Response to anonymous Referee#1

We thank referee#1 for the helpful comments. Point-by-point responses to reviewer's comments are listed below (in italic).

General comment
This study examines characteristics of cloud phases in five, frequently occurring, overlapping configurations, over a wide area of southeast Asia. For this purpose, the authors use combined CloudSat-CALIPSO and MODIS data. The different cloud phases are examined in terms of their seasonality and relationship with meteorology, and frequency of occurrence. Their heterogeneity and spectral radiance characteristics are examined in combination with corresponding MODIS data. Associations with MJO and ENSO are also investigated.
The study is to a large extent comprehensive. The results are discussed adequately, and the findings combine verification of previously known characteristics of specific cloud phases/types and their combinations, with new insights over their future usefulness in field campaigns and GCM evaluations. For these reasons, I recommend acceptance of this manuscript for publication in ACP. I include a list of minor comments and technical corrections for the authors to consider.

Comments
Page 5, lines 25-28: it would be useful to report how often these "multi-layer, same phase" vertical structures occur, and discuss possible consequences of this simplification.

Thanks for this great question.

*First, the multi-layer, same-phase clouds occur much less frequently than one-layer cloud (see figure below). For example, **for the ice-only clouds**, the total frequency is 28.6% composed by 20% one-layer and 8.6% multi-layer cloud. **For the ice clouds above liquid clouds**, one-layer ice cloud frequency is 13.8% and multi-layer ice cloud frequency is 6.4%. Similarly, for **the liquid-only cloud** (total frequency ~16%), one-layer liquid cloud is 14.0% and multi-layer liquid cloud is only 2%.*
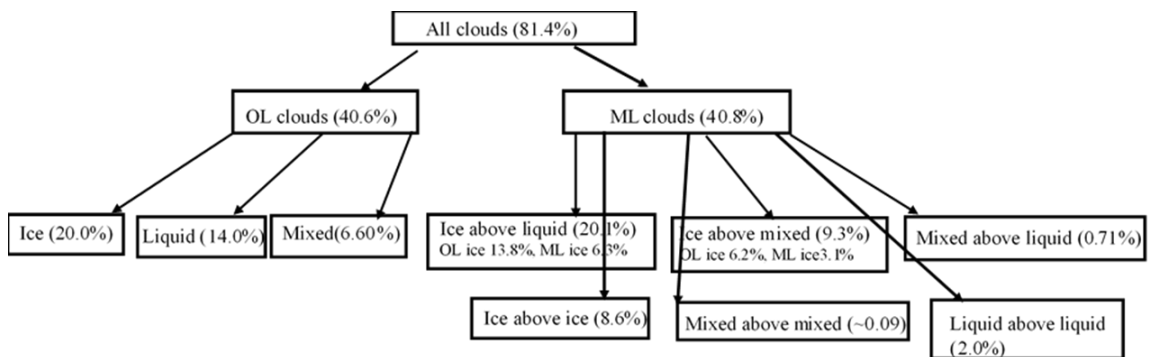

Fig. 1 cloud phase classification.

Second, though the frequency of multi-layer, same phase cloud is relatively small, we have carefully examined the biases due to our simplified classification to cloud distributions, cloud

spatial heterogeneity and spectral radiative features. For example, the distributions (Fig. 2) of one-layer and multiple-layer ice clouds above liquid clouds are similar, i.e. relatively large frequency of multiple-ice clouds occurs where frequent one-layer ice clouds occur.

Third, to further check the bias to spatial heterogeneity and radiation, we have selected 10-days data in January 2007 to compare the difference between the one-layer and multiple-layer, same phase clouds. Figure 3 shows the results for ice-above-liquid clouds – the multi-layer ice cloud above liquid cloud moves the PDF a little off that of all-cloud, but the bias is small and doesn't change our analysis.
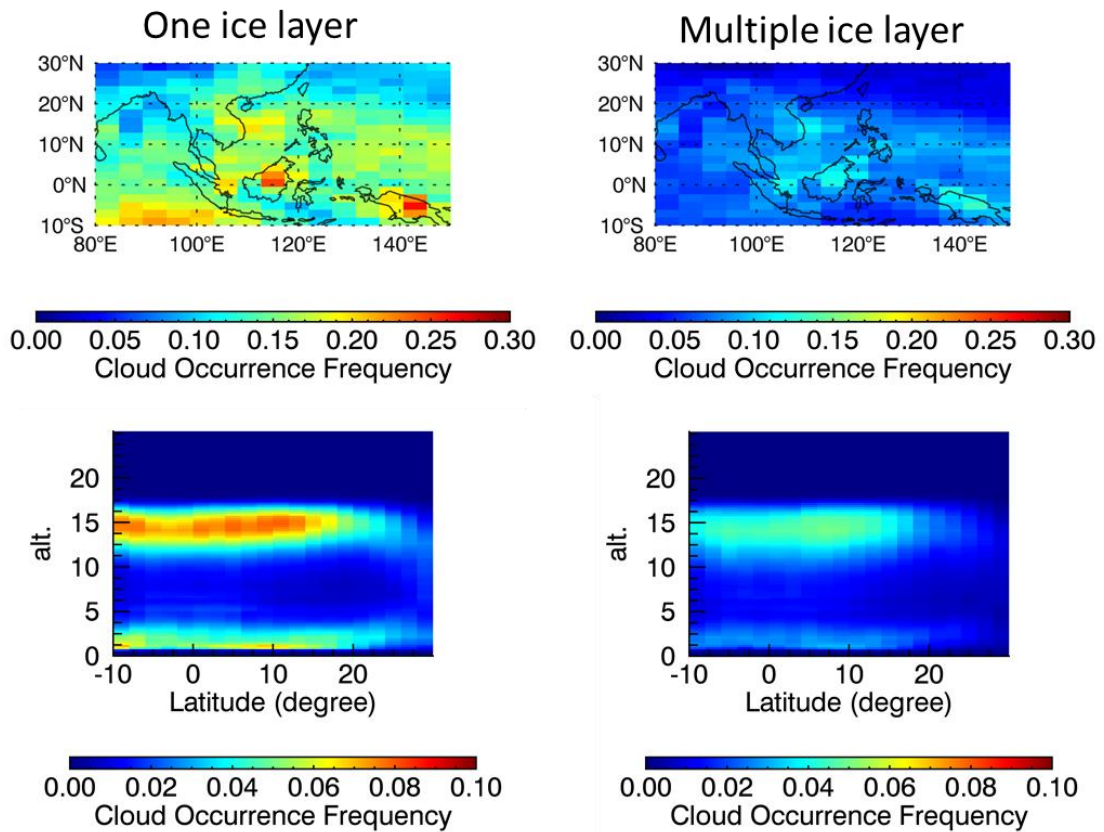

Fig.2 Distributions of ice-above-liquid clouds decomposed to two cases: one-layer ice cloud above liquid cloud (first column) and multiple-layer ice clouds (second column) above liquid clouds.
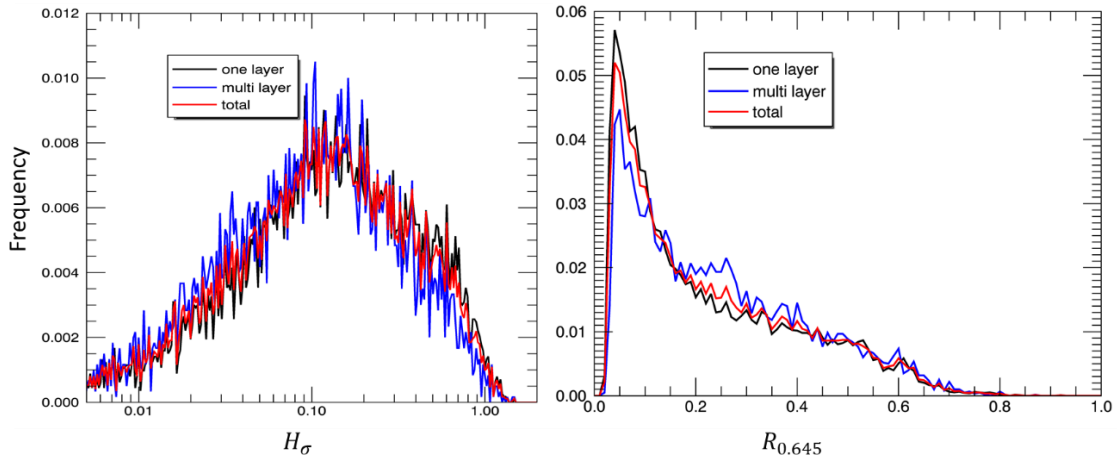
Fig. 3 H_σ *and* $R_{0.645}$ *PDF for ice-above-liquid clouds: black for one-layer ice cloud above liquid cloud, blue for multi-layer ice cloud above liquid cloud and red for all ice-above-liquid cloud.*

We have responded by summarizing these finding in Sect. 2.2 (Page8, Lines 40-41 and, Page 8, Lines 1-7 in revised version) and by adding the following statements and with appropriate additions to Table 3:

'As stated in Sect. 2.2, we classify clouds according to cloud phase and cloud layer in five main groups: ice-only, liquid-only, mixed-only, ice-above-liquid, ice-above-mixed clouds. Each group contains both single and multiple layers of the same phase. Our analysis (Table 3) shows that one-layer-one-phase clouds have much larger frequency than multi-layer-same-phase clouds. For example, multi-layer ice-only cloud (~8.6%) occurs less frequently than one-layer ice-only cloud (20%). Liquid-only clouds mostly form in a single layer (14%) and the frequency of multi-layer liquid-only cloud is only 2%. A careful comparison between single and multiple layers of the same phase clouds shows no significant difference in the properties that we're interpreting, which justifies our simpler classification.'

Page 6, lines 24-25: I don't understand how MODIS detects less clear-sky cases than CC by missing some cloudy cases. Shouldn't it be the other way around?

Yes, you're correct. MODIS detects more clear sky than CC. As displayed in Table 2, MODIS clear sky samples are 4 623 583 (32%), while CC clear sky samples are 2 587 635 (17.9%).

Now in Page 6, Lines 20-22, it is corrected as:

'We also found that 29% of CC ice-only clouds are reported as clear sky by MODIS, indicating that MODIS misses some thin cirrus in the SEA region – a point also made in Reid et al. (2013).'

Figure 5: this figure is hard to read. Please consider replacing with 2D plots.

As suggested, Figure 5 is replaced with 2D plots.

Page 16, lines 26-27: how is the frequency of occurrence related to the average reflectance? Shouldn't they be thicker to have higher R?

The averaged reflectance is not weighted by occurrence frequency, and thus you're right that thicker clouds have higher R.

Now in Page 13, Lines 30-32, it is modified as:

'The averages of the reflectance and the brightness temperature (BT) (not weighted by cloud occurrence frequency) for each cloud group are shown over SEA.'

Page 18, lines 25-27: it is hard to verify this statement based on Fig. 14d. For example, ice-above-liquid after 07/08 does not agree well.

Thanks for this comment. We have updated our results using the up-to-date CC data (R05), which show better cloud phase variation with ENSO. To verify this statement, we calculate the correlation coefficient between MODIS ice cloud anomaly and CC ice-only, ice-above-liquid, ice-above-mixed and mixed-only clouds, respectively. Results show that the CC 'ice-contained clouds' are well correlated with MODIS ice clouds as listed in the following table:

	Ice-only	Ice-above-liquid	Ice-above-mixed	Mixed-only
Coefficient correlations with MODIS ice cloud	*0.7*	*0.75*	*0.86*	*0.72*

Original statement: 'The MODIS ice cloud anomaly agrees with that of ice-only, ice-above-liquid, ice-above-mixed and mixed-only clouds from the CC observations (Fig. 14d), because most of these CC clouds are reported to be ice by MODIS (Table 2).'

Now in Page 17, Lines 28-30, it is revised as:

'The MODIS ice cloud anomaly correlates well with that of CC ice-only, ice-above-liquid, ice-above-mixed and mixed-only clouds (Fig. 14d) with correlation coefficients greater than 0.70 (significant at 99% confidence level).

Page 18, lines 29, 30: what is considered "abnormal" in the heterogeneity index variation?

We call the positive (negative) anomaly as abnormally high (low). To avoid this confusion, we discard the wording 'abnormal' and rephrase our results accordingly.

For example, the original statement "H_σ is observed to be abnormally small in La Niña year due to the increase of 'ice-contained clouds' and abnormally large in El Niño year because of decreased 'ice-contained clouds and the expose of liquid clouds",

Now in Page 17, Lines 32-34, it is revised as:

'H_σ anomaly is observed to be negative in La Niña year due to the increase of 'ice-contained clouds' and positive in El Niño year because 'ice-contained clouds' decrease, exposing more liquid clouds.'

Page 19, line 41: "where are relatively cold". Are you referring to the lower troposphere conditions? Please clarify.

Yes, you're right.

It is now in Page18, Lines 38-40 corrected as:

'Liquid-only clouds appear frequently in winter and spring over southeast China and East China sea where the lower troposphere is relatively cold, dry and stable'

Figure 6: what are the vertical dashed lines?

Thanks for pointing out this issue. We now add the explanation in Figure 6 caption: The vertical dashed lines in a)-e) indicate the median values of the PDFs.

Figure 9: seasonality symbols are not clear. Please consider plotting differently or including a table.

The values of each symbols are now summarized in Table 5.

Page 2, line 14: "macrophyscial" should read "macrophysical".

Corrected

Page 2, lines 28-31: please consider rephrasing or breaking this long sentence.

Original statement: "Particularly, cloud radiative effects in the LW are reduced at the top of atmosphere (TOA) for high over low clouds compared to single-layer high clouds and much stronger than single-layer low clouds, which nicely demonstrates the importance of accurately representing cloud vertical structures in GCMs."

Now in Page 2, Lines 26-28, it is revised as:

'Particularly, the radiative effects at the TOA in the LW of high over low clouds are weaker than high clouds but much stronger than single-layer low clouds. These studies nicely demonstrate the importance of accurately representing cloud vertical structures in GCMs.'

Page 3, lines 8-9: do you mean "has not yet been examined"?

Yes, it is corrected.

Page 9, line 1: "cloud" should read "could".

Thanks, it is corrected.

Page 10, line 4: "summaries" should read "summarizes".
Thanks, it is corrected.

Page 11, line 22: "CLIPASO" should read "CALIPSO".
Thanks, it is corrected.

Page 13, line 3: please omit "that".
Corrected.

Page 13, line 42: "spatial" should read "spatially".
Corrected.

Page 14, line 2: "it" should read "its".
Corrected.

Page 14, line 35: "reflected" should read "reflective".
Corrected.

Page 14, lines 42-43: do you mean "refractive index"?
Thanks for your correction. It is corrected.

Page 15, line 16: please consider replacing "aware" with e.g. "note that".
As suggested, we replace 'aware' to 'note that'

Page 16, line 25: "and thicker" should read "and they are thicker".
Corrected.

Page 16, line 33: 0.546 should read 0.645.
Corrected.

Page 17, lines 18-20: please rephrase.

The original statement:

'Area with small $H\sigma$ is surrounded by relatively large $H\sigma$ values, indicating the locations where occur suppressed MJO phase associated with more liquid clouds.'

Now in Page 16, Lines 16-18, it is revised as:

'Areas surrounding the convective center are with relatively large H_σ values, indicating that the locations of suppressed MJO phase are associated with more liquid clouds.'

Page 17, line 22: please consider replacing "are with" with e.g. "display".

Revised as suggested.

Page 17, line 24: "connective" should read "convective".

Corrected.

Page 19, lines 13-14: please rephrase.

The original statement, 'As cloud phases vary interannually and hence change the spatial heterogeneity, i.e., being smoother in La Niña year than normal and vice versa in El Niño year.'

Now in Page 18, Lines 10-11, it is rephrased as:

Overall, the cloud phase varies interannually, as does H_σ , i.e., being smoother in La Niña years compared to El Niño years.

Page 19, line 15: "well correlates" should read "correlates well".
Corrected.

Page 20, line 18: "heterogenous" should read "heterogeneous".
Corrected.

Page 21, line 5: please replace "attribute" with "contribute".
Corrected.