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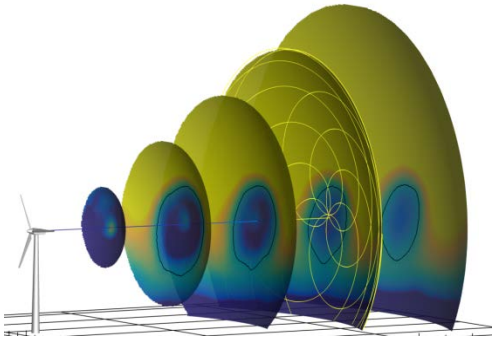

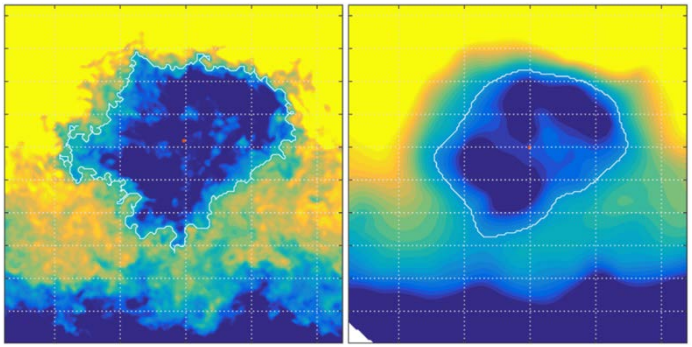

SWiFT Overview and Proposed Benchmarks

Thomas Herges and David Maniaci

IEA Task 31 Meeting

29 May, 2017

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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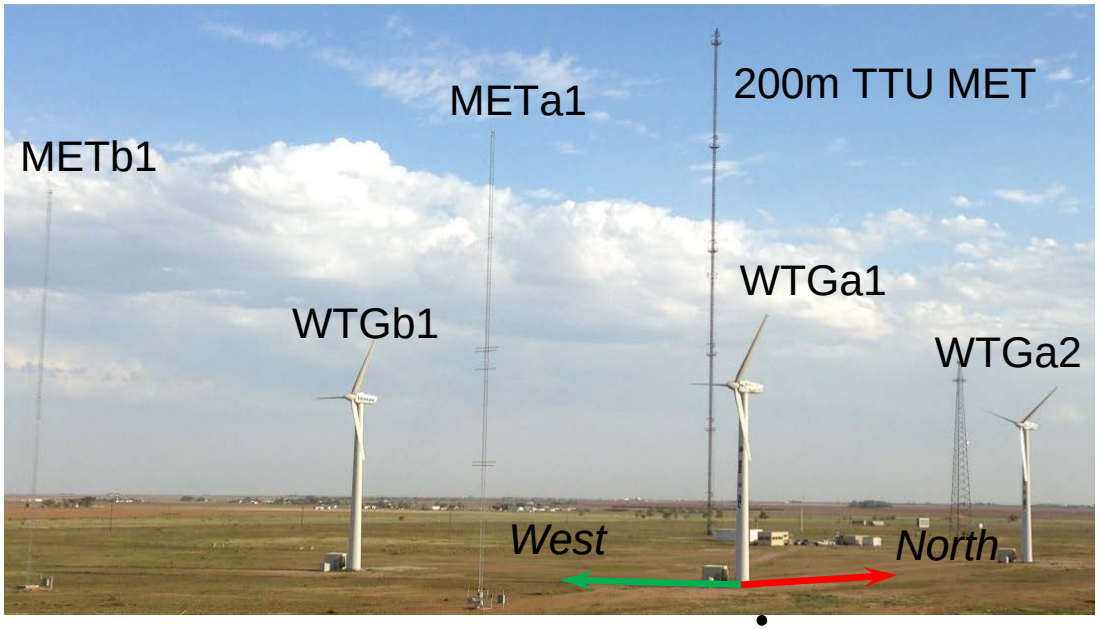
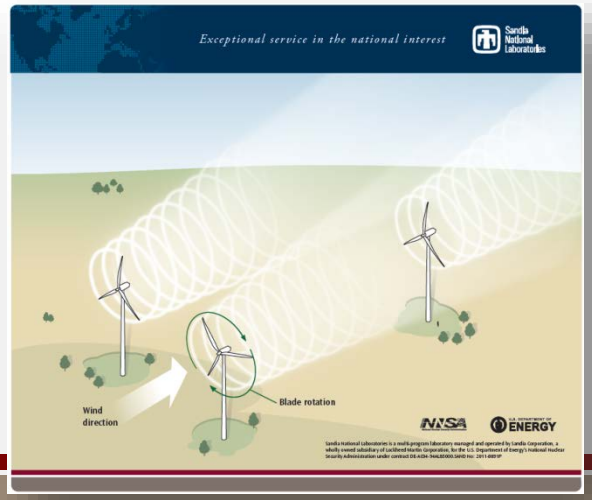
SWiFT Site Layout and Capabilities

DOE/SNL Scaled Wind Farm Technology (SWiFT) facility hosted by Texas Tech University (TTU)

SWiFT exists to:

- Reduce turbine-turbine interaction and wind plant underperformance
- Public, open-source validation data
- Advance wind turbine technology





Facilities:

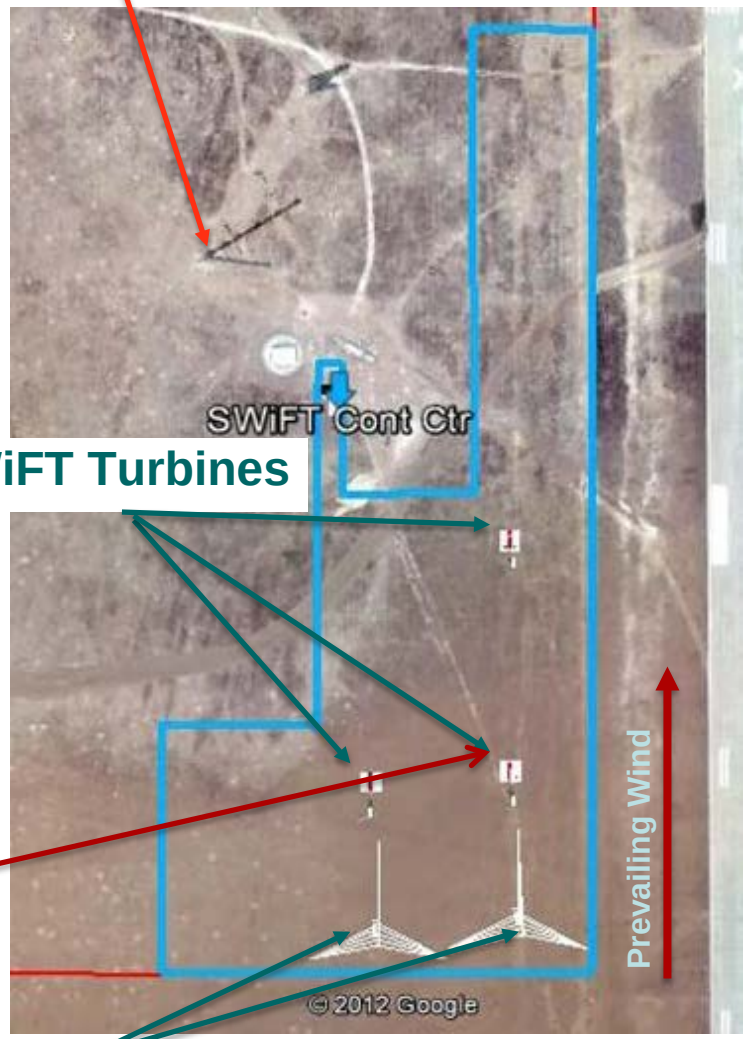
- Three variable-speed variable-pitch heavily-modified V27 wind turbines with full power conversion and extensive sensor suite
- Two heavily instrumented inflow anemometer towers
- Site-wide time-synchronized data collection

SWiFT Wake Steering Campaign

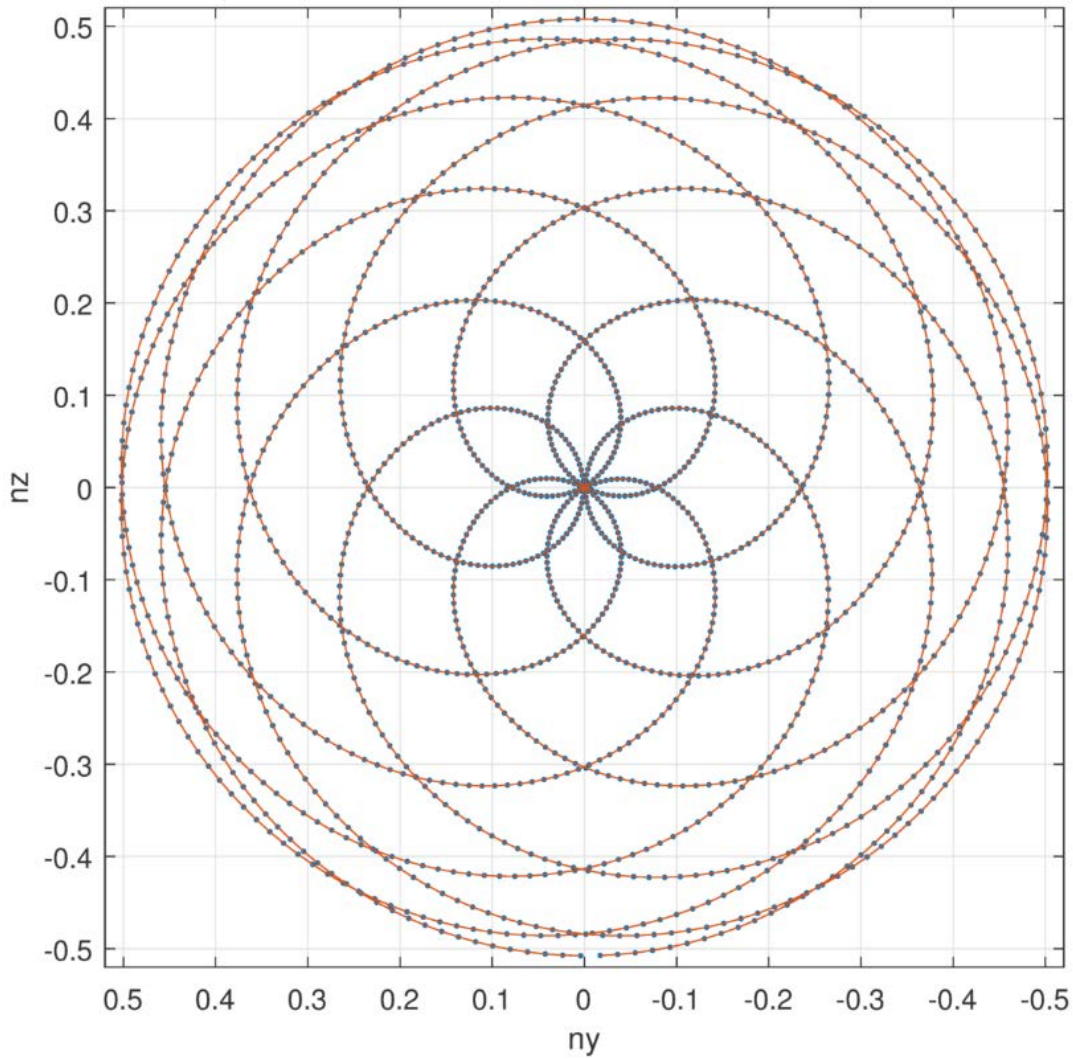
Goal: Demonstrate the influence of wake steering control on downstream rotor power and loads using two instrumented turbines with inter-turbine wake measurements.

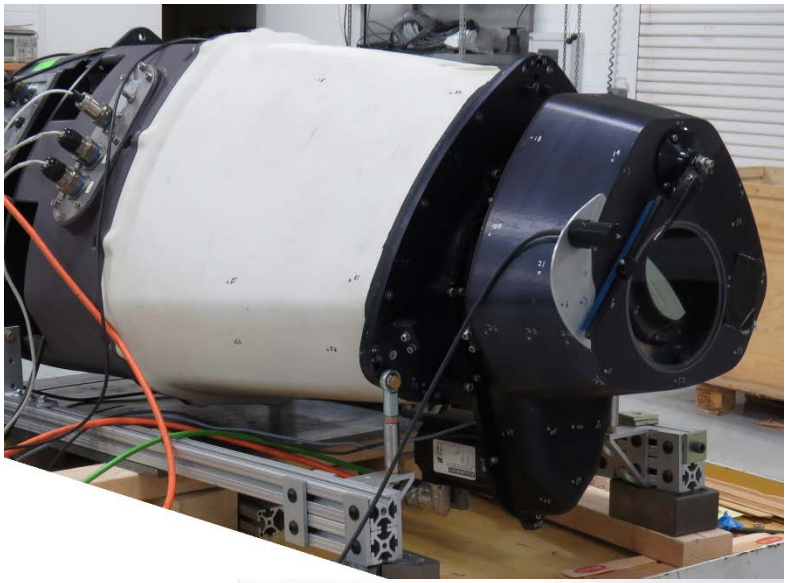
Measurements:

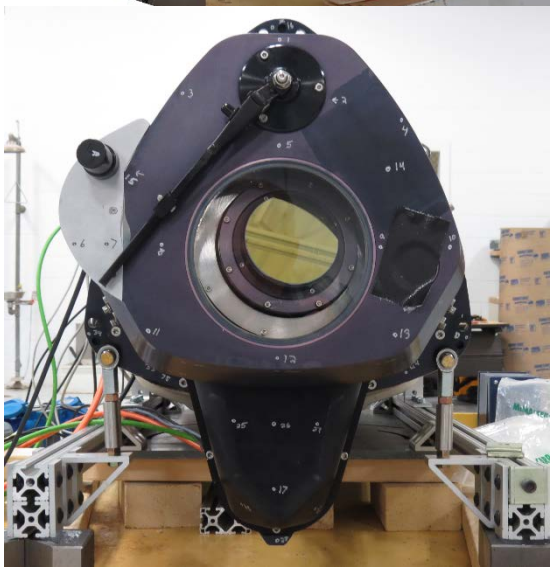
- ABL Conditions: 200m MET tower
- Inflow: Dual 58.5m MET towers
- Rotor and Tower Strains and Accels.
- Wake Flow Diagnostic: DTU SpinnerLidar
- Other Flow Diagnostics: Spidar, Windar



Wake Measurements: DTU SpinnerLidar







table

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in the roll and pitch angle orientation

Wake Measurements: DTU SpinnerLidar

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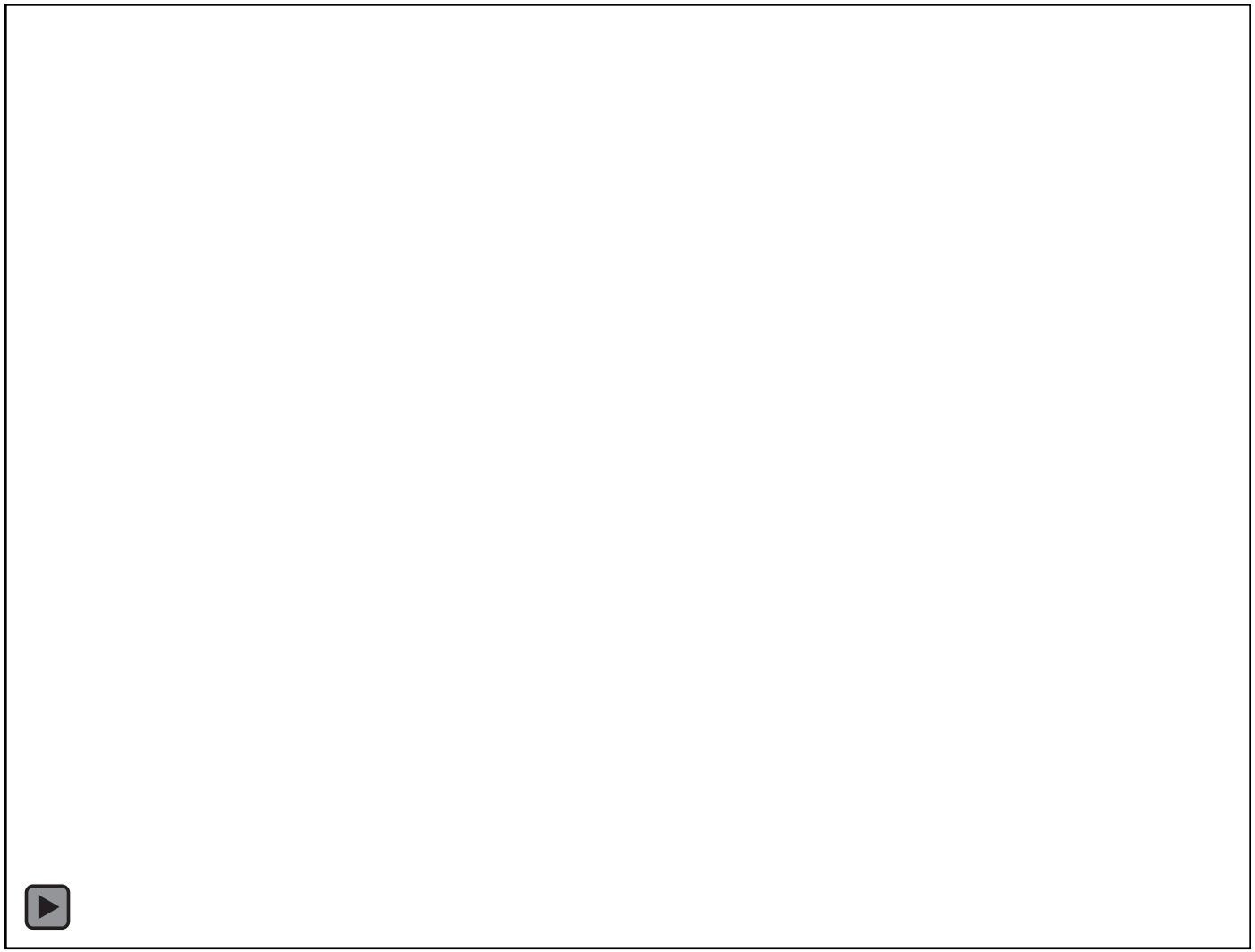

Simulate Instrumentation

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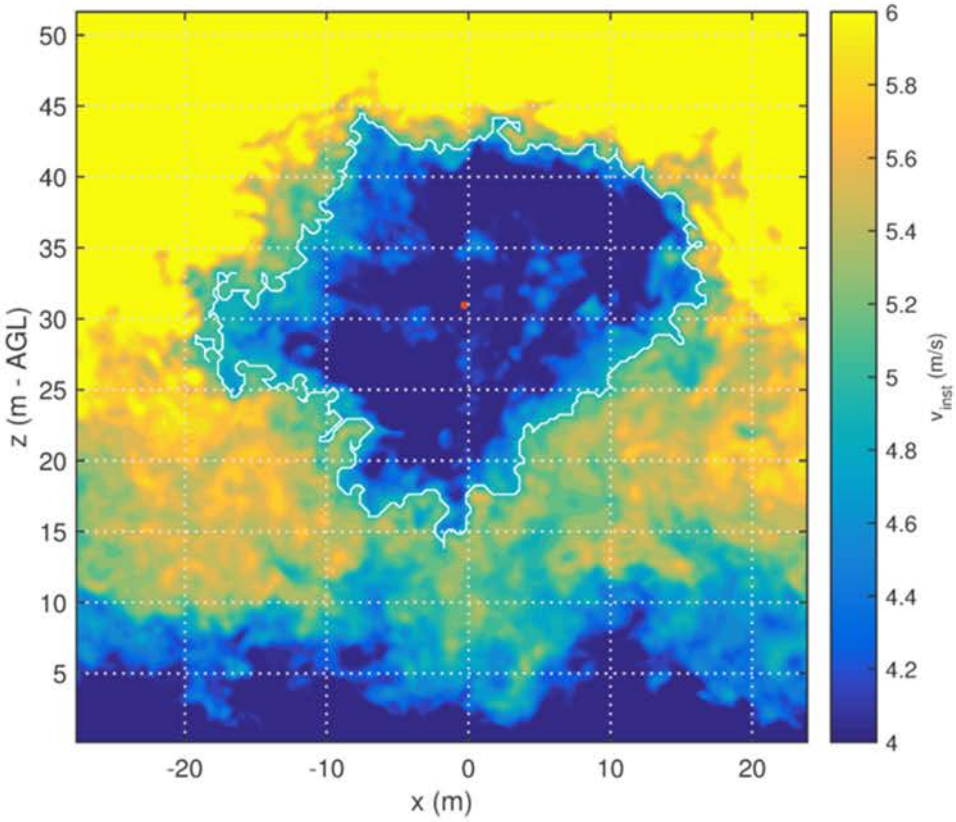
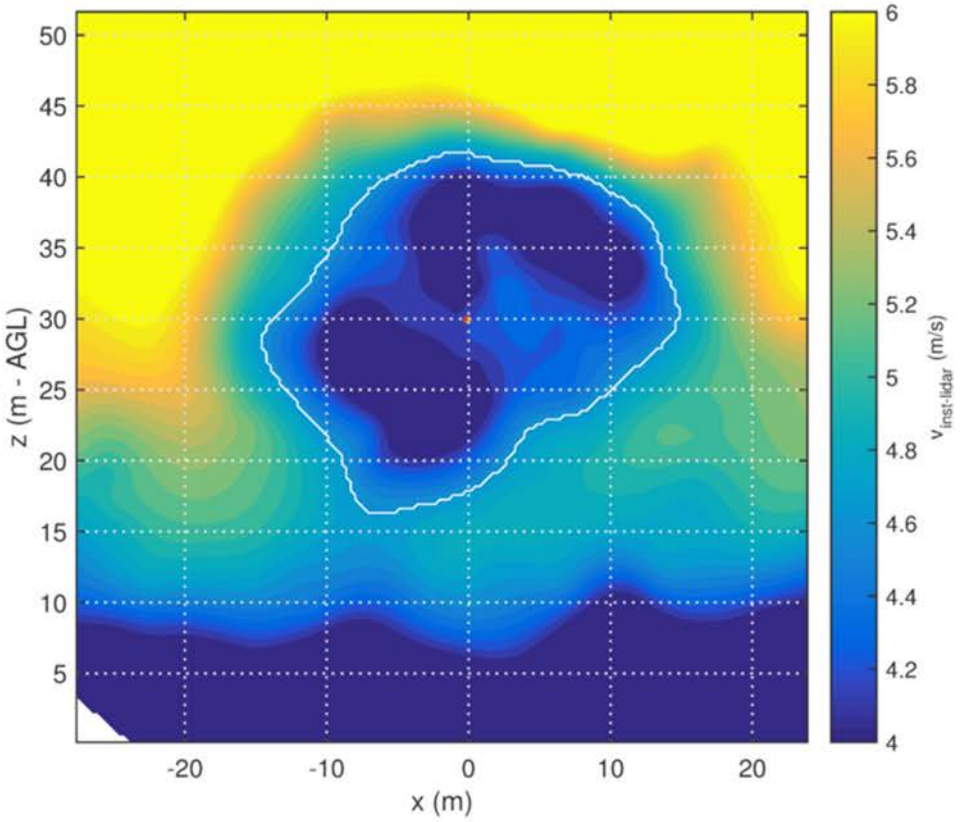
SOWFA Simulated Velocity



Simulated Lidar Measurements



- Comparison of identical time steps in order to show effect of Spinner Lidar on measurements and how that impacts wake position determination
- Measurements at 3D downstream of turbine

Measuring Impact of Inflow

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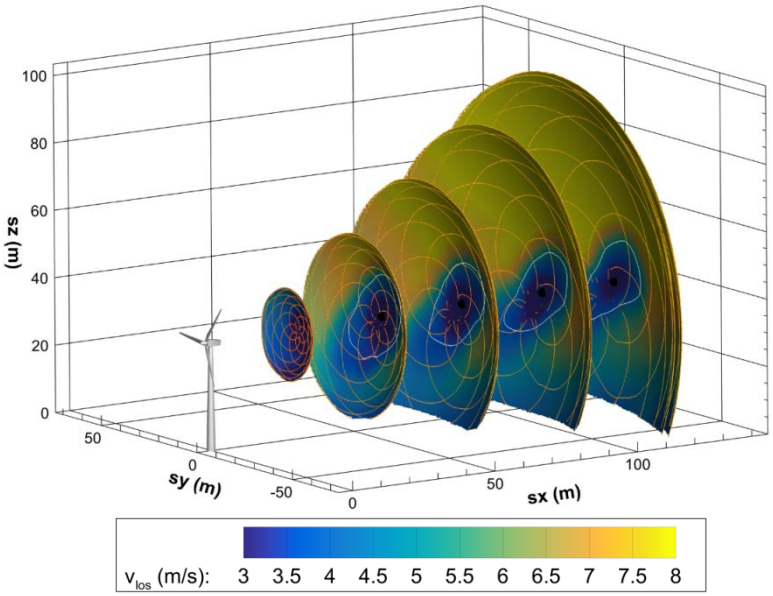
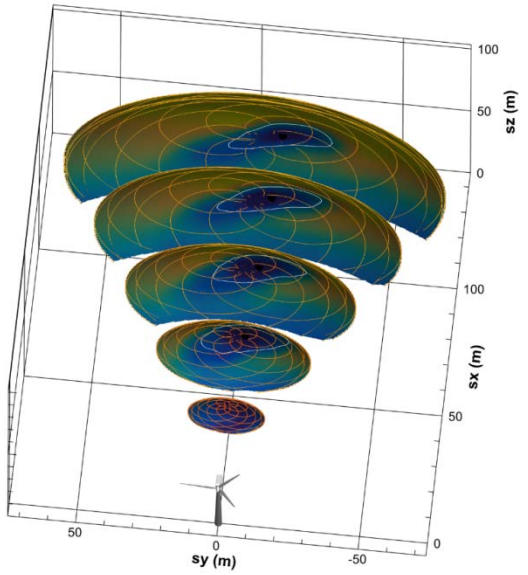
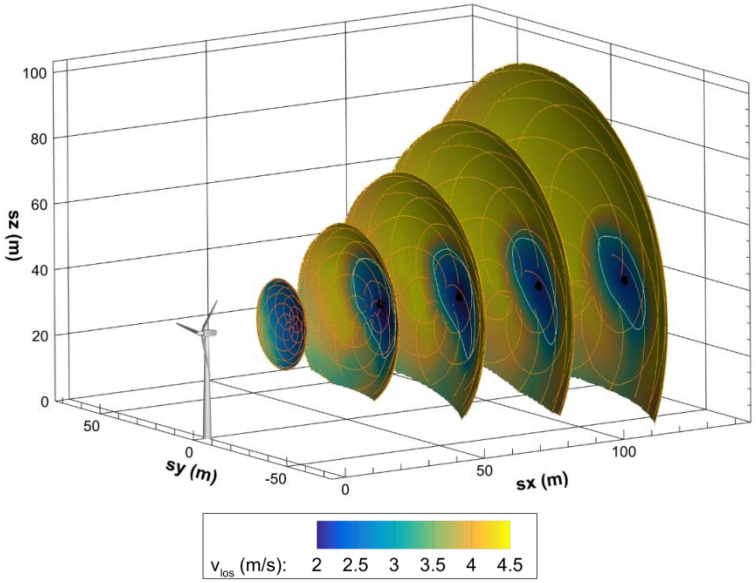
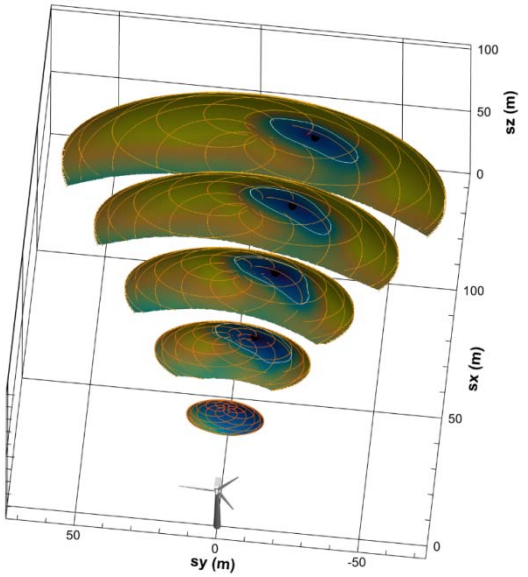
Stable ABL
Positive Veer





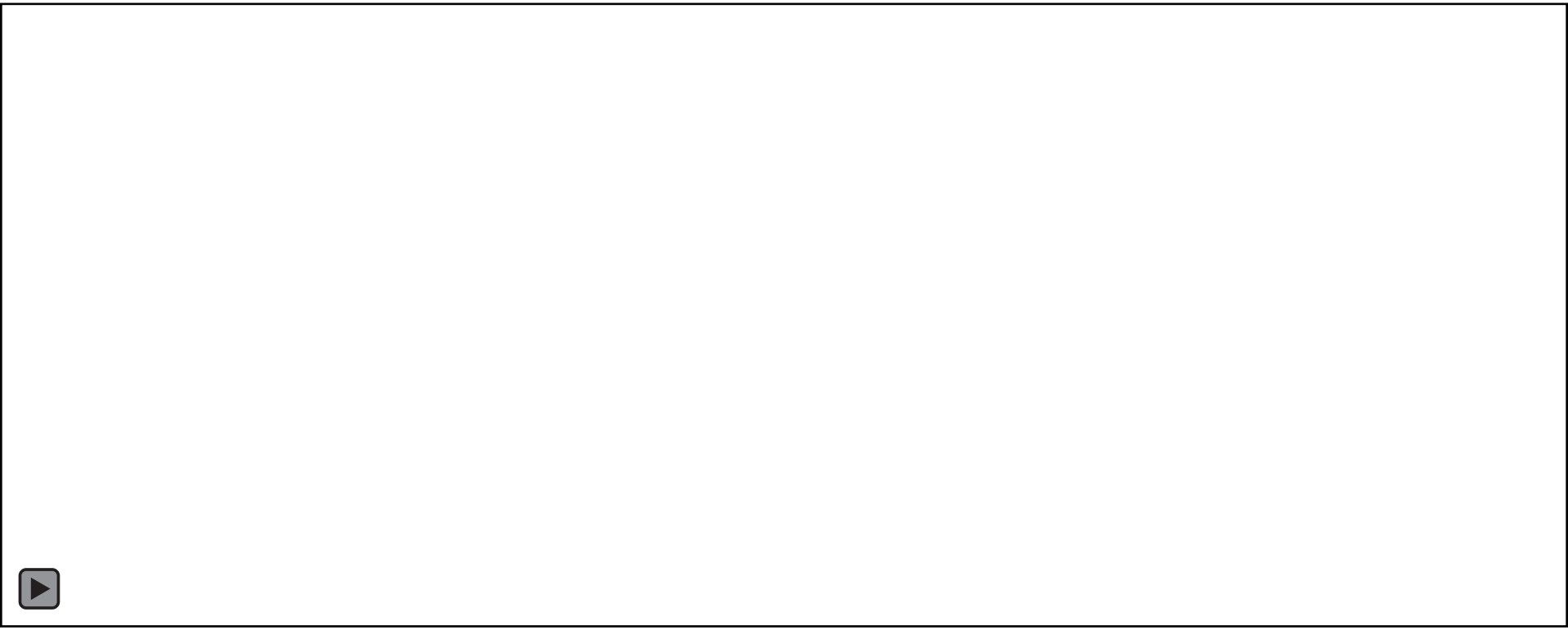
Stable ABL
Negative Veer





Wake Tracking

Lidar data viewed 3D (81m) downstream looking downwind



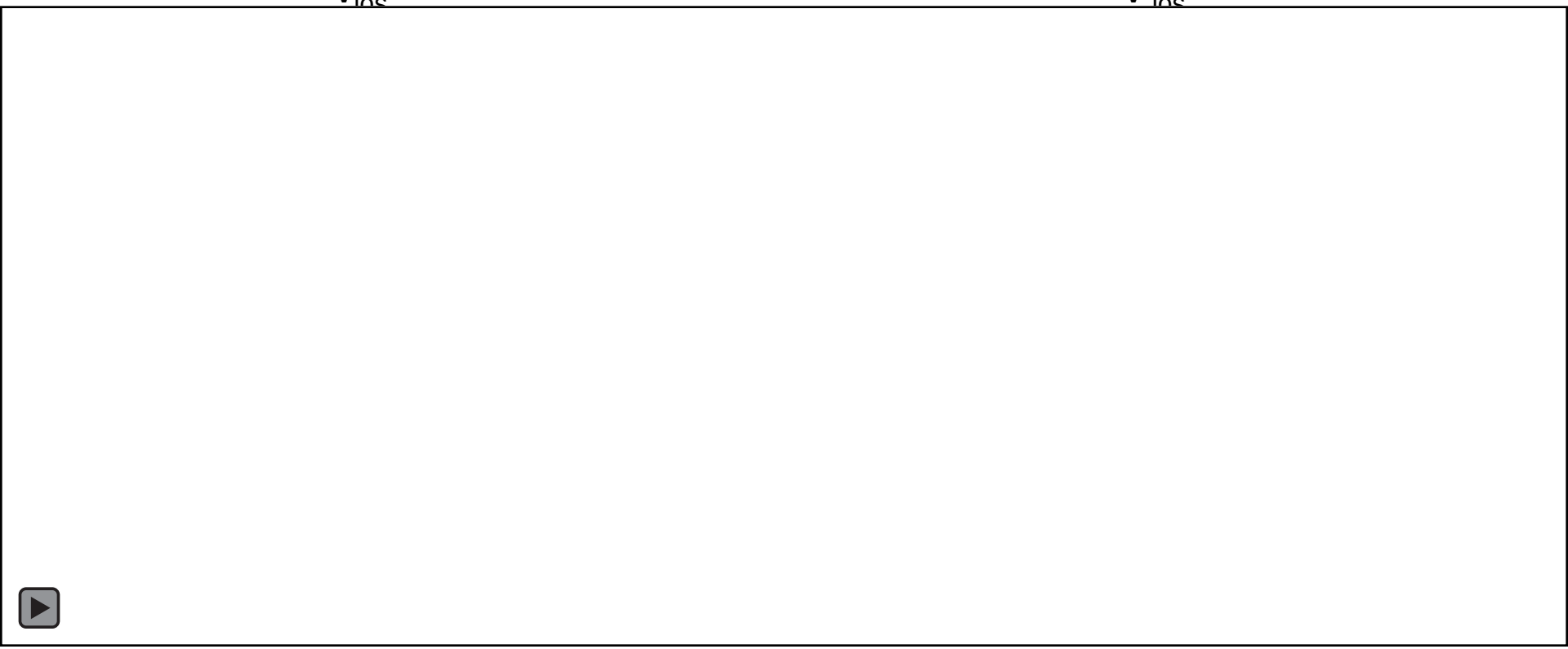
Wake Tracking with Higher Order QoIs

Lidar data viewed 2.5D (67.5m)

- Bulk Richardson = 0.78
- α = 0.25
- wind speed = 5.7 m/s
- TI = 0.04
- veer = 5.7°
- yaw offset = 7.43°
- yaw heading = 145.6 degN

- Note that you can see turbulence coming off the nacelle and tower before the turbine turns on and the wake forms

V_{los} V'_{los}



Initial Model Assessment

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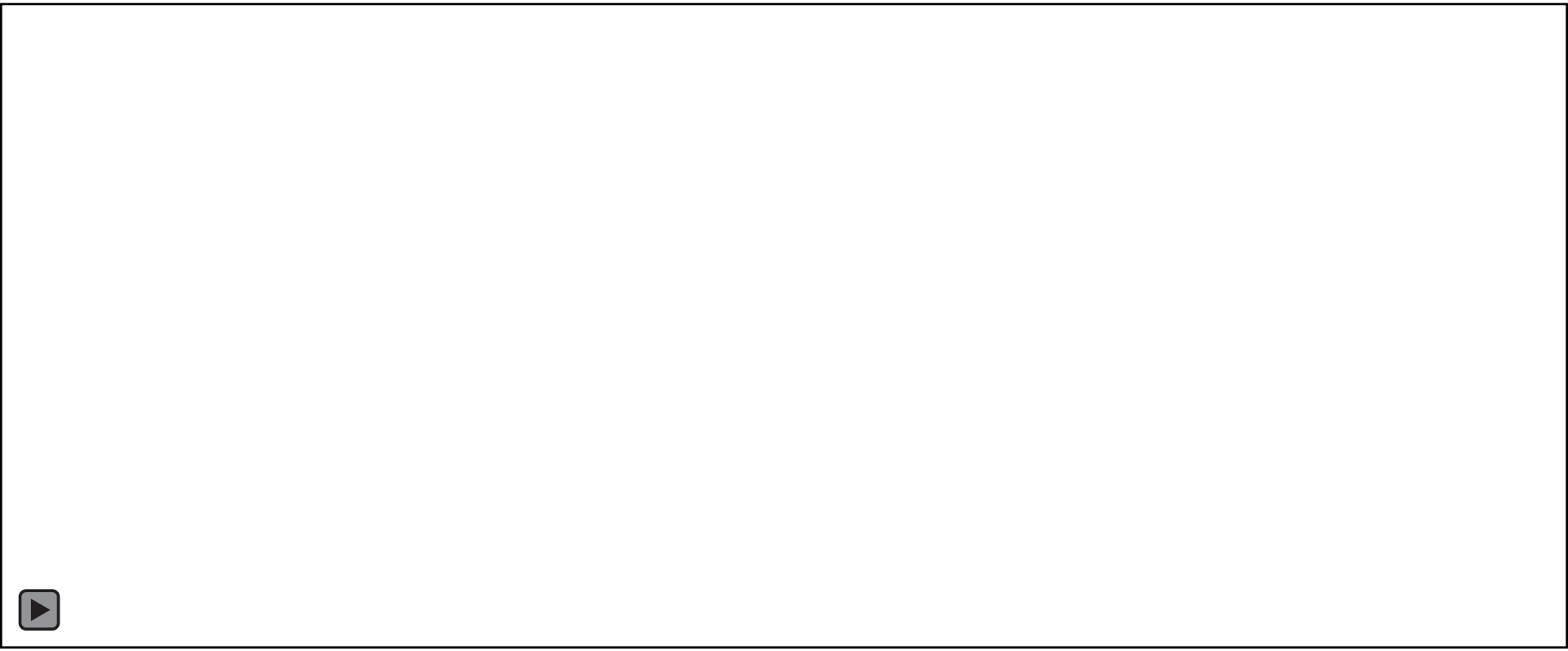
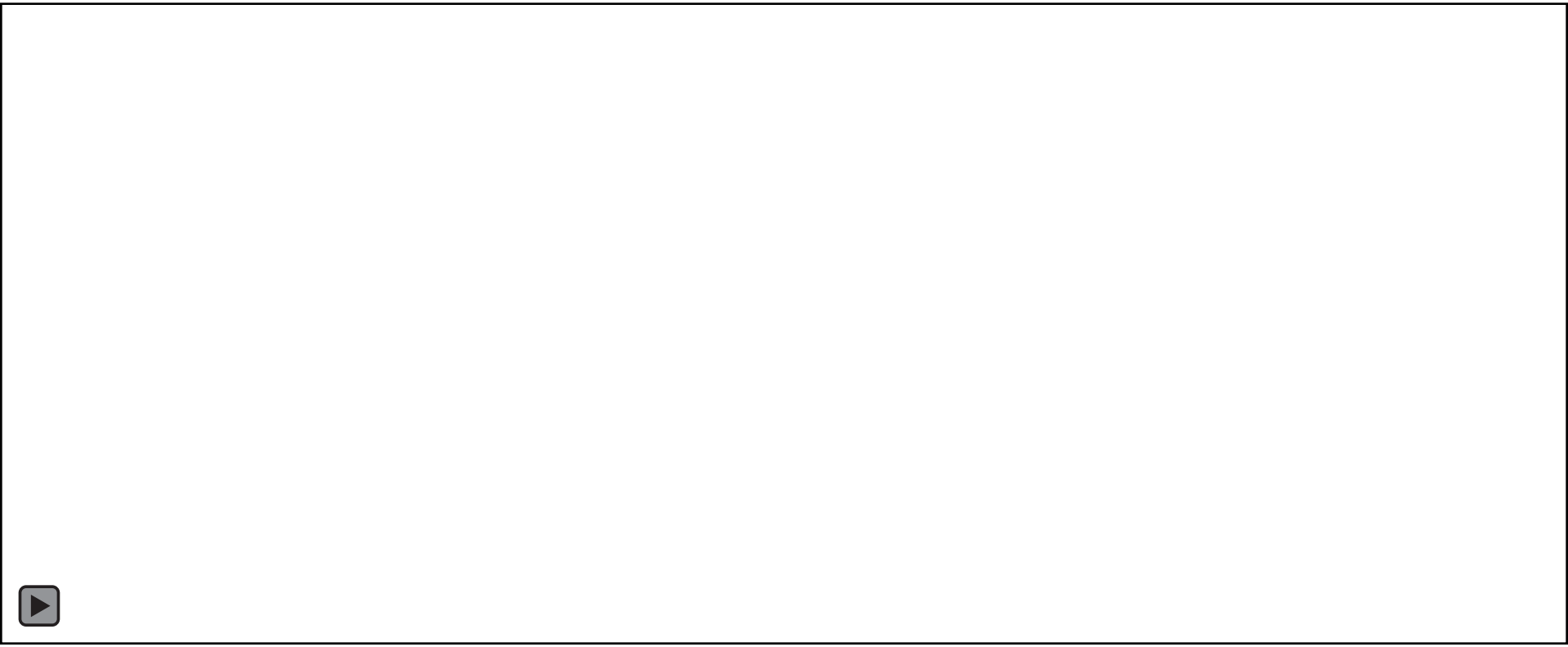
Measured and Simulated v_{los}



Initial Model Assessment

Sandia National Laboratories

Measured and Simulated v'_{los}



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PROPOSED SWIFT BENCHMARKS

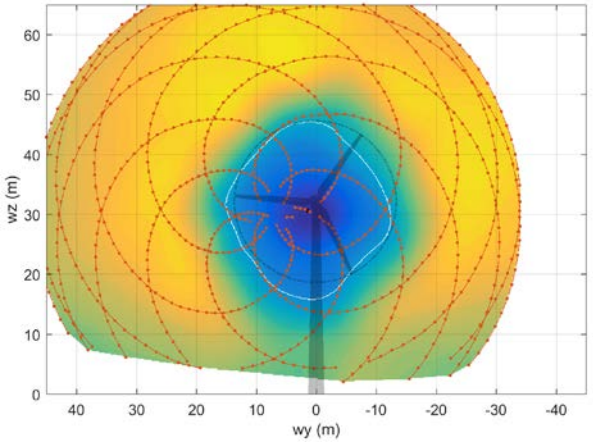
Case 1: SWiFT V27 Wake Deflection, Strength, and Shape

Objective: Develop and verify wake metrics and tracking algorithms. Utilize wake identification algorithms to assess the ability of models to predict ***wake shape, strength, and deflection***. Focus on a few datasets, looking at time histories.

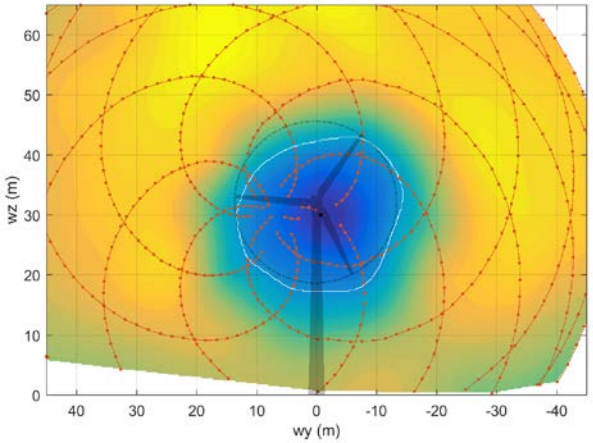
Inputs: Time history: wind speed, direction, turbulence intensity, shear, veer, temperature profile, and stability.

Metrics: Wake deflection, strength, and shape, 1-5D

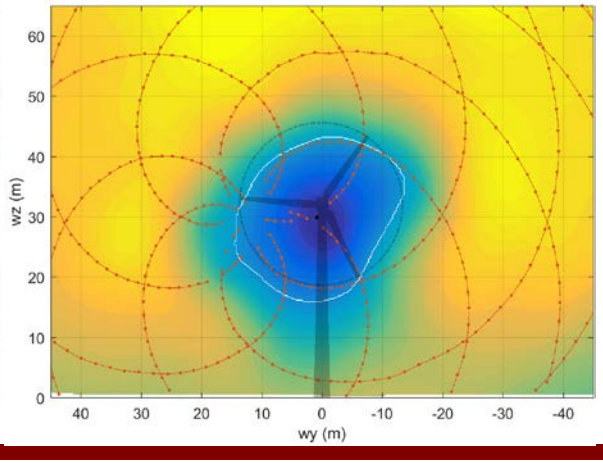
3D



4D



5D



Case 2: SWiFT V27 Wake Dynamics

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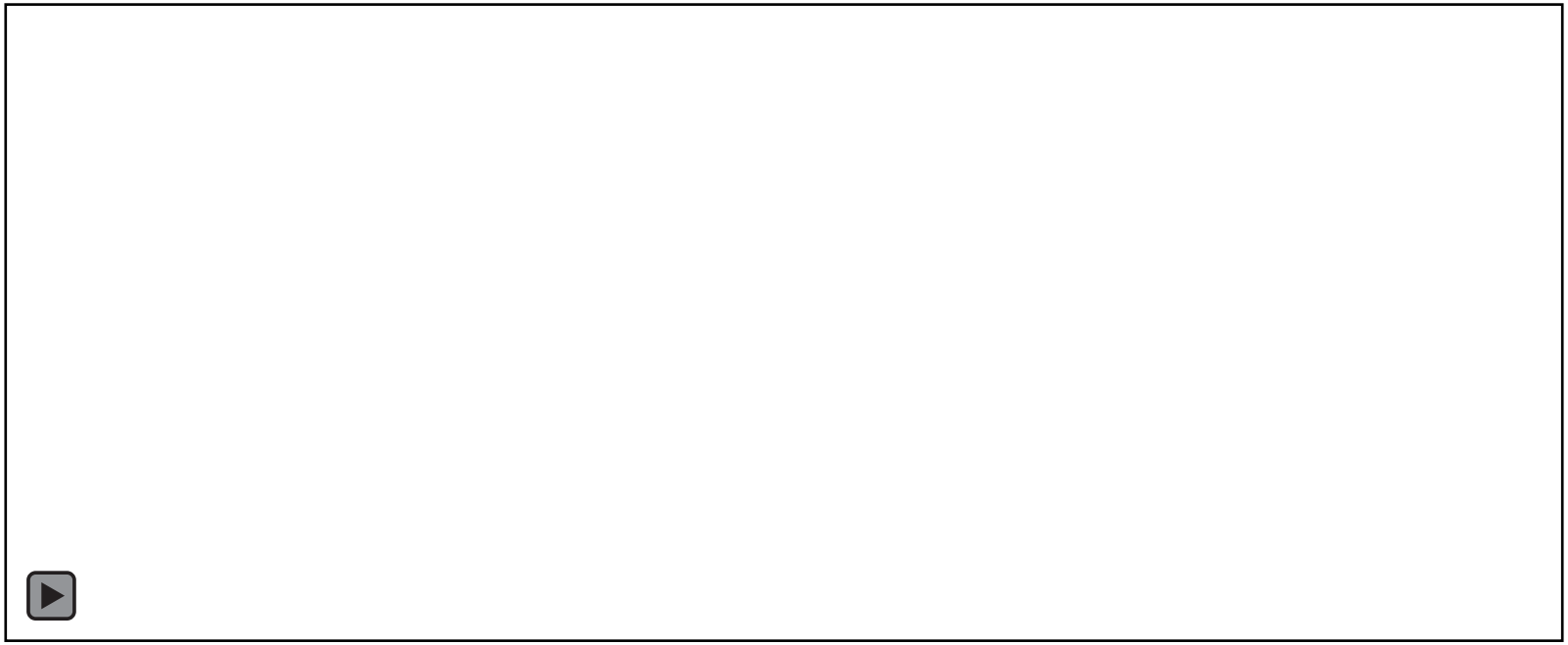
Objective: Assess the ability of models to predict the ***amplitude and frequency of wake deficit movement***. Focus on a few datasets, looking at time histories.

Inputs: Time history: wind speed, direction, turbulence intensity, shear, veer, temperature profile, and stability.

Metrics: Wake movement, amplitude and frequency, 3-5D



Case 3: SWiFT Ensembles of Wake Metrics

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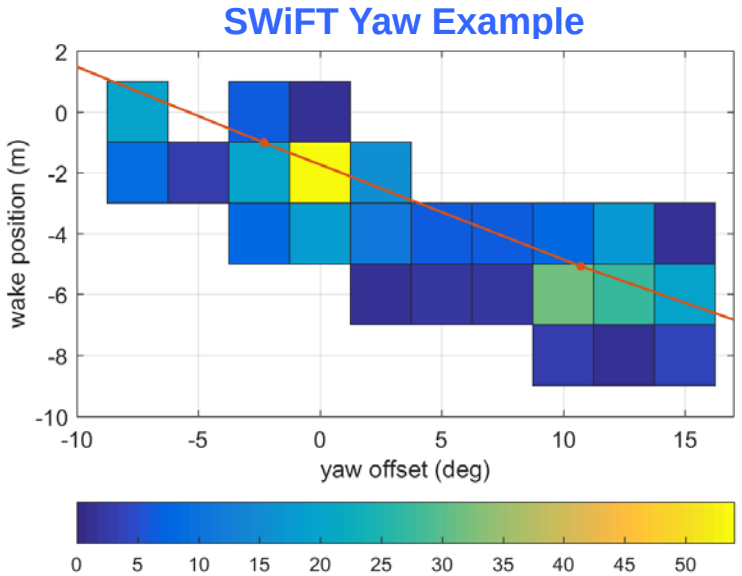
Objective: Develop and verify wake tracking algorithms. Utilize wake identification algorithms to assess the ability of models to predict wake shape, strength, and deflection. Focus on many datasets for a ***variety of inflow cases***.

Inputs: Hub height wind speed, direction, turbulence intensity, shear, veer, temperature profile, and stability statistics.

Metrics: Wake deflection, strength, and shape, 1-5D



Case 3: SWiFT Ensembles of Wake Metrics

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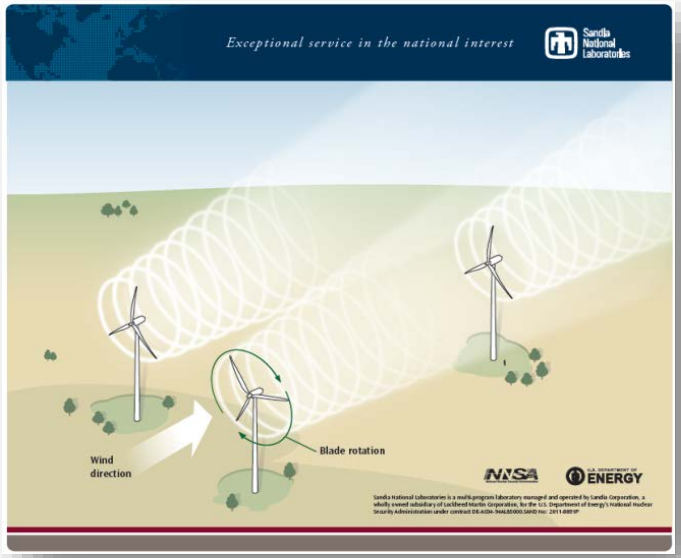
SWiFT Yaw Example

Case 4: SWiFT Downstream Turbine Loads

Objective: Assess the ability of models to predict the impact of a range of wake conditions on downstream turbine loads. Focus on many datasets for a variety of inflow cases.

Inputs: Hub height wind speed, direction, turbulence intensity, shear, veer, temperature profile, and stability statistics.

Metrics: Downstream turbine loads.



Conclusions

- The DTU Spinner Lidar is measuring the wakes from 1-5D behind a V27 turbine at the SWiFT, with changing yaw control input angles over a range of inflow conditions.
- Currently applying an experimental uncertainty quantification process for the inflow, wind turbines, and lidar measurements.
- Initial data campaign results anticipated for public release.
  - Some datasets will be held back for blind validation cases
- First benchmark proposed to look at several wake time histories.
- Future benchmarks will investigate model performance over many datasets of wake data and downstream turbine loads.

Thank You

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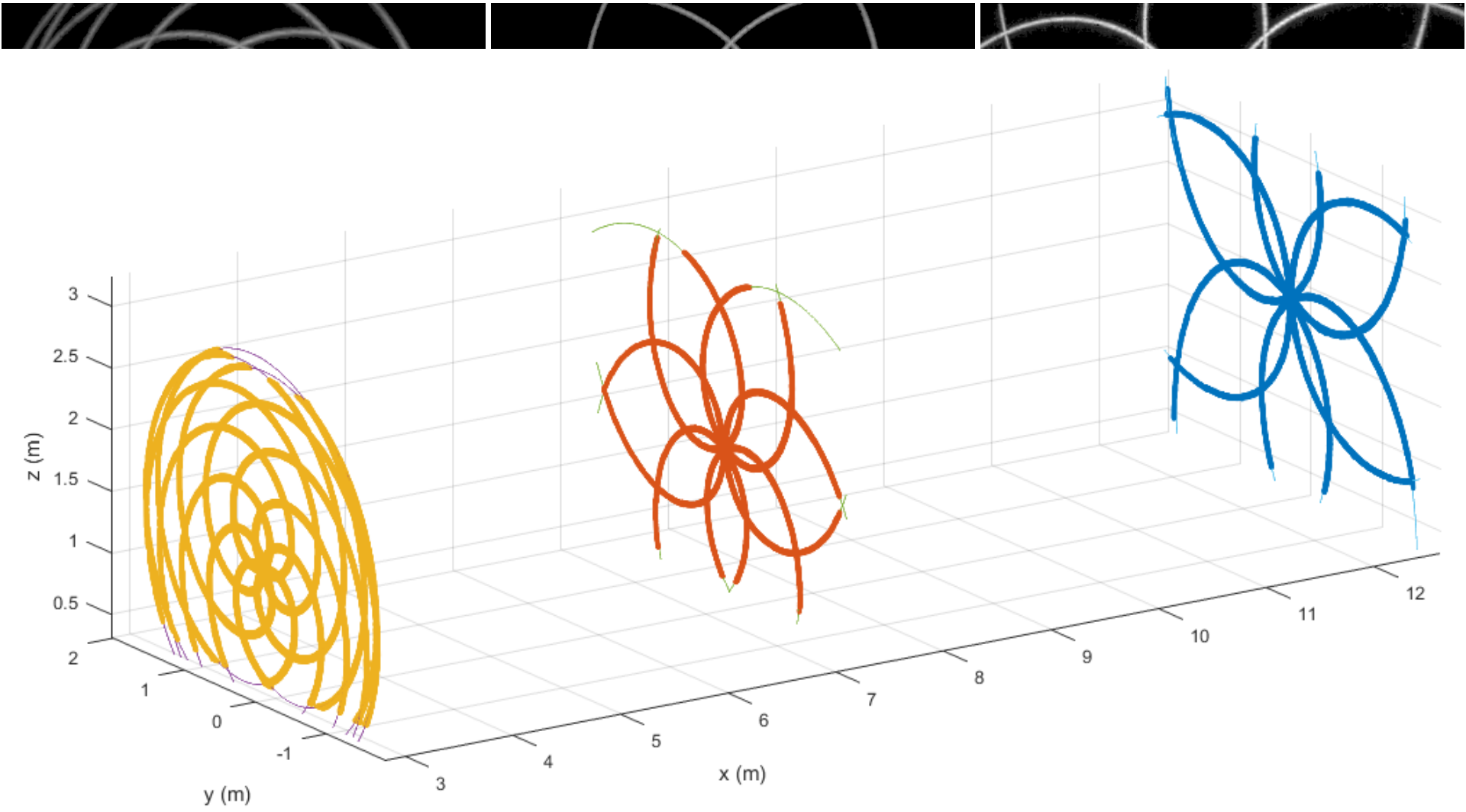
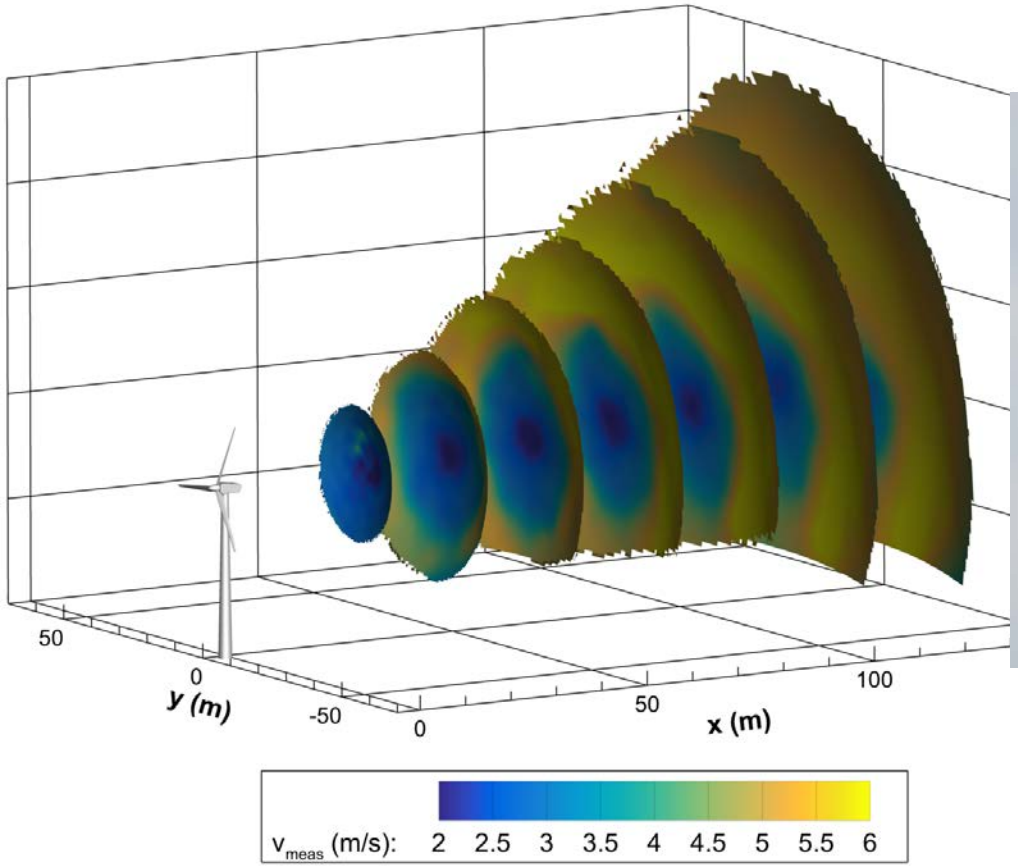
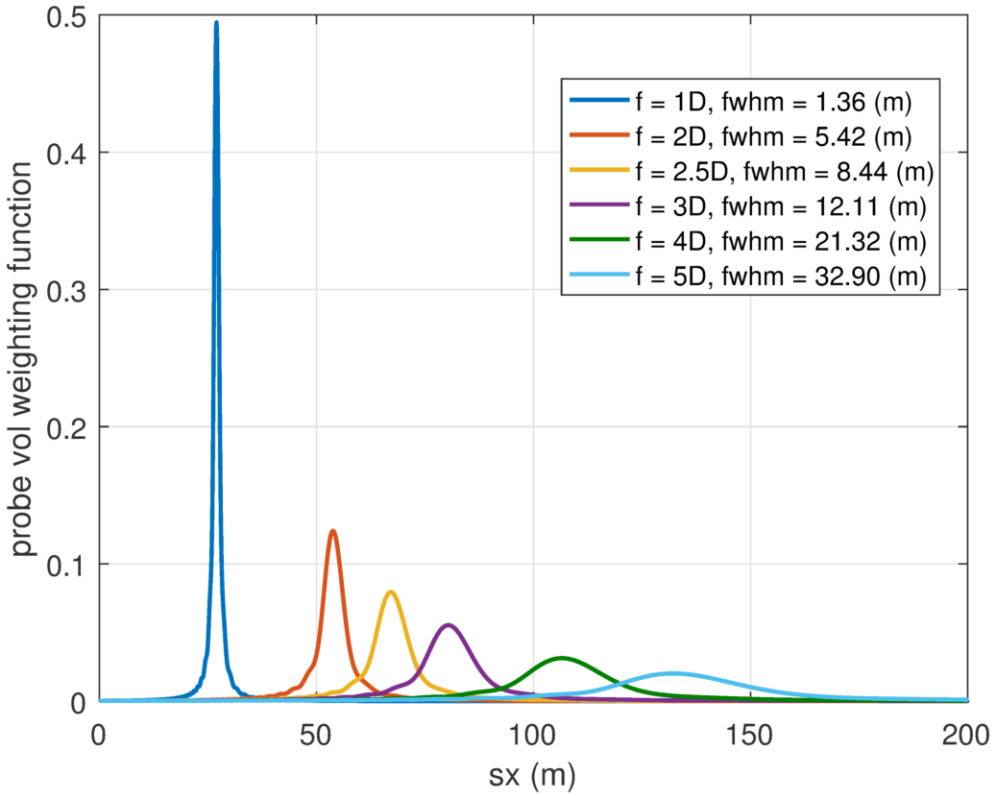
Spatial Measurement Uncertainty



Initial Wake Measurements



Focus Distance Probe Length



Case 3: SWiFT Ensembles of Wake Metrics

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SWiFT Yaw Example