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Heat and momentum fluxes and their spectra over the western coast of India during Monex-1979

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सार — मोनेक्स-79 आंकड़ों का प्रयोग करके भारतीय उपमहाद्वीप के पश्चिमी तट पर ऊष्मा और संवेग अभिगमन का परिकलन किया गया है और क्षोभमंडल में उसके उध्वार्धर वितरण का परीक्षण किया गया है। स्थानीय परिसंचरणों के कारण ये अभिवाह मौसमी माध्यों और भंवर घटकों में अपघटित हुए हैं। सतह से 300 मि. बार तक ऊर्ध्वाधर में प्रत्येक सतह पर माध्य और भंवर अभिगमन के सापेक्षिक योगदान का परीक्षण किया गया है। ऊष्मा और संवेग अभिवाहों के भंवर घटकों का ऊर्ध्वाधर माध्य मानावलीय विश्लेषण का विषय है। इन अभिवाहों में भारत के पश्चिमी तट पर अक्षांश के साथ-साथ आवर्तिताओं में विशिष्ट अंतर देखा गया है। भंवर संवेद ऊष्मा और भंवर संवेग अभिवाह की तुलना में भंवर गुप्त ऊष्मा अभिवाह अधिक आवर्तिता दर्शाते हैं।

ABSTRACT. The heat and momentum transport over western coast of Indian subcontinent have been computed using Monex-79 data and its vertical distribution in troposphere is examined. These fluxes are decomposed into seasonal mean and the eddy component due to local circulations. The relative contributions of mean and eddy transport at each level in the vertical from surface to 300 mb are examined. The vertical mean of eddy component of heat and momentum fluxes are subjected to spectral analysis. Remarkable variations in periodicities with latitude over west coast of India in these fluxes are noticed. The eddy latent heat flux shows larger periodicity as compared with eddy sensible heat and eddy momentum flux.

1. Introduction

The Indian summer monsoon is the largest local perturbation embedded in the general circulation of the atmosphere and the most important seasonal standing eddies. During the monsoon period, heat and momentum sources are disturbed due to large scale cloudiness. Hence, the study of heat and momentum fluxes is of vital importance. Among the several investigators Sankar Rao (1962), Sankar Rao and Ramanadham (1963), Singh and Singh (1987) noted that the transient local eddies play a minor role in heat and momentum transports. Bavadekar and Mooley (1978), Appa Rao (1981, 1985) observed that the moisture transport over Indian subcontinent is essentially due to mean circulation.

Bhalme and Parasnis (1975), Murakami (1976) noted the 5-day periodicity in wind and pressure fields. Murakami (1976, 1977), Krishnamurty and Bhalme (1976) revealed quasi-biweekly periodicity in rainfall and lower and upper wind and pressure fields over India and Zangvil (1975) in cloudiness over tropical Indian Ocean. Yasunari (1980, 1981) and Sikka *et al.* (1986) observed 30-40 day periodicity in cloudiness and revealed its association with the fluctuation of intertropical convergence zone. Singh and Singh (1988) noted the substantial change in periodicity with latitude in heat and momentum transport over east coast of India.

In the present paper we have attempted to compute the heat and momentum transport using Monex-79 data and examined the possible existence of periodicity and its variation with latitude over west coast of India.

2. Evaluation of parameters

2.1. *List of symbols*

u = zonal component of wind,

v = meridional component of wind,

T = temperature (°K),

c_p = specific heat of air at constant pressure,

P_0 = pressure at the earth surface.

P = pressure,

Q = time averaged total meridional heat flux per unit time,

X = humidity mixing ratio and

L = latent heat of vaporization.

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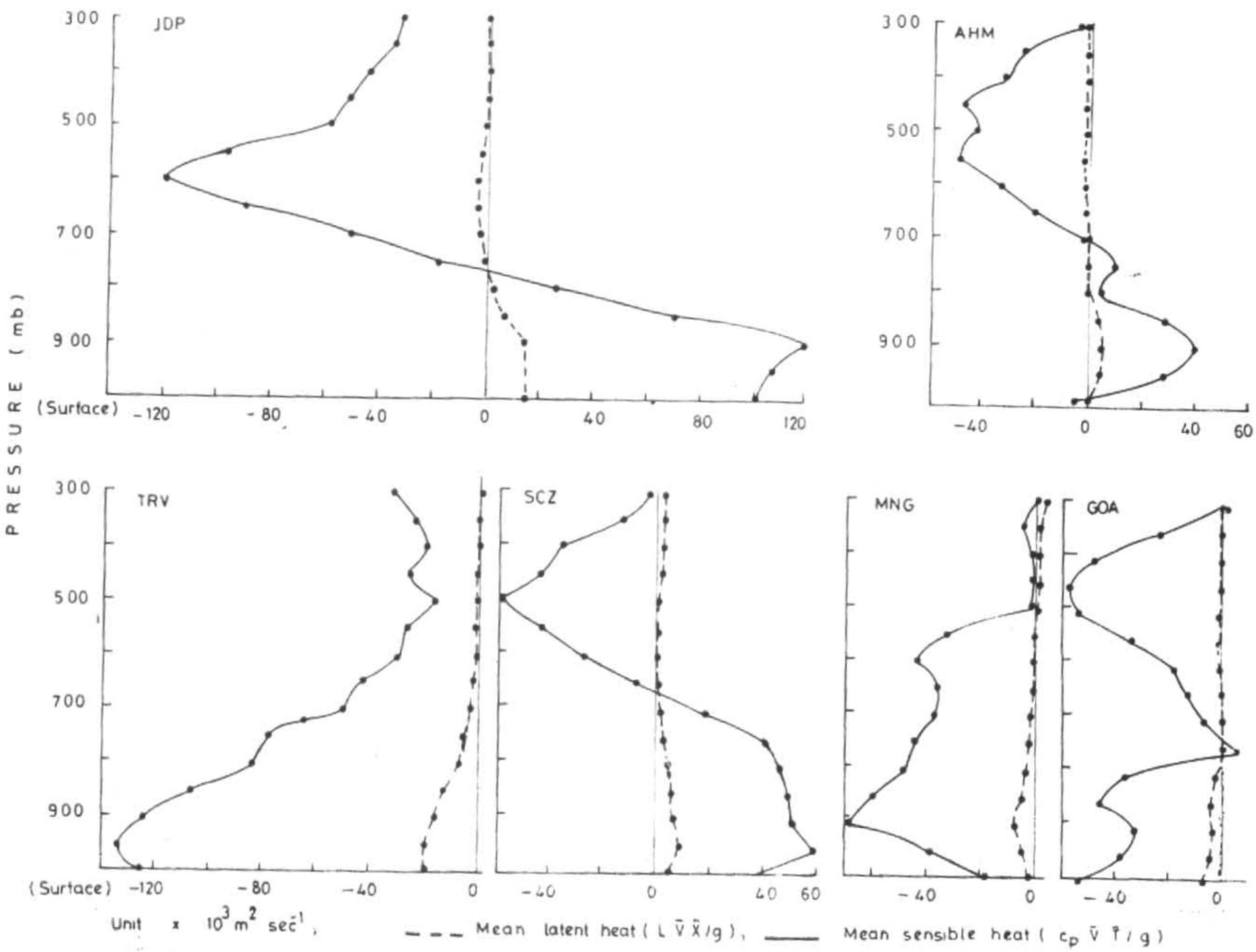

Fig. 1. Vertical variation of seasonal mean poleward flux of heat

2.2. Computation of fluxes

The time averaged total meridional flux of heat per unit time across a zonal plane of length unity and pressure interval 1000 mb (or surface) to 300 mb accomplished by the atmosphere at any station is given by :

$$Q = c_p/g \int_{300}^{P_0} \overline{VT}\, dP + L/g \int_{300}^{P_0} \overline{VX}\, dP \qquad (1)$$

where the bar denotes the time average. If the deviation from time-mean is denoted by prime, then :

$$(\ ) = (\overline{\ }) + (\ )', \quad \text{hence,}$$

$$Q = c_p/g \int_{300}^{P_0} \bar{V}\,\bar{T}\, dP + L/g \int_{300}^{P_0} \bar{V}\bar{X}\, dP$$

$$+ c_p/g \int_{300}^{P_0} \overline{V'\,T'}\, dP + L/g \int_{300}^{P_0} \overline{V'\,X'}\, dP \qquad (2)$$

The first two terms on the right of Eqn. (2) measure the effect of mean meridional circulation and the standing eddies while the last two terms measure the local eddy flux of sensible and latent heat respectively.

The meridional flux of relative U-momentum at any station across a zonal plane of length unity and pressure interval 1000 mb (surface) to 300 mb is given by :

$$M = 1/g \int_{300}^{P_0} \overline{VU}\, dP$$

$$= 1/g \int_{300}^{P_0} \bar{V}\,\bar{U}\, dP + 1/g \int_{300}^{P_0} \overline{V'\,U'}\, dP \qquad (3)$$

The first term on the right of Eqn. (3) represents the flux of relative momentum due to mean meridional circulation and the standing eddies while the second term represents the local meridional eddy flux of relative momentum at any station. These vertically integrated local eddy fluxes were subjected to spectral analysis in time domain following Blackmon and Tukey (1958).

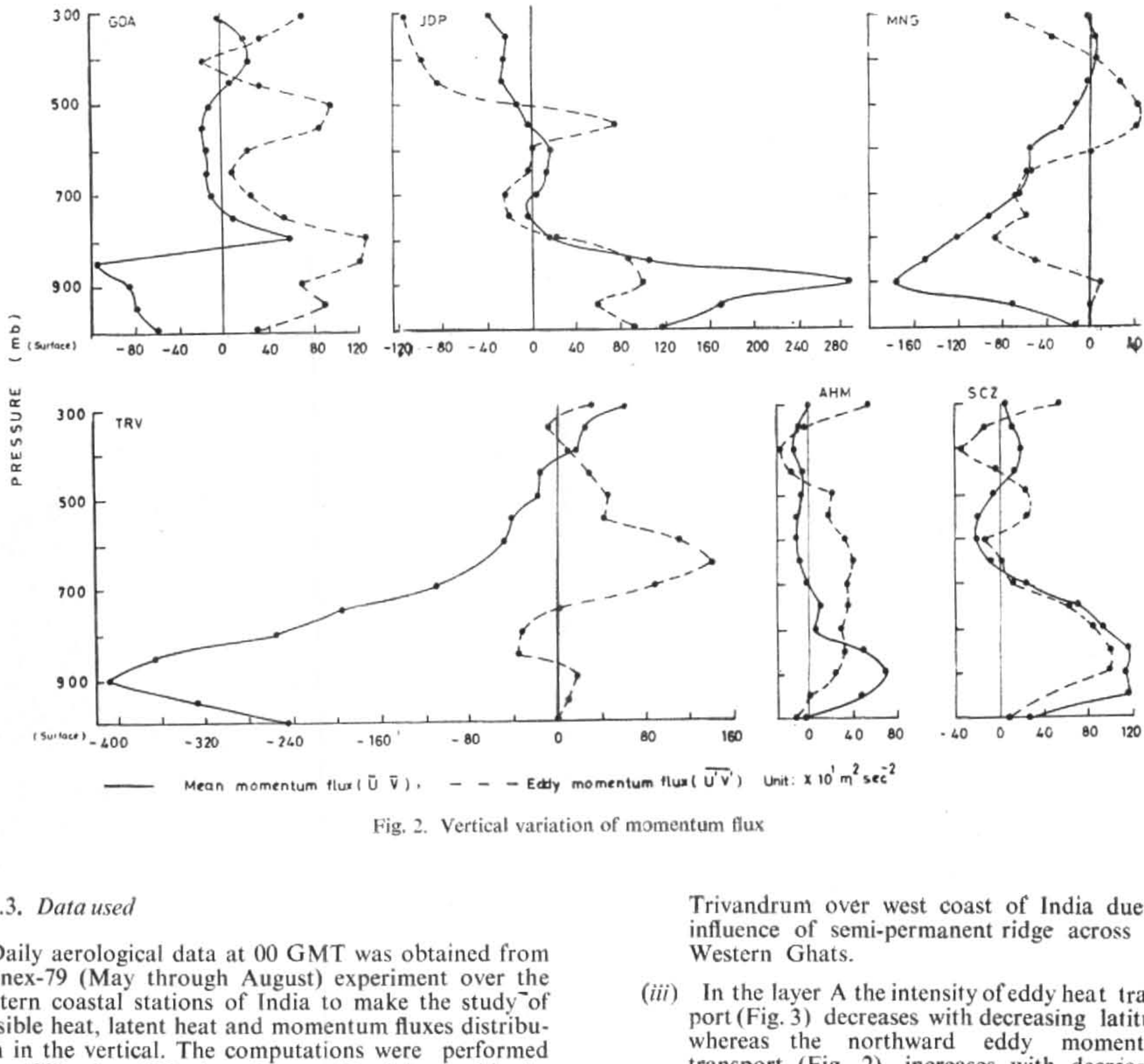

Fig. 2. Vertical variation of momentum flux

2.3. *Data used*

Daily aerological data at 00 GMT was obtained from Monex-79 (May through August) experiment over the western coastal stations of India to make the study of sensible heat, latent heat and momentum fluxes distribution in the vertical. The computations were performed from 1000 mb to 300 mb surfaces at 50 mb interval in the vertical.

3. Results

The computed fluxes and their vertical distribution are presented in Figs. 1-3. For better understanding of direction of the fluxes, the layer below 700 mb has been designated as layer A and that above 700 mb as layer B. The results of the spectral analysis are presented in Fig. 4.

The findings of the study are as follows :

(*i*) The sensible heat transport due to mean circulation over west coast of India (*see* Fig. 1) is an order of magnitude larger than the latent heat transport in layer A whereas the latent heat transport is insignificant and negligible in layer B.

(*ii*) In layer A (Figs. 1 and 2) the sensible and latent heat transport and the momentum transport due to mean circulation is northward, north of Goa and is changed to southward at Goa through Trivandrum over west coast of India due to influence of semi-permanent ridge across the Western Ghats.

(*iii*) In the layer A the intensity of eddy heat transport (Fig. 3) decreases with decreasing latitude whereas the northward eddy momentum transport (Fig. 2) increases with decreasing latitude north of west coast ridge and is changed to southward, the magnitude of which decreases with decreasing latitude over west coast of India. The northward latent heat and momentum transport due to local eddies in layer B gradually weakens with the increasing latitude over the west coast of India.

(*iv*) In general, the eddy latent heat transport is more than the eddy sensible heat transport at each level in the vertical over west coast of India during the monsoon season (Fig. 3). The ratio of seasonal mean eddy latent heat to the seasonal mean eddy sensible heat transport varies from 1.5 to 9 times over west coast of India whereas at Jodhpur, Santacruz and Mangalore, this ratio is decreased resulting into increase in seasonal mean eddy sensible heat transport by about 3 to 10 times above 500 mb surface. In the middle and upper troposphere, the transport of momentum due to seasonal mean eddies dominates over the seasonal mean circulation whereas in the

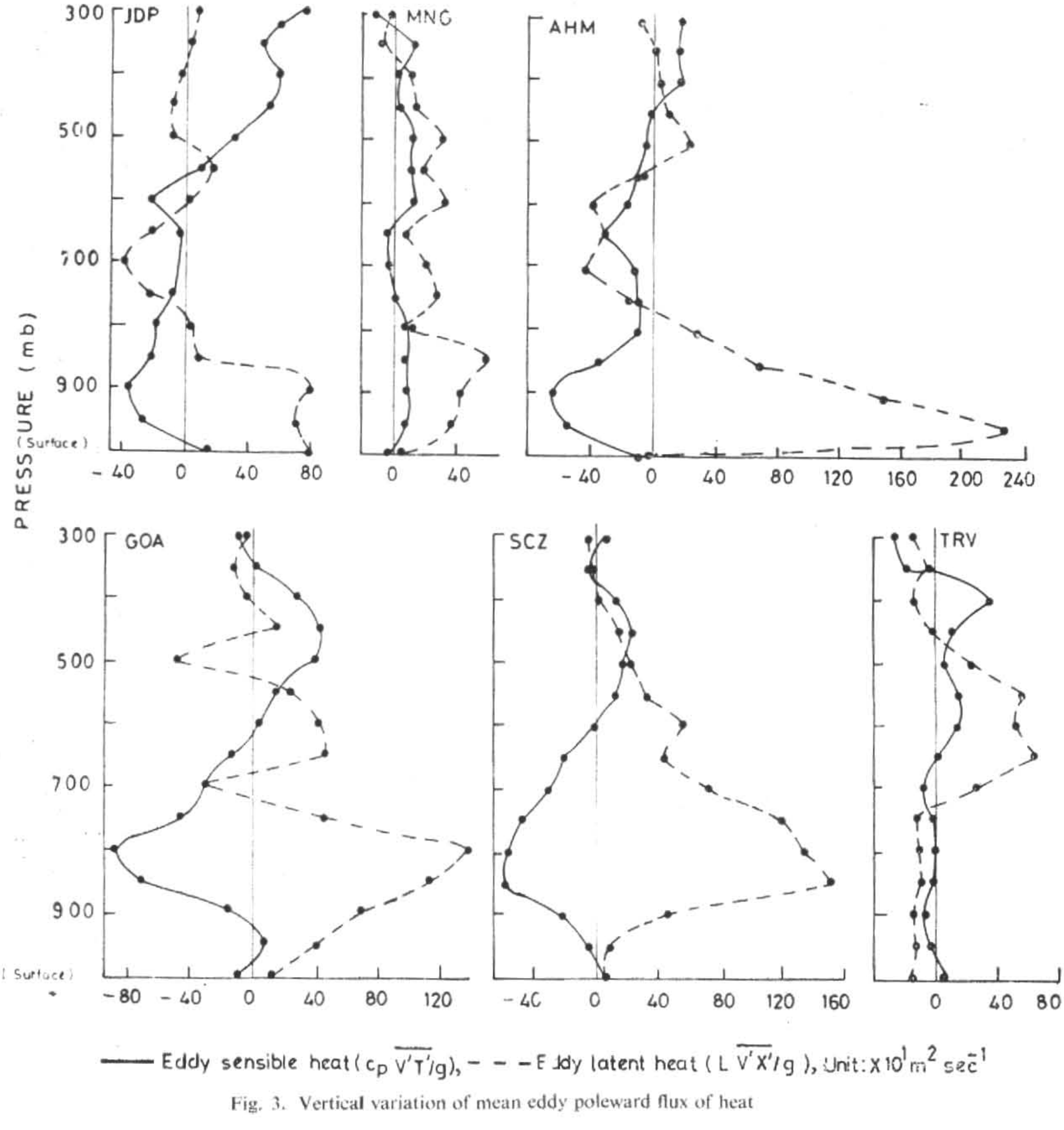

Fig. 3. Vertical variation of mean eddy poleward flux of heat

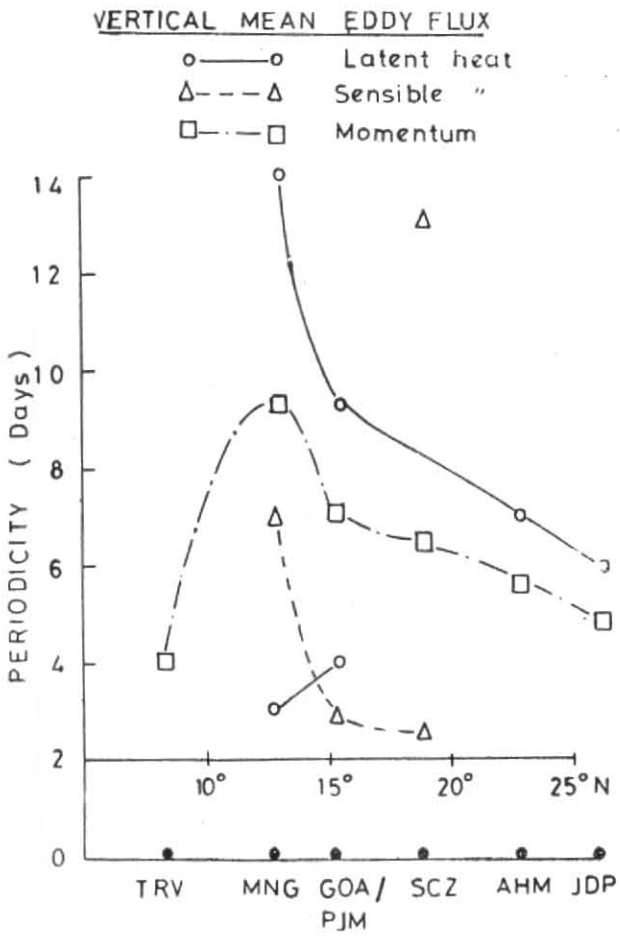

Fig. 4. Variations of periodicities in different fluxes with latitude

lower troposphere the momentum transport due to seasonal mean circulation exceeds that of the seasonal mean eddy transport of momentum over west coast of India (Fig. 2).

(*v*) The eddy latent heat flux shows larger periodicity (Fig. 4) as compared with the eddy sensible heat and eddy momentum flux over the west coast of India. These fluxes show similar variation with latitude which in general increases with decreasing latitude up to 10° N over the west coast of India during the summer monsoon season.

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