Responses to Reviewer 1

We are very grateful to reviewer 1 for his/her/their comments on our manuscript. We have considered the comments carefully, and we hope that the reviewer and editor are happy with our responses. The reviewer's report is reproduced below (in red), together with our responses. Where changes have already been made to the manuscript, these are underlined.

Comments of Reviewer 1

This manuscript extends the existing dry ABC model to include mixing ratios of water vapor and cloud water, termed the 'hydro-ABC model'. This manuscript introduces and evaluates the extended equations for the 'hydro-ABC model'. The success of simulation for a realistic-looking anvil cloud offers the possibility of exploring convective-scale DA strategies within a low-cost model. Investigations of error statistics are also conducted. Generally, this manuscript is a complete work and provides a cheaper approach to studying convective-scale DA. My overall recommendation is for acceptance pending minor revisions.

- Many thanks to the reviewer for the very positive and insightful comments. We have numbered the reviewer's points below, with our responses.

1. Line 7: "-"is missing after "Hydro". Change made.
2. Line 101: Check the equation. The first "=" sign seems to be "+"? Change made.
3. Fig. 5: I am confused about the vertical correlations of w with q and qc at 80 and onward. Both correlations show strong positive values in the low levels. Intuitively, the increased qc means the reduced q. Why do we see positive correlations for both of them? This is a very interesting point. We have added the following text (underlined): "This suggests that the region of positive q_c-w covariances just mentioned is not caused by advection (the covariances would have negative sign if they were), but instead by the process of more condensate being produced in association with stronger w. Note that in most parts of the cloud layer q and q_c are both positively correlated with w (and in fact positively correlated with each other, not shown), which may appear counter-intuitive. In the convection zone, convergence and condensation processes are happening. The convergence can increase q while the condensation will decrease q, but increase q_c. As long as the increase of q caused by convergence is larger than the loss of q by condensation, there is a net increase in q, in which case both q and q_c could have a positive correlation with the vertical wind."
4. The proposed "hydro-ABC model" does not include the precipitation processes. However, the precipitation can lead to the development of cold pools, which facilitate the maintenance of convections. Will the authors have plans to include the processes related to cold pools in the proposed model? We have added the following text to the end of the paper: "Another interesting avenue that may be explored is to add a precipitation process (i.e. an additional fast downward transport of condensate), which could give rise to cold pools."
5. Figure 6: It is unclear how the authors define the three zones in this figure. Because Figure 7 suggests that the authors attempt to find indicators for determining the three zones. Three zones are defined ("convection", "moist", and "dry") in order to choose representative points for study in Fig. 7.
    (a) Labels of the zones have been added to Fig. 2, and the following text has been added to the caption, "Three zones are defined, the convection zone (columns close to the convection), the moist zone (columns of non-zero moisture in the initial conditions), and the dry zone (zero moisture in the initial conditions)."
    (b) The following text has been added to the discussion of Fig. 6 (underlined), "Figure 6 shows vertical correlations between a different selection of quantities. The top three rows show auto-correlations of $\tilde{\rho}'$ for the convection, moist, and dry zones respectively (see Fig. 2 for definition of the zones where the columns are selected, and Fig. 6 caption for their specific lateral positions)."

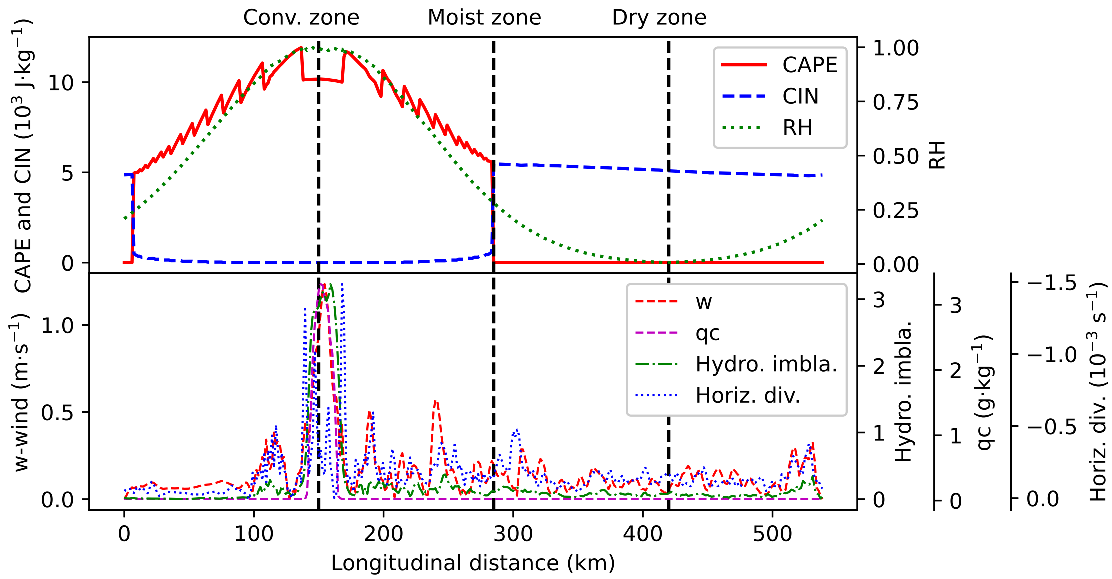

Figure 7: The geographical variation of various indicators/harbingers of convection at $t = 10$min. Plotted in the top panel are: convective available potential energy (red line), convective inhibition (blue), and relative humidity (green). Plotted in the bottom panel are column maximum values of: vertical wind (red), condensate mixing ratio (magenta), hydrostatic imbalance (green), and horizontal divergence (blue). The black vertical lines mark locations that are within the convection, moist, and dry zones (see Fig. 2).

(c) The following text has been changed in Fig. 7, "The black vertical lines mark locations that are within the convection, moist, and dry zones (see Fig. 2)."

6. Figure 7: I suggest using qc, w, or their variants, and they may be good potential choices for the indicators as well. Figure 7 has been modified to include these quantities (see Fig.), and discussion has been added to the revised paper as follows:
To recap, CAPE is "Convective Available Potential Energy", CIN is "Convective INhibition", RH is "Relative Humidity", HI is "Hydrostatic Imbalance", and HD is "Horizontal Divergence".
"Figure 7 shows how these quantities vary with horizontal position in the domain at $t = 10$min, which is before convection has developed. The CAPE (red, top panel) increases towards the convection zone, but is not a smooth function of position and drops slightly at the future convection point. The CAPE increases abruptly at $\sim$ 0km and drops at $\sim$ 285km, even though these points are within the region where $q > 0$ in the initial conditions. The CIN (blue, top) also changes abruptly at these positions, but in the opposite way: the CIN is small where the CAPE is large and vice-versa. The RH (green, top) in this case is a smooth function of position, peaking at unity around the convection zone. While the CAPE, CIN, and RH give physically reasonable indications of where convection is possible, they do not pin-point where convection develops (namely in the convection zone).

The $w^{\max}$ (red, bottom), $q_c^{\max}$ (magenta, bottom), and HI (green, bottom) are fields with a finer scale than CAPE, CIN, and RH, and do peak at the precise location where convection develops. The HD (blue, bottom) is also fine-scale, but does not peak at the correct location of the future convection. The quantities $w^{\max}$, $q_c^{\max}$, and HI are therefore promising harbingers of convection, which may be useful for selecting vertical background error statistics that are characteristic of convection (rather than quiescent conditions) for data assimilation. This is the case especially when the data assimilation method is otherwise non-flow-dependent, as in traditional variational schemes. Further work will be required to test the reliability of these indicators."