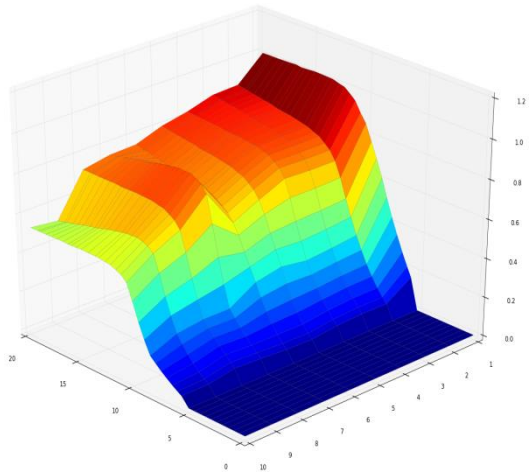

Icing induced production loss module for a forecasting system

Winterwind final conference

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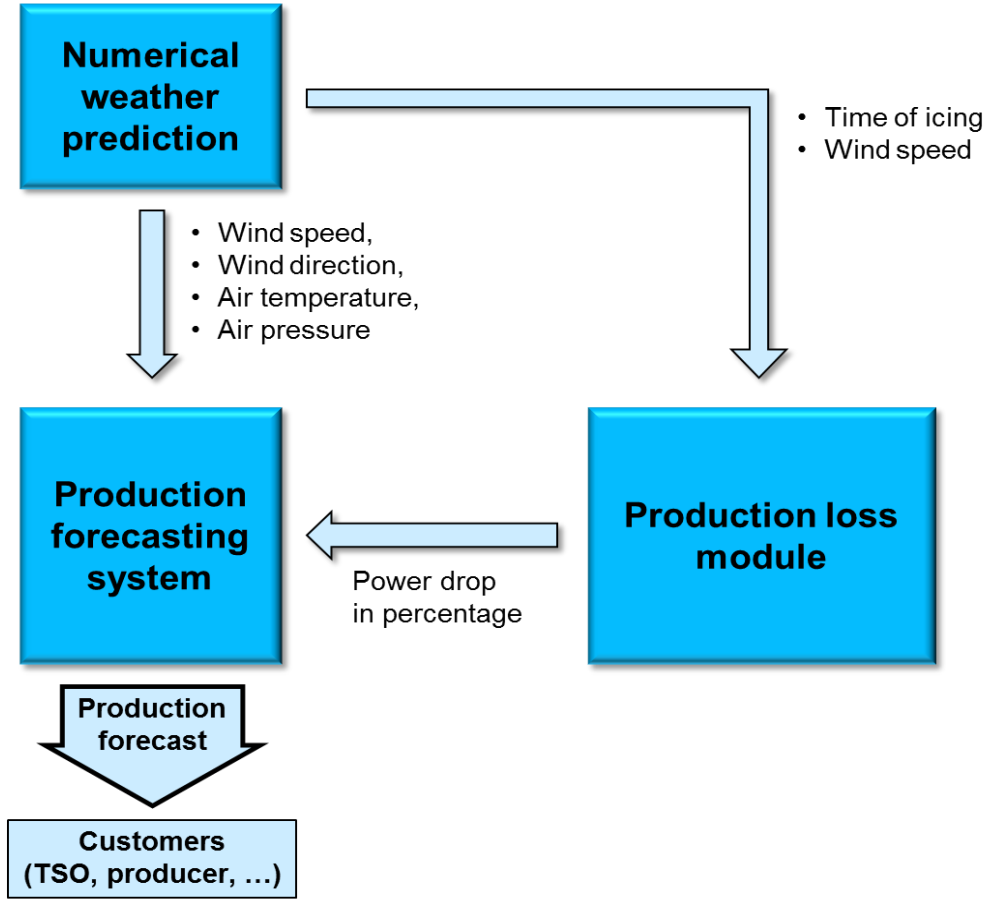
Goal

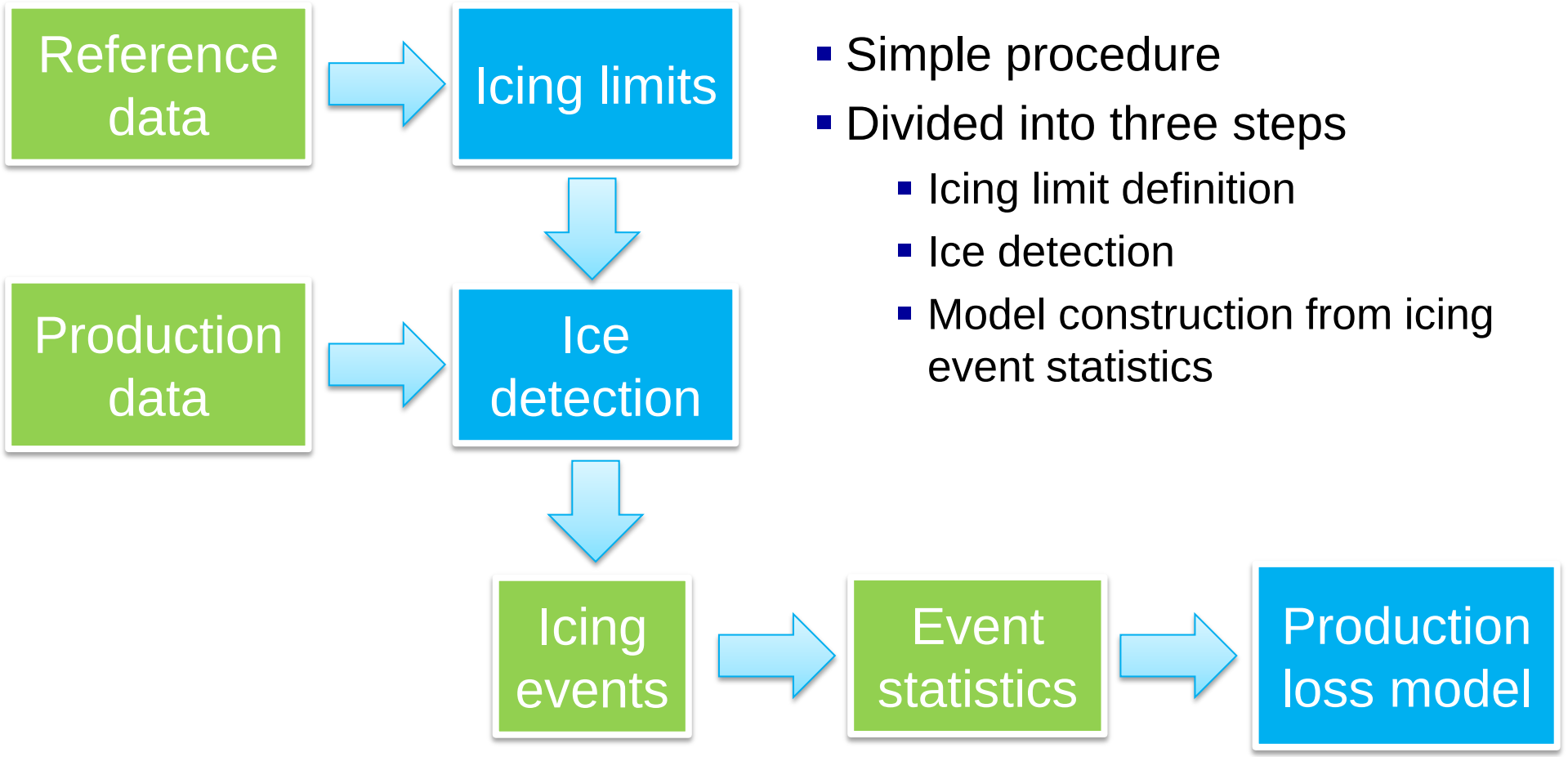
- estimate production losses caused by icing
- Use statistical methods on real production data
- Create a module that can be used as an add-on on a existing forecasting system



Design Requirements

- Generality
  - No site or weather or forecasting model specific inputs
- Statistical model
  - Based on production data
  - Observations from multiple sites used to build a generic model
- Simplicity
  - “as simple as possible, but no simpler”
  - Try to find most significant parameters

Module construction



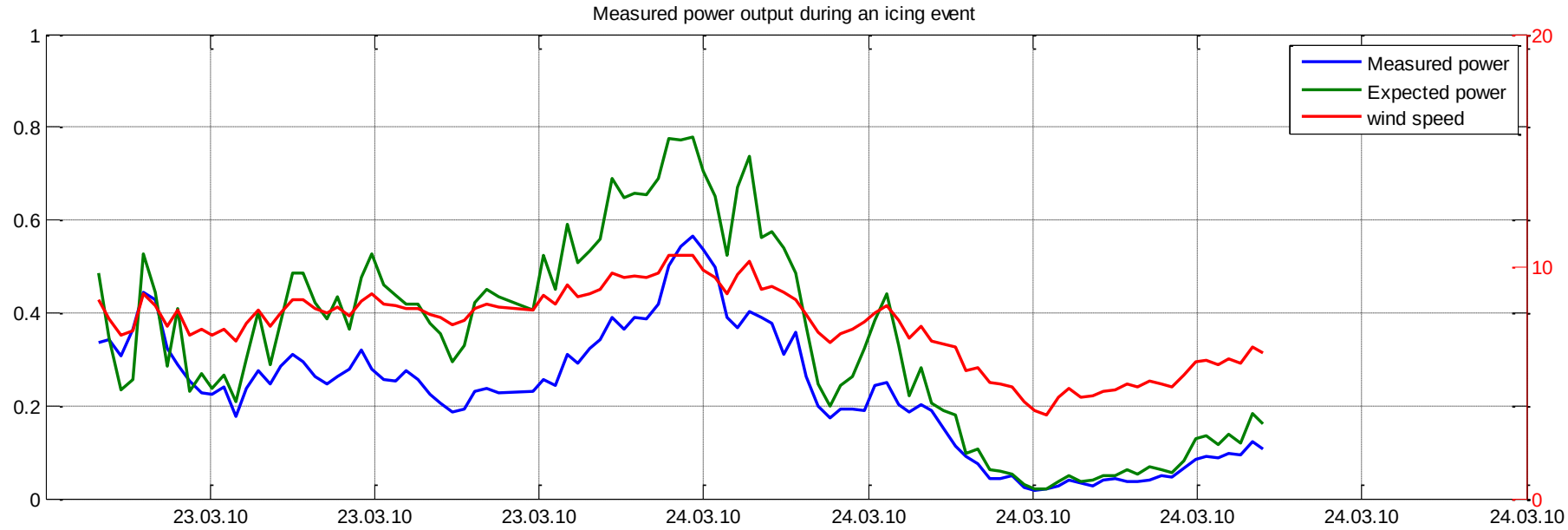
- Simple procedure
- Divided into three steps
  - Icing limit definition
  - Ice detection
  - Model construction from icing event statistics

Reference dataset

- Build a ”clean” dataset to use as reference
  - Represents normal turbine behavior
  - Remove all stops, faults, starts, stops
  - Filter based on temperature so that icing not happening

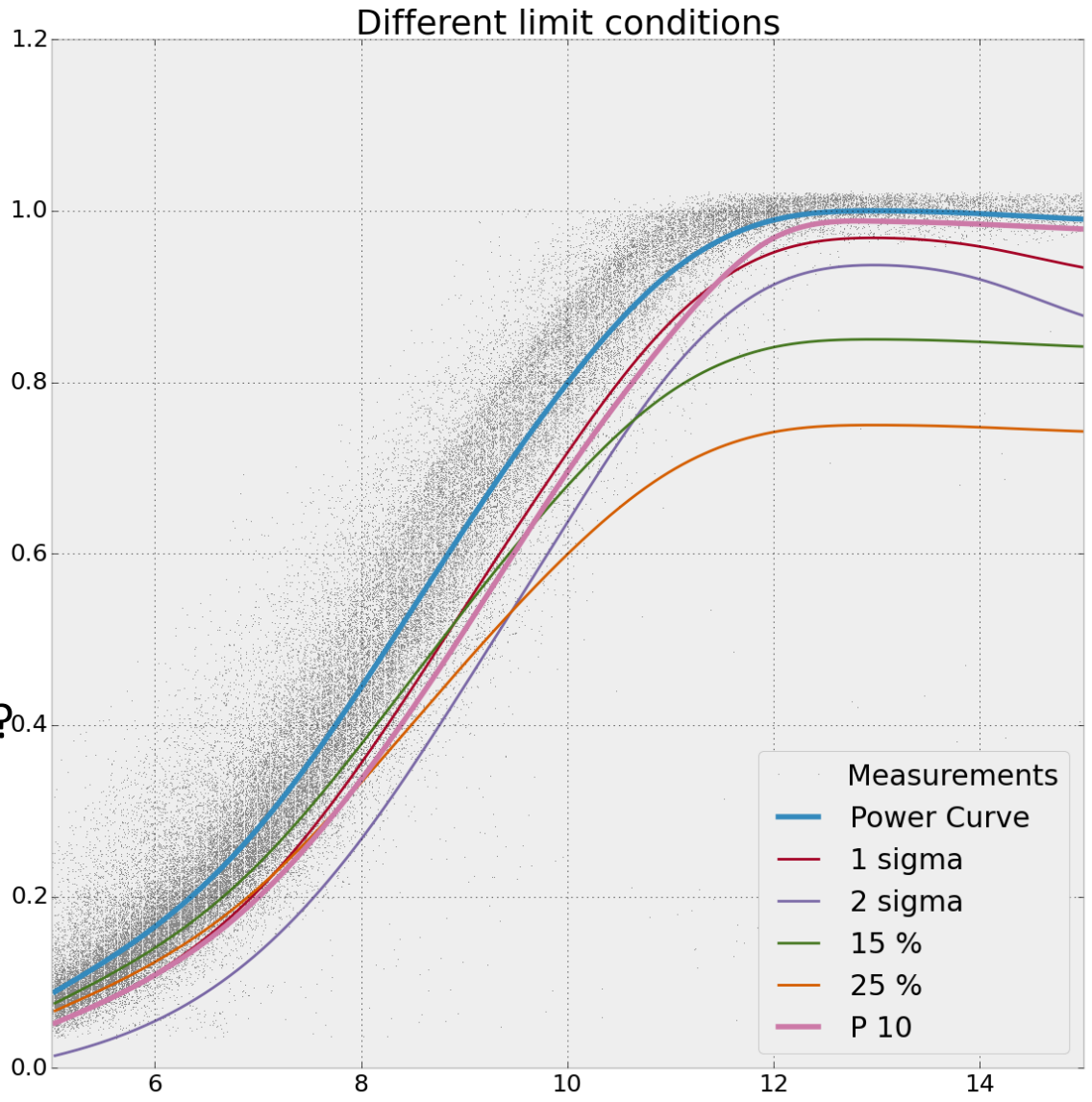
Ice case definition

- Power + ambient conditions (temperature, wind speed + direction always available)
- Icing induces power drop in output



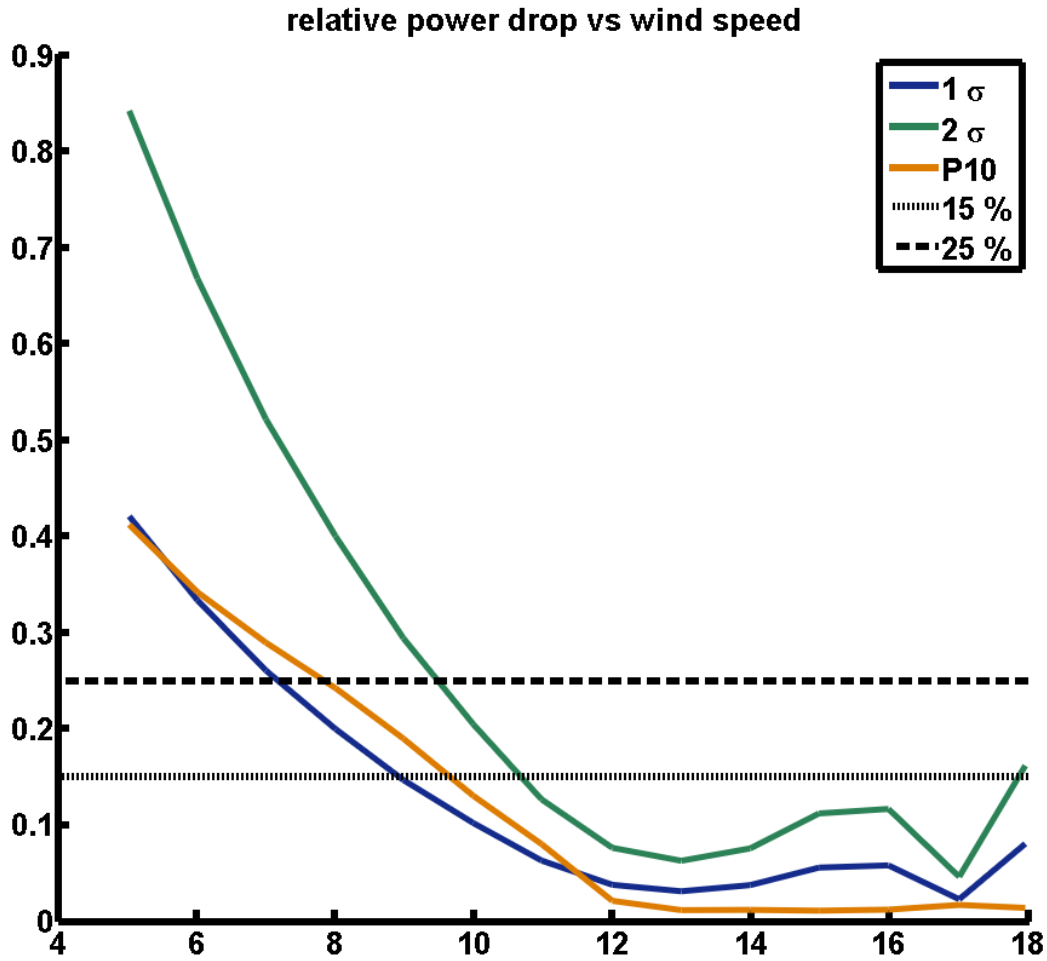
Icing limits

- Ice induced changes can be detected by defining a set of limit
  - Temperature below t_lim
  - Power below p_lim(v_w)
- How to calculate power limit?
  - Fixed percentage point drop?
  - Use standard deviation?
  - Others?



Icing limits (cont.)

- Setting the drop limit to constant percentage overestimates the losses on low wind speeds and underestimates them at high wind speeds
- Standard deviation too sensitive to measurement noise



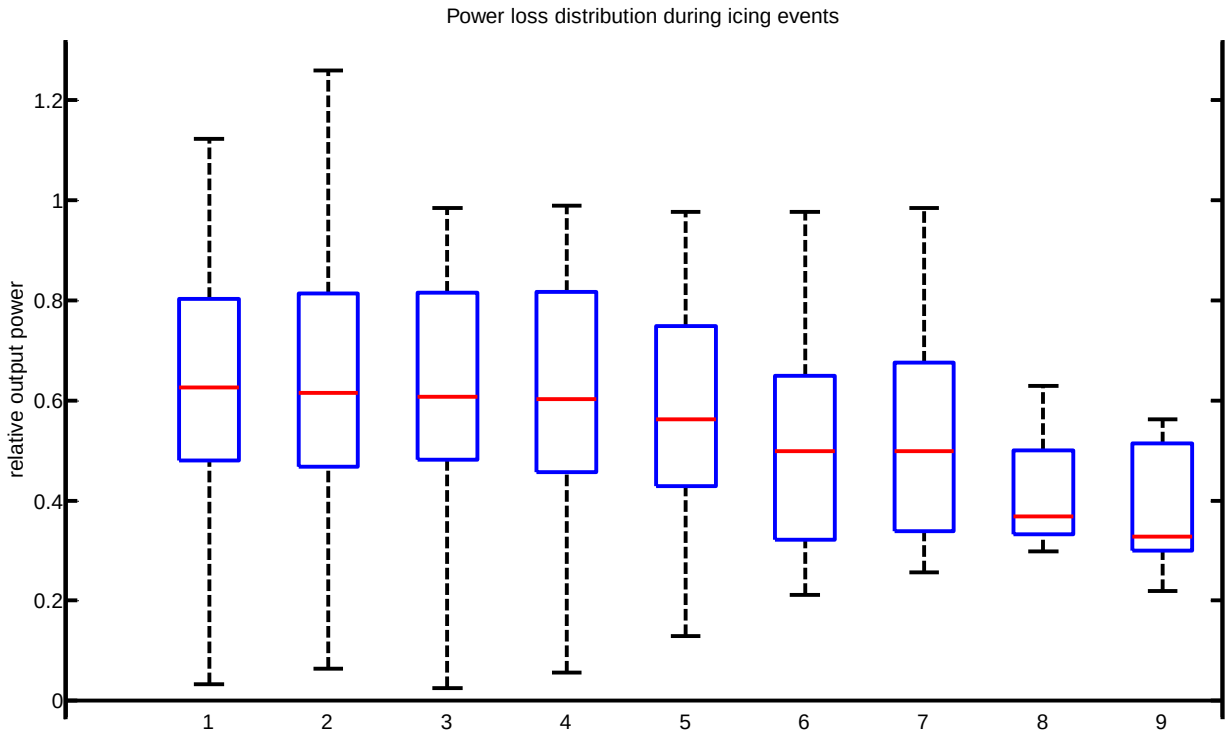
Robust statistics

- Data has a lot of outliers
  - Noise in measurements etc.
- Need a way to differentiate icing induced drops from normal measurement noise
  - Icing is slow, demand drops to be longer

- Define limits as
  - Power <= P10 AND temperature < limit

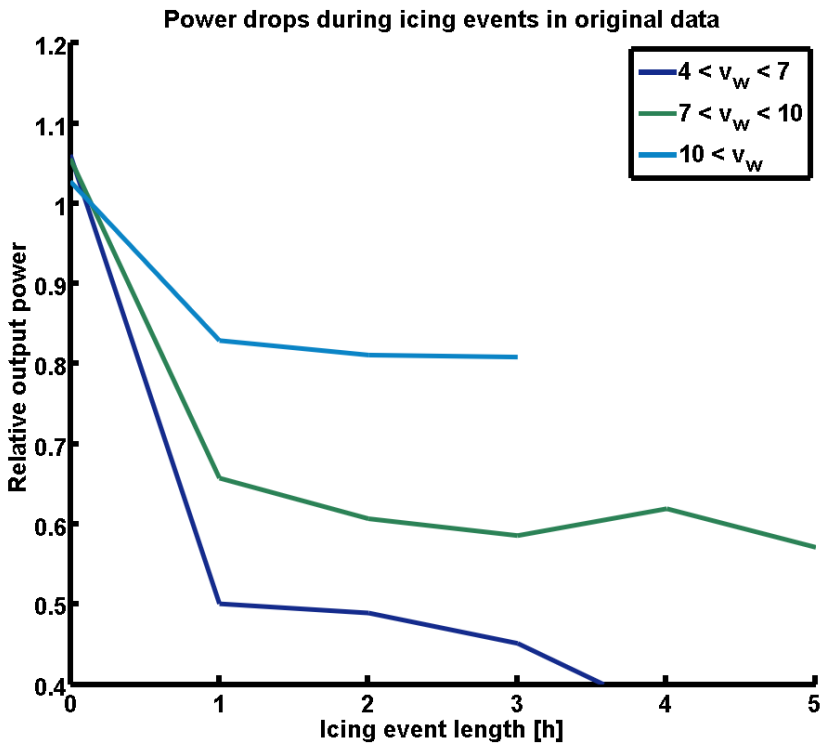
Production losses

- Massive variance in the data
- big median losses even after just one hour
- median loss trending down along with event length



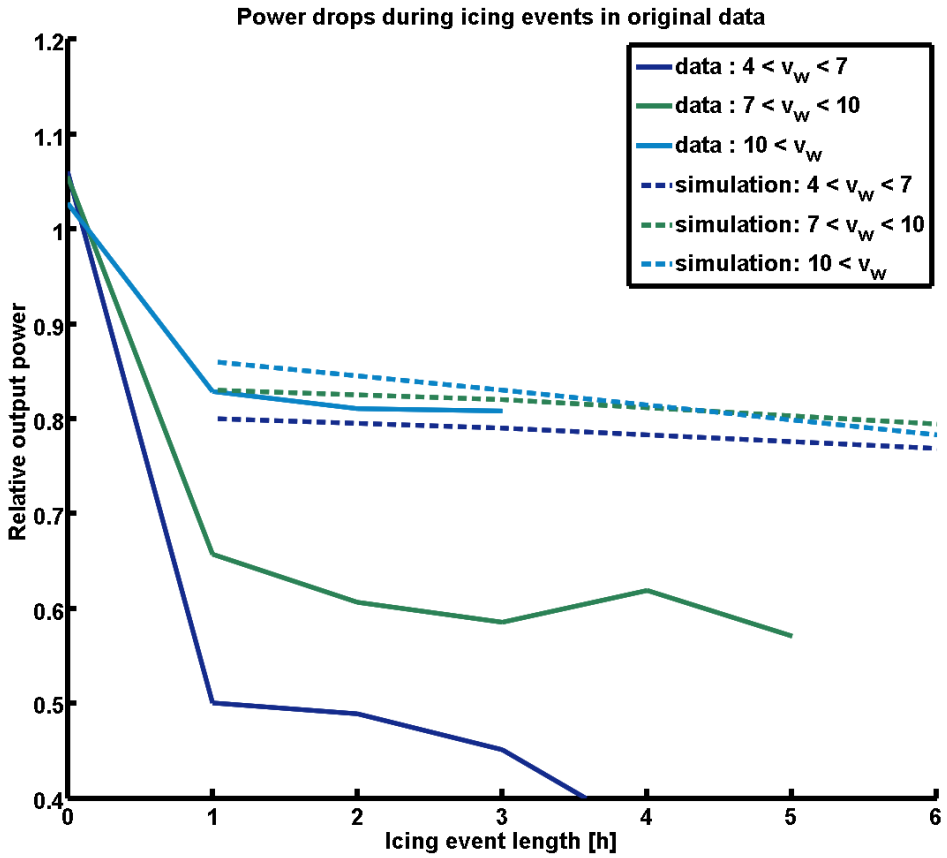
Event statistics

- Collect icing induced power drops from several different sites
  - Scale as % of output
- Sort by several parameters
- Look at contributions, pick only most significant & most common ones
- => event length & wind speed



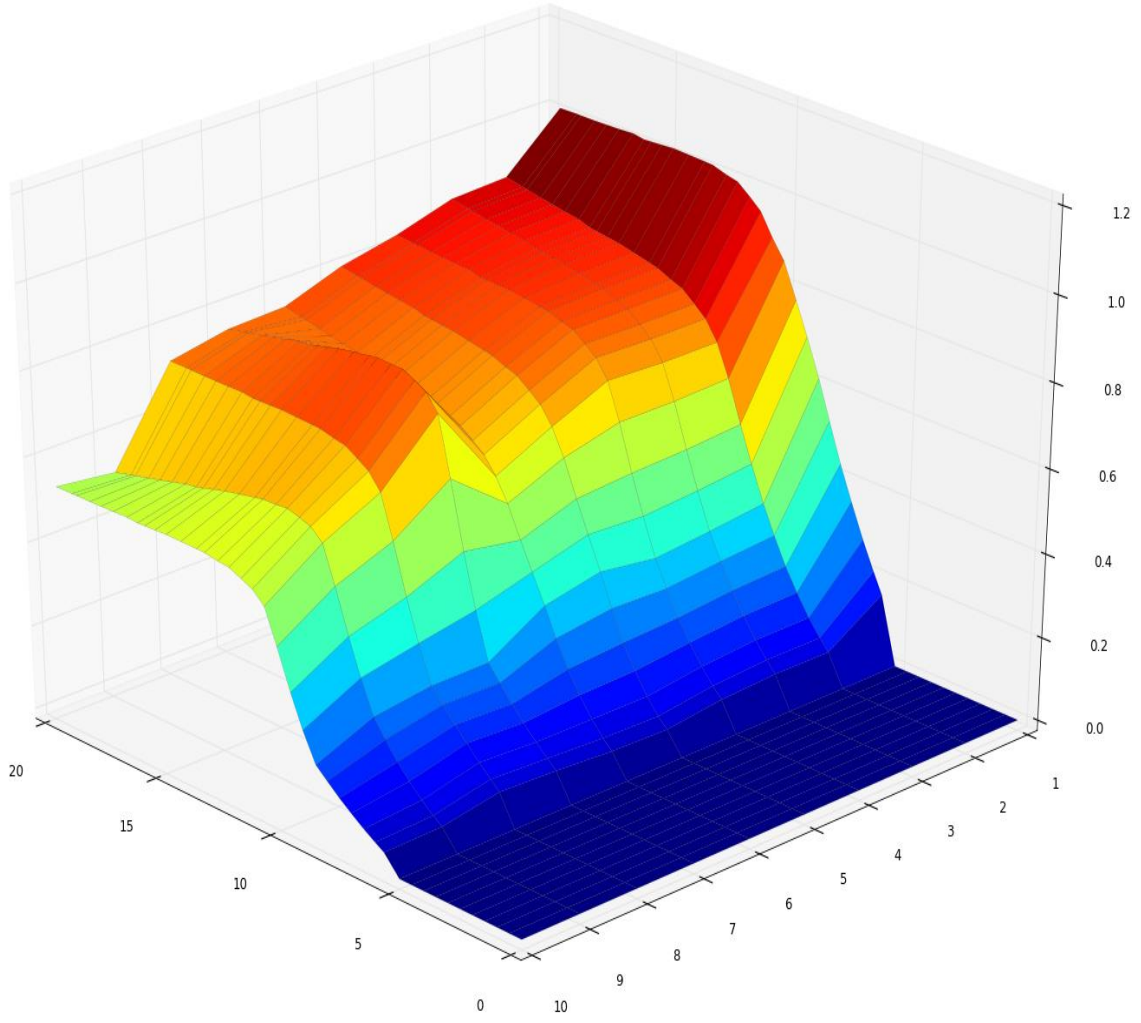
SImulations

- Comparing results to erlier simulations show that drops in data larger than in simulations
  - Surface roughness was difficult to model



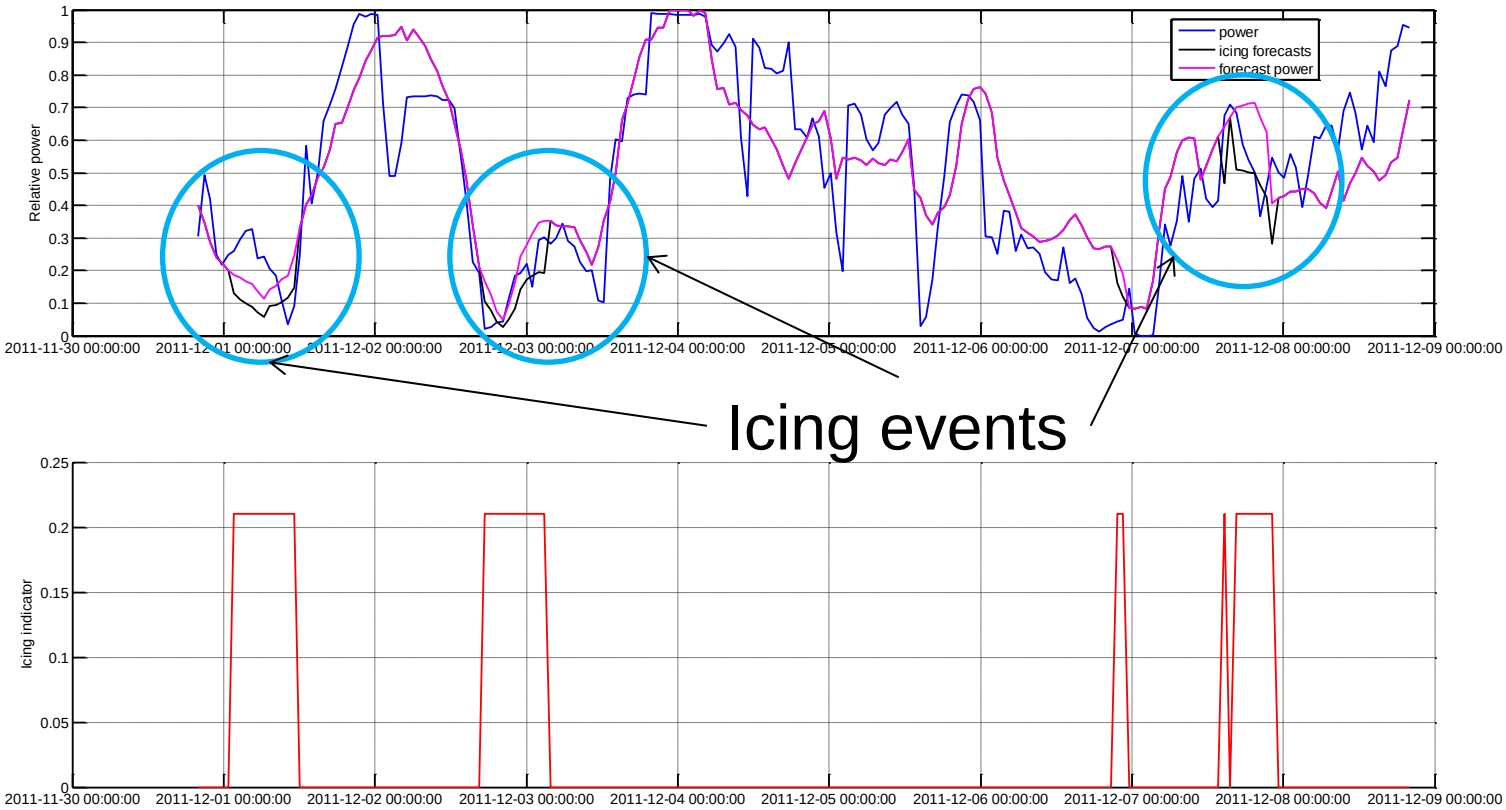
3-d power curve

- Model output can be used to scale forecasted power in case of icing
- Based on forecasted icing event length and forecasted wind speed



Usage

- 3-d power curve is used to scale the normal forecast



Problems

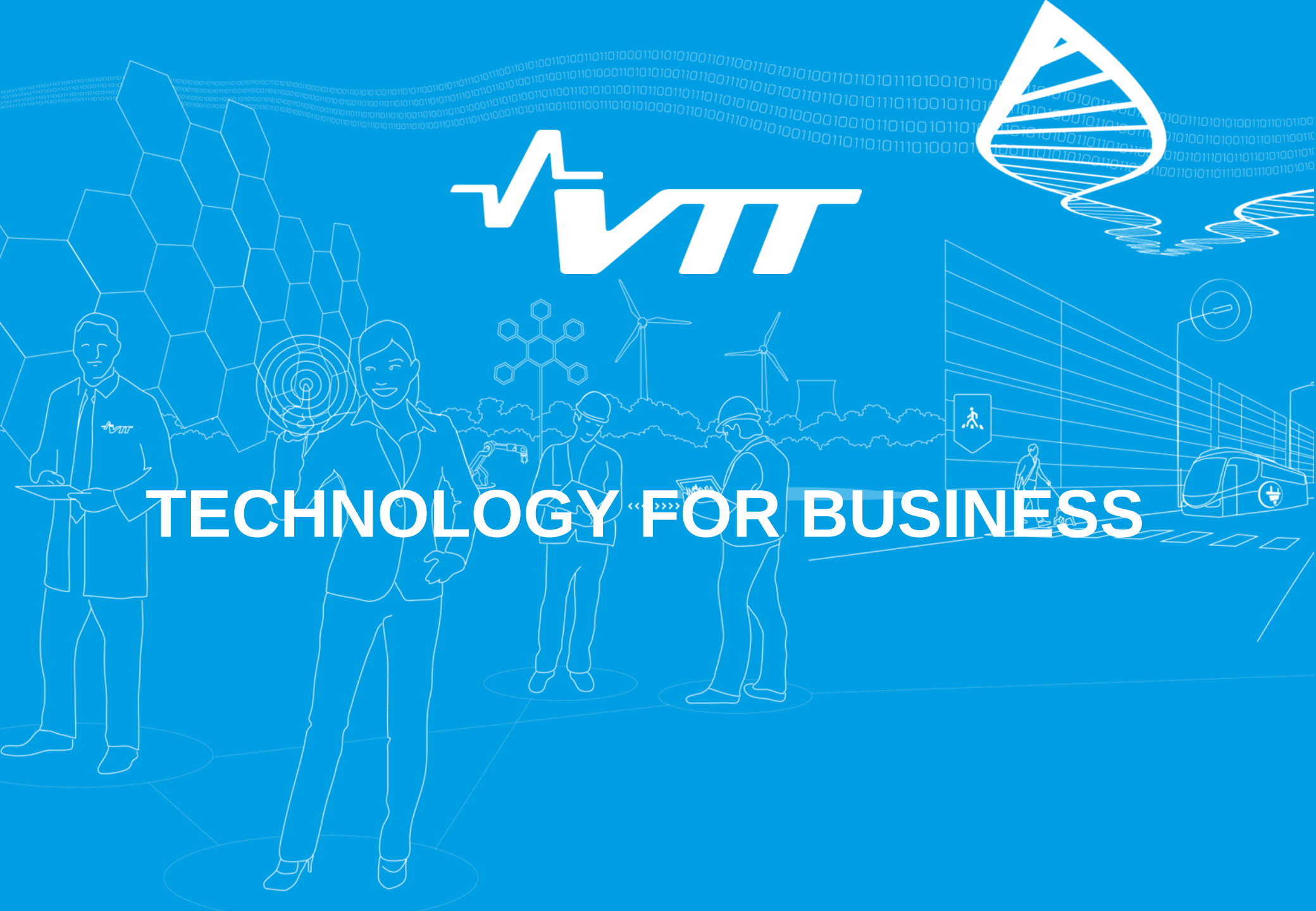
- Sensitive to forecast accuracy
- Source data variance lost
- Requires large amounts of data to build
  - Multiple years preferably from different sites
- Majority of production losses come from unplanned stops

Benefits

- Simple
- Scales well
- Can produce "good enough" outputs

More

- More detailed descrption of the methodology in report available at
  - Karlsson T., Turkia V., Wallenius T. Icing production loss module for wind power forecasting system. Espoo 2013. VTT Technology 139. 20 s.
  - www.vtt.fi/inf/pdf/technology/2013/T139.pdf
- Report on the simulation study:
  - Turkia V., Huttunen S., Wallenius T. 2013. Method for estimating wind turbine production losses due to icing. VTT Technology 114. VTT, Espoo.
  - www.vtt.fi/inf/pdf/technology/2013/T114.pdf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