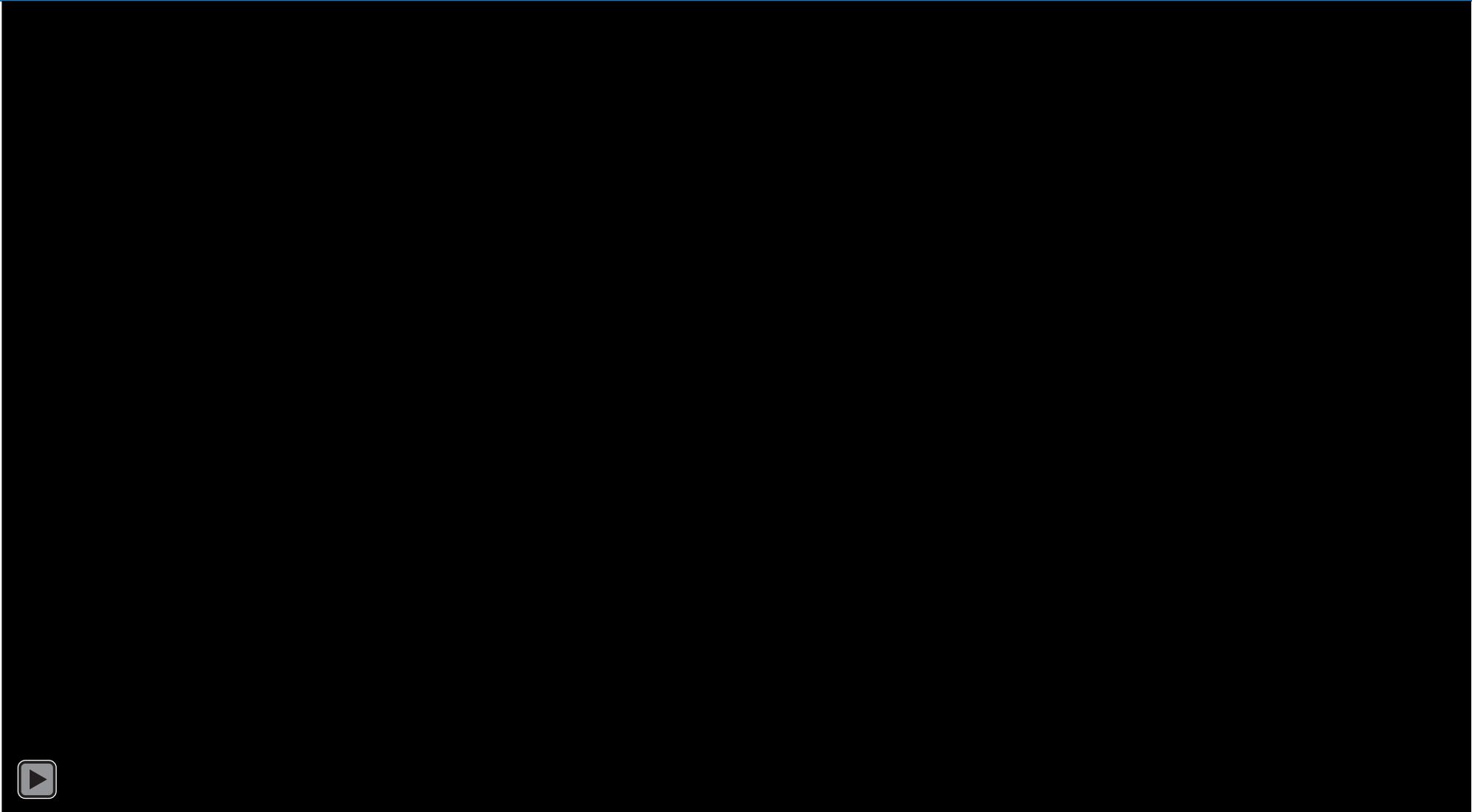


# Modeling for Controls

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>

NREL / floris

Unwatch 9 Star 1 Fork 7

Code Issues 0 Pull requests 0 Projects 0 Wiki Security Insights Settings

A controls-oriented engineering wake model. Documentation at <http://floris.readthedocs.io/>

Manage topics

736 commits 4 branches 9 releases 7 contributors Apache-2.0

Branch: master New pull request Create new file Upload files Find File Clone or download

paulf81 Merge pull request #11 from NREL/develop Latest commit 20094e0 20 hours ago

.github	Update the github issue and pr templates	3 months ago
docs	Add v1.1.0 changelog	12 days ago
examples	Fix n sim	21 days ago
floris	changing Ct for wind speeds below min. wind speed to 0.99	21 hours ago
share	Propagate the new wake model names	last month
tests	Update unit tests to new ct/yaw	21 hours ago
.gitignore	Update documentation build settings	2 months ago
.travis.yml	Update requirements	4 months ago
LICENSE.txt	Attach the complete Apache 2.0 license	last year
README.rst	Add the FLORIS v1.0.0 DOI	last month
requirements.txt	Separate dependencies by module	last month
setup.py	Update version number to v1.0.0.	last month

README.rst

## FLORIS Wake Modeling Utility

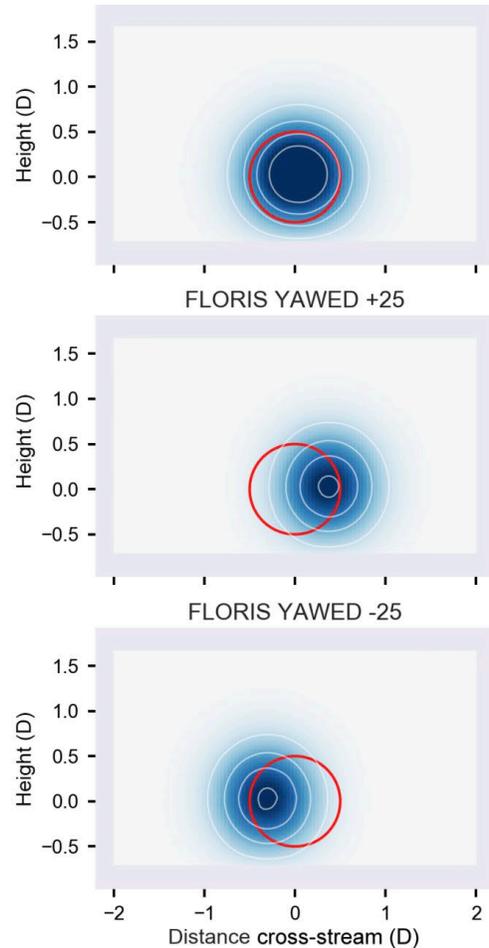
# What are some open questions?

- 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?

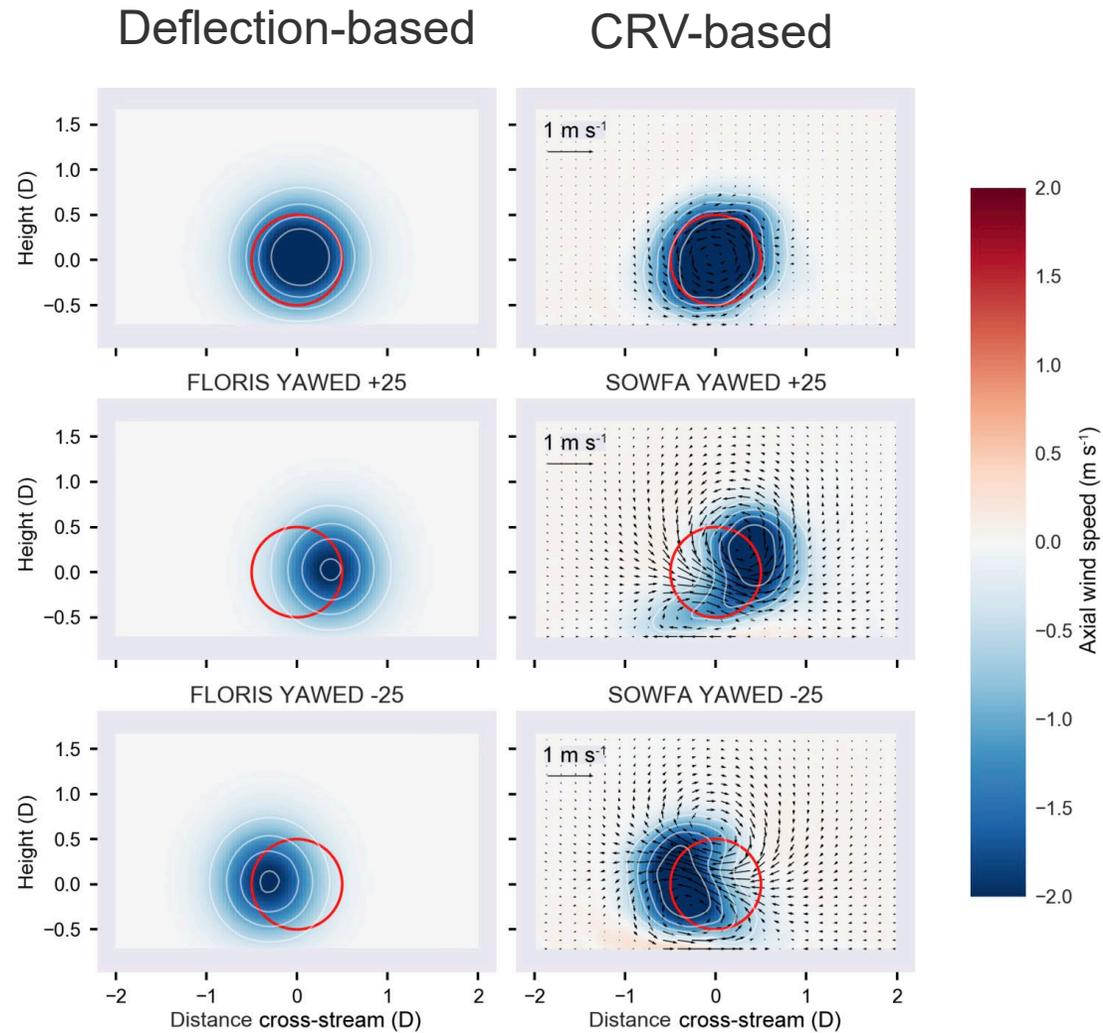
*In this talk, will review some highlights of NREL's research into these questions*

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

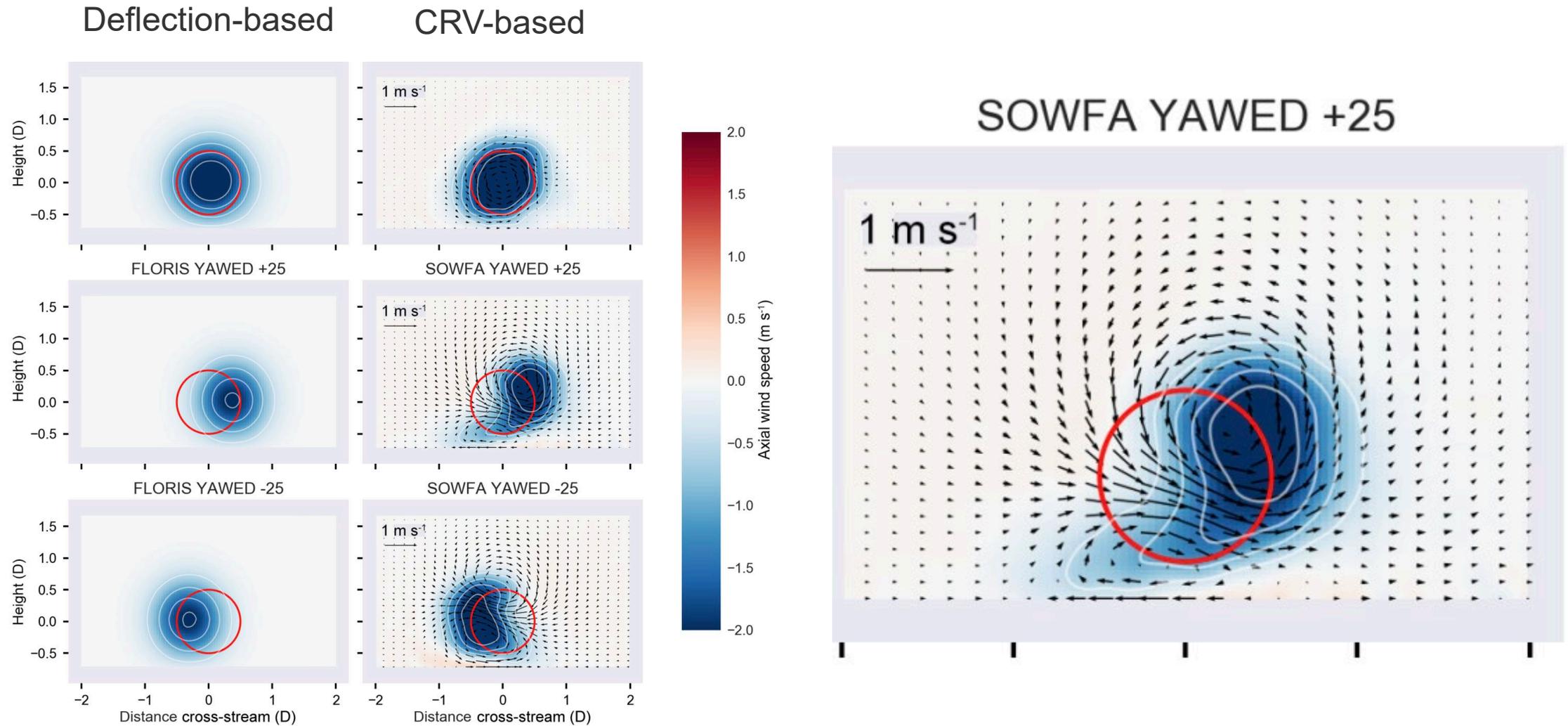
## Deflection-based



# 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

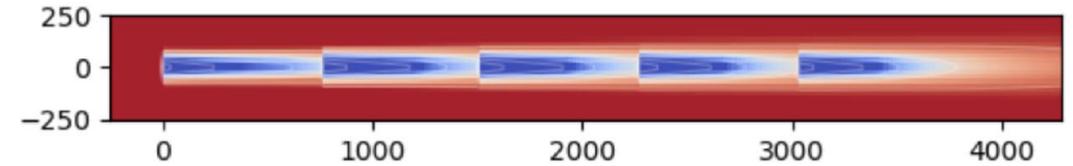


# New Gauss-Curl Hybrid (GCH) Model in FLORIS seeks to include these second order effects in analytical approximation

## Controls-Oriented Model for Secondary Effects of Wake Steering

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

Received: 10 Jan 2020 – Accepted for review: 04 Feb 2020 – Discussion started: 11 Feb 2020

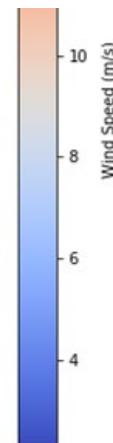
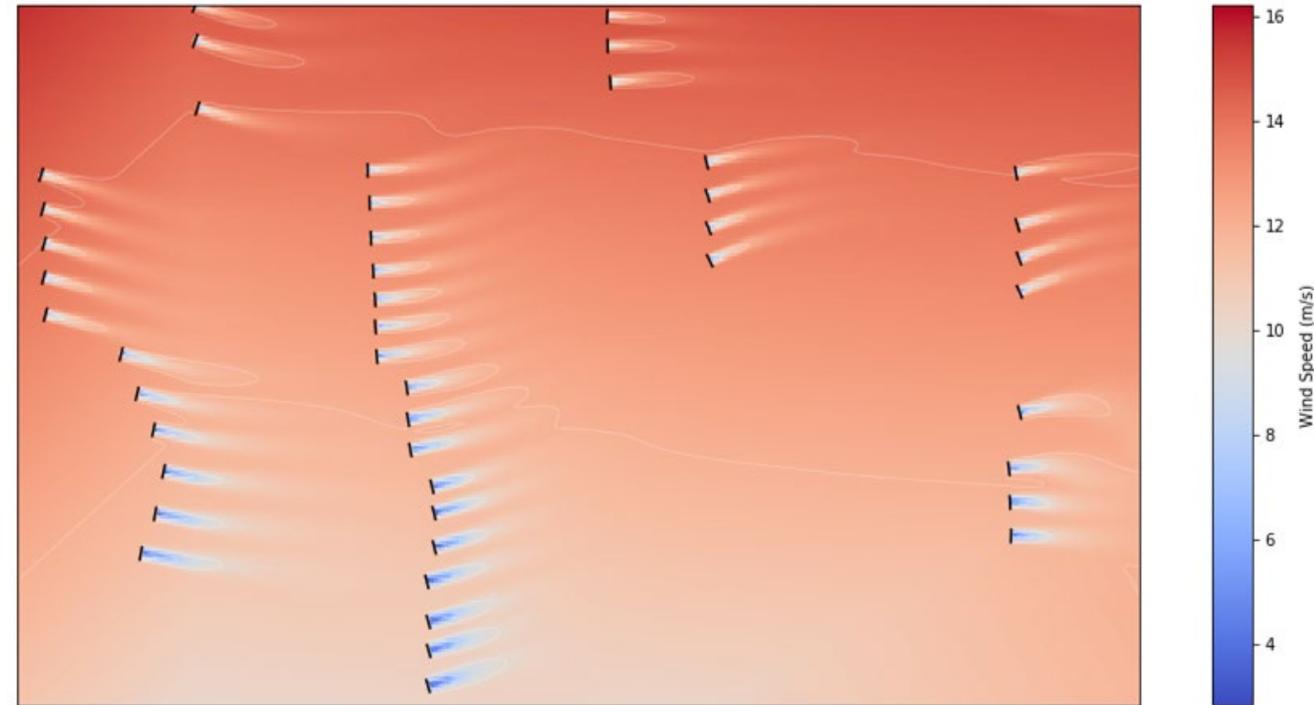
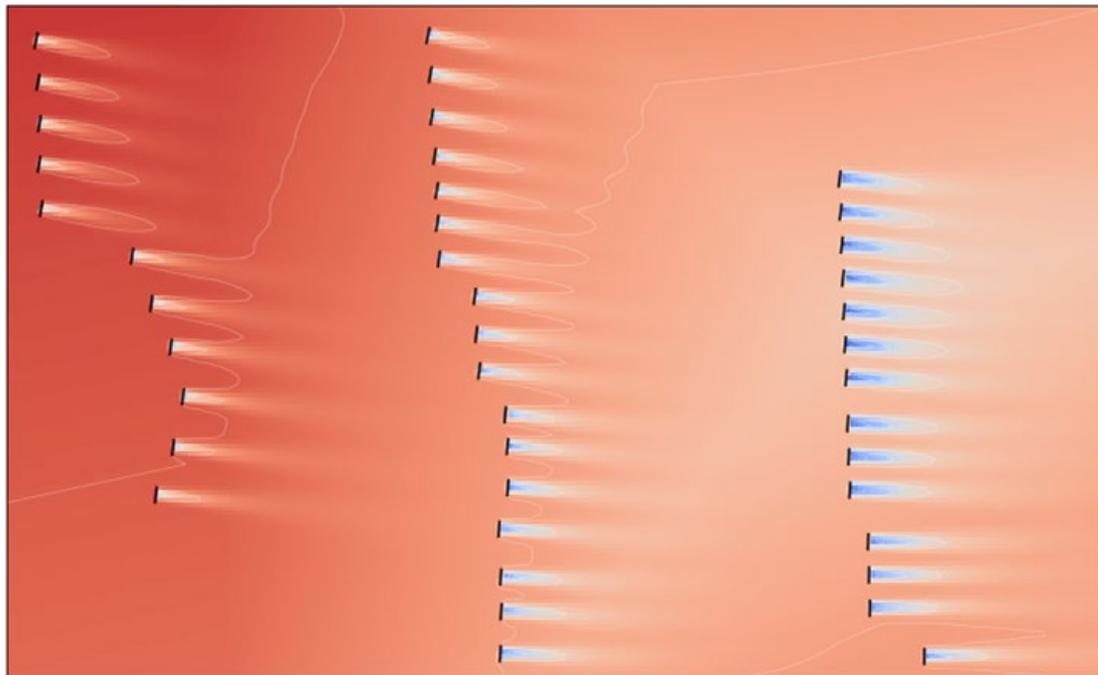


Case	Turbine 1	Turbine 2	Turbine 3	Turbine 4	SOWFA Gain	Gauss Gain	GCH Gain
Low Turbulence							
Gauss optimized angles	24.0	25.0	25.0	25.0	22.7%	9.9%	23.1%
GCH optimized angles	25.0	25.0	22.1	18.7	23.7%	9.4%	23.5%
Max yaw angles	25.0	25.0	25.0	25.0	22.9%	9.8%	23.3%
High Turbulence							
Gauss optimized 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

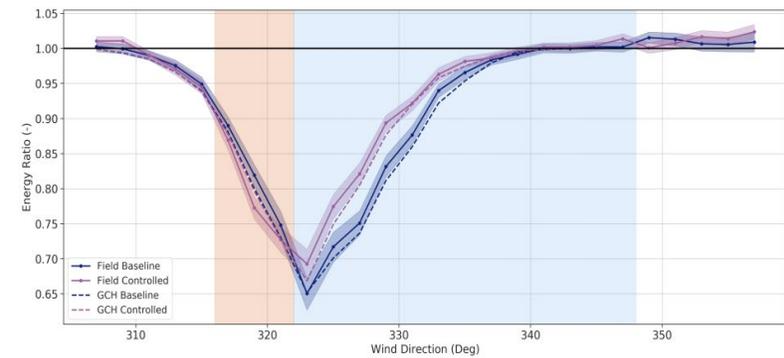
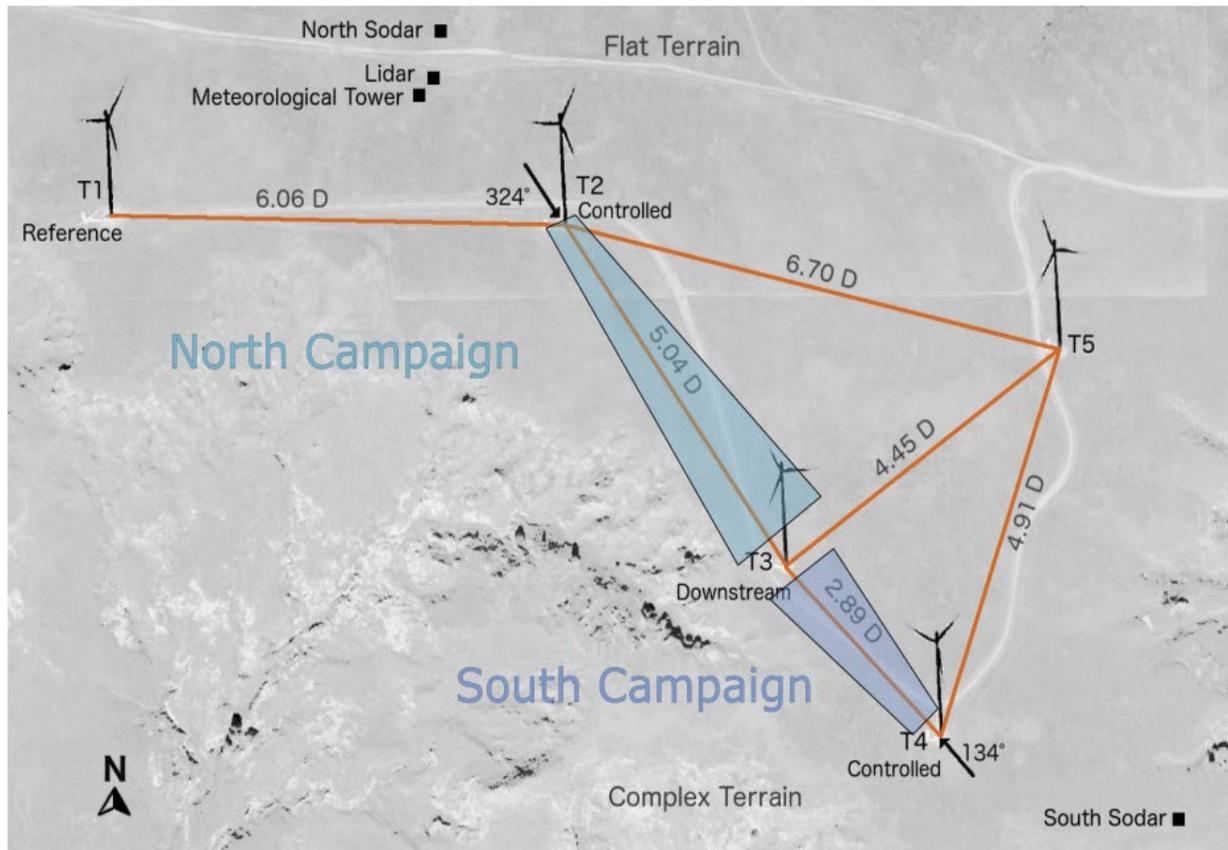


## Design and analysis of a spatially heterogeneous wake

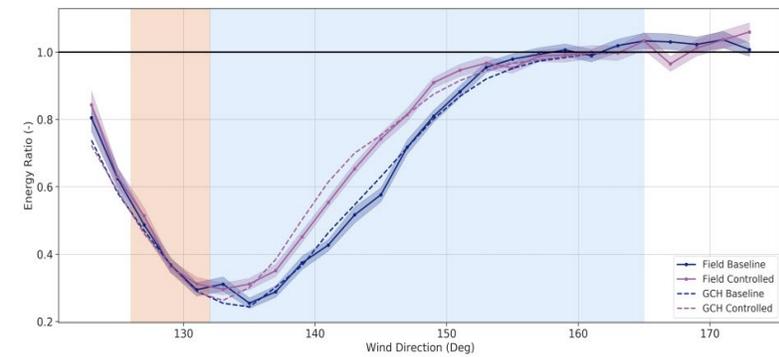
Alayna Farrell, Jennifer King, Caroline Draxl , Rafael Mudafort, Nicholas Hamilton, Christopher J. Bay , Paul Fleming , and Eric Simley   
National Renewable Energy Laboratory, Golden, CO, 80401, USA

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

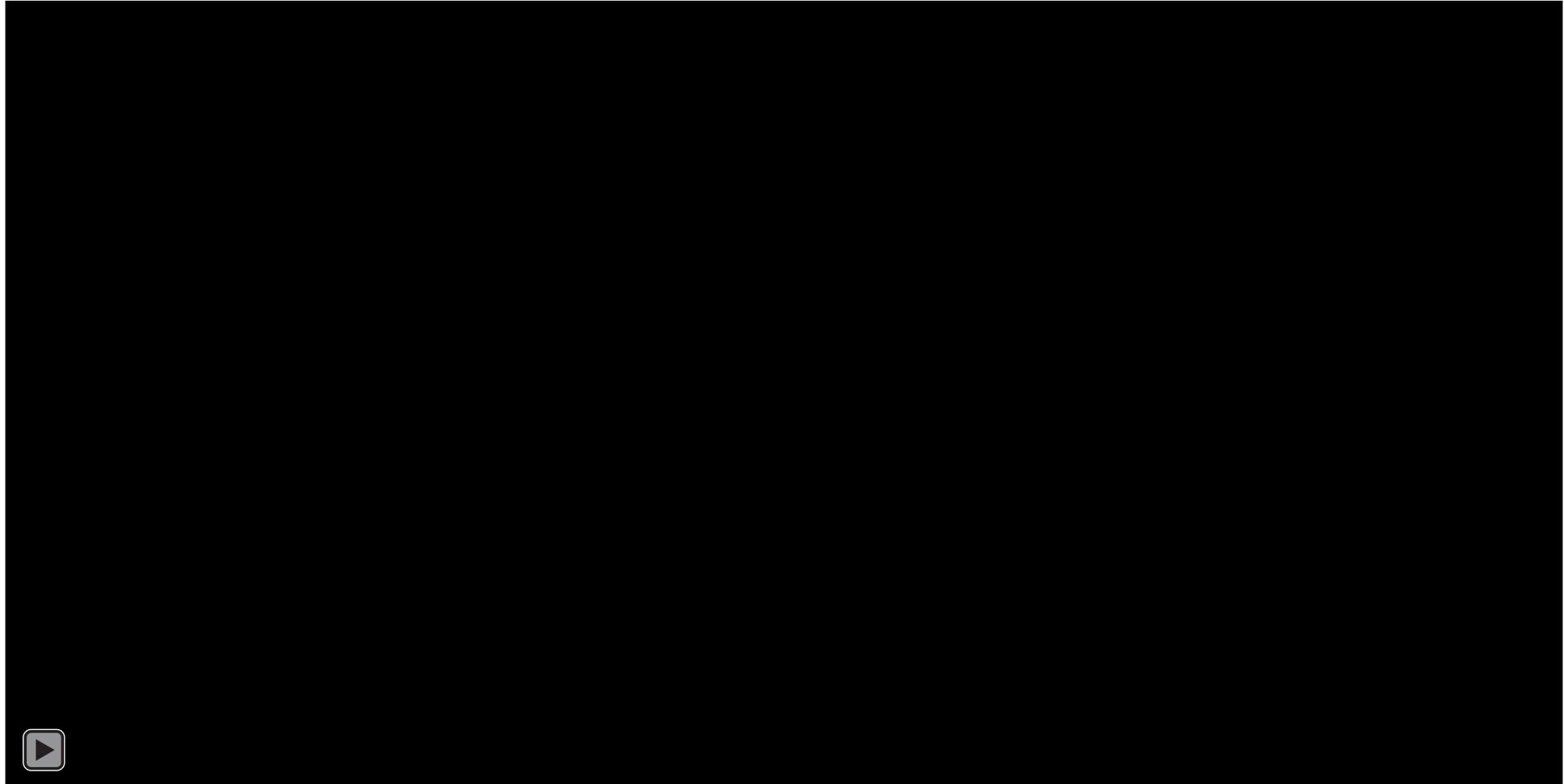


(b) South Campaign

# 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

