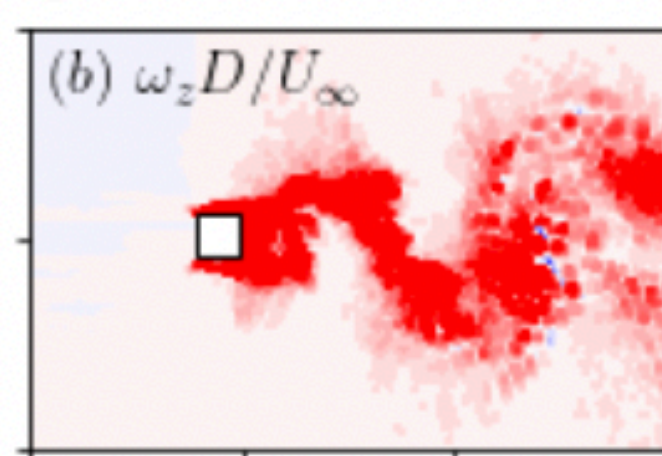
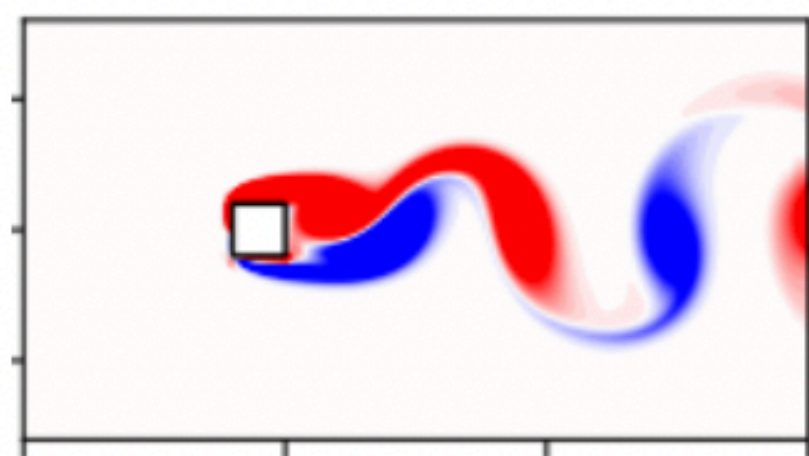
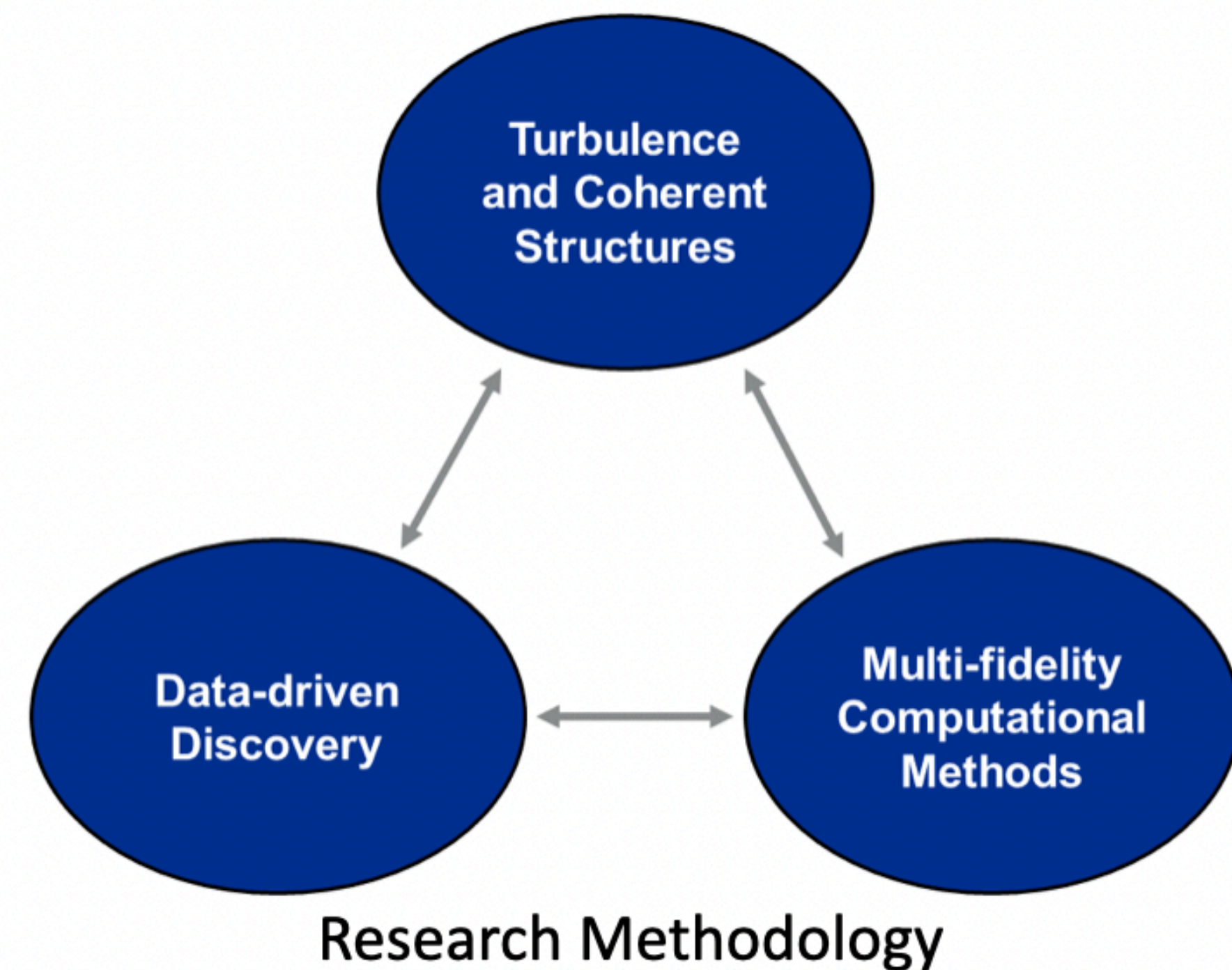
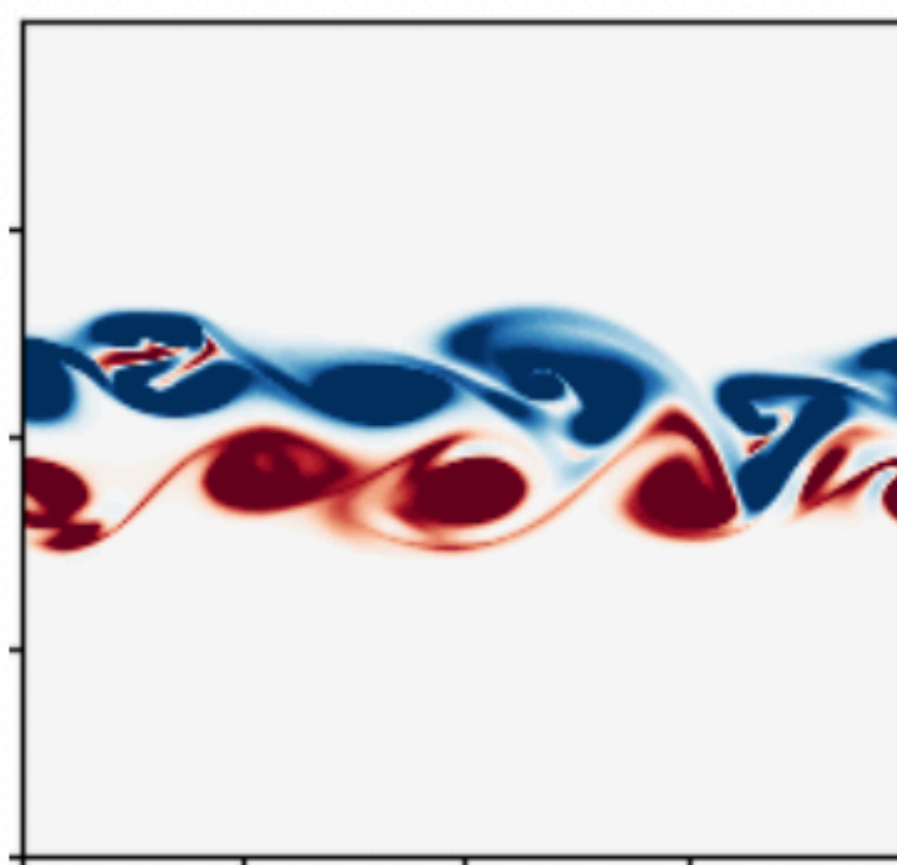
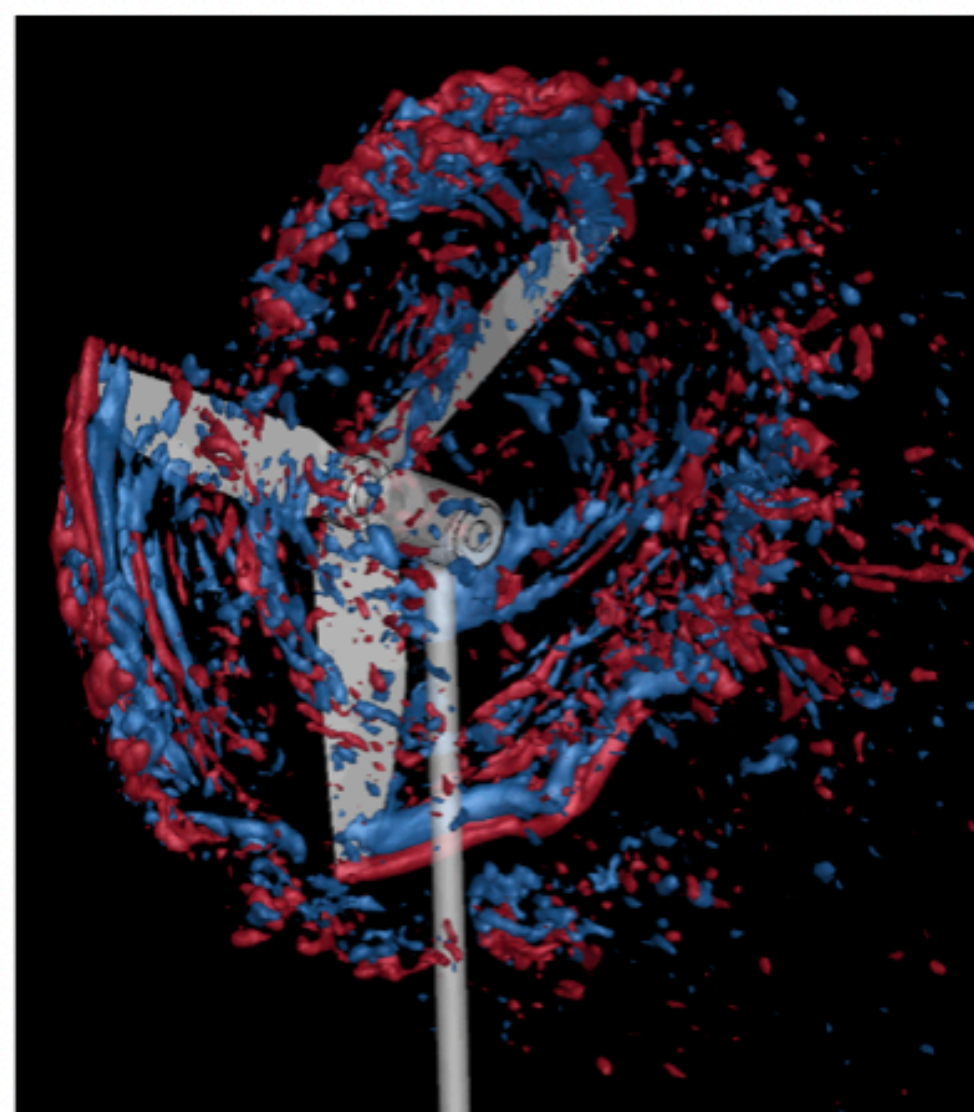
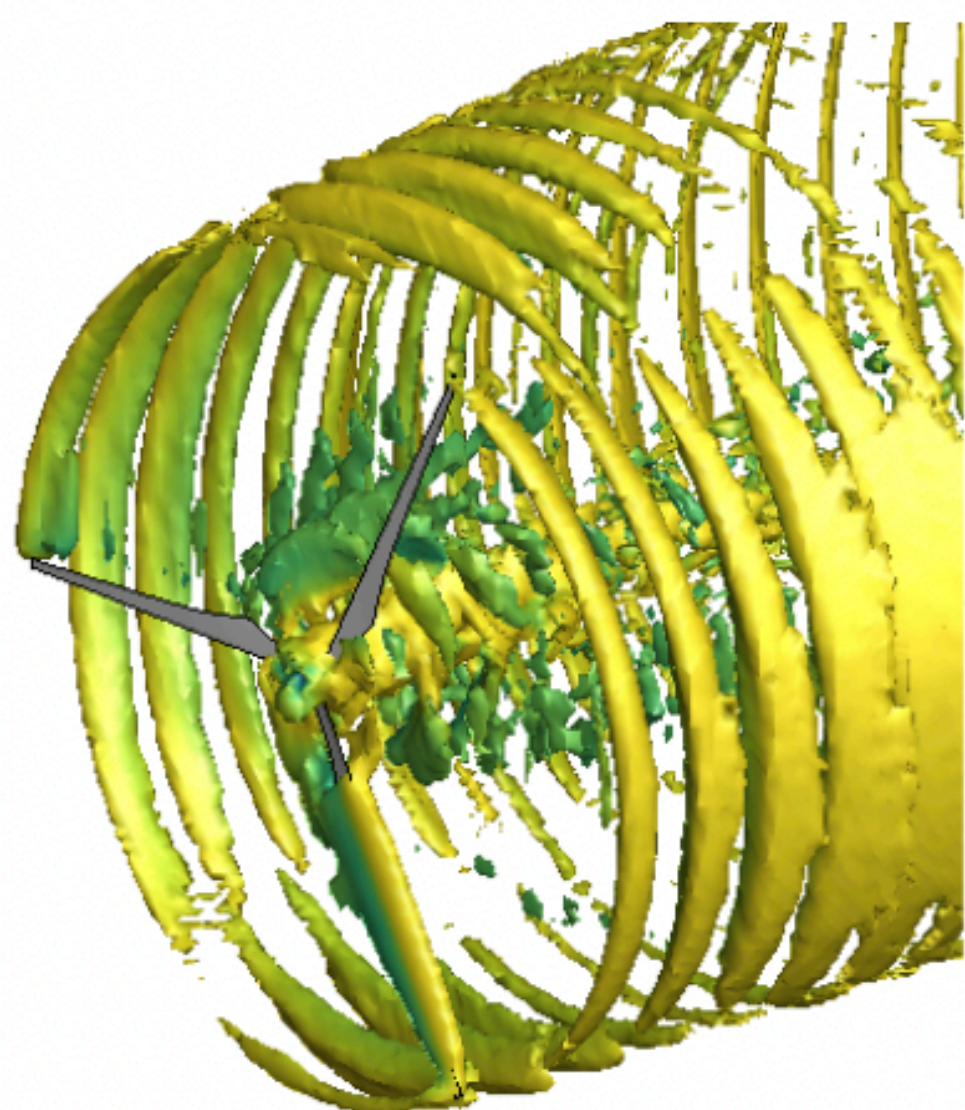




# Organizing chaos: Understanding turbulence in large-scale applications



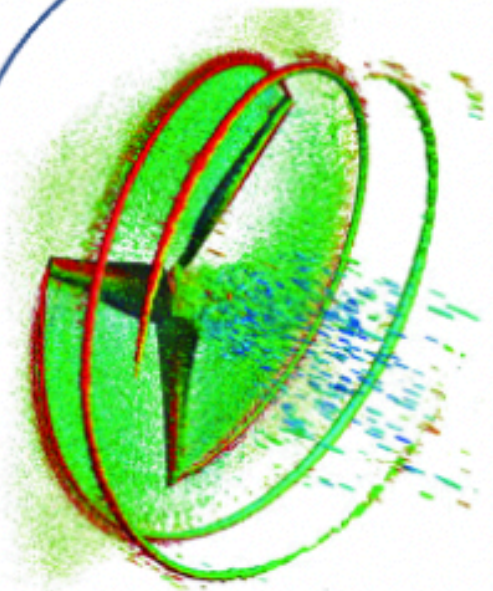
Exploit physical features to create expedient models

- Coherent structures: Important dynamic features in a variety of flows
- Computational methods: Simulation and reduced-order models
- Data-driven: Machine learning and analysis employing simulation data

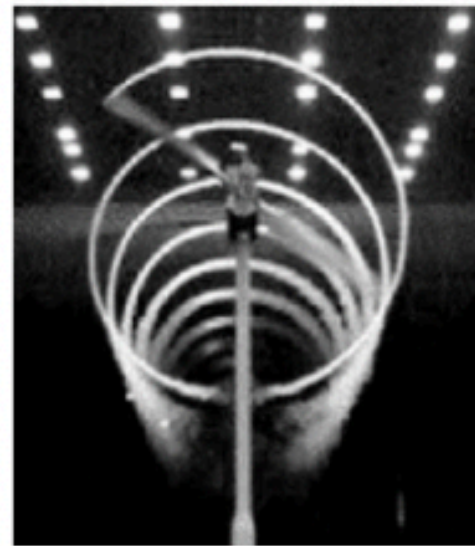


# Organizing chaos: Understanding turbulence in large-scale applications

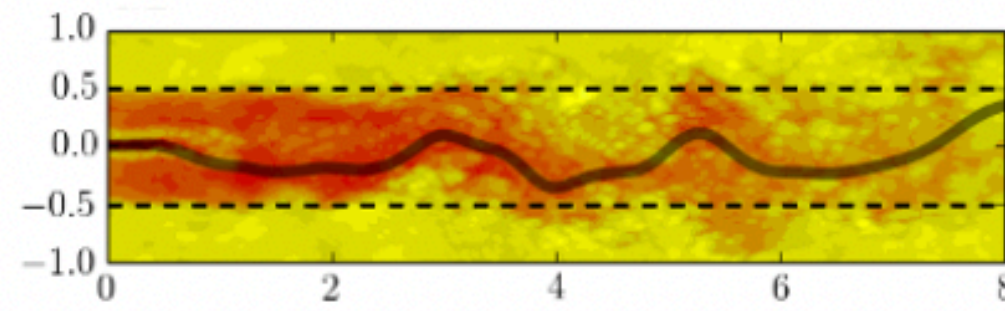
## Turbulence Coherent Structures



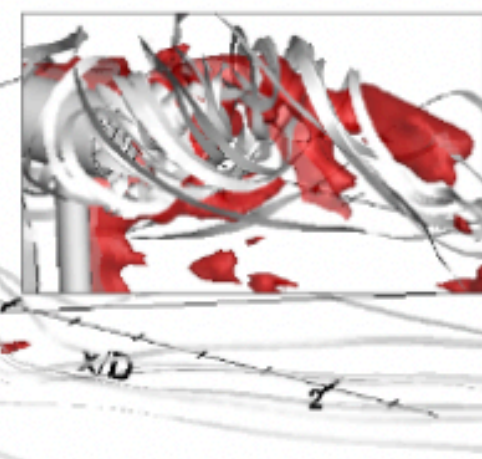
(a) Helical Tip Vortices



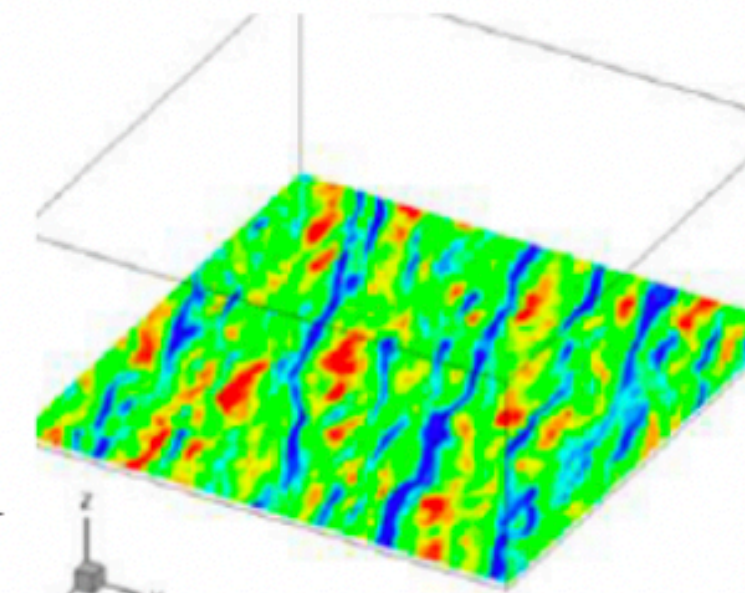
(b) Hub Vortex



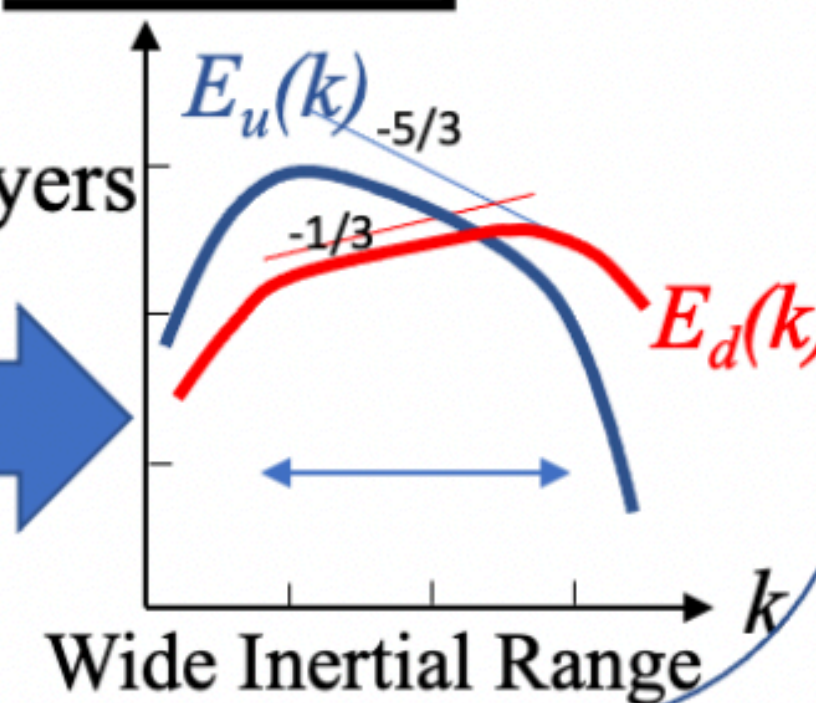
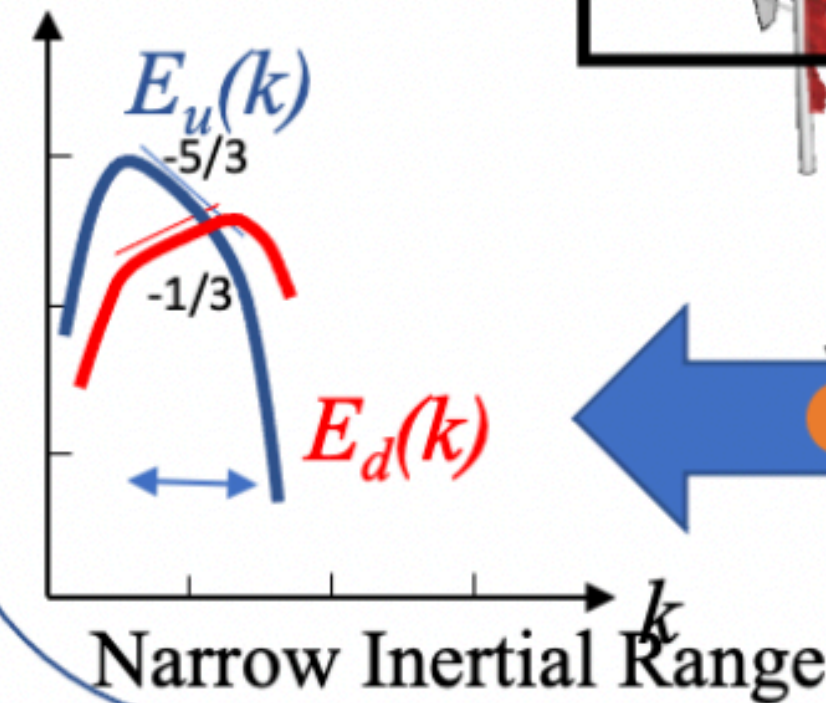
(c) Wake Meandering



(d) Turbulent Boundary Layers



(e) ABL VLCS

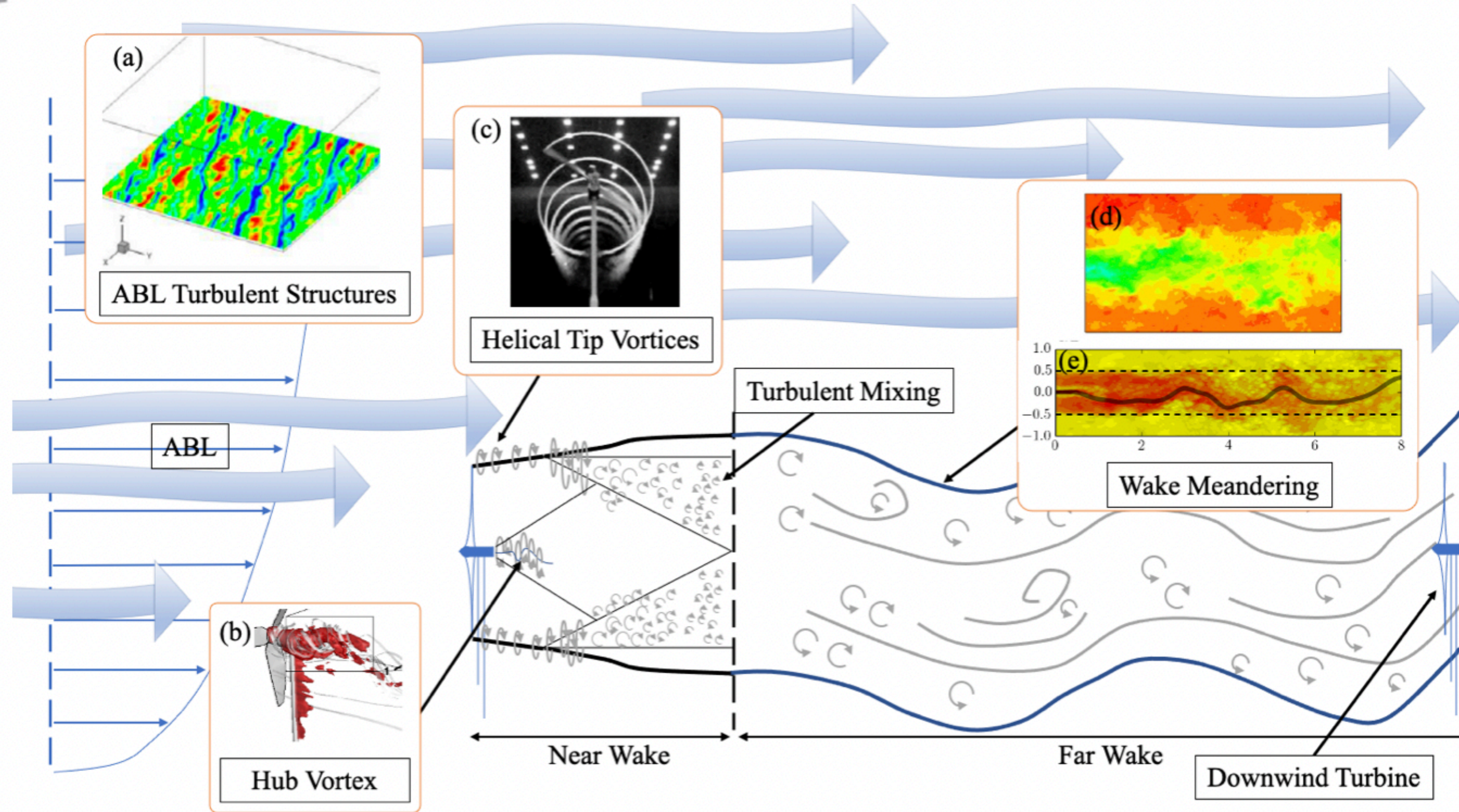


- Require diverse computational simulation tools to capture
- Utilize many forms of machine learning to analysis
- Flows are at high Reynolds numbers and difficult to understand through measurement alone.

Coherent structures in turbulent flows are multi-scale



# Organizing chaos: Understanding turbulence in large-scale applications

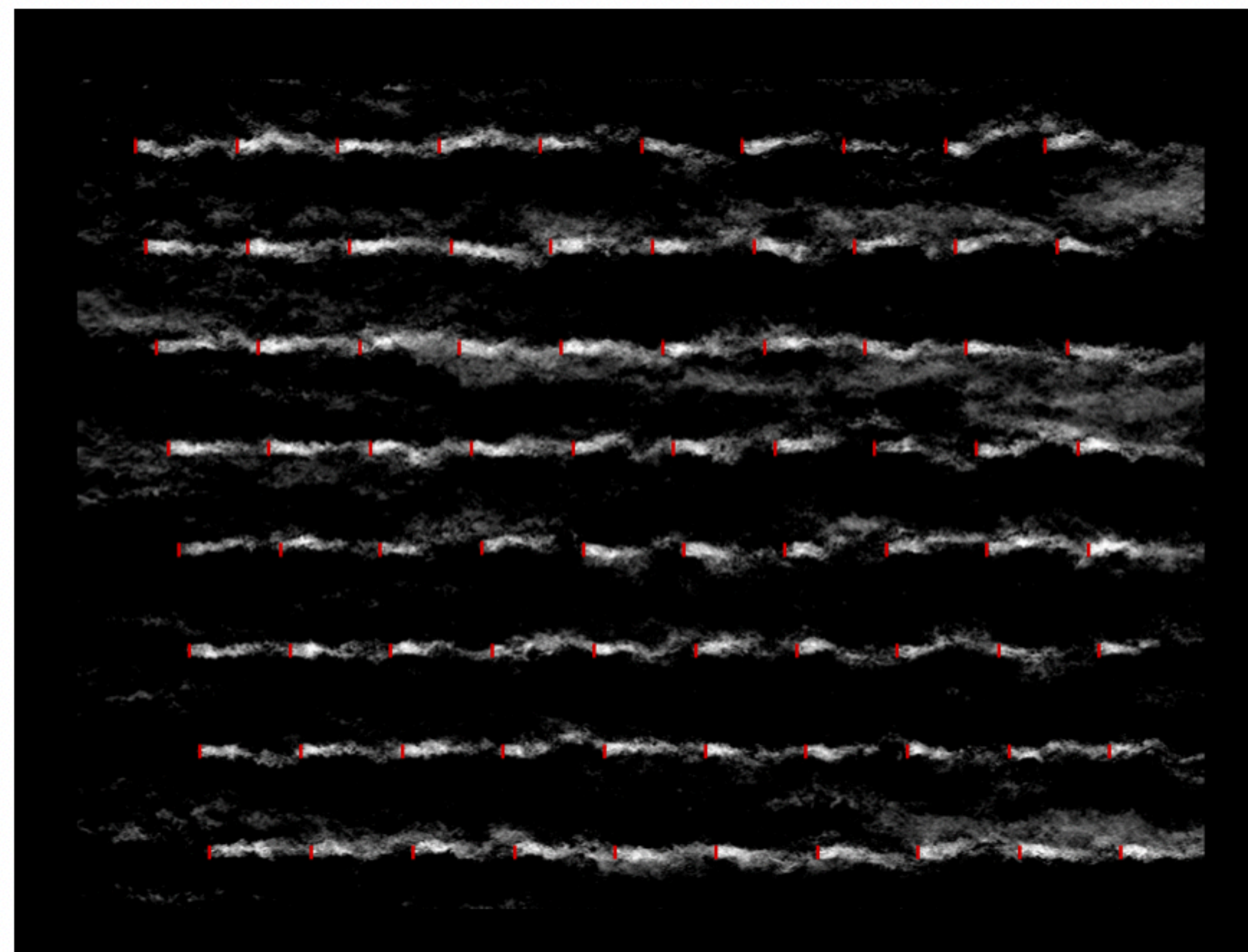


Cost of wind energy affected by turbulence upwind and downwind



# Organizing chaos: Understanding turbulence in large-scale applications

Horns Rev Wind Farm



We simulated flow fields over decades of length and time scale

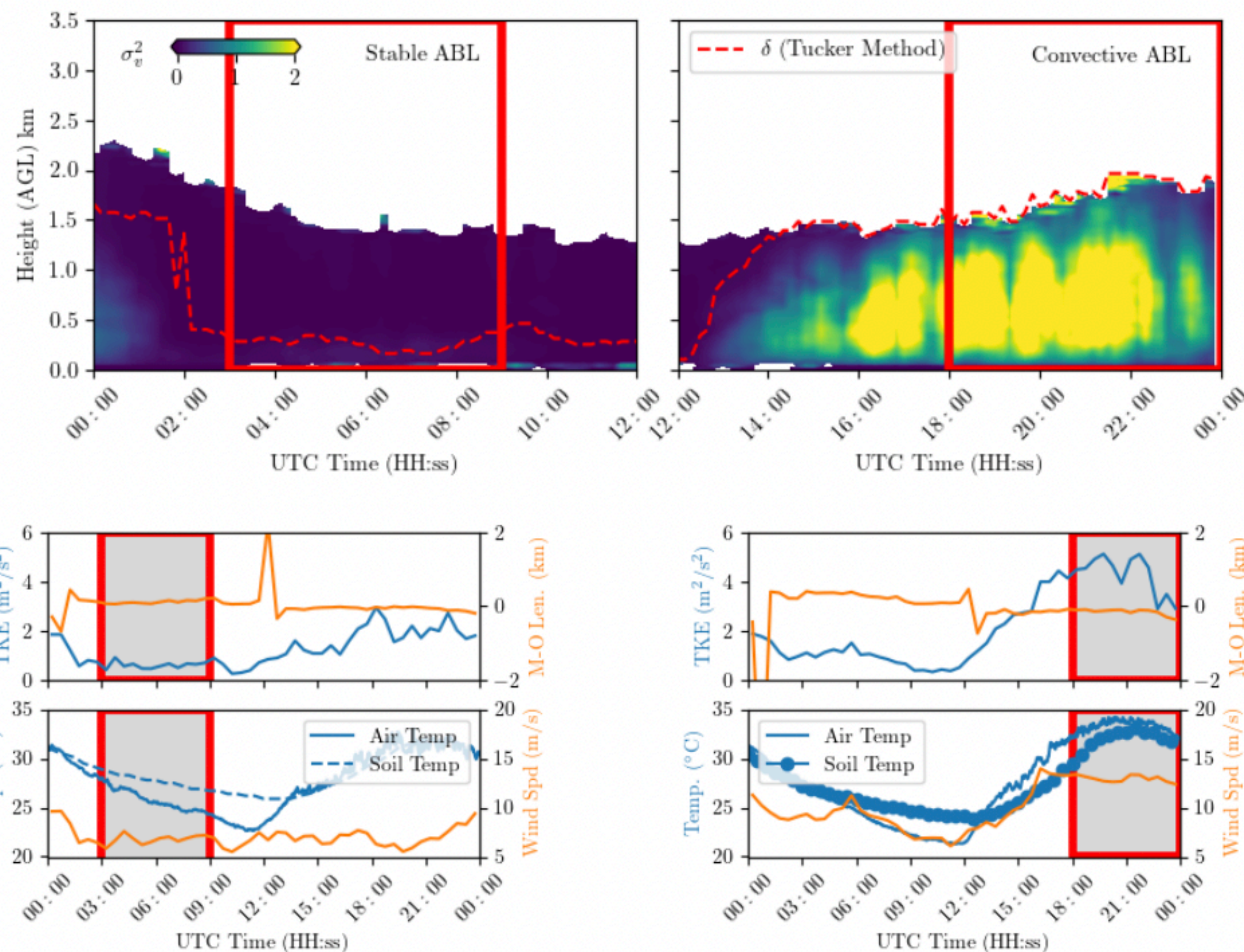


# Organizing chaos: Understanding turbulence in large-scale applications



DOE ARM Southern Great Plains Site

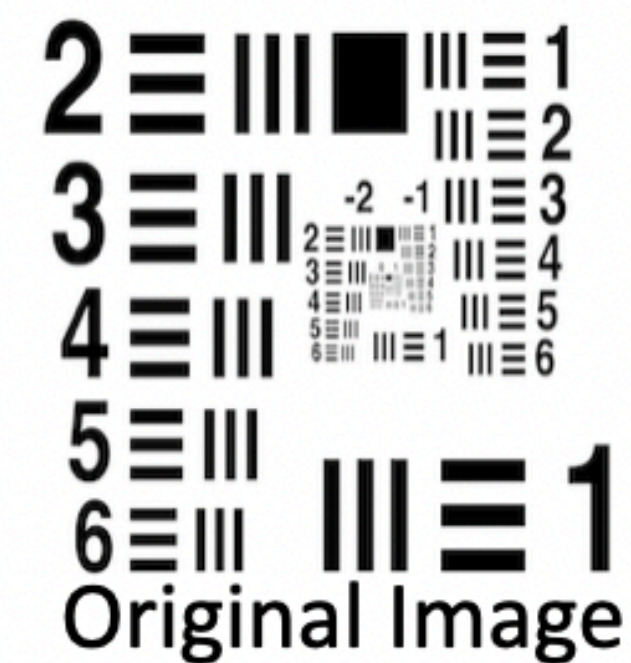
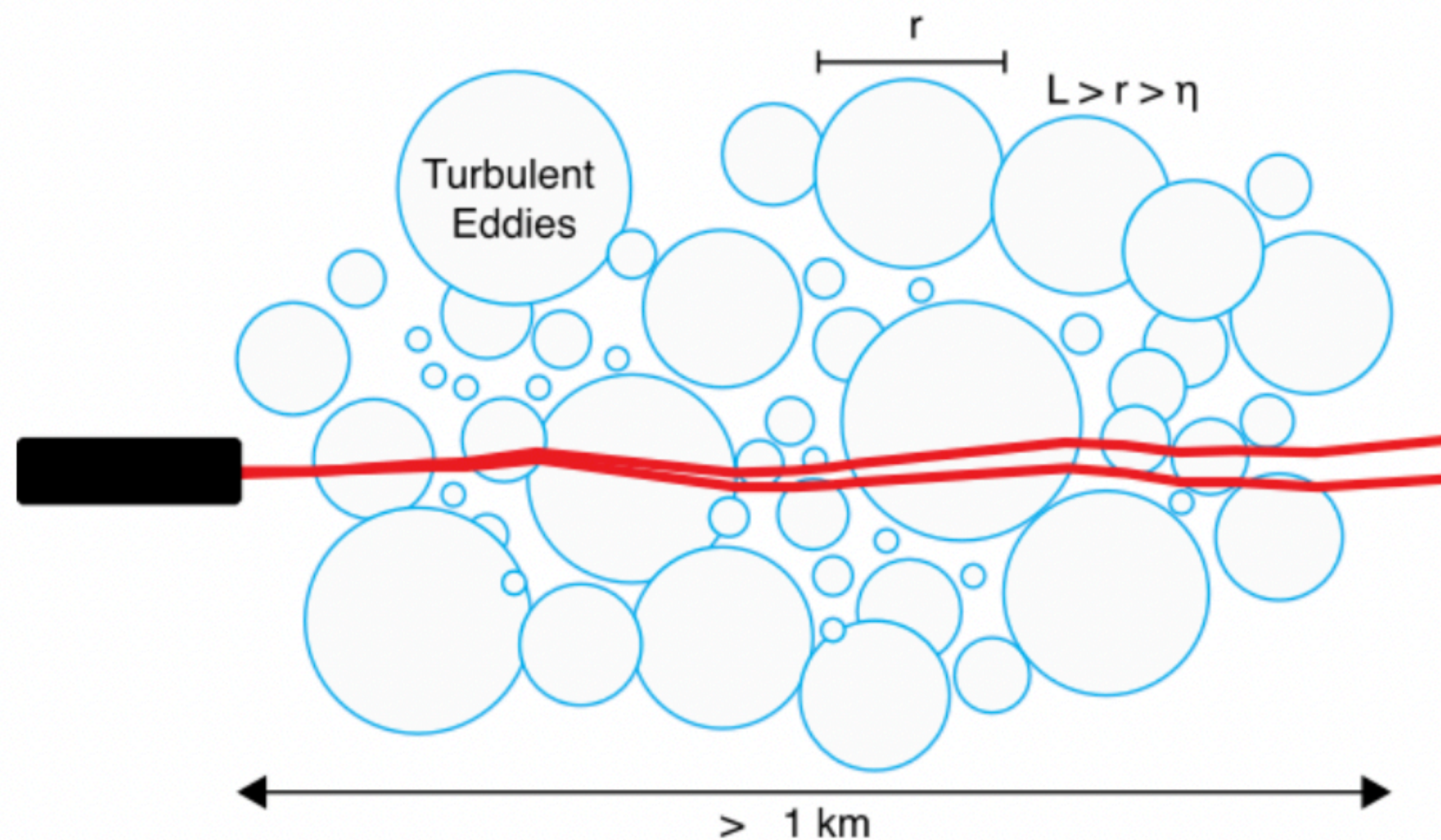
- Petabytes of measurements recorded for analysis



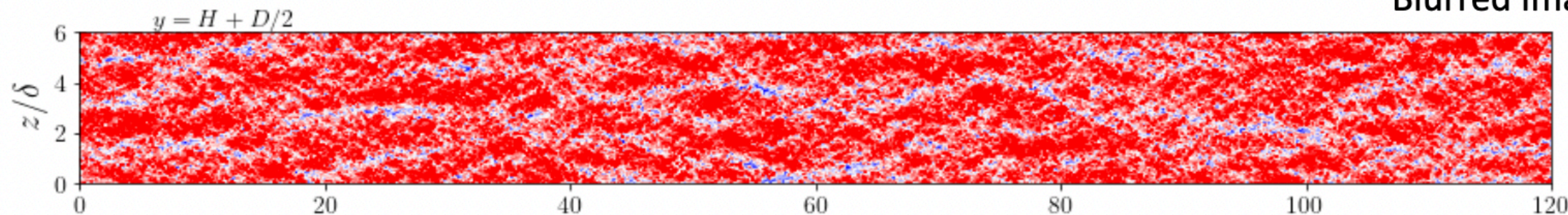
We leverage atmospheric observations to understand the atmospheric boundary layer



# Organizing chaos: Understanding turbulence in large-scale applications



Blurred Image



We investigate how optical imaging is affected by turbulent fluctuations in the atmosphere



# Organizing chaos: Understanding turbulence in large-scale applications

Experience students will gain:

- Understanding of turbulence and fluid dynamics
- How to analyze large quantities of data (big data)
- Programming, Linux, and scripting skills
- Experience with high performance computing
- Concepts in numerical methods and machine learning
- Skills with processing grids and data with software
- Experience with data visualization and written and oral communication