Review of:

"Influence of gravity wave temperature anomaly and its vertical gradient on cirrus clouds in the tropical tropopause layer – a satellite-based view" by K-W Chang and T. L'Ecuyer

General Comments:

This paper extends the TTL gravity wave analyses of Kim et al. (2016), hereafter "K16" and Podglajen et al. (2018), hereafter "P18", by using satellite-derived temperature profiles using Radio Occultation (RO) techniques, cloud detection and effective ice crystal radius data from the Cloud-Aerosol Lidar and CloudSat radar from CALIPSO, and water vapor measurements from the Aura MLS. The focus is on identifying phases of TTL gravity waves most likely to generate and maintain ice clouds, and what environmental conditions influence their behavior.

I found the paper to be a measured expansion of previous work on the topic. I do think the authors need to perform some additional analyses to expand the scope and to focus and/or sharpen their findings, and provide additional explanations at certain points of the text, as outlined in my specific comments. Overall, I find the manuscript to be well-organized and written, so while some added study is desired, my suggested technical corrections are brief.

Specific Comments (by Line Number):

45: Your narrative suggests P18 agreed with K16 in placing the highest cloud frequencies in phase 1 of the gravity wave perturbation cycle. But in P18's figure 3, large ice crystals can also be found in phase 3 (where they are sublimating). Putting aside the effect of background relative humidity, P18's abstract says "The precise location where the confinement (i.e., wave-driven localization of ice crystals) occurs … is always characterized by… a positive vertical wind anomaly." So while P18 agrees that ice is suspended in phase 1, I would mention their finding that upward vertical motions permitted the presence of TTL ice clouds within phase 3 as well.

76: Why is the effective vertical resolution of RO profiles ~200m when temperature estimates are given at 30m spacing? Are the temperature data too noisy, and require vertical averaging? Are you using a version of the RO temperature retrievals that removes fine scale artifacts?

90: Explain what a "retrieval to flight ratio" means. Is that the ratio of the satellite-retrieved r_e to that determined from aircraft measurements? How does the +/- 20% uncertainty of retrieved r_e values compare with those derived from in-situ flight measurements?

140: How large is the sample of CALIPSO cloud profiles corresponding to each RO profile? In terms of the spatial collocation criteria I'd like to see the results of a sensitivity analysis, where you try both a smaller- and larger-sized diameter range with respect to the RO perigee point. Depending on sample size, I might try 50 km and 200 km and see if your results are affected in any significant way. A larger diameter incorporates more data, which is statistically preferable. But as wave phase surfaces slope with increasing distance from the RO perigee point, a smaller diameter mitigates the possibility of associating the presence of clouds with the incorrect phase. Bound by these constraints, what spatial collocation criteria is optimal?

145: What is the mean (and standard deviation) of tropopause altitude in your RO dataset? It would follow that convective detrainment would only occur below this level; is this consistent with your finding that warm phase clouds decrease markedly above 16.5km? Or above an even lower altitude? Does this impact your comparison with K16's cloud fraction results? How so?

155: I think it would be worth re-running this analysis, having deleted altitudes that are below the mean tropopause for each geographical region and season. Does this reduce the influence of deep convection that is likely impacting your results for the western Pacific winter, or the Asian monsoon region during summer? Then either update figure 4 with new "filtered" results or else explain the difference (or lack thereof).

165: In regards to your comparison with K16's ATTREX results, I recommend re-computing your RO-derived T' values using a 30-day rather than a 7-day mean temperature. Does making this change result in a significant difference?

168: Re-word "line segments in Figure 1 according to each phase." Do you mean "…defined as the amount of vertical overlap between individual cloud boundaries and wave phases?"

For example, what if a profile's Phase 1 region extends from 14.8 – 15.2 km, but the cloud layer product indicates a cloud only from 14.9 – 15.1 km. In that layer, is CF = 0.2km/0.4km = 0.5?

Table 1: I wonder if this is necessary or can you just incorporate this information into the text? If you keep the table, I would (at least) eliminate the CF=0 column, and explain why the number of cases where CF=1 far exceeds the number of cases for which 0 < CF < 1 (shown in figure 5).

207: Are the weak anomalies of figure 7 simply the result of variability in sampled cloud top heights diluting the overall result? Explain.

221: How can you compute cloud fractions with 50m vertical spacing when the CALIOP 5 km cloud profile product only reports the presence of cloud every 60m?

238-250: This explanation seems overly detailed and tedious. I would shorten this narrative, focusing on your statistical goals, and eliminate Figure 9(g)-(i), since these panels just look like averaged cloud fractions within the column, and show very minor differences between them. I would attempt to make the remaining 12 panels of figure 9 each a little bigger for visibility.

272-281: I'm surprised that distributions of r_e from 2C-ICE data are so uniform. I doubt that the difference between altitude bins is significant. I'd prefer that in figure 10, you keep the results for all TTL altitudes (panel (a)), but delete the vertical stratification presented in panels (b)-(d). Instead, I'd like to see three panels of r_e distributions from a more limited temporal and spatial domain (but for all altitudes combined), namely: (a) the region from 180W-120W during

DJF; (b) from 120E-180E during DJF; and (c) from 60E-120E during JJA. Then as per figure 4, discuss whether convective influence might have an impact on observed ice crystal sizes.

329: I would interpret this a bit differently. I think there is a clear trend in partitioning between phases 1 and 2 from low RH_{ic} values, up to 100%. Thereafter it makes little difference, except for the highest supersaturation values.

<u>Technical Corrections</u>:

Title: Suggest "Influence of a gravity wave temperature anomaly…"

183: Try "-35, -33, … , -1, 1, … 33, 35"

Figure 4: Can you include the number of profiles that contain clouds for each latitude bin?

298-300: Try something like, "We conclude that our analyses of r_e and RH_{ic} data is qualitatively consistent with P18's results."

345-348: Suggest, "…as well as upward vertical motion all impact wave anomalies (…), it remains to be determined whether one has a stronger role in favoring cloud formation."

Figure 11: Add percentage symbols (%) to each of the RH_{ic} labels and add the number of cloud encounters each panel represents.