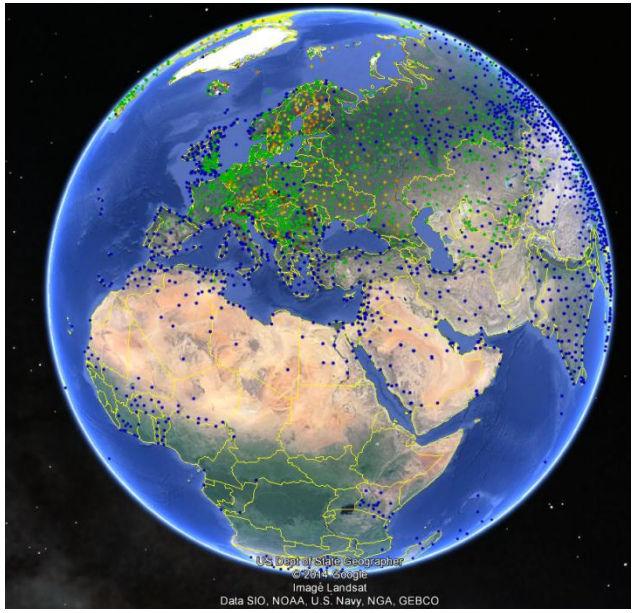


Wind Power Icing Atlas (WIceAtlas) & icing map of the world

Winterwind 2015, Piteå Sweden
Simo Rissanen, Ville Lehtomäki
VTT Technical Research Centre of Finland

Content

- Motivation
- Introduction
- Global Low temperature map
- Global Icing map
- Interannual variation of icing
- Validation
- Conclusions

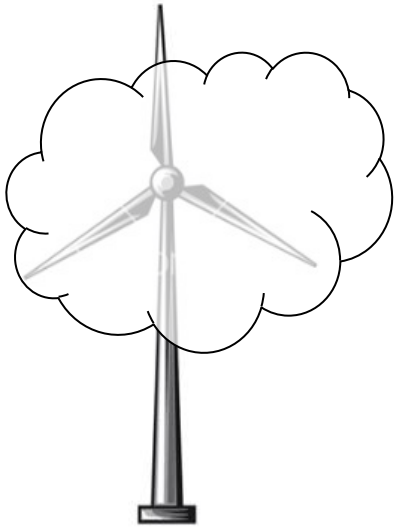
Motivation

- All currently available icing maps are based on mesoscale weather models. Cloud and icing modelling is challenging for mesoscale weather models.
- Only country specific icing maps available
- All available icing maps use different models and methods -> not comparable

➢ Large need to assess AND compare icing on a global scale from measurements and observations

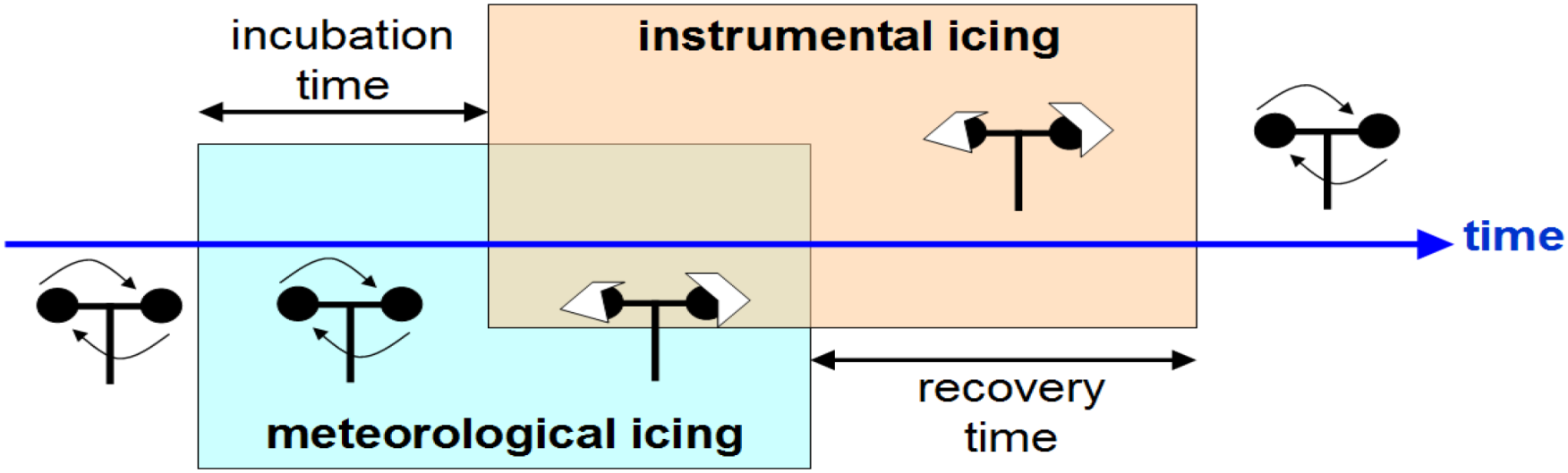
Wind Power Icing Atlas (WIceAtlas)

- Observations from 4500 meteorological stations NO SIMULATIONS!
- 20 - 34 years of data per station
- Requirement: > 70% availability
- WIceAtlas is based on cloud base height and temperature measurements ⇨ in-cloud icing only!



Icing conditions

- Low level clouds & T<0°C = in-cloud icing (most typical)



Source: IEA Wind Recommended Practices for wind energy projects in cold climates edition 2011

Ice classes: IEA Ice Classification[1]

IEA ice class	Duration of Meteorological icing [% of year]	Duration of Instrumental icing [% of year]	Production loss [% of AEP]
5	>10	>20	>20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0-0.5

[1]: IEA Wind Recommended Practices for wind energy projects in cold climates edition 2011

Low Temperature Climate

- Use global MERRA reanalysis data at 60 m agl

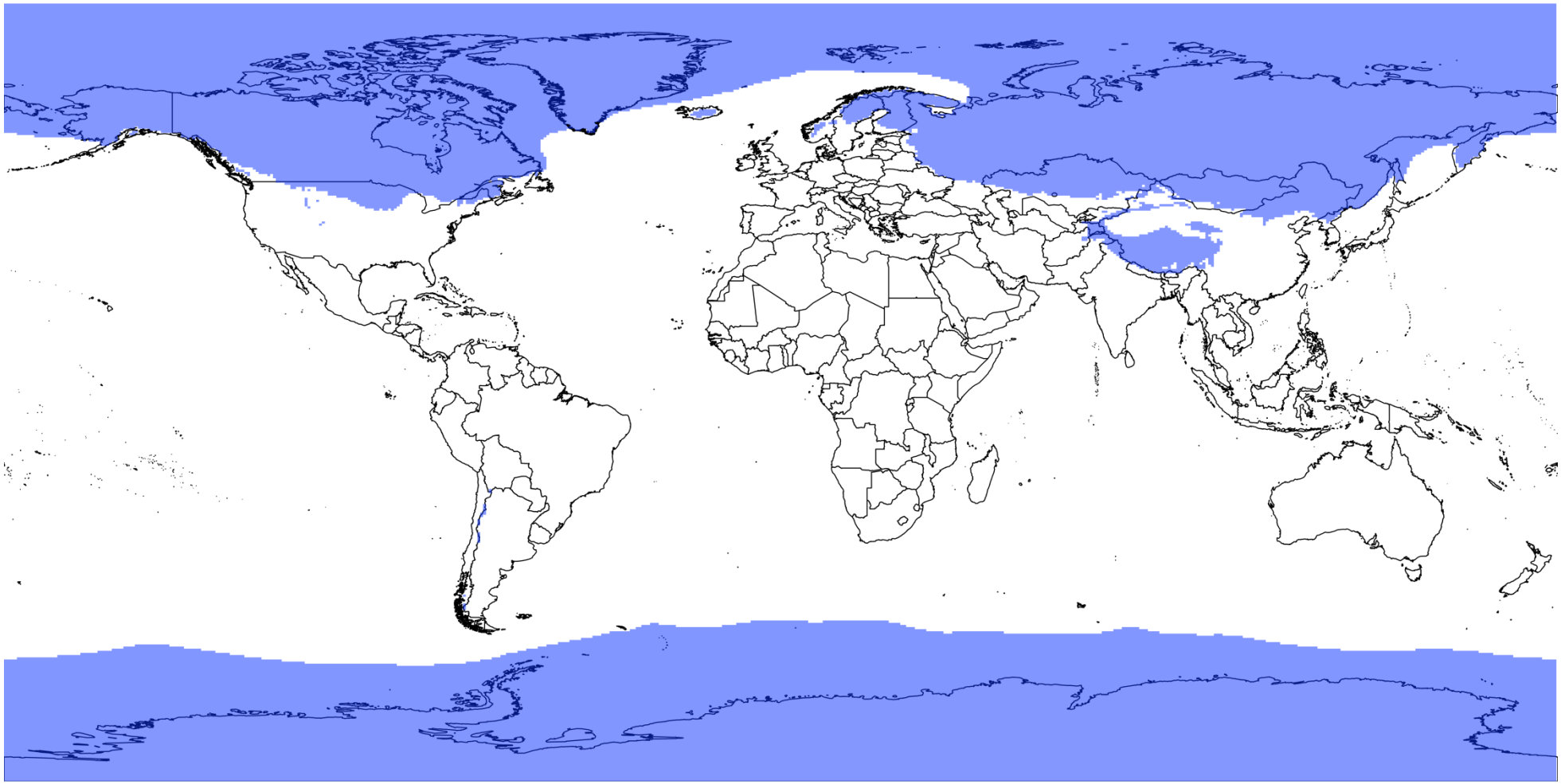
DNV GL Technical Note 067 – Certification of Wind Turbines for Extreme Tempratures (2011):

- ≥ 10 years data required
- Average annual air temperature below **0°C**

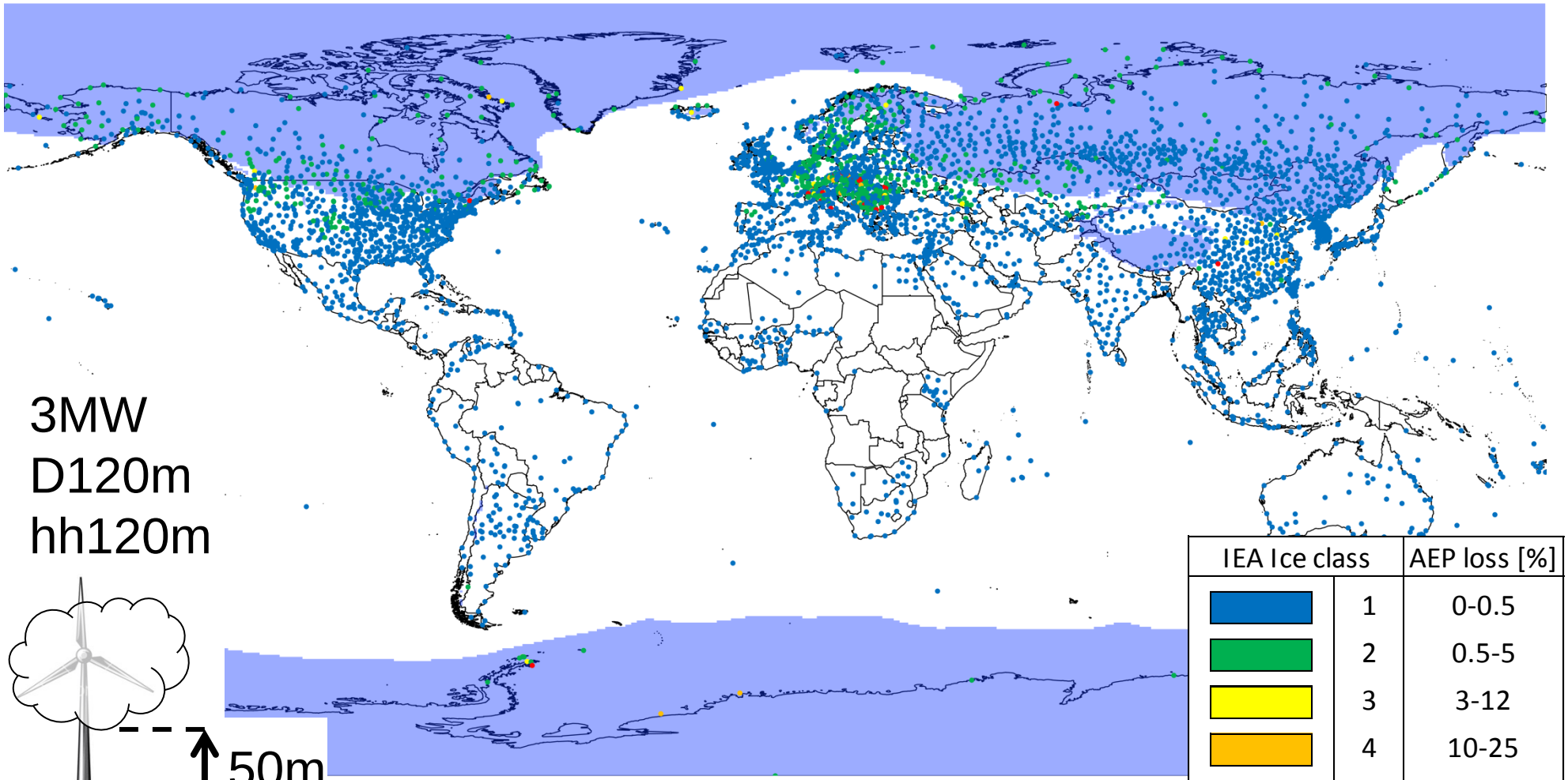
OR

- Air temperature below **-20°C** on more than 9 days per year (hourly value)

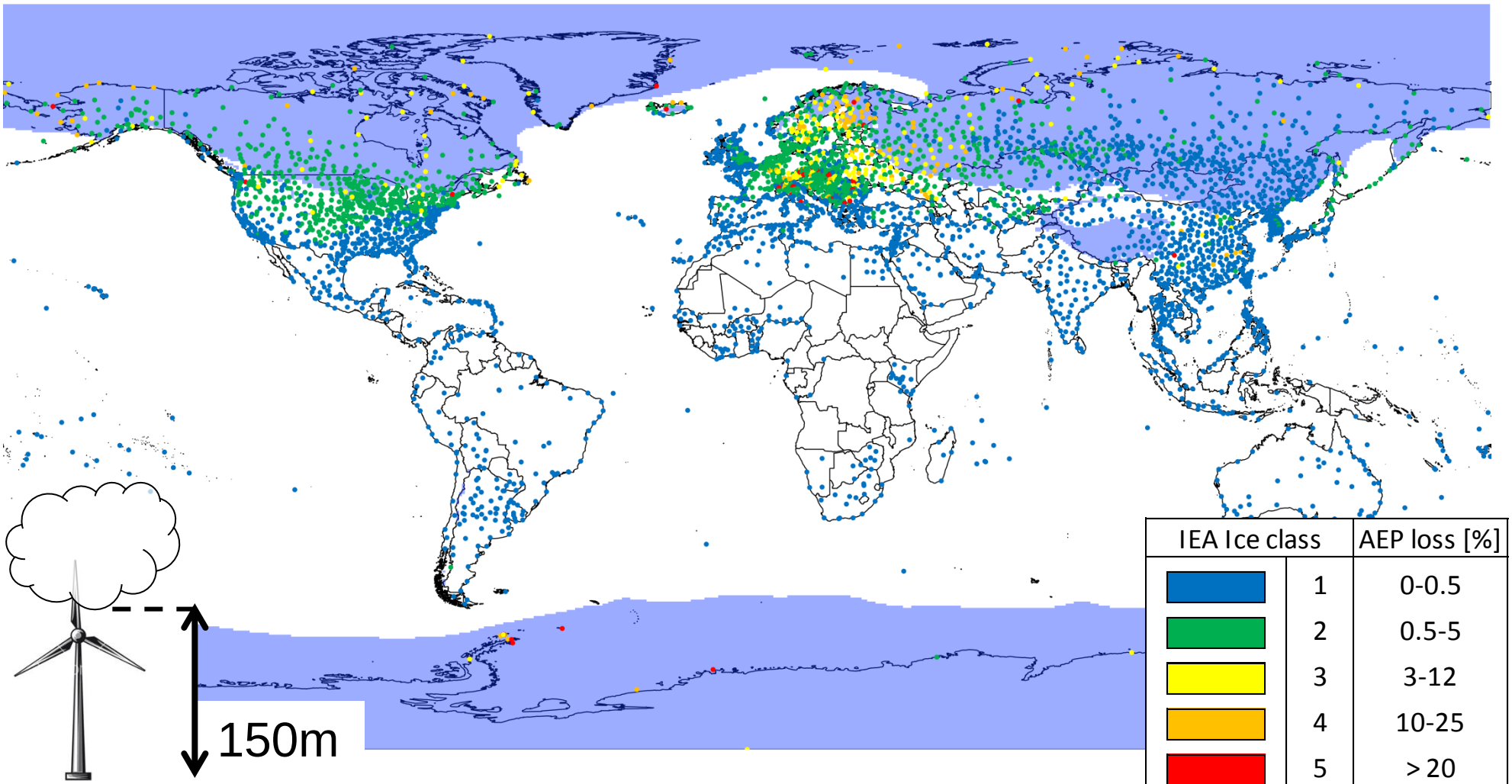
Low Temperature Climate, 34 years average



WIceAtlas: world icing map 50 m agl

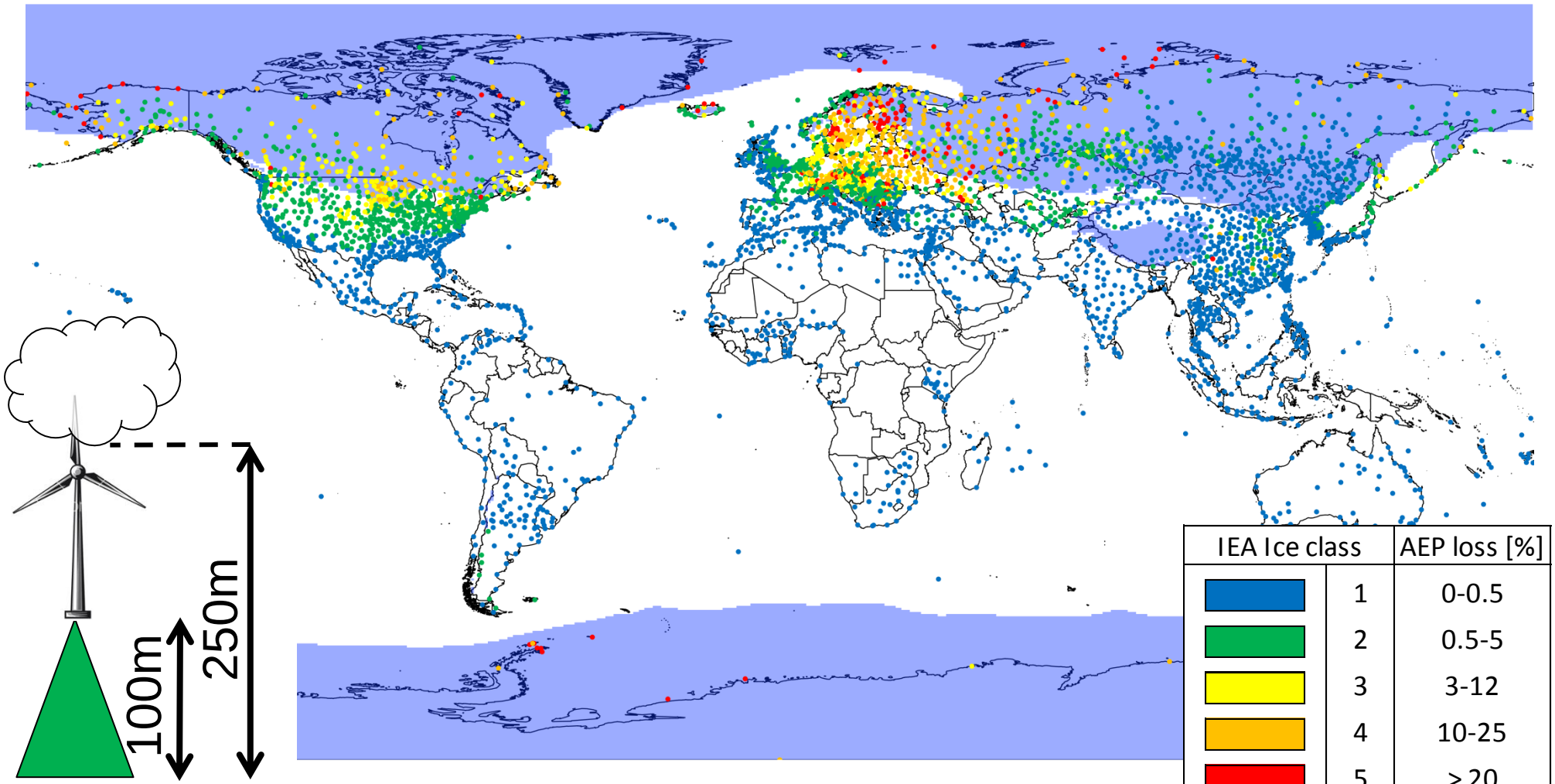


WIceAtlas: world icing map 150 m agl



IEA Ice class		AEP loss [%]
	1	0-0.5
	2	0.5-5
	3	3-12
	4	10-25
	5	> 20

WIceAtlas: world icing map 250 m agl



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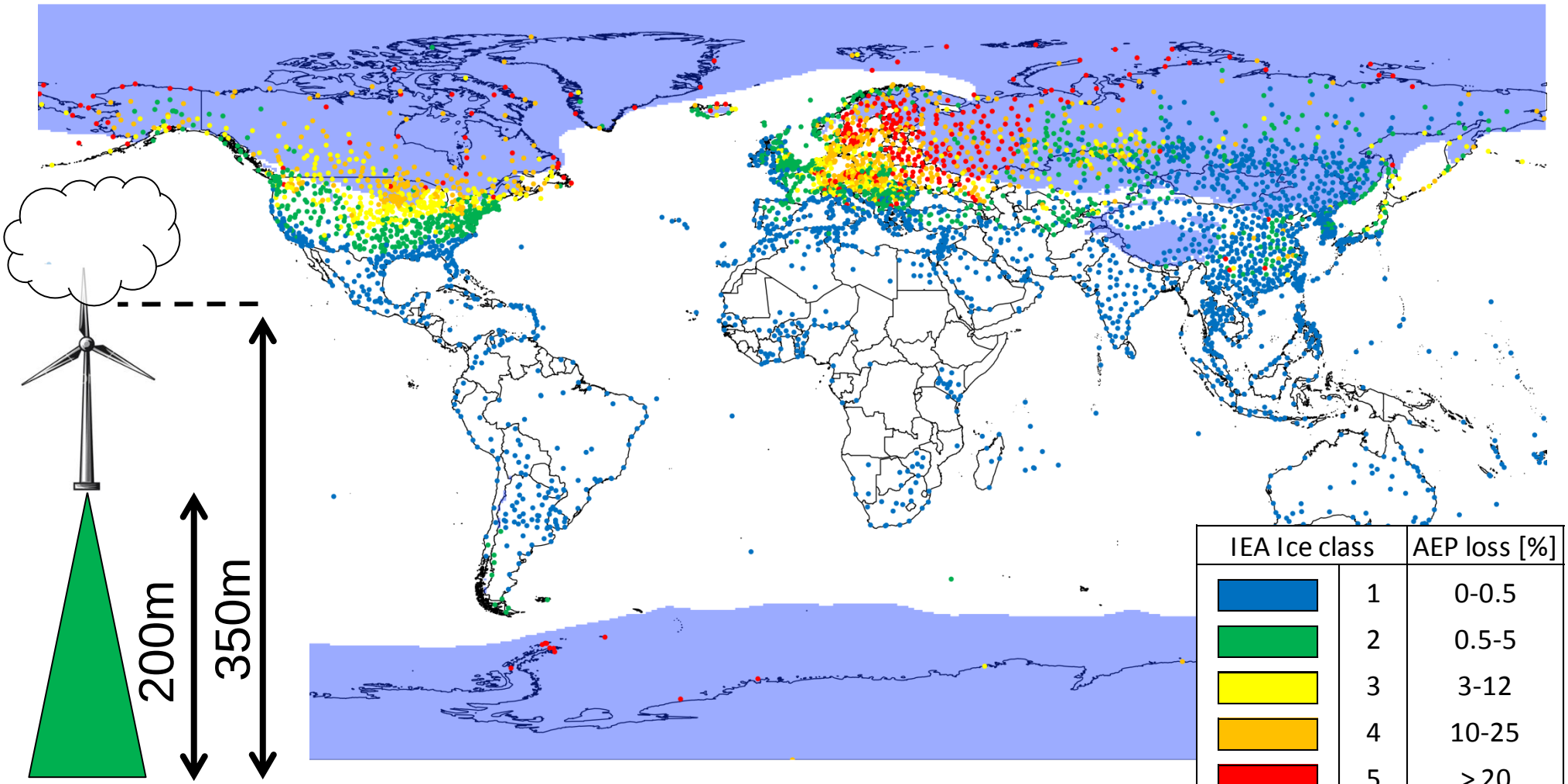
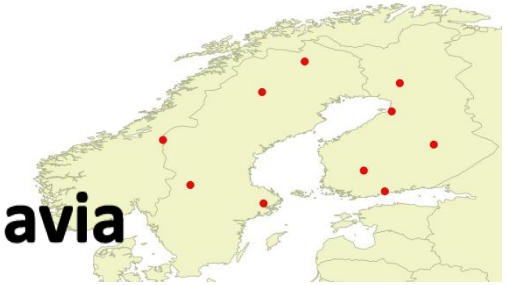
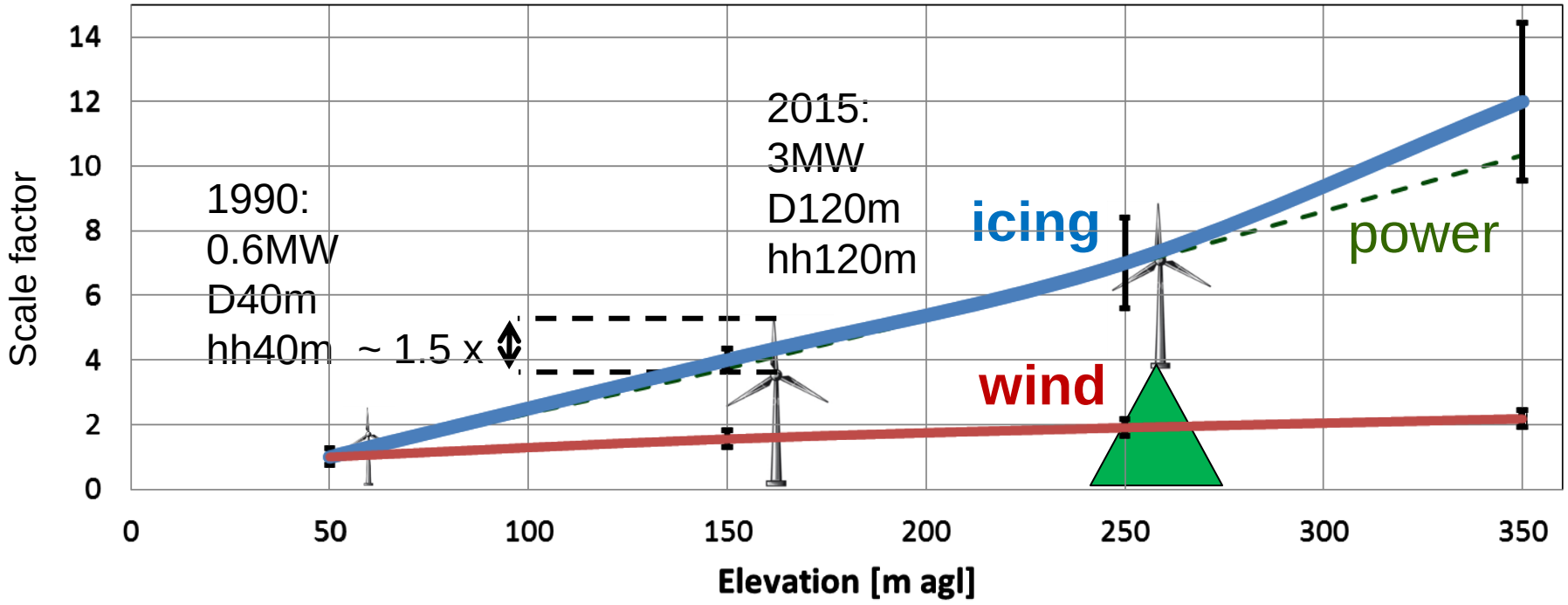
WIceAtlas: world icing map 350 m agl



Ice assessment considerations

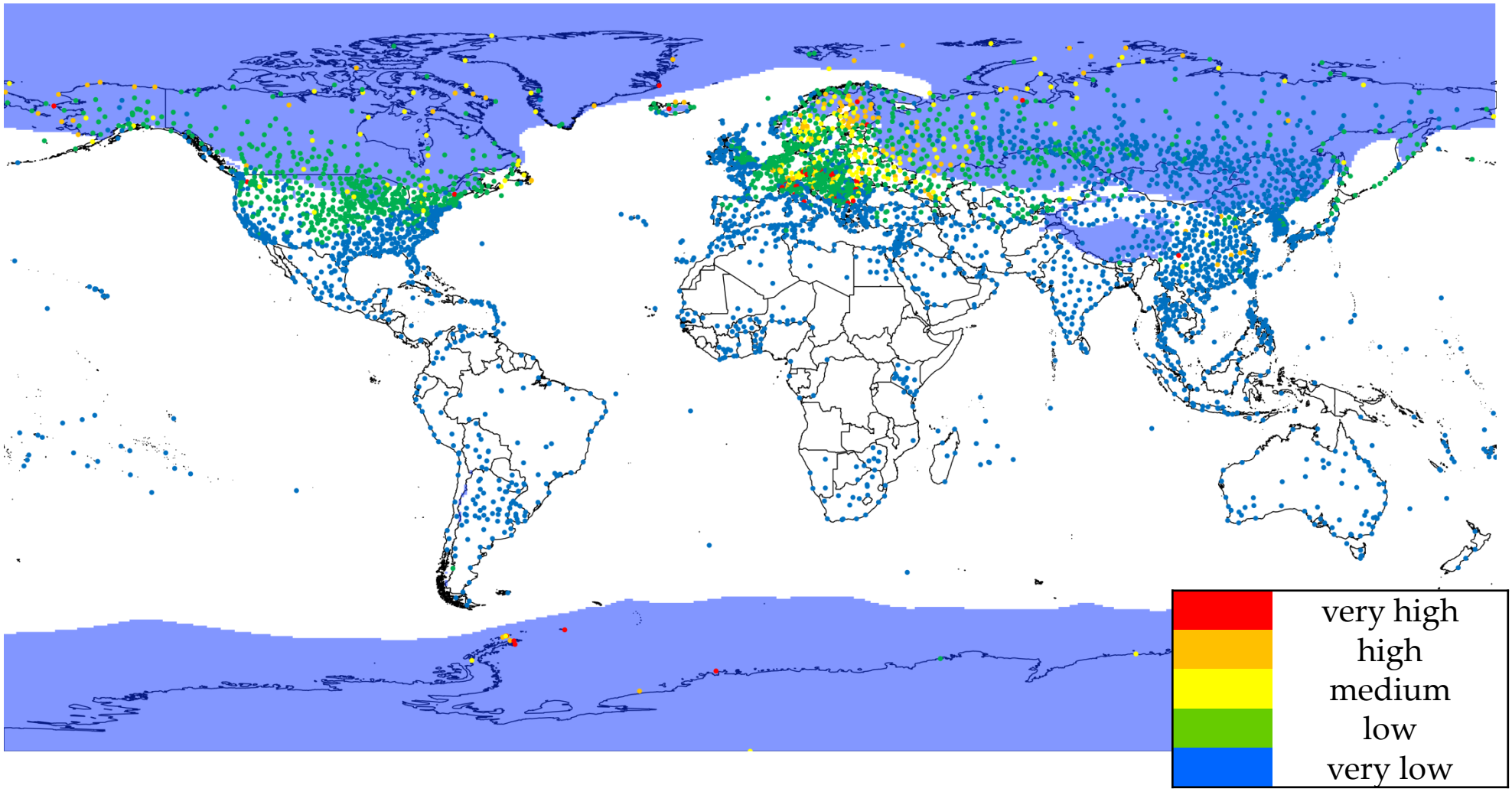


Typical wind & icing profile in Scandinavia

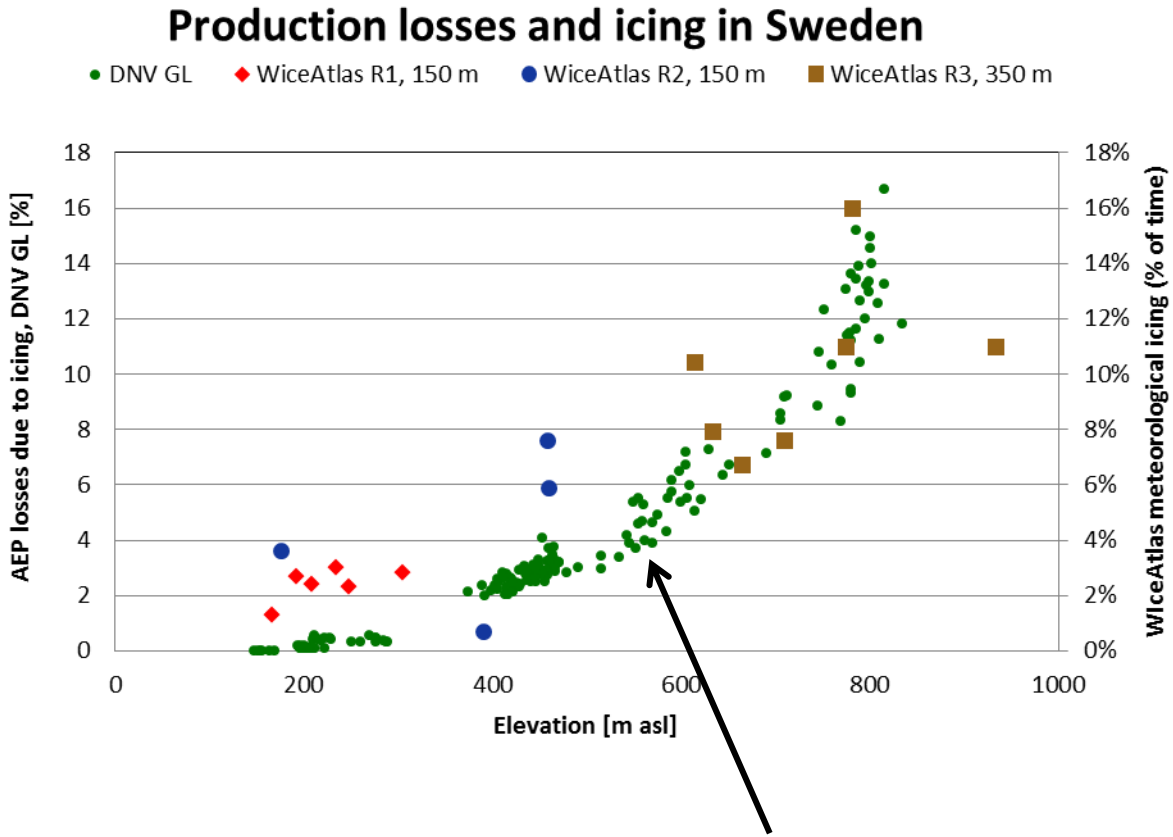


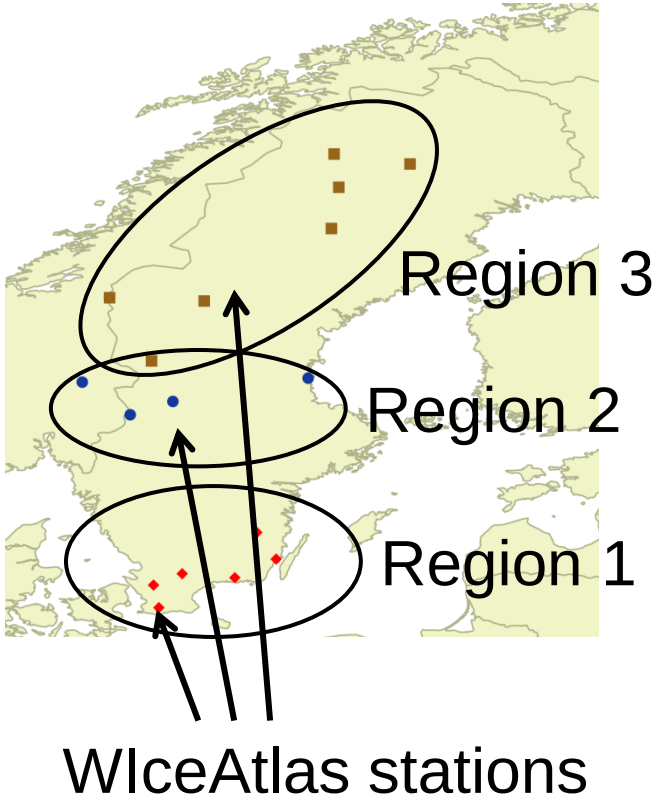
1. Icing risk increases with altitude much faster than wind speed potential!!
2. Icing has 5 x higher interannual variation than average wind speed!!

Standard deviation of yearly averages 150m agl



New validation case

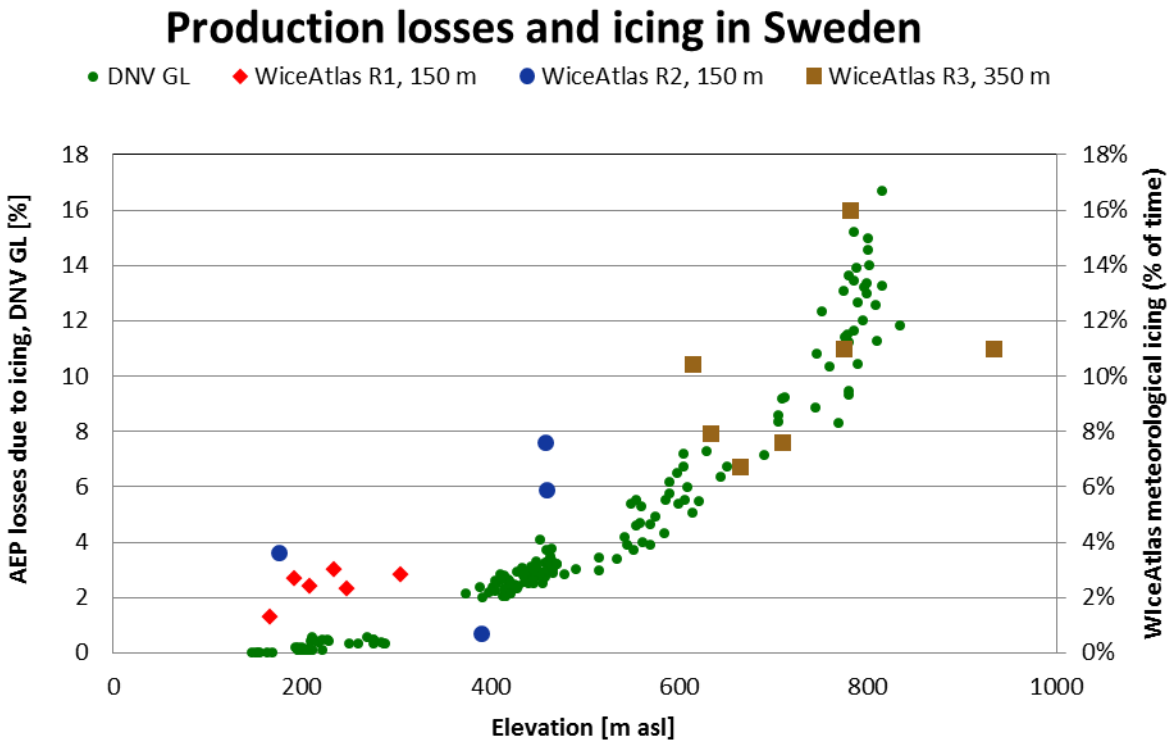




DNV GL: ~200 turbines, ~15 wind farms, 1-6 years/ turbine

Source: Estimating energy losses caused by blade icing from preconstruction wind data and DNV GL's experience analysing scada data from Scandinavian wind farms, Till Beckford, DNV GL, WinterWind 2015

New validation case



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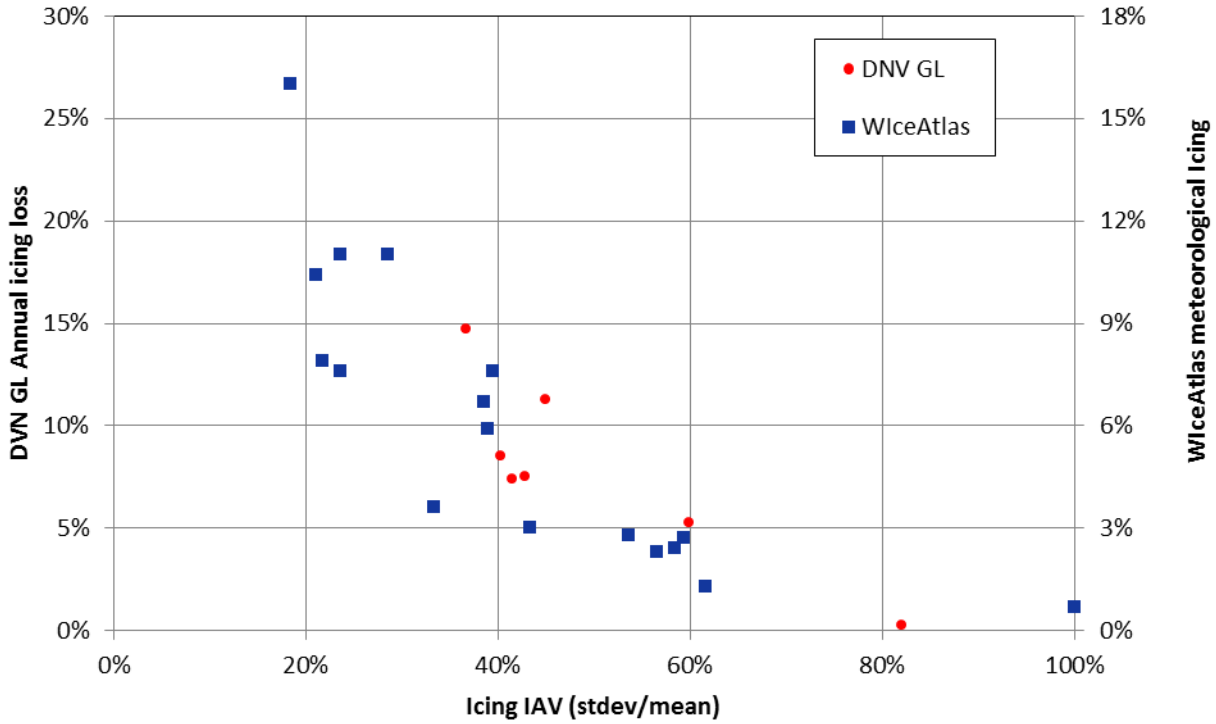
Source: Estimating energy losses caused by blade icing from preconstruction wind data and DNV GL's experience analysing scada data from Scandinavian wind farms, Till Beckford, DNV GL, WinterWind 2015

New validation case, interannual variation



More validation cases: Lehtomäki V., Wind Power Icing Atlas – tool for financial risk assessment, Winterwind 2014

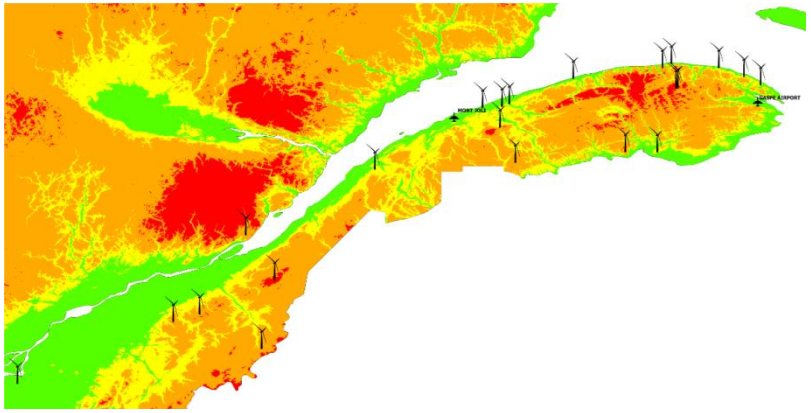
Source: Estimating energy losses caused by blade icing from preconstruction wind data and DNV GL's experience analysing scada data from Scandinavian wind farms, Till Beckford, DNV GL, WinterWind 2015

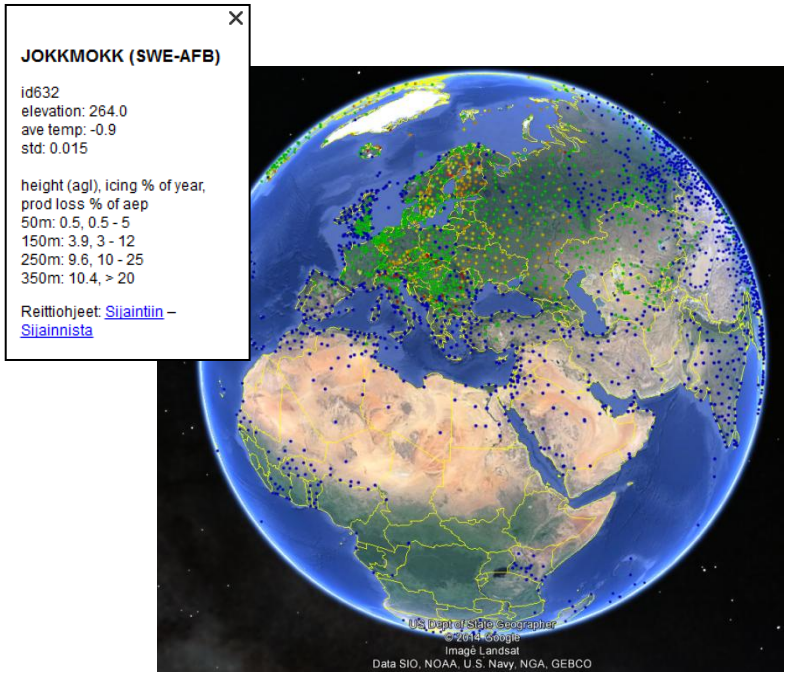
Conclusions

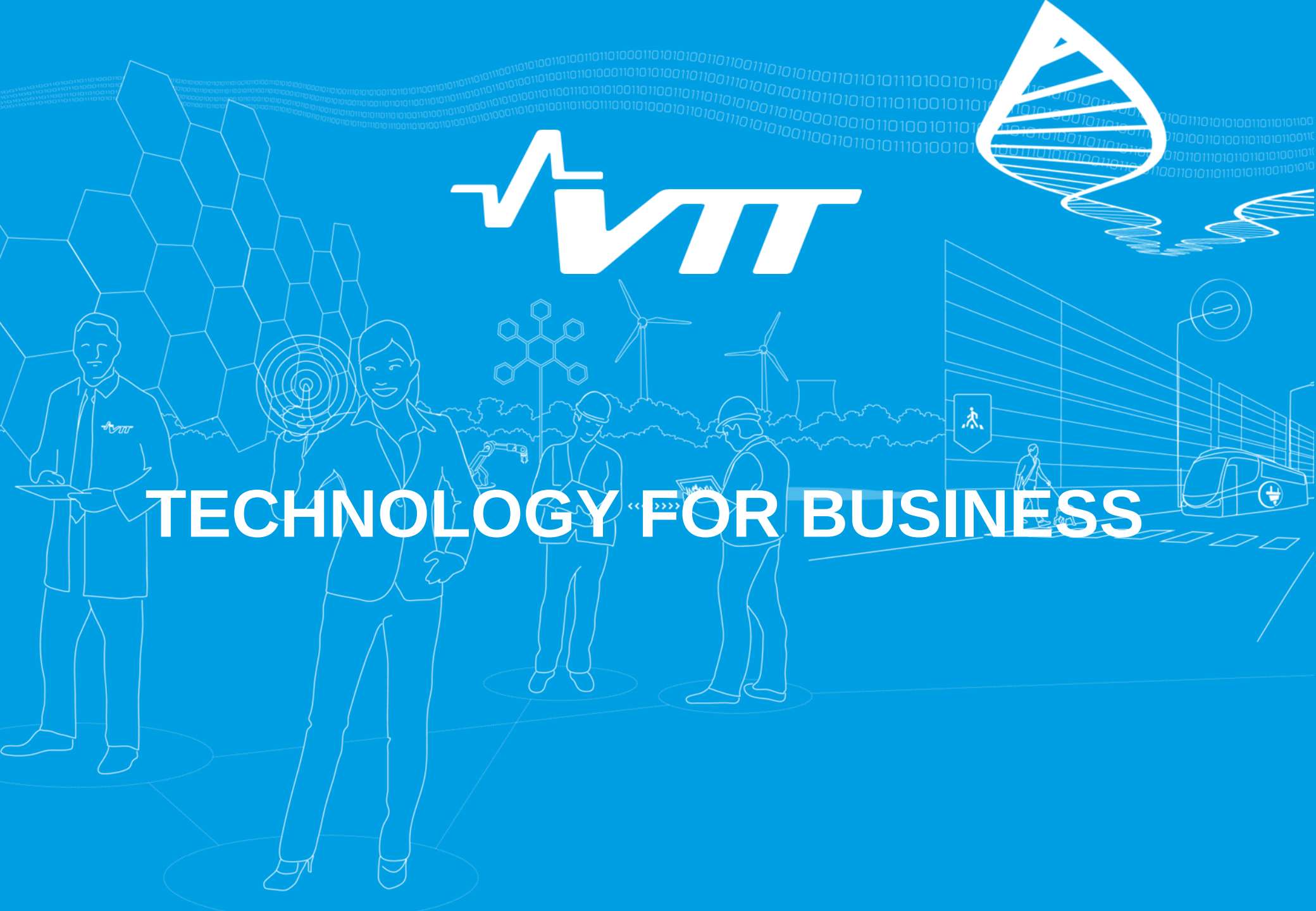
- WIceAtlas is based on long-term historical measurements, not simulations
- WiceAtlas has been validated extensively with SCADA data
- In-cloud icing frequency increases rapidly with elevation, modern large turbines will face more icing than old & small turbines
- Icing has 5 x higher interannual variation than average wind speed!! Scandinavia largest interannual variation globally
  - **Critical** to perform long term correlation to site ice assessment measurements

How to use Wiceatlas

- Fast estimation of meteorological icing and AEP losses before site installations (site screening)
- One year site and/or turbine measurements can be compared to long term observations -> UNIQUE!
- Google Earth user interface
- More detailed icing maps



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