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On the skewness of air temperature and humidity near the air-sea interface

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Background

Improving the understanding of surface fluxes is important to improve weather and climate models. Most of the parametrizations for surface fluxes are based on Monin-Obukhov (MO) theory. In MO theory the physics is based on surface layer parameters. A recent paper from van de Boer et al. (2014) asserts that top processes, such as entrainment, could be important in surface fluxes.

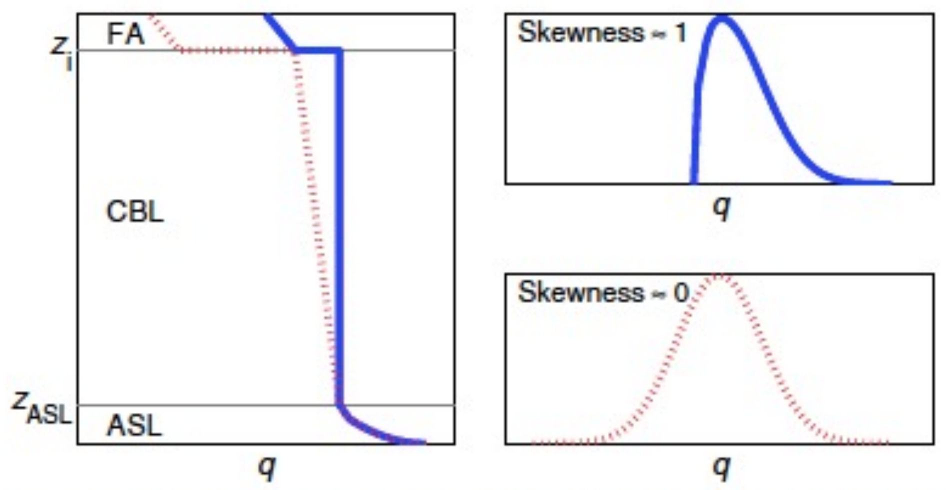

Fig. 1: This figure from van de Boer shows the vertical profile of the humidity (q) and distribution of the humidity in the Atmospheric Surface Layer (ASL) under two conditions; one of weak entrainment (blue), and one of strong entrainment (red)[1]. In the vertical profile CBL refers to the connective boundary layer and FA refers to the free atmosphere

This asserts a relationship between the skewness of the humidity and entrainment. A similar effect is not expected on the skewness of temperature because air warms according to the adiabatic lapse rate. van de Boer also states that in cases where the skewness of the humidity is not zero the skewness of the temperature should be. This allows us to use the measure of the difference of the skewness of the temperature and the humidity as a measure of entrainment.

The data used in this analysis was collected from three field experiments:

- Surface Wave Dynamics Experiment (SWADE), occurred in 1991 in the Coastal-Atlantic[2]
- Gas Exchange Experiment (GasEx), occurred in 2001 in the Equatorial Pacific[3]
- Deep Ocean Gas Exchange Experiment (DOGEE), occurred North Atlantic in 2006 and 2007[4]

Objectives

- To test whether the skewness of the humidity is zero, and if deviations from zero relate to cases of entrainment.
- To test if the skewness of the humidity is top down driven and not bottom up driven.
- To test that in cases where the skewness of the humidity is significantly different from zero the skewness in temperature should not be significantly different from zero.

Methods

- The data used was collected from three field experiments
- All of the data analysis was done in MATLAB
- New variables were created for this analysis within a pre-existing code that processed the initial measurements and data files
- Experimental runs were examined in quality control, for instrumental error
- Variables for the standard deviation, the mean, and the skewness of the temperature, humidity, and horizontal and vertical wind velocities were made.

Results

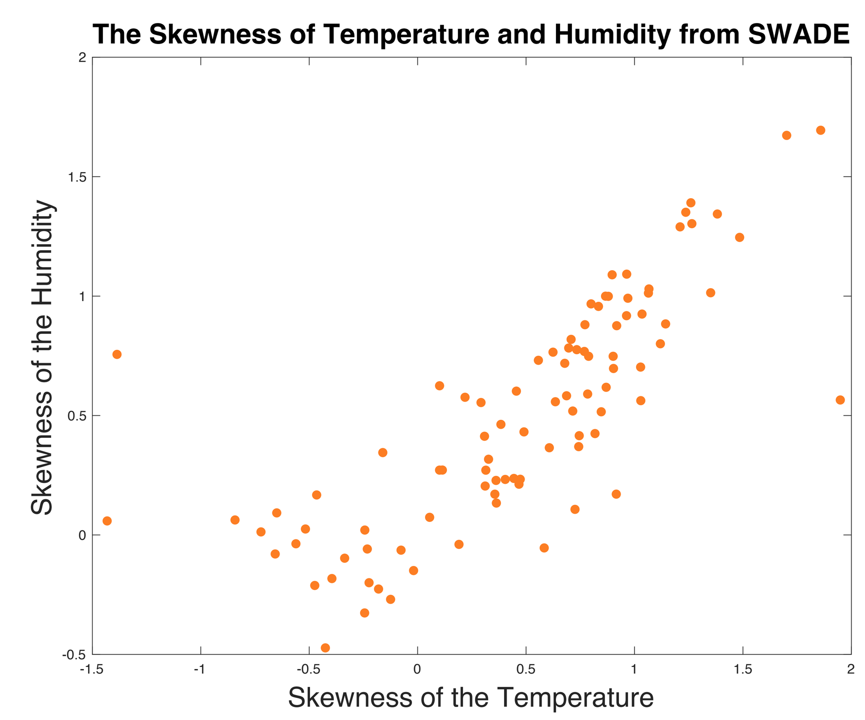

Fig. 2 (left): The skewness of the temperature and the humidity from SWADE. The correlation coefficient for these two variables was 0.77, with a p-value of 1.9×10^{-19} since the p-value is smaller than 0.05 it is significant. The high correlation coefficient and the low p–value indicate a strong relationship between the two variables

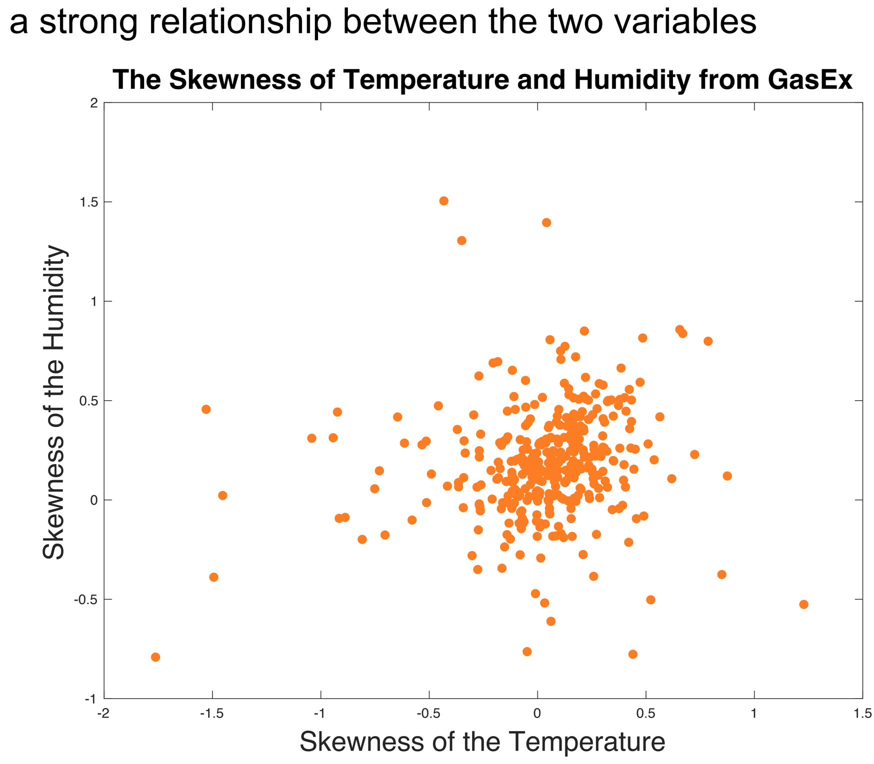

Fig. 3 (above): The skewness of the temperature and the humidity from GasEx. The correlation coefficient in this experiment was 0.15, with a p-value of 3.4×10^{-3}, since the p-value is smaller than 0.05 it is significant.

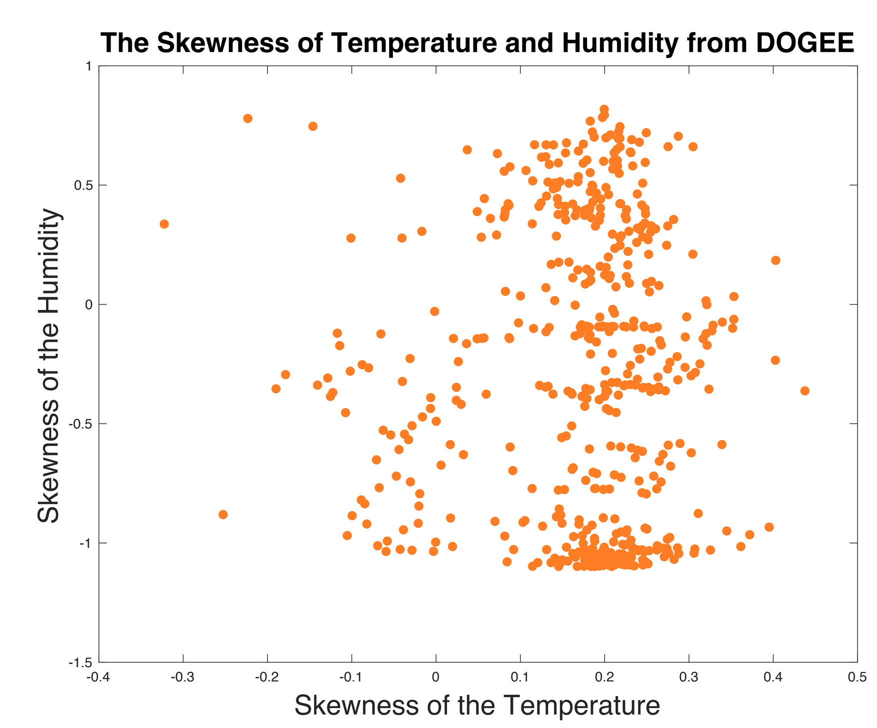

Fig. 4 (left): The skewness of the temperature and the humidity from DOGEE The correlation coefficient in this experiment was -0.01, with a p-value of 0.14, since the p-value is greater than 0.05 it is not significant. The low correlation coefficient and the high p–value indicate a weak relationship between the two variables

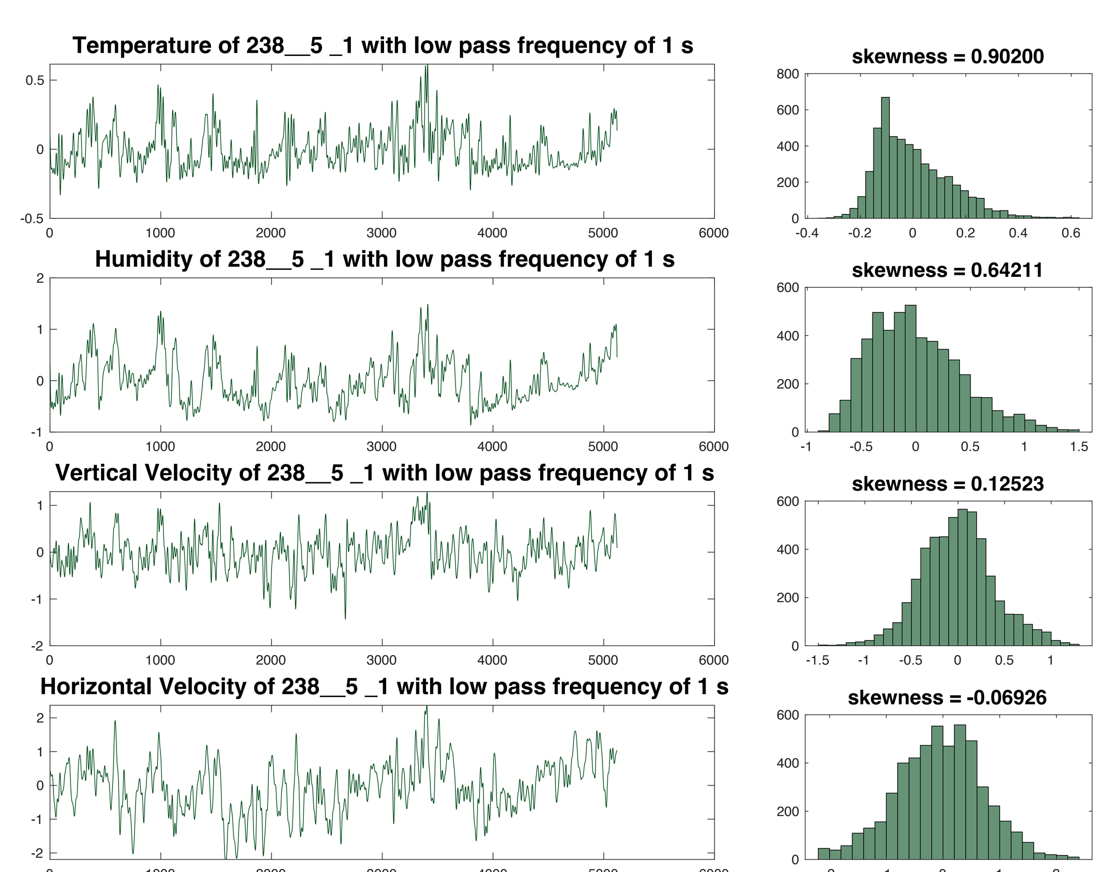

Fig. 5 (right): A segment of the data from the SWADE experiment, taken from the beginning of the frontal pass. A high pass with a frequency of 1 second was applied to the data to remove noise and the data was detrended to remove low frequency environmental changes. The histograms showcase the similarities in the skewness of the temperature and the humidity of this run. A burst in the vertical velocity at around 3300s is accompanied by changes in the humidity and temperature signals. This indicates the connection between the three and the importance of 'bottom up' atmospheric processes in air-sea interaction.

Conclusions

- The relationship between the skewness of the temperature and the skewness of the humidity was very different between the three experiments
- No evidence was found that when the skewness of the humidity deviated from zero that the skewness of the temperature would be zero
- The temperature, humidity, and vertical velocity are strongly correlated in time series runs – evidence of effects of bursts and sweeps
- Unlike the van de Boer results, collected over
- agricultural areas, signatures of entrainment were not seen in our data
- Figure 3 shows that GasEx had the expected relationship as it was centered around (0,0)
- The only experiment that had a strong correlation between the skewness of the humidity and the skewness of the temperature was SWADE.
- SWADE was also the only experiment examined that went through a front
- In future experiments it could be important to investigate whether a front could have a systemic impact on the connectivity between the skewness of the temperature and the skewness of the humidity.

References

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