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A STATISTICAL STUDY OF VARIATIONS OF INTERNAL GRAVITY WAVE ENERGY CHARACTERISTICS IN METEOR ZONE

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Internal gravity wave (IGW) parameters obtained by the radiometeor method have been considered by SPIZZICHINO, (1975); GAVRILOV et al., (1976); GAVRILOV and DELOV, (1976); KARIMOV and LUKYANOV, (1979); KAZANIKOV and PORTNYAGIN, (1981) and KALCHENKO et al., 1983. This paper presents the results of the processing of regular radiometeor measurements taken during 1979-1980 in Obninsk (55.1°N, 36.6°E).

The Obninsk meteor radar takes simultaneous measurements in four areas of the meteor zone which correspond to antenna directions northwards, westwards, southwards and eastwards. The instrumentation used is described in PORTNYAGIN and SHIRENGER (1978), and the method of statistical data processing - in GAVRILOV (1984). The meteor station determines for each of the four directions a number of wind velocity values at random time moments at the average height of the meteor zone $z = 93$ km. To analyze the IGW horizontal structure, the area observed is divided in the direction of the antenna beam into horizontal subareas of width $x = 100$ km with the centers x_ℓ biased by $\Delta x_\ell = 25$ km. For every group of meteor echoes in each of the horizontal subareas, a high frequency filtration (averaging over 10 minute intervals) and a low frequency filtration are performed (GAVRILOV, 1984), after which amplitude and phase spectral analyses of data over sliding 12-hour time intervals are carried out. The subsequent statistical analysis of the spectra obtained makes it possible to recognize the IGW spectrum from the background of noise (GAVRILOV, 1984), as well as to determine the values of projections of horizontal wave numbers k_h and phase velocities c_h of IGW to horizontal axes oriented along the antenna beams (see above).

Radiometeor data obtained in Obninsk for 582 days during the period from February 1979 to November 1980, were processed by the above-mentioned method.

Fig. 1 shows histograms of the distributions of IGW parameters for summer for all the sounded directions. They look alike and have maxima at the values of $c_h \sim 50\text{-}75$ mps, $V \sim 4\text{-}5$ mps and $k_h \sim (1\text{-}2)\ 10^{-2}\ \text{km}^{-1}$. Of similar appearance are histograms of the distributions of IGW parameters for other seasons. Analysis of the IGW quantities propagating in various directions has revealed that IGW propagating southeastwards prevail in winter, whereas those propagating northwestwards prevail in summer. The same seasonal dependence of the prevailing directions of the IGW propagation was earlier found out from observations of night airglow wave variations (GAVRILOV, 1982). Causes for this regular feature can be seasonal variations in the location of IGW sources and those in the direction of the zonal flux in the stratosphere which influences the IGW propagation from tropospheric sources (GAVRILOV, 1982).

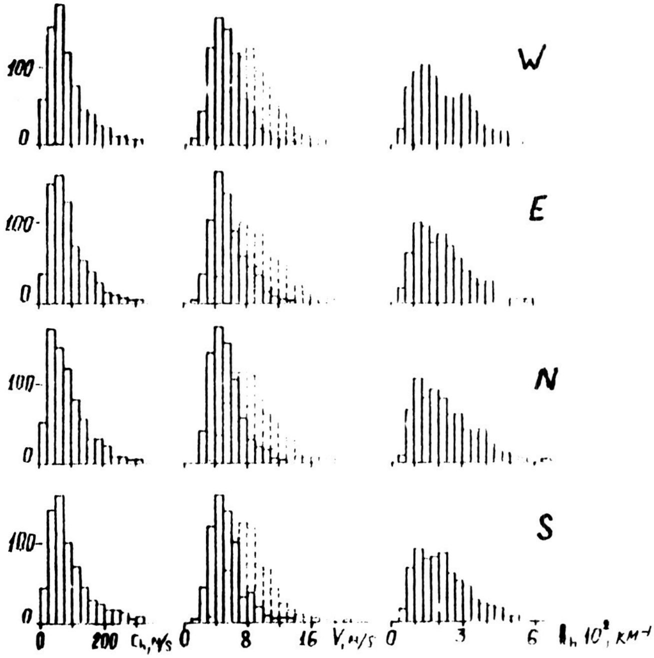

Fig. 1 Histograms of the distributions of the IGW parameters for all the IGW directions. Dotted lines correspond to the corrected values of V_{corr}.

Fig. 2 shows the mean values of c_h, V and k_h calculated separately for each month of the observation period and for the four groups of the IGW directions considered. It can be seen that c_h and k_h have no pronounced seasonal variations. The phase velocity of c_h changes within $c_h \sim 30\text{-}150$ mps and decreases with the increase of τ. The values of k_h lie within (1.5 - 2.5) 10^{-2} km^{-1} and are hardly dependent on τ at all. The most pronounced variation is observed only in the amplitudes of the velocity V; for IGW propagating in all the directions and for all the frequency groups, the maximum of V ~ 7-8 mps is observed during the winter months (November to March), and the minimum of V 4-6 mps - in summer (Fig. 2). In Figs. 1 and 2 the histograms and V_{corr} are shown by dotted lines for the values corrected for the effect of the finite number of registered meteors (GAVRILOV, 1984). The mean winter values increase up to $V_{corr} \sim$ 12-15 mps, and the mean summer ones - up to $V_{corr} \sim$ 8-9 mps.

The components of the wave fluxes of energy F_i, heat F_{Ti}, momentum F_{ij} and mass F_{mi} are described by formulae of the type:

$$F_i = \langle p'v'_i\rangle + Ev_{io}\ ;\ F_{TC} = \rho_o C_\rho \langle T'v'_i\rangle;\ F_{ij} = \langle v'_i v'_j\rangle;\ F_{mi} = \langle \rho'v'_i\rangle, \quad (1)$$

where dashes denote the wave components and the subscript o the background components of pressure p, density ρ, temperature T, the wind velocity component v_i; c_p is the specific heat capacity at constant pressure; E is the wave energy; the sign < > denotes averaging over the wave period; i = x, y, z correspond to the x, y, z axes oriented eastwards, northwards and upwards. The value of p', ρ', T' and v'_z required for calculations according to (1) are found from the measured v'_x and v'_y by making use of hydrodynamics equations.

To perform the calculations, apart from the zonal wave number k_x, one must also know the meridional wave number k_y. Statistical analysis has revealed that in the meteor zone the "noise" of IGW coming from various incoherent sources is mainly observed, and that harmonics with identical periods are found in mutually perpendicular directions only occasionally. Therefore, it is impossible to calculate the values of (1) for individual harmonics.

However, considering the problem of the influence of IGW on the thermal regime and circulation of the upper atmosphere, not individual but long term averages of wave flux are important. The measured probability densities of the distributions of k_y (Fig. 1) and statistically reliable measurements data make it possible to use the methods of statistically modelling (Monte-Carlo) to calculate the mean values of (1). On a computer, by transformation of data from a random number generator, the random value k_y is modelled which has a probability distribution equal to the experimental. Wave fluxes (1) and their monthly mean values are calculated. To minimize the error, calculations are made for 10 different realizations of the random value k_y and the results are then averaged again.

Fig. 3 shows seasonal variations of the mean values of wave fluxes, all of which have a pronounced seasonal variation. The vertical energy flux F_z varies from 6 x 10^{-3} Wm^{-2} in winter to $1\text{x}10^{-3}Wm^{-2}$ in summer. The

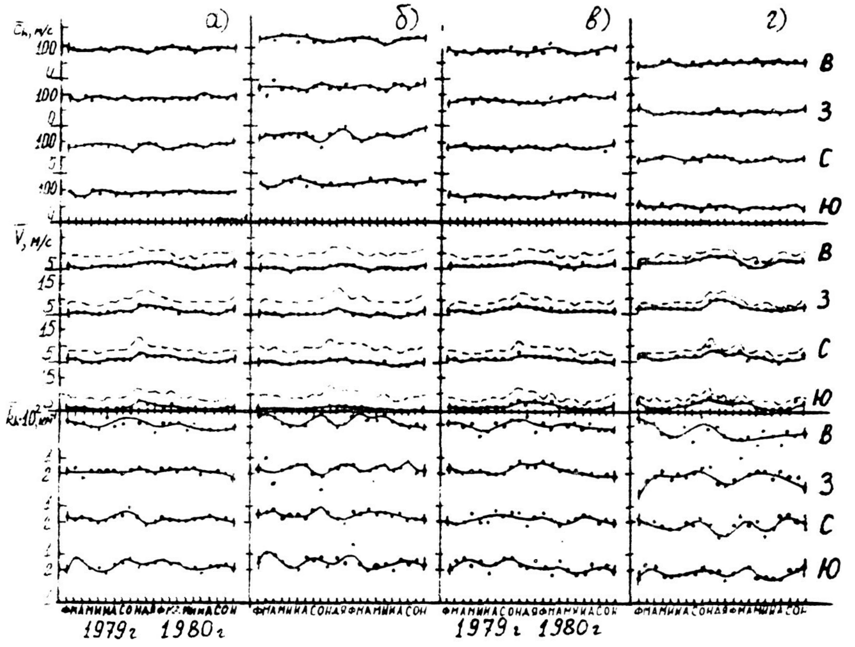

Fig. 2 Mean values of c_h, V and k_h for the groups of IGW propagating to the North (N), West (W), South (S) and East (E).

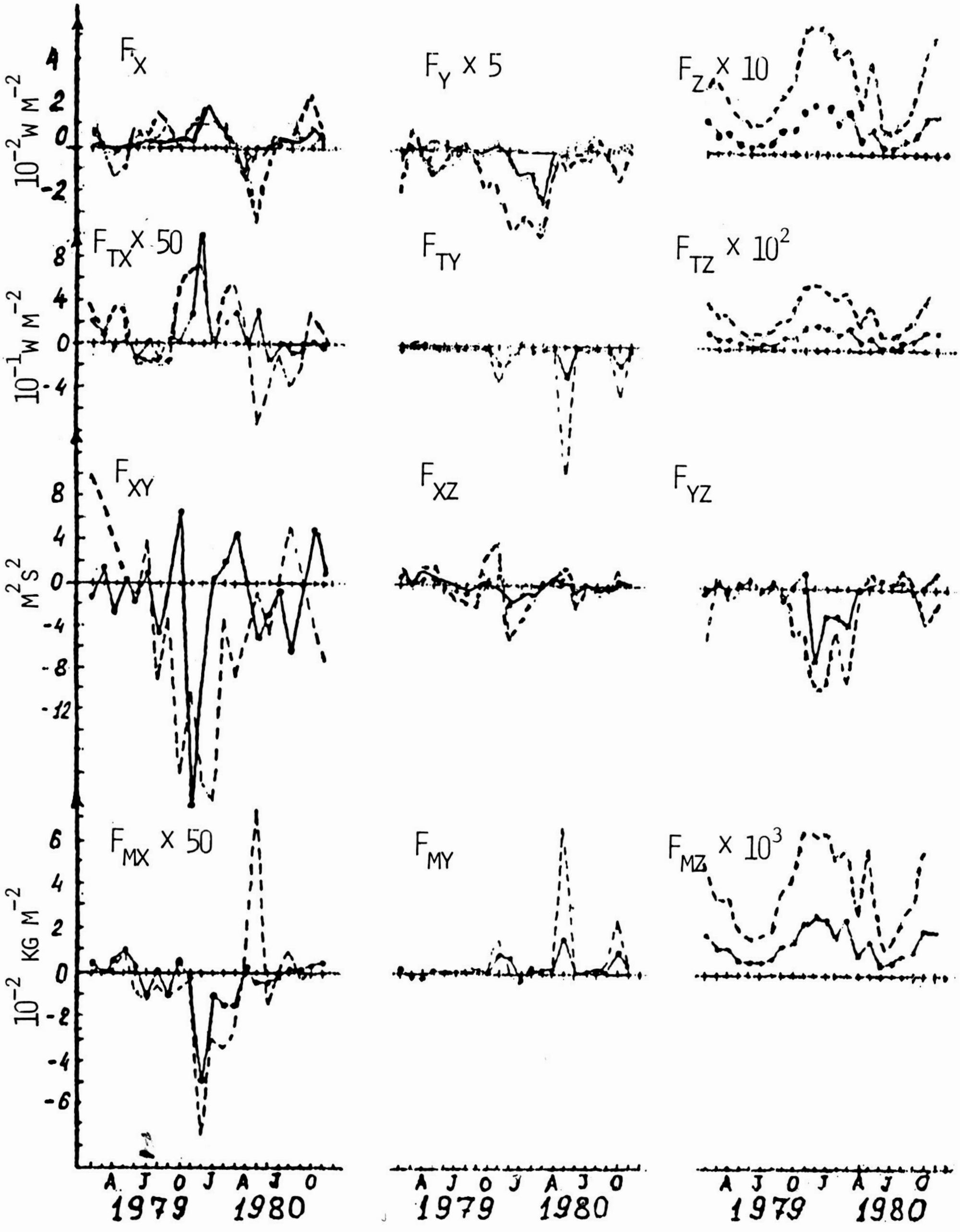

Fig. 3 Seasonal variations of the mean values of wave fluxes. Dashed lines correspond to the corrected values V_{corr}.

directions of F_x and F_y correlate fairly well with the signs of the background wind components V_{xo} and V_{yo}. The vertical mass flux F_{mz} is always directed upwards and is maximal in winter. The variations of F_{mx} and F_{my} are in antiphase with the variations of F_{Tx} and F_{Ty}. The velocity of the vertical wave transport of mass is comparable with the background vertical velocity. The vertical wave flux is of the type of $F_{Tz} = F_z$. The values and signs of the moment fluxes F_{xz} and F_{yz} in Fig. 3 correspond to wave accelerations in the zonal direction in winter of -(80-100) ms^{-1}/day westwards, and in summer +(10-20) m s^{-1}/day eastwards; in the meridional direction, to +(10-50) m s^{-1}/day in spring and autumn and -(10-50) m s^{-1}/day in winter and summer. This gives an experimental confirmation to the existing hypothesis that IGW in the upper atmosphere contribute to the drag of the zonal flux and the formation of meriodional circulation. However, the values of wave accelerations obtained are somewhat lower than those used in numerical modelling (HOLTON, 1983), particularly for summer.

The variations of the IGW energy E with $\tau \sim 0.5$-6 hrs in the course of a 48-day cycle from July 8 to August 24, 1979, were investigated. The results of the spectral analysis of E and the background wind for four sounded directions in the period mentioned show that the main harmonics of the background wind are two day and semi-diurnal, whereas that of the wave energy is diurnal. The energy spectra of the wave variations of the meriodional wind increase in the region $\tau \geq 2$ days in contrast to the spectra of E for zonal directions. Since tides in the middle latitudes are mostly stable, the main mechanism of the formation of diurnal and semi-dirunal variations of E is the modulation of IGW propagating from below under the influence of the vertical profiles of temperature and wind produced by tides. The diurnal tide in the meteor zone has much smaller vertical wavelengths than the semi-diurnal tide and a quasi-two diurnal variation. Therefore, it produces the largest amplitude of modulation of E.

The variations of E with 4 to 8 day periods can be accounted for by first possible modulation of the propagating IGW by planetary waves and second, meteorological processes in the troposphere with 4 to 8 day periodicity causing an enhanced generation of IGW propagating upward to the meteor zone.

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