First Eddy-Covariance measurements at FINO1
The influence of humidity fluxes on atmospheric stability
Preliminary results

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Introduction: Knowledge of turbulence fluxes over the sea is relevant for a better general understanding of air-sea exchange processes and is essential to improving bulk parameterizations used in numerical modeling to be applied in wind energy. Of particular importance is the assessment of atmospheric stratification or static stability of the marine boundary layer (MABL) which depends on the wind speed and temperature, but also the humidity content of the air close to the marine surface and above.

Although the impact of the humidity effect in the stability estimation is well-known, the contribution of the latent heat flux is often neglected and rarely monitored in offshore conditions. As a part of the RAVE research initiative within the new project **TUFFO** (Detection and assessment of the impact of **tu**rbulent humidity (**F**euchte) **f**luxes on turbulence in **o**ffshore wind parks), an eddy-covariance measurement system has been installed at FINO1 and has been operating since June 2012. The infrared fast-response hygrometer (Licor LI-7500A) was installed close to the existing sonic anemometer (Gill R3-50) at 41.5 m LAT (Figure 1). Turbulent measurements of temperature, wind velocity components and humidity are recorded at a sampling rate of 20 Hz.

This new measurement set-up at FINO1 gives us the opportunity to accurately determine fluxes of momentum, heat and moisture between the sea and atmosphere. This poster presents the measurement set-up together with preliminary results concerning the relative impact of the humidity fluxes on the estimation of atmospheric stability.

Experimental setup

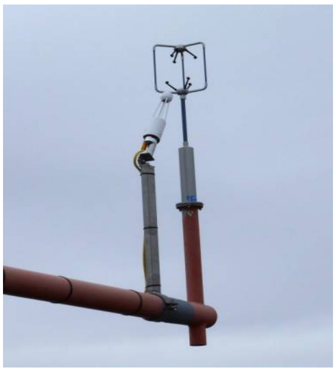


Figure 1. Eddy-covariance system at FINO1.

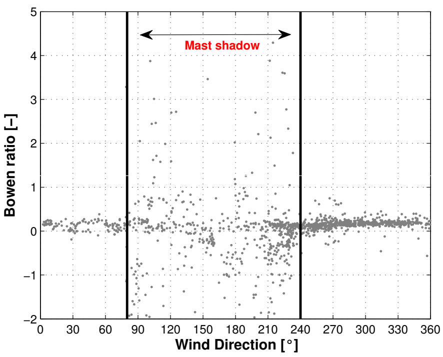
- **Location**: FINO1 offshore mast (lat. 54°0.86'N, long. 6°35.26'E)
- **Height**: 41.5 m LAT
- **Data resolution**: 20 Hz
- **Instruments**:
  - Sonic anemometer: Gill Instrument SOLENT R3-50.
  - Open path infrared H_2O/CO_2 gas analyzer: LI-COR LI-7500A.

Fluxes are calculated on a 30-min basis using the eddy-correlation (E-C) technique [1]. Rain data are discarded.

Additional mean meteorological data (temperature, pressure, relative humidity,...) are used for the bulk formulation.

Importance of Humidity Flux on Static Stability

In Figure 2 the contribution of latent heat flux to the total buoyancy is evaluated by using the Bowen ratio =(Q_{LH}/Q_{LE}).



It can be seen that outside of the mast shadow, the mean Bowen ratio is about 0.1, the expected value in the MABL.

Figure 2. Bowen ratio as a function of wind direction.

As shown in [1], the static stability (zL^{-1}), using the definition of virtual potential temperature, can be partitioned between contributions due to temperature (zL^{-1}_H) and humidity (zL^{-1}_{LE}) flux, i.e.,

$$\frac{z}{L} = -\frac{g\kappa z}{u_*^3\theta_v} < w'\theta' > -0.61\frac{g\kappa z\theta}{u_*^3\theta_v} < w'q' > = \frac{z}{L_H} + \frac{z}{L_{LE}} \quad [1]$$

where θ and θv are the potential and virtual potential air temperature respectively, κ the Von Karman constant (=0.40), g the gravity, u* the friction velocity and <w'θ'> and <w'q'> the mean covariance of temperature and humidity.

Figure 3 shows the importance of humidity to stability (zL^{-1}), zL^{-1} increasing (conditions become more unstable) if zL^{-1}_{LE} is added in unstable conditions and zL^{-1} decreasing (conditions become closer to neutral) if zL^{-1}_{LE} is added in stable conditions.

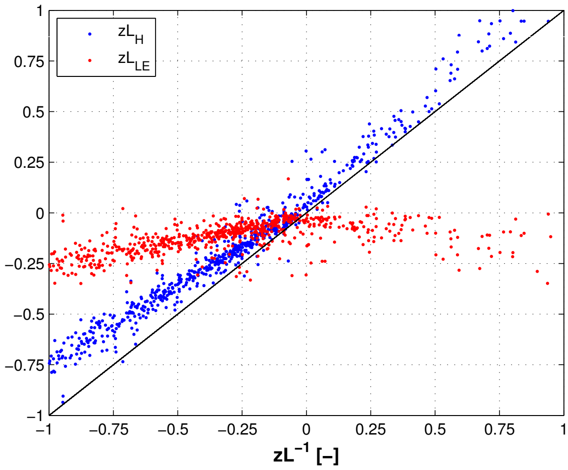


Figure 3 : Contribution of zL^{-1}_{LE} (latent heat flux contribution) and zL^{-1}_H (sensible heat flux contribution) to the total value of zL^{-1} (Eq. 1) in different stability conditions.

Fluxes: Eddy covariance versus bulk formula

In Figure 4, the wind stress, heat and humidity fluxes are compared with a bulk formulation [2] which also calculates the amount of latent heat transfer based on the generation of sea spray. The sea spray component of the total humidity flux is negligible at low wind speeds but will tend to increase to roughly 10% of the total humidity flux at 15 ms^{-1}.

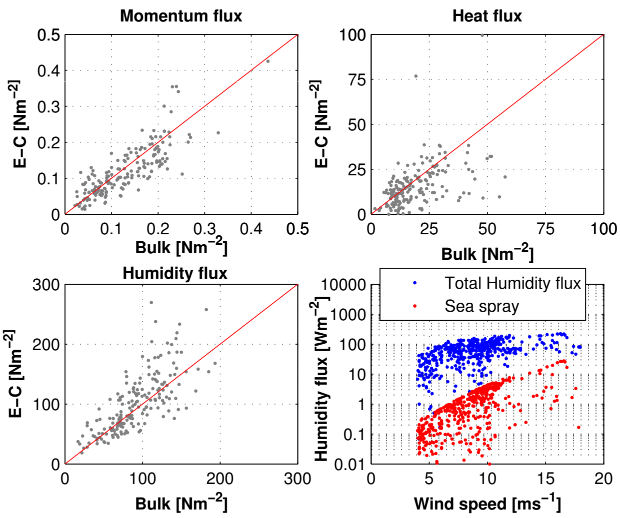


Figure 4. Comparison between measurements of the wind stress, heat and humidity fluxes with that calculated by a bulk meteorological model. Also included is a model estimate of the contribution from sea spray to the total humidity flux as a function of wind speed.

Conclusions

The humidity flux can contribute up to 25% of the magnitude of the static stability. In general, this means that humidity fluxes make the ABL more unstable (and hence less wind shear).

Acknowledgements

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