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Extreme gust wind estimation using mesoscale modeling

Larsén, Xiaoli Guo; Kruger, Andries

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Extreme gust wind estimation using mesoscale modeling

Xiaoli Guo Larsén
Wind Energy Department, Risø campus, Technical University of Denmark

Andries Kruger
Climate Service, South African Weather Service, Pretoria, South Africa

Review: Gust from Gaussian process

$$u_{gust} = u_{mean} + k_p \sigma_u$$

$$k_p = \sqrt{2\ln(\nu T)} + \frac{\gamma}{\sqrt{2\ln(\nu T)}}$$

$$\nu = \sqrt{m_2 / m_0} \qquad m_n = \int_0^\infty \omega^n S(\omega)\, d\omega$$

Review: Gust from Gaussian process

Gust duration e.g. 3 s

T is often set as 10 min

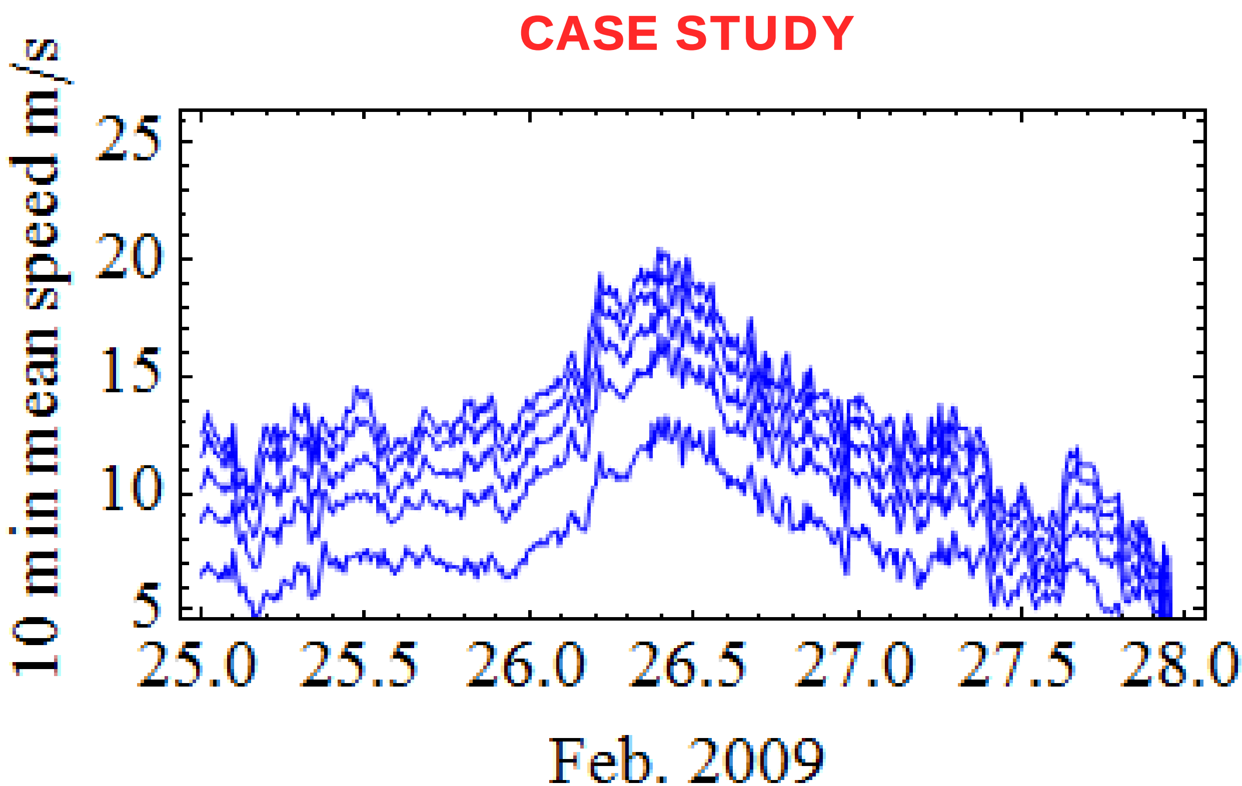
Steady turbulence

Neutral stability

Negligible turbulence from upstream separation zone

Spectral model (e.g. here, the neutral Kaimal)

Review: Gust from Gaussian process

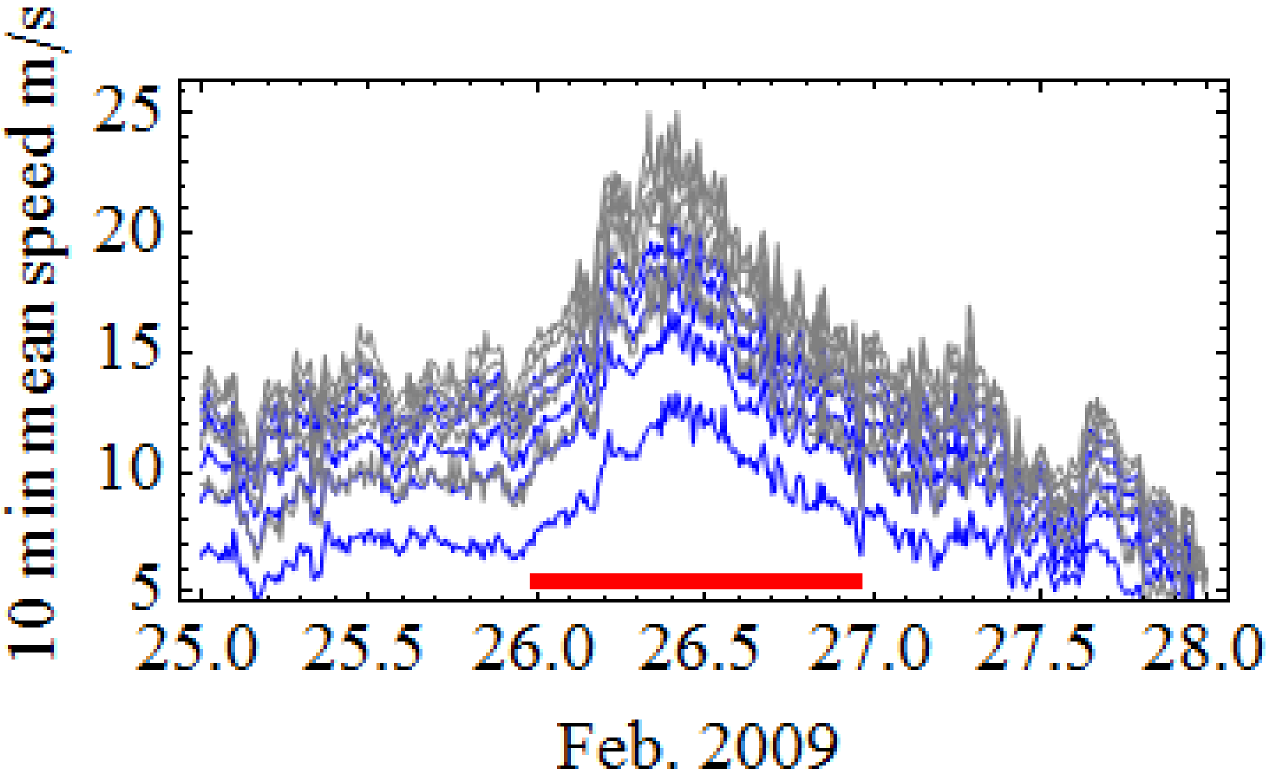


Mean wind measurements
100 m
80 m
60 m
40 m
10 m

Høvsøre, due to the availability of profiles of mean wind, direction and turbulence data

Review: Gust from Gaussian process

CASE STUDY

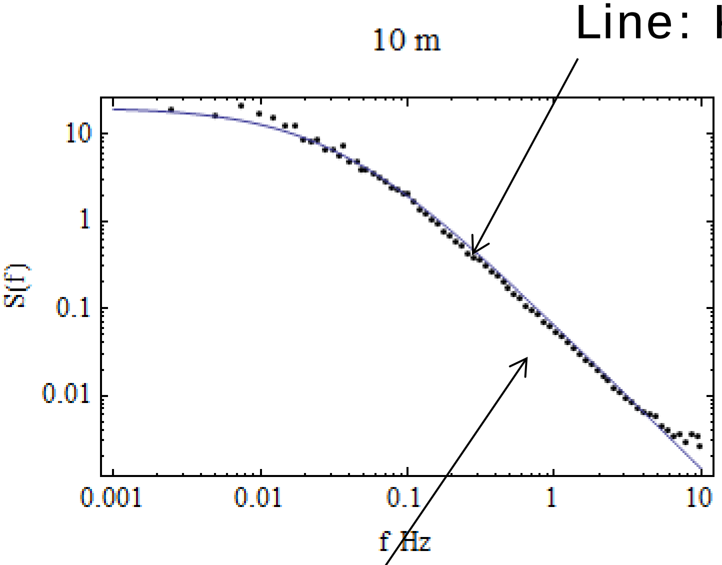


Mean wind and gust measurements
100 m
80 m
60 m
40 m
10 m

Høvsøre, due to the availability of profiles of mean wind, direction and turbulence data

Review: Gust from Gaussian process

CASE STUDY

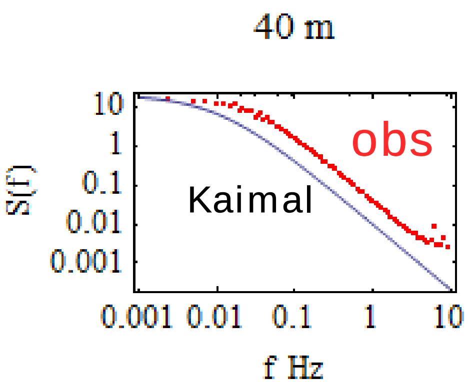


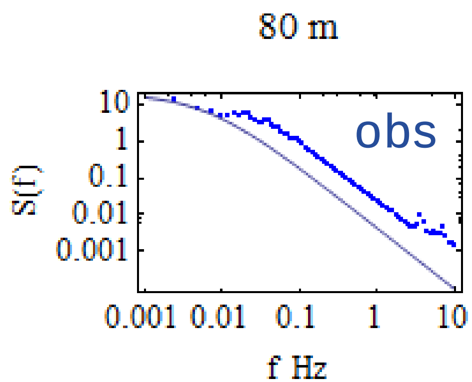
Line: Kaimal

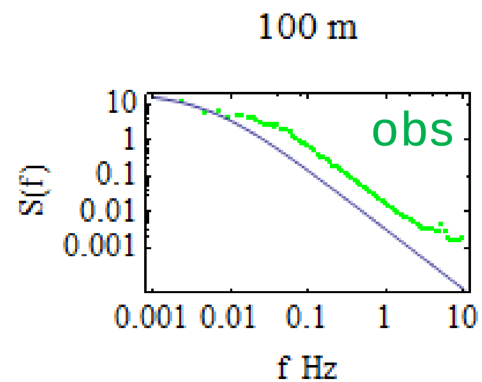
Dots: Mean spectrum of 144 10-min wind speed at 10 m on 26th

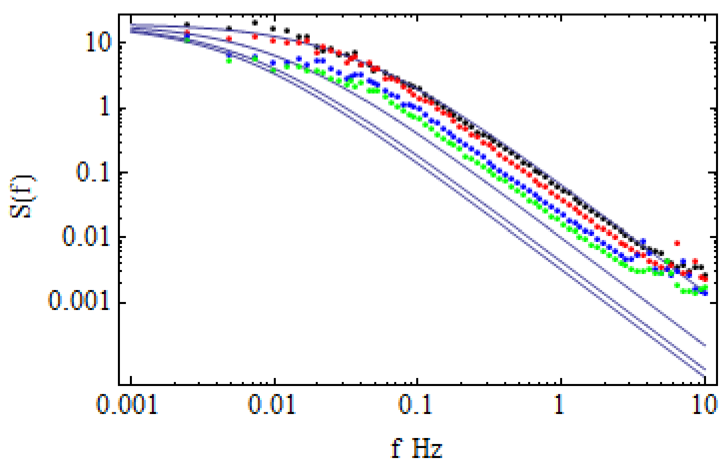
Review: Gust from Gaussian process

CASE STUDY









Review: Gust from Gaussian process

CASE STUDY

$$u_{gust} = u_{mean} + k_p \sigma_u$$

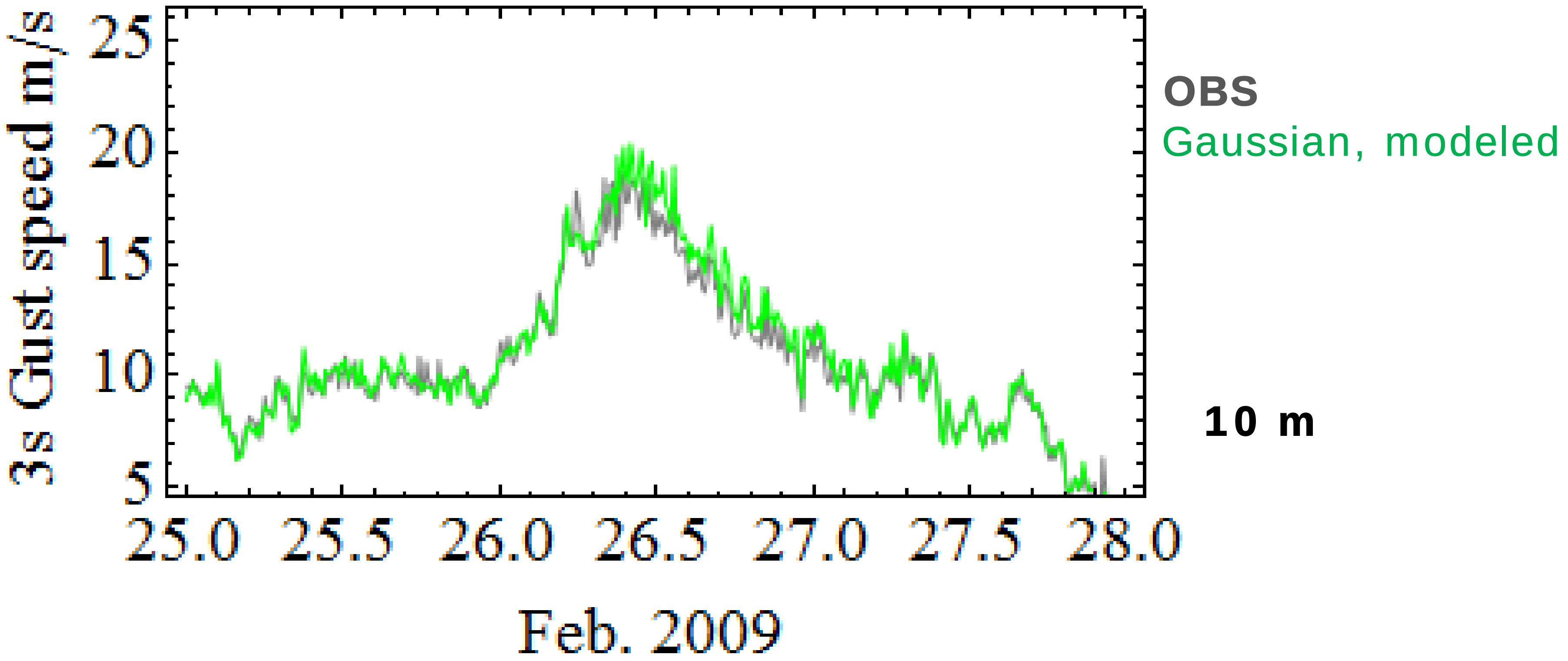
$$k_p = \sqrt{2\ln(\nu T)} + \frac{\gamma}{\sqrt{2\ln(\nu T)}}$$

	10m	40m	80m	100m
OBS	3.13	3.04	3.16	3.22
Gaussian Kaimal	3.39	3.29	3.25	3.24

$$\nu = \sqrt{m_2 / m_0} \qquad m_n = \int_0^{\infty} \omega^n S(\omega) \, d\omega$$

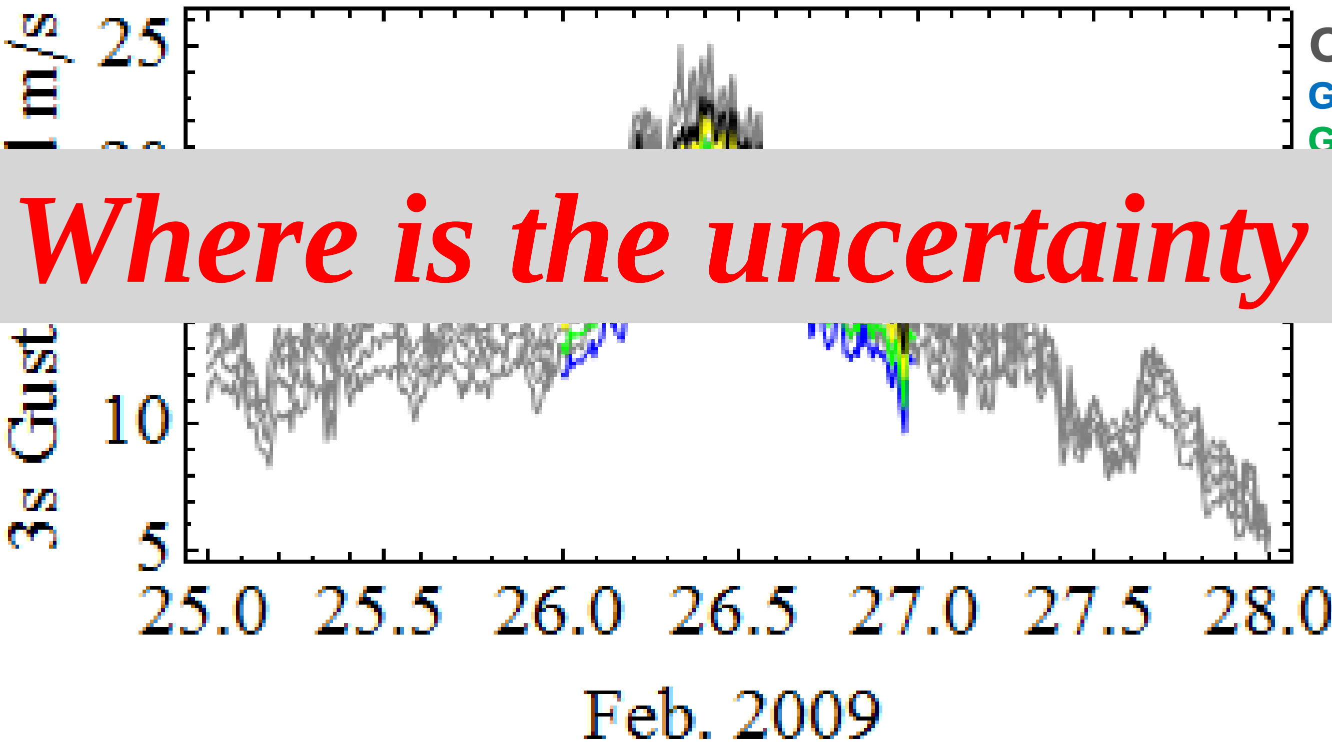
Review: Gust from Gaussian process

CASE STUDY



Review: Gust from Gaussian process

CASE STUDY



Where is the uncertainty highest?

40 m – 100 m

The non-local gust

Brausseur’s concept of the gust

Purpose here

Purpose here

- To verify the non-local gust concept introduced by Brasseur (2001)
- To apply this to obtain atlas of extreme gust for the South Africa Wind Atlas project

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- To apply this to obtain atlas of extreme gust for the South Africa Wind Atlas project

Methods

- To apply Brausseur’s concept of the gust
- To use WRF to model storms
- To estimate the 50-year extreme gust value

Method

- Brausseur’s concept of the gust and estimation

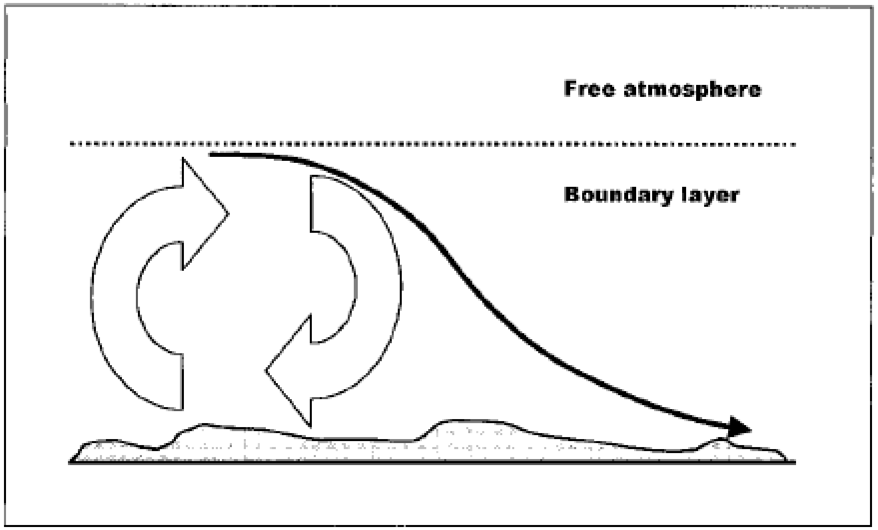


FIG. 1. Proposed mechanism explaining gusts observed at the surface: turbulent eddies are triggering the deflection of air parcels flowing in the boundary layer downward to the surface.

Method

- Brausseur’s concept of the gust and estimation

Lower and upper bound

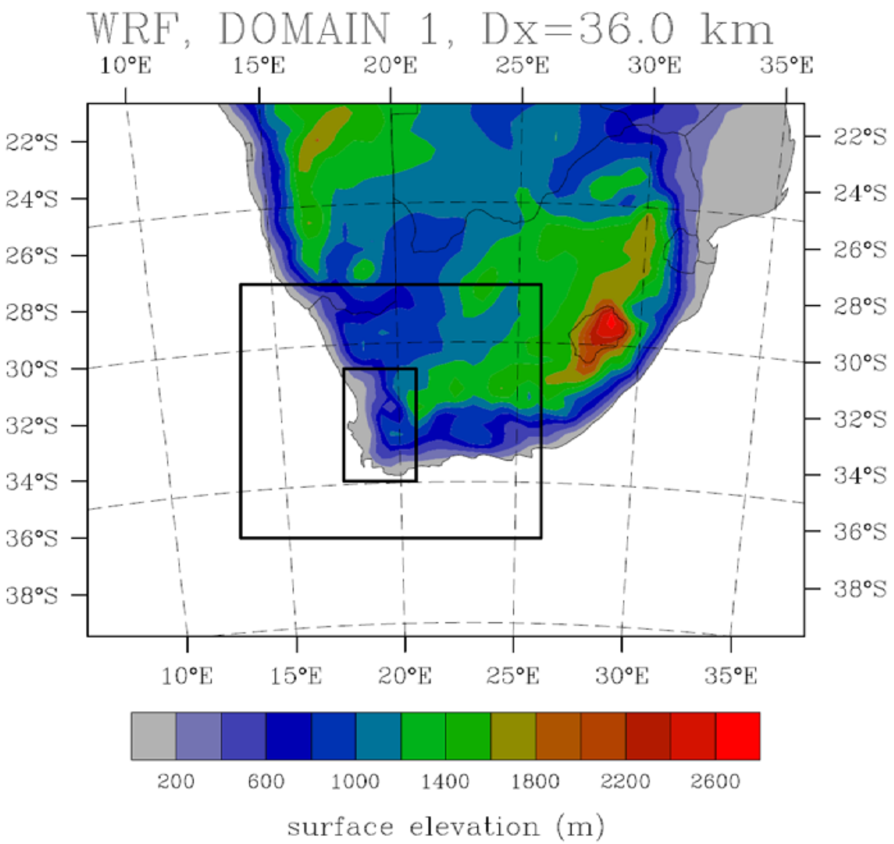
Method

- WRF modeling of storms, Western Cape

1. Run WRF for the 72 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.



Method

- WRF modeling of storms, Eastern Cape

1. Run WRF for the 175 cases

2. WRF setup:
   - WRF V3.2.1
   - CFSR data, 6 hrly, 1998 - 2010
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   - 36 – 12 – 4 km
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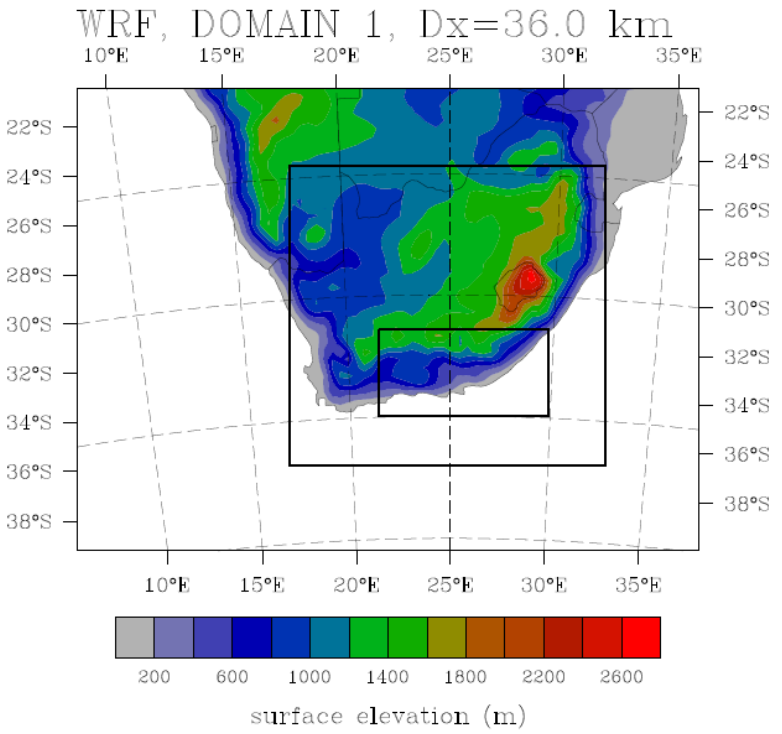
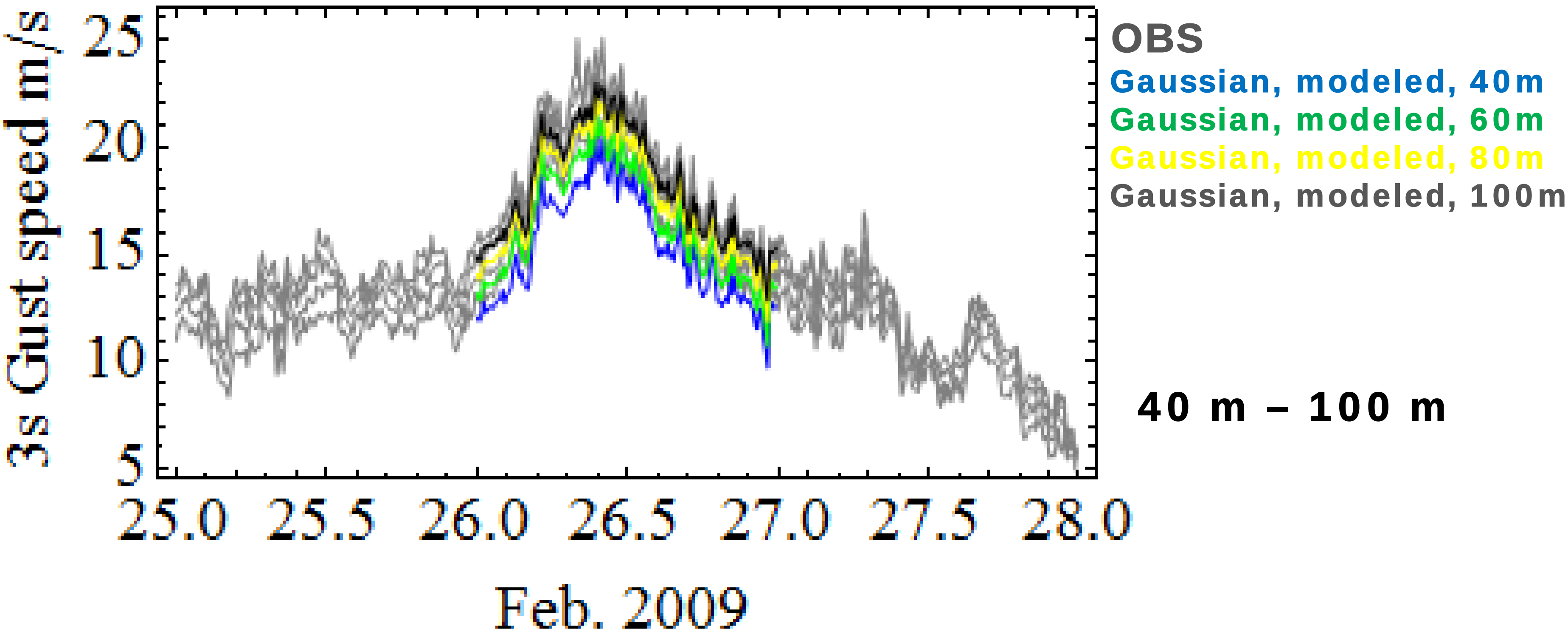


Results

- Verification of the WRF modeled Brasseur gust during individual storms

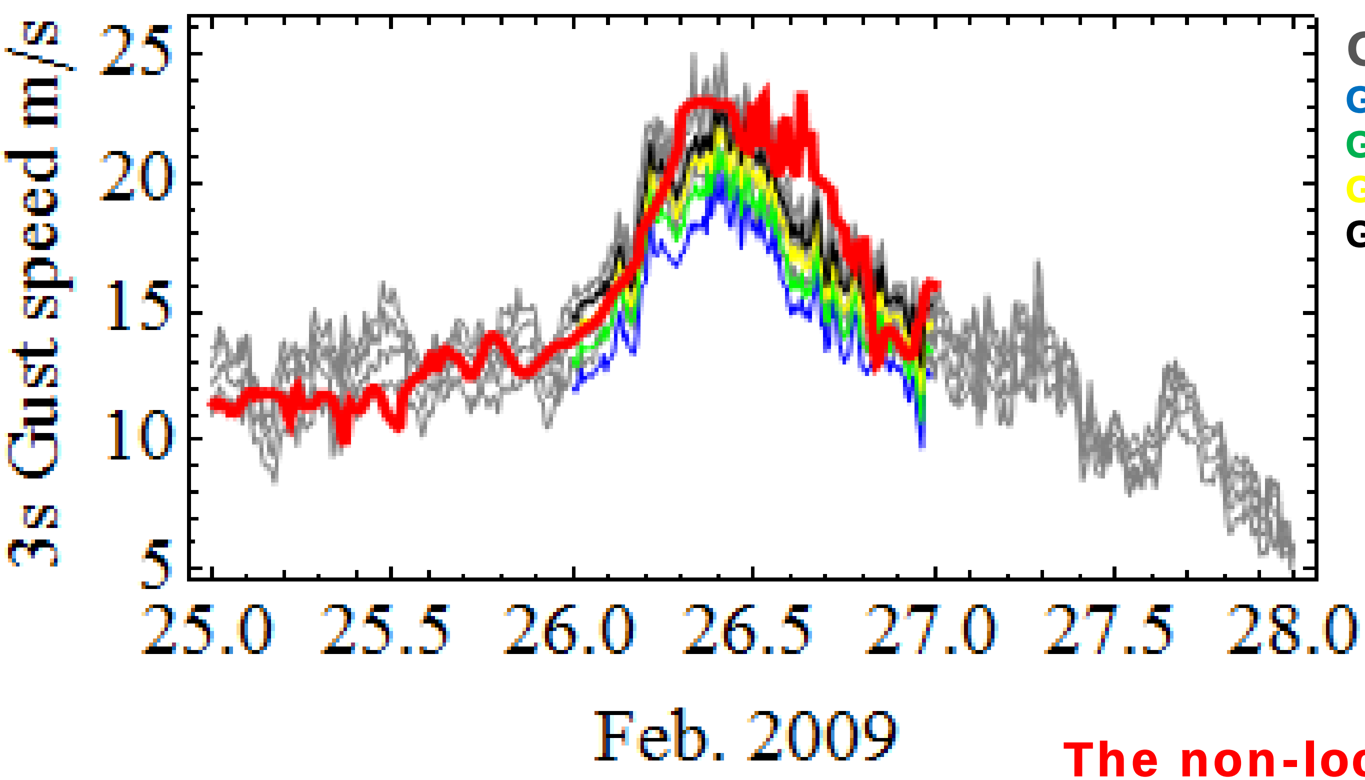
CASE STUDY



40 m – 100 m

Results

- Verification of the WRF modeled Brasseur gust during individual storms



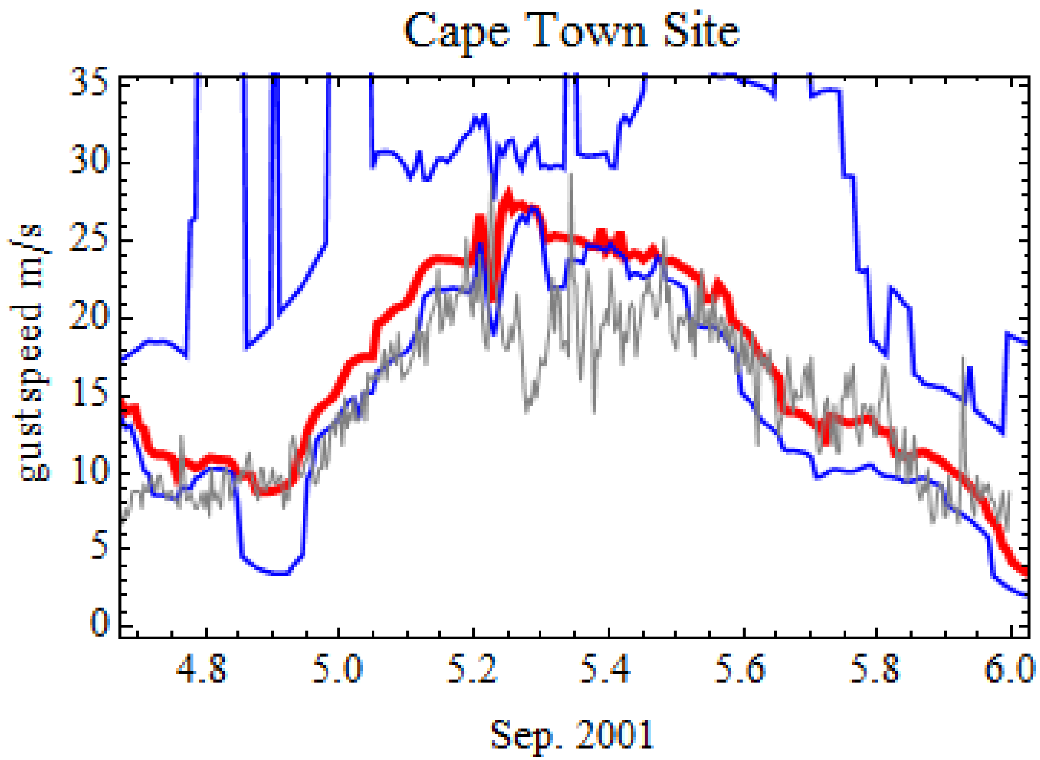
OBS, 3 s
Gaussian, modeled, 40m
Gaussian, modeled, 60m
Gaussian, modeled, 80m
Gaussian, modeled, 100m

WRF, 20s

The non-local gust concept is supported!

Results

- Verification of the WRF modeled Brasseur gust during individual storms



OBS, 10m, 3s

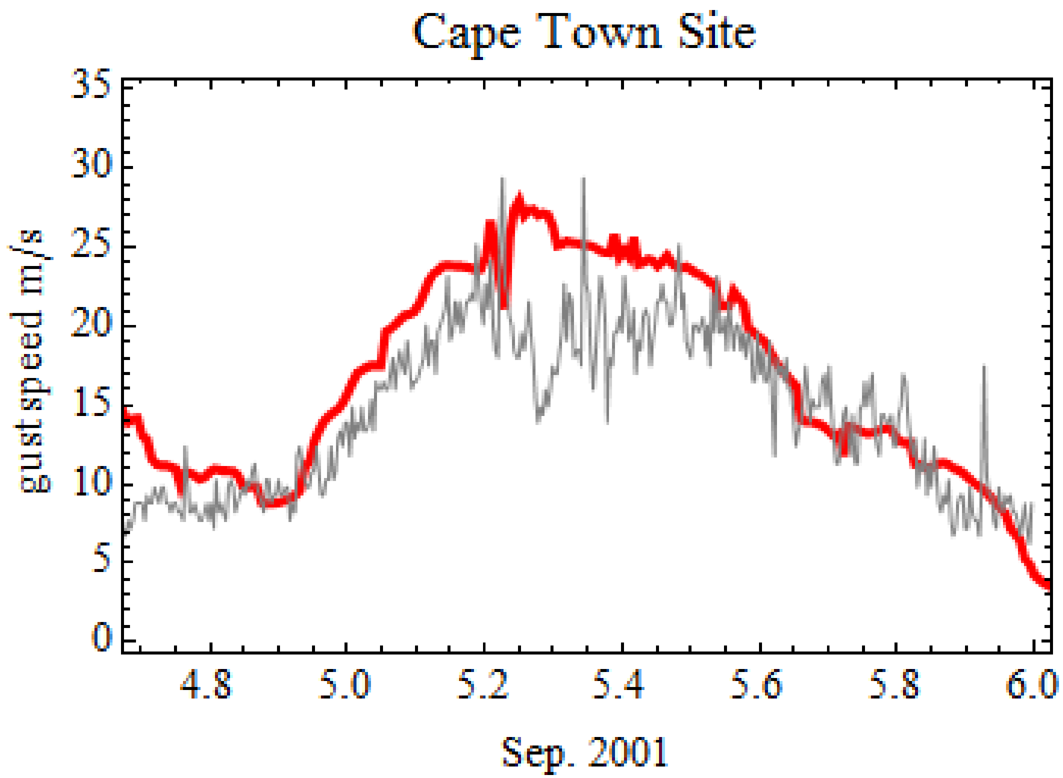
WRF, 20s

WRF,
upper & lower limit

The non-local gust concept is supported!

Results

- Verification of the WRF modeled Brasseur gust during individual storms



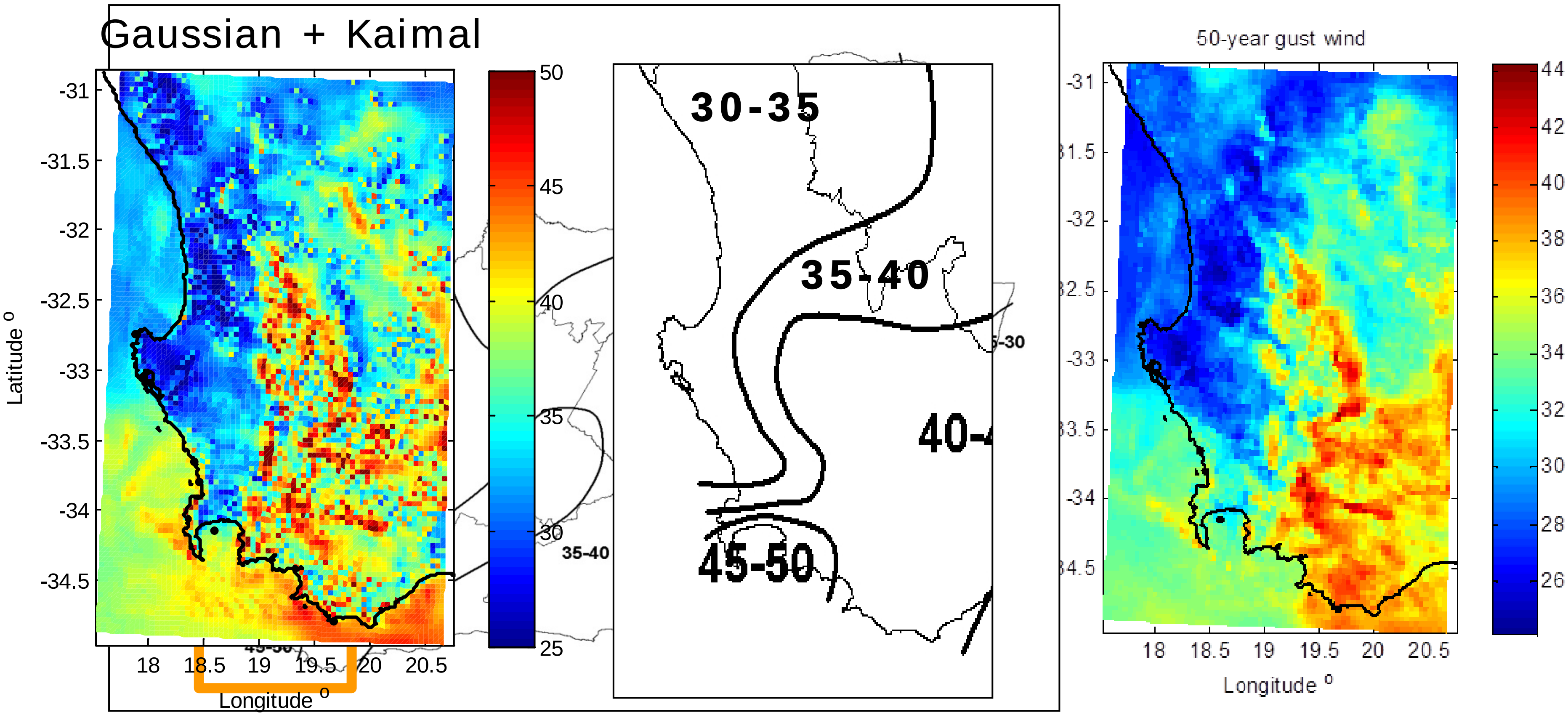
OBS, 10m, 3s

WRF, 20s

The non-local gust concept is supported!

Results

- Atlas of the extreme gust values for South Africa (comparison of measured and modeled values)



Results

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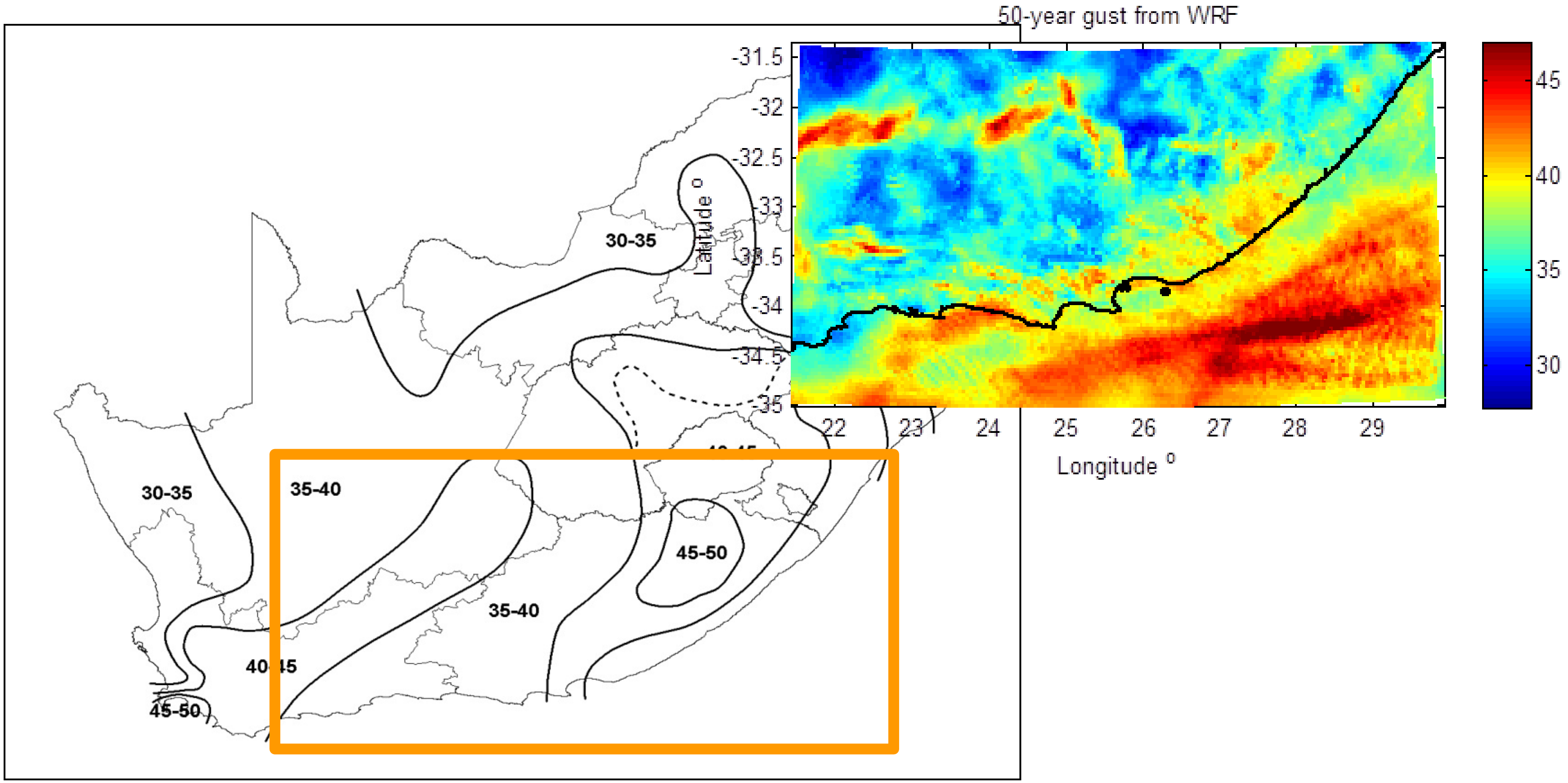
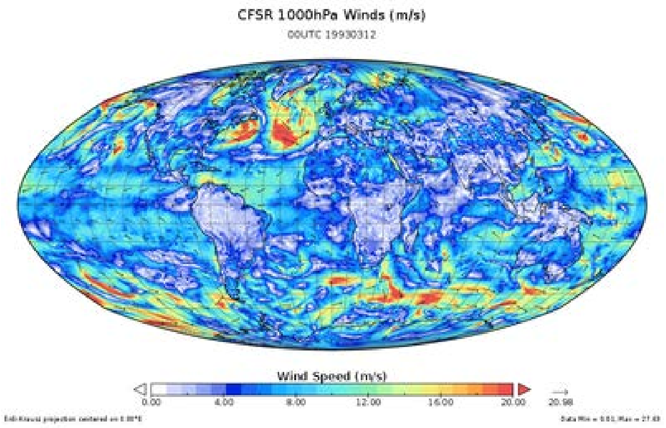
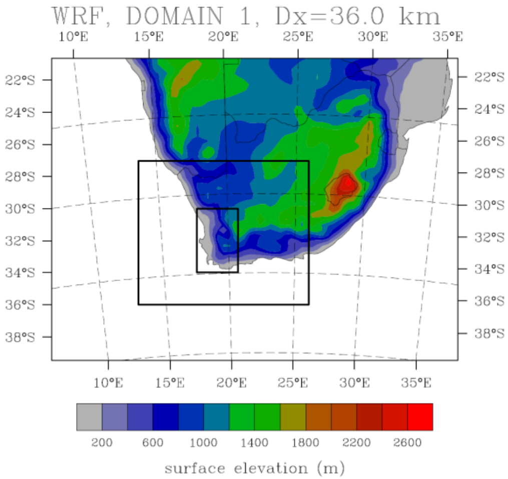
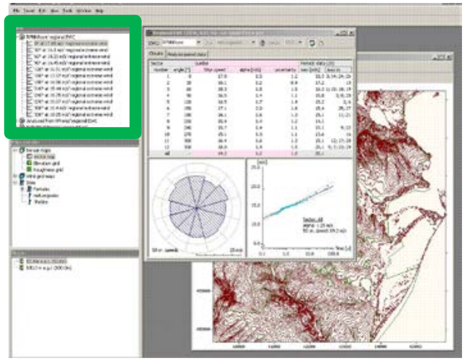


Conclusions

- The model chain







Global **Mesoscale** **Microscale**

Conclusions

- The comparison of Gaussian gust and the non-local gust
  - **Gaussian + neutral Kailmal spectrum**: overestimation of peak factor kp, good estimate of σ_u at 10m but increasing underestimation of σ_u at higher levels. General underestimation of gust at hgiher levels. Heavily dependent on the roughness length. Better for small turbines.
  - **Non-local gust** concept is supported by our study for cyclones/anticyclones. The estimation is good but misses the local impact close to the surface. Useful for tall turbines.

Acknowledgement

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Wind Atlas of South Africa

Danish PSO: X-WiWa

Danish DSF: The Flow Center