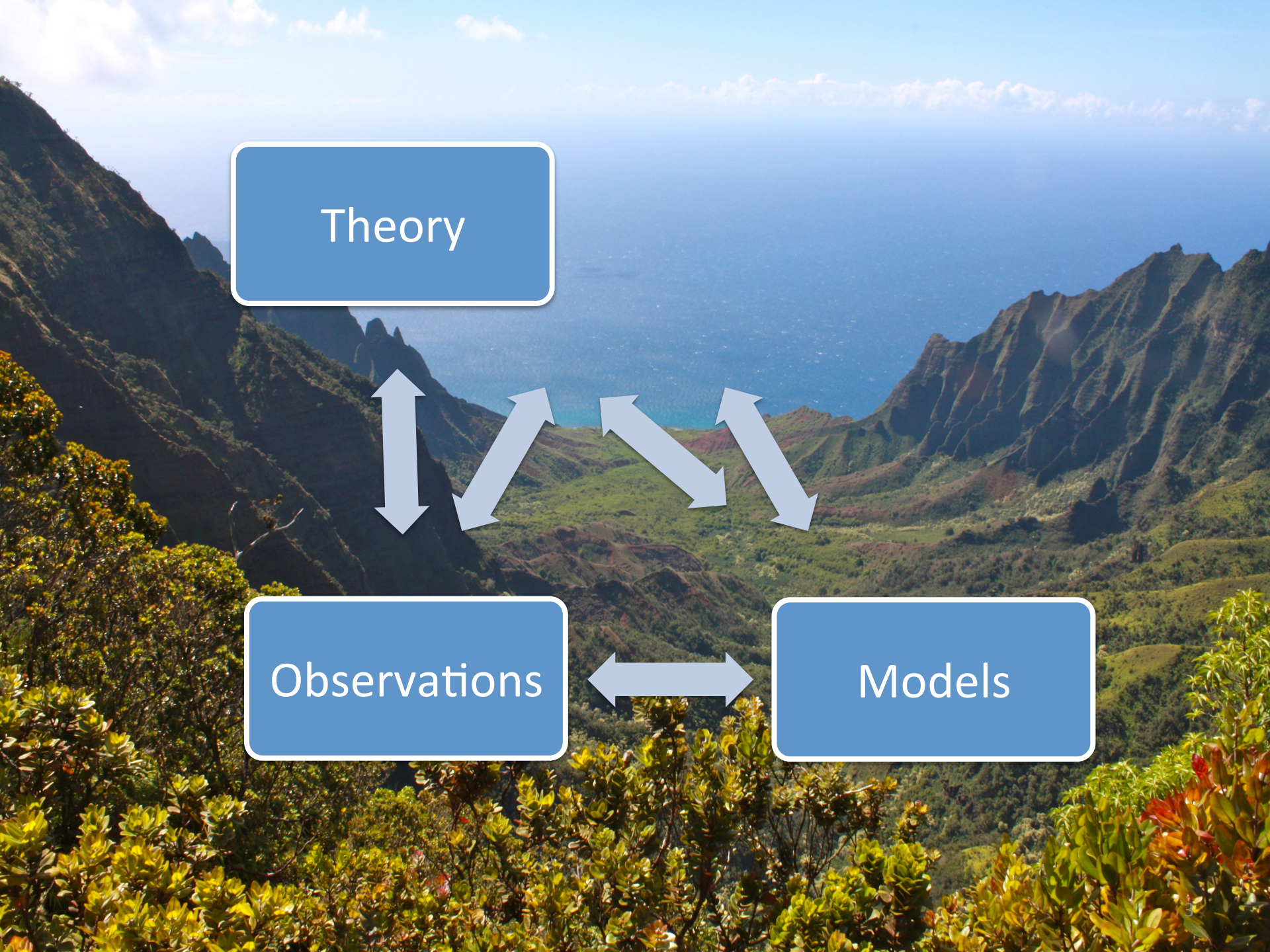
Soil biogeochemistry in a changing world

Will Wieder

2016 CLM Tutorial

Q1: How may environmental change alter terrestrial biogeochemical cycles?

Q2: How does an ecologist use and improve CLM?


Theory
Observations
Models

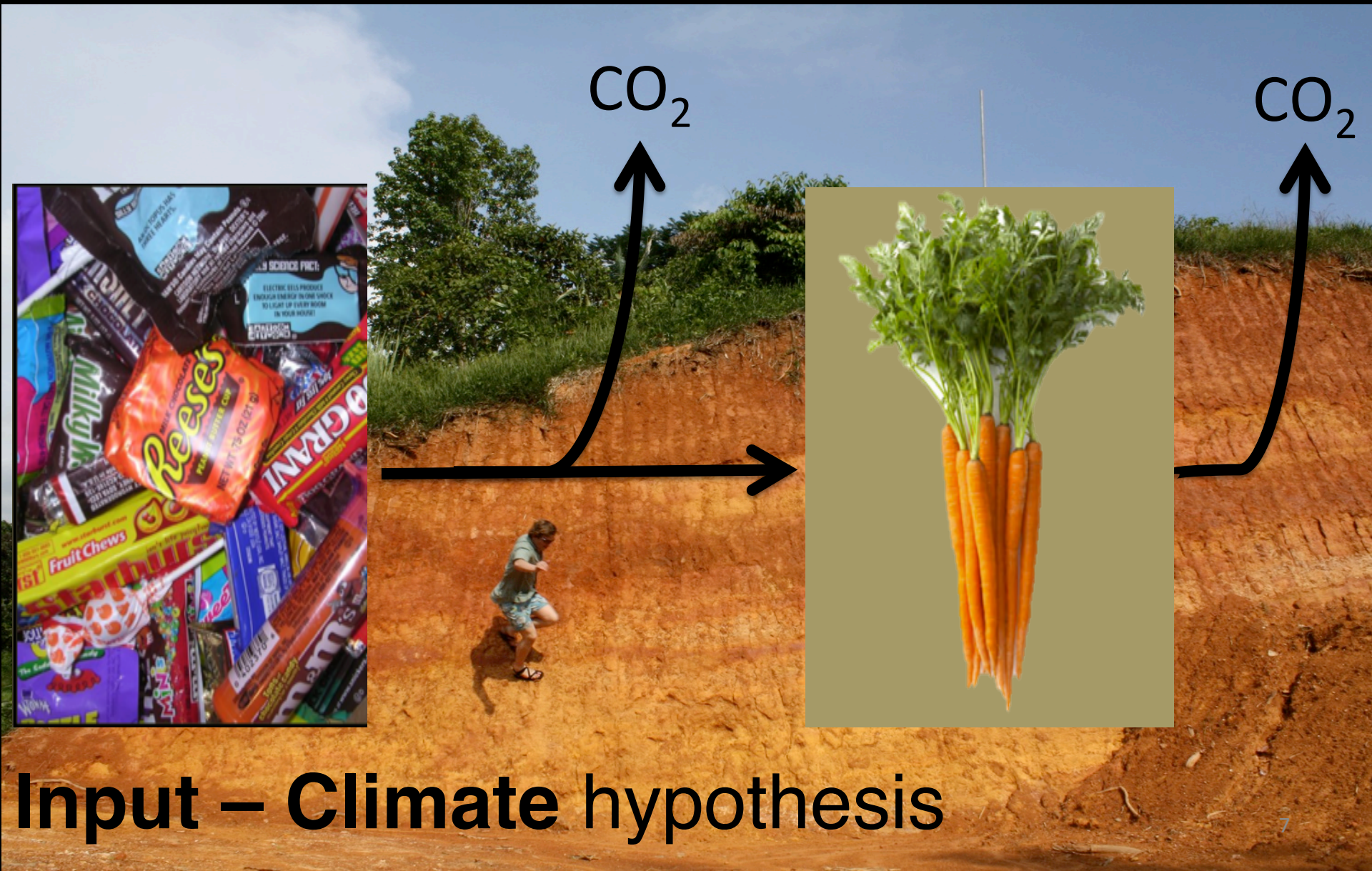
CLM soil biogeochemistry

- Past (CLM4cn)
- Present (CLM4.5bgc)
- Future (CLM5 & beyond)

Soils Store Carbon

Soils Store Carbon and Nitrogen

soil biogeochemical models



Input – Climate hypothesis

soil biogeochemical models

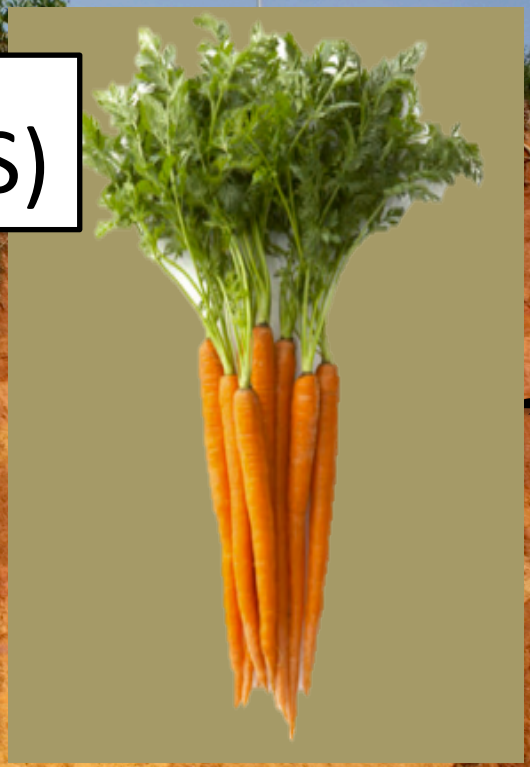
I=NPP

$\hat{C} = I / k$

CO_2

$e=f(S)$

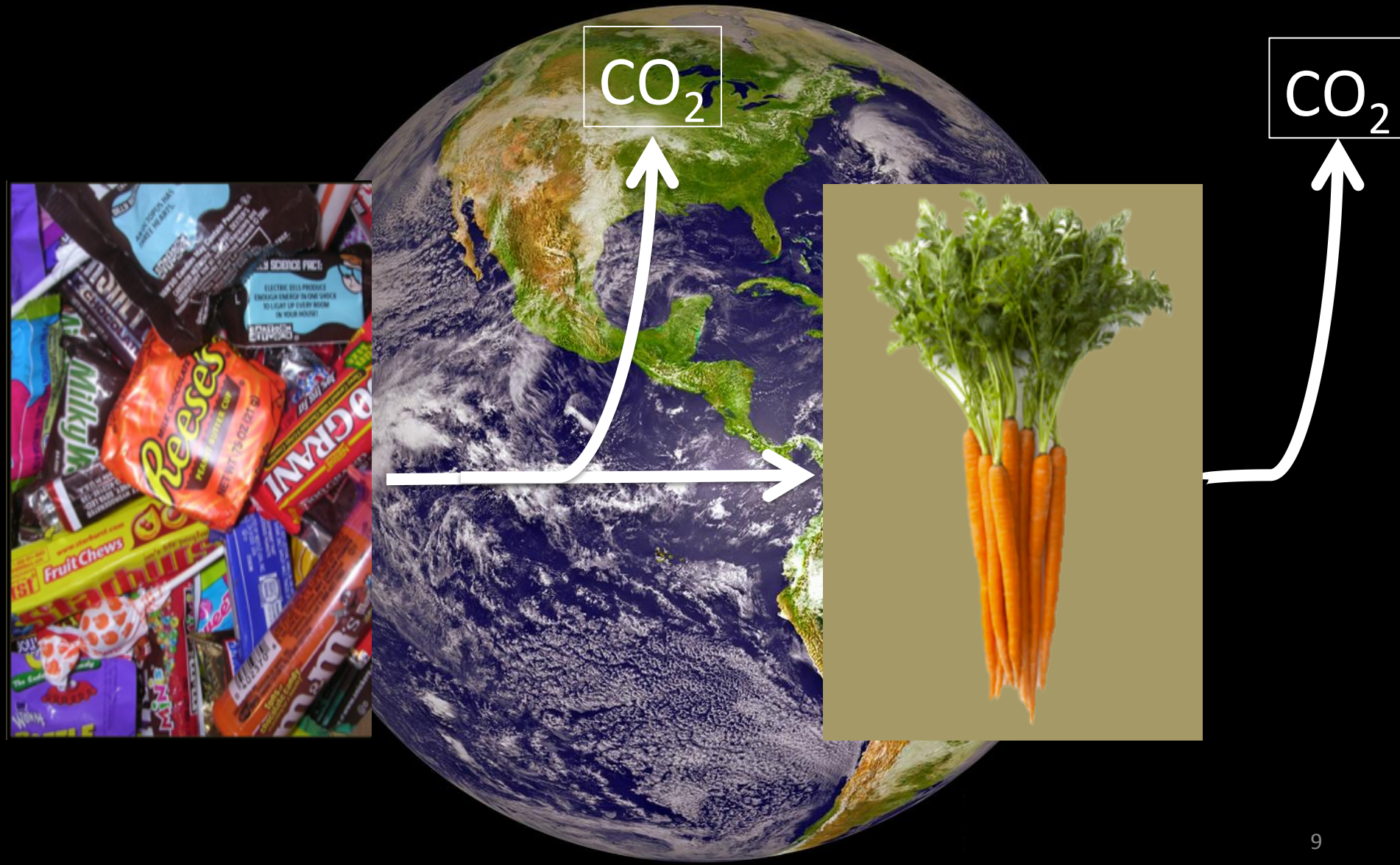
$k=f(T,M,S,...)$



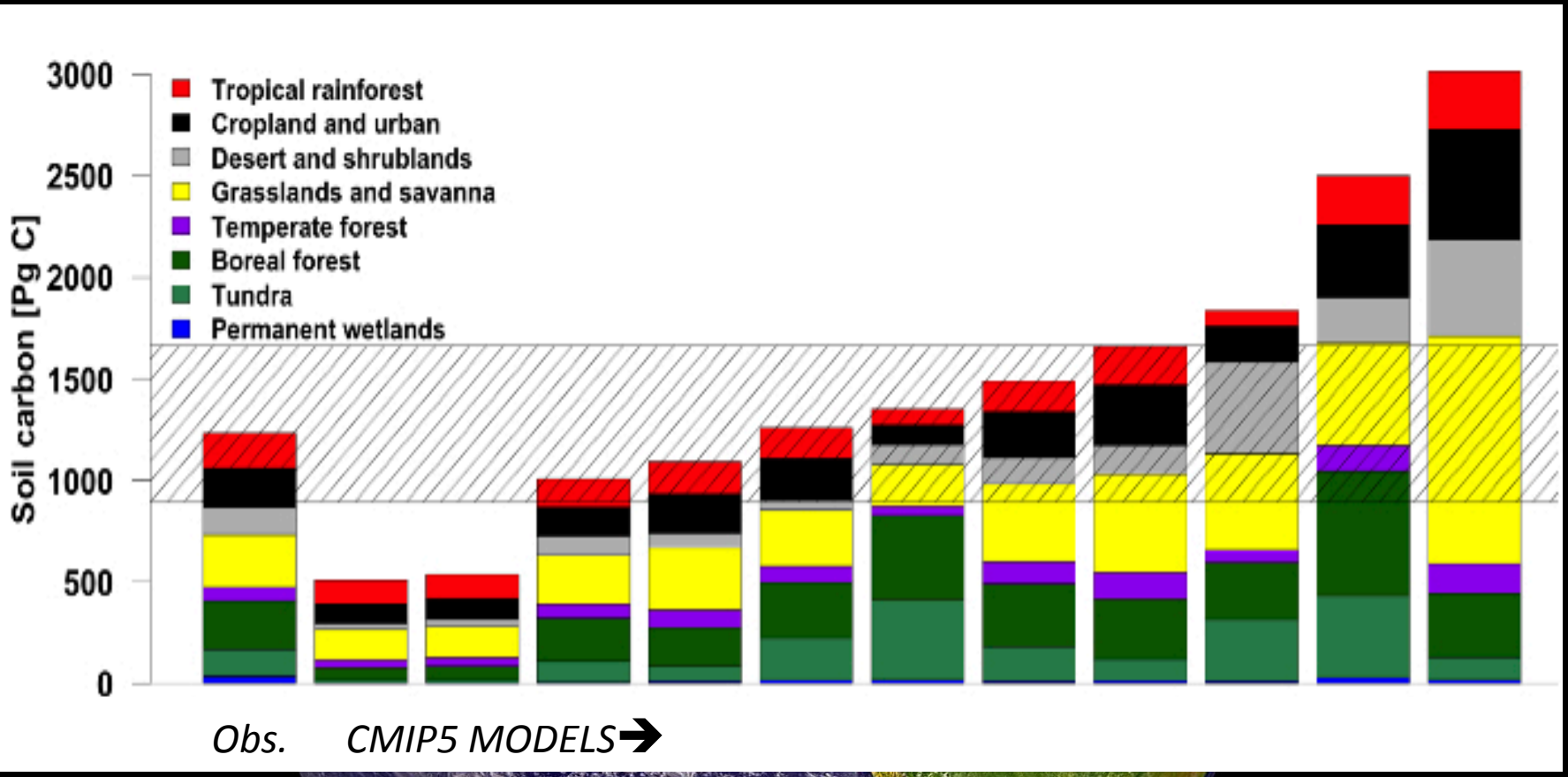
CO_2

Input – Climate hypothesis

Global soil biogeochemical models



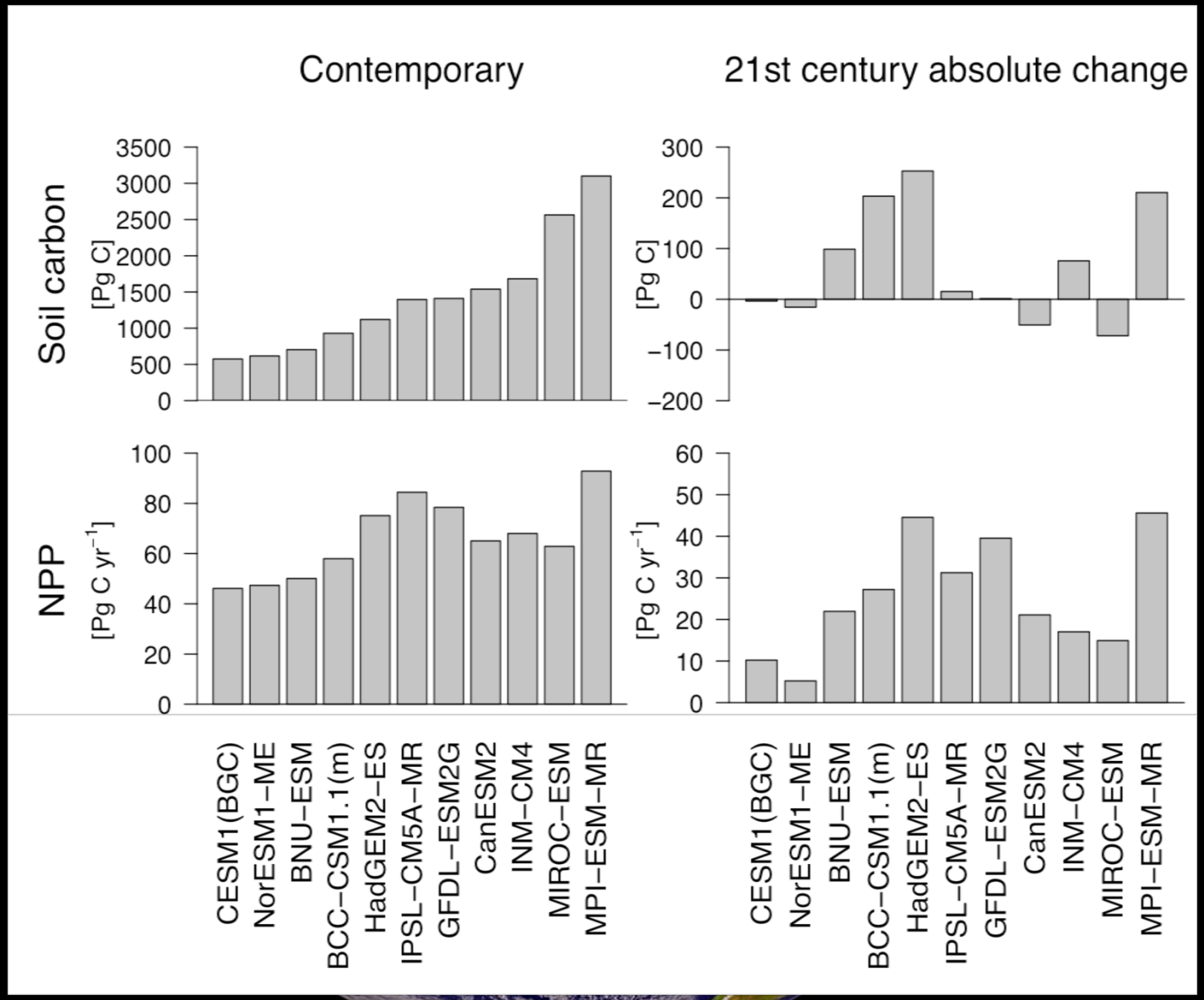
CMIP5 Models = 6x variation



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

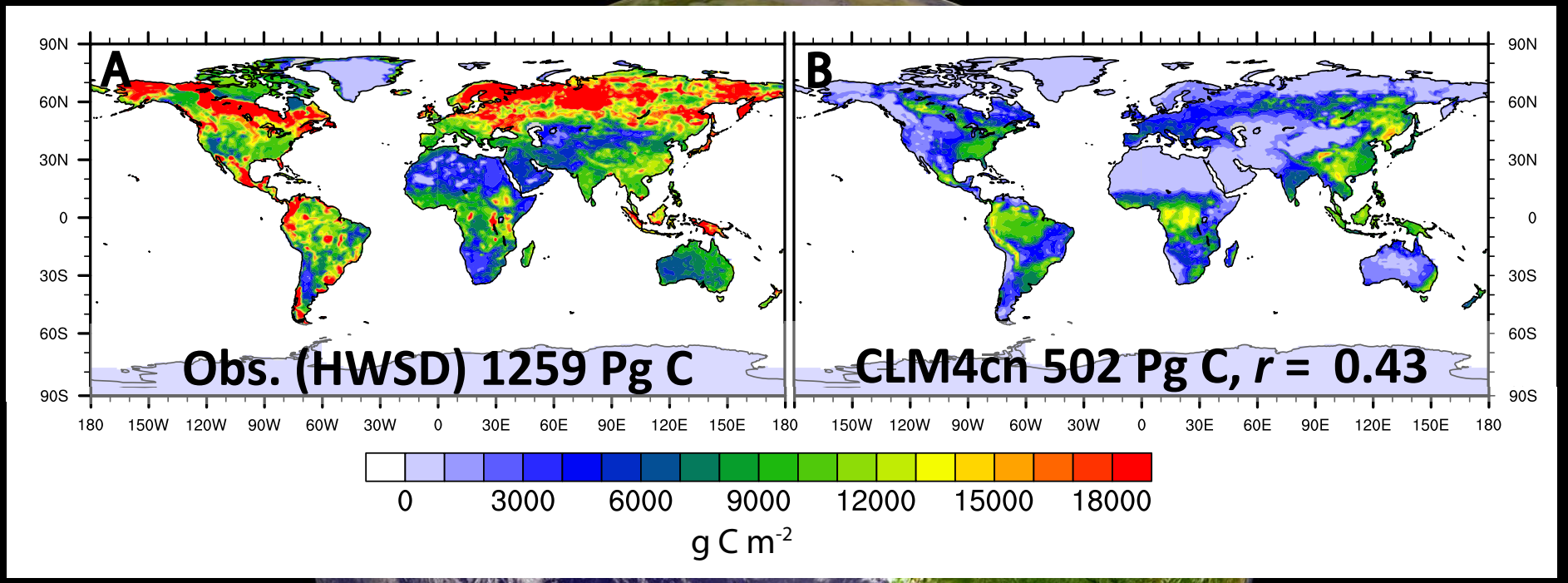
Todd-Brown et al. Biogeosciences 2013, Friedlingstein et al. 2006; Jones et al. 2003

CMIP5 Models RCP8.5



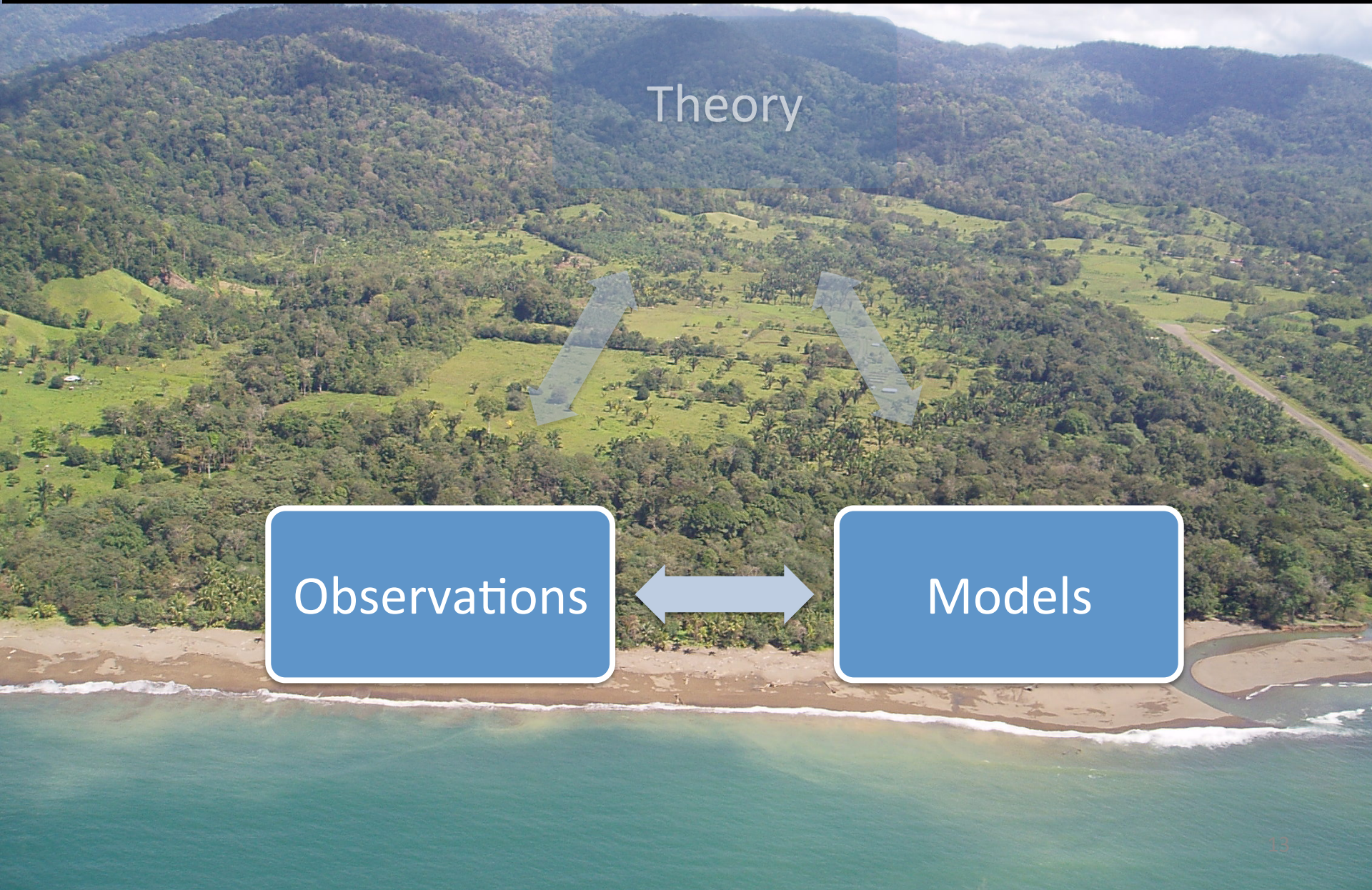
Todd-Brown et al. Biogeosciences 2014

CLM4.0-cn (CLM “past”)



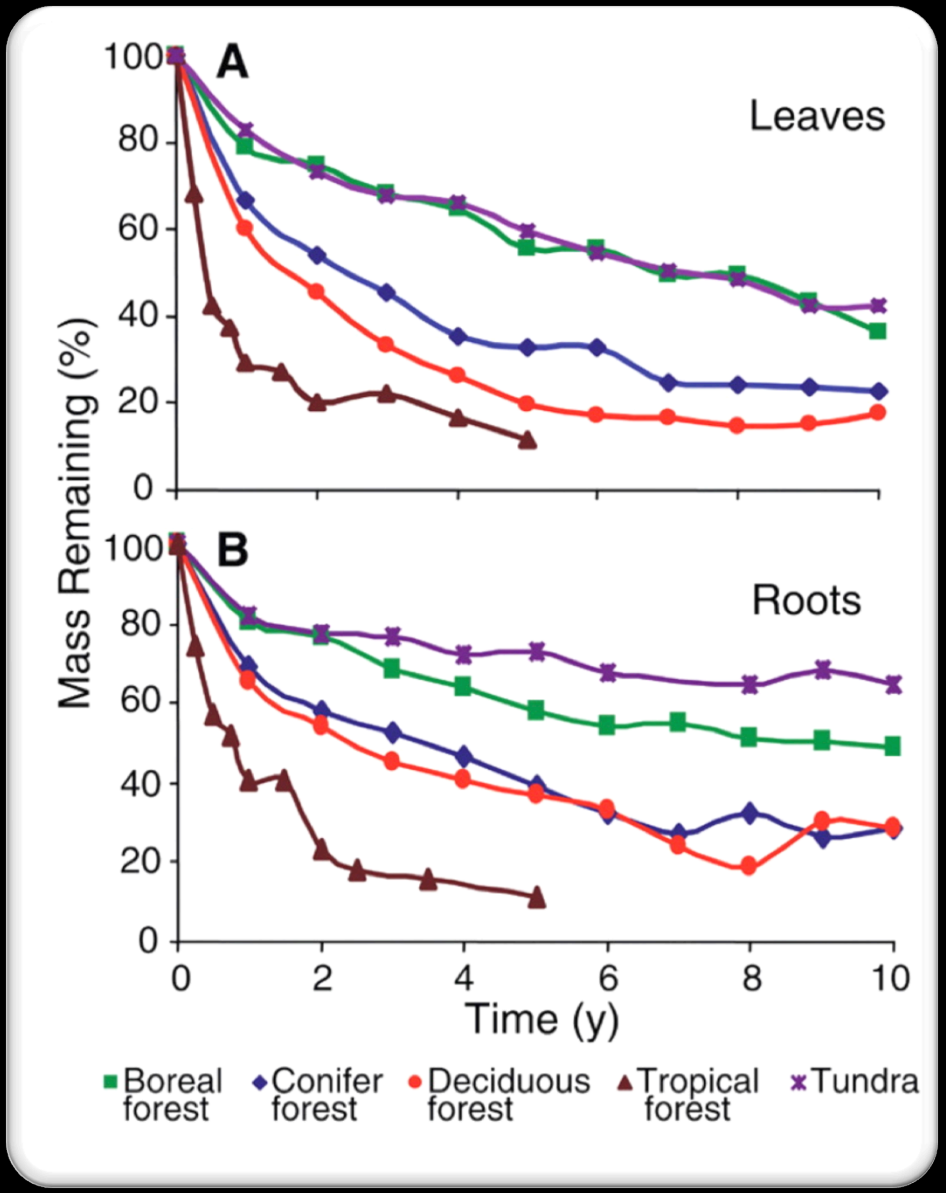
$$\hat{C} = I / k$$

Using DATA to evaluate models



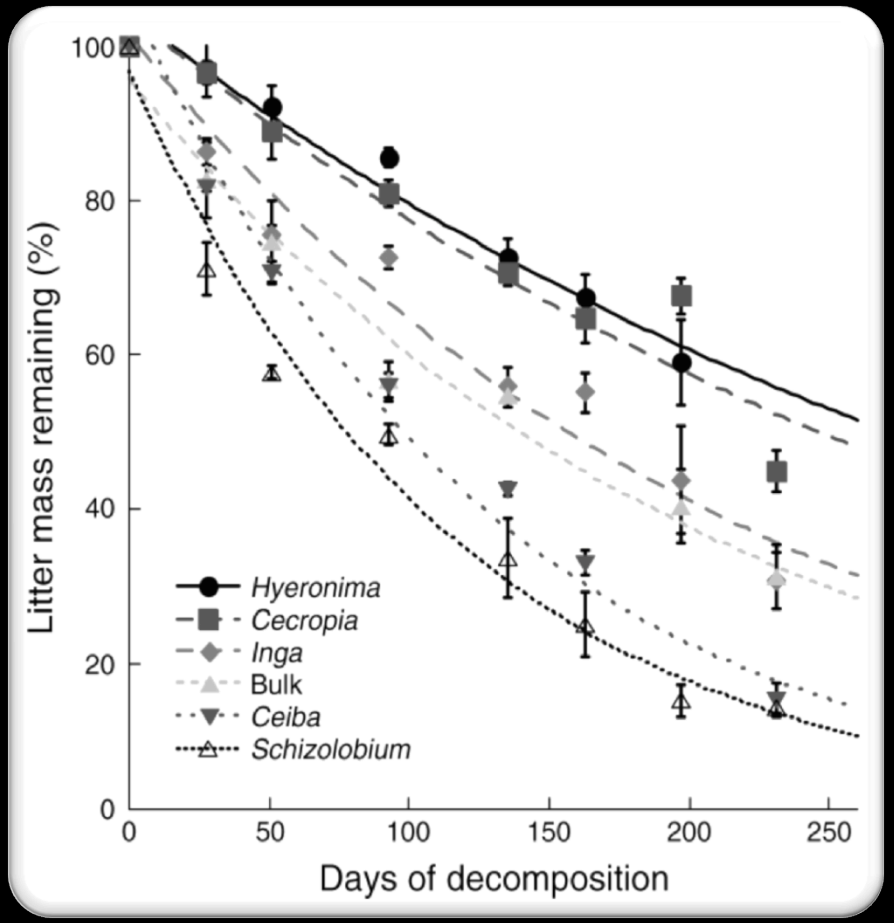



Climate matters



Parton et al. Science 2007

Chemistry matters



Wieder et al. Ecology 2009

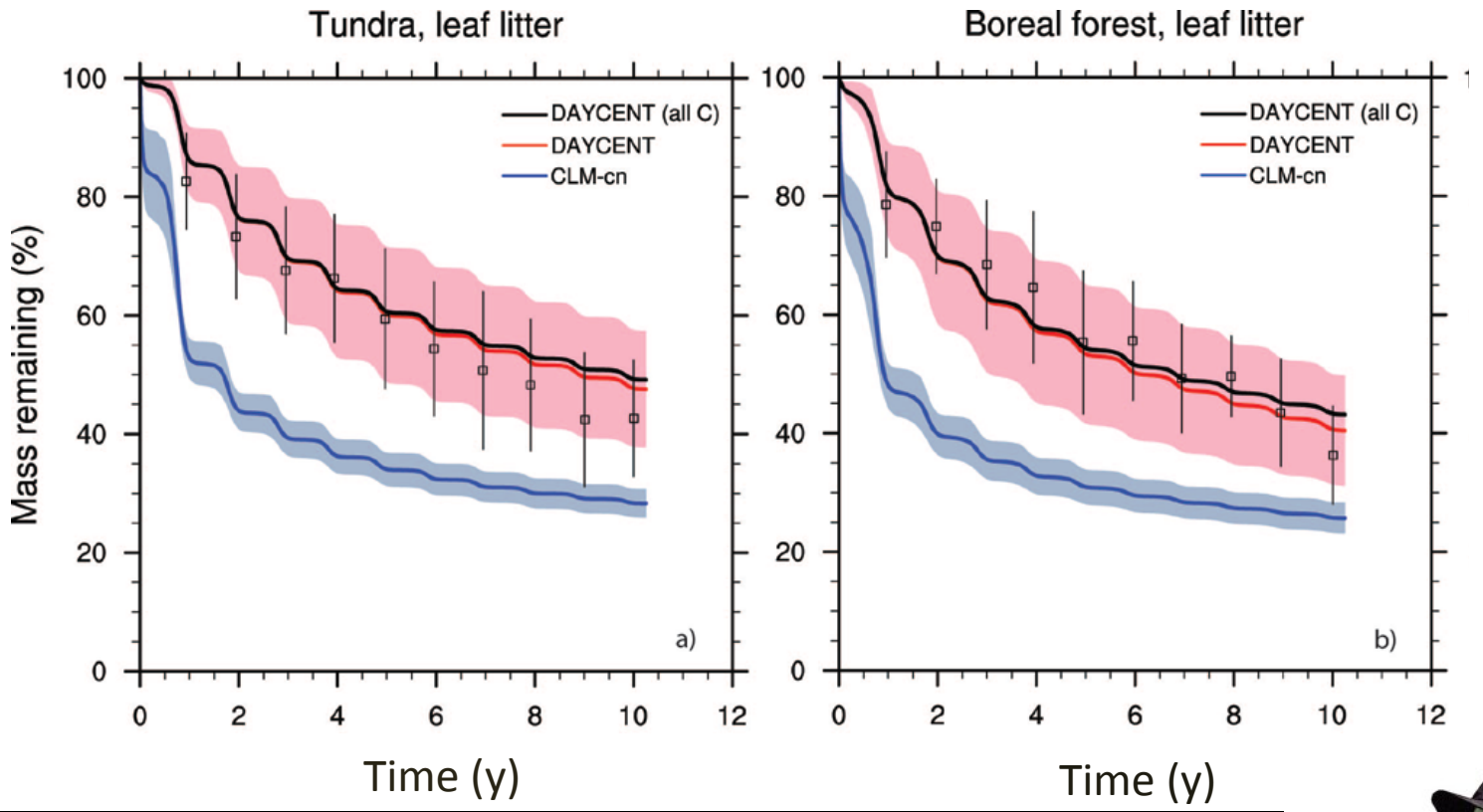
Which model looks more like reality?

CLM4.0-cn
DAYCENT

vs.

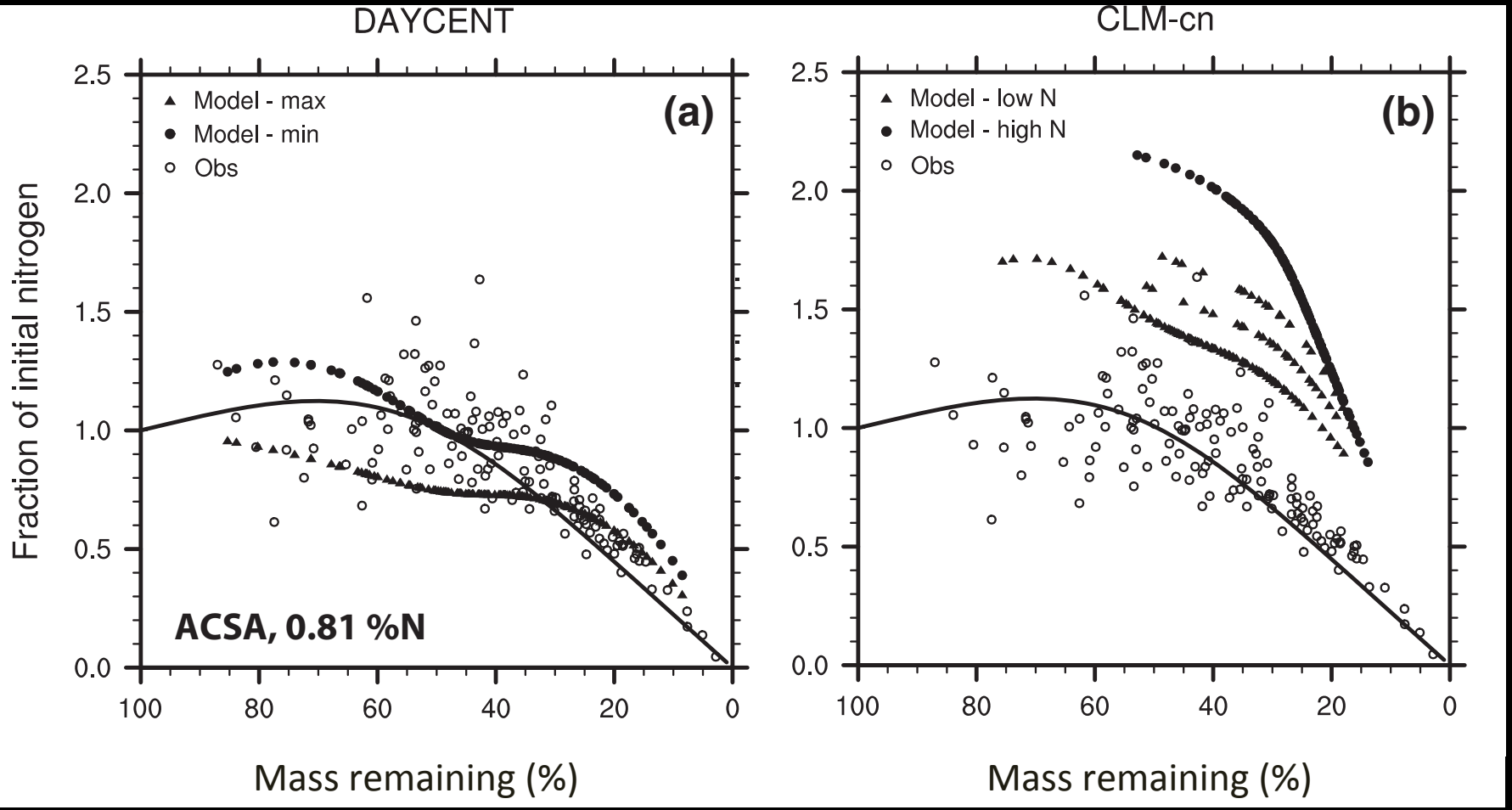
LIDET

Rapid soil C turnover in CLM4.0-cn



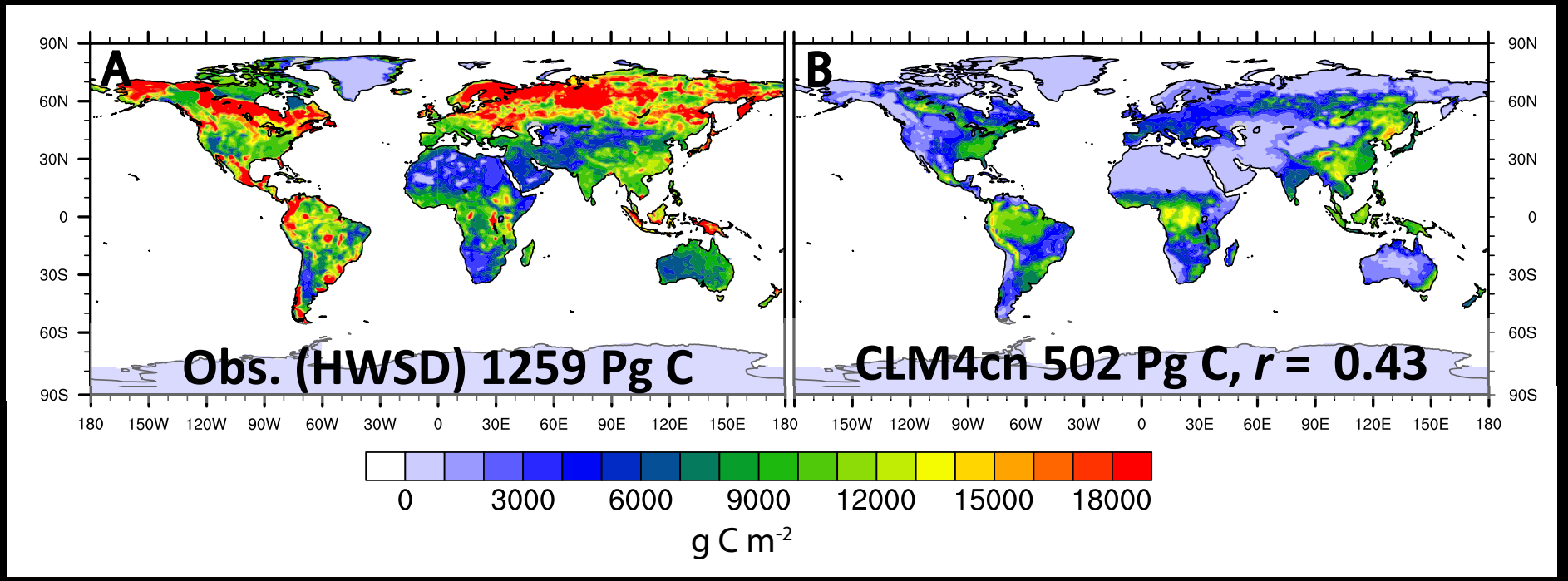
Bonan et al. Global Change Biology 2013

Absurd soil N behavior in CLM4.0-cn

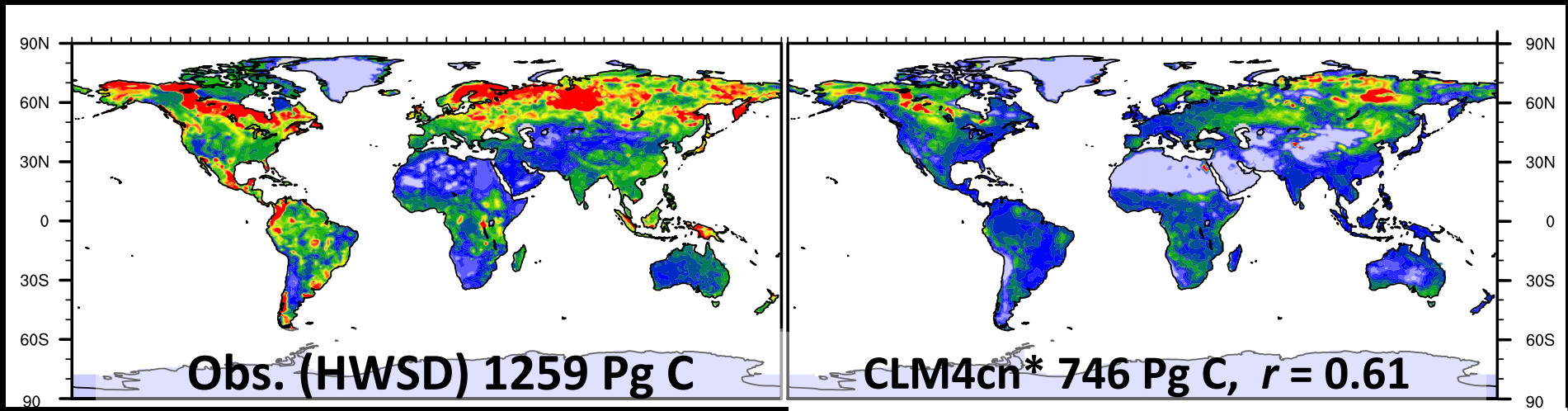


Bonan et al. Global Change Biology 2013

Soil C improved w/ DAYCENT?

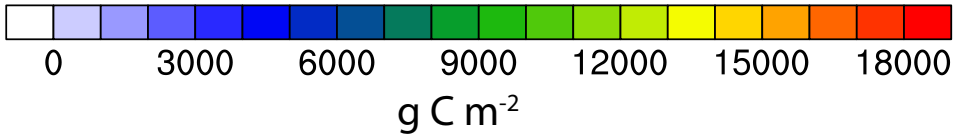


Soil C improved w/ DAYCENT?



* Analytical Solution
"observed" litter inputs

§Modified to simulate soil 0-1 m



Wieder et al. GBC 2014

CONCLUSIONS

CLM4-cn: Anemic soil C pools
Rapid litter turnover
Bizarre soil N dynamics

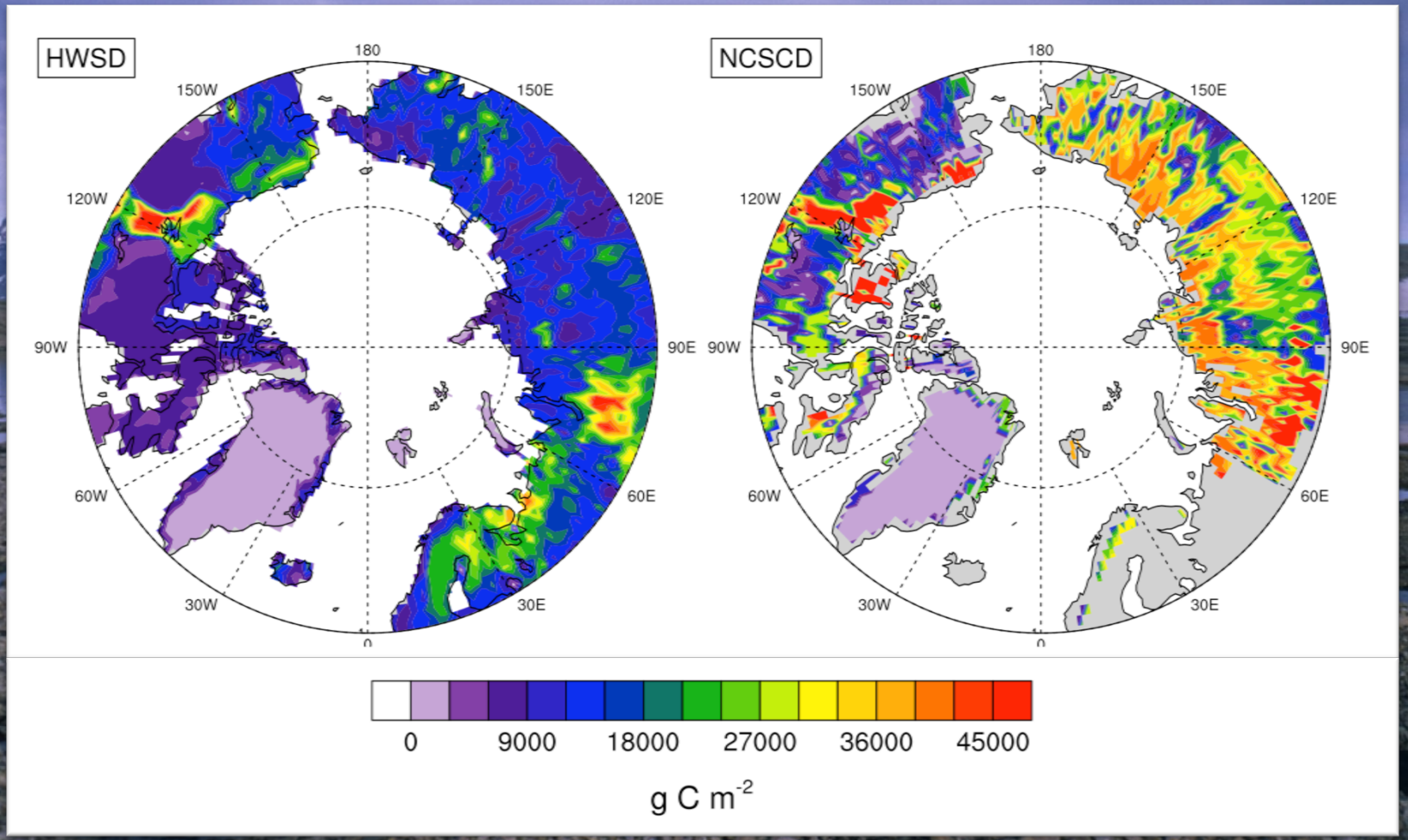
DAYCENT: Better litter turnover
Better soil C pools*

*with modifications for depth

CLM4.5bgc & 5.0 (CLM “present”)

www.fedre.org

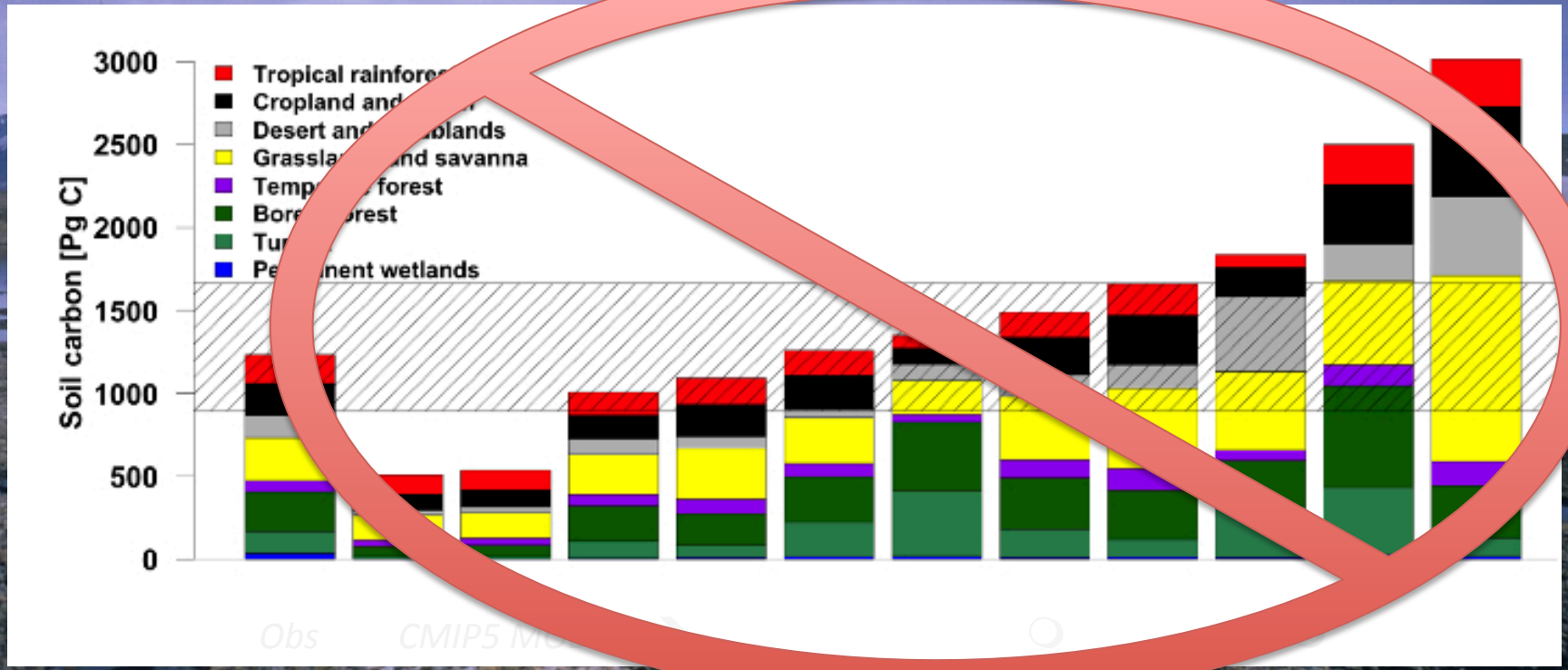
Permafrost C “observations”



www.fedre.org

NCSCD from Hugelius et al. 2013

Permafrost C in models

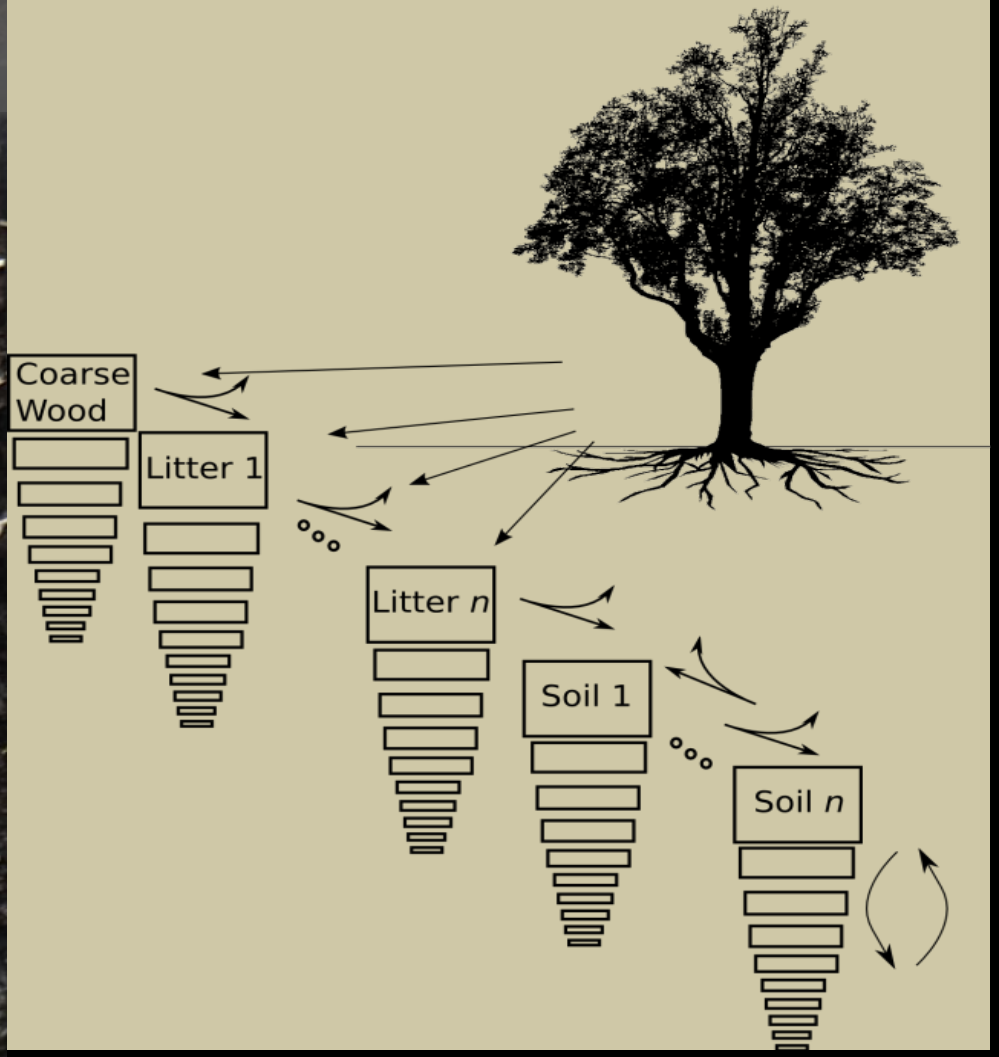


Todd-Brown et al. Biogeosciences 2013

Permafrost soils CLM4.5bgc & 5.0

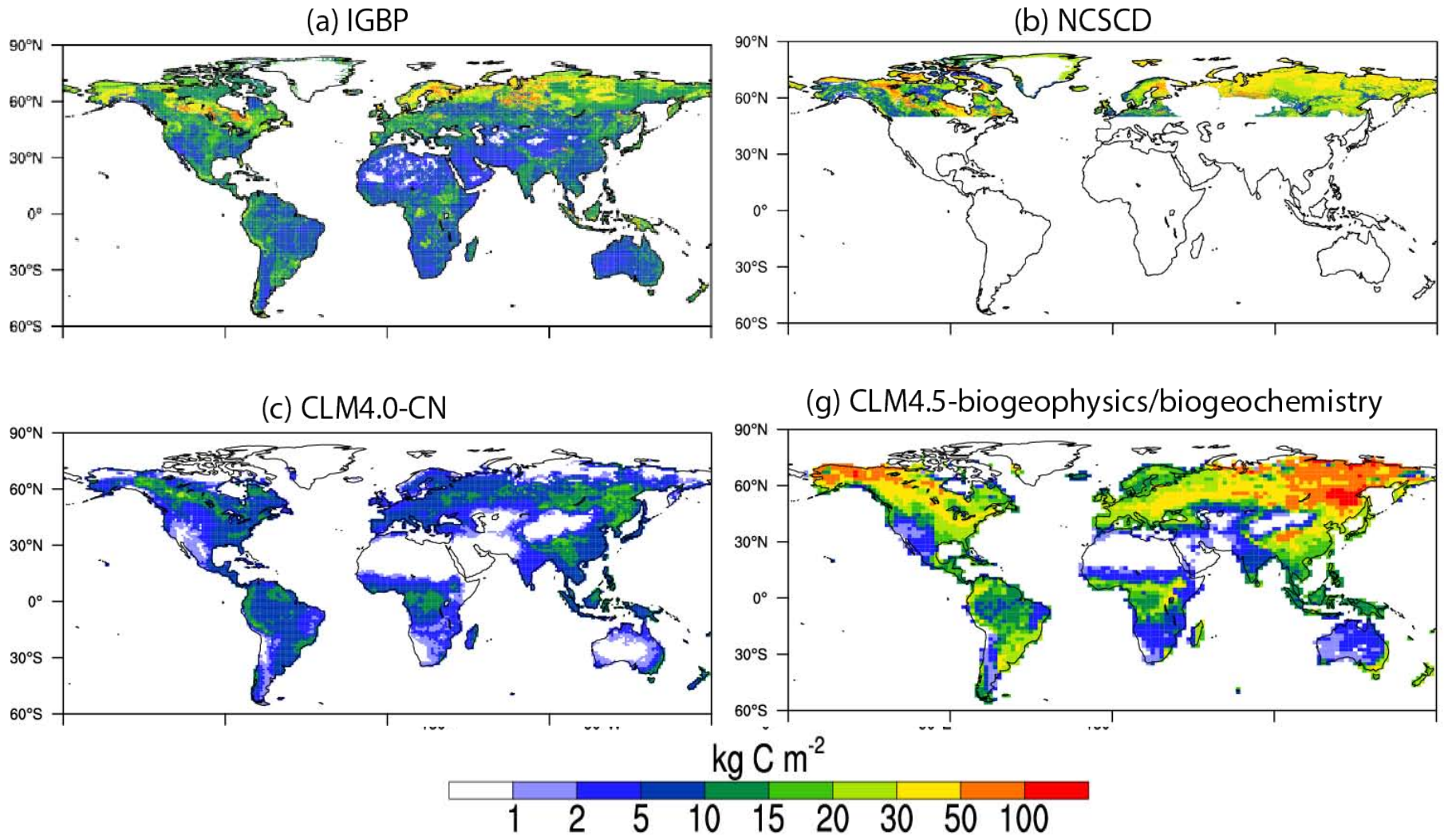
Carbon rich
Vertically complex

CENTURY-like soil biogeochemistry

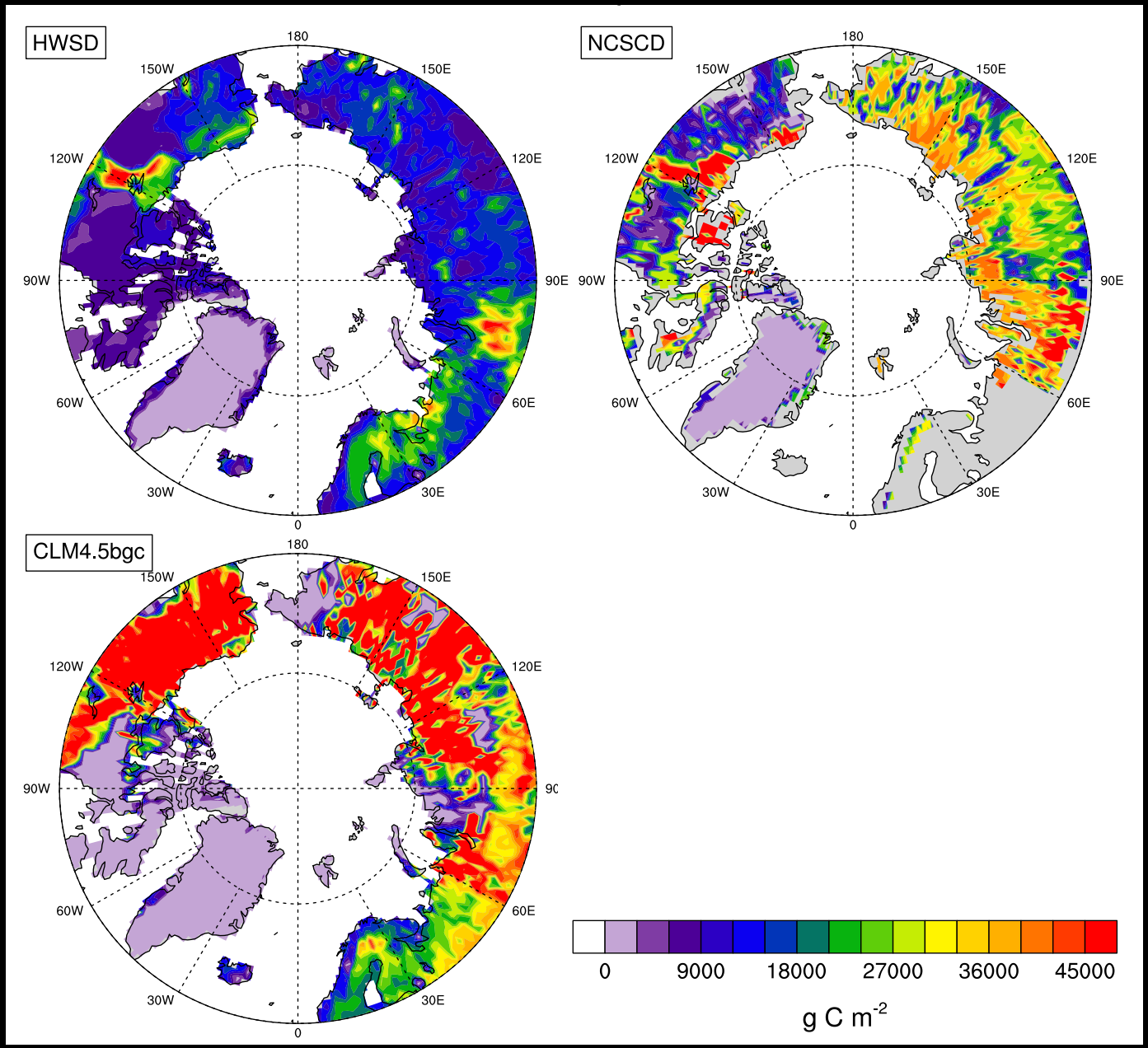


Koven et al. *Biogeosciences* 2013

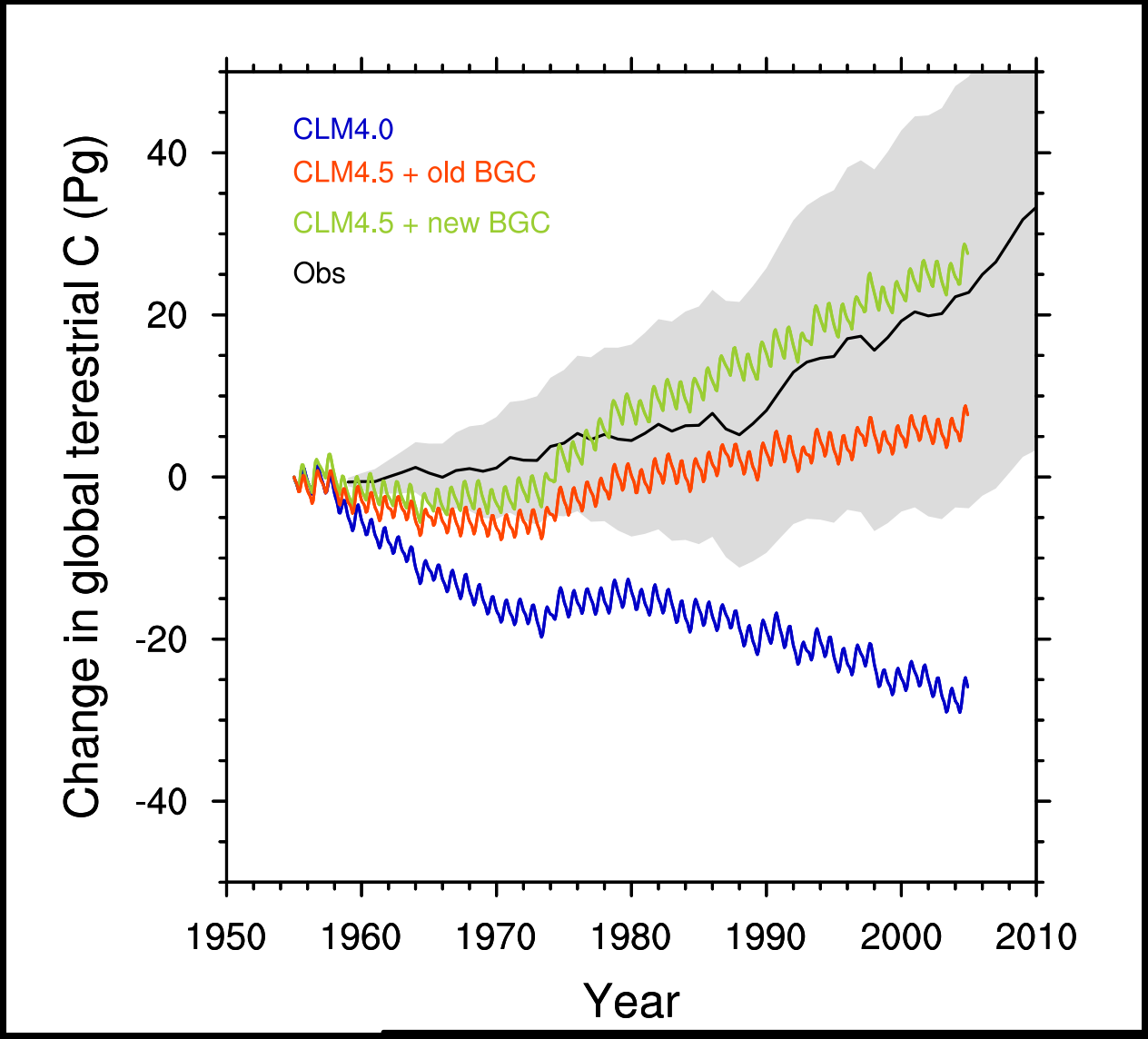
Permafrost soils CLM4.5bgc



Koven et al. *Biogeosciences* 2013

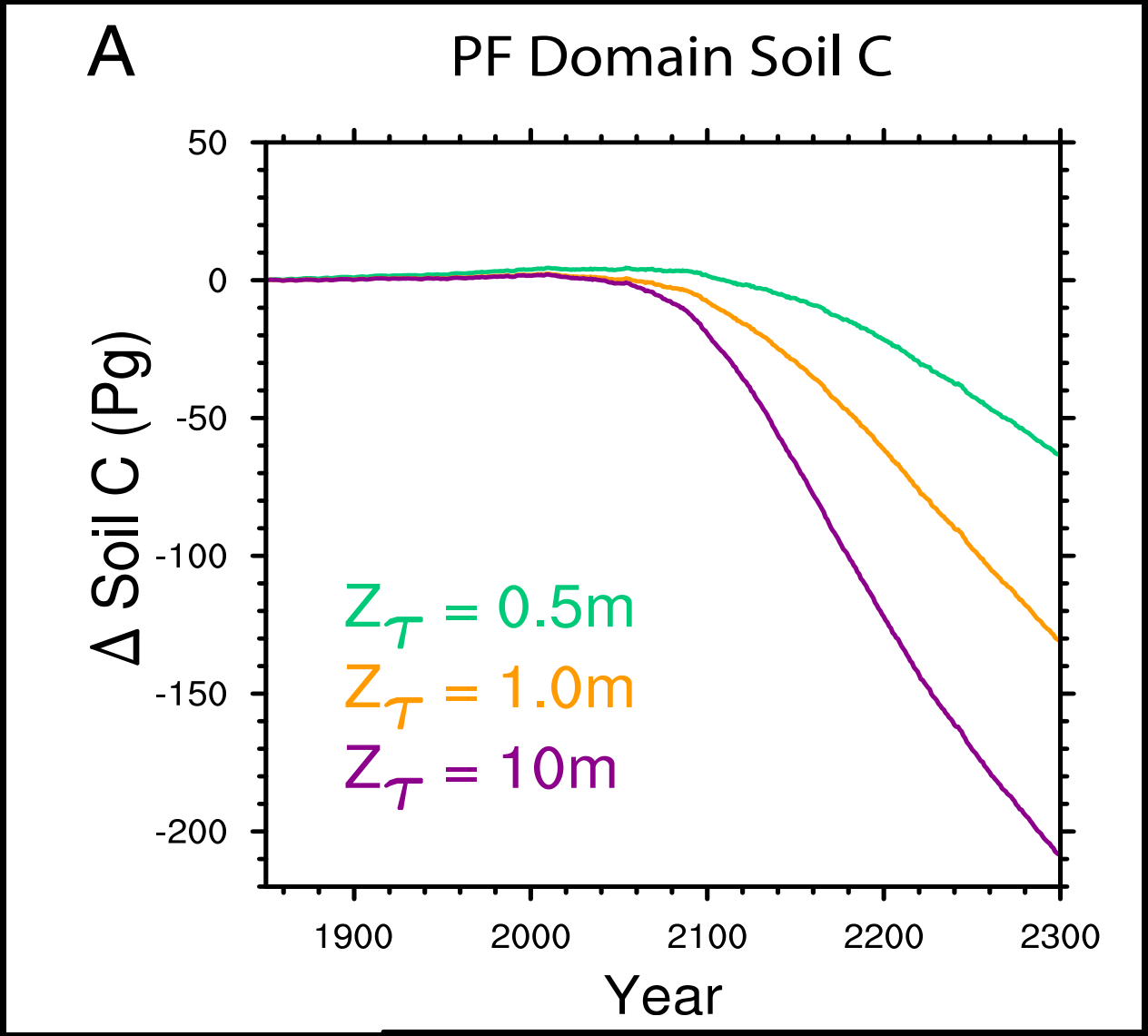

HWSD
NCSCD
CLM4.5bgc
180
150W
150E
120W
120E
90W
90E
60W
60E
30W
30E
0
0
9000
18000
27000
36000
45000
g C m-2

20th century land C sink



Koven et al. *Biogeosciences* 2013

Permafrost soil C loss



Koven et al (2015) PNAS

Conclusions

CLM4.5bgc: Vertically resolved
Large soil C pools
20th century land sink
Permafrost dynamics

CLM 5: beyond C

Land surface heterogeneity
CLM subgrid tiling structure

Gridcell

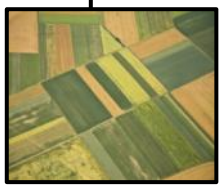
Landunit

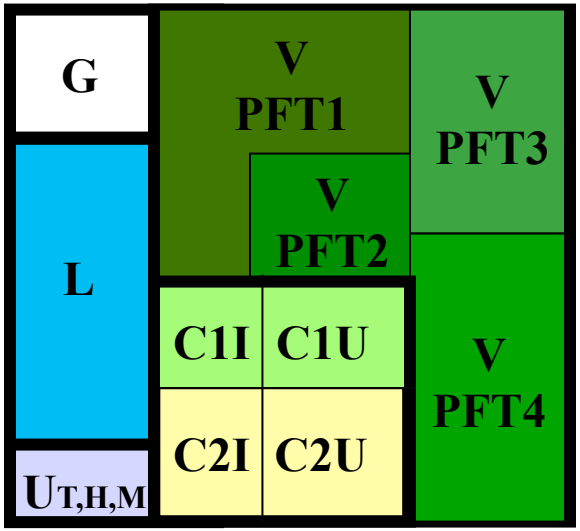

Vegetated


Lake

Urban


Glacier


Crop



Column


Soil


Unirrig

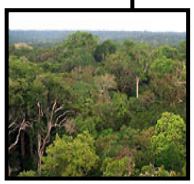

Irrig


Unirrig


Irrig

PFT


PFT1


PFT2


PFT3


PFT4 …


Crop1


Crop1


Crop2

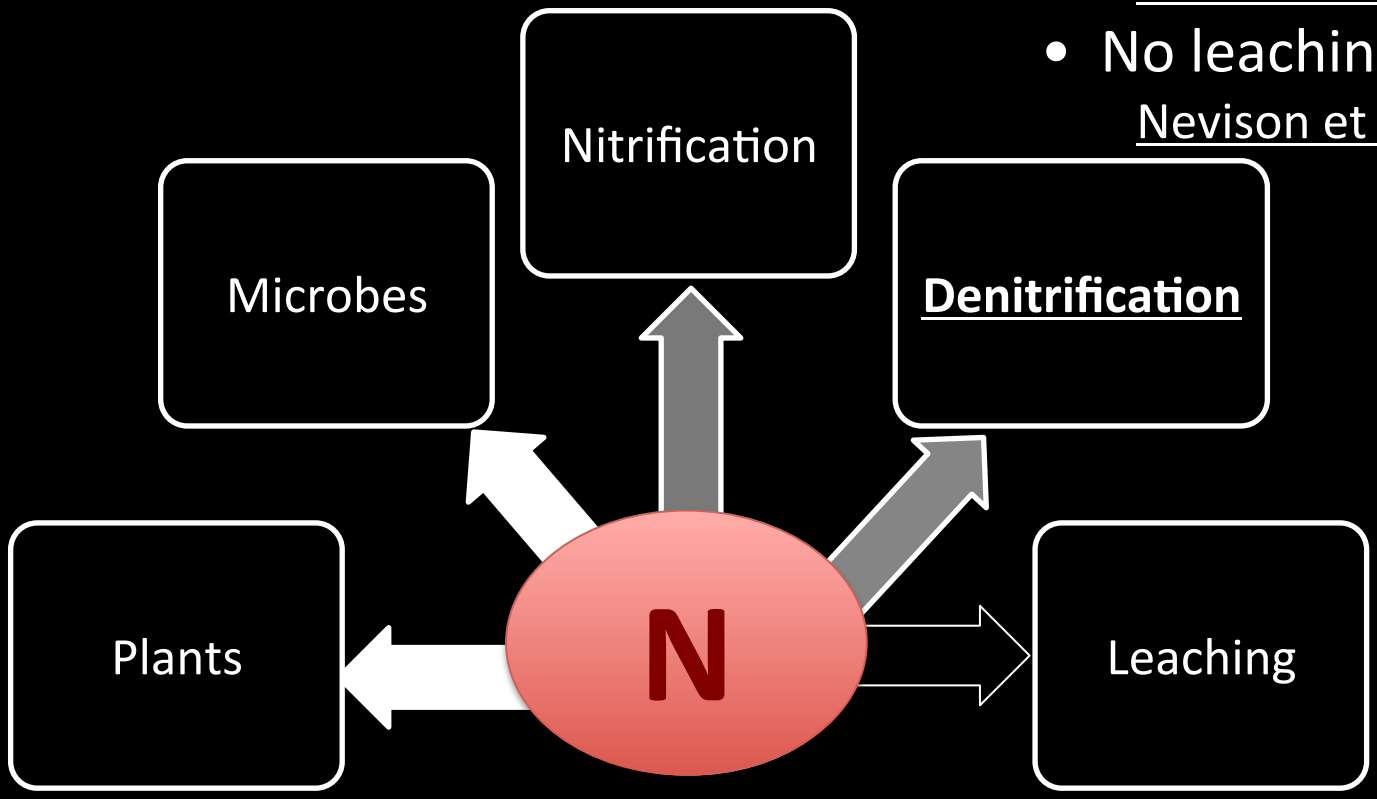

Crop2 …

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 + ACME

Known Issues:

- TBD…

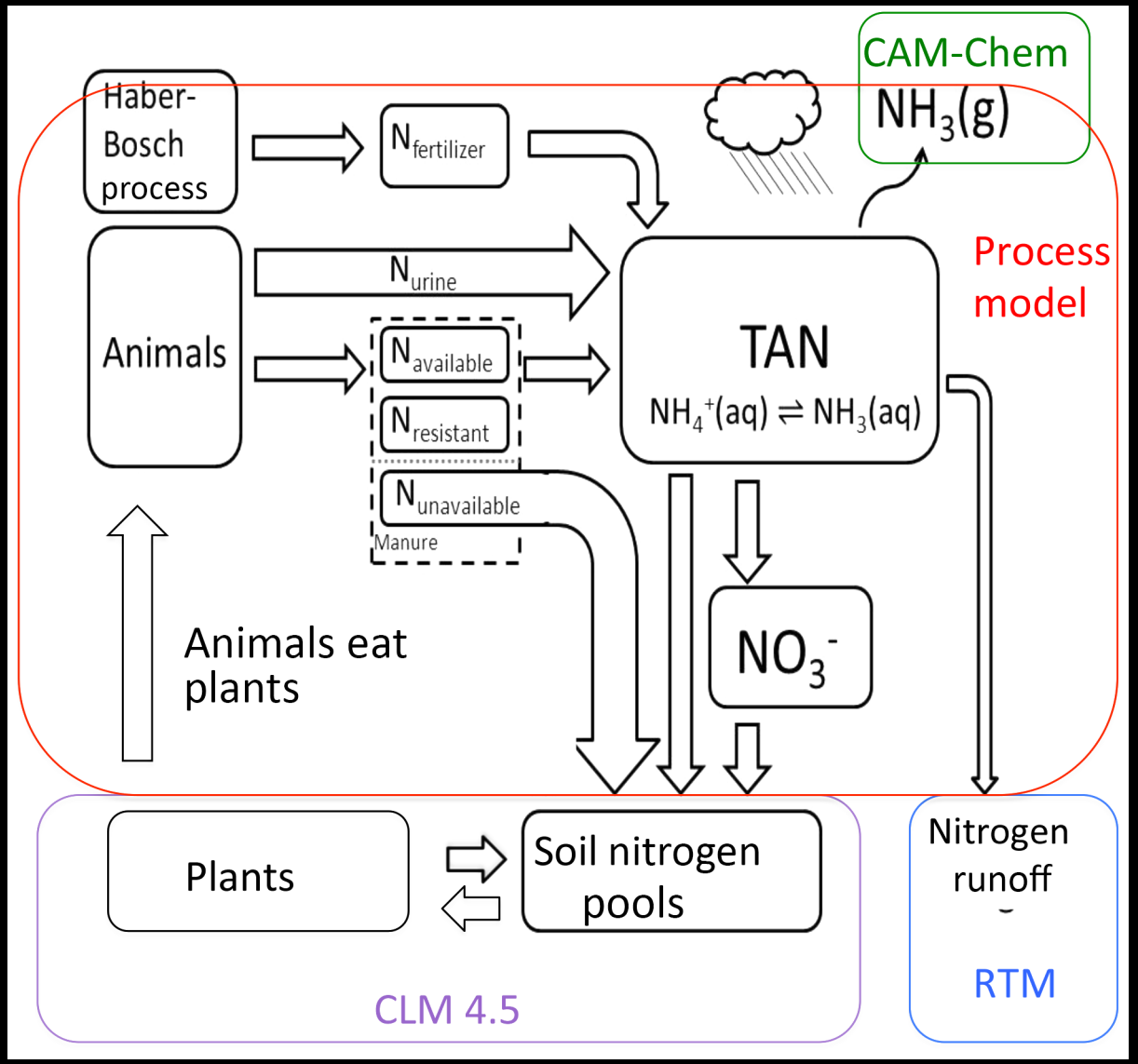
ECA approach

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

Soil Biogeochemistry in CLM 5+

Adding functionality & reality

Soil Biogeochemistry in CLM 5+
Integrate the TAN model



Riddick et al. (2016) BG

N uptake & competition

CLM5 + ACME

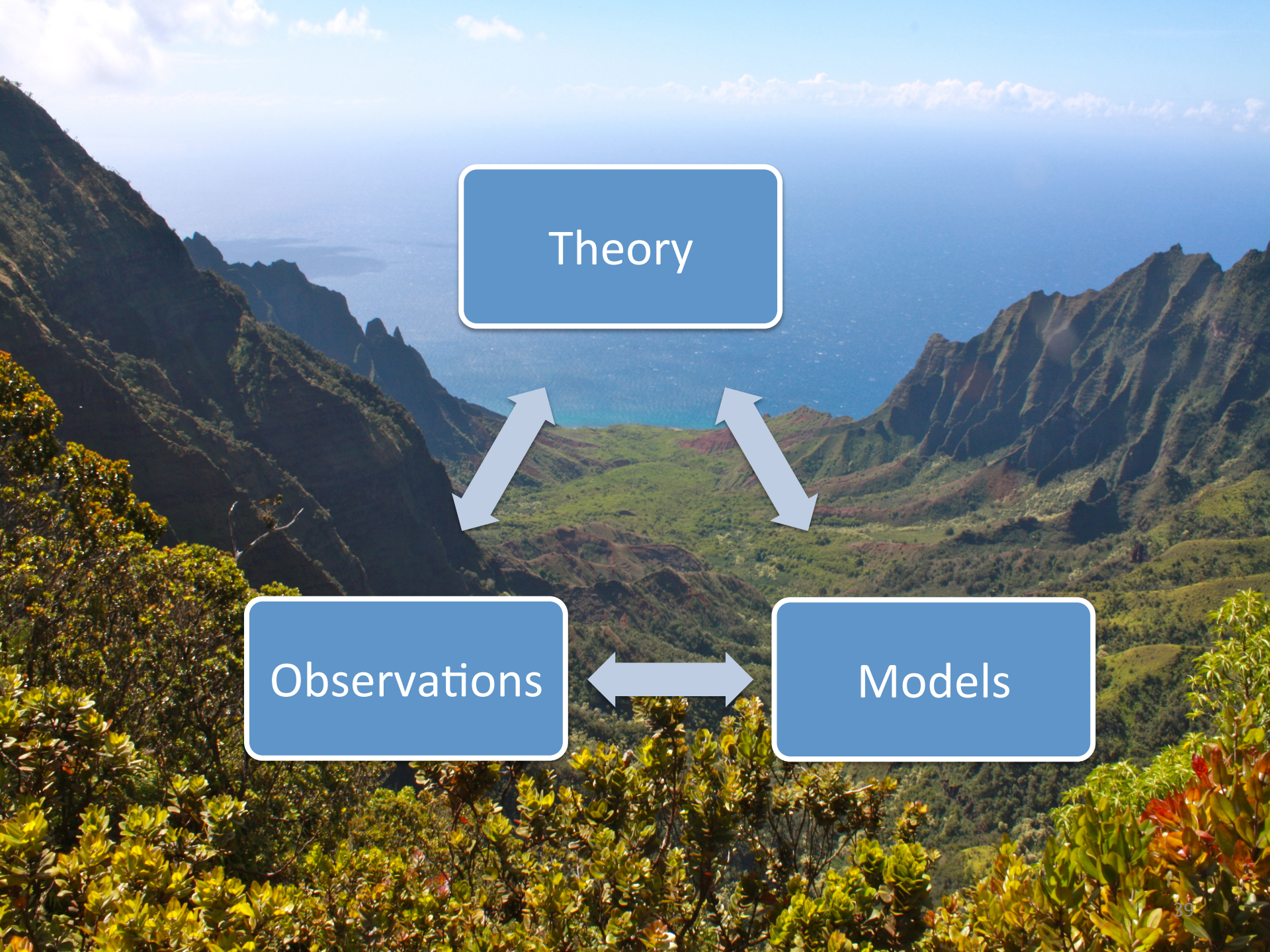
Known Issues:

- TBD…

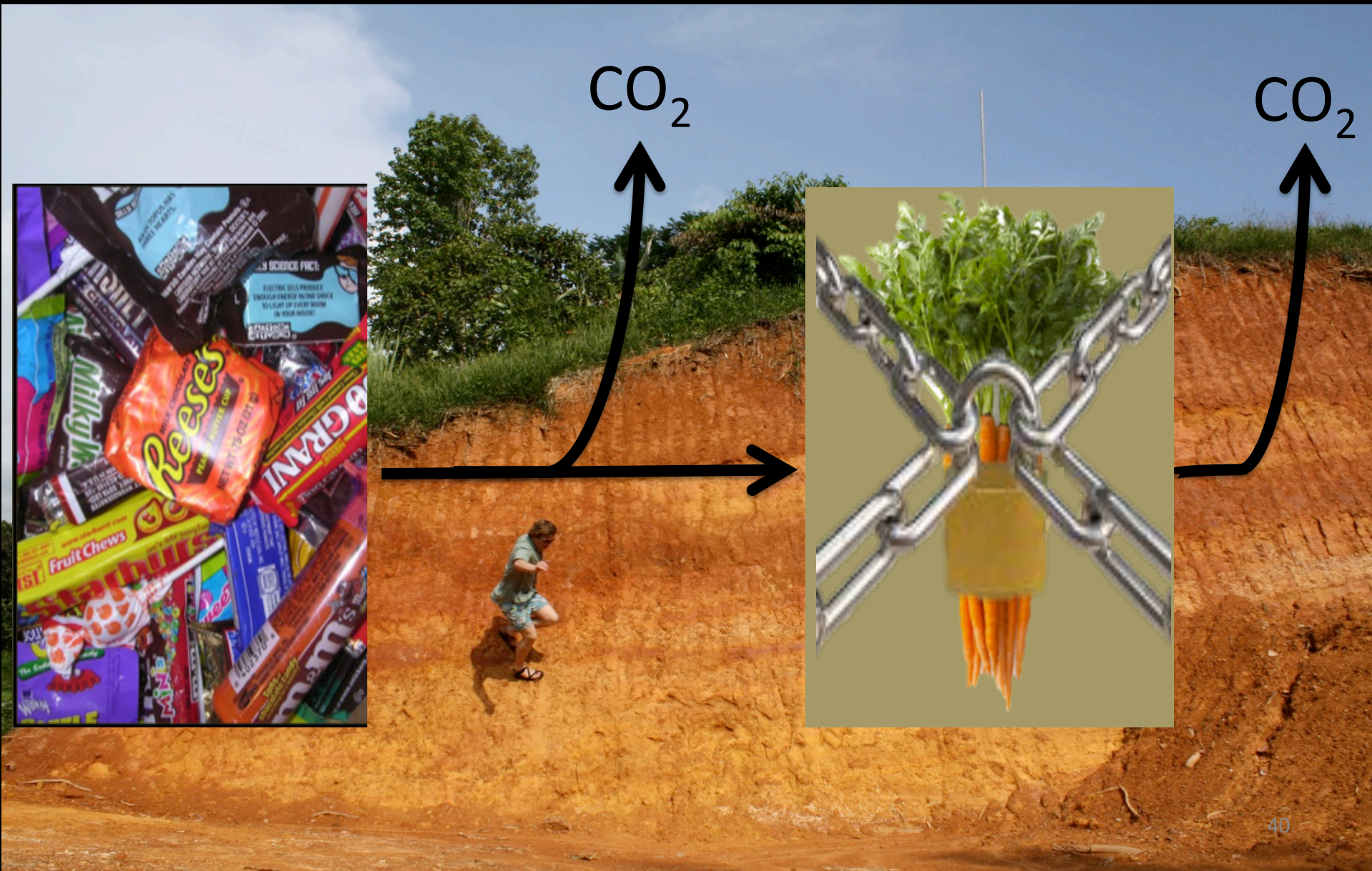
ECA approach

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

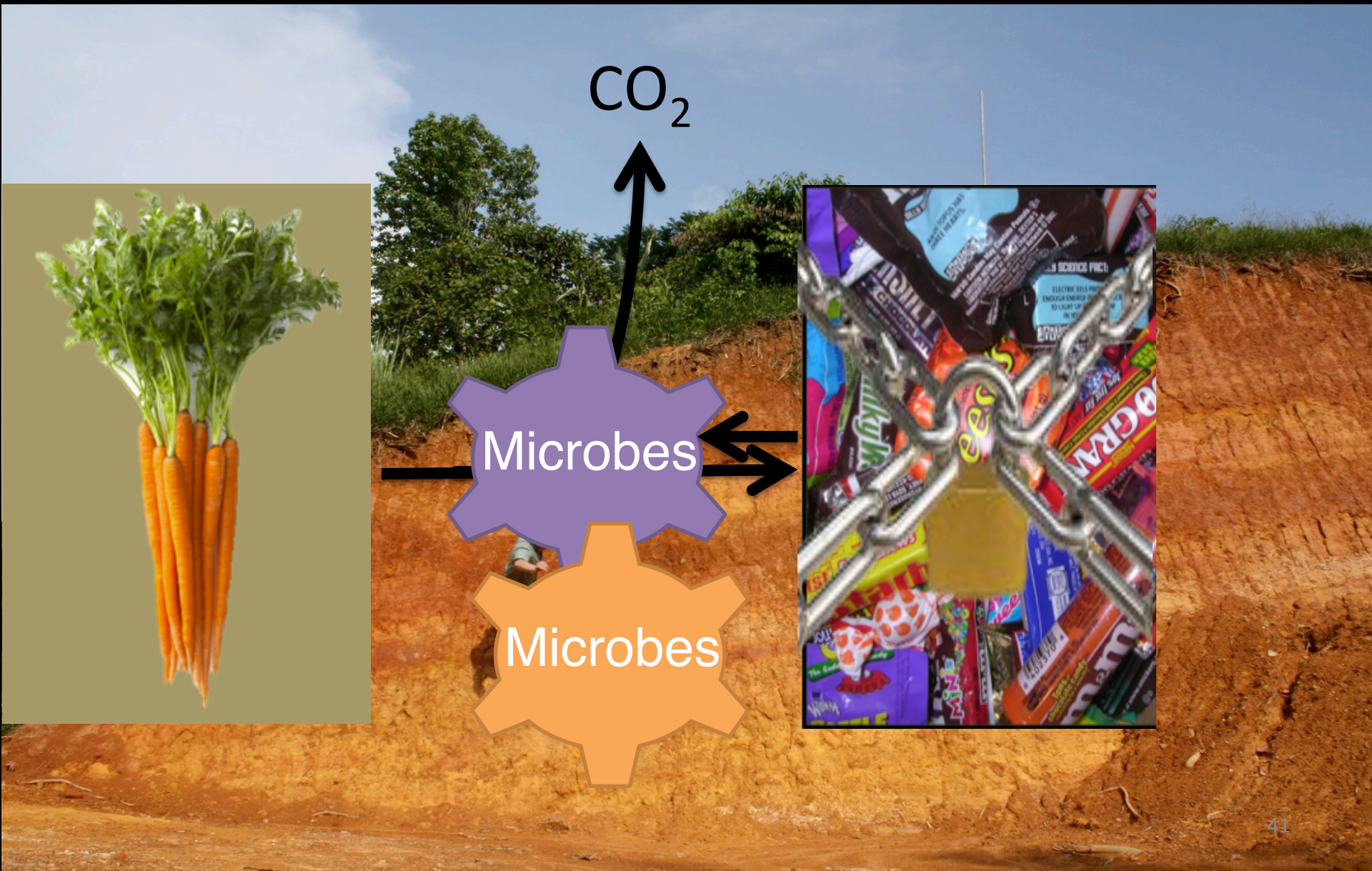
[Greater] Sub-grid heterogeneity


Theory
Observations
Models

Time to **rethink** soil biogeochemical models?

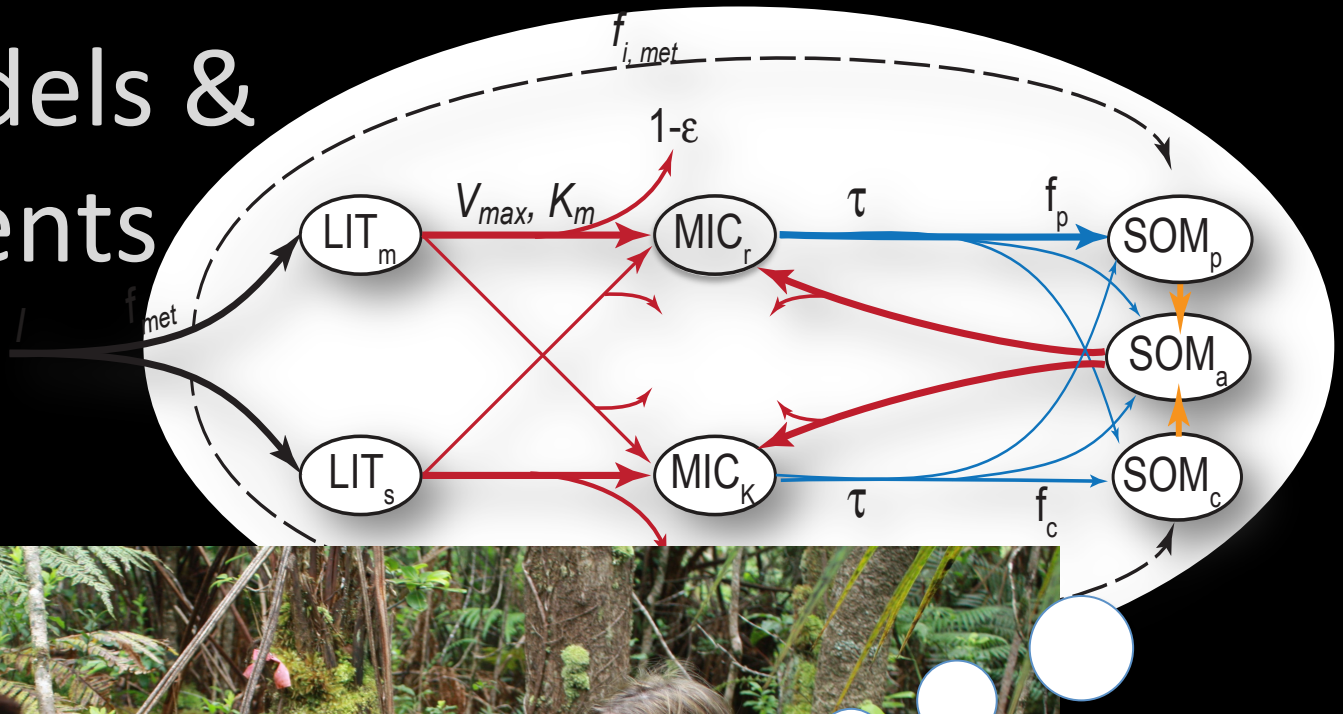


The **catalyst & conditions** matter

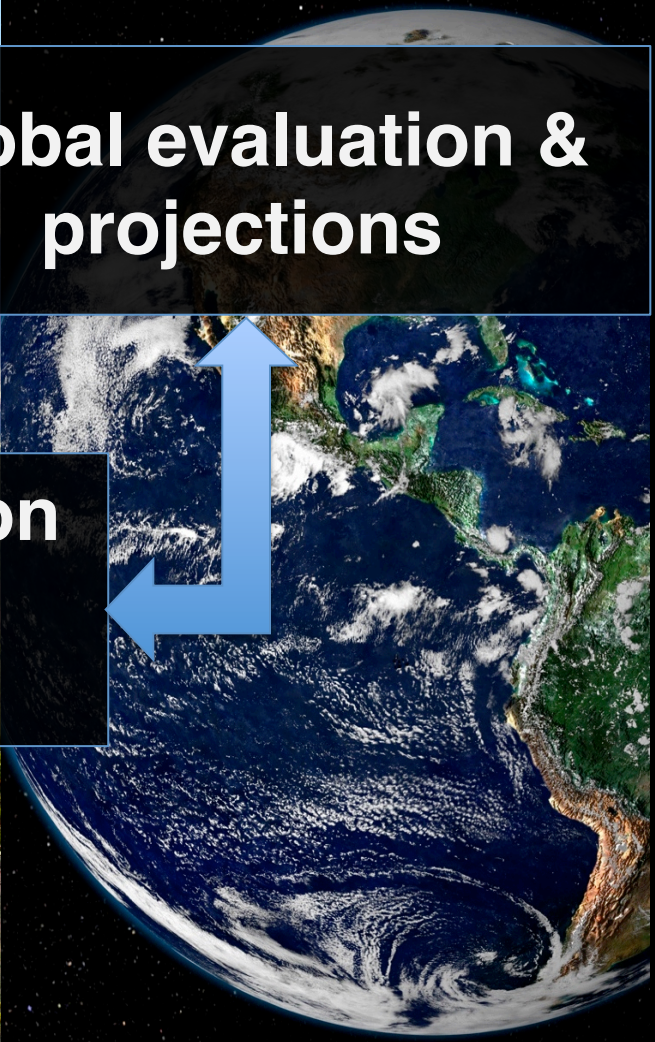


Functional traits and the global C cycle

Linking models & measurements



Moving forward?



Global evaluation & projections

Landscape variation & response to perturbations

Functional diversity & physiological traits

Building confidence

by considering **life**