Project: R.Ice ‘Risk Analysis of Wind Turbine Icing’

funded by the
Austrian Climate & Energy Fund

Main Topics:

- Stereo imaging of ice fall events
- Icing map for Austria
- Verified with observations & survey
- Ice fall probability maps (for 5 regions)
- Legal perspective and policies

Partners:

IG WINDKRAFT
Austrian Wind Energy Association

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

Wegener Center

UNI GRAZ

TU Graz

WIEN ENERGIE

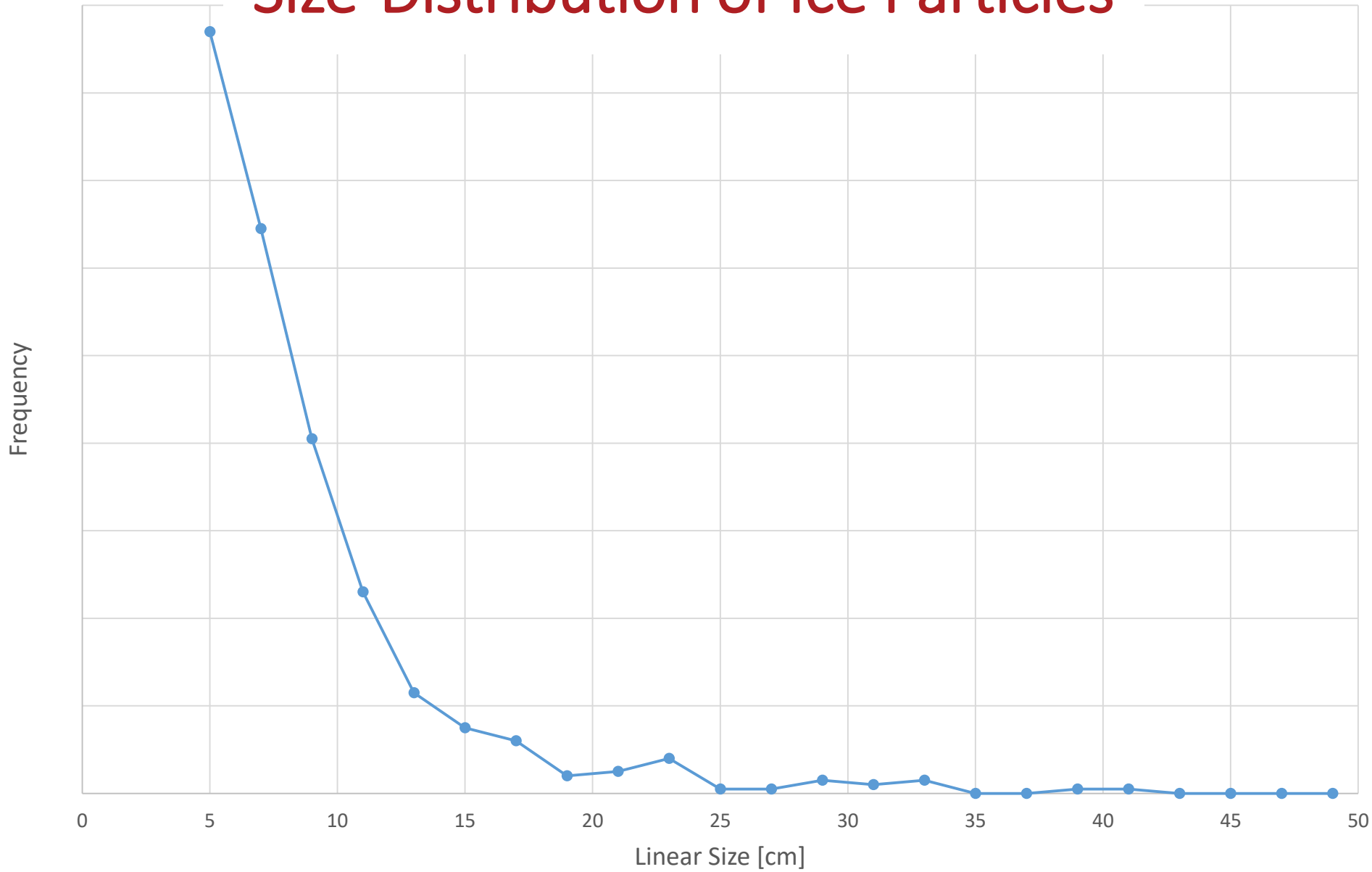
energiewerkstatt
VEREIN & TECHNISCHES BÜRO FÜR ERNEUERBARE ENERGIE

Stereo Imaging of Ice Fall Events

- Stereo imaging provides 3D coordinates and projected size of the ice pieces
- Hampered by bad visibility (fog, snowfall, darkness)
- Successful observation of only one ice-fall event
- Several hundred particles with trajectories
- Size-distribution ranges from 2 cm^2 to beyond 1000 cm^2
- Unfortunately unsuitable for overall assessment of the total number of pieces

Pictures: Energiewerkstatt and AIT

Size-Distribution of Ice Particles

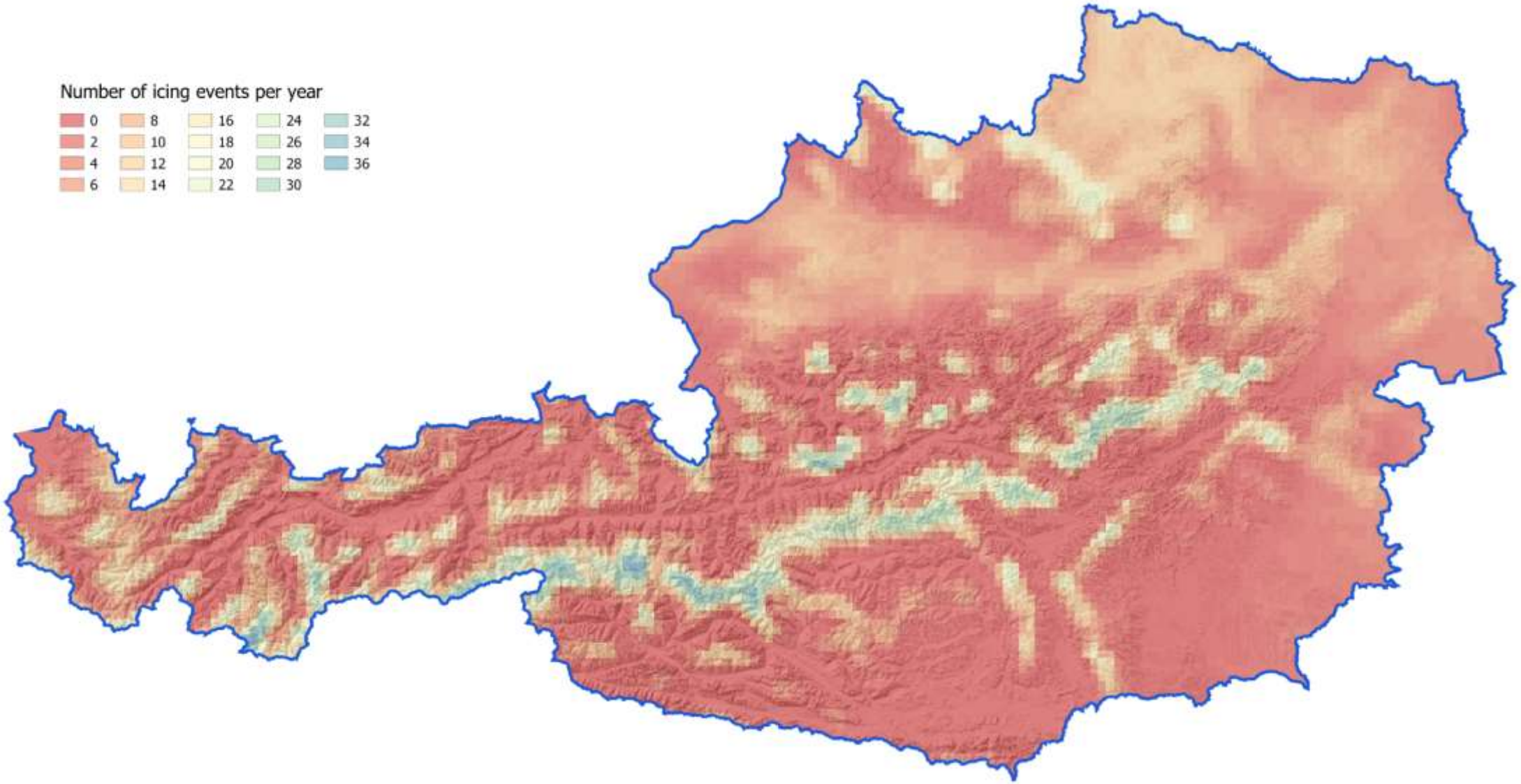


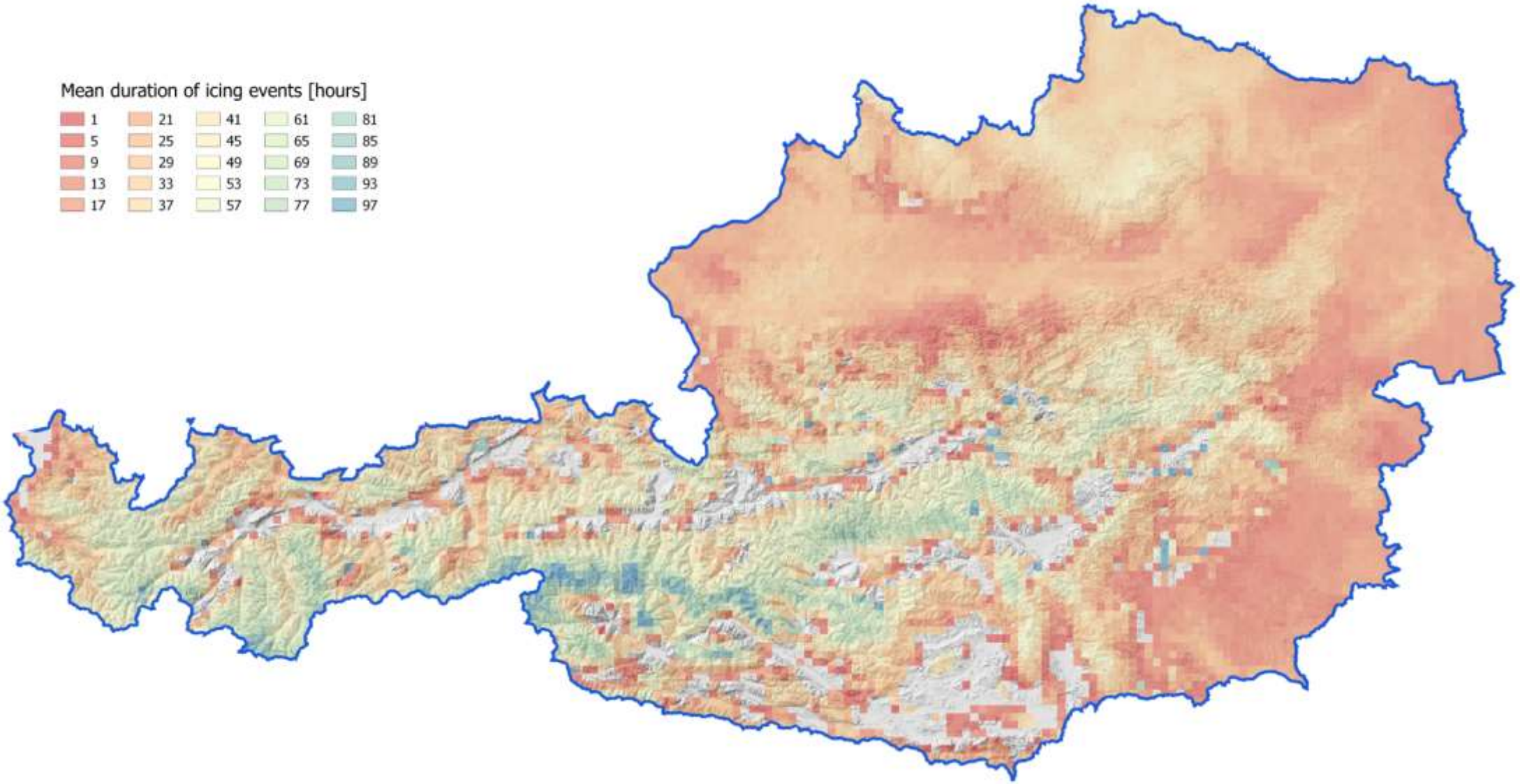
Icing Map for Austria – Aim & Concept

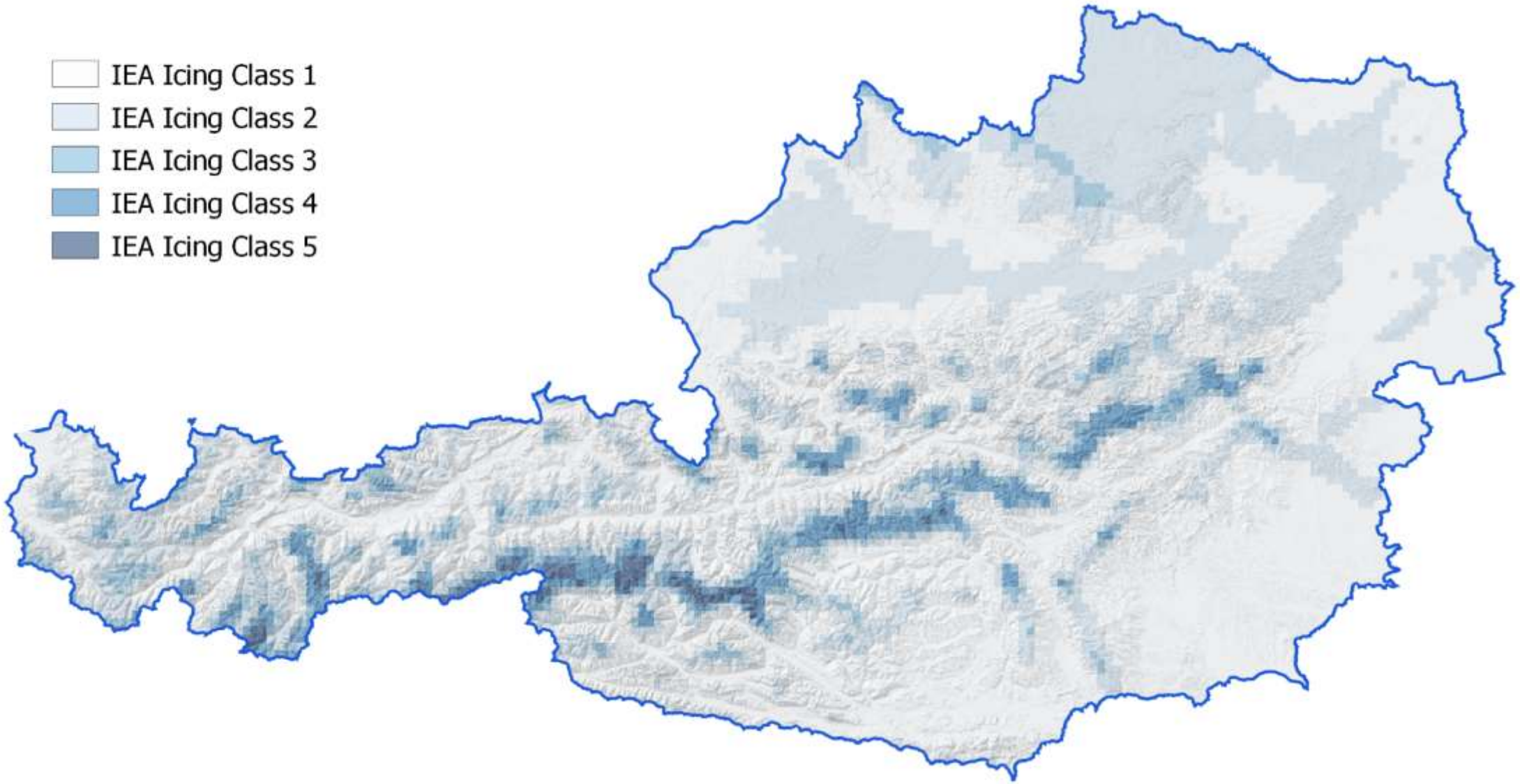
- Visualization of ‘Icing conditions’
- Estimation of icing conditions for any point in Austria
- Allows cross-comparison of icing and ice fall results from different locations in Austria
- Useful also for icing of other structures than wind turbines

Icing Map for Austria – Method

- Icing conditions = No. of events & duration of instrumental icing
- Based on meteorological models for a period of 26 years (1989-2015)
- CCLM and WRF model are used (see Poster by Truhetz et al.)
  - CCLM - COSMO-ClimateLimited-areaModelling
  - WRF - Weather Research and Forecasting Model
- Icing according to Makkonen model for a 3 cm standard cylinder
- Results for wind speeds and icing have been compared with observational data
- Corrections applied (-5% to +8%) to regional wind distributions (see below)


Number of icing events per year
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36


Mean duration of icing events [hours]
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97


IEA Icing Class 1
IEA Icing Class 2
IEA Icing Class 3
IEA Icing Class 4
IEA Icing Class 5

Survey among Wind Park Operators

- To confirm the real-world relevance of the numerical results
- Questionnaire covered: Turbine configuration incl. RBH, number and duration of shutdowns, estimates for ice mass and number of ice pieces per event
- Strong individual bias has to be expected
- On the other hand examples of multiple wind parks run by a common operator
- Gives a first hand impression of the severity of the problem (in AT iced WT must be stopped)
- Results from 42 wind parks, mostly from eastern Austria
- Overall agrees well with results from icing simulations

Five Regions

- Risk analysis focuses on five regions that cover important wind energy areas in Austria

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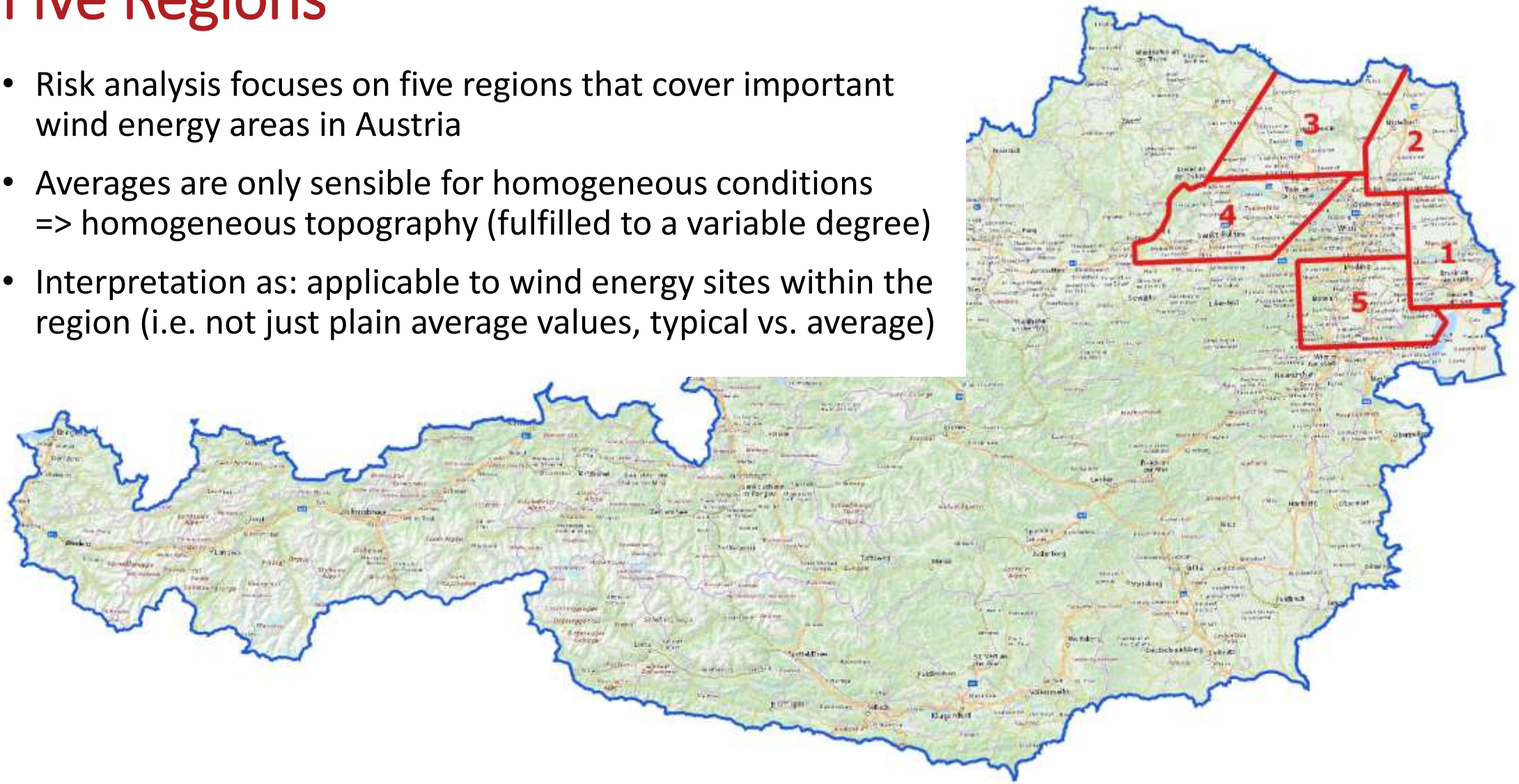
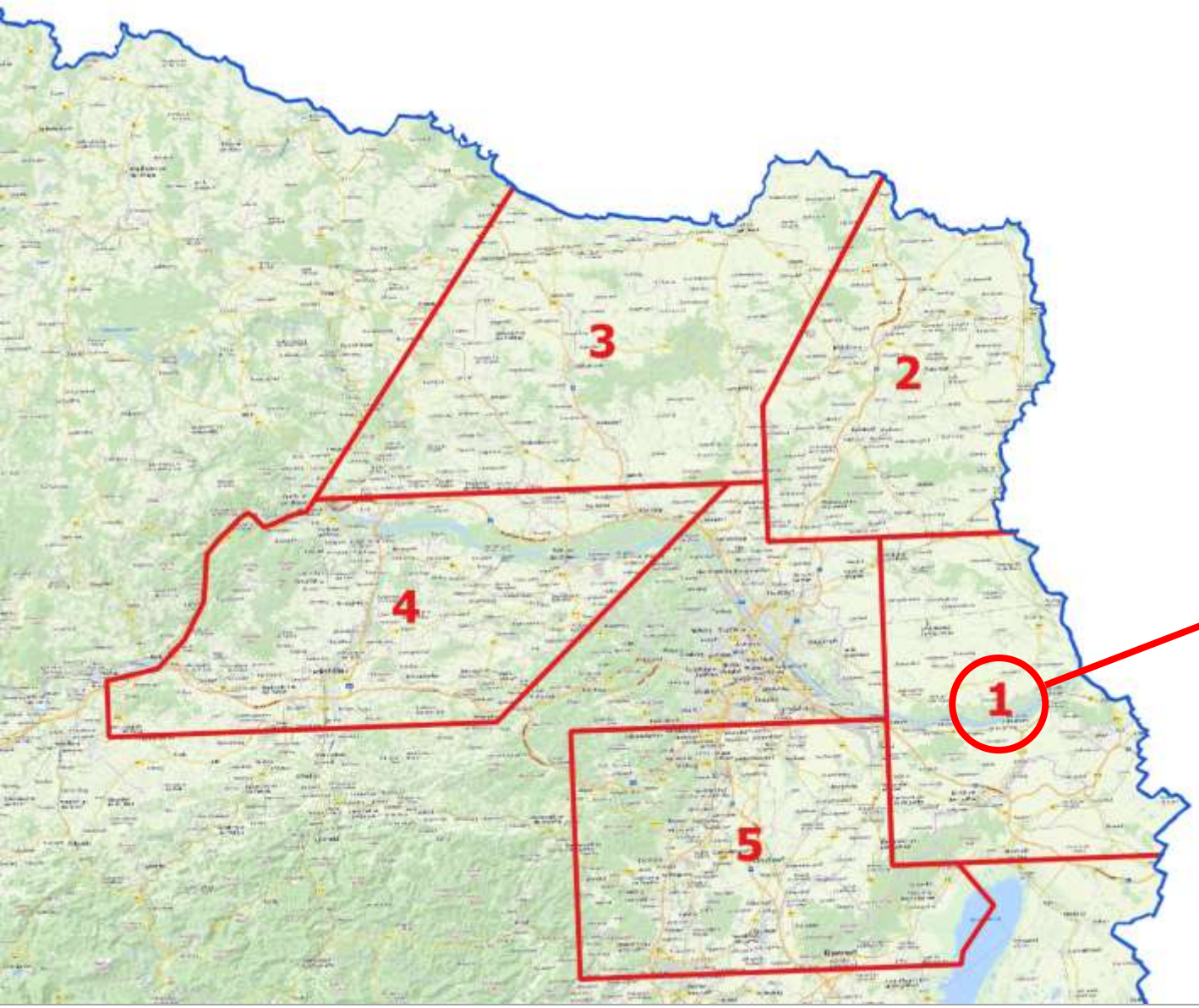
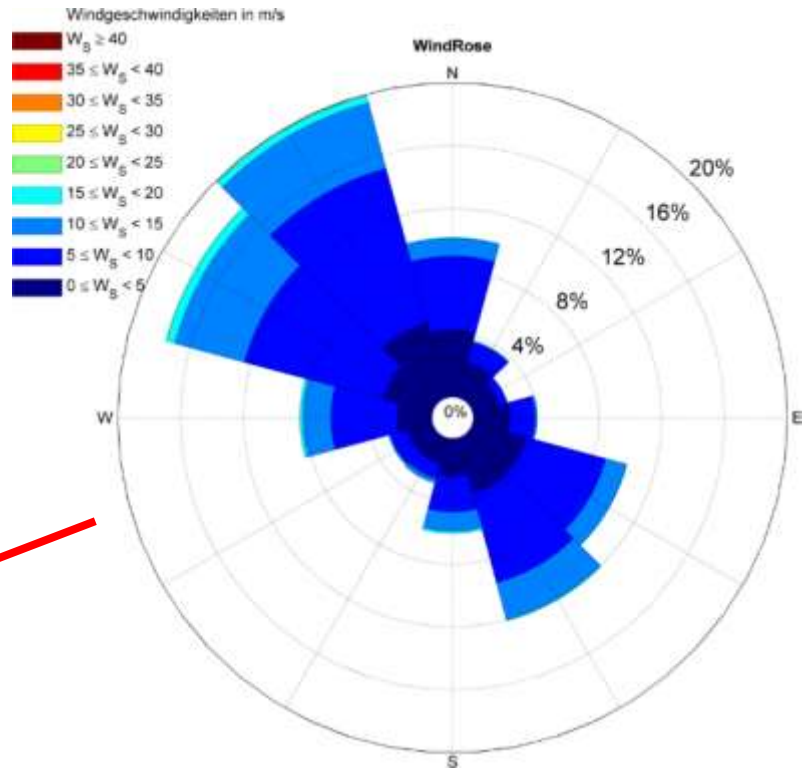
- Risk analysis focuses on five regions that cover important wind energy areas in Austria
- Averages are only sensible for homogeneous conditions
  => homogeneous topography (fulfilled to a variable degree)
- Interpretation as: applicable to wind energy sites within the region (i.e. not just plain average values, typical vs. average)

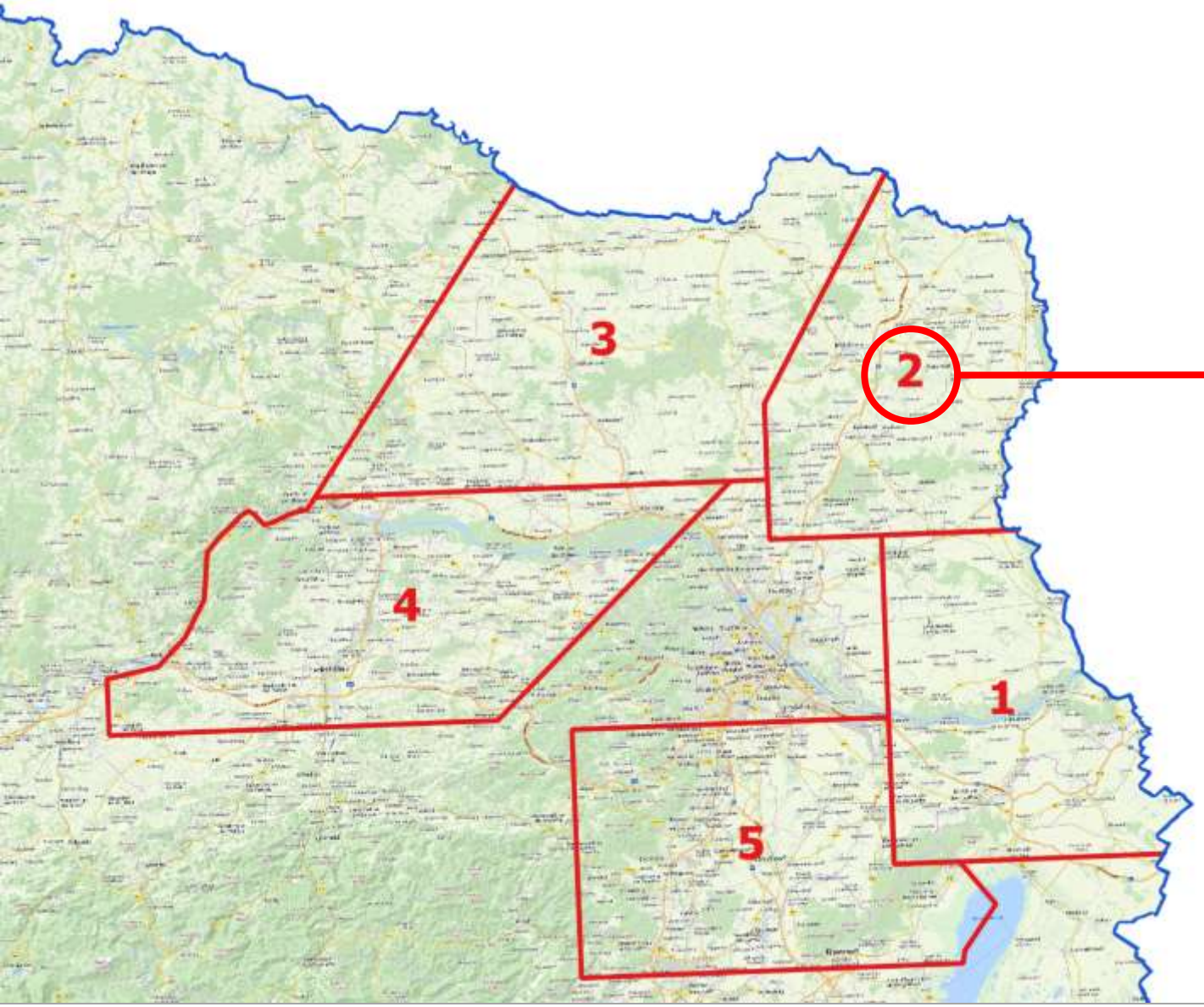


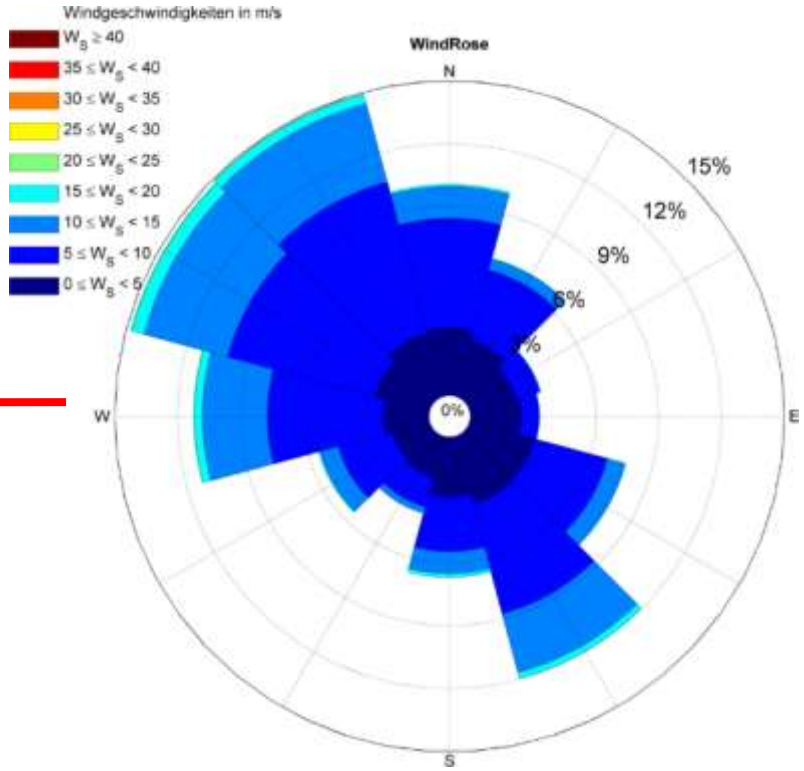
Wind Distributions for the Five Regions @ 100m





Wind Distributions for the Five Regions @ 100m





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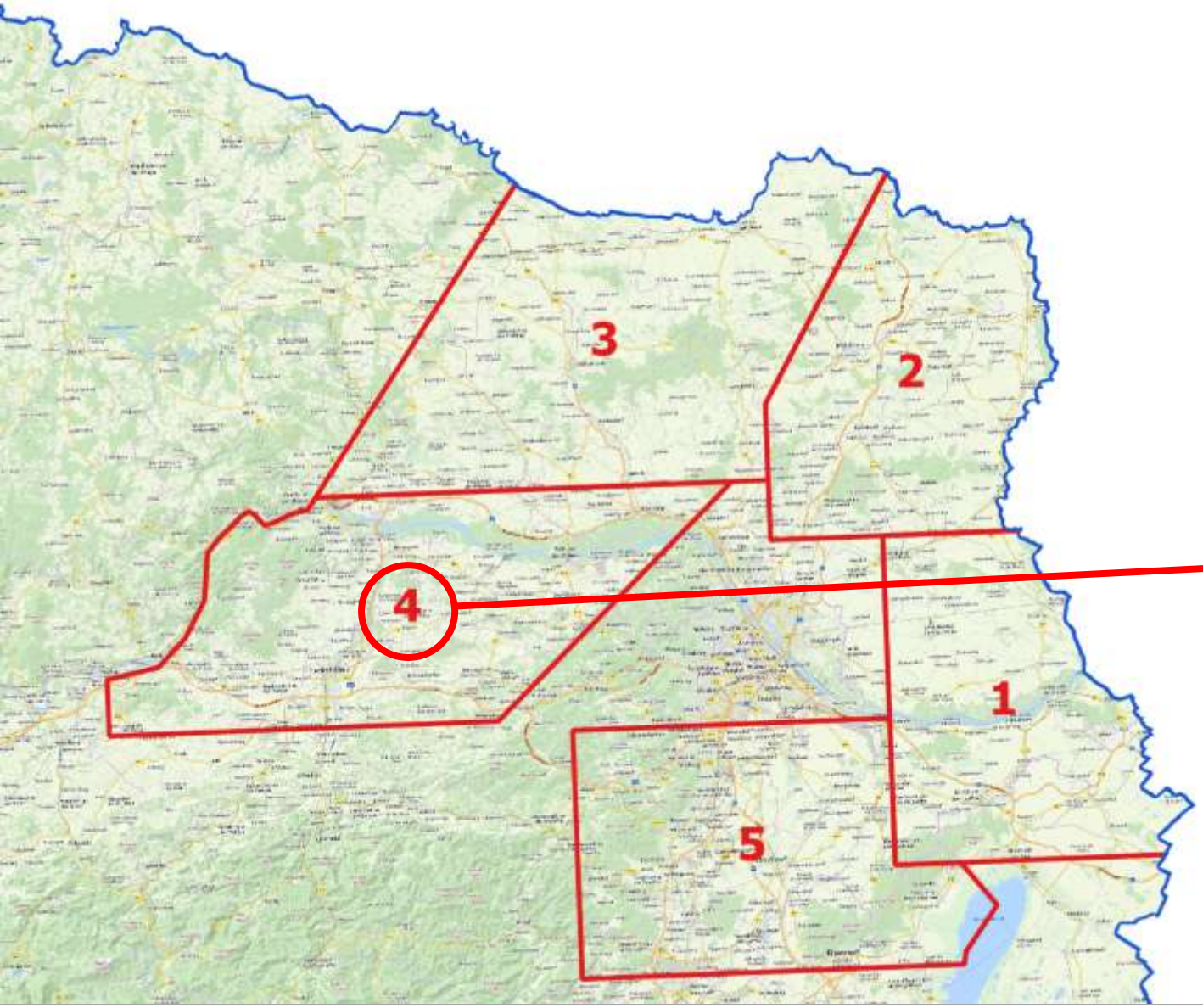
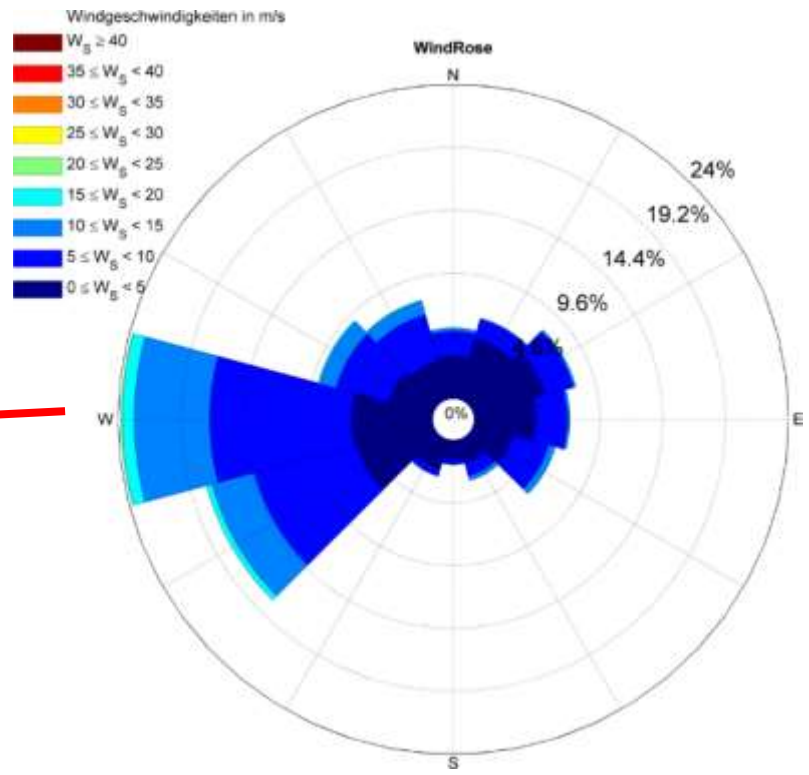




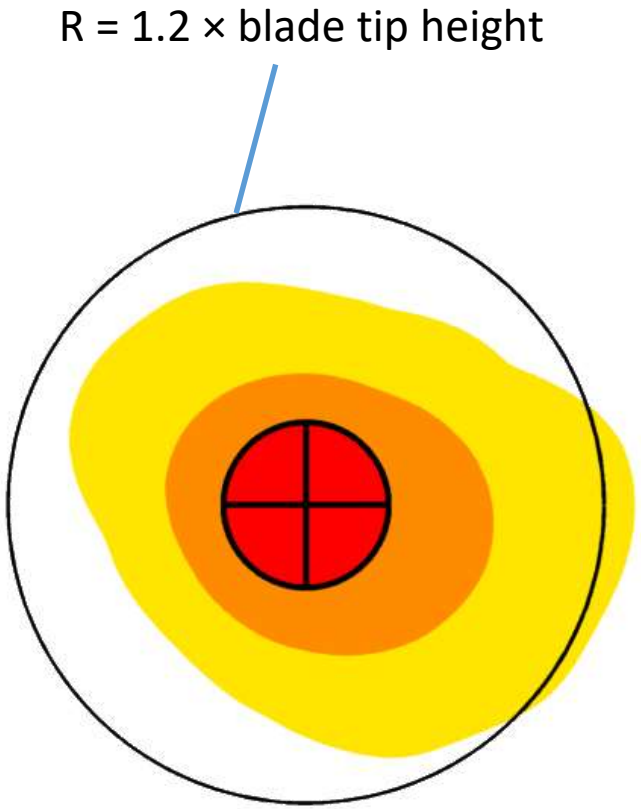
Ice Fall Simulations – Aim & Concept

- Provide Ice fall probability maps for each of the five regions
- Straightforward application and interpretation
- Tool for wind energy planning
- Simplified risk assessment for uncritical wind sites (well-known conditions & no significant infrastructure)

Ice Fall Simulations – Method

- Aggregated results for the five regions (wind distribution & icing)
- Ice fall simulations for these ‘typical’ conditions for each region.
- Three WT configurations: Dia & HH = 100m, 125m, 150m
- For idling and operational WT
- Number of ice pieces scaled linearly with blade length (between 8 and 16 pieces m^{-1} yr^{-1}).

Table of Risk Levels

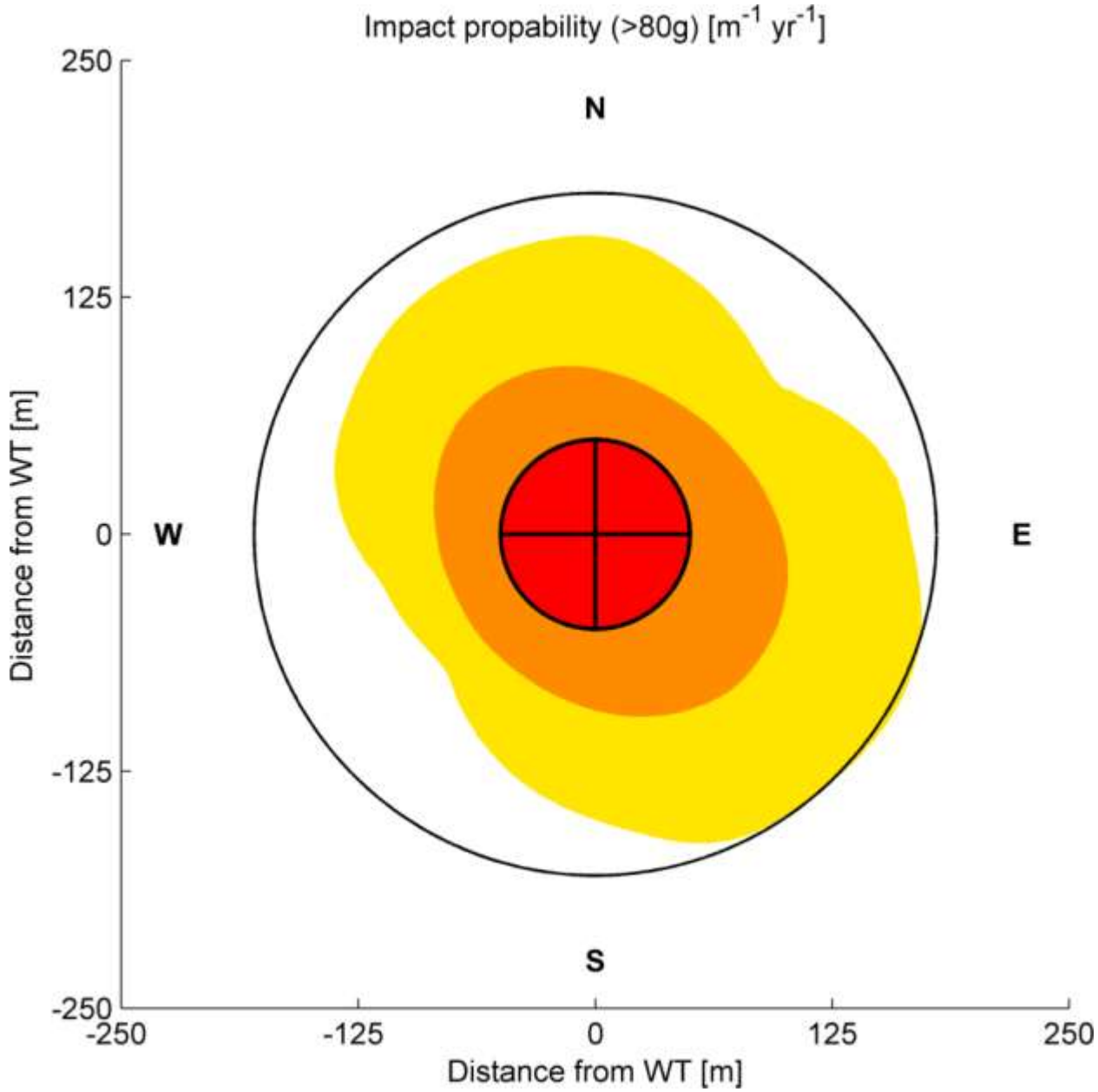


Color scheme	Presence of people	Transportation ways
Yellow	Up to 1/2 hour a day	Ok for hiking trails and municipal roads (less than 1000 vehicles per day)
Orange	Not permitted (Presence of people must be avoided through an ice warning system)	Ok for non-asphalted service roads (taking into account the effect of an ice warning system)
Red	Not permitted (Presence of people must be avoided through an ice warning system)	Detailed analysis required

To allow for uncertainties and local effects, this table includes a safety factor of 10.

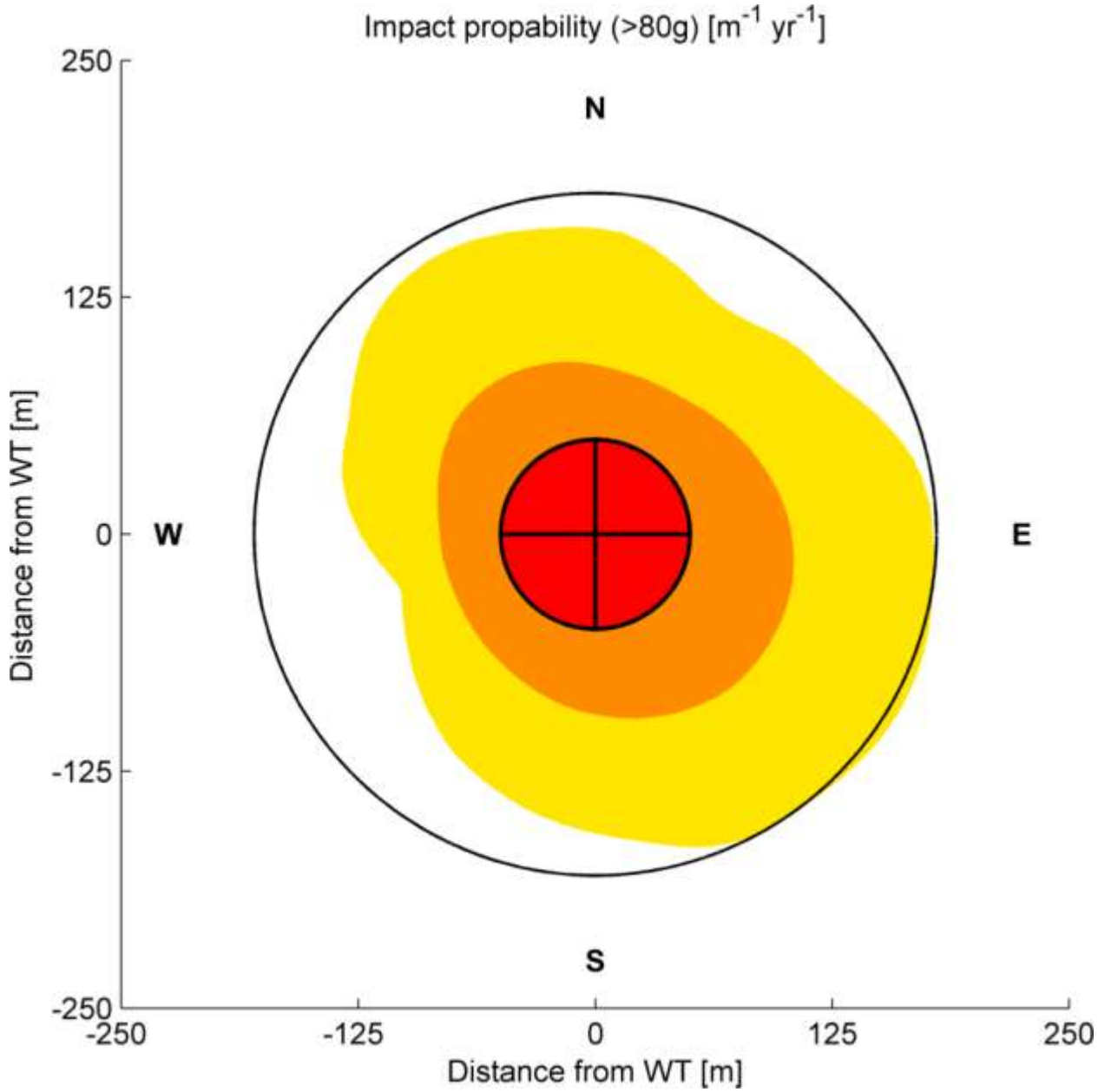
Region 1


3
2
4
1
5


Impact propability (>80g) [m-1 yr-1]
250
125
0
-125
-250
N
W
E
S
Distance from WT [m]
-250
-125
0
125
250
Distance from WT [m]

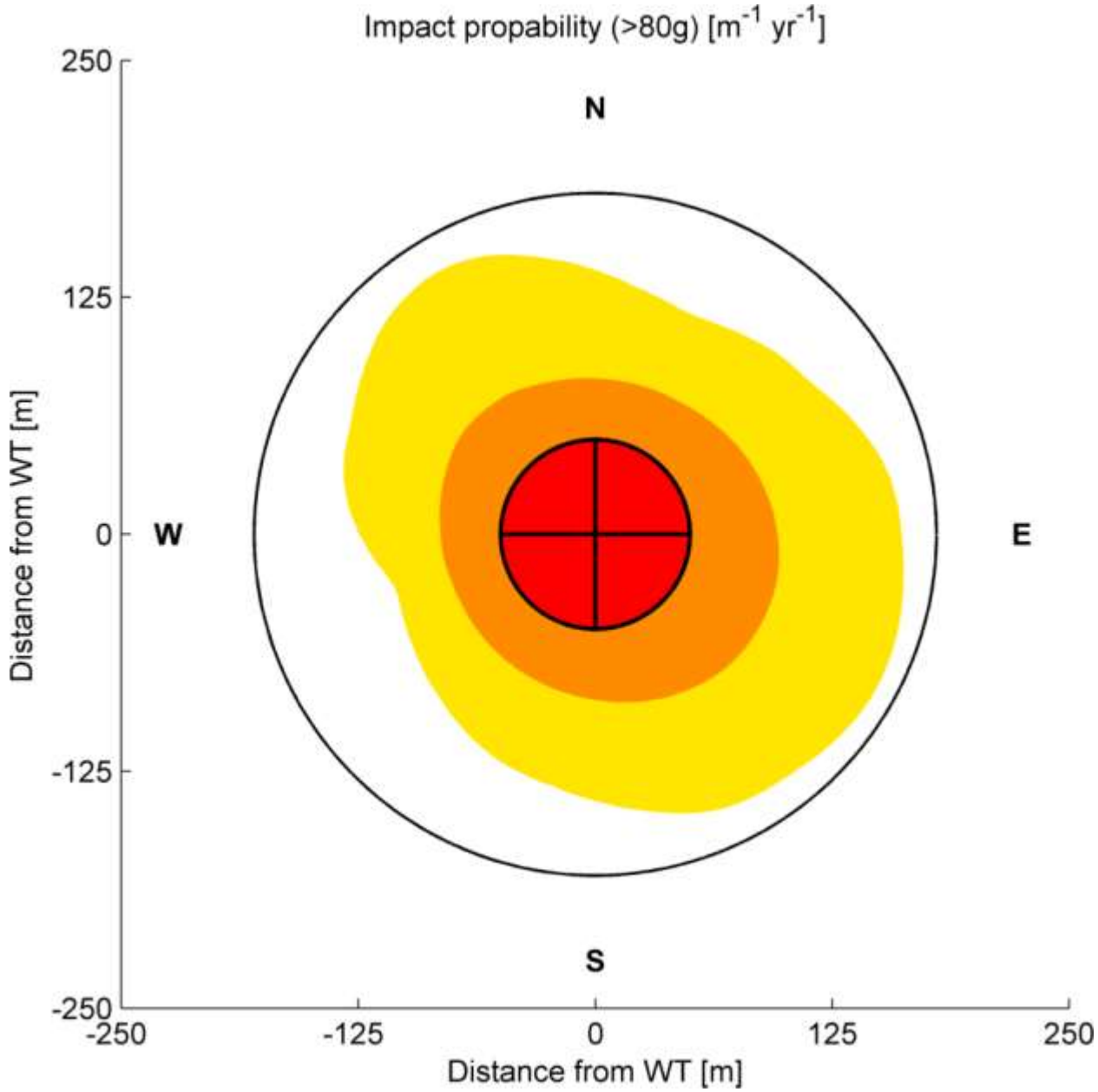
Region 2


3
2
4
1
5


Impact propability (>80g) [m-1 yr-1]
250
125
0
-125
-250
N
W
E
S
Distance from WT [m]
-250
-125
0
125
250
Distance from WT [m]

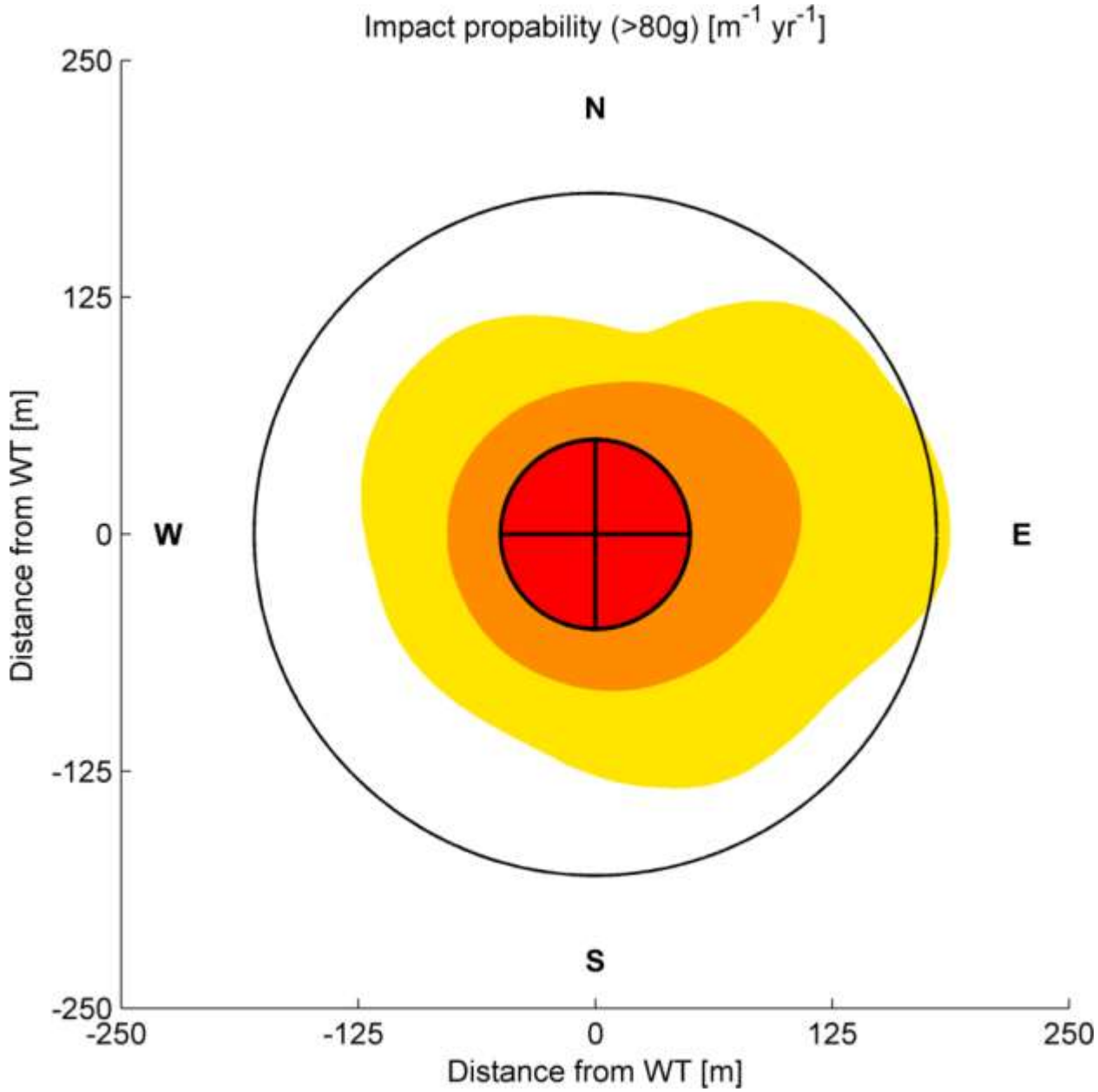
Region 3


3
2
4
1
5


Impact propability (>80g) [m-1 yr-1]
250
125
0
-125
-250
N
W
E
S
Distance from WT [m]
-250
-125
0
125
250
Distance from WT [m]

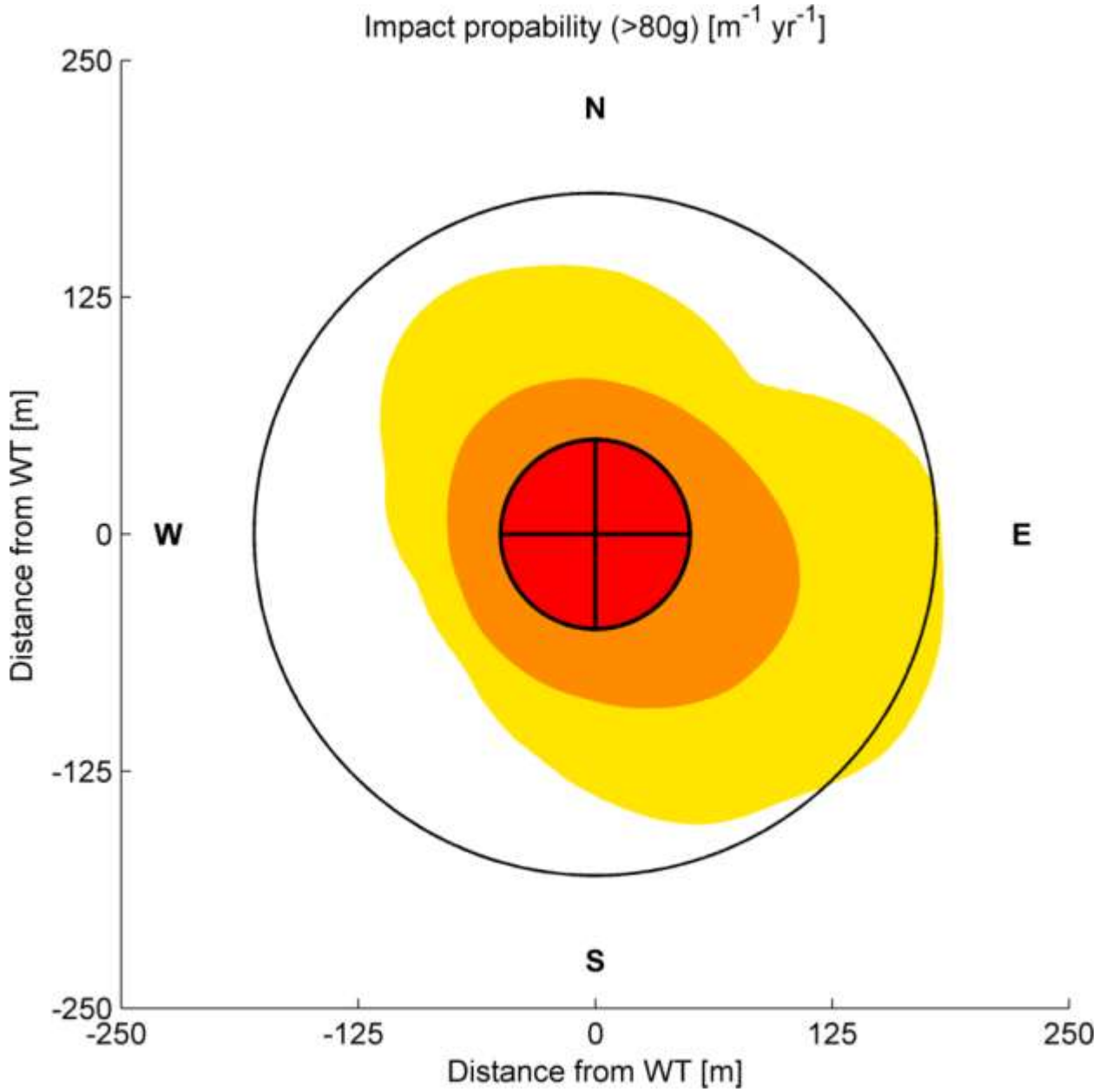
Region 4


3
2
4
1
5


Impact propability (>80g) [m-1 yr-1]
250
125
0
-125
-250
N
W
E
S
Distance from WT [m]
-250
-125
0
125
250
Distance from WT [m]

Region 5


3
2
4
1
5


Impact propability (>80g) [m-1 yr-1]
N
W
E
S
250
125
0
-125
-250
Distance from WT [m]
Distance from WT [m]

Legal Perspective and Policies

- Will be the topic of a national workshop to be held this spring
- Based on the results as presented above (+ IEA recommendations)
- Considering the legal and technical perspective

Aims:

- Common basis with regard to the actual level of the ice-fall hazard (depending on site location, turbine size and operational mode)
- Realistic assessment of the effect of different safety measures
- More uniform requirements and procedures for wind energy projects in Austria