



Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

MACRO-based modelling tools - Recent development and future plans

¹Mats Larsbo, ²Roger Holten, ²Ole Martin Eklo, ²Marianne Stenrød
and ¹Nick Jarvis

¹Department of Soil and Environment, Swedish University of Agricultural Sciences (SLU)

²Division of Biotechnology and Plant Health, Norwegian Institute of Bioeconomy
Research (NIBIO)



Two parts:

- MACRO-DB: A tool for risk assessments for permits in drinking water abstraction zones
- Modelling soil freezing



MACRO-tools

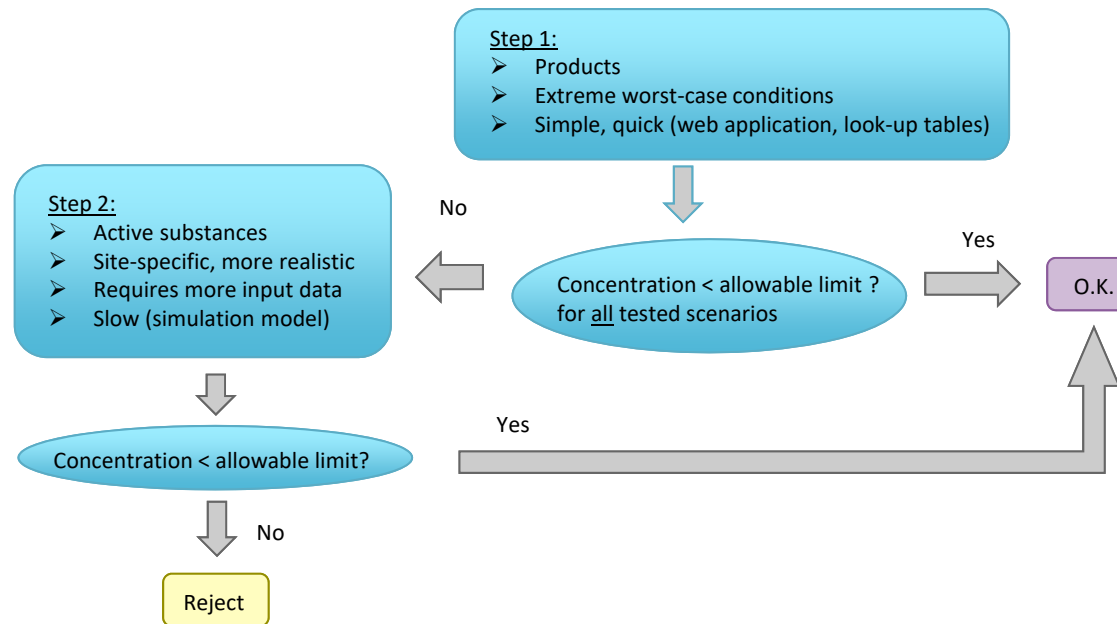
Tool	Use	End-users
MACRO in FOCUS	Registration (nationally and EU)	National authorities (e.g. Swedish Chemicals Agency), EFSA, industry
+MACRO-DB	Application permits in drinking water protection areas	Local authorities, landowners, consultants, advisors
+MACRO-SE	Support for risk reduction/mitigation (EU Water Framework Directive), targeted environmental monitoring	Regional water authorities (EPA, SGU)

+Development of MACRO-DB/SE is supported by CKB and HaV, the Swedish Agency for Marine and Water Management



MACRO-DB: risk assessment for permits in drinking water abstraction zones

A two-step procedure

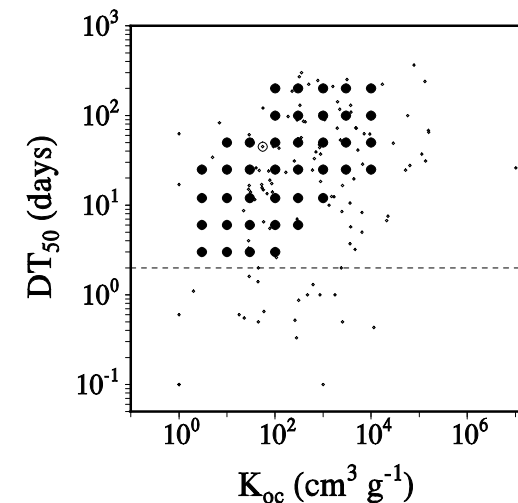




MACRO-DB: risk assessment for permits in drinking water abstraction zones

Step 1

- Web-application (immediate answers)
- Simple input data
 - Product, dose, application timing and climate zone
 - How often is the product applied? (i.e. every year, every other year, every third etc.),
 - Proportion of arable land in catchment area
- Already run 'worst-case' simulations
 - Eleven common soil types (hydrology/texture):
 - 5th percentile SOM in topsoil
 - 95th percentile for texture (sandy sand soils, clayey clay soils)
 - 51 hypothetical compounds
- Model
 - Linear adsorption isotherm



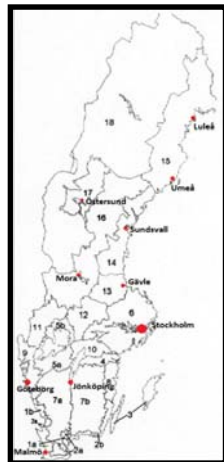


MACRO-DB: risk assessment for permits in drinking water abstraction zones

Step 2

Applications

Crop, compound properties (PPDB), dose, timing (2 week periods), method



Climate data
Daily data for 26 years
Climate zones in Sweden

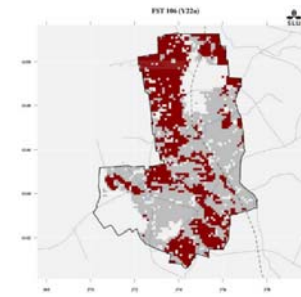
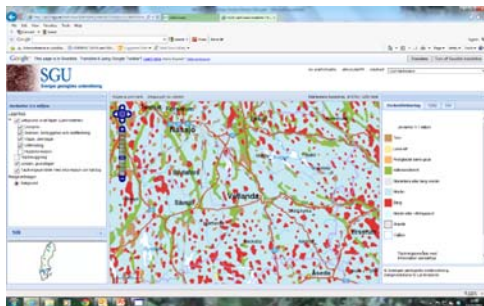


Pedotransfer rules and functions (FOOTPRINT)



Parent material
Quaternary geology

Soil properties
Texture, SOM



Tabell över jordarter

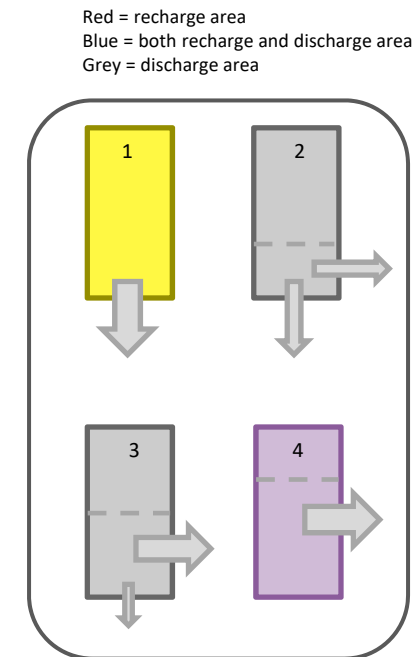
Tabellen nedan sammanfattar de olika jordarterna samt andra markegenskaper i det utpekade området. De redovisade tabellerna för en beskrivning av varje variabel i tabellen.

Jordart	Area (km ²)	Antal jordarter	Medelvärdet	Standardavvikelse	Medelvärdet för jordarter	Standardavvikelse för jordarter
1 122a	2 423	623	1028	medium (2)	medium (2)	17 29 53 15 2,6
2 122a	2 18 4	618	646	medium (2)	medium (2)	18 31 61 15 2,6
3 122a	2 12 1	73 9	425	grovskog (1)	grovskog (1)	19 21 69 15 2,5
4 122a	8 7 6	89 9	291	medium (2)	medium (2)	17 31 52 21 3,7
5 122a	2 5 6	16 9	177	grovskog (1)	medium (2)	13 21 68 14 2,4
6 122a	8 3 4	89 4	121	medium (2)	medium (2)	17 28 54 14 2,9
7 122a	8 2 1	91 9	89	grovskog (1)	grovskog (1)	8 16 79 14 2,5
8 122a	8 2 4	18 2	82	grovskog (1)	grovskog (1)	6 16 78 22 3,8
9 122a	2 2 2	16 5	79	grovskog (1)	grovskog (1)	10 20 75 21 3,6
10 122a	2 8 9	87 4	31	grovskog (1)	grovskog (1)	5 14 89 14 2,4
11 122a	2 0 5	16 8	19	medium (2)	medium (2)	15 29 56 15 2,6
12 122a	2 0 8	18 6	18	grovskog (1)	medium (2)	16 19 66 15 3,3
13 122a	2 0 4	18 8	13	grovskog (1)	grovskog (1)	6 17 77 23 4,0
14 122a	8 0 3	89 1	10	grovskog (1)	medium (2)	13 21 68 14 2,4
15 122a	2 0 3	18 4	9	grovskog (1)	medium (2)	12 22 66 15 2,8
16 122a	2 0 3	18 6	9	medium (2)	medium (2)	16 31 64 22 3,8
17 122a	8 0 1	18 8	9	grovskog (1)	medium (2)	15 18 67 20 3,4
18 122a	2 0 1	18 9	3	grovskog (1)	medium (2)	14 20 66 15 3,3
19 122a	8 0 1	18 9	3	medium (2)	grovskog (1)	6 28 64 24 4,1
20 122a	2 0 8	168 0	1	grovskog (1)	grovskog (1)	6 19 74 15 2,9
21 122a	2 0 8	168 0	1	medium (2)	grovskog (1)	9 27 64 23 4,0

Anmärkning: Tabellerna skiljer från kolumnen för „jordan_ark_Mingentrol“.

Soil hydrological classification

Quaternary geology	Subsoil texture	Hydrological class	
		Drained	Undrained
Coarse esker materials		-	1
Sedimentary rocks		-	1
Moraine (till)	Coarse	-	2
	medium, medium-fine	3	2
	Fine	3	-
Rock		-	3
Coarse silt/fine sand, sand or gravel		4	2
Clay/silt		4	2
Organic soil (peat)		4	-
Alluvium/outwash		4	-





Development plans (feedback welcome!)

- The current version is time-consuming for farmers and authorities to use and also difficult (expensive) for us (CKB) to maintain
- *HaV* are supporting a recently-started project to develop meta-models to replace the current two-step procedure
 - Web application
 - Meta-model(s) based on ca. 900,000 simulations
 - Ca. 40 major/sensitive soil-hydrological types,
 - 16 climate zones
 - 3 generic crop types
 - 3 application timings (spring, summer, autumn)
 - Ca. 120 hypothetical pesticides (3 Freundlich exponents, 50 combinations of DT_{50}/K_{oc})
 - Best statistical method? We will test CART (classification and regression trees)



Modelling soil freezing

Background



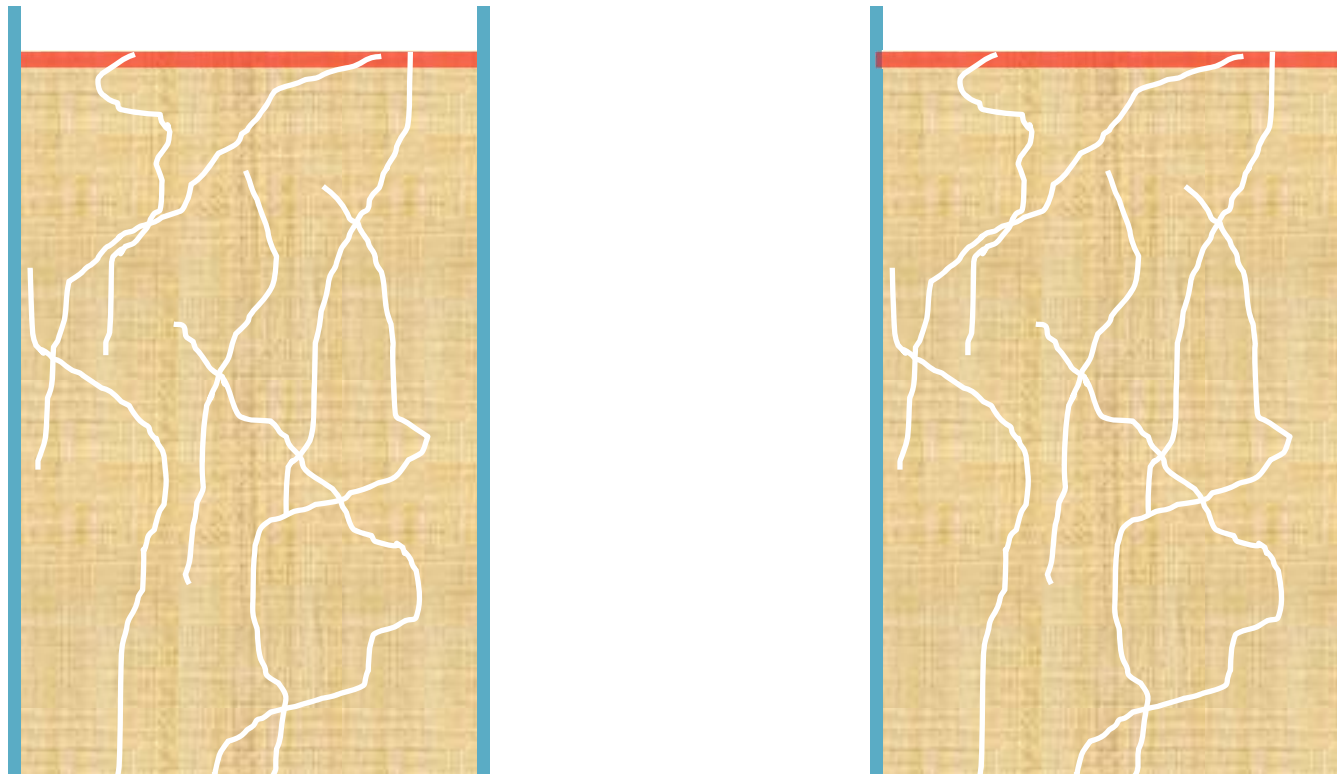
- Significant losses of pesticides may occur when the soil is partly frozen (Riise et al., 2004; Ulén et al., 2013)
- Soil freezing is not accounted for in risk assessments for pesticides
- As far as we know there are no models that account for both freezing and preferential flow and transport

Riise, G., H. Lundekvam, Q. L. Wu, L. E. Haugen and J. Mulder (2004). "Loss of Pesticides from Agricultural Fields in SE Norway – Runoff Through Surface and Drainage Water." *Environmental Geochemistry and Health* **26(2): 269-276.**

Ulen, B. M., M. Larsbo, J. K. Kreuger and A. Svanback (2013). "Spatial variation in herbicide leaching from a marine clay soil via subsurface drains." *Pest Management Science* **70(3): 405-414.**



Schematic illustration of solute transport in frozen soil



Schematic illustration of solute transport in frozen soil



Frozen



Unfrozen

Schematic illustration of solute transport in frozen soil



Frozen



Unfrozen

Objective

Develop and evaluate a dual-permeability approach for simulating water flow (and solute transport) in soil under freezing and thawing conditions.

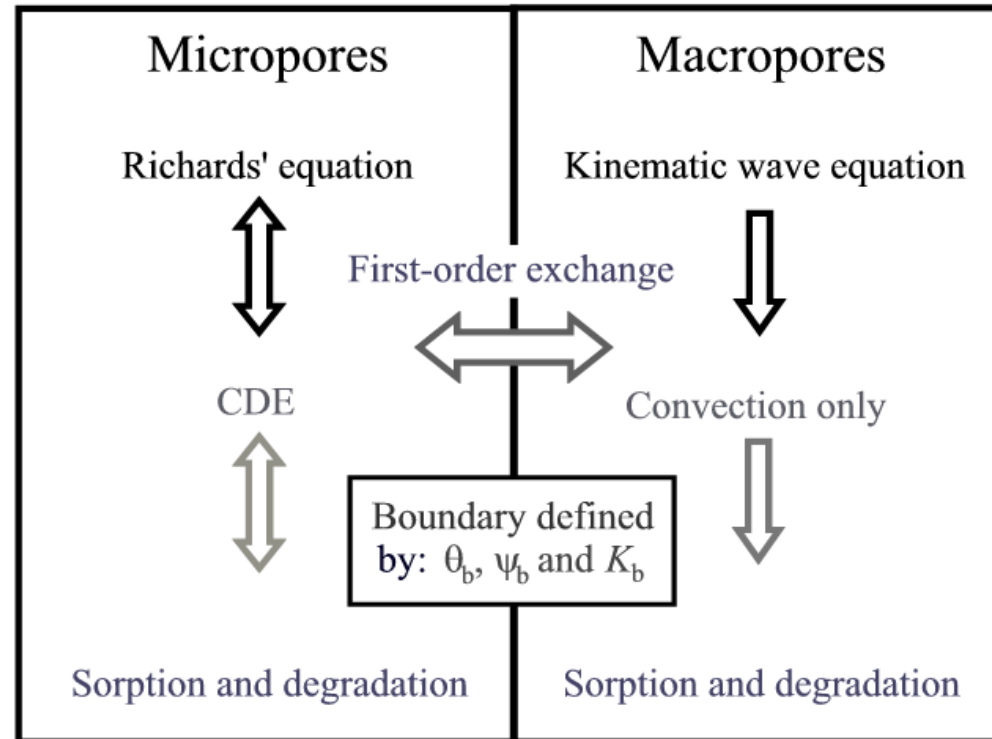


Frozen



Unfrozen

The MACRO model



- Dual-permeability approach for water flow and solute transport
- Single domain for soil temperatures
- Freezing and thawing not simulated



Modelling approach freezing

Micropore domain

- Large (water-filled) pores freeze first
- Large effect on hydraulic conductivities
- “Freezing = drying”



Macropore domain

- No effects of capillary pressure on freezing
- Smallest (water-filled) macropores freeze first



Modelling approach freezing

Micropore domain


Heat flow equation
(conduction and
convection)



Generalized
Clapeyron equation

Richard's equation

Macropore domain

- Heat convection only
- 
- Macropores will only freeze through exchange with the micropore domain

Hansson, K., J. Šimůnek, M. Mizoguchi, L.-C. Lundin and M. T. van Genuchten (2004). "Water Flow and Heat Transport in Frozen Soil." Vadose Zone J. **3(2): 693-704.**

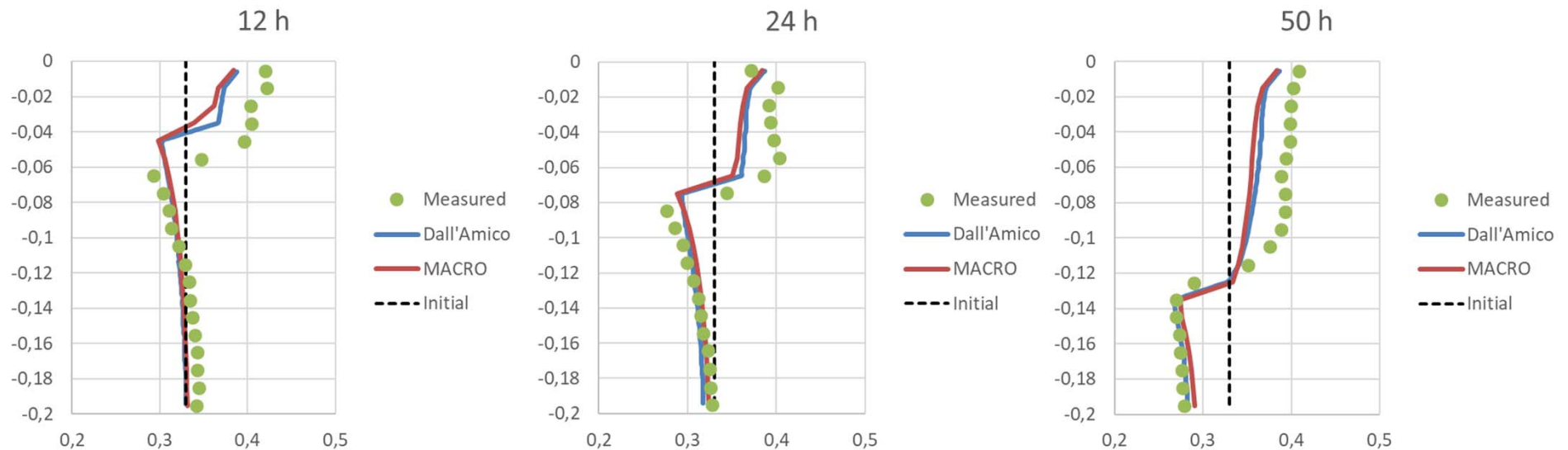
Stähli, M., P. E. Jansson and L. C. Lundin (1996). "Preferential water flow in a frozen soil - A two-domain model approach." Hydrological Processes **10(10): 1305-1316.**



Model evaluation

Redistribution of water – freezing from the soil surface Only soil matrix

Initial conditions: Water content = 0.33; Soil temperature = 6.7 °C
Top boundary condition: Temperature = -6 °C; No water flow
Bottom boundary: No flow

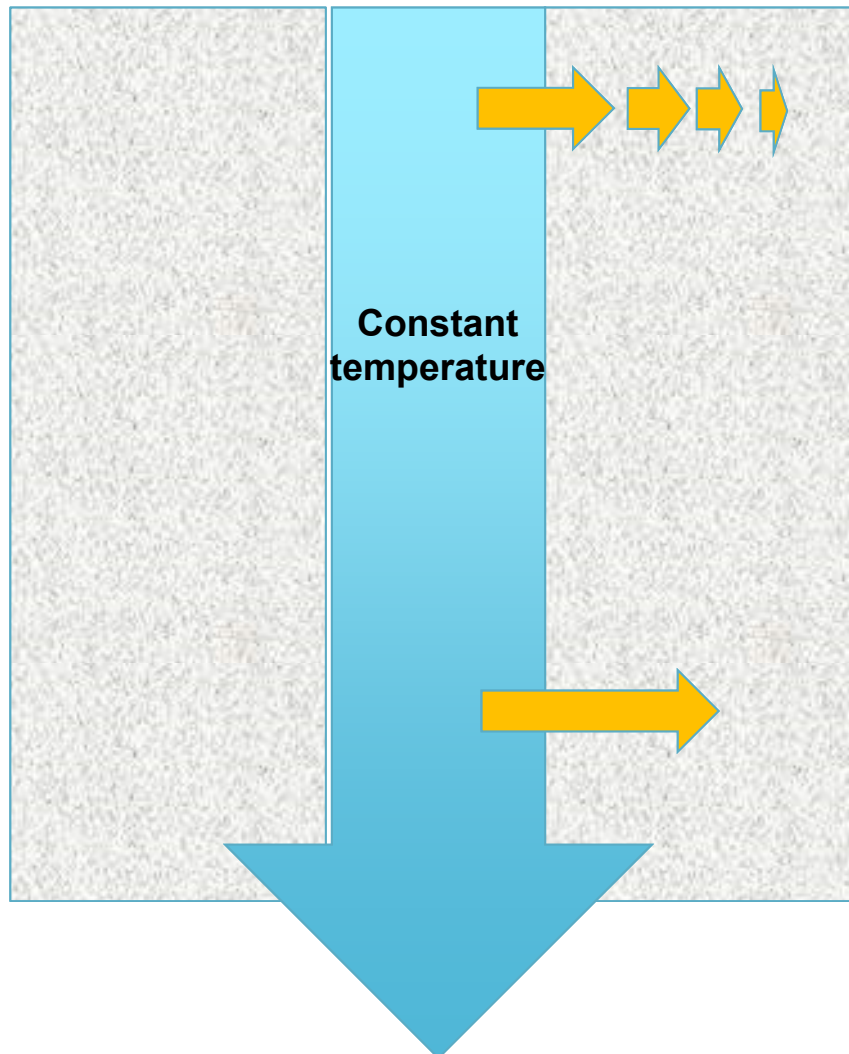


Mizoguchi, M. 1990, Water, heat and salt transport in freezing soils. PhD thesis (In Japanese), University of Tokyo.

Dall'Amico, M., S. Endrizzi, S. Gruber and R. Rigon (2011). "A robust and energy-conserving model of freezing variably-saturated soil." Cryosphere 5(2): 469-484.

Model evaluation

Energy exchange between pore domains



Heat conduction equation

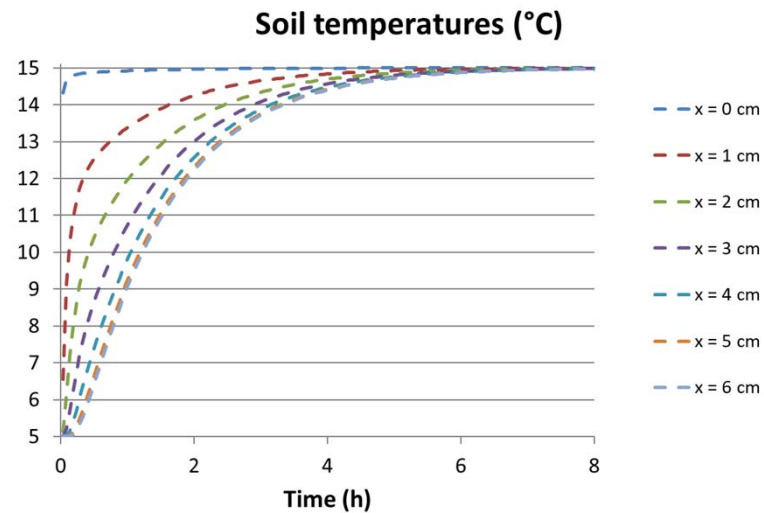
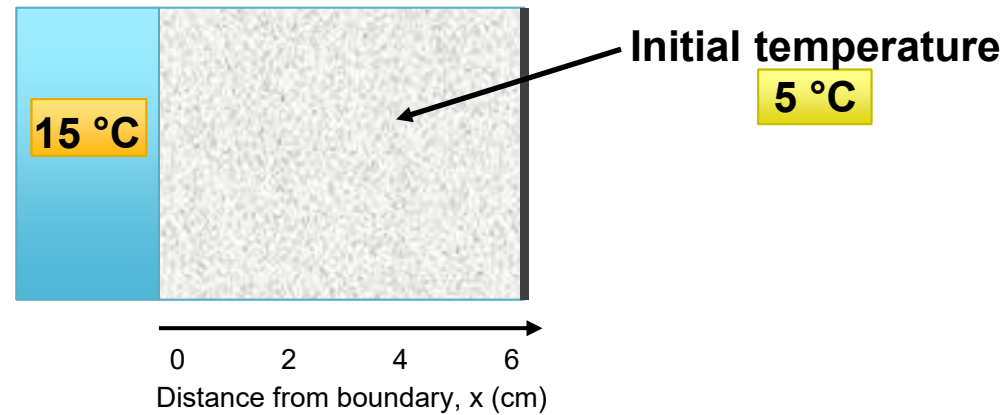
$$\frac{\partial C_v T}{\partial t} = \frac{\partial}{\partial x} \left(k_h \frac{\partial T}{\partial x} \right)$$

First-order approximation to the heat conduction equation

$$\frac{\partial C_v T}{\partial t} = \frac{G_f k_h S_{mac,tot}}{d^2} (T_{mic} - T_{mac})$$

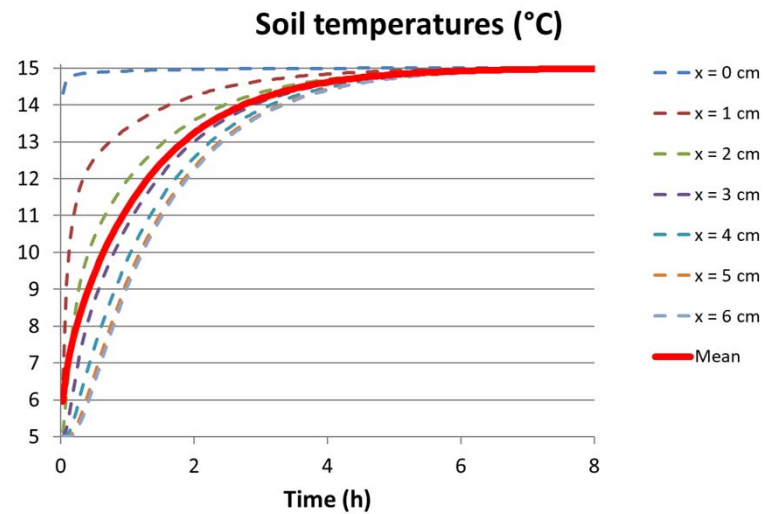
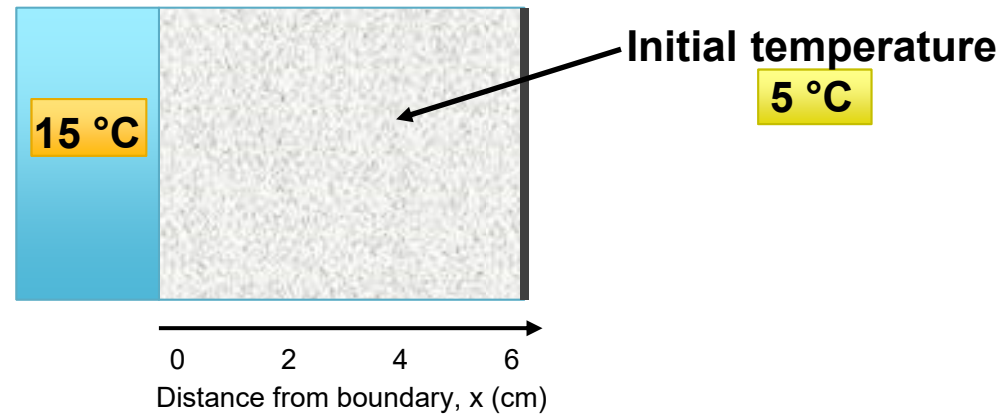
Model evaluation

Energy exchange between pore domains



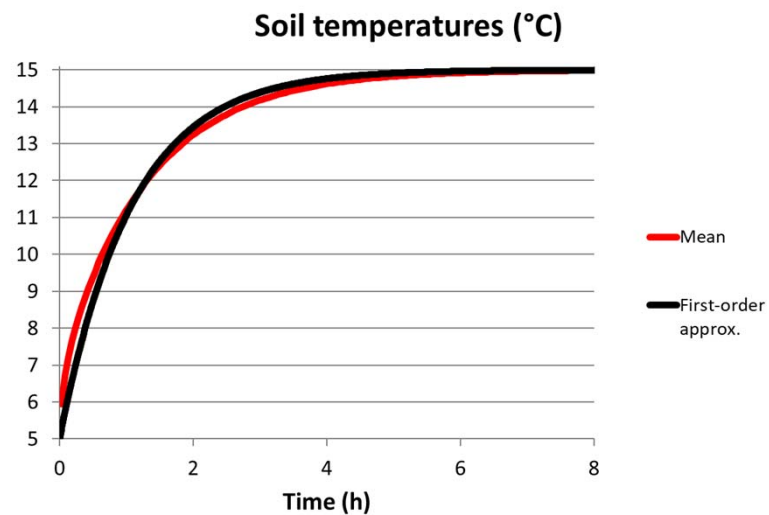
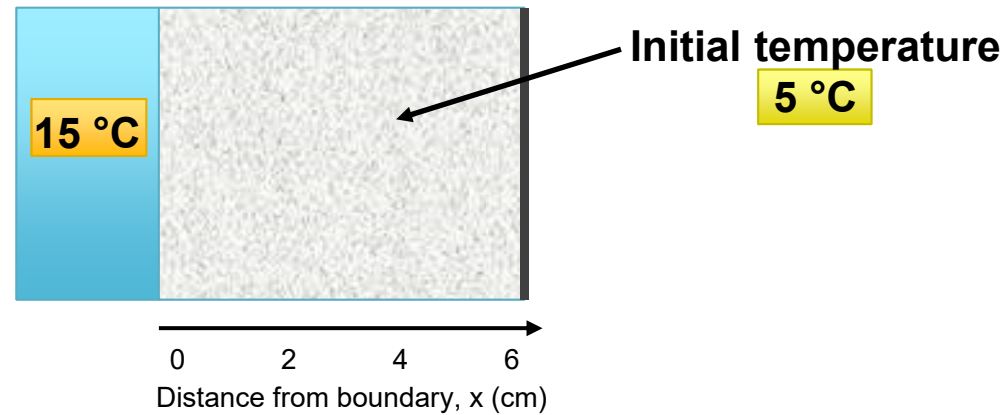
Model evaluation

Energy exchange between pore domains



Model evaluation

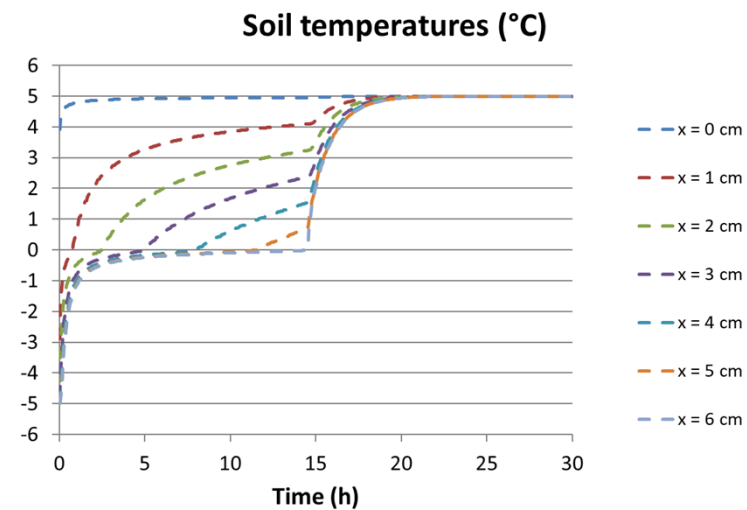
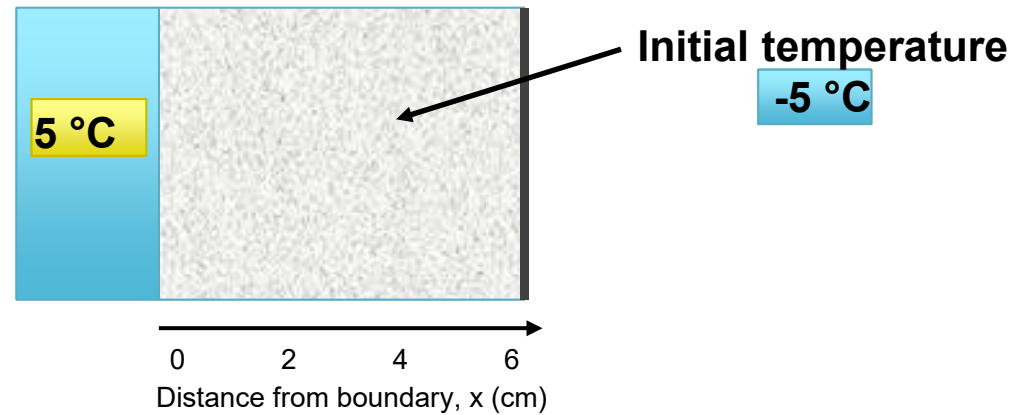
Energy exchange between pore domains





Model evaluation

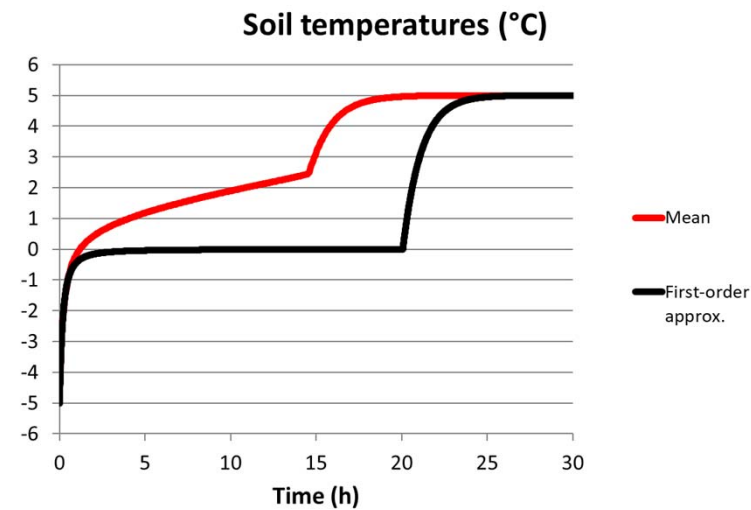
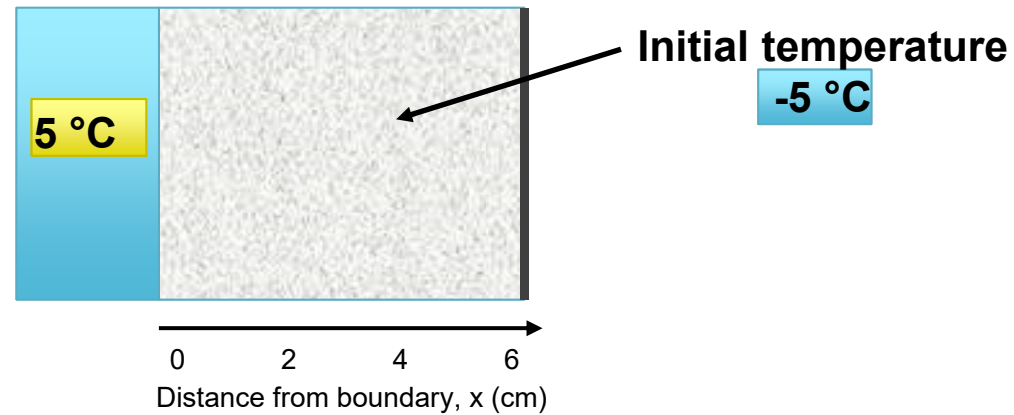
Energy exchange between pore domains





Model evaluation

Energy exchange between pore domains





Model evaluation

Water flow in macropores

Surface boundary condition:

6 min irrigation every 30 min

Temperature of water 1 °C

Initial condition:

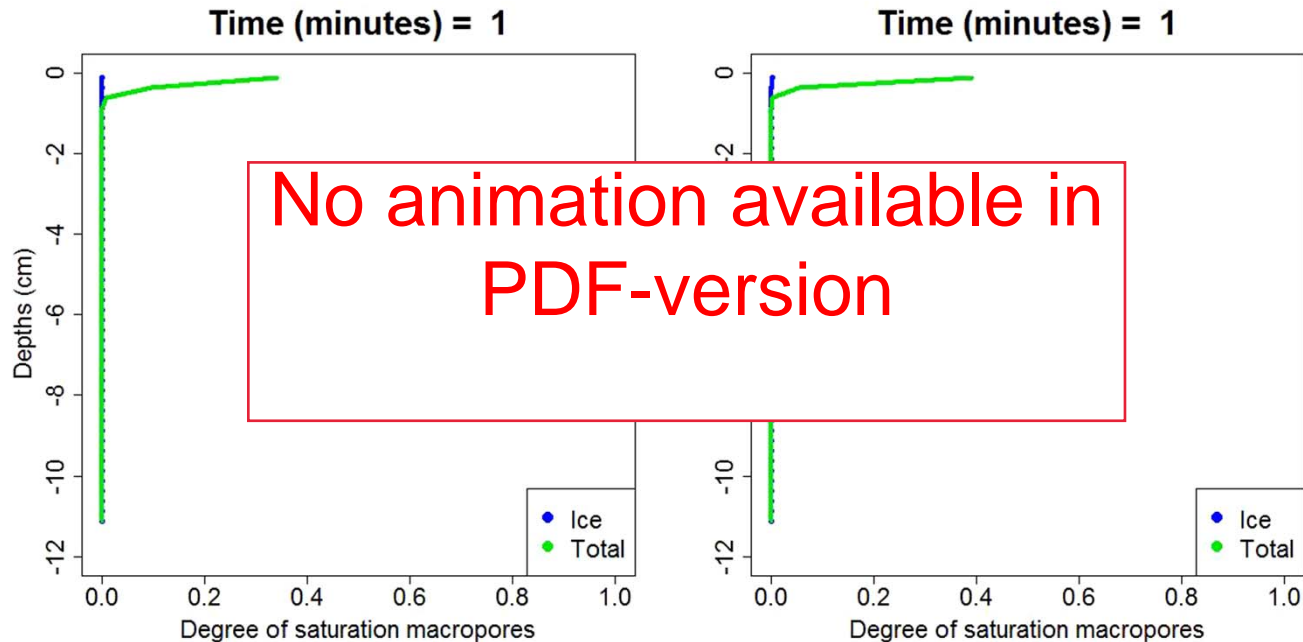
Air-filled macropores

Saturated matrix at 1 °C

Initial condition:

Air-filled macropores

Saturated matrix at -2 °C

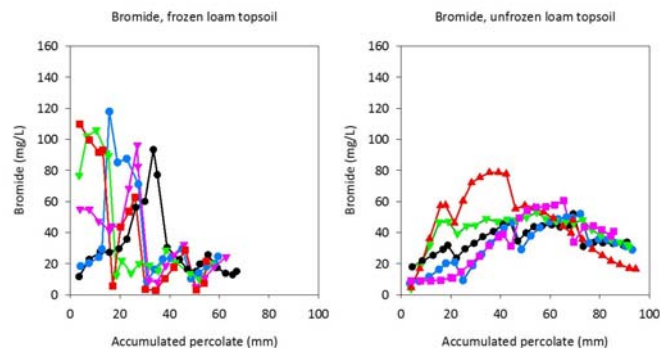


Conclusions...

- The model results are in agreement with the limited available data
- Inclusion of freezing effects in risk assessments for pesticides lies in the future

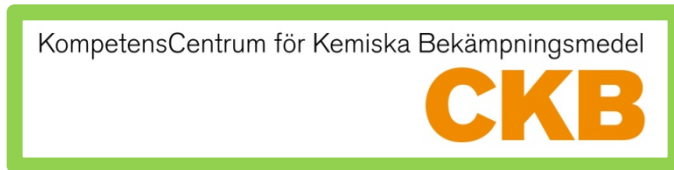
...and future plans

- “Validation” of the macropore freezing/water flow model
- Connect water flow and solute transport
- Evaluation of the complete model using data from column experiments





Acknowledgements



Research Council of Norway

Thanks for listening!