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

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Outline

Motivation

Humidity effects at the North Sea - FINO 1

Estimate humidity fluxes - original idea

Estimate humidity fluxes - new idea

Conclusions
Importance of humidity for marine conditions

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

Anholt (Sempreviva & Gryning, 1996), Bowen Ratio (2m)

\[ \text{Bowen Ratio} = \frac{c_p <wT>}{L_v <wq>} \]

- Marine Conditions: (Bowen Ratio \(\approx 0.1\));
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:
  \( < wT_v > = < wT > + 0.61 T < wq > \)

- An ultrasonic anemometer measures:
  \( < wT_s > = < wT > + 0.51 T < wq > \)

- 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.
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 $\langle wT_s \rangle = \langle wT \rangle + 0.51 T \langle wq \rangle$.
- There, use $Ri = \frac{z}{L}$, valid in unstable conditions, where $Ri \approx -\frac{\kappa gz \langle wT \rangle}{Tu^3}$
- Rearranging gives: $\langle wT \rangle = -\frac{RiTu^3}{kzg}$
- Use humidity dependent sonic measurement to estimate the humidity flux: $\langle wq \rangle = \frac{1}{0.51T} (\langle wT_s \rangle - \langle wT \rangle)$.
- 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:
\[
<w_q> = \frac{1}{0.51T} (\langle wT_s \rangle - \langle wT \rangle) \approx -2 \times 10^{-4}.
\]

Typical humidity flux (Sempreviva & Gryning, 1996):
\[+3 \times 10^{-5}.\]
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

Temperature gradient between 70 & 50m with $<wT_s>$

Measured heat flux (60m), $<wT_s>$ (m/s.K)
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, \( \langle wT_s \rangle = +0.013 \) (m/s.K)
If humidity flux were zero, averaged heat flux would pass through the origin when plotted against the potential temperature.

Therefore, since \( \langle wT_s \rangle = \langle wT \rangle + 0.51T \langle wq \rangle \), then \( \langle wT_s \rangle (\Delta \theta = 0) = 0.51T \langle wq \rangle \).
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: $\langle wq \rangle \approx 0$
- April-September: $\langle wq \rangle \approx +1 \times 10^{-5}$. (Sempreviva & Gryning, 1996, June, $\langle wq \rangle = +3 \times 10^{-5}$)
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 $1 \times 10^{-5}$ (m/s.kg/kg) during the middle of the year, but could be neglected in colder months.
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