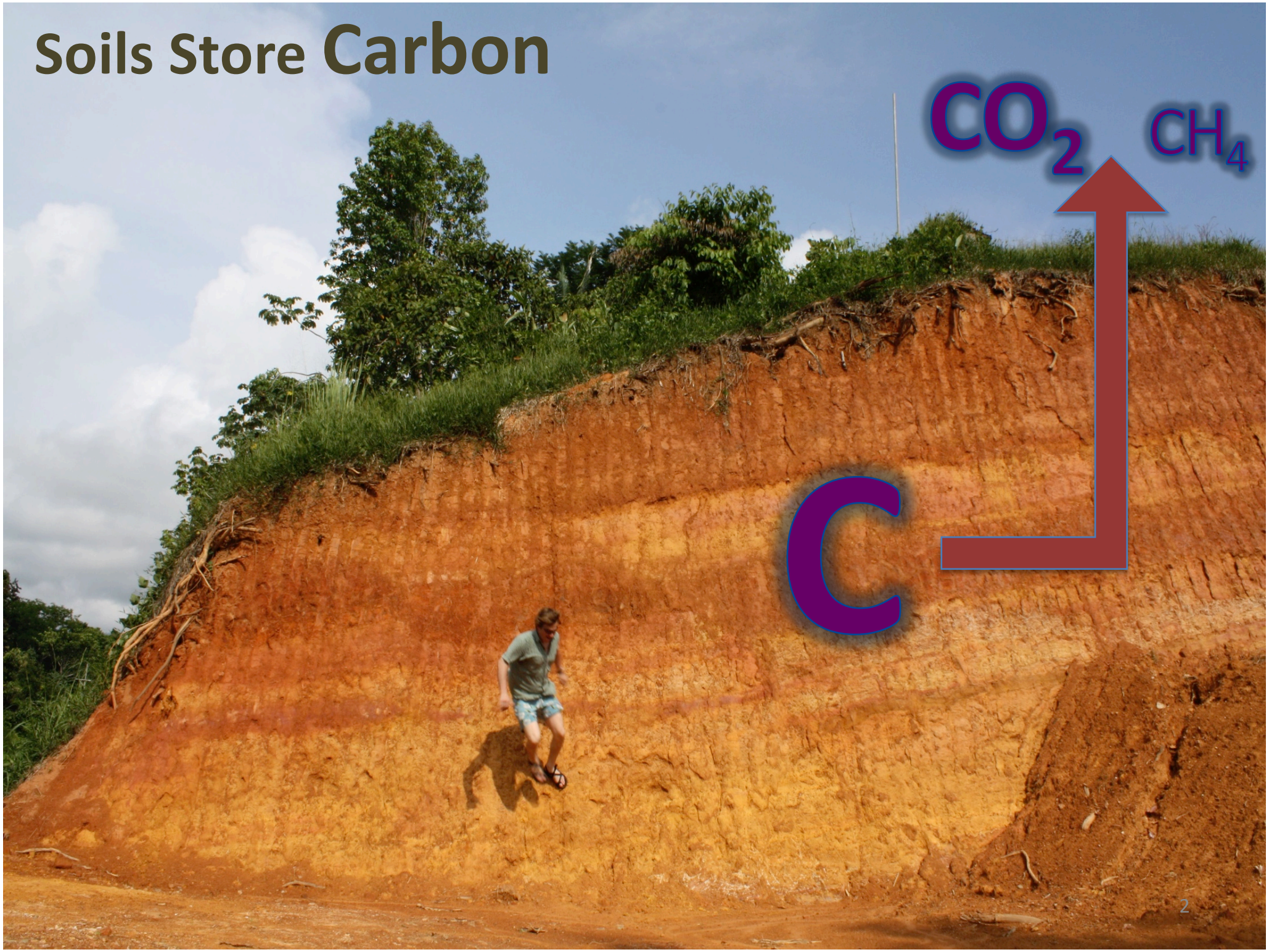
Soil biogeochemistry in a changing world

Will Wieder

2019 CTSM Tutorial

Soils Store Carbon



Soils Store Carbon and Nitrogen

soil biogeochemical models

CO_2

CO_2

Input – Climate hypothesis

soil biogeochemical models

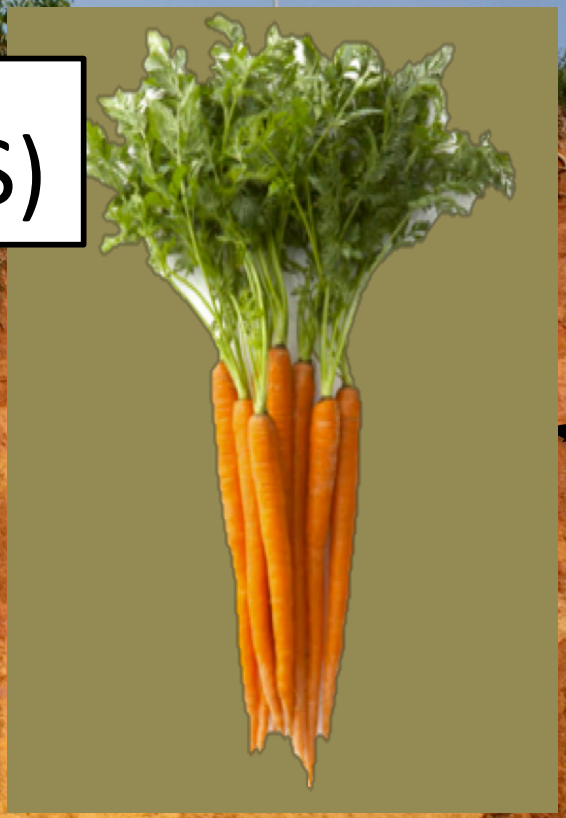
I=NPP

$\hat{C} = I / \tau$

CO_2

$\varepsilon = f(S)$

$\tau = f(T,M,S,\ldots)$



CO_2

Input – Climate hypothesis

Code base: src/soilbiogeochem
esp. SoilBiogeochemDecompCascadeBGCMod.F90
Technical note 2.21: Decomposition

Rate constant (τ)
- Water function
- Temperature function

Transfer coefficients
- (among pools & **respiration**)

Stoichiometry

C:N

CO_2

$\varepsilon = f(S)$

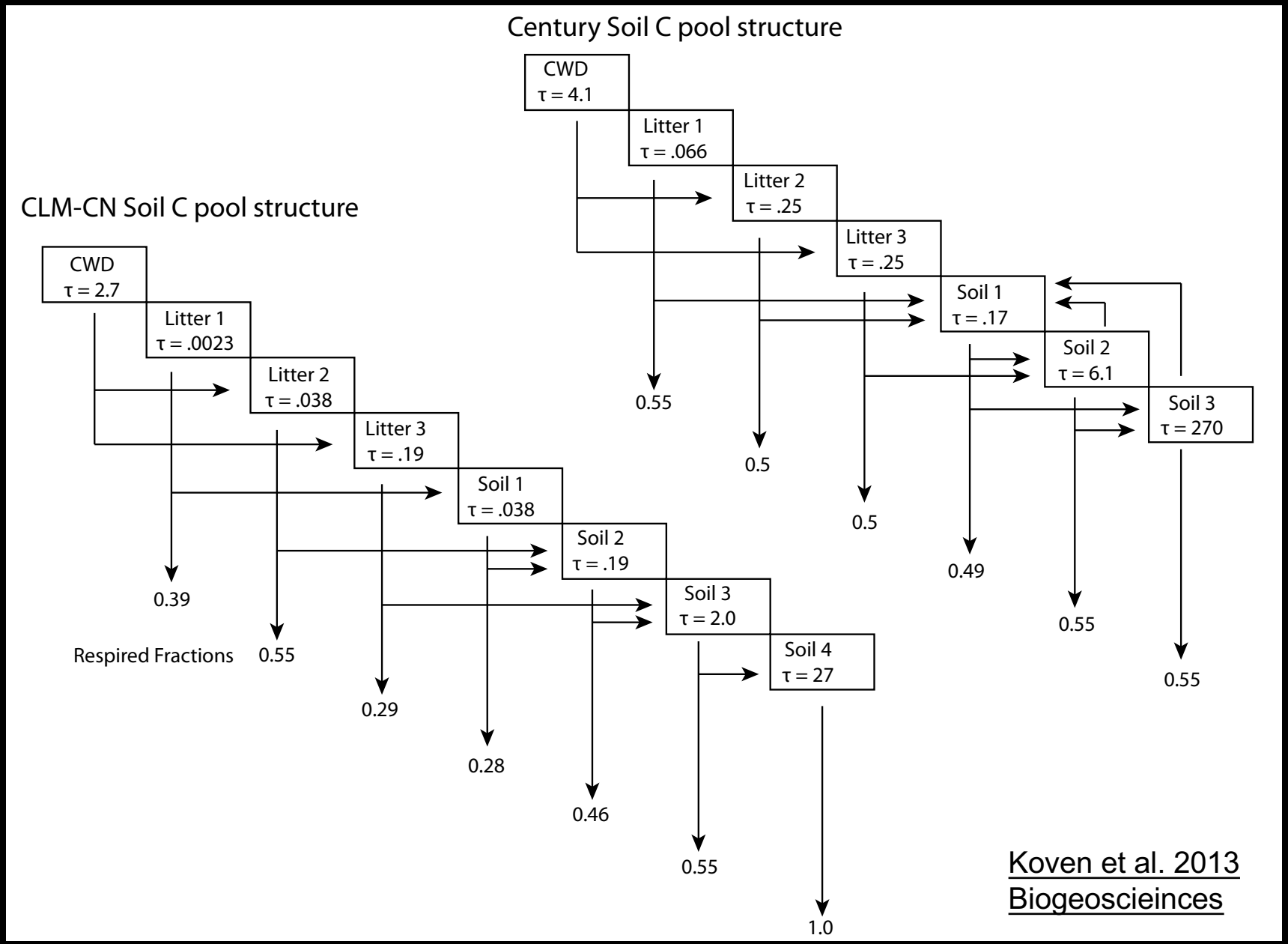
$\tau = f(T,M,S,\ldots)$

C:N

Code base: src/soilbiogeochem
esp. SoilBiogeochemDecompCascadeBGCMod.F90
Technical note 2.21: Decomposition

	Parameter file
Rate constant (τ)	tau_l1, tau_s1, tau_s2, etc.
Water function	
Temperature function	
Transfer coefficients	
(among pools & **respiration**)	rf_l1s1_bgc, rf_s1s2_bgc
Stoichiometry	cn_l1_bgc, cn_s1_bgc, etc

Code base: src/soilbiogeochem
esp. SoilBiogeochemDecompCascadeBGCMod.F90
Technical note 2.21: Decomposition



Code base: src/soilbiogeochem
esp. SoilBiogeochemDecompCascadeBGCMod.F90
Technical note 2.21: Decomposition

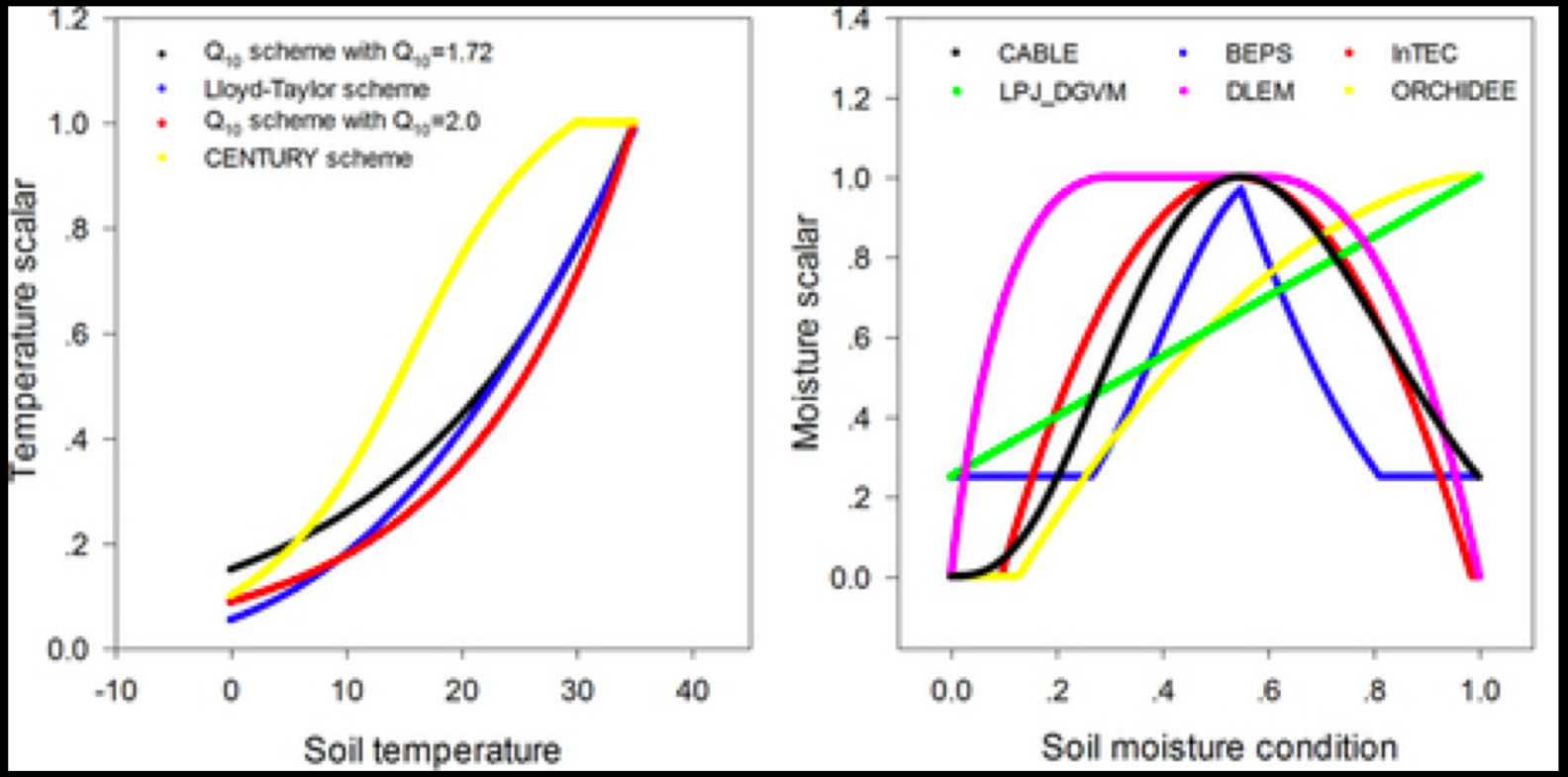
Parameter file

Rate constant (τ)

- Water function
- Temperature function

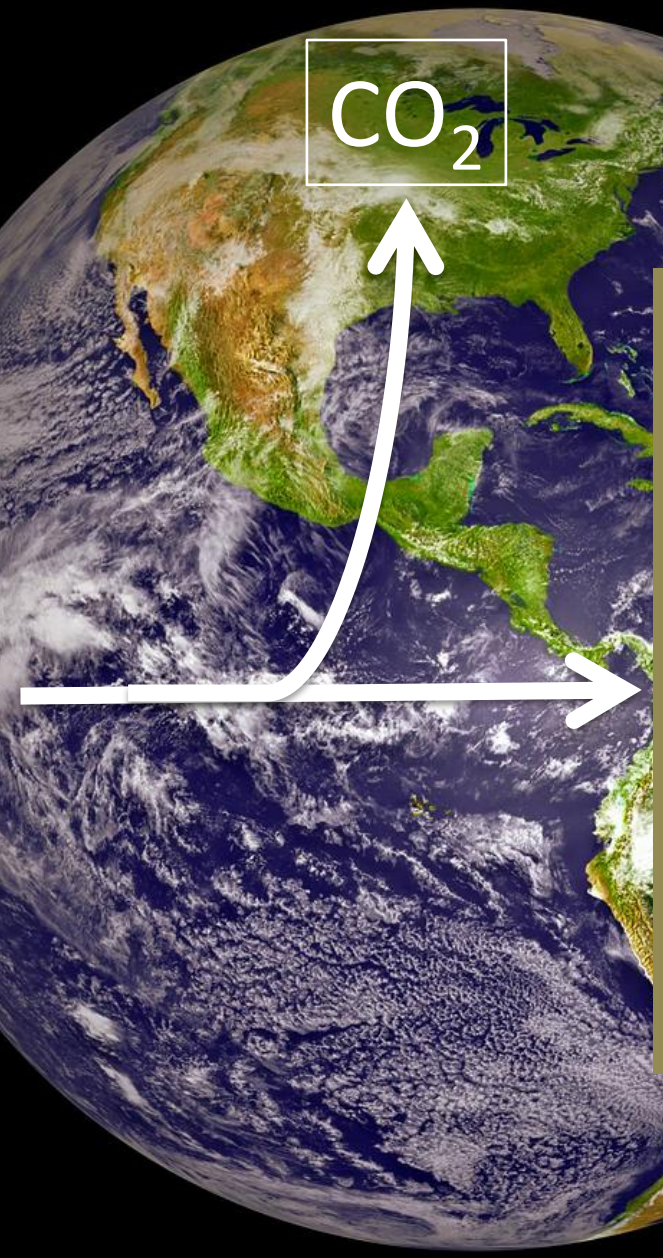
Transfer coefficients

minpsi_hr = -2 CLM5 & -10 CLM4.5
q10_hr = 1.5



Yizhao et al.
2015 Sci Reports

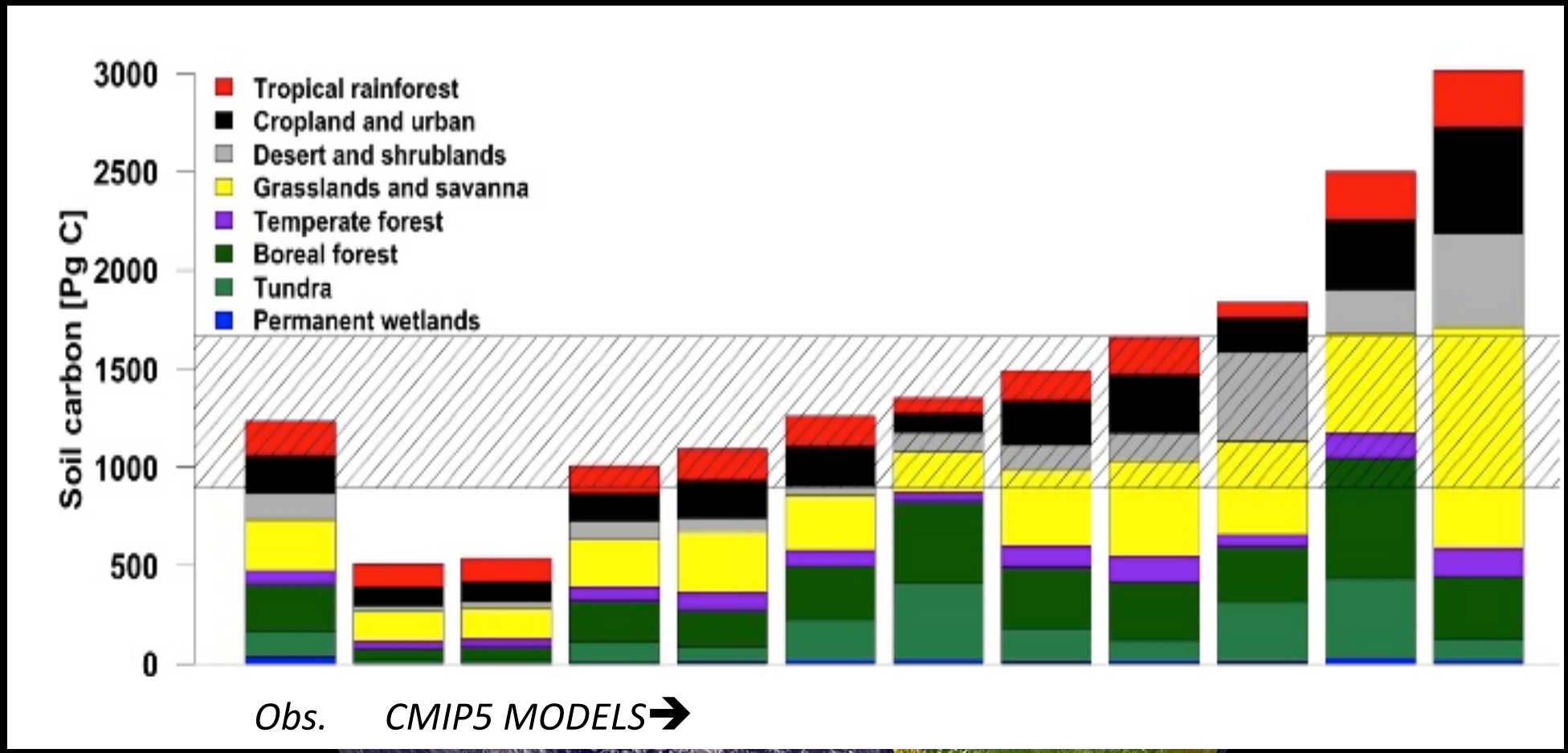
Global soil biogeochemical models



CO_2

CO_2

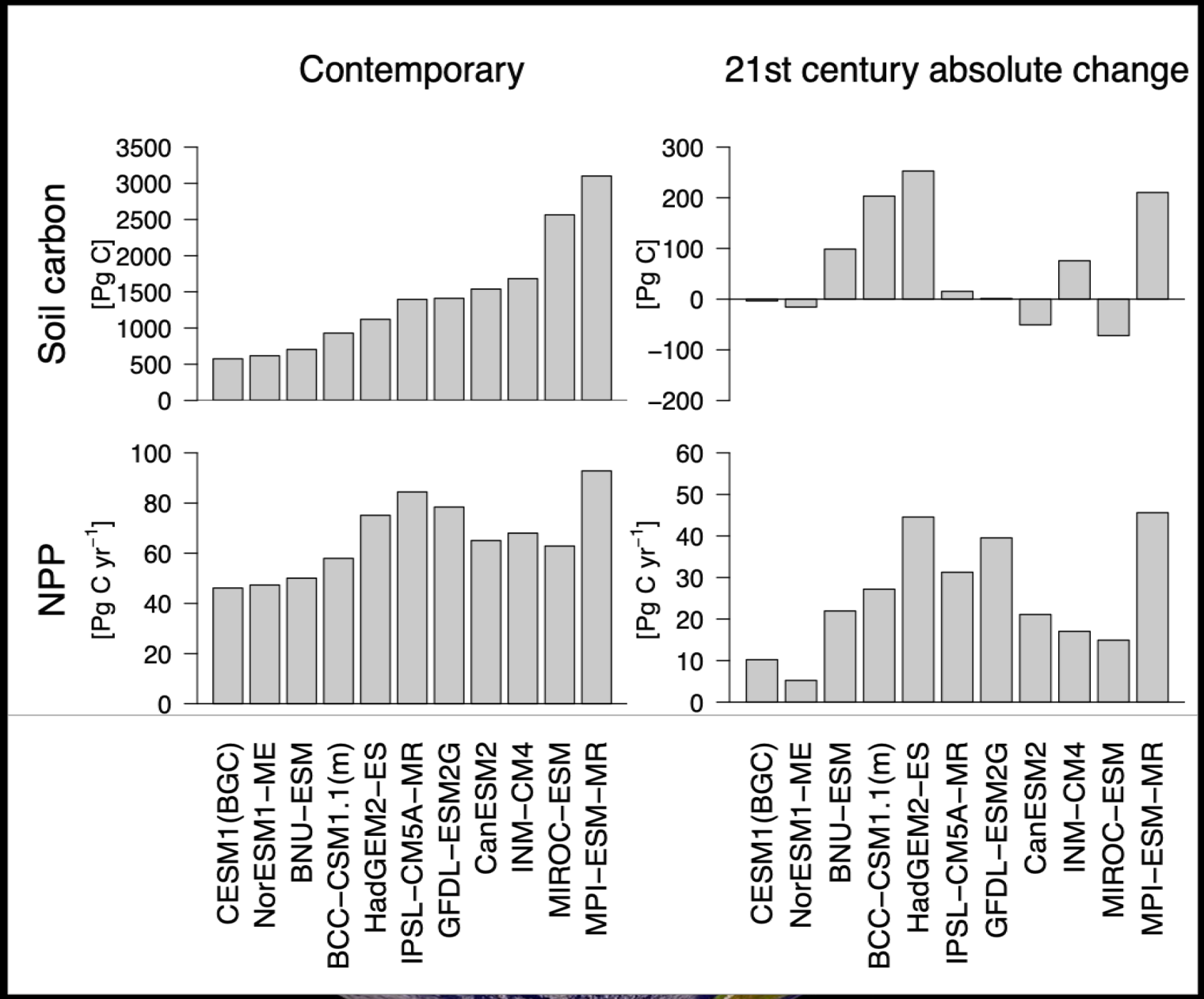
CMIP5 Models = 6x variation



$$\hat{C} = I / k$$

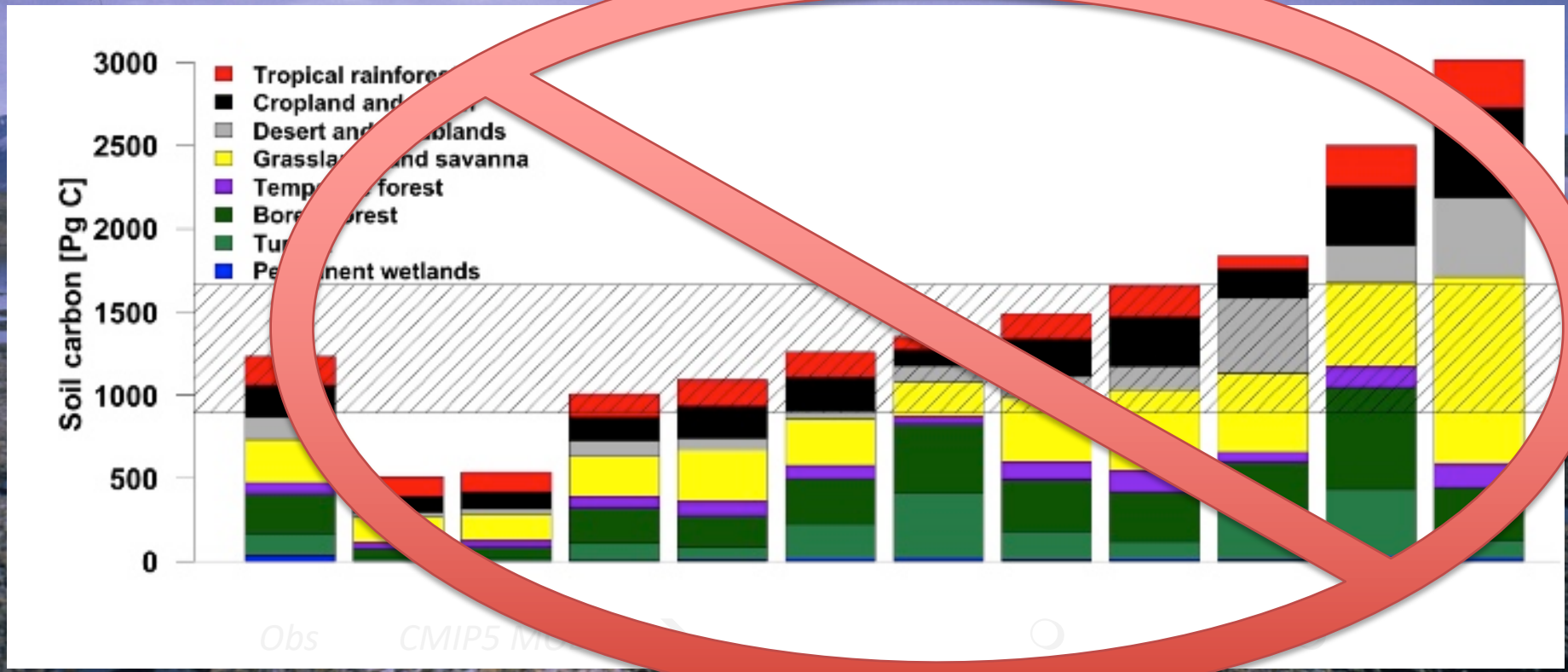
Todd-Brown et al. Biogeosciences 2013, Friedlingstein et al. 2006; Jones et al. 2003

CMIP5 Models RCP8.5



Todd-Brown et al. Biogeosciences 2014

Permafrost C in models

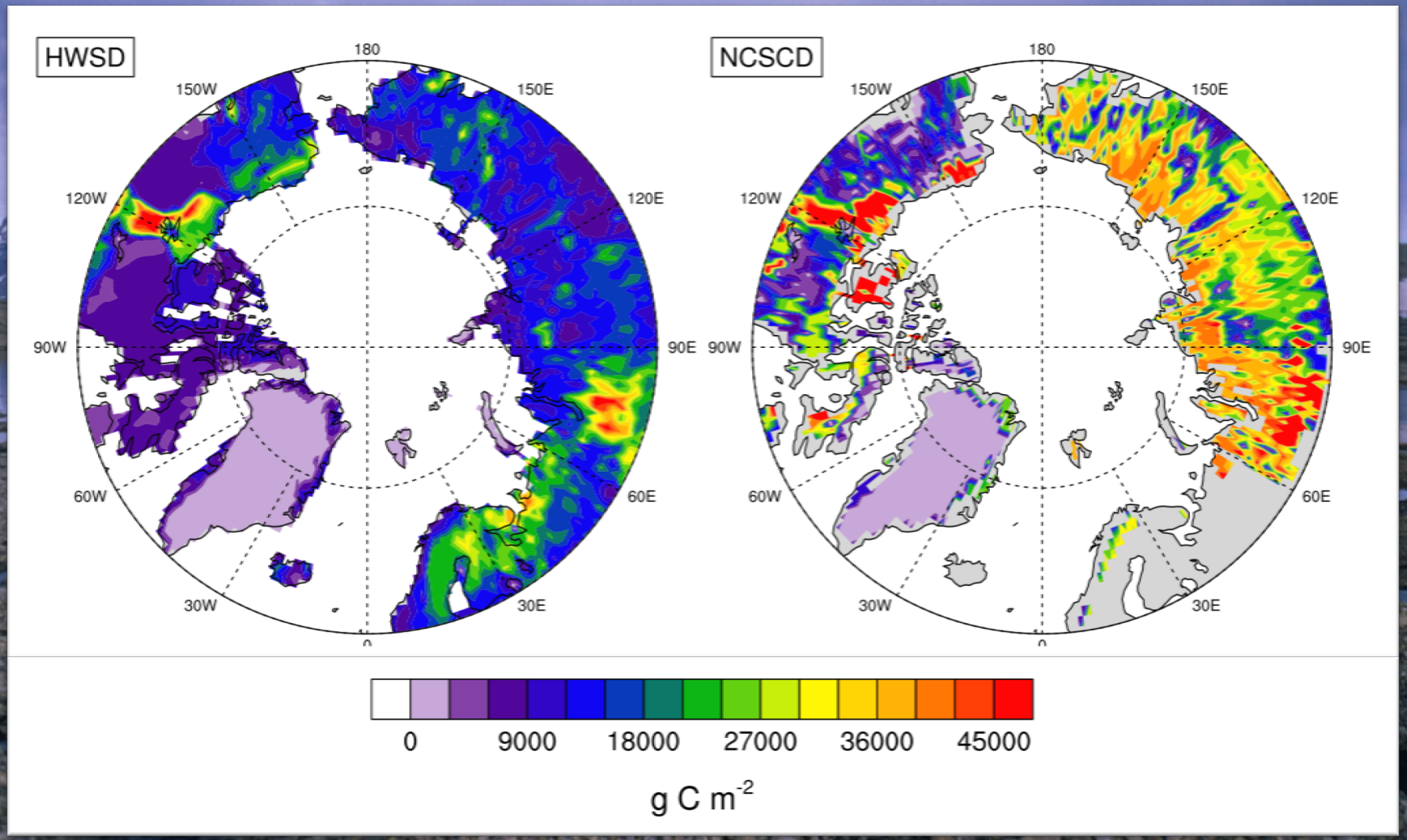


Todd-Brown et al. Biogeosciences 2013

CLM4.5bgc & 5.0

www.fedre.org

Permafrost C “observations”

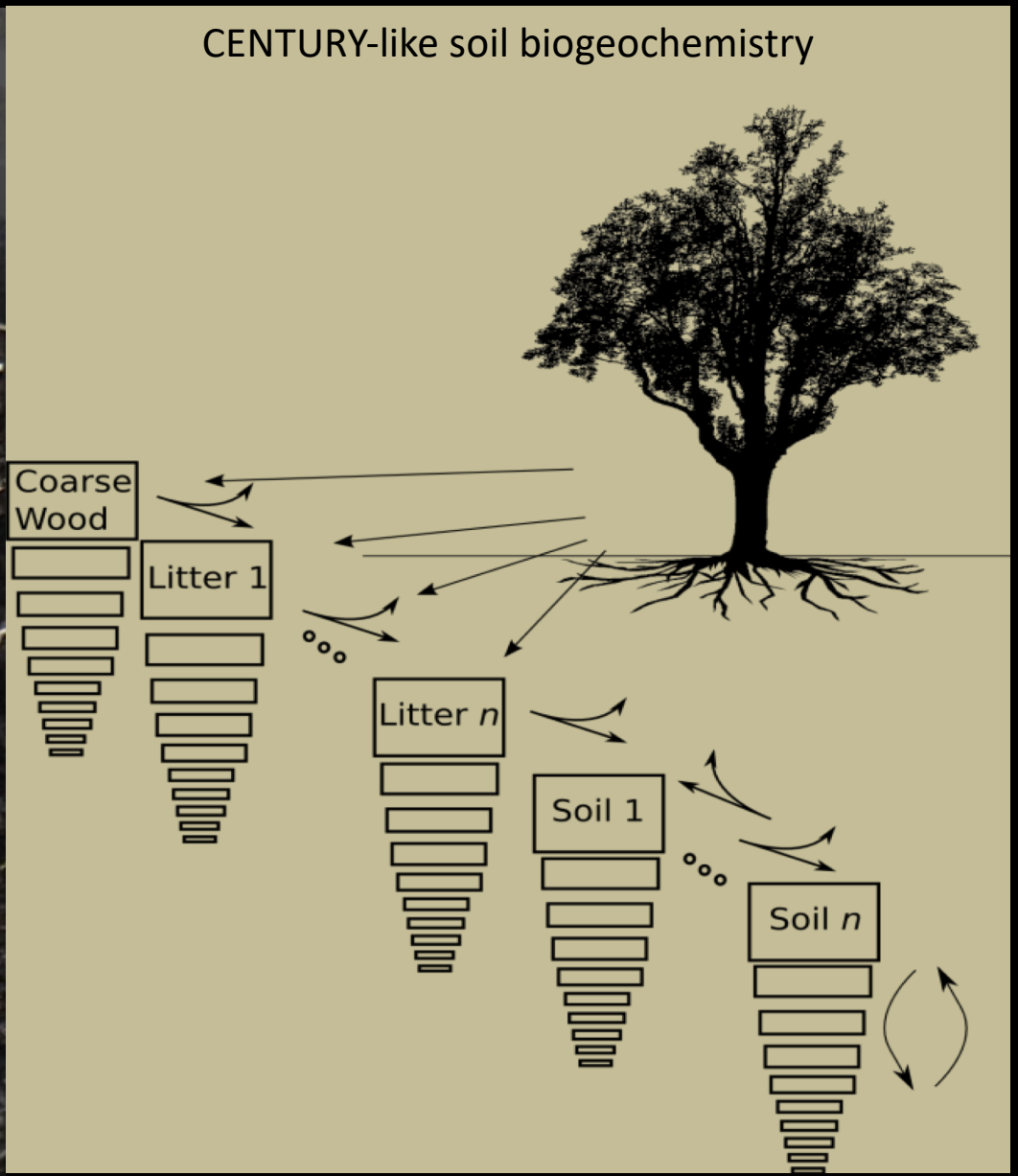


NCSCD from Hugelius et al. 2013

Permafrost soils CLM4.5bgc & 5.0

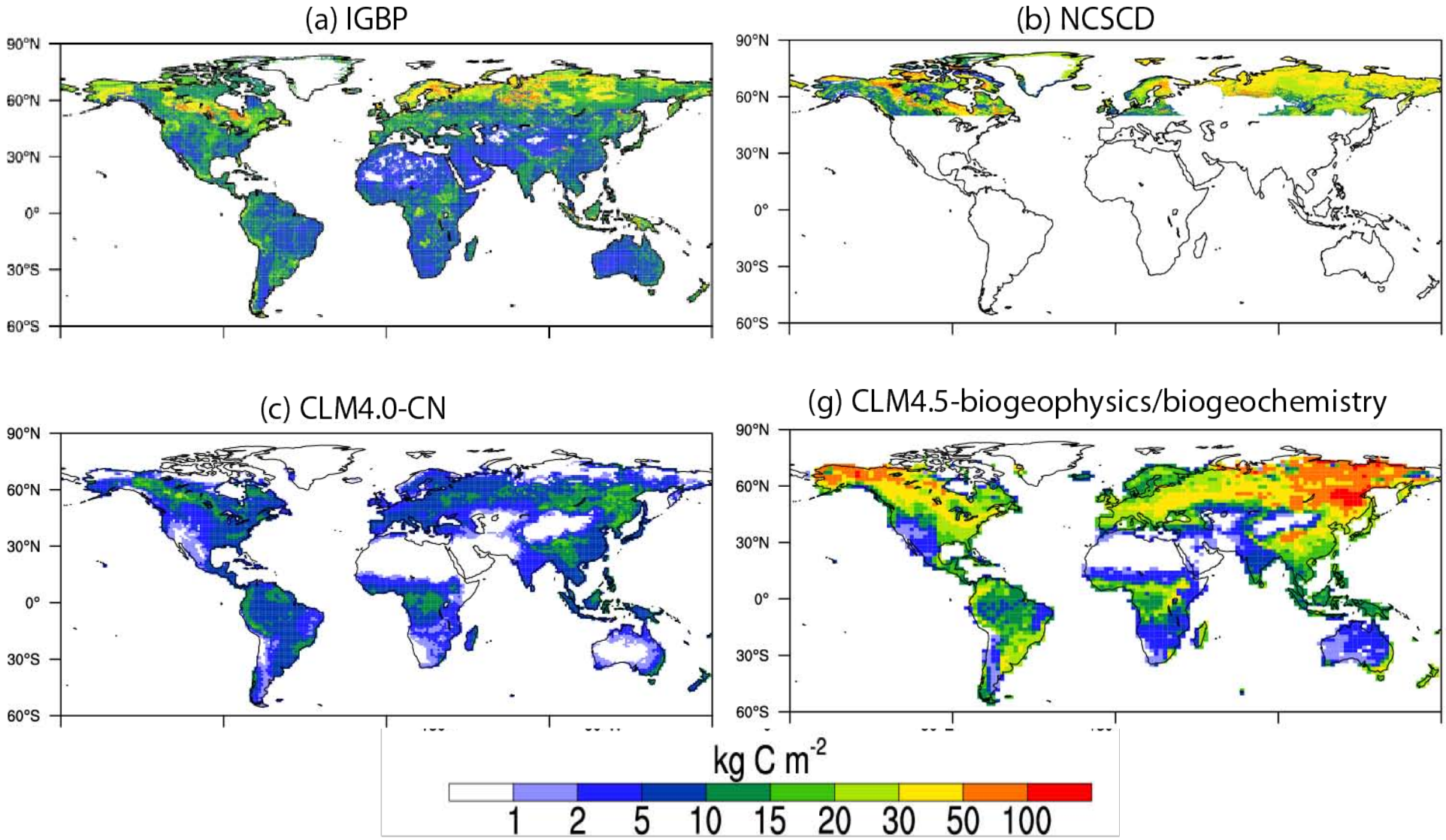
Carbon rich
Vertically complex

CENTURY-like soil biogeochemistry

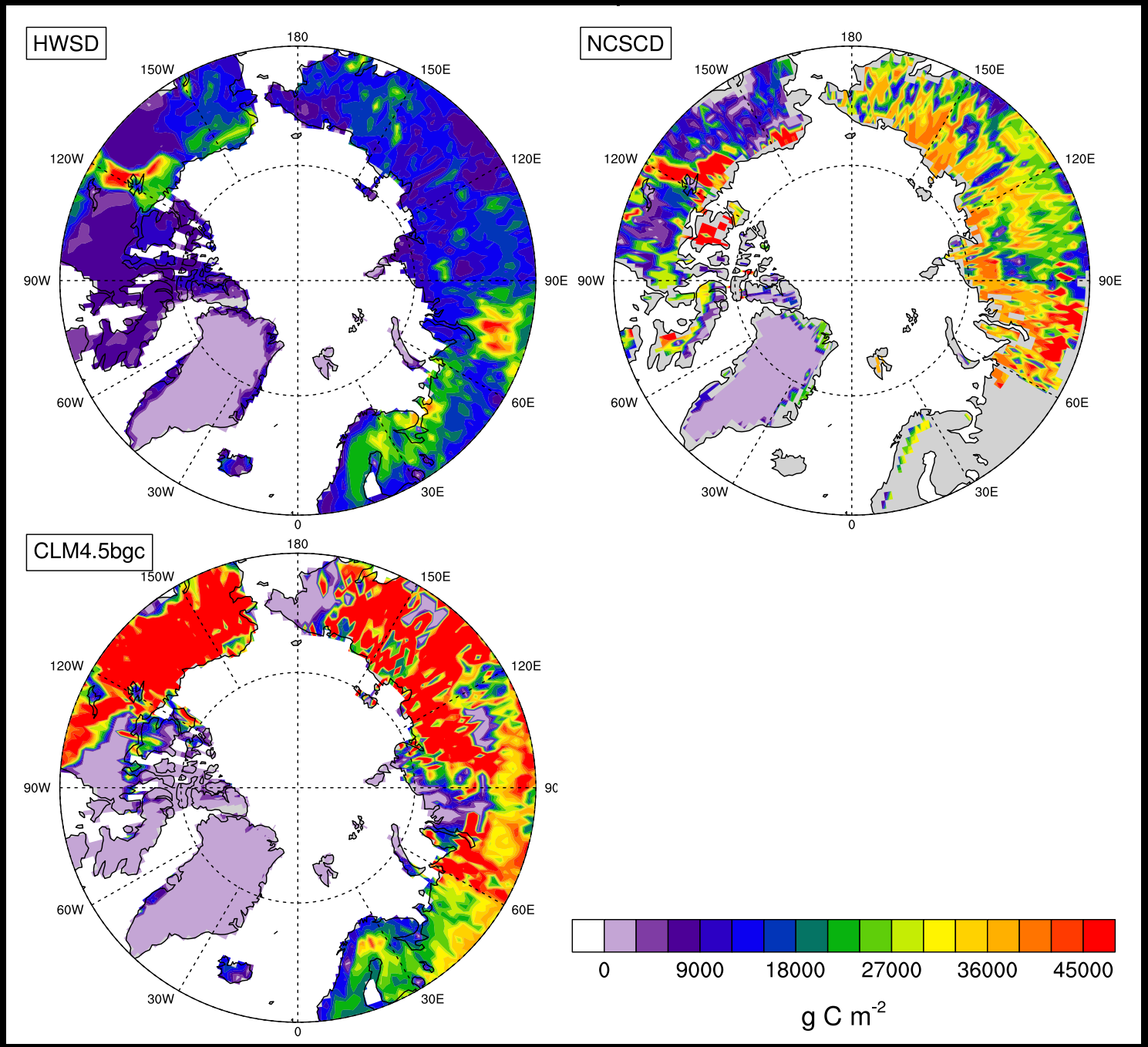


Koven et al. *Biogeosciences* 2013

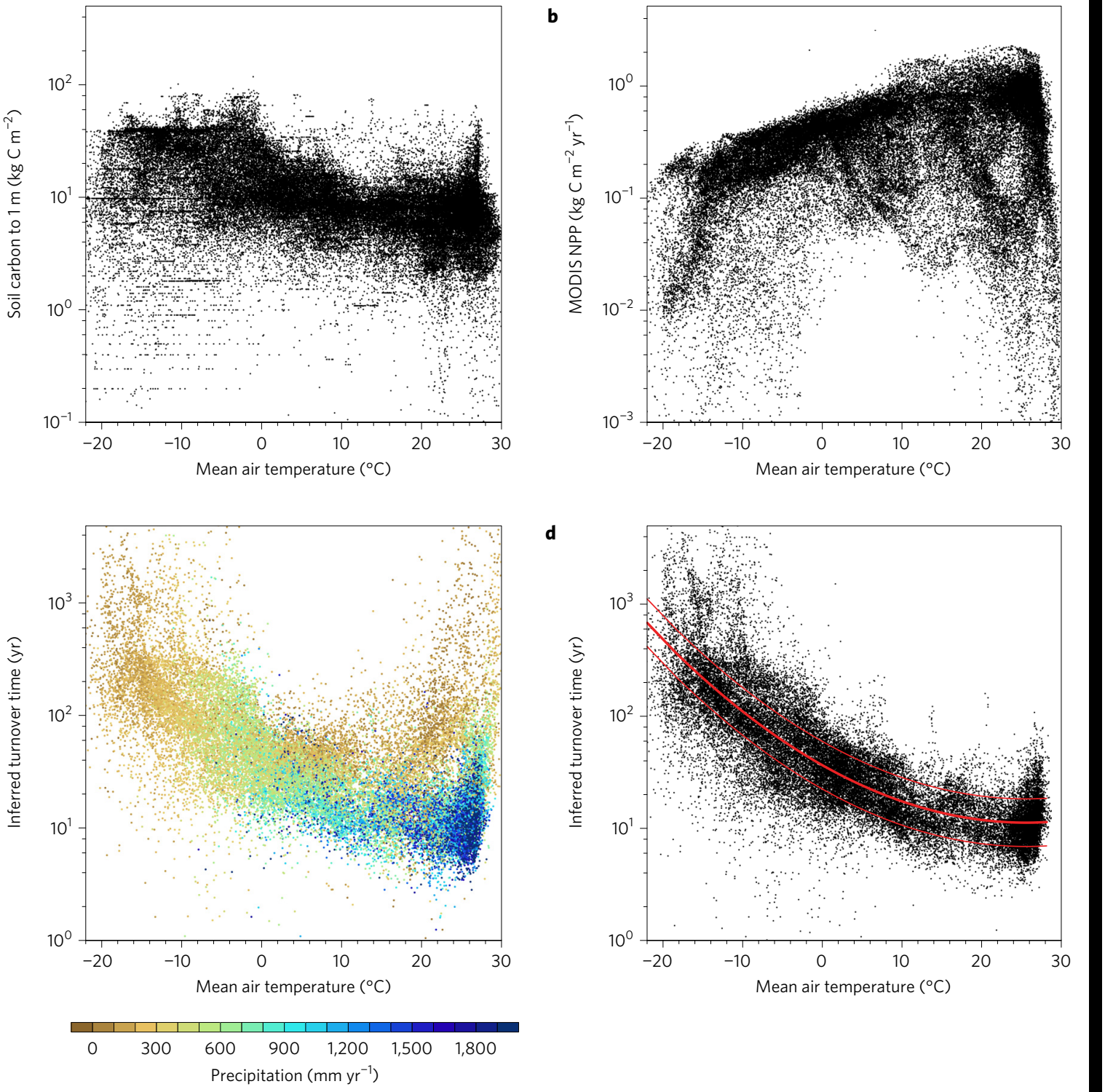
Permafrost soils CLM4.5bgc



Koven et al. *Biogeosciences* 2013

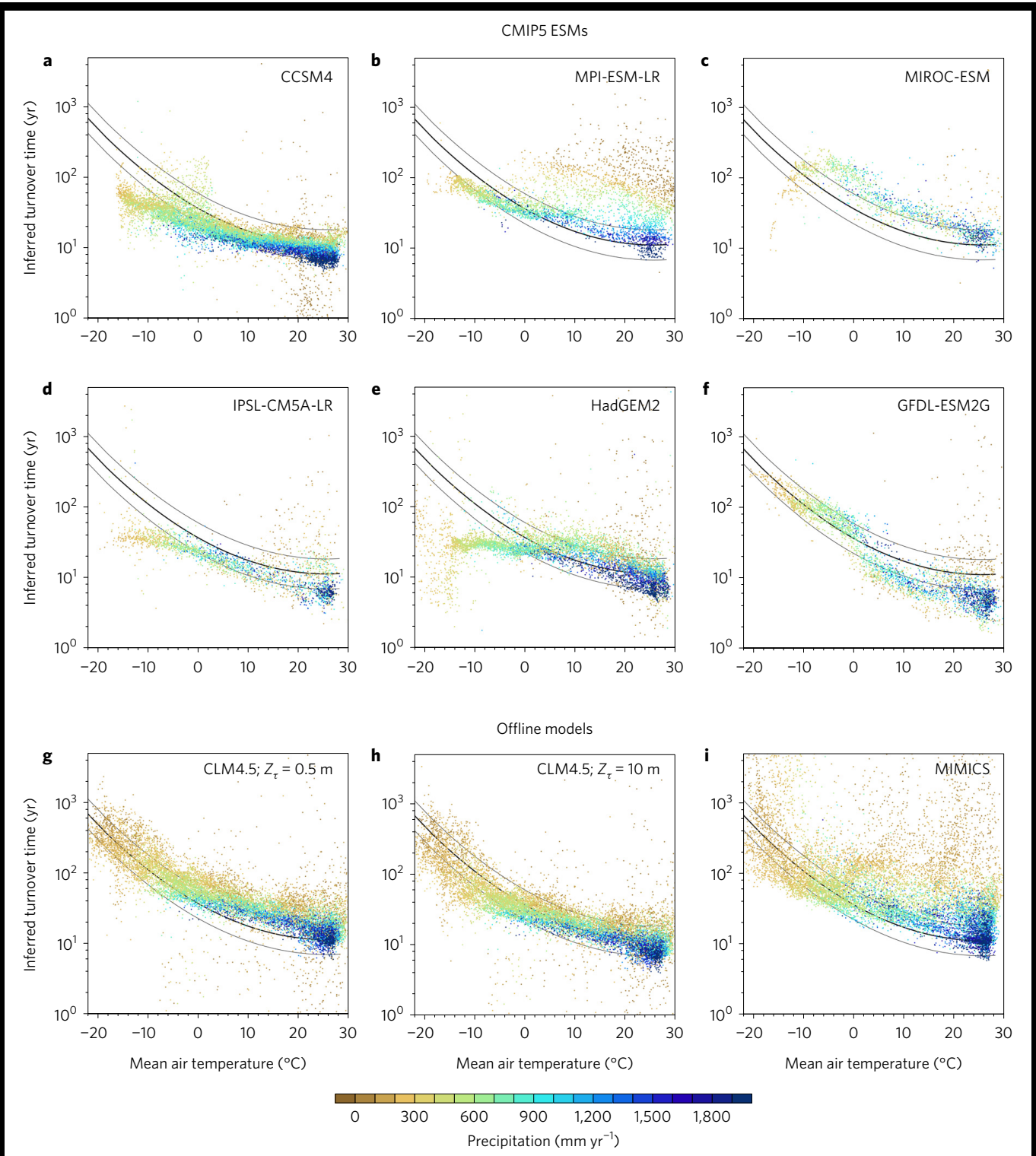

HWSD
NCSCD
CLM4.5bgc
180
150W
150E
120W
120E
90W
90E
60W
60E
30W
30E
0
0
9000
18000
27000
36000
45000
g C m-2

Turnover times



Koven et al. 2017 NCC

Turnover times

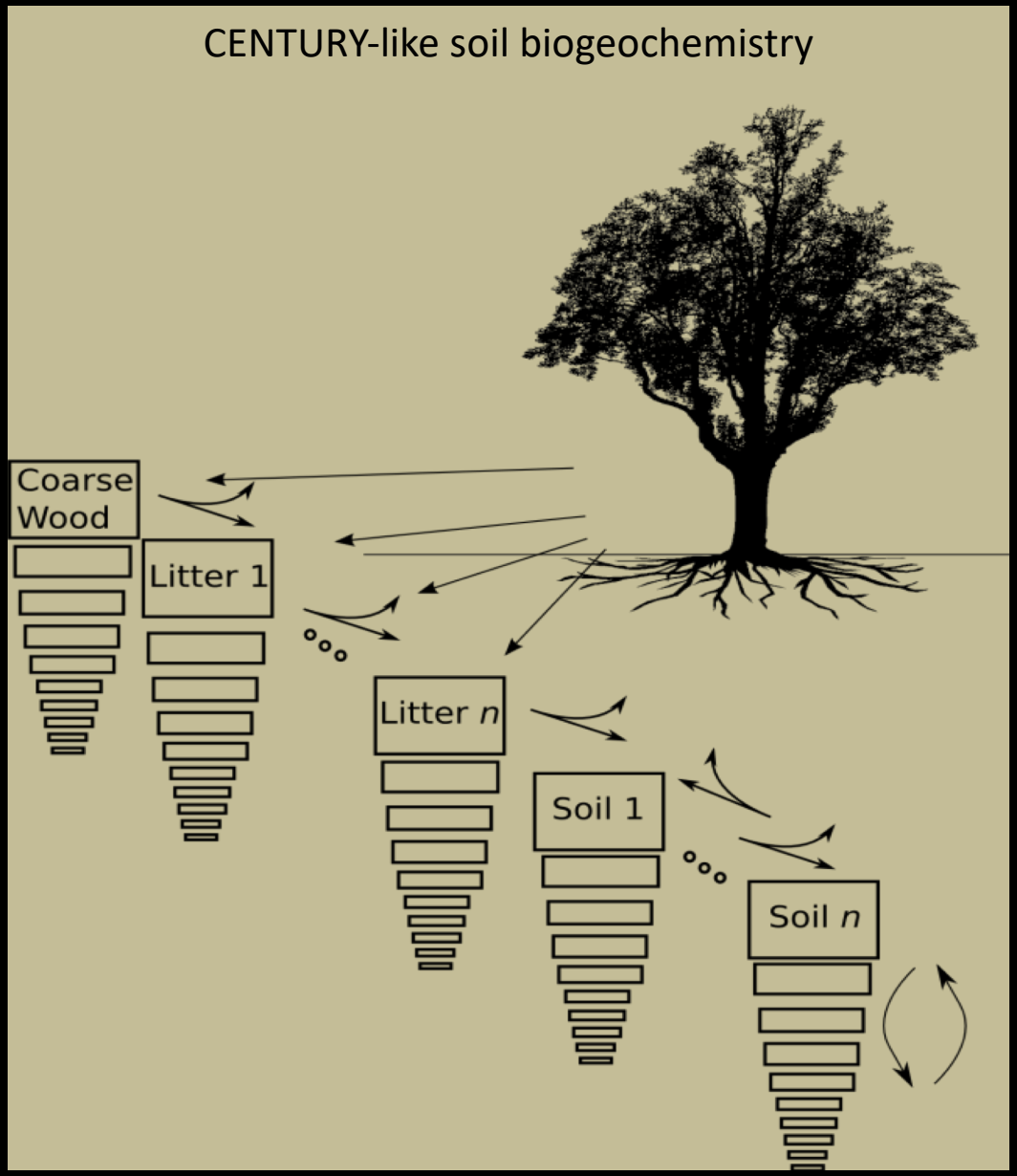


Koven et al. 2017 NCC

Permafrost soils CLM4.5bgc & 5.0

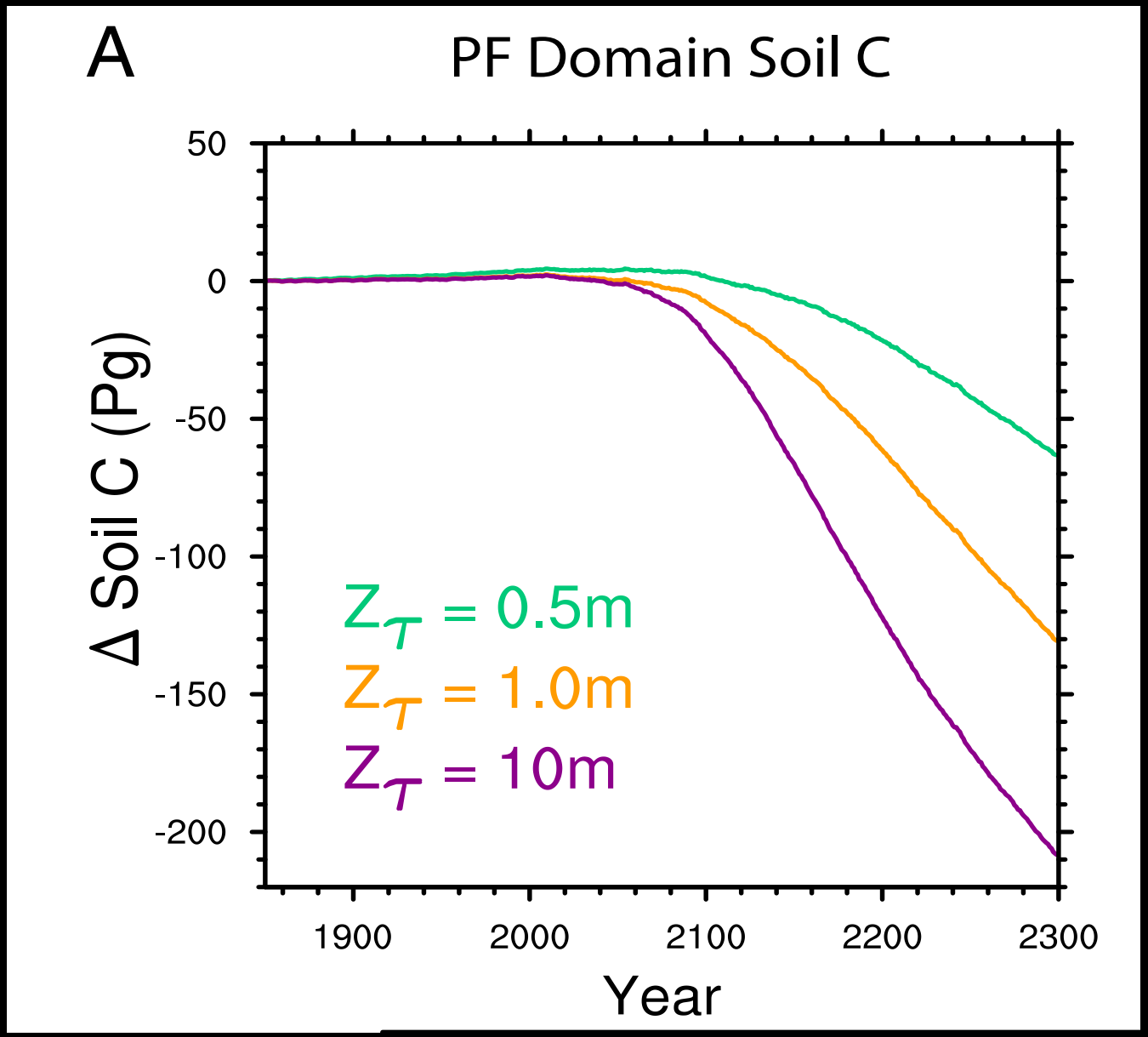
Stoichiometry
Rate constant (k)
    Water function
    Temperature function
Transfer coefficients
    (among pools & respiration)

O_2 function
Advection
Diffusion
E-folding depth
    (depth dependence of turnover)



Koven et al. *Biogeosciences* 2013

Permafrost soil C loss



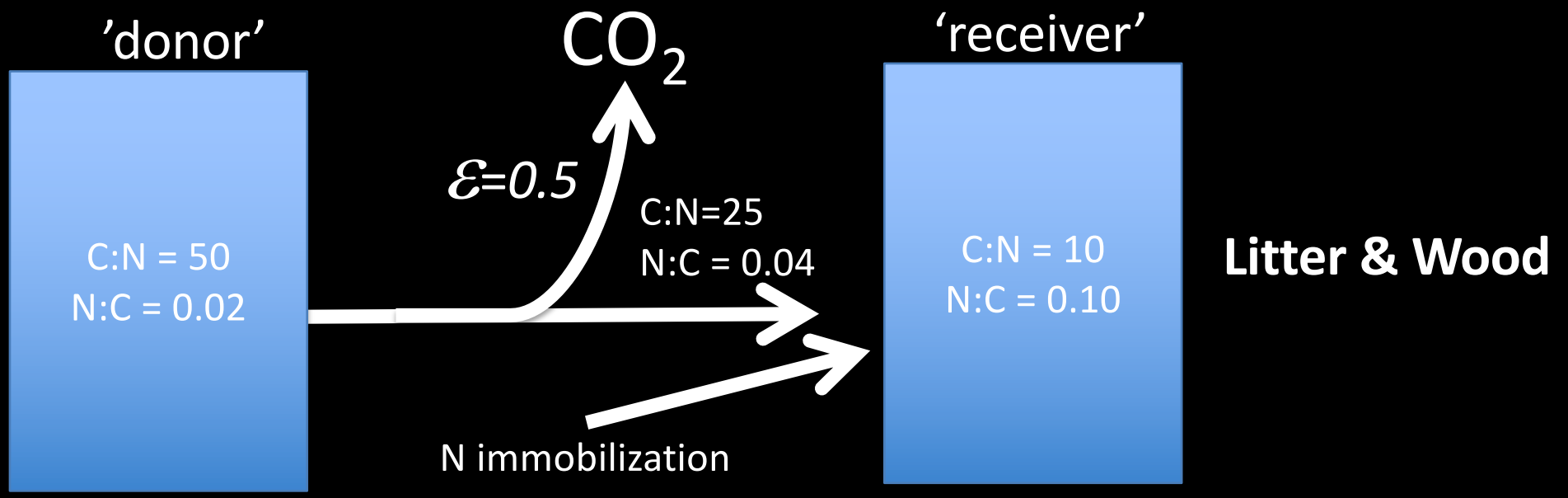
Koven et al (2015) PNAS

Coupled C:N Biogeochemistry

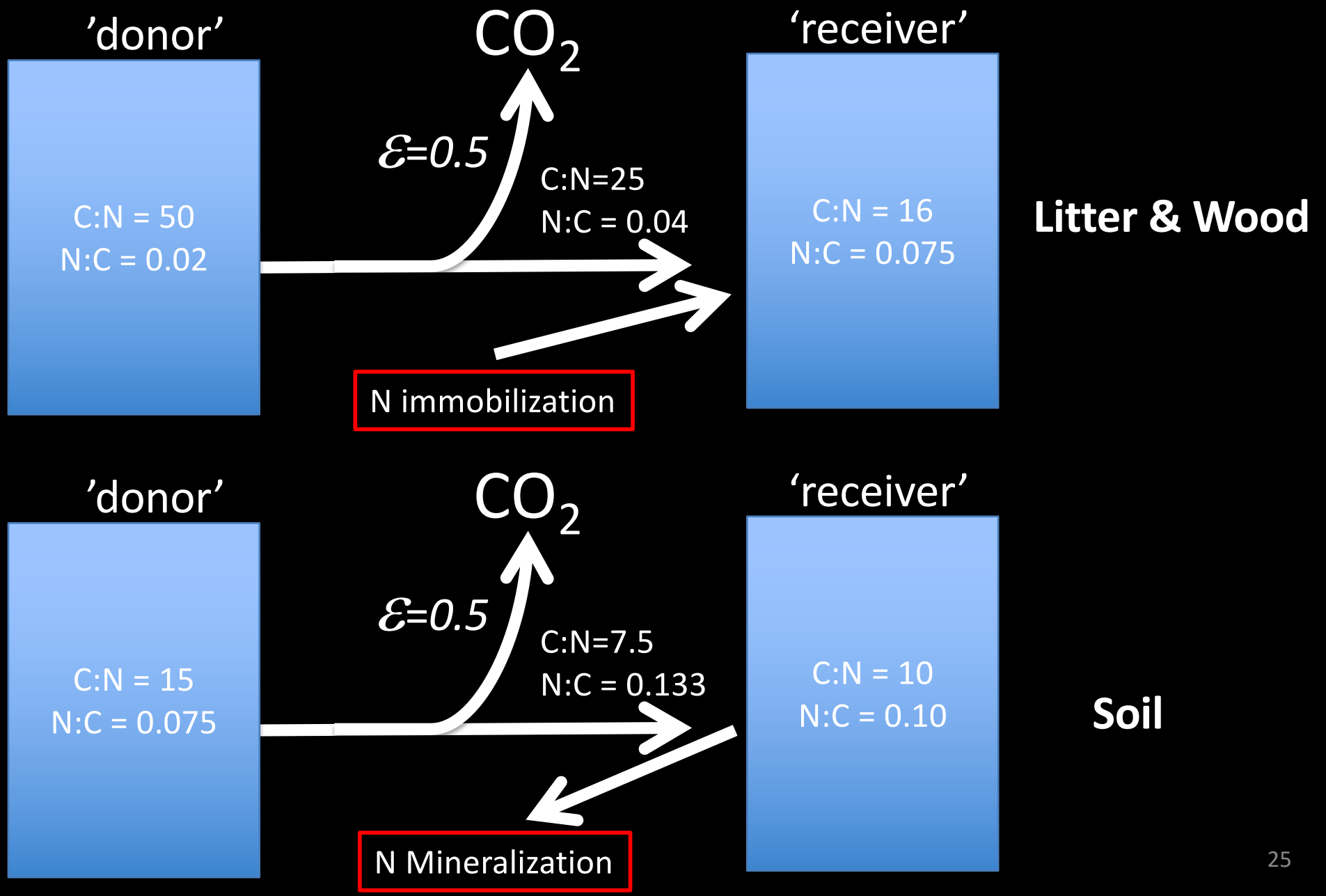
"N limitation of Decomposition fluxes"

Yes, that's really a thing in CLM &
other demand-based models

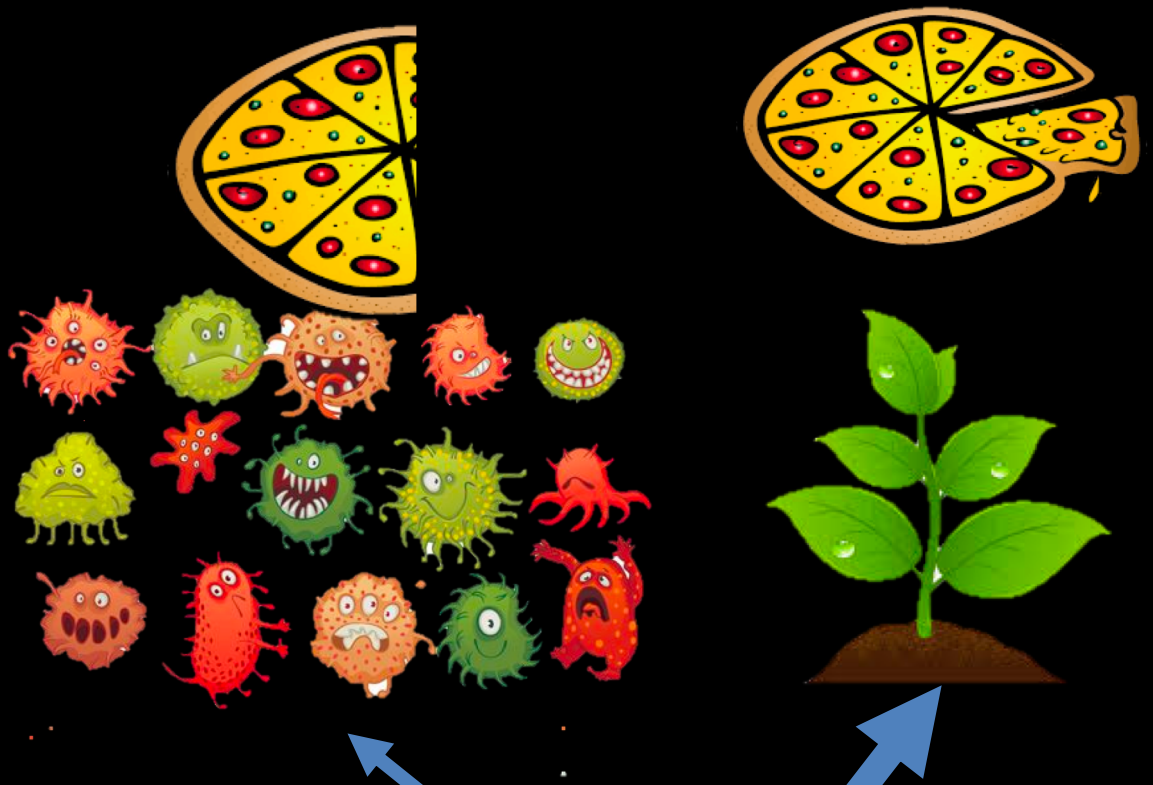
Coupled C:N Biogeochemistry



Coupled C:N Biogeochemistry



N Demand



N Available

allocated proportional to demand

CLM 5 & beyond

Land surface heterogeneity
CLM subgrid tiling structure

Gridcell

Landunit

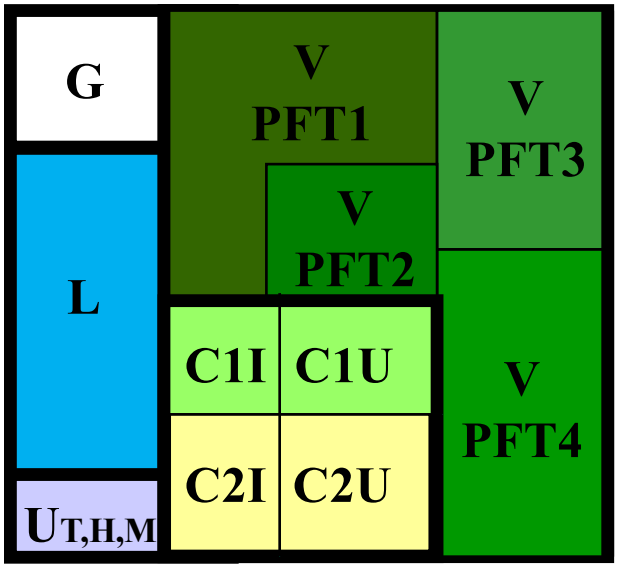
Vegetated

Lake

Urban

Glacier

Crop



Column

Soil

Unirrig Irrig Unirrig Irrig

PFT

PFT1 PFT2 PFT3 PFT4 …

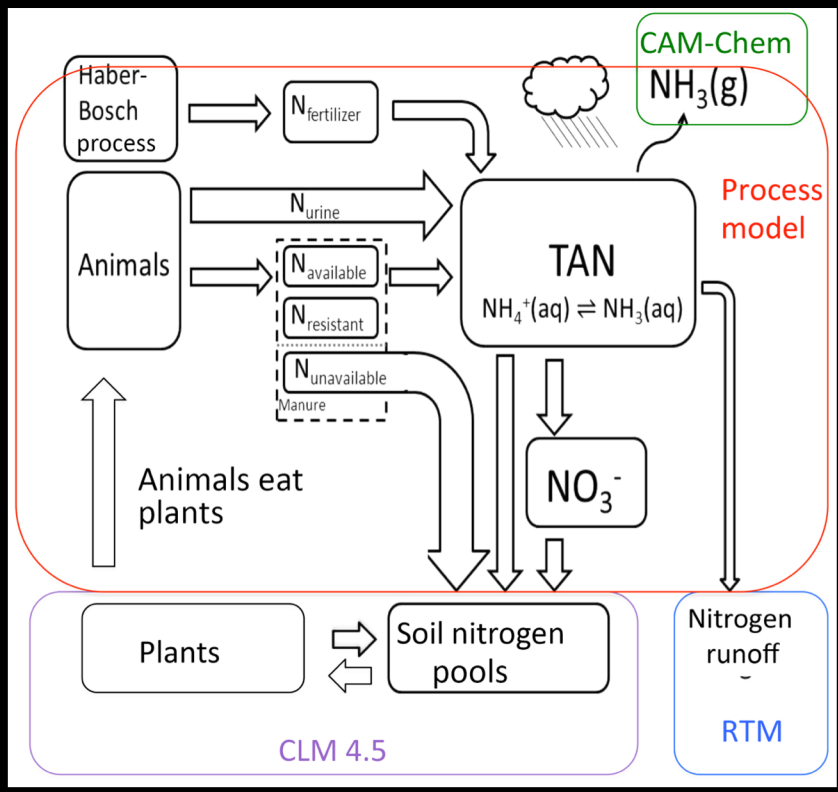
Crop1 Crop1 Crop2 Crop2 …

Subgrid hillslope hydrology

Tillage

Levis et al 2014 GMD

NH_3 emissions



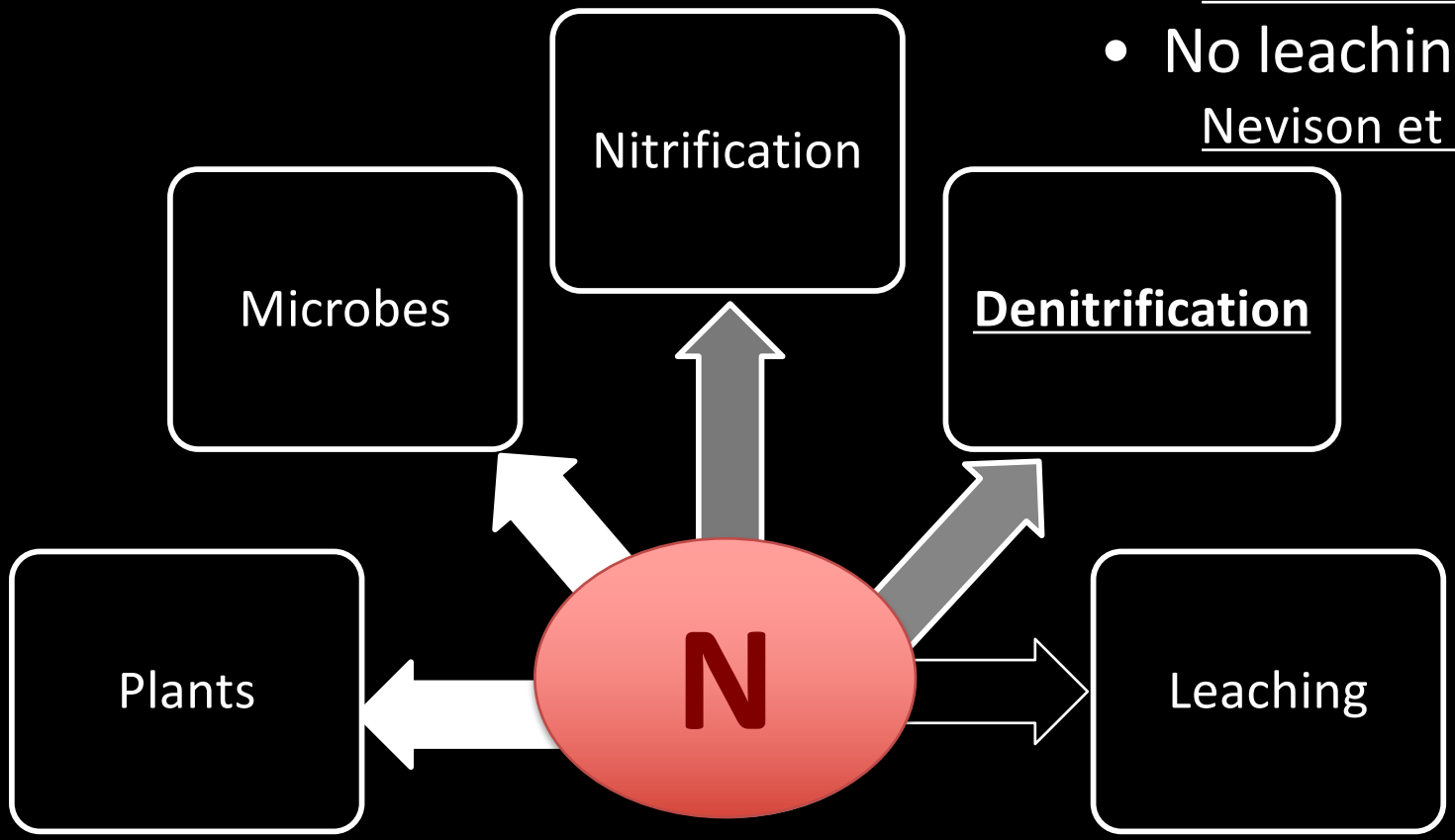
Riddick et al. (2016) BG

N uptake & competition

CLM4.0cn [inorganic N]
CLM4.5bgc [NH_4^+, NO_3^-]

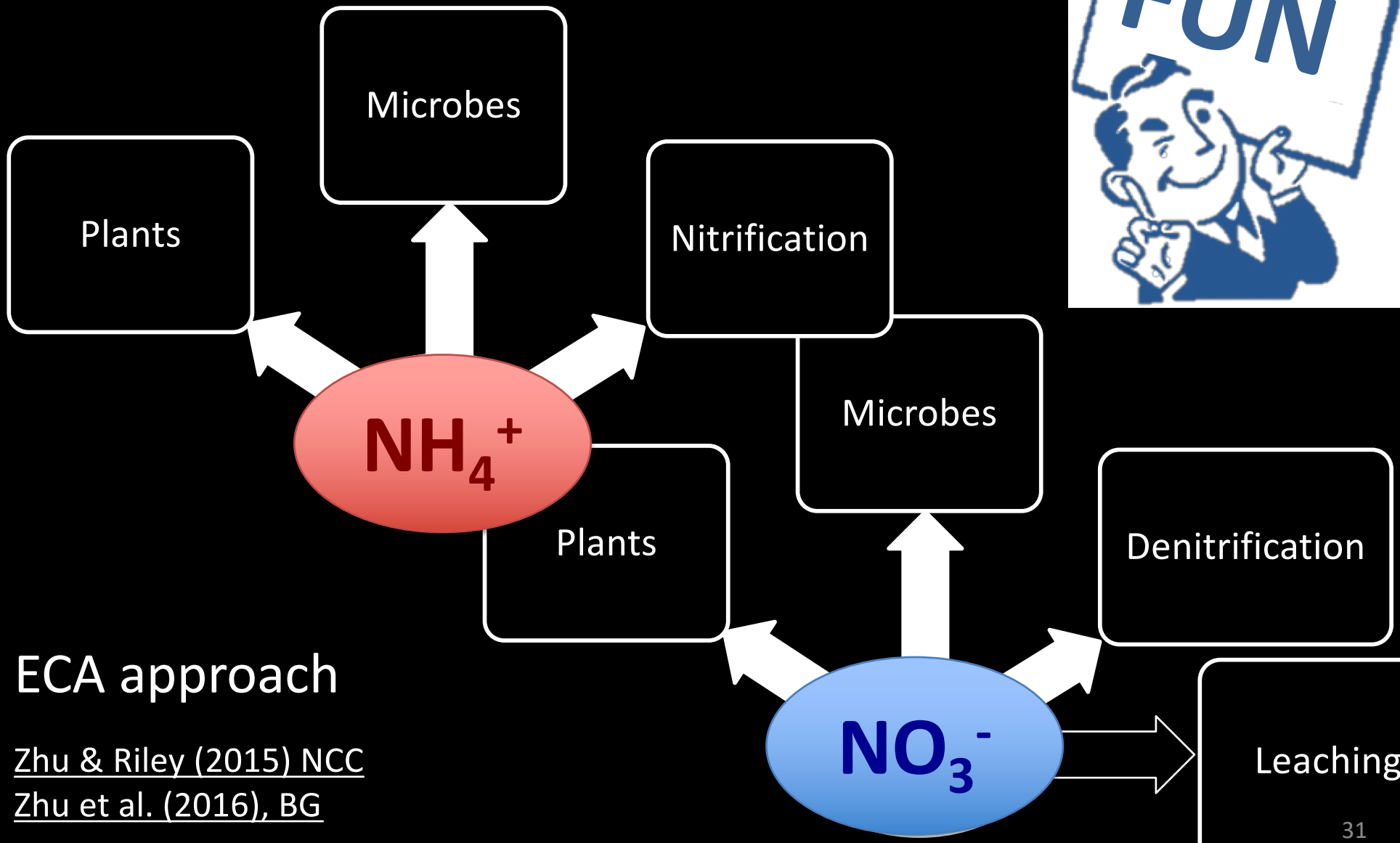
Known Issues:

- High N fertilization effects
  Thomas et al (2013) GBC
- Huge denitrification fluxes
  Thomas et al. (2013) BG
  Houlton et al. (2015) NCC
- No leaching (or DON losses)
  Nevison et al. (2016) JAMES



N uptake & competition

CLM5 + ELM



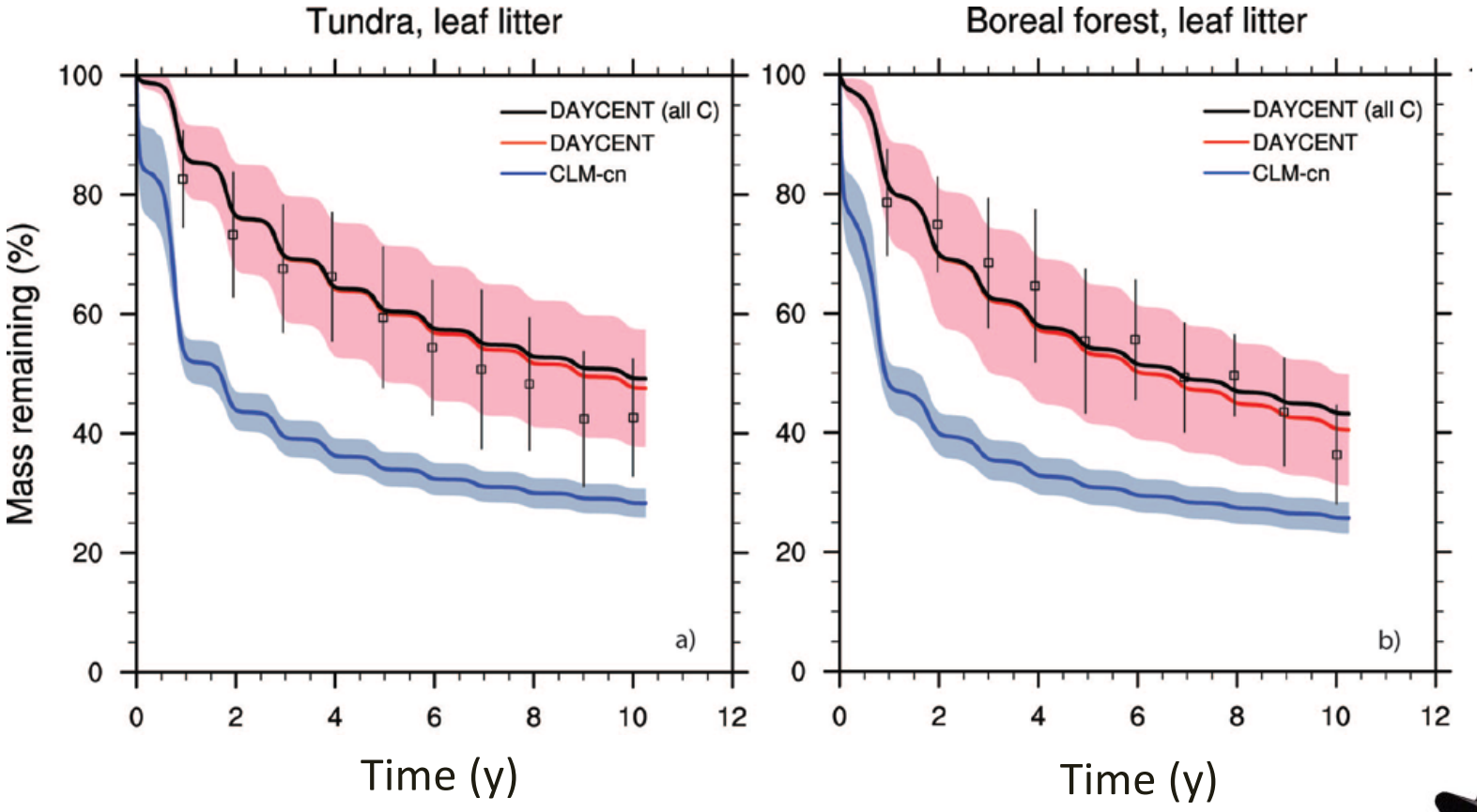
ECA approach

Zhu & Riley (2015) NCC
Zhu et al. (2016), BG

Soil Biogeochemistry in CLM 5+

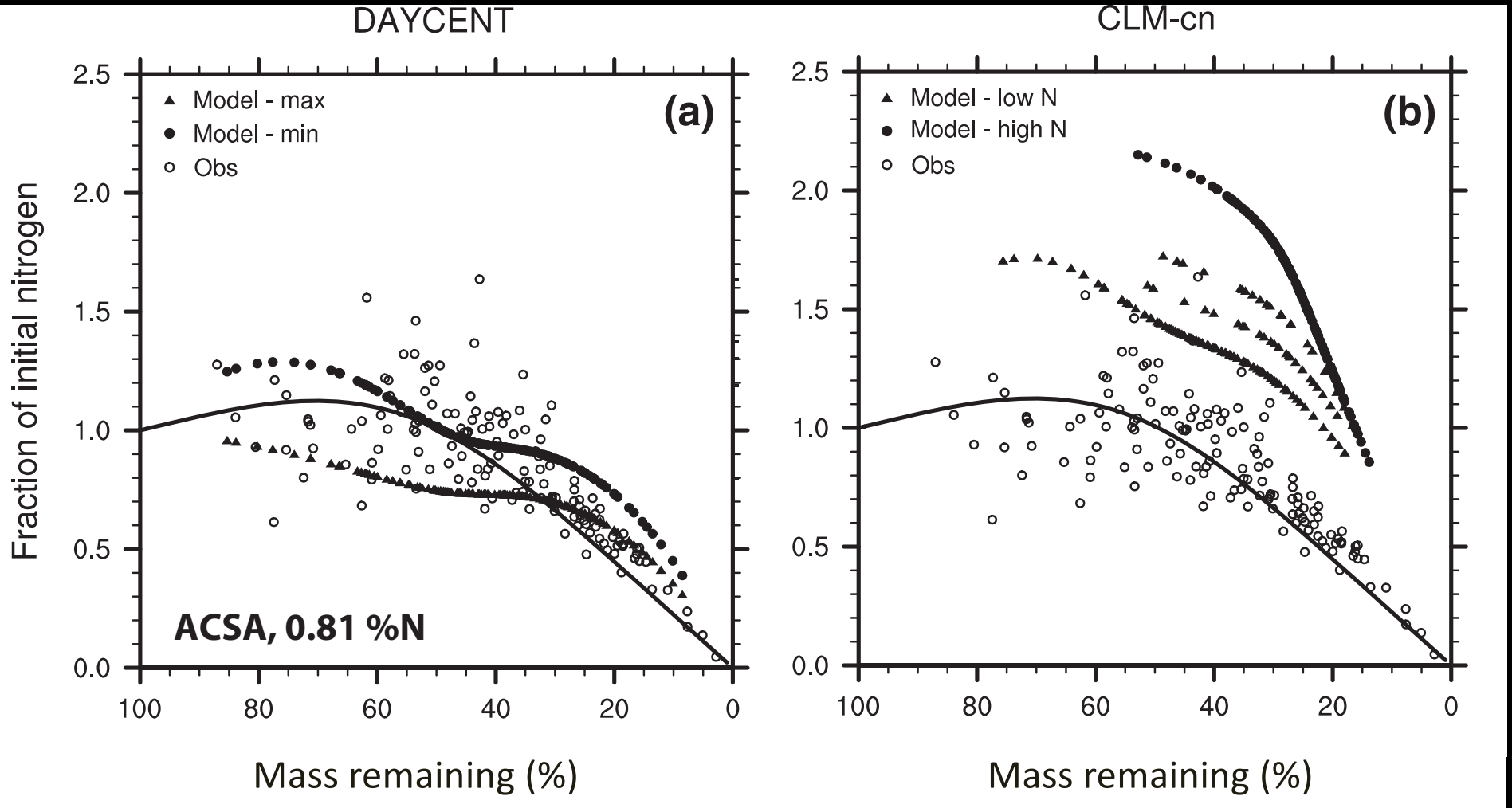
Adding functionality & reality

Rapid soil C turnover in CLM4.0-cn



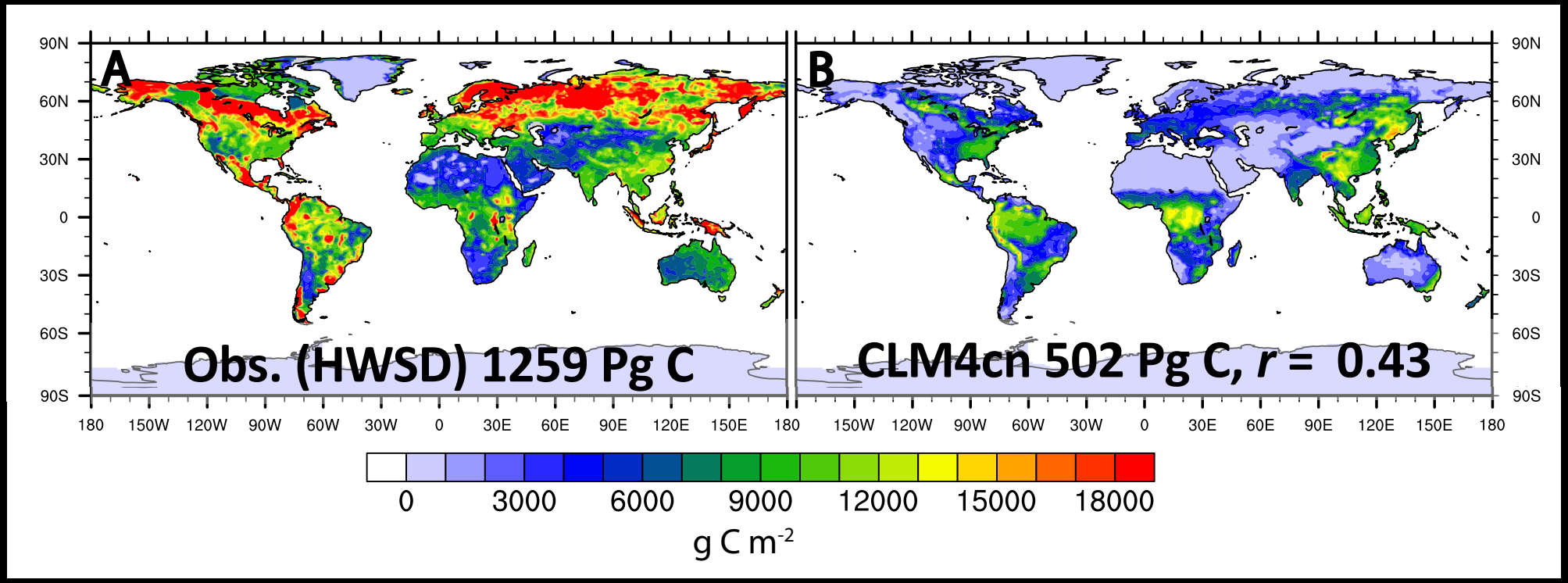
Bonan et al. Global Change Biology 2013

Absurd soil N behavior in CLM4.0-cn

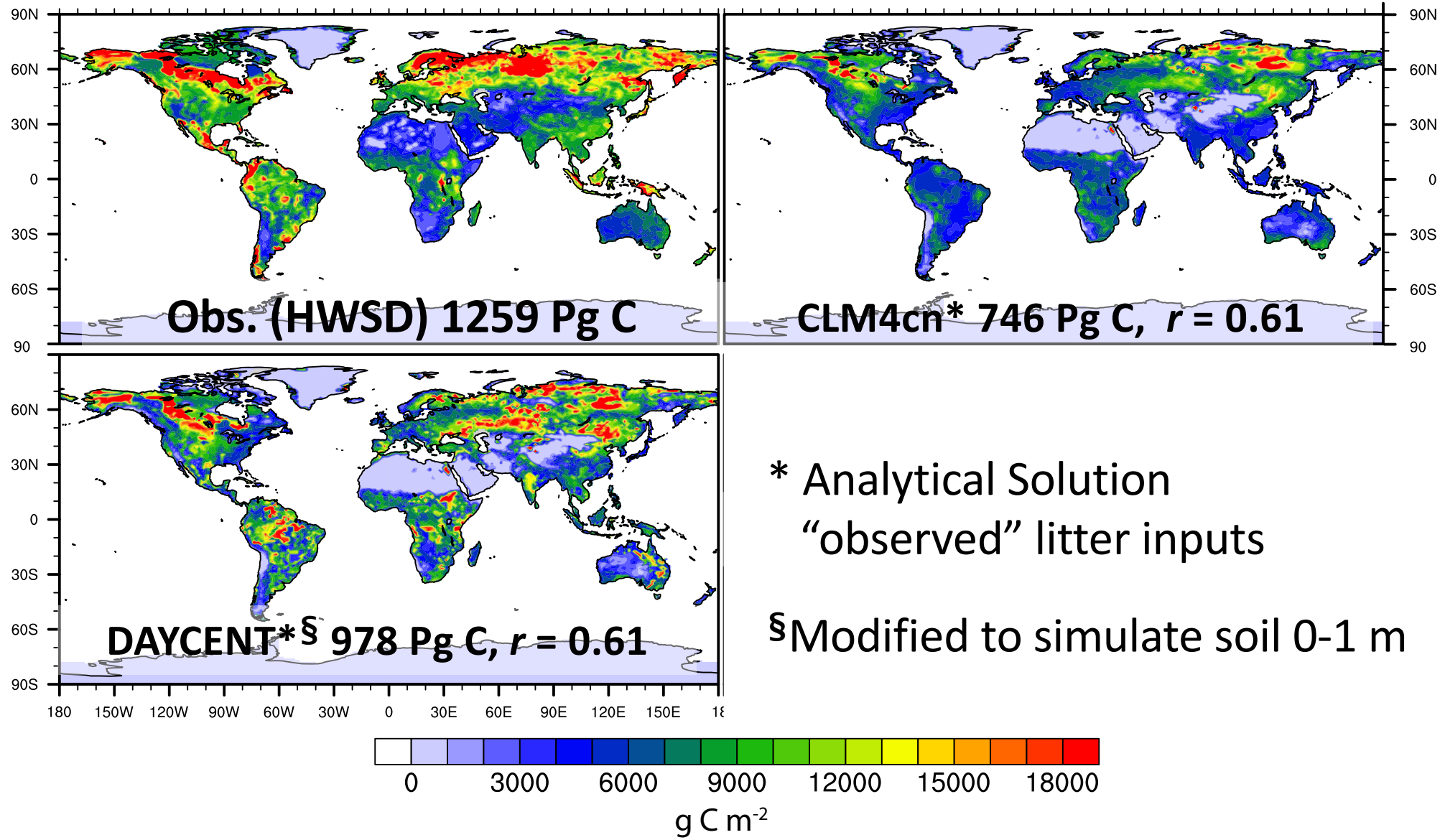


Bonan et al. Global Change Biology 2013

Soil C improved w/ DAYCENT?



Soil C improved w/ DAYCENT?



* Analytical Solution
"observed" litter inputs

§Modified to simulate soil 0-1 m

Wieder et al. GBC 2014