SPACE AND TIME VARIATIONS AND TURBOPAUSE DYNAMICAL STRUCTURE

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Studies of different characteristics of turbulence in middle atmosphere are being carried out at present by means of MST-radars, by partial reflections (up to 100 km), radar and photographic observations of meteor trails (80-100 km), and also by rocket (80-140 km) and grenade (30-90 km) measurements. The least studied level here is a turbopause - a transitional zone between the regions of turbulent and non-turbulent motion at the height of more than 100 km. At the same time, regular ionospheric observations of the sporadic E layer make it possible to get information of the turbopause behaviour.

Indeed, the E_s layer is the only large-scale formation in the midlatitude ionosphere whose parameters are for the most part determined by dynamical characteristics of the middle atmosphere (GERSHMAN et al., 1976). The region of most frequent occurrence of E_s coincides with the zone of wind shears maxima (OVEZGELDIYEV et al., 1976), wind shears being the sources of hydrodynamic turbulence at h>100 km. Thus, the conditions of E_s formation and those of dynamical stability conservation prove to be interconnected, a fact which allows us to consider E_s to be a natural indicator of the turbopause.

An important property of E_s is transparence, caused by the scattering of radio waves at small-scale irregularities of electron density, those are from random turbulent motions (GERSHMAN and OVEZGELDIYEV, 1973). The increase of turbulence intensity leads to the increase of E_s inhomogeneity extent and to the increase of the scattered energy part. It leads to the increase of E_s transparence range ($\Delta f_b/f_b$). We say in this respect that the value of the transparence range is a measure of the turbulence intensity at the height of the sporadic layer. Thus, studying E_s behaviour one can realize some of the characteristics of lower thermosphere turbulence. These statements are confirmed by investigating the dynamical structure of the turbopause by means of a spectrum analysis method.

To illustrate the above mentioned, see Figure 1 where the profiles of E_s transparence range are given for Ashkhabad, the data having been obtained by hourly observations in 1957-65 at daytime (solid line). The dotted line represents the probability of E_s occurrence at various heights. A common feature for all profiles is the transparence increase at the height of 90-100 km, indicating turbulence intensification at this height level. Since a transparence range of less than 0.1 (in relative units) is induced by radio wave reflection from a thin layer but not by a scattering on the irregularities (KORSUNOVA, 1974), its corresponding height indicates a level where turbulence does not play any significant part, i.e., the turbopause. It is evident that the height of maximum E_s occurrence coincides with this level within a few kilometers.

Time spectra of the critical frequency f_oE_s and blanketing frequency f_bE_s for the records of a spaced chain of ionosphere vertical sounding stations have been studied by means of a maximum entropy method, while coherence spectra were analysed with the Blackman and Tukey method (KARADZHAYEV, 1982). It has been found out that the frequency parameters spectrum of E_s within the range of 1-10 cycles/h is discrete with one or two maxima (Figure 2). The first, a low frequency maximum with T=40 min, is of larger amplitude, stable and

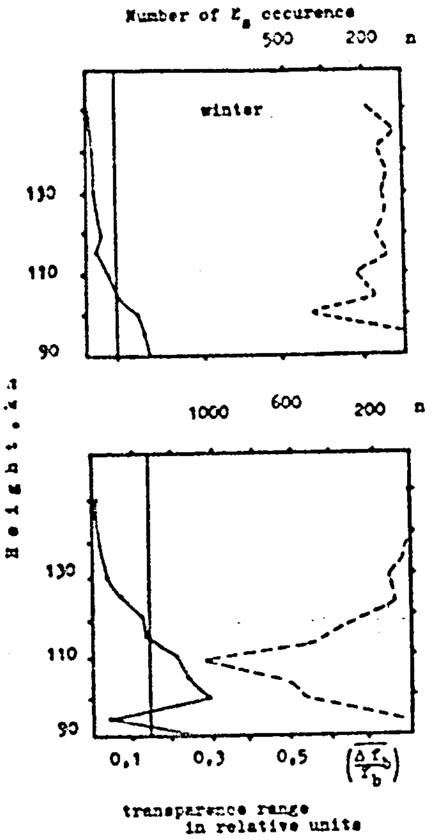

Figure 1. Height profiles of E_s occurrence and transparence range $(\overline{\frac{\Delta f_b}{f_b}})$ for Ashkhabad.

exists permanently; the second one with T=10 min is less stable, occurs irregularly and more often so within f_oE_s spectra. Further, the first maximum corresponds to a higher level of coherence which decreases as the distance between the stations increases. Analysing these results in terms of the theory of E_s formation at mid-latitudes, one can conclude that the low-frequency maximum is induced by cellular eddies, usually interpreted as wind shears with horizontal dimensions of not more than 300 km. Irregularity, small amplitude and low coherence in the range of the second maximum are indicative of the fact that turbulence must be its only source. Horizontal dimensions of the corresponding eddies, which are about 40 km, may be regarded as an indication of the outer scale of turbulence. A corresponding spectrum of turbulence in the region of the outer scales is defined by the expression $E(k) \sim k^{-3}$.

Figure 3 shows diurnal variations of (a) the most probable heights of E_s and (b) transparence range characterizing the behaviour of the turbopause height and of turbulence intensity for summer solstice conditions. It is obvious that

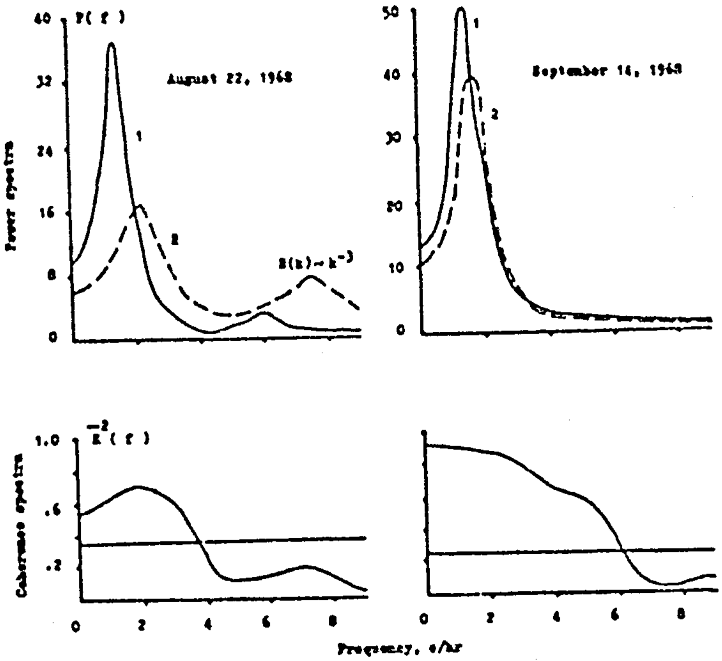

Figure 2. MEM power spectra f_0E_s(1), f_bE_s (2) and coherence spectra of these parameters.

at mid-latitudes h_T varies with a semi-diurnal period, reaching its maximum at 0600 and 1800 LT with an amplitude of ~10 km. As it is clear from transparence range variations, turbulence intensity varies with a diurnal period, reaching its maximum at night. The amplitude of variations from day-time till night is by a factor of 3.

Annual variations of the above-mentioned turbopause parameters for night hours are represented in Figure 4 where the vertical lines give the dispersion when computing the average. Figure 4 shows that the character of h_T variations depends upon latitude. At $\phi<50°$N the turbopause height varies with an annual period, increasing in summer and decreasing in winter. At $\phi>50°$N besides a summer maximum there exists a winter maximum as well. The amplitude of variations increases with latitude, but does not exceed 7 km. Turbulence intensity has a semi-annual variation with maxima at solstices, the winter maximum amplitude increasing as the latitude increases. Circles in the figure represent the results of the turbopause height measurements in the rocket experiments and a small-scale turbulence (1-5 km) intensity, defined by the fading meteor trail reflections for the corresponding latitudes (TEPTIN, 1976; VON ZAHN, 1970; SCHOLZ and OFFERMANN (1974); ROSENBERG et al., 1973); GOLOMB, 1974; SCHAEFER, 1969; TRINKS et al., 1978). It may be noted that there exists a satisfactory agreement in the order of values of the turbopause height and with the character of the annual variations of turbulence intensity, measured by different methods. Regularities of the turbopause space and time variations deduced, are also characteristic of the southern hemisphere stations, situated in other longitudinal zones.

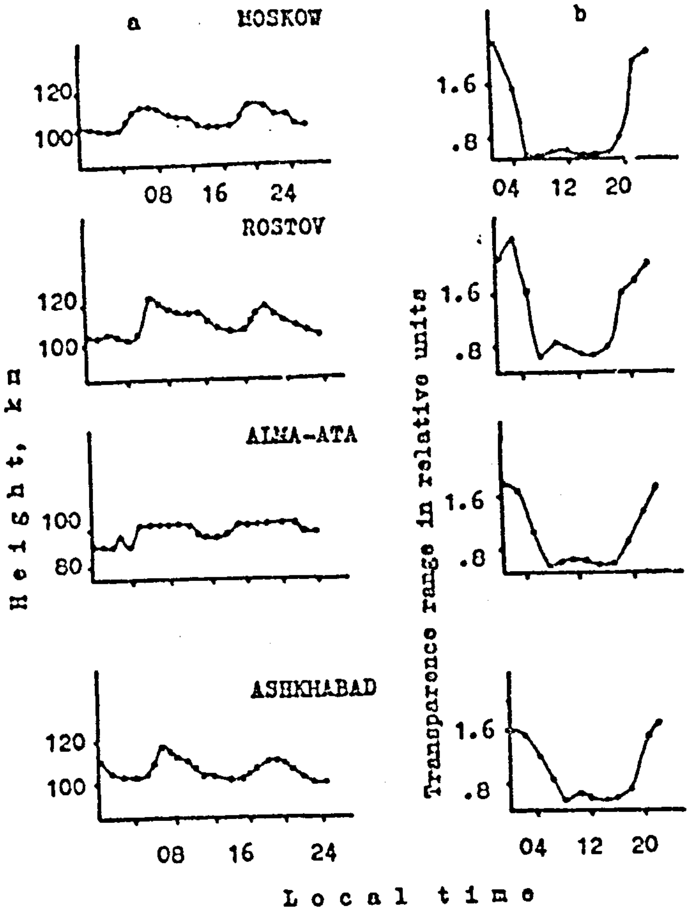

Figure 3. Diurnal variations of the most probable heights of E_s ($\overline{hE_s}$) and transparence range ($\frac{\overline{\Delta f_b}}{f_b}$) for summer solstice.

Thus, from the above, one can come to the following conclusions:

(1) turbulence intensity is higher at night than in the daytime;
(2) the height of the turbopause in latitudes 30–60°N is higher in summer than in winter and at equinoxes;
(3) variations of the intensity of the turbulent processes are characterized as semi-annual, with maxima at solstices and minima at equinoxes;
(4) the amplitude of both turbopause parameters increases as the latitude increases.

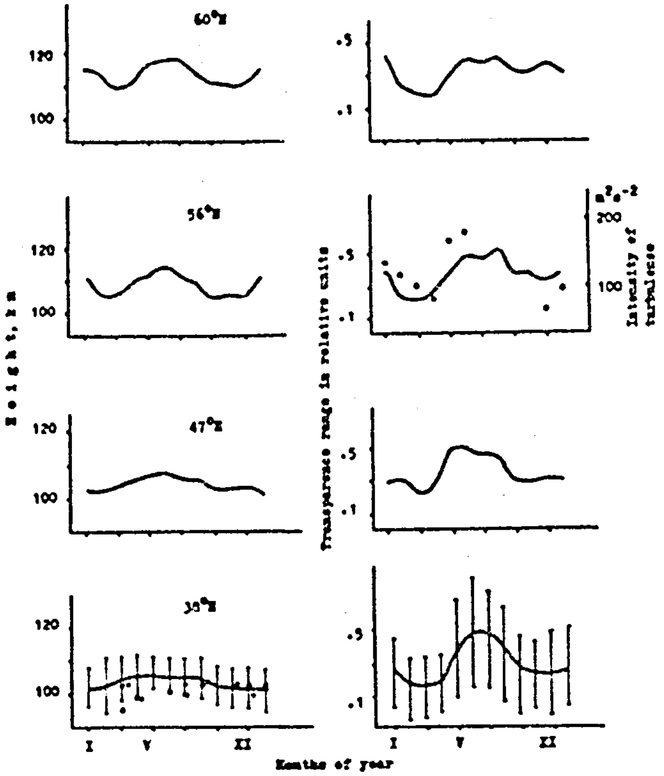

Figure 4. Annual variations of the turbopause heights and intensity of turbulence for nighttime. Circles refer to the results of rocket measurements.

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