

# VIS 2020-SciVis Contest

<https://kaust-vislab.github.io/SciVis2020/>

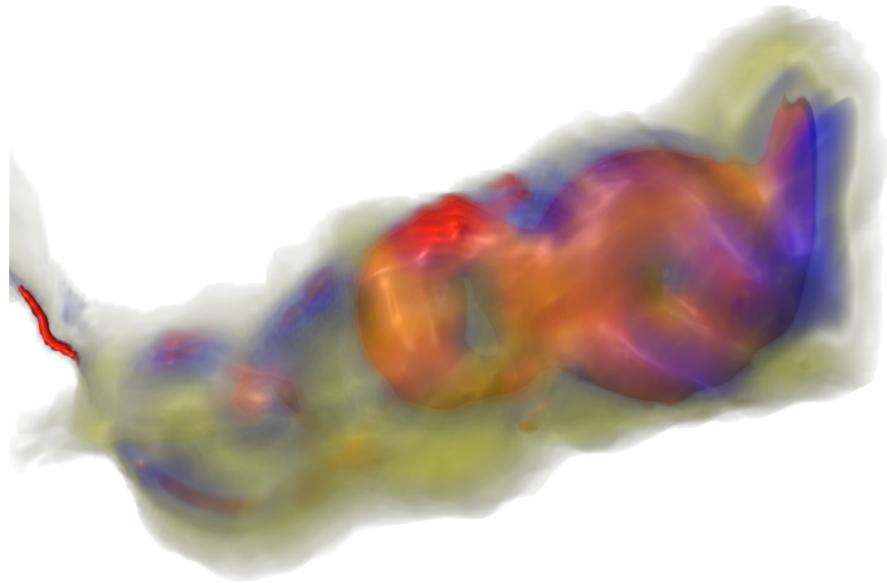


## Statistical Rendering for Visualization of Red Sea Eddy Simulation Data

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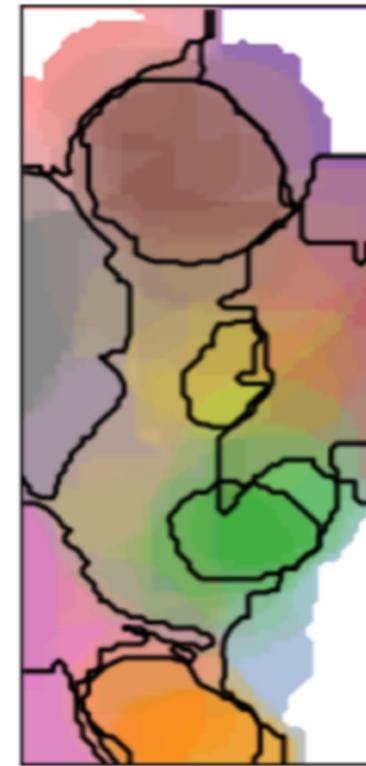
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# Statistical Rendering Techniques



## Statistical volume rendering

- Velocity magnitude
- Temperature



## Statistical summary maps

- Velocity magnitude
- Water surface elevation ( $\eta$ )

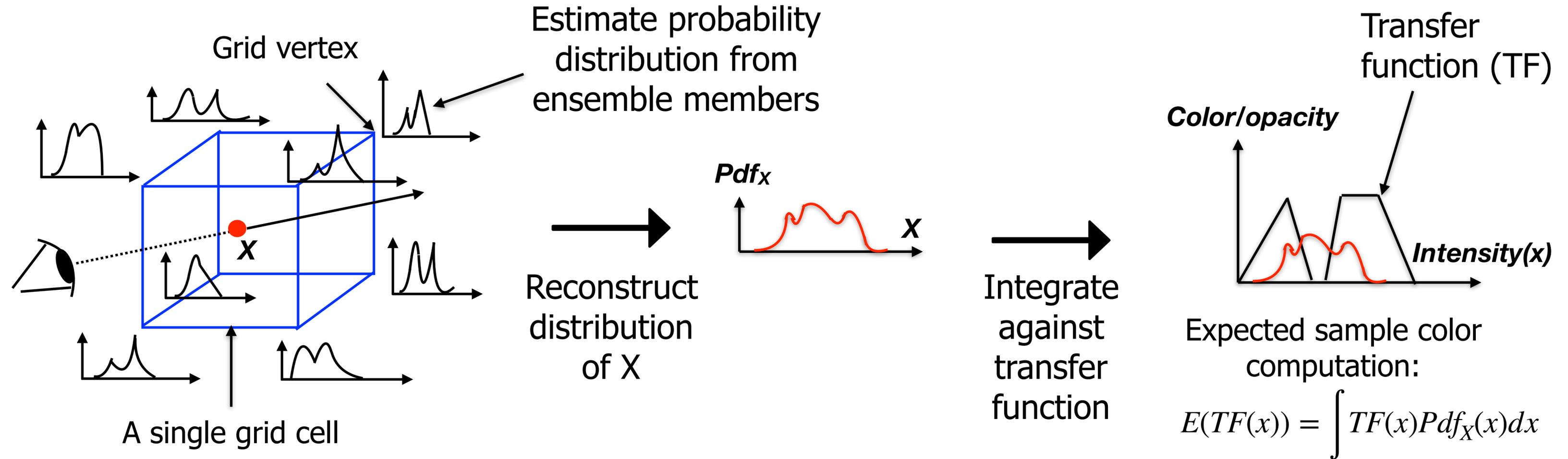
# Statistical Volume Rendering

# Statistical Volume Rendering: Pipeline

Gaussian mixture models: [Liu et al., 2012]

Parametric: [Sakhaee and Entezari, 2017]

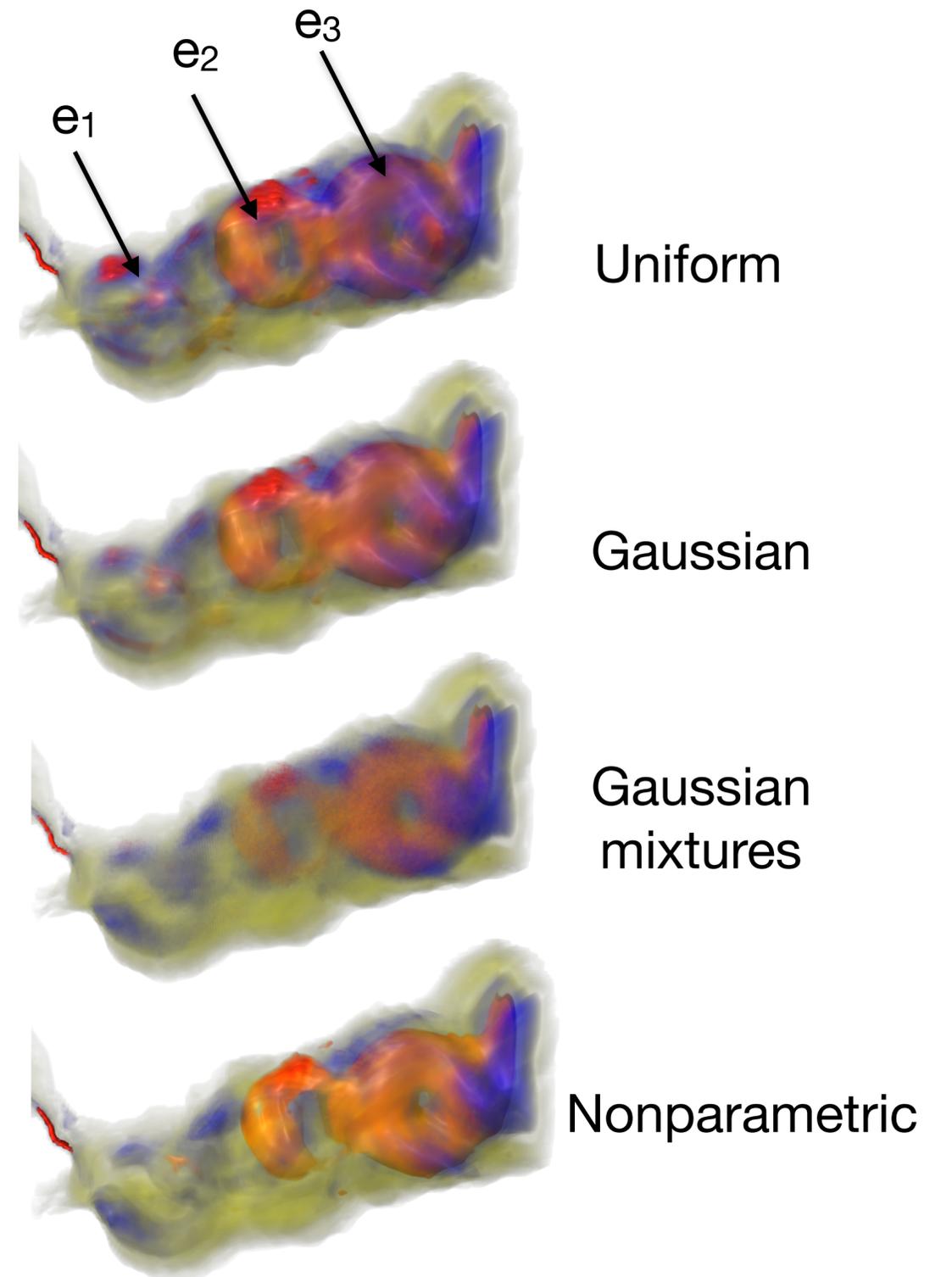
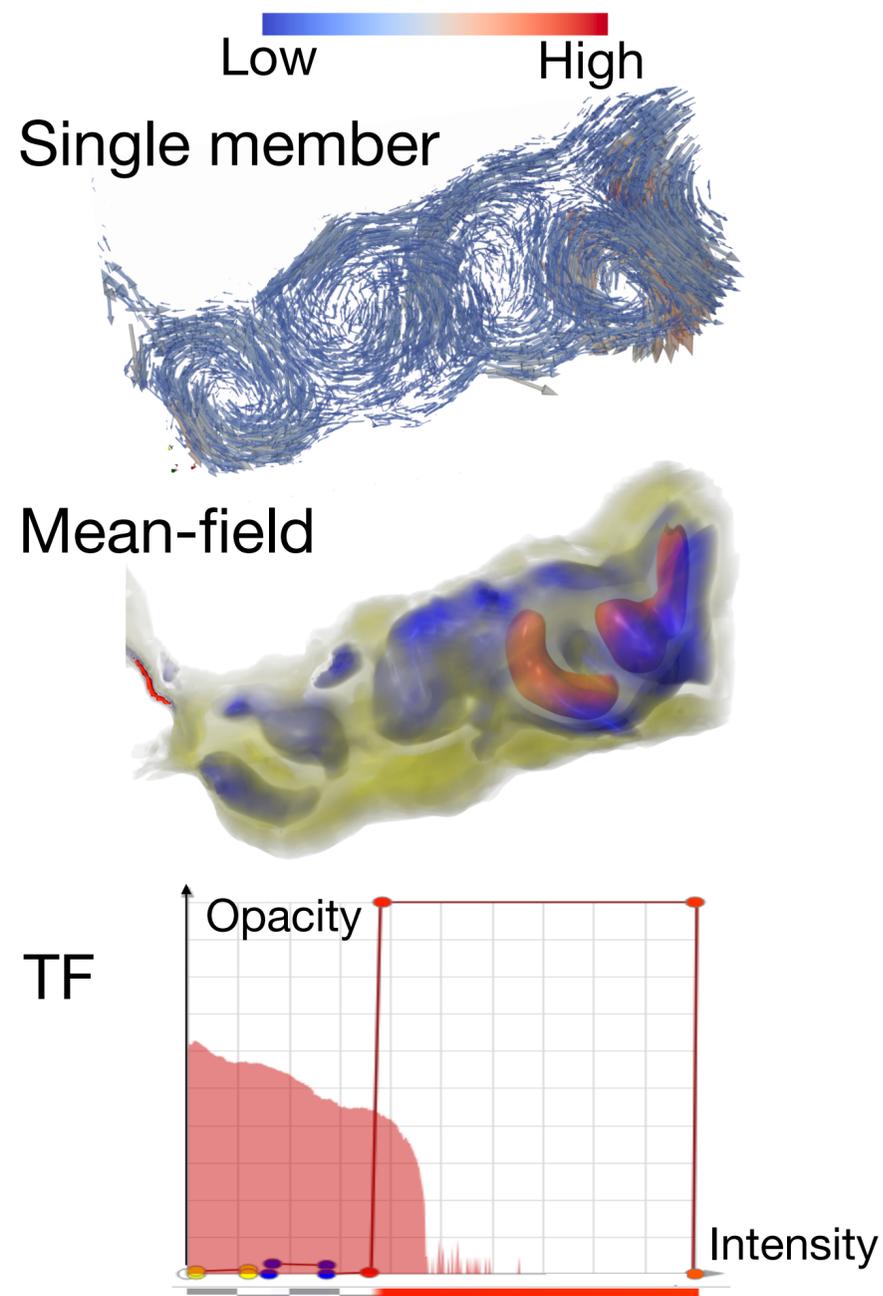
Nonparametric: [Athawale et al., 2020]



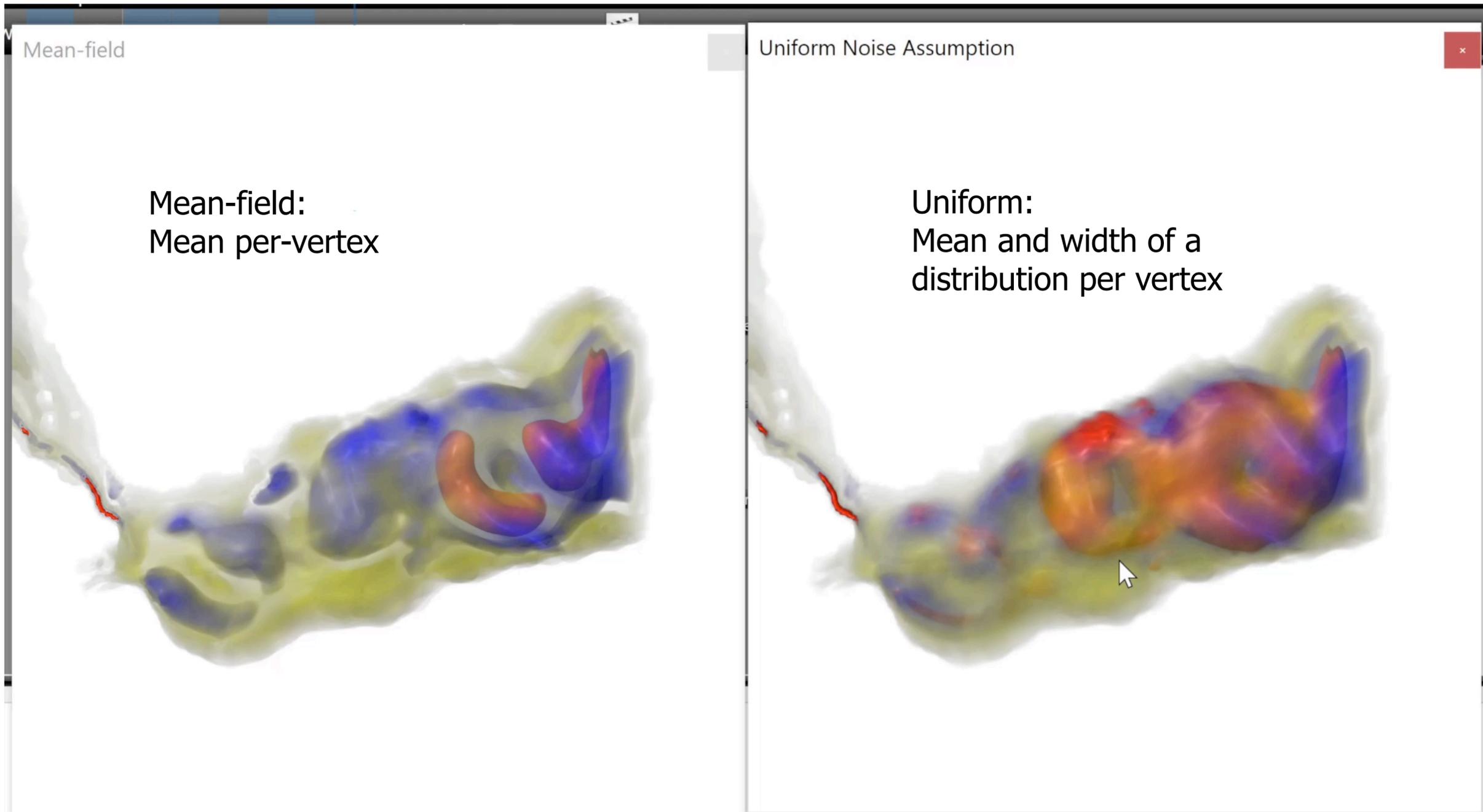
# Statistical Volume Rendering

- Visualization of uncertain velocity magnitude field (time step = 40)
- Confidence regarding the eddy presence/position:  
e<sub>3</sub>: High  
e<sub>2</sub>: Moderate  
e<sub>1</sub>: Low

Visualization software: Voreen  
(<http://voreen.uni-muenster.de>)

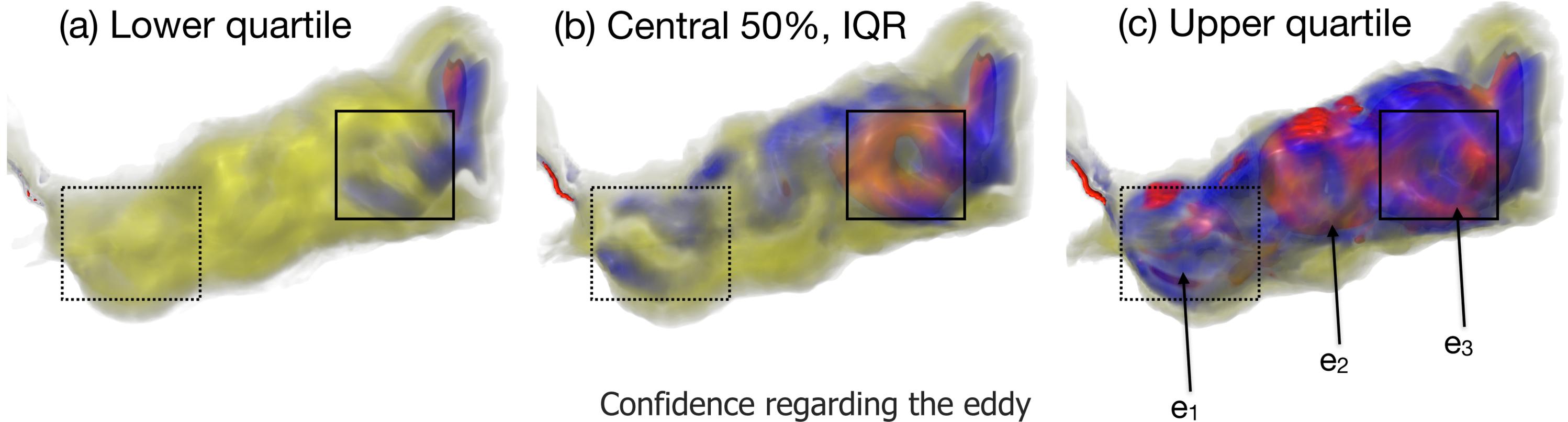


# Statistical Volume Rendering: Interactive Exploration

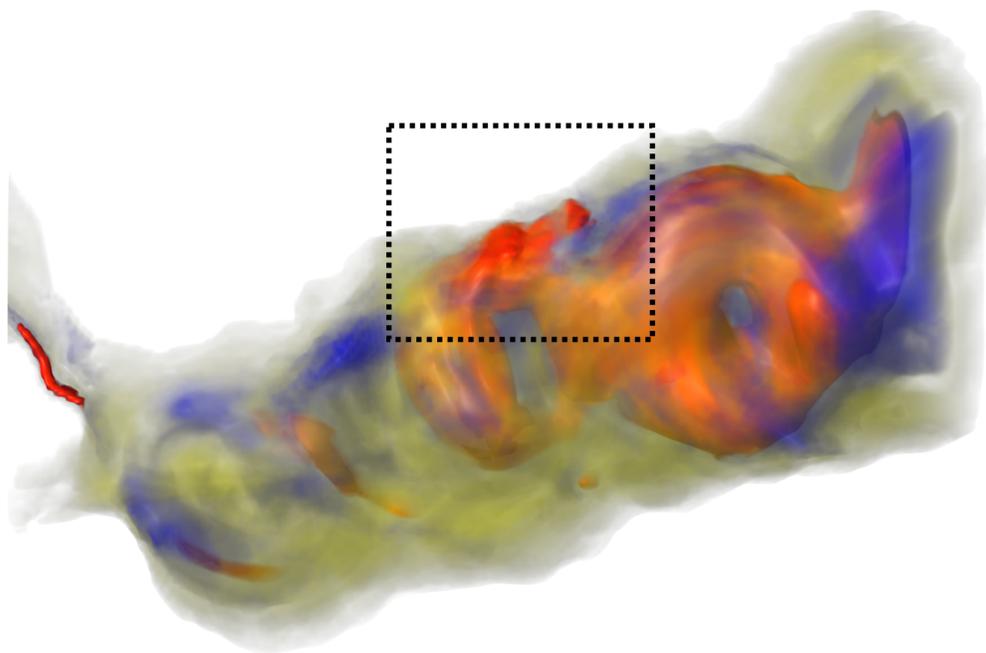


# Quartile View: Uncertainty Visualization

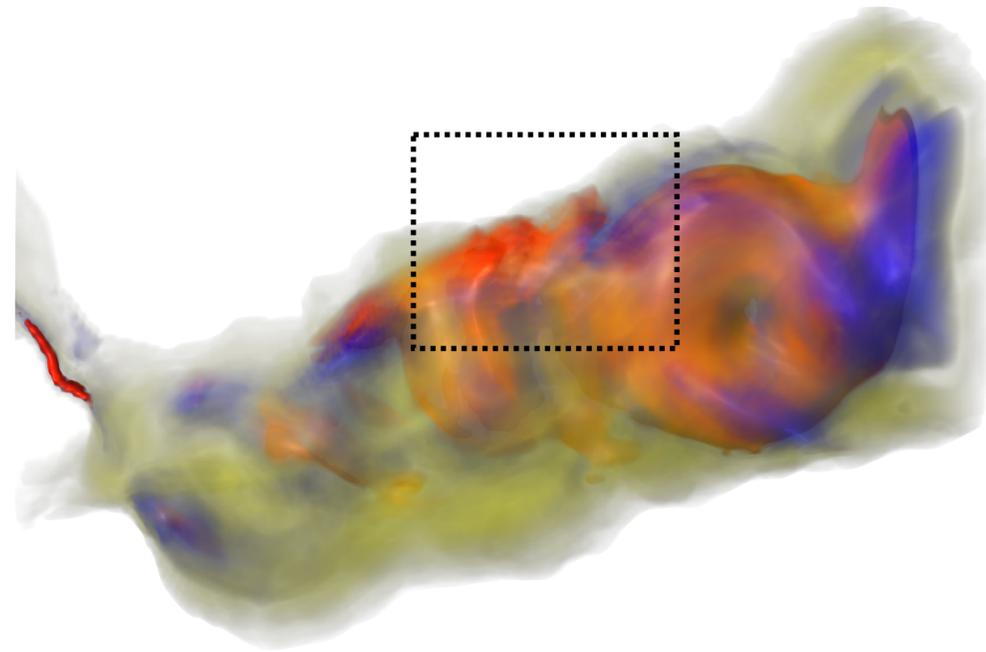
[Athawale et al., 2020]



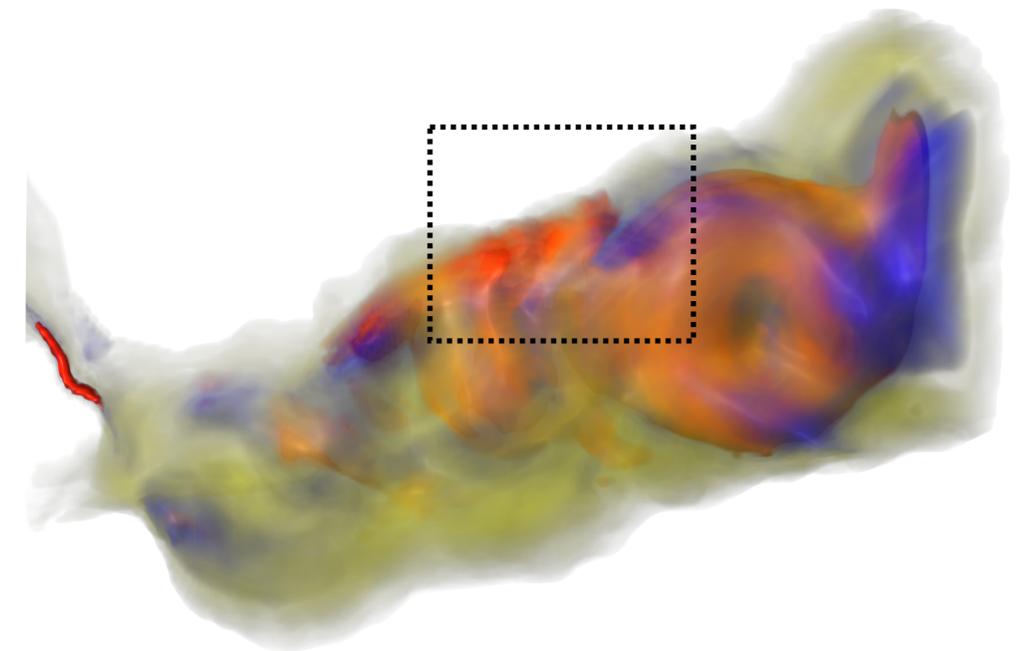
# Effect of Sample Size: Uncertainty Visualization



n=10



n=25

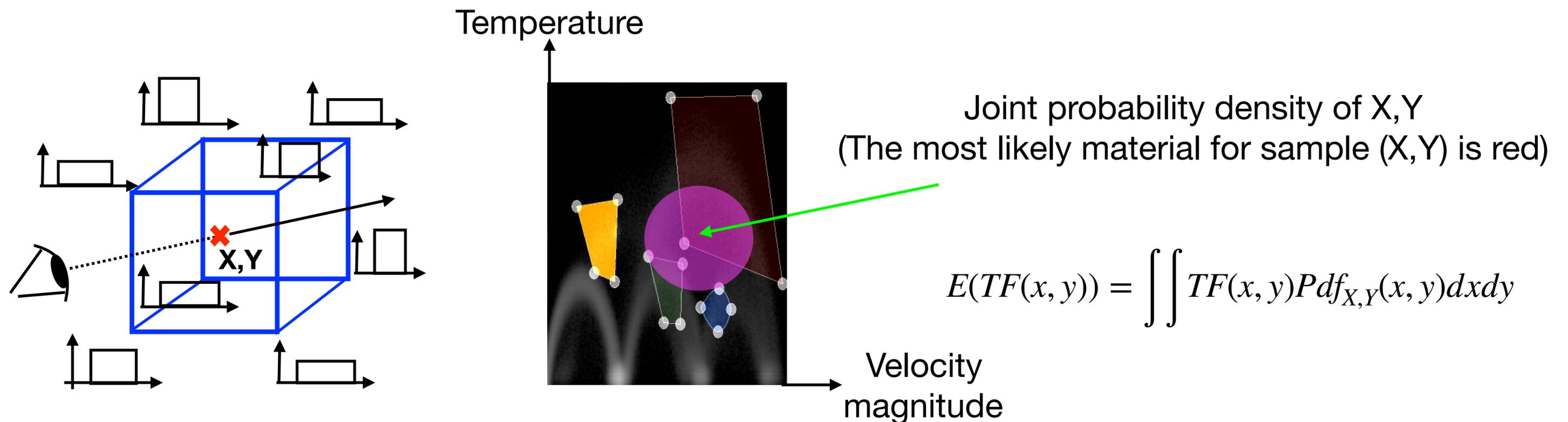


n=40

# Statistical Volume Rendering: 2D Transfer Functions

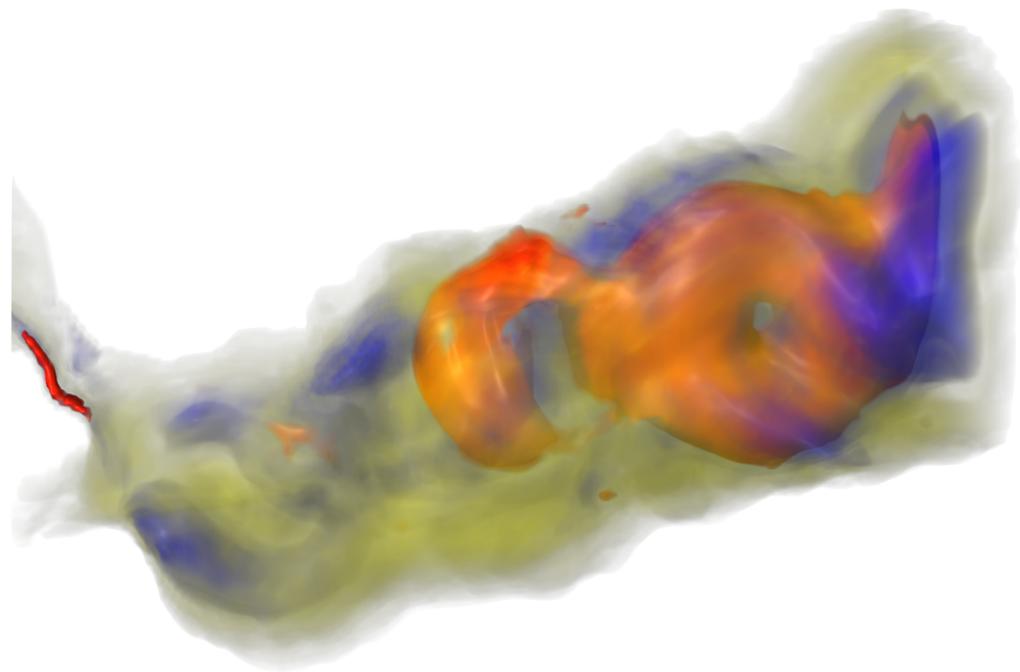
[Athawale et al., 2020]

Uncertain field [Sakhaee and Entezari, 2017] + 2D transfer functions (TFs) [Kniss et al., 2001]

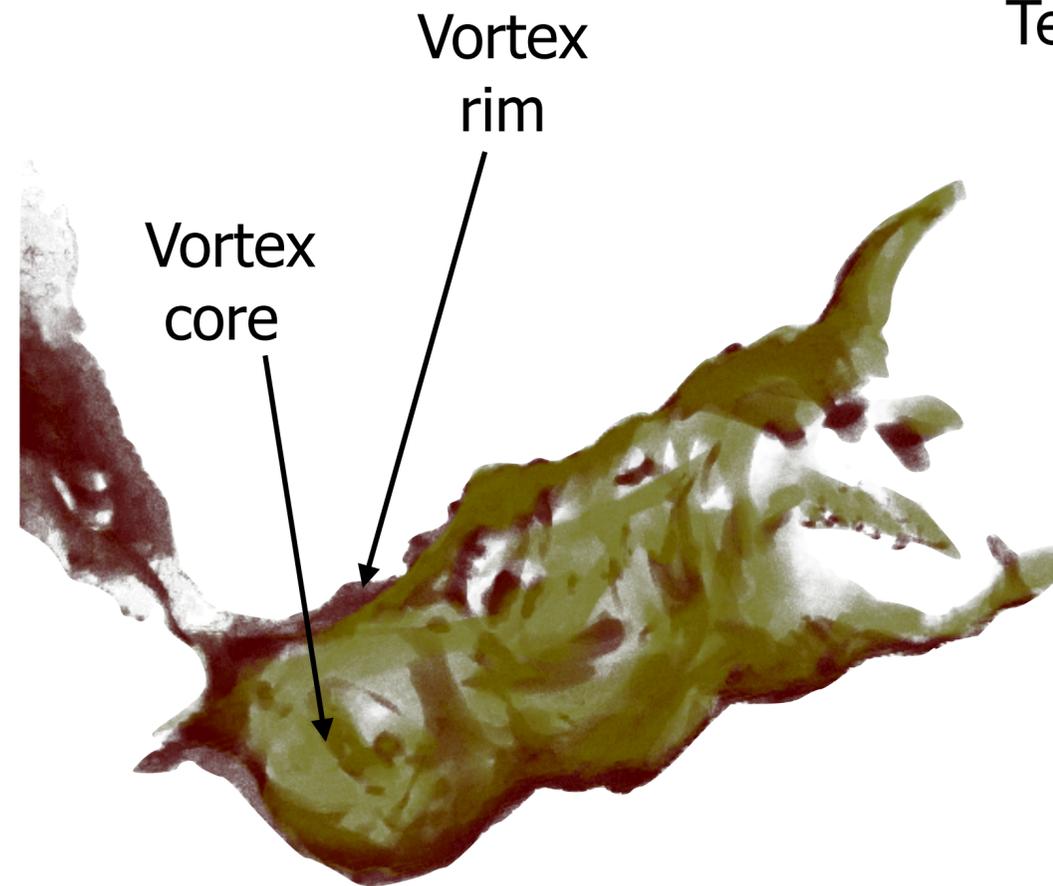


# Statistical Volume Rendering: 2D Transfer Functions

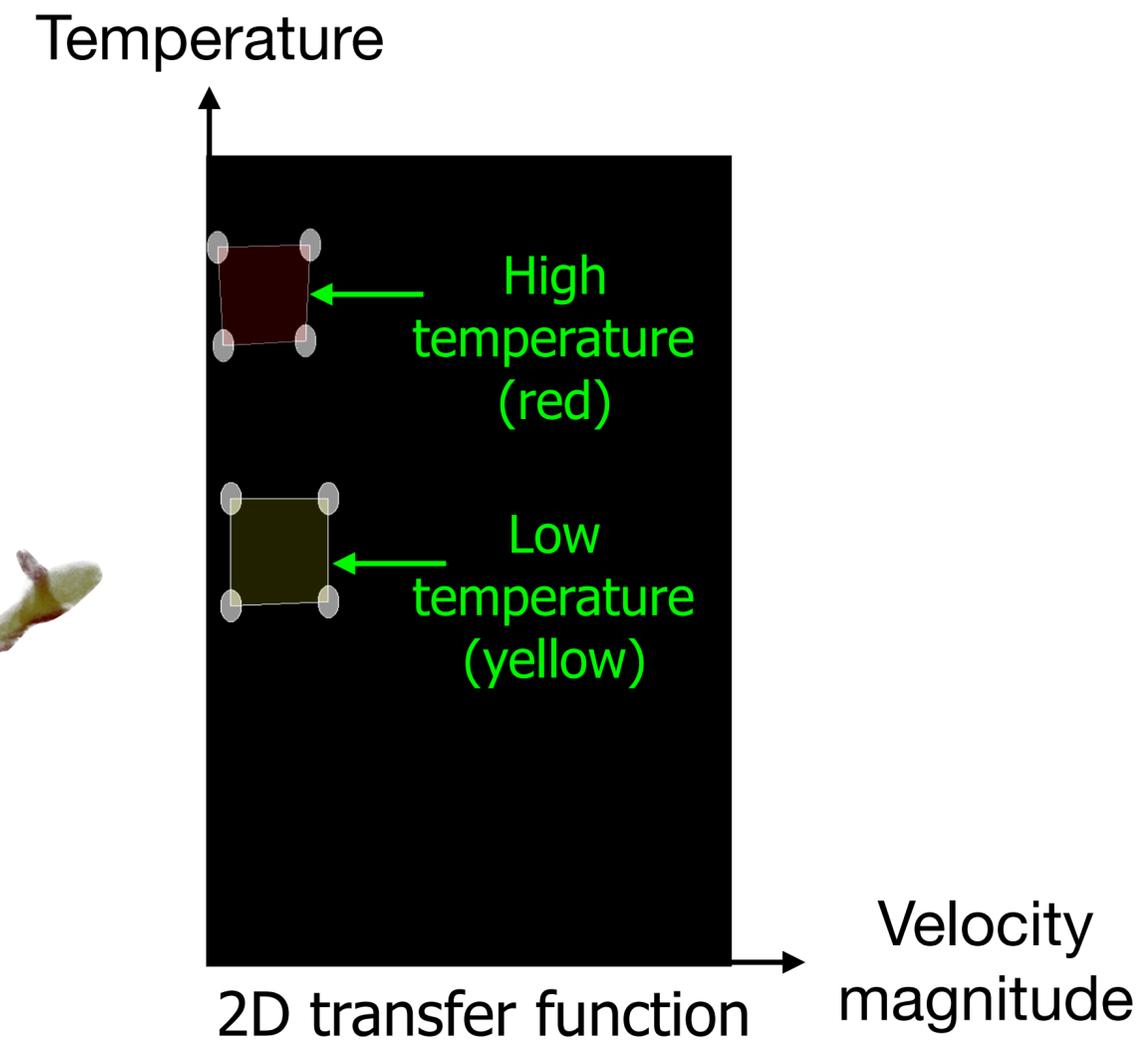
[Athawale et al., 2020]



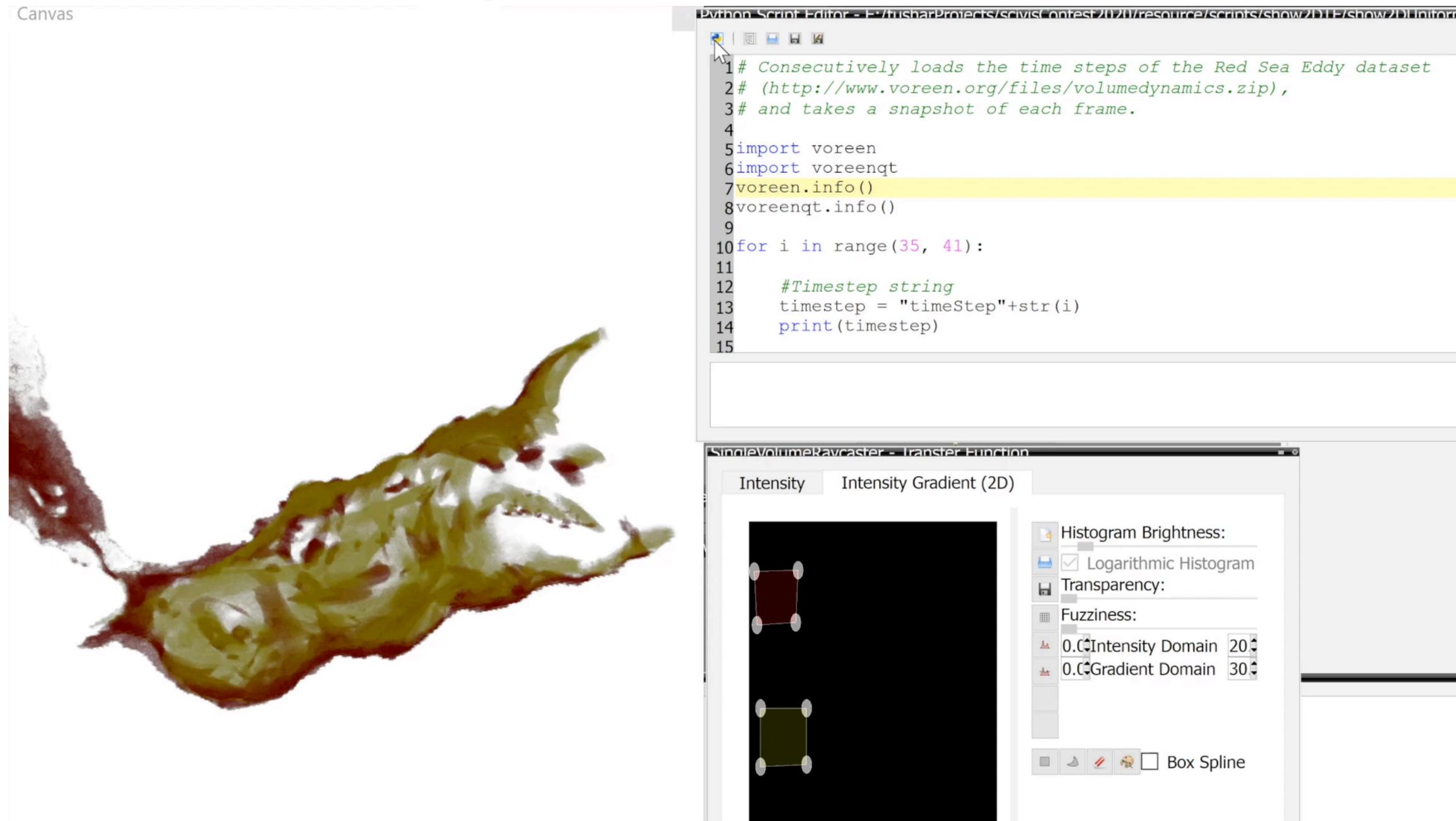
Visualization of expected eddy positions



Visualization of a bivariate field



# Statistical Volume Rendering: Python Scripts for Time-dependent Visualizations



The image displays a workflow for statistical volume rendering. On the left, a 3D visualization of a Red Sea Eddy dataset is shown, rendered with a color gradient from dark red to light yellow. The top right window shows a Python script in a text editor, which is used to load and process the dataset. The script includes the following code:

```
1 # Consecutively loads the time steps of the Red Sea Eddy dataset
2 # (http://www.voreen.org/files/volumedynamics.zip),
3 # and takes a snapshot of each frame.
4
5 import voreen
6 import voreenqt
7 voreen.info()
8 voreenqt.info()
9
10 for i in range(35, 41):
11     #Timestep string
12     timestep = "timeStep"+str(i)
13     print(timestep)
14
15
```

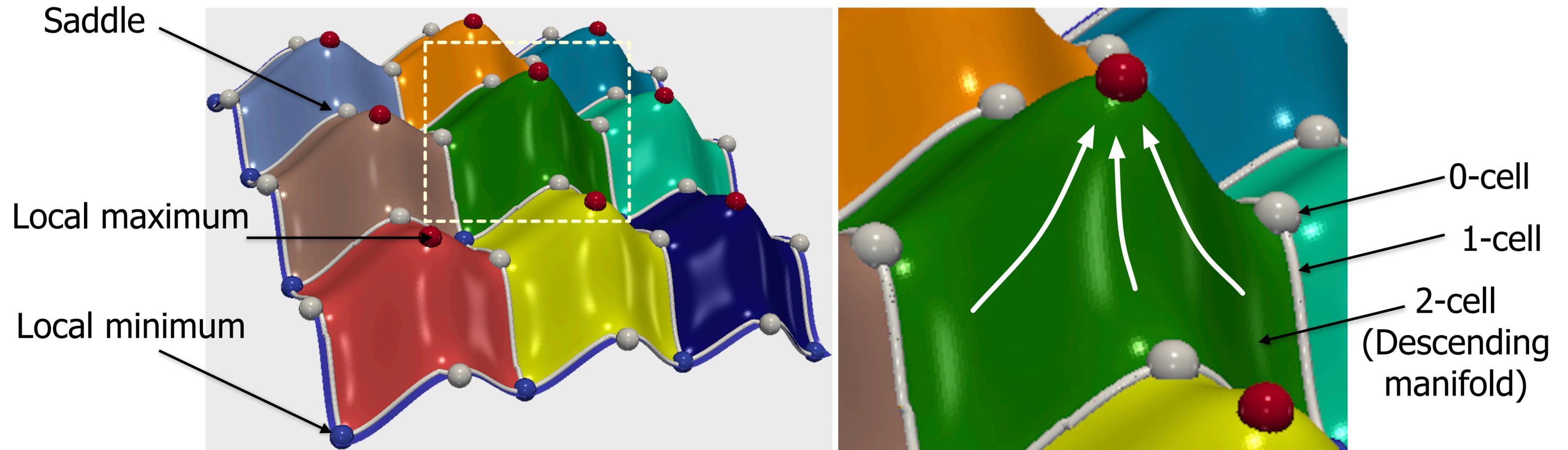
The bottom right window shows the 'SingleVolumeRaycaster - Transfer Function' control panel. It features two tabs: 'Intensity' and 'Intensity Gradient (2D)'. The 'Intensity Gradient (2D)' tab is active, showing a histogram and various control parameters:

- Intensity Gradient (2D) histogram
- Intensity Domain: 0.0 to 20.0
- Gradient Domain: 0.0 to 30.0
- Logarithmic Histogram:
- Transparency:
- Fuzziness:
- Box Spline:

# Statistical Summary Maps

# Morse Complexes

Gradient-based topological descriptors of scalar fields



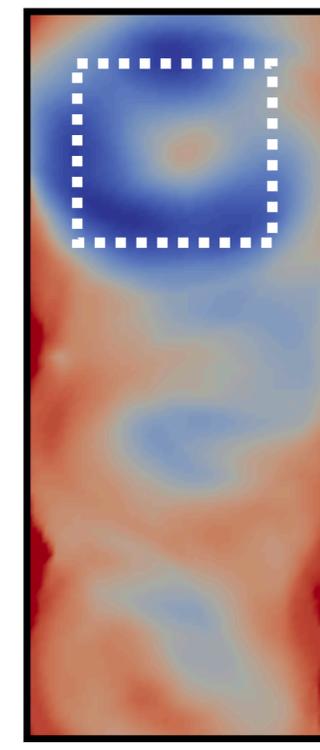
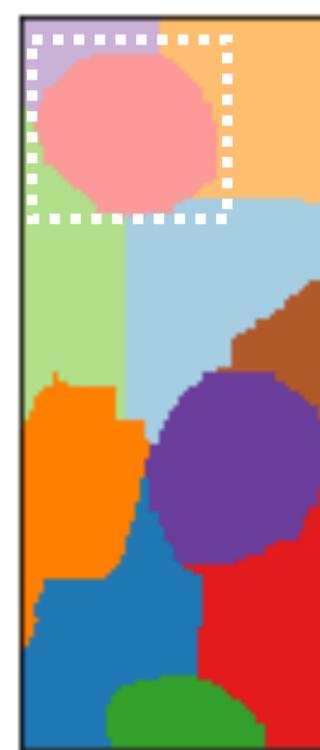
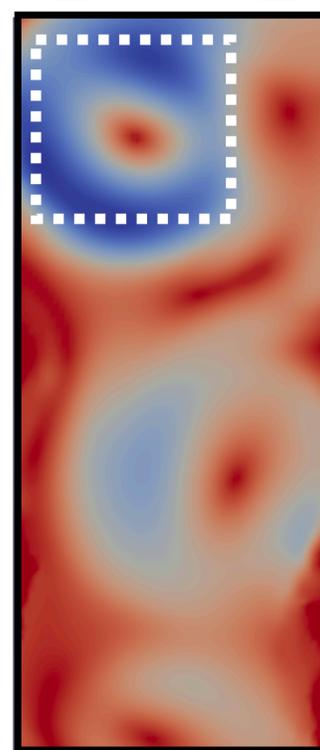
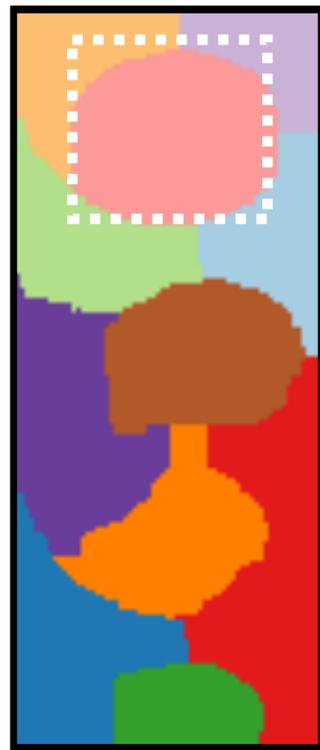
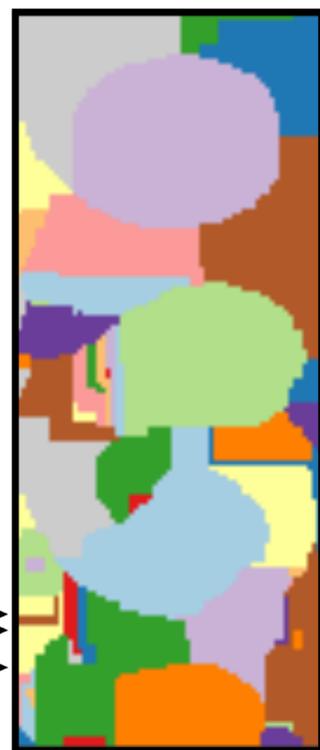
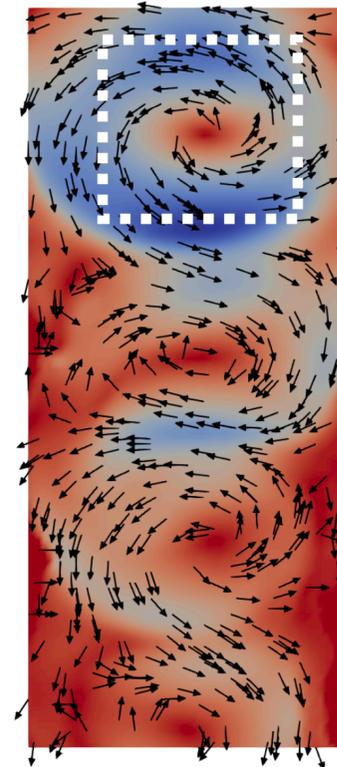
(Visualization software: The Topology Toolkit (TTK) [Tierny et al., 2017])

# Morse Complexes for Velocity Magnitude Field

Analysis for time step=40 and  $z=1$

Scalar field    Before simplification    After simplification

Low    High



(a) Ensemble member 1

(b) Ensemble member 2

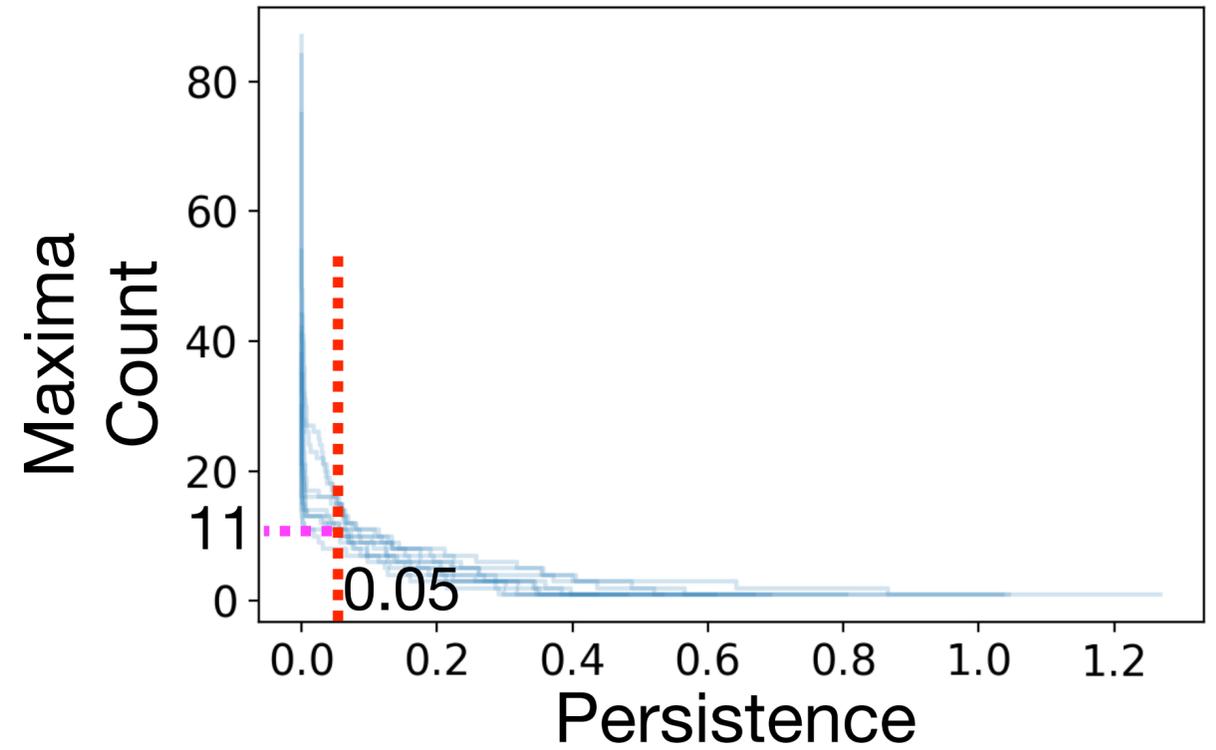
(c) Mean-field

# Probabilistic Map [Athawale et al., 2020]

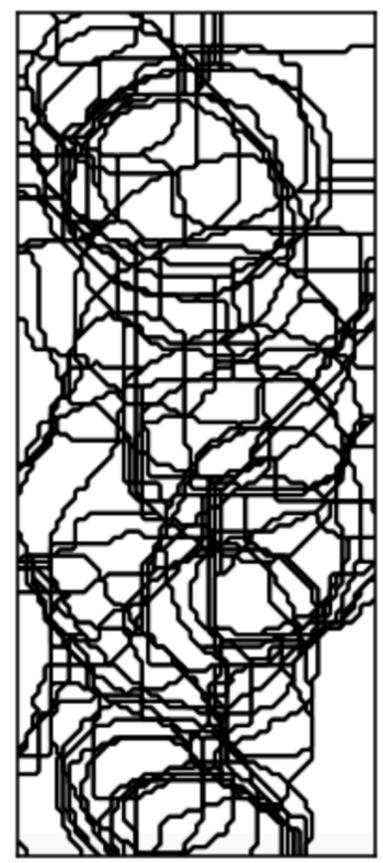
## Step 1: Topological simplification



Persistence graph  
[Gerber et al., 2010]



Spaghetti plot of Morse complexes for simplification level 0.05

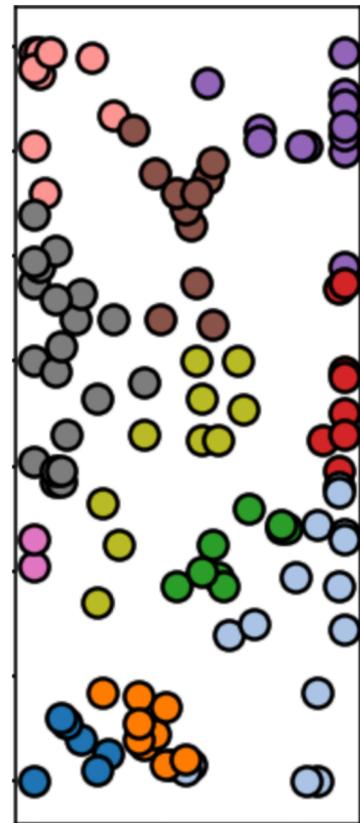
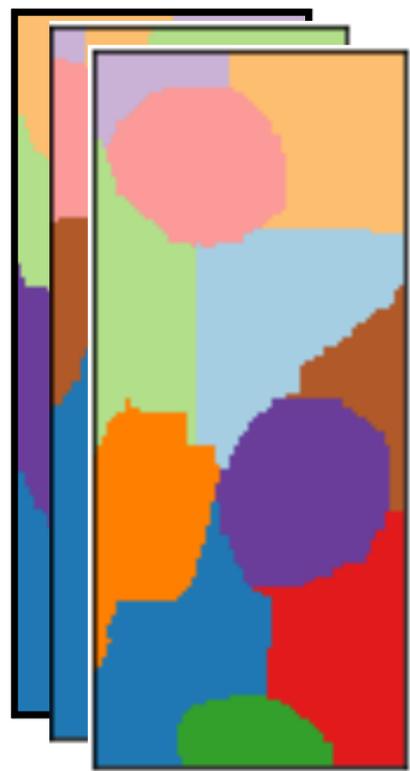


Maxima count = 11

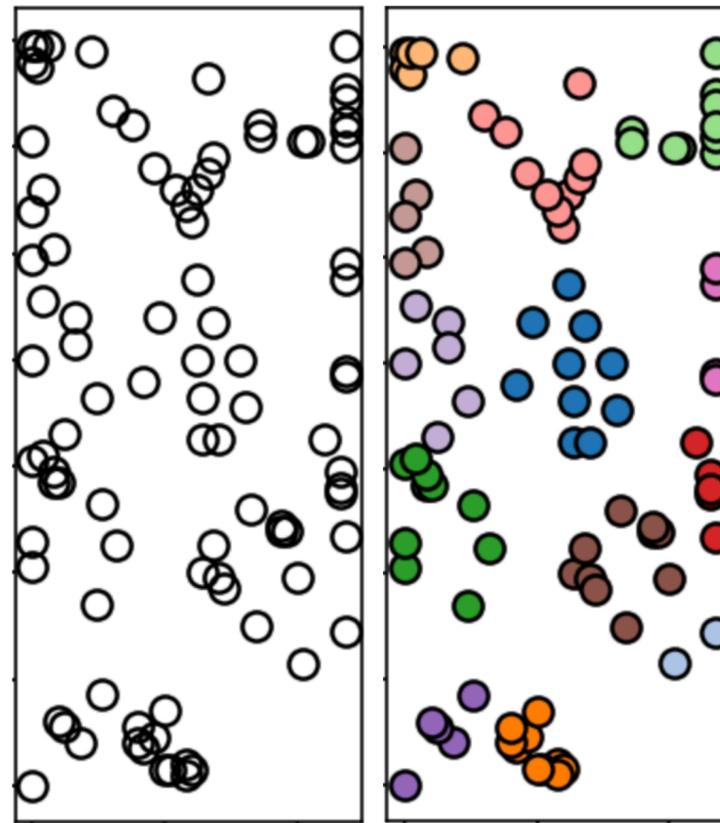
Input Morse complex ensemble

# Probabilistic Map

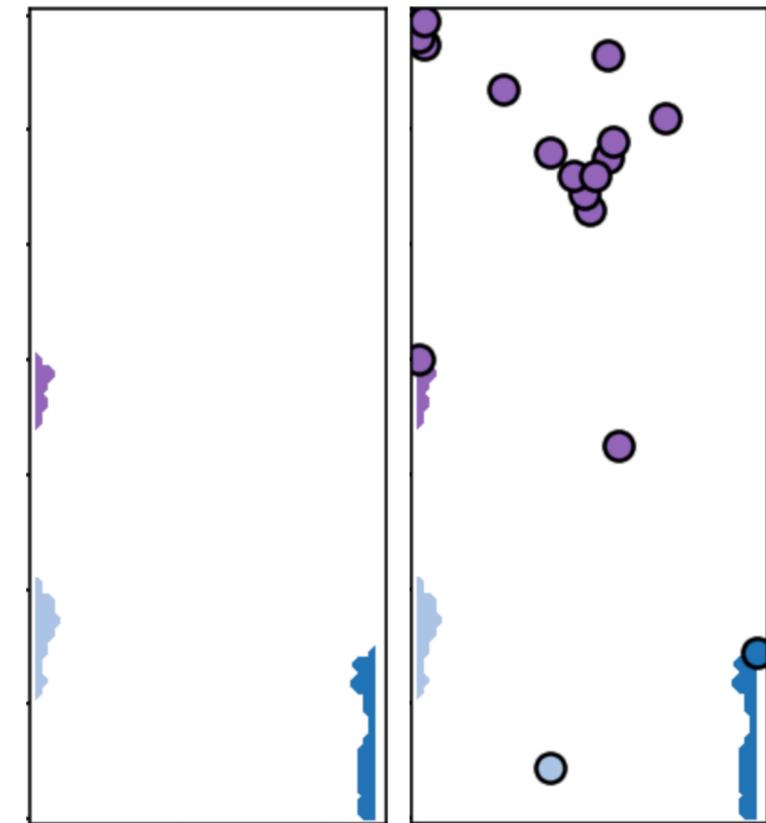
## Step 2: Labeling of local maxima



Morse mapping  
[Reininghaus et al., 2012]



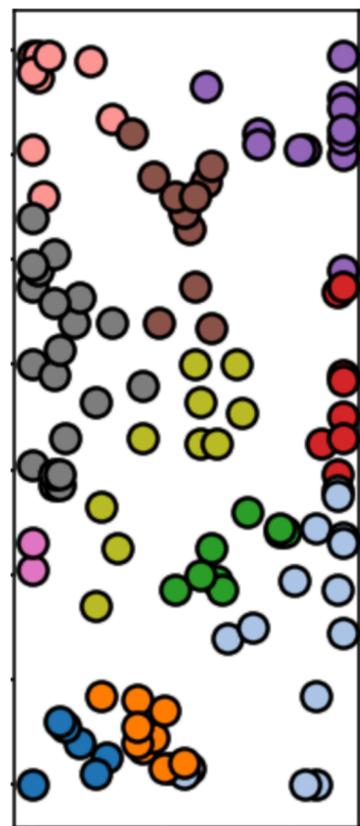
K-means clustering  
with  $k=11$



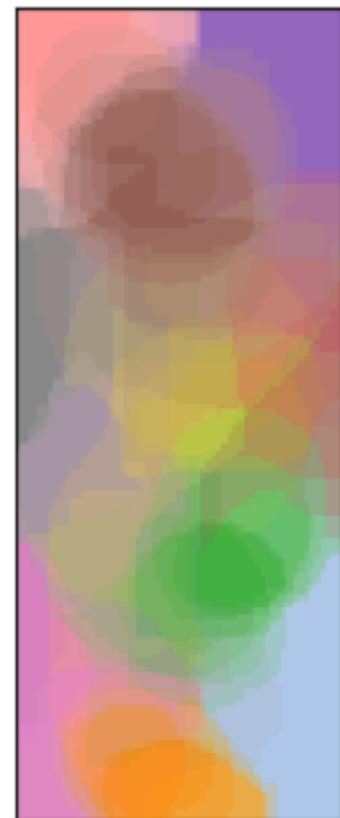
Mandatory maxima  
[Günther et al., 2014]

# Probabilistic Map

Step 3: Quantify gradient destination probabilities and visualize them

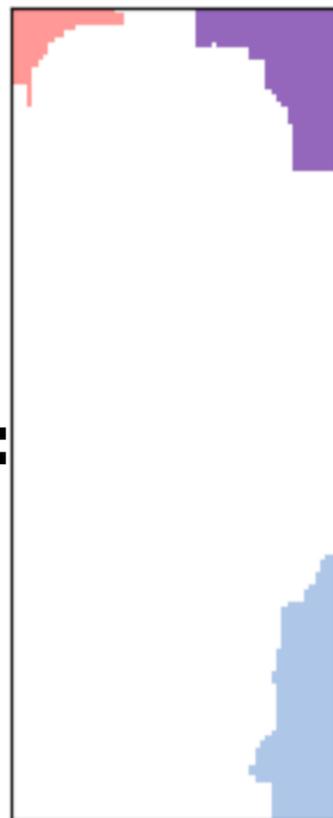


Morse mapping



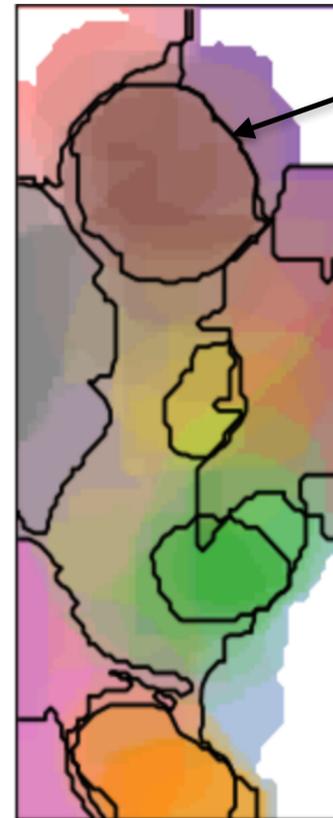
Probabilistic map

=



Certain

+



Uncertain

0.5 probability of flowing to a single label (expected Morse complex)

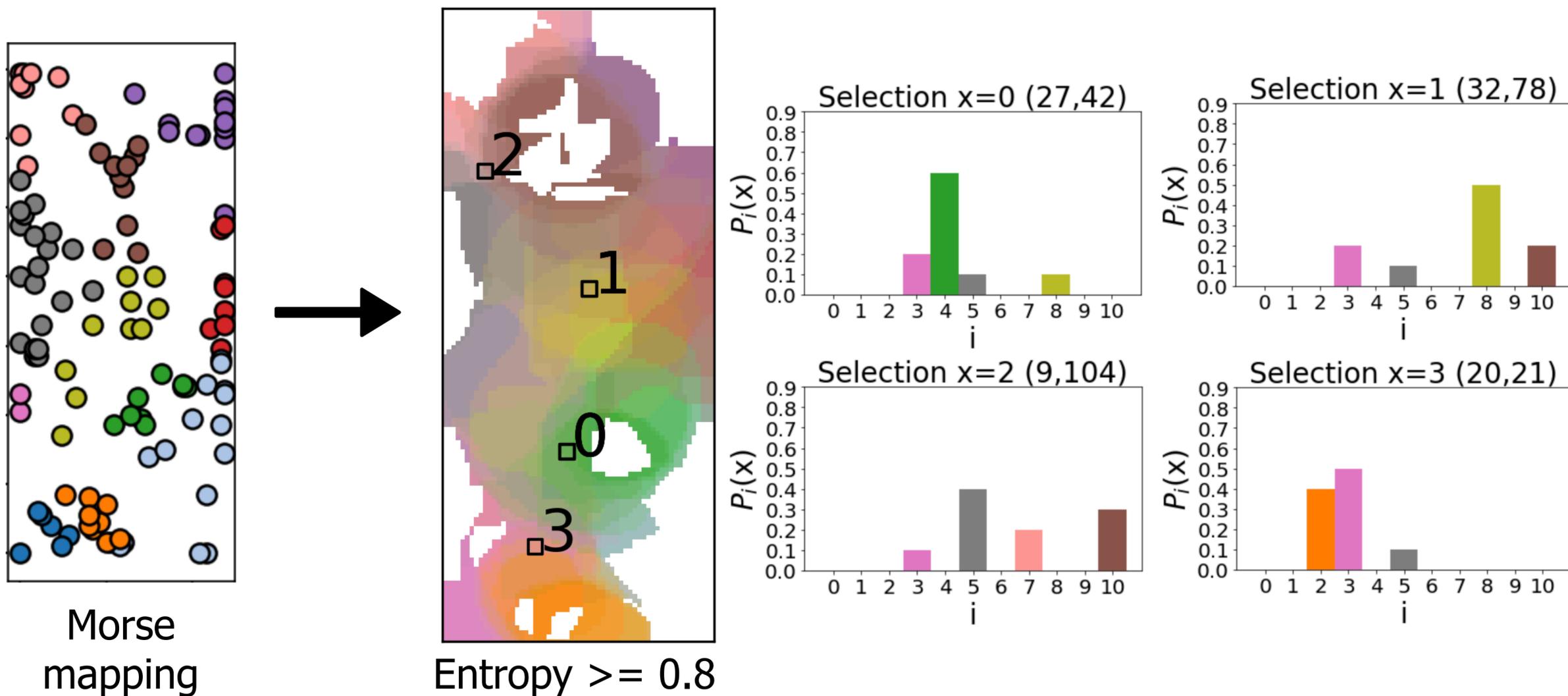
$$\text{Expected color} = \sum_i c_i p_i$$

$c_i$ : Color denoting a label

$p_i$ : Probability of gradient flow terminating in label  $c_i$

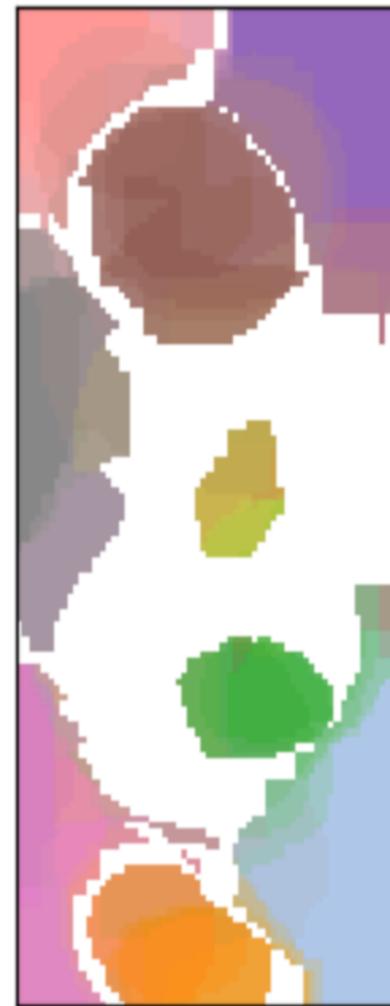
# Entropy-based Uncertainty Exploration + Interactive Probability Queries [Potter et al., 2011]

The uniform distribution yields maximum uncertainty, and therefore, maximum entropy.

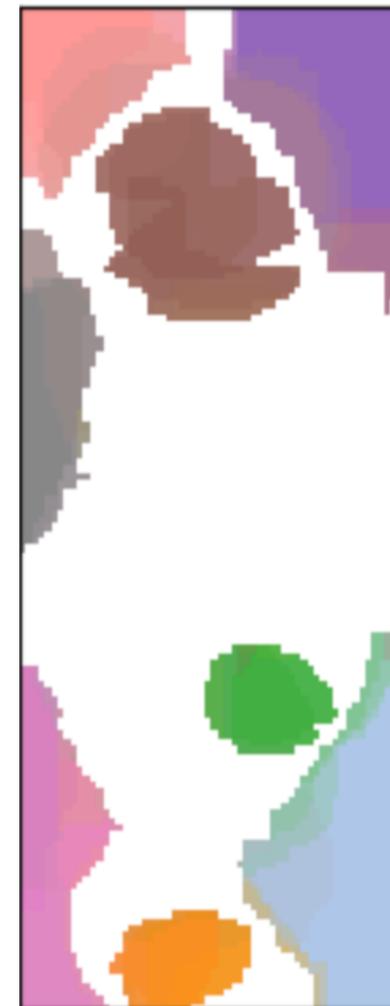


# Agreement Exploration

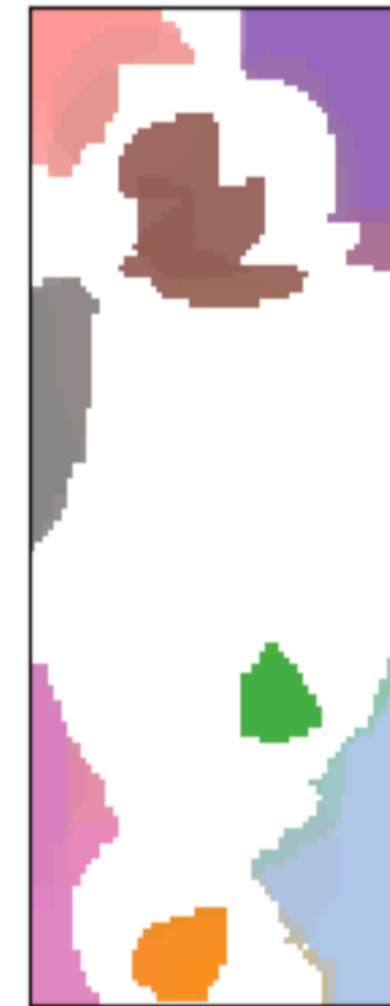
Visualize positions with consistency in gradient destinations for the specified lower agreement threshold.



60%



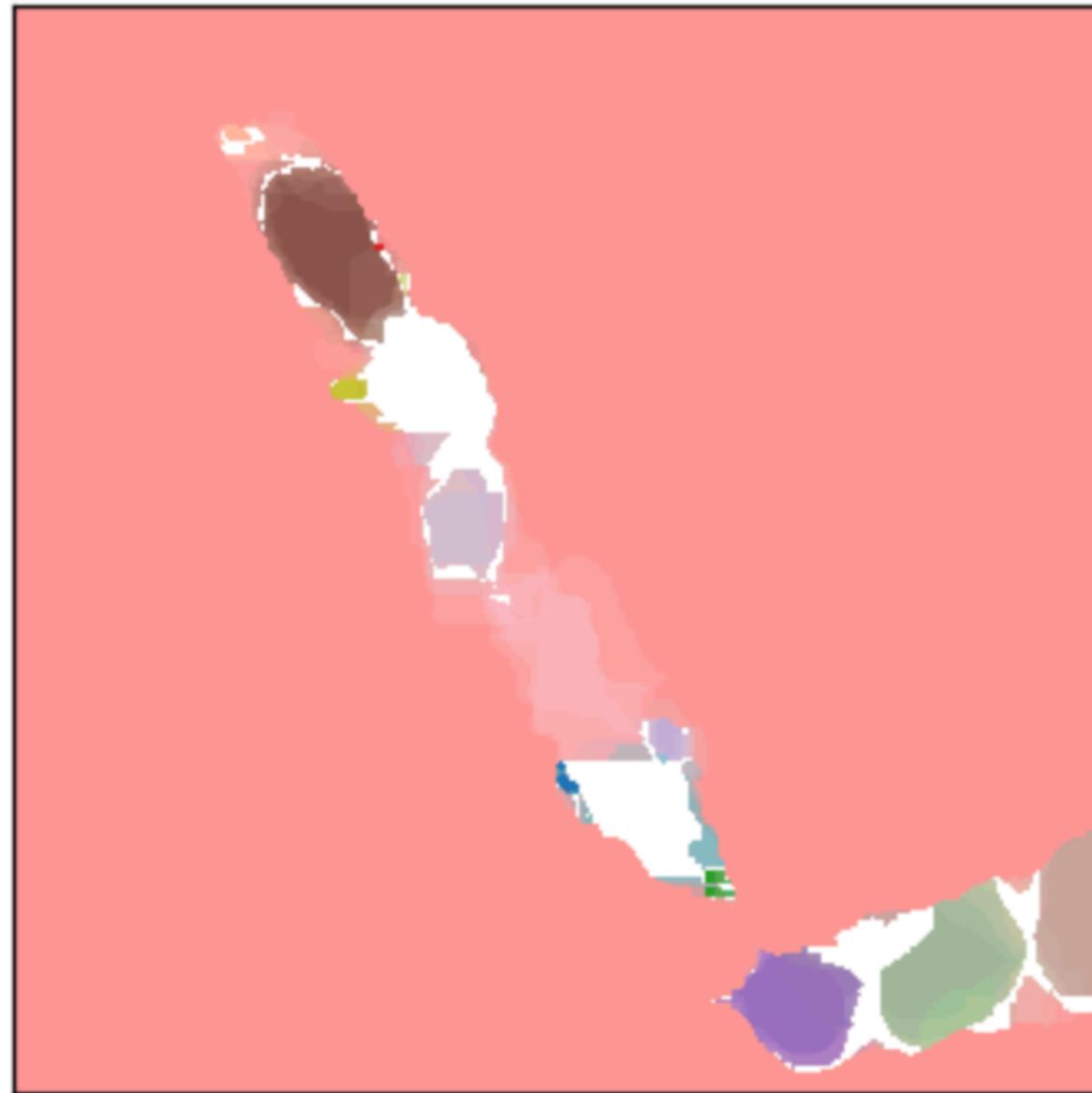
70%



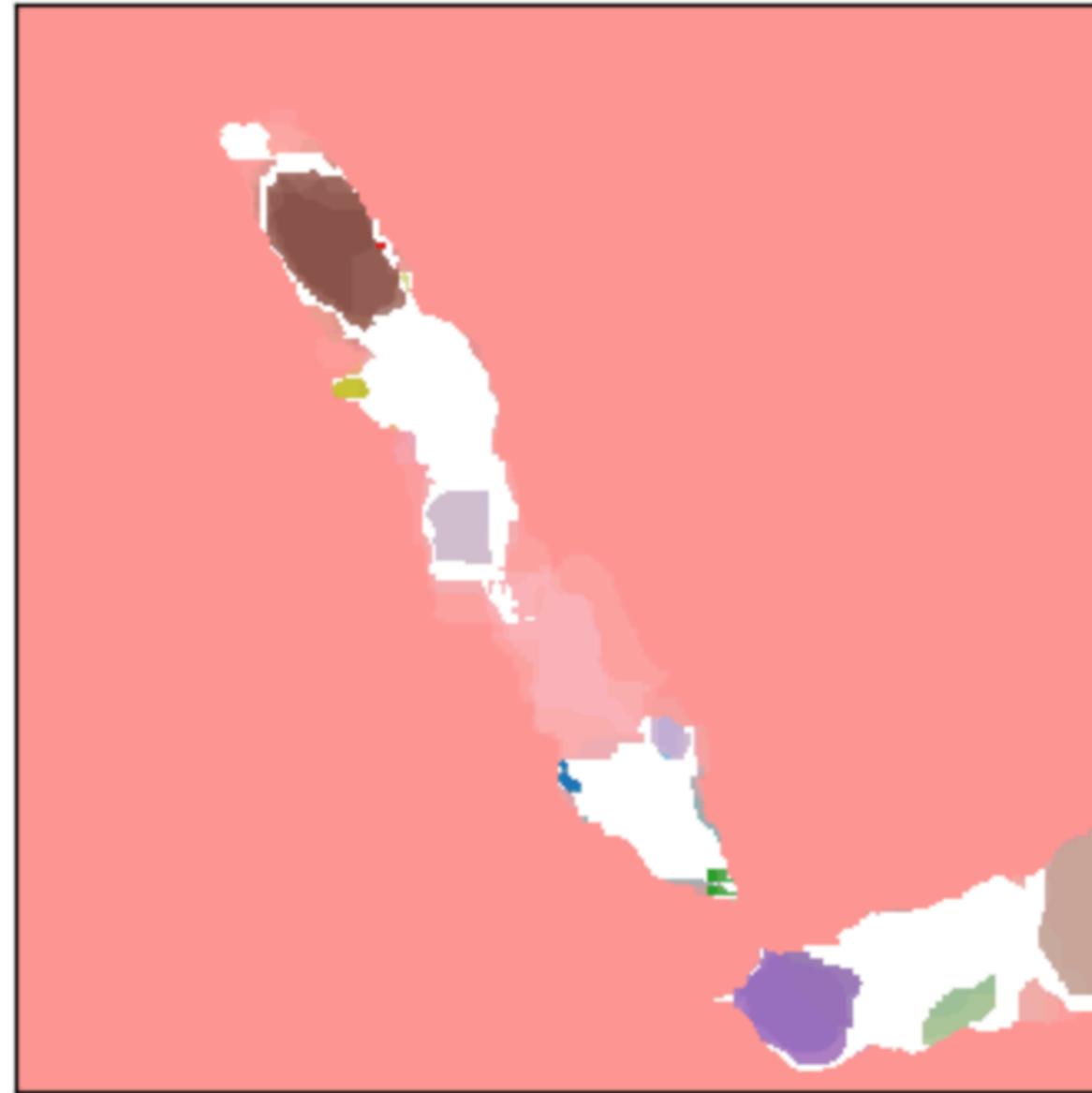
80%



# Agreement Exploration



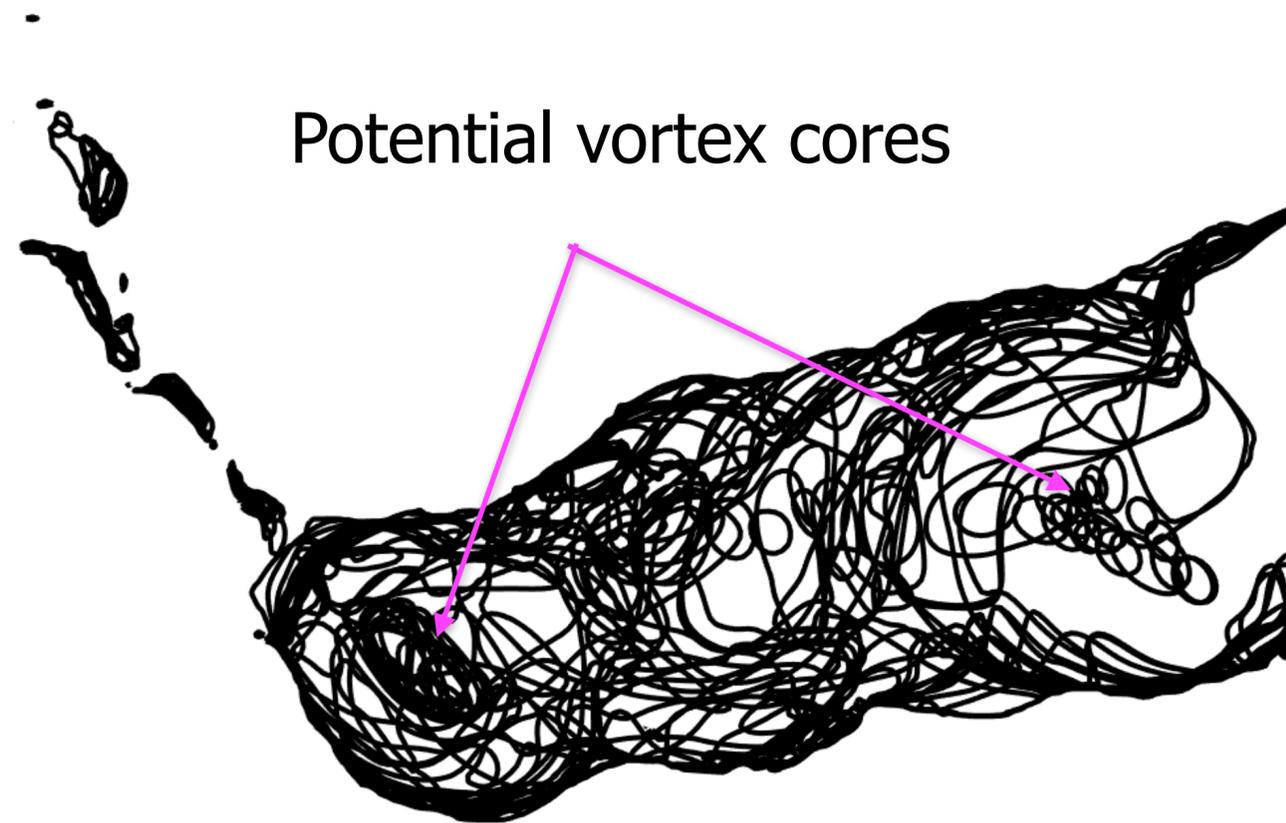
60%



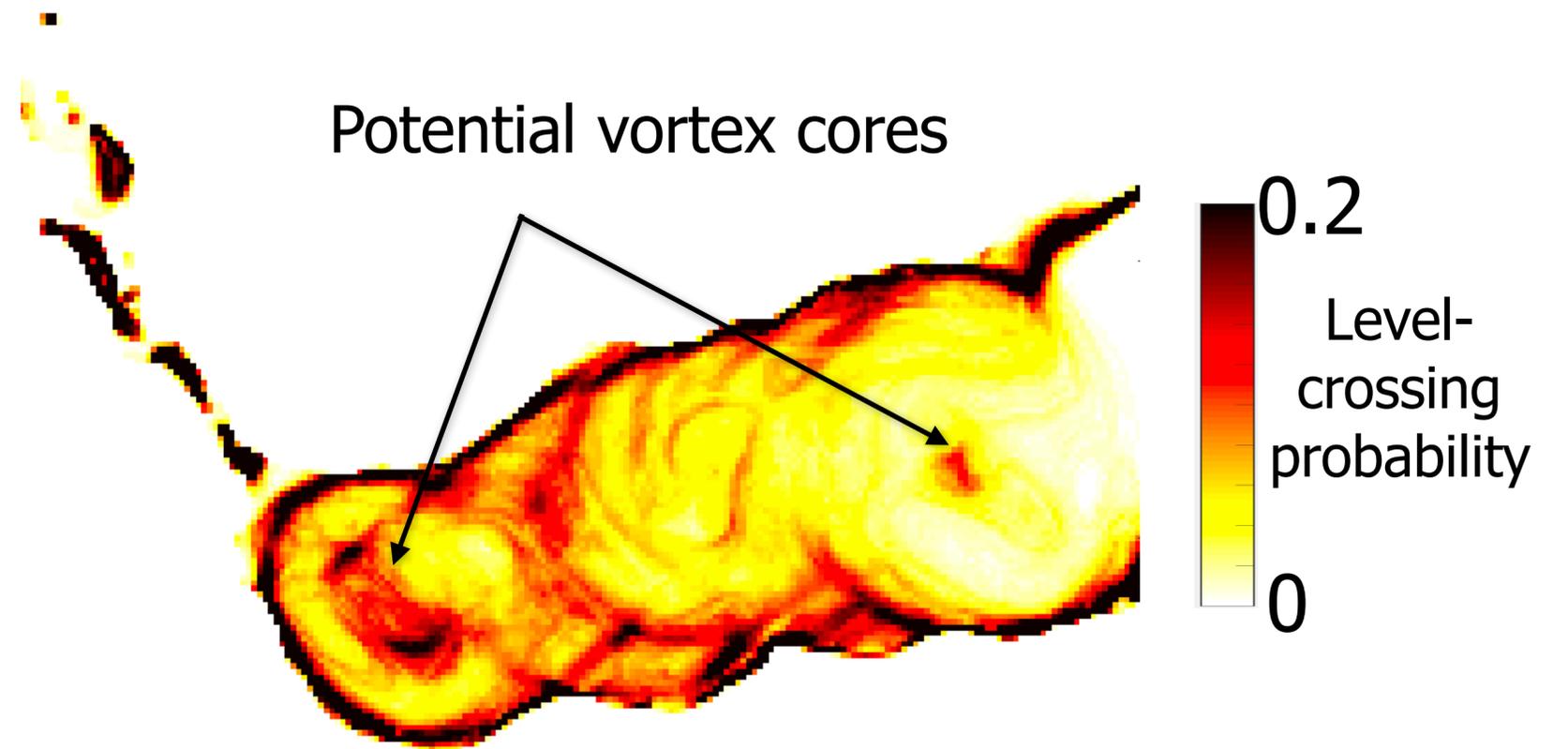
70%

# Statistical Level-Set Visualizations

Visualization for the low velocity-magnitude level set (isovalue = 0.2) for time step 40 and  $z=10$



Spaghetti plot



Probabilistic marching cubes  
[Pöthkow et al., 2011, 2013]

# Conclusion

- Efficient statistical volume rendering for 3D visualizations of expected (likely) eddy positions
- Statistical summary maps for 2D visualizations of expected (likely) eddy positions
- Quartile view, entropy-based/agreement-based thresholding, interactive probability queries for uncertainty visualization of eddy positions
- Statistical volume rendering with 2D transfer functions for analyzing correlation between variables, such as velocity magnitude and temperature

# Thank you for your attention!

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