N90-28178

ATMOSPHERIC PLANETARY WAVES INDUCED BY SOLAR ROTATION

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It is known that there are variations in the atmospheric processes with a period close to that of the rotation of the Sun (27 days). The variations are discovered in tropospheric processes (WASSERFAL, 1935), rainfalls (ROSENBERG, 1974), geopotential (KING et al., 1977) and in stratosphere (EBEL and BATZ, 1977; EBEL, 1981; KRIVOLUTSKY, 1982; KRIVOLUTSKY et al., 1987).

The main theoretical problem is the identification of the physical process by which these heterogeneous solar and meteorological phenomena are connected. VOLLAND (1979) using the astronomical observations found a 27-day harmonic of the solar constant with amplitude of about 0.1% and considering the process of heat transfer from surface of the Earth due to its periodic heating as a forcing effect and using methods accepted in the theory of tides obtained that the induced wave corresponding to a selected Rossby--Haurwitz mode (2,-6) should have an amplitude of almost an order of magnituder smaller than that obtained by King. IVANOVSKY and KRIVOLUTSKY (1979) proposed that the periodic heating of the ozone layer by the short wave radiation would be the reason of excitation the 27-day oscillations. It was also assumed that excitement takes place in condition of resonance with an excited mode (1,-5) corresponding to the conditions present in the stratospheric circulations. Now we shall discuss the possibility of the resonant excitation and make the presentation of the data analysis results which support this idea.

THE STRUCTURE OF RESONANCE WAVES

Linear tidal theory may be used to study the generation and the structure of the planetary waves generated by a heat ozone source. With the boundary conditions that the vertical wind should disappear at the ground and that the radiation condition is at infinite, it is found (IVANOVSKY and KRIVOLUTSKY, 1979) that for isothermal atmosphere the height structure becomes:

$$\frac{P_n^s(z)}{P_0(z)} \approx \frac{i(\gamma-1)K_2\cdot\left(K_1-\frac{\gamma-1}{\gamma}\right)e^{\frac{K_2 z}{H}}}{\delta'\cdot(K_2-K_1)\cdot\left(K_2-\frac{\gamma-1}{\gamma}\right)\cdot P_{00}} \times$$

$$\times \int_0^\infty e^{K_2 \xi} g_n^s(\xi)\,d\xi \qquad (1)$$

where $\gamma = C_p/C_v$, $K_1 = 1/\gamma$, $K_2 = (1/4 - \gamma-1/\gamma \cdot x \; H/h_n^s)^{-1/2}$, h_n^s – equivalent depth, $\sigma' = \sigma + \alpha s$, α – index of zonal circulation, $\alpha = u/a \cos\Theta$, u – zonal wind, a – radius of the Earth, σ – the frequency of 27-day rotation, $P_o(Z) = P_{oo} \exp(-Z/H)$.

It is known that near $h_o^s \approx \gamma H_{oo}$ the atmospheric waveguide behaves like a resonance cavity, so near this region:

$$h_n^s - H\gamma \approx \frac{\sigma - \sigma_n^s + i\nu_z/\bar{H}^2}{2\Omega} \cdot \frac{\partial h_n^s}{\partial f}$$

where $f = \sigma/2\Omega$, Ω – the angular frequency of the Earth's rotation.

We can use the expression for eigenfrequencies (DIIKY, 1969):

$$\sigma_n^s \approx \alpha \cdot s - \frac{2\Omega s}{n(n+1) + \frac{4a^2\Omega^2}{g h_n^s} B_n^s} \qquad (2)$$

where:

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

Using the expression (2) we find a value:

$$\frac{\partial h_n^s}{\partial f} = \frac{4a^2\Omega^2}{f^2 \cdot g} \cdot \frac{s}{B_n^s}$$

So that one can rewrite the expression (1) in the form:

$$\frac{P_n^s}{P_o(z)} = \frac{i(2-\gamma)\gamma H}{\frac{\partial h_n^s}{\partial f} \cdot P_{oo} \cdot \sigma'} \cdot \frac{\Omega\, e^{(K_2 z)/H}}{(\sigma - \sigma_n^s + i\nu_z/\bar{H}^2} \int_0^\infty e^{K_2 \xi} g_n^s(\xi)\, d\xi \qquad (3)$$

where ν_z is eddy viscosity coefficent, $\bar{H} = \gamma H/\gamma-1$. For example, the amplitude of the resonant wave ($\sigma \approx \sigma_n^s$) near the surface is:

$$\frac{P_n^s}{P_o(0)} \approx \frac{(2-\gamma)\gamma H}{\frac{\partial h_n^s}{\partial f} \cdot P_{oo}} \cdot \frac{\Omega}{\sigma} \cdot \frac{\bar{H}^2}{\nu_z} \int_0^\infty e^{\frac{\gamma-1}{\gamma}\xi} g_n^s(\xi)\, d\xi$$

The 27-day variability of the UV radiation (HEATH, 1973; ROTTMAN, 1983) and the existence of "ozone waves" - global longitudinal inhomogeneity - helps to calculate the value of P^s_n/P (Z) corresponding to ozone heating function:

$$q^s_{n,\sigma}(z) = \frac{1}{2\pi}\int_{-1}^{1}\int_{0}^{2\pi} Q(z,\varphi,\mu)\, e^{-i(s\varphi+\sigma t)}\,\Theta_n^s(\mu)\, d\varphi\, d\mu,$$

$$\mu = \cos\theta$$

$$Q(z,\varphi,\mu) = \sum I_{\lambda\infty}\sigma_\lambda \cdot n_{O_3} \cdot e^{-\frac{\tilde{\tau}_{\lambda,O_3}}{\cos Z}}$$

$$300\,\mathrm{nm} < \lambda < 360\,\mathrm{nm}$$

where $I_{\lambda\infty}$ - solar irradiance, σ_λ - crossection of absorption, n_{O3} - concentration of ozone, Z - zenit angle, Θ^s_n - function of Hough. With using the values of variability such as:

$$\Delta I_{\lambda\infty}/I_{\lambda\infty} \approx 0.005\ (0.5\%)$$

$$\Delta M_{O_3}/M_{O_3} \approx 0.1\ (10\%)$$

and:

$$\nu_z \approx 5\times10^4 \mathrm{cm}/\mathrm{c}^2$$

we get the estimation of the 27-day wave amplitude:

$$P^1_{-5}/P_{00} \approx 0.005\ (5\ \mathrm{mb})$$

We have used $n = -5$ and $s = 1$ because these values of wave-numbers give the eigenperiod near 27 days. The value of the wave disturbance according to our estimation and the expression (3) is near to 100 gpm or more if the resonance conditions exist (on 30 mb).

RESULTS OF DATA ANALYSIS

Now we shall make the presentation of some improvements for the existence of the resonant mechanism.

Figure 2 borrowed from KRIVOLUTSKY et al. (1987) presents evolution of amplitudes of the 27-day harmonic in series of H and W (solar spots number). It could be seen that the curves for H_{30} and W are rather well synchronised and periods exist when the amplitudes of the oscillations with the period close to 27 days are significant (more than 100 gpm).

Figure 3 showes the evolution of the phase difference in 27-day oscillations of H_{30} and W. The relative invariance of the difference should testify to the coherency of the solar and atmospheric oscillations of this period. It could be seen that the curves for H_{30} and W are rather well synchronised when the amplitudes are significant.

Figure 4 allows to see the longitudinal behaviour of the phase for the period when the amplitude is large. It is clear that the wave is westward with the wave-number s = 1.

CONCLUSIONS

Theoretical calculations with the use of the tidal theory reveal the possibility of resonance in the atmospheric system to the 27-day oscillations (mode n = -5, s - 1) with amplitude of the wave more than 100 gpm on 30 mb surface due to the absorption in Huggins bands which changes by about 1% and to the existence of longitudinal inhomogeneity of total ozone. The data analysis reveals such waves in the atmospheric processes and the correlation with the solar activity.

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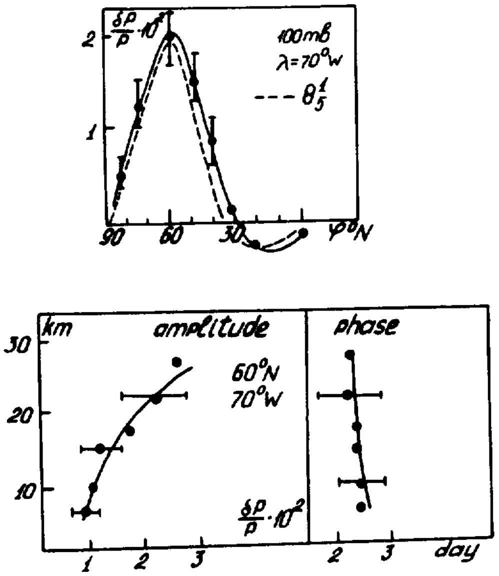

Fig.I.Spatial structure of a transient wave with the27-day period(I972/I973,70 w,60 N)

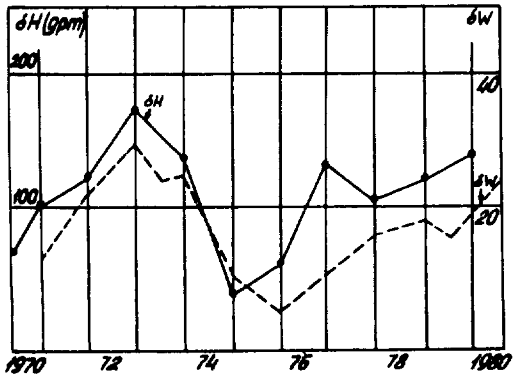

Fig.2.Evolution of amplitudes of the 27-day harmonic in series of H_{30} (60 N,70 W) and W(solar spots number)

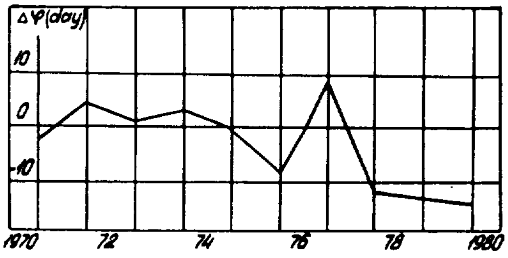

Fig.3.Evolution of the phase difference in the 27-day oscillations of H_{30} (60 N,70 W) and W(solar spots)

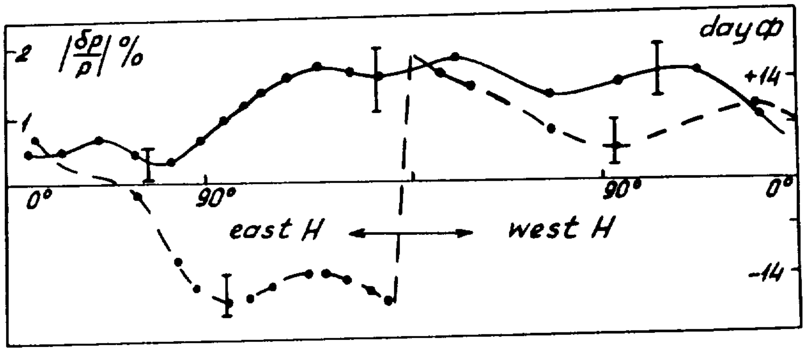

Fig.4. The longitudial structure of the 27-day harmonic in series H_{I00}(60 N,I972/I973 ,phase—dashed line)