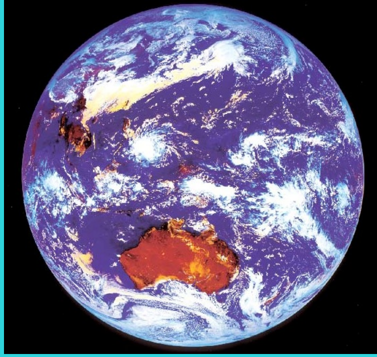


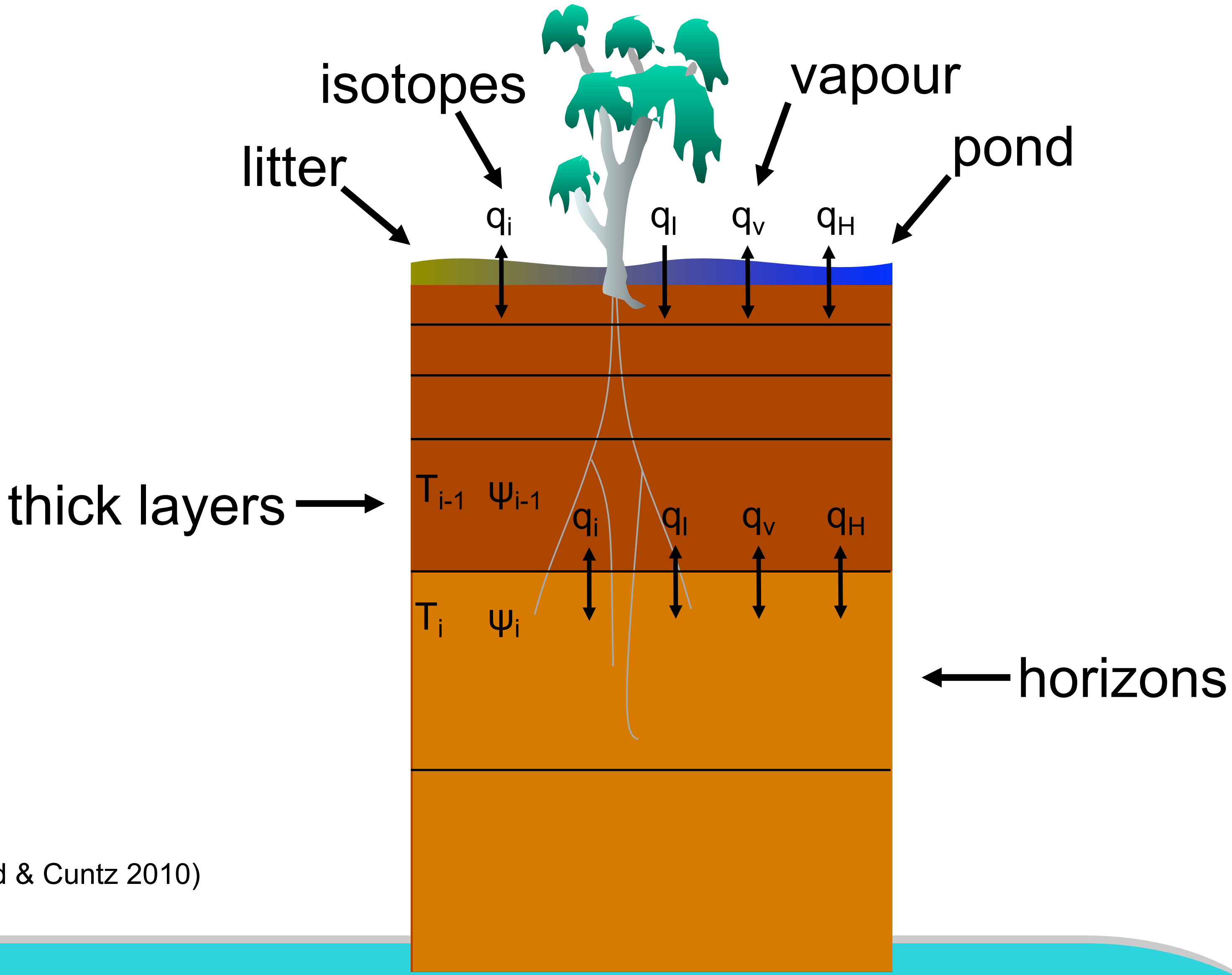
The Soil-Litter-Iso (SLI) soil model and its coupling to CABLE

And Extension to Freezing Conditions

Vanessa Haverd | Research Scientist

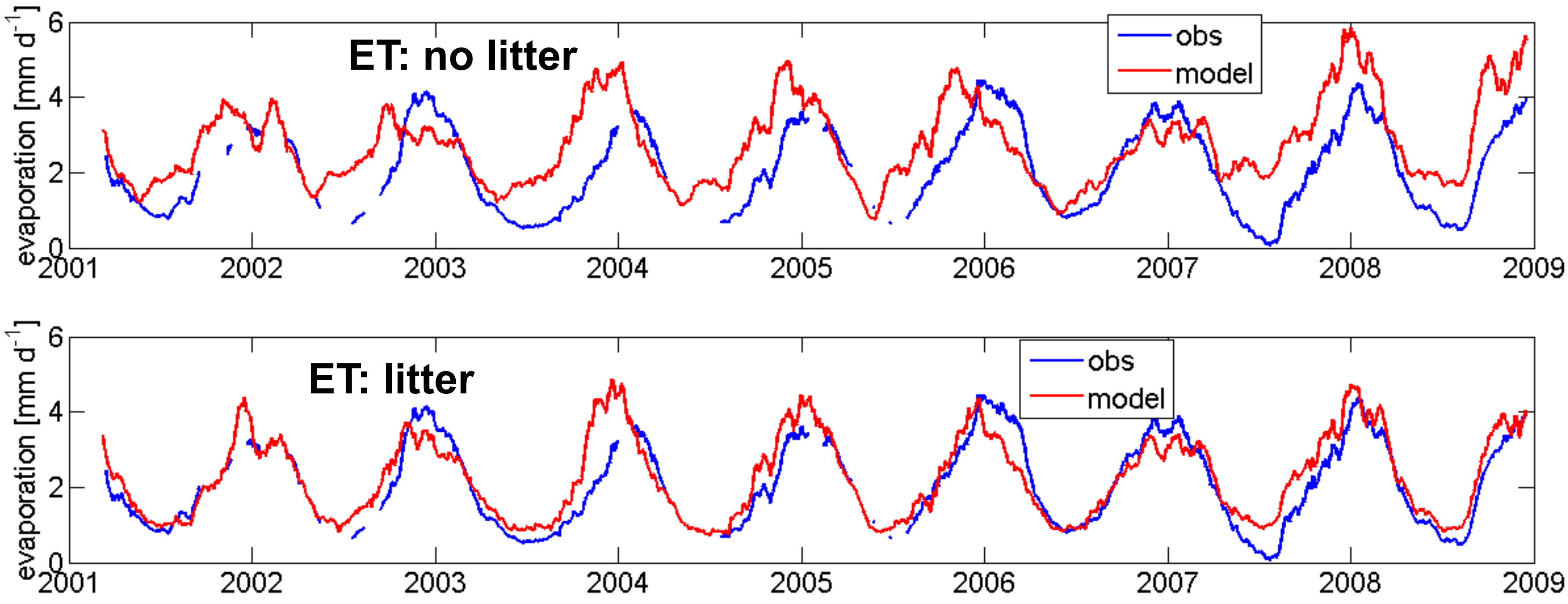
25 October 2012

Coupled soil heat, water and isotope model: Soil-Litter-Iso



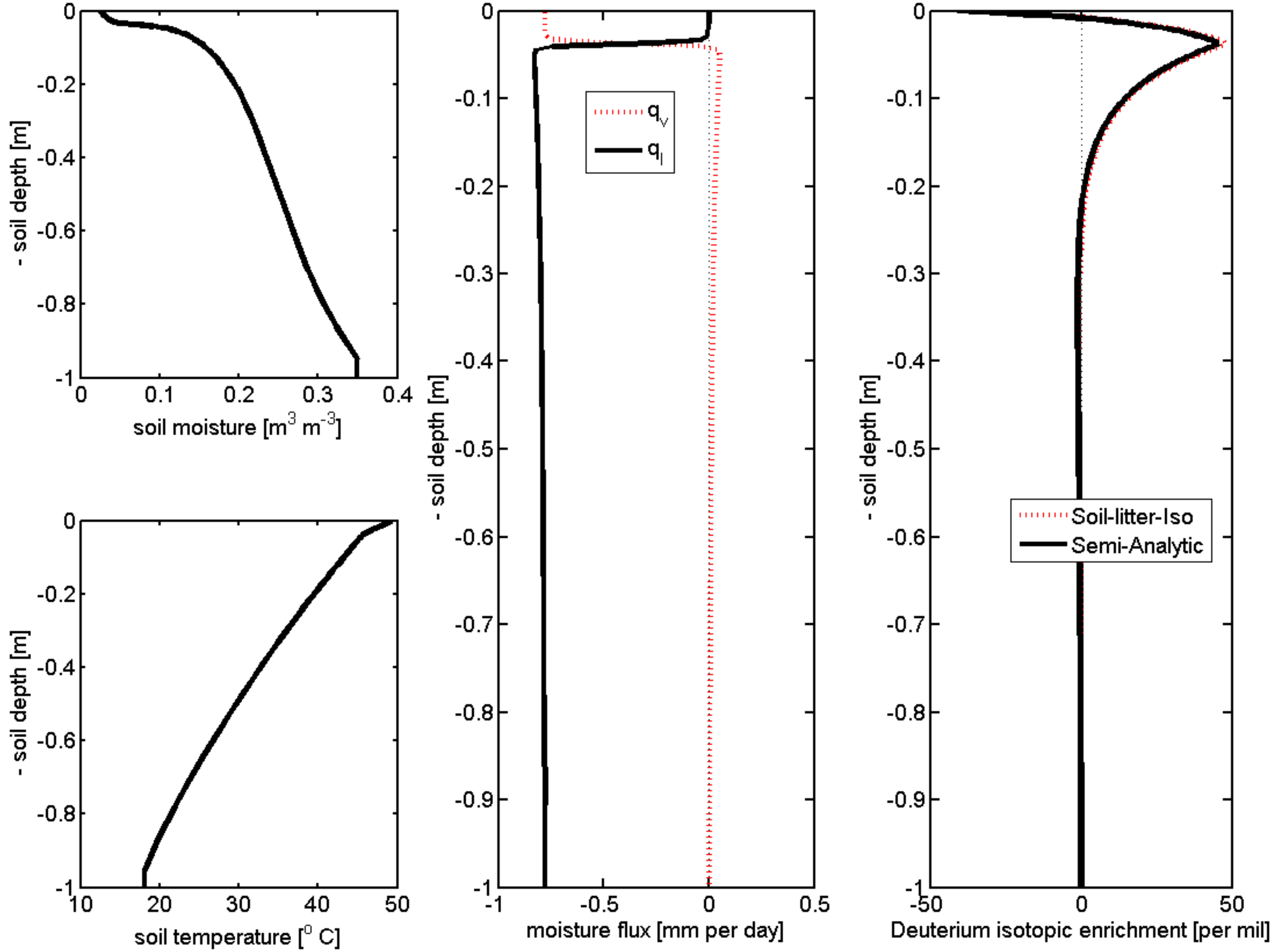
(Haverd & Cuntz 2010)

Litter improves simulation of ET at Tumbarumba



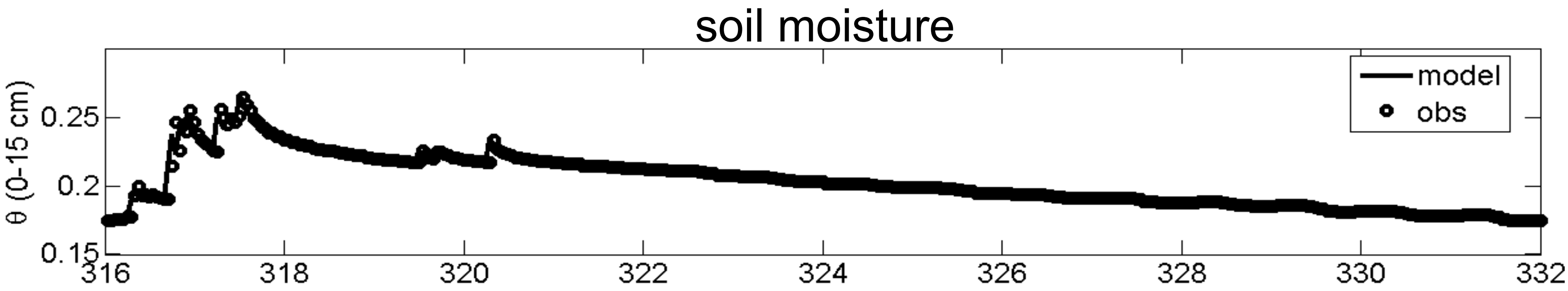
Haverd and Cuntz 2010

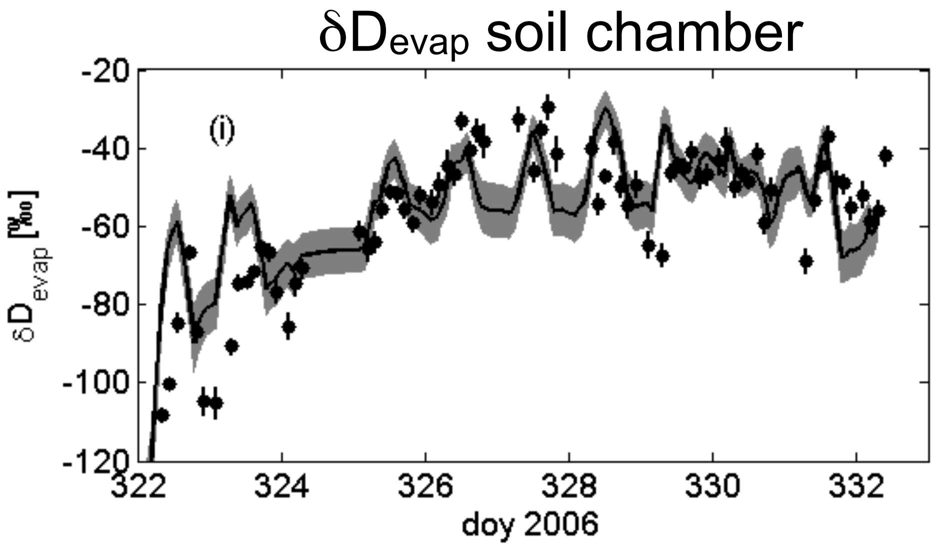
Vapour transport is important for isotopes

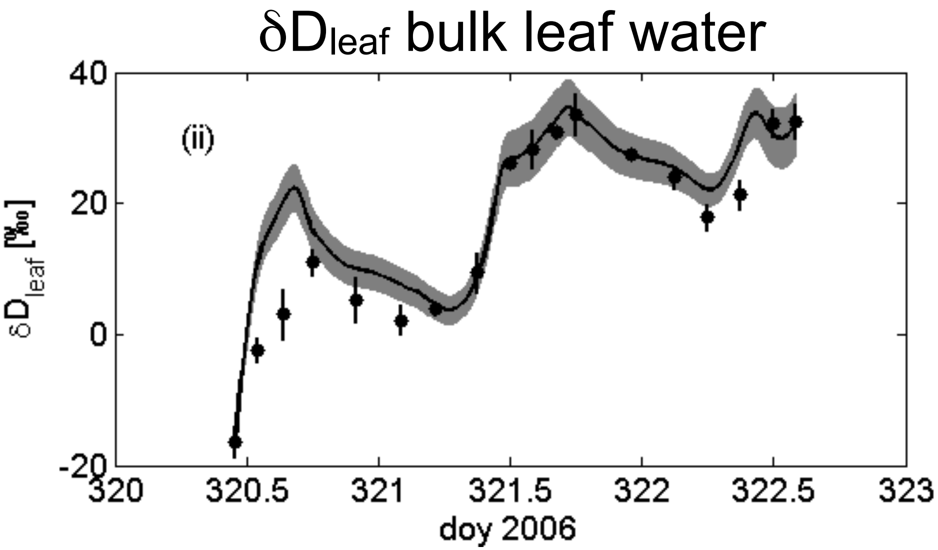


(Haverd & Cuntz 2010)

Validation of isotope modelling



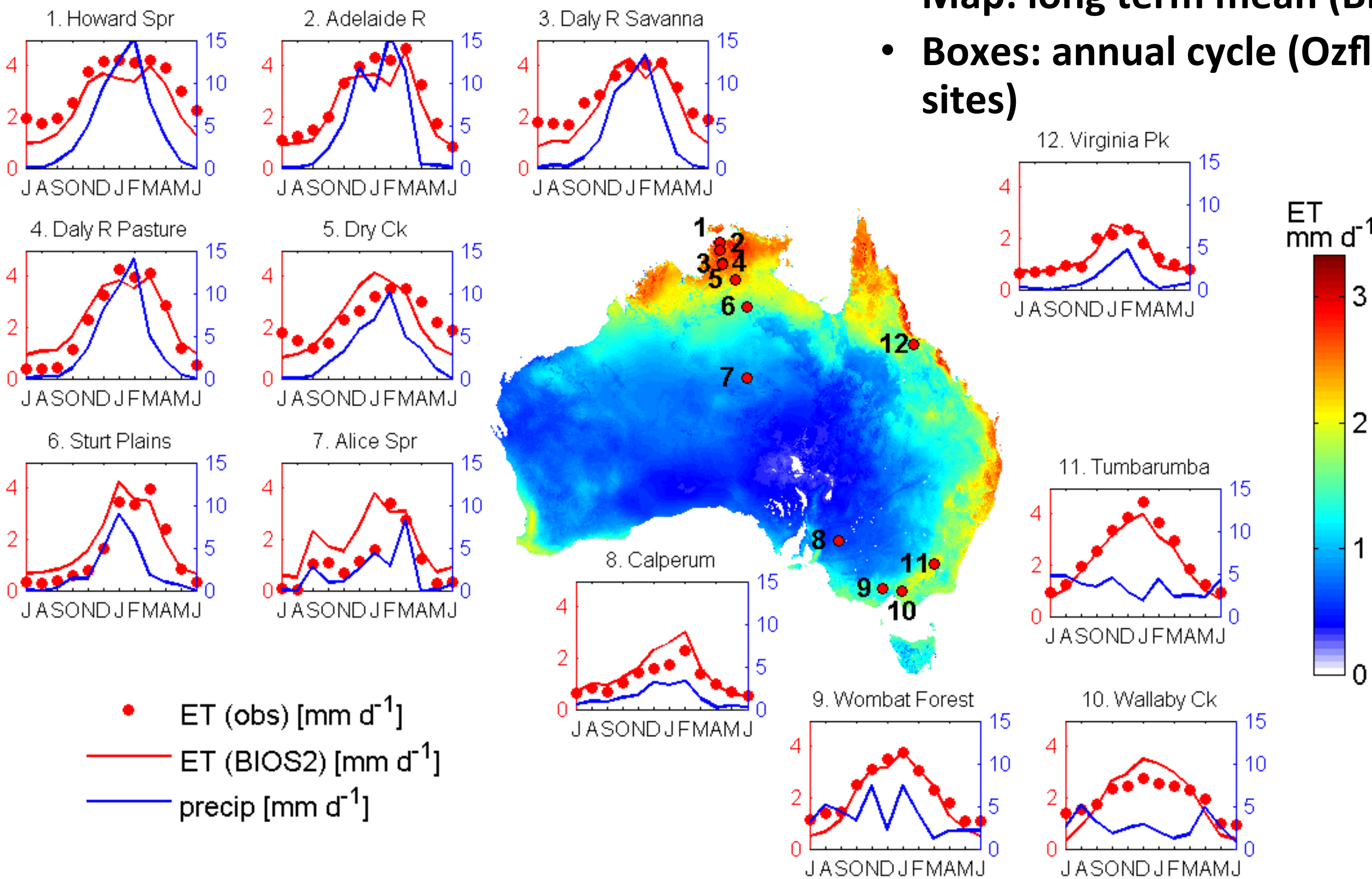




(Haverd et al. 2011)

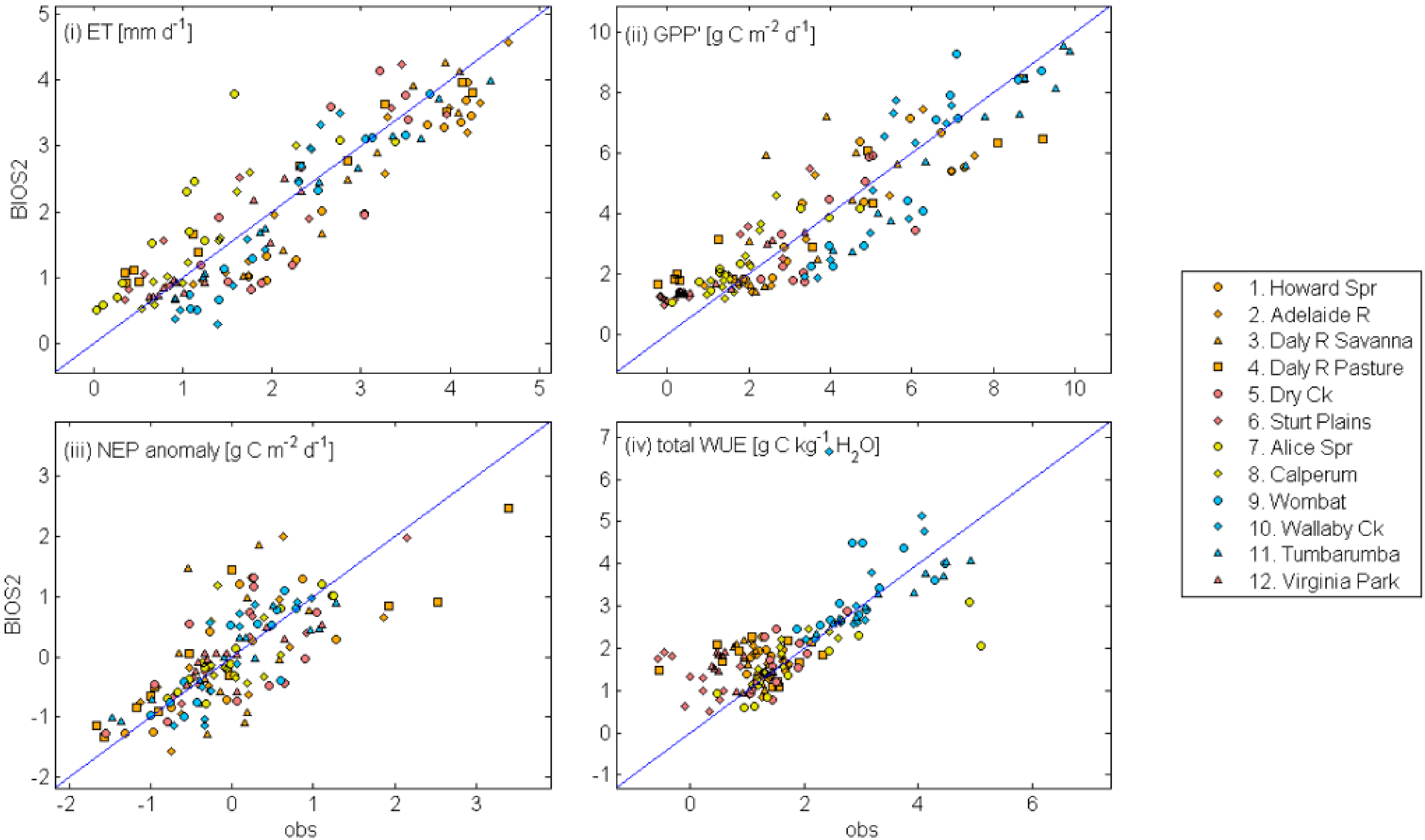
BIOS2 evaluation: **Evapotranspiration from 12 OzFlux sites**

- **Map: long term mean (BIOS2)**
- **Boxes: annual cycle (Ozflux sites)**

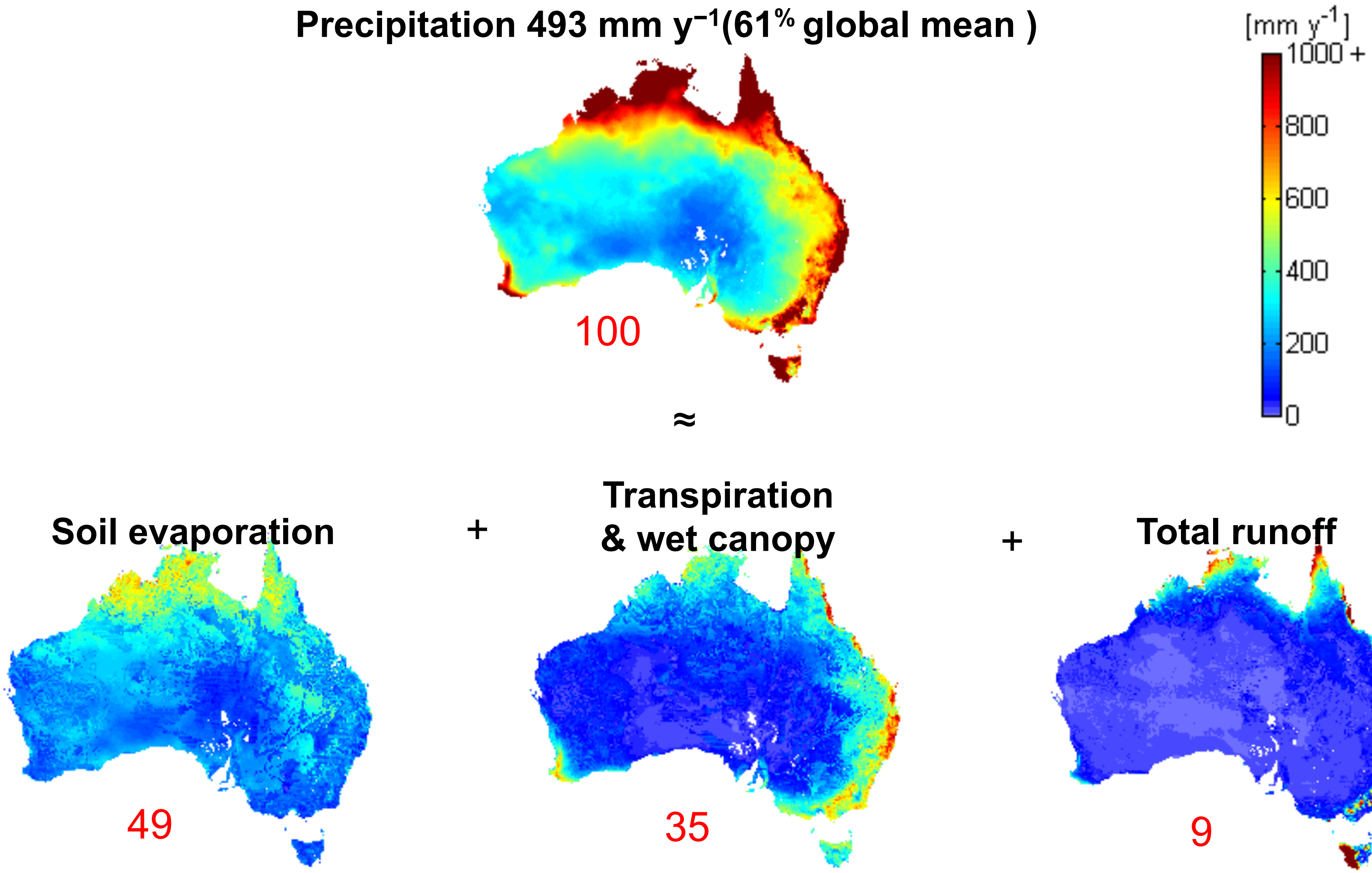


Haverd et al. 2012

BIOS2 evaluation: **monthly mean carbon and water fluxes (OzFlux)**



BIOS2 results: **Soil evaporation is largest outward flux in continental water balance (1990-2011)**

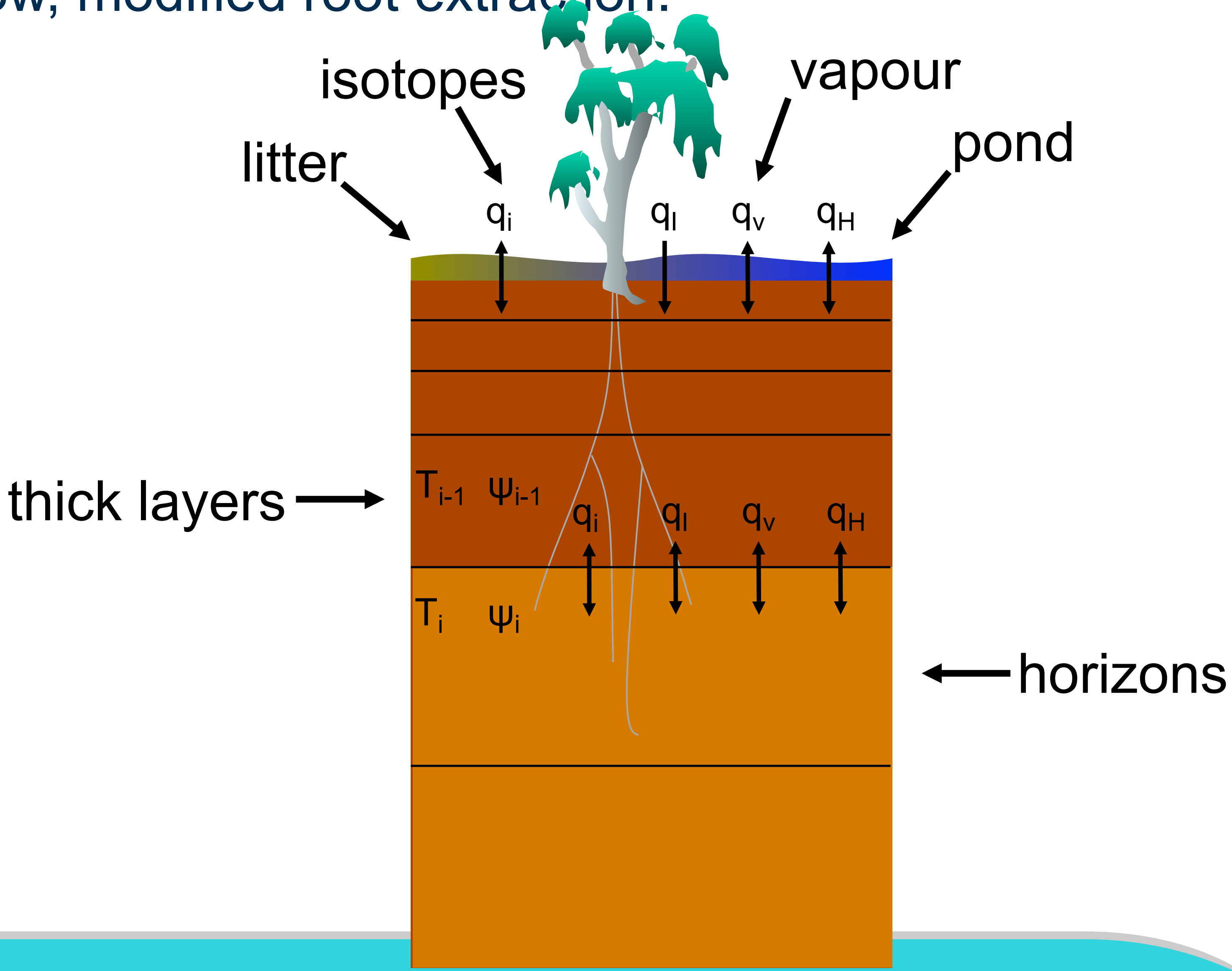


Soil evaporation fraction: comparison with obs

Table 4. Observed soil evaporation flux: total and as a fraction of ET at 3 field sites, and corresponding BIOS2 estimates.

site	obs reference	obs period	Soil evap ($mm\,d^{-1}$)		Soil evap fraction	
			obs	BIOS2	obs	BIOS2
Tumbarumba	Haverd et al. (2011)	Nov 2006 (clear sky days)	0.75	0.34	0.15	0.09
Howard Springs	Hutley et al. (2000)	Mar 1998	1.85	2.23	0.50	0.58
Corrigin	Mitchell et al. (2009)	Mar 2006–Feb 2007	0.42	0.42	0.44	0.52

Recent Updates to Soil-Litter-Iso: freezing and heat advection, snow, modified root extraction.

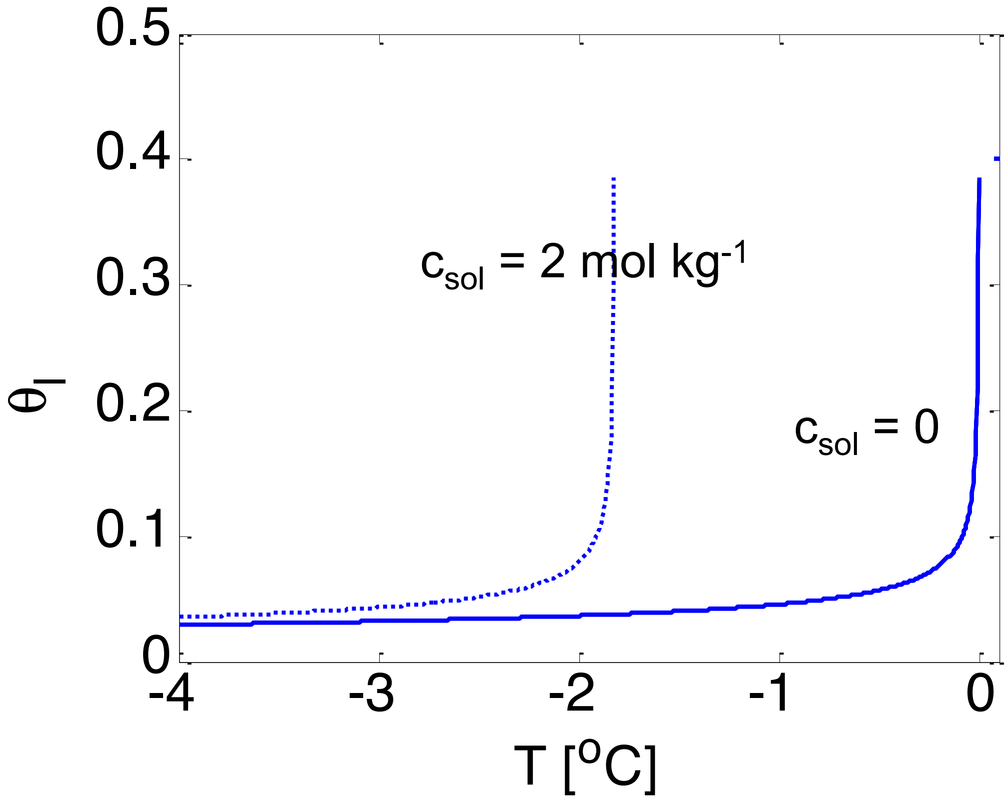


Incorporation of additional physics: it's all in the matrix!

$$
\begin{pmatrix}
c_1 & d_1 & e_1 & f_1 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
c_{H,1} & d_{H,1} & e_{H,1} & f_{H,1} & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
a_2 & b_2 & c_2 & d_2 & e_2 & f_2 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
a_{H,2} & b_{H,2} & c_{H,2} & d_{H,2} & e_{H,2} & f_{H,2} & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & a_3 & b_3 & c_3 & d_3 & e_3 & f_3 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & a_{H,3} & b_{H,3} & c_{H,3} & d_{H,3} & e_{H,3} & f_{H,3} & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & a_4 & b_4 & c_4 & d_4 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & a_{H,4} & b_{H,4} & c_{H,4} & d_{H,4} & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & a_{n-3} & b_{n-3} & c_{n-3} & d_{n-3} & e_{n-3} & f_{n-3} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & a_{H,n-3} & b_{H,n-3} & c_{H,n-3} & d_{H,n-3} & e_{H,n-3} & f_{H,n-3} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & a_{n-2} & b_{n-2} & c_{n-2} & d_{n-2} & e_{n-2} & f_{n-2} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & a_{H,n-2} & b_{H,n-2} & c_{H,n-2} & d_{H,n-2} & e_{H,n-2} & f_{H,n-2} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & a_{n-1} & b_{n-1} & c_{n-1} & d_{n-1} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & a_{H,n-1} & b_{H,n-1} & c_{H,n-1} & d_{H,n-1} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & a_n & b_n \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & a_{H,n} & b_{H,n}
\end{pmatrix}
\begin{pmatrix}
\Delta y_1 \\ \Delta T_1 \\ \Delta y_2 \\ \Delta T_2 \\ \Delta y_3 \\ \Delta T_3 \\ \Delta y_4 \\ \Delta T_4 \\ \vdots \\ \Delta y_{n-3} \\ \Delta T_{n-3} \\ \Delta y_{n-2} \\ \Delta T_{n-2} \\ \Delta y_{n-1} \\ \Delta T_{n-1} \\ \Delta y_n \\ \Delta T_n
\end{pmatrix}
=
\begin{pmatrix}
g_1 \\ g_{H,1} \\ g_2 \\ g_{H,2} \\ g_3 \\ g_{H,3} \\ g_4 \\ g_{H,4} \\ \vdots \\ g_{n-3} \\ g_{H,n-3} \\ g_{n-2} \\ g_{H,n-2} \\ g_{n-1} \\ g_{H,n-1} \\ g_n \\ g_{H,n}
\end{pmatrix}
\tag{A.50}
$$

Haverd and Cuntz 2010

Soil water does not freeze completely at a single temperature.

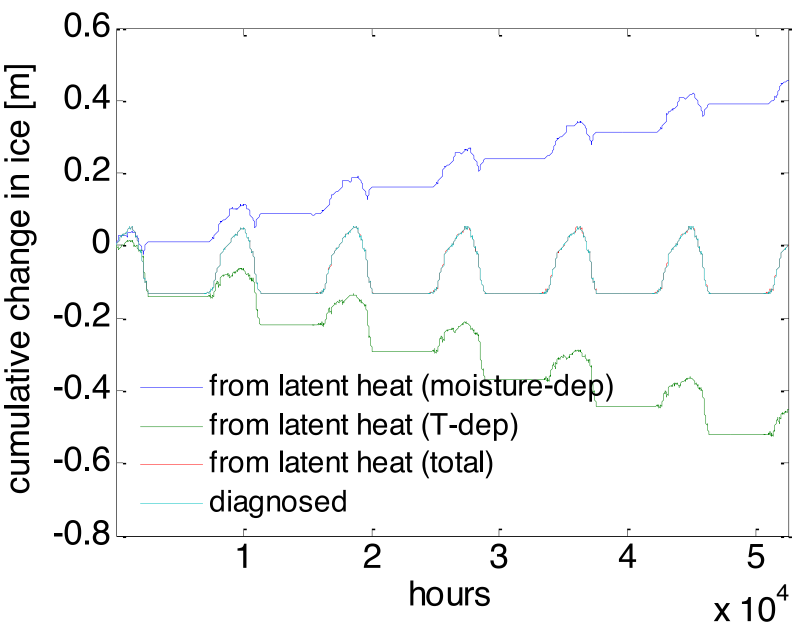


Depends on solute concentration and pore size distribution.

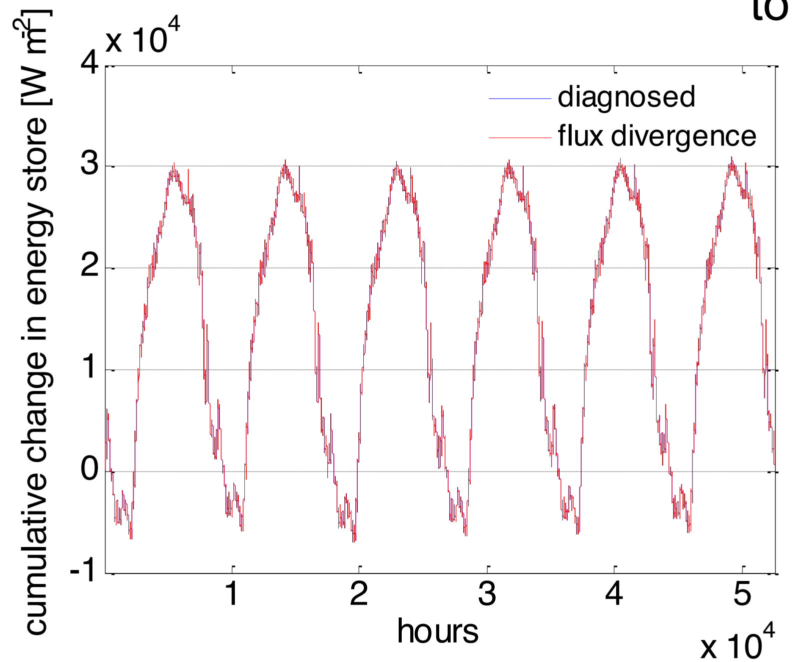
Slope determines effective heat capacity
(strong T-dependence)

Liquid fluxes are driven by gradients in T

Importance of Precision in $d\theta_l/dT$



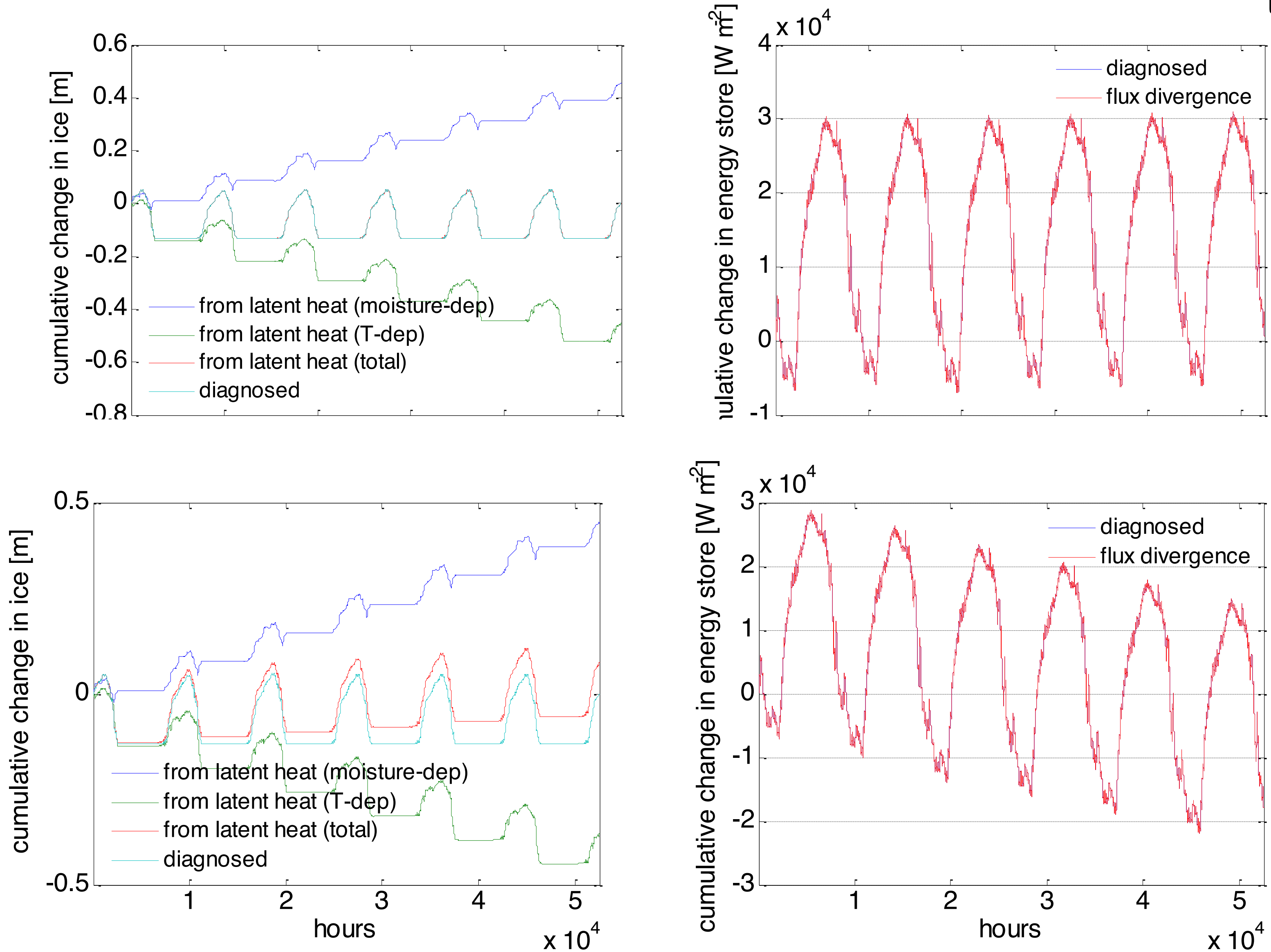
tolerance



10^{-8} K^{-1}

Importance of Precision in $d\theta_l/dT$

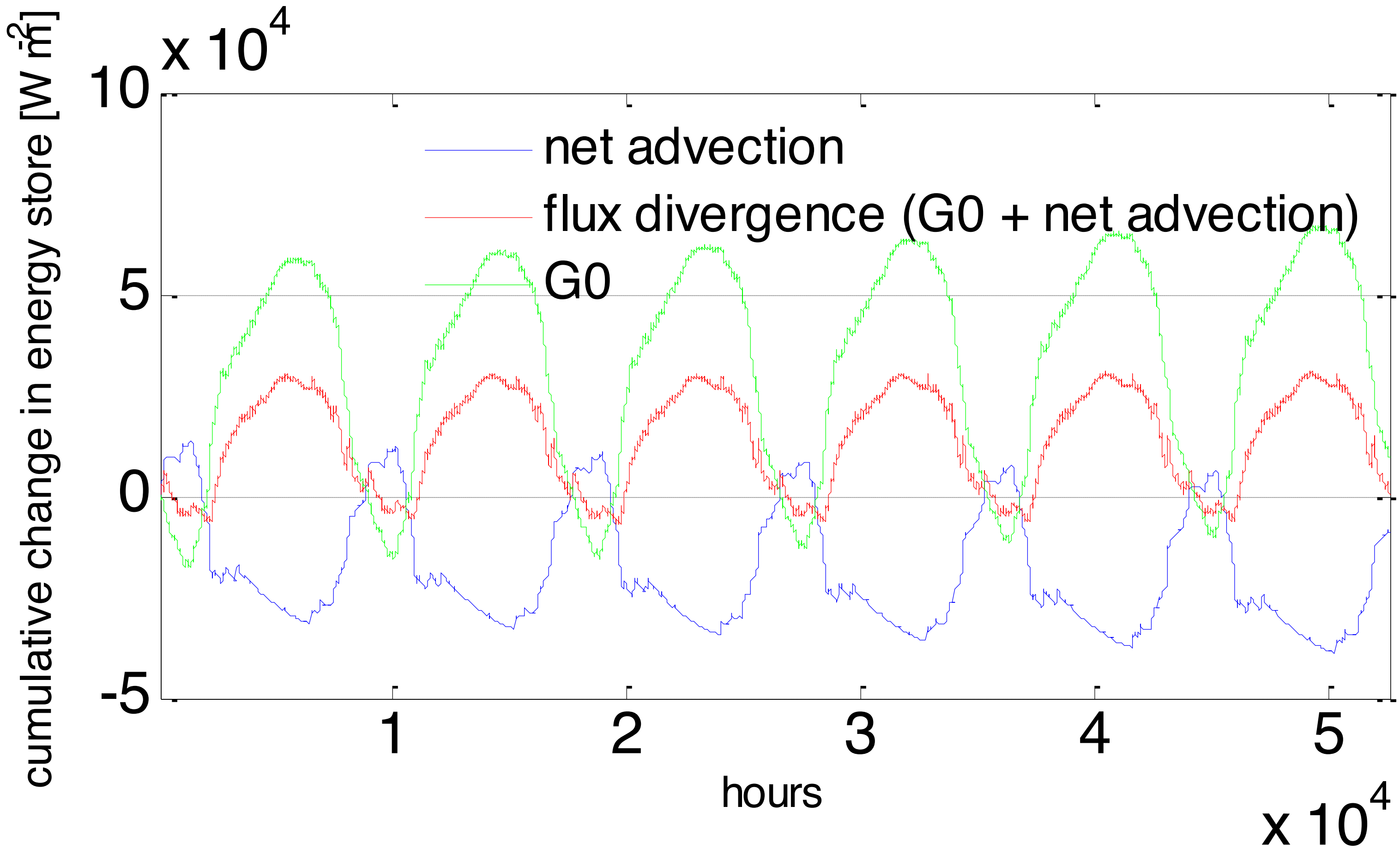
tolerance



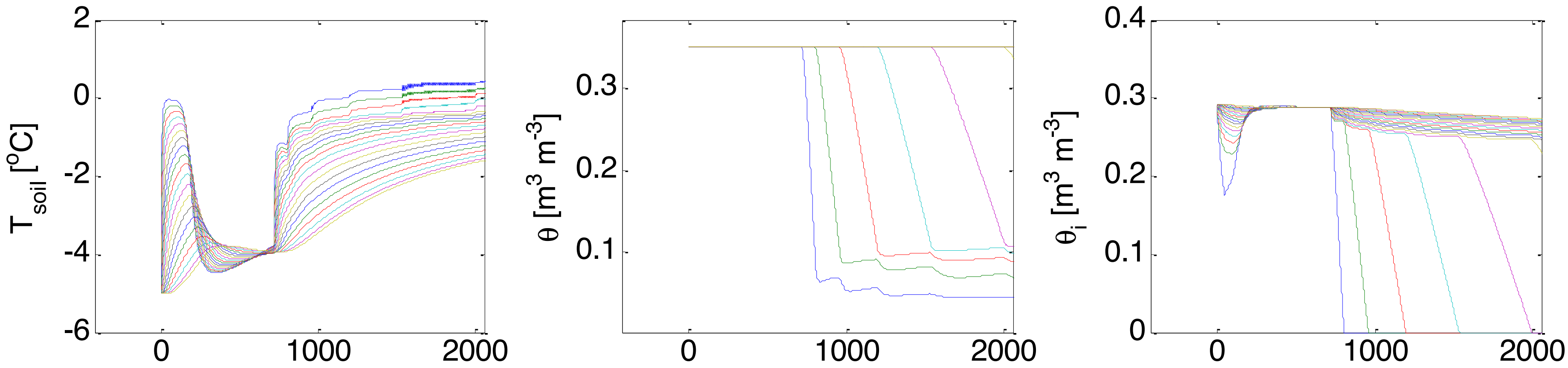
10^{-8} K^{-1}

10^{-2} K^{-1}

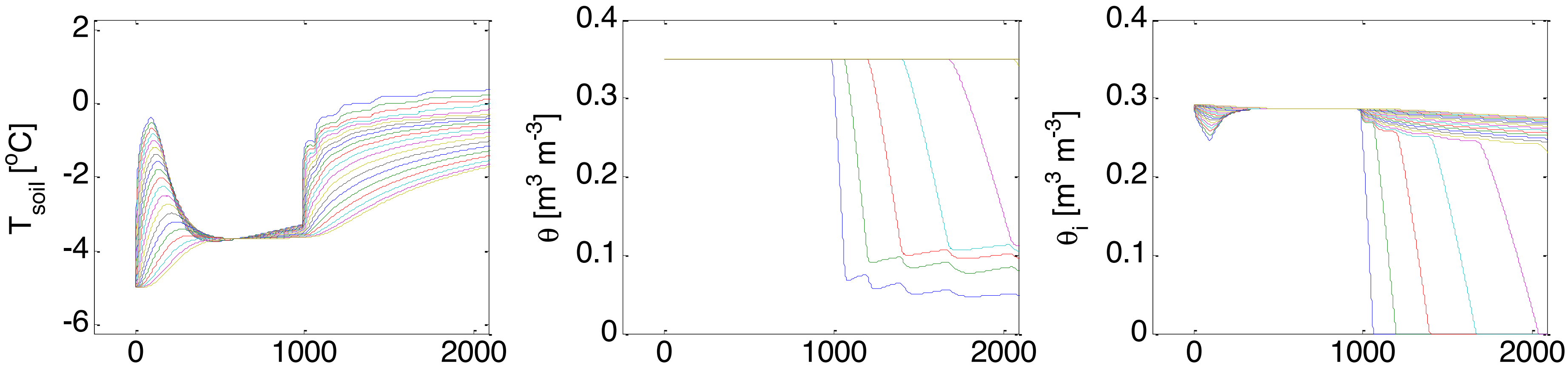
Importance of Heat Advection



Idealised Melting Simulation: effect of advection

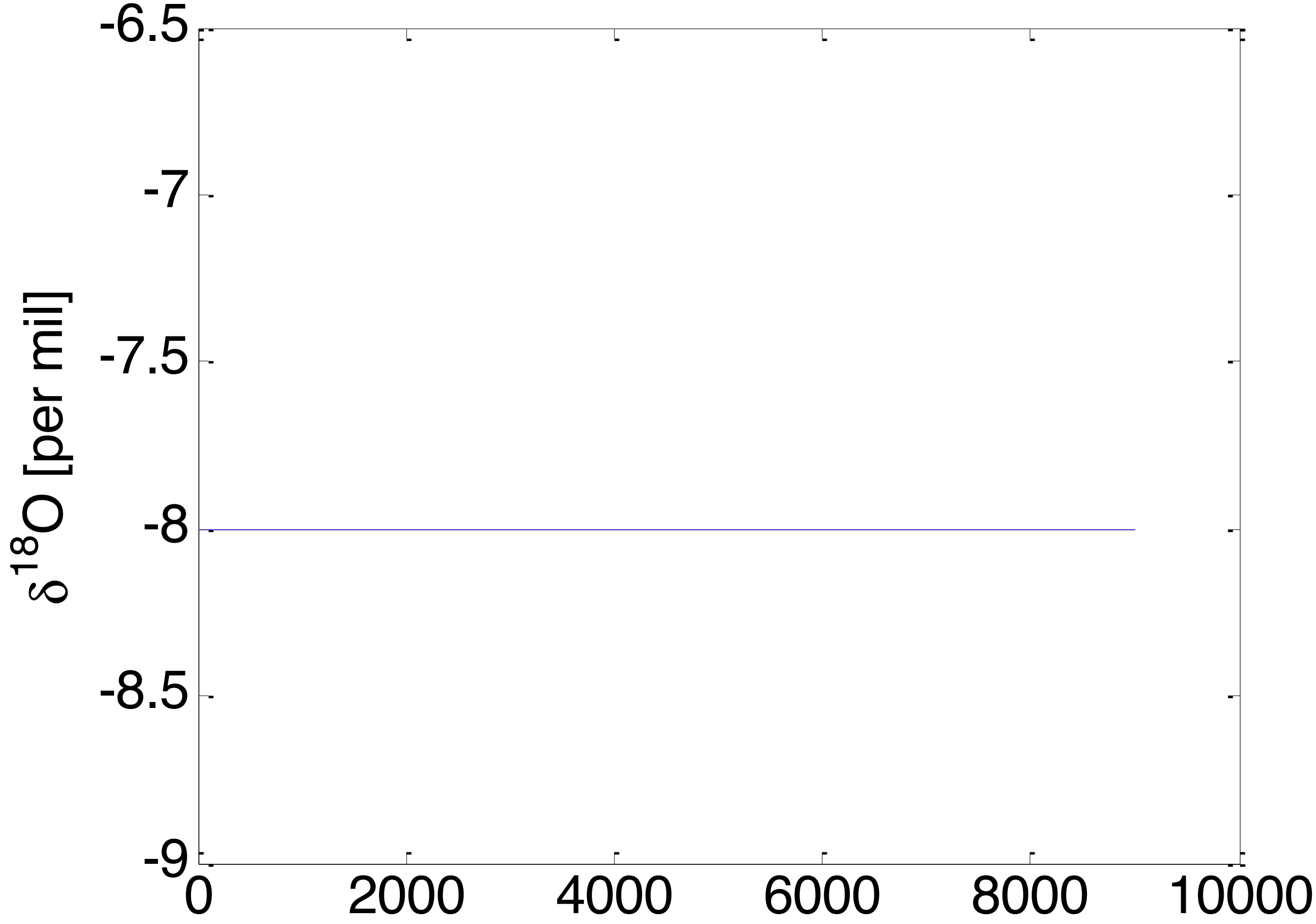


Heat advection switched on

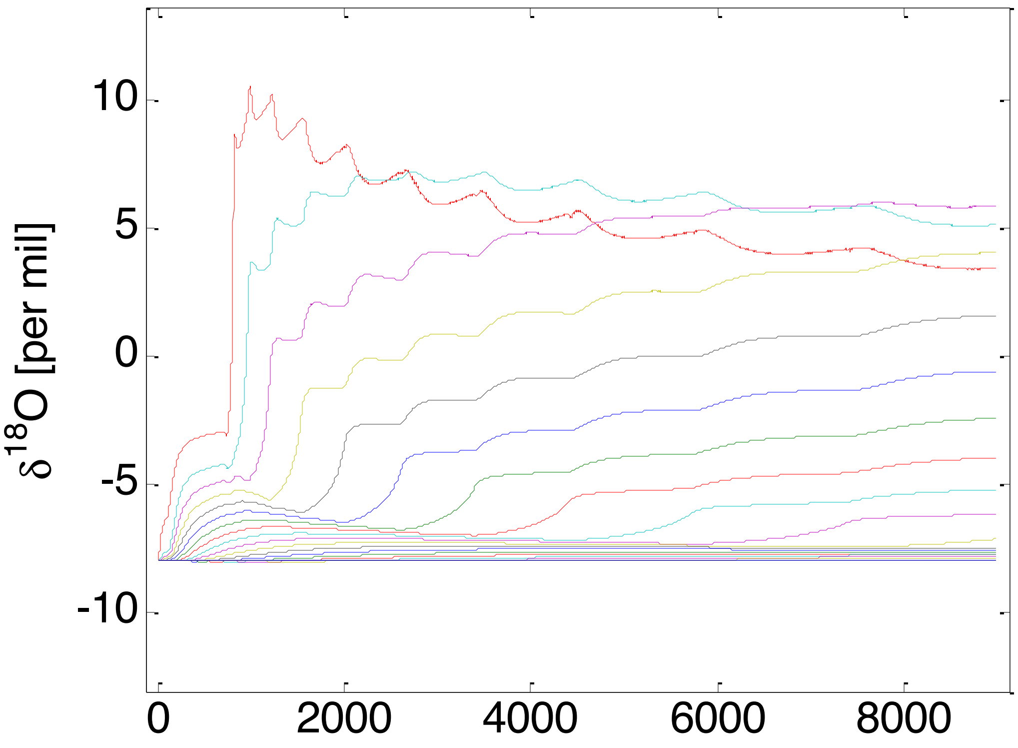


Heat advection switched off

Conservation of soil water isotopes : idealised melting simulation; no fractionation



Variation of soil water isotopes : idealised melting scenario



Conclusions

- SLI significantly upgraded
  - Frozen soil
  - Heat Advection
  - Isotopes conserved with new processes
  - Snow scheme under final developments (just add a few lines to the martix!)
  - Perfect mass and energy closure

- Useful to check change in stored energy is equal to flux divergence: implications for land/atmosphere exchange?

- Upcoming interaction with interesting data sets:
  - Frozen soil on Tibetan Plateau (UFZ)
  - Snow and soil isotopes in Lostchental (link to tree-ring studies) (WSL)
  - Soil water isotopes in relation to soil carbonate formation (UC Berkeley)

References

1 ET partitioning without isotopes

Haverd V, Leuning R, Griffith D, van Gorsel E & Cuntz M (2009)
The turbulent Lagrangian time scale in forest canopies constrained by fluxes, concentrations and source distributions, Boundary-Layer Meteorology 130, 209–228

2 Soil water isotope model

Haverd V & Cuntz M (2010)
Soil–Litter–Iso: A one-dimensional model for coupled transport of heat, water and stable isotopes in soil with a litter layer and root extraction, Journal of Hydrology 388, 438-455

3 ET partitioning with isotopes

Haverd V, Cuntz M, Griffith DW, Keitel C, Tadros C & Twining J (2011)
The evapotranspiration partition and turbulent lagrangian time scale in a forest canopy, constrained by deuterium in water vapour, Agricultural and Forest Meteorology, accepted 30.11.2010

4 Application to Australian continental carbon and water cycles

Haverd, V., Raupach, M.R., Briggs, P.R., Canadell, J.G., Isaac, P., Pickett-Heaps, C., Roxburgh, S.H., van Gorsel, E., Viscarra Rossel, R.A. and Wang, Z., 2012. Multiple observation types reduce uncertainty in Australia's terrestrial carbon and water cycles. Biogeosciences Discuss., 9(9): 12181-12258.

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CSIRO

BIOS2

- BIOS2 = CABLE-SLI-CASAcnp in AWAP operational framework

CABLE = Community Atmosphere-Biosphere-Land Exchange model

Water, energy, carbon fluxes

Wang et al. (2011)

SLI = Soil-Litter-Iso

Soil hydrology, soil evaporation

Haverd et al. (2011)

CASAcnp = Biogeochemical model

Soil and plant C, N, P dynamics

Wang et al. (2007)

AWAP = Australian Water Availability Project

Continental processing framework

Met and soil data

Model-Data Fusion

Raupach et al. (2009)