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

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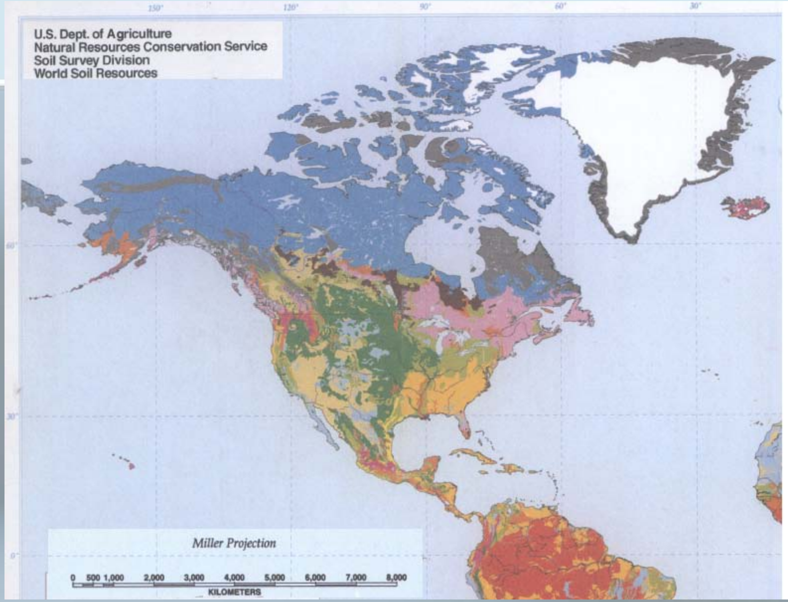
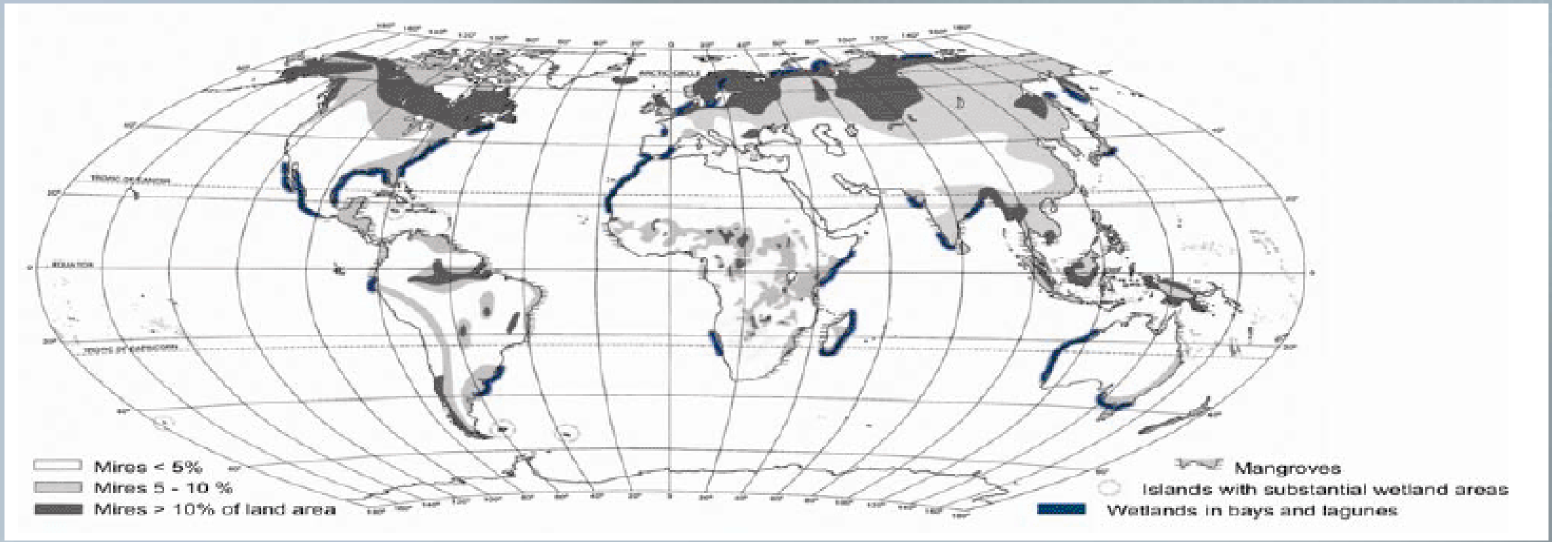
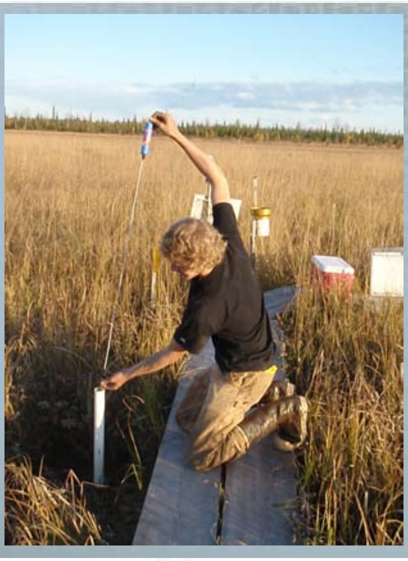


- •25-30% of the world's soil C
- •Predominant in N Latitudes
- •Up to 21% global CH_4 emissions
- •Net sink of CO_2



Ecological Research Site

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



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Permafrost
N
200 m
UAF
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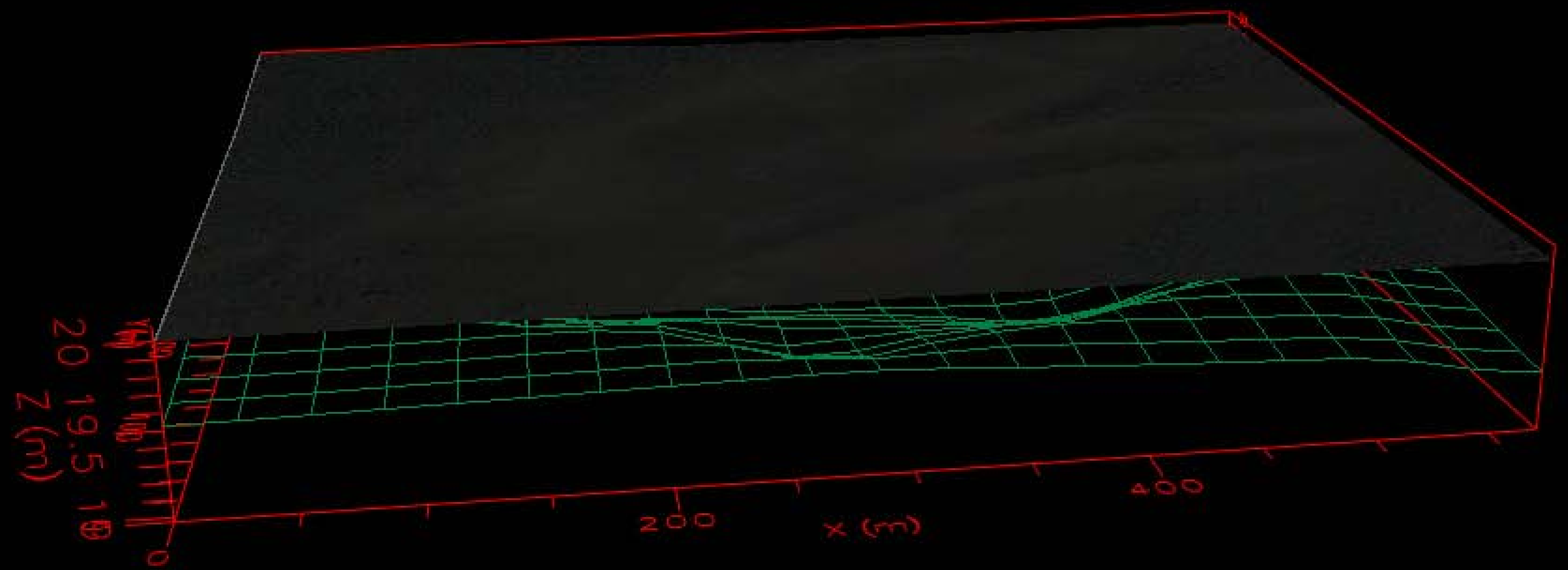
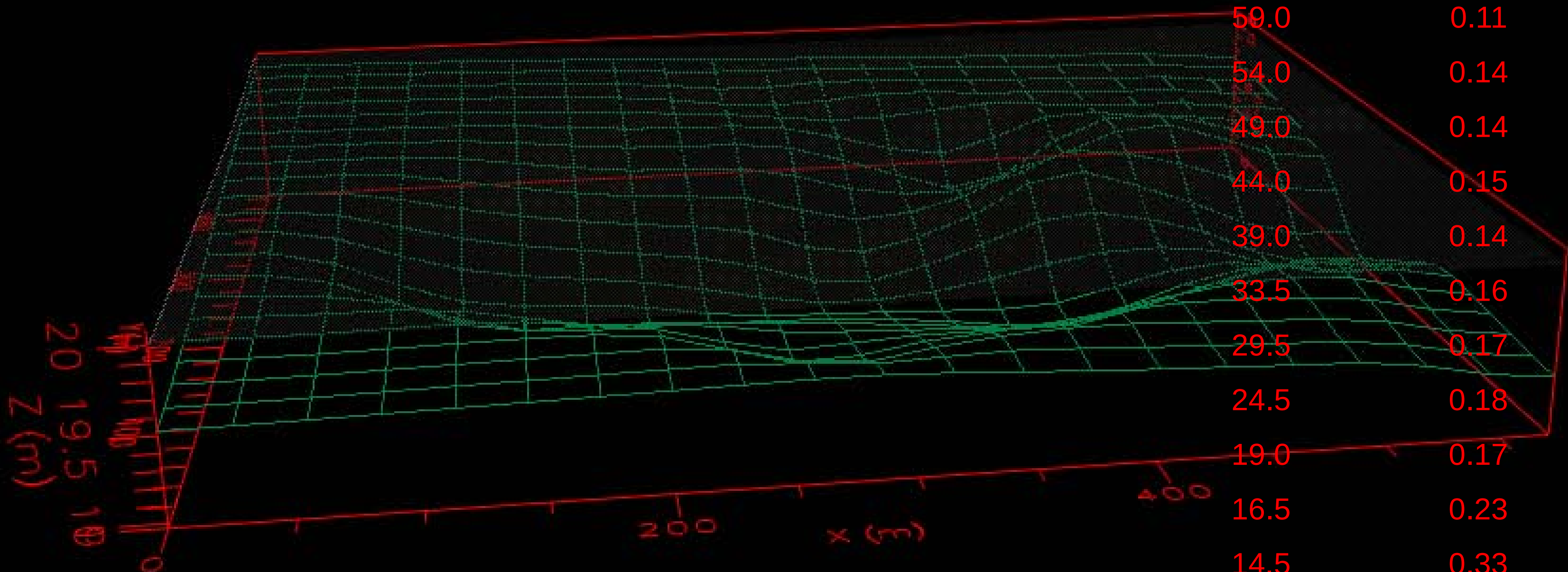

200
400
x (m)
Z (m)
20
19.5
0

Hydraulic Conductivity

Depth	10-30cm	30-50cm	70-90cm	200-250cm
	cm/s	*cm/s*	*cm/s*	*cm/s*
	0.03	0.02	2.2×10^{-3}	6×10^{-7}

Abvove Mineral	Bulk Density	Porosity
cm	*g/ccm*	*%*
74.0	0.07	95
69.0	0.09	94
64.0	0.10	94
59.0	0.11	93
54.0	0.14	91
49.0	0.14	91
44.0	0.15	91
39.0	0.14	91
33.5	0.16	90
29.5	0.17	89
24.5	0.18	88
19.0	0.17	89
16.5	0.23	85
14.5	0.33	79
10.0	0.12	92
7.0	0.14	91
4.0	0.25	84
0.0	0.23	85
-4.0	0.44	73



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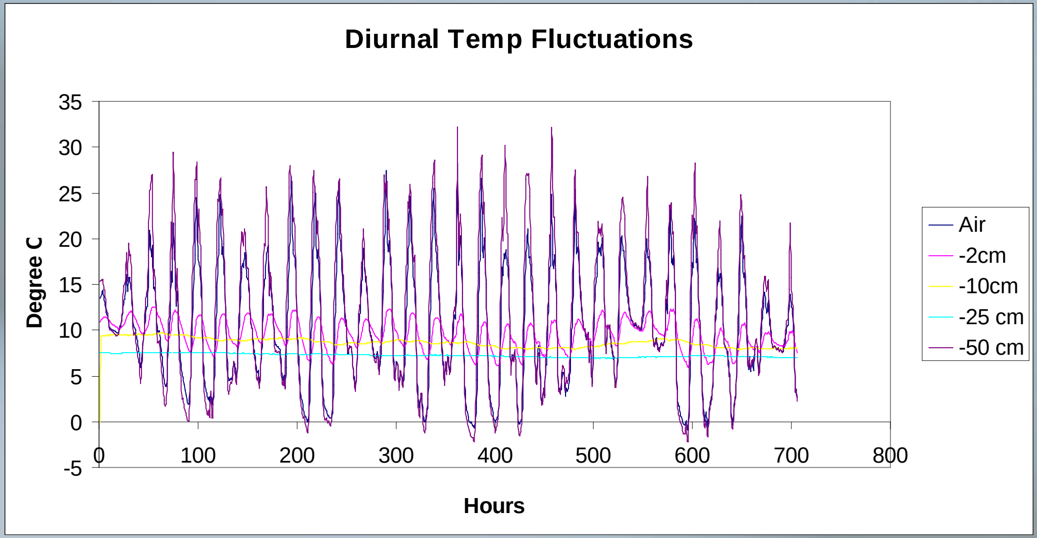
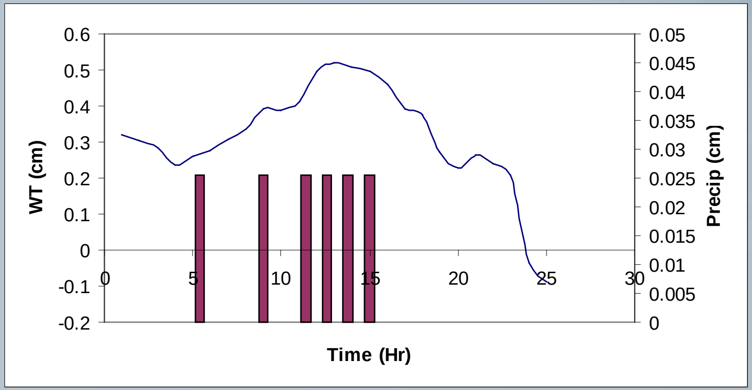
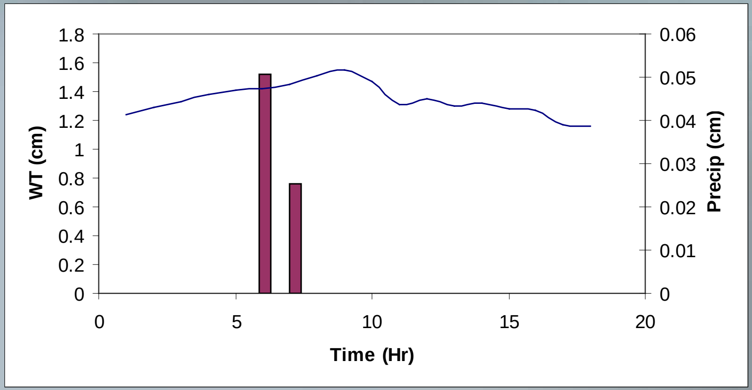
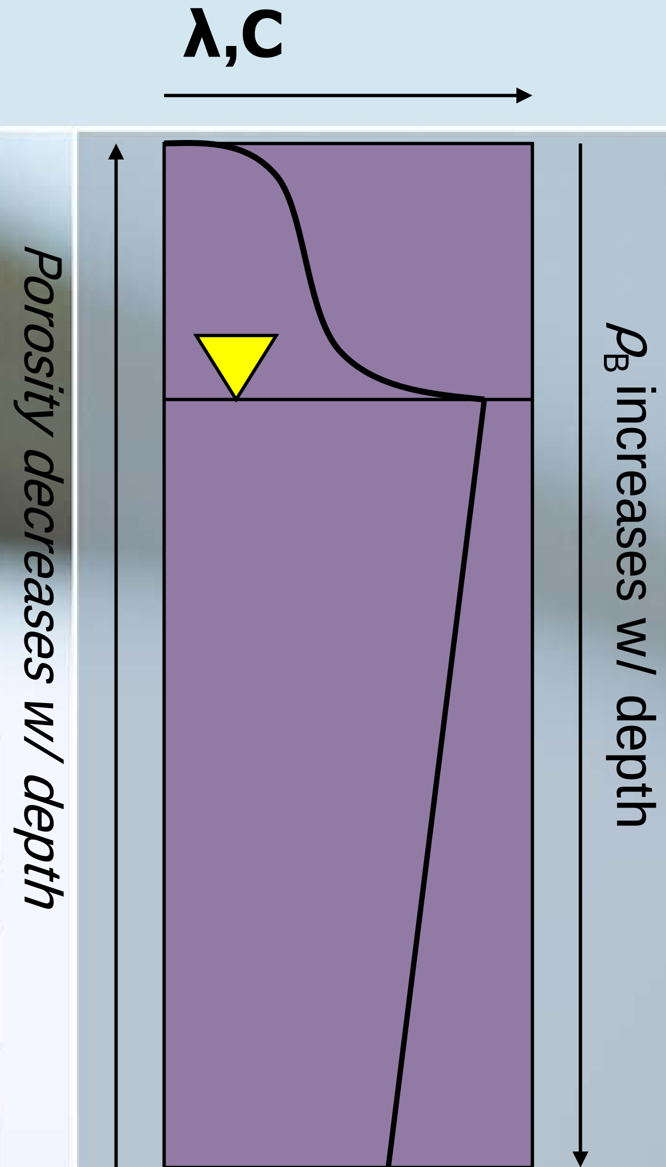
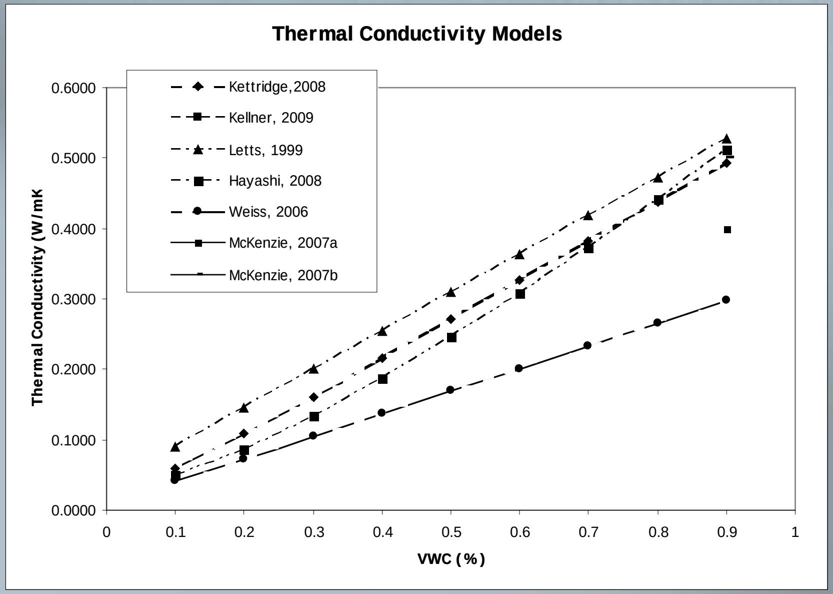

Diurnal Temp Fluctuations
Degree C
Hours
Air
-2cm
-10cm
-25 cm
-50 cm


WT (cm)
Precip (cm)
Time (Hr)


WT (cm)
Precip (cm)
Time (Hr)


λ,C
Porosity decreases w/ depth
ρ_B increases w/ depth


Thermal Conductivity Models
Kettridge,2008
Kellner, 2009
Letts, 1999
Hayashi, 2008
Weiss, 2006
McKenzie, 2007a
McKenzie, 2007b
Thermal Conductivity (W/mK)
0.0000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
VWC (%)

Thermal conductivity functions

- Weighted average of soil constituents

(De Vries, 1963)

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

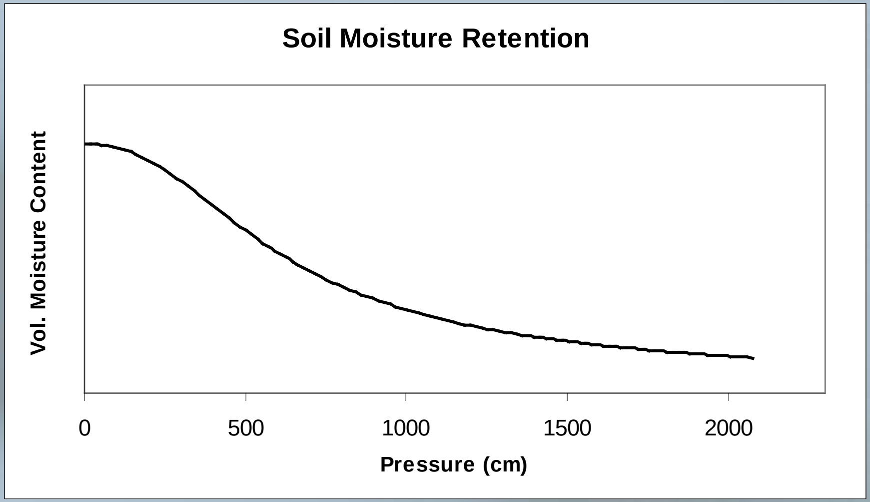
- Similar to an Arithmetic mean (Forouki, 1986)

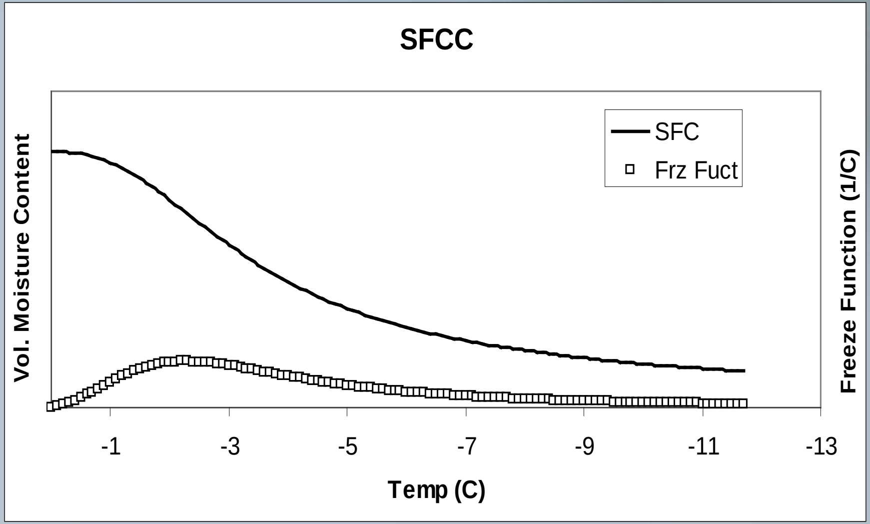
$$k = (n - \theta) k_a + (f_o + \theta) k_o^{(\frac{f_o}{f_o + \theta})} k_w^{(\frac{\theta}{f_o + \theta})}$$

- Summation of Heat Capacities

$$C = \sum_{i=1}^{n=3} f_i C_i$$

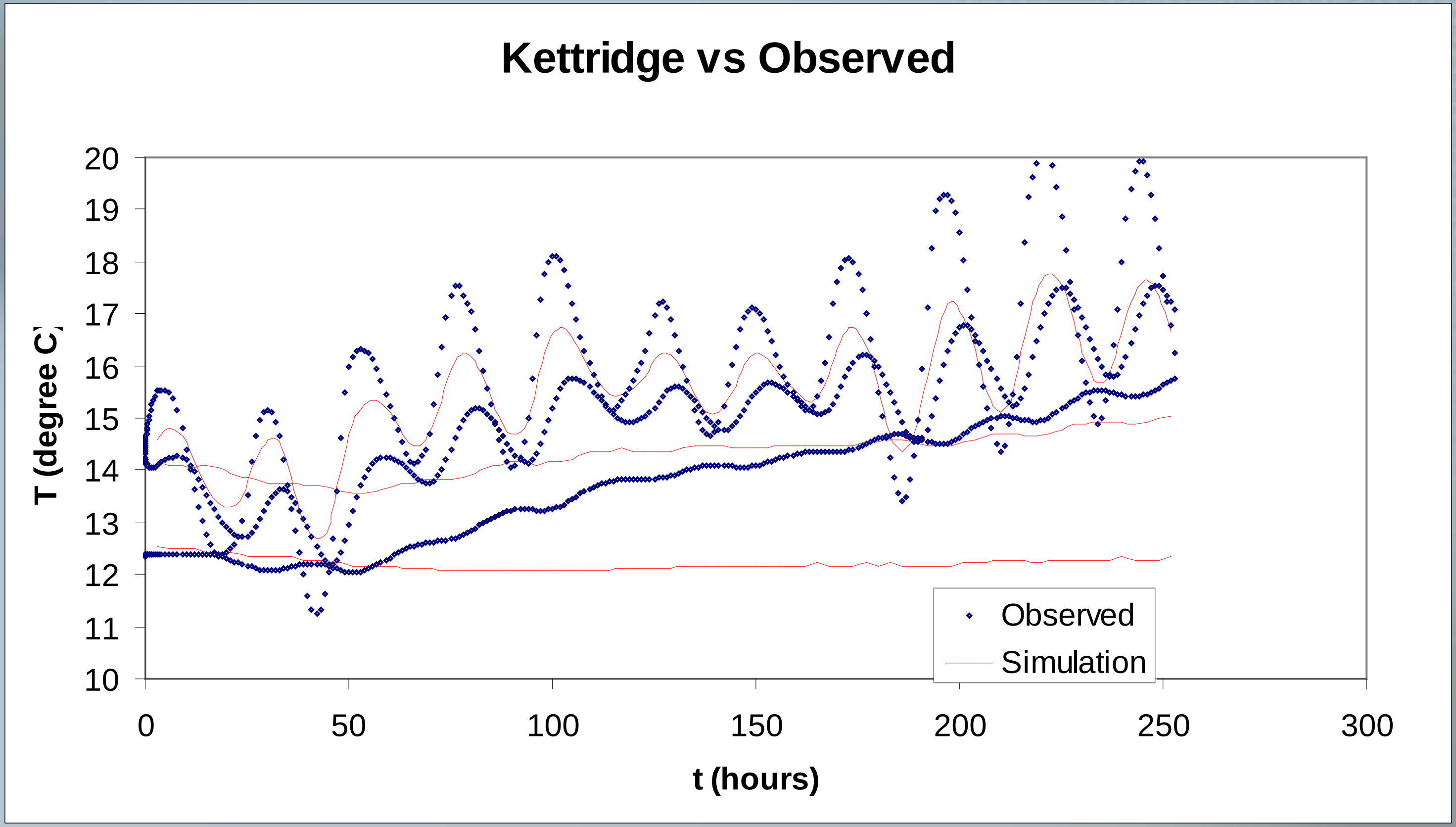
$$\theta(\Psi) \approx \theta\left(-\frac{\gamma_{wa}}{\gamma_{iw}}\,\frac{\Delta_s^l H_m^*}{T_{fus}\Delta_s^l V_m^*}\,\frac{t}{\rho_w^l g}\right).$$





Applied in HYDRUS (2D/3D)

R^2=0.54, RMSE=7.5C



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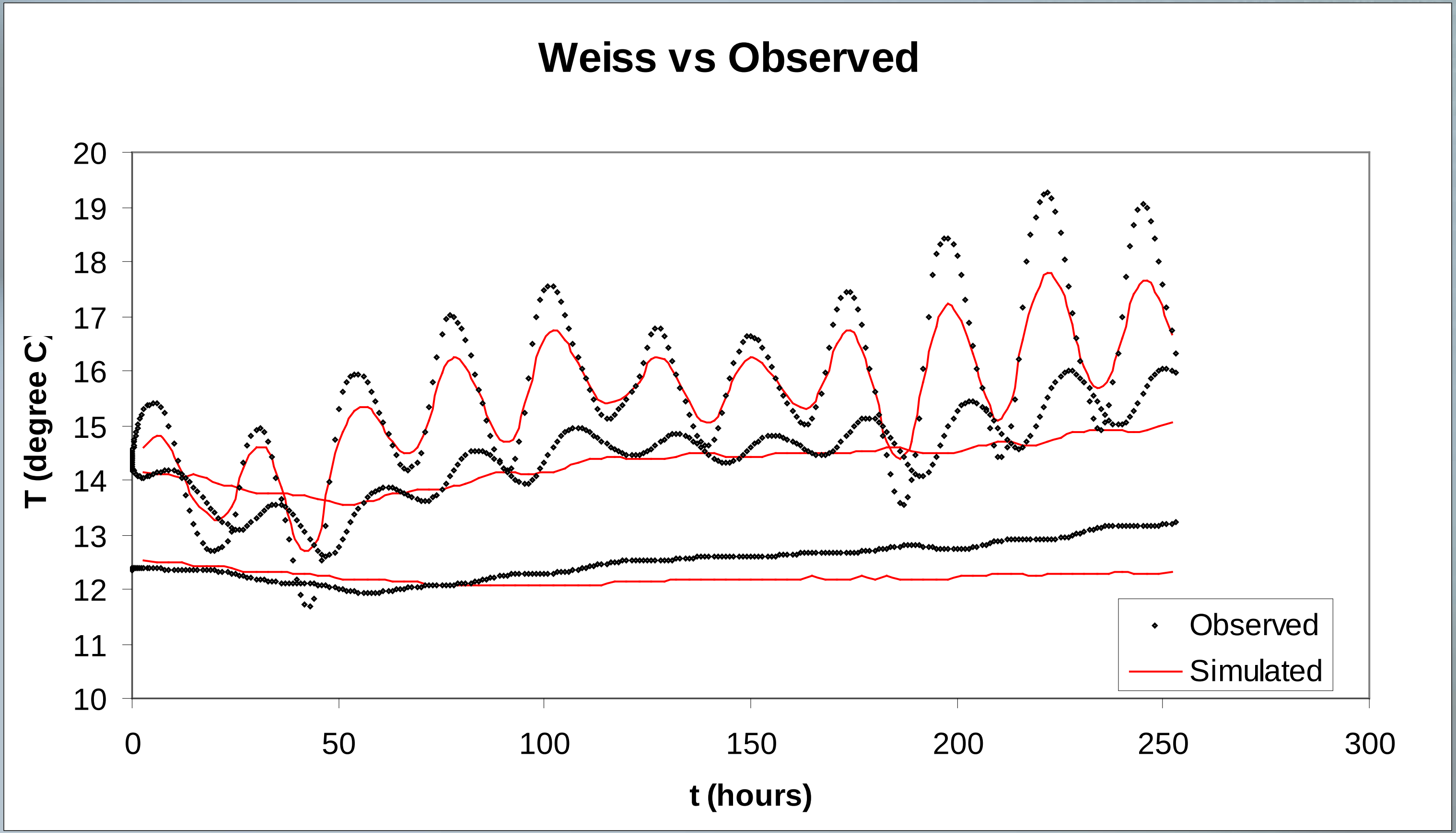
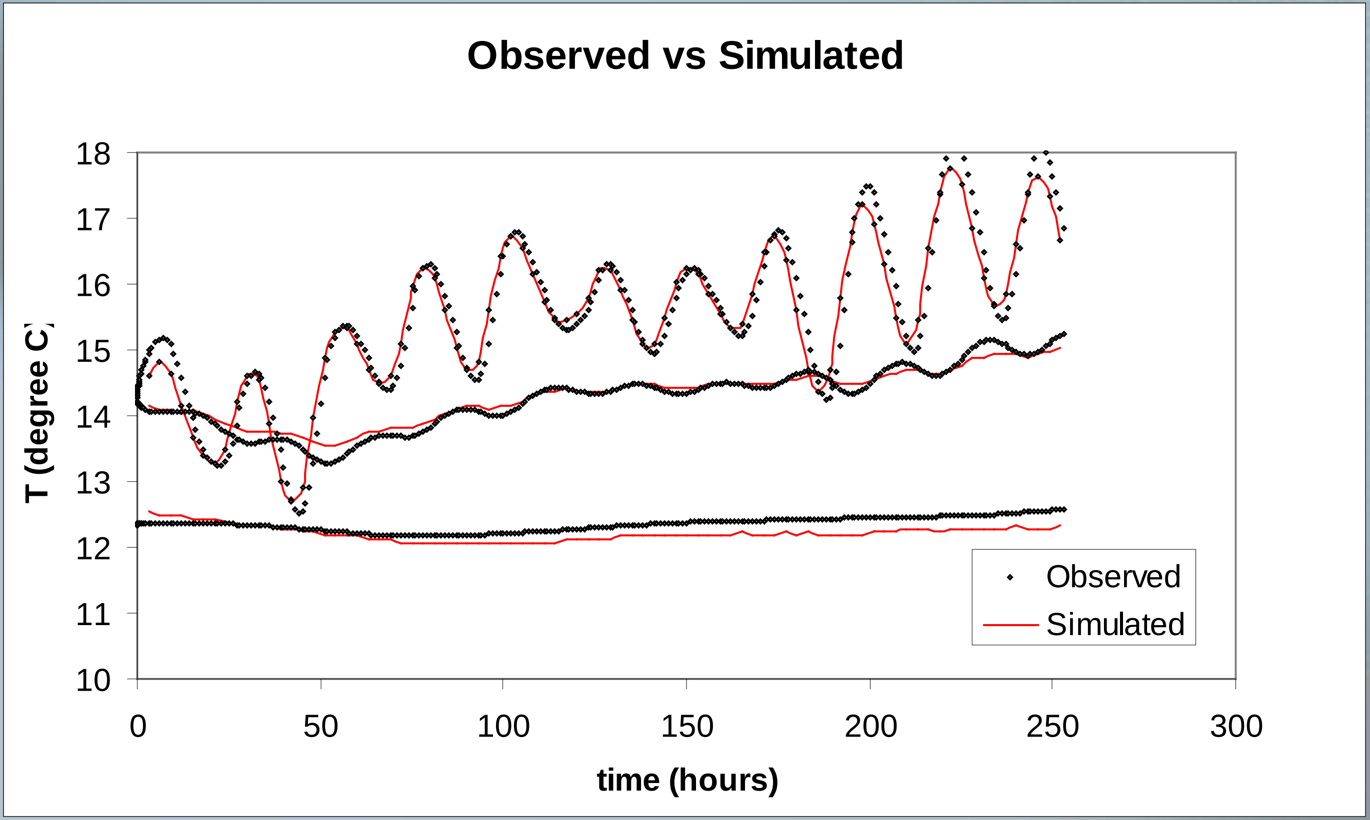
Applied in HYDRUS (2D/3D)

R^2=0.75 RMSE=1.7C



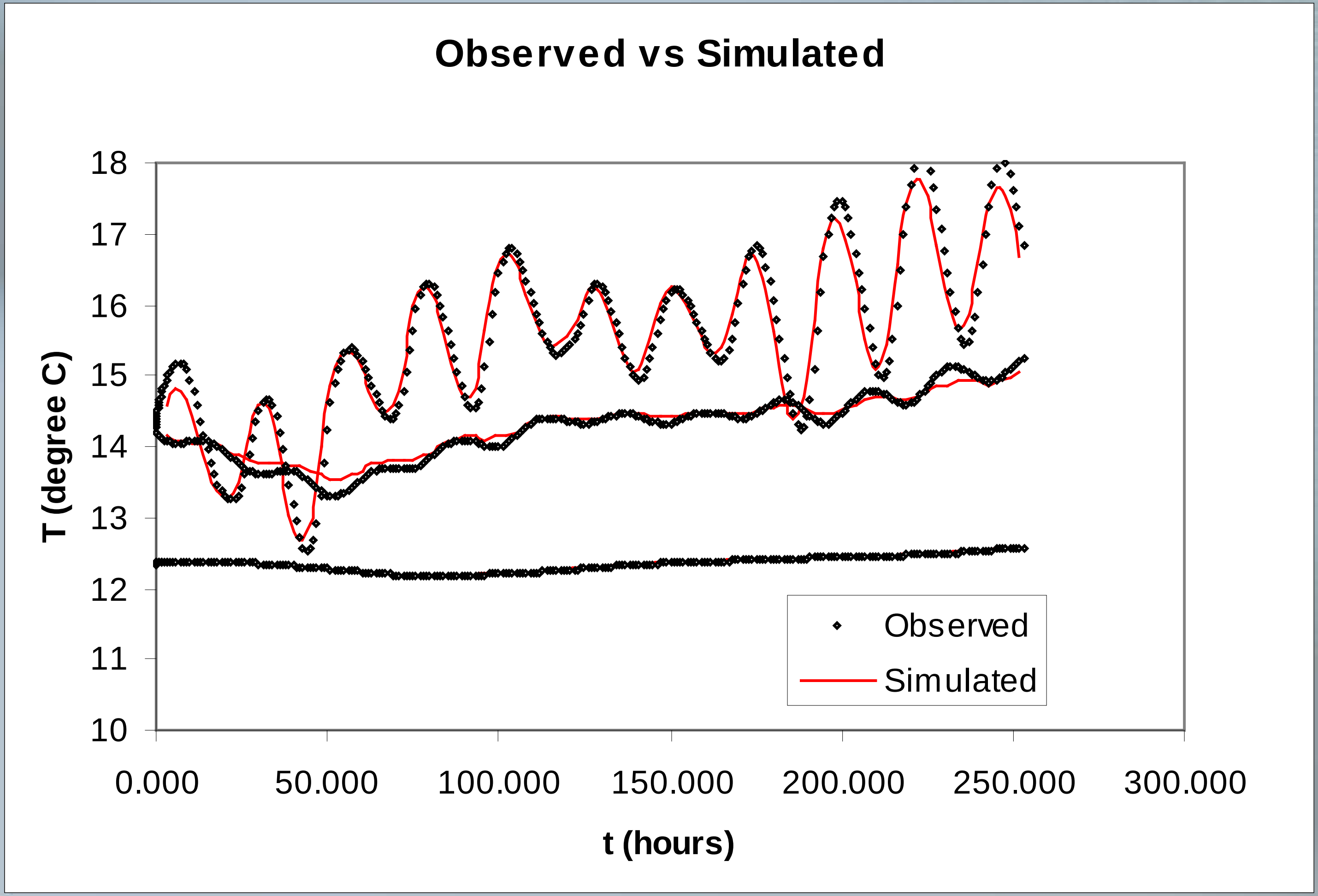
Inverse Solution Tools

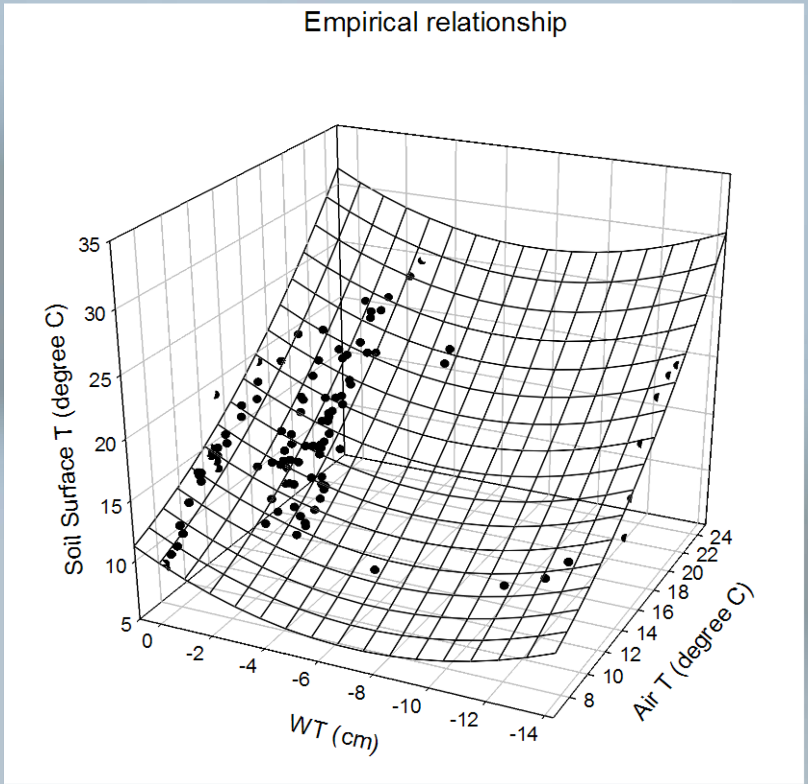
R^2=0.90, RMSE=1.2C



Inverse Solution Tools

R2=0.989, RMSE=0.37C





$R=0.83$, $R^2=0.74$, $SE=1.78$ $n=113$

- Assuming Soil Surface Temp dependent on three variables
- Air T, WT and time/season
- Regression characterized by multi-variable paraboloid

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