Predicting wind gusts by realistic LES weather forecast simulations

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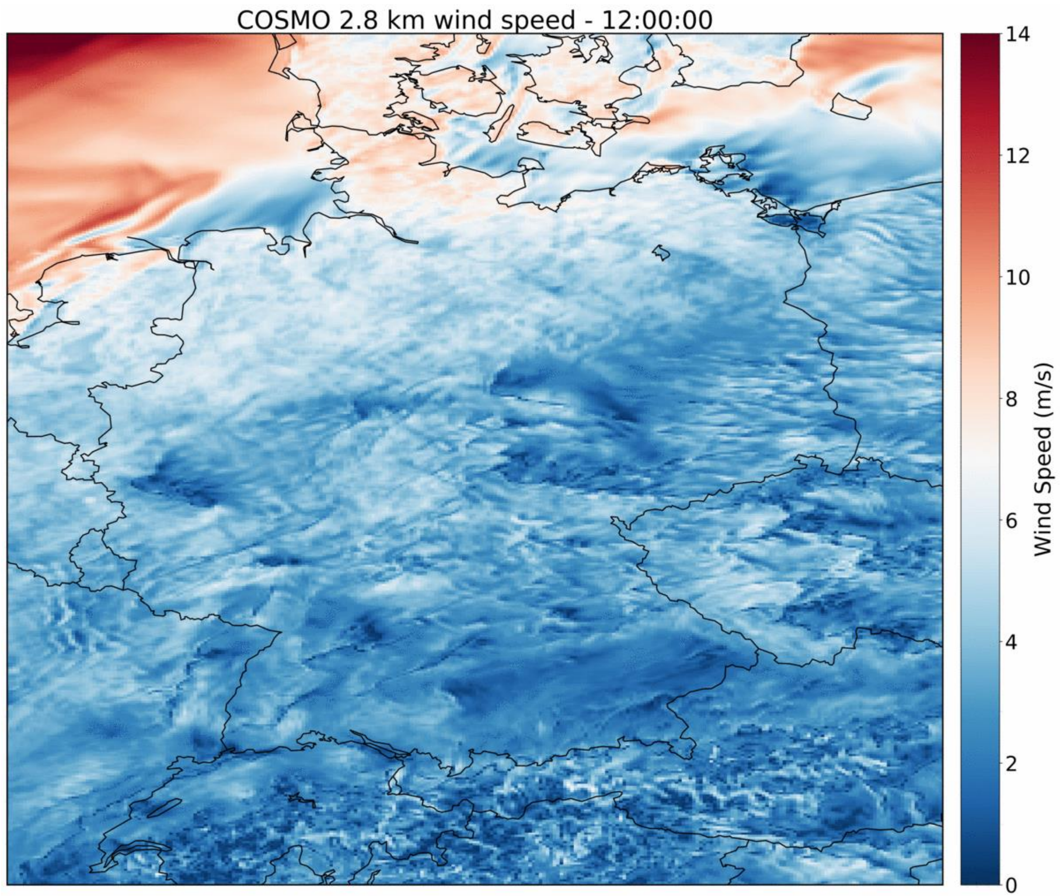
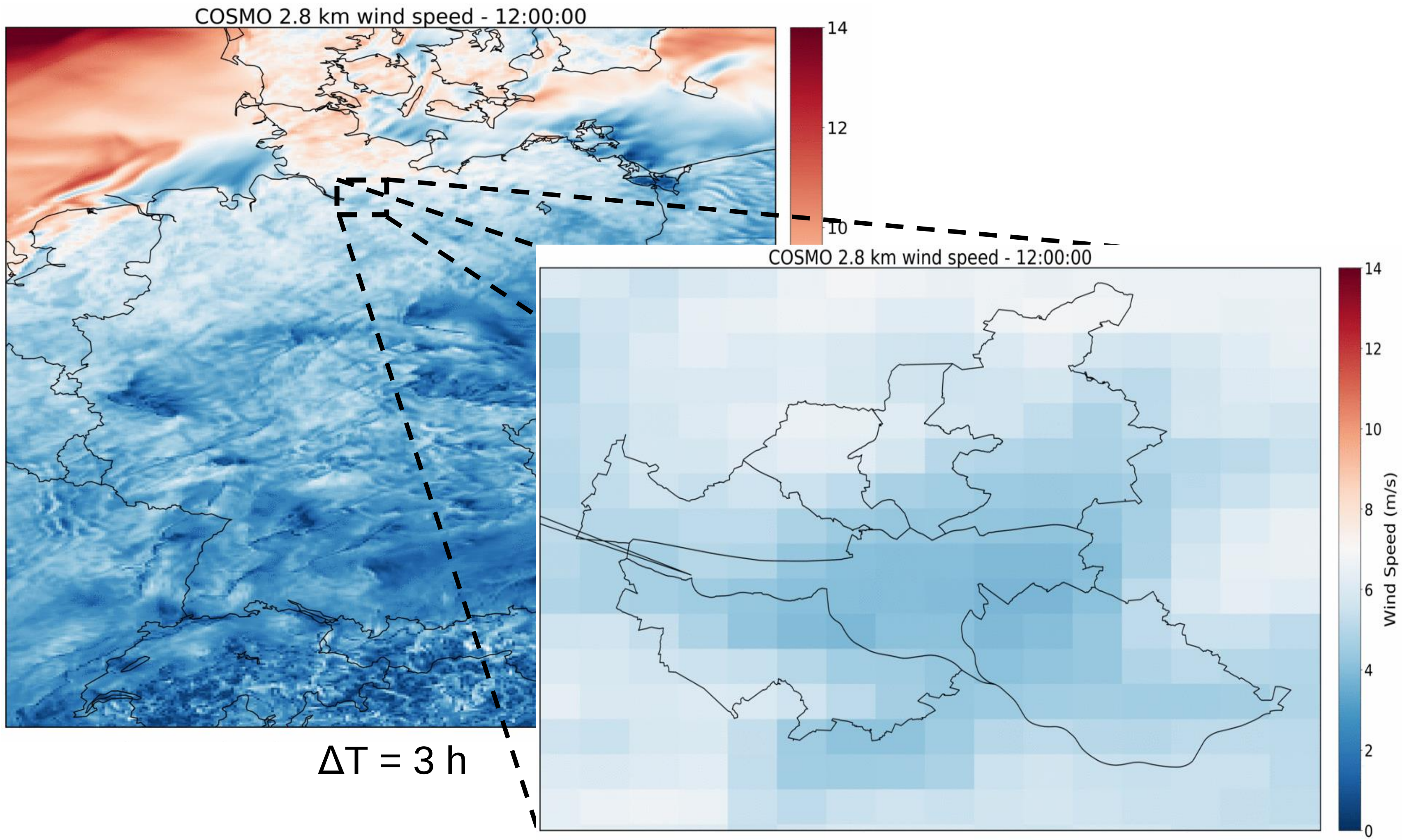
Resolving small wind structures



ΔT = 3 h

Resolving small wind structures



ΔT = 3 h

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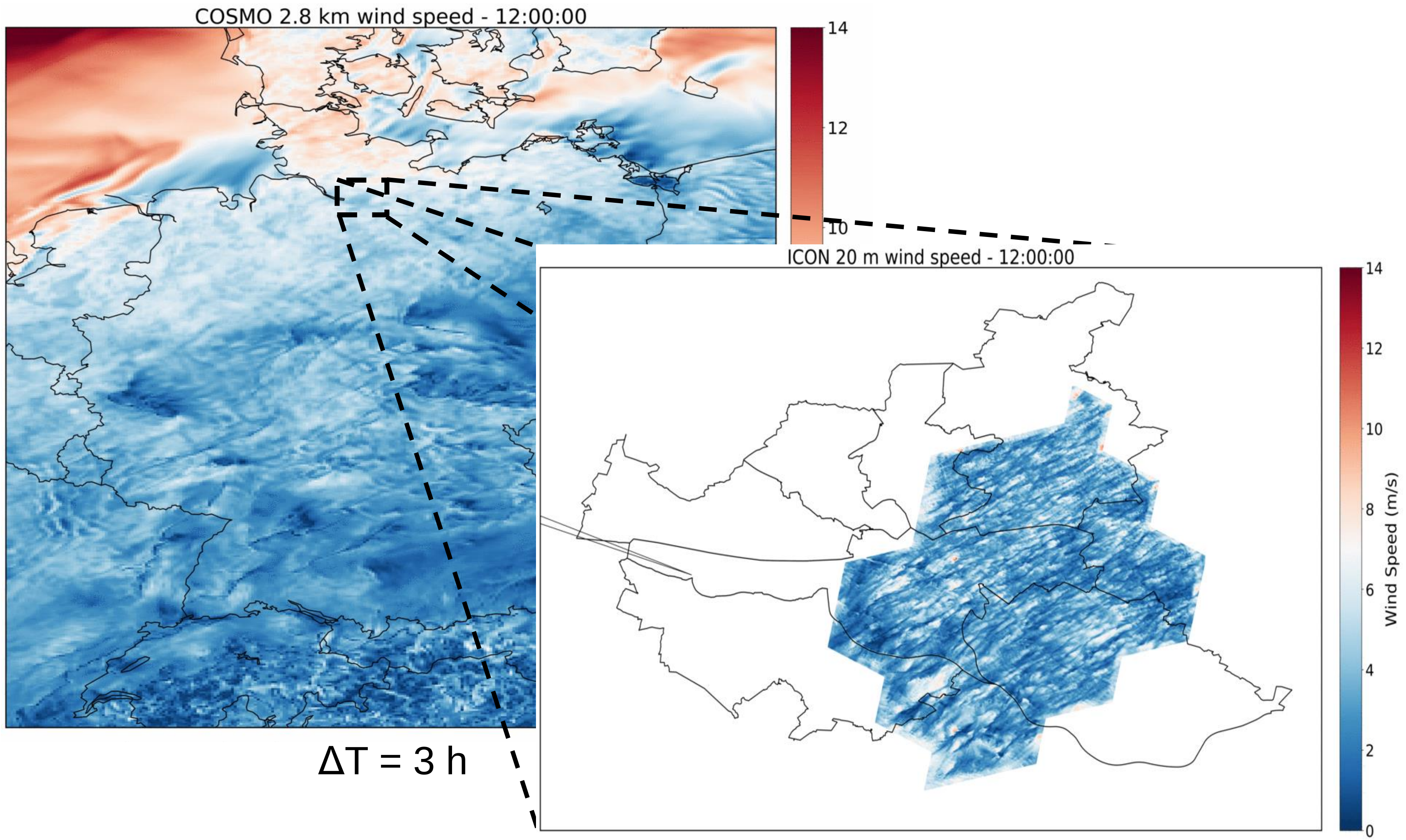
Resolving small wind structures



ΔT = 3 h

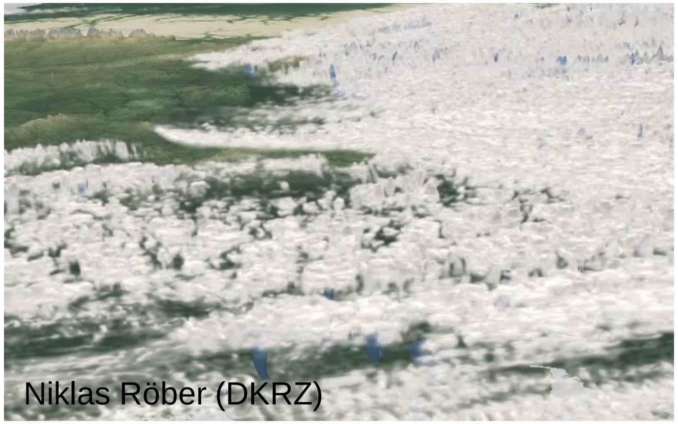
ΔT = 2 min

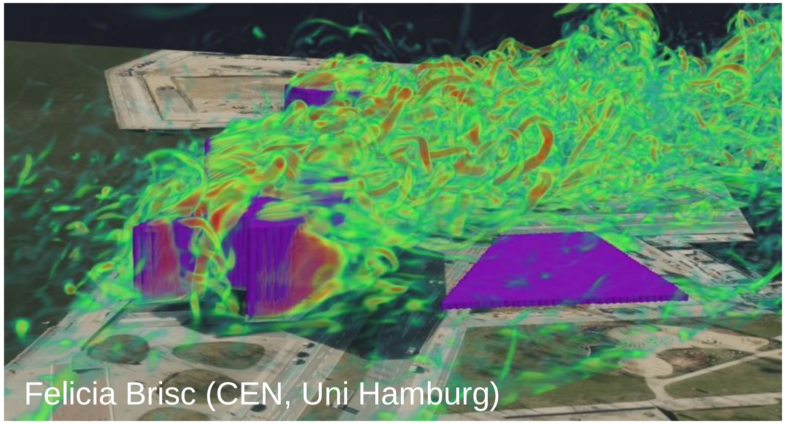
Motivation

- Increasing computational power allow for large **realistic** Large Eddy Simulations (LES).
- Valuable dataset to learn about wind gusts and improve our **understanding of relevant processes**.

Questions:

- How does the vertical wind gust profile look like at an LES model?
- Can a 20 m LES model resolve wind gusts directly?

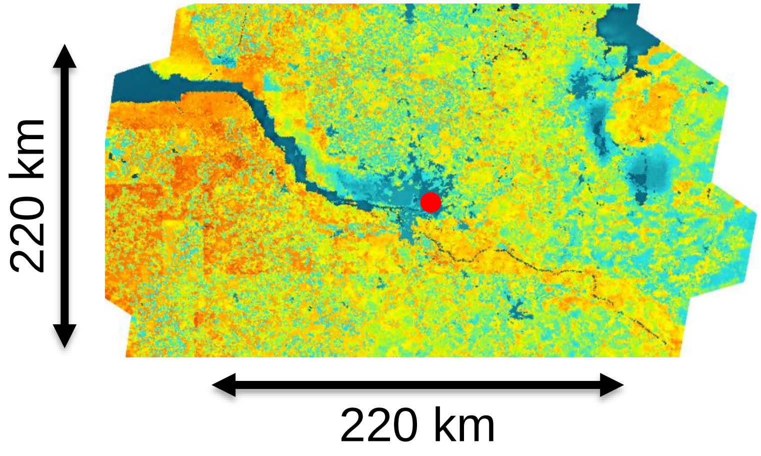

Niklas Röber (DKRZ)


Felicia Brisc (CEN, Uni Hamburg)

ICON-LES and Wettermast Hamburg

ICON LES with 6 nests:

- 624, 312, 156, 78, 39, 20 m.
- Hourly initial-/boundary conditions of COSMO-DE analysis.

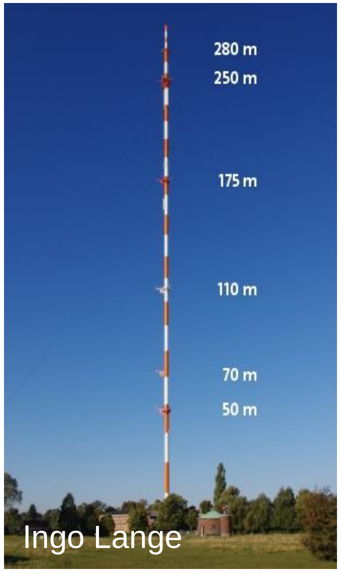


Gust definition:

- Mean wind**:** 10 minute average.
- Wind gust**:** Highest wind speed of 10 min. interval with 3 sec output.

Wettermast Hamburg:

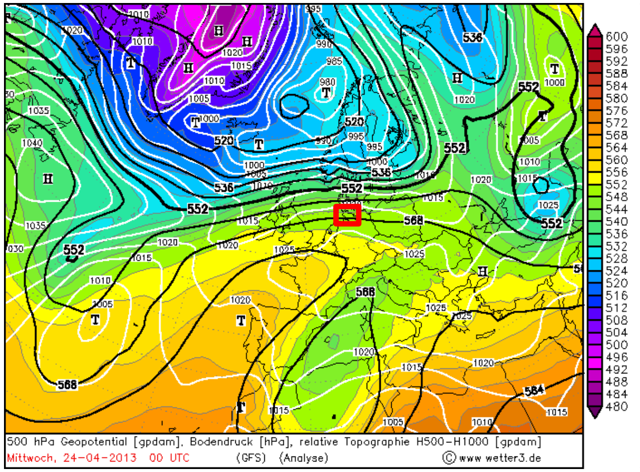
- 300 m height tower.
- 20 Hz ultrasonic wind sensors at 6 heights.
- Located in an industrial area in Hamburg.
- www.wettermast.uni-hamburg.de

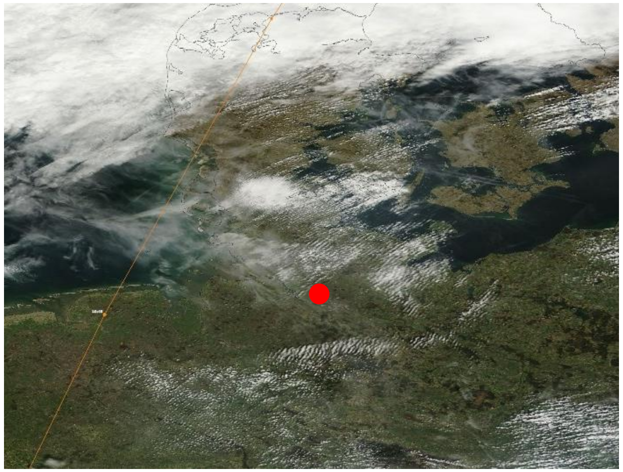


Single Day Case Study

Case 24/04/2013:

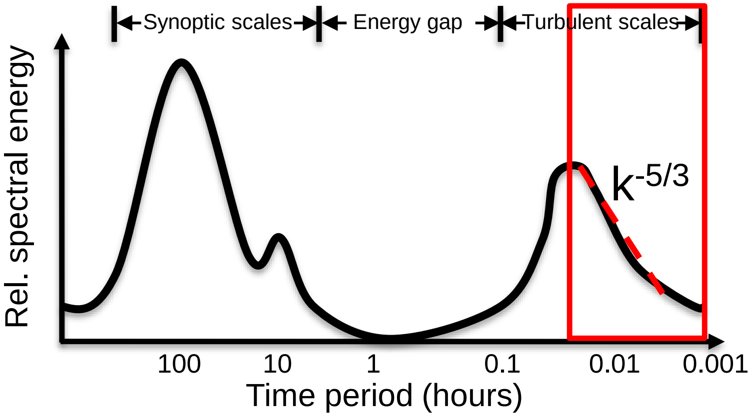
- Almost clear sky, few boundary layer cumulus clouds.
- Back of trough, westerly winds from North Sea.





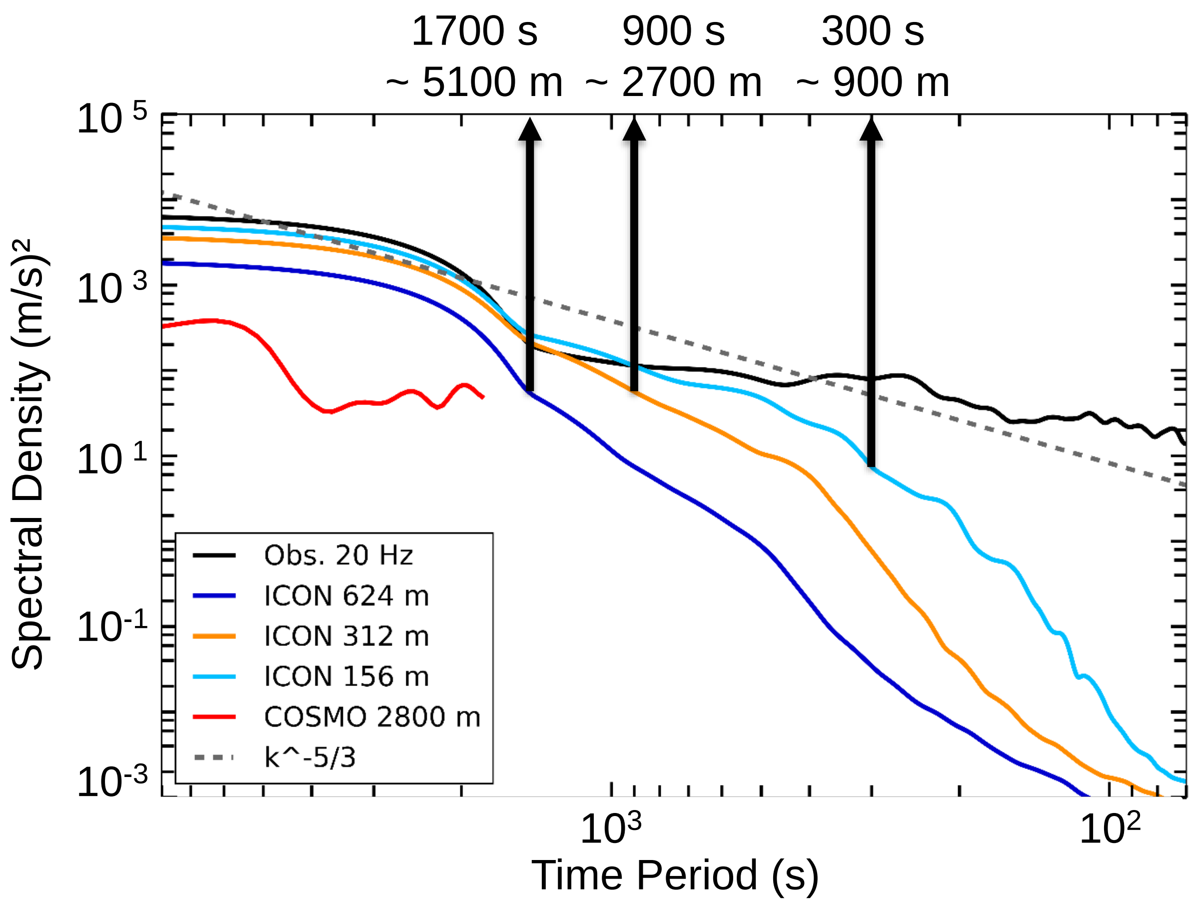
Turbulence Spectrum:

- Empirical Kolmogorov law with $k^{-5/3}$ decrease.



Source Picture: Wetter3.de, NASA Terra Satellite, www.e-education.psu.edu

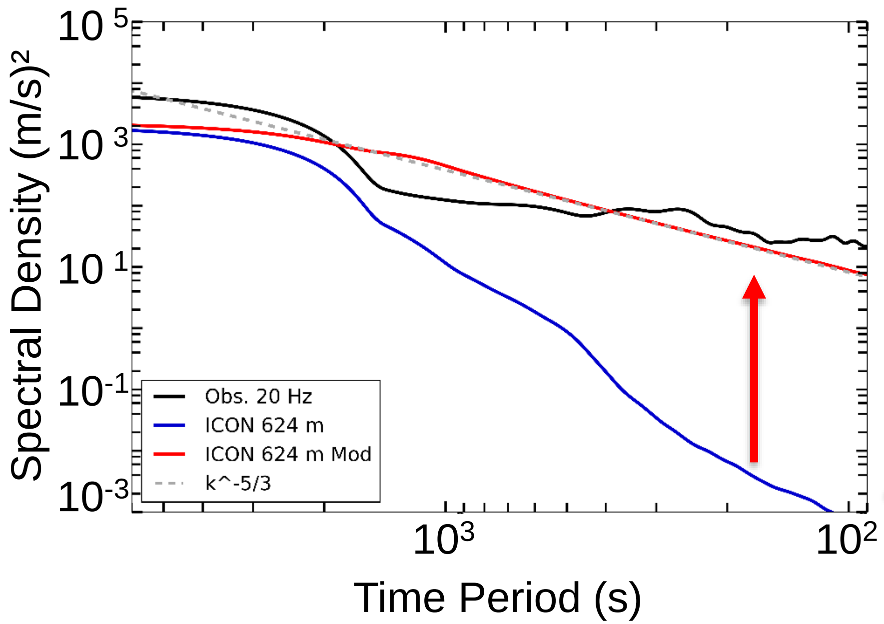
Power Spectrum: 10 m wind – 24/04/2013

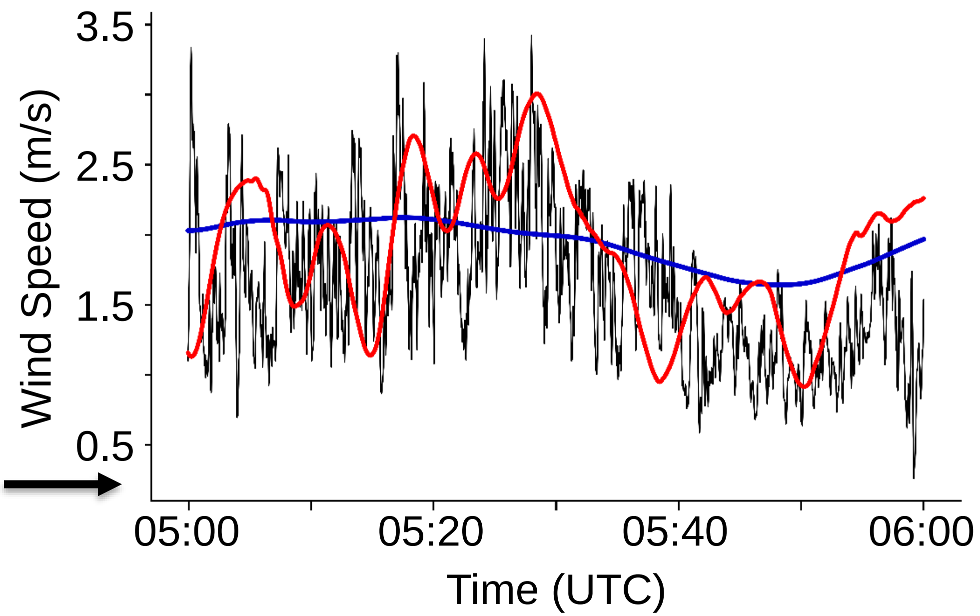


⇒ **Missing turbulence:**

1. Approach: Parameterization by power spectra
2. Approach: Dynamical downscaling

1. Approach: Power Spectrum Parameterization



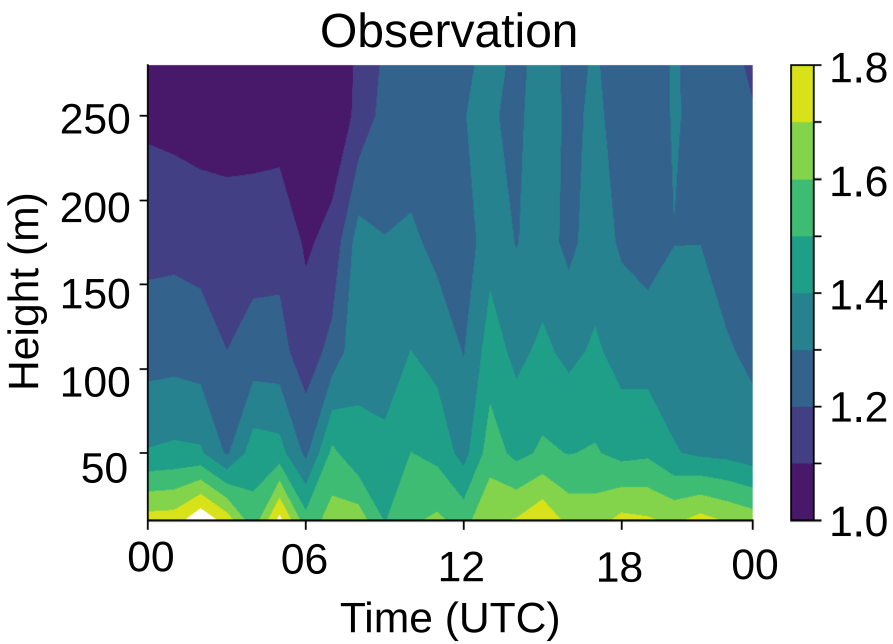


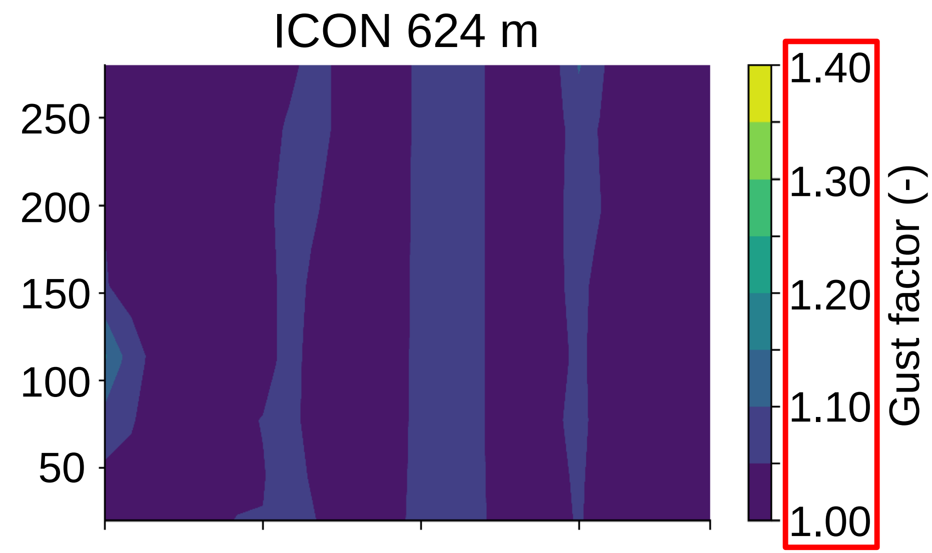
Assumption: Turbulence damped at lower periods.

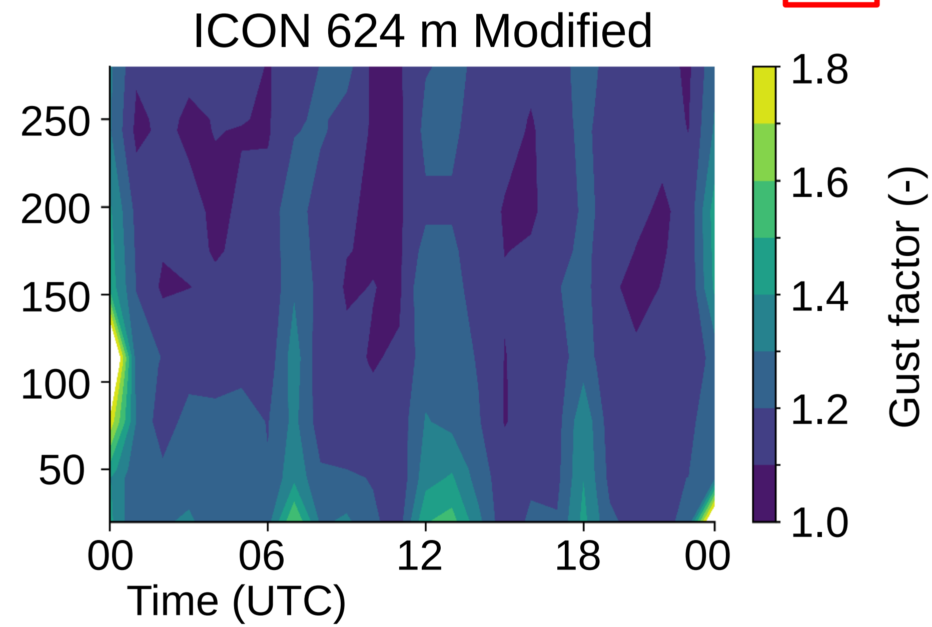
Parameterisation: Add energy to small eddies by adjusting to Kolmogorov law.

- Reconstruction by inverse Fourier transformation.
- Introduces wind speed variability.

1. Approach: Power Spectrum Parameterization

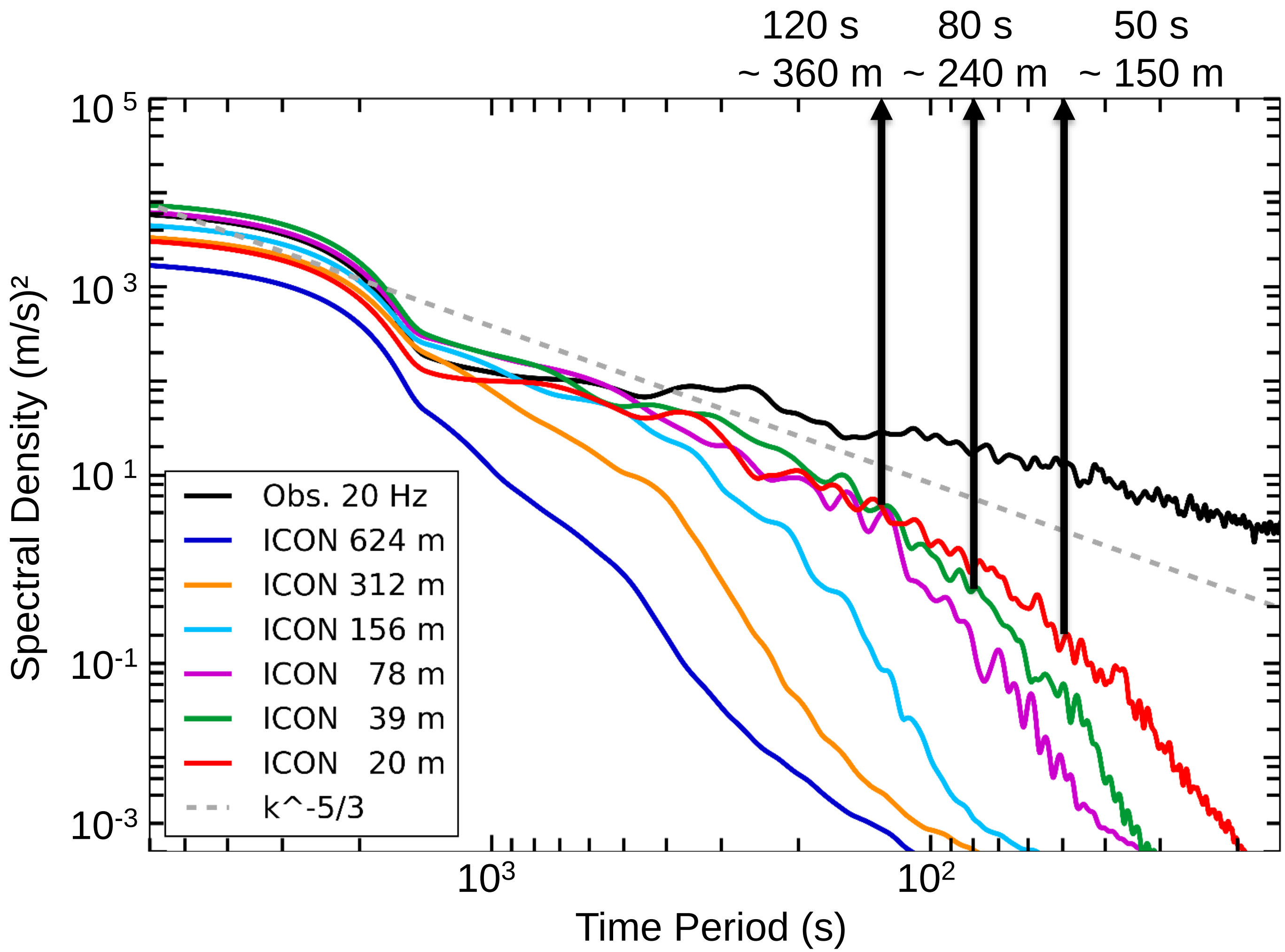






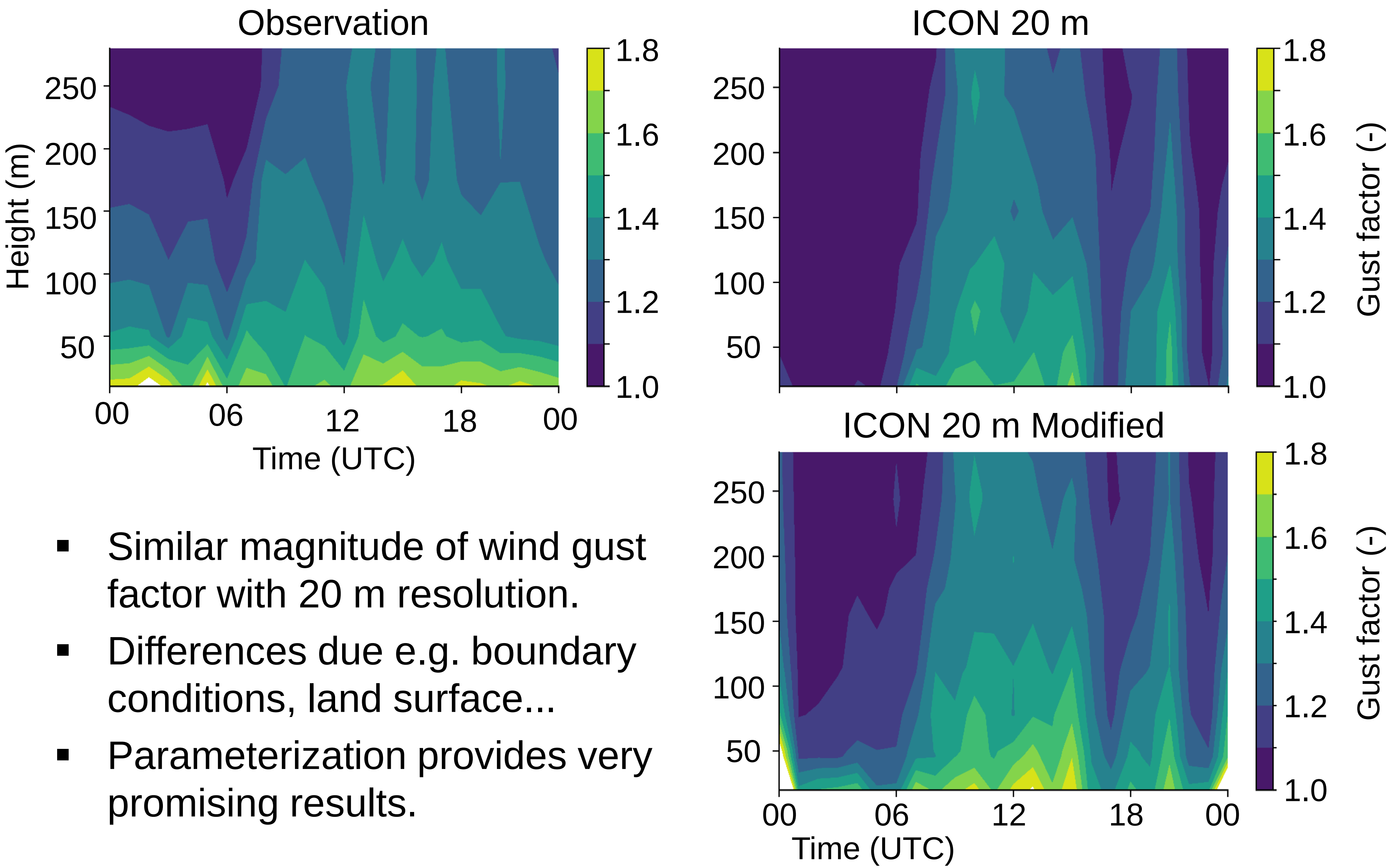
- Almost no wind gusts visible at 624 m resolution.
- Parameterization amplifies small gust structures.

2. Approach: Dynamical Downscaling



Higher resolution resolves more turbulence, e.g. wind gusts.

1. Approach: Power Spectrum Parameterization



- Similar magnitude of wind gust factor with 20 m resolution.
- Differences due e.g. boundary conditions, land surface...
- Parameterization provides very promising results.

Conclusions

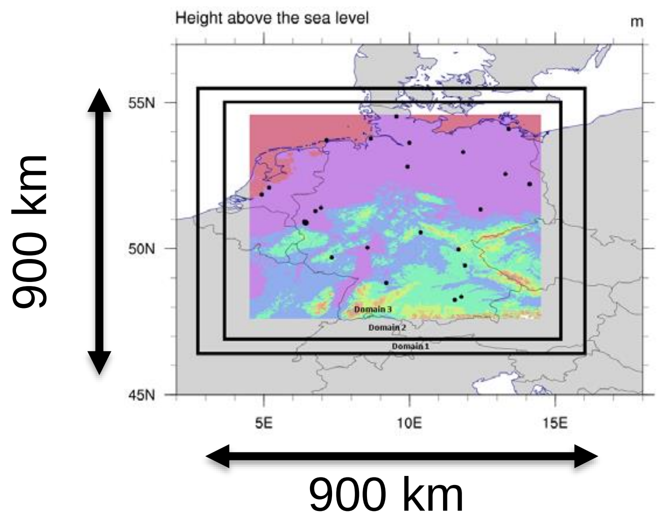
- Wind gusts are significantly underestimated by ICON 624 m.
- Spectrum parameterization inserts additional variability for wind gusts, but not the right structure using ICON 624 m.
- ICON LES with 20 m resolution shows wind gust structures, but effective time resolution is still one magnitude away form gusts.
- Spectrum parameterized wind gusts of ICON 20 m look promising.
- LES Simulations provide new insights into underlaying processes of wind gusts and offer great potential for case studies.

Thank you for your attention!

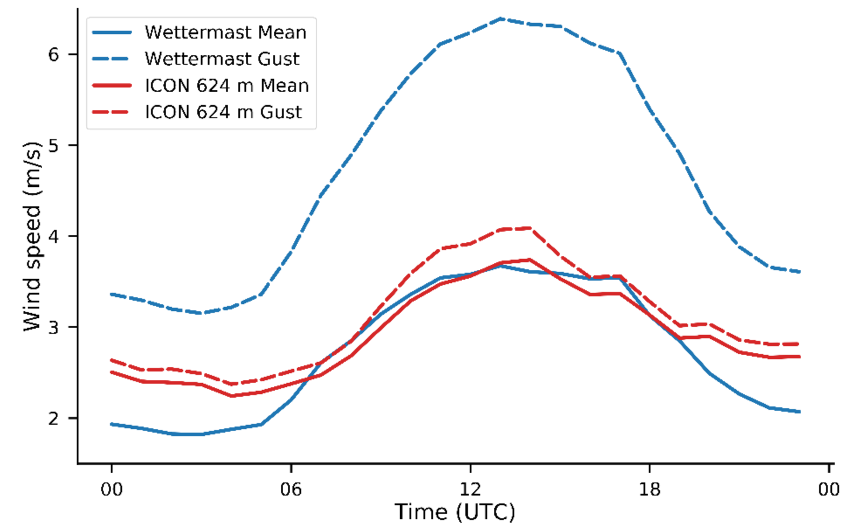
Questions?! Ideas?!

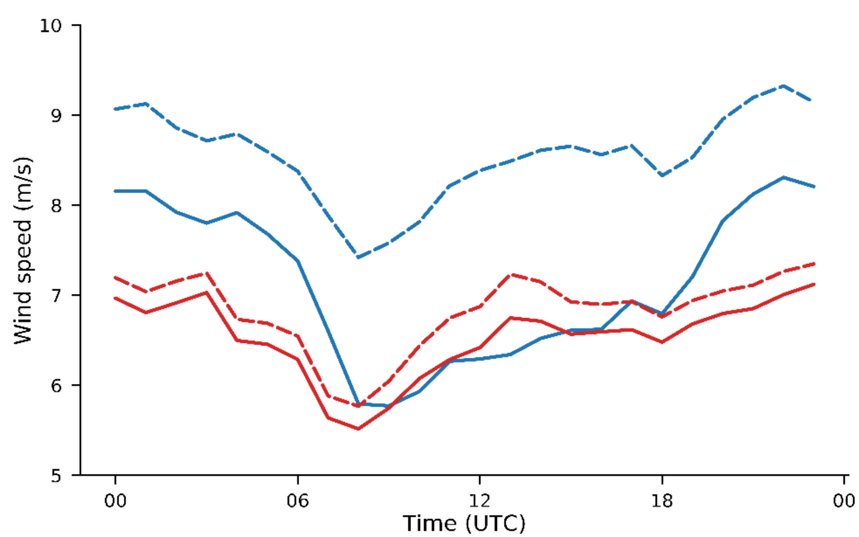
Mean diurnal cycle wind and gusts

HD(CP)^2 High definition clouds and precipitation for advancing climate prediction



- Germany wide realistic ICON LES with 624 m for June 2016.





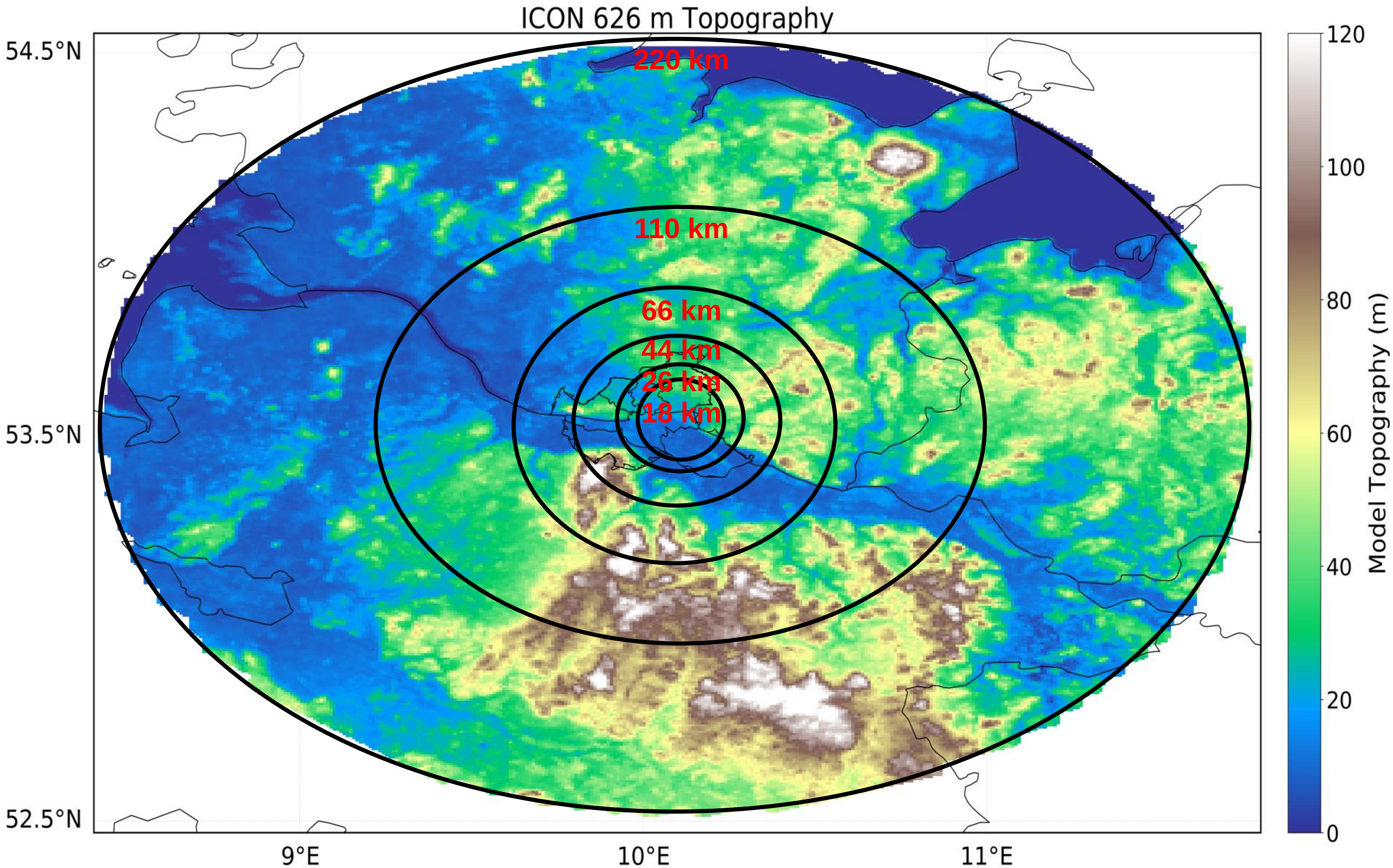
- Diurnal cycle well captured, except during night.
- Underestimation of wind gusts by up to 8 m/s.

Source Picture: Forschung Aktuell MPG, Januar 2016

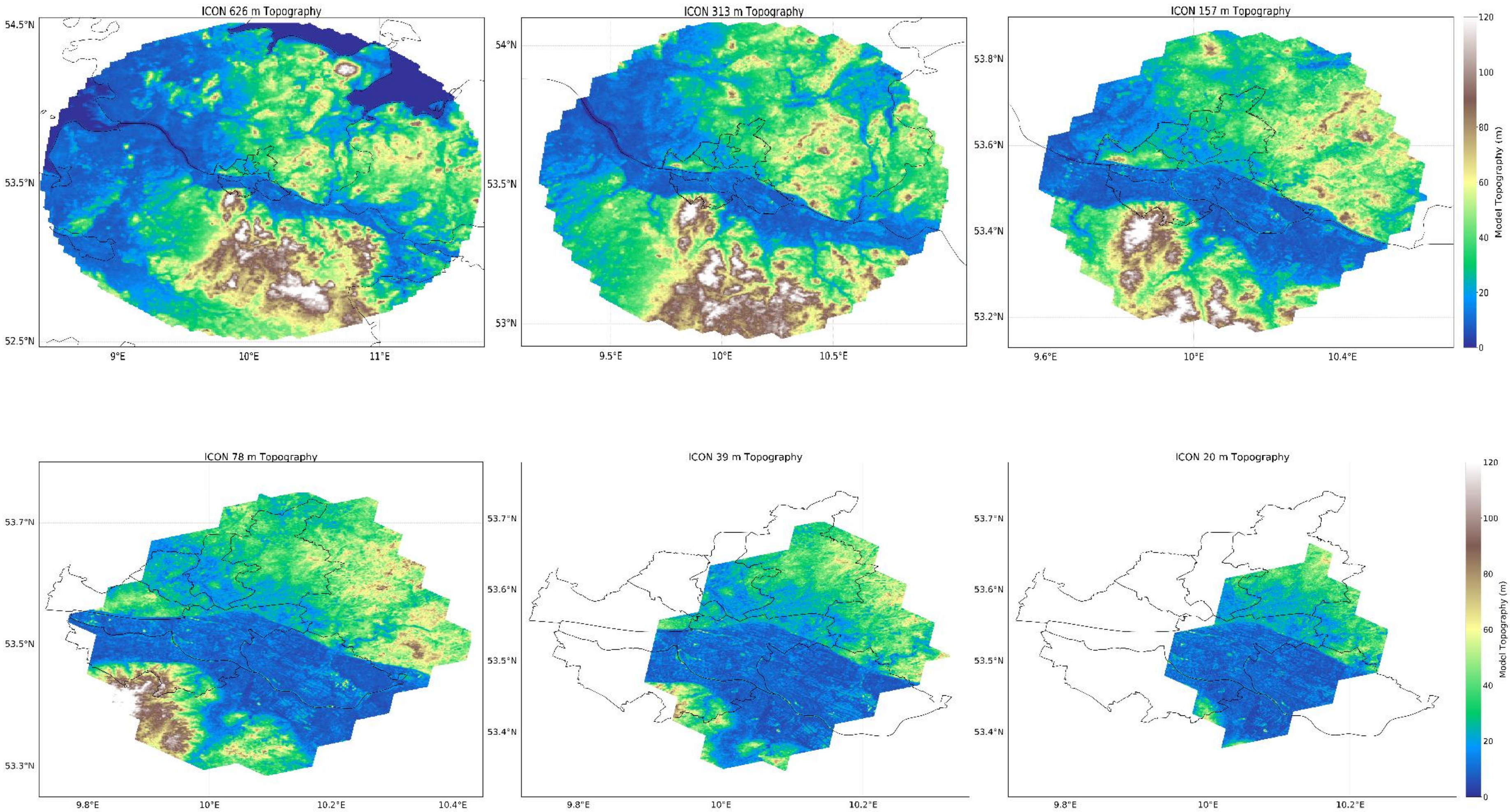
ICON Height Levels

Level number:	**Height of half levels (m)**	**Layer thickness (m)**
140	466.982	55.417
141	411.564	53.570
142	357.994	51.609
143	306.385	49.507
144	256.878	47.231
145	209.648	44.728
146	164.919	41.923
147	122.997	38.683
148	84.314	34.760
149	49.554	29.554
150	20.000	20.000
151	0.000	0.000

ICON Domains – 6 Nests



ICON Domains – 6 Nests



ICON 20 m Zoom