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The FINO3 Wind Energy Research Platform in the North Sea:
First Results & Comparisons to Concurrent FINO1 Data

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Outline

- Introduction FINO platforms 1, 2, 3
  → facts, specs and GL GH involvements
- Design of FINO3 wind measurements
  → flow distortion by mast effects
- FINO3 first results – wind statistics
- Comparisons to FINO1
- Conclusion & outlook

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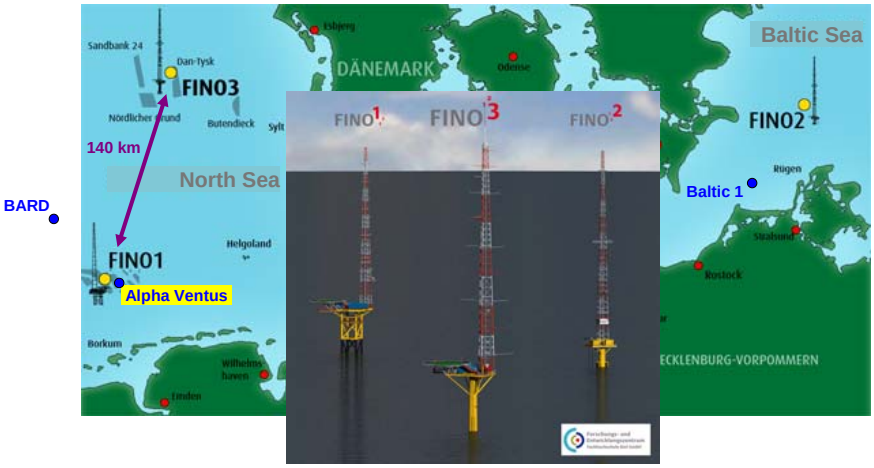
FINO Platforms in the North Sea and Baltic Sea



BARD

Platforms	2003	2009	2007
Near Wind Farms	2009/10	2011/12	2010 / 2011

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FINO 1 2 3: Facts, Specs & GL GH Involvements

- FINO1: O&M since 2003, development of specs, tendering, construction, installation, commissioning
- FINO2: O&M since 2010 pre-siting activities
- FINO3: wind meas. since 2009. design, engineering, installation of meteo. system, O&M, data collection and processing

Research Platform	O & M	In service	Mast shape	Height	Water depth	Distance to coast	Foundation	Platform size	Heli pad
FINO 1 North Sea	GL GH	Sep 2003	Square	101 m	28 m	45 km	Jacket	16 x 16 m	yes
FINO 2 Batic	GL GH	May 2007	Square	101 m	24 m	31 km	Monopile	12 x 12 m	no
FINO 3 North Sea	Univ. Kiel	Sep 2009	Triangular	106 m (120 m)	23 m	80 km	Monopile	13 x 13 m	yes

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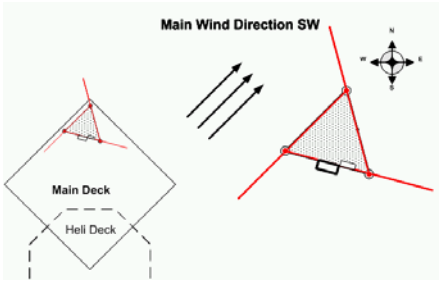
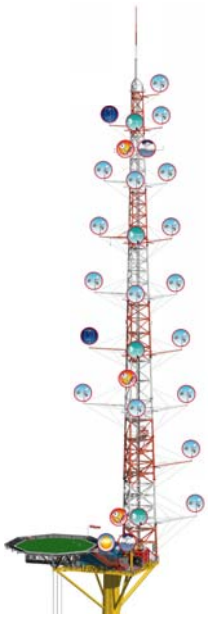
FINO3 – Platform and mast design

- Triangular mast on Northern edge
- Three boom directions
- Upper most cup (NOT top) height 106m
- 9 wind measurement levels 30 to 106m





Cup
Sonic
Vane
T & RH
Precip.
Radiat.

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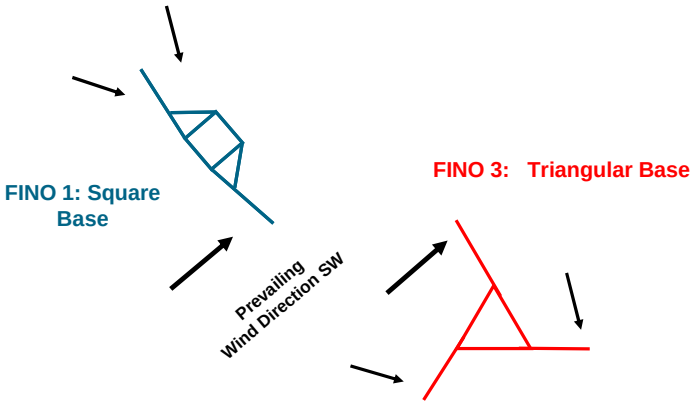
FINO1 vs. FINO3 – Different mast and boom layout



Serious flow distortion effects at FINO1
→ lessons learned: switch to triangular mast shape

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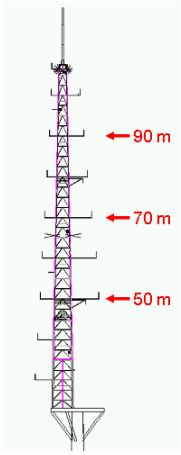
FINO3 – Boom layout

- Massive lattice tower structure
- Solid main columns
- Boom lengths 3.2 – 8.5m
- 3 levels with 3 cups
  → one for each of 3 directions



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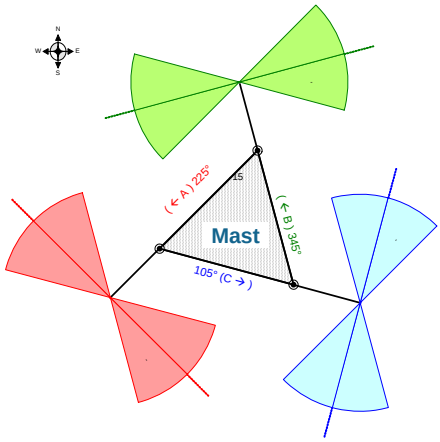
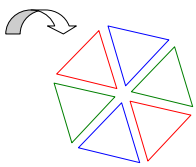
Handling the flow distortion caused by mast structure





Selection of undisturbed sectors, 2 x 60° for each of 3 boom directions
→ composition of undisturbed wind speed data set

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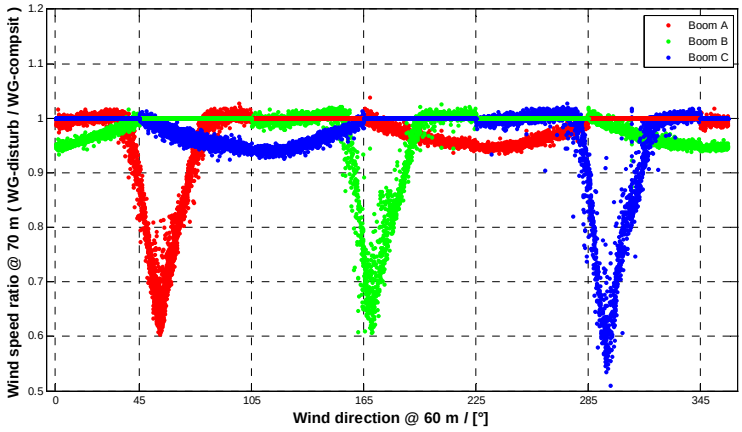
Downwind and upwind wake effects on wind speed



Ratio of disturbed over undisturbed (composed) wind speed
→ deficit up > 40%

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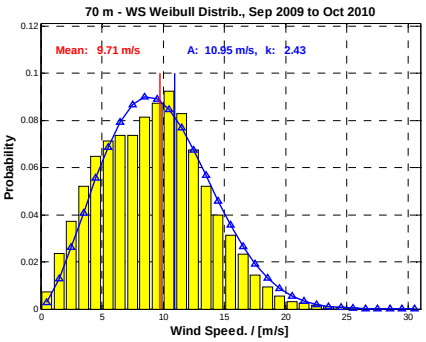
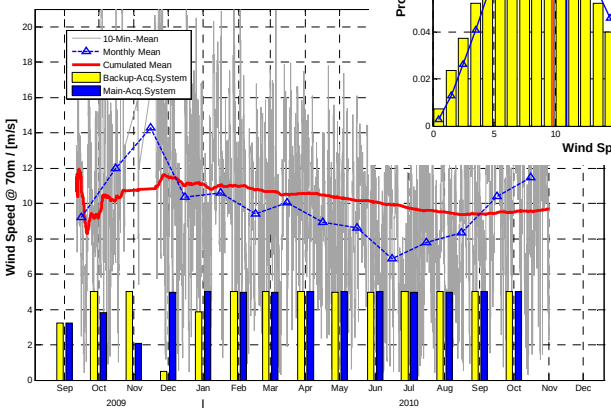
FINO3 – Data yield
Sep 2009 to Oct 2010





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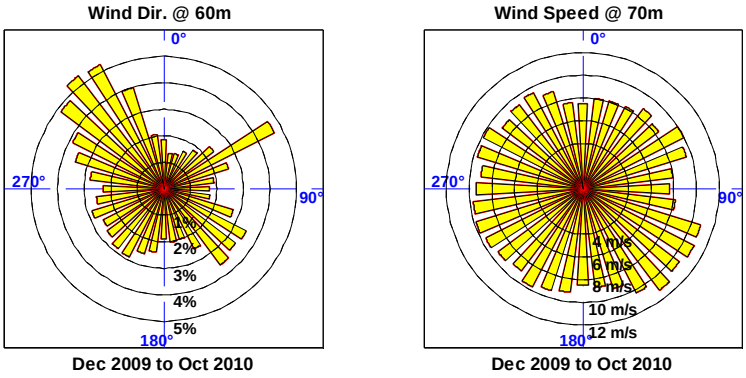
FINO3 – Wind Distribution



- NW and SE sectors with highest probability
- SW and SE sectors with highest WS > 10 m/s

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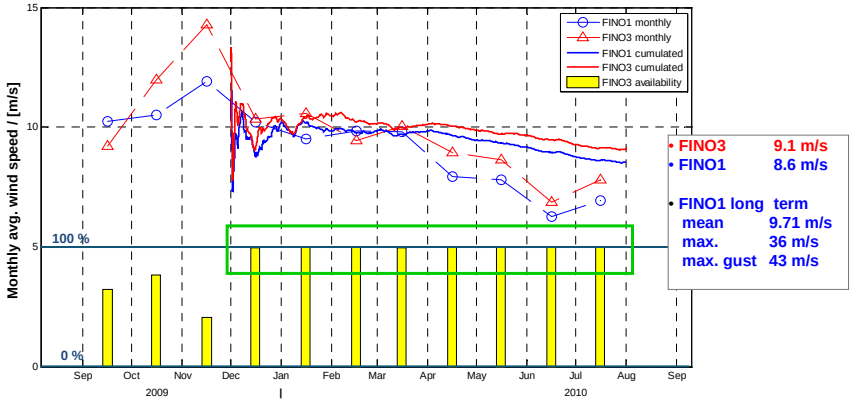
FINO3 vs. FINO1 – 70m mean wind speeds: monthly, accumulated



Higher wind speeds at FINO3 - TBC for long term

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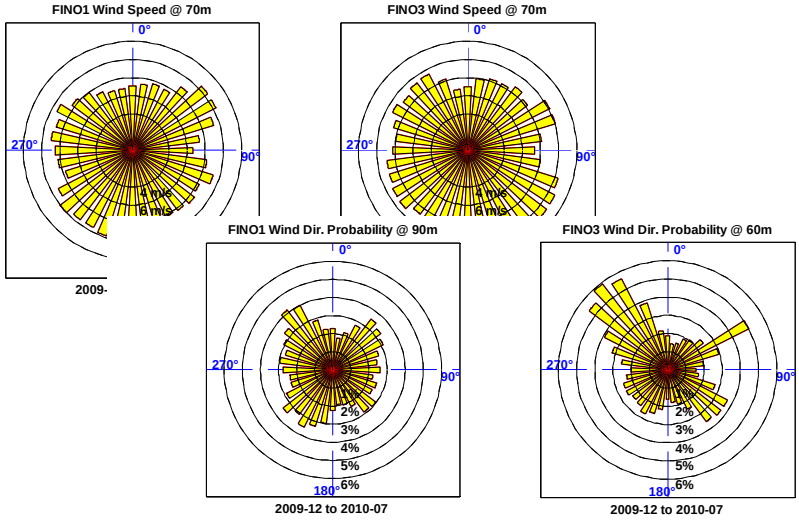
FINO1 vs. FINO3 – Wind distribution



FINO3 pronounced NW-SE wind distribution → farm layout

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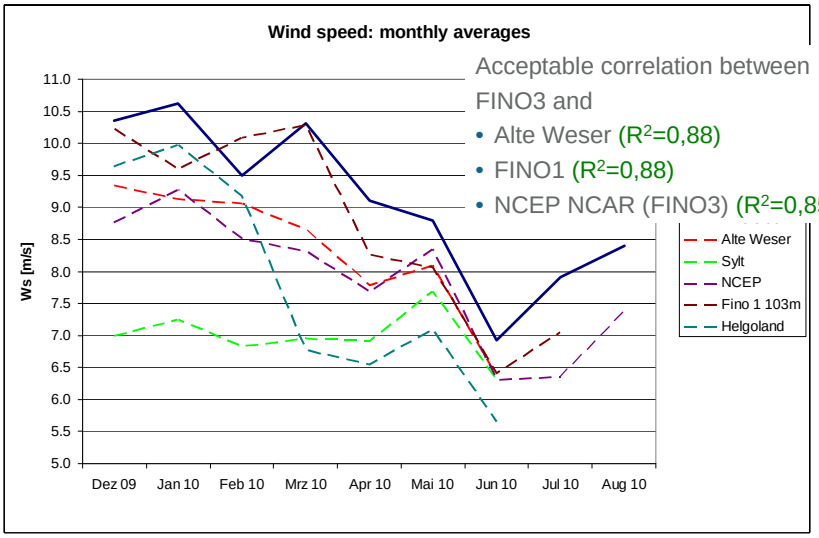
FINO3 long-term correlations, based on monthly averages



Acceptable correlation between FINO3 and

- Alte Weser (R^2=0,88)
- FINO1 (R^2=0,88)
- NCEP NCAR (FINO3) (R^2=0,85)

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Long-term adjustment of FINO3 data using FINO1

Applying slope and offset of the linear regression to the FINO3 data
→ „Speed Up“ of FINO3 wind speed by +3,1 %

	Reference Fino1	Site Fino3	Spliced Fino 3
January	11.93	10.62	11.85
February	10.59	9.50	10.55
March	11.07	10.31	11.03
April	8.95	9.10	9.40
May	8.91	8.79	9.34
June	8.09	6.93	8.61
July	8.09	7.91	8.68
August	8.66	8.36	9.01
Septemb	9.57	9.22	9.85
October	10.21	12.00	10.53
Novembe	11.57	14.43	11.44
Decembe	10.91	10.36	10.91
MOMM	9.9	9.8	10.1

Summary	
R ^ 2	0.878161
R (Pearson)	0.937103
Slope	0.799
Offset	2.204

	MoMM	Uncertainty
MON MCP	10.094	
MON Splice	10.100	
Years Measured	0.9	
Years Synthesised	5.9	
Total Spliced Years	6.7	
Ratio Synth/Splice	87.78%	
Spliced / Meas	103.1%	

short term average wind speed

long-term adjusted estimate of average wind speed

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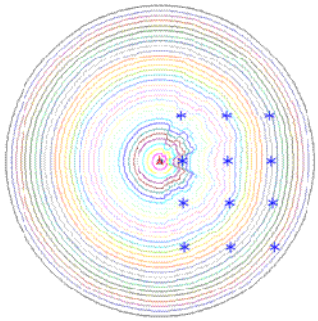
Correlation & Alpha Ventus Wake Effects ?

- Correlation FINO1 vs FINO3 found for monthly averages, only ... failing for other averaging periods (e.g. 10 min.)
- Alpha Ventus effect on correlations?
- 1st Attempt to estimate Alpha Ventus wake effects on FINO1 data for Jan – Aug 2010

  → simple, linear N.O. Jensen wake model (uses turbine power curves, thrust coefficient curves)

  → first results, assuming all turbines in operation = approx. -0,1 m/s on average for given period



reduction of wind speed caused by Alpha Ventus using simple, linear N. O. Jensen wake model

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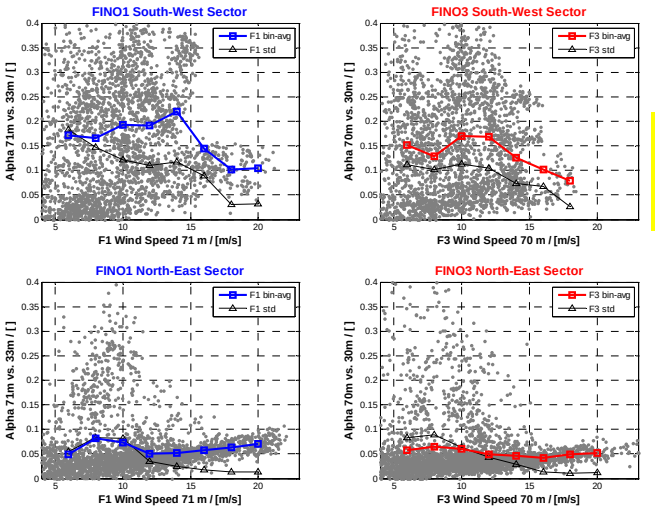
FINO1 vs. FINO3 – WS profiles using Hellmann's power law



$$v_2 = v_1 \cdot \left(\frac{z_2}{z_1}\right)^{\alpha}$$

power law exp. α derived from wind speeds at 30 and 70 m

SW sectors much stronger shear then NW sector

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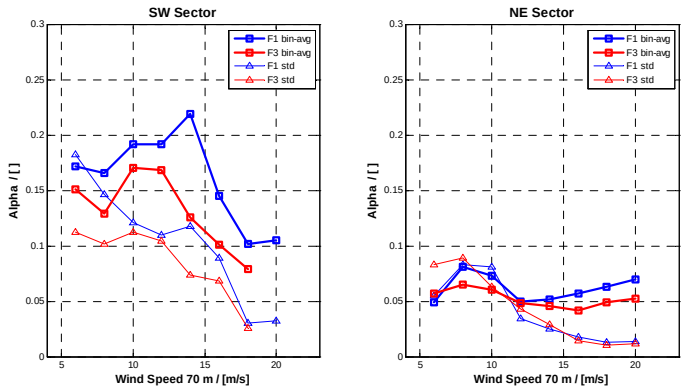
FINO1 vs. FINO3 – WS profiles using Hellmann exponent α



(for selected sectors) FINO1 shows larger WS shears then FINO3

FINO3

Concluding Remarks

- **FINO3 in operation since Sep 2009**
  → high data availability since Dec 2009
- **Compensation of flow distortion**
  → promising 3-boom approach
- **Comparisons FINO3 vs. FINO1**
  → different wind direction distribution
  → slightly higher mean wind speed at FINO3, TBC for long term
  → stronger shears at FINO3, TBC for long term
  → reasonably good correlation to FINO1 on monthly basis
  → Alpha Ventus impact on FINO1 mean wind speeds ~ -0.1 m/s
- **Data for BSH FINO data bank**
  → now available for public use – registration and fees: http://fino.bsh.de/

Outlook

- **Investigaton of mast effects by**
  (a) wind tunnel / CFD modelling,
  (b) direct wind LiDAR comparisons
- **Investigation of turbulence, wind profiles and stratification**

Thanks

- **to the auditorium !!!**
- **for German Federal and State funding**

FINO Web sites

http://www.fino3.de
http://www.fino-offshore.de/
http://fino.bsh.de/