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Appearance of lower thermosphere and ionosphere F2 region dynamical coupling caused by tidal motions over Abastumani

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Abstract. The presence of planetary scale motion characteristic variations in the Earth's upper atmosphere is shown in the intensities of the nightglow mesopause hydroxyl OH(8-3) band, the lower thermosphere oxygen green OI 557.7nm line and the ionosphere F2 region red OI 630.0 nm line, observed from Abastumani(41.75N, 42.82E). There is demonstrated the simultaneous observation for the mentioned intensities characterized by vertical propagation of 4-8 hour tidal motions, which are considered as the manifestation of the lower and upper atmosphere-ionosphere F2 layer dynamical coupling in the Caucasus region.
It is shown that in the considered cases, for terdiurnal tidal motions, is possible to estimate the wavelength of the vertical propagation, which is equal to the distance between luminous layers (about 130-150 km) or its multiple values (65-75, 32-37 km). The profile of the electron content is necessary to reveal smaller wavelengths.

1. Introduction

Tidal motions are mainly planetary scale dynamical processes [2] and play an essential role in the climatology of the mesosphere and thermosphere regions of the Earth's atmosphere [3, 4]. The main source of the thermal tidal motions is the periodical absorption of the Solar electromagnetic radiation by Earth's surface and atmosphere during daily rotation of the planet. In the upper atmosphere, such thermal tidal movements can be characterized by periods of 24 and 12 hours [2], and also with a low periods of 4-8 hours [12]. Tidal motions are important processes for the dynamical coupling between lower and upper atmosphere under various helio-geophysical conditions in the given region of the globe. The interest of this kind investigations increases in the last decade [1, 6, 8, 11].

The dynamical coupling between lower and upper atmosphere is shown in the mesosphere-thermosphere-ionosphere interaction and the simultaneous observations and monitoring on the airglow intensities for mentioned atmosphere regions are important to study the development of this processes.

In this paper the nightly variations of the intensities of the mesosphere hydroxyl OH(8-3) band (maximum luminous layer about 87 km), the lower thermosphere green OI 557.7 nm line (maximum luminous layer about 95 km) and the ionosphere F2 region red OI 630.0 nm line (with maximum luminous layer about 230-280 km) are considered, where the 4-8 hours period tidal characteristic changes occurs simultaneously. Mention phenomenon will be considered as a manifestation of importance of the tidal motions in the lower and upper atmosphere-ionosphere dynamical coupling processes. Its investigation is important to manifest the characteristic parameters of the tidal motions in the (Caucasus) region, which source could be as at the near Earth surface as well *in situ* generation in the atmosphere.

2. Tidal variations in the hydroxyl OH band, the green 557.7 nm and the red 630.0 nm line nightglow intensities

The systematic simultaneous photometrical observations of the nightglow intensities of the mesosphere hydroxyl OH bands, the lower thermosphere green OI 557.7 nm line and the ionosphere F2 region red OI 630.0 nm line are carrying out in Abastumani Astrophysical Observatory from 1957 year. These data is important to investigate dynamical and structural processes in the Caucasus region of the upper atmosphere during different helio-geophysical conditions [3, 4]. The brightest object of the nightglow spectrum of these observations is hydroxyl OH(8-3) band, which is mainly emitted from the coolest region of the atmosphere - mesopause. Main process for OH(8-3) band excitation is the reaction $O_3+H=OH+O_2$ and its volume emission rate ε_{OH} [10]

$$\varepsilon_{OH} \propto [H][O_3] \tag{1}$$

where $[O_3]$ and $[H]$ are densities of the O_3 ozone molecule and the H atoms of hydrogen in the emitted region of the mesosphere. These parameters change during the seasons and during the night as well. They are sensitive to vertical flux changes of neutral components in the mesosphere and lower thermosphere, which can be induced by tidal motions.

The source of the upper atmosphere tidal motions sometimes is in the lower atmosphere and it propagates to the lower thermosphere and the ionosphere F2 region [7]. The nightglow intensity of the green 557.7 nm line ($O(^1S) \xrightarrow{557.7nm} (^1D)$) in the lower thermosphere is also sensitive on mention atmospheric disturbances. The green line in the lower thermosphere is excited during the Barth two step mechanism [9] and its volume emission rate ε_{5577}

$$\varepsilon_{5577} \propto [O]^3 \tag{2}$$

where $[O]$ is atomic oxygen density. Atomic Oxygen O, eq.1, Ozone O_3 and Hydrogen atom H, eq.2, are small components of the atmosphere and their changes significantly could be modulated by atmospheric tidal motions. Their changes are mutually coupled. For example the relative part of ozone increases during increase of vertical flux which in turn increases luminosity of hydroxyl *OH(8-3)* band (eq.1). Also, the green line intensity decreases caused by decreasing in the relative part of atomic oxygen density in the same region. The picture is vice versa when the stream is downward - the increase in the green line intensity is accompanying with decreasing in the hydroxyl OH bands intensity. This phenomenon occurs in most seasons of the year and gives additional information on characteristic periods of tidal motions and on their vertical distribution as well.

We are using the nightly behavior of the red OI 630.0 nm line intensity emitted from the ionosphere F2 region beside the green 557.7 nm line and hydroxyl OH(8-3) band intensities to illustrate the propagation of the tidal motions to the heights of mentioned region. The volume emission rate of the red line intensity ε_{6300} [3]

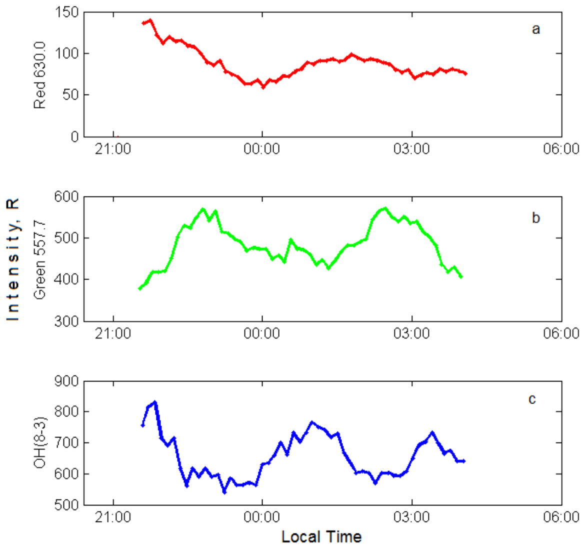
$$\varepsilon_{6300} \propto \frac{[O_2](h)Ne(h,t)}{1+\dfrac{d_D}{A_D}} \qquad (3)$$

here $[O_2](h)$ is the height distribution of the density of oxygen molecules and $Ne(h,t)$ is the time varying height profile of the F2 layer electron density, d_D is the rate of the collisional deactivation of $O(^1D)$ atoms with the dominant neutrals (O, N_2, O_2) [5] in the same region. Note, that the electron density Ne behavior is sufficiently determined by vertical motion of the neutrals and also on changes in horizontal wind velocity [3] which in turn is characteristic for tidal motions and comparatively less noticeable for the hydroxyl OH bands and the green line intensities, eq.1-2.

The tidal motions and its horizontal and vertical velocities and their vertical propagation can be described by the following equation [2]:

$$V_{tid} = (U,W)\cdot e^{\frac{z}{2H}}\cdot \cos\left[\frac{2\pi}{T}t-\frac{2\pi}{\lambda_z}z+\psi\right] \qquad (4)$$

here U and W are the horizontal and vertical component of tidal velocity, respectively; t is time (in hours) and T corresponds to period of tidal motion which is 4-8 hour (the terdiurnal type tides) in our case; $z=h-h_0$ is the difference between actual and some initial height and H is the atmospheric scale height; λ_z is the vertical wavelength and ψ corresponds to some initial phase of tidal velocity.



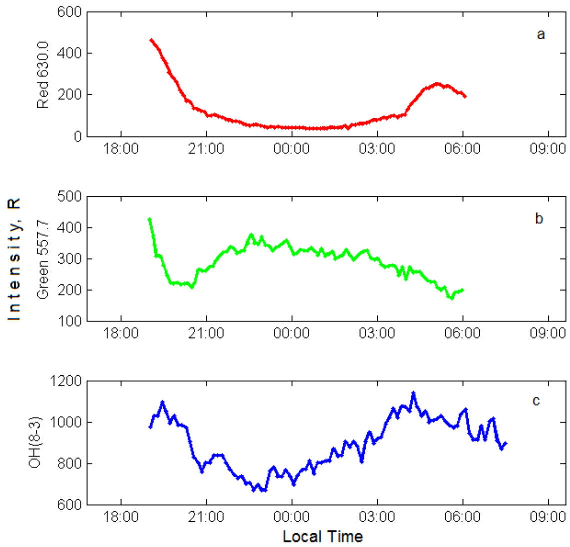


Figure 1 **Figure 2**

The night behavior of the Hydroxyl OH(8-3) band (panels c), OI 557.7 nm line (panels b) and red OI 630.0 nm line (panels a) observed column intensities from Abastumani (41.75N, 42.82E) for 2-3 September 1989 (Figure 1) and 13-14 January 1991 (Figure 2).

The Figures 1 and 2 shows an existence of the 4-8 hour periods tidal type disturbances in the mesosphere-thermosphere regions and their propagation to the ionosphere F2 region heights. The Figure 1 and 2 corresponds to different phase of development of the same kind of tidal motions.

The propagated disturbance in the ionosphere corresponds to decrease of neutral wind vertical component (*W*), eq. (4), or increase of northward wind (*U*) phase on the Figure 1. Another plot (Figure 2) shows the similar process in case of 4 hour dallying of phase, when electron density *Ne* is decreased during the vertical downward neutral wind ($W<0$) or increase in northward wind velocity ($U>0$) in the ionosphere F2 region which corresponds the downward flux in the lower thermosphere (the intensity of the green line increases and hydroxyl intensity decreases).

Note, that the demonstrated observations correspond to geomagnetically quiet conditions (the values of daily *Ap* index 8 and 12 corresponds to demonstrated observation for 02-03 September of 1989 and 13-14 January of 1991) and other planetary scale disturbances then tidal motions are less supposed.

3. Conclusion

The existence of the planetary scale characteristic motions in the Earth's upper atmosphere by the mesopause region hydroxyl OH(8-3) band, the lower thermosphere green OI 557.7 nm line and the ionosphere F2 region OI 630.0 nm line intensities observed from Abastumani, has been shown. There was demonstrated the simultaneous observation for the mentioned intensities characterized by vertical propagation of 4-8 hour tidal motions during the geomagnetically quiet conditions, which are considered as the manifestation of coupling between the lower and upper atmosphere in the Caucasus region. The wavelength of the terdiurnal motion vertical distribution could be equal to the distance between 557.7 nm and 630.0 nm lines luminous layers (about 130-150 km) or its multiple values (65-75, 32-37 km) in the considered cases. The source of these tidal motions could be at the Earth surface or *in situ* generated in the lower and upper atmosphere.

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Reference

[1] Chang, L. C., C.-H. Lin, J.-Y. Liu, N. Balan, J. Yue, and J.-T. Lin, J. Geophys. Res. Space Physics, 2013, v.118, pp.2545–2564;

[2] Chapman, S. and Lindzen, R.S., *D.Reidel Press, Dordrecht, Holland*, 1970, 200 pp.;

[3] Didebulidze, G.G., Chilingarashvili, S.P., Toroshelidze, T.I., *J. Atmos. Sol.-Terr. Phys.*, 2002, v.64, pp.1105-1116;

[4] Fishkova, L.M., *Metsniereba Press, Tbilisi*, 1983 (in Russian);

[5] Gudadze, N. B., Didebulidze, G. G., Javakhishvili, G. Sh., Shepherd, M. G., and Vardosanidze, M. V., *Can. J. Phys.*, 2007, v85, pp189–198;

[6] Guharay, A., P.P. Batista, B.R. Clemesha, S. Sarkhel, R.A. Buriti, *J. Atmos. Sol.-Terr. Phys.*, 2013, v.104, pp.87–95;

[7] Luan, X., Dou,, X. Lei, J., Jiang, G., *JGR*, 2012, 117(A11). DOI: 10.1029/2012JA018199;

[8] Mthembu, S.H., V.Sivakumar, N.J.Mitchell, S.B.Malinga, *J. Atmos. Sol.-Terr. Phys.*, 2013, v.102, pp.59–70;
[9] McDade, I.C., Murtagh, D.P., Greer, G.H., Dickinson, P.H.G., Witt, G., Stegman, J., Thomas, I., Jenkins, D.B., *Planetary and Space Science*, 1986, v.34, pp.789–800;
[10] Mcdade, I.C., Llewellin, E.J., Murtagh, D.P., Greer, G.H., *Planetary and Space Science*, 1987, v. 35 (9), pp.1137–1147;
[11] Yue Jia, Jiyao Xu, Loren C.Chang, Qian Wu, Han-Li Liu, Xian Lu, James RussellIII, *J. Atmos. Sol.-Terr. Phys.*, 2013, v.105-106, pp.191–198;
[12] Zhao, G., Liu, L., Ning, B., Wan, W., and Xiong, J., Earth Planets Space, 2005, v.57, pp.393–398.

ქვედა თერმოსფეროსა და იონოსფეროს F2 არის მიმოქცევითი მოძრაობებით გამოწვეული ზოგიერთი დინამიური კავშირები აბასთუმანთან

ნიკოლოზ გუდაძე, გოდერძი გ. დიდებულიძე, გიორგი შ. ჯავახიშვილი

რეზიუმე

ნაჩვენებია დედამიწის ზედა ატმოსფეროში პლანეტარული მასშტაბის მოძრაობებისათვის დამახასიათებელი ცვლილებების არსებობა აბასთუმნიდან (41.75N, 42.82E) დამზერილი მეზოპაუზის ჰიდროქსილის OH(8-3) ზოლის, ქვედა თერმოსფეროს მწვანე OI 557.7 ნმ ხაზის და იონოსფეროს F2 არის წითელი OI 630.0 ნმ ხაზის ღამის ცის ნათების ინტენსივობებში. დემონსტრირებულია მათ ინტენსივობებში 4-8 საათიანი მიმოქცევითი მოძრაობების ვერტიკალური გავრცელებისათვის დამახასიათებელი ერთდროული დაკვირვებები, რომლებიც განხილულია კავკასიის რეგიონში ქვედა და ზედა ატმოსფეროს კავშირების გამოვლინებად. ნაჩვენებია, რომ მსგავს შემთხვევებში შესაძლებელია შეფასდეს მიმოქცევითი მოძრაობების (8საათიანი პერიოდით) ვერტიკალური გავრცელების ტალღის სიგრძე, რომელიც დემონსტრირებულ შემთხვევაში მნათ ფენებს შორის მანძილის ტოლი (დაახლოებით 120-140 კმ) ან ჯერადია (60-70, 30-35 კმ-ია). უფრო მცირე ტალღის სიგრძეებისათვის ამ კავშირების გამოვლენა საჭიროებს ელექტრონების კონცენტრაციის პროფილს.

Выявление динамисческой связи между нижней термосферой и ионосферной F2 областями с помощью приливного движения над Абастумани

Николз Гудадзе, Годердзи Г. Дидебулидзе, Гиорги Ш. Джавахишвили

Резюме

По наблюдениям из Абастумани (41.75N, 42.82E) интенсивности излучения собственного свечения ночного неба, в частности, полосы гидроксила OH(8-3) из области мезопаузы, линий атомного кислорода OI 557.7 нм из нижней термосферы и OI 630. 0нм из ионосферной F2 области, выявлены характерные вариации движения планетарных масштабов в верхней атмосфере Земли.

Продемонстрированы данные одновременных наблюдений указанных интенсивностей, с характерными приливными движениями и вертикальным распространением продолжительностью 4-8 часов, что рассматривается как проявление динамической связи между нижней и верхней атмосферой и ионосферой в Кавказском регионе.

Показано, что в рассматриваемых случаях, для приливных движений (с периодом около 8 часов), возможно оценить длину волны вертикального распространения приливного движения, которая приблизительно равна расстоянию между слоями излучения (приблизительно 130-150 км) или их частным величинам (65-75, 32-37 км).