MANIFESTATIONS OF INTERACTION BETWEEN ATMOSPHERIC AND SPACE CLIMATE SYSTEMS

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Abstract

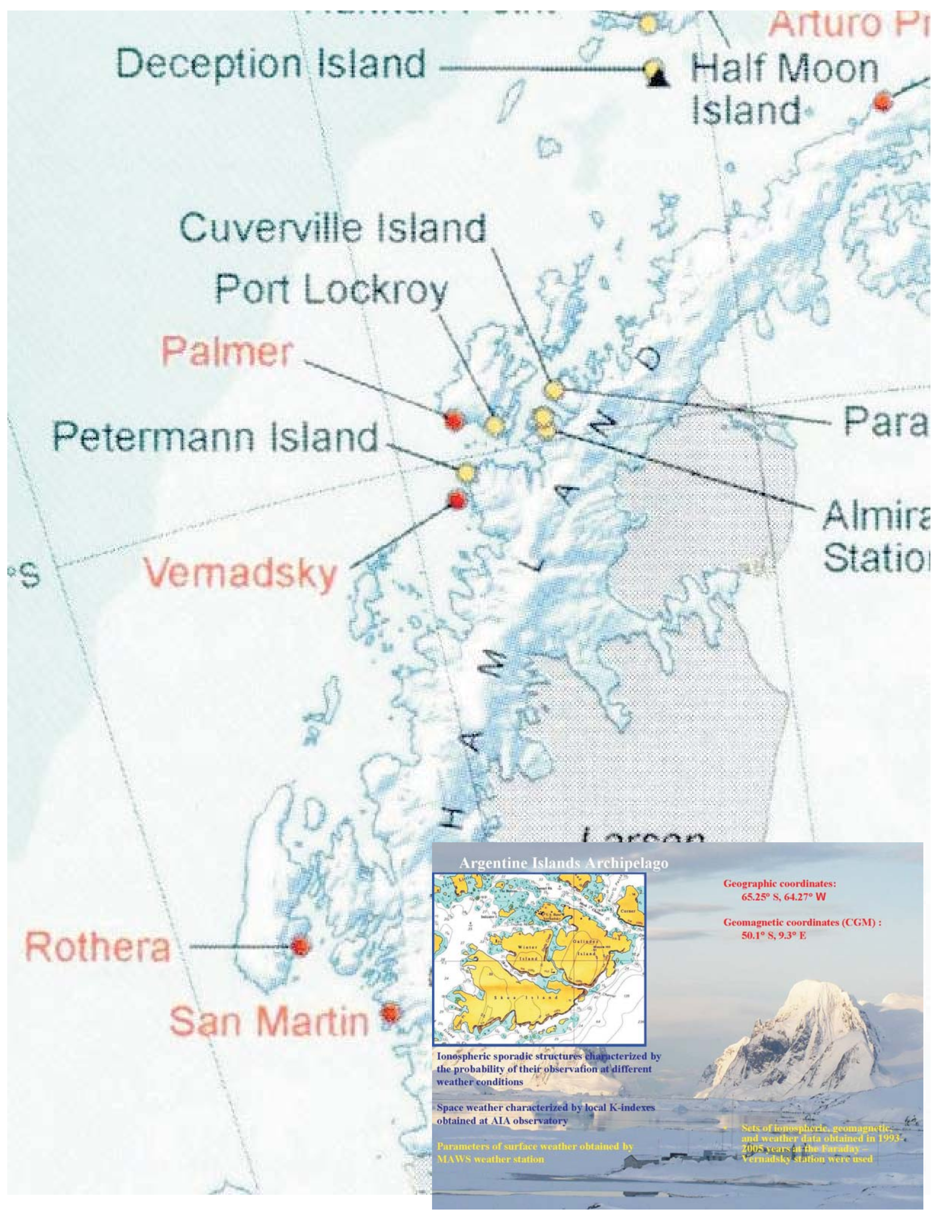
The impact of meteorological processes near the Earth's surface upon the upper atmosphere cannot be ignored in conceptual space weather models. This paper will suggest examples of physical interactions between the atmospheric and space climates. The key question about the importance of near-surface energy releases and energy transport from "bottom to top", i.e. to the geospace, is identification of a transport agent capable of transferring the mechanical (or thermal) energy released in the neutral atmosphere, to the terrestrial plasma. One of the prospective carriers of near-surface disturbances might be associated with the atmospheric gravity waves (AGW) traveling upwards to ionospheric heights and producing the effects known as traveling ionospheric disturbances (TIDs). Evidence is provided by the ionospheric signatures of natural disasters, like earthquakes or volcanic eruptions, powerful industrial processes like explosions, large rockets or spacecraft launches; accidental thermal, chemical or radiation releases, and powerful radio emission radiated from the Earth's surface by the HF heating transmitters.

The problem discussed in this paper in more detail is that of projection to geospace altitudes of the atmospheric phenomena of greatest power, cyclones. The original material that the research was started from had been provided by experiments in a region of high meteorological activity, namely the Antarctic Peninsula, where the Ukrainian Antarctic station Akademik Vernadsky is located (UK's Faraday base till 1996). The data used for the analysis were collected over the thirteen years.

The magnetically conjugate region of Akademik Vernadsky station lies not far from the US East coast. Simultaneous records of magnetic and meteorological measurements were conducted in the Boston area, for comparison with the Antarctic data. The comparison was done for events that occurred on magnetically quiet days in the Northern hemisphere. The results of cross-analysis of the magnetic field variations in Antarctica and in New England (upon passage of a cyclone in the South) demonstrate a high degree of statistical relation. It can therefore be stated that powerful meteorological processes are projected to geospace not only directly above their location but also to the other hemisphere (at least, in the vicinity of the conjugate point, with the disturbance traveling along the appropriate L-shell).

It was also found that the probability of occurrence of sporadic plasma structures in the ionospheric E and F layers above cyclones and atmospheric fronts is increased. All meteo-effects are observed mostly in the winter time, and inside the ozone hole area in spring. The ozone layer was revealed to play the role of a kind of screen impeding vertical propagation of AGWs. As a result of numerical simulations, it was shown that the conditions for vertical propagation of AGWs in the middle and upper atmosphere are more favourable between May and September (that is austral winter). It was also found that the conditions for AGW to propagate in the middle atmosphere through the ozone hole remain quite good in the spring as well.

By using the multiposition GNSS technique the impact of cyclone activity on the ionospheric disturbances is demonstrated

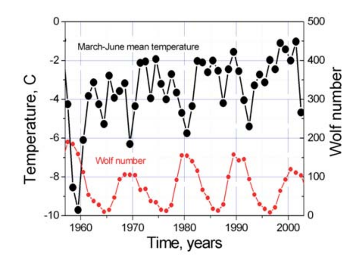


Introduction
Advantages of the Antarctic Peninsula and *Akademik Vernadsky* station for investigation of the troposphere-ionosphere interaction

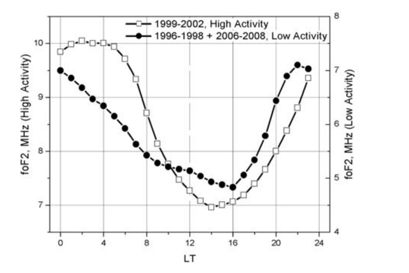
- Big difference between geographic and geomagnetic latitudes;
- Middle geomagnetic latitudes lead to quiet background of the ionospheric and geomagnetic variations;
- High cyclonic activity;
- Geomagnetic anomaly, and Weddell Sea anomaly;
- Ozone hole in the spring time;
- Experimental tools allows to measured the atmospheric parameters from the earth surface up to magnetospheric heights;
- Long continuous sequences of the weather, ozone, ionosphere and geomagnetic data (weather data since 1947; other since late 50-th).

Long-term variations of environmental parameters show unexpected behavior of some of them.

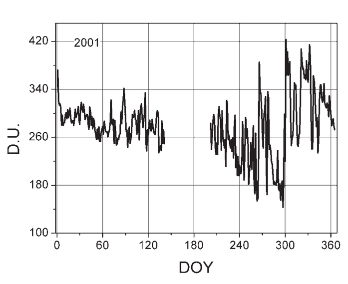
11-year circle in the mean temperature of March-June



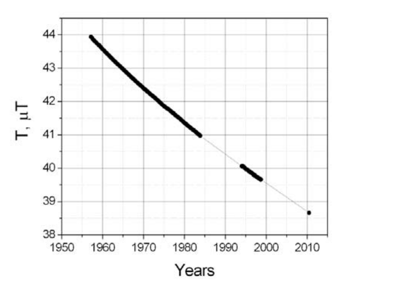
Weddell sea anomaly



Ozone hole in the spring

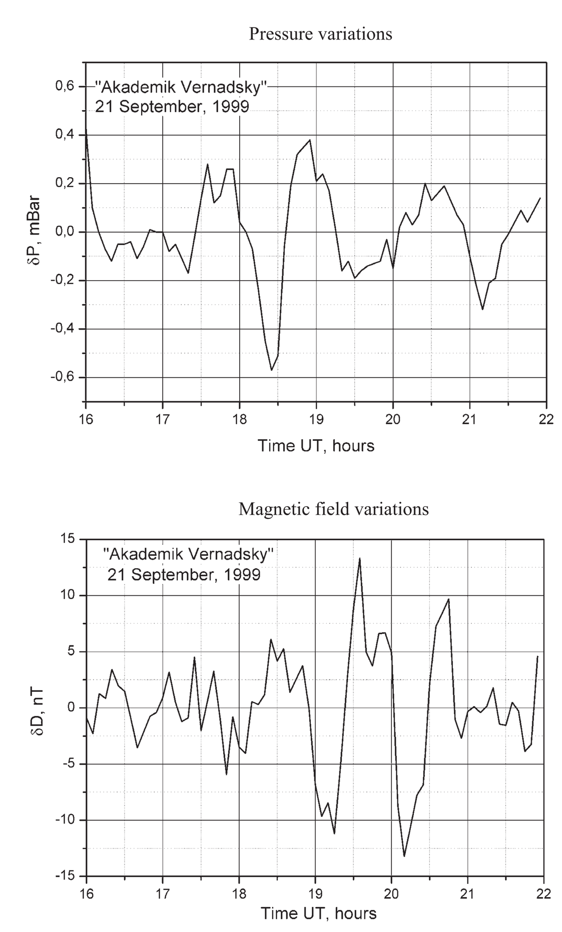


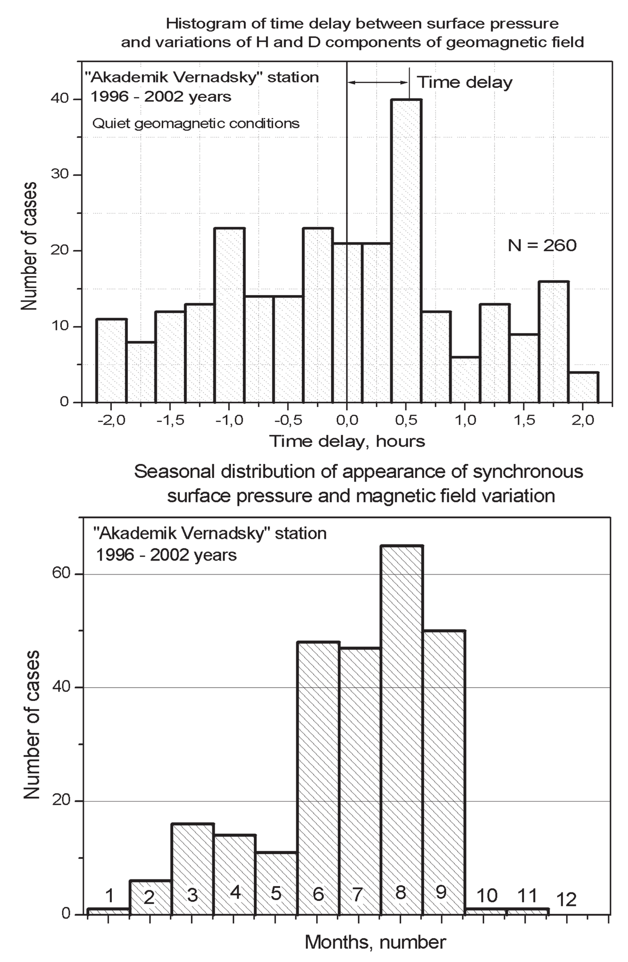
Geomagnetic field intensity



EXPERIMENTAL RESULTS

1. Magnetic field variations. Long-term synchronous records of surface pressure and geomagnetic field variations at the Ukrainian Antarctic station *Akademik Vernadsky* have been analyzed. Excitation of AGW by powerful atmospheric fronts above the Antarctic Peninsula has been found, and their projection to ionospheric and magnetospheric altitudes. A distinctive feature of the wave processes is the half-hour delay of the magnetic field variations with respect to such of the surface pressure. Similar magnetic field variations were detected near the conjugate region in the Northern hemisphere (New England, USA).



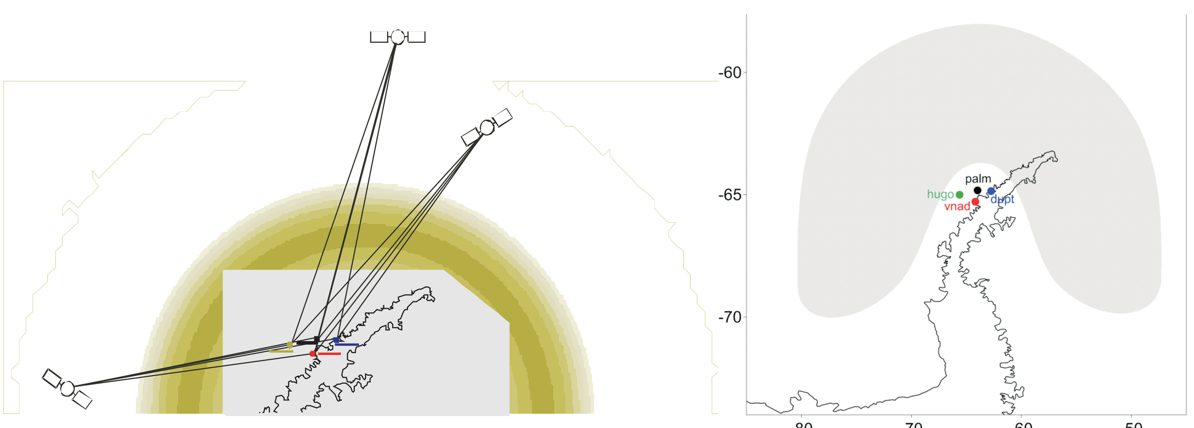


2. TEC

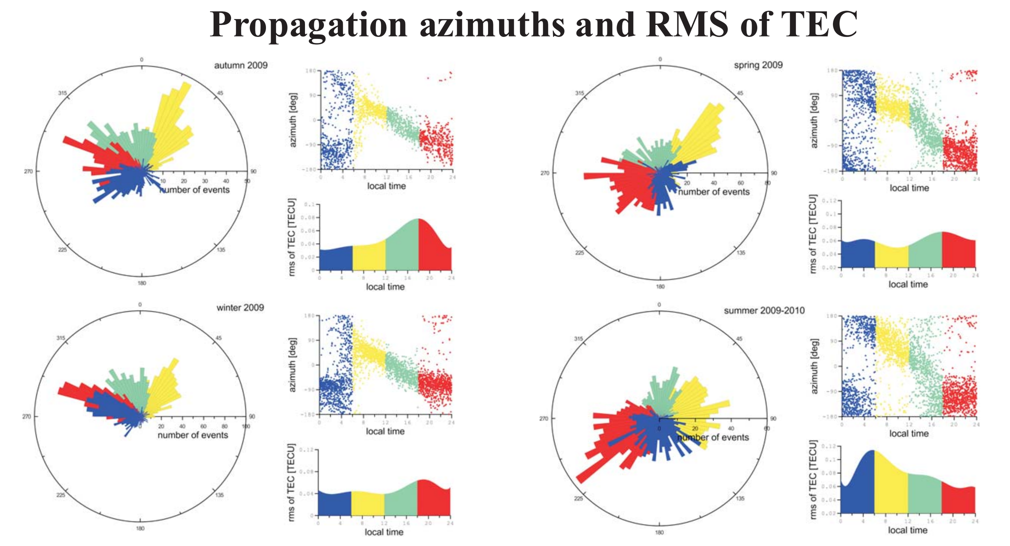
The strategy of traveling ionospheric disturbances identification by total electron content measurements, which realized in Antarctic Peninsula region are presented. The data of global navigation satellite system signals registration continuously carrying out since April, 2005 at *Akademik Vernadsky* station and also data from three nearest permanent GNSS-stations were used for this work.

Diurnal and seasonal variations of the motion direction and horizontal velocities of ionospheric irregularities have been analyzed. It has been found that TID parameters are dependent on the local time and season. In the daytime TIDs propagate mostly equatorward with velocities about 300-400 m/s. The motion direction was varying from NE in the morning to NW in the evening. After the sunset the disturbances propagated within a rather broad angular sector thus showing no preferential direction.

TEC distribution



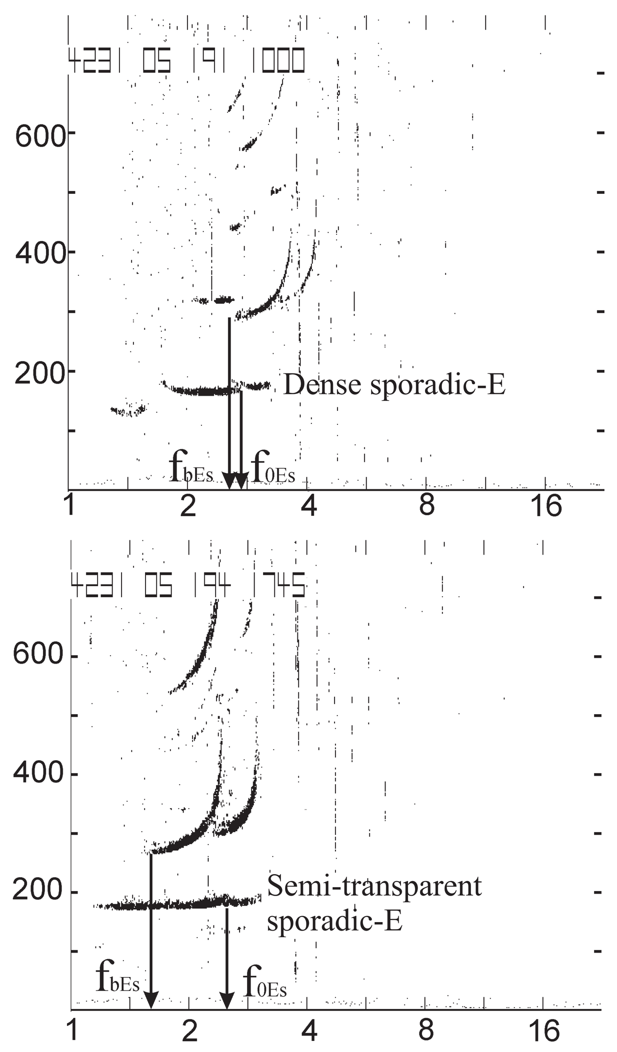
Propagation azimuths and RMS of TEC

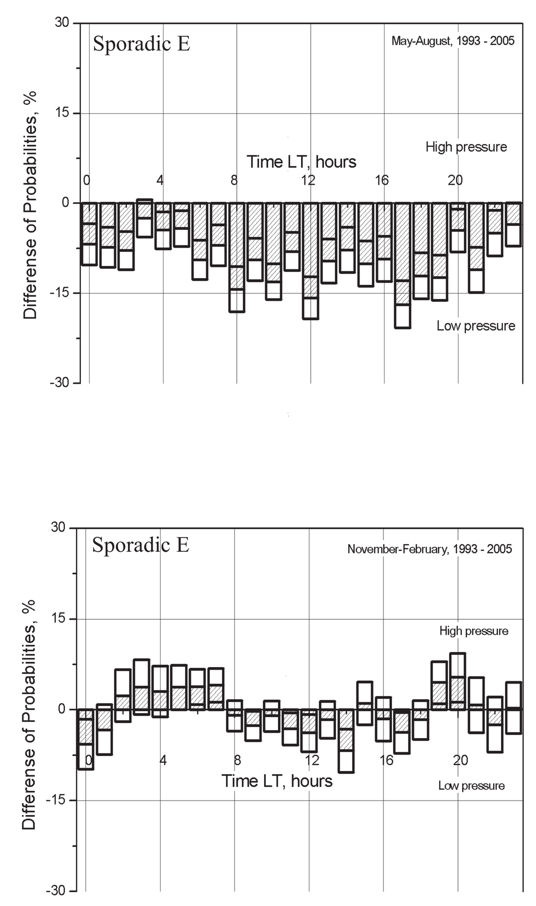


Meteo-effects in sporadic ionospheric structures

3. Sporadic E layers

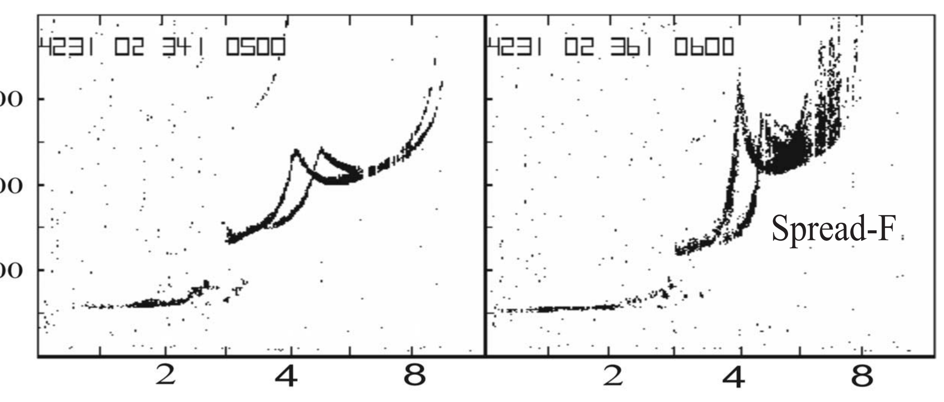
The impact of tropospheric weather on the excitation of sporadic E layers (Es) over the Antarctic Peninsula was considered, based on the experimental data obtained at the station *Akademik Vernadsky* in 1993 through 2005. The amount of connection between the Es and weather is investigated by comparing the conditional probabilities of Es appearance for various weather conditions. A statistically significant relation between the Es and weather parameters has been established for the winter months. Namely, the probability of Es appearance increases during the low values of surface air pressure. The low pressure increases the probability of appearance of both dense and semi-transparent Es layers. Whereas the North-Eastern wind projection (associated with frontal activity) increases the probability of semi-transparent layers, while reducing the repetition of dense ones. The experimental facts were interpreted as a result of propagation of atmospheric gravity and planetary waves from the troposphere up to ionospheric heights. The probability of Es appearance grows in winter in minimal phase of pressure of planetary wave. The role of atmospheric gravity waves are in exciting of small- and mesoscale plasma irregularities and destruction of the regular structure of the Es.

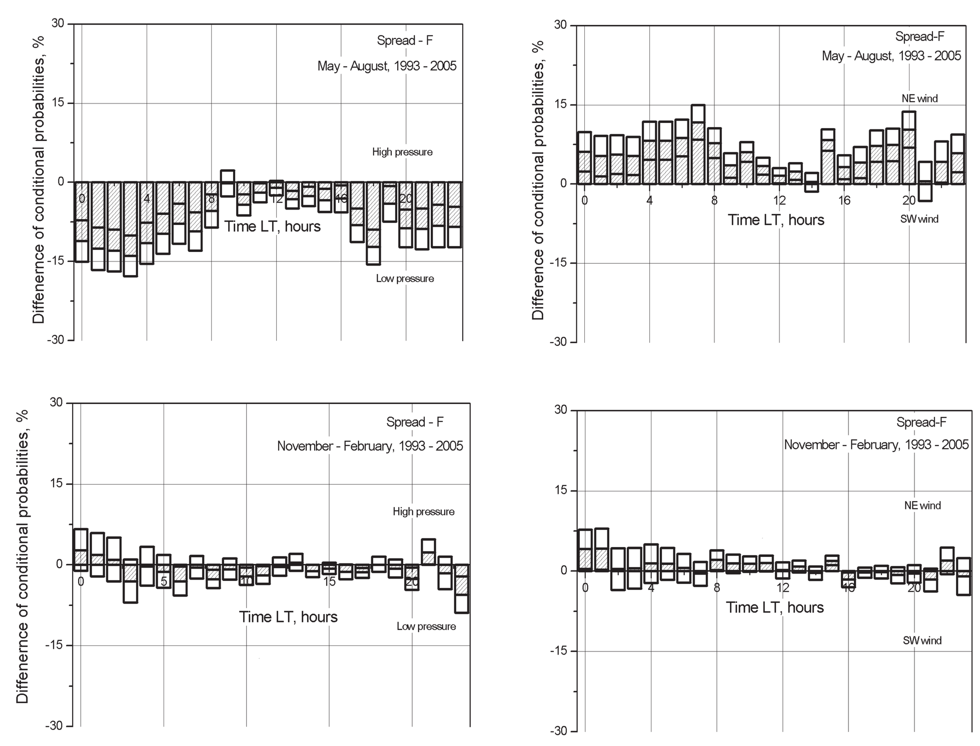




4. Spread-F

The spread-F effect is analyzed as a manifestation of troposphere-ionosphere coupling. The observational data discussed were obtained in 1993 through 2005 at the *Akademik Vernadsky* station. Among the weather parameters were found those that have the highest statistical connection with the probability of spread-F observation. These parameters at *Akademik Vernadsky* are the North-Eastern projection of wind speed and surface pressure. Indeed, the conditional probability of detecting spread-F in winter was higher by a factor of four with the North-Eastern speed projection of positive rather than negative sign. In the seasonal variation the highest impact of the troposphere on the upper ionosphere condition was in winter. As for diurnal variations, the tropospheric effects in ionosphere were highest at night and during twilight hours. These observational findings have been interpreted within the hypothesis of AGW propagating through the atmosphere. It has been suggested that AGWs are excited by atmospheric fronts, their good local indicator near the surface is the North-Eastern wind speed projection. The observed diurnal and seasonal variations in the amount of impact of tropospheric AGW on the ionosphere might be due to varying conditions of AGW propagation through the atmosphere

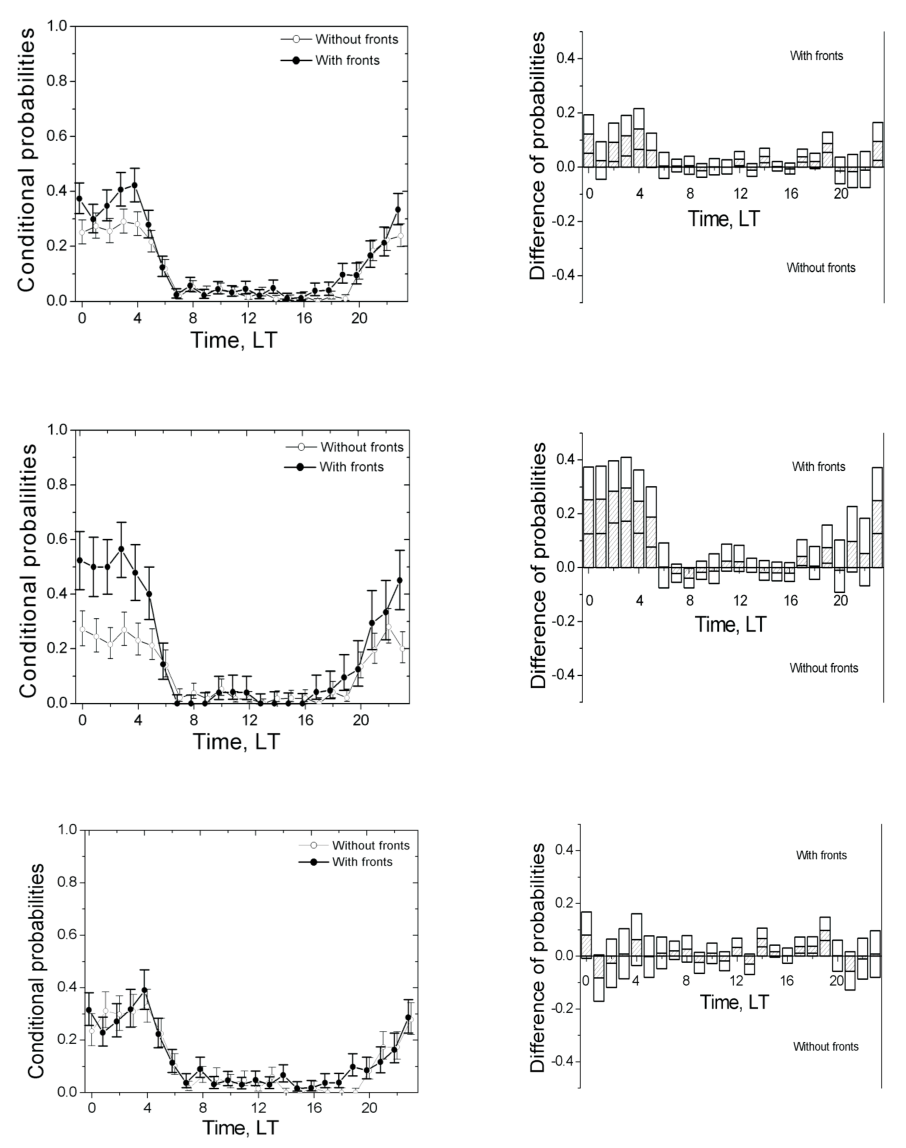




5. Role of ozone

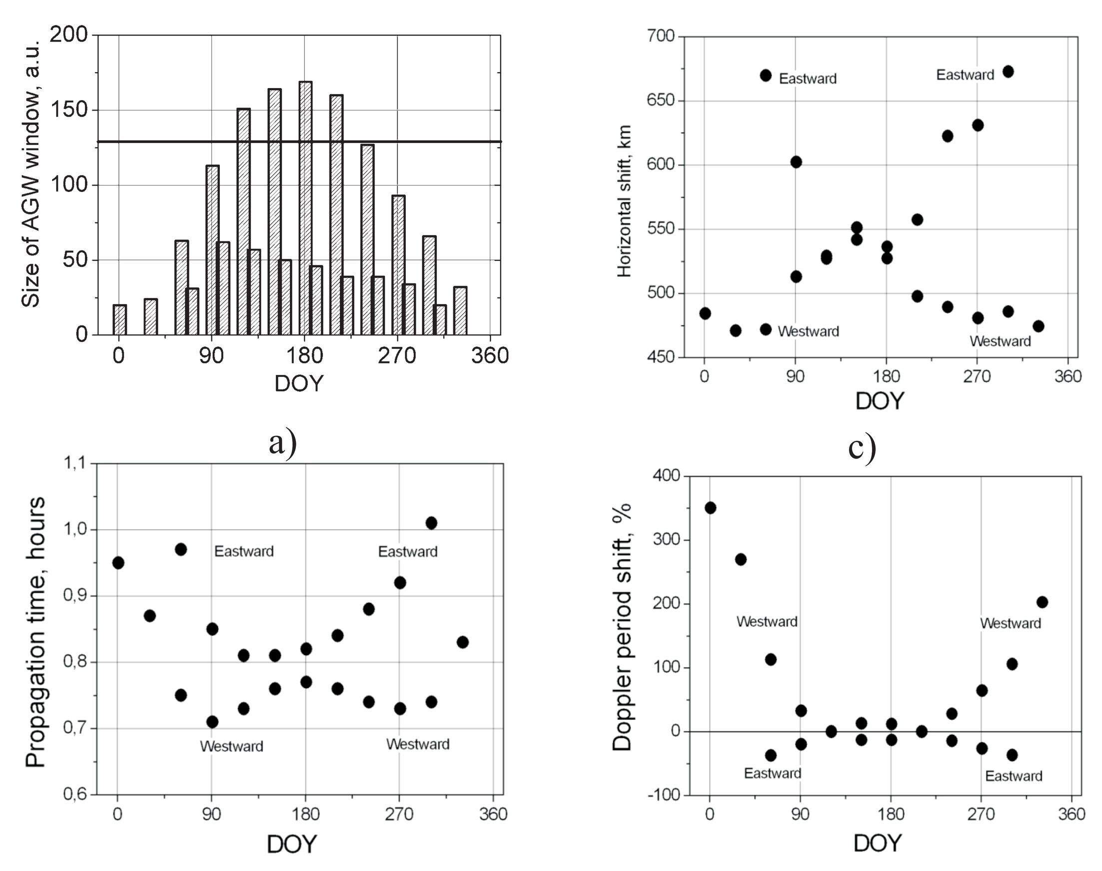
The role of the ozone layer in the troposphere-ionosphere coupling was experimentally investigated using the fluctuations of the total ozone value at the time of "ozone hole", at austral spring. The conditional probabilities of spread-F appearance at the different weather and daily ozone values have been calculated. It was found, that the weather impact on the spread-F in September became much stronger under the low total ozone levels. To the right of this text you can see the figures with daily variations of probabilities of spread-F observation in presence and absence of atmospheric fronts (left panels) and their differences (right panels); independently on ozone value (top panels), under the low (less then 180 D.U.) and high (more than 180 D.U.) ozone values.

So, the channel of troposphere-to-ionosphere energy transfer depends on the total ozone level and opens at the low ozone concentration.



Numerical simulation

Experimental results show that the tropospheric weather essentially impacts on the space weather over Antarctic Peninsula region. Seasonal variations of the conditions for AGWs propagation at this area have been estimated in the temperature and wind vertical profiles obtained in frames of NRL MSISE-00 model of neutral atmosphere. The results of modeling of seasonal variation of the AGWs propagation conditions over the Antarctic are below. The first plot (a) shows the relative size of window of AGWs that can propagate to the height of 200 km. The figures (b-c) show the parameters of most quick AGW mode such as propagation time (b), space shift of the wave from the source in the troposphere (c), Doppler period shift (d). So, the results of modeling of seasonal variation are in good correspondence with the experimental data.



a) c) b) d)

CONCLUSION

The tropospheric weather is the important factor which controls the space weather and space climate over Antarctic Peninsula region, especially in winter time and inside the area of ozone hole in the spring.

Ozone layer in the summer time plays the role of screen for AGWs that propagate from lower to higher atmospheric layers.

It should be taken into account that the troposheric weather can be an significant factor which can disturb parameters of space weather and effects on space climate, especially in the winter time and at mid geomagnetic latitudes.