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Consequences of pre-monsoon thunderstorm -A fuzzy logic approach

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सार – पश्चिमी बंगाल के गांगेय क्षेत्र (जी. डब्ल्यू. बी.) में घटने वाले विनाशकारी मौसम की घटनाओं के साथ ही साथ मानसून ऋतु से पूर्व के गर्ज भरे तूफान भी महत्वपूर्ण हैं। इस शोध–पत्र का मुख्य उद्देश्य भीषण तूफानों के दौरान कुछ महत्ववूर्ण प्राचलों के परिणामों की जाँच करने के लिए फज़ी लॉजिक की अवधारणा को प्रस्तुत करना है। इन परिणामों से यह ज्ञात होता है कि भीषण तूफ़ानों के समय धरातलीय तापमान में गिरावट के साथ ही साथ सापेक्षिक आर्द्रता और अवदाब में वृद्धि अत्यधिक महत्वपूर्ण घटनाएँ हैं। इन परिणामों से आगे यह पता चलता है कि तापमान में अत्यधिक गिरावट और अवदाब में प्रभावी वृद्धि का होना इस प्रकार के तूफानों की घटनाओं के लिए सबसे आवश्यक सम्मिश्रण है। इन परिणामों से यह भी स्पष्ट होता है कि जब उच्च पवन गति सापेक्षिक आर्द्रता और वायुदाब में तीव्र परिवर्तन के साथ संबंद्ध रहती है तब इस प्रकार की मौसम आपदा के घटने की संभावना और भी अधिक बढ़ जाती है। इस अध्ययन के महत्वपूर्ण परिणामों से यह ज्ञात होता है कि भीषण तूफान की पवन गति का पूर्वानुमान करने के लिए, पूर्व सूचक के रूप में सापेक्षिक आर्द्रता और वायुदाब का उपयोग करते हुए बहुसमाश्रयणों की जाँच आवश्यक है।

ABSTRACT. Pre-monsoon thunderstorms are important as well as devastating weather events occurring over Gangetic West Bengal (GWB). The prime aim of the current paper is to introduce the concept of Fuzzy Logic to view the consequences of some important parameters during the occurrence of severe thunderstorms. The result reveals that fall in surface temperature as well as rise in relative humidity and pressure are the most important consequences during the occurrence of severe thunderstorms. The result further indicates that colossal fall in temperature and massive rise in pressure are the most desirable combination for the occurrence of such storms. The result discloses that when high wind speed is associated with sharp change in relative humidity and air-pressure, the possibility of occurrence of such weather hazards is more. The important finding of the study suggests that, for prediction of the wind speed associated with severe thunderstorms, multiple regressions, using relative humidity and air pressure as predictor, needs to be investigated.

Key words – Fuzzy logic, Belief measure, Focal element, Pre-monsoon thunderstorm, Gangetic West Bengal.

1. Introduction

Severe thunderstorms of pre-monsoon season (March-May) are important and devastating weather event over GWB. It connotes the most intense of meteorological phenomena when accompanied by large hailstones, high wind speed and tornadoes. These high frequency weather hazards are most difficult to forecast as they belong to meso-scale systems. They cause damage to crops and properties on the ground and aviation aloft. Besides being a disastrous phenomena thunderstorms are the only source of soil and atmospheric moisture content, the essential atmospheric parameters on which the cultivation and agriculture of our country depend. Extensive researches have been transacted upon the said weather system in India as well as abroad. Some important contributions are Normand (1938), IMD project (1941), Mull and Rao (1948), Desai and Rao (1954), Koteswaram and Srinivasan (1958), Koteswaram and De (1959), Mull *et al*., (1963), Mukherjee and Chaudhuri (1979), Chaudhuri and Chattopadhyay (2001).

The principal objective of the present study is to introduce the concept of soft computing as fuzzy logic to view the consequences of some important surface parameters during the occurrence of severe thunderstorms of the pre-monsoon season over GWB.

2. Methodology

Pre-monsoon thunderstorms, in general, depict huge vertical extent. To start with, only the surface parameters are considered in the study, because the weather events initiate over the surface. The concept of fuzzy set theory is

TABLE 1

The fuzzy subsets of different Universes of discourse constructed using the parameters associated with pre-monsoon thunderstorms (ts)

Universe of discourse	Fuzzy subset G	Fuzzy subset M	Fuzzy subset B
X1	Combination of high T before ts and low T after ts	Combination of low T before ts and low T after ts	Combination of high or low T before ts and high T after ts
X2	Combination of low R/H before ts and high R/H after ts	Combination of high R/H before ts and high R/H after ts	Combination of high or low R/H before ts and low R/H after ts
X3	Combination of low P before ts and high P after ts	Combination of high P before ts and high P after ts	Combination of high or low P before ts and low P after ts
X4	Combination of high value of ΔT and high value of V during ts	Combination of high or low value of ΔT and low or high value of V during ts	Combination of low value of ΔT and low value of V during ts
X5	Combination of high value of ΔT and high value of ΔR/H during ts	Combination of high or low value of ΔT and low or high value of ΔR/H during ts	Combination of low value of ΔT and low value of ΔR/H during ts
X6	Combination of high value of ΔT and high value of ΔP during ts	Combination of high or low value of ΔT and low or high value of ΔP during ts	Combination of low value of ΔT and low value of ΔP during ts
X7	Combination of high value of ΔP and high value of ΔR/H during ts	Combination of high or low value of ΔP and low or high value of ΔR/H during ts	Combination of low value of ΔP and low value of Δ R/H during ts
X8	Combination of high value of ΔP and high value of V during ts	Combination of high or low value of ΔP and low or high value of V during ts	Combination of low value of ΔP and low value of V during ts
X9	Combination of high value of V and high value of ΔR/H during ts	Combination of high or low value of V and low or high value of ΔR/H during ts	Combination of low value of V and low value of ΔR/H during ts

then applied to identify the consequences of some parameters during the occurrence of these severe thunderstorms.

In fuzzy logic, a fuzzy set 'A' in an universe of discourse X= {x} represents a class of elements in which each parameter is characterized by a degree of belief that it belongs to, 'A' .Each element of the set 'A' is exposed to the possibility of belonging to other fuzzy subsets of the universe of discourse X with different degrees of belief (Pal and Mitra 1999, Klir and Folger 2000). This exposure to various possibilities has made fuzzy logic able to deal with dataset acquired from a complex system. A data set from a complex system always contains some degree of vagueness. The usefulness of fuzzy logic is that it can exploit the vagueness inherent in the dataset to give result more crisp than the result given by any method based upon ordinary set theory. Construction of a fuzzy set is subjective in nature, and reflects the context in which the problem is viewed (Pal and Mitra 1999). Observations disclose that as a consequence of the occurrence of such thunderstorms, it is expected that there would be fall in surface temperature and rise in air-pressure, relative humidity and wind speed. Fuzzy set necessary for the study are constructed using the aforesaid parameters.

A belief measure is analytically defined as a function

$$m : P(X) \rightarrow (0,1) \qquad (1)$$

where

$$m(\Phi) = 0 \qquad (2)$$

and

$$\sum_{A \varepsilon P(X)} m(A) = 1$$

where

m(A) → The degree of evidence that a specific element of the universe of discourse X belongs to the set A but not to any special subset of A.

P(X) → Power set of X.

Expression (1) resembles a probability distribution. The function 'm' is usually termed as a basic probability assignment. But, in this problem, instead of the set X, the power set P(X) is used as the set on which the function 'm' is to be applied. Thus, to avoid confusion, it is preferable to call 'm' as basic assignment.

Each set Aε P(X) for which, m(A) > 0 is called a focal element of 'm'.

In the present study, surface temperature, relative humidity, air pressure and wind speed associated with the

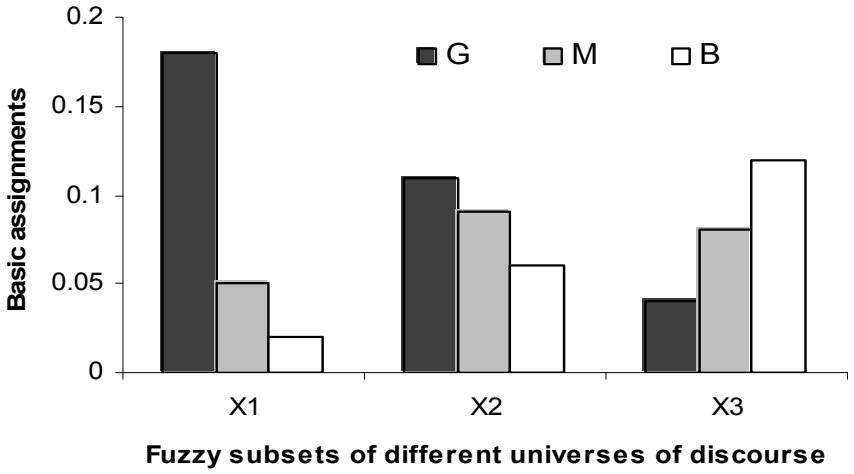

Fig. 1. Basic assignments due to different fuzzy subsets associated with universes of discourse X1, X2 and X3 constructed on the basis of surface temperature, relative humidity and pressure associated with pre-monsoon thunderstorms

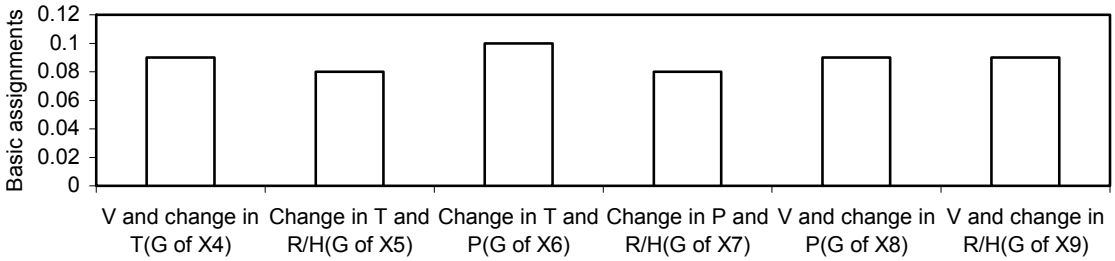

Fig. 2. Basic assignments due to the fuzzy subsets G of the universes of discourse X4, X5, X6, X7, X8 and X9 constructed by using different parameters associated with pre-monsoon thunderstorms

pre-monsoon thunderstorms are regarded as the basic parameters. The observed values of these physical parameters before and after the occurrence of the thunderstorms and magnitudes of the changes in the values of these parameters during the thunderstorms are used to construct different fuzzy subsets within appropriate universes of discourse. Nine universes of discourse ruminated in the present study are :

X1 → Combination of temperature (*T*) before and after the thunderstorm.

X2 → Combination of relative-humidity (R/H) before and after the thunderstorm.

X3 → Combination of air pressure (P) before and after the thunderstorm.

X4 → Magnitude of change in temperature (ΔT) and wind speed (V) during thunderstorms.

X5 → Magnitude of change in temperature (ΔT) and change in relative humidity (ΔR/H), during thunderstorms.

X6 → Magnitude of change in temperature (ΔT) and change in air-pressure (ΔP), during thunderstorms.

X7 → Magnitude of change in air-pressure (ΔP) and change in relative humidity (ΔR/H), during thunderstorms.

X8 → Magnitude of change in air-pressure (ΔP) and wind speed (V), during thunderstorms.

X9 → Magnitude of change in relative humidity (ΔR/H) and wind speed (V), during thunderstorms.

In each universe of discourse, fuzzy subsets G, M, and B (Table l) are constructed. Thus, each universe of discourse has the power set

$$(\varphi, G, M, B, G \cup M, G \cup B, M \cup B, G \cup M \cup B)$$

where

φ is the null set.

and $(\varphi, G, M, B, G \cup M, G \cup B, M \cup B, G \cup M \cup B)$ are the focal elements.

3. Result and discussion

Based upon the observations often years data (130 thunderstorms) made available from the Regional Meteorological Office, Kolkata, the basic assignments associated with the various fuzzy subsets are displayed in Figs. 1& 2. Fig. 1 depicts that the basic assignment due to the fuzzy subset G of the universe of discourse X1 dominates the basic assignments due to M and B of X1. The basic assignment due to the fuzzy subset G of the universe of discourse X2 dominates the basic assignments due to M and B of X2. Whereas; for the universe of discourse X3, the basic assignment due to the fuzzy subset B dominates that due to G and M.

It is also observed from the figure that the basic assignment due to G of X1 dominates that due to G of X2 and X3. Basic assignment due to M of X2 and X3 are almost the same but highly dominate M of X1. For each focal element B, the most dominant is the B of X3 and then of X2. Fig. 2 shows the basic assignments due to G of X4, X5, X6, X7, X8 and X9. The maximum and almost equally dominant basic assignments are due to G of X6, X8 and X9.

Thus the study reveals the following:

(*i*) Fall in surface temperature is the most important consequence of severe thunderstorms of pre-monsoon season. A rise in the relative humidity is another important consequence, but less important than the fall in the surface temperature. The least important is the rise in the air-pressure.

(*ii*) High magnitude of change in temperature combined with high magnitude of change in pressure is extremely important to understand the occurrence of pre-monsoon thunderstorms.

(*iii*) During pre-monsoon thunderstorms, high wind speed is mostly associated with significant change in relative humidity and air-pressure.

(*iv*) To predict wind speed that may occur during severe thunderstorm, multiple regressions using relative humidity and air pressure as predictor needs to be studied.

4. Conclusion

The finding of the present study lead to conclude that fall in surface temperature is the most important consequence during the occurrence of pre-monsoon thunderstorms. Relative humidity and air pressure play significant role only when they are associated with high wind speed.

References

Chaudhuri, Sutapa and Chattopadhyay, Surajit, 2001, "Measure of CINE-A relevant parameter for forecasting pre-monsoon thunderstorm over GWB", *Mausam*, **52**, 679-684.

Desai, B. N. and Rao, Y. P., 1954, "On the cold pools and their role in the development of Nor'westers over West Bengal and East Pakistan", *Indian J. Met. & Geophys*., **5**, 243-248.

India Meteorological Department, 1941, "Nor'westers of West Bengal", India Meteorological Department, Tech. Note, No. 10.

Klir, J. G. and Folger, T. A., 2000, "Fuzzy sets, Uncertainty and Information", Prentice Hall, USA, 110-120.

Koteswaram, P. and Srinivasan, V., 1958, "Thunderstorm over Gangetic West Bengal in the pre-monsoon season and the synoptic factors favourable for their formation", *Indian J. Met. & Geophys*., **9**, 301-312.

Koteswaram, P. and De, A. C., 1959, "Study of pre-monsoon thunderstorms over GWB by radar", *Indian J. Met.& Geophys*., **10**, 275-282.

Mukherjee, A. K. and Chaudhuri, A. K., 1979, "Excessive overshooting of Cb", *Indian J. Met. & Geophys*., **30**, 485-492.

Mull, S. and Rao, Y. P., 1948, "Effect of vertical acceleration on pressure during thunderstorms", *Q. J. R. Meteorol. Soc*., **71**, 419-421.

Mull, S., Mitra, H. and Kulshrestha, S. M., 1963, "Tropical thunderstorms and radar echoes", *Indian J. Met. & Geophys*., **14**, 23-26.

Normand, C. W. B., 1938, "On instability from water vapour", *Q. J. R. Meteorol. Soc*., **64**, 47-66.

Pal, Sankar, K. and Susmita, Mitra, 1999, "Neuro-Fuzzy pattern recognition: Methods in Soft Computing", John Wiley & Sons. Inc. New York, 30-36.