Modeling for Controls

Paul Fleming

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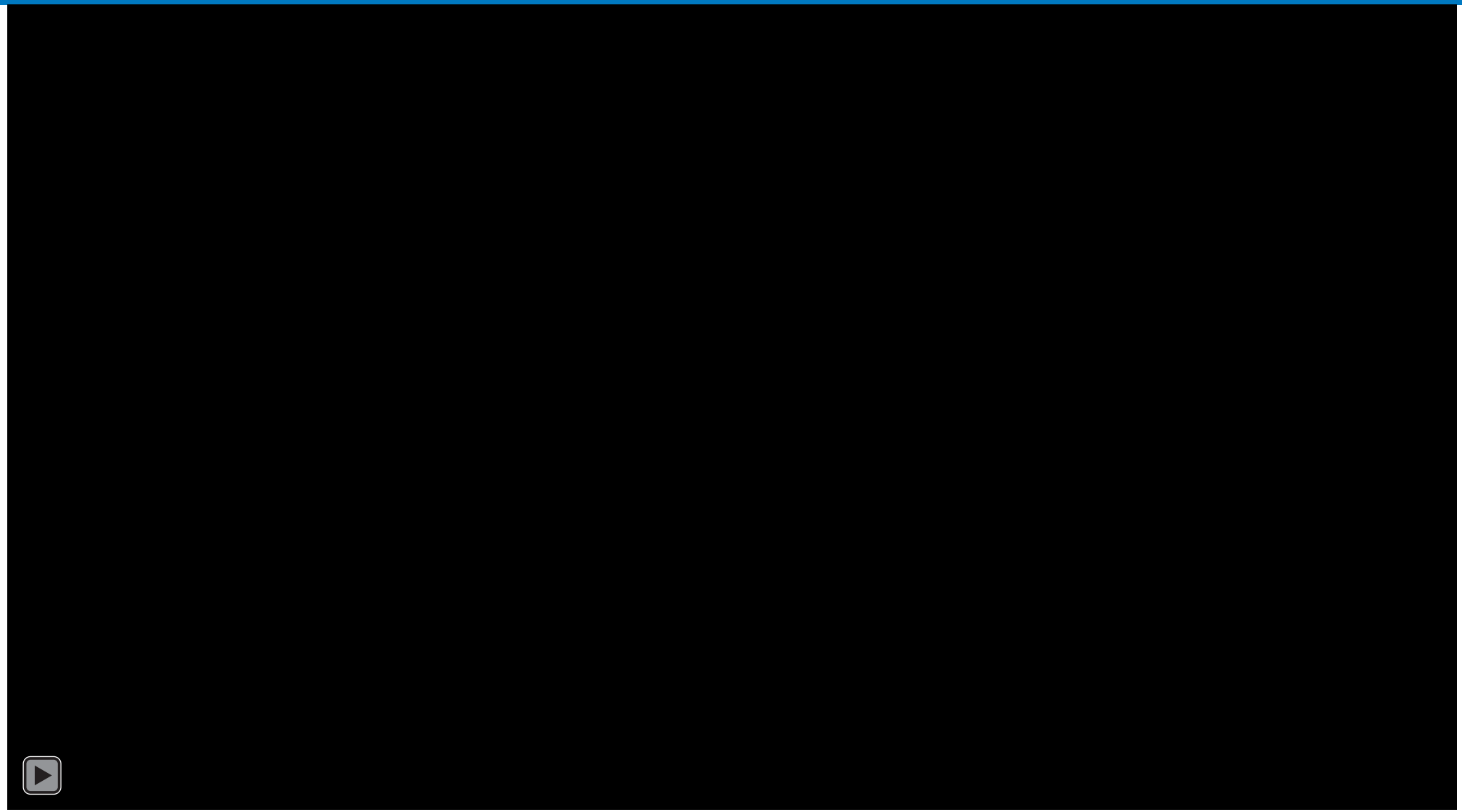
Wind Farm Control



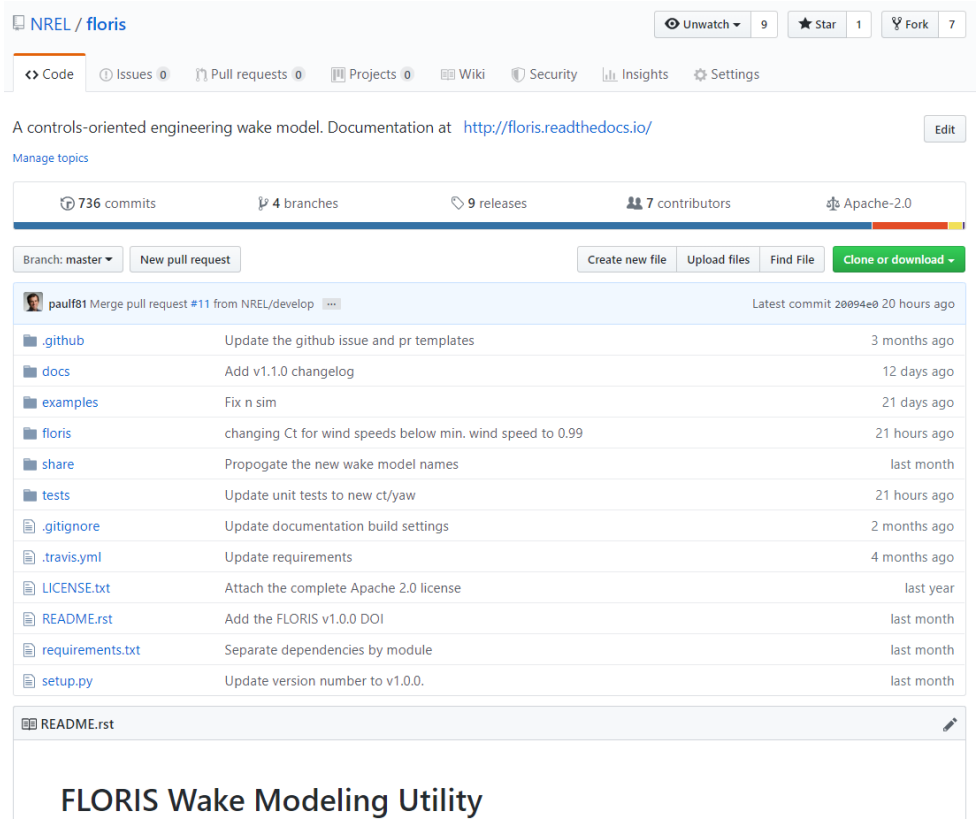
FLORIS: Open-source and Collaborative

Available at: https://github.com/NREL/floris

Divided into two packages:

- simulation:
  - Contains code for FLORIS models
- tools:
  - Modules for interacting with FLORIS models and data

Documentation and examples available at:
https://floris.readthedocs.io/en/develop/index.html



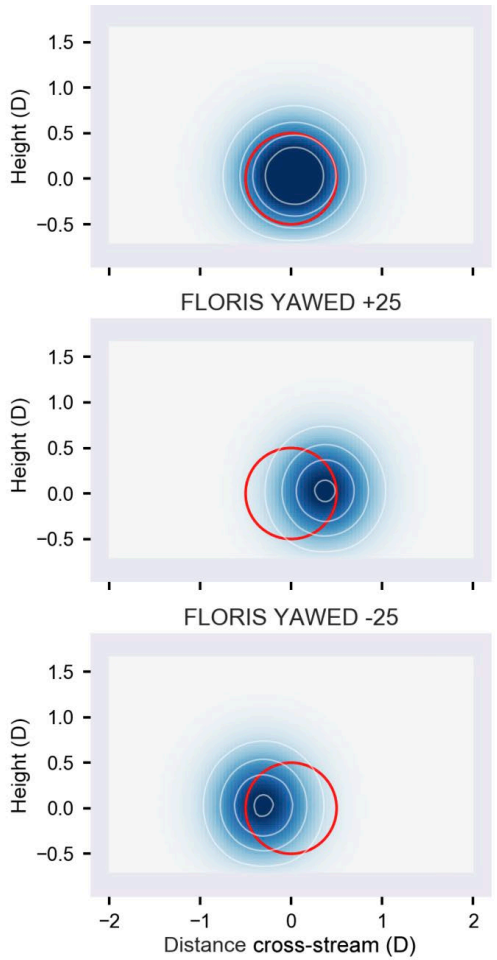
What are some open questions?

- What are the most important atmospheric characteristics for predicting wind farm control behavior?
- Do engineering wake models capture all the important physics for wind farm control?
- What can be said (with what confidence) given current validation studies?
- What additional validation is needed?
- How best to balance code-performance (eg enable many runs on a laptop) and fidelity by application in engineering wake models?
- How to implement wind farm control in dynamic environments?

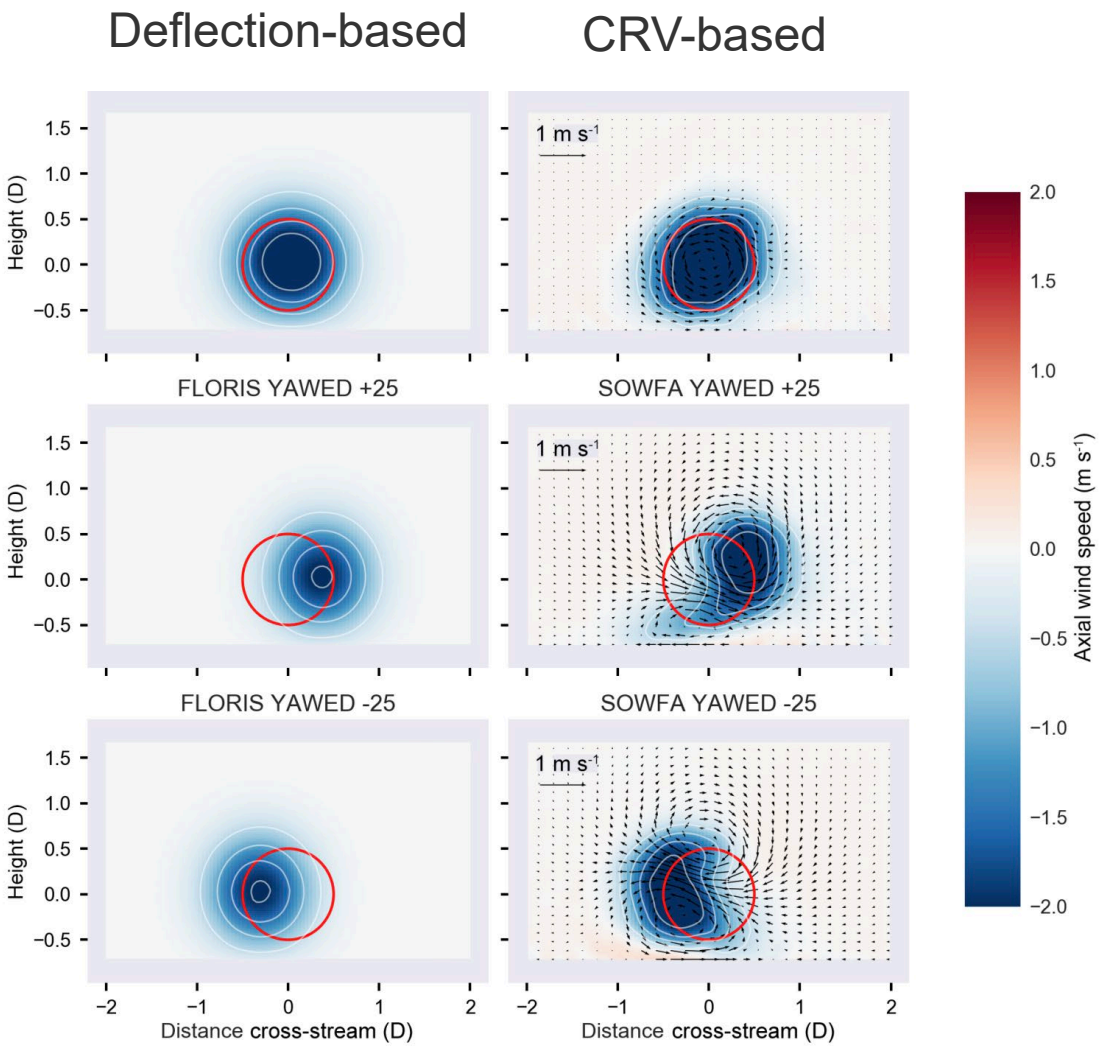
In this talk, will review some highlights of NREL's research into these questions

Models of wake steering are getting more complex and dependent on atmospheric conditions

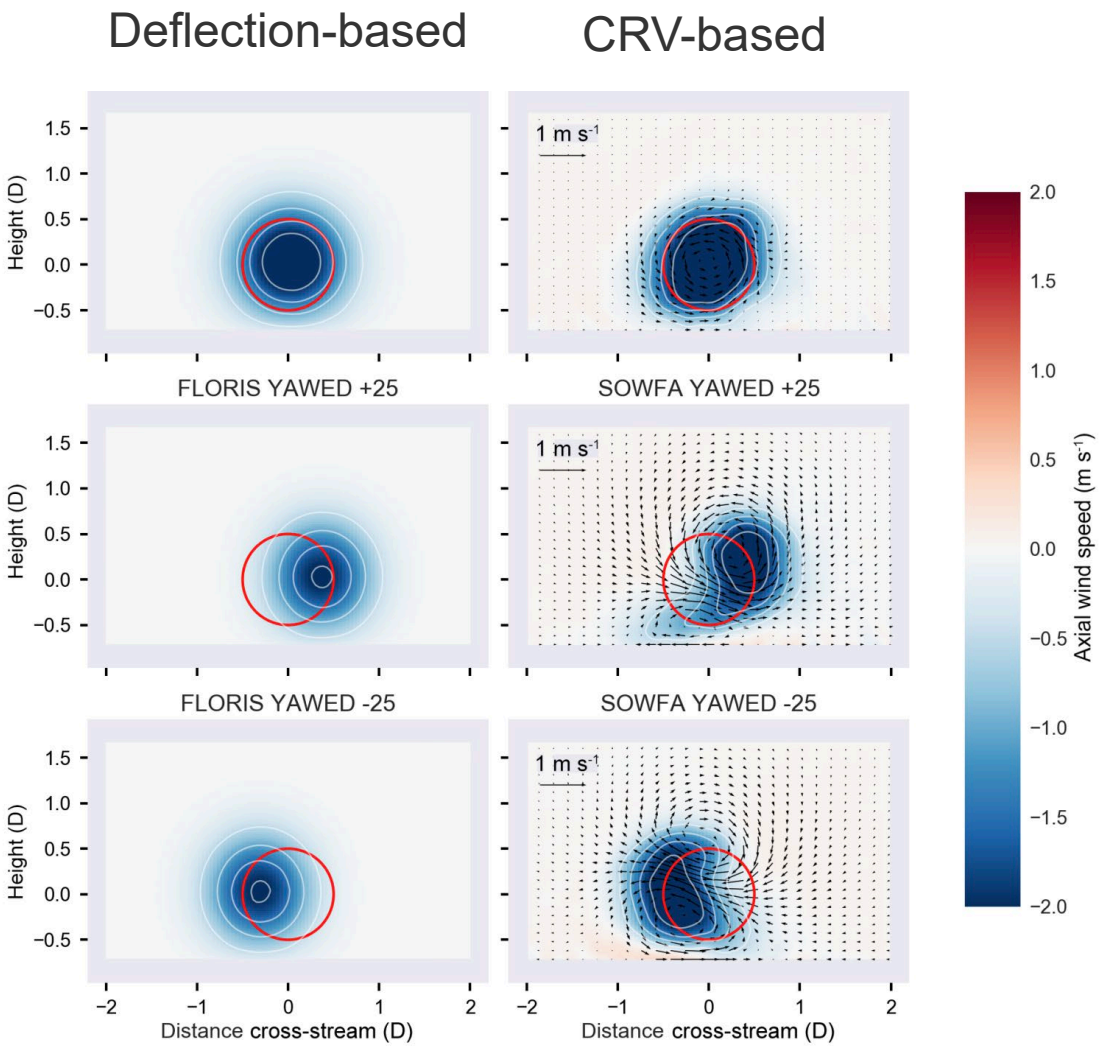
Deflection-based

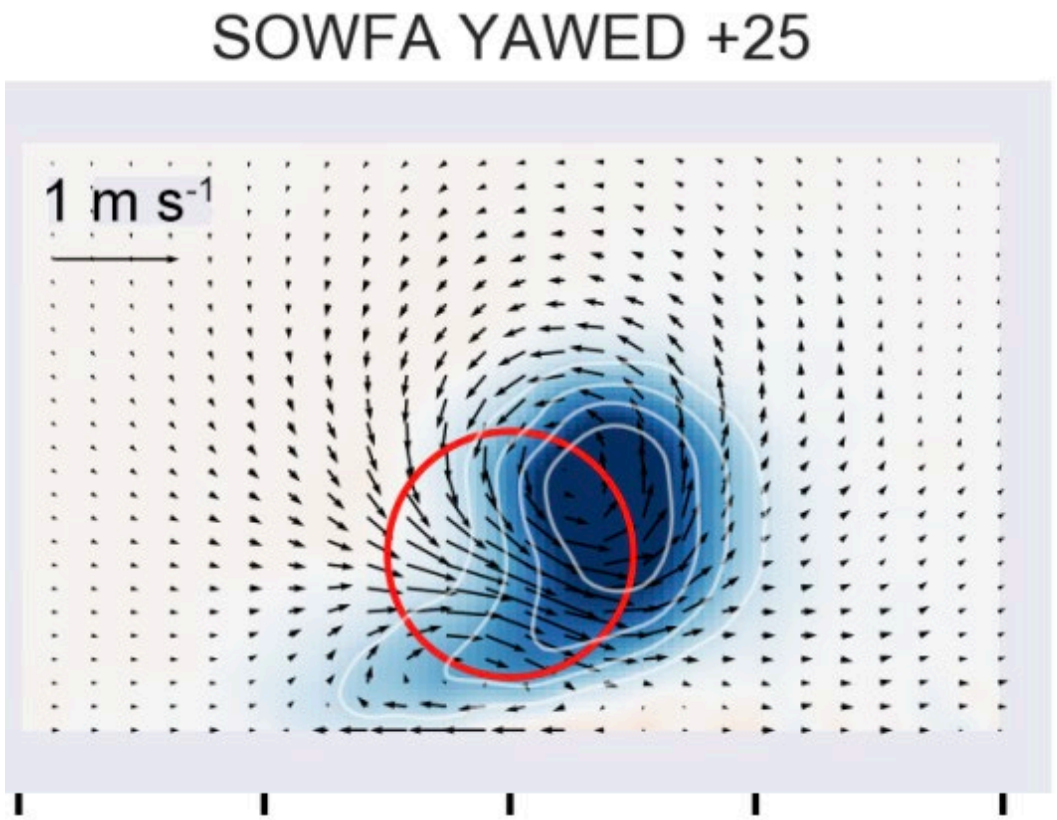


Models of wake steering are getting more complex and dependent on atmospheric conditions



Models of wake steering are getting more complex and dependent on atmospheric conditions





New Gauss-Curl Hybrid (GCH) Model in FLORIS seeks to include these second order effects in analytical approximation

Controls-Oriented Model for Secondary Effects of Wake Steering

Jennifer King, Paul Fleming, Ryan King, Luis A. Martínez-Tossas, Christopher J. Bay, Rafael Mudafort, and Eric Simley
National Wind Technology Center, National Renewable Energy Laboratory, Golden, CO, 80401, USA

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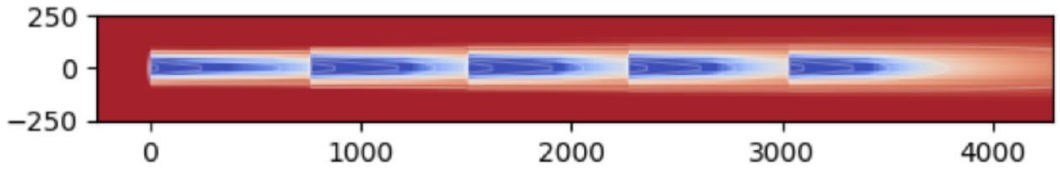
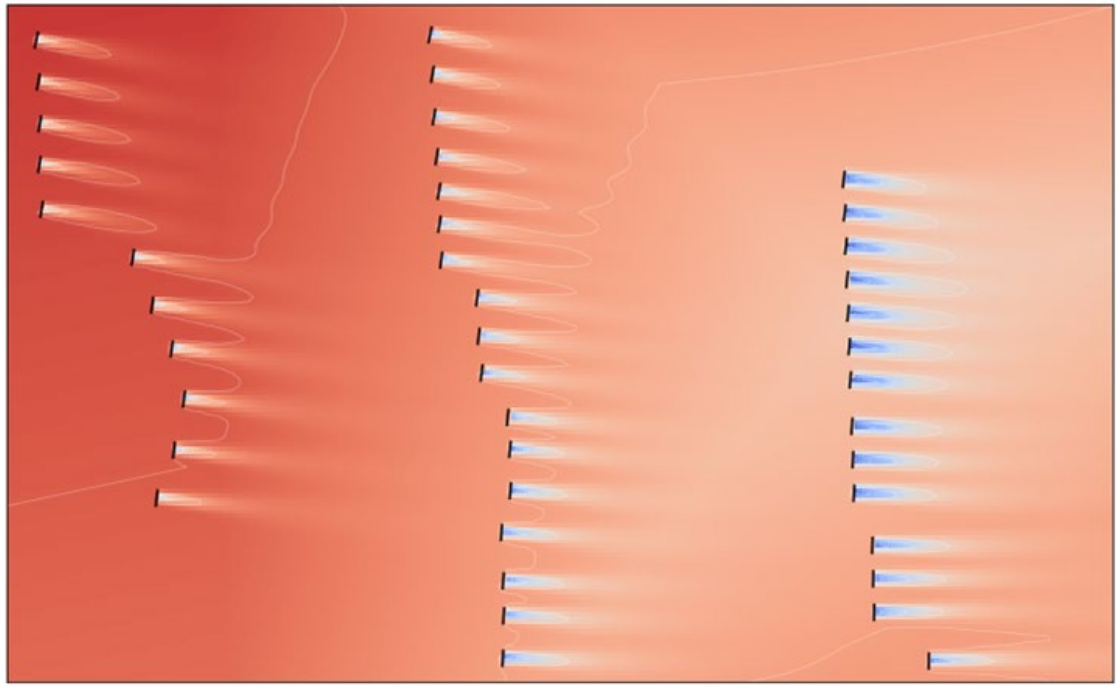


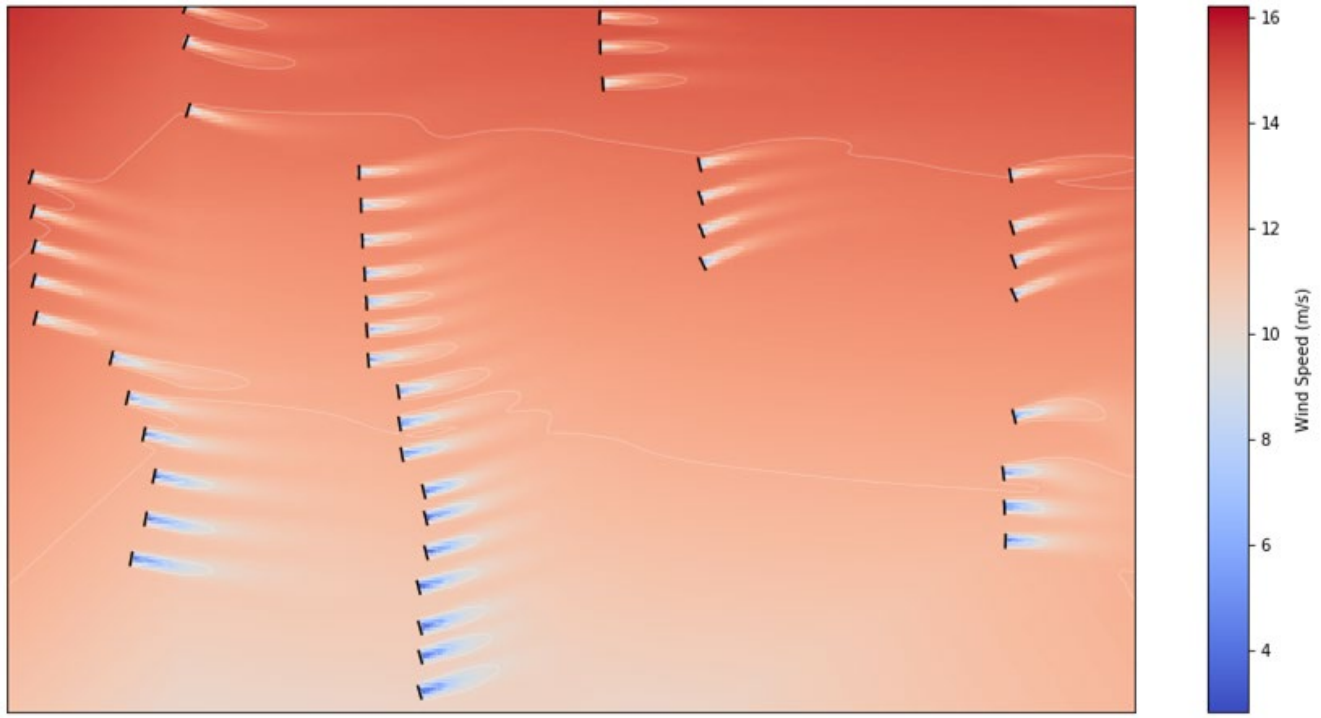
Case	Turbine 1	Turbine 2	Turbine 3	Turbine 4	SOWFA Gain	Gauss Gain	GCH Gain
Low Turbulence							
Gauss optimized angles	24.0	25.0	25.0	25.0	22.7%	9.9%	23.1%
GCH optimized angles	25.0	25.0	22.1	18.7	**23.7%**	9.4%	23.5%
Max yaw angles	25.0	25.0	25.0	25.0	22.9%	9.8%	23.3%
High Turbulence							
Gauss optimized angles	12.9°	23.4°	19.7°	14.1°	7.5%	1.2%	9.2%
GCH optimized angles	24.2	24.4	22.7	16.5	**14.3%**	-0.2%	11.0%
Max yaw angles	25.0	25.0	25.0	25.0	13.1%	-0.9%	10.1%

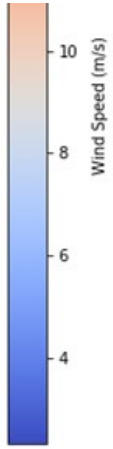
Table 1. Five turbine results for low and high turbulence conditions using SOWFA, the Gaussian model, and the GCH model.

Including heterogeneity in FLORIS

Heterogeneity can improve model accuracy in “postdicting” existing SCADA data but complicates forward-looking optimizations





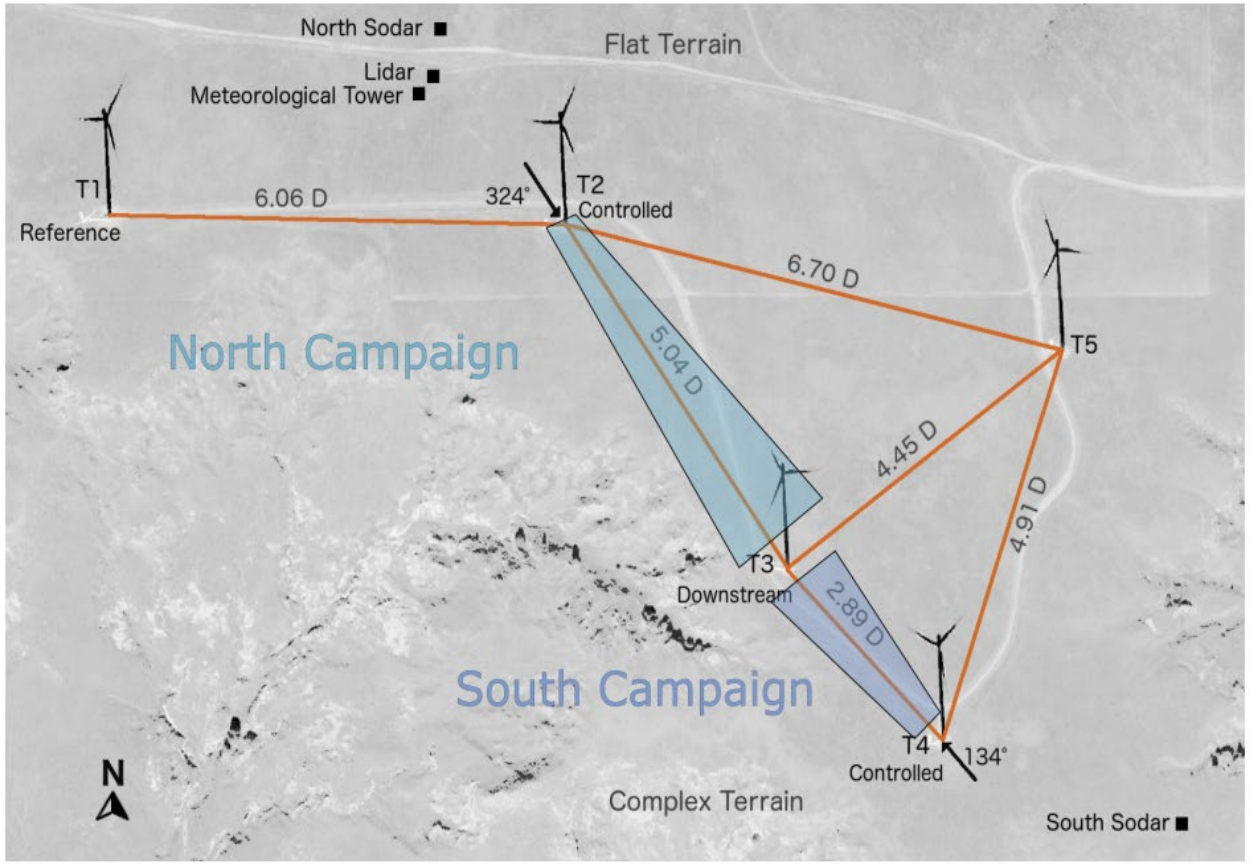


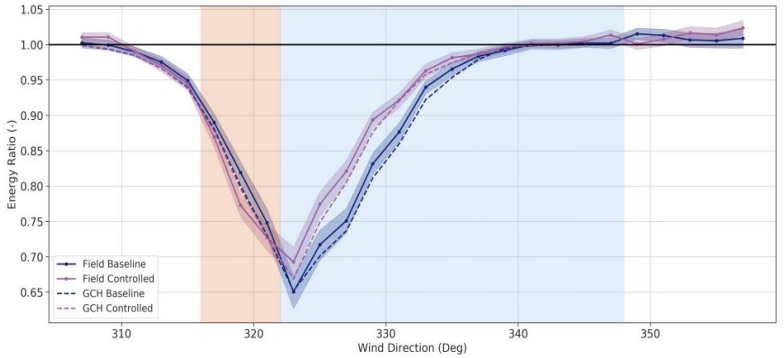
Design and analysis of a spatially heterogeneous wake

Alayna Farrell, Jennifer King, Caroline Draxl, Rafael Mudafort, Nicholas Hamilton, Christopher J. Bay, Paul Fleming, and Eric Simley
National Renewable Energy Laboratory, Golden, CO, 80401, USA

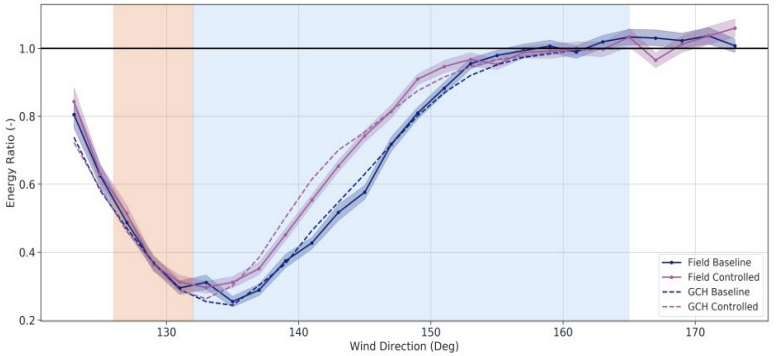
Received: 28 Feb 2020 – Accepted for review: 13 Mar 2020 – Discussion started: 17 Mar 2020

Validation for wind farm control is increasing





(a) North Campaign

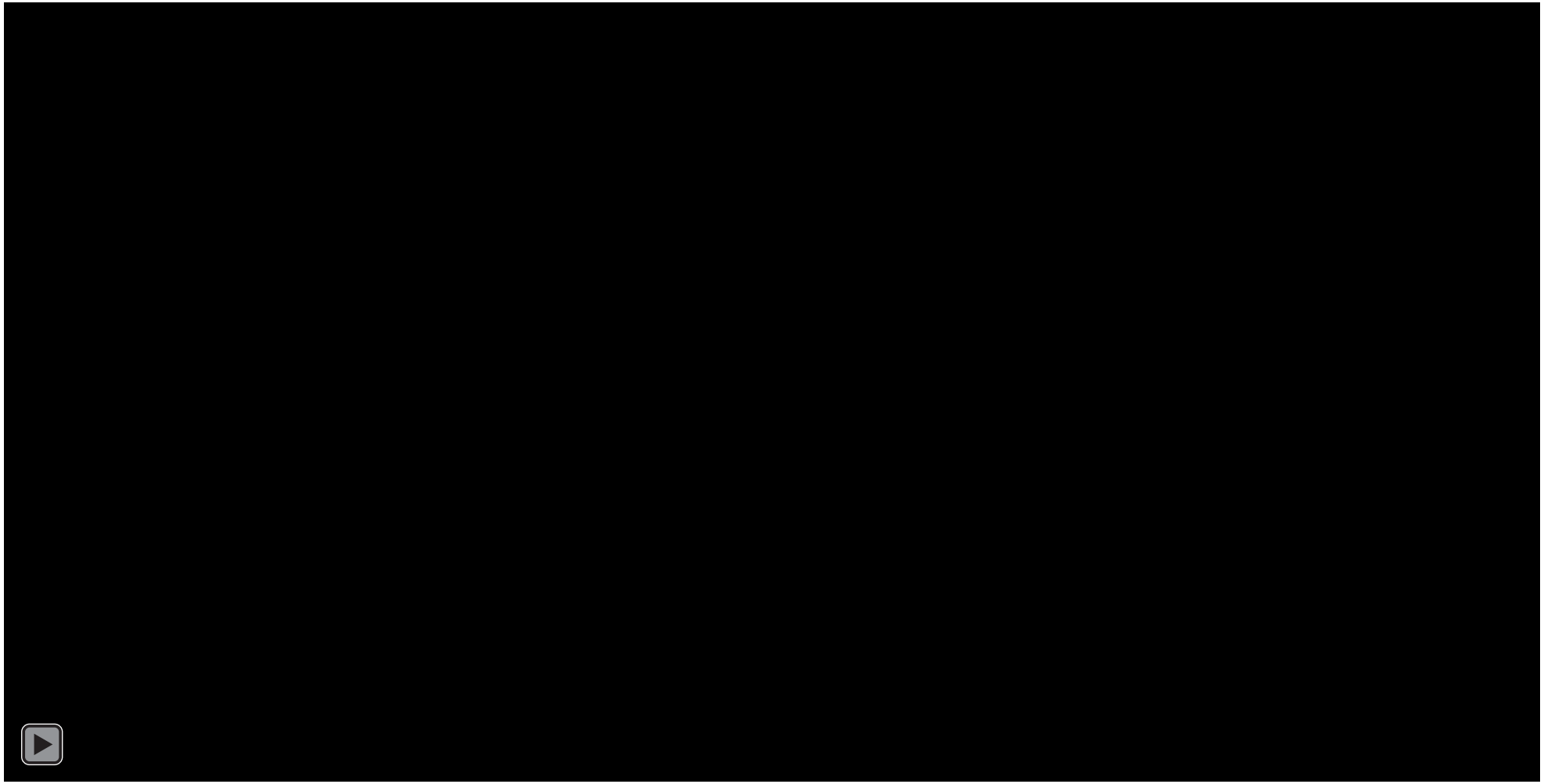


(b) South Campaign

Implementation in dynamic environments

- Much to date research focused on steady simulations of fixed conditions
  - For example, LES simulations of one atmospheric condition with a fixed wind direction
- Future control research will examine performance in dynamic conditions
  - For example, meso-micro coupled LES simulations which implement a full 24 hour period to capture changes across several dimensions
- What control strategies will address these challenges?

Dynamic flow and control



Dynamics, uncertainty and control