ICETHROWER

Mapping and tool for risk analysis

Winterwind, Skellefteå 7 February 2017
Jenny Lundén, Pöyry Sweden

WHAT IS THE PROBLEM?


Photo: Vattenfall

WHAT IS THE PROBLEM?

1. Wind turbines drop ice pieces occasionally

2a. The emotional conclusion is “often” and “long distance” (km!)
2b. The pragmatic approach is ”now and then” and “within 1D”

3. Risk level is generally poorly investigated and hard to calculate

IS THERE A SOLUTION TO THE PROBLEM?

Level of confidence can be increased by more observations

Discrepancies between different turbines can be investigated

A generic tool to increase the possibility to calculate and communicate risk both for service personnel and for the public

ICETHROWER – mapping and tool for risk analysis

Project:

- Mapping ice throws in Sweden
- Develop a model to simulate ice throw and assess health & safety risks
- Client: Swedish Energy Authority
- Partners: Dala Vind, Vattenfall Vindkraft and Skellefteå Kraft
- Location: 3 wind farms in Sweden
- Field study: 2013 – 2016

Photo: Vattenfall

WHICH IS OUR APPROACH?

Joint research project within Energimyndigheten's research program "Wind power in cold climate"

Pöyry Sweden
Project leader
Data analysis / development of statistical ice throw model

ProgramoGrafik
Validation KASTIS model

Dala Vind
Field study
1 turbine in mid-Sweden
forest
without blade heating

Skellefteå Kraft
Field study
2 turbines in northern Sweden
mountain terrain
with blade heating

Vattenfall Vindkraft
Field study
1 turbine in northern Sweden
forest
without blade heating

THE ICETHROWER PROJECT

The project is divided into three parts:

- Field study to collect ice data from 3 wind farms in Sweden and create a database for common use
- Verify and integrate the existing tool KASTIS into a common tool box
- Develop a usable simulation tool for risk evaluation based on collected data


Photo: B. Göransson

THE FIELD STUDY - METHOD

Three wind farms in Sweden
Collect information:
- Physical properties of ice lumps
- Throwing distance
- Meteorological data at the time of ice throw

Data collection during winter 2013 - 2016

Challenges in field work:
- Severe winters -> increased risk
- Mild winters -> less data

THE FIELD STUDY - METHOD

Systematic approach in the search for ice lumps

- Ice lump measurement and classification
- Location of ground impact and throwing distance
- Photographs

Vindkraftverk | X-koordinat | Y-koordinat | oordinatsyster RT90 2,5 gon V

Nr	Observation				Kasttid				Vid kasttillfället						Fyndplats		Kastavstånd	Isegenskaper					
	år	månad	dag	tid	år	månad	dag	tid	Driftsm	Vindsty	Riktni	Ber rik	Temp	Tryck	X-koordir	Y-koordi	m	Istyp	Vikt kg	Ursprung	Längd cı	Bredd (	Markens hårdhe
1																							
2																							
3																							
4																							
5																							

Ice Sheding data for the wind turbine

the Excel sheet is designed to to get the relevant data needed of the ice fragments and should be used as a standardised document for all ice fragments collected.

When there is no data avaiable for the column *Nn* is used and the coordinate system used is RT 90 2,5 gon V.

When collecting the ice fragments and the time for when the ice was shedded is not avaiable the lowest value and the highest value troughout that day has been used as a intervall and the letter *m* denotes the average value troughout the day

The parameters at shed time can be collected from tsvind02.

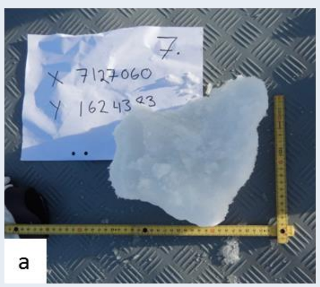
Ice type
A - Clear ice B - Rime ice C - Snow ice blend

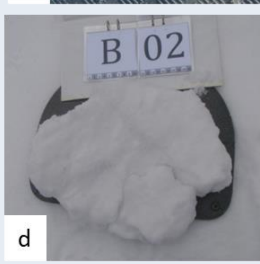
Origin/part
1 - Front edge of the blade 2 - Surface blade 3 - trailing edge of the blade
4 - Nacelle 5 - Tower

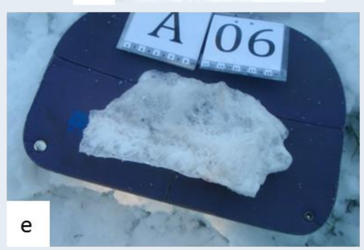
Shape
S - Cuboid, C - Cresent moon, Sp - Spheric, Co - Cone

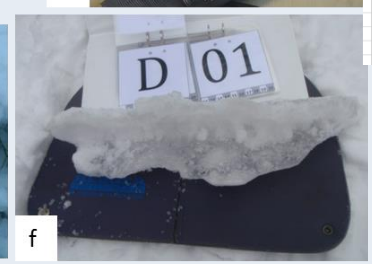
Driftsmod
R - Operational
0 - Not operational

Wind direction should be specified as *0-360, 0 is North 180 is south, etc..*









THE FIELD STUDY - METHOD

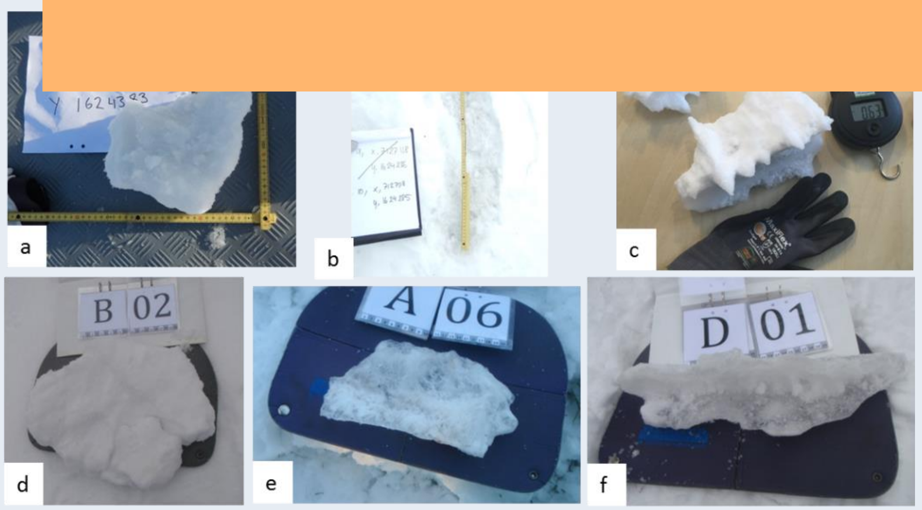
Three wind farms in Sweden

Collect information:

- Physical properties of ice lumps
- Throwing distance
- [illegible]

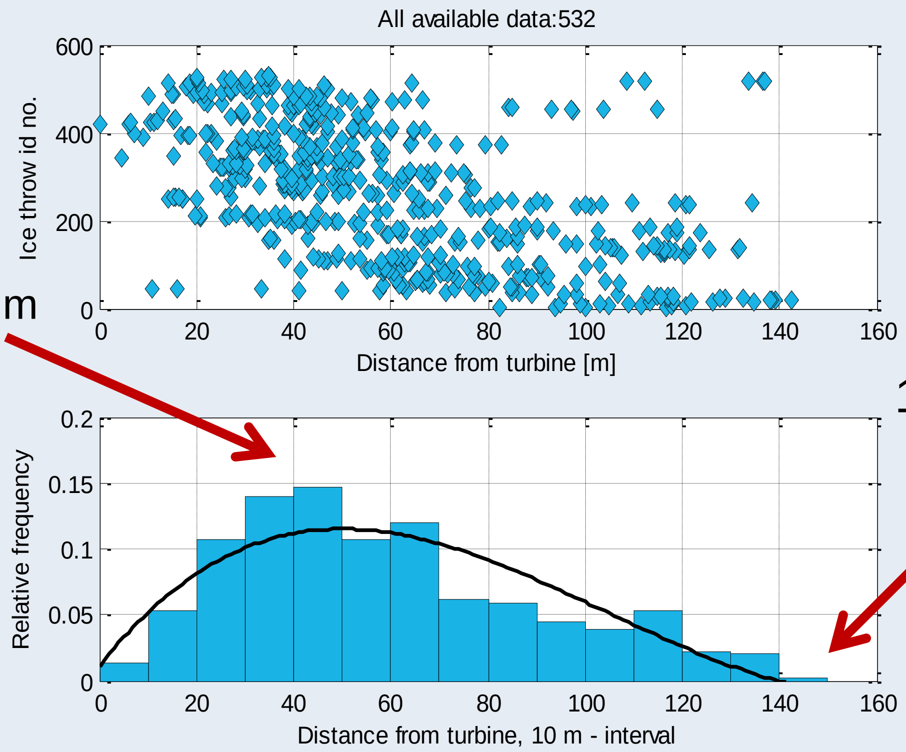
D[illegible]

Over all data from 530 ice lumps was collected!



THE FIELD STUDY – RESULTS (ALL DATA)

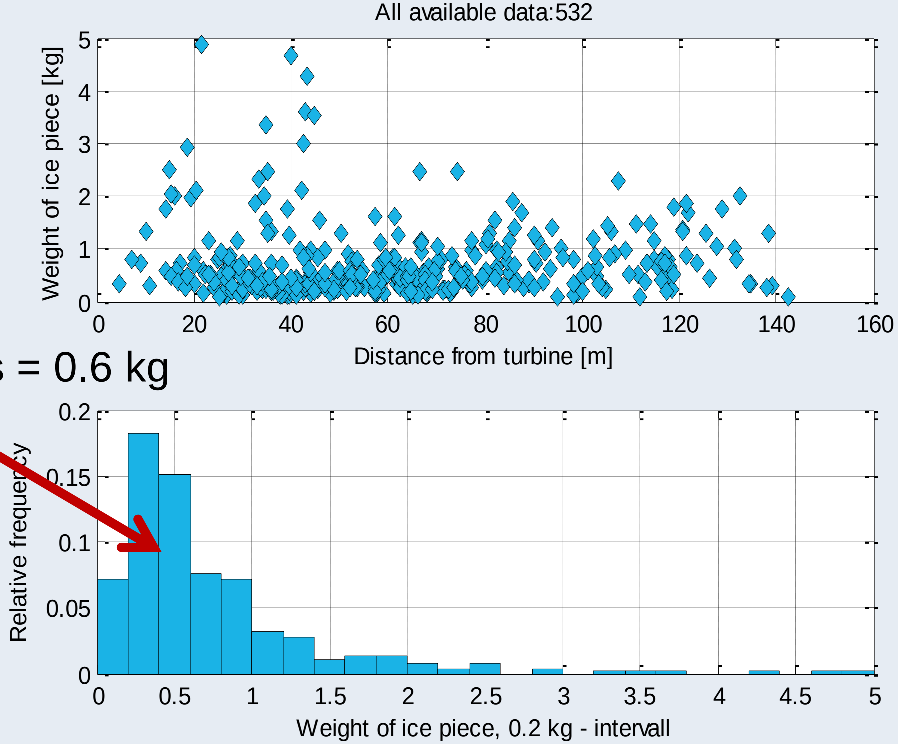
75% of ice lumps between 20 – 90 m



140 m = 1.55 RD

Turbines in the field study had 90 m rotor and 95 m tower (no de-icing system)

THE FIELD STUDY – RESULTS (ALL DATA)



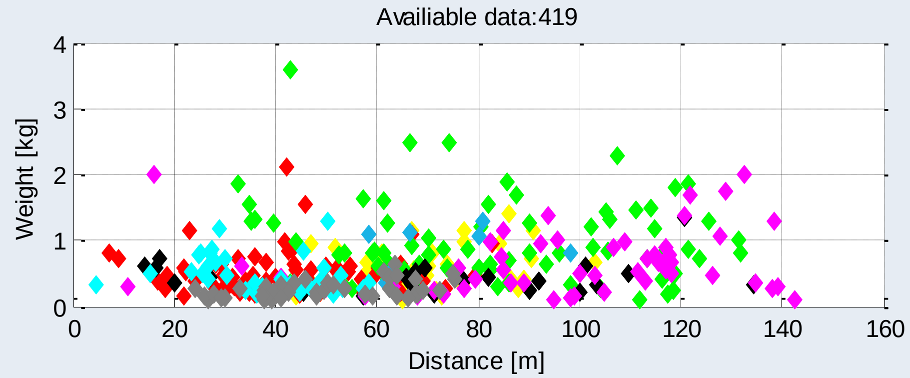
No trend between distance and ice mass

Average ice mass = 0.6 kg

Turbines in the field study had 90 m rotor and 95 m tower (no de-icing system)

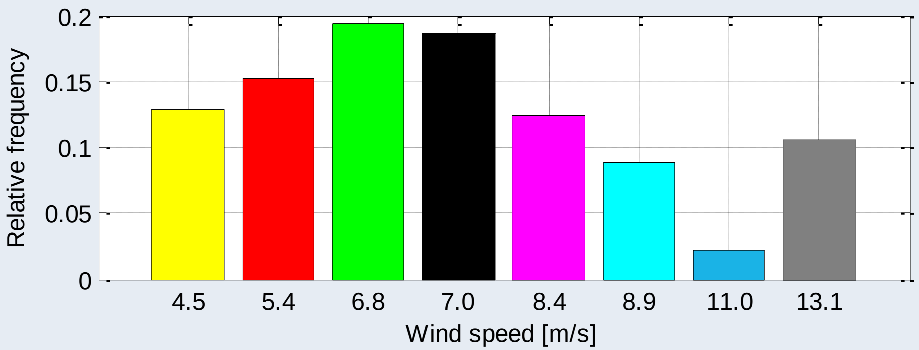
THE FIELD STUDY – RESULTS (CASE STUDY)

No trend between
- distance and wind speed
- distance and ice mass



2013: 2 ice days
2014: 2 ice days
2015: 1 ice day
2016: 3 ice days

10 – 80 ice lumps / ice event

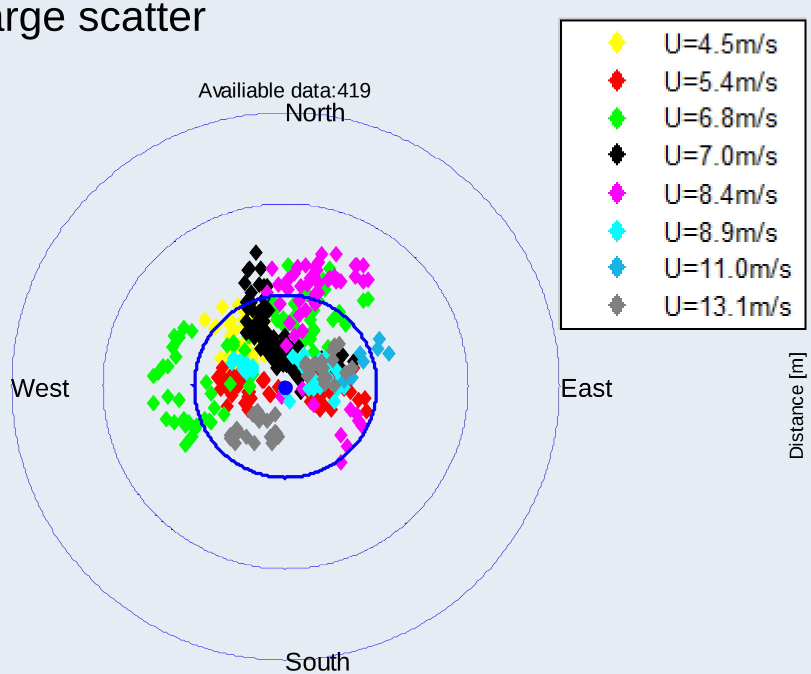


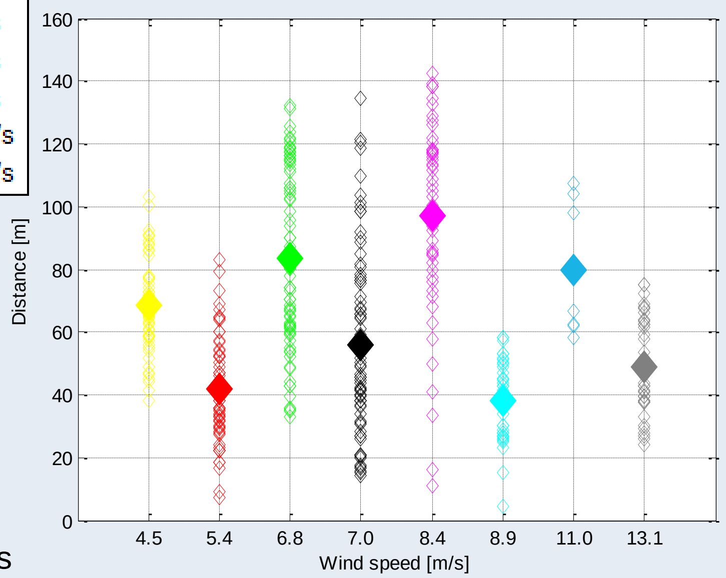
Turbine in the case study had 90 m rotor and 95 m tower (no de-icing system)

THE FIELD STUDY - RESULTS (CASE STUDY)

Ice lumps fall in the wind ward direction.
All ice lumps were found within 2 RD
Large scatter

Wind speed between 4.5 – 13 m/s
at the time of ice release





The blue circles show one, two respective three rotor diameters (e.g. 90, 180 and 270 m)

Turbine in the case study had 90 m rotor and 95 m tower (no de-icing system)

THE KASTIS MODEL – SELECTED OUTCOME

Purpose: calibrate and tune the previously developed model KASTIS.

- A developed version of KASTIS was derived in the project, called iceThrow
- The program calculates trajectories for ice lumps released from wind turbine blades during operation using very detailed information of the ice lump

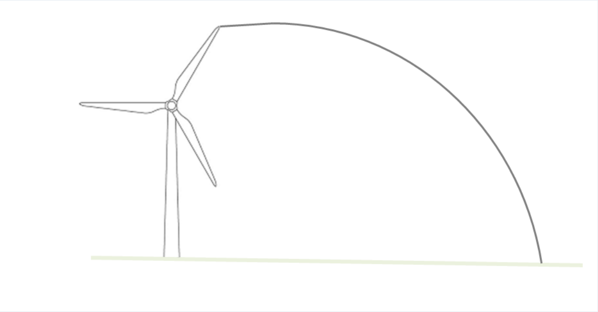
Result:

- The iceThrow model showed that most of the ice lumps in the range 0.1 – 0.4 kg hit the ground with a speed, converted to energy, in the potential lethal region i.e. in excess of 40 J


Photo: B. Göransson

THE ICE THROW MODEL - METHOD

A statistical ice throw model was developed using the equations of motion in combination with Monte Carlo simulations.



$$M\frac{d^2x}{dt^2} = -\frac{1}{2}\rho C_D A\left(\frac{dx}{dt} - U\right)|V|\ Eq.3$$

$$M\frac{d^2y}{dt^2} = -\frac{1}{2}\rho C_D A\left(\frac{dy}{dt}\right)|V|\ Eq.4$$

$$M\frac{d^2z}{dt^2} = -Mg - \frac{1}{2}\rho C_D A\left(\frac{dz}{dt}\right)|V|\ Eq.5$$

The relative wind speed is given by,

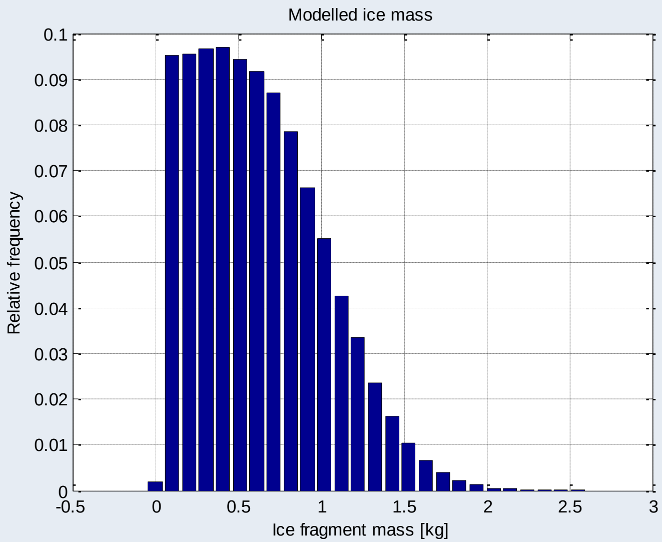
$$|V| = \sqrt{\left[\left(\frac{dx}{dt} - U\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right]}\ Eq.\ 6$$

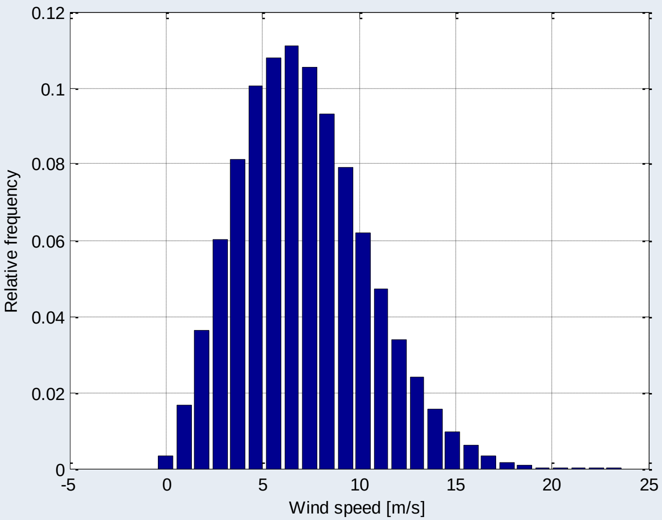
Where M is the mass of the ice fragment, C_D is the drag coefficient, ρ is air density, $U(z)$ is the wind speed with x-axis parallel to the wind and g is the gravity.

THE ICE THROW MODEL - ASSUMPTIONS

Assumptions used in the ice throw simulations

- Random normal distribution of mass
- Random Weibull distribution based on wind speed and direction
- Turbine specifics (rotor radius, hub height, rotor revolution)

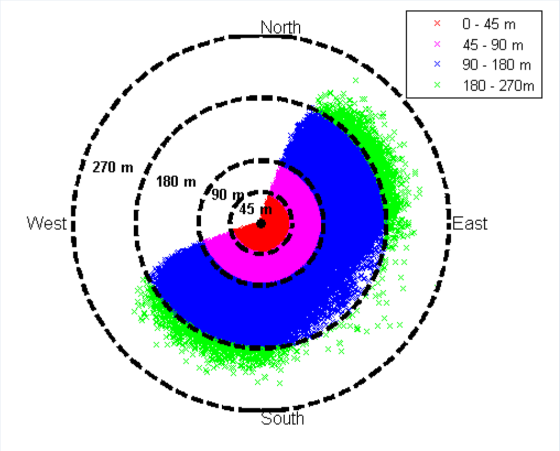




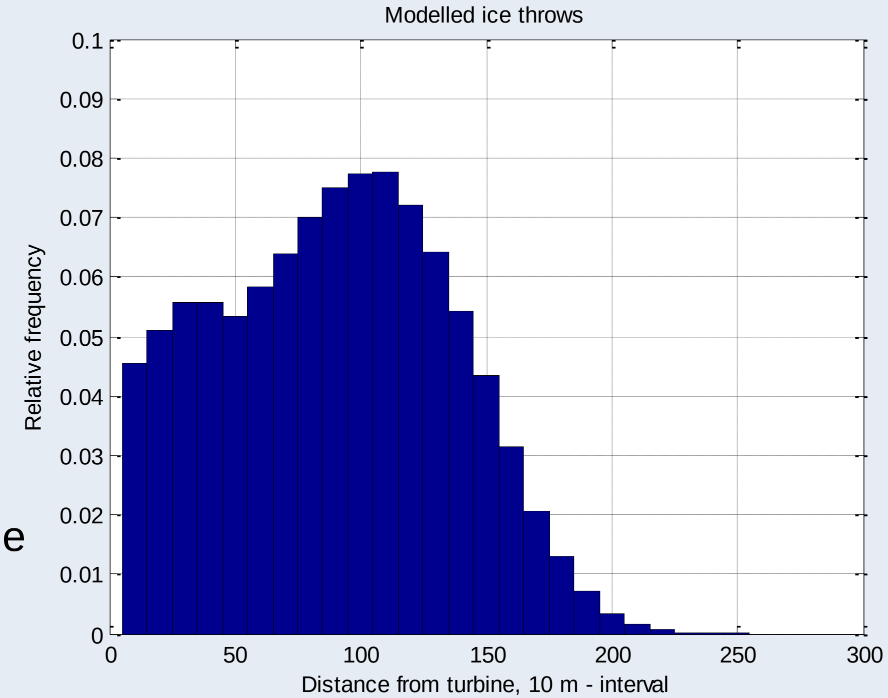
Turbine used in the simulation had 90 m rotor and 95 m tower

THE ICE THROW MODEL - RESULTS

Example:
Turbine with 90 m rotor diameter and 95 m hub height
Only using wind from the prevailing wind direction (WNW & NNW)

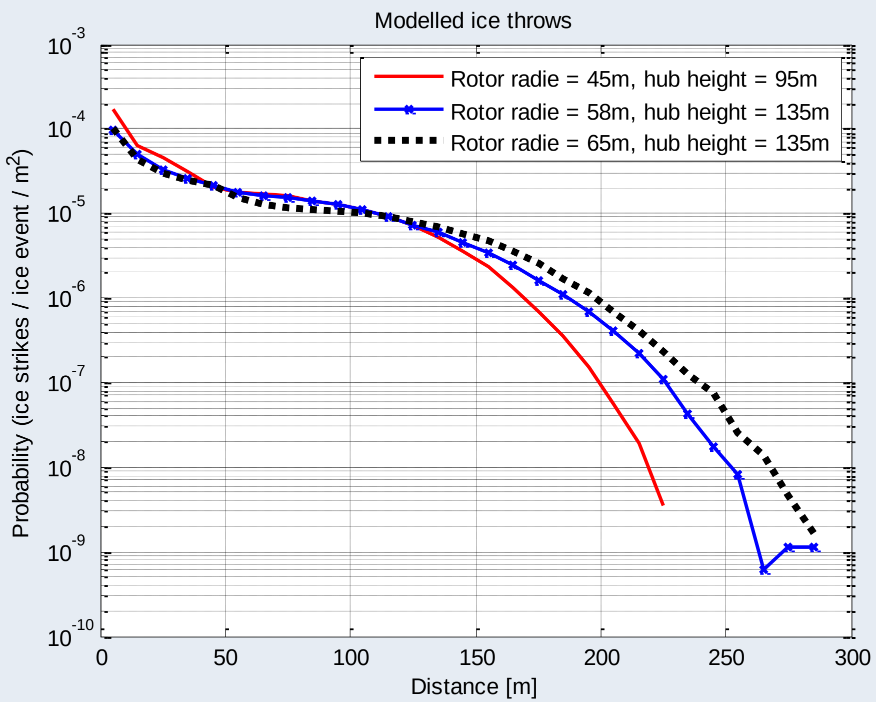


Ice lumps land on the wind ward side



The furthest modelled throwing distance: 250 m

THE ICE THROW MODEL - RESULTS



Larger wind turbine -> longer throwing distance
However the probability rapidly decreases with distance

Based on 100 000 simulated ice throws, all wind directions included

EXAMPLE OF RISK ESTIMATE

Two service personnel visit wind farm after indication of icing on the turbines.

- Park the car 10 m from entrance
- Get tools, walk to the turbine (5 min)
- Work for 1 hour inside the turbine
- Walk back to the car, load tools (5 min)

During a working day they visit 5 turbines.

The estimated total risk is then

- 0.009 for the car or 1 in 115 year
- $1.5*10^{-4}$ for 2 service personnel on one working day or 1 in 6 900 years.

Photo: Vattenfall

Assumptions: car = $10m^2$, one person = $0.5\ m^2$
70 ice lumps released per icing day and turbine.
Probability from the red curve on previous slide.

EXAMPLE OF RISK ESTIMATE CONT.

High or low risk?

In the example the total risk (one working day)

- $1.5*10^{-4}$ for 2 service personnel

  or 1 in 6 900 years.

- In comparison the risk of car accident is $5*10^{-5}$

The estimated risk is considerable high and not acceptable without certain safety provisions.

For the public the risk is lower since they do not know if the turbine are affected by ice.

(e.g. the number of ice day / the winter season)

It is important to have warnings signs at the wind farm entrance to alert the public of the potential hazard.

Photo: Vattenfall

Thank you!

PÖYRY
Engineering balanced sustainability™

CONTACT:

Jenny Lundén and Bengt Göransson
MAIL: jenny.lunden@poyry.com, bengt.goransson@poyry.com