Review of *"Aircraft observations of cold pools under marine stratocumulus"* **by Terai and Wood.**

Overview

This manuscript presents aircraft observations of cold pools in the stratocumulus topped boundary layer from the VOCALS-REx field campaign. The observations show that the observed cold pools tended to form in environments associated with a deeper marine boundary layer, thicker clouds and lower aerosol concentrations, all factors that make the stratocumulus more susceptible to drizzle. The importance of precipitation as the key driver for cold pool formation is highlighted. Individual cold pool observations are then composited to show how various thermodynamic and chemical variables change across the cold pool edge, and mechanisms to explain the observations discussed. These observations will provide useful constraints for testing high resolution model simulations of precipitating stratocumulus, which are required to better understand the role that cold pools play in modifying the mesoscale cloud field. Overall I found the manuscript very interesting, it was well written and is suitable for publication in ACP. I do have a number of comments below that I would like to see the authors consider when producing a revised manuscript.

Comments

Section 2.1 pp 11027 line 11: change "(REX) is" to "(REX) was".

Section 2.2 pp 11030 line 4: It is not clear at this stage in the paper (i.e. Fig 1) that drops in θ typically coincide with thick clouds and heavy precipitation. For example the first drop in θ in Fig 1 is associated with a thin cloud layer and relatively low radar reflectivities at cloud base. Presumably this could be due to a time lag between the measurement and the precipitation event that created the cold pool. It may be worth noting here that thicker clouds and heavier drizzle are shown to be typical when all cold pools are analysed later in the paper.

Section 2.2 Equations 1 to 4 and Fig 2: Can you rewrite the equations or modify the figure so that they are consistent. For example Eq. 1 has $\theta(t - t_2) - \theta(t)$ which corresponds to $\Delta\theta_a$ in the figure. Also in Equation 1 you have $\Delta\theta_2$ whereas when you define this in the text below you just have $\theta_2 = 0.12$K i.e. no Δ.

Section 3.1 and Fig 3: Here you discuss the algorithm to calculate cold pool size. I have difficulty reconciling this algorithm with the colour bars presented in Fig 3 and think some clarification is needed. For example taking the first cold pool edge in Fig 3 at approx 7 km, there is a blue bar identifying a cold pool that extends to another identified edge at approx 12 km. Assuming that the algorithm is run in the forward direction I don't see how the second edge at 12 km is identified as the same cold pool because the potential temperature hasn't recovered to that of the first edge. I can see how this would have been identified as a distinct cold pool if the algorithm was run in the reverse direction. In contrast, when looking at the cold pool identified from approx 46 to 56 km I can only see the algorithm detecting this if it was run in the forward direction. So I can only reconcile the results in Fig 3 with the algorithm if it was run in both the forward and reverse directions. However, the implication from line 2 pp 11032 in section 3.1 is that the algorithm was only run in the forward direction. Perhaps I am missing something?

Section 3.1: When calculating the distance travelled by the aircraft the authors assume that the aircraft is flying at 100 ms^{-1} as stated in the caption of Fig 1. Why not use the measured true air speed of the aircraft? This would give a more accurate measure of the distance travelled. I suspect that the error may be minor, but it makes sense to use the true air speed, particularly when one of the cold pool diagnostics analysed is size.

Fig 4: The caption refers to Eq 6 when it should be Eq 5.

Section 3.1 pp 11032 line 18 and Fig 4: Would a better lognormal fit be possible in Fig 4, where the slope is shifted to the left so that it passes through the median point of the distribution. It would therefore better represent the first 90% of the data at lower sizes where the statistics are better. It would be worthwhile including the fit parameters in the text as well to compare against future LES model output etc.

Section 3.3 pp 11034 line 11: It is mentioned that cold pools are expected to form preferentially in deeper MBLs. How is this different to the factors that affect the discussion in the previous paragraph about cold pools preferentially forming when thicker clouds are present as these are more susceptible to drizzle formation? At least in the VOCALS region, measurements along 20S show that thicker clouds are typically associated with a deeper MBL (Bretherton et al., 2010).

Section 3.3 pp 11034 line 24 and Fig 8: You show cases where cold pool formation occurs under moderate PCASP aerosol concentrations up to 200 cm-3. Are these cases those that have the higher cloud thickness (presumably LWP which you could look at using the data from the microwave radiometer) and drizzle rates shown in Fig 7? One would imagine that if the LWP was high enough the cloud could precipitate easily at these CCN concentrations and then potentially lead to cold pool formation. Presumably it is a combination of LWP and cloud droplet number concentration that will dominate whether the cloud can precipitate and hence form cold pools. After all, those are the key factors that will determine if the cloud droplets can grow sufficiently to form drizzle drops. In order to highlight additional dependencies in these plots you could perhaps modify the symbols in Fig 8 so that the size of the symbols represented either the cloud thickness or the amount of drizzle. Similarly in Fig 7 you could relate the size of the symbols to the PCASP aerosol concentration.

Section 3.4 pp 11035 line 11: Would it be better to centre the 1 x 1 degree box on the centre of each cold pool rather than the centre of each flight leg? This would better capture the mesoscale variability around the cold pool. From Fig 3 it is clear that this would lead to more mesoscale variability for the cold pools to the west of the flight leg where the cloud is more broken.

Section 3.4 pp 11035 line 23: It is stated that legs with cold pools have a **markedly different** T_B distribution (Fig 9). When looking at the results in Fig 9, I think this is a bit overstated given the low statistics (22 flight legs with cold pools out of 87 - section 2.2). In fact you then go on to say that cold pools are not necessarily associated with broken cloud fields, again suggesting that the prior statement perhaps needs to be toned down.

Section 3.4 pp 11036 paragraph related to Fig 10: I think the paragraph describing the analysis of satellite LWP with ECMWF back trajectories and the corresponding Fig 10 could be removed as I am not sure it adds anything to the paper. You have already shown that cold pools preferentially form under thicker clouds, and so I would assume that these typically have higher LWP values. In fact why not just look at the microwave LWP retrievals from the aircraft.

Section 4.1 pp 11037 line 20: Suggest you change the equation $C_P\theta = -Lq_v$ to $C_P\Delta\theta = -L\Delta q_v$ to make it obvious that θ and q_v correspond to a difference in the various parameters with respect to the cold pool edge.

Section 4.1 Eq 6: The text states that θ is the in situ density when this should be ρ. The incorrect symbol is used a few lines below this as well.

Section 4.1 pp 11038 line 18: Can you postulate why the pressure is sometimes lower in the cold pool? How often did this occur?

Section 4.2: From here on the figure numbers in the text are incorrect and need changed.

Section 4.2 and Fig 12: It looks like the data in Fig 12 does not have the $4/\pi$ correction factor applied as the numbers in the text don't correspond to the results in the figure. Can you state this in the text or modify the figure caption.

Section 4.2 pp 11039 line 20: Is the derived Froude number an average over those cases where

h estimates were possible from Eq 6? What is the variability in the Froude number from the different cases?

Section 4.3 pp 11041 line 4: It is stated that cold pools have the potential to lift the decoupled surface layer above its LCL to form cumulus clouds. Are these cumulus clouds formed at the cold pool edge where there are enhanced vertical velocities (Fig 12)? Can this be observed from the aircraft data?

Section 4.3: How is the in-situ drizzle water content calculated in Fig 14? Is this from the 2DC?

Fig 14 c) caption: Change "reflectivity does not follow (a) Gaussian" to "reflectivity does not follow a Gaussian".

Section 4.4 and Fig 15 b): The composite CDP measurements show an increase in coarse mode aerosol concentration in the cold pool. Is the relative humidity in the cold pools typically higher than outside of the cold pools? I would imagine this is the case if drizzle evaporation is the key driver in their formation. If so I could envisage that there is enhanced hygroscopic growth of accumulation mode aerosol particles inside the cold pools, such that they grow large enough to be measured by the CDP. Can you show that the impact of this is not the major factor that leads to the increase in concentration shown in Fig 15 b)?

Section 5 pp 11046 line 14: It is stated that the significant drop in LCL inside the cold pool is largely due to increases in q_v instead of the θ decreases (not shown). As this is a statement made in the conclusions I think some evidence should be presented in the paper.

Section 5 line 17: Change "cloud bases is a result" to "cloud bases are a result".