CAMS41: Potential futur steps for CTESSEL !

Atmosphere Monitoring

Philippe Peylin, Fabienne Maignan, Vladislav Bastrikov, Nicolas Vuichard, Nicolas Viovy, and many other collaborators

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Outline

1. **Context: model spread**
2. **Parameter Optimisation strategy**
3. Coordination approach
4. New model developments
    1. Nitrogen cycle implementation
    2. Soil water stress and hydraulic architecture
    3. Gap model and 2 stream RT scheme
    4. Multi-layers energy budget
5. Accounting for management

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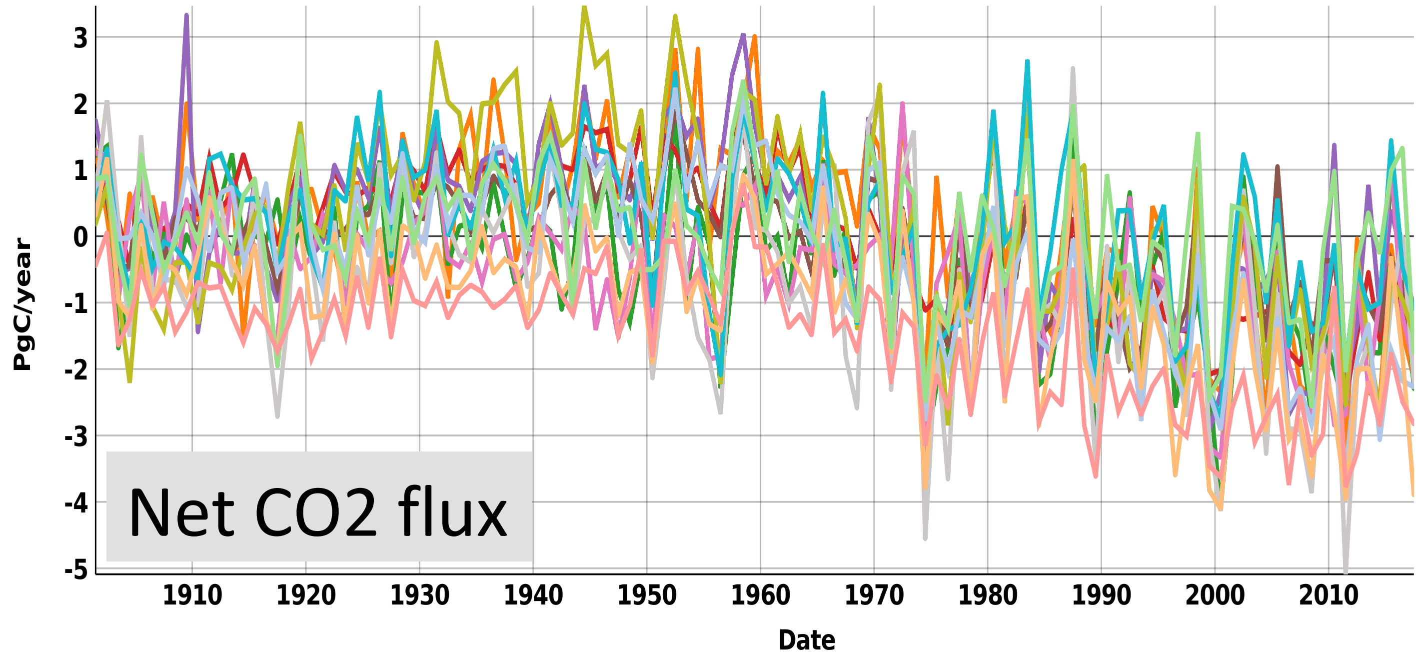
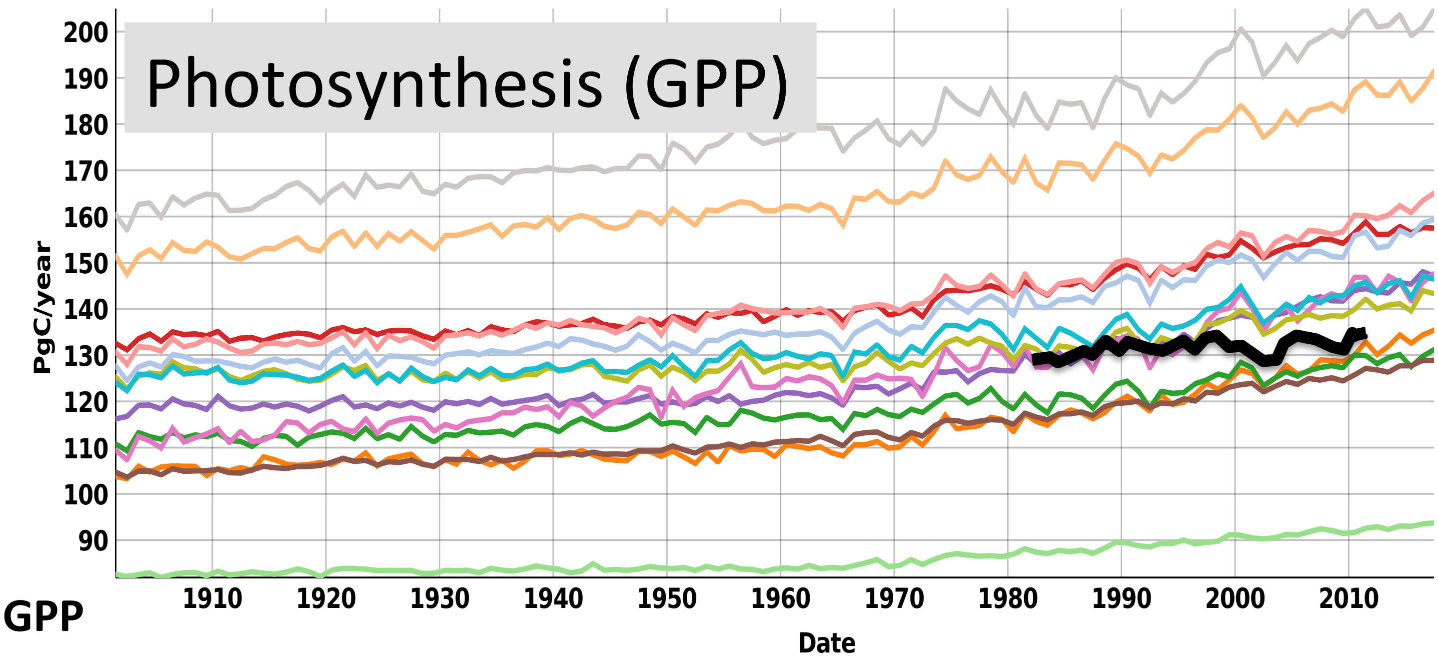
Current models: large spread !

Example: TRENDY – 2018 ensemble of model runs

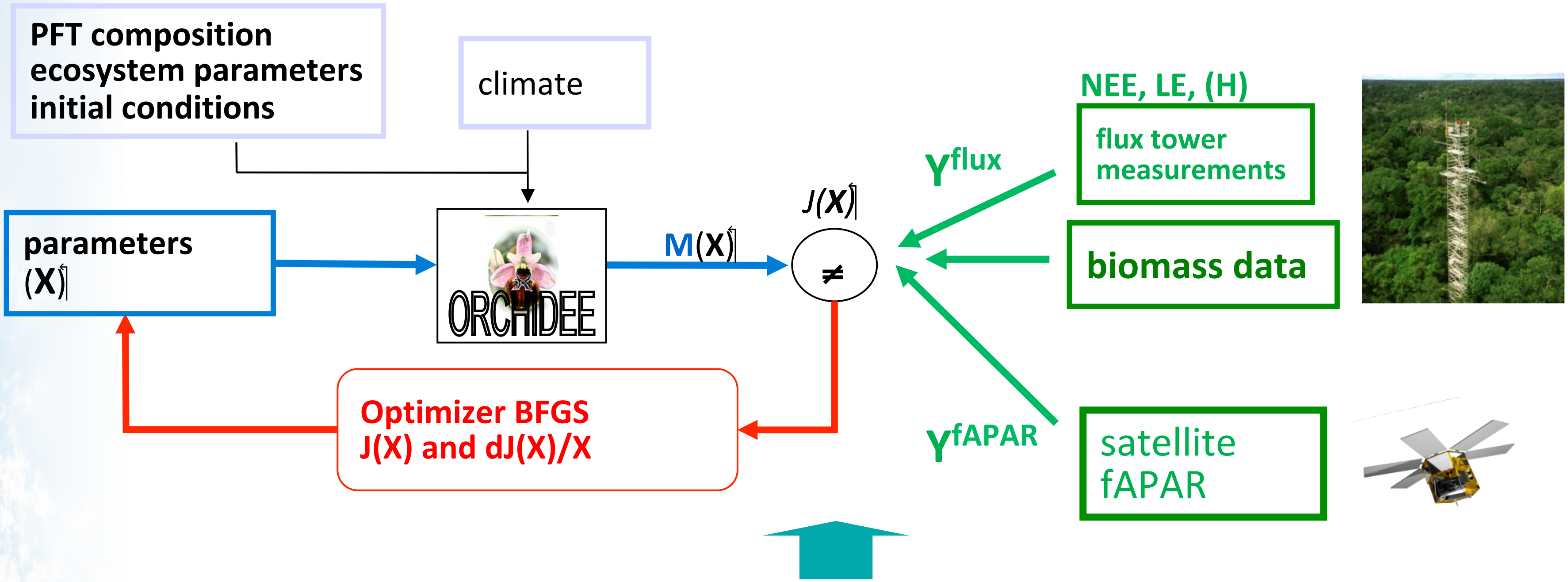




- CABLE
- CLASS
- CLM5 (
- DLEM
- ISAM /
- JSBACH
- JULES
- LPJ /
- LPX /
- OCN
- ORCHIDEE
- ORCHIDEE CNP
- SURFEX

● JUNG-MTE - GPP

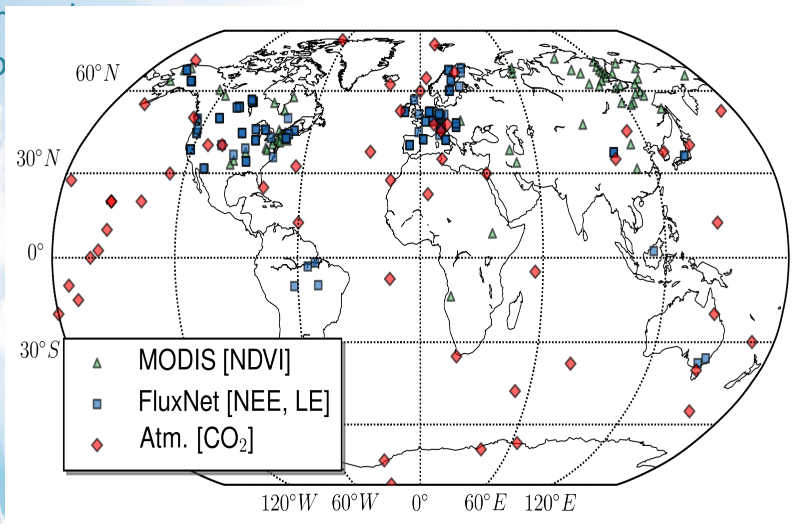
Parameter optimisation strategy

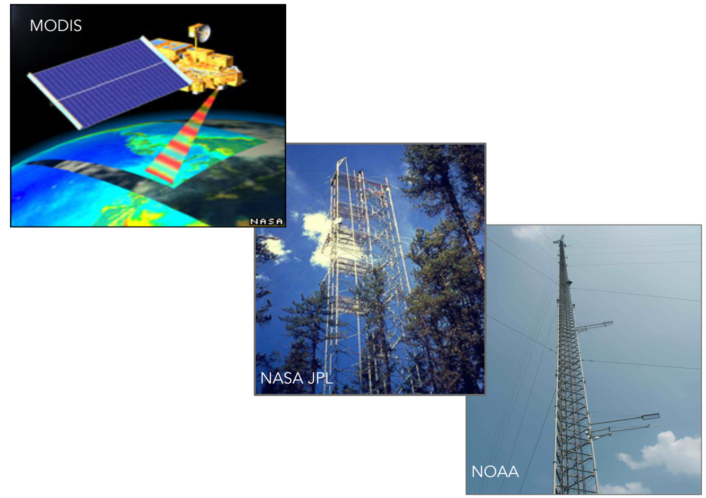


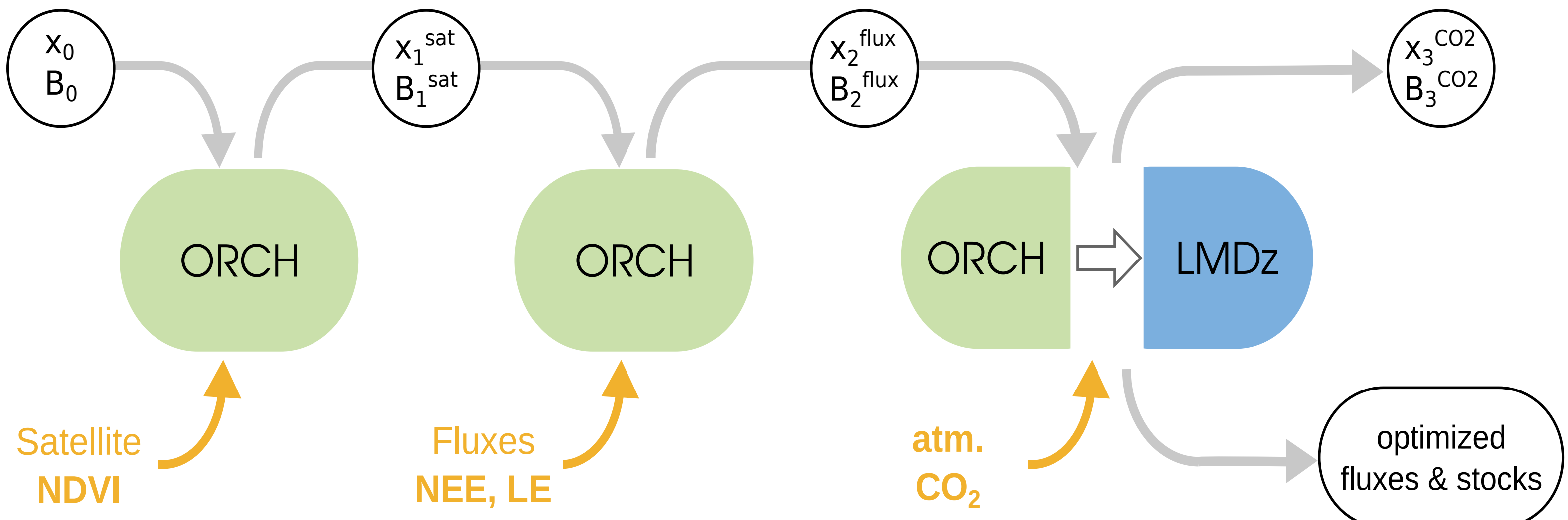
- **Cost function:** $J(x) = \frac{1}{2}\left[\left(y - M(x)\right)^t R^{-1}\left(y - M(x)\right) + (x - x_b)^t P_b^{-1}(x - x_b)\right]$

- **Iterative minimization using either:**
  - **Variational approach (with Tangent Linear model for DJ/dx)**
  - **Monte Carlo approach**

Multiple constraint on C fluxes







MacBean et al. (2015) — *40 params*

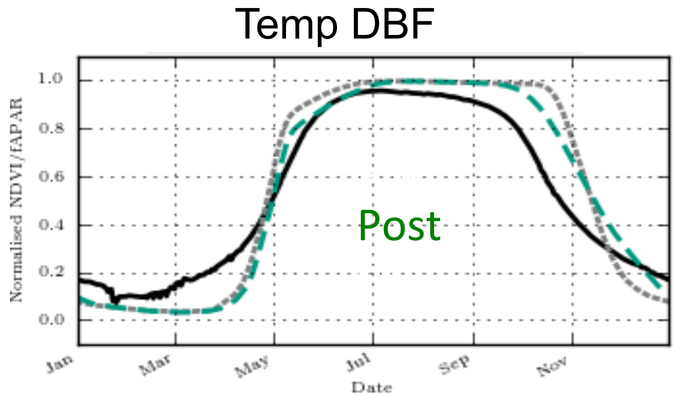
Kuppel et al. (2014) — *≈ 100 params*

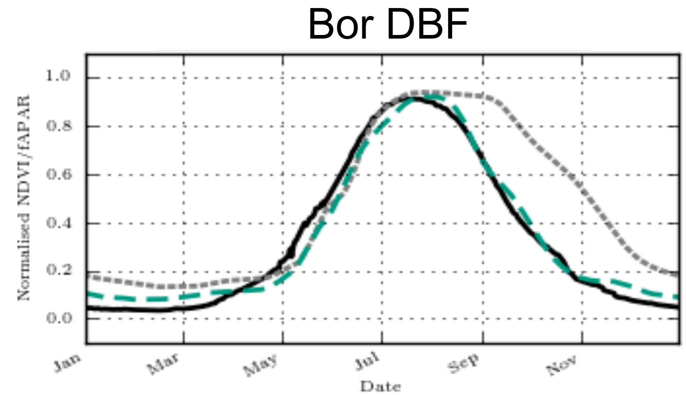
Peylin et al. (2016) — *≈ 80 params*

A step by step optimisation approach !

Step 1:
MODIS-NDVI

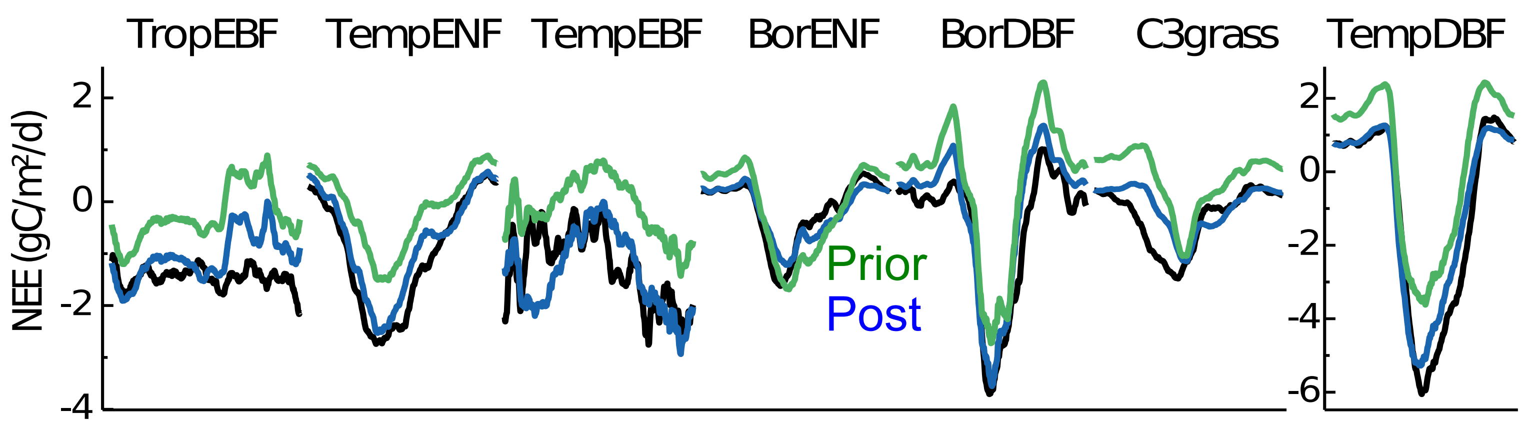
4 params /PFT





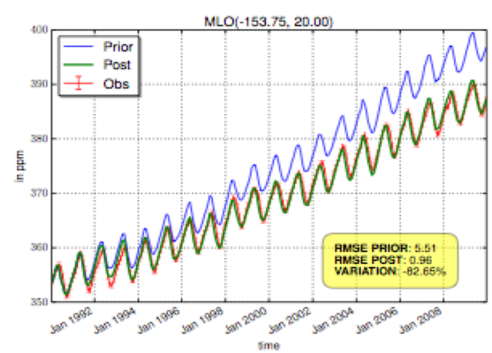
Step 2:
75 fluxnet data

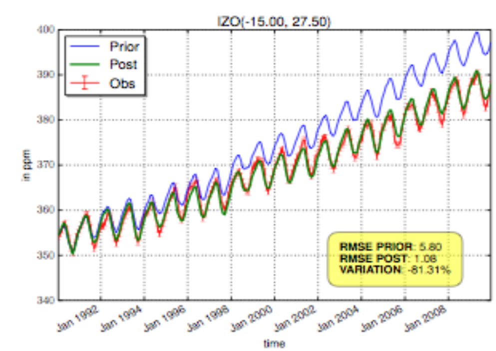
≈ 20 params /PFT



Step 3:
Atmospheric data

≈ 100 params total





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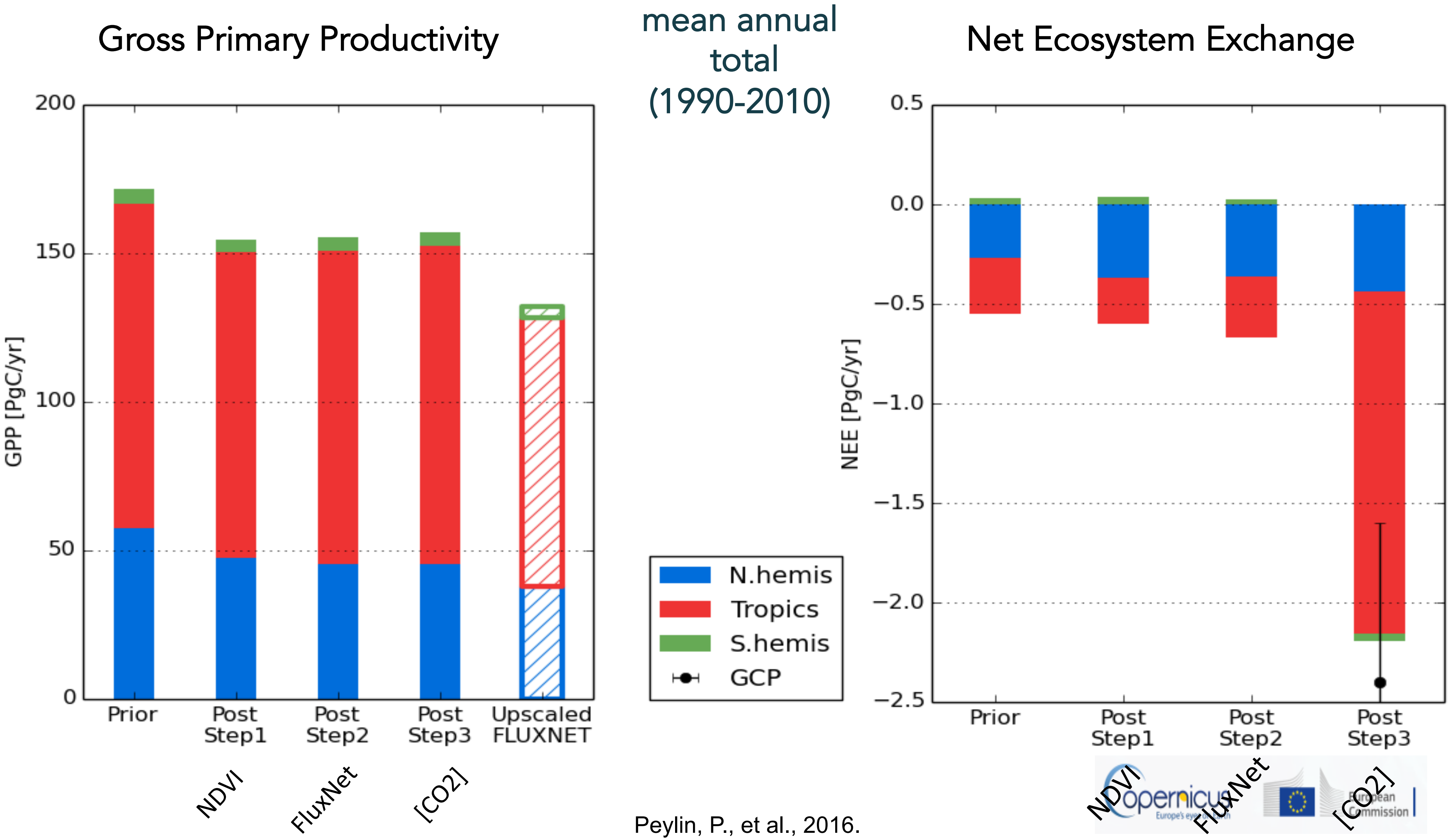
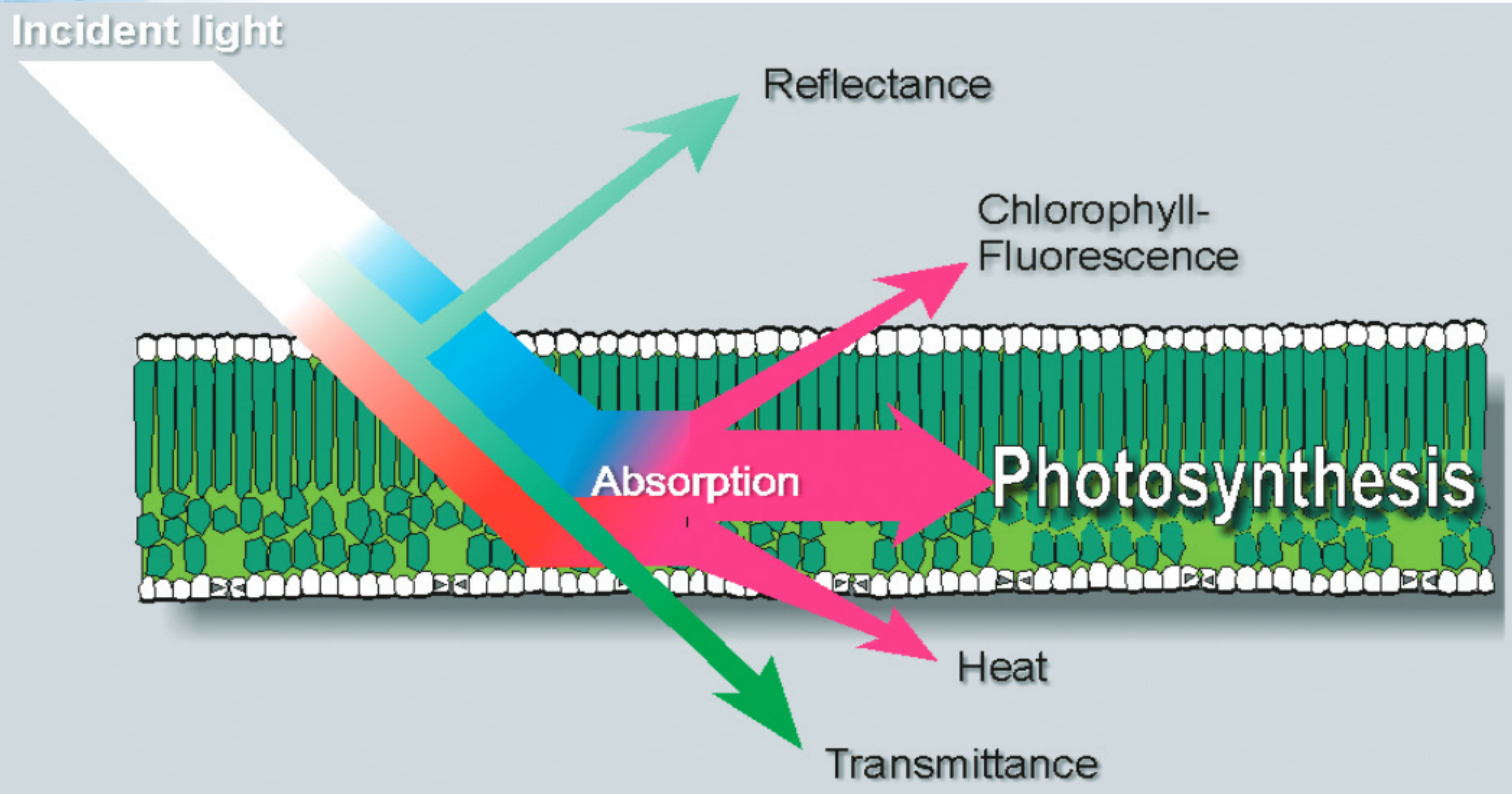
Impact on global net & gross C budgets



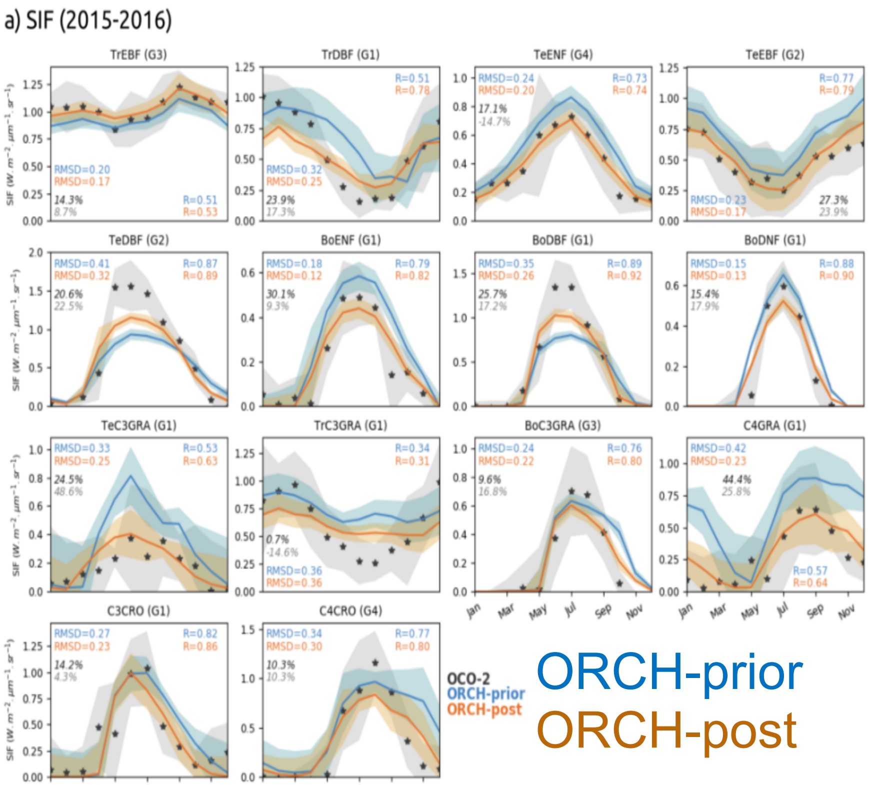
Peylin, P., et al., 2016.

Potential of reltated obs: SIF



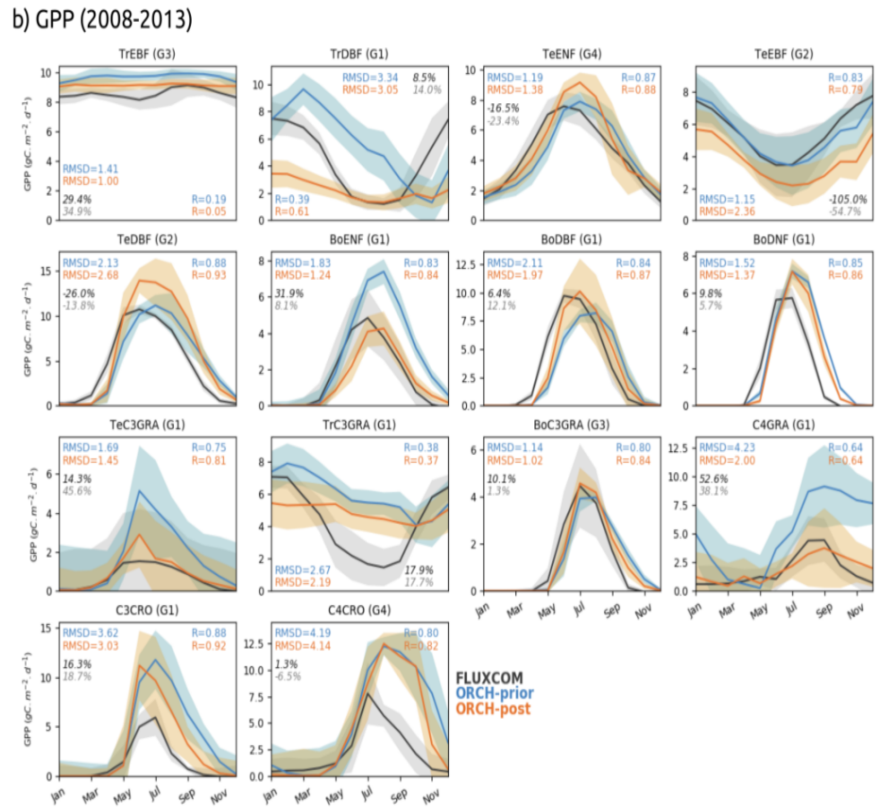
Pixel scale assimilation results

Improvement of the mean SIF OCO-2 (2015-2016)



ORCH-prior
ORCH-post

Change in GPP relative to FLUXCOM (2008-2013)



- Optimization of SIF results in a closer agreement of optimized GPP wrt FLUXCOM (for 10 PFTs out of 14)
- Opposite change in SIF and GPP for 3 PFTs
- GPP seasonality is "improved" but magnitude between FLUXCOM and ORCH depends on PFT
- PFT dependency to be resolved: *Radiative transfer* (canopy level) and *Physiological mechanisms* (leaf level)

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Including trait plasticity in ORCHIDEE

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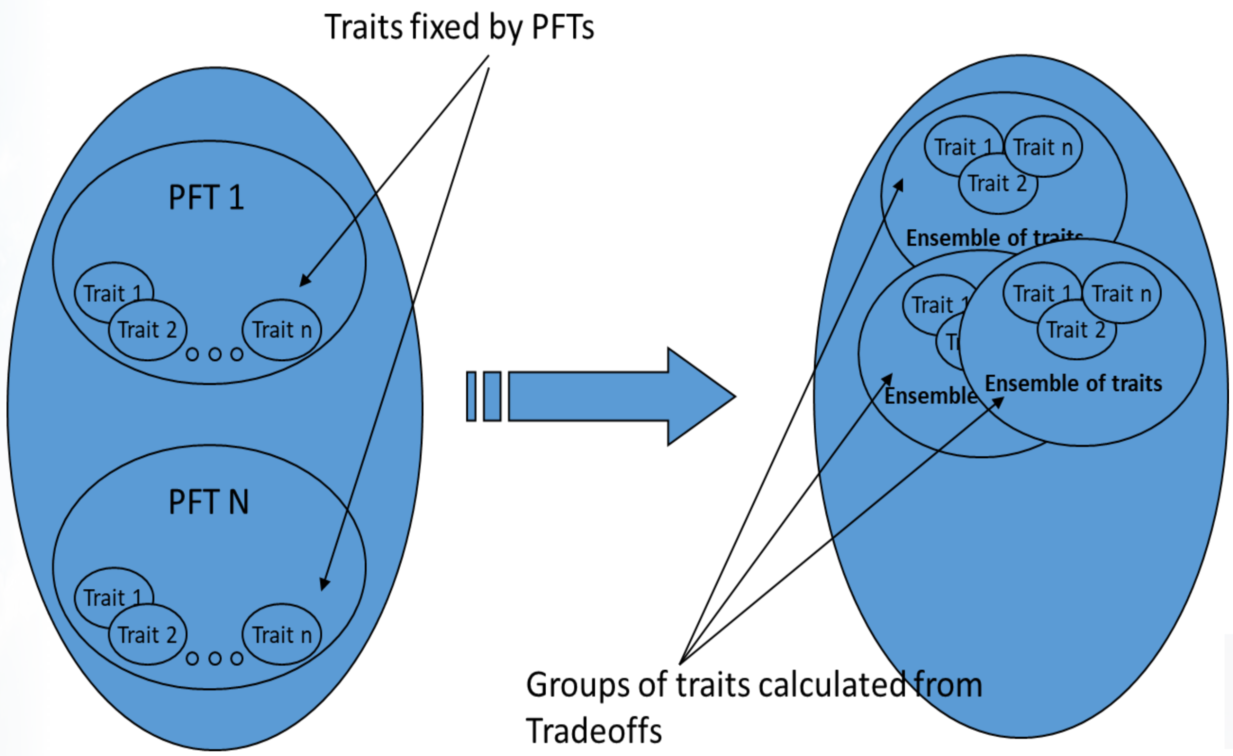
- Current limit of DGVM: vegetation is represented as PFT with a set of fix parameters ➔ no spatial variation, no biodiversity, no adaptation of traits

- Strategy: progressively replace fixed traits by PFT by traits calculated to go toward a continuous representation of vegetation.



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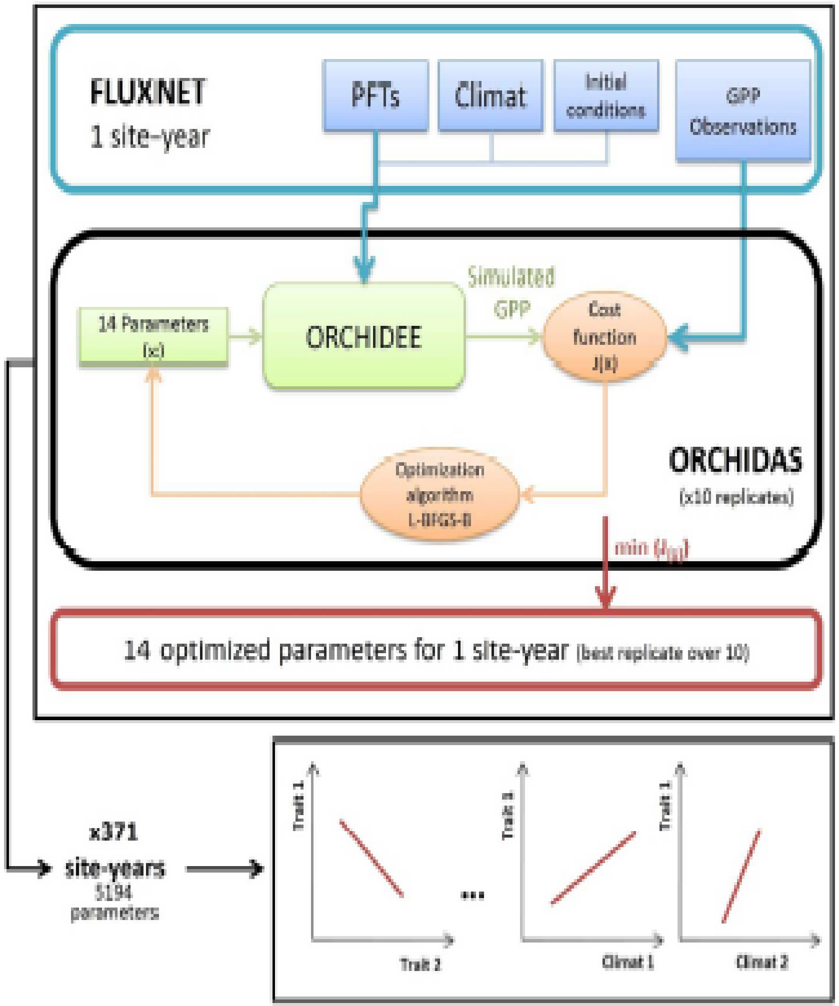
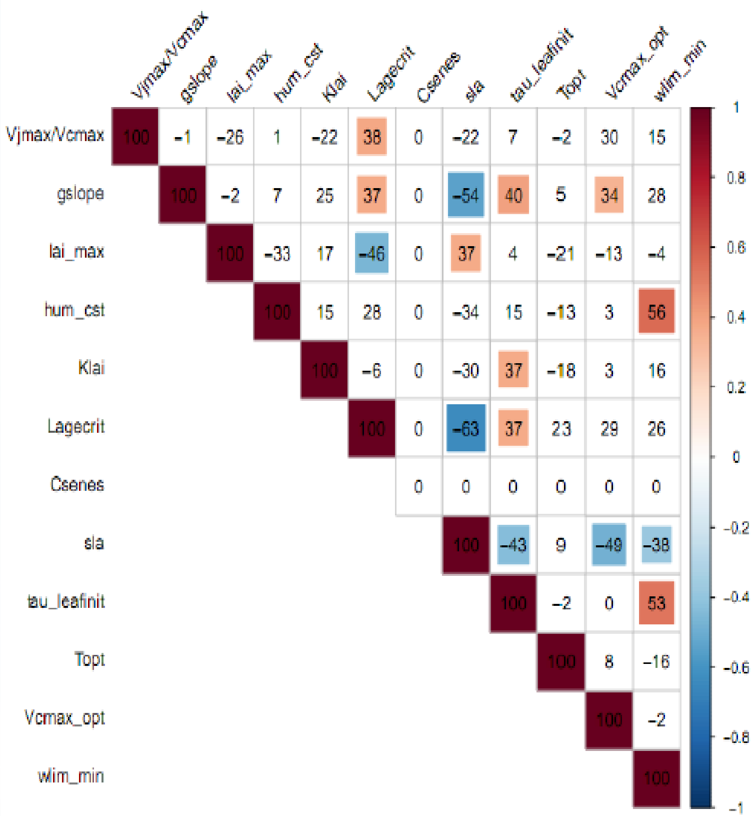
Explore trait variability in the model world

Model parameters can be optimized for each fluxnet site



How retrieved parameters co-vary and vary in response to climate ?

Correlation between parameters



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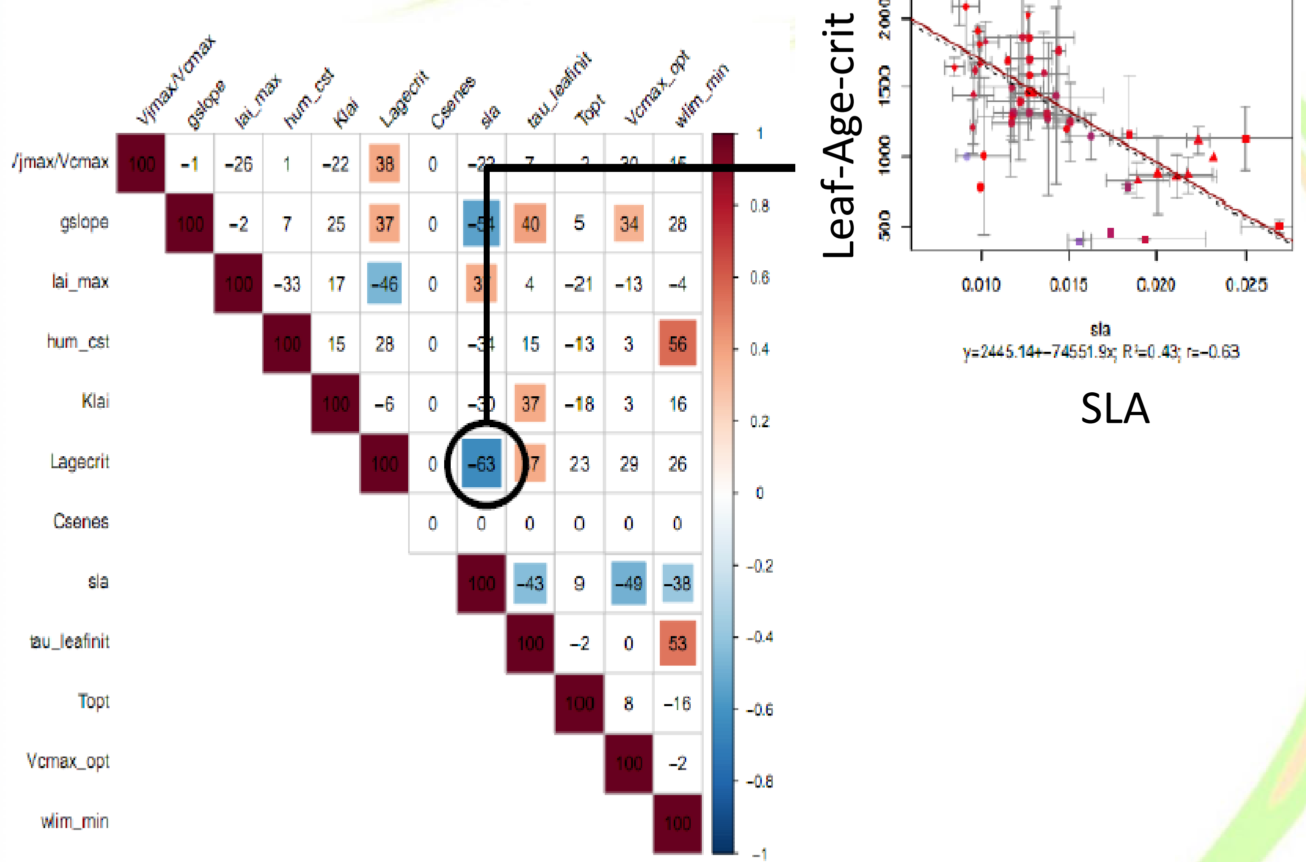
Correlation between parameters



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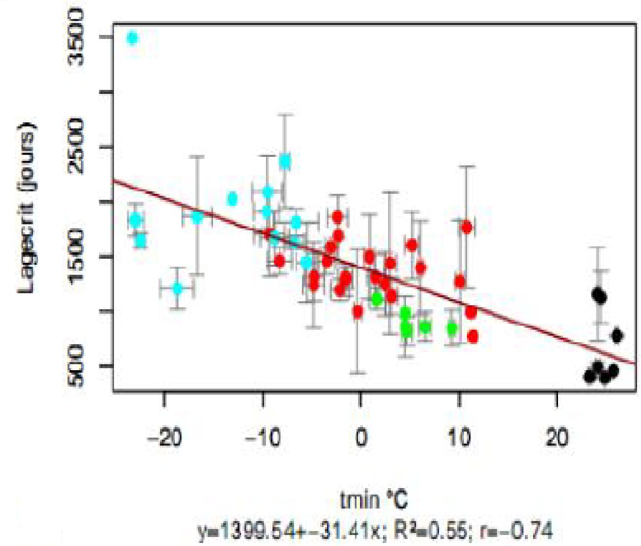
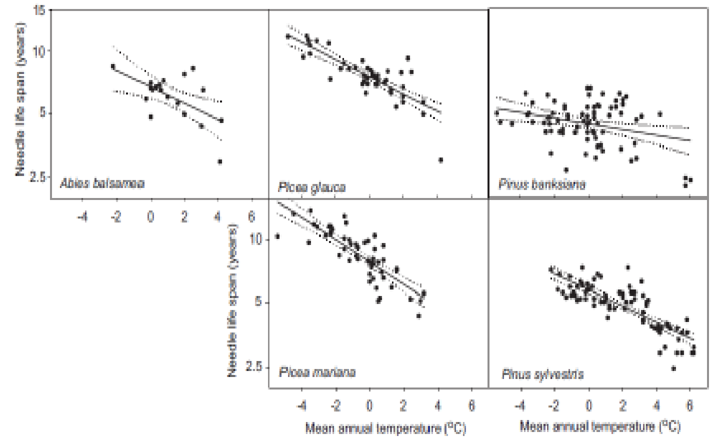
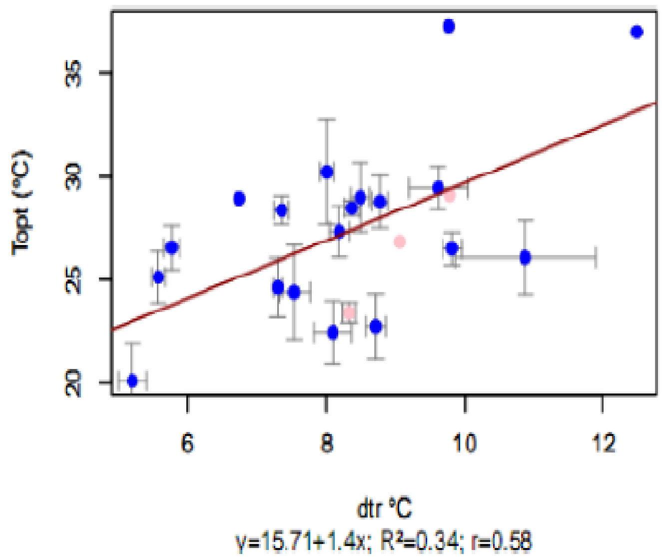
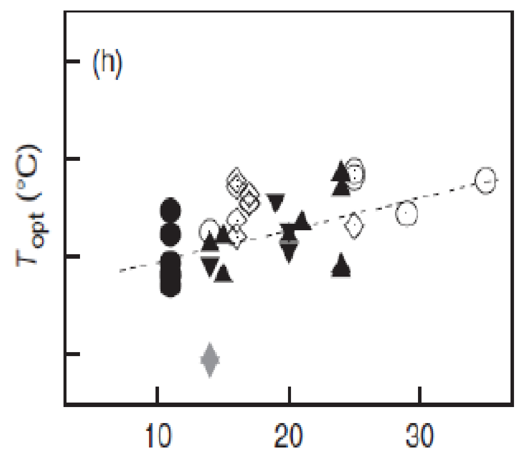
Emerging properties are in agreement with observations ...





(Reich et al., 2014)





(Kattge and Knorr, 2007)

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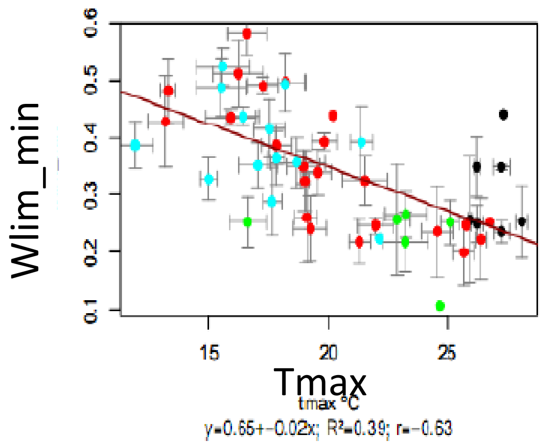
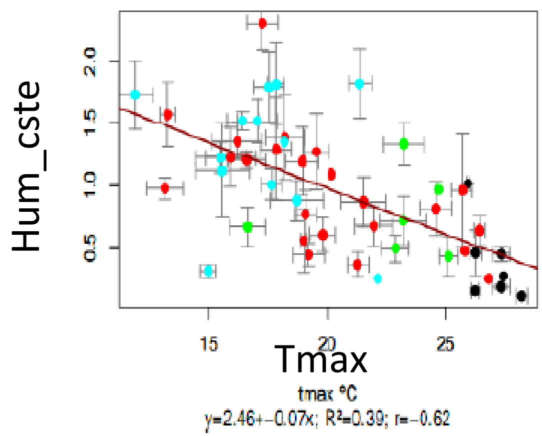
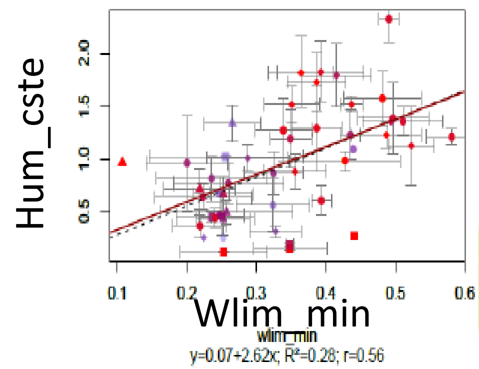
.. But method allow to find emerging properties not observable







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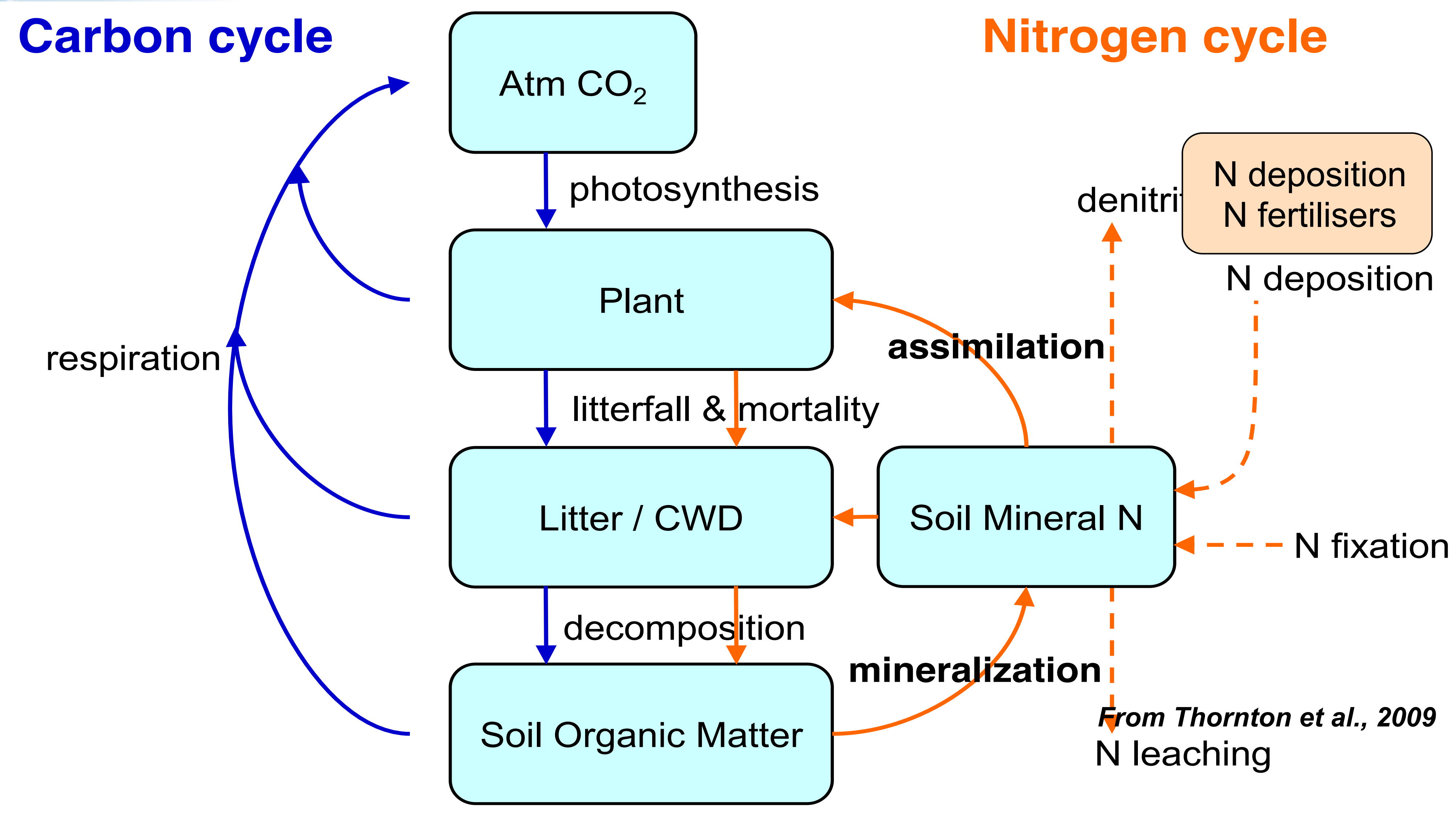
C & N land interactions



From Thornton et al., 2009

Photosynthesis scheme

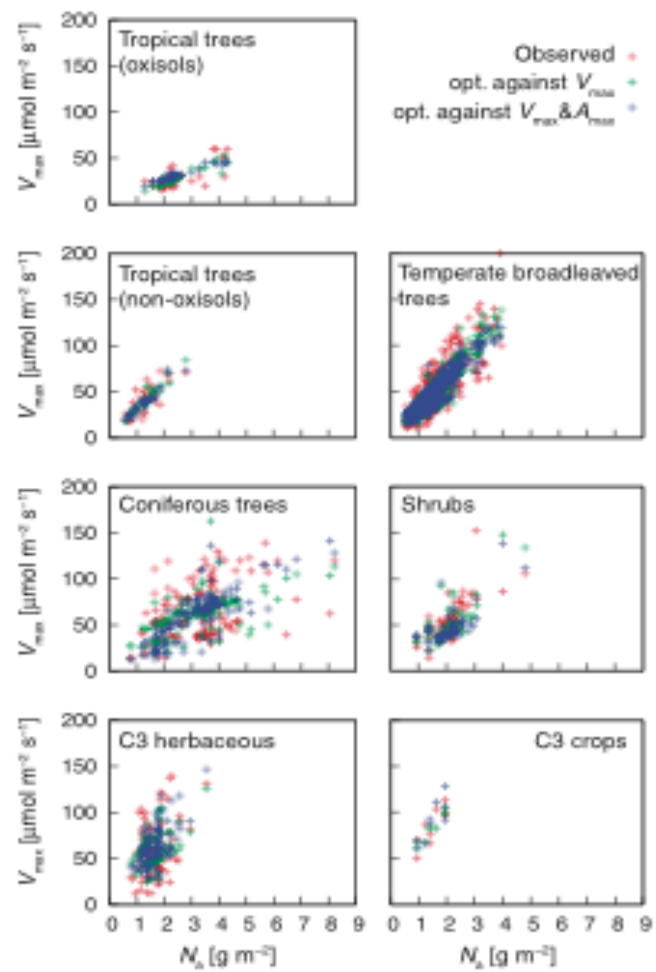
- Based on Farquahr model
- Vc_{max} : photosynthetic capacity ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$)
- Modified based on the work of Kattge et al. (2009)

$$Vc_{max} = NUE \times N_L$$

with *NUE* the Nitrogen Use Efficiency (PFT-dependant)

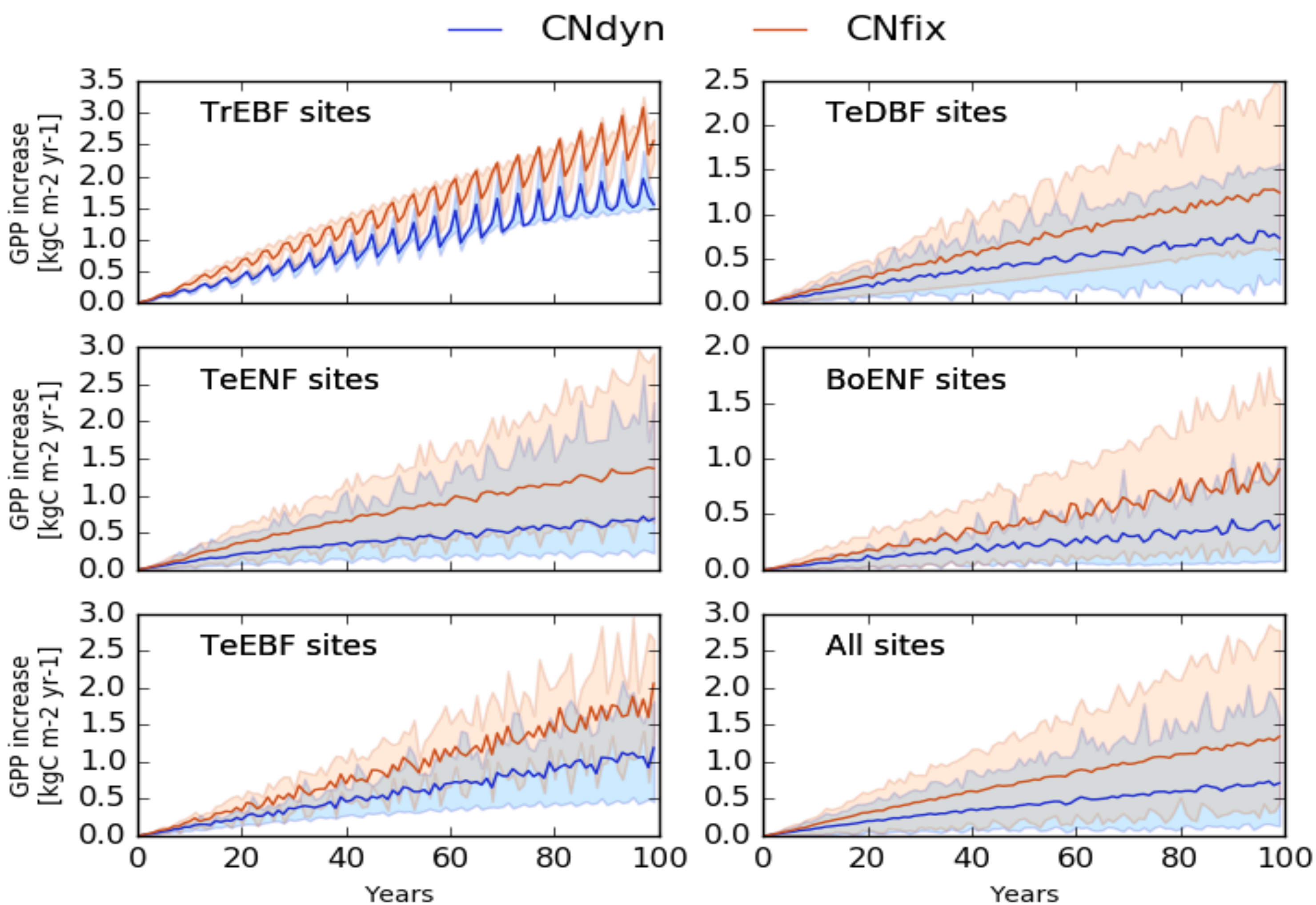
and N_L the leaf N content ($gN\ m^{-2}_{[leaf]}$)

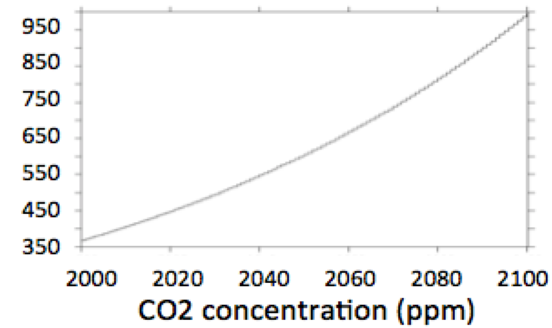
Vmax vs. Leaf N content



Adding the Nitrogen cycle: impact on the C cycle !

- Using ORCHIDEE-CN version – FluxNet sites
- 1% yr-1 CO_2 increase experiment

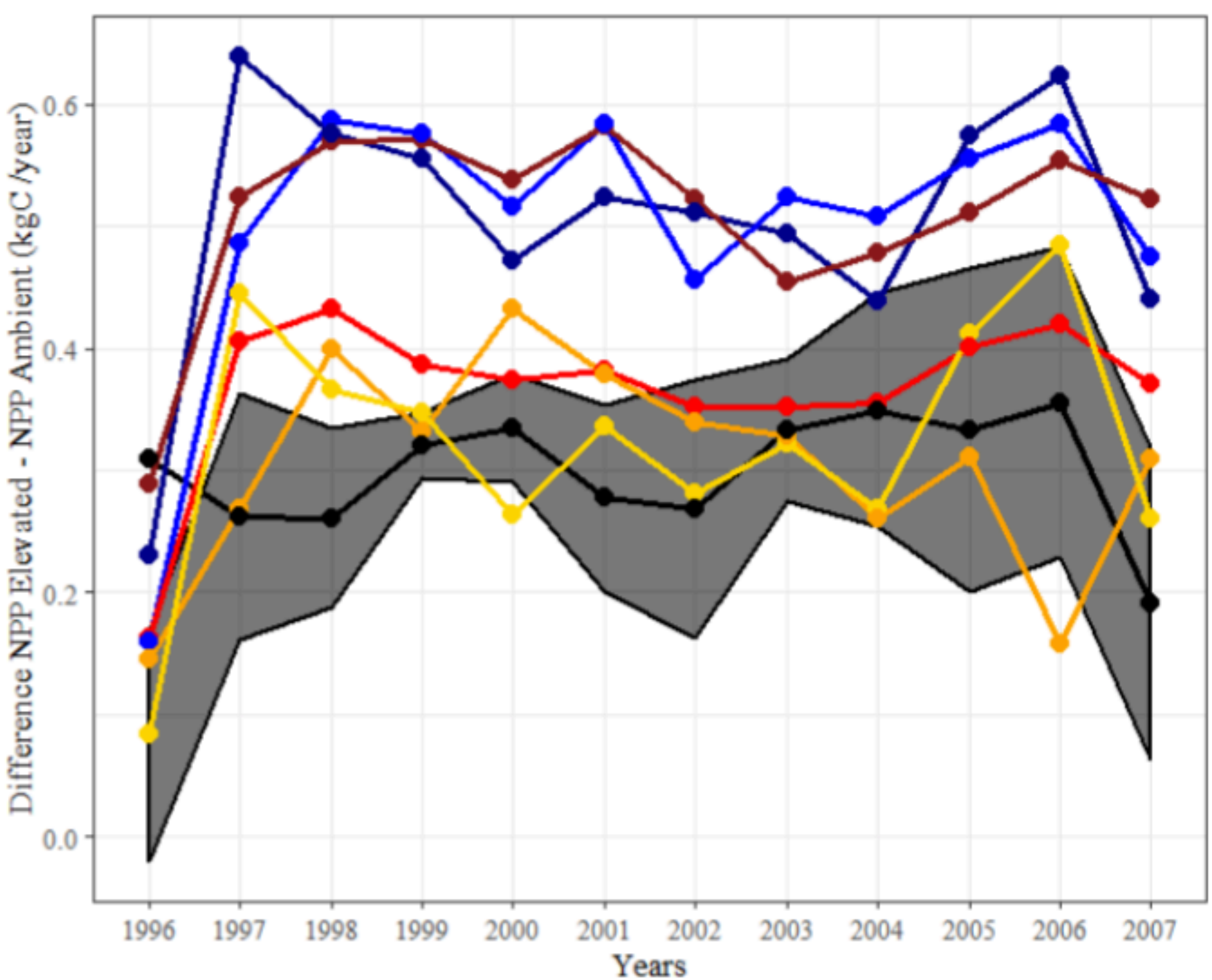




➔ Large reduction of the fertilisation effect at all sites (half the effect)

Optimisation using FACE data : DUKE site !

NPP : difference ELEVATED-CO2 minus AMBIENT CO2



Observations

Prior
FluxNet optimisation
Ambient-FACE optimisation

Elevated-FACE optimisation
Amb+Elev-FACE optimisation
Amb – Elevated optimisation

Hydraulic architecture

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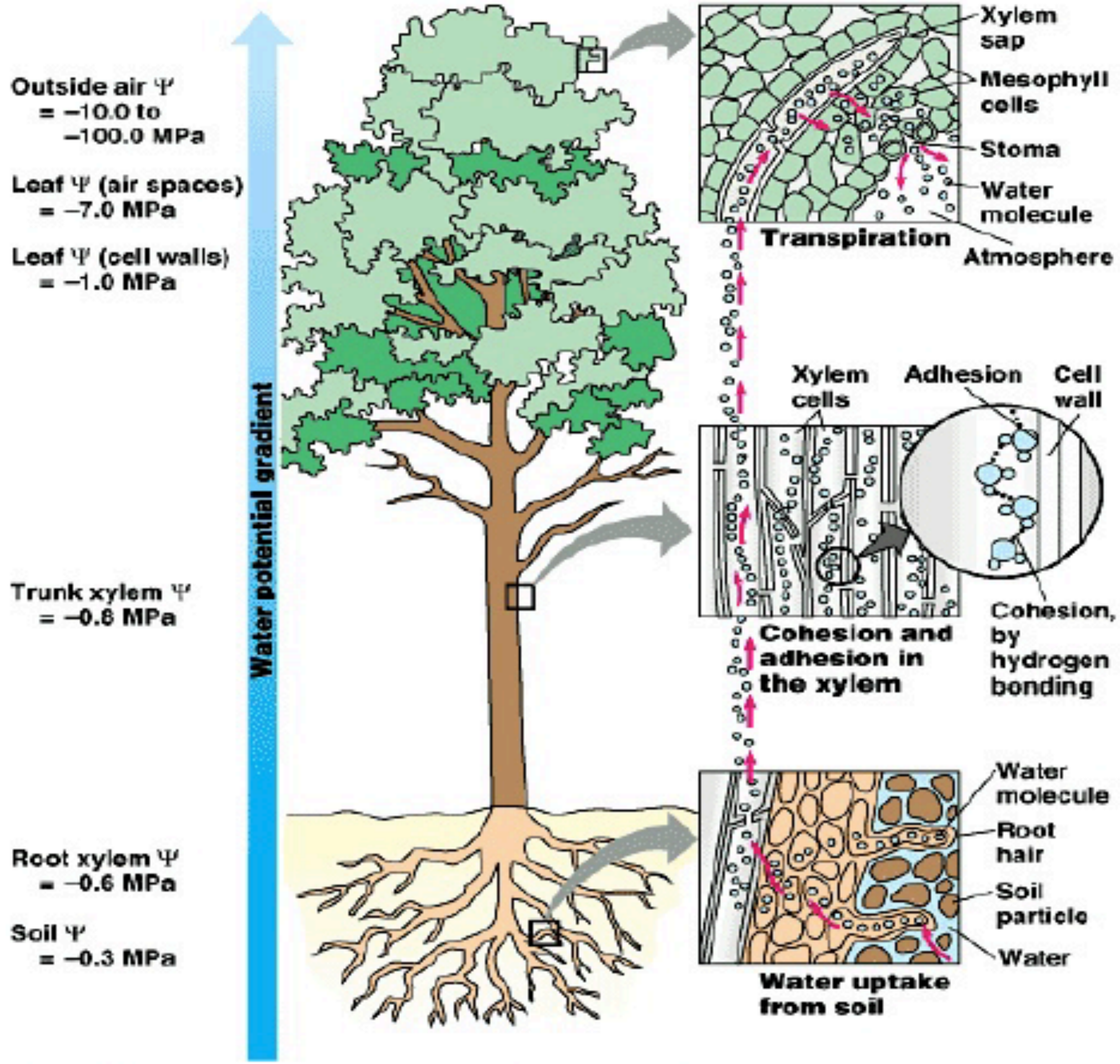
Pipe model theory

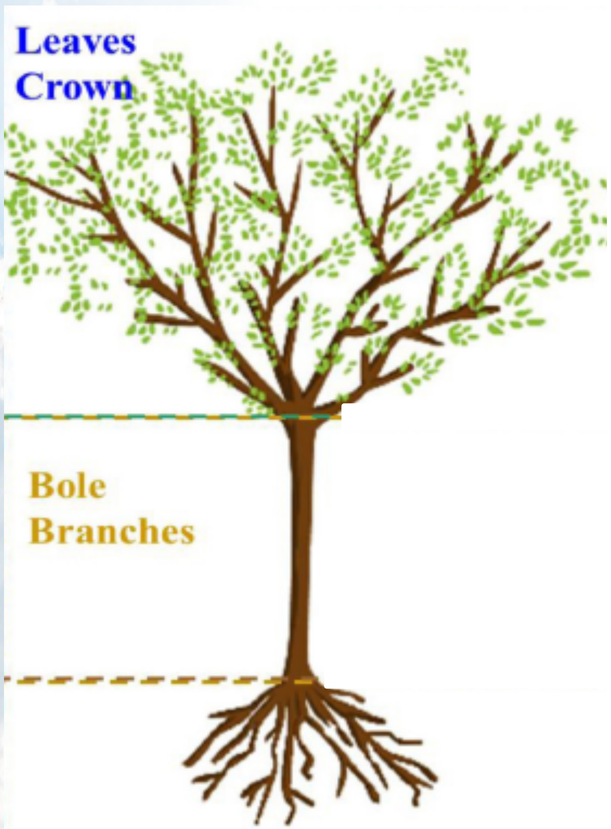
- Recognize how stomata is hydrological connected to the roots and the need to invest carbon in building roots and stem
- Allometric relationships, leaf to sapwood area ratio, relationship between diameter and height

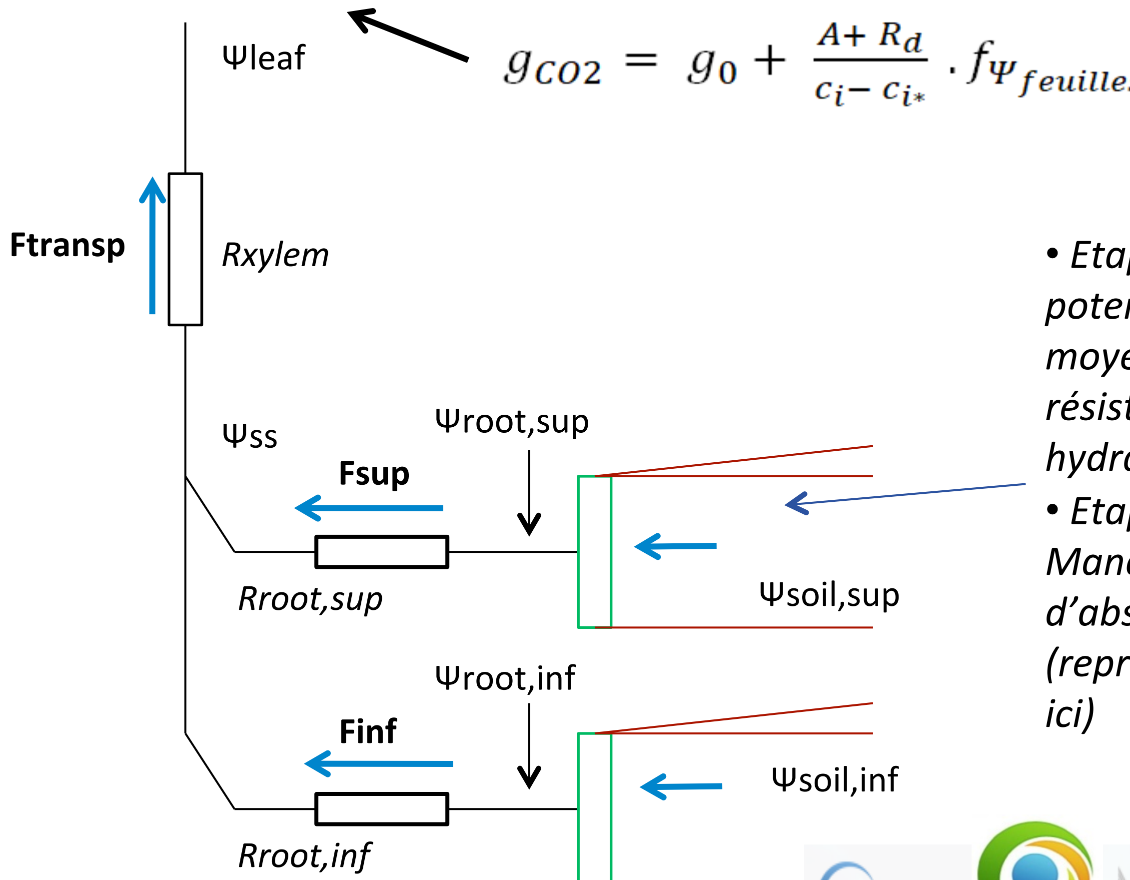
Water stress

- Hydraulic architecture



Hydraulic architecture



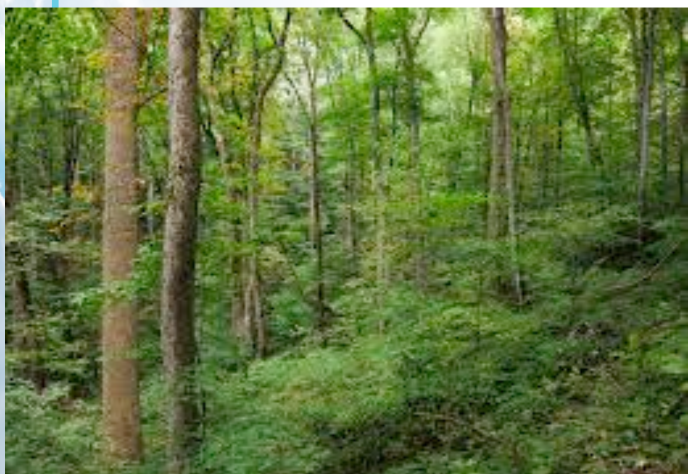


- *Etape 1 : potentiel moyen et résistance hydraulique*
- *Etape 2 : Manchons d'absorption (représentés ici)*

Horizontal & vertical structure of the canopy : to be improved

- Current assumption

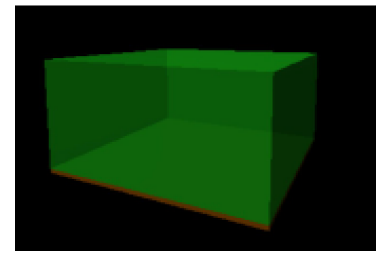
Ecosystem structure



Model representation

Big leaf model

=



- Current issues

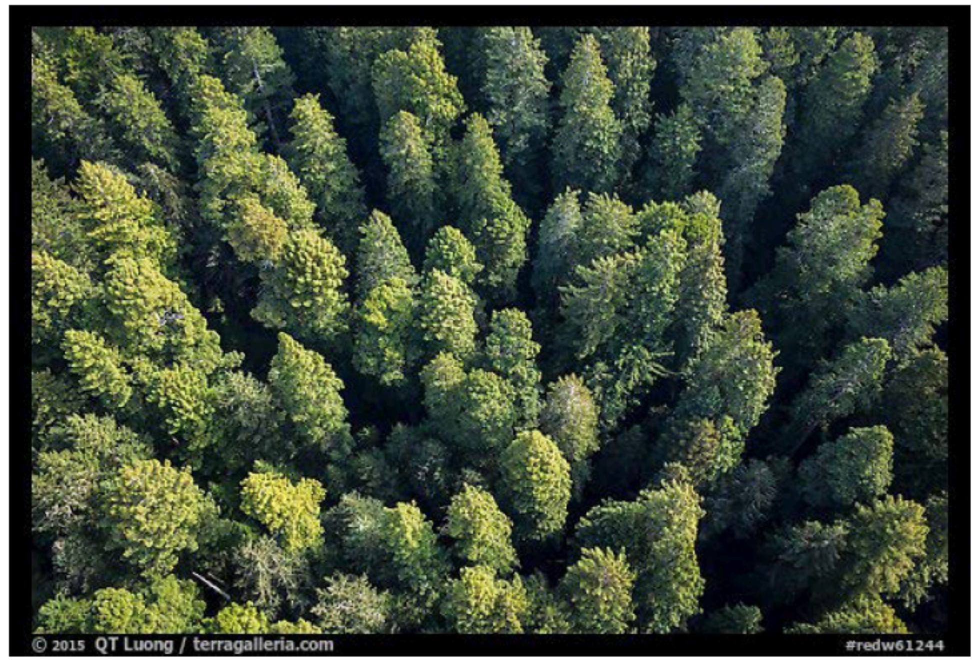
➢ Model still poorly represent site-level heat fluxes

➢ Canopy space and Trunk crown have different behaviours

➢ Under-storey vs over-storey representation !

Simulating canopy gaps (ex.: P_gap model)

- The trees are horizontally distributed following a Poisson distribution
- The structured canopy allows for calculations of light penetration within the canopy.
- Statistic approach to reduce memory allocation



Next: Add more physic for the vertical upscaling !

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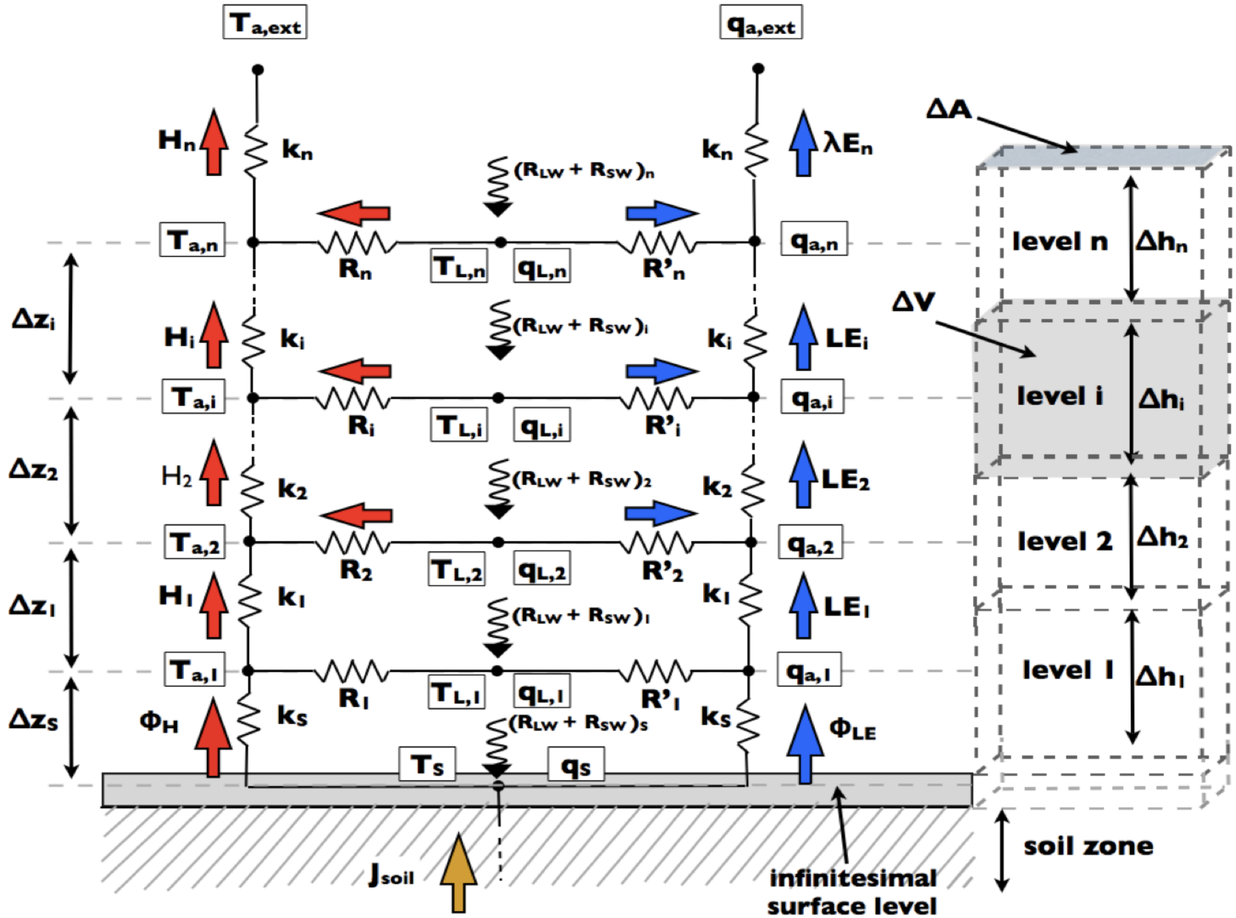
Ryder et al., 2015

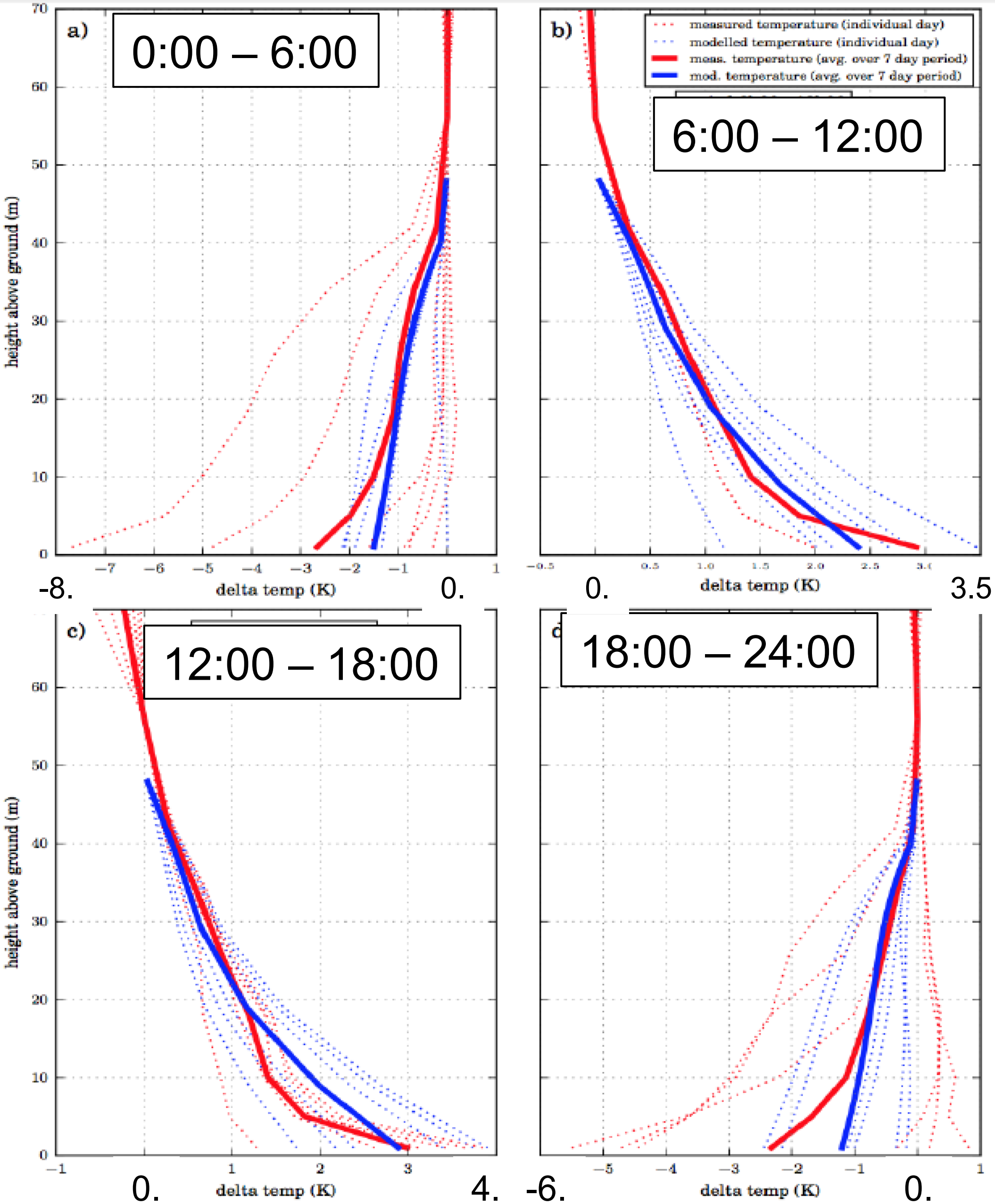
- Free number of layers
- E / W / C exchange at each level
- Turbulance mixing within air canopy
- Light penetration following Pgap model



Implementation constraints :

- Coupling with plant growth / harvesting module (variable plant height)
- Implicit coupling with Atmospheric model (30’ step)
- Parametrisation of intra-canopy turbulence

Future step: Add more physic for the upscaling !



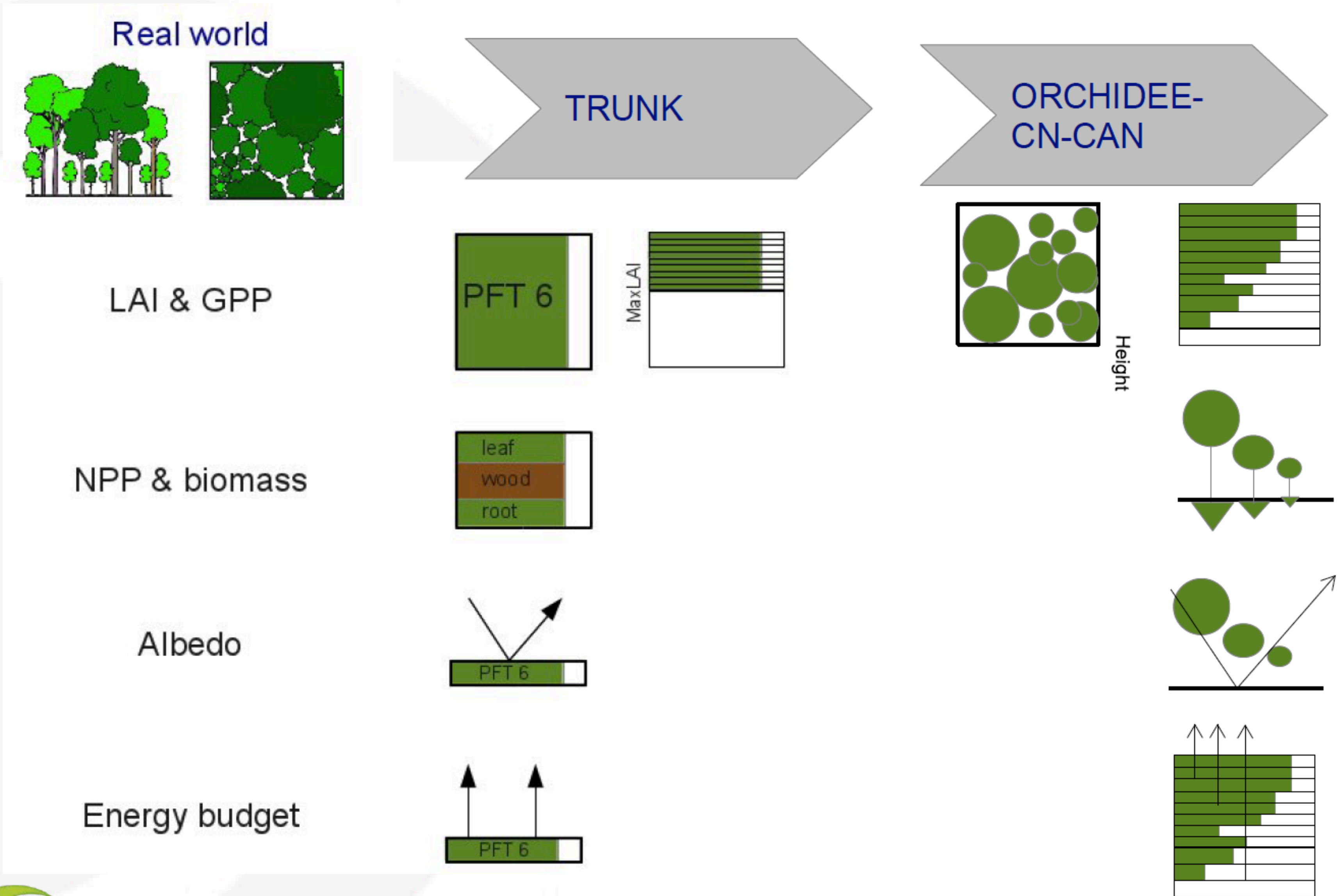
Daily temperature

Temperature profile at Tumbarumba site

Observations
Model

Ryder et al., 2015

Vertical & horizontal heterogeneity is crucial !



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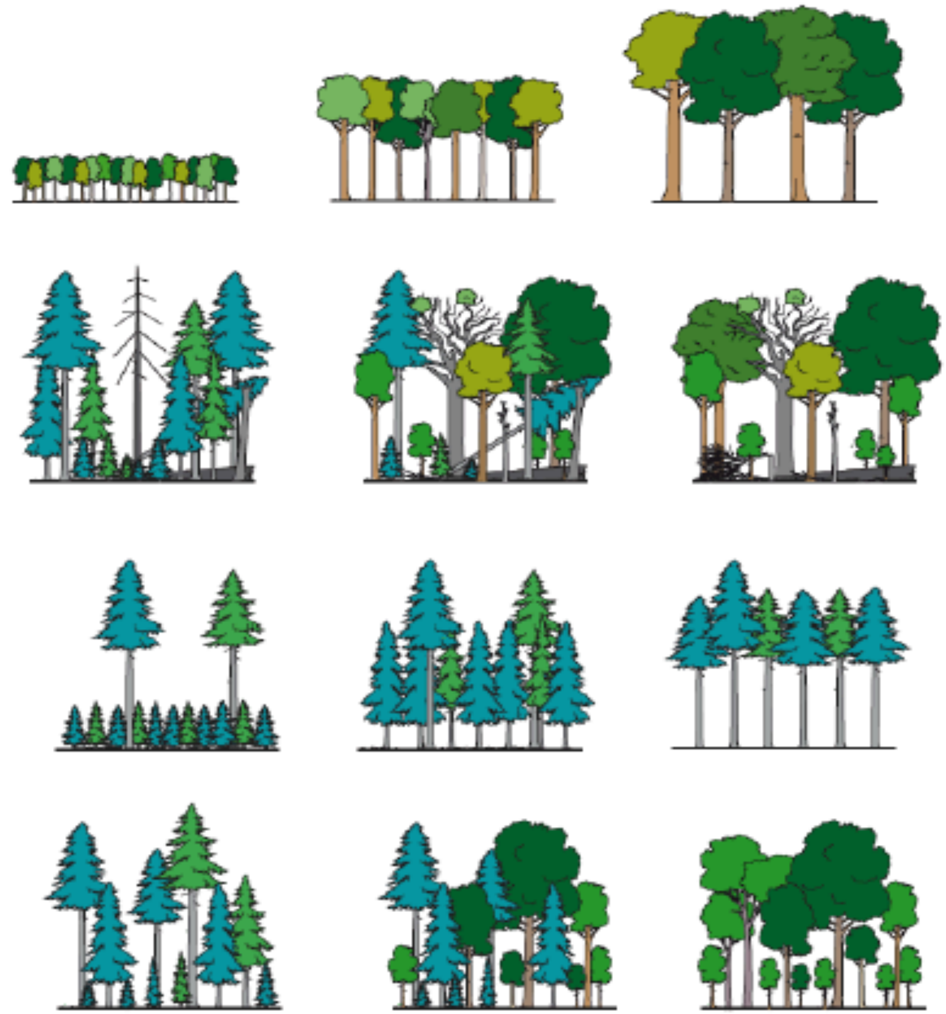
Forest management !

Simulating the canopy

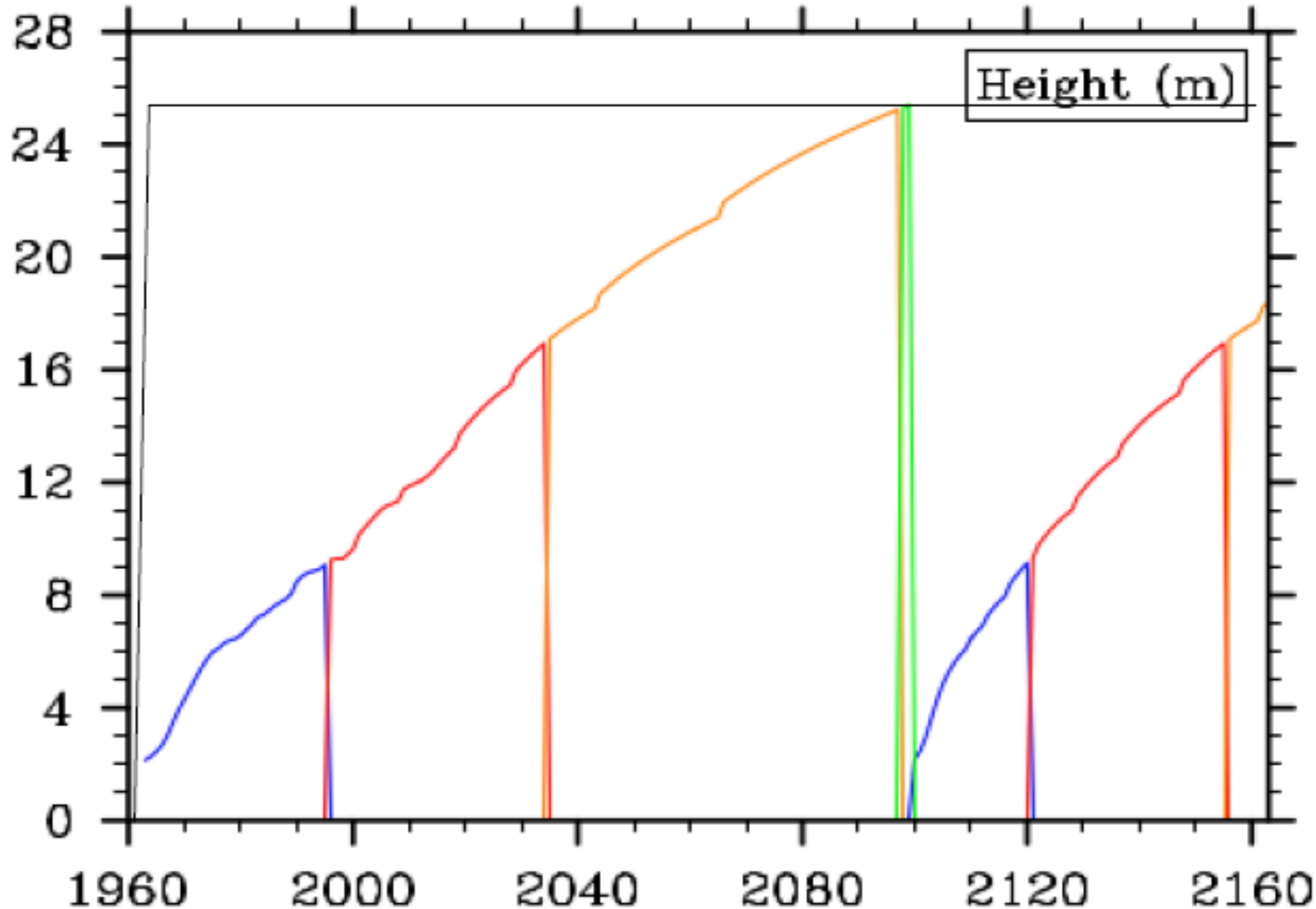
- Diameter classes and age classes are introduced
- Number of PFTs depend on number of age classes
- Each PFT has x numbers of diameter class
- Each diameter class has x number of trees depending on basal area - self-thinning rule



➔Large impact on the turbulent fluxes

Forest management !

Simulating the canopy



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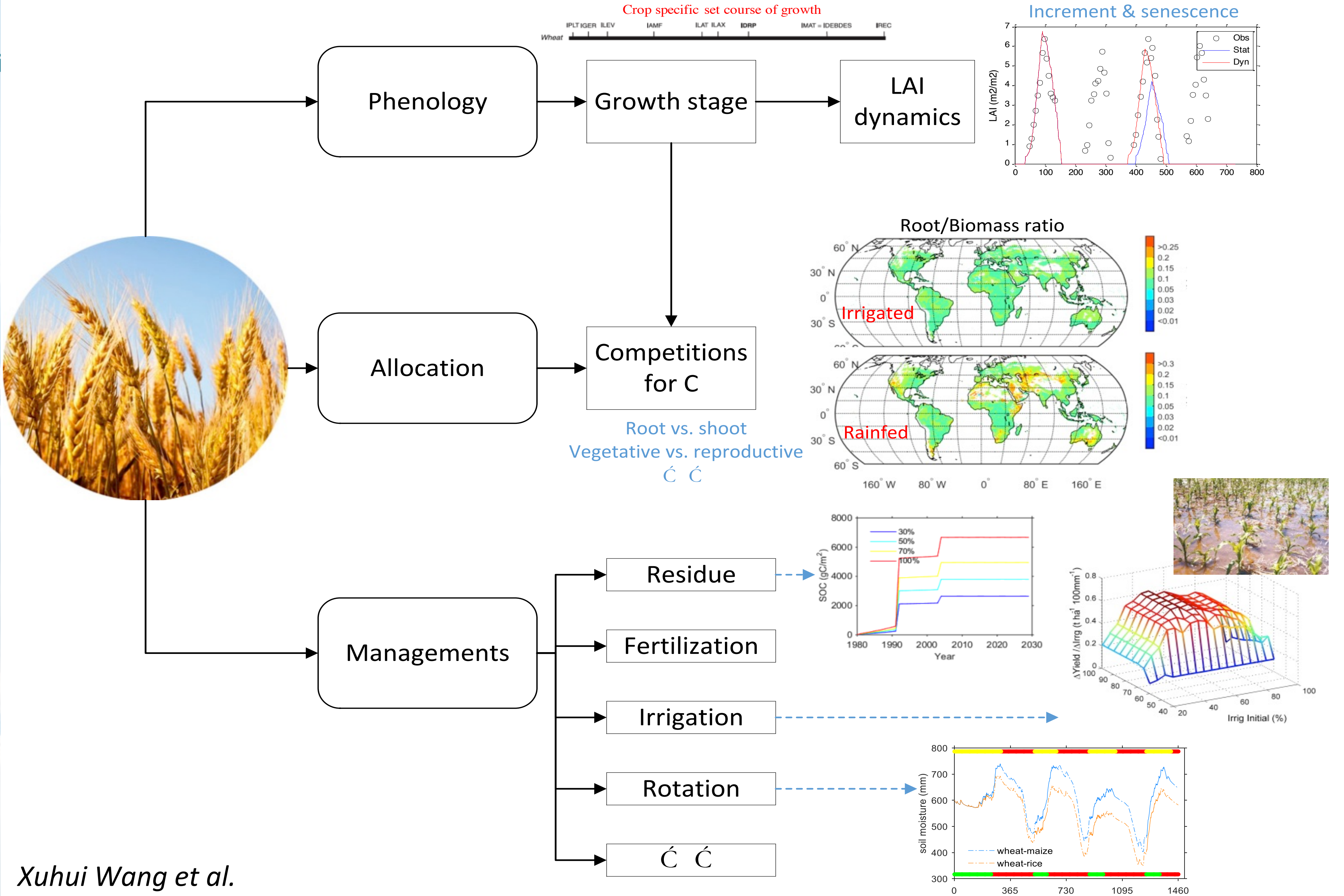
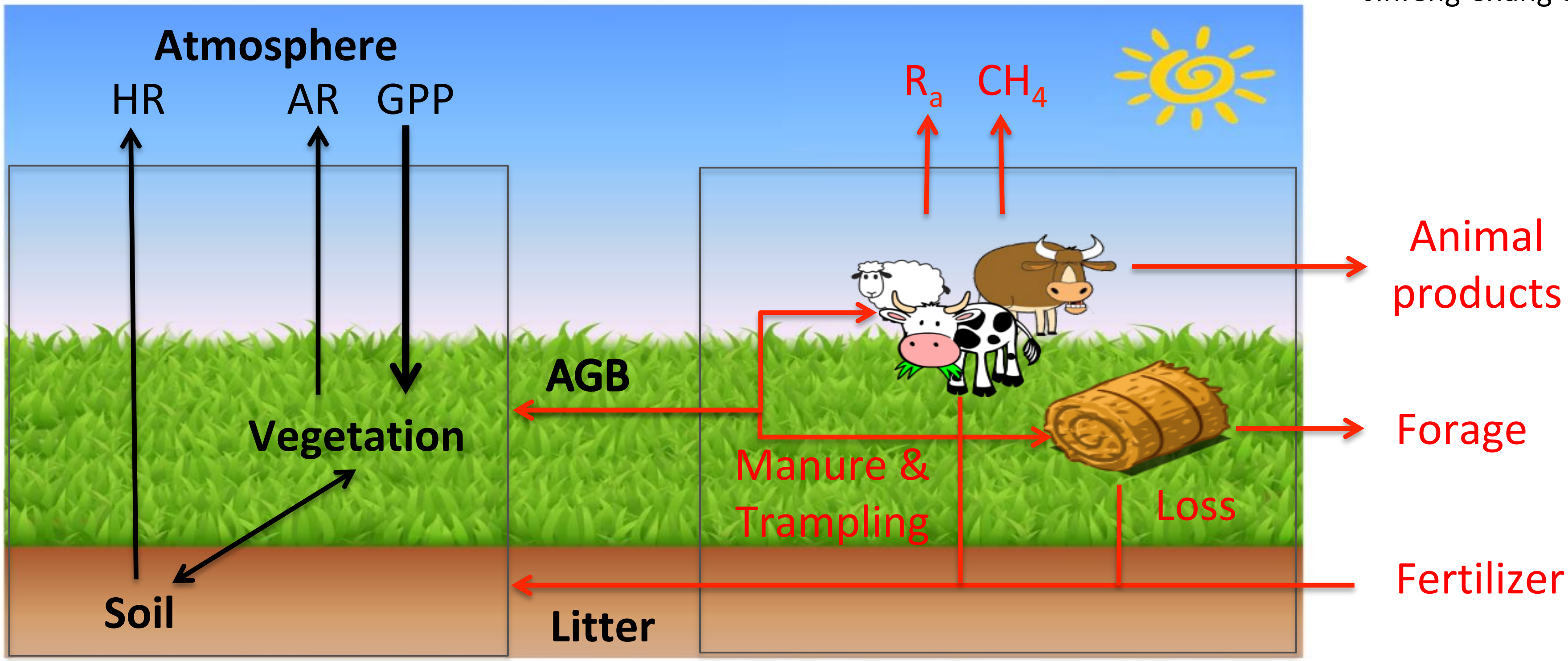
Crop ecosystem !



Xuhui Wang et al.

Grassland: from intensive pasture to rangeland

Jinfeng Chang et al.



ORCHIDEE

Management module from PaSim

(Graux et al., 2012 ; Vuichard et al.,2007)

Applications:

- Grassland management optimization/adaptation (simulating potential productivity)
- Reconstruction of historical management intensity
- Long-term carbon and GHG balance of grassland ecosystem and livestock farm.
- Milk production simulation and projection.

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Summary !

- Large improvements can be brought to CTESSEL using the expertise from ORCHIDEE : model development ←→ parameter optimisation

- All initiatives should consider at the same time Water / Energy / Carbon – Nutrient budgets !

- Synergies between the different initiatives/contributions would be optimal !

- LSCE is willing to invest in these directions !

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Accounting for management

Crop management

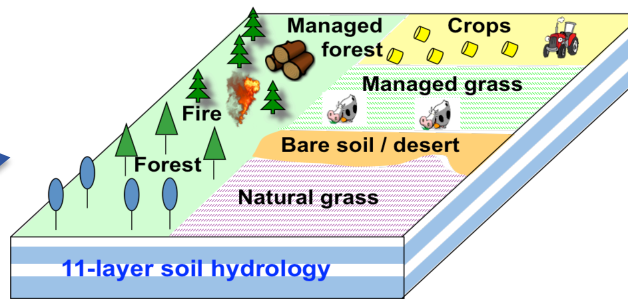
Wang et al., 2017

Grassland management

CO_2
CH_4
N_2O

Climate mitigation potential

Chang et al. 2015, 2016



Forest management

Naudts et al., 2015, 2016
MacGraph et al, 2015

Irrigation

Adding the Phosphorus cycle

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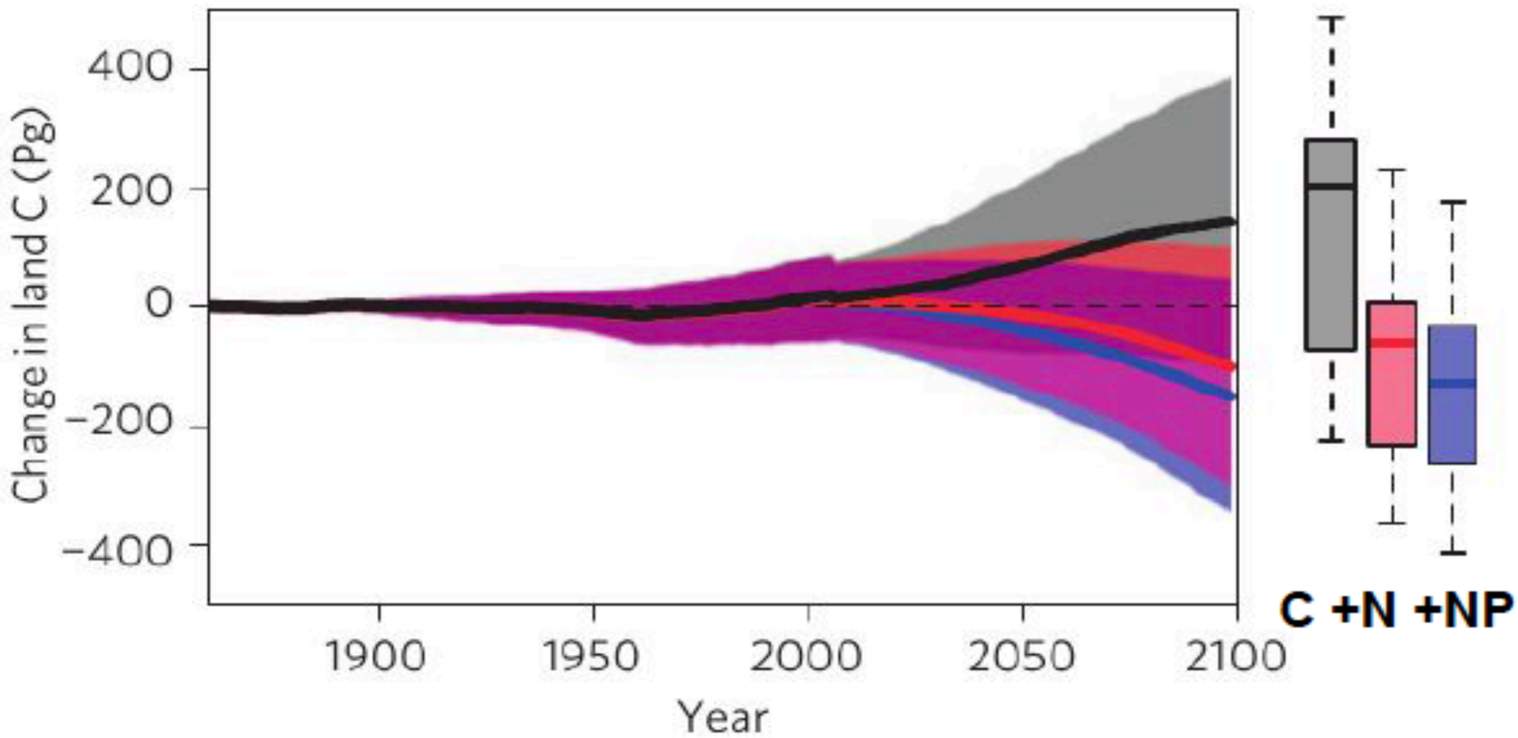
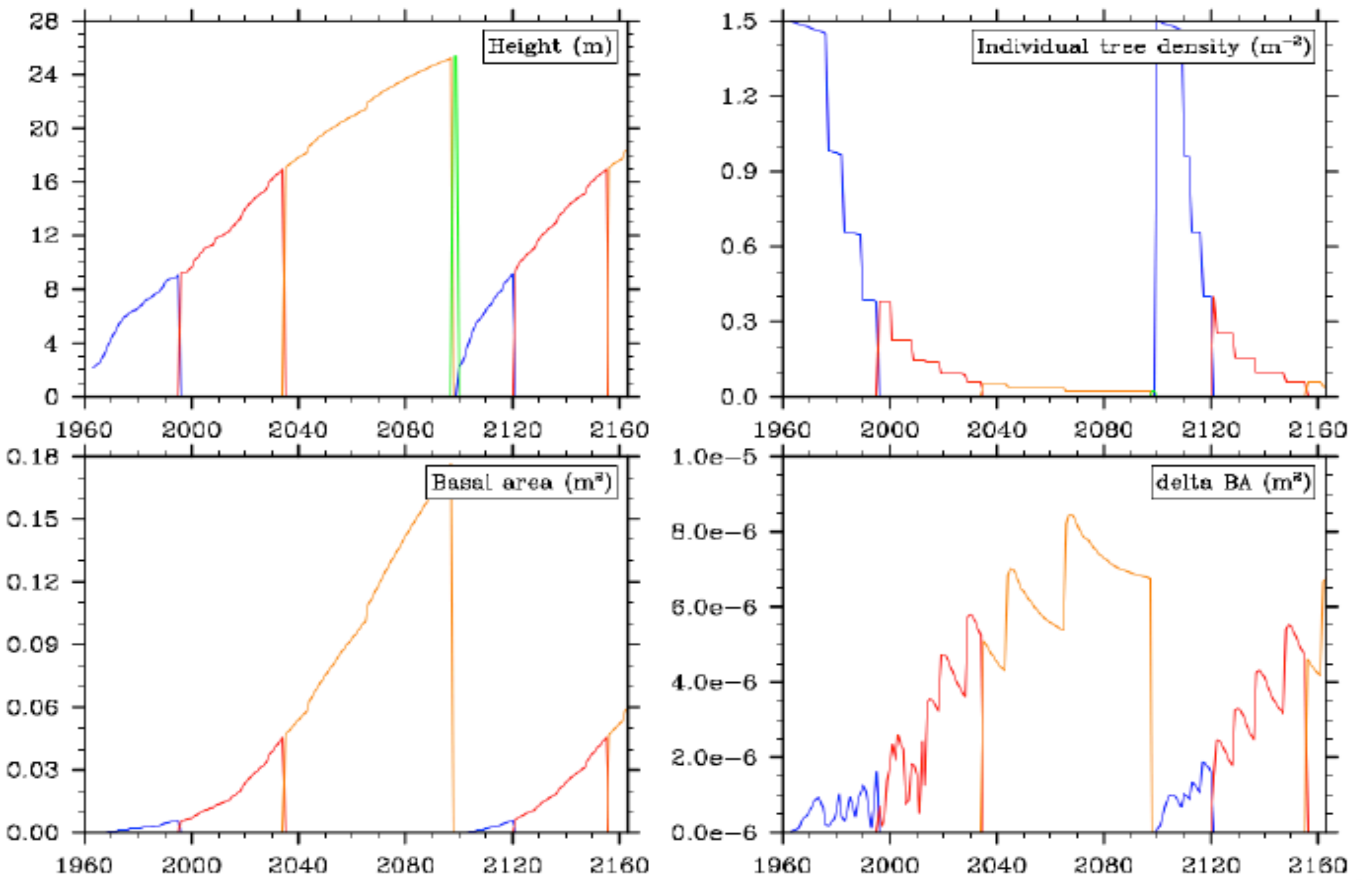


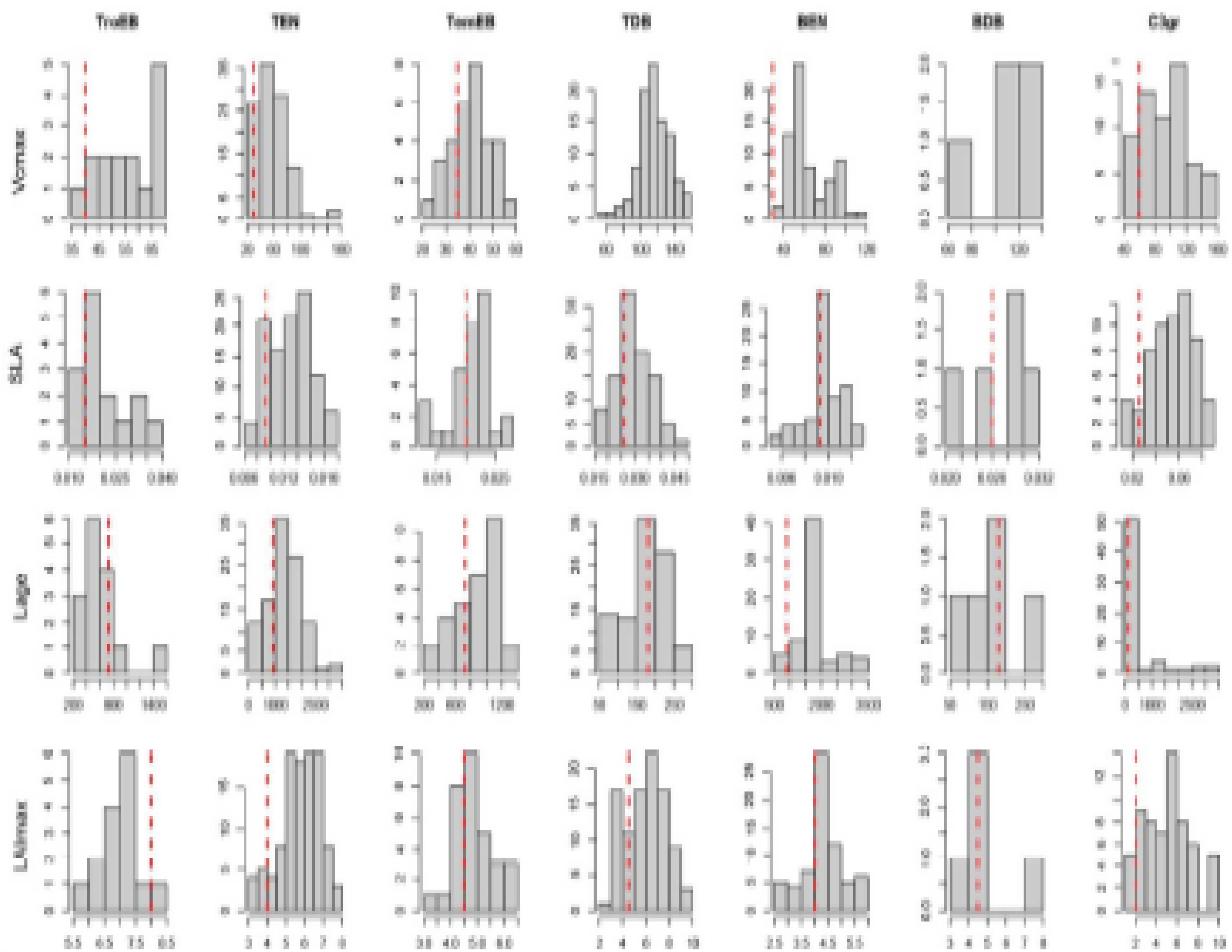
Wieder et al., Nat. Geosc., 2015

➔ Work done with ORCHIDEE-CNP version : Goll et al. 2017

Ecosystem dynamics



A distribution of traits values for each PFT



Peaucelle et al. Submitted

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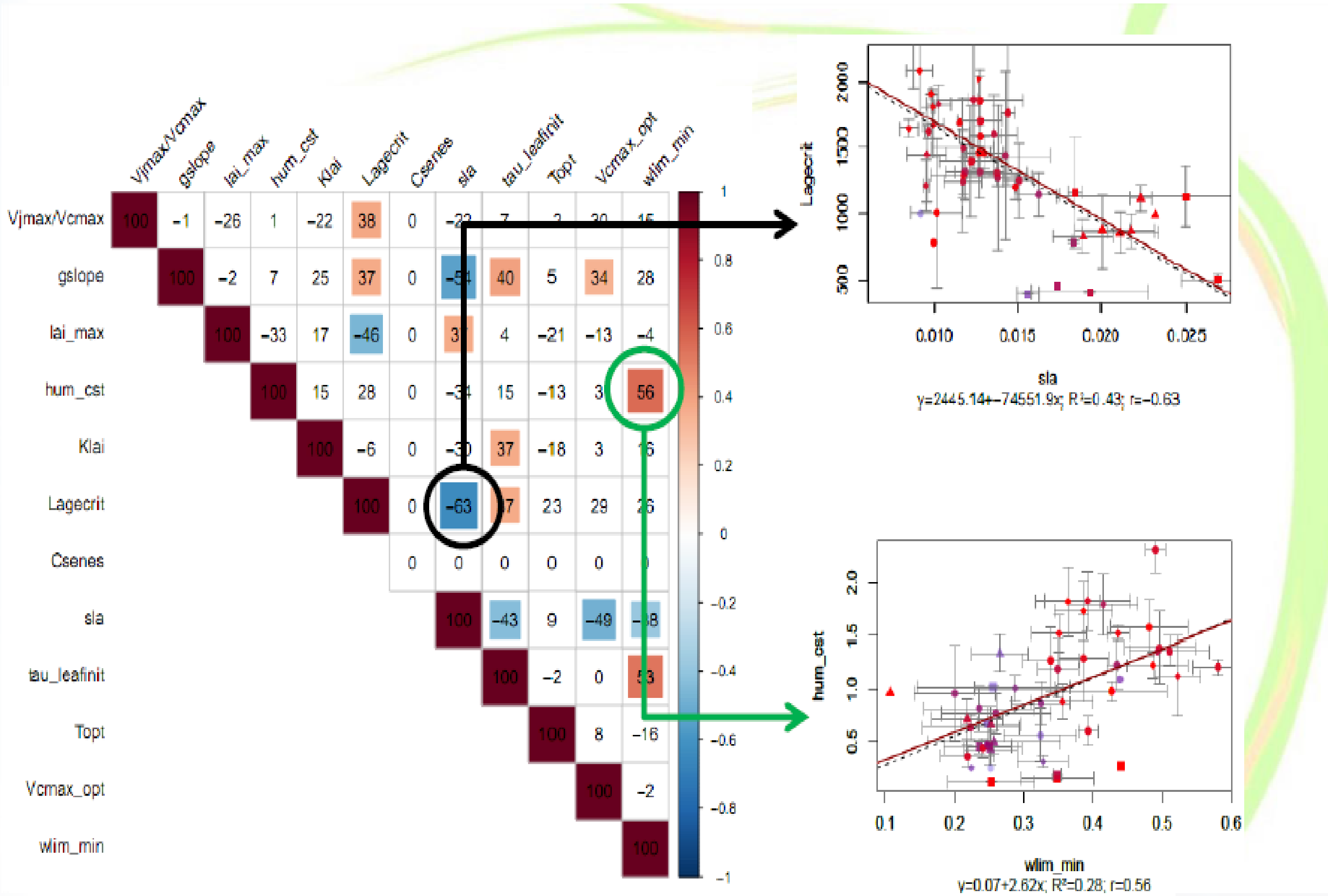
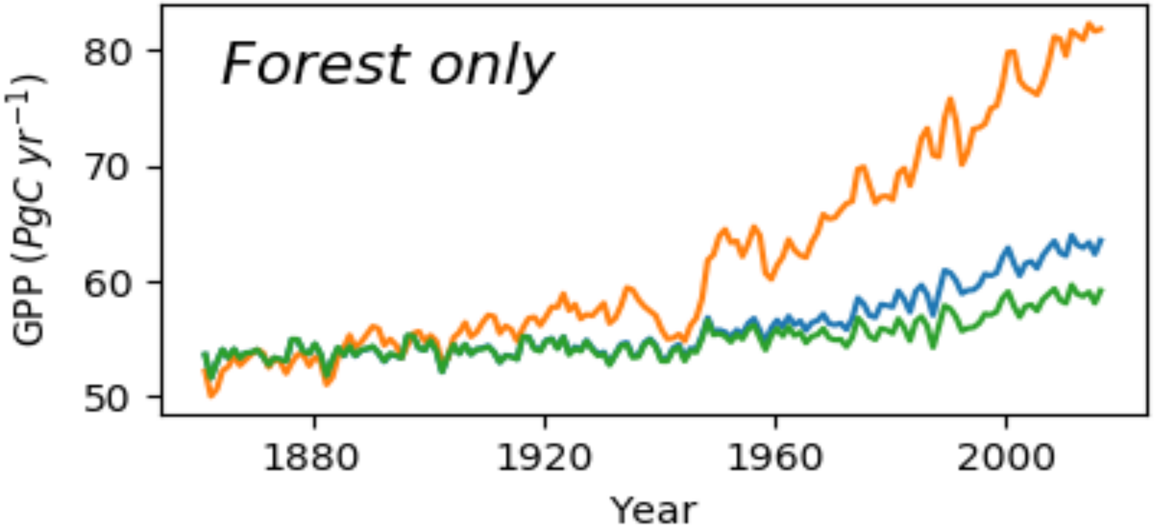
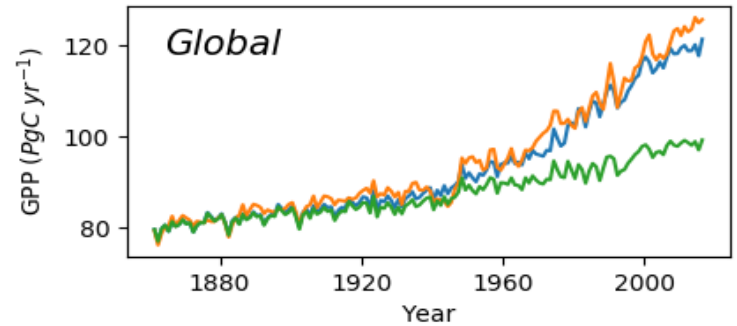
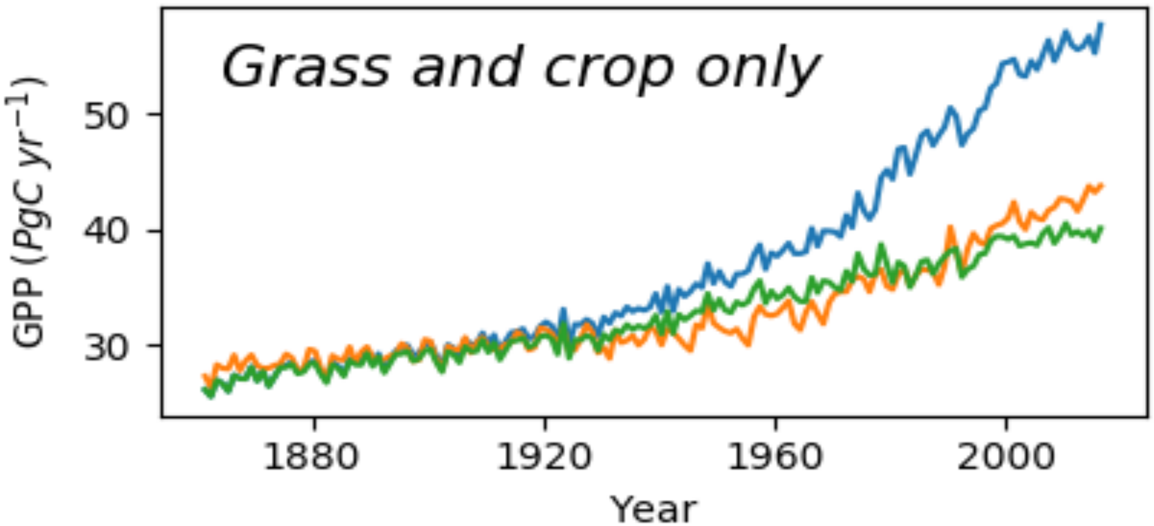
Correlation between parameters



Role of the C/N interactions on GPP







CN fix – 1850
Clim + LUC + CO2

CN dyn
Clim + LUC + CO2 + N input

CN dyn
Clim + LUC + CO2