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Prediction of Potential Thunderstorm Over Ocean near Sriharikota

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Abstract: **A study with primary importance given to the potential value of parameters derived from Radio sounding and scatterometer wind data for forecasting the thunderstorm associated with convective storm is presented here. The main aim of this study is to predict the thunderstorm with a lead-time by making use of four parameters i.e. lifted index, K index, Vorticity and divergence respectively. In the present work, we have used data for 2 years out of which the first year data is used for deciding the criteria or finding the threshold value for prediction. These parameters are applied to the second year data for verification. It was observed that the chosen parameters shows good linearity to the thunderstorm occurrence for about 6 hours I advance. The reported work bears importance as it used just 2 input parameters information from Radio Sounding and Scattterometer each to predict the thunderstorm occurrence over the consider region.**

Keywords: **Radio sounding, scatterometer, Lifted Index, K-index, Vorticity and Divergence.**

1. INTRODUCTION

As thunderstorm is a strong evidence of convection development, we targeted isolated thunderstorm prediction as a case study for finding out initialization of convective thunderstorm. The region of interest is to find out the convection development over ocean near to Satish Dhawan Space Centre (SDSC), Sriharikota. As this is the leading satellite launching station in India therefore, we try to find out a clear view of weather near to this station. In addition, if we have suitable prior information about thunderstorm over ocean, it would help in saving a lot of human lives and goods. Prediction over ocean is a difficult task owing to heavy convection schemes. In this work, we have tried to use four parameters together to find out isolated thunderstorm activity over the said region. Here, we report our initial results for prediction of thunderstorm can be made more accurate using a long-term data over this region as well as for other selected regions also. We used lifted index and k-index derived from radio sounding data whereas, vorticity and divergence derived from scatterometer wind data to predict the possibility of thunderstorm well in advance. Radio sounding gives atmospheric profile, which is a source of proper information about atmospheric temperature, pressure and water vapor pressure. Scatterometer data gives u and v component of speed and direction of wind over ocean.

2. DATA AND METHODOLOGY

Weather forecasters use various techniques to predict the occurrence of convective storms that produce thunder and lightning or thunderstorms (Groenemeijer et al, 2007). Convective storms are a manifestation of the overturning of the entire troposphere or a large part thereof. We used some of these parameters to predict time of thunderstorm occurrences, which are derived from radio sounding data namely: Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Lifted Index (LI), and K Index (KI). In this work, we have also used vorticity and divergence derived from Scatterometer wind data over the ocean to find possibility of convection development over ocean.

2.1 Lifted Index:

The lifted index (°C) provides an estimate of the instability in the atmosphere due to the difference between the 500mb level temperature and the temperature that an air parcel would acquire when lifted from the surface to 500 mb. A parcel of air will rise freely when it is warmer than its surroundings. When a parcel is "lifted", it obtains an upward vertical velocity which can be a result of a surface front or trough, surface heating (convection).Lifted index is defined as,

$$LI = T_{500} - T_{p500} \quad \text{……………….(2.1)}$$

where LI (°C) is the lifted index, T_{500} is the 500mb environmental temperature (°C), T_{p500} is the 500mb temperature (°C) which a parcel will achieve if it is lifted dry-adiabatically from the surface to its lifted condensation level (LCL) and then moist-adiabatically to 500mb. Lifted dry adiabatically from the surface to its LCL and then lifted moist adiabatically to the equilibrium level (EL) where the parcel becomes negatively buoyant.

2.2 K Index:

The K index was composed for forecasting air mass thunderstorms or thunderstorms with no dynamic triggering mechanism. To compute this index, first take the 850 mb temperature and then subtract the 500 mb temperature. Secondly, we add the 850 mb dew point temperature to this difference. A larger value of this dew point indicates present of low level moisture and an increase in the chances of convection. Finally, we subtract the 700 mb dew point depression for moisture input at the mid-levels. A small dew point depression at 700 mb indicates the possibility for deep convection. In the absence of significant moisture at 700mb, there is a greater chance of entrainment of dry air, given a parcel were lifted from beneath the 700 mb level. If entrainment of dry air occurs, the parcel will become less buoyant (Bluestein, 1993).KI is defined as,

$$K = T_{850} - T_{500} + T_{d850} - (T_{700} - T_{d700}) \quad \text{………………… (2.2)}$$

Where T_{850} is the temperature at the 850 mb level, T_{500} is the temperature at the 500 mb level, T_{d850} is the dew point temperature (°C) at the 850 mb level, T_{700} is the temperature (°C) at the 700 mb level, and T_{d700} is the dew point temperature (°C) at the 700 mb level.

George (1960) defined the first term as a lapse rate term, while the second and third are related to the moisture between 850 and 700 mb, and are strongly influenced by the 700-mb temperature–dew point spread. As this index increases from a value of 20 or so, the likelihood of showers and thunderstorms is expected to increase.

2.3 Vorticity:

The vertical motion patterns associated with synoptic scale divergence/ convergence are directly connected both with development of surface pressure systems and the development of the vertical motion fields that lead to the creation of cloud/precipitation systems in association with the surface lows.

Vorticity is used to describe the curved motion of fluid parcels without reference to a center of rotation (Lynch and Cassano, 2006).

$$\xi = \frac{\partial c}{\partial A} = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) \quad \text{…………………………….(2.3)}$$

Vorticity could be determined by marking the particles of the fluid in a small neighborhood of the point in considered area, and watching the relative displacements are monitored as they move along the flow.

2.4 Divergence:

The divergence (flux density) of a wind vector at the point (u, v) is

$$\text{Divergence} = \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) \quad \textbf{…………………… (2.4)}$$

This is a scalar, and gives the rate of change of field strength in the direction of field (Lynch and Cassano, 2006).

Positive divergence- Expansion (source)

Negative divergence-contraction (sink)

2.5 Calculation Methodology:

The stability indices have been calculated from radio sounding data obtain from Wyoming University for Chennai (Madras) station. For each radio sounding, the various stability indices have been calculated and stored together for the number of lightning strokes recorded in an area around Sriharikota during a certain time window.

Data from an automatic lightning stroke detection system (http://webflash.ess.washington.edu/) have been used to identify days with lightning. The system can detect the occurrence of a lightning stroke and then calculate its position and strength. The number of lightning strokes occurring in an area around Sriharikota during a time window of 24 hours from 00 to 23 UTC are counted and stored together with the value of the indices on that particular day.

The data sample covers the period from 01-01-2009 to 31-12-2010. This data sample has been divided into two sub periods, one from 01-01-2009 to 31-12-2009[P1] and a second from 1-01- 2010 to 31-12-2010[P2]. Data from the first period was used to determine the parameters in a probabilistic indication model and data from the second period was used to verify this probabilistic model.

2.5.1 Analysis of Radio sounding data:

Raw Radio Sounding data was obtained from the database of University of Wyoming in the section of upper air data. (http://weather.uwyo.edu/upperair/sounding.html)

From this, we calculated lifted and k index for the selected cases of thunderstorm using equation 2.1 and 2.2. The data was arranged in two groups for periods P1 and P2 respectively. The calculated values of K and lifted index a threshold value was fixed for period P1 which is shown in Table 2.1.

Table 1

Lead Time (Hour)	**Lifted Index (°C)**	**K Index (°C)**	**Vorticity (S^{-1})**	**Divergence (S^{-1})**
2.1	-7.19	42	4.24E-06	-4.01E-06
4.1	-6.4	39.2	3.50E-06	-3.41E-06
5.1	-5.84	36.7	2.97E-06	-3.01E-06
6.1	-5.19	35.9	2.81E-06	-2.68E-06
8.1	-4.65	33.4	2.71E-06	-2.53E-06
9.1	-4.02	33	2.65E-06	-2.51E-06
10.1	-3.85	32.5	2.63E-06	-3.61E-06
12.1	-3.85	31.7	1.14E-06	-4.16E-06
14.1	-3.85	30.1	3.20E-06	-3.87E-06
16.1	-3.85	30	3.33E-06	-4.60E-06

2.5.2 Analysis of Scatterometer wind data:

Scatterometer data was used to find out vorticity and divergence over the ocean. Wind data over ocean is available with a time interval of 6 hours i.e. 4 times a day. Using u and v components of wind over ocean the vorticity and divergence over the region have been computed using equation 2.3 and 2.4.

From the calculated values of vorticity and divergence, a threshold value was fixed as shown in table 2.1 with respect to lead time before the occurrence of thunderstorm.

The above obtained threshold values were used to study the instability in behavior of atmosphere in same region for the succeeding year [P2]. The values of Vorticity, Divergence, Lifted Index and K index were plotted on Y-axis with respect to the lead time from the occurrence of thunderstorm on X-axis.

3. RESULT AND DISCUSSION

Using the threshold values listed in Table 2.1, a graph of lead time with respect to lifted index (LI) and K Index (KI) was plotted as shown by the solid line, in Fig. 1 and 2 respectively. It could be seen that low values of LI indicates higher probability of thunderstorm occurrence (Fig. 1). On the other hand, a higher value of KI indicates a higher probability of thunderstorm occurrence (Fig. 2).This graph was used as reference to verify the data from period P2. Using similar calculation as done for period P1, values of LI (or KI) was determined for period P2 as shown by dotted point in Fig.1 and Fig.2 respectively. It can be seen that the data for the period P2 follows the same trend as shown by that of period P1 thereby verifying the reliability of our predictors.

It should be noted that Fig.1 and 2 shows data only for 6 hours prior to the thunderstorm occurrence. However, if we consider the duration from 9 to 15 hours prior to the thunderstorm occurrence, the predictors for P2 do not follow the same trend so that of P1. This makes it slightly difficult to predict the occurrence of thunderstorm in advance of 15 hours. Nevertheless, fair prediction can be made for 6 hours prior to the thunderstorm occurrence.

In a similar way as done above, the reliability of other two predictors' vorticity and divergence was also tested as shown in Fig.3 and 4, which are also in good agreement with that of LI and KI for prediction of thunderstorm of thunderstorm occurrence prior to 6 hours.

Thus, by combining the threshold value for all four predictors, a fairly accurate prediction for the thunderstorm occurrence can be made prior to 6 hours.

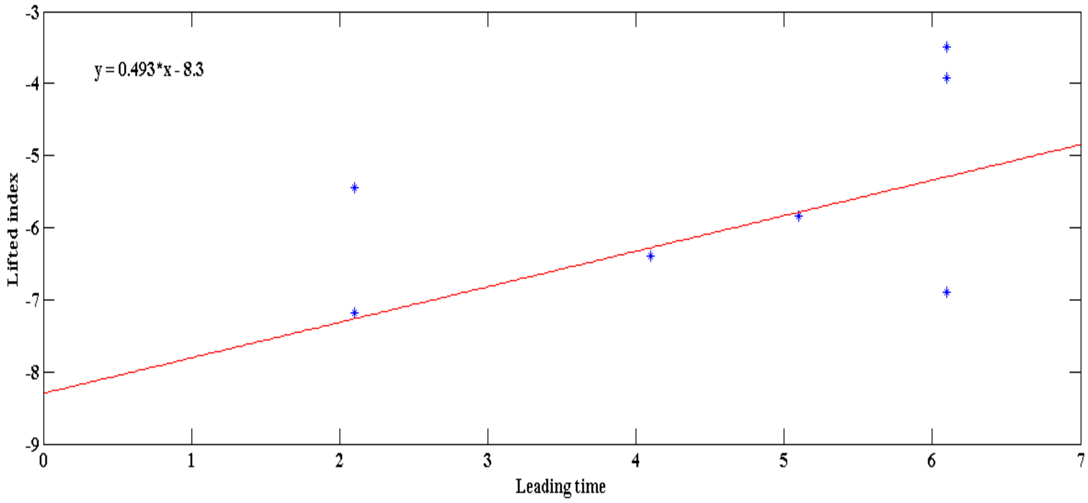

Fig.1

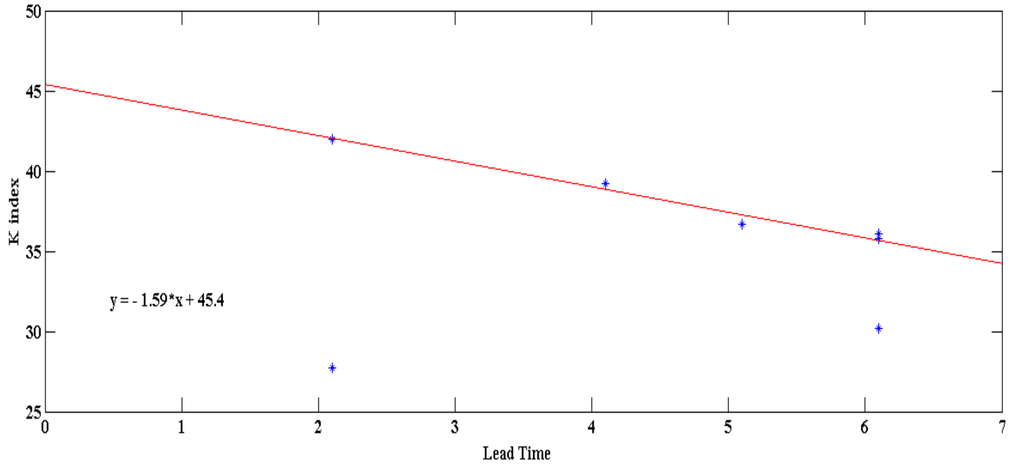

Fig.2

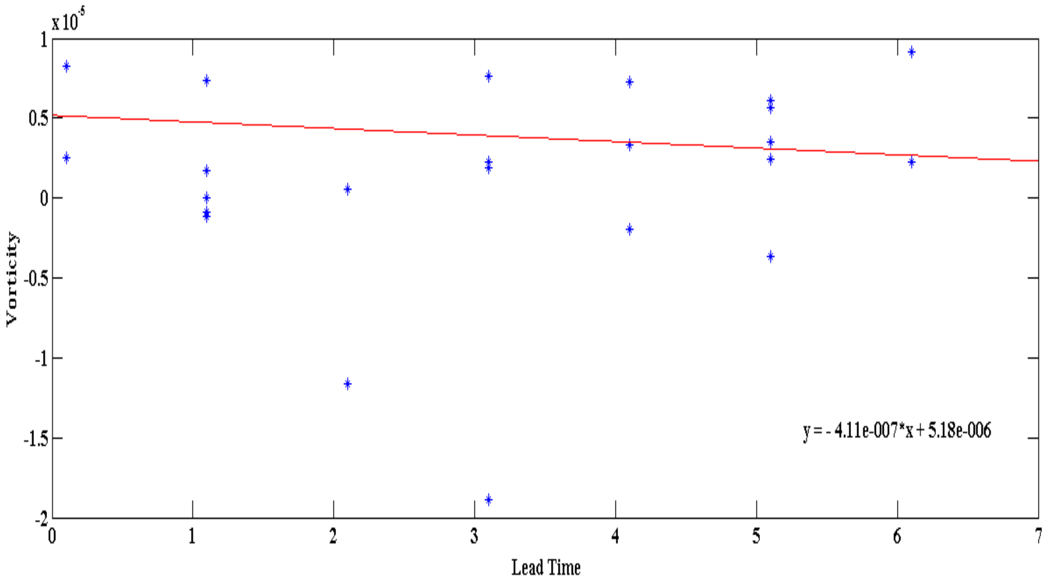

Fig.3

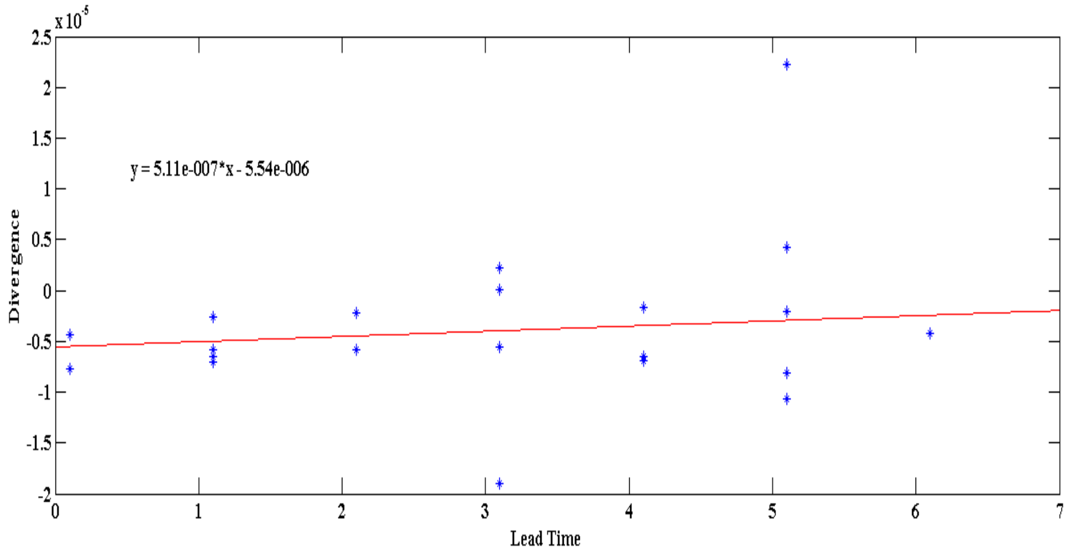

Fig.4

In this work, we studied the four parameter i.e. LI, KI, Vorticity and Divergence to find out the possibility of occurrence of thunderstorm over a given region with a certain lead time. Result shows that prediction has a fluctuating relation between predictor and time of thunderstorm between 9 to 15 hr. Hence it becomes slightly difficult to go for prediction of thunderstorm in advance 15 hr. Fig. (4.7 and 4.8) shows that the Lifted index and K index are in good agreement with predicted time of thunderstorm for the period of 6 hr. Fig.(4.15 and 4.16) shows that the vorticity and divergence are also in good agreement with predicted time of thunderstorm for the period of 6 hr. We get a clear picture of time of occurrence of thunderstorm, 6 hours in advance by combining threshold value of all four predictor.

Table 3.1 Result: Threshold value verified for thunderstorm prediction

Lead Time before the occurrence of thunderstorm (Hour)	Lifted Index (°C)	K index (°C)	Vorticity (S^{-1})	Divergence (S^{-1})
2	-7.19	42	4.24E-06	-4.01E-06
4	-6.4	39.2	3.50E-06	-3.41E-06
5	-5.84	36.7	2.97E-06	-3.01E-06
6	-5.19	35.9	2.81E-06	-2.68E-06

The prediction of convection development is a complex task. Herein, we have made use of linear relationship between the parameters that affect the convection development over ocean. The development of a thunderstorm requires fine condition for upliftment of convective moisture which can be measured by the vorticity. Positive increase in value of vorticity imply a good possibility of uplifting. Simultaneously, the divergence of wind over ocean must also be considered to predict the thunderstorm formation. As the value of divergence declines with time, the possibility of thunderstorm occurrence increases. In this study we are able to obtain good agreement of our observation with theory.

4. CONCLUSION

The present study reports a correlation between four chosen parameters Li, KI, vorticity and divergence that can be used to predict the occurrence of thunderstorm well in advance.

Threshold values of the selected parameters with a lead time were fixed for data from a certain period and were successfully verified by applying to data from some other period. Using these parameters, it become possible to fairly prediction of thunderstorm occurrence with good lead time of 6 hr.

REFERENCES

[1] Holton, James R., and Gregory J. Hakim. An introduction to dynamic meteorology. Academic press, 2012,(86-114,449-475)

[2] Lynch, Amanda H., and John J. Cassano. Applied atmospheric dynamics. Wiley, 2006, (119-132).

[3] Navy operational ocean circulation and tide models (Department of oceanography, Naval postgraduate school), march 2003.

[4] Pickard, George L., and William J. Emery. Descriptive physical oceanography. 5th ed. Oxford: Pergamon Press, 1990.(110-147)

[5] Tomczak, Matthias, and J. Stuart Godfrey. Regional oceanography: an introduction. Daya Books, 2003.(175-198).

[6] Hemmati, Hamid, ed. Deep space optical communications. Vol. 11. Wiley-Interscience, 2006.

[7] Knudsen, B. M., Andersen, S. B., & Gross, A. Contribution of the Danish Meteorological Institute to the final report of SAMMOA, 1999.

[8] Kotal, S. D., Roy Bhowmik, S. K., Kundu, P. K., & Das Kumar, A. A statistical cyclone intensity prediction (SCIP) model for the Bay of Bengal. Journal of Earth System Science, 117(2), 157-168(2008).

[9] Stoffelen, Ad, and David Anderson. "Scatterometer data interpretation: Estimation and validation of the transfer function CMOD4." Journal of Geophysical Research 102.C3 (1997): 5767-5780.

[10] S Mahesh Anand, Ansupa Dash, M S Jagadeesh Kumar, Amit Kesarkar “Prediction and classification of thunderstorms using artificial neural network.-” (2011).

[11] Hernandez, Michael Kevin. "Utilizing COSMIC radio occultation soundings to estimate convective potentials over oceans." 12th Conference on IOAS-AOLS. 2008.

[12] Bluestein, Howard B. Synoptic-dynamic Meteorology in Midlatitudes: Observations and theory of weather systems. Vol. 2. Taylor & Francis, 1993.

[13] Groenemeijer, P. H., and A. Van Delden. "Sounding-derived parameters associated with large hail and tornadoes in the Netherlands." Atmospheric research 83.2 (2007): 473-487.