Responses to the referee comments

We thank the reviewer for his/her insightful comments and suggestions. We have modified the figures and text as directed by the reviewer. Below is our point-wise response to the specific comments raised in the second review.

Major comment 1: One of the change concerns figure 1 for the LFR values. Apparently, there was an error in the plot, especially in the phase La-Nina. The LFR is now much weaker. Of course, it clarifies the comments, but is a little surprising to have made comments that were not consistent with the figure.

Response to major comment 1: LFR is weaker only during the post-monsoon season in India. Previous studies also reported a similar LFR distribution (Kamra et al., 2014). Those comments were made for anomalous lightning flash rate (LFR) in figure 2, and concerning figure 2, the description was reasonable in terms of anomaly. Figures 1 and 2 were inconsistent during the initial submission stage because of the error in figure 1. Accordingly, we rectified those mistakes during the second revision and believe that the revised description is robust for the figures. We are immensely thankful for these comments, which have helped to improve our manuscript significantly.

Major comment 2: Another change is the colored scale with a degraded resolution. It is not easy to appreciate some low values difference although the authors made comments about low values as for example in the case of post-monsoon period. The Indian peninsula at that moment is concerned by very weak lightning activity and it is difficult to see a difference between the different regions and the different ENSO phases.

Response to major comment 2: Correction included, and the colour scale is adjusted to reflect the prominent features of regions having maximum LFR. The edited version of the manuscript provides figure 1 with a colour scale with an enhanced resolution. The text is also changed according to your suggestions. Kindly see the revised manuscript.

Major comment 3: We can also wonder why the authors choose to plot such a large area for the maps of the LFR since they make comments and analysis about India? It is especially true for the south part of the maps and for the western part too. With a reduced area, the visibility should be better?

Response to major comment 3: Correction included. As suggested by the reviewer, we have restricted the geographical area to 60-110º E, and 0-40º N for better visibility of the prominent features of LFR discussed in the text.

Major comment 4: The first comment in the abstract at line 10 about three hotspots: “three hotspots of LFR over the Indian land region became more prominent in the last decade of the monsoon season” is not obvious. I do not see three hotspots?

Response to major comment 4:

We modified this sentence to "It is striking to note that there are three hotspots of lightning flash density (LFD) over the Indian land region, which became more prominent during the monsoon seasons of last decade." The hot spots regions discussed here is in agreement with earlier studies.

Ahmad and Ghosh (2017) reported that lightning activity is higher over the North-Eastern part and southern part of India during the pre-monsoon season than in other regions of India. They also observed that the maxima of lightning during post-monsoon is also lying over India's southern and eastern areas. Saha et al. (2017) confirm that the north-western and north-eastern regions of India and the southern tip of peninsular India are the three main zones prone to deep convection.

The three hotspots of LFD discussed in the manuscript is more discernible from modified figure 1 and highlighted as coloured boxes. The LFD becomes more prominent in the last decade of the monsoon season, as evident from the area-averaged anomaly presented in figure 4.

Major comment 5: Lines 150-155: about the values of ice particle concentration, the value range is wide but for convective clouds we can suppose large values within the range are more probable. The range is presented with this interval [10-4 – 1 g m-3] which corresponds with values measured during a campaign. My feeling is that most values are in the upper part of the interval. Thus, as I noted in the first review, the values for the anomalies in figures 4 and 5 are < 0.0005 g m-3. Again, I do not understand such low values when the concentration is close to 1 g m-3. What does it mean? Are these values valuable for the convective clouds? They are issued from the NCEP/NCAR database with a resolution of 0.5°x0.5° but at which time do they correspond? How are these values representative of the convective clouds when they occur? For the case of the NNWI region and pre-monsoon season, the LH anomaly is < 0.01 °/hr, it is also very low values.

Response to major comment 5: This study aims to understand the seasonal variability of LFD over the Indian region with respect to different ENSO phases. Hence this study utilized monthly mean values of LFD and cloud hydrometeors from TRMM observations. We agree that the values are insignificant as far as individual clouds are concerned but significant for seasonal composite analysis. The area averaging also reduces the absolute values as compared to individual cloud cases. Monthly averaged TRMM-3A12 data is available for graupel and snow from January 1998 to December 2013 with a spatial resolution of 0.5*0.5 degrees. The parameter averaged for the pre-monsoon (March-May), monsoon (June-sept) and post-monsoon (October-December) season from 1998 to 2013 with respect to La-Nina, El-Nino and Neutral phases of ENSO are used in this work. Anomalies of these parameters are calculated in the following way.

Graupel/snow anomaly in this study indicates the difference between the composite of graupel/snow concentration during a particular ENSO phase in a specific season and the composite of graupel/snow concentration during all three ENSO phases for that particular season. e.g., Graupel/snow anomaly during pre-monsoon during La-Nina = (Composite of graupel/snow concentration during La-Nina in pre-monsoon) - (Composite of graupel/snow concentration during all the three ENSO phases in pre-monsoon). The seasonal average and anomaly of latent heat with respect to ENSO phases are also calculated similarly.

According to CAIPEEX measurement, Patade et al. (2015) showed that ice particle concentration inside the convective system varies with seasons. During the pre-monsoon season, they found that most values exist between 10^{-2} and 10^{-3}. While their values mainly exist between 10-1 to 10-3 during monsoon and post-monsoon season. So it is not easy to say that ice concentration is close to the upper part of the interval. From TRMM observations and high-resolution model simulations, Abhilash et al. (2008) reported ice concentrations of 10^{-2} to 10^{-3} for convective storms over the Indian region.

For signifying the importance of anomalous concentration, we have included the seasonal average of graupel and snow content with the ENSO phase in the modified figures. From these revised figures, we can see that actual values of the seasonal average of graupel with respect to the ENSO phase are less than 2 $mg.m^{-3}$ over NEI, NNWI and SPI. The same is true for the seasonal average of snow content and suggests that anomalous values are significant compared to their actual values.

LH anomaly is < 0.01 in magnitude, and their absolute values are also less when averaging over a large domain, and the sentence is now modified accordingly. Hence while averaging over the season and over a larger region, we can expect values less than one order of magnitude as compared to individual clouds averaged over a small region.

Major comment 6: Line 163, the authors write: “the cold ENSO phase suppresses LFR over NEI and SPI with enhanced LFR over CI (Figure 2 (b))”. It is in contradiction with line 109, when they wrote “Irrespective of ENSO phases, the LFR peak is located over northeast India (NEI) during the pre-monsoon season:” They cannot say the LFR is suppressed during the pre-monsoon season and the cold ENSO phase, by looking at Figure 1, even if the anomaly is negative! The LFR is displayed in Figure 1. The LFR in NEI is between 0.08 and 0.12 according to Figure 1b for the cold phase and the anomaly according to Figure 2 is between -0.01 and -0.014, it is about 10% of the LFR value.

They cannot talk about "suppress" it is only lower than the average between the three ENSO phases if I understand well.

Response to major comment 6: Correction included. The sentence is rewritten according to your suggestion. Thank you for the valuable feedback.

Major comment 7: Lines 162-168: For the comparison of different ENSO phases the mirror image effect is not surprising since the anomaly is calculated by the difference with the average value. If one phase involves a decrease another (or both others) has to involve an increase according the definition of the anomaly. Again, at line 168, they cannot say "that the cold phase suppresses the LFR over NEI" since it is not suppressed. Anyway, if they talk about an increase or a decrease, they have to quantify it to discuss the relative variation.

Response to major comment 7: Correction included. The wordings are changed according to your suggestion. Thank you.

Major comment 8: Line 169: Figure 4a shows the anomaly of graupel concentration in NEI and during the pre-monsoon season. According to the definition of the anomaly as a difference to the mean value for each phase, the sum of the anomaly values must be zero. Apparently, it is not the case for this graupel concentration. The same comment can be made for other panels of Figure 2: d, e, h, l and the same for Figure 5 and Figure 6. Can the authors explain these results? Anyway, for the parameters of microphysics issued from re-analysis, the description added in the new version of the paper is insufficient to understand the signification of these concentrations. Are they average and for which time and location are they representative?

Response to major comment 8: Thank you for this valuable suggestion. We rechecked the data and found that some missing values in the data set created this problem. Now it is corrected and the figures are redrawn. Please see the revised figures 2, 5 and 6. We did a correlation analysis between lightning flash rates with microphysical parameter (graupel concentration) and included in the revised manuscript with a detailed explanation.

Since the data sets are only available from January 1998, the microphysical parameter is averaged for the pre-monsoon (March-May), monsoon (June-September) and post-monsoon season (October-December) from 1998 to 2013 with respect to La-Nina, El-Nino and Neutral phases of ENSO over NEI (85˚ E-95˚ E, 20˚ N-30˚ N), NNWI (25˚ N-40˚ N, 65˚ E-80˚ E) and SPI (5˚ N-15˚ N, 75˚ E-80 ˚ E).

The authors are obliged to the reviewer for pointing out this important issue and allowing us to incorporate the corrections, and now the figures maintain the budget.

Major comment 9: For section 3.3, it is a little the same problem with the comparison of region NNWI during the different phases. They cannot use "suppress" for the LFR and again, a quantitative analysis could be made.

Response to major comment 9: Correction included. Thanks for the suggestion.

Minor comments:

Minor comment 1: I said in my first review the parameter LFR could be LFD as lightning flash density since it is a density (km-2 day-1). It is a daily density. Is it more consistent to talk about density? As in Albrecht et al. (2016) a combination is used when the double scale (time and space) is used for the flash count: for example "The TRMM LIS total lightning flash rate density (FRD – fl km-2 yr-1)" is generally used at the scale of the year. Ref Albrecht, R., Goodman, S., Buechler, D., Blakeslee, R., and Christian, H.: Where are the lightning hotspots on Earth?, Bull. Amer. Meteor. Soc., 97, 2051-2068, doi:10.1175/bams-d-14-00193.1, 2016.

It is also the case in Christian et al. (2003): in the abstract: "The Congo basin, which stands out year-round, shows a peak mean annual flash density of 80 fl km-2 yr-1 in Rwanda, and includes an area of over 3 million km2 exhibiting flash densities greater than 30 fl km-2 yr-1 (the flash density of central Florida)." It sounds better with "density", but if the authors prefer "rate" it is also possible, some authors use it, as Cecil et al. for example.

Response to minor comment 1: Thank you for this suggestion. We admit that initially, we were a bit confused on which term is more accurate and now realize that 'flash density' is better usage than flash rate. We have changed LFR to LFD throughout the manuscript. Thank you very much.

Minor comment 2: Line 20-22: the annual death rate has to be 2,266 with a total of 31,725 in 14 years?

Response to minor comment 2 : Correction included. Thank you.

Minor comment 3: Line 23: "they find" and not "they finds"

Response to minor comment 3: Correction included. Thank you.

Minor comment 4: Line 77: the power numbers at exponent for the units of flash rates

Response to minor comment 4: Correction included. Thank you.

Minor comment 5: Line 83: LRMTS

Response to minor comment 5: Correction included. Thank you.

Minor comment 6: Line 104: Write “If the ONI value is above (below) +0.5° (-0.5°) C…”
Response to minor comment 6: Correction included. Thank you.

Minor comment 7: Line 137: Is it possible to talk about three hotspots? That in the southern part of Indian Peninsula is not very visible and the LFR does not reach high values there. It was not clear in the initial maps with a better color resolution (figure 1 of the previous version), it seems there is an effect of amplifying with the new color scale.

Response to minor comment 7: Ahmad and Ghosh (2017) reported that lightning activity is higher over the North-Eastern part and southern part of India during the pre-monsoon season than in other regions of India. They also observed that the maxima of lightning during post-monsoon is also lying over India's southern and eastern areas. Similarly, we are getting higher LFR over NEI, NNWI and SPI. We have enhanced the resolution of the colour scale of figure 1 in this revised version and now higher LFD is better visible over SPI. Please see the revised figure 1 in the manuscript. Thank you.

Minor comment 8: Line 141: The comment is about the values of LFR that are low during the pre-monsoon, therefore the figure for reference is Figure 1 that displays directly the LFR values. Figure 2 displays the anomaly that is a comparison with other phases of ENSO. Even if the anomaly is negative (positive) it does not mean the LFR is low (large).
Response to minor comment 8: Correction included. Thank you.

Minor comment 9: Line 142: Since the anomaly is the comparison between the different ENSO phases for a given season, a negative anomaly in a region for one phase implies a positive anomaly for another phase. Therefore, why to say “however” at the beginning of the sentence since it is an evidence?
Response to minor comment 9: Correction included, text modified. Thank you.

Minor comment 10: Lines 142-144: the sentence needs to be referred to the figure 3 and to say at which region it is applied.
Response to minor comment 10: Correction included. Thank you.

Minor comment 11: Line 189: “analyzing”

Response to minor comment 11: Correction included. Thank you.

Reference

Abhilash, S., Mohankumar, K., & Das, S. (2008). Simulation of microphysical structure associated with tropical cloud clusters using mesoscale model and comparison with TRMM observations. International Journal of Remote Sensing, 29(8), 2411-2432.

Ahmad, A., & Ghosh, M. (2017). Variability of lightning activity over India on ENSO time scales. Advances in Space Research, 60(11), 2379-2388.

Kamra, A. K., & Athira, U. N. (2016). Evolution of the impacts of the 2009–10 El Niño and the 2010–11 La Niña on flash rate in wet and dry environments in the Himalayan range. Atmospheric Research, 182, 189-199.

Patade, S., Prabha, T. V., Axisa, D., Gayatri, K., & Heymsfield, A. (2015). Particle size distribution properties in mixed-phase monsoon clouds from in situ measurements during CAIPEEX. Journal of Geophysical Research: Atmospheres, 120(19), 10-418.

Saha, U., Siingh, D., Midya, S. K., Singh, R. P., Singh, A. K., & Kumar, S. (2017). Spatio-temporal variability of lightning and convective activity over South/South-East Asia with an emphasis during El Niño and La Niña. *Atmospheric Research*, *197*, 150-166.