Single-well tracer test sensitivity w. r. to hydrofrac and matrix parameters (case study for the Horstberg site in the N-German Sedimentary Basin)

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gebo focus area
'Geosystem'

BAKER HUGHES

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MOTIVATION : evaluating innovative, single-well techniques for geothermal heat extraction from deep tight (lowly permeable) rock

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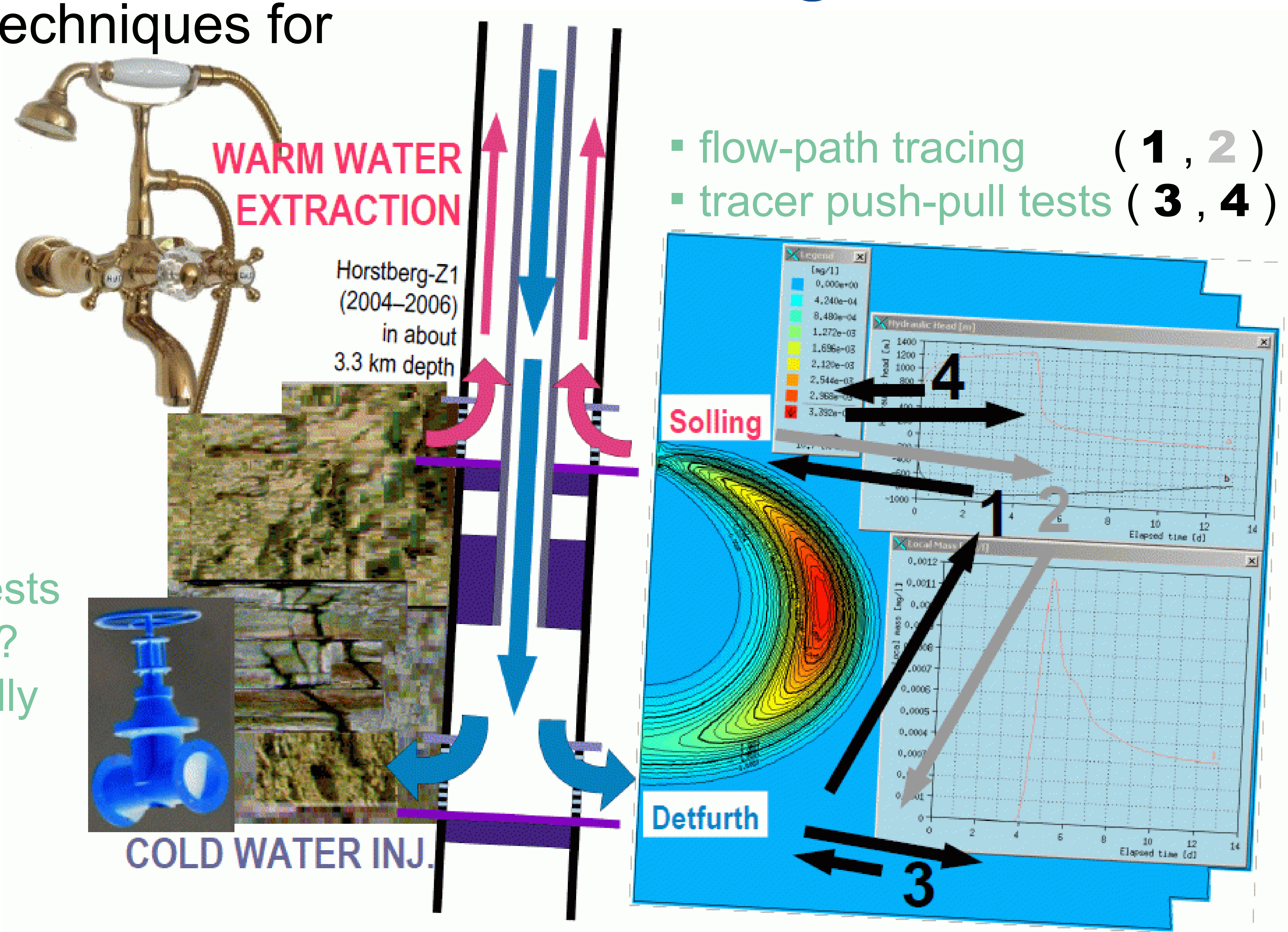
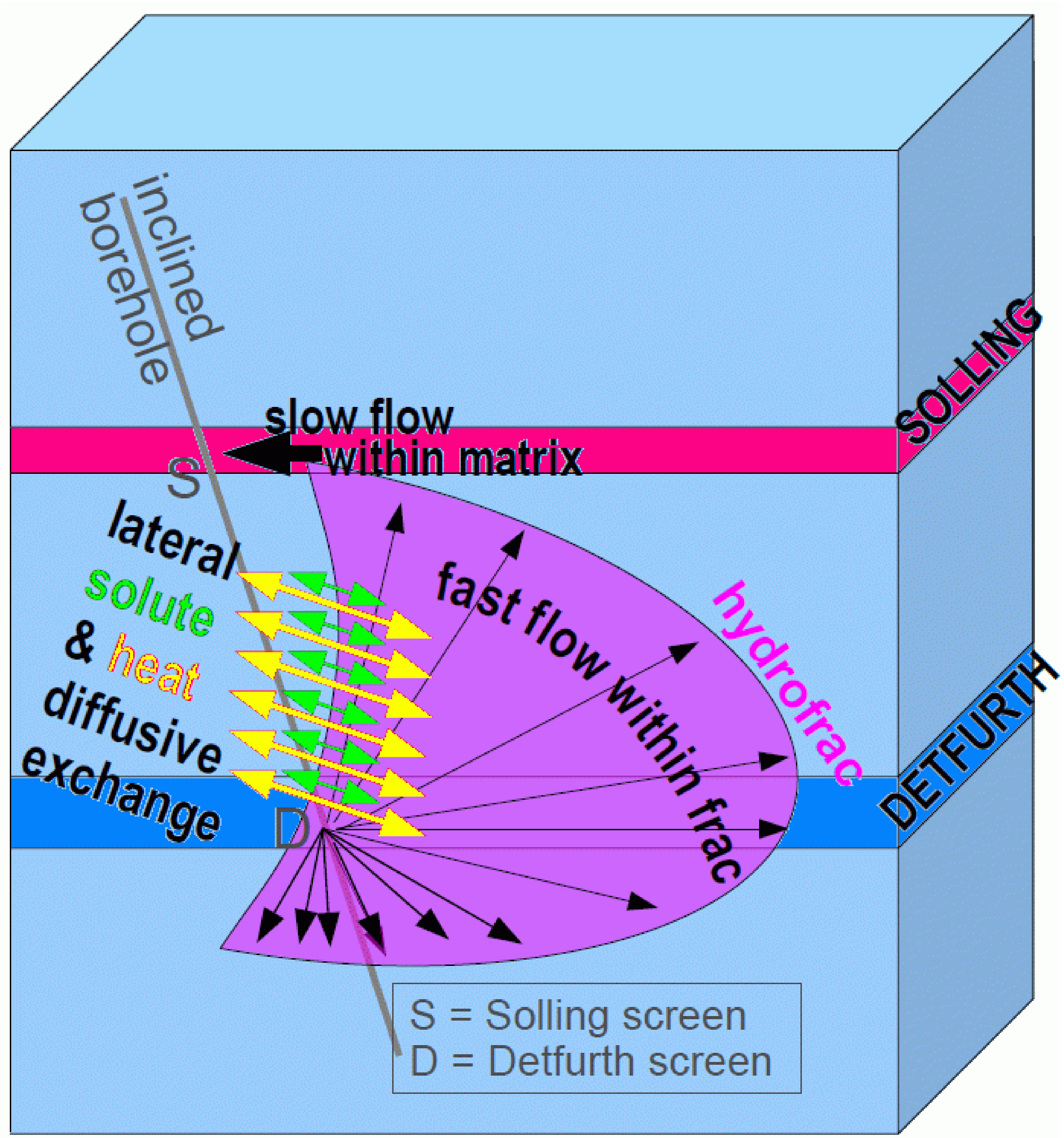
- flow-path tracing (1 , 2)
- tracer push-pull tests (3 , 4)



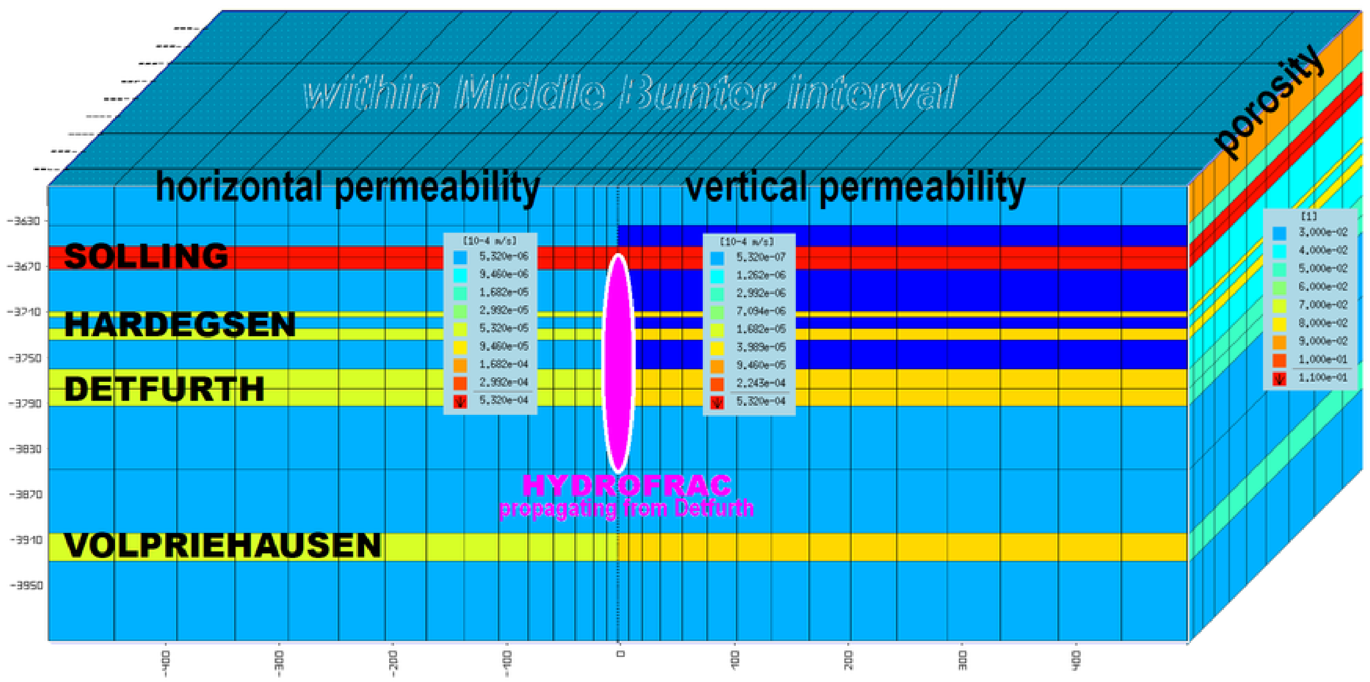
what kind of tests
– make sense?
– are technically feasible?

PROCESSES

- rapid flow (Hagen-Poiseuille) within frac
- slow flow (Darcy) within matrix
- advection-dispersion within frac
- diffusion-dominated transport within matrix
- diffusive exchange (‘matrix diffusion’) of heat and solute (tracer) frac ↔ matrix



MODEL PARAMETRIZATION



INTER-LAYER TEST (1)

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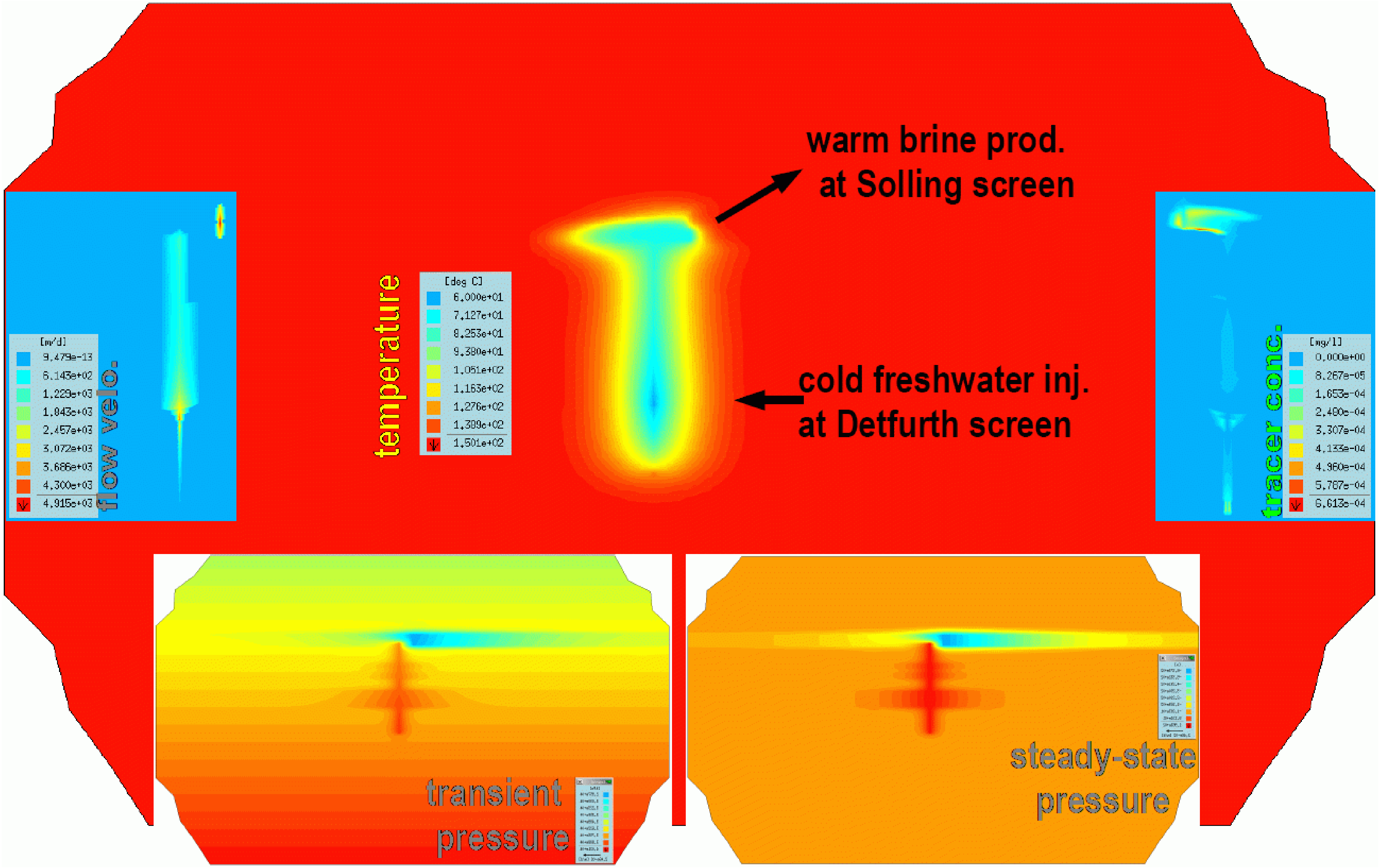

SINGLE-LAYER TESTS **(3,4)**

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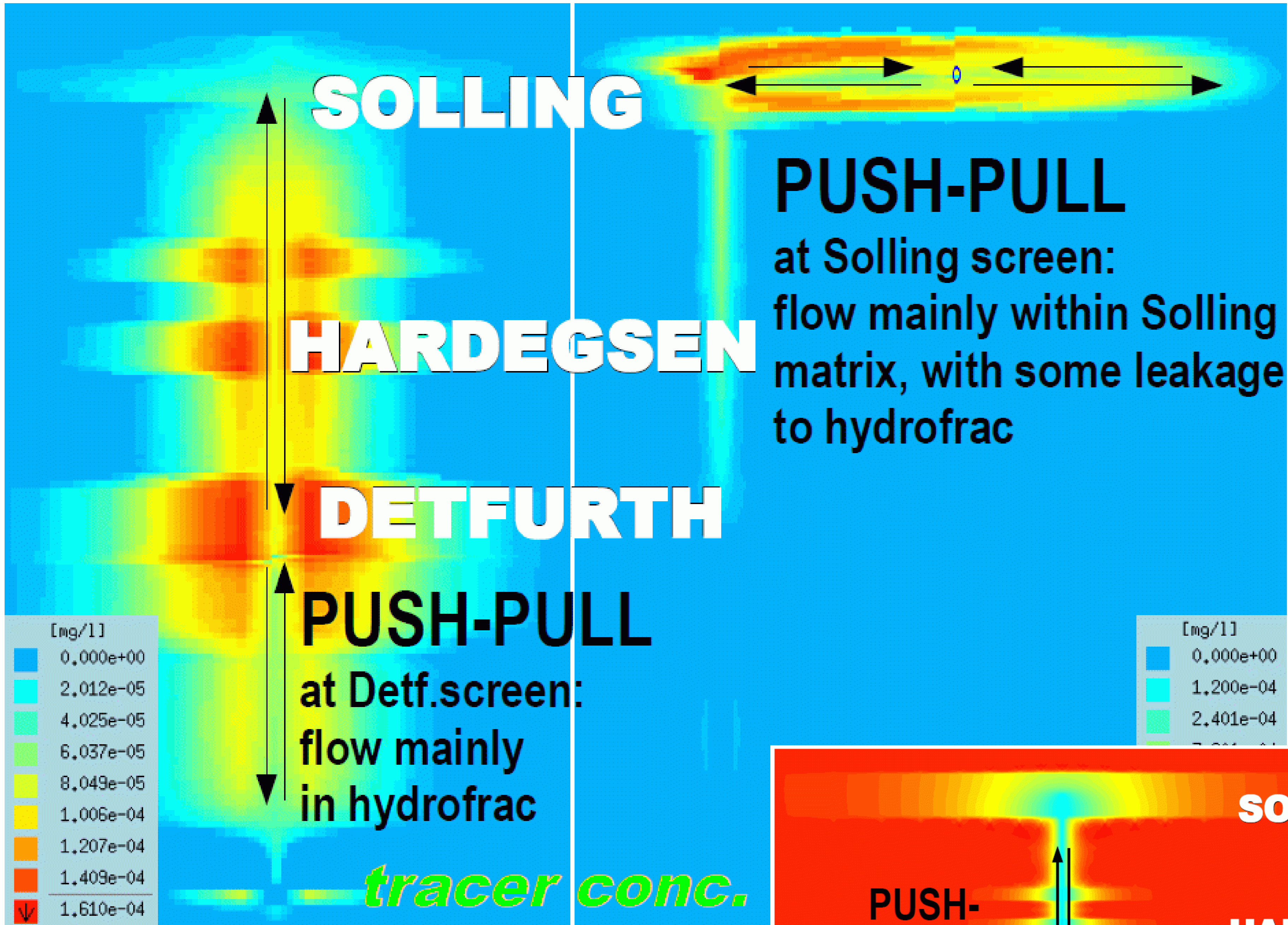
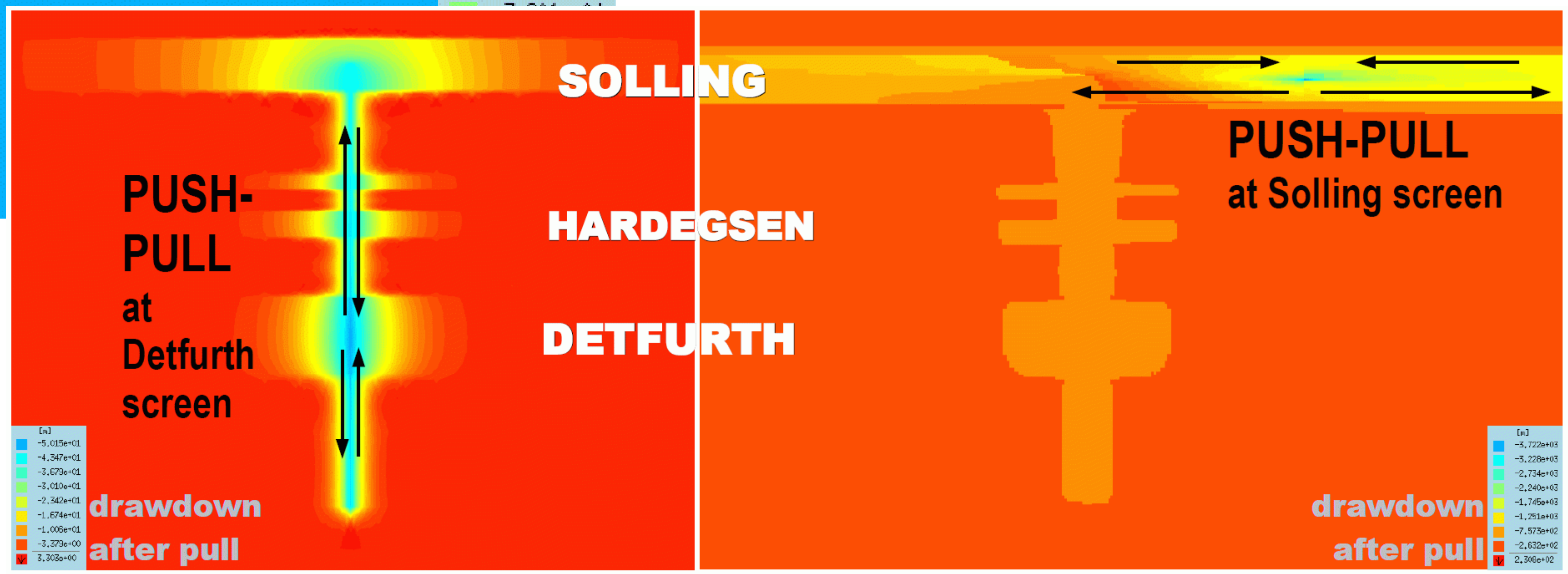




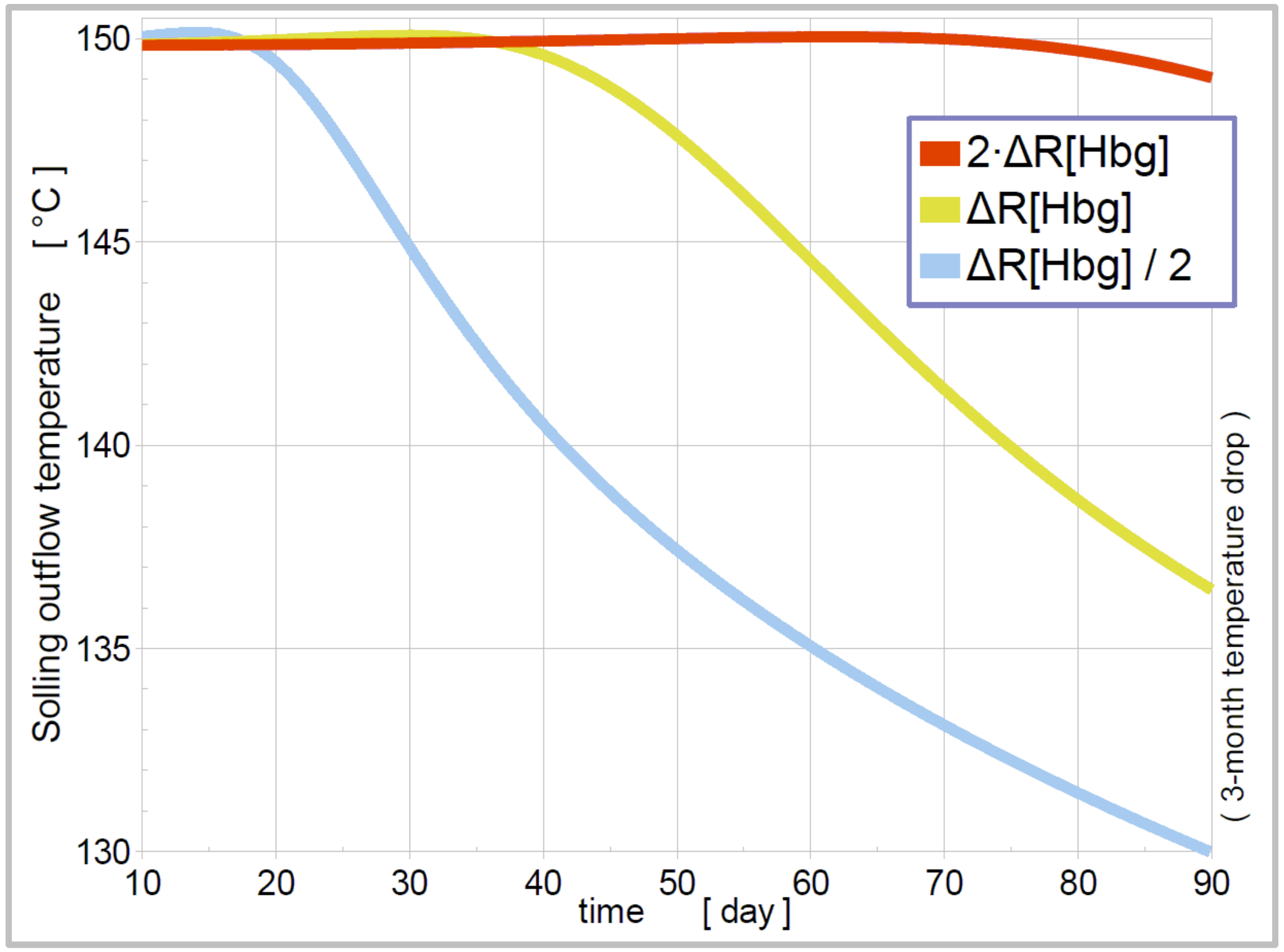
tracer push-pull tests

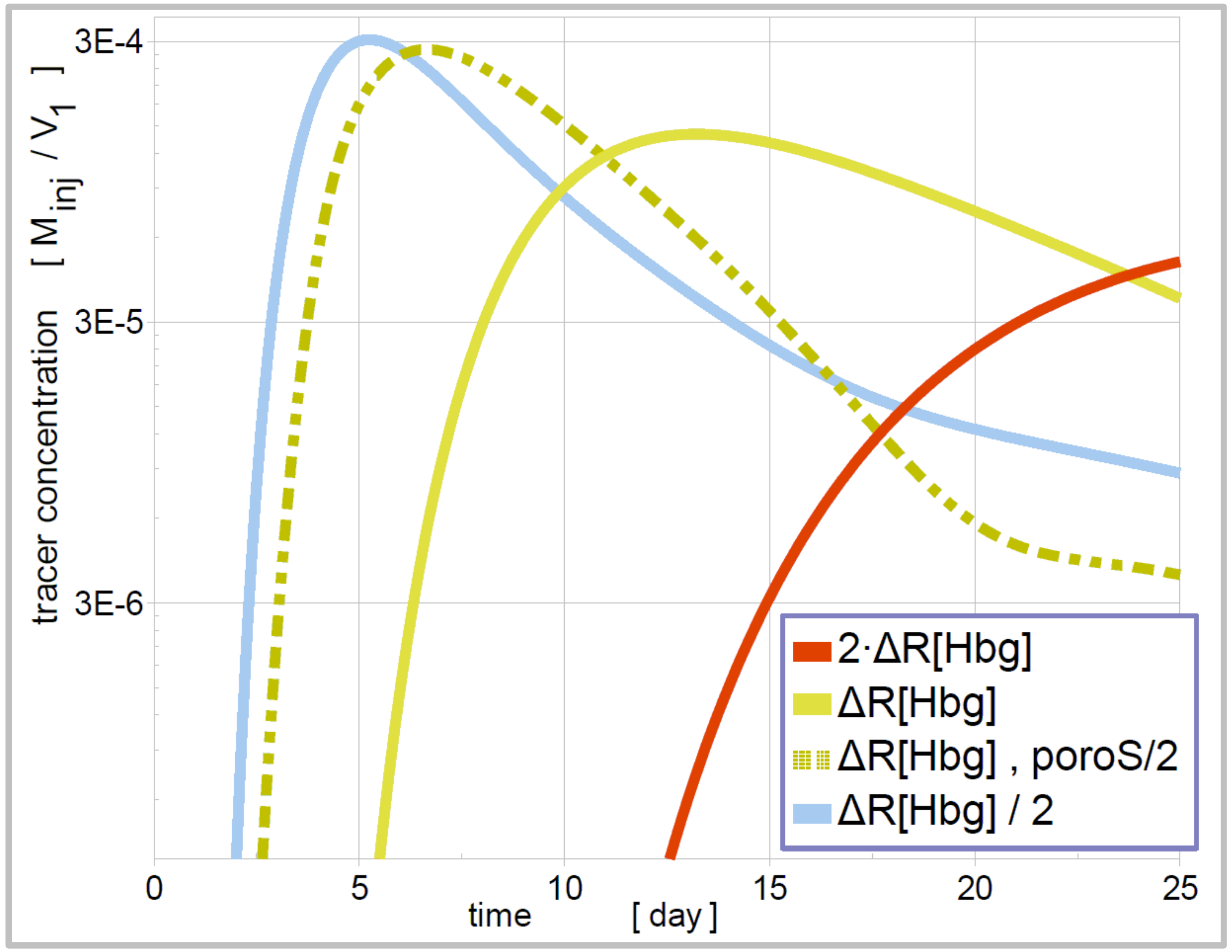
- at Detfurth screen:
  - insensitive w.r.to matrix parameters
  - ambiguously sensitive w.r. to frac aperture
- at Solling screen:
  - sensitive w.r.to matrix parameters
  - limited sensitivity w.r.to frac parameters

HEAT – TRACER CORRELATION

Which parameters determine the system‘s thermal lifetime?

Which parameters can be determined from tracer tests?





PARAMETER SENSITIVITY (summary)

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PARAMETER controlling for …? invertible from...?	... thermal lifetime?	… tracer signal from inter-/single-screen experiment?		
	1 , 2		**3**	**4**
frac dist. (ΔR) from Solling screen	yes : via **MRT**	yes; **mT**	no	only with large PUSH volume; **m∞**
frac length (L_2) at Solling bottom	yes : via **HEA**	yes; **mT** , **m∞**		
frac aperture (b, dynamical)	no		with restrictions; **mX**	
Solling porosity (ω)	weak influence via **MRT**	yes; **mT**	no	only indirectly, via Peclet no. PE (not really quantifiable)
Solling fissure density ($1/a$)	only at low fissure density ambiguous via **HEA**	yes; **m∞**		generally yes; a non-trivial task
	MRT = mean residence time **HEA** = heat exchange area	**mT** : multiple residence-time inversion **m∞** : multiple (PULL) tailing inversion **mX** : multiple PULL (peak) inversion		
reason for **mT** :	**MRT** (**1,2**) ← product ($\omega \times L_2 \times \Delta R$), individual factors not uniquely determinable			
reason for **m∞** :	tailing (**1,2**) increases with ($1/a$) as well as with L_2 PULL tailing (**4**) results from ≥5 mutually-independent parameters			
reason for **mX** :	PULL signal (**3**) relates uniquely with b only above a certain *P*E-threshold (not likely to be reached within frac flow)			

FOR COMPARISON :

Same test type, conducted at different wellbore screens or different reservoir life stages, yields different parameters:

<table>
<tr><th colspan="2">Tracing Design</th><th colspan="2">Where</th><th>When</th><th>Which parameters best determined?</th></tr>
<tr><td rowspan="4">single-well</td><td>flow-path</td><td rowspan="3">Horstberg</td><td>Detfurth → Solling clay layers + sandst.</td><td rowspan="2">reservoir creation
early post-frac stage</td><td>frac distance from prod. wellscreen</td></tr>
<tr><td rowspan="3">push-pull</td><td>Detfurth sandst.</td><td>frac aperture</td></tr>
<tr><td>Solling sandst.</td><td>reservoir operation</td><td>matrix rock-fluid interface area</td></tr>
<tr><td rowspan="2">Groß Schönebeck</td><td>selected sandst. or volc. intervals</td><td>reservoir creation
early post-frac stage</td><td>frac size</td></tr>
<tr><td>inter-well</td><td>flow-path</td><td>sandstone and volcanics layers</td><td>reservoir operation</td><td>fluid resid.time</td></tr>
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