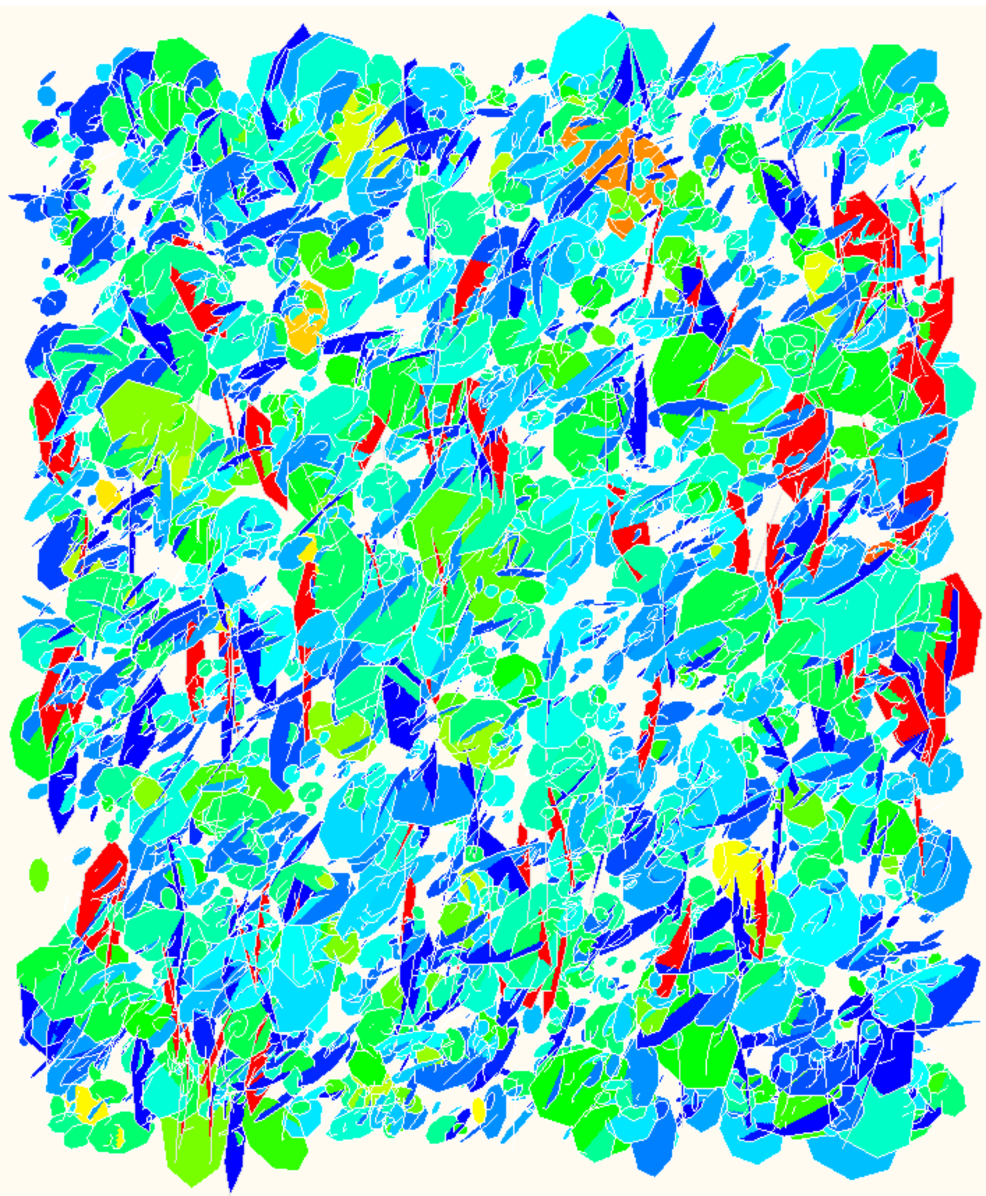
25th Anniversary Meeting of the Stanford Center for Reservoir Forecasting, May 9 2012

Accounting for Uncertainty in Dual Porosity Descriptions of Fractured Systems

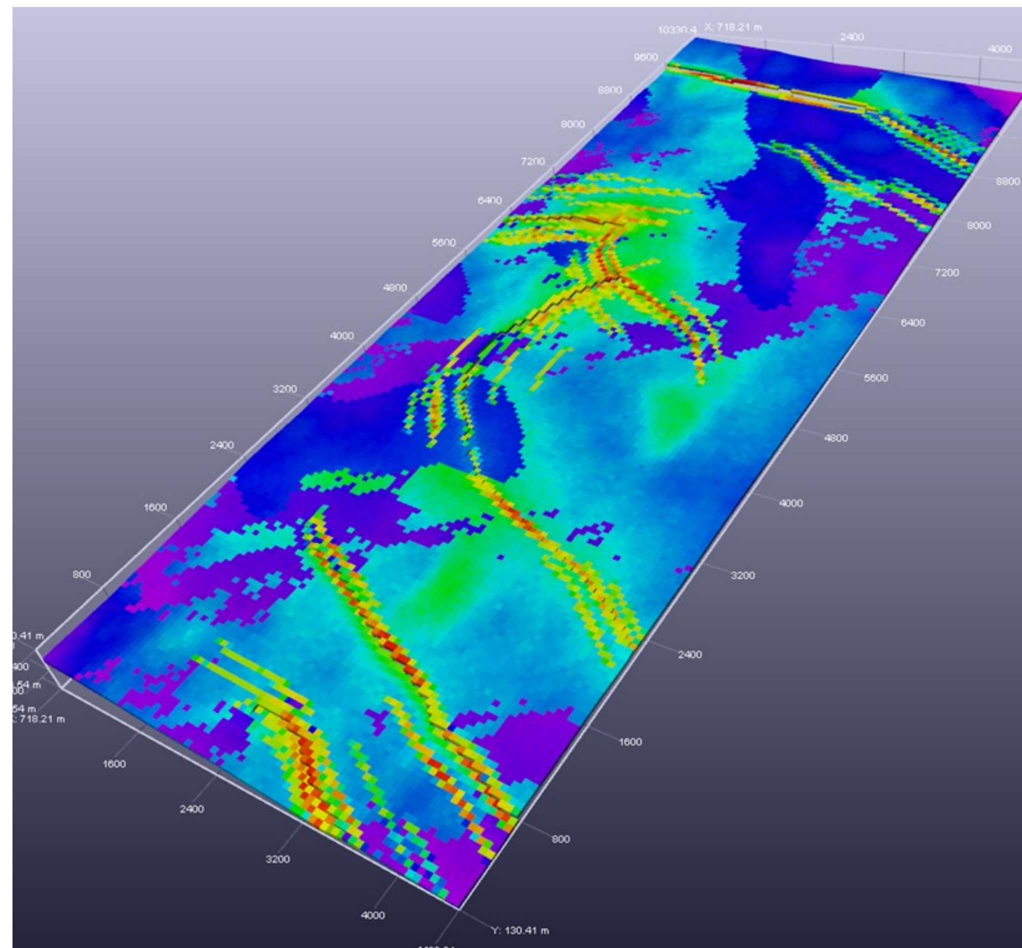
Andre Jung, Jef Caers, Stanford University
Darryl Fenwick, Streamsim Technologies

Two Worlds

Models <u>built</u>
by Geologists



Models <u>used</u>
by Engineers



Naturally Fractured Reservoirs

The Purpose:

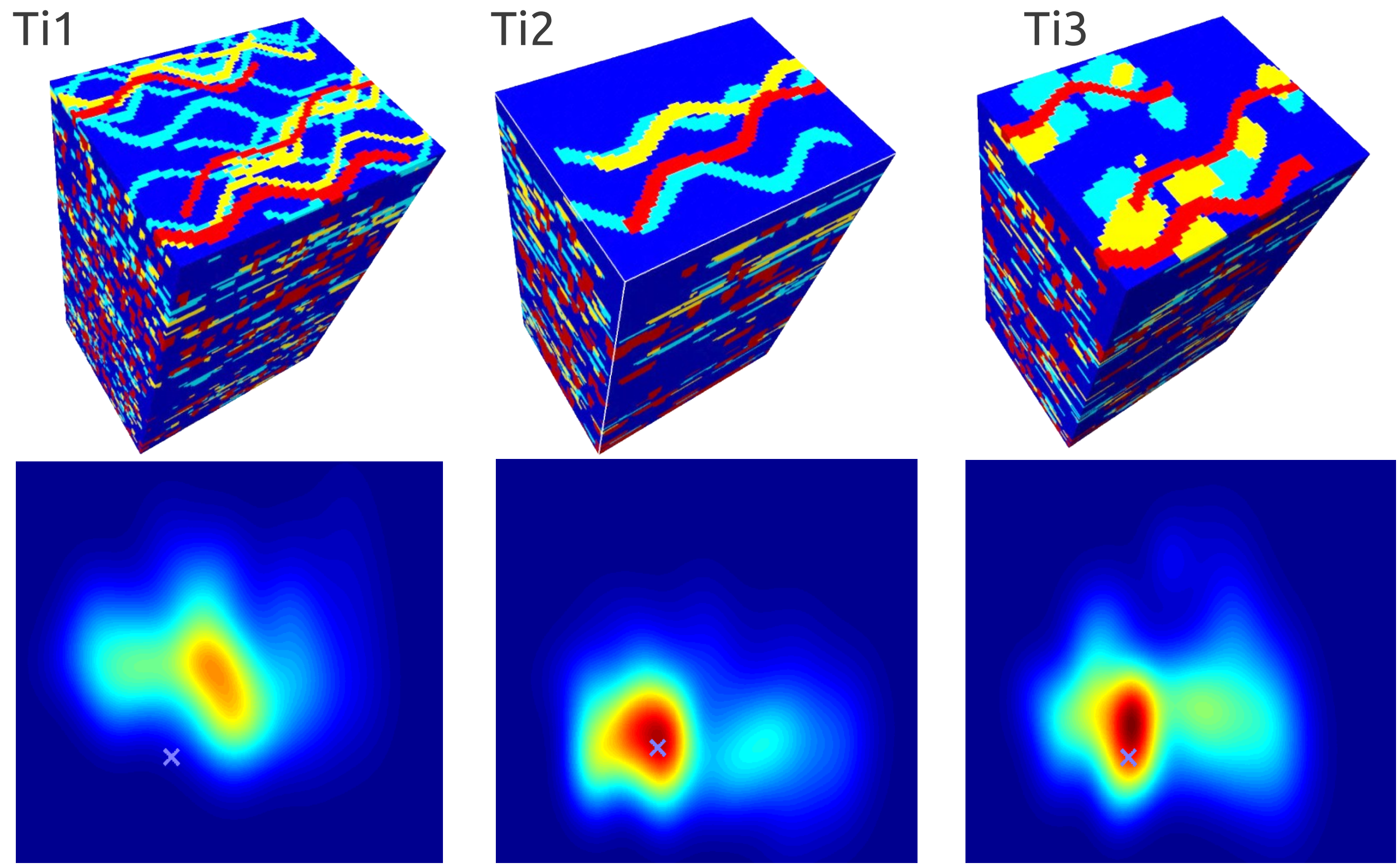
- Uncertainty Quantification
- History Matching

The Challenge:

- Geologically consistent
- Field Scale
- Integration with existing Software

… this morning: Scenario Uncertainty

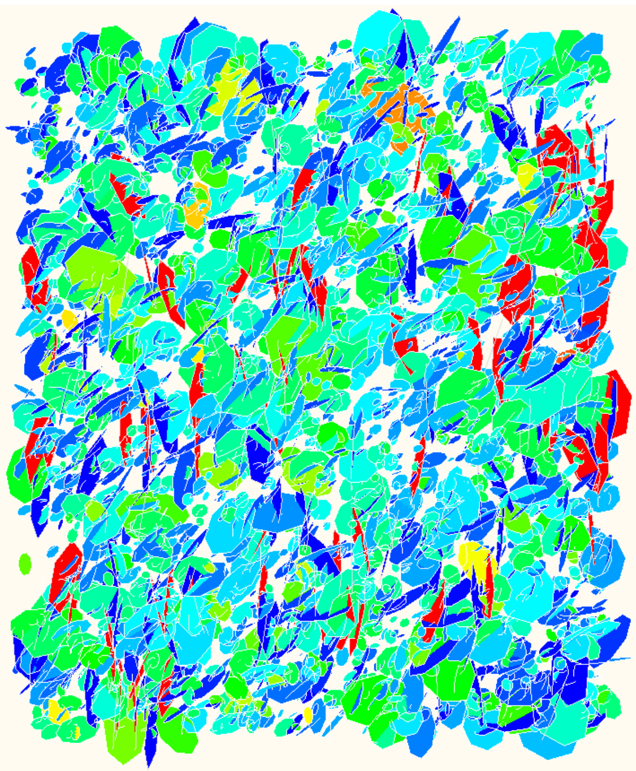
Rejection of
Geological Scenarios / Training Images
based on the data



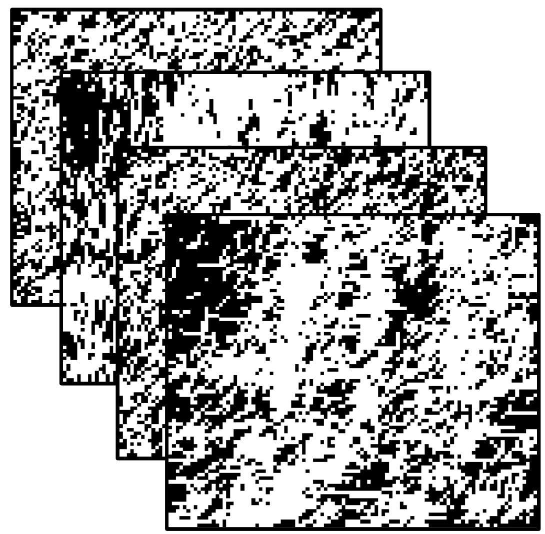
Hyucksoo Park, Céline Scheidt and Jef Caers

Can we build
Training Images for Fractures?

General Overview of Methodology



Complex Fracture Models

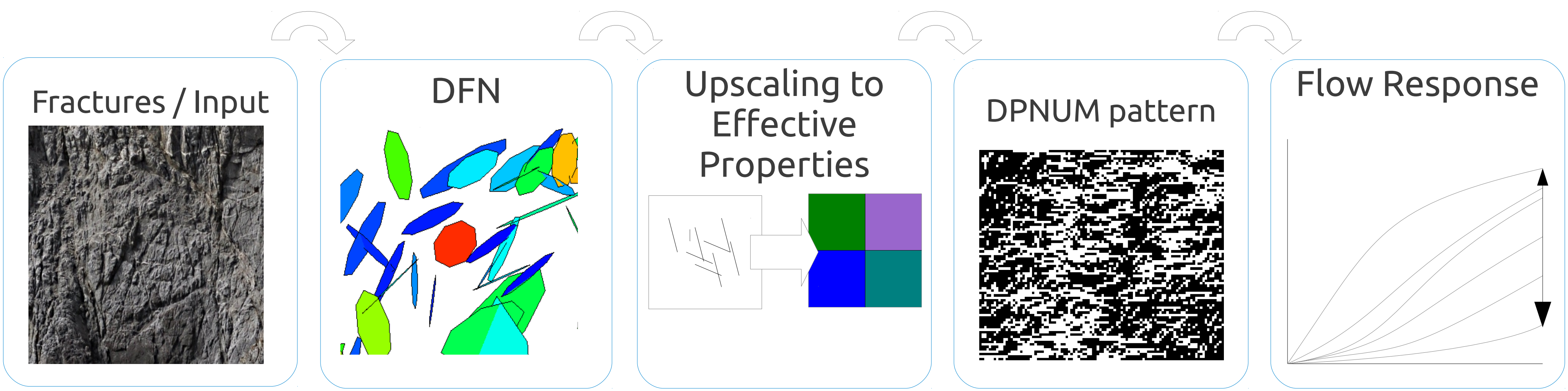


Limited / Manageable Set of flow-based scenarios for Training Images

- Geostatistics
- History Matching
- PPM
- ...

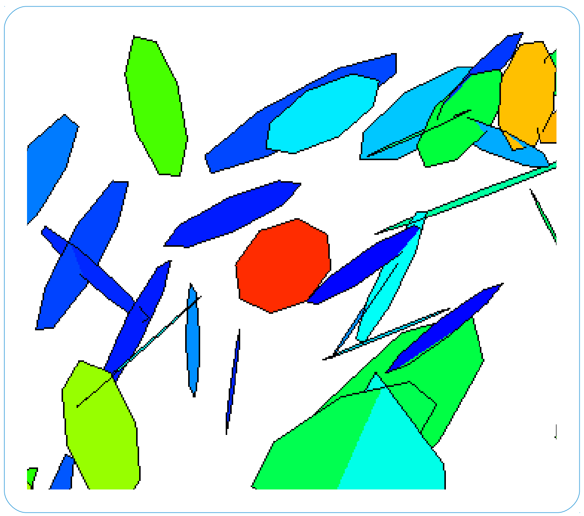
The Idea

- Generate Discrete Fracture Network (FracMan)
- Upscale to Effective Properties (grid)
- Decide which cells are Dual-Porosity → pattern
- Run Streamline Simulation (3DSL)
- Select flow responses via pattern-based distances



Upscaling Fracture Model (DFN) to Flow Model

Fracture Model



1 grid block

Effective Properties

“Oda (Gold)” (analytical), BlockK (flow based), … → Permeability $K_{X,Y,Z}$

“Shape Factor” fracture/matrix interaction Sigma, Gilman & Kazemi, … (analytical) → Sigma

Fracture Volume → Porosity

DP model: ON/OFF

Effective Properties

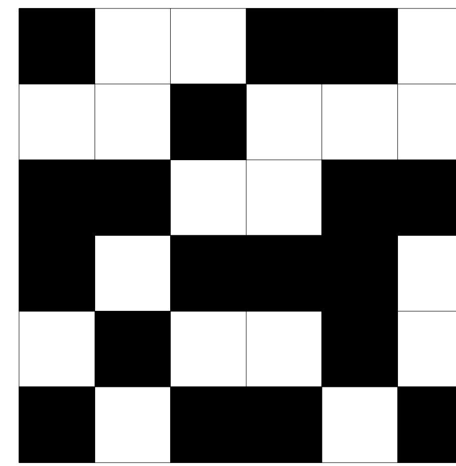
Permeability
$K_{X,Y,Z}$

Porosity

Sigma

Threshold
$(Kx,Ky,Kz,\varphi,\sigma) > \varepsilon$

DPNUM pattern



ON: fractured

OFF: non-fractured

DPNUM pattern

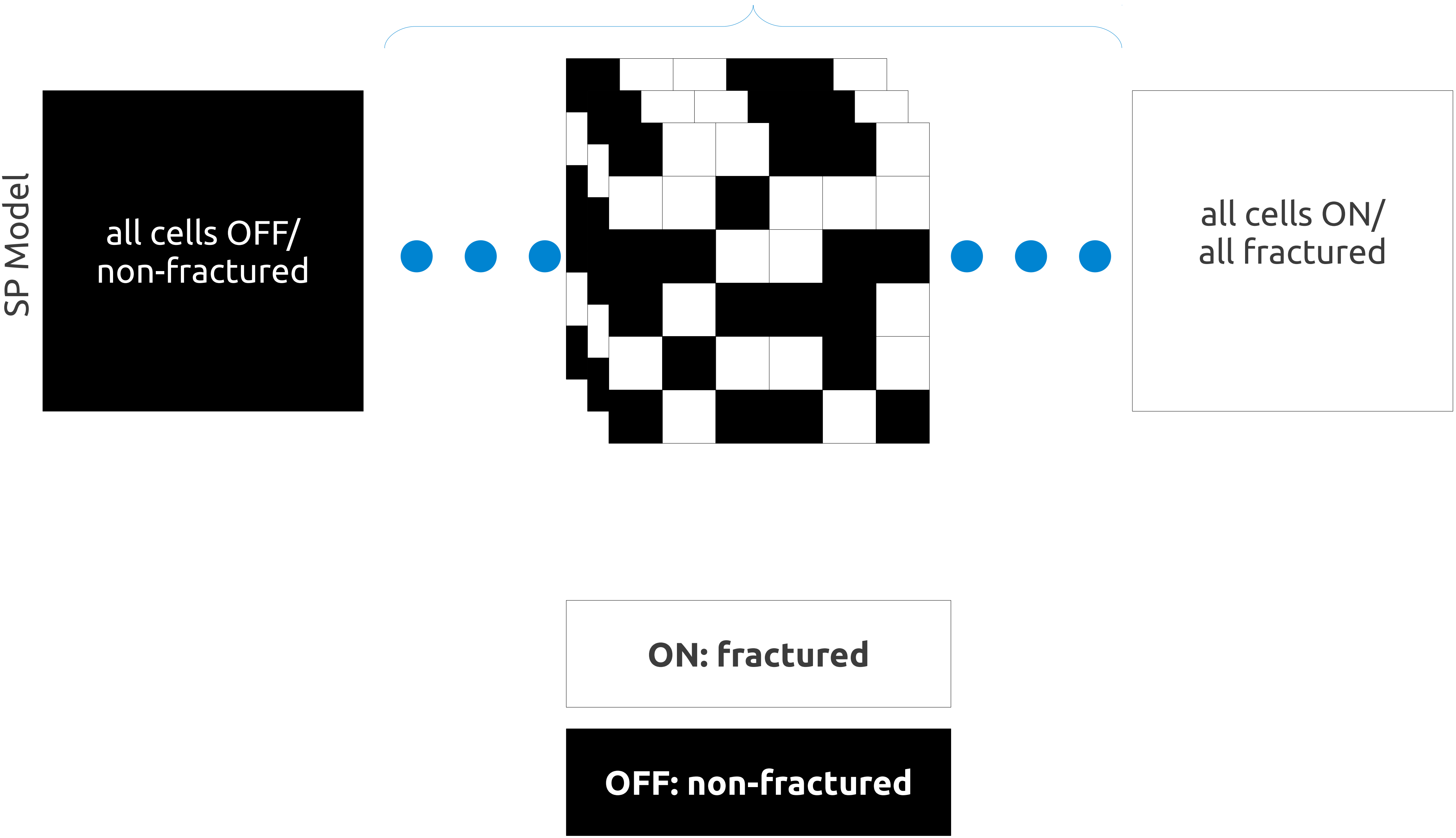
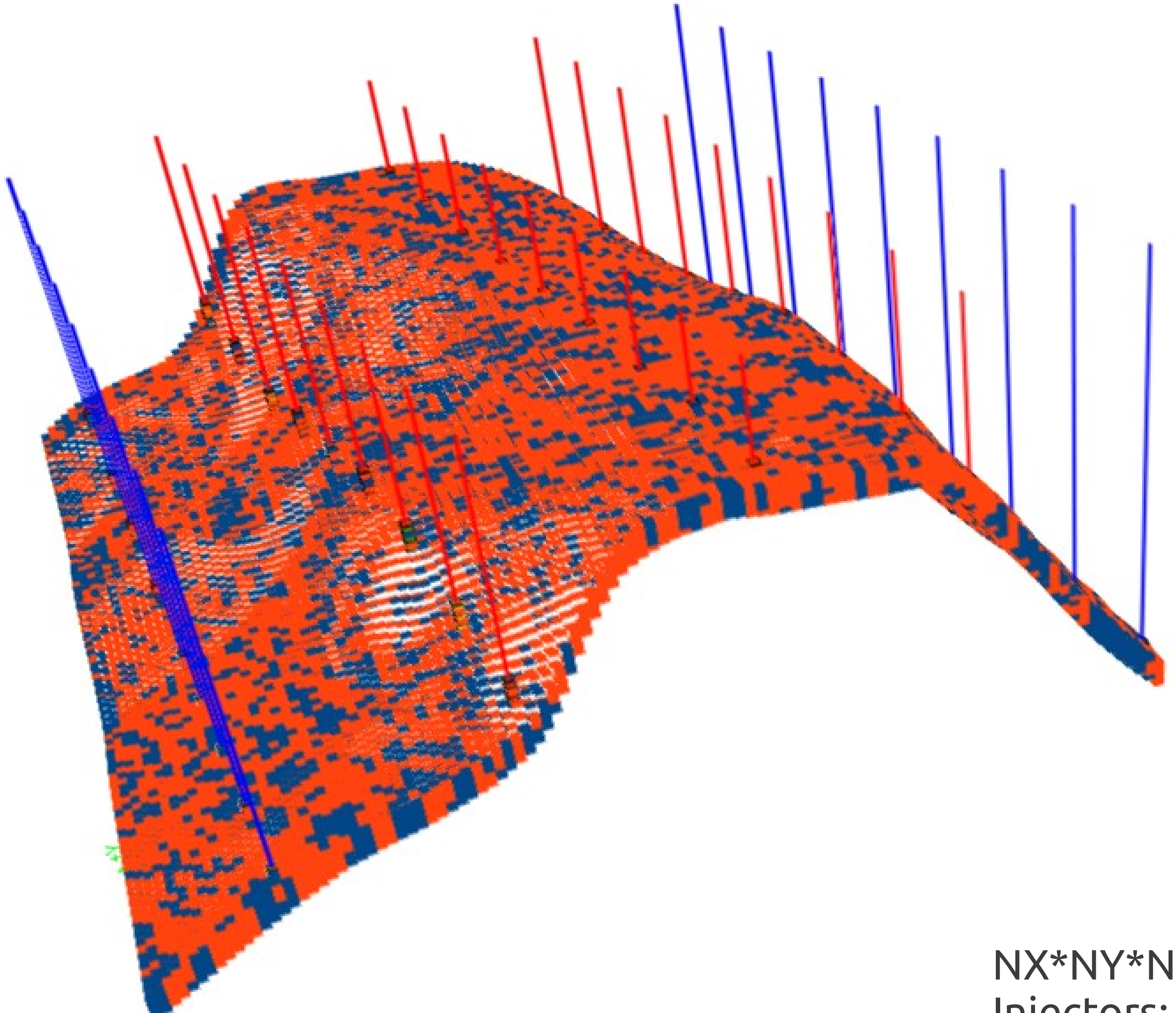


Illustration 1

Streamline Simulation Model



NX*NY*NZ: 102*86*5
Injectors: 18
Producers: 27

Building the Illustration Case

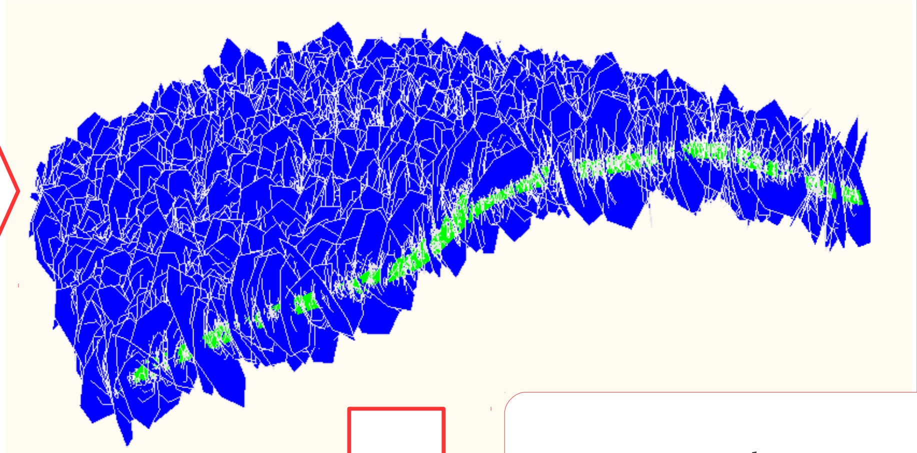
Varied Fracture Parameters:

- intensity
- size (distribution)
- trend (azimuth)
- orientation (distribution)
- constrained to structure
- 2^{nd} fracture set

→ 96 combinations

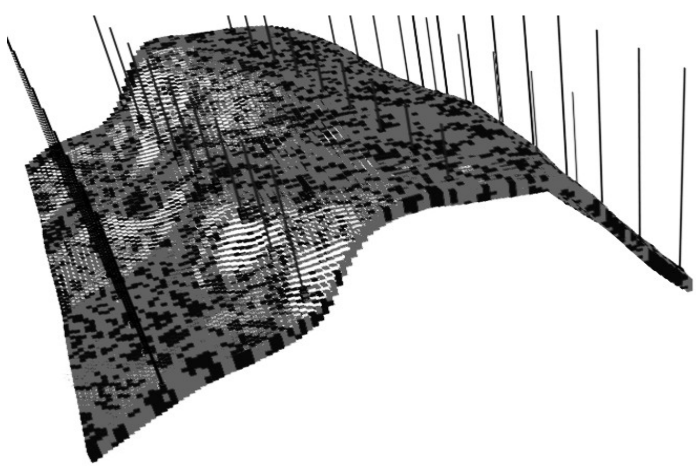
Fixed: hydraulic parameters

Fracture Models

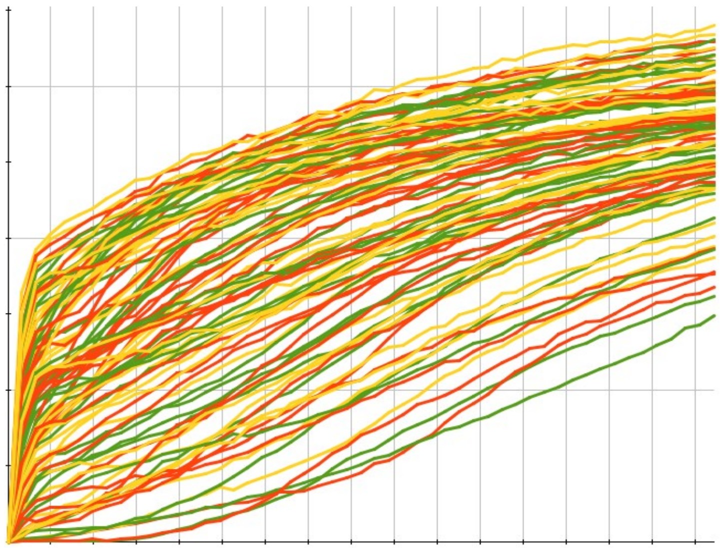


Upscaling to Effective Properties & Threshold

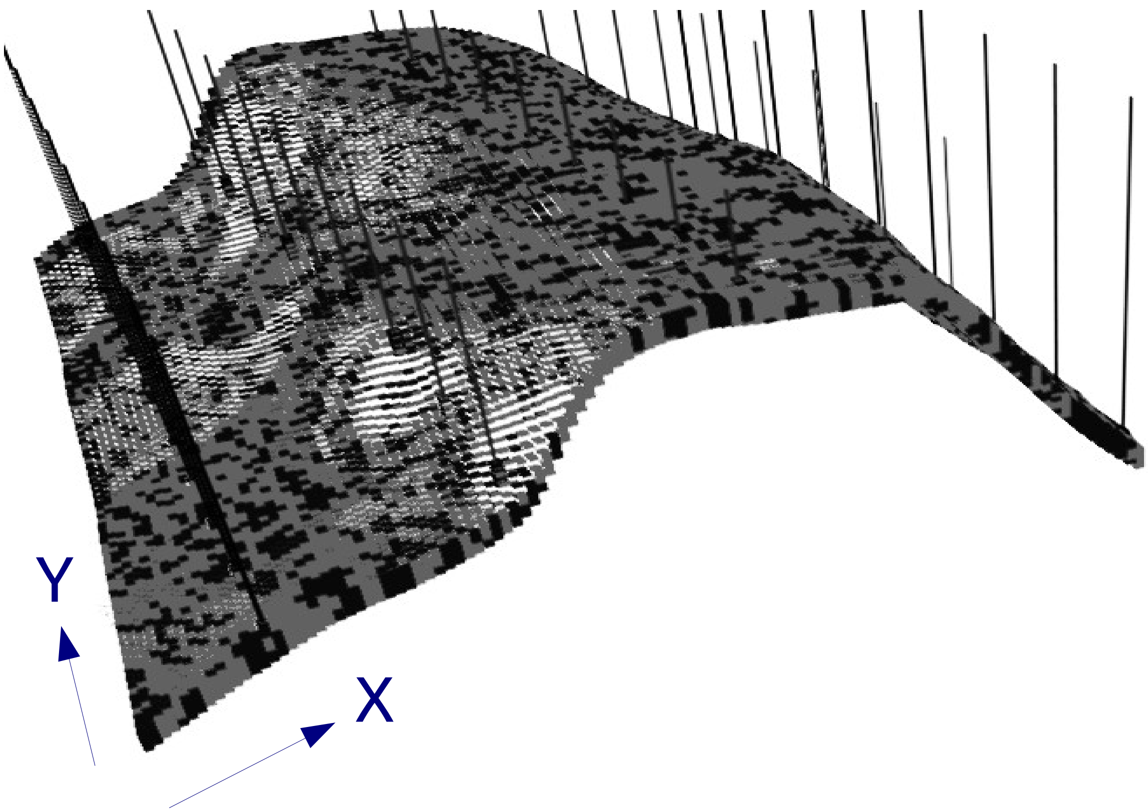
DPNUM pattern



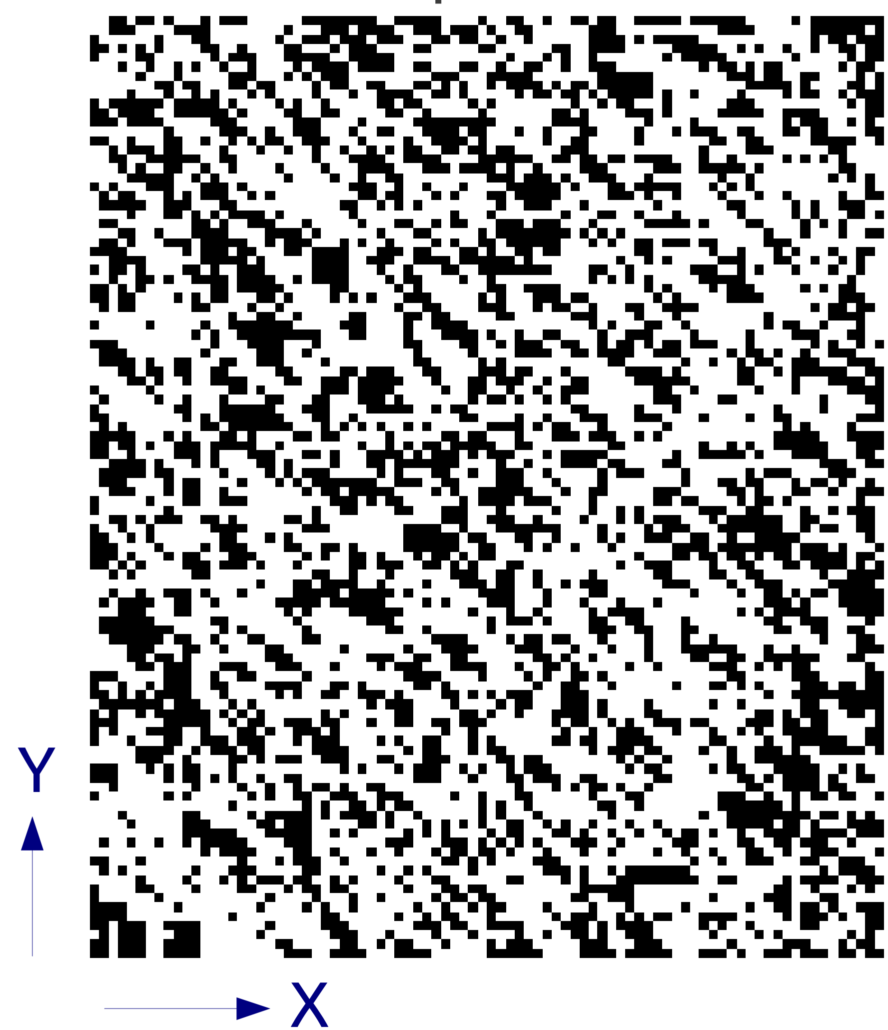
Flow Responses



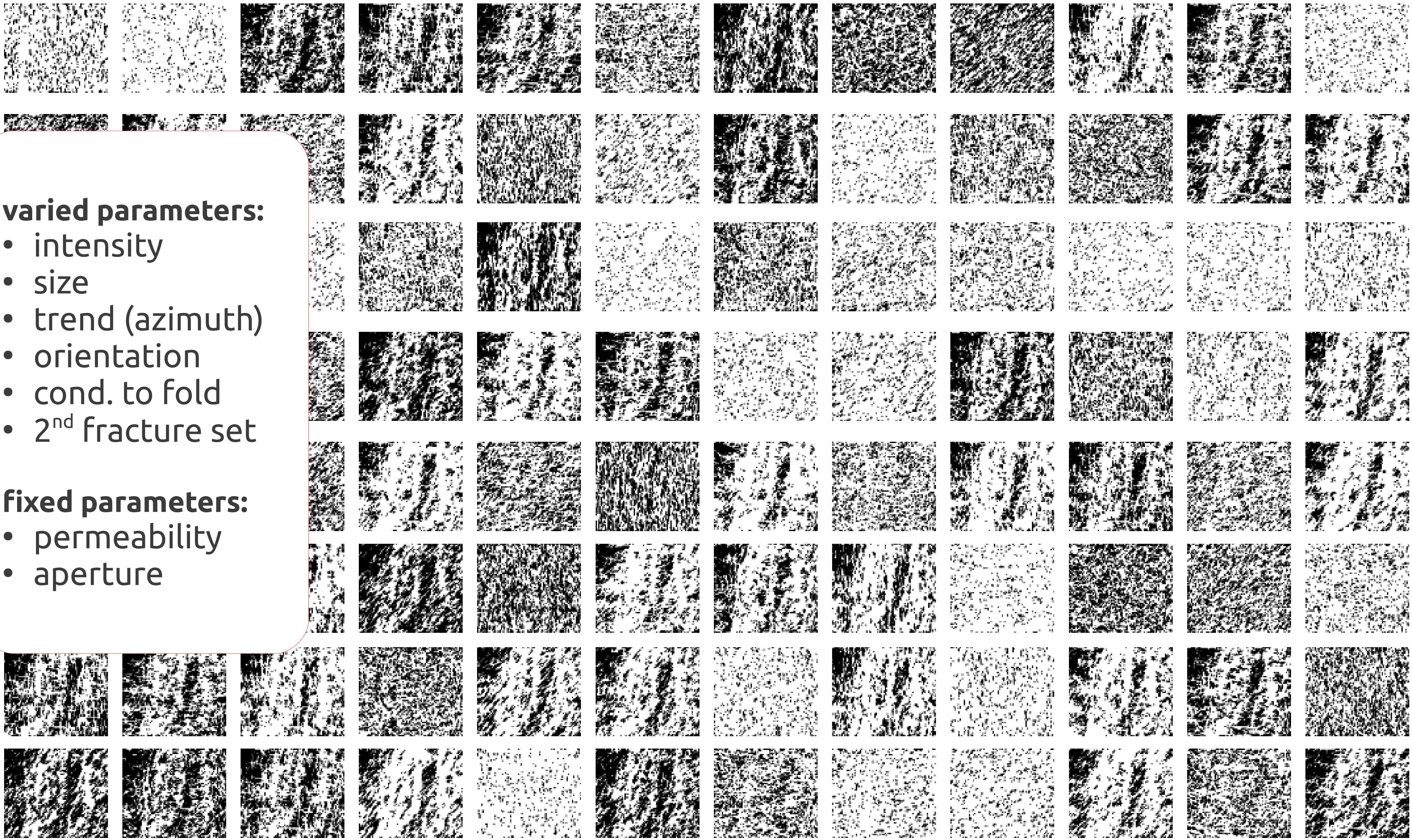
pattern from different perspectives



top view



96 patterns through parameter variation

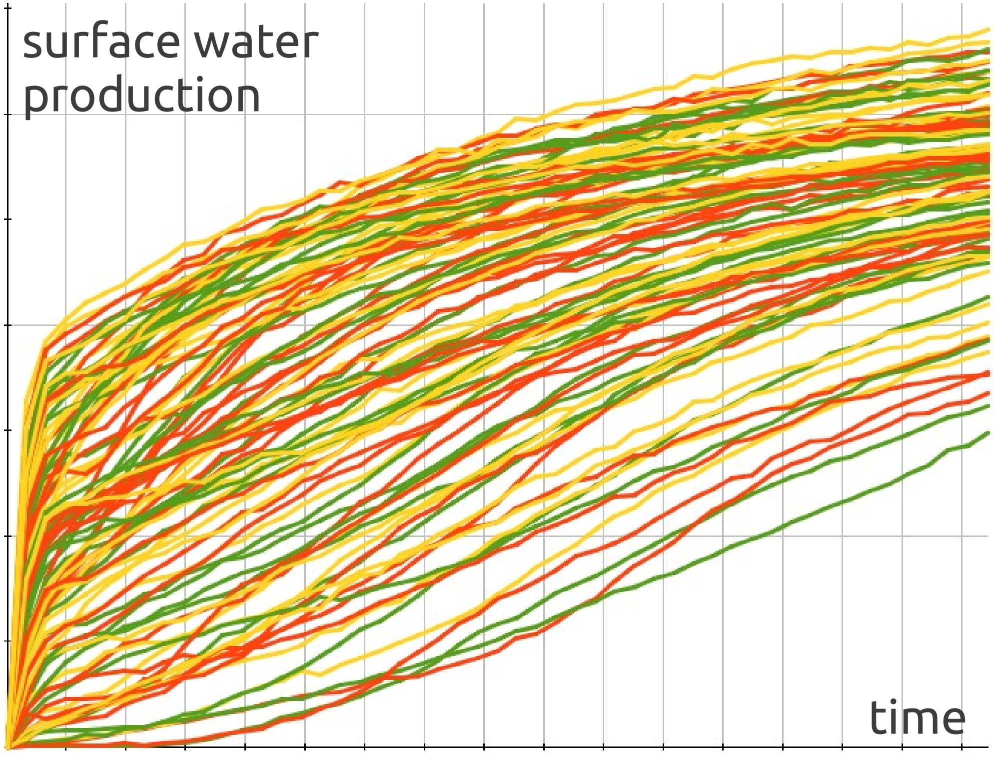


varied parameters:
- intensity
- size
- trend (azimuth)
- orientation
- cond. to fold
- 2^{nd} fracture set

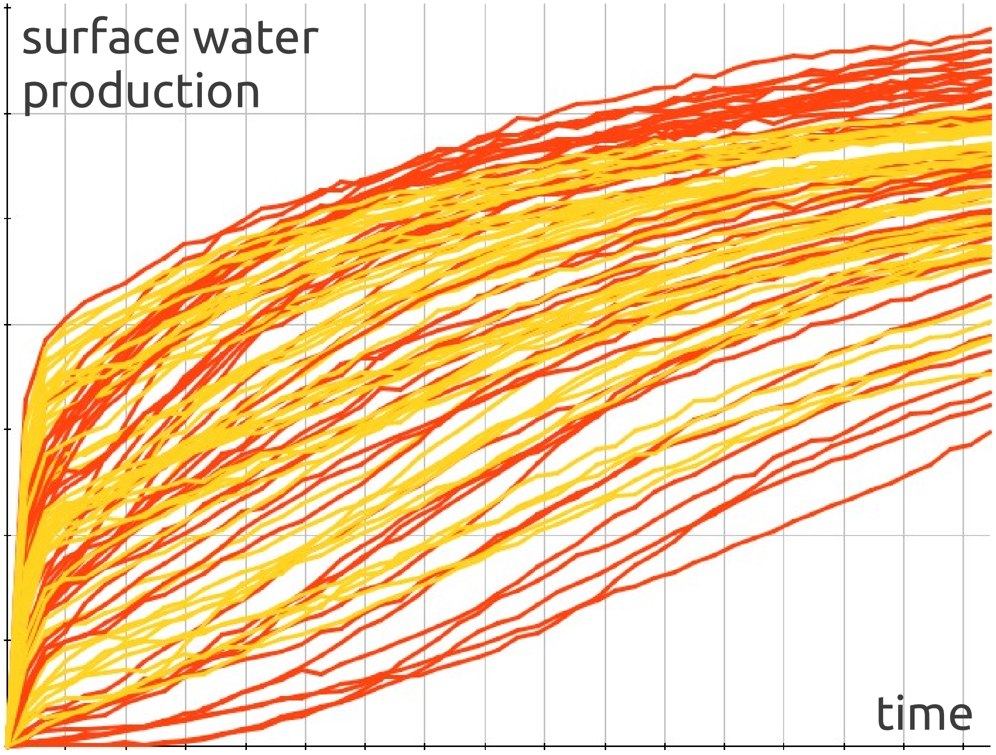
fixed parameters:
- permeability
- aperture

96 Field Responses: sensitivity to DFN input parameters

Trend (Azimuth) of Fractures

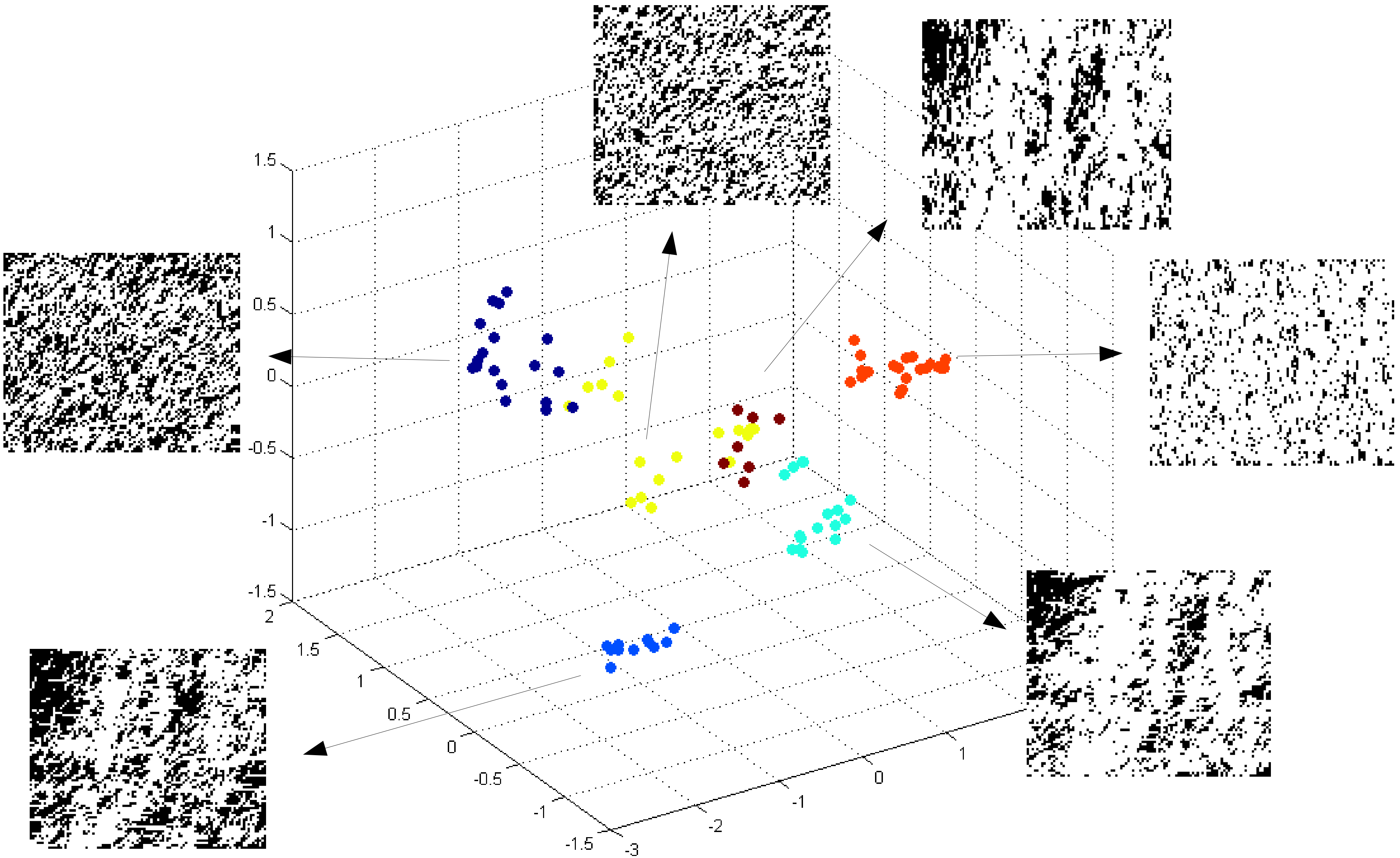


Intensity constraint to structure: yes/no



Let's try an approach based on the patterns

Patterns clustered by Modified Hausdorff Distance



96 Field Responses by pattern

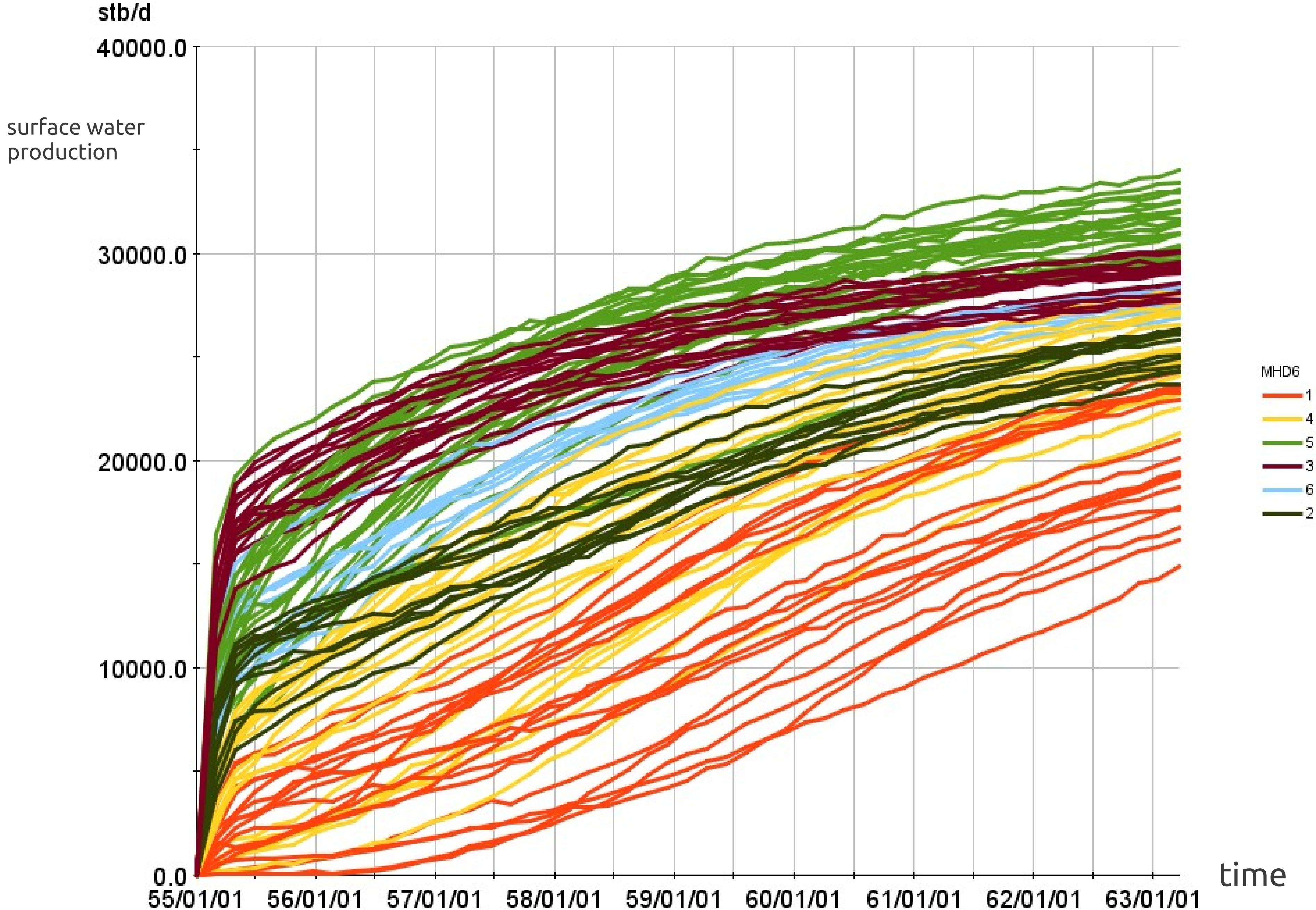


Illustration 2

Spatial Uncertainty

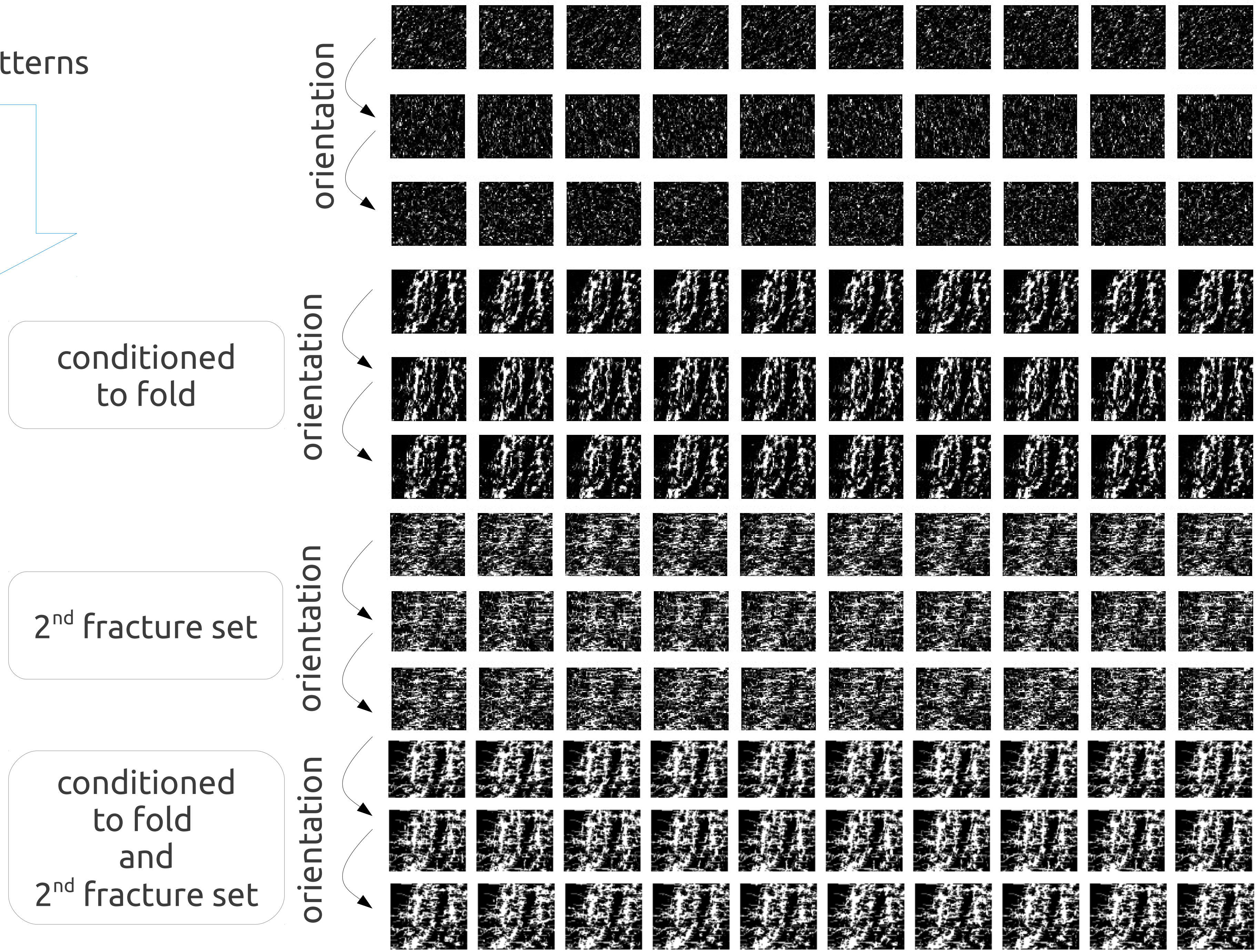
Spatial Uncertainty

- Pick 4 DFN parameter sets (distinct patterns)
- Apply 3 variations (trend of fractures)
- Run 10 Realizations of DFN per parameter set
  - ➔ 120 Flow Responses
- Group Flow Responses by parameter set

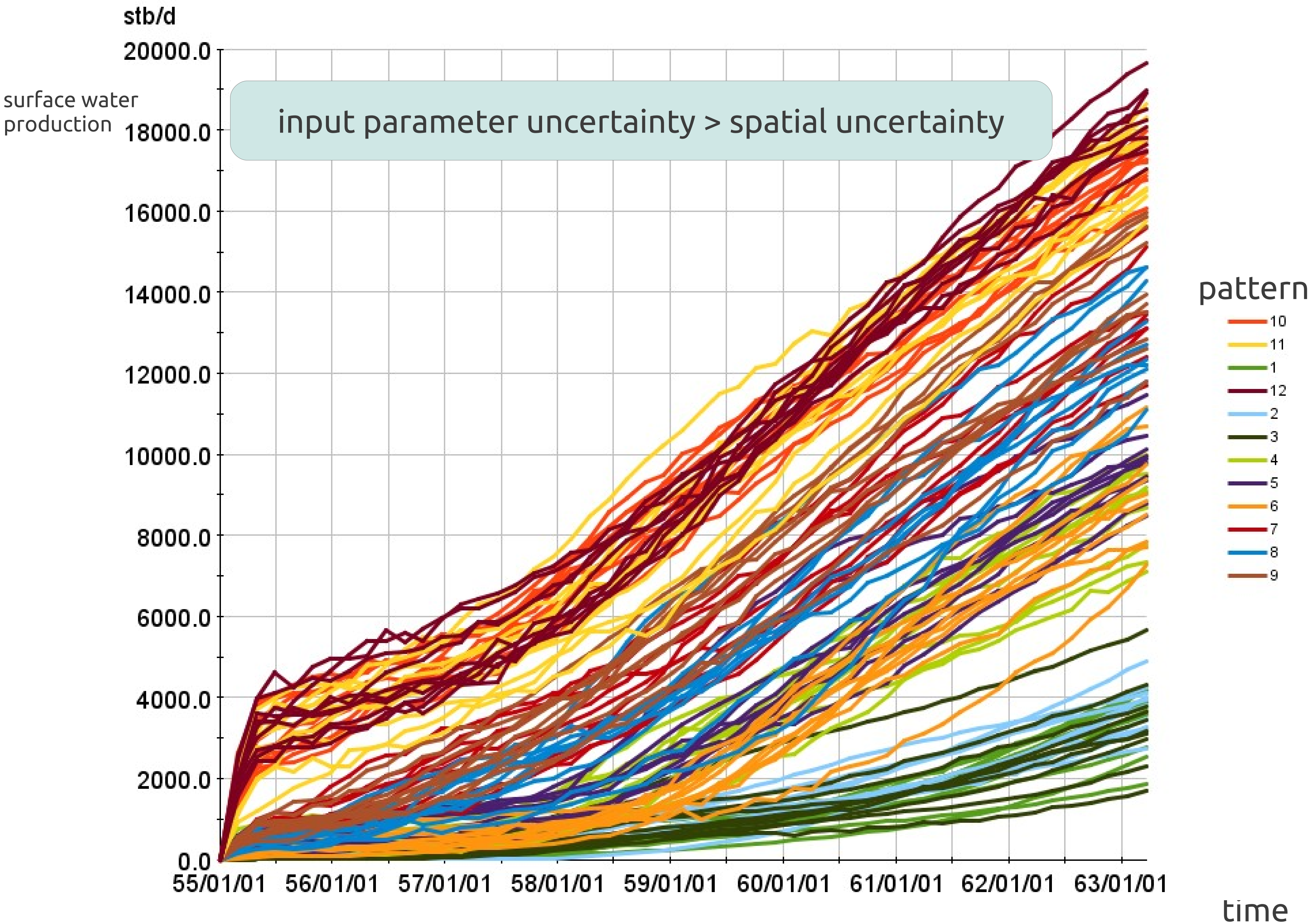
Spatial uncertainty of patterns

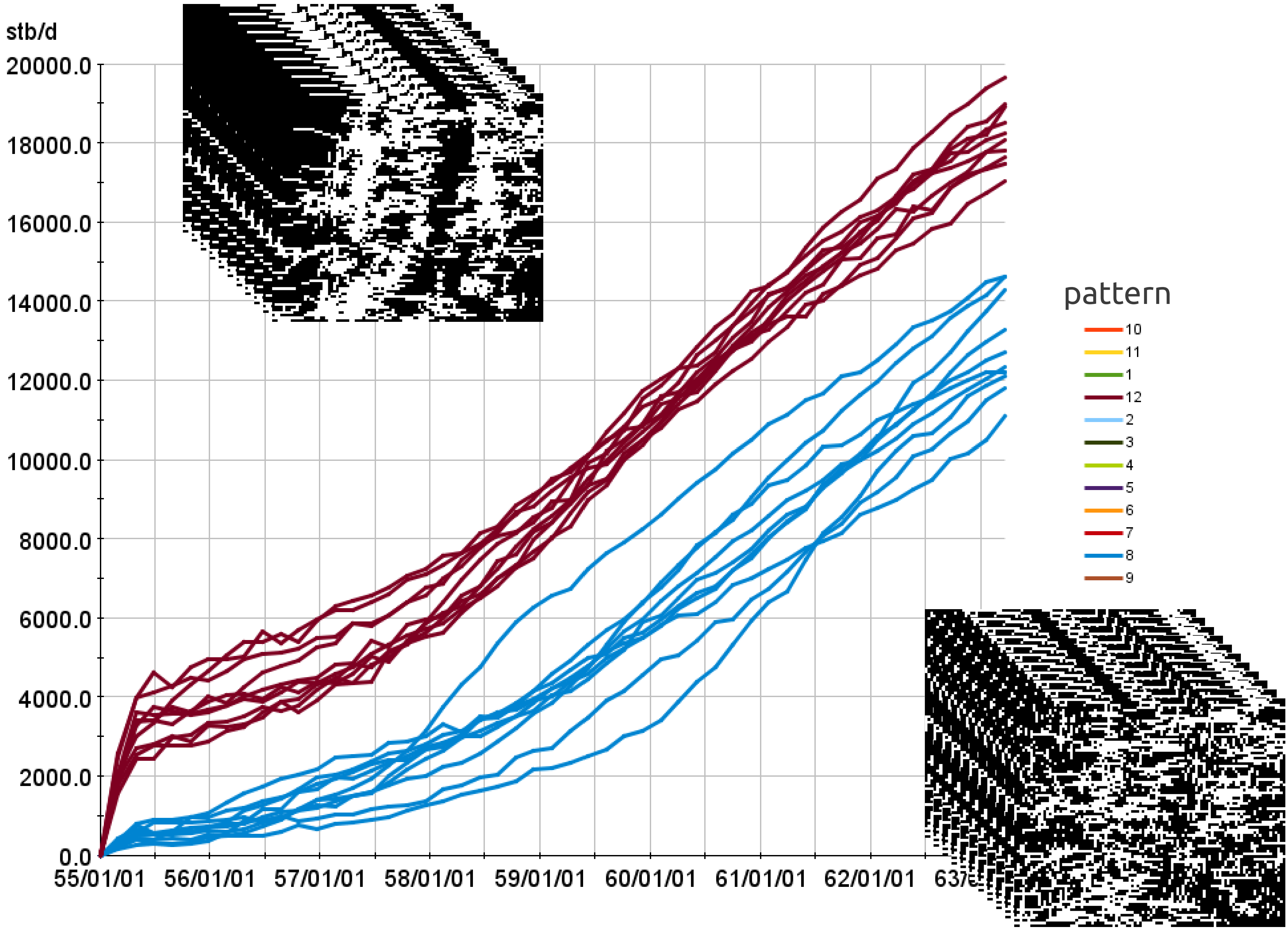
10 realizations

12 patterns

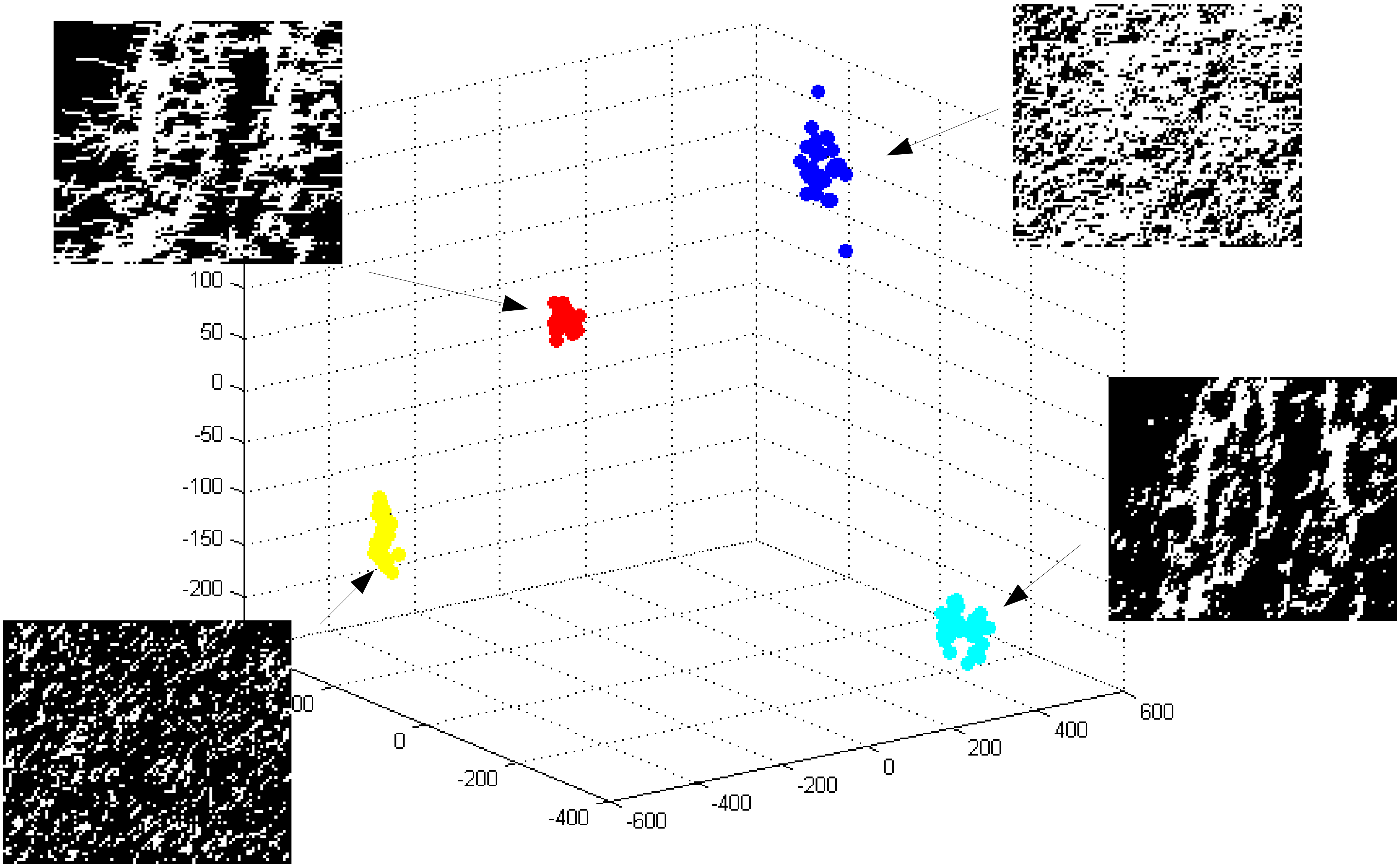


Field response by parameter set / pattern

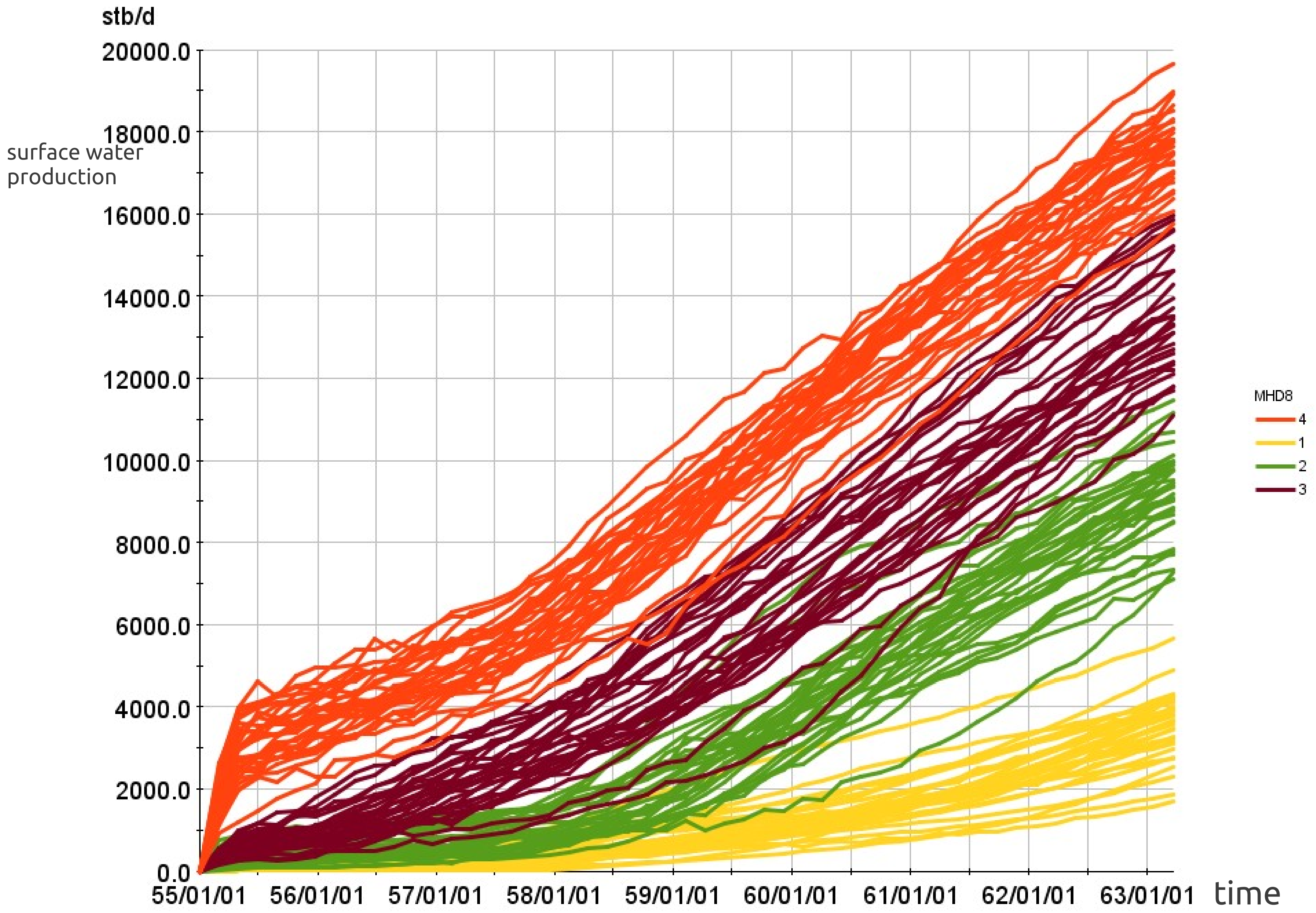



stb/d
20000.0
18000.0
16000.0
14000.0
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
55/01/01
56/01/01
57/01/01
58/01/01
59/01/01
60/01/01
61/01/01
62/01/01
pattern
10
11
1
12
2
3
4
5
6
7
8
9

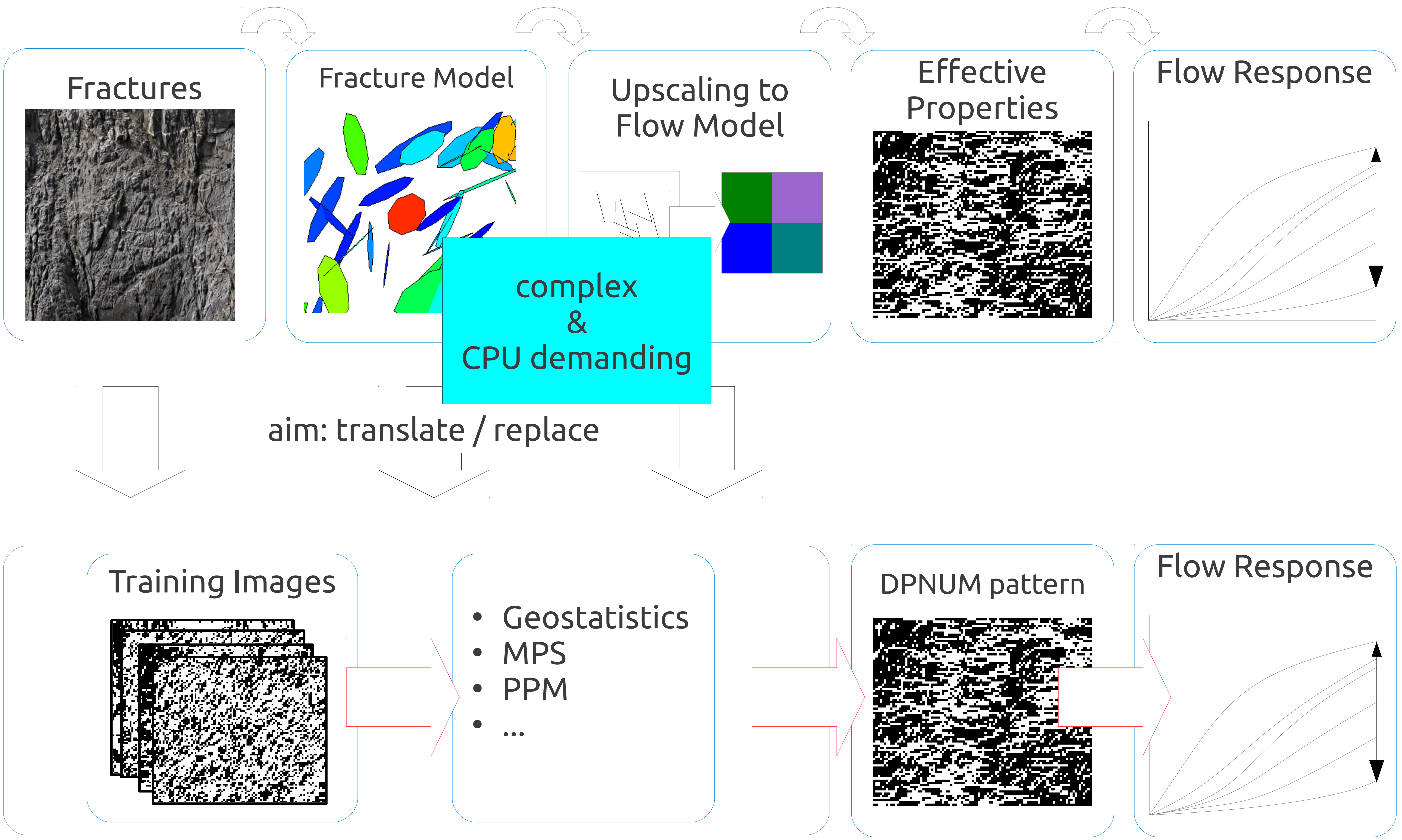
Patterns clustered by Modified Hausdorff Distance



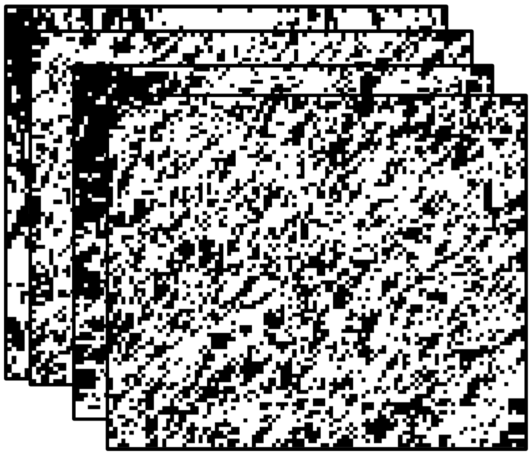
Field response by pattern



establishing a new workflow

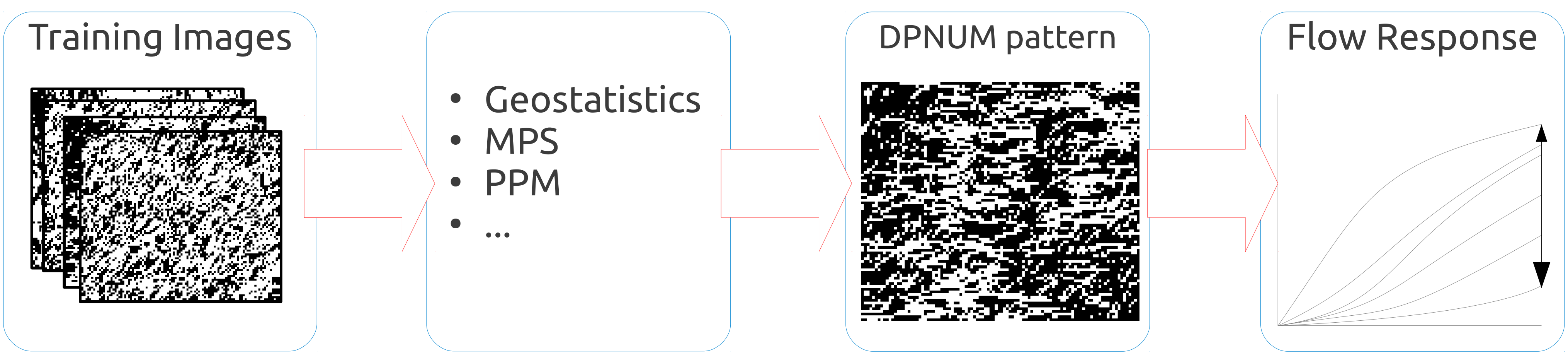


establishing a new workflow



- bypass complexity of DFN modeling & upscaling
- by using fracture patterns as training images
- conserve geologic realism via training images
- simulate fracture patterns directly
- less CPU demanding

training images for fractures

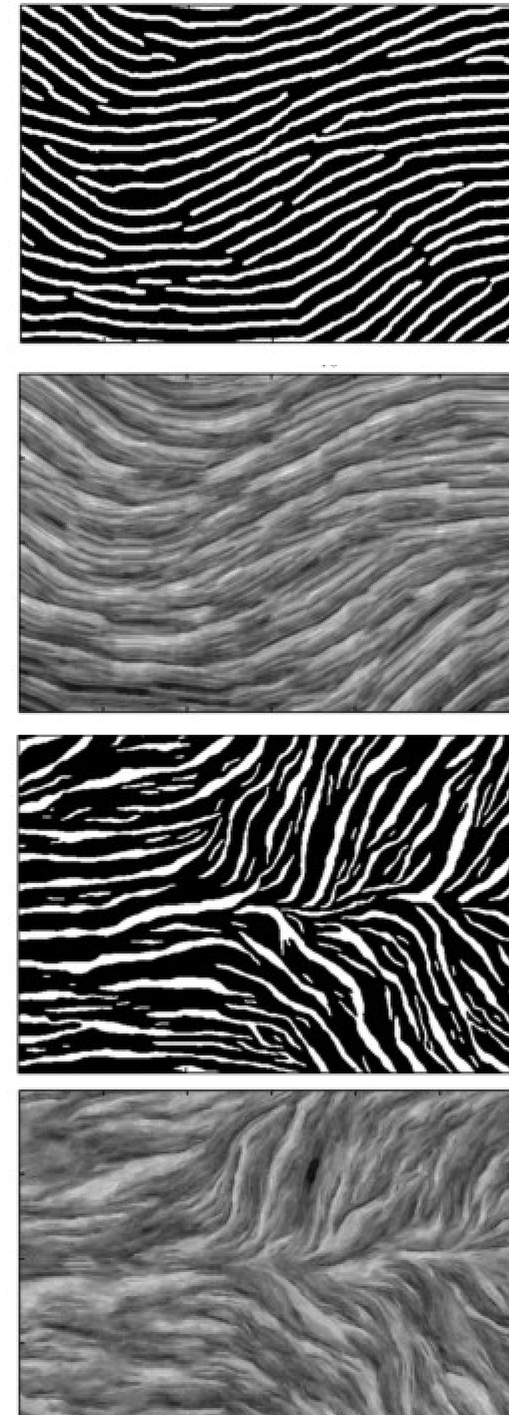


reasonably
capture uncertainty

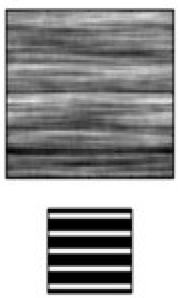
scale?

possible approach

MPS Realizations



Training Images



non-stationary
transformation

Mariethoz and Kelly (2011)

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Conclusions

- Translation of DFN Models to Grid/Pattern Domain
- Training Images for Fractures
- Preservation of Geological Realism
- Easy Integration with existing Software

Acknowledgments

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- Neal Josephson
- Aaron Fox
- Glori Lee

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