P18

T4b - Safety across time – methods for evaluating the post-closure safety of a deep geological repository

Get the current state right first – lessons learnt from a groundwater modelling perspective

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Author in attendance time:
Thursday, 18 September 2025, 17:30-18:30

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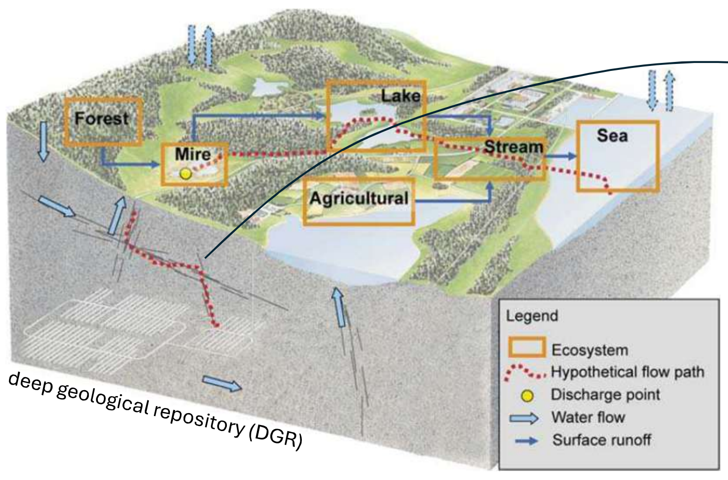


Berglund et al. (2009). Hydrogeol. J. 2009, 17, 95–11.

MOTIVATION

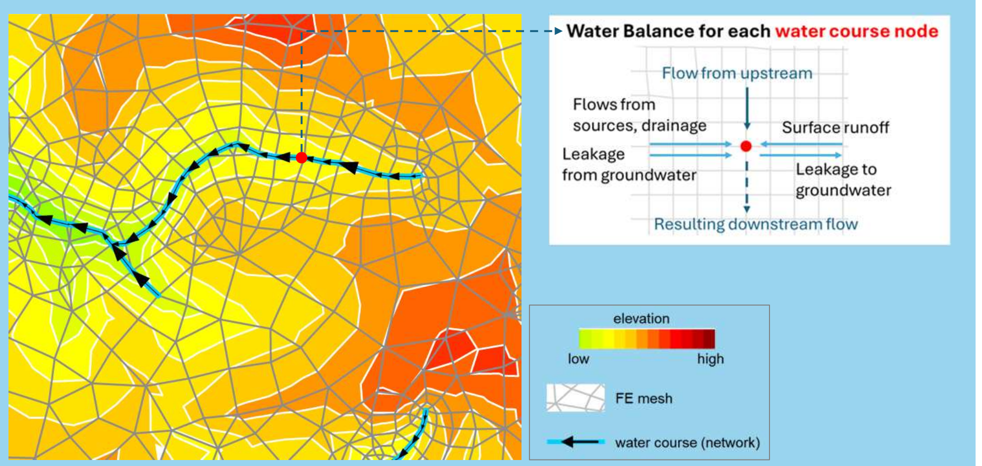
long-term prognoses (1 million years) to assess potential flow paths of radionuclides or other pollutants migrating from the deep geological repository (DGR) to the near surface environment

CONDITIONS (REALITY)

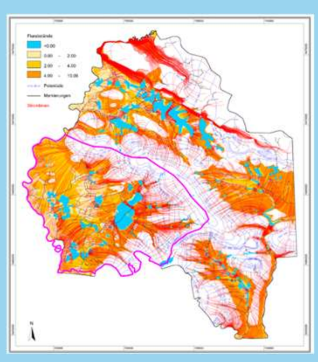
- Limited time for setting up the model
- Limited available input data
- Limited time for calibration
- Limited time for prognoses
- Limiting factors: computing time, total number of simulations

near surface groundwater flow system

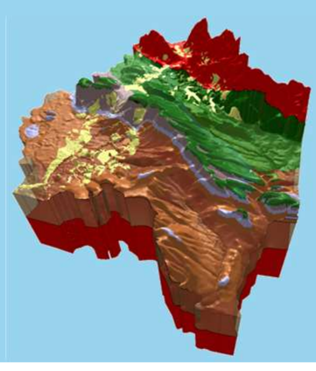
surface water groundwater interaction



from 2D … to 3D

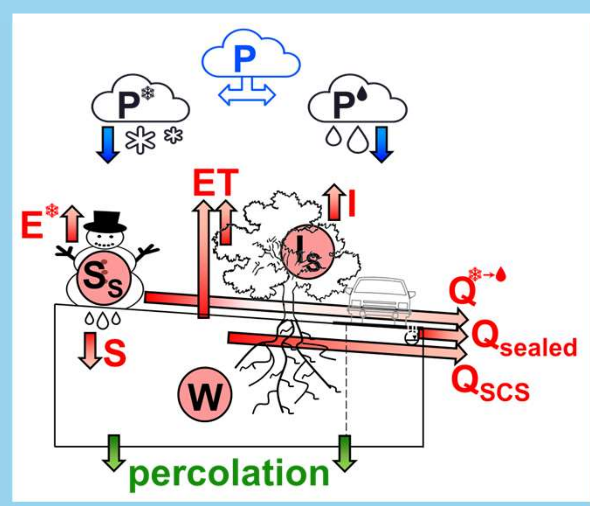


- transient groundwater recharge
- surface water groundwater interaction
- surface runoff
- drainage, sources



- aquifer aquiclude systems
- vertical flow components
- deep groundwater flow system
- density dependent calculation

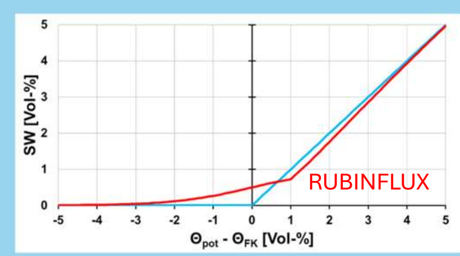
transient groundwater recharge

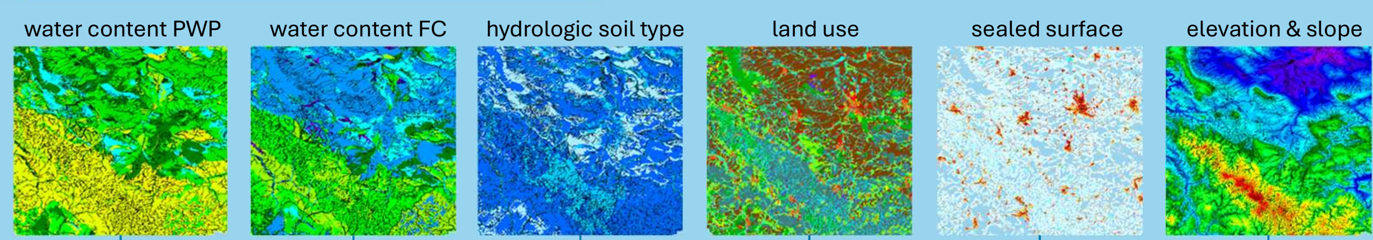


RUBINFLUX soil water content model
developed by Ruhr University of Bochum and delta h

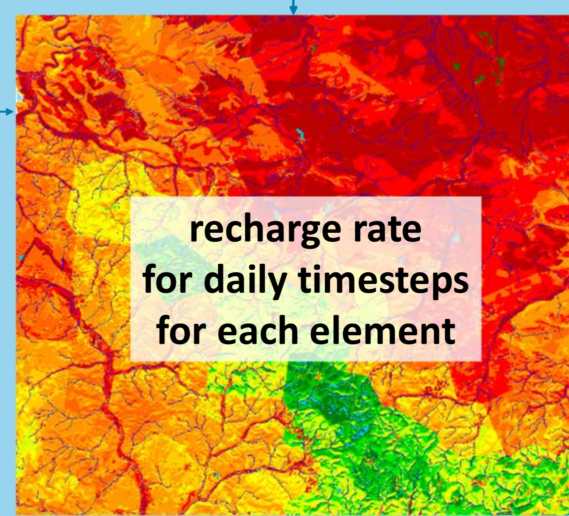
is based on field observations

- percolation starts before the soil water content reaches Θ_{FC}
- percolation decelarates after the soil water content has reached Θ_{FC}





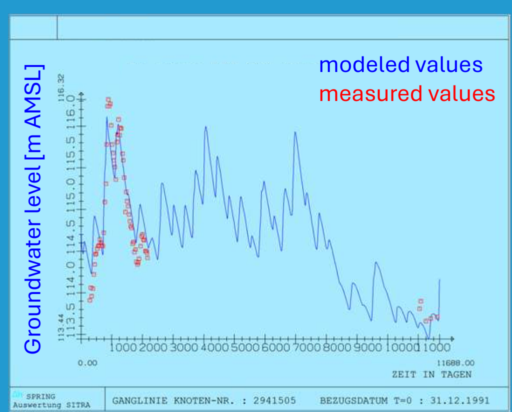
weather data



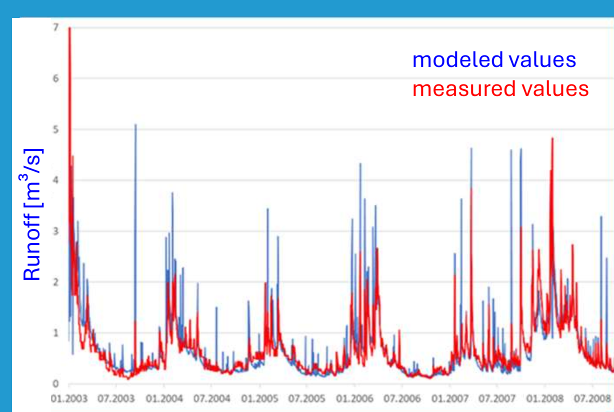
Zepp et al. (2017): Implizite Berechnung der Grundwasserneubildung (RUBINFLUX) im instationären Grundwasserströmungsmodell SPRING. Eine neue Methodik für regionale, räumlich hochaufgelöste Anwendungen. – Grundwasser 22: 113-126, https://link.springer.com/article/10.1007/s00767-017-0354-3.

BASE FOR LONG-TERM PROGNOSES?

groundwater & surface water



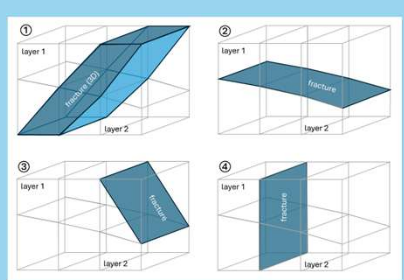
Example: 32 years, 11,688 time steps (1 day)



Example: 50 years, 18,260 time steps (1 day)

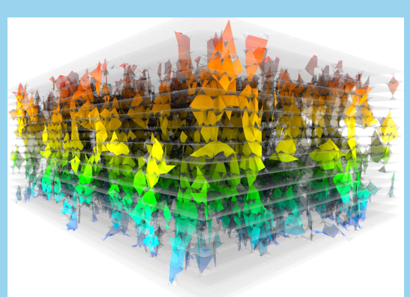
Transient calibration based on measured values from the past to the present

flow in fractures

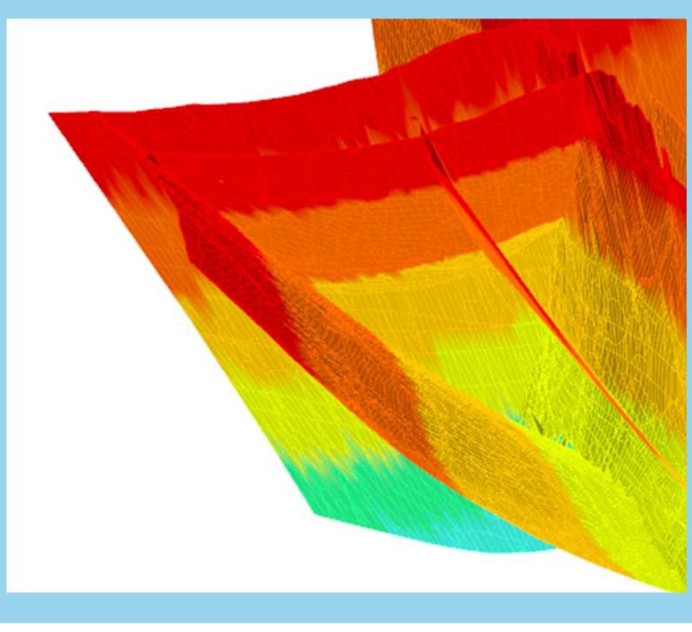


Discrete fractures: coupled matrix-fracture-system based on cubic law

Different methods for their implementation



Micro-fractures: homogenization based on detailed models

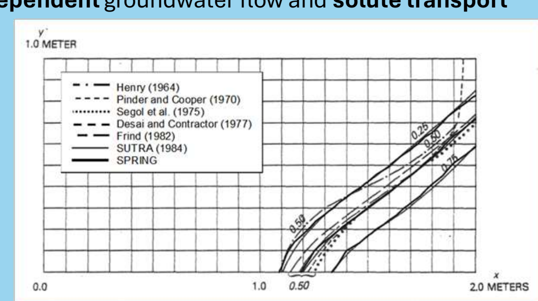


Discrete 2D fractures (methods 2 & 3)

verified software code

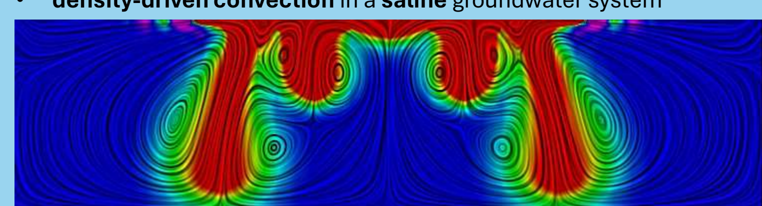
Henry Problem

- **density-dependent** groundwater flow and **solute transport**



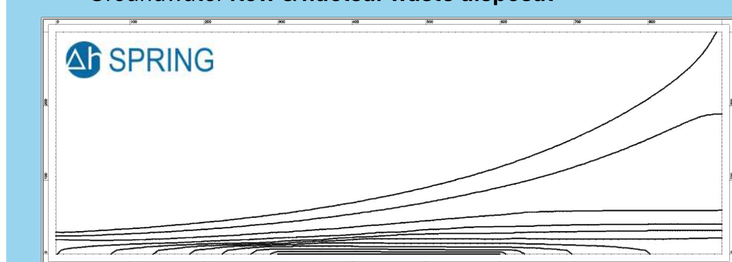
Elder problem

- **density-driven convection** in a **saline** groundwater system

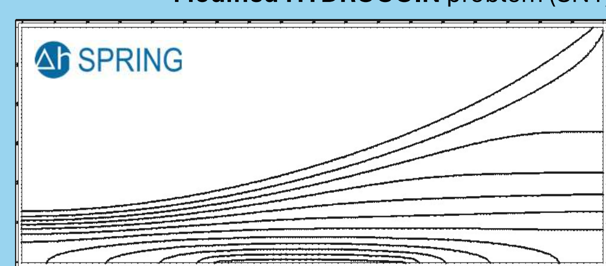


HYDROCOIN problem (Level 1 Case 5, also called Salt Dome problem)

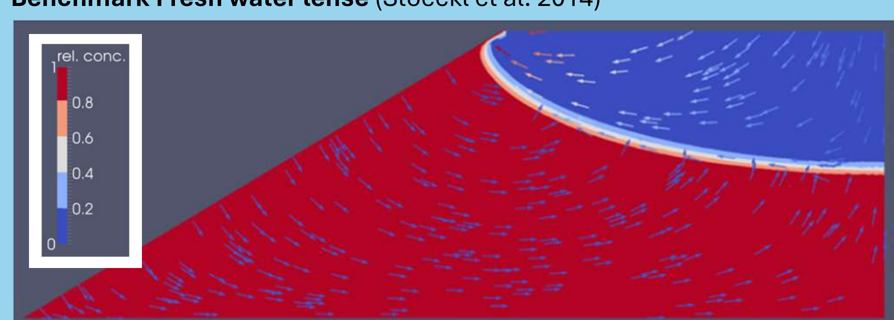
- Groundwater **flow** & **nuclear waste disposal**



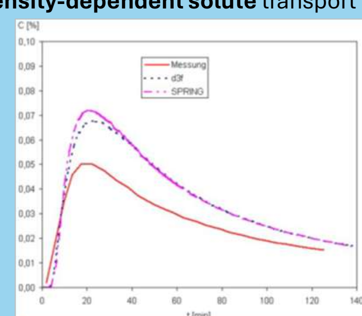
Modified HYDROCOIN problem (SN1)



Benchmark Fresh water lense (Stoeckl et al. 2014)



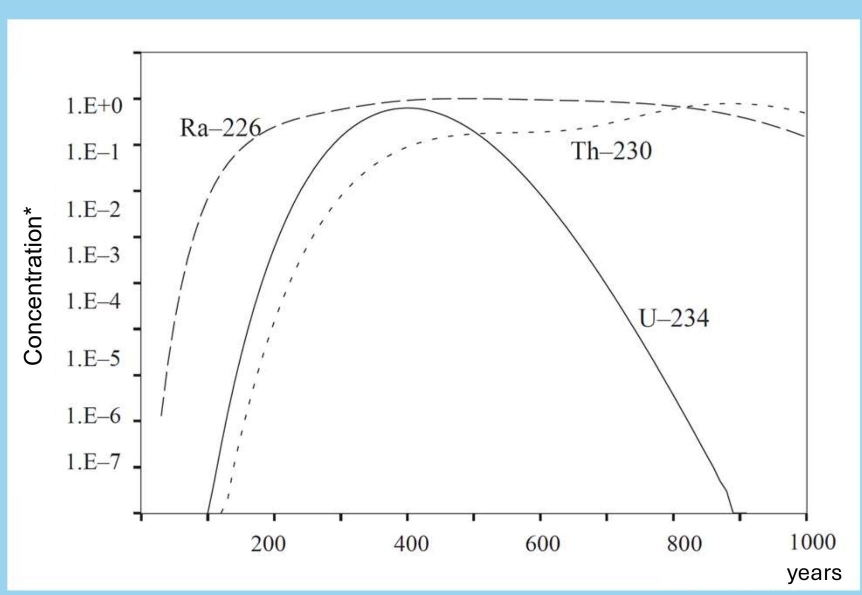
Saltpool problem:
density-dependent solute transport



Larue, J., Weyand, T., Mayer, K.-M. (2016): Untersuchungen zum Transportverhalten von Schadstoffen in Süß-/Salzwassersystemen unter Berücksichtigung von Dichteunterschieden, GRS – 436, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, ISBN 978-3-946607-18-2, Köln. https://www.grs.de/sites/default/files/publications/grs-436.pdf.

Stoeckl, L., Walther, M., Schneider, A., Yang, J., Graf, T. (2014): Comparison of numerical models using a two-dimensional benchmark of density-driven flow. http://www.swim-site.nl/pdf/swim23/a-80.pdf.

multi-component transport



Combination of different components

- Tracer
- Salt
- Nuclide (parent, daughter)
- Energy

$$(nS_r\varrho)\frac{\partial c_i}{\partial t} + ((1-n_a)\varrho_s)\frac{\partial c_{s,i}}{\partial t} + (nS_r\varrho)\,\mathbf{v}\nabla c_i - \nabla\left(nS_r\varrho\left(d_{m,i}\,\mathbf{I} + \mathbf{D}\right)\nabla c_i\right)$$
$$= q\left(c_i^{in} - c_i\right) + q_{c,i} - \lambda_i\left\{(nS_r\varrho)\,c_i + ((1-n_a)\varrho_s)\,c_{s,i}\right\} \qquad i = 1,\dots,k$$
$$+ \sum_{\substack{j=1 \\ j \neq i}}^{k} m_{i,j}\lambda_j\left\{(nS_r\varrho)c_j + ((1-n_a)\varrho_s)c_{s,i}\right\}$$

* standardized with regard to the maximum concentration of the respective nuclide)

C. Blömer, Ch. König, J. Larue, Th. Beuth: **A Threedimensional Model for Radionuclid Transport in Groundwater and its Application to an Industrial Settling Pont**; Uran - Bergbau und Hydrogeologie, Freiberg, 1998