Representing life in the Earth system

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Stuart Grandy, Cythia Kallenbach, Gordon Bonan
CESM Workshop June 2014
We simulate **diversity** on land and sea

can we in **soils**?
Functional traits and the global C cycle
Diverse ways to make a living...

in soil
Functional traits

- Plant Litter
- Microbes
- Soil Organic Matter

- Fast
- Slow
MIcrobial-MIneral Carbon Stabilization
MIMICS model

Wieder et al. Biogeosciences 2014
Evaluation across scales

- Global soil C pools
- Leaf litter decomposition
- Soil warming experiments
- N enrichment studies
a) Global carbon pools

Observations: 1260 Pg C (1m depth)

CLM 4.5: 1740 Pg C RMSE 13.0 kg m$^{-2}$

* 0-100cm, all models w/ same forcing from CLM4.5 output
a) Global carbon pools
b) Response to N enrichment
b) Response to N enrichment

Leaf litter inputs

Organic layer C

Microbial Biomass

Mineral Soil C

Observed MIMICS DAYCENT

Wieder et al. In prep
Liu & Greaver Eco. Lett. 2010
b) Response to N enrichment

- Leaf litter inputs
- Organic layer C
- Microbial Biomass
- Mineral Soil C

Observed
MIMICS
DAYCENT

Fast
Slow

se Ratio

Liu & Greaver Eco. Lett. 2010
Wieder et al. In prep
b) Response to perturbations

- $V_{\text{max}}, K_m$
- $1-\varepsilon$
- $\tau$
- $f_p$
- $f_c$
- $f_{i, \text{struc}}$
Evaluation across scales...

Response to perturbations
We simulate diversity on land and sea

can we in soils?

YES, and it improves simulations
Reducing uncertainty
…for the right reasons.

Microbial activity

Microbial diversity
Thank you
b) Process representation: LIDET

Wieder et al. *BGD* 2014; see also Bonan et al. *GCB* 2013
b) Process representation: LIDET

Wieder et al. in prep; see also Bonan et al. GCB 2013
b) Process representation: LIDET
Microbial implicit

Substrate quality

Microbial activity

Substrate availability
Soil C Stabilization

DAYCENT
CLM 4.5
CLM 4.0

CLM$^3$
c) Response Perturbations

- Soil Warming
- N Enrichment
c) Response to Soil Warming, HFR

1. Substrate limitation
2. Microbial acclimation
3. Change C inputs
c) Response to Soil Warming, HFR

1. Substrate limitation
2. Microbial acclimation
3. Change C inputs

\[ \frac{\text{MIC} \times \text{\(V_{MAX}\)} \times \text{SOM}}{(\text{\(K_m\)} + \text{SOM})} \]

Wieder et al. In prep
c) Response to Soil Warming, HFR

1. Substrate limitation
2. Microbial acclimation
3. Change C inputs
c) Response to Soil Warming, HFR

1. Substrate limitation
2. Microbial acclimation
3. Change C inputs

![Graph showing response to soil warming with three key points: MIMICS warming, DAYCENT warming, and observed changes from Melillo et al. 2002 and 2011.](image)

Wieder et al. In prep
c) Response to Soil Warming, HFR

Wieder et al. In prep
Scaling microbial traits

- **Vmax**
- Predicted
- Uncertainty
- Interpolated
- Measured

**Temperature**
Global change response

Wieder et al. Nature Climate Change 2013
Model structure matters

(a) Increasing Litterfall

(b) Increasing temperature

Wieder et al. Nature Climate Change 2013
Microbial *theory* at *global* scales
Climate-regulated decomposition; captures less variation in decomposition at regional scales.

The regression line is similar despite marked context-dependency in local decomposition rates.

Local-scale variation is large, suggesting that mean site temperature is a relatively weak control at regional scales and local-scale variation assumes greater importance.
**MIcrobial-MIneral Carbon Stabilization**

**MIMICS model**

Decomposition = \( \frac{\text{MIC}_r \times V_{\text{max}} \times \text{SOM}_a}{(K_m + \text{SOM}_a)} \) (mg cm\(^{-3}\))

- **Plants**
- **Microbes**
- **Minerals**