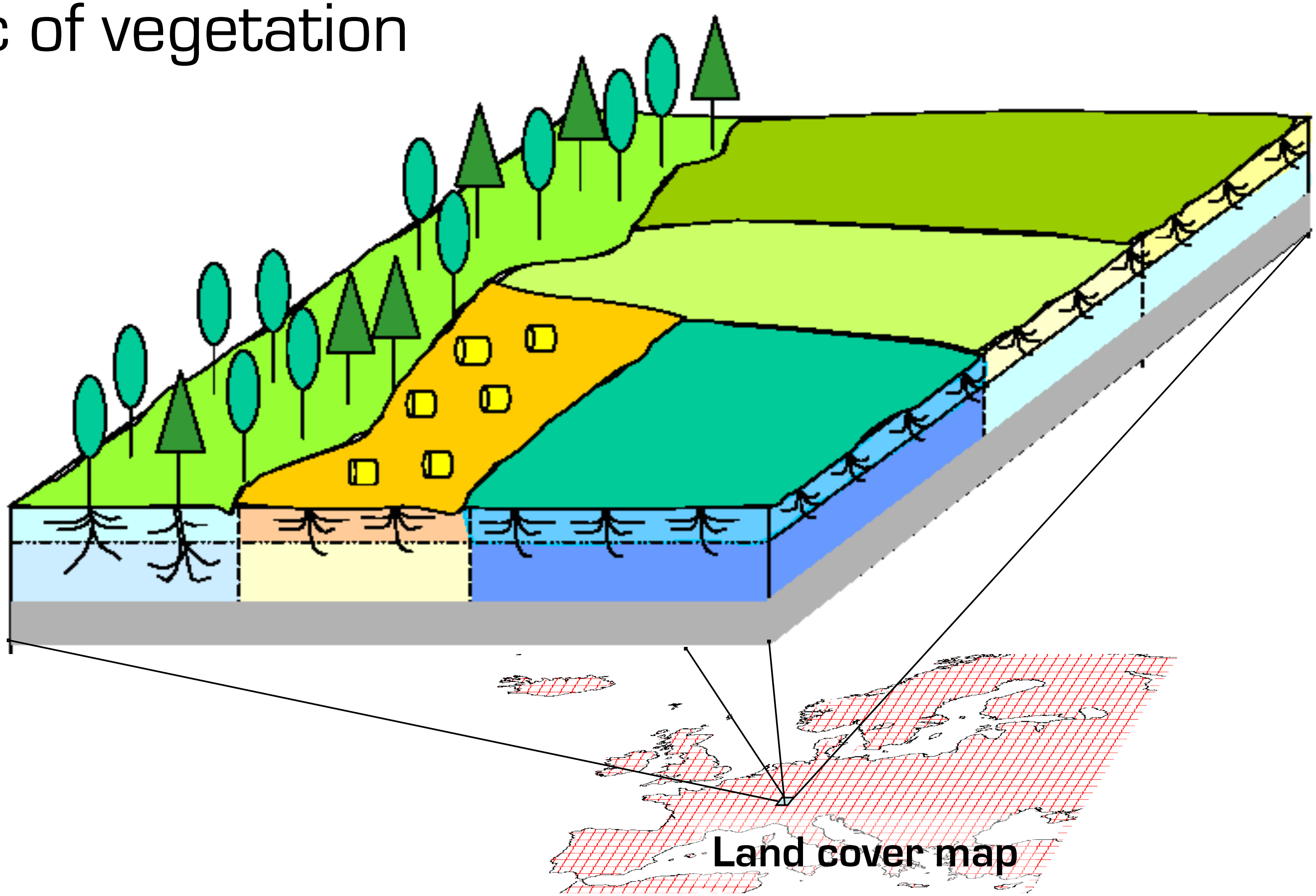
How the surface is represented ?

- A mosaïc of vegetation



How the surface is represented ?

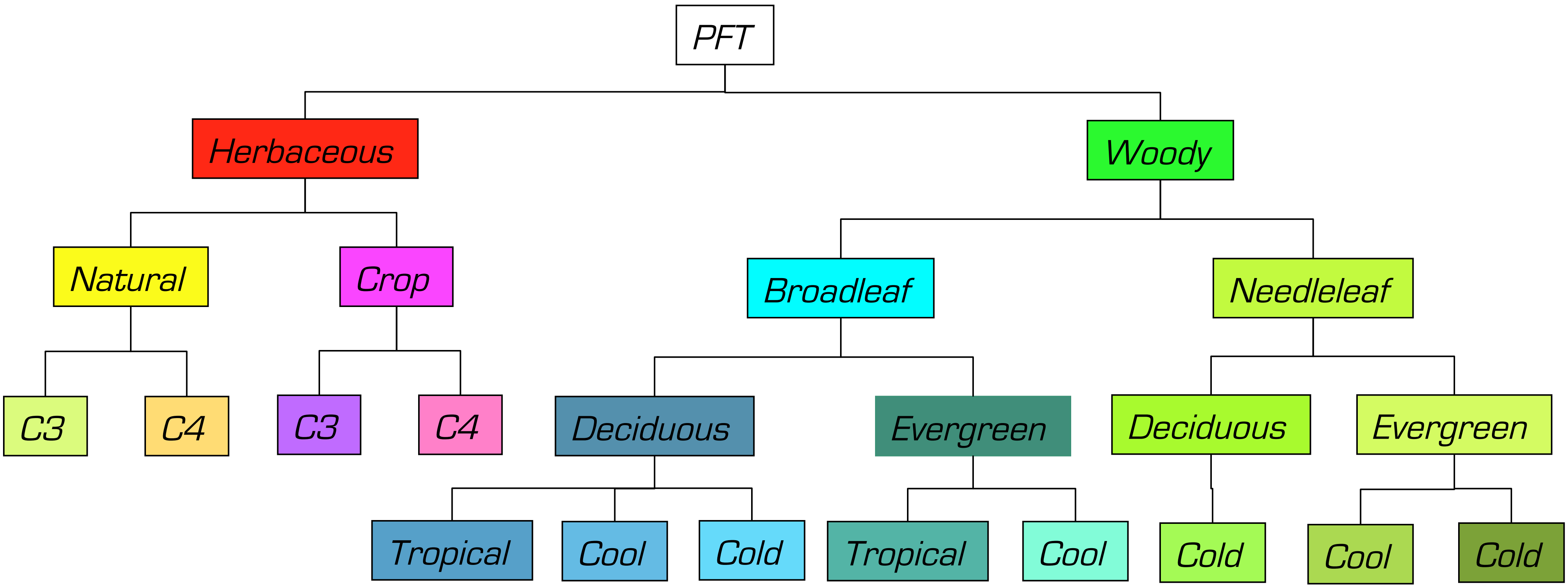
- In each grid cell, we account for:
  - Bare soil
    - *veget_max(1)*
  - Vegetated lands
    - *veget_max(2:nvm)*
  - Other lands (so far, only the continental ice)
    - *frac_nobio*

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

- One soil type per grid cell

Vegetated lands

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



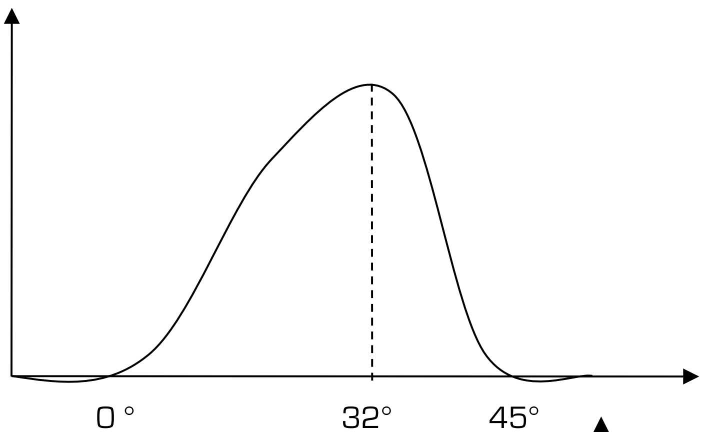
Plant Functional Types

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

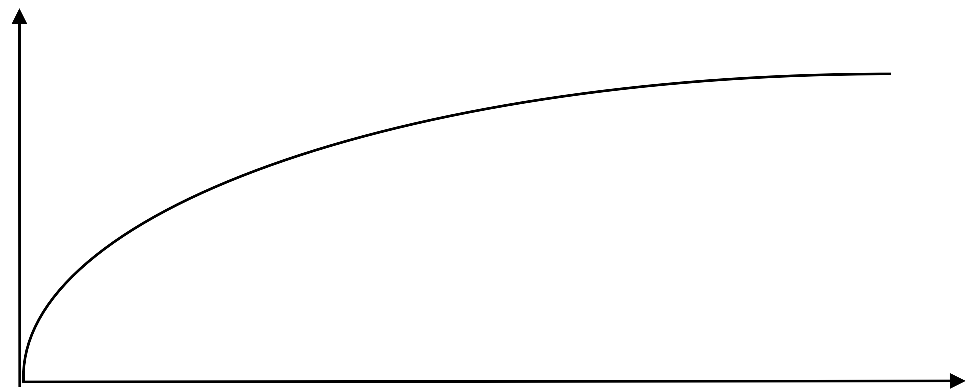
PFT	$V_{cmax,opt}$	T_{opt}	λ_{max}	z_{root}	α_{leaf}	h	A_c	T_s	H_s
TrBE	50	37	10	1.25	0.12	25	910	-	0.3
TrBR	60	37	10	1.25	0.14	25	180	-	0.3
TeNE	37.5	27	5	1.	0.14	15	910	-	-
TeBE	37.5	32	5	1.25	0.14	15	730	-	-
TeBS	37.5	28	5	1.25	0.14	15	180	12.5	-
BoNE	37.5	25	4.5	1.	0.14	10	910	-	-
BoBS	37.5	25	4.5	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

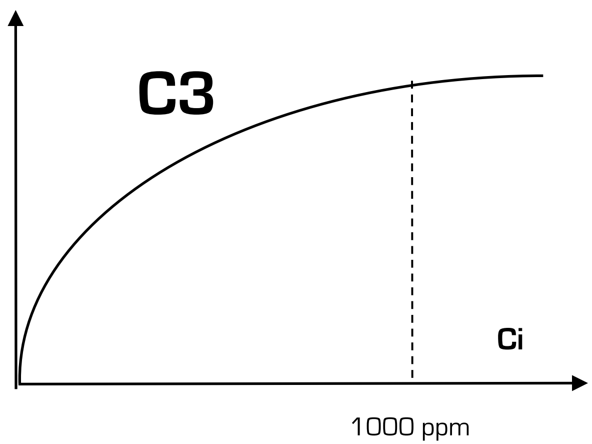
Temperature

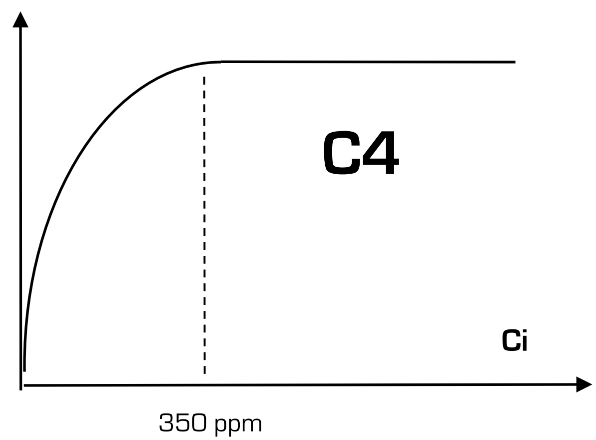


Light



[CO_2]





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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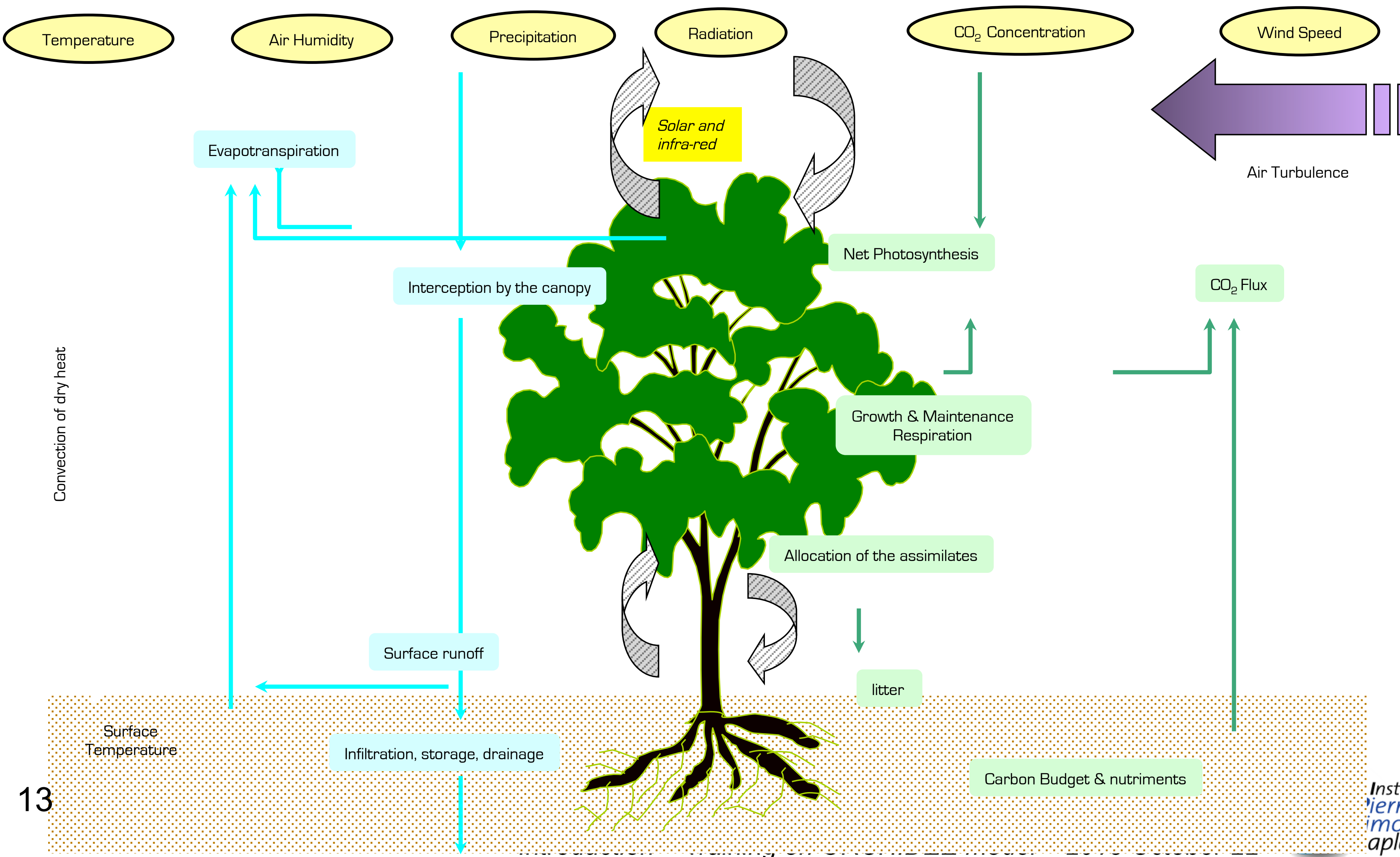
Main processes



Energy budget & Resistance terms

- Calculation of the *enerbil module*
  - 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*

diffuco module

- vbeta1 : sublimation
- vbeta2 : interception loss
- vbeta3 : transpiration
- vbeta4 : bare soil evaporation
- vbeta5 : flood plains

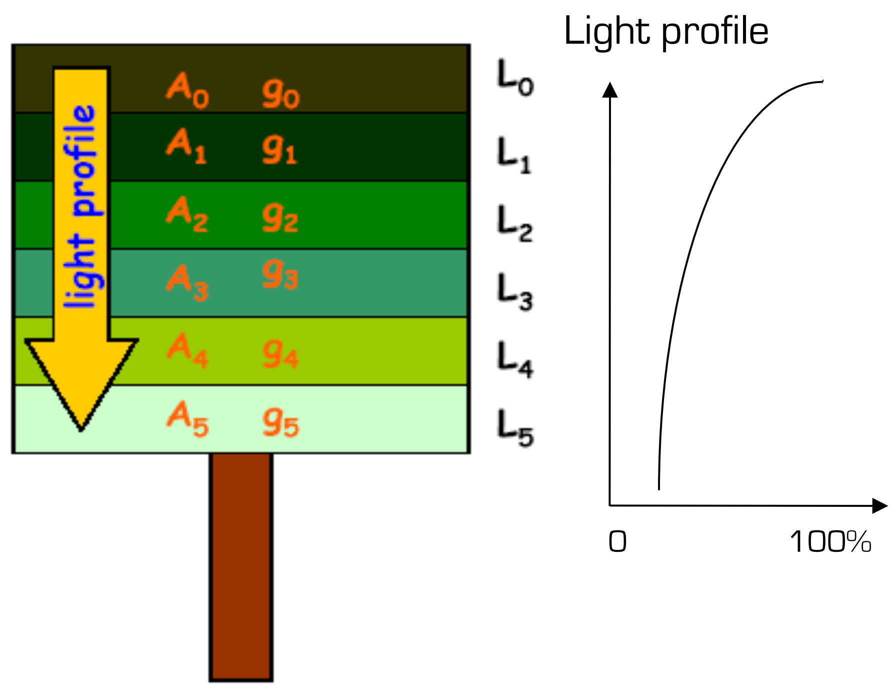
C assimilation / stomatal conductance

diffuco module

diffuco_trans_co2 routine

- A and G_s 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.

From the leaf to the canopy



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Soil temperatures

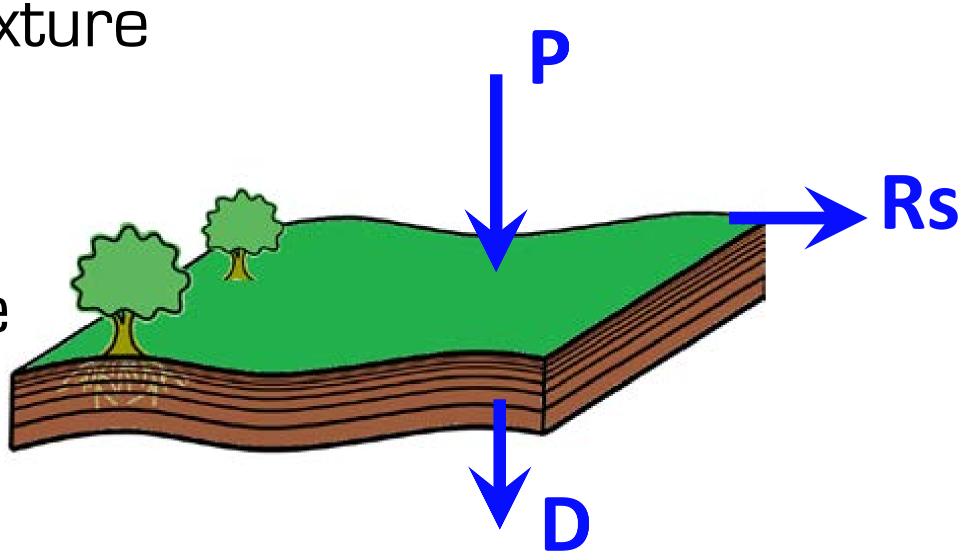
thermosoil module

- One calculates the soil temperatures by solving the heat diffusion equation within the soil
  - the soil is divided into several layers, reaching 10m down within the soil, with thisckness following a geometric series.
  - No more interpolation with soil water layers

Soil water balance

hydrol module

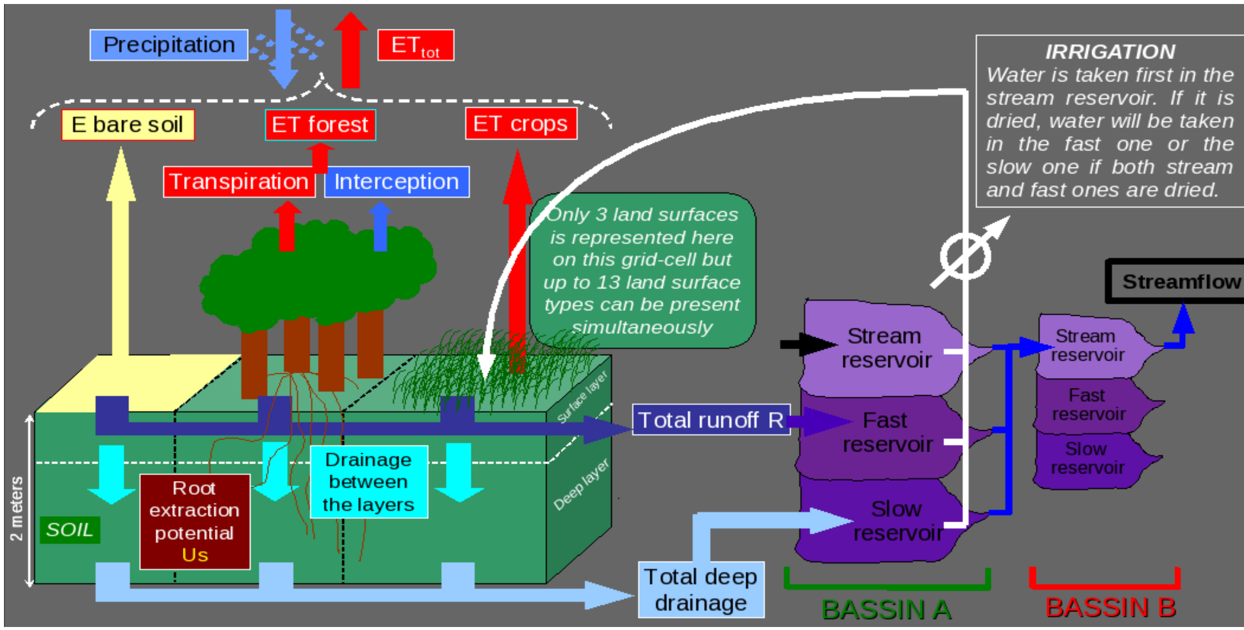
- Physically-based description of soil water fluxes using Richards equation 2-m soil and 11-layers
- Formulation of Fokker-Planck
- Hydraulic properties based on van Genuchten-Mualem formulation
- Related parameter based on texture (fine, medium, coarse)
- Surface runoff = P – Esol – Infiltration ; Free drainage at the bottom



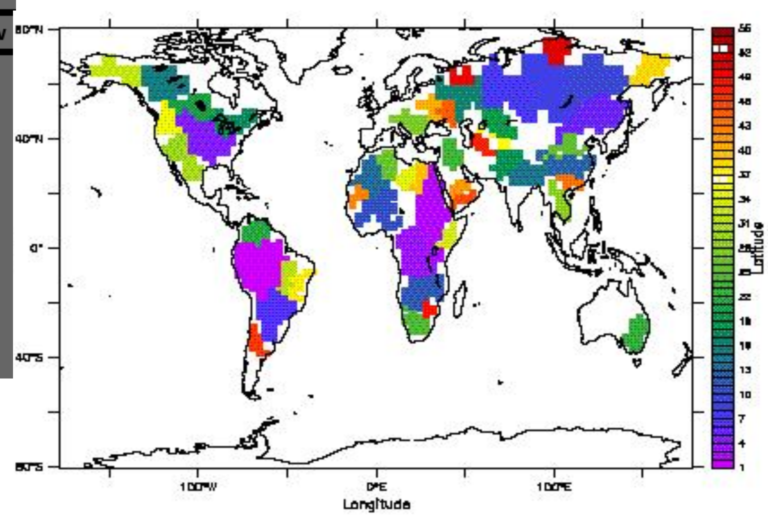
Routing / Irrigation

routing module

- Routing parametrization to calculate water discharge to river



From Guimberteau (thesis, 2010)



The 50 major river basins on the LMD-GCM grid

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Biomass and soil pools

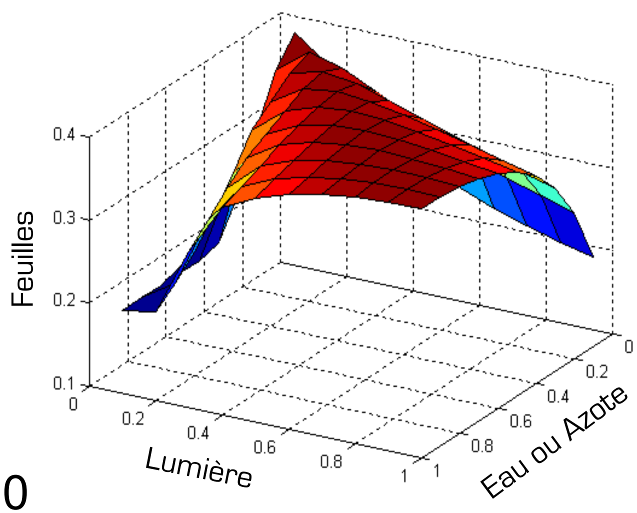
- 8 pools of living biomass
  – Leaves, fine roots, above and below sapwood, above and below heartwood, 'fruits' and 'reserves'
- 4 pools of litter
  – Above/below, Structural & Metabolic
- 3 pools of soil
  – Active, Slow and Passive

Allocation of assimilates

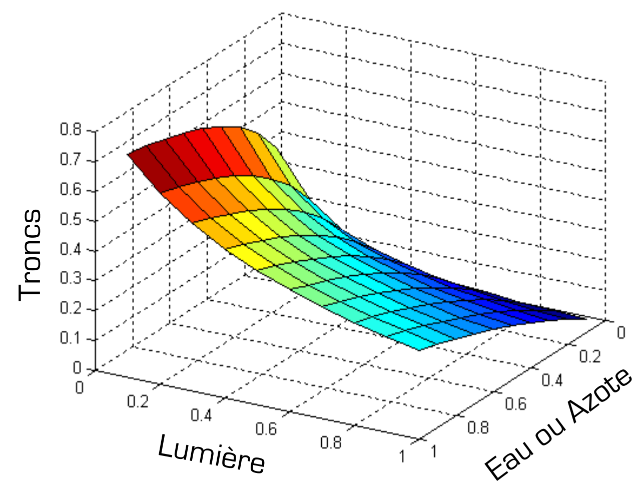
stomate_alloc module

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

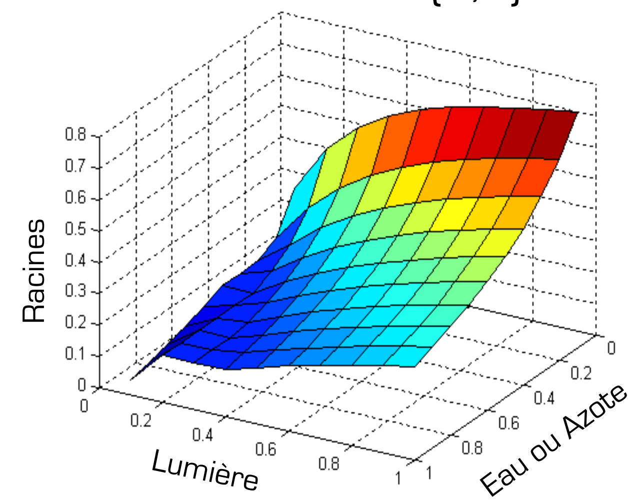
$$\text{Leaf} = 1 - \text{Branch} - \text{Root}$$



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



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



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

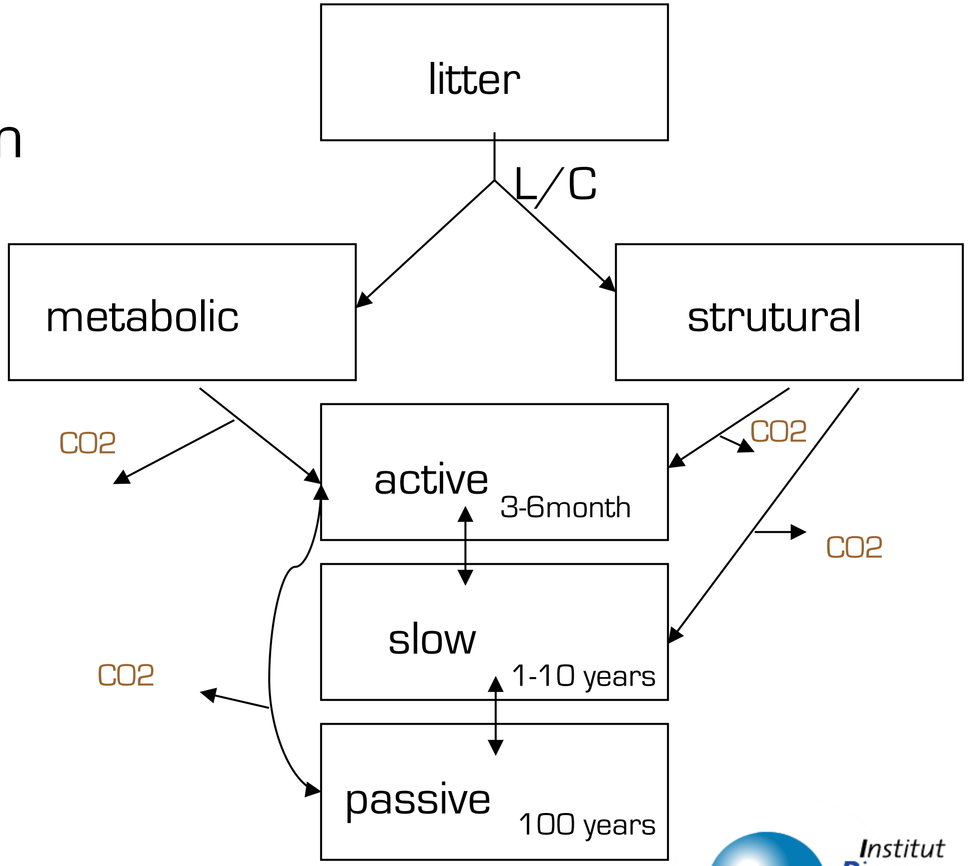
  stomate_turnover module

  - 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



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Land cover change

- 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

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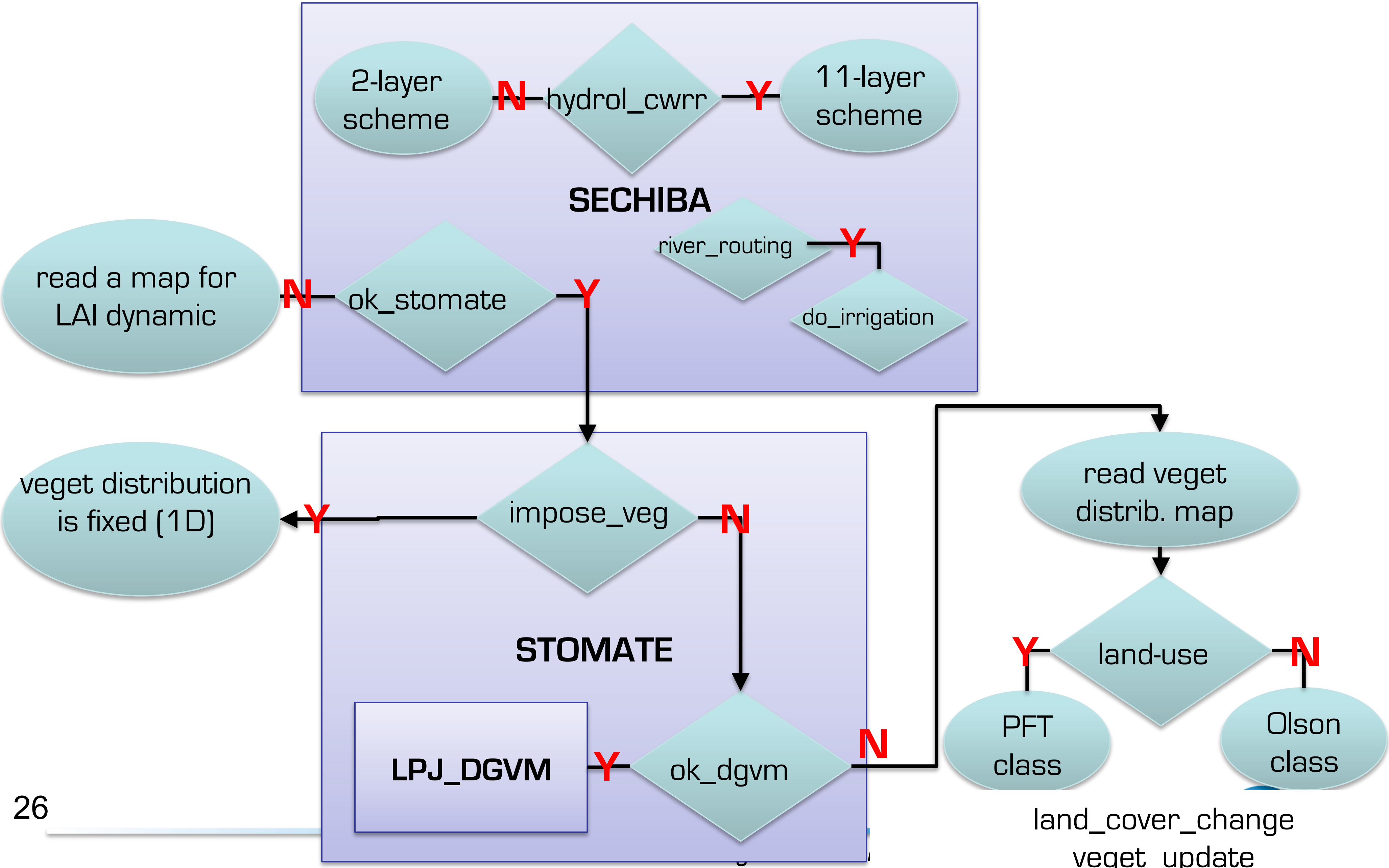
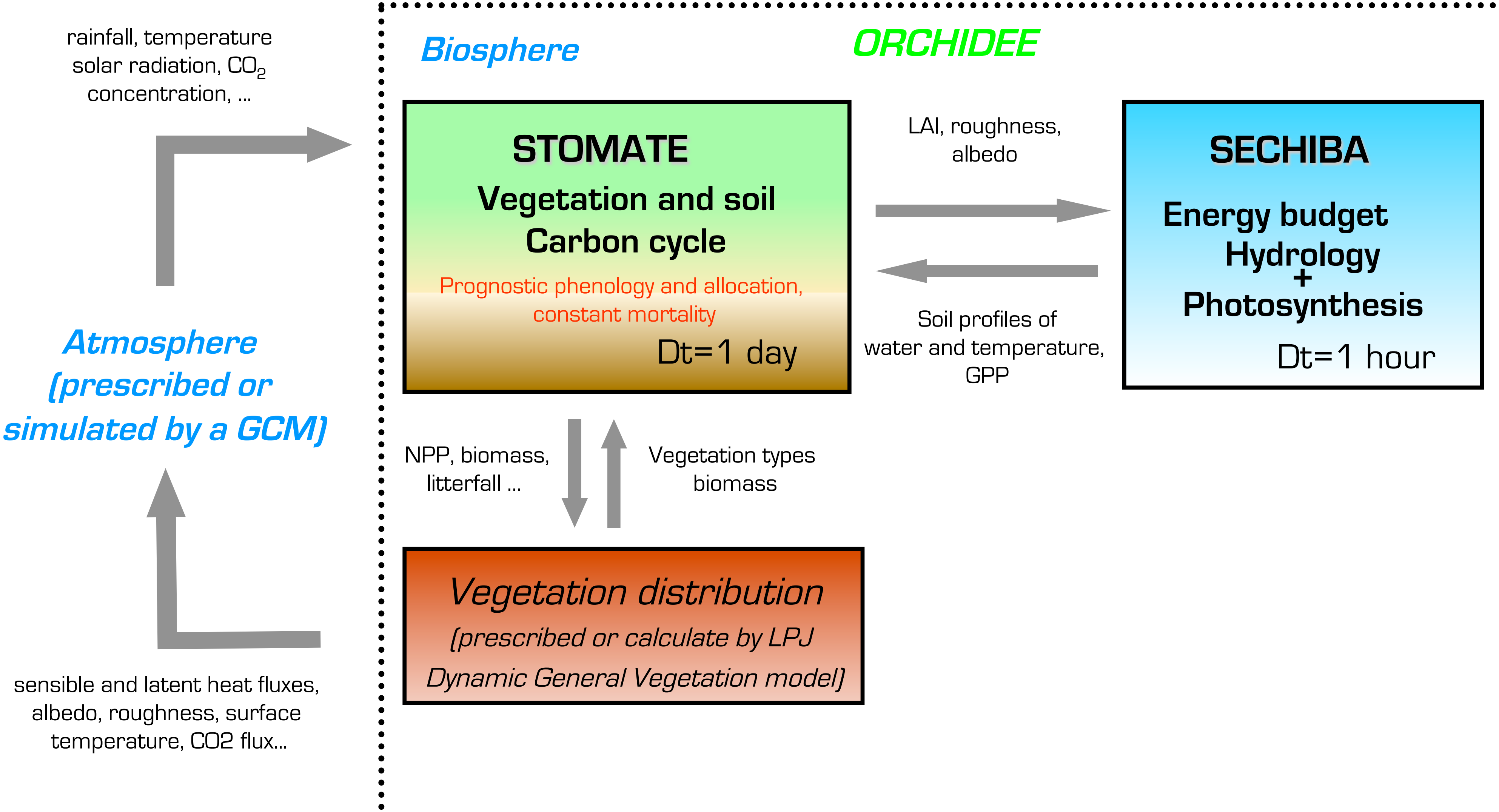
Configurations



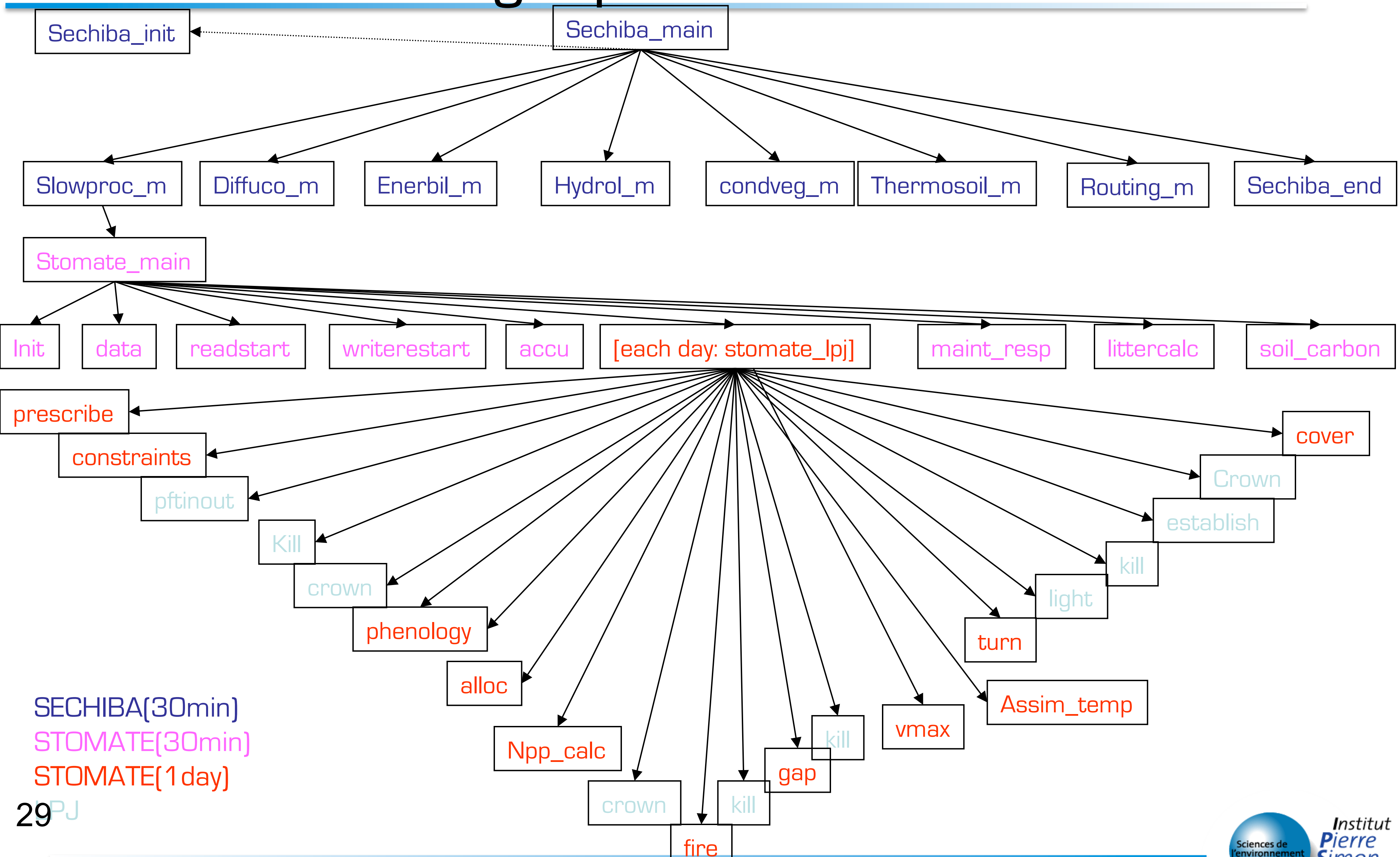
ORCHIDEE, standard version



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



SECHIBA(30min)
STOMATE(30min)
STOMATE(1day)
LPJ

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)

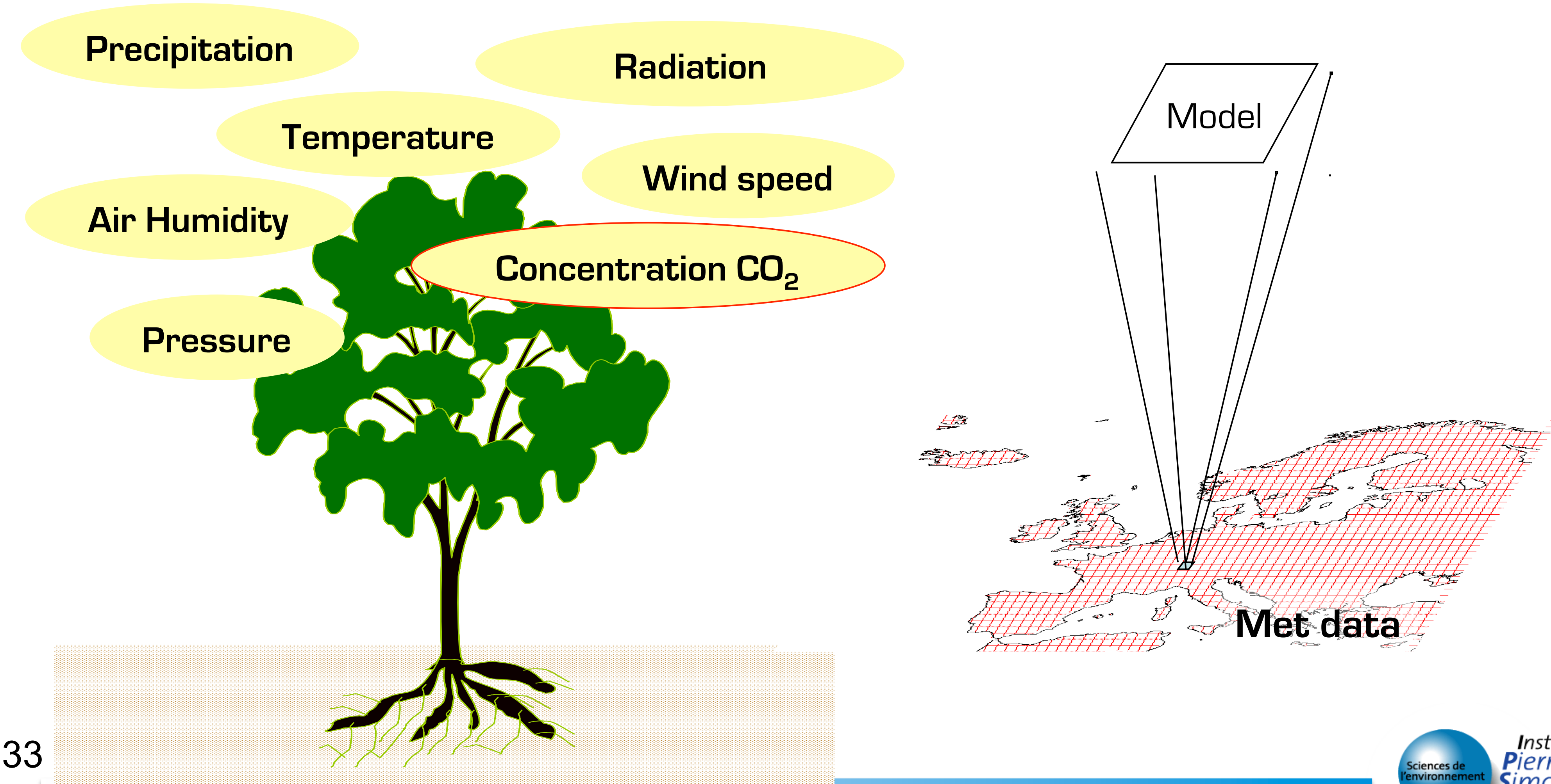
- STOMATE
  - Stomate: main point of stomate: accu of variables+ writing of forcing…
  - Stomate_lpj: interface to 1 day processes
  - Main_resp: maintenance respiration
  - Littercalc: litter respiration and pools
  - Soil_carbon: soil respiration and pools
  - Prescribe: prescribe some parameters where 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
  - Turn: leaf turnover
  - Light: estimation of light competition
  - Establish: rate of PFT expension
  - Cover: estimation of veget_max (max fractionnal coverage)
- LPJ
  - Constraints(DGVM): constrain for PFT survival
  - Pftinout: estimation of PFT that appear/disappear
  - Kill: killing of a PFT

Model Interface

- Meteorological forcings (from monthly to half-hourly)



Forcing files

- Meteorological data
  - One often uses reanalysis or in-situ data with different time resolution (3h, 6h, ½ hour, ...)
  - The spatial resolution of the simulation is driven by the resolution of the meteo forcing file
  - The time step of a simulation is defined by the parameter DT_SECHIBA (30 min by default)
- Other data (PFT map, soil texture)

  Will be interpolated at the resolution of the meteo data