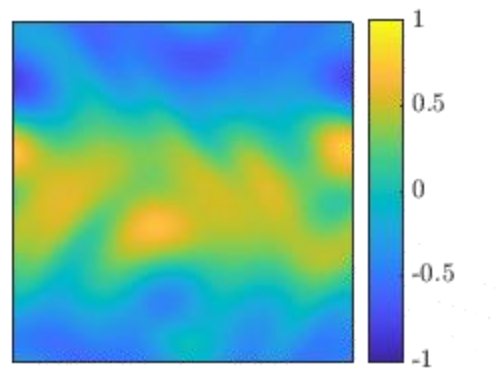


# Prediction of Extreme Events Derived from Latent Space Compression of 2D Kolmogorov Flows

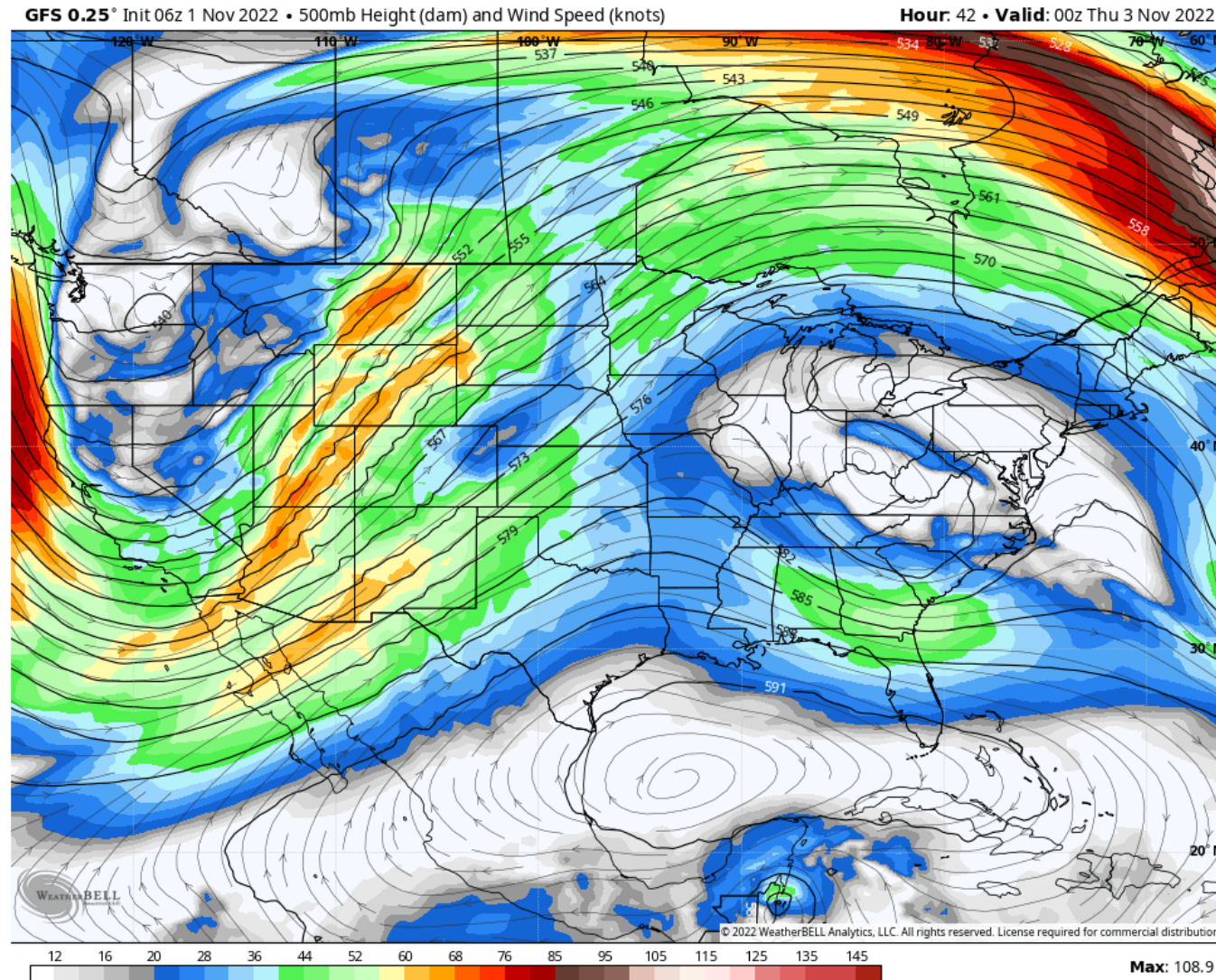
*Final Presentation*

*Thibault Clara, Ali Alper Ataşoğlu, Miłosz Pluciński, Björn Kleipool, Daniela Luca, Jacob Schut*



source: Anh Khoa Doan

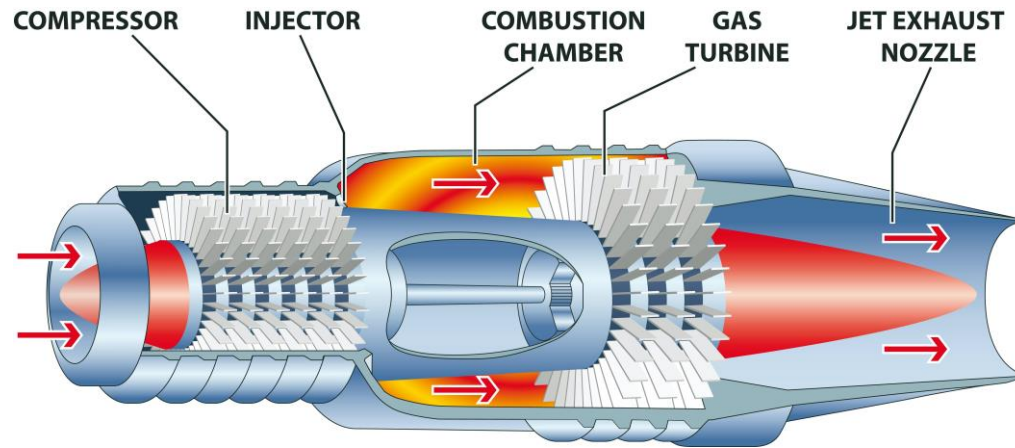
# Extreme Events – Applications



## Extreme Weather Patterns (United States, Nov 22)

source: Washington Post

# Extreme Events – Applications



Gas Turbine Engine

source: Shutterstock.com/Stanimislav-Z

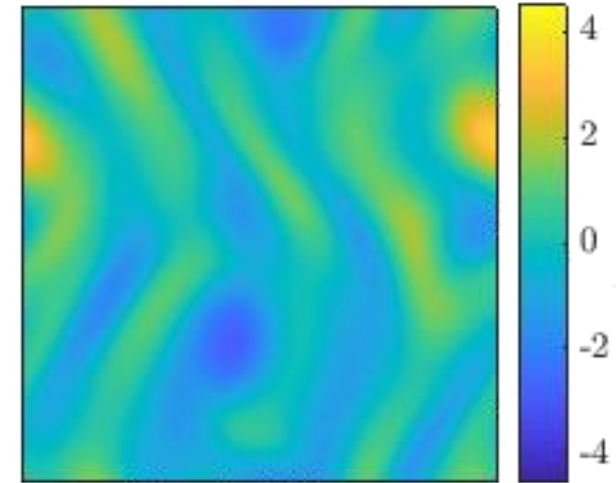


Combustor Flame  
Flashback (GH2)

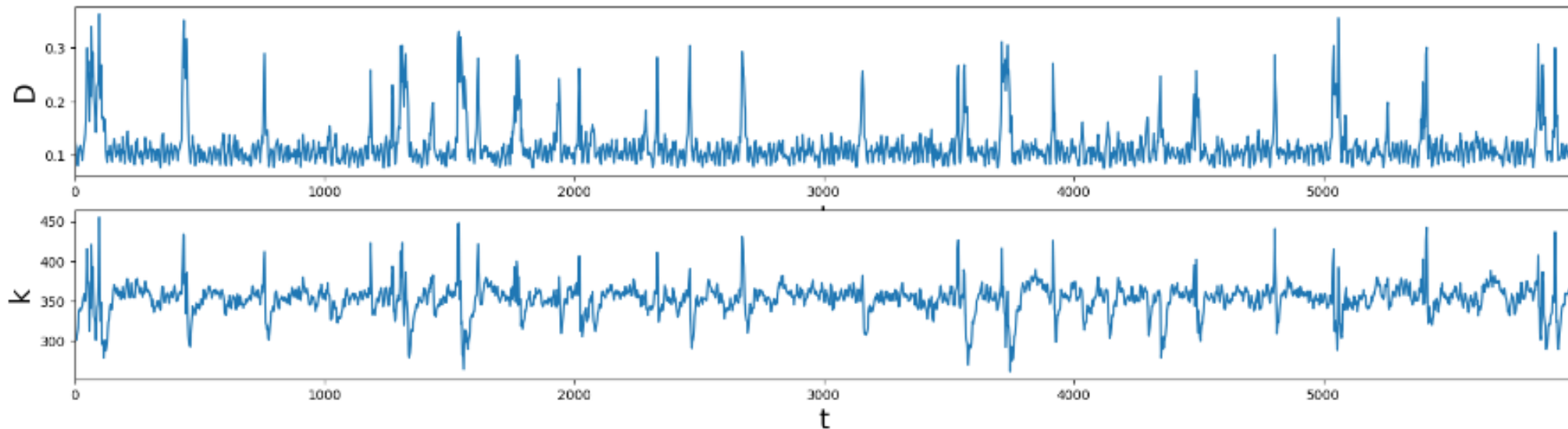
source: TU Delft, IISc

# Extreme Events – Physics

- High Energy Dissipation
- Flow Laminarization
- Sporadic Occurrence in Flows
- Precursor States



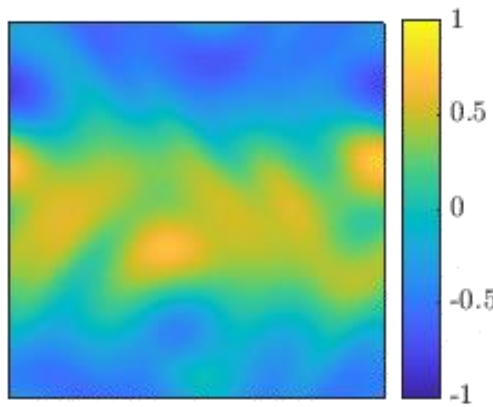
source: Anh Khoa Doan



# Table of Contents

- Extreme Events
- Model
- Results
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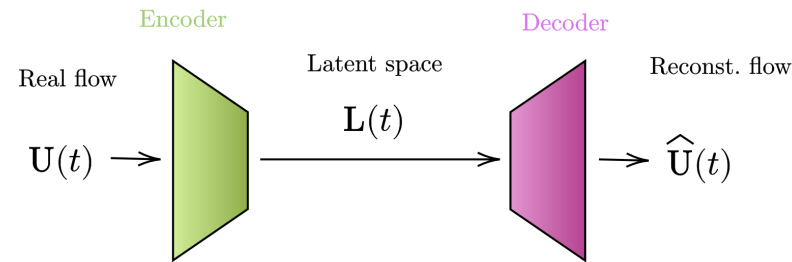
# Model – Project Proposal



source: Anh Khoa Doan

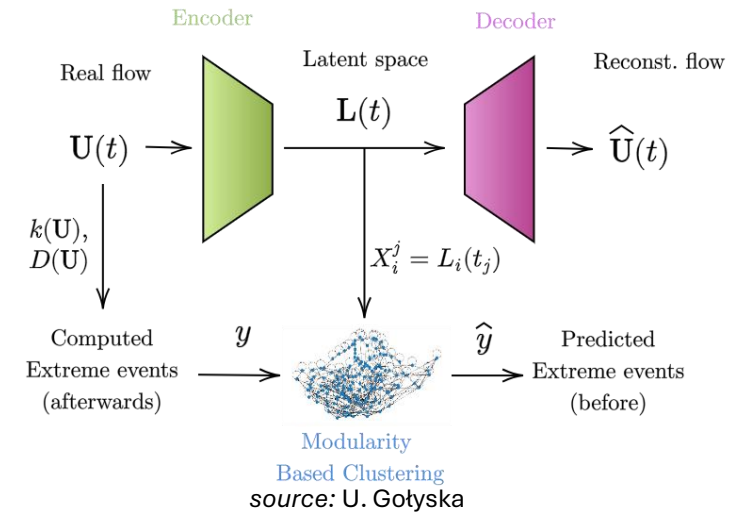
## Kolmogorov Flow:

Quasi-2D Artificial  
Turbulent Flow with  
Periodic Forcing Term  
(Function of  $Re$ )



## Variational Autoencoder Construction:

Compressed Latent Space  
Representation



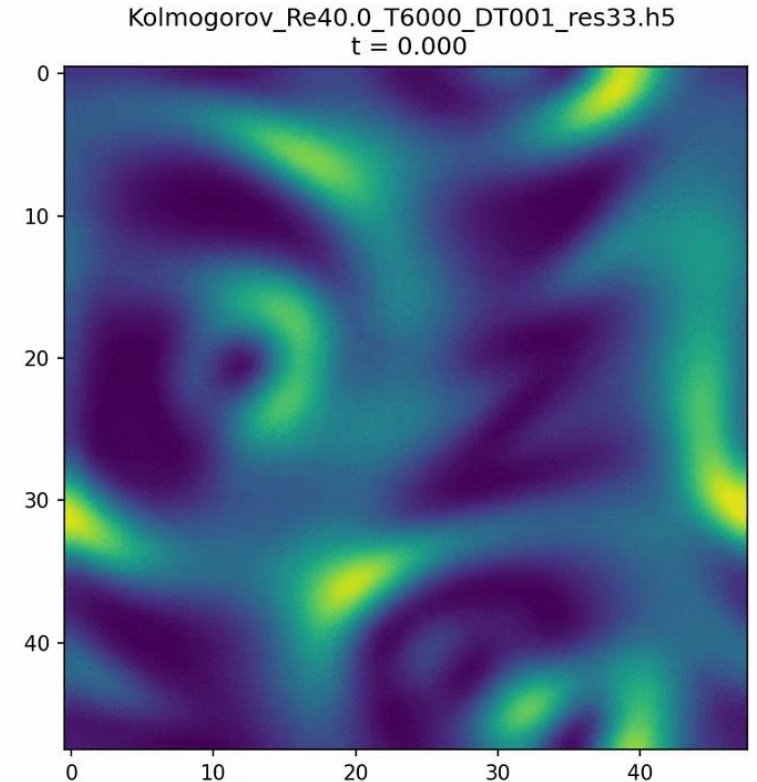
## Analysis via Clustering:

Extreme Events derived from  
Precursor States, and  
Prediction Time Horizon

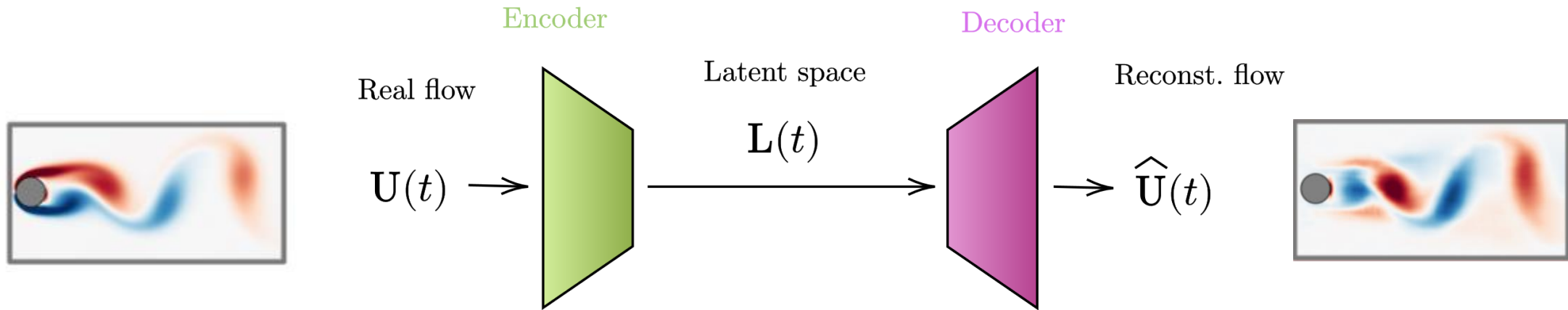


# Model – Flow Generation

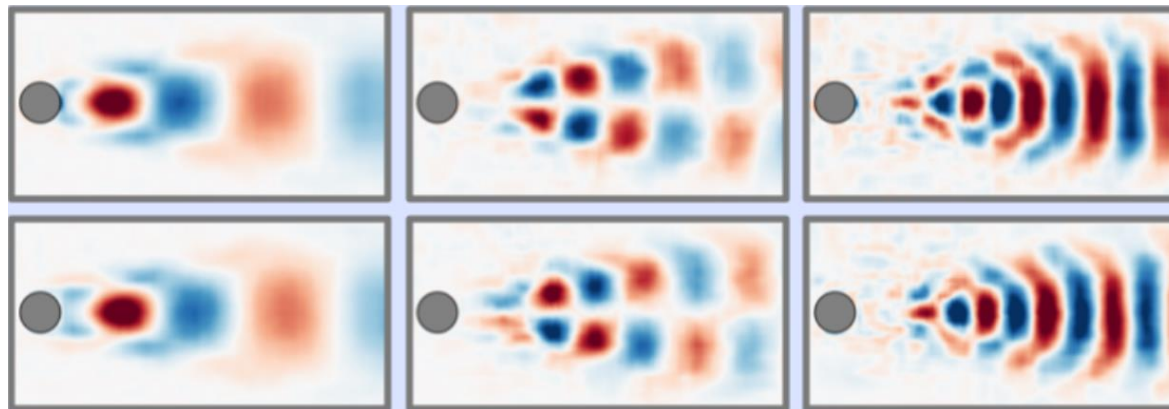
- For generating sequence of 2D Kolmogorov flows, the code from the publicly available [KolSol GitHub repository](#) was used
- Trade-off between available computational resources and sufficient resolution to achieve meaningful results: 33×33 mesh



# Model - Latent Space Generation: Variational Autoencoder Architecture



**Dimensionality of latent space synonymous to # modes.**



source: doi:10.1063/5.0020721



# Model – Latent Space Generation: Variational Autoencoder Architecture

- Regular Latent Space
- Better Trajectories

Reconstruction Loss:

1526.1

Kullback-Leibler Divergence  
Loss:

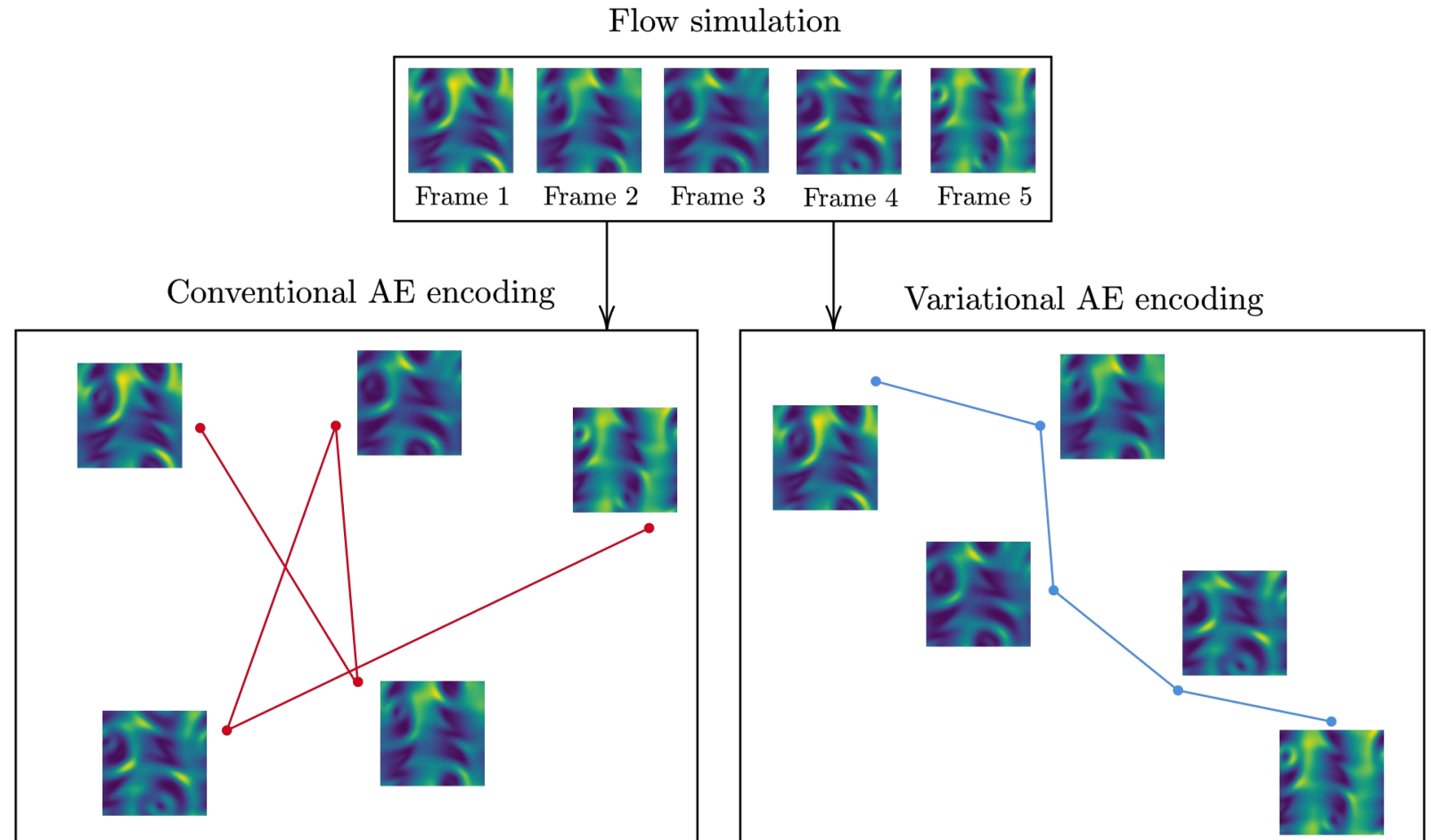
1.3

Absolute Accuracy:

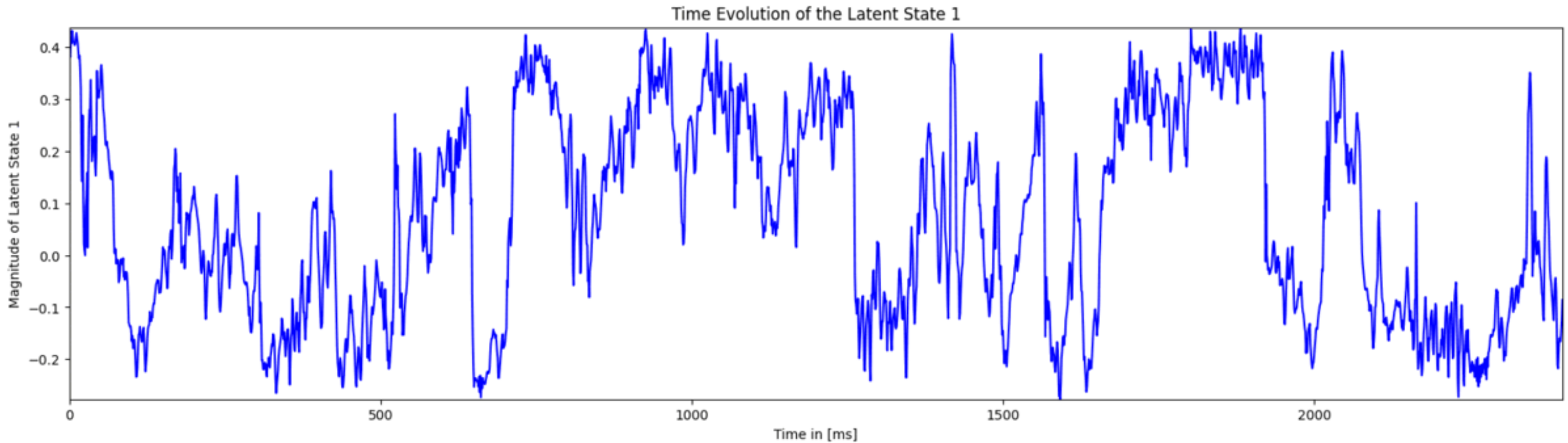
82.0%

Squared Accuracy:

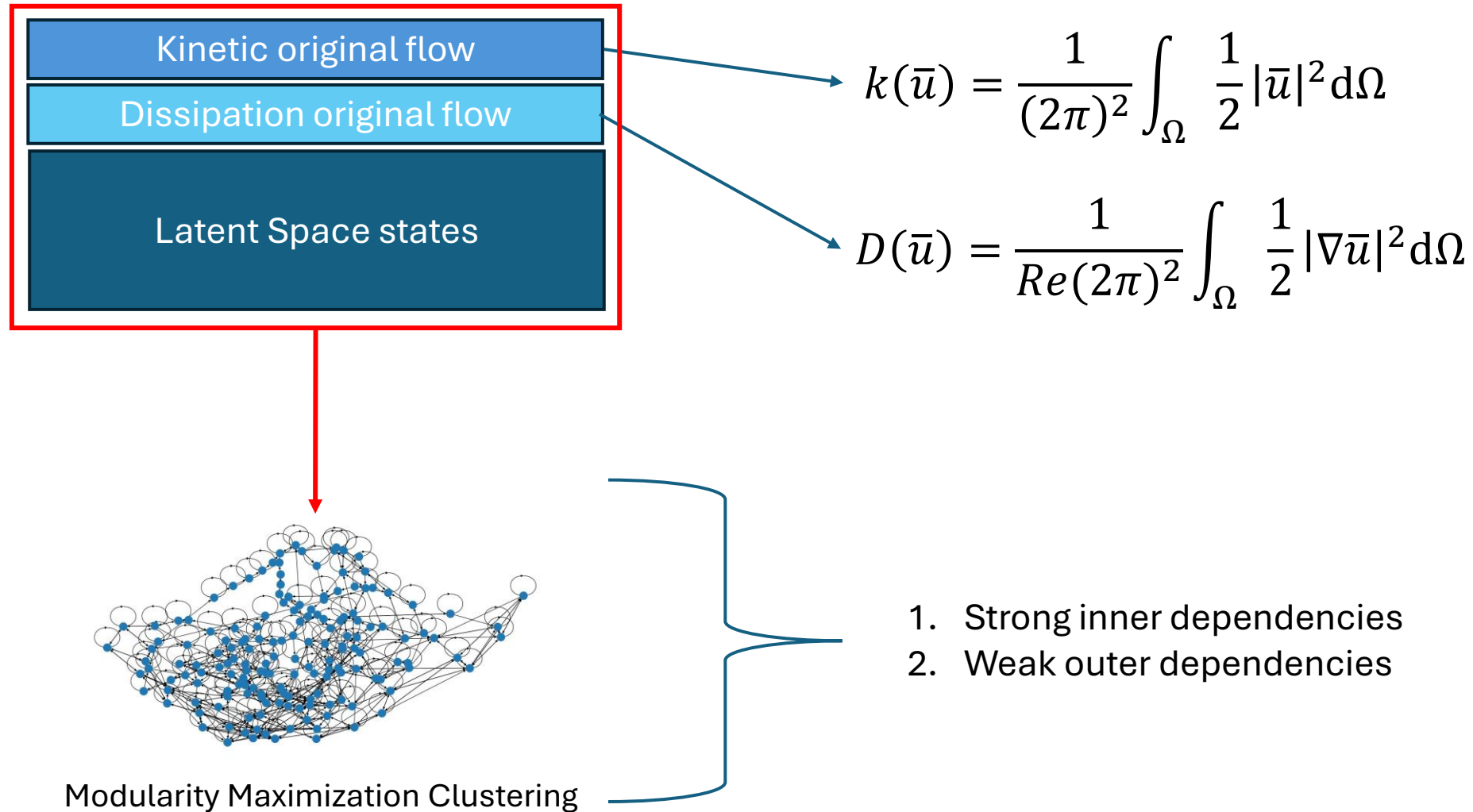
97.7%



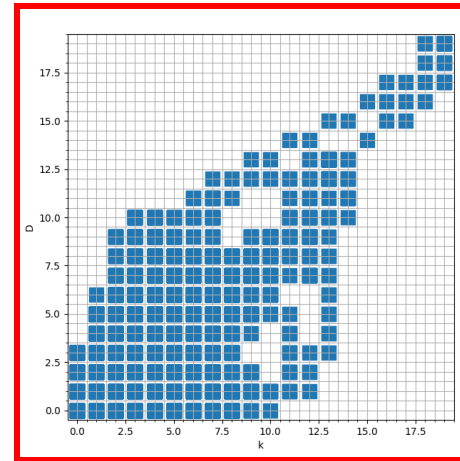
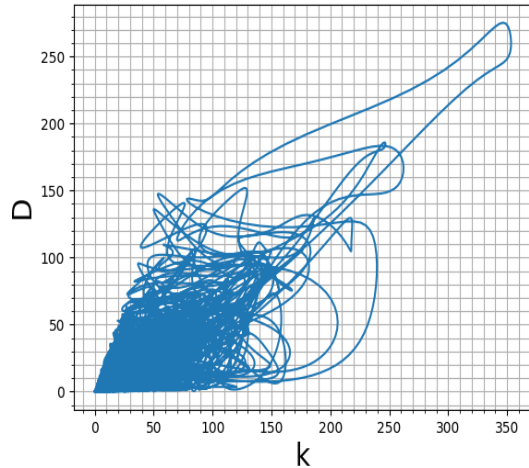
# Latent Space Time Evolution



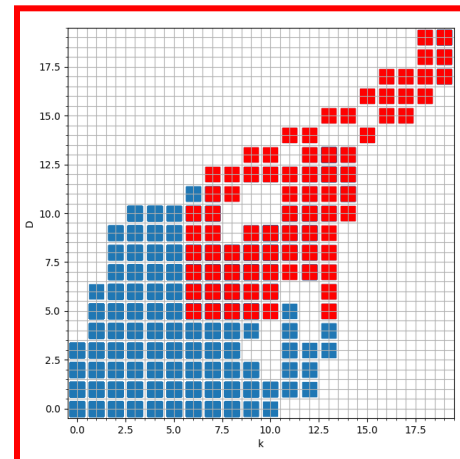
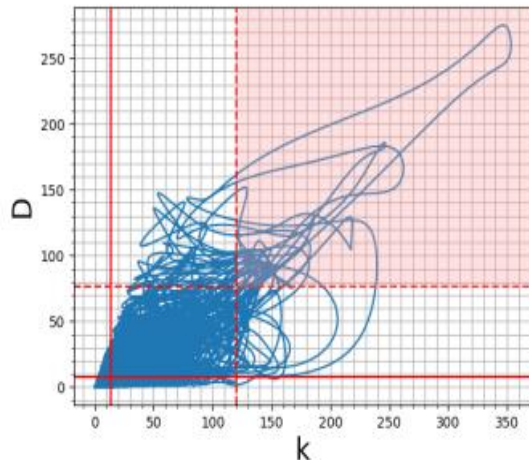
# Modularity – Data Preprocessing



# Modularity – Phase Space Tessellation

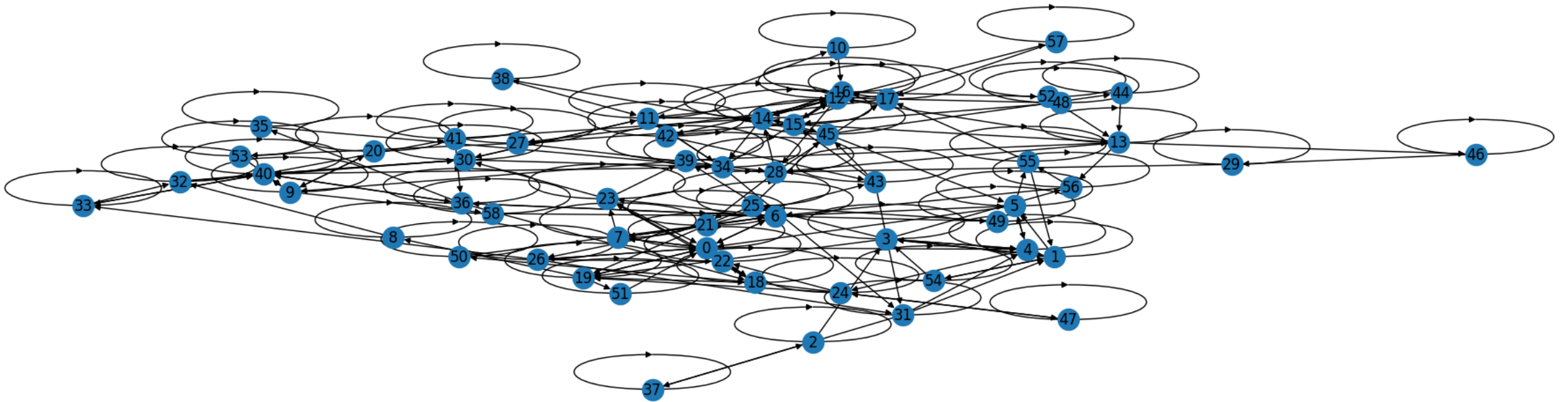


→ Preserve occupied hypercubes



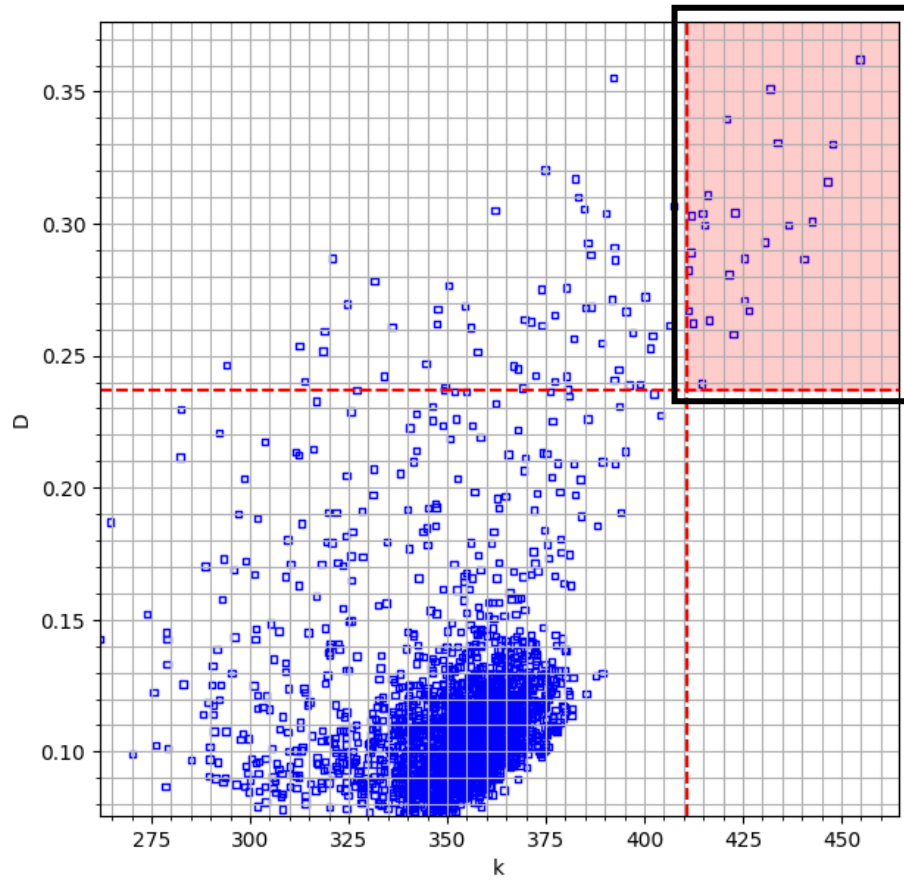
→ Statistical thresholds placed to correlate with extreme events

# Modularity – Nodal Graph



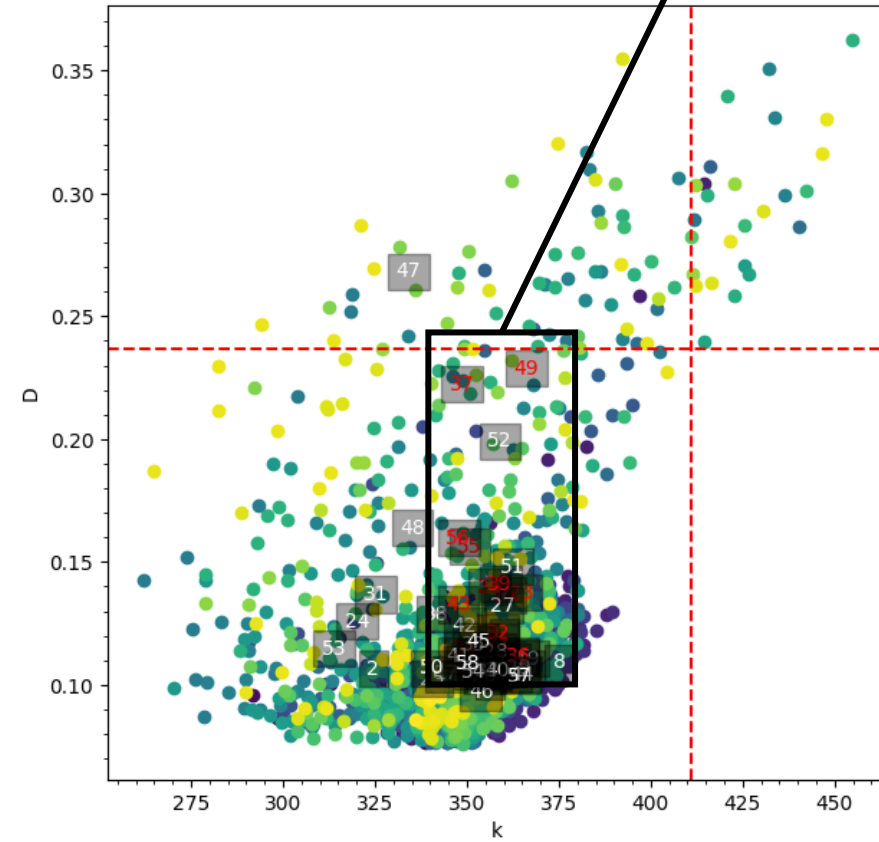
Not indicative of time-dependent dynamics! Clustering based on flow structures.

# Modularity – Clusters



Expected Extreme  
Events

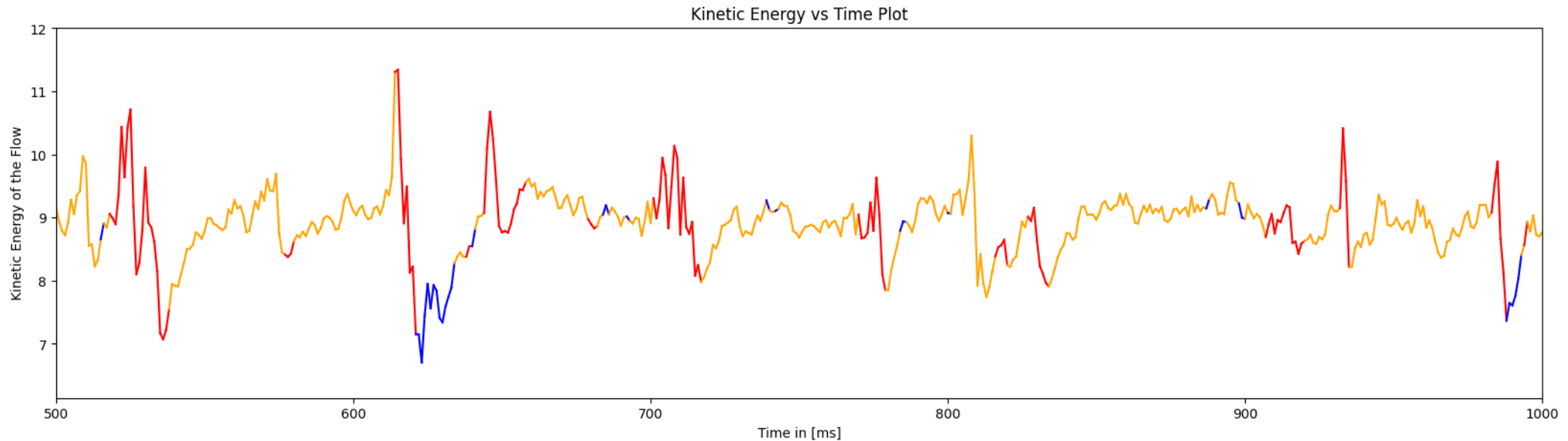
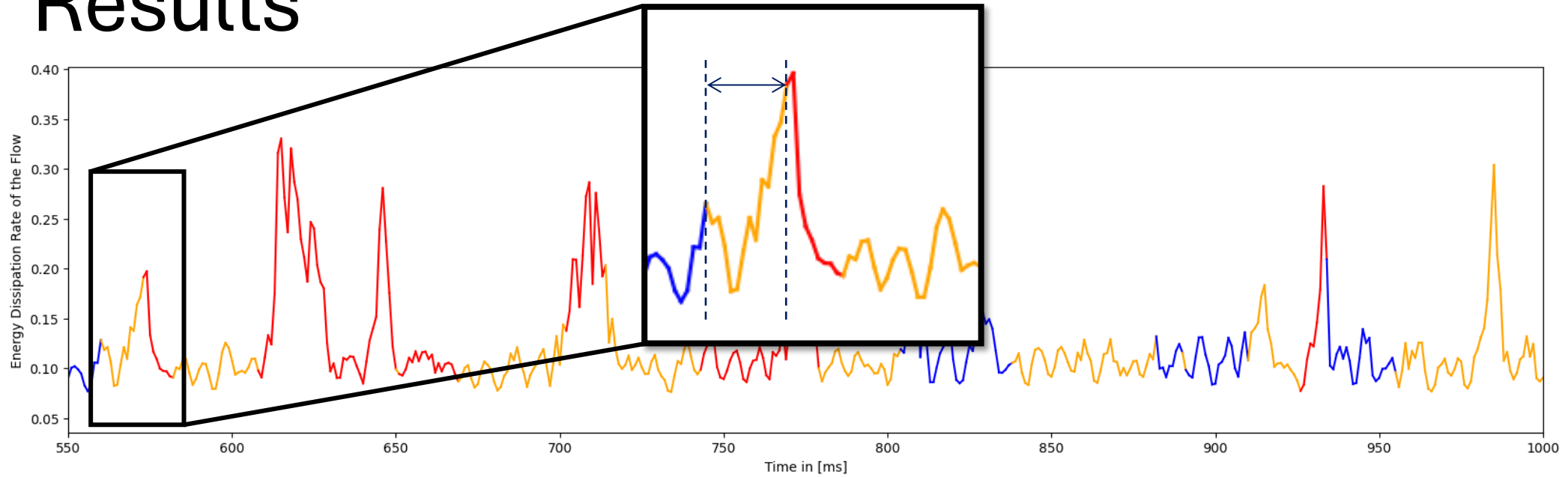
Predicted Extreme  
Cluster Centroids



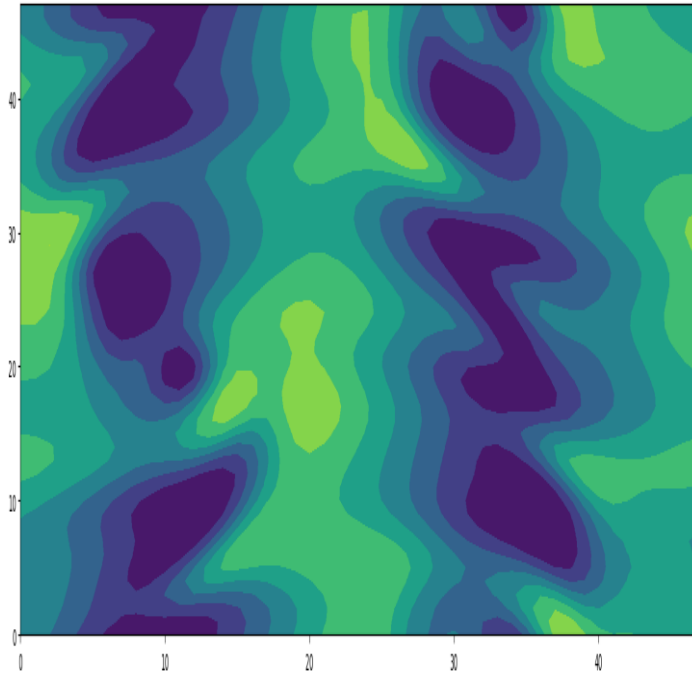


# Results

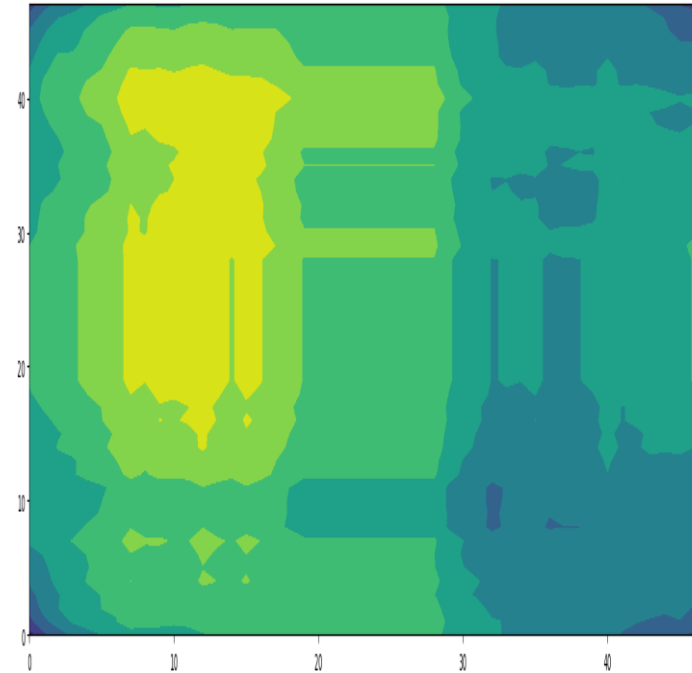
Extract Time Horizon  $\tau$



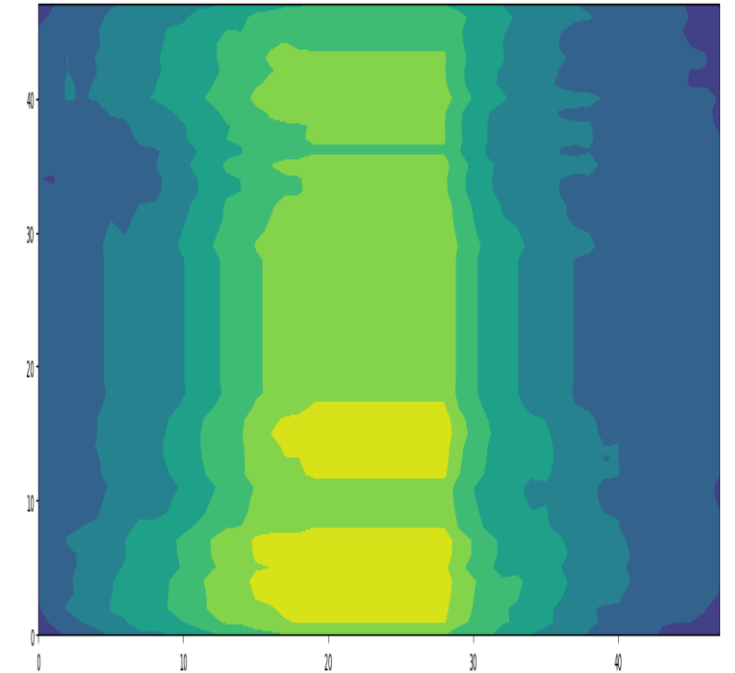
# Results – Average k-Energy Fields



Normal State



Precursor State



Extreme State

# Conclusion

- Visually-identifiable differences across 3 states.
- Latent space representation (150-fold compression) limits significantly the performance of the clustering, causing frequent oscillations across labels.
- Due to the nature of the problem, thresholds are arbitrarily-set as a function of standard deviation, which limits tuning of the model.
- The representation of high-dimensional dynamic system is capped to 3D.
- For further research, additional computational resources are required.