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Longitudinal variability in the dynamical regime of the midlatitude lower thermosphere

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Abstract. The longitudinal dependence and regional features of the dynamical regime in the lower thermosphere may be considered as an important part of the middle atmosphere spatial structure. The longitudinal variability is demonstrated on the basis of the coordinated upper mesosphere/lower thermosphere long-term wind measurements along one latitude circle (52°N) at two sites. We have used the radio measurements at Badary (East Siberia) and Collm (central Europe). The longitudinal variability in the prevailing wind, tidal structure, planetary wave activity, and large-scale variations (semiannual, annual and quasi-biennial oscillations) could be interpreted as consequence of "coupling from below". This concept is supported by results of some international campaigns.

1. Introduction

The terrestrial thermosphere and ionosphere form the most variable (in time and in space) part of the Earth's atmosphere. Because our society depends on technological systems that can be affected by thermospheric and ionospheric phenomena, understanding, monitoring and ultimately forecasting the changes of the thermosphere-ionosphere system are of crucial importance to communications, navigation and the exploration of near-Earth space.

The reason for the extreme variability of the thermosphere/ionosphere system is its rapid response to external forcing from the various sources, i.e., solar ionizing flux, energetic particles and electric fields imposed through the interaction between the solar wind, magnetosphere and ionosphere as well as coupling from below ("meteorological influences") by the upward propagating broad spectrum internal atmospheric waves (planetary waves, tides, acoustic-gravity waves) generated in the stratosphere and troposphere.

The influence from above is controlled mainly by geographical and geomagnetic latitude, whereas the meteorological influence could be controlled by geographical longitude because of the well-known longitudinal inhomogeneity of the lower atmosphere processes, the regional peculiarities of the internal waves sources and the longitudinal differences in the conditions for upward propagation of internal atmospheric waves from the lower atmosphere.

The dynamical regime of the midlatitude lower thermosphere/ionosphere certainly must be sensitive to the coupling from below. The close connection between the circulation in the lower thermosphere, mesosphere and stratosphere were demonstrated not once [e.g., *Kazimirovsky*, 2002]. Therefore the upper mesosphere/lower thermosphere (MLT) wind field nonzonality could be sign of the external forcing [*Kazimirovsky et al.*, 1999]. This effect may significantly manifest itself in the different amplitudes of the prevailing wind (especially zonal wind), in the different moments of the winter-to-spring transition of the zonal lower thermospheric circulation, in the different response to the sudden stratospheric warmings, and in the different response to the geomagnetic storms and solar proton events [*Kazimirovsky and Vergasova*, 2001]. The longitudinal variability in the tidal structure, planetary wave activity and large-scale variations could be interpreted as consequence of coupling from below as well. We have demonstrated the longitudinal variability in the dynamical regime in the MLT region revealed on the basis of the coordinated wind measurements along one latitude circle at two or more sites [e.g., *Kazimirovsky and Kokourov*, 1991; *Kazimirovsky and Vergasova*, 2001; *Kazimirovsky et al.,* 1982a, 1982b, 1988, 1999;

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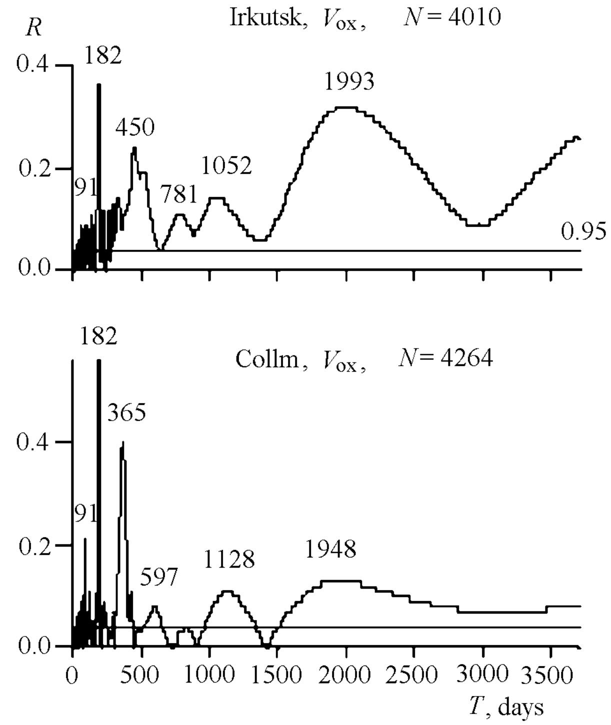

Figure 1. Spectra of daily zonal prevailing wind variations for two observatories along 52°N latitude. N, number of values. Significance level ≥ 0.95. V_{ox} is positive eastward.

Schminder et al., 1980, 1987]. With respect to the above mentioned results the aim of this paper is to present the further evidences of the longitudinal variability.

2. Data and Results

We have used the results of the continuous wind measurements at the upper mesosphere and lower thermosphere, provided at two stations: Badary, East Siberia (52°N, 102°E, geomagnetic latitude $\varphi = 41°$) and Collm, central Europe (52°N, 15°E, geomagnetic latitude $\varphi = 50°$). At Collm and Badary, spaced antennas are used (D1 techniques), but they are on low-frequency (200 kHz for Badary, 177, 225, 270 kHz for Collm) nighttime broadcast radiostations whose signals have experienced an oblique single reflection (one hop). The ionized irregularities below ~ 110 km move with neutral air. The mean height for these reflections is 90–95 km. Similar fades analysis is applied to the E-W/N-S components and harmonic analysis used to determine the mean (prevailing) wind and 12 hour tidal oscillations. The D1 technique has been calibrated repeatedly and independently by meteor radars and by rocket wind measurements, so we may be sure that the motions considered are the MLT neutral winds.

Figure 1 demonstrated the zonal prevailing wind spectra for Badary and Collm, calculated for daily-averaged values. The semiannual periods are well obvious for two points, but annual variations have small input for Badary and are rather intensive for Europe. There are intensive variations with ~5.5 year period, especially for Badary.

As well known, the planetary waves contribute significantly to the variability of MLT winds. In the mesosphere and lower thermosphere, wave-like fluctuations are sufficiently large to often mask the prevailing or mean state of the atmosphere. Tropospheric ally forced planetary waves with periods of between 2 and 30 days have been observed to penetrate up to heights near 110 km under favorable conditions. For the comparison of the quasiperiodical structure of the prevailing wind and semidiurnal tidal amplitudes we have used the statistical analysis based on high spectral resolution technique, the "correloperiodogram" type of periodogram analysis. This method is described by *Vitinsky et al.* [1986] and allows assessment of the amplitude and significance level of the signal at particular frequencies where the frequency considered can be incremented in steps of arbitrary size. This method is similar to Lomb-Seargle's well-known method. The main advantage of this method is that it can obtain spectral estimates in a frequency range of interest by use of arbitrarily small frequency steps [*Pancheva et al.,* 2000].

The results of periodogram analysis of the zonal prevailing wind and the zonal semidiurnal tide for Badary and Collm are presented in Table 1. The periods and amplitudes were calculated for each 1-year interval and for the periods 1975–1995 (solar cycle) for Badary and 1979–1997 for Collm. Only statistically significant results (≥ 0.95) are shown in Table 1. The differences between the observatories with different longitudes are evident in the spectral structure and in the amplitudes of the similar periods. It is necessary to mention that observed periods form so-called "period bands" [*Lastovicka*, 1997] possibly due to Doppler shifting.

It is interesting to also compare the seasonal variations of the zonal semidiurnal tide because tides could be preferred carrier of upward influence (especially for planetary waves) across the mesopause. Figure 2 demonstrates the variations of the amplitude of fluctuations with three typical "bands" of periods 7–13 days, 14–18 days and 19–25 days. Figure 3 presents the variations of the amplitude of fluctuations with four typical periods 8–11 days, 14–17 days, 20–23 days and 26–29 days for zonal prevailing wind and zonal semidiurnal tide. The annual-averaged data were calculated for winter (December, January, February) and summer (June, July, August) separately. Sometimes (especially for summer) the variations for both observatories are in opposite phases.

We know that in principle the variations of solar and geomagnetic activity may affect the mesospheric and lower thermospheric wind systems even at midlatitudes [e.g., *Singer et al.,* 1994]. Really, the variability of the zonal prevailing wind is well correlated with the number of geomagnetic disturbances (Figure 4). As a measure of the wind variability we used the number of maximal deviations from the annually averaged velocity value (±20 m s^{-1}) during the year. However, we have shown recently that we have an opposite relationship between zonal wind and solar activity index $F_{10.7}$

Table 1. Results of the Periodogramanalysis

	Periods (days), Significance level ≥ 0.95	
	The Zonal Prevailing Wind	Zonal Semidiurnal Tide
Badary 1975–1995	27(1.2), 35(1.6), 57(2.3)	13(0.5), 43(0.5)
Collm 1979–1997	No significant periods	23(0.4), 30(0.5)
Badary 6.1981–5.1982	13(2.3), 15(1.5), 19(1.3), 22(1.7), 27(1.9), 30(3.0), 37(2.2), 47(3.3), 56(3.4)	13(1.3), 18(1.4), 21(1.4), 23(1.3), 26(3.1), 29(1.4), 32(2.1), 47(1.6)
Collm 6.1981–5.1982	No data	No data
Badary 6.1982–5.1983	12(0.9), 17(1.2), 22(1.1), 27(1.3), 32(1.5), 36(1.6), 45(1.0)	12(1.0), 17(1.2), 20(1.3), 22(2.4), 27(1.2), 30(1.2), 34(2.2), 55(1.8)
Collm 1.–2.1983	9(2.1), 16(3.3), 23(4.5), 47(3.3)	10(1.6), 12(1.4), 16(1.1), 23(2.6), 49(2.6)
Badary 6.1983–5.1984 54(1.8)	21(1.7), 23(1.8), 28(2.8), 34(2.0), 40(1.8), 42(1.8), 56(1.3)	15(1.4), 22(1.3), 27(0.8), 31(1.5), 36(1.4),
Collm 1.–3.1984	23(7.7)	9(1.1), 14(1.8), 21(1.8), 28(2.5), 49(2.6)
Badary 6.1984–5.1985	14(2.6), 21(2.9), 27(3.5), 32(2.5)	11(1.1), 13(1.5), 18(1.0), 21(1.7), 23(1.3), 28(1.2), 32(1.0), 40(1.9), 52(2.8)
Collm 9.1984–1.1985	13(1.5), 26(3.1), 47(4.6)	12(1.3), 14(1.9), 16(1.7), 19(1.3), 25(1.7), 44(3.0)
Badary 6.1985–5.1986	12(1.7), 14(1.8), 19(1.9), 21(3.1), 36(4.5)	8(1.1), 11(1.1), 16(1.4), 24(1.3), 28(1.8), 34(2.5), 38(1.3), 43(1.8), 58(1.7)
Collm 6.1985–5.1986	16(1.3), 18(2.0), 23(1.3), 28(1.7), 40(1.4)	10(0.6), 12(0.5),14(0.7), 18(0.8), 22(1.2), 29(0.7), 37(1.0), 43(1.0)
Badary 9.1986–5.1987	19(2.9), 26(3.2), 39(6.0), 50(3.4)	10(1.6), 16(1.9), 21(1.9), 26(2.3), 29(1.5), 37(1.2), 53(2.6)
Collm 9.1986–5.1987	25(1.4), 31(1.3), 43(3.1)	13(0.8), 18(0.8), 22(1.4), 25(1.7), 31(1.4), 39(1.1)
Badary 6.1987–5.1988	22(2.0), 39(3.1), 58(2.4)	12(1.0), 18(1.2), 21(1.1), 25(1.3), 29(1.4), 32(1.4), 38(2.9), 48(1.5), 57(2.1)
Collm 6.1987–5.1988	12(1.8), 30(1.7), 39(2.9), 45(2.8)	17(0.9), 24(1.1), 28(0.7), 31(0.7), 36(0.9), 42(0.6), 49(1.2)
Badary 12.1988–11.1989	19(2.2), 21(2.5), 23(2.3), 27(2.3), 31(2.6), 56(5.3)	10(0.9), 16(1.5), 19(1.5), 25(2.2), 29(1.6), 55(2.2)
Collm 12.1988–11.1989	16(1.7), 31(2.4), 42(2.3)	31(2.8), 44(1.4), 52(1.3)
Badary 12.1989–11.1990	13(1.6), 17(1.7), 22(2.2), 25(2.2), 28(2.2), 48(1.5)	14(0.7), 16(1.2), 18(1.2), 25(1.1), 27(1.6), 30(1.6), 37(0.9)
Collm 12.1989–11.1990	21(2.1), 33(1.8), 42(2.2)	13(0.7), 15(0.7), 21(0.8), 27(1.2), 39(0.7)
Badary 12.1990–10.1991	12(1.2), 16(2.2), 23(1.4), 36(1.8), 52(3.3)	18(1.3), 22(1.4), 24(2.4), 28(2.1), 32(2.0), 37(1.6), 40(1.8), 48(1.9)
Collm 12.1990–10.1991	12(1.8), 15(1.5), 21(2.2), 27(1.9), 31(2.4), 40(2.4)	10(0.9), 14(1.1), 22(2.1), 24(1.2), 29(1.4), 36(1.4), 42(1.3), 55(1.4)
Badary 2.1992–6.1992	14(1.8), 22(1.6), 26(1.2), 32(1.1), 45(1.4)	11(0.9), 13(1.4), 18(1.8), 22(1.7), 30(1.2), 37(1.7)
Collm 12.1991–11.1992	22(1.8), 27(2.6), 31(1.7), 39(2.1), 54(3.3)	11(0.9),13(0.8), 16(0.9), 19(0.7), 22(0.8), 25(1.5), 33(0.9), 43(0.9), 54(1.4)
Badary 2.–3.1993	12(2.7), 22(4.9)	9(1.4), 11(1.2), 15(2.3)
Collm 12.1992–11.1993	27(2.1), 32(2.4), 46(2.2)	9(0.9), 11(1.0), 13(1.2), 22(1.4), 29(1.1), 34(0.9), 39(1.5), 45(1.2), 54(2.1)
Badary 1.–4.1994	20(3.3), 43(7.7)	15(2.9), 23(5.2)
Collm 12.1993–11.1994	9(1.8), 18(1.7), 20(1.7), 24(2.7), 36(2.1), 45(1.7)	13(0.9), 15(0.8), 17(0.8), 20(1.3), 27(0.9), 37(1.3), 52(1.0)

† Amplitudes, m s^{-1}, in brackets.

for two stations Collm and Badary [*Kazimirovsky*, 1994]. Now we have calculated the correlation between meridional prevailing wind and solar activity index Wolf number, and Figure 5 again demonstrates the opposite relationship for Collm and Badary. We think that if the long-term response of zonal wind at the same geographical latitude on solar activity variations depends on the longitude, it means that there is no direct solar control of MLT wind field.

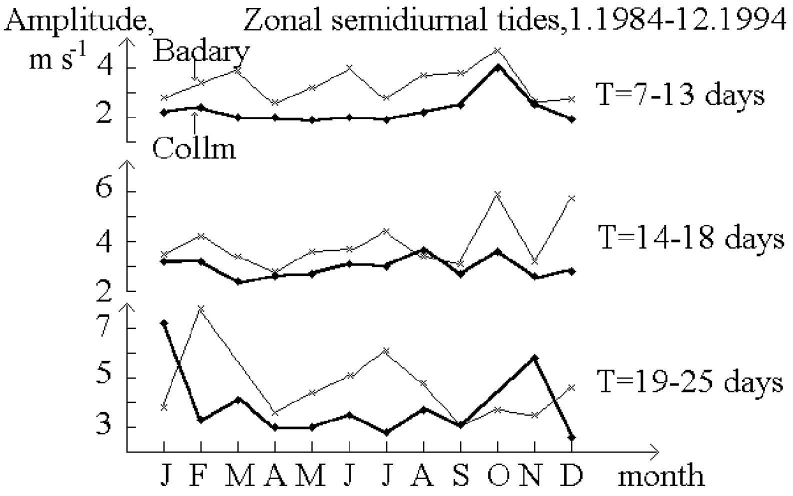

Figure 2. Seasonal variation of the amplitude of some planetary wave-like oscillations (zonal semidiurnal tide).

3. Discussion and Conclusion

Thus, in the present study, as an extension of the preceding investigations, we have demonstrated the nonzonality or longitudinal variability in the dynamical regime of the midlatitude lower thermosphere. The differences of the MLT field features between areas located on the same geographical latitude but different longitudes and meteorological conditions are evident. We know now that prevailing wind climatology, quasiperiodical structure of wind and tidal amplitudes variations, response on the stratospheric warmings and geomagnetic storms, the correlation of wind with solar activity variations, etc., are really depending on the longitude.

The observed longitudinal effect may be partly interpreted as resulting from large-scale stationary planetary waves formed in the lower thermosphere. In this case the longitudinal variation of the prevailing wind is due to the existence of such waves. The nonlinear coupling of planetary waves and tides could depend on the longitude as well. It is important also that in the mesopause there is a definite transition from mesospheric and thermospheric circulation. The possible longitudinal variations in the mesopause height complicate the seasonal structure.

As for geomagnetic storm-related effects, geomagnetic latitudes of Badary (41°N) and Collm (50°N) are different enough to produce some site to site variations.

The general concept of significant longitudinal structure in the MLT winds was supported and developed during the international experimental campaigns during last decade, but a lot of important problems are still insufficiently understood. It is the reason why the new INTAS coordinated

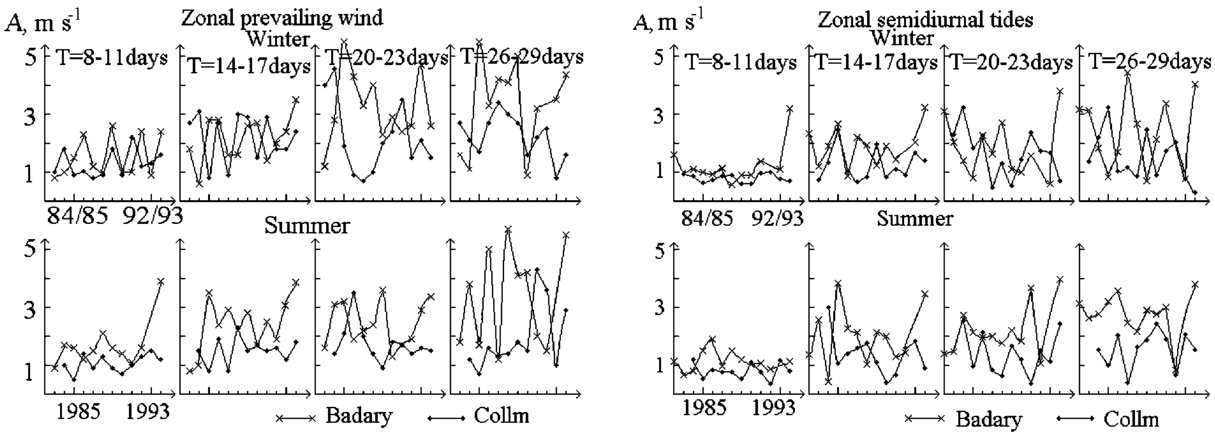

Figure 3. Year-to-year variations of some planetary wave-like oscillations in the zonal prevailing wind and the zonal semidiurnal tide.

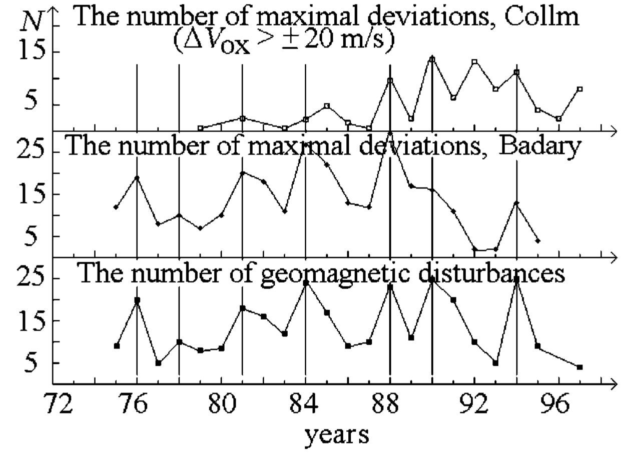

Figure 4. Variations of maximal deviations number in the zonal prevailing wind and number of geomagnetic disturbances. Maximal deviation is the difference between daily wind speed value and averaged for the whole period of measurements. V_{ox} is positive eastward.

program of simultaneous measurements of winds proposed by C. Jacobi (Germany), N. Mitchell (UK) and Y. Portnyagin (Russia) is still actual and important. It would improve our understanding of the coupling between tropospheric–stratospheric nonzonal circulation systems and those one that may exist in the MLT region.

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References

Kazimirovsky, E. S., The peculiarities of wind field in the upper middle atmosphere in the East Siberian region, *Adv. Space Res., 14*(9), 89, 1994.

Kazimirovsky, E. S., Coupling from below as a source of ionospheric variability: A review, *Ann. Geophys., 45*(1), 1, 2002.

Kazimirovsky, E. S., and V. D. Kokourov, The tropospheric and stratospheric effects in the ionosphere, *J. Geomagn. Geoelectr., 43*, suppl., 551, 1991.

Kazimirovsky, E. S., and G. V. Vergasova, The non-zonal effect in the dynamical structure of the midlatitude MLT-region, *Adv. Space Res., 27*(10), 1673, 2001.

Kazimirovsky, E. S., G. V. Vergasova, M. P. Rudina, and G. Ya. Khachikjan, Meteorological effects in the variations of ionospheric parameters. I. The lower ionosphere, *J. Atmos. Terr. Phys., 44*(11), 913, 1982a.

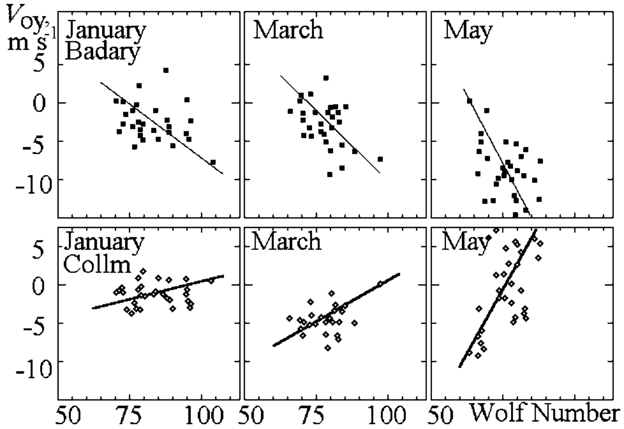

Figure 5. Correlation of the meridional prevailing wind and solar activity (1978–1995). V_{oy} is positive northward.

Kazimirovsky, E. S., R. Schminder, D. Kuerschner, and V. F. Petrukhin, The continental effects in the upper mesopause wind field in midlatitudes, *Geomagn. Aeron. (in Russian), 22*(5), 782, 1982b.

Kazimirovsky, E. S., A. H. Manson, and C. E. Meek, Winds and waves in the middle atmosphere, *J. Atmos. Terr. Phys., 50*(3), 243, 1988.

Kazimirovsky, E. S., O. M. Pirog, and G. V. Vergasova, The upper mesosphere/lower thermosphere wind field nonzonality as possible sign of the external forcing from above and from below, *Adv. Space Res., 24*(5), 607, 1999.

Lastovicka, J., Observations of tides and planetary waves in the atmosphere–ionosphere system, *Adv. Space Res., 20*(6), 1209, 1997.

Pancheva, D., P. Mukhtarov, N. G. Mitchell, A. G. Beard, and H. G. Muller, A comparative study of winds and tidal variability in the mesosphere/lower thermosphere region over Bulgaria and the UK, *Ann. Geophys., 18*, 1304, 2000.

Schminder, R., et al., The 1978/79 winter half year in the circulation of the upper mesosphere region over central Europe and East Siberia, *Phys. Solariterr.*, no. 12, 92, 1980.

Schminder, R., D. Kuerschner, K. M. Greisiger, E. S. Kazimirovsky, and V. F. Petrukhin, Uebereinstimmende Merkmale im Jahresgang des hochatmosphaerischen Windfeldes ueber Mitteleuropa und Ostsibirien, *Z. Meteorol., 37*(6), 367, 1987.

Singer, W., et al., Geomagnetic influences upon tides-winds from MLT radars, *J. Atm. Terr. Phys., 56*, 1301, 1994.

Vitinsky, Y. L., M. Kopecky, and G. V. Kuklin, *Statistics of Sunspot-Creating Activity of the Sun (in Russian),* 296 pp., Nauka, Moscow, 1986.

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