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Short-period AGWs of the measopause region observed by all-sky imager over Abastumani

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Abstract

The short-period (about 5-10 min) atmospheric gravity waves (AGWs) were observed in the mesopause region over Abastumani in by the hydroxyl infrared all-sky imager. The specifics of their propagation are given. The importance of these small-scale AGWs for monitoring the wave-like processes in the mesopause and study the lower-upper atmosphere coupling in the Caucasus region caused by orographic effects are also noted.

1. Introduction

Atmospheric gravity waves (AGWs) play important role in the lower and upper atmosphere dynamical processes [1,2]. It is important to study the generation of these waves, the influence of their propagation and dissipation on the atmospheric structure and behavior as well. Luminous layers of the upper atmosphere, including hydroxyl OH bands (maximum luminous layer about 87 km height), sensitive to propagation AGWs [3, 4, 5]. The observed mesopause short-period (with duration 5-10 min) and longer period waves activity express the properties of the seasonal variations of the regional and global scale dynamical phenomena [6, 7]. The modern imager systems allow us to study two-dimensional pictures of AGWs propagation in the upper atmosphere including mesopause [8].

In this work the parameters and two-dimensional picture of the short-period AGWs propagation in the mesopause observed from Abastumani Astrophysical Observatory by the hydroxyl infrared all-sky imager are demonstrated which are obtained for the first time in the Caucasus region. The importance of these phenomena is noted for study the lower and upper atmosphere coupling processes under various helio-geophysical conditions. By use of dispersion equation for AGWs, the importance of background wind velocity for their vertical propagation and identification of a possible source of their generation in the lower atmospheric layers are noted.

2. Short-scale mesopause region AGWs observed by hydroxyl infrared all-sky imager and its possible theoretical description

The mesopause hydroxyl OH bands are one of the brightness objects in the upper atmosphere nightglow spectrum [7, 9. 10, 11]. The sufficient part of hydroxyl emission is in the infrared region of its spectrum. The mesopause temperature is estimated by OH bands emission [Fishkova, Shefov]. Ground based observations of the nightly behavior of the hydroxyl emission intensities show the propagation of atmospheric waves and their properties in the mesopause region [7]. The monitoring of dynamical processes by the hydroxyl infrared all-sky imager (wavelength >1500 nm) have been carried out in Abastumani Astrophysical Observatory since September 2014. The field of view of the imager system covers the region over the Big and Small Caucasus and Black Sea within the radius of 150 km in the mesopause, which could play an important role in dynamical processes in this region.

In the wave-like processes observed by all-sky imager system the presence of waves with 6-10 min periods are noted. Such short-period AGW-type waves appear occasionally and the duration of their presence do not exceed 40-45 min. Such short-period waves - so called ripples [3,4,7] - can be excited in situ by nonlinear as well as possibly other processes, also can be coupled with lower atmospheric variations, including orographic effect.

In figure 1 the pictures of temporal development of the short-period AGWs observed from Abastumani by the hydroxyl infrared all-sky imager on September 1-2, 2014 (upper panels) and on August 11-12, 2015 (lower panels), are shown. In analogy with [8, 12, 13, 14] for 1-2.09.2014 observation, the estimated wave period is T≈7.5 min, horizontal wavelength ≈7 km and phase velocity of horizontal propagation (to the North-East) ≈15 m/s. For 1-2.08.2015 observations, the estimated wave period is T≈9.8 min, horizontal wavelength ≈13.5 km and phase velocity of horizontal propagation (to the to the North-East) ≈23 m/s.

The waves demonstrated in figure 1 correspond to the propagation of short-period AGWs in the mesopause region. The observed phase velocities (15 m/s and 23 m/s) of these waves are close to background wind velocities characteristic to the mesosphere and lower thermosphere regions and can influence their propagation and evolution [3, 4, 7].

The propagation of AGWs with ω_g frequency in the isothermal atmosphere in the case of presence the horizontal (x directed) background wind with velocity u_o can be described by the following

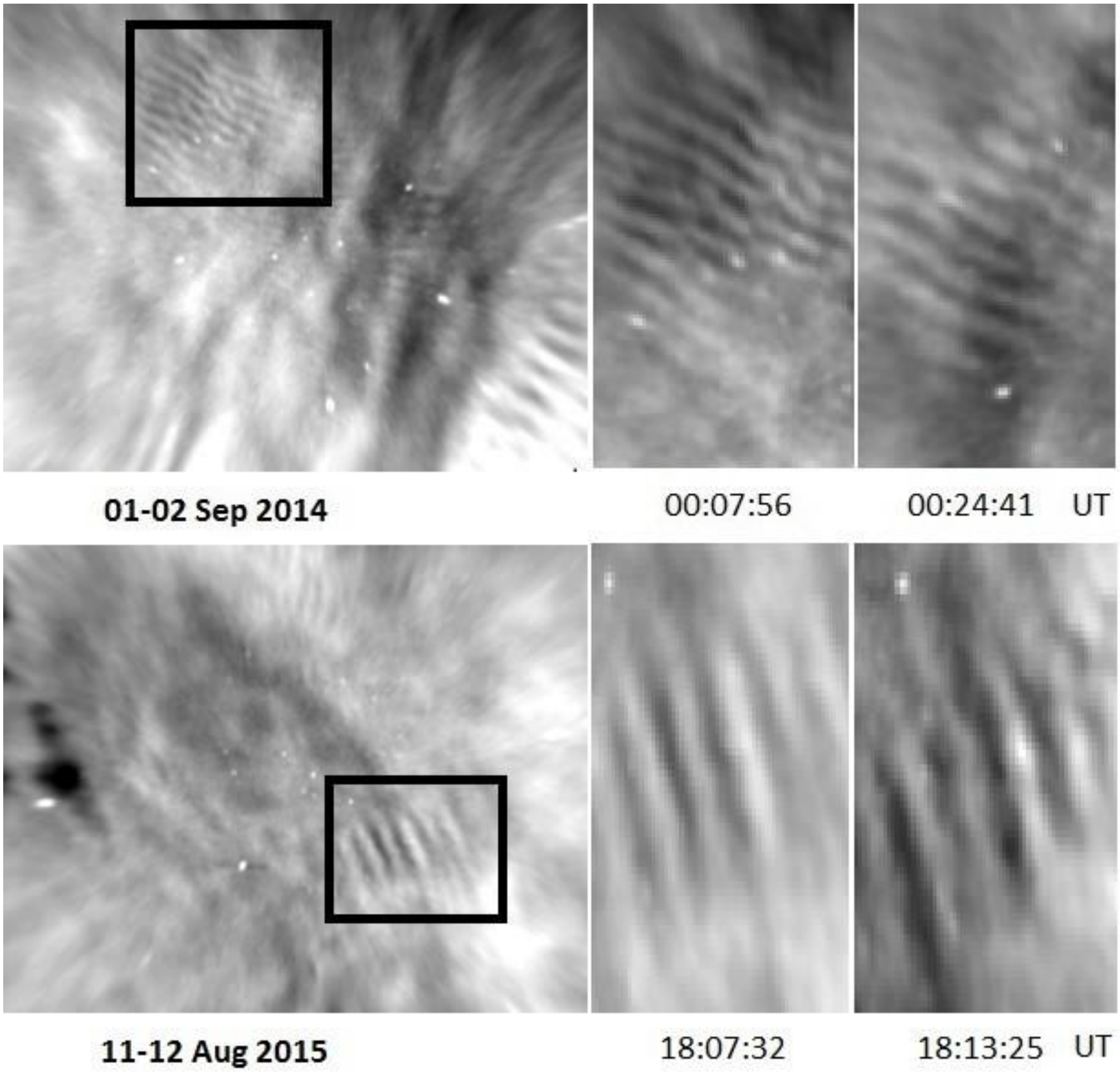

Fig. 1. The short-scale atmospheric gravity waves in the mesopause region observed from Abastumani by the hydroxyl infrared all-sky imager on September 1-2, 2014 night UT= 00:07:56, UT=00:24:41 (upper panels) and August 11-12, 2015 night UT= 18:07:32, UT=18:13:25 (lower panels).

dispersion relation [1,3]:

$$\omega_g = k_x u_o + \left\{ \frac{1}{2} c_s^2 \left(k_x^2 + k_z^2 + \frac{1}{4H^2} \right) - \sqrt{ \frac{1}{4} c_s^4 \left(k_x^2 + k_z^2 + \frac{1}{4H^2} \right)^2 - \omega_b^2 c_s^2 k_x^2 } \right\}^{\frac{1}{2}} . \tag{1}$$

Here $\omega_b = [(\gamma - 1) g / (\gamma H)]^{1/2}$ is the isothermal Brunt-Väisälä frequency. $\mathbf{g}$ is the acceleration due to gravity, $c_s = (\gamma g H)^{1/2}$ is the speed of sound, γ is the ratio of the specific heats $(\gamma = 1.4)$, H is atmospheric scale height, $k_x = \frac{2\pi}{\lambda_x}$, and are horizontal and vertical wavenumbers, λ_x and λ_z are the horizontal (x directed) and vertical wavelengths, respectively.

The maximal frequency of AGWs (cut-off frequency) described by Eq. (1) is the Brunt-Väisälä frequency ω_b and corresponding minimal period for the mesopause region is about 5 min for atmospheric scale height H=5 km. In the case of absence of the background horizontal wind ($u_o = 0$) we can estimate the vertical λ_z wavelength of the observed AGWs, Eq. (1), the direction of propagation and consequently a possible source of its generation in the lower atmospheric layers.

In the figure 1, in case of short-period AGWs of the mesopause region, the dispersion Eq. (1) for the vertical wavenumbers (in case $u_o = 0$) give the values $\lambda_z = 6\ km$ (1-2.09.2014) and $\lambda_z = 8\ km$ (11-12.08.2015) are demonstrated. According to Eq. (1), the background wind velocities around $u_o = 10 - 40\ m/s$, typical for the mesosphere-lower thermosphere heights [15], can change AGWs frequency by $\Delta\omega_g = k_x u_o$, which is about the same order as AGWs frequency $\omega_g = \omega_g(u_o = 0)$, in case of absence of the background horizontal wind.

Figure 1 shows that the short period AGWs activity can cover the whole field of view of the all-sky imager above Abastumani. In this case it is possible to estimate mean background wind and its horizontal inhomogeneity, which influence wave propagation, as well as their dissipation [5]. So, the mesopause region observations, using modern imager technique, allow us to reveal short and long scale variations characteristic for this region, which cannot be described by current global circulation models [15] and is the field of our future investigation.

3. Conclusion

The monitoring of the mesopause over Caucasus by all-sky imager in the hydroxyl infrared band from Abastumani shows that short-period AGWs propagate quite frequently in this region. The two-dimensional images of AGWs evolution gives possibility to find location of their generation, taking into account background wind. It also shows their importance in investigation the lower and upper atmosphere coupling caused by orographycal effects of the Caucasus region. The importance of the observed short-period AGW in the region caused by orographic effects are noted to study the lower-upper atmosphere coupling.

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გიორგი ჯავახიშვილი

ე.ხარაძის აბასთუმნის ასტროფიზიკური ობსერვატორია

ილიას სახელმწიფო უნივერსიტეტი

რეზიუმე

აბასთუმნიდან ჰიდროქსილის ინფრაწითელი ზოლის სრული ცის იმიჯერული სისტემის გამოყენებით მეზოპაუზის რეგიონში დამზერილია მოკლეპერიოდიანი (დაახლოებით 5-10 წთ პერიოდის ხანგრძლივობით) ატმოსფერული გრავიტაციული ტალღები (აგტ) და ნაჩვენებია მისი გავრცელების ზოგიერთი თავისებურებანი. აღნიშნულია ამ მცირემასშტაბოვანი ტალღების მნიშვნელობა, როგორც მეზოპაუზაში ტალღური პროცესების მონიტორინგისათვის, ასევე კავკასიის რეგიონში ოროგრაფიული ეფექტებით გამოწვეული ქვედა და ზედა ატმოსფეროს კავშირების შესასწავლად.