Precision and Bias in Field Methods for Measuring Soil Saturated Hydraulic Conductivity

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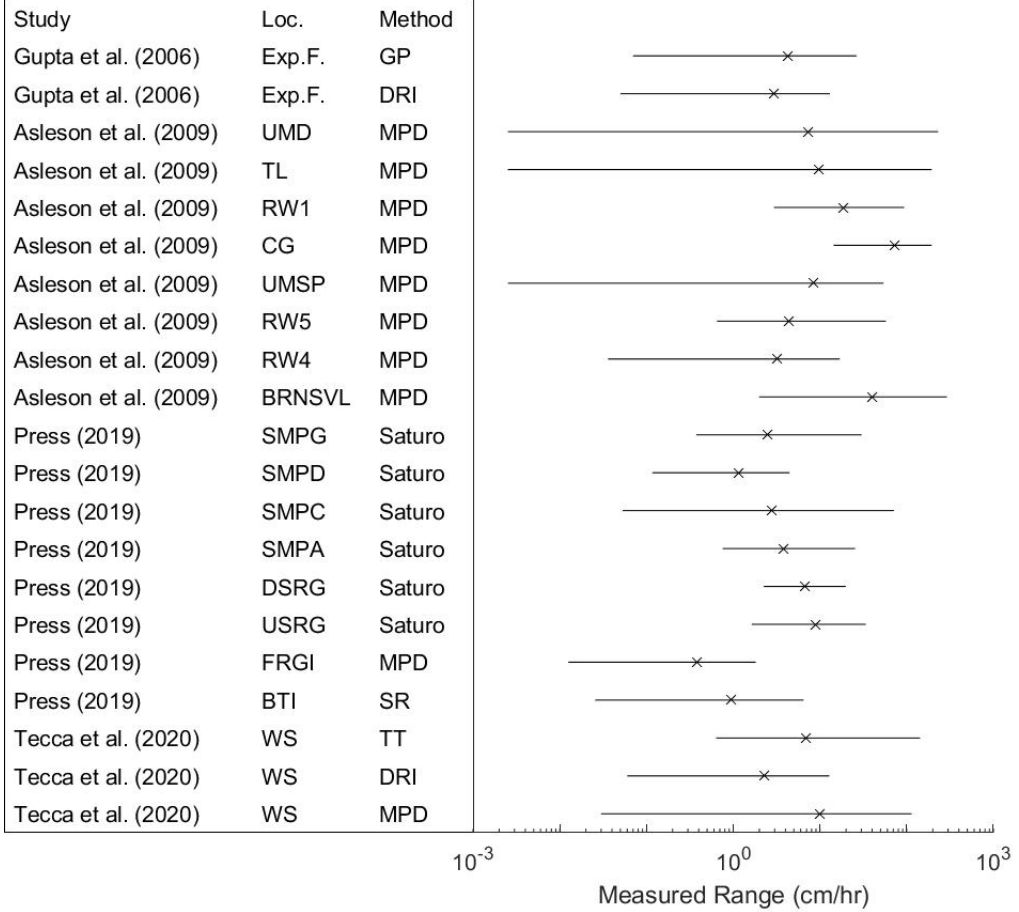
Variability in the Field

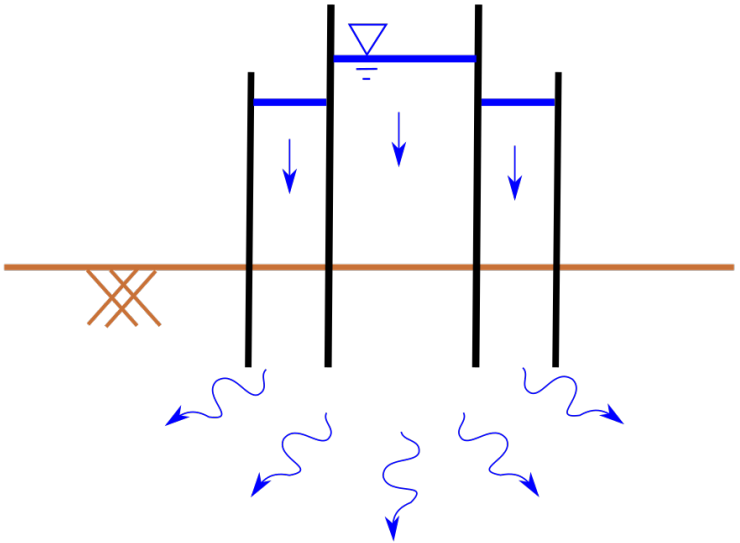


Objective

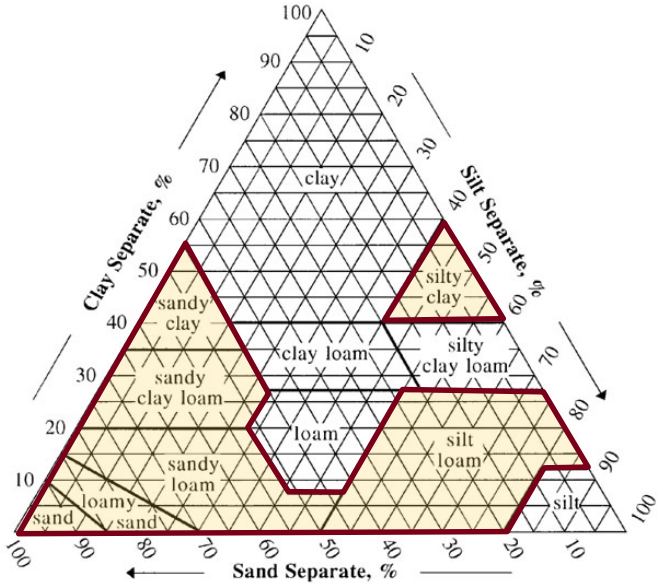
- Numerically estimate the accuracy (precision and bias) of infiltration measurement methods
  - 6 methods
  - 7 soil types
  - 5 antecedent soil moistures
  - Full factorial design
    - 210 simulations

	Flow Condition		Dimensionality	
Field Methods	Constant	Falling	1-D	3-D
Turf-Tec		X	X	
MPD		X		X
Saturo	X			X
Double Ring	X		X	
Well Permeameter	X			X
Pilot Infiltration Test	X		X	

Turf-Tec Infiltrometer



Simulated Soils



	Operating Range (in/hr)		SiC 0.008	SC 0.047	SiL 0.18	SCL 0.52	SL 1.7	LS 5.7	S 11.7
TT	0.25	42							
MPD	0.098	590.6							
Sat.	0.0015	45.3							
DRI	0.014	14.2							
WP	0.014	141.7							
PIT	?	4							

Image Credits: USDA NRCS Soil Texture Calculator

Workflow

Input Soil Properties

↓

Simulate field procedure using COMSOL

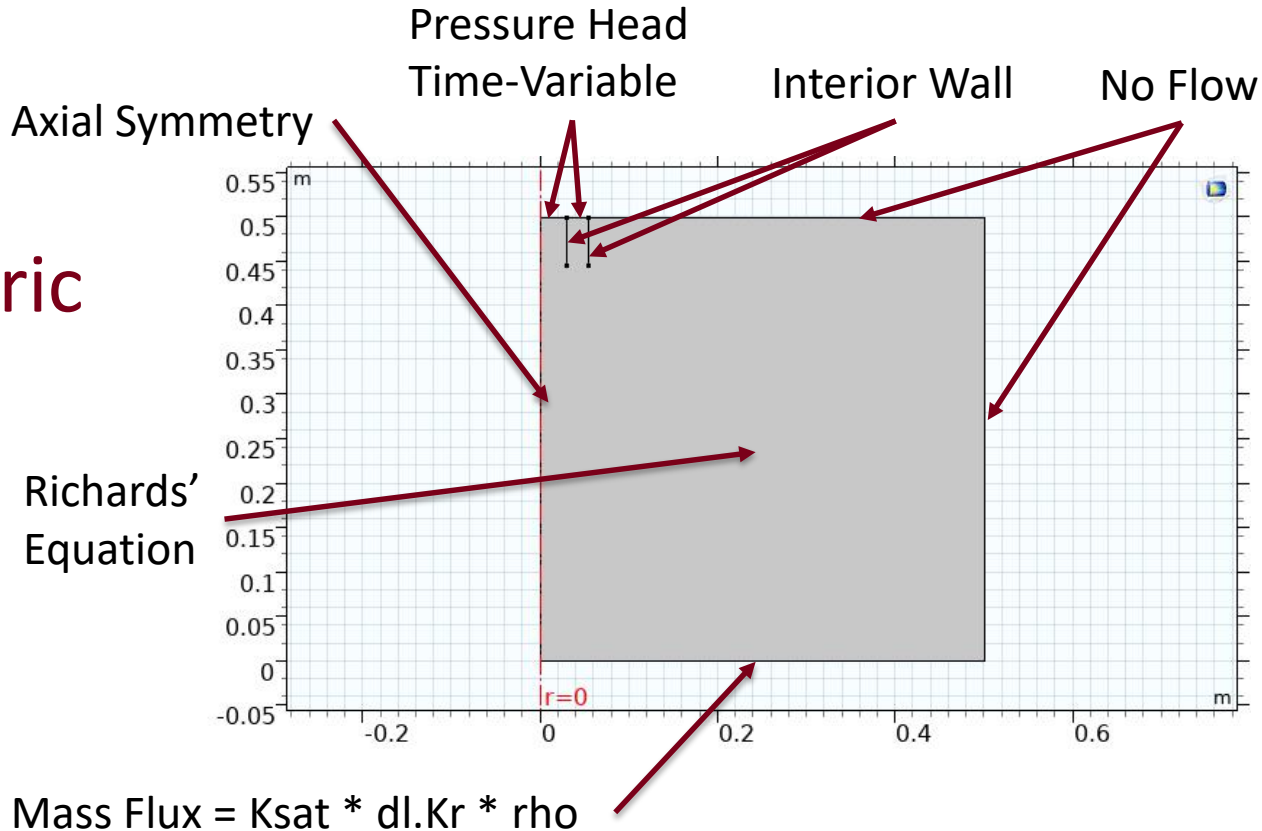
↓

Post-process output to calculate simulated Ksat or infiltration rate

↓

$$\text{bias} = \frac{\text{simulated}}{\text{input}}$$

2-D Axisymmetric
Homogenous
Isotropic
Free-Draining



ELSEVIER

Advances in Water Resources 24 (2001) 133–144

Advances in Water Resources

www.elsevier.com/locate/advwatres

Effect of the shape of the soil hydraulic functions near saturation on variably-saturated flow predictions

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Received 8 May 1998; received in revised form 10 June 2000; accepted 24 June 2000

modified form of van Genuchten retention model

Retention Model

Retention model: User defined

Unsaturated condition:

un	dl.Hp<hs	1

Liquid volume fraction:

θ	if(dl.un,thetar+(thetam-thetar)/((1+abs(VGalpha*dl.Hp)^VGn)^VGm),thetas)	1

Effective saturation:

S_e	if(dl.un,(dl.theta-thetar)/(thetam-thetar),1)	1

Specific moisture capacity:

C_m	if(dl.un,d(dl.theta,p)*rho*dl.g,0)	1/m

Relative permeability:

k_r	if(dl.un,dl.Se^0.5*((1-FSe)/(1-F1))^2,1)	1

Initialization

0s < t < 900 s

t > 900 s

Name	Expression
Htout	nojac(step3(t*1[1/s])-(totinfin2*step1(t*1[1/s])+totinfin2b)/(A2*rho))
Htin	nojac(step2(t*1[1/s])-(totinfin1*step1(t*1[1/s])+totinfin1b)/(A1*rho))

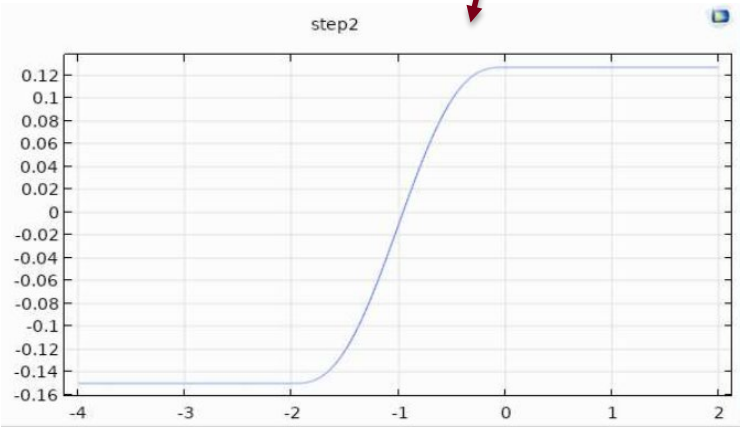
Inner and outer rings are independent

Equations do not contribute to Jacobian (Thanks to advice from COMSOL Technical Support)

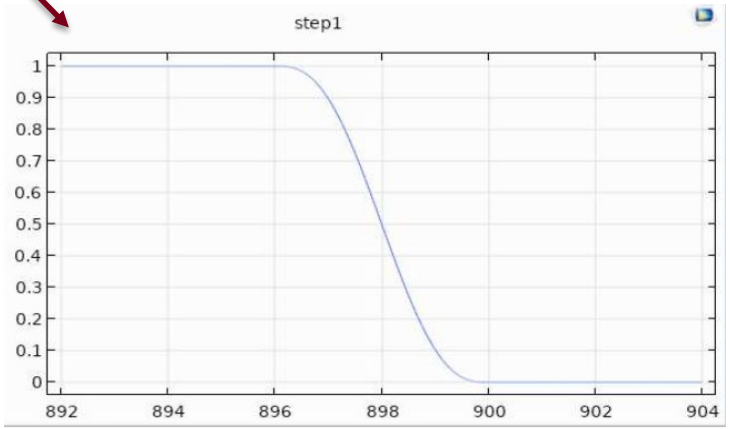
Cumulative mass flux evaluated in Global ODE

Convert mass to equivalent depth

Name	Expression
Htout	nojac(step3(t*1[1/s])-(totinfin2*step1(t*1[1/s])+totinfin2b)/(A2*rho))
Htin	nojac(step2(t*1[1/s])-(totinfin1*step1(t*1[1/s])+totinfin1b)/(A1*rho))

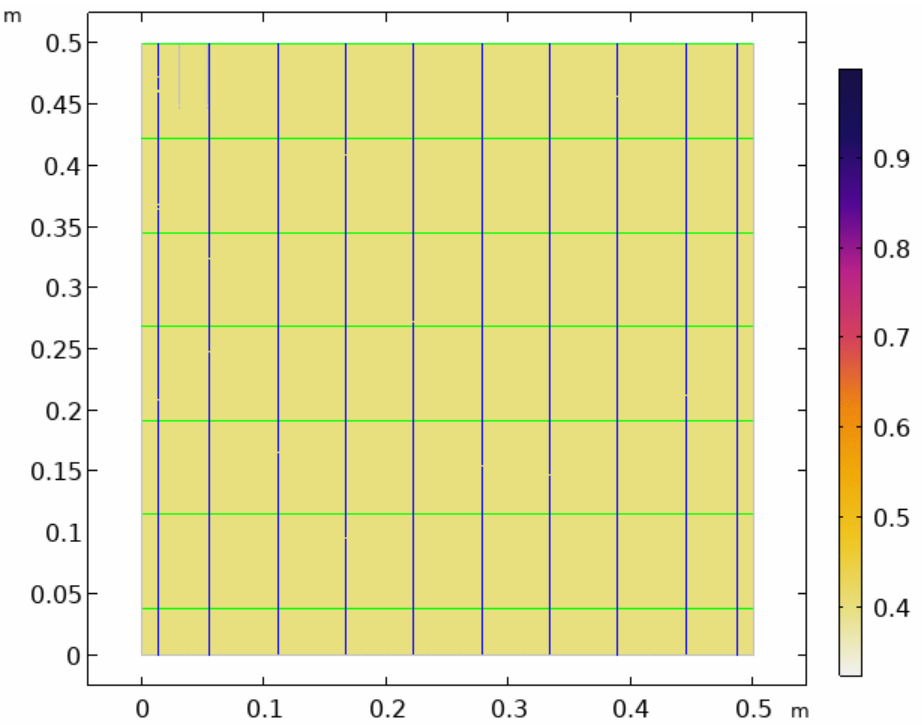


Initial filling of rings at t = 0 sec

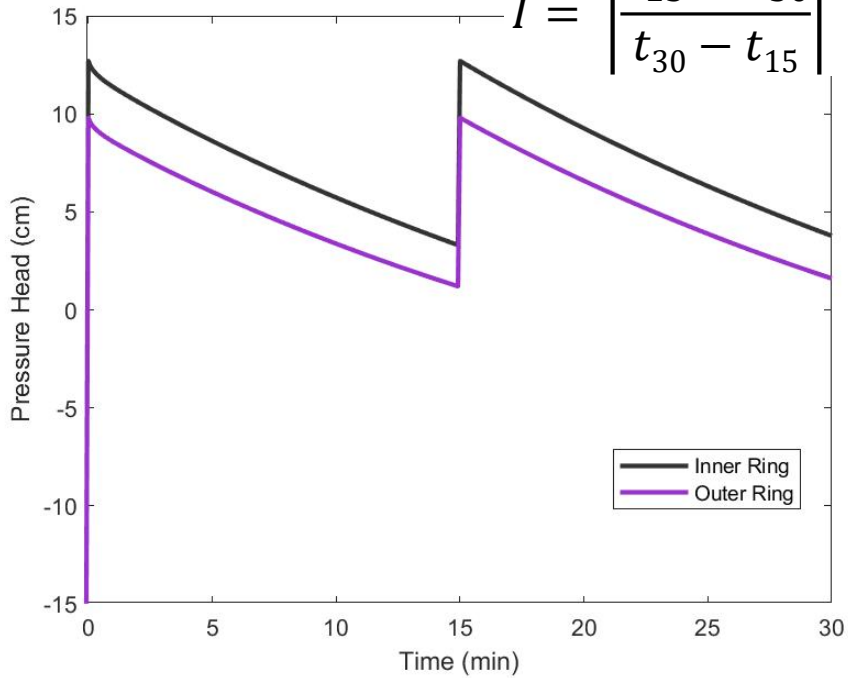


Refilling rings at t = 900 sec

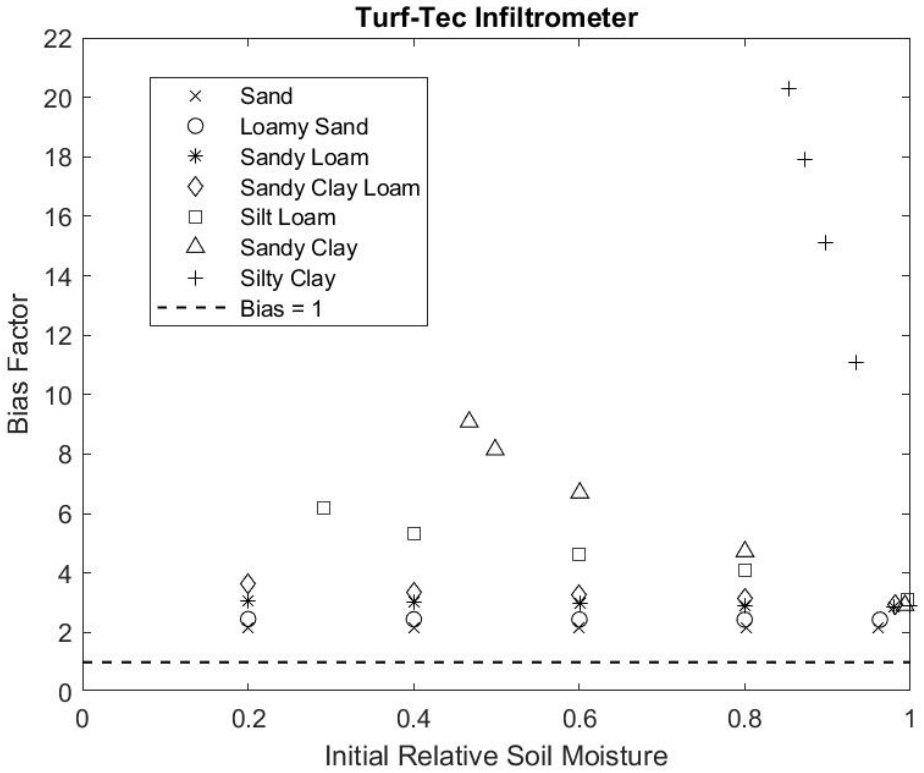
Loamy Sand at 40% Initial Relative Soil Moisture



$$I = \left| \frac{P_{15} - P_{30}}{t_{30} - t_{15}} \right|$$



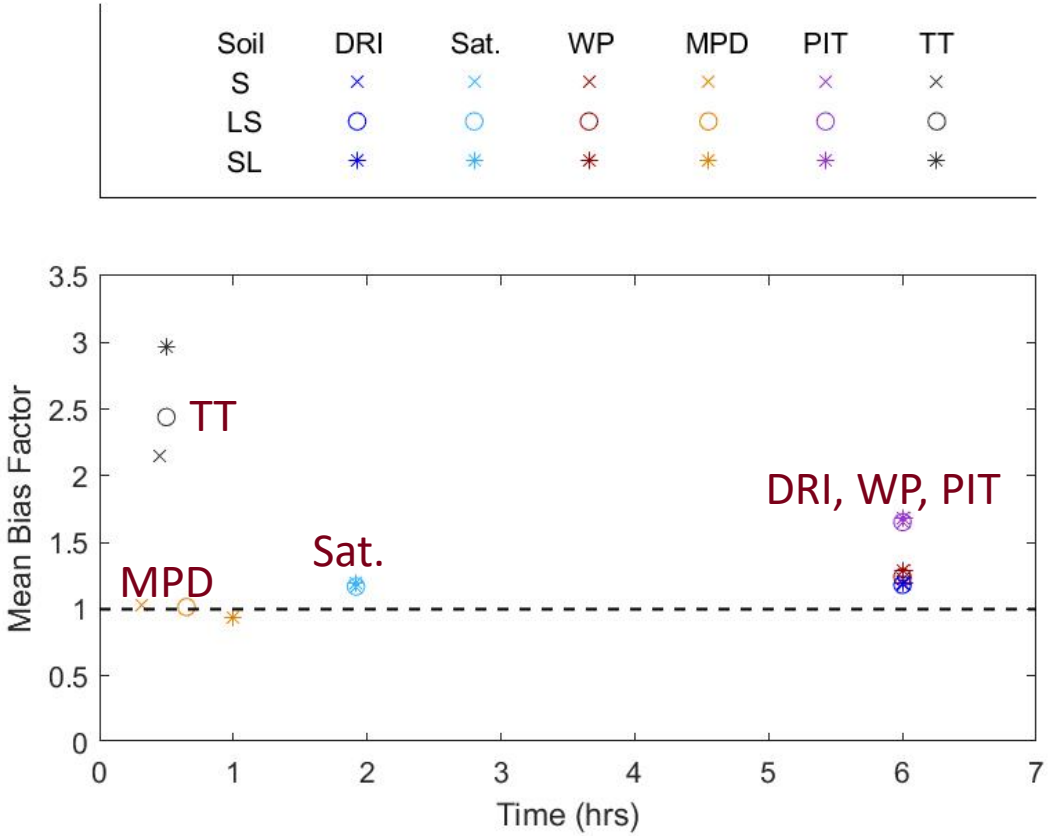
$$Bias\ Factor = \frac{Simulated\ Infiltration\ Rate}{Input\ K_{sat}}$$



Likely sources of bias:

- For methods like TT that assume 1-D flow, lateral divergence violates assumption
- For methods that assume 3-D flow, flow approximations may not reflect actual flow pattern

Coarse Soils Typical of Infiltrating Green Stormwater Infrastructure



Questions or Comments?

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