

Integration of vertically heterogeneous soils in TERRA-ML

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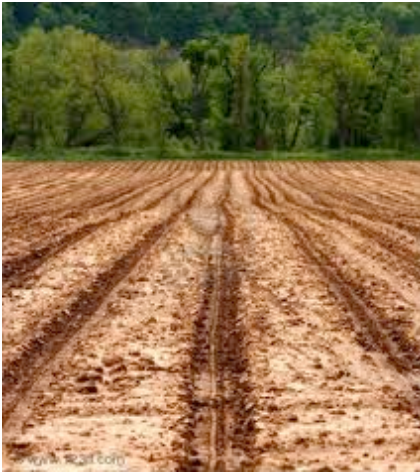
05/03/2012

Overview

- Background
- Objectives
- Vertically resolved soil data for TERRA
- Model adaptations
- Validation
- Summary
- Outlook

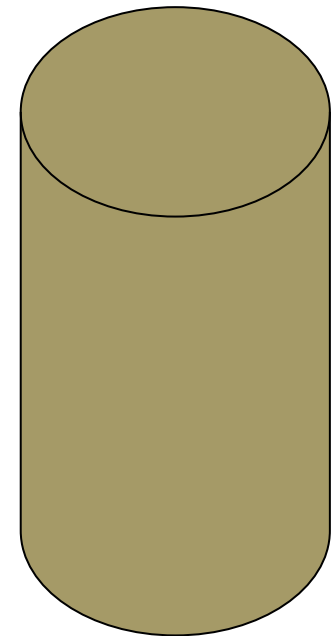


Background



Treatment of the soil in TERRA-ML

- in the „old“ version of TERRA-ML soil is treated as a (set of) homogeneous column(s)
- distinction of 5 soil types
- soil information is derived from the Digital Soil Map of the World (upper 30 cm), 5 arcmin resolution



Objectives

- improve the representation of physical soil properties / processes in TERRA-ML
 - use data sets with more detailed information, also in vertical direction, e.g. BUEK
 - adapt model code for new demands
- validation with observation data



New soil data for TERRA

	old data	new data
data set	FAO-UNESCO Digital Soil Map of the World	Harmonized World Soil Database v1.1; Nutzungsdifferenzierte Bodenübersichtskarte der Bundesrepublik Deutschland (BÜK 1000 N)
spatial resolution	5 arcmin (~ 10 km)	30 arcsec (~ 1km)
vertical resolution	1 layer	30 layers (5 cm from 0-100 cm, 10 cm from 100-200 cm)

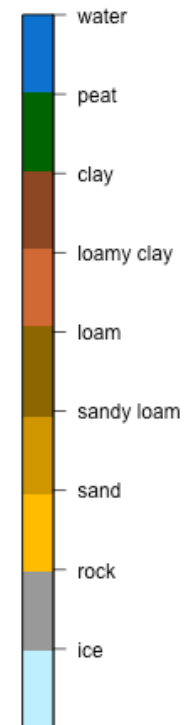


New soil data for TERRA

0-5 cm



30-35 cm



Simulation of soil water flow

- water flow in unsaturated or partly saturated soils can be described with the Richards equation (Richards, 1931):

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left(K \frac{\partial h}{\partial z} - K \right)$$



Simulation of soil water flow



Impossible d'afficher l'image. Votre ordinateur manque peut-être de mémoire pour ouvrir l'image ou l'image est endommagée. Redémarrez l'ordinateur, puis ouvrez à nouveau le fichier. Si le x rouge est toujours affiché, vous devrez peut-être supprimer l'image avant de la réinsérer.

- if soil is homogeneous and unsaturated, Richards equation can be expressed in dependence on water content only (van Genuchten et al., 1991):

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left(D \frac{\partial \theta}{\partial z} - K \right) \quad D = K \frac{dh}{d\theta}$$

➤ implemented in TERRA



Necessary adaptations in TERRA



Impossible d'afficher l'image. Votre ordinateur manque peut-être de mémoire pour ouvrir l'image ou l'image est endommagée. Redémarrez l'ordinateur, puis ouvrez à nouveau le fichier. Si le x rouge est toujours affiché, vous devrez peut-être supprimer l'image avant de la réinsérer.

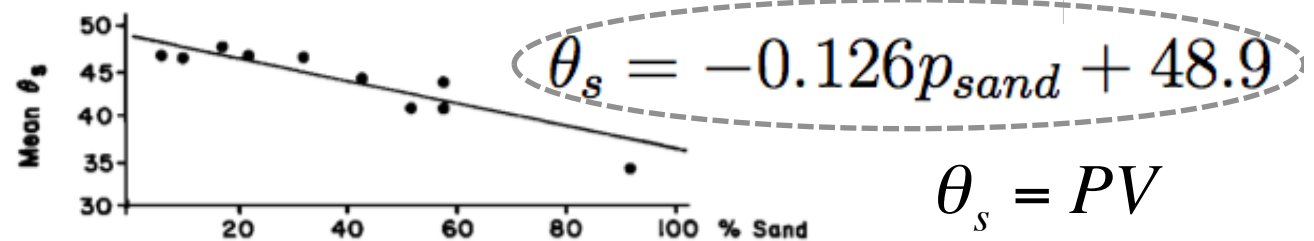
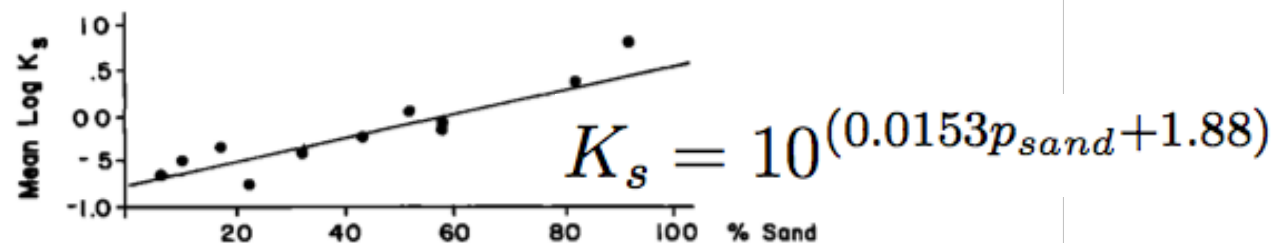
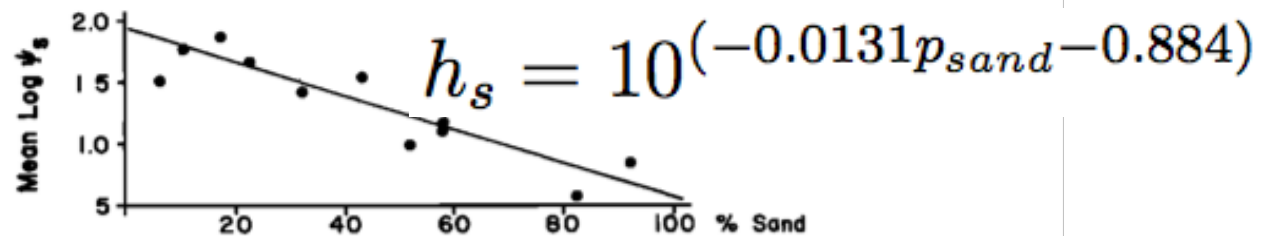
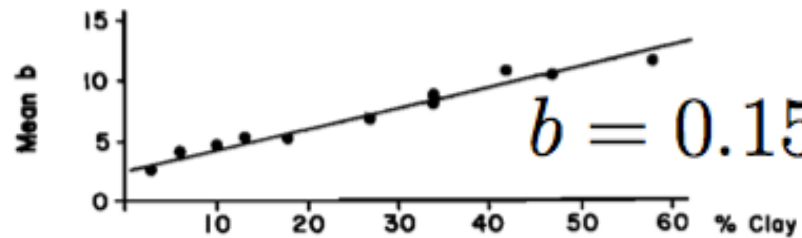
- reading 3D soil information
- implementation of the mixed form of Richards equation
 - new parameterisation
(Zeng & Decker, 2009)



Parameterisations according to Clapp & Hornberger (1978)

$$h = h_s \left(\frac{\theta}{\theta_s} \right)^{-b}$$

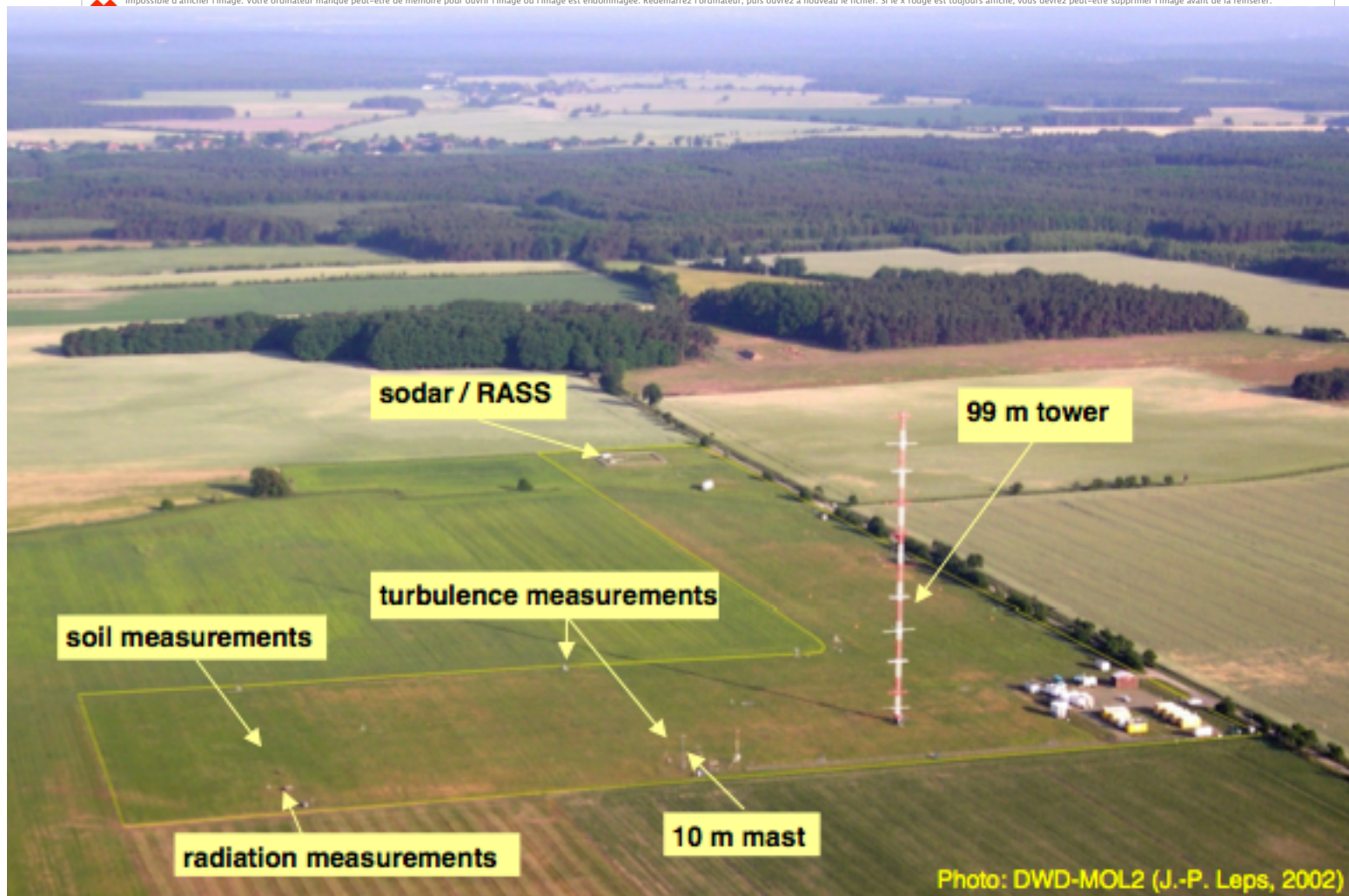
$$K = K_s \left(\frac{\theta}{\theta_s} \right)^{2b+3}$$



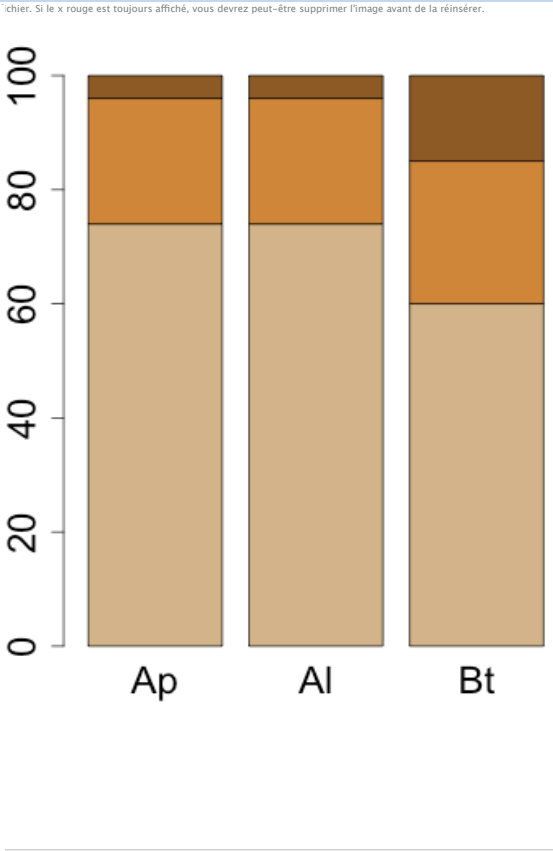
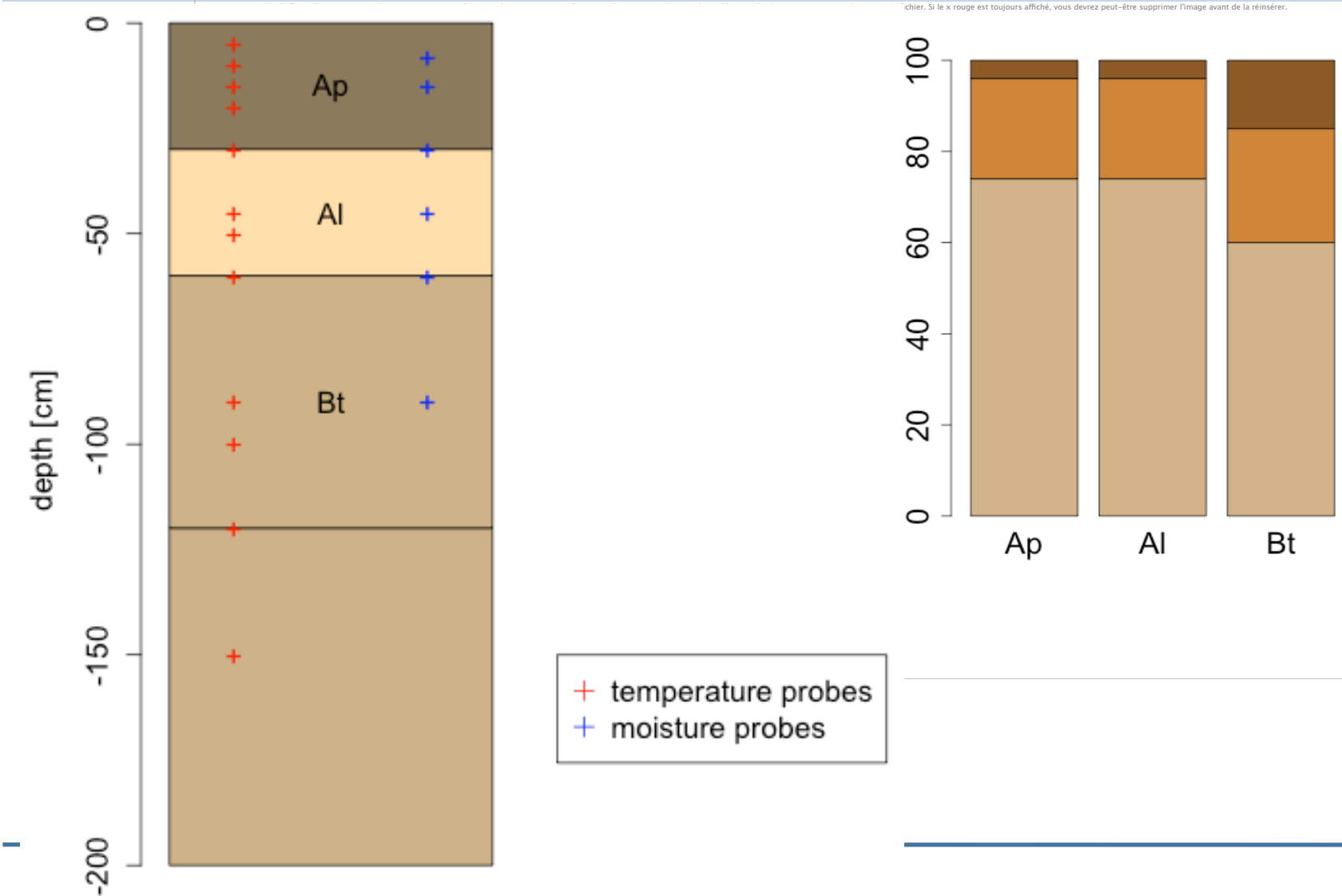
(Cosby et al., 1984)



Validation – Lindenberg data set



Soil characteristics



- + temperature probes
- + moisture probes

Translation of soil properties into TERRA soil types



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TERRA soil types

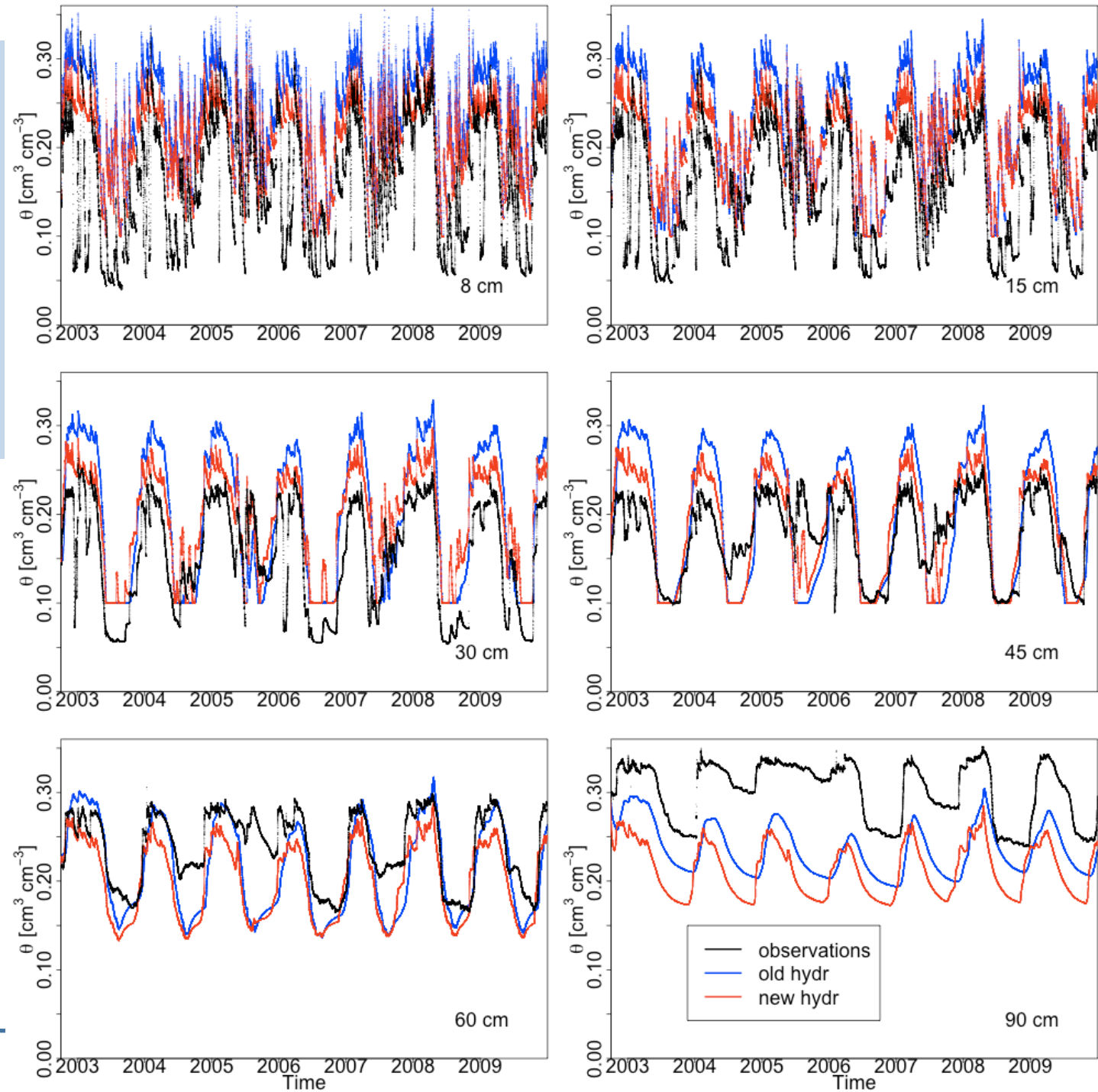
soil type	sand	sandy loam	loam	loamy clay	clay
Sand [%]	90	65	40	35	15
Clay [%]	5	10	20	35	70
Silt [%]	5	25	40	30	15

Soil characteristics at Lindenberg field site

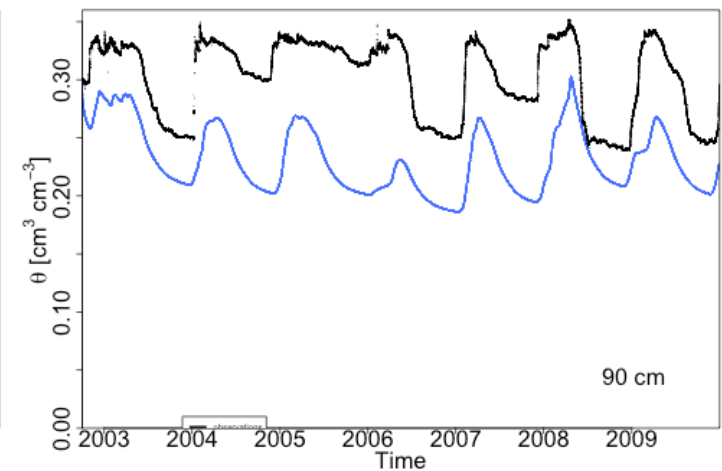
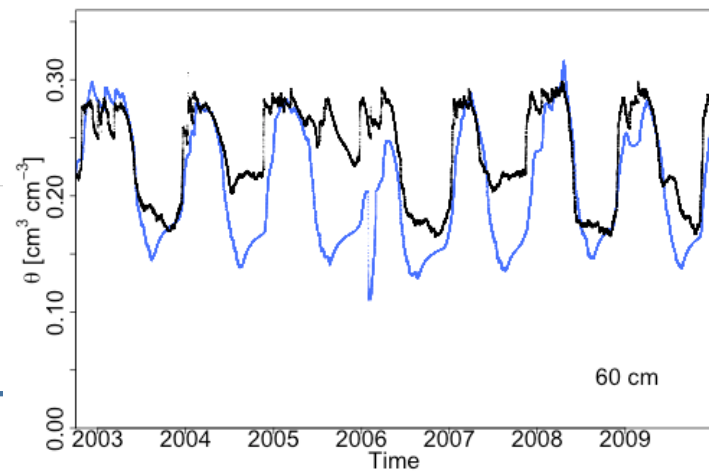
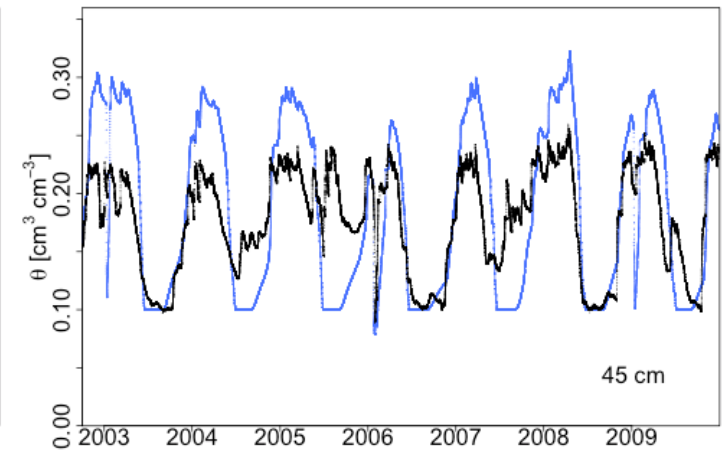
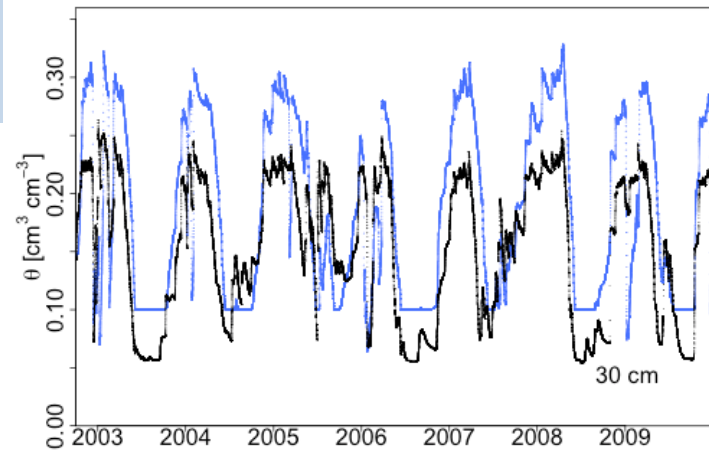
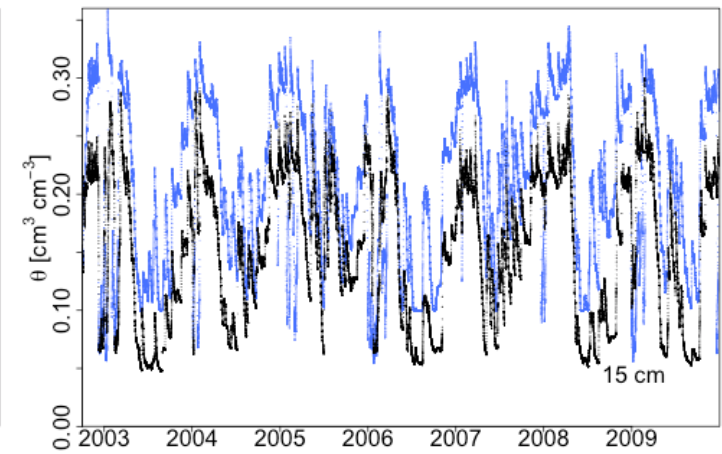
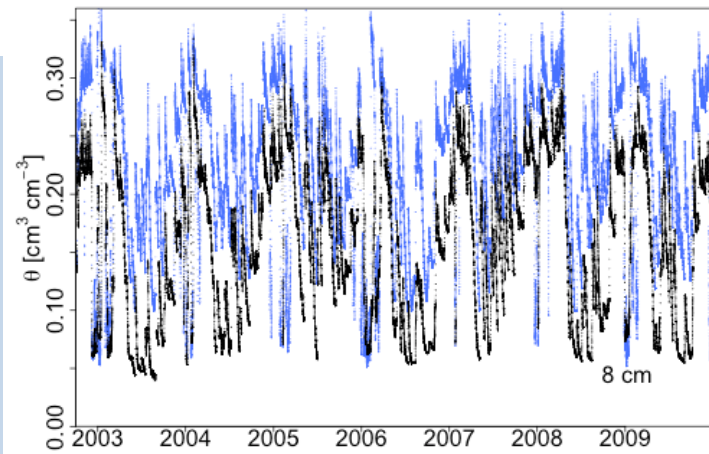
Horizon	Sand content [%]	Silt content [%]	Clay content [%]	Soil type acc. to TERRA
Ap	74	22	4	Sandy Loam
Al	74	22	4	Sandy Loam
Bt	60	25	15	Sandy Loam



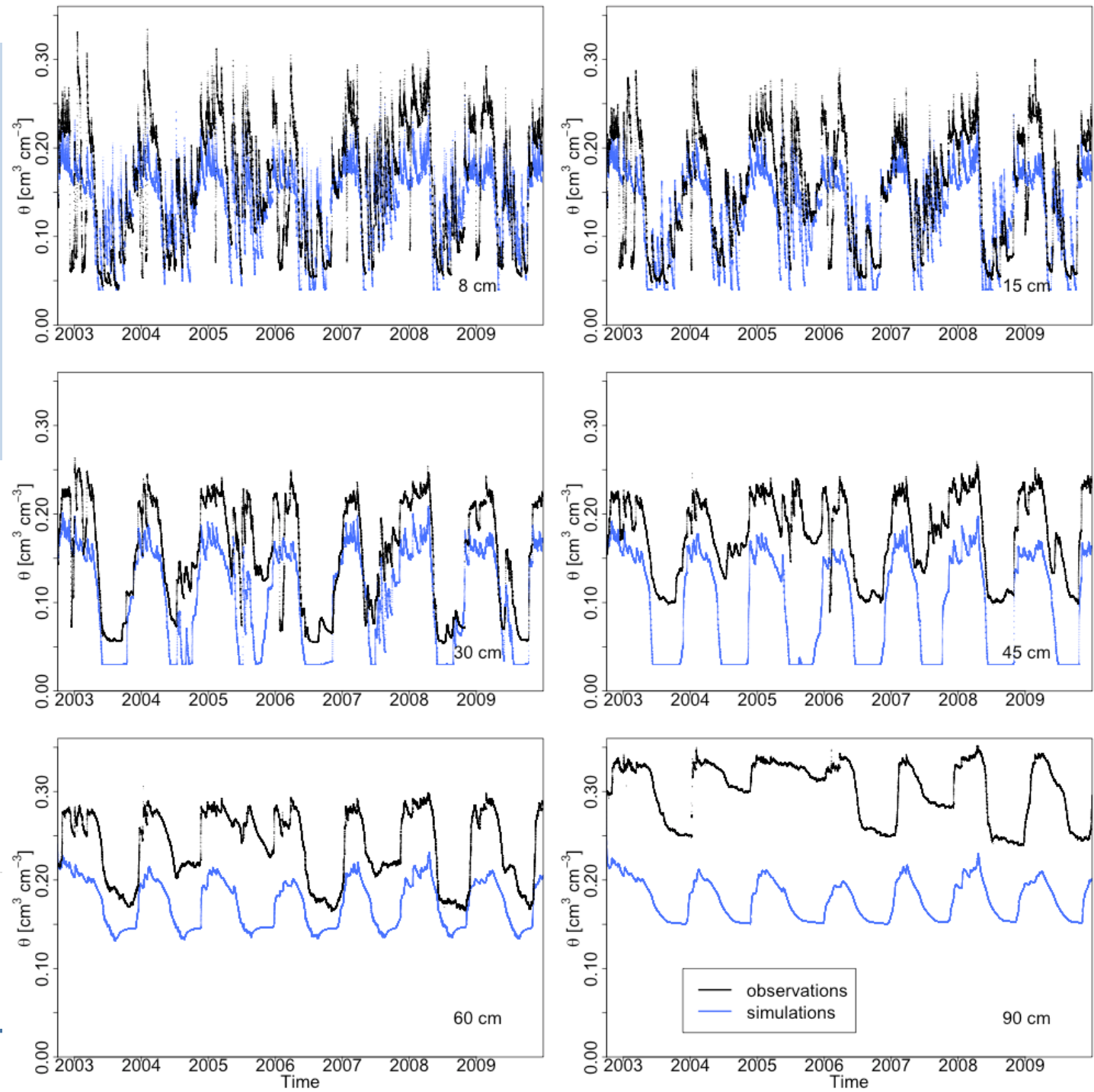
Results
for
homog.
Profile
(no freezing)



Results for homog. Profile (freezing)



Results for heterog. Profile



Summary



Impossible d'afficher l'image. Votre ordinateur manque peut-être de mémoire pour ouvrir l'image ou l'image est endommagée. Redémarrez l'ordinateur, puis ouvrez à nouveau le fichier. Si le x rouge est toujours affiché, vous devrez peut-être supprimer l'image avant de la réinsérer.

- New soil data set with vertically resolved information generated
- Mixed form of Richards equation was implemented in TERRA
- Improvement of soil water content prediction by “new approach” for homogeneous soil (upper layers)
- Further improvement by consideration of freezing process
- Underestimation of soil water contents for heterogeneous soil profile



Outlook



Impossible d'afficher l'image. Votre ordinateur manque peut-être de mémoire pour ouvrir l'image ou l'image est endommagée. Redémarrez l'ordinateur, puis ouvrez à nouveau le fichier. Si le x rouge est toujours affiché, vous devrez peut-être supprimer l'image avant de la réinsérer.

- Fix bug for freezing conditions in “new approach”
- Clarify dependence of hydraulic / thermal parameters on soil type
- Validation using further observational data sets
 - lysimeter data



Table 11.1: Hydraulic and thermal parameters of the different soil types

soil type	1 ice	2 rock	3 sand	4 sandy loam	5 loam	6 loamy clay	7 clay	8 peat
volume of voids w_{PV} [1]	-	-	0.364	0.445	0.455	0.475	0.507	0.863
field capacity w_{FC} [1]	-	-	0.196	0.260	0.340	0.370	0.463	0.763
permanent wilting point w_{PWP} [1]	-	-	0.042	0.100	0.110	0.185	0.257	0.265
air dryness point w_{ADP} [1]	-	-	0.012	0.030	0.035	0.060	0.065	0.098
minimum infiltration rate I_{K2} [kg/(m ² s)]	-	-	0.0035	0.0023	0.0010	0.0006	0.0001	0.0002
hydraulic diffusivity parameter D_0 [10 ⁻⁹ m ² /s]	-	-	18400	3460	3570	1180	442	106
hydraulic diffusivity parameter D_1 [1]	-	-	-8.45	-9.47	-7.44	-7.76	-6.74	-5.97
hydraulic conductivity pa- rameter K_0 [10 ⁻⁹ m/s]	-	-	47900	9430	5310	764	17	58
hydraulic conductivity pa- rameter K_1 [1]	-	-	-19.27	-20.86	-19.66	-18.52	-16.32	-16.48
heat capacity $\rho_0 c_0$ [10 ⁶ J/(m ³ K)]	1.92	2.10	1.28	1.35	1.42	1.50	1.63	0.58
heat conductivity λ_0 [W/(K m)]	2.26	2.41	0.30	0.28	0.25	0.21	0.18	0.06
$\Delta\lambda$ [W/(K m)]	0.0	0.0	2.40	2.40	1.58	1.55	1.50	0.50
exponent B [1]	1.0	1.0	3.5	4.8	6.1	8.6	10.0	9.0



Soil parameters Lindenberg



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Table 2 - Physical parameters of the soil at the Lindenberg reference stations

layer no.	horizon	upper boundary [cm]	lower boundary [cm]	clay [M%]	silt [M%]	sand [M%]	dry density [g/cm ³]	pore volume [%]	field capacity * [V%]	wilting point [V%]	hydraulic conductivity [cm/d]	soil heat capacity [$\cdot 10^6$ J/(K $\cdot$ m ³)]
Lindenberg – Falkenberg Station												
1	Ap	0	30	4	22	74	1.6	37	16	4	110	1.32
2	Al	30	60	4	22	74	1.7	36	18	3	80	
3	Bt	60	120	15	25	60	1.7	34	24	11	20	

