WP5 Extreme Winds: Calculating the extreme winds

Xiaoli G. Larsén – DTU Wind Energy

Andries Kruger – South African Weather Service

Why
do we need to know the extreme wind?

IEC 61400-1 site assessment rules

Checklist

- Extreme winds
- Turbulence Intensity
- Vertical wind shear
- Flow inclination
- Wake turbulence

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Table 1 – Basic parameters for wind turbine classes[2]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values
A	I_{ref} (-)	0,16			specified
B	I_{ref} (-)	0,14			by the
C	I_{ref} (-)	0,12			designer

V_{ref} hub-height, 10-min, fifty-year extreme wind

I_{ref} reference turbulence intensity at 15 m/s in a 10-min period

Why

do we need **new** extreme wind atlases?

How

did we obtain the new extreme wind atlases?

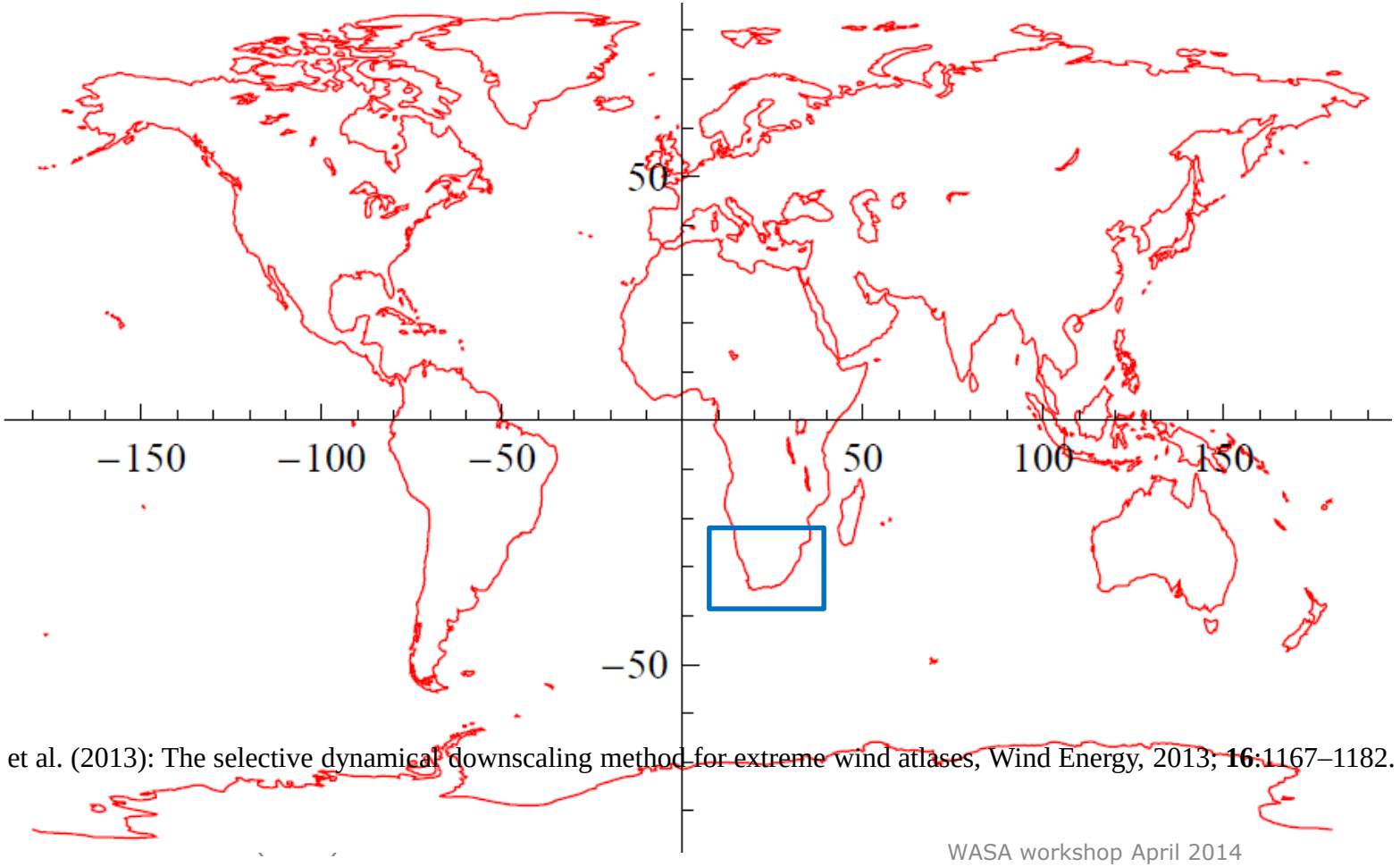
&

What

are the data?

The selective dynamical downscaling method (SDDM)

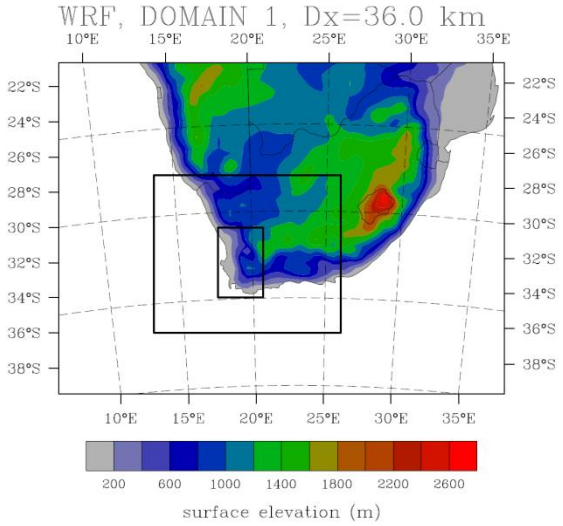
STEP 1: identification of storms



Larsén et al. (2013): The selective dynamical downscaling method for extreme wind atlases, Wind Energy, 2013; **16**:1167–1182.

The selective dynamical downscaling method (SDDM)

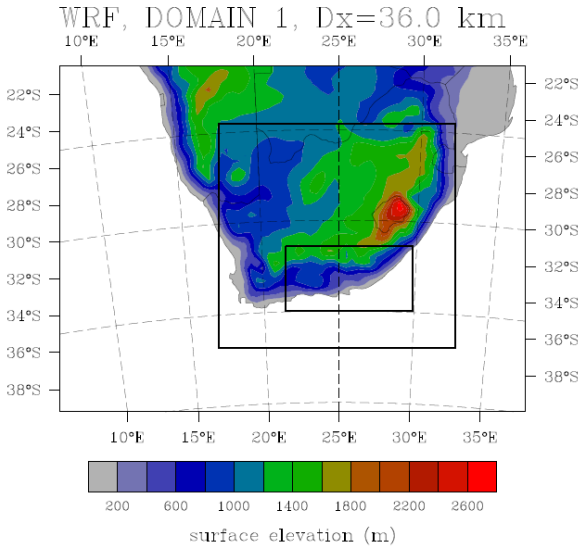
STEP 2: mesoscale modeling



1. Run WRF for the 72+175 cases

2. WRF setup:
   - WRF V3.2.1
   - **CFSR data, 6 hrly, 1998 - 2010**
   - SST 0.5°
   - 36 – 12 – **4** km
   - 41 vertical layers
   - **MYNN PBL scheme**
   - Run time <=72 hrs, nudging
   - **10 min output**
   - **20 s time step**

3. The 50-year wind using the Annual Maxima Method.



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The selective dynamical downscaling method (SDDM)

STEP 3: post-processing procedure

All 50-year winds are corrected to the standard condition: 10 m & roughness length of 5 cm – needed for microscale modeling

Using Linear Computational Model (LINCOM) to obtain mesoscale speedup factors from upwind orography and roughness length

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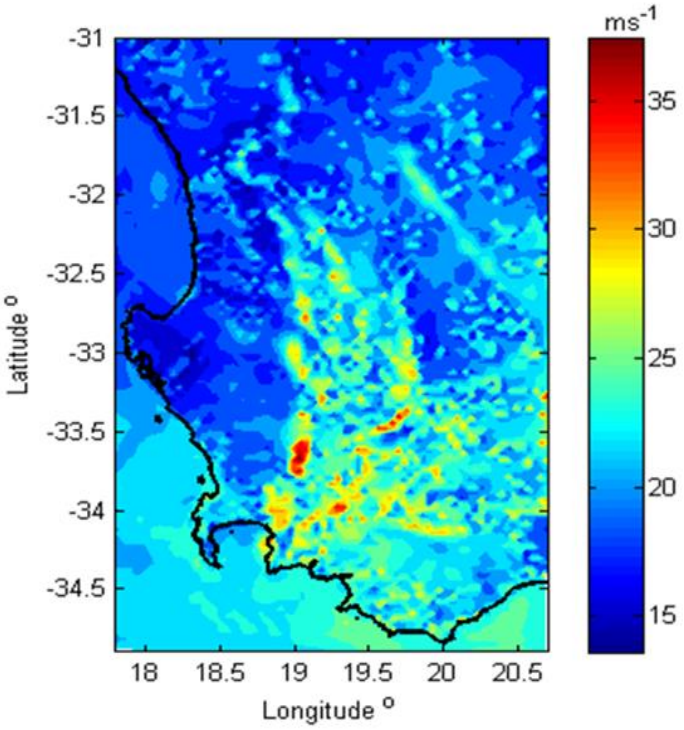
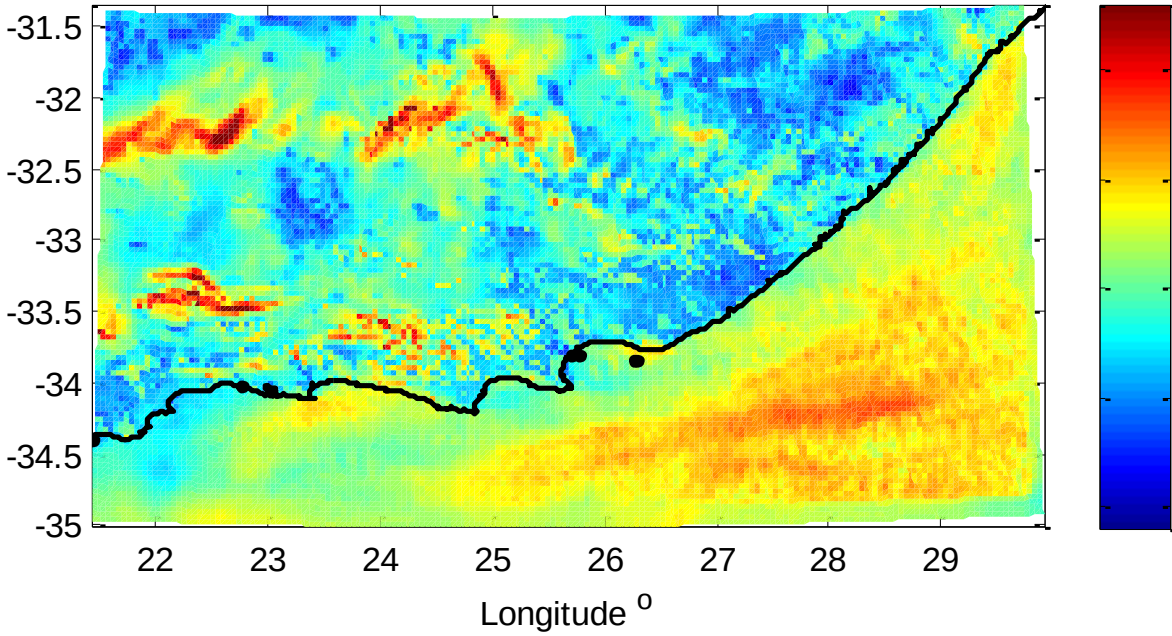
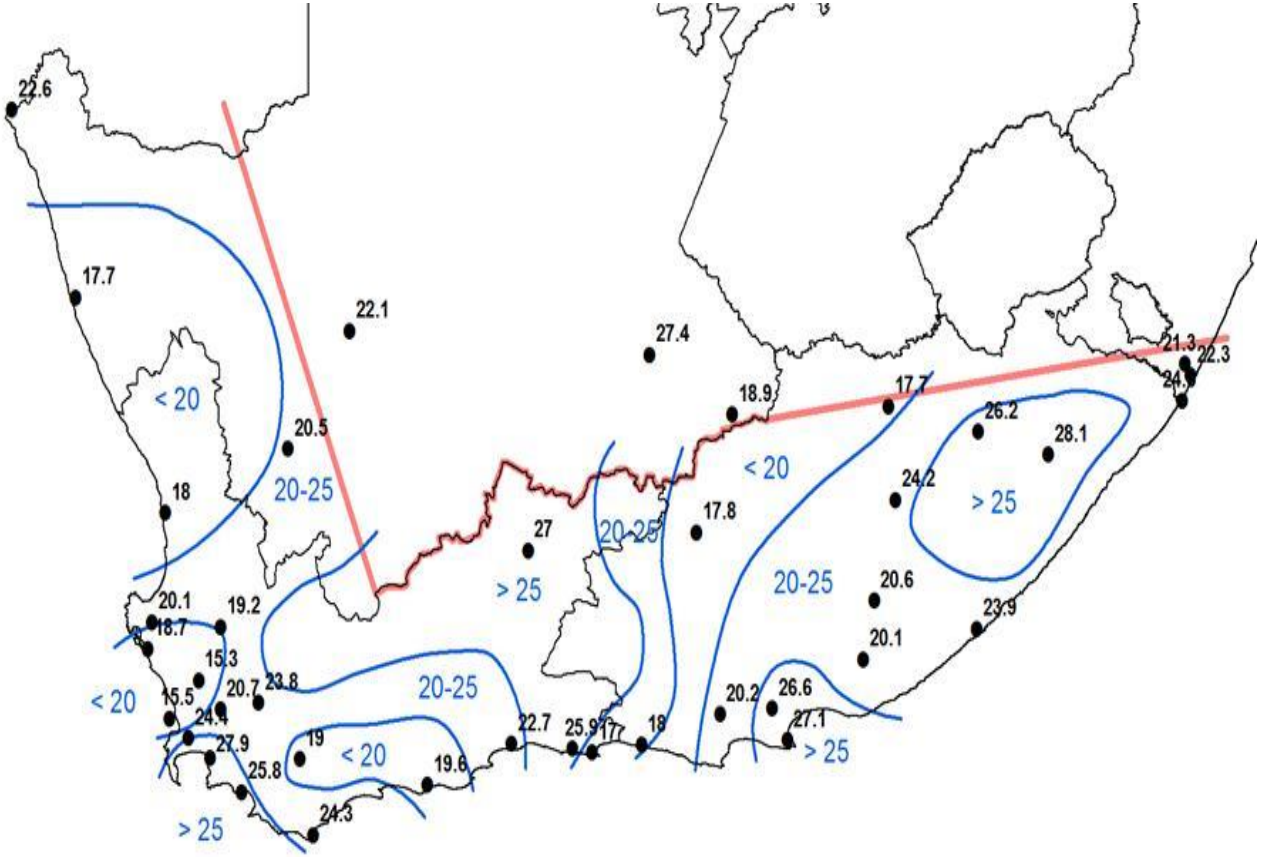
The selective dynamical downscaling method (SDDM)

Outputs

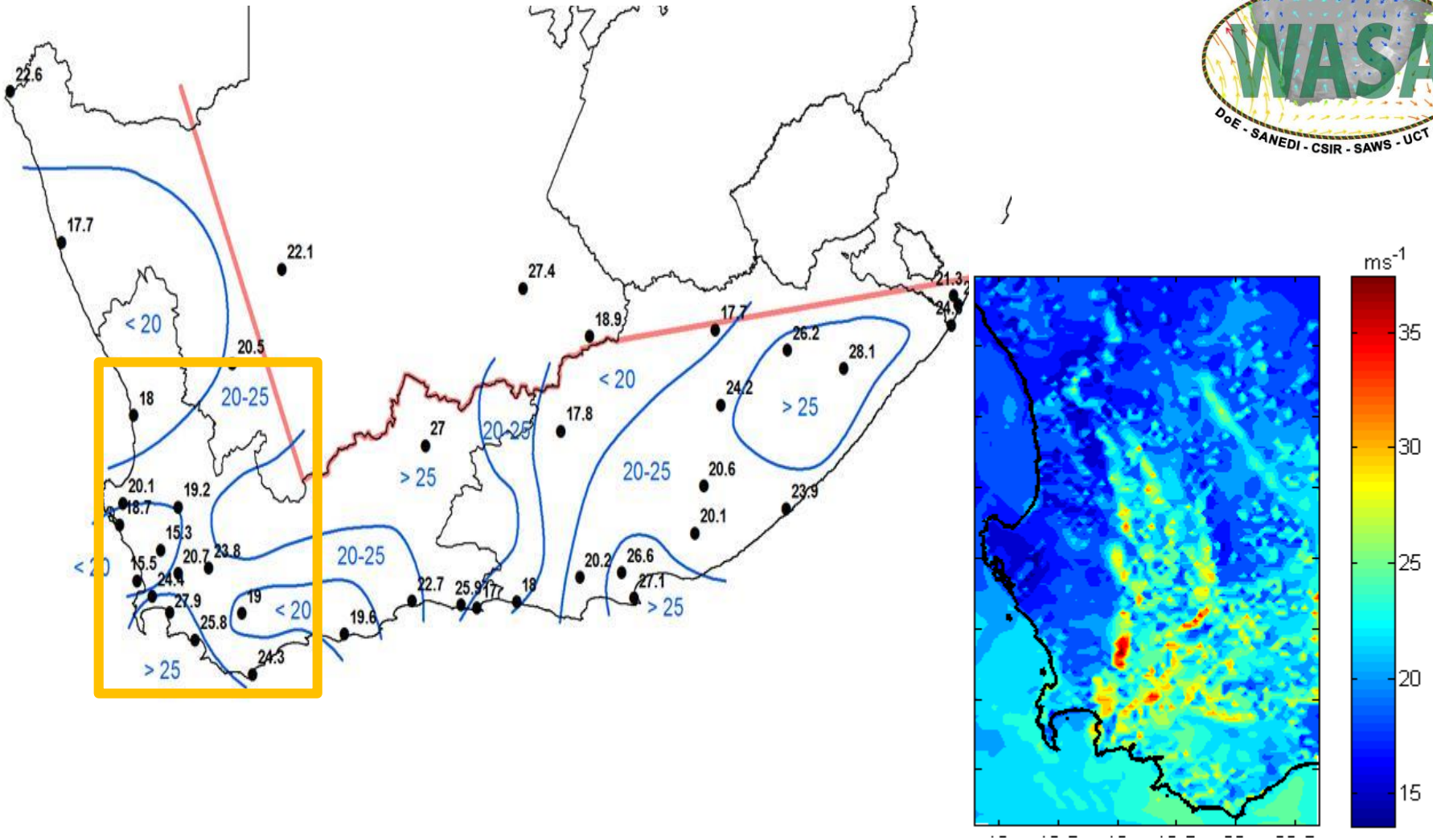




1:50 year 10-min wind at 10 m over roughness length = 5 cm
Horizontal resolution: 4 km



1:50 yr 10-min wind speed for WASA project area



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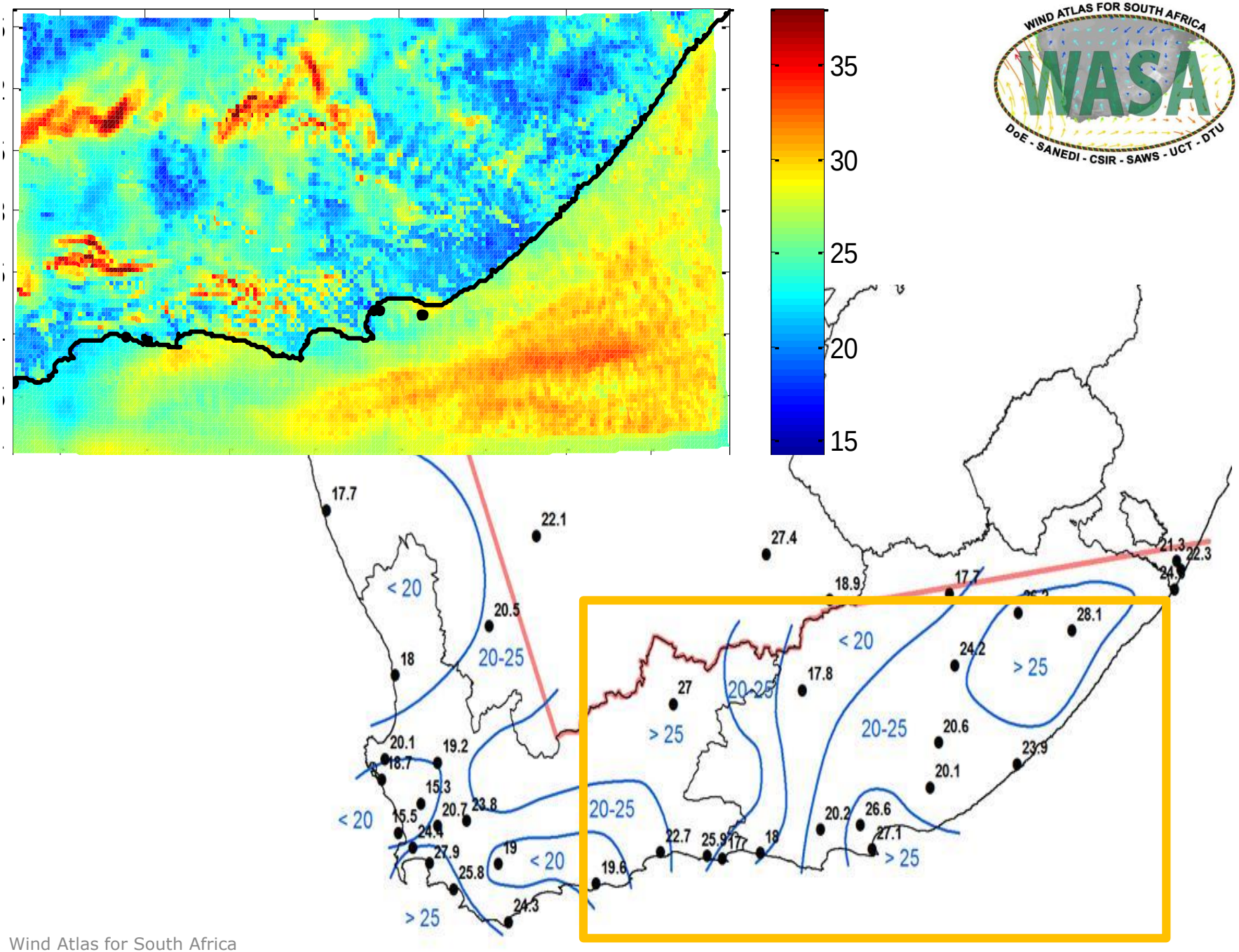
35
30
25
20
15
17.7
22.1
27.4
21.3
22.3
18.9
17.7
< 20
20.5
20-25
18
28.1
24.2
> 25
17.8
27
20-25
> 25
20-25
20.6
20.1
23.9
20.1
19.2
18.7
15.3
< 20
15.5
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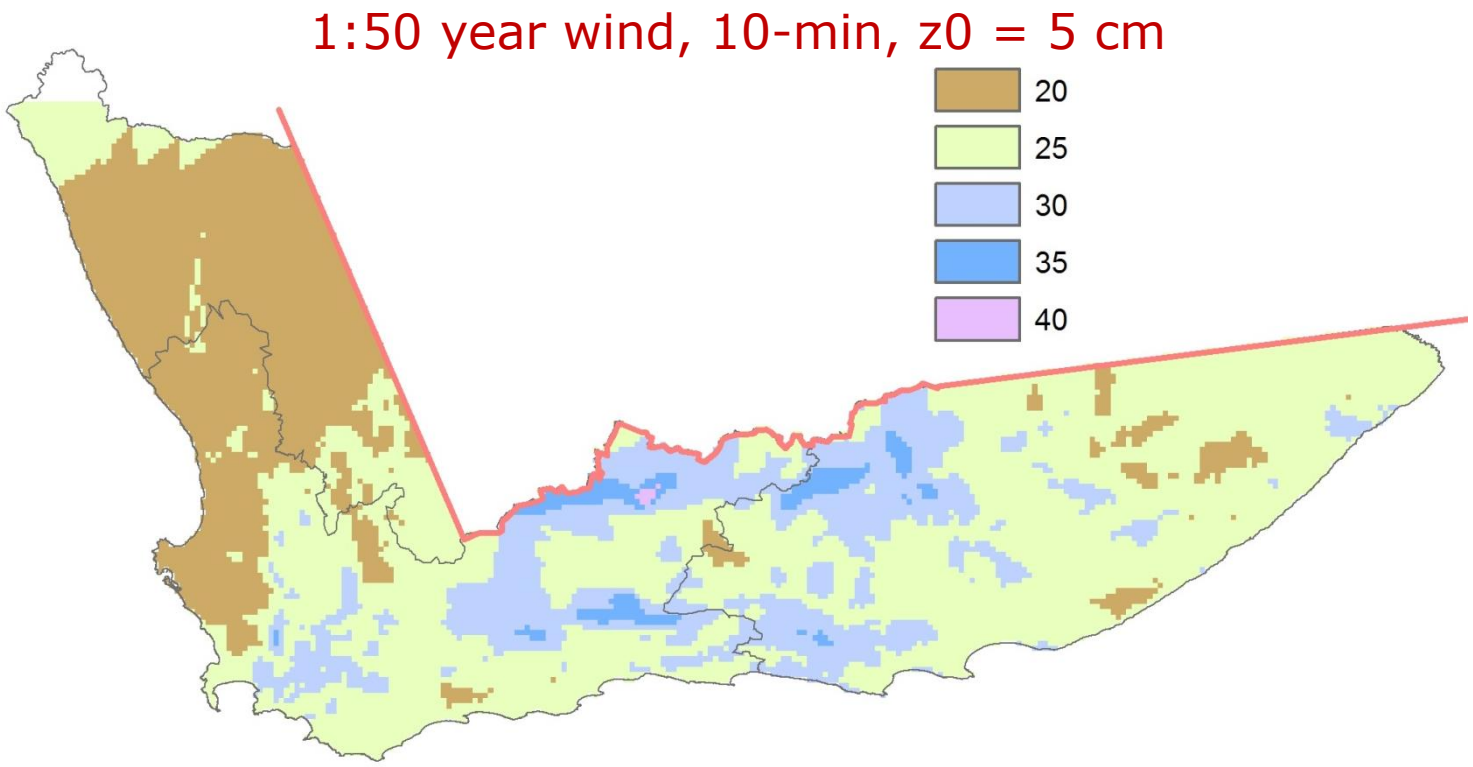
26.6
24.4
22.7
25.9
17
18
27.1
27.9
19
< 20
> 25
19.6
25.8
24.3
> 25

3. The final map (obs + SDDM)



Other design parameters

Gust…

Larsén and Kruger: Extreme gust wind estimation using mesoscale modeling, in *Proceedings of European Wind Energy Associations*, 10 – 13 March, 2014, Barcelona Spain.

GUST

- Brausseur's concept of the gust and estimation

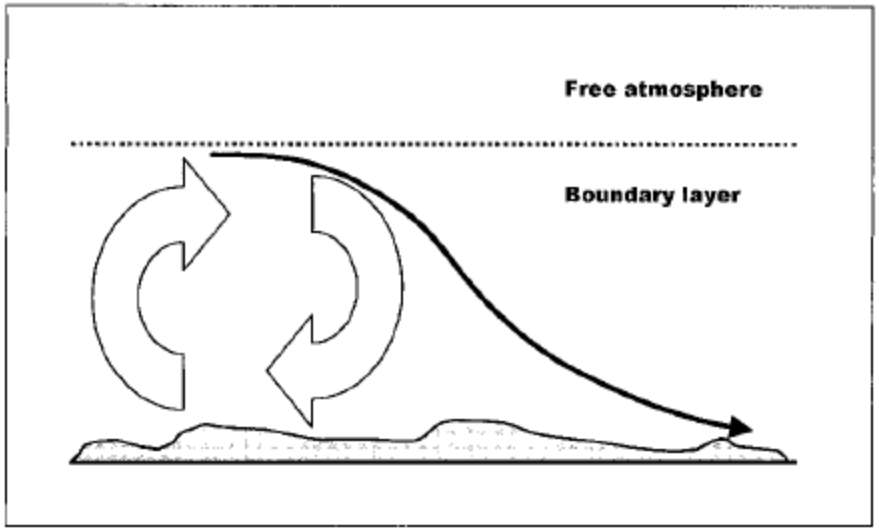


FIG. 1. Proposed mechanism explaining gusts observed at the surface: turbulent eddies are triggering the deflection of air parcels flowing in the boundary layer downward to the surface.

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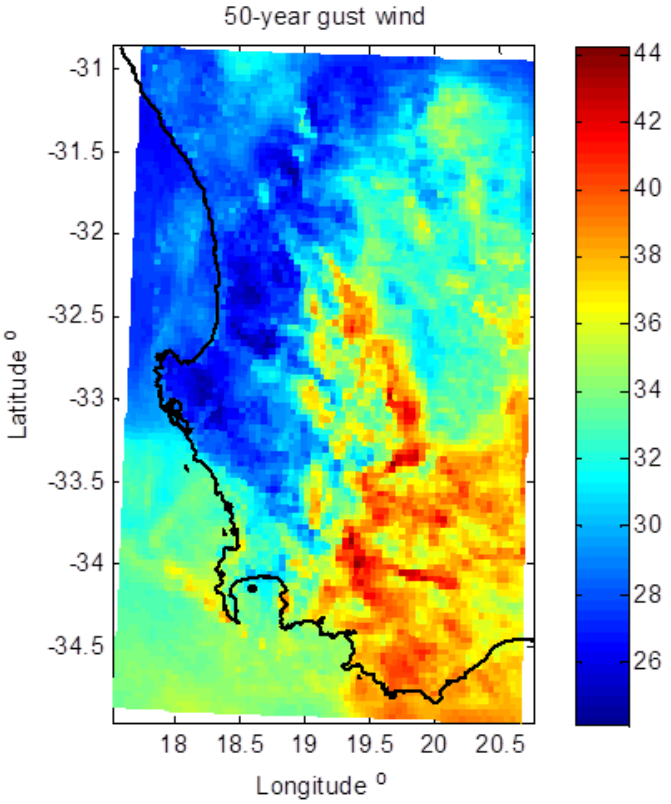
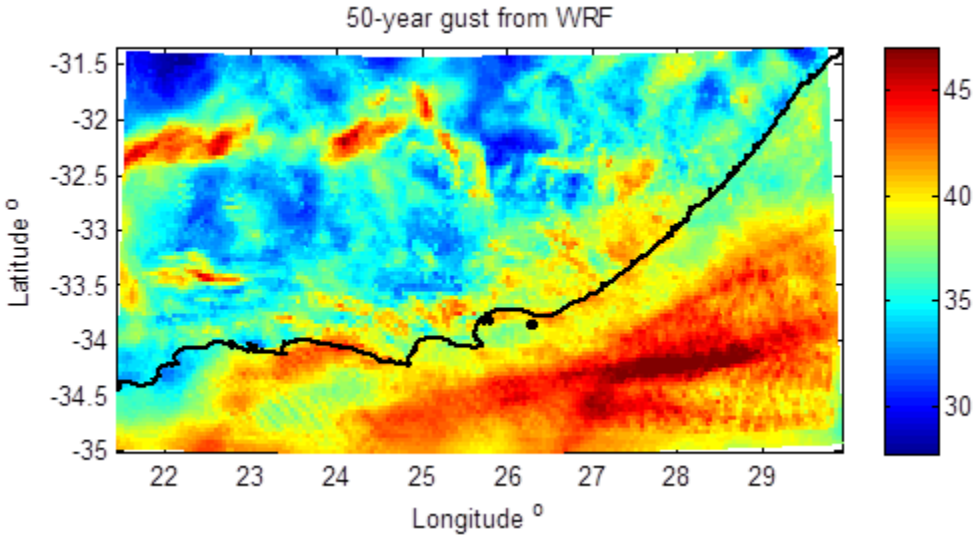
GUST





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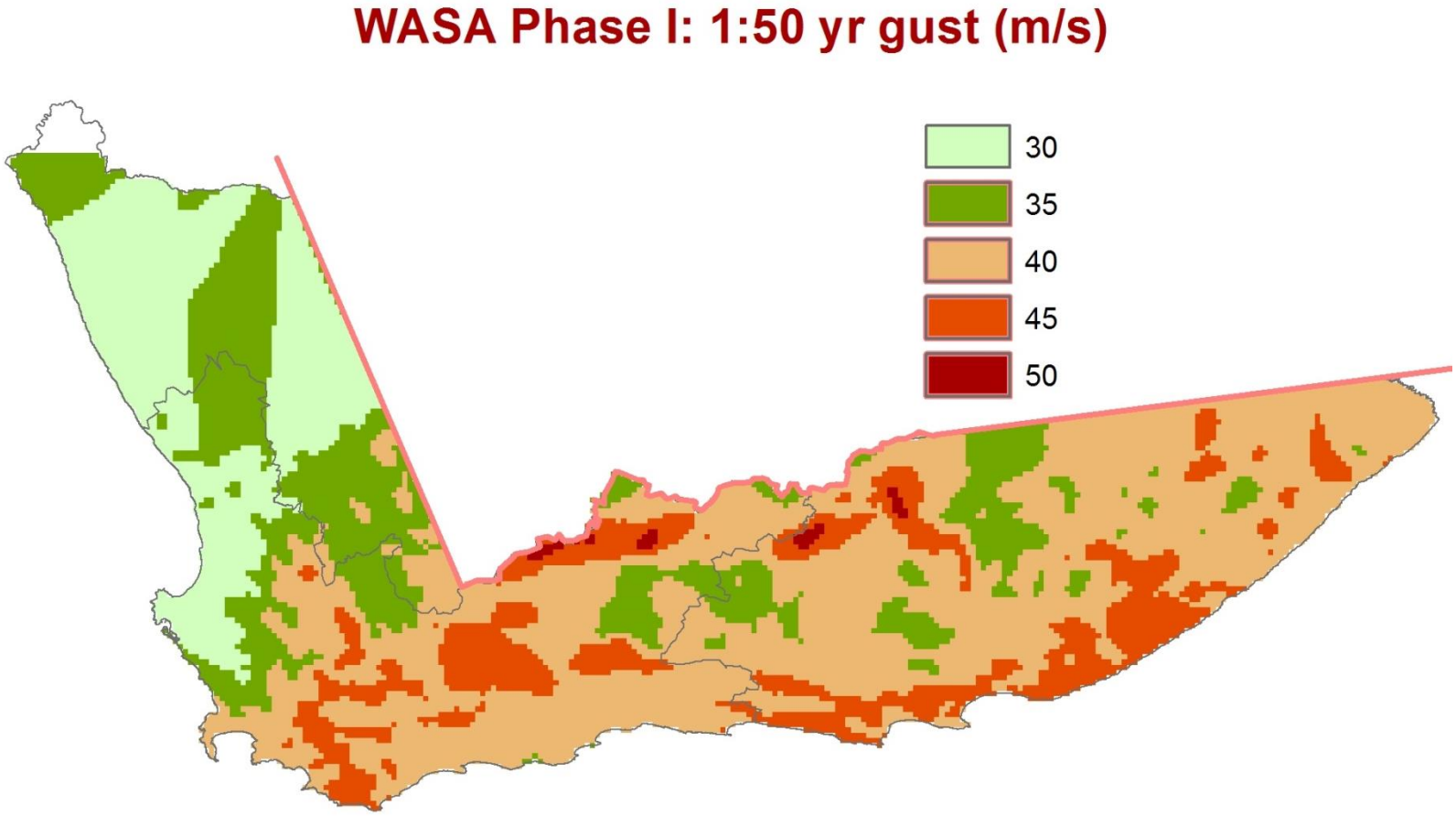


The data description

Guidelines for using the extreme wind data from the selective dynamical downscaling method

Xiaoli Guo Larsén, Andries Kruger and Tom Cronin

This guideline is to obtain design parameters as required in the IEC standard, by the application of the 1:50 year 10 minute wind speed.

We will introduce here how to use the software WEng to calculate the 50-year return wind at a particular site, at a certain height (e.g. hub height). The calculation in WEng is done through the linear computational model LINCOM.

For a particular site, the input data required by WEng could be available in one or more forms as described below:

(1) One single value of the 50-year wind of standard condition (10 m high over homogenous surface with a roughness length of e.g. 5 cm) from measurements or modeling.
(2) A collection of annual maximum wind speed, corrected to the standard condition already.
(3) A collection of annual maximum wind speed, directly from mesoscale modeling, using the selective dynamical downscaling method (SDDM) (see Larsén et al. 2013).

The following sections describe the recipes for applying WEng with input from the three possible data formats.

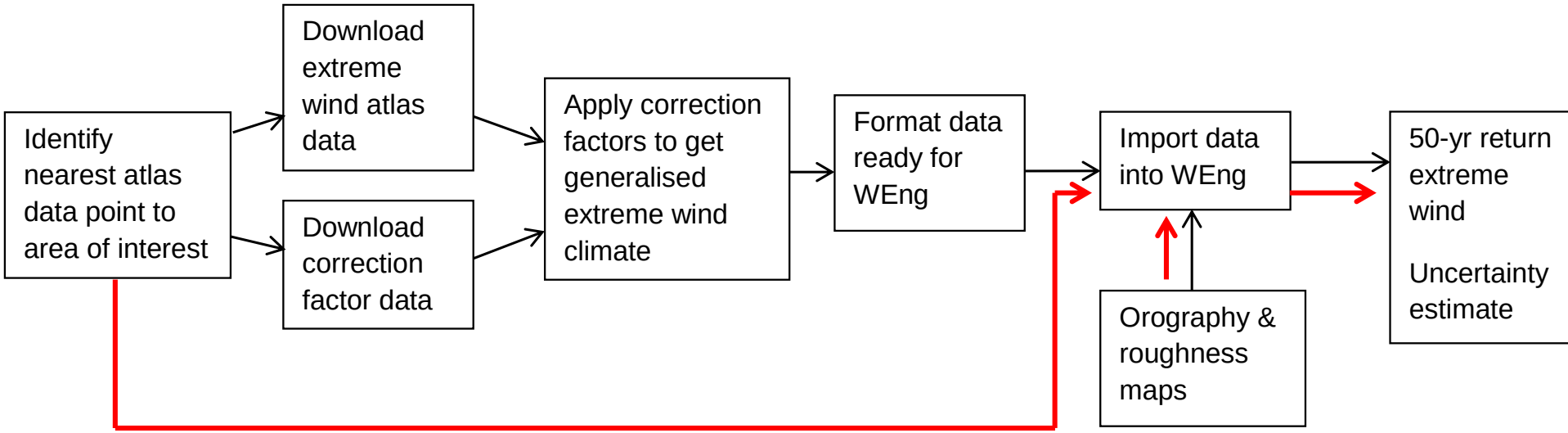
To prepare WEng, the orographical and roughness length maps should be made ready. The details of making such maps can be found in Mortensen et al. (2014).

1. With input as data format (1)

Figure 1 is a photo shot of WEng applied to a site M5. The input is the wind at standard conditions from a certain direction (see the red arrow). The window in the middle (Wind Editor: insert new wind) is the table for writing the information. The example here is the generalized wind from 180 degrees with a speed of 20.94 m/s. The surface condition is as described: 0.05 m for roughness length and at 10 m height. The calculation gives the results shown in the window "Site/wind view"; the estimate is 31.49 m/s (see the thin blue arrow).

The largest 1:50 year value is 33 m/s, indicated as from the direction of 270 degrees. This is a conservative estimate, as it is assumed that the strong wind dara from which the 1:50 year estimate was initially calculated from are from this specific direction. However, with no extreme wind direction information available, it is recommended that the conservative estimate be used. In reality, the results, whether with or without directional information, should not differ in the recommendation regarding the ISO class of wind turbine.

Links to the data are provided at the end of this document.

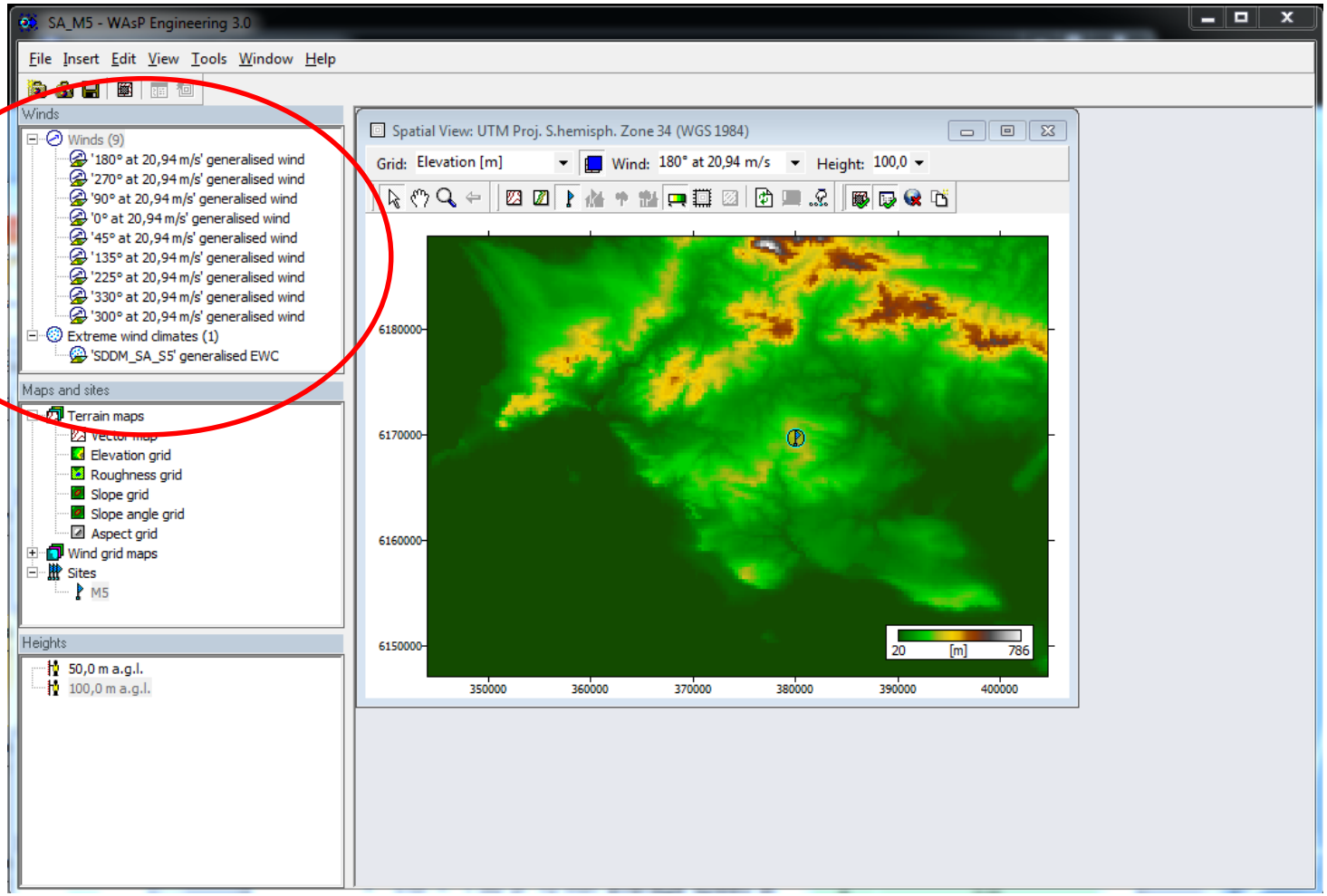

Identify nearest atlas data point to area of interest
Download extreme wind atlas data
Download correction factor data
Apply correction factors to get generalised extreme wind climate
Format data ready for WEng
Import data into WEng
Orography & roughness maps
50-yr return extreme wind
Uncertainty estimate

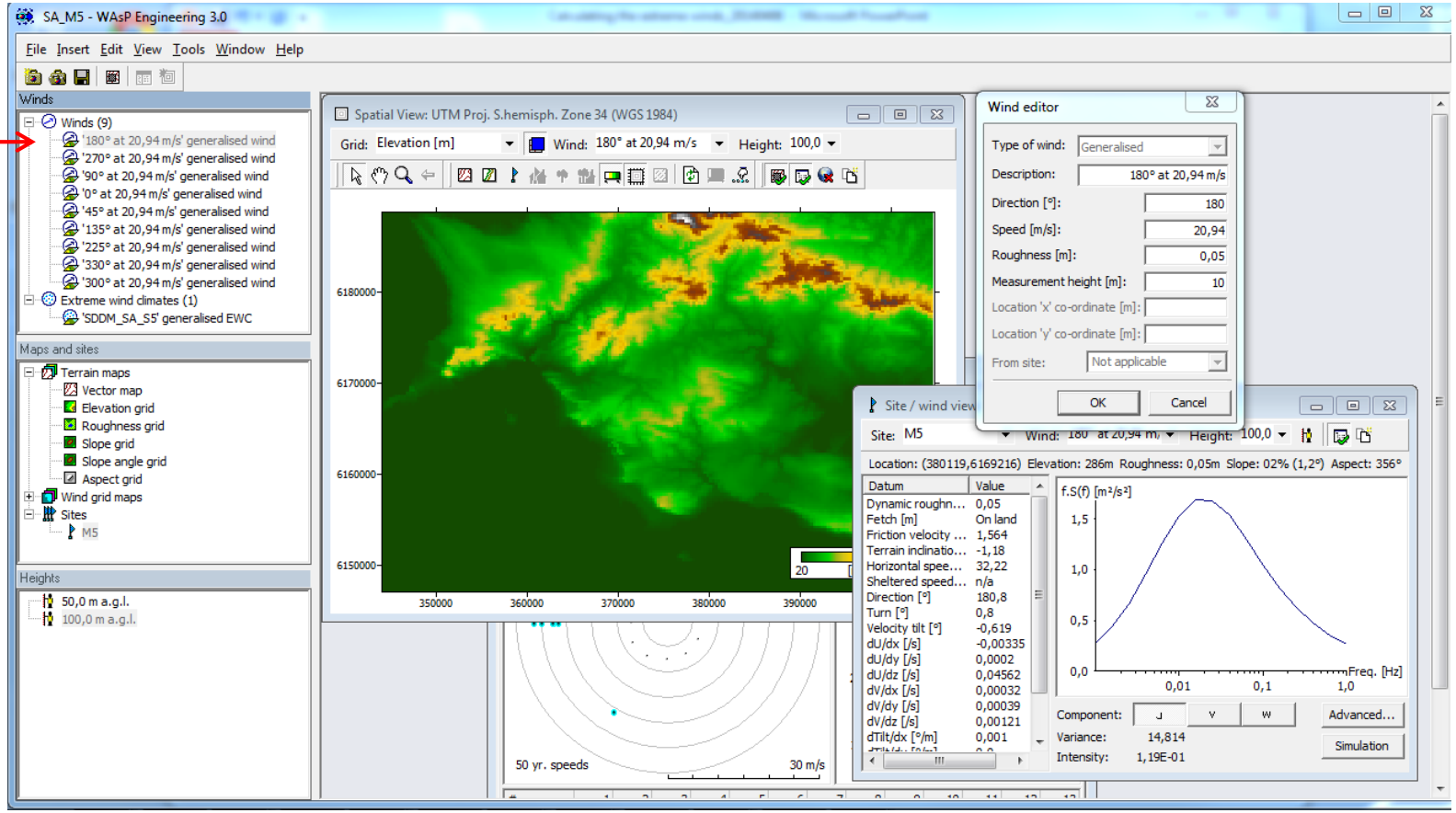
The application

Demo WAsP Engineering…

How

to obtain site-specific extreme wind?


SA_M5 - WAsP Engineering 3.0
File Insert Edit View Tools Window Help
Winds
Winds (9)
'180° at 20,94 m/s' generalised wind
'270° at 20,94 m/s' generalised wind
'90° at 20,94 m/s' generalised wind
'0° at 20,94 m/s' generalised wind
'45° at 20,94 m/s' generalised wind
'135° at 20,94 m/s' generalised wind
'225° at 20,94 m/s' generalised wind
'330° at 20,94 m/s' generalised wind
'300° at 20,94 m/s' generalised wind
Extreme wind climates (1)
'SDDM_SA_S5' generalised EWC
Maps and sites
Terrain maps
Elevation grid
Roughness grid
Slope grid
Slope angle grid
Aspect grid
Wind grid maps
Sites
M5
Heights
50,0 m a.g.l.
100,0 m a.g.l.
Spatial View: UTM Proj. S.hemisph. Zone 34 (WGS 1984)
Grid: Elevation [m]
Wind: 180° at 20,94 m/s
Height: 100,0
6180000
6170000
6160000
6150000
350000
360000
370000
380000
390000
400000
20 [m] 786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6180000
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360000
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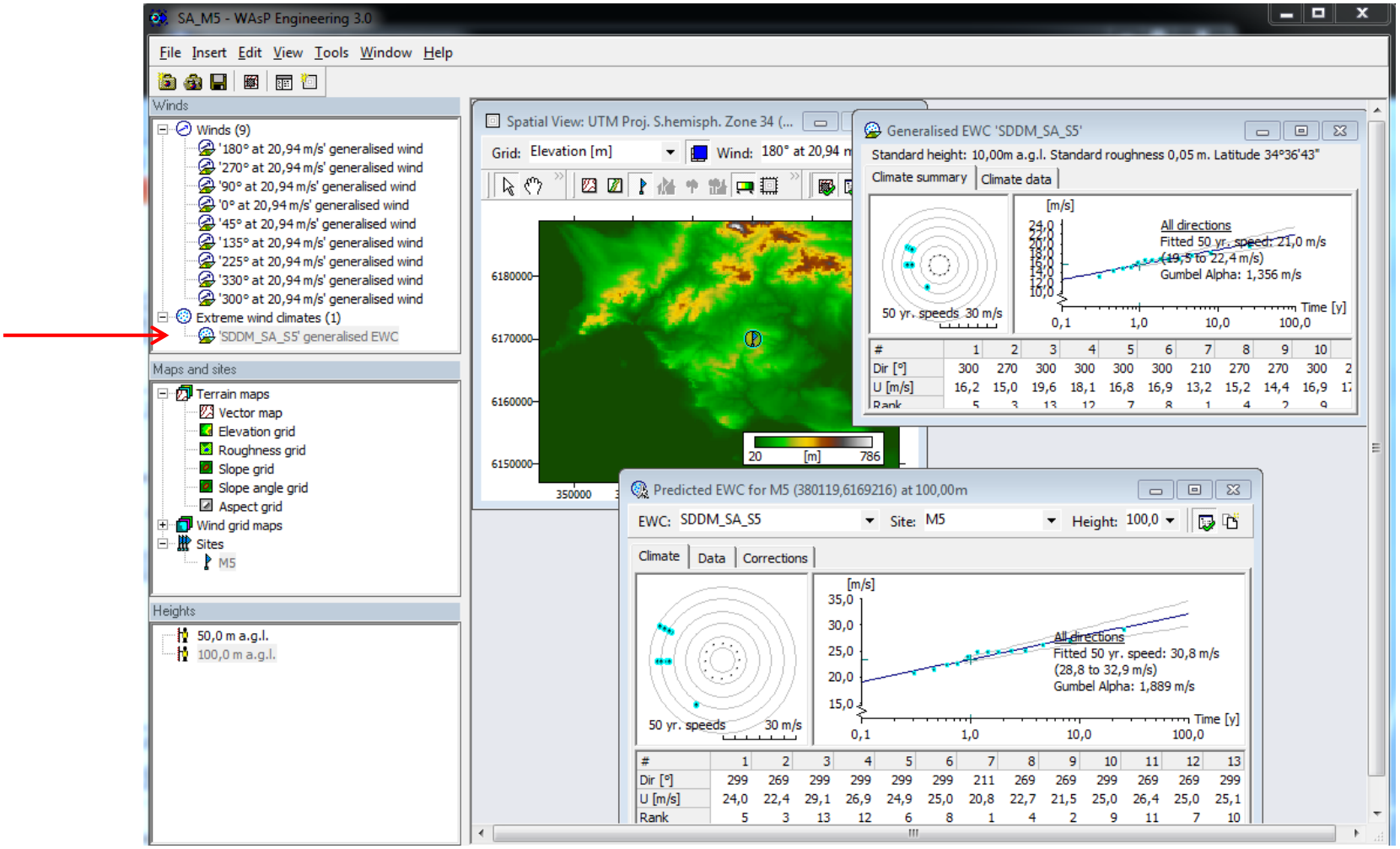
380000
390000
20
50 yr. speeds
30 m/s
Wind editor
Type of wind: Generalised
Description: 180° at 20,94 m/s
Direction [°]: 180
Speed [m/s]: 20,94
Roughness [m]: 0,05
Measurement height [m]: 10
Location 'x' co-ordinate [m]:
Location 'y' co-ordinate [m]:
From site: Not applicable
OK
Cancel
Site / wind view
Site: M5
Height: 100,0
Location: (380119,6169216) Elevation: 286m Roughness: 0,05m Slope: 02% (1,2°) Aspect: 356°
Datum
Value
Dynamic roughn... 0,05
Fetch [m] On land
Friction velocity ... 1,564
Terrain inclinatio... -1,18
Horizontal spee... 32,22
Sheltered speed... n/a
Direction [°] 180,8
Turn [°] 0,8
Velocity tilt [°] -0,619
dU/dx [/s] -0,00335
dU/dy [/s] 0,0002
dU/dz [/s] 0,04562
dV/dx [/s] 0,00032
dV/dy [/s] 0,00039
dV/dz [/s] 0,00121
dTilt/dx [°/m] 0,001
f.S(f) [m²/s²]
1,5
1,0
0,5
0,0
0,01
0,1
1,0
Freq. [Hz]
Component: U V W
Advanced...
Variance: 14,814
Intensity: 1,19E-01
Simulation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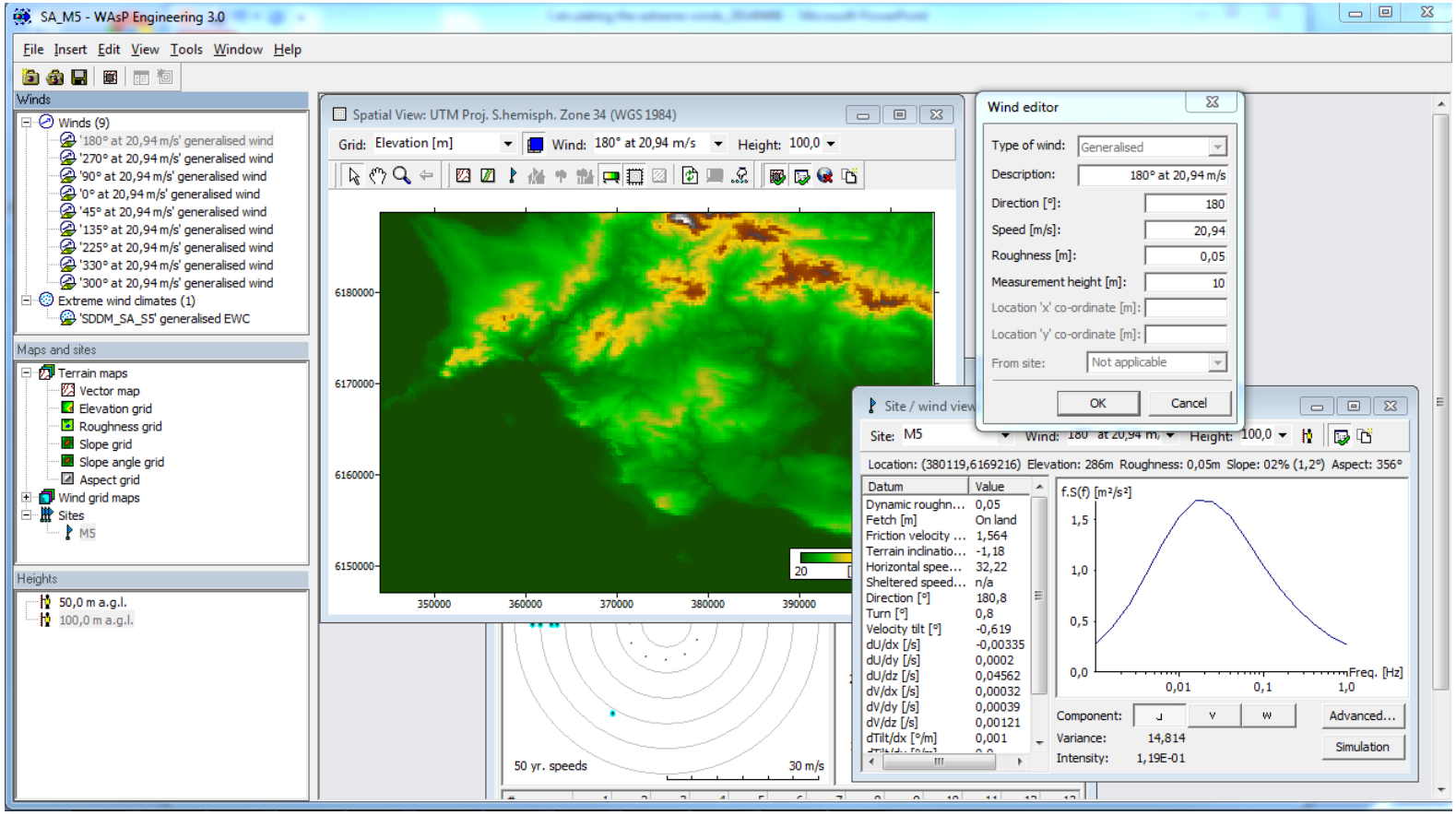
Grid: Elevation [m]
Wind: 180° at 20,94
6180000
6170000
6160000
6150000
350000
20 [m] 786
Generalised EWC 'SDDM_SA_S5'
Standard height: 10,00m a.g.l. Standard roughness 0,05 m. Latitude 34°36'43"
Climate summary
Climate data
[m/s]
All directions
Fitted 50 yr. speed: 21,0 m/s
(19,5 to 22,4 m/s)
Gumbel Alpha: 1,356 m/s
50 yr. speeds 30 m/s
Time [y]
0,1 1,0 10,0 100,0
1 2 3 4 5 6 7 8 9 10
Dir [°] 300 270 300 300 300 300 210 270 270 300
U [m/s] 16,2 15,0 19,6 18,1 16,8 16,9 13,2 15,2 14,4 16,9
Rank 5 3 13 12 7 8 1 4 2 9
Predicted EWC for M5 (380119,6169216) at 100,00m
EWC: SDDM_SA_S5
Site: M5
Height: 100,0
Climate
Data
Corrections
[m/s]
35,0
30,0
25,0
20,0
15,0
All directions
Fitted 50 yr. speed: 30,8 m/s
(28,8 to 32,9 m/s)
Gumbel Alpha: 1,889 m/s
50 yr. speeds 30 m/s
Time [y]
0,1 1,0 10,0 100,0
1 2 3 4 5 6 7 8 9 10 11 12 13
Dir [°] 299 269 299 299 299 299 211 269 269 299 269 269 299
U [m/s] 24,0 22,4 29,1 26,9 24,9 25,0 20,8 22,7 21,5 25,0 26,4 25,0 25,1
Rank 5 3 13 12 6 8 1 4 2 9 11 7 10

Other design parameters

Turbulence Intensity,
Flow Inclination…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