Influence of elevation, rotor diameter and hub height on blade icing duration

Dipl.-Ing. Stefan Reimann
Monitoring

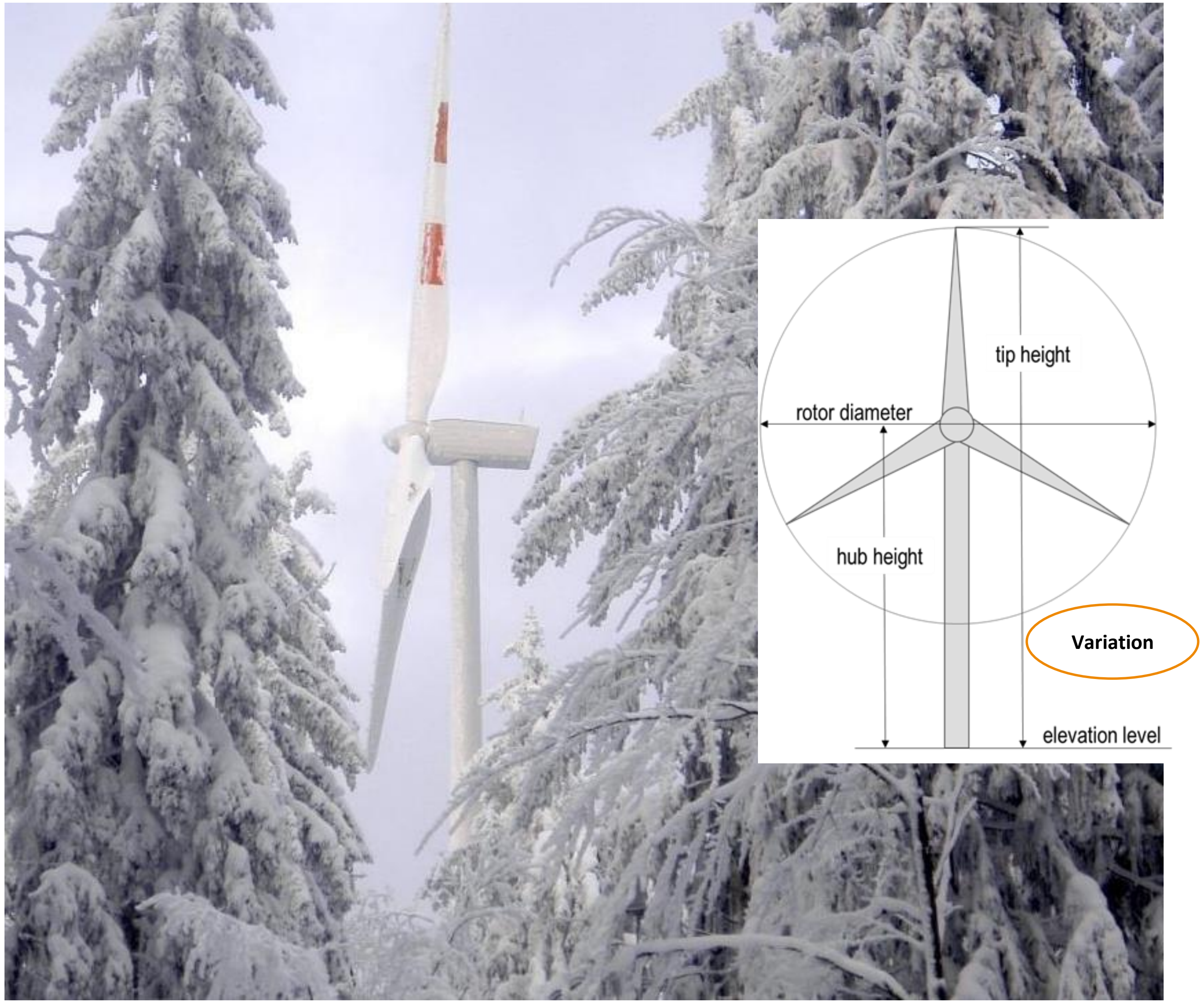
Skelleftea, February 4th 2025

www.bladecontrol.de

Weidmüller

Agenda

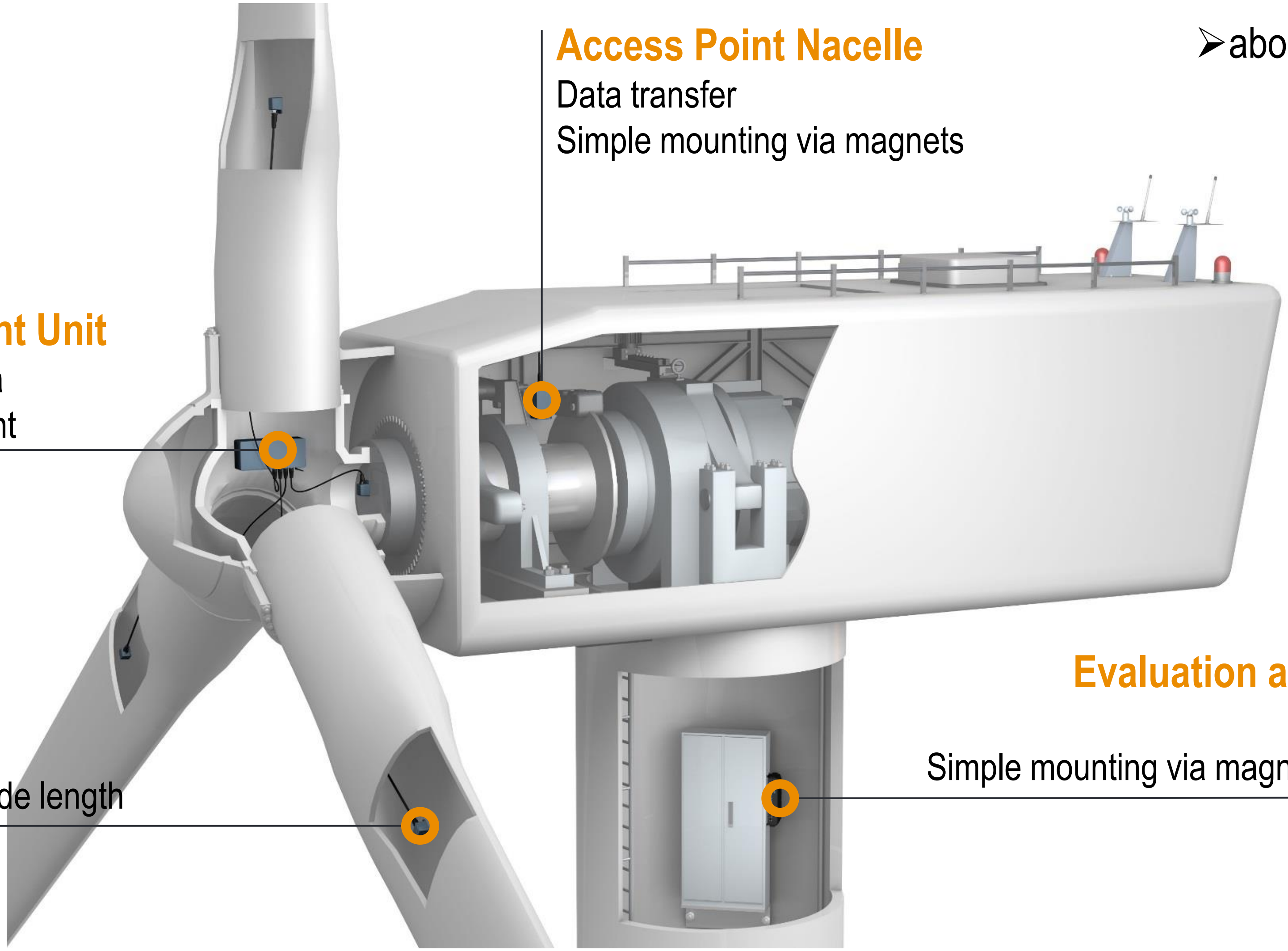
- ➢ Introduction to **BLADEcontrol®**
- ➢ Factors influencing blade icing duration:
  - elevation
  - hub height
  - max. blade tip height
  - operational state
- ➢ Influence of operational state on ice growth rate (IGR)
- ➢ Summary



Introduction to BLADEcontrol®

Architecture

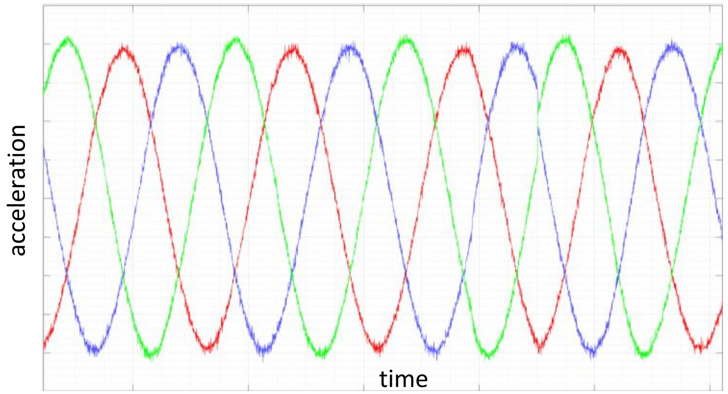
- **BLADEcontrol®** Ice Detector is certified by DNV since 2008
- about 6000 installations worldwide



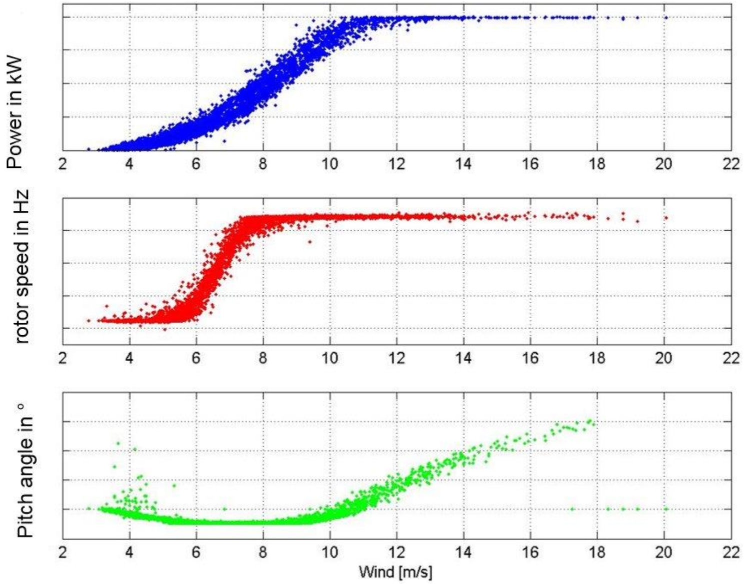
Introduction to BLADEcontrol®

Sensor data and required turbine data

- For ice detection **BLADEcontrol®** measures acceleration data in each blade.

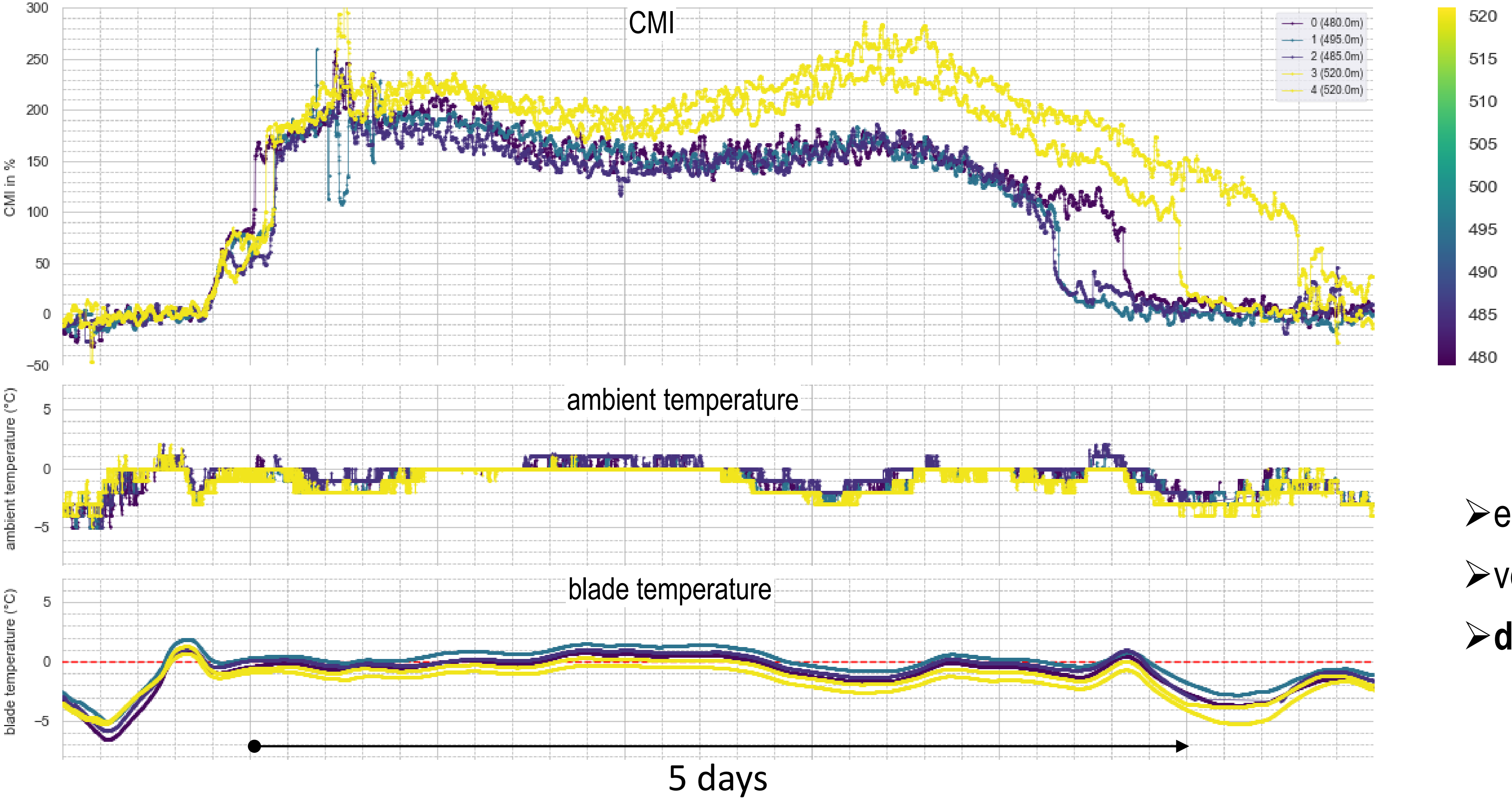


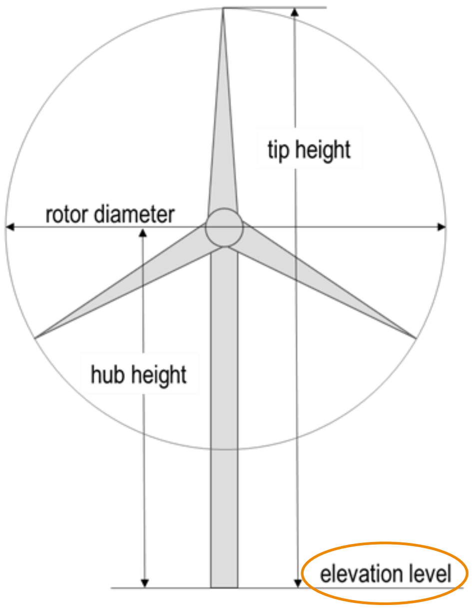
- These data are combined with some turbine data:
  - wind speed
  - power
  - rotor speed
  - pitch angle
  - temperature



Influence of elevation on icing duration

Example 1 - Mountains Germany - Winter 2023 / 2024

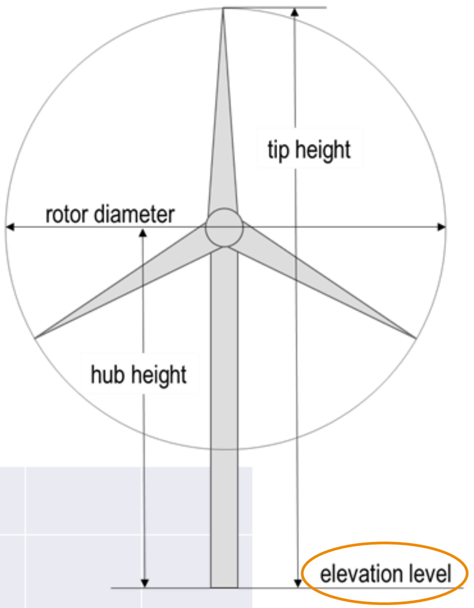




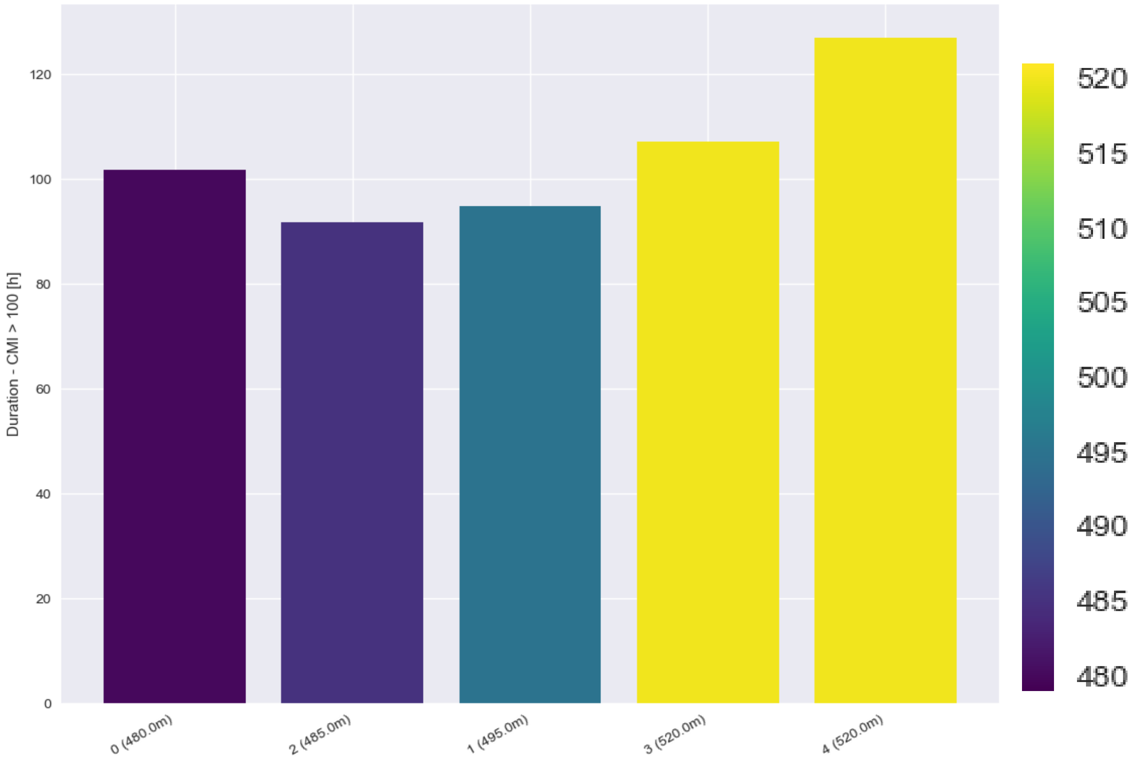
- elevation differences: <40m
- very small temperature differences
- **duration difference up to 1 day**

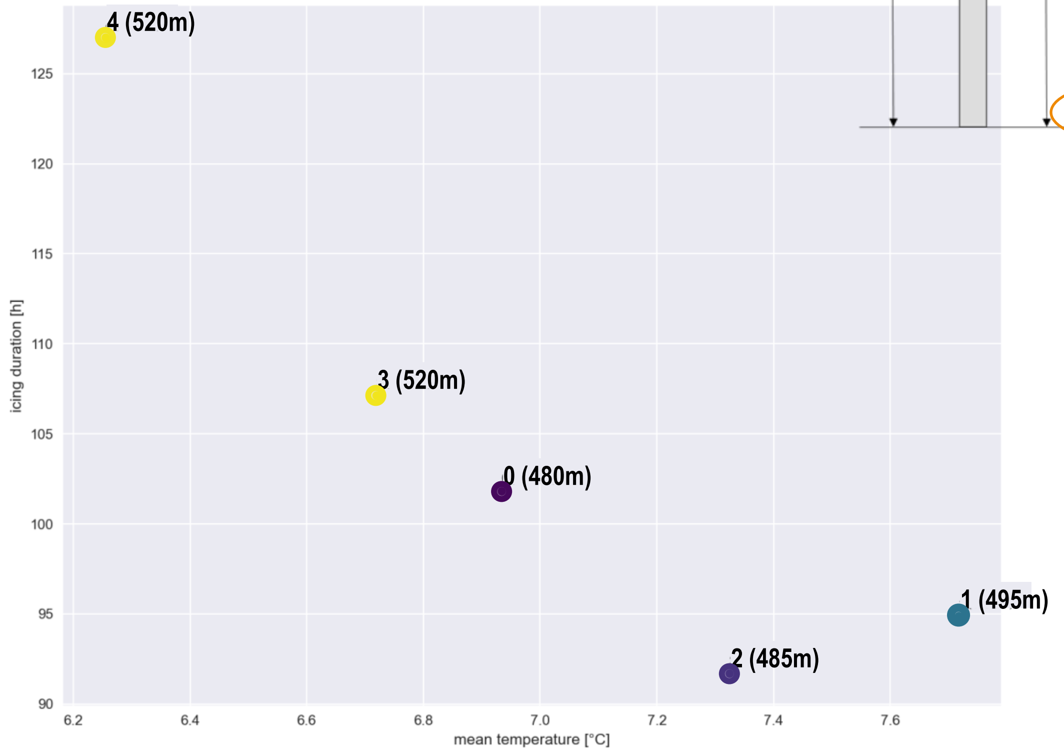
Influence of elevation on icing duration

Example 1 - Mountains Germany - Winter 2023 / 2024



- higher elevations ➔ lower temperatures ➔ longer icing duration

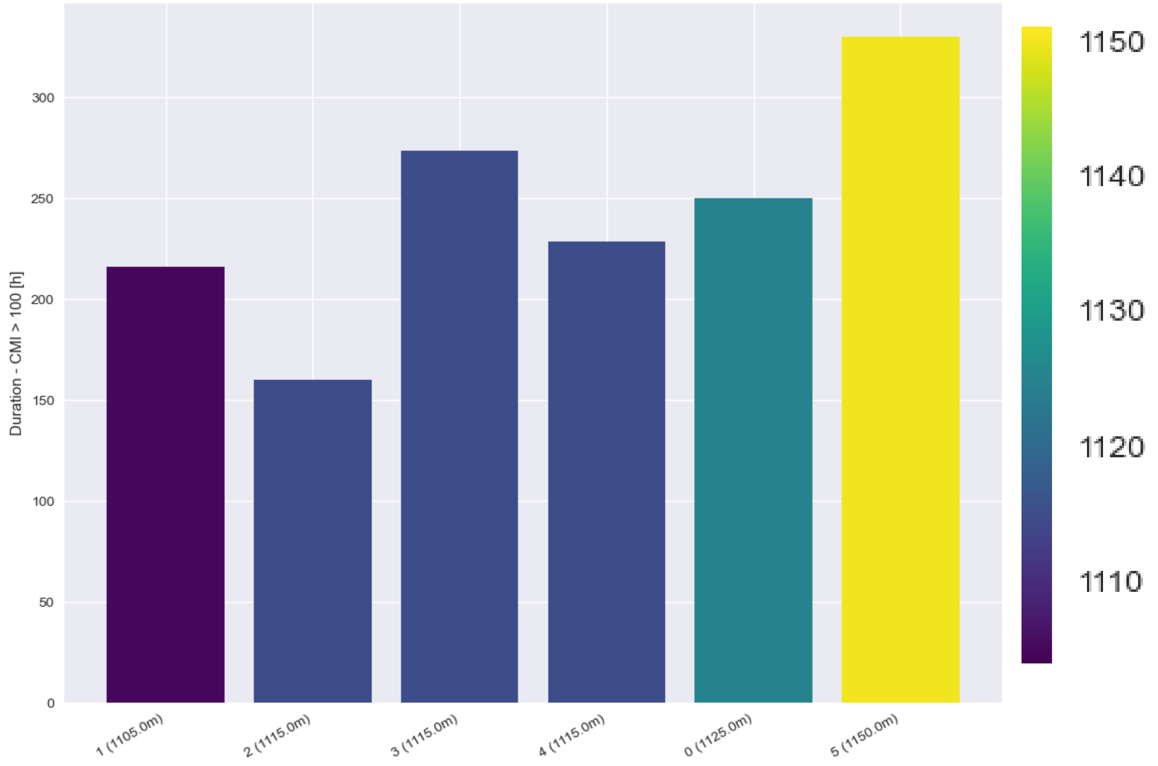


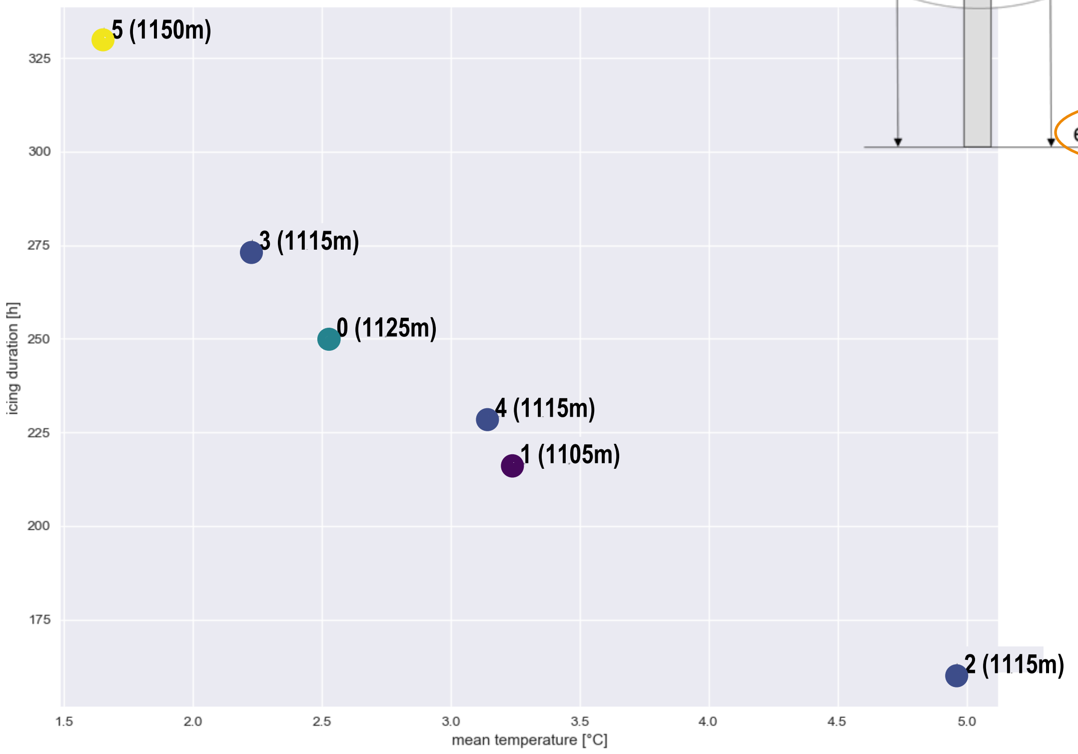


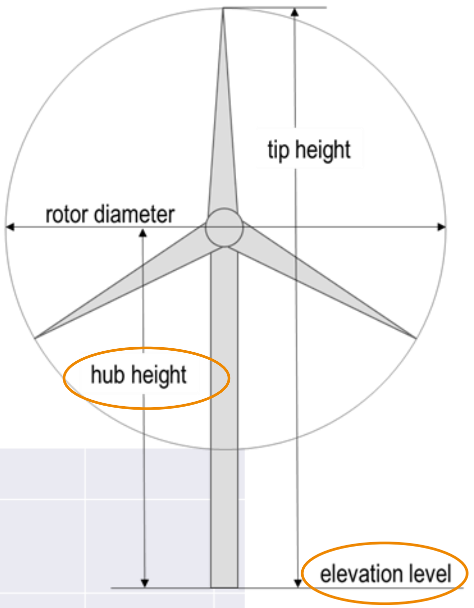
Influence of hub height on icing duration

Example 2 - Mountains Central Europe - Winter 2022 / 2023

- many ice events
- hub heights alone no clear indicator for icing durations

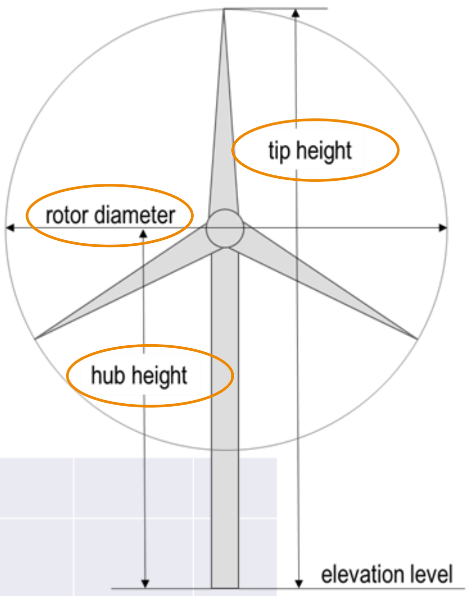




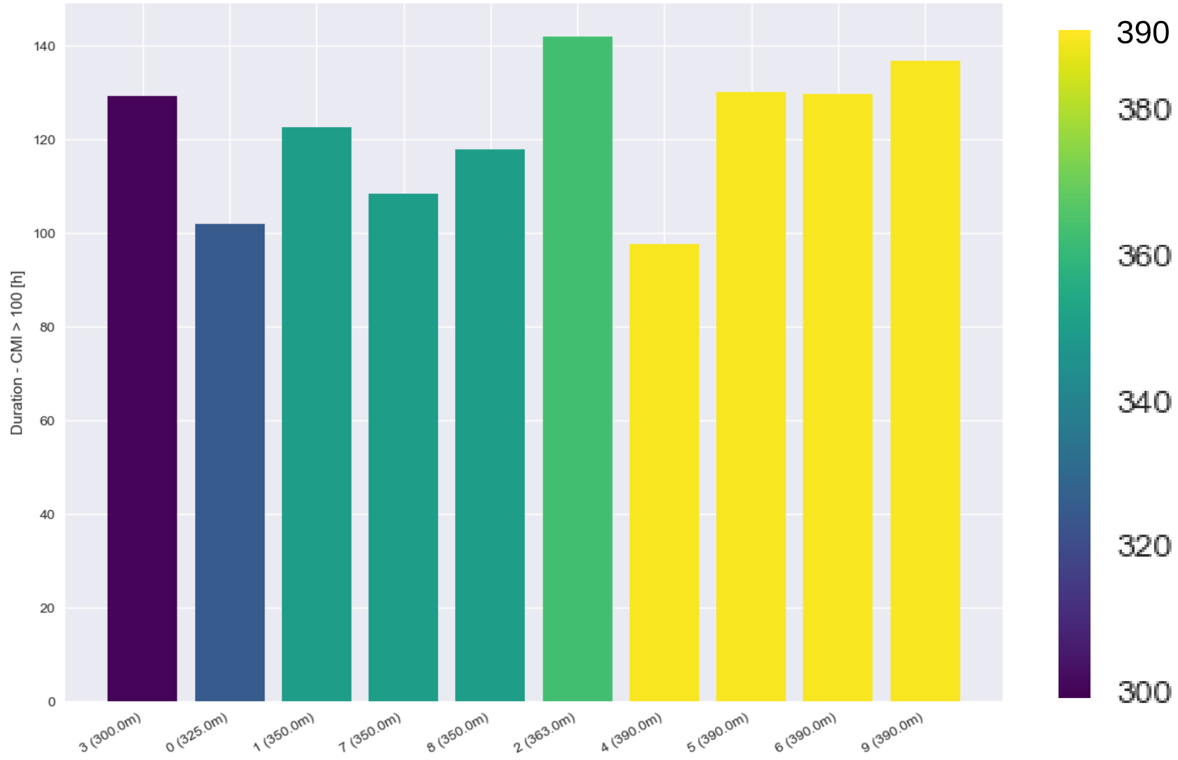


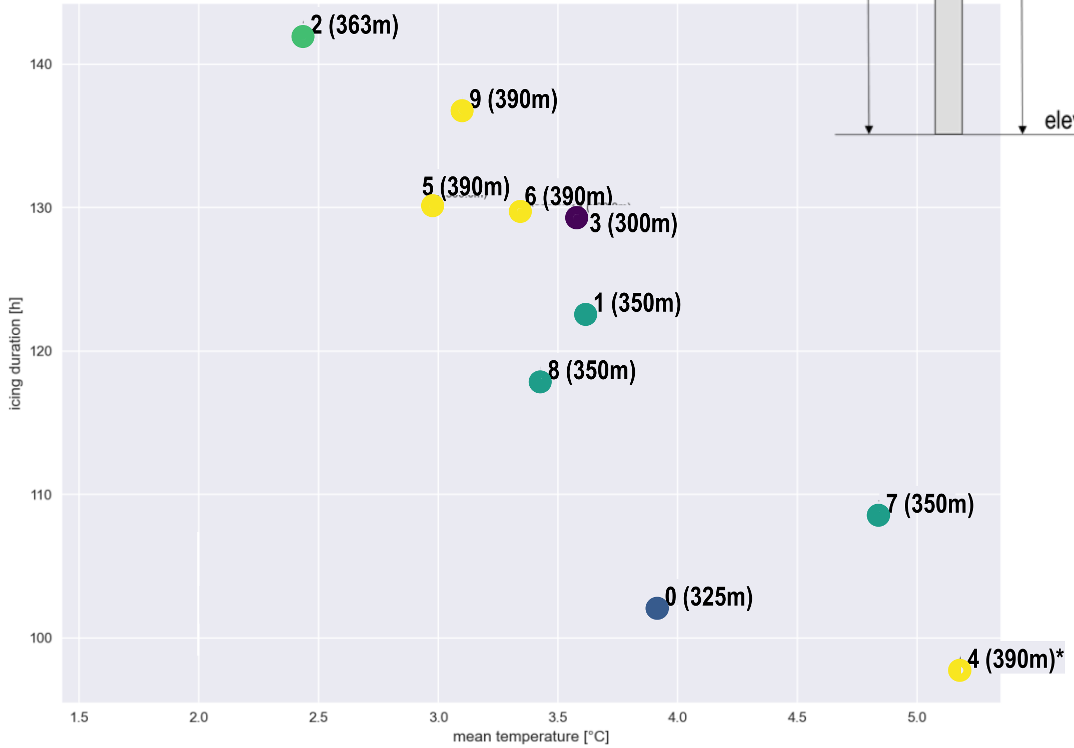
Influence of max. tip height on icing duration

Example 3 - Flats Central Europe - Winter 2024 / 2025



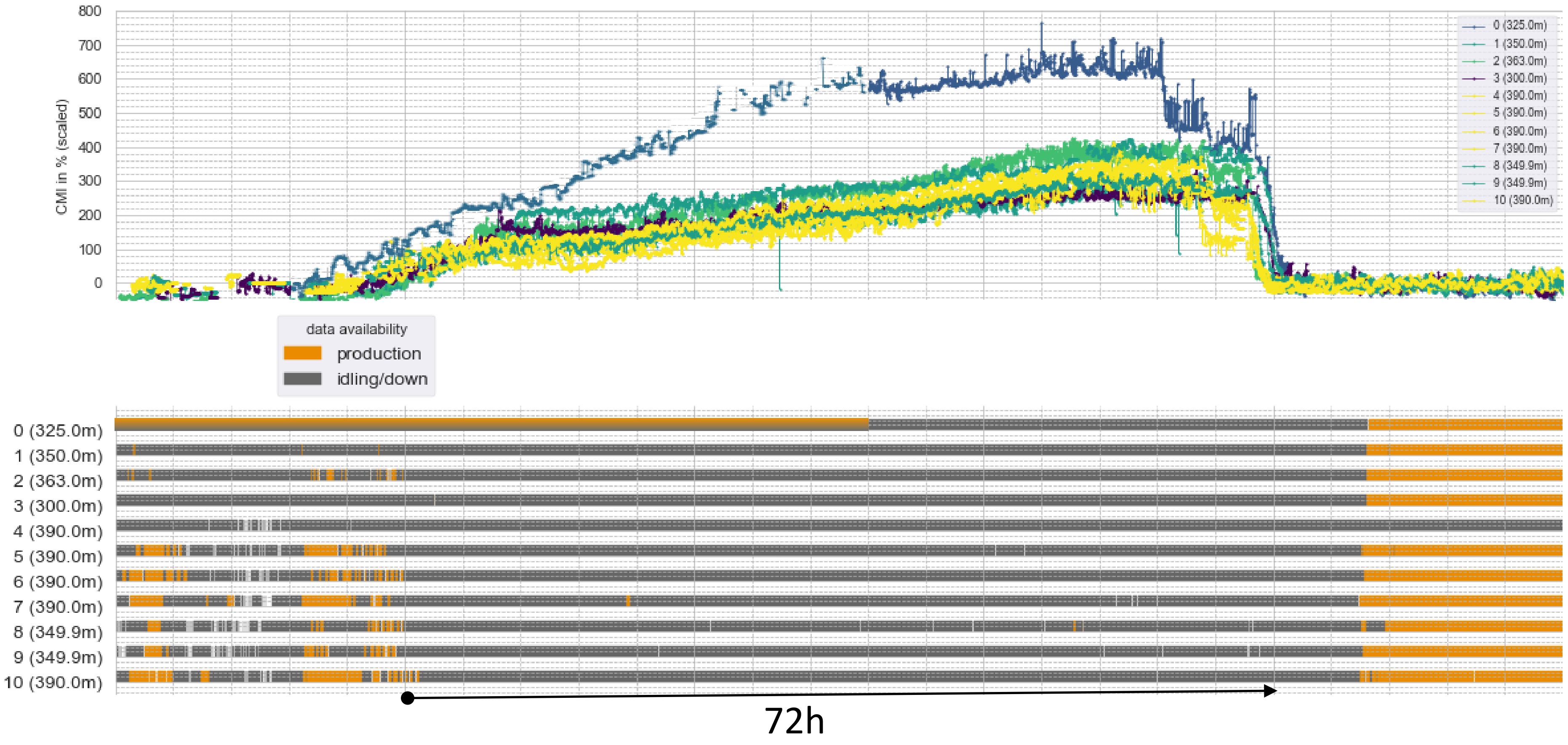
➢different turbine types with different tip heights

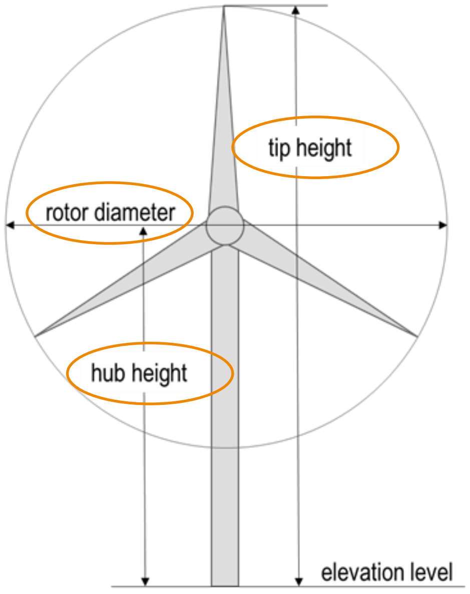




Influence of operational state on icing duration

Example 3 - Flats Central Europe - Winter 2024 / 2025

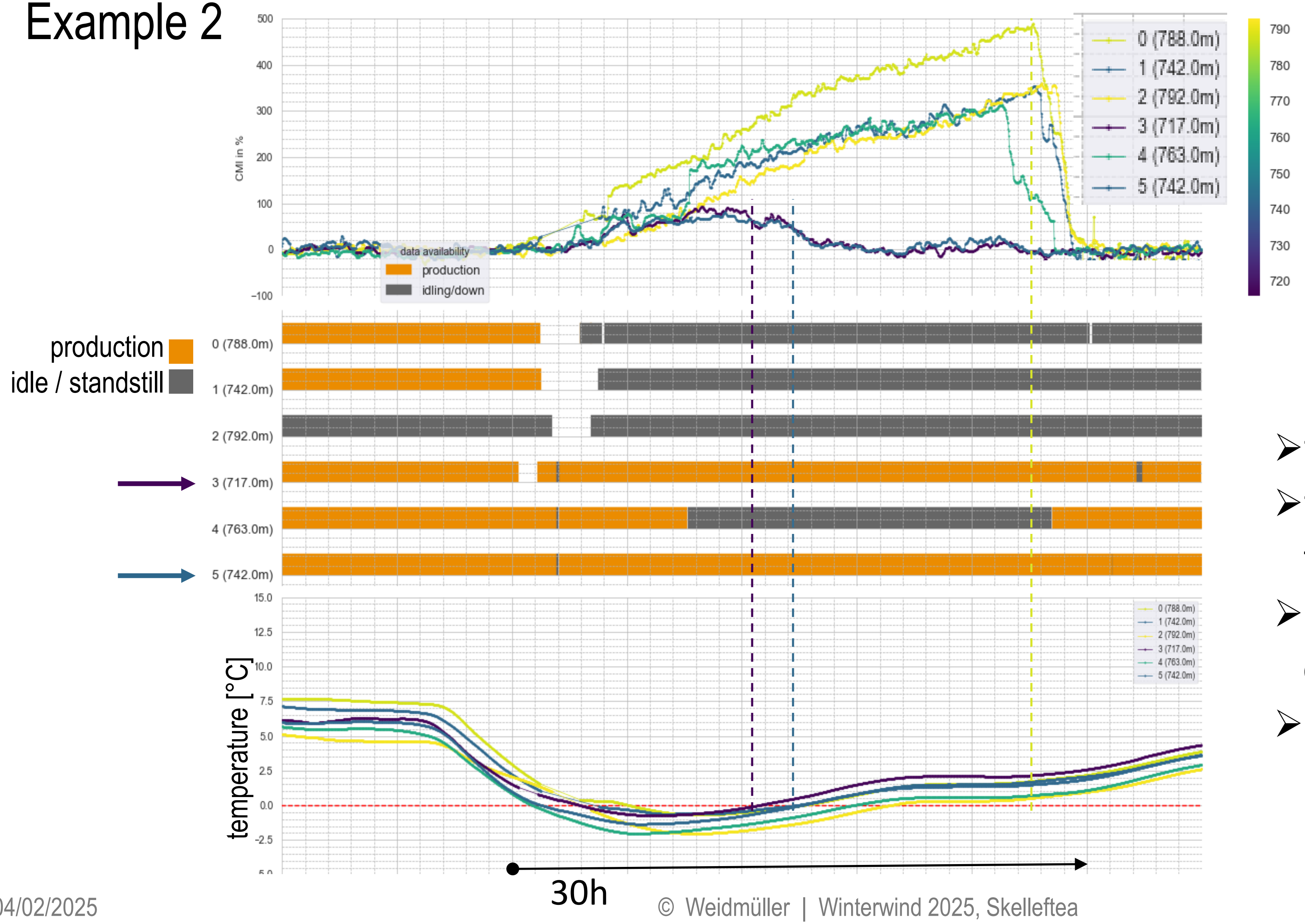


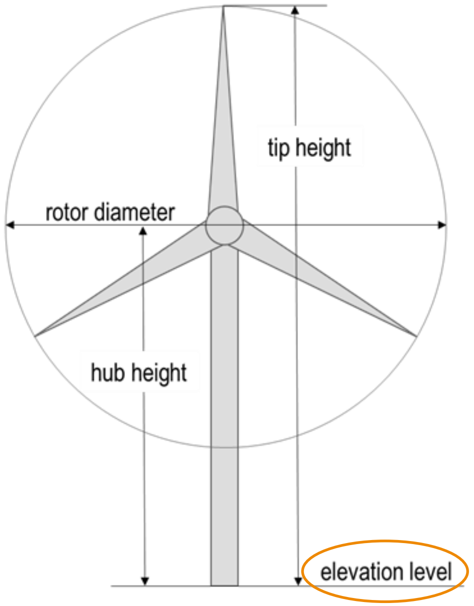


- ice accretion of stopped turbines similar
- turbine **0 rotates** during ice event
- **rotating** turbine collects twice as much ice than stopped turbines (**170 kg** vs. **85 kg**)
- icing duration about 10 h longer

Influence of operational state on icing duration

Example 2

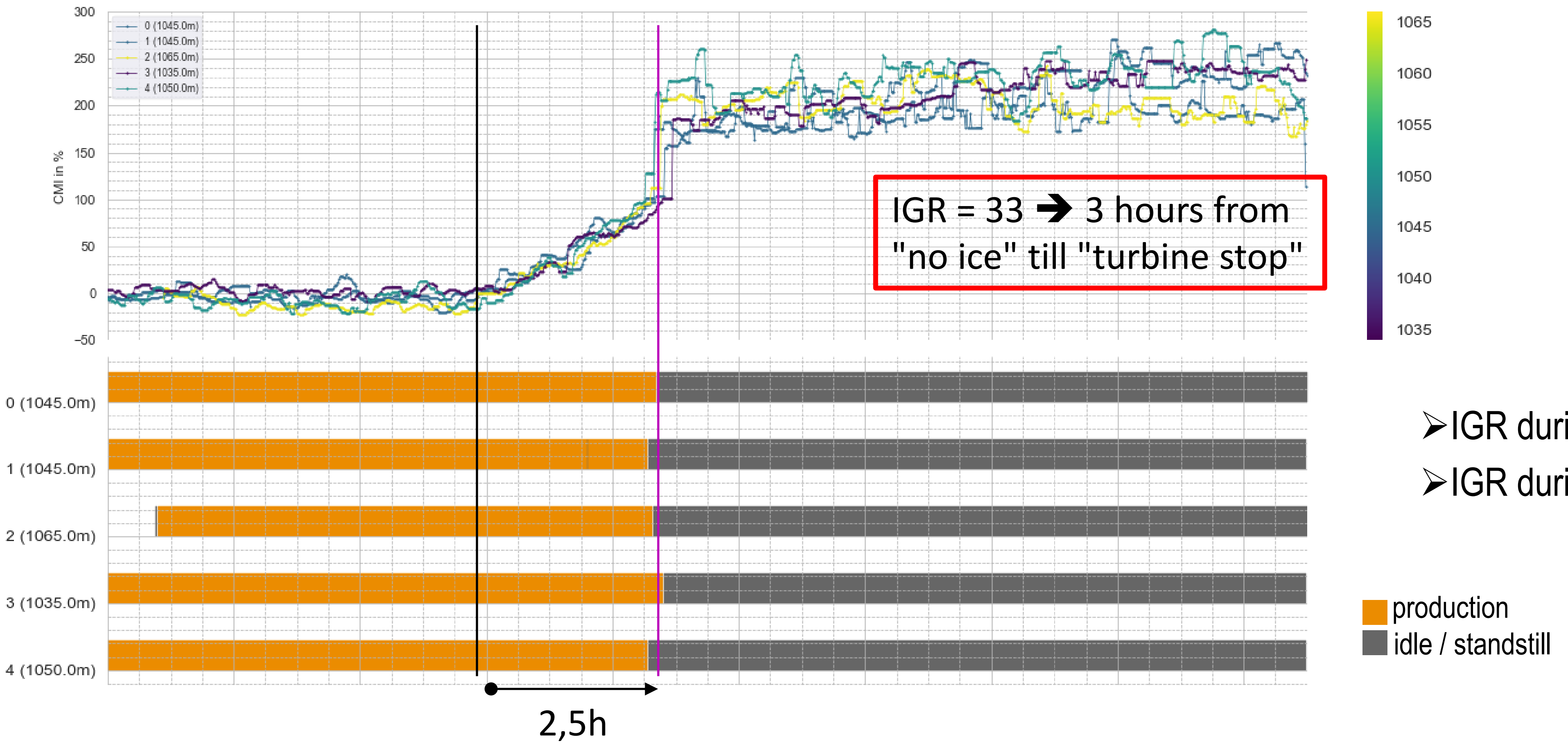


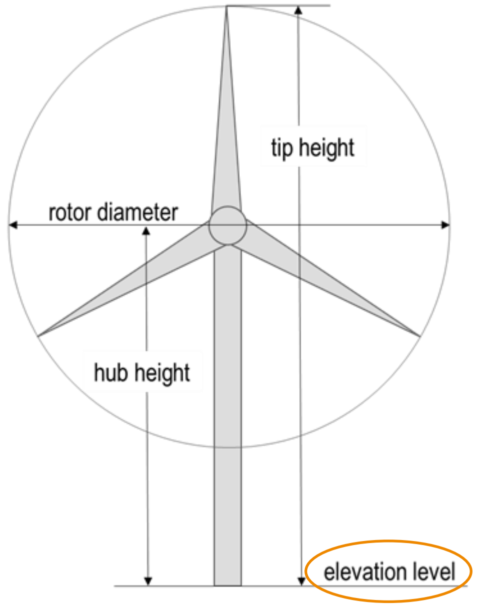


- turbines 3 and 5 don‘t stop
- turbines 3 and 5 lose ice after temperature turns positive
- height variations can‘t explain icing duration differences
- icing duration differs a lot (~12h)

Influence of operational state on ice growth rate (IGR)

Example 1 - Mountains Germany - 2024

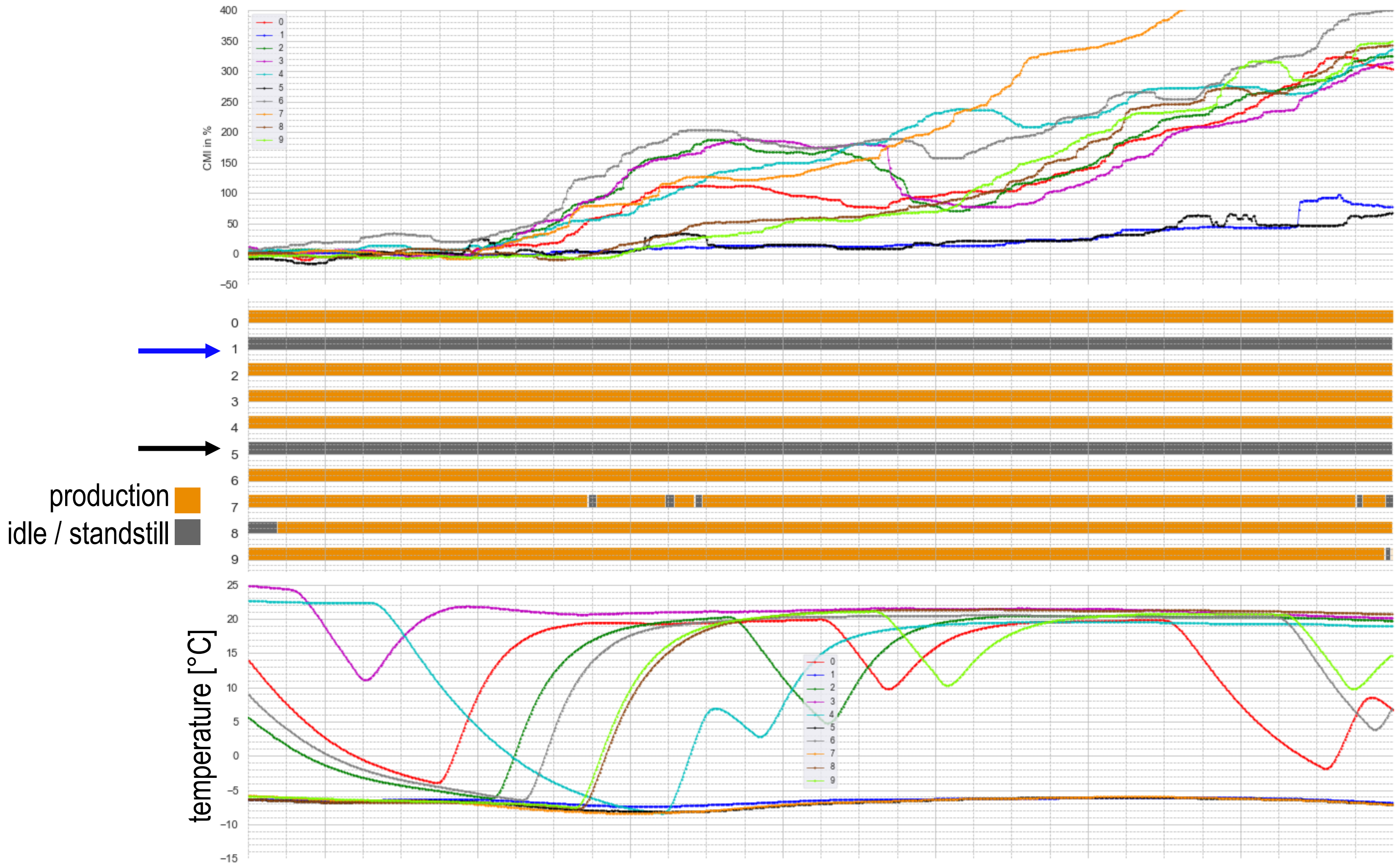


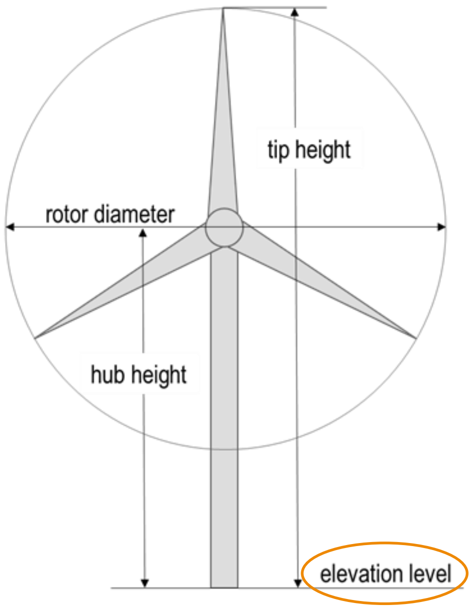


- IGR during production = 33 %/h
- IGR during standstill = <5 %/h

Influence of operational state on ice growth rate (IGR)

Example 4 - Mountains Scandinavia - 2024





- $IGR_{standstill,\textbf{unheated}} << IGR_{production,\textbf{heated}}$
- standing turbines **don‘t heat**
- anti icing system cannot avoid icing when it is snowing

- blade temperature shows effect of hot air blower (at 1/3 blade length)

Summary

- even small temperature differences at different elevations and heights can have a significant impact on icing duration
- decision to stop is an important factor for icing duration
- anti icing systems benefit from feedback strategies that take individual turbine conditions (ice growth rate, temperature and operational state) into account
- Optimal turbine operation (stop vs. run, heat y/n) for maximum energy production only possible with blade-based icing information