

Can geostatistical models reproduce nature's variability?

An analysis and synthesis of flume experiments

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When models are off...



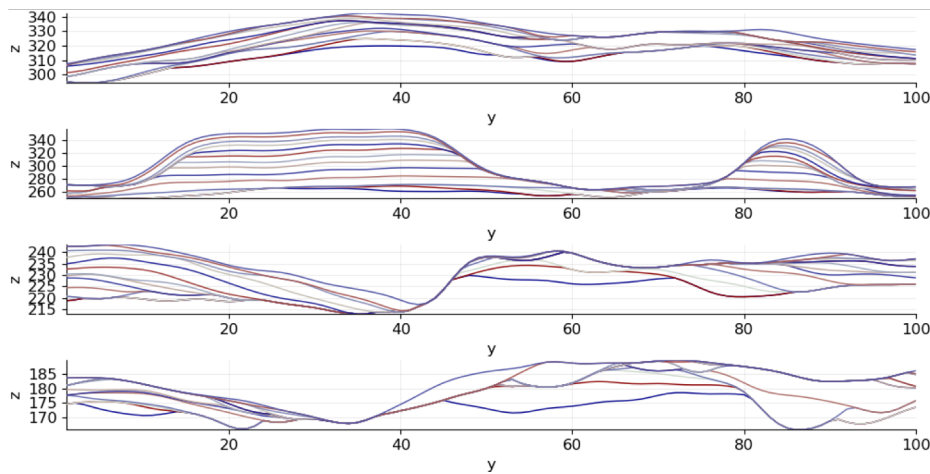
2011 Tōhoku earthquake

"...the Tōhoku earthquake came as a surprise to seismologists. While the Japan Trench was known for creating large quakes, it had not been expected to generate quakes above an 8.0 magnitude."

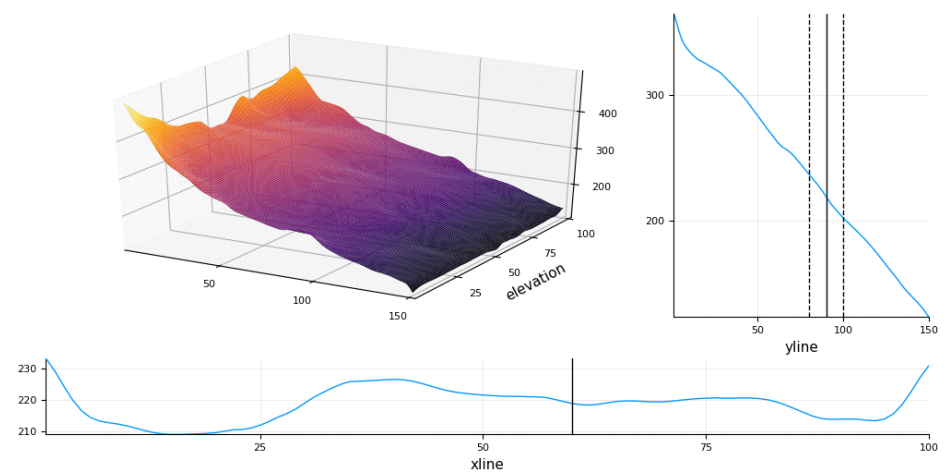
Fundamentally...

- To what extent can physical observations be used for *statistical learning*?
- How can we reproduce experiment statistics with a (stochastic) model?

LiDAR measurements

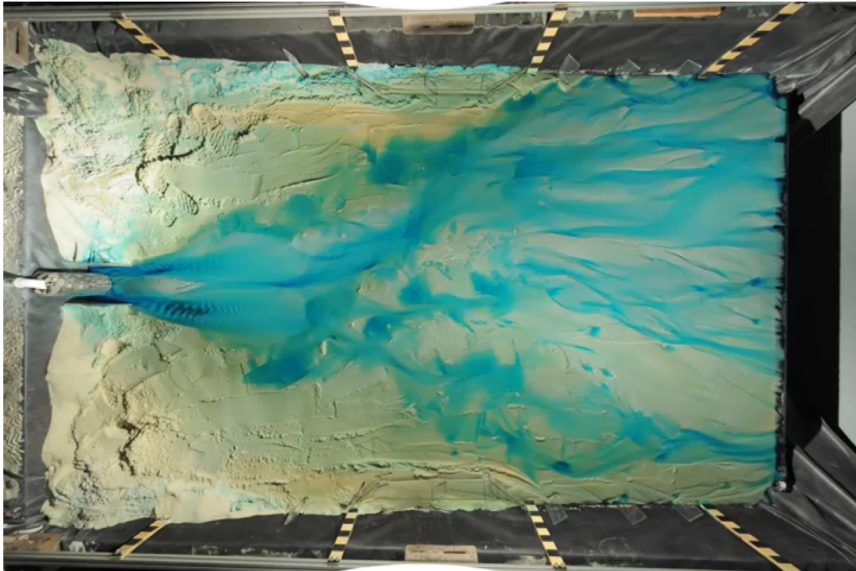


Synthetic stratigraphy



Practical challenges

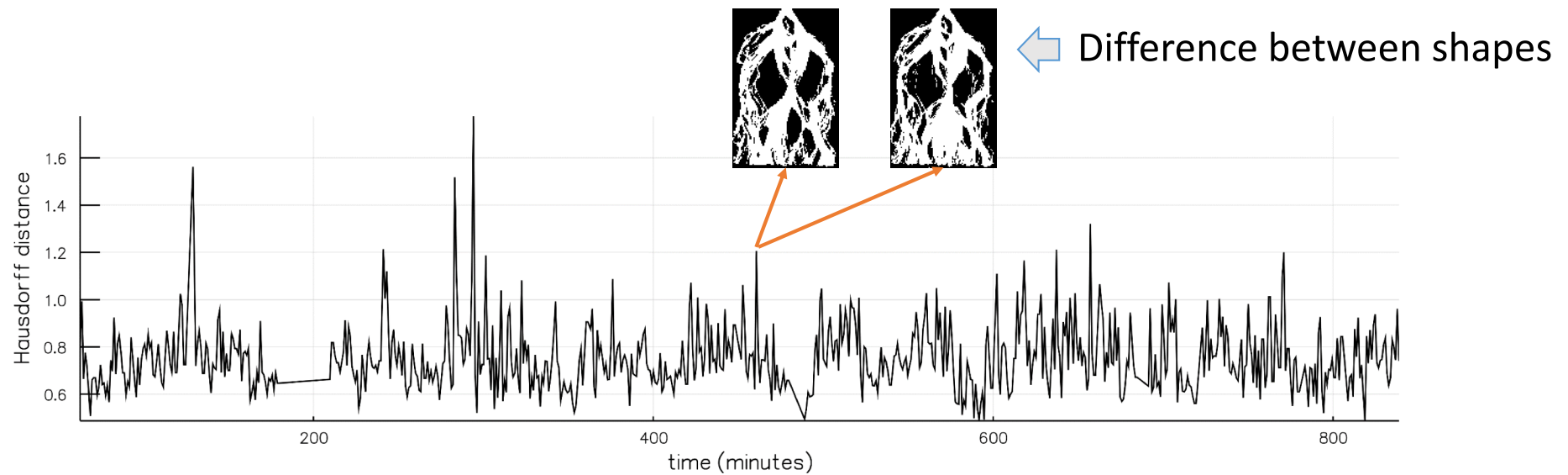
Processes caught on camera



Bufe et al. 2016

- Experiment data is being generated at an unprecedented rate
- Calibrating forward models is often a frustrating and time-consuming task
- Slight changes in boundary conditions invalidate the calibrated model
- It is hard to deal with process uncertainty

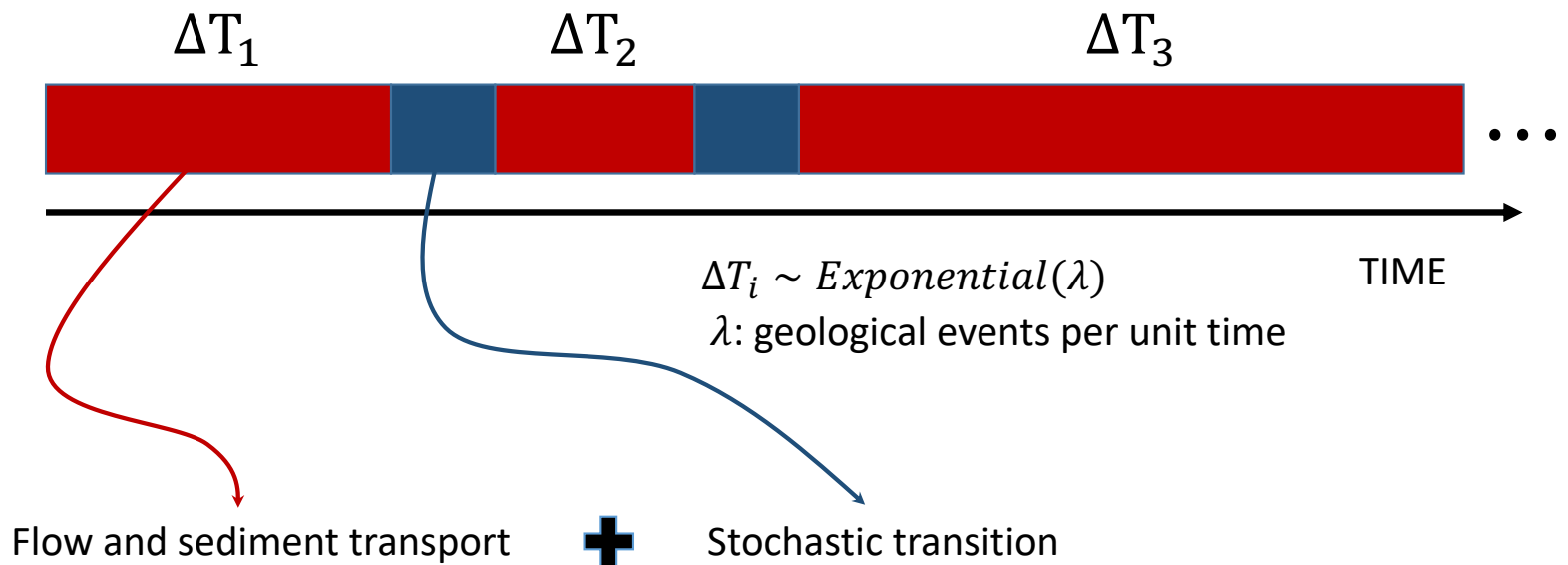
A case study with flume experiments



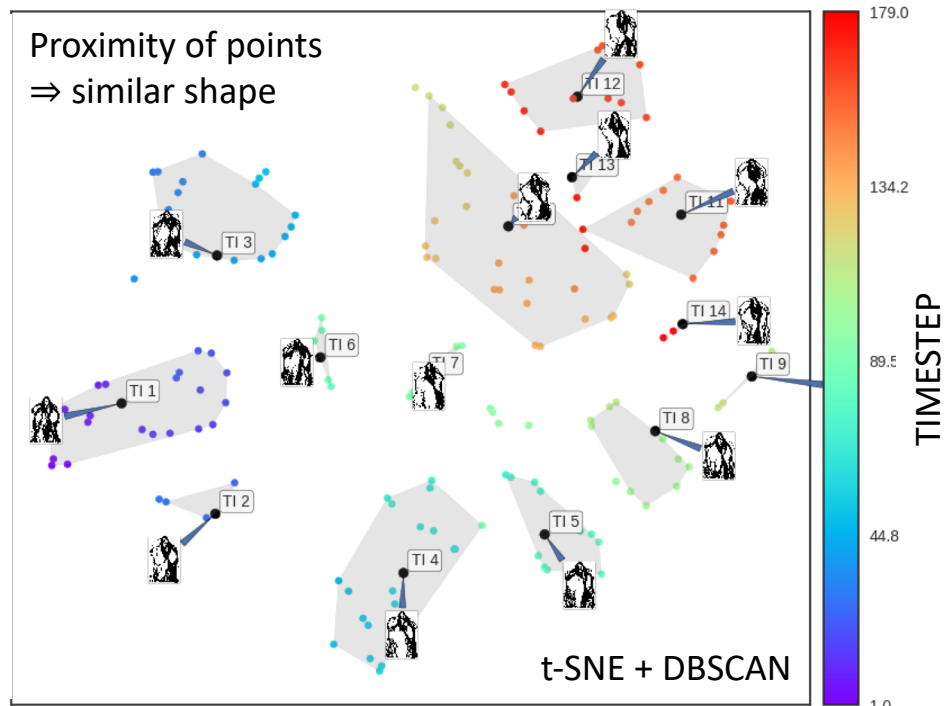
- Erratic yet systematic evolution
- Calls for a random process model
- What should this model entail?

Random process model

Flow dynamics \rightarrow *Poisson*(λ) process



Geomorphological transitions



- Flow patterns can be clustered into a subset of **representative images**
- The system evolves from cluster to cluster stochastically
- How to recover the remaining variability given just representative “training images”?

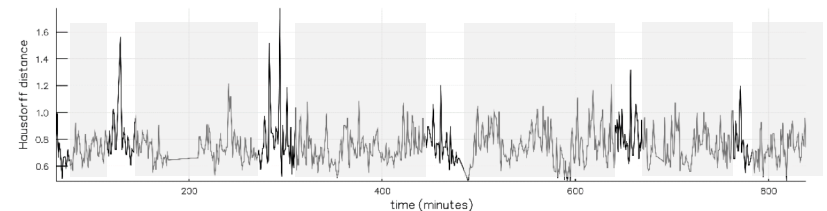
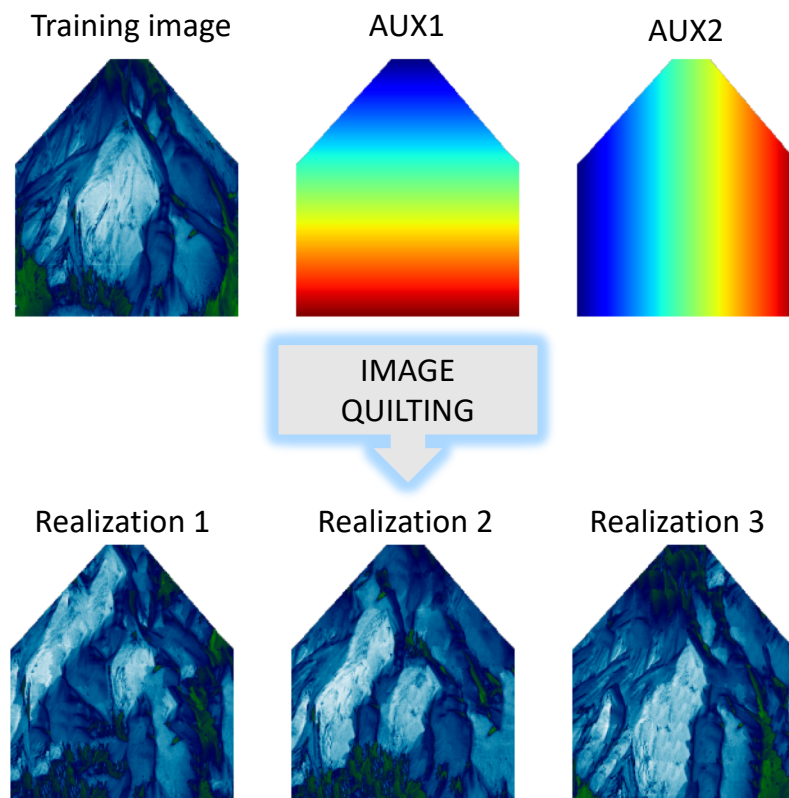


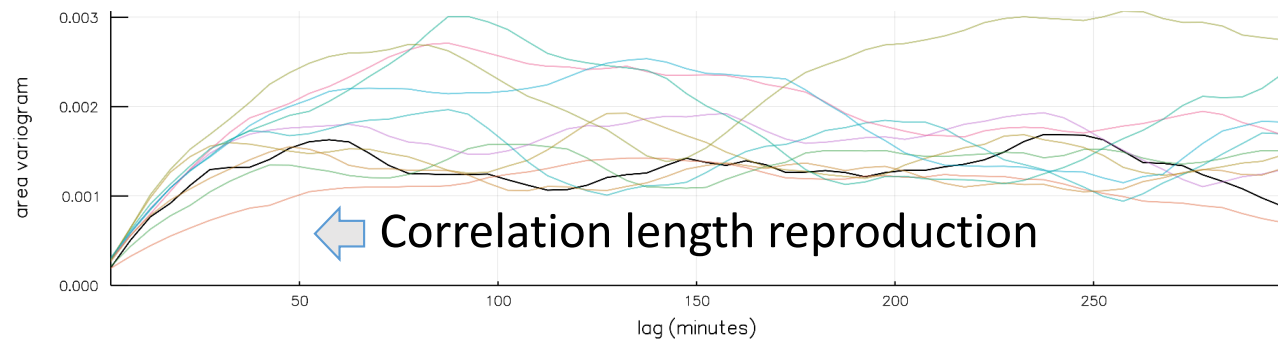
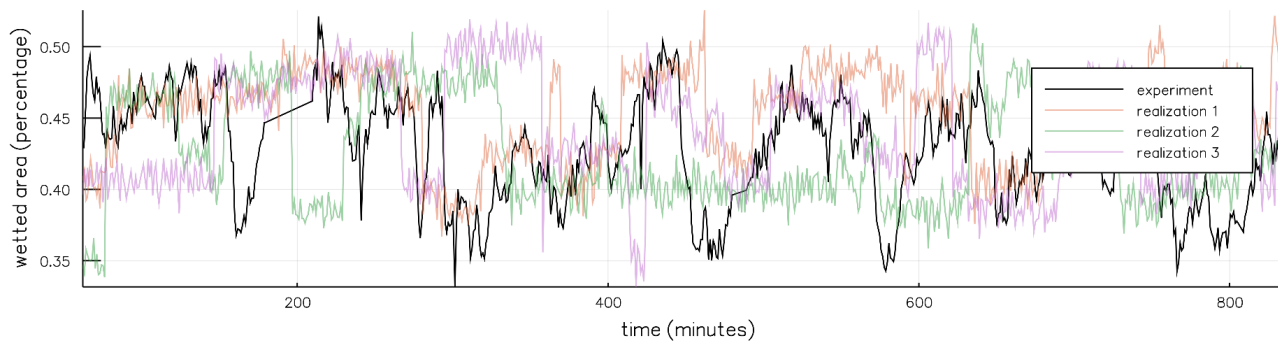
Image quilting simulation



- Data-driven, stochastic, no physics
- Can be conditioned to well data and remote sensing data
- Fast synthesis for Monte Carlo studies and hypothesis testing

Hoffmann et al. 2017 - *Stochastic simulation by image quilting of process-based geological models*

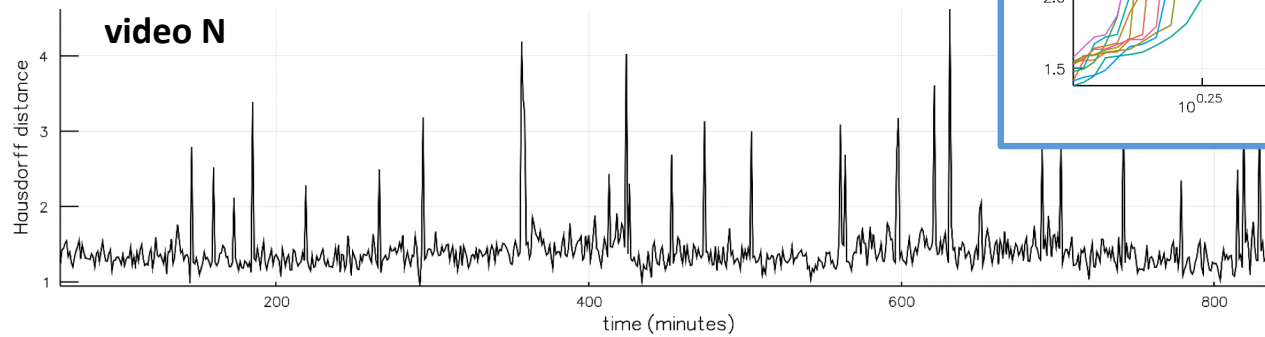
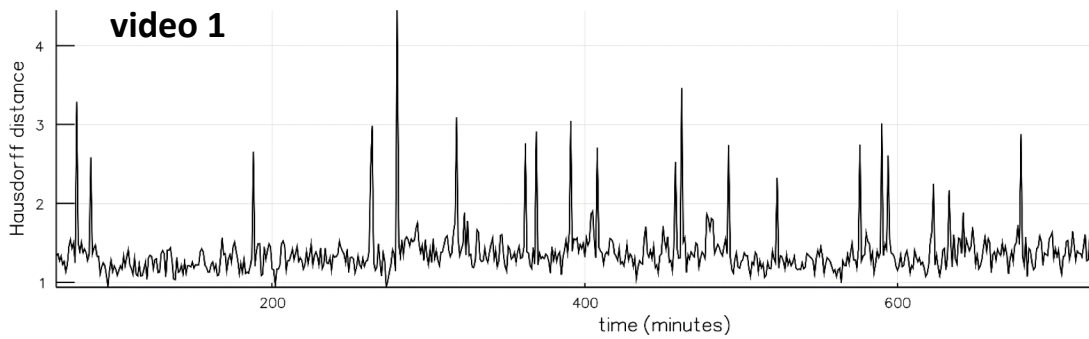
Is the model useful?



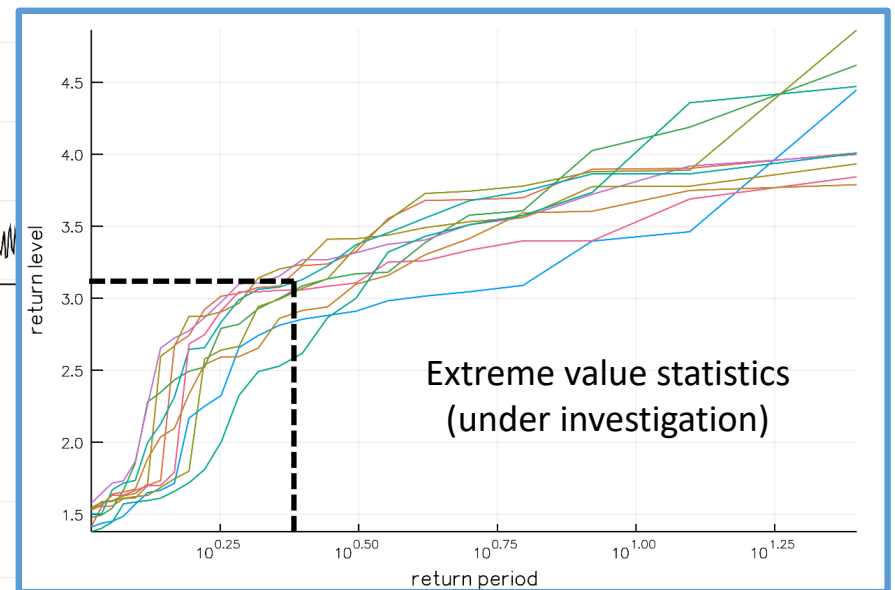
1. Synthesize videos
2. Measure processes:
 - Wetted area
 - Flow perimeter
 - ...
3. Check statistics:
 - Empirical variogram

Recall the initial observation...

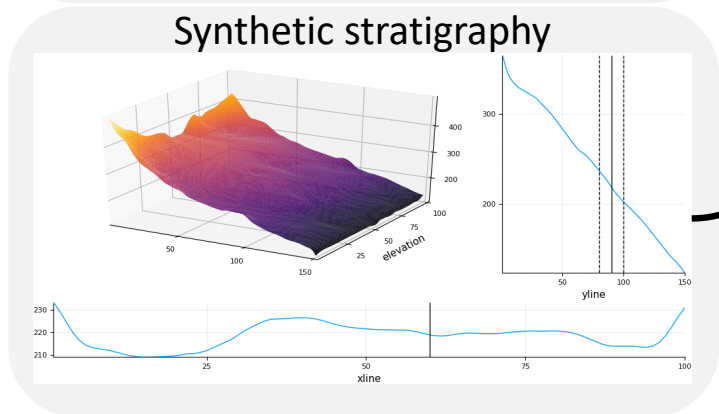
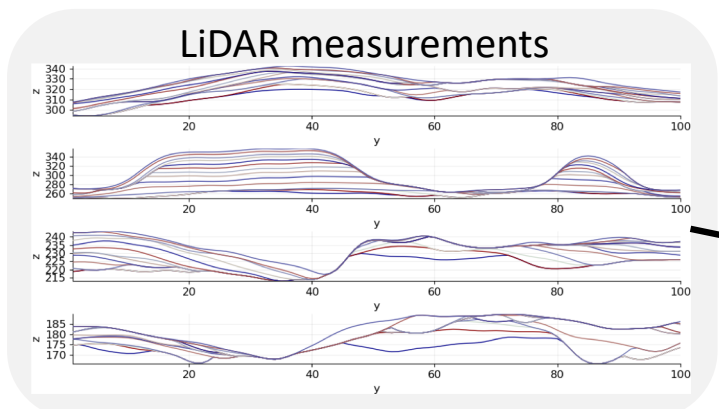
Synthetic videos



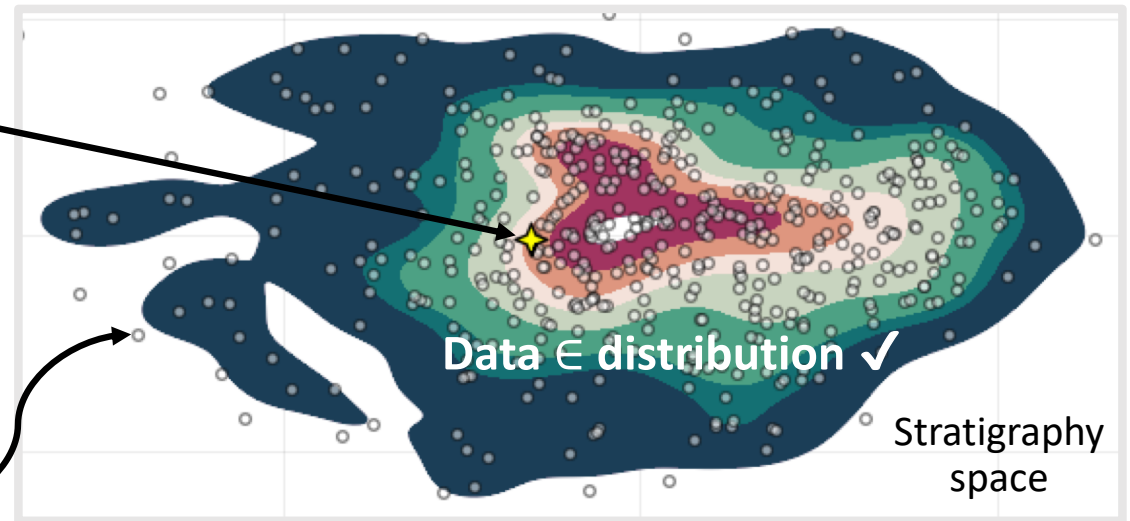
Can the model reproduce return levels?



Flow statistics → stratigraphy statistics



Ultimate goal is to quantify **uncertainty** in processes



Monte Carlo helps achieve generality

THANK YOU

Seek simplicity and distrust it.
Alfred Whitehead

