Development of a reliable modeling system for the calculation of rime ice loads on overhead transmission lines

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FRonTLINES - main objective :

”To develop a toolbox for assessing frost and rime ice impacts on overhead power lines”

Development of icing test stations

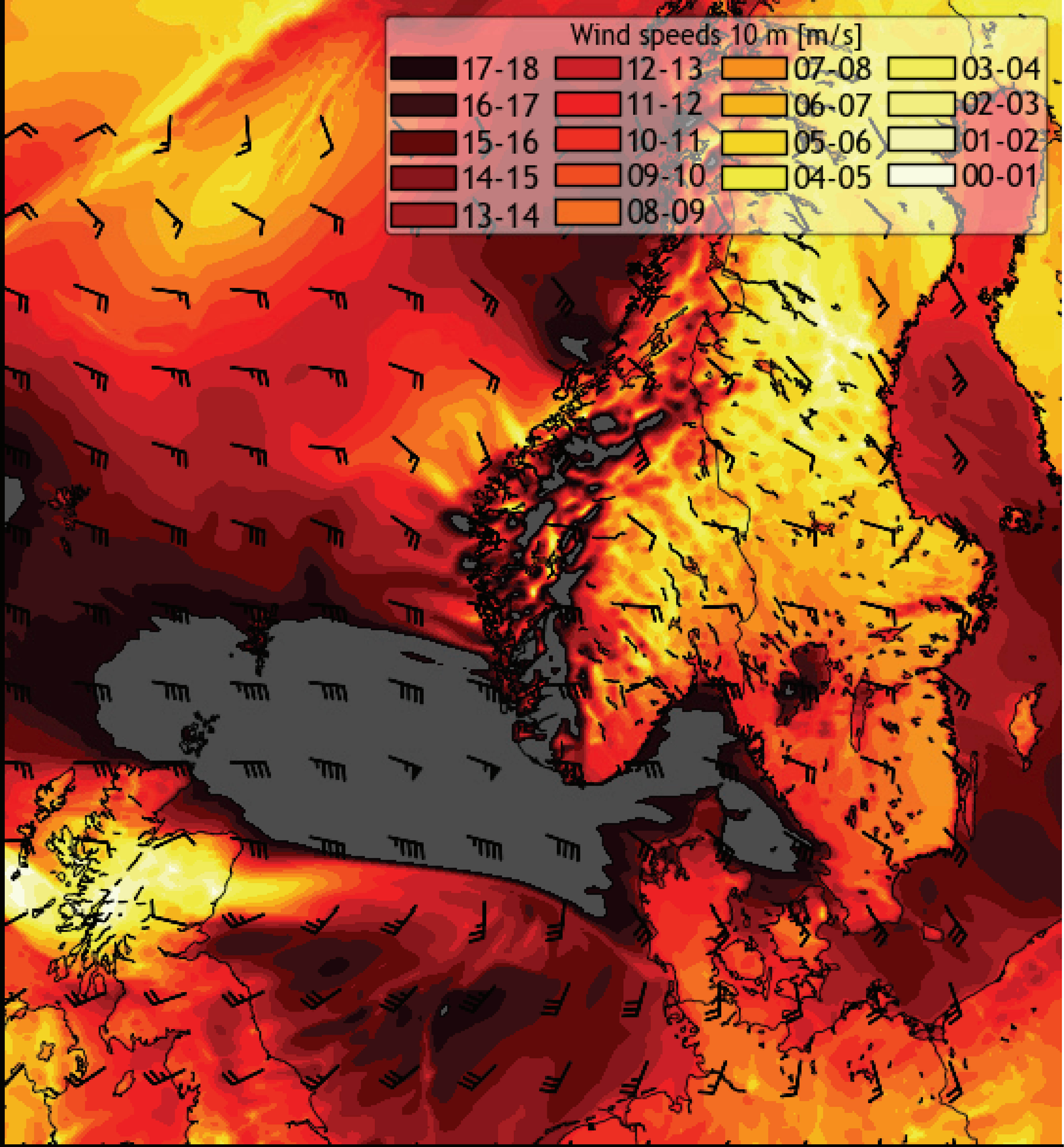
Test station - Instrumentation

- **Ice load** measurements with vertical cylinder with forced forced rotation (**IceTroll**)
- **Load tension** recorders on the power line and test span
- **Wind** measurements with a heated ultrasonic anemometer
- **Temperature** measurements
- **Web cameras**

WRF model simulations

Understand and explain the meteorological processes that result in icing buildup

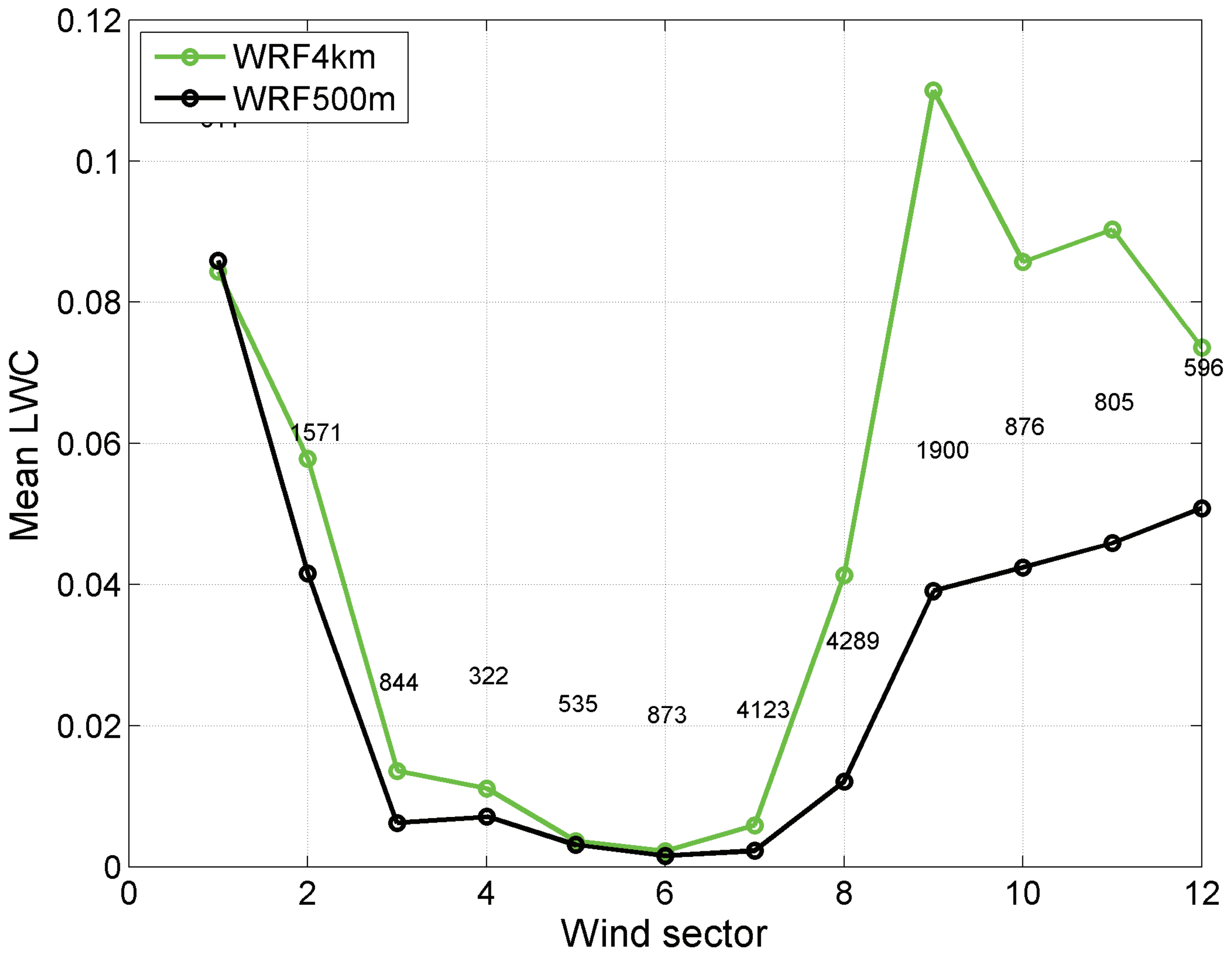
- Long term calculations 1979-2017:
  - 4 km resolution
  - Large coverage
- Fine scale simulations:
  - 500 m resolution
  - Local coverage



Statistical downscaling methods

- Account for **unresolved terrain** in the long term time series
- By the use of **quantile regression** methods the sectorvise distribution of LWC is adjusted to the results from the fine scale model.

Liquid water content



Example: Location with considerable sheltering in sectors 8-11

Statistical downscaling methods

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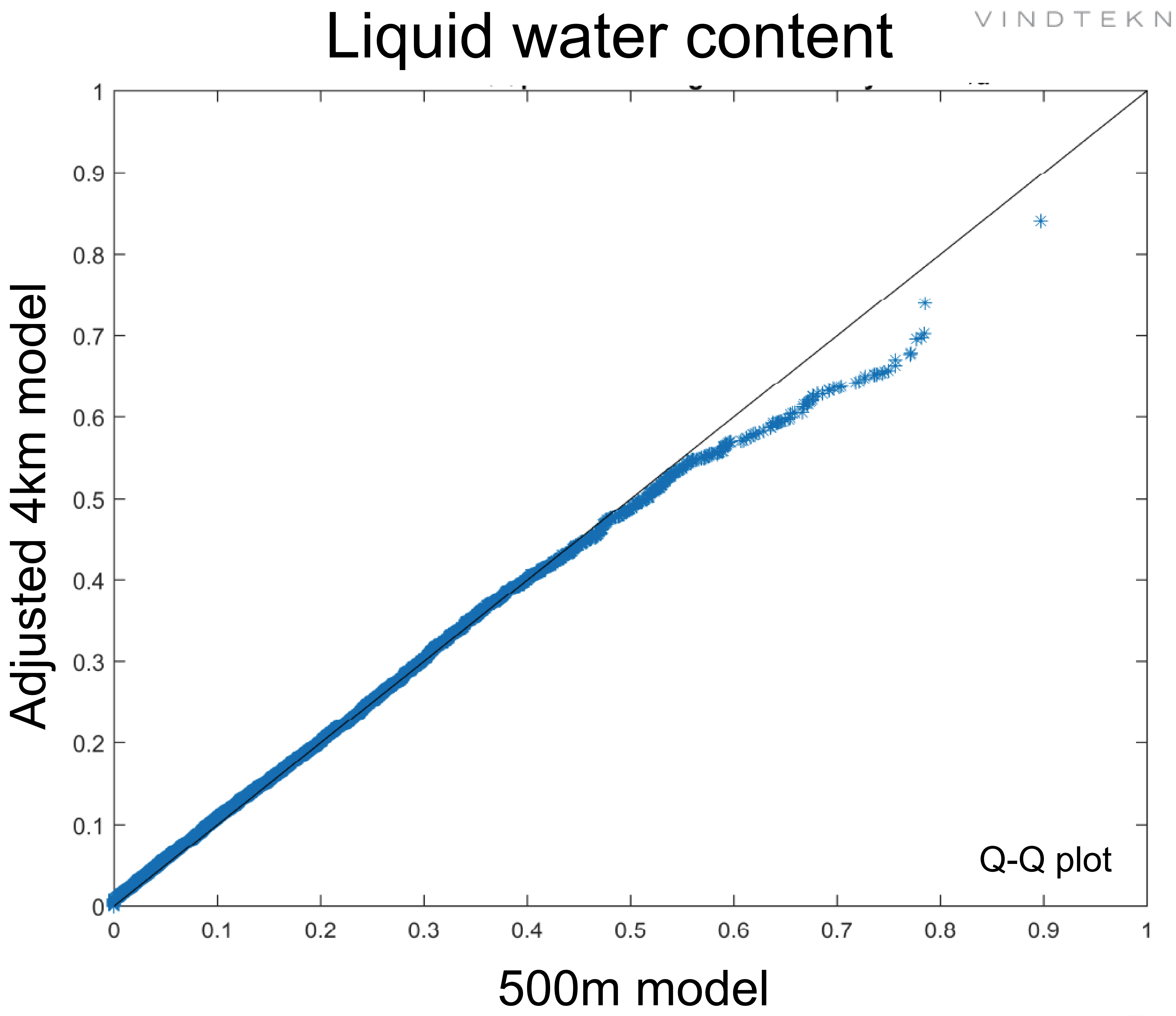


Modelling ice accretion

Icing intensity on rotating cylinder (reference object):

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 \cdot LWC \cdot A \cdot V$$

α_1 – collision efficiency, $\alpha_1 = f(V,d,D)$
α_2 – sticking efficiency, $\alpha_2 \approx 1$
α_3 – accretion efficiency, $\alpha_3 = f(V,d,LWC,T,e,D,\alpha_1)$
LWC – cloud liquid water content
A – collision area, perpendicular to flow
V – wind speed
d – droplet diameter
D – cylinder diameter

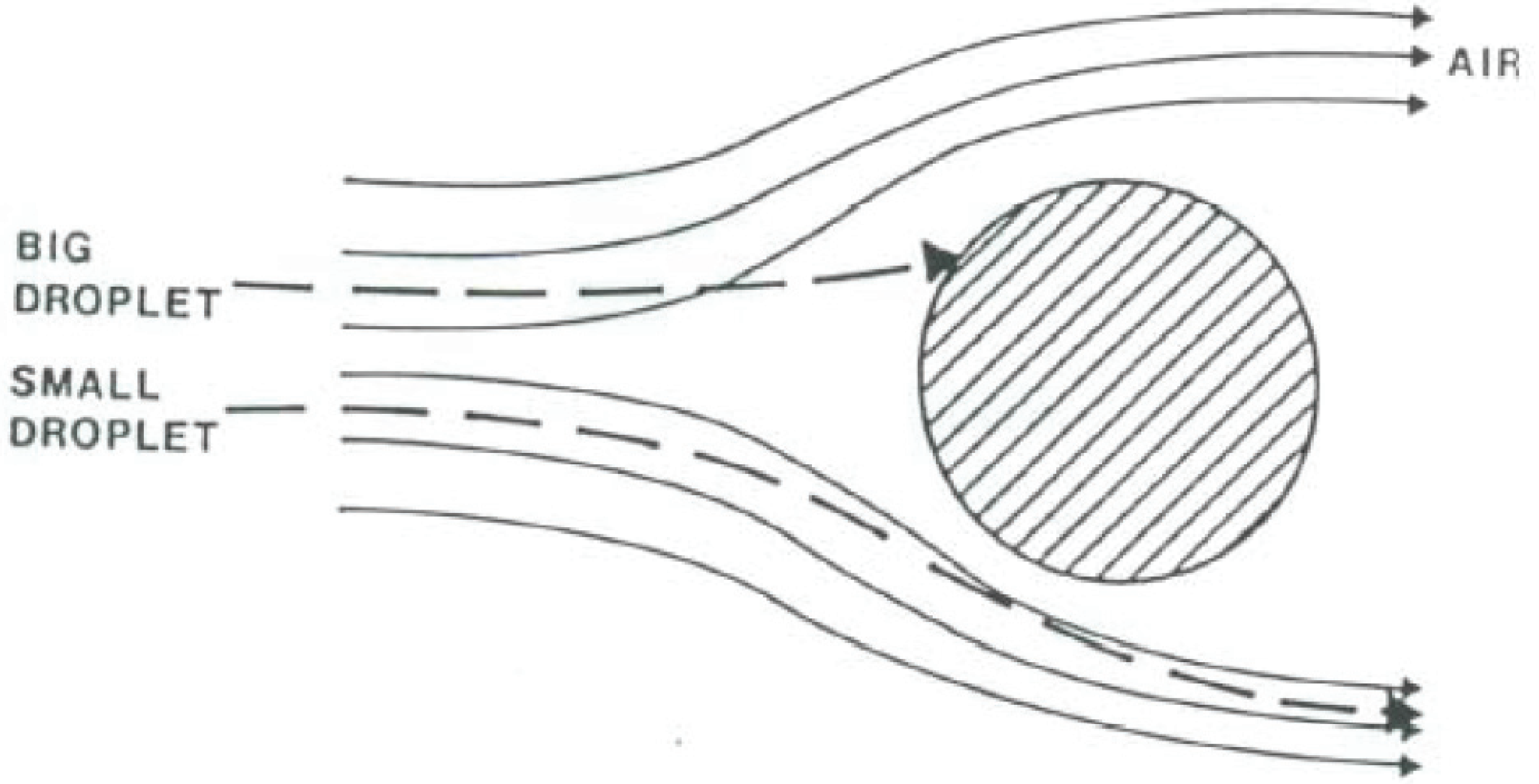
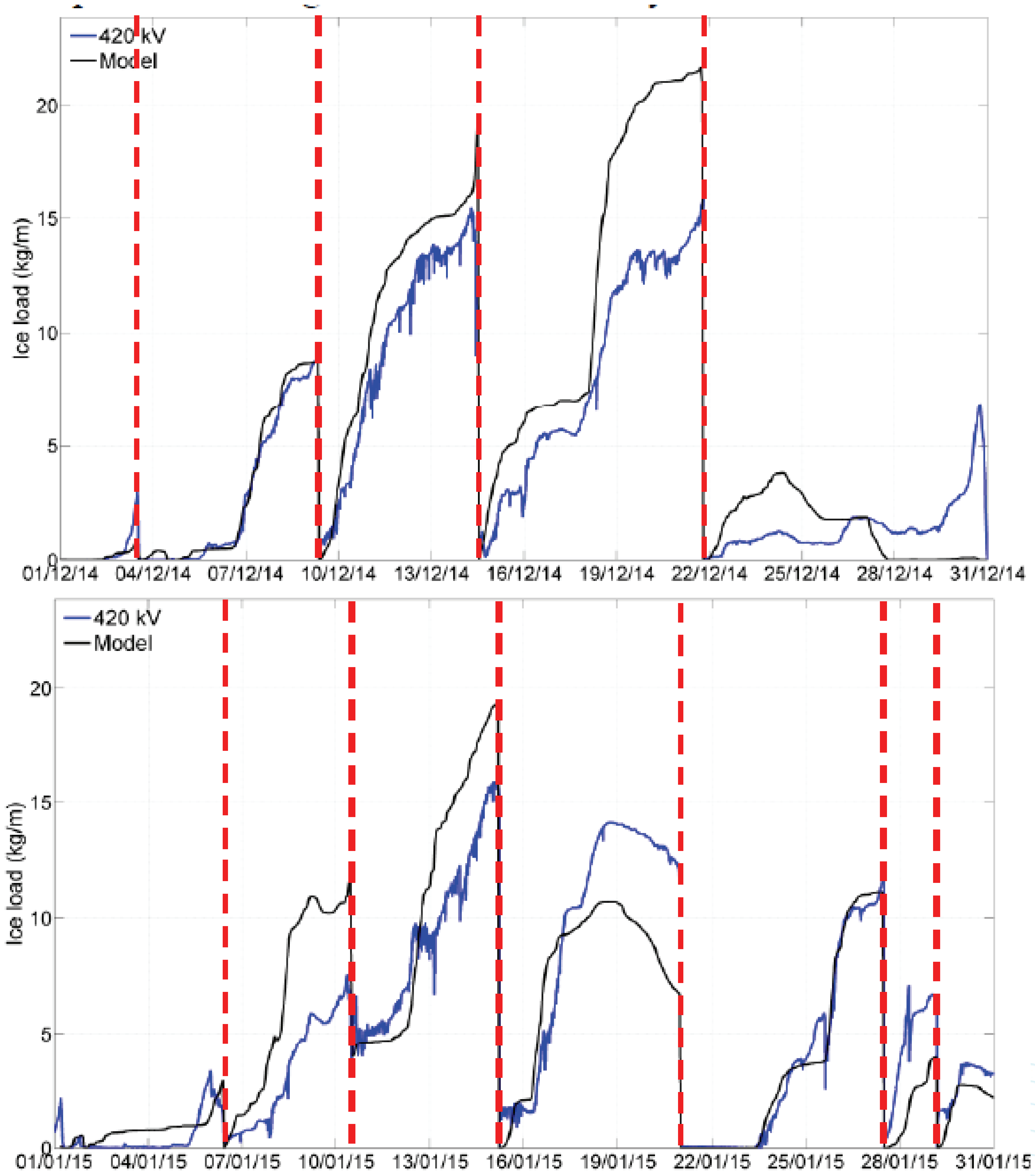


Figure 9 Air flow around a cylinder (from ISO 12494, Annex C, Figure 1)

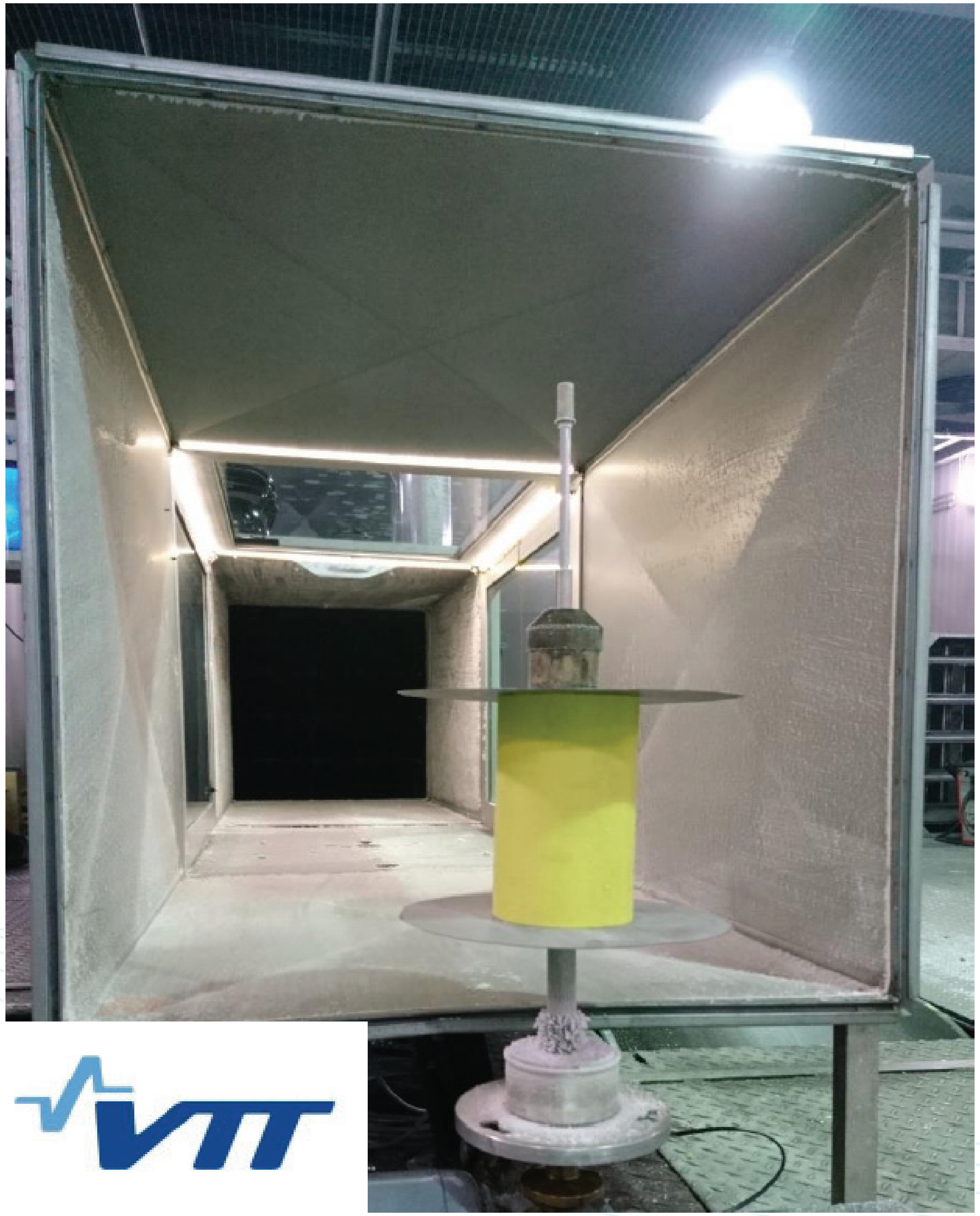
Modeling the ice load

- Ice load modeled from WRF compared to observations from the 420 kV power line
- Ice shedding not modeled. The ice load in the model is reset every time the ice sheds off the power line



Wind tunnel tests

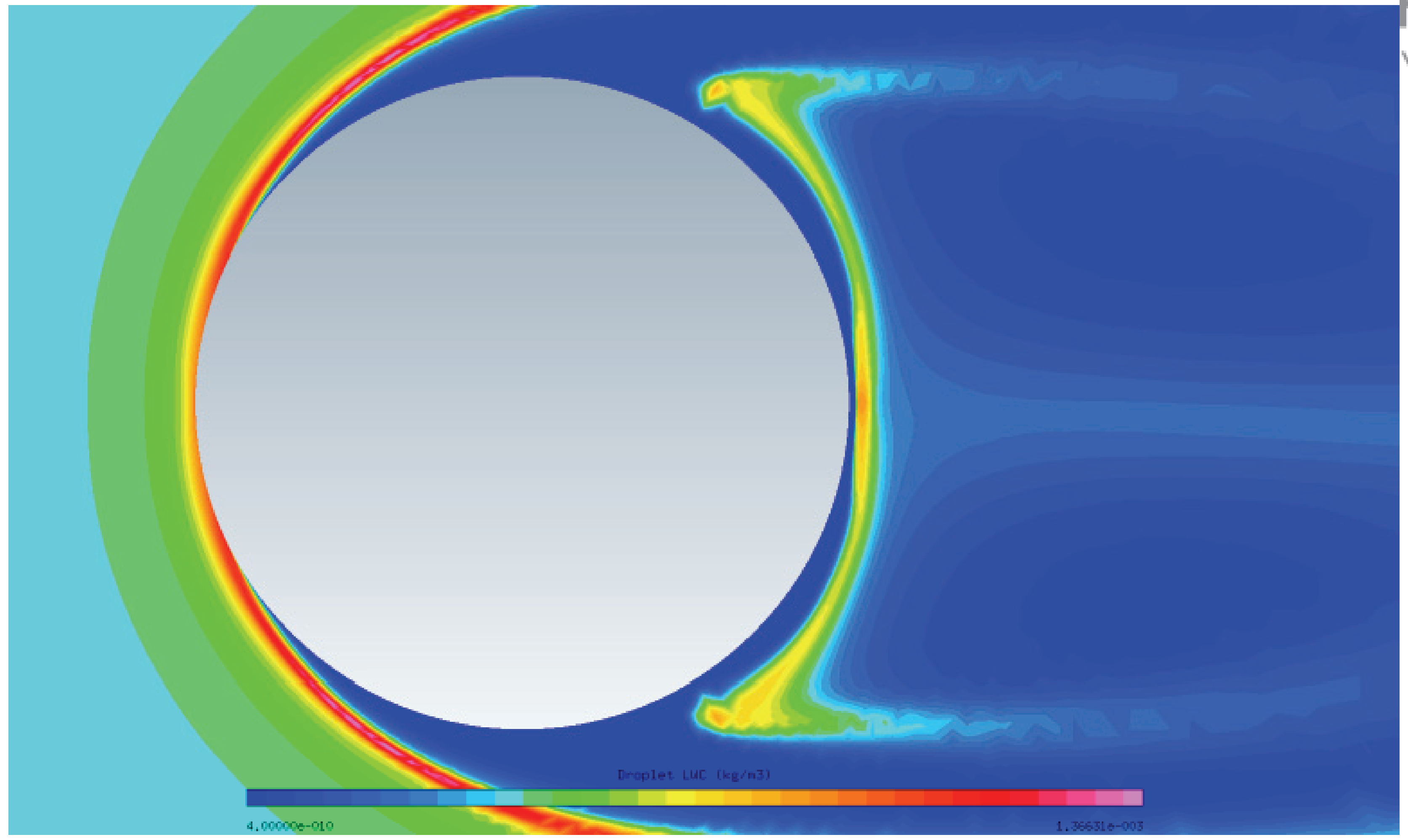
- Study ice accretion under controlled conditons:
  - Influence of surface roughness
  - Large cylinders
  - Low wind speeds
  - Conductor bundles
- Validation and development of ice accretion models



CFD calculation of ice accretion

- FENSAP ICE
- Revealed **limitations to ISO 12494** under the following conditions:
  - Low wind speeds (<10m/s)
  - Large objects (>15 cm diameter)
- Under such conditions the collision efficiency is highly dependent on the **droplet distribution spectra.**

Liquid water content



D=30mm
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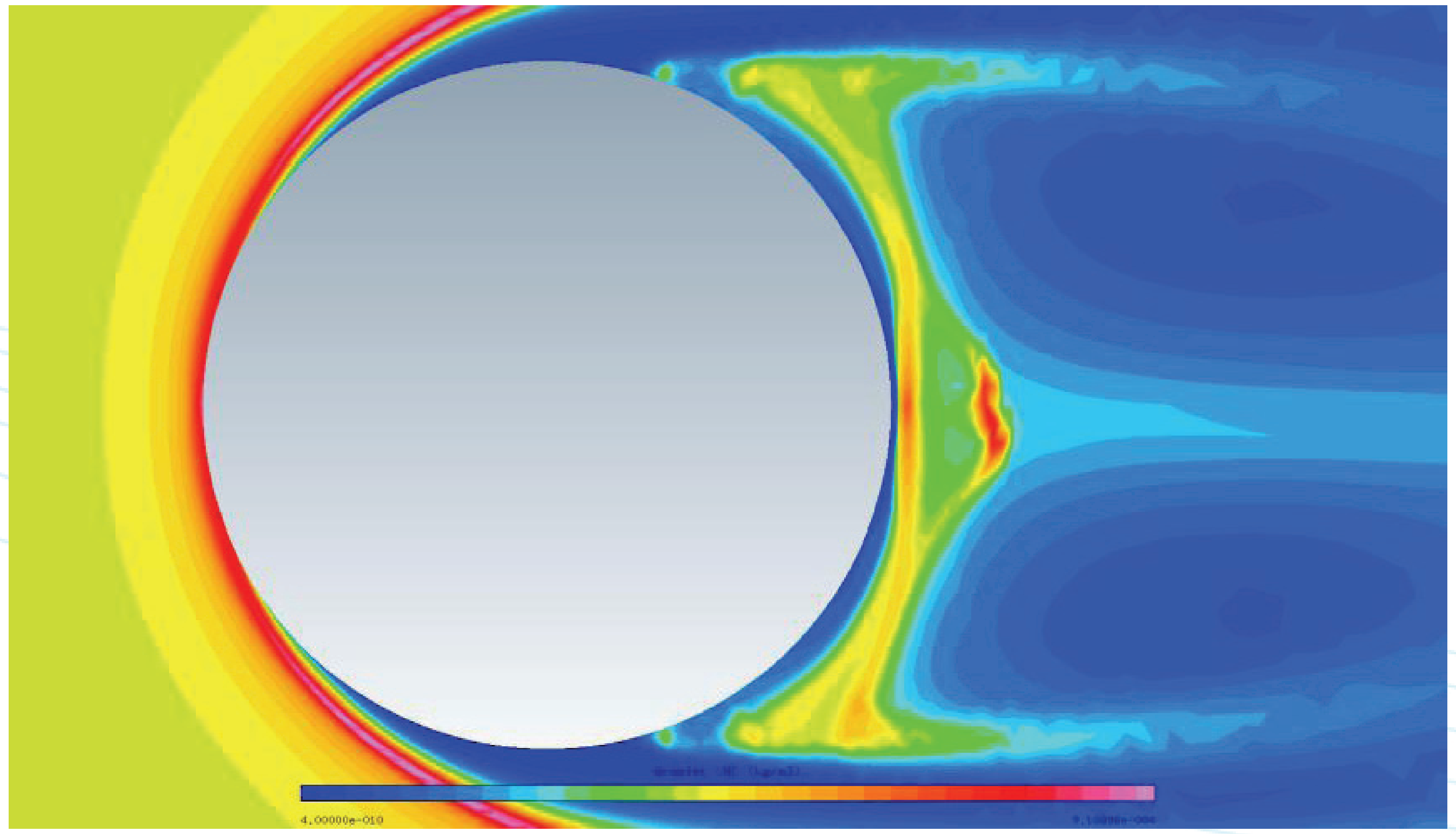

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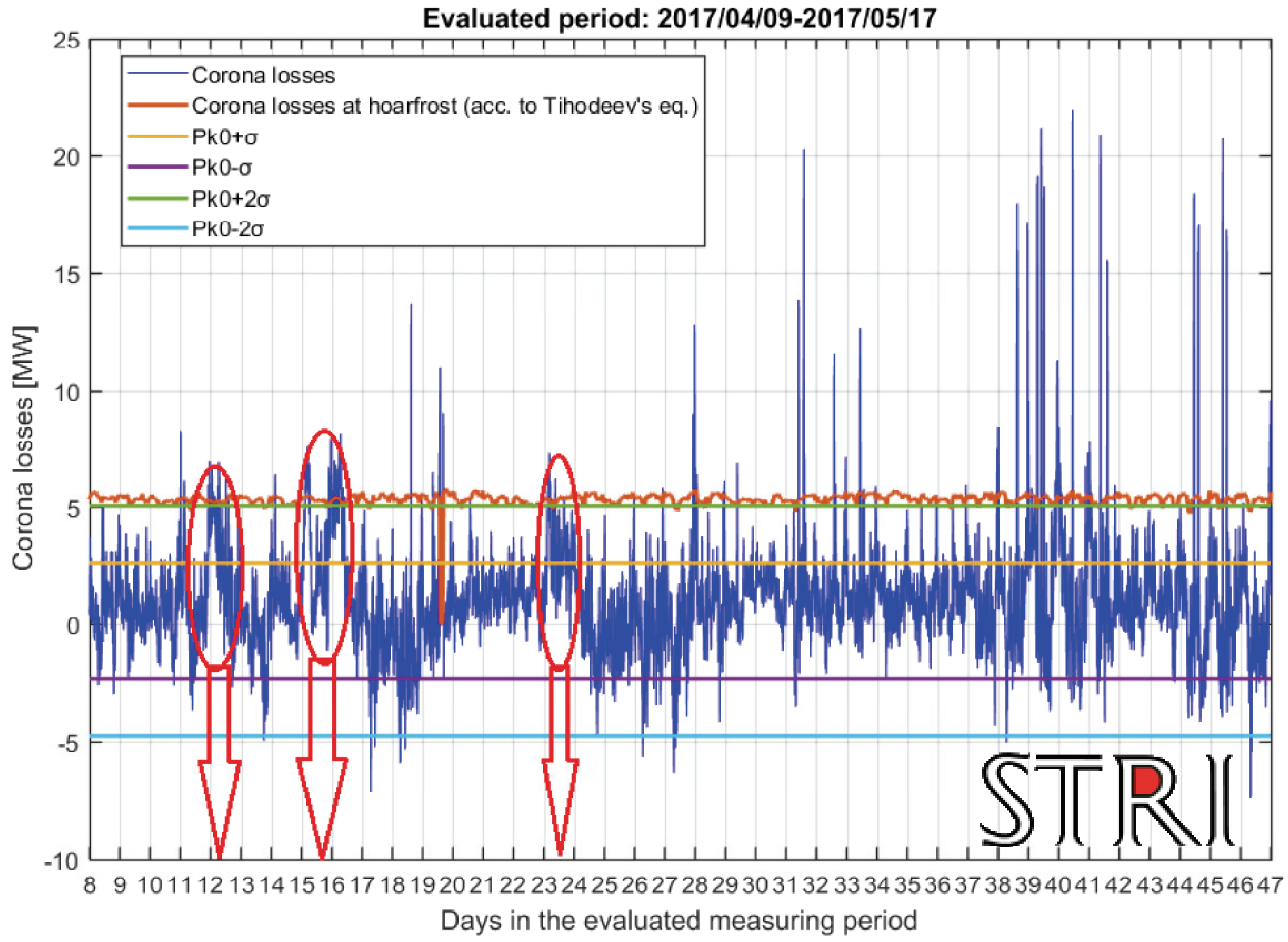
Hoar frost

Hoar frost on conductors may cause high power losses due to **corona discharge activity** on the hoar frost needles.

Example of hoar frost on a conductor

Hoar frost

- A method to identify and quantify hoar frost corona losses has been developed
- The example shows 3 such events during April 2017 on a 420 kV line



FRonTLINES in summary

- **3 icing test stations** has been established
- Meteorological models have been developed and improved to **calculate icing in complex terrain**
- CFD calculations and wind tunnel experiments have been applied **to increase our understanding and study the limitations** to the current ice accretion models.
- Methods to **identify and quantify hoar frost corona losses** from power lines have been developed

Ålvikfjellet test station
(Photo: Øyvind Welgaard, Statnett, Feb 02 2018)

Thank you for your attention!

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