IEA Wind Tasks, Wind Turbine LES, Wind Turbine Aerodynamics, Wind Farm Modelling

Ryan Kilpatrick, Research Engineer, CanmetENERGY – Ottawa, Natural Resources Canada / Government of Canada

March 24, 2021

Canadian Wind Energy Research Network

In Memory of Prof. Christian Masson (1963 – 2021)

BIng’87 & MScA’89 (Polytechnique M)

PhD’93 (McGill)

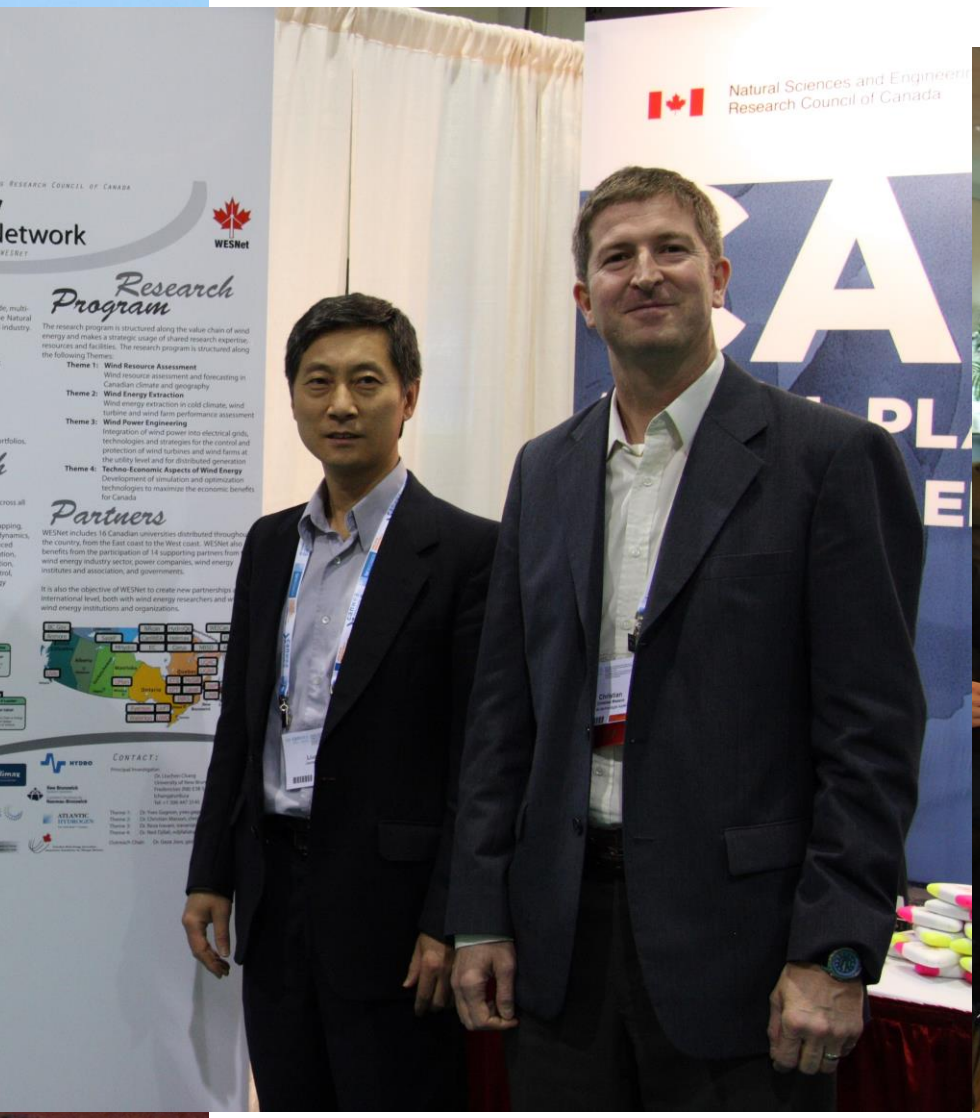
Professor of Mech. Eng., ETS (1997 – 2021)

Expert in aerodynamics

Canada Research Chair

Leader of Theme 2 of WESNet

Instrumental in Wind TechnoCentre


Natural Sciences and Engineering
Research Council of Canada
WESNet
Research Program
Partners
Contact:

International Energy Association Task 28

Social Science of Wind Energy Acceptance

Jamie Baxter, University of Western Ontario

Canadian Wind Energy Research Network

Western SocialScience

Jamie Baxter

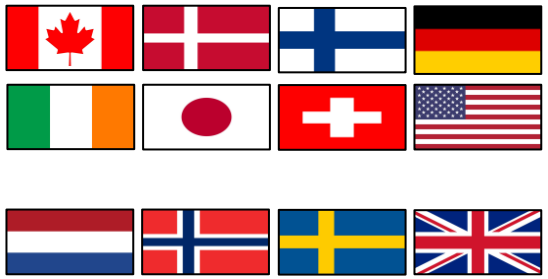
Professor, Department of Geography and Environment

<u>Overview</u>: Task 28 (Social Science of Acceptance)

- Phase IV (2020-2024)
- To study and mobilize knowledge about community-focused strategies based on numerous systems working together to reach agreement on energy planning for the good of the host communities and others
- 8 members countries:
  - Canada, Denmark, Finland, Germany, Ireland, Japan, Switzerland, USA
- 4 observer countries
  - Netherlands, Norway, Sweden, UK

Task 28

Social Acceptance of Wind Energy Projects



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Jamie Baxter

Professor, Department of Geography and Environment

Activities Task 28 (Social Science of Acceptance)

- **Representatives**
  - Academics (mostly), industry, regulators
- **Meetings**
  - Face-to-face (pre-covid) Spring and fall
  - Virtually according to the work packages
- **Knowledge Mobilization**
  - https://community.ieawind.org/task28/home
  - Symposia, webinars, workshops, pamphlets, guidebooks

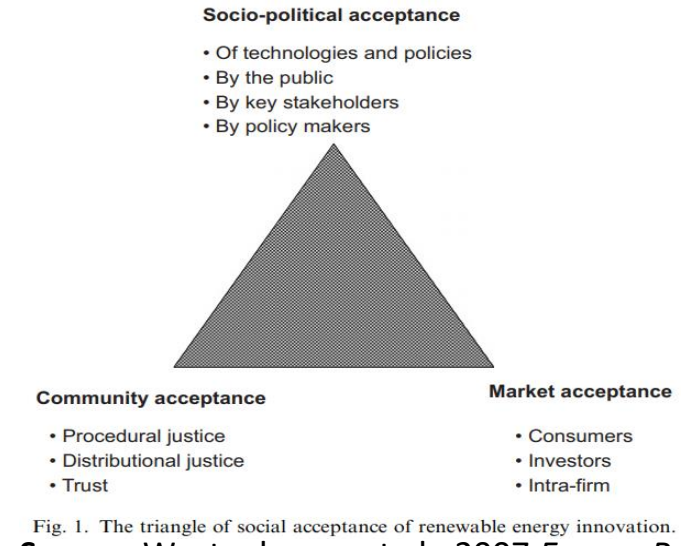

Fig. 1. The triangle of social acceptance of renewable energy innovation.

Source: Wustenhagen et al., 2007 *Energy Policy*

MOCWE: meaning of "community wind energy"
Includes meaning of Indigenous ownership

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Work Packages Task 28 (Social Science of Acceptance)

Track 1: Research Synthesis and Gap Analysis

1. Innovations in value additions and benefit schemes from wind projects.

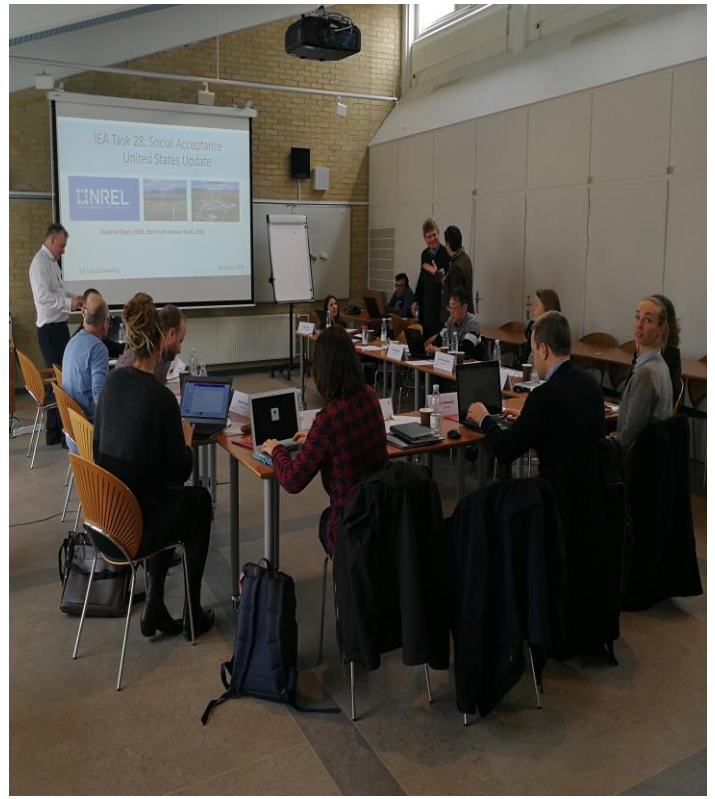
2. Understanding costs associated with community engagement and opposition

3. New and emerging issues in wind energy acceptance (e.g., supersized turbines, decommissioning/repowering, floating offshore systems)

Track 2: Research Dissemination, Facilitation, and Knowledge Exchange

4. Increased global engagement and knowledge exchange of wind energy acceptance and social science

5. Offshore wind working group on social acceptance: expert convening and information dissemination



Task 28 meeting Roskilde, Denmark March 2018 (Phase III)

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Outcomes Task 28 (Social Science of Acceptance)

- **Knowledge generation**
  - Coordination of research efforts (shared questionnaire items)
  - Avoid duplication
- **Deeper networks**
  - Academic collaborations
- **Focused training**
  - E.g., MISTRAL EU (PhD) training network
    - community-university-industry partnerships
    - Trainees required to spend a term working in the industry

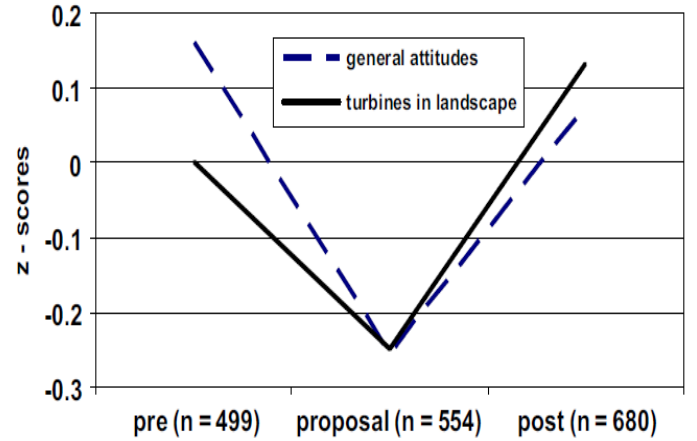


Fig. 2. The evolution of evaluation of turbines in the landscape, compared with the U-shape development of wind power attitudes.

Source: Woolsink, 2007 *Energy Policy*

MISTRAL: Training a new generation of renewable energy experts

NERGICA

Marc Defossez

Lead Project Manager, Nergica

- Task 32 in brief: to indentify/mitigate barriers to the use of Lidar for Wind Energy Deployement
  - Includes: site assessment, power performance, load/control, complex flow
- Current activities (groups):
  - Wind Lidar in complex terrain (academic + commercial application, usefulness of increased accuracy, errors of numerical methods, scanning whole park instead of flow modelling, data availability)
  - Wind Lidar in cold climates (icing detection, physics of aerosols, data availability)
  - Floating Lidar systems (normative reference for wind measurements from floating Lidars)
  - Turbulence intensity (TI definition, TKE/TI, need for high freq. data, academic solutions for industry)
  - Lidar-assisted control (design, certification process, OEM's needs <-> manufacturers)
  - Forecasting (horizontal scans, weather prediction models for forecasting)
  - Collaboration on wind Lidar HW and SW (Open source SW may help to adopt standards)

NERGICA

iea wind

Sergio Gualteros

Project manager, Nergica

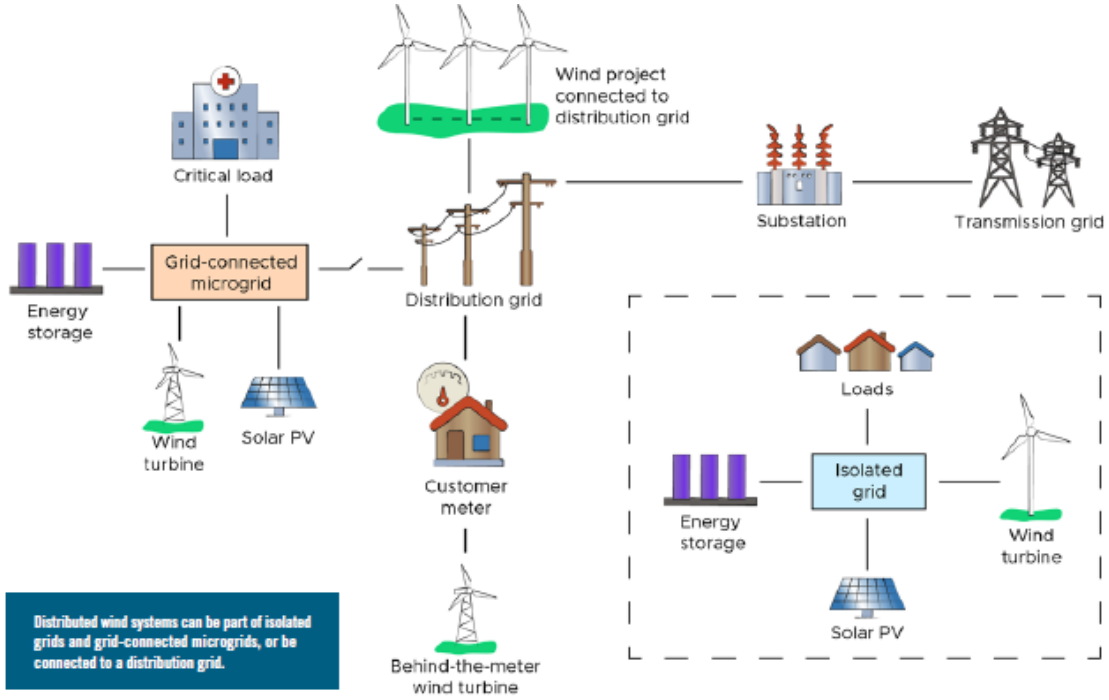
Task 41 IEA Wind: Enabling wind to contribute to a distributed energy future

Objectives:

- Coordinate international distributed wind energy research
- Facilitate collaboration on priority research topics
- Increase the visibility of wind technology as a distributed energy resource

IEA Wind Task 41's Work Packages

- **Standards:** Research to support development of design and testing guidelines for small and mid-sized wind turbines (CSA 61400-2 / AWEA SWT-1)
- **Data Catalog:** Create an information sharing platform for distributed wind research and data
- **Integration:** Enable efficient and reliable integration of wind technology into evolving electricity systems
- **Outreach and Collaboration:** Facilitate and coordinate distributed wind research with other IEA tasks and international organizations
- **Innovation and Downscaling of Large-Scale Wind Technology:** Apply advances of large-scale wind technology to smaller-scale wind technology



LES Simulation of Flow Over Wind Turbines in Complex Terrain

Arjun Ajay
PhD Student, UBC-Okanagan

Canadian Wind Energy Research Network

Introduction

- Modeling of wind farms in complex terrains due to terrain topology and roughness effects.
- Understand their impact on downstream wake growth and upstream blockage effect of the wind turbine
- Develop local induction model incorporating the effects of complex terrain to predict blockage upstream of single rotor.

EcoPower, Hirokawa-Hidakagawa Windfarm (Wakayama Pref., Japan, 10x2MW DWT)
Source:https://www.ecopower.co.jp/image/wind_power/hirogawa_gallery01.jpg

Numerical Modeling

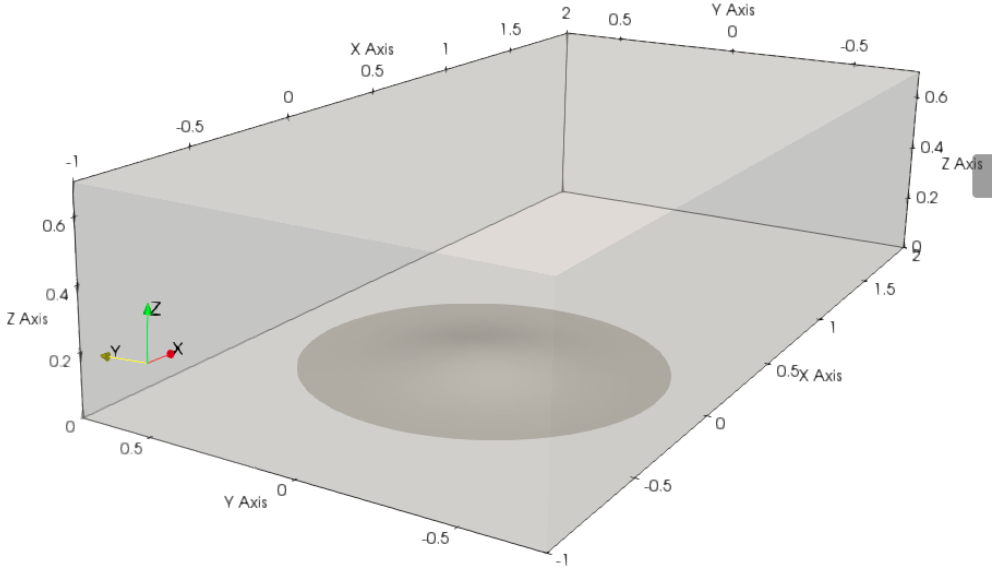
- Large eddy simulation to model the neutral atmospheric boundary layer flow
- Sharp interface immersed boundary method to model the complex terrain (here a gaussian hill)
- Wind turbine is modeled as an actuator disk

Modeling parameters

	Domain
Dimensions	(X–3.0, Y–1.5, Z-0.7) m
Number of cells	150 x 100 x 100

	Turbine and flow conditions
Velocity at Hub height(Uhub)	8 m/s
Hub height (zhub)	0.06 m
Turbine Diameter (D)	0.045 m
Roughness length	3.3 microns
Friction Velocity (m/s)	0.326 m/s

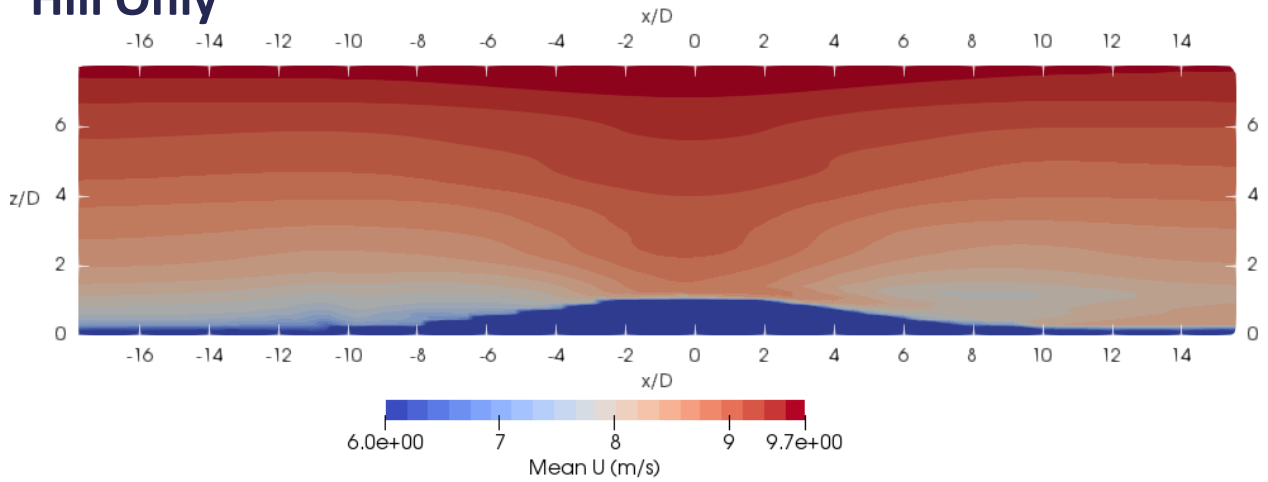
	Hill Dimension
Hill Height	1D = 0.045m
Hill Profile	Gaussian surface which reduces to 0.01D within 13D



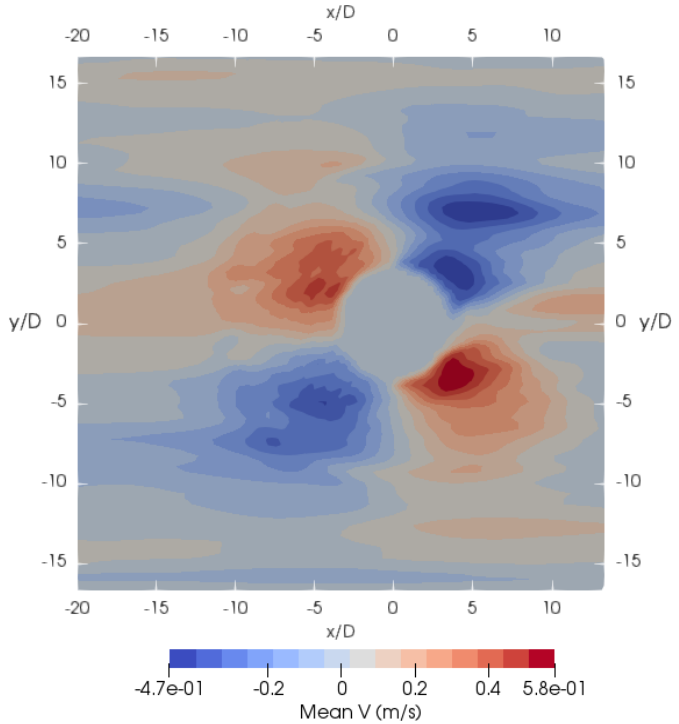
Simulation domain with the gaussian hill profile

Preliminary Results

Hill Only

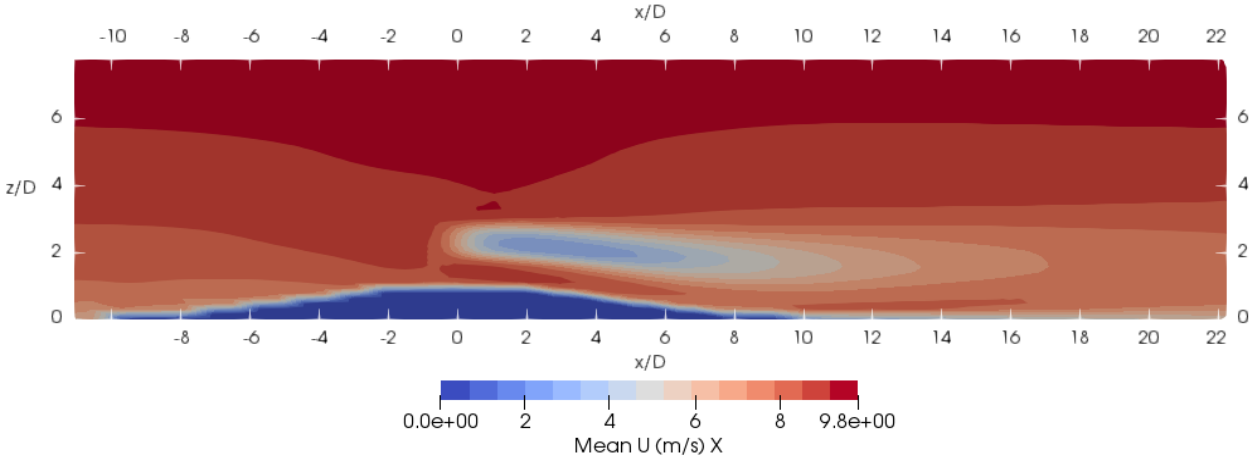


Streamwise mean velocity on a surface y/D = 0 (middle of the domain)



Spanwise mean velocity on a surface z/D = 0.75

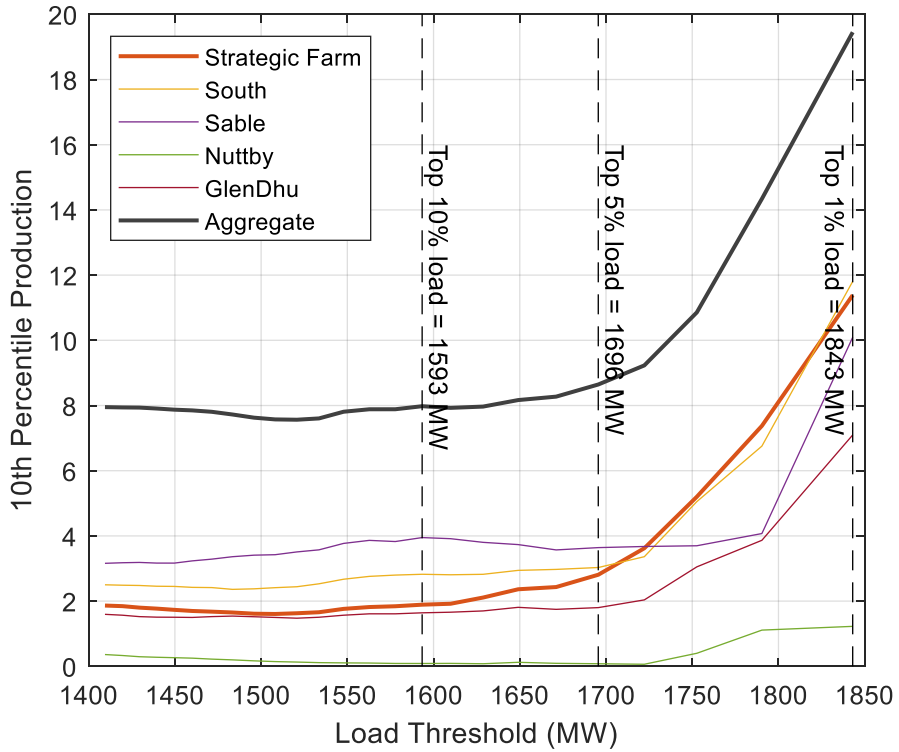
Hill + Turbine



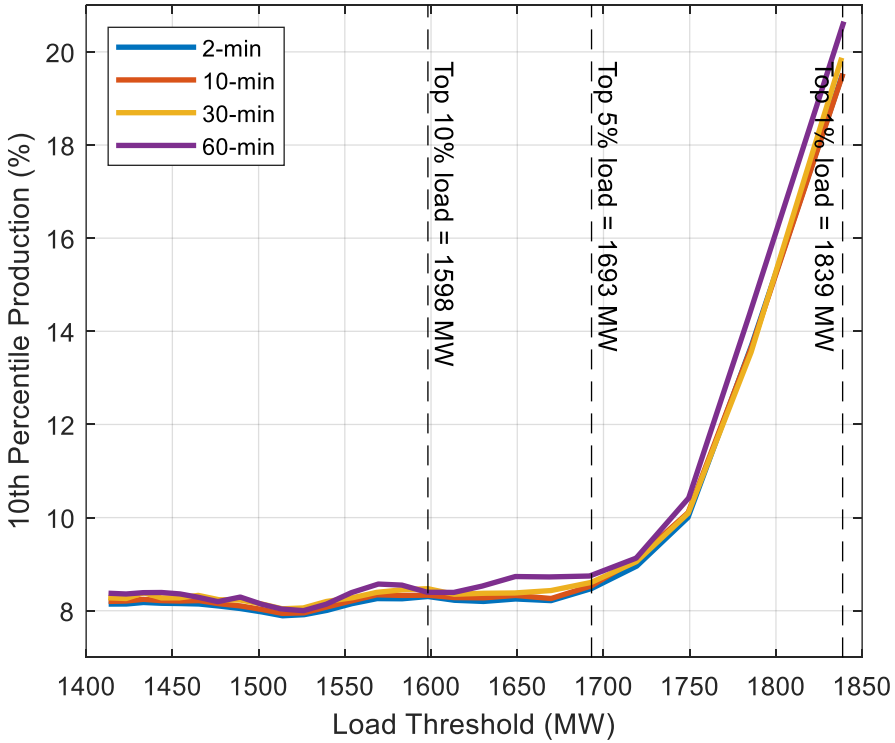
Streamwise mean velocity on a surface y/D = 0 (middle of the domain)

David Kiefte (MASc Student), Nathaniel Pearre (PhD), Lukas Swan (PhD)
Renewable Energy Storage Lab – Dalhousie University – David.Kiefte@dal.ca

- Capacity value quantified as *reliable production at high loads* for wind farms in Nova Scotia. Data provided by Nova Scotia Power (NSP)
- Capacity value *differences between wind farms*
  - Four NSP wind farms compared to one wind farm with strategic maintenance
  - No observed impact to capacity value by maintenance strategy, instead impacted by siting location



- Capacity value *differences between data resolution*
  - Using aggregate wind production in NS – Resolution artificially altered between capacity value calculations
  - There is little impact to capacity value when resolution is changed from 2-minutes to 60-minutes, however at greater timesteps there is a significant impact



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David Wood

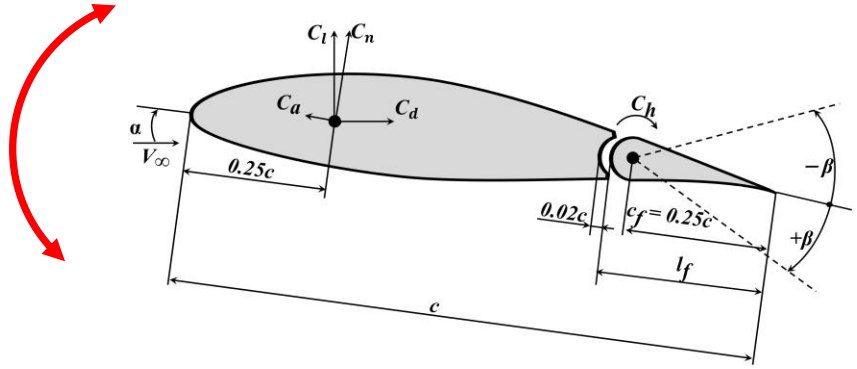
Professor of Renewable Energy

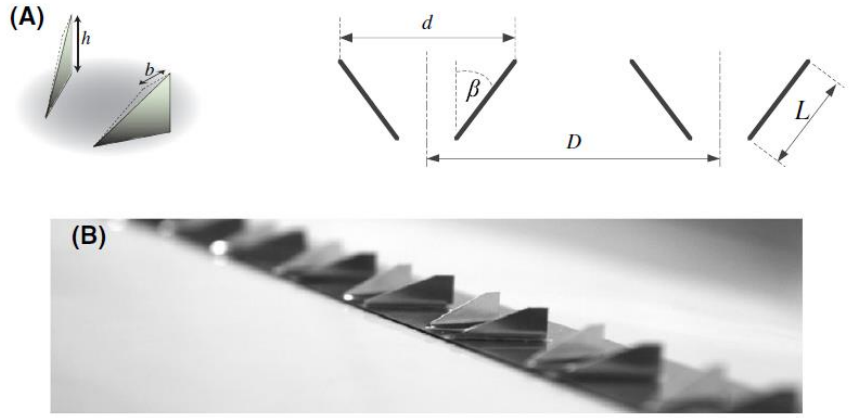
Unsteady Behaviour of Smart Airfoils

- Unsteady lift and drag are much more complex than steady forces
- Accurate models needed for aerodynamic modelling and real time control
- Experiments and modeling of bare airfoils, controlled trailing edge flaps (TEFs) and vortex generators (VGs)
- Direct measurement of lift and drag and particle image velocimetry (PIV) of the flow field

U

Sinusoidally pitched airfoils





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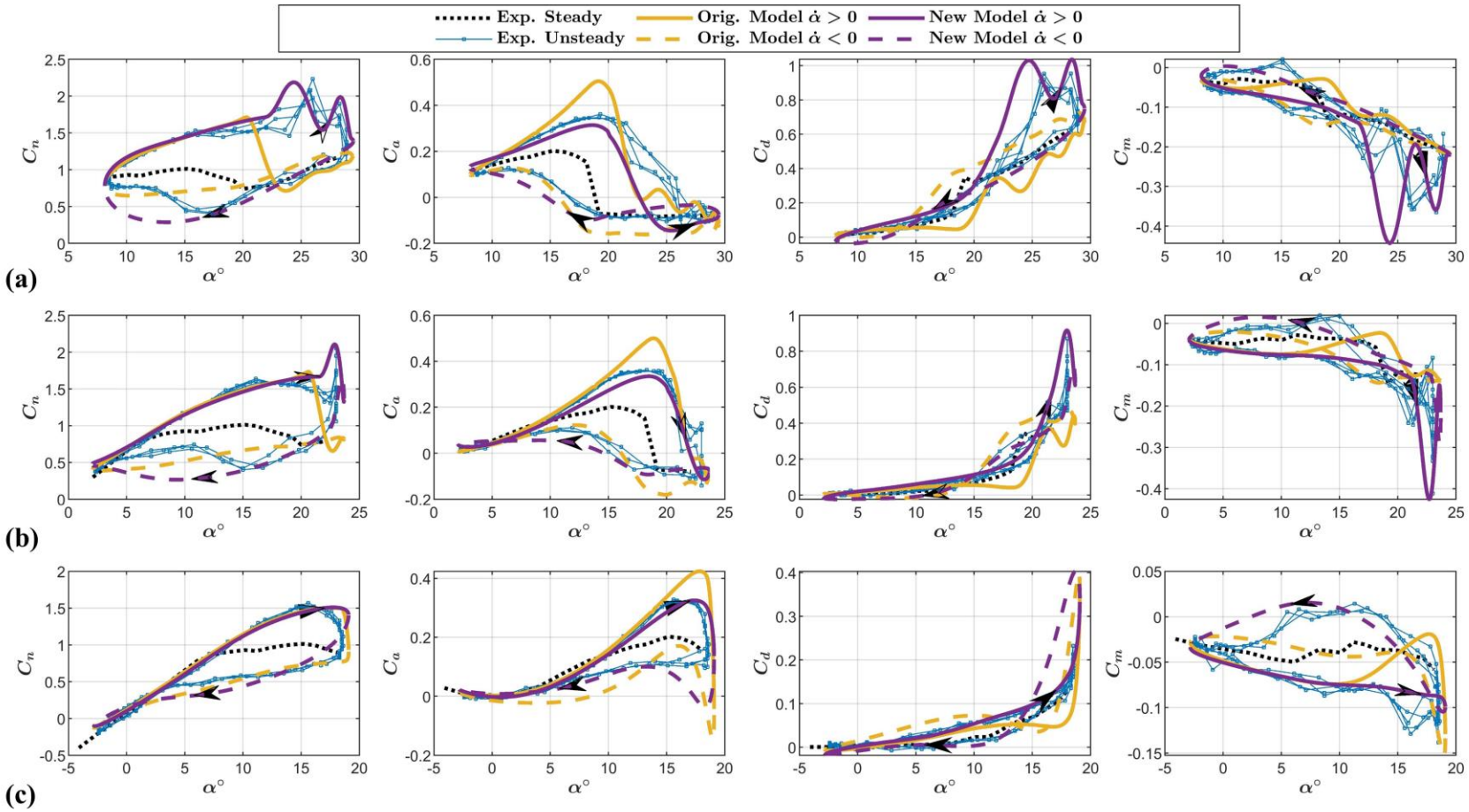
Model response for sinusoidal pitching of the S809 airfoil

$$\alpha = \alpha_m + \alpha_o \sin \omega t$$

α_m mean pitch angle
α_o pitch amplitude
$k = \omega c/(2U)$ is the reduced frequency. It measures the level of unsteadiness.

k = 0.077 for results at right



Chord-normal force | Chordwise force | Drag | Pitching moment

Ayman Mohamed, D.H. Wood, "Modeling dynamic loads on oscillating airfoils with emphasis on dynamic stall vortices", *Wind Energy* (to appear).

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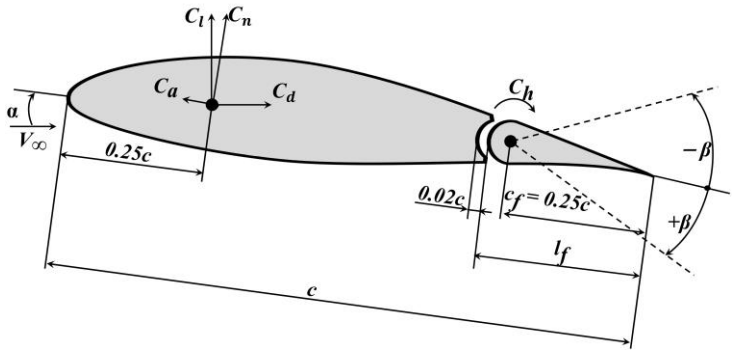
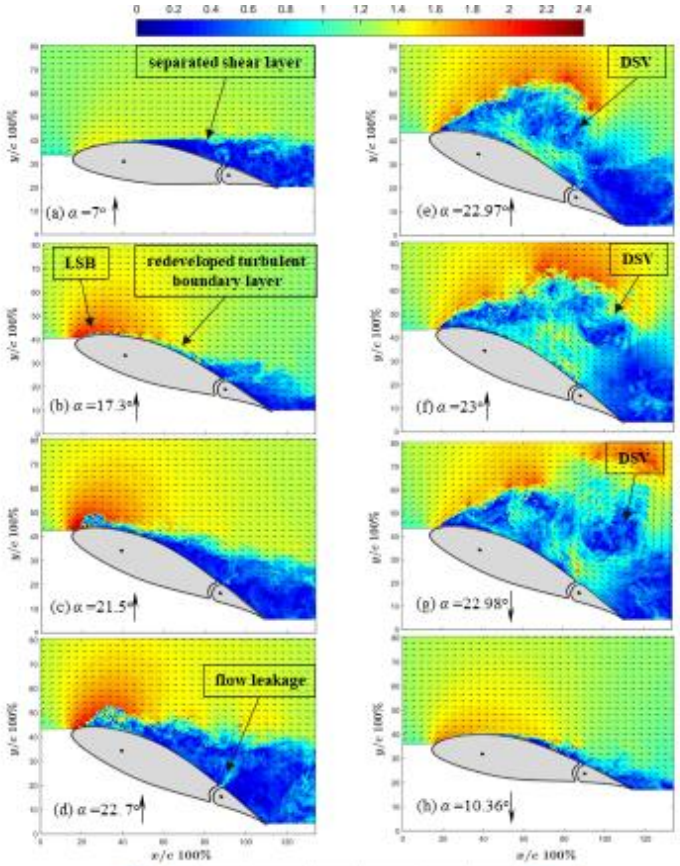
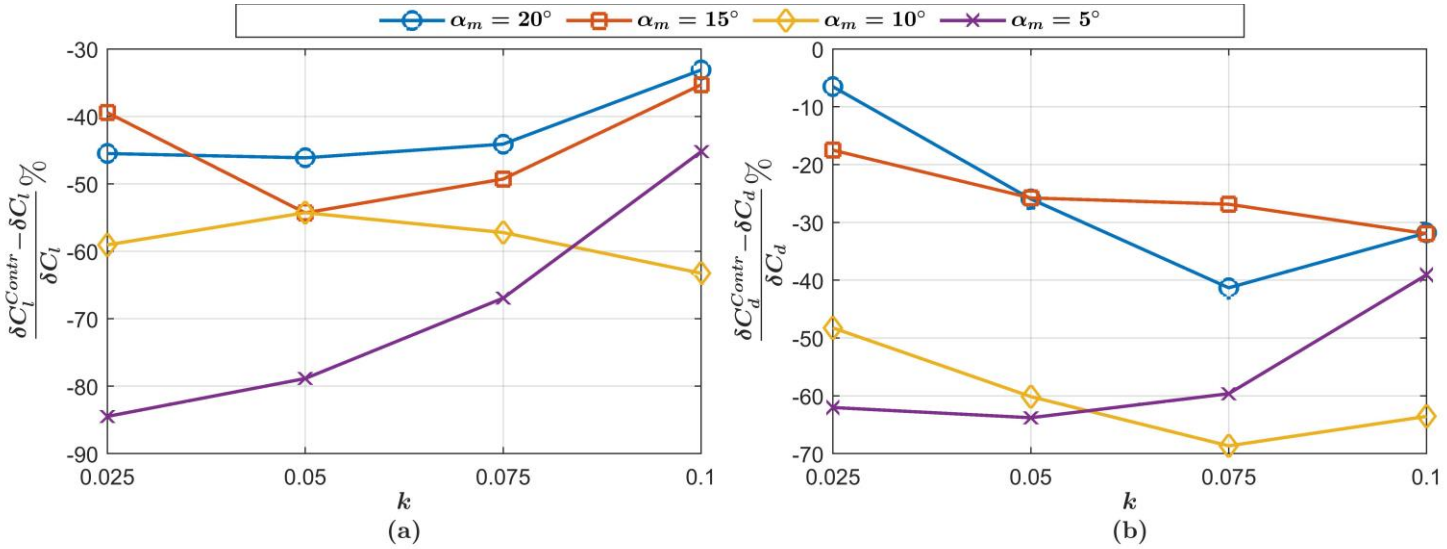
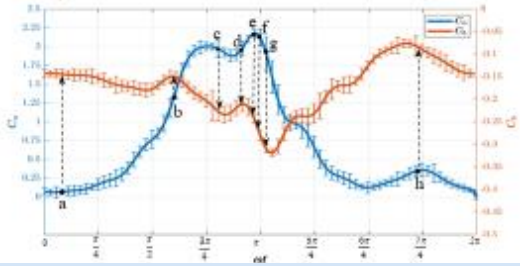


PIV of the instantaneous velocity







Ayman Mohamed, Mohamed Abdelhady, David H. Wood, Using the hinge moment of a trailing edge flap for controlling dynamic stall loads, *Experiments in Fluids* (to appear).

Ayman Mohamed, Jeff Pieper, David H. Wood, Modeling and Control of Dynamic Stall Loads on Smart Airfoils, in preparation

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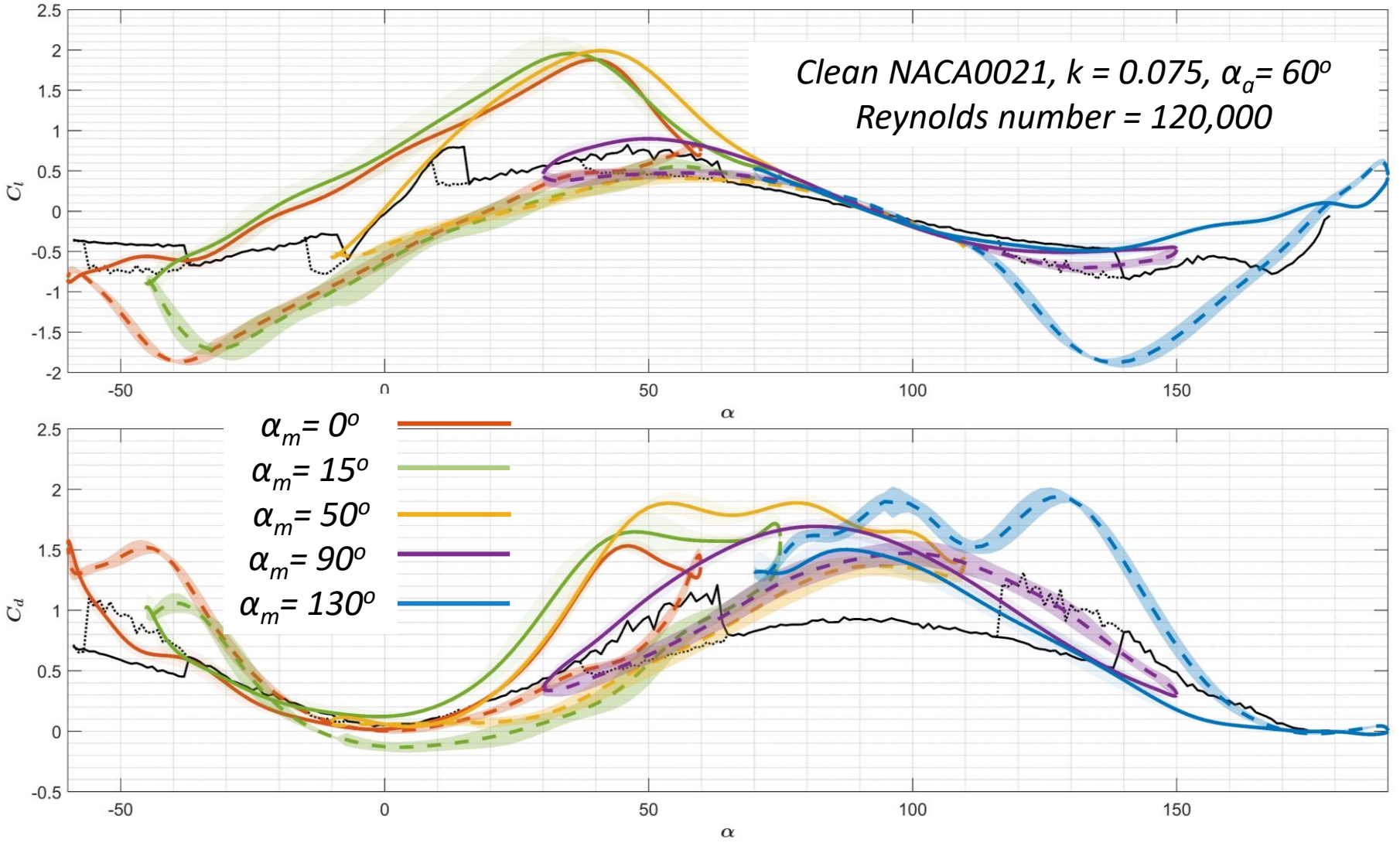
David Wood

Professor of Renewable Energy

Lift and drag over a wide range of α for application to vertical axis wind turbines. Steady lift and drag shown as thin black lines.

Measurements were done for “clean” airfoil and airfoil with vortex generators. VG results are not shown. This work is very recent and not fully analyzed.



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Future Work

- Extend the impulse analysis of Limacher & Wood (2021) to unsteady flow
- Develop generic blade element model for pitch changes
- Combine this with control strategy to minimize unsteady loads during pitching

NSERC CRSNG

SCHULICH School of Engineering — UNIVERSITY OF CALGARY

Limacher, E. J., & Wood, D. H. (2021). An impulse-based derivation of the Kutta–Joukowsky equation for wind turbine thrust. *Wind Energy Science*, *6*(1), 191-201.

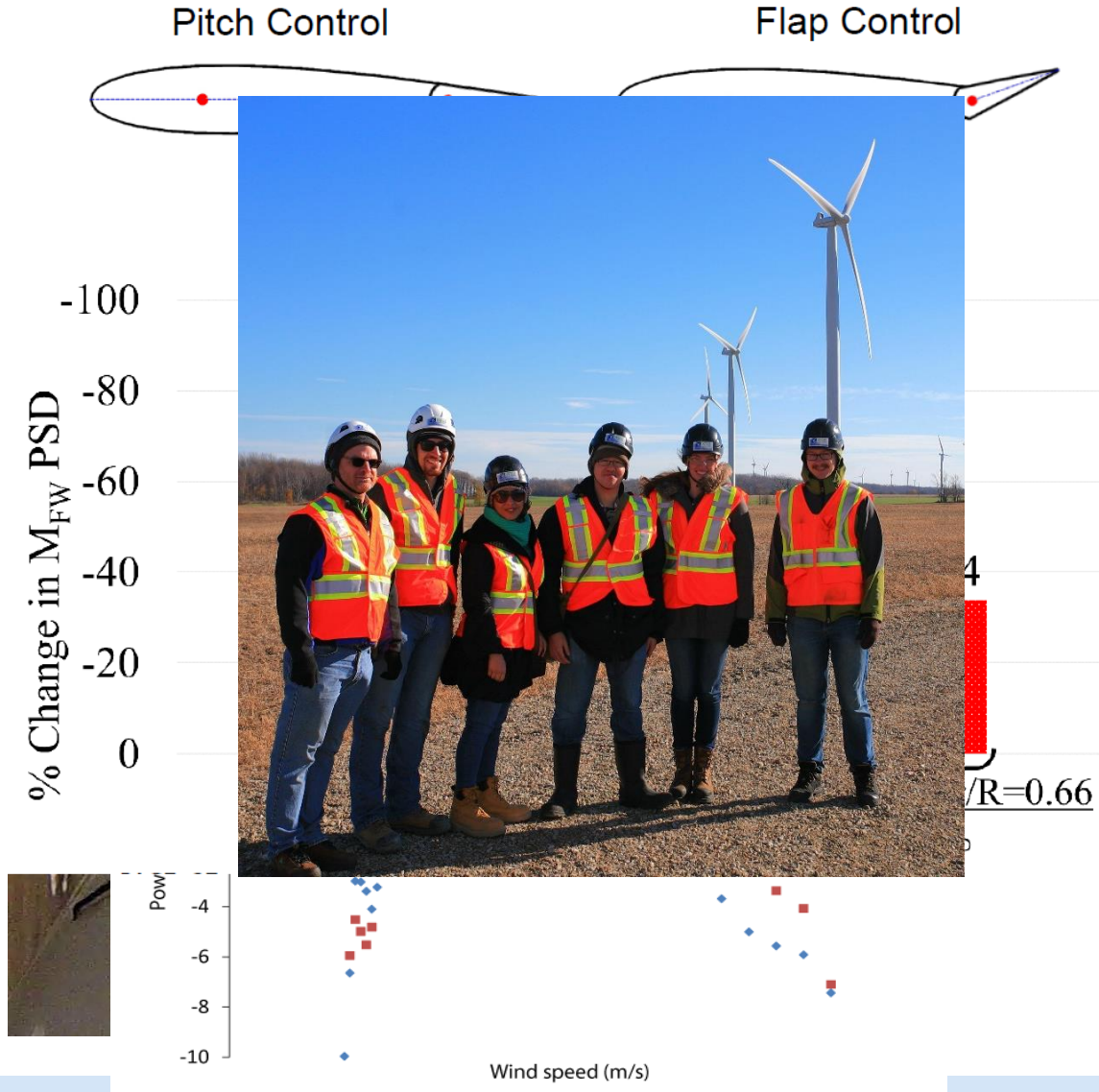
UNIVERSITY OF WATERLOO

David Johnson

Professor, Wind Energy Group, University of Waterloo

Aerodynamics and acoustics of wind turbines

- Large indoor test facility
- Test Turbine
- Field turbine
- Winglets, VG, trailing edge flaps
- Turbine performance in yaw/high shear load
- Projects with operators, supply chain, consultants e.g. blade erosion/monitoring
- Graduates working in most provinces (and internationally) in wind energy industry
- Interactions with other researchers welcome
- Regular exchanges/interaction with European researchers/industry
- Completed applied projects in remote/indigenous communities

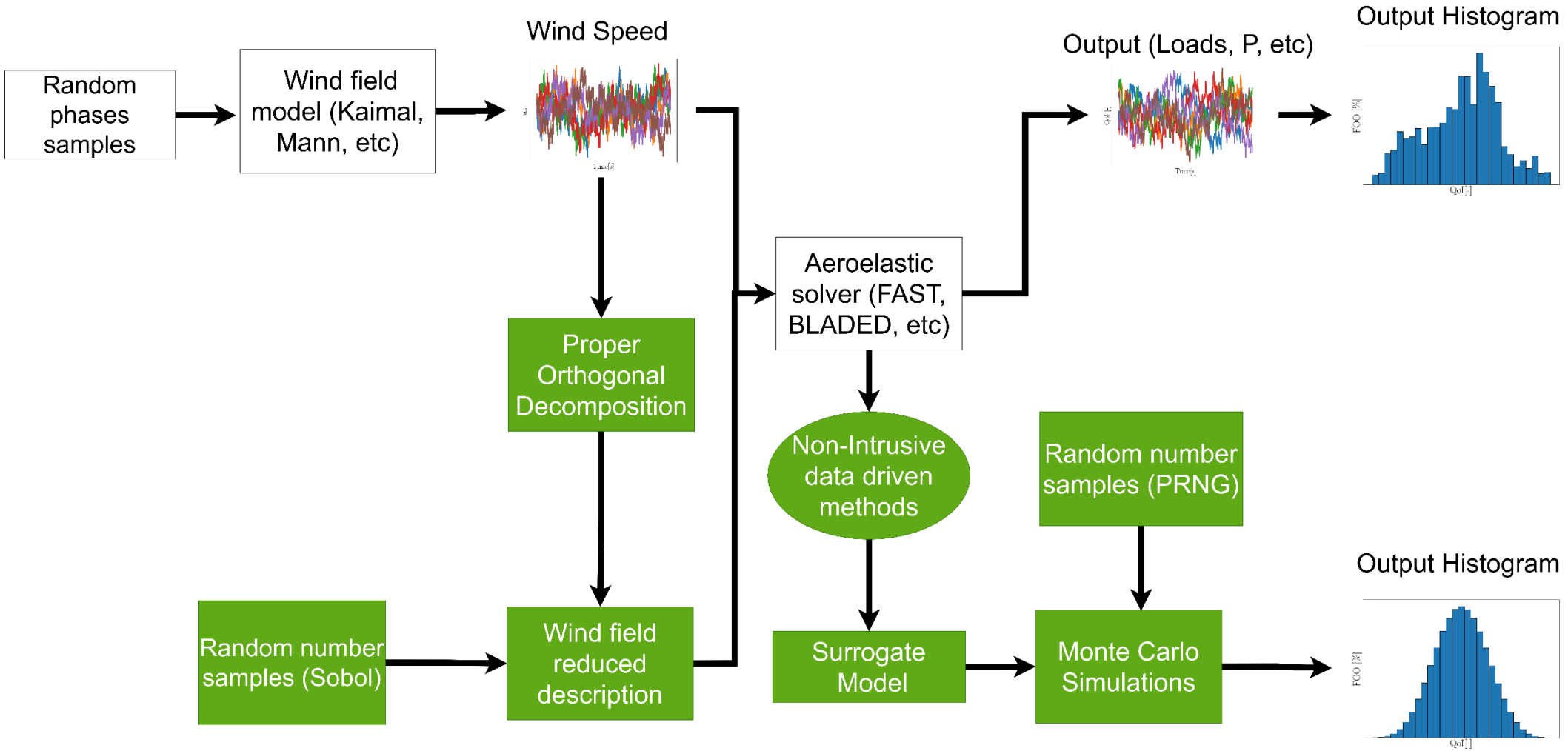


University of Victoria | Institute for Integrated Energy Systems

Rad Haghi, Curran Crawford

IESVic, University of Victoria

Uncertainty Quantification (UQ) Derived Surrogate Models for Wind Turbine Simulations



Discussion