551.51 (540.11)

STUDY OF VARIATION OF THERMODYNAMIC PARAMETERS OVER SRINAGAR

1. It is well known that meso-scale weather phenomena are associated with the development of strong convections. These meso-scale weather phenomena are reflected by the occurrence of moderate to heavy rainfall/snowfall on some days, succeeding and preceding the days with comparatively less rainfall/snowfall depending on the availability of moisture. In winter, the precipitation comes mainly in the form of snow and associated with mid-latitude eastward moving systems or trough in westerlies. Keeping this fact into mind a statistical analysis of convective parameters of last 21 years for Srinagar has been given. Further, studies of Williams and Renno (1993) have shown that isolated heavy rainfall on any isolated day results not only from a higher value of Convective Available Potential Energy (CAPE), rather it results from the combined effect of a high positive value of CAPE and low negative value of Convective Inhibition Energy (CINE). It has been shown that CAPE plays an important role in mesoscale convective systems (Moncrieff and Miller, 1976), especially in the tropical atmosphere (Bhat *et al*., 1996, Basu and Mandal, 2002 and Roy and Roy Bhowmik, 2005). In cases when Level of Neutral Buoyancy (LNB) is not clearly found then can be extended up to 200 hPa (Dutta and De, 1999) for computation of CAPE and CINE.

2. Upper air radiosonde (R.S.) data used in the study has been taken from the Meteorological complex Srinagar. In the present study CAPE in J/kg has been calculated using the formula

$$\text{CAPE} = \int_{Z_{\text{LFC}}}^{Z_{\text{LNB}}} \frac{g(T_{\text{VP}} - T_{\text{VE}})}{T_{\text{VE}}} \text{d}z = \int_{P_{\text{LFC}}}^{P_{\text{LNB}}} \frac{-R(T_{\text{VP}} - T_{\text{VE}})}{P} \text{d}p \quad (1)$$

Where,

T_{VE} = Virtual temperature of the environment at pressure level p.

T_{VP} = Virtual temperature at pressure level p of an air parcel following pseudo adiabat through surface wet bulb temperature.

P_{LFC} = Pressure at the level of free convection (LFC)

P_{LNB} = Pressure at the level of neutral buoyancy (LNB)

Z_{LFC} = Height of the LFC and

Z_{LNB} = Height of the LNB.

Physically CAPE may be interpreted, as the maximum amount of potential energy, possessed by air parcel, solely due to convection, convertible to vertical

TABLE 1

Statistics of computed thermodynamic parameters for CAPE at 0000 UTC and 1200 UTC during the 21 years (1986-2006)

Month	CAPE (J/kg) at 0000 UTC					CAPE (J/kg) at 1200 UTC				
	μ	σ	α	W_{max}	L	μ	σ	α	W_{max}	L
Jan	60.71	57.25	0.94	11.02	1.85	58.07	58.72	1.01	10.78	0.10
Feb	57.31	73.76	1.29	10.71	0.76	110.60	84.94	0.77	14.87	0.11
Mar	100.04	117.19	1.17	14.15	0.92	314.47	344.93	1.10	25.08	0.11
Apr	186.10	137.47	0.74	19.26	1.16	562.57	428.58	0.76	33.04	0.17
May	296.80	200.65	0.68	24.36	1.81	957.87	461.83	0.48	43.77	0.17
Jun	475.72	305.85	0.64	30.85	2.47	884.08	472.17	0.53	42.05	0.12
Jul	842.13	588.29	0.70	41.04	11.02	1151.81	595.37	0.52	48.00	0.22
Aug	603.86	359.14	0.59	34.75	7.64	1041.50	522.34	0.50	45.64	0.17
Sep	326.40	309.05	0.95	25.55	2.18	641.66	378.53	0.59	35.82	0.05
Oct	89.06	80.20	0.90	13.25	0.38	378.44	309.33	0.82	27.51	0.05
Nov	37.84	51.19	1.35	8.70	0.70	191.57	149.22	0.78	19.57	0.04
Dec	31.28	38.84	1.24	7.91	-0.13	44.84	45.66	1.02	9.47	0.03

Where, μ = Mean of CAPE, σ = Standard deviation, α = Coefficient of variation, W_{max} = Convective updraft and L = Non-dim parameter

kinetic energy. In T - ϕ diagram it represents the positive area. In some soundings LNB is not found and then the integral representing CAPE is evaluated numerically between the pressure level P_{LFC} and 200 hPa. The convectively generated maximum updraft (W_{max}) is calculated using CAPE given by the formula

$$W_{max} = \sqrt{2 \times \text{CAPE}} \qquad (2)$$

(Williams and Reno, 1993)

CINE in J/kg has been computed using the formula of William and Renno (1993) as shown below:

$$\text{CINE} = \int_{Z_{SFC}}^{Z_{LFC}} \frac{g(T_{VP} - T_{VE})}{T_{VE}} dz = \int_{P_{SFC}}^{P_{LFC}} \frac{-R(T_{VP} - T_{VE})}{P} dp \qquad (3)$$

Where, Z_{SFC}, Z_{LFC} are the height of the surface and LFC respectively above mean sea level and P_{SFC}, P_{LFC} are the pressures at the surface and at LFC respectively.

Physically, CINE may be interpreted as the amount of energy that must be supplied to an air parcel up to LFC following pseudo adiabat through the surface wet bulb temperature, to overcome the resistance inhibiting convection, owing to the low level stability of the atmosphere. By using CAPE and CINE, computed earlier, following Basu and Mandal (2002) here also we have computed a non-dimensional kinetic parameter (L) by using the formula

$$\text{L} = \frac{|\text{CAPE}| - |\text{CINE}|}{|\text{CINE}|} \qquad (4)$$

Clearly L is large, when CAPE is large and CINE is small. Atmospheric state is favorable for convective activity when the value of L is large and moisture is available up to considerable depth in the atmosphere. Both the integrals in (1) and (2) are evaluated numerically using Trapezoidal rule. CAPE, W_{max}, CINE, & L obtained over the station.

3. The daily CAPE values computed using radiosonde data at Srinagar station for January to December for the period of year 1986 to 2006. During winter the weather over the Srinagar area is mainly affected by the synoptic scale systems called western disturbances. The time of observation is broadly divided into 0000 UTC and 1200 UTC. The mean monthly or yearly CAPE is derived from the daily CAPE values for both 0000 UTC and 1200 UTC for all the 21 years. It is well known fact that highest CAPE value is associated with the more moisture and which possibly is an indicator of more rainfall/snowfall over the area.

4. It has been observed from the Table 1, that the mean value of CAPE at 1200 UTC is more than at 0000 UTC in 21 years except for January month. This possibly due to that the convective build up is more in evening hours than in morning hours.

5. Convectively generated maximum updraft (W_{max}) have been computed from CAPE values for each case and given in Table 1. More will be the value of the up thrust parameter more will be the convective build up of the system. The maximum mean values of updraft were found 41.04 m/sec and 48.00 m/sec at 0000 UTC and 1200 UTC respectively for the month of July during 21 years. The standard deviation (σ) and

TABLE 2

Statistics of computed thermodynamic parameters for CINE at 0000 UTC and 1200 UTC during the 21 years (1986-2006)

Month	CINE (J/kg) at 0000 UTC			CINE (J/kg) at 1200 UTC		
	μ	σ	α	μ	σ	α
Jan	-21.34	25.32	-1.33	-24.39	17.52	-0.72
Feb	-32.48	47.16	-1.45	-31.41	23.83	-0.76
Mar	-51.98	40.21	-0.78	-52.03	36.99	-0.70
Apr	-86.27	75.60	-0.88	-57.99	92.63	-1.60
May	-105.63	71.04	-0.62	-75.83	48.22	-0.64
Jun	-137.23	101.48	-0.74	-87.06	53.75	-0.62
Jul	-70.04	26.83	-0.38	-72.97	40.00	-0.55
Aug	-69.87	29.28	-0.42	-78.92	35.50	-0.45
Sep	-102.75	106.52	-1.04	-111.97	84.69	-0.76
Oct	-64.48	69.49	-1.08	-90.94	44.69	-0.49
Nov	-22.20	25.31	-1.14	-72.57	61.74	-0.85
Dec	-35.99	23.79	-1.49	-36.82	71.74	-1.95

Where, μ = Mean of CAPE, σ = Standard deviation, α = Coefficient of variation, W_{max} = Convective updraft and L = Non-dim parameter.

coefficient of variation (α) are also given in Table 1. The standard deviation and coefficient of variation for each months shows that how the mean values of convective parameters deviates from the mean. Larger variation can be taken as thrust area of study.

6. CINE has been computed similar to CAPE, and given in the Table 2 for 0000 UTC and 1200 UTC. It is basically the work of expansion needs to lift a parcel from the surface to the Level of Free Convection (LFC). The maximum mean negative values of CINE have been observed at 0000 UTC for the month of June during last 21 years.

7. Non-Dimensional Kinetic Parameter (L) from the Table 1, it is clear that L lies between 0.03 to 11.02 during the last 21 years with negative mean value for the month of December at 0000 UTC. Based on the different values of CAPE and CINE the computed valves of L are given in Table 1.

8**.** The following conclusions are drawn from the present study:

(*i*) The sudden increase in moisture, normally associated with the passage of Western disturbance, can enhance the value of CAPE which is later utilized in monitoring the meso-scale system development.

(*ii*) The mean values of CAPE have been found more at 1200 UTC than at 0000 UTC for all the months except the January month.

(*iii*) Mean value of CINE has been found more at 0000 UTC than at 1200 UTC during last 21 years.

(*iv*) Atmosphere in the lower tropospheric levels over the area was quite convectively unstable this fact is very well inferred from convectively generated up thrust and non – dimensional convective parameter.

(*v*) The correlation coefficient between monthly mean value of CAPE and observed mean monthly rainfall for 0000 UTC and 1200 UTC are 0.07 and 0.10 respectively. This indicates that CAPE is feebly correlated with the rainfall. The higher value of correlation at 1200 UTC suggests that during this time the convective development is more than at 0000 UTC. It is clear from the above study the rainfall is not mainly associated with convection but its lifting of moisture mechanism will be different and it is subject of further study.

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References

Basu, G. C. and Mandal, D. K., 2002, "Forecasting aspects of thunder squall over Calcutta and its parameterization during pre-monsoon season", *Mausam*, **53**, 3, 271-280.

Bhat, G. S., Srinivasan, J. and Gadgil, S., 1996, "Tropical deep convection, convective available potential energy and sea surface temperature", *J. Meteorological. Soc. Japan*, **74**, 155-166.

Dutta, S. N. and De, U. S., 1999, "A diagnostic study of contrasting rainfall epochs over Mumbai", *Mausam*, **50**, 1, 1-8.

Moncrieff, M. W. and Miller, M. J., 1976, "The dynamics and simulation of tropical cumulonimbus and squall lines", *Q. J. R. Meteorol. Soc*., **102**, 373-394.

Roy, S. S. and Roy Bhowmik, S. K., 2005, "Analysis of thermodynamics of atmosphere over the northwest India during the passage of western disturbance as revealed by model analysis field", *Current Science*, **88**, 6, 847-951.

Williams, Earle and Renno, Niltan, 1993, "An analysis of the conditional instability of the tropical atmosphere", *Mon. Wea. Rev.*, **121**, 21-36.

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