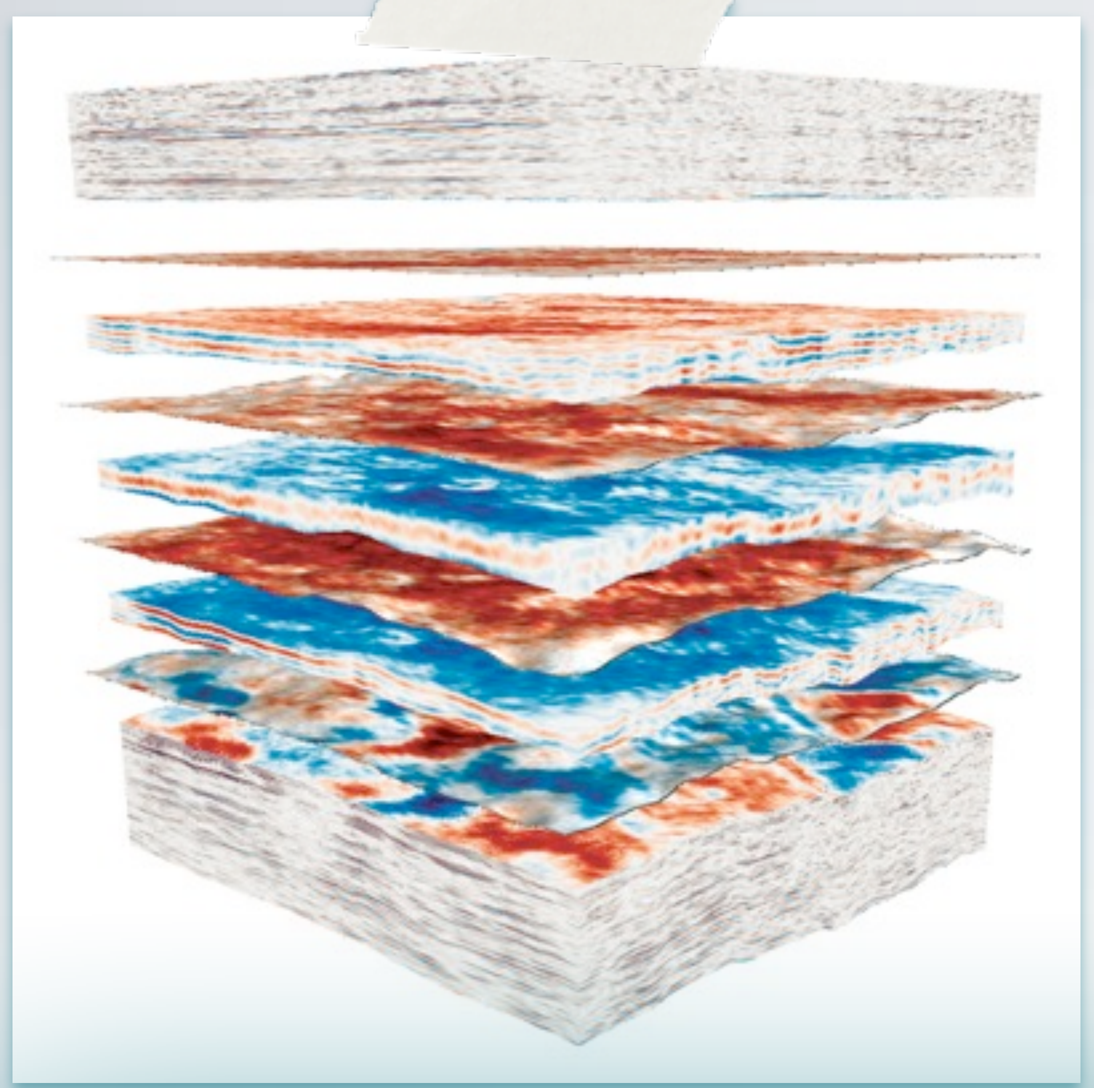
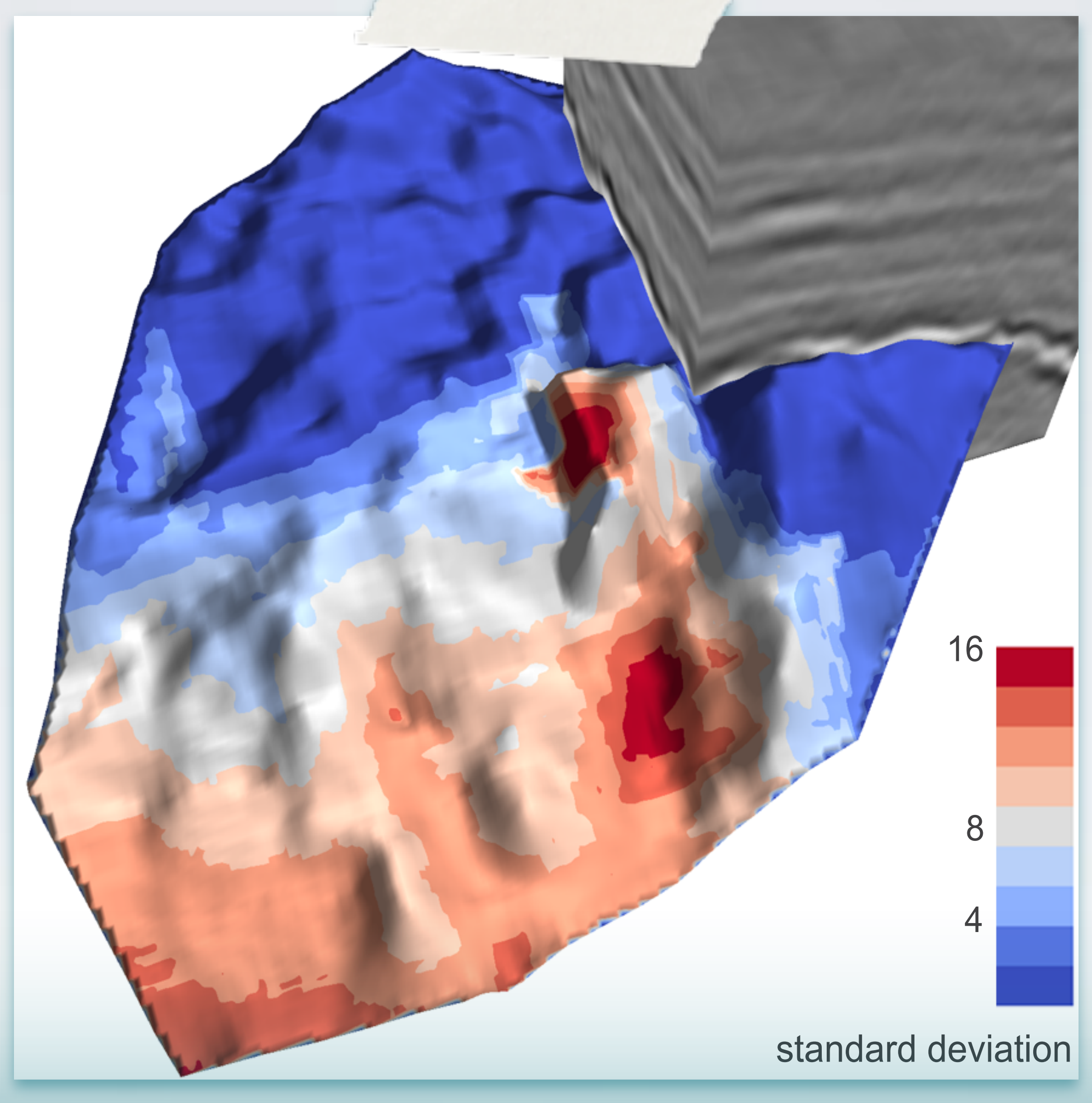
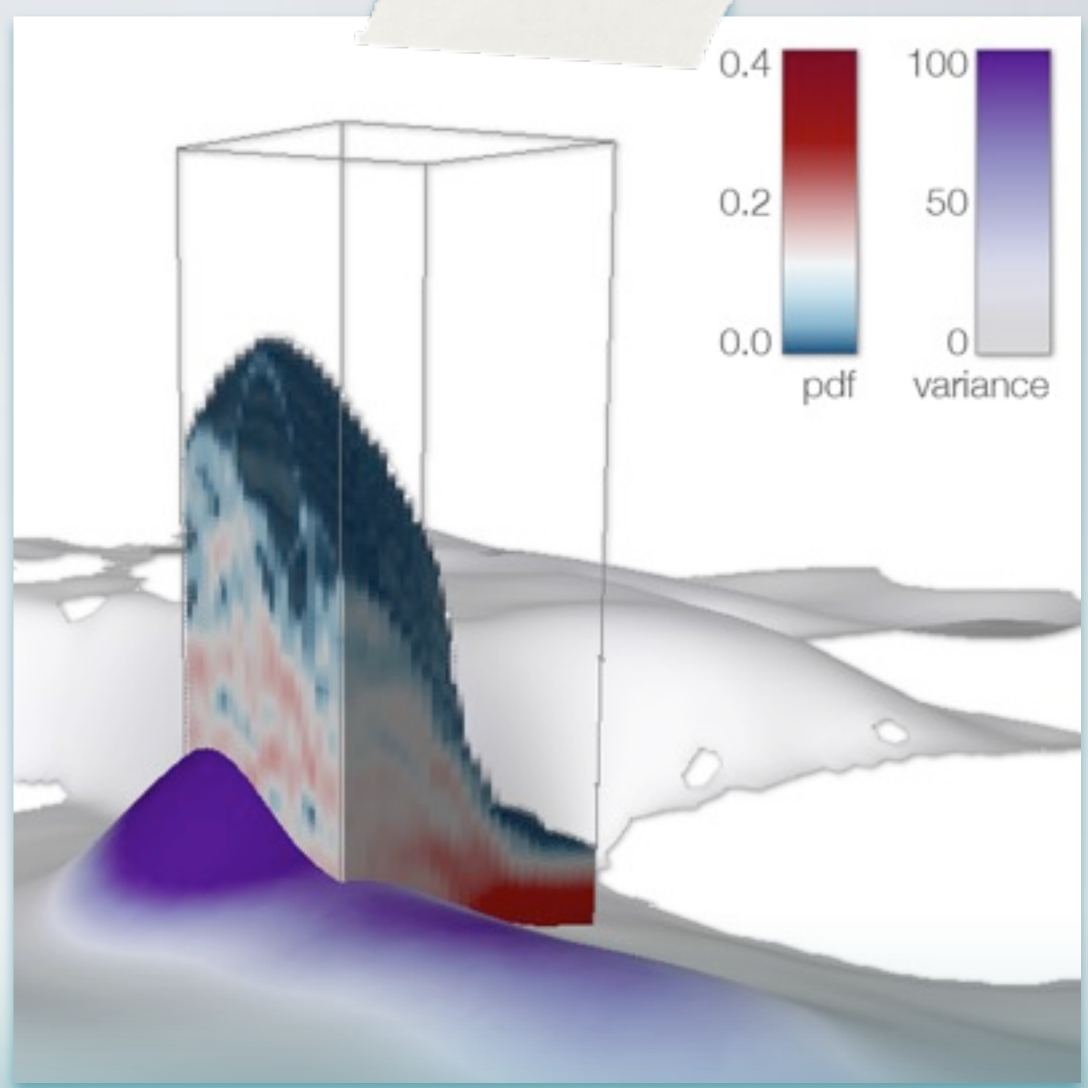
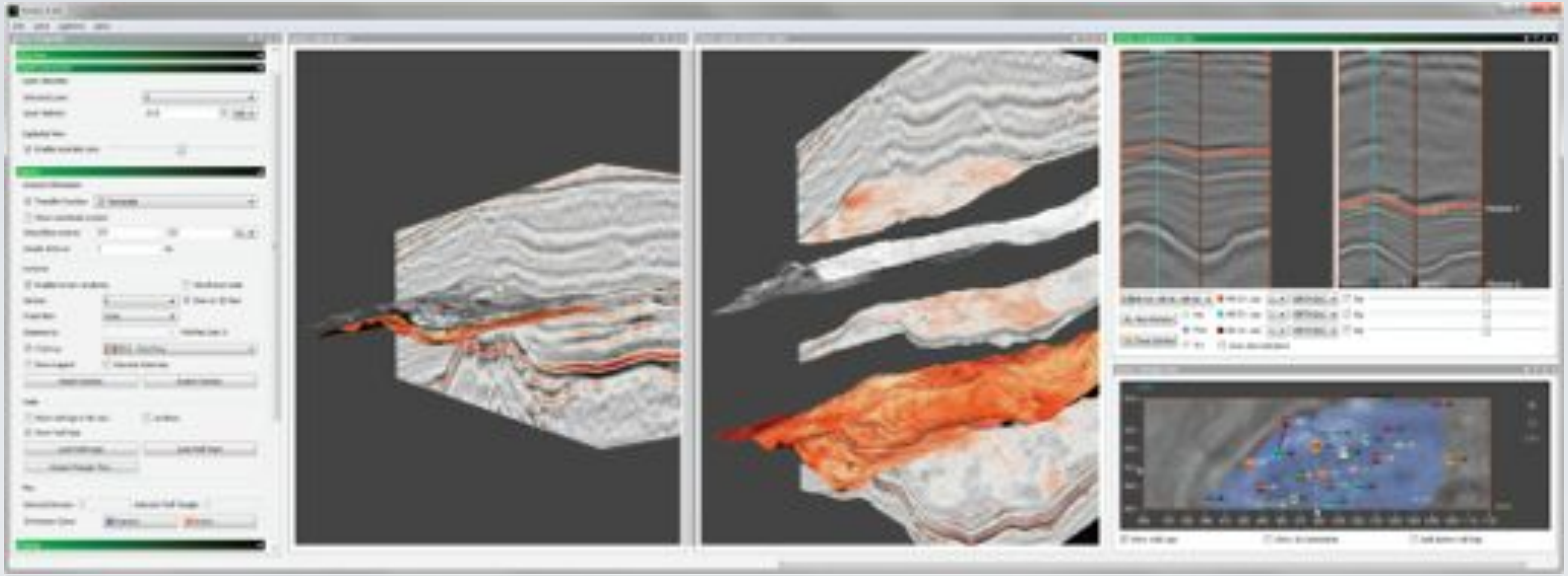






Visual Workflows for Oil and Gas Exploration

Thomas Höllt // 14. April 2013



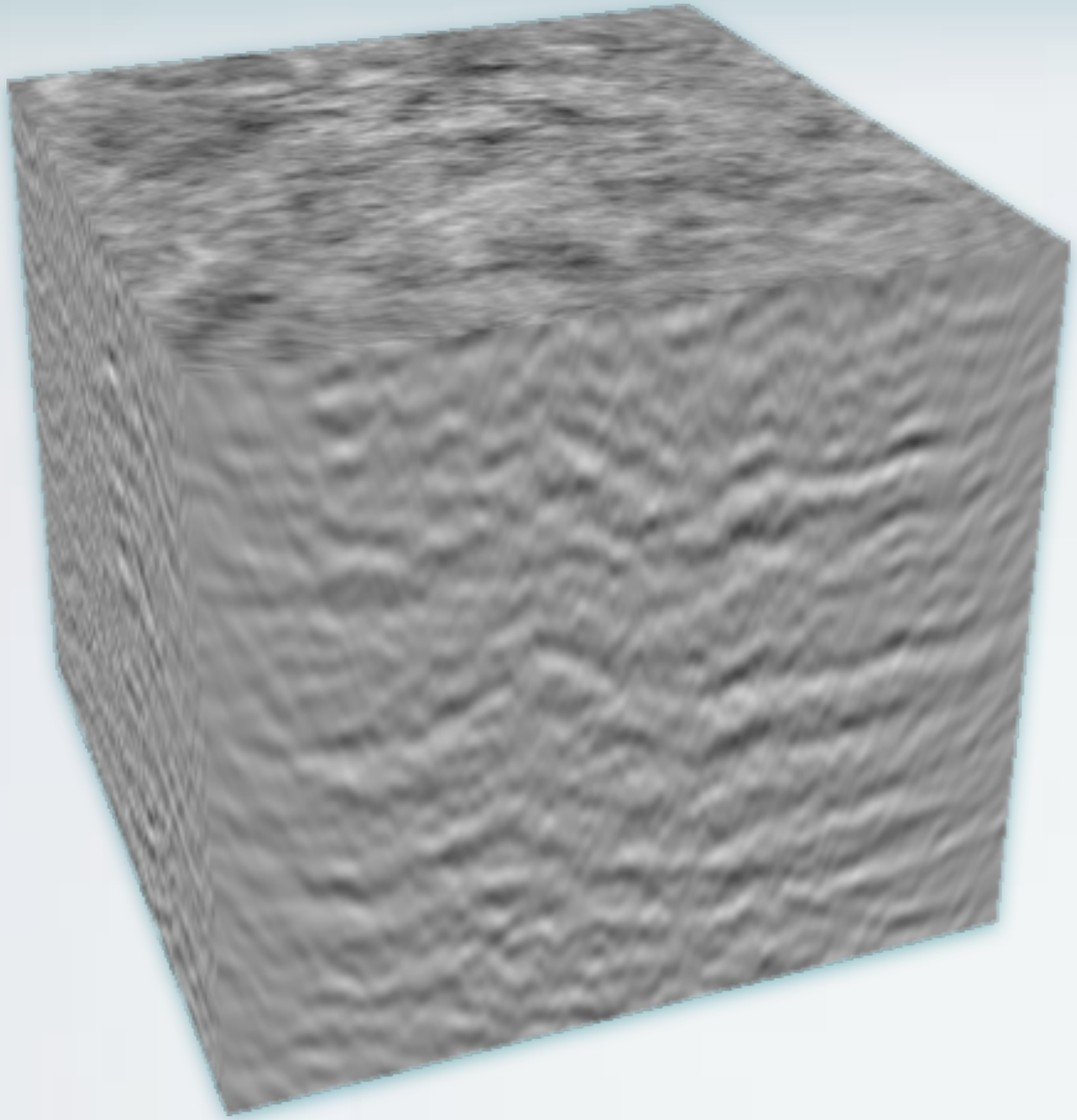
Interactive Visual Subsurface Modeling

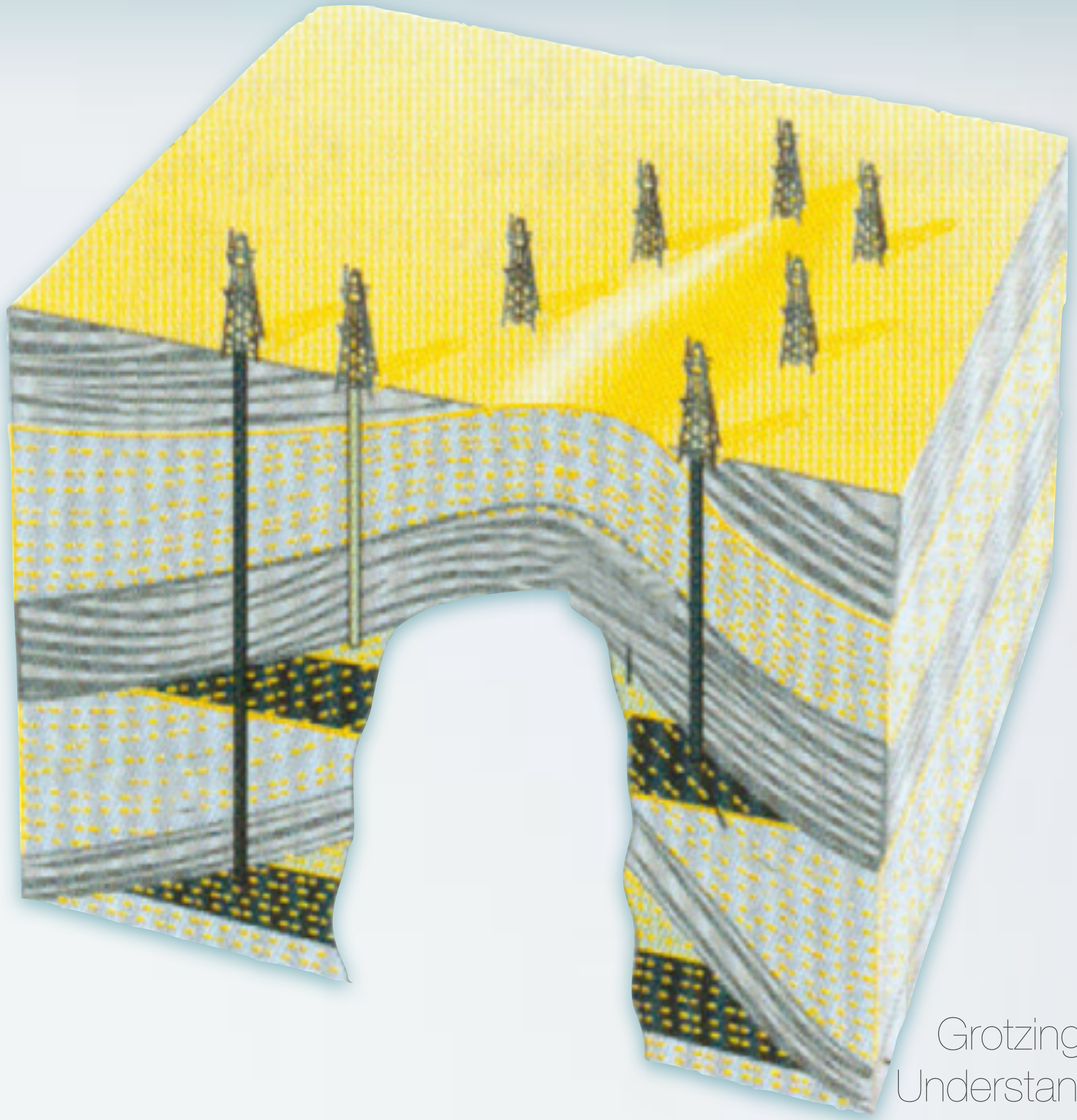
Publications

T. Höllt, J. Beyer, F. Gschwantner, P. Muigg, H. Doleisch, G. Heinemann, and M. Hadwiger.
Interactive Seismic Interpretation with Piecewise Global Energy Minimization.
In *Proceedings of IEEE Pacific Visualization Symposium 2011*, pages 59—66, 2011.

T. Höllt, W. Freiler, F.M. Gschwantner, H. Doleisch, G. Heinemann, and M. Hadwiger.
SeiVis: An Interactive Visual Subsurface Modeling Application.
IEEE Transactions on Visualization and Computer Graphics, 18(12): 2226—2235, 2012.

Visual Subsurface Modeling

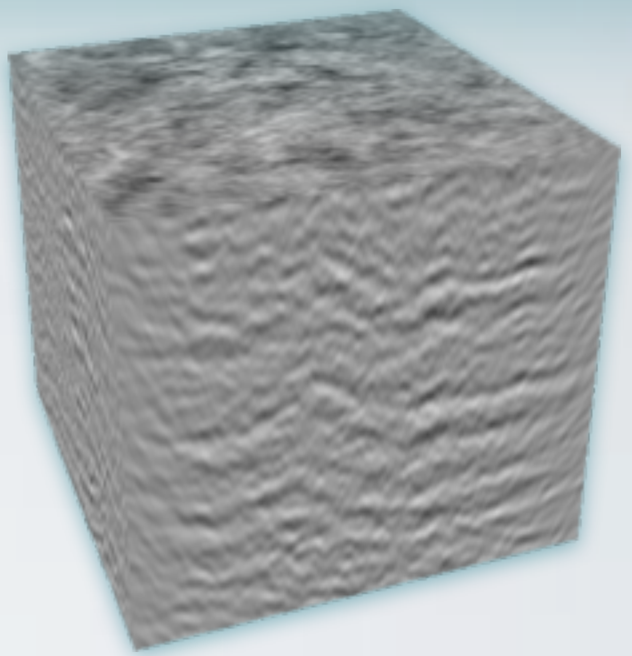


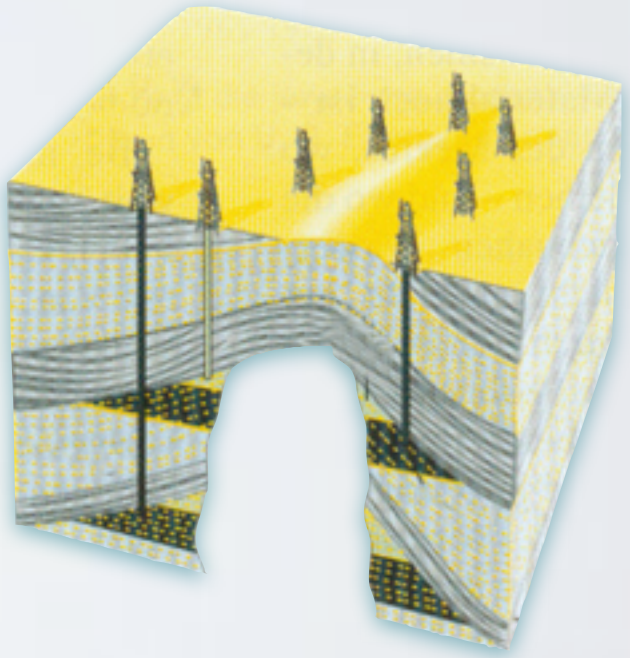


Grotzinger et al.
Understanding Earth

Seismic To Model

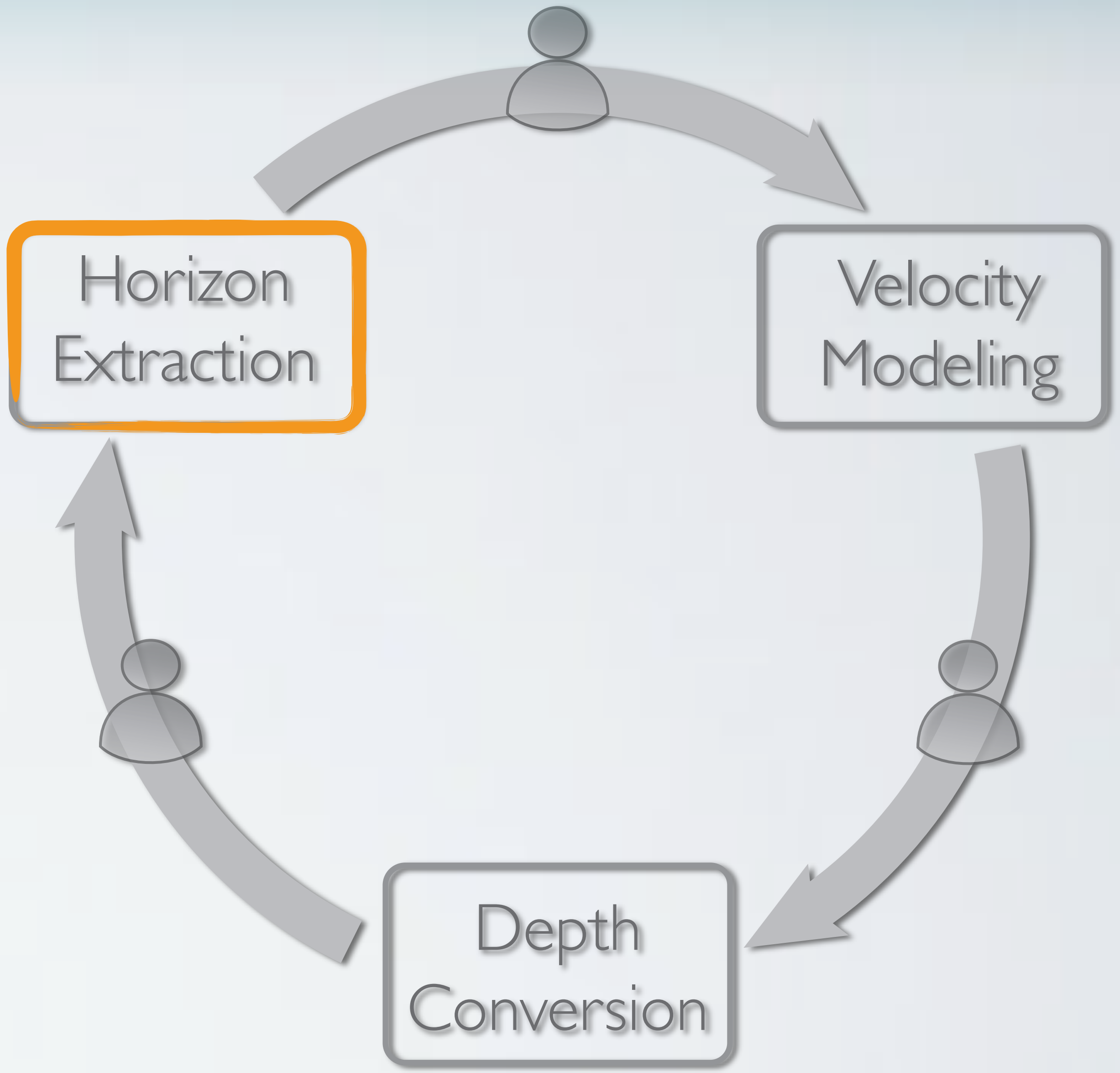
- Description of subsurface layers
  - horizons
  - faults
- Created from seismic survey
  - well data + seismic tomography
- Seismic tomography
  - recorded depth dimension is time
  - target depth dimension is lateral depth





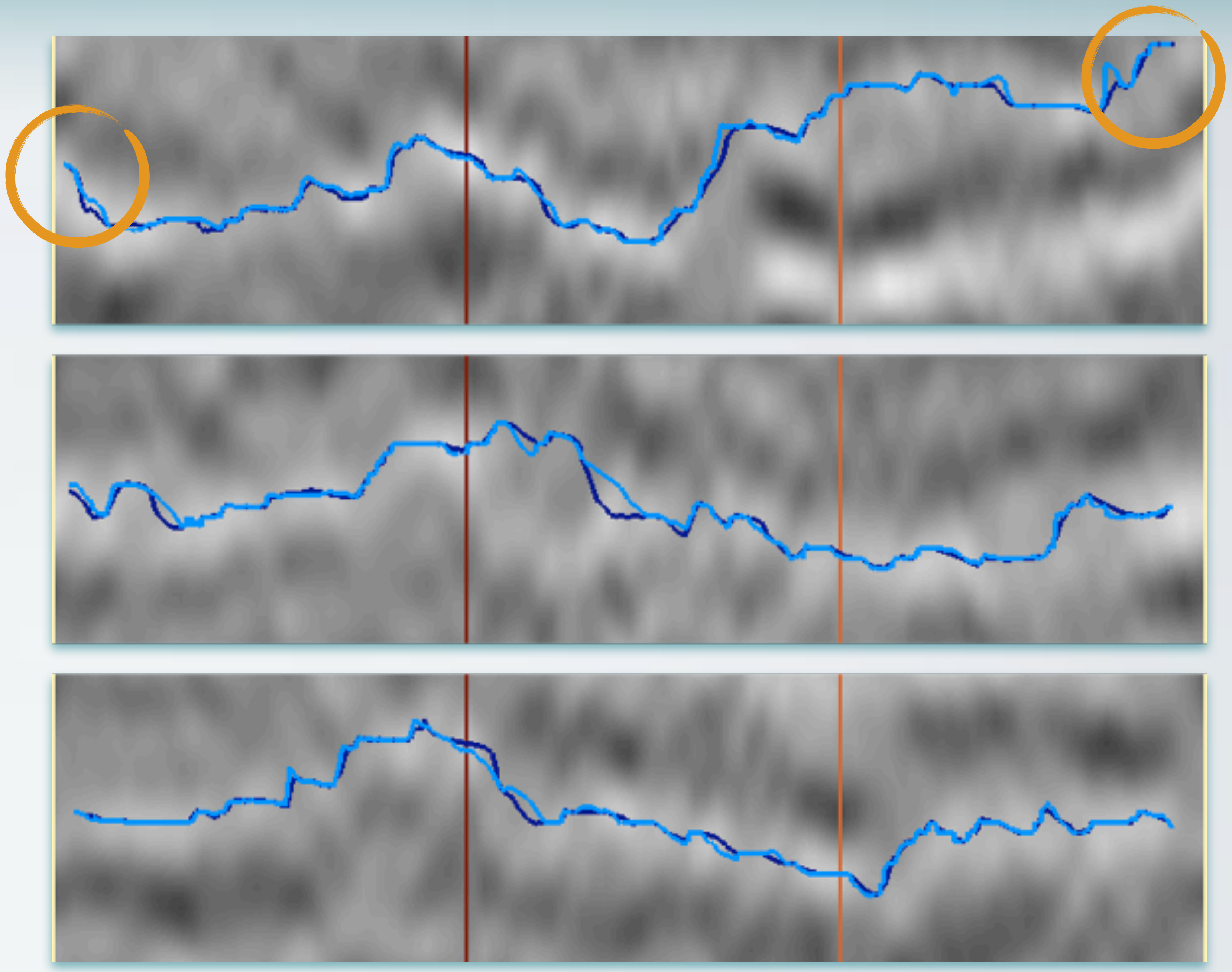
Conventional Workflow

- Feature extraction
  - based on seismic tomography
  - results in model in time domain



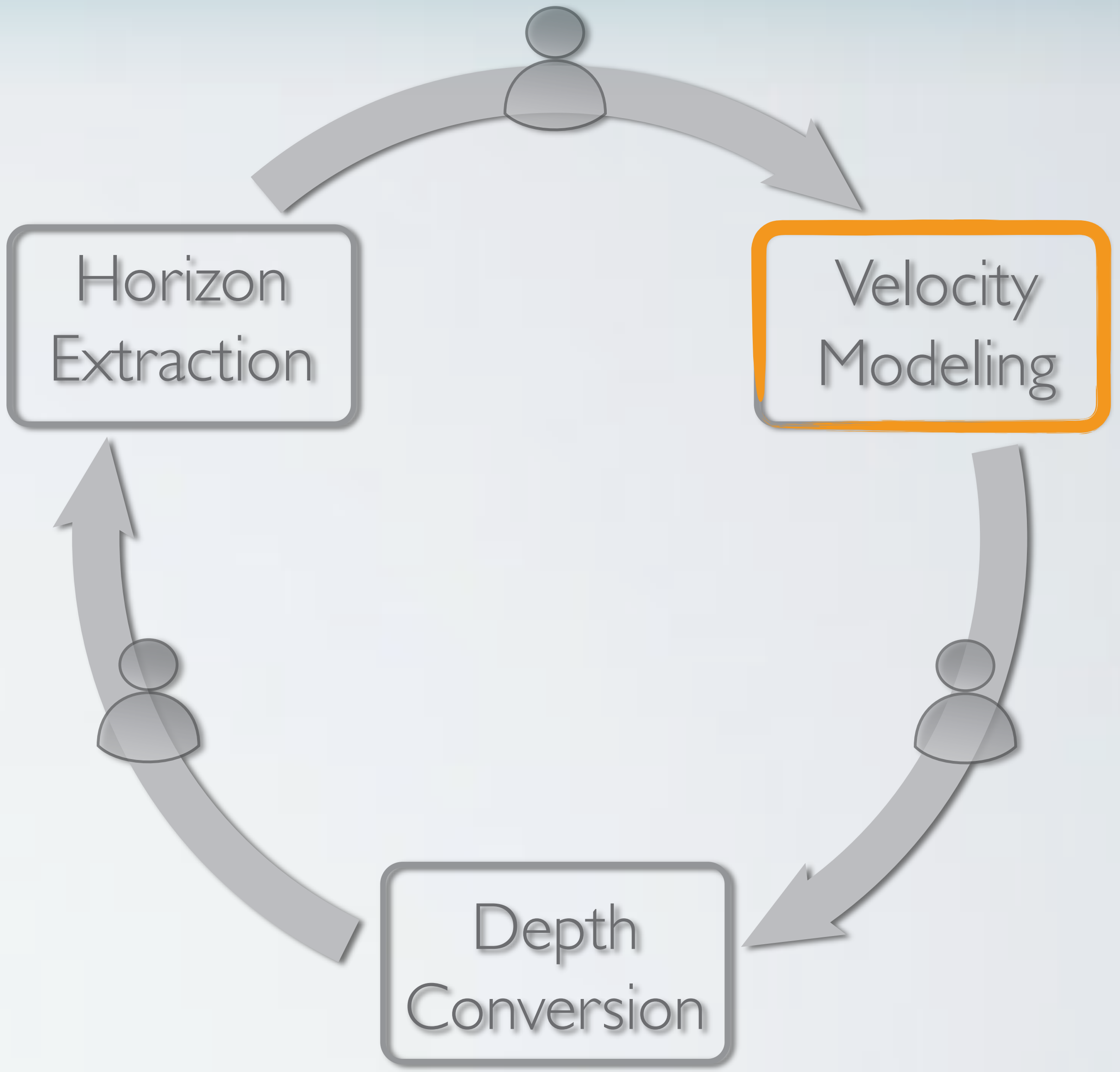
Conventional Workflow // Feature Extraction

- Based on local solvers
  - no constraints, hard to interact with
  - no guarantee for a closed contour
  - no guarantee for a complete surface



Conventional Workflow

- Feature extraction
  - based on seismic tomography
  - results in model in time domain
- Velocity modeling
  - per layer velocity based on model in time
  - results in velocity model
- Depth Conversion
  - transforms model from time to depth



Conventional Workflow

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  - per layer velocity based on model in time
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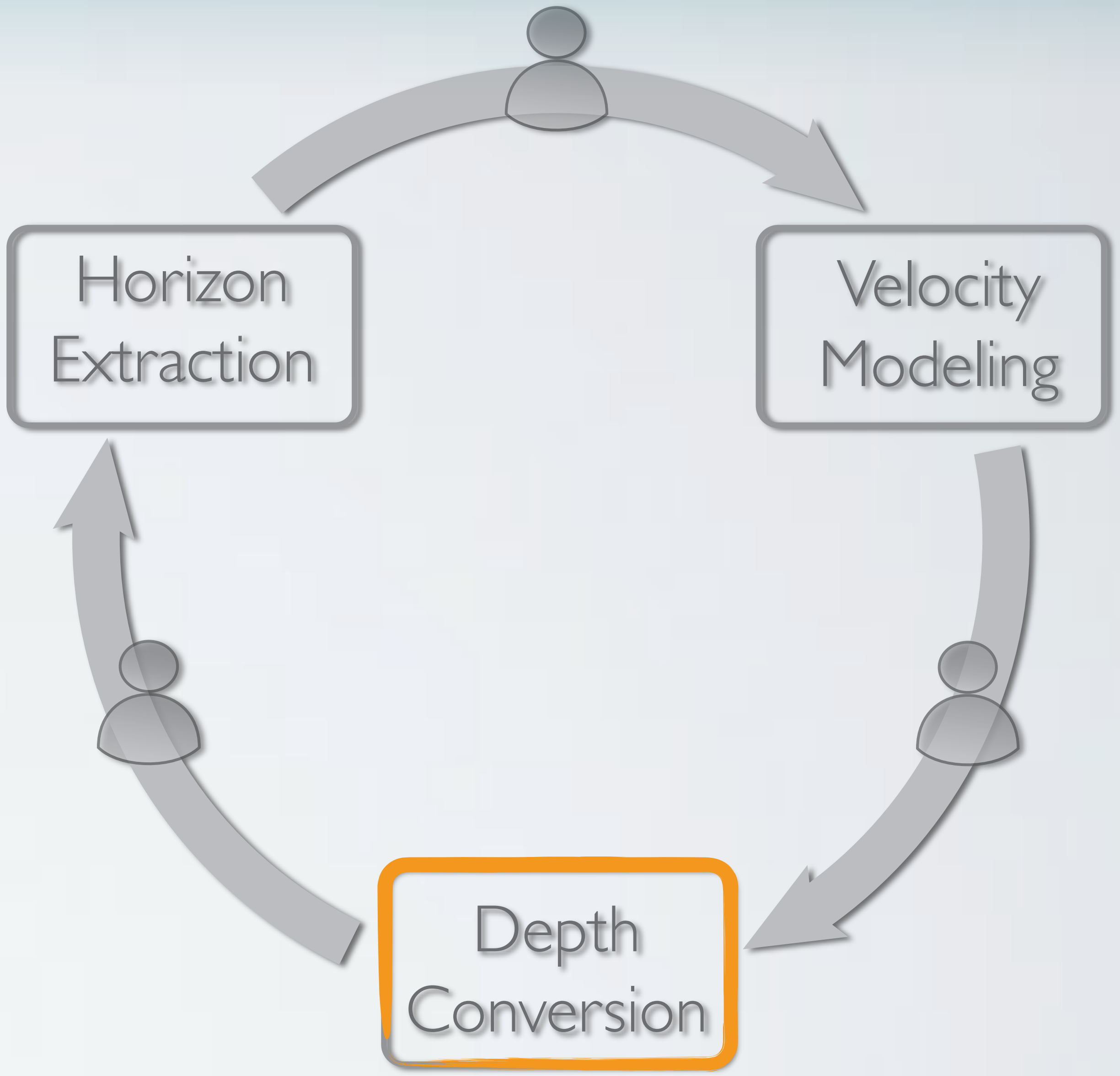
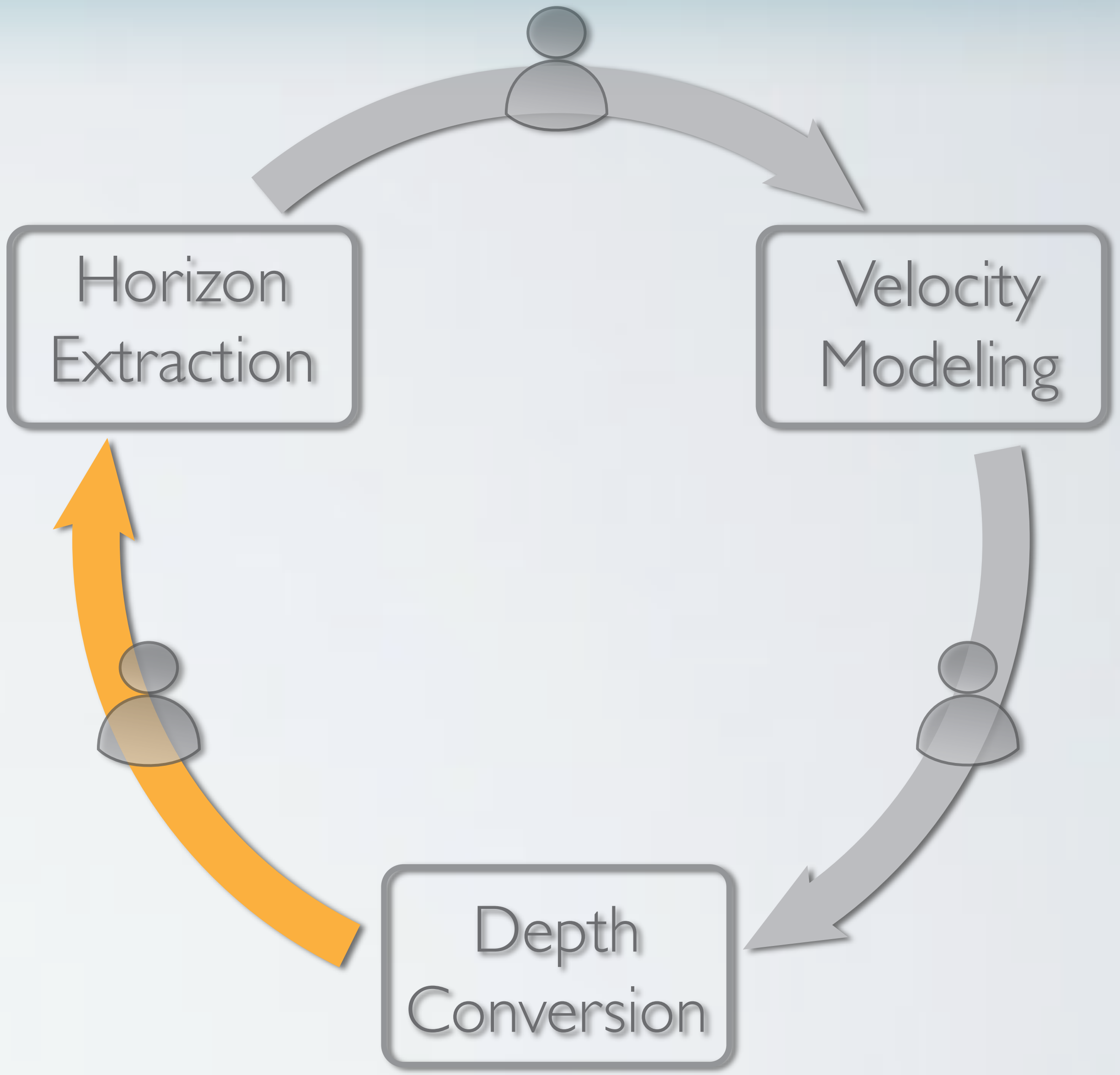


Conventional Workflow // Problems

- Additional data only at the end of pipeline
- Errors become visible after depth conversion
  - propagating fixes back into interpretation is time-consuming and hard
  - instead locally hot-fixing velocity model

  \+ might fix the layer model

  – might result in unphysical velocity model



Conventional Workflow // Problems

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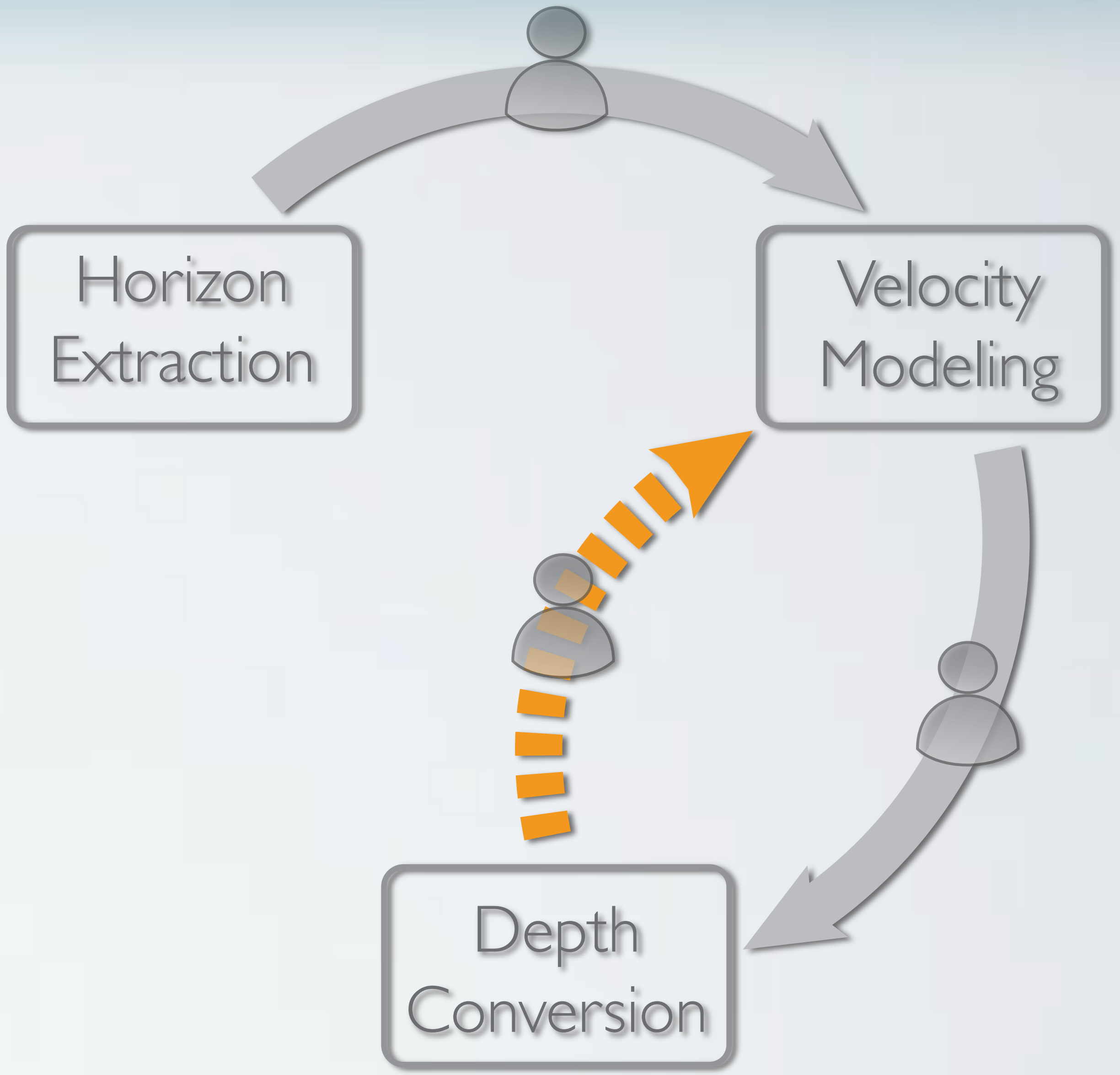
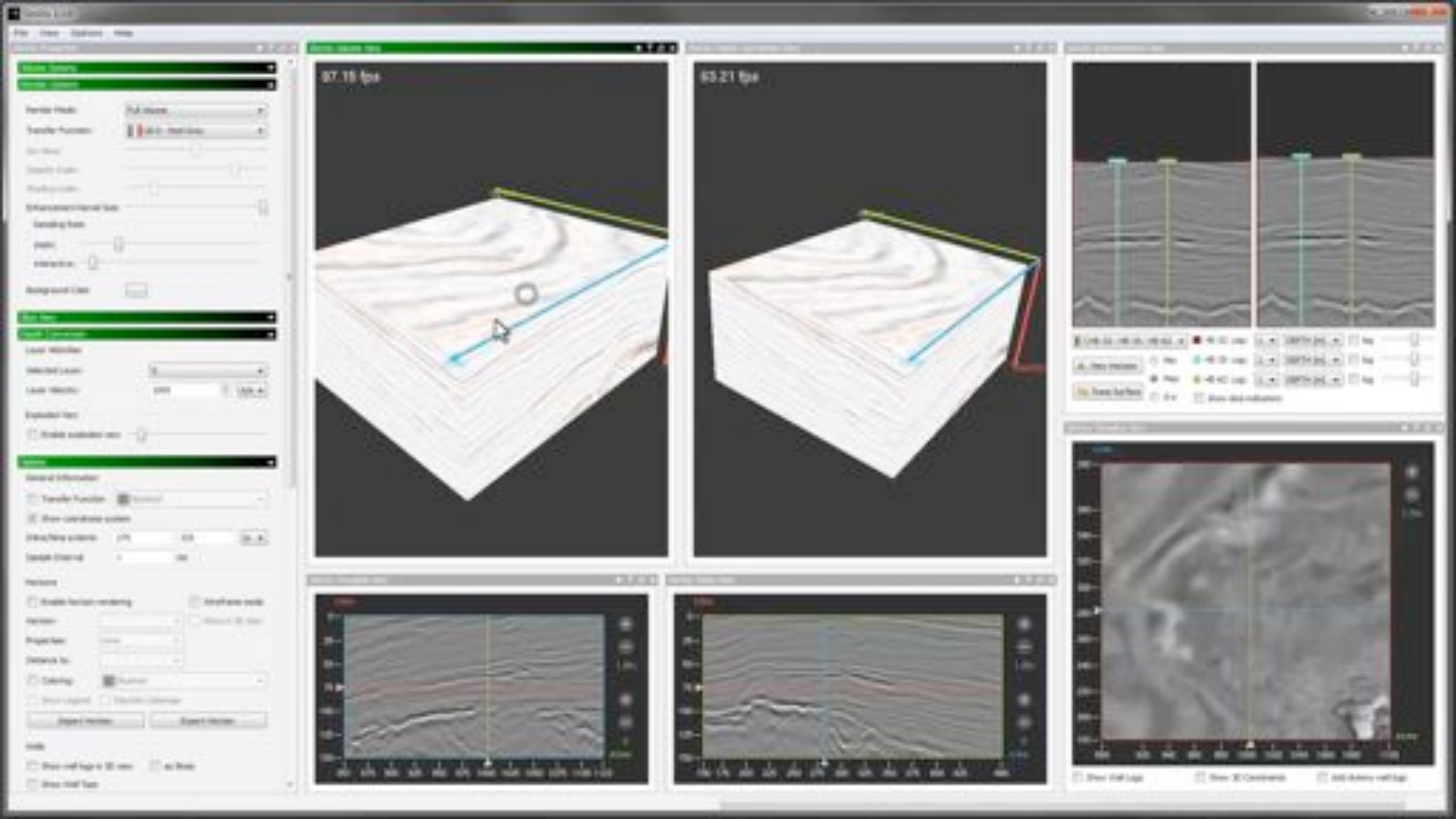
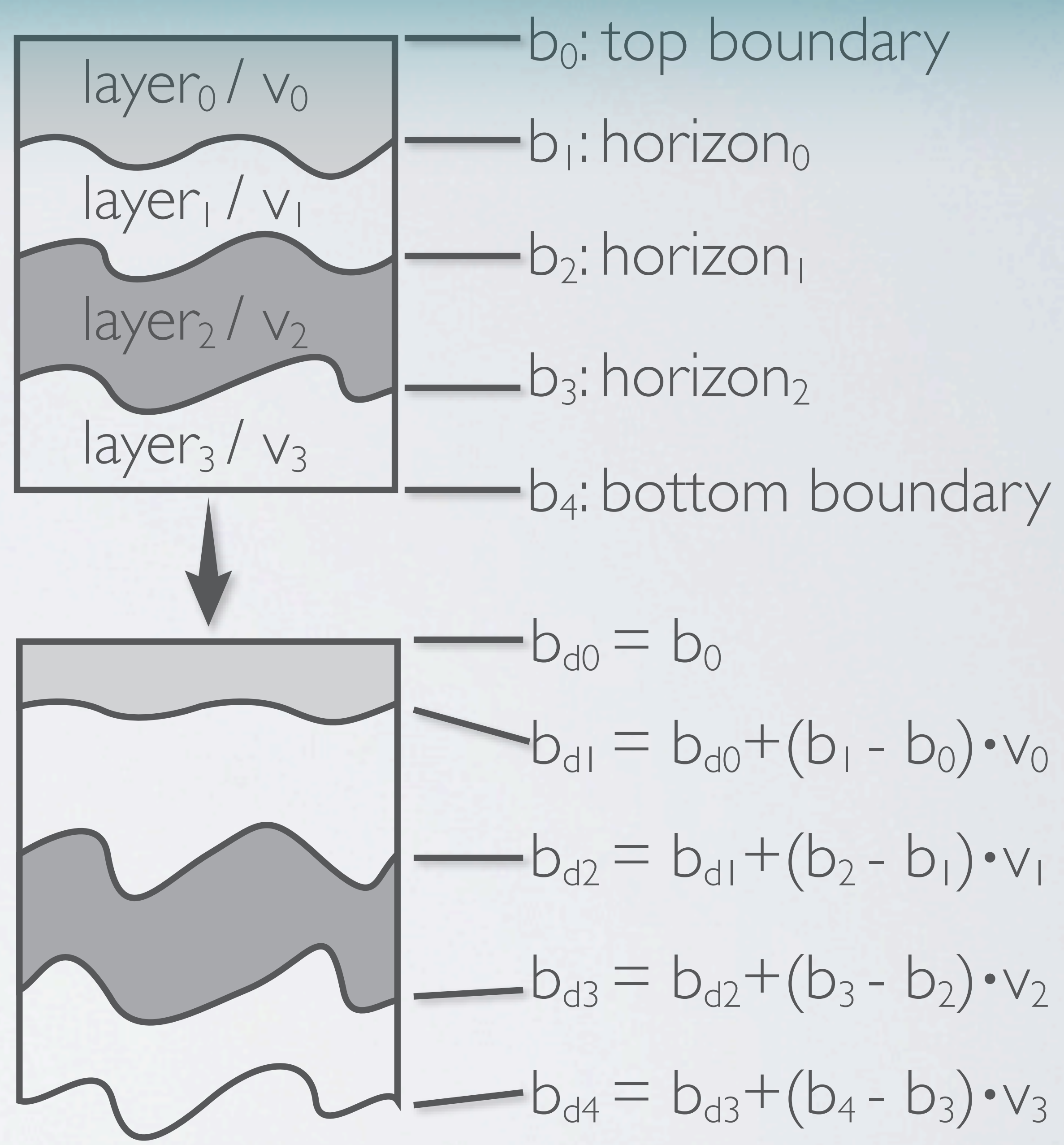


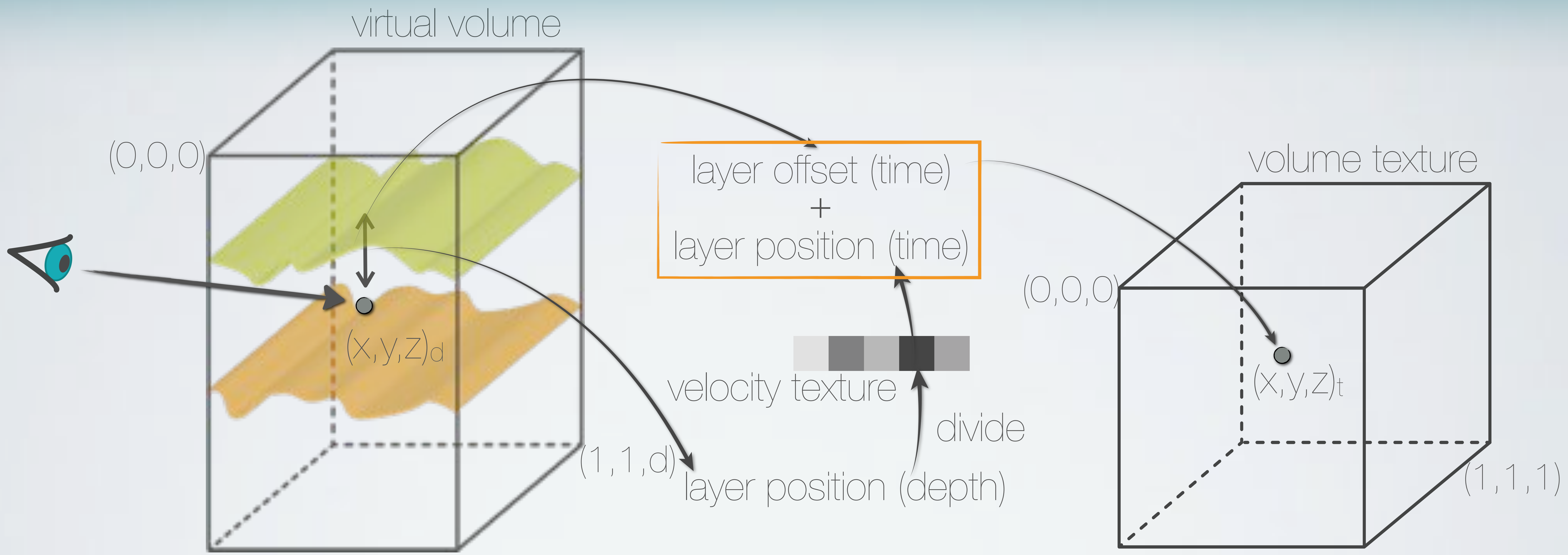

97.19 fps
63.21 fps

Joint Time/Depth Domain // Deformation

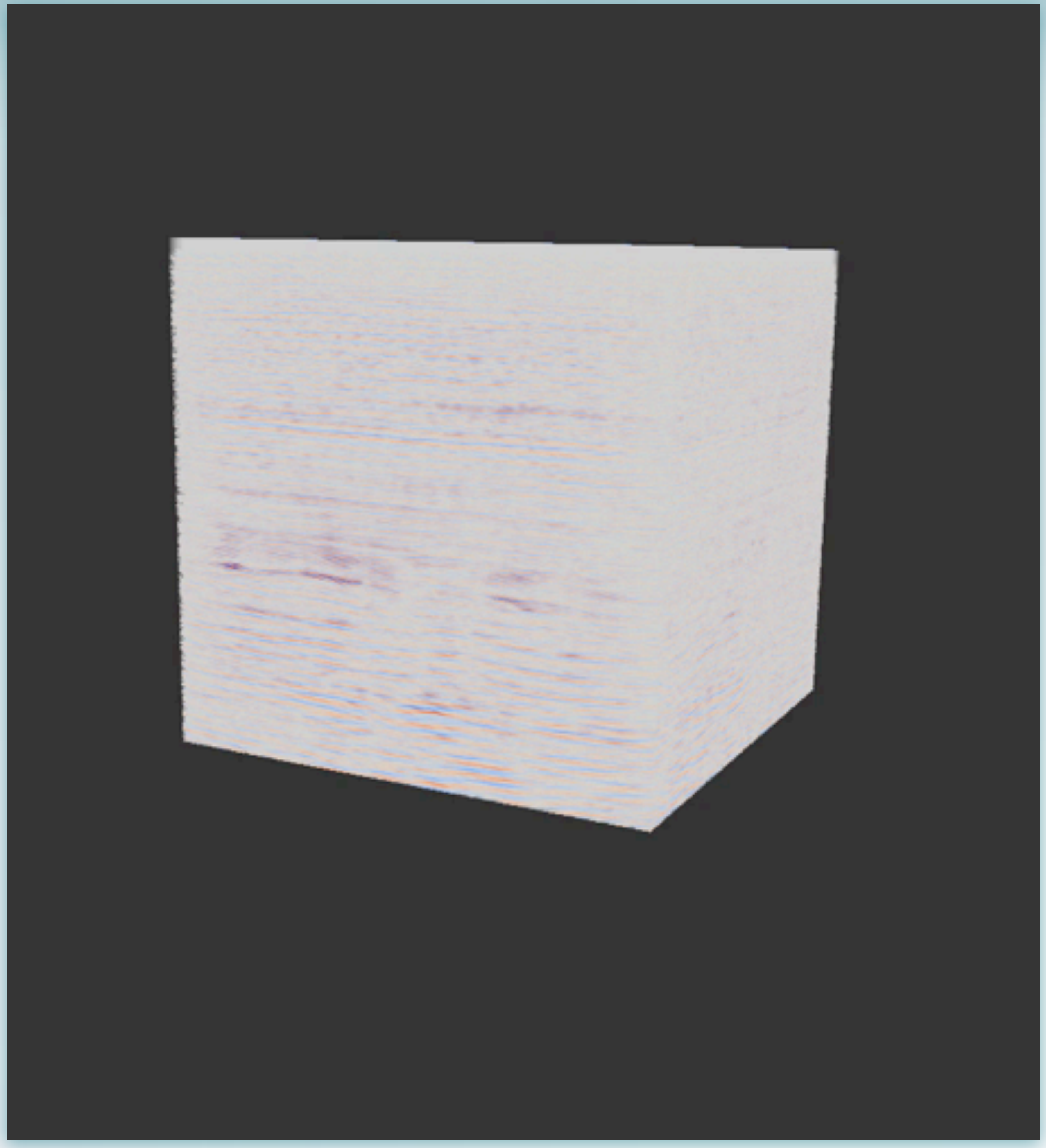
- Horizon deformation
  - iteratively deform boundaries from top to bottom
  - top boundary is equal in time & depth
  - following boundaries are sum of previous deformed boundary and deformed layer
  - all x,y-coordinates are independent

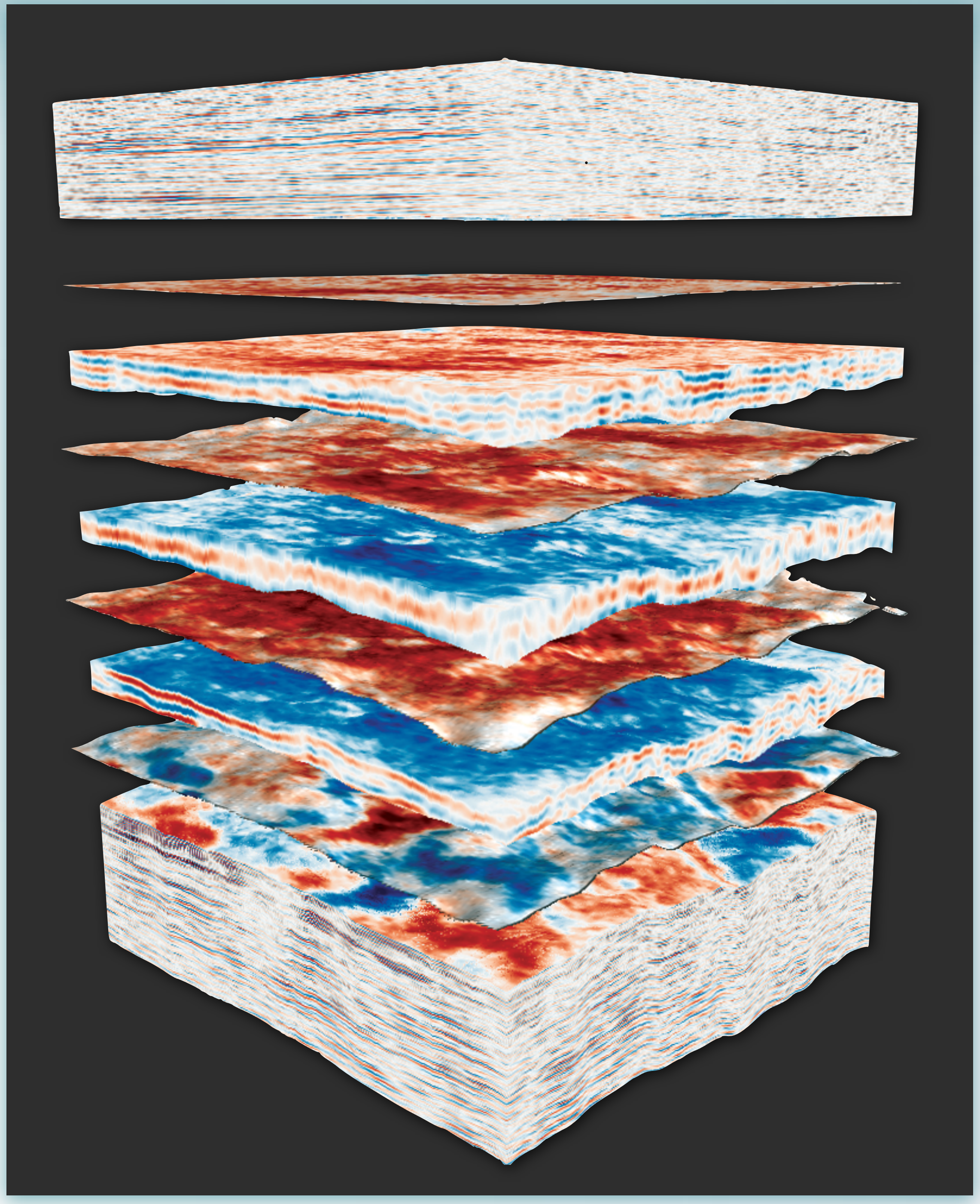


Joint Time/Depth Domain // Deformation



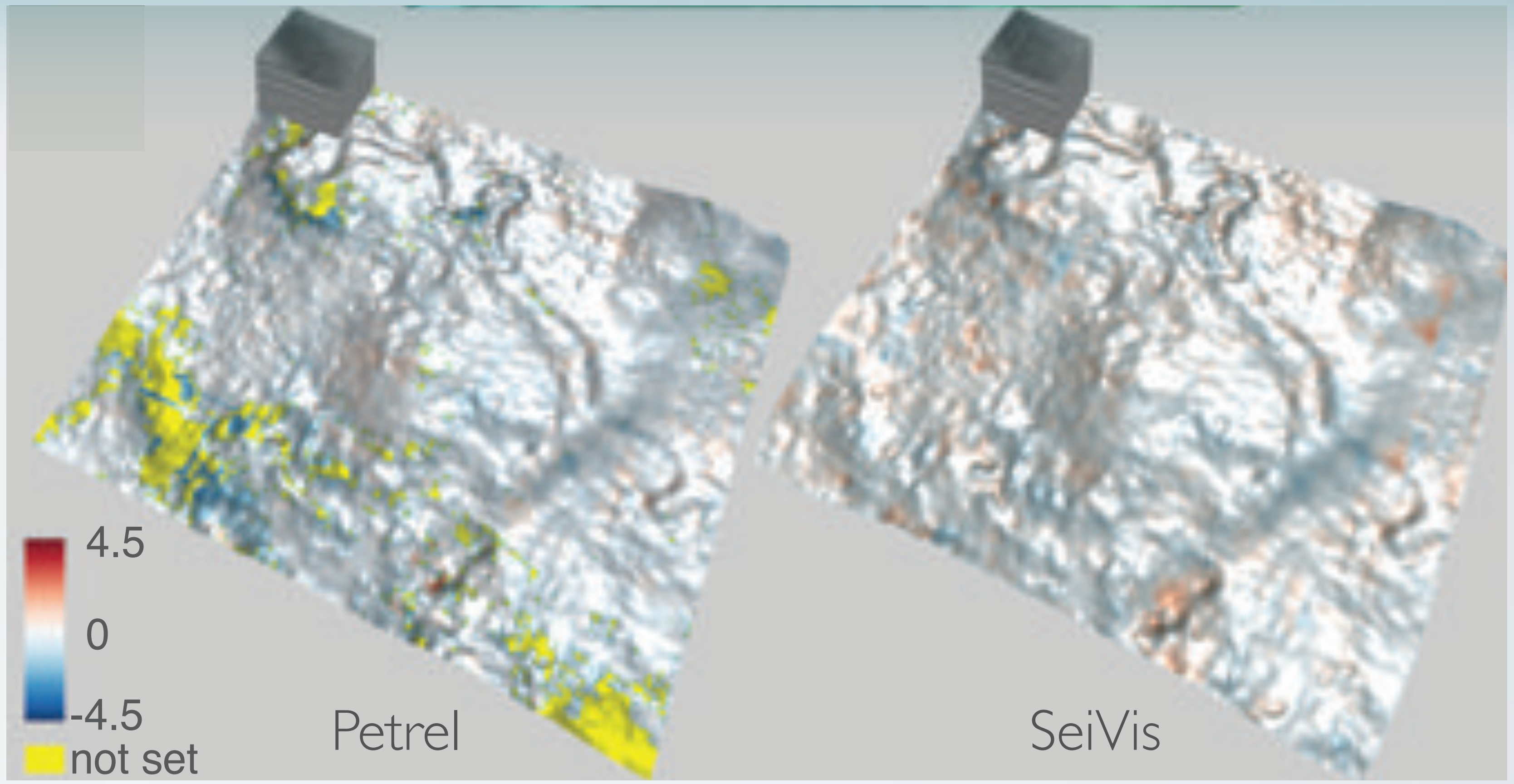
Volume Deformation // Exploded Views



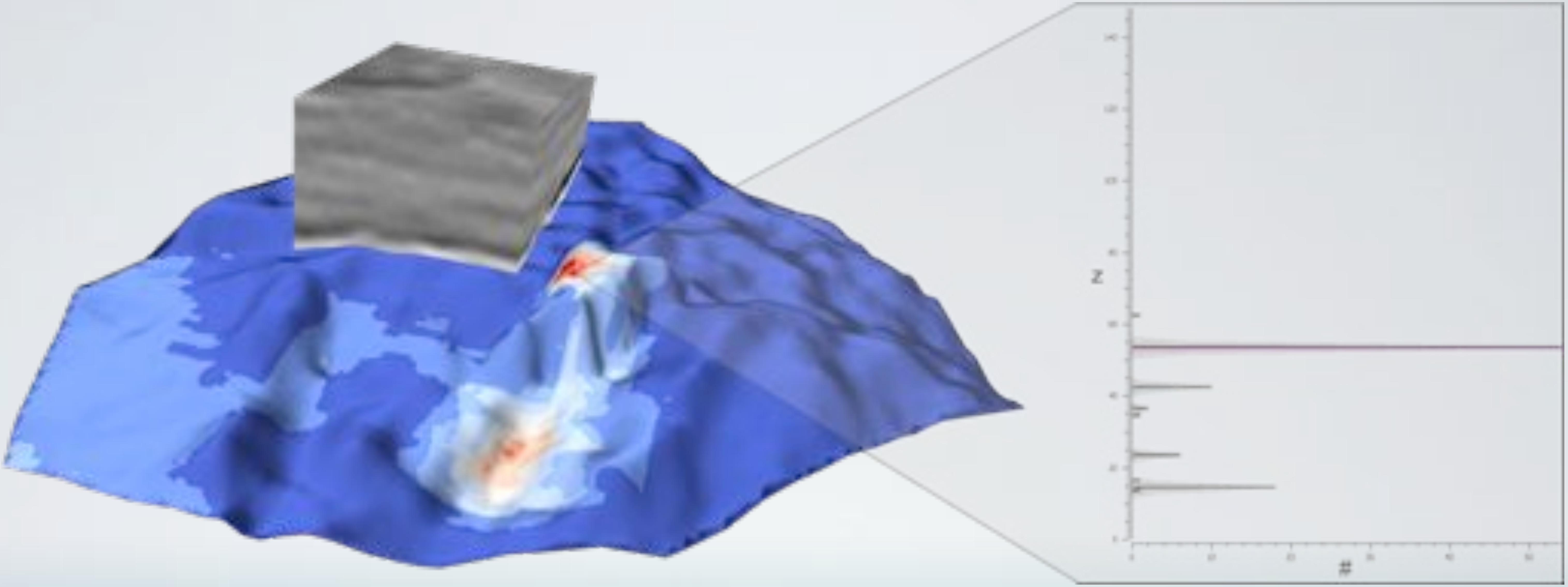


Results // Expert Evaluation

- 60 minutes for both apps (after introduction to our tool)
- Expert likes prism based workflow
- Live depth conversion is very helpful



App	Initial Interpret.	Velocity computation	Depth conv. computation	Refine	# slices / prisms	Avg. time
Petrel	>60min	21s	29s	n/a	18	200s
SeiVis	~45min	on the fly	on the fly	<10 min	63	43s



Visual Parameter Exploration for Horizon Extraction

Publications

T. Höllt, G. Chen, C.D. Hansen, and M. Hadwiger.
Extraction and Visual Analysis of Seismic Horizon Ensembles.
To appear in *Proceedings of Eurographics 2013 (short papers)*.

Motivation // Cost Function

- Three components, linearly blended:
  - gray value-based term, g_{gray}
  - waveform-based term, g_{wave}
  - similarity-based term, g_{smooth}
- Penalty for larger surfaces
- Final cost with three user adjustable parameters:

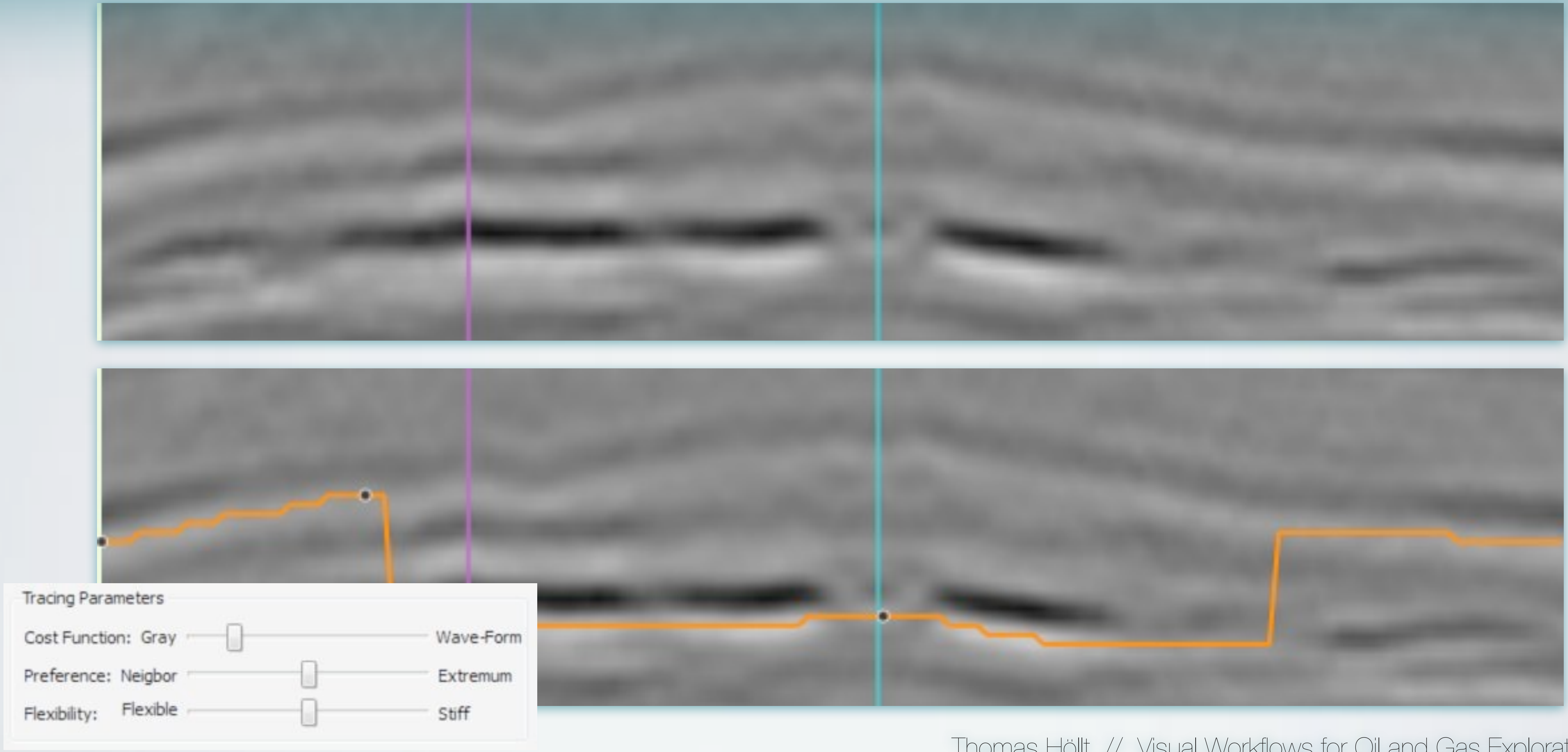
$$g_{\text{gray}}(e) = \sum_{(x,y,z)\in\mathcal{N}(e)} |t - f(x,y,z)|$$

$$g_{\text{wave}}(e) = \sum_{(x,y,z)\in\mathcal{N}(e)} \left(1 - \sum_{k=1}^{m} \varphi_s(x,y,z,k)\right)$$

$$g_{\text{smooth}}(e) = \sum_{(x,y,z)\in\mathcal{N}(e)} |f(x,y,z) - \text{avg}(e)|$$

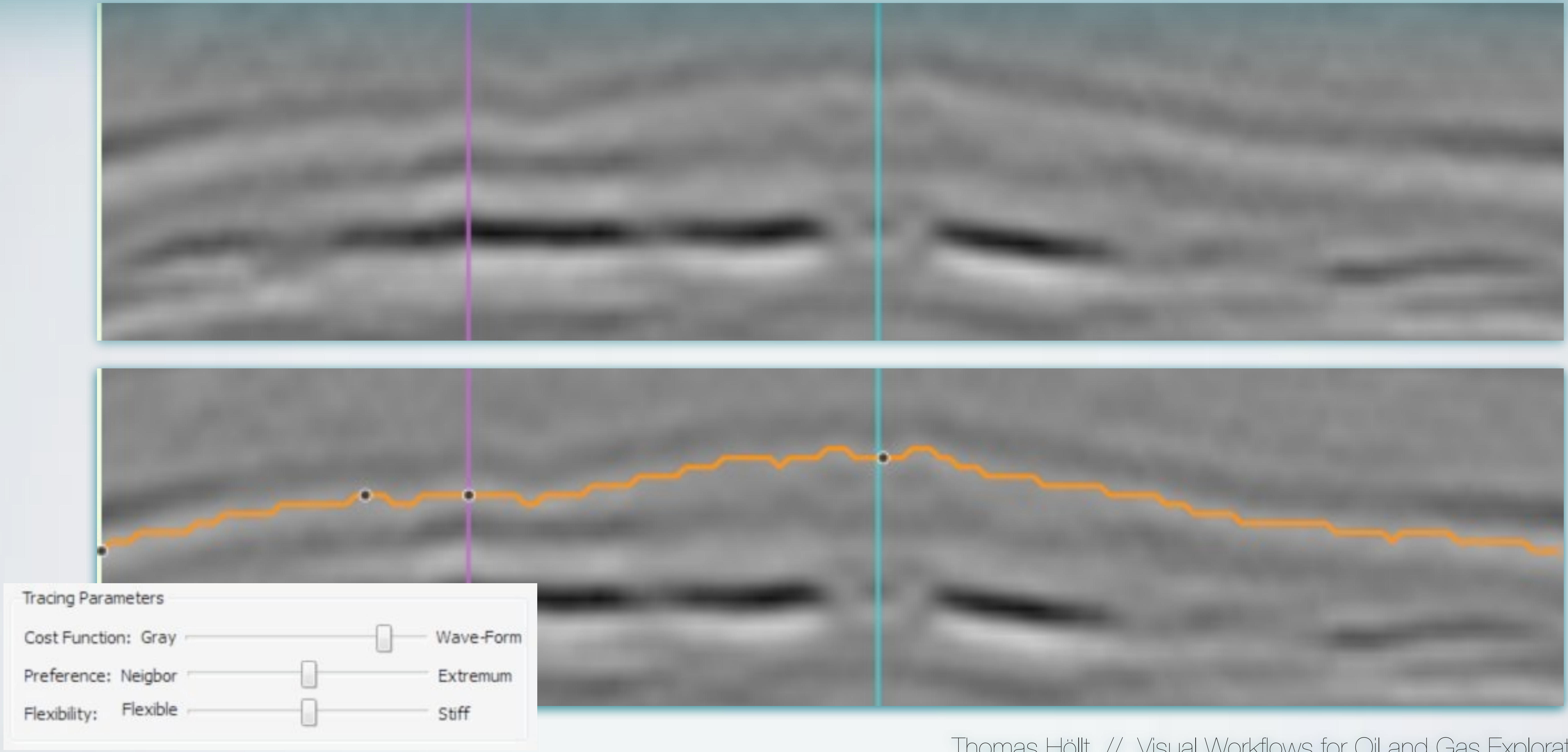
$$\text{cost}(e) = p_2 \cdot \left(p_1 \cdot \left(p_0 \cdot g_{\text{gray}} + (1-p_0) \cdot g_{\text{wave}}\right) + (1-p_1) \cdot g_{\text{smooth}}\right)$$

Motivation



Tracing Parameters
Cost Function: Gray
Wave-Form
Preference: Neigbor
Extremum
Flexibility: Flexible
Stiff

Motivation


Tracing Parameters
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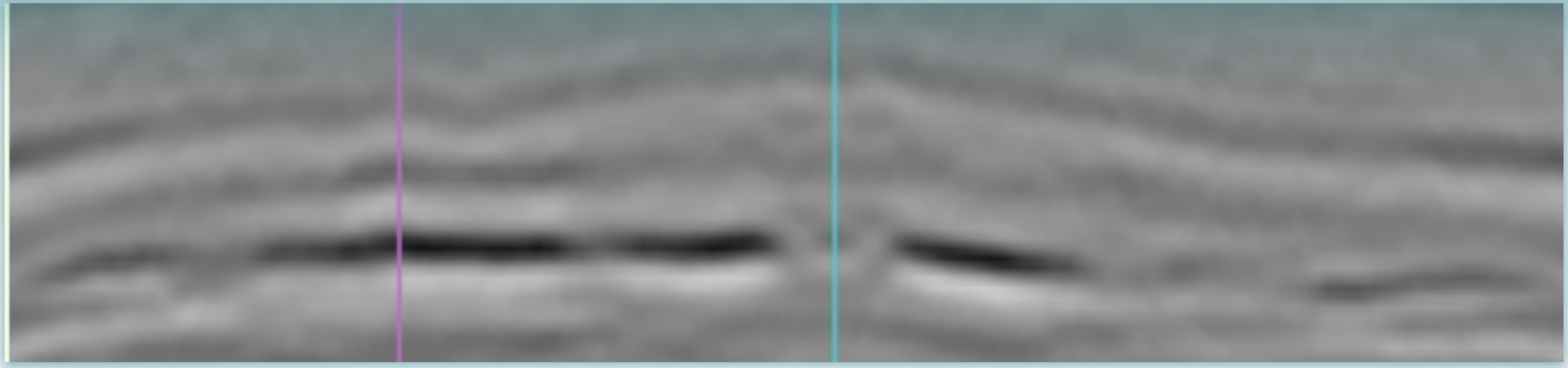
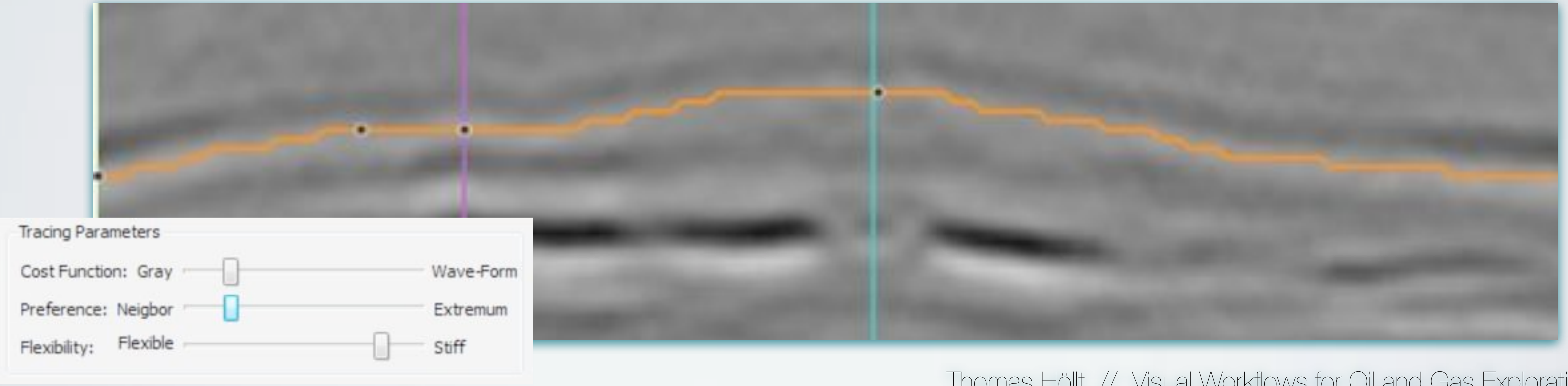
Motivation




Tracing Parameters
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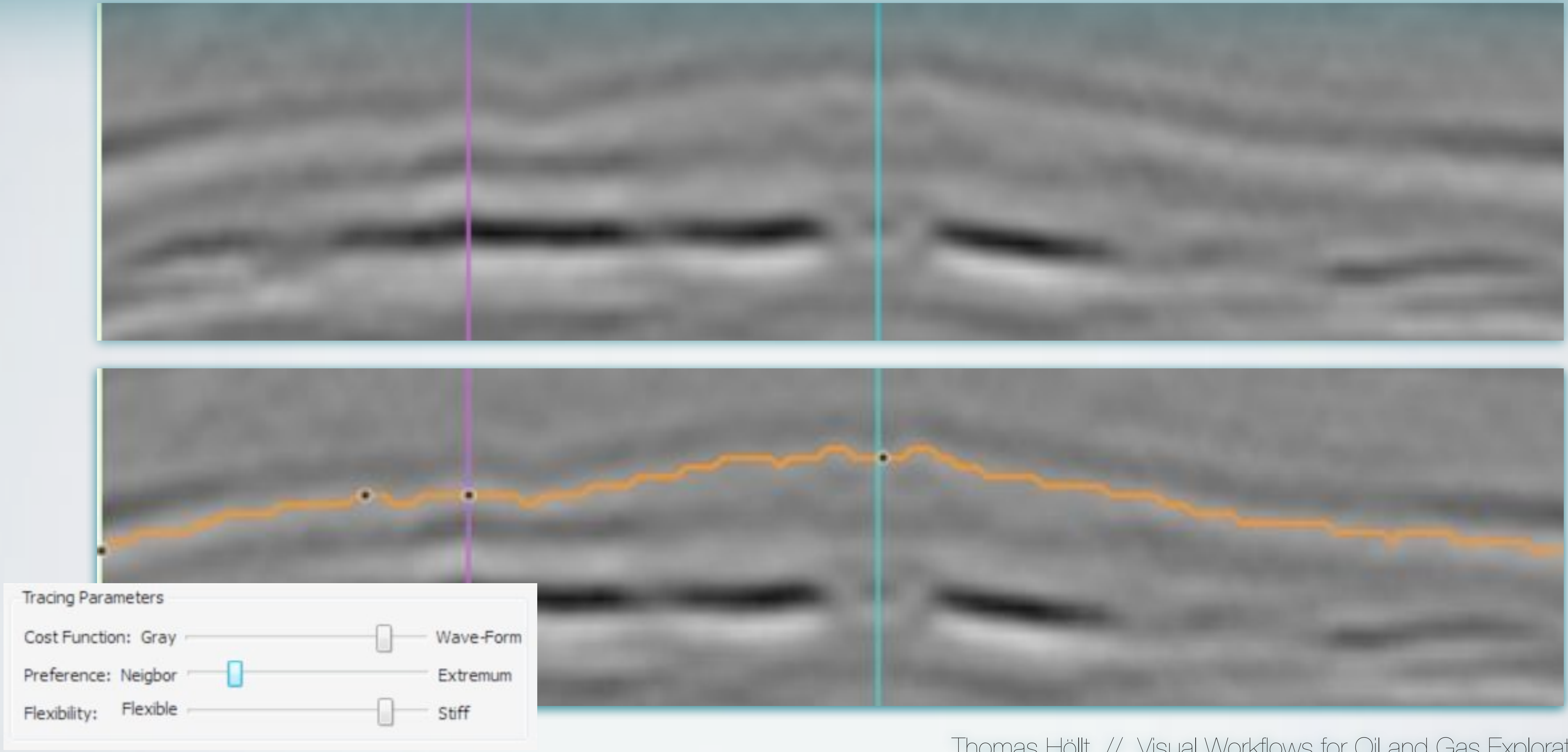
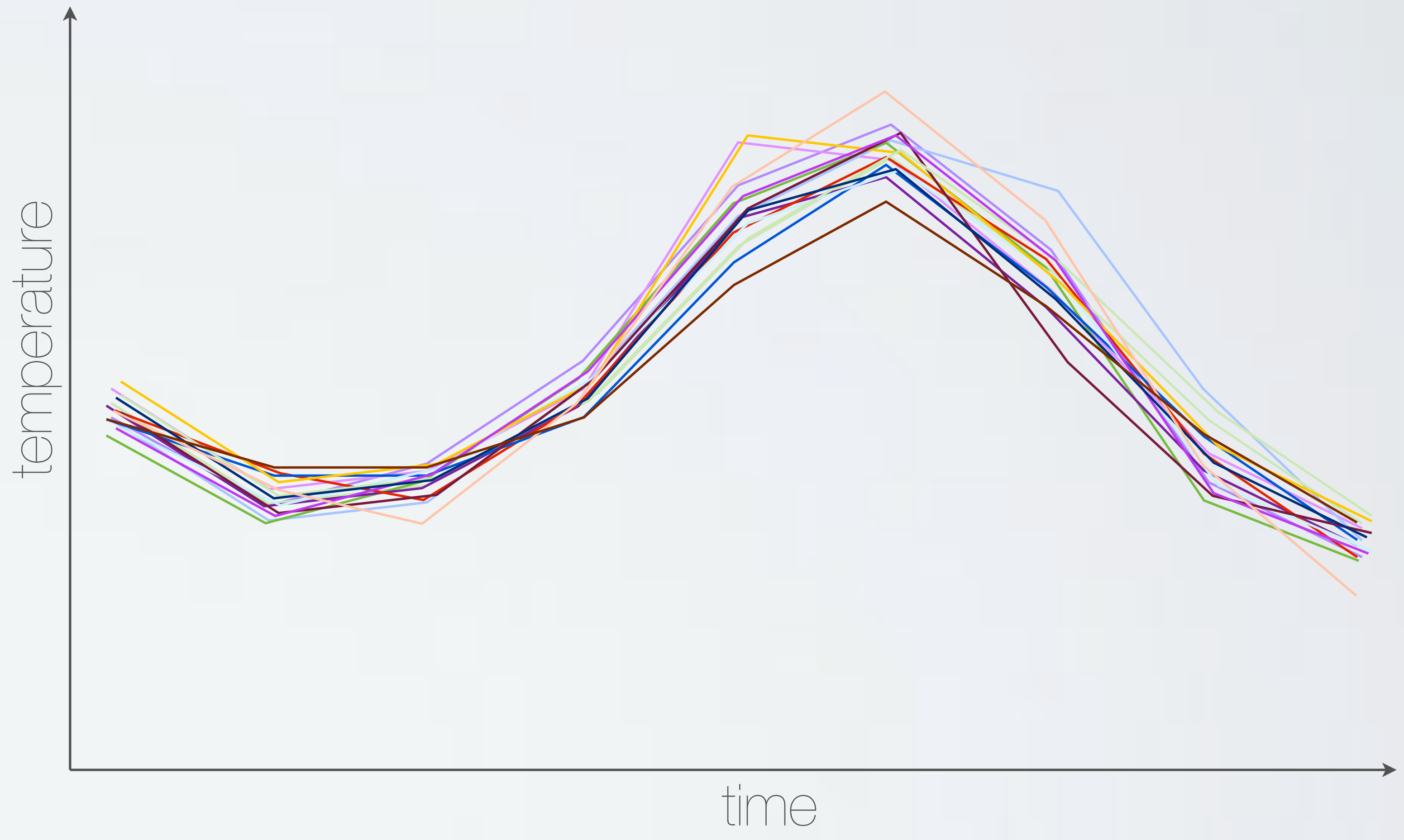
Motivation


Tracing Parameters
Cost Function: Gray
Wave-Form
Preference: Neigbor
Extremum
Flexibility: Flexible
Stiff

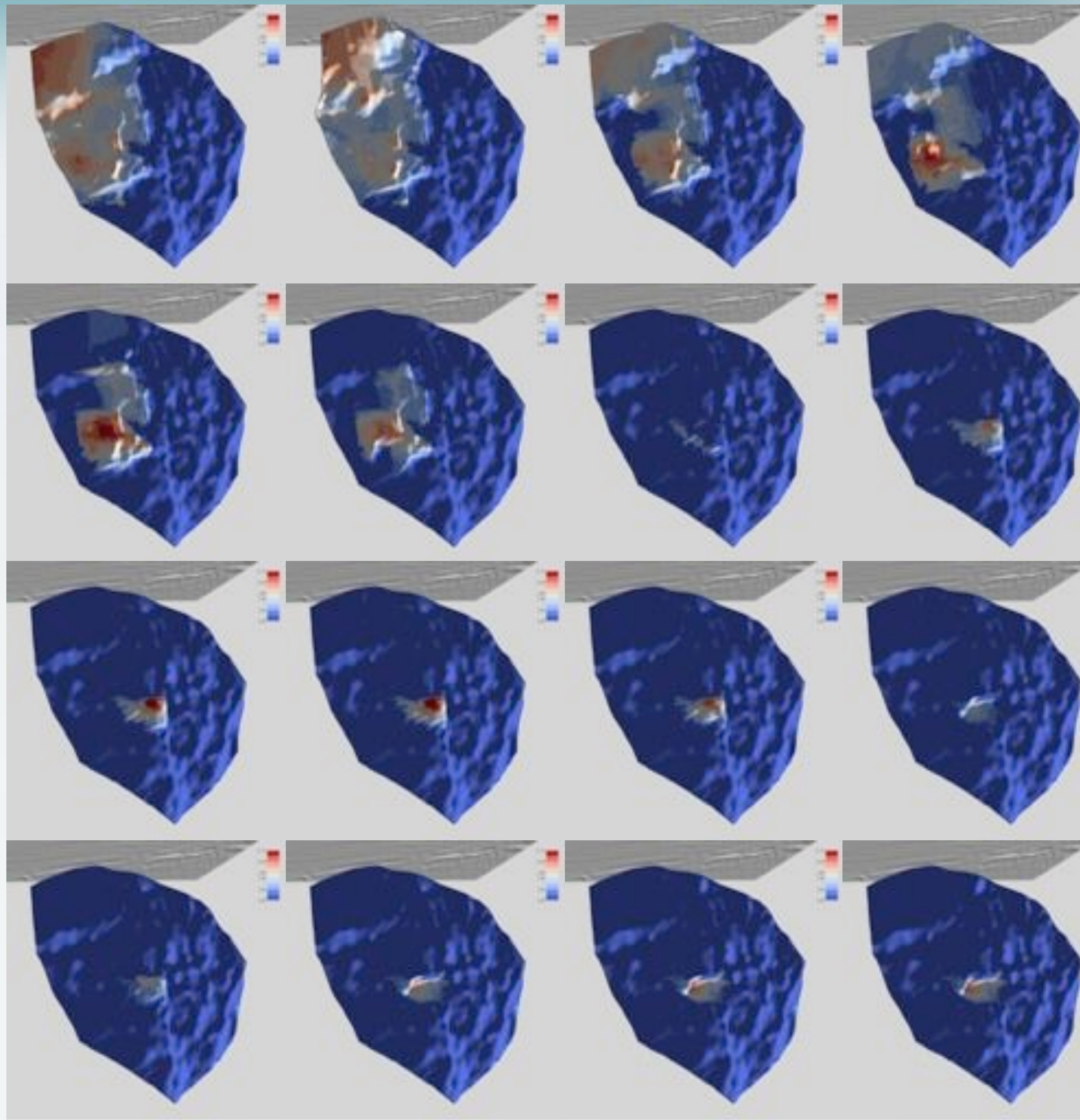
Ensemble Data

- Idea: compute multiple solutions for a single simulation/feature/event
- An ensemble usually is
  - multivalued
  - multivariate
  - multidimensional



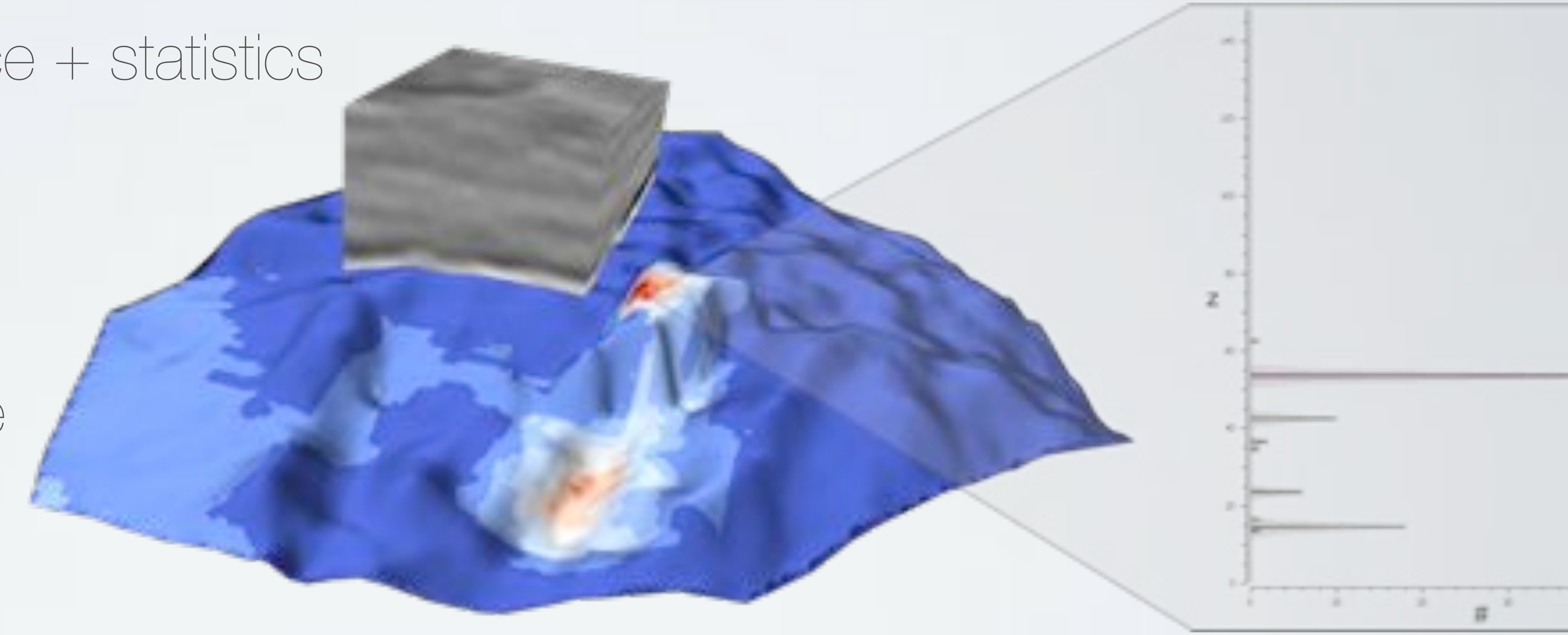
Ensemble Extraction

- We have global optimization surface extraction technique with a parameterized cost function
  - sample parameter space
  - extract surface for each sample without interaction
  - results in a set of possible surfaces for each horizon



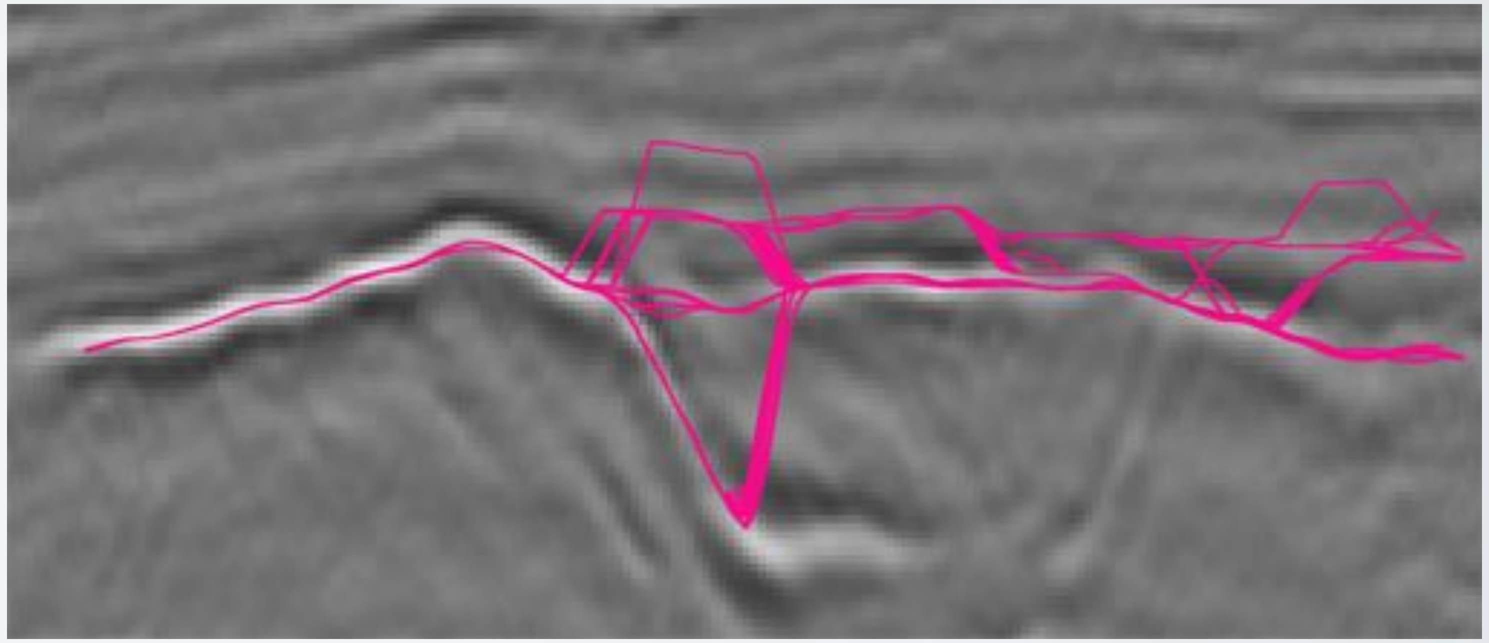
Multivalue Visualization

- Statistical analysis
- Overview first
  - representative surface + statistics
- Details on demand
  - interactive probing
  - live parameter-space exploration

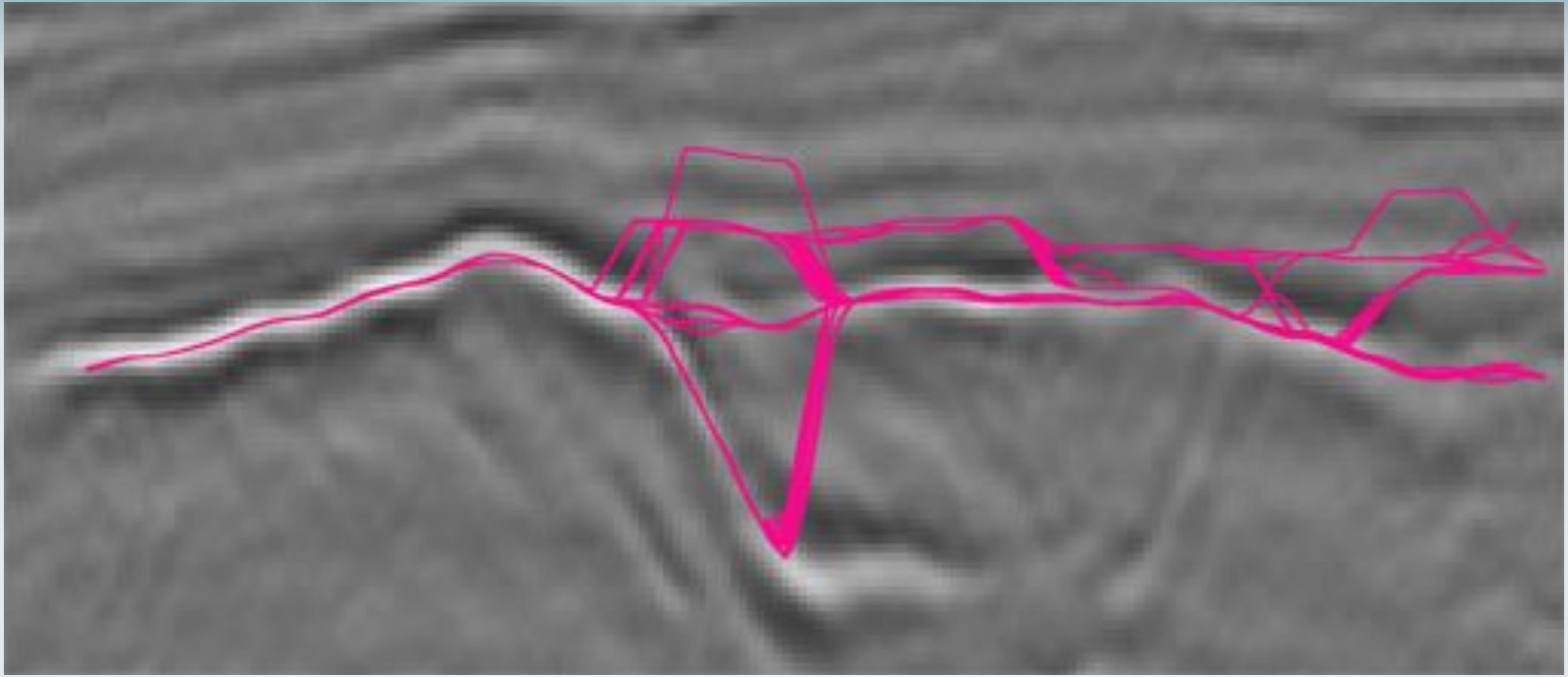


Representative Surface

- Surface extraction leads to clustering
  - mean surface is not a good fit

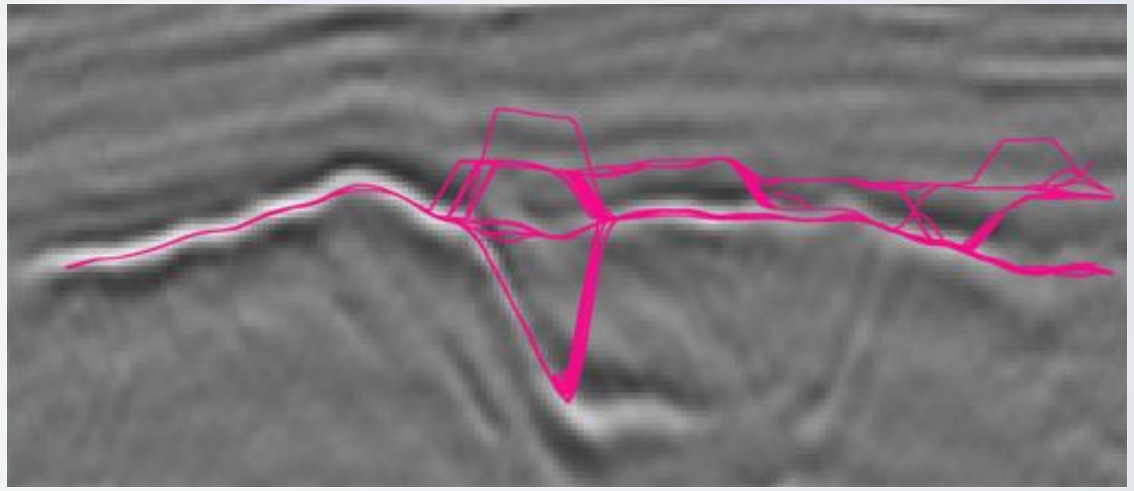


Representative Surface

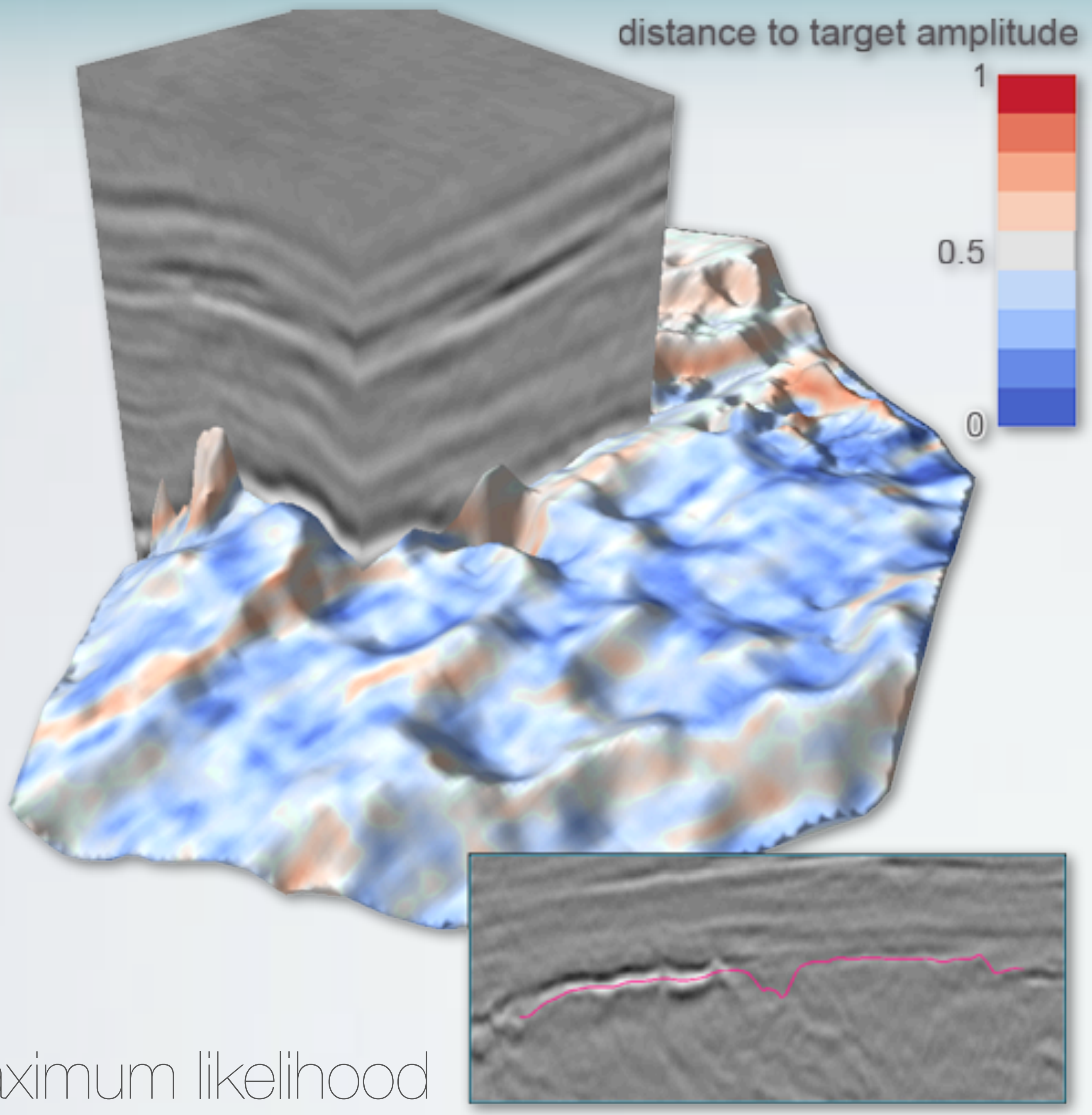


Representative Surface

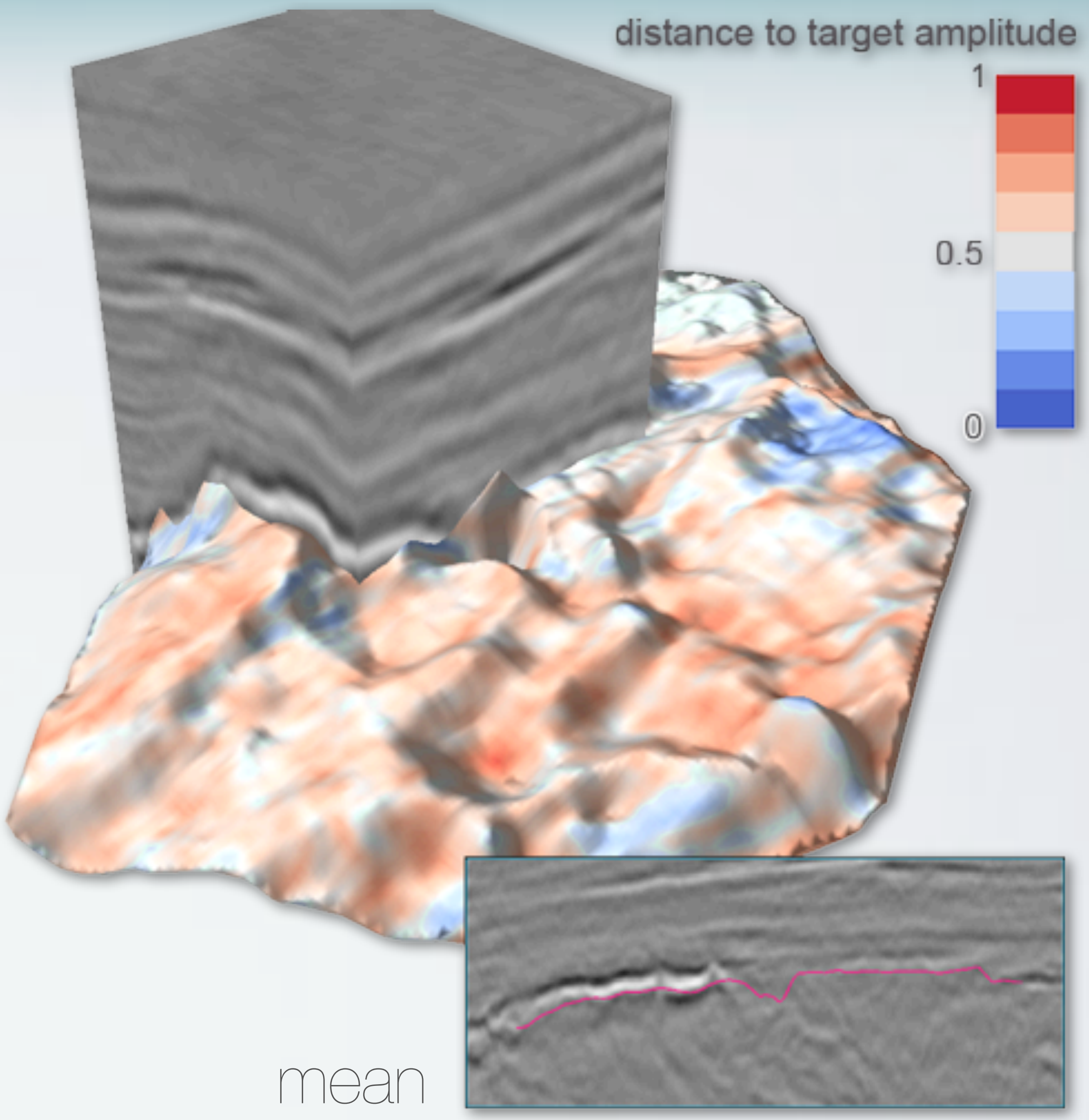
- Surface extraction leads to clustering
  - mean surface is not a good fit
  - ➩ use a 'maximum likelihood' surface instead
    - compute a probability for each surface patch
    - sum up probabilities for all patches
    - use surface with the highest sum



Maximum Likelihood Surface II

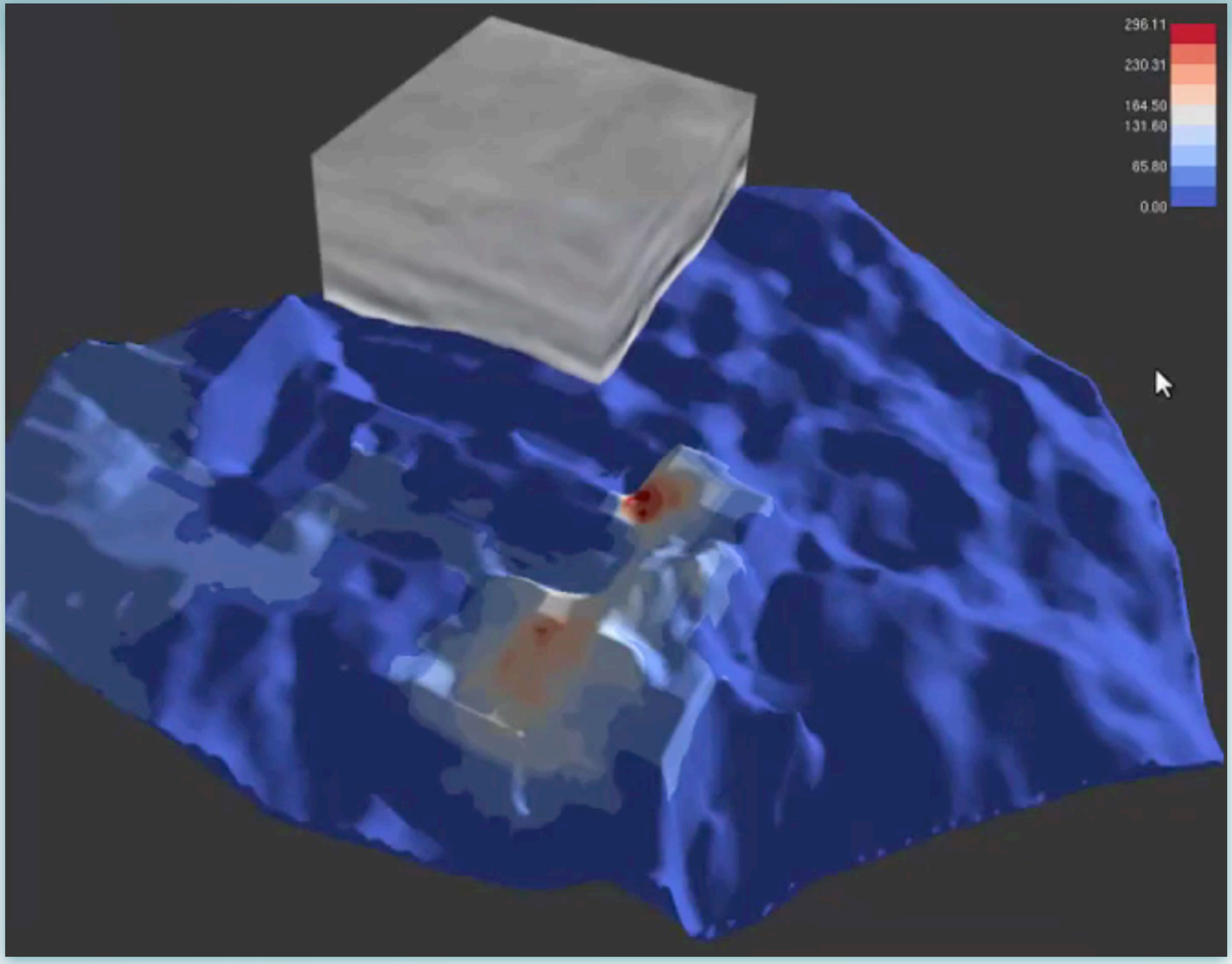


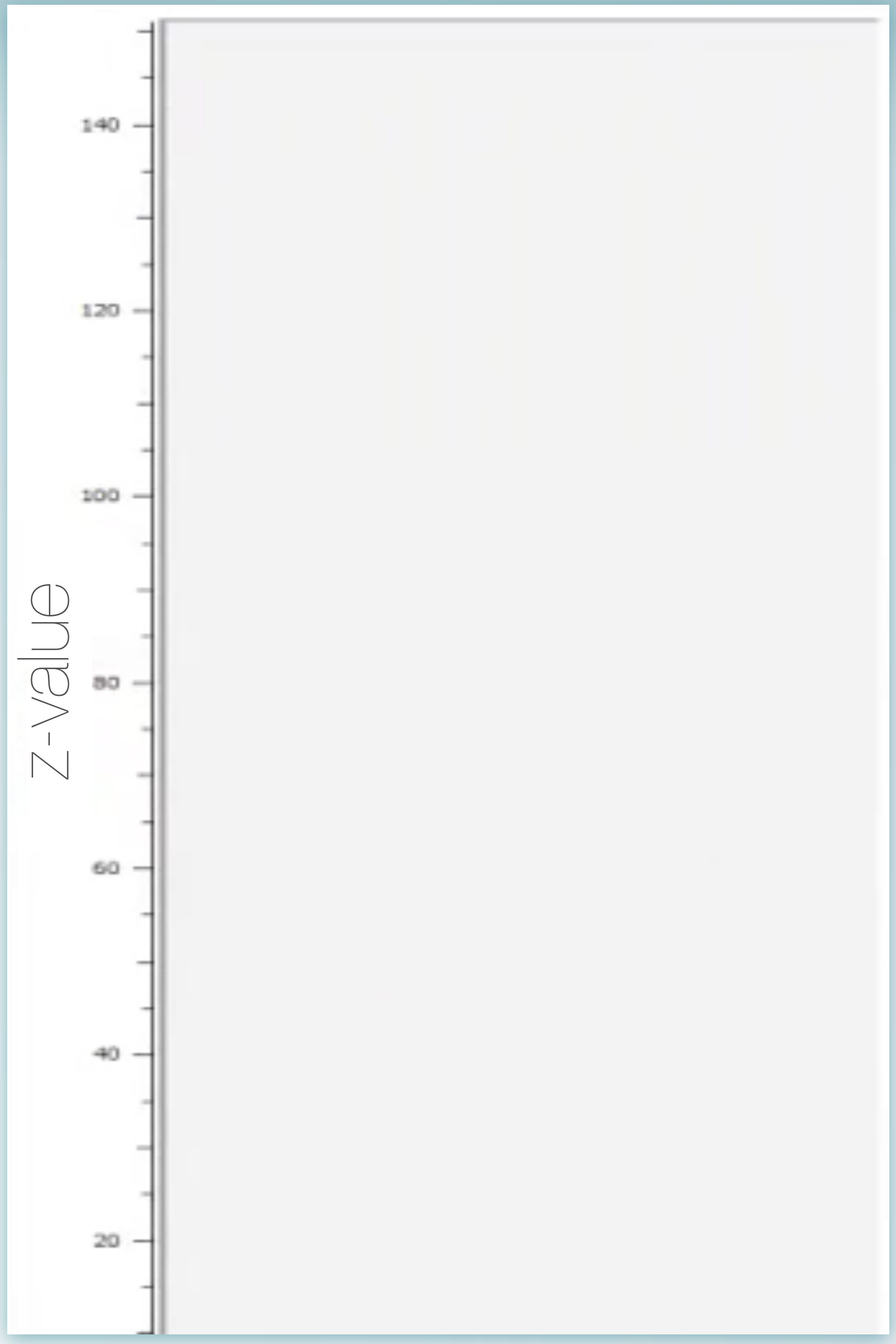
maximum likelihood



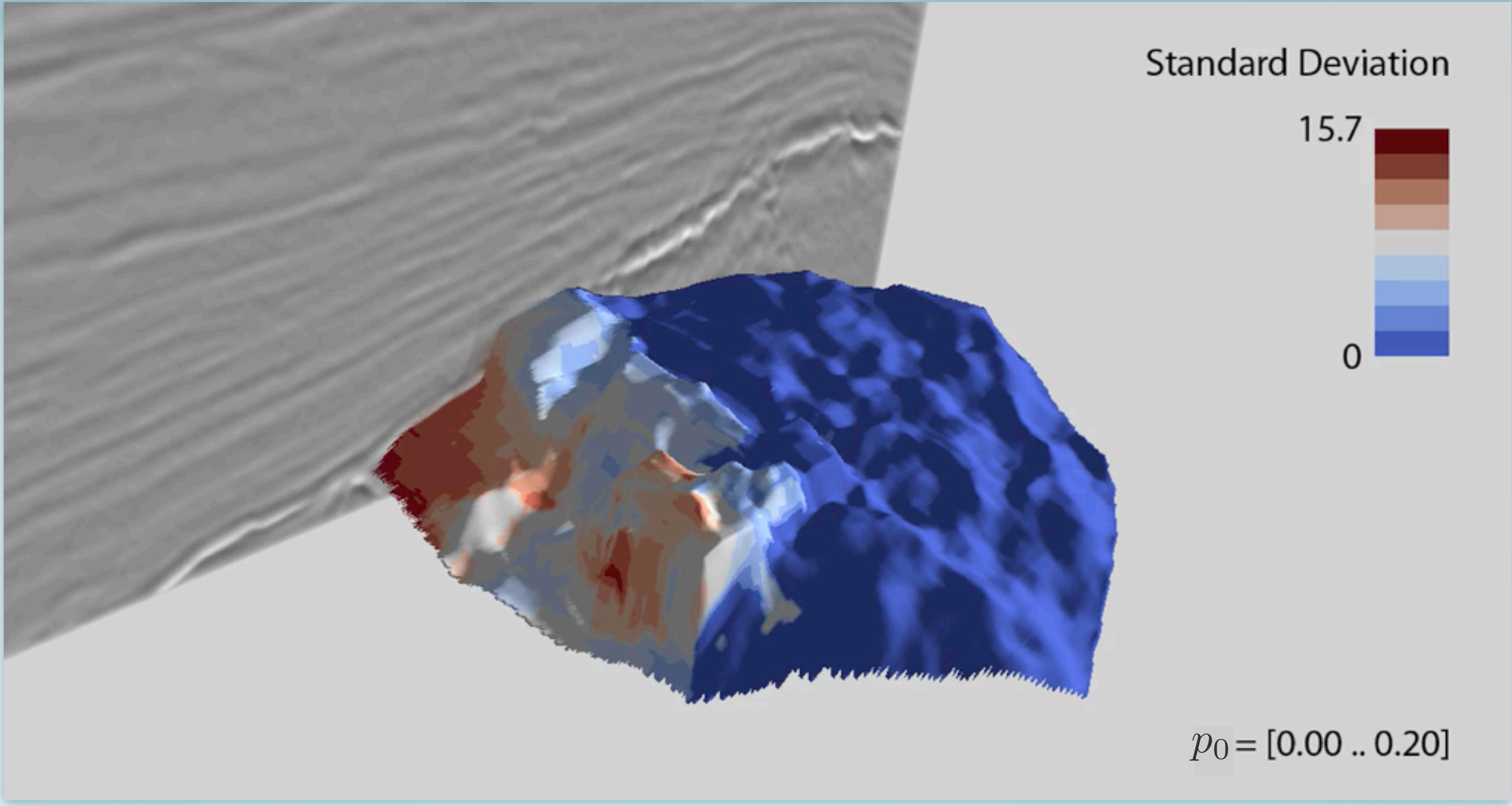
mean

Interactive Probing

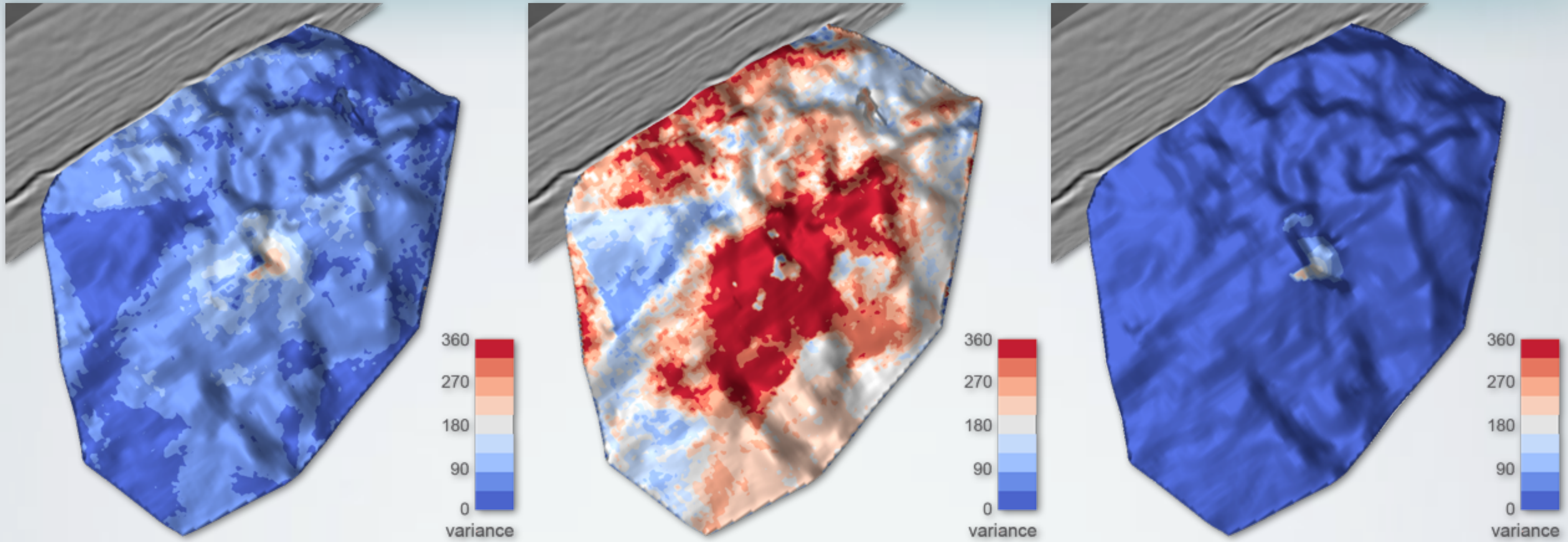




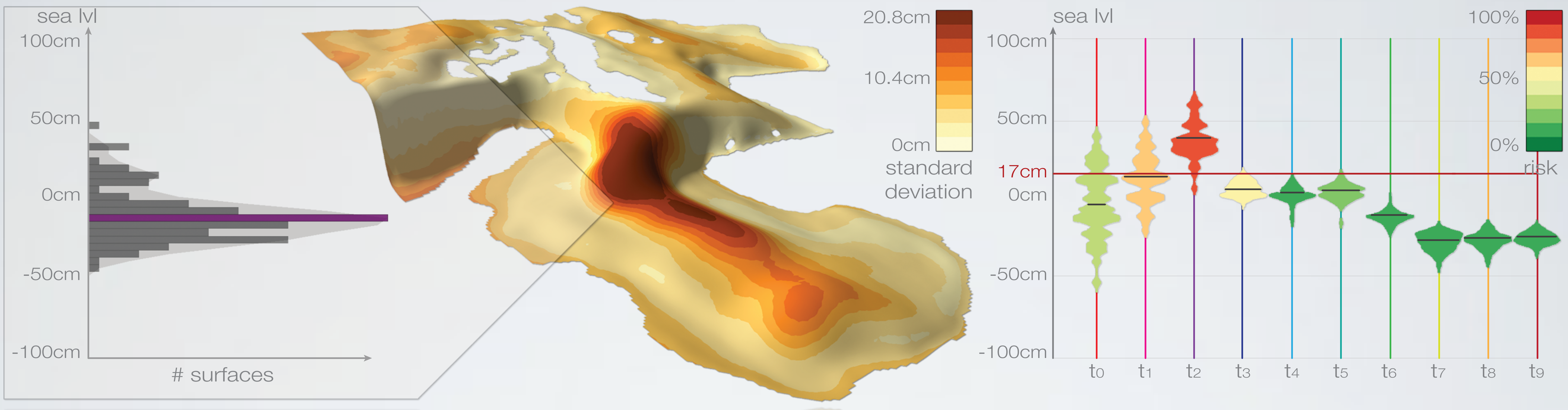
Parameter Space Exploration



Parameter Space Exploration II



$p_1 = [0..1]$ $p_1 = [0.9..1.0]$ $p_1 = [0.0..0.9]$



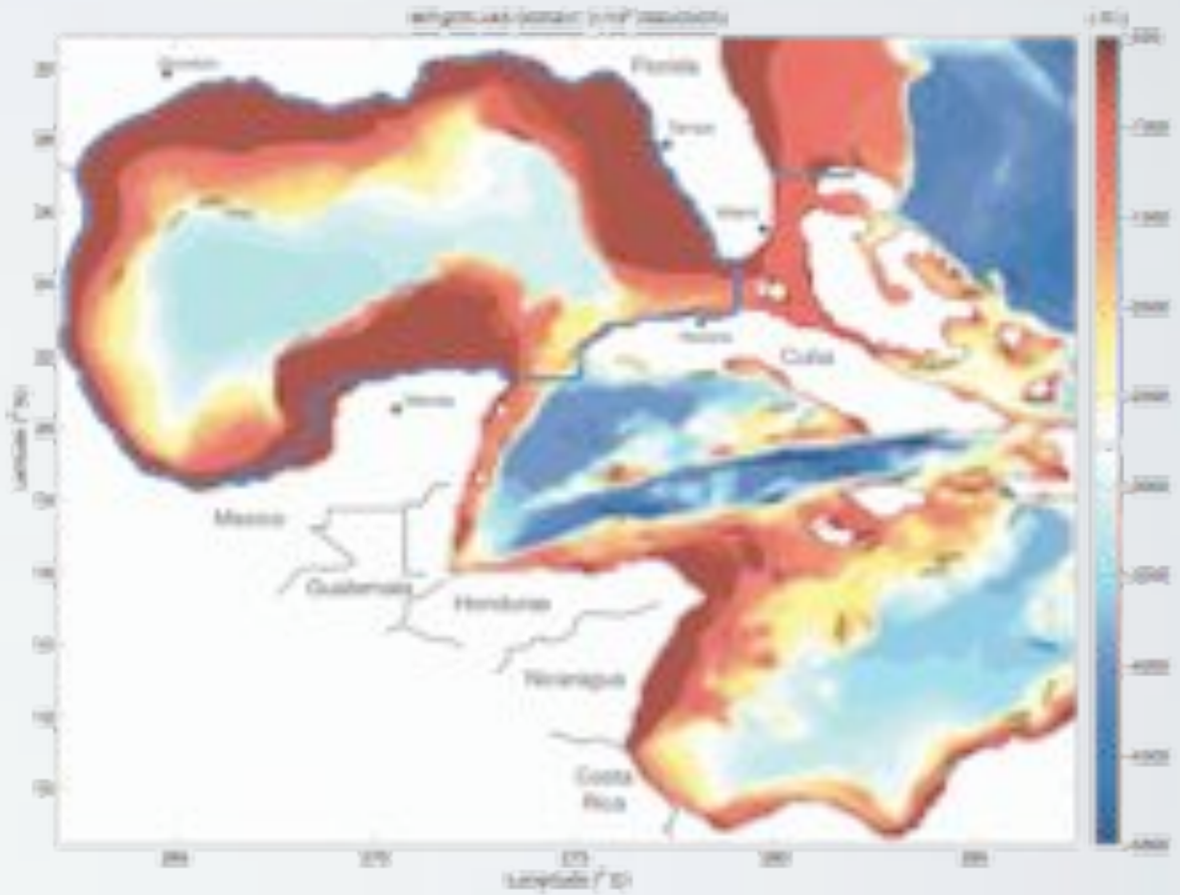
Visual Analysis of Uncertainties in Ocean Forecasts

Publications

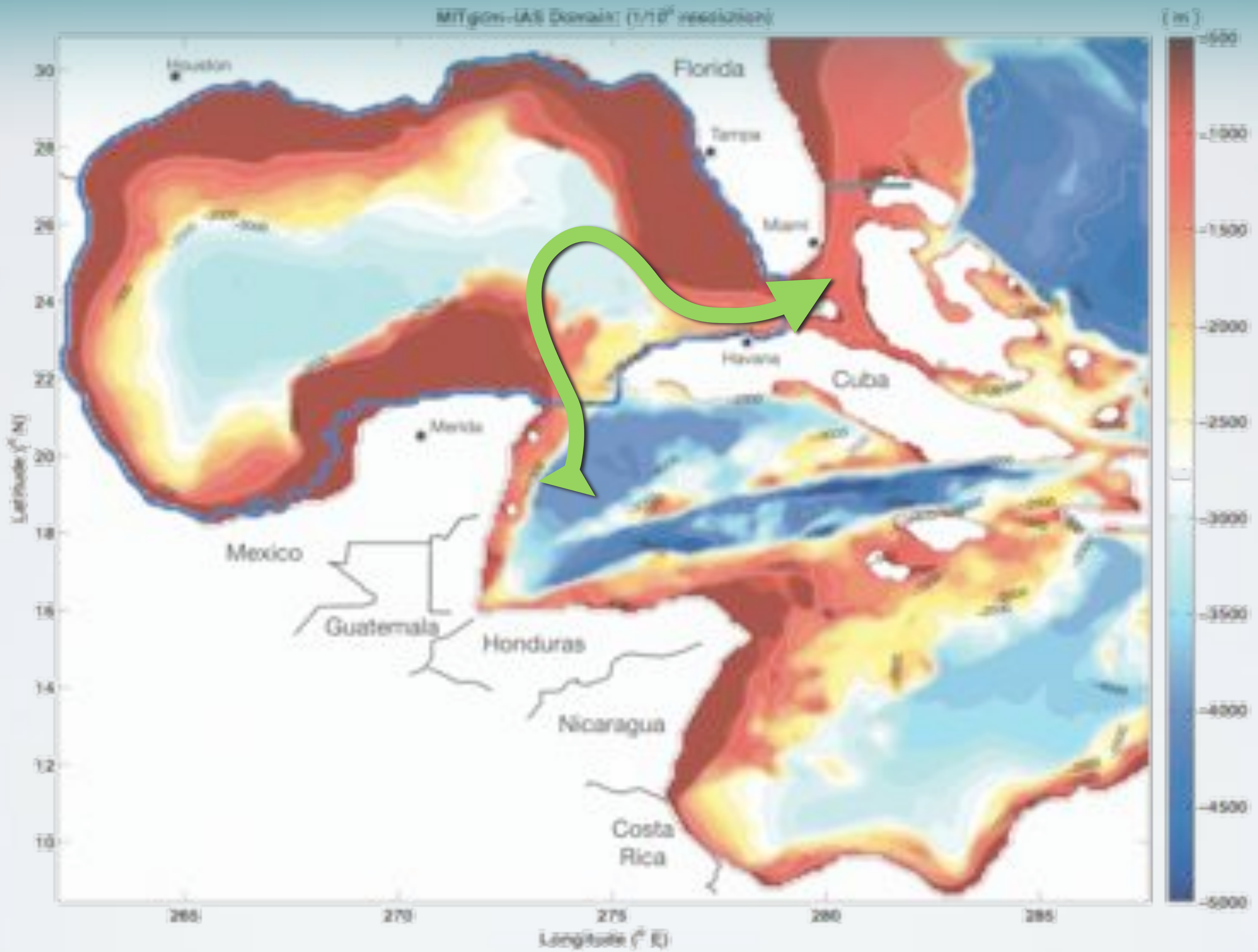
T. Höllt, A. Magdy, G. Chen, G. Gopalakrishnan, I. Hoteit, C.D. Hansen, and M. Hadwiger.
Visual Analysis of Uncertainties in Ocean Forecasts for Planning and Operation of Off-Shore Structures.
In *Proceedings of IEEE Pacific Visualization Symposium 2013*, pages 185—192, 2013.
Honorable mention for best paper award.

Motivation

- Planning off-shore rig operation
  - off-shore oil exploration vulnerable to hazards

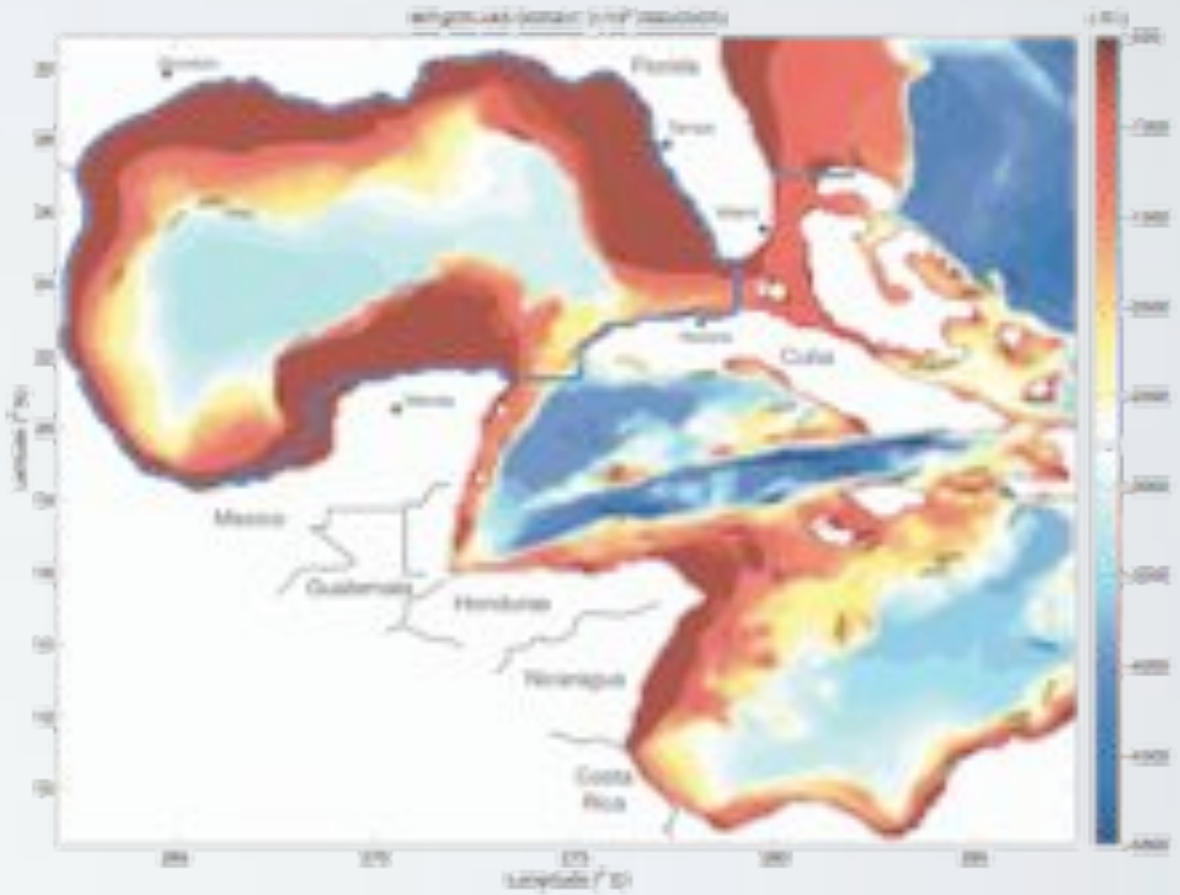


Motivation // GoM Eddy Shedding



Motivation

- Planning off-shore rig operation
  - off-shore oil exploration vulnerable to hazards
  - ocean forecasts allow planning operation
  - forecasts based on ensemble simulation



Ensemble Forecasts

- Ensemble simulation
  - multiple simulation runs for the same event
  - maps model or starting condition uncertainty to variation in simulation results

+ allows more precise forecasts

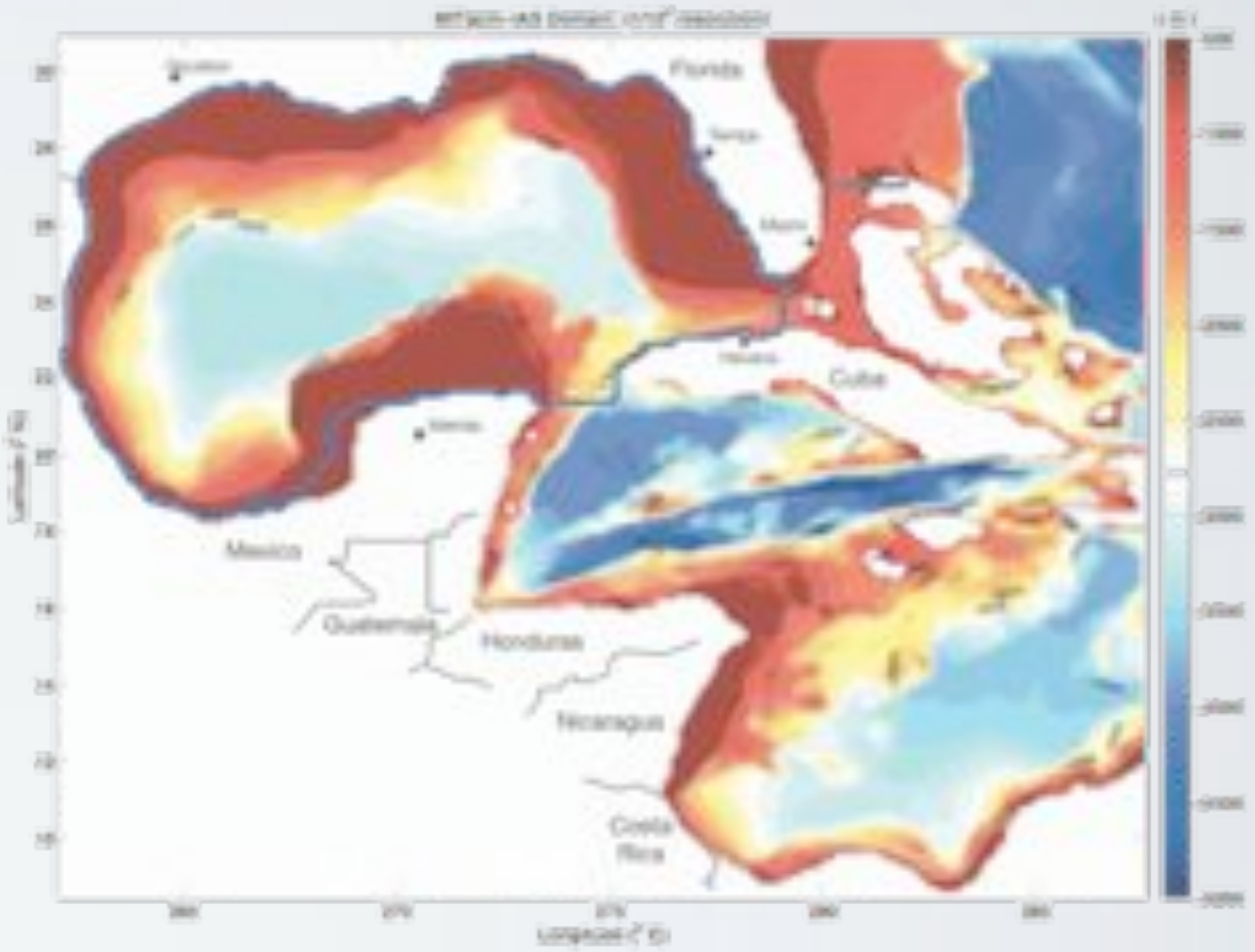
– results in large amount of data

– hard to visualize

“There is a 70% chance for rain tomorrow.”

Input Data

- Sea surface simulation of the GoM
  - height fields / 2D functions
  - 1/10° grid of the GoM ⇨ 275 x 325 samples
  - 10 time steps
  - 100 simulation runs each

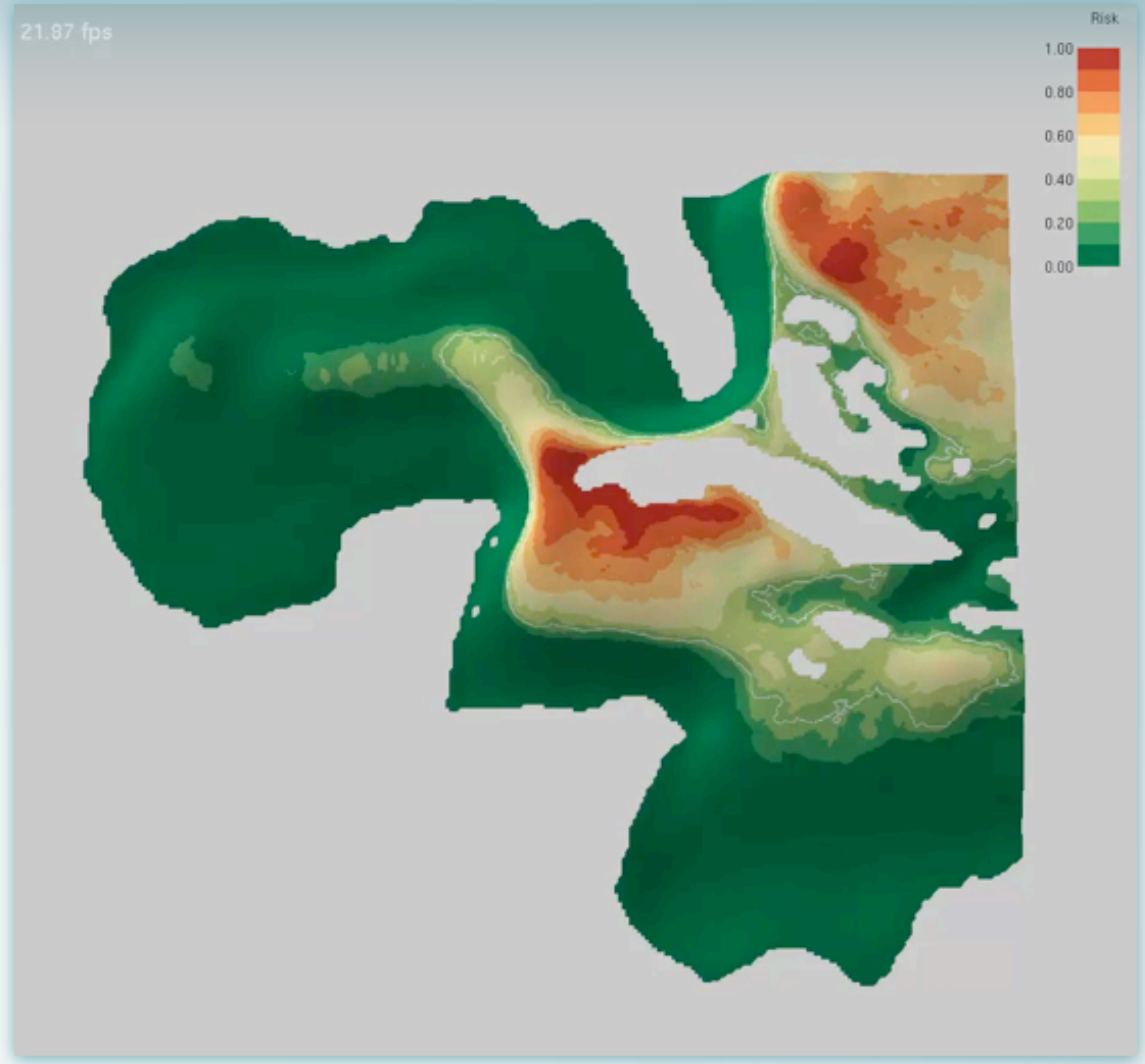


On the Fly Analysis

- Interactive parameter space exploration
  - statistics based on user defined ensemble subset
  - GPU-based computation
- Statistical analysis
  - histogram, pdf
  - mean, median, maximum mode ➾ surfaces
  - variance, kurtosis, risk estimate … ➾ textures
- Iso Contouring

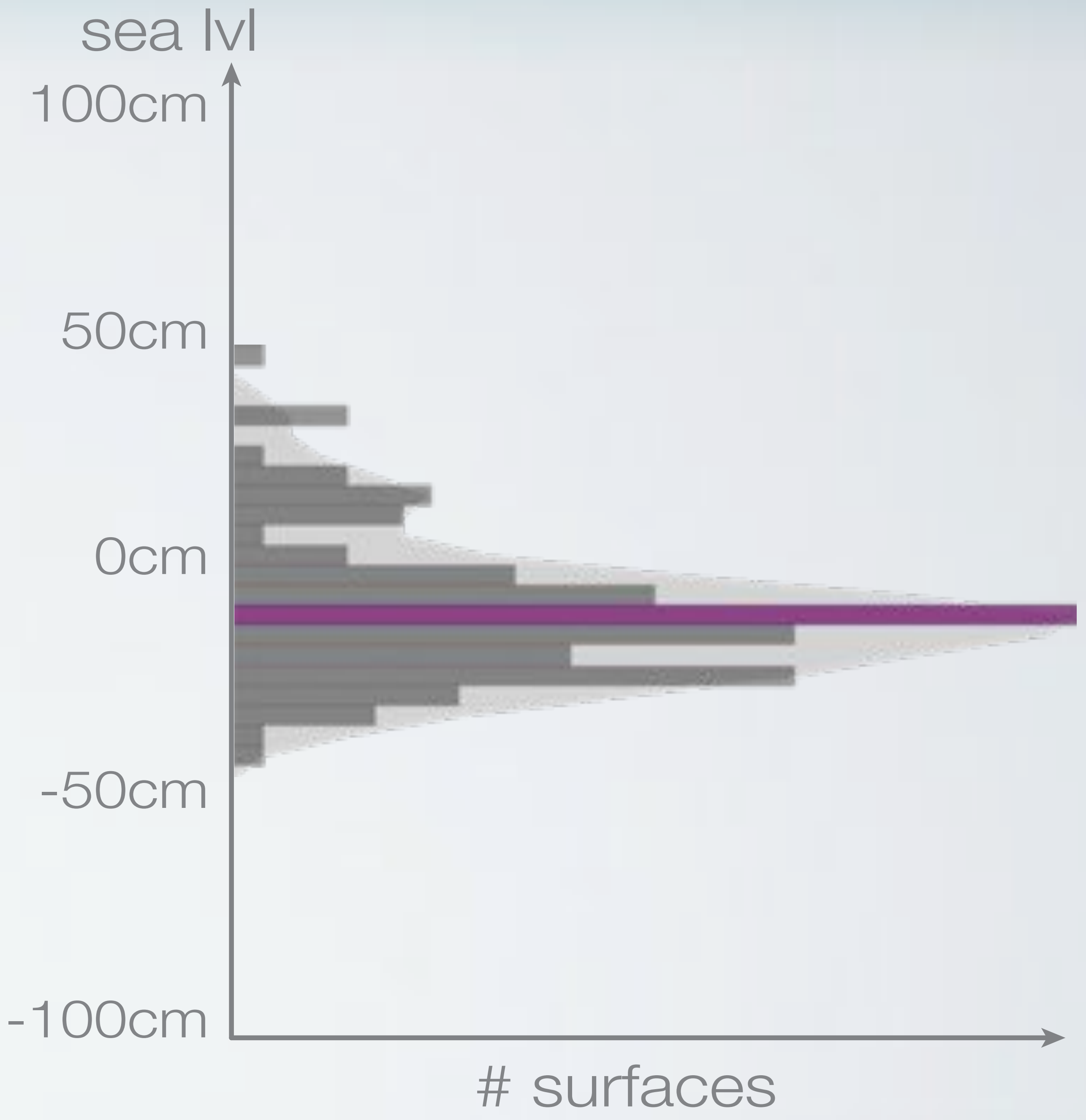
Statistical Analysis // Risk

- Based on user defined critical sea-level
  - fraction of surfaces above critical value
- On the fly adjustment of sea-level
- Live parameter space exploration
- Iso contouring for precise area definition



Statistical Analysis // 3D Histogram

- Complete distribution for each x,y position
  - histogram + pdf
- 3D volumetric cursor
  - user adjustable size
  - avoids clutter of rendering complete volume



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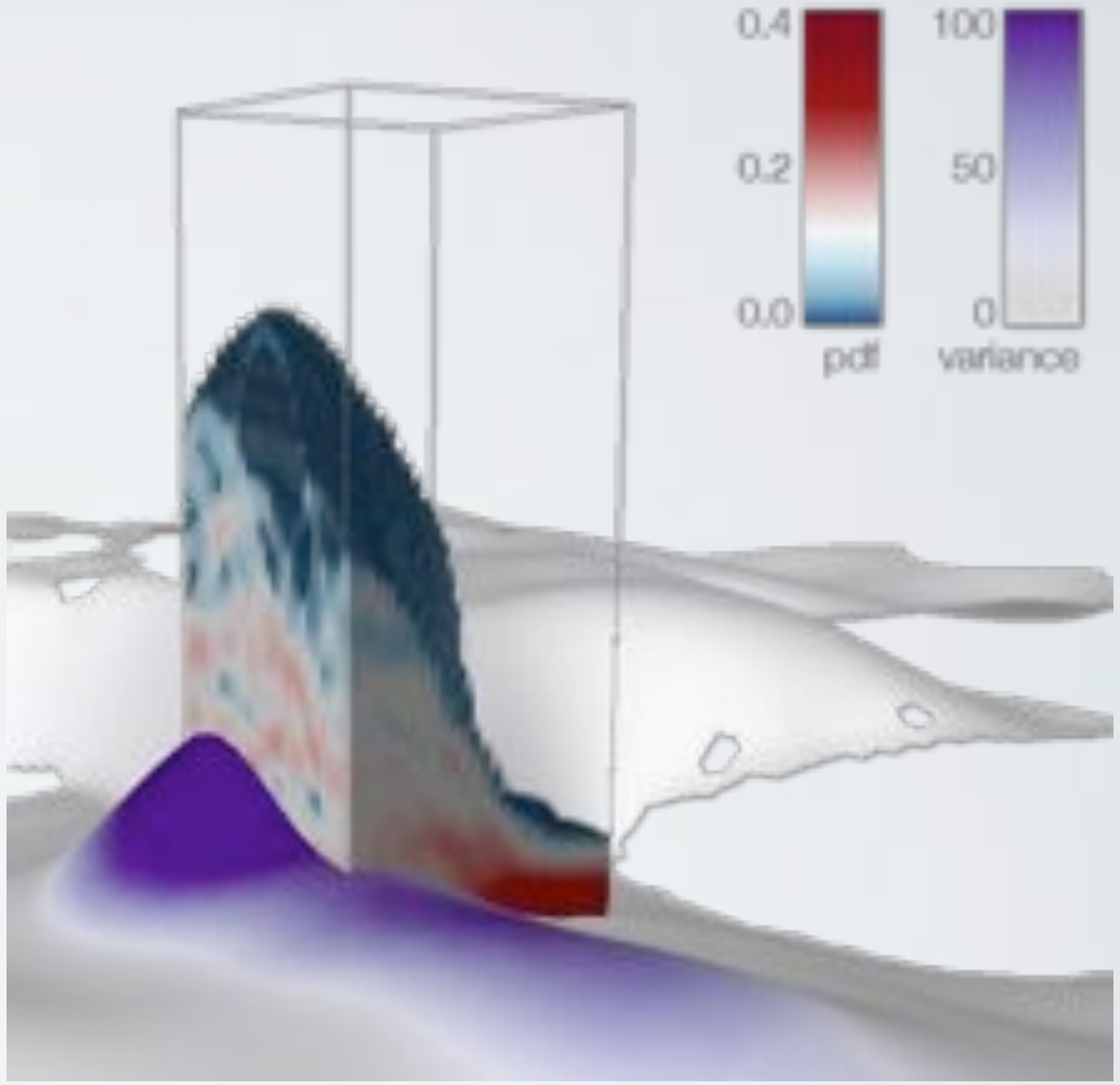
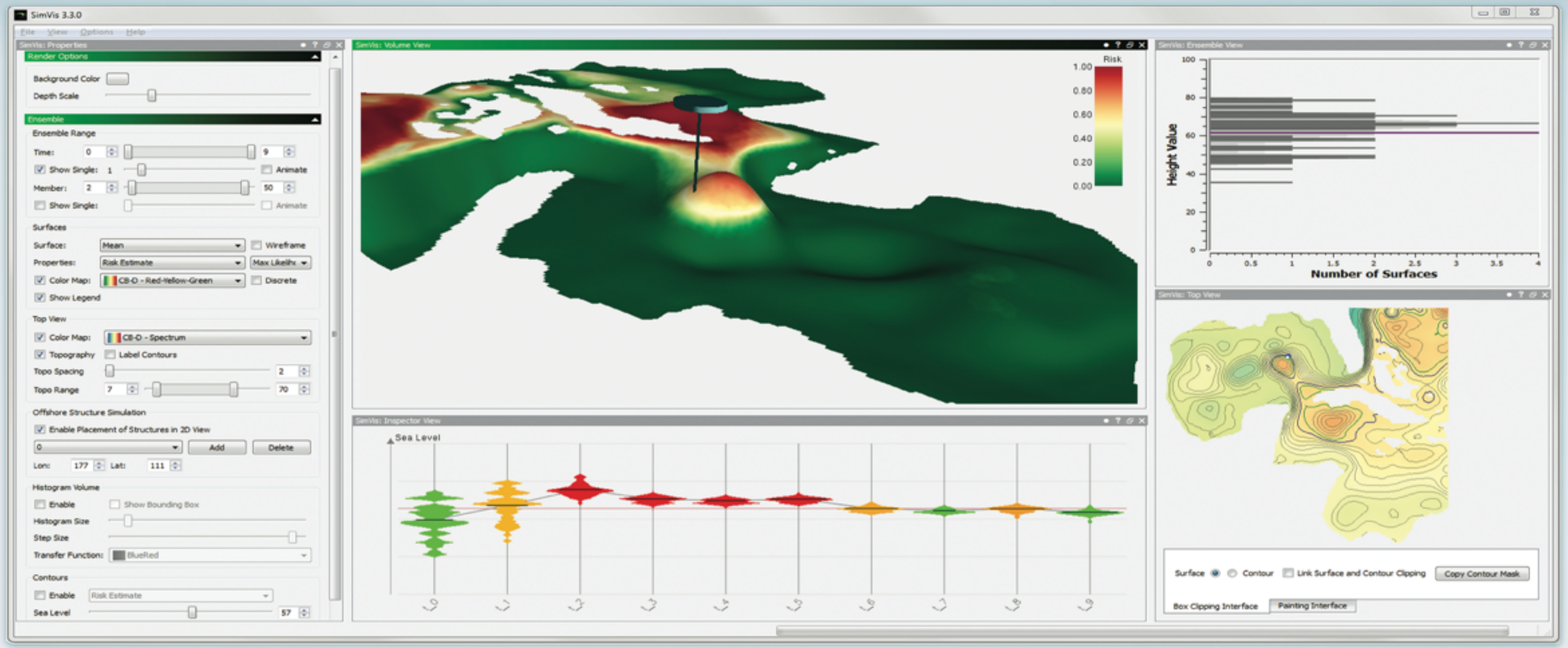
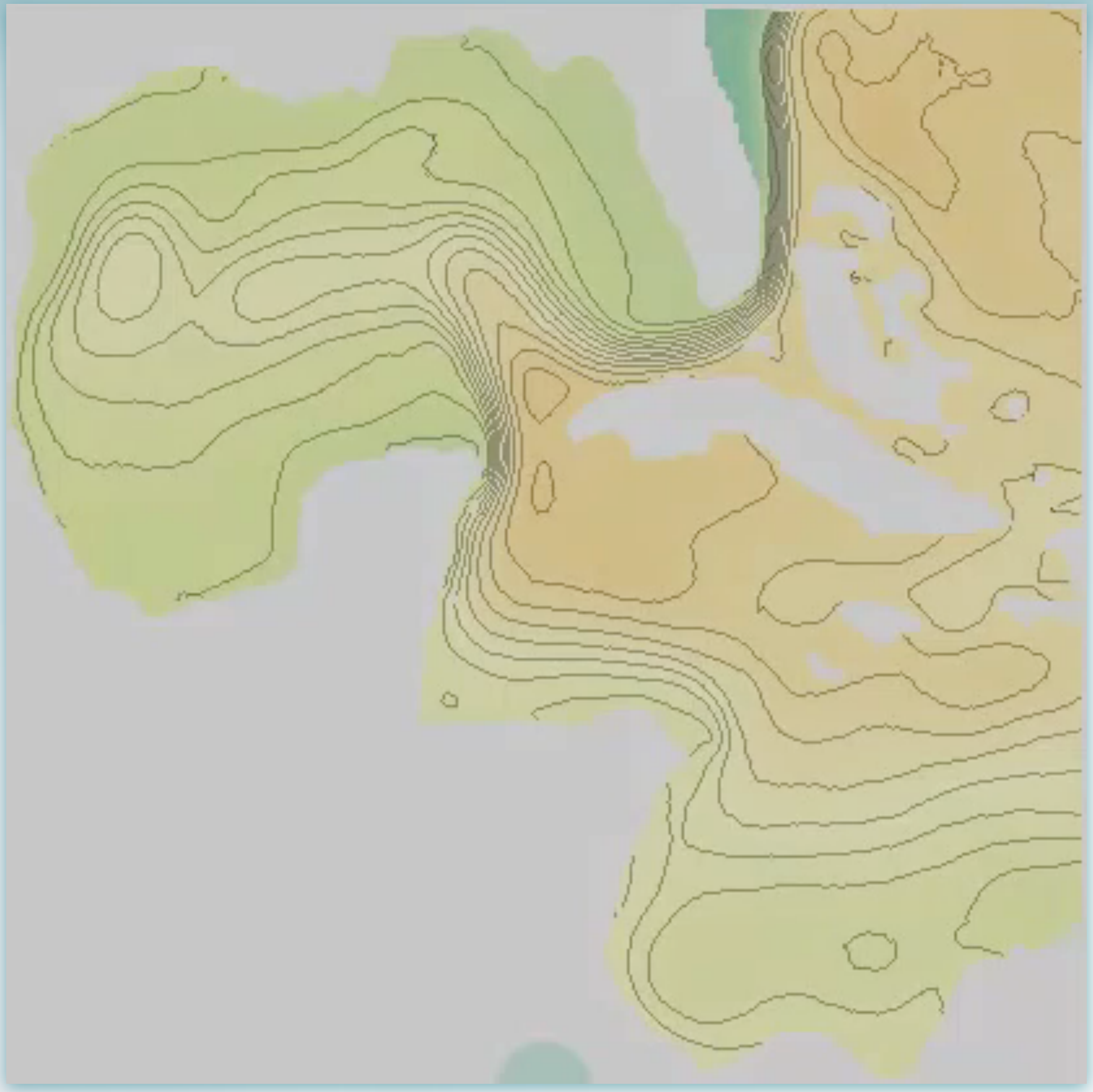
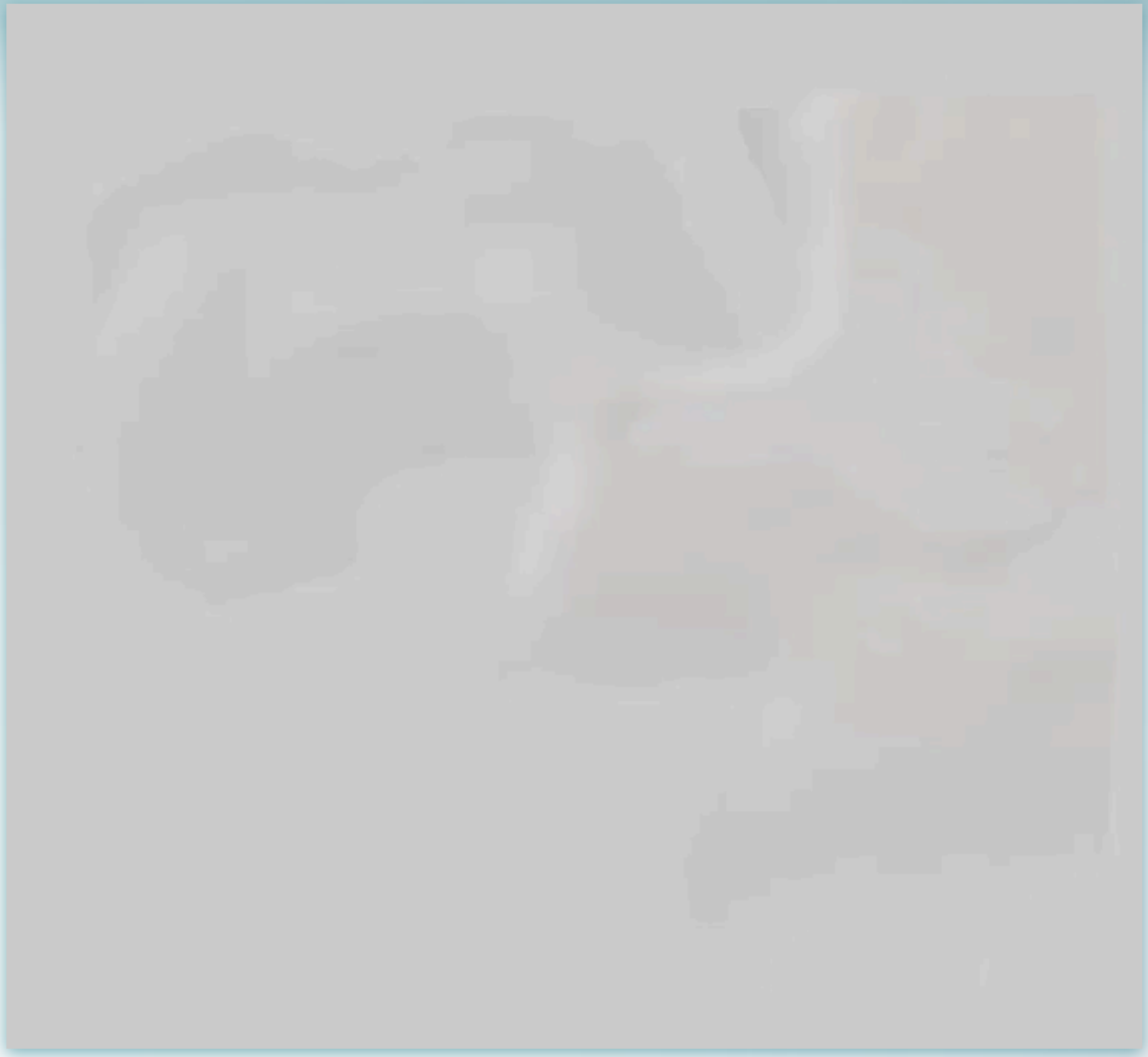


Workflow I

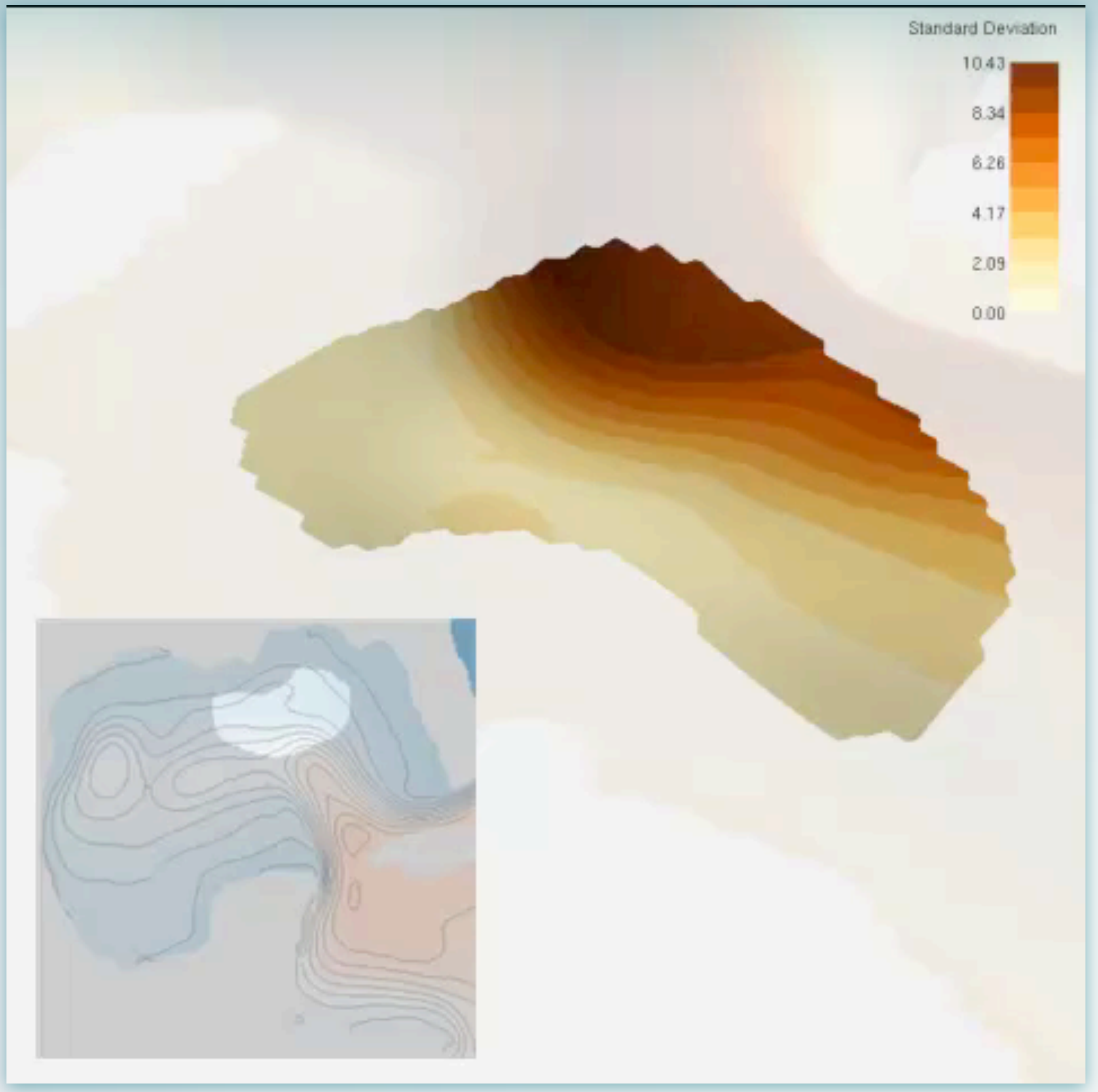

SimVis 3.3.0
Render Options
Background Color
Depth Scale
Ensemble
Ensemble Range
Time:
Show Single:
Animate
Member:
Surfaces
Surface:
Mean
Wireframe
Properties:
Risk Estimate
Color Map:
CB-D - Red-Yellow-Green
Discrete
Show Legend
Top View
CB-D - Spectrum
Topography
Label Contours
Topo Spacing
Topo Range
Offshore Structure Simulation
Enable Placement of Structures in 2D View
Add
Delete
Lon:
Lat:
Histogram Volume
Enable
Show Bounding Box
Histogram Size
Step Size
Transfer Function:
BlueRed
Contours
Sea Level
Risk
1.00
0.80
0.60
0.40
0.20
0.00
Height Value
Number of Surfaces
Surface
Contour
Link Surface and Contour Clipping
Copy Contour Mask
Box Clipping Interface
Painting Interface

Workflow II

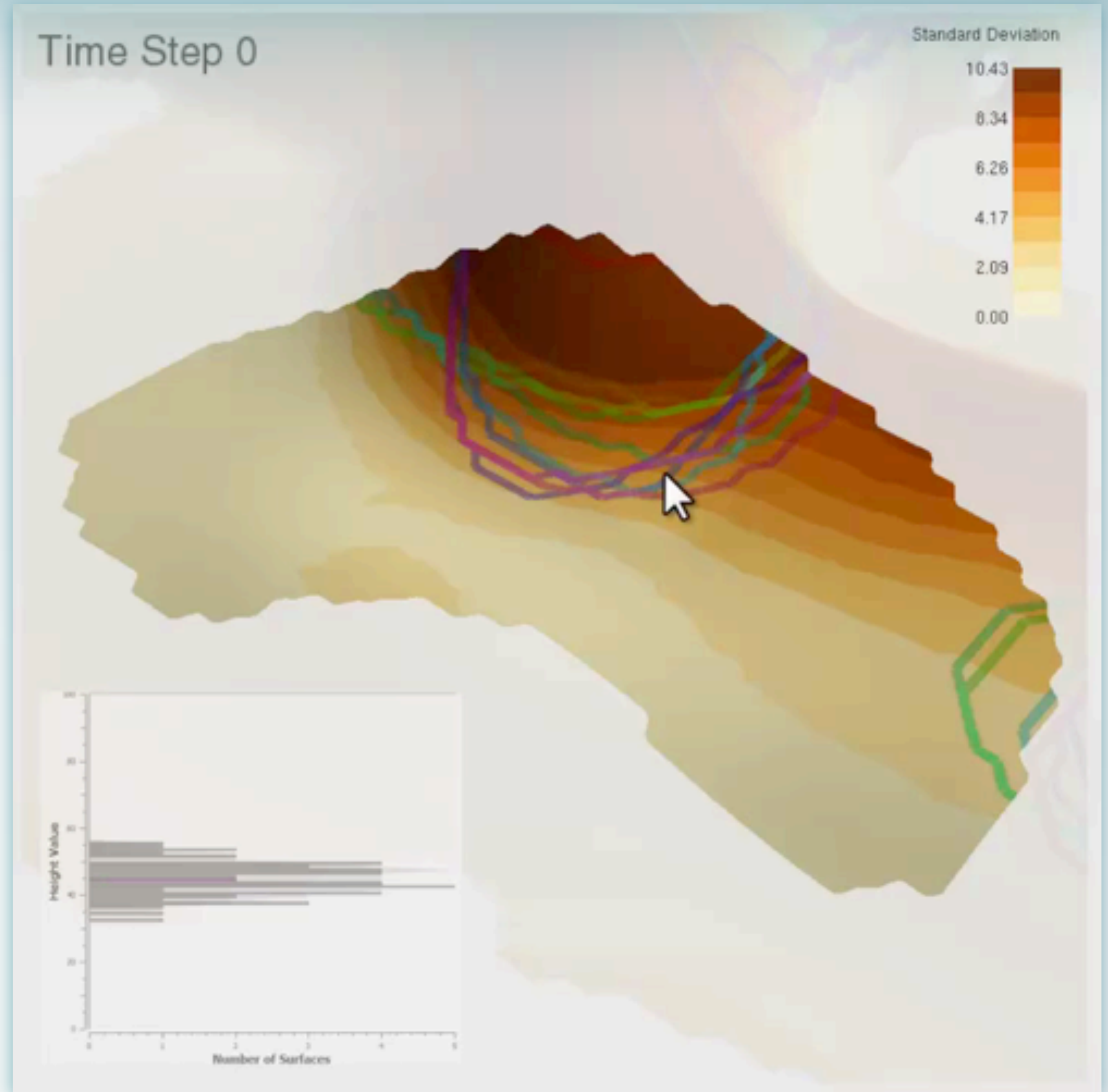




Workflow III



Workflow III



Workflow IV