Bulgarian Geophysical Journal, 2013, Vol. 39
National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences

CONDITION OF THE STRATOSPHERIC AND MESOSPHERIC OZONE LAYER OVER BULGARIA FOR THE PERIOD 1996-2012: PART 2 - TOTAL OZONE CONTENT, SHORT TERM VARIATIONS

P. Kaleyna, Pl. Muhtarov, N. Miloshev

National Institute of Geophysics, Geodesy and Geography, str. Acad. G. Bonchev, bl 3, Sofia1113, Bulgaria, e-mail: pkaleyna@geophys.bas.bg, pmuhtarov@geophys.bas.bg, miloshev@geophys.bas.bg

Abstract. An evaluation of the general characteristics of the short term variability of the Total Ozone Content (TOC) over Bulgaria has been made in the article. The impact of the planetary wave activity of the stratosphere on the total ozone has been studied and the climatology of the oscillation amplitudes with periods of 4, 7, 11 and 25 days has been defined.

Key words: total ozone content, short term variability, trigonometric approximation, sliding time segment, planetary waves, climatology.

Introduction

The seasonal cycle pattern of the Total Ozone over Bulgaria has been studied in the first part of the work with the means of its basic components corresponding to the components of the decomposition of one periodical (with a period of one year) process in Fourier series. There are also other types of oscillations in the atmosphere which are of a quasi-periodical character called planetary waves. They represent wave processes developing in an elastic medium as is the atmosphere. They originate from baric and thermal discontinuities arising at certain altitude regions. As a rule, those oscillations occur in random moments and continue for a relatively short time (several periods) in contrast to the oscillations which are generated by periodic influences related to the rotation of the Earth on its axis and around the Sun. The quasi-periods of the planetary waves, defined by the presence of resonant modes in the atmosphere, vary in wide ranges but are less than a month. Those waves are regarded as zonally (along a given geographic parallel) distributed variations of a given atmospheric characteristic (temperature, pressure, wind speed), sinusoidal by time and geographic longitude. The different types of waves posses different wave numbers and directions of propagations. The waves manifest themselves as an oscillation in time in a point with given geographic coordinates.

A detailed resume of the studies in this area is given in Pancheva and Mukhtarov, 2011.

Variability of the total ozone content in years 1996-2012

For the purpose of the present research, the row of daily values of TOC, described in detail in the first part of the work, is filtered while the sliding mean value is extracted from every value in a segment of 31 days centered on the respective day. In this way, all variations with a temporary scale over 31 days (including the seasonal cycle) are filtered. The curve of the daily values received in this day is displayed on Fig. 1.

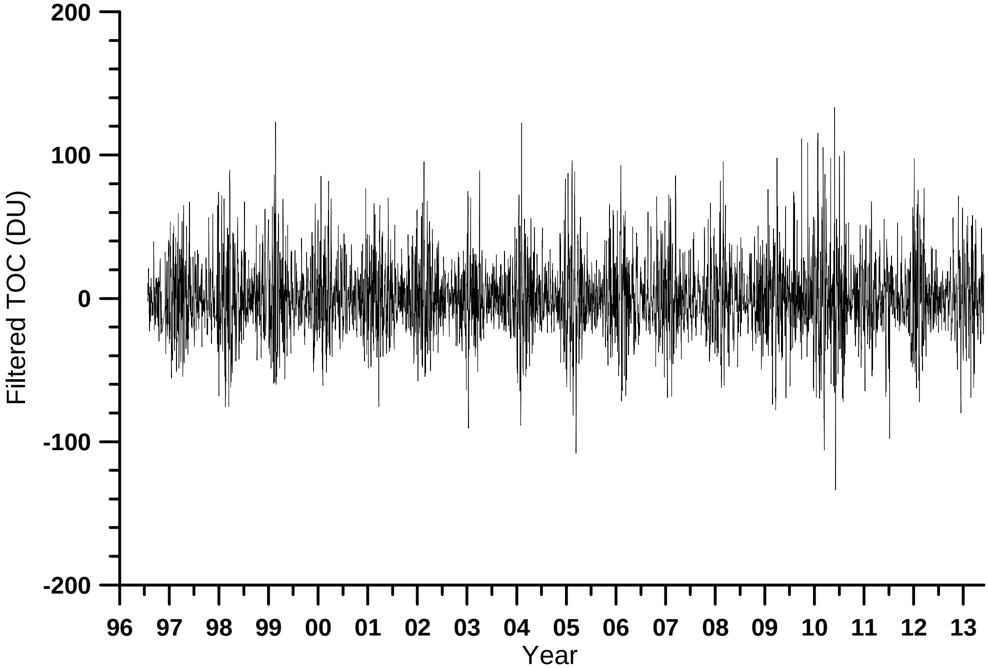

Fig. 1. Curve of the filtered values of the Total Ozone Content for 1996-2013.

It is obvious that short term variations have a considerable swing which is in the range of the mean seasonal cycle in some cases. Naturally, not only the assumed impact of the planetary wave activity but also local variations are included in those variations. A general characteristic of the total variability of the total ozone content over Bulgaria give the statistical characteristics displayed on Fig. 2: probability density, mean value and standard deviation.

Empirically, the output probability density deviates significantly from Gaussian model and shows a greater similarity to Laplacian model.

The mean value is practically zero which is a characteristic of the used filtering method. The probability of a short term variation in a given day in absolute value not more than the standard deviation, 24 DU, is 75% which value is obtained through integration of the empirical probability density.

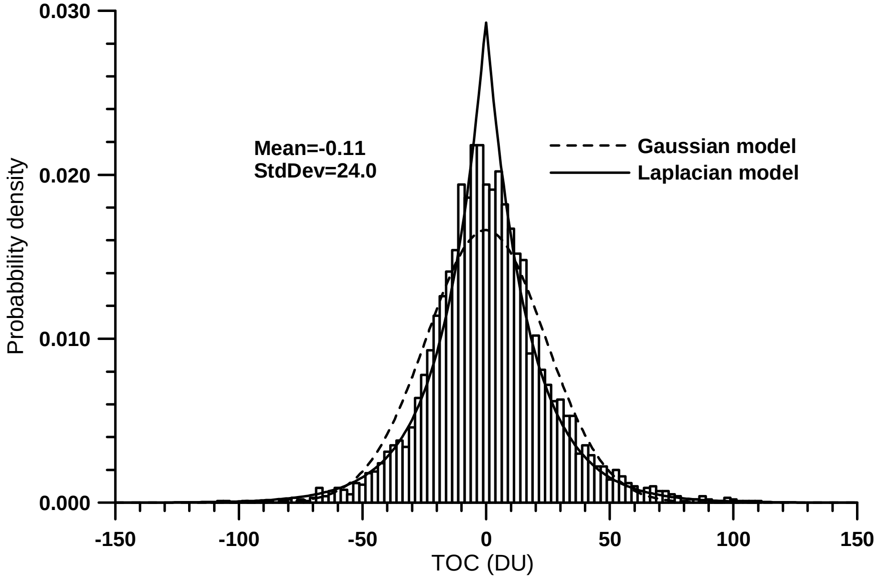

Fig. 2. Main statistical characteristics of the short term variability of Total Ozone Content over Bulgaria.

Influence of planetary waves over total ozone content

It is necessary to make an additional data filtering in order to evaluate the quality and quantity of the probable impact of the planetary wave activity on the total ozone. It is not feasible to use the strongest criterion for defining planetary waves, namely the analysis of the zonal structure which requires global data, by single-point data. The only opportunity is to look for such oscillations in time that will respond to the manifestation of planetary waves in one point – quasi-periodical oscillations with periods which correspond to the prevailing periods that are defined by the studies of global data. The move of the filtered data, displayed on Fig. 1, shows a distinctive nonstationarity expressed in a visible seasonal dependence of the amplitudes of the variations (increased during winter season) which does not allow to use effectively the different kinds of spectral analysis on the basis of Fourier transform. The wavelet analysis is suitable in this case (Pancheva and Mukhtarov, 2000) adjusted to the case when there are data gaps (Mukhtarov et all, 2010). Wavelet analysis based on the function of Morlet reveals oscillations with a given period which are expressed only in the area of a given moment of time.

A wavelet spectrum for two years of the studied period is displayed on Fig. 3. The presence of quasi-periodical oscillations with periods of about 7 days, about 10 days and about 22 days is visible during winter periods. Those oscillations are of a localized character as it is characteristic for the planetary waves.

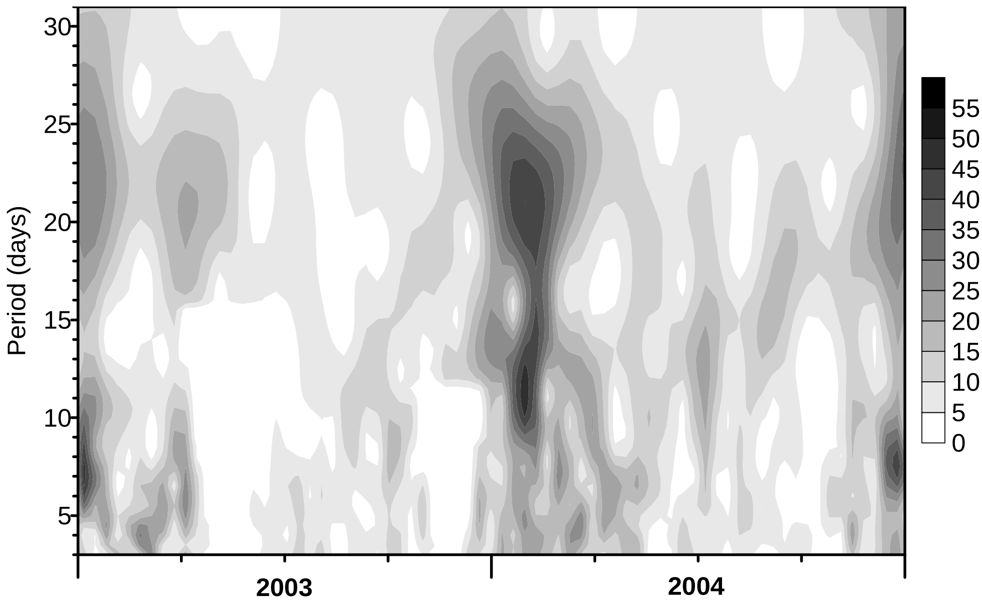

Fig. 3. Wavelet spectrum of filetered TOC in yeares 2003-2004.

A mean spectrum has been calculated to obtain a general idea of the prevailing periods by averaging the amplitudes of the oscillations with a given period in all the days of the years from 1997 to 2012, displayed on Fig. 4.

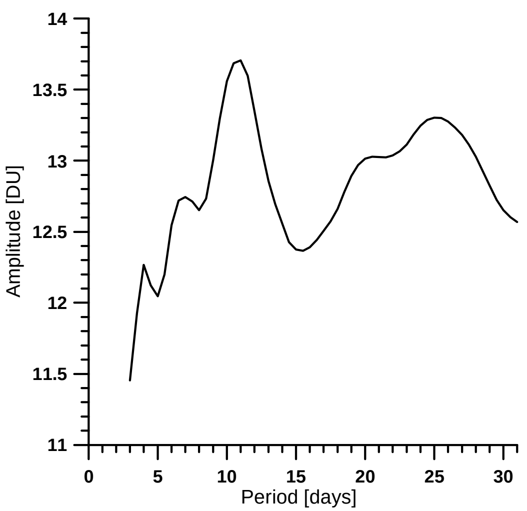

Fig.4. Mean wavelet spectrum of filetered TOC in yeares 1997-2012.

The spectrum is continuous which means that there are oscillations in the data within all periods from 3 to 31 days but there are readily seen prevailing ones about 4, 7, 11 and 25 days which periods are characteristic for the planetary waves in the stratosphere (Pancheva et al., 1994). The output mean spectrum confirms the assumption that the planetary wave activity is reflected in the concentration of ozone in the stratosphere (Fusco and Salby, 1999).

Having defined the prevailing periods, it is possible to study the curve of their amplitude with time by means of decomposition with sliding segments (Pancheva et al., 2009). Naturally, the method is used in its one dimensional version, in functions only of time. This filtering method of oscillations with predefined periods just like the wavelet-analysis has the property of localization in time. The simultaneous defining of the amplitudes and phases in the vicinity of a given moment of time (a sliding segment of 31 days has been used) makes the method effective in the cases when there are oscillations with different periods that are close by day of existence.

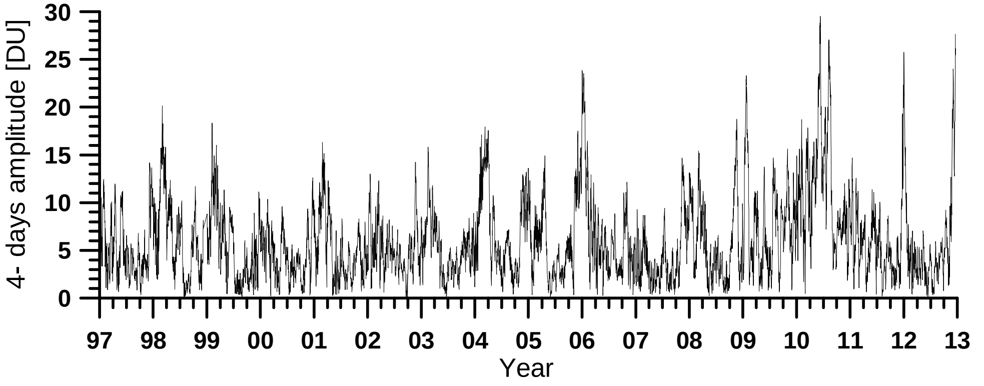

Fig. 5. 4- days amplitude.

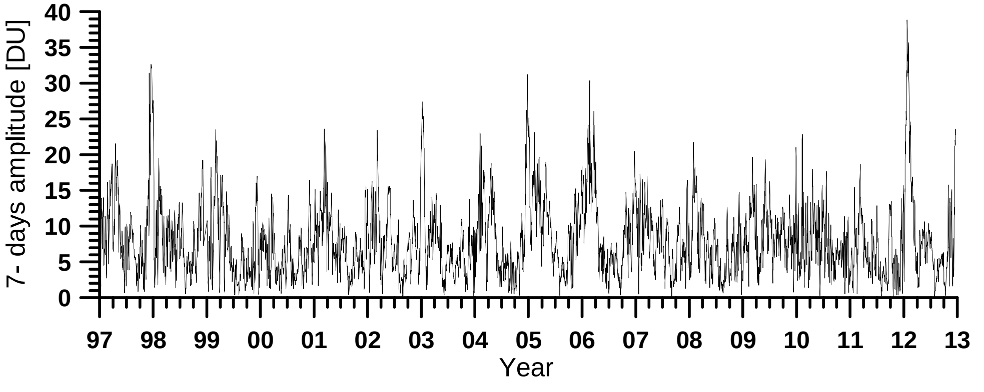

Fig. 6. 7- days amplitude.

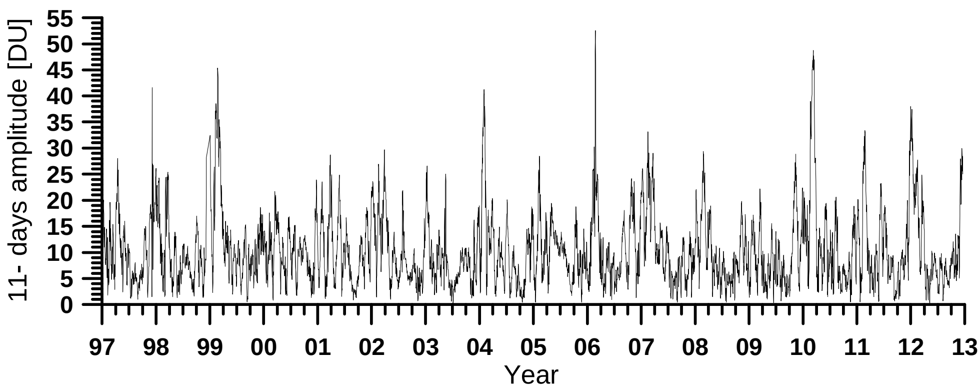

Fig. 7. 11- days amplitude.

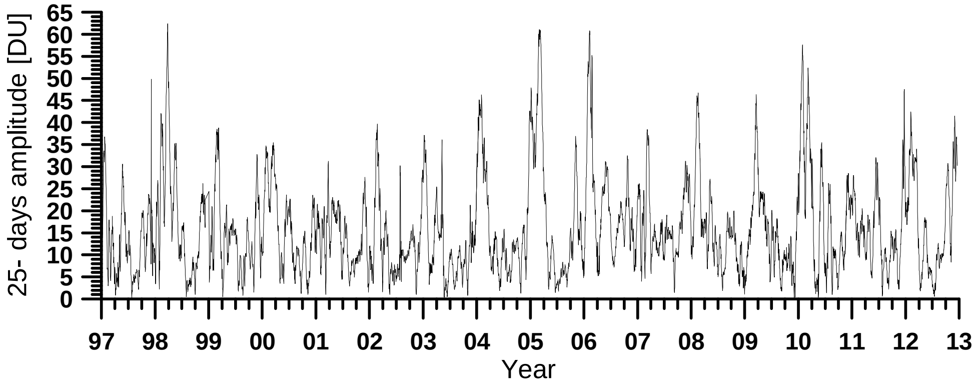

Fig. 8. 25- days amplitude.

The curve of the oscillation amplitudes by days with periods 4, 7, 11 and 25 days, for the period 1997-2912, is displayed on Fig. 5, 6, 7 and 8. An increase of the amplitudes in the winter season is noticed which is characteristic of the planetary wave activity as a whole. The amplitudes of the oscillations with longer periods are also bigger which is characteristic of the planetary wave activity, too. The mean amplitudes for every calendar month are calculated and displayed on Fig. 9. The interval of 16 years is long enough and provides statistical reliability of the obtained mean values (every mean monthly value is obtained from, for example, 30x16=480 values).

It may be assumed for the oscillation with a period of 4 days which was noted in the total ozone data is a reflection of the westward propagating Rossby wave (Pancheva et al., 2010). The climatology of this kind of waves in a temperature field, presented in this work, is expressed the strongest namely at latitude 40N but the seasonal cycle of Rossby wave shows seasonal maximums in the months of the equinox (March and September-October) in contrast to the present results for the total ozone while the climatology of the 4-day wave in the total ozone shows distinctive maximum values in December-March, and the annual minimum is in September. Besides, the average period in the total ozone proves to be smaller than the conventional Rossby waves' range of 5-7 days.

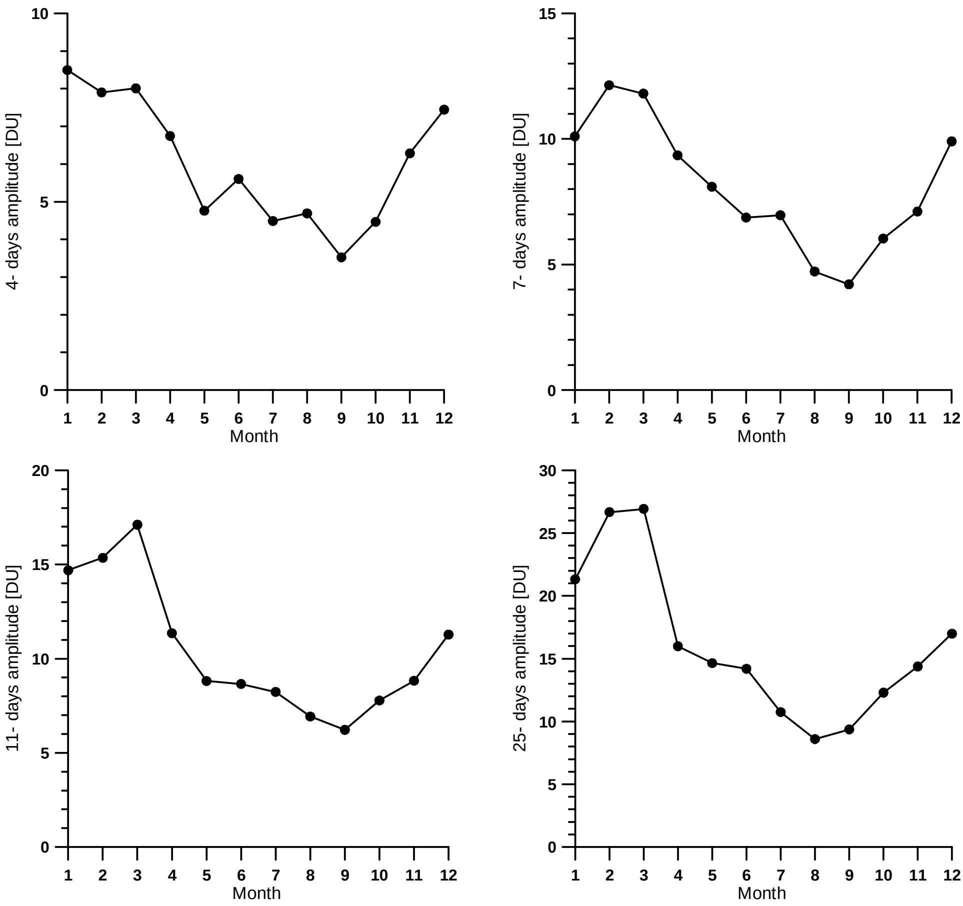

Fig. 9. Seasonal distribution of the amplitudes of the 4, 7, 11 and 25-day oscillations.

Oscillations with a period of 5-7 days are observed in ground and satellite data for the temperature and wind speed while their characteristics prove to be of Rossby (1,1) normal mode (Shepherd et al., 2007) but at low latitudes.

Eleven-day planetary waves with wave number 1 are observed in the field of stratospheric temperature (Pancheva and Mukhtarov, 2011). They activate themselves at middle latitudes and have maximal amplitudes in the winter season which coincides with the behavior of the 11-day oscillation in TOC over Bulgaria.

The studies of planetary waves with a period of about 25 days (Hua Lu et al., 2012) at geopotential height show that those waves in the stratosphere activate themselves in the winter season (from October to March) at middle latitudes which coincides with the climatology of the analogous oscillations in TOC (Fig. 9).

An offset in the seasonal cycle (the maximum is in February-March, and the minimum – in August-September) from that typical for the planetary waves in the other atmospheric characteristics is characteristic of the seasonal amplitude dependence of all oscillations in TOC which coincides with the seasonal cycle of the very TOC. Global data are required to clarify this phenomenon.

Conclusions

The analysis of the short term variability of the Total Ozone Content over Bulgaria that has been made shows that short term deviations from the stationary seasonal cycle have significant values – 24 DU with 75% probability which is in the range of the annual wave amplitude of the seasonal cycle obtained in the first part of the present work (about 35 DU on the average for the studied period of time). The spectral analysis of the short term variations has shown that they are not of a completely random character and quasi-periodical variations in them are readily seen, the periods of which coincide with the periods of the planetary waves in the stratosphere (in the regions of temperature, pressure and wind speed). Certain caution is necessary by identifying the observed oscillations with periods of 4 and 7 days with Rossby waves because of the deviations of the seasonal cycle of the observed oscillations in TOC from the seasonal and latitudinal dependence of the analogous ones in the temperature and pressure. The behavior of the 11 and 25- day oscillations in TOC coincides better with the well-known characteristics of the analogous planetary waves with the exception of a certain offset (with about two months forward) of the seasonal cycle of the amplitudes in TOC.

Acknowledgements. The study was funded by FP7-PEOPLE-2009-IRSES (Grant No.247608) IGIT- Integrated geo-spatial information technology and its application to resource and environmental management towards the GEOSS.

References

Fusco, A., M. Salby, 1999. Interannual Variations of Total Ozone and Their Relationship to Variations of Planetary Wave Activity, *Journal of Climate*, V. 12, 1619- 1629.

Hua Lu, D. Pancheva, Pl. Mukhtarov, I Cnossen, 2012. QBO Modulation of Traveling Planetary Waves During Northern Winter, *Journal Of Geophysical Research*, VOL. 117, D09104, doi:10.1029/2011JD016901.

Mukhtarov Pl., B. Andonov, C. Borries, D. Pancheva, N. Jakowski, 2010. Forcing of the Ionosphere From Above and Below During the Arctic Winter of 2005/2006, *Journal of Atmospheric and Solar-Terrestrial Physics* 72, 193–205.

Pancheva D., Pl. Mukhtarov, M. Todorova, 1994. Simultaneous Observations of Quasi-Periodical Fluctuations in the TCO, Mesospheric Neutral Wind And Ionosperic Absorption, *Bulgarian Geophysical Journal*, Vol XX, No 3, 72- 81.

Pancheva, D., P. Mukhtarov, 2000. Wavelet Analysis on Transient Behaviour of Tidal Amplitude Fuctuations Observed by Meteor Radar in the Lower Thermosphere above Bulgaria, *Ann. Geophysicae* 18, 316±331.

Pancheva, D., P. Mukhtarov, B. Andonov, N.J. Mitchell, J.M. Forbes, 2009. Planetary Waves Observed by TIMED/SABER in Coupling the Stratosphere–Mesosphere–Lower

Thermosphere During the Winter of 2003/2004: Part 1— Comparison with the UKMO Temperature Results, *Journal of Atmospheric and Solar-Terrestrial Physics* 71, 61–74.

Pancheva, D., P. Mukhtarov, B. Andonov, N.J. Mitchell J.M. Forbes, 2010. Planetary Waves Observed by TIMED/SABER in Coupling the Stratosphere–Mesosphere–Lower Thermosphere During the Winter of 2003/2004: Part 2— Altitude and Latitude Planetary Wave Structure, *Journal of Atmospheric and Solar-Terrestrial Physics* 72, 26–37.

Pancheva, D., P. Mukhtarov, 2011. Atmospheric Tides and PlanetaryWaves: Recent Progress Based on SABER/TIMED Temperature Measurements (2002–2007) in Aeronomy of the Earth's Atmosphere and Ionosphere, edited by M.A. Abdu, D. Pancheva (eds.), A. Bhattacharyya (Coed.), *IAGA Special Sopron Book Series 2*, pp 19-56, DOI 10.1007/978-94-007-0326-1_2.

Shepherd, M.G., Wu, D.L., Fedulina, I.N., Gurubaran, S., Russell, J.M., Mlynczak, M.G., Shepherd, G.G., 2007. Stratospheric Warming Effects on the Tropical Mesospheric Temperature Field. *Journal of Atmospheric and Solar-Terrestrial Physics* 69, 2309–2337.

Сътояние на стратосферния и мезосферен озон над България за периода 1996-2012 г: Част 2 - Краткосрочни вариации на тоталното съдръжание на озон

П. Калейна, Пл. Мухтаров, Н. Милошев

Резюме: В статията е направена оценка на общите характеристики на краткосрочните вариации на тоталното съдържание на озон (ТСО) над България. Изследвана е проявата на планетарната вълнова активност на стратосферата върху тоталния озон и е определена климатологията на амплитудите на колебанията с периоди 4, 7, 11 и 25 денонощия.