N90-28179

RESONANT ROSSBY WAVES AND SOLAR ACTIVITY

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Large-scale transient waves are essential part of atmospheric dynamics. Some of these waves (like 27-day waves, KRIVOLUTSKY, 1982; EBEL, 1981; KING, 1977) would have a solar nature. In this paper we want to investigate the contribution of the 27-day planetary waves to a total long-period spectrum of the atmospheric processes during one solar cycle.

DIIKY (1969) showed that the eigenfrequencies of Rossby waves are

$$\sigma_n^s = \alpha S - \frac{2\Omega S}{n(n+1) + (4a^2\Omega^2/gh_n^s) \times B_n^s}$$

where $\sigma^s = 2\pi/T_n^s$, T_n^s - periods of the waves, α - zonal circulation index, a - radius of the Earth, (n,s) - wavenumbers, Ω - frequency of the Earth's rotation, h_n^s - equivalent depth and

$$B_n^s = \frac{(n-s)(n+s)(n+1)}{(2n-1)(2n+1)\ n^2} + \frac{(n-s+1)(n+s+1)\ n^2}{(2n+1)(2n+3)(n+1)^2}$$

IVANOVSKY and KRIVOLUTSKY (1979) proposed that the 27-day wave has a resonant nature ($h_n^s \approx \gamma H$). We shall try to investigate the real atmospheric processes. The method of two-dimensional wave analysis which we can use is described by KRIVOLUTSKY (1981). In this method of analysis a two-dimensional meteorological field is writen in the form

$$Y(t,\lambda) = \sum_{n}^{\infty} \sum_{S=0}^{\infty} \Big\{ R_n^S \cdot \mathrm{Cos}\,(\omega_n t + s\lambda + \vartheta_n^S) + S_n^S \cdot \mathrm{Cos}\,(\omega_n t + \eta_n^S) \cdot \mathrm{Cos}\,(s\lambda) \Big\}$$

where λ - longitude, $\omega_n = 2\pi n/T$, T - time scale, s - zonal wave number, R_n^s, S_n^s - amplitudes of transient and standing waves. The sign of the R_n^s determines the direction of the wave propagation.

Using the following trigonometrical identicals

$$\int_0^T \int_0^{2\pi} \left\{ \begin{array}{l} \mathrm{Cos}(\omega_n t \pm s\lambda)\, \mathrm{Sin}\,(\omega_n t \pm m\lambda) dt d\lambda \\ \mathrm{Cos}\,(\omega_n t - s\lambda)\, \mathrm{Cos}\,(\omega_n t + m\lambda) dt d\lambda \\ \mathrm{Sin}\,(\omega_n t - s\lambda)\, \mathrm{Sin}\,(\omega_n t + m\lambda) dt d\lambda \end{array} \right\} = 0$$

$$\int_0^T \int_0^{2\pi} \left\{ \begin{matrix} \cos(\omega_n t + s\lambda)\cos(\omega_n t + m\lambda) \\ \cos(\omega_n t + s\lambda)\cos(\omega_n t - m\lambda) \\ \sin(\omega_n t - s\lambda)\sin(\omega_n t - m\lambda) \end{matrix} \right\} dt\,d\lambda =$$

$$= \begin{cases} \pi T, & s = m \\ 0, & s \neq m \end{cases}$$

we can the next system

$$\Psi_1^{n,s} = \frac{1}{\pi T} \int_0^T \int_0^{2\pi} Y(t,\lambda)\cos(\omega_n t + s\lambda)\,dt\,d\lambda =$$

$$= R_n^s \cos(\vartheta_n^s) + \frac{S_n^s}{2}\cos(\eta_n^s)$$

$$\Psi_2^{n,s} = \frac{1}{\pi T} \int_0^T \int_0^{2\pi} Y(t,\lambda)\sin(\omega_n t + s\lambda)\,dt\,d\lambda =$$

$$= -R_n^s \sin(\vartheta_n^s) - \frac{S_n^s}{2}\sin(\eta_n^s)$$

$$\Psi_3^{n,s} = \frac{1}{\pi T} \int_0^T \int_0^{2\pi} Y(t,\lambda)\cos(\omega_n t - s\lambda)\,dt\,d\lambda =$$

$$= \frac{S_n^s}{2}\cos(\eta_n^s)$$

$$\Psi_4^{n,s} = \frac{1}{\pi T} \int_0^T \int_0^{2\pi} Y(t,\lambda)\sin(\omega_n t - s\lambda)\,dt\,d\lambda =$$

$$= -\frac{S_n^s}{2}\sin(\vartheta_n^s)$$

So we can find the amplitudes of transient waves

$$|R_n^s| = \left|\frac{\psi_1^{n,s} - \psi_3^{n,s}}{\cos \vartheta_n^s}\right| \equiv \sqrt{(\psi_1^{n,s} - \psi_3^{n,s})^2 + (\psi_2^{n,s} - \psi_4^{n,s})^2}$$

$$|S_n^s| = \left|\frac{2\psi_3^{n,s}}{\cos \eta_n^s}\right| \equiv 2\sqrt{(\psi_3^{n,s})^2 + (\psi_4^{n,s})^2}$$

$$\vartheta_n^s = \operatorname{arctg}\left(\frac{\psi_4^{n,s} - \psi_2^{n,s}}{\psi_1^{n,s} - \psi_3^{n,s}}\right); \quad \eta_n^s = \operatorname{arctg}\left(-\frac{\psi_4^{n,s}}{\psi_3^{n,s}}\right)$$

Figure 1, shows the results of two-dimensional analysis for the period 1971-1981. The main result is that the periods of large-scale transient waves are close to the resonant situation ($h \approx \gamma H$). The amplitudes of the waves attain the value of about 100 gpm. Figure 2 shows the vertical structure of the 27-day wave and the role of the wave motions with $s = 1,2,3$. It could be seen that there is a dominant scale in transient stratospheric waves ($s = 1$).

So we may conclude that the resonant nature of the 27-day wave is not unicum. There are long-periods waves (50-day wave) in stratosphere which belong to the resonant waves, too. It is a very interesting fact for the solar activity-weather problem.

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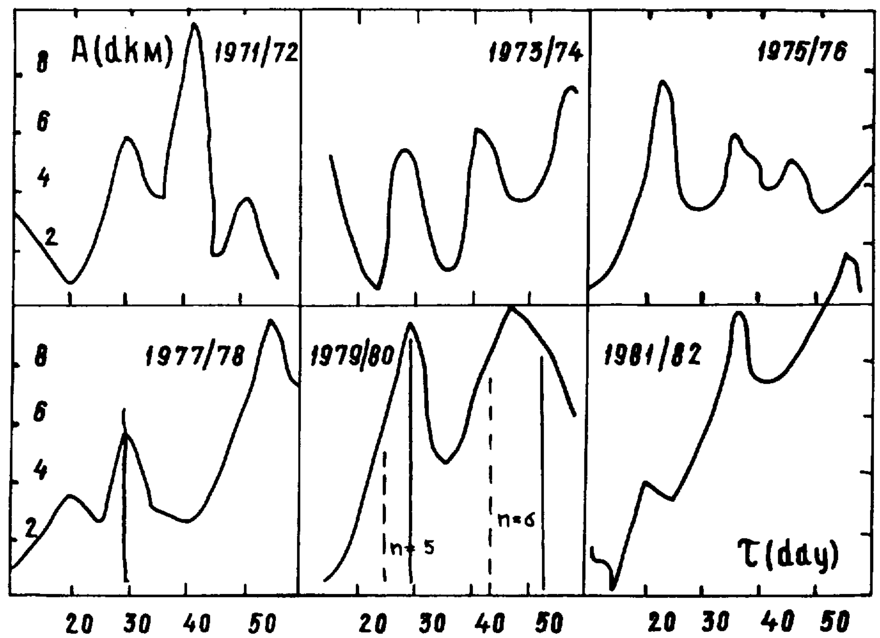

Fig.I.Results of two-dimensional analysis for daily values of the 30 mb heights (60N,transient waves only ,s=1, ---- h=∞, —— h=10 km)

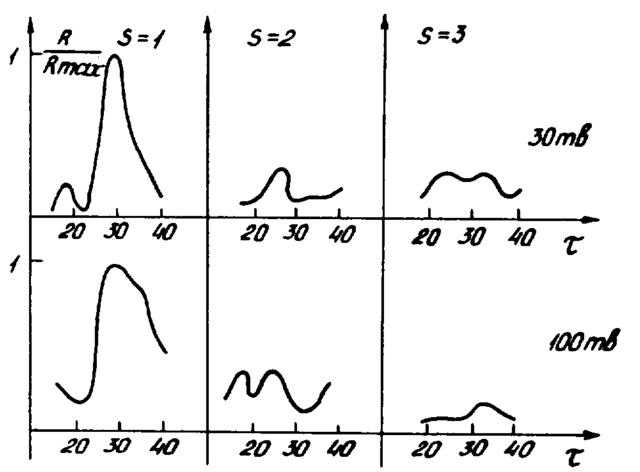

Fig.2.Vertical structure of the transient waves for different zonal wave-numberes(1972/1973)