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Measurement of high frequency pressure fluctuations at German off-shore platform FINO3

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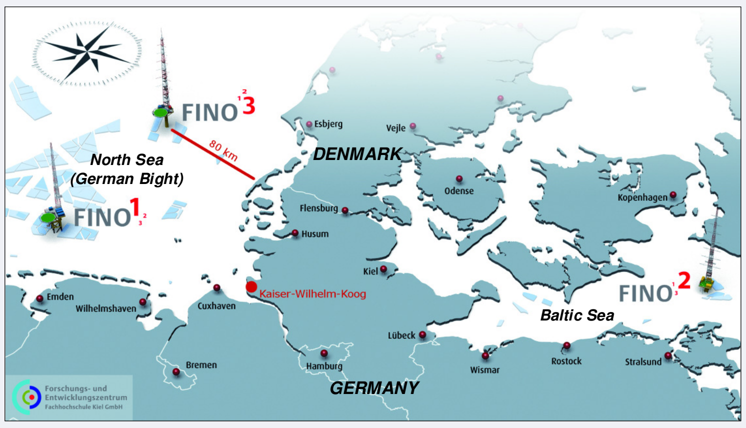
FINO 3 Forschungsplattformen in Nord- und Ostsee Nr. 3

Abstract

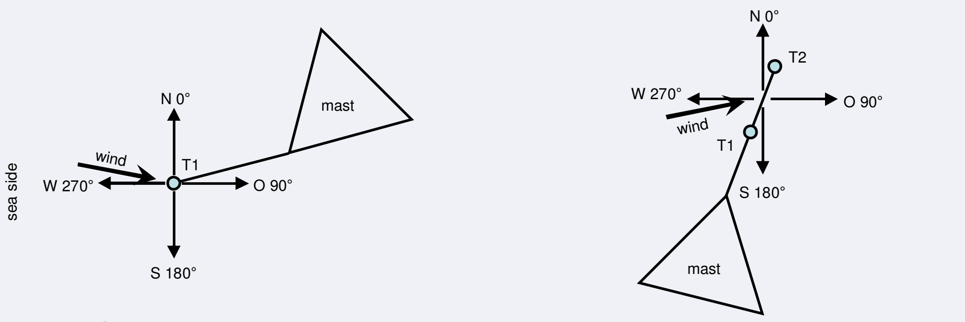
- Measurement of turbulent pressure at high frequency
- Ongoing work at University of Applied Sciences Kiel (see [1], [2] and [3])
- Measurements done at wind speed classes of 6 m/s, 12 m/s and 16 m/s at on-shore and off-shore test sites
- Here two data sets at similar conditions for on-shore and off-shore compared
- Is there a difference in turbulence between on-shore and off-shore atmosphere?
- Does off-shore turbulence allow laminar profiles at blades for higher efficiency?

Experimental setup



Locations of test sites Kaiser-Wilhelm-Koog (on-shore) and FINO3 in the German Bight (off-shore)

- Applied Measurement equipment
  - Piezo electric microphone (ICP) with 0.13 Pa pressure resolution
  - Time resolution between 2.5 Hz and 80,000 Hz
  - Piezo probe tested in wind tunnel and gives identical results to hot wire probe
  - Meteorological equipment available at test sites for environmental data
- On-shore measurements
  - At Kaiser-Wilhelm-Koog test site of Germanischer Lloyd (former WINDTEST)
  - Height of 60 m above ground level on meteorological measurement mast
  - One pressure sensor, sampling rate was 50 kHz, measurement time 100 s
- Off-shore measurements
  - At FINO3 off-shore measurement platform, German Bight
  - Height of 100 m above sea level on meteorological measurement mast
  - Two pressure sensors, sampling rate 50 kHz, measurement time 100 s



Sensor, mast and wind direction for on-shore (left) and off-shore (right) measurements

Environmental data of on-shore and off-shore measurements (mean ± standard deviation)

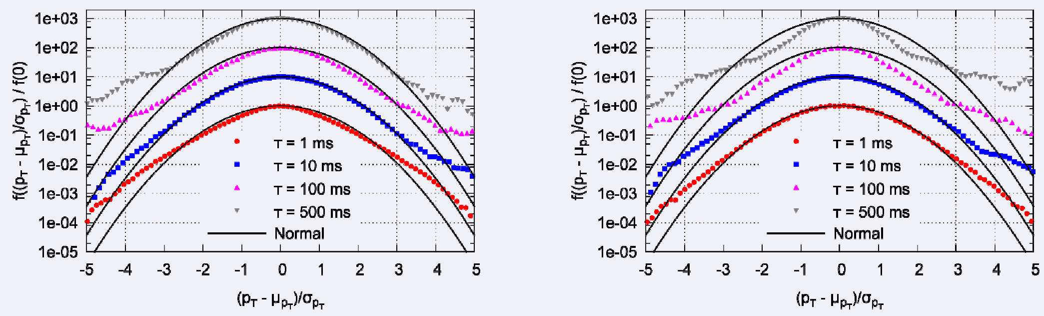
Parameter	On-shore		Off-shore	
Measurement date	Mar 26, 2008		Aug 19, 2010	
Wind speed (m/s)	12.05	± 0.82	12.04	± 0.57
Wind direction (°)	280.9	± 3.5	259.0	± 2.4
Environmental pressure (hPa)	988.2	± 0.1	996.1	± 0.0
Air temperature (°C)	1.3	± 0.1	15.4	± 0.0
Turbulence degree* (%)	6.80		4.75	

* The turbulence degree was derived from wind speed measured by cup anemometers.

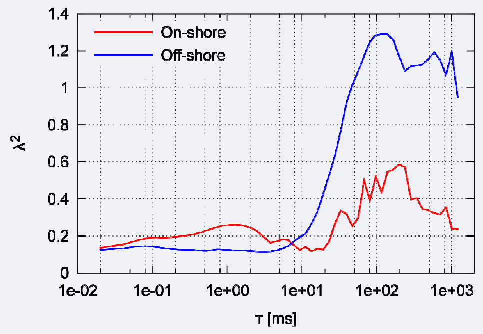
Results

- Histograms and Form factor λ^2 [4]:
  - on-shore histograms show almost normal distribution within 3σ
  - off-shore histograms show difference to normal distribution for $\tau \geq 100$ ms
  - observed "heavy tails" with higher probability for extreme events
  - high value of form factor λ^2 coincides with strong difference to normal distribution [5]
  - very low form factors for on-shore wind compared to off-shore wind

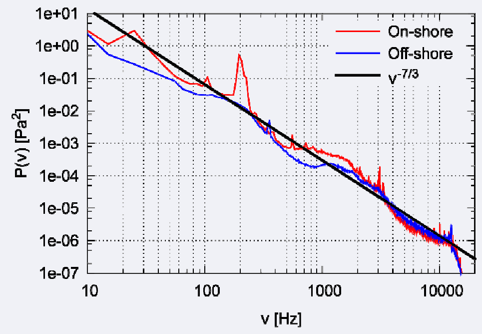
Results (continued)



Histograms of pressure increments $p_\tau = p(t+\tau) - p(t)$ for on-shore (left) and off-shore (right) measurement

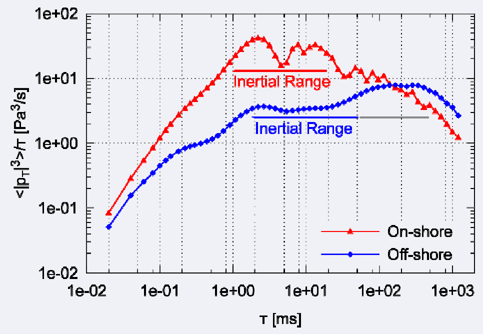


Form factor λ^2

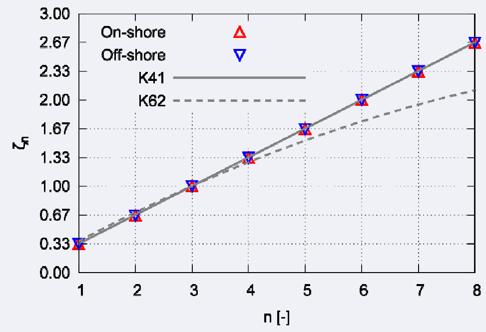


Power spectrum with Oboukhov scaling

- Power spectrum:
  - almost identical behavior for on- and off-shore, both follow Oboukhovs -7/3 scaling law
  - First verification of Oboukhov scaling law, as known to the authors



Kolmogorov function $\langle|p_\tau|^3\rangle/\tau$



Intermittency exponent ζ_n

- Kolmogorov function suggests an inertial range, but no clear scaling possible
- Applied Extended Self-Similarity hypothesis from [6] to get intermittency exponent ζ_n
- Intermittency exponent follows Kolmogorovs K41 [7] ($\zeta_n = n/3$) → no intermittency!

Summary and Outlook

- Differences in increments distribution and form factor λ^2 for on-shore and off-shore turbulence
- Verified Oboukhovs -7/3 scaling law in turbulent pressure fluctuations
- Found no intermittency in atmospheric turbulence, which is surprising and not conforming to other literature findings [8]
- Further evaluation of data is ongoing and to be published soon
- New laser cantilever anemometer for turbulent wind speed measurements is in test phase

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