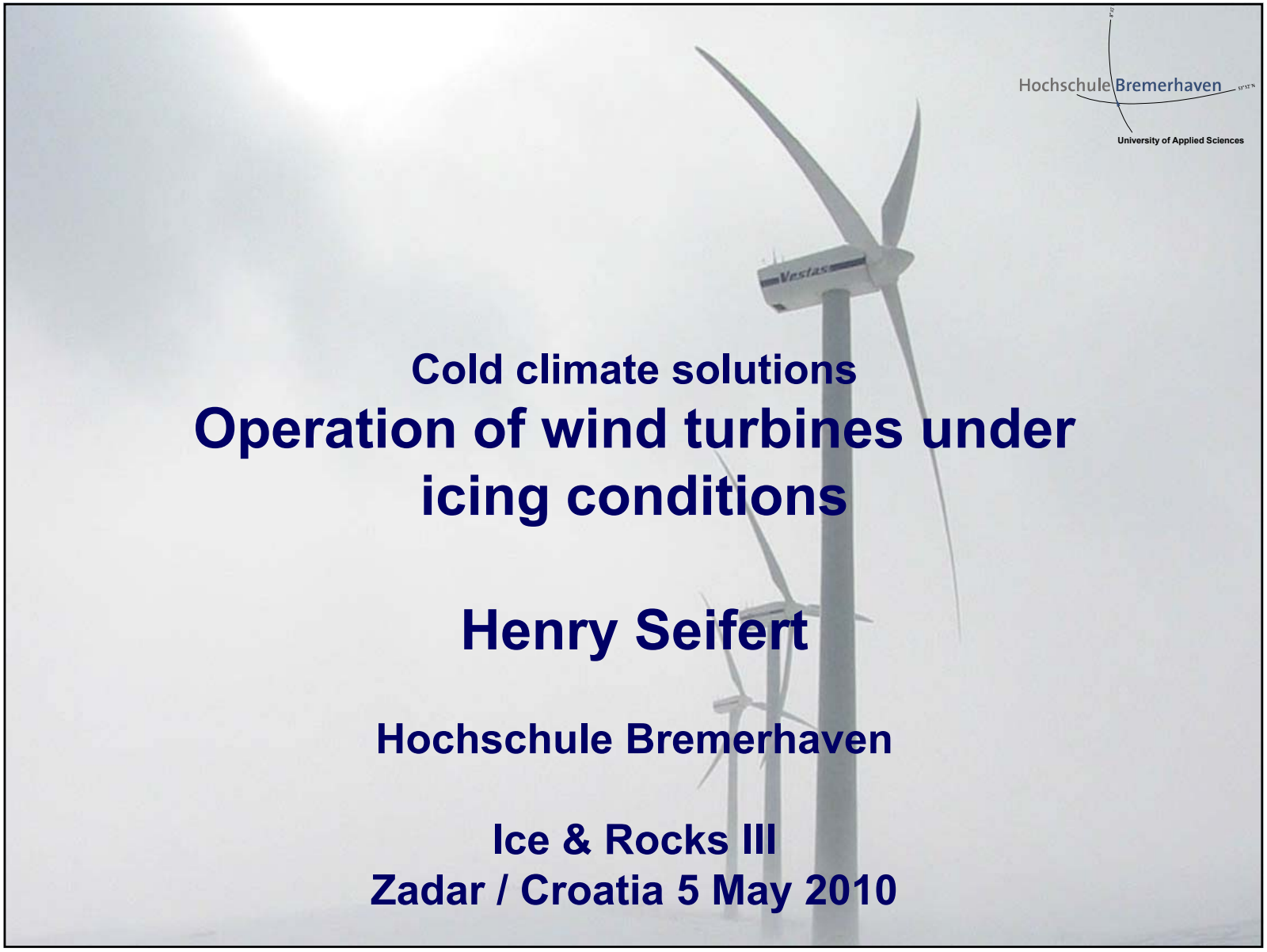



Hochschule Bremerhaven
University of Applied Sciences

## Cold climate solutions

# Operation of wind turbines under icing conditions

**Henry Seifert**

**Hochschule Bremerhaven**

**Ice & Rocks III**
**Zadar / Croatia 5 May 2010**

European cold climate research started at the ewec 1990 in Madrid at temperatures of +35° C


icing of wind turbines, BOREAS, WECO, .....

Foto: Shigeo Kimura

# Icing of Wind Turbines

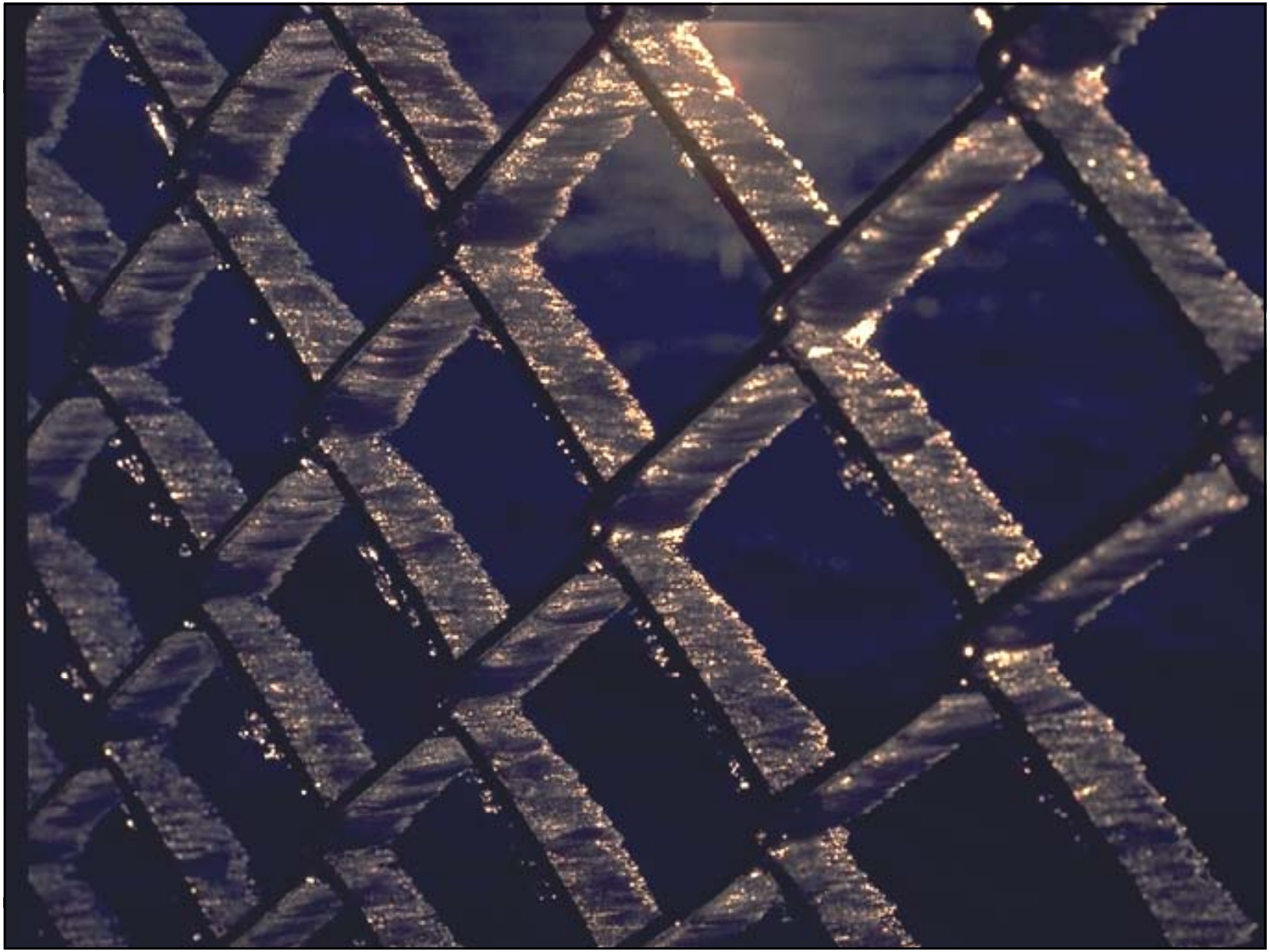
## Project partner:

## DEWI GmbH

## FMI
## Finnish Meteorological Institute

The project was partially supported by the European Commission DGXII Non-Nuclear Energy Programme JOU2-CT93-0366

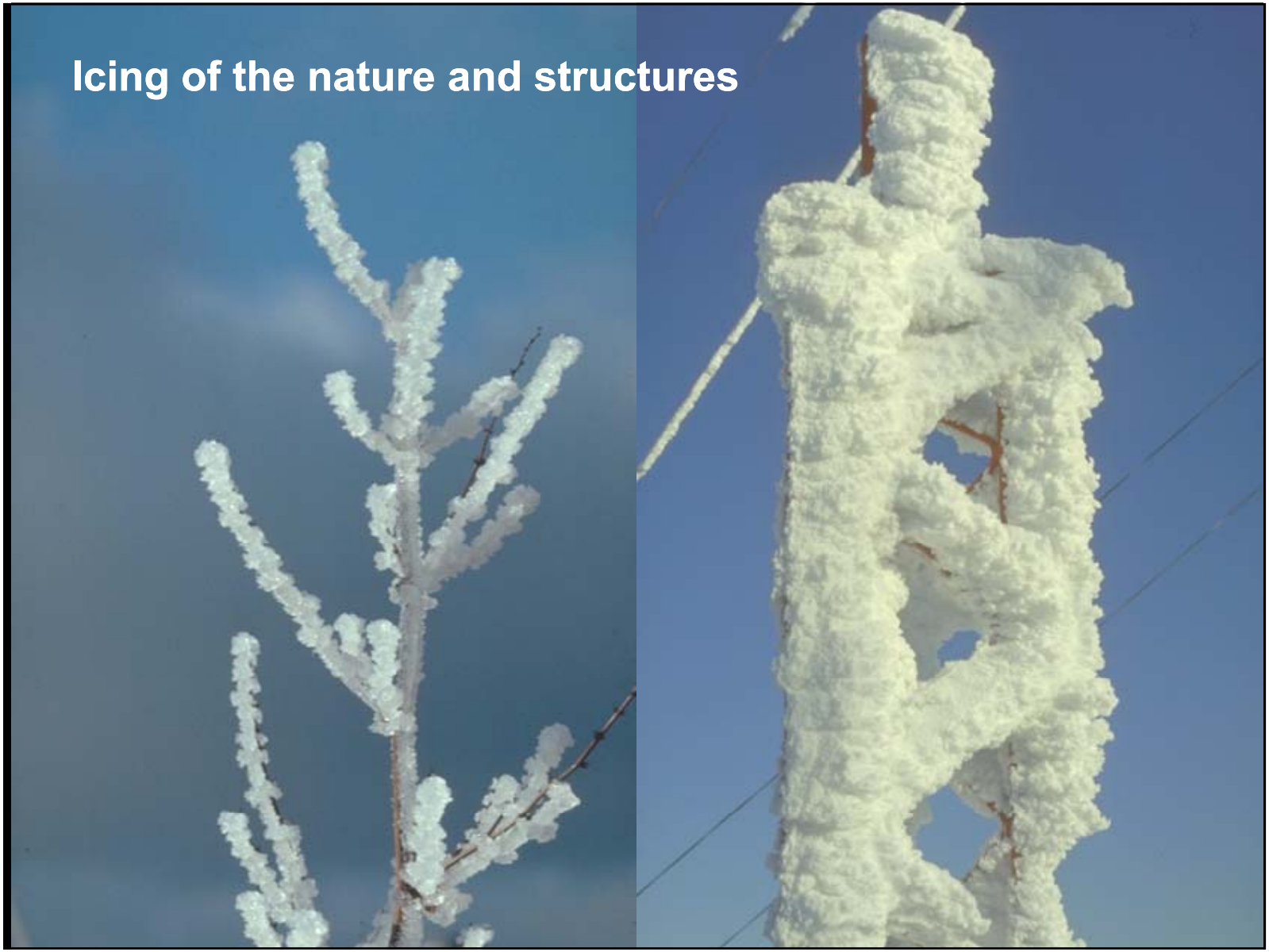

The icing conditions have to be investigated first

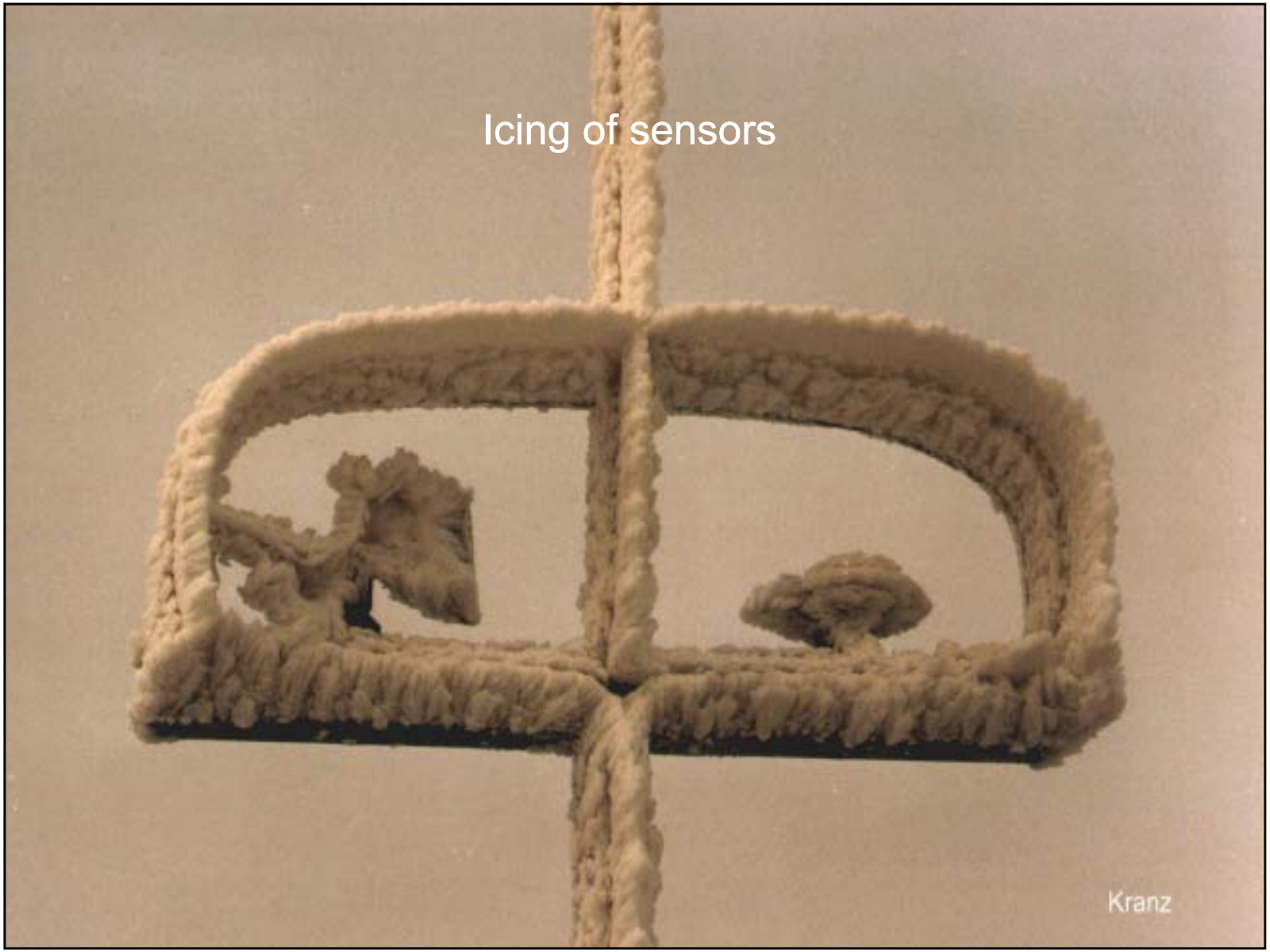



Icing conditions at the coast of an inland lake
Ref.: Internet

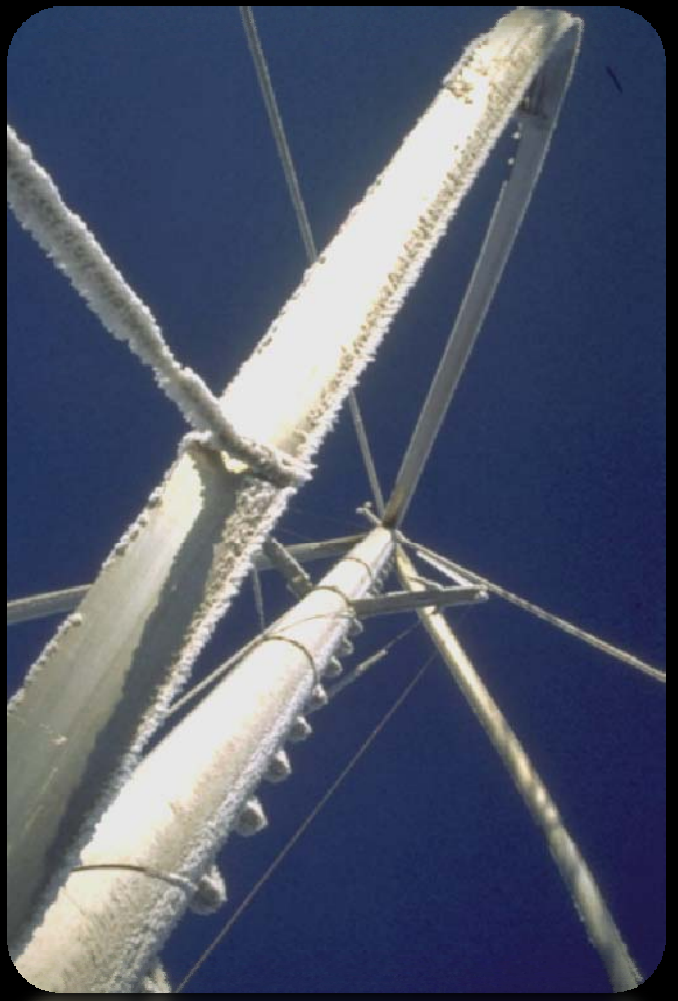

Cold climate in the mountains

# Icing of the nature and structures




Icing of sensors
Kranz

# Icing of wind turbines at stand still



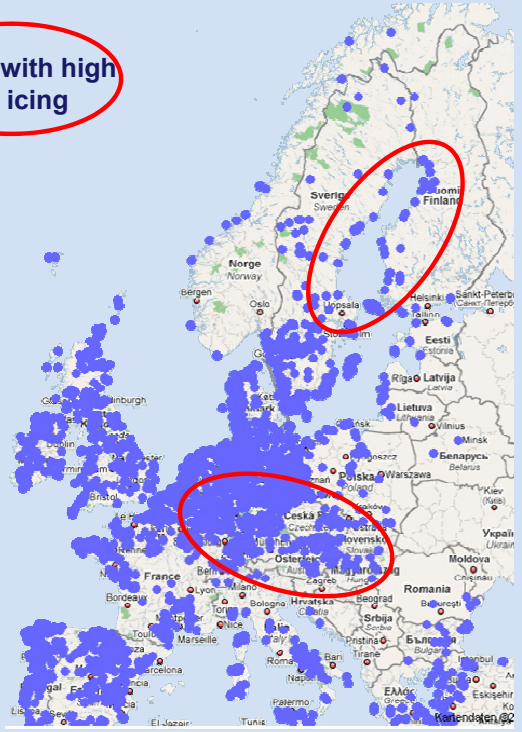
# Icing of wind turbines during operation

Photo: Christoph Lucks

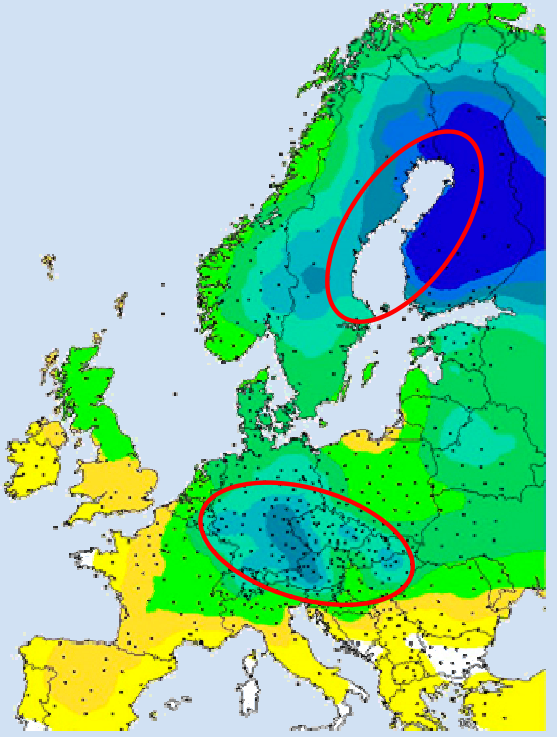
Hochschule Bremerhaven
University of Applied Sciences

# Cold climate operation: Is it worth to investigate?

Areas with high risk of icing




Wind parks in Europe



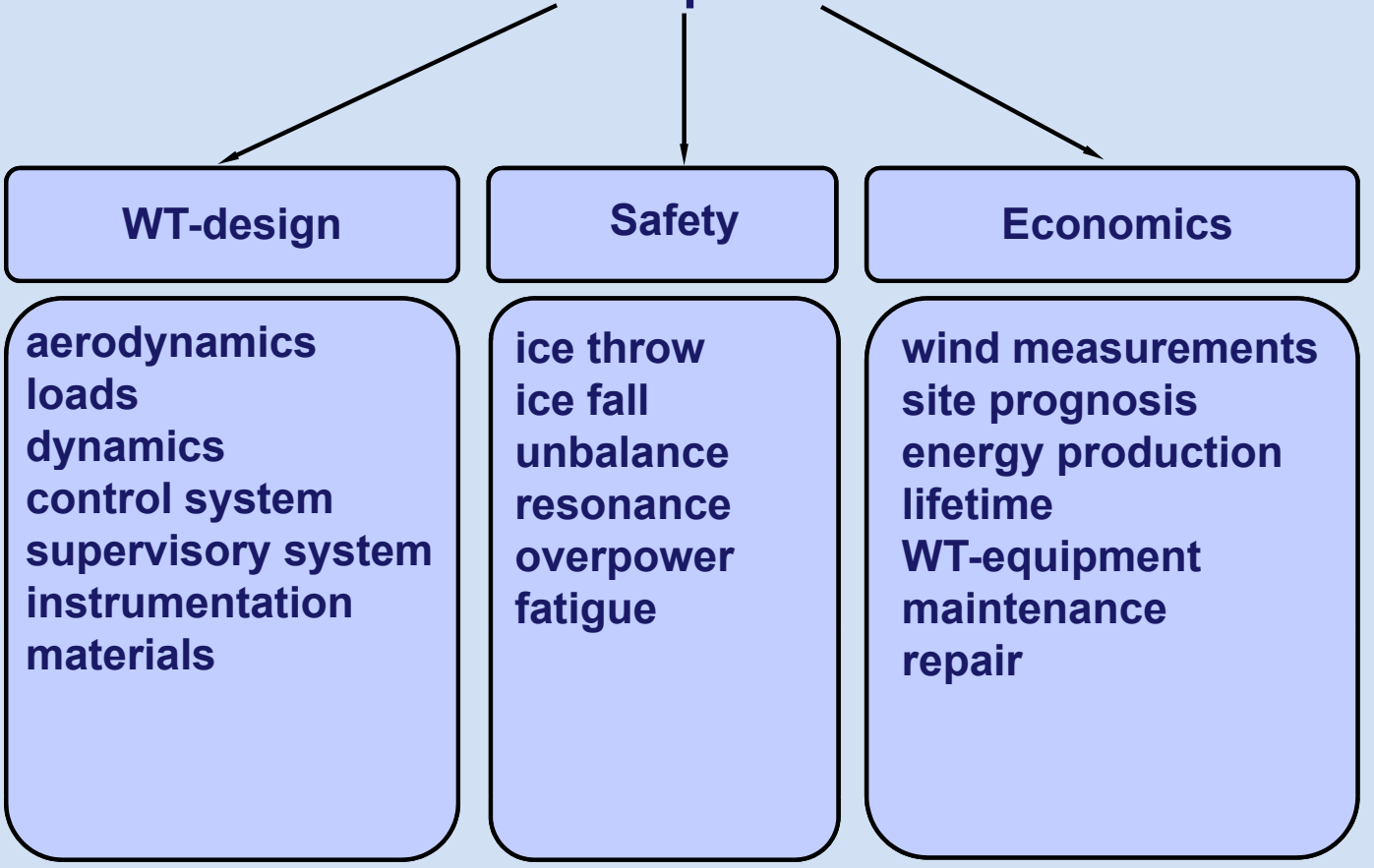
Ice map of Europe

Number of icing days

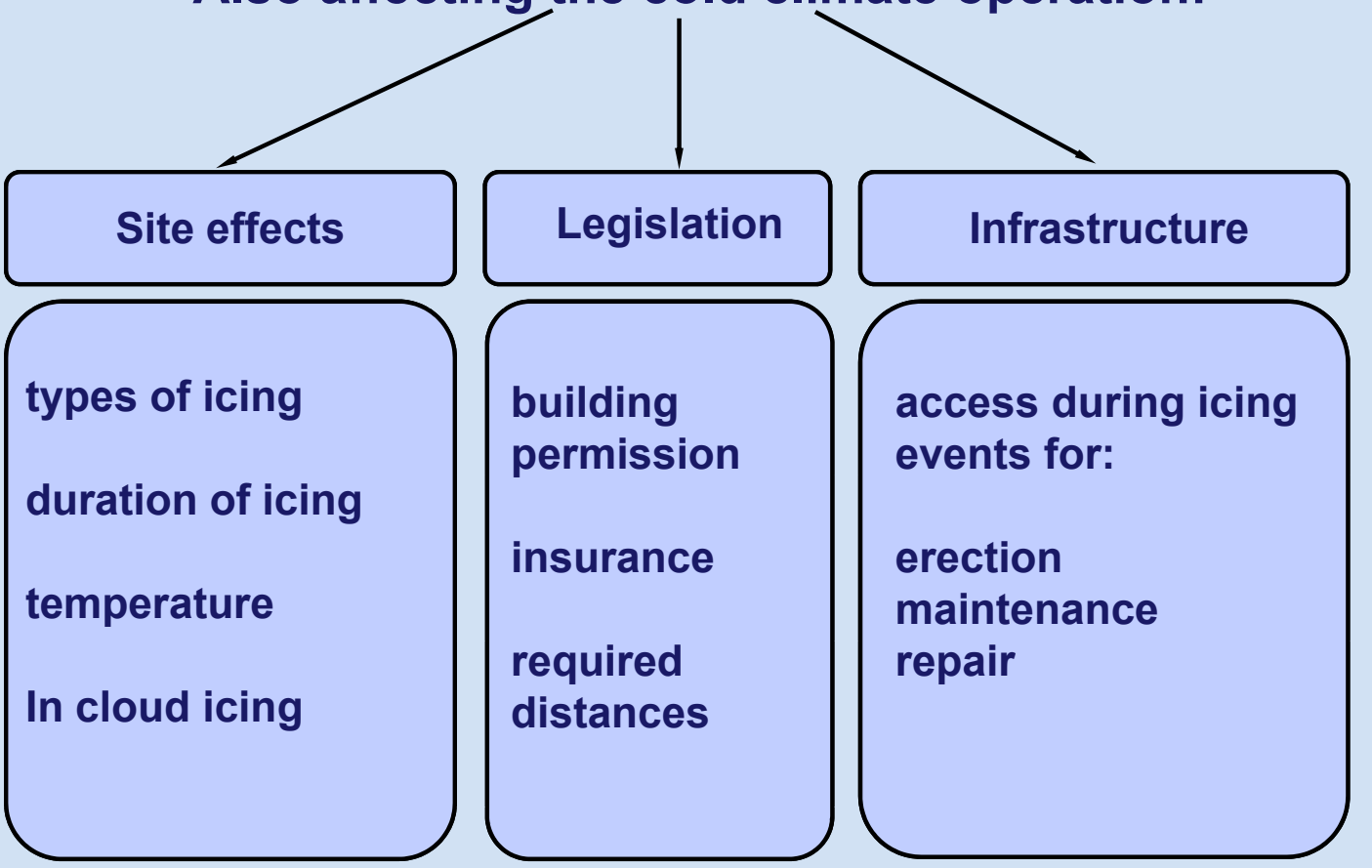
- No icing
- 1 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- > 70
- No Data

Ref.: New Icetools

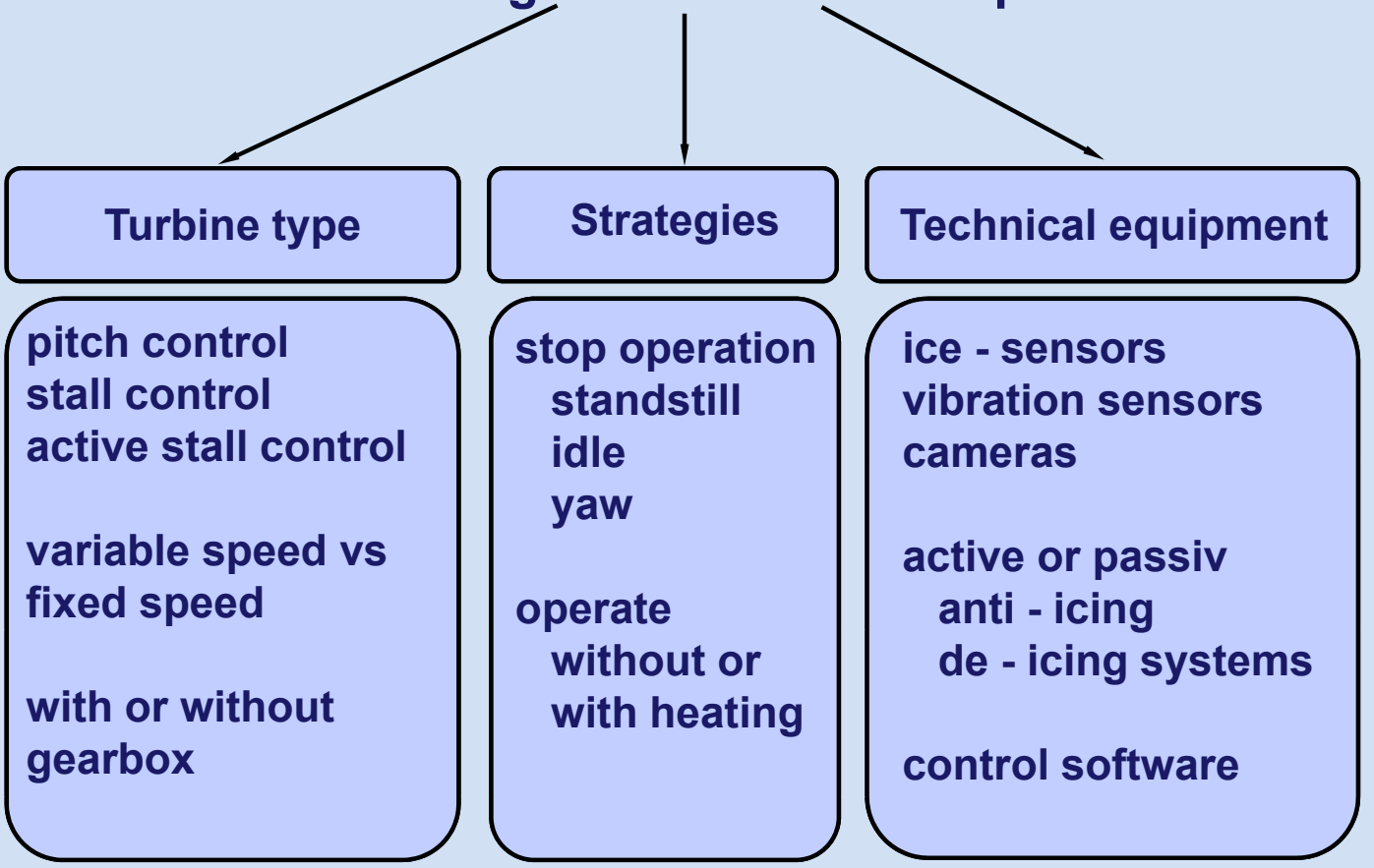
# Cold climate operation affects:



# Also affecting the cold climate operation:



# Also affecting the cold climate operation:



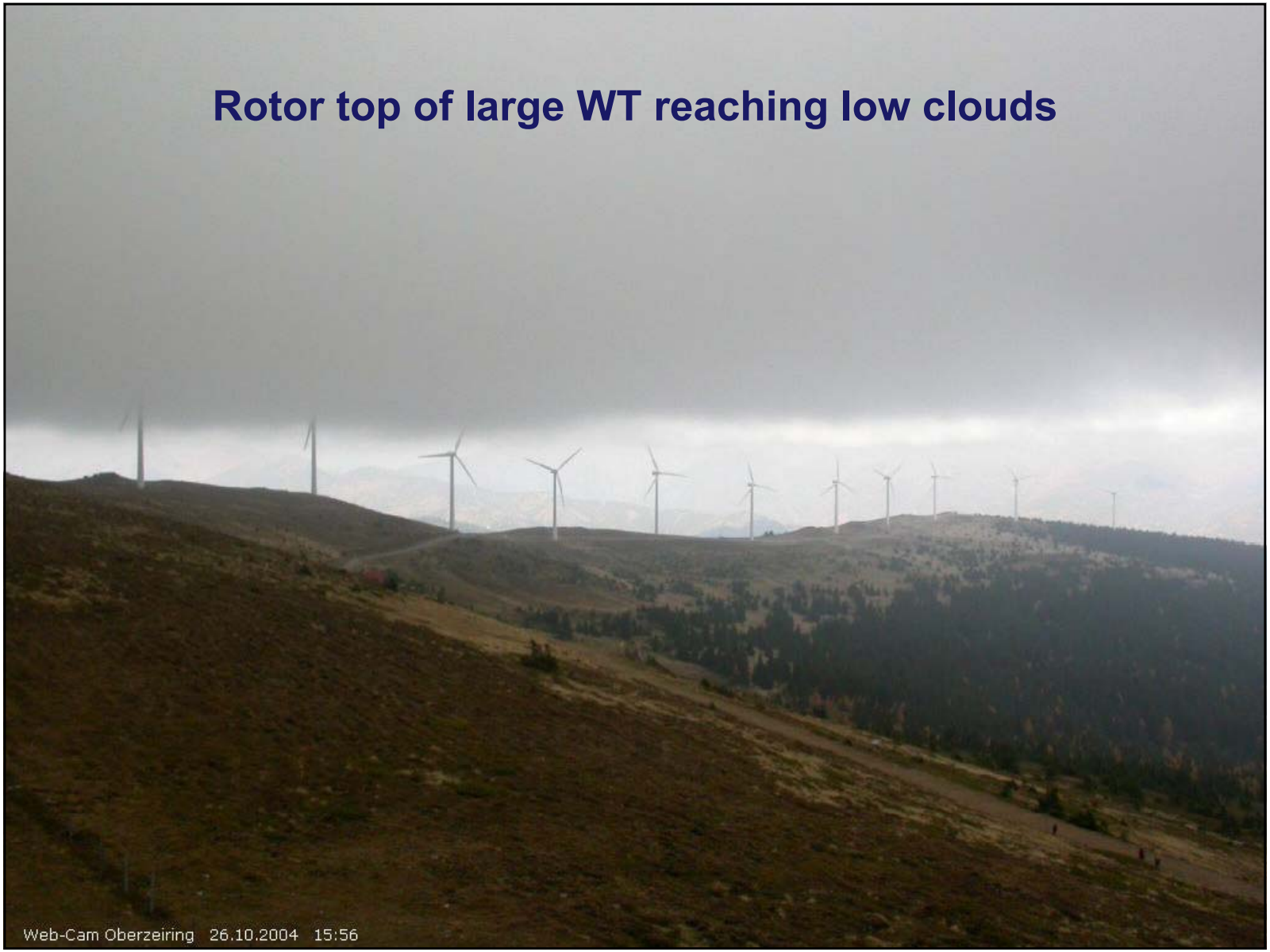
# Icing at the site?

## Definition of sites

- no icing
- rare icing
- frequent icing

# In cloud icing, undercooled fog, etc.

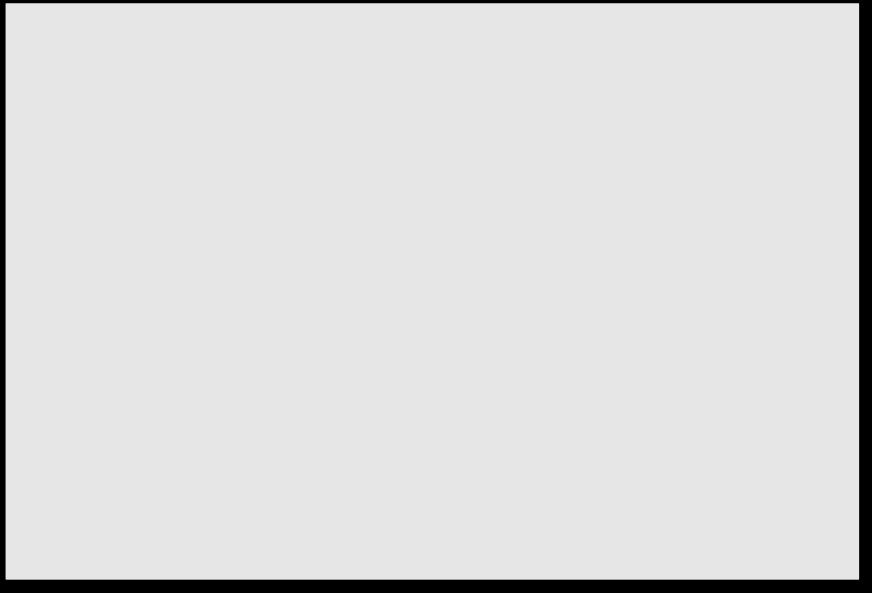
# Rotor top of large WT reaching low clouds



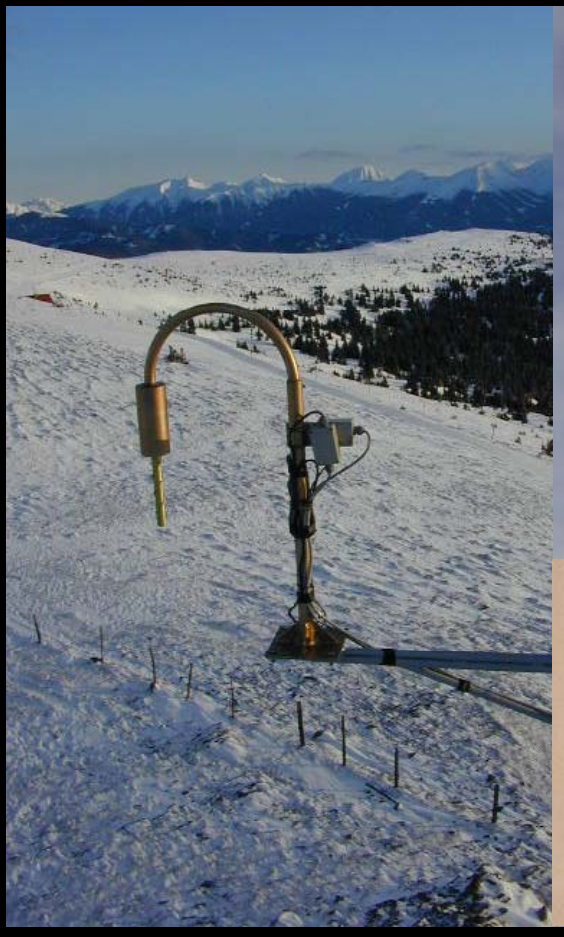
# Ice detected by observation of the results

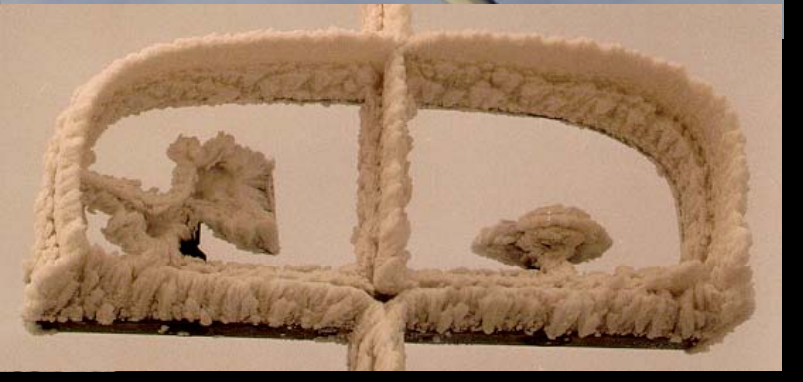

Ice detected by observation of the results

However, no ice fragments can be found in high snow



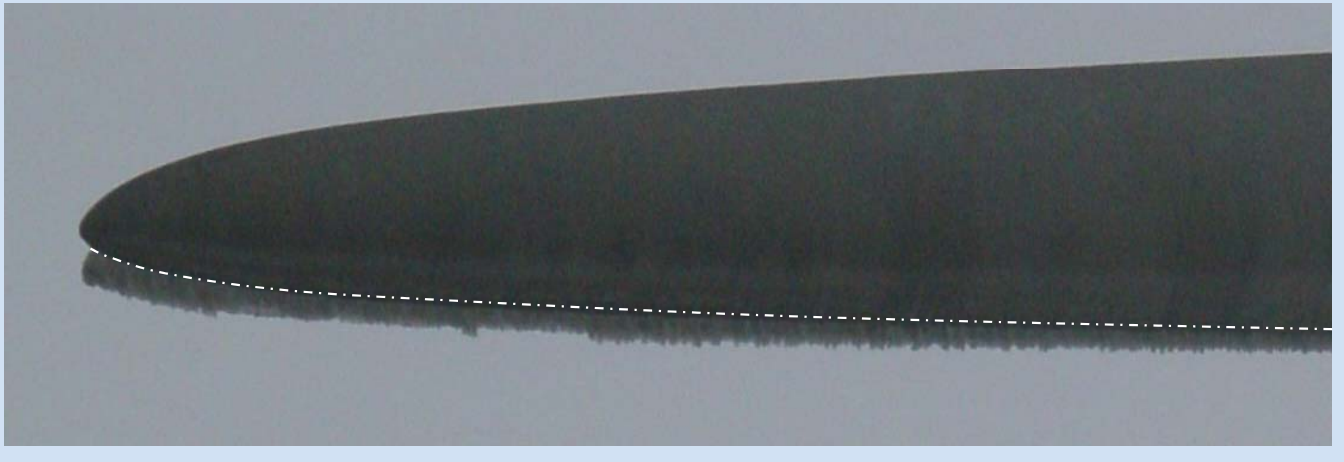
# Ice detected by sensors





# Typical ice accretion at leading edges (LE) of blades

66 m ∅



77 m ∅

# Types of rotor blade LE icing during operation

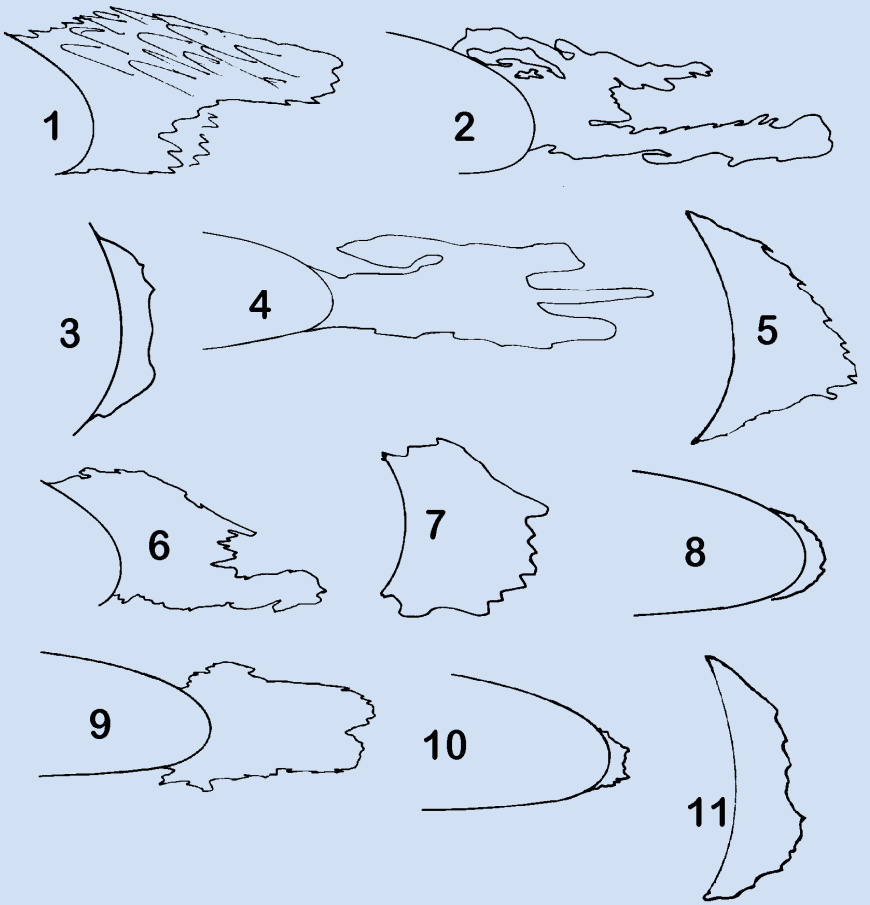
Same ice accretion at all rotor blades ?

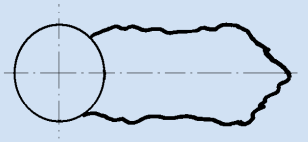
## Types of rotor blade icing


# Types of rotor blade icing

**Fragments from MW turbines**

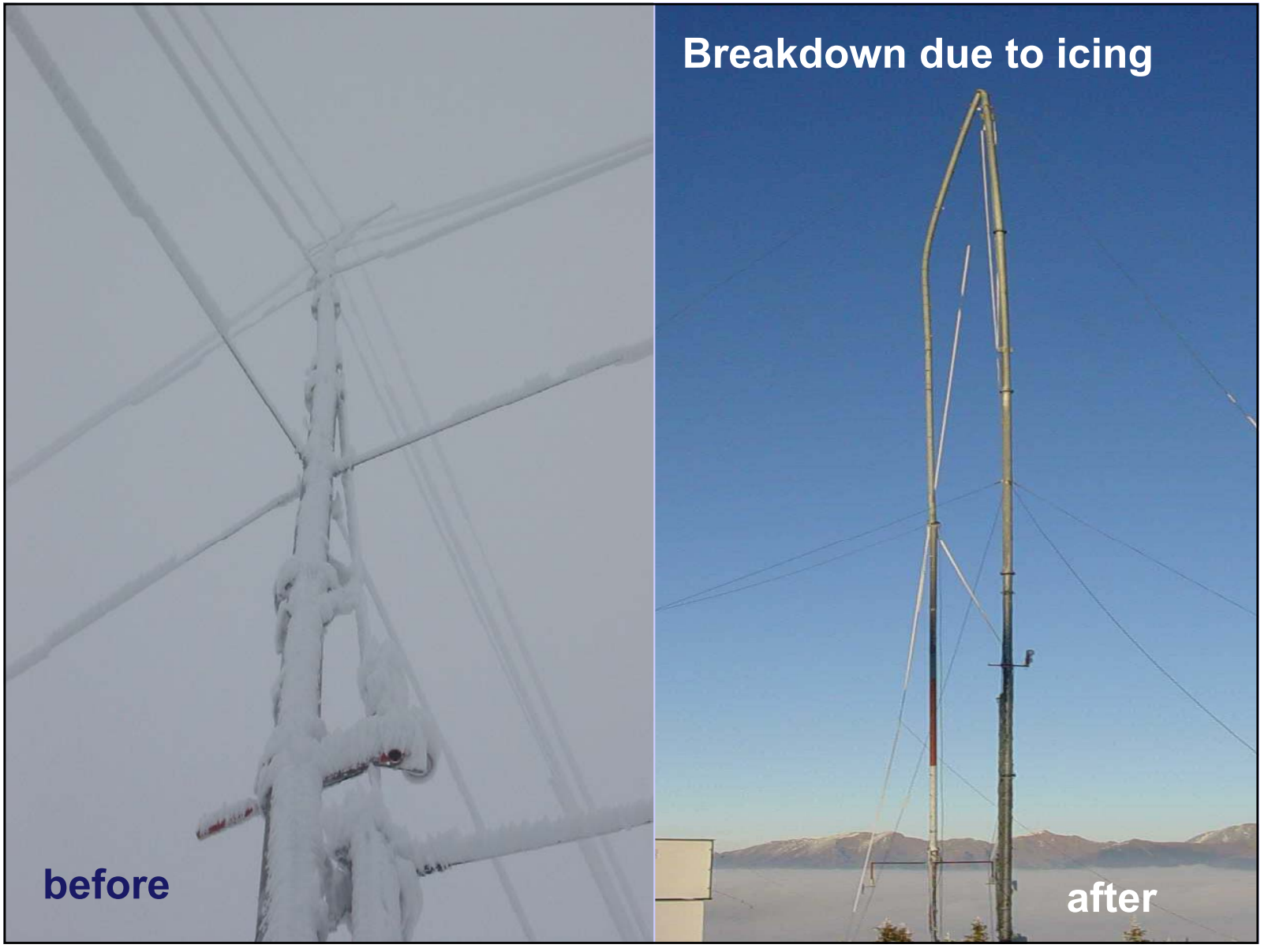
# Classification of leading edge ice accretion



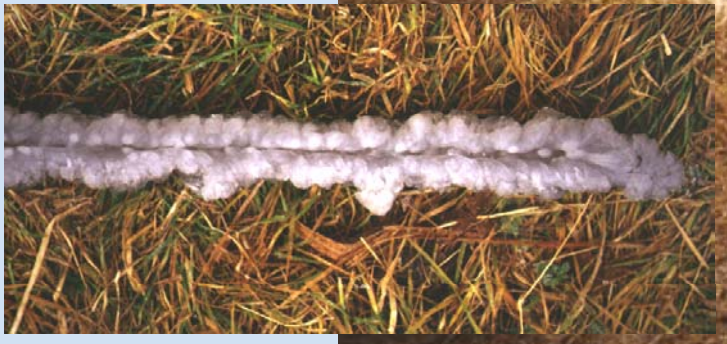



**Pipe as a reference**

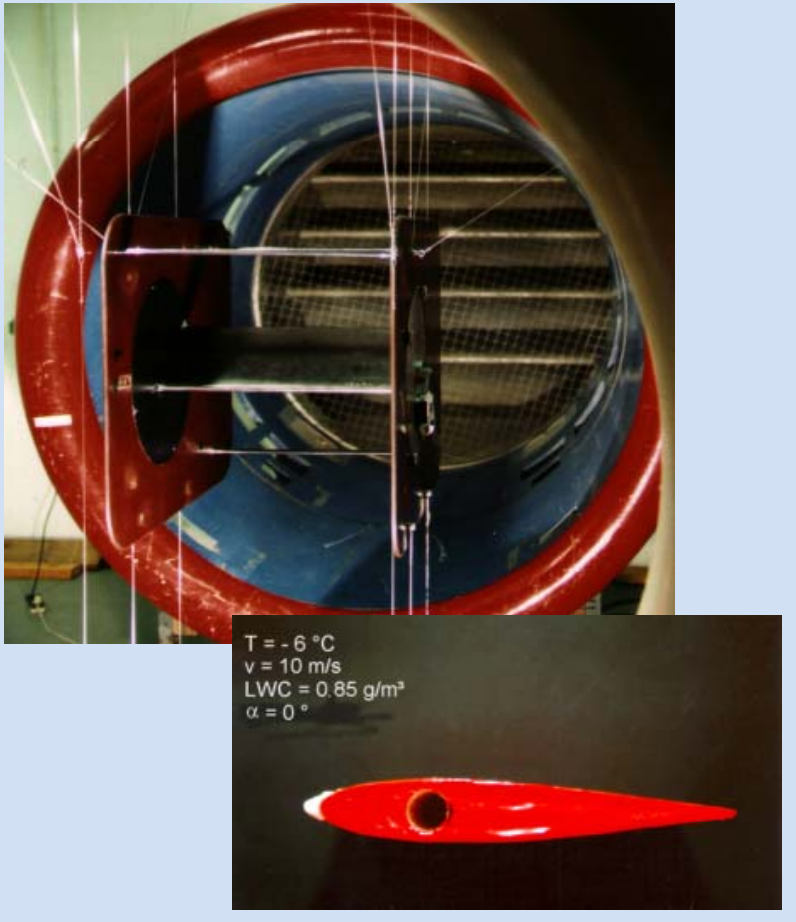
Ref.: Icing of wind turbines, WECO

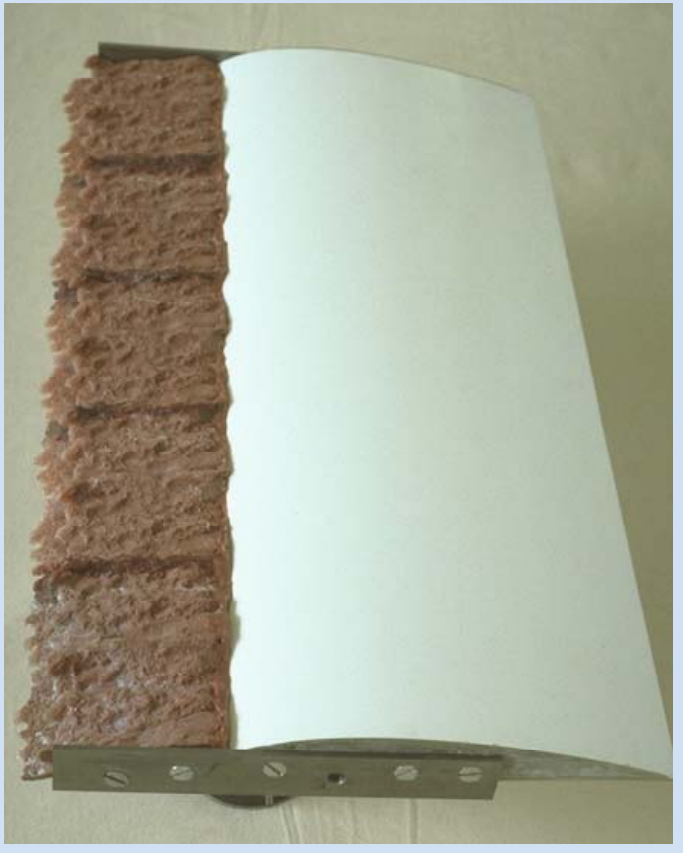

Breakdown due to icing
before
after

# Aerodynamics and loads of iced rotor blades



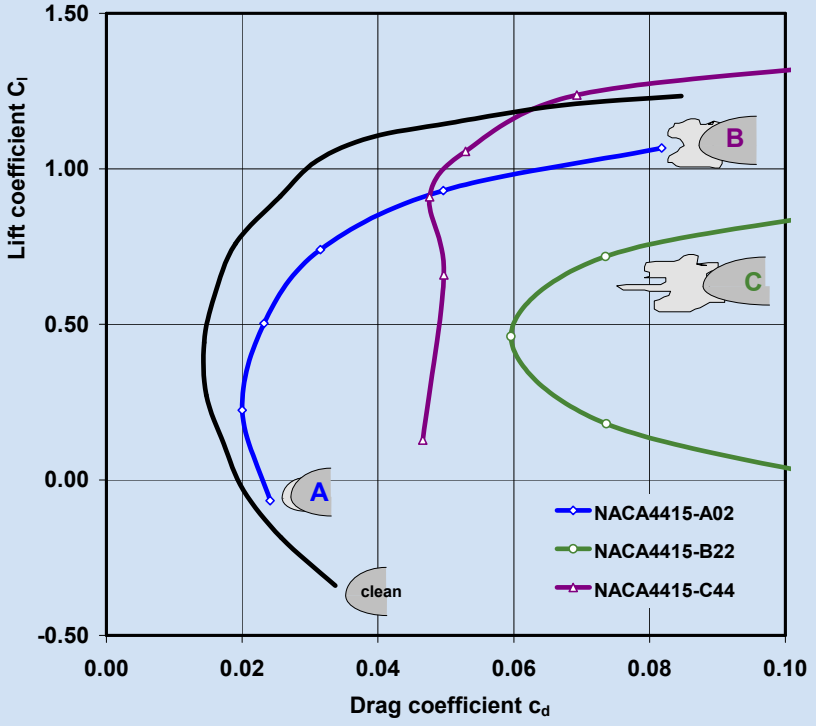
# Wind tunnel tests

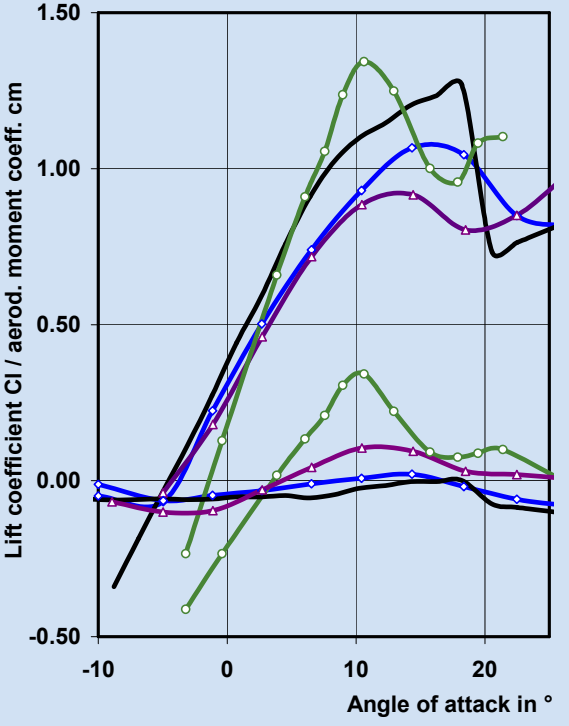


Ref: DLR, TUB, S. Kimura

# Aerodynamic coefficients at different types of LE ice accretion

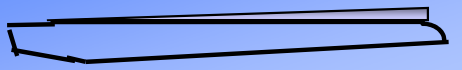


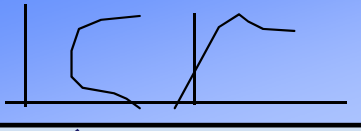

Ref: DEWI, TUB

# Simplified load assumptions

Blade geometry and ice accretion

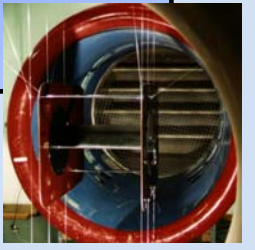


Airfoil data



Transformation

WECO wind tunnel measurements with iced profils



Aerodynamic Loads due to leading edge ice accretion

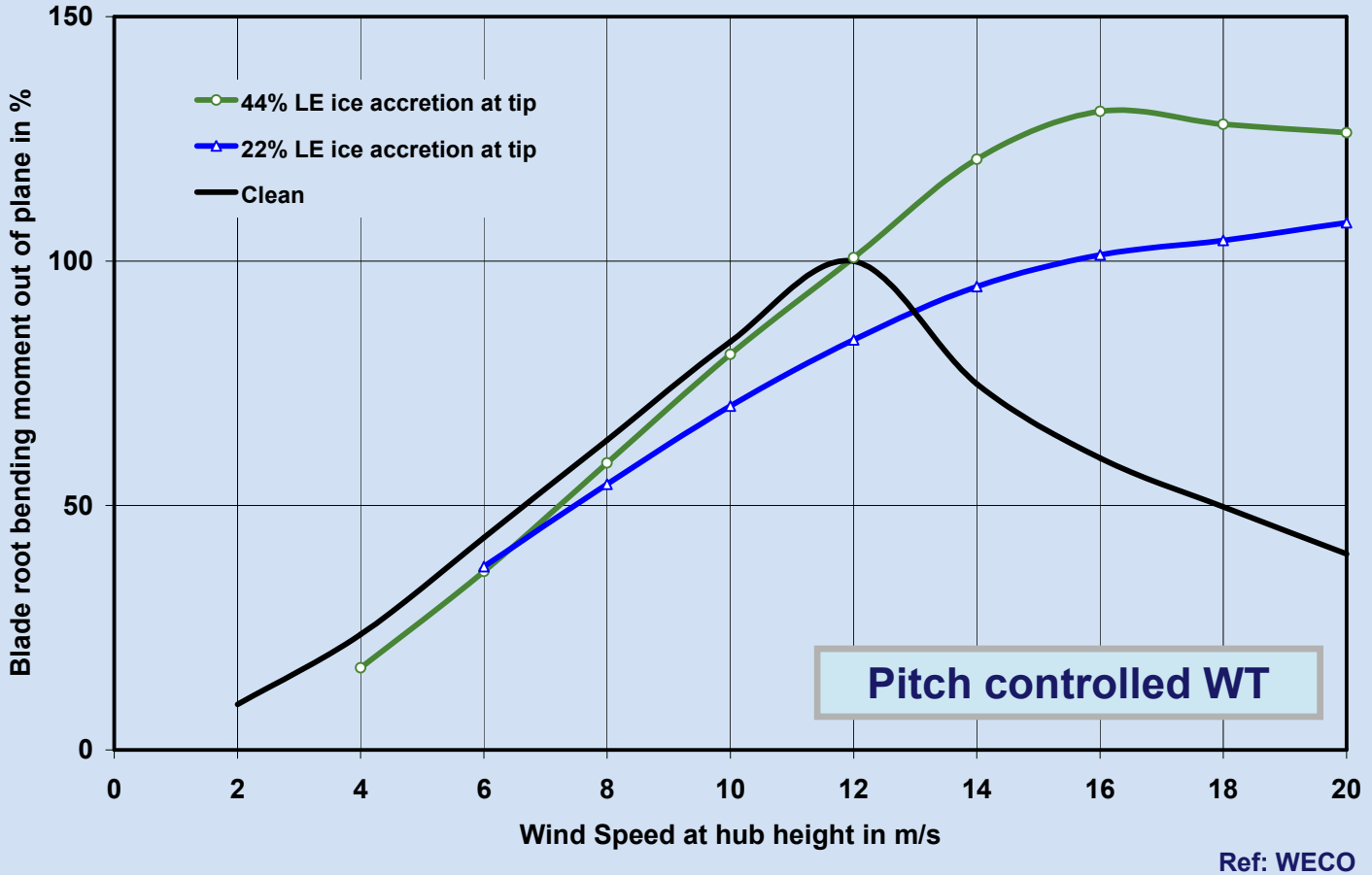
Estimation of mechanical loads

$$\frac{t_{Ea}(R)}{t_a} = 0.45 \cdot e^{-.05 R_0} + 0.14$$

AEP prediction

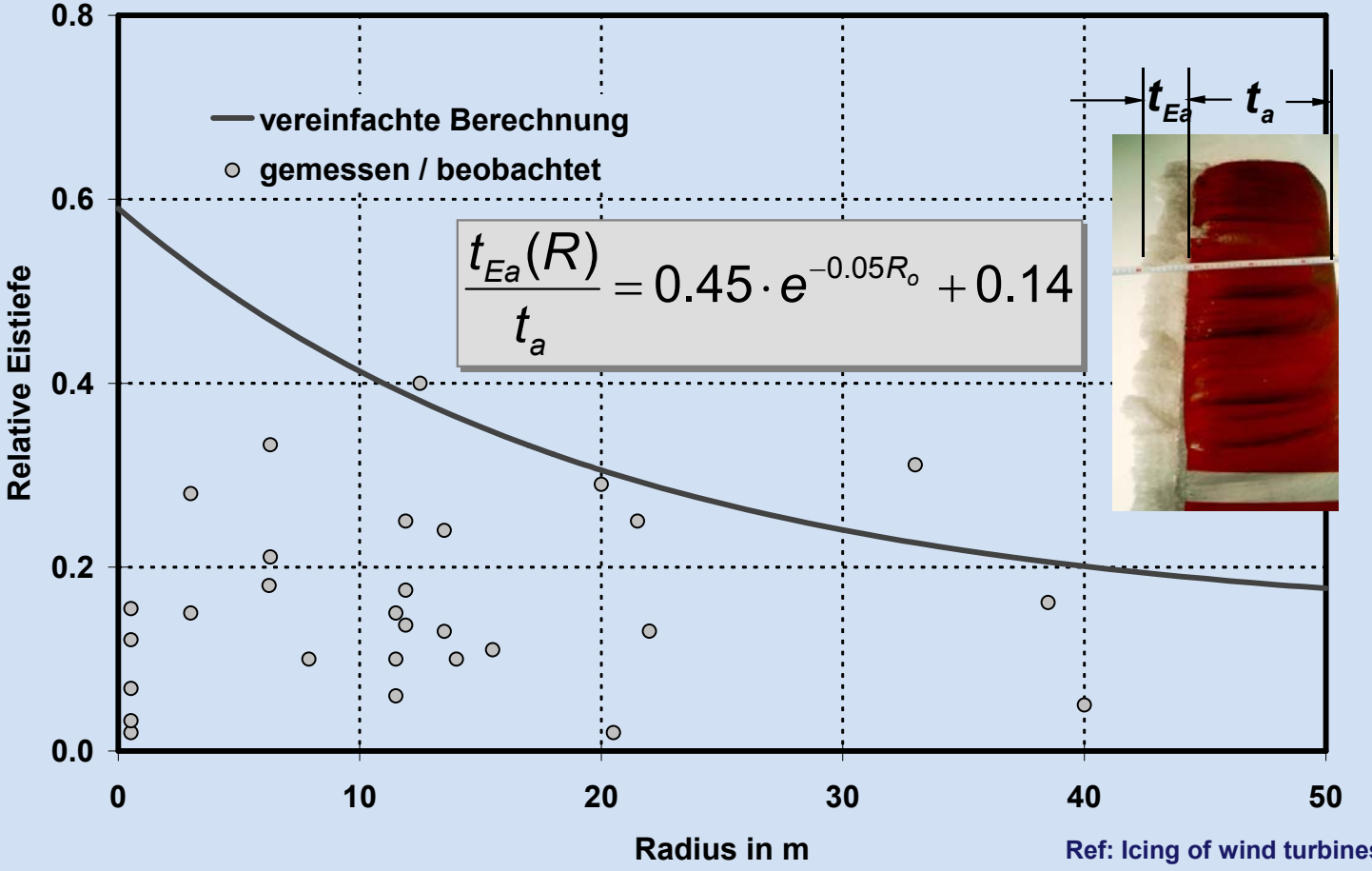
Load case icing

# Blade root bending moment flatwise



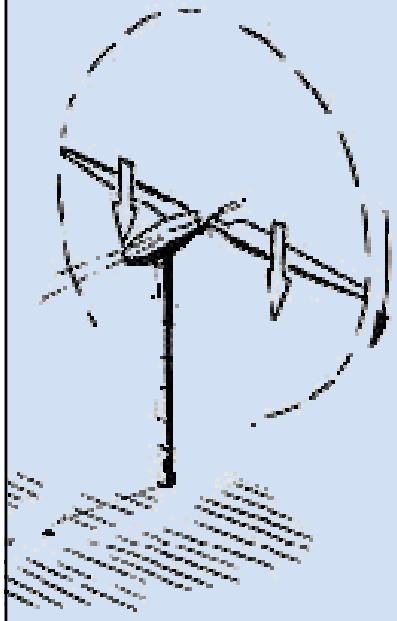

Ref: WECO

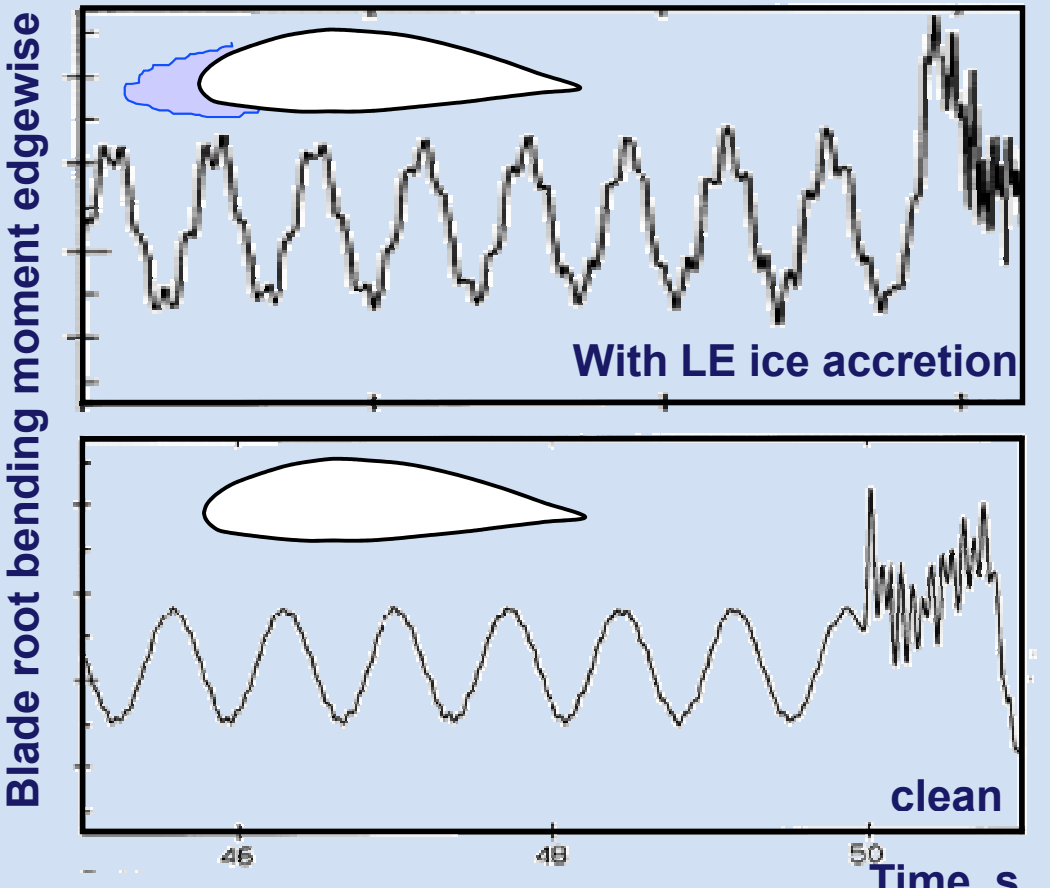
# Prediction of ice accretion



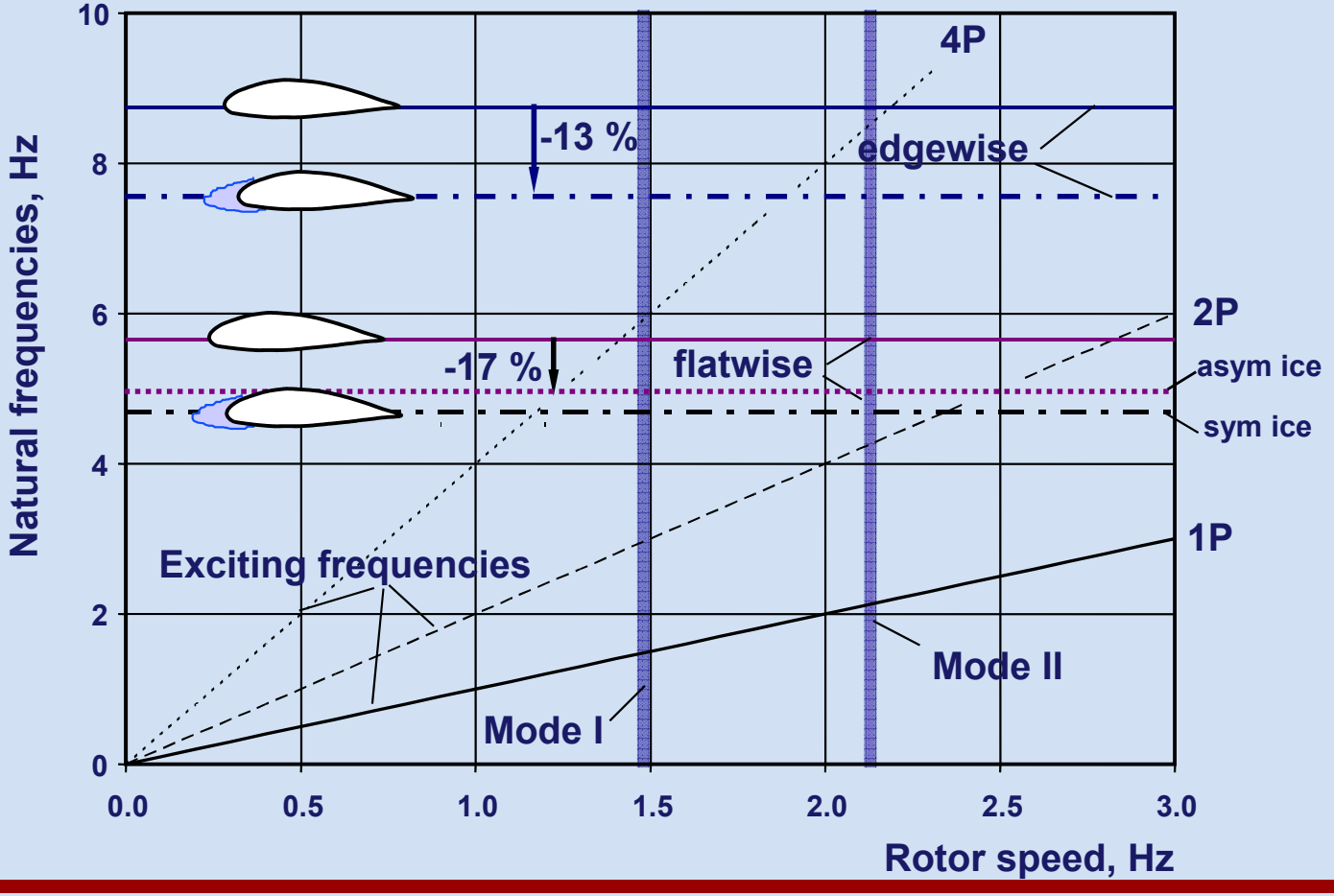

Ref: Icing of wind turbines

# Mechanical load measurements

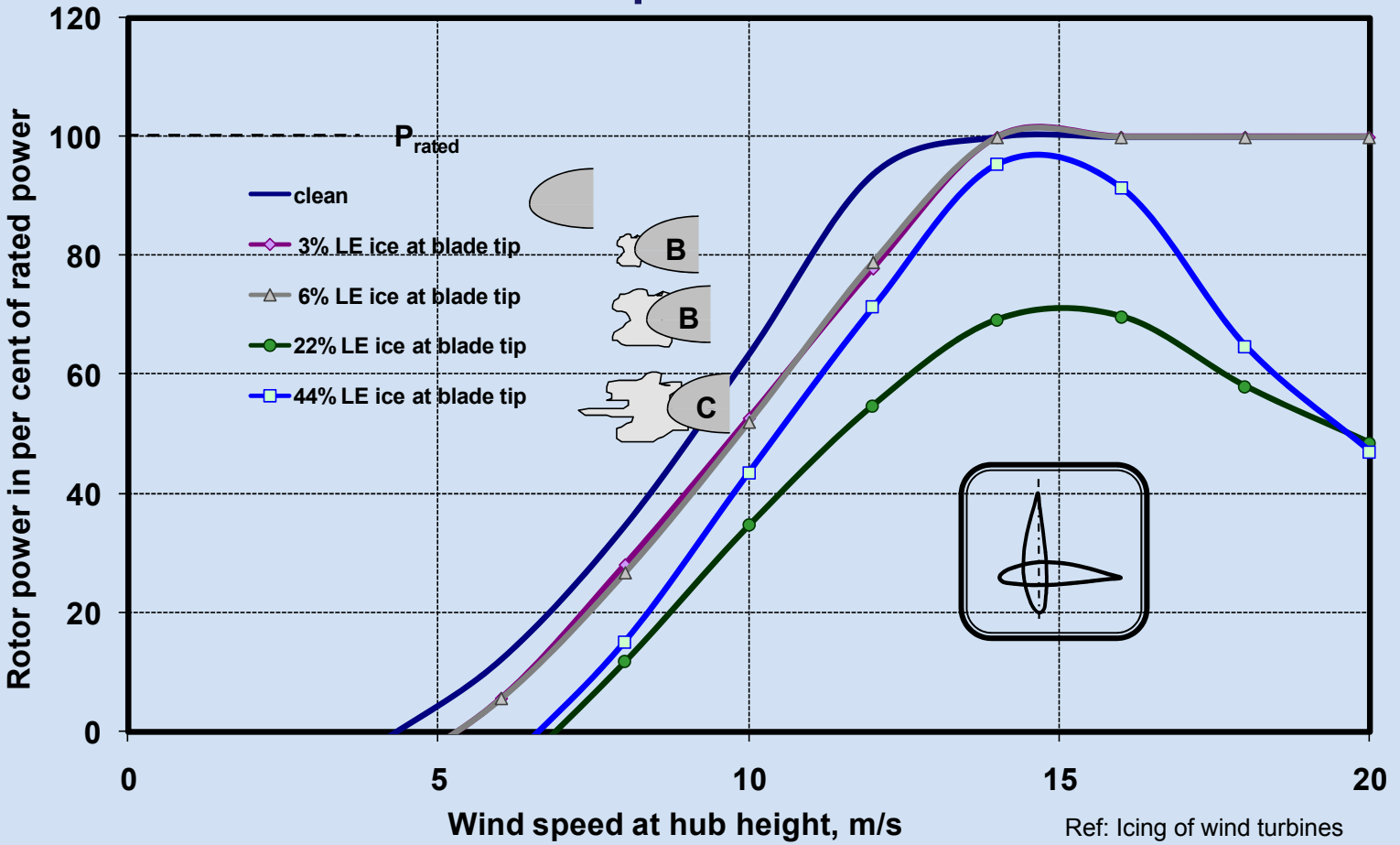




# Measured frequencies: Campbell Diagram

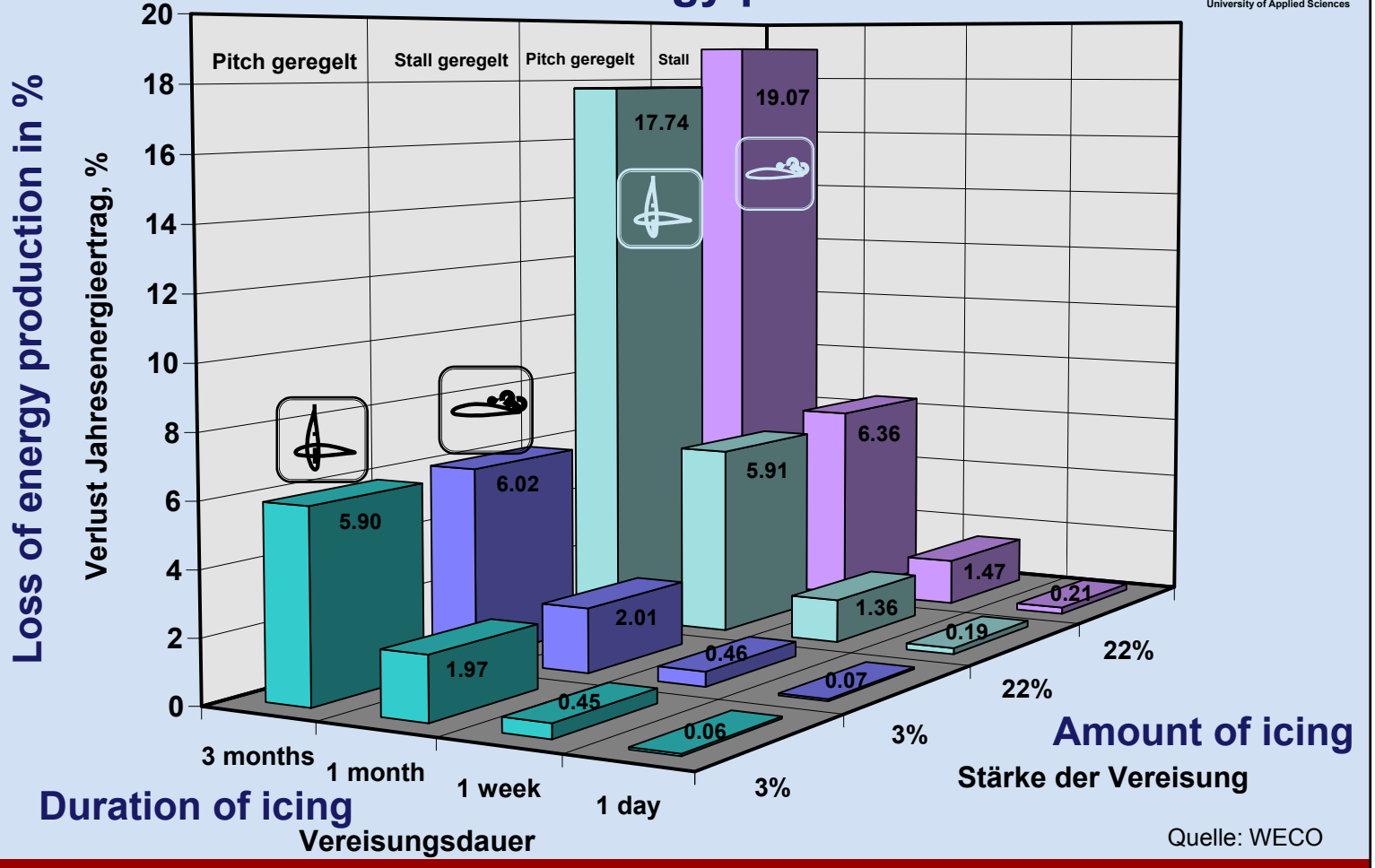


# Calculated power curves




Ref: Icing of wind turbines

# Prediction of annual energy production losses




Quelle: WECO