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Sandia National Laboratories

DOE/SNL SWiFT Facility; Future Data Case

Brandon Ennis

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SWiFT Facility Overview

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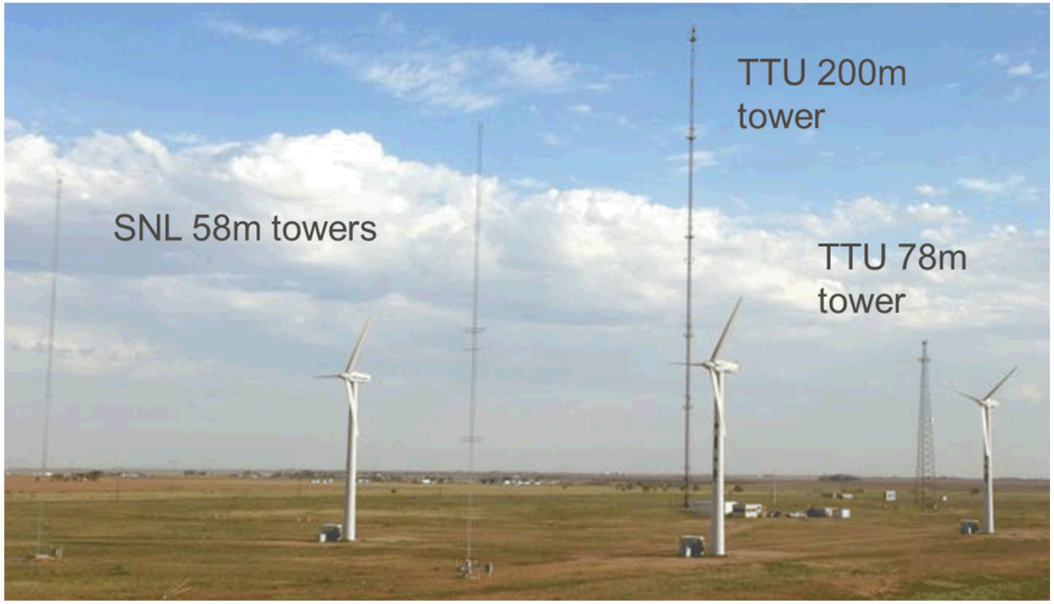


SWiFT Exists to:

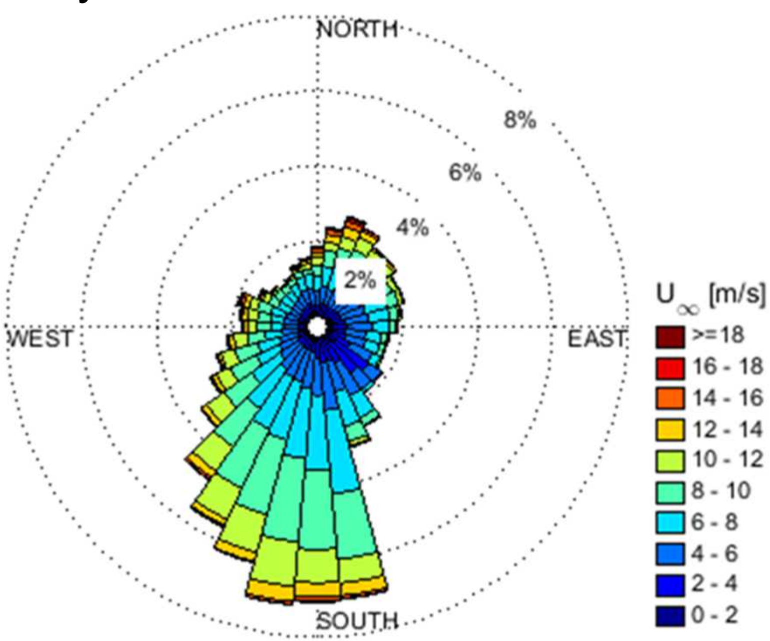
- Produce public, open-source validation quality data to advance simulation capabilities
- Reduce or more accurately predict turbine-turbine interaction and wind plant underperformance
- Develop and test advanced wind turbine rotors

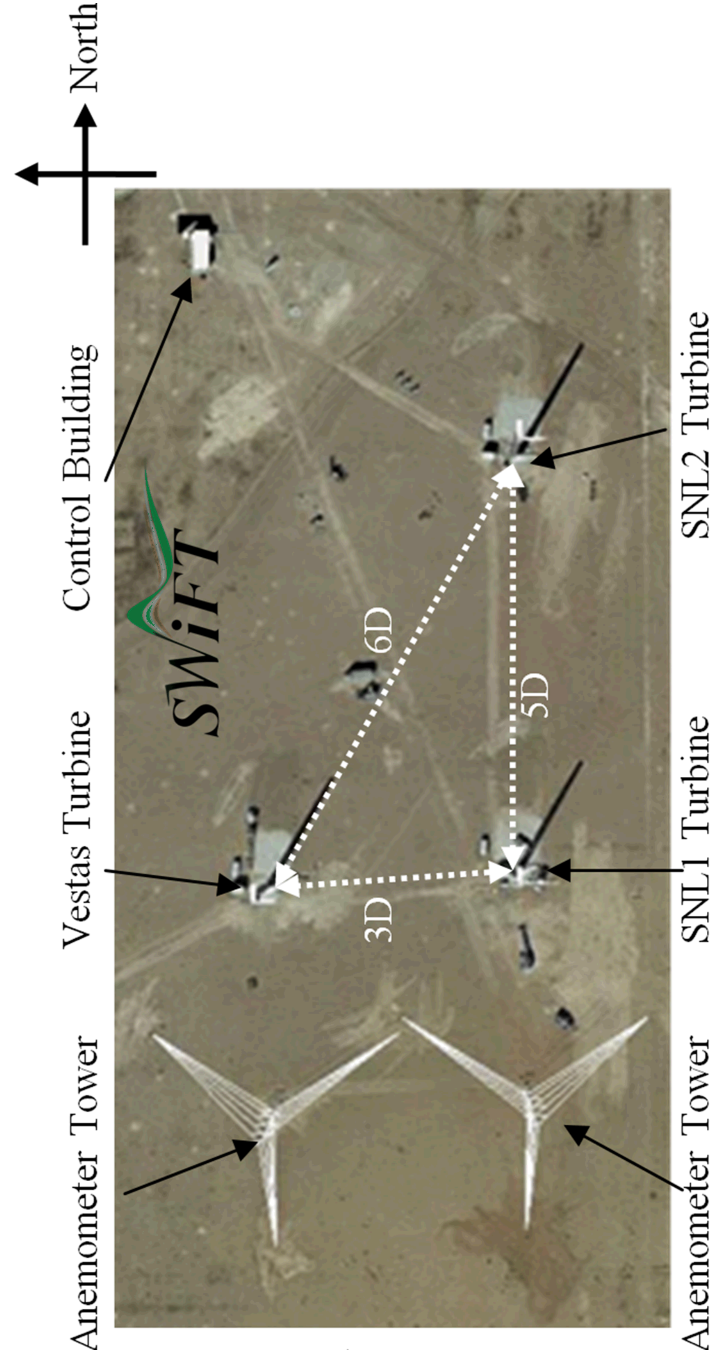
Facilities:

- Three variable-speed variable-pitch modified wind turbines with well characterized performance
- Two heavily instrumented inflow meteorological towers
- Extensive, high resolution sensor suite
- Site-wide time-synchronized data collection
- Partnership with Texas Tech University's National Wind Institute; site atmospheric measurements

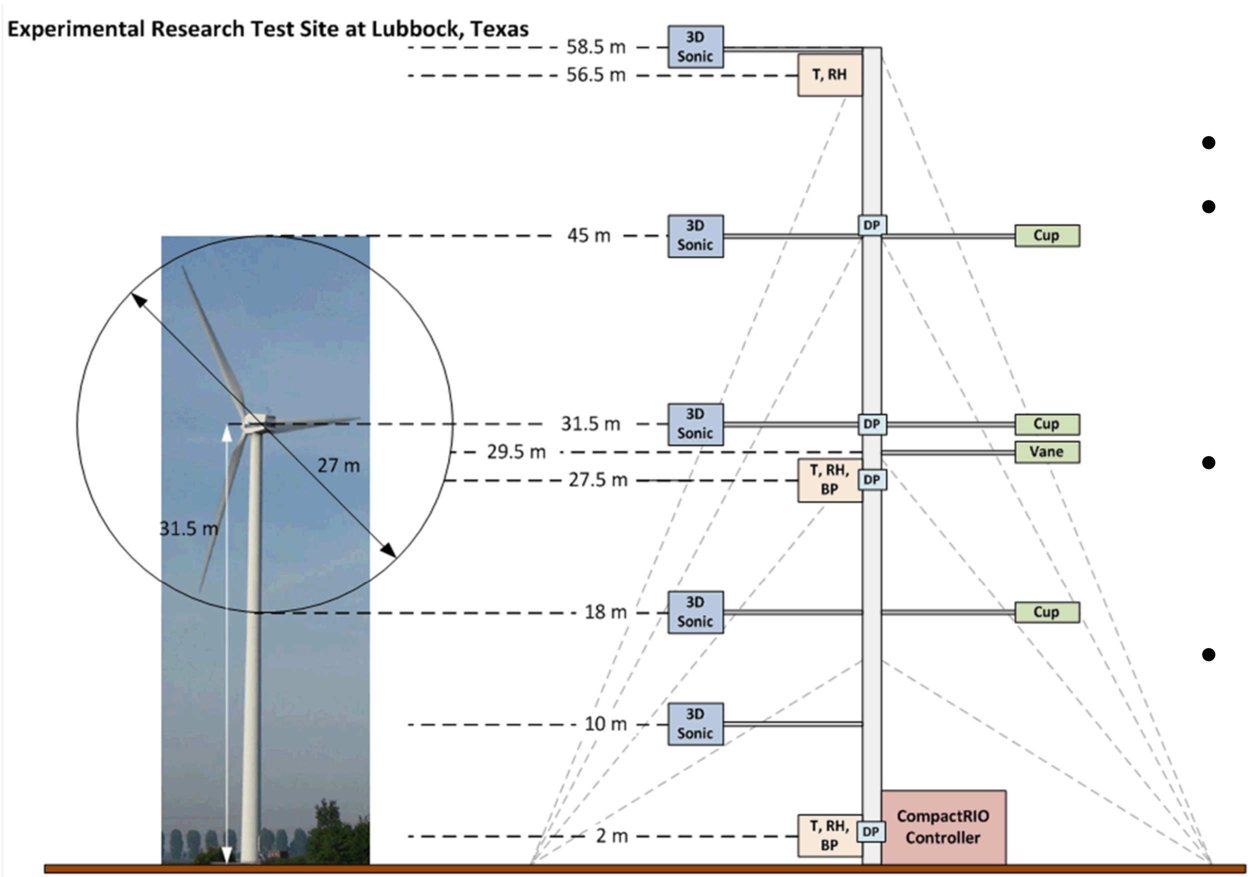
SWiFT Facility Overview

- Three turbines with a triangular 3-5-6 rotor diameter spacing layout
- Wind is consistently and dominantly from the south, producing a 5 rotor diameter spacing turbine-turbine interaction
- For the SWiFT OEM rotor, wind averages are within the design Region II operation with a 60% frequency





SWiFT 58m Meteorological Towers



- Data are logged at 50-hz
- 5 stations with 3-d sonic anemometer measurements; 3 across the rotor disk
- Atmospheric Stability measurement capability being added
- Spatial coherence calculations (towers spaced 80 m)

Met mast sensors

3D Sonic: ATI SATI/3A Sonic Anemometer
Cup: Thies Wind Sensor First Class Advanced (IEC accred)
Vane: Thies Wind Direction Sensor First Class
T: 592 Met One Temperature sensor
BP: 092 Met One Barometric Pressure sensor
RH: 593 Met One Relative Humidity sensor
DP: ATI PAD-401 DataPacker

Met mast heights*

58.5 m: 3D Sonic
56.5 m: T, RH
45 m: 3D Sonic, Cup
31.5 m: 3D Sonic, Cup
29.5 m: 3D Sonic, Vane
27.5 m: T, RH, BP
18 m: 3D Sonic, Cup
10 m: 3D Sonic
2 m: T, RH, BP

Guy wires
Radius 47.5m

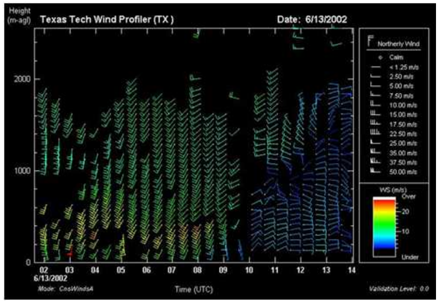
57.91 m
45.11 m
29.87 m
14.63 m

Texas Tech University Facilities

200m Met Tower;
50hz historical data

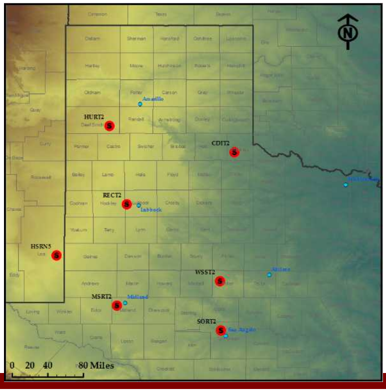
TTU 200m meteorological tower
- 10 measurement station heights
- 3-d Sonic anemometers and common atmospheric measurements
- Data are saved at 50-hz

Radar Profiler; 20 min data logs



Vaisala LAP-3000 radar profiler
- configured to log wind speed, direction, and temperature (RASS virtual temperature) profiles every 20-min.
- Resolution is 60m between 150-2000m AGL, 200m between 600-6000 m AGL

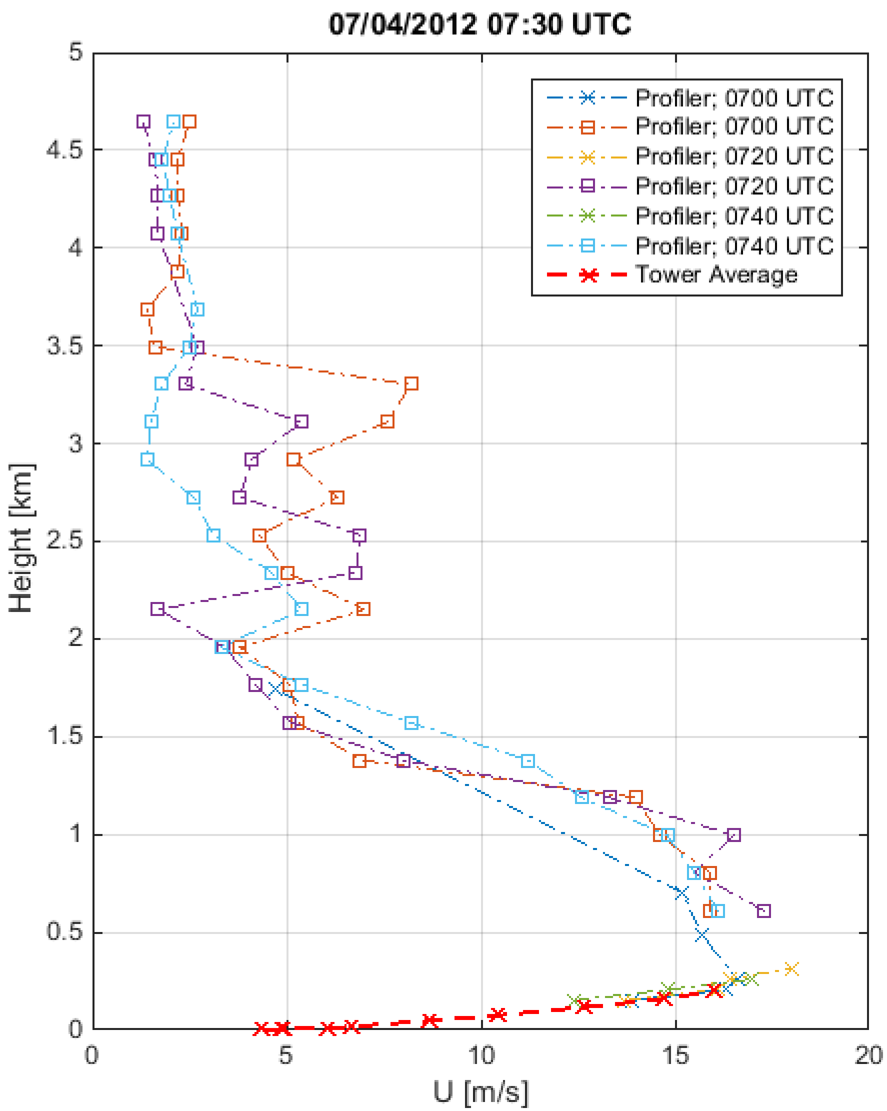
West Texas Mesonet and SODAR network



Mesonet and Sodar Networks

Historical data from weather stations in surrounding area
- West Texas Mesonet
- SODAR network

Texas Tech University Facilities



Example dataset from the TTU National Wind Institute Facilities for a stable overnight condition.

- 200m meteorological tower and radar profiler data
- Low Level Jet development typical of SWiFT site

Box markers are high-power signal

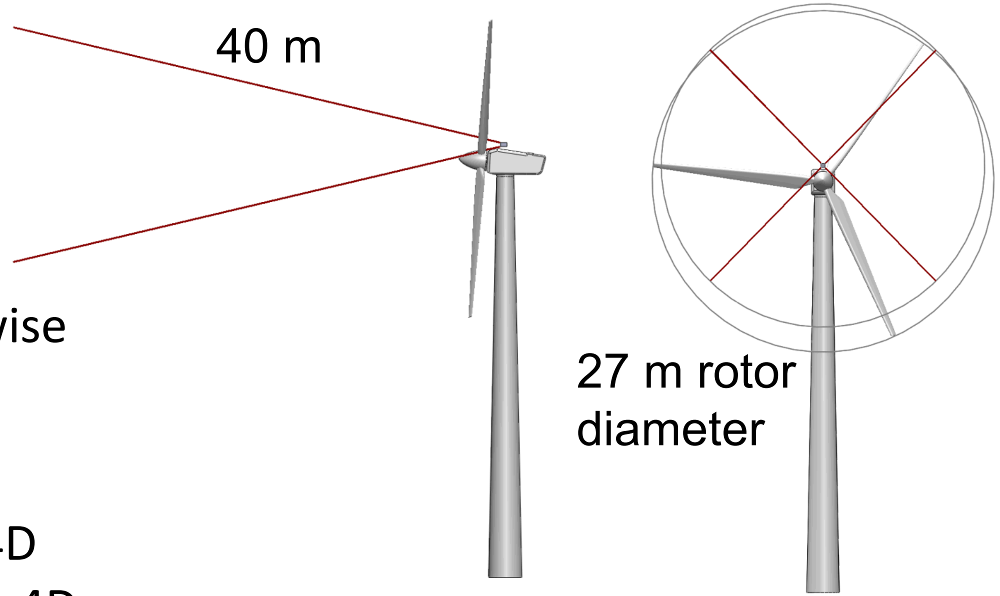
X markers are low-power signal

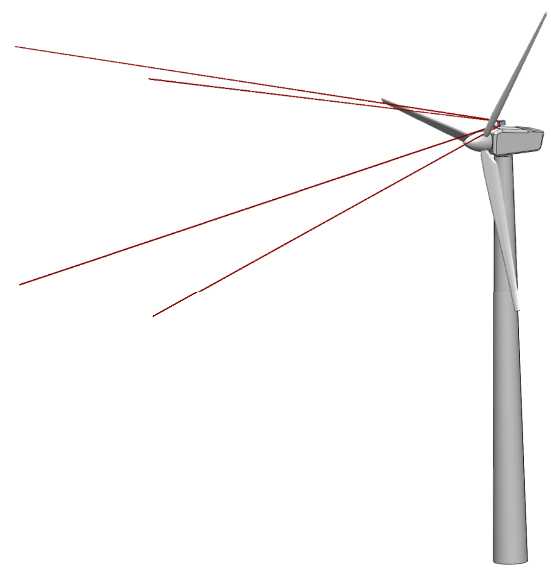
SWiFT Turbine Hardware

- Collective Pitch System
- Synchronous turbine controller and data acquisition
- Complete turbine / rotor state instrumentation
  - Fiber Optic blade strain
  - Generator torque/power
  - Rotor speed, rotor azimuth
  - Tower strain
  - Tower top inertial measurement unit
  - Nacelle yaw heading

SWiFT Nacelle Mounted Lidars

- 6 Windar Lidars; forward and rearward facing
- 4-beam, +/- 13° half angle
- 40 m focal length (38 m streamwise distance)
- 1 - 4 Hz sample rate
- (5-D spacing) 1.4D upstream; 1.4D and 3.6D downstream of SNL1; 1.4D downstream of SNL2





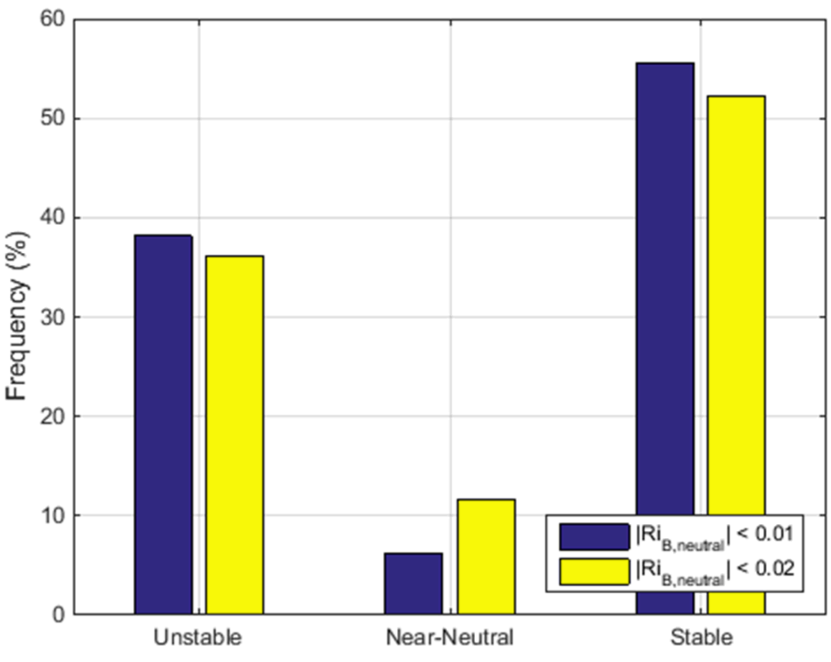
SWiFT Facility Data Campaigns

Summary:

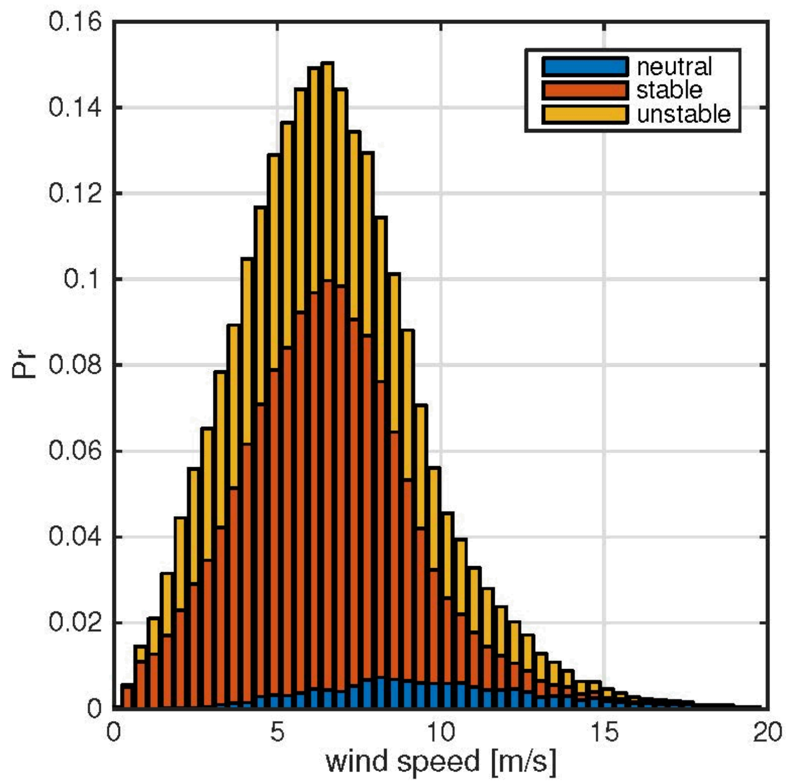
- Subscale (27m diameter) turbines operating in a wind farm with multiple single turbine spacing's present
- High resolution data acquisition of turbine operation and flow characterization
- Operation in highly characterized atmospheric conditions; including atmospheric boundary layer and mesoscale data
- Data will be collected in the various atmospheric conditions common to the site
  - Idealized neutral cases which reduce the model complexity
  - Complex stratified cases; such as overnight stable atmospheric boundary layer with veer

SWiFT Site Atmospheric Conditions

- **At the SWiFT site, neutral conditions occur 5-10% of the time**
- Near-neutral cases allow for more of a "component test" of the wake code

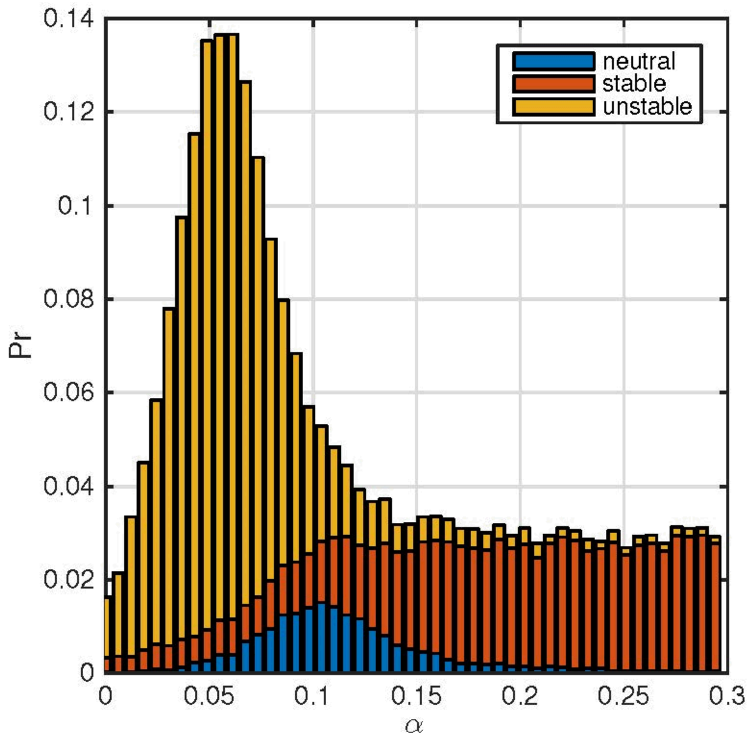


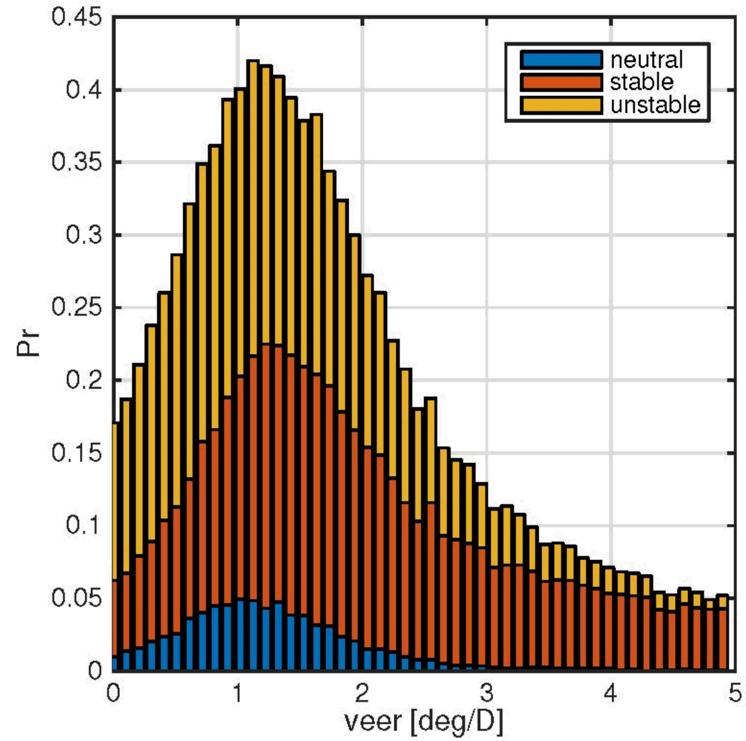
- Atmospheric stability trends shown with the wind speed distribution



SWiFT Site Atmospheric Conditions

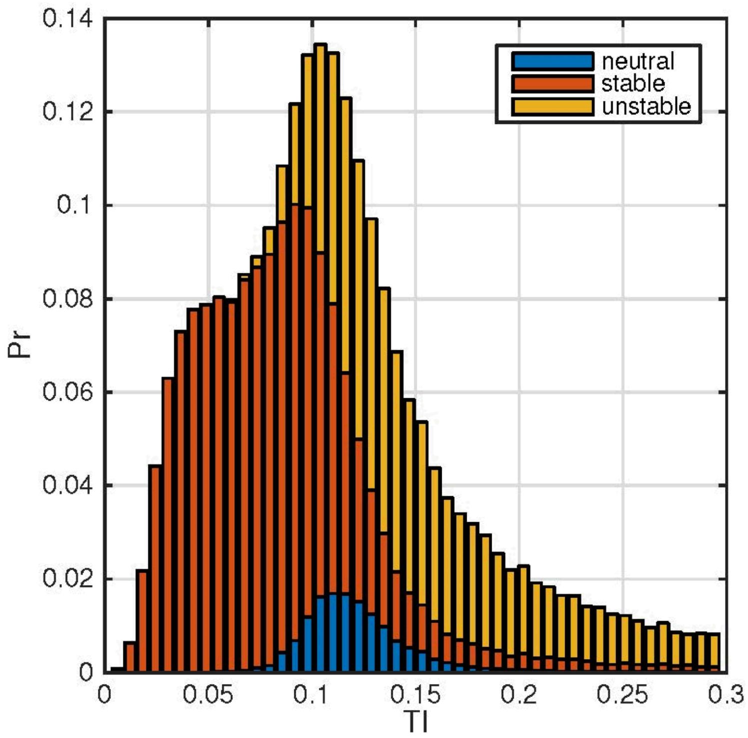
- Due to turbulent mixing, unstable ABL's have the lowest shear
- Shear exponent peak = 0.05
- Highest veer conditions occur during the overnight stable boundary layer development

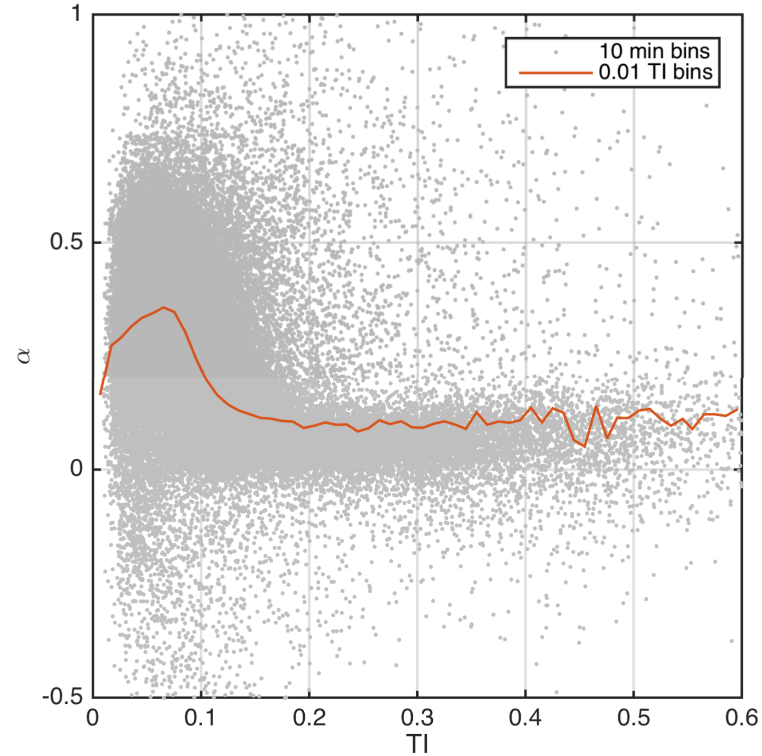




SWiFT Site Atmospheric Conditions

- TI is strongly dependent on atmospheric stability
- Finding very low TI unstable case would be challenging
- Correlation between turbulence intensity and the velocity profile is observed
- Low TI typically has high shear

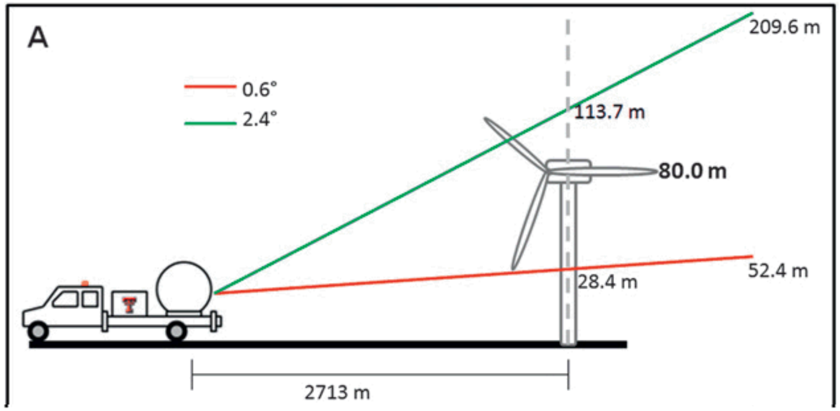




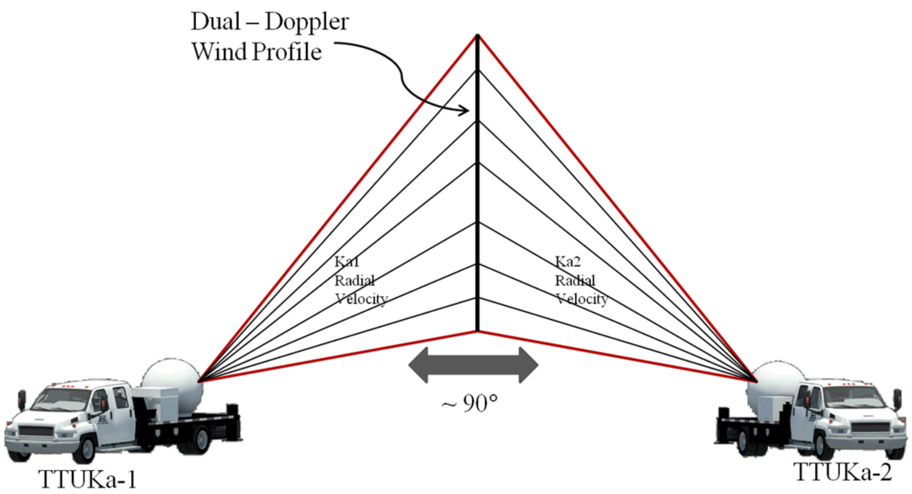
Experimental Campaigns

TTU Dual-Doppler Radar

- Scanning strategies:
  - PPI Sector Volumes
    - 20-30° sectors
    - 6 elevation angles
    - Revisit times less than 1 min.
  - Coordinated RHI Virtual Towers
    - 10-20° in elevation
    - Wind profiles up to 500 m
    - Revisit times between 3 and 16 s (depending on scan speed)
  - Dual-Doppler Stare
    - New radar technique developed for XPIA



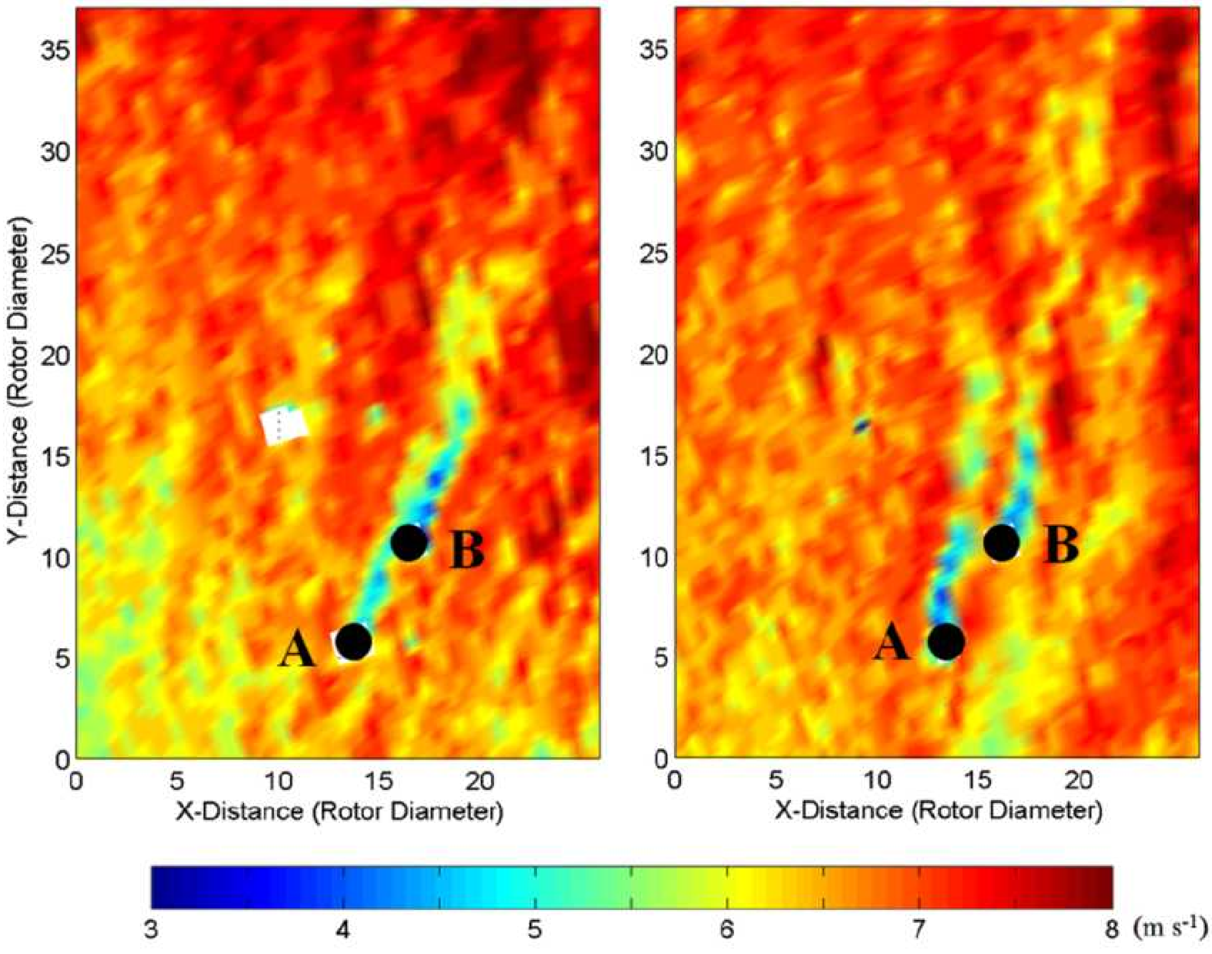
Wind Profiles from Coordinated RHIs



Experimental Campaigns

TTU Radar Measurements at the SWiFT Site

- No dual-Doppler data was collected, rather only single PPI sector scans
- Lightly precipitating environment
- Turbine yaw manually offset for brief period of time
- Turbine wake structure and evolution evident



SWiFT Integrated Experimental Planning

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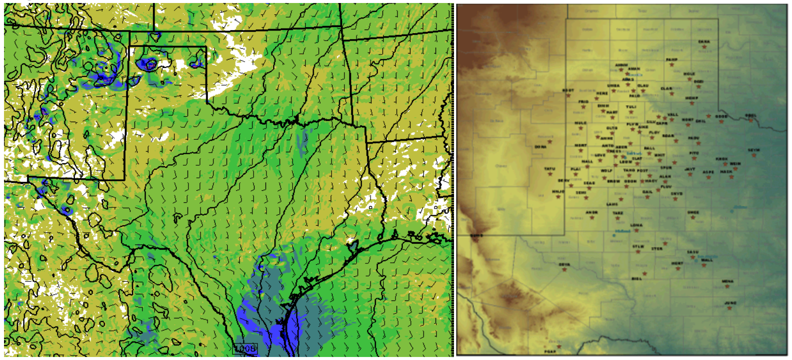
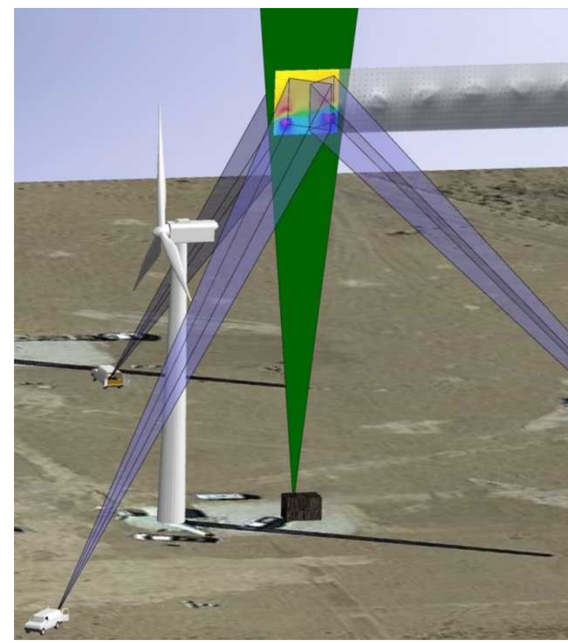
Regional Atmosphere, Mesoscale Forcing's

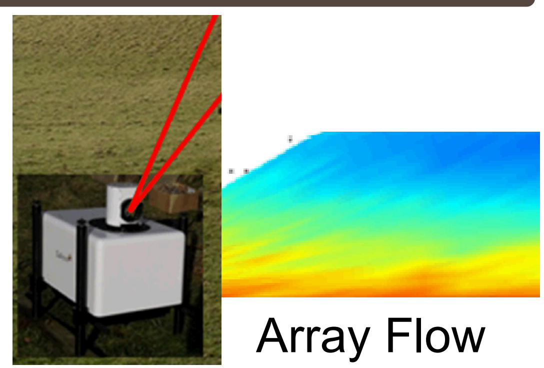


Atmospheric Boundary Layer



Wake Flow Structures

Wind Farm Flow



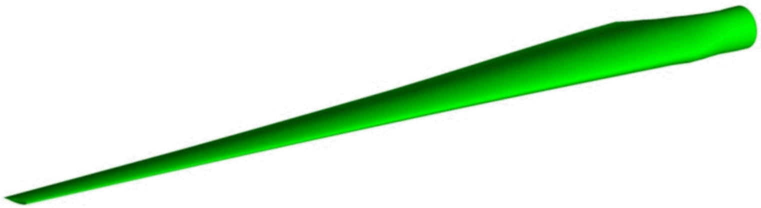
Array Flow

Thank you!

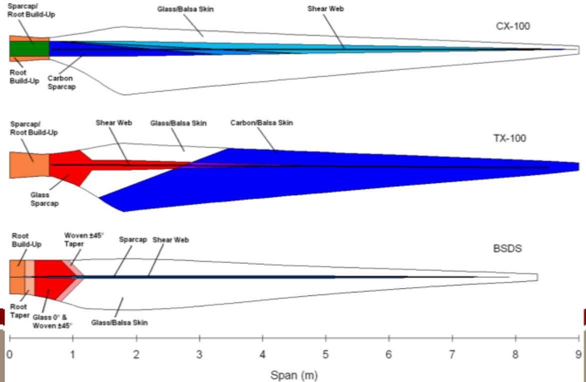
BACKUP SLIDES

National Rotor Testbed

- The National Rotor Testbed is a rotor innovation to enable technology acceleration

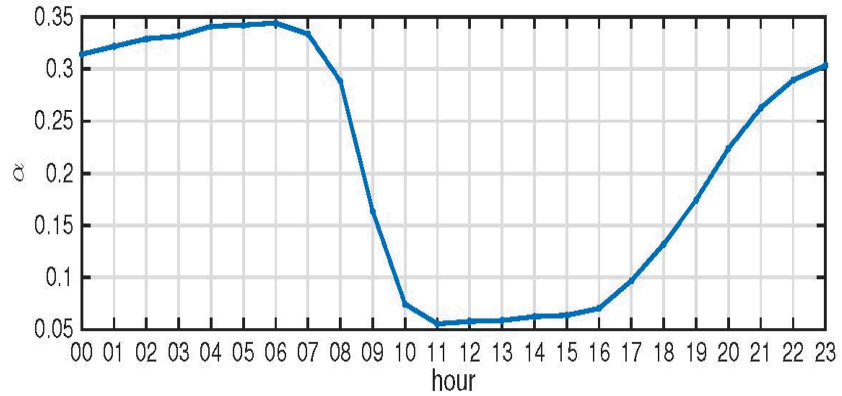


- Baseline blades represent functionally scaled-down aerodynamics and structural dynamics of a modern megawatt-scale rotor
- Baseline blade design is public and open
- Enables research in: wake interactions, aero-acoustics, inboard aerodynamics, controls, aeroelastic dynamics

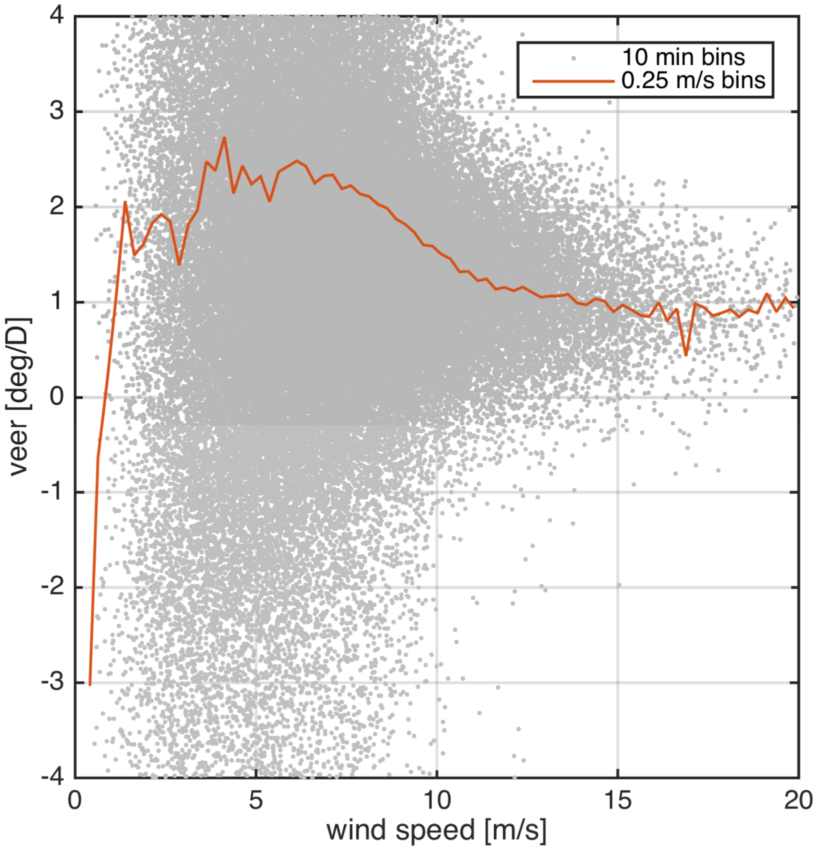


Velocity Profile Shear Trends

- In the average day, the shear exponent varies from about 0.35 to 0.05
- For a statistically significant amount of high shear cases testing should be performed at night or early morning
- The highest shear cases occur in late Fall where there is less turbulence



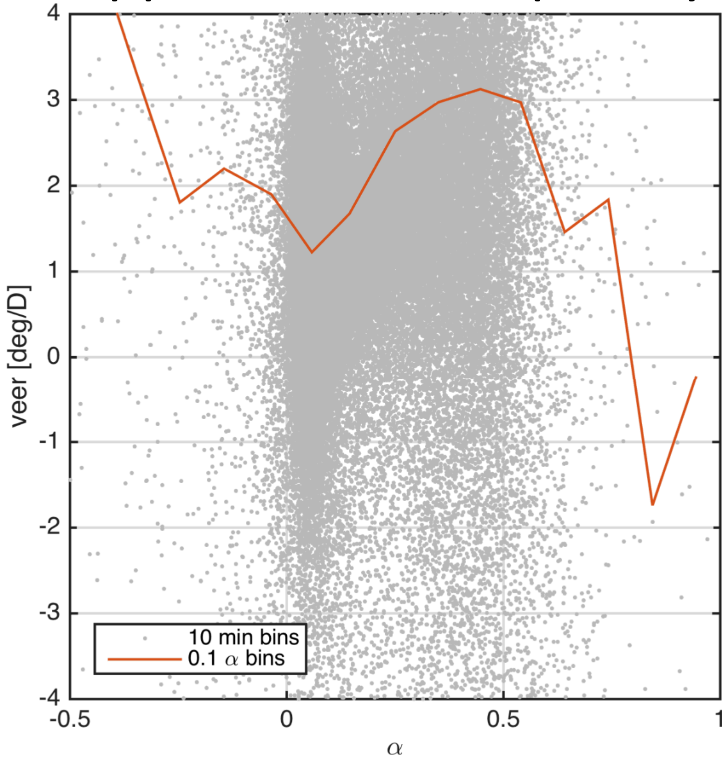
Velocity Profile Veer Trends



- Highest values of veer occur most commonly at lower wind speeds (up to about 10 m/s)
- Due to the correlation between stable cases and wind speed
- Veer averages of 2 degrees are seen, with 10 min average data points exceeding 4 deg of veer

Velocity Profile Veer Trends

- High values of veer are mostly seen with high values of shear
- But, veer with low shear happens – less frequently



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