Estimation of the humidity flux at FINO 1 (North Sea)

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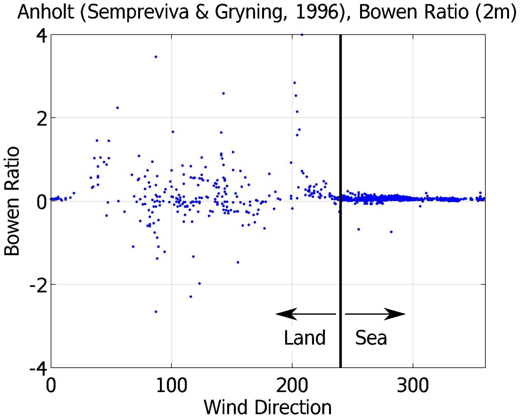
Outline

Importance of humidity for marine conditions

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

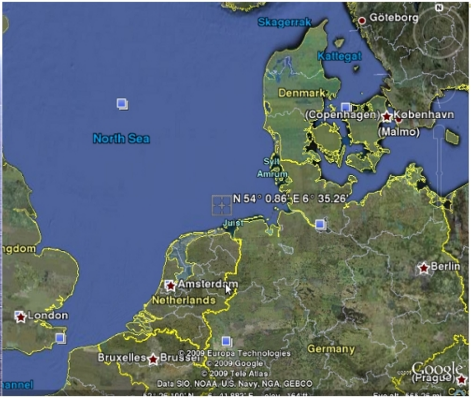


- Bowen Ratio $= \frac{c_p <wT>}{L_v <wq>}$
- Marine Conditions: (Bowen Ratio ≈ 0.1);

Motivation - Importance of humidity for stability

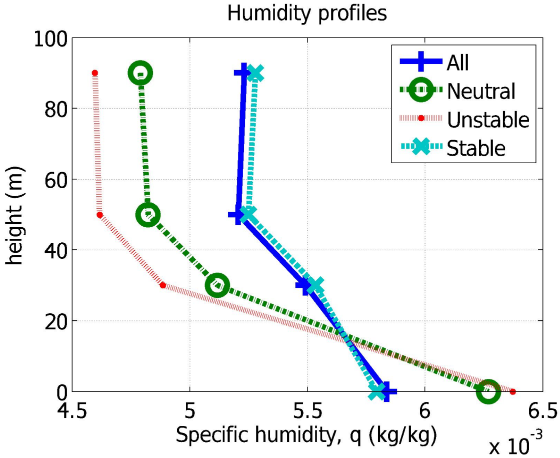
- Monin-Obukhov stability parameter: $\frac{z}{L} = \frac{zkg<wT_v>}{T_v u_*^3}$
- Virtual potential heat flux can be estimated from: $< wT_v >=< wT > +0.61T < wq >$
- An ultrasonic anemometer measures: $< wT_s >=< wT > +0.51T < wq >$
- In dry and/or cold conditions, $< wq >$ = humidity flux and can be neglected: hence $< wT_v >\approx< wT_s >$.
- 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.
- What then is the magnitude of $< wq >$ at FINO 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 presented here from 2005.

Humidity at FINO 1 - hygrometers?

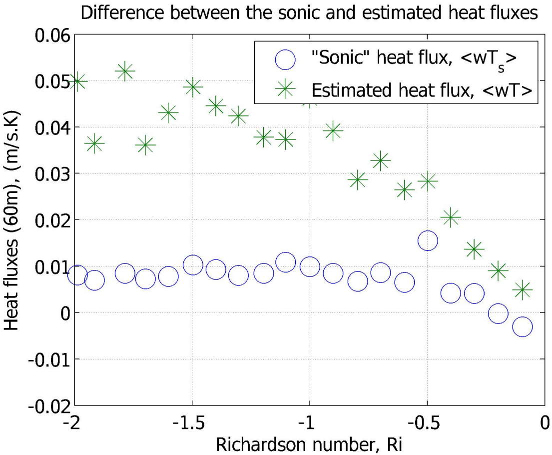


- Above 50m – Negative humidity flux for stable conditions, positive humidity flux for neutral & unstable conditions.
- It is unclear whether fluxes driven by local gradients above 50m, or by non-local gradients? Here, sea surface relative humidity assumed = 100%.

Estimate humidity fluxes - original idea:

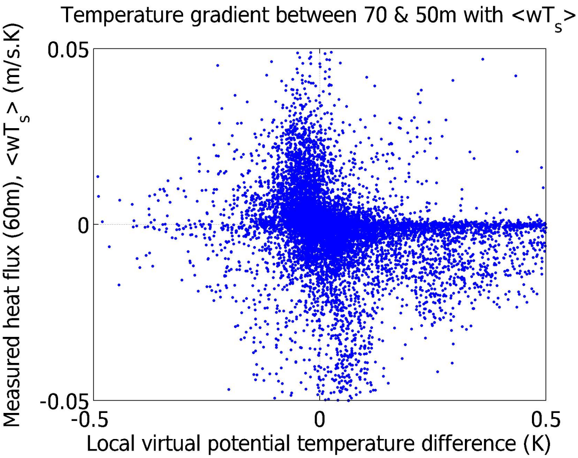
- Assume $< wT_s > = < wT > + 0.51T < wq >$.
- There, use $Ri = \frac{z}{L}$, valid in unstable conditions, where $Ri \approx -\frac{\kappa g z < wT >}{T u_*^3}$
- Rearranging gives: $< wT > = -\frac{Ri T u_*^3}{kzg}$
- Use humidity dependent sonic measurement to estimate the humidity flux: $< wq > = \frac{1}{0.51\overline{\overline{T}}}(< wT_s > - < wT >)$.
- The humidity flux can then supposedly be estimated as a residual between the sonic measured heat flux and the heat flux based on a local gradient.

Results:



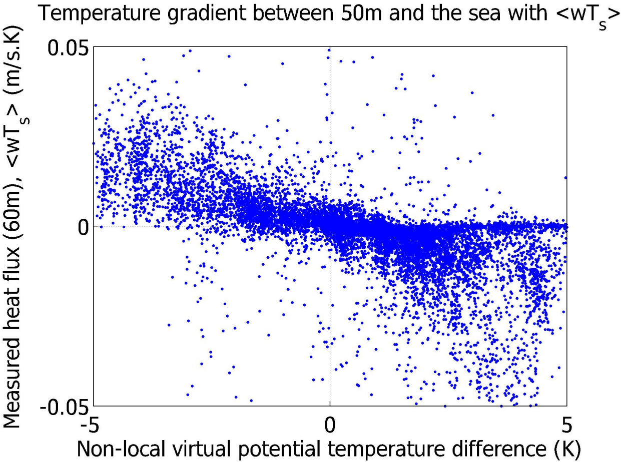
- Average humidity flux:
  $\overline{< wq >} = \frac{1}{0.51\overline{\overline{T}}}\overline{(< wT_s > - < wT >)} \approx -2x10^{-4}$.
- Typical humidity flux (Sempreviva & Gryning, 1996): $+3x10^{-5}$.

Heat Flux - Profile Relationship



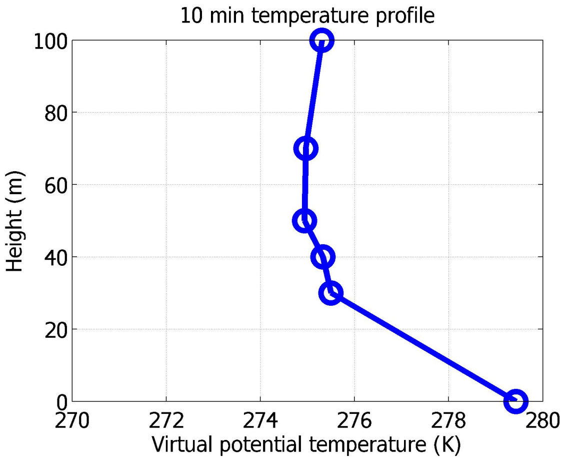
- Local heat fluxes are poorly correlated with local temperature gradients. (Correlation coefficient: -0.06)
- Using local gradients to infer fluxes not valid, hence $Ri \neq \frac{z}{L}$.

Heat Flux - Profile Relationship



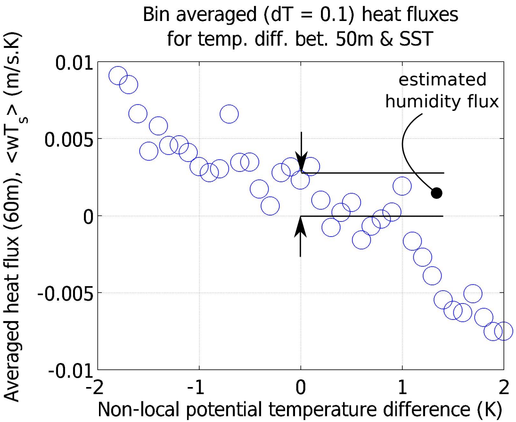
- Heat fluxes are driven by non-local temperature gradients. (Correlation coefficient: -0.47)

Example: Temperature profile



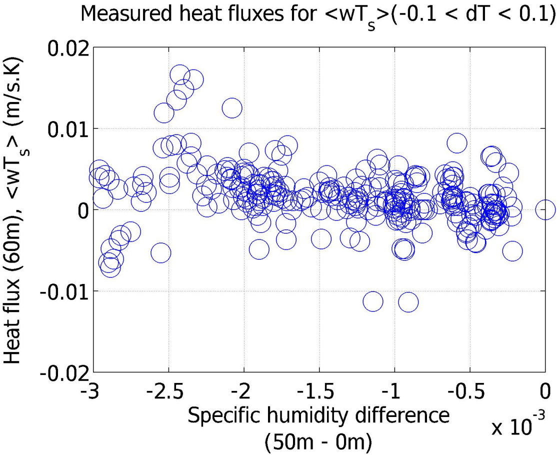
- At 60m: Locally stable, non-locally unstable.
- Heat flux, $< wT_s >= +0.013$ (m/s.K)

Estimation of temperature and humidity fluxes - new idea



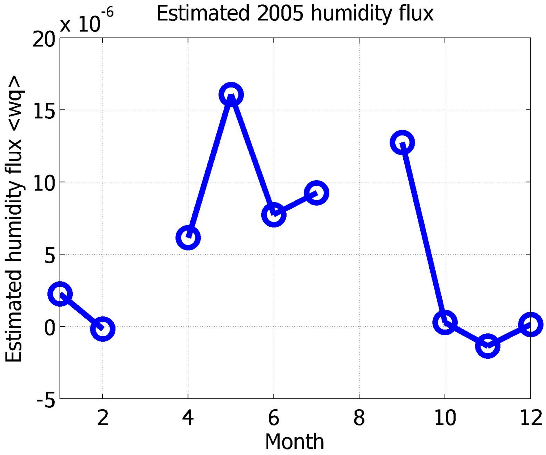
- If humidity flux were zero, averaged heat flux would pass through the origin when plotted against the potential temperature.
- Therefore, since $< wT_s > = < wT > + 0.51T < wq >$, then $< wT_s > (\Delta\theta = 0) = 0.51T < wq >$.

Estimated humidity fluxes



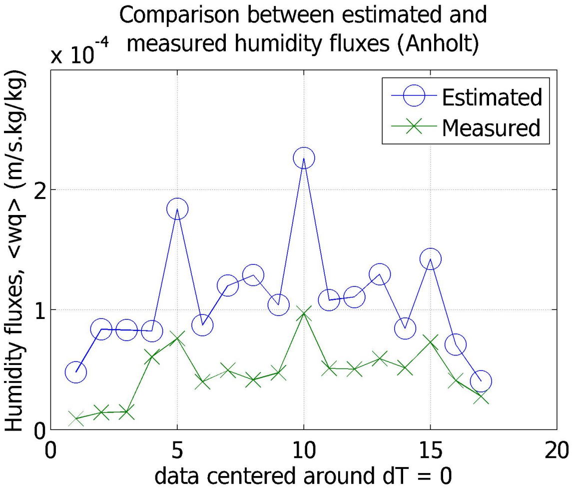
- Estimated humidity fluxes very weakly correlated with both fine humidity gradients and (shown here) bulk differences.
- Humidity flux a function of larger atmospheric scales? (ref?)

Annual variation of humidity flux estimate:



- October-February: $\overline{< wq >} \approx 0$
- April-September: $\overline{< wq >} \approx +1x10^{-5}$. (Sempreviva & Gryning, 1996, June, $< wq > = +3x10^{-5}$)

Estimate humidity fluxes - Anholt (Sempreviva & Gryning, 1996)



- Estimation possibly overestimates humidity flux by factor of 2?

Conclusions

- Precise calculation of stability of the marine boundary layer requires direct measurement of the humidity flux since it may not be governed by local gradients.
- Currently, there is no way of directly measuring humidity fluxes at FINO 1.
- Estimates indicate that humidity flux is roughly $1x10^{-5}$ (m/s.kg/kg) during the middle of the year, but could be neglected in colder months.

Acknowledgements

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