Responses to the reviewer #2:

General Comments

This paper uses observational data from the ACE-ENA campaign to assess the horizontal variability and coverability of cloud water content and number concentration. The motivation for this study is the implication of these covariances on the parameterization of autoconversion in coarse resolution models. The study is unique in 2 regards: 1) it focuses on q-N covariability which is often ignored, and 2) it's evaluation of the coavaribilities as a function of cloud height. The study finds that the so-called enhancement factor for autoconversion decreases robustly from cloud base to cloud top due to increasing correlation between q and N at cloud top. These results have important implications for the representation of unresolved cloud microphysical processes in climate and weather models.

Reply: We thank this reviewer for the encouraging, insightful and constructive comments, which really help improve the manuscript significantly.

Before addressing your comments/questions below, first we would like to provide a summary of the major revisions made to the manuscript:

- We revised significantly the part about the bimodal joint distribution between qc and Nc in section 4. In particular, we pointed out that it is most likely just a coincidence that each side of the "V" shape track sampled one mode of the bimodal distribution. The along/across wind difference between the two sides is unlikely to be the cause of the bimodality.
- Three new cases that are either non-precipitating or weakly precipitating were added to the paper and they have no overall impacts on the conclusions. The flight track and radar reflectivity plots for all the cases, except for July 18, 2017, are provided in the supplementary material.
- A small bug in our code was found and fixed. This bug affects the computation of the EF based on lognormal distributions. As a result, the E_q based on the lognormal PDF agrees very well with the observation-based E_q (new Figure 6a), and the E based on the bivariate lognormal distribution agrees well with the observation-based E (new Figure 6d). Because of this, the Figure 8 was removed from the paper.
- Most figures are revised/updated per request/suggestion of the reviewers.

After these revisions, we think the paper is much improved and more focused, although the general conclusions still hold.

I only have one critique of this paper. The authors should add non-precipitating clouds to the study. Once the clouds are drizzling the accretion process effectively dominates autoconversion in precipitation production, so in a sense we care more about the autoconversion process (and all of these covariabilities in non-precipitating clouds than we do in the precipitating clouds shown here. Also, there may be important differences between the covariability in non-precipitating and precipitating clouds and it would be informative to understand those differences if they exist.

Reply: Thanks for the suggestion. Indeed, in the original manuscript, we selected only 4 heavily drizzling cases with strong radar reflectivity and precipitation reaching the ground. We didn't select the non-precipitating cloud cases for a couple of reasons. The first reason is to ensure that autoconversion and accretion processes are active in the selected case. The relevance of an enhancement factor for a cloud not producing precipitation is nebulous. The second reason is more practical. It is because non-precipitating clouds are usually physically thinner than precipitating clouds, which makes it difficult for the airplane to sample different vertical locations of the clouds. As a result, there is often only one or two in-cloud hlegs for the non-precipitating clouds.

Nevertheless, per your suggestion, we selected three non-precipitating or weakly precipitating cases: 1) 2017-07-13 (non-precipitating) 2) 2018-01-26 (weakly precipitating at cloud base but no perception on the ground) 3) 2018-02-07 (very weakly precipitating at cloud base but no perception on the ground) and added them to the revised manuscript. The radar reflectivity curtain with vertical flight track for these three cases are shown in Figure 1 below. The abovementioned challenge of sampling thin non-precipitating cloud can be clearly seen in Figure 1a for the 2017-07-13 case. The selected hlegs and vlegs for these cases are summarized in Table 1. We repeated the same analyses for these new cases as for other cases, i.e., the vertical and horizontal structures of qc and Nc, as well as the EF, for these newly added cases. Overall, the results from these newly added non-precipitating cloud cases are highly similar to those based on the July 18, 2017 case as discussed in section 4. Take the 2018-02-07 case for example. Figure 2 shows the vertical variation of the inverse relative variances ν_q and ν_N. Apparently, both ν_q and ν_N demonstrate a pattern similar to that of the July-18, 2017 case (see Figure 4c of the paper), i.e., increasing first from cloud base (hleg 1 -> hleg 2) and then decrease toward cloud top (hleg 3). Therefore, these newly added cases do not affect the general conclusion although they add to the statistics.

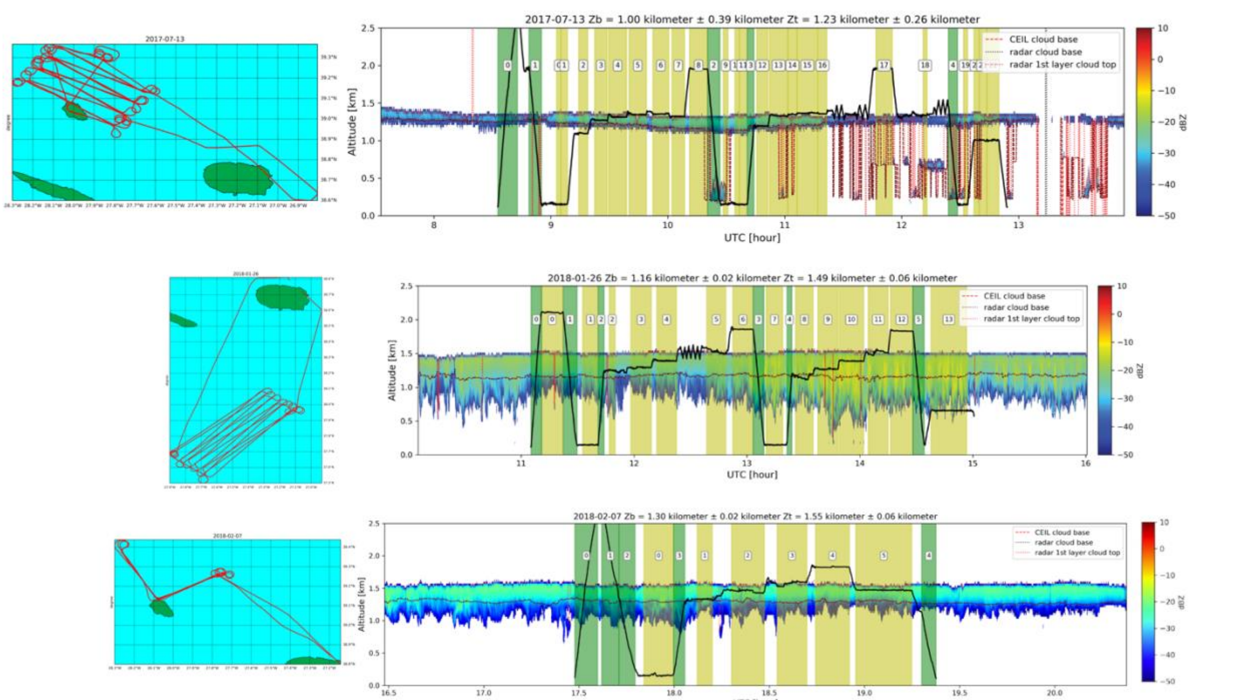

Figure 1 Three non-precipitating (or weakly precipitating) clouds added to the revised manuscript.

Table 1 A summary of selected RFs, and the selected hlegs and vlegs within each RF. (newly added non-precipitating cases are highlighted in bold font)

Research Flight	**Precipitation**	**Sampling pattern**	**Selected hlegs**	**Selected vlegs**
July 13, 2017	**Non- Precipitating**	**Straight-line**	**3, 4, 5**	**0, 1, 3**
July 18, 2017	Precipitation reaching ground	"V" shape	5, 6, 7, 8, 10, 11, 12	0, 1, 3
Jan. 19, 2018	Precipitation reaching ground	"V" shape	6, 7, 8, 15, 16	0, 1, 3
July 20, 2017	Precipitation reaching ground	"V" shape	5, 6, 7, 8, 9, 13, 14	0, 1
Jan. 26, 2018	**Precipitation only at cloud base**	**Straight-line**	**3, 4, 5, 9, 10, 11**	**0, 1, 3**
Feb. 07, 2018	**Non- Precipitating**	**"V" shape**	**1, 2, 3, 5**	**0, 1**
Feb. 11, 2018	Precipitation reaching ground	Straight-line	4, 5, 6, 7, 12, 13	0, 1

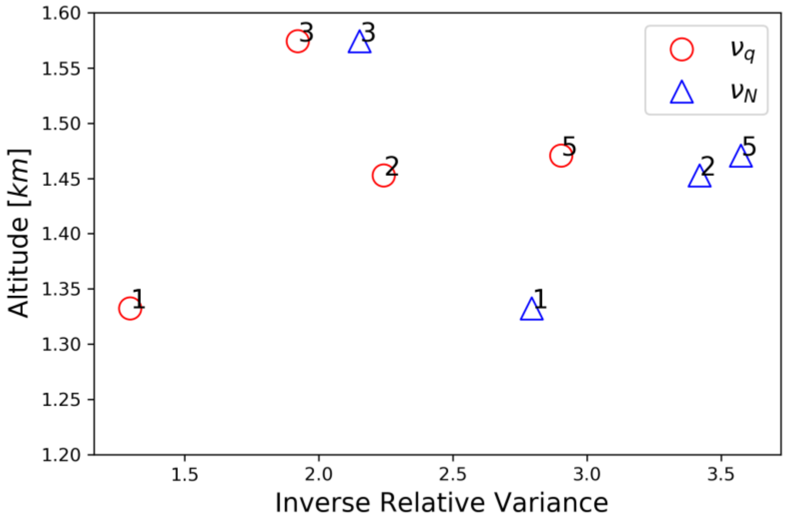

Figure 2 vertical dependence of the inverse relative variances for the Feb. 07 2018 case.

The paper is very well written, adds to the field, and the methods are sound. I haves some editorial comments below and a suggestion for future study. In future studies (not in this paper) I would encourage the authors to look at height dependent correlations between qc and qr as they relate to accretion. Also understand in the height dependence of the precipitation fraction is critical in representing these unresolved processes.

Specific Comments:

None

Technical corrections:

Line 58: process -> processes

Reply: corrected

Line 370: explain -> explained

Reply: corrected

Figure 6: Can you put descriptive titles on each subplot or refer to the physical assumptions that correspond to each subplot in addition to referencing the equations to make it easier to figure out what everything means.

Reply: Good suggestion. We added titles to each subplot of Figure 6 and some other figures.

Line 485 abroad -> broad

Reply: corrected

Lines 537: Eq is used twice to mean two different things.

Reply: The second E_q should be E