We would like to thank the reviewer 2 for their efforts. The critical comments and questions have been very helpful for improving the manuscript.

General Comments

This study faithfully follows ECMWF's methodology (Geer et al, 2009, 2011, 2013, 2014) on microwave radiance simulation affected by precipitation, specifically in frozen phase. The specific contribution to this research subject is to investigate one high frequency channel from GMI in one meteorological condition i.e. tropical storms in Bay of Bengal.

Comment 1:

The model inputs to RTTOV are from WRF simulation of storms. It is not clear how WRF forecasts are conducted, e.g. are they straight many hours of simulation initialized by ERA from certain moment during the storm lifetime?

Judging from the storm figures, the model simulated precipitation spatial distributions are not good comparing to the observed that in turn would have negative impact to sampling of Tb departures.

Response 1:

As per the reviewer suggestions, for clarity we have stated the brief summary of WRF simulation experiment in the revised manuscript from line 149 to 156 as below:

"The present study used the WRF model in control run mode (without assimilation). The experiment is designed for each cyclone as per the timing of GMI observations. For e.g. GMI observation for hudhud cyclone is at 0005 UTC 07th October 2014, the model is initialized at 0000 UTC 06th October 2014 with ERA-I datasets and then integrated up to 30 hours (06 UTC 7th October 2014) and the boundary conditions regularly updated at every 6h intervals from ERA-I datasets. The same procedure is repeated again for other GMI observations. In all the experiments, the analysis were generated within ±3 hour of the observations for every pass during the cyclonic event."

Studies on Tb simulations (Fabry and Sun, 2010; Roberts and Lean, 2008; Rysman et al., 2016) show that it was very difficult to match the exact position and intensity of cloud and precipitation features in NWP models because of lack of cloud and precipitation predictability at smaller scales. In addition, Yesubabu et al., (2016) found that control run experiment in WRF model have tendency to predict the cloud earlier than observation. Tb departures are contributed by many factors including unknown size, shape and intensity of hydrometeors in modelling of cloud features which are significant around 20-40 K in convective environment (Geer and Baordo, 2014; Geer and Bauer, 2011). For clarity, we have included lines 214-216 in revised manuscript as follow.

"In this study, the precise location and intensity of cloud and precipitation is not being captured. One of the possible reasons might be model tendency to predict the cloud earlier than observation in control run experiment (Yesubabu et al., 2016) which causes large FG departures."

Comment 2:

The RTTOV simulation uses Field's PSD and particle density (Field 2007). However, the WRF simulation here uses one-moment 6-class microphysics (Hong and Lim 2006) that has different assumptions on PSD and density. This inconsistency can introduce model errors to the Tb departure statistics. As previous studies have shown, the simulated Tb in presence of frozen particles is sensitive to PSD and density assumption as much as to the non-spherical shape assumption.

Response 2:

We agree with the reviewer that WRF simulation uses different assumptions for PSD and density and that this can introduce model errors into the Tb departure statistics. But, the model error is very small (~2 K) as compare to large observation errors (~20-40 K) in convective environment (Geer and Bauer, 2011). Hence we can ignore the model errors in all-sky radiance assimilation framework. For clarity, we have included line173 to 179 as given below:

"Di Michele et al., (2012) suggested for independent assumptions to both NWP and RT models because of following reasons. (1) the assumptions related to parametrization (clouds and radiation) are not consistent within NWP model, (2) uncertainty in representing the spatial and temproral variation in PSDs and scattering information accurately in NWP model. However, independent assumptions can introduce model errors which is very small (~2 K) as compared to large systematic errors (~20-40 K) in convective environment (Geer and Bauer, 2011). Hence we ignore the model errors in all-sky radiance assimilation framework."

In accordance with reviewer comment, due to model complexity, varying PSD and particle shape together is not an feasible solution as stated below in lines 183-188.

"For frozen hydrometeors, it would be preferable to vary PSD and DDA shapes together for accurate scattering properties but this will be complicated for RTTOV model (Geer and Baordo, 2014). In the present study, we decided to fix PSD and density and keep varying the DDA shapes of frozen hydrometeor shape for Tb simulations. In literature, (Doherty et al., 2007; Kulie et al., 2010), Field et al., (2007) is well known PSD for frozen hydrometeors over tropical and mid-latitude regions. Hence we selected the same PSD over Indian region."

."

Comment 3:

The WRF serves dynamic downscaling of ERA and introduces microphysics hydrometeors, However, at the model resolution chosen for this study, microphysics is not as relevant and effective as the cumulus convective parameterization scheme. As a specific regional study a finer model resolution should be more appropriate to resolve what microphysics is designed to resolve, and avoid averaging Tb observations.

Response 3:

We thank the reviewer for the useful suggestions. If we select finer resolution (for e.g. 5 km), there will be high possibility of horizontally correlated errors and this may also increases the computational effort (Liu and Rabier, 2002). Moreover, past studies on all-sky radiance assimilation has been performed at 15 km model resolution for cyclonic event (Yang et al., 2016). Hence, we selected 15 km in our study.

For clarity, we include lines 131-133 in revised manuscript as below:

"We selected the 15 km model resolution grid as compromise between the small number of samples and less effect of horizontally correlated errors (Liu and Rabier, 2002)."

We agree with reviewer suggestions. Finer resolution (grid size < 10 km) can resolve the mixed phase processes that can produce large grapual and hail, particular in convective situations (Skamarock et al., 2008). But, RTTOV model version 12.1 does not consider grapual and hail and also their occurrence is very less over Indian region as compared to US and European regions (Baker et al., 2005). Hence, the present work does not consider finer resolution.

Lines 382 to 386 stated as: "In our simulations, we consider only DDA shapes for snow, however in reality there are also high density particles such as hail, aggreagate and graupel hydrometeors which produces very low brightness temperature (Figure 1). Further efforts shall be directed towards including varieties of frozen hydrometeors in RTTOV model."

Comment 4:

The three storms presented are in the same region, same season, with similar meteorological characteristics. It would be a stretch to state that the study applies to "all meteorological conditions". Therefore the presentation of statistics should combine the samples from three storms, which can increase the sample size for each of the statistical parameters evaluated, and improve readable quality of the graphics presentation.

Response 4:

We thank the reviewer for this suggestion. Though combining samples from three storms is a good approach but our hypothesis is to independently analyze the simulations of each cyclonic event and we intent to utilize the same for RTM configuration during assimilation of GMI radiances for better forecasting of each event. Further, previous studies on radiance assimilation have adopted similar techniques to evaluate the independent storm events (Madhulatha et al., 2017; Routray et al., 2016; Yang et al., 2016). Hence, for clarity we have removed the following lines from the revised manuscript" all meteorological conditions. "

Comment 5:

With all respect to model simulations, I wish something could be done independent of ERA or WRF, i.e. find locally observed inputs to radiative transfer model to obtain Tb departures that do not contain model background errors. It is difficult to get that in general global study. It would be a much more meaningful contribution if a regional study like this one makes effort in that direction.

Response 5:

Thank you for encouraging us with new suggestions. Existing studies used ERA-Interim (Zou et al., 2016), NCEP/NCAR reanalysis datasets (Mohanty et al., 2010) directly as input to RTTOV model for Tb simulations in clear-sky conditions. However, these datasets have lack of cloud ice and rain properties which cannot simulate the scattering properties accurately in all-sky conditions (He et al., 2016). Hence, we do not use this direct approach at this stage and consider it extremely useful for future studies in all-sky situations. For clarity, we have included 393-397 lines in revised manuscript are stated as:

Moreover, independent studies with ERA datasets are not found useful for simulation especially for microwave humidity sounders because scattering properties of cloud and precipitation are not simulated accurately in all-sky conditions (He et al., 2016). This happens due to lack of accurate information about cloud ice and rain profiles in ERA-I datasets."

Our future work is directed towards assimilating all-sky GMI radiances in WRF model to improve the initial conditions which reduces the model background errors and Tb departures.