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Atmospheric Energy Conversion Characteristic of Heavy Rainfall in Sindh during Monsoon 2011

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South Asian monsoon occurs in most parts of Indian subcontinent including Pakistan, India and Bangladesh during the period of June to September every year, which is characterized by heavy rainfall events. In this study, based on atmospheric energetics theory and WPD method, we have derived a new energy parameter$E$. Meanwhile, the characteristic of atmospheric energy conversion during heavy rainfall in Sindh, Pakistan was discussed.

In terms of atmospheric energetics, the energy can be shown as (*Xie*, 1978)

$$E = C_v T + gz + \frac{1}{2}V^2 + Lq \tag{1}$$

where $C_v T$ is atmospheric internal energy,$gz$is gravitational potential energy, $\frac{1}{2}V^2$ is kinetic energy and Lq is latent heat energy.

The heavy rainfall system can be approximated as an energetics system. Internal energy and latent heat is equivalent to the elastic potential energy of wave-packets. In the period of heavy rainfall system development, the characteristic of atmospheric energy conversion is very significant. Hence, the energy E can be expressed as

$$E = E_k + E_a = \frac{1}{2}\left(u^2 + v^2\right) + \frac{1}{2}A^2 \tag{2}$$

where u, v is wind speed, $\frac{1}{2}A^2$ is the elastic potential energy of wave-packets. The gravitational potential energy compared to kinetic and elastic potential energy can be ignored.

From the atmospheric energetics theory and the wave-packet propagation diagnosis (WPD) method (*Chang et al.*, 1999; *Miao et al.*, 2002), we know, the wave energy is propagating by wave packet envelopes. Thus the wave amplitude$A_i\left(x, y, z, t\right)$ represents elastic potential energy E_a.

Meteorological data can be regarded as combination of different waves. Based on the WPD method, the data can be written as

$$P\left(x, y, z, t\right) = \sum_{i=1}^{\infty} A_i\left(x, y, z, t\right) \cos\left(k_i x + l_i y + m_i z + \omega_i t + \phi\right) \tag{3}$$

where $A(x, y, z, t)$ is the wave amplitude of $P\left(x, y, z, t\right)$, k, l, m represents the wave number of x, y, z direction respectively, ω is the circular frequency, φ is the argument.

By using Hilbert transformation (*Miao et al.*, 2002; *Zimin et al.*, 2003), the signal $P\left(x, y, z, t\right)$ can be transformed to analytic signal $\hat{P}\left(x, y, z, t\right)$

Thus, elastic potential energy can be written as

$$E_a = \frac{1}{2}A^2(x, y, z, t) = \frac{1}{2}\left\{P^2\left(x, y, z, t\right) + \hat{P}^2\left(x, y, z, t\right)\right\} \tag{4}$$

So, from **Eq. (2)** and **Eq. (4)**, the energy E can be calculated and the characteristic of atmospheric energy conversion can be discussed. The result shows that atmospheric energy interconversion played a significant role during the heavy rainfall periods. In the three rainfall spells, under the influence of the circulation and terrain conditions,

the kinetic energy is converted into potential energy in the form of standing wave. The local oscillation of potential energy also enhanced precipitation. The distributions of E_a was similar to E and high energy value corresponds to the heavy rainfall region.

Keywords: heavy rainfall spells, energy, atmospheric kinetic energy, potential energy

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