
T.J. Bohn¹, E. Podest², K.C. McDonald², L. C. Bowling³, and D.P. Lettenmaier¹

¹Dept. of Civil and Environmental Engineering, University of Washington, Seattle, WA, USA
²JPL-NASA, Pasadena, CA, USA,
³Purdue University, West Lafayette, IN, USA

NEESPI Workshop
CITES-2009
Krasnoyarsk, Russia, 2009-July-14
Western Siberian Wetlands

West Siberian Lowlands

Wetlands: Largest natural global source of CH$_4$

30% of world’s wetlands are in N. Eurasia

High latitudes experiencing pronounced climate change

Response to future climate change uncertain

(Gorham, 1991)

Fig. 2. The location of Soviet peatland resources (modified from Neustadt 1984).
Climate Factors

- CO2
- CH4

Relationships non-linear

Water table depth not uniform across landscape - heterogeneous

Living Biomass

- Acrotelm
- Water Table
- Catotelm

Temperature (via metabolic rates)

Temperature (via evaporation)

Precipitation

Aerobic $R_h$

Anaerobic $R_h$

Note: currently not considering export of DOC from soils
Water Table Heterogeneity

- Many studies assume uniform water table distribution within static, prescribed wetland area
  - *Can lead to “binary” CO2/CH4 partitioning*
- Distributed water table allows smoother transition and more realistic inundated area
  - *Facilitates comparisons with:*
    - remote sensing
    - point observations
Questions

How does taking water table heterogeneity into account affect:

• comparisons of inundated area with remote sensing observations?
• estimates of greenhouse gas emissions?
Modeling Framework

- VIC hydrology model
  - Large, “flat” grid cells (e.g. 100x100 km)
  - On hourly time step, simulate:
    - Soil T profile
    - Water table depth $Z_{WT}$
    - NPP
    - Soil Respiration
    - Other hydrologic variables...

How to represent spatial heterogeneity of water table depth?
Spatial Heterogeneity of Water Table: TOPMODEL* Concept

Relate distribution of **water table** to distribution of **topography** in the grid cell

Start with DEM (e.g. SRTM3)

For each DEM pixel in the grid cell, define **topographic wetness index**

\[ \kappa_i = \ln(\alpha_i / \tan \beta_i) \]

- \( \alpha_i \) = upslope contributing area
- \( \tan \beta_i \) = local slope

**Essentially:**
- flat areas are wet (high \( \kappa_i \))
- steep areas are dry (low \( \kappa_i \))

Local water table depth

\[ Z_{wt_i} = Z_{wt_{mean}} - m(\kappa_i - \kappa_{mean}) \]

\( m \) = calibration parameter

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**Wetness Index Distribution**

- All pixels with same \( \kappa \) have same \( Z_{wt} \)

**Pixel Count**

- Soil surface

\( Z_{wt_{mean}} \) (from VIC)

*Beven and Kirkby, 1979*
Using Farquhar C assimilation, dark respiration, etc. from BETHY (Knorr, 2000)
Study Domain: W. Siberia

Close correspondence between:
• wetness index distribution and observed inundation of wetlands from satellite observations
Chaya/Bakchar/Iksa Basin

Wetness Index from SRTM3 DEM

ALOS/PALSAR Classification

(JAXA, NASA/JPL)
Comparison with PALSAR

- Spatial distribution of inundation compares favorably with remote sensing
- This offers a method to calibrate model soil parameters

<table>
<thead>
<tr>
<th>ROI 1</th>
<th>2006-06-09</th>
<th>Observed Inundated Fraction (PALSAR Classification)</th>
<th>Simulated Inundated Fraction (at optimal Zwt)</th>
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<td>2007-07-06</td>
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<td><img src="image2.png" alt="Image" /></td>
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<td><img src="image6.png" alt="Image" /></td>
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Approx. 30 km
How do resulting emissions differ between uniform water table and distributed water table?

**Experiment:**

- Calibrate methane model to match in situ emissions at a point (Bakchar site, Friborg et al, 2003)
- **Distributed case:** calibrate distributed model water table depth to match observed inundation
- **Uniform case:** select water table timeseries from single point in the landscape having same long-term average methane emissions as the entire grid cell in the distributed case; apply this water table to entire grid cell
Interannual Variability, 1948-2007

Possible trend in temperature, also in CH4

Uniform Water Table:
Shallower than average of distributed case
But never reaches surface; no inundation
Resulting CH4 has higher variability than for distributed case
Distributed case is buffered by high- and low-emitting regions
Impact on trends?
Net Greenhouse Warming Potential

CH4 makes up small part of C budget, but large contribution to greenhouse warming potential

On 100-year timescale, GHWP(CH4) = approx. 23 * GHWP(CO2)

NPP and RhCO2 approximately cancel

Net GHWP essentially follows GHWP(CH4)

Uniform water table:
- CH4 has larger interannual variability
- So does net GHWP
- Impact on trend assessment?
Interannual Variability, 1948-2007

How do spatial distributions of inundation and CH4 emissions change in response to climate?

Example Years to investigate:
- 1980: “average”
- 1994: warm, dry
- 2002: warm, wet
Response to Climate

1980 = “average” year, in terms of T and Precip
1994 = Warm, dry year
  • Less inundation
2002 = Warm, wet year
  • More inundation

- Increase in Tsoil increases CH4 emissions in wettest areas only
- Increase in saturated area causes widespread increase in CH4 emissions
Conclusions

• Advantages of distributed water table:
  – Facilitates comparison with satellite measurements and point measurements
  – More realistic representation of hydrologic and carbon processes

• Spatial distribution of water table has large effect on estimates of greenhouse gas emissions and their trends
Thank You

This work was carried out at the University of Washington and the Jet Propulsion Laboratory under contract from the National Aeronautics and Space Administration.

This work was funded by NASA grant NNX08AH97G.
Calibration – Bakchar Bog, 1999

Soil T

ZWT (water table depth)

CH₄

VBM = VIC-BETHY-Methane

(Bohn et al., 2007)