Modeling the global biogeochemical cycles in the terrestrial biosphere: Progress and limits

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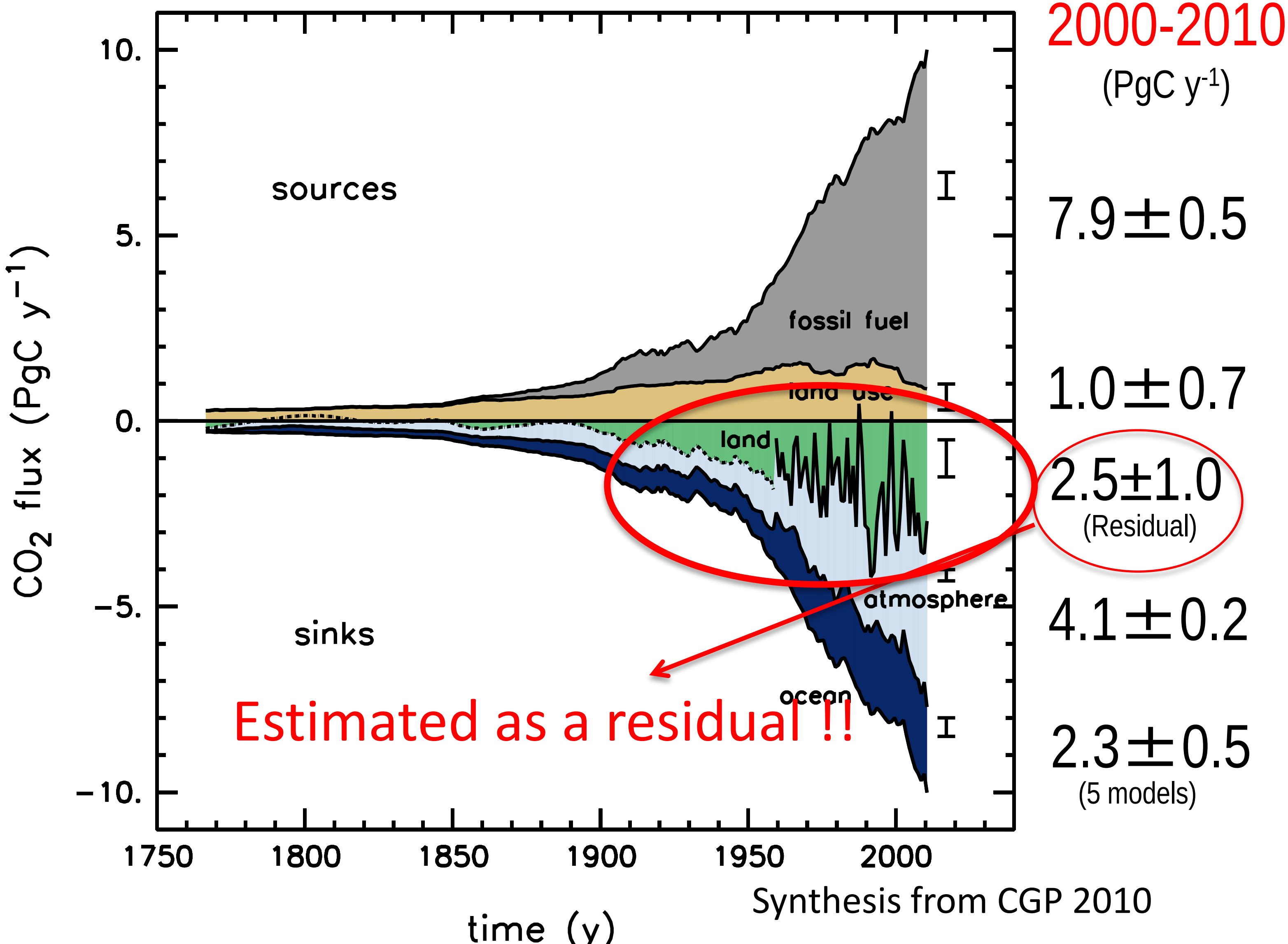
LSCE

Introduction

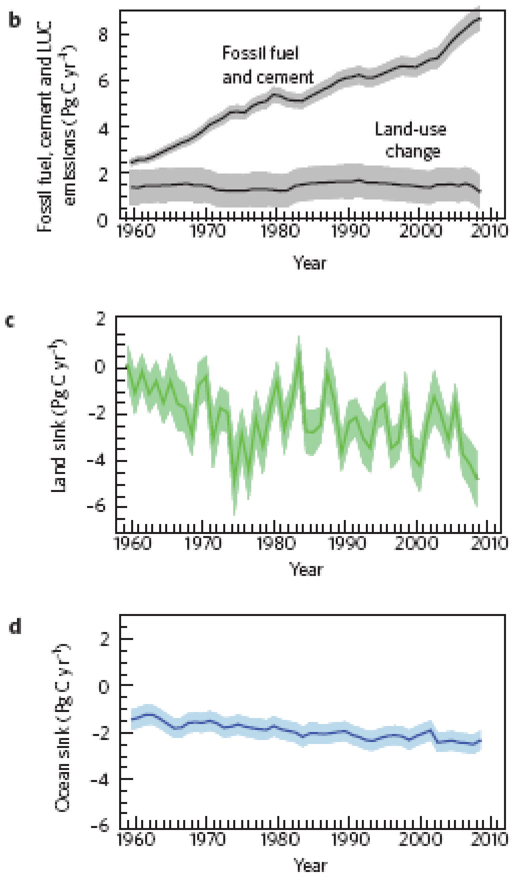
- The Interest for understanding the global biogeochemical cycles of terrestrial biosphere has largely increased in the last decades
  - Impact of climate on vegetation (e.g crops) is of first importance
  - Role of vegetation on climate is more and more stressed
  - Role of the terrestrial ecosystem on the global carbon cycle also very important

Important and highly uncertain component



Synthesis from CGP 2010

Only firsts attempts to directly estimate fluxes from bottom-up modeling (e.g Le Queré et al 2009)

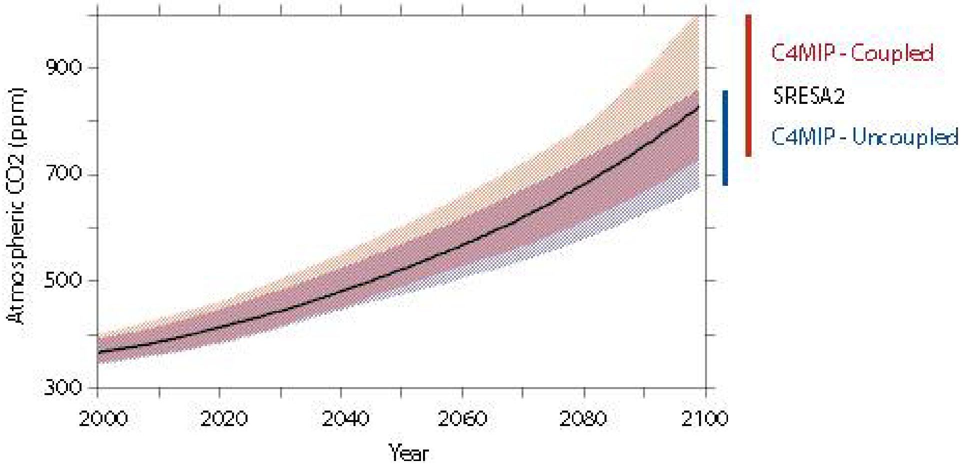


- Still High uncertainty
- 90% of the interannual variability of atmospheric CO2

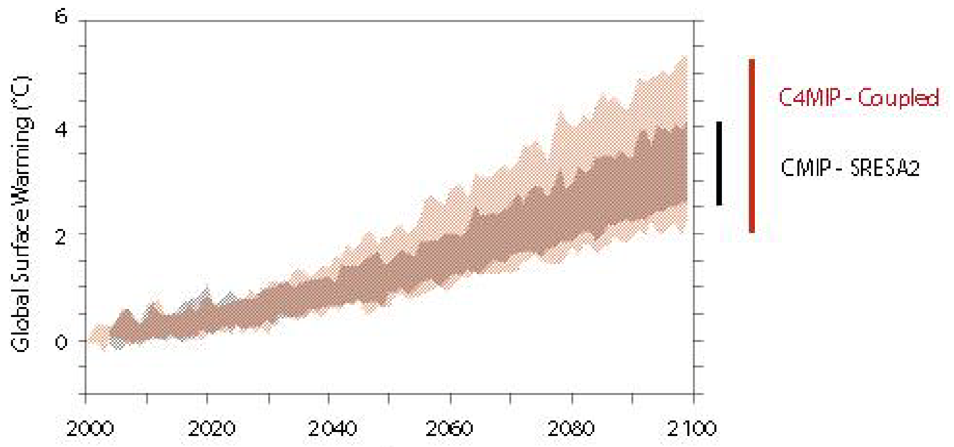
Le quere et al. 2009

Recent coupling in climate models (C4mip)

Change in atmospheric CO2



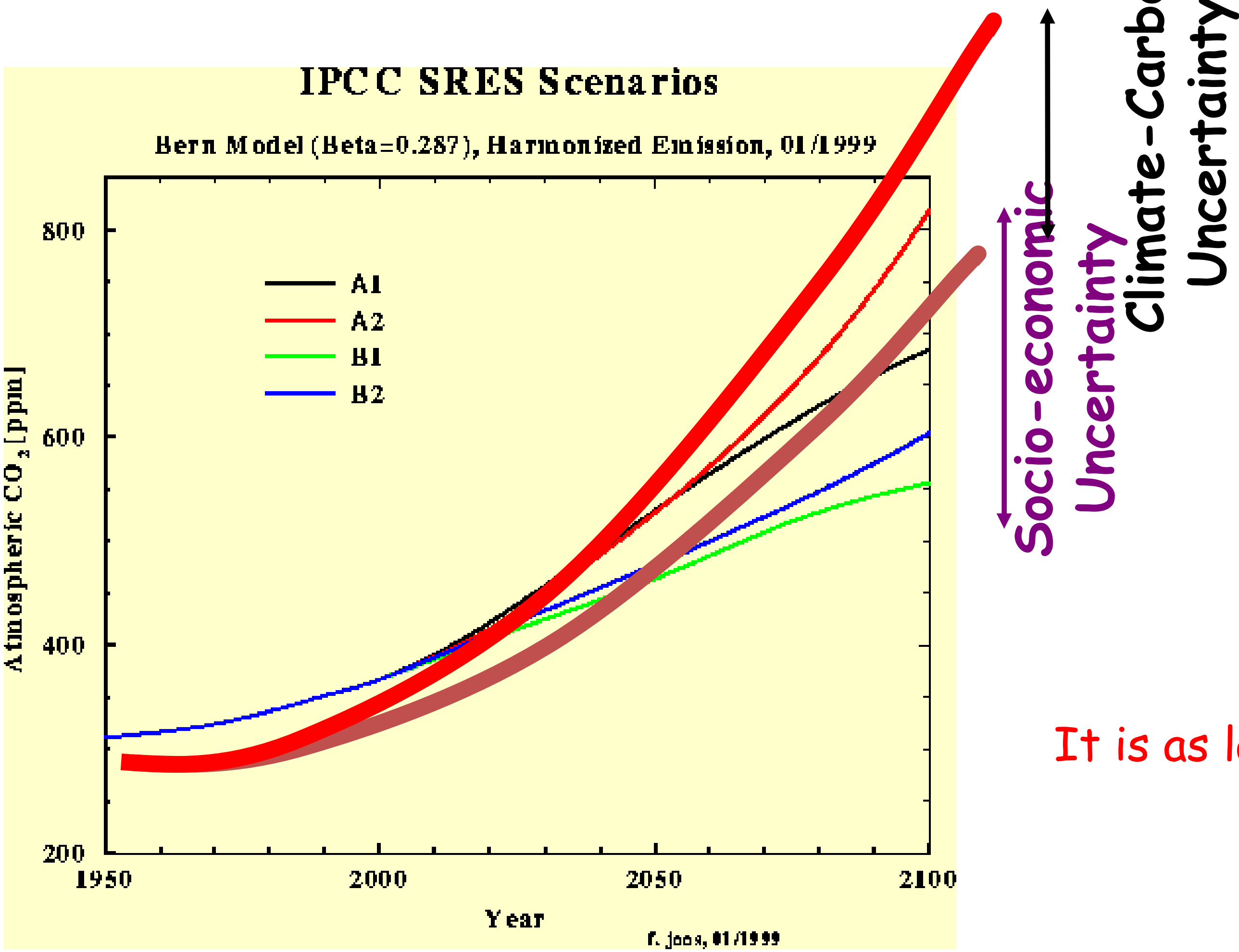
Change in temperature



Friedlingstein et al, J. Climate, 2006

Important feedback to climate

Here again a large source of uncertainties



It is as large

See Dr Piao lecture on impact on vegetation growth in NH

See Dr Lui lecture on vegetation dynamics in drylands

Vegetation modeling: an historical point of view (1)

before 90..

Land surface scheme (physics)

Bucket+penman-monteith

Biogeochemical models

Statistical regression between NPP T et P

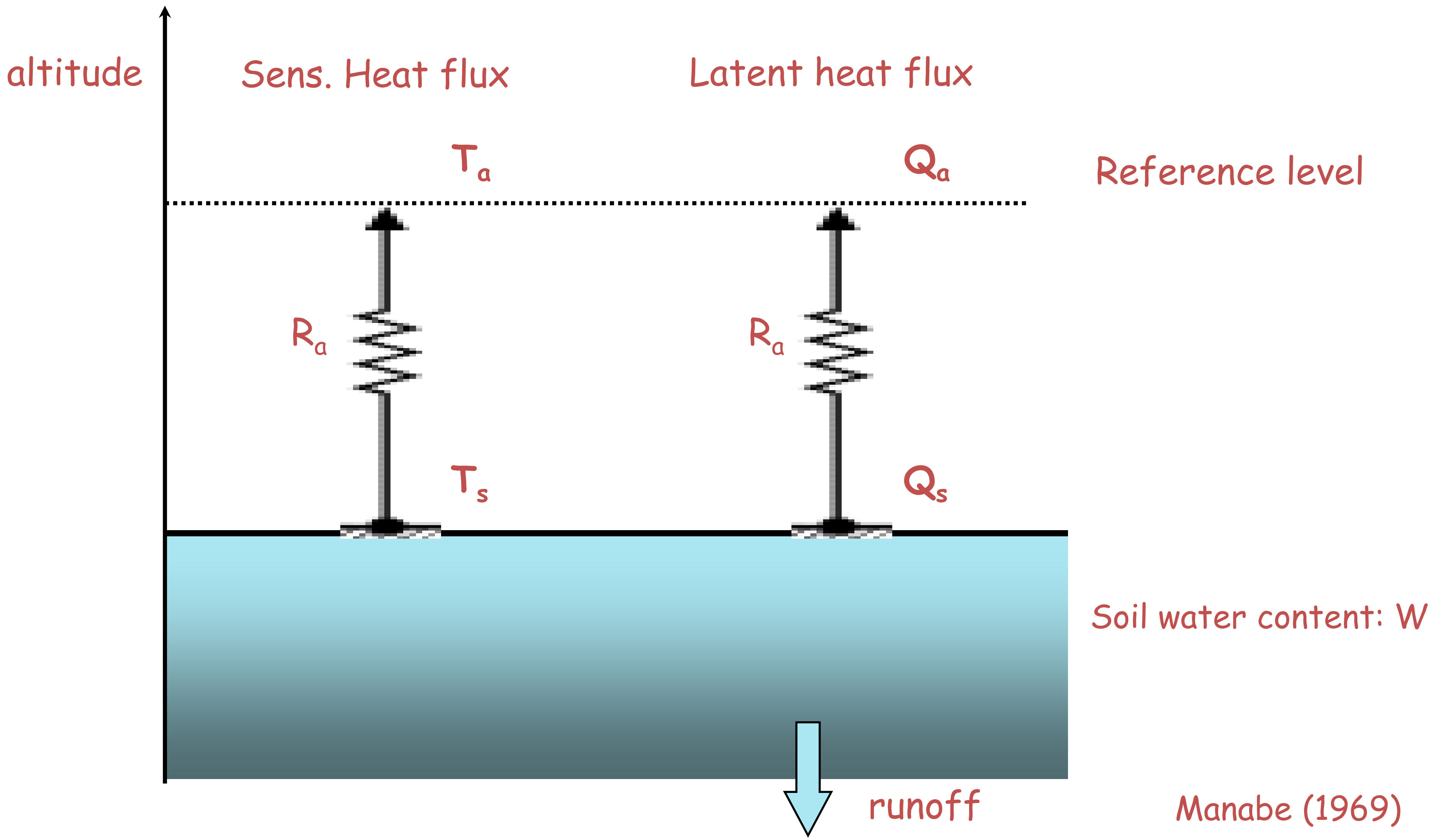
MIAMI

Biogeographical models

Statis. Regression In the T,P space

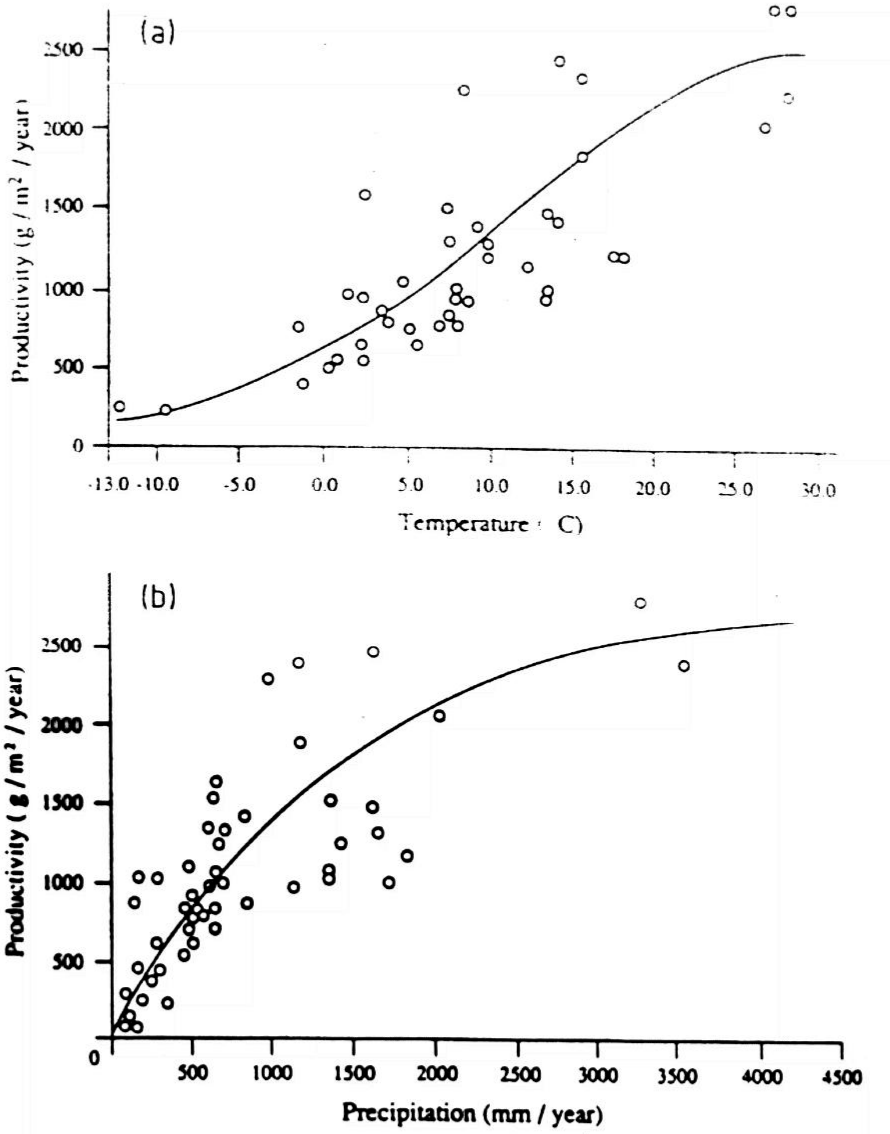
Holdridge

Physics: soil is a bucket, no vegetation



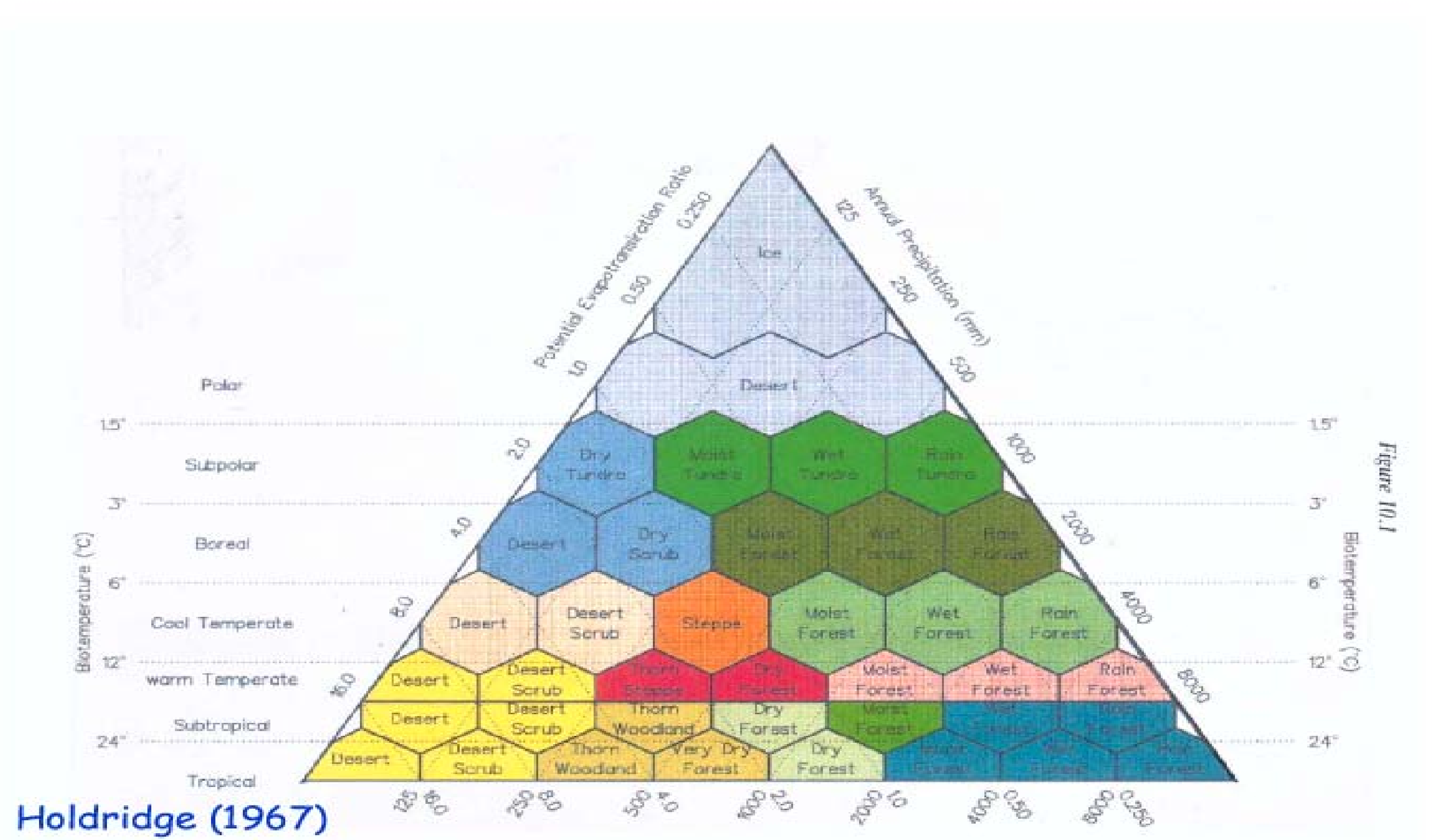
Manabe (1969)

Modeling of productivity



The MIAMI model:
Annual NPP=maxprod*f(T)*f(P)

Biogeographical models



Vegetation modeling: an historical point of view (2)

Land surface scheme (physics)

before 90.. Bucket+penman-monteith

90-95 Mutllayer soil + vegetation

Bats Sib LSM ISBA SECHIBA

Biogeochemical models

Statistical regression between NPP T et P

MIAMI

Mecanistic models

TEM, BIOME-BGC,CARAIB SILVAN, CENTURY,Pnet,FBM HRBM, STOMATE

Biogeographical models

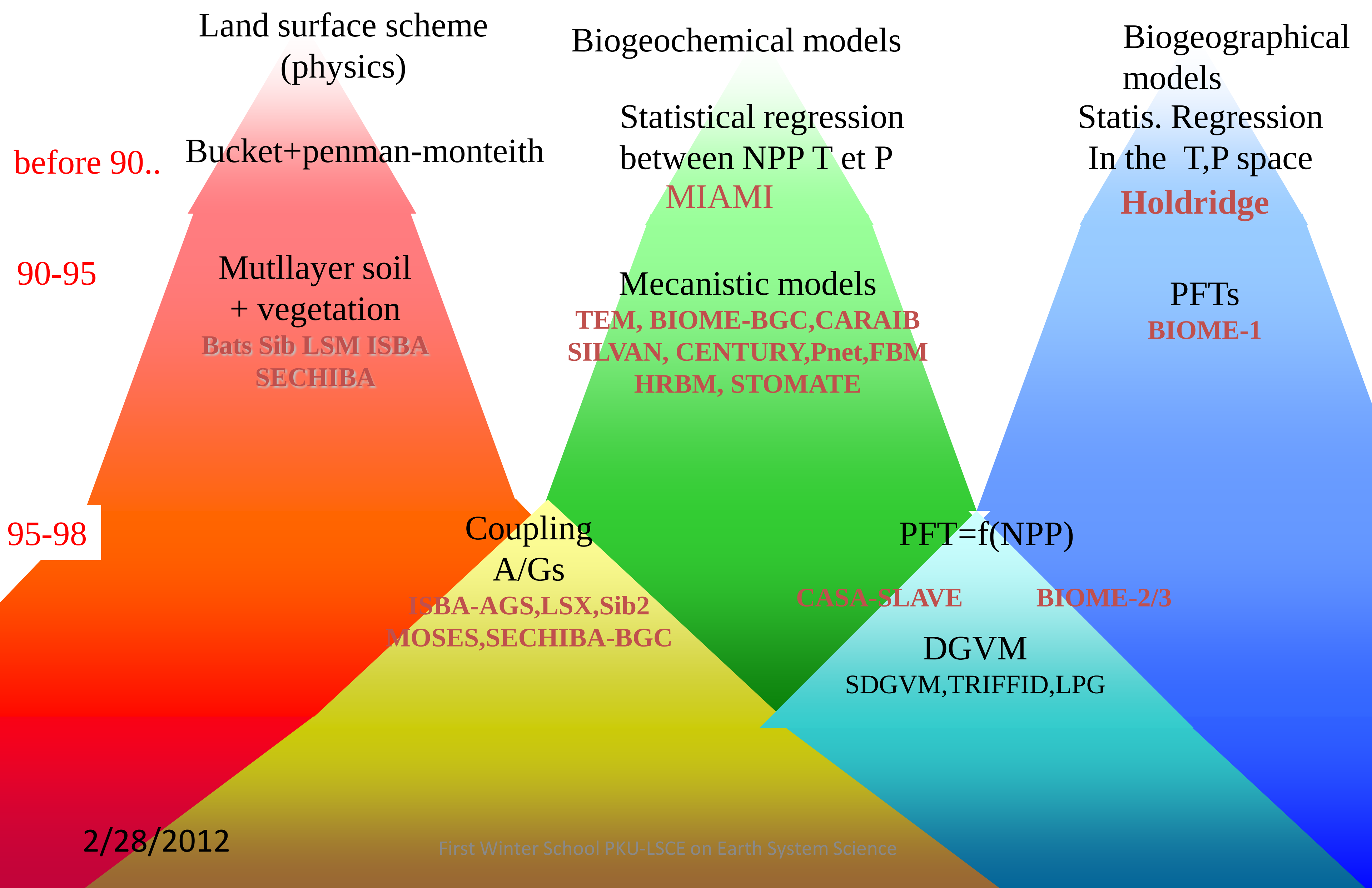
Statis. Regression In the T,P space

Holdridge

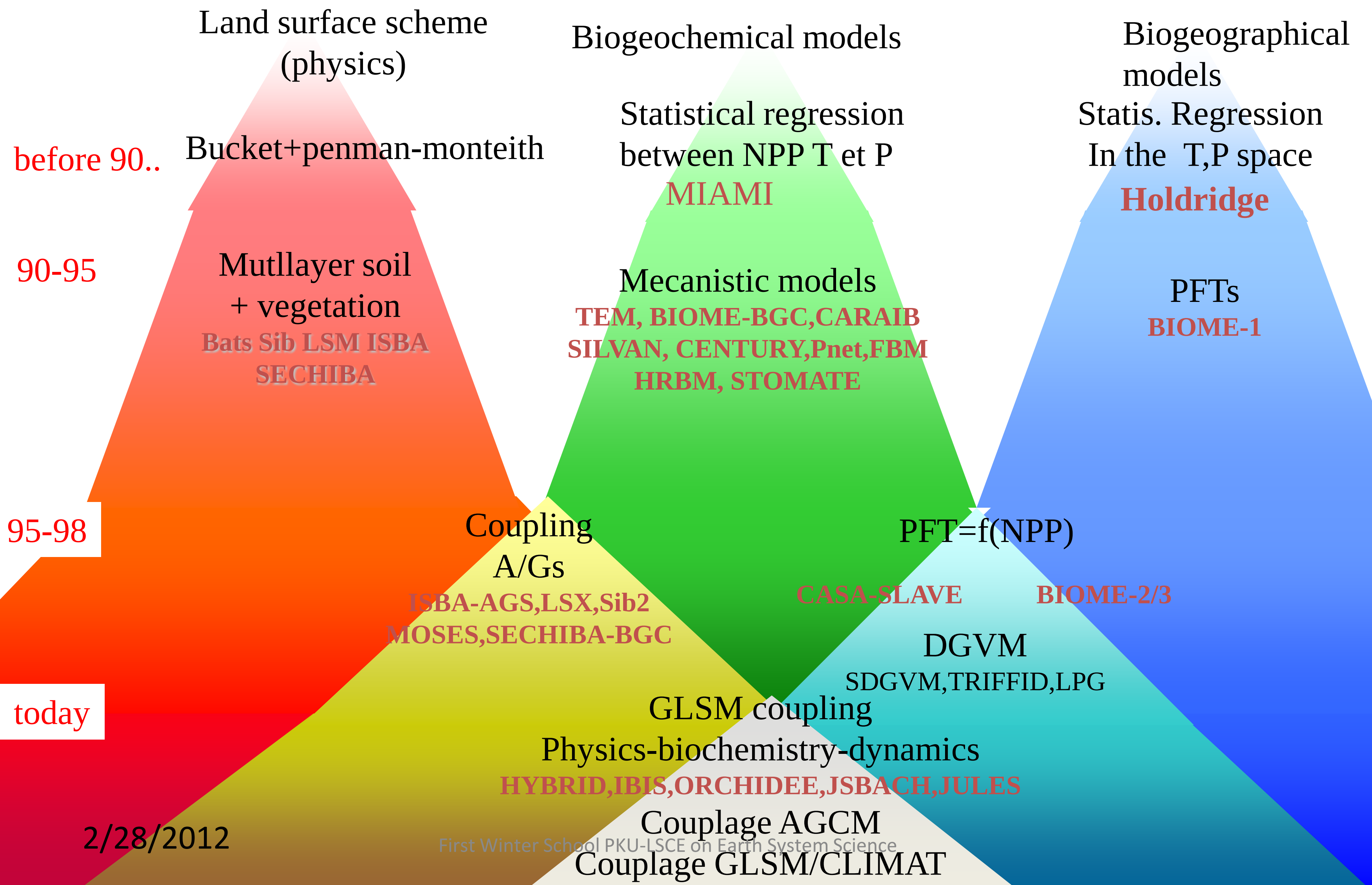
PFTs

BIOME-1

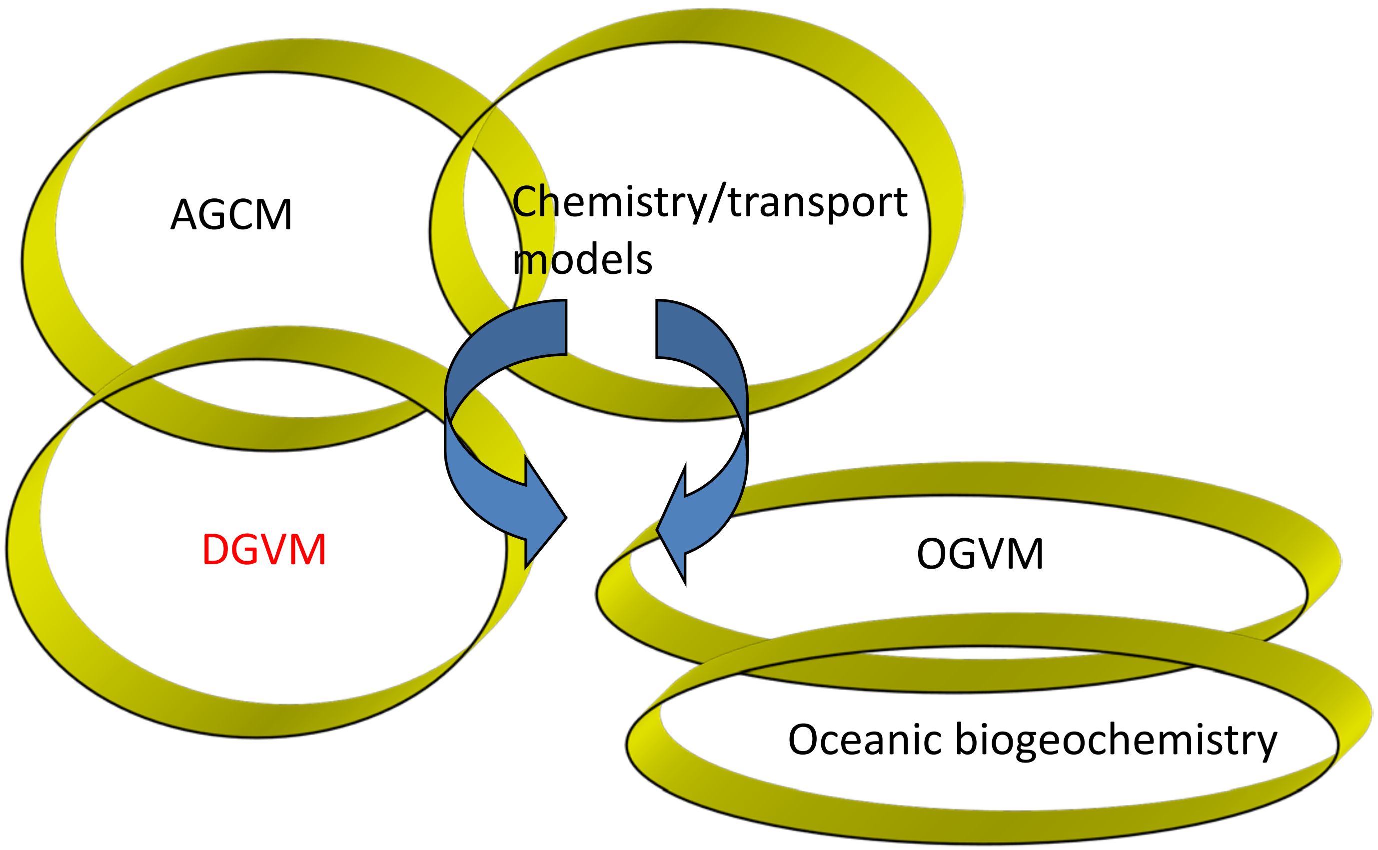
Vegetation modeling: an historical point of view (3)



Vegetation modeling: an historical point of view (4)



Toward « earth system models »



What inside the models ?

- **Vegetation is described as Plant functional types**

➔An average plant represented by a set of parameters and parameterisation

Typicaly about 15 PFTs in global models:

e.g deciduous v.s evergreeen, broadleaves v.s needleleaves, C3 vs C4 photosynthesis and different

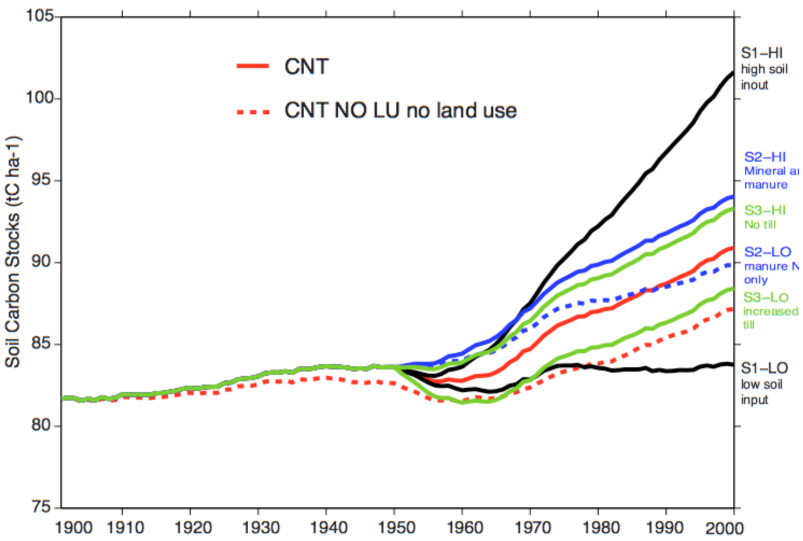
Climatic zones (boreal, temperate, tropical)

See Dr Poulter lecture for detail on processes

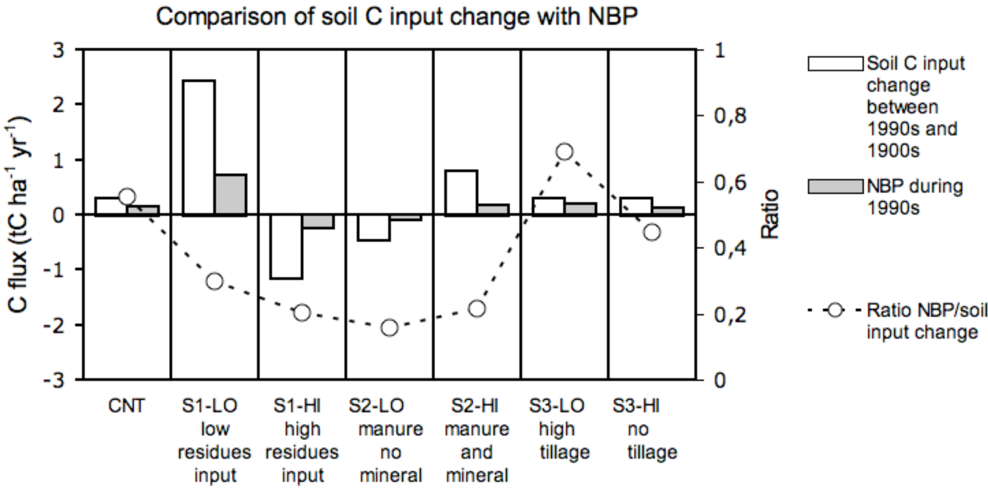
Recent development in DGVMs

- Include land use and land use change
  - including crops: different approaches.
    - LPJml: Simplified crops simulation
    - ORCHIDEE-STICS: coupling with agronomical model
  - Including pasture
  - Including forestry (***see Dr Bellassen lecture***)
- Include others cycles than carbon (Nitrogen,Phosporus)
- Include plant functional traits

e.g: estimation of management on carbon mitigation



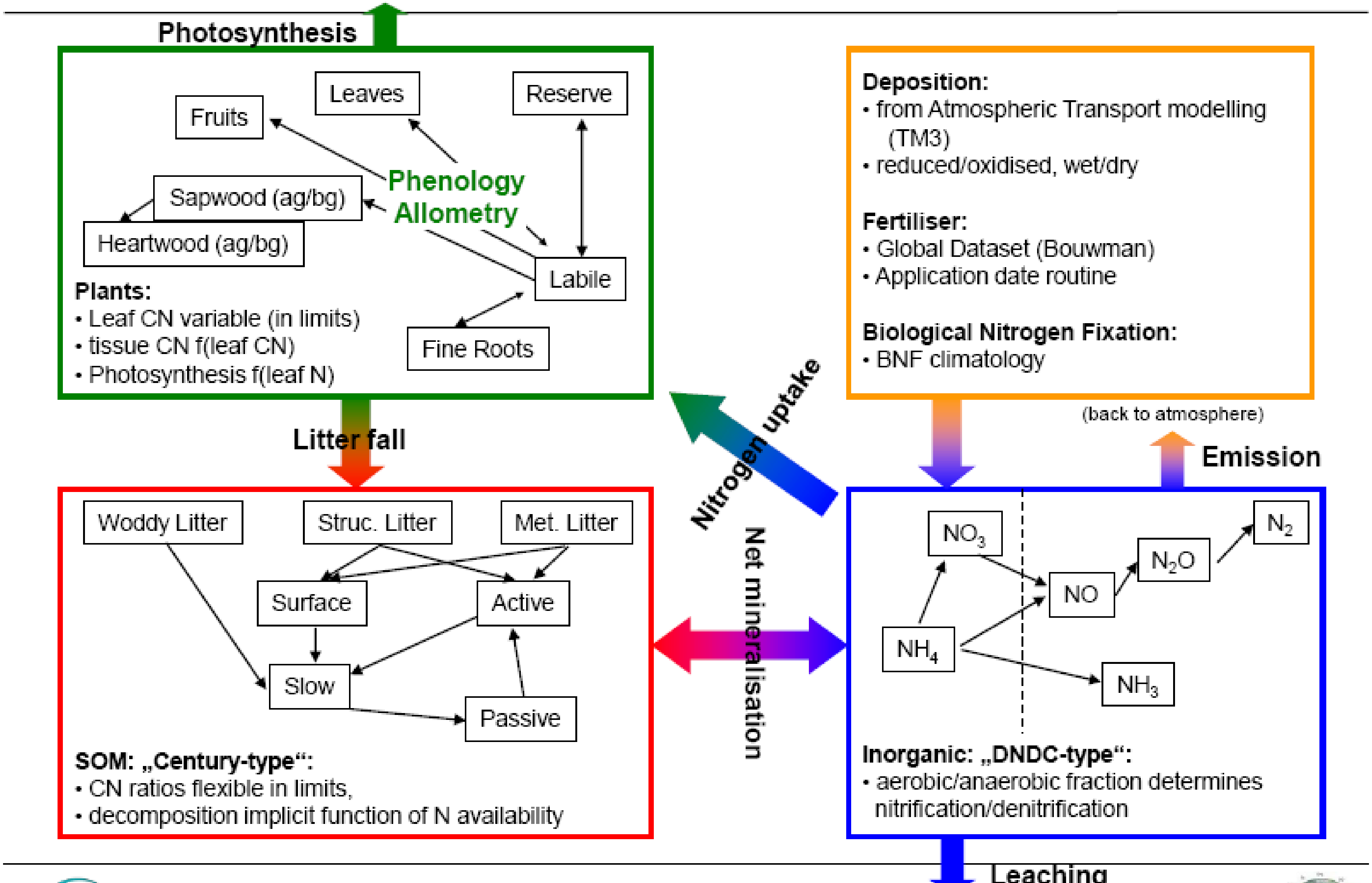
Change in soil carbon with land use practices



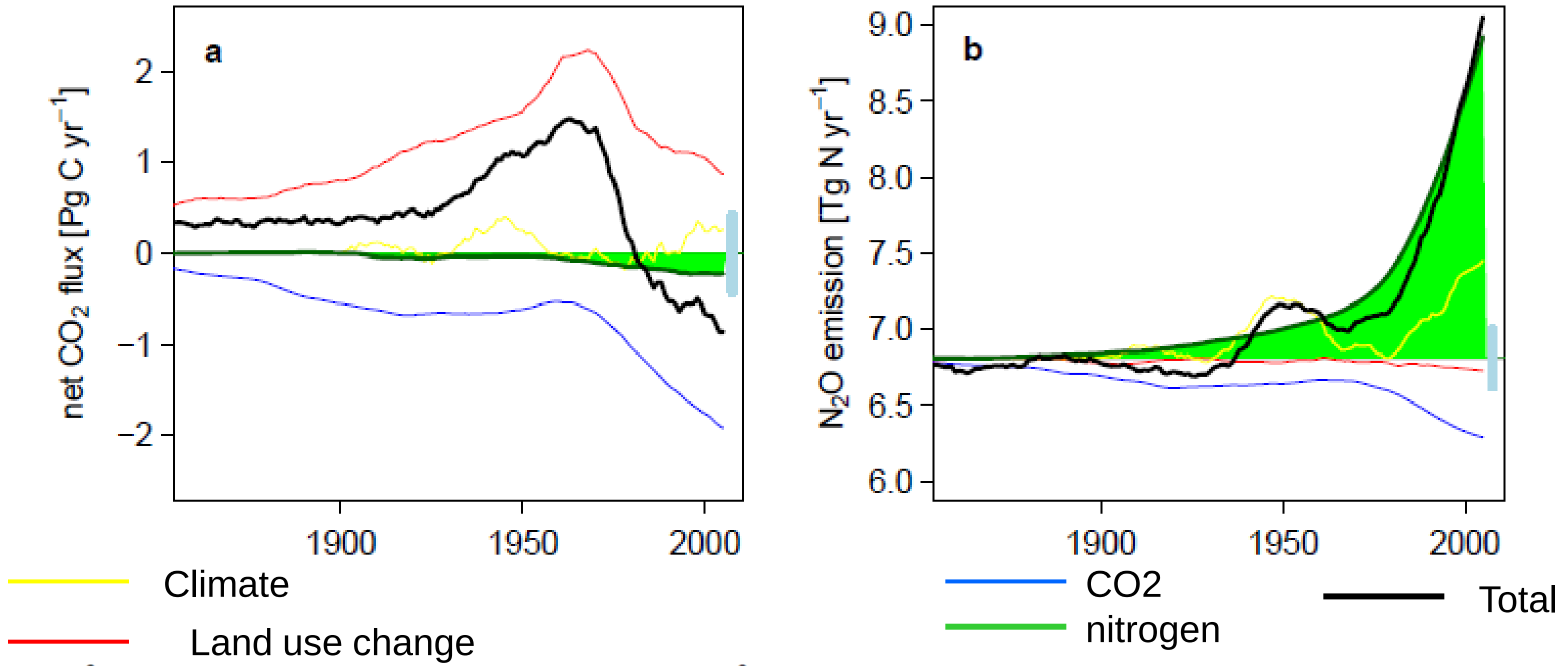
Impact on net carbon flux
And mitigation efficiency

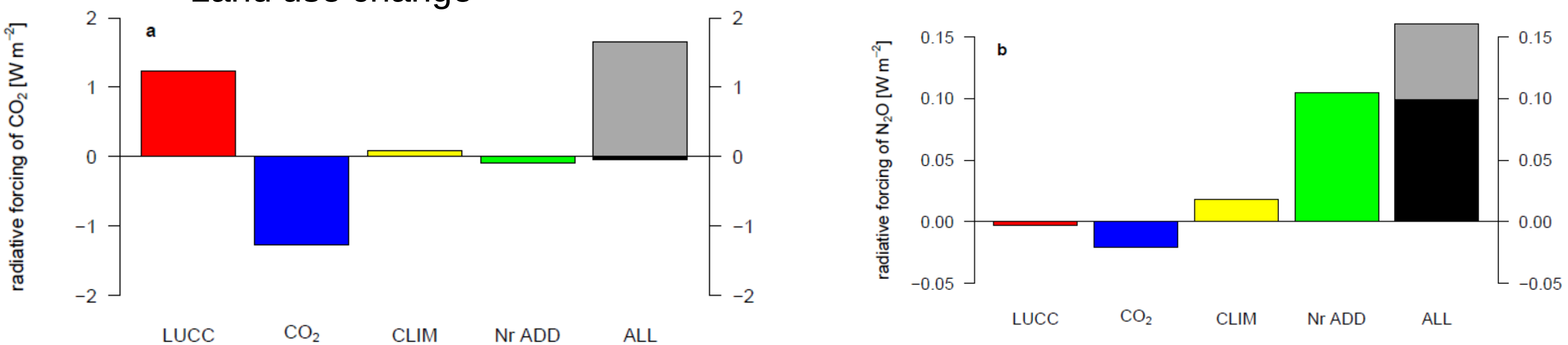
Ciais et al 2010

Nitrogen Cycling in ORCHIDEE



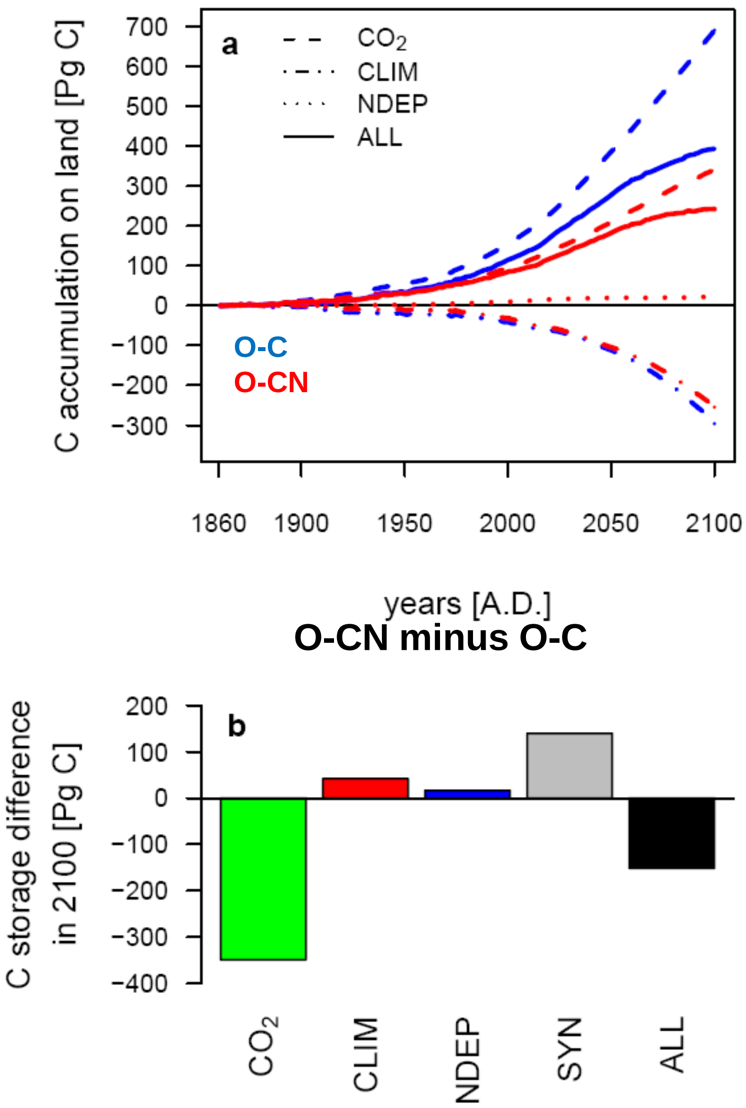
Contribution de différents facteurs sur le CO_2/N_2O et impact radiatif





Effect of Nr on the global warming potential: N_2O: + 104mWm^2 CO_2: - 94mWm^2

Effects of N on future projections



N dynamics

- consistently reduce net land C storage due to N limitation of CO_2 fertilisation in boreal & temperate ecosystems
- lead to an additional accumulation of 48 (41-55) ppm CO_2 than when considering C dynamics alone
- Imply an addition radiative forcing of 0.29 (0.28-0.35) W m^{-2}
- Corresponding to 0.31 (0.18 – 0.37) K additional surface warming

by the year 2100

Zaehle et al, 2010, GRL

Toward including functional traits…

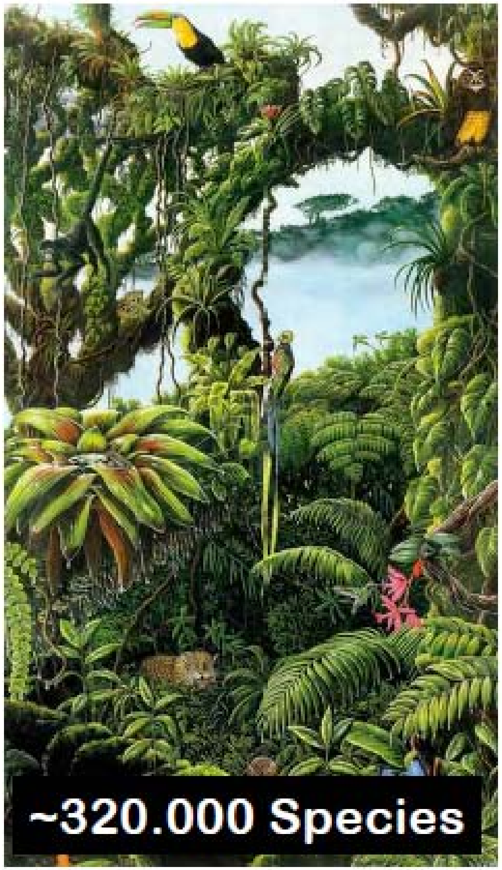
Current representation of vegetation in DGVM

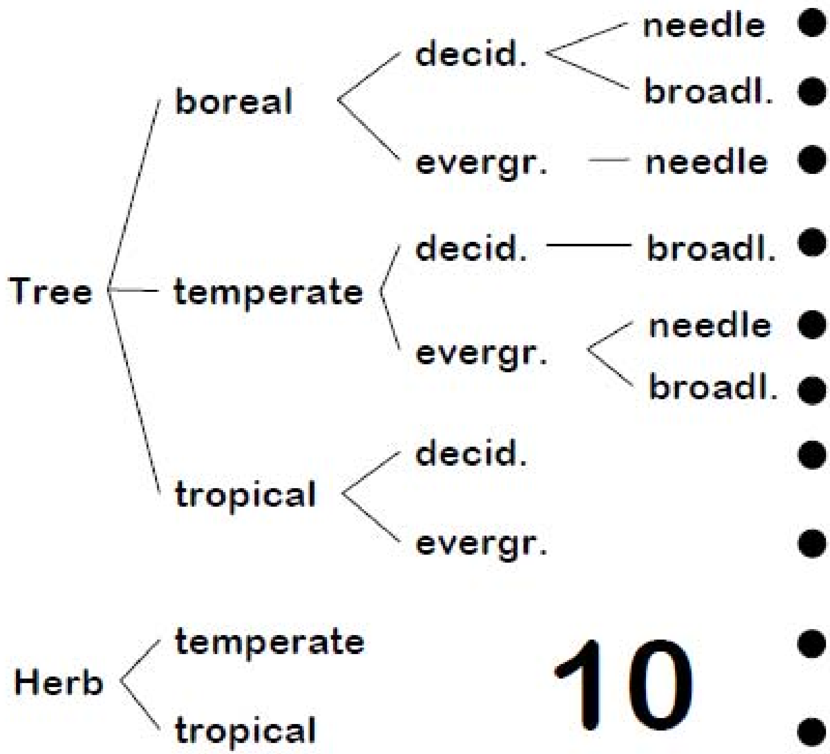
Based on Plant Functional types (PFT):

➔ represented in the model by a set of parameters and parameterization

➔ Model simulate a « mean plant » replicated everywhere

How functional diversity is included in DGVMs ?





Is functional traits represented ?

Yes aggregated traits are implicit in models BUT

Most of the traits have a fixed value in one PFT

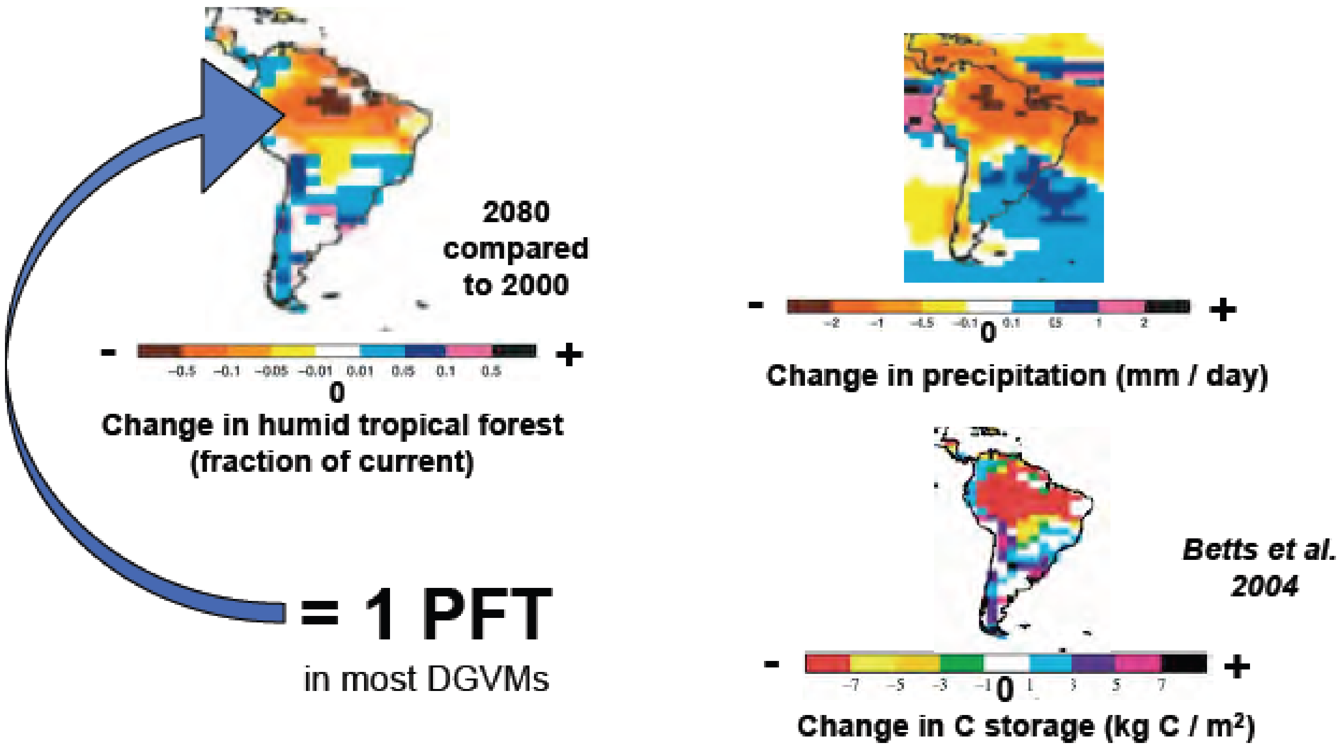
➔No spatial variability

➔ No traits plasticity

➔ No biodiversity

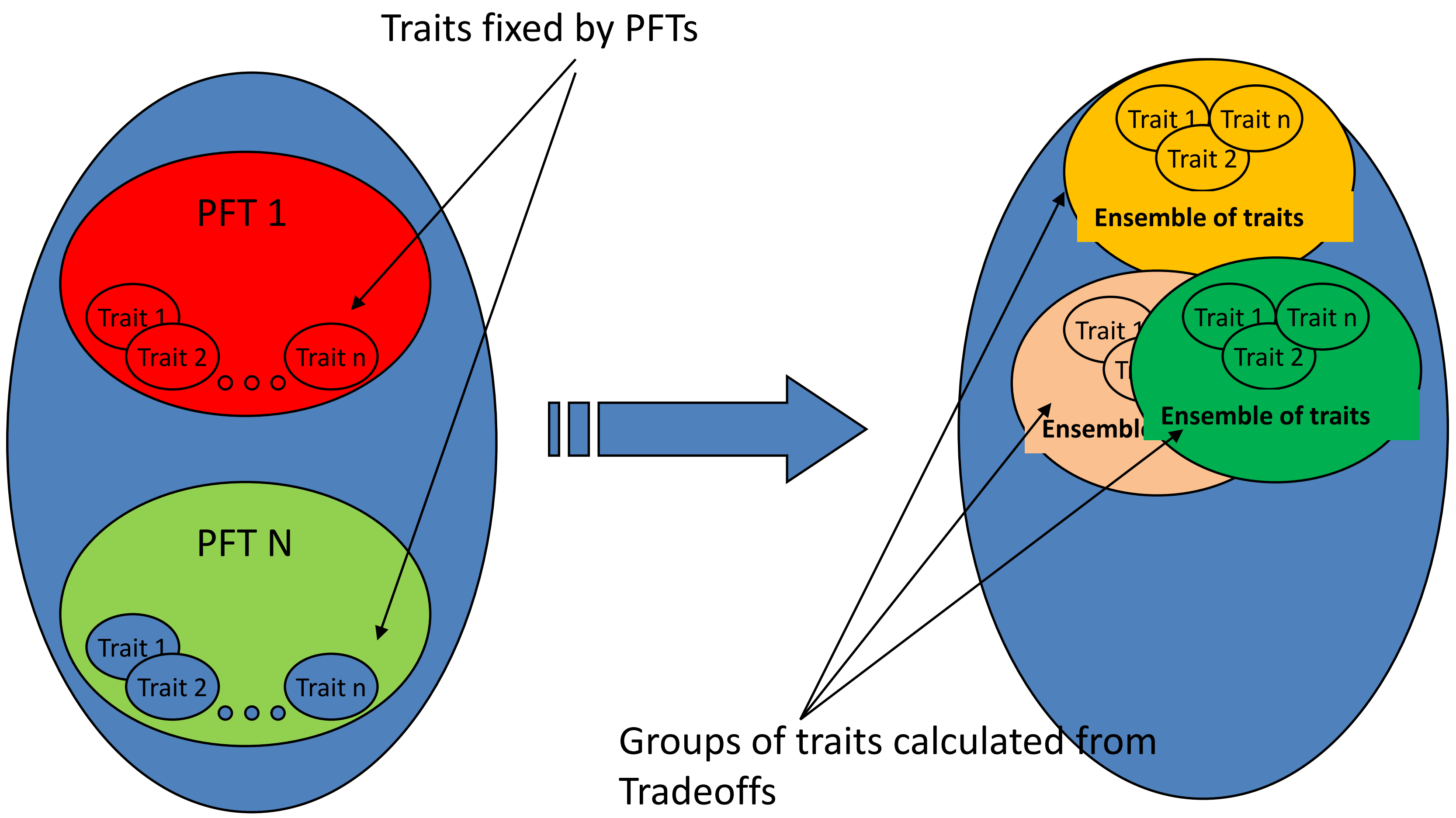
An exemple of PFT approach limitation

- The future of amazonian forest: Betts et al. 2004



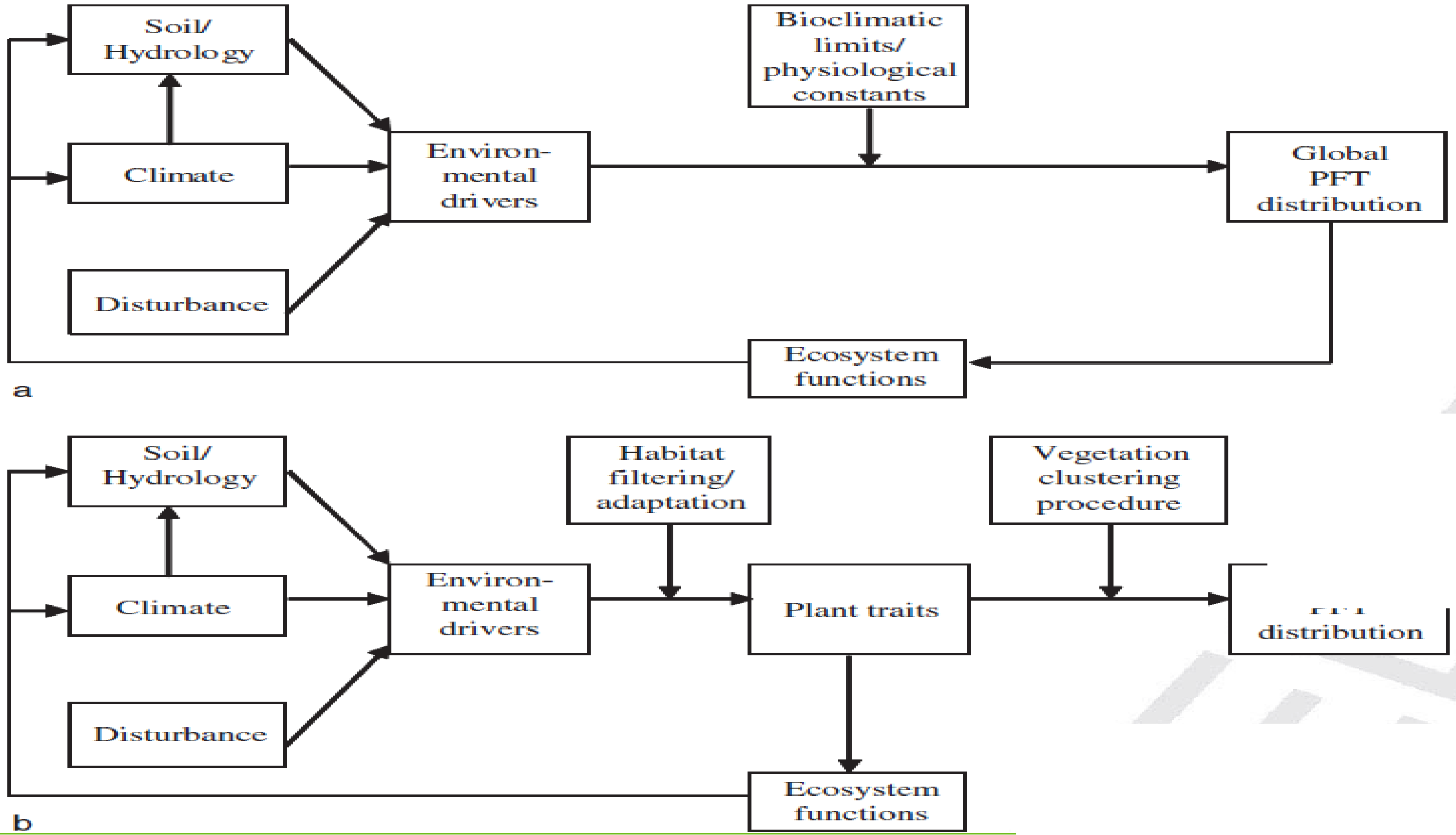
First climate/carbon coupled simulation shows a total forest dieback with large feedback with climate.

What is the future for DGVMs ?

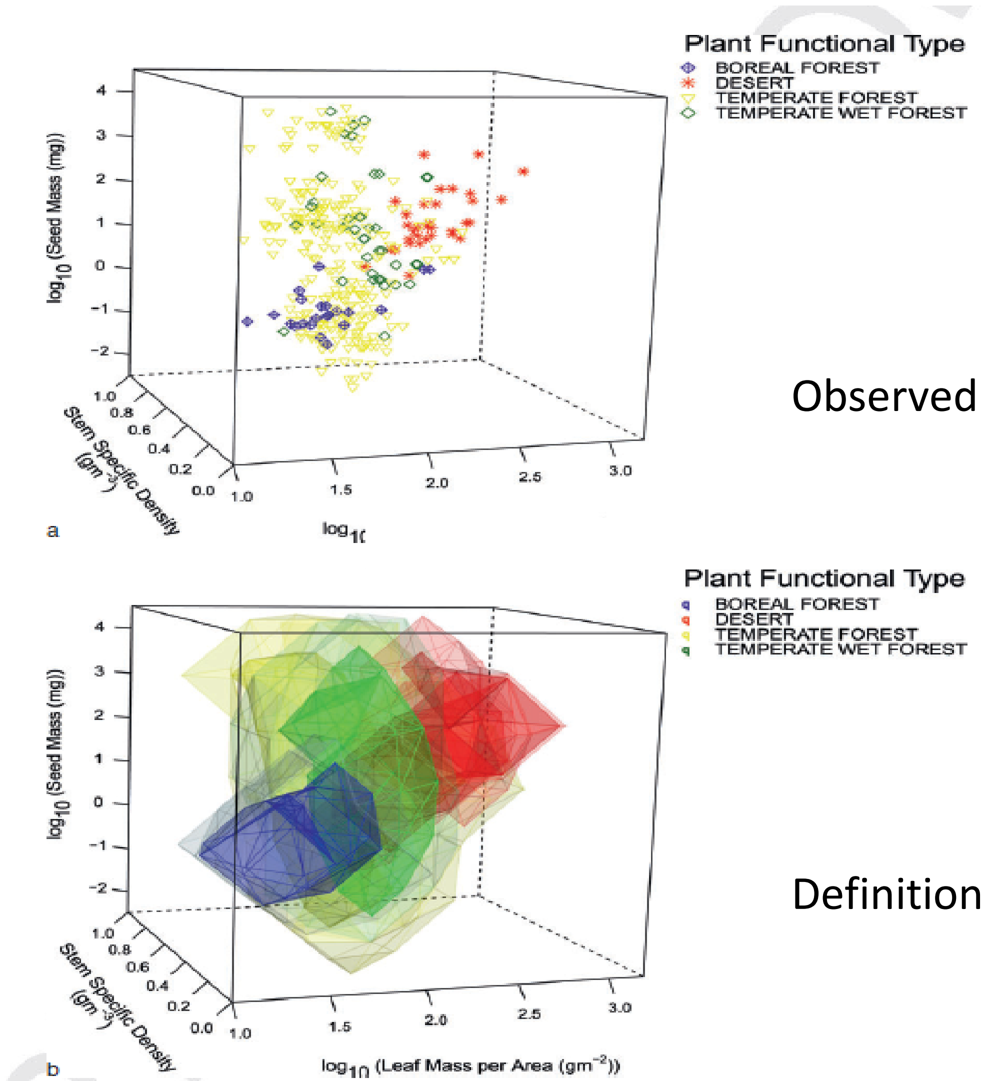


2 exemples of traits based models

- TRiCYCLE model(Van Bodegom et al.)



PFT defined as classes in the traits space

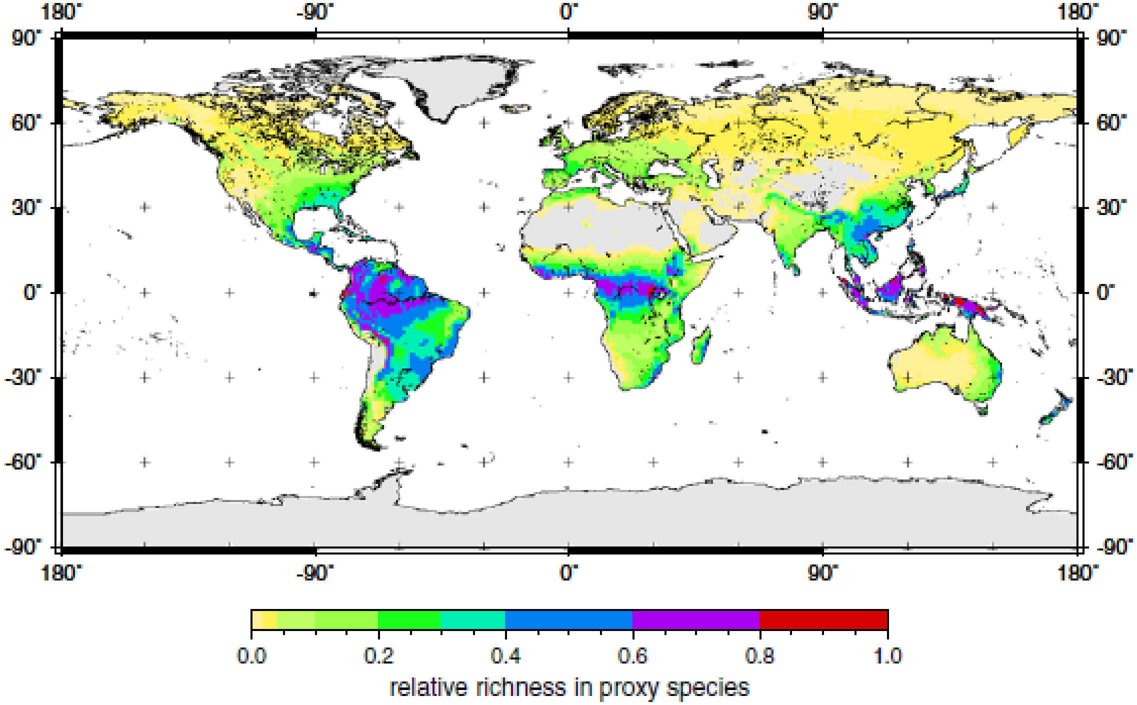


Observed traits

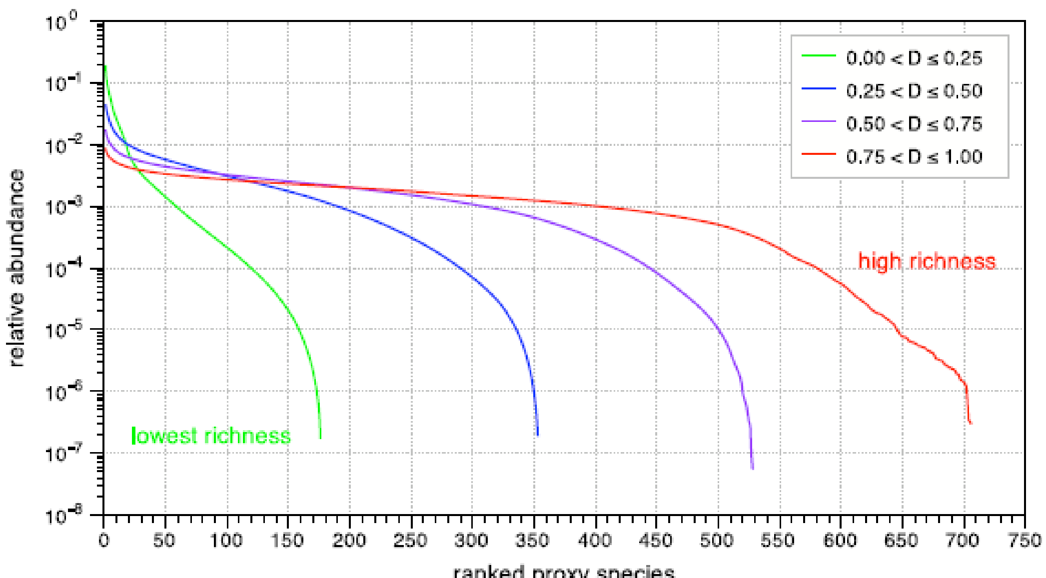
Definition of PFTs as clusters in the traits space.

Modeling biodiversity from traits (Kleidon et al.)

- Principle: « pseudo species defined as traits groups »
- Radom selection of species from traits values
- Selection of species able to survive

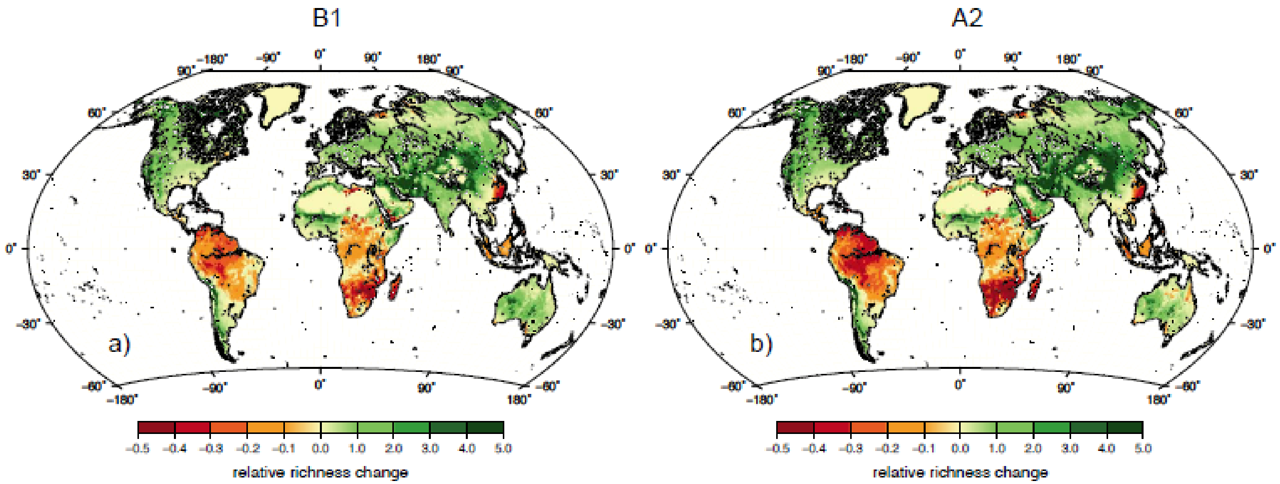


Relative species richness

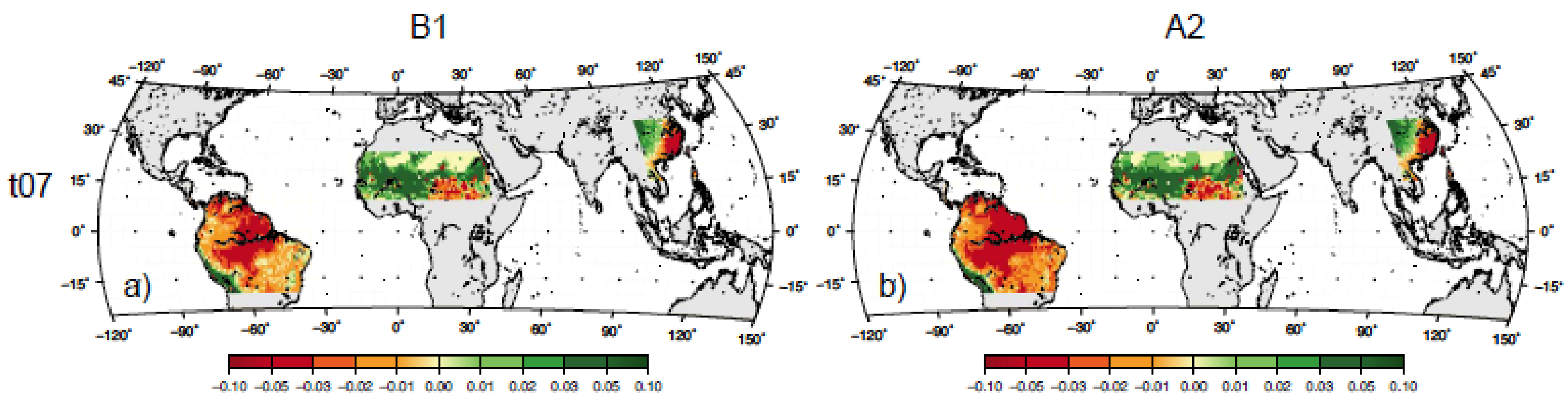


Species abundance

Results for futur climate



Change in species diversity



Changes in traits: e.g allocation between below/above ground

Models processes still to address

- Disturbances effects to be improved
  - Fire
  - Storm
  - Biotic diseases (e.g insects)
- Vegetation dynamics to be improved
  - Better representation of regeneration/fitness
  - Lag effects
  - Tree mortality

Conclusion

- Increasing number of studies on terrestrial biosphere leading to a large improvement of models from the last decade.
- Less a less difference between global and field level models

But still large improvement to be expected:

- Improving agrosystems
- Including all the biogeochemical cycles
- Trait based approaches (adaptation)
- Better representation of vegetation dynamics:
- Better representation of disturbances