The importance of humidity for stability at FINO 1 (North Sea)

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August 12, 2009

Outline

Key features of the Marine Boundary Layer

Compared with land, marine conditions feature:

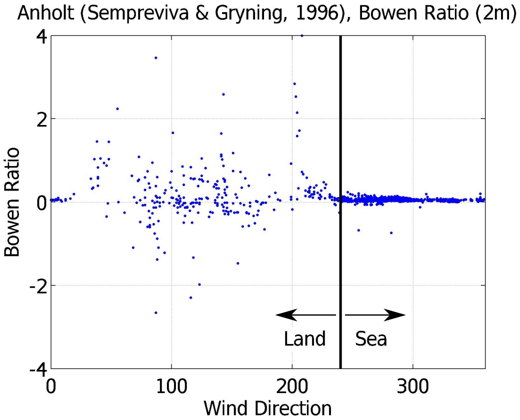
- Highly irregular, dynamic surface
- Less surface friction
- Little diurnal variation of boundary layer
- Effect of moisture on stability may not be neglected...

Motivation - Importance of humidity for stability

- Monin-Obukhov stability parameter: $\frac{z}{L} = \frac{zkg<wT_v>}{T_v u_*^3}$
- Virtual potential heat flux can be estimated from: $< wT_v > = < wT > + 0.61T < wq >$
- An ultrasonic anemometer measures: $< wT_s > = < wT > + 0.51T < wq >$
- In dry and/or cold conditions, $< wq >$ = humidity flux can be neglected, hence $< wT_v > \approx < wT_s >$
- Relative importance of heat to humidity fluxes: Bowen Ratio $= \frac{c_p<wT>}{L_v<wq>}$.
- For example, Andreas et al. (2006) - Evaluations of the von Karman constant in the atmospheric surface layer, assume $< wT_v > = < wT_s >$ in arctic conditions (Bowen Ratio $= \infty$).
- How valid is this assumption in marine conditions?

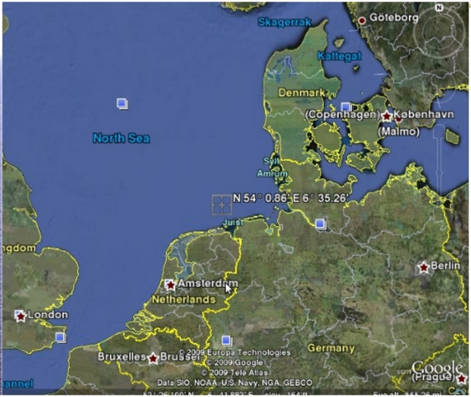
Review

Sempreviva & Gryning (1996) - Humidity Fluctuations in the Marine Boundary Layer measured at a coastal site...



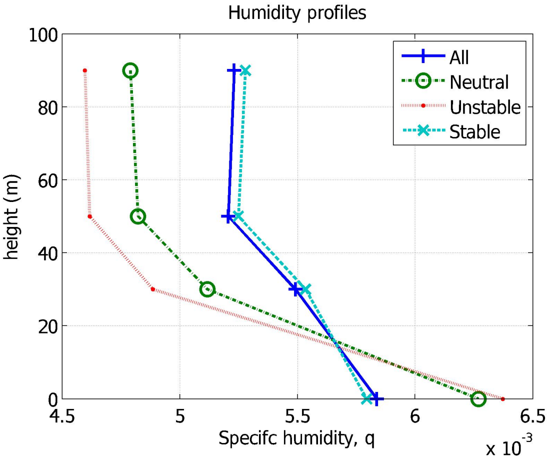
- Marine Conditions: (Bowen Ratio ≈ 0.1);

FINO 1 - Measurement platform in the North Sea



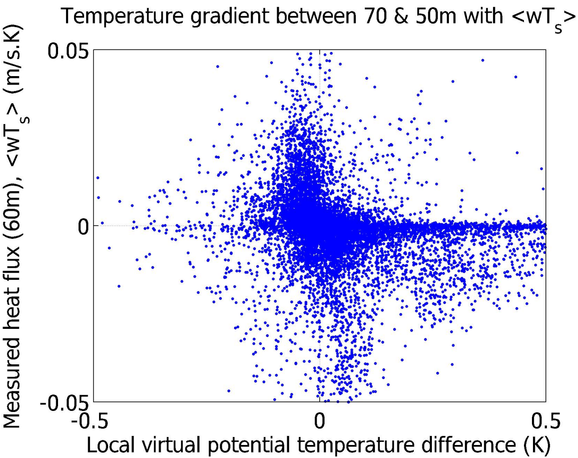
- In operation since 2003, approx. 45km North of Borkum Island.
- Cup anemometers, wind vanes, temperature sensors, ultrasonic anemometers, hygrometers at multiple levels.
- Data here presented for the period 01/01/05-15/05/05.

Humidity at FINO1?



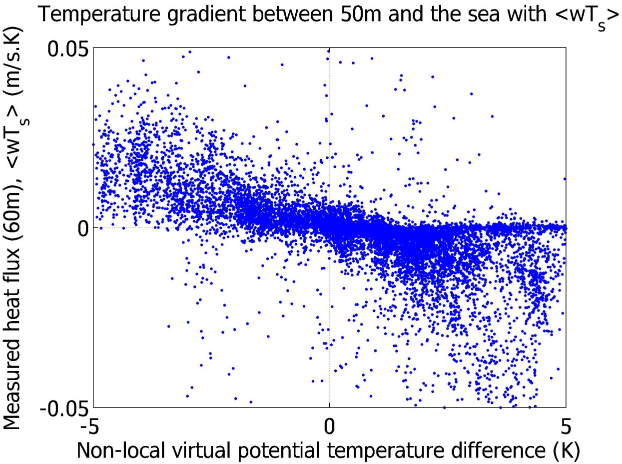
- Above 50m – Negative humidity flux for stable conditions, positive humidity flux for neutral & unstable.
- Are fluxes driven by local gradients above 50m, or by non-local gradients, i.e. sea surface relative humidity = 100%?

Heat Flux - Profile Relationship



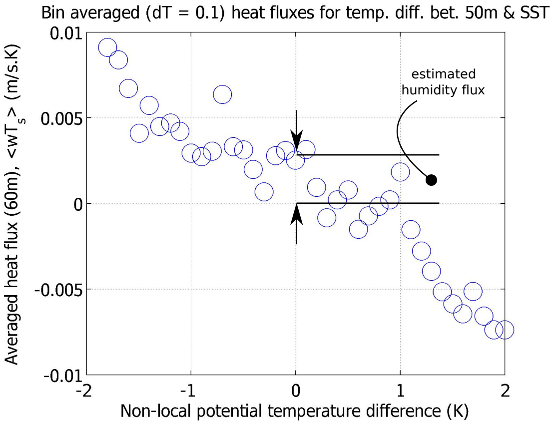
- Local heat fluxes are poorly correlated with local temperature gradients. (Correlation coefficient: -0.06)

Heat Flux - Profile Relationship



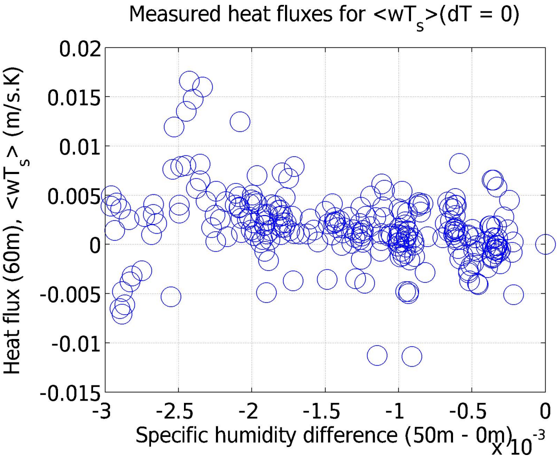
- Heat fluxes are driven by non-local temperature gradients. (Correlation coefficient: -0.47)
- Non-locally driven fluxes make it difficult to derive fluxes from profiles.

Estimation of temperature and humidity fluxes:



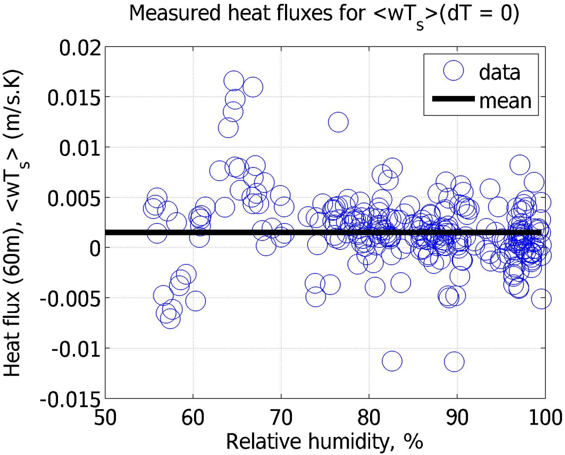
- If humidity flux were zero, averaged heat flux would pass through the origin when plotted against the potential temperature.
- Therefore, since $< wT_s > = < wT > + 0.51T < wq >$, then $< wT_s > (\Delta\theta = 0) = 0.51T < wq >$.

Estimated humidity fluxes



- Estimated humidity fluxes poorly correlated with both fine humidity gradients and (shown here) bulk differences.
- Humidity flux a function of larger atmospheric scales?

Estimated humidity fluxes

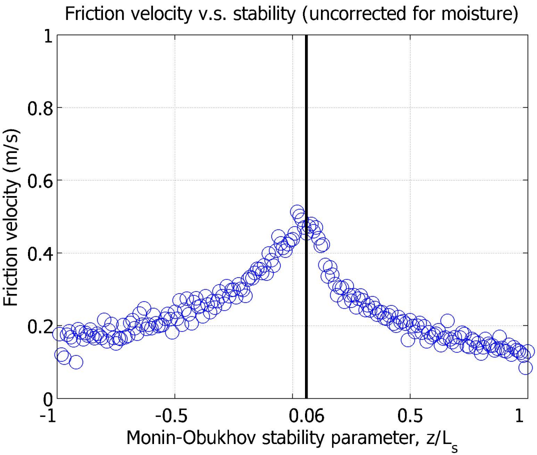


- Mean humidity flux, $< wq >= \frac{<wT_s>(\Delta\theta=0)}{0.51\,T} = 1x10^{-5}$.
- Assuming value representative of all stabilities (poor humidity flux correlation with temperature gradient):
  - Average Bowen ratio over all stabilities $= 0.31$ (Sempreviva & Gryning, 1996: Bowen ratio over all stabilities ≈ 0.1)

Effect on buoyancy

- Total Buoyant flux: $\frac{g}{T} < wT > +0.61g < wq >$
- Ratio of these two terms, Buoyancy ratio: $\frac{0.61T<wq>}{<wT>}$
- Converting Bowen ratio (≈ 0.3) to the Buoyancy ratio gives $\frac{0.61T<wq>}{<wT>} \approx 0.2$
- Lower than that reported in literature (Possibly because of the lower temperatures at FINO 1 early in the year):
  - Sempreviva & Gryning: Buoyancy ratio ≈ 0.4.
  - Edson et al. (2004) "the moisture flux component...provided more than half of the total buoyancy flux...and this component kept the surface layer slightly unstable".

Consequences for stability: u_* v.s. z/L_s



- Stability is over predicted since the peak friction velocity is detected on the slightly stable side if the stability parameter is not corrected for humidity effects (Here, $\frac{z}{L_s} = \frac{zkg<wT_s>}{T_v u_*^3}$).

Conclusions

- Precise calculation of stability of the marine boundary layer requires direct measurement of the humidity flux since it is not governed by local gradients.
- Currently, there is no way of directly measuring humidity fluxes at FINO1 or in the recently completed FINO3 platform, also in the North Sea.
- Neglect of humidity underestimates buoyancy by approximately 20% during the analysed measurement period. This could be corrected by estimating the bulk contribution of humidity to the buoyancy.

Acknowledgements

- We acknowledge the reception of valuable data and advice from Dr. Anna-Maria Sempreviva which has aided this work greatly.
- The work was done in the project VERITAS (work package 5 of OWEA) which is funded by the German Ministry of the Environment (BMU) via the PTJ (FKZ 0325060).