Updating of Uncertainty in Fractured Reservoirs driven by Geological Scenarios

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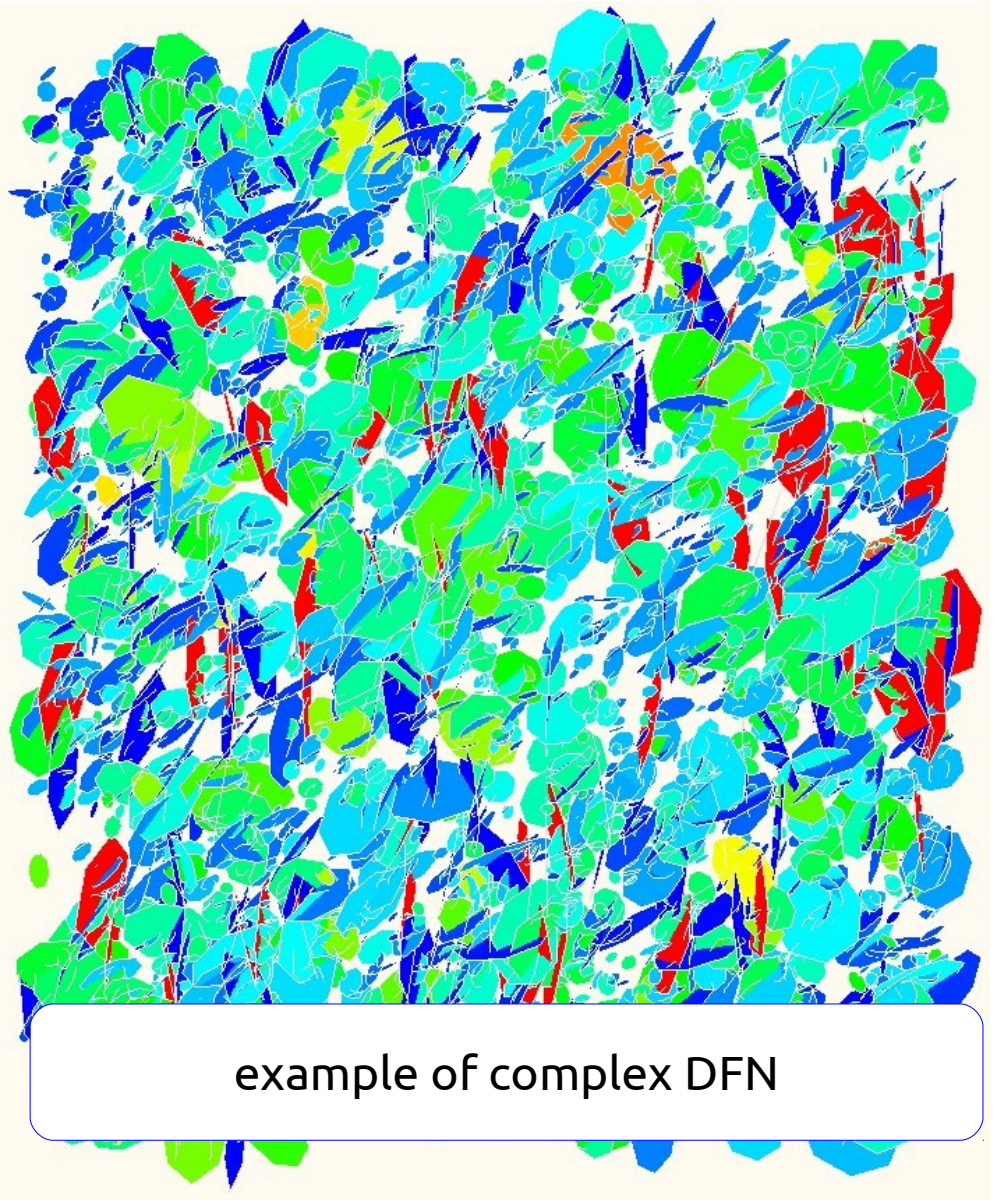
Darryl Fenwick, Streamsim Technologies

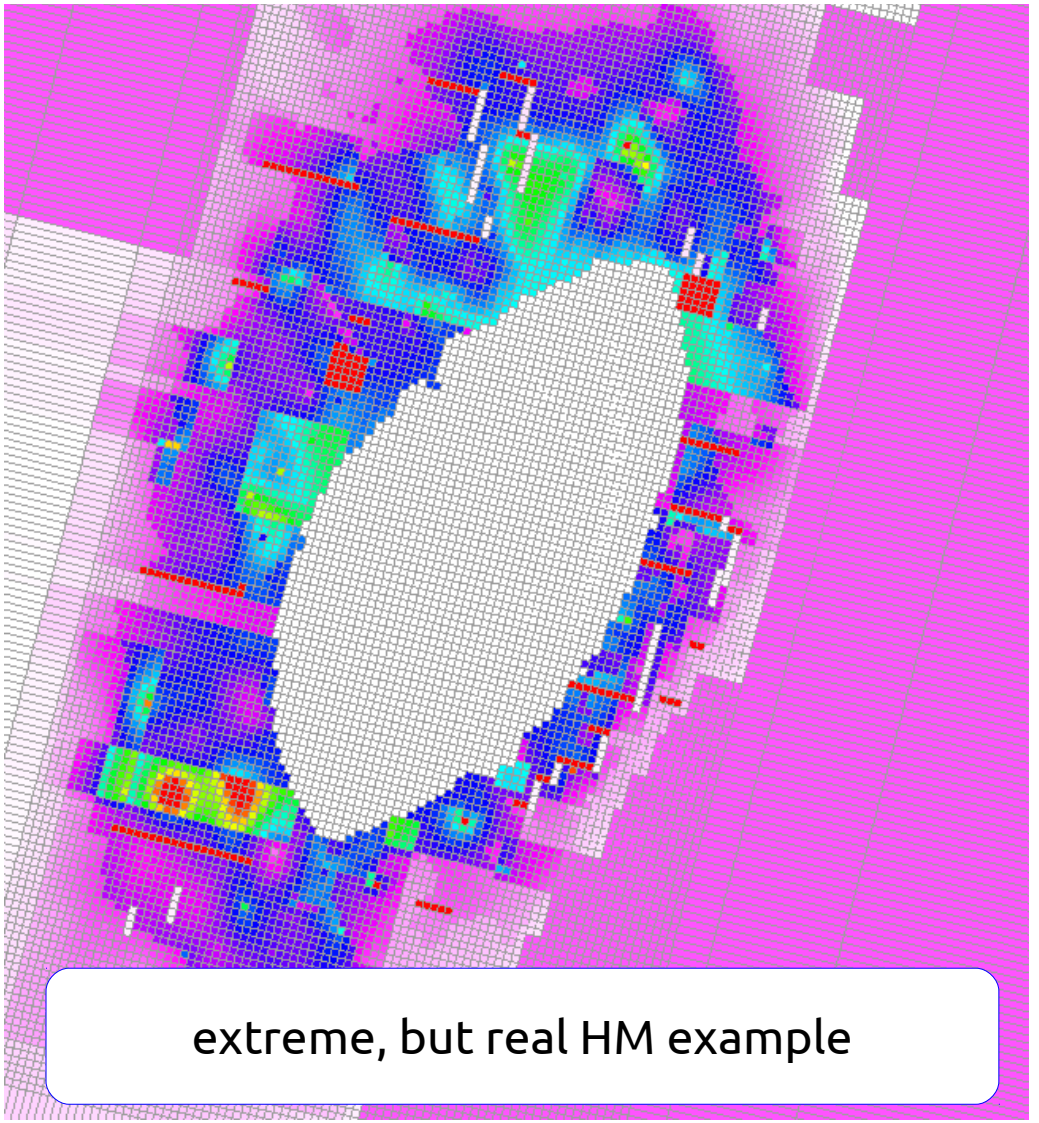
Overwhelming complexity → Two Worlds

Models <u>built</u>
by Geologists



example of complex DFN

Models <u>used</u>
by Engineers



extreme, but real HM example

Scenario-driven workflow for Naturally Fractured Reservoirs

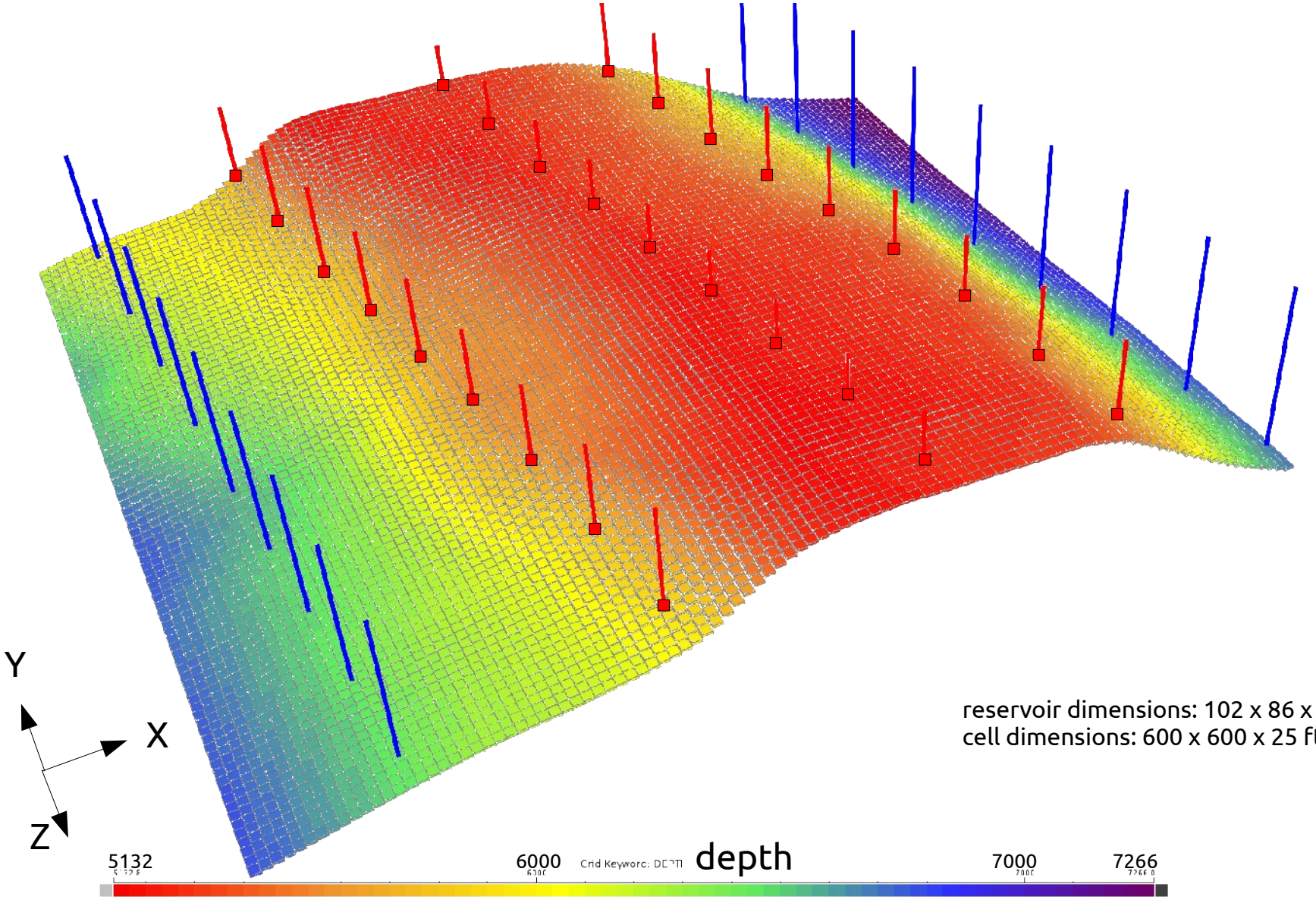
The Purpose:

- Uncertainty Quantification
- Uncertainty Updating / History Matching
- Dual-Medium description

The Challenge:

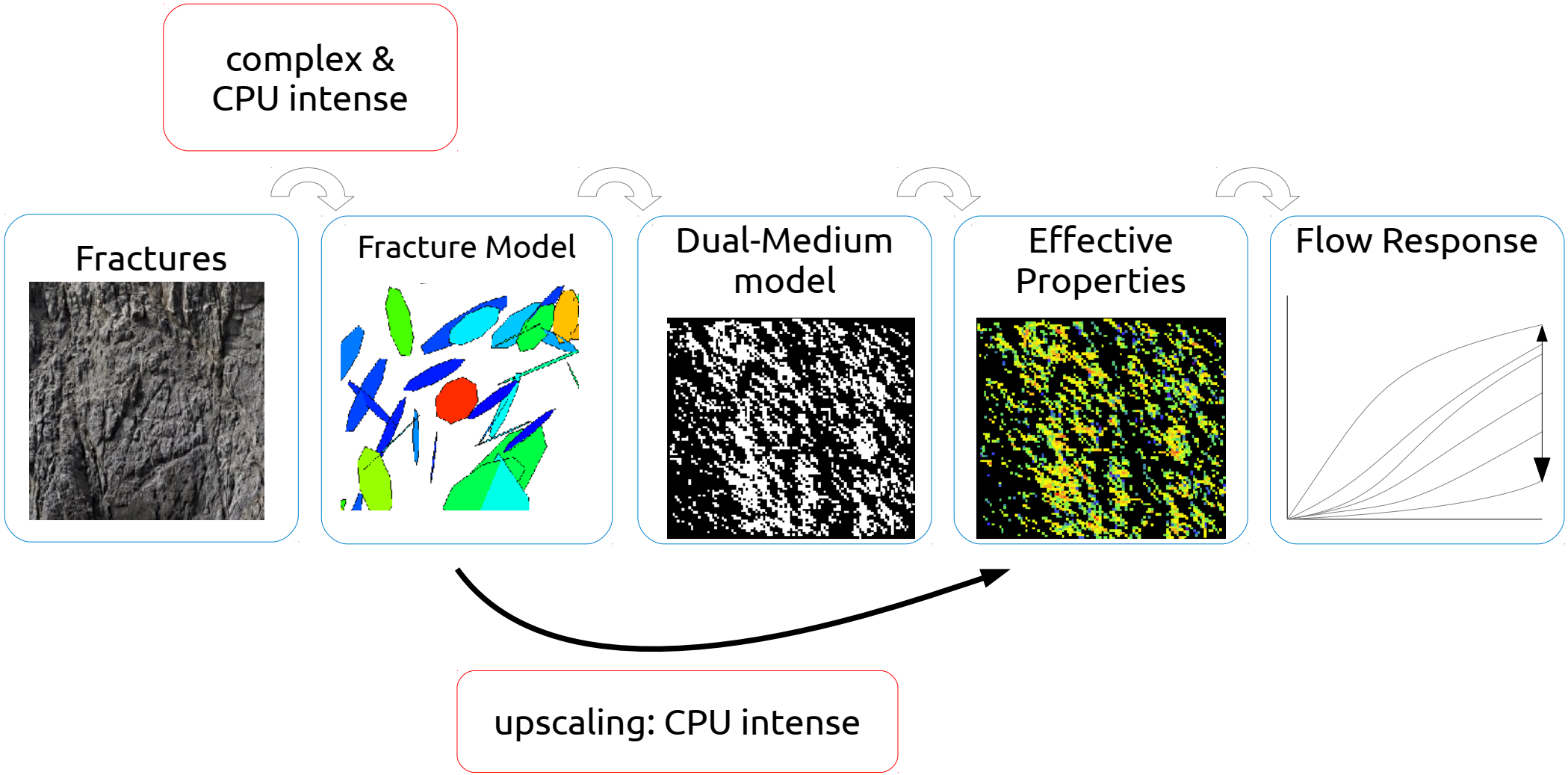
- Geologically consistent
- Field Scale (global!)
- Integration with existing Software
- Rapid

Naturally Fractured Reservoir



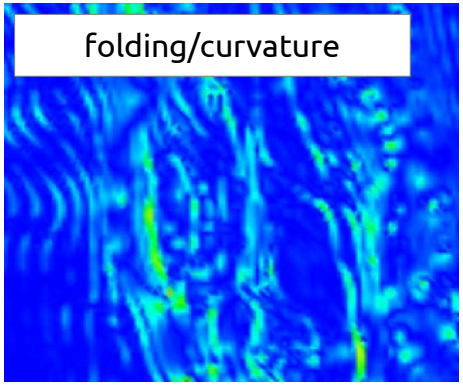
reservoir dimensions: 102 x 86 x 1 cells
cell dimensions: 600 x 600 x 25 ft

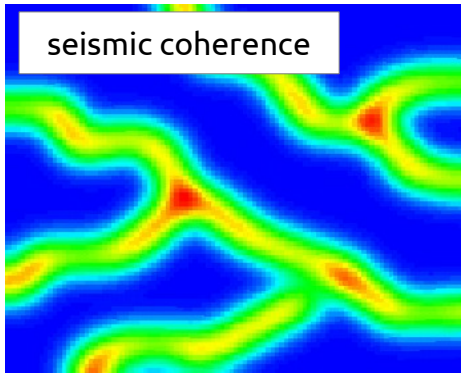
DFN-workflow



Uncertainties in DFN modeling

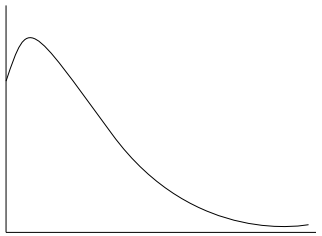
conceptual / interpretation



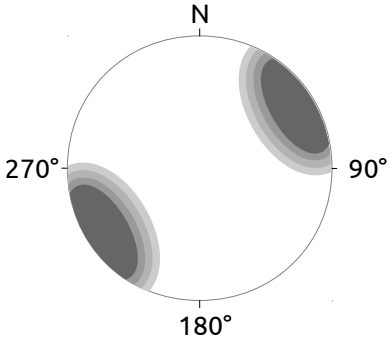


1 or 2
fracture sets

parameters



equiv. radius (length)

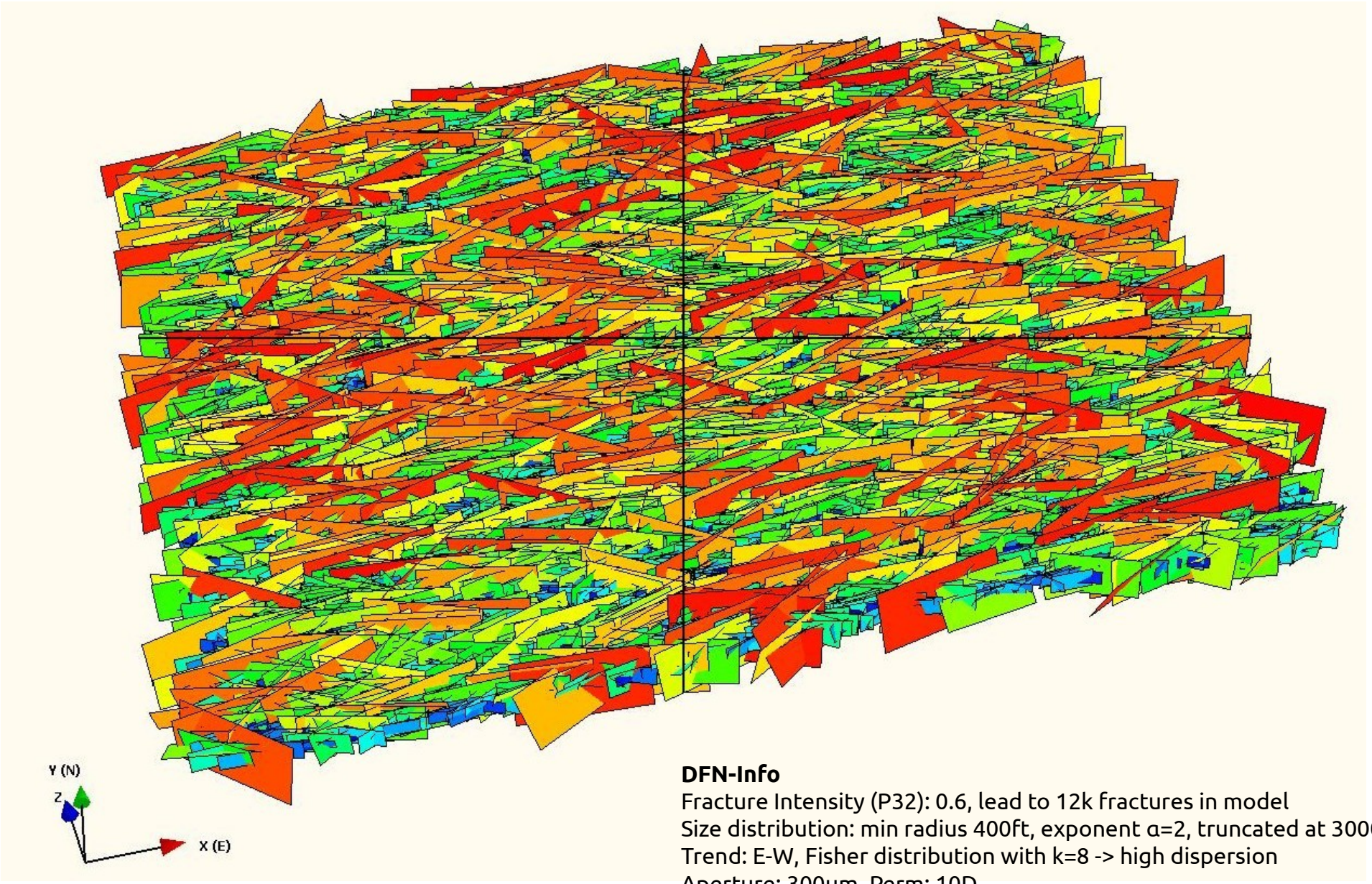


trend

full factorial experimental design

156 DFN models

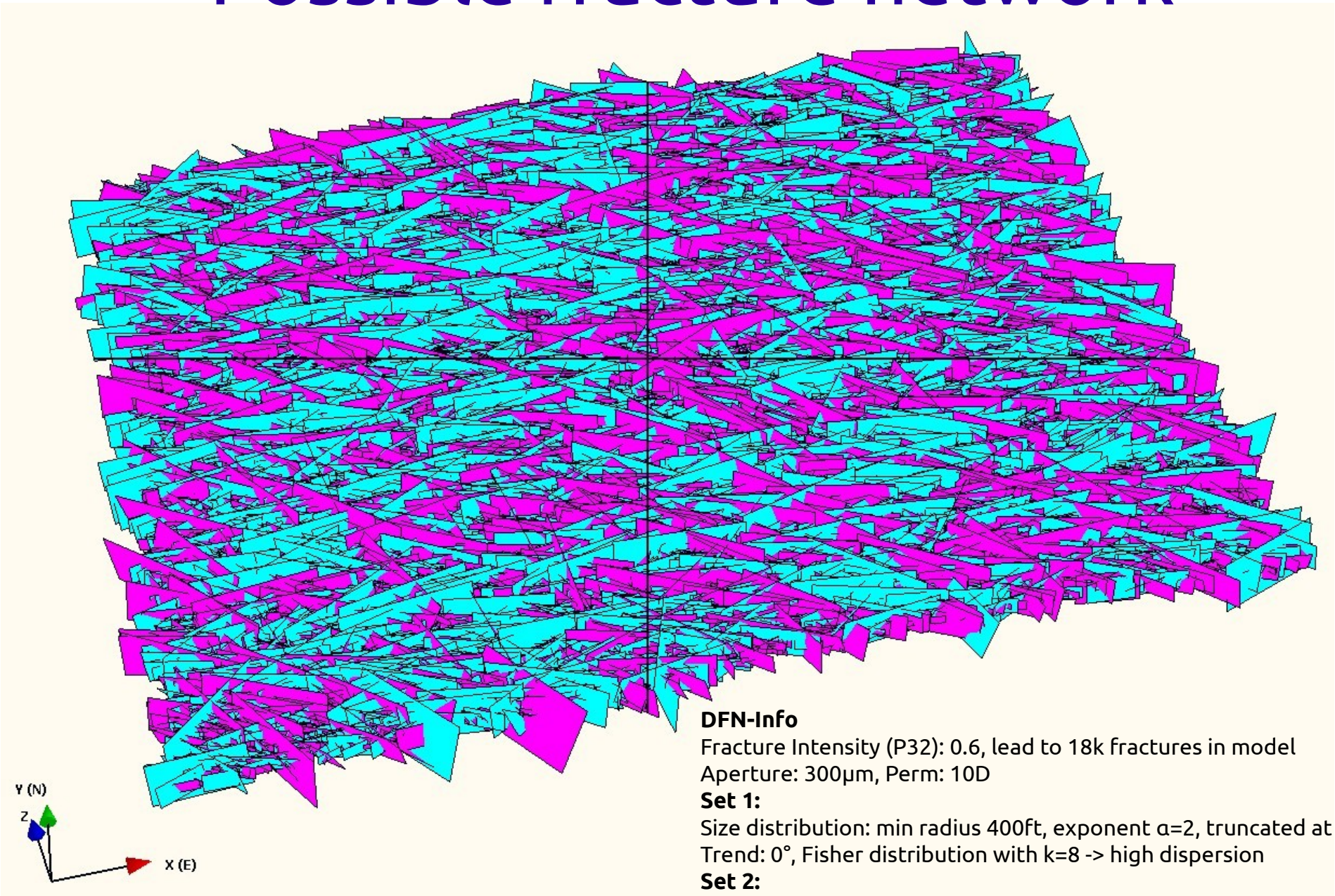
Possible fracture network



DFN-Info
Fracture Intensity (P32): 0.6, lead to 12k fractures in model
Size distribution: min radius 400ft, exponent α=2, truncated at 3000ft
Trend: E-W, Fisher distribution with k=8 -> high dispersion
Aperture: 300µm, Perm: 10D

Fractures colored by size

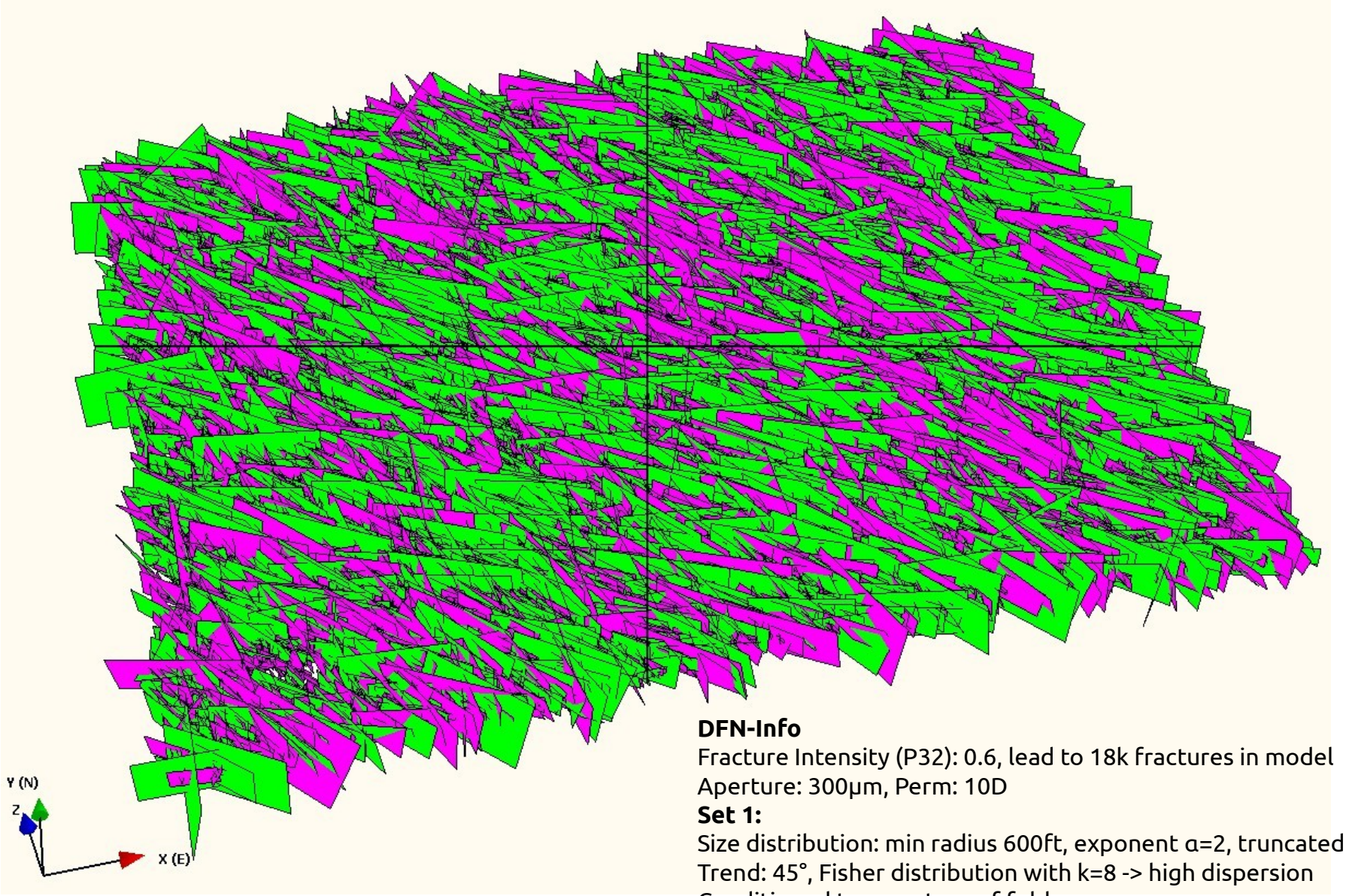
Possible fracture network



DFN-Info
Fracture Intensity (P32): 0.6, lead to 18k fractures in model
Aperture: 300µm, Perm: 10D
Set 1:
Size distribution: min radius 400ft, exponent α=2, truncated at 3000ft
Trend: 0°, Fisher distribution with k=8 -> high dispersion
Set 2:
Size distribution: min radius 200ft, exponent α=2, truncated at 3000ft
Trend: 30°, Fisher distribution with k=8 -> high dispersion

Fractures colored by set

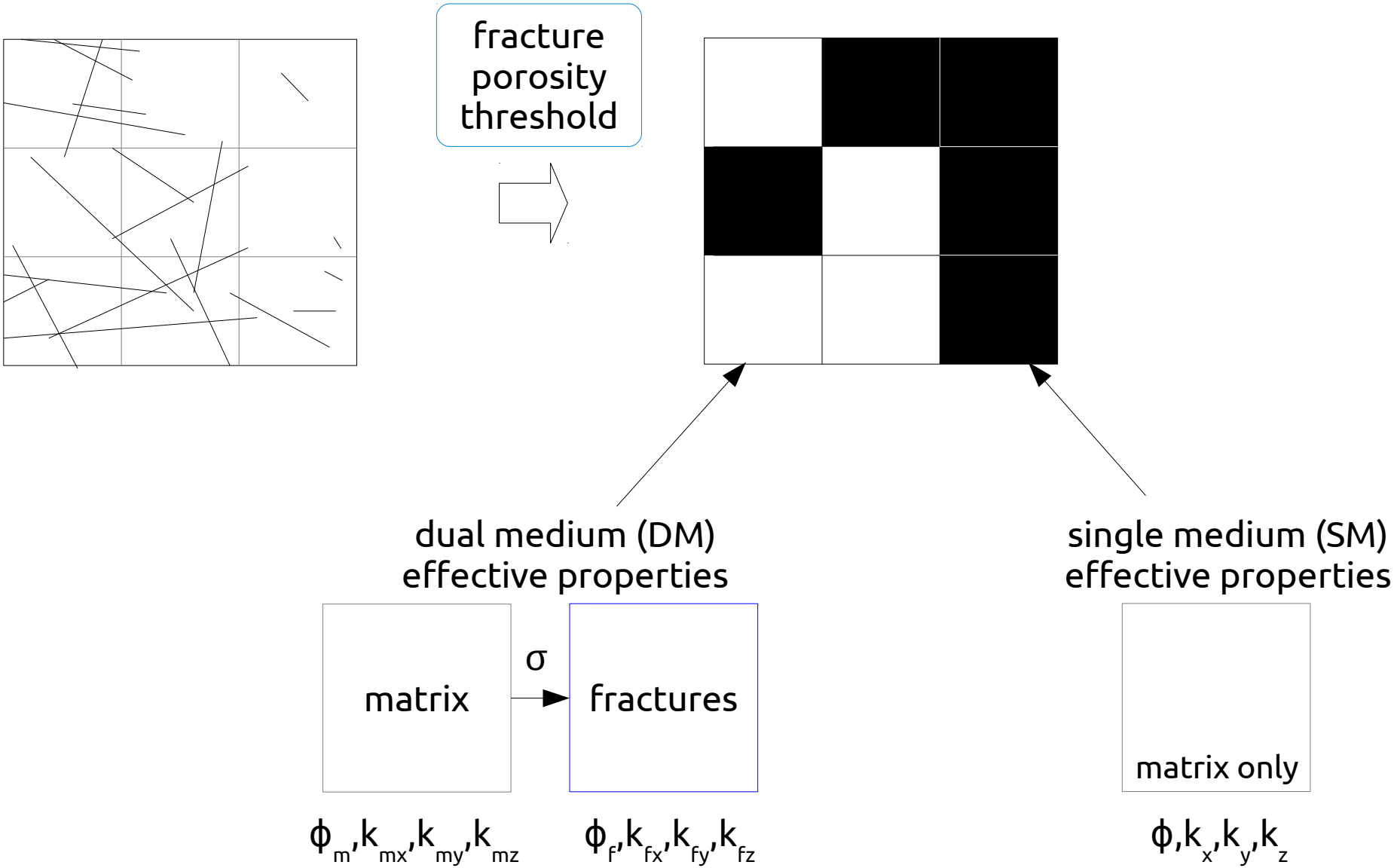
Possible fracture network



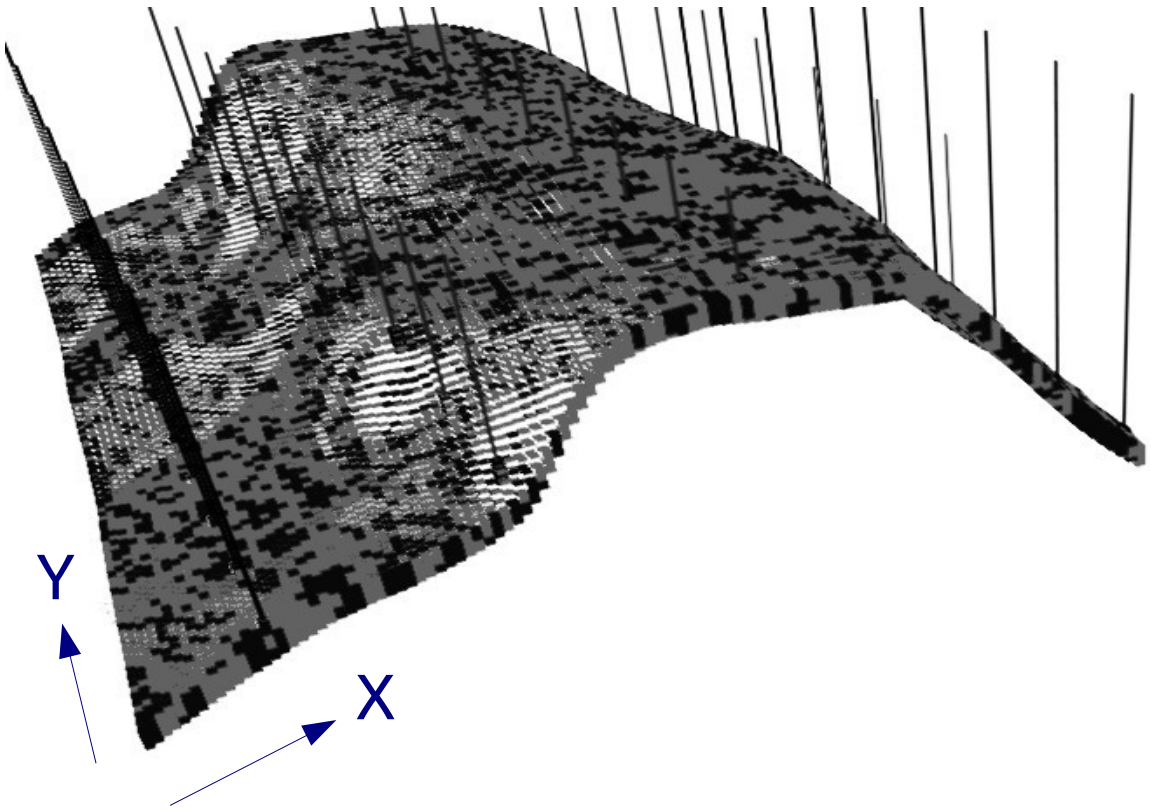
DFN-Info
Fracture Intensity (P32): 0.6, lead to 18k fractures in model
Aperture: 300µm, Perm: 10D
Set 1:
Size distribution: min radius 600ft, exponent α=2, truncated at 3000ft
Trend: 45°, Fisher distribution with k=8 -> high dispersion
Conditioned to curvature of fold
Set 2:
Size distribution: min radius 200ft, exponent α=2, truncated at 3000ft
Trend: 60°, Fisher distribution with k=8 -> high dispersion

Fractures colored by set

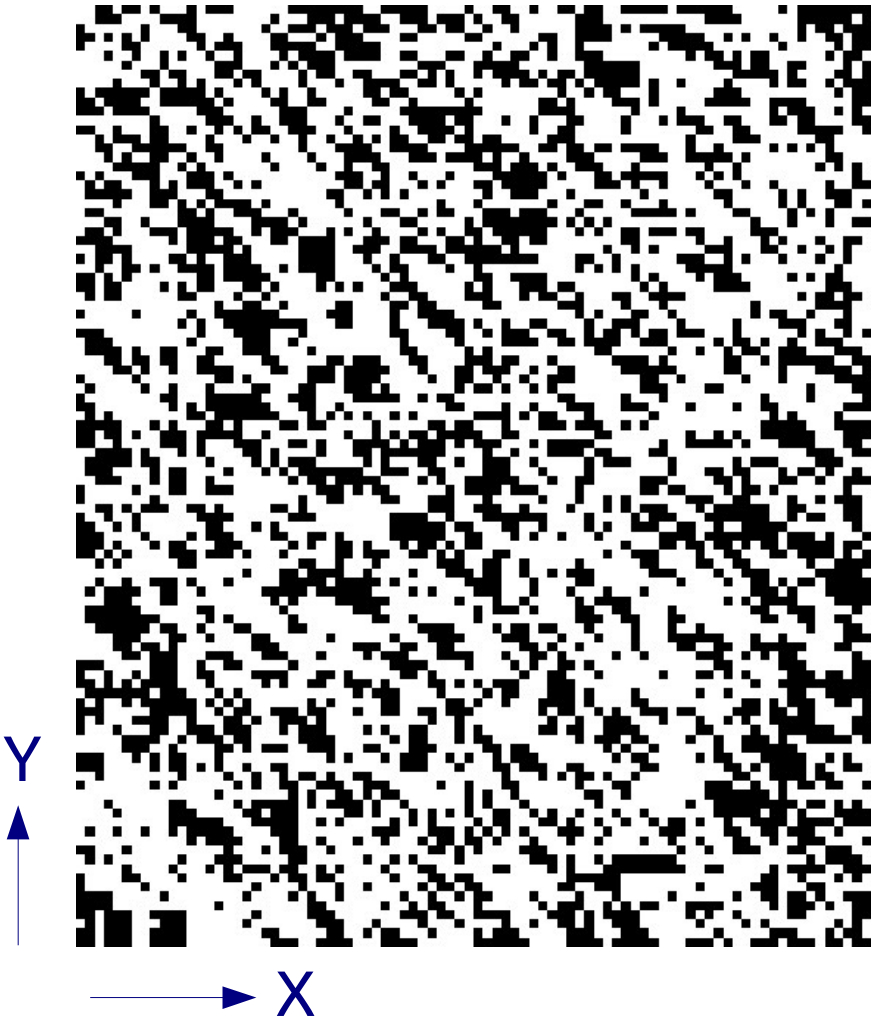
Identification of Dual-Medium cells



Dual Medium pattern at field scale

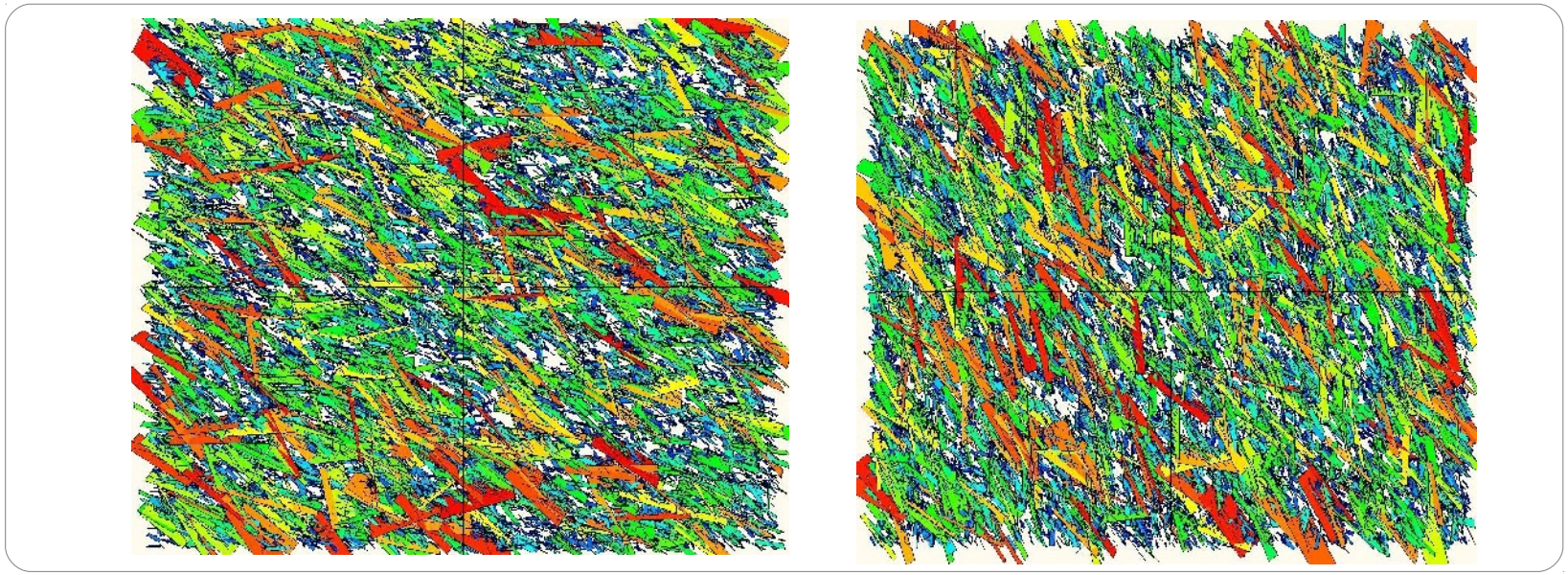


top view

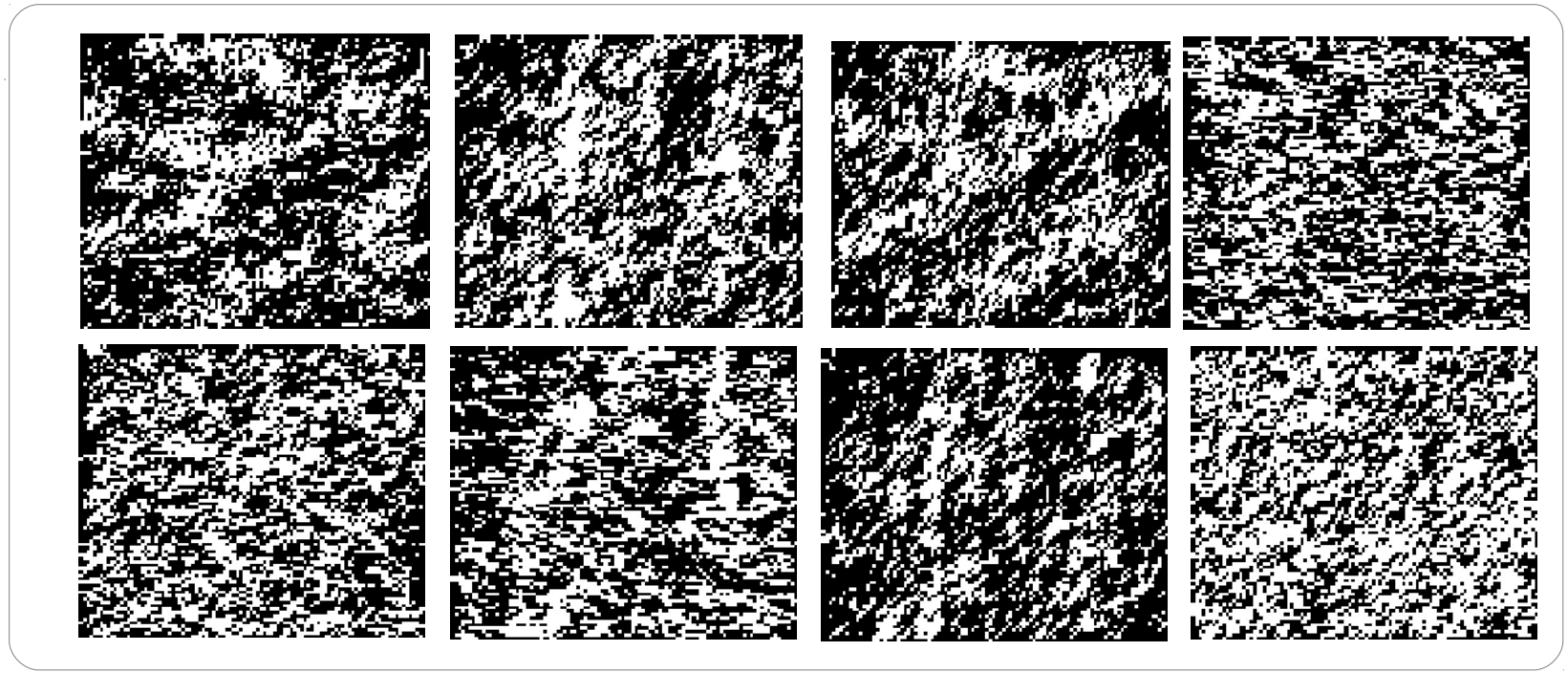


DFN models → Dual Medium models

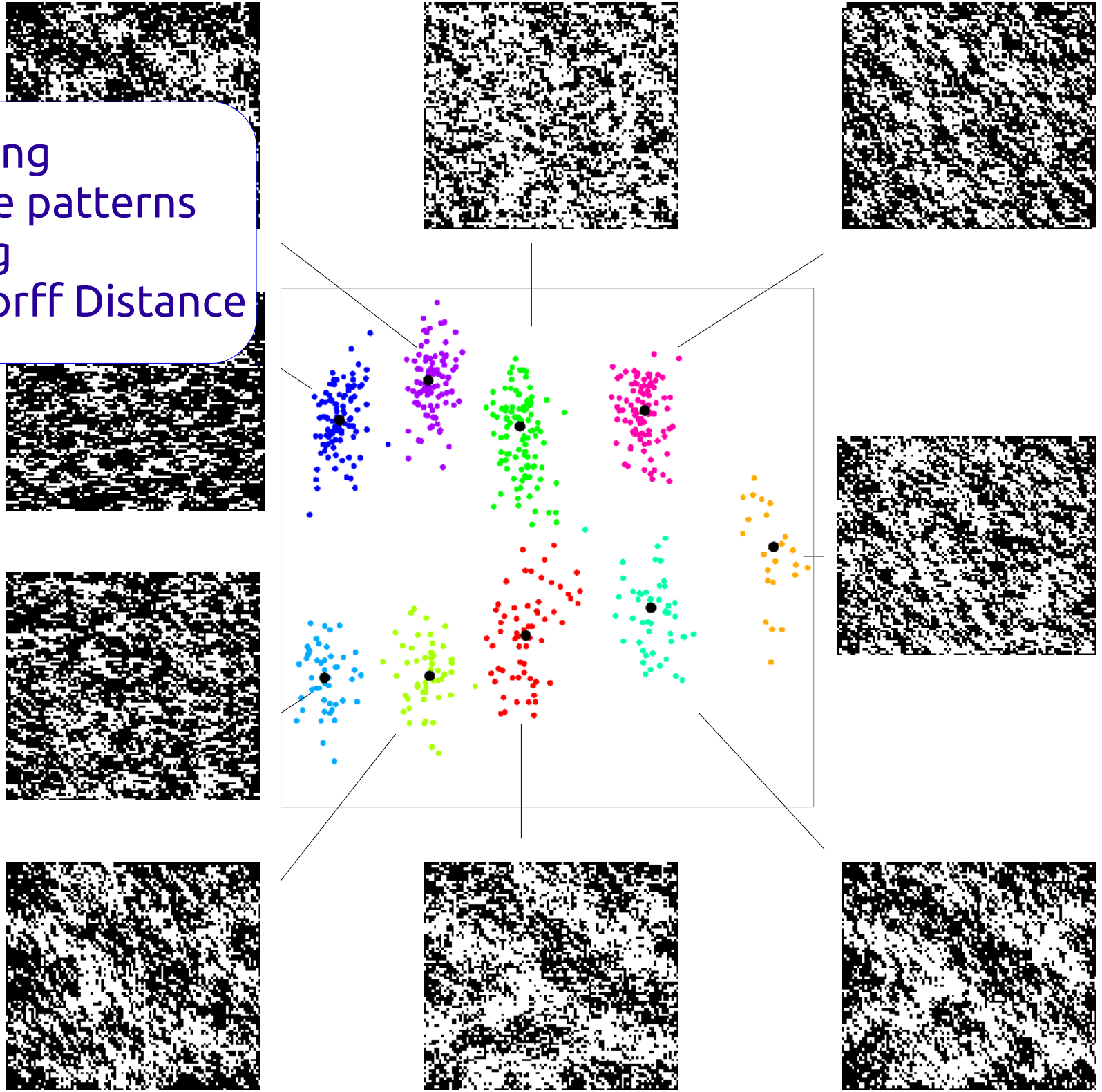
4 x 156 DFN



624 pattern



Selecting representative patterns using Modified Hausdorff Distance

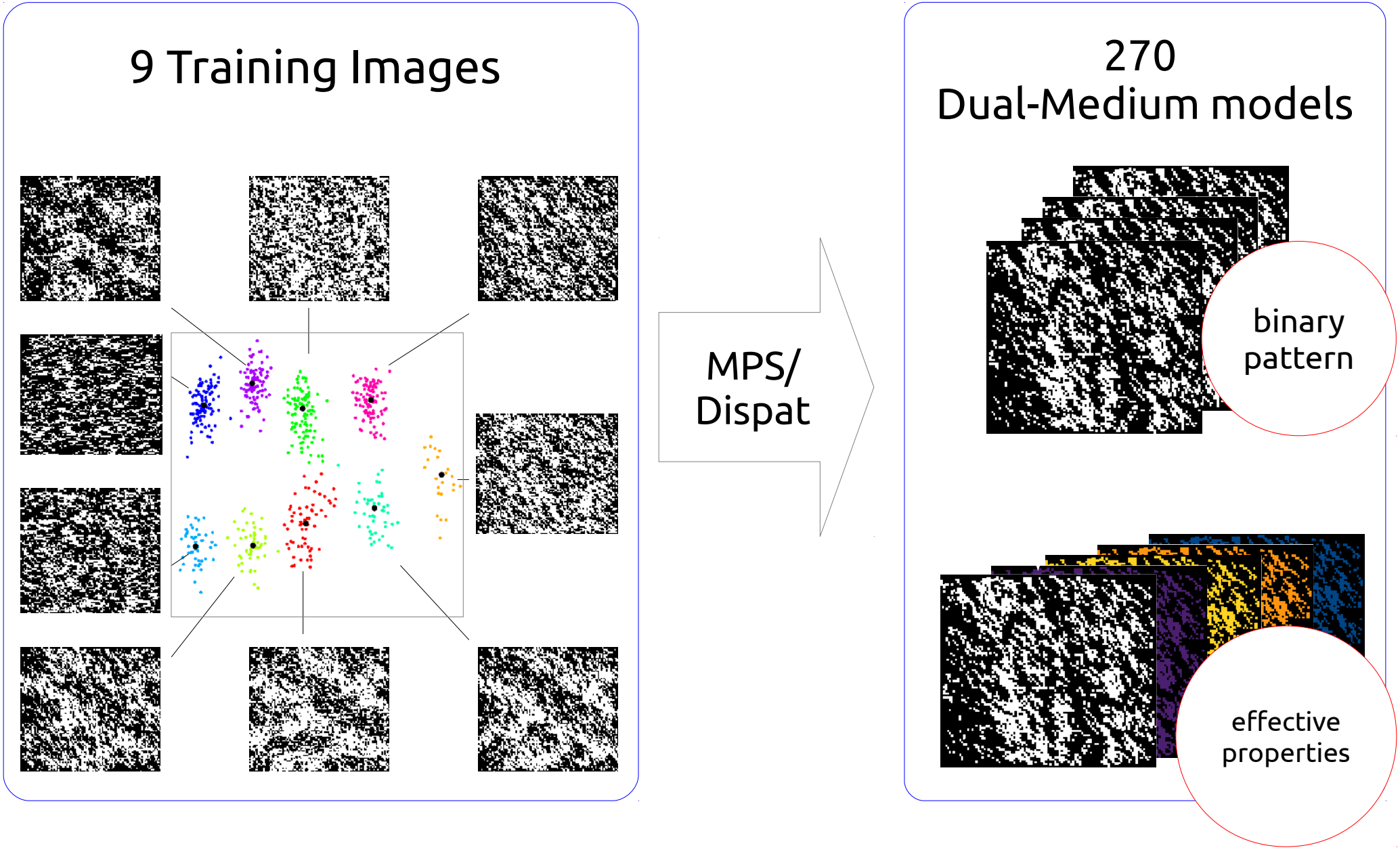


624

↓

9

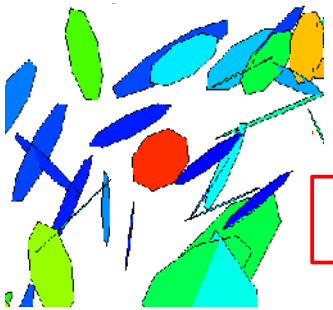
Generating Dual-Medium realizations with MPS



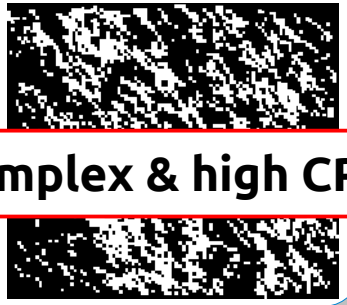
DFN-workflow

Fractures

Fracture Model

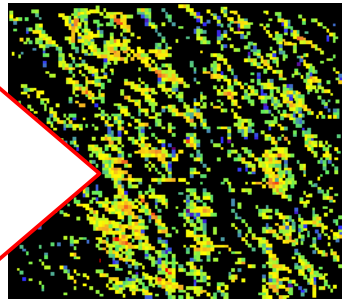


Dual-Medium model

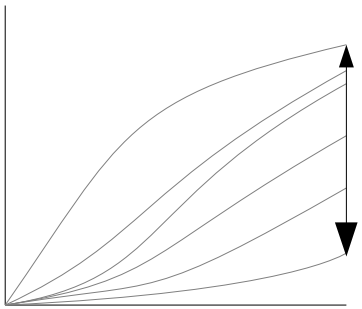


complex & high CPU

Effective Properties



Flow Response

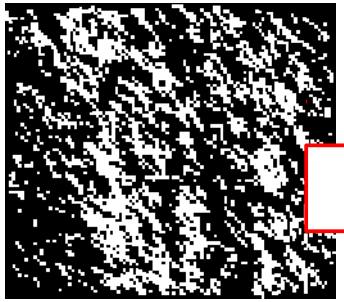


translate / replace

no flow simulation so far

MPS-workflow

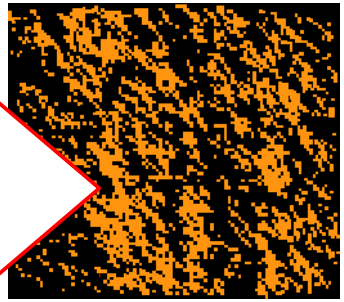
Training image



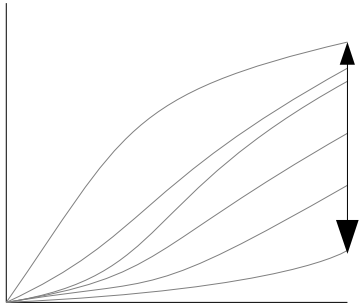
Dual-Medium model

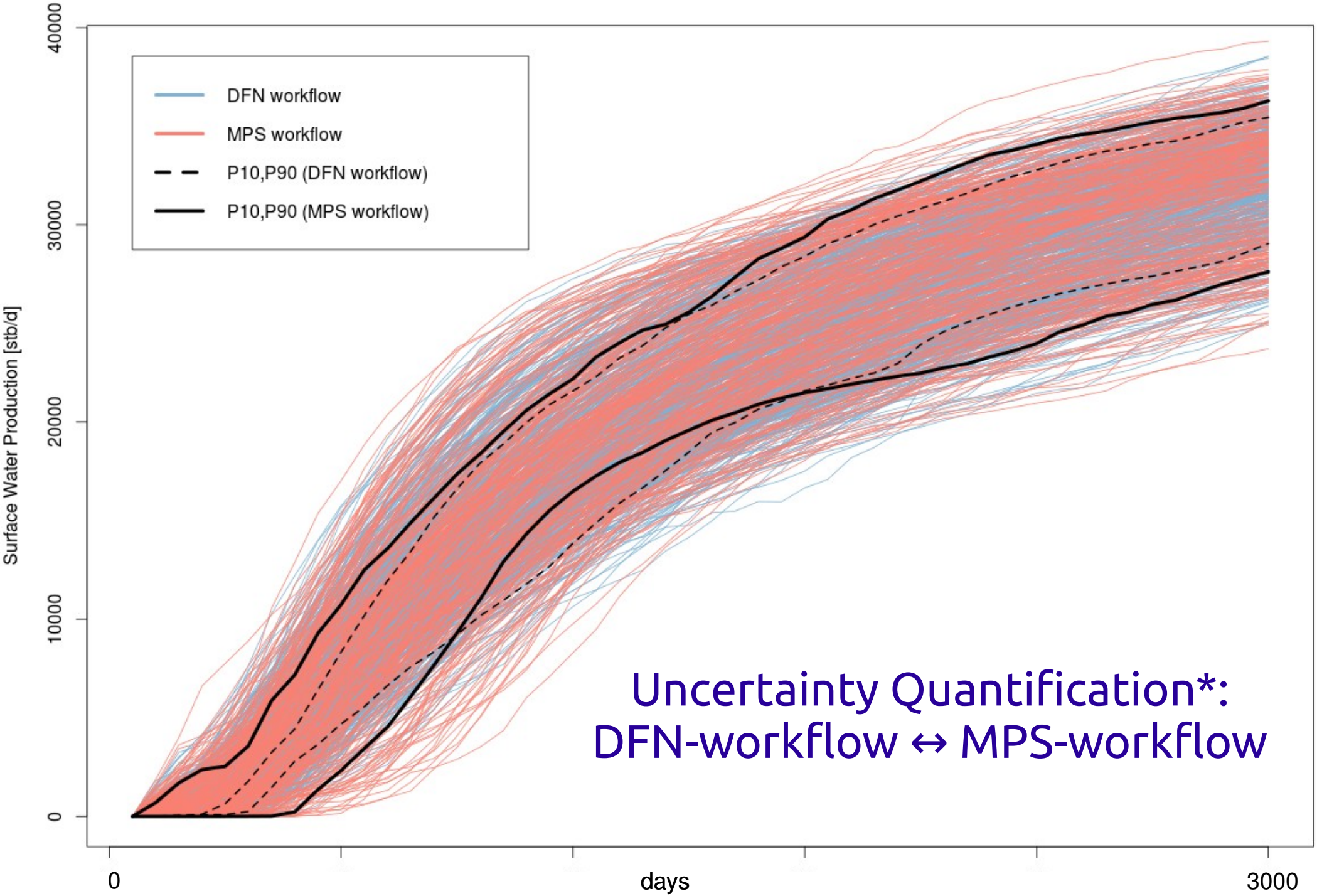
fast

Effective Properties



Flow Response





Uncertainty Quantification*:
DFN-workflow ↔ MPS-workflow

156 DFN x 4 Realizations
9 TIs x 30 Realizations

* no production data

Scenario-driven updating of uncertainty <u>with</u> production data

Dual-Medium scenario uncertainty

generate/find models
matching production data

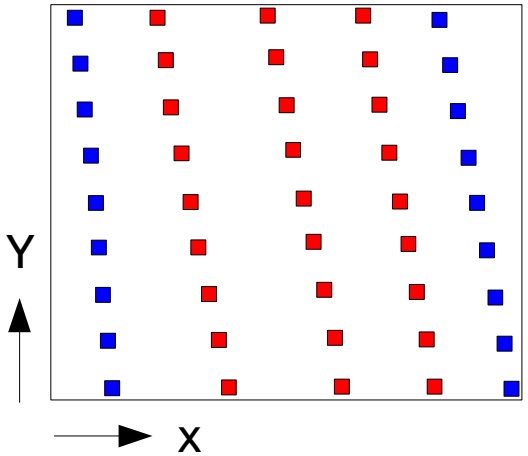
$$P(\boldsymbol{M}odel, dualTI|\boldsymbol{D}ata) = \Sigma_k P(\boldsymbol{M}|dualTI_k, \boldsymbol{D}) P(dualTI_k|\boldsymbol{D})$$

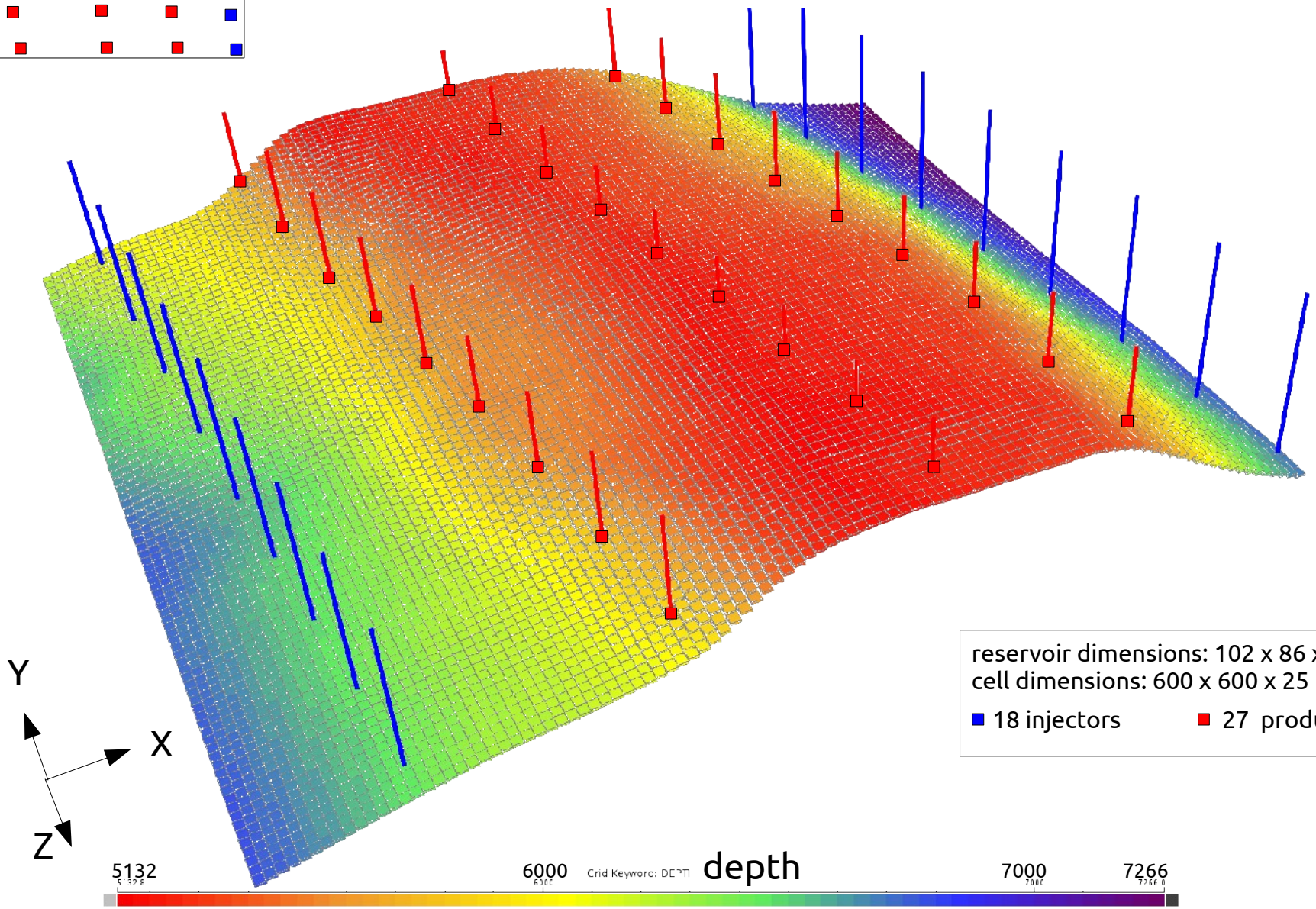
update probabilities
of scenarios

$P(dualTI_k|\boldsymbol{D})$ eliminate/reject Dual-Medium scenario without HM

$P(\boldsymbol{M}|dualTI_k, \boldsymbol{D})$ HM with accepted (not eliminated) Dual-Medium scenarios

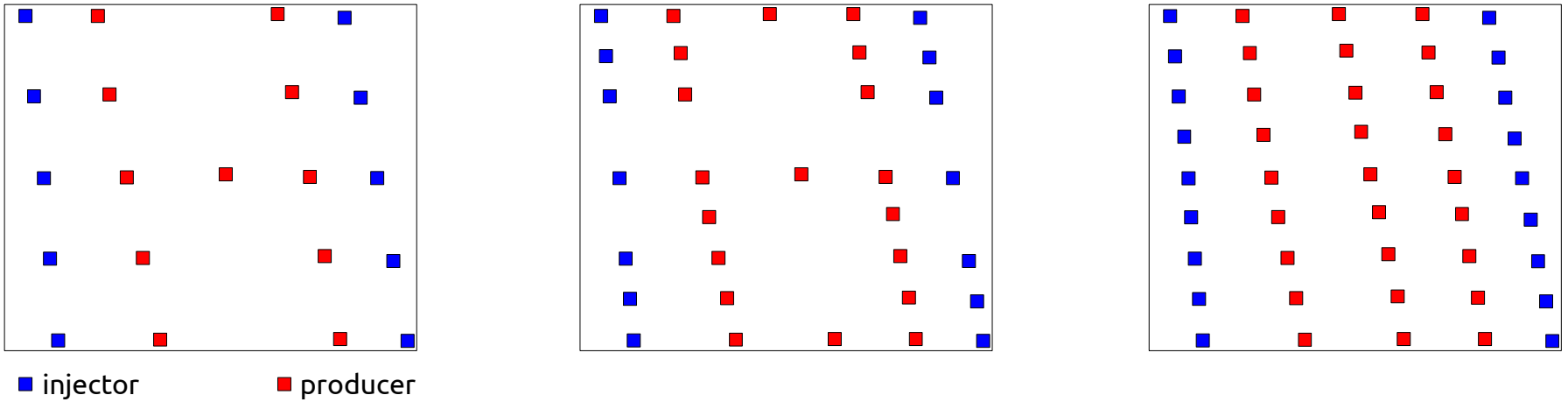
Well configuration



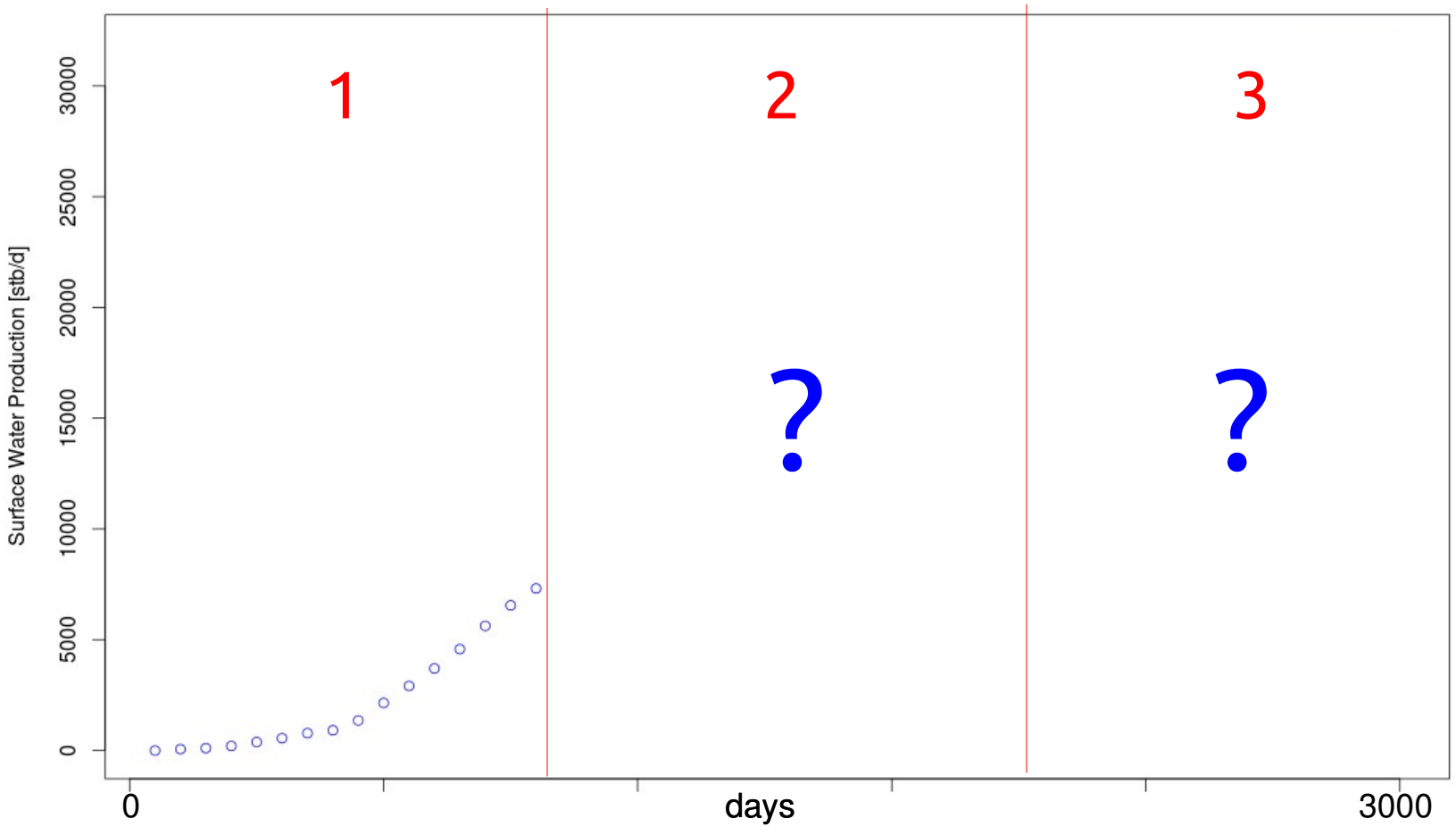


reservoir dimensions: 102 x 86 x 1 cells
cell dimensions: 600 x 600 x 25 ft

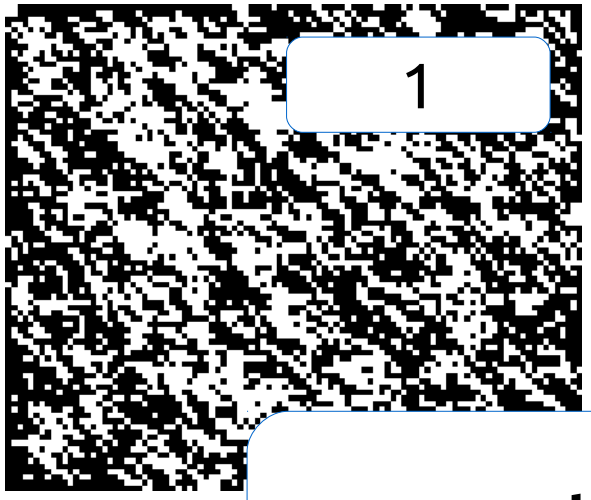
■ 18 injectors ■ 27 producer

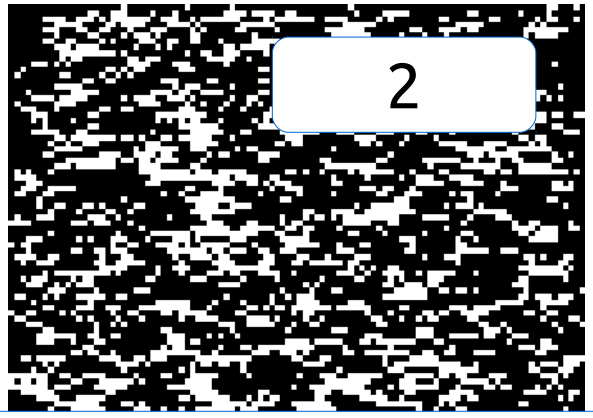


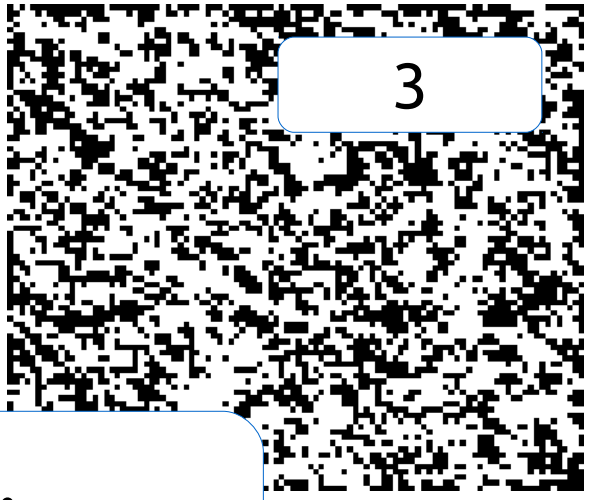
field response

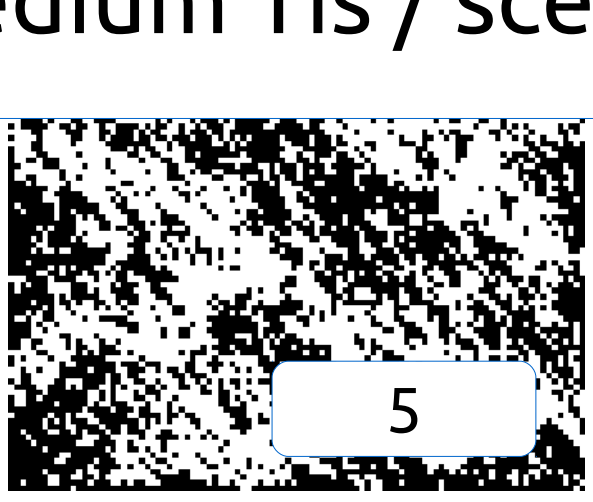


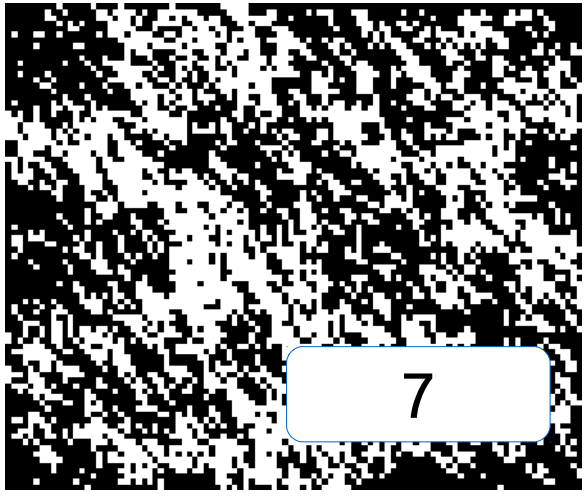
Dual Medium Tis / scenarios

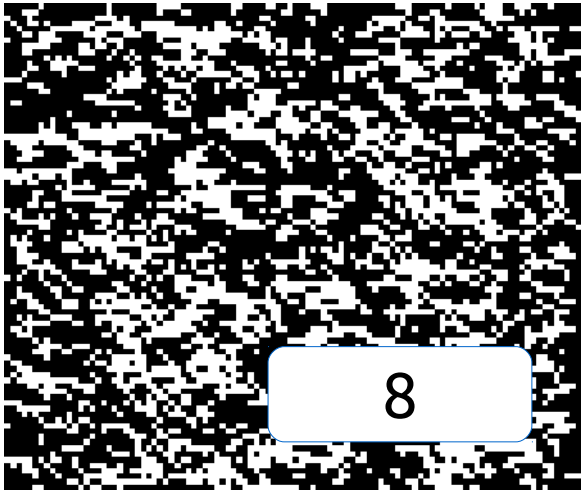


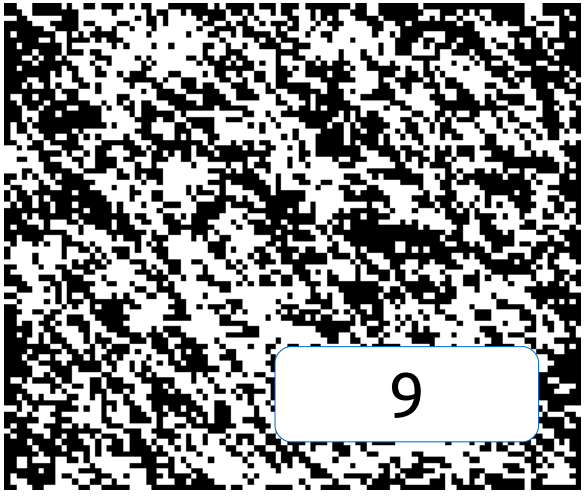




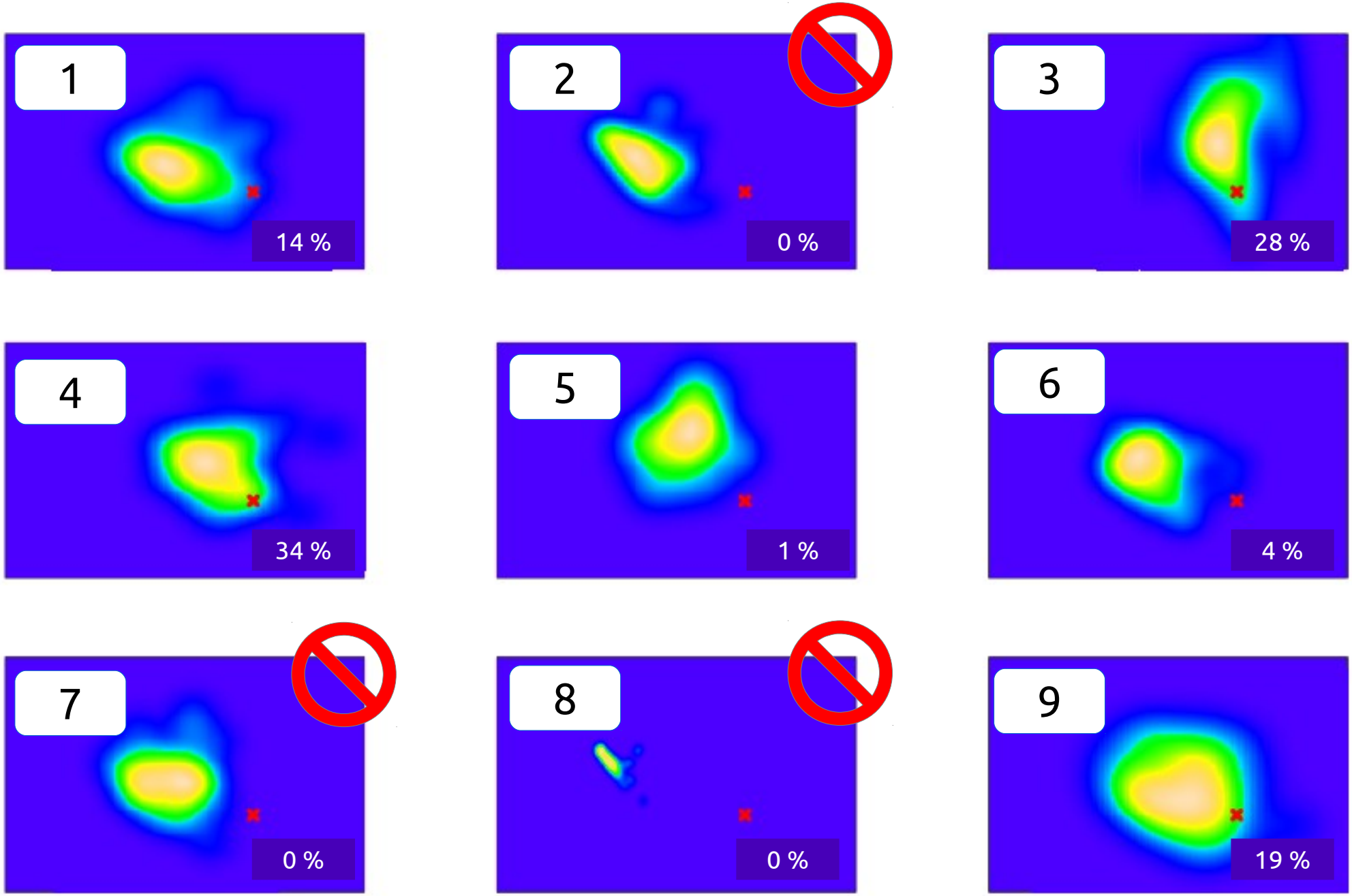








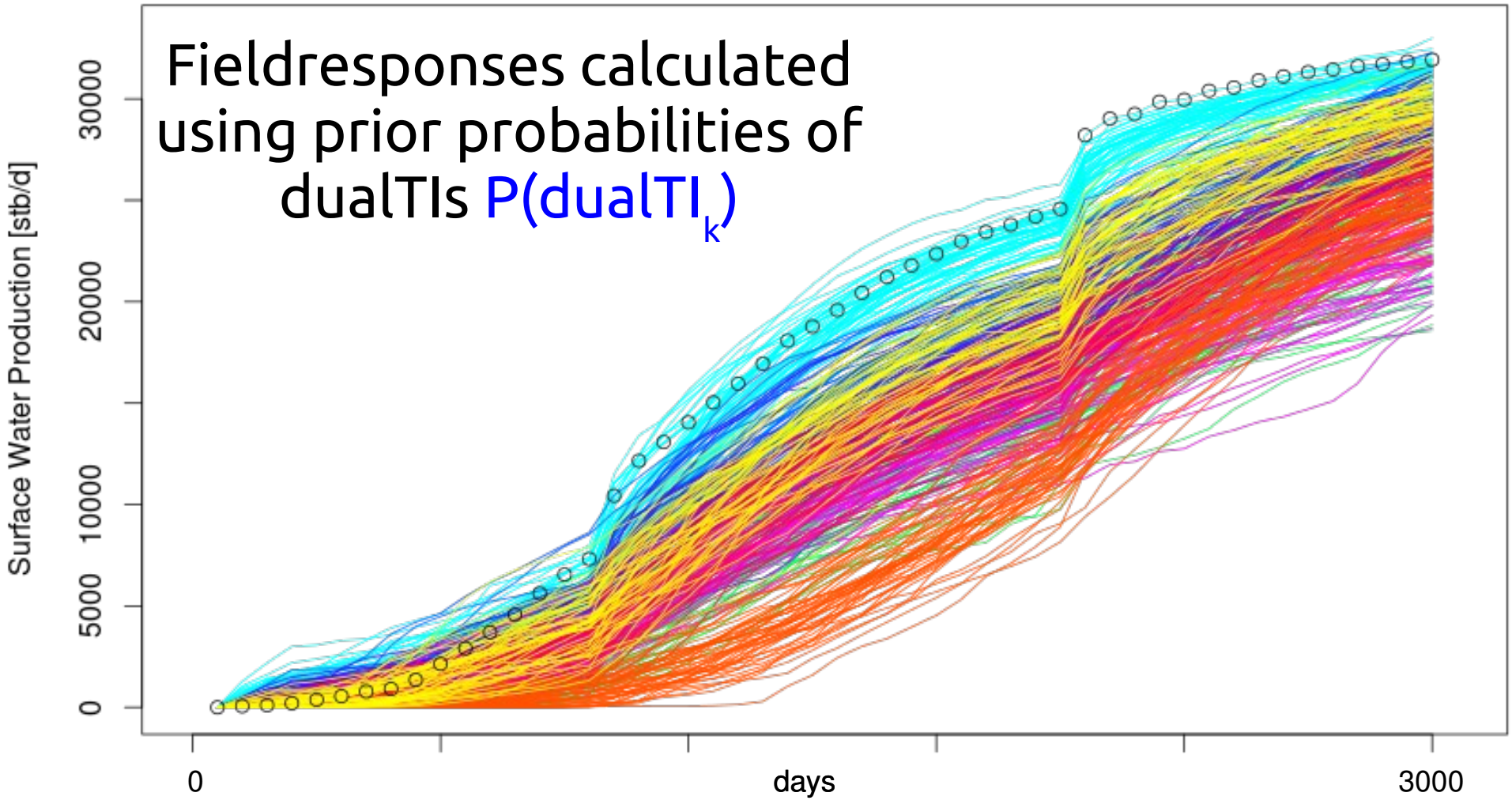
Phase 1: Kernel Density Estimation



Updating of scenario uncertainty

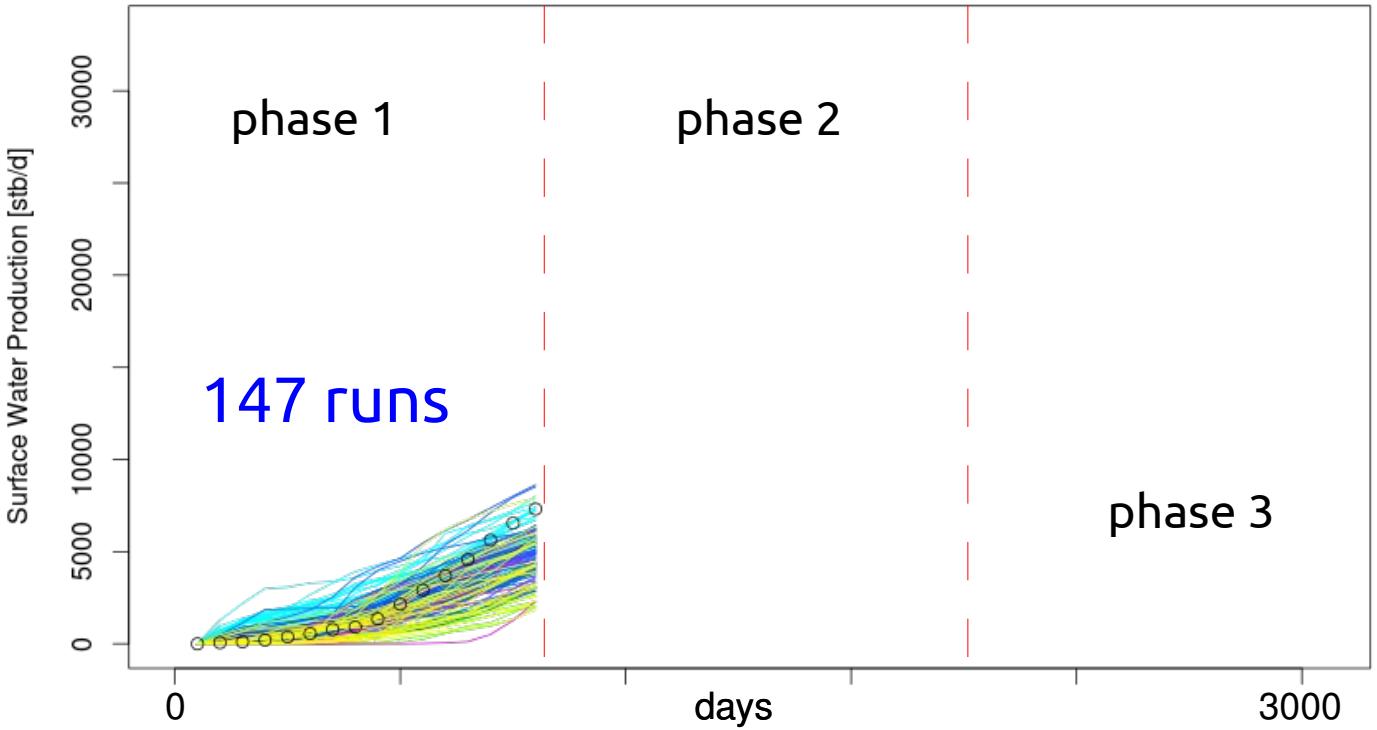
		phase 1	phase 1+2	phase 1+2+3
Ti 1	11 %	14 %	0 %	0 %
Ti 2	11%	0 %	0 %	0 %
Ti 3	11%	28%	90 %	100 %
Ti 4	11 %	34 %	7 %	0 %
Ti 5	11 %	1 %	1 %	0 %
Ti 6	11 %	4 %	0 %	0 %
Ti 7	11 %	0 %	0 %	0 %
Ti 8	11 %	0 %	0 %	0 %
Ti 9	11 %	19 %	2 %	0 %

Forecasting: without HM ↔ with HM



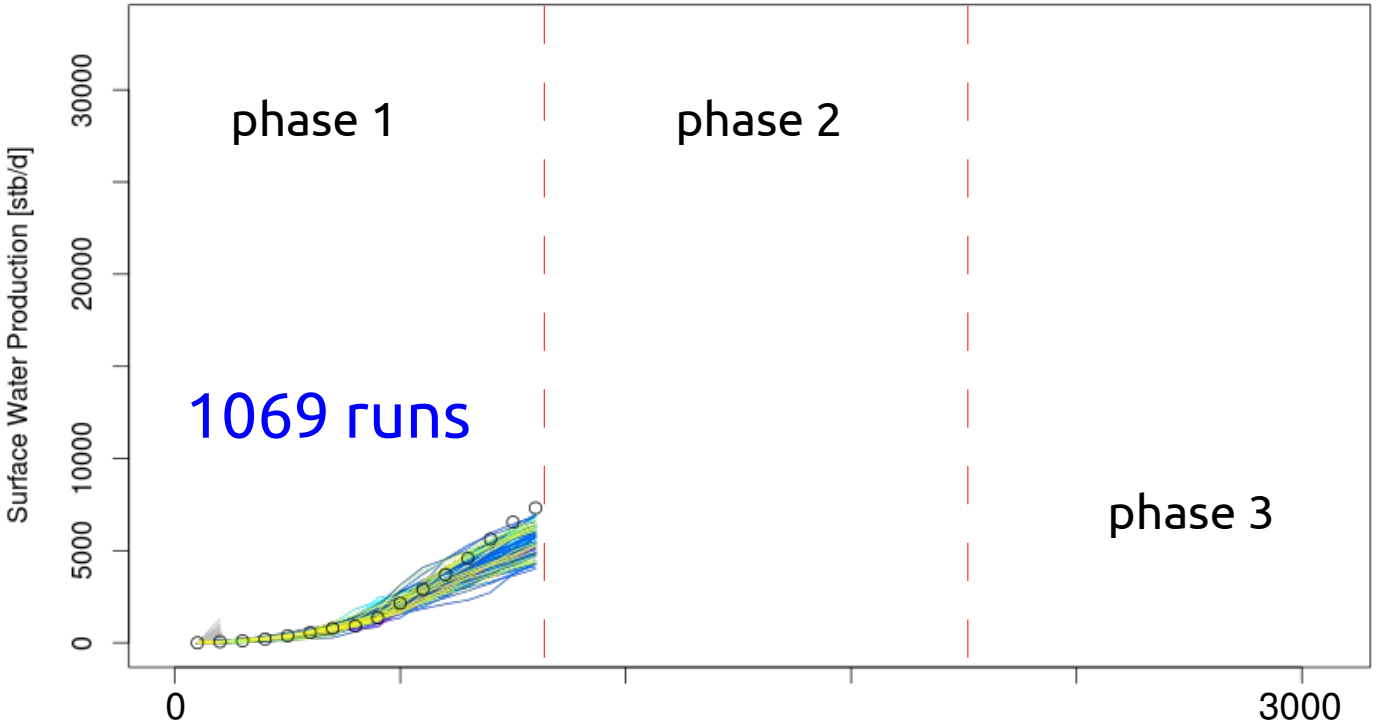
Forecasting <u>without</u> HM

using only
$P(dualTI_k|\boldsymbol{D})$



Forecasting <u>with</u> HM

using both
$P(dualTI_k|\boldsymbol{D})$
and
$P(\boldsymbol{M}|dualTI_k,\boldsymbol{D})$



Forecasting <u>without</u> HM

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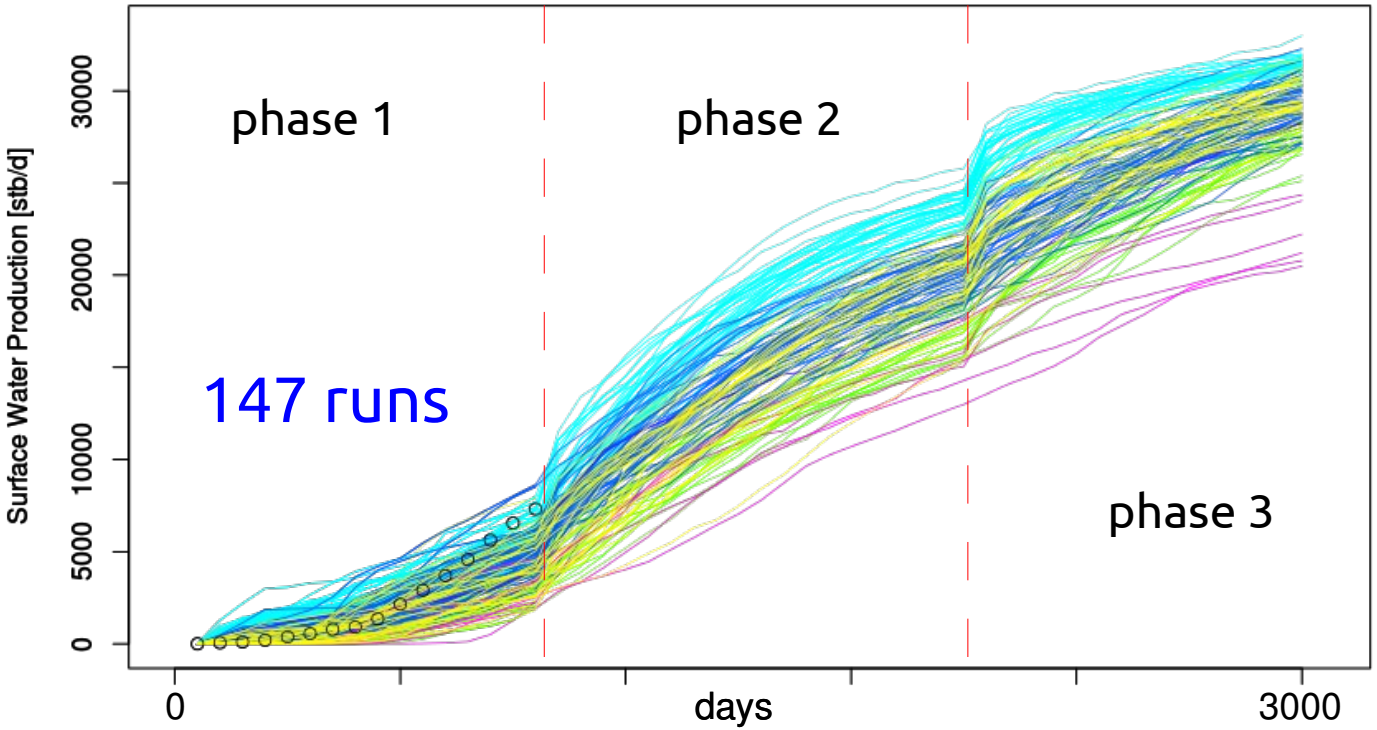
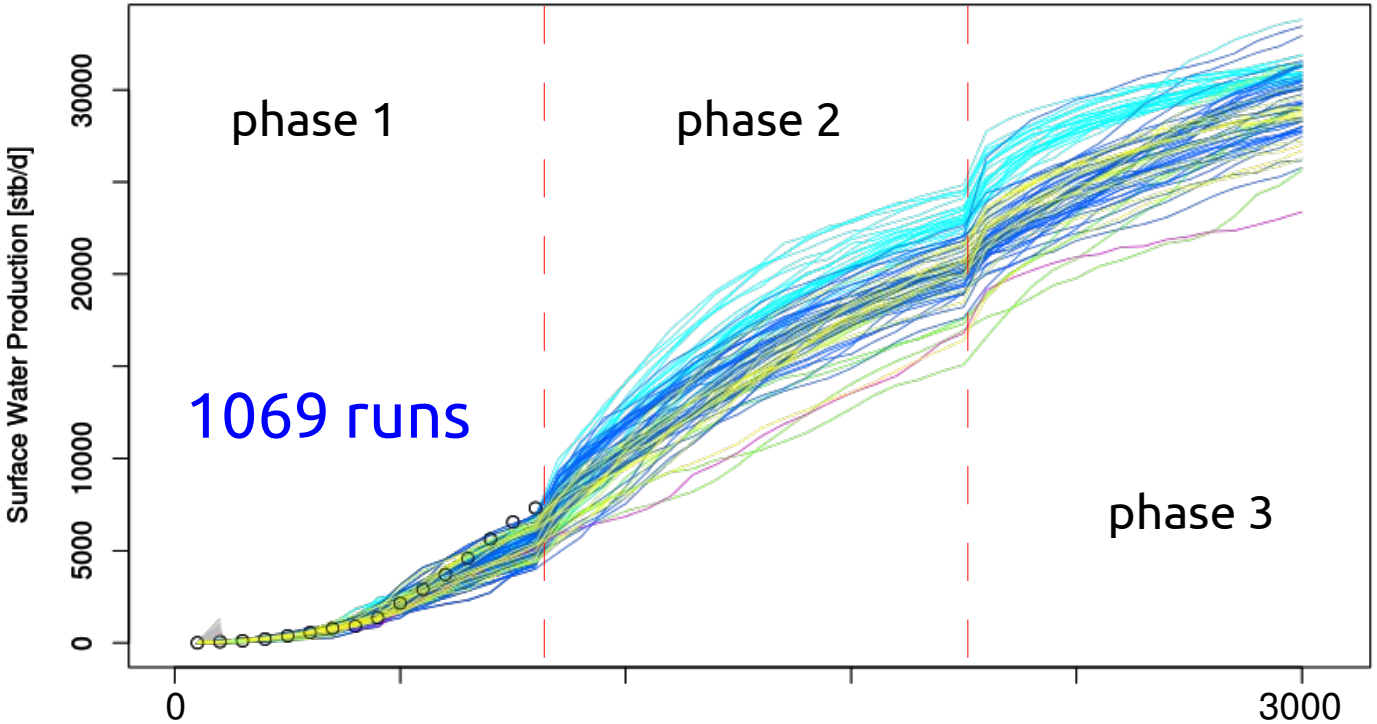


Forecasting <u>with</u> HM

using both
$P(dualTI_k|\boldsymbol{D})$
and
$P(\boldsymbol{M}|dualTI_k,\boldsymbol{D})$



Conclusions

- pattern-based approach to fractured reservoirs
- easy to implement with existing software
- rapid uncertainty quantification (MPS & SL)
- fast, scenario-based forecasting

Acknowledgments

FracMan (Golder Associates)

- Neal Josephson
- Aaron Fox
- Glori Lee

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