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Estimates of heat and moisture over the Indian monsoon trough zone during monsoon 1979

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सार — 1979 में दक्षिण-पश्चिम मानसून के कई विशिष्ट लक्षण थे। यह वर्ष अधिकांशतः कमी वाले मानसून का रहा। सामान्यतः जुलाई माह में मानसून कमजोर था तत्पश्चात अगस्त के मध्य के बाद इसमें दीर्घकालीन व्यवधान था। इस वर्ष मानसून द्रोणिका क्षेत्र की निम्न और मध्य क्षोभमण्डल में संहति और उष्मा फलक्सों के अनुमानों में विभिन्नताओं का, 1951 से 1970 तक 20 वर्षों के आंकड़ों पर आधारित सामान्य मानसून अवस्थाओं की तुलना में अध्ययन किया गया है।

ABSTRACT. Southwest monsoon in 1979 had many unique features. It was largely a deficient monsoon year. Generally the monsoon was weak in the month of July and then there was a prolonged break after the middle of August. During this year the differences in the estimates of mass and heat fluxes in lower and middle troposphere of the monsoon trough area are studied in comparison to the normal monsoon conditions based on 20 years data, 1951 to 1970.

1. Introduction

After four successive years of good monsoon, the monsoon failed in 1979 and led to drought conditions in many parts of north and central India. Monsoon was weak over many parts of the country in first and third week of July and in northwest India in last week of July. There was a prolonged break in monsoon from 15 August till the end of the month.

Summer monsoon rainfall failure can be associated with a smaller seasonal shift of the ITCZ, with a reduction of area covered by the rain-producing synoptic systems or with a reduction of moisture convergence into the area.

In the monsoon season 1979, out of three cyclonic storms and four depressions developed in Indian area only three systems affected the central parts of the country which is quite abnormal (*Indian Daily Weather Reports*, Oct-Dec 1979).

One of the most important synoptic features of the southwest monsoon circulation is the location and intensity of the mean monsoon trough running from Pakistan to north Bay of Bengal. This monsoon trough is responsible for establishment of the summer monsoon. The variation in its position has a vital bearing on the monsoon rains.

General circulation studies have shown the tropics as source region of heat and angular momentum in maintaining global balance. This mean pattern of tropics is completely disturbed by the monsoon perturbation.

The balance of various parameters in the monsoon region is worth studying. The southwest monsoon area is not a closed system. No well defined boundaries can be fixed on any physical basis for this monsoon area. We can only identify the inflow and outflow at different levels into the Indian area, their connections, particularly through vertical motions and role on maintaining balance of other parameters. There can be difference in inflow and outflow from year to year depending upon the location and activity of the monsoon trough.

There are some earlier studies by Riehl and Malkus (1958), Berson (1961) and Anjaneyulu (1969). Anjaneyulu has discussed the flux of sensible heat and latent

TABLE 1

Level (mb)	July '79	July (Normal)	August '79	August (Normal)
	(a) Mass flux (10^{18} gm/day)			
Srf-900	—0.54	—1.21	—0.53	—1.13
900-800	—0.40	—1.15	—0.47	—1.06
800-700	—0.20	—0.89	—0.34	—0.84
700-600	—0.06	—0.55	—0.23	—0.58
600-500	0.27	—0.21	0.29	—0.08
	(b) Sensible heat flux (10^{18} cal/day)			
Srf-900	—39.14	—89.15	—38.31	—81.49
900-800	—29.97	—83.60	—35.33	—78.00
800-700	—15.30	—67.30	—25.43	—63.20
700-600	—4.80	—42.00	—17.78	—44.70
600-500	20.70	16.69	22.74	—6.20
	(c) Latent heat flux (10^{18} cal/day)			
Srf-900	—6.21	—13.15	—5.85	—12.97
900-800	—3.32	—10.01	—3.63	—8.89
800-700	—1.25	—5.26	—1.87	—5.04
700-600	—0.25	—2.53	—0.84	—2.69
600-500	0.64	—0.47	0.70	—0.25

TABLE 2

Convergence values (10^{-5} per sec) with height

Level (mb)	July 1979	July (Normal)	August 1979	August (Normal)
Srf.	—0.162	—0.319	—0.182	—0.273
900	—0.226	—0.533	—0.267	—0.464
800	—0.174	—0.486	—0.218	—0.407
700	—0.171	—0.384	—0.191	—0.410
600	—0.031	—0.180	—0.096	—0.216
500	—0.015	—0.083	0.119	0.004

heat in an ellipse of area 19.6×10^{15} cm^2 and lateral boundary 6.6×10^8 cm around the monsoon trough. The area had inflow upto 2.1 kt below 600 mb and outflow upto 2.4 kt between 500 and 100 mb. In the present study, the quantitative estimates of mass and heat flux in the lower and middle troposphere of the monsoon trough area in July, August 1979 are made and they are compared with the normal values based on 20 years (1951-1970). data

2. Data and area of study

In this study, monthly mean data of 11 radiosonde stations and 12 pilot balloon stations around the elliptical boundary of monsoon trough for July and August 1979 as well as for the years 1951 to 1970 has been used (Appendix). Due to large scale missing data, computations have been made from 1000 to 500 mb only.

3. Procedure

Sensible heat balance and latent heat balance equations can be written as

$$Q_s+Q_p-R=\iint C_n\,(c_pT+Agz)\,ds.\frac{dp}{g}+\rho V F\,d\alpha \quad (1)$$

$$Q_p - Q_e = \iint C_n . L_q . ds \ \frac{dp}{g} \qquad (2)$$

where, A = Reciprocal of the mechanical equivalent of heat

c_p = Specific heat of air at constant pressure

C_n = Component of wind normal to the ellipse

F = Frictional force

g = Acceleration due to gravity

L = Latent heat

P = Pressure

z = Contour heights

V = Velocity vector

s = Perimeter of the monsoon ellipse $\approx$ 5000 km

ρ = Density

$c_pT + Agz$ = Sensible heat

R =Net radiational cooling

Q_p = Precipitation heating

Q_s = Surface sensible heat source

Q_e = Surface latent heat source.

The flux integrals of sensible heat and latent heat from Eqns. (1) and (2) can be broken into contributions of mean and eddy motions.

$$H = \bar{H} + H' = \iint (c_pT + Agz) C_n . ds . \frac{d\rho}{g}$$
$$= \iint (\overline{c_pT} + \overline{Agz}) \ C_n . ds . \frac{d\rho}{g} +$$
$$+ \iint (c_pT + Agz)' \ C_n' \ ds . \frac{d\rho}{g} \qquad (3)$$

$$L = \bar{L} + L' = \iint L_q . C_n . ds . \frac{d\rho}{g}$$
$$= \iint \overline{L_q} . \overline{C}_n ds . \frac{d\rho}{g} + \iint L_q' C_n' \ ds . \frac{d\rho}{g} \qquad (4)$$

where bars and primes represent mean and eddy motions respectively.

Mass flux is obtained from the value $C_n.ds.d\rho/g$ and mean sensible and latent heat fluxes around the boundary have been evaluated from Eqns. (3) and (4). Table 1 gives the vertical profile of mass flux, sensible and latent heat flux (+ve outward) in July and August 1979 as well as in normal monsoon conditions. Table 2 gives the convergence values with height.

4. Results

From Table 1, it can be seen that in July and August 1979, mass inflow and inward flux of sensible and latent heat occurred upto 600 mb only. The layer 600-500 mb seems to be different from normal. The mass and heat flux are 20 and 40 per cent of the normal in July and August 1979 respectively. Table 2 shows that maximum convergence occurs at 900 mb level in 1979 as well as in normal monsoon and it goes on decreasing with height. The magnitude of convergence gives the idea about the intensity of the monsoon trough with height. In 1979, the intensity of the monsoon trough was much less than normal.

5. Conclusion

It can be concluded for the monsoon of 1979 that there were :

(*i*) Below normal mass inflow and inward flux of sensible and latent heat in the lower troposphere of the monsoon trough area (20 and 40 per cent of the normal in July and August 1979 respectively).

(*ii*) Absence of mass inflow and inward flux of sensible and latent heat in middle troposphere. This was probably the reason for the monsoon trough to be much weaker than normal and deficient rainfall.

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Appendix

List of radiosonde and pilot balloon stations

Radiosonde stations	Pilot balloon stations
Agartala	Bikaner
Ahmedabad	Churu
Aurangabad	Delhi
Bhubaneswar	Bareilly
Bombay	Bahraich
Calcutta	Gangtok
Gauhati	Gauhati
Jodhpur	Agartala
Lucknow	Bhubaneswar
	Aurangabad
Nagpur	Veraval
Delhi	Bhuj