Predicting production losses due to ice accretion

Johan Revstedt[1], Robert Szasz[1], Heiner Körnich[2], Henrik Asmuth[3], Stefan Ivanell[3]

1: Lund University

2: SMHI

3:Uppsala University

UPPSALA UNIVERSITET

LUND UNIVERSITY

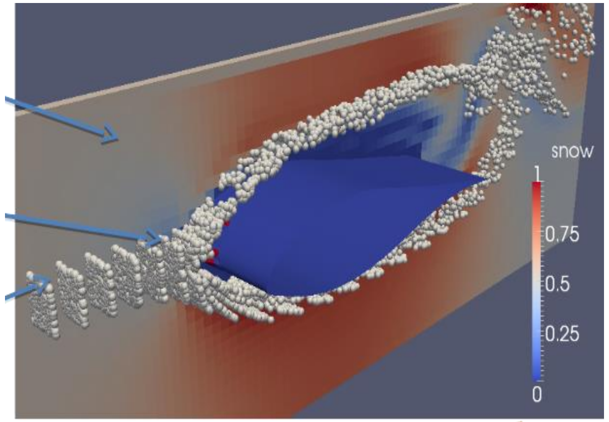
Campus Gotland
WIND ENERGY

Overview

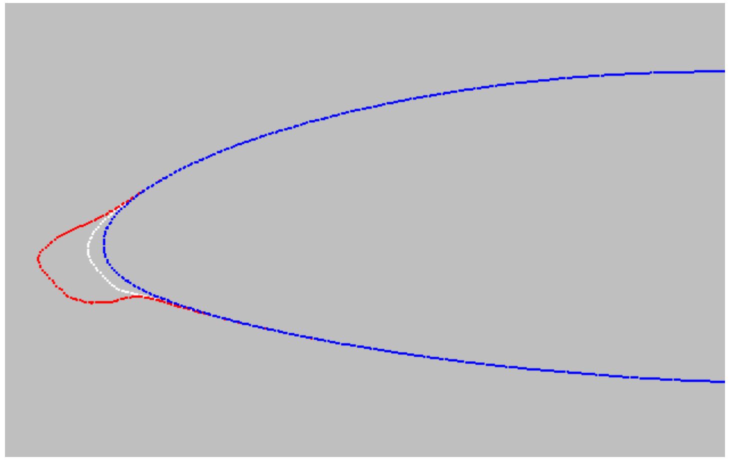
- The idea is to create a complete modelling chain for predicting production- and load variations for wind power sites under icing conditions.
- Starting from simulated meteorological data we will predict the ice accretion on and the change in aerodynamic loads of the turbine blades. This information will then be used in whole turbine simulations to predict the changes in production.

Method

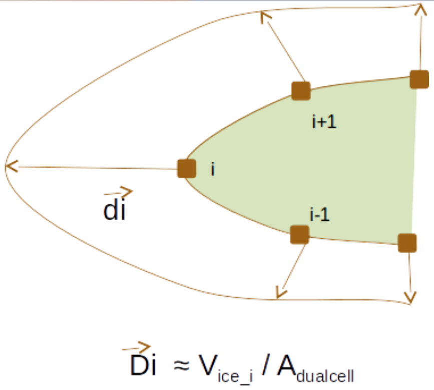
Based on meteorological data we perform two-phase simulations of flow around an blade section



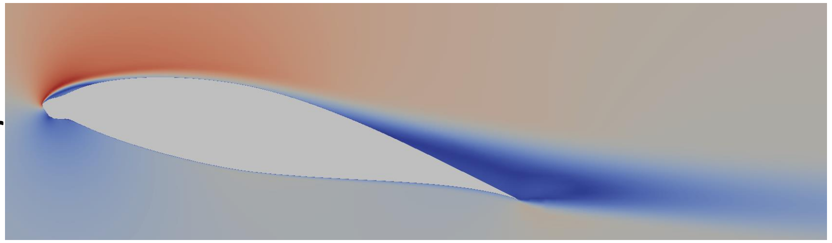
Based on the number of droplets hitting the surface at different positions we can calculate the amount of ice



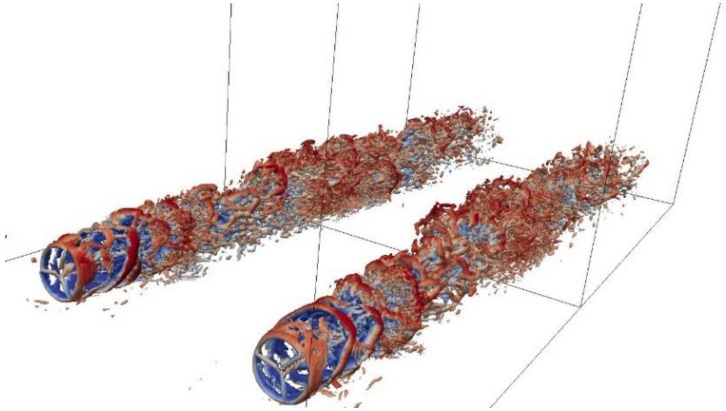
This information is used to alter the blade shape.



The altered shape is then simulated either for continued ice accretion or to extract aerodynamic data

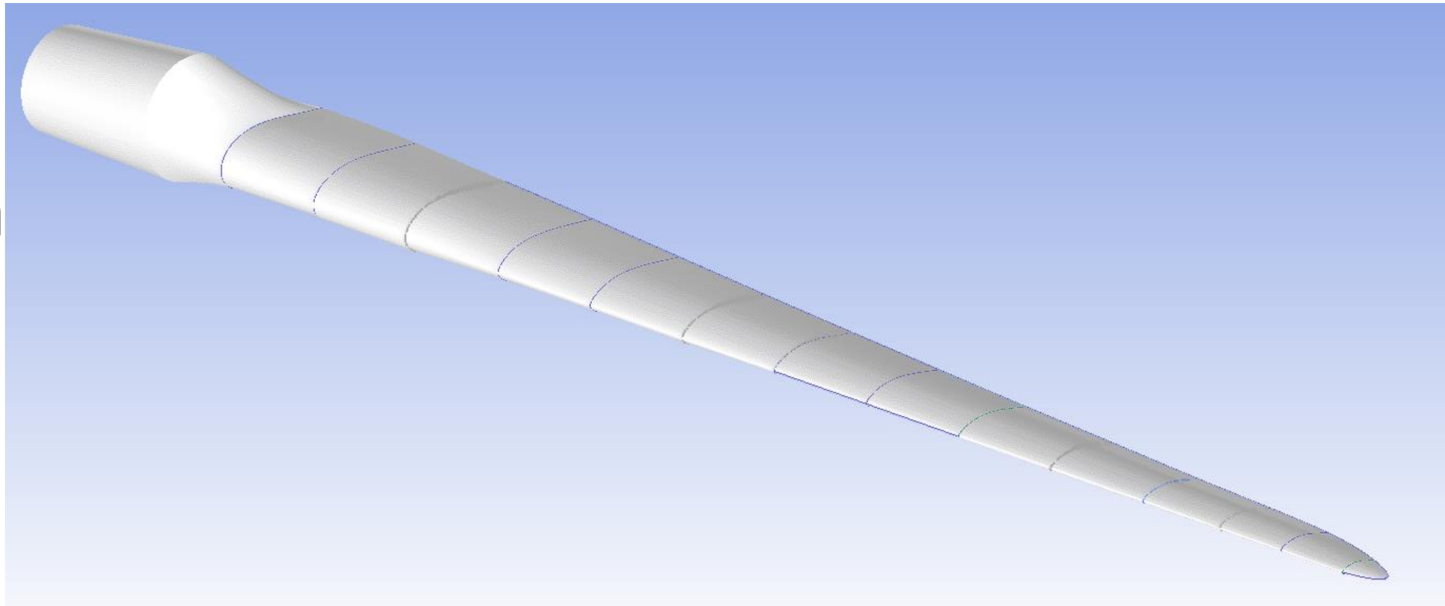


The aerodynamic data is input to the actuator line model used in the whole turbine simulations



Set-up, ice accretion simulations

- Turbine: NREL 5MW
- Simulation tool: OpenFOAM
- 2D RANS using the SST k-ω model
- One-way Lagrangian particle tracking
- Updating the aerofoil shape every 150 s (icing time)
- Considering 14 sections along the blade
- Total time 4 hours
- Rime ice only, LWC= 0.5g/m^3
- Wind speed 10 m/s; Rotation 11 rpm



Comparing to wind tunnel data

- Comparing accreted ice mass with the wind tunnel data from Hochart et. al.[1]

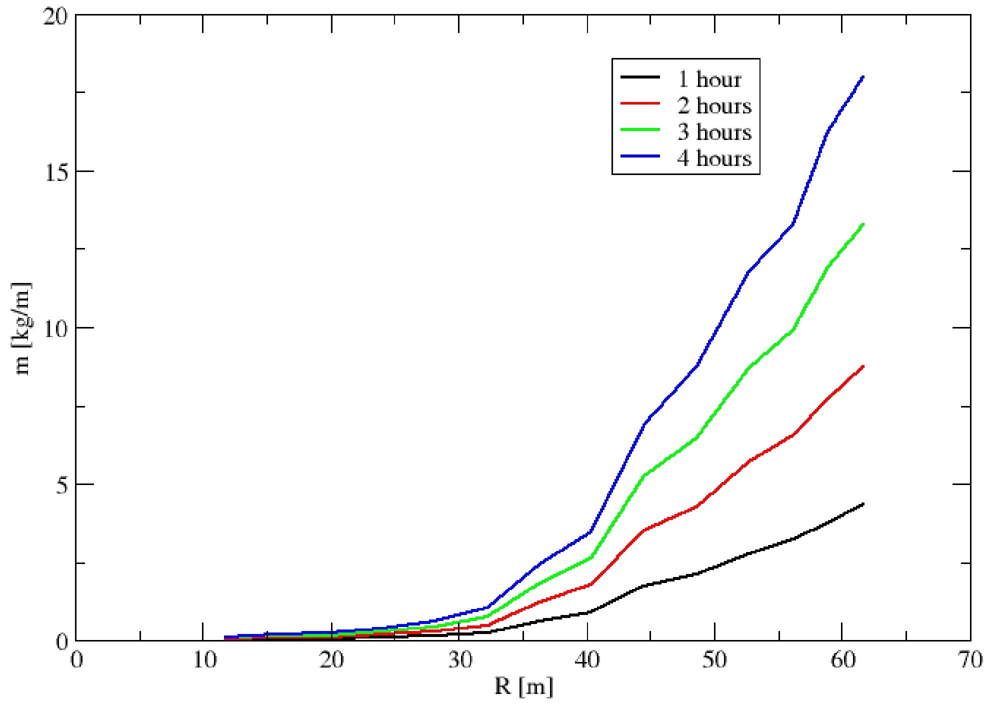
Accreted ice mass in kg/m

Test	Hochart et al	Simulation	deviation
4	0.048	0.044	8%
5	0182	0.208	14%
6	0.440	0.664	50%

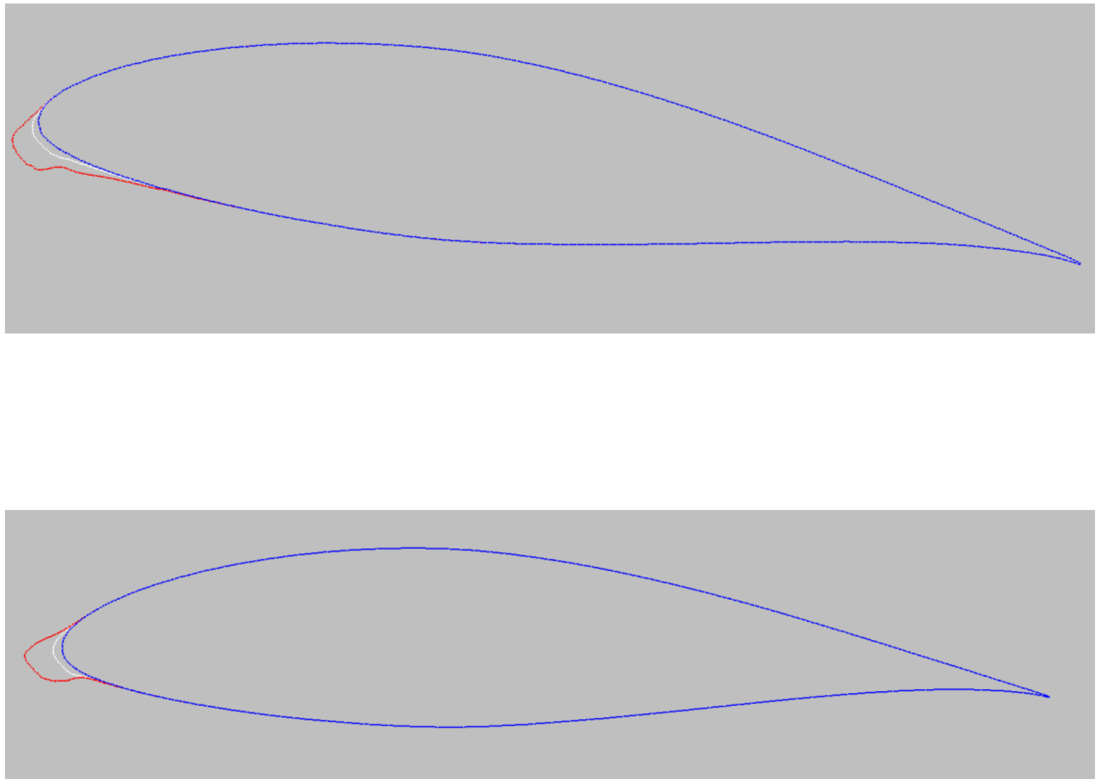
1. C. Hochart, G. Fortin, J. Perron, *Wind Energy*, 11:319-333, 2008

Ice on the blade

Ice mass along the blade



Iced blade profiles at 8 deg. (top) and 3 deg. (bottom) AoA.

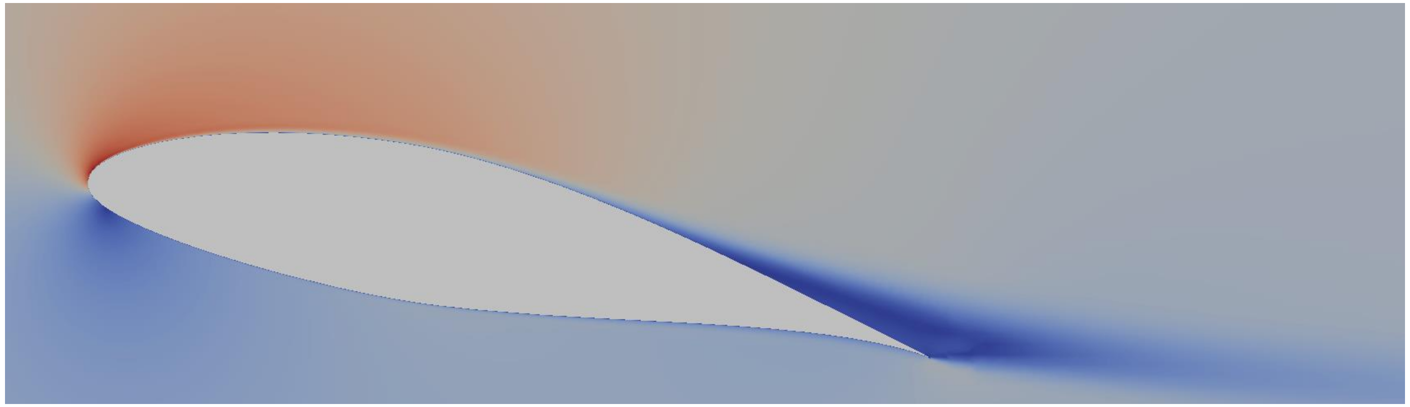


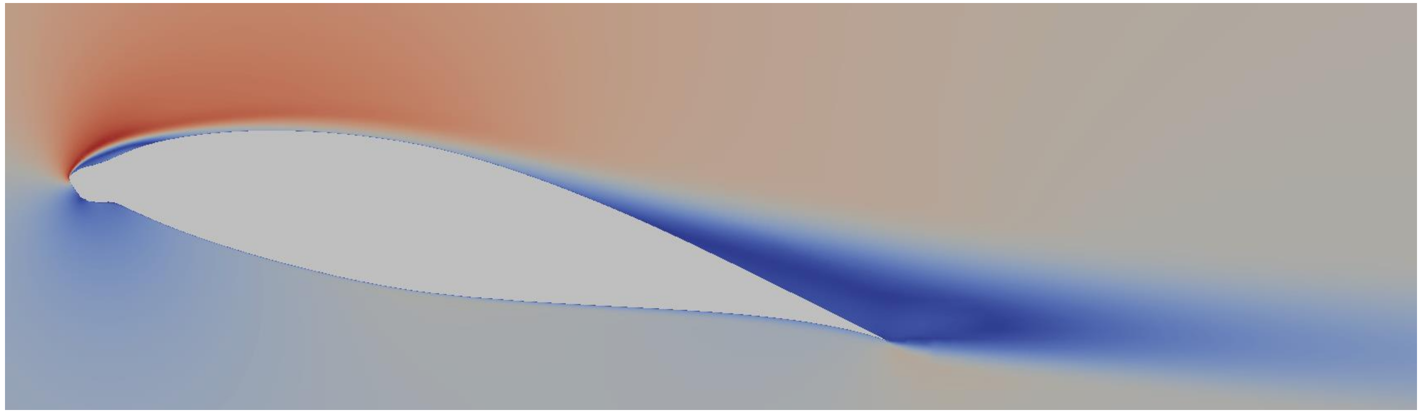
Aerodynamic forces

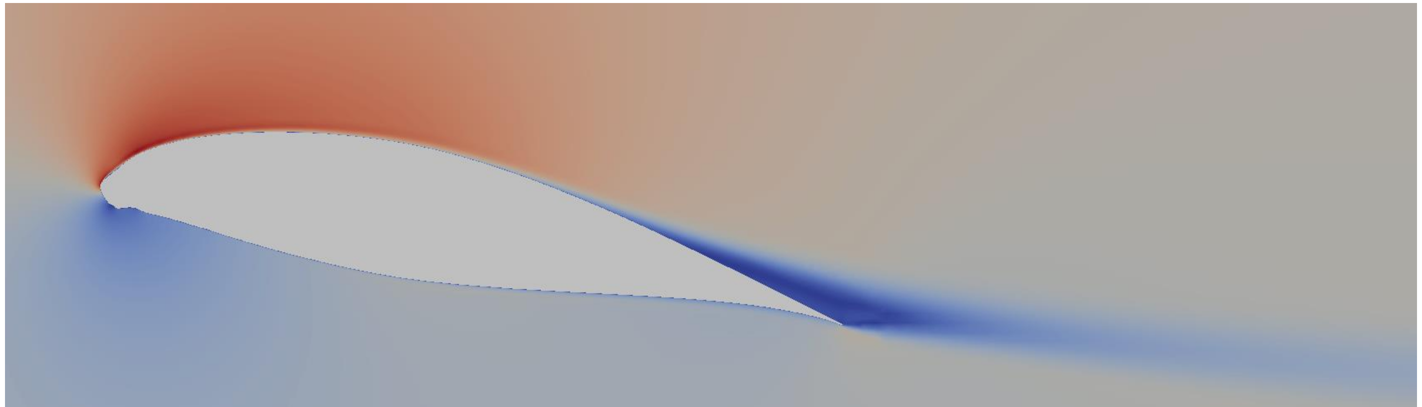
Velocity fields at AoA=12 deg. For

- A clean profile
- Icing AoA=3deg
- Icing AoA=8 deg

Profiles with ice are from the outermost section of the blade and taken after 4 hours



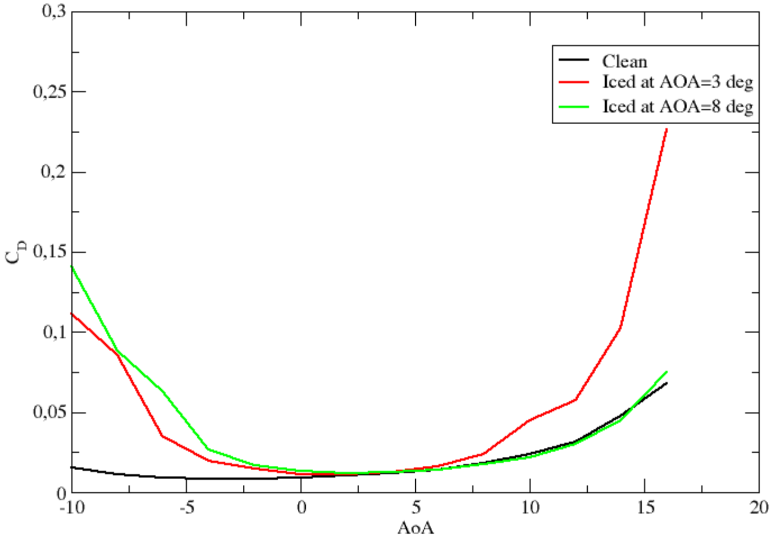




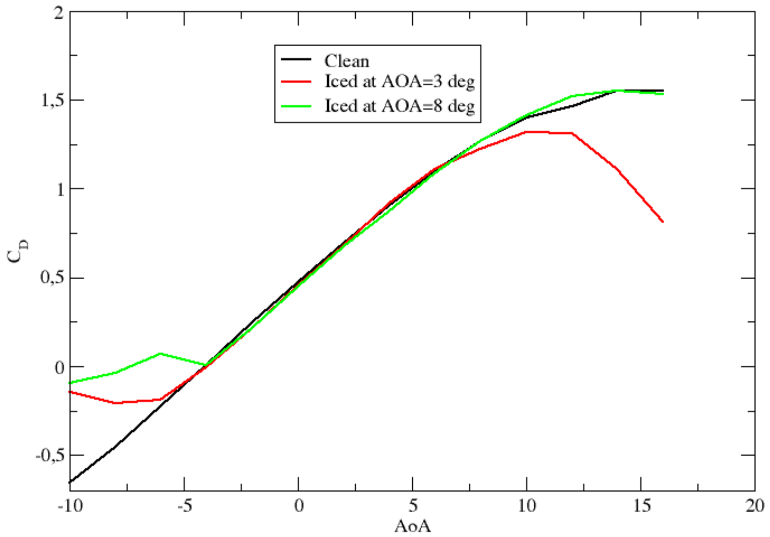
Aerodynamic forces

- Comparing the cases with ice accretion at 3 and 8 deg AoA to the clean profile for the outermost section of the blade

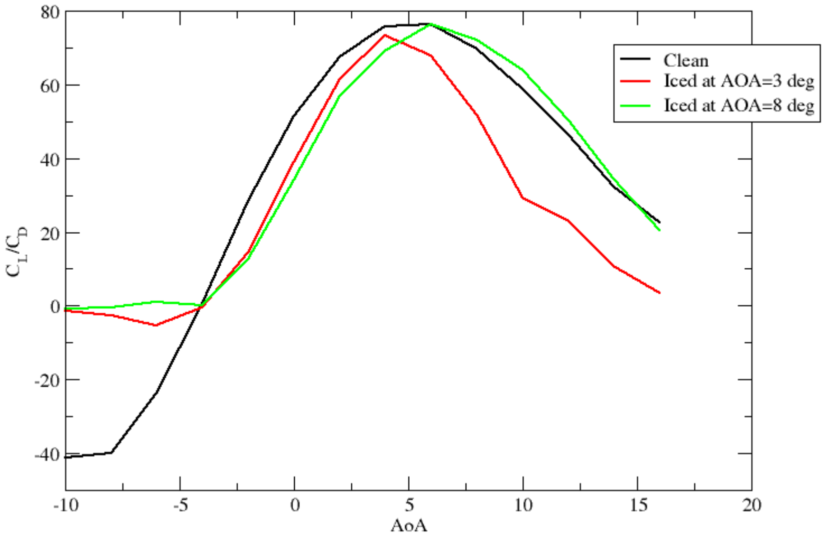
Drag



Lift

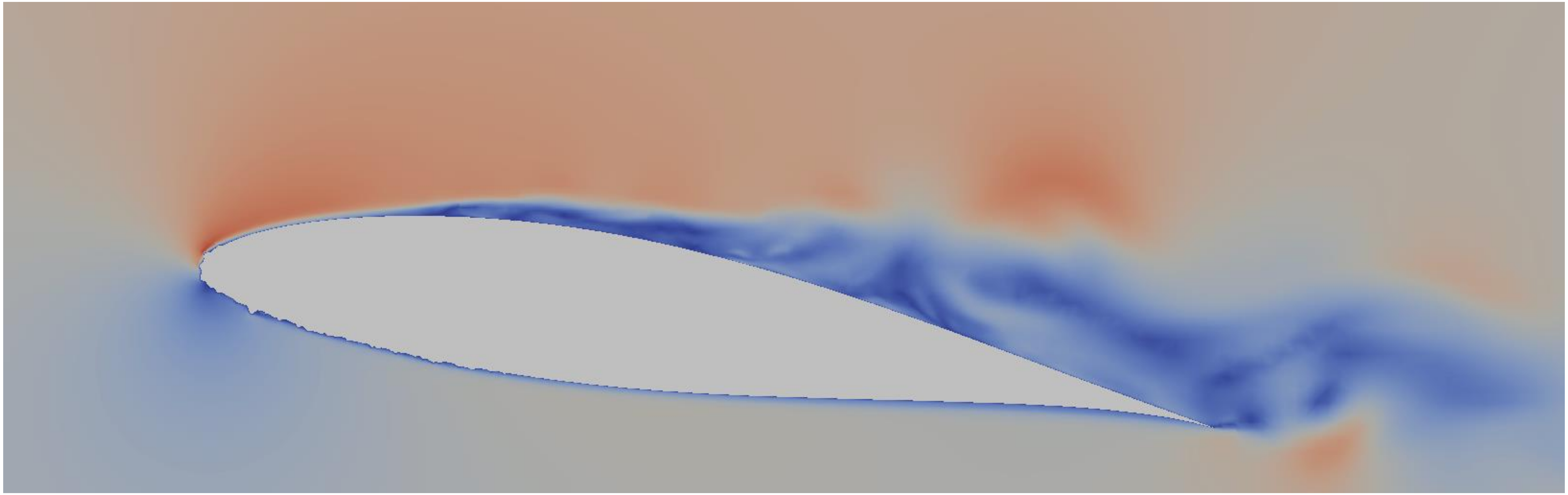


Glide ratio



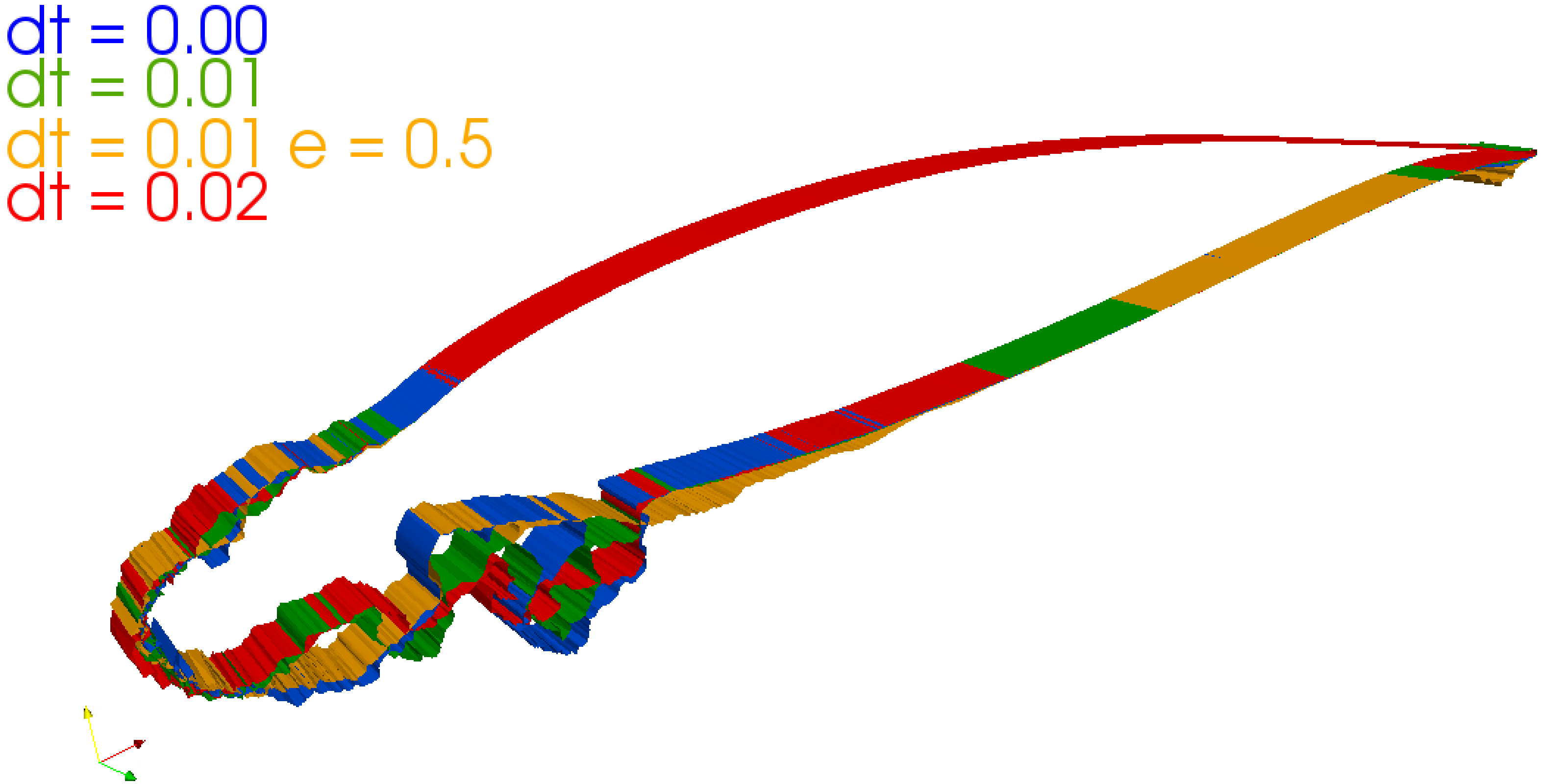
Outlook 1

- Large eddy simulation (LES) is expected to give results with higher accuracy
- Significant increase in computational resources and time required



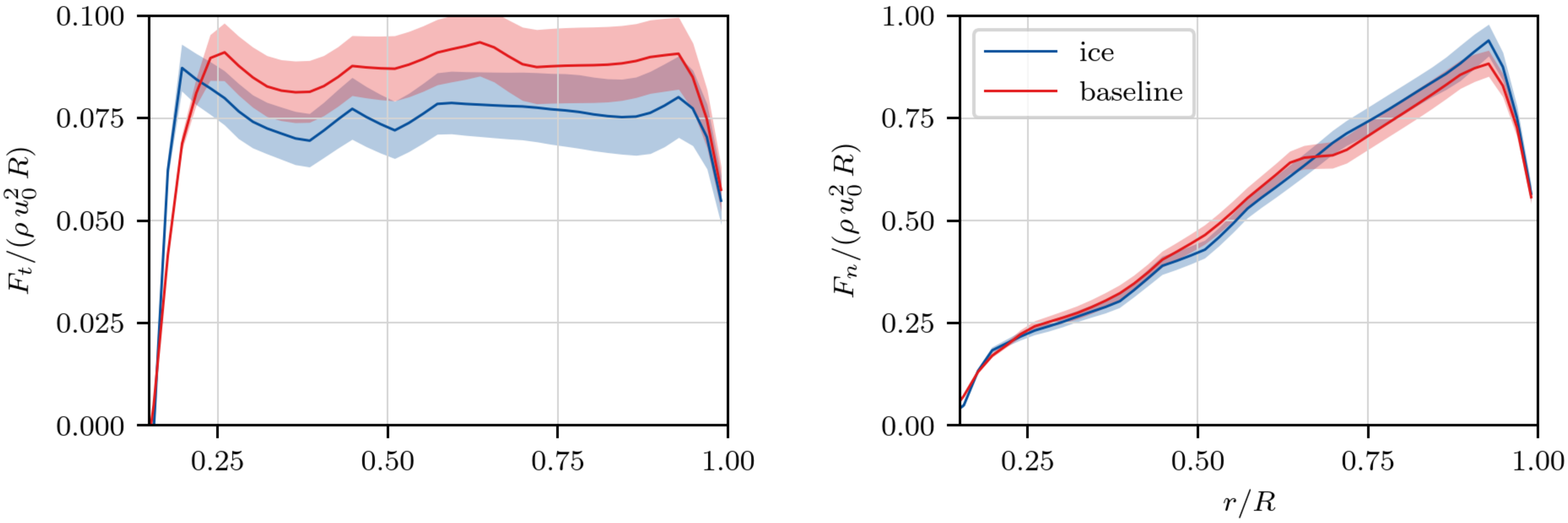
Outlook 2

- Simplified modelling of glaze ice
- Specifying freezing delay (dt) and droplet friction on the surface (e)



Outlook 3

- Turbine simulations using the actuator line method
- Tangential and normal forces on the actuator line with and without ice



Acknowledgement

- This project is financed by the Swedish Energy Agency, project no. 47053-1
- Computational resources are provided by SNIC@Lunarc