

U.S. DEPARTMENT OF  
**ENERGY**

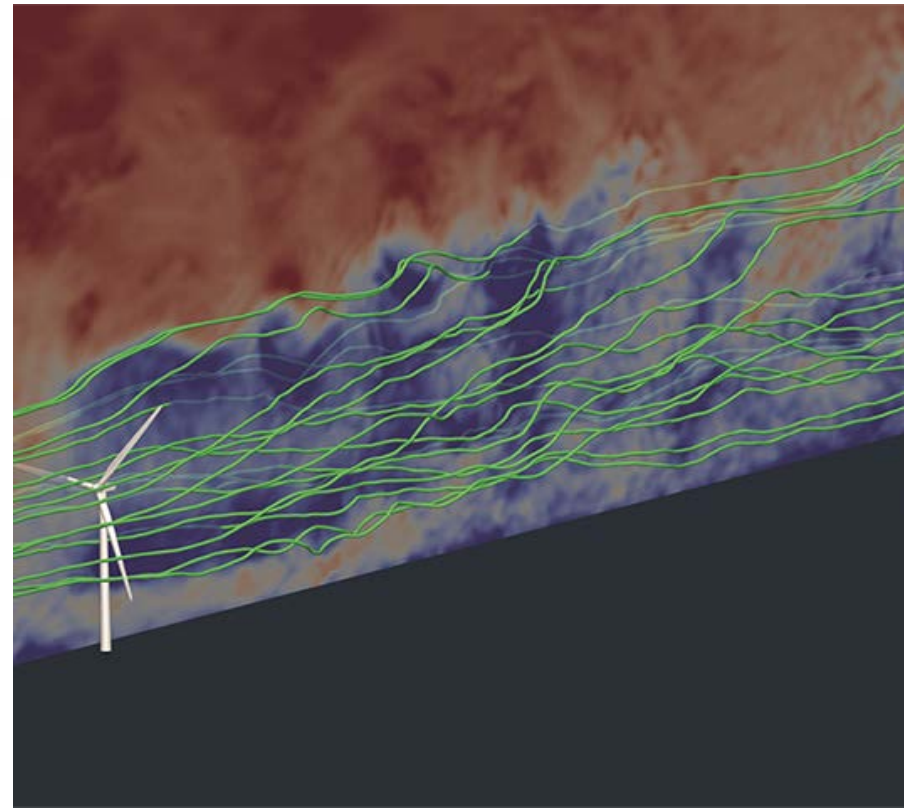
Office of  
**ENERGY EFFICIENCY &  
RENEWABLE ENERGY**

# Rotor Wake Measurements & Predictions for Validation

## Project ID # T7

Patrick Moriarty

National Renewable Energy Laboratory



# FY17-FY18 Wind Office Project Organization

“Enabling Wind Energy Options Nationwide”

Technology Development

Atmosphere to Electrons

Offshore Wind

Distributed Wind

Testing Infrastructure

Standards Support and International  
Engagement

Advanced Components, Reliability, and  
Manufacturing

Market Acceleration & Deployment

Stakeholder Engagement, Workforce  
Development, and Human Use Considerations

Environmental Research

Grid Integration

Regulatory and Siting

Analysis and Modeling (cross-cutting)

# Project Overview

## T7: Rotor Wake Measurements & Predictions for Validation

### Project Summary

- This project is the experimental validation hub of the DOE Atmosphere to Electrons (A2e) program, supporting multiple projects. The project is focused on the collection and application of high fidelity validation data sets of wind plant complex flow interactions to gain a better understanding of wind farm atmospheric interactions and validation of newly developed simulation tools.

### Project Objective & Impact

- The overall objective of this project is to make high fidelity measurements of wind turbines and plants operating in representative atmospheric conditions and to use the data to advance the understanding of wind plant physics. The data gathered were used to validate computational simulation tools developed under the A2e initiative. Results and validated tools are publicly shared to ensure dissemination of this work to the wind R&D community.

### Project Attributes

#### Project Principle Investigator(s)

Patrick Moriarty (NREL)  
Brian Naughton (SNL)

#### DOE Lead

Michael Derby

#### Project Partners/Subs

NextEra Energy, Inc.  
Texas Tech University  
University of Colorado

#### Project Duration

3 Years – October 2017 – September 2020

# Technical Merit and Relevance

- **Problem**
  - Average wind farm ~ **10%** annual energy production (AEP) lost to wake interaction
  - Uncertainty of industry wake loss models ~**20-50%** (**2-5%** AEP)
- **Needs**
  - Better physical understanding of wind farm interactions
  - Validation of improved models
  - New observations



# Approach and Methodology

- **Subscale Testing (SWiFT)**
  - National Rotor Testbed
- **Utility Scale Testing**
  - DOE 1.5 Testing
  - Peetz Table Wake Steering Test
  - American Wake Experiment (AWAKEN) planning
- **Validation studies**
  - International Energy Agency (IEA) Wind Task 31:Wakebench






# Approach and Methodology

- **A2e Observation and Validation support**
  - High-Fidelity Modeling
  - Advanced Flow Control Science for Wind Plants
  - Integrated Systems Design and Analysis projects
- **Additional questions**
  - Does wake steering increase energy production in the field?
  - How can subscale facilities like SWiFT be used to study wake dynamics?

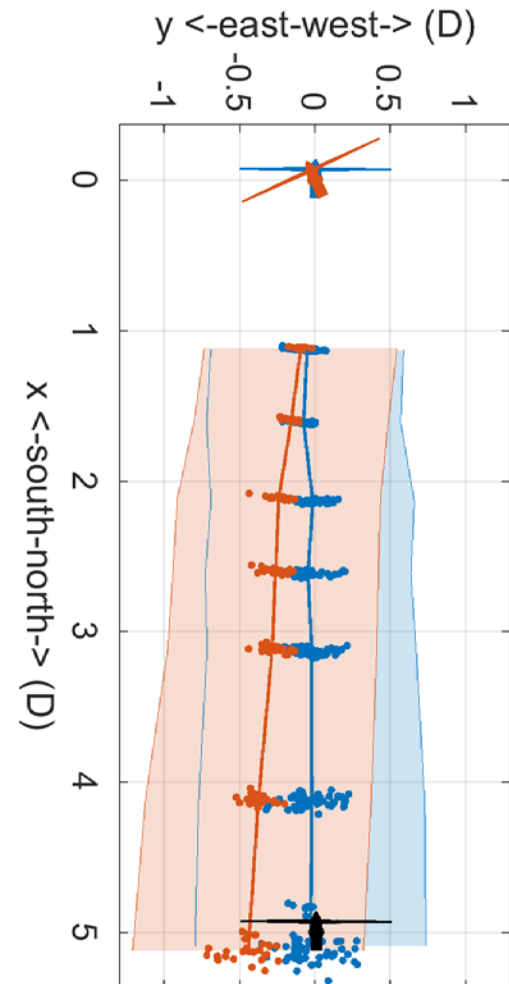
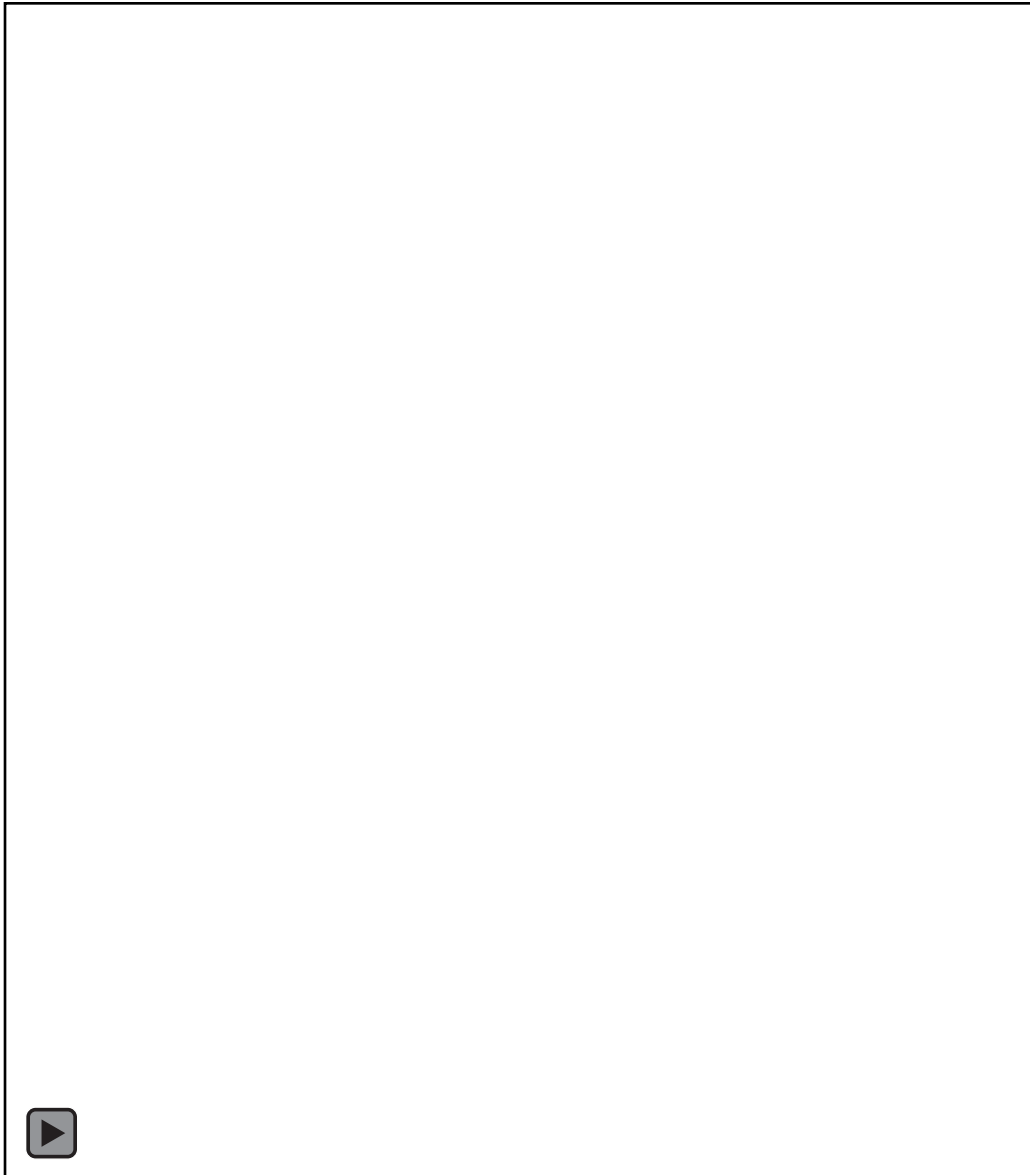


# Accomplishments and Progress

Task / Event	Q1 - FY17	Q2 - FY17	Q3 - FY17	Q4 - FY17	Q1 - FY18	Q2 - FY18	Q3 - FY18	Q4 - FY18	Q1 - FY19	Q2 - FY19	Q3 - FY19	Q4 - FY19
<b>Wake Dynamics</b>												
<b>SWiFT Site Testing</b>												
SWiFT Wake Steering Test												
NRT rotor development												
NRT Blade Sets 2 and 3 Manufacture												◆
Aero Blade Design												
NRT rotor commissioning and testing												
<b>Utility Scale Testing</b>												
DOE GE 1.5 Wake and Loads Testing												
Go/No-Go for Peetz Wake Experiment				◆								
Peetz Wake Steering Test												
AWAKEN Planning												
<b>Validation Studies</b>												
IEA Wind Task 31: Wakebench												
Validation roadmap												
Existing SCADA data validation studies												
SWiFT benchmark												

Legend	
	Summary
	Task
	Go/No-Go Decision Points

# Accomplishments and Progress





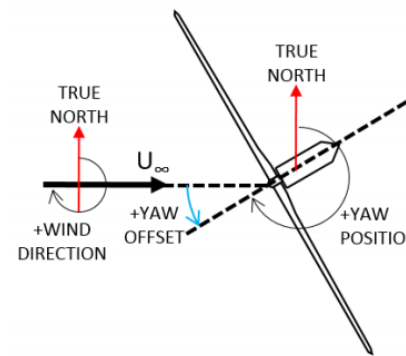
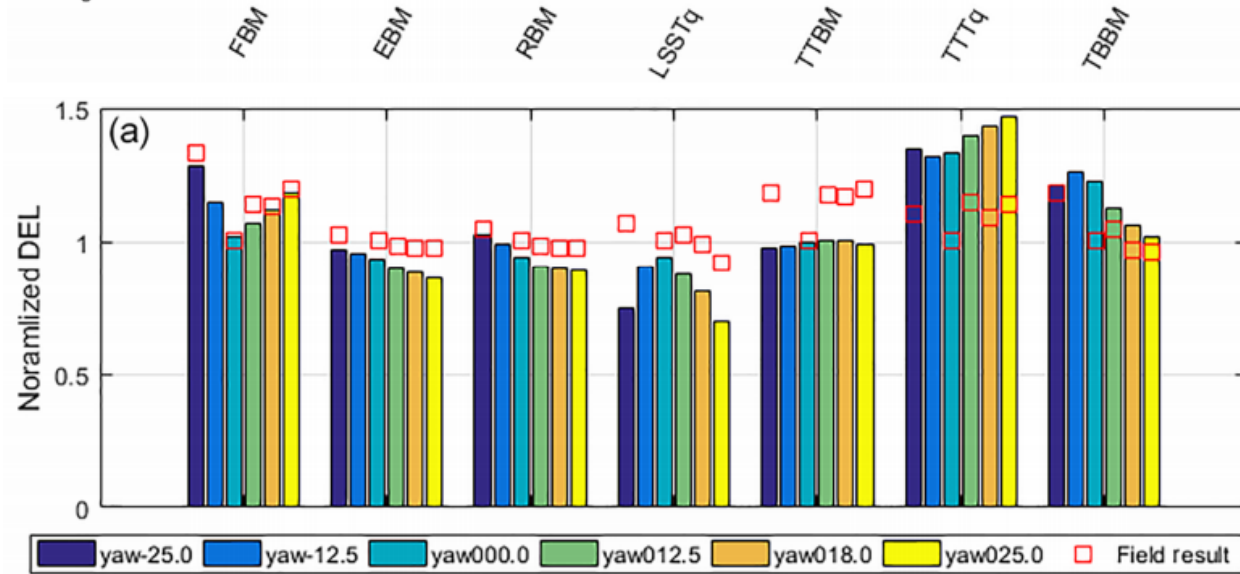
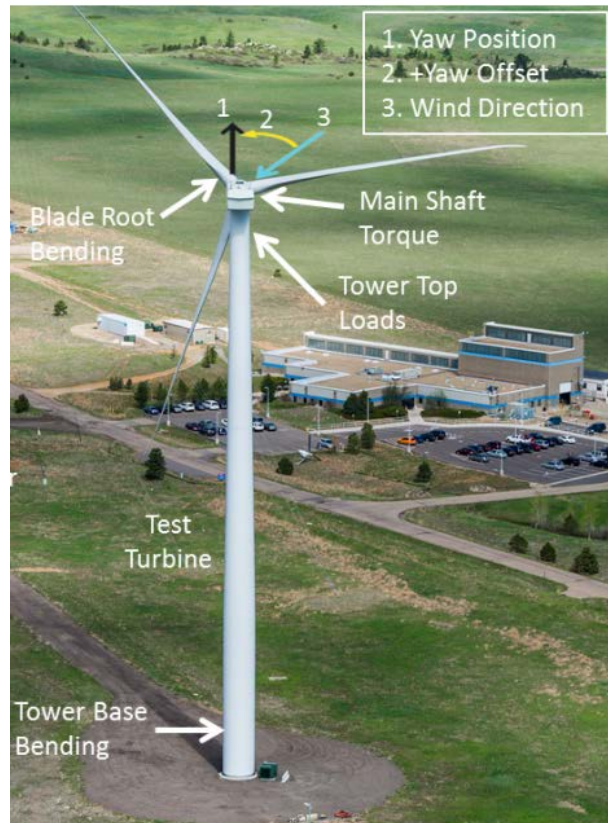
# Accomplishments and Progress



National Rotor Testbed (NRT)



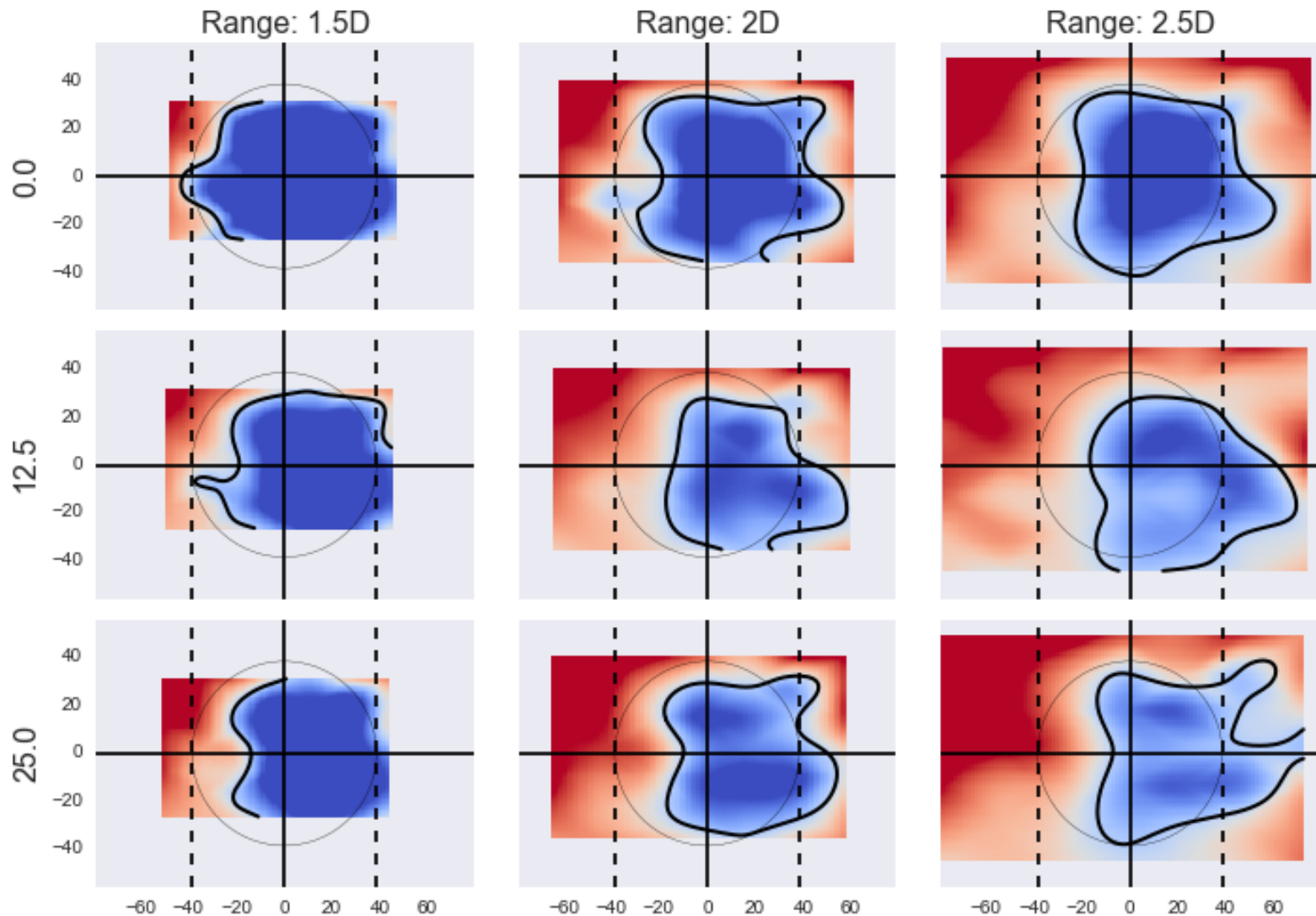
# Accomplishments and Progress



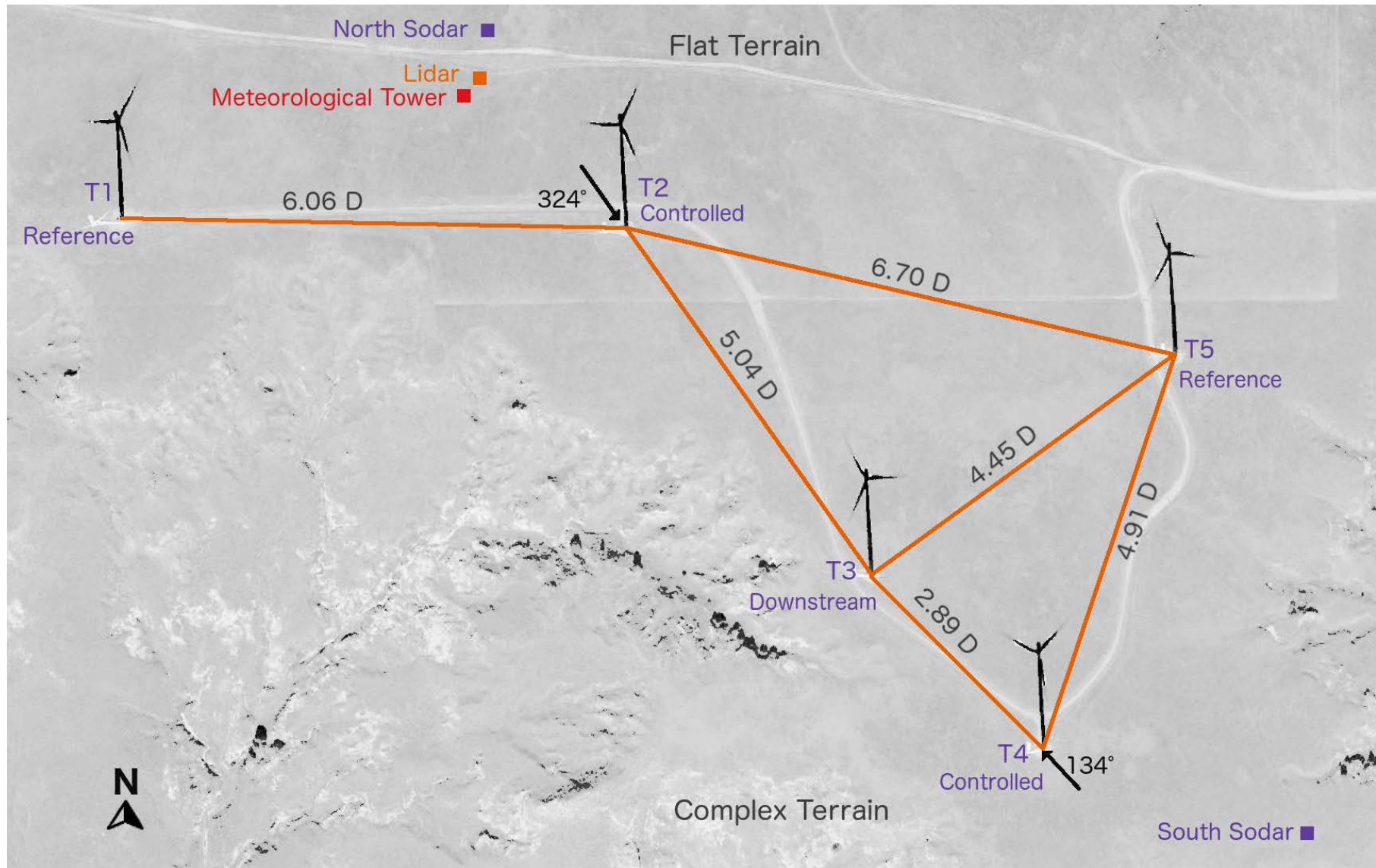
Damiani, R., Dana, S., Annoni, J., Fleming, P., Roadman, J., Dam, J. V., & Dykes, K. (2018). Assessment of wind turbine component loads under yaw-offset conditions. *Wind Energy Science*, 3(1), 173-189.

# Accomplishments and Progress

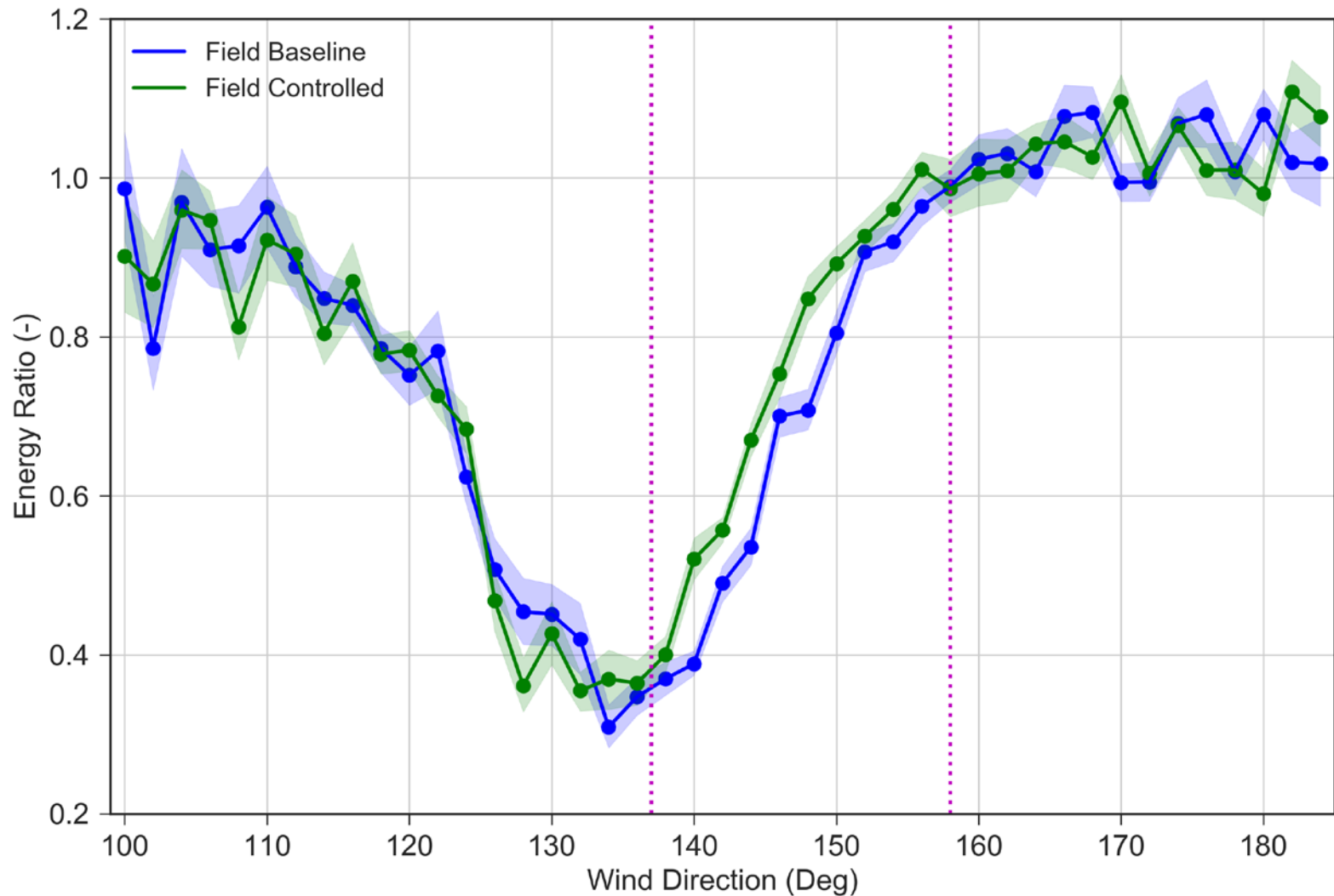
Yaw Offset



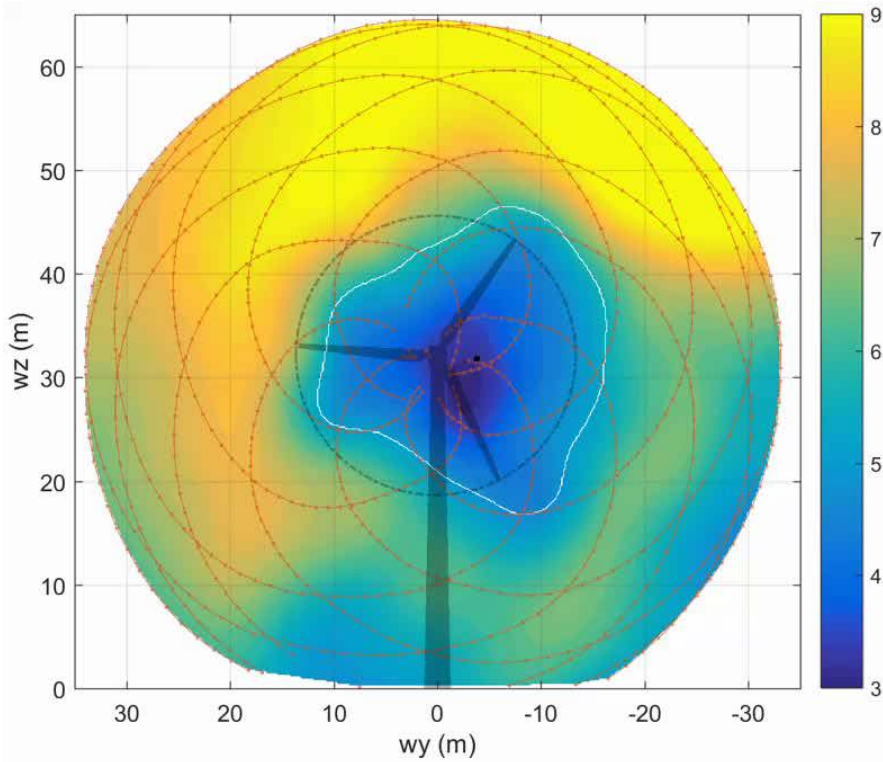
# Accomplishments and Progress



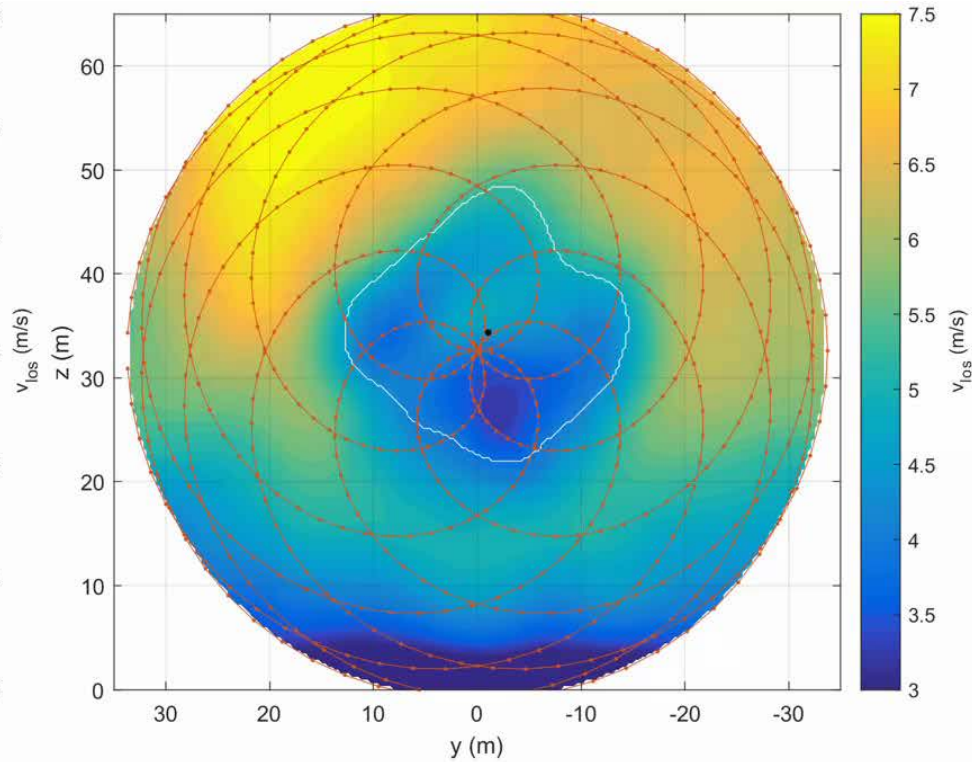
# Accomplishments and Progress



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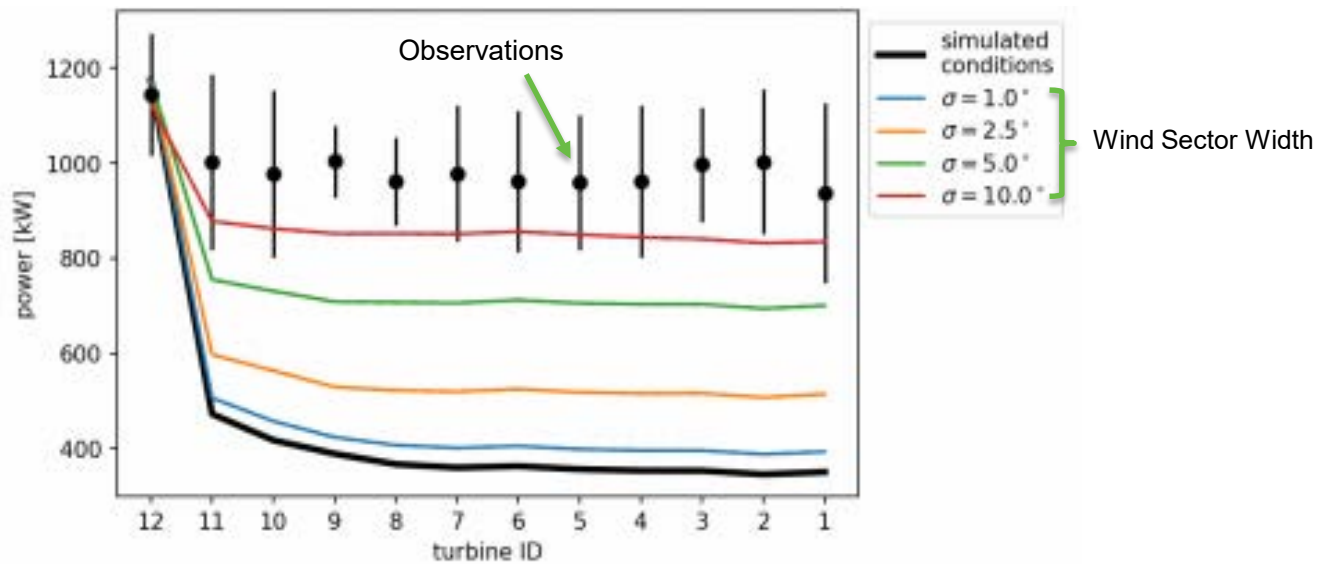
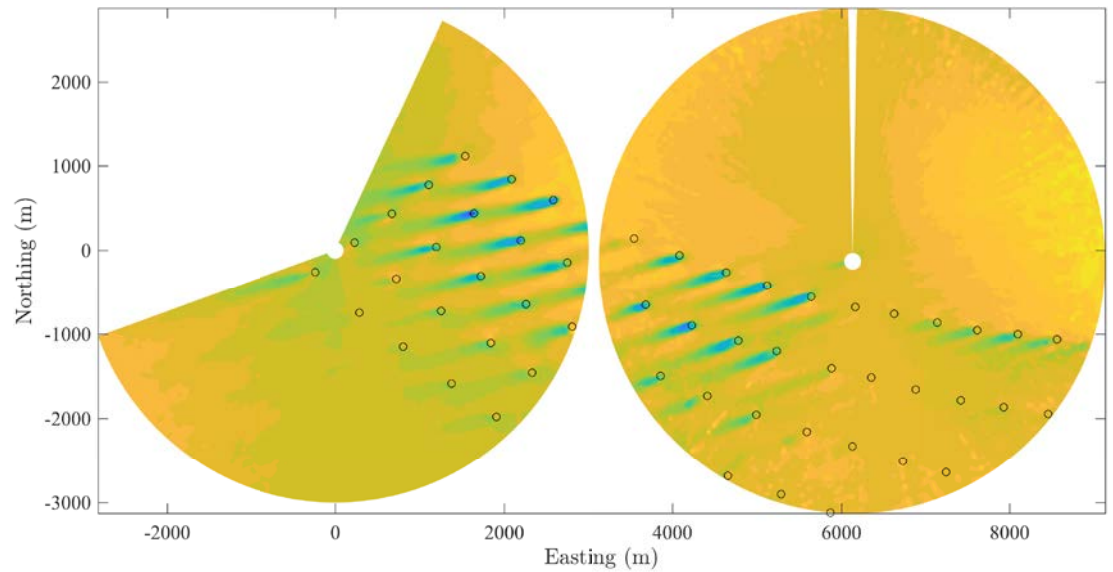


Observation



Simulation

# Accomplishments and Progress



# Communication, Coordination, and Commercialization

- **Publications**
  - FY17 – 6 peer reviewed
  - FY18 – 13 peer reviewed
  - Numerous conferences (e.g. Torque 2018)
- **SWiFT Data**
  - Uploaded to A2e Data Archive and Portal (DAP)
  - International benchmark through IEA Wind Task 31: Wakebench
- **Validation studies improved open source NREL models**
  - FLORIS, FAST.Farm and SOWFA





# Upcoming Project Activities – Short Term

- **Subscale wake testing at SWiFT**
- **Utility Scale Testing**
  - Peetz Table
    - Extended until June 2020
    - Lidars and loads
- **Model validation**
  - Peetz validation study
  - IEA Task 31 Wakebench
    - SWiFT Benchmark and others
    - Phase III - until June 2021



# Upcoming Project Activities – Long Term

- **Subscale blade-resolved testing at SWiFT**
- **American Wake Experiment (AWAKEN)**
  - Land-based
  - Midwestern United States
  - Multi-institutional and international
  - 5-year plan
  - Advanced instrumentation development
  - Began FY19 with international science meeting
  - Developing partnerships and Request for Interest to be released soon

