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VERTICAL WINDS IN THE AURORAL ZONE IN QUIET AND DISTURBED CONDITIONS

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Abstract. Vertical winds behavior within the auroral zone was investigated. There was demonstrated that under disturbed conditions, vertical winds undergo considerable (up to 100 m/s) variations both at night and from night to night. In quiet conditions, if there are no any aurora, the vertical wind velocity remains constant within the range of 5 m/s, during the entire observation period, which allows us to use it as a zero reference point, when neutral winds are measured. Large variations of wind velocity are connected to aurora and spatial size of these disturbances is more then 200 km. While during the 1998-1999 season, vertical wind is predominantly upward under disturbed conditions. Some sources of wind disturbances are discussed

Introduction

The circulation of neutral winds in the upper atmosphere can be determined, using optical methods, after Doppler shift of spectral lines, mainly for oxygen emissions 630.0 nm (Hays and Roble, 1971; Hernandez and Roble, 1976) and 557.5 nm (Rodger and Stewart, 1990; Galakhov et al., 1996). The Doppler shift has the value of 10^{-4} Å, so for its determination, devices of high resolution capacity, mainly Fabry-Perot interferometers were used, with various ways of scanning by spectrum and various methods of interference image registering (Hernandez and Mills, 1973; Rees et al., 1990). Usually wind velocities are determined as wave lengths difference in various directions from a zero reference point. At the same time, spatial wind gradients and vertical winds can be obtained. The main difficulty, arising, when trying to determine the wind velocity, using these methods, is locating the zero reference point, i.e. the wave ("true") length, quiescent gas would emit. The most suitable source for this wave length determination could be a spectral lamp, that causes the emission under investigation. However, the lamps like these do not exist and, therefore, the only source of oxygen lines luminosity is atmosphere, which is in constant motion, thus, producing spectral line Doppler shift. In the most of interferometer observations, the value, obtained by averaging vertical winds per night, was taken as a zero point (Sica et al.,1986; Hernandez et al., 1990; Conde and Dyson, 1995). While some authors (Cogger et al., 1985) ignored those nights, when there was a large variations in vertical winds. With this method of determining the zero point, it is suggested that the amounts of upward and downward flows during the night are equal, or the velocity value of vertical winds is insignificant. One can agree with the cited suggestions, if winds are measured at medium and low latitudes, but doubts arise, concerning observations, carried out in the auroral zone, where areas of large vertical and horizontal wind gradients are formed during aurora (Rees et al., 1984; Walterscheid and Lyons, 1989; Bogdanov and Leontyev, 1994; Aruliah and Rees, 1995).

Below, a statistical analysis is given, concerning vertical winds in the E-layer of auroral region (Lovozero observatory, 67º 59' N, 35º 05'E) during 1998-1999 season and the criterion of the true wave length selection, that uses vertical wind measurements, is suggested for determining wind velocities at high latitudes.

Technique for determining neutral winds velocity

The most advanced way of interference image registering has been lately thought to be the one, which used the CCD (charged-coupled device) camera (Batten and Rees, 1990). The image obtained from the CCD camera appears as interference rings and it is possible to obtain the emission profile in the form I=I(r) where r is the distance from the ring center. The half-width of this profile depends on the temperature of the emitting gas, whereas its maximum location is determined by the emission wavelength (λ_0). The change of the emission profile maximum location is due to the wave length Doppler shift and may be scaled as the velocity of neutral gas, causing this emission. Thus, it is possible to measure the wind velocity variations, but one should know the maximum location of the profile of the emission, caused by the quiescent gas, in order to determine the absolute velocity.

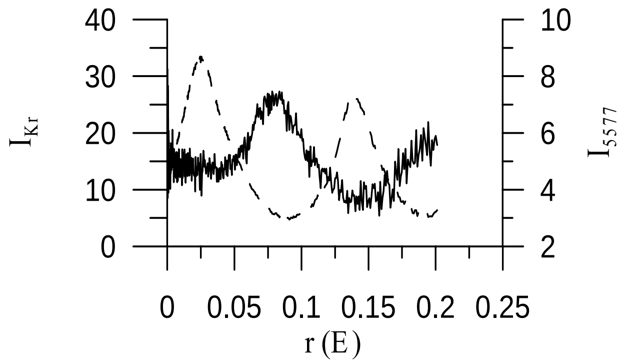


Fig.1. Profiles of krypton (dashed line) and green (557.7 nm) emissions (solid line) obtained by Fabry-Perot interferometer with CCD camera.

For the interferometer operation control, when registering the green emission, krypton lamp, emitting as much as 557.0 nm, is regularly registered. Fig.1 shows krypton line and green (557.7 nm) emission profiles. The X-coordinate shows the distance from the center in Angstrom units, and the Y-coordinate represents the relative intensity. The dotted lines demonstrate profiles approximation, using Gauss function. In practice, not the location of the emission profile maximum is determined, but the distance ($\Delta\lambda$) between the location of the maximum of contour of the krypton reference line, which is registered for each measurement cycle and the location of maximum of the line under investigation. This makes it possible to automatically allow for the effect of small temperature and pressure changes at the profile maximum location. The challenge of defining the reference point persists and the absolute velocity value may be found only, when we know this distance ($\Delta\lambda_0$) for the true length of wave, emitted by the quiescent gas. We should note, that the comparison of results is only possible during the period between two adjustments of the device.

Experimental data

During the observation period of 1998-1999, the interferometer performance in Lovozero was very stable and was not adjusted at all from December to March. This made it possible for us to analyze the vertical wind velocity behavior, both, during separate nights and the averaged velocity per one night as well, during a long period. 20 nights were chosen for the analysis, while 12 nights were characterized by disturbed conditions, including bright active aurora forms, whereas 8 nights can be characterized by quiet conditions, when aurora were not observed.

Disturbed conditions

During 12 disturbed nights, about 700 measurements of the vertical wind velocity were done above the Lovozero observatory.

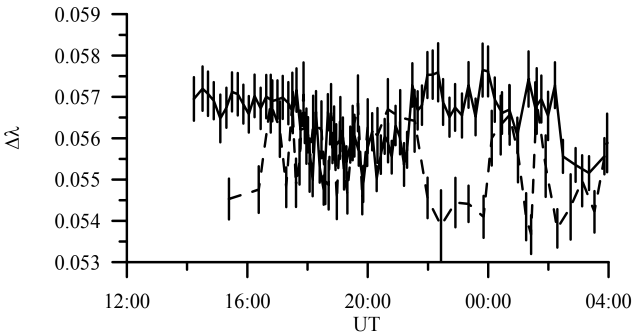


Fig.2. Locations of green emission maximums during two disturbed nights.

Fig. 2 shows the behavior of 557.7 nm line contour maximum locations, relative to the maximum of the krypton line contour ($\Delta\lambda$),during 2 disturbed nights (December, 23, 1998 and January, 24, 1999). As one can see from the drawing, the location of 557.7 nm line contour maxima, undergoes significant variations during the night. At the same time, the mean per every night, values of the 557.7 nm line contour maxima locations differ from each other by the value of the order of 9.4 10^{-4} Å, which corresponds to the velocity difference of about 60 m/s.

Fig.3 provides the location of the 557.7 nm line contour maximum, relative to the krypton profile maximum, averaged per night, for all 12 disturbed nights. As it is seen from the figure, concerning the disturbed nights, the mean maximum location varies from one night to another and its variation can measure up to 1.6 10^{-3} Å, which corresponds to changing mean vertical velocity about 100 m/s.

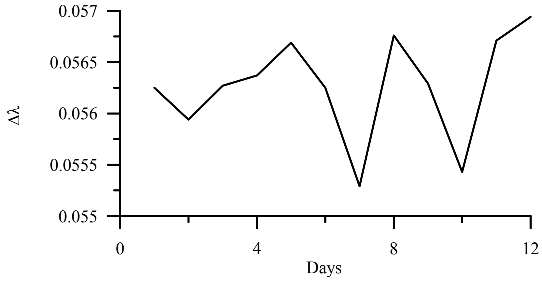


Fig.3. Locations of green emission maximums, averaged per night, for all disturbed nights.

Thus, we have come to the conclusion, that in the disturbed conditions, the mean per night location of the 557.7 nm line contour maximum does not represent the location of the maximum corresponding to that emitted by the quiescent gas. Using it as a reference point (Sica et al., 1986; Hernandez et al., 1990; Conde and Dyson, 1995) enables us to obtain only the variation, not the absolute value of the neutral wind velocity and, the data, obtained during various nights can not be comparable. While long observations (for example, studies of the solar or magnetic activity effect on the neutral winds velocity) do not make sense.

Undisturbed conditions

Under undisturbed conditions the signal is significantly lower, and the longer time of accumulation is required. However, during 8 undisturbed nights, ~ 120 vertical wind velocity measurements were carried out. All the measurements were done under low magnetic disturbance and the absence of aurora (the intensity of green line was below 500 R).

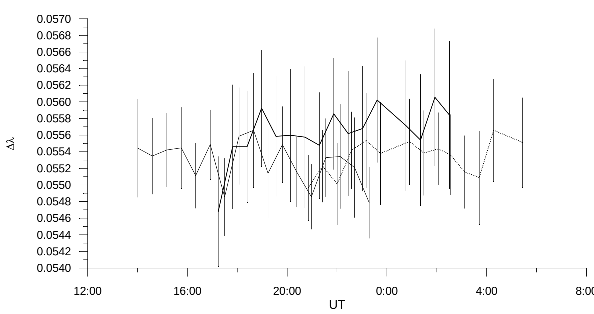


Fig.4. Locations of green emission maximums for three quiet nights.

Fig.4 shows the behavior of the location of 557.7 nm line contour maximum, relative to krypton maximum for three nights. Vertical bars show errors of the maximum location determination. As one can see from Fig.4, unlike the disturbed conditions (Fig.2), the location of the 557.7 nm emission maximum remains constant (within error) during both separate nights, and from night to night. Fig.5 illustrates the behavior of the night mean location of the 557.7 nm emission maximum, during 8 quiet nights. As it follows from Fig.5, although statistic data are scarce, the maximum location within the limits of standard deviation remains

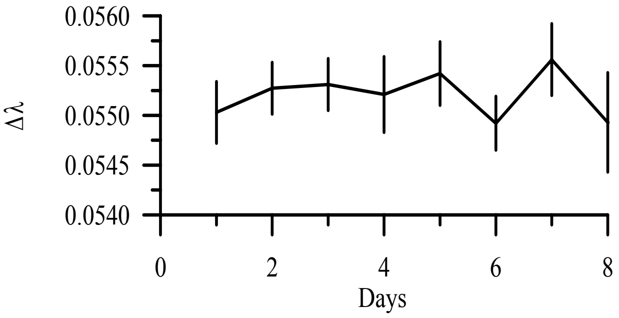
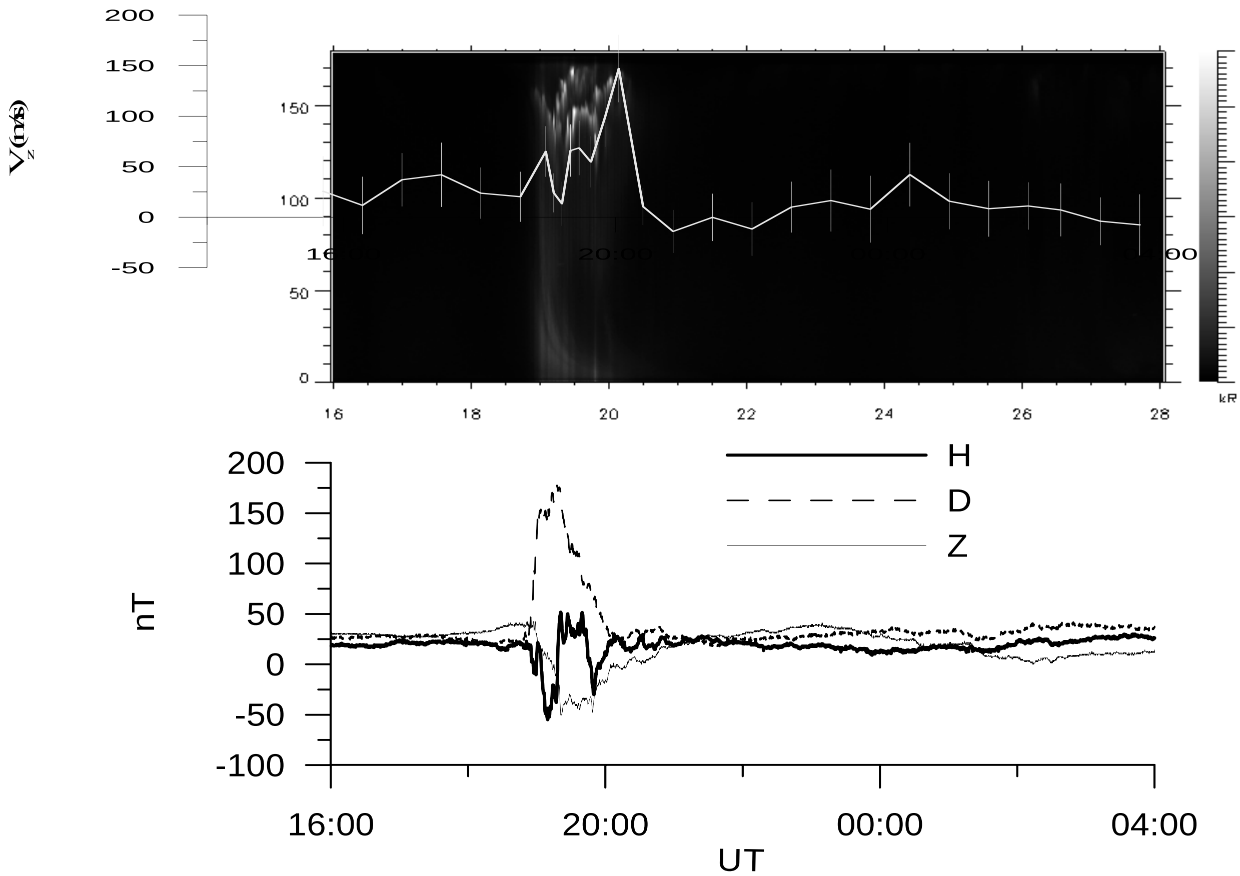


Fig.5. Locations of green emission maximums, averaged per night, for all quiet nights.

invariable, during the entire period of observations. If this maximum location variation is scaled in the wind velocity, the wind velocity turns out to be constant ± 5m/s, within limits of error.

Thus, we have established, that in quiet conditions, the 557.7 nm emission profile maximum location is constant both during one night and from night to night, and it, hence, may be used as a reference point, when determining velocities of the neutral gas.

A bright, convincing example of this fact can be an example, provided in Fig.6, where the behavior of neutral wind and auroral situation at the station meridian on the night of December, 22 - 23, 1998 are shown. We have to note, when calculating the wind velocity, the location of the green emission maximum, averaged for all quiet nights, was taken as a reference point. Almost during all that night conditions were quiet and only at 19-21 UT, magnetic disturbances of ~ 100 nT were observed, auroral activity increased and aurora appeared. At the same time, upward flows were registered, attaining the value 100 m/s. As aurora disappeared, the wind velocity came back to the previous value, which was close to 0.



Discussions

As it follows from the above said, aurora essentially affect the vertical winds. This fact was referred to in papers (Peteherych et al., 1985; Bogdanov and Leontyev, 1994). In the paper (Peteherych et al. 1985), it was noted, that when passing two intensive arcs, there were observed both upward and downward directed winds. The downward wind was associated with high, weak aurora, at the height of about 135 km. The upward wind was observed during low, bright aurora at the height of 110 km. Another mechanism of vertical wind generation by aurora was suggested in the paper (Lyatsky and Leontyev, 1982). According to this mechanism, the neutral vortex occurs, due to neutrals' dragging by ions, within aurora, so that oppositely directed vertical winds occur on either side of the arc.

According to our studies, the wind velocity undergoes considerable (up to 100 m/s) variations under disturbed conditions, whereas, if we compare the mean wind velocity for all disturbed nights, it turns out, the wind is upward directed and has the velocity of ~ 60 m/s in the disturbed conditions. This problem needs further investigation.

An important, in our opinion, fact, that can help define the mechanism of vertical winds generation, is presented in Fig.6. The vertical wind is measured in the station zenith (it corresponds to the zenith angle 90^0 in the keogramm). If velocity variation at 19-21 UT is due to the development of active forms of aurora, than this means the typical size of the disturbance exceeds 200 km, as aurora are observed far from zenith.

Conclusions

The presented study enables us to draw the following conclusions: 1. When defining absolute velocities of the neutral gas, it is necessary to use the location of the emission profile maximum, determined under quiet geomagnetic conditions, when there were no aurora as a reference point. 2. It is necessary to define the reference point a new, after each adjustment of the device. Only in such case, the obtained results can be comparable. 3. Under disturbed conditions, the vertical wind velocity is increased. In the time of the mentioned observations, it was directed upwards and made, on the average, ~ 60 m/s. 4. The typical scale of the neutral gas velocity disturbance, induced by aurora, exceeds 200 km.

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