Inverse modelling of the evaporation method for estimating soil hydraulic properties using stochastic simulation

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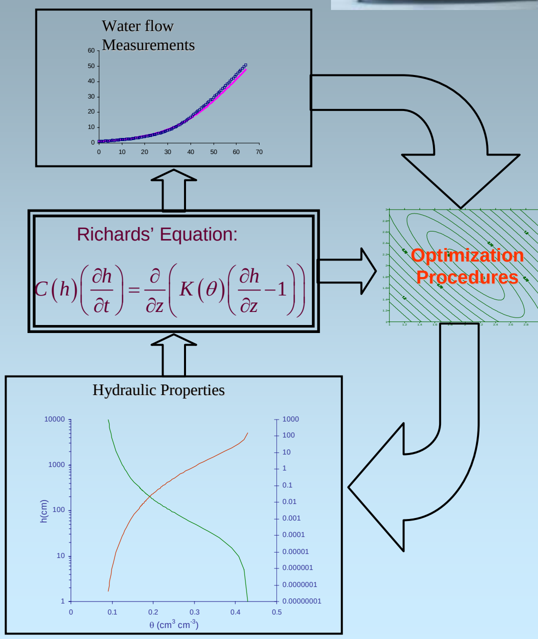
Inverse modelling



Methods for inverse solution

Nonlinear least squares

Conventional method, minimising:

$$\mathrm{SSR}=\sum_{t}^{N_t}\left(\hat{y}_t(\beta)-y_t\right)^2$$

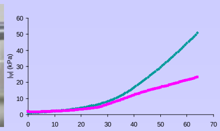
Problem:
- Non-unique solution
- Uncertainty in measurement

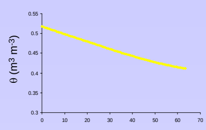
GLUE (Generalised Likelihood Uncertainty Estimates)

- Recognition that many parameter sets will give similar output of a model.
- It is only possible to assign the likelihood of each parameter set to be able to predict the system.

GLUE uses Monte Carlo simulation, where the parameter space is sampled randomly. Each parameter set is then fed into the model, and a quantitative measure of performance is used to assess its capability to reproduce the experimental data.

Evaporation experiment





1-D Soil-water flow

$$C(h)\left(\frac{\partial h}{\partial t}\right)=\frac{\partial}{\partial z}\left(K(\theta)\left(\frac{\partial h}{\partial z}-1\right)\right)$$

$h(z,t)=h_i(z)$ $t=0, 0<z\le L$

$q(z,t)=q_e(t)$ $t>0, z=0$

$q(z,t)=0$ $t>0, z=L$

Hydraulic properties model

$$\theta(h)=\theta_r+\frac{\theta_s-\theta_r}{\left(1+\left|\frac{h}{h_b}\right|^n\right)^m}$$

$$K(S_e)=K_o S_e^l\left[1-\left(1-S_e^{1/m}\right)^m\right]^2$$

The GLUE method:

- Define a feasible range of parameter for θ_r, θ_s, h_b, n, and $\log(K_o)$.
- Sample the parameter space uniformly within the prescribed range N_s times using LHS.
- Run the soil-water flow simulation program N_s times, each time using random parameter, and calculate the modelling efficiency $E=1-\frac{\sigma_r^2}{\sigma_o^2}$, $\sigma_r^2=\frac{1}{N_t}\sum_t^{N_t}\left(\hat{y}_t(\beta)-y_t\right)^2$.
- Rank E values, and determine the threshold value E_T. Accept parameter that gives E value > E_T, called this acceptable parameter.
- For each acceptable parameter, calculate water retention and hydraulic conductivity curves from 0 to -1000 cm.
- Calculate the average and standard deviation of θ and $\log(K)$ at different potentials.

References

Beven K, Binley A. 1992. The future of distributed models: Model calibration and uncertainty prediction. Hydrological Processes 6, 279–298.

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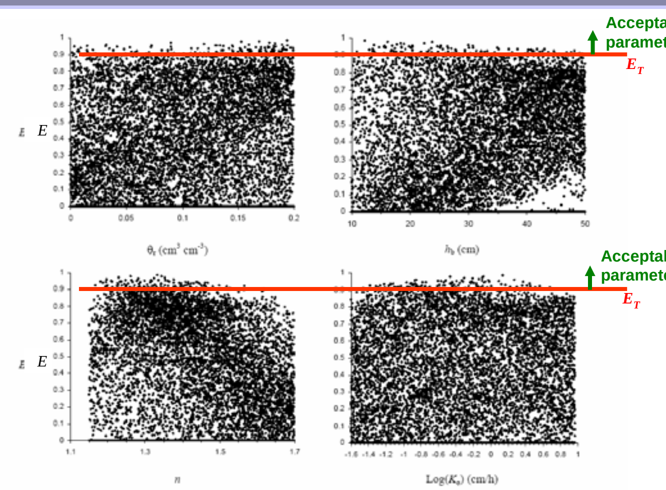
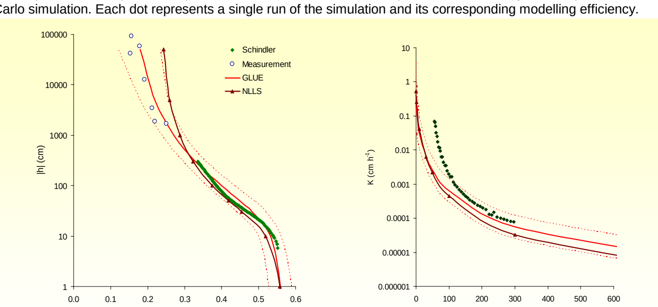
Schindler, U., 1980, Ein Schnellverfahren zur Messung der Wasserleitfähigkeit im teilgesättigten Boden. Archiv für Acker- und Pflanzenbau und Bodenkunde 24, 1-7.



Scatterplot relationship between parameters of the van Genuchten equation and modelling efficiency E from Monte Carlo simulation. Each dot represents a single run of the simulation and its corresponding modelling efficiency.



Green dots represent values calculated using the standard method (Schindler, 1980). White circles in water retention curves are measured water retention using the WP4 water potentiameter. Solid lines (red) are the predicted using the GLUE method, and the outer dotted red lines represent the 95% confidence intervals. Curves with triangles are predicted using the NLLS method.