COMSOL CONFERENCE 2016 MUNICH

Importance of Wintertime Phase Change in Modeling Moisture Dynamics in Road Systems, Sweden

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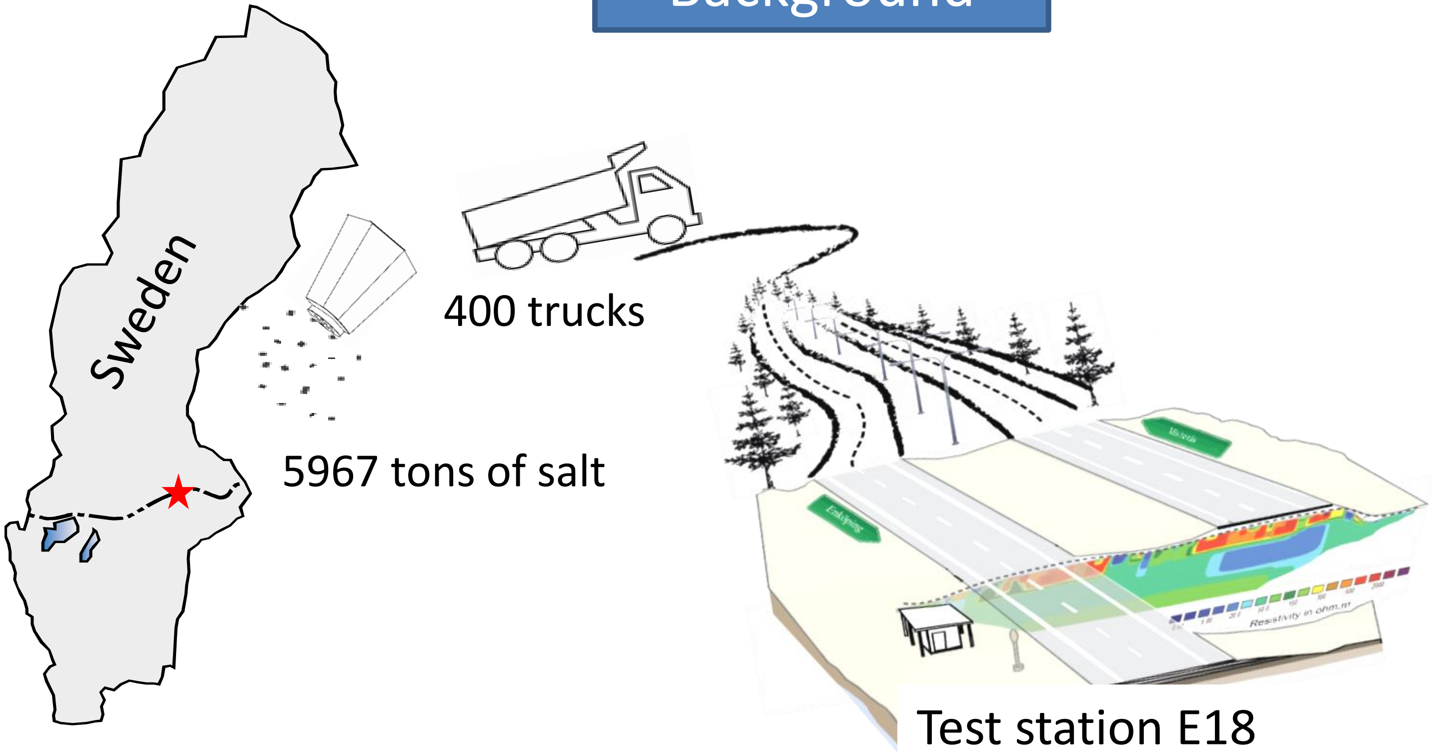
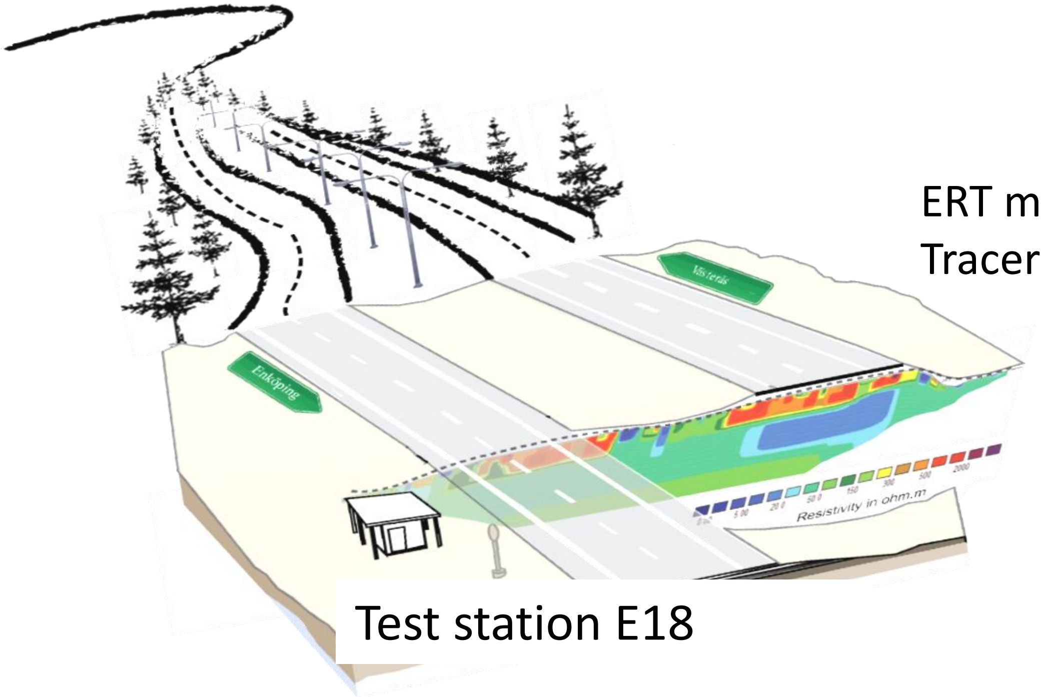
Outline

- Background
- Aim
- Method
- Result & Discussion
- Conclusion

Background





Test station E18

ERT measurements
Tracer test

Modeling needed to describe the dynamics

COMSOL 5.1

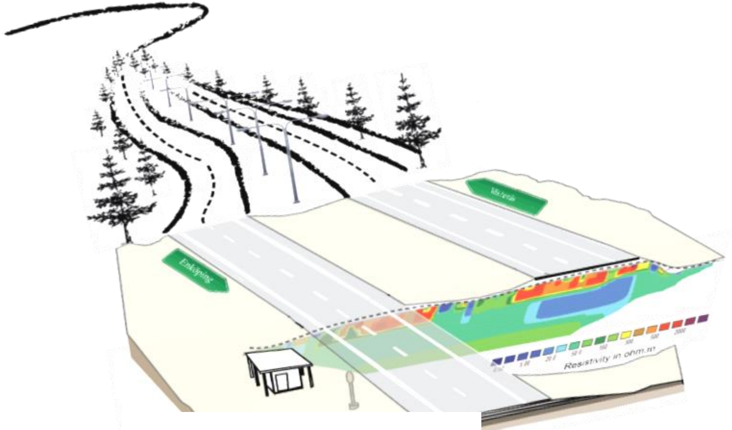
Aim

Aim : to show the importance of phase change in modeling moisture dynamics in road system.

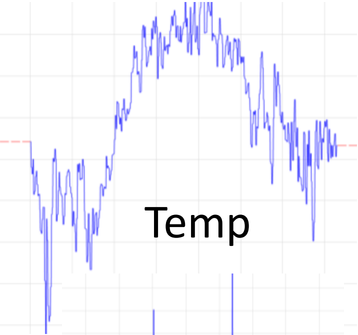
Method

Data from E18 :

www.testsitee18.se



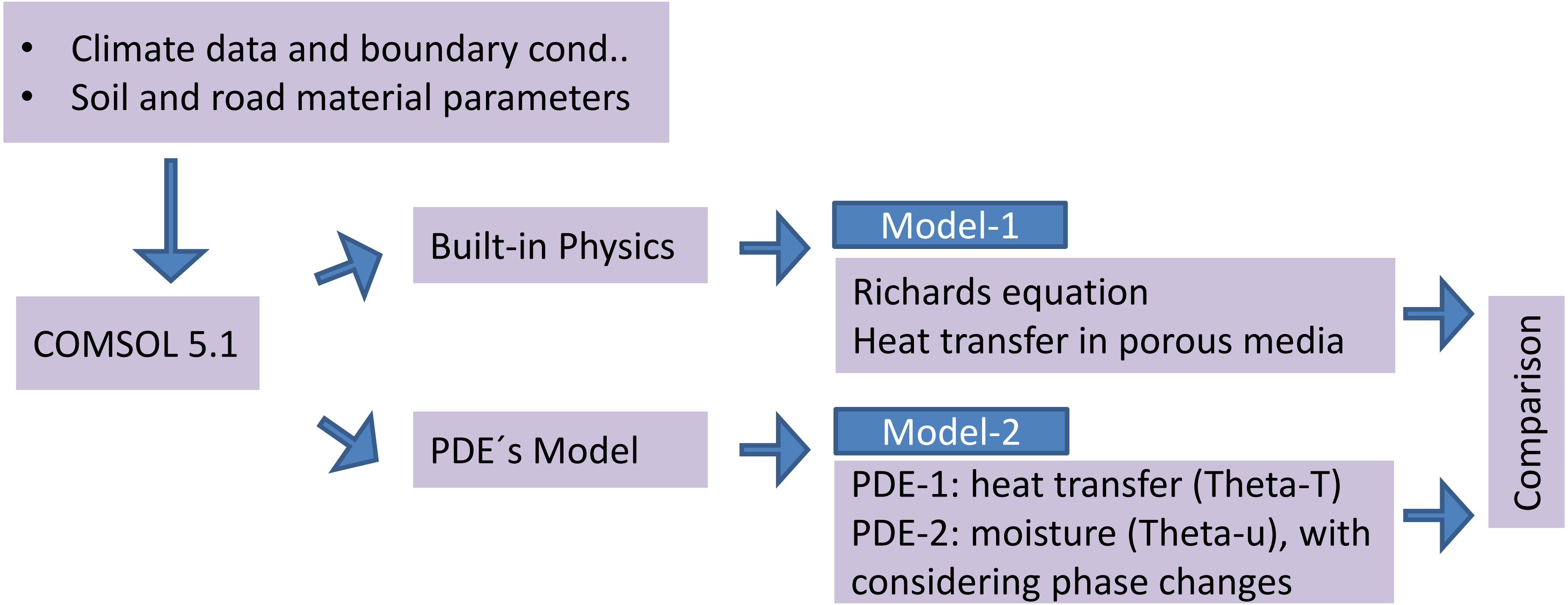
Test station E18

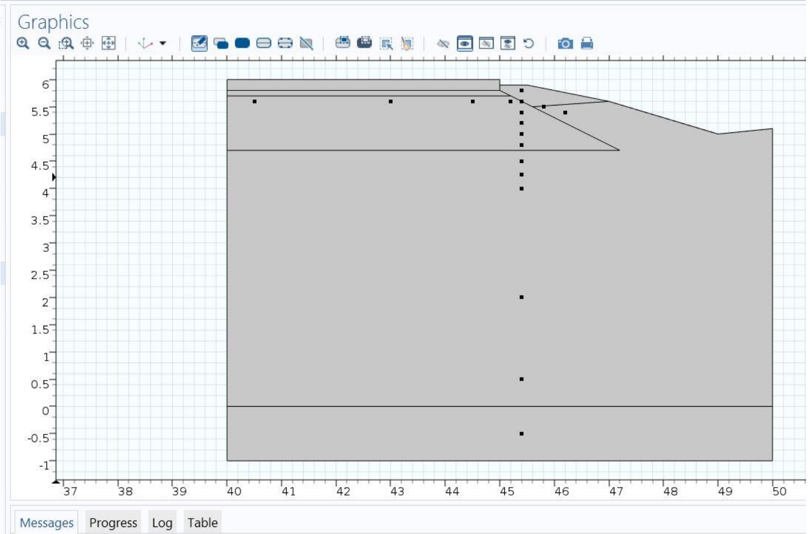


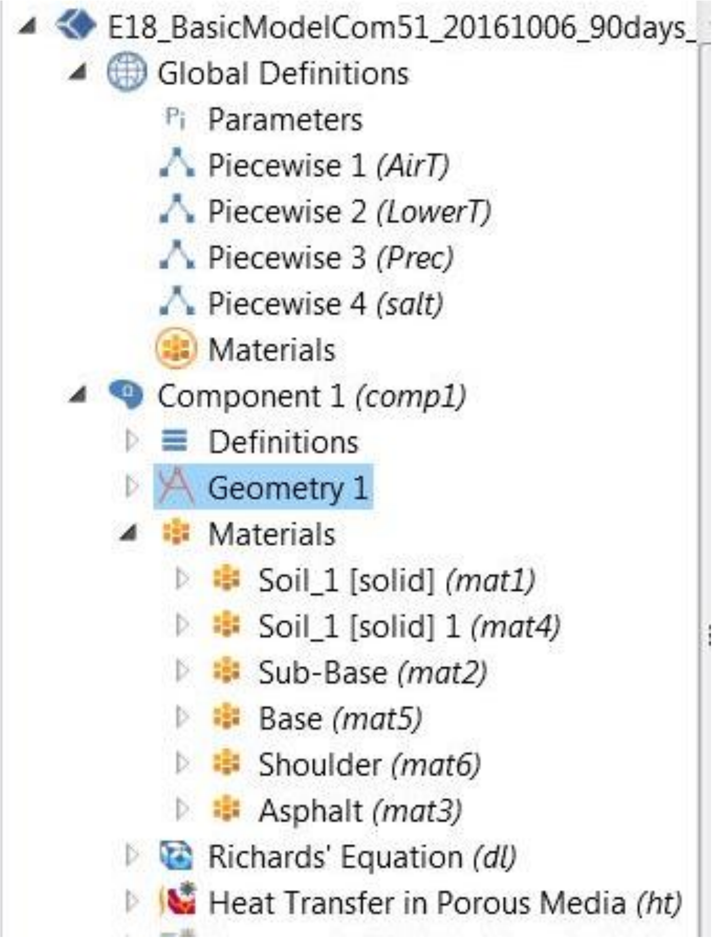
Temp

Precipitation

Moisture


• Climate data and boundary cond..
• Soil and road material parameters
COMSOL 5.1
Built-in Physics
PDE´s Model
Model-1
Richards equation
Heat transfer in porous media
Model-2
PDE-1: heat transfer (Theta-T)
PDE-2: moisture (Theta-u), with considering phase changes
Comparison


Graphics
Messages
Progress
Log
Table


E18_BasicModelCom51_20161006_90days_
Global Definitions
Parameters
Piecewise 1 (AirT)
Piecewise 2 (LowerT)
Piecewise 3 (Prec)
Piecewise 4 (salt)
Materials
Component 1 (comp1)
Definitions
Geometry 1
Materials
Soil_1 [solid] (mat1)
Soil_1 [solid] 1 (mat4)
Sub-Base (mat2)
Base (mat5)
Shoulder (mat6)
Asphalt (mat3)
Richards' Equation (dl)
Heat Transfer in Porous Media (ht)

Model-1

Model-2

- Coefficient Form PDE *(theta_u)*
  - Coefficient Form PDE 1
  - Zero Flux 1
  - Initial Values 1
  - Flux/Source 1
  - Flux/Source 2
  - Flux/Source 3
  - Flux/Source 4
- Coefficient Form PDE 2 *(T)*
  - Coefficient Form PDE 1
  - Zero Flux 1
  - Initial Values 1
  - Dirichlet Boundary Condition 1
  - Dirichlet Boundary Condition 2
- Mesh 1
- Study 1
  - Step 1: Time Dependent

Parameters

Variables

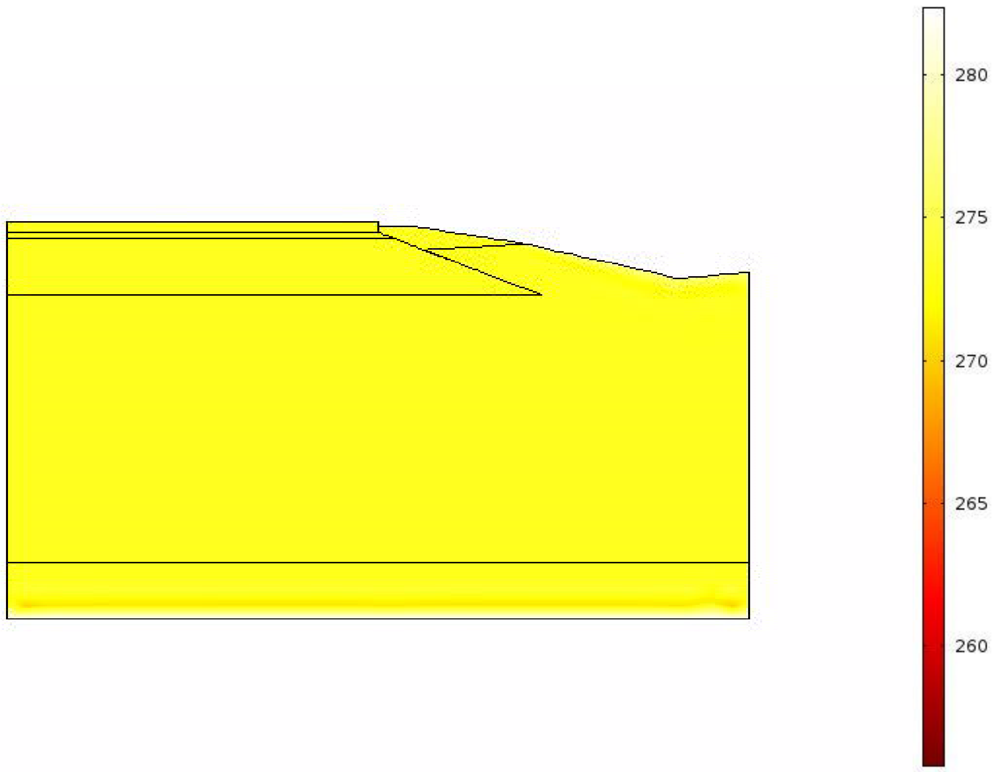
Name	Expression	Unit	Description
Kh	Ks*S^l*(1-(1-S^(1/m))^m)^2	m/s	Hydraulic conductivity
Imp	10^(-10*theta_ice)		Impedance factor
S	min(max((theta_u-theta_r)/(theta_s-theta_r),0.01),0.9)		Saturation
C_water	a0 [1/m]*m/(1-m)*S^(1/m)*(1-S^(1/m))^m	1/m	Specific water capacity
theta_ice	min((theta_s-theta_r),(theta_u*B))		Ice content
Cp	Cp_water*theta_u+Cp_solid*(1-theta_s)+Cp_ice*theta_ice	J/(kg·K)	Heat capacity of soil
K_thermal	K_ice*theta_ice+K_water*theta_u+K_solid*(1-theta_s)	W/(m·K)	Thermal conductivity of soil
D_water	Kh*Imp/(theta_s-theta_r)/C_water	m^2/s	Diffusivity of water
Kg	Ks*S^l*(1-(1-S^(1/m))^m)^2	m/s	Vertical hydraulic conduct...
B	FT(T[1/K])		Freezing characteristic
theta	theta_u+rho_ratio*theta_ice		Total water content

Cp_solid	700[J/kg/K]	700 J/(kg·K)	Heat capcaity of solid
K_ice	2.31[W/m/K]	2.31 W/(m·K)	Thermal conductivity of ice
K_water	0.613[W/m/K]	0.613 W/(m·K)	Thermal conductivity of w...
K_solid	8.09[W/m/K]	8.09 W/(m·K)	Thermal conductivity of s...
Tf	272.44[K]	272.44 K	Freezing point
g	9.81 [m^2/s]	9.81 m^2/s	Gravity

Result & Discussion

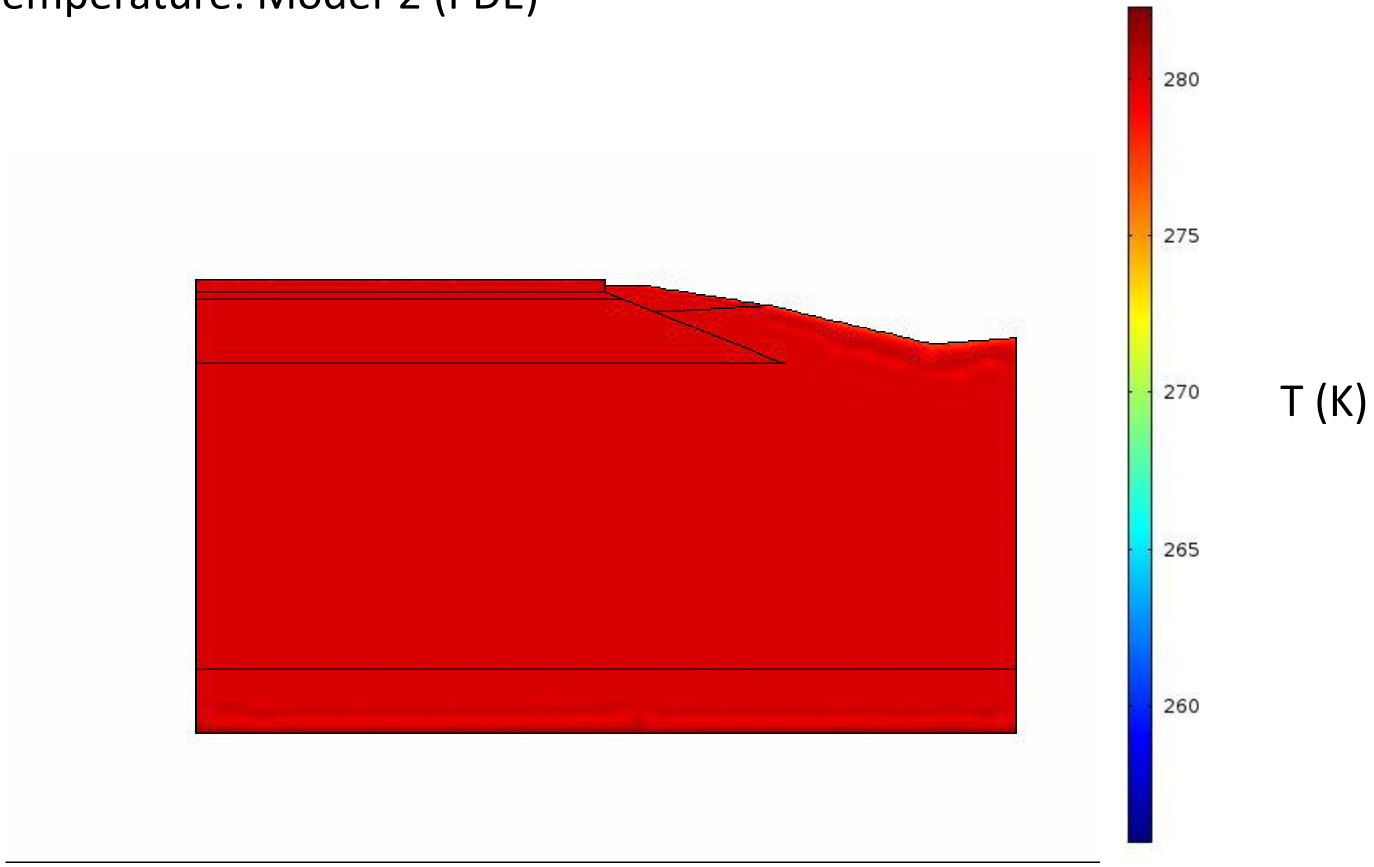
- Temperature
- Moisture content changes

Temperature: Model-1 (Built-in)



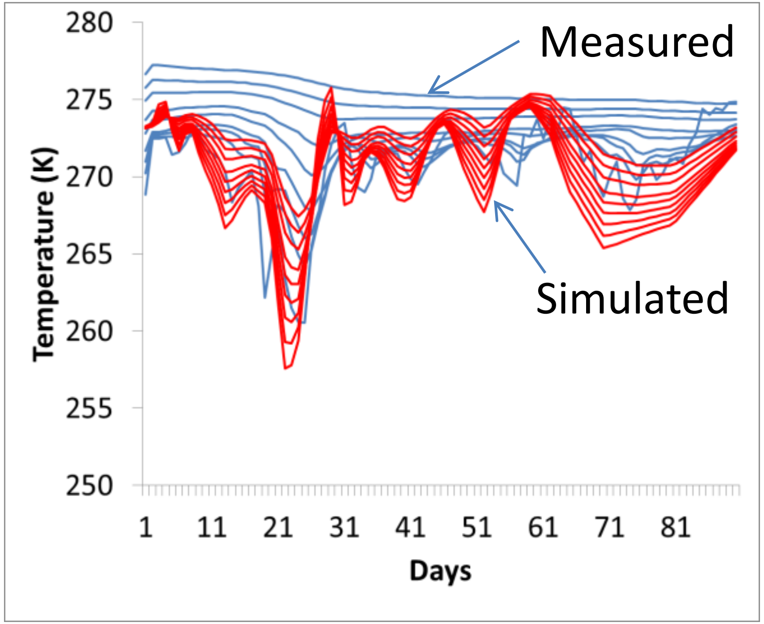
T (K)

Temperature: Model-2 (PDE)

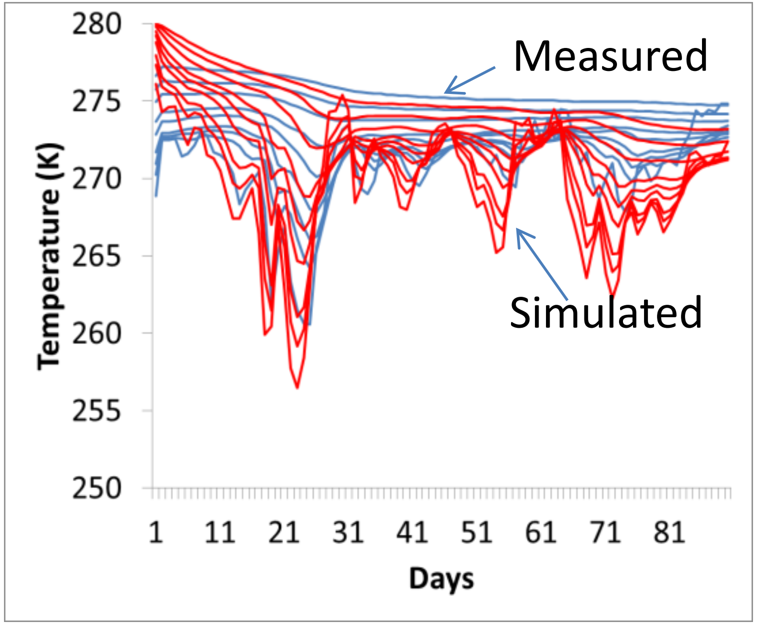


Temperature comparison

Model-1 (Built-in)

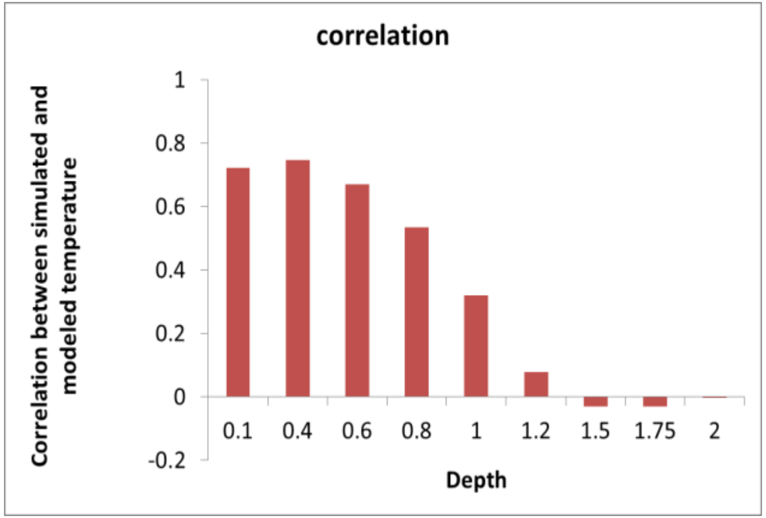


Model-2 (PDE)

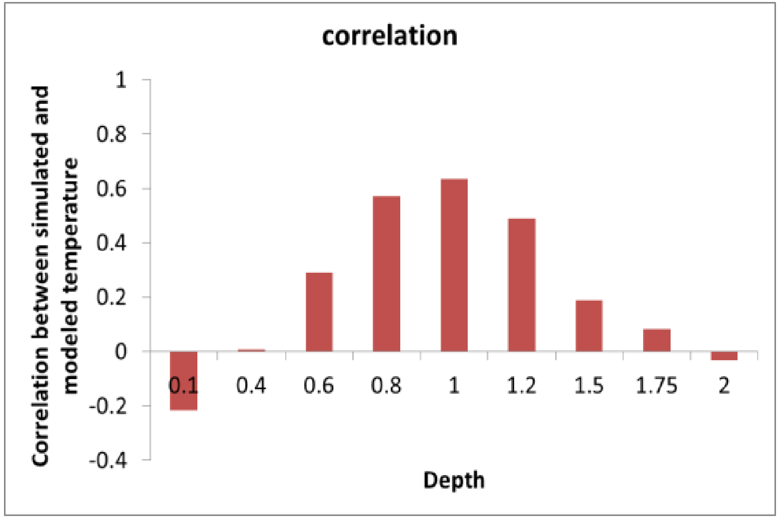


Temperature comparison

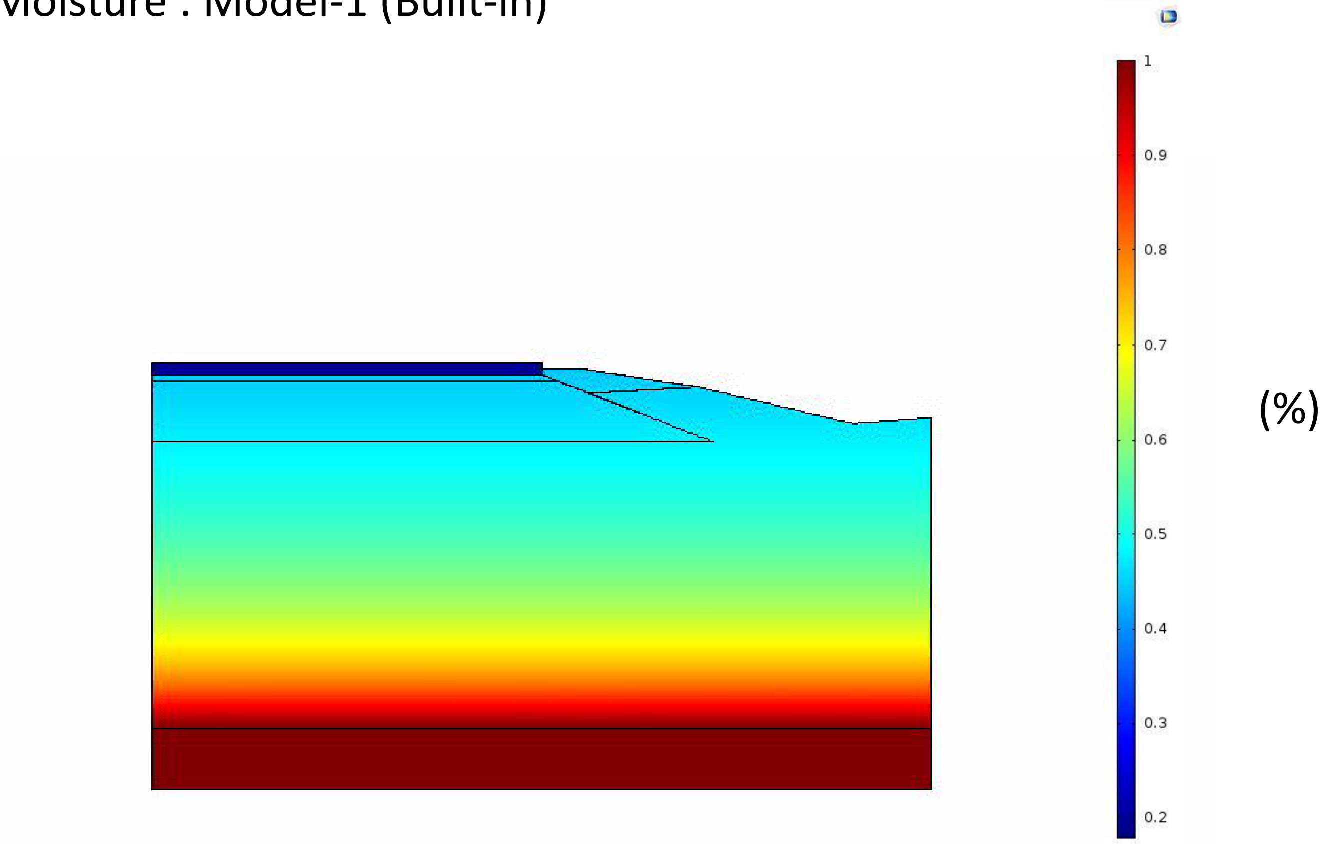
Model-1 (Built-in)



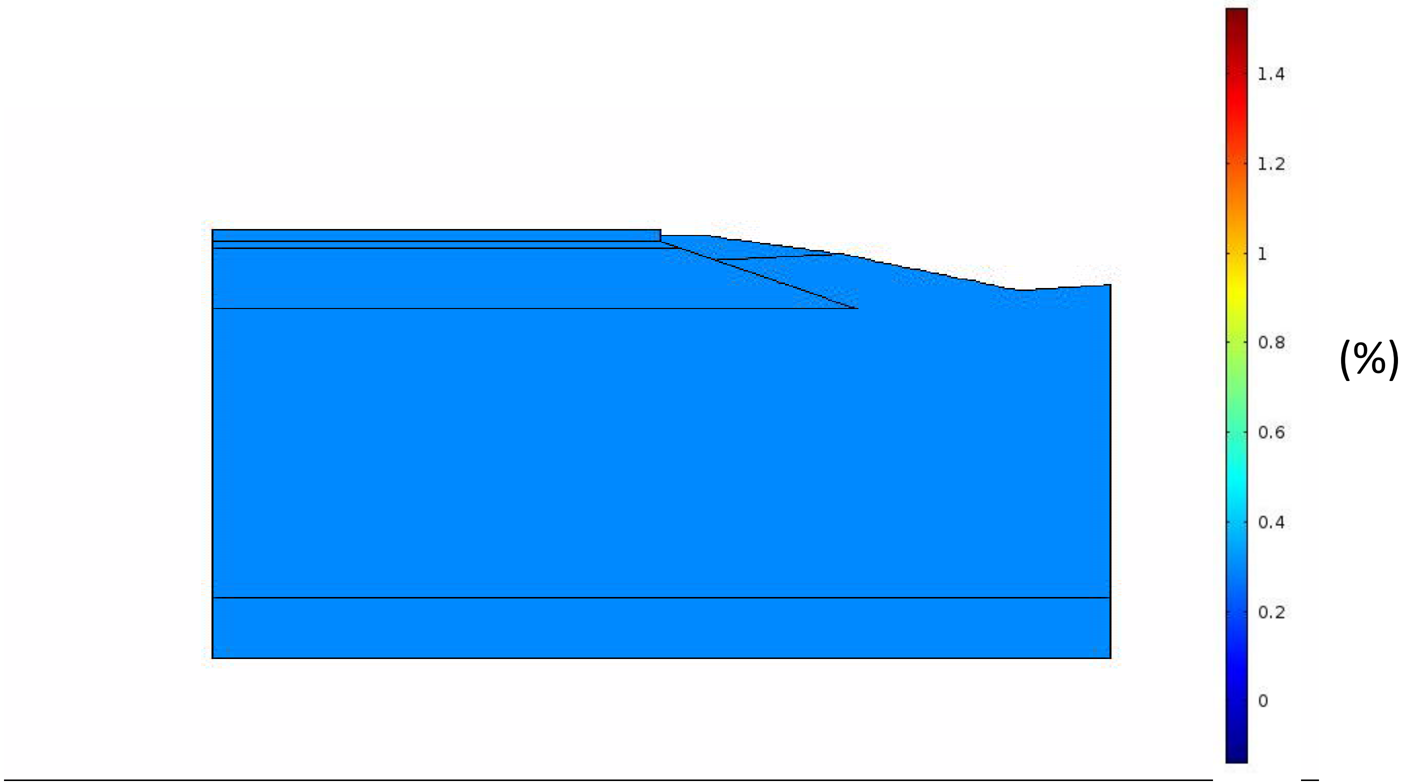
Model-2 (PDE)



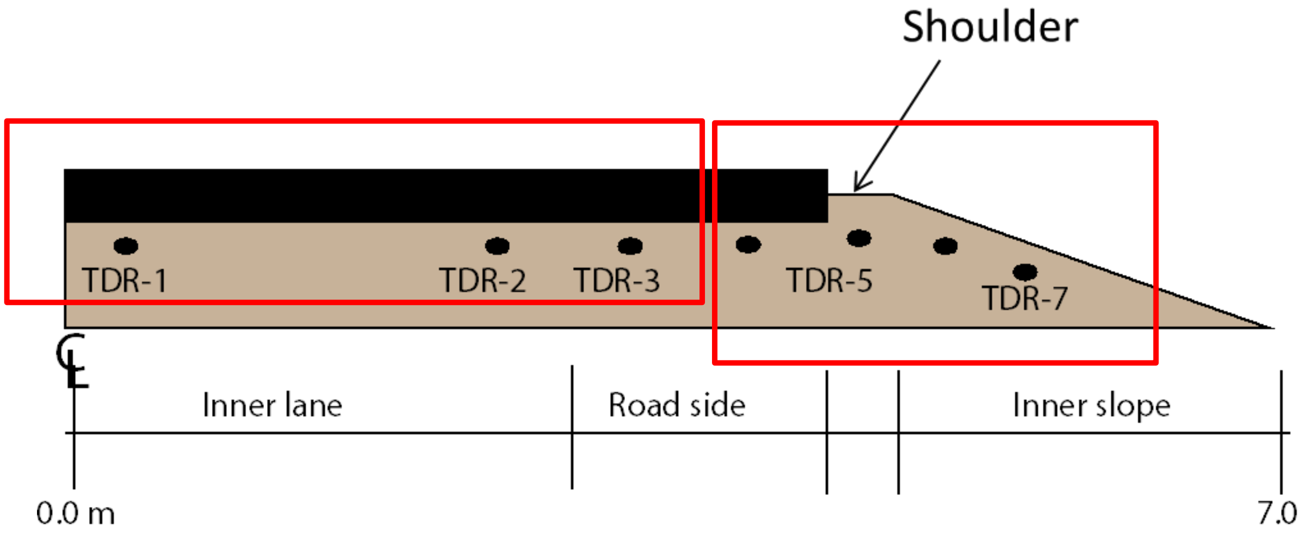
Moisture : Model-1 (Built-in)



Moisture : Model-2 (PDE)

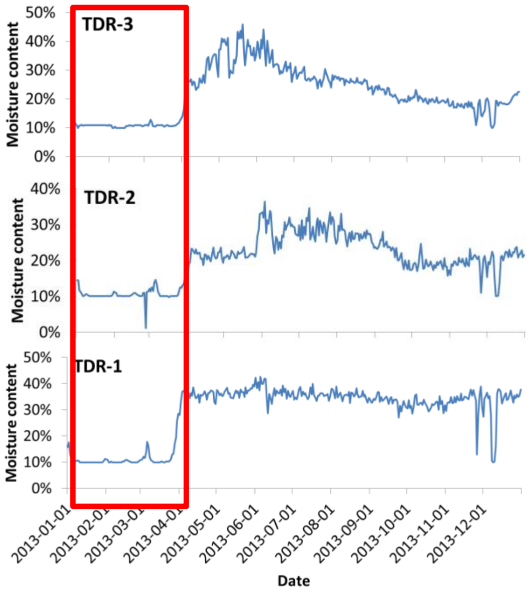


Moisture comparison (TDR locations)

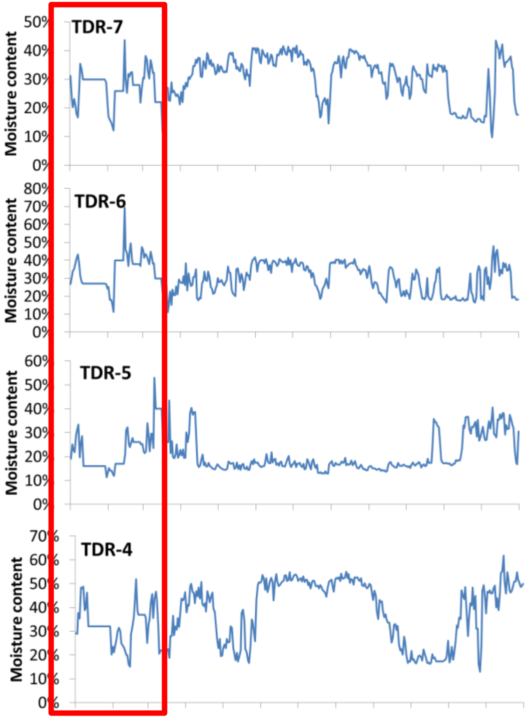


Moisture comparison
TDR_Moisture (Measured data)

TDR_ under the road asphalt

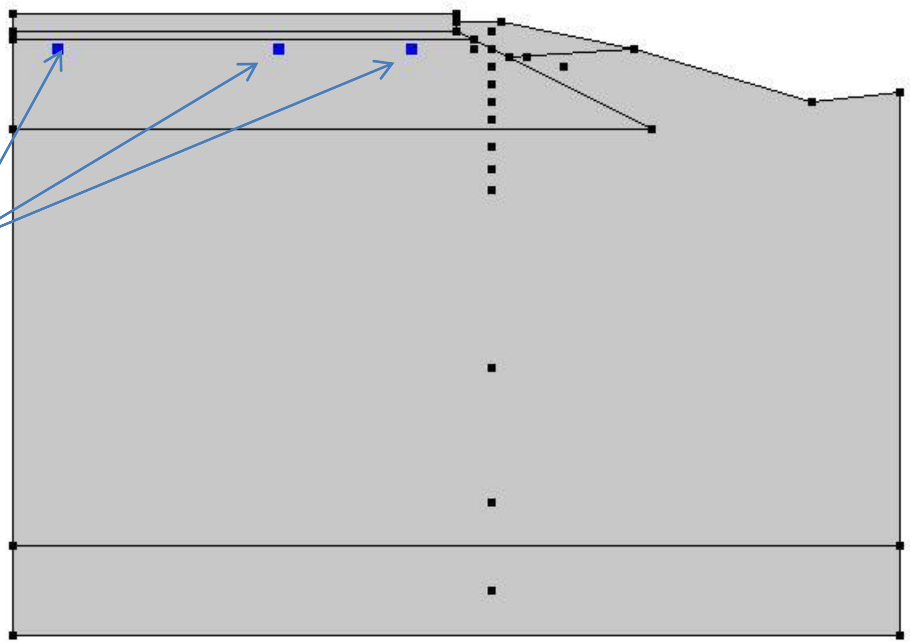


TDR_ under the road Shoulder

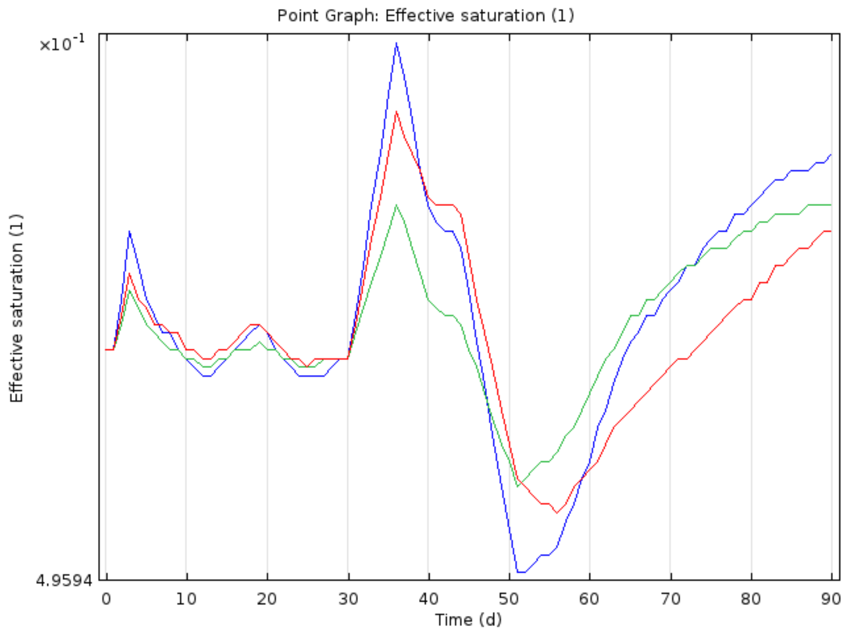


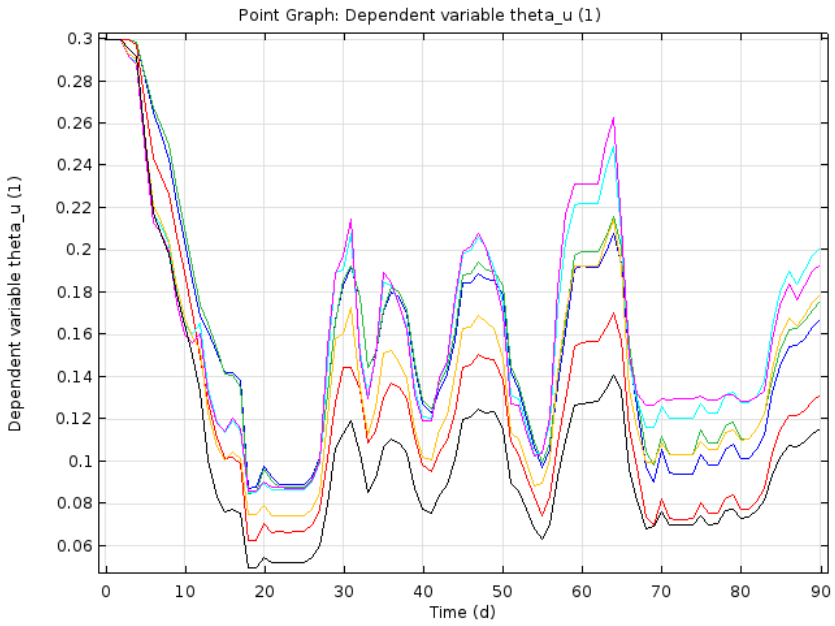
Moisture comparison

Only for data points under the road, where the TDR data available



Moisture comparison



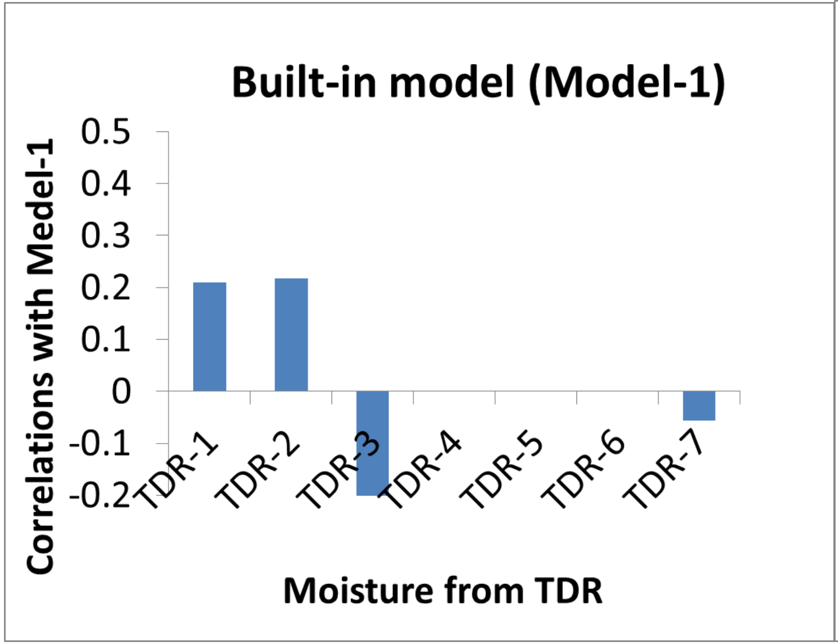


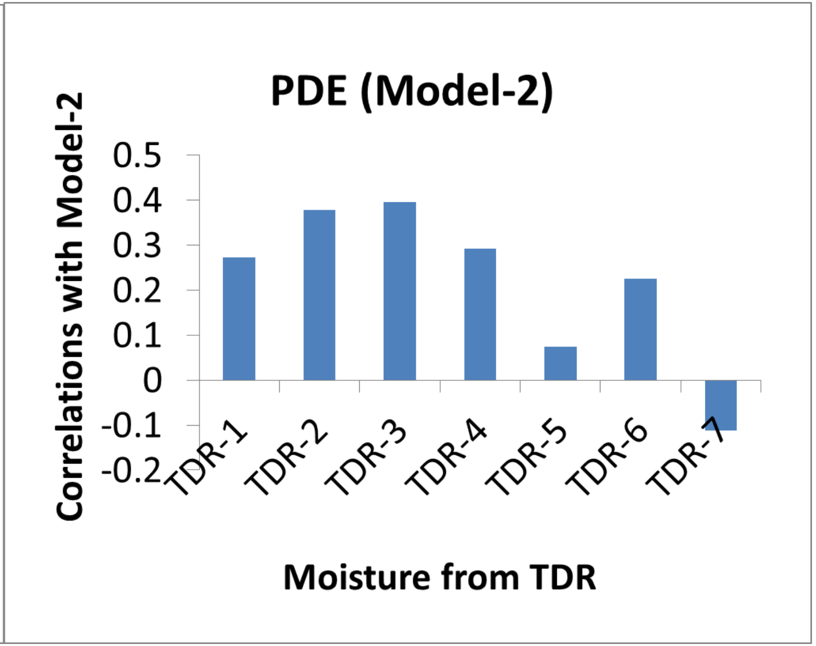
From Built-in model, only 3 points under the asphalt

From PDE-model, for points under the asphalt the road shoulder

Background | Aim | Method | Result & Discussion | Conclusion

Moisture comparison (Correlations)





From Built-in model, only 3 points under the asphalt

From PDE-model, for points under the asphalt the road shoulder

Conclusion

- Temperature simulations were not affected much by considering freezing and thawing.
- Moisture content simulations performed better with PDE model with considering freezing and thawing.
- PDE model can predict the fluctuations both under the road and the road shoulder.

Future works

- Sensitivity analysis with simulating longer periods
- Simulations and comparisons with other field monitoring data, i.e; ERT and Tracer test.
- New application for solving heat and solute transport in road layers

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Thanks!
Questions?

Ministry of Higher Education & Scientific Research 2006 KRG Iraq

KOYA UNIVERSITY

nvf NORDISK VEGFORUM

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