The Challenging Offshore Wind Conditions

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RAVE 2012 – Bremerhaven, Germany

May 9 2012

Outline

Issues and facts

- Few measurements (harsh and expensive), fewer good measurements
- Large wind turbines installed offshore (no knowledge curve)
- Surface layer theory generally applied (in the best cases)
- Wind and wave (and current) interaction rather unknown
- Sea-land interaction poorly investigated
- NWP models relatively 'easier' on offshore conditions
- Satellite winds available (SAR and QuickSCAT)

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Modeling of the vertical wind speed profile

- Over flat and homogeneous terrain

$$\frac{U}{u_{*o}} = \frac{1}{\kappa}\left[\ln\left(\frac{z}{z_o}\right) - \psi_m\right] \tag{1}$$

where ψ_m is a function of z/L

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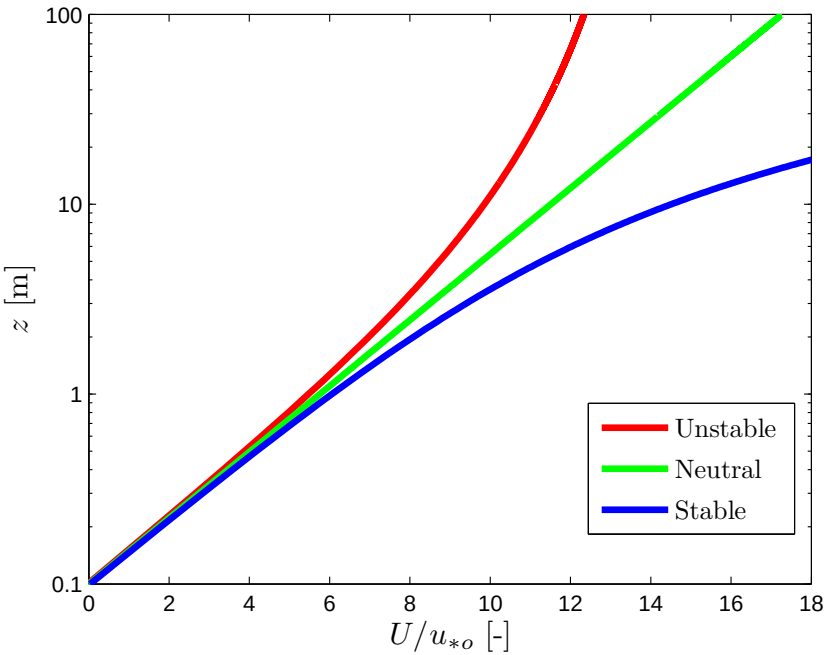
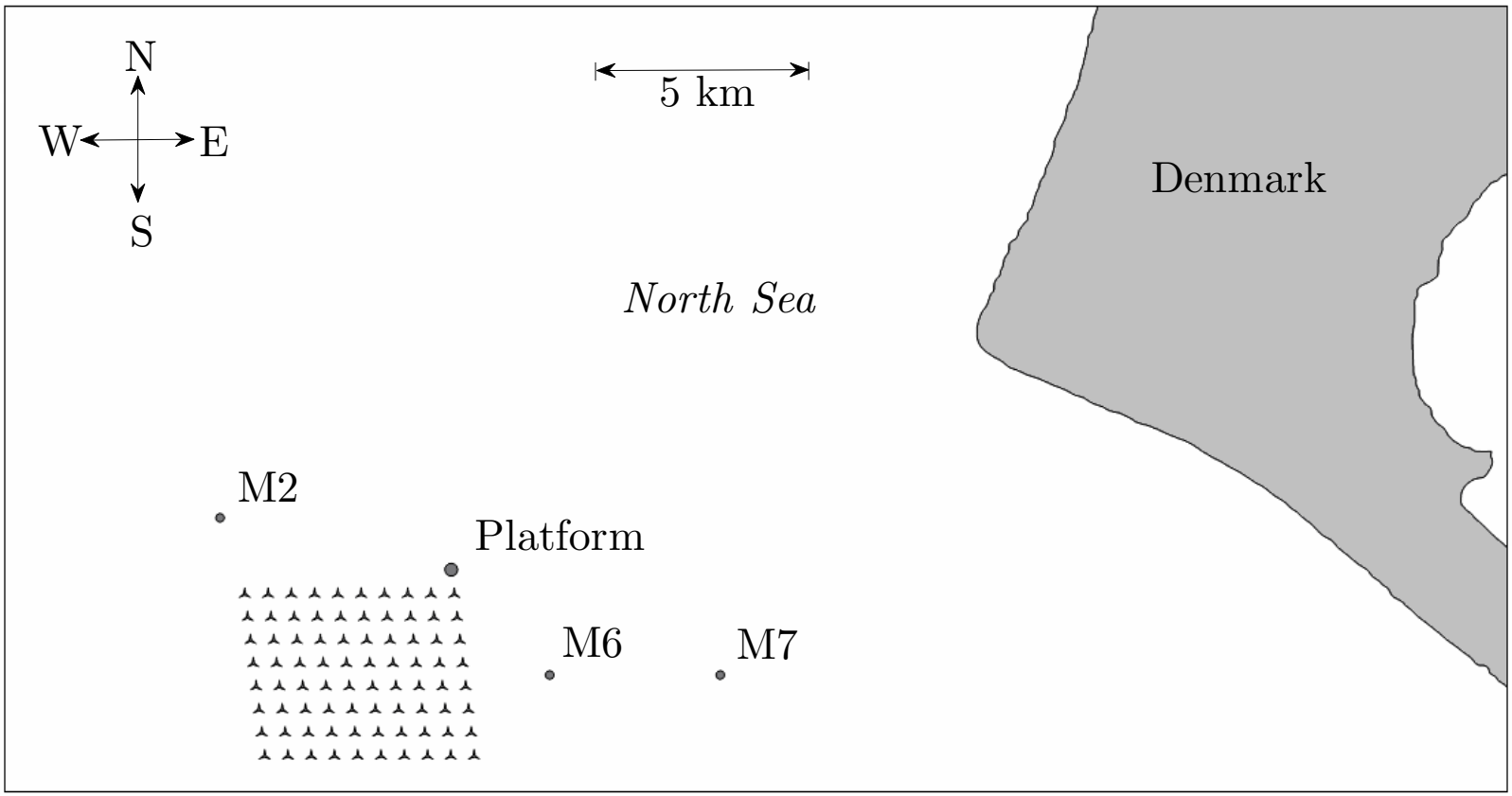


Horns Rev I



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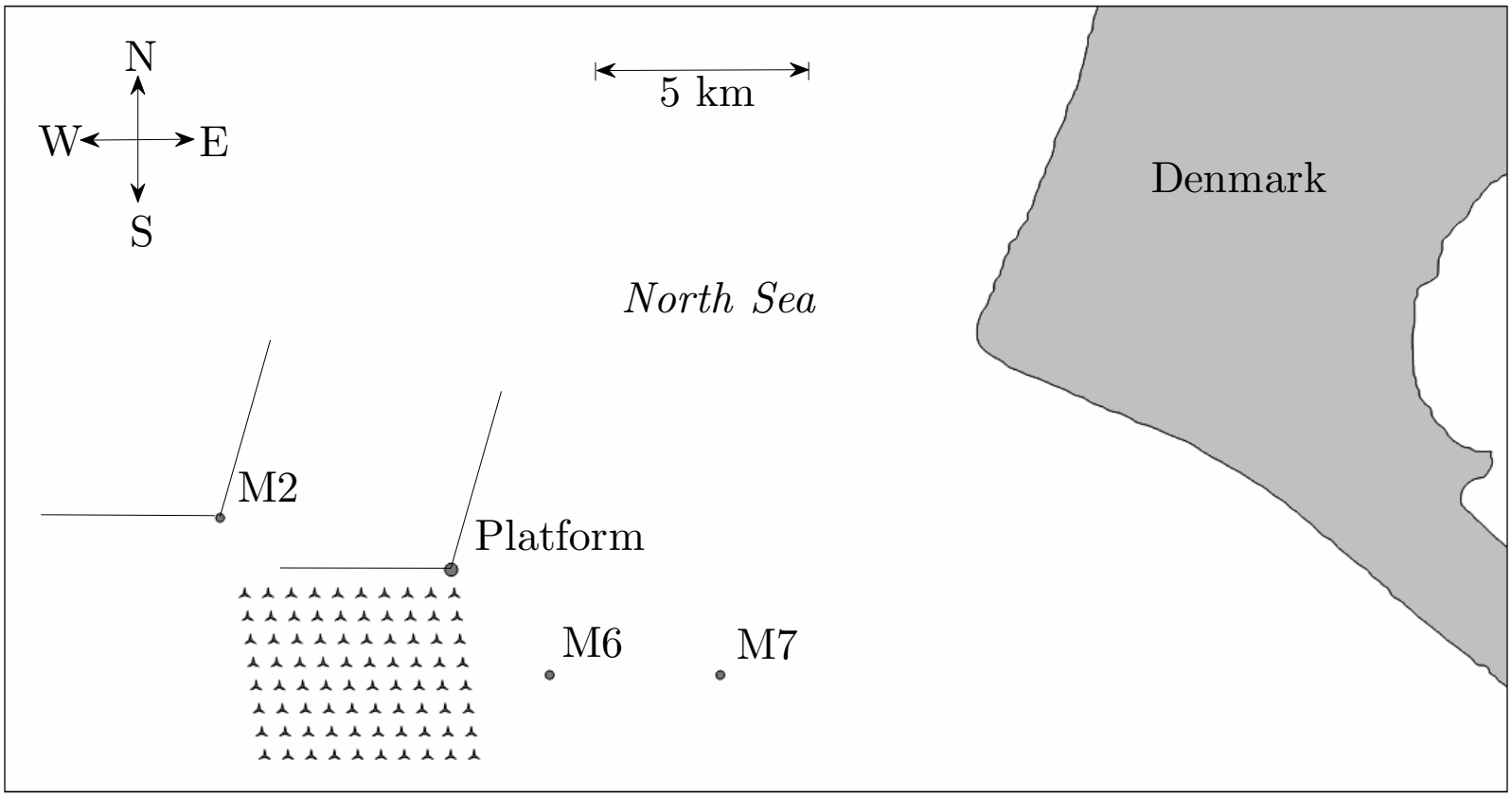
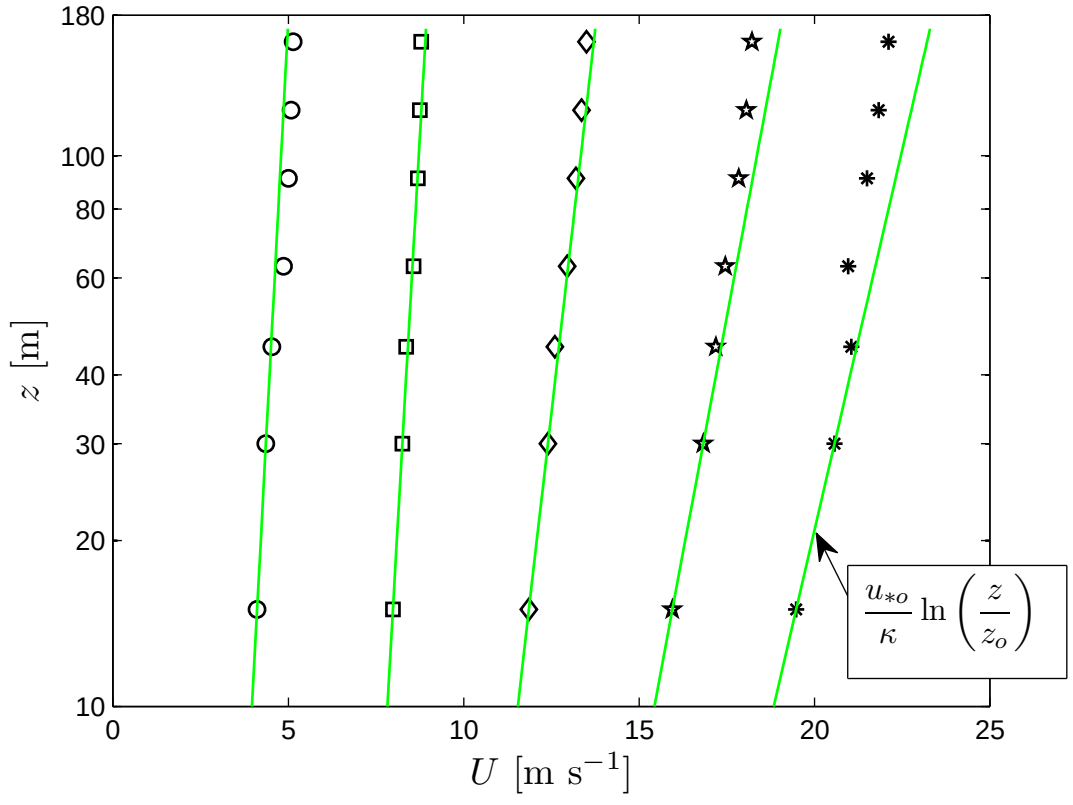


Cup/wind lidar profiles



- z_o is not constant over the sea. Charnock (1955):

$$z_o = \alpha_c u_{*o}^2 / g$$

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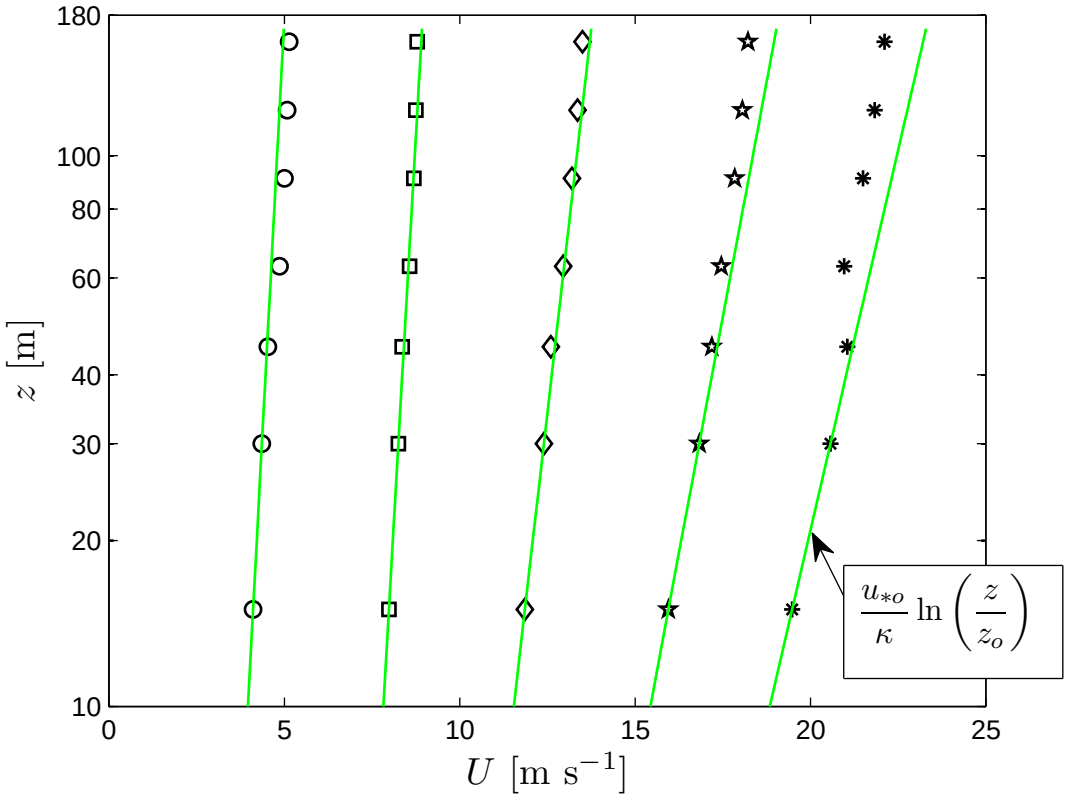

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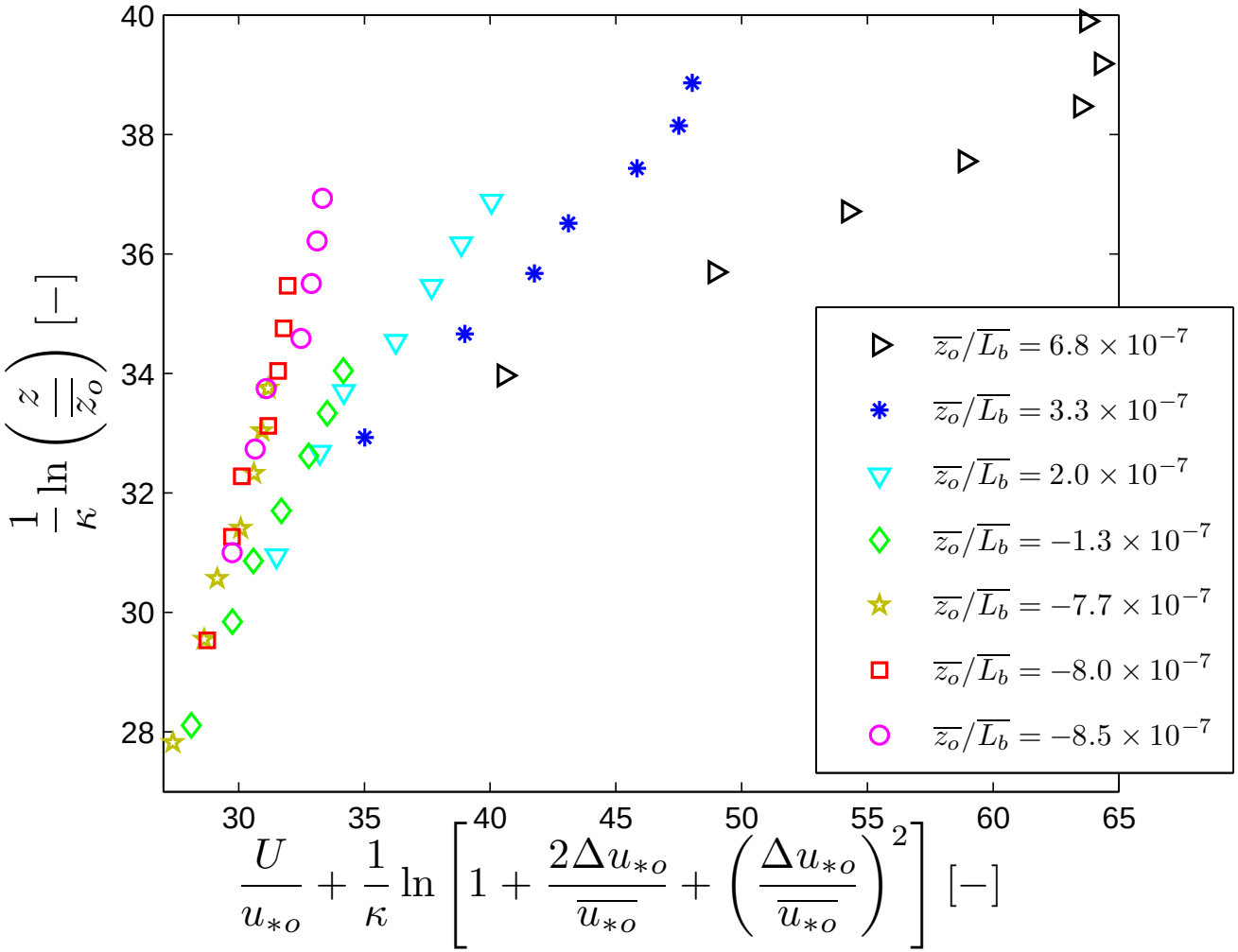
Meteorology for the Horns Rev experiment

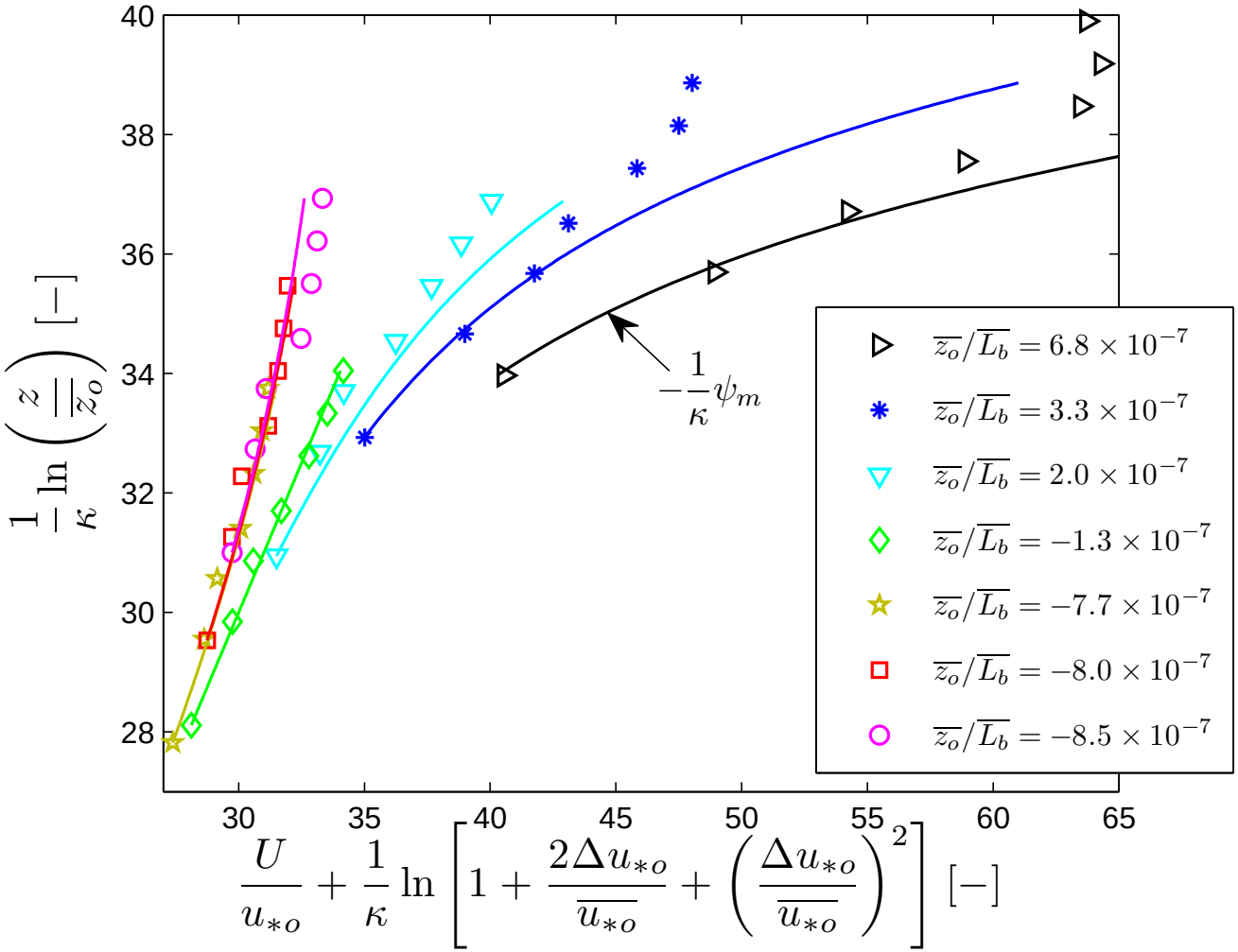
Stab. class	L_b [m]	u_{*o} [m s^{-1}]	U_{15} [m s^{-1}]	$\overline{z_o}$ [m]	z_i [m]	No. of profiles
vs	28	0.12	4.94	1.9×10^{-5}	122	109
s	85	0.15	5.33	2.9×10^{-5}	150	73
ns	314	0.23	7.08	6.3×10^{-5}	223	18
n	-1531	0.40	11.10	19.6×10^{-5}	393	314
nu	-288	0.42	11.54	22.0×10^{-5}	-	600
u	-139	0.30	8.60	11.1×10^{-5}	-	544
vu	-73	0.22	6.65	6.2×10^{-5}	-	358

where $z_i = 0.12 u_{*o}/f_c$

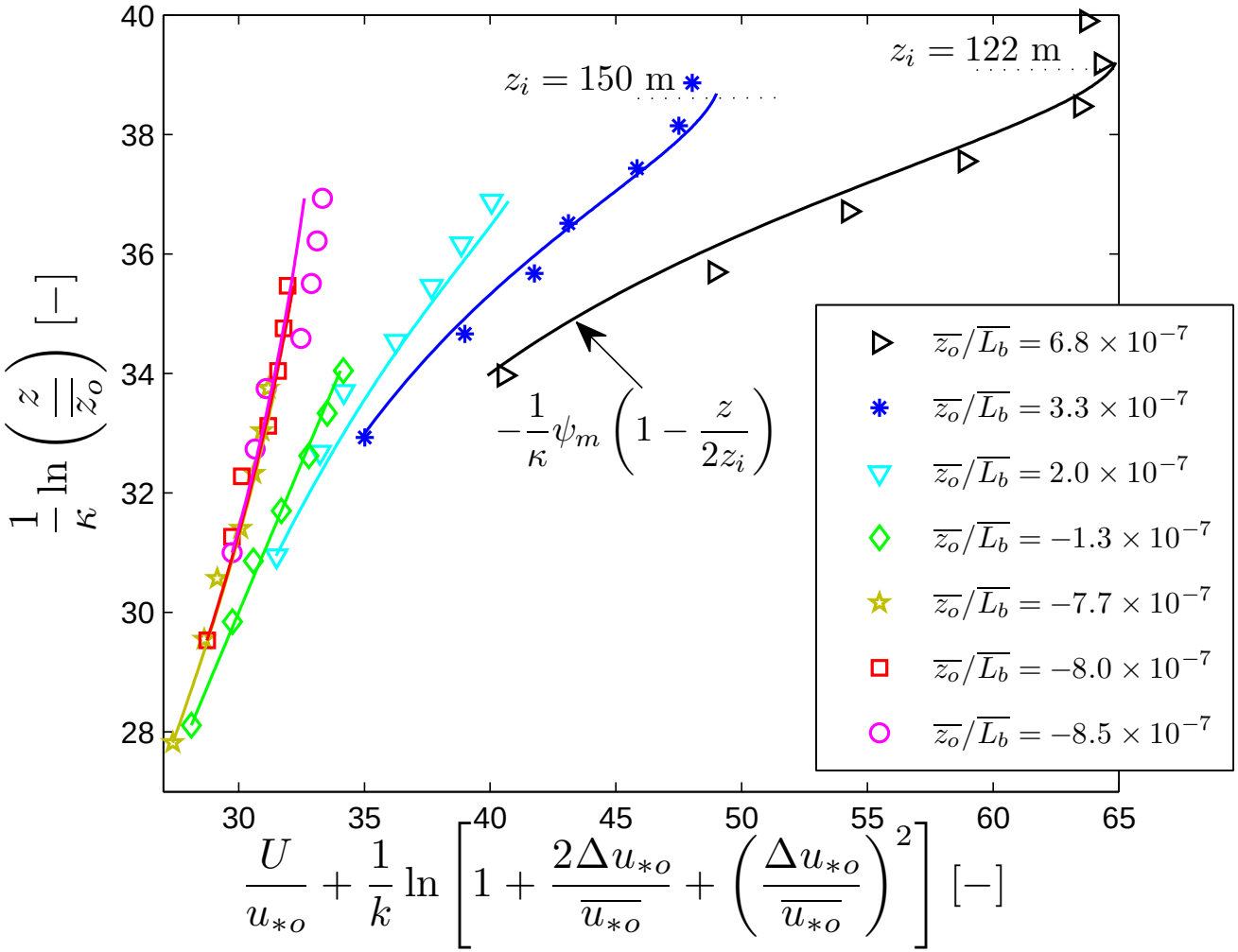
Cup/wind lidar wind speed observations



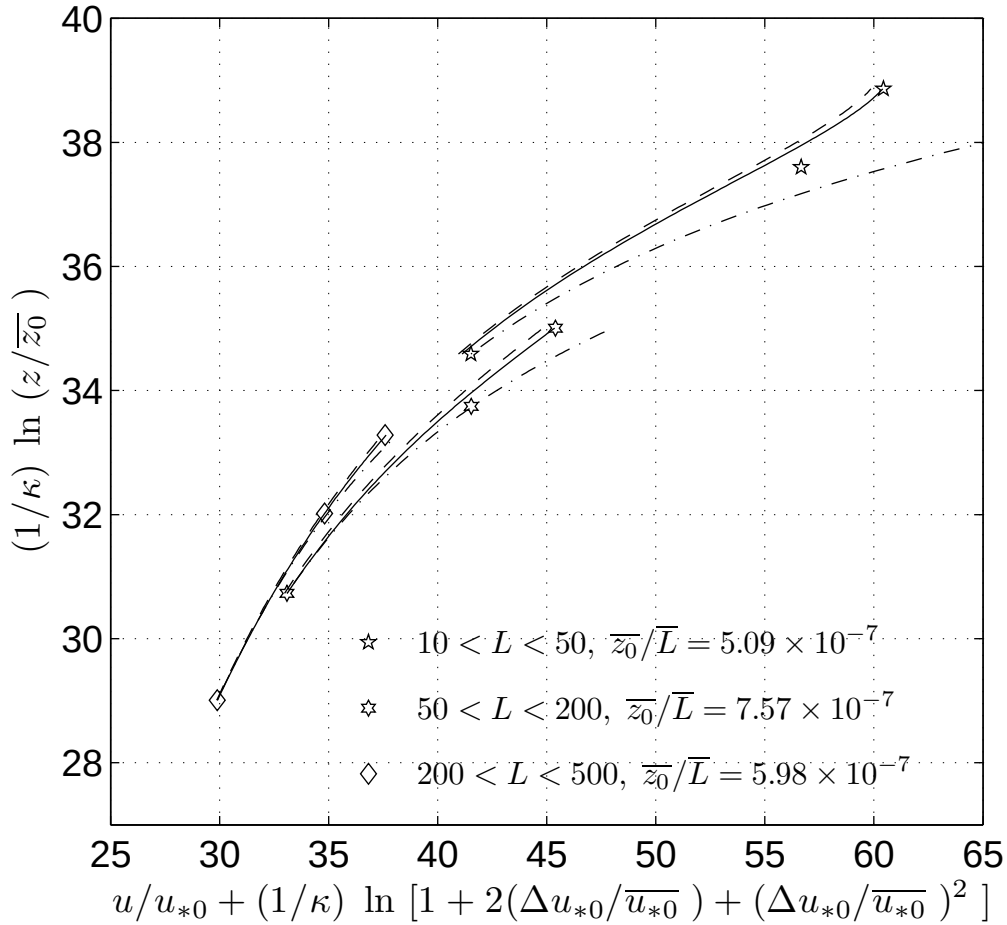
Traditional MOST wind speed profiles



Non-traditional wind speed profiles

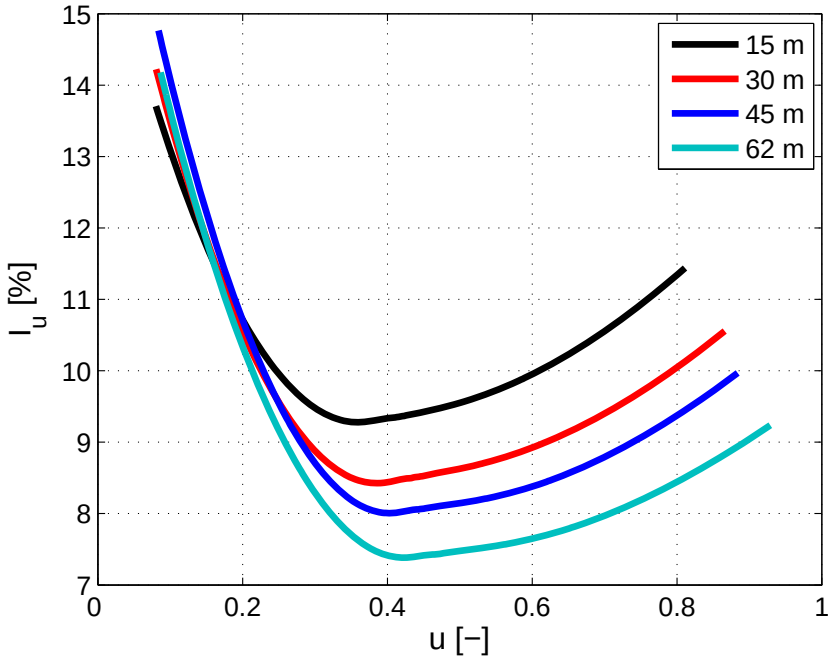


Non-traditional wind speed profiles – EAZ

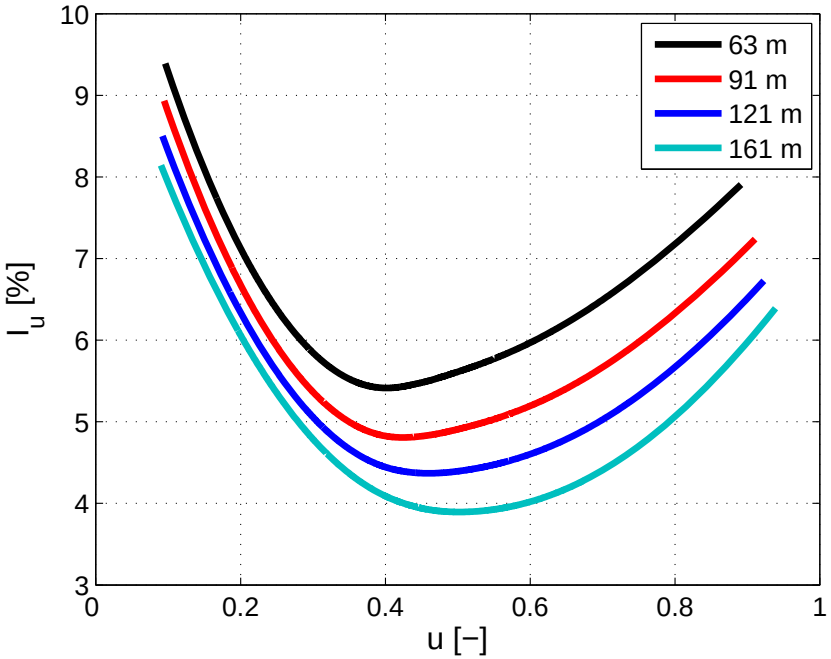


Turbulence intensity

Mast 2

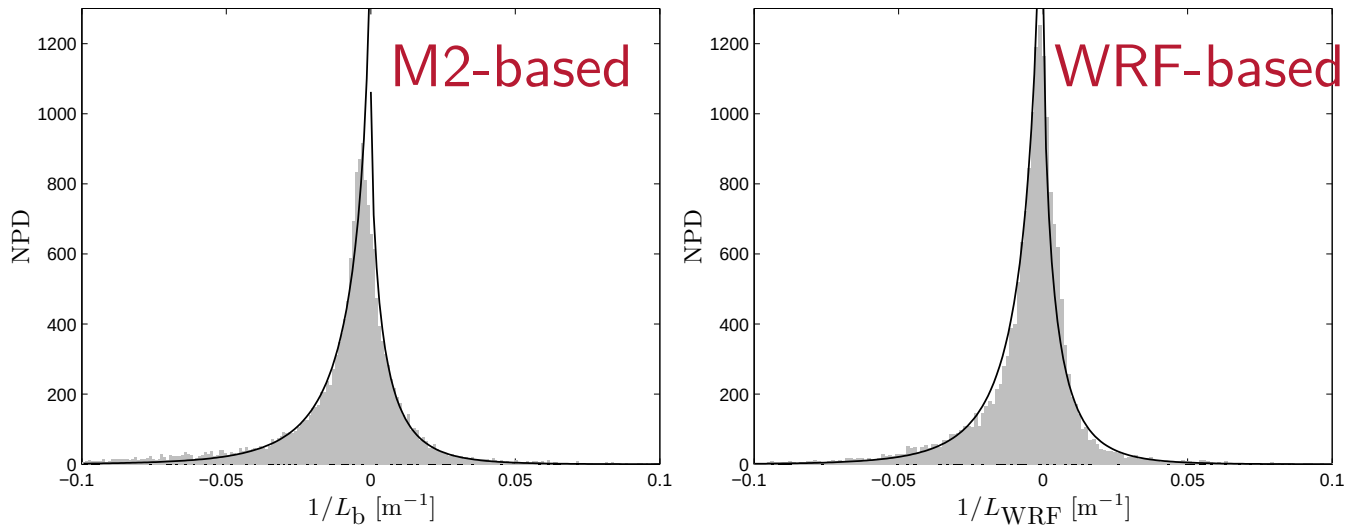


Wind lidar



$$I_u = \sigma_u / u \approx \left[\ln\left(z/z_o\right) - \psi_m\right]^{-1}$$

Long-term analysis – M2 + WRF



$$P = n_{\pm} \frac{C_{\pm}}{\sigma_{\pm}} \frac{\exp\left[-\left(C_{\pm}\left|1/L\right|/\sigma_{\pm}\right)^{2/3}\right]}{\Gamma\left[1+3/2\right]}$$

$$\sigma_{\pm} = \frac{g}{\langle \overline{T} \rangle} \frac{\left\langle \left(\overline{w'\theta'_v} - \langle \overline{w'\theta'_v} \rangle_{\pm} \right)^2 \right\rangle^{1/2}}{\langle u_*^3 \rangle}$$

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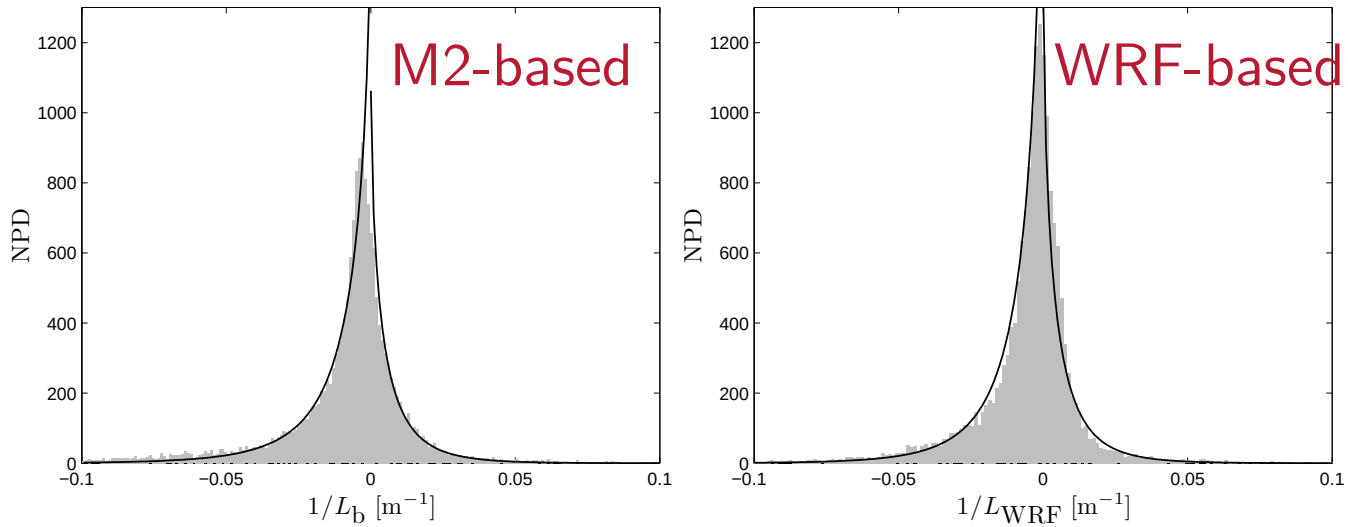

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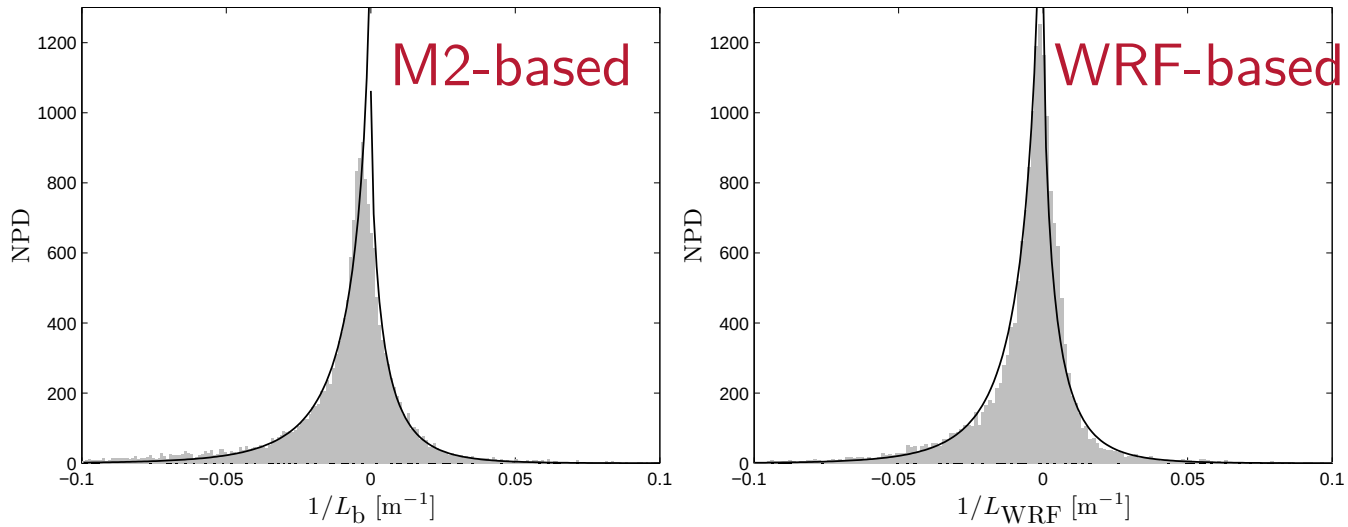

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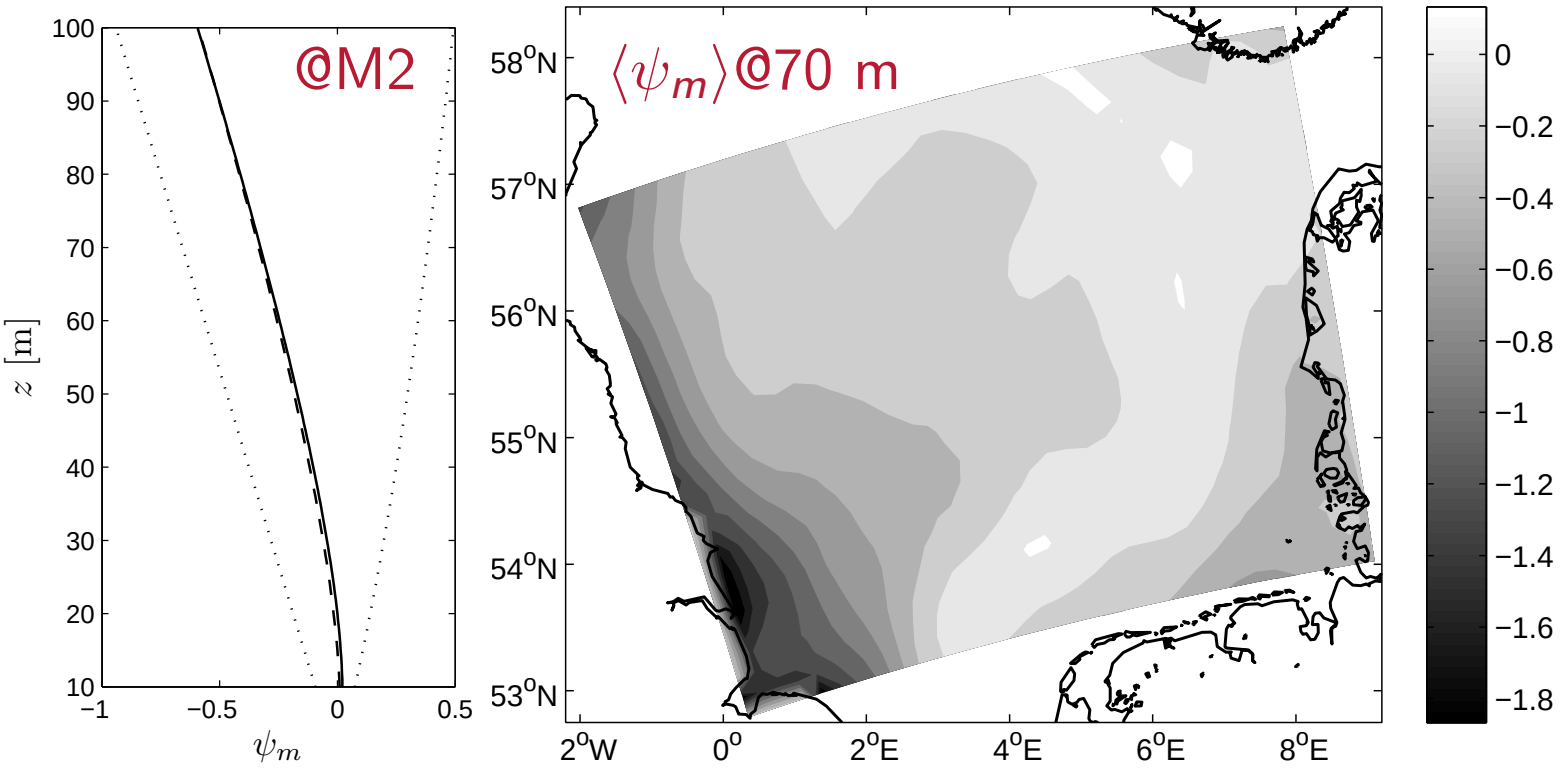
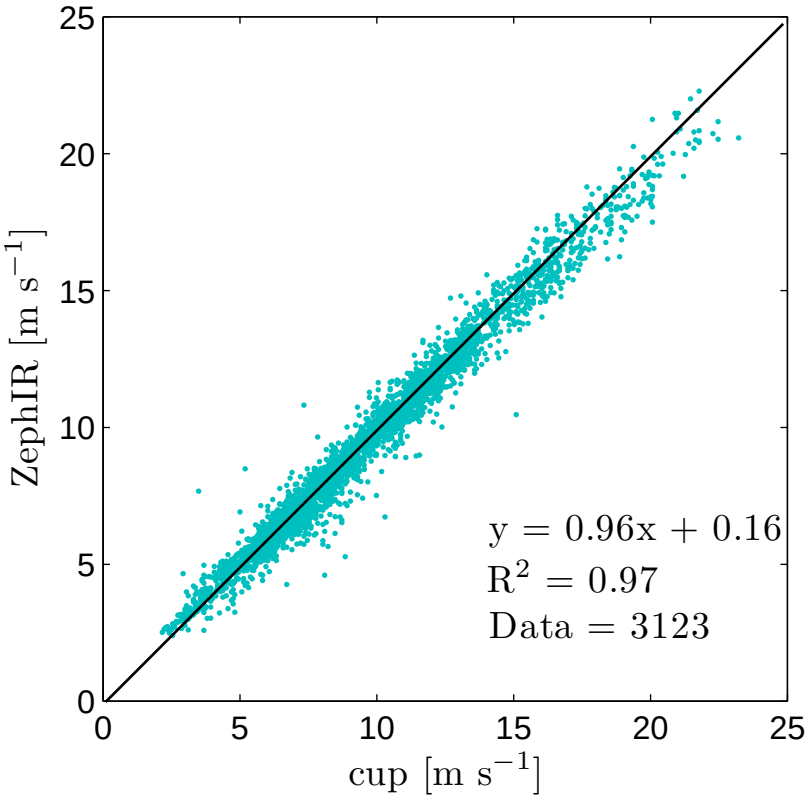
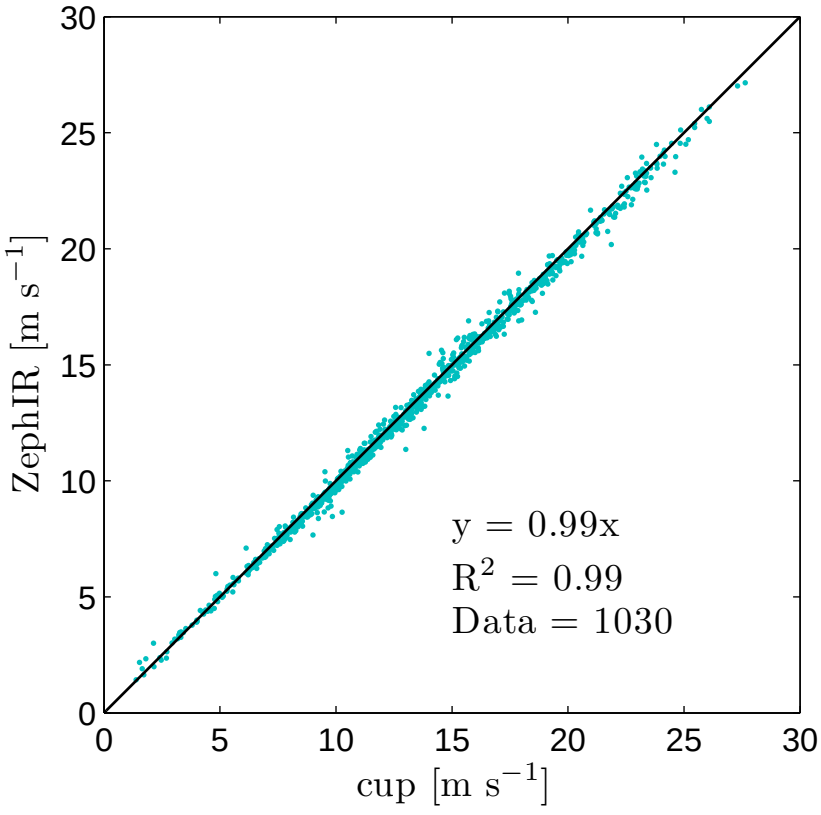


$$\text{LT}: \psi_m(z/\langle L\rangle) \neq \langle\psi_m(z/L)\rangle = -n_+ \frac{3\sigma_+}{C_+} b'\ z + n_-\ f_-(\sigma_-, C_-, \beta, z)$$

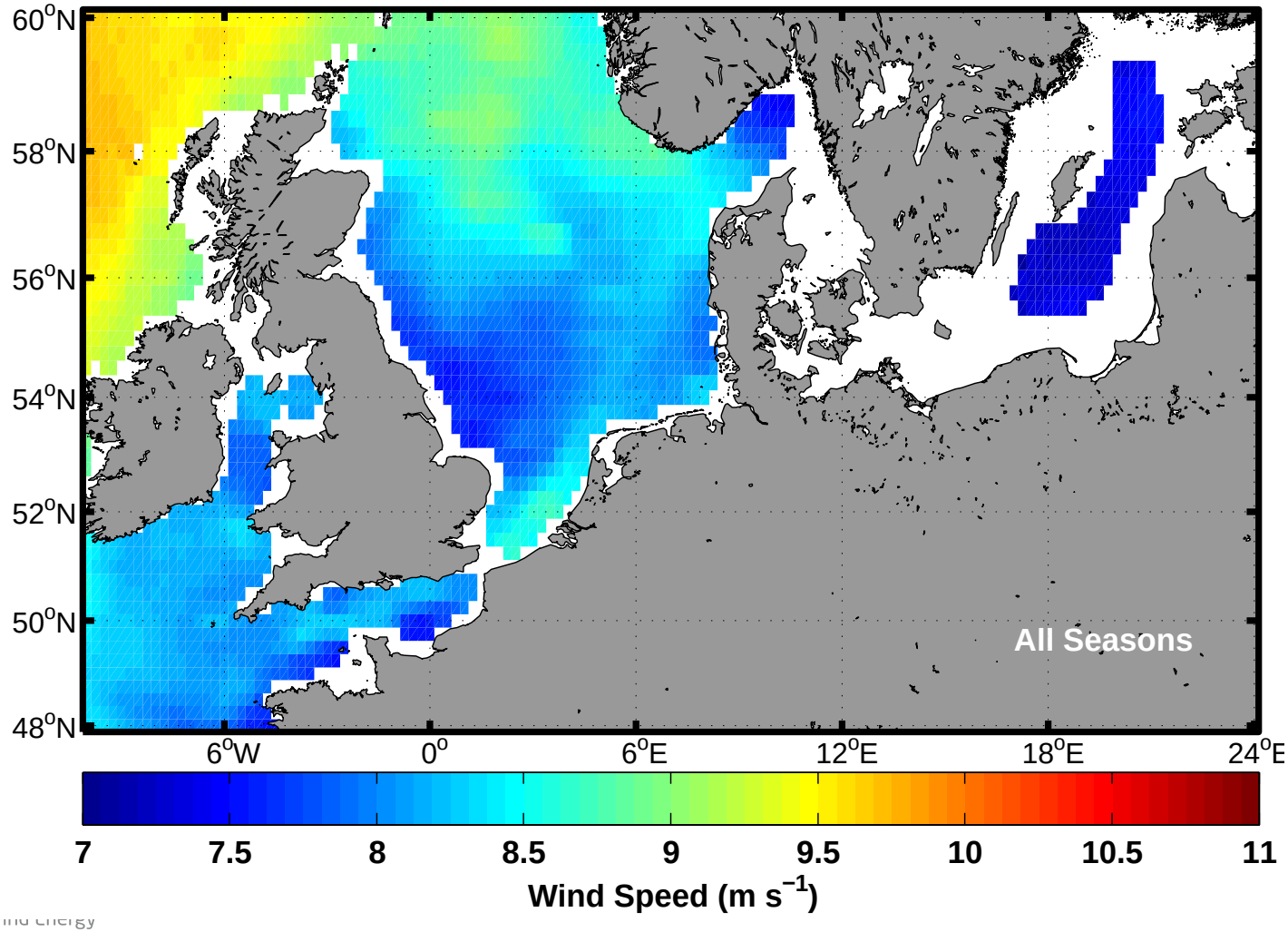
Thanks for your attention!

Wind lidar observations

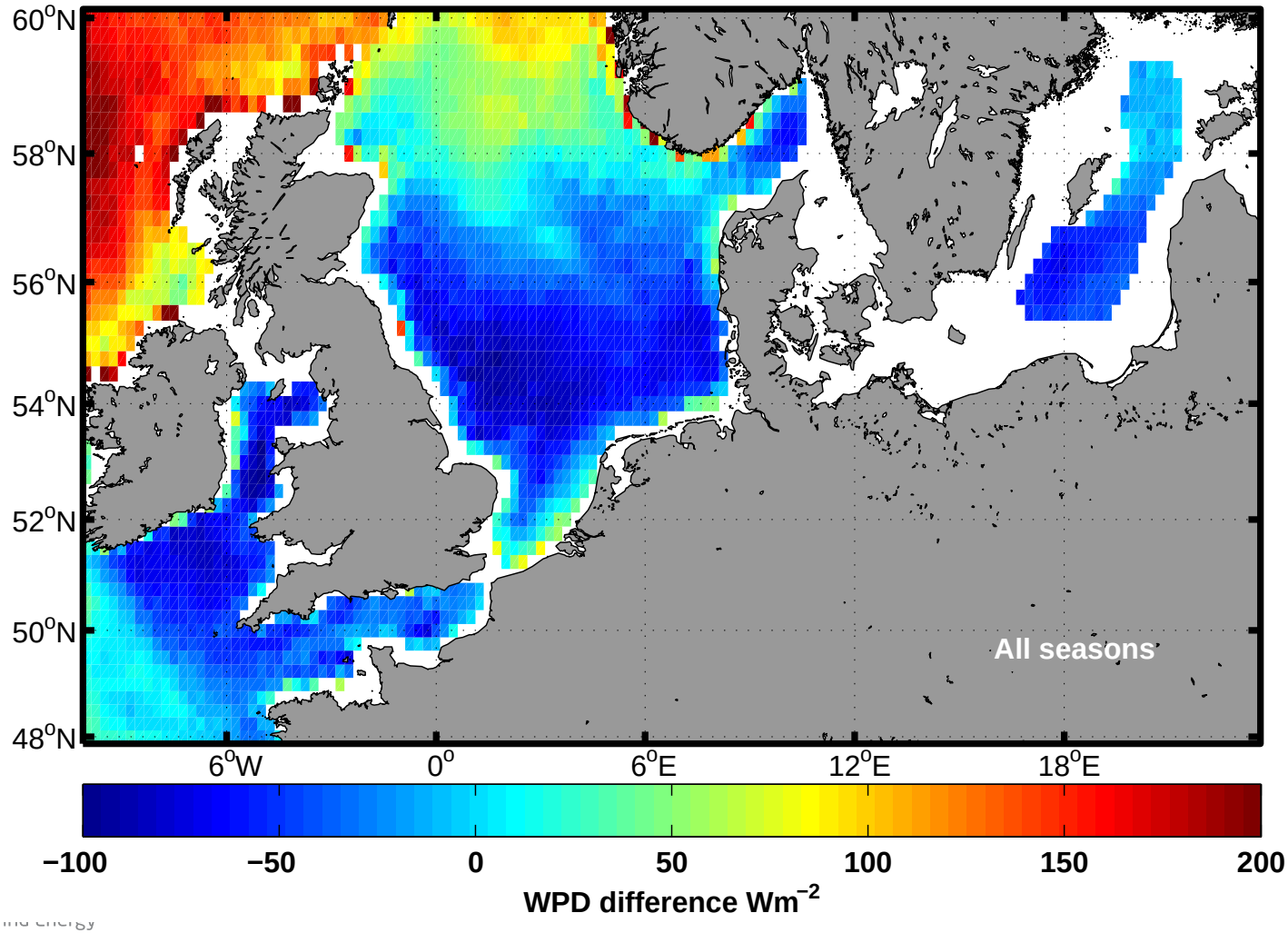




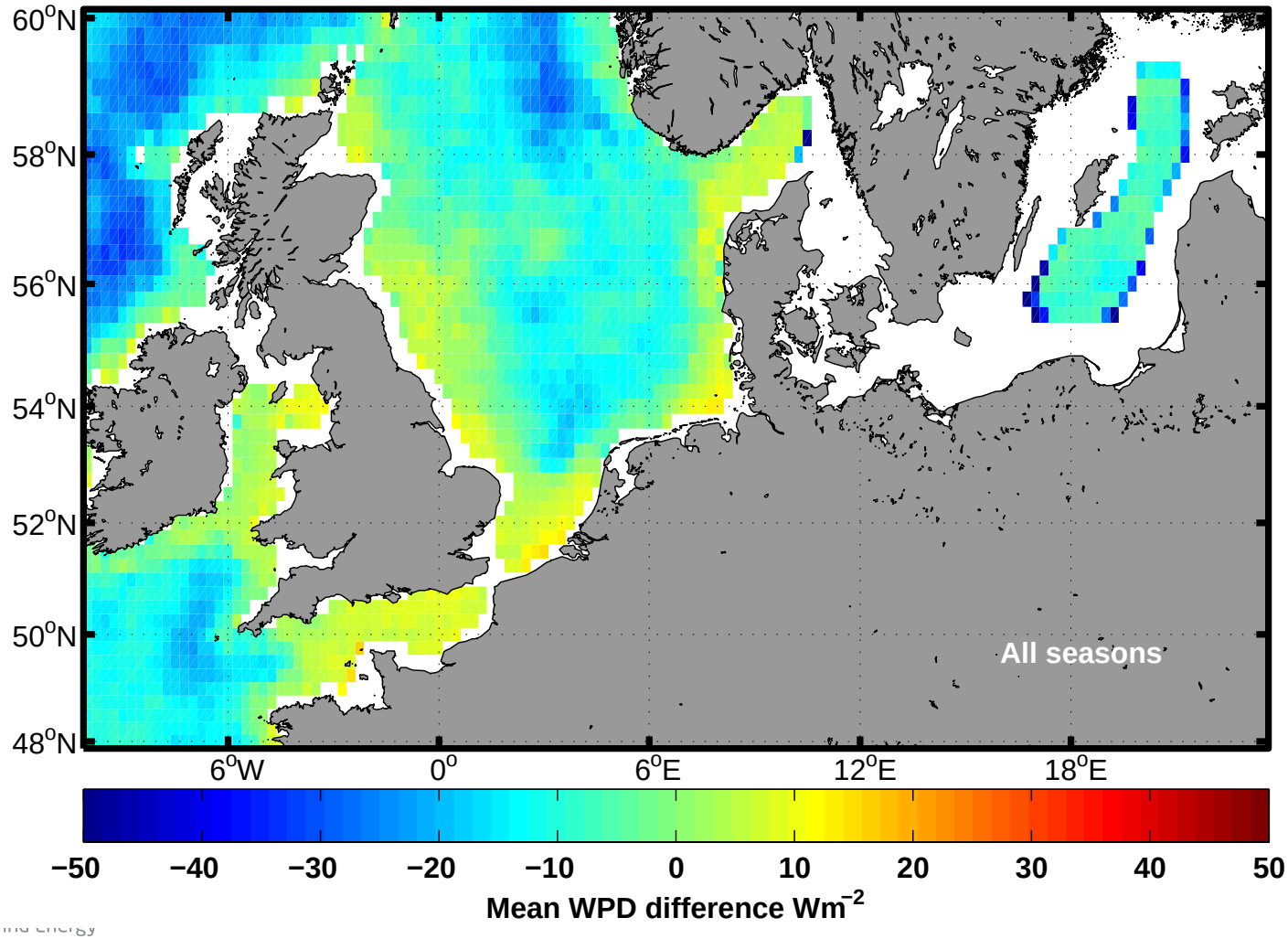
Satellite winds – QuickSCAT



Satellite winds – QuickSCAT/WRF



WRF winds


60°N
58°N
56°N
54°N
52°N
50°N
48°N
6°W
0°
6°E
12°E
18°E
All seasons
−50
−40
−30
−20
−10
0
10
20
30
40
50
Mean WPD difference Wm−2