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Modeling peatland carbon dynamics on decadal to millennial time scales

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Modeling peatland carbon dynamics on decadal to millennial time scales
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Jill Bubier (*Mt. Holyoke College*)

Postcard of peat cutting for fuel, Co. Galway, Ireland
Peatlands are complex ecosystems:

- hydrology & biogeochemistry
- vegetation dynamics & interactions
- spatial heterogeneity
- microbial communities, decomposition
- role of landscape setting & disturbance

What do scientists typically do?
Mer Bleue Bog, Ontario
Photo: Elyn Humphries

Look more closely.
Describe more features.
Identify more interactions.
Raise more questions.

Photo: CJ Fallon Ltd.

Sphagnum moss leaf cross section

Wim van Egmond/Visuals Unlimited, Inc.
Modeling goal: describe system – state, functions, dynamics, feedbacks

- **synthesis**: identification of knowledge/data gaps
- **extrapolations** – e.g., 21st century scenarios
- **interpolations** – e.g., regional/national assessments
Modeling goal: describe system – state, functions, dynamics, feedbacks in a model with a 40-word vocabulary.

Photo credit: A. Baird
The Peatland Carbon – Hydrological System

Net primary production

Living Biomass

Dead plant litter

Aerobic decomposition

Anaerobic decomposition

Sluggan Bog, N. Ireland
Photo: NT Roulet
Feedbacks in the plant-peat-water system that control peat accumulation

- Water table
- Vegetation productivity
- Peat decomposition
- Peat depth
Feedbacks in the plant-peat-water system that control peat accumulation

- Water table
- Vegetation types
- Vegetation productivity
- Peat decomposition
- Litter/peat tissue quality
- Peat depth
Feedbacks in the plant-peat-water system that control peat accumulation

- Water table
- Vegetation types
- Peat hydraulic properties
- Peat bulk density
- Peat decomposition
- Litter/peat tissue quality
- Vegetation productivity
- Run-off

- Peat depth
The Peatland Carbon – Hydrological System

Net primary production

Ei → P

Living Biomass
Dead plant litter

Aerobic decomposition

Anoxia
vascular/moss NPP

Run-on
Run-off

Precipitation
Evapotranspiration

Peat humification

Permanent saturation
Unsaturated

RO

GW?

YEAR i

NPP

leaf

root

Decomp

YEAR i+1

Sluggan Bog, N. Ireland
Photo: NT Roulet
HPM 8500-year simulation of hypothetical sub-boreal peatland annual peat accumulation and water table depth (also simulating net C balance, plant community composition)

HPM – Holocene Peat(land) Model
Frolking et al. 2010. Earth System Dynamics, 1, 1–21, 2010
Mer Bleue Bog, Ontario, Canada
peat accumulation through the Holocene

PJH Richard core data
Mer Bleue core – MB930

Lac Hertel
high
low
high
low
low
high
high
apparent C accumulation

g C m\(^{-2}\) y\(^{-1}\)

Photo: Elyn Humphries
Precipitation history - reconstructed from pollen & lake-level data

Postglacial climate in the St. Lawrence lowlands, southern Québec: pollen and lake-level evidence

Serge D. Muller a,b,c,*, Pierre J.H. Richard a,b, Joël Guiot d, Jacques-Louis de Beaulieu e, David Fortin a

simulations start at 8500 BP

stochastic precipitation consistent with paleo-reconstruction
Mer Bleue core and simulated ‘core’

- Vascular PFTs: 65% of total NPP; 35% of final peat.
- Ombrotrophic PFTs: 65% of total NPP; 80% of final peat.
- 6.5% of total NPP over 8500 years remains as peat.
Modeling peatland carbon dynamics

Characterizing anthropogenic disturbances

'Mer Bleue Bog' scenario for 6000 years...

- Peat depth (m)
- Net C flux to atmosphere (kg C m$^{-2}$ y$^{-1}$)
- Water table depth (m)

Year of simulation

- Peat depth fairly steady around 0.2 m
- Net C flux weakly uptake around 0.2 t C ha$^{-1}$ y$^{-1}$
- Water table fairly steady around 0.2 m

Slow peat accumulation ~0.04 m per century

At which time...

- Drainage ditch blocked

5500 5700 5900 6100 6300 6500
‘Mer Bleue Bog’ scenario, ditch installed in year 6000, maintained, then blocked in year 6100.

Modeling peatland carbon dynamics
Characterizing anthropogenic disturbances

<table>
<thead>
<tr>
<th>Year of Simulation</th>
<th>Peat Depth (m)</th>
<th>Water Table Depth (m)</th>
<th>Net C Flux to Atmosphere (kg C m(^{-2}) y(^{-1}))</th>
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</tr>
<tr>
<td>6500</td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

‘Drainage ditch’ installed, water table drops ~0.2m.

‘Drainage ditch’ blocked.
Modeling peatland carbon dynamics

Characterizing anthropogenic disturbances

'Mer Bleue Bog' scenario, ditch installed in year 6000, maintained, then blocked in year 6100.

- Peat depth (m)
- Net C flux to atmosphere (kg C m^{-2} y^{-1})
- Water table depth (m)

- Peat surface lowers about 0.4 m. Physical subsidence not modeled.
- Initial net loss of about 3 t C ha^{-1} y^{-1}
- Declining net C loss as peat surface lowers and effective drainage depth decreases.
- Enhanced C uptake following blocking
- 'Drainage ditch' installed; water table drops ~0.2 m
- 'Drainage ditch' blocked

Year of simulation:
- 5500
- 5700
- 5900
- 6100
- 6300
- 6500
Modeling tropical peatland carbon dynamics – challenges

- much less studied than temperate and boreal peatlands.
- no models developed to simulate tropical peatland C dynamics?
- a number of challenges to developing and applying effective & useful models.

1 – Characterizing tropical peatland vegetation…
   e.g., northern peatland studies focus on mosses more than trees

2 – Characterizing tropical peatland hydrology…
   e.g., are C/H₂O internal feedbacks of northern peatlands relevant?

3 – Parameterizing tropical peatland decomposition…
   e.g., how to handle coarse woody debris in peat profile?

4 – Characterizing anthropogenic disturbances…
   e.g., drainage, fire, restoration

5 – Mapping tropical peatlands…
   e.g., vegetation community, peat depth, bulk density, hydrological setting
Modeling tropical peatland carbon dynamics – challenges

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- a number of challenges to developing and applying effective & useful models.

1 – Characterizing tropical peatland vegetation…
2 – Characterizing tropical peatland hydrology…
3 – Parameterizing tropical peatland decomposition…
4 – Characterizing anthropogenic disturbances…
5 – Mapping tropical peatlands…

Thank you!
Essentially, all models are wrong, but some are useful.

-George Box
Essentially, all models are wrong, but some are useful.

- George Box

-or-

Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.

- George Box & Norman Draper