Numerical Simulations of Variably Saturated Flow with Energy and Water Phase Change in Northern Latitude Peatland

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• 25-30% of the world’s soil C
• Predominant in N Latitudes
• Up to 21% global CH₄ emissions
• Net sink of CO₂
Ecological Research Site

- Subsurface temperature
- Water fluxes and climatic data
- Water level manipulations
- Microbial populations
- Vegetative response to WT and climate manipulations
Diurnal Temp Fluctuations

- Air
- -2cm
- -10cm
- -25 cm
- -50 cm
Porosity decreases with depth

\( \rho_b \) increases with depth

\[ \lambda, C \]

Thermal Conductivity Models

- Kettridge, 2008
- Kellner, 2009
- Letts, 1999
- Hayashi, 2008
- Weiss, 2006
- McKenzie, 2007a
- McKenzie, 2007b

![Thermal Conductivity Models](image)

```latex
\text{Thermal Conductivity} \quad \text{W/mK}
```
Thermal conductivity functions

- Weighted average of soil constituents 
  (De Vries, 1963)

\[ k = \frac{f_w k_w + y_o f_o k_o + y_a f_a k_a}{f_w + y_o f_o + y_a f_a} \]

- Similar to an Arithmetic mean (Forouki, 1986)

\[ k = (n - \theta)k_a + (f_o + \theta)k_o \left( \frac{f_o}{f_o + \theta} \right)k_w \left( \frac{\theta}{f_o + \theta} \right) \]

- Summation of Heat Capacities

\[ C = \sum_{i=1}^{n=3} f_i C_i \]
Soil Moisture Retention

\[ \theta(\Psi) = \theta \left( -\frac{\gamma_{wa} \Delta_s^1 H_m^*}{\gamma_{iw} T_{fus} \Delta_s^1 v_m^* \rho_{wg}} \frac{t}{1} \right). \]

SFCC

Vol. Moisture Content vs. Pressure (cm)

Temp (C) vs. Freeze Function (1/C)
Applied in HYDRUS (2D/3D)

$R^2=0.54$, $RMSE=7.5°C$
Applied in HYDRUS (2D/3D)

R^2=0.75 RMSE=1.7C

Weiss vs Observed

T (degree C)

t (hours)
Inverse Solution Tools

$R^2=0.90$, $RMSE=1.2C$
Inverse Solution Tools

R² = 0.989, RMSE = 0.37°C
• Assuming Soil Surface Temp dependent on three variables

• Air T, WT and time/season

• Regression characterized by multi-variable paraboloid

\[
R=0.83, \quad R^2=0.74, \quad SE=1.78 \quad n=113
\]
Acknowledgements

- Dr. David McGuire for making travel to the annual AEG Conference at Lake Tahoe possible. Support from the National Science Foundation grant DEB-0425328, the Bonanza Creek Long-Term Ecological Research program (funded jointly by NSF grant DEB-0423442 and USDA Forest Service, Pacific Northwest Research grant PNW01-JV11261952-231. Also legal advice from the attorneys at Dewey, Cheatum and Howe.