Importance sampling for ice throw in QBlade

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Bad Marketing?

Why run simulations?

Ice Fall and Throw presents risk to:

- People
- Commercial and Residential Structures

We need to prove it is unlikely to:

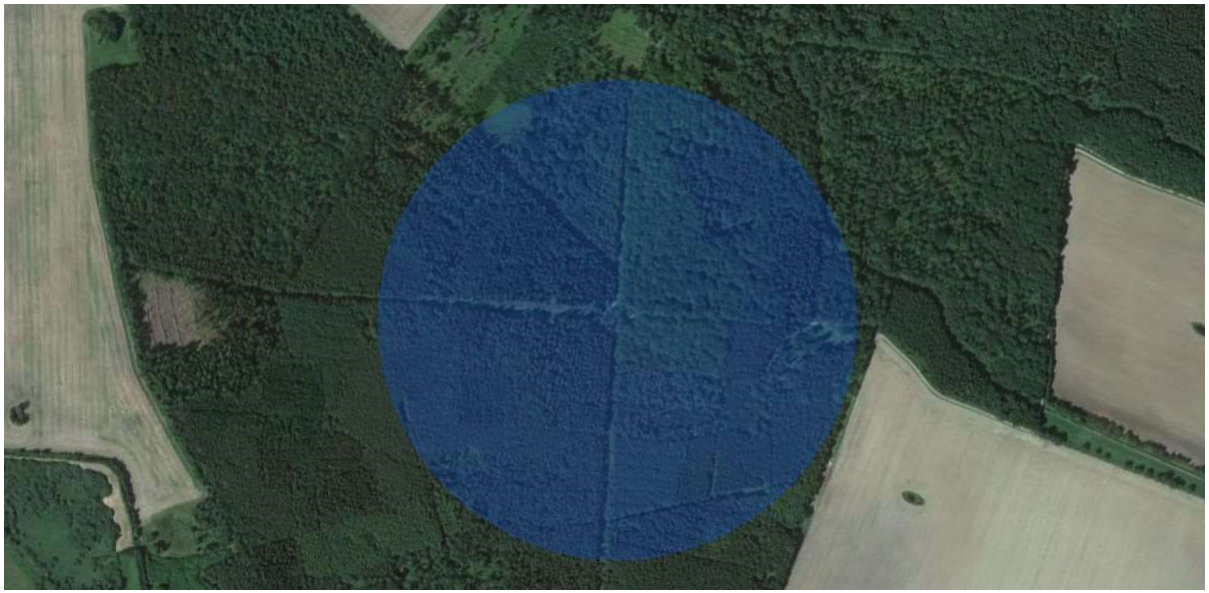
- Local community
- Building Owners
- Insurers
- Media?
- ….

http://i.huffpost.com/gen/1333831/images/o-WIND-FARM-HOUSE-facebook.jpg
http://winterwind.se/risk-of-ice-throw-exaggerated/

Ice Throw

SIMULATION APPROACH

- Draw a big circle based on rotor size with very large safety margin



Estimated Outcomes: No simulation, very large offset required, projects in jeopardy.

Simulation Approach – Very High Fidelity

- Complex metrology to predict icing
- Complex physics for ice release
- Full unsteady CFD of a tumbling ice chunk.

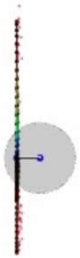
Estimated Outcomes: 3 research grants, 4 PhD, 20000 hours of simulation time, a Nobel prize in physics and no meaningful result

Simulation Approach – Reduced Order Model

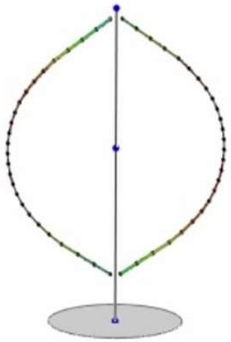
- Treat ice chunks as a particle with simple properties
- Randomly select ice particles
- Use simple metrological properties
  - Wind Rose
  - Number of Ice days predicted.

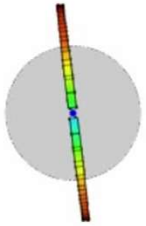
Estimated Outcomes: Risk at each location around the turbine (1/2 day work)

QBlade Approach - HAWTS

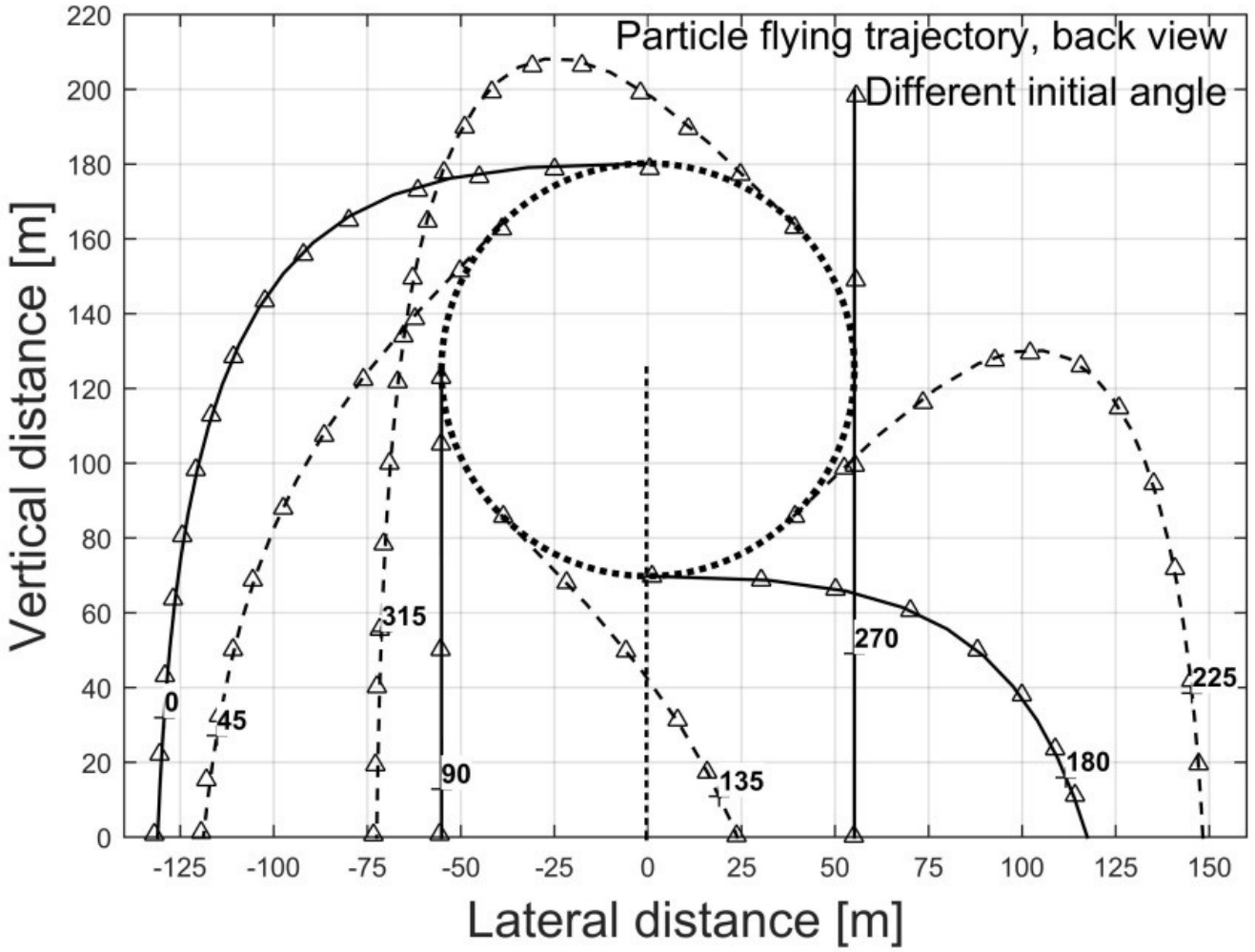


QBlade Approach - VAWTS





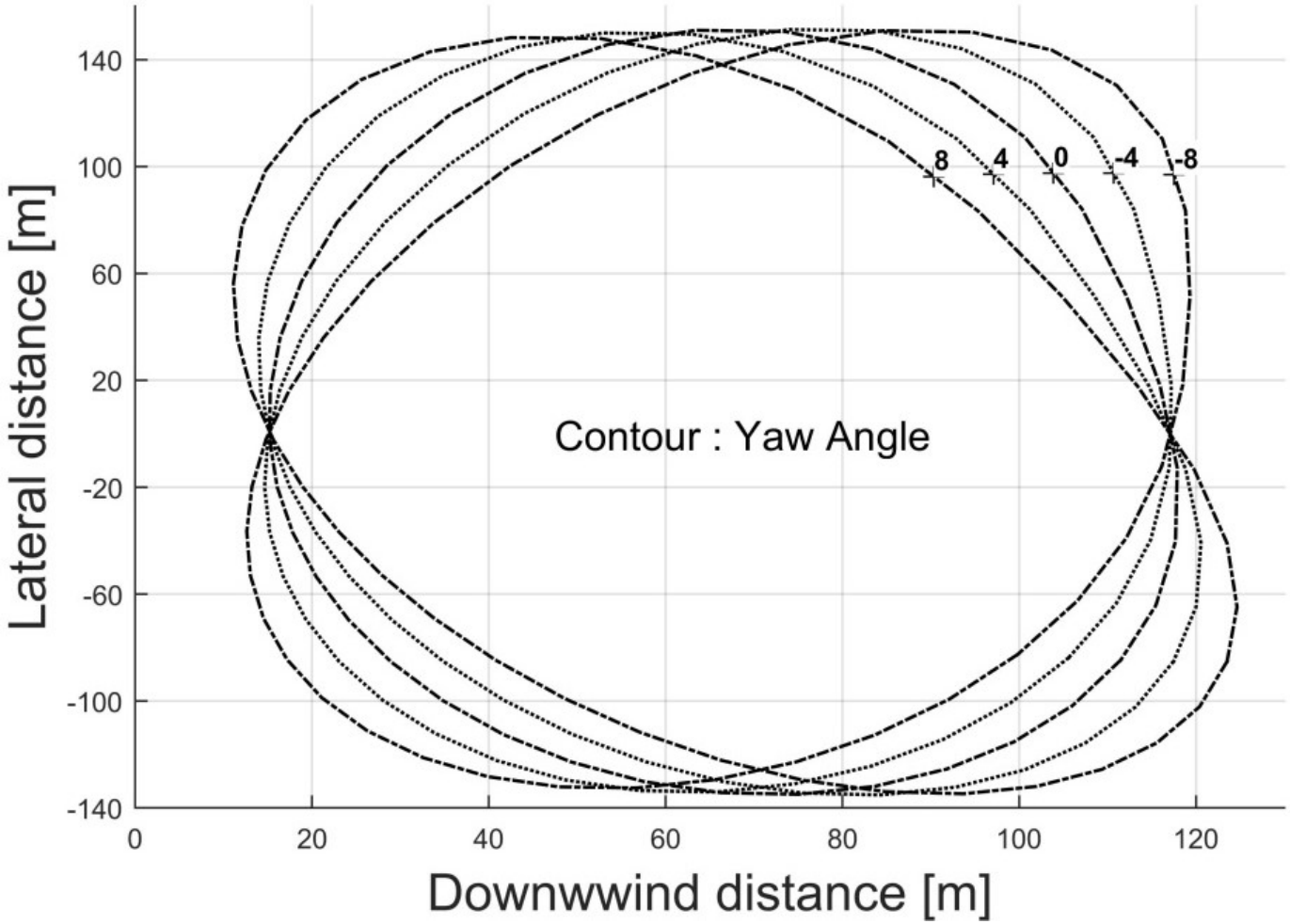
Model Validation – It works!



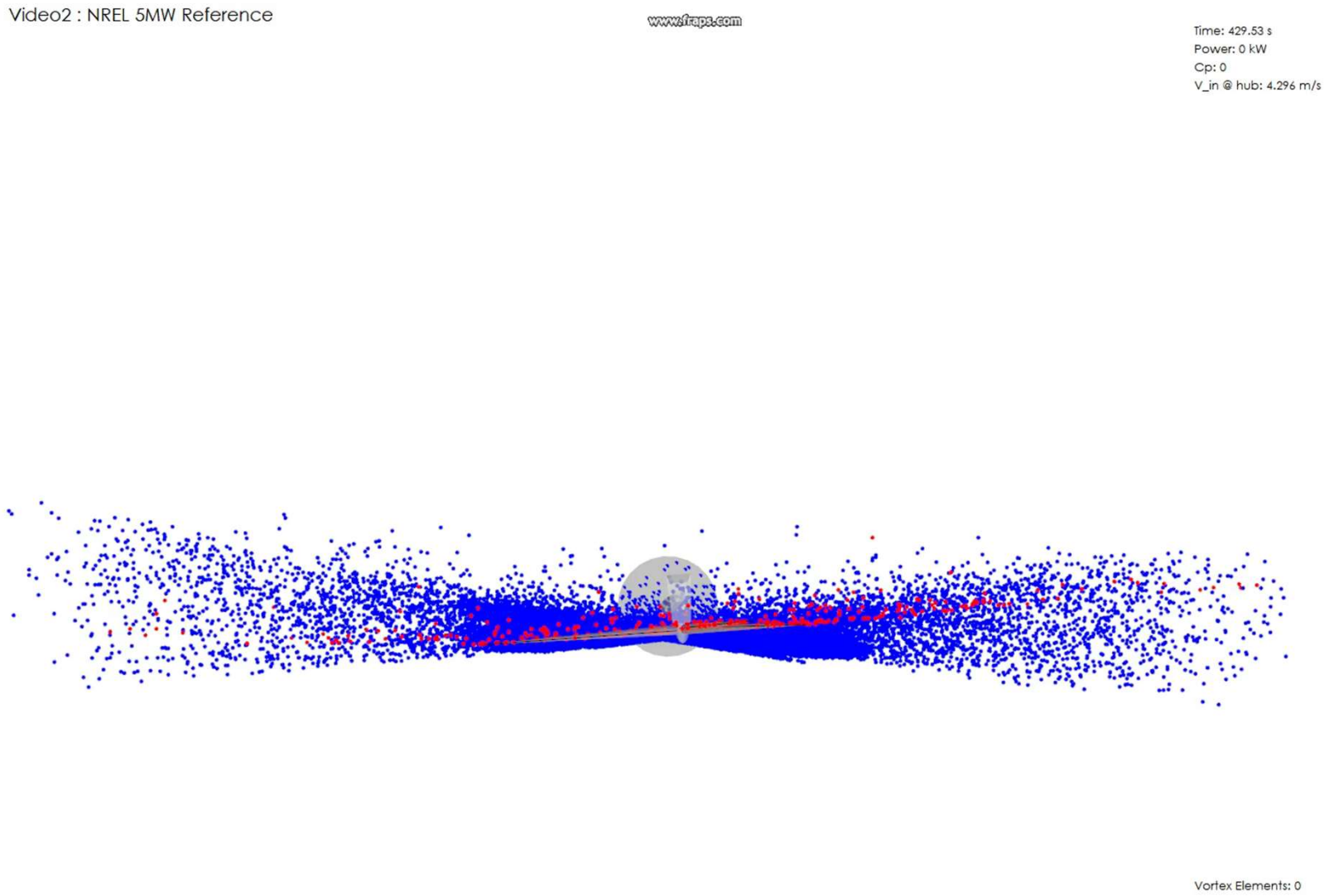
Ice Throw

WHICH VARIABLES MATTER?

Which variables matter?



Which variables matter?



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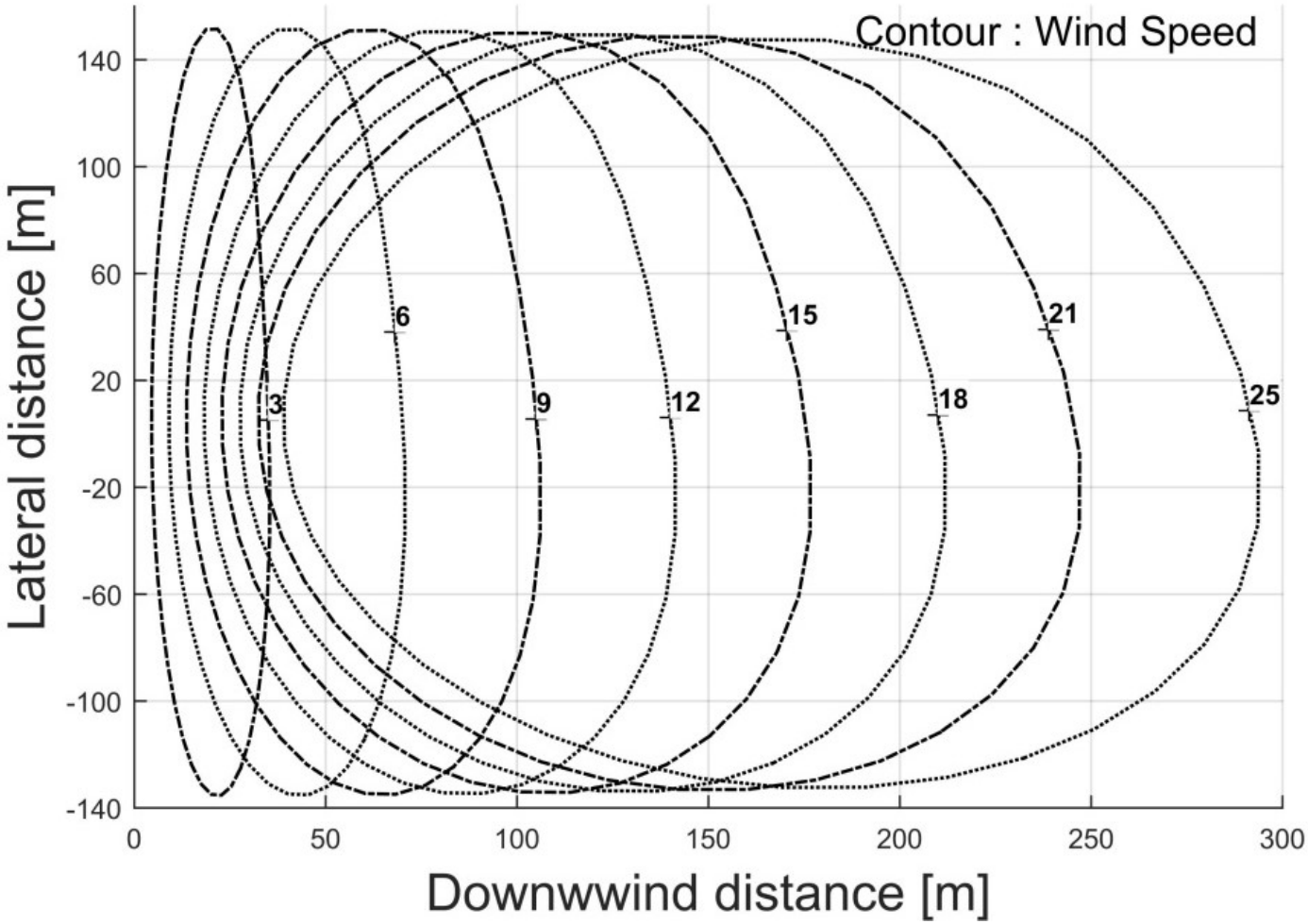

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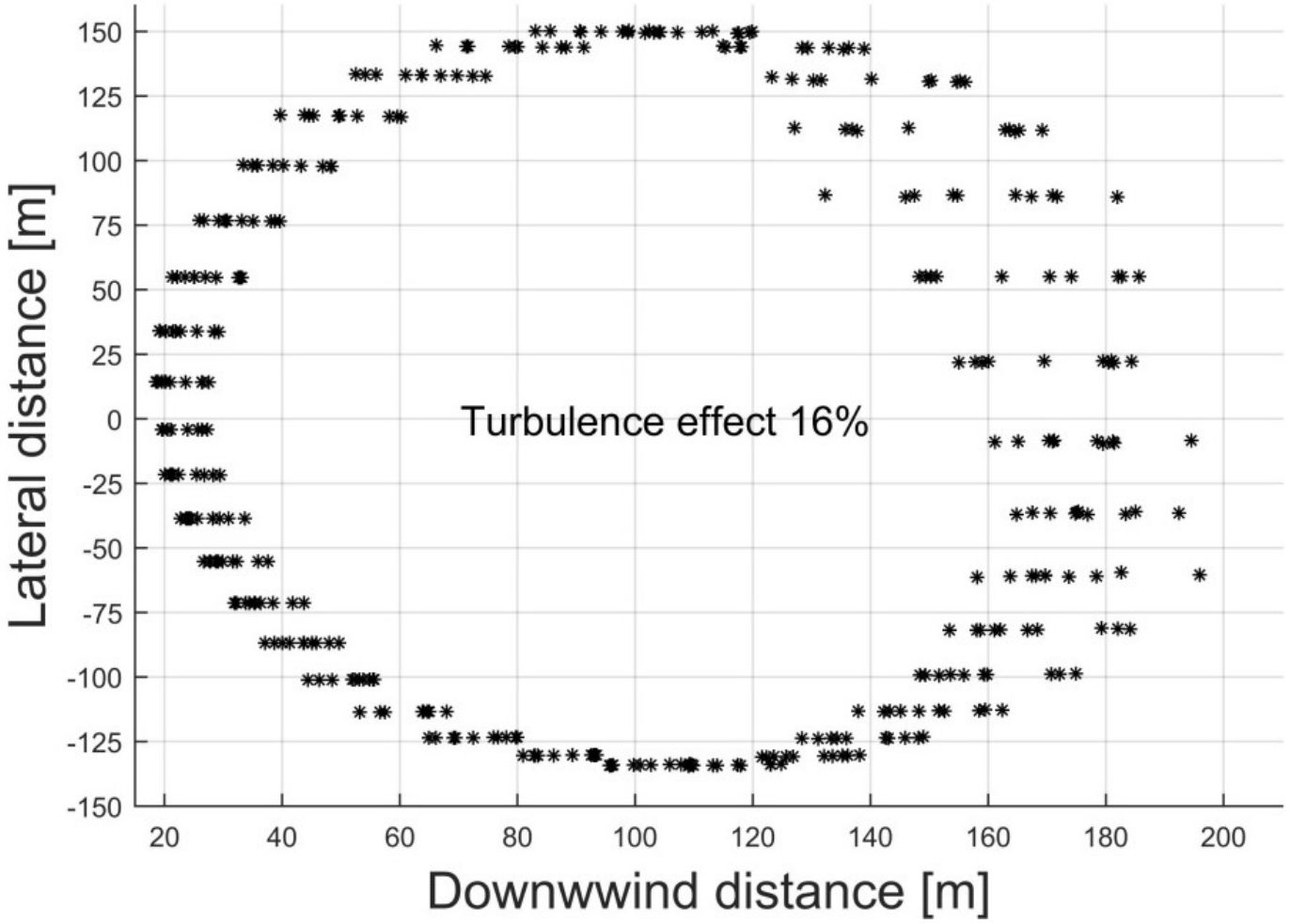

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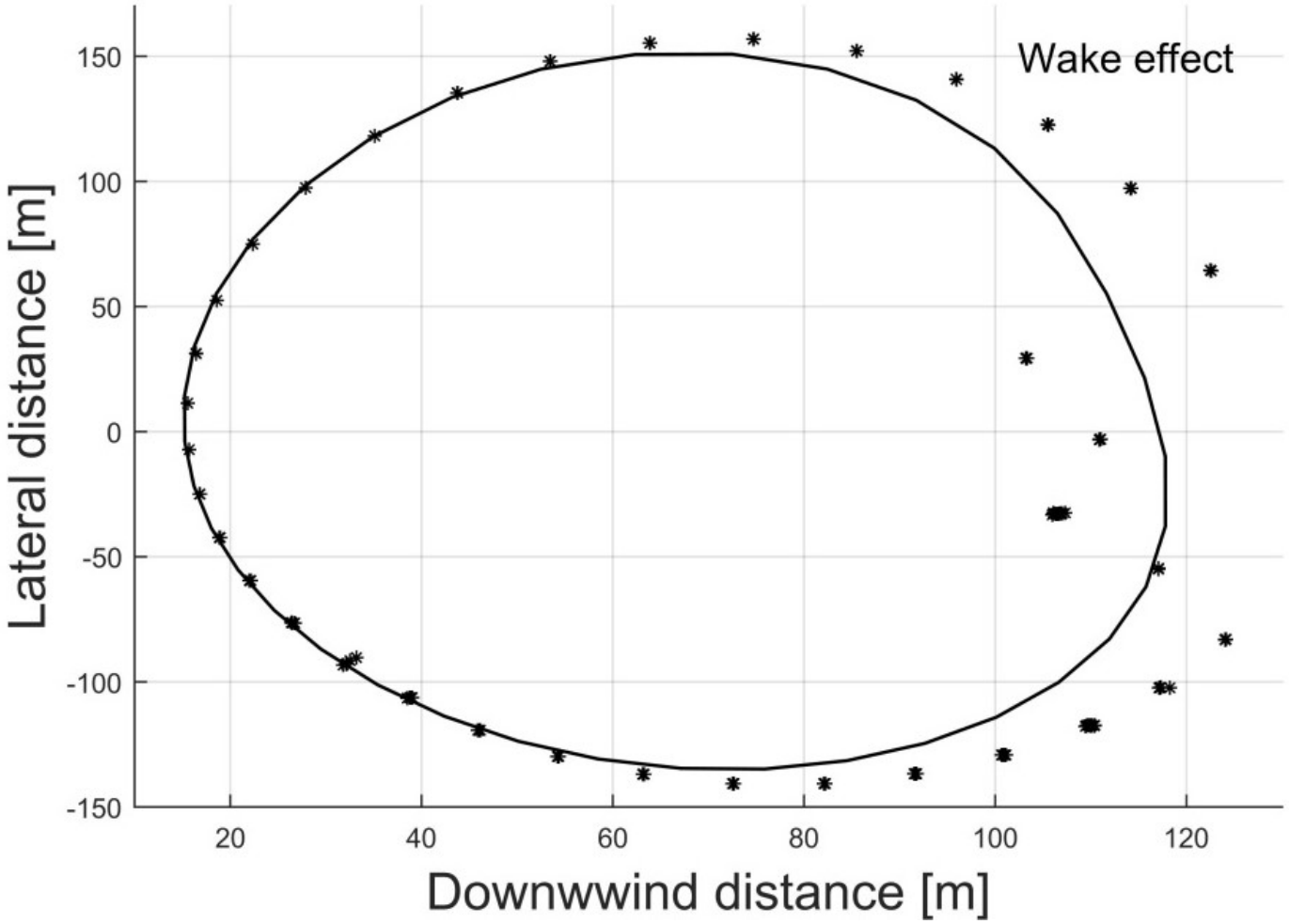
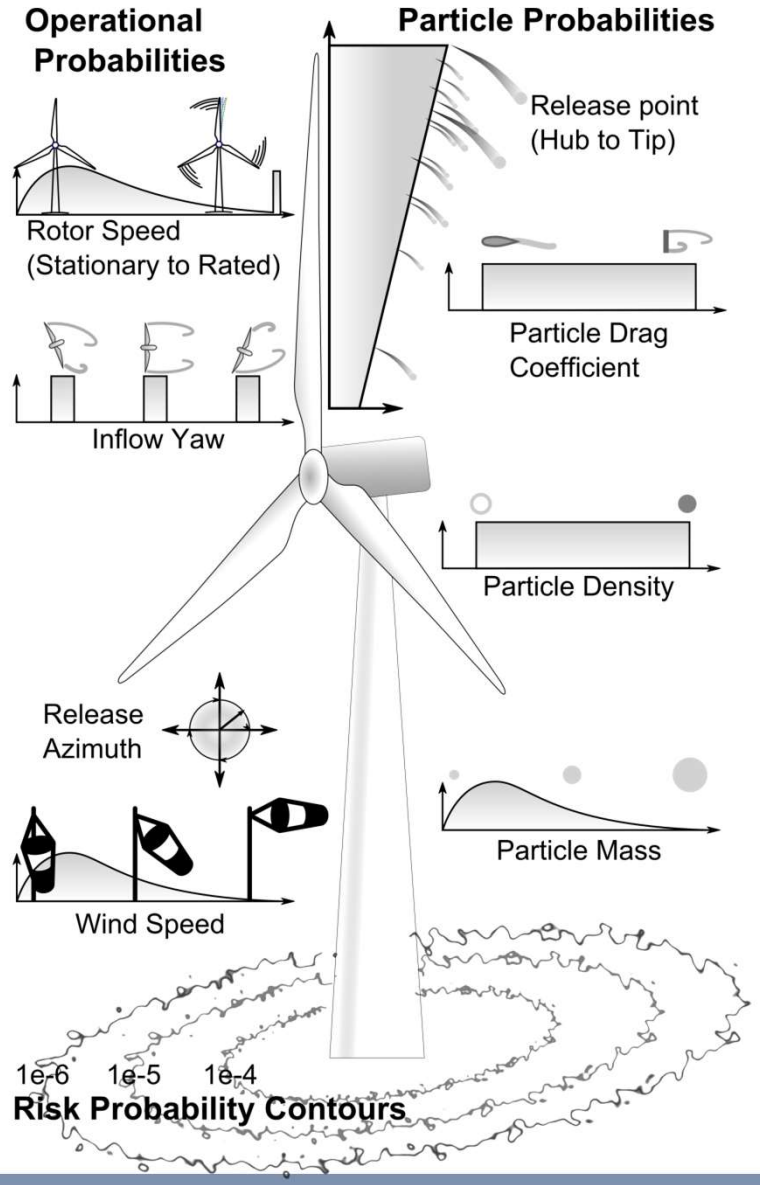


Ice Throw

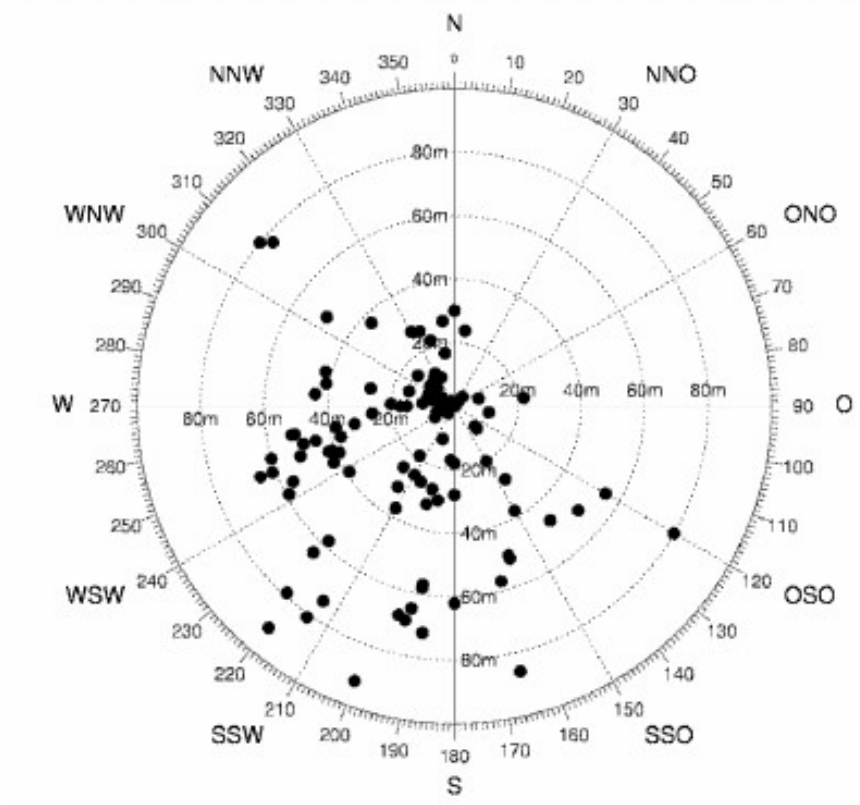
WHAT DATA EXISTS?

How much do we know?

Drag coefficient	✓
Ice fragment mass	✓
Initial radial position	✗
Azimuth position	✗
Rotor speed	✓
Wind speed	✓
Wind direction	✓
Yaw angle	✓
Wake	✓

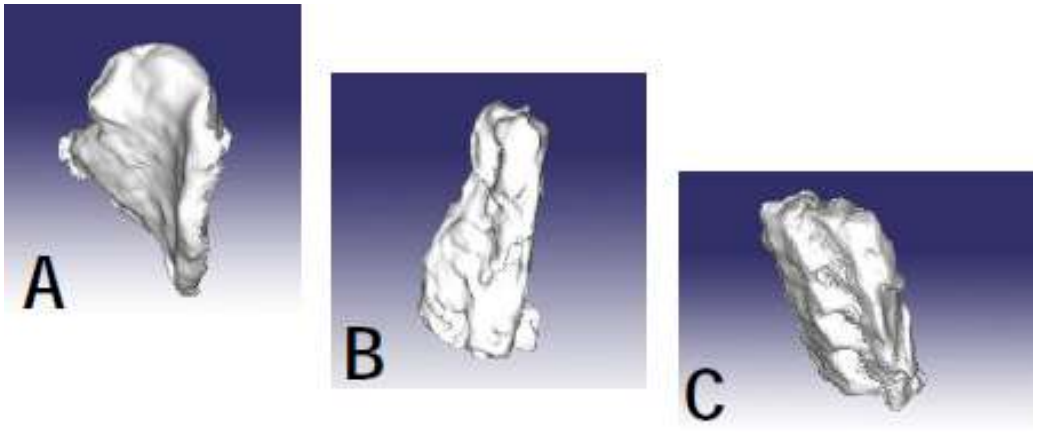


Gutsch Test Site.



Cattin, Heimo, Russi et al. Wind turbine ice throw studies in the swiss alps. Wind Energy Conference and Exhibition

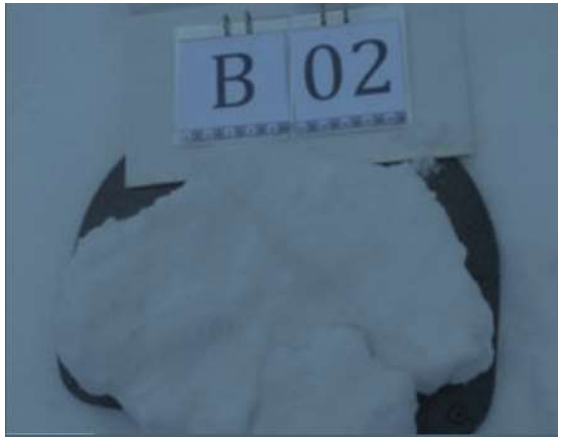
Drapalik Experimental Dataset



Drapalik, M. (2017). Experimental Investigation of Risk from Ice Shed and Ice Throw. In Winterwind International Wind Energy Conference. Skelleftea. Retrieved from http://winterwind.se/wp-content/uploads/2015/08/3_1_03_Drapalik_Experimental_investigation_of_risk_from_ice_throw_and_ice_shed_Pub_v1.pdfa

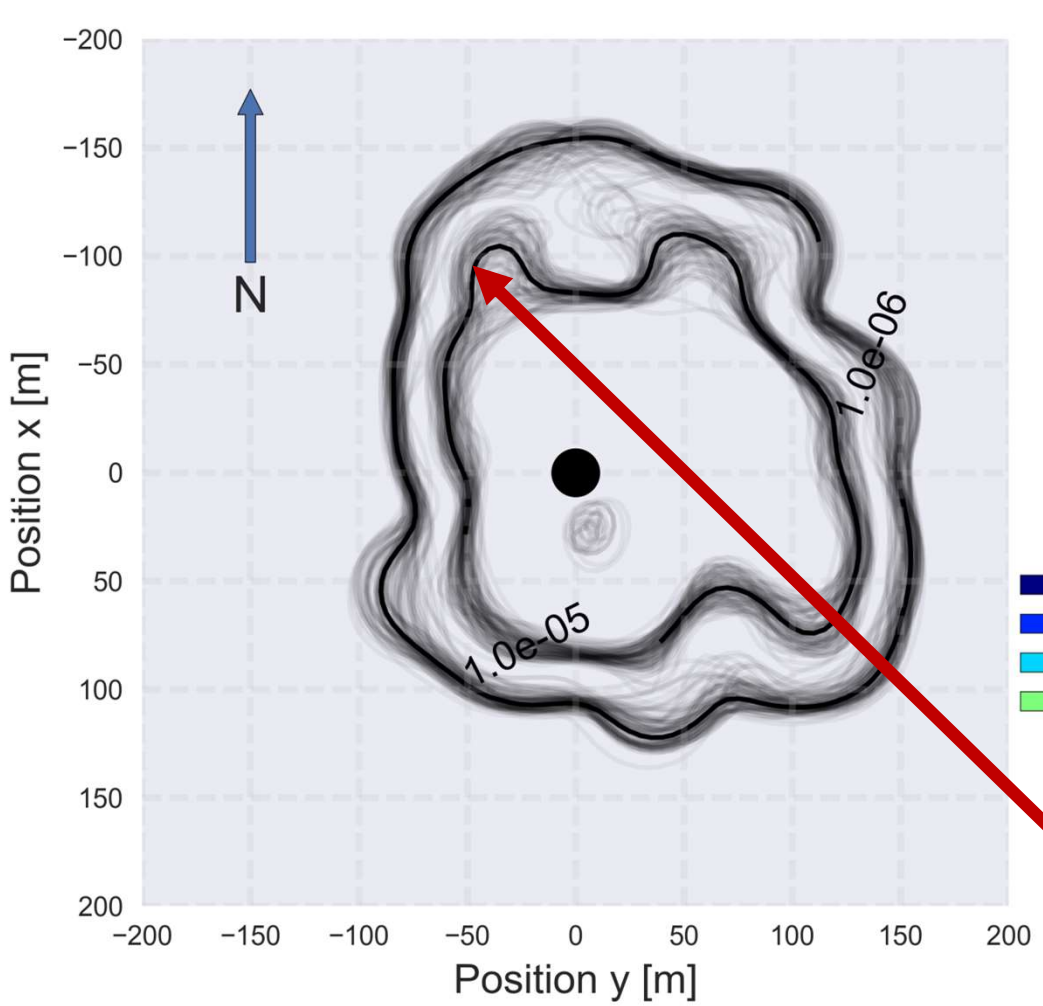
Swedish Consortium

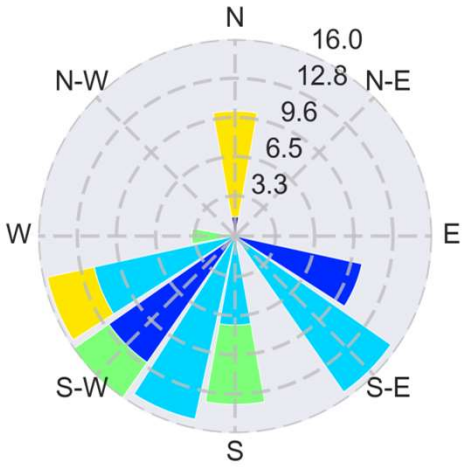
- 3 sites (4 turbines), Sweden
- 3 Year field study
- Database of ice particles
  - Physical Properties.
  - Throwing distance
  - Meteorological data at time of ice throw

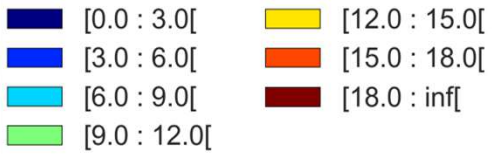


Icethrower Mapping and tool for risk analysis. Jenny Lunden, Winterwind Skelleftea 7 Feb 2017 Pöyry Sweden

Swedish Dataset

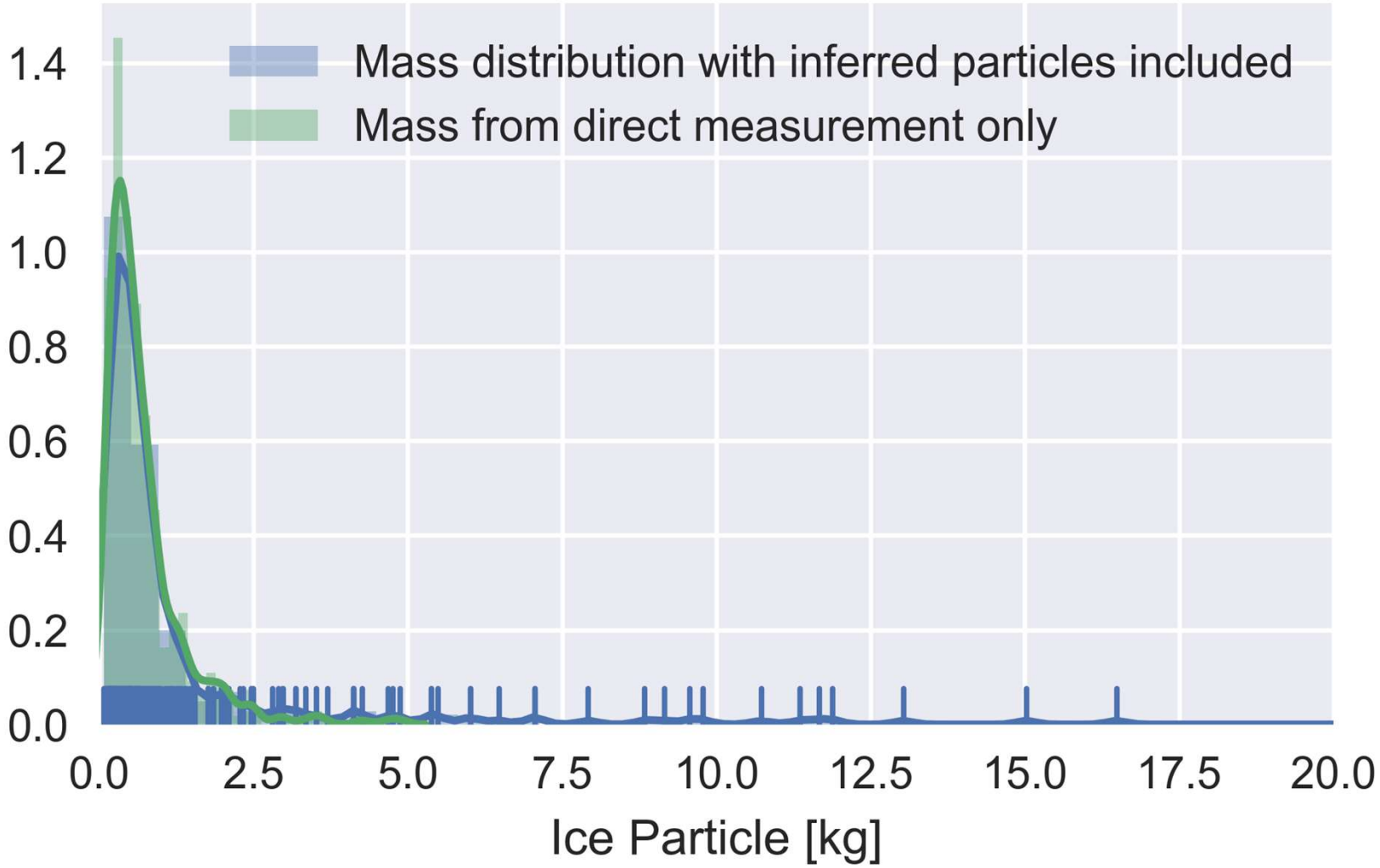






Up to 100m uncertainty in measured data

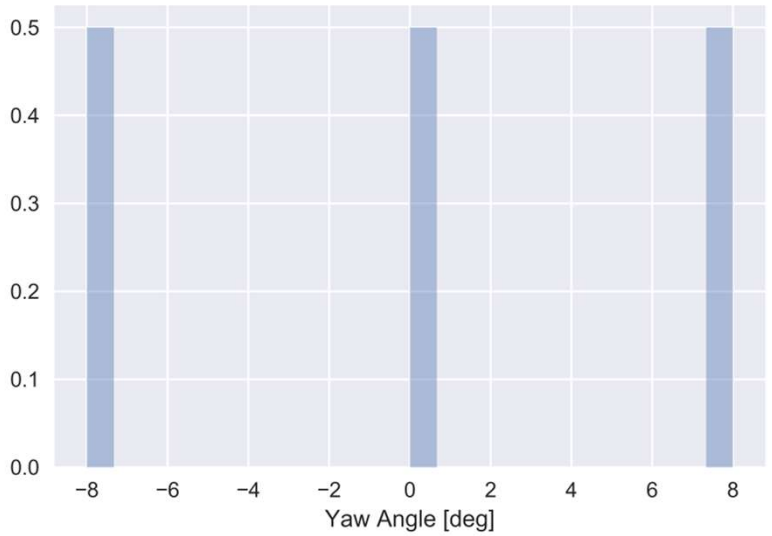
Missing Mass Data

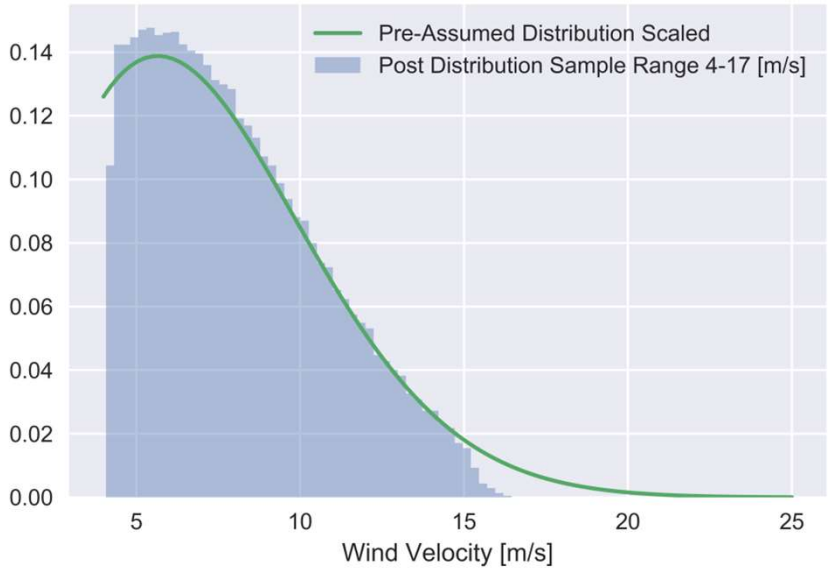


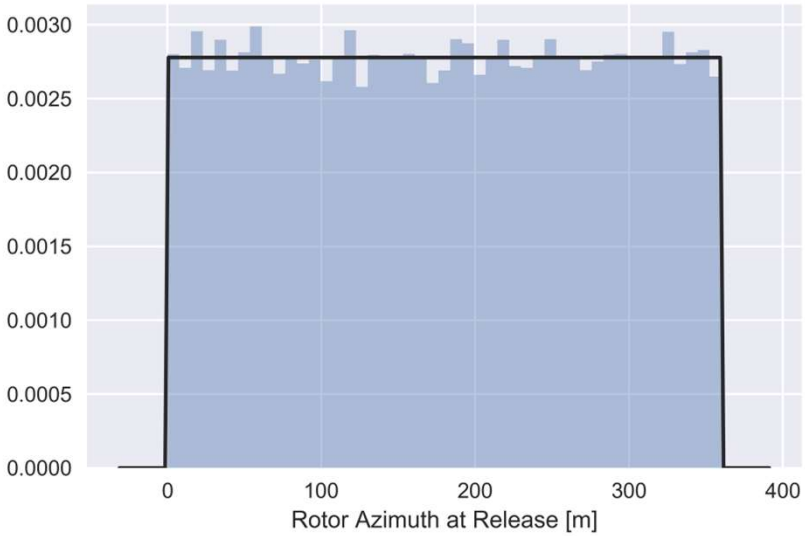
Statistical Analysis

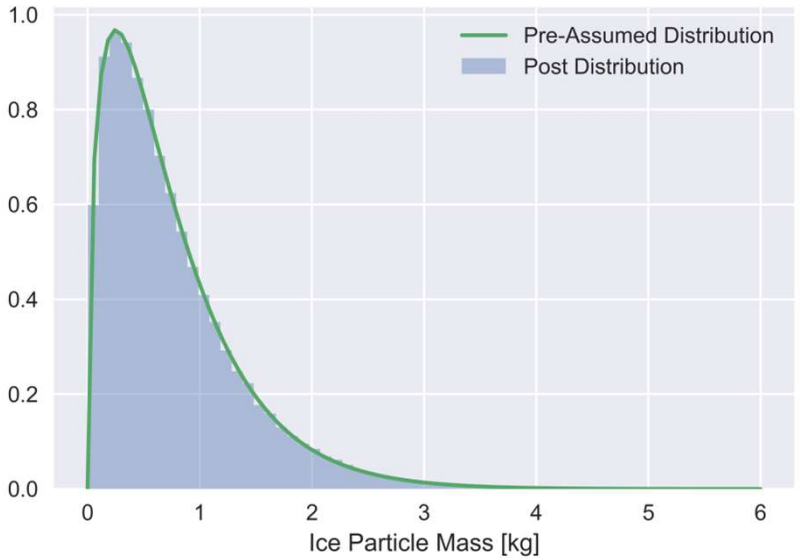
MONTE-CARLO

Input Assumptions – Random Sampling

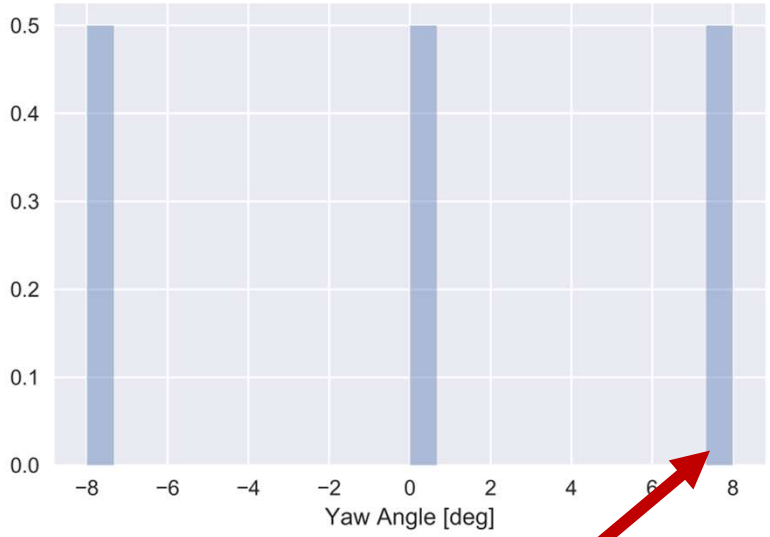


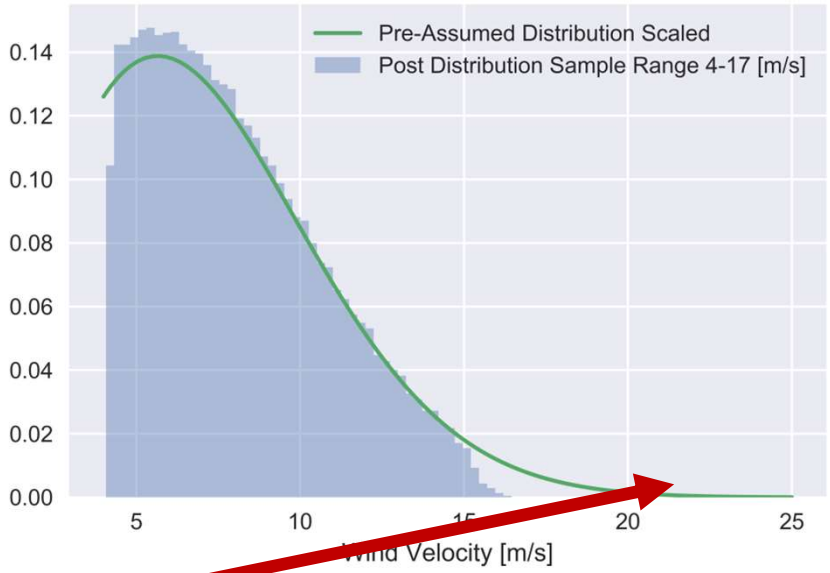


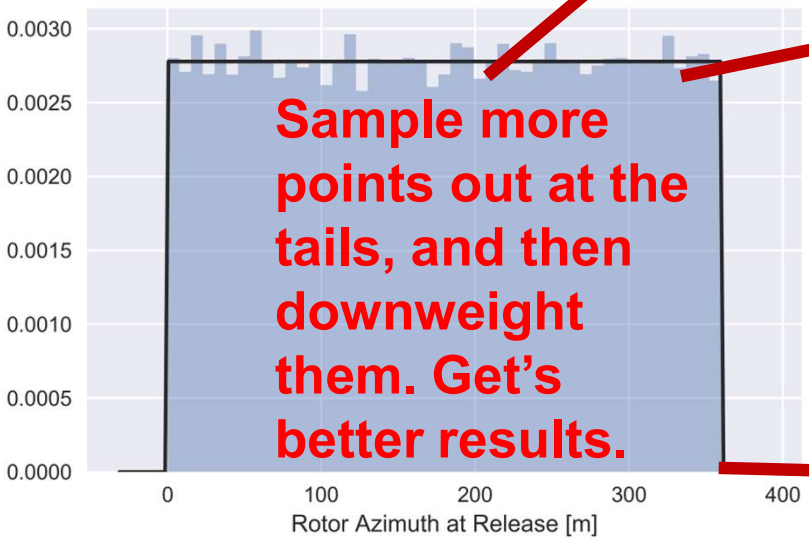




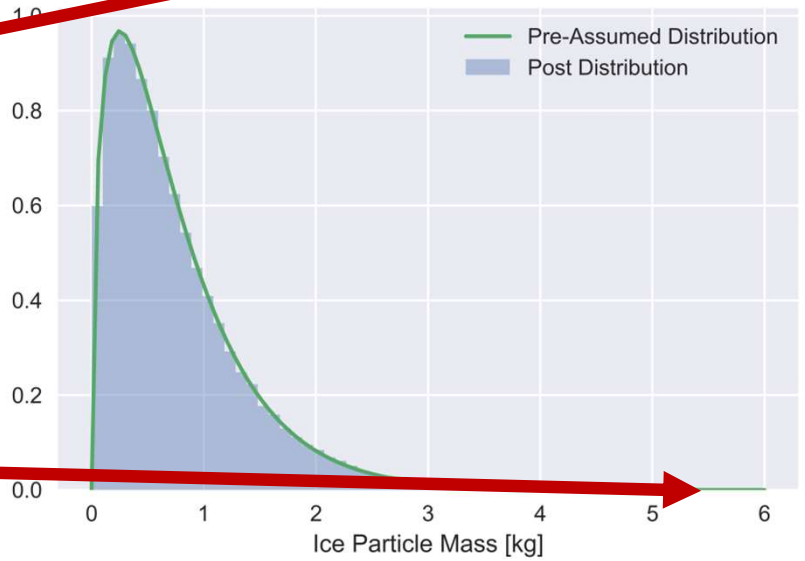
Random Sampling – Importance Sampling



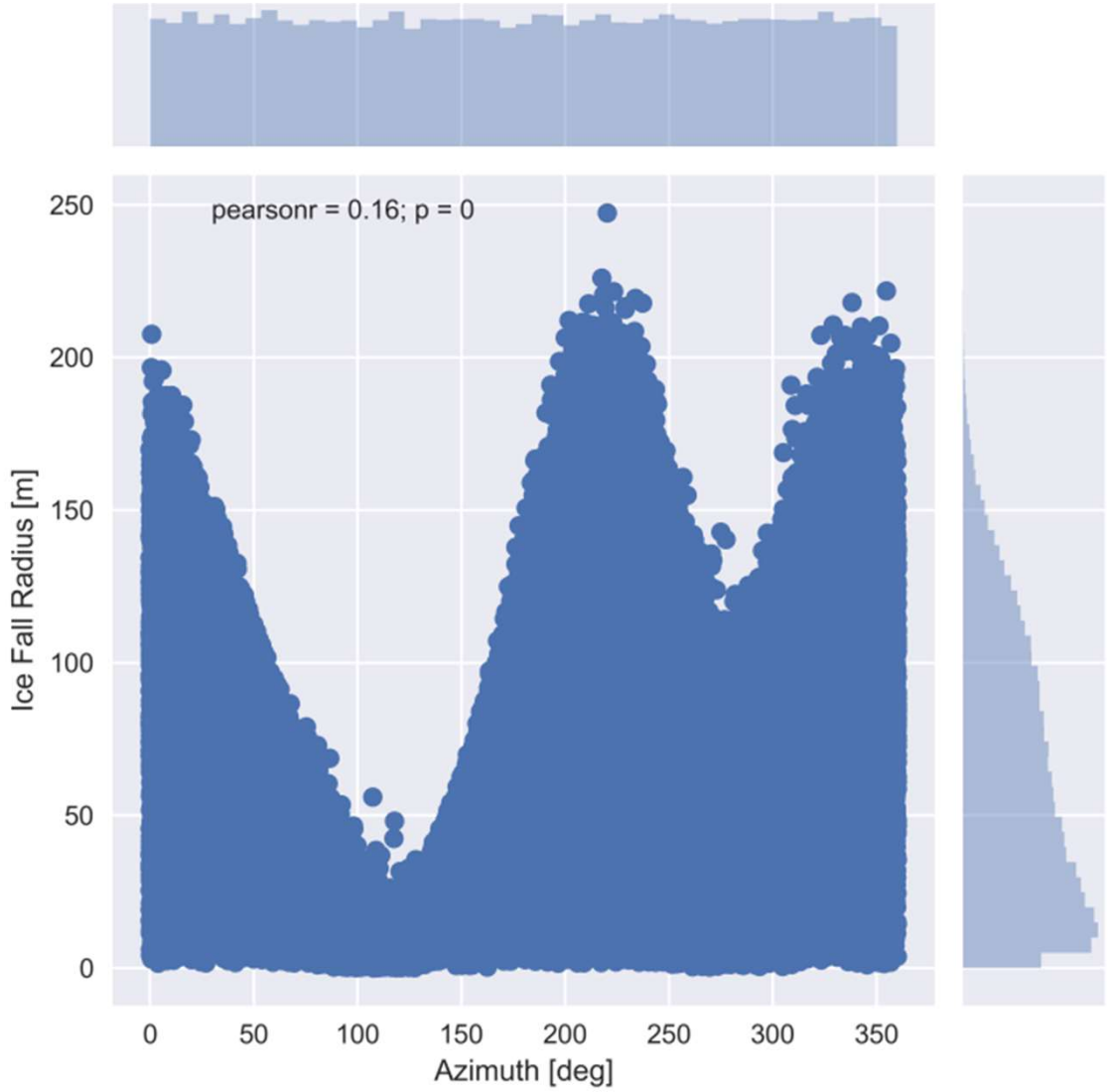


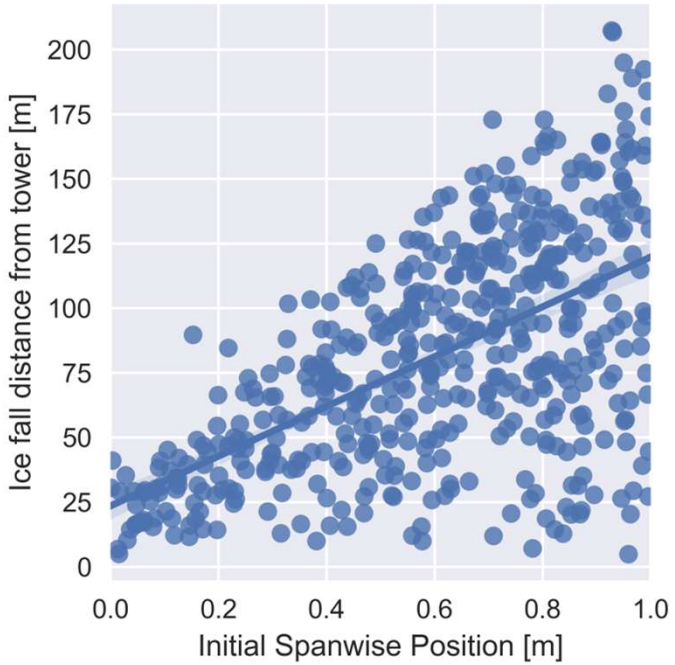


Sample more points out at the tails, and then downweight them. Get's better results.

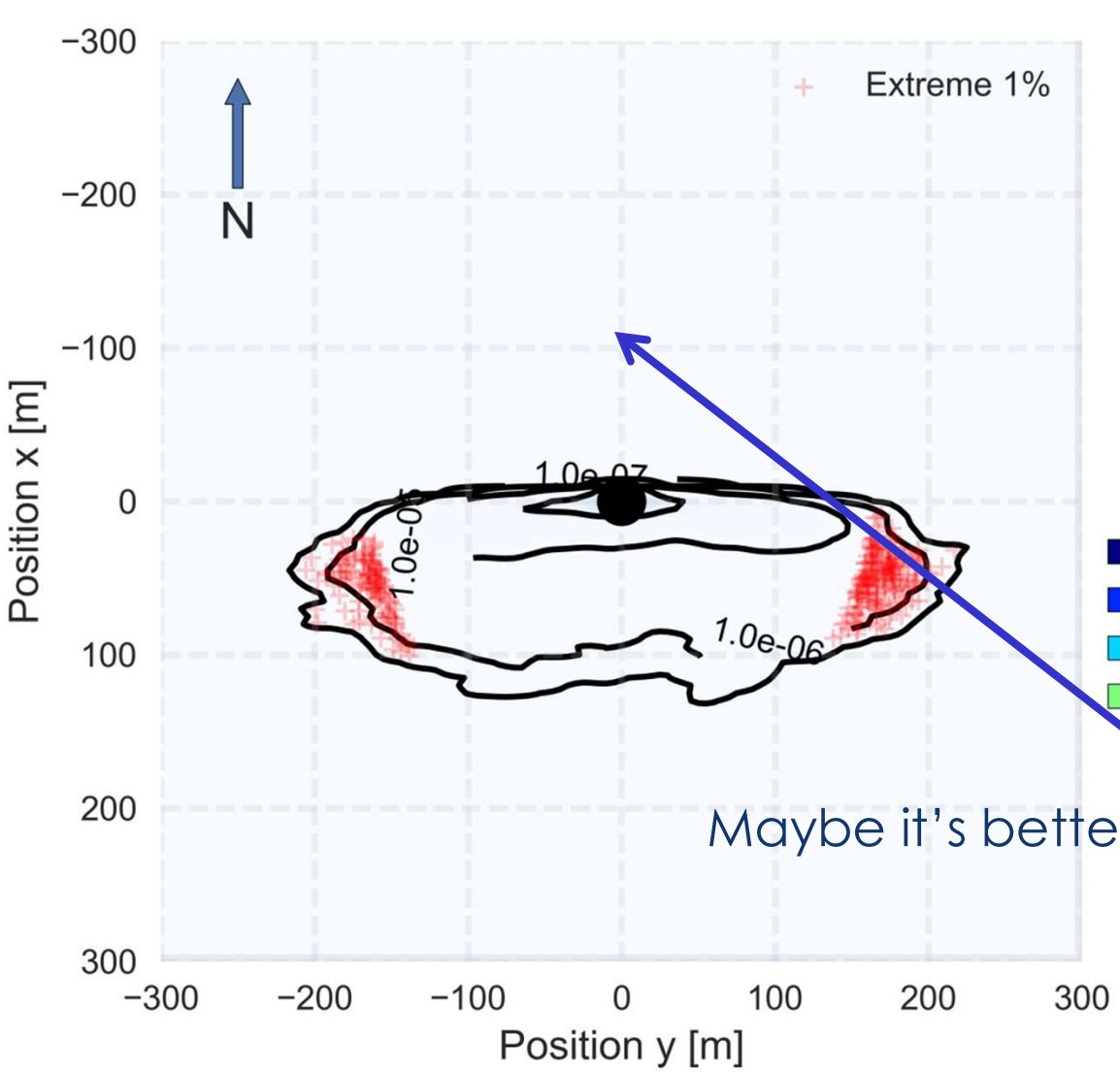


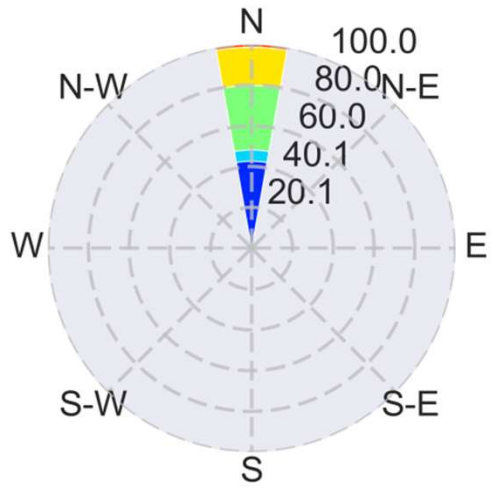
Ice Starting Point





Final Risk Contours – Probability Distributions



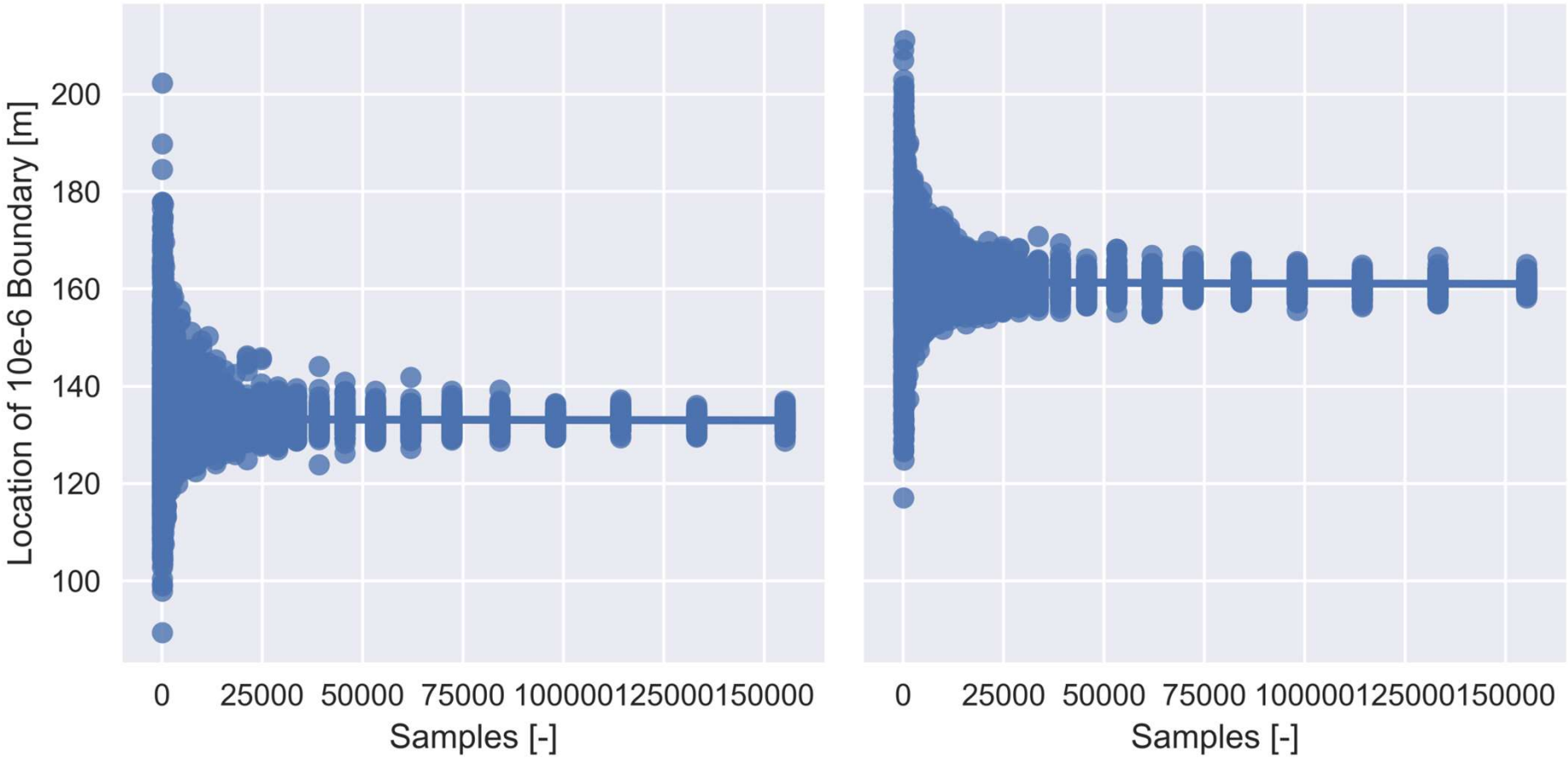


Wind Speed [m/s]

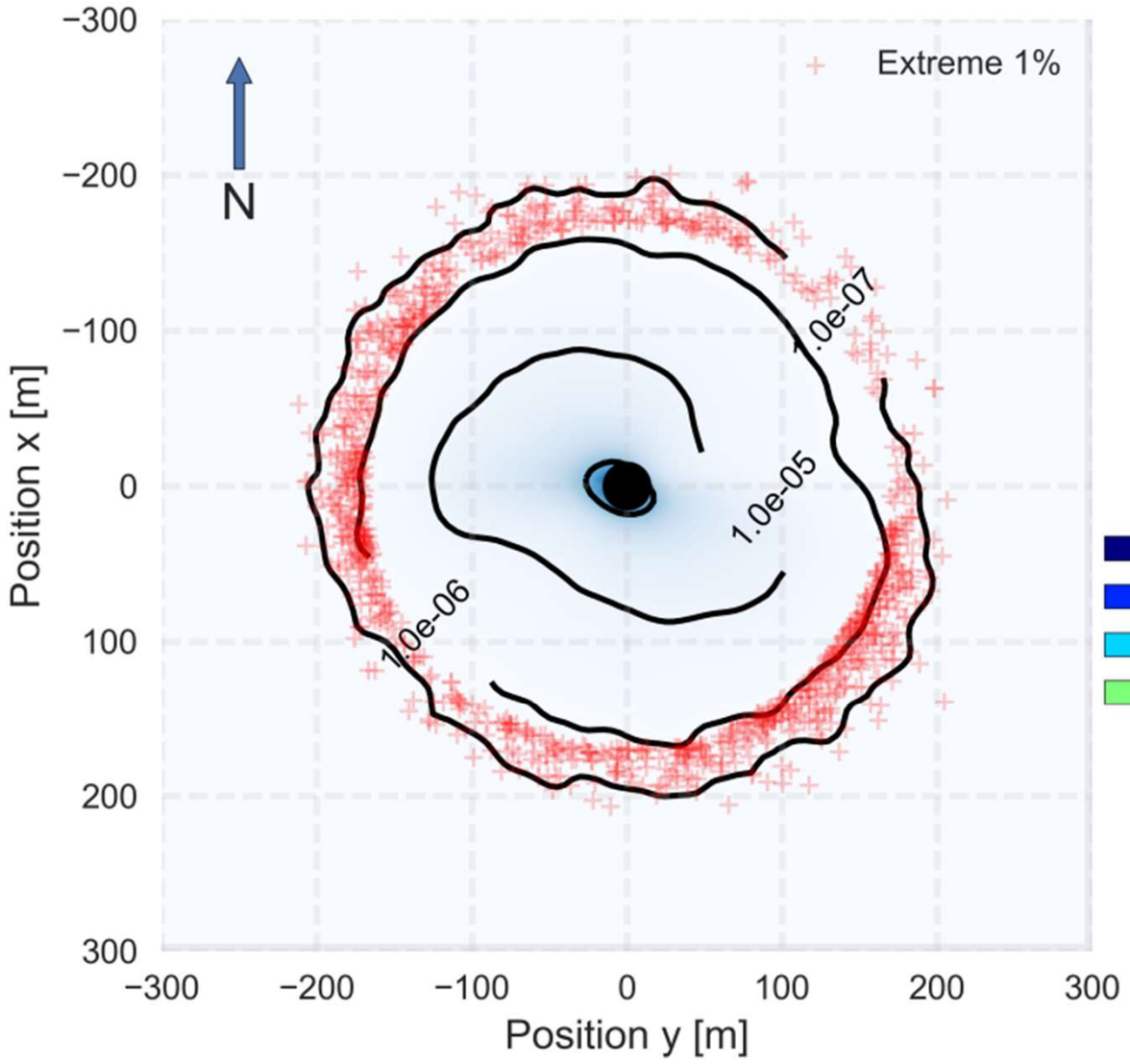
[0.0 : 3.0[	[12.0 : 15.0[
[3.0 : 6.0[	[15.0 : 18.0[
[6.0 : 9.0[	[18.0 : inf[
[9.0 : 12.0[	

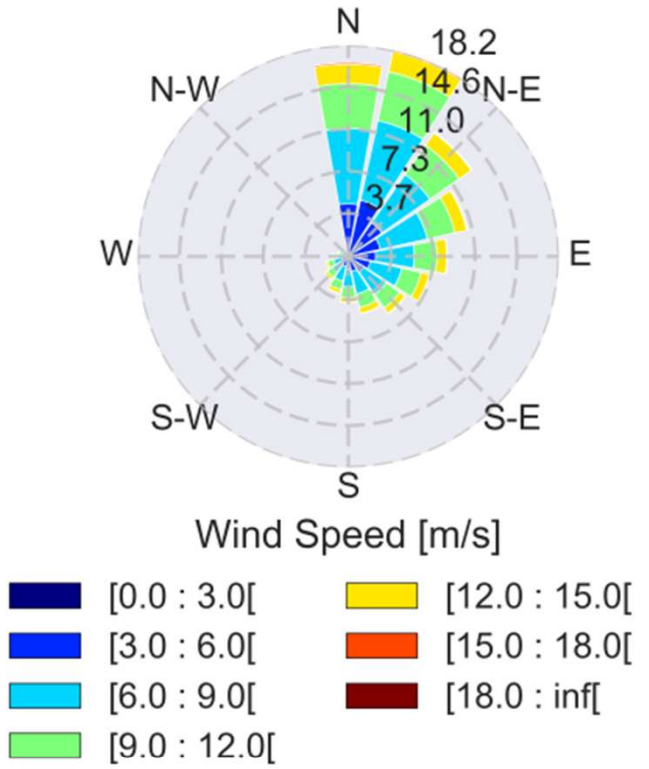
Maybe it's better to park the car here?

Convergence

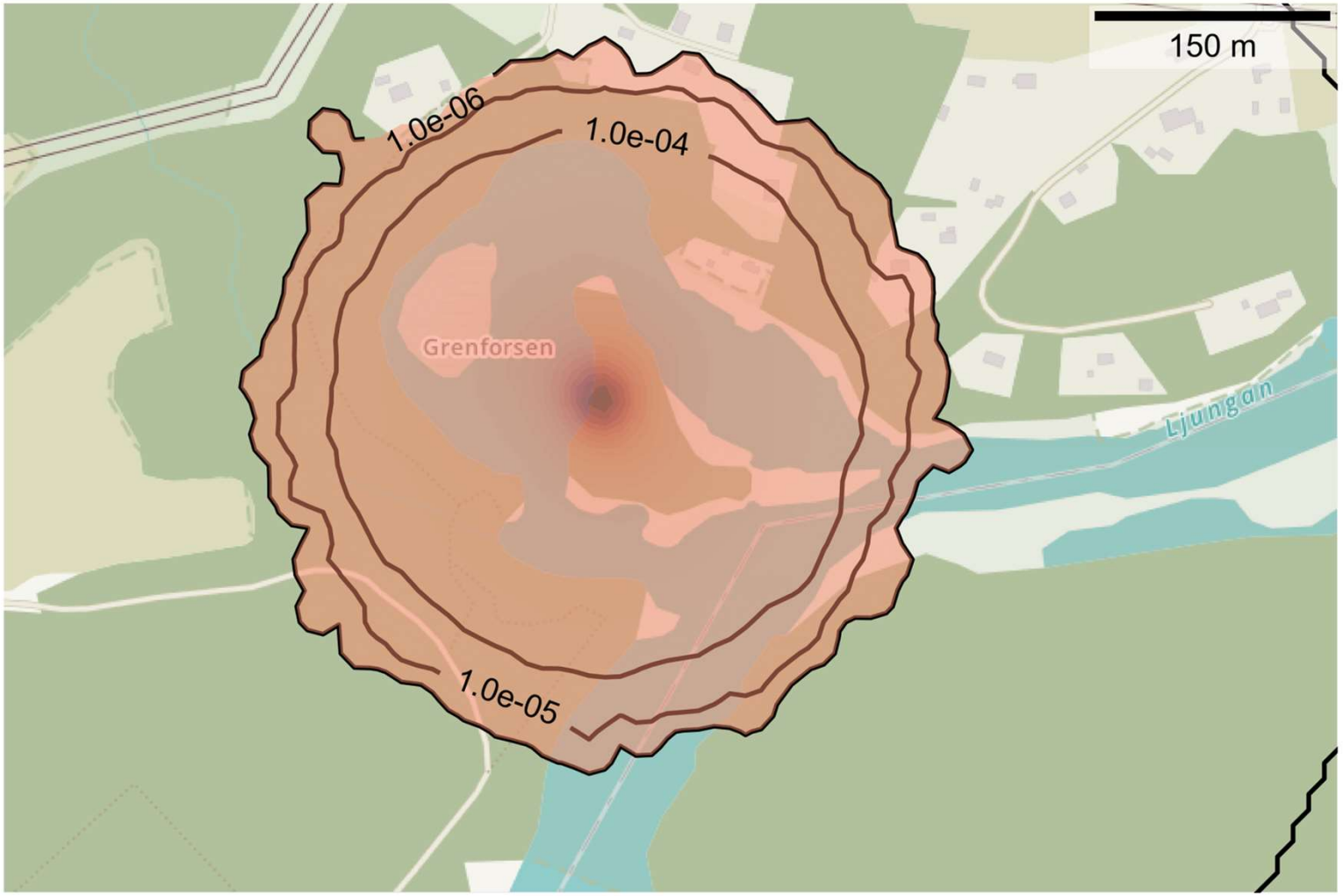


Applying the Wind Rose





On Site



Test Case

EFFICIENT ANTI-ICING DESIGN

Normal

Video : NREL 5MW Reference

www.fraps.com

Time: 0.1412 s
Power: 0 kW
Cp: 0
V_in @ hub: 30 m/s

Vortex Elements: 0

Anti Icing on outer 70%

Video : NREL 5MW Reference

www.fraps.com

Time: 0.2824 s
Power: 0 kW
Cp: 0
V_in @ hub: 30 m/s

Vortex Elements: 0

Shut down

Video2 : NREL 5MW Reference

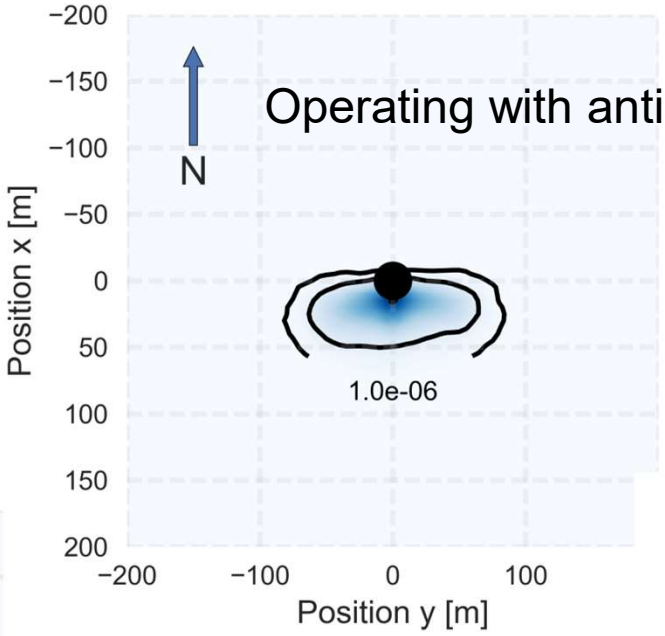
www.fraps.com

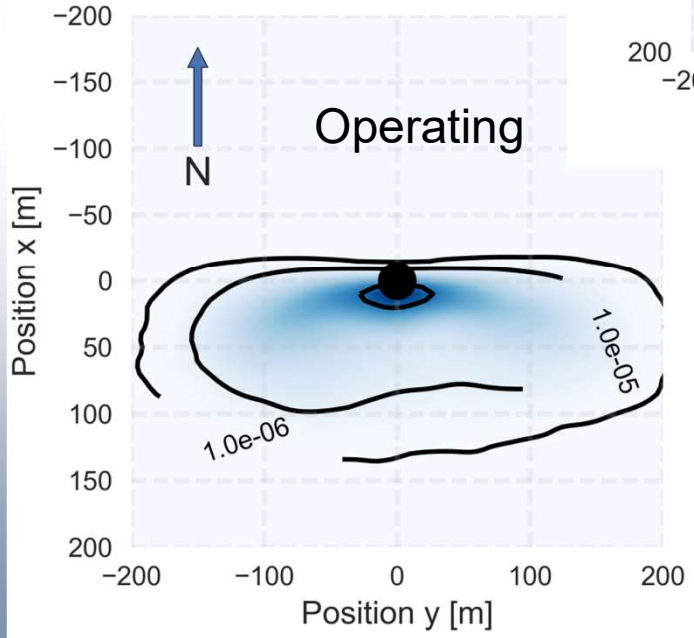
Time: 0.28 s
Power: 0 kW
Cp: 0
V_in @ hub: 50 m/s

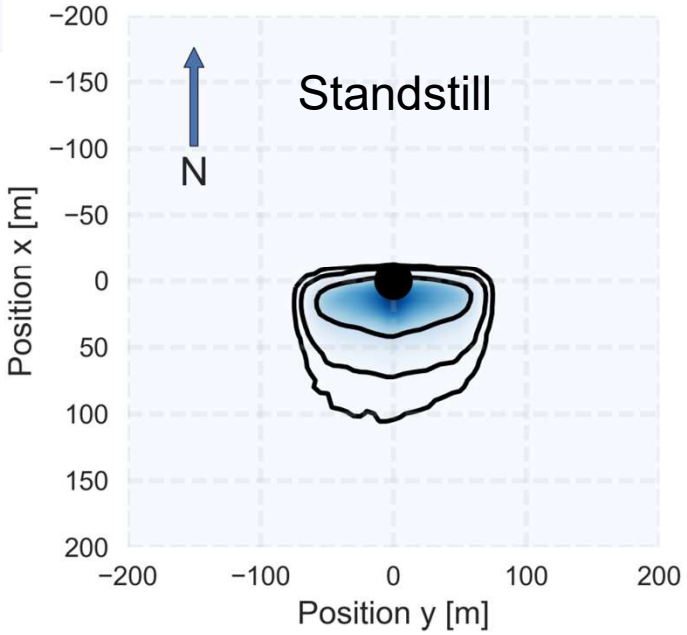
Vortex Elements: 0

Inner Heating Case

Video : NREL 5MW Reference

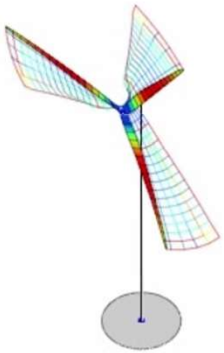
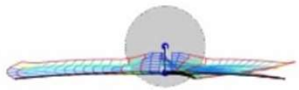






Better Marketing?

Shameless marketing?

Free download from SourceForge.
The Qblade team is:

- David Marten, Joe Saverin, Sebastian Perez-Becker, Me
- George Pechlivanoglou - Eunice Wind
- Sean Dominin – Previous Master's Student Ice throw