ForWind
Center for Wind Energy Research

RAVE
RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums

Characterization of Wind Power Fluctuations and Prediction

RAVE-Project: Grid Integration of Offshore Wind Farms

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Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

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Forschungszentrum Jülich

Coordination

Fraunhofer IWES

Outline

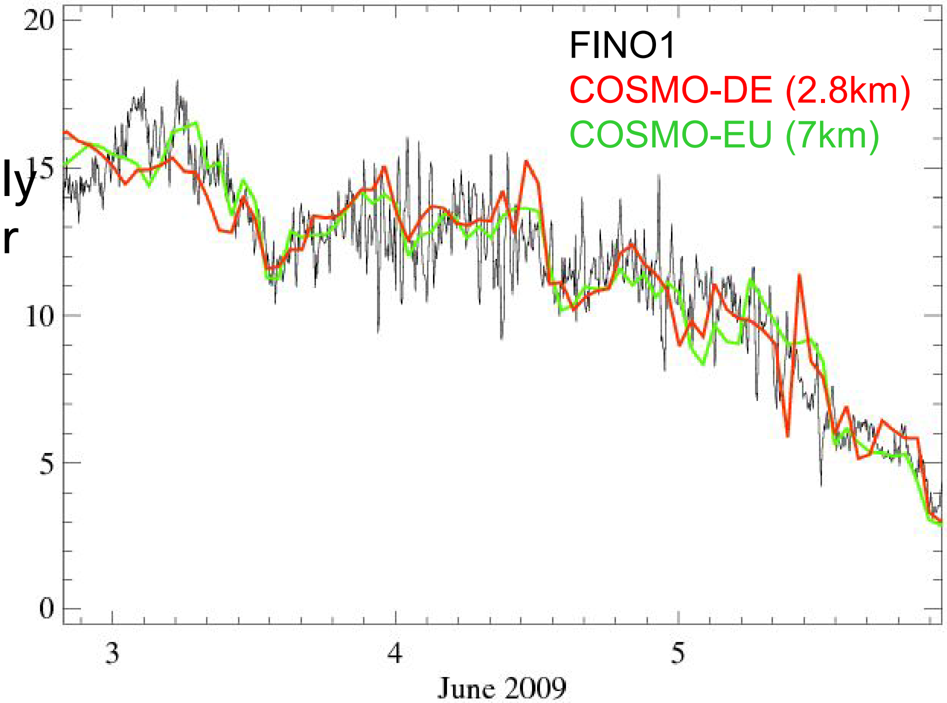
- ➢Motivation
- ➢Test Case: Cold Surge over the North Sea
- ➢Metric to quantify wind power fluctuations
- ➢Dependence on wind speed and thermal stability
- ➢Summary and Outlook

Motivation:

➢Known wind power fluctuations at Horns Rev

➢Very strong wind speed fluctuations are observed at FINO1 in 5min averages from 1Hz cup anemometer (equivalent to spatial smoothing at Alpha Ventus)

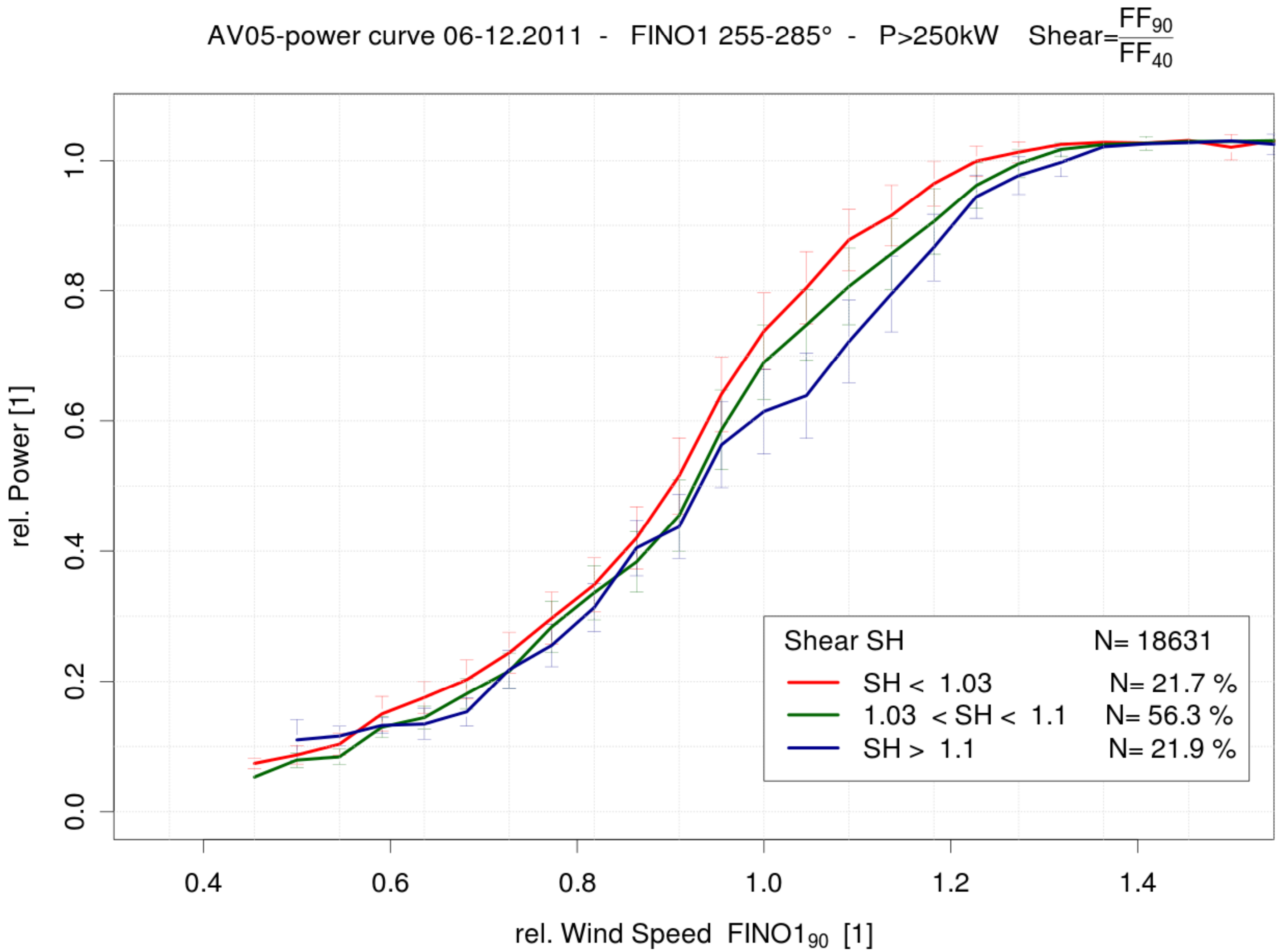
Operational NWP models have hourly time resolution (or coarser)



Key Problem:
wind fluctuations occur due to sub-grid processe that are not explicitely modelled yet (in NWP).

→link with large-scale variables (e.g. stability)

Influence of Thermal Stability on Wake Effects



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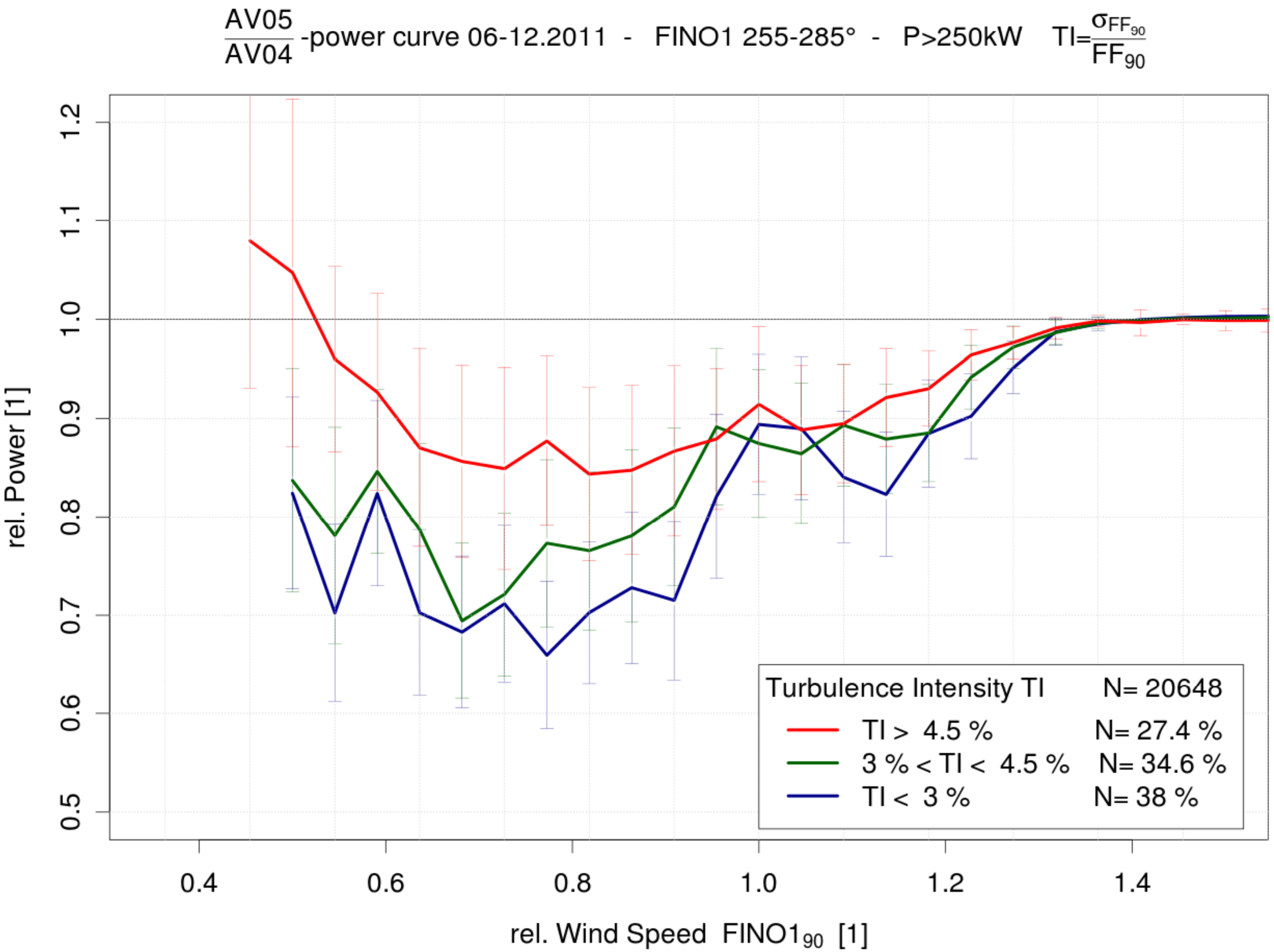
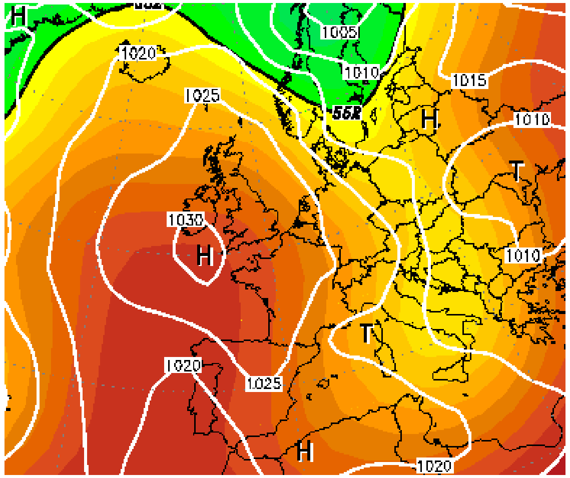
Influence of Turbulence on Wake Effects

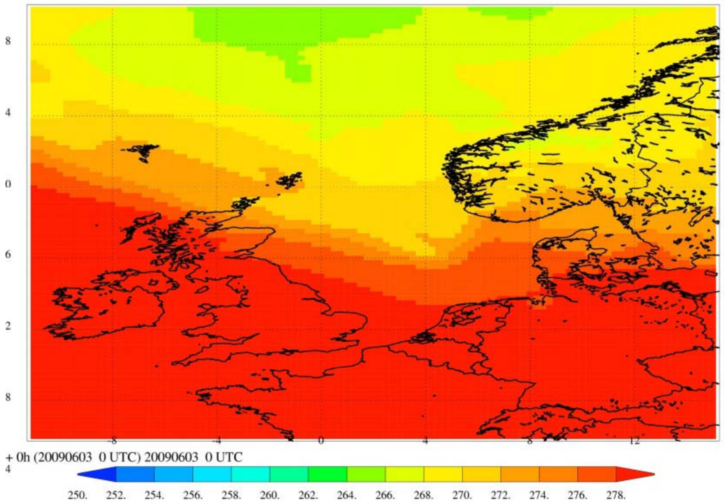


Test Case: Cold surge (4 June 2009)

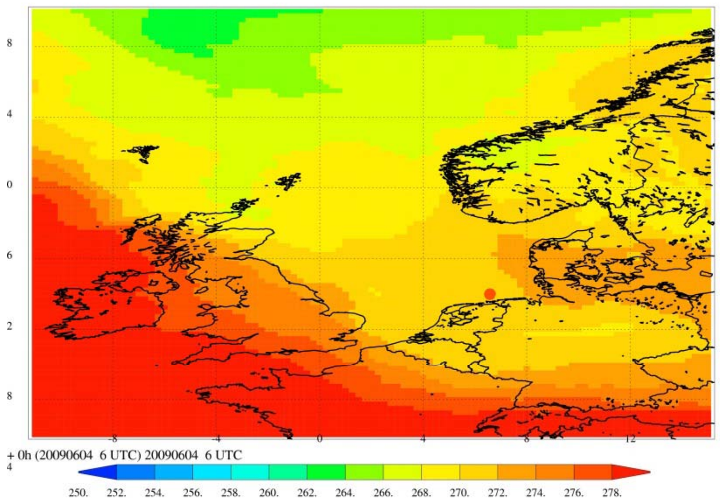
Synoptic Situation at 4 June 2009, 0UTC



850hPa Temp at 3 June, 0UTC

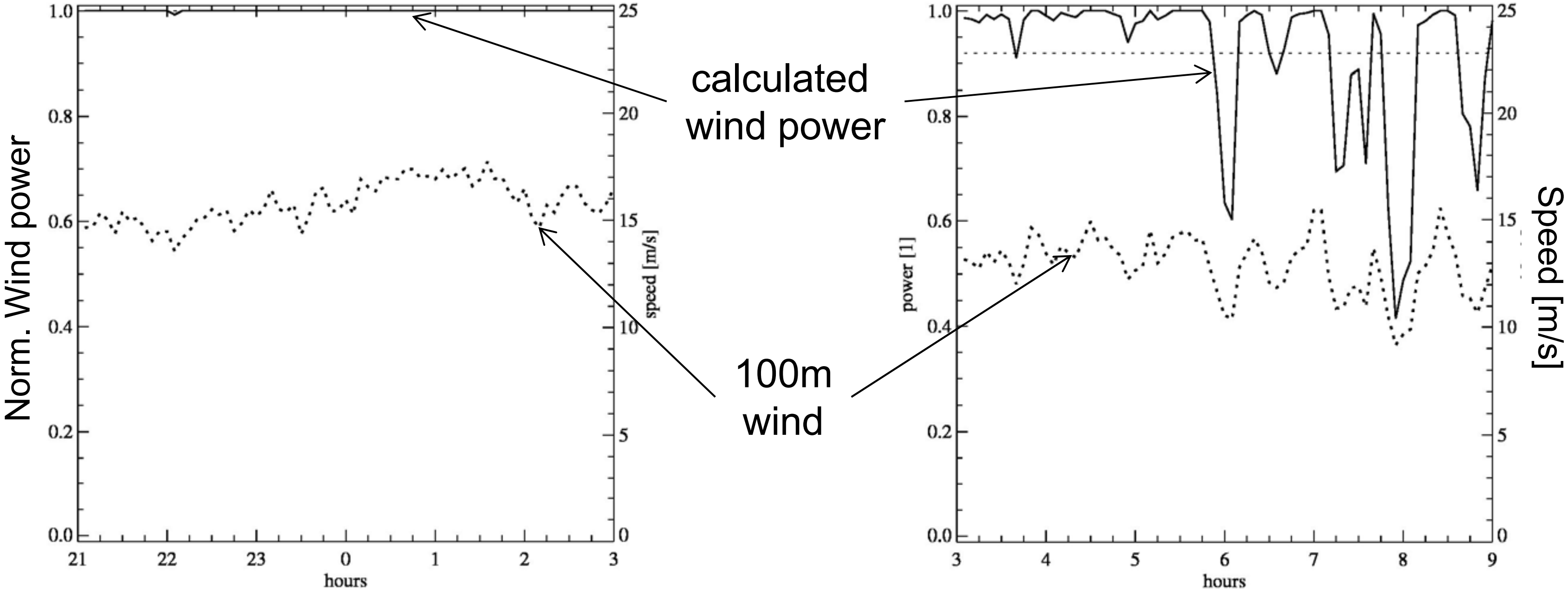


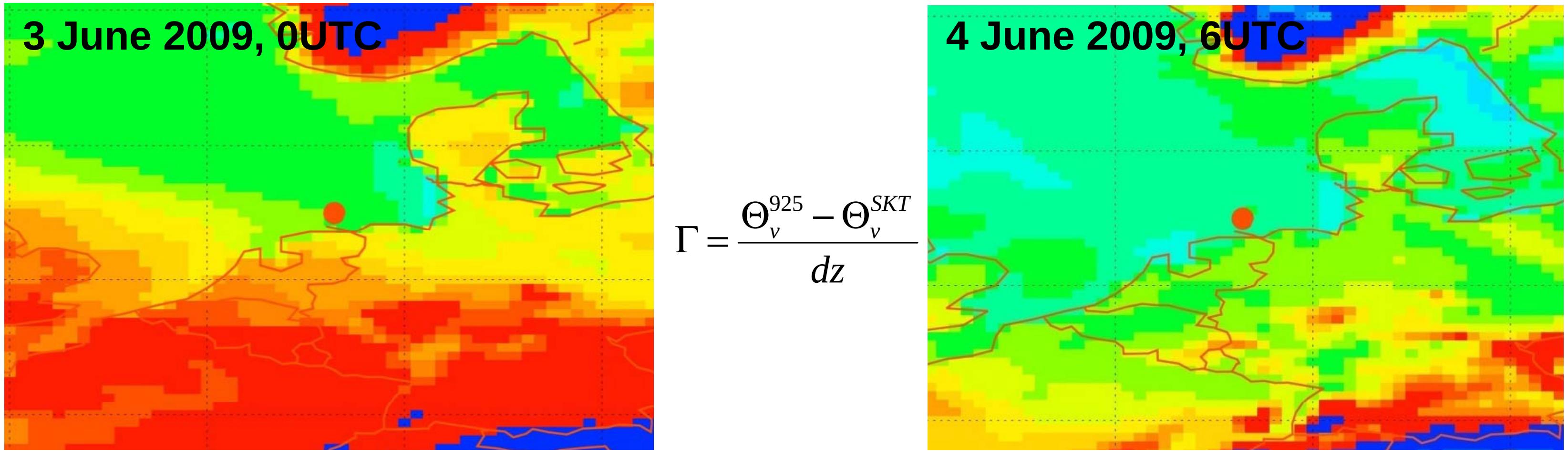
30h later: 850hPa Temp at 4 June, 6UTC



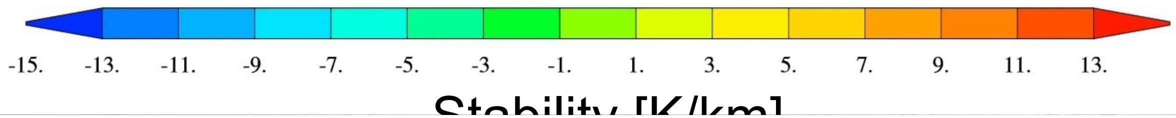
Test case: Cold surge (4 June 2009)

Fluctuation (FINO1) at 3 June, 0UTC | **30h later: 4 June, 6UTC**





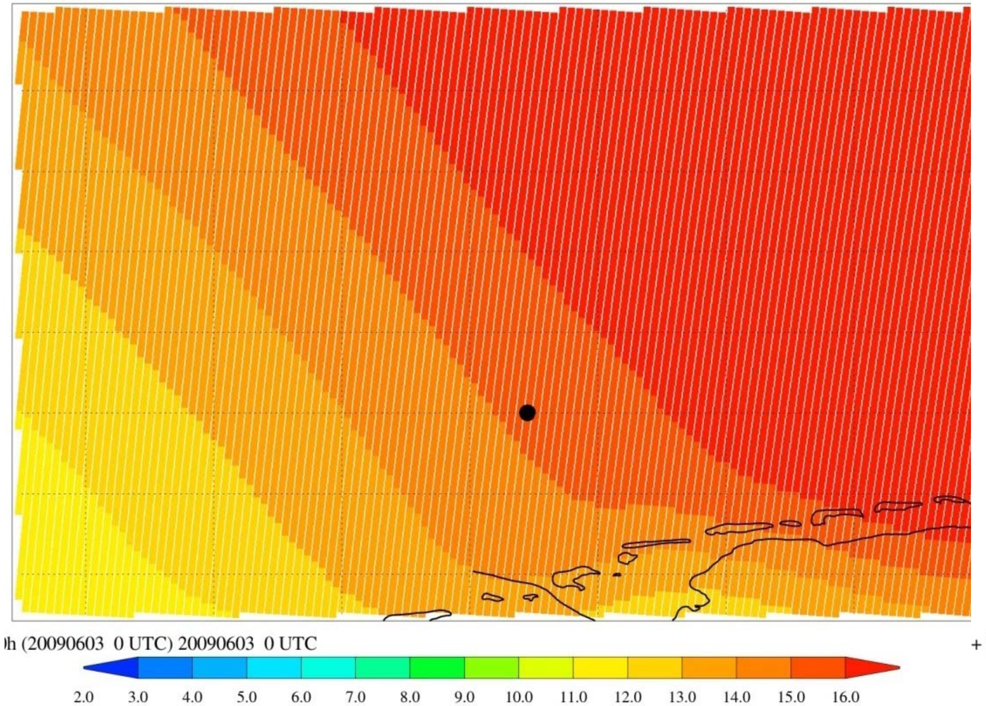
$$\Gamma = \frac{\Theta_v^{925} - \Theta_v^{SKT}}{dz}$$



Test case: Cold surge (4 June 2009)

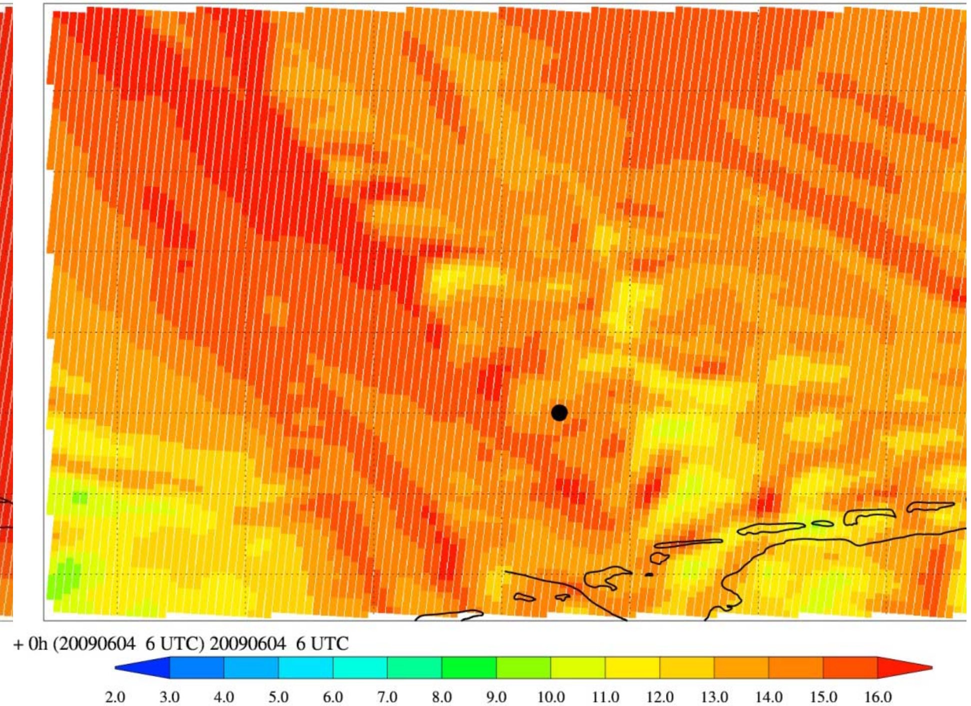
- Downscaling Experiment: Wind field at 100m with COSMO (dx=1.6km)

3 June 2009, 0UTC



m/s

30h later: 4 June 2009, 6UTC



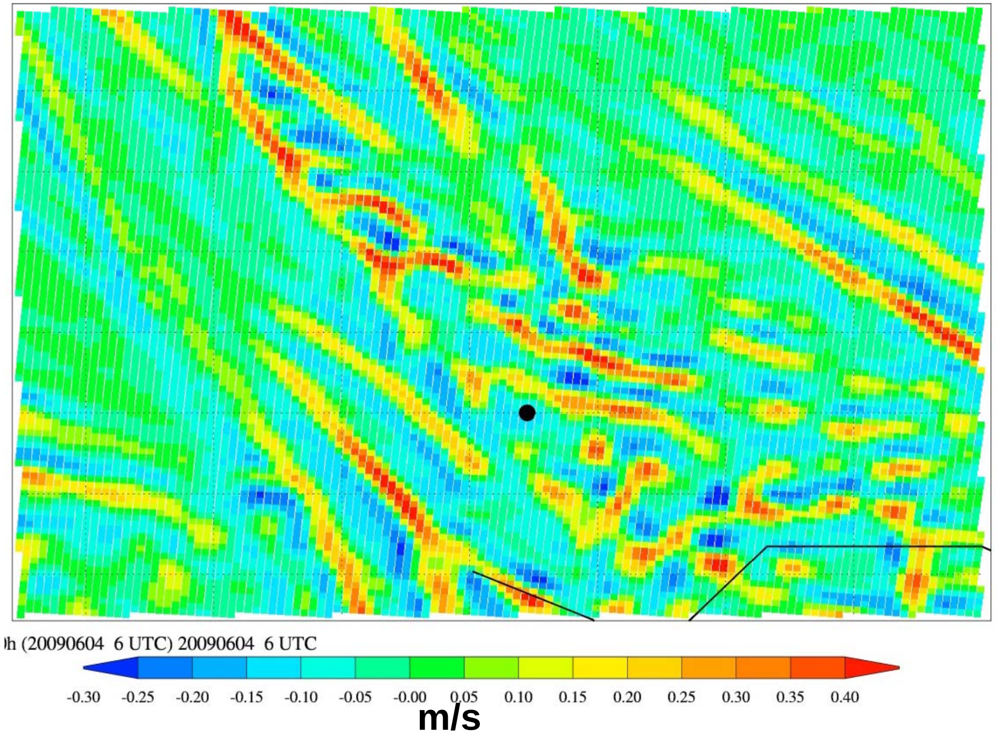
Source: E. Mohr 2010,
Diploma Thesis, Uni Trier & ForWind Oldenburg

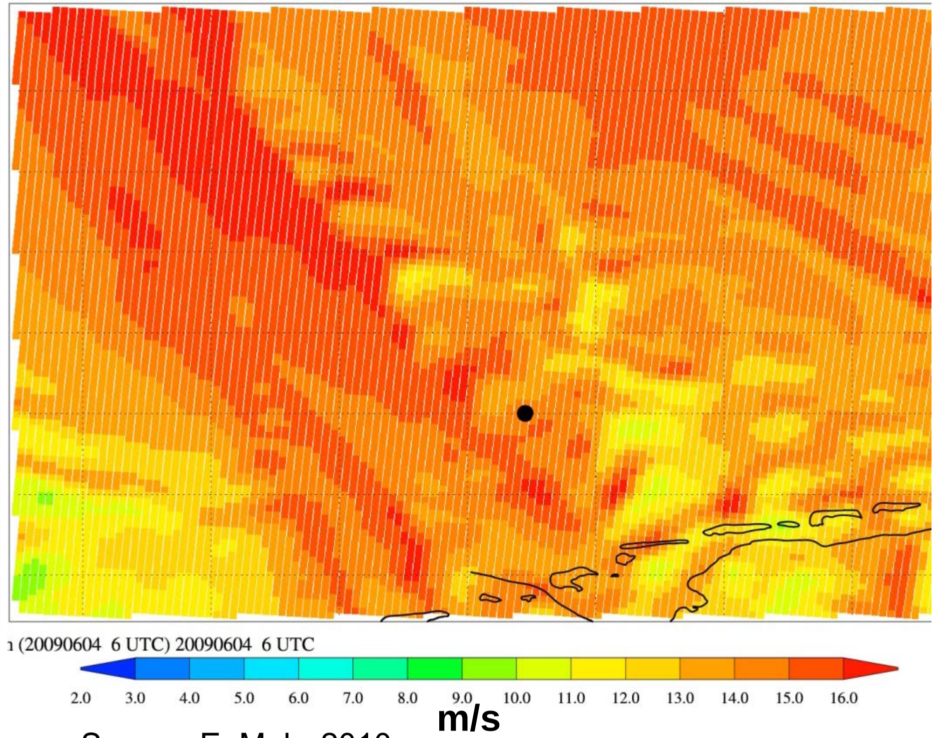
- **COSMO simulates very heterogeneous wind field in unstable thermal stratification**

Test case: Cold surge (4 June 2009)

- Downscaling Experiment: COSMO, dx=1.6km

Vertical wind speed | 4 June 2009, 6UTC | Horizontal wind, 100m

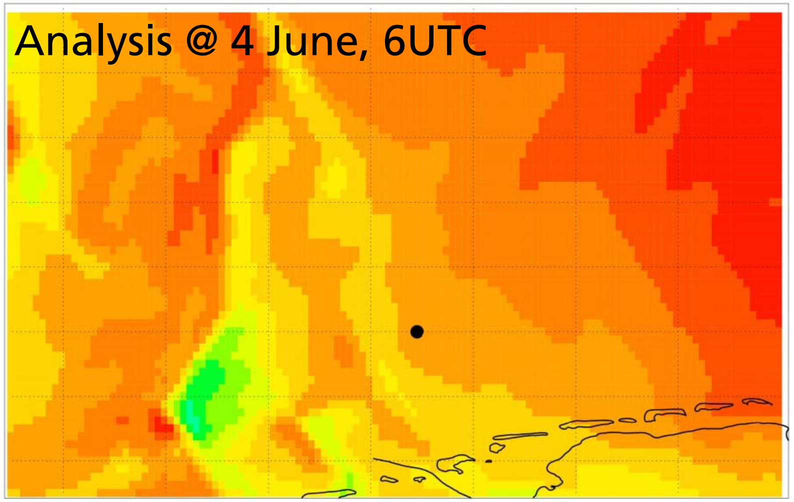




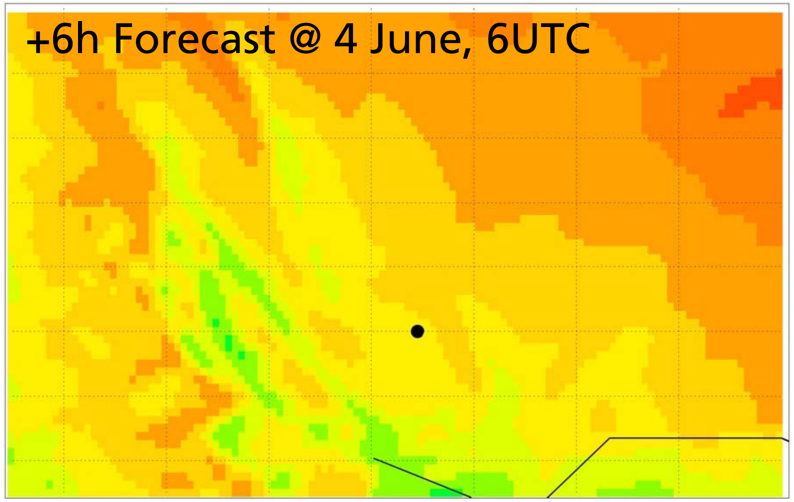
Source: E. Mohr 2010,
Diploma Thesis, Uni Trier & ForWind Oldenburg

- **COSMO simulates very heterogeneous wind field in unstable thermal stratification**

NWP Resolution matters!

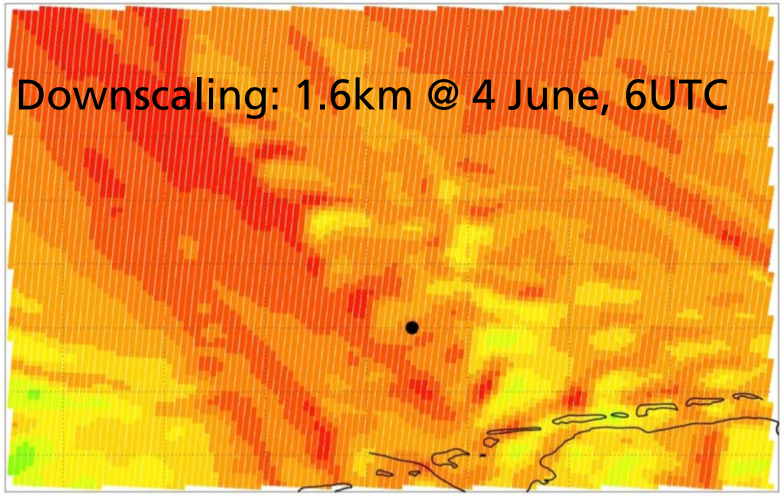


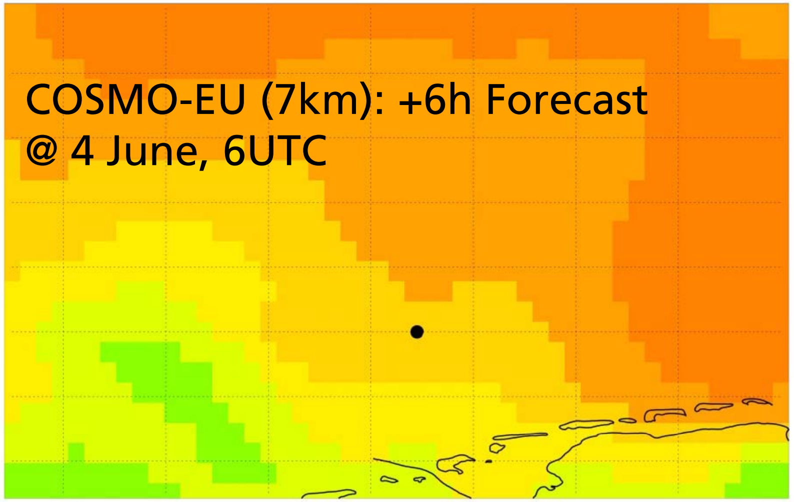
Operational:
COSMO-DE
(2.8km)



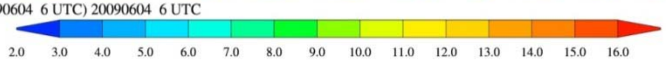
+ 6h (20090604 6 UTC) 20090604 0 UTC

+ 0h (20090604 6 UTC) 20090604 6 UTC

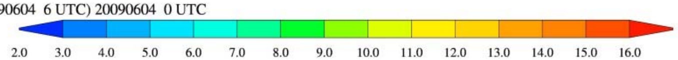




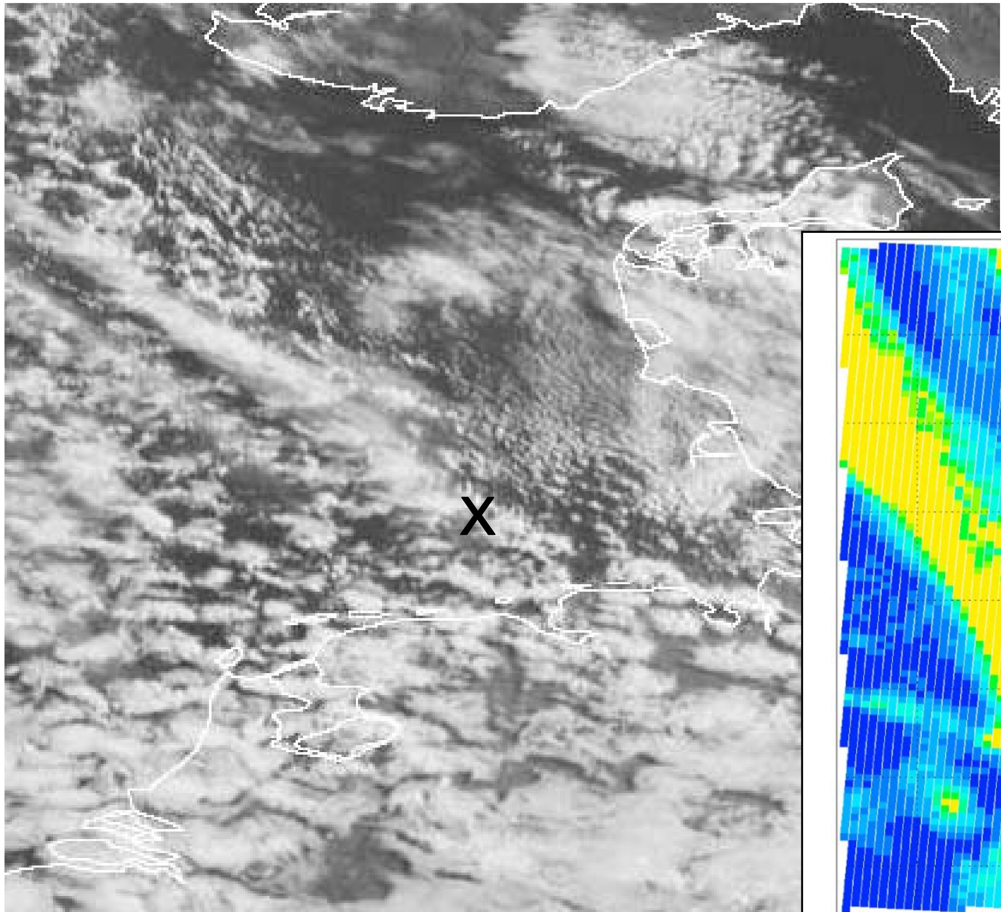
+ 0h (20090604 6 UTC) 20090604 6 UTC



+ 6h (20090604 6 UTC) 20090604 0 UTC

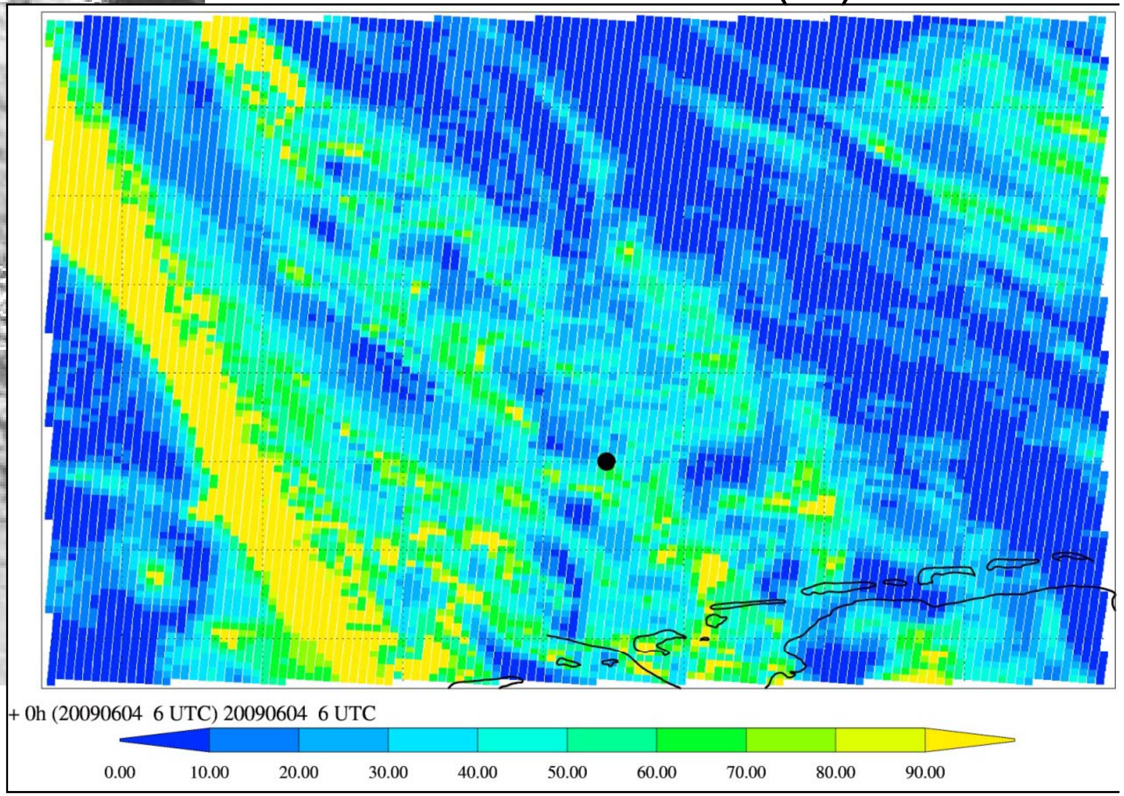


Open cellular convection at June 4, 2009 6UTC



Source: Meteosat 9,Vis
Dundee Receiving Station

COSMO downscaling (1.6km)
low cloud cover (%)

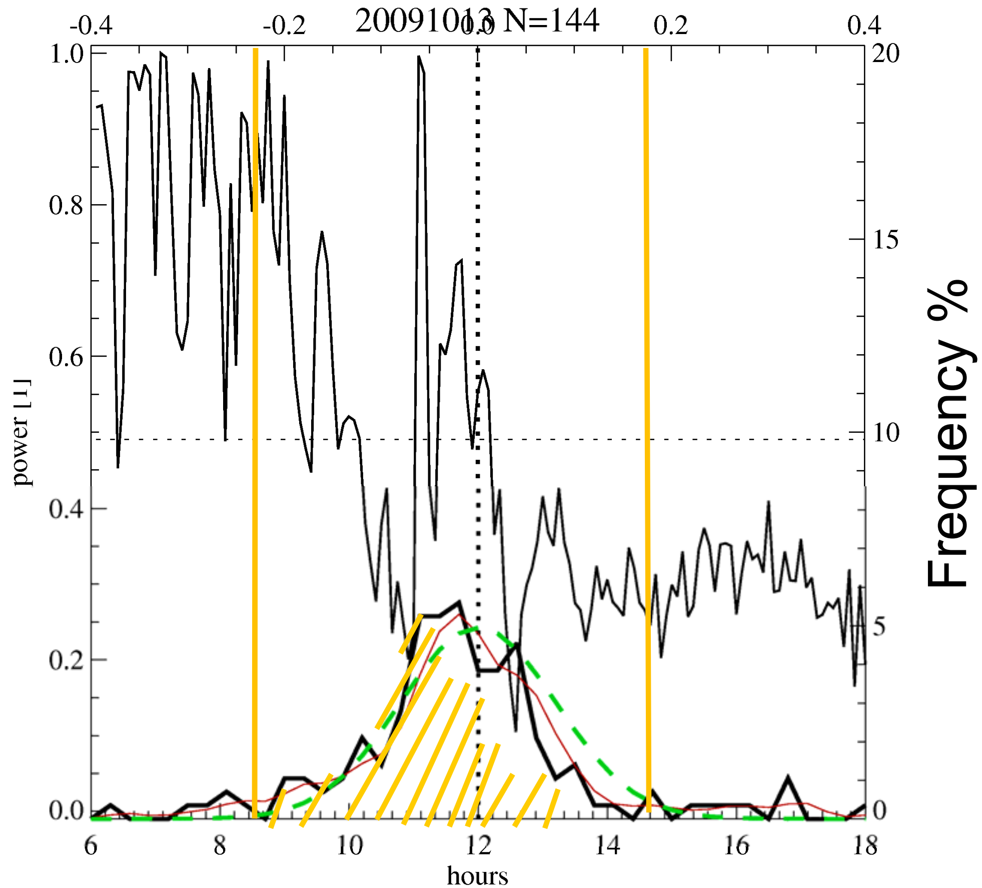


(Calculated) Wind Power Fluctuations at FINO1 (13 Oct 2009)

- Metric: Sum of gradients within a certain time period
- Optional: only gradients that exceed a certain threshhold

$$totalfluc = \sum_{i}^{6h} \left| P_i - P_{i-1} \right|$$

For this study:
Time period: 6h
Gradient Threshold: 20%

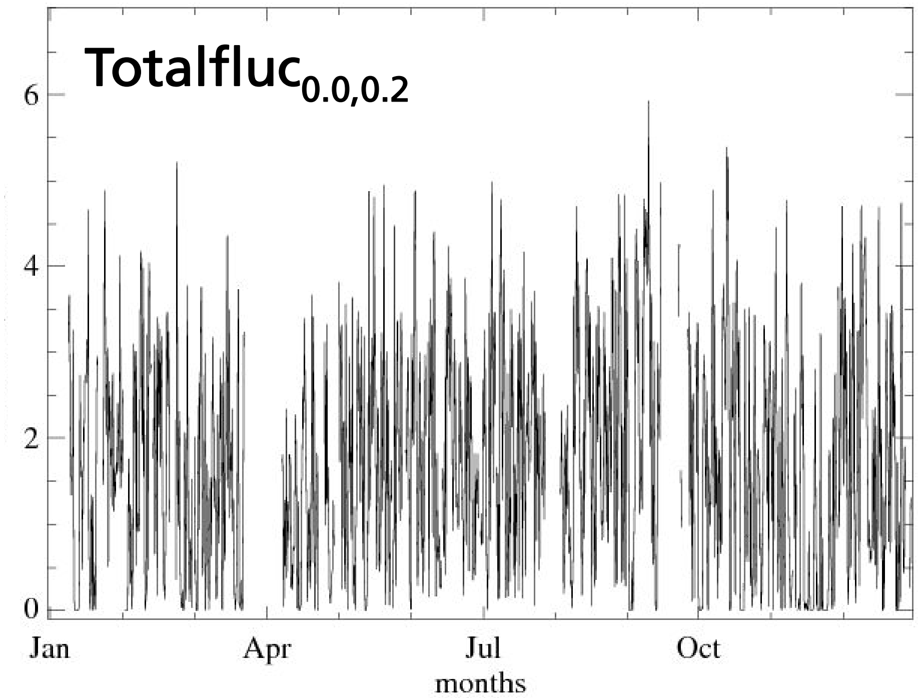


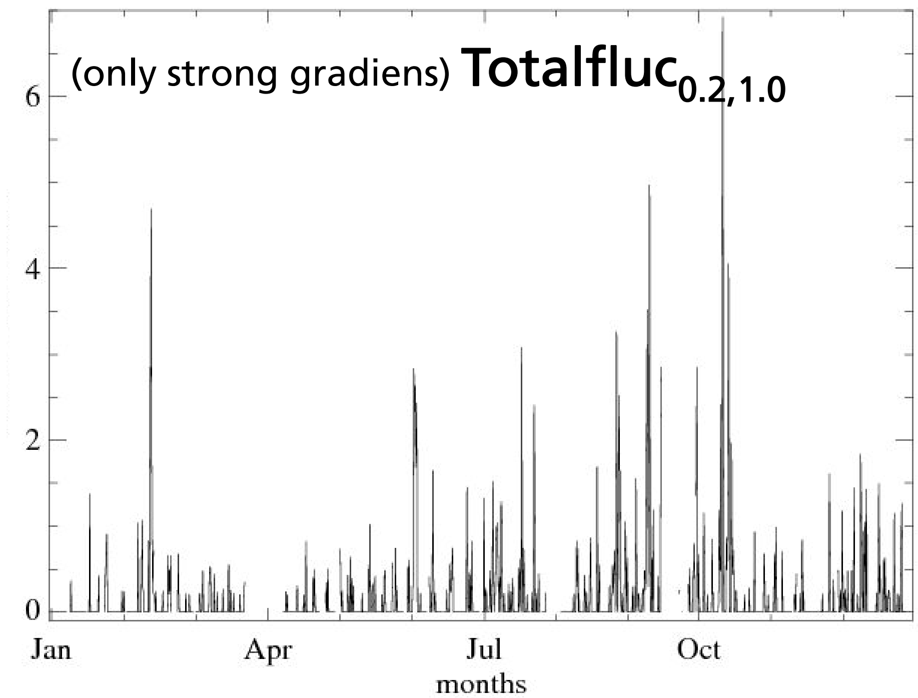
Example 1:

Totalfluc$_{0.0,0.2}$=4.53

Example 2: **Totalfluc$_{0.2,1.0}$=5.41**

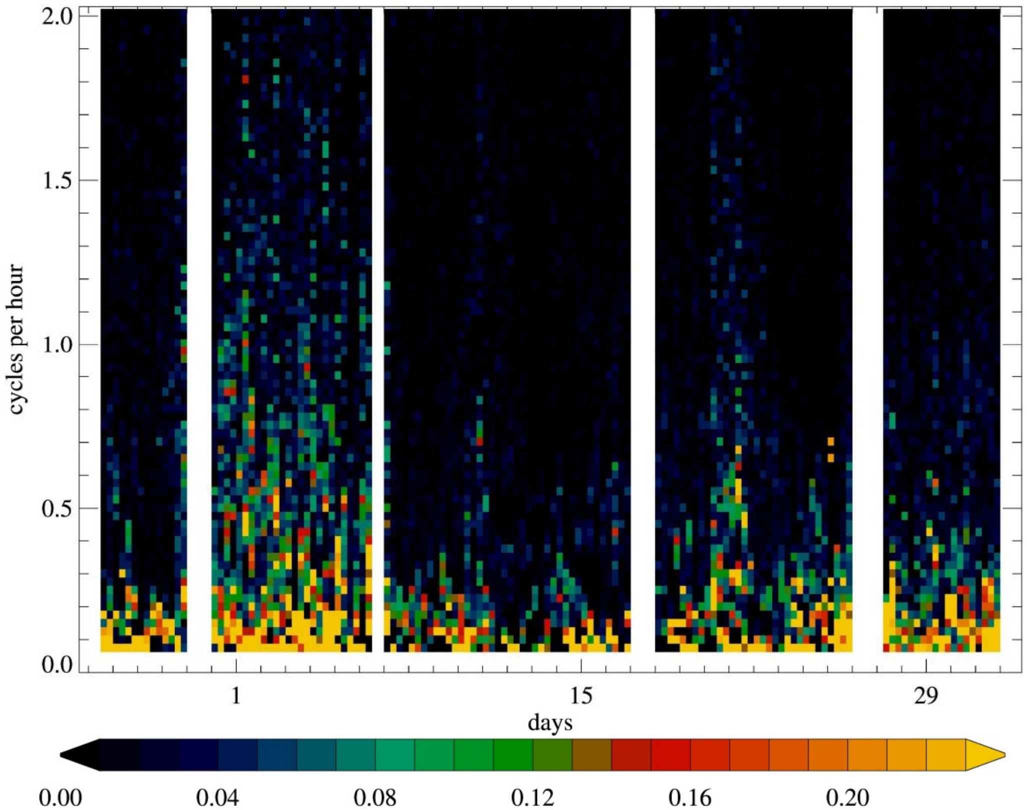
Time series of totalfluc in 2009 (6h time window)

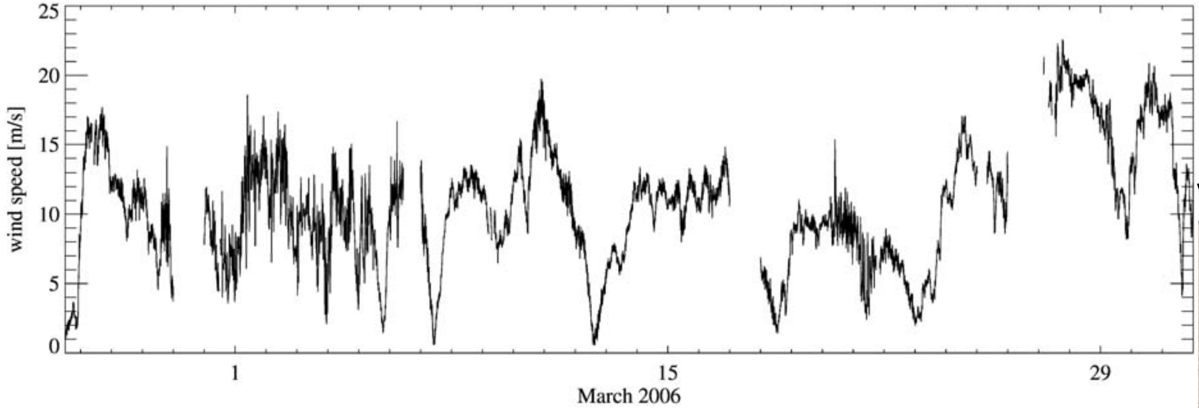




- Strong fluctuations (>20% of installed power) occur predominantly in autumn

Alternative (but complicated) approach HHT: Hilbert-Huang-Transform

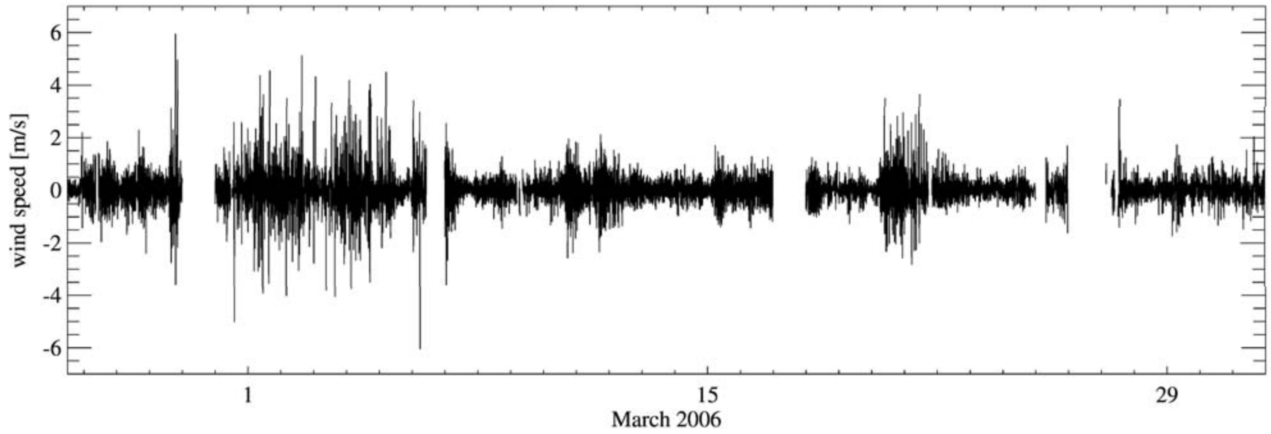




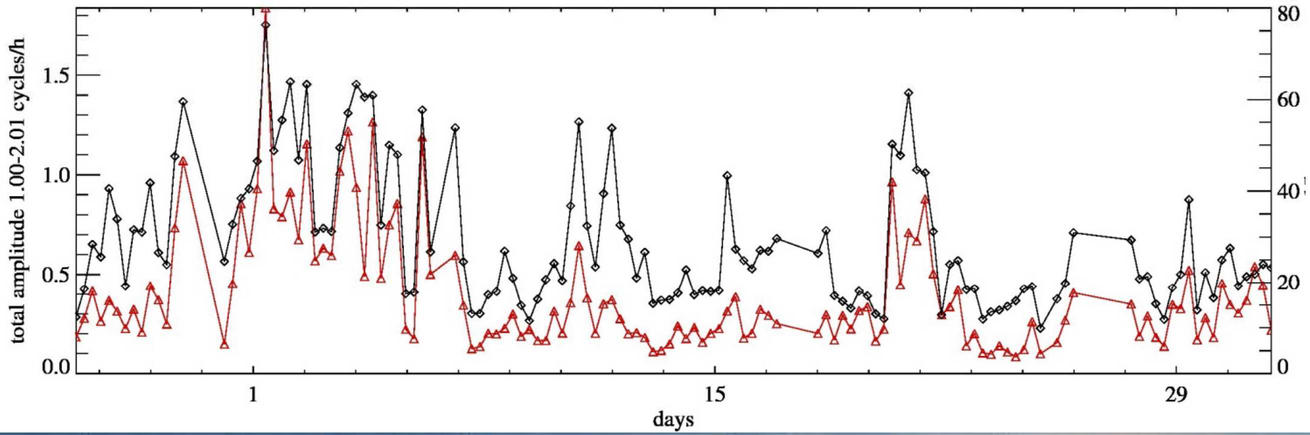
wind speed time series

Comparison HHT and totalfluc

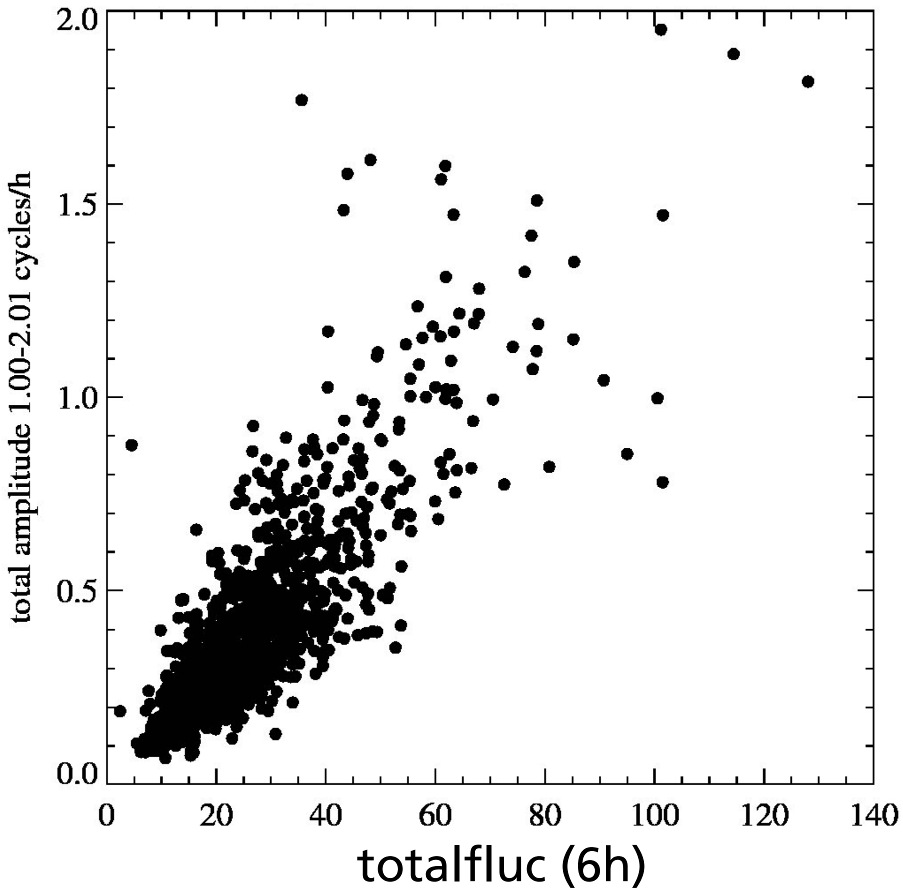
Wind speed gradient (5min)



totalfluc, total amplitude of HHT

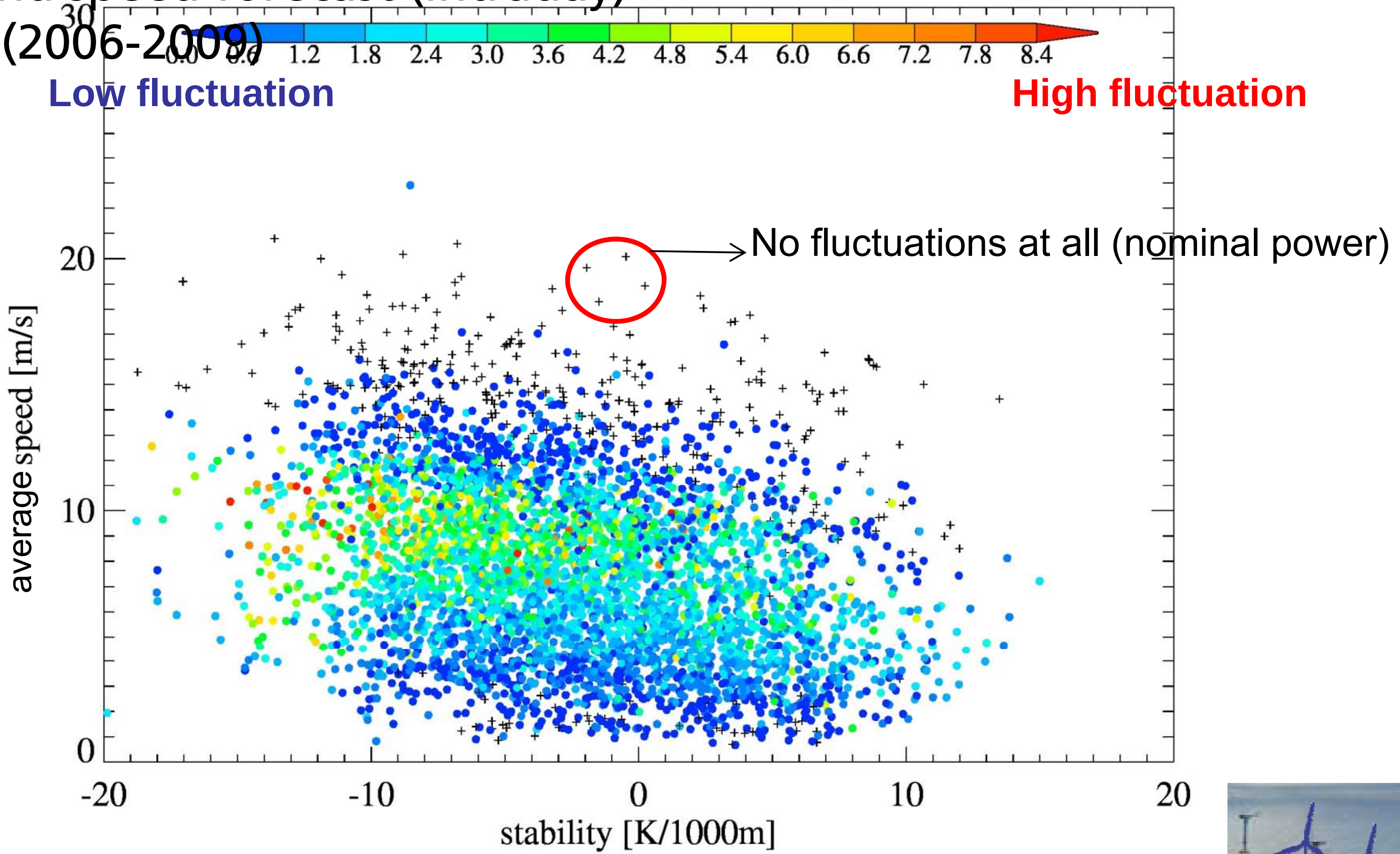


Comparison HHT and totalfluc (one year, 6hourly)



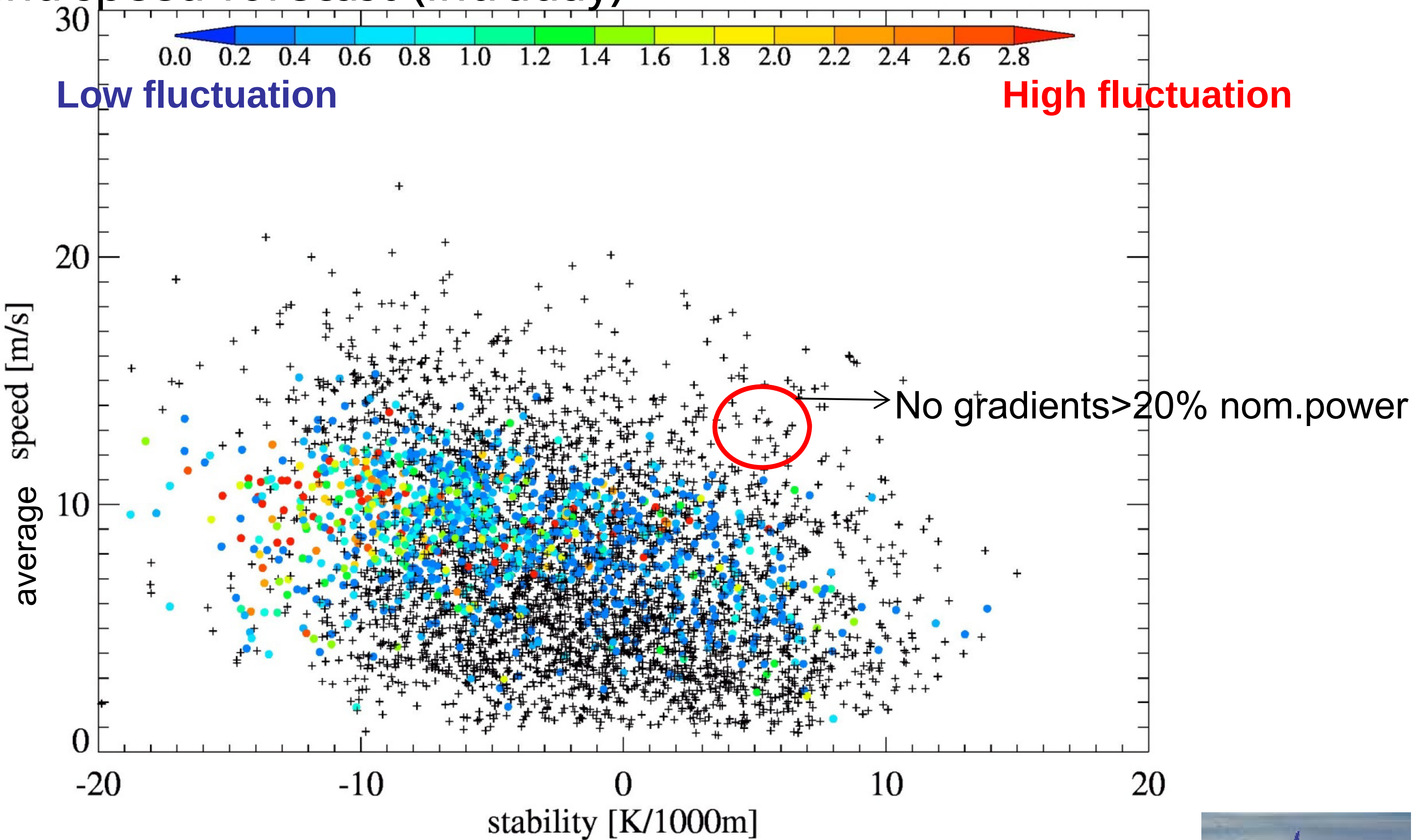
All Totalfluc$_{0-1}$ depending on thermal stability and wind spee

- Thermal stability -> gradient of pot.virt Temp=(Θ_{925}-$\Theta_{surface}$)/dz, here: from ECMWF analysis
- 10m wind speed forecast (intraday)
- 4 years (2006-2009)

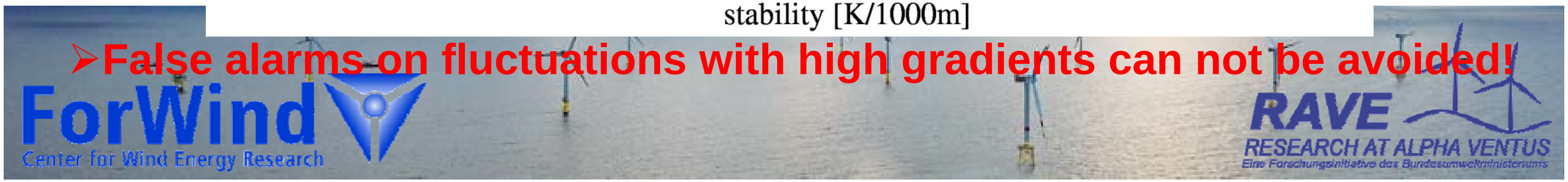


Strong Totalfluc$_{0.2\text{-}1}$ depending on thermal stability & wind speed

- Thermal stability (=gradient of pot.virt Temp=(Θ_{925}-$\Theta_{surface}$)/dz, here: from ECMWF analysis)
- 10m wind speed forecast (intraday)



- **False alarms on fluctuations with high gradients can not be avoided!**



Summary and Outlook

- Sum of relevant gradients (totalfluc) is a simple metric for wind power fluctuations and is related to i) Wind speed and ii) atmospheric stability

- Atmospheric conditions (large scale synoptic situation (cold surge)) leading to fluctuations can be forecasted by NWP

- Mesocale model COSMO simulates heterogeneous wind field in unstable thermal stratification (but resolution matters)

- Evaluate totalfluc with measured wind power and establish relation to more large-scale forecast variables (cyclonicity) or small-scale variables (TKE, vertical wind speed)

- Use heterogeneous fields from mesoscale modelling to define a „spatial“ fluctuation metric and link with „temporal“ totalfluc

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*Acknowledgements: The work has been done in the project **RAVE-Grid Integration of Offshore Wind Parks** funded by BMU.*

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