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AMPLIATIVE REASONING TO VIEW THE PREVALENCE OF SEVERE THUNDERSTORMS

1. Thunderstorms of pre-monsoon season (March – May) over northeastern part of India, locally known as Nor'wester or Kalbaisakhi, delineate Local Severe Storms (LSS). Nor'westers, when accompanied by hail, tornado and high wind speed, beseems tremendous devastation conducing catastrophe. Initially all the investigations on thunderstorms over India were based on the observations of surface parameters before and immediately after the occurrence of thunderstorm. Though not well defined in earlier days, thunderstorm was first studied in a scale, which is now called meso-scale. Priority was given to thermodynamic parameters especially the wet bulb and wet bulb potential temperature (Normand, 1921). Indian meteorologists (IMD, 1941) could appreciate well before the publication of thunderstorm project report in United States (Byers and Braham Jr., 1949) that not only the discontinuity in temperature and moisture in the vertical plane was a favorable environment for the genesis of thunderstorm but the large-scale flow pattern to advect temperature and moisture was also found to be important. Major contributions to the study of thunderstorms in India between 1940 and 1975 came from Mull and Rao (1948) , Desai and Rao (1954), Ramaswamy (1956) , Das *et al*. (1957), Koteswaram and Srinivasan (1958) , Koteswaram and De (1959), De and Sen (1961), Mull *et al*. (1963).All of the studies used conventional and radar data. CAPE, regarded to be the most important parameter, so far, for the occurrence of severe thunderstorms over Great plains of America, is found to play a neutral role in the genesis of pre-monsoon thunderstorms. The purpose of the present study is to introduce the method of ampliative reasoning, to discern the role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in the genesis of severe thunderstorms of pre-monsoon season over the northeastern part of India.

2. Indian subcontinent is normally barotropic during the period of pre-monsoon season as the horizontal temperature gradient is negligible. Besides the presence of feeble induced low-pressure areas on the surface level, there exists no significant synoptic system, which can be observed from climatological charts. Attention is, therefore, drawn here towards small – scale and lower level features that tend to minimize CINE. Thus, for forecasting the genesis of pre-monsoon thunderstorms over northeastern part of India, it is surmised that minimization of CINE is more relevant than the maximization of CAPE. The comprehension is made legitimate by employing the method of ampliative reasoning.

3. The main purpose of the study is to see whether minimization of CINE or maximization of CAPE is pertinent for the genesis of severe thunderstorms of pre – monsoon season over the northeastern part of India. Since the purpose involves inferences that are not entailed in the available sample of CAPE and CINE of 108 thunderstorms, collected from Regional Meteorological Office, Kolkata, the technique of Ampliative Reasoning is adopted for this study. Ampliative Reasoning declares that, in any ampliative inference one can use all but no more information than available (Klir and Folger, 2000). Ampliative Reasoning is a probabilistic adaptation of a more general principle of reasoning in which the conclusions are not entailed in the given premises. This principle is based on two statements :

(*i*) Knowing ignorance is strength and

(*ii*) Ignoring knowledge is sickness.

When applied within the framework of probability theory, employing Shannon Entropy as the unique measure of information makes this principle operational. At this juncture, among all probability distributions that conform to the evidence, the chosen distribution needs to be ensured to have maximum uncertainty (*i.e.*, minimal information).

Thus, attempt is made to estimate probability distribution of different average values of CAPE and CINE. To ensure that all information pertaining to the estimated probability distribution is fully utilized, the probability distributions that conflict with the available evidence are dislodged. Among the remaining probability distribution, the maximum entropy probability distribution is identified. These two steps are accomplished by solving an optimization problem in which the maximum of Shannon Entropy within the domain of relevant probability distributions restricted by some constraints is searched for.

Thus, the problem is to determine a probability distribution, $P = (P_1, P_2, ..., P_{108})$ that maximizes the function;

$$H(P_1, P_2, ..., P_{108}) = -A\sum_{i=1}^{108} P_i \ln P_i \tag{1}$$

The constraints are;

$$(i) \quad P_i > 0 \quad \forall \quad i \in [1,108] \tag{2}$$

$$(ii) \quad \sum_{i=1}^{108} P_i = 1 \tag{3}$$

$$(iii) \quad E(x) = \sum_{i=1}^{108} P_i x_i \tag{4}$$

Where

$H(P_1, P_2, ..., P_{108}) \rightarrow$ Shannon entropy,

$A \rightarrow \log_2 e$

$(P_1, P_2, ..., P_{108}) \rightarrow$ Probability distribution of a variable 'x' that assumes the values x_1, x_2,……………….., x_{108}

Classical Lagrange Multiplier optimization method is employed to solve Eqn. (1).

The Lagrange function is framed as;

$$L = -A\sum_{i=1}^{108} P_i \ln P_i - \alpha\left(\sum_{i=1}^{108} P_i - 1\right) - \beta\left[\sum_{i=1}^{108} P_i x_i - E(x)\right] \tag{5}$$

Where

α and β $\rightarrow$ Lagrange's Multipliers.

Partial differentiation of Eqn. (5) yields;

$$\frac{\partial L}{\partial P_i} = -A \ln P_i - A - \alpha - \beta x_i = 0 \; ; \; i \in [1,108] \tag{6}$$

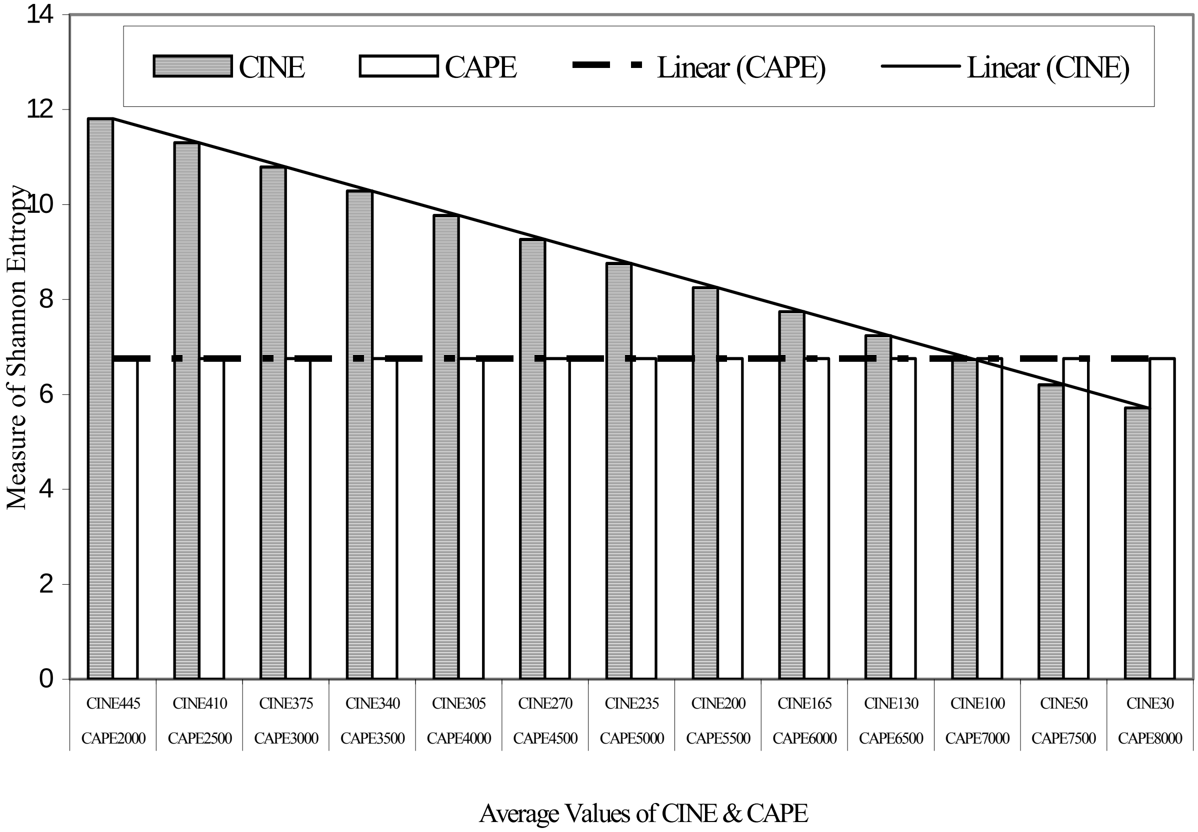

Fig. 1. Change in Shannon Entropy with change in average values of CINE & CAPE in J/kg

$$\frac{\partial L}{\partial \alpha} = -\sum_{i=1}^{108} P_i + 1 = 0 \quad (7)$$

$$\frac{\partial L}{\partial \beta} = -\sum_{i=1}^{108} P_i x_i + E(x) = 0 \quad (8)$$

Equation (6) implies;

$$\left.\begin{aligned} P_i &= (e^{-\frac{A+\alpha}{A}})(e^{-\gamma x_1}) \\ P_2 &= (e^{-\frac{A+\alpha}{A}})(e^{-\gamma x_2}) \\ P_{108} &= (e^{-\frac{A+\alpha}{A}})(e^{-\gamma x_{108}}) \end{aligned}\right| \quad (9)$$

Where $\gamma = \frac{\beta}{A}$

Combining Eqns. (2) and (9), we obtain;

$$P_i = \frac{e^{-\gamma x_i}}{\sum_{k=1}^{108} e^{-\gamma x_k}} \text{ for } i \in [1,108] \quad (10)$$

Thus,

$$E(x) = \frac{\sum_{i=1}^{108} x_i e^{-\lambda x_i}}{\sum_{i=1}^{108} e^{-\gamma x_i}} \quad (11)$$

Multiplying Eqn. (11) by $e^{\gamma E(x)}$, we obtain;

$$\sum_{i=1}^{108} [x_i - E(x)]\ e^{-\gamma [x_i - E(x)]} = 0 \quad (12)$$

TABLE 1

Change in the amount of Shannon Entropy with change in the average values of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in J/kg

Average CINE (J/kg)	Shannon Entropy	Average CAPE (J/kg)	Shannon Entropy
445	11.807160820	2000	6.754887502
410	11.298884960	2500	6.754887504
375	10.790609090	3000	6.754893205
340	10.282333230	3500	6.754898906
305	9.774057360	4000	6.754904607
270	9.265781494	4500	6.754910308
235	8.757505628	5000	6.754916009
200	8.249229762	5500	6.754921710
165	7.740953896	6000	6.754927411
130	7.232678030	6500	6.754933112
100	6.732348931	7000	6.754938813
50	6.200232766	7500	6.754944514
30	5.715797199	8000	6.754950215

Eqn. (12) is solved for γ using Newton – Raphson method. Substitution of γ in Eqn. (10) yields the solution that proffers the maximum entropy probabilities. The computed values are displayed in Table 1.

4. Fig. 1 shows that maximum entropy or maximum uncertainty in the occurrence of pre-monsoon thunderstorms over north-eastern part of India decreases sharply for decrease in the average value of CINE. In other words, decrease in the average value of CINE increases the probability of occurrence of severe thunderstorm during the pre-monsoon season over northeastern part of India. No such change is indicative for the average value of CAPE. This discloses that minimization of CINE is imperative for the genesis of severe thunderstorms of pre-monsoon season over northeastern part of India where as neither maximization nor minimization of CAPE is required for these severe weather hazards. The figure further depicts important information that if CAPE and CINE attain the values of 7000 J/kg and 100 J/kg respectively then the occurrence of severe thunderstorms over the study region is definite.

5. The study leads to conclude that for the genesis of severe thunderstorms of pre-monsoon season over northeastern part of India, minimization of CINE is fundamental whereas neither maximization nor minimization of CAPE is of any significance.

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