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The SWiFT Benchmarks

Part of IEA Wind Task 31 Phase 3 (2018-2019)
Kick-Off Webinar -- October 30, 2018 08:00 MDT

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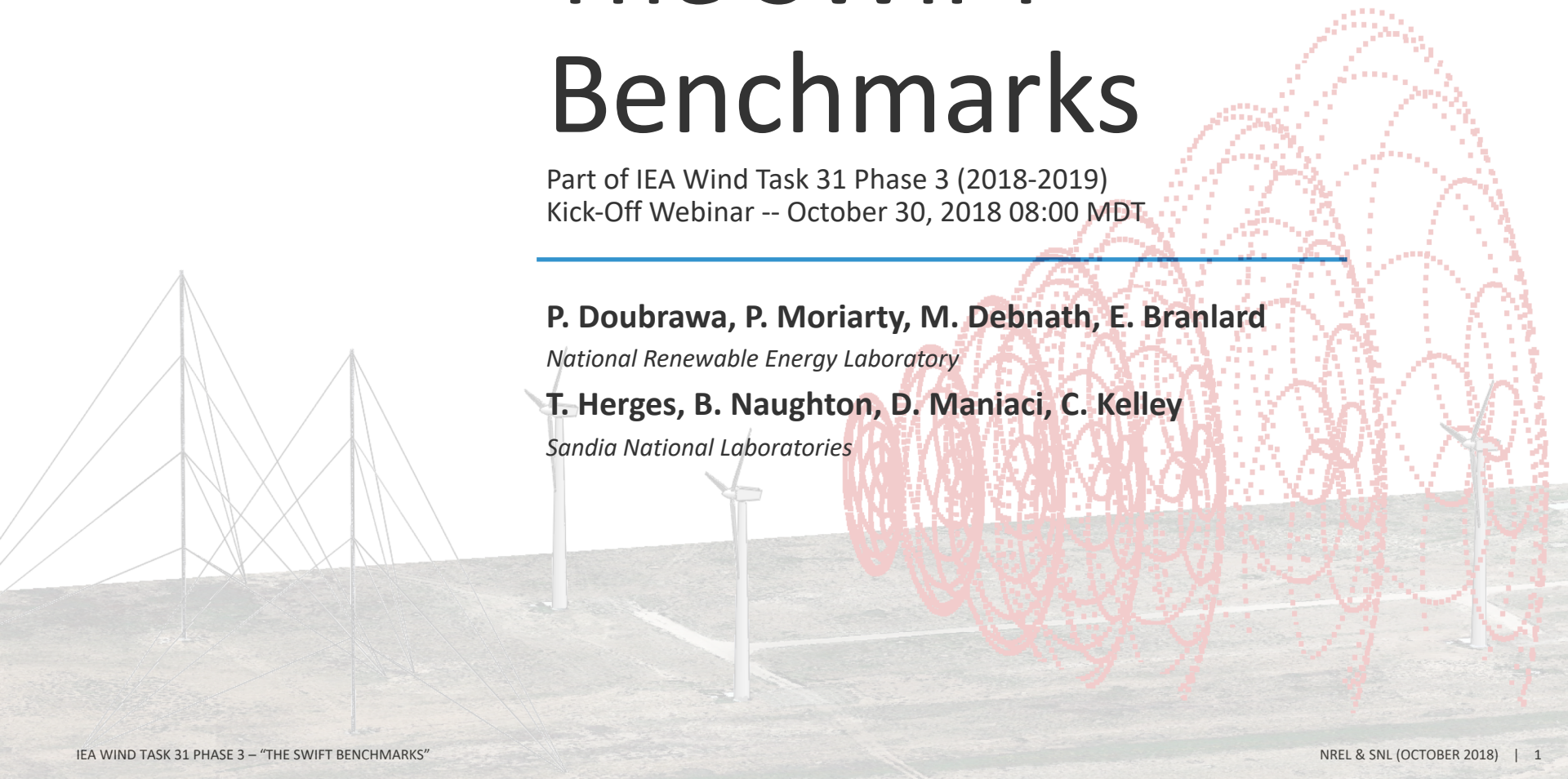
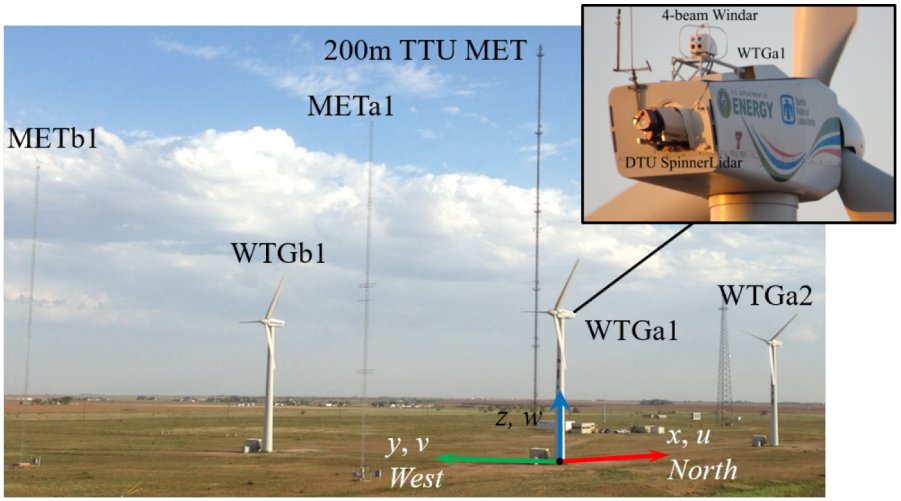


The U.S. Department of Energy SWiFT Facility

More info: https://wakebench-swift.readthedocs.io

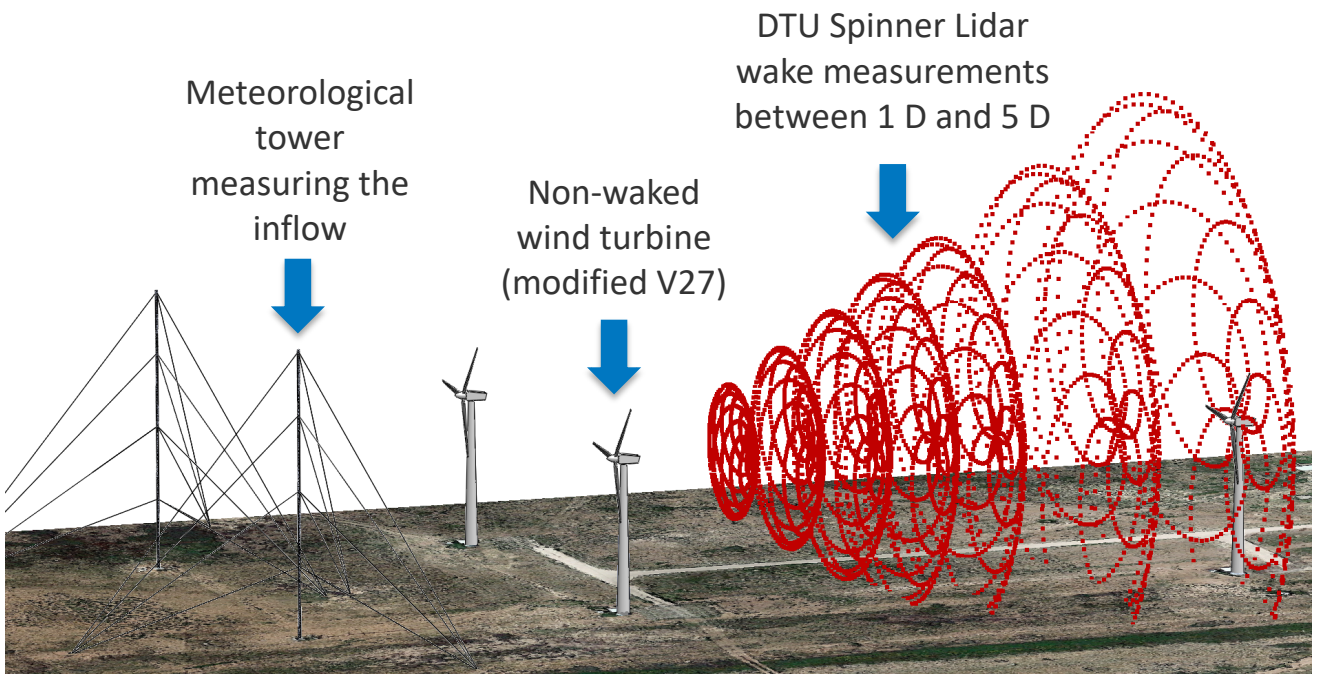
- Heavily instrumented
- Freely available data
- Located in the U.S. Great Plains
  - Flat terrain and clear response to radiative forcings in the absence of weather events
- Unique opportunity to validate simulations of wind-turbine wakes in response to different surface forcings (e.g., stable, neutral, unstable)



The SWiFT Benchmarks: Measurements Selection

More info: https://wakebench-swift.readthedocs.io

- All available data were aggregated based on their similarity in terms of
  - Atmospheric inflow
    - Wind speed, turbulence intensity, shear, veer, Obukhov length
  - Wind turbine operation
    - Yaw offset
  - Wake measurements available
    - Measurement strategy
    - Quality of retrievals
- Data with similar inflow, turbine operation, and measurement strategy were used to define each benchmark



The SWiFT Benchmarks: Unstable, Neutral, Stable

We propose to take advantage of the clear diurnal cycles observed at SWiFT to evaluate the ability of various models to simulate the **mean and dynamic behavior of wakes under stratified atmospheric conditions**

Daytime, Unstable Atmosphere

Transition, Nearly-Neutral Atmosphere

Nighttime, Stable Atmosphere

Measurement strategy:

- High-frequency ($\Delta t \sim 2$ s) measurements at one distance downstream

Validation focus:

- **Wake dynamics** (i.e., turbulence-driven phenomena)

Measurement strategy:

- Lower-frequency ($\Delta t \sim 25$ s) measurements at seven distances downstream (1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 D)

Validation focus:

- **Wake evolution** (i.e., spatial evolution of temporally averaged quantities) as it propagates and dissipates downstream,
- Wake dynamics is also considered for these benchmarks despite the lower measurement frequency

The SWiFT Benchmarks: Unstable, Neutral, Stable

Daytime, Unstable Atmosphere

- Upstream measurements
  - U_{hub} = 6.7 m/s
  - TI_{hub} = 12.6%
  - α = 0.14
  - $z/L\,|_{10m}$ = -0.089
- Wake measurements used
  - x = 3 D
  - T = 50 minutes
  - Δt ~ 2 s

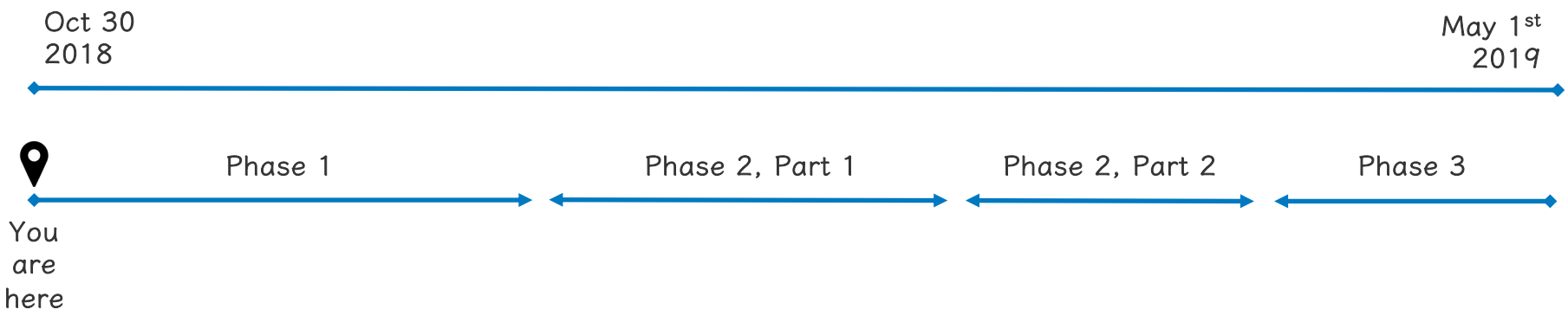
Transition, Nearly-Neutral Atmosphere

- Upstream measurements
  - U_{hub} = 8.7 m/s
  - TI_{hub} = 10.7%
  - α = 0.14
  - $z/L\,|_{10m}$ = 0.004
- Wake measurements used
  - x = 2 D to 5 D
  - T = 60 minutes
  - Δt ~ 25 s

Nighttime, Stable Atmosphere

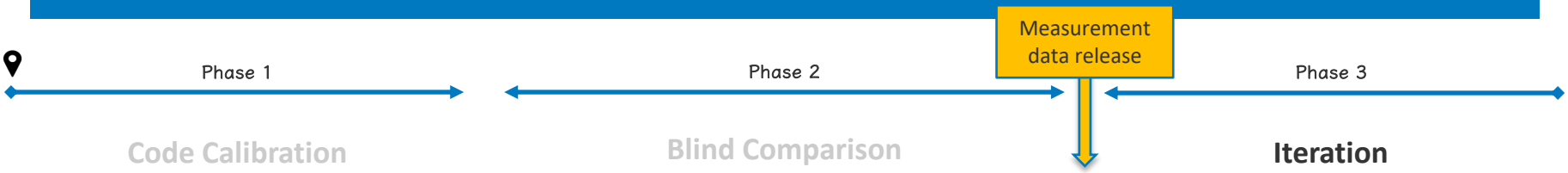
- Upstream measurements
  - U_{hub} = 4.8 m/s
  - TI_{hub} = 3.4%
  - α = 0.50
  - $z/L\,|_{10m}$ = 1.151
- Wake measurements used
  - x = 2 D to 5 D
  - T = 60 minutes
  - Δt ~ 25 s

The SWiFT Benchmarks: Status



- Collective exercise lasts 6 months
- Open to all participants of IEA Wind Task 31 “WakeBench”
- Open to all models
- Guidelines
  - Time-stepped simulations should be run to convergence
  - The choice of domain size, grid spacing, time step, and other model configuration parameters is left to the discretion of the participants
- Multi-model benchmark results will be published in journal article and co-authored by all participants who choose to release their results and participate in the publication effort

The SWiFT Benchmarks: Phases and Deadlines



Code Calibration

Objective

Provide an opportunity for model calibration before the blind comparison (wake is **not** included)

Provided

- Turbine model
- Mean atmospheric state

Requested

- Simulation setup
- Flow upstream[1]
- Wind turbine response[2]

End of Phase

December 21, 2018

Blind Comparison

Code-to-Code Comparison

Objective

Identify potential errors in model configuration

End of Phase

February 11, 2019

Code-to-Measurements Comparison

Objective

Provide a first assessment of the skill of the simulation tool

End of Phase

March 18, 2019

Requested

- Simulation setup
- Flow upstream[1]
- Wind turbine response[2]
- Flow downstream up to 8 D[3]

Iteration

Objective

Interrogate results to understand where models work well and where improvements are required

Requested

- Simulation setup
- Explanation of updates to simulation setup
- Flow upstream[1]
- Wind turbine response[2]
- Flow downstream up to 8 D[3]

End of Phase

May 1st, 2019

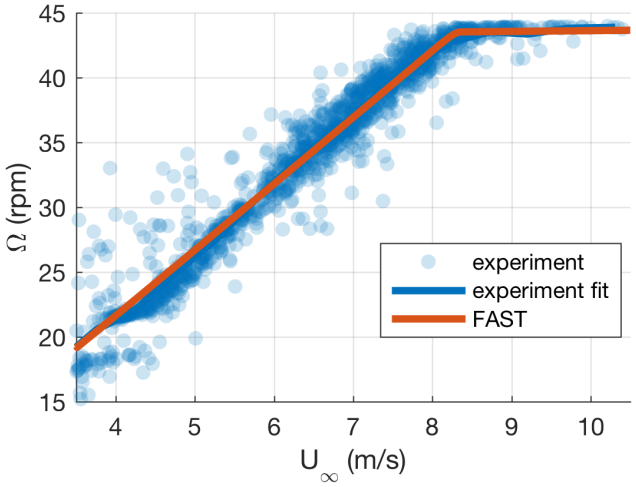
[1]upstream refers to met. tower location at x=-2.5 D
[2]includes generator power, rotational speed, generator torque, thrust, blade-root loads
[3]u, v, w in two-dimensional (y-z) planes between x = 0 D and x = 8 D in 1 D increments

The SWiFT Benchmarks: Provided Supporting Models

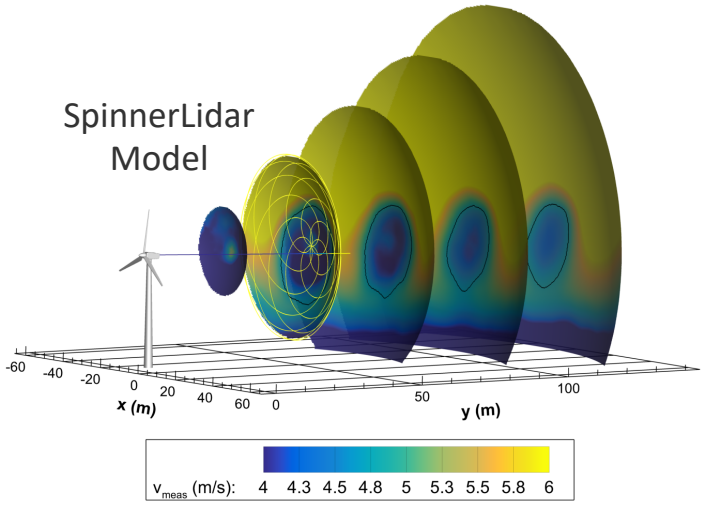
- Wind turbine models

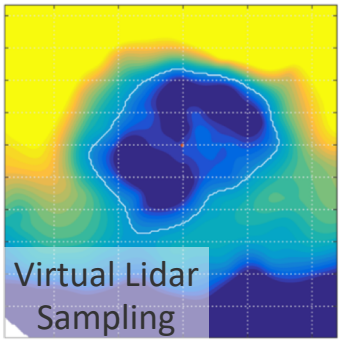
https://github.com/NREL/wakebench_swift

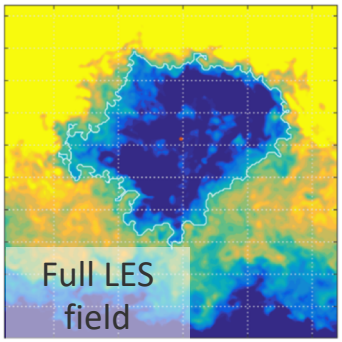
  - FAST 7 model
  - OpenFAST model
  - Performance curves



- LIDAR scan geometry (coming soon)
  - Participants are encouraged to add a "virtual lidar" to sample data from their simulations
  - Sandia will release a report of the model describing the DTU SpinnerLidar geometry and weighting function before the start of Phase 2







References for V27 models:

- Christopher L. Kelley and Jonathan White, *An Update to the SWiFT V27 Reference Model*, Sandia report SAND2018-11893, 2018
- Brian R. Resor and Bruce LeBlanc, *An Aeroelastic Reference Model for the SWIFT Turbines* , Sandia report SAND2014-19136, 2014

Next Steps

1. Sign up

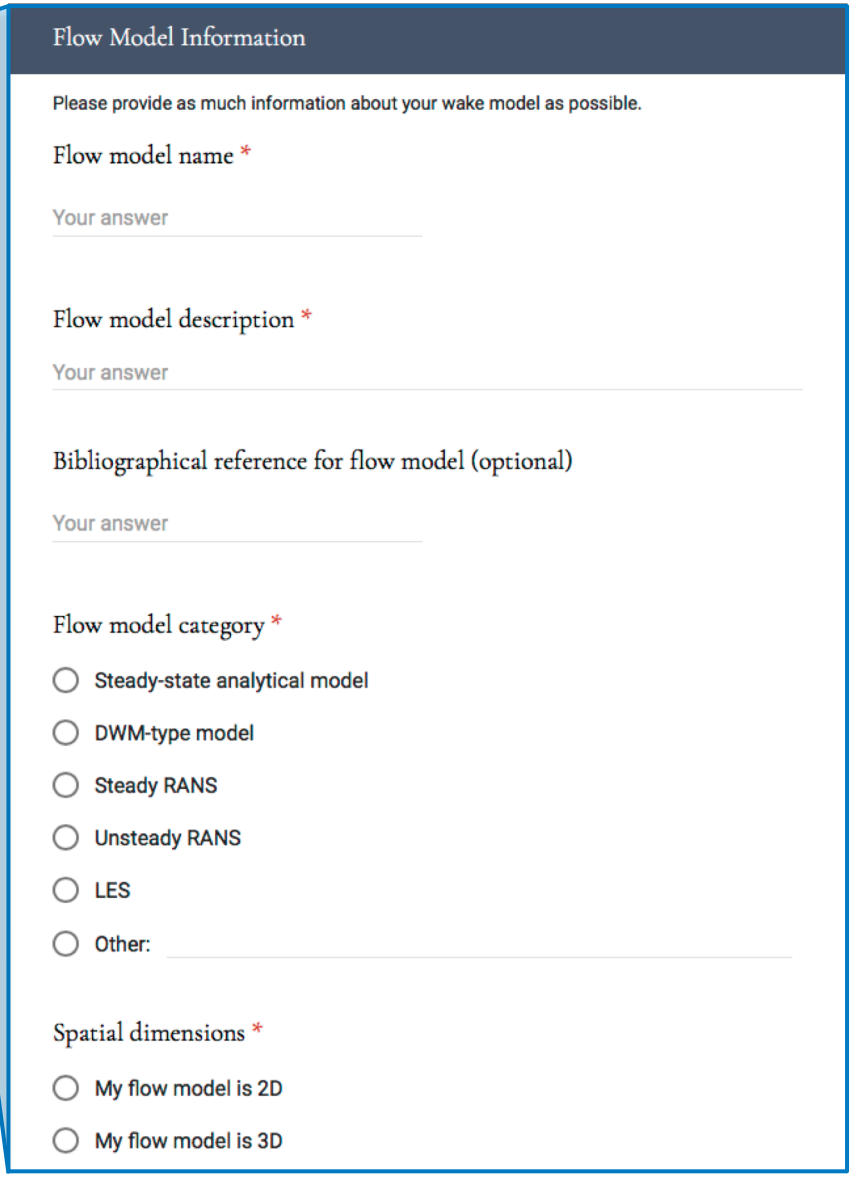
Participant

Sign up with google form:
https://goo.gl/forms/cCMnRHAkXQ6VNm3c2

1. Contact Information
2. Flow Model Information
3. Turbine Model Information
4. Your Benchmark Plans

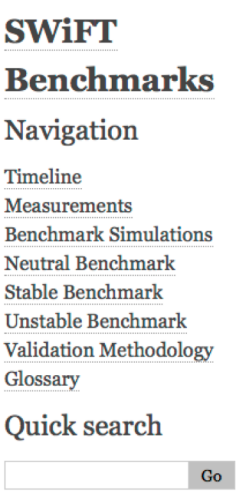
Organizers

- … will assign you a <participant_id>
- … will create a private, secure "box" for you to upload results



2. Familiarize yourself with the benchmarks

- Bookmark the documentation: https://wakebench-swift.readthedocs.io
  - Definition of benchmarks
  - Schedule of upcoming meetings
- Bookmark the github page: https://github.com/NREL/wakebench_swift
  - Examples of files which are requested in the benchmark
  - Any code used will be uploaded as we go to this repository
  - Wind turbine models and performance curves
- Sign up for Q&A forum: https://wind.nrel.gov/forum/wind/
- See story at Wind Vane blog https://thewindvaneblog.com



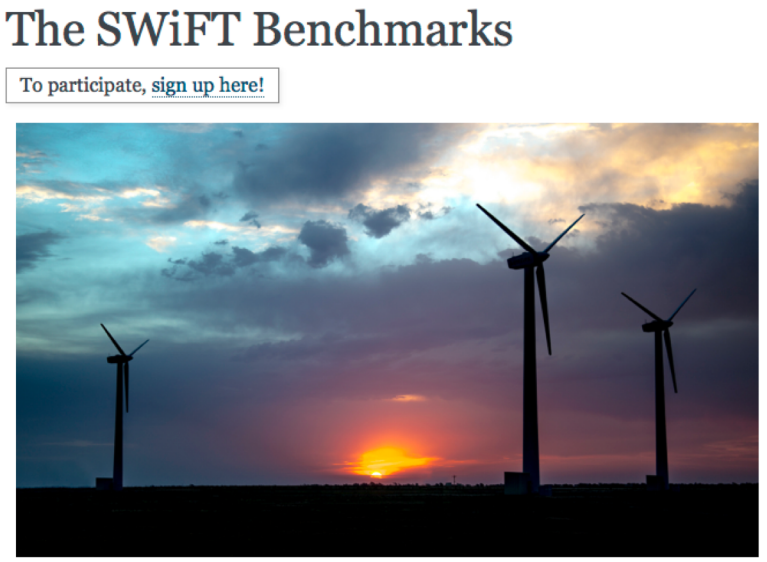


Figure: The DOE SWiFT facility in Lubbock, Texas

What is SWiFT?

The Scaled Wind Farm Technology (SWiFT) facility is a ground for research and technology innovation in the field of wind-turbine and wind-plant aerodynamics. The facility is funded by the United States (U.S.) Department of Energy (DoE), and located at Texas Tech University's National Wind Institute Research Center in Lubbock, Texas. All data collected at SWiFT through the wake-steering experiment are available free of charge through the DoE Data Archive Portal (DAP).

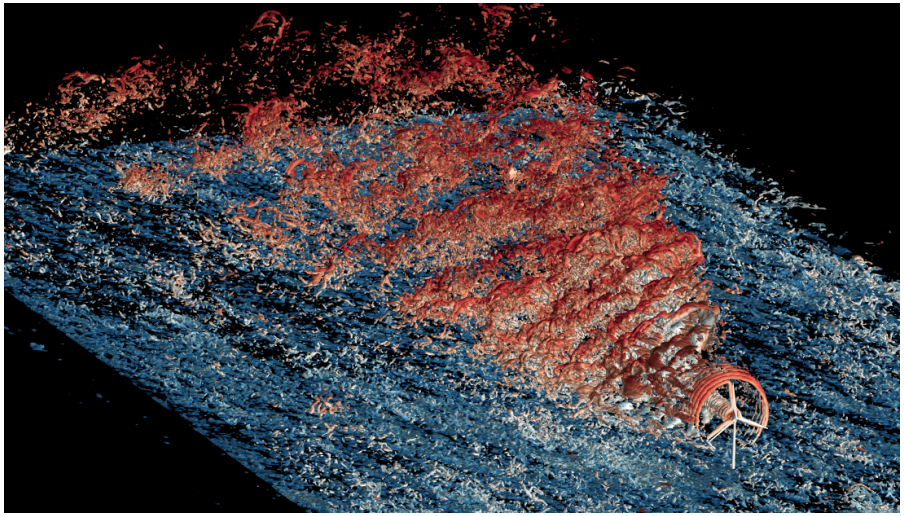
Atmospheric Conditions at SWiFT

SWiFT is located in the U.S. Great Plains and is therefore exempt from complex, terrain-induced flow patterns. In the absence of weather phenomena (e.g., fronts, storms) the atmospheric conditions at SWiFT approximate canonical diurnal cycles. The relative simplicity of atmospheric conditions at the site make it a valuable resource for research in complex turbulent flows such as wind-turbine wakes. In other words, the mean and dynamics characteristics of wakes and their effect on downstream turbines can be considered without the influence of complex terrain and weather. For more detail on the atmospheric conditions at this site, see Kelley and Ennis (2016).

3. Start your simulations

- Use the data provided
  - Turbine model
  - Mean atmospheric conditions for each benchmark
- Observe the requested file formats

  Example template is provided for all requested files (links in documentation). The templates are reduced versions of the requested file, intentionally made smaller so they can be hosted in the repository.



Simulation Setup

- At each submission, one ***.yaml** file which you can modify as needed to include relevant parameters of your model

Atmosphere and Wake

- ***.nc** files (NetCDF 4.0)
- Python code provided in the github page shows how to write data to this format

Turbine Response

***.txt** files

- For **consistency**, all submitted data will be processed by benchmark organizers
- For **transparency** and **repeatability**, all code used to process the data will be publicly released
- If any information is missing or contradictory, please post in the forum
- If you think any of this will be challenging for your model, please contact Paula.Doubrawa@nrel.gov

Summary

1. Sign up with google form: https://goo.gl/forms/cCMnRHAkXQ6VNm3c2
2. Familiarize yourself with the benchmarks
   - Bookmark the documentation: https://wakebench-swift.readthedocs.io
   - Bookmark the github page: https://github.com/NREL/wakebench_swift
   - Sign up for Q&A forum: https://wind.nrel.gov/forum/wind/
   - See story at Wind Vane blog https://thewindvaneblog.com
3. Start your simulations! Use the provided data to
   - Set up turbine model
   - Generate initial/boundary conditions
   - Run turbine simulation
   - Submit your results!

Next Meeting
November 27, 2018

Regular monthly meetings during Phase 1 (frequency can be increased as needed)

Questions?

Use the forum! Find the thread "SWiFT Benchmarks" at https://wind.nrel.gov/forum/wind/

Q&A

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