General Comments:
This is a well-written paper that clearly demonstrates the importance of considering the sub-grid variability of cloud and precipitation when applying the COSP MODIS and CLOUDSAT satellite simulators. The authors demonstrate that the radar reflectivities derived from the sub-grid CRM cloud and precipitation properties, versus the grid mean properties, are vastly different and excluding sub-grid variations can lead to misinterpretation of model performance (leading to the conclusion that the drizzle or rain is triggered too frequently).

I find this work to be important as its results will impact the analysis of CMIP6 model simulations, many of which will very likely be using the oversimplified COSP subcolumn generator in version 1.4.

Thank you very much for the encouraging comments. We have revised our manuscript based on your constructive advices.

Specific Comments:
Line 83: What is the pixel resolution of MODIS?
Ans: The MODIS data we used in this study is the C6 Aqua MODIS products that include the 1km geolocation products and the cloud mask product (Ackerman et al., 1998). As mentioned in Section 2.3 of our manuscript, we collocated 5 years (2006 ~ 2010) of pixel-level (i.e., level-2) MODIS and CloudSat observations using the collocation scheme developed in Cho et al. (2008). We aggregated these CloudSat and MODIS collocated level-2 data to the level-3 (gridded) data with the horizontal resolution as that in our CAM5.3, which is 1.9° latitude × 2.5° longitude.

Line 129: A more detailed description regarding clouds and microphysics in SPCAM would be appreciated. How can microphysical processes be resolved at 4km? Does SPCAM use the Morrison and Gettelman (2008) microphysical scheme mentioned?
Ans: As suggested, we have added a short paragraph to describe the physical parameterizations in SPCAM. SPCAM uses the two-moment cloud microphysics scheme of Morrison et al. (2005) to resolve microphysical processes at 4km. The Morrison and Gettelman (2008) microphysical scheme is based loosely on the approach of Morrison et al. (2005).

Fig 2 (& related Caption) - Add experiment name to plot and caption. In regards to Subplot e) Add title to columns (ie mixing ratio / eff. radius). (FYI - I like that the authors added the variable and routine 'fracout from scops.f' to the caption. This will be very helpful for other modelers).
Ans: We have modified Figure 2 as suggested in our revised manuscript.

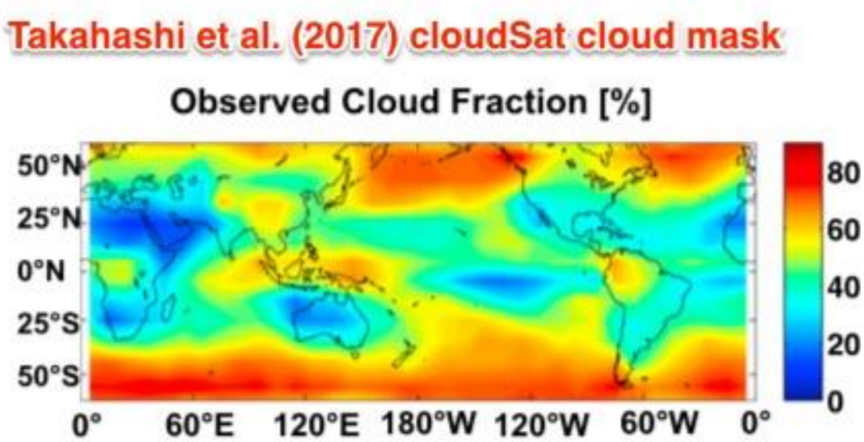
Line 218: Consider sharing the modification to COSP to the community.
Ans: The latest version of COSP (v2.0) might have already implemented the capability for sub-column sampling. But yes, we will share our finding with the COSP to the community (through personal communication and COSP user google group https://groups.google.com/forum/#!forum/cosp-user).

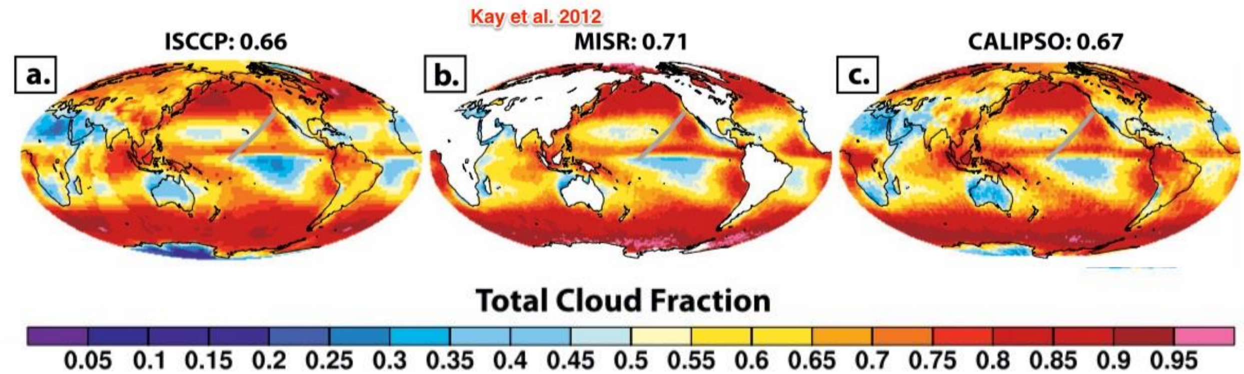
Line 274-247: The obs. pdf needs to be further analyzed. Finding that CloudSat only detects 54% of collocated warm clouds MODIS detects is a significant problem that needs to understood/explained further. Are you saying that a large chunk of the 46% of undetected clouds are too thin and can explain the sharp decline in the pdf around -40 to -25dBZ? If so, how often are warm liquid clouds too thin to be detected by CloudSat (check with CALIPSO)? Ground clutter really only influences the lowest approx. 1_km. This would imply that nearly half (or some significant fraction) of the clouds MODIS detects are within the lowest 1_km (again, check with CALIPSO). Also, is there a way of checking for frequency of attenuation (for a given altitude) in the Observations? While I understand this will very likely not change the results of this plot, it is important to note which types of clouds are being eliminated in the observations.

Ans:

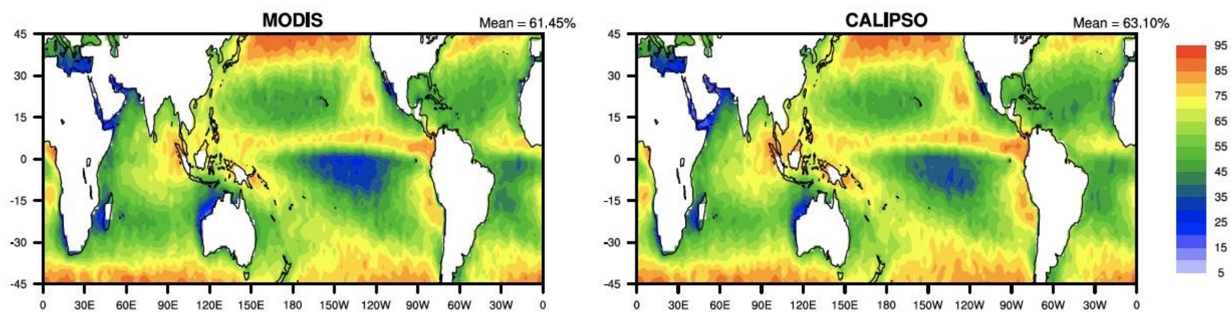
Yes, using only the CloudSat cloud mask alone (i.e., 2B-GEOPROF product) would miss significant amount of liquid-phase clouds. In addition to surface cluttering problem, some clouds are either too thin or their particle sizes are too small to generate detectable radar echo (i.e., >−30dBz), and therefore would be missed by CloudSat. Though it should be kept in mind that CloudSat is designed to detect "hydrometer" which include both cloud and more importantly precipitation. Moreover, as you pointed out, CloudSat is flying side by side with CALIPSO which is much more sensitive to thin clouds. That is why the CloudSat team developed the 2B-GEOPROF-LIDAR product which combined the CALIPSO and CloudSat for cloud detection. In our study, we mainly use CloudSat to detect drizzle and use MODIS to detect clouds.

We could not find a published reference to quantify and explain the clouds missed by CloudSat (maybe because it is well known?), but we found two papers, one by Takahashi et al. (2017) who used CloudSat only cloud mask and the other by Kay et al. (2012) who used ISCCP, MISR and CALIPSO cloud masks. Below are the cloud fractions from the two study. It is evident that the CloudSat only cloud mask detects significantly lower cloud fraction than CALIPSO or the other two passive sensors. In particular, over the stratocumulus cloud regions (e.g., SE pacific off coast Peru and NE pacific off coast of California) the cloud fraction based on CloudSat alone is only around 50% much lower than the CALIPSO values ~ 75%~85%.





One more point to note is that many studies have shown that the MODIS cloud mask agrees well with CALIPSO cloud mask. In fact, in our early paper, Song et al. (2018), we found that the total cloud fraction from MODIS is about 61% between 45S and 45N, only 2% lower than the CALIPSO cloud fraction. See Figure below.



The cloud masking product of CloudSat is beyond the scope of this study. We believe our result is robust and consistent with previous studies.

Takahashi, H., M. Lebsock, K. Suzuki, G. Stephens, and M. Wang (2017), An investigation of microphysics and subgrid-scale variability in warm-rain clouds using the A-Train observations and a multiscale modeling framework, Journal of Geophysical Research-Atmospheres, 138(669), 2151.

Kay, J. E. et al. (2012), Exposing Global Cloud Biases in the Community Atmosphere Model (CAM) Using Satellite Observations and Their Corresponding Instrument Simulators, Journal of Climate, 25(15), 5190–5207, doi:10.1175/JCLI-D-11-00469.1.

Song, H., H. Song, Z. Zhang, P.-L. Ma, S. J. Ghan, and M. Wang (2018), An Evaluation of Marine Boundary Layer Cloud Property Simulations in the Community Atmosphere Model Using Satellite Observations: Conventional Subgrid Parameterization versus CLUBB, Journal of Climate, 31(6), 2299–2320, doi:10.1175/JCLI-D-17-0277.1.

Line 339 / Section 4: Can you state which other COSP simulators, and how a few selected variables, would be influenced by the sub-grid cloud variability (and in-cloud microphysical properties)? Otherwise, I recommend changing broad statements of about the COSP simulator to more specific statements regarding the CloudSat simulator.

Ans: COSP includes simulators that are compatible with the ISCCP, PARASOL, CALIPSO, MISR, MODIS, and CloudSat observational products. In our research,

we mainly focus on three COSP simulators: MODIS, CALIPSO, and CloudSat. As shown in the below figure (Figure S1), the simulated total cloud fraction by these three simulators, and the in-cloud properties by the MODIS simulator are all influenced by the sub-grid cloud variability but with different magnitudes. The CloudSat simulation is affected most obviously since the calculation of radar reflectivity is strongly sensitive to the inhomogeneous distribution of cloud droplet size.

Section 4: It needs to be emphasized that the 'sub-grid variability of mass and microphysics within each hydrometeor type' is key.

Ans: As suggested, we have added a sentence in Section 4 to emphasize the key role of sub-grid variability of mass and microphysics within each hydrometeor type.

Double check references.

Ans: We have double checked the references and made some corrections. Thank you.