Using sonic anemometer temperature to measure sensible heat flux in strong winds

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General Comments

The authors report an interesting phenomenon concerning the Campbell CSAT3 sonic anemometer. During high wind situations sensible heat fluxes based on sonic temperature H_Ts are much higher than compared to H_Tc, which are based on thermocouple temperatures. The deviations start at 8 m s^{-1} and reach values of around 250 W m^{-2} at 18 m s^{-1}. The authors demonstrate that in a well prepared manuscript. It is however not clear to me whether it is a peculiarity of the special set-up at the extreme site (vibrations or snow drift as other reviewer suggested) or whether it is a general deficiency of the CSATs, which would be alarming. Some additional work is needed to answer this question.

Specific comments

Starting with the conclusions, the statement from Campbell Scientific, as reported in L243 to 248, is somewhat unsatisfying. Any hint from Campbell what could be the cause? Although an important finding it would be unneeded to initiate speculations and then it is a software problem which is not communicated. More information on what are the manufacturer's comments is certainly necessary.

In order to understand better what is going on there are some points that need clarification.

1. Positive offset depending on wind speed

What you call "more positive" is a positive offset which adds to H_Ts both during day- and nighttime. During high wind speed situations nocturnal downward (negative) fluxes can change sign and are measured as upward fluxes, while daytime are measured too high. This means that the "artificial" contribution comes from the +w+T and –w-T quadrants, i.e. a positive correlation is introduced. As the w-component is claimed not to be the cause of the discrepancies how can high wind speeds cause the positively correlated overestimations of Ts fluctuations? I suggest to look at the w'Ts' distribution of half hourly runs of extreme cases which might help to better understand the nature of the error.

(other reviewer's comment: I don't see how snow drift would introduce a positive correlation during night-time. I would rather expect a contribution to all quadrants and thus and increase or decrease of the up- or downward fluxes)

2. Spikes

The statement in the caption of Tab. 1 "but for higher winds around 2−4% of the samples were flagged" should be clarified. More information is needed. Were all CSAT3 affected by spikes? Was there a correlation to wind speed, higher wind speed - more spikes?

(In the meantime I saw the answer of the first author to Laubach's comment. Well, it's quite a spiky record)

3. Wind direction

How is the wind direction during high wind speed situations? Are the CSATs all oriented in the same way? Flow distortion can affect Ts. I guess you had a look at that, but how are H_Ts-H_Tc related to wind direction for wind speed >10 ms^{-1}?

4. Energy balance

This part is not supporting the search for the causes of the overestimation which is demonstrated by the comparison to H_Tc. Looking at nocturnal values of DOY 43 immediately shows that there is a

serious problem and which estimate is likely wrong. This needs no support from very obvious EB considerations where the available energy is afflicted with uncertainties of estimated storage and net radiation measurements (see below).

5.

We have ongoing measurements in a desert environment. There we measured with three CSAT3 and had 300 cases with wind speed (30 min average) above 10 ms^{-1} up to 15 ms^{-1}. No unusual high fluxes are detected. In contrary the ratio to net radiation is rather smaller than at low wind speeds. Preliminary checks did also not show spiky records similar to the ones presented in the manuscript.

Not only technical comments

L1 and L101

The surface energy balance (SEB) is something different than the ratio of the sum of turbulent heat fluxes to the available energy. You may call it closure ratio CR. So define these terms clearly.

L19

In brackets also downward fluxes should be included or better omit the explanation. Readers of this manuscript probably know what is meant with latent or sensible heat flux.

L29

Desert environments are also affected by the limitations of the eddy covariance method, i.e. if there is a small average w-component (up or down) induced by larger scale influences then “advective” parts are missed. It is just that in dry conditions underestimating the latent heat flux is not that important.

L74

“Equation” at begin of sentence.

L110

That is strange. It is not only that the spurious correlation contributes to the covariance as you say, but additionally the sign of the flux is reversed. First I thought this is similar to what I experienced with our measurements in a desert. Often we observe upward night-time fluxes which are not plausible regarding the stable stratification. This happens, when there are strong temperature gradients and the wave-like motions causing apparent fluctuations which are not connected to mixing. The use of much smaller averaging intervals (1 to 4 min) results in reasonable fluxes, both in sign and magnitude. However this can be ruled out in your case, as H_Tc shows a reasonable behavior.

L143

Although it is clear what is meant I would not say “becomes more positive”. A number is either positive or negative. The effect of this strange behavior is that H_Ts is increased by a certain amount depending on wind speed. The effect is similar during day- and night-time. This means, that either in the quadrants +w+T or –w-T gain more weight. Especially during night-time this is strange and should show up as a prominent feature. Instead of looking at averages like in Fig. 3 and Fig. 4 it might be instructive to look at the distribution of w’Ts’ for single runs and compare it to w’Tc’.

L170

“that enhances (Co)wTs during the day and degrades it at night”. What is meant with “degrades it at night”? If it changes from -50 to +150 W m^{-2} then degrading is not the right description (compared to “enhances”). What is remarkable, is that H_Ts is larger. And this is only possible if …. see above (L143).

L175

One cannot rule out vibration in that way. If transit times are affected, then the temperature error is much larger than the speed error. A rough estimate: a 1% error in axis speed corresponds to 1.7 K error in temperature. Transit time offset 1 μs, path length 0.15 m, speed of sound 340 m s^{-1}.

L205 (net radiation)

A side note in this context, but is shows how unproven statements stay alive: “Also similar to Turnipseed et al. ….”. To my experience the Q*7.1 underestimates the magnitude of net radiation during nighttime, therefor the closure is better (see also L221-229). In Turnipseed et al. (2002) it is written: “However, further testing is advised to determine the source of this discrepancy.” Has that been done? Then refer to it, otherwise it is repeating a most likely wrong statement.

L221-229

I recommend to omit the discussion concerning the radiation sensors. The discussion is general and not very precise and does not draw the right conclusions. It is well known that the Q*7.1 has different responsivities in the long and short-wave range. Normally they are used with only one responsivity which leads to an underestimation of the nocturnal net radiation. More information on that can be found e.g. in Halldin and Lindroth (1992, J.Atmos.Oceanic Technol., 9, 762) or in Kohsiek et al. (2007, BLM, 127,55) or in Vogt et al. (1996, Theor. Appl. Climatol., 53, 23). In the latter it is described, how the short- and long-wave responsivities can be derived if independent measurements of the net short- and long-wave balances are available. These relatively old findings were confirmed with comparisons to better reference sensors like the CG4 from Kipp and Zonen (partly done in Michel et al. 2008). But again, this part is not relevant for the problem discussed here so it can be omitted.

L240

“At night H is typically…. HCSAT smaller than it should be”. This is a confusing statement. Even if you say magnitude it is not true e.g. for day 43 in Fig. 1.

References

Be consistent with using abbreviations of journals. E.g. L269 and L282 and some more

Fig. 1

Legend is above curves.

Fig. 2, 3, 4, 5

Minor point, but what is the benefit of DOY = 271.24 – 365.99, especially .24 and .99? Many characters can be omitted without missing relevant information (Nov 2010, 67 out of 1438 30-min periods). Or in the caption: “30-min” and “30-minute” in the same caption. Where you refer to differences or fluctuations K should be used instead of °C.