Observation and comparisons of variation in instability indices in different weather regions of India through radiosonde data

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Abstract **:** This study is intended to explore the observations and comparisons of variation in instability parameters (Showalter index, Lifted index, K index and Total Totals index) in different weather regions using Radiosonde data over India. The duration of IGRA data is 20 years from Jan 1996 to Dec 2016 for the present study and we are planning to extend this data up to December 2019 for further studies. Six different regions (New Delhi, Mumbai, Kolkata, Hyderabad, Bangalore and Chennai) have been selected for the study. Profiles of the above mentioned parameters for the six regions have been plotted for the duration. We have observed maximum and minimum values of the parameters for six regions and have been tabulated. For the six regions it observed that SI depicts positive maximum predicting no thunderstorms and negative values compared to critical values revealing possibility of occurence of more thunderstorms. While comparing the six regions we observe , Mumbai, is more prone to severe weather. Similar to SI, it is observed that the LI values show negative for all the regions indicating occurence of more thunderstorms. LI also predicts that the region Mumbai, is influenced to severe weather. The K index values lie in the range 45 to 50 corresponding to high instability are increasing as we move towards north which indicated increase in thunderstorm probability.

Index Terms - Showalter index, Lifted index, K index and Total Totals index.

I. Introduction

Instability in the atmospheric is an event occurring in the Earth's atmosphere accordingly with the weather subjecting to a high degree of variability in the radiation with time. In general atmospheric stability indices are used for better perceptive of monsoon dynamics and its variability. The Indian Summer Monsoon is one of the most important tropical circulation systems over Indian subcontinent. During the monsoon season, the troposphere in tropical region has profound impacts on temperature, relative humidity and stability indices. Hence it is necessary to consider these parameters for better perceptive of monsoon dynamics and its variability. These indices, as well as atmospheric instability itself, involve temperature changes through the troposphere with height, or lapse rate. Effects of atmospheric instability in moist atmospheres include thunderstorm development. Many investigations have made an attempt to explain seasonal changes in tropical areas using MST Radar at various locations [Basley et al. 1988; Rao et al. 1991; Gage et al 1991; Jagannadha Rao et al. 2002; Jagannadha Rao et al. 2003]. The condition of the atmosphere to be stable depends partially on the moisture content. In a very dry troposphere the temperature decrease with height less than 9.8C per kilometre ascent indicates stability while greater changes indicate instability. This lapse rate is known as the dry adiabatic lapse rate [Murry L. Salby]. In a completely moist troposphere, a temperature decrease with height less than 6C per kilometre ascent indicates stability while greater changes indicate instability. In the range between 6C and 9.8C temperature decrease per kilometre with altitude ascent, the term conditionally unstable is used. The rationale of the present study is to look at the nature of troposphere that progress over six regions related to the variation in the above mentioned for the years 1996 to 2016.

II. Data and Methodology

High resolution and high accuracy radiosonde data of six different regions (New Delhi, Mumbai, Kolkata, Hyderabad, Bangalore and Chennai) in India have been selected in the present study. Indian Space Research Organisation (ISRO) systematically launching high resolution radiosondes reaching to high altitude from a few Indian stations during middle atmospheric program. The parameters (Showalter index, Lifted index, K index and Total Totals index) data for the duration January 1996 to December 2016 for the above mentioned six different regions have been used for the present study. Every day there were two flights, viz 00 UTC and 12 UTC, have been observed for the complete period. While computing the parameters the efficacy of the present data obtained is compared with the data studied by Santhi et al. (2014). The deviations found were mostly centered close to zero concluding to get desired results from the data. The sub section presents variation of all instability parameters to investigate instability in different regions.

III. Results and Discussion

3.1) Long term variation of Showalter index(SI)

This index proposed by Showalter (1953) to study and present a general view of a whole condition of thermodynamic instability. Mathematically it is given by SI = T500 - T', where T' is the temperature of air parcel lifted from 850 mb to 500 mb and T500 is the environmental temperature. The below table1 having range of vlues for the Showalter Index which explains the behaviour of the atmospheric stability, Showalter (1953). The Showalter index gives evidence of the potential instability and in addition present an approximate situation of the latent instability. The negative value interprets the existence of positive buoyant energy above the level of free convection and the possibility of subsequent free convection. Showalter observed showers and possible thunderstorm activity when this indexvalues are less than +3 activity and for the values less than -3 were associated with severe convective activity. The Showalter index, as will be shown right through segment has been used as one of the regularly functional consequent for the most part of the stability indices. In general the cumulonimbus cloud structures do not usually appear while the value of SI is larger than +4 as mentioned by the Glossary of Meteorology; Huschke, R. E., Ed., 1959., but predicts the possibility of thunderstorms and showers with the decrease in SI value from +4. For the values of SI less than +2 there will be a threshold for severe thunderstorms for the eastern two-thirds of the United States during 1966-1969 as predicted David and Smith (1971) and these values were also implemented as a parameter for forecasting thunderstorms Gulf Stream area by Ellrod and Field (1984). The SI index put forward to be a comparatively good indicator of rain conditions stated by R. A. Peppier while making another study of static stability indices and its associated thermodynamic parameters and M.V. Ratnam et al., put side by side in fine concurrence with MWR observations over Gadanki, India. While making study in forecasting of thunderstorms in pre-monsoon season over northwest India by Dhawan et al., (2008), observed some fraction of probability of occurrence of thunderstorms in relation with the range of SI values for cause of thunderstorm events over Delhi which renders no occurence of thunderstorm for values above +3 but there were indication for occurence of thunderstorm for values less than +2.

Table1: Threshold values of Showalter Index	
Values	Condition of Atmosphere
Greater than 0	Stable, but weak with convection
between 0 and -3	Moderately unstable
between -4 and -6	Very Unstable
less than -6	Extremely Unstable

The significant values of Showalter Index specify increasing instability with decreasing value for predicting severe weather. For six regions the showalter index is observed and tabulated in table2. All the above six regions show positive maximum values indicating no thunderstorms and all the regions show negative values less than critical values which indicates occurence of more thunderstorms. While comparing negative values the regions west coast area, Mumbai, is more prone to severe weather than other sea coastal areas like Chennai, Kolkata. It is also observed that the regions covered with land show more negative values indicating happening of more thunderstorms. According Saha et al., in Kolkata there is a decrease in the occurrences of severe thunderstorms, suppression of the severity of thunderstorms and also observed decreasing trend for the pre-monsoon rainfall and an increasing trend in the monsoon rainfall. The observations of Showalter index for the above mentioned six regions for the duration January 1996 to December 2016 have been plotted as shown in figure 1.

Table2: Observations of Showalter Index		
Regions	Maximum	Minimum
New Delhi	18.2069	-6.4000
Mumbai	12.2800	-7.3333
Kolkata	15.3636	-3.9118
Hyderabad	14	-5.6667
Bangalore	13.2500	-8
Chennai	11	-3.4167

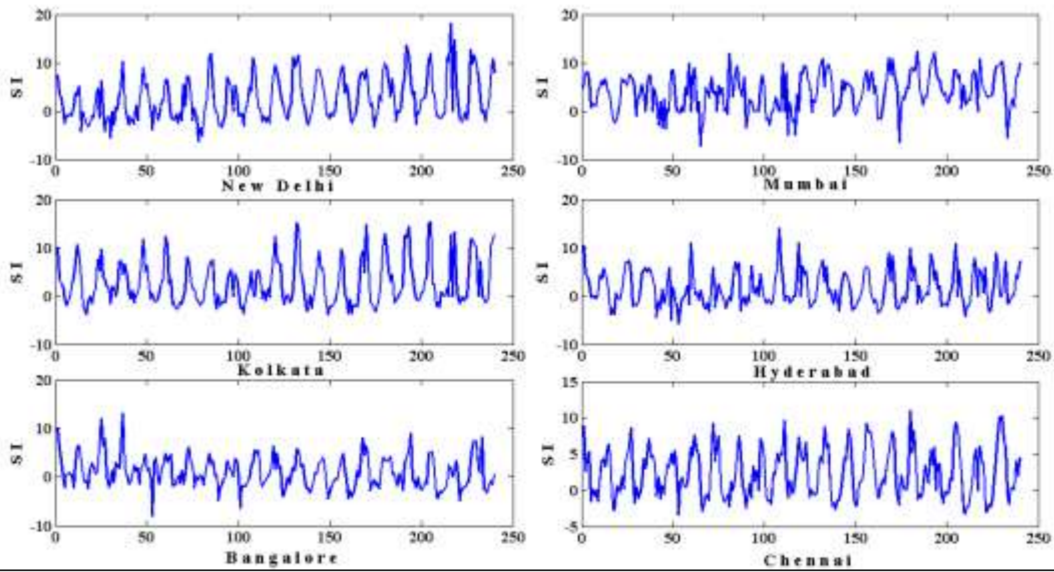

Fig 1: Observation profiles of Showalter Index of six stations for the duration Jan 1996 to Dec 2016

3.2) <u>Long term variation of Lifted index(LI)</u>

Lifted Index proposed by Galway (1956) is one of the atmospheric stability indices to assess the instability in the atmosphere and thunderstorms. Mathematically it is given by LI = Te (p) – Tp (p) where Te and Tp are environmental and parcel temperature respectively at 500 mb. The Lifted index was proposed to predict the latent instability to give support in the forecasting of severe local storms. This index has been used frequently to analyse and predict severe weather patterns. The Lifted Index is analogous to the Showlter index with the exception that the parcel is lifted from the surface to 500 mb level. This index is used to find the deep convection, stable atmosphere could be observed with positive values of this index where as the negative values gives the sign of potential for deep convection in which the atmosphere is unstable to a large extent and severe convection takes place for the values less than -4. More the values of this index more the stability of the atmosphere while the values less than zero and negative sign gives towards instability in the atmosphere. This index also used to find the instability in the atmosphere and thunderstorms. Y.D. Santhi et al., observed and put in the picture about the LI and brought into light more instability over Gadanki, India, using GPS RO. Ratnam et al., drive up with additional details on the diurnal variation of the convective indices acquired by means of high temporal resolution radiosonde observations over Gadanki, India. At lower levels the Indian monsoon region shows signs of convectively unstable consequently becomes unstable in monsoon seasons. Pattanaik D.R., stated that moisture is maximum over Head of Bay of Bengal (HBOB) and decreases towards Arabian Sea. He also observed interannual variability in precipitable water. D Jagadheesh et al., expressed that the negative values of lifted index indicates instability in the atmosphere but this index could not give any support to rainfall events occuring over 2◦×2◦ latitude–longitude spatial scale but produced a design which gives evidence in the possibility of heavy rainfalls with the decrease in refractivity based lifted index thereby supporting the convective events in the atmosphere. Chakraborty et al., also noted the variation in lifted index and made a note with increase in lifted index from 3 K to 6 K over Kolkata and Ahmadabad while analysing for 16 years. Saha et al., also expressed the same results. Even though no specific LI threshold values were established but many researchers have predicted and presented the approximate bounded values which is shown in table 3. The below table 3 having range of values for the Lifted Index which explains the behaviour of the atmospheric stability.

Table3: Predicted values of Lifted Index		
Values	Condition of Atmosphere	Observed by
Less than 0	Predictive form to be associated with severe thunderstorms and tornadoes	David and Smith (1971)
-2	an upper bound for severe storm formation	Miller forecasting scheme (Miller, 1967, 1972, 1975)
less than +2	Occurrence of convective activity, thunderstorm forecasting	Ellrod and Field (1984)
-4 and less	Potential for severe convection, Extremely Unstable	

The significant values of Lifted Index specify increasing instability with decreasing value for predicting severe weather and as well as latent instability. For six regions the LI is observed and tabulated in table4. All the above six regions show positive maximum values indicating no convective activiy and all the regions show negative values less than threshold values which indicates occurence of convective activity. While comparing negative values the regions west coast area, Mumbai, is more prone to severe weather than other sea coastal areas like Chennai, Kolkata. It is also observed that the regions covered with land like Hyderabad show more negative value indicating happening of more convection and unstable. According Saha et al., in Mumbai there is increase in instability and existence of a moist and conditionally unstable environment. The observations of lifted index for the above mentioned six regions for the duration January 1996 to December 2016 have been plotted as shown in figure 2. The regional distribution of LI show variation in the range of -16 to 17 with the lowest value of -16 observed at Hyderabad and highest value 16.7692 observed at New Delhi which is inland region. The other inland regions are Hyderabad and Bangalore. Kolkata and Chennai were mostly affected with the variation of atmosphere over Bay of bengal where as Mumbai is affected with Arabian sea. There were large variations from maximum to minimum over New Delhi and Kolkata for a year. The inland region Hyderabad show small variations from maximum to minimum for a year. The regions Kolkata, Bangalore and Chennai show approximately two convective activities for a year as these regions were prone to south-west monsoon as well as north-east monsoon owing to its distinctive locations in India.

Table4: Observations of Lifted Index		
Regions	Maximum	Minimum
New Delhi	16.7692	-9.5000
Mumbai	16	-11
Kolkata	16.7105	-10.8333
Hyderabad	13.5000	-16
Bangalore	11.6667	-8.5000
Chennai	6.7000	-8.8718

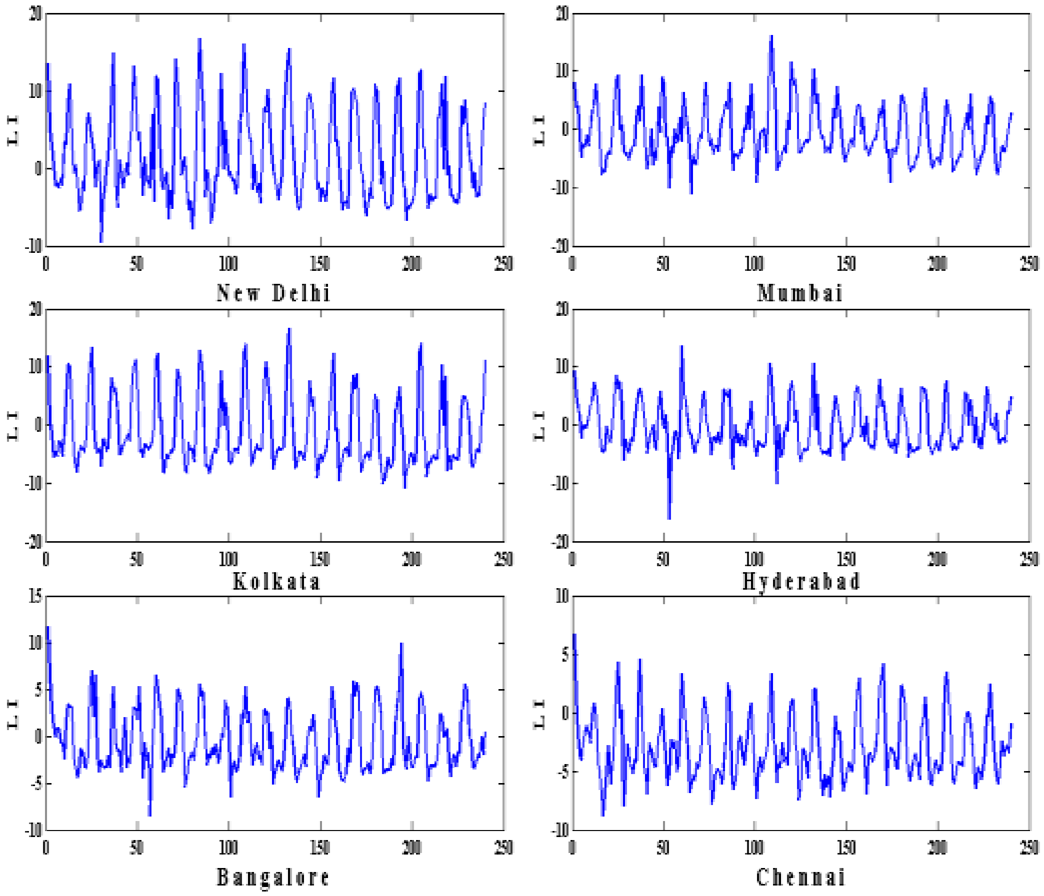

Fig 2: Observation profiles of Lifted Index of six stations for the duration Jan 1996 to Dec 2016

3.3) <u>Long term variation of K index(KI)</u>

It is another atmospheric stability index developed by George (1960) particularly useful in detecting the possibility for convection and predicting the occurrence of thunderstorm. Mathematically it is expressed as KI = (T850 – T500) + T D850 – (T700 – TD700) where T850 is the temperature at 850 mb, T500 is the temperature at 500 mb, T700 is the temperature at 700 mb, T D850 is the dewpoint temperature at 850 mb and TD700 is the dewpoint temperature at 700 mb. This index is also useful to predict moisture content in the atmosphere with mean values of relative humidity at 800mb to 500 mb level. This index have been useful to predict happening of precipitation quantity and unperturbed thunderstorm occurrence with severe weather predictions.

Table 5: Threshold values of K Index

Values	Condition of Atmosphere
$K \geq +20$	indicate an increasing frequency in air mass thunderstorm activity.
between 15 and 20	indicates less likelihood of occurrence of thunderstorm.
Greater than 30	Observe Mesoscale Convective Complexes
Greater than 40	More chances of occurrence of thunderstorm.

The threshold values of K Index specify increasing instability with increasing value for predicting severe weather and atmospheric instability. For six regions the K index is observed and tabulated in table 6. All the above six regions show positive maximum values indicating more chances of thunderstorms occurrences and all the regions show negative values less than critical values which indicates no thunderstorms. While comparing positive values the regions west coast area, Mumbai, is more prone to severe weather than other sea coastal areas like Chennai, Kolkata. It is also observed that the regions covered with land show more positive values indicating happening of more thunderstorms. From tabulated values we observe that the K index values are increasing as we move towards north which indicated increase in thunderstorm probability. When KI values lie in the range 35 to 40, Jayakrishnan and Babu observed the probability for maximum percentage for the formation of convection over Thiruvantapuram and Cochin. The observations of K index for the above mentioned six regions for the duration January 1996 to December 2016 have been plotted as shown in figure 3. David and Smith (1971) revealed that this index to be a moderately poor indicator of severe thunderstorm but observed good indicator for predicting diverse temperament of rainfall and considerable convective activity.

Table 6: Observations of K Index		
Regions	Maximum	Minimum
New Delhi	42.4000	-24.1552
Mumbai	44	-12.5000
Kolkata	40.2692	-11.7500
Hyderabad	41.1136	-0.4286
Bangalore	41.9649	-4
Chennai	38.5000	-2.7692

The K index (Fig. 3) values were plotted which is most associated with the finest predictor for the common convection and the probability of precipitation occurrence in particular with noon time signifying the unstable atmosphere conditions.

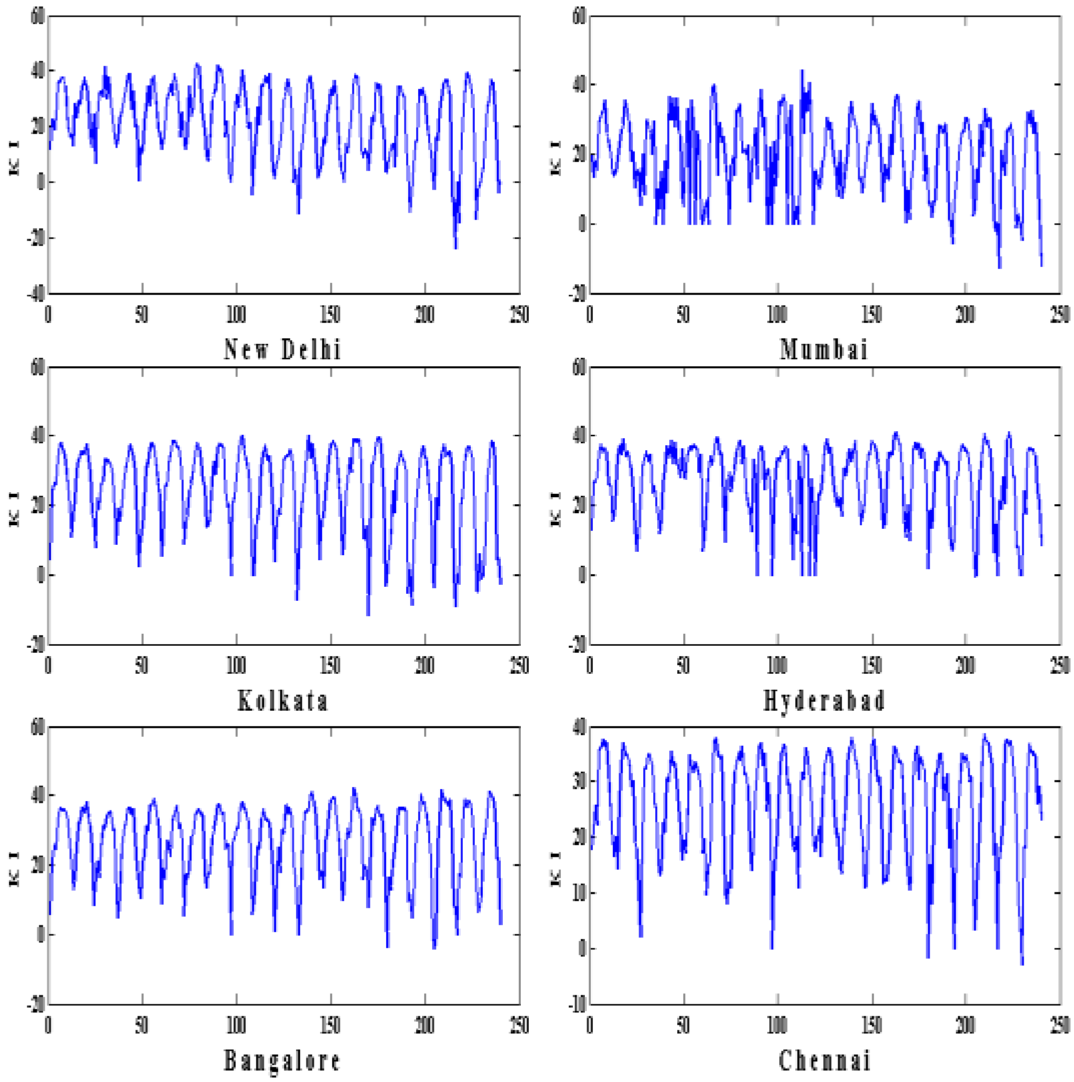

Fig 3: Observation profiles of K Index of six stations for the duration Jan 1996 to Dec 2016

3.4) Long term variation of Total Totals Index (TTI)

A further additional stability index which is evaluated simply by the sum of cross total index and vertical total index. Therefore total totals index is TTI = CT + VT = T D850 –+ T 850 – 2(T 500). This index is an improvement in the stability indices and is variably easy to compute not including via tephigram. Cross total index is computed with the difference between dewpoint temperature at 850 mb (T D850) and parcel temperature at 500 mb (T 500) and the expression is CT = T D850 – T 500. Similar to cross total index, Vertical total index is computed with the difference between parcel temperature at 850 mb (T 850) and 500 mb (T 500) or it can be understood that vertical total index is just the lapse rate between 850 mb and 500 mb of the parcel temperature and the expression is given as VT = T 850 – T 500.

By combining CT and VT we get total totals index and mathematically it is given as

TTI = CT + VT = T D850 –+ T 850 – 2(T 500)

During calculation of this index, temperature at dewpoint and the temperature of the parcel were taken into consideration. Since temperature at dewpoint is included hence this index also express moisture distribution along vertical. For this reason it is favourable for identifying thunderstorm activity. Critical Values of TTI ranges from 20 to 55, as tabulated in the table 7, indicating stable atmosphere to the high instability predicting probability of severe thunderstorm. Even though the threshold values taken into consideration which convey the instability at a particular location but vary slightly by geographic location and were found to be the boundaries which relates storm intensity at severe local storms.

Table 7: Threshold values of Total Totals Index	
Values	Condition of Atmosphere
TTI < +20	Stable Atmosphere
Between 20 and 25	Low instability
Between 26 and 35	Large unstable during pre-monsoon
Between 45 and 55	High instability.

The below table 8 describes the range of variations of TTI over six regions for the duration January1996 to December 2016. It is observed that the Hyderabad region shows maximum as compared to other predicting more unstable and having more probability of severe thunderstorm. This region also show least value forecasting more stable during non monsoon period. For the above mentioned duration and six regions, profiles of TTI is plotted as shown below in figure 4. TTI signifies the possibility for thunderstorm occurrences in addition to it this index also illustrate minimum values at some point in winter and medium values for the period during other seasons. However, TTI shows largest values during premonsoon corresponding to high instability with ranges between 45 and 55.

Table 8: Observations of Total Totals Index		
Regions	Maximum	Minimum
New Delhi	52.8667	26.6296
Mumbai	56.3333	18
Kolkata	52.0556	19.2414
Hyderabad	60	23.4000
Bangalore	52.3750	28.5000
Chennai	49.9800	27.8947

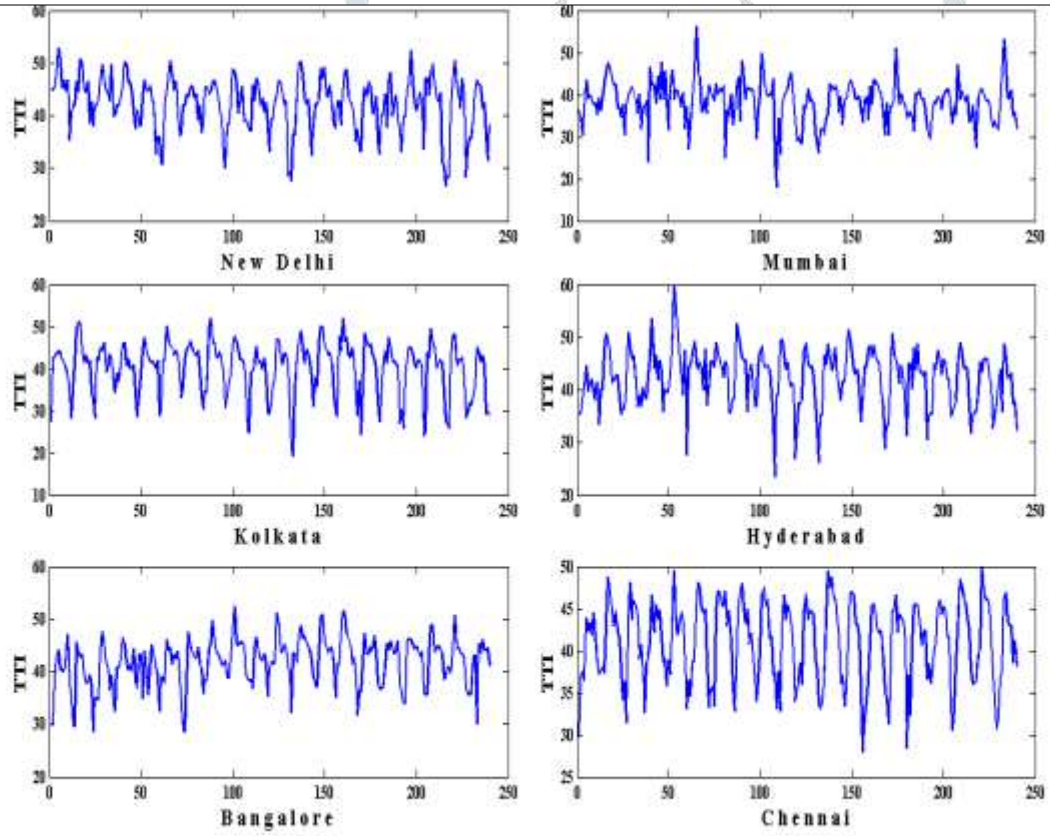

Fig 4: Observation profiles of Total Totals Index of six stations for the duration Jan 1996 to Dec 2016

While covering all it can be concluded that present study provides a thorough geometric point of view regarding the atmospheric instability parameters and their bounded values in various regions. Variations are further enumerated to set the point of reference for possible growth of convective instabilities over various areas covering inland and coastal regions which can be used for forecasting relevance. Also a light has been thrown away on maximum and minimum values of these regions for analysis so as to explain how instability is agitated by mesoscale to synoptic scale events during monsoon at various regions. In the end the long term variation appear like a novel approach to be evident for how atmospheric instability in itself is varying in the last two decade which can be probed in more details in future attempts.

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