Response to Reviewer # 2's Comments

General Comment *This paper presents the temporal and spatial distribution of convective available potential energy (CAPE) estimated using INSAT-3D measurements. Initially, these CAPE estimates are compared with that estimated using ERA-Interim reanalysis and the radiosonde measurements obtained from 20 stations that are distributed across India. Statistical analysis has been made to get confidence on the estimated CAPE values. Finally, the diurnal and seasonal variability in the CAPE is also presented at different geographical locations.*
In general, paper is well written and contains significant original contribution. Authors have fully taken advantage of the high spatial and temporal measurements available from INSAT-3D to investigate the diurnal and season variability of CAPE. However, there are few mistakes and sometimes interpretation is missing at some instances without proper literature survey which demands careful editing or re-writing the sentences. Below are the some of the issues which authors need to take care before rendering judgment on the manuscript. Authors are strongly encouraged to revise and re-submit this manuscript.

Response **We are indebted to the reviewer for his valuable and thoughtful comments on the manuscript. We greatly appreciate the reviewer's time and efforts for evaluating the manuscript. We went through all the referee comments and suggestions and implemented the same in the revised manuscript. Point-to-point clarifications for referee's comments and how we have addressed each recommendation is given below.**

Comment 1 *There are few studies where global measurements of CAPE are available using GPS RO observations (Santhi et al., 2014). Since no observations are there to validate the CAPE at high spatial resolution, small analysis can be made how INSAT-3D estimated CAPE match with GPS RO measured CAPE, particularly over the ocean. Qualitative comparison can also be made.*

Response **The GPS RO measurements are very sparse for a particular location and hence are statistically insignificant to compare GPS-RO CAPE with INSAT-3D CAPE. For instance, Santhi et al. (2014) observed a total number of 6 occultations in a month over $2^o \times 2^o$ grid around Gadanki, India. Among these occultation's, only 2 and 4 occultations reached below 0.5 km and 1 km respectively above the surface. When we looked into the number of occultation during the present study period over a particular station ($0.25^o \times 0.25^o$ grid), the total number of occultations are less than 40, which may not be statistically significant. Hence, the reviewer is requested to consider author's proposal for not including the GPS-RO measurements in the revised manuscript.**

Comment 2 *To the best of my knowledge, INSAT-3D data will not be available during the cloudy times. Since there are two monsoon seasons (SW and NE monsoon) over Indian region, huge data gaps are expected during these two seasons. While*

making composite analysis at both spatial and temporal scales, results are expected to be biased. How the authors have taken care this issue need to be discussed.

Response **We agree with the reviewer. However, for the present analysis we have taken only cloud free conditions. The confidence level for the identification of the cloud free region is based on the cloud flag which is set to zero (CLD_FLG=0).**

The total number of data for the 20 stations considered in the study during different seasons is provided in Table 1. Since the INSAT-3D data are available for every one hour, the data gaps are not huge during both the monsoon seasons.

The relative sentences and Table are added in the revised manuscript.

Table 1: The total number of data available in 20 stations during different seasons for the period from April 2014 to March 2017.

Station	**Latitude**	**Longitude**	**Total Number of Data**			
			Winter	**Pre-monsoon**	**Monsoon**	**Post-monsoon**
Agarthala (AGR)	23.88	91.25	3614	3272	2615	2613
Ahmedabad (AHB)	23.06	72.63	3808	4034	3686	2891
Amini Divi (AMD)	11.12	72.73	3985	3776	3327	2362
Bhuvaneswar (BHU)	20.25	85.83	3701	3450	2389	2488
Chennai (CHE)	13.00	80.18	3816	3712	2956	1985
Cochin (COC)	9.95	76.26	3867	3072	2905	1758
Delhi (DEL)	28.58	77.20	2910	3316	3845	2894
Dibrugarh (DIB)	27.48	95.01	3287	2260	2536	2595
Gorakhpur (GRK)	26.75	83.36	2871	3383	2769	2833
Guwahati (GUW)	26.10	91.58	3610	3058	2956	2796
Hyderabad (HYD)	17.45	78.46	2550	394	327	1045
Karaikal (KAR)	10.91	79.83	3660	3458	3632	1846
Kolkata (KOL)	22.65	88.45	3488	2924	2500	2677
Machilipatnam (MAP)	16.20	81.15	4001	3706	2564	2322

Mangalore (MAN)	12.95	74.83	4063	3542	2705	2232
Minicoy (MIN)	8.30	73.15	3882	3346	3320	2040
Mumbai (MUM)	19.11	72.85	4294	4321	3405	2756
Port Blair (PB)	11.66	92.71	3676	3458	2381	2178
Trivandrum (TVM)	8.48	76.95	3675	3116	3608	1805
Visakhapatnam (VSP)	17.70	83.30	3972	3747	2632	2415

Comment 3 *It is mentioned (Line 101) that 'They observed that the INSAT-3D measurements compare better with GPS sonde observations at middle levels (from 900 hPa to 500 hPa).'. In this case how it is going to affect the estimates of CAPE need to be discussed. Further, how large bias observed in water vapor measurements from INSAT-3D is going to affect the CAPE estimates need to be discussed in detail.*

Response **CAPE is associated with the changes in the temperature and moisture in the troposphere. However, the changes in CAPE are more related to the moisture present in the boundary layer. Zhang (2002) showed that the net changes in the CAPE come from the thermodynamic changes in the boundary layer. They also showed that the changes in CAPE due to the changes in the temperature and moisture in the free troposphere is about 10% or less when compared to changes in temperature and moisture in the boundary layer. Hence, the changes in the INSAT-3D measurements at the lower levels affect much the changes in the CAPE compared to the changes in the middle levels.**

The error in estimating the CAPE is determined by applying the standard error propagation formula (Bevington and Robinson, 1992). The error in the CAPE calculation depends on the temperature and water vapour retrievals. In this study, an error of 5% in the measured relative humidity and temperature corresponds to an error of 8% in the calculated CAPE from the INSAT-3D measurements.

Comment 4 *Do authors have any explanation why there is a consistent positive (negative) bias (most of the cases) in CAPE values measured by INSAT-3D (ERA-Interim)?*

Response **The exact reason is very difficult to be pointed out. However, the reanalysis in general is an assimilated output with prior assumptions. The meteorological parameters of the reanalysis are always underestimated with respect to the observations. For example, Ratnam et al. (2013) have shown the comparison of humidity obtained from SAPHIR–A megha tropiques payload with respect to all reanalysis over the tropics. The humidity was underestimated in reanalysis. This may be the reason for the**

negative bias in the reanalysis. Radiosonde and INSAT-3D being both observations shows a positive bias.

Comment 5 *Do authors have any explanation why no variation is seen for large spatial gird in Fig.6 during pre-monsoon?*

Response **In India, the pre-monsoon season is most favourable for the development of thunderstorms over land regions. The surrounding oceanic regions have frequent development of depressions and these depressions sustained over oceanic region for few days. This results in higher values of CAPE over a large spatial extent for few days. This is the reason why no variation in CAPE is observed over large spatial grid during pre-monsoon season.**

Comment 6 *Introduction is too long without focus. It can be cut to 50% while retaining only relevant information. Diurnal and high spatial resolution studies only need to be highlighted.*

Response **As per the referee's suggestion, the introduction section has been modified in the revised manuscript.**

Minor Comments

Comment 1 *Line 142: It is mentioned that radiosonde data has been taken from University of Wyoming website. Note that this is not the quality checked data. Instead, it will be better to use data from IGRA2.*

Response **We appreciate the referee for his suggestion.**

The analysis is performed with IGRA2 dataset for the 20 stations considered in the study. As an example, the scatter plot between INSAT-CAPE and IGRA2-CAPE is shown in fig. 1. Even in the case of IGRA2 data also, the INSAT derived CAPE shows good correlation with a correlation coefficient of 0.72.

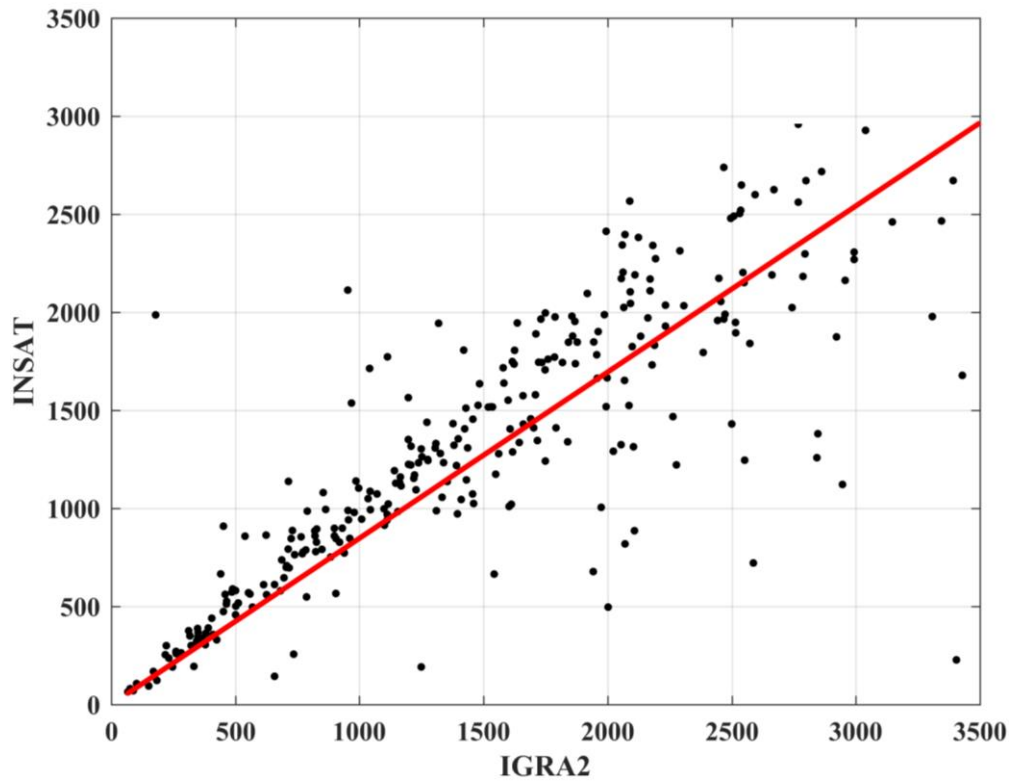

Fig. 1: Scatter plot between IGRA2 derived CAPE (J kg^{-1}) and INSAT derived CAPE (J kg^{-1}) for Chennai during April 2014 to March 2017.

Similarly, the correlation coefficient for CAPE derived from IGRA2 dataset and INSAT-3D data is provided for the reviewer in table 2. The INSAT-3D derived CAPE shows better correlation for most of the stations considered in the study. This shows the consistency of the INSAT-3D derived CAPE over IGRA2 dataset.

Table.2: ***Correlation coefficient in the comparison of INSAT-3D CAPE with IGRA2 and Wyoming derived CAPE for 20 stations in India for the period from April 2014 to March 2017.***

Station	***IGRA2***	***Radiosonde***
AGR	0.61	0.62
AHB	0.56	0.38
AMD	0.48	0.46
BHU	0.59	0.62
CHE	0.72	0.84

COC	0.50	0.81
DEL	0.65	0.31
DIB	0.72	0.44
GRK	0.64	0.46
GUW	0.72	0.59
HYD	0.51	0.59
KAR	0.73	0.56
KOL	0.57	0.55
MAP	0.57	0.62
MAN	0.42	0.68
MIN	0.56	0.64
MUM	0.43	0.64
PB	0.40	0.48
TVM	0.71	0.52
VSP	0.55	0.68

It can be observed from the above table that the correlation coefficient in the comparison of INSAT-3D CAPE with IGRA2 and radiosonde CAPE are almost similar for most of the stations. Hence, the inclusion of IGRA2 data in the manuscript is not going to affect the results of the study. So, the reviewer is requested to consider the use of Wyoming university data in the manuscript.

Comment 2 *Line 155: It was mentioned that the resolution of the data utilized is 0.75^o_0.75^o from ERA-Interim and 0.25^{o}X0.25^o from INSAT-3D. How this different spatial resolutions grids are taken care while comparing the CAPE estimates.*

Response **The authors apologize for the typographical error. For the present study, the authors make use of the ERA-Interim data at 0.25^o×0.25^o spatial resolution.**
The relative sentence is modified in the manuscript.

Comment 3 *Line 282: It is mentioned that 'The estimated CAPE is divided into four categories: weak instability (<500 J kg-1), moderate instability (501-1500 J kg-1), strong instability (1501-3000 J kg-1), and extreme instability (>3000 J kg-1).' Do you have any scientific justification to choose these thresholds? You may provide suitable reference.*

Response **These CAPE ranges are considered arbitrarily.**

Comment 4 *Line 338: It is mentioned that 'These regions are: the Arabian Sea (AS; 8-20oN, 65-72oE), Bay of Bengal (BoB; 8-20oN, 80-90oE), South Peninsular India (SP; 8-20oN, 72-80oE), Central India (CI; 20-25oN, 73-82oE), North India (NI; 25-35oN, 73-80oE), and Northeast India (NE; 24-29o34o N, 90-96oE).' Is there any scientific justification to choose these latitude longitude grids? You may provide suitable reference.*

Response **To understand the diurnal variation of CAPE over different parts of India, the study region is divided (latitude-wise for uniformity) into six sub-regions; Arabian Sea (AS; 8-20°N, 65-72°E), Bay of Bengal (BoB; 8-20°N, 80-90°E), South Peninsular India (SP; 8-20°N, 72-80°E), Central India (CI; 20-25°N, 73-82°E), North India (NI; 25-35°N, 73-80°E), and Northeast India (NE; 24-29°N, 90-96°E) as given in Raut et al. (2009).**
The relative reference is added in the text in the revised manuscript.

Comment 5 *Line 411: It is mentioned that several interesting features are noticed. 'The weak instability is predominant during the winter season, the moderate instability is higher during the post-monsoon, the strong instability is more during the monsoon period and the extreme instability is higher during the pre-monsoon months.' Note that these things are well known to the scientific community.*

Response **The above sentence is re-written as "The spatial and temporal distribution of CAPE reveals that the weak instability is predominant during winter season, moderate instability is higher during post-monsoon, strong instability is more during monsoon period and extreme instability is higher during pre-monsoon months".**

Comment 6 *It seems INSAT-3DR is being launched as a follow up of INSAT-3D. Did you tested how CAPE behaves between these two instruments?*

Response **INSAT-3DR is a redundancy payload for INSAT-3D and hence we have not attempted to calculate CAPE with INSAT-3DR data. In future, this will be our follow-up study.**

Comment 7 *Figure 1 caption: It is better to shift the latitude and longitude along with the name of the station to the running text rather keeping lengthy figure caption.*

Response **Referee's suggestion is implemented in the manuscript.**

Comment 8 *Figure 8: There are white patches over Tibetan high and also over the central India in few panels. Hope the reasons for the data gaps at these two places is not the same?*

Response **The white patches in the Tibetan high are due to the non-availability of data due to topography. Over Central India, it is mostly due to non-availability of data.**

Refrences:

Venkat Ratnam, M., Basha, G., Krishna Murthy, B. V., & Jayaraman, A. (2013). Relative humidity distribution from SAPHIR experiment on board Megha-Tropiques satellite mission: Comparison with global radiosonde and other satellite and reanalysis datasets, *Journal of Geophysical Research Atmospheres*, 18, 1–9, doi:10.1002/jgrd.50699.

Raut, B. A., Karekar, R. N., & Puranik, D. M. (2009). Spatial distribution and diurnal variation of cumuliform clouds during Indian Summer Monsoon. *Journal of Geophysical Research Atmospheres*, *114*(11), 1–12. https://doi.org/10.1029/2008JD011153

Santhi, Y. D., Ratnam, M. V., Dhaka, S. K., & Rao, S. V. (2014). Global morphology of convection indices observed using COSMIC GPS RO satellite measurements. *Atmospheric Research*, *137*, 205–215. https://doi.org/10.1016/j.atmosres.2013.10.002

Zhang, G. J. (2002). Convective quasi-equilibrium in midlatitude continental environment and its effect on convective parameterization. *Journal of Geophysical Research Atmospheres*, *107*(14), 1–16. https://doi.org/10.1029/2001JD001005