

# IceRisk

Forecast system for operational wind farms

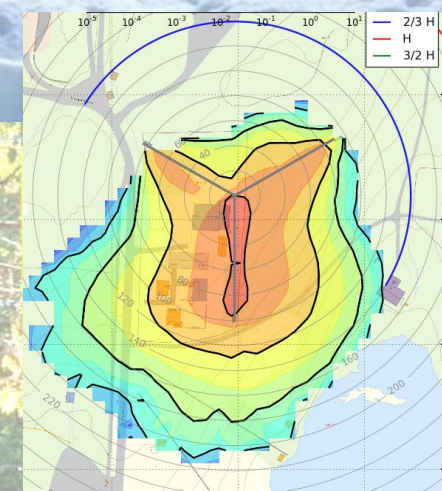
**Rolv Erlend Bredeesen**  
[rolv.bredeen@vindteknikk.no](mailto:rolv.bredeen@vindteknikk.no)

Winterwind, Åre  
 February 8, 2016

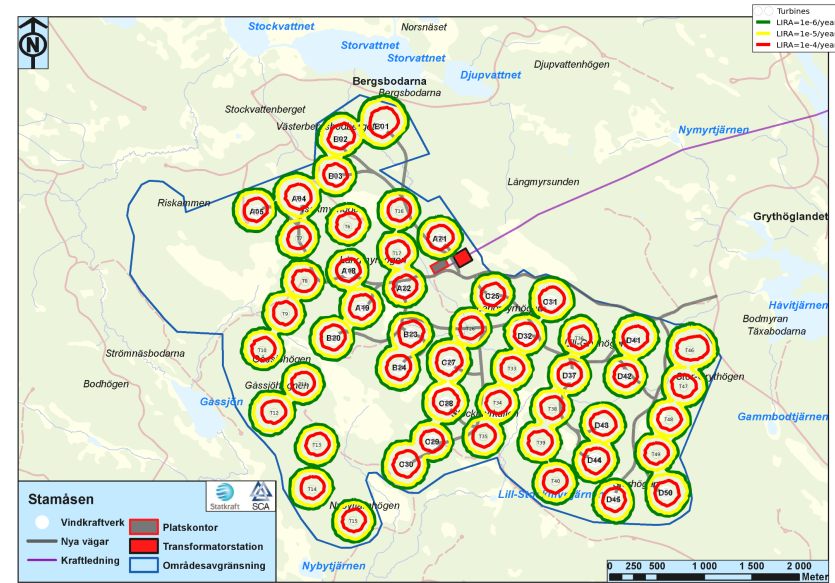
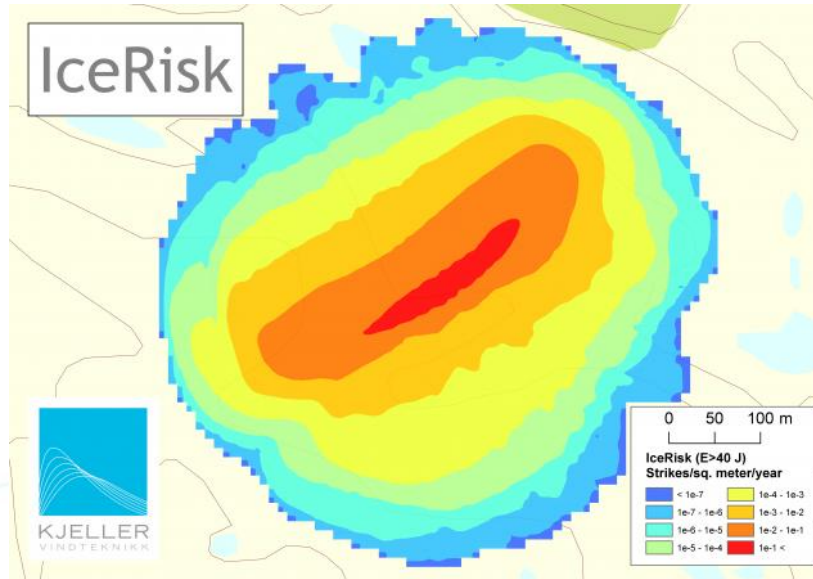




# Ice warning system



# Forecasts of safetyzones: when, where, and how much ice can be thrown in your wind farm

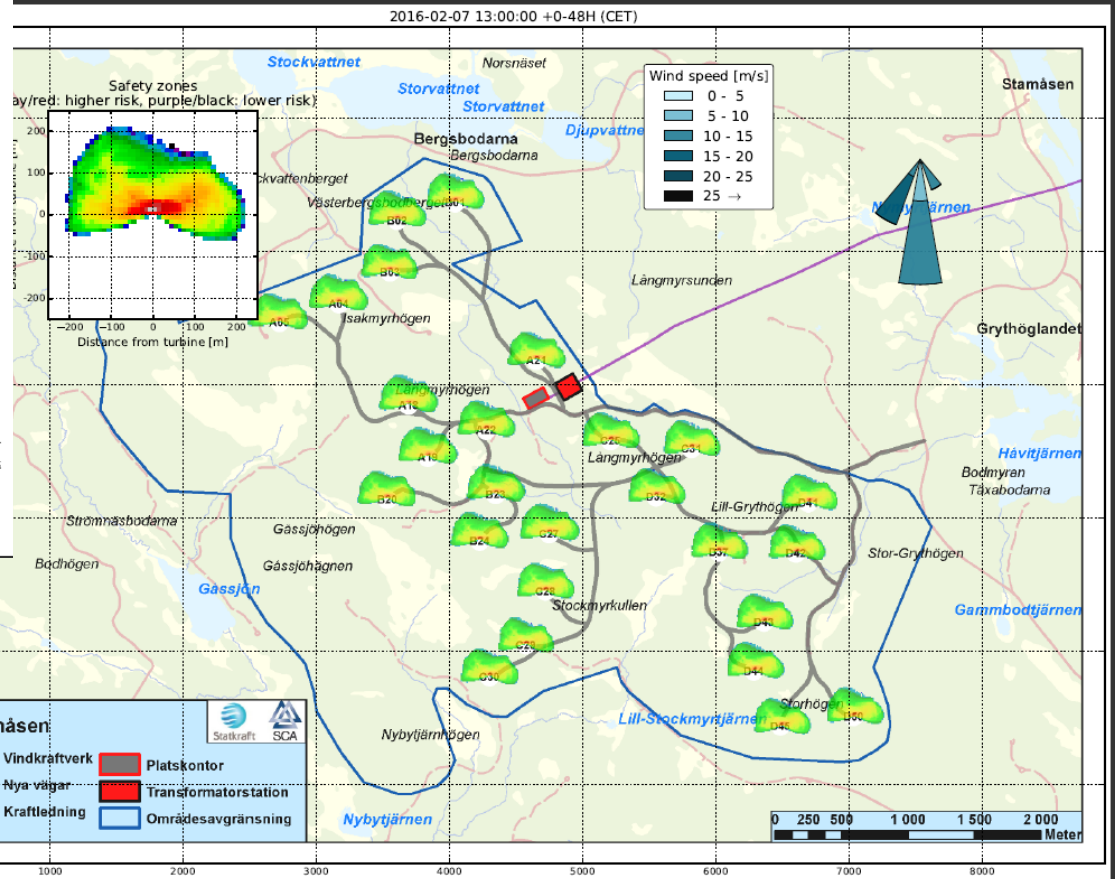
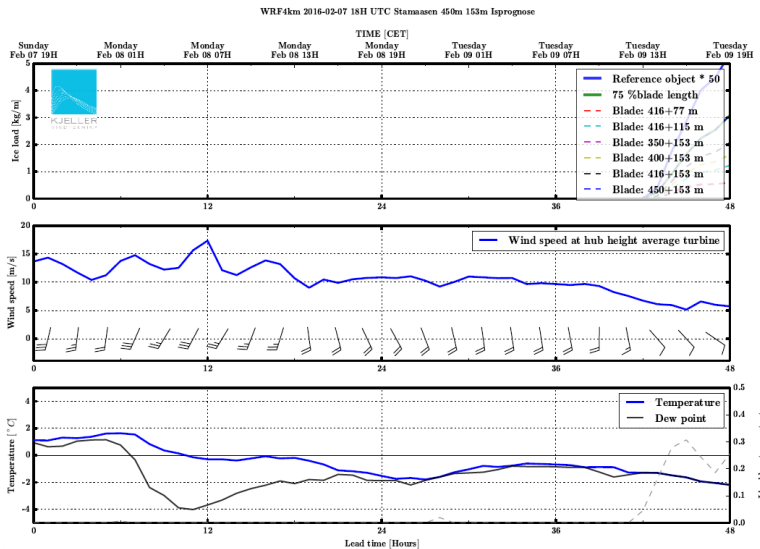


- **Detailed description of IceRisk methodology in IWAIS 2015 article:**
- Bredesen, R.E., Refsum, H.A., 2015. Methods for evaluating risk caused by ice throw and ice fall from wind turbines and other tall structures. Kjeller Vindteknikk, NO (38). IWAIS 2015. 16th International workshop on atmospheric icing of structures. ISBN 978-91-637-8552-8. Uppsala, Sweden, June 28 - July 3 2015. [www.iwais.org](http://www.iwais.org)

# Ice warning system

## Decision support system - IceRisk

- 48 hour forecasts issued 4 x daily with WRF4km
- Meteogram with ice accretion and removal
- Maps of risk zones



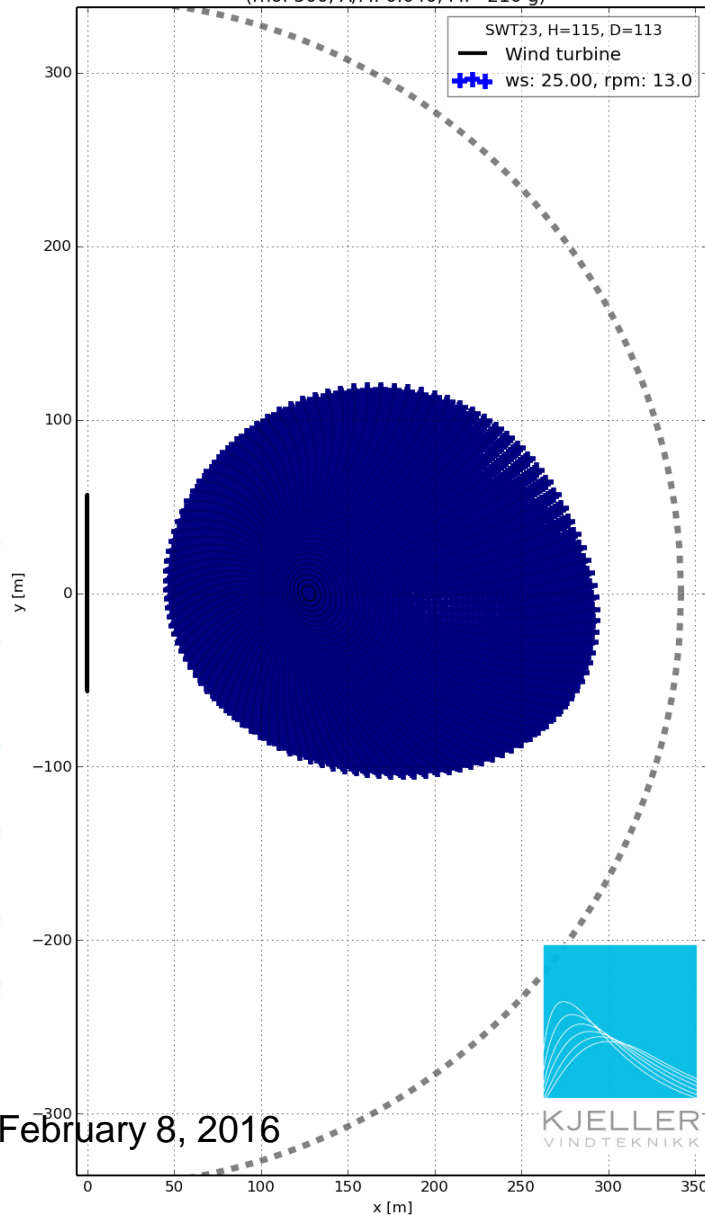
February 8, 2016

# Stamåsen wind farm (Statkraft)

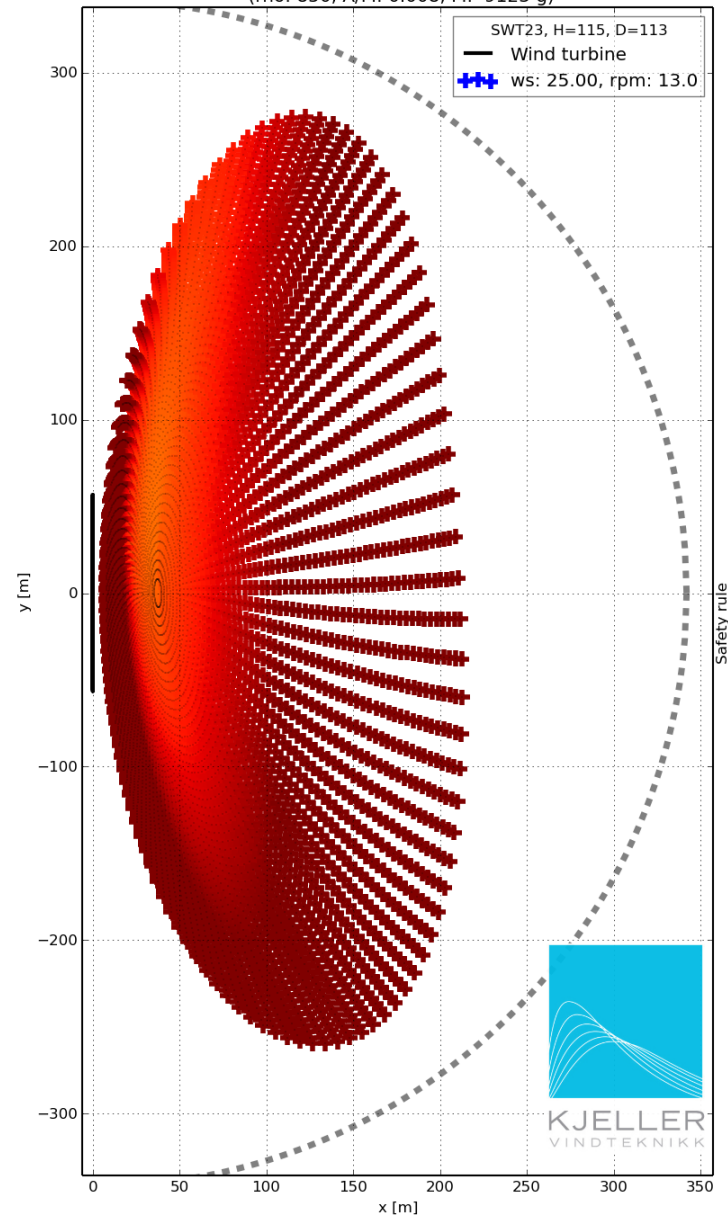
- IceRisk warning system in operation
- Ongoing validation and improvements

# Furthest expected icethrow at Stamåsen

Impact Kinetic Energy (40-800 [J]) of  
icethrow from blade 7.5 cm icecube  
(rho: 500, A/M: 0.040, M: 210 g)

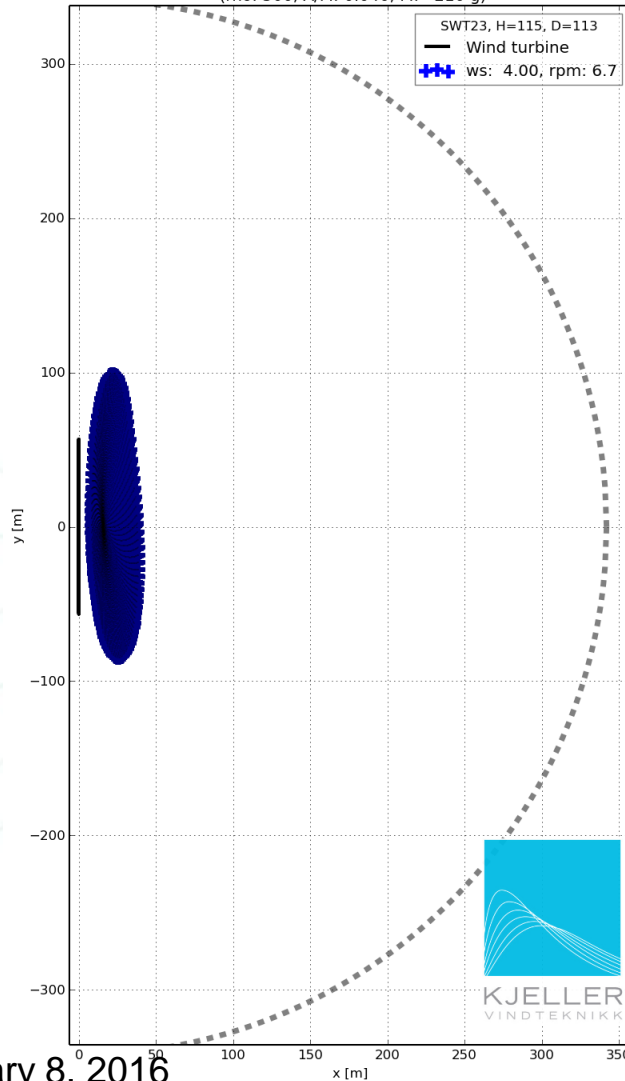


Impact Kinetic Energy (40-800 [J]) of  
icethrow from blade 22.1 cm icecube  
(rho: 850, A/M: 0.008, M: 9123 g)

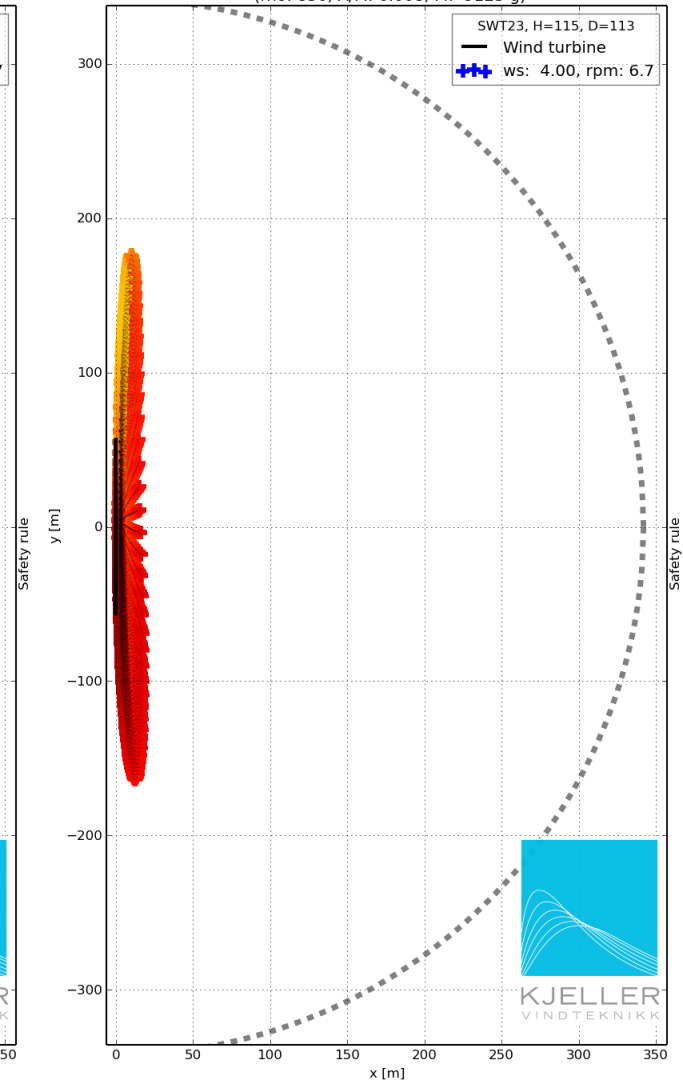


# Large ice pieces can be thrown far to the side during 4 m/s winds

Impact Kinetic Energy (40-800 [J]) of  
Icethrow from blade 7.5 cm icecube  
(rho: 500, A/M: 0.040, M: 210 g)

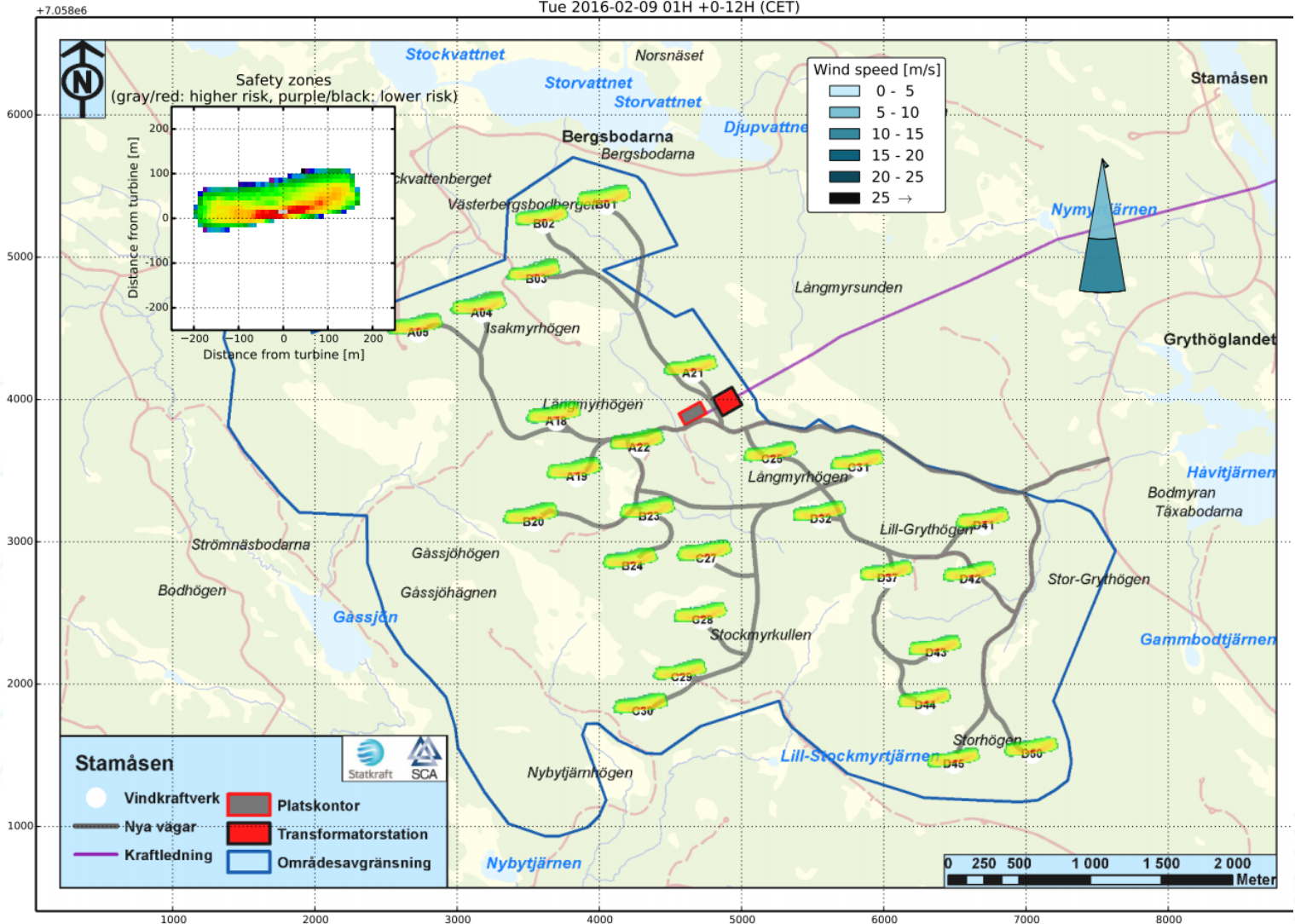


Impact Kinetic Energy (40-800 [J]) of  
Icethrow from blade 22.1 cm icecube  
(rho: 850, A/M: 0.008, M: 9123 g)



February 8, 2016

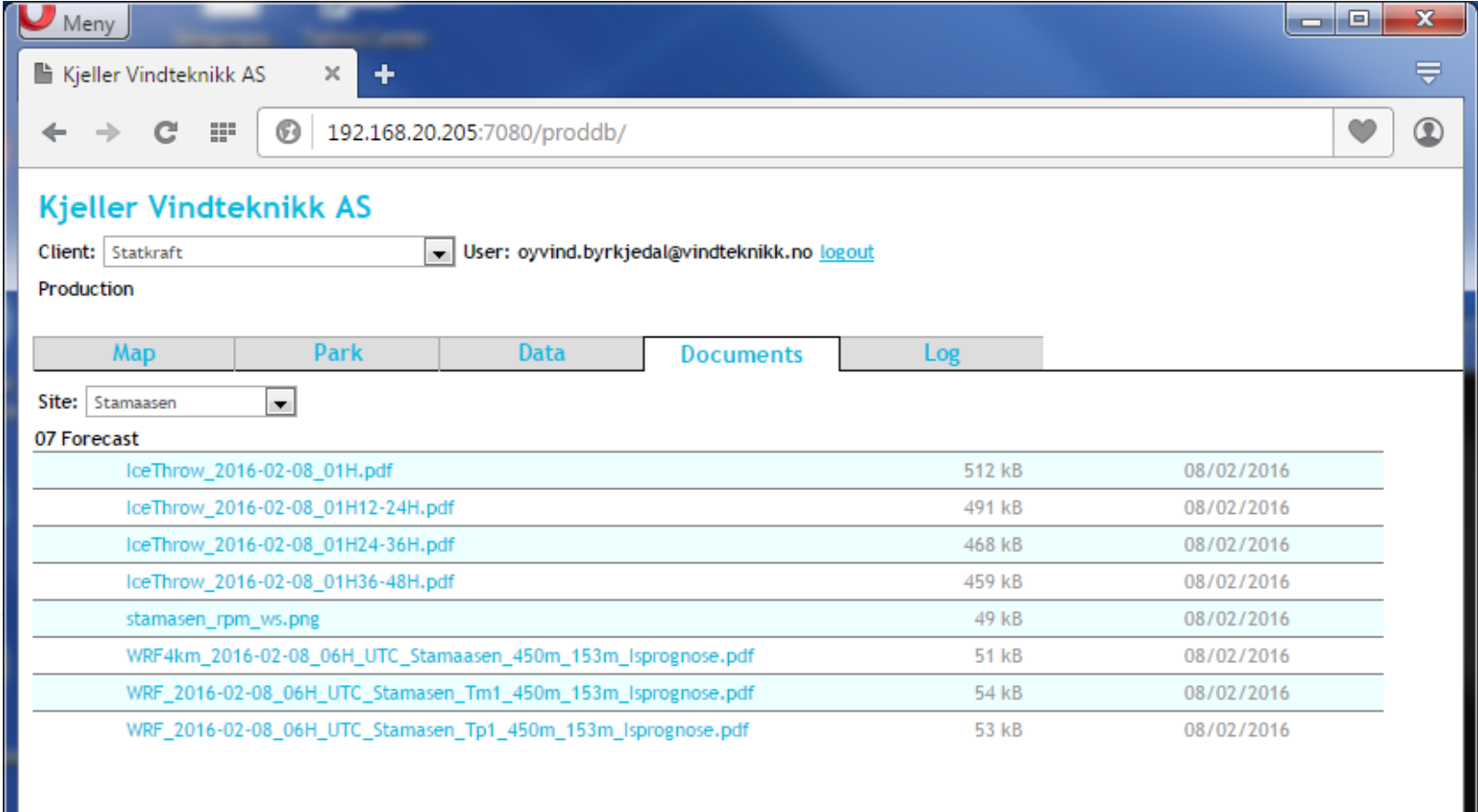
# Risk zones tuesday morning (12 hour period)





# Forecasts are made available through the KVT Database

- Tailor-made access interface:  
Automated emails, FTP, app engine etc.



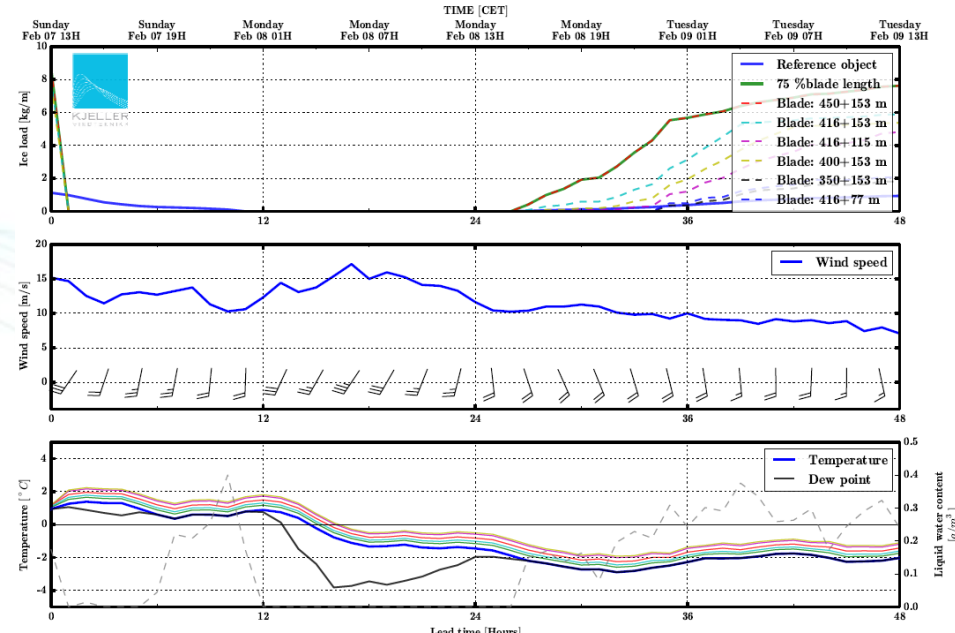
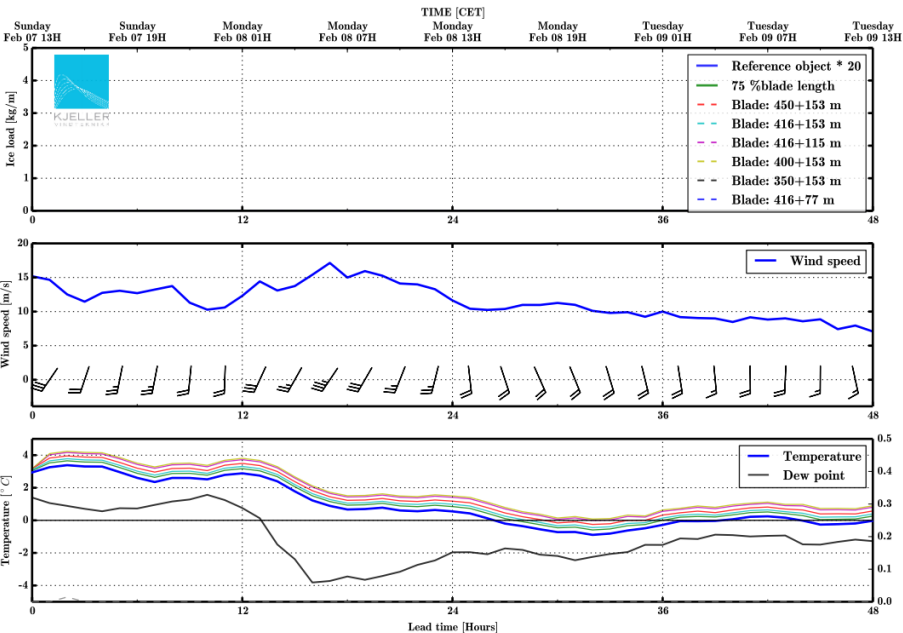
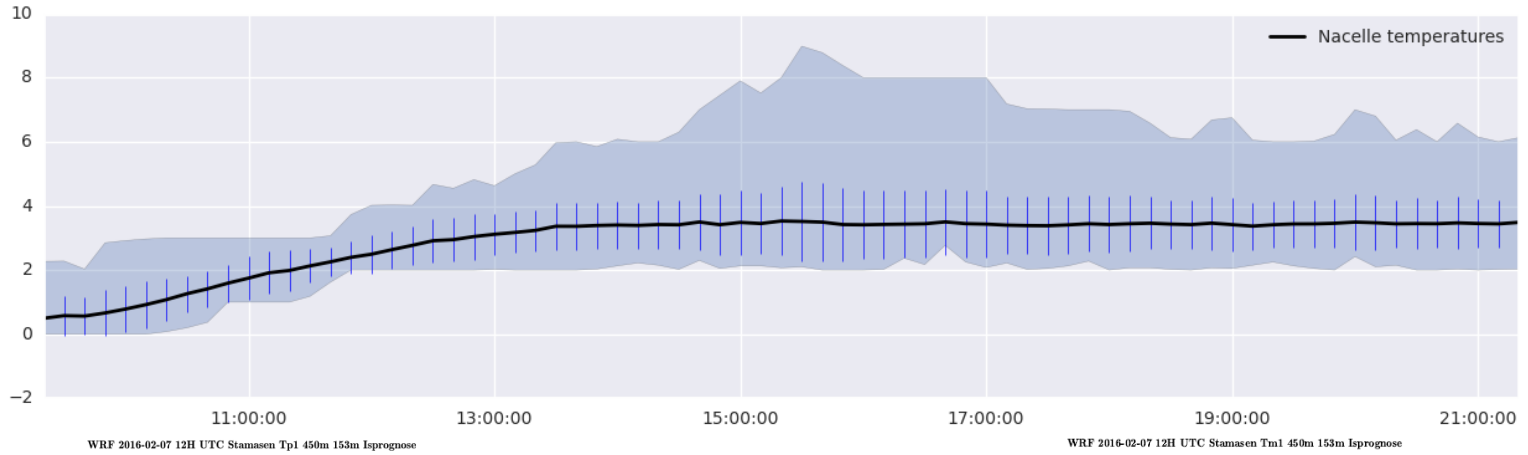
The screenshot shows a web browser window with the following details:

- Browser: Google Chrome
- Page Title: Meny
- Address Bar: 192.168.20.205:7080/proddb/
- Page Content:
  - Client: Statkraft
  - User: oyvind.byrkjedal@vindteknikk.no [logout](#)
  - Production
  - Navigation: [Map](#), [Park](#), [Data](#), [Documents](#), [Log](#)
  - Site: Stamaasen
  - 07 Forecast
  - Table of forecast files:

File Name	Size	Date
IceThrow_2016-02-08_01H.pdf	512 kB	08/02/2016
IceThrow_2016-02-08_01H12-24H.pdf	491 kB	08/02/2016
IceThrow_2016-02-08_01H24-36H.pdf	468 kB	08/02/2016
IceThrow_2016-02-08_01H36-48H.pdf	459 kB	08/02/2016
stamasen_rpm_ws.png	49 kB	08/02/2016
WRF4km_2016-02-08_06H.UTC_Stamaasen_450m_153m_Isprognose.pdf	51 kB	08/02/2016
WRF_2016-02-08_06H.UTC_Stamasen_Tm1_450m_153m_Isprognose.pdf	54 kB	08/02/2016
WRF_2016-02-08_06H.UTC_Stamasen_Tp1_450m_153m_Isprognose.pdf	53 kB	08/02/2016

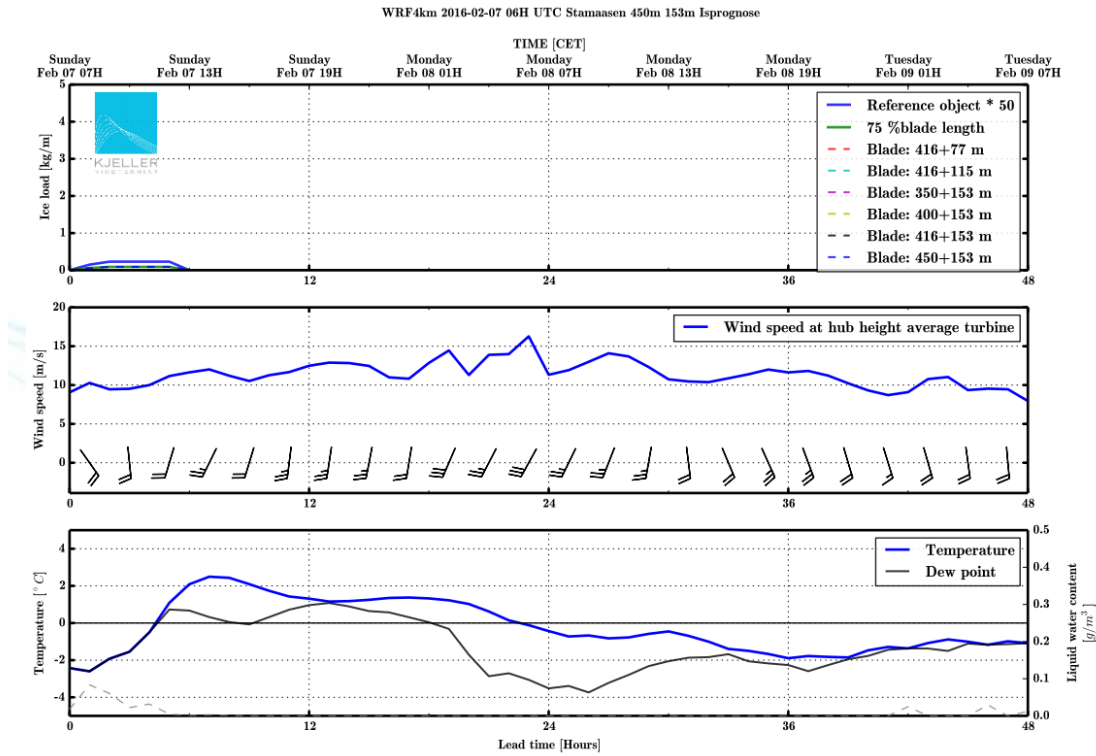
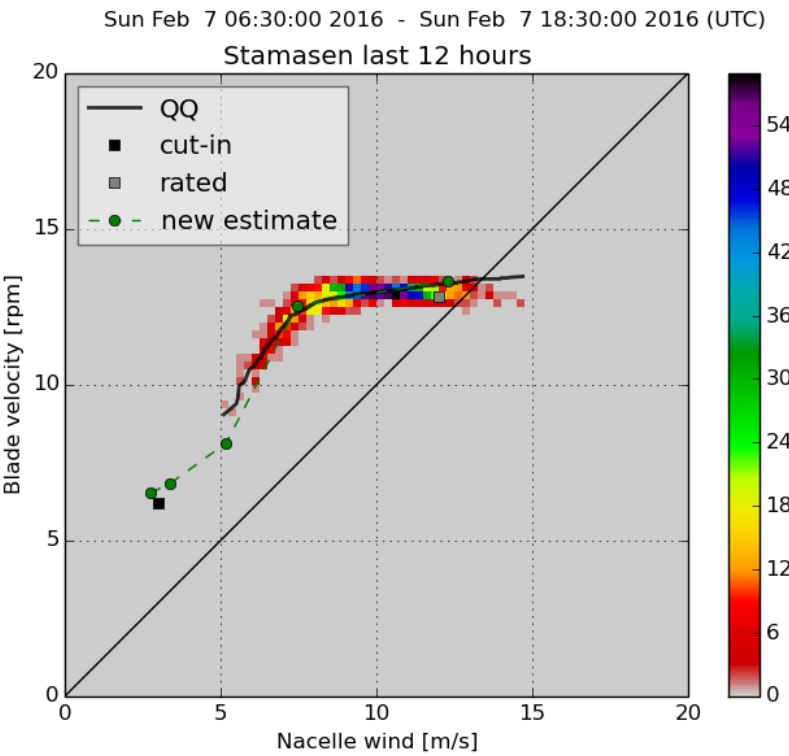
# Ensemble with temperature perturbations $\pm 1^\circ$

- Observations, forecast 1 degree warmer 1 degree colder



# Uncertainty is reduced by redundancy

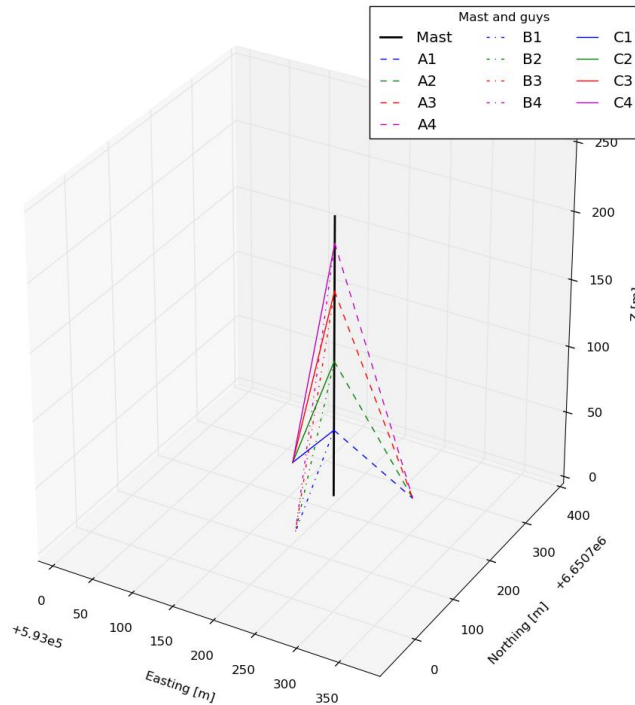
- Here, real-time SCADA data supports the trustworthiness of the windfarm forecasts
- rpm, temperature, nacelle wind, turbine yaw directions etc.



# IceRisk warning system - Telecom mast

Example system where warning decisions are made together with owner of mast.

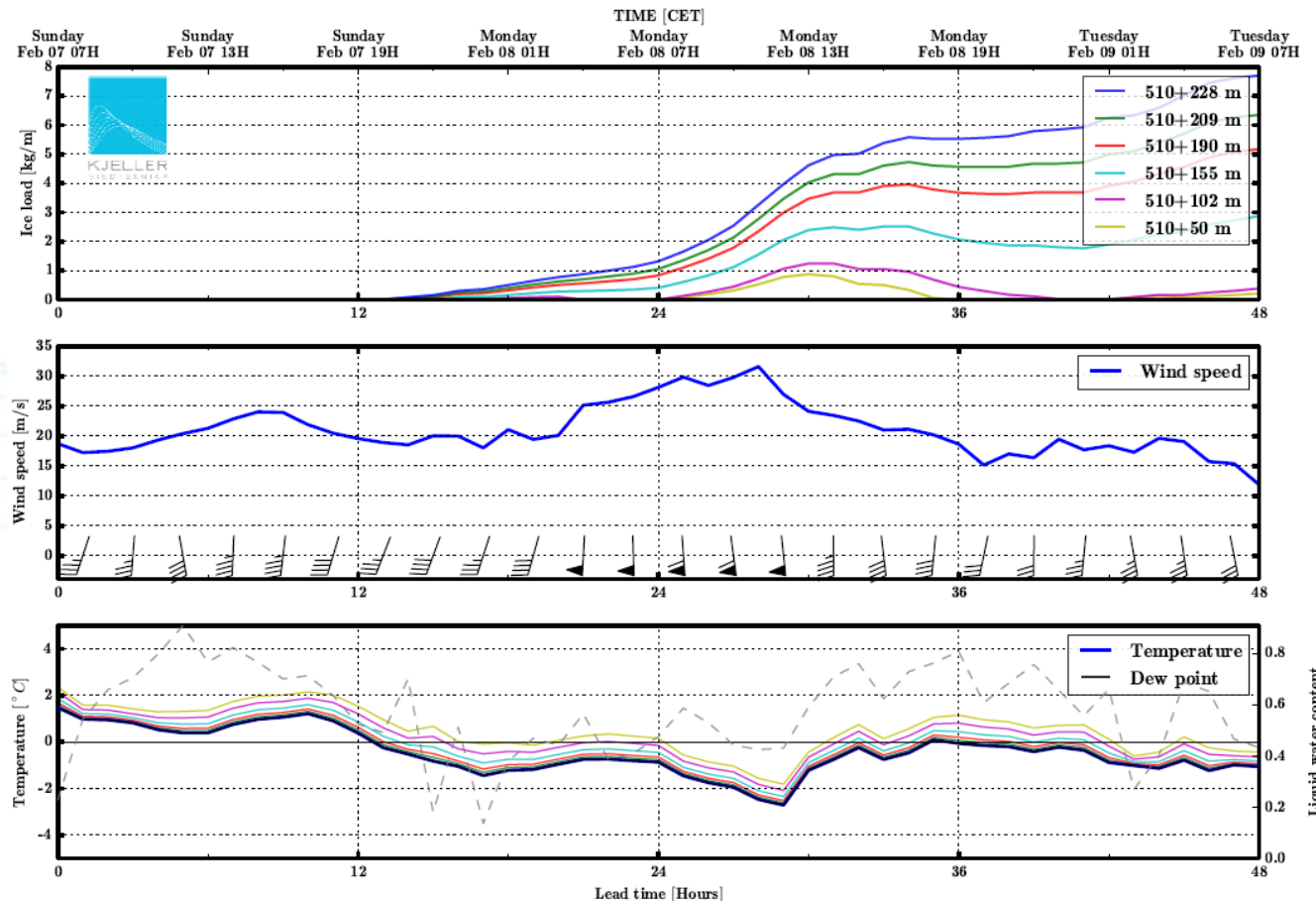
- 209 m telecom mast in Oslo



# Warning decisions are supported by temperature measurements and online camera system



WRF6km 2016-02-07 06H UTC Tryvasshogda 510m 228m Isprognose



February 8, 2016

# Forecasted risk zone for ice shed

- SMS warning plan
- Signs and lights
- Public risk maps

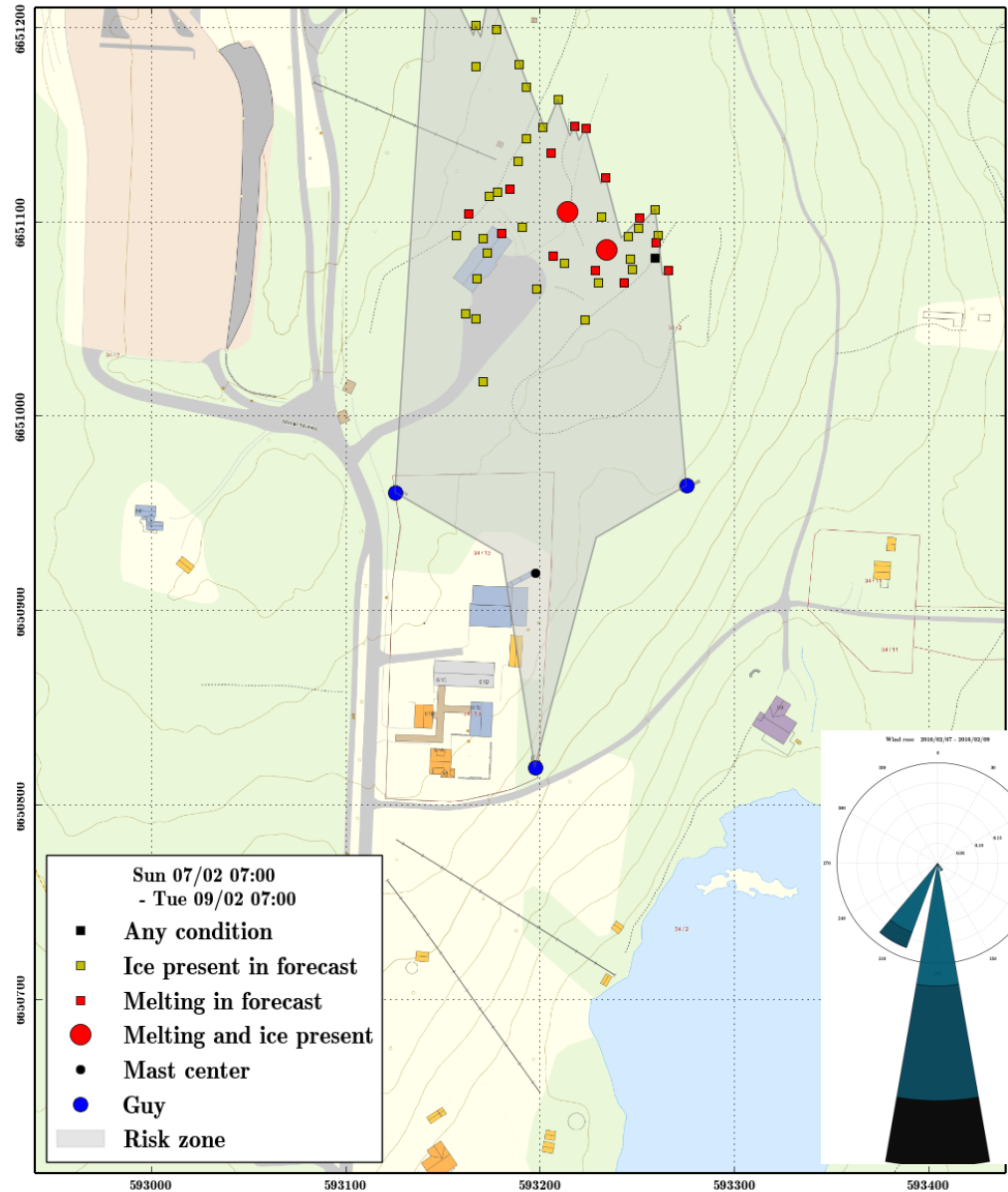
YR

Today, Monday 08/02/2016

Time	Forecast	Temp.	Precipitation	Wind
Sleet For the period: 01:00-06:00				
01:00-06:00			0.1 - 2.6 mm	Moderate breeze, 8 m/s from south
06:00-12:00		1°	4.8 - 9.4 mm	Moderate breeze, 7 m/s from south
12:00-18:00		-1°	6.6 - 11.3 mm	Gentle breeze, 5 m/s from south-southeast
18:00-00:00		1°	1.9 - 5.8 mm	Light breeze, 4 m/s from south-southeast

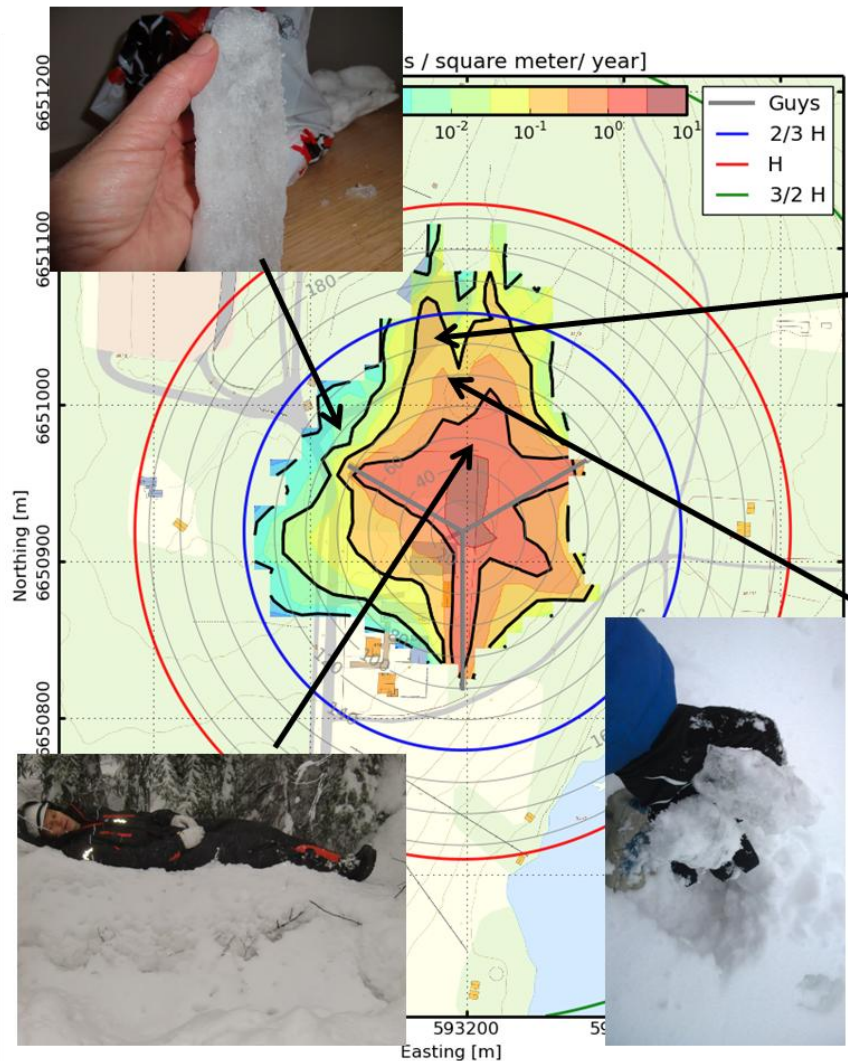
Tomorrow, Tuesday 09/02/2016

Time	Forecast	Temp.	Precipitation	Wind
00:00-06:00		0°	2.3 - 7.1 mm	Gentle breeze, 5 m/s from south-southeast
06:00-12:00		0°	0.7 - 1.8 mm	Light breeze, 3 m/s from south-southeast
12:00-18:00		-1°	0 mm	Light breeze, 3 m/s from south-southwest
18:00-00:00		0°	0 mm	Light breeze, 2 m/s from south



February 8, 2016

# Model validation



30 cm craters

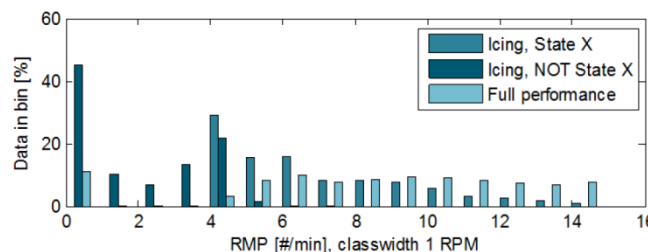
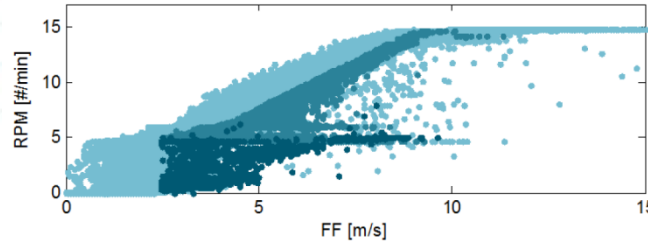
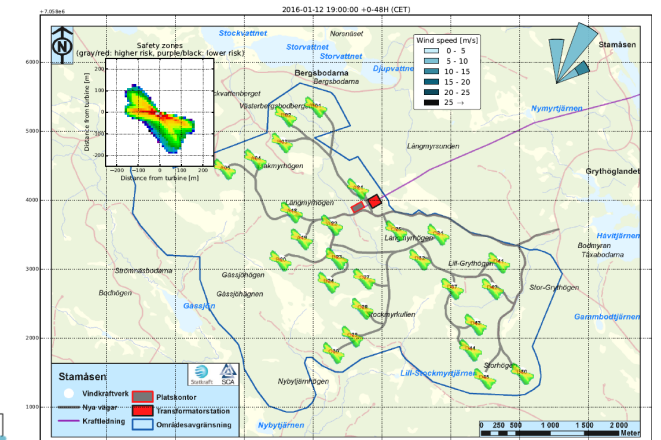
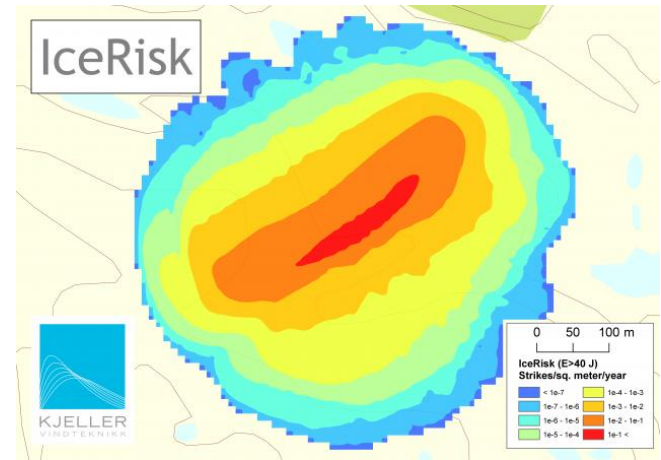


50 cm craters



# IceRisk warning system

- Decision support system
  - Met forecasts, live IceRisk maps
  - SCADA-data
  - Cameras
- Automatic system
  - Measurements
  - Uncertainty reduction through redundancy of information





# Acknowledgement

- Statkraft: Michael Pedersen, Niklas Sondell, Dag Haaheim, Gert Andersson and others.
- Norkring, owner of telecom mast at Tryvann (Oslo)
- Risk evaluation in cooperation with Lloyd's Register Consulting



**Statkraft**

February 8, 2016



Lloyd's Register  
Consulting