Soil dynamics in a changing world

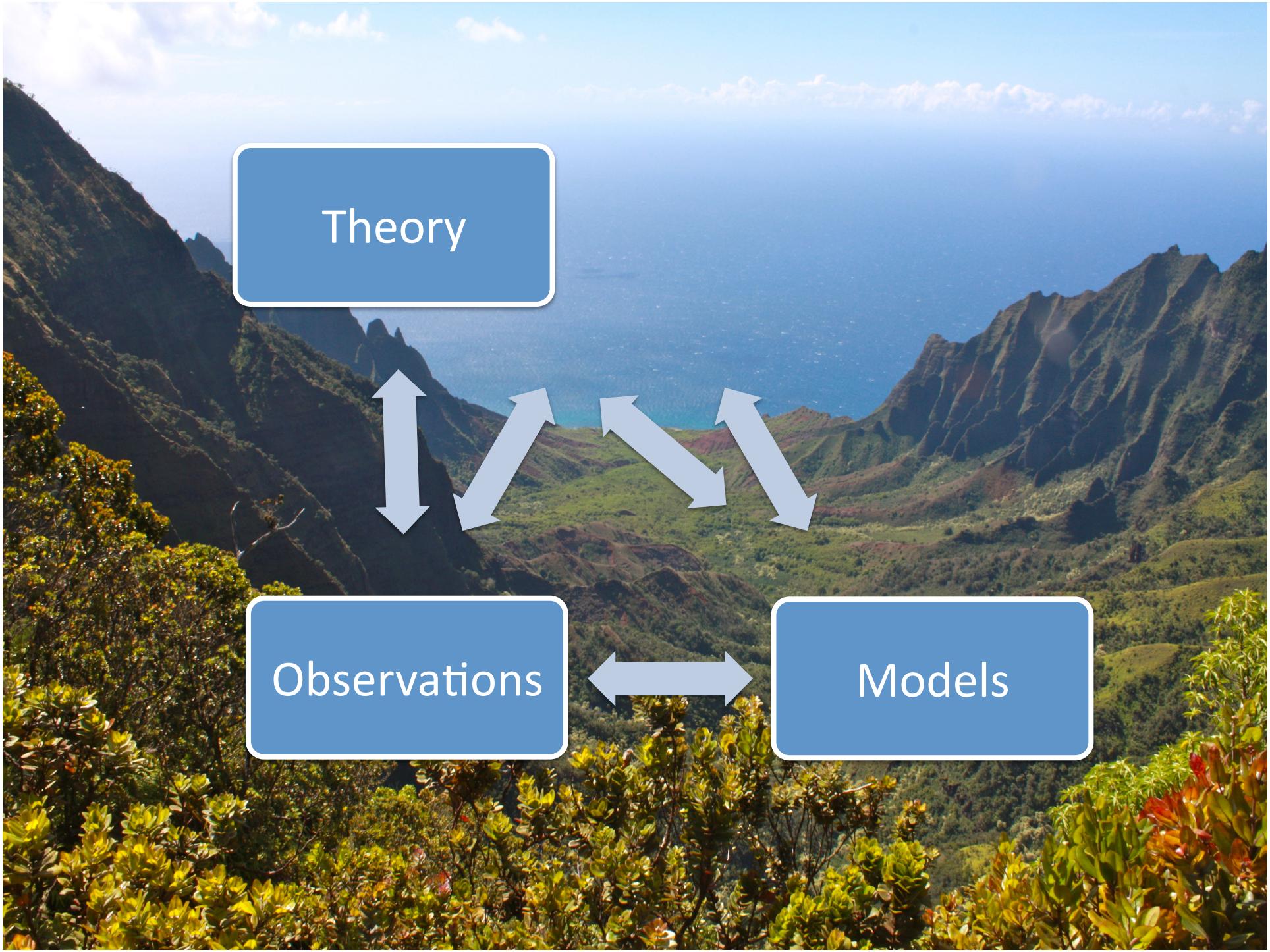
Will Wieder

2014 CLM Tutorial

NCAR

NSF

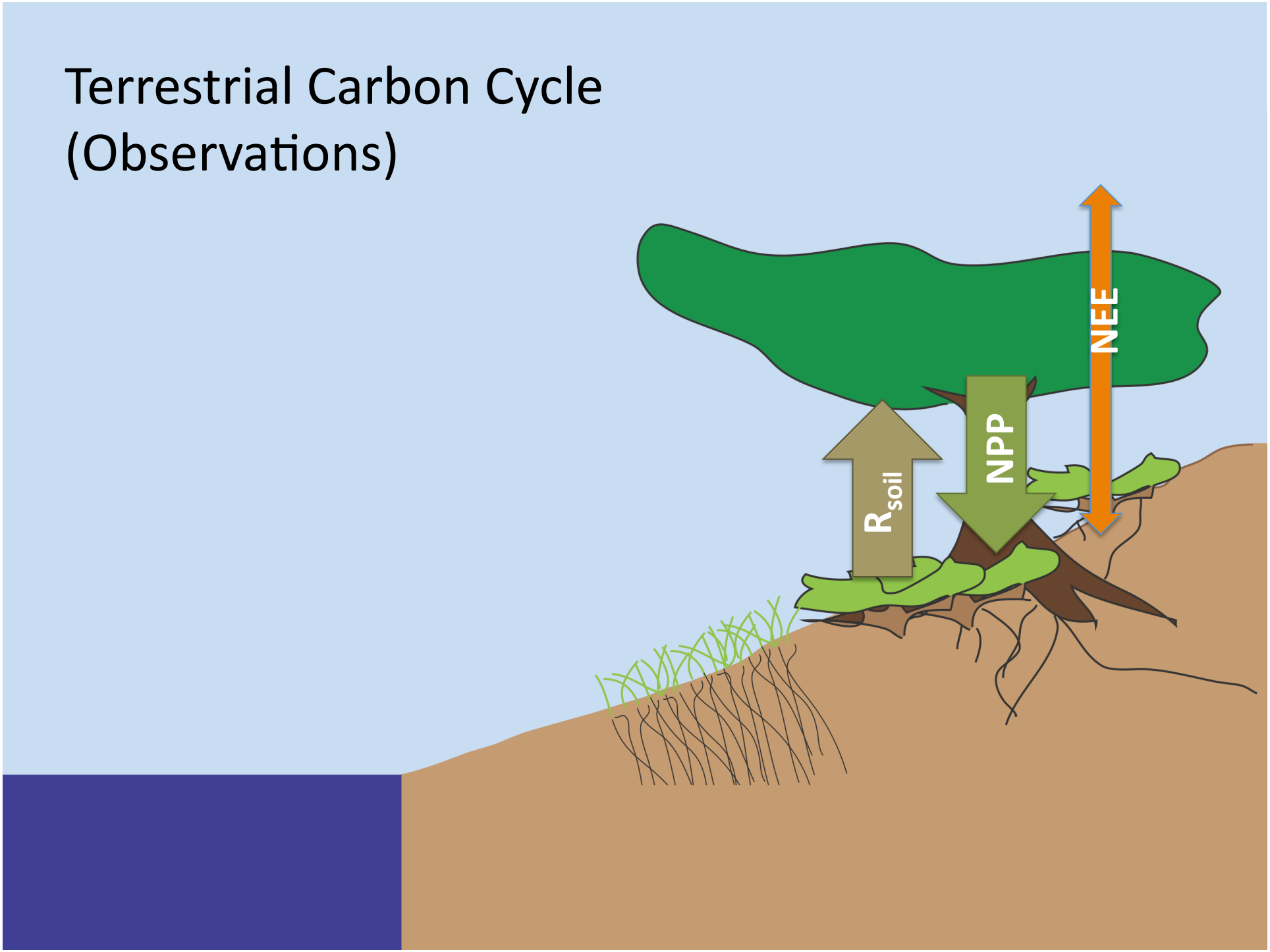
How does an ecologist use and improve CLM?


Theory
Observations
Models

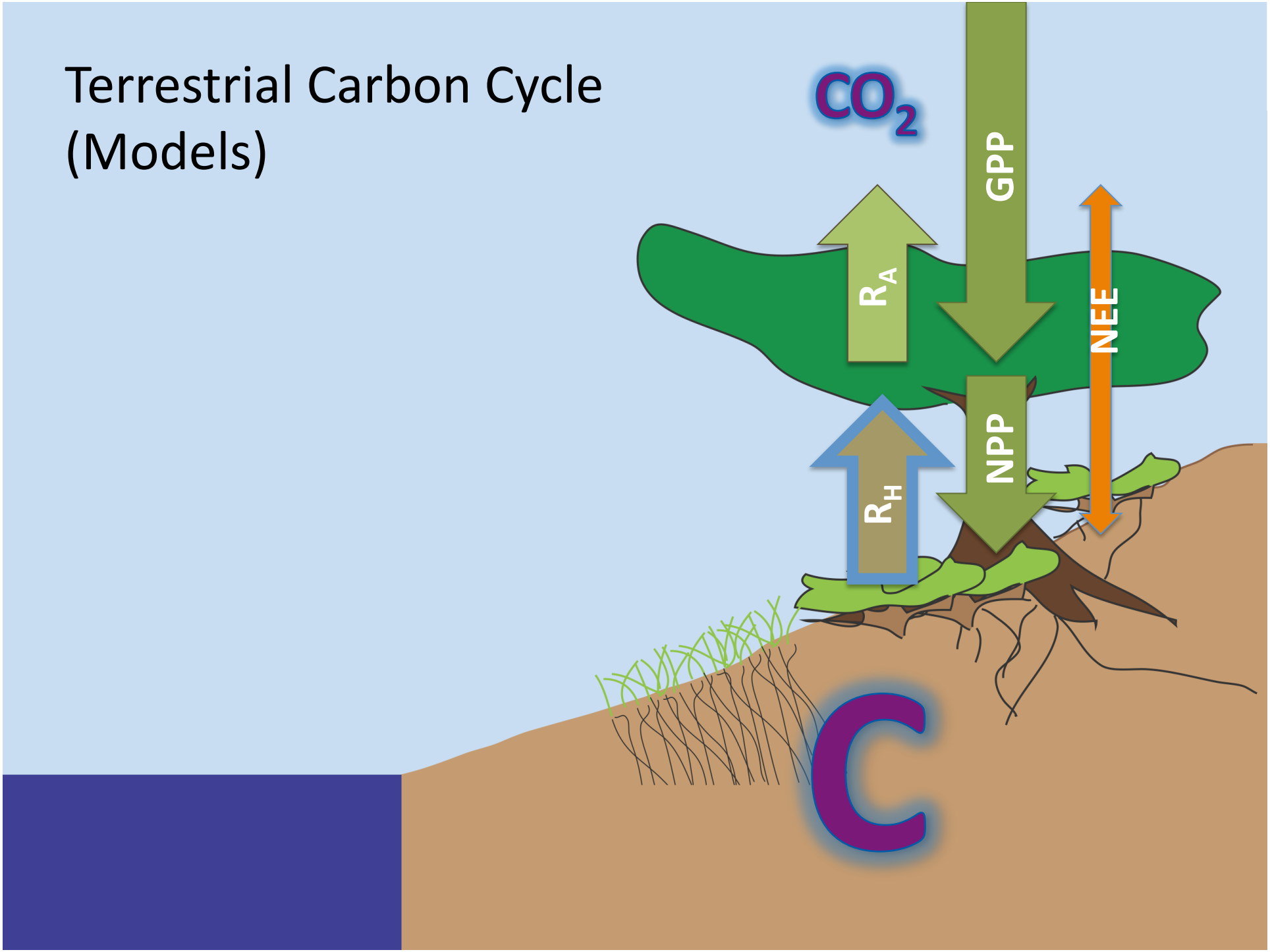
Perspectives on the C cycle

1. Global C cycle (esp. soils)
2. CLM soil biogeochemistry:
    - Past
    - Present &
    - Future

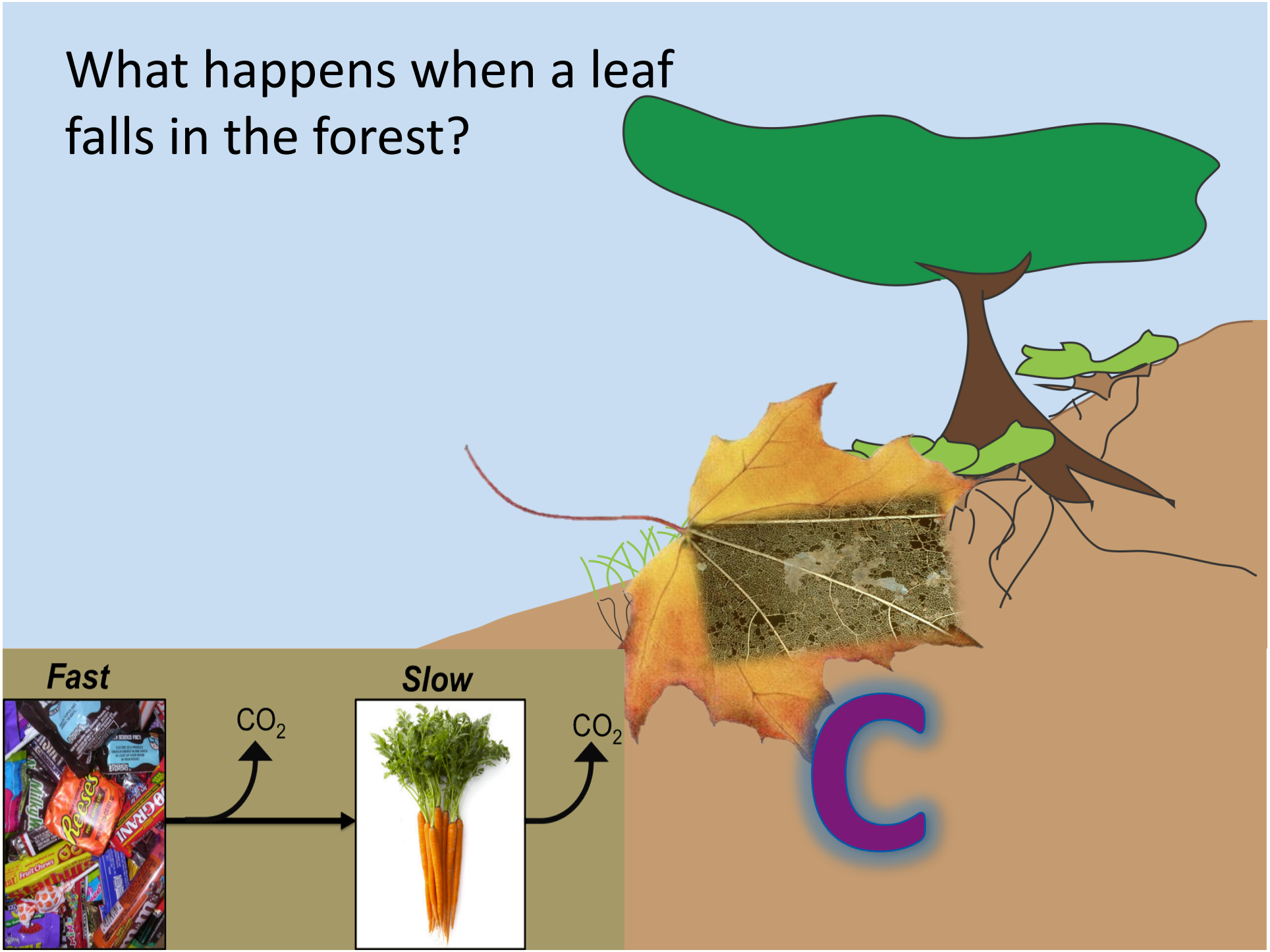
Terrestrial Carbon Cycle (Observations)



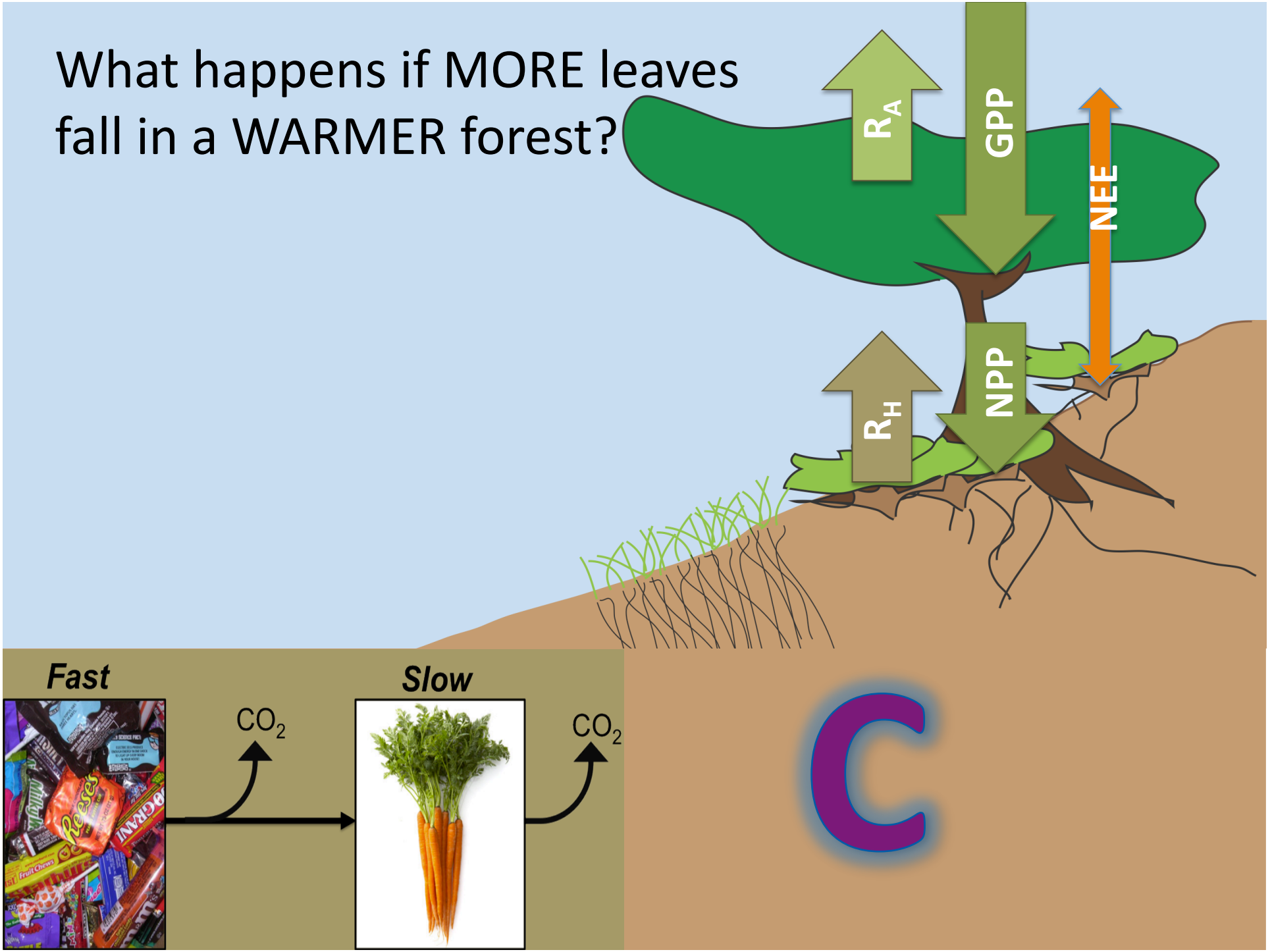
Terrestrial Carbon Cycle (Models)



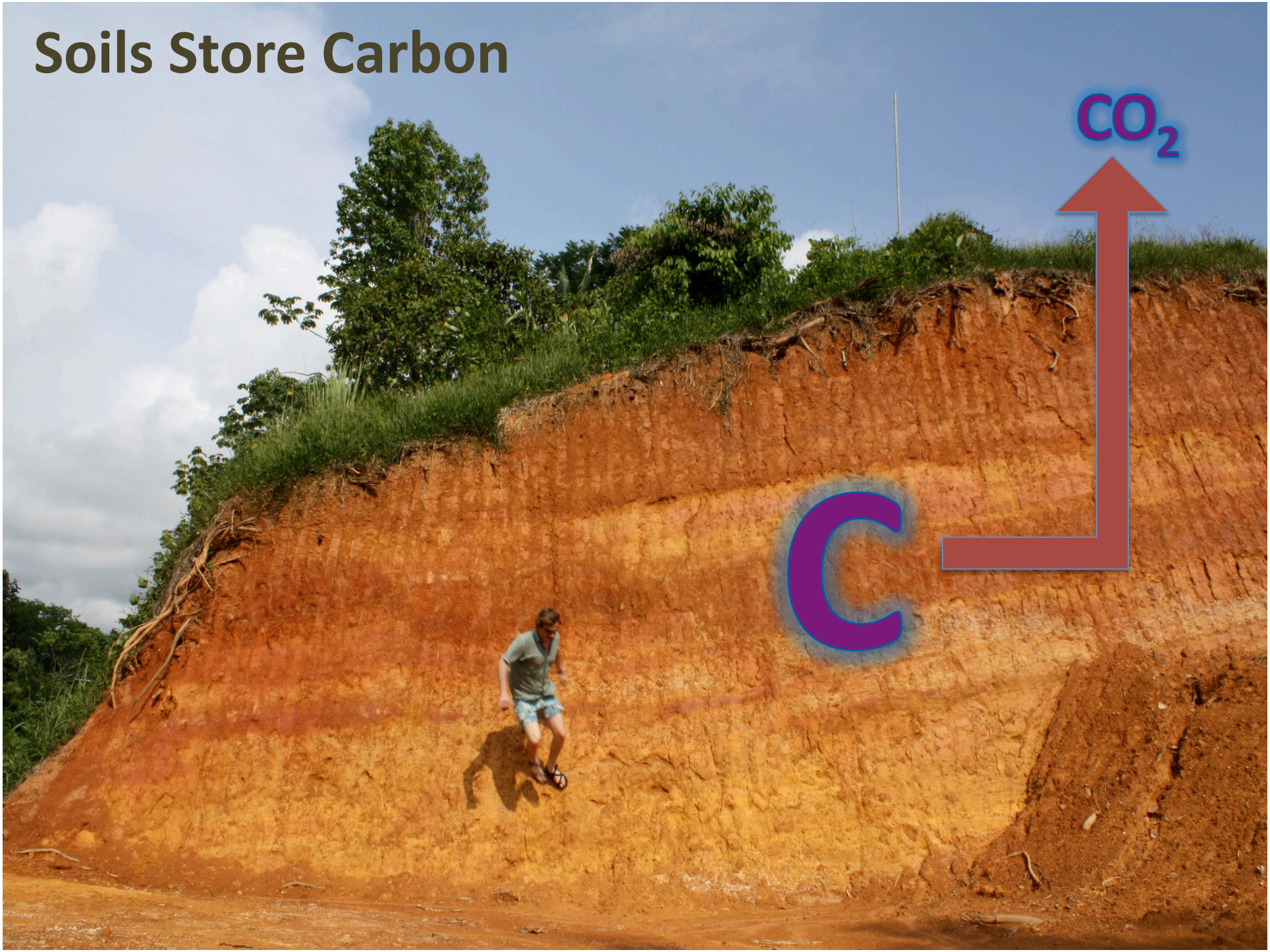
What happens when a leaf falls in the forest?



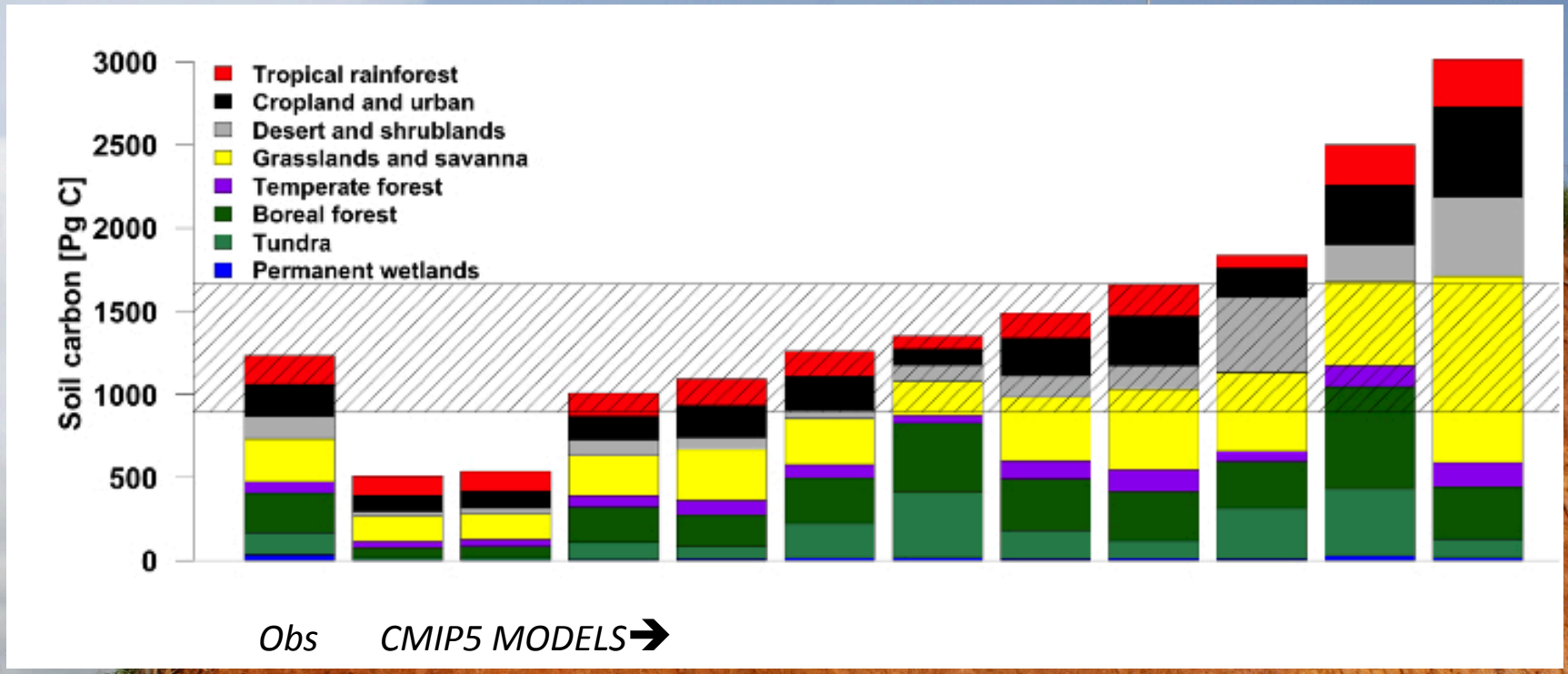
What happens if MORE leaves fall in a WARMER forest?

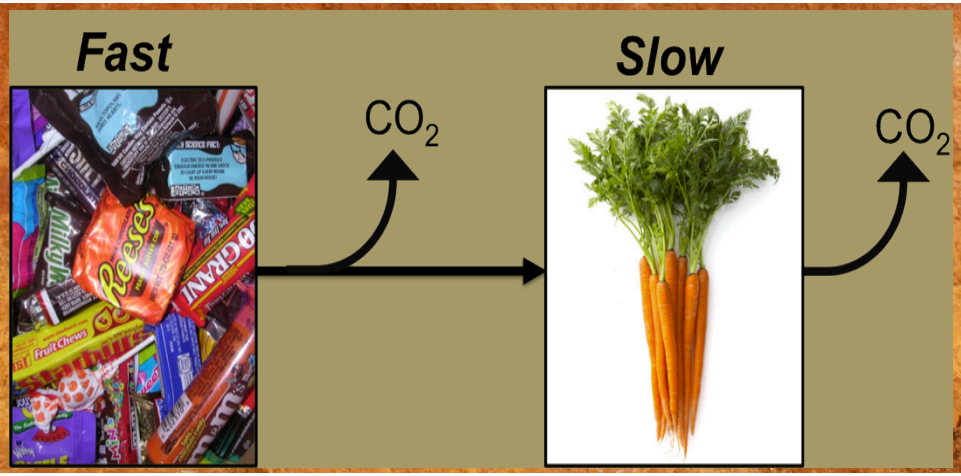


Soils Store Carbon



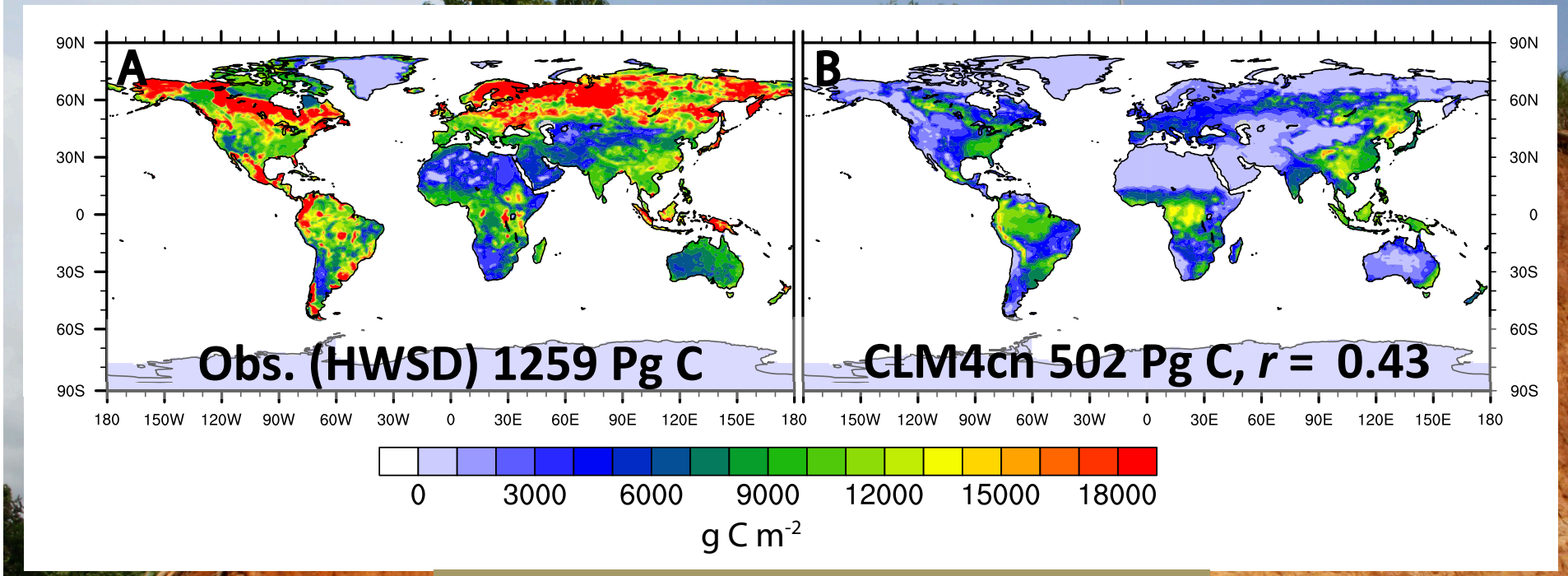
CMIP5 Models = 6x variation

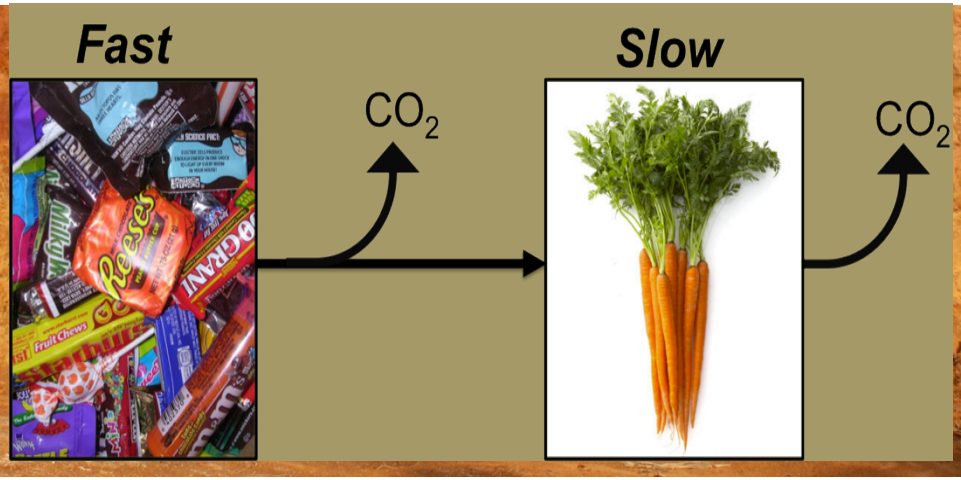




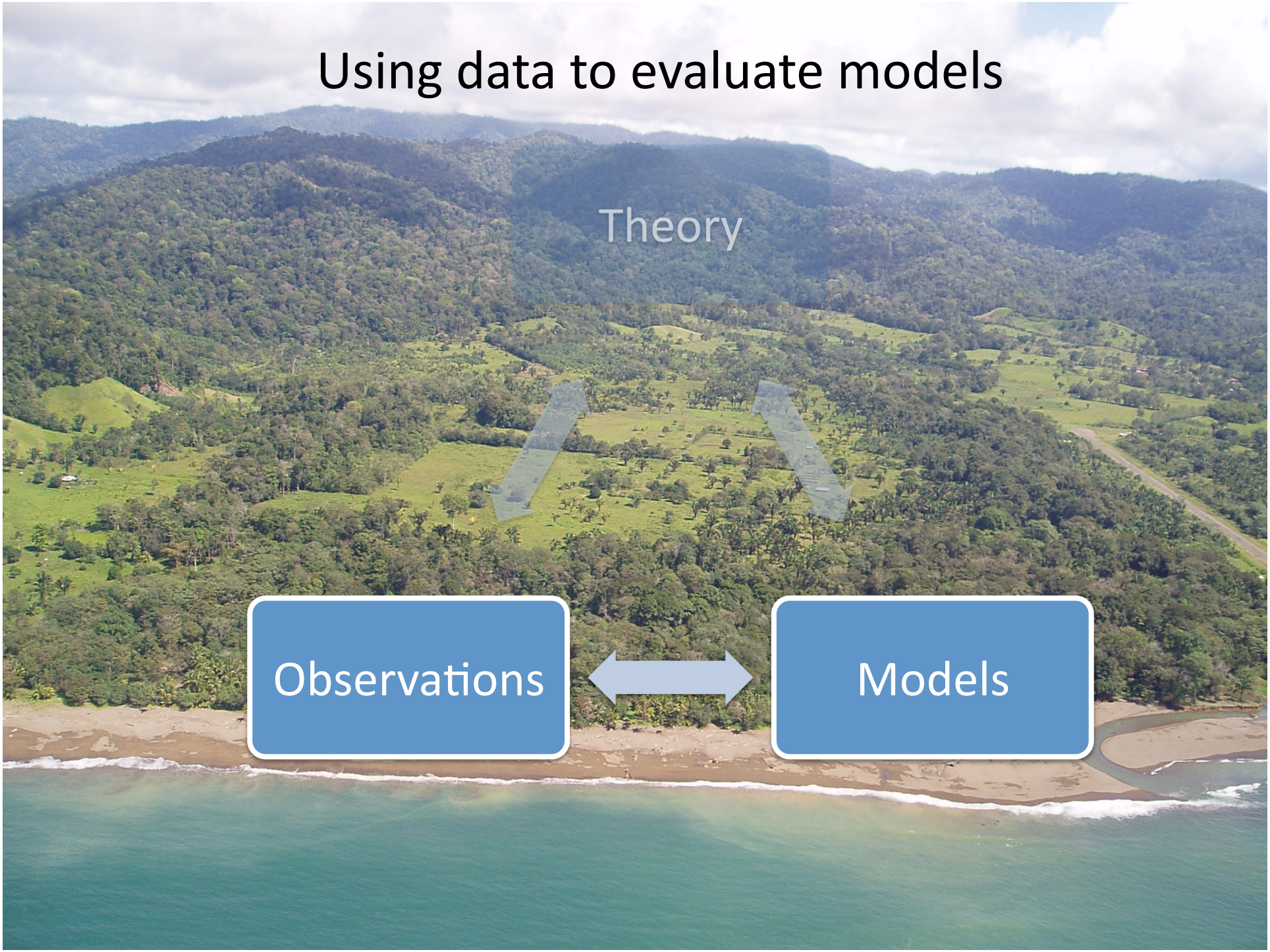
Todd-Brown et al. Biogeosciences 2013, Friedlingstein et al. 2006; Jones et al. 2003

CLM4.0-cn (CLM “past”)



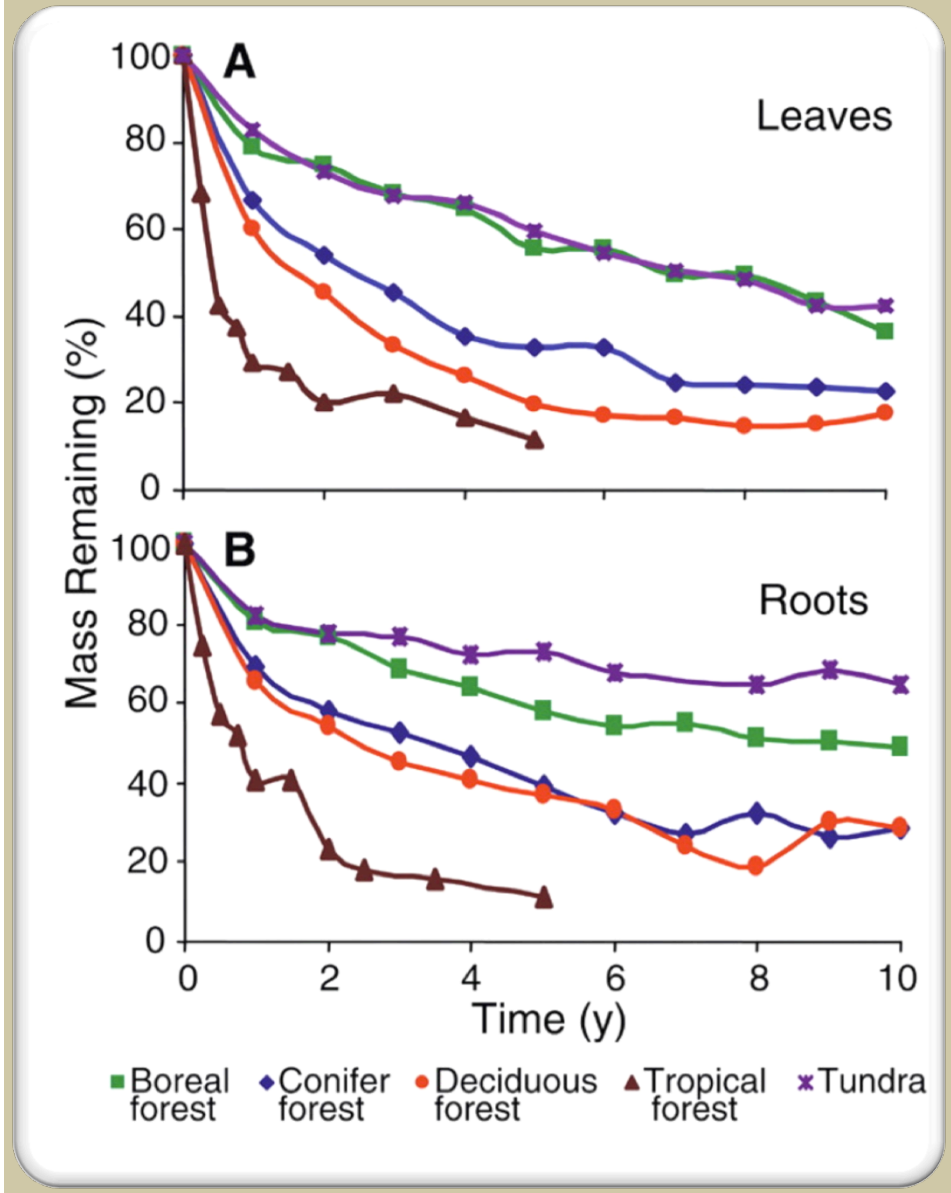


Using data to evaluate models



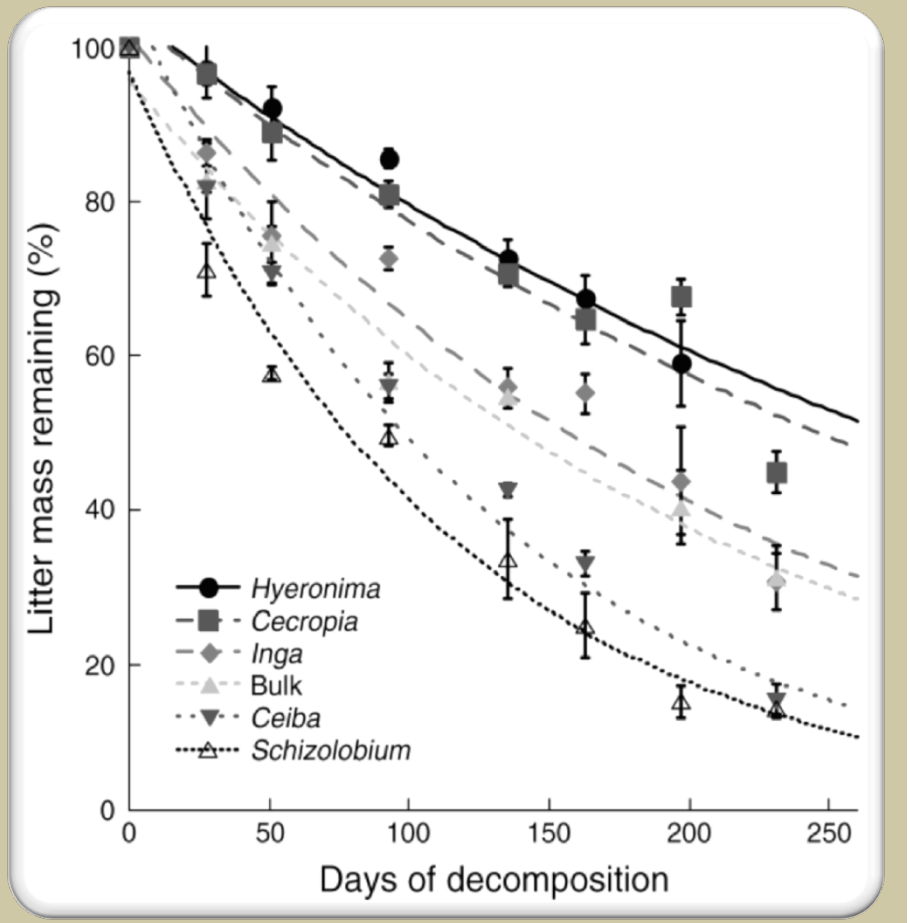



Climate matters



Parton et al. Science 2007

Chemistry matters



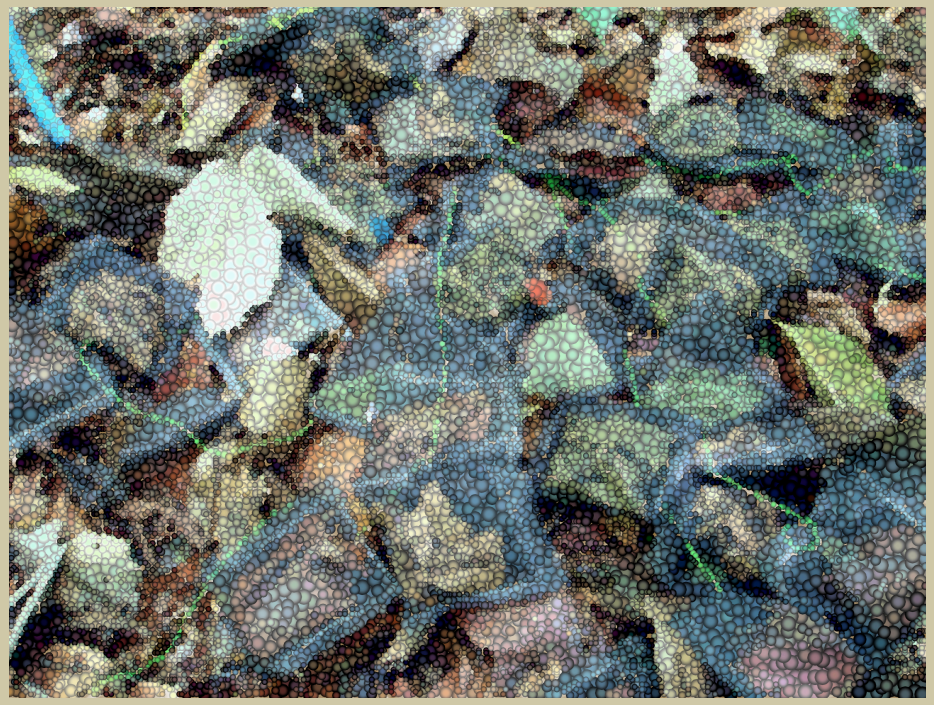
Wieder et al. Ecology 2009

Which model looks more like reality?

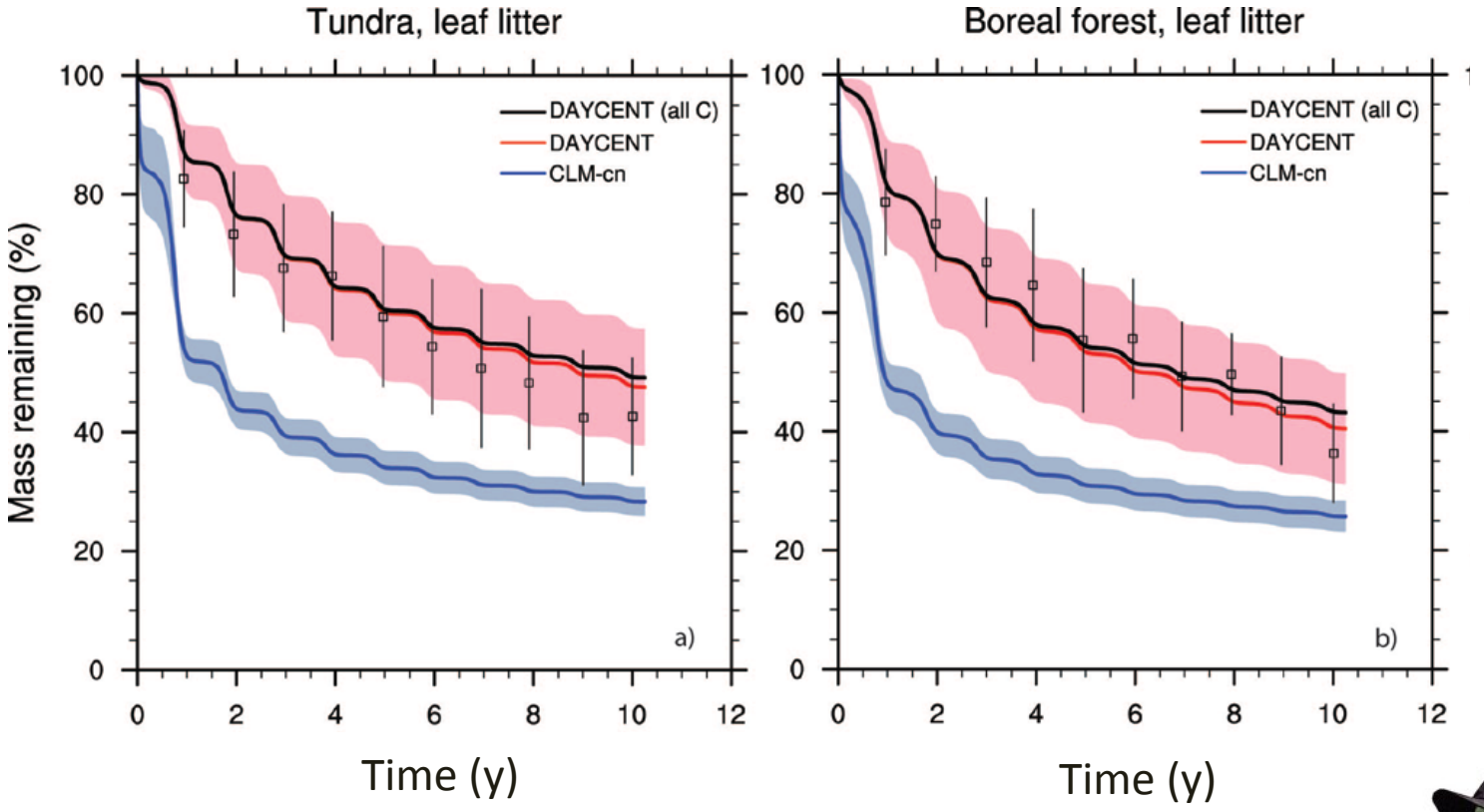
CLM4.0-cn
DAYCENT

vs.

LIDET

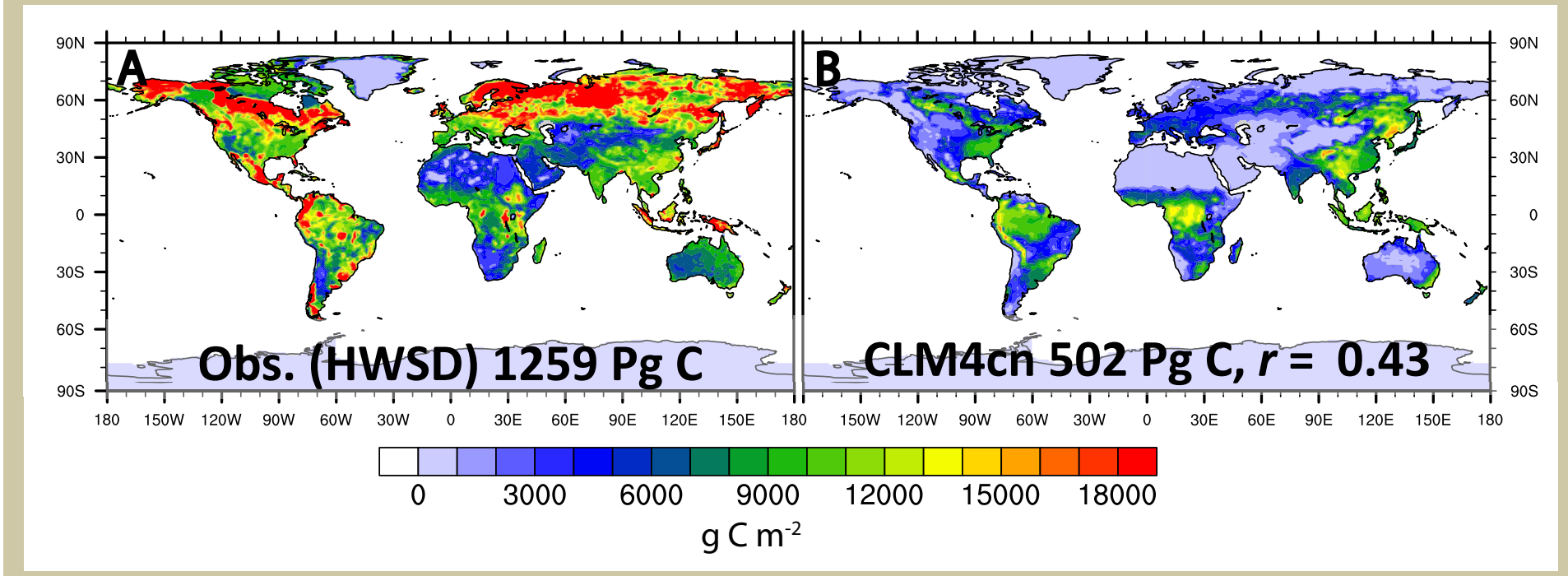


Rapid soil C turnover in CLM4.0-cn

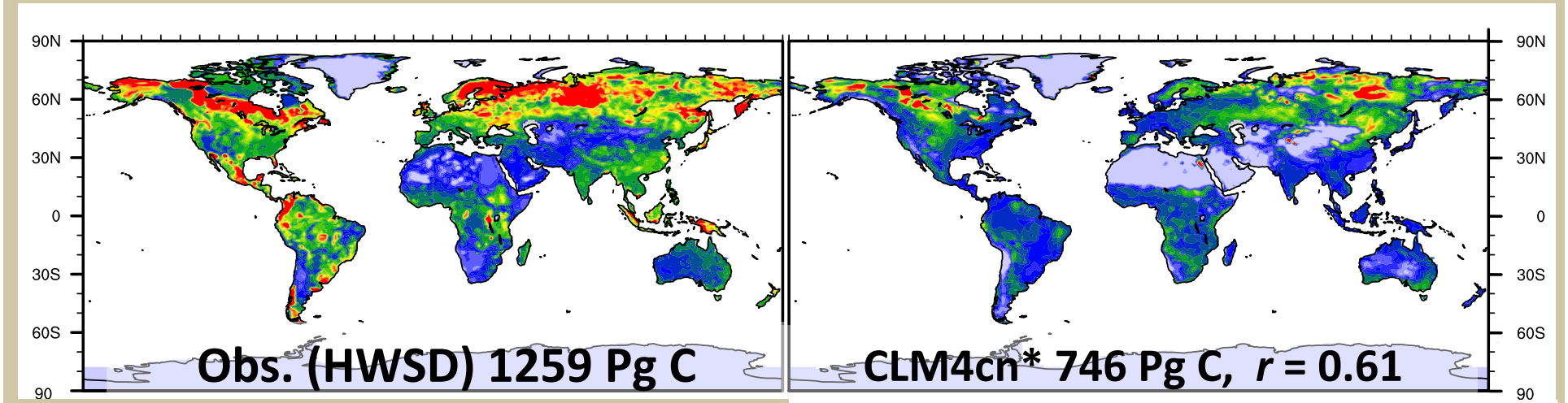


Bonan et al. Global Change Biology 2013

Soil C improved w/ DAYCENT?

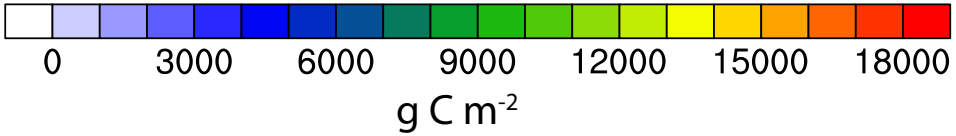


Soil C improved w/ DAYCENT?

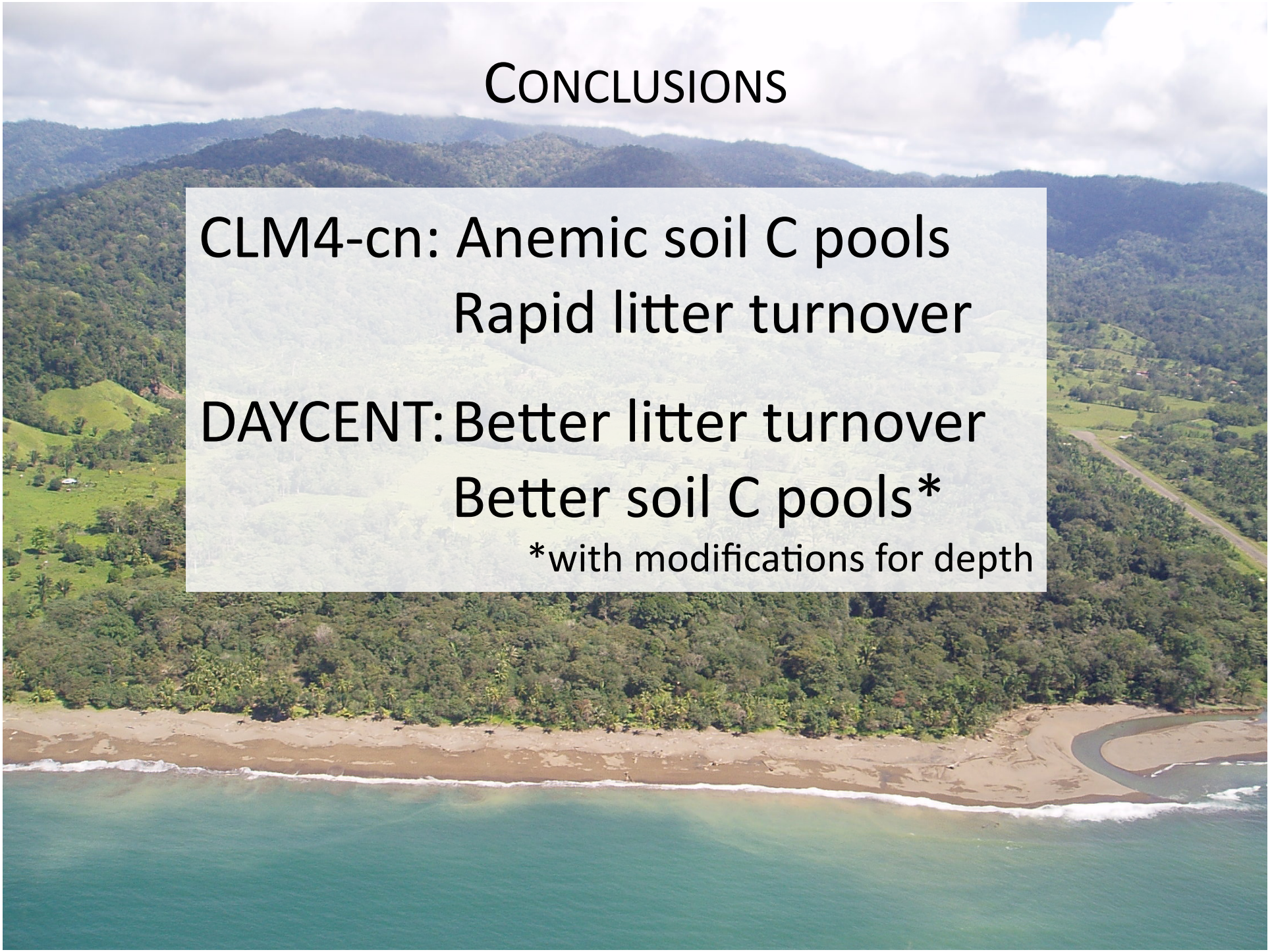


* Analytical Solution
"observed" litter inputs

§Modified to simulate soil 0-1 m



Wieder et al. GBC 2014



CONCLUSIONS

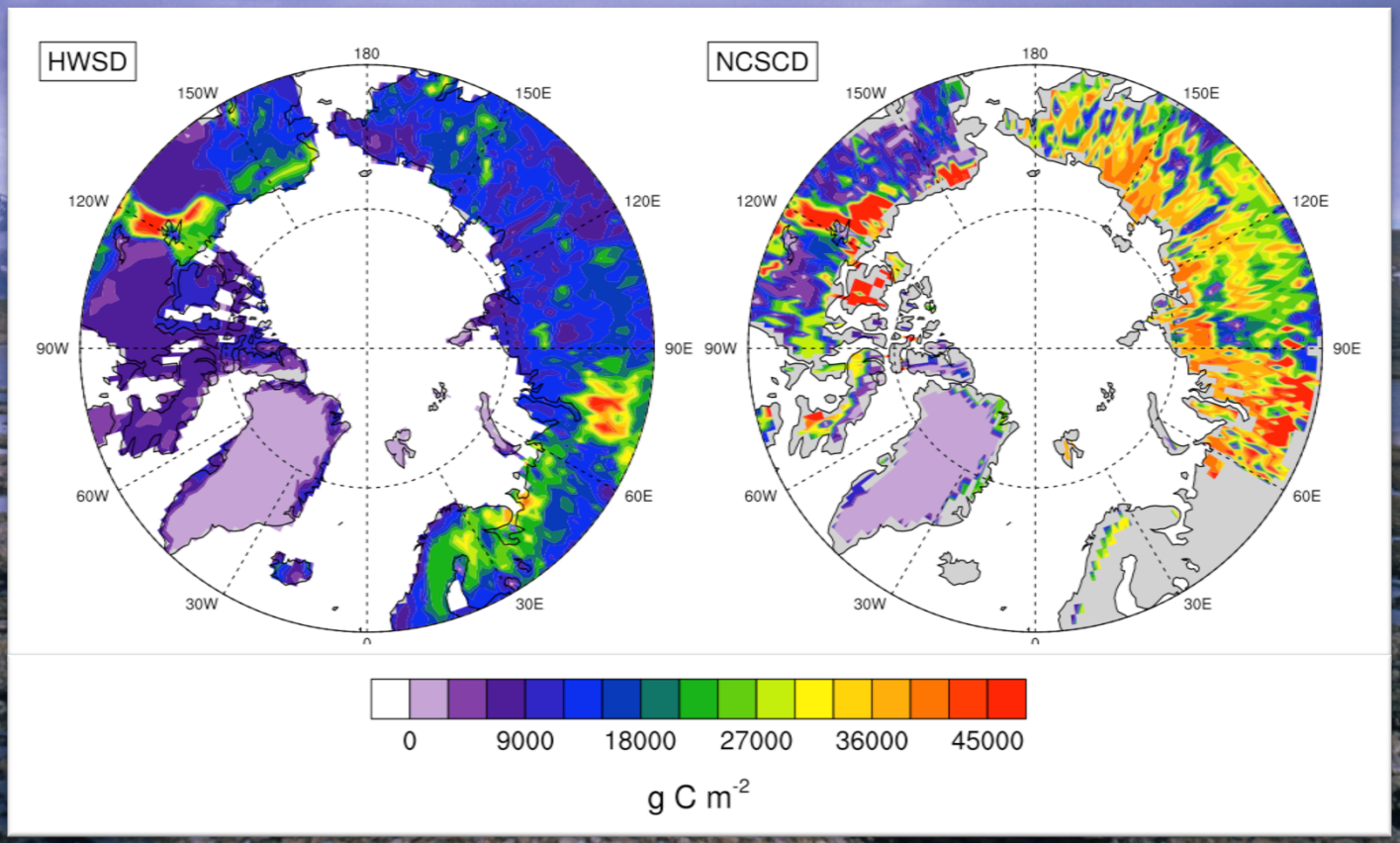
CLM4-cn: Anemic soil C pools
Rapid litter turnover

DAYCENT: Better litter turnover
Better soil C pools*

*with modifications for depth

CLM4.5bgc (CLM “present”)

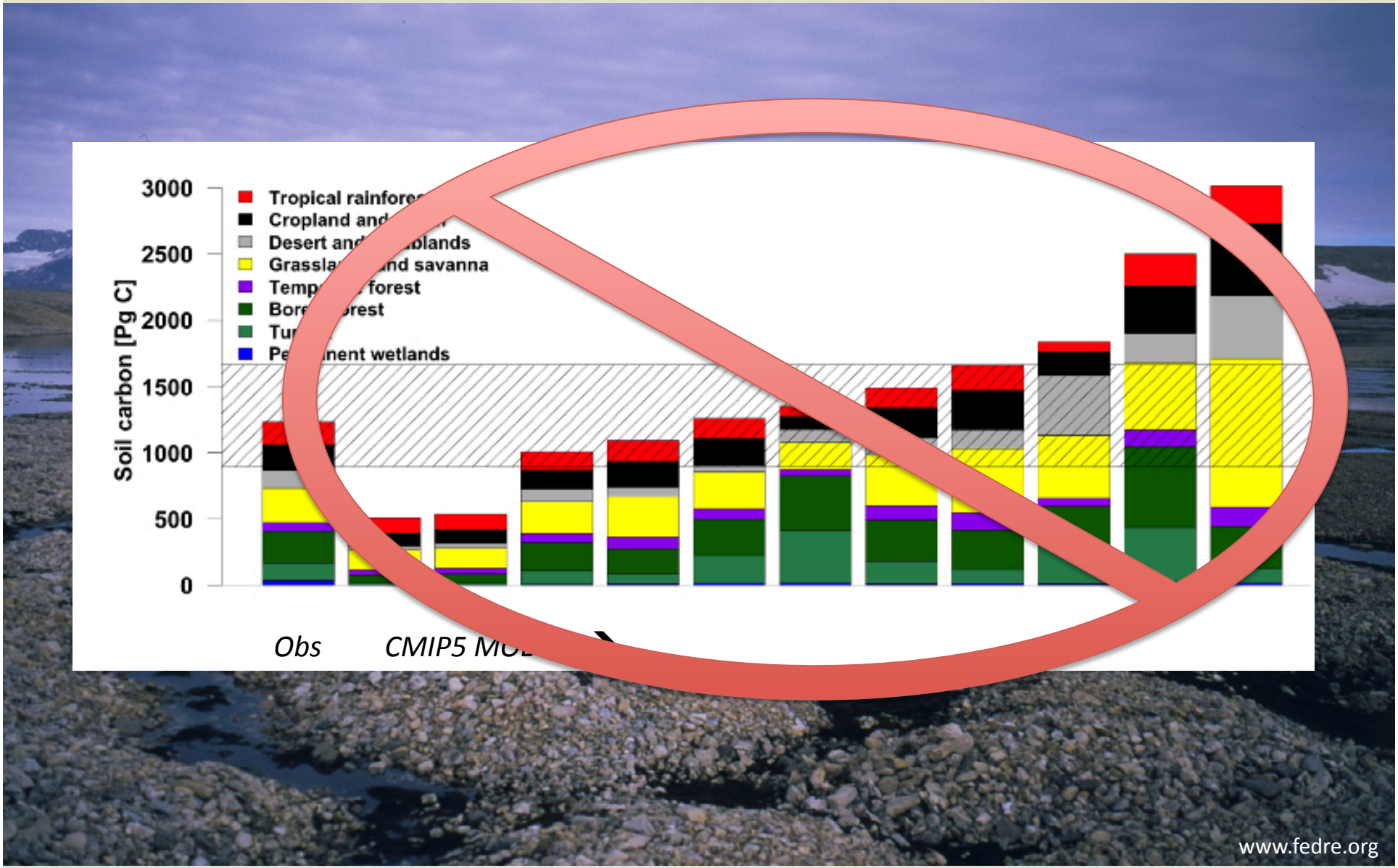
Permafrost C “observations”



www.fedre.org

NCSCD from Hugelius et al. 2013

Permafrost C in models

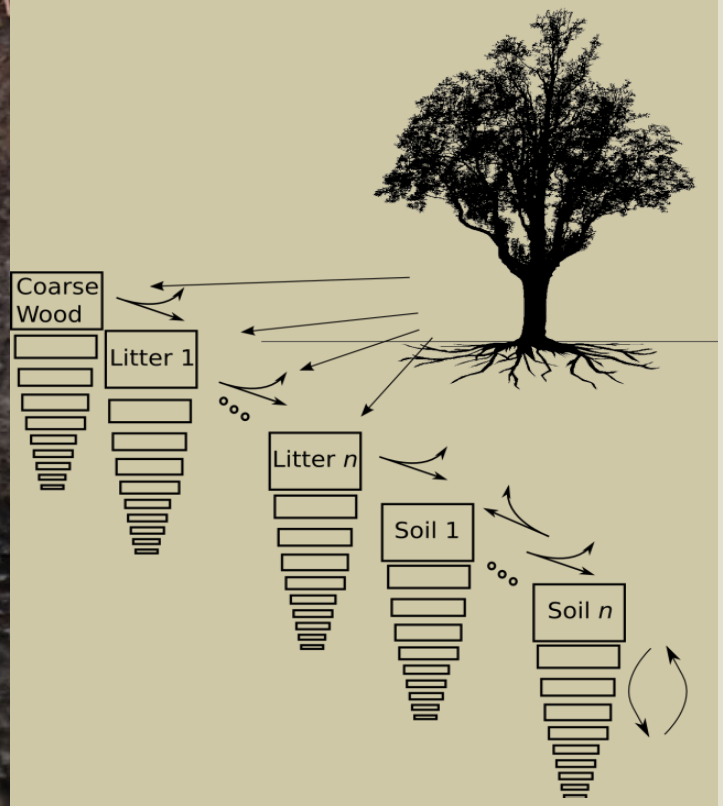


Todd-Brown et al. Biogeosciences 2013

Permafrost soils CLM4.5bgc

Carbon rich
Vertically complex

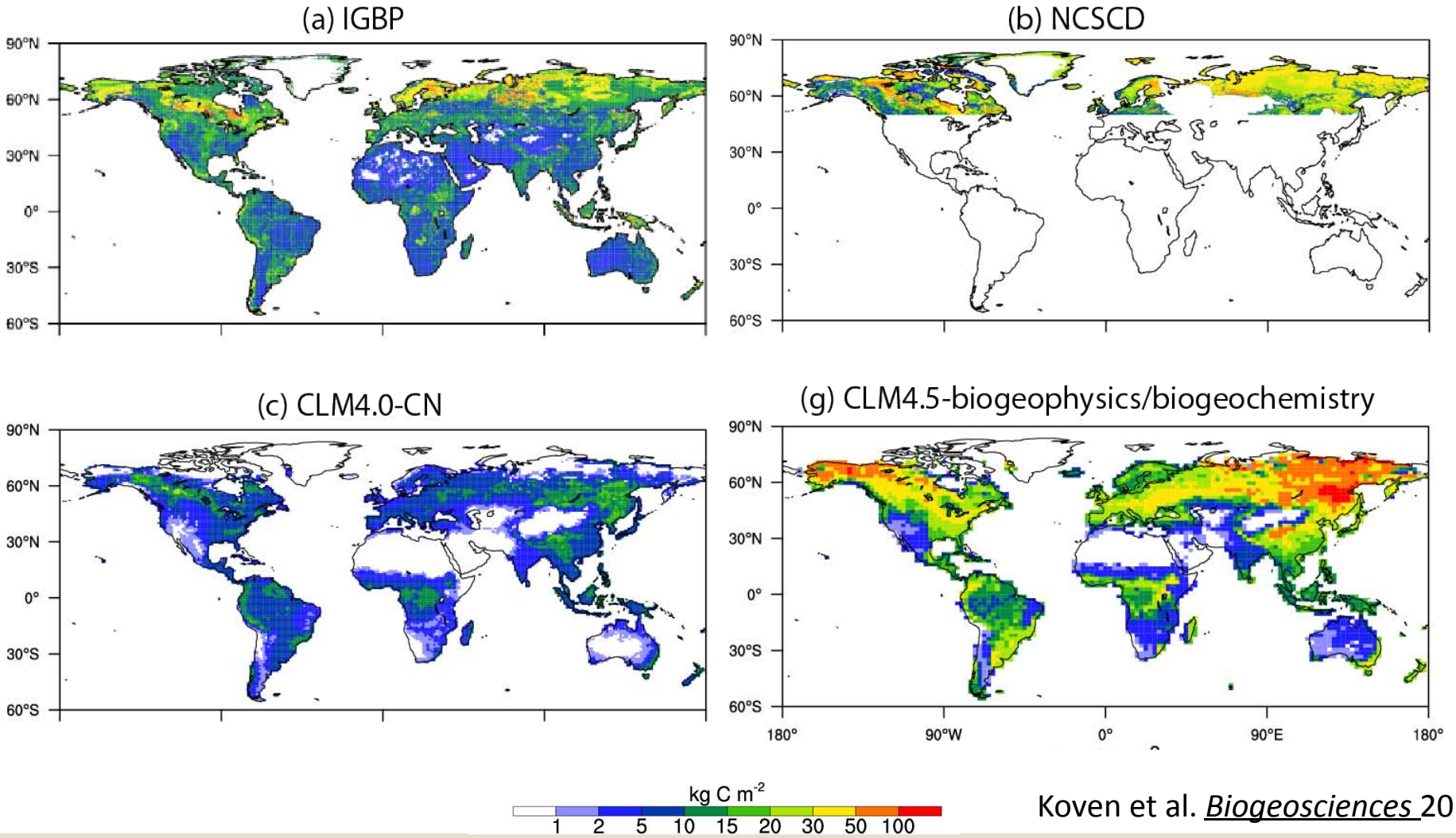
CENTURY-like soil biogeochemistry



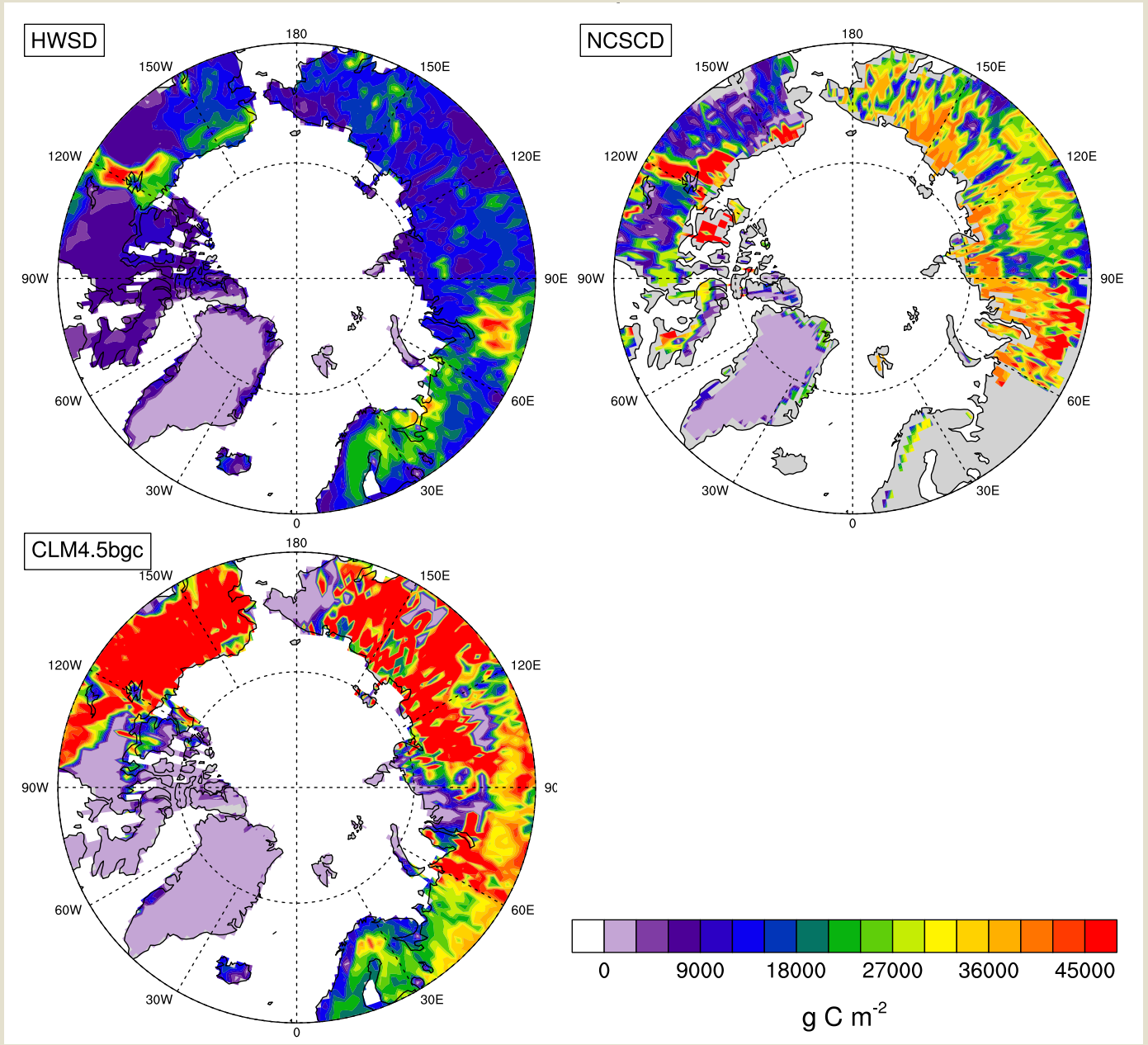
Koven et al. *Biogeosciences* 2013

www.bio.anl.gov

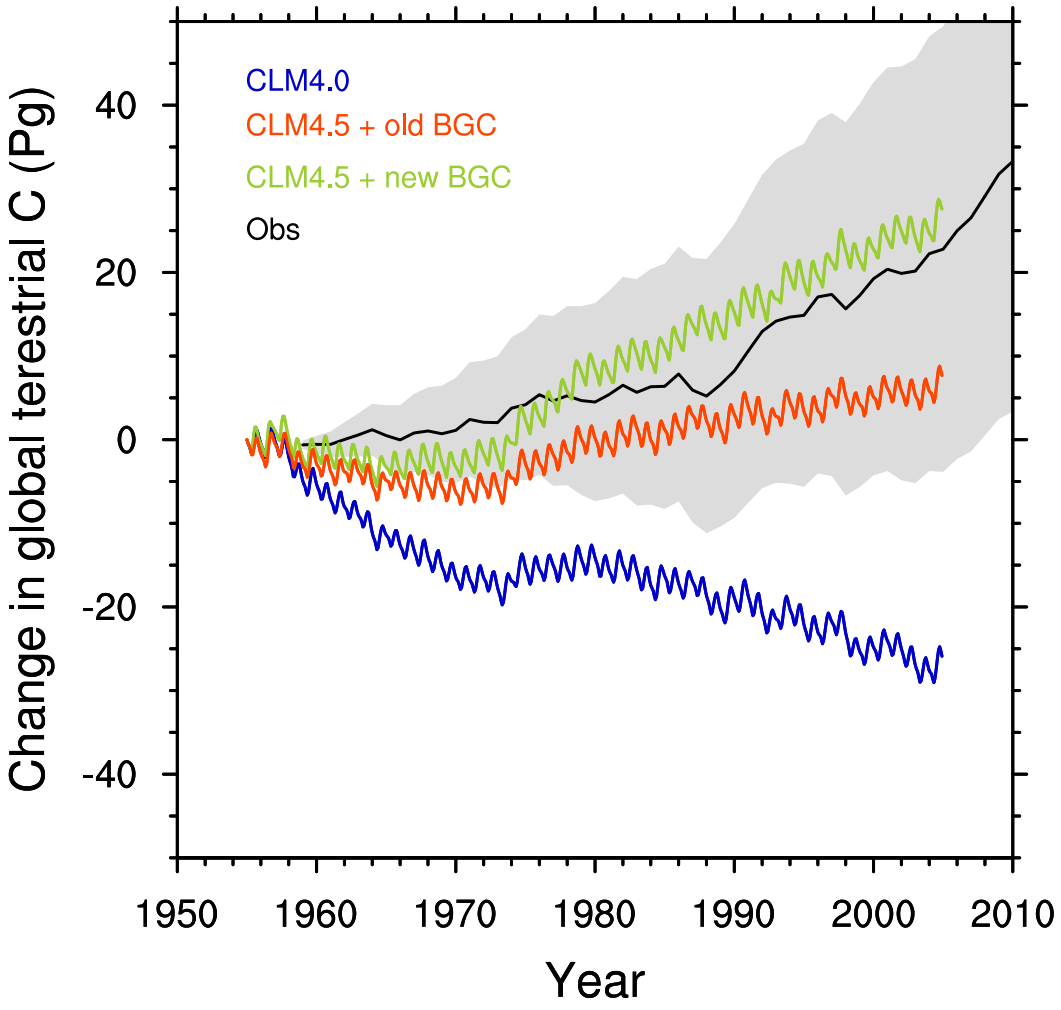
Permafrost soils CLM4.5bgc



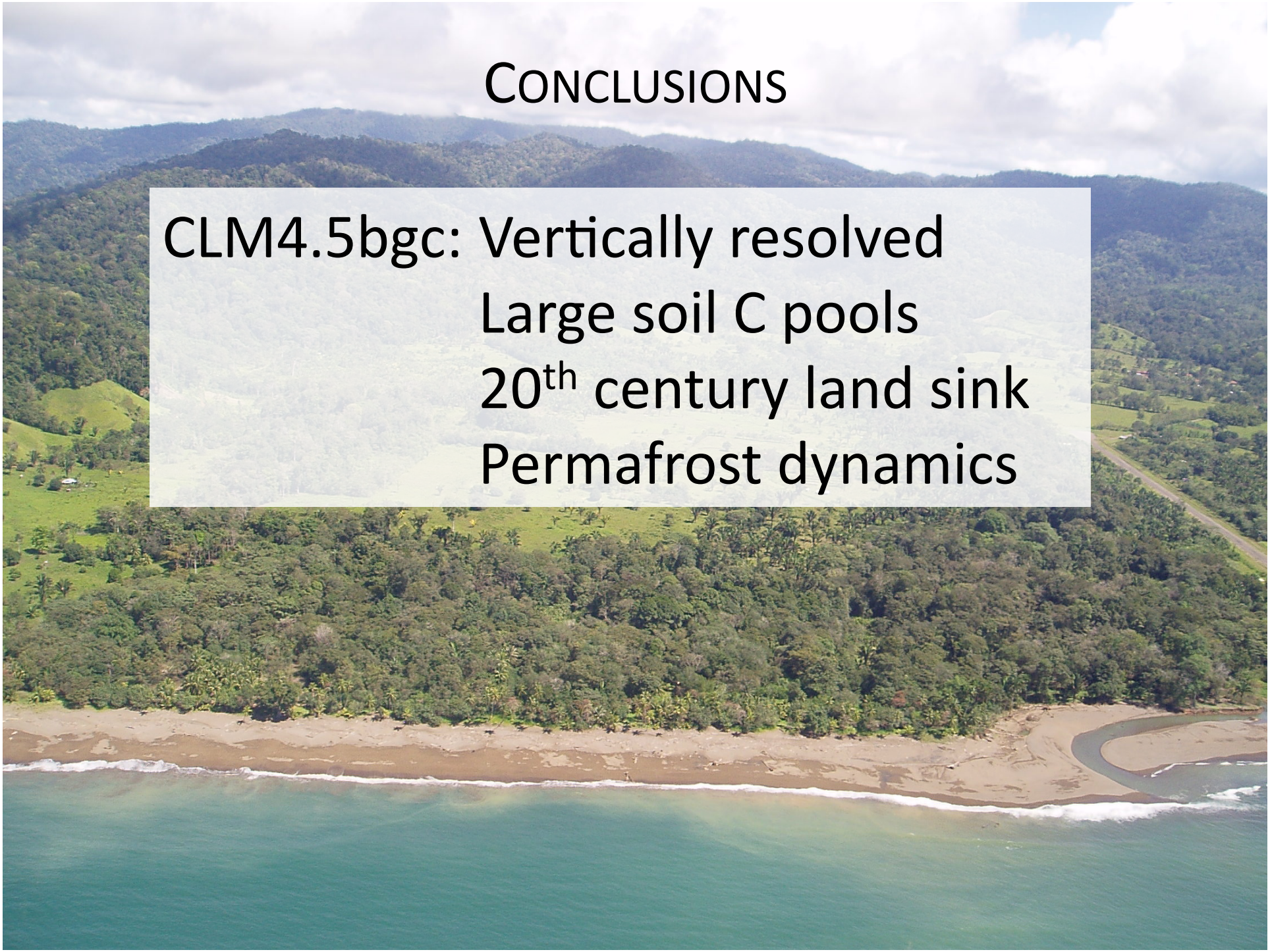
Koven et al. *Biogeosciences* 2013


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

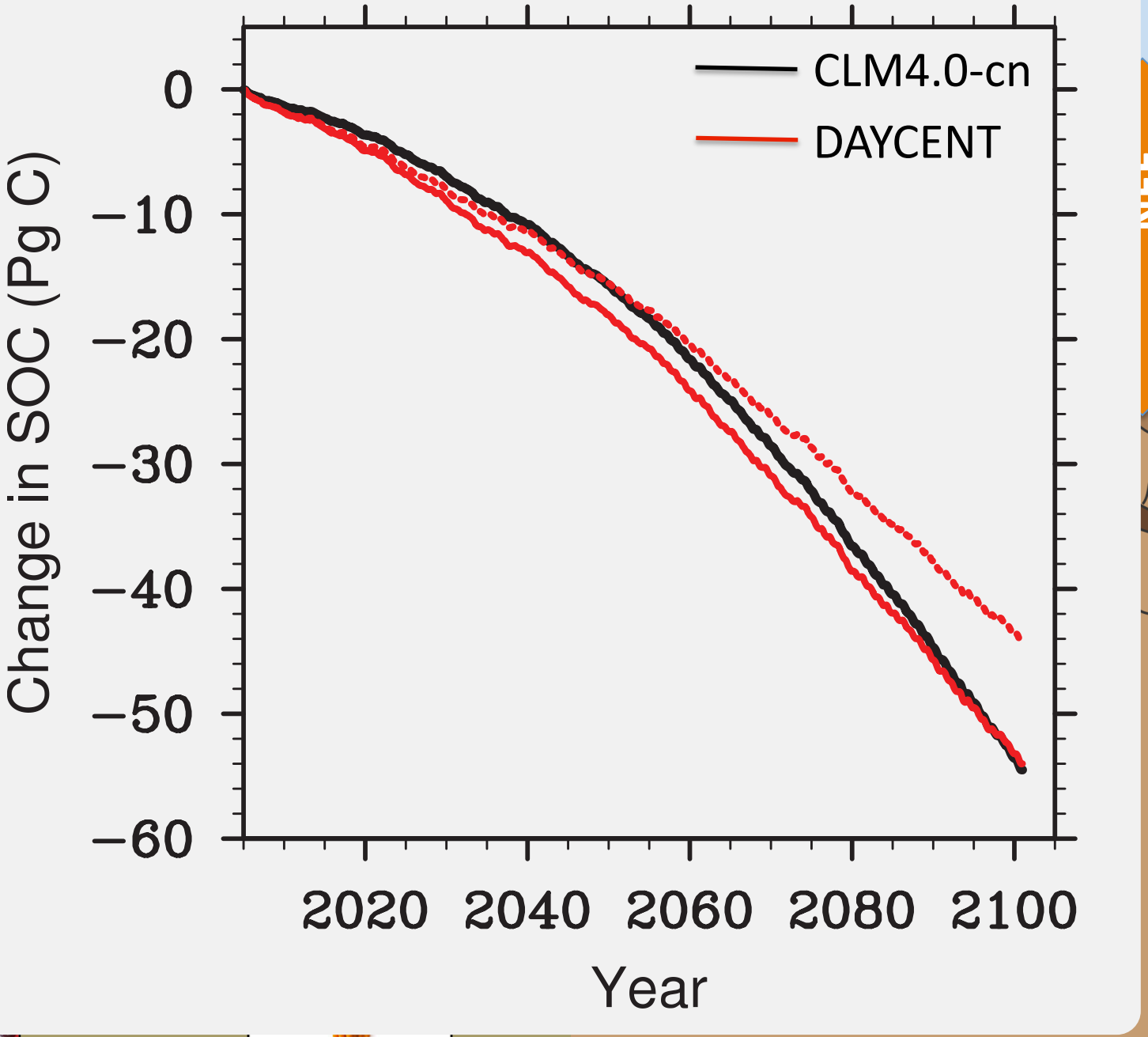


CONCLUSIONS

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

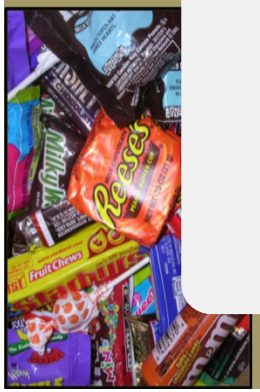
Microbial models (CLM “Future”)

Wh
fall

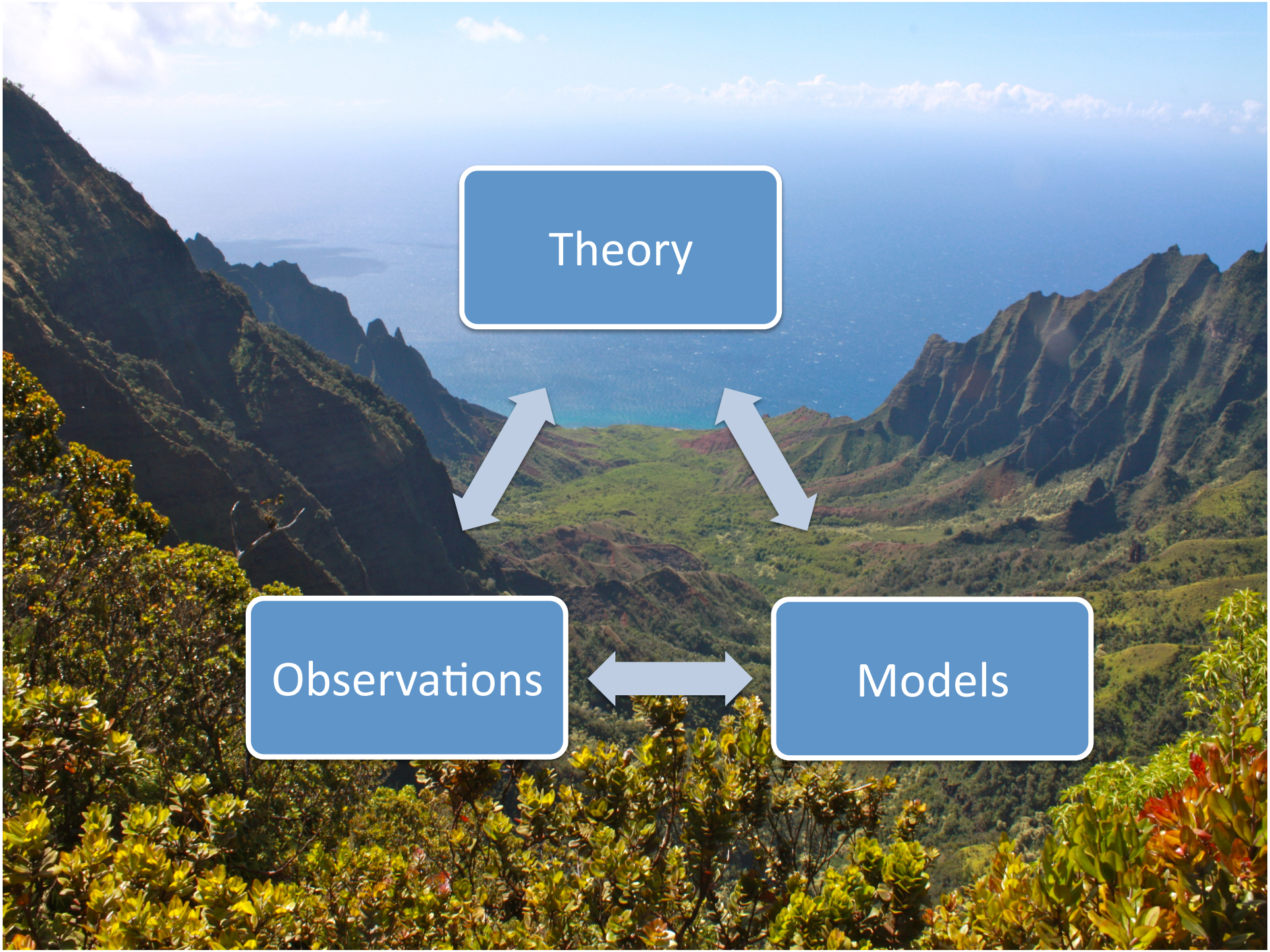


NEE

Fast

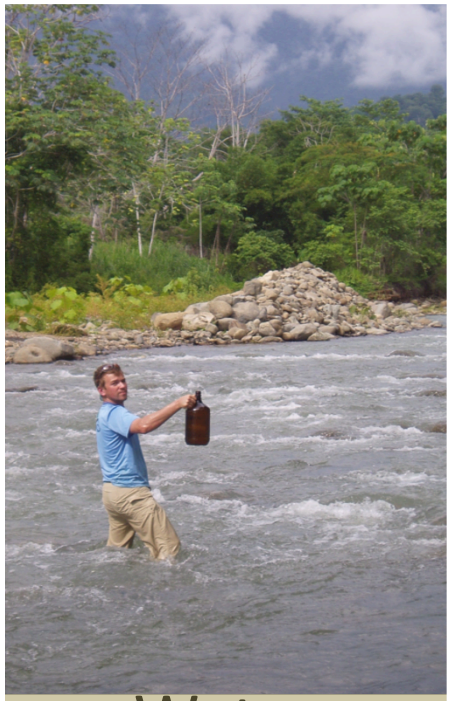


Wieder et al. GBC 2014


Theory
Observations
Models

What are soils?

Soils Sustain Life



Water

Agroecosystems

Habitat

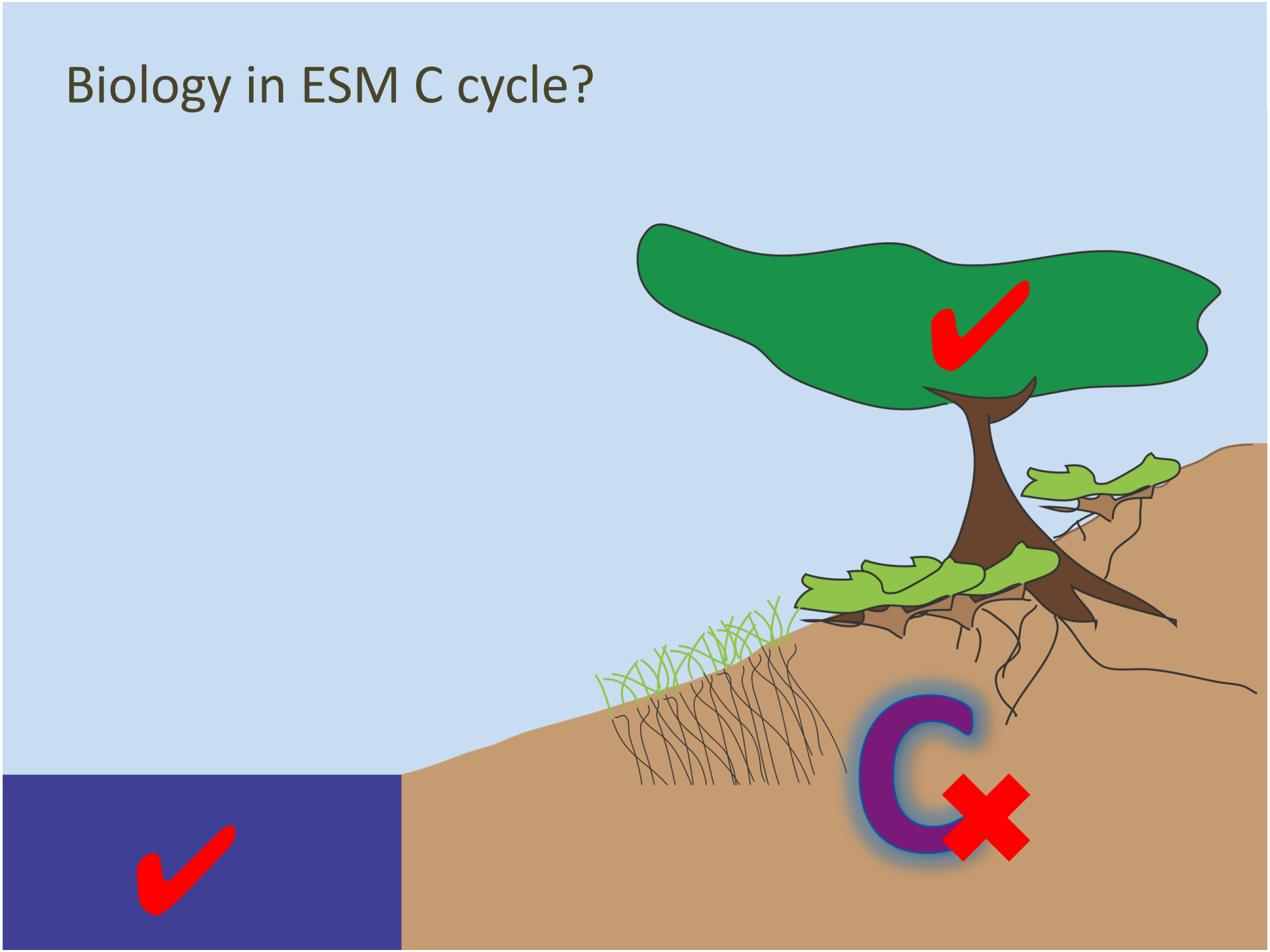
Medicine

Ecosystems

Foundation

Waste

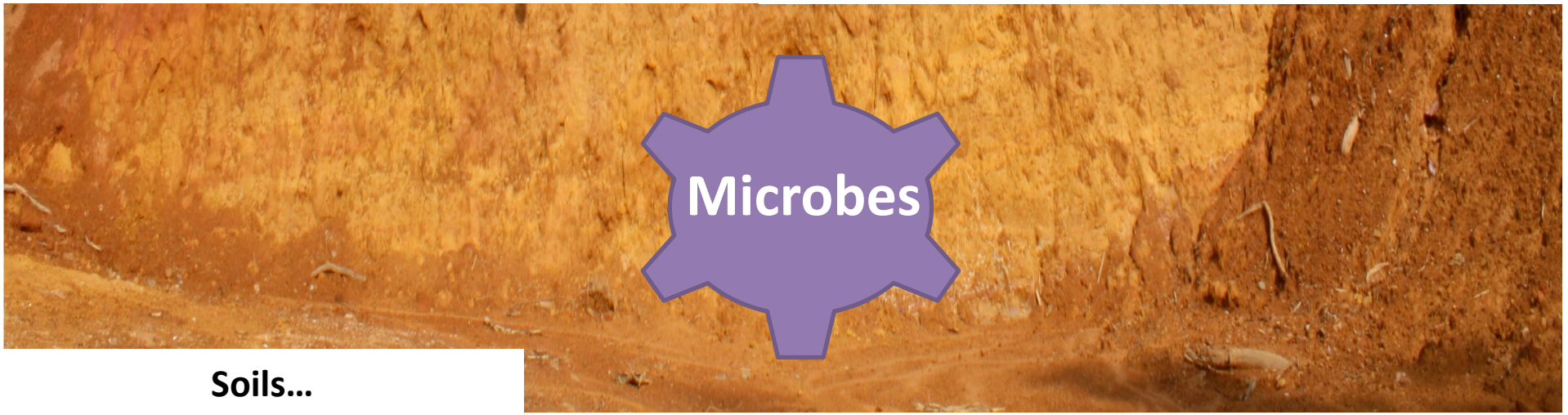
Biology in ESM C cycle?



Biological drivers of the terrestrial C cycle:

Plant functional diversity

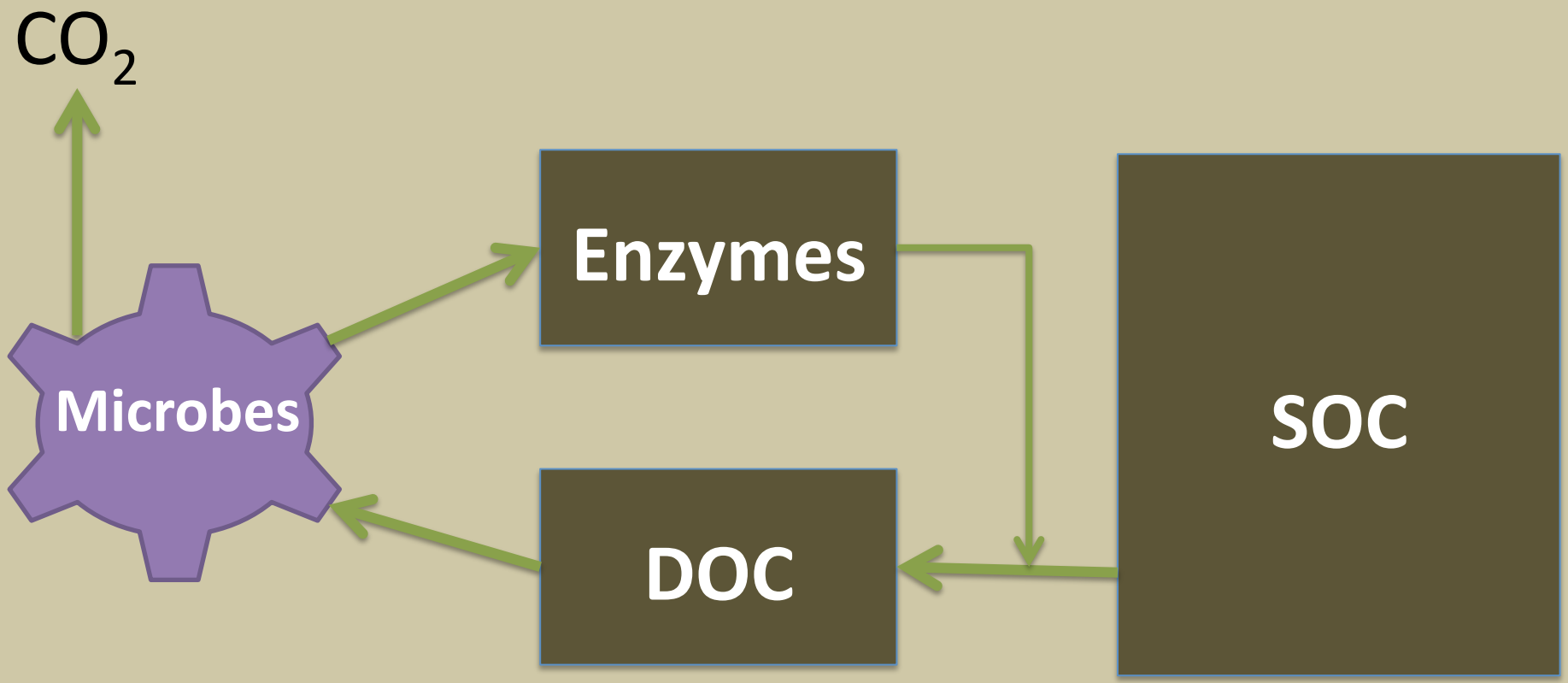
Agriculture



Soils…

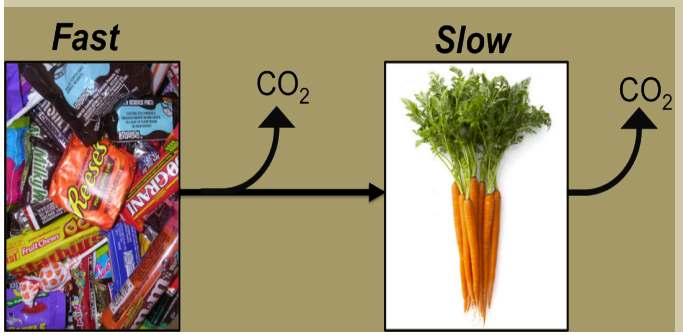
Microbial theory in models

The catalyst matters



Schimel & Weintraub SBB (2003);Moorhead & Sinsabaugh Eco. Mono. (2006); Lawrence et al. SBB (2009); Allison et al. Nat. Geo. (2010); Moorhead et al. SBB (2012); Wang et al. Eco Apps. (2013)

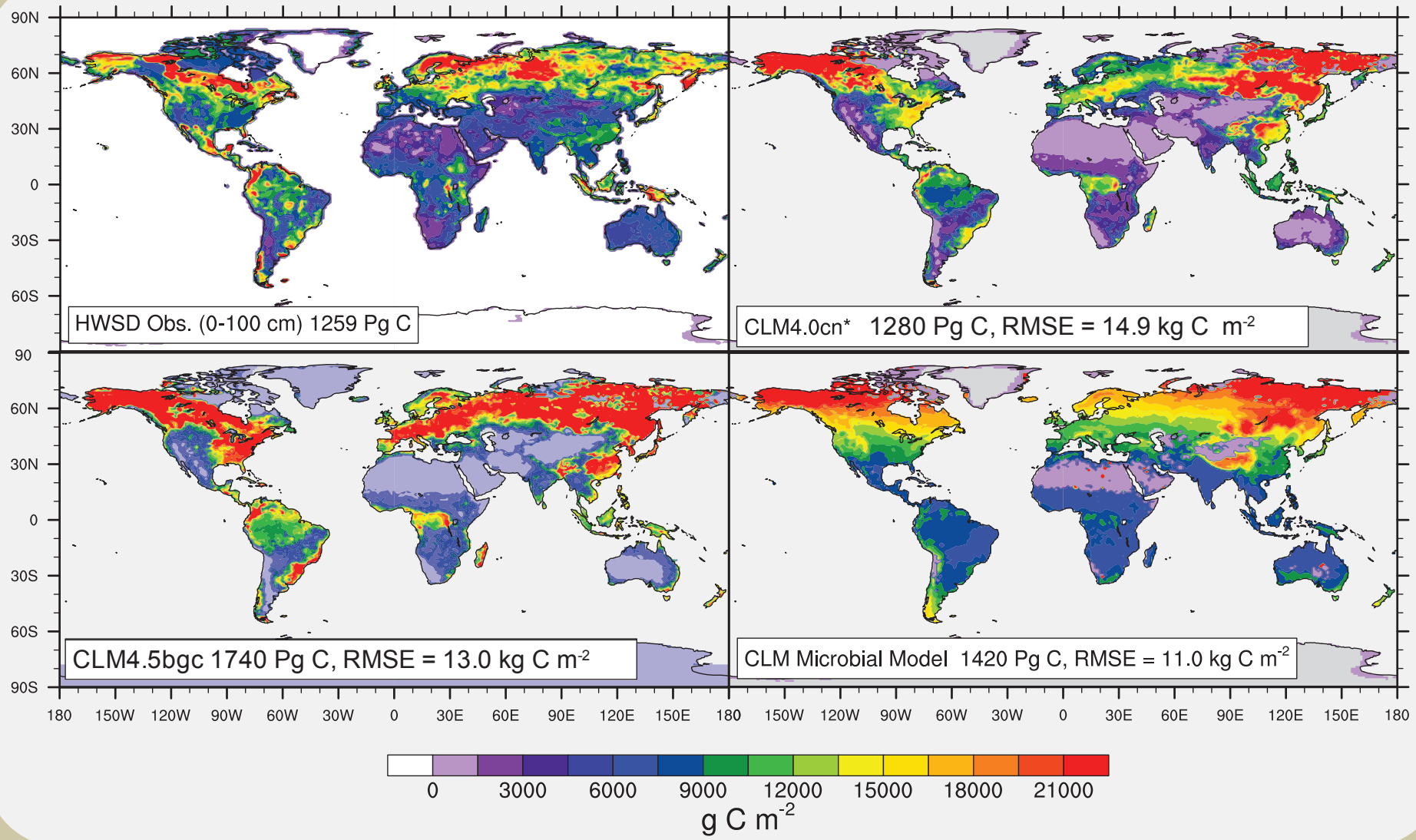
Microbial theory in global models



Wieder *et al.* Nature Climate Change (2013)

Microbial models work

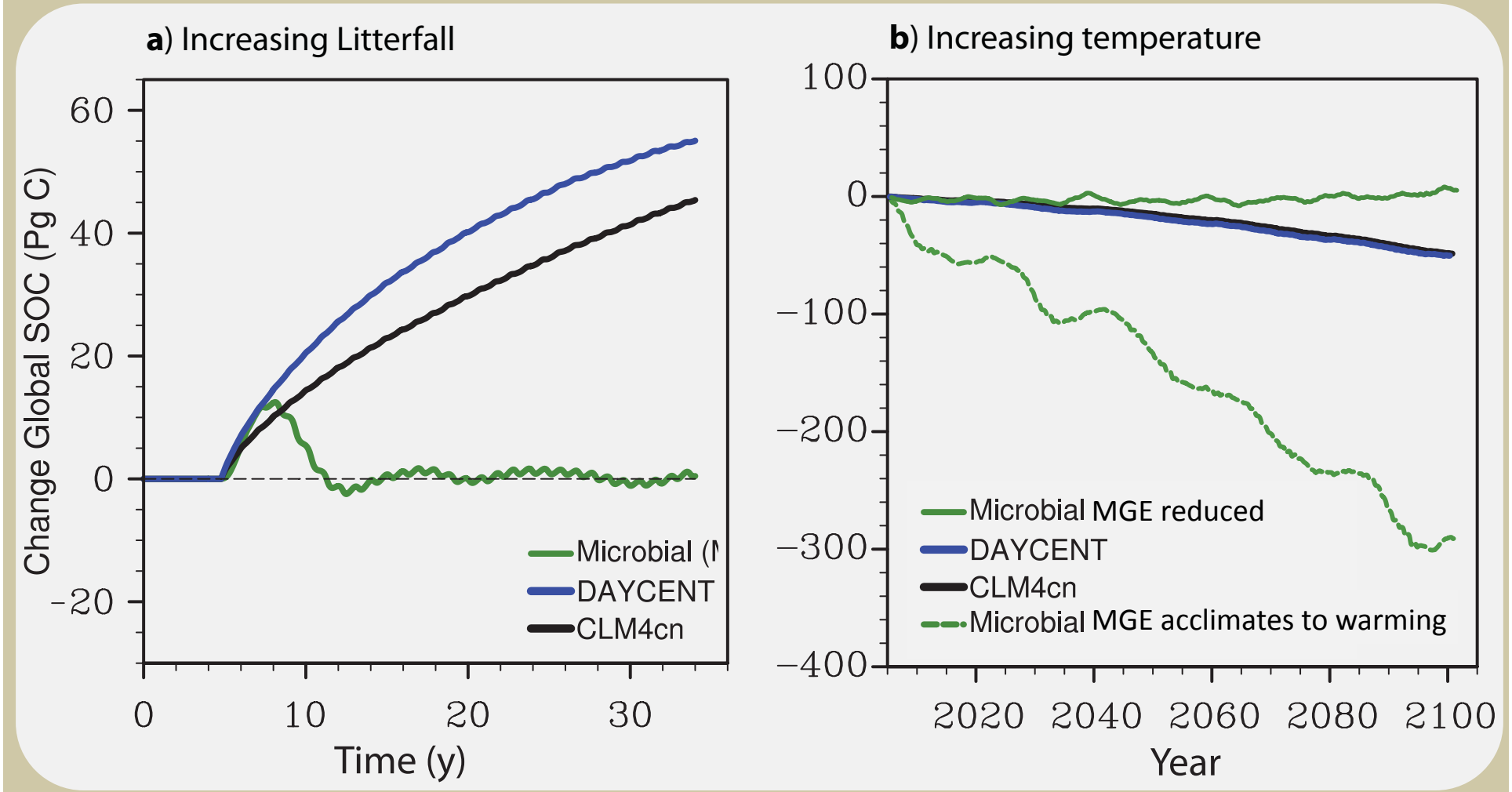
at global scales



* All models w/ same forcing from CLM4.5 output

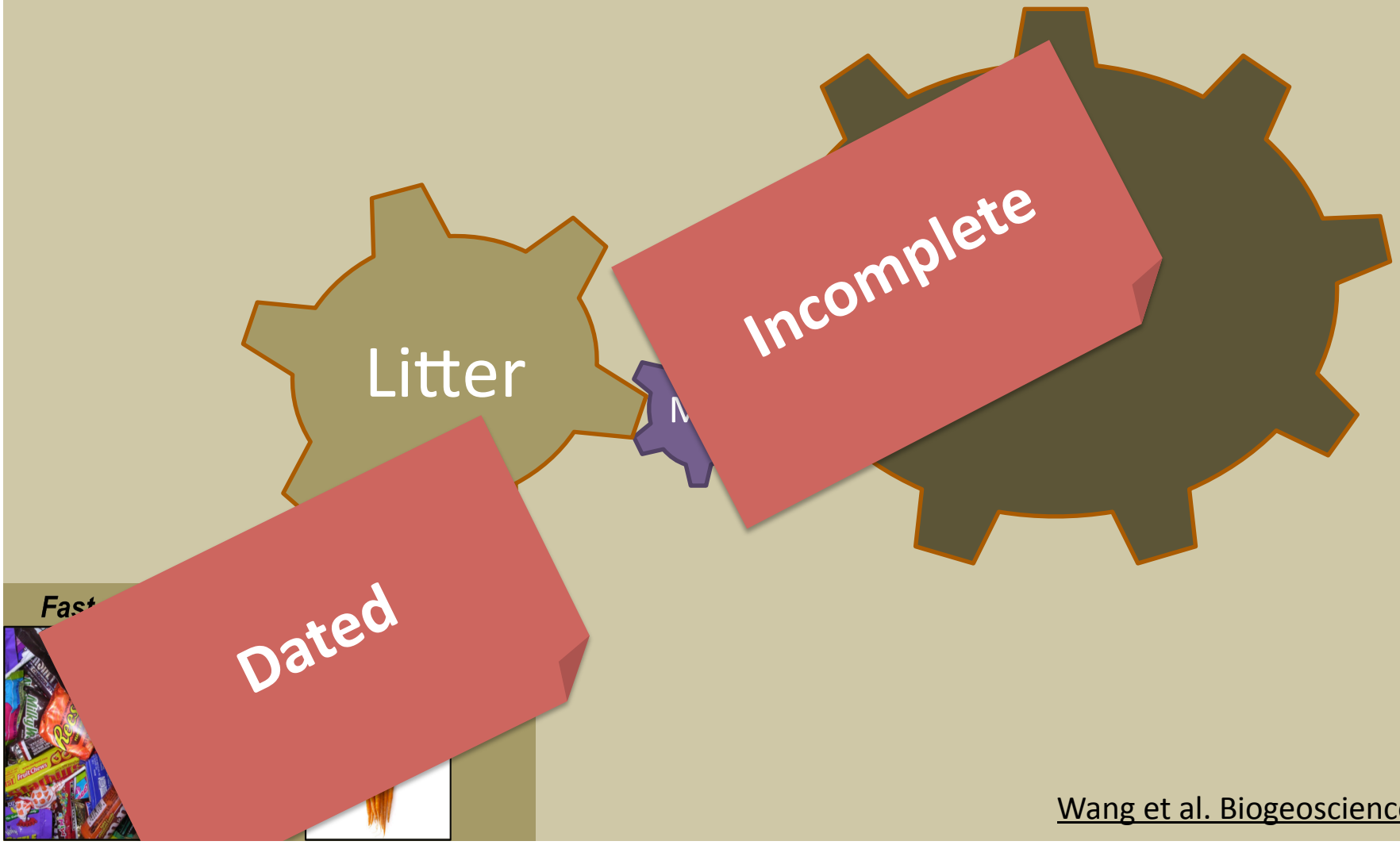
Wieder *et al.* Nature Climate Change 2013

Model structure matters
(in global change settings)



Wieder *et al.* Nature Climate Change 2013

Microbial theory in global models

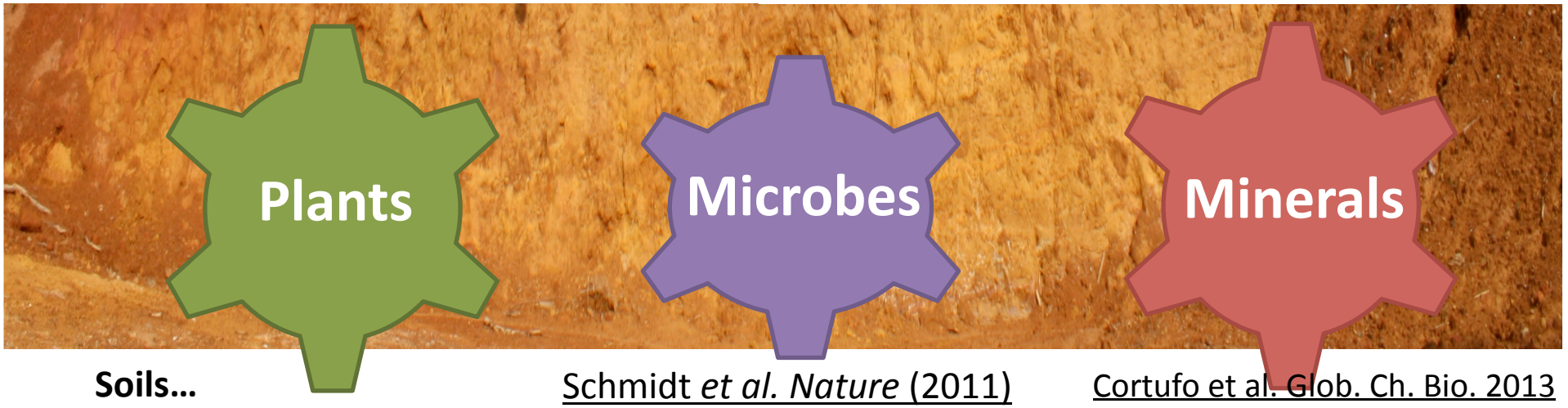


Wang et al. Biogeosciences 2014

Biological drivers of the terrestrial C cycle:

Plant functional diversity

Agriculture

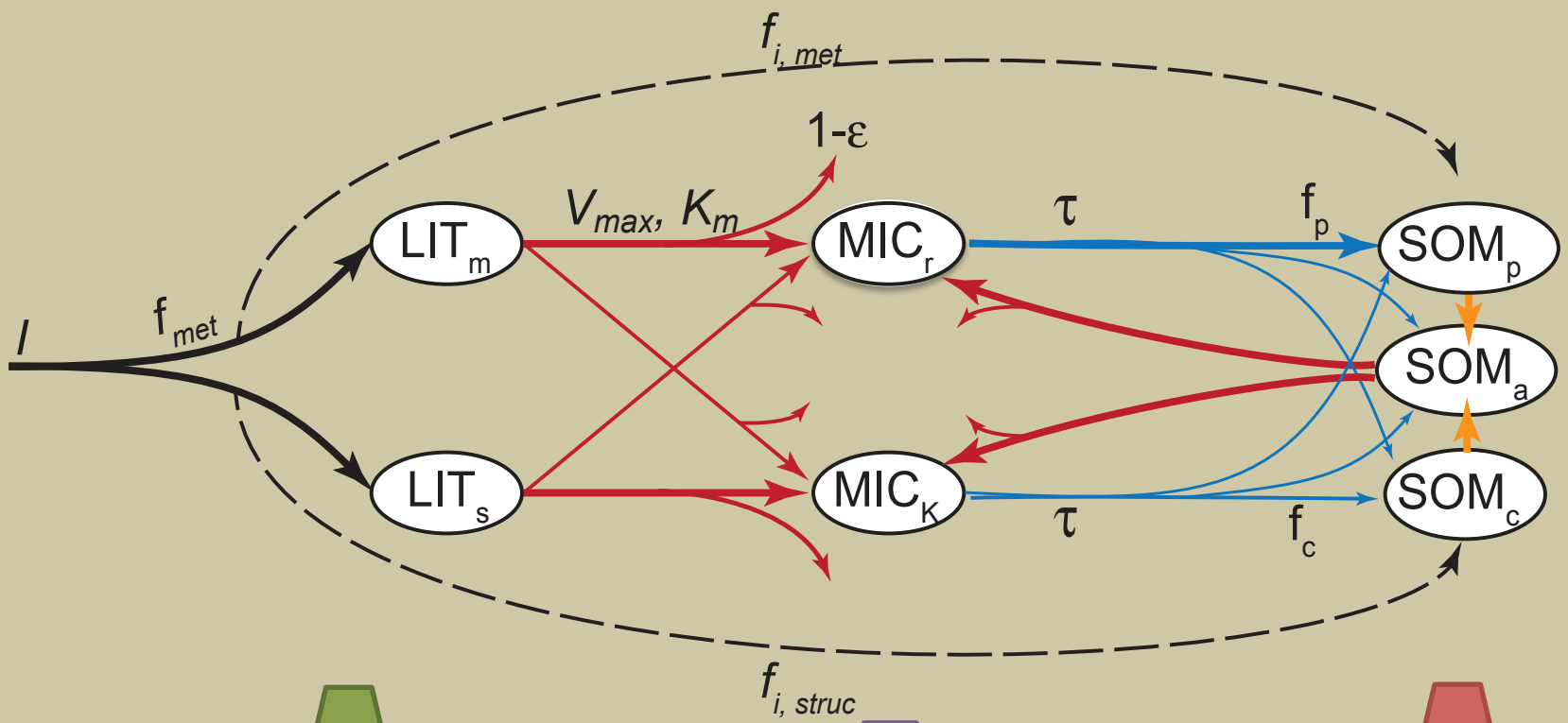


Soils…

Schmidt *et al. Nature* (2011)

Cortufo et al. Glob. Ch. Bio. 2013

MIcrobial-**MI**neral **C**arbon **S**tabilization
MIMICS model

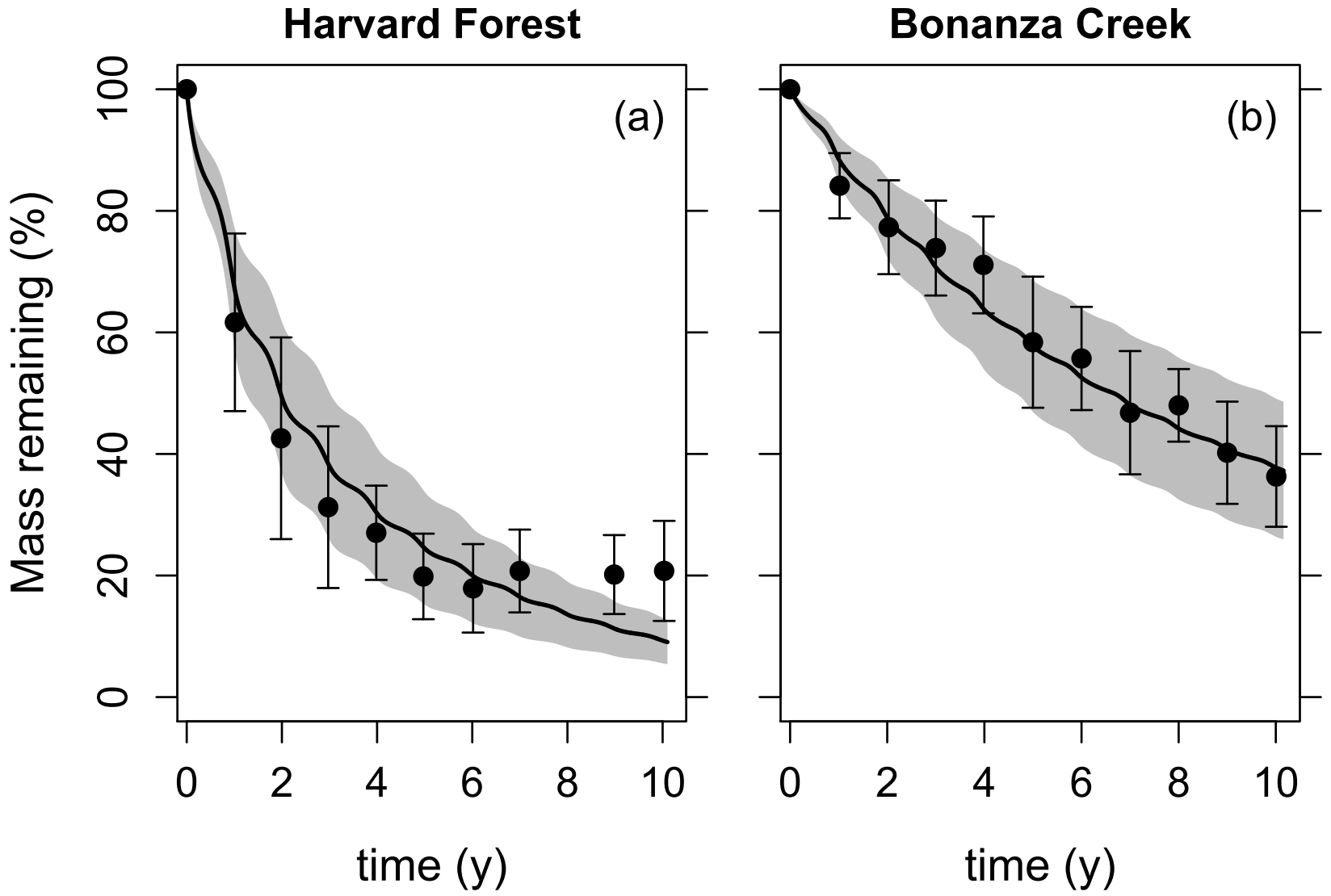


Plants

Microbes

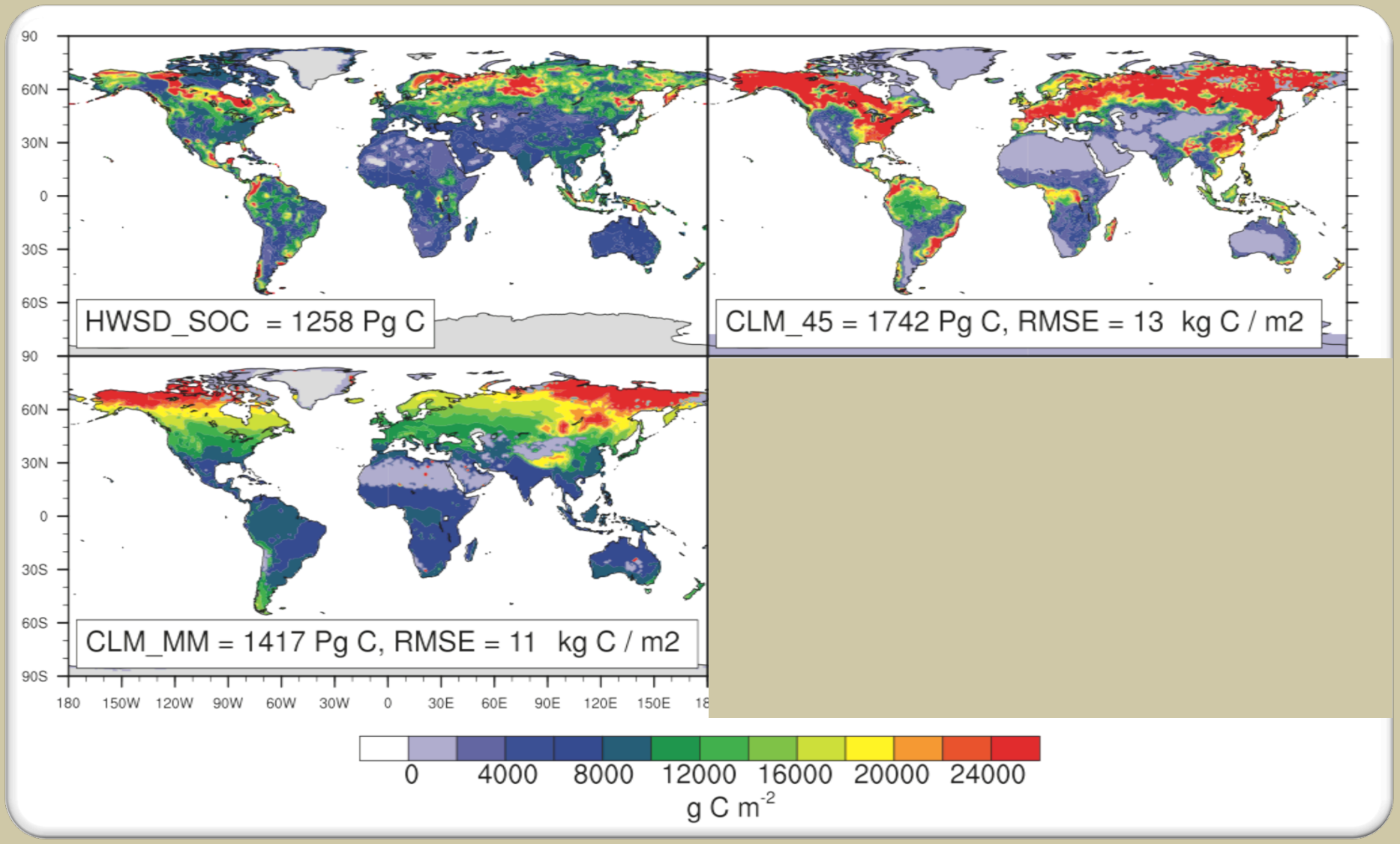
Minerals

Validating MIMICS



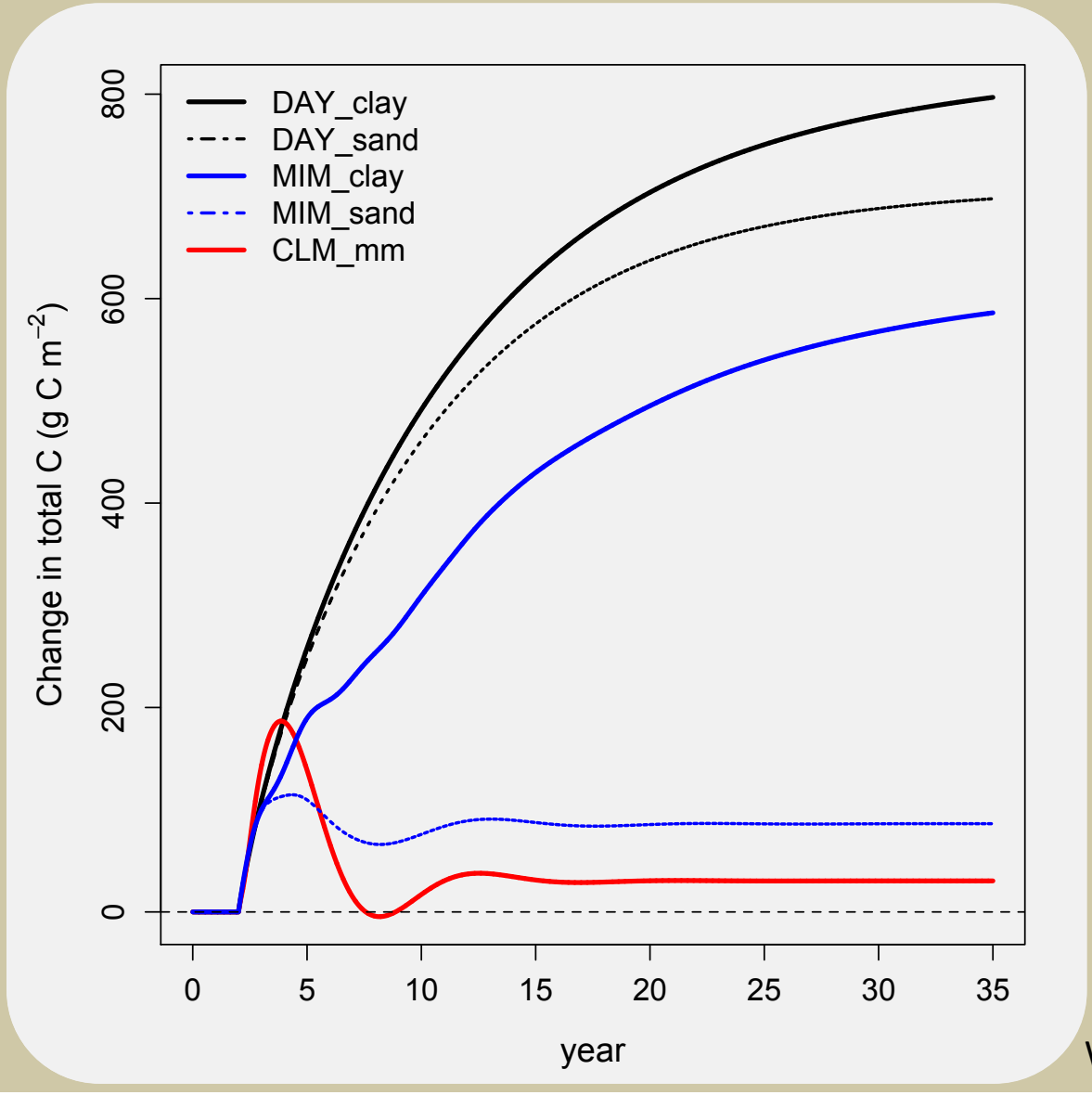
Wieder et al. BGD (2014); see also Bonan et al. GCB (2013)

Validating MIMICS

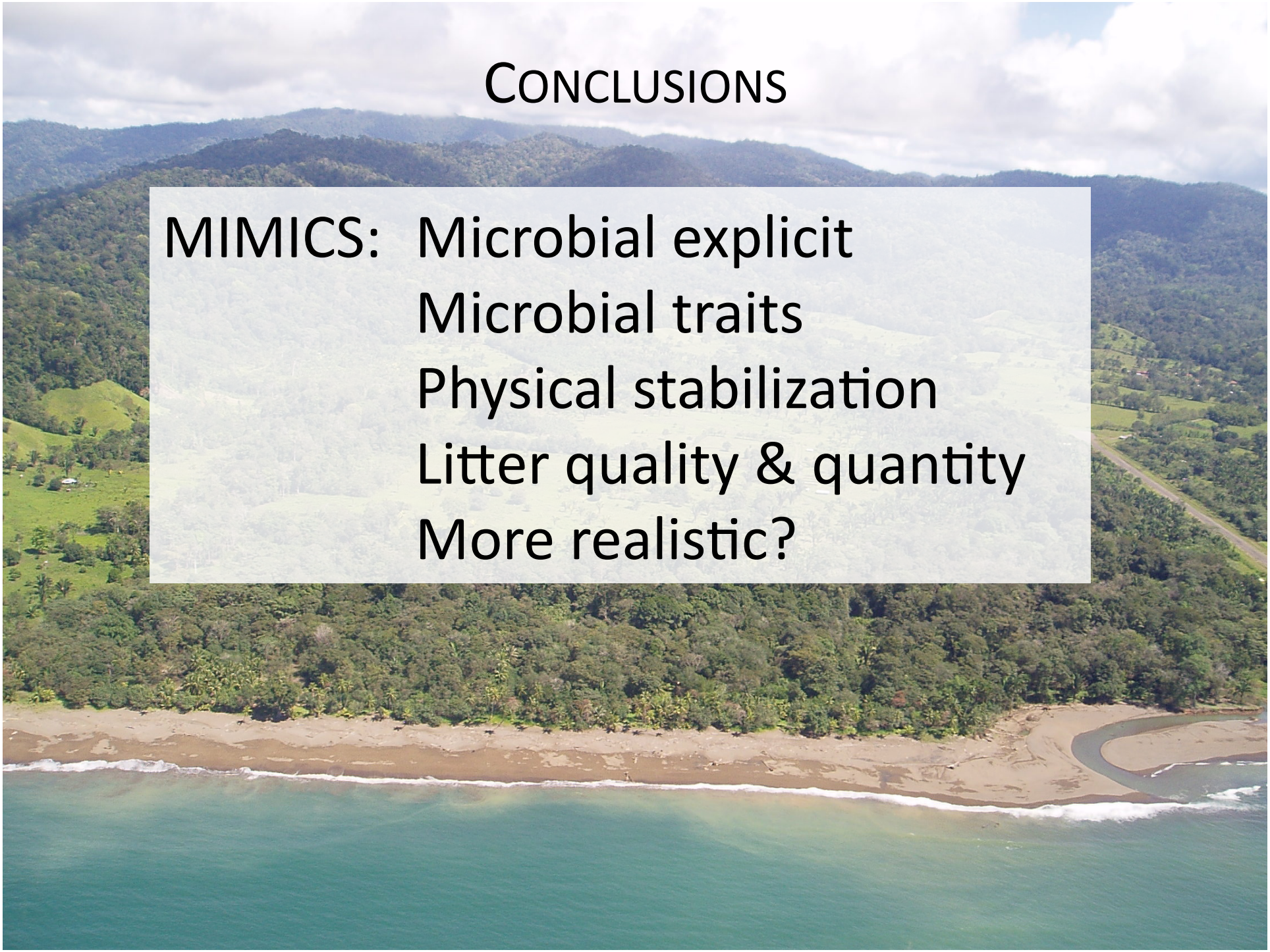


* 0-100cm, all models w/ same forcing from CLM4.5 output

Model structure matters (increase litter quantity)



Wieder, unpublished

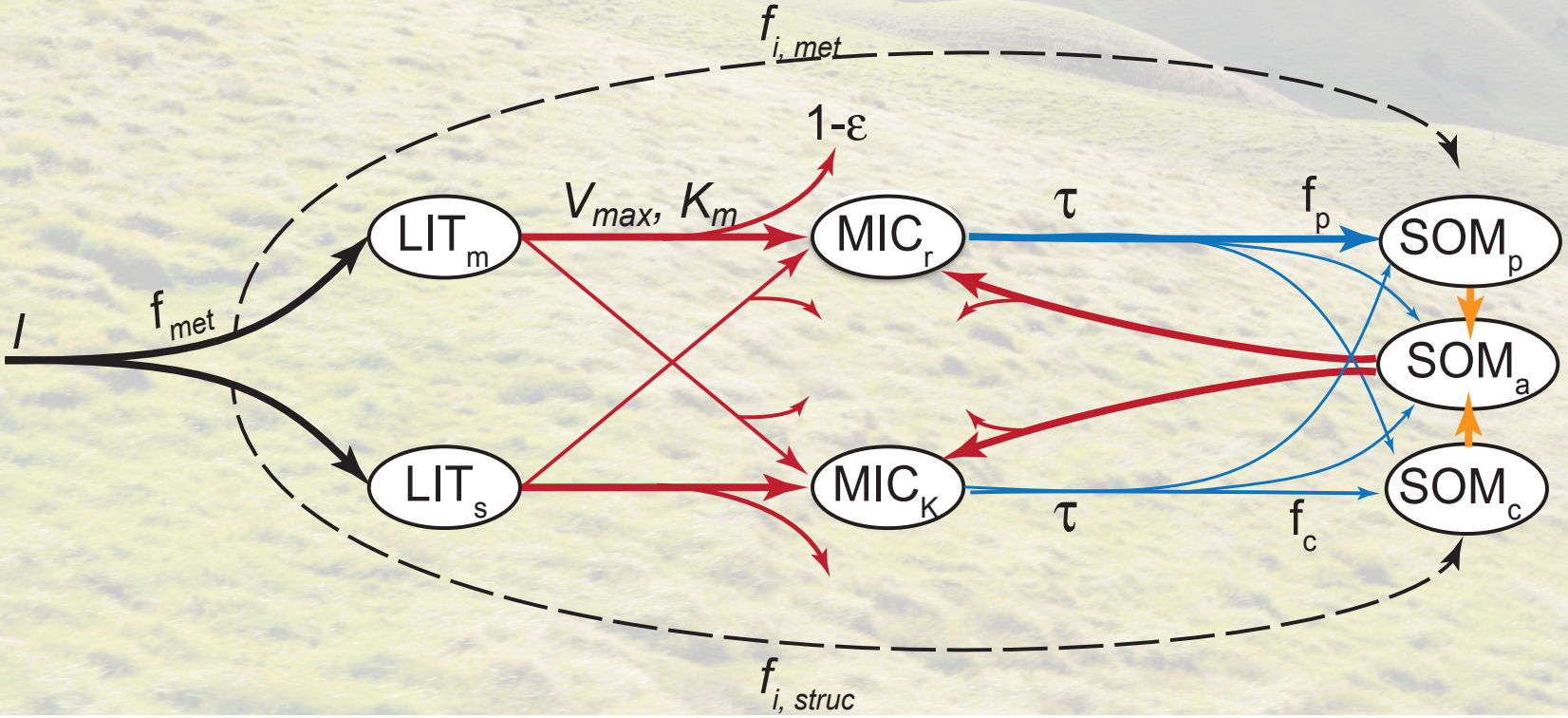


CONCLUSIONS

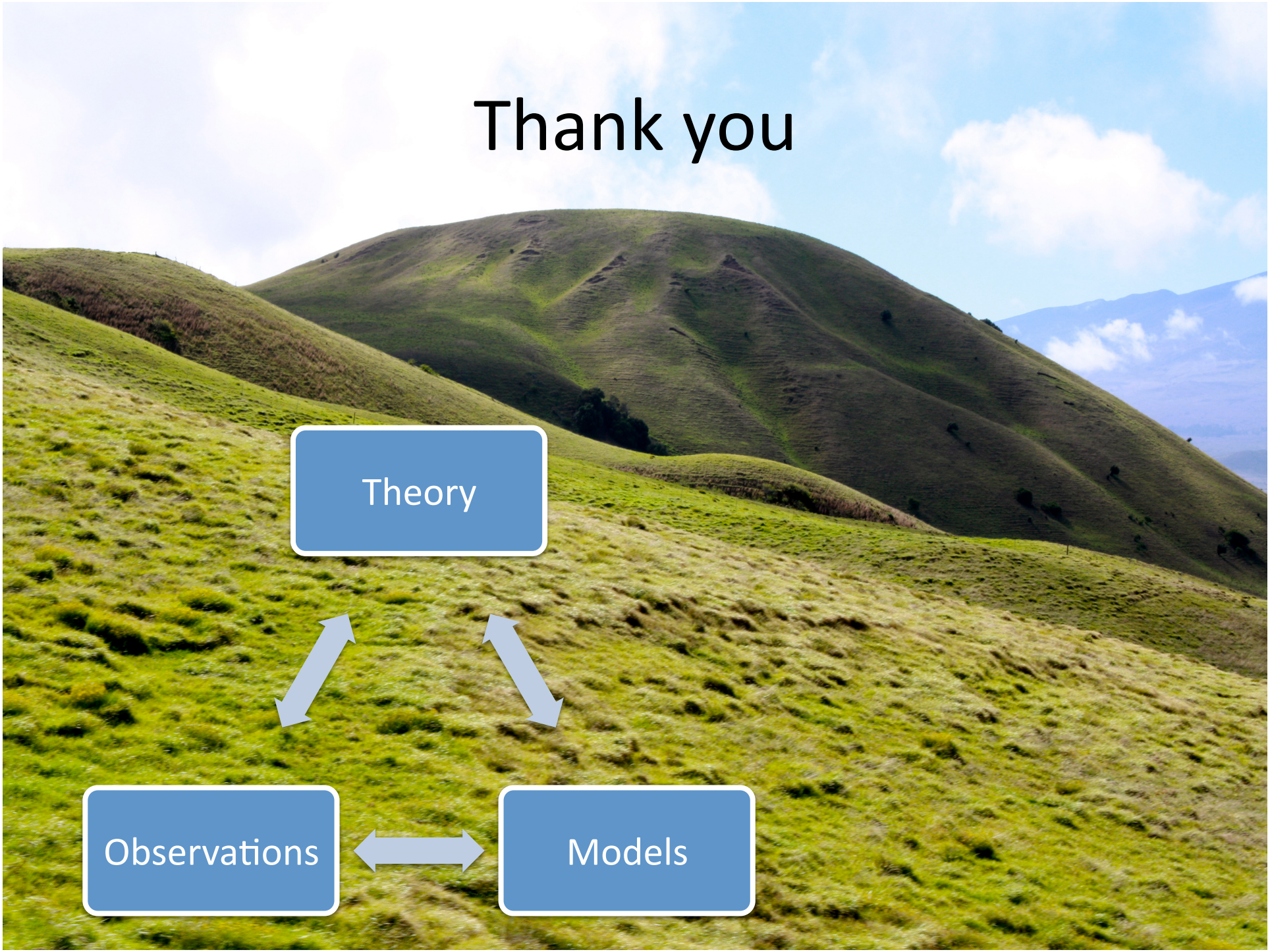
MIMICS: Microbial explicit
Microbial traits
Physical stabilization
Litter quality & quantity
More realistic?

New Directions

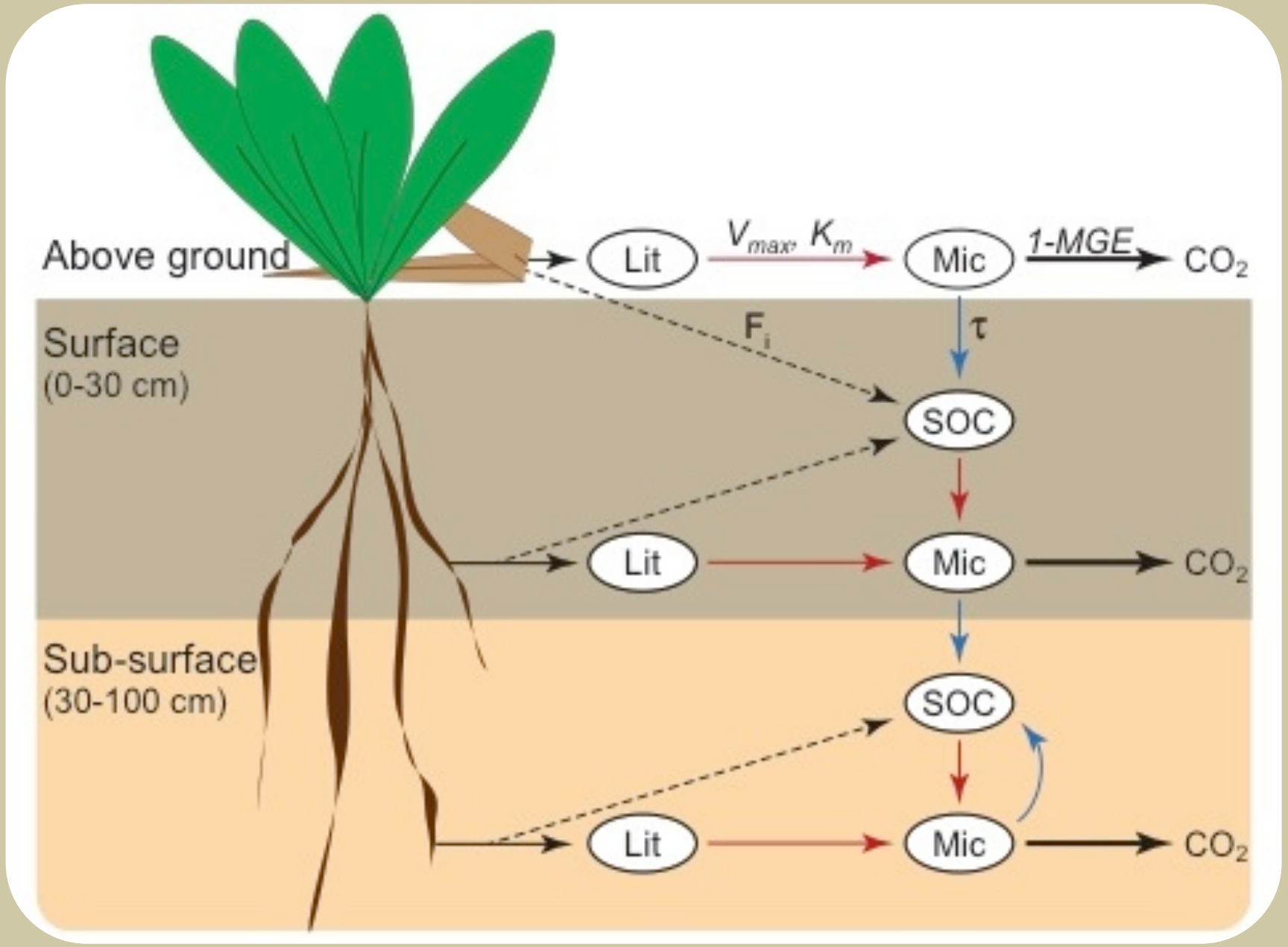
- Test ecological theory
- Evaluation & Validation
  - Functional traits (MGE, turnover)
  - Transient response
- Parameterization
  - scaling relationships (Climate, N, etc.)



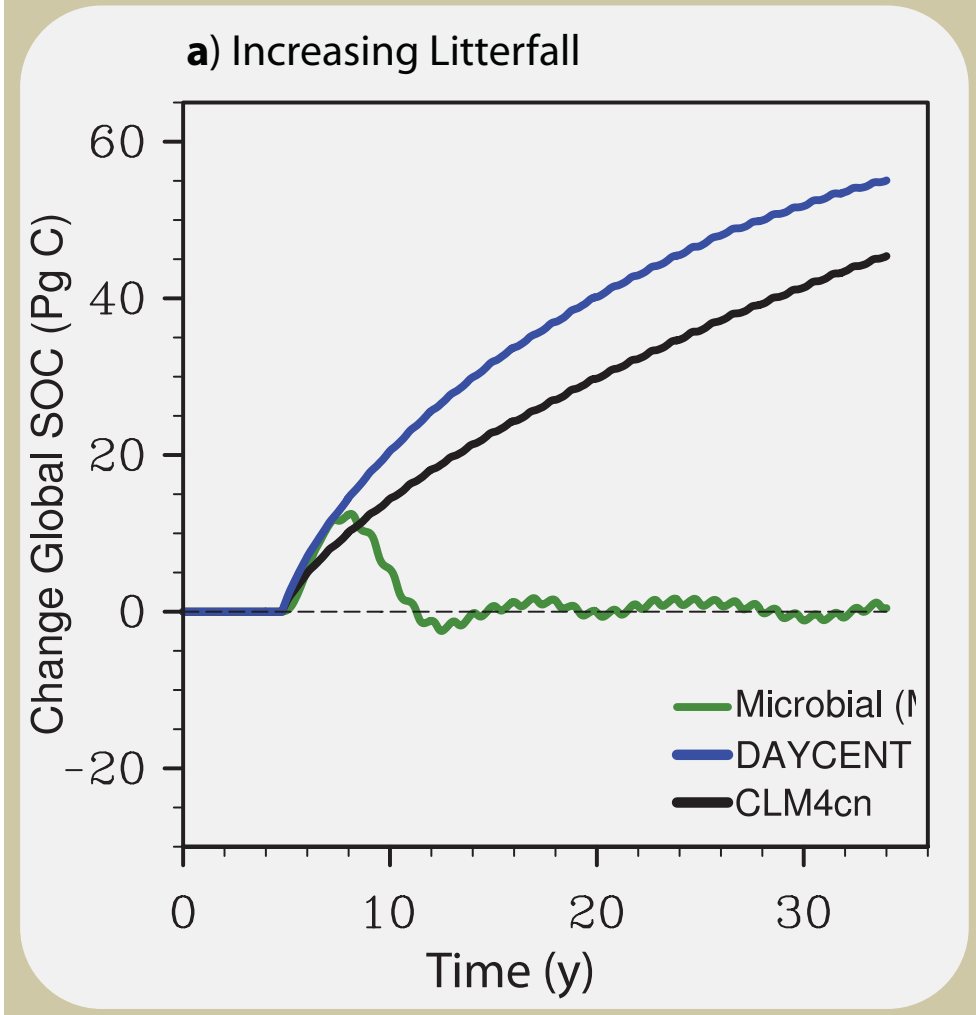
Thank you

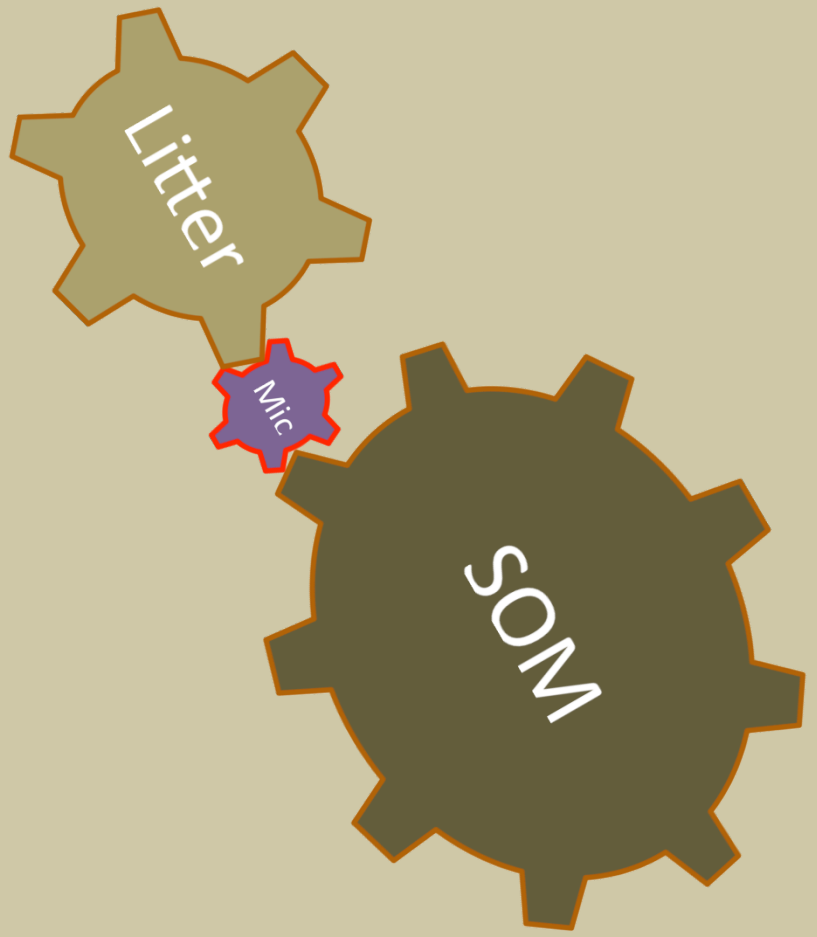


CLM-microbial model



Model structure matters
(in global change settings)





Wieder *et al.* Nature Climate Change 2013

Model structure matters
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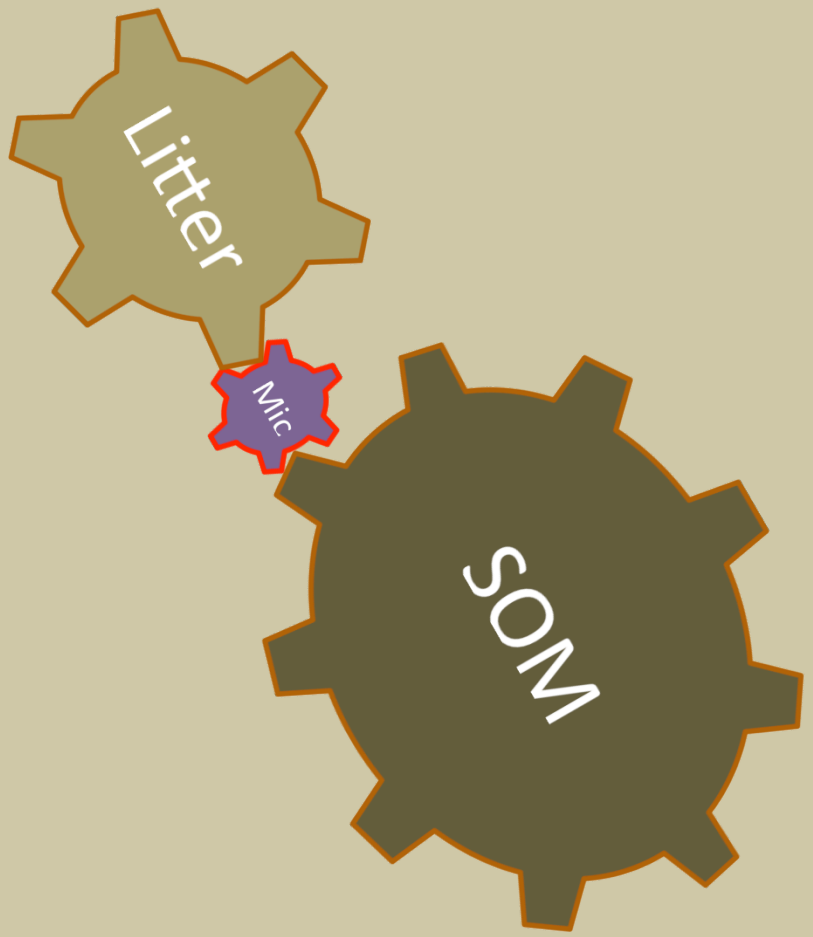
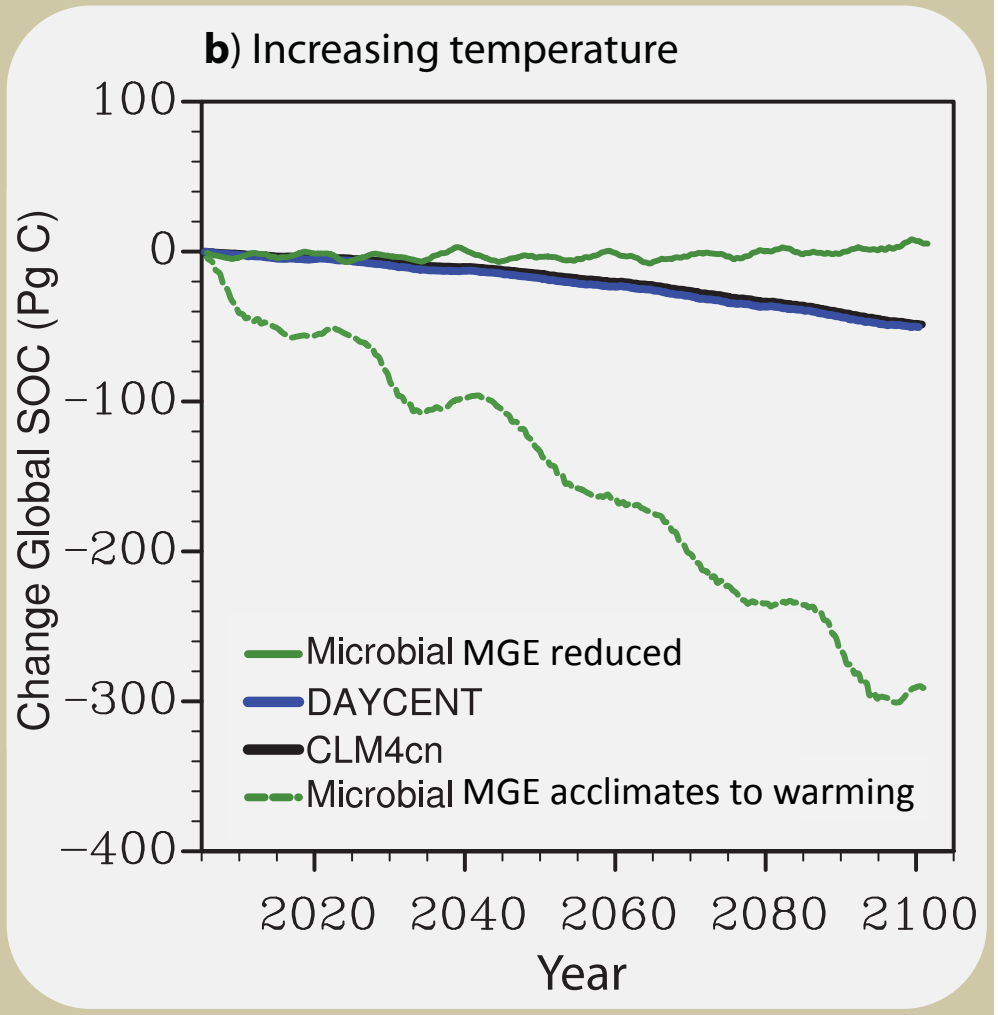
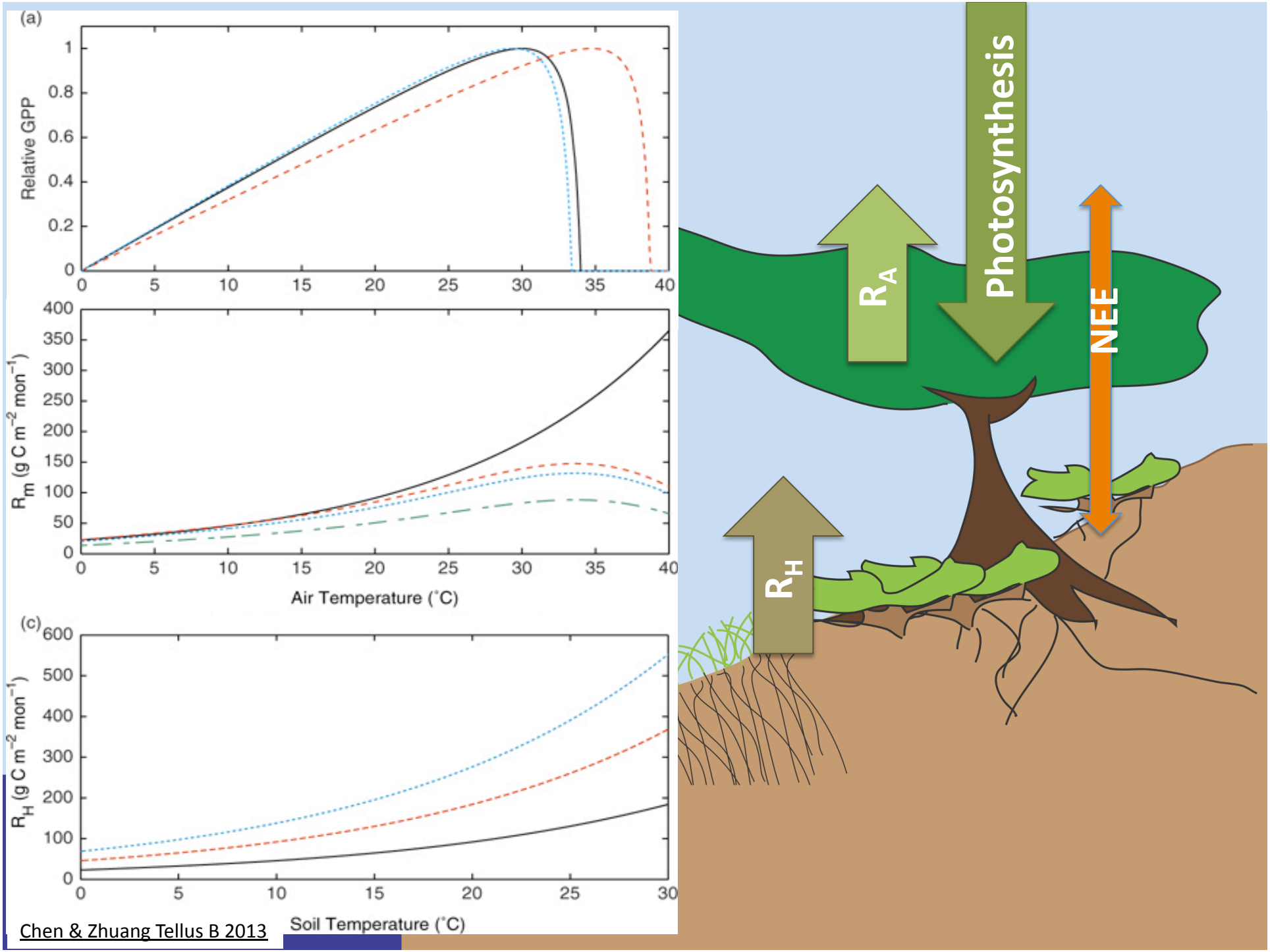


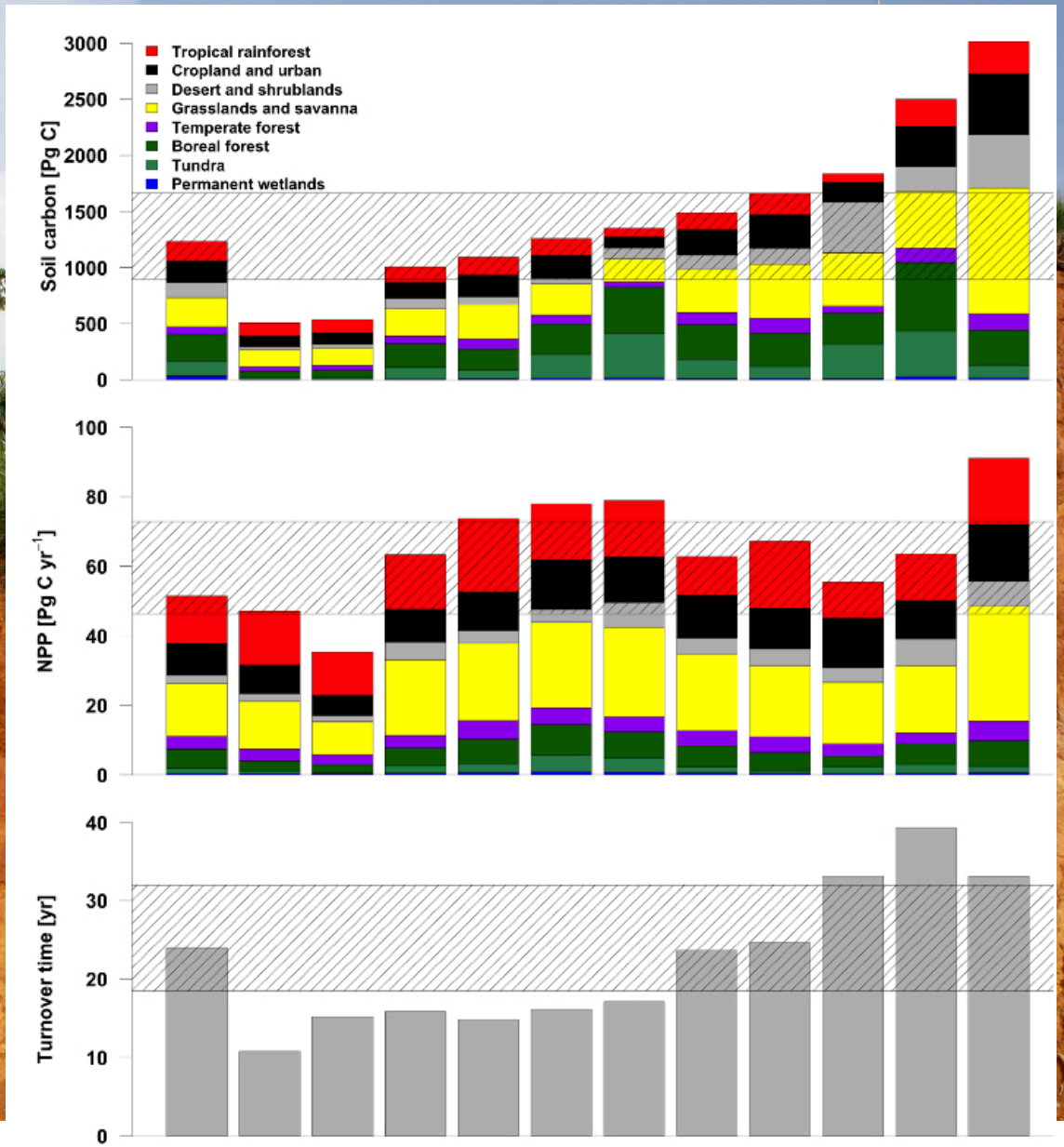


Wieder *et al.* Nature Climate Change 2013



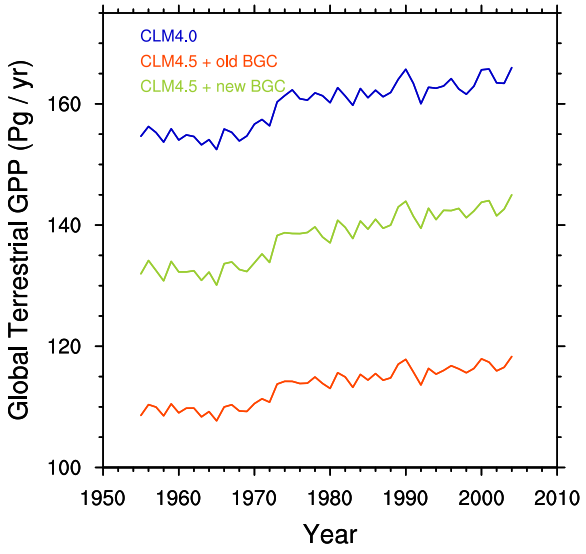
Chen & Zhuang Tellus B 2013

CMIP5 Models = 6x variation

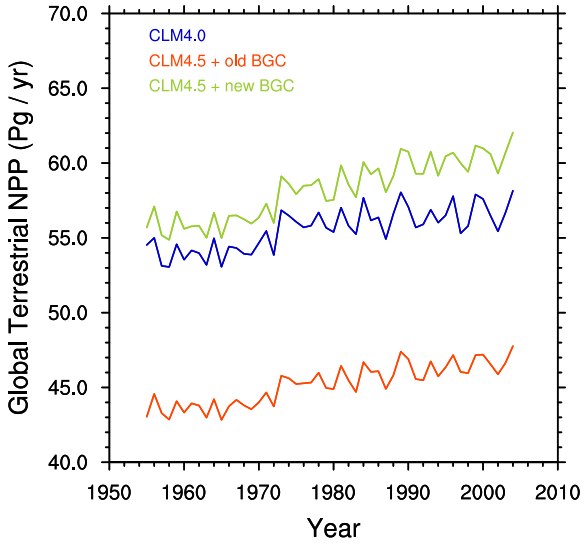


Todd-Brown et al. Biogeosciences 2013, Friedlingstein et al. 2006; Jones et al. 2003

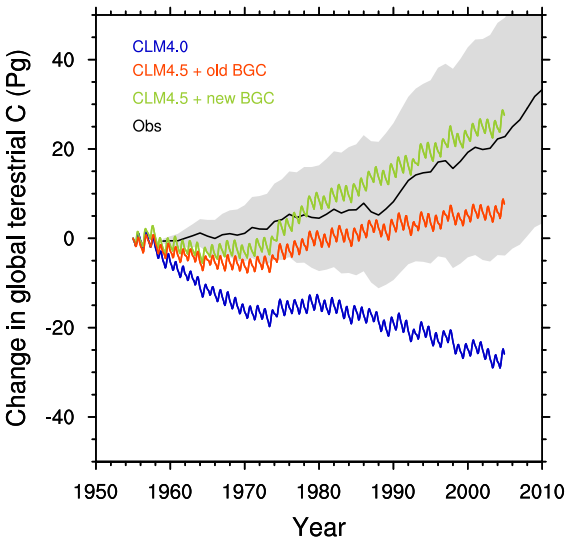
Permafrost soils CLM4.5bgc



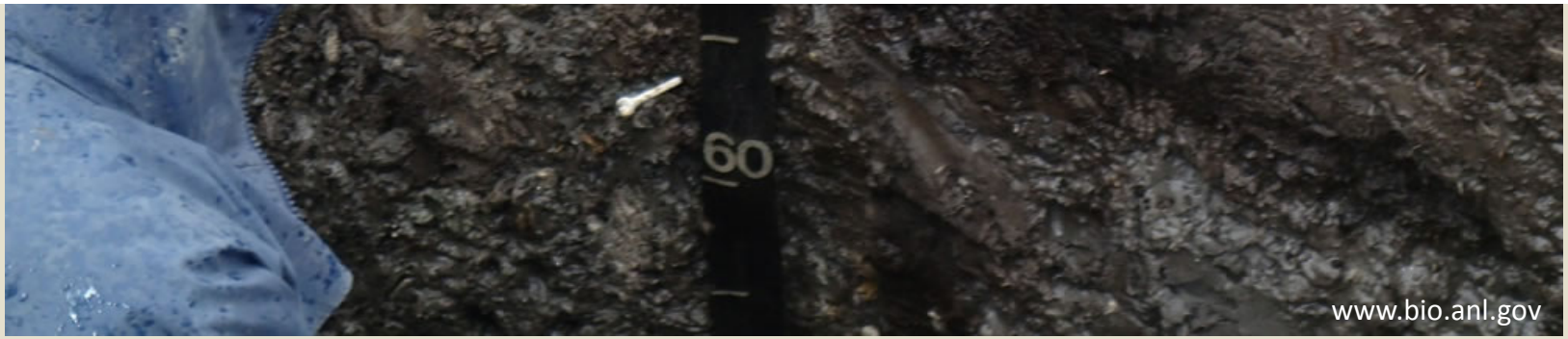
(a) Terrestrial GPP



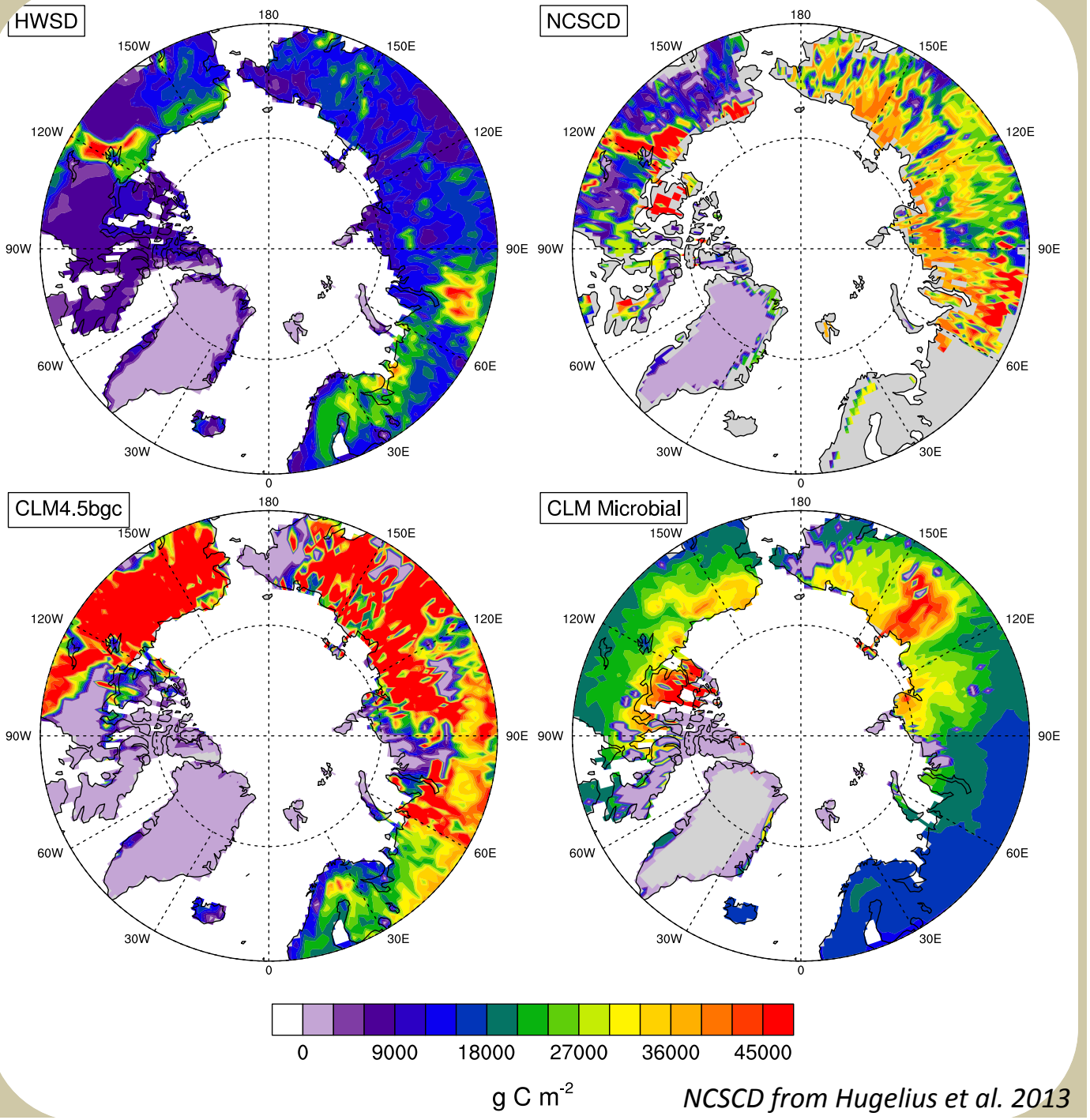
(b) Terrestrial NPP



(c) Change in total terrestrial C



Arctic SOC



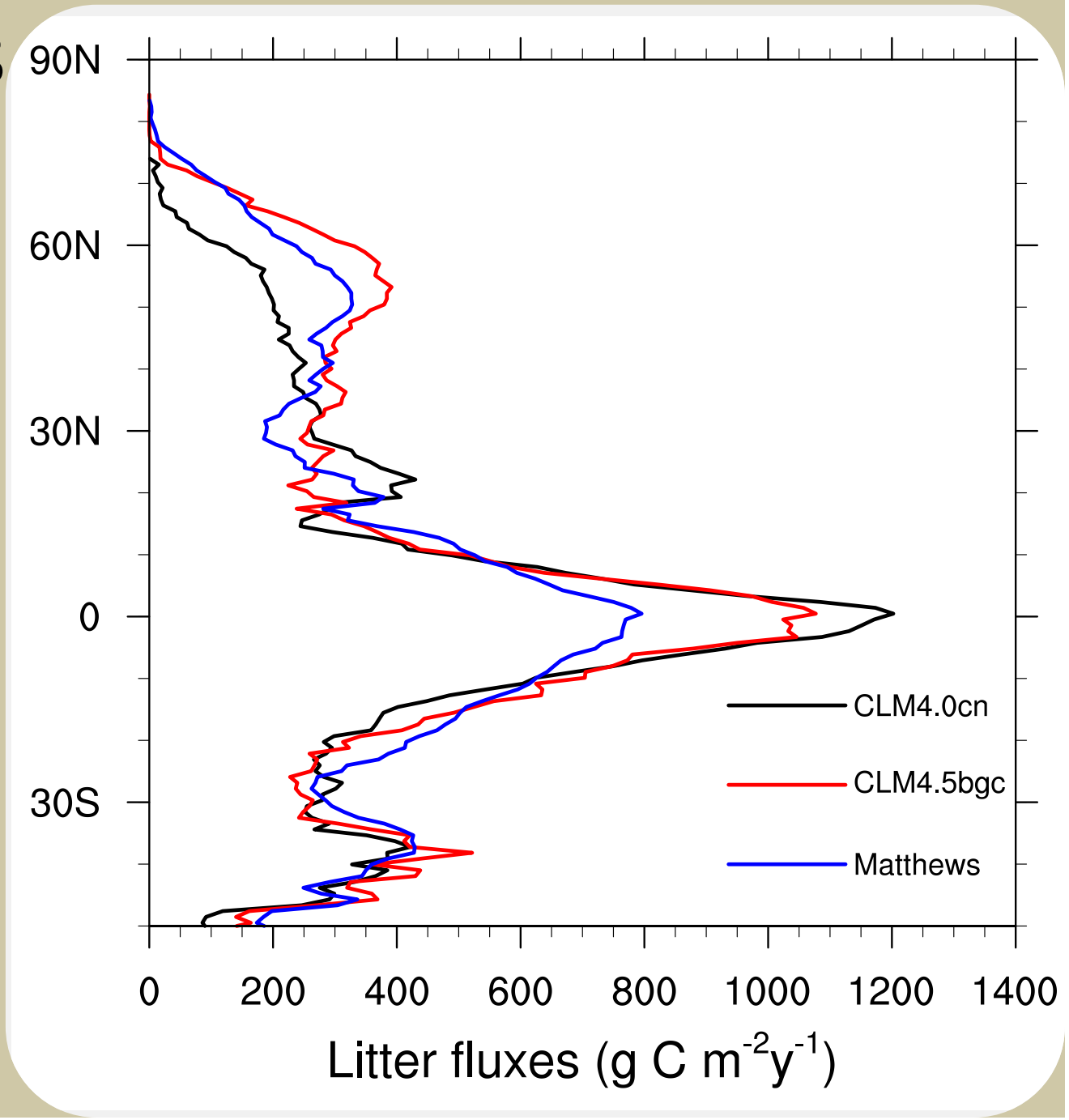
NCSCD from Hugelius et al. 2013

Litter inputs
(Pg C y^{-1})

CLM4.0 = 43

CLM4.5 = 49

Matthews = 45



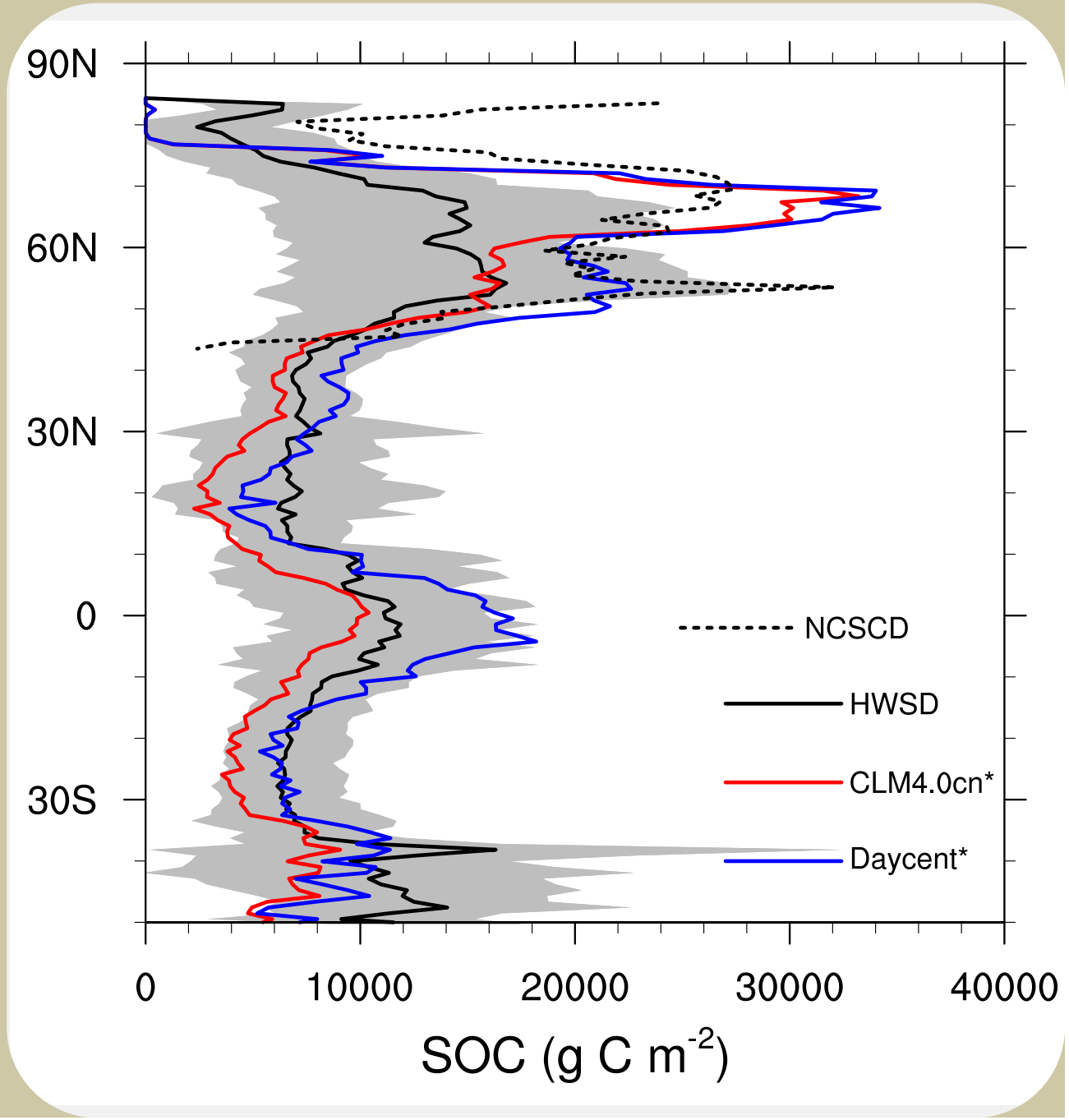
“Old” SOC (Pg C)

HWSD = 1260

CLM4.0 = 1280

DAYCENT = 1710

*CLM4.5 litter fluxes



“New” SOC (Pg C)

HWSD = 1260

CLM4.5 = 2090

Microbial= 1420

*CLM4.5 litter fluxes