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Meridional eddy flux of energy in the atmosphere

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ABSTRACT. Eddy transport of heat, both in the sensible and latent forms, has been evaluated for three stations in India, namely, Allahabad (25° 25′ N 81° 51′ E), New Delhi (28° 39′ N 77° 17′ E) and Jodhpur (26° 18′ N 73° 1′ E) which all lie near about 27° N. Across 27° N in India the mean seasonal and annual eddy transport of *sensible heat* is weak and directed mainly equatorwards but that of latent heat is more marked and directed polewards.

1. Introduction

In recent years the study of meridional flux of energy which is an important factor in maintaining the general circulation of the atmosphere has received considerable attention. Priestley (1949) has developed a method to compute the meridional eddy transfer of heat based on observational data; some other workers, *e.g.*, White (1951) and Nyberg and Schmacke (1951) have carried out similar calculations. In the present paper the data for meridional flux of heat in both sensible and latent forms for three Indian stations, namely, Allahabad, New Delhi and Jodhpur, have been calculated and discussed.

2. Data

The upper air temperatures, humidities and wind data utilised in the paper have been collected from the Daily Weather Reports published by the India Meteorological Department. As simultaneous radio soundings and upper wind measurements are needed for the present work, the period that could be chosen is only one year from March 1948 to February 1949. Even throughout this period observations are not available at a single synoptic hour. In Table 1, are given the times of observations in various months.

As is seen from the table, evening data were used for January, February and March. In these months, the observations for wind were also not quite simultaneous with those for temperature, humidity and pressure. The effect of this difference on the final results cannot be estimated at present for lack of appropriate data.

The investigation has been extended upto 500 mb for sensible heat transport and upto 600 mb for latent heat transport, owing again to the lack of upper wind measurements and humidity observations respectively above these levels. In some months upper wind data and humidity observations are not available even for these levels. Wherever necessary, the values for flux of heat have been extrapolated to these levels. This introduces some uncertainty in the integrated flux values.

3. A brief review of the method

Before presenting the computations, we briefly state the method of Priestley (1949).

(*a*) *Computation of eddy flux of sensible heat*—The amount of sensible heat carried poleward per unit area per unit time is given by $c_p \rho V T$ where ρ, V, T represent respectively the density, northward component of horizontal velocity and absolute temperature of a sample of damp air, and c_p its specific heat at constant pressure. The average flux per unit time per unit area in the west-east and the vertical plane is $c_p \overline{\rho V T}$, the bar representing the mean value over the period,

TABLE 1

Times of observation in various months

Year	Month	Radio-sonde data at	Pilot-balloon data at
1948	March	2000 IST	1600 IST
1948	April-December	0700 ,,	0700 ,,
1949	January and February	2000 ,,	1600 ,,

the individual values being taken at a fixed point of space.

Integrating vertically, the total flux per unit length of longitude is

$$c_p \int_{z=0}^{\infty} \overline{\rho V T}.dz$$

or approximately $\frac{c_p}{g}\int_{0}^{\bar{p}_0} \overline{VT}.dp$

where $\bar{p}_0$ is the mean surface pressure over the period under consideration and g the acceleration due to gravity. But

$$\overline{VT} = \bar{V}\bar{T} + \overline{V'T'} \qquad \ldots \qquad \ldots (1)$$

since $V = \bar{V} + V'$ and $T = \bar{T} + T'$ according to Reynolds, the primes denoting the deviations from the means. In equation (1) the first term on the right hand side represents the advective flux and the second the eddy flux. Now

$$\frac{c_p}{g}\int_{0}^{\bar{p}_0} \overline{V'T'}.\,dp$$

gives the vertically integrated eddy flux. In the following only eddy flux has been calculated.

(*b*) *Computation of eddy flux of heat in the latent form*—If L is the latent heat of vaporisation of water and q the specific humidity, the eddy flux of heat in the latent form is obtained by replacing T by $\frac{L}{c_p}.q$ in the discussion for sensible heat. Humidity mixing ratio x is used for q as it would not significantly affect the result.

In the above V is taken positive when polewards and negative when equatorwards. c_p is given the value 0·24 cal/gm/°C and L the value 590 cal/gm. Variations in L due to temperature and pressure and in c_p due to humidity are neglected as they do not significantly affect the eddy flux.

4. Eddy flux of heat

(*a*) *Sensible heat flux*—The eddy flux of sensible heat has been evaluated for each month at the levels, ground, 900, 850, 800, 700, 600 and 500 mb. Tables 2 to 4 respectively give these values together with the vertically integrated flux of sensible heat as expressed in g cal cm^{-1} min^{-1} for Allahabad, New Delhi and Jodhpur. To study the mean seasonal variation of the flux the year has been divided into four seasons, *viz.*, winter or northeast monsoon season (December-February), summer (March-May), southwest monsoon season (June-September) and post monsoon season (October and November).

Mean monthly variation with height—In the distribution with height of the flux of sensible heat, reversals of flow are noticed, but from the available data it is at present not possible to state whether there is any regular variation. Further data have to be awaited to study this feature.

Mean monthly variation—From the results obtained for the monthly variation of integrated flux for the three stations, it is found that the transport is equatorwards in most months of the year. Though more data are again necessary to put this conclusion on a firm basis, it seems to verify White's (1951) statement that 'there are indications that at very low latitudes, *the eddy sensible heat transport* is directed equatorwards'. Appreciable poleward transport is found in January and August at Allahabad and in January, February and April (probably during the period January—April) at Jodhpur. At Delhi the poleward transports, though indicated in October and March, are not at all significant.

If the figures for the three stations are averaged to give mean values for the belt of latitude (27°N) covered by the three stations, quite a weak poleward flow is noticed during January-March, but it is equatorwards during the rest of the year.

Mean seasonal transport—From the means for different seasons in Table 6, it is seen that at Allahabad the transport of sensible heat is quite small though it is equatorwards in the summer and post monsoon seasons; at Delhi it is equatorwards in all the seasons,. being maximum in summer, but quite small in the post monsoon season. At Jodhpur, it is polewards in winter and equatorwards in summer and rainy season, being of maximum magnitude in the last season. The average for 27°N latitude is, however, equatorwards in all the seasons, *though the amount is small.*

A characteristic fact brought out by these data is that the transport of sensible heat is quite small, being almost negligible, in the post monsoon season.

Mean annual transport—The mean annual transport of sensible heat (Table 6) is equatorwards at all the three stations. The average for 27° latitude is also equatorwards.

Vertical variation of flux—The following statements regarding the distribution with height of the flux of sensible heat, as given in Table 7, can only be regarded as tentative requiring further data for verification. The values at each level are the averages of the twelve monthly values. At Allahabad there are two reversals in the direction of flow, one at 850 and the other at 600-mb level. At these levels the flow is directed polewards, the maximum magnitude being at 500 mb indicating that above this level, it may be quite appreciable. At New Delhi, a reversal is met with at 850 mb only, becoming polewards; but at Jodhpur, the first reversal is at 850 mb, the flow becoming directed equatorwards, but at the second level of reversal at 500 mb it again becomes polewards, as it is from ground to 900 mb.

Both at Allahabad and Jodhpur at the second higher level of reversal, the transport is again towards the north, but no such indication is given by the available data for New Delhi. It would be interesting to know whether such a second level exists for New Delhi.

(*b*) *Latent heat flux. Mean monthly variation*—The data for eddy flux of heat in the latent form upto 600 mb along with the integrated values have been presented in Tables 2 to 4 for Allahabad, New Delhi and Jodhpur respectively.

In Table 8 the total eddy flux of latent heat from ground upto 600 mb level at the three stations and at 27° latitude is given. At Allahabad, a maximum poleward eddy flux of latent heat ($\cdot 50 \times 10$ g cal cm^{-1} min^{-1}) is found in November and a flux of nearly the same magnitude and in the same direction ($\cdot 45 \times 10$ g cal cm^{-1} min^{-1}) in June also. Compared to this the maximum equatorward flow in December ($-\cdot 11 \times 10$ g cal cm^{-1} min^{-1}) is small. At New Delhi the maximum poleward flow is in December and March ($\cdot 45$ and $\cdot 41 \times 10$ g cal cm^{-1} min^{-1}) and the maximum equatorward flow is found in February ($-\cdot 10 \times 10$ g cal cm^{-1} min^{-1}) and this is again small compared to the poleward flow. At Jodhpur, however, the maximum poleward flow is $0 \cdot 28 \times 10$ g cal cm^{-1} min^{-1} in February and the maximum equatorward flow is in July which is roughly double ($-\cdot 51 \times 10$ g cal cm^{-1} min^{-1}) of the poleward flow. The average for 27° latitude is poleward flow in all the months excepting April and July when the flow is equatorwards. In April, however, the magnitude of equatorward flow is small.

Mean seasonal transport—Table 9 gives the seasonal transports for various stations. At Allahabad and New Delhi the transports are polewards in all the seasons but at Jodhpur it is so only in winter and summer, the transports during southwest monsoon and post monsoon seasons, being equatorwards. Poleward transport is maximum in the post monsoon season at Allahabad and New Delhi and in winter season at Jodhpur. However, at Jodhpur, the transport is strongest in the southwest monsoon season but is directed equatorwards. The average for 27° latitude is poleward flow in all the seasons, but the transport during southwest monsoon season is of negligible magnitude.

Mean annual transports—The mean annual eddy flux of latent heat (Table 9) is polewards at Allahabad and New Delhi but equatorwards and quite small at Jodhpur. At 27° latitude it is polewards.

Vertical variation of flux—The general feature in the vertical variation of latent heat flux is that the flux rapidly increases to a maximum at about 900—850 mb level and then gradually decreases upwards.

The vertical variation at Jodhpur is rather peculiar. The poleward flux first increases upto 900-mb level, decreases to zero at 850-mb level, changes sign becoming equatorwards and then increases, the magnitudes at 900 and 600-mb levels being roughly the same.

The values at ground level are apparently affected by turbulence.

Maximum transport occurs at a lower level in the case of latent heat than in the case of sensible heat because moisture content is generally higher in the lower layers.

It can be said from the nature of distribution of humidity with height in India that the transport of latent heat is not negligible at least at some levels above 600 mb, but unfortunately data are not available to calculate it.

(*c*) *Total heat transport*—The total heat transport by eddies is obtained by adding the sensible and latent heat fluxes. In the present investigation the sensible heat flux could be evaluated only upto 500 mb and the latent heat flux upto 600 mb; so the sum of the two quantities cannot represent the total heat flux from surface to the top of the atmosphere. It gives an idea of the total heat flux in the lower troposphere only.

The mean seasonal eddy flux (Table 11) of total heat up to the levels computed is polewards in all the seasons at Allahabad, in post monsoon season at Delhi and in winter and summer at Jodhpur, and equatorwards in the remaining seasons at New Delhi and Jodhpur. Average for 27°N latitude is poleward transport in all except southwest monsoon season during which the transport is equatorwards.

Some interesting feature in the direction of transport of total heat at 27°N may be observed in the monsoon seasons especially. In the northeast monsoon season the direction of transport is polewards when the prevailing winds in the lower layers have a component equatorwards and in southwest monsoon season it is equatorwards when the winds have a component polewards.

Similarly in the post monsoon season when the winds from a northerly direction, (northwesterly to northeasterly), are being established in the lower troposphere over upper India, the flow of total heat is polewards. There is a decrease in the amount of heat flow from winter to summer, and finally a reversal in the rainy season.

Mean annual transport (Table 11) of total heat is polewards at Allahabad; at New Delhi the magnitude is quite small but polewards. At Jodhpur, however, the transport is equatorwards and small. The mean transport at 27°N latitude is polewards and quite small.

The results obtained in this preliminary study of eddy flux of sensible and latent heat in the northern latitudes of India are to be considered as tentative. Further work is in progress for some other stations in India.

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REFERENCES

Nyberg and Schmacke (1951). *Tellus,* **3**, 2, p. 89.

Priestley, C. H. B. (1949). *Quart. J. R. met. Soc.,* **75**, 323, p. 28.

Priestley, C. H. B. (1951). *Quart. J. R. met. Soc.,* **77**, p. 200.

White, R. M. (1951). *Quart. J. R. met. Soc.,* **77**, p. 189.

TABLE 2

		1948 (Evening)	*1948 (Morning)*									*1949 (Evening)*		
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Northward eddy flux of sensible heat at Allahabad														
Flux expressed as $\overline{V'T'}$	Ground	—2·1	0·3	0·3	—2·4	5·5	—1·0	—3·1	0·5	—0·3	0·8	2·3	0·0	$\times 10^2$ °A $\times$ cm/sec
	900 mb	(0·0)	(1·4)	—2·3	—5·4	—1·6	0·1	—1·9	—1·6	1·6	2·0	1·8	—3·0	
	850	1·1	1·1	—3·5	2·3	—0·7	3·5	1·0	—3·3	2·8	—1·6	—0·1	0·2	
	800	(1·5)	(—0·3)	3·3	—2·0	—0·4	—0·3	—2·1	—1·9	3·3	—3·5	—0·4	3·1	
	700	0·6	—4·8	—3·1	0·5	—6·1	3·7	—0·6	4·4	—1·5	—2·5	—2·6	—3·1	
	600	(—1·0)	(—6·5)	5·0	—0·5	—4·7	7·6	6·4	—0·7	—5·4	—4·6	4·6	1·3	
	500	—2·7	(—5·5)	(4·0)	—0·7	0·5	3·9	3·3	—4·2	—8·8	3·8	(6·2)	(3·2)	
Mean surface pressure (mb)		999	994	988	987	986	988	993	999	1004	1005	1004	1001	
Northward eddy flux vertically integrated up to 500 mb		—0·1	—·18	0·5	—·08	—·18	·21	·05	—·04	—·08	—·11	·12	—·01	$\times 10^7 g$ cal cm^{-1} min^{-1}
Northward eddy flux of heat in the latent form at Allahabad														
$\frac{L}{c_p}\overline{V'x'}$	Ground	—3·7	0·9	—6·1	—1·4	0·8	2·3	5·0	—6·1	—2·3	0·9	—1·8	3·7	$\times 10^2$ °A $\times$ cm/sec
	900 mb	(0·0)	(2·0)	17·6	29·8	—3·7	6·6	2·1	4·7	—0·8	1·5	1·4	11·1	
	850	1·4	1·8	12·0	11·5	3·7	7·7	4·9	9·1	0·2	1·2	11·7	—0·8	
	800	(3·0)	(0·0)	11·9	2·6	—2·8	7·5	12·1	10·1	10·3	2·0	7·2	—1·8	
	700	5·3	—6·0	—2·3	6·8	—3·1	5·2	—2·3	—7·7	12·3	—4·9	—4·7	5·8	
	600	(7·2)	(—15·0)	—6·4	—7·4	(1·1)	(2·0)	-10·5	0·2	11·7	(—9·5)	3·9	(11·5)	
Northward eddy flux vertically integrated upto 600 mb		0·14	—0·12	0·32	0·45	-0·09	0·31	0·11	0·05	0·50	—0·11	0·10	0·30	$\times 10^7 g$ cal $cm^{-1} min^{-1}$

NOTE—Values put inside brackets denote extrapolated values of flux

TABLE 3

		1948 (Evening)	*1948 (Morning)*									*1949 (Evening)*		
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Northward eddy flux of sensible heat at New Delhi														
Flux expressed as $\overline{V'T'}$	Ground	—0·7	1·3	0·5	1·6	2·5	—0·2	—0·8	0·1	—3·6	0·4	—6·4	—0·6	$\times 10^2$ °A $\times$ cm/sec
	900 mb	(—0·8)	(—2·9)	7·2	—3·0	—3·9	0·9	—4·5	0·2	0·1	2·1	—4·4	—1·7	
	850	—0·1	—5·2	4·7	0·5	—5·3	—11·3	0·0	2·2	0·1	0·4	7·7	14·6	
	800	(4·1)	(—6·0)	—6·2	—2·2	—5·5	—1·6	—2·7	2·8	2·0	—0·9	3·1	7·0	
	700	6·8	—4·7	—7·9	—3·3	—7·1	—0·1	—0·9	2·7	—11·1	—5·6	—1·1	—9·3	
	600	(—1·5)	(—4·5)	(—3·4)	1·9	—4·2	1·5	0·2	0·3	6·6	5·2	—9·6	—13·7	
	500	—10·6	—12·7	(—4·2)	8·1	(0·1)	(3·1)	—1·3	—12·9	3·1	—2·7	6·7	—10·7	
Mean surface pressure (mb)		986	982	976	974	973	975	979	985	991	993	991	988	
Northward eddy flux vertically integrated upto 500 mb		0·04	—0·41	—0·19	—0·01	—0·29	—0·05	—0·08	0·02	—0·04	0·00	—0·15	—0·28	$\times 10^7 g$ cal cm^{-1} min^{-1}
Northward eddy flux of heat in the latent form at New Delhi														
$\frac{L}{c_p}\overline{V'x'}$	Ground	0·5	—10·5	—3·9	—5·0	—9·9	—1·3	1·9	—0·3	0·2	8·4	—2·3	15·2	$\times 10^2$ °A $\times$ cm/sec
	900 mb	(3·7)	(1·1)	16·0	7·3	4·9	—1·7	8·1	0·4	0·3	7·8	6·3	4·0	
	850	5·7	5·8	7·4	10·6	1·2	2·6	9·5	5·8	3·1	6·7	13·6	6·3	
	800	(7·6)	(4·1)	—7·1	2·3	—0·9	—5·7	4·5	5·5	6·8	9·9	—0·6	2·4	
	700	12·9	—1·1	0·5	—6·9	1·9	—1·9	1·4	5·2	8·8	7·8	—3·1	—12·9	
	600	(7·5)	(—6·8)	—4·4	—2·4	—5·3	(4·5)	9·4	5·6	—0·4	(4·1)	(-2·6)	-(10·2)	
Northward eddy flux vertically integrated upto 600 mb		0·41	—0·03	0·12	0·00	0·03	-0·04	0·27	0·22	0·22	0·45	0·07	—·10	$\times 10^7 g$ cal cm^{-1} min^{-1}

NOTE—Values put inside brackets denote extrapolated values of flux

TABLE 4

		1948 (Evening)	*1948 (Morning)*									*1949 (Evening)*		
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Northward eddy flux of sensible heat at Jodhpur														
Flux expressed as $\overline{V'T'}$	Ground	—1·9	0·2	6·5	—8·0	9·5	—0·6	—1·3	—0·5	—1·7	1·5	—4·8	7·9	× 10² °A × cm/sec
	900 mb	(1·1)	(—1·1)	—1·7	—9·0	1·3	—5·2	3·4	—2·0	0·4	—0·8	13·0	4·0	
	850	2·9	—0·8	-18·6	—8·0	—1·5	—8·0	—0·8	—1·7	13·8	—0·3	13·1	4·9	
	800	(3·5)	(0·9)	-10·8	3·0	—6·3	—1·3	—2·3	—1·3	2·9	—2·5	—9·0	14·7	
	700	2·3	4·2	—4·6	—0·3	2·2	—1·5	1·7	0·9	—3·2	—2·4	—9·0	—10·9	
	600	(—1·4)	(6·9)	—7·9	(-4·0)	—2·2	(-2·3)	—3·1	—1·3	0·6	—5·0	4·5	2·5	
	500	—7·4	8·7	(-13·5)	(-8·0)	—8·5	(-2·8)	—3·0	—5·1	0·6	11·2	15·5	(15·9)	
Mean surface pressure (mb)		982	979	974	972	970	972	977	986	991	991	991	987	
Northward eddy flux vertically integrated upto 500 mb		·03	·21	— ·49	—·25	—·18	—·19	—·06	—·08	·08	—·07	·14	·28	× 10⁷g cal cm⁻¹ min⁻¹
Northward eddy flux of heat in the latent form at Jodhpur														
$\frac{L}{c_p}\ \overline{V'x'}$	Ground	2·7	0·0	7·7	—1·3	—2·7	—3·4	1·3	2·7	—1·1	7·4	— 8·5	5·5	× 10² °A × cm/sec
	900 mb	(6·3)	(1·0)	6·2	—0·3	1·1	0·2	0·7	—8·8	3·0	0·9	16·1	6·9	
	850	7·2	1·3	11·4	1·1	—7·4	9·7	-13·5	—7·7	1·9	1·0	0·6	12·2	
	800	(5·6)	(0·3)	1·4	-14·9	—4·1	—5·8	— 6·2	—1·0	—3·1	0·5	1·4	7·6	
	700	1·8	—2·3	2·0	—8·7	-20·4	—2·5	—4·1	4·7	—2·8	3·0	1·5	1·9	
	600	(—2·5)	(—1·3)	(5·6)	—9·3	(-14·2)	(3·1)	—1·0	0·5	—8·8	2·0	(—0·1)	(-2·2)	
Northward eddy flux vertically integrated upto 600 mb		·21	—·02	·23	—·30	—·51	—·04	—·23	— ·06	—·09	·12	·16	·28	× 10⁷g cal cm⁻¹min⁻¹

NOTE—Values put inside brackets denote extrapolated values of flux

TABLE 5

Mean monthly transports of sensible heat at various stations and at 27°N latitude

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Allahabad	—·11	·12	—·01	—·01	—·18	·05	—·08	—·18	·21	·05	—·04	—·08	× 10⁷g cal cm⁻¹ min⁻¹
New Delhi	0	—·15	—·28	·04	—·14	—·19	—·01	—·29	—·05	—·08	·02	—·04	
Jodhpur	—·07	·14	·28	·03	·21	—·49	—·25	—·18	—·19	—·06	—·08	·08	
At 27°N	—·06	·04	0	·02	—·13	—·21	—·11	—·22	—·01	—·03	—·02	—·01	

TABLE 6

Mean transports of sensible heat for various seasons and for the year at various stations and at 27 °N latitude

	Winter or northeast monsoon	Summer	Southwest monsoon	Post monsoon	Year	
Allahabad	0	—·05	0	—·02	—·02	× 10⁷ g cal cm⁻¹ min⁻¹
New Delhi	—·14	—·19	—·11	—·01	—·12	
Jodhpur	·12	—·08	—·17	0	—·07	
At 27°N	—·01	—·11	—·09	—·01	—·06	

TABLE 7

Vertical variation of mean annual sensible heat transport at various stations

	Pressure (mb)							
	Ground	900	850	800	700	600	500	
Allahabad	—·20	—·70	·16	·03	—1·26	·33	2·41	× 10^2 °A × cm/sec
New Delhi	—·60	—·89	·68	—·67	—3·49	—2·02	—1·20	
Jodhpur	·57	·29	—·42	—·71	—1·72	—1·06	·31	

TABLE 8

Mean monthly transports of latent heat at various stations and at 27°N latitude

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Allahabad	—·11	·10	·30	·14	—·12	·32	·45	—·09	·31	·11	·05	·50	× $10^7 g$ cal cm^{-1} min^{-1}
New Delhi	·45	·07	—·10	·41	—·03	·12	0	·03	—·04	·27	·22	·22	
Jodhpur	·12	·16	·28	·21	—·02	·23	—·30	—·51	—·04	—·23	—·06	—·09	
At 27°N	·15	·11	·16	·25	—·06	·22	·05	—·19	·08	·05	·07	·21	

TABLE 9

Mean transports of latent heat for various seasons and for the year at various stations and at 27°N latitude

	Winter or northeast monsoon	Summer	Southwest monsoon	Post monsoon	Year	
Allahabad	·10	·11	·22	·27	·16	× $10^7 g$ cal cm^{-1} min^{-1}
New Delhi	·14	·17	·07	·22	·14	
Jodhpur	·19	·14	—·27	—·07	—·02	
At 27°N	·14	·14	·01	·14	·09	

TABLE 10

Vertical variation of mean annual latent heat transport at various stations

	Pressure (mb)						
	Ground	900	850	800	700	600	
Allahabad	—·66	5·96	5·39	5·16	0·37	1·42	× 10^2 °A cm/sec
New Delhi	—·59	4·68	6·47	2·32	1·03	—0·09	
Jodhpur	·84	2·76	1·49	—1·52	—2·16	—2·35	

TABLE 11

Mean transports of total heat for various seasons and for the year at various stations and at 27°N latitude

	Winter or northeast monsoon	Summer	Southwest monsoon	Post monsoon	Year	
Allahabad	·10	·06	·22	·25	·14	× $10^7 g$ cal cm^{-1} min^{-1}
New Delhi	0	—·02	—·04	·21	·02	
Jodhpur	·31	·06	—·44	—·07	—·07	
At 27°N	·14	·03	—·09	·13	·03	