Application and Development of Dynamic Global Vegetation Model in IAP/CAS

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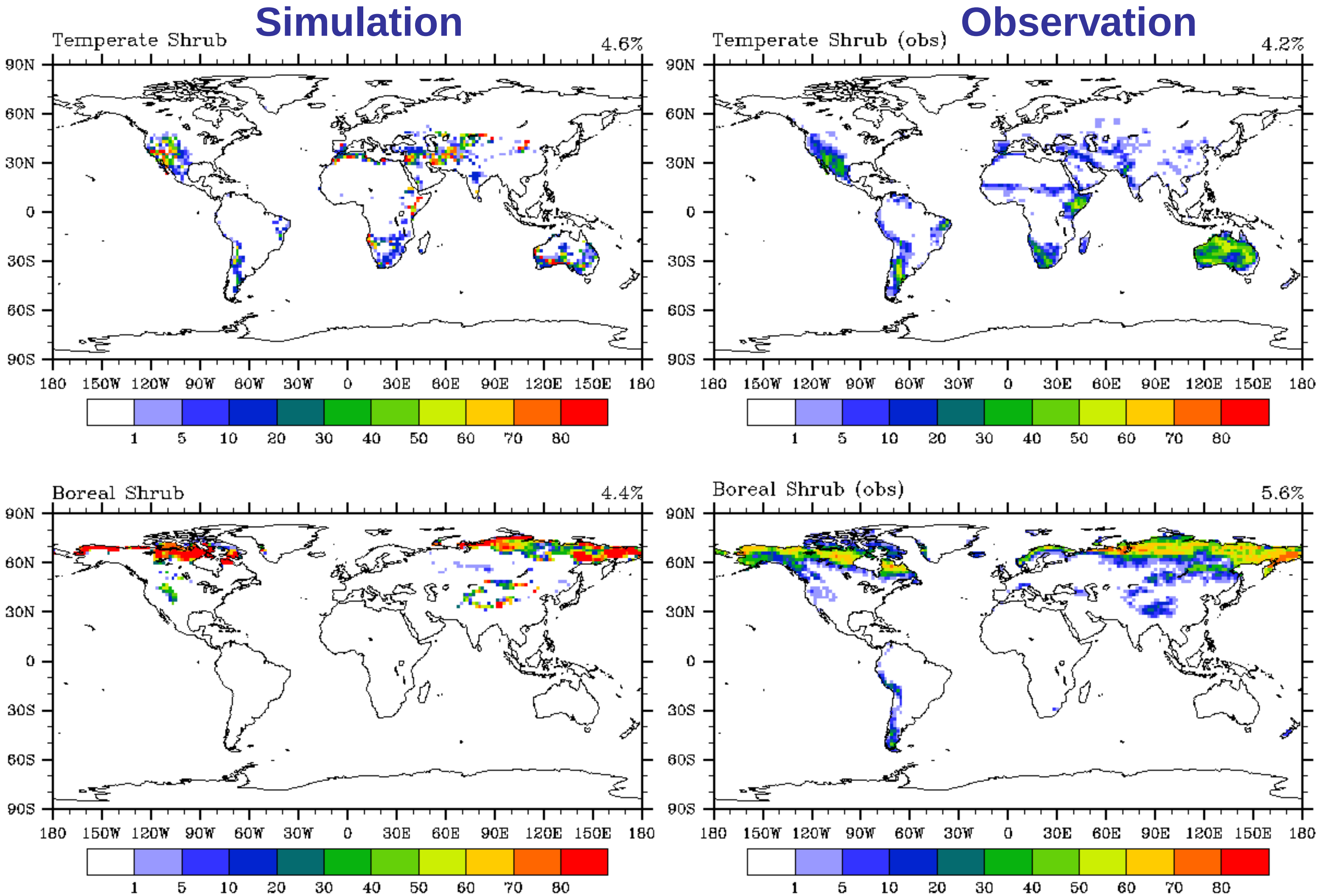
Outline

- **Evaluation of the Global Vegetation Simulation by the Modified CLM-DGVM**
  - **Global Vegetation Distribution**
  - **Vegetation-Climate Relationship**
- **Analysis of Model Bias**
  - **Ecosystem Formation**
  - **Population Density**
- **Development of the IAP-DGVM**
  - **Uncertainty of Establishment Scheme**
  - **Intermediate Process-based Fire Parameterization**

Modified CLM-DGVM

- **Submodel of temperate and boreal shrubs**
  - **An explicit consideration of shrubs' drought tolerance in the photosynthesis computation;**
  - **Phenology type and morphology parameters for shrubs;**
  - **The competition hierarchy of tree/grass/shrub.**
- **"Two-leaf" scheme of photosynthesis with nitrogen limitation factor**
- **Definition of fractional coverages of PFTs**
- **Improvement of the new allocation scheme**

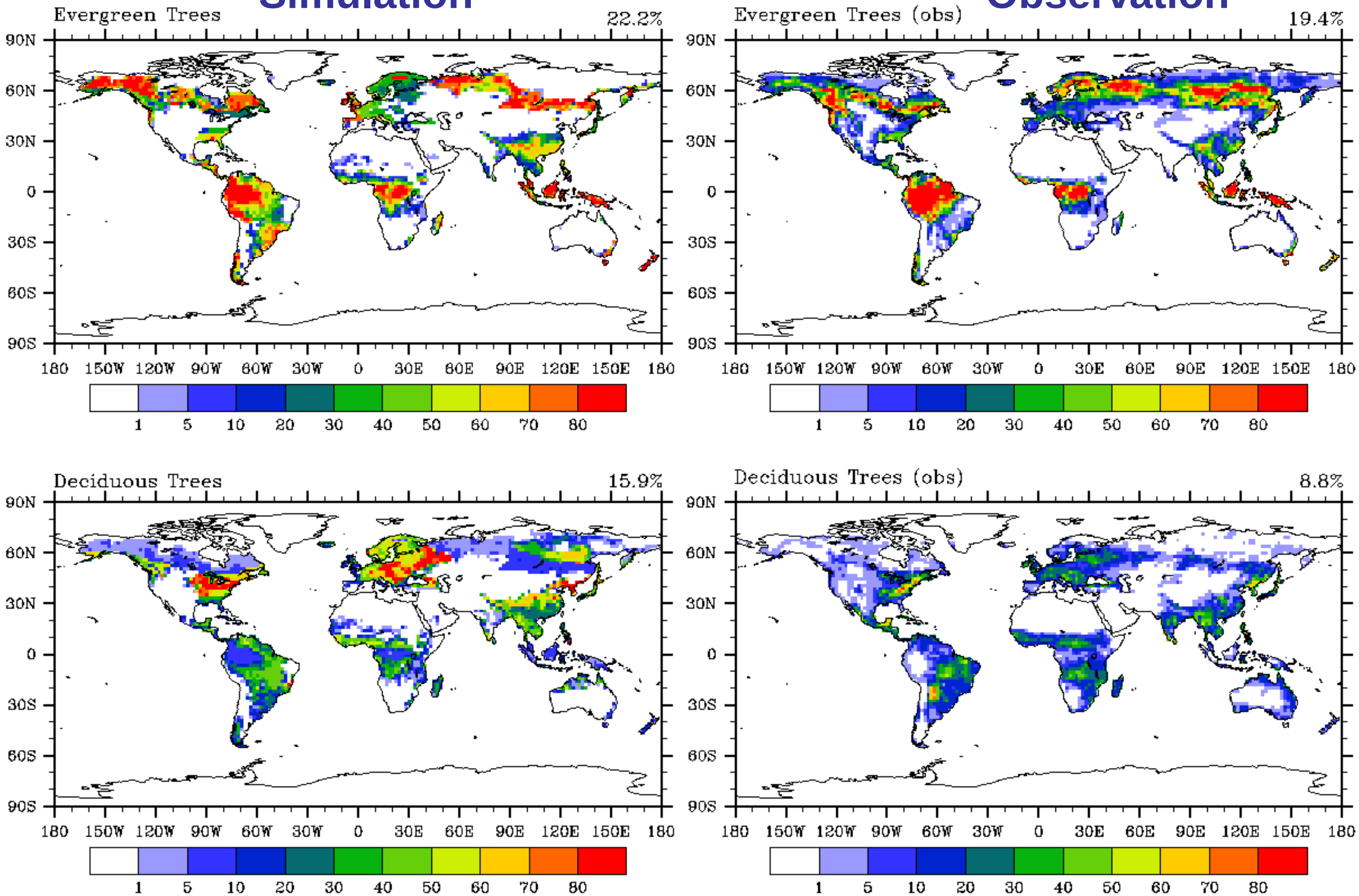


Temperate Shrub

Boreal Shrub

Global Distribution of Shrub

Simulation | **Observation**



Evergreen Forest

Deciduous Forest

Global Distribution of Forest

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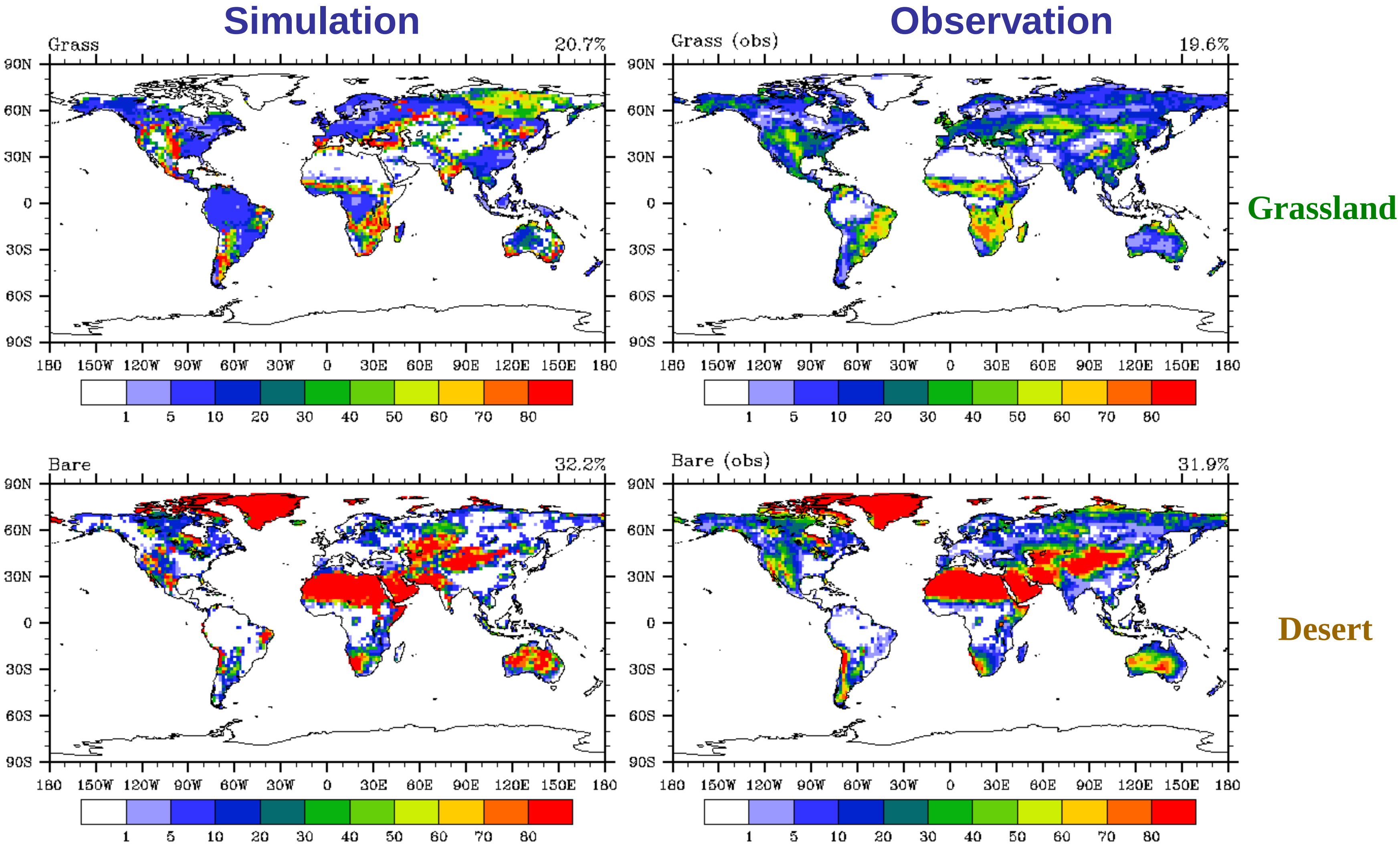
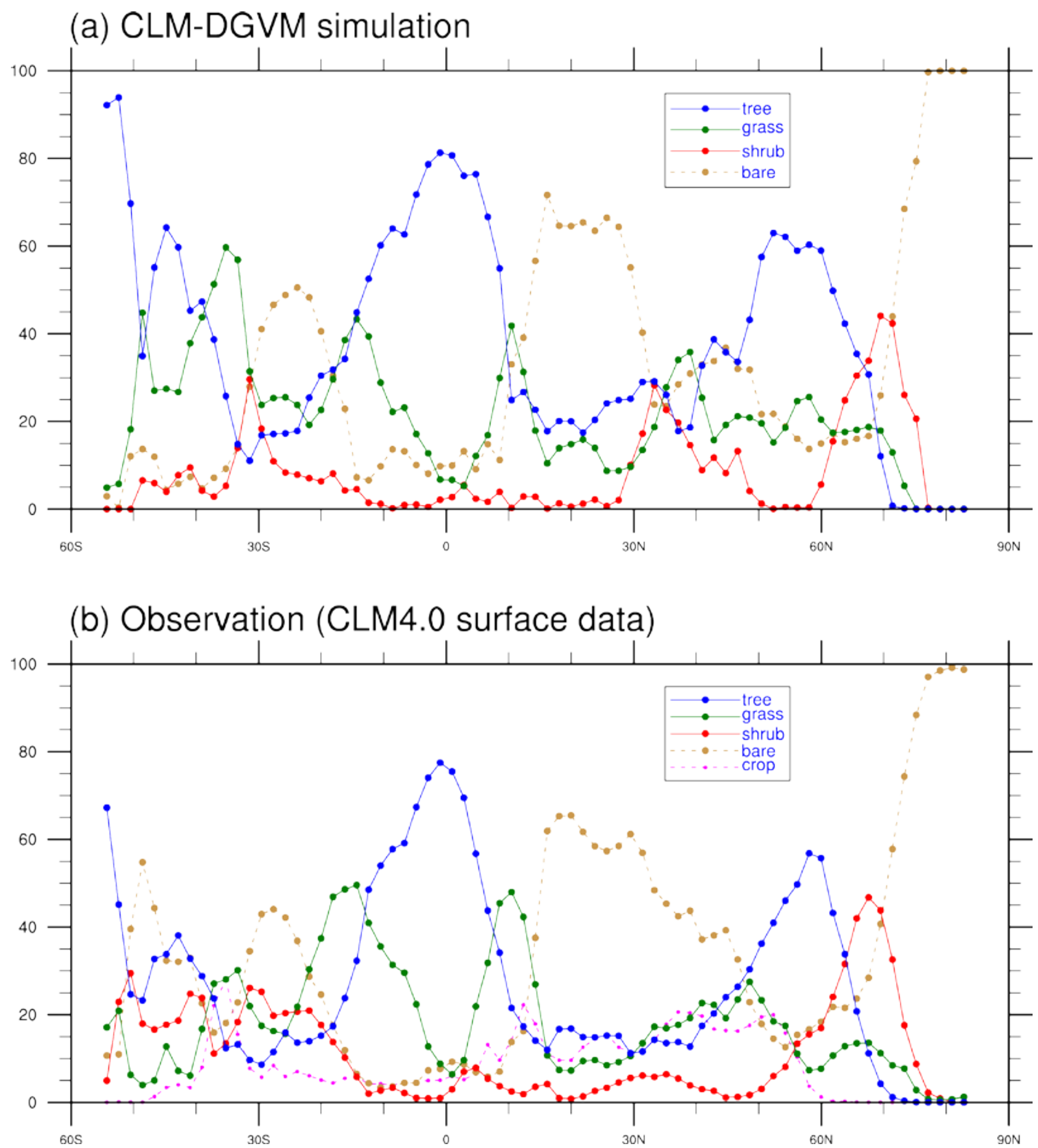


Global Distribution of Grassland and Desert

	new	3.0	3.5	obs
Trees	50.7	40.2	63.8	37.5
BET_Tr	13.3	5.9	15.3	11.0
BDT_Tr	8.1	11.9	8.4	5.8
BEM_Tr	3.5	2.7	5.3	1.6
NEM_Tr	2.8	1.0	9.3	3.3
BDM_Tr	11.1	8.0	8.8	4.4
NEB_Tr	9.9	4.9	5.4	8.5
BDB_Tr	2.0	5.8	11.3	2.9
Bare	55.0	58.3	41.1	54.7

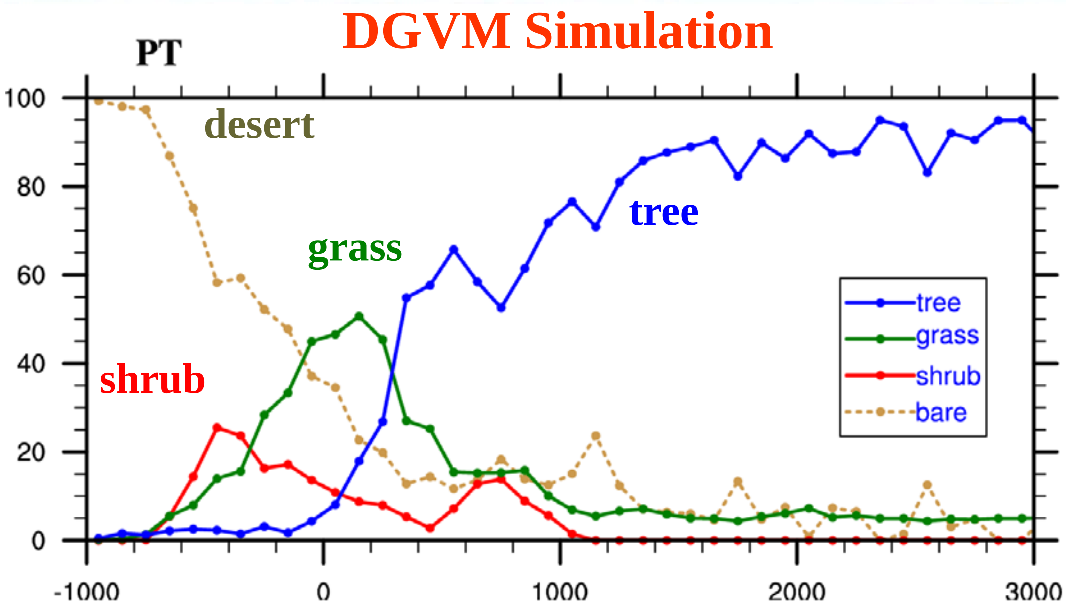
	new	3.0	3.5	obs
Shrubs	11.9	0.0	0.0	13.1
BDM_Sh	6.1	0.0	0.0	5.6
BDB_Sh	5.8	0.0	0.0	7.4
BE_Sh	0.0	0.0	0.0	0.1
Grasses	27.5	46.6	47.7	26.0
C4	9.6	14.8	14.0	10.5
C3_NA	12.2	19.8	16.9	11.7
C3_AR	5.7	12.0	16.8	3.9
Crops	0.0	0.0	0.0	13.7

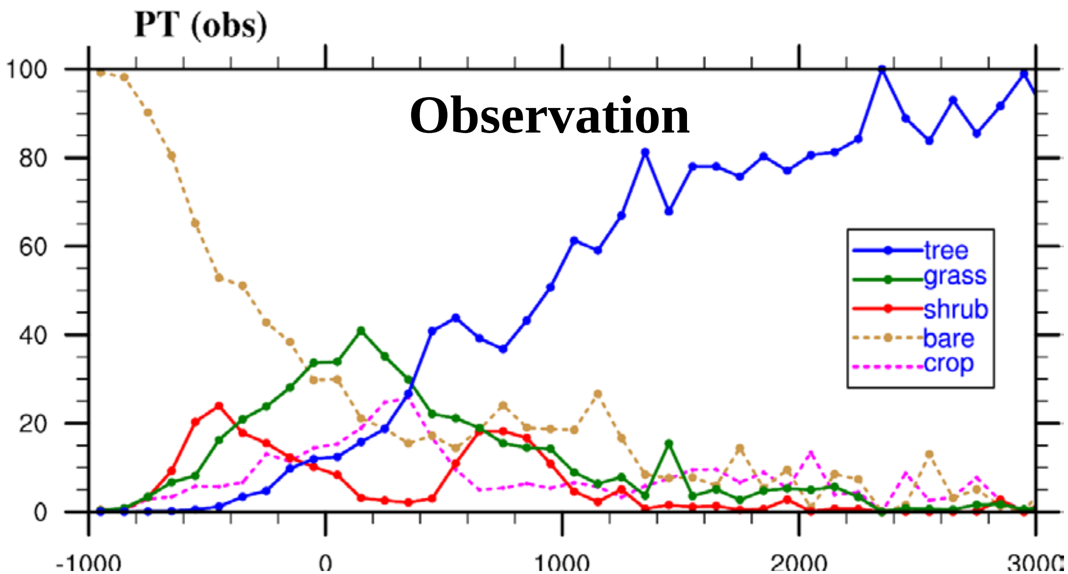
Total area (in 10^6 km^2) by major vegetation class (tree, shrub, grass, crop, and bare soil) and for various PFTs calculated from the Modified CLM-DGVM, the default CLM-DGVM 3.0, CLM-DGVM 3.5, and observation (CLM4 surface data).



The zonal mean of vegetation coverage calculated from (a) the modified model and (b) the CLM4 surface dataset.

The modified model correctly reproduces the location of zonal peaks of vegetation distributions.

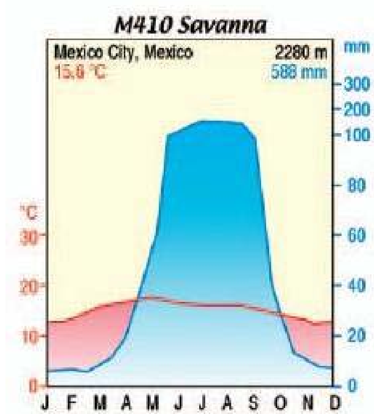




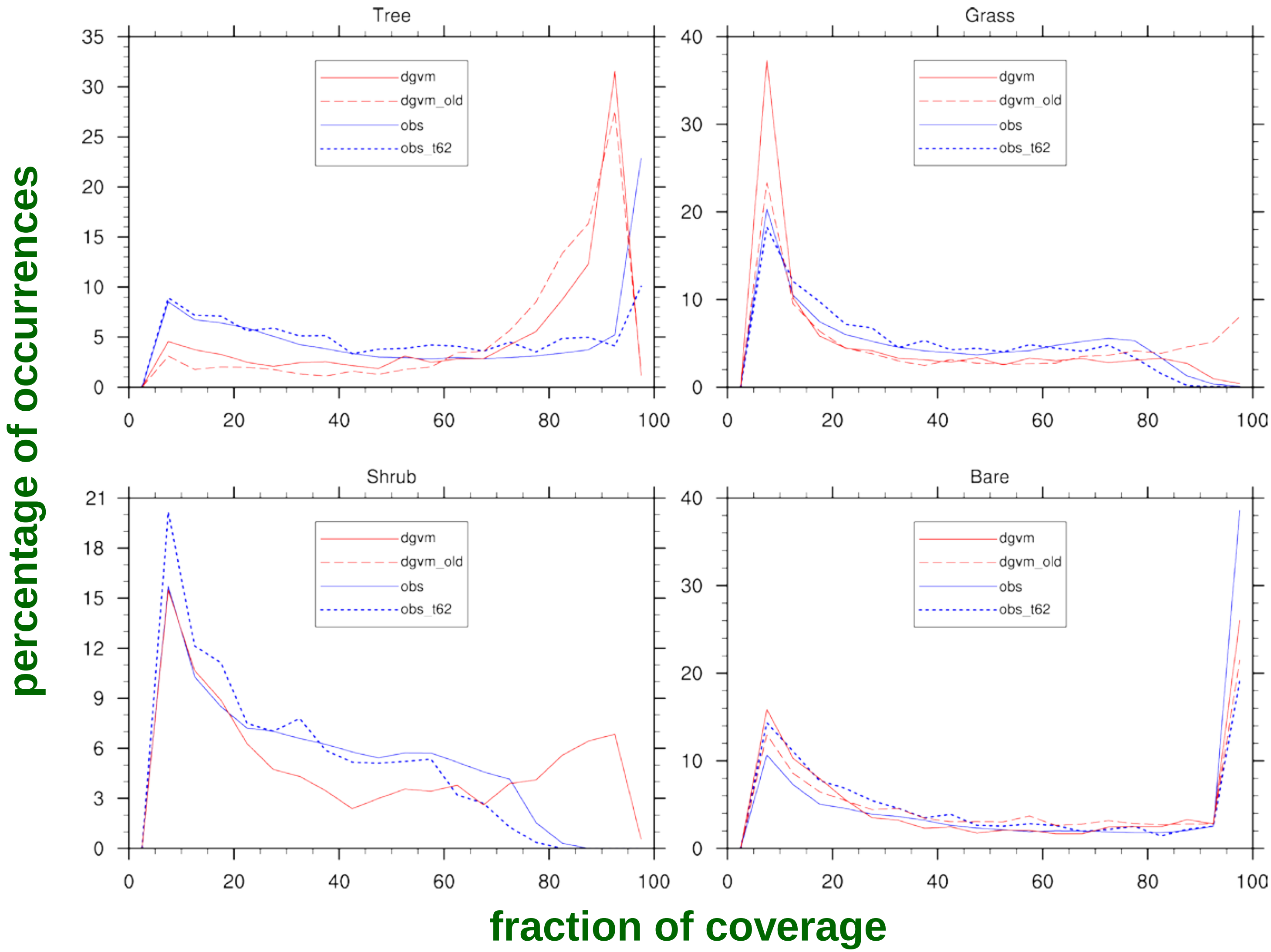
Following the Walter climate diagram, a climate index PT is defined as:

PT=MAP－*k* MAT, where factor *k*=36 mm ºC^{-1} converts 10ºC of monthly average temperature into 30 mm of monthly precipitation.

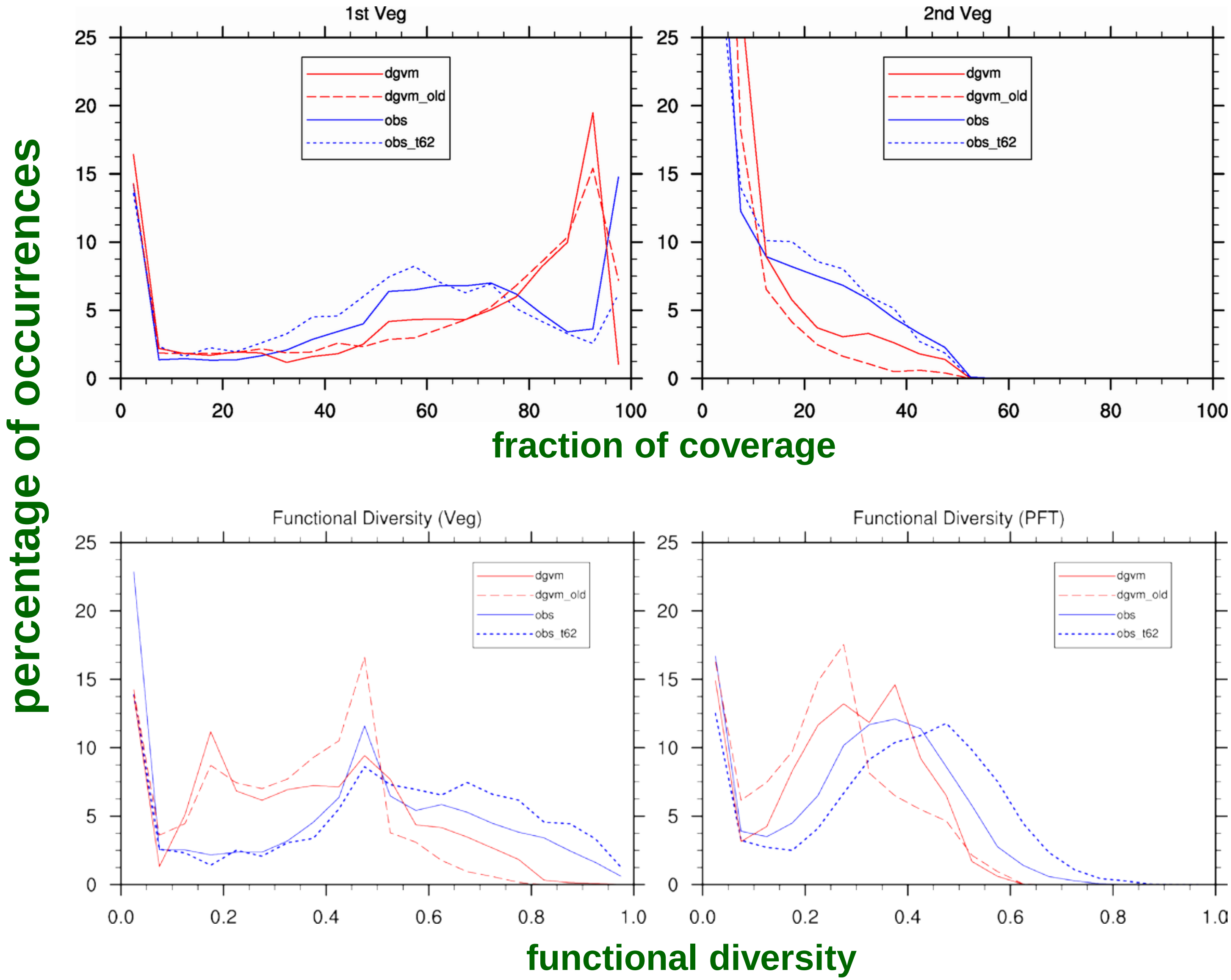
The favored conditions for different ecosystem are very well separated as a function of PT, in excellent agreement with the results from observation.

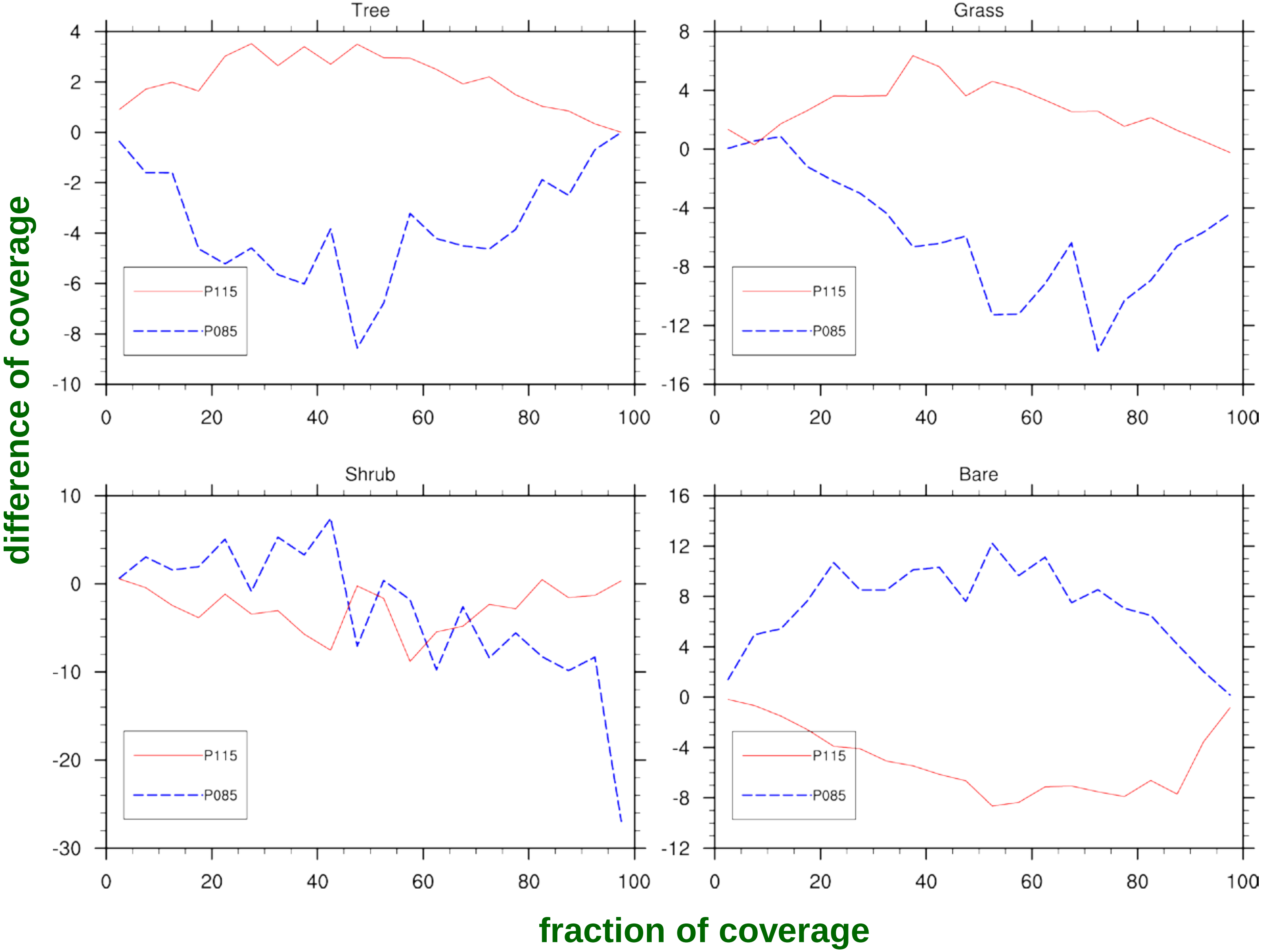


Walter Climate Diagram

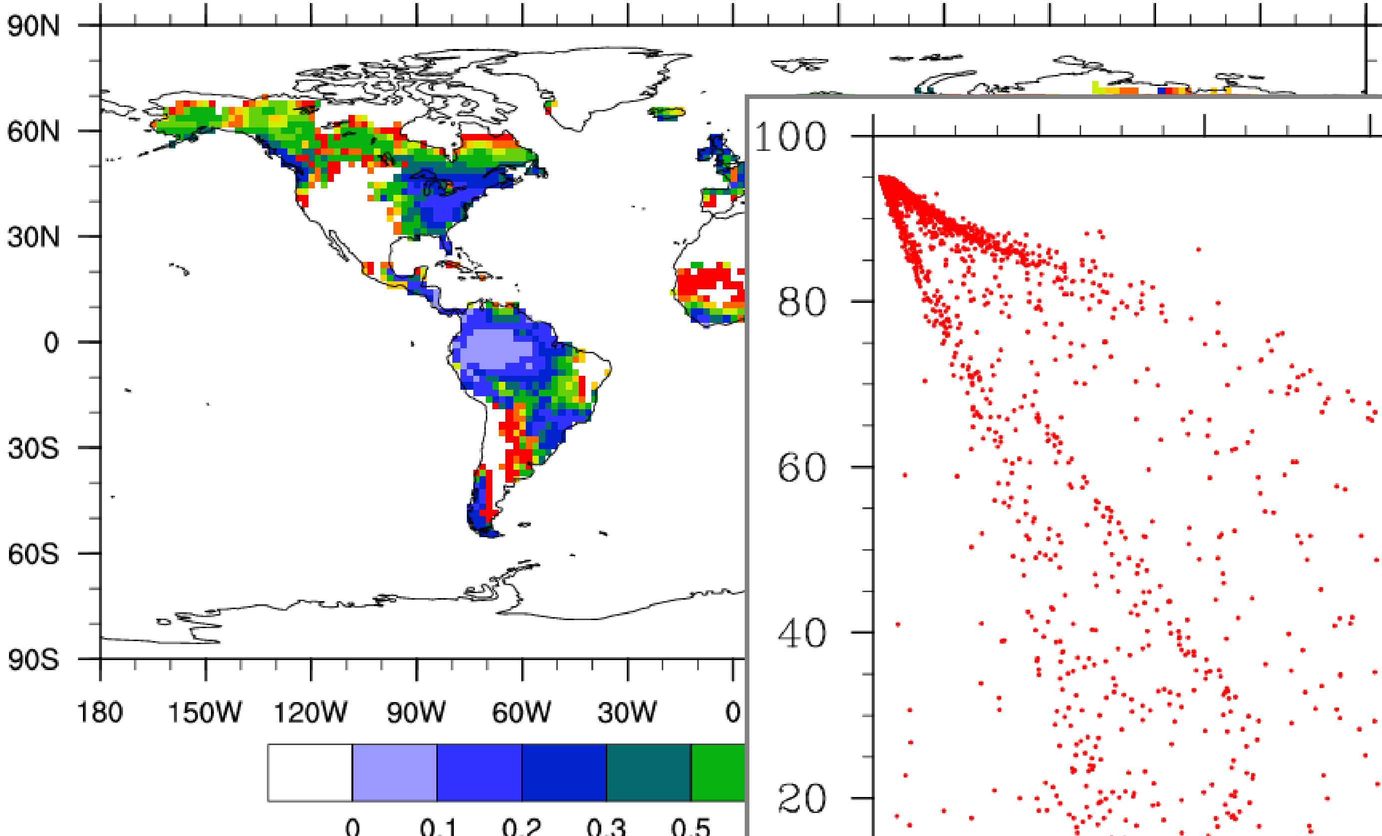


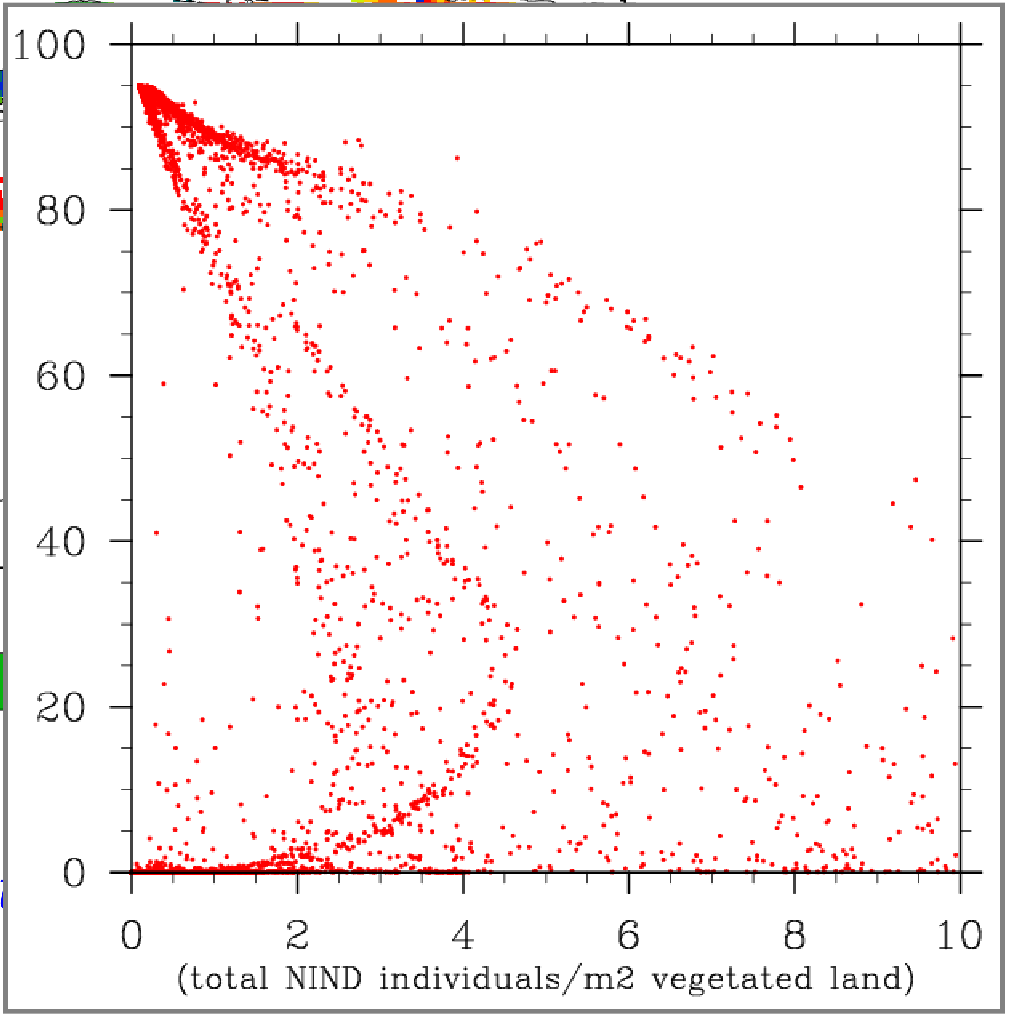
Both simulations overestimate the density distributions over regions with tree coverage larger than 70% (i.e., the core area), but underestimate the density distributions over regions with tree coverage less than 40%.


1st Veg
2nd Veg
dgvm
dgvm_old
obs
obs_t62
fraction of coverage
percentage of occurrences
Functional Diversity (Veg)
Functional Diversity (PFT)
dgvm
dgvm_old
obs
obs_t62
functional diversity



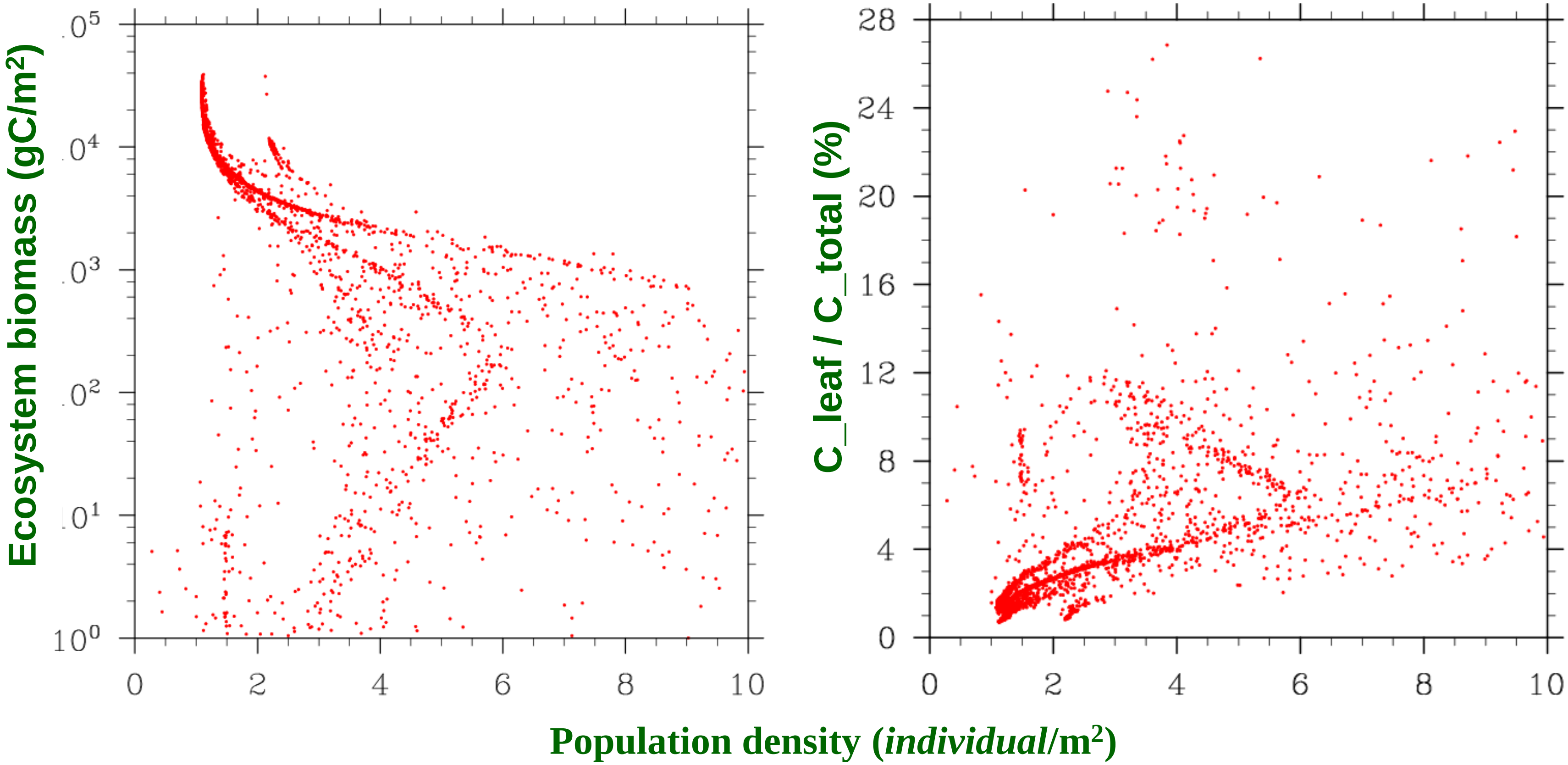
Trees are sensitive to the precipitation change mainly in the region with tree covers between 20~60%.





Distribution of Tree

(individ



Ecosystem with higher tree population density has lower total biomass but higher c_leaf : c_total ratio.

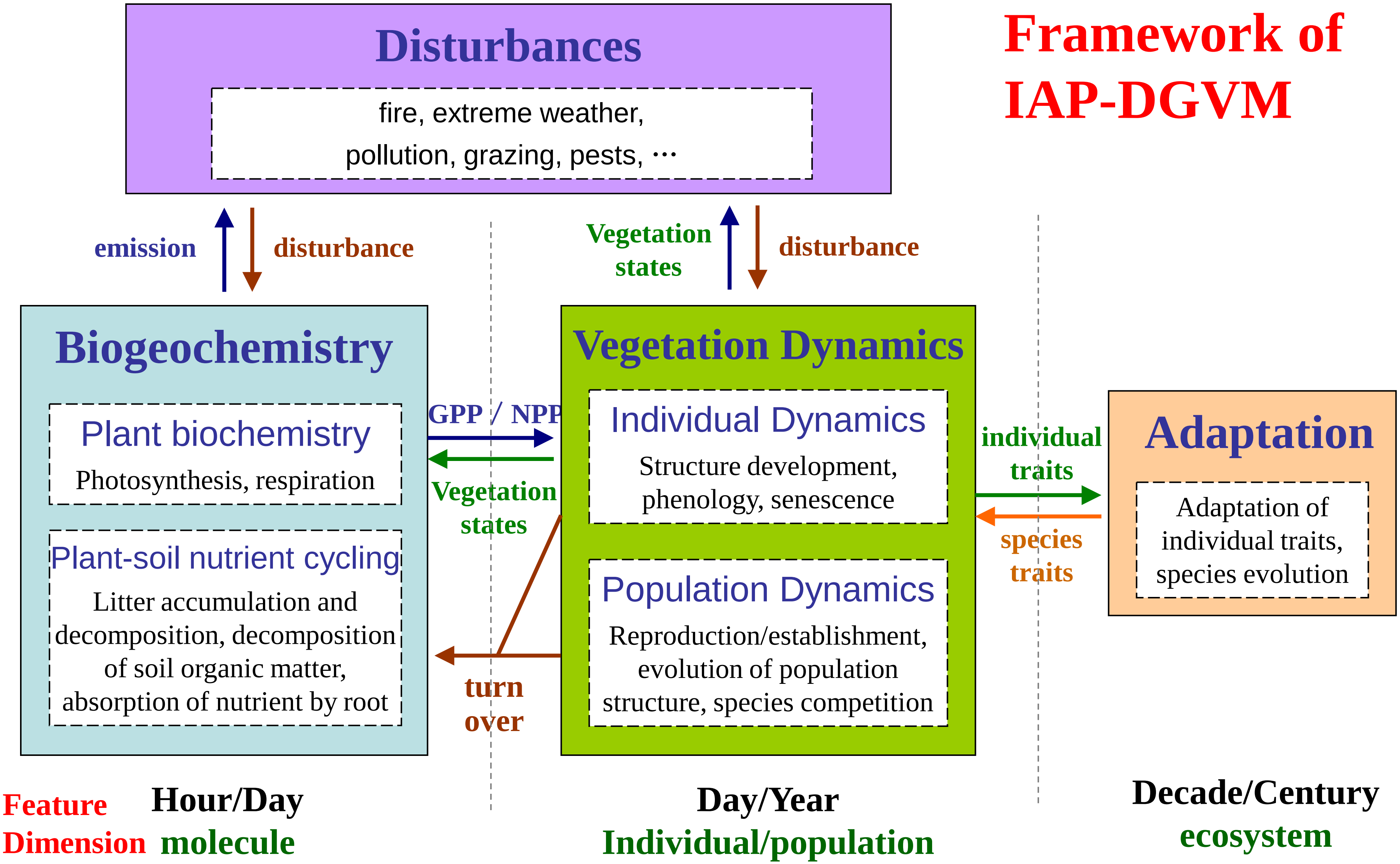
Such system needs much shorter time to build up.

2007, Chinese Academy of Sciences supported key research project of “Development of Earth System Model”

2010, Ministry of Science and Technology of China supported 19 key research projects of global change studies, including:

- **Development of the High Definition Climate System Model**
- **Development of Ecological and Environmental System Model**
  - **Terrestrial Ecosystem Model**
  - **Land Biogeochemistry Model**
  - **Marine Biogeochemistry Model**
  - **Aerosol and Atmospheric Chemistry Model**

Framework of IAP-DGVM



Establishment is a large source of uncertainty in DGVM

- **It determines the balance of population density**
- **It also influences the calculation of averaged crown area**
- **A major uncertainty remains in the partitioning of establishment among different PFTs**
    - **current CLM-DGVM assumes that all woody PFTs share the same rate of establishment (even for PFTs which fail to survive);**
    - **actually establishment rate should be related to current vegetation states (e.g., fractional coverage, NPP) and PFT related traits.**

Default establishment scheme:

$$\Delta P_i = \Delta P_{max} \frac{1 - e^{-5(1-FC_{woody})}}{n_{est,woody}} (1 - FC_{woody})$$

Or rewritten as:

$$\Delta P_i = [\Delta P_{max}(1 - e^{-5(1-FC_{woody})})(1 - FC_{woody})] \frac{g_i}{\sum_{k=1}^{n_{est,woody}} g_k}$$

$$g_i \equiv 1$$

New scheme 1:

$$g_i = g_{i0}[\varepsilon_0 + (1 - \varepsilon_0) FC_i]$$

New scheme 2:

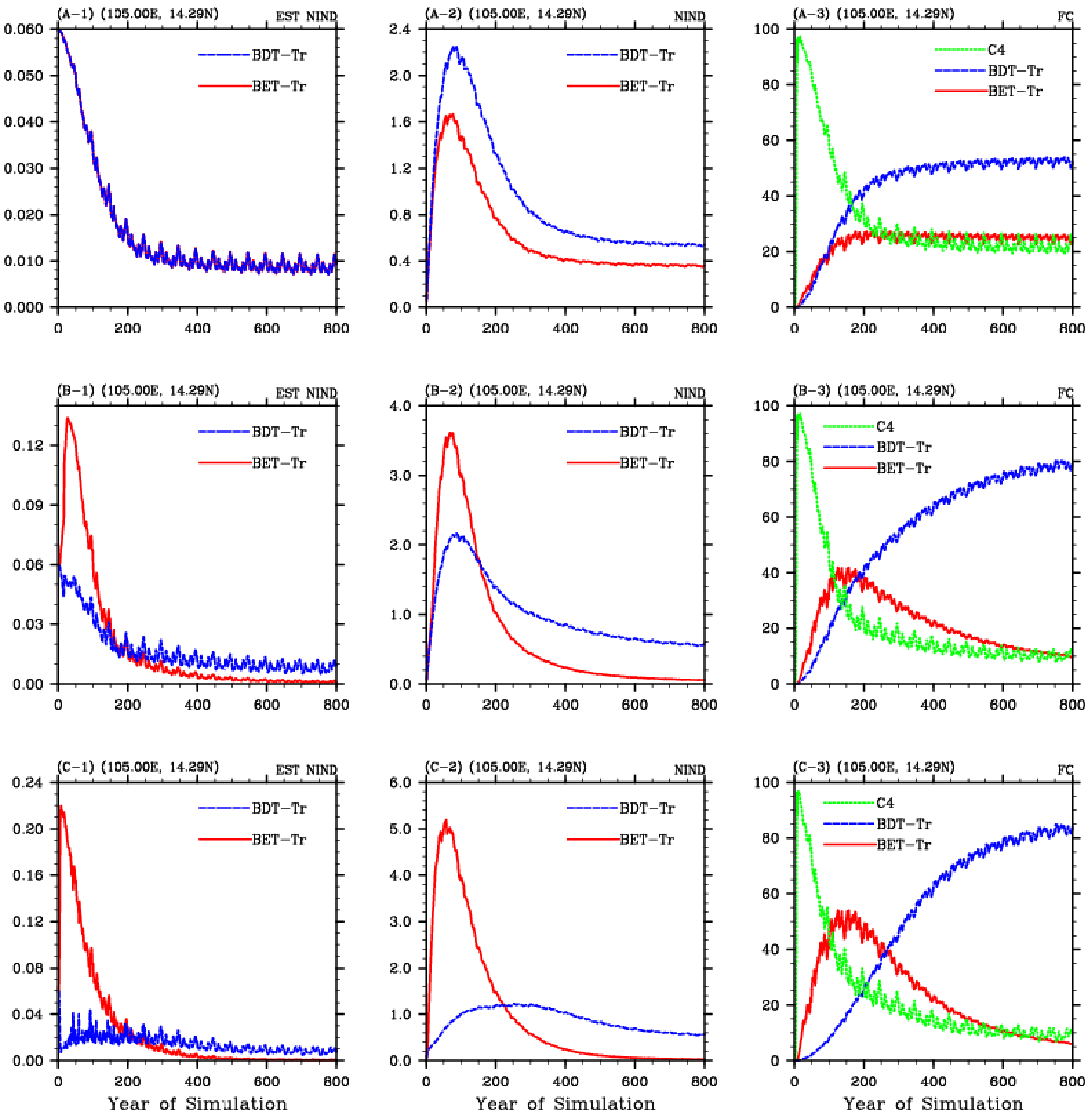
$$g_i = g_{i0}[\varepsilon_0 + (1 - \varepsilon_0) \cdot \beta \cdot P_i \frac{C_{reprod,i}}{C_{seed}}]$$

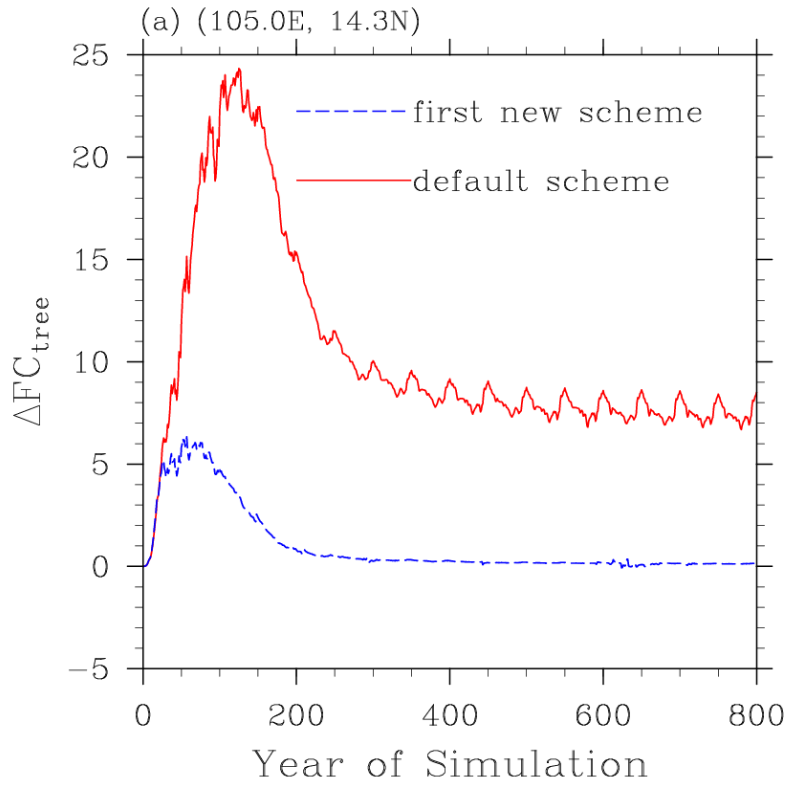
ε_0: background establishment

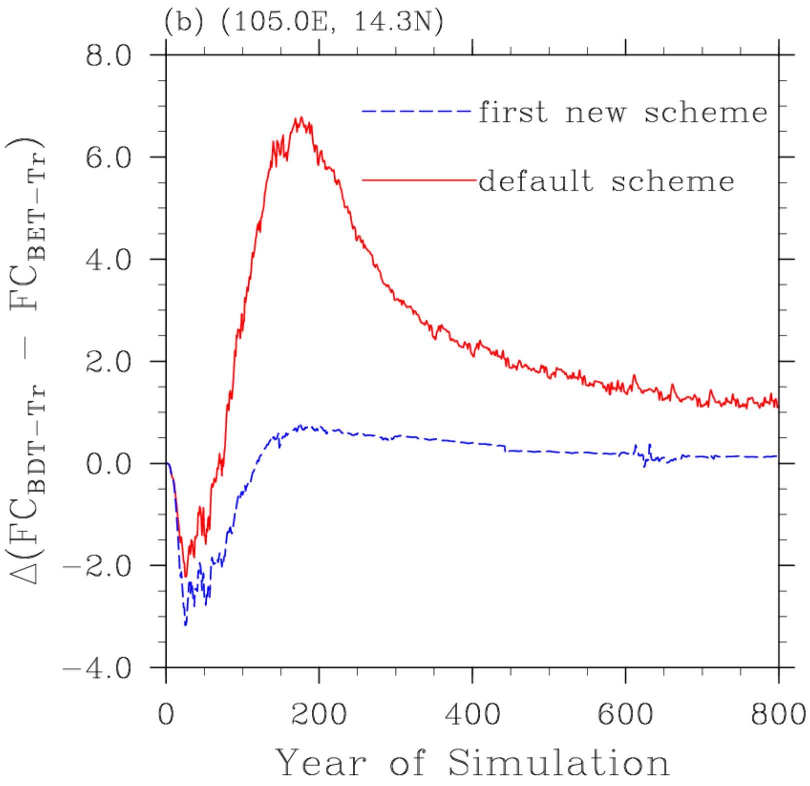
default

New 1

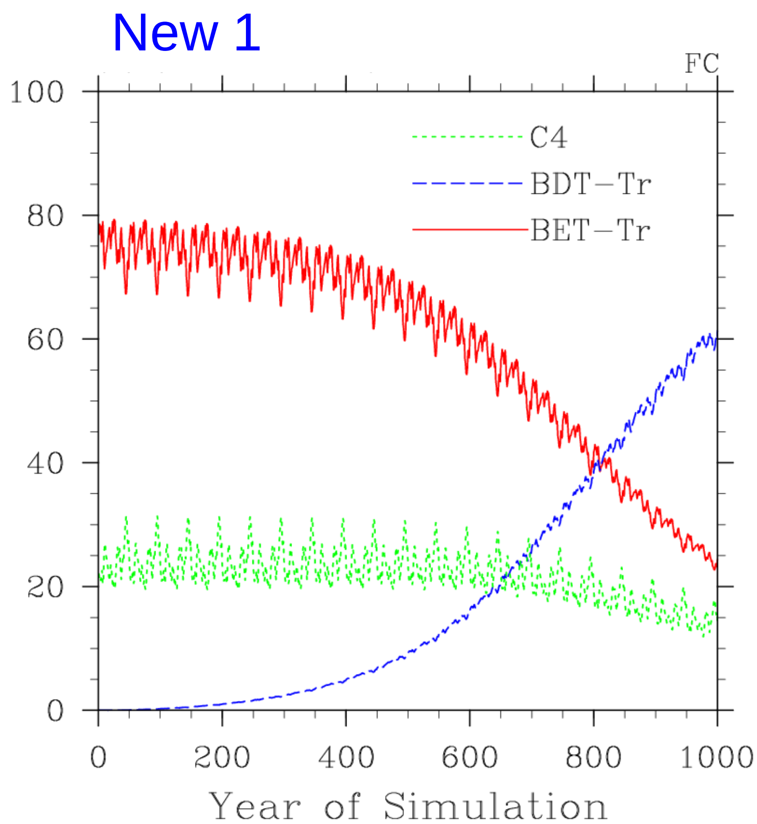
New 2

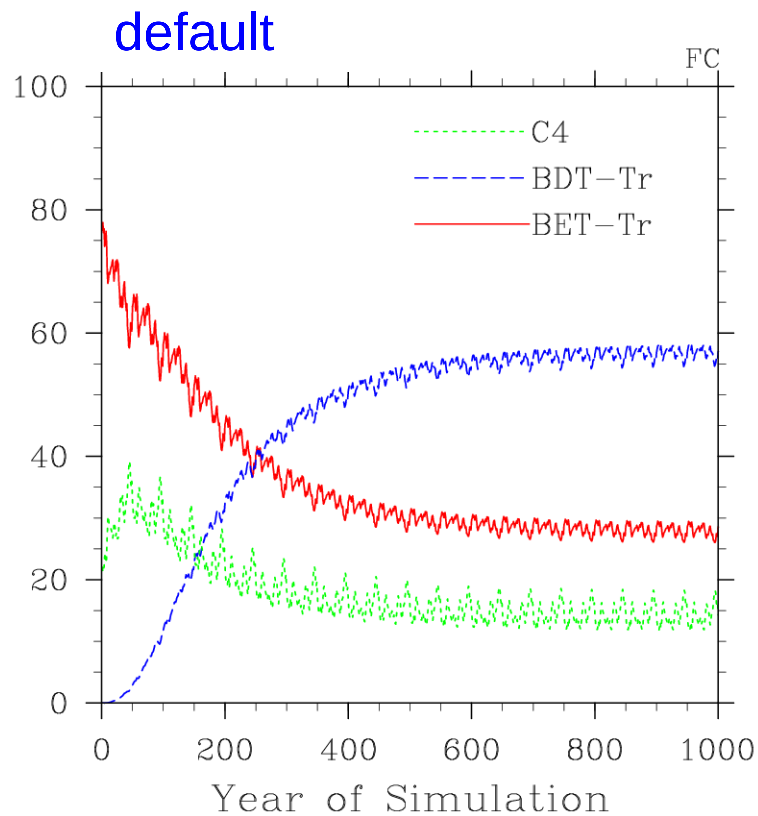






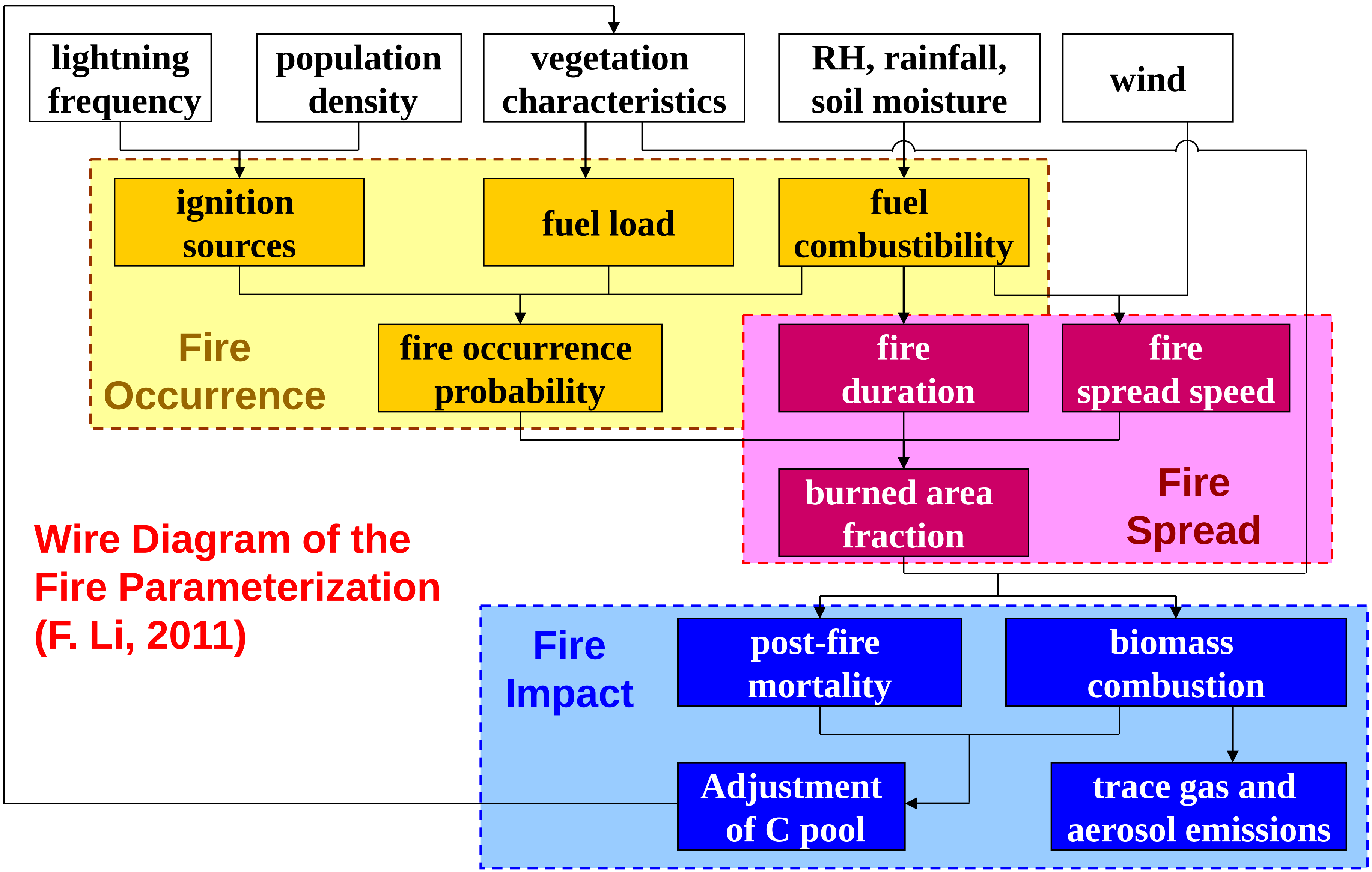
Removal of the woody PFTs with low FC may causes big change for the dominant PFTs in the default scheme.

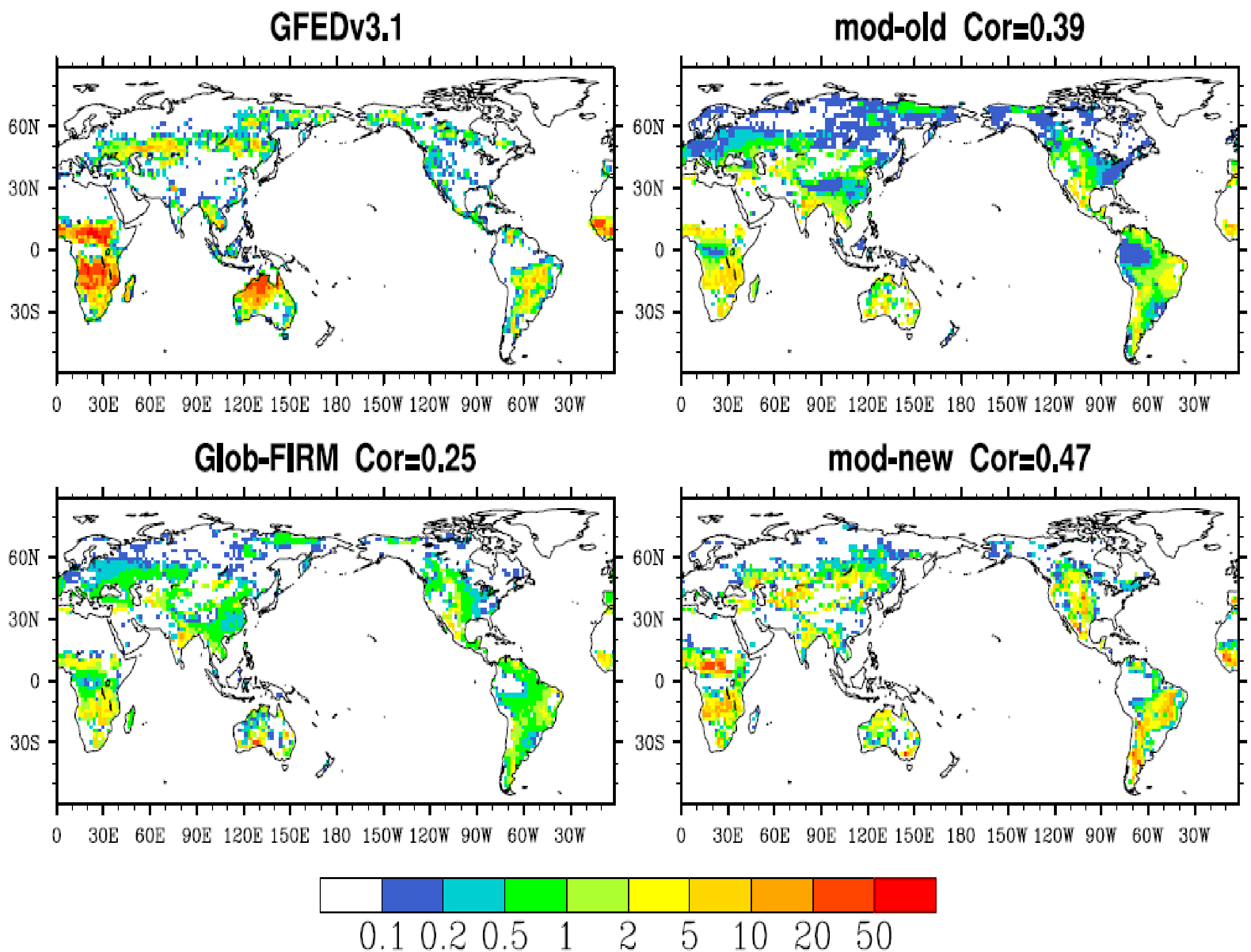




The default and new schemes have very different time scales in response to perturbation.

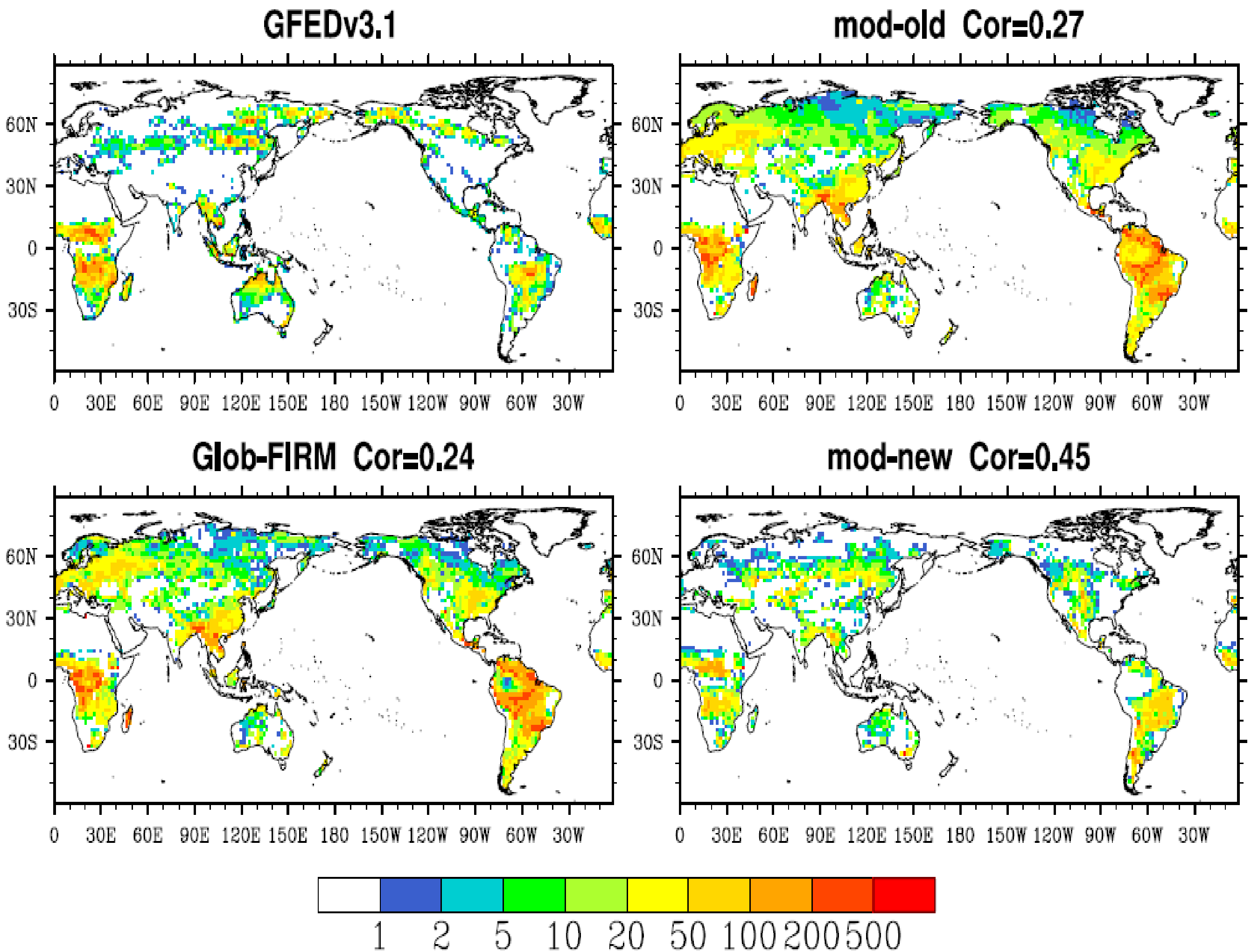
Wire Diagram of the Fire Parameterization (F. Li, 2011)





Burned area fraction

- **Mod-new successfully reproduces the global spatial distribution of annual burned area fraction**
- **Mod-new is more skillful than mod-old** (Levis et al. 2004) **and Glob-FIRM** (Thonicke et al. 2001), **especially in the tropics and in the middle-high latitude**



Fire carbon emission (gC/m^2/year)

- **Mod-new successfully reproduces the global spatial distribution of annual fire carbon emissions**
- **Mod-old and Glob-FIRM overestimate fire carbon emissions evidently**