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Soil-Litter-Iso: a new isotopically-enabled model for one-dimensional heat and moisture transfer in soils

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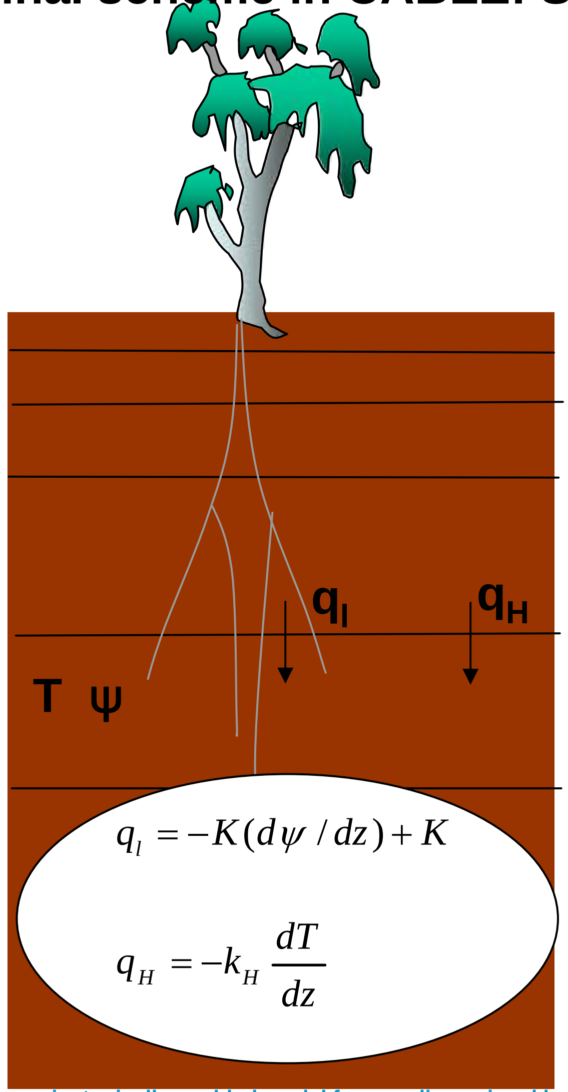
New soil scheme accounts for vapour-phase soil moisture, litter, isotopes

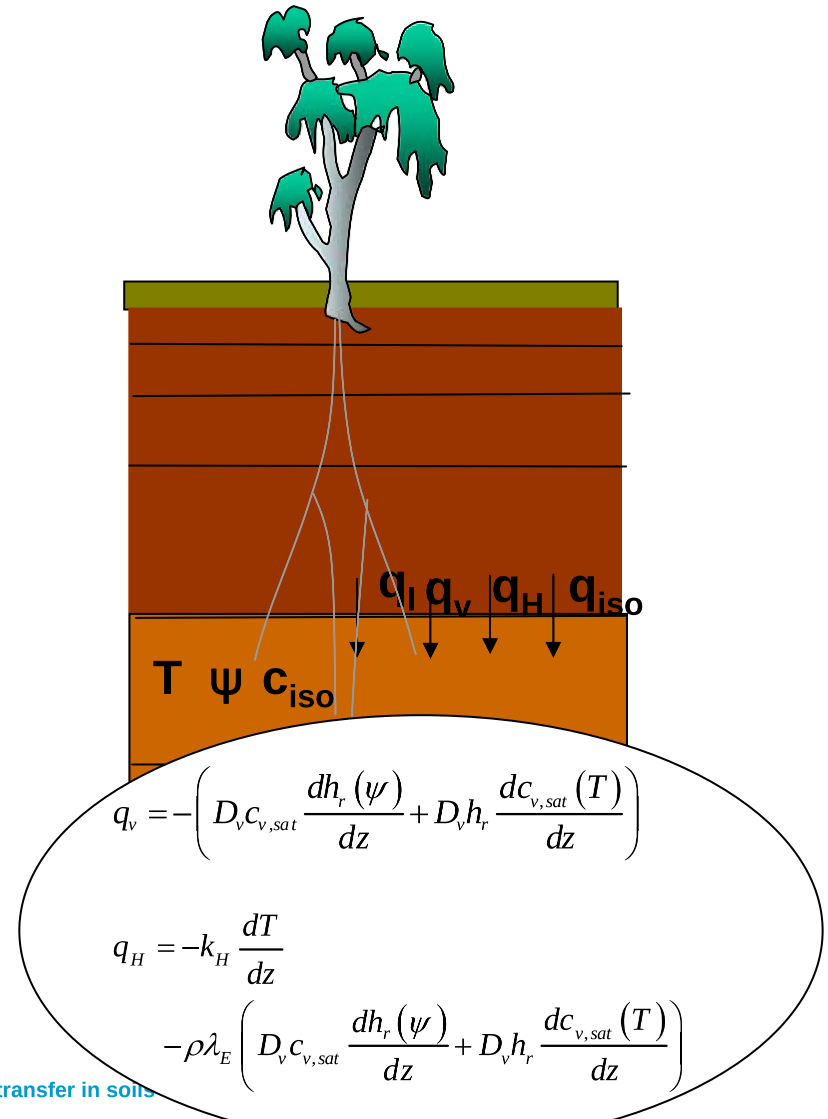
Original scheme in CABLE: Soil-Snow



$$q_l = -K(d\psi / dz) + K$$

$$q_H = -k_H \frac{dT}{dz}$$

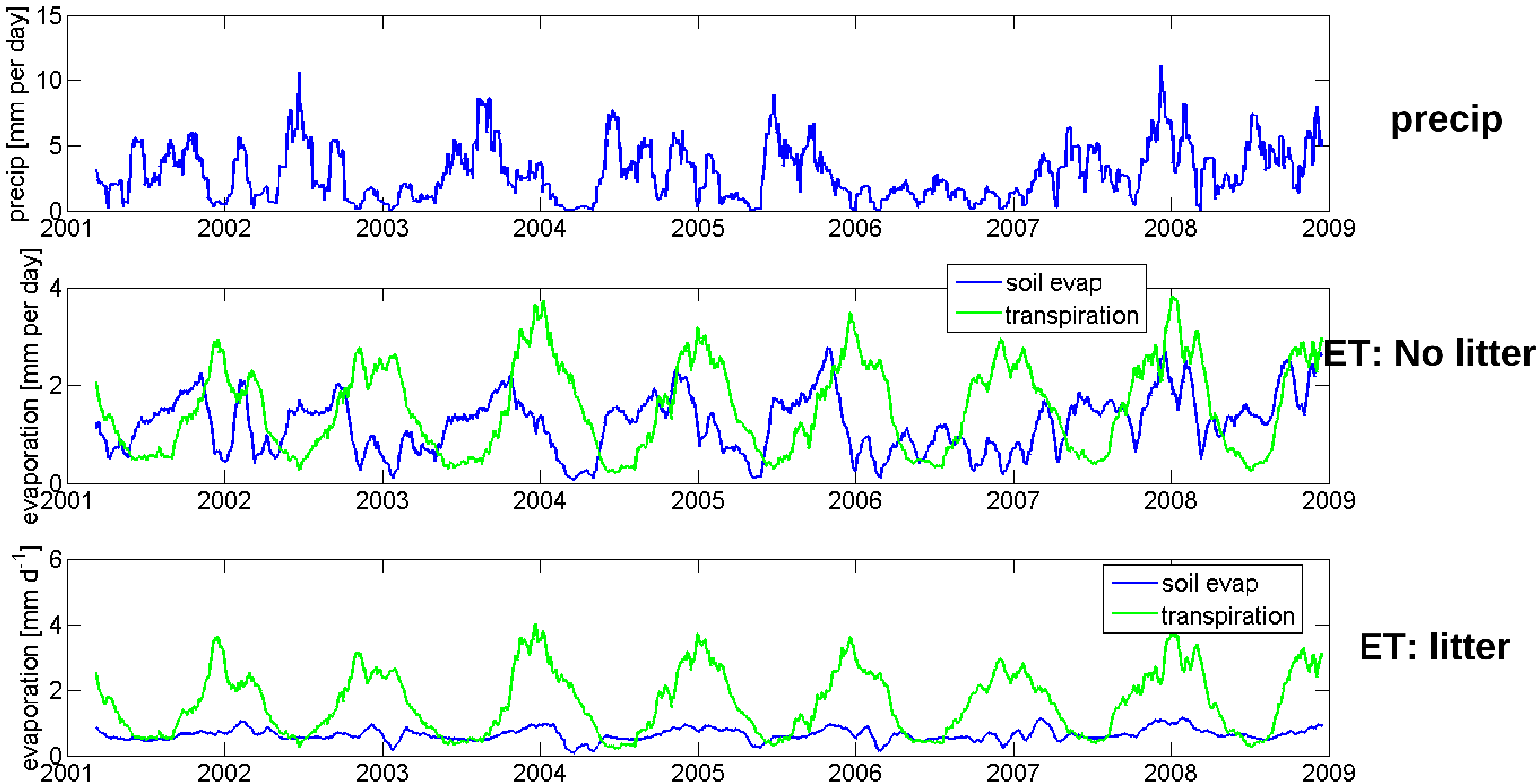
New scheme: Soil-Litter-Iso



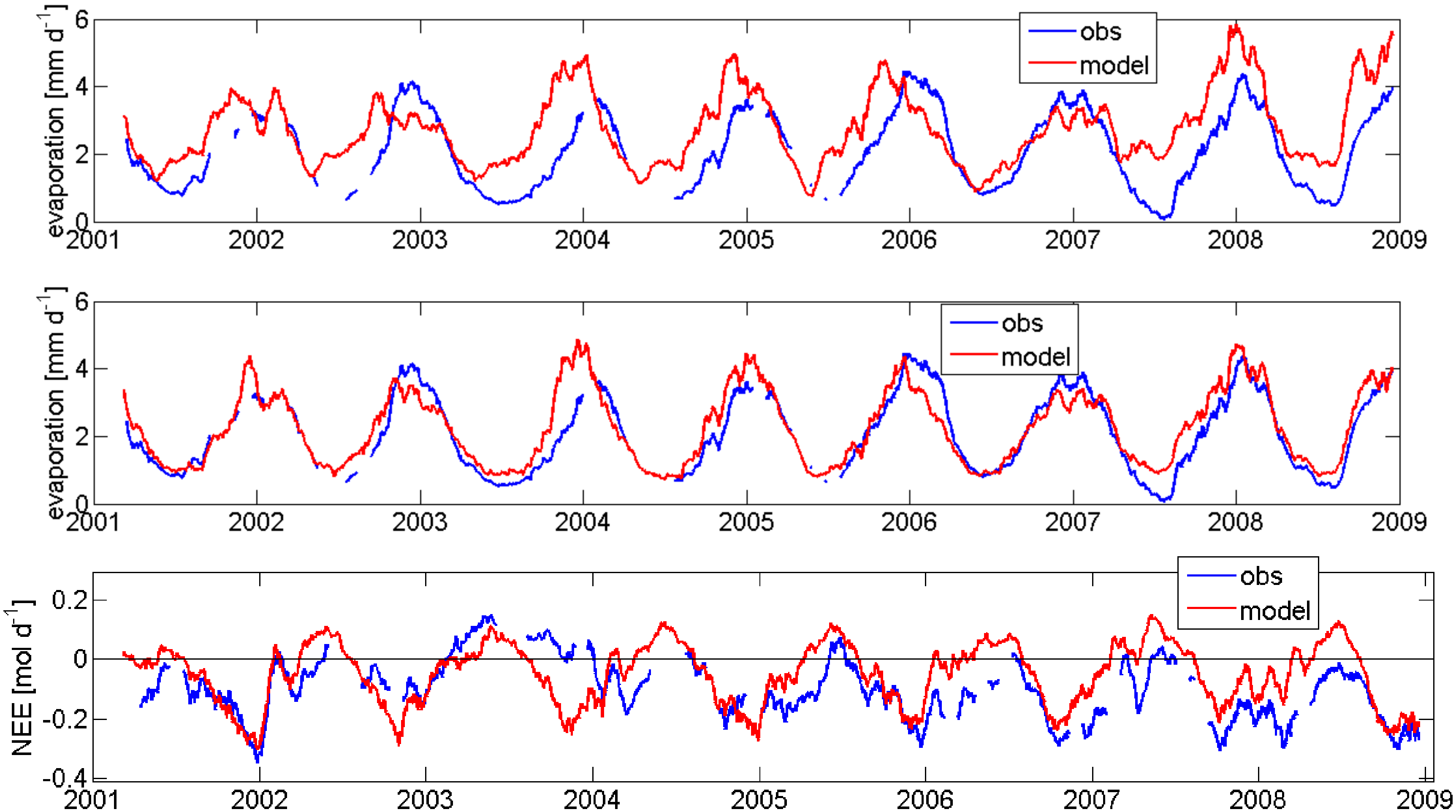
$$q_v = -\left(D_v c_{v,sat} \frac{dh_r(\psi)}{dz} + D_v h_r \frac{dc_{v,sat}(T)}{dz} \right)$$

$$q_H = -k_H \frac{dT}{dz} - \rho \lambda_E \left(D_v c_{v,sat} \frac{dh_r(\psi)}{dz} + D_v h_r \frac{dc_{v,sat}(T)}{dz} \right)$$

Litter supresses predicted soil evaporation (Tumbarumba)



Litter improves simulation of ET at Tumbarumba

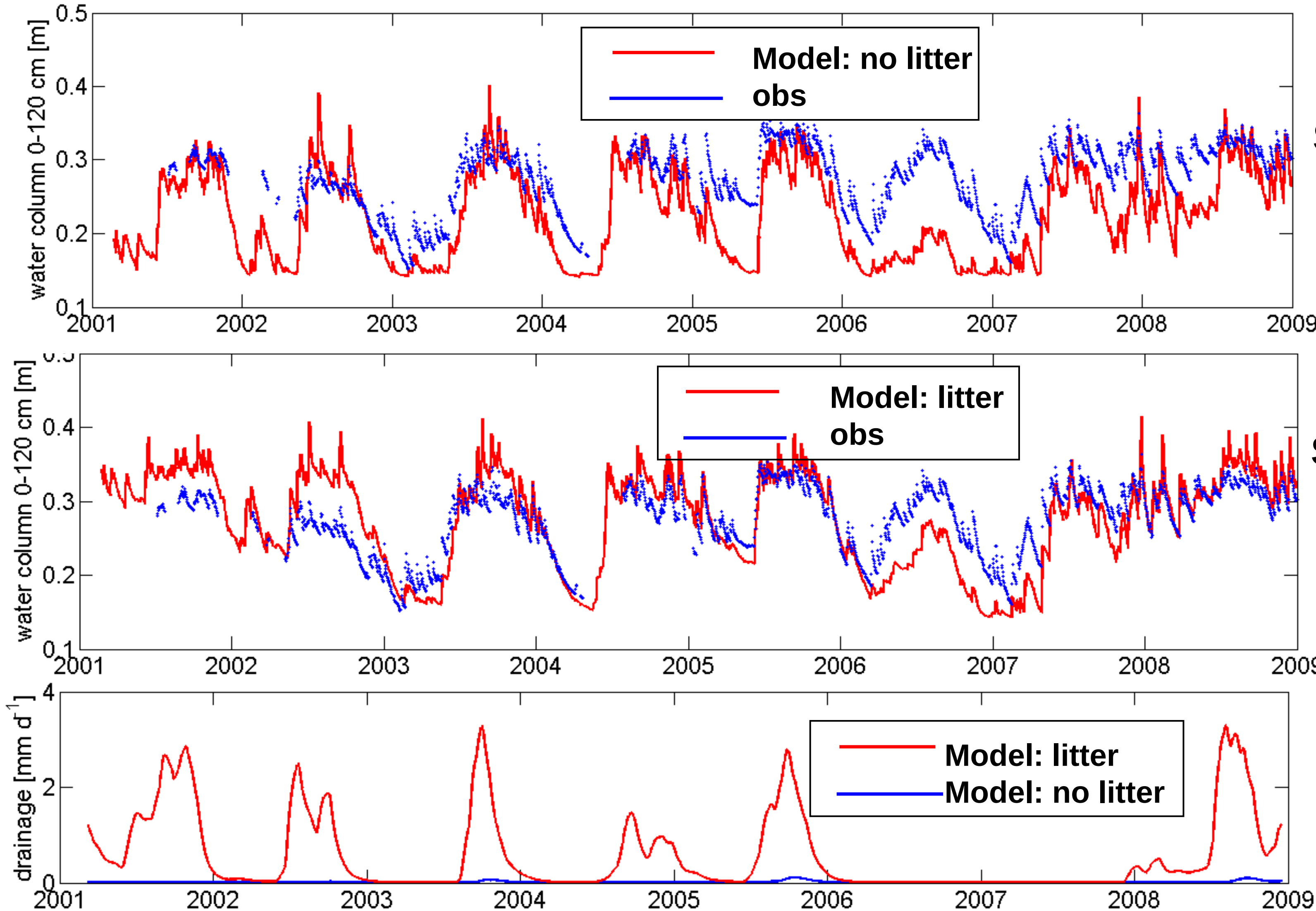


ET: no litter

ET: litter

NEE: litter

Litter improves simulation of soil moisture at Tumbarumba



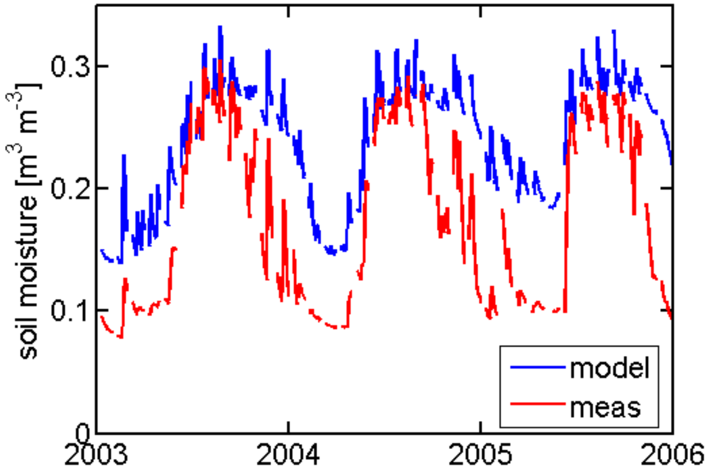
Soil moisture

Soil moisture

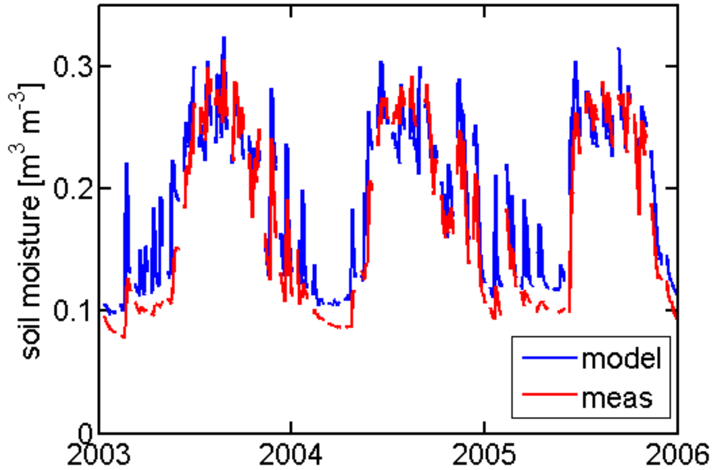
drainage

Inclusion of vapour diffusion within soil improves prediction of surface soil moisture

CABLE 1.4 with Soil-Snow



CABLE 1.4 with Soil-Litter-Iso



(Data for Adelong from Jeff Walker, U. Melb.)

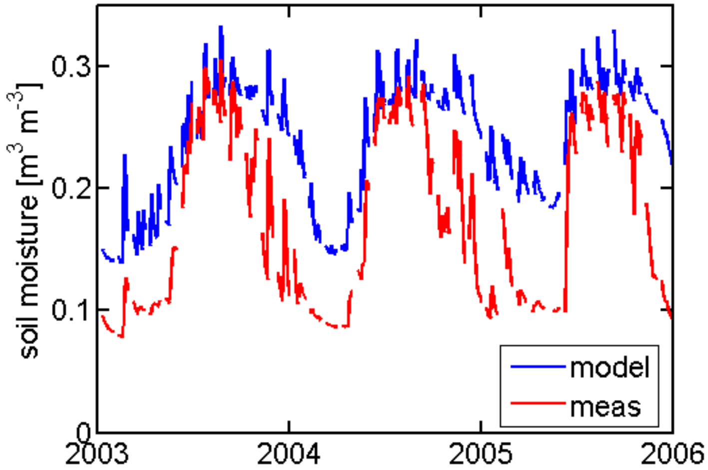
Expect better prediction of remotely-sensed microwave brightness temperature, which is very sensitive to soil moisture in the top 2 cm

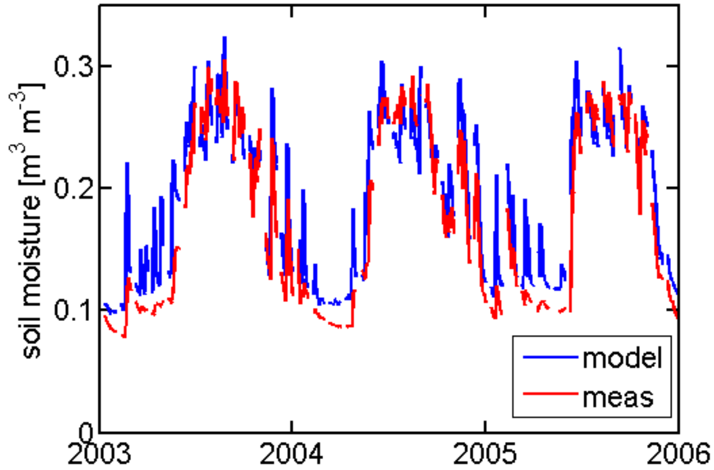
→ Testing of model at continental scale

Oznet Soil Moisture: 0-8 cm

CABLE 1.4 with Soil-Snow | **CABLE 1.4 with Soil-Litter**

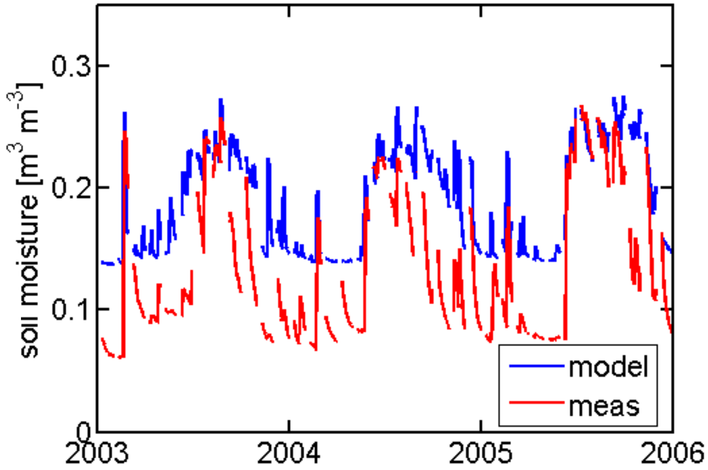
Adelong

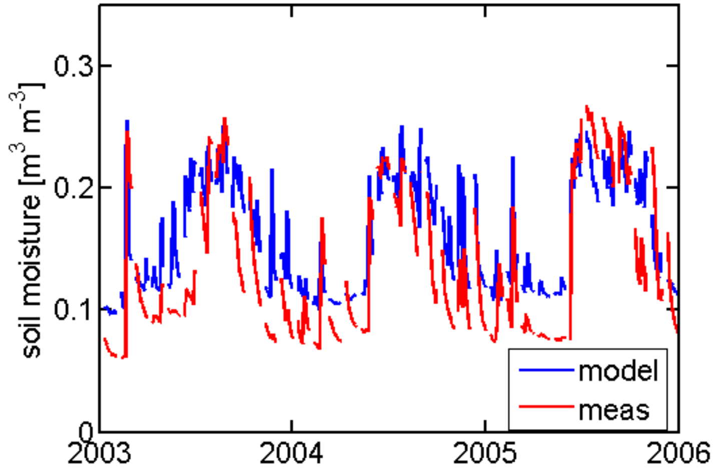




Murrumbidgee

(Jeff Walker
U. Melb.)





Modelling stable isotope species (HDO and $H_2{}^{18}O$) in soil moisture. Why?

- **Provide excellent tests of numerical robustness and vapour/liquid fluxes in main code**
- **^{18}O in atmospheric CO_2 is a potentially strong constraint on the partition between photosynthesis and respiration at global scale**
  - **Requires accurate formulation of ^{18}O exchange at the land surface**
- **Advection/diffusion equation required for isotopes could be adapted to model transport of any other soil solute**
- **Lack of robust, efficient isotopically-enabled soil models in literature**
  - **Particularly no inclusion of vapour diffusion**

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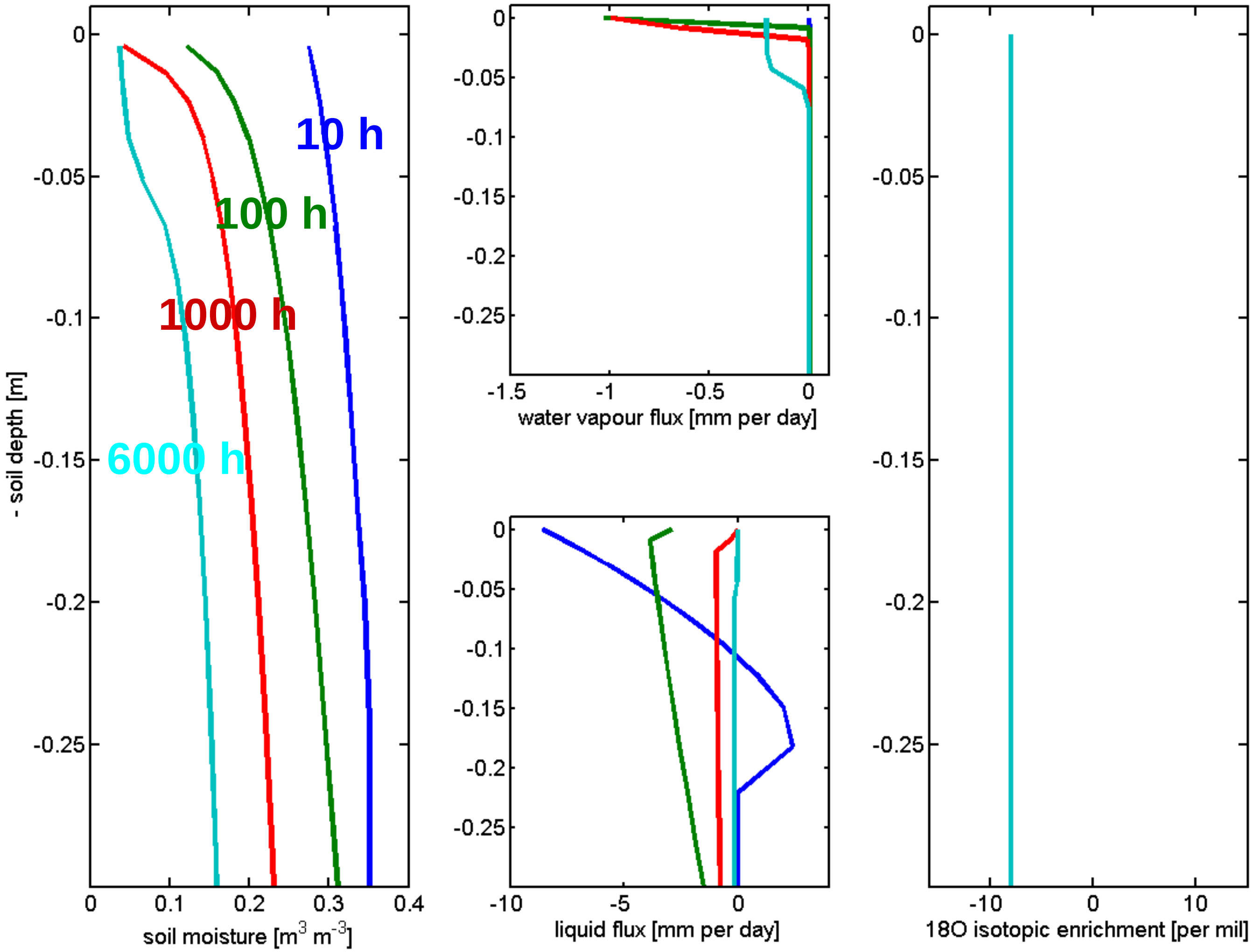
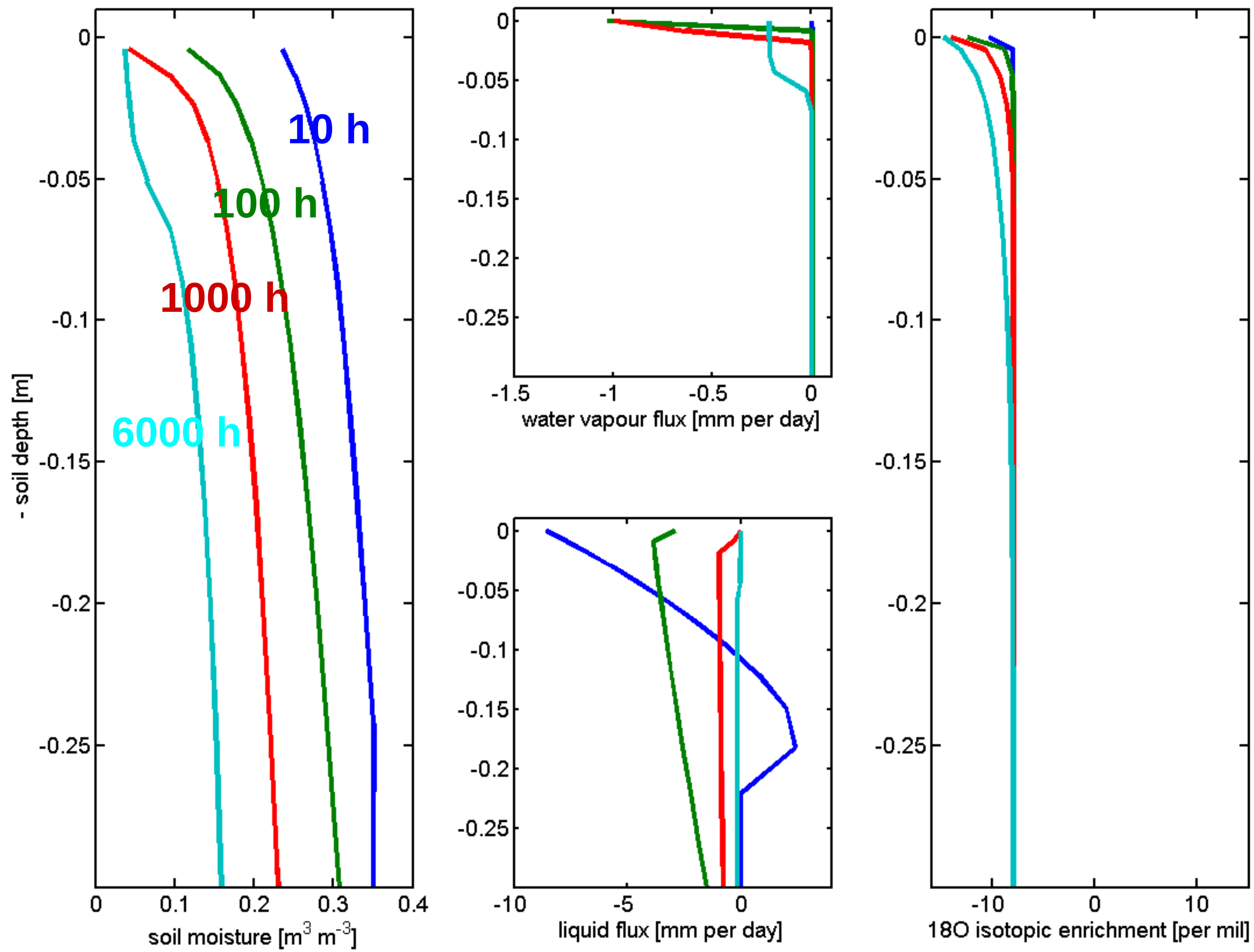
Stable isotope transport: processes

	H_2O	HDO
Liquid advection	q_l	$c_{HDO,l}q_l$
Liquid diffusion	zero	$-D_l^{HDO}\frac{dc_{HDO,l}}{dz}$
Vapour advection	q_v	$\frac{D_v^{HDO}}{D_v^{H_2O}}\alpha^+ c_{HDO,l}q_v$
Vapour diffusion	zero	$D_v^{HDO}c_v\alpha^+\frac{dc_{HDO,l}}{dz}$
Exchange with atmosphere	$\frac{c_{v,s}-c_{v,a}}{r_{bw}}$	$\frac{\alpha^+ c_{HDO,l,s}c_{v,s}-R_a c_{v,a}}{r_{bw}/\alpha_k}$

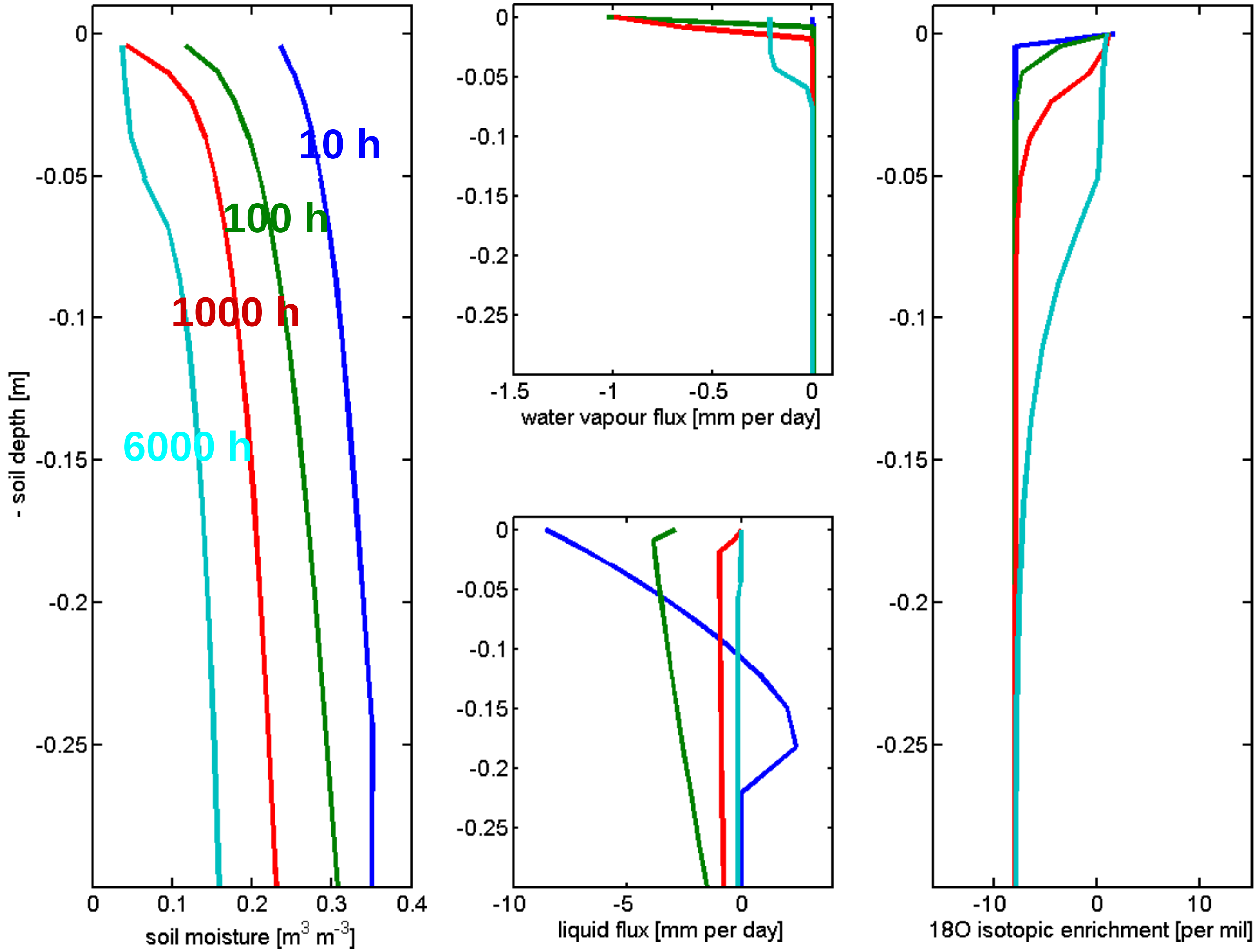
Test Case 1: No fractionating processes ($\delta_{soil,0} = \delta_a = -8$ ‰)



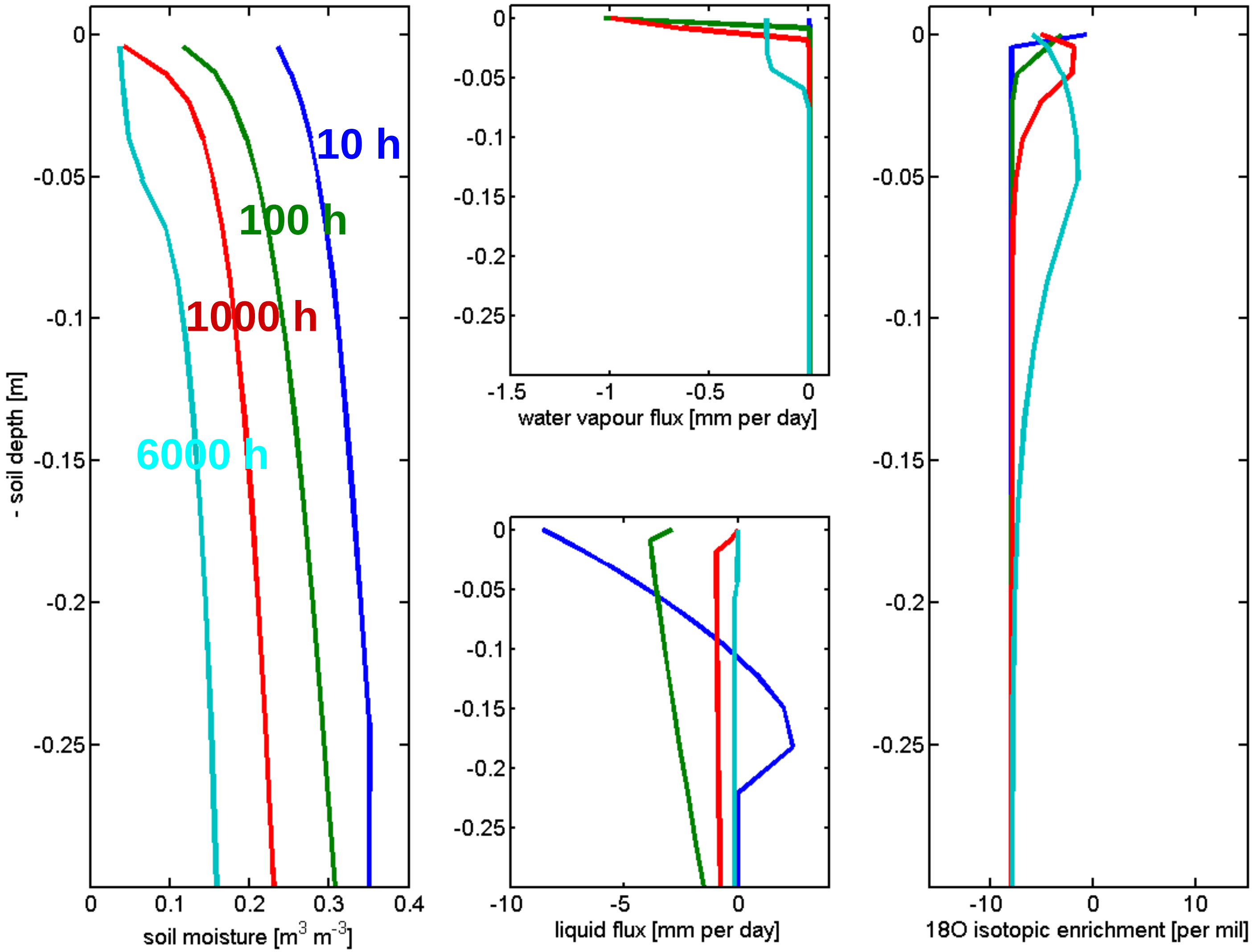
Test Case 2: No fractionating processes ($\delta_{soil,0}$ = -8 ‰ ; δ_a = -15 ‰)



Test Case 3: Equilibrium fractionation ($\delta_{soil,0} = \delta_a = -8$ ‰)



Test Case 4: Equilibrium fractionation ($\delta_{soil,0}$ = -8 ‰ ; δ_a = -15 ‰)



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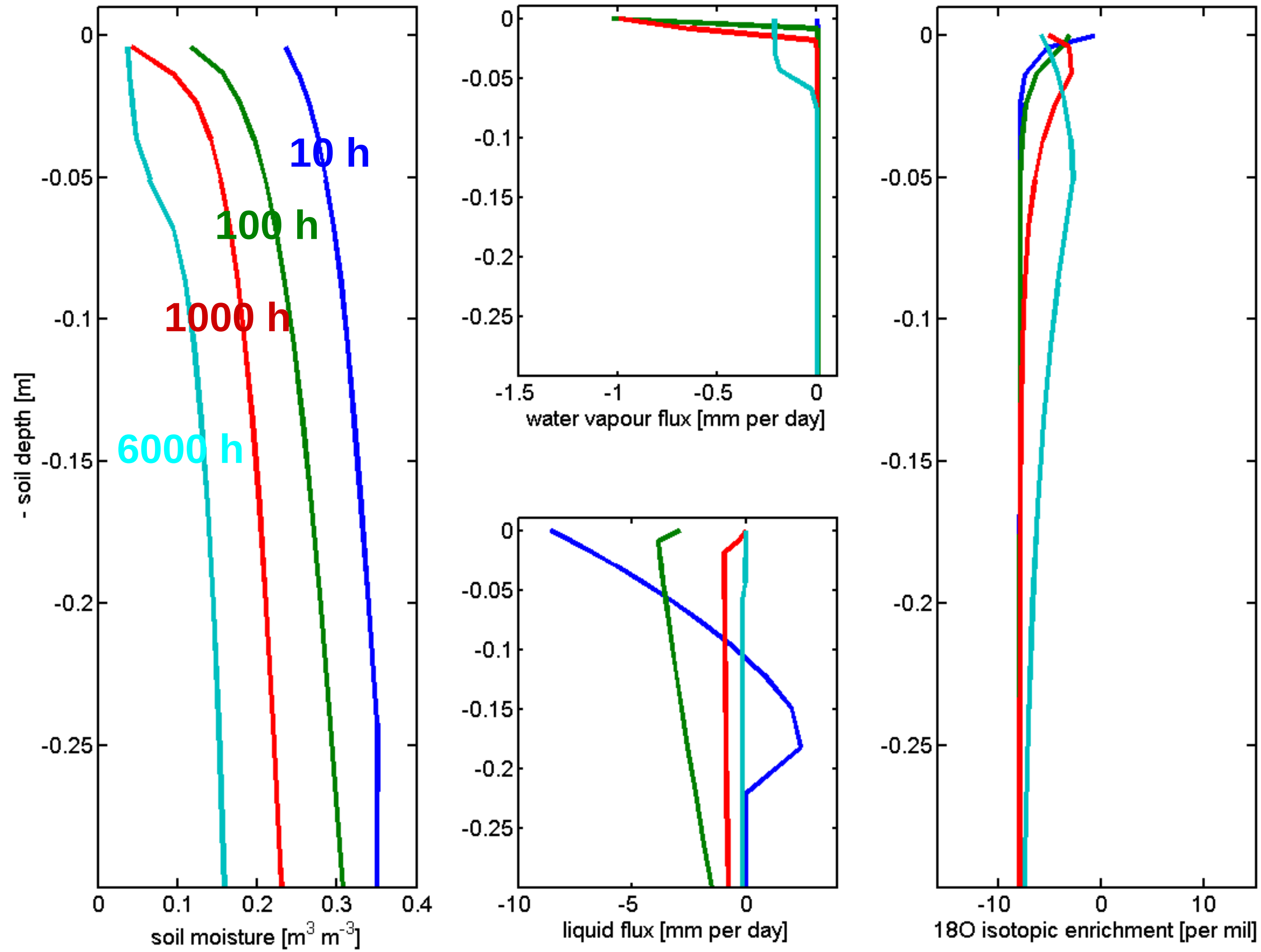
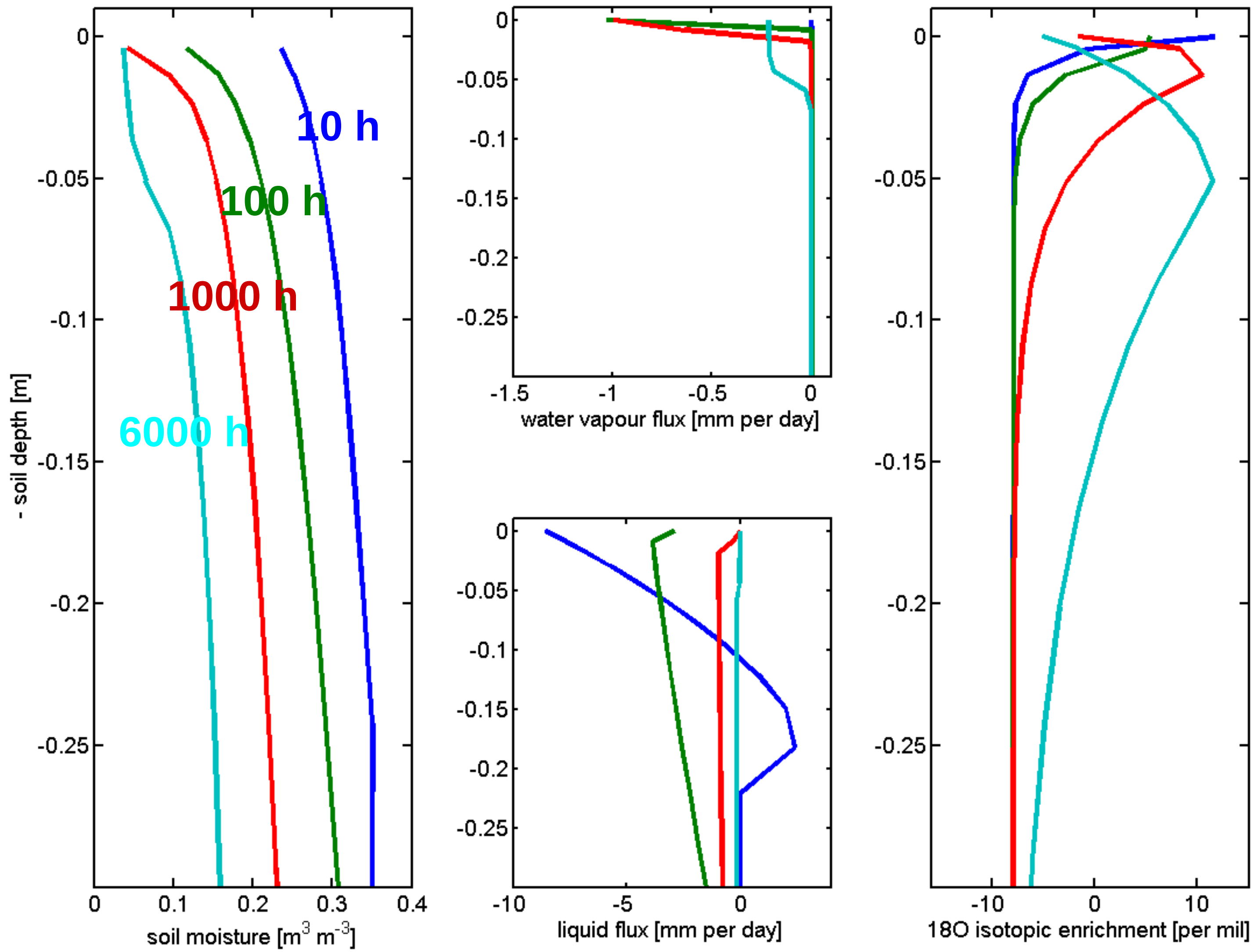
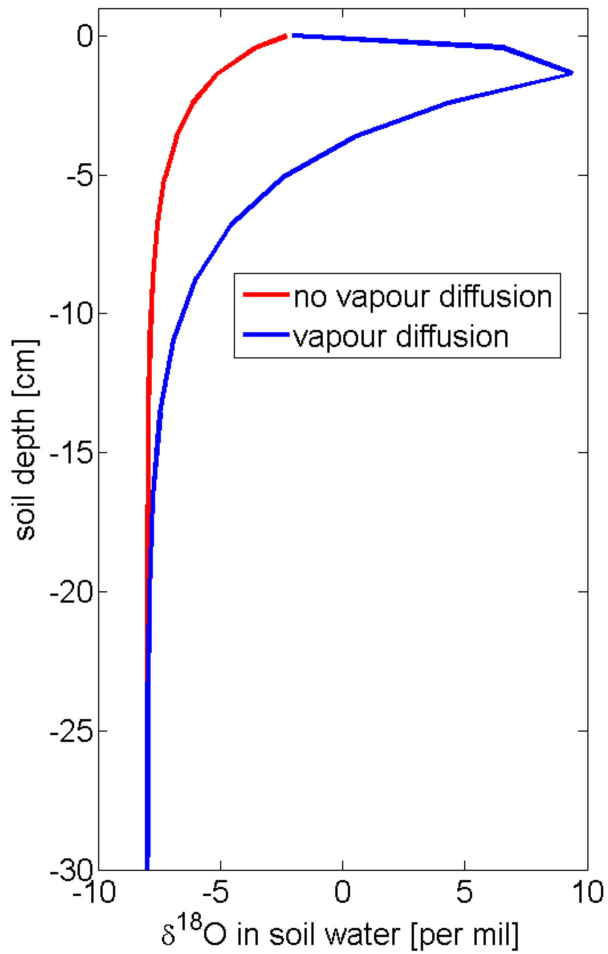
Test Case 5: Equilibrium fractionation and liquid diffusion ($\delta_{soil,0}$ = -8 ‰ ; δ_a = -15 ‰)



Test Case 6: Equilibrium fractionation, liquid diffusion and vapour diffusion ($\delta_{soil,0}$ = -8 ‰ ; δ_a = -15 ‰)

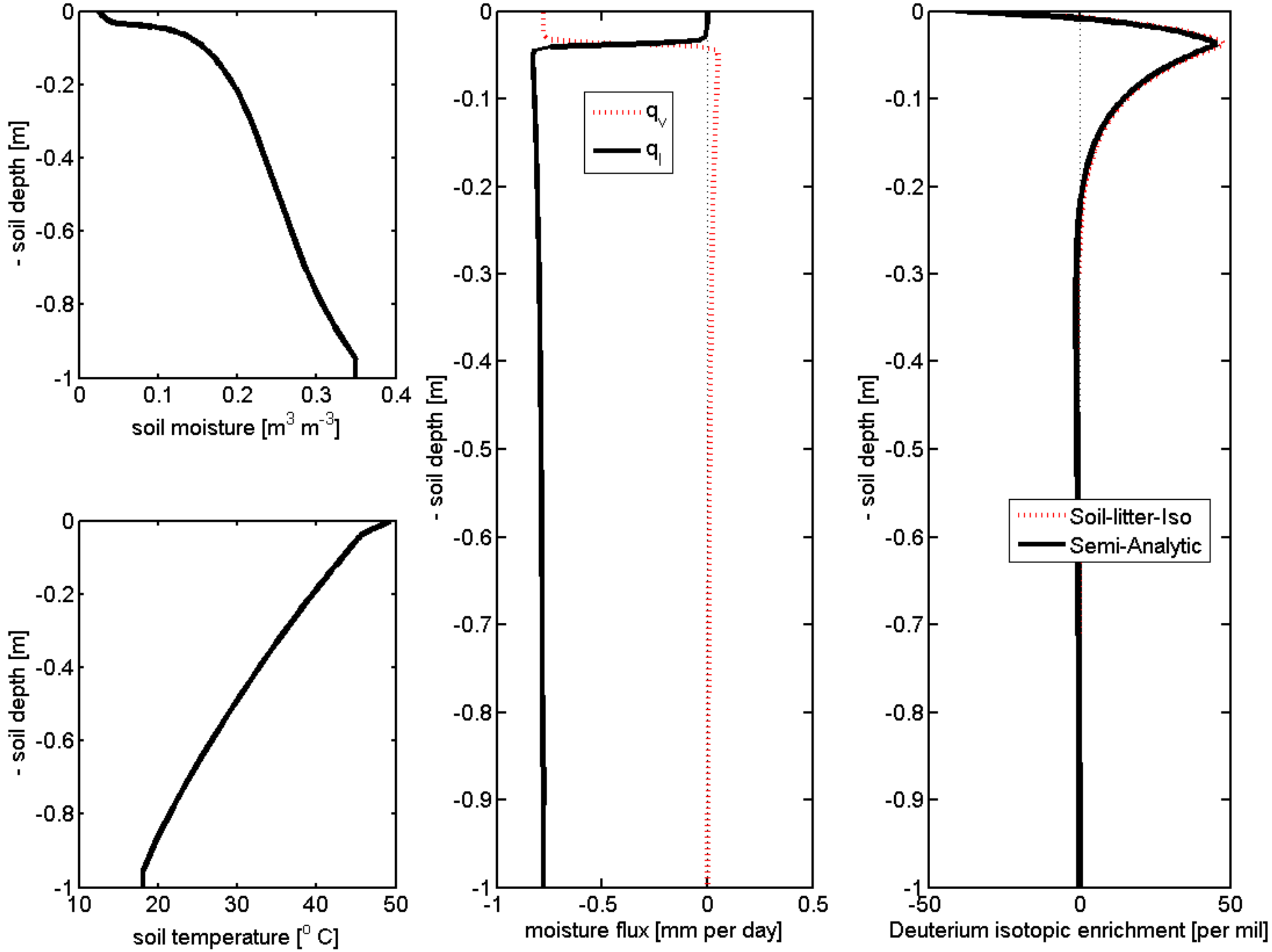


^{18}O in soil moisture: importance of vapour diffusion

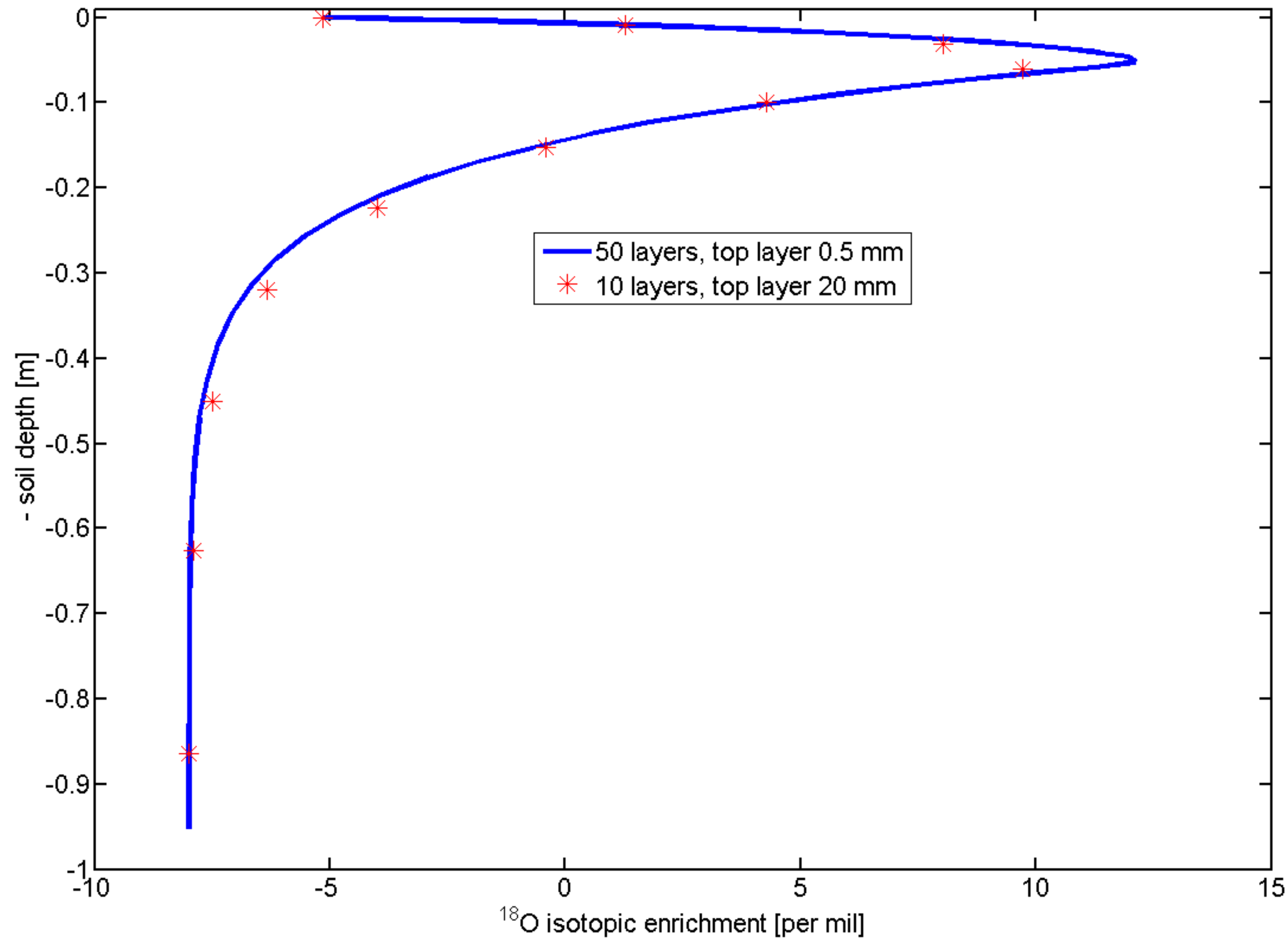


Simulated δ^{18}O after 50 days of drying

Semi-Analytical Solution: steady state evaporation from non-isothermal unsaturated soil column (Barnes and Allison 1984)



Robustness to model layer thicknesses



Summary

Consideration of vapour-phase transfer of soil moisture important for predicting:

- soil evaporation from dry soils
- surface soil moisture content
- Isotopic composition of soil moisture

Soil-Litter-Iso

- Currently being tested as a switchable option in CABLE
- Numerically robust and efficient
- Accurate even with thick (2 cm) surface layer
- Passes the same tests as state-of-the-art model (Sispat-Iso 2005) but much more applicable due to efficiency

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Thank you

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