Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmosphärische Umweltforschung

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

RAVE
RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums

TUFFO – Influence of humidity fluxes on turbulence and static stability of the marine atmospheric boundary layer

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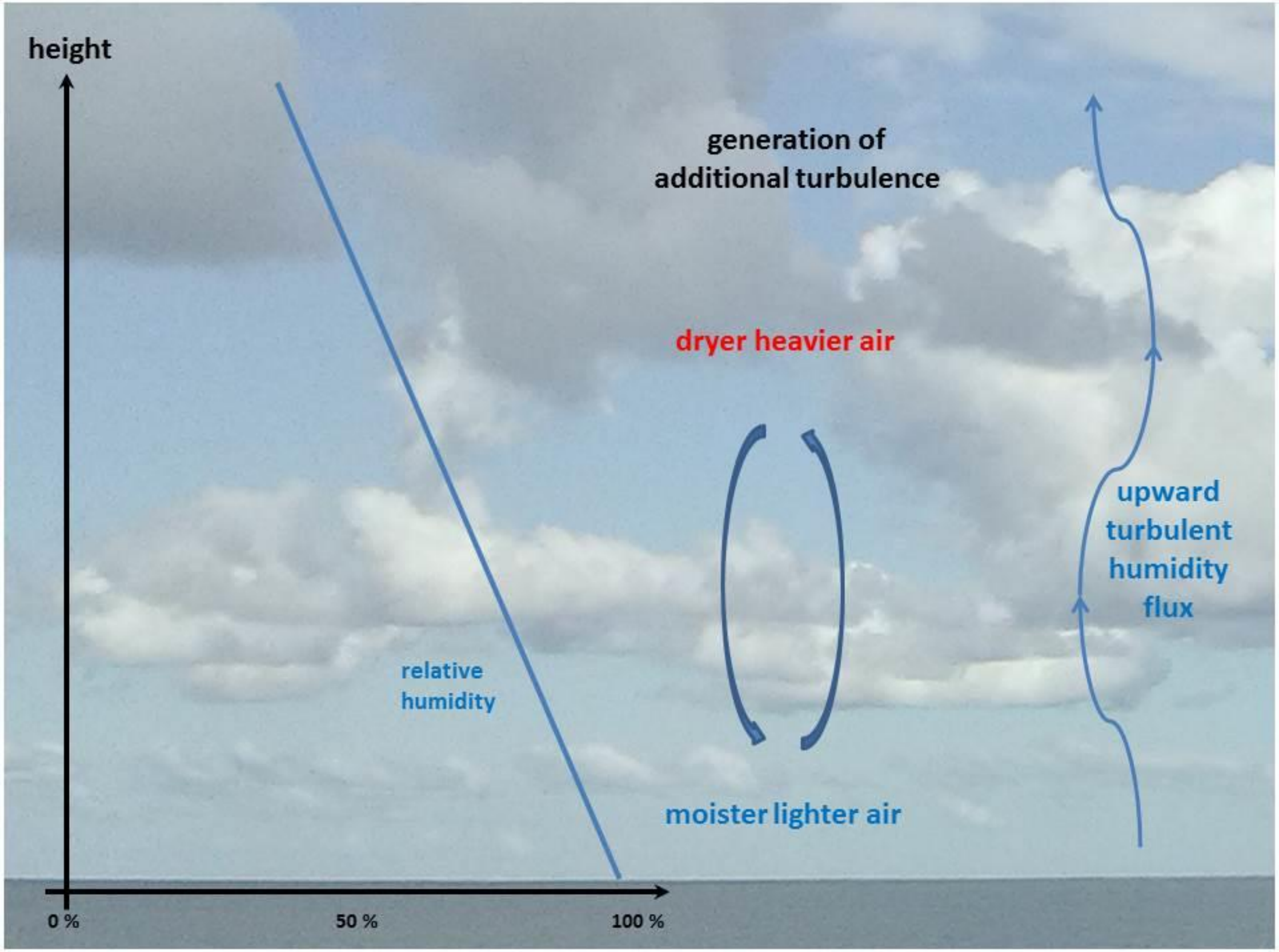
[2] DEWI, UL International GmbH, Wilhelmshaven, Germany

Impact of the vertical turbulent humidity flux on the MABL



known from near surface measurements

destabilises the MABL

how high does it reach?

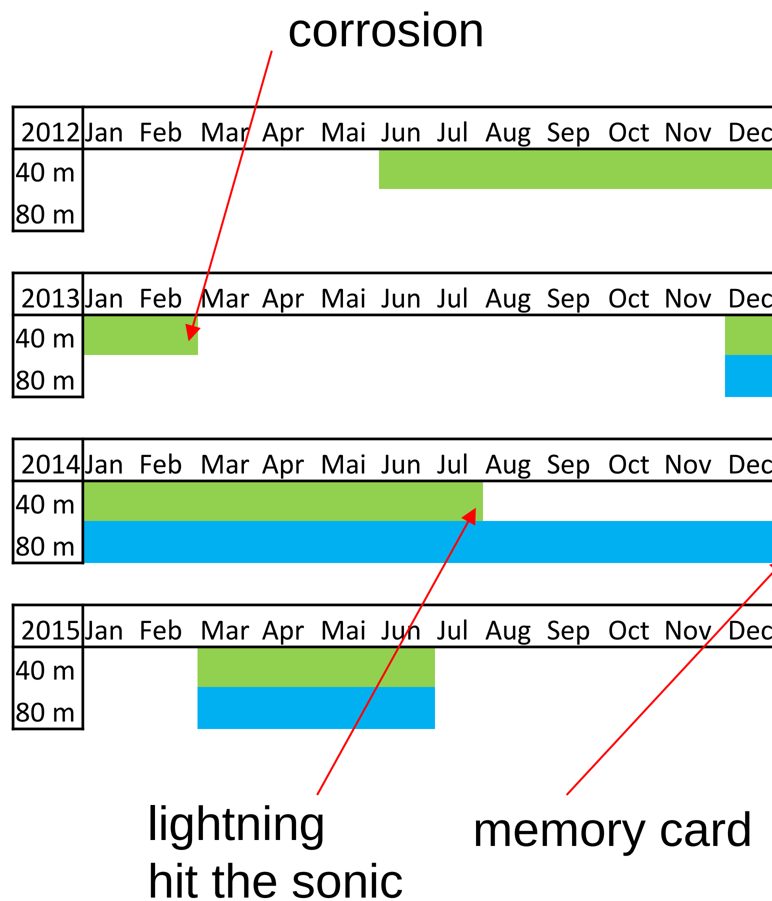
how strong is it?

how does it change turbulence?

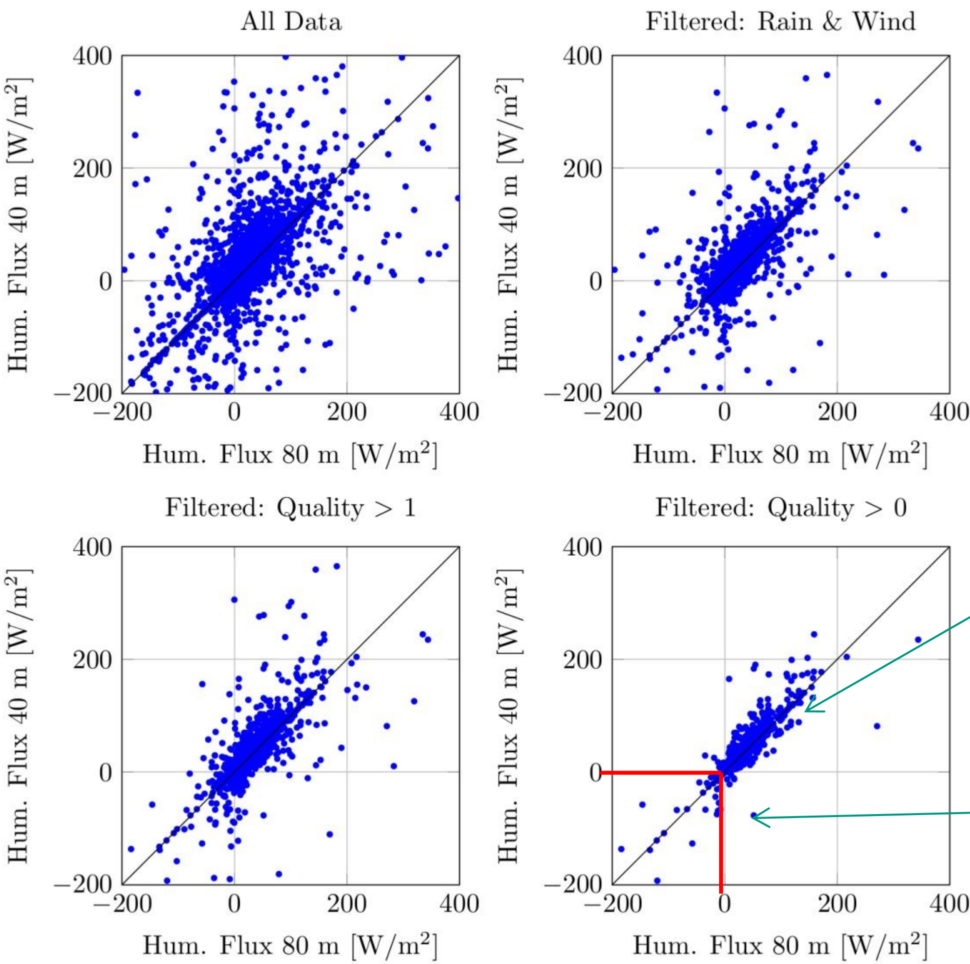
does it influence wind profiles?

…and wakes?

- At least one year measurement at both heights



size of turbulent humidity fluxes



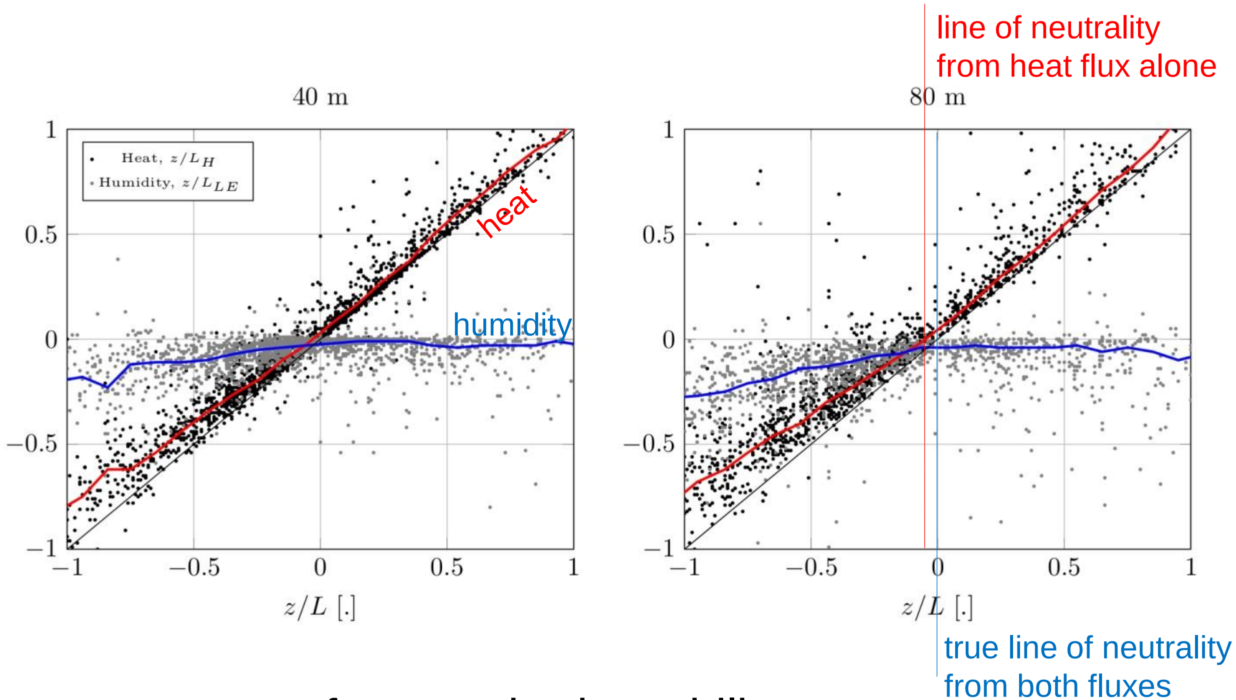
turbulent humidity fluxes have equal sign and size at both heights

nearly all fluxes upward

upward fluxes

downward fluxes

atmospheric stability



measure of atmospheric stability

$$\frac{z}{L} = -\frac{g\kappa z}{u_*^3\theta_v}\overline{w'T'} - 0.61\frac{g\kappa z\theta}{u_*^3\theta_v}\overline{w'q'} = \frac{z}{L_H} + \frac{z}{L_{LE}}$$

heat

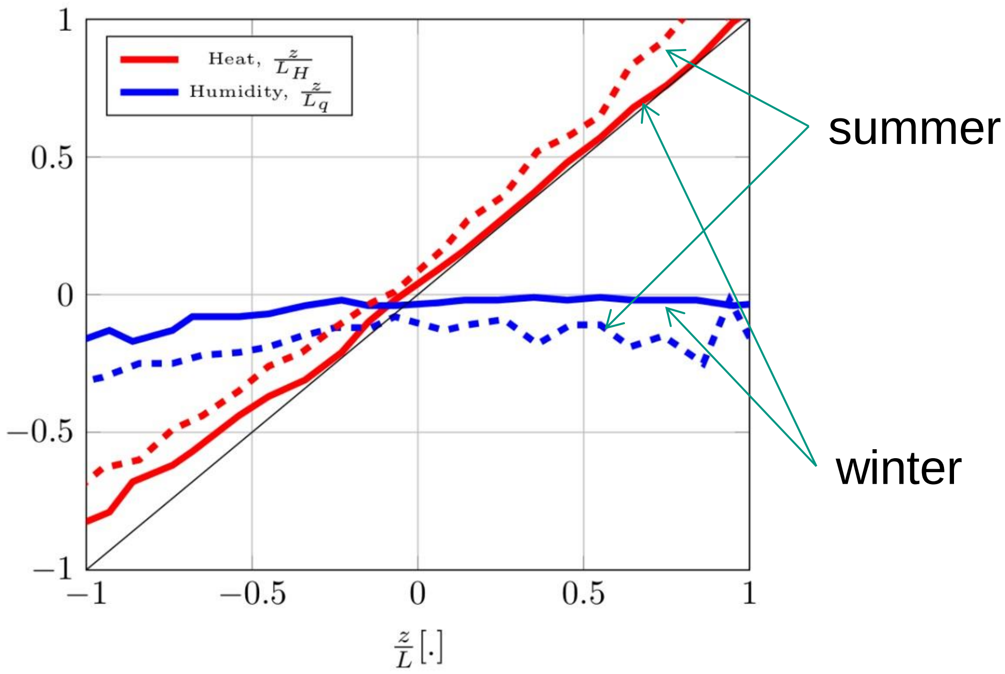
humidity

turbulent humidity flux nearly always contributes to instability

shifts line of neutrality to the right

strongest contribution for unstable stratification (left)

atmospheric stability

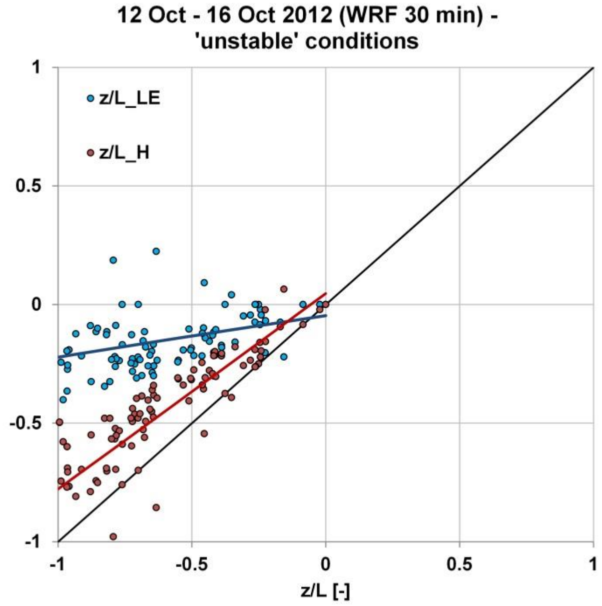


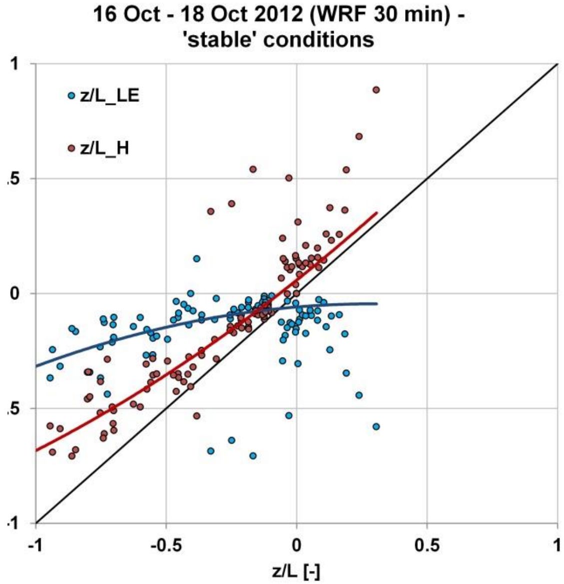
the impact of the turbulent humidity flux is much stronger in summer than in winter

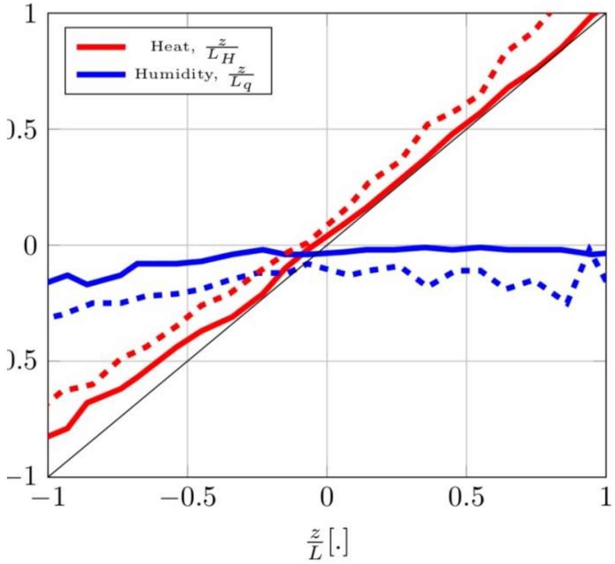
atmospheric stability

comparison to fluxes from WRF model

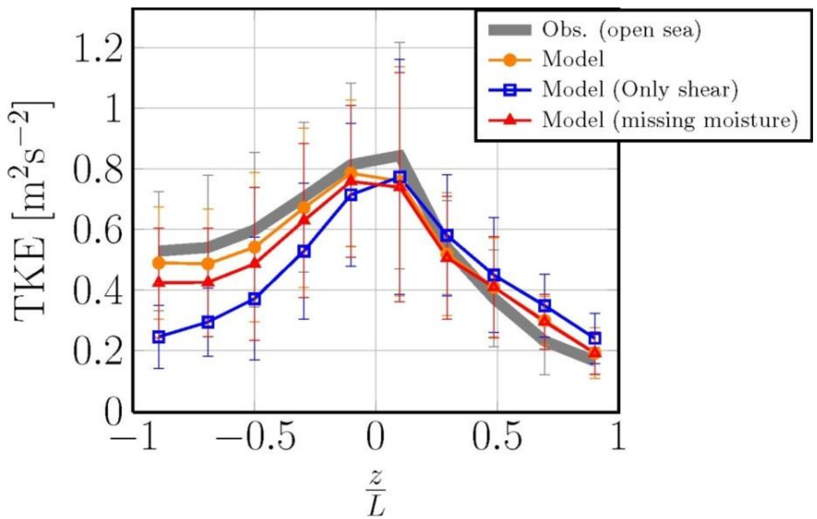
Grenier–Bretherton–McCaa (GBM) boundary layer mixing scheme







turbulent kinetic energy



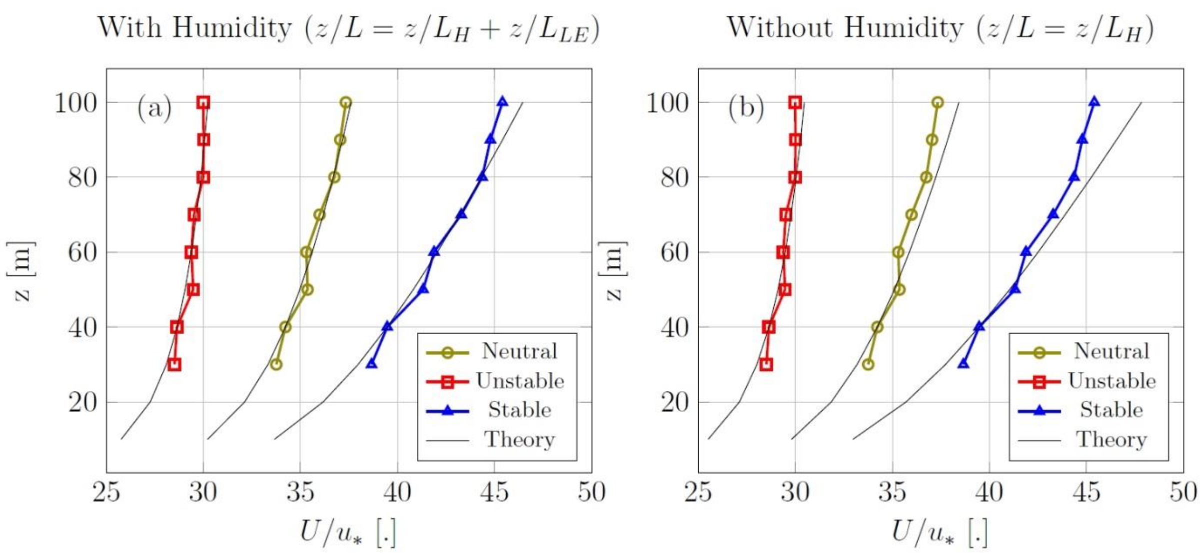
the impact of the turbulent humidity flux on the level of turbulent kinetic energy is stronger for unstable stratification

turbulent kinetic energy equation (simplified)

$$\boxed{TKE} = \frac{1}{2}\left[\kappa z B_1 \left(-\overline{u'w'}\frac{\partial U}{\partial z} + \left(\frac{g}{\theta}\right)\left(\overline{w'\theta'} + 0.61T\overline{w'q'}\right)\right)\right]^{2/3}$$

shear + heat + humidity

mean wind profiles



the impact of the turbulent humidity flux on the vertical wind profile is strongest for stable stratification (4% less wind speed at 100 m when extrapolating from 40 m)
i.e. vertical wind shear is slightly reduced

coloured curves: summer measurements at FINO 1

grey curves: extrapolation from 40 m to other heights

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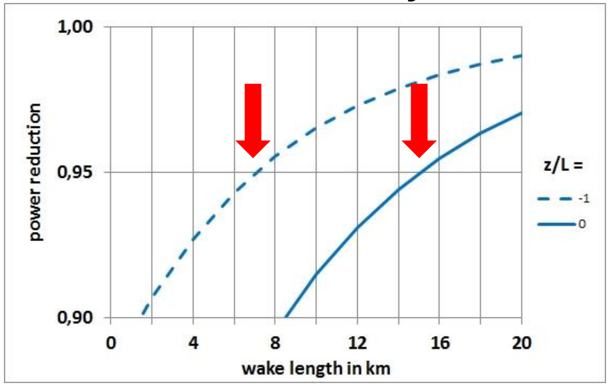
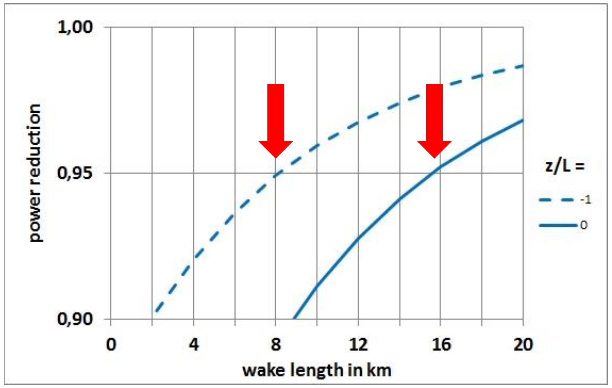
wind farm wakes

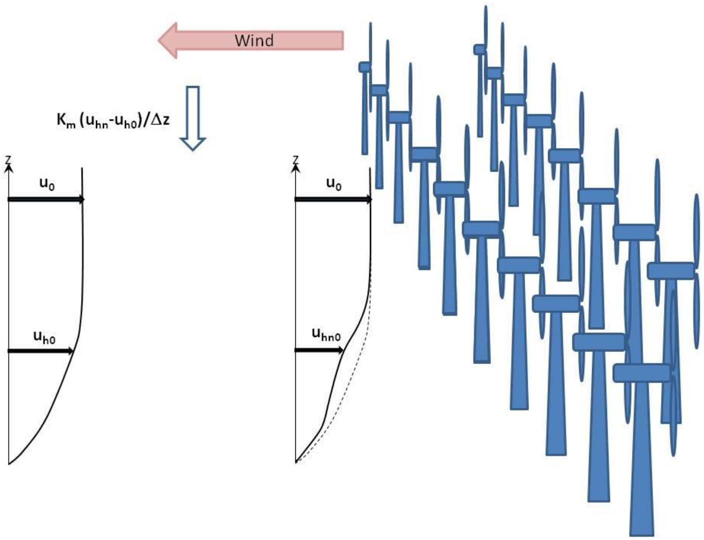
with humidity



without humidity



wake length: 95% recovery of power



results from a simple analytical model

(Emeis 2012)

the impact of the turbulent humidity flux on the length of a wake behind a very large wind farm is strongest for unstable stratification. Here the wake is about 10% shorter.

Summary and Conclusions

► Turbulent Humidity Fluxes:

- at 81.5 m as strong as seen in earlier studies at much lower heights
- nearly always directed upwards, destabilise the marine boundary layer
- impact much larger in summer than in winter
- contributes to an increase of tke of up to 20% under unstable conditions
- modify vertical wind profiles up to 4% under stable conditions (less shear)
- contributes to a shortening of farm wakes by about 10% (reduced especially for unstable conditions)

► fast-response humidity measurements are important for offshore wind energy

► trade-off between higher turbulence and less shear and shorter wakes

► especially important over warmer water (summer, lower latitudes)


Vielen Dank für
Ihre
Aufmerksamkeit