GEOPHYSICAL OBSERVATIONS AND PREDICTION OF GEOPHYSICAL FIELDS FOR USERS

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ABSTRACT

Daily and weekly predictions of geomagnetic activity were produced and transmitted regularly to the News Desk of Czech Television and the headquarters of the International Space Environmental Service (ISES). More detailed predictions of geomagnetic activity were used in airborne prospecting by the firm IMPULS. It was explained to the company MERO why voltage and currents are induced in oil pipelines during geomagnetic storms. The accuracy of predictions of geomagnetic activity was analysed. The Internet page of ISES RWC Prague was currently updated in co-operation with the ISES headquarters in Boulder, USA. The project helped to realise not only the ionospheric service and the creation of regular ionospheric predictions in the IAP, AS CR but also supported the activity of the ISES RWC Prague. Ionospheric predictions were regularly directed to the Czech Army. Real-time ionograms were transmitted to the data and prediction centre of the RAL in Great Britain to contribute to a solution of short-term predictions. Effects of geomagnetic storms, planetary and gravity waves on processes in the ionosphere were studied in detail. The standard maps of earthquake hazard in the terms of macroseismic intensity and effective peak acceleration for the territory of the Czech Republic, Poland and Slovakia were calculated. The map of seismic zones of the Czech Republic in terms of the reference peak ground acceleration was prepared for the national application document Eurocode-8. The long-term effects of geodynamic processes on the Earth's surface were studied. Long-term displacement trends, responsible for local deformations, were determined from GPS data. General procedures of a geodynamic hazard assessment were suggested and exemplarily were applied to a wider region of the Červená hora Saddle, where the motorway will be constructed. The GI virtual seismic network, providing rapid and quality localisations and estimates of the magnitudes of regional earthquakes in Central Europe, was established to be prepared to inform government and Civil Protection authorities, the media and the public. Up-dated catalogues of regional seismic events are published on the WWW site of the GI AS CR.

KEYWORDS: prediction, geomagnetism, ionosphere, seismic network, seismic zones, GPS, earthquake hazard, geodynamic hazard, Czech Republic

1. PROJECT OBJECTIVES

The aim of the project was a significant improvement of quality of predictions of geophysical fields for a broad spectrum of users and the compilation of map of seismic zones of the Czech Republic for the National Application Document Eurocode -8. The predictions of geomagnetic, ionospheric and seismic fields require long-term monitoring of related parameters. This monitoring on the territory of the Czech Republic and its surrounding are carried out by the institutes involved in the project. These institutes contribute to the World Data Centres and use their interplanetary, solar and geophysical data in prediction methods. They develop both short-term (hours to day) and long-term (months to years) prediction methods.

2. PREDICTION OF GEOMAGNETIC ACTIVITY AND IONOSPHERE STATE

For the whole duration of the project, daily and weekly predictions of geomagnetic activity were produced and transmitted regularly to the News Desk

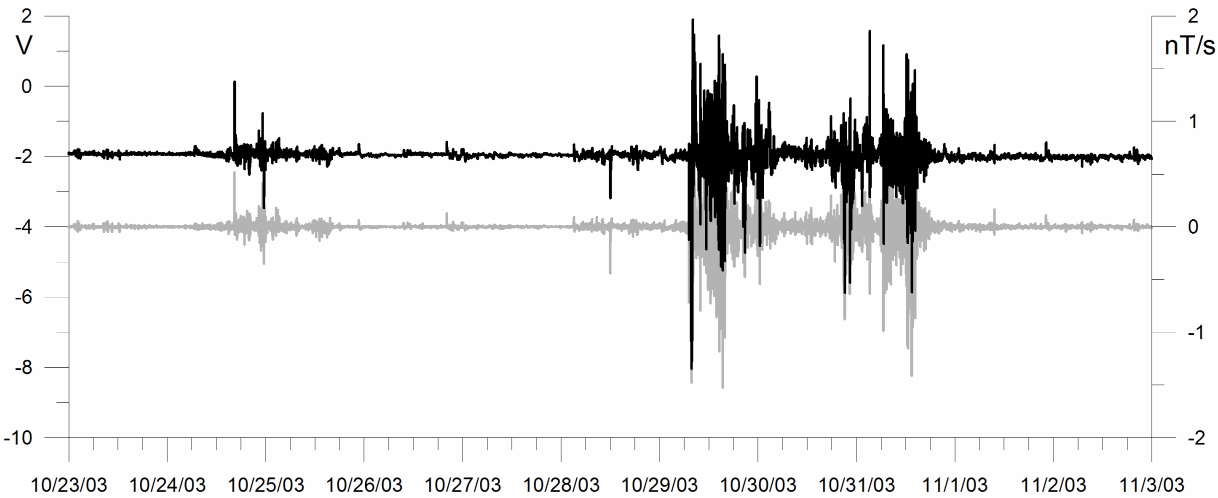

Fig. 1 Voltage between pipe and soil recorded at Svatá Kateřina (West Bohemia) on the Ingolstadt – Kralupy nad Vltavou pipeline at the end of October 2003 (black) and time derivatives of the north component of the geomagnetic field measured at Observatory Budkov (grey).

of Czech Television and the headquarters of the International Space Environmental Service (ISES) which take care of the exchange of data and predictions relating to the geomagnetic field, ionosphere and Sun. In the period of the most severe geomagnetic storms of 2003, more detailed predictions of geomagnetic activity were produced for the firm Impuls, which uses also geomagnetic methods in airborne prospecting. Thanks to the predictions of geomagnetic activity, this company avoided financial losses, which it would have incurred, if the prospecting flights had been carried out at times on enhanced geomagnetic activity. We provided the company MERO, operating Czech oil pipelines, with the explanation why voltage and currents are induced in pipelines during severe geomagnetic storms.

The graph in Figure 1 demonstrates the close correspondence of voltage between pipe and soil recorded on the Ingolstadt – Kralupy nad Vltavou pipeline and of time derivatives of the north component of the geomagnetic field measured at Observatory Budkov.

The analysis of the prediction of enhanced geomagnetic activity, issued in the course of this project, indicated that the accuracy of these predictions depends on the nature of the event causing the geomagnetic disturbance (Bochníček and Hejda, 2002). If the geomagnetic disturbance is caused by a regular event (co-rotating high-velocity solar wind stream) the predominating source of prediction inaccuracies is usually an incorrect estimate of the magnitude and behaviour of the north-south component of the interplanetary magnetic field Bz. If the geomagnetic disturbance is due to an irregular event (X-ray flare, erupting prominence) the predominating source of prediction inaccuracies is usually either a lack of information about its existence, or the hitherto not completely clarified dependence of the degree of its geoeffectivity on the position of its occurrence on the solar disk.

The estimation of the magnitude and behaviour of the Bz component of the interplanetary magnetic field, the most significant geoeffective parameter, is a very difficult problem, which in the case of co-rotating streams of solar wind cannot be solved theoretically. The reasons is that in co-rotating streams the said parameter is given by small-size turbulence, i.e. a process, which cannot be foreseen by means of solar observations. Experience has indicated that certain estimates of the magnitude of the geomagnetic response in this case can indeed be made, because the intensity of the repetitive disturbances remains unchanged sometimes even over several solar rotations, and the disturbances reach their maximum on the day the “leading edge” of the co-rotating streams, formed by the interface between the slow and fast solar wind, reacts with the magnetosphere. This day is the first day of the disturbance. In the case of irregular events, the magnitude and behaviour of the Bz component can, however, be estimated, although just theoretically for the time being.

The Internet page of ISES RWC Prague was currently updated in co-operation with the ISES headquarters in Boulder, USA. The project helped to realise not only the ionospheric service and the creation of regular ionospheric predictions in the Institute of Atmospheric Physics (exploited, inter alia, by the Ministry of Defence of the CR) but also supported the activity of the RWC Prague. Ionospheric predictions were regularly sent to the Czech Army. The prediction of the total electron concentration in the ionosphere was included in the monthly predictions in the year 2000. Although Czech customers have as yet not requested predictions of

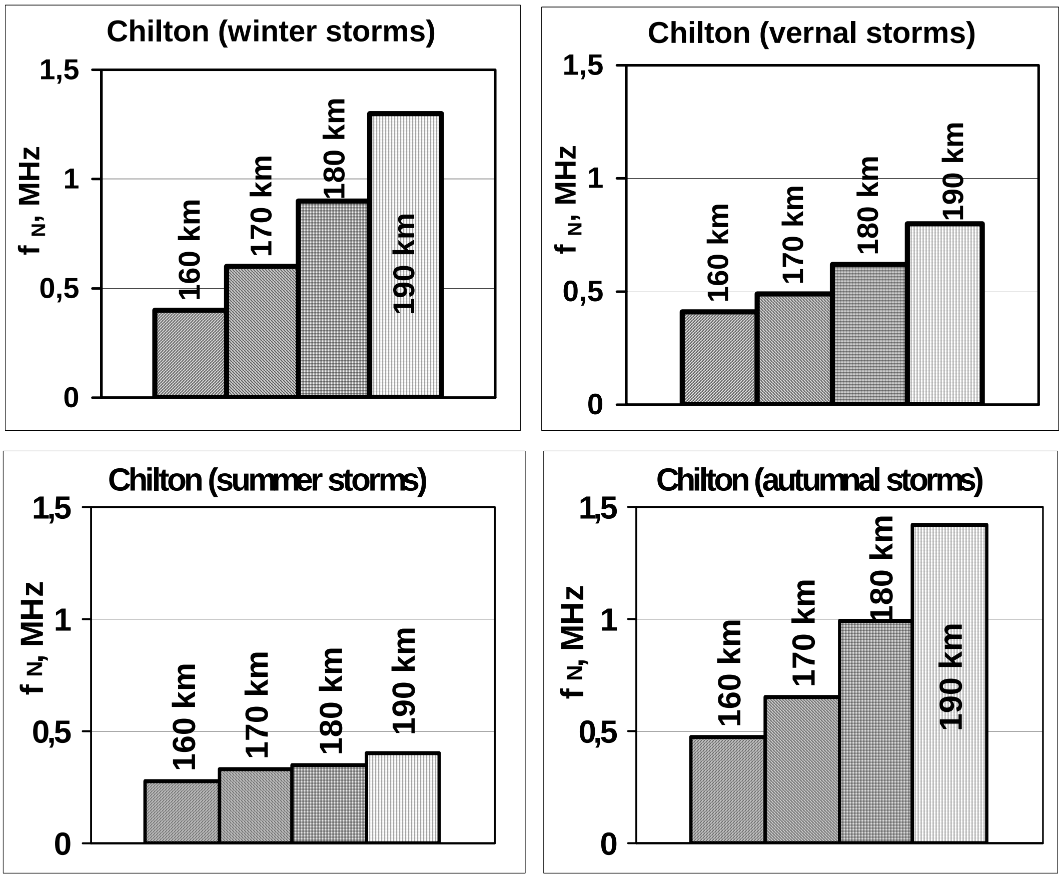

Fig. 2 The magnitude of the mean electron density decrease at the fixed F1 region heights (the difference between pre-storm quiet days and the storm main phase at 11:00 – 13:00 UT) for all analysed 35 geomagnetic storms, which occurred during different seasons, for Chilton (Burešová and Laštovička, 2002).

electron profiles, we did contribute to their development (Burešová et al., 2004a, 2004b; Mosert et al., 2004; Stanislawska et al., 2004b). Short-term predictions have proved to be a very complicated and hitherto unsolved problem worldwide. We are contributing to its solution also be real-time ionograms sent to the data and prediction centre of RAL in Great Britain. This began with the installation of the new digisonde in January 2004. From a customer's point of view this involves predictions of disturbances.

The results concerning the effects of geomagnetic storms on ionsopheric layers F1 and F2 have been reported in (Burešová et al., 2004a, 2004b; Burešová and Laštovička, 2001, 2002; Laštovička, 2002; Mosert et al., 2004, 2002; Stanislawska et al., 2004a). Special attention was devoted to the little studied ionospheric layer F1 (altitude 150-200 km), insufficiently described even by the International Reference Ionosphere (IRI). We have proved that a severe geomagnetic storm always causes a decrease of electron density in the daytime layer F1 above midlatitudes Europe. The example for Chilton and 35 geomagnetic storms is given in Figure 2. This decrease is independent of the change of electron density in the maximum of the F2 layer. The effect is strongest in winter; it enhances with increasing intensity of the geomagnetic storm, displays no evident dependence on solar activity, and weakens with decrease of altitude. We have contribute to the accuracy of parameter D1 of ionospheric layer F, to improving the methods of ionospheric mapping during geomagnetic storms, and to the development of methods enabling the determination of the electron density profile in the ionosphere at the time of geomagnetic storms. At the request of customers, an overview of the state of knowledge of effects of geomagnetic storms on the ionosphere, of monitoring and prediction storms (Laštovička, 2002) was produced, as well as an overview of the knowledge concerning the impact of geomagnetic storms on ionospheric layer F1 and on the propagation of radio waves.

In the area of effects of gravity waves we found a systematic effect of the morning terminator (sunrise) suitable for inclusion in predictions; for other disturbances of the gravity wave type, suitable atmospheric predictors are still lacking. An effort was made to solve the problem of short-term predictions of the effect of not only geomagnetic storms, but also of planetary and gravity waves on processes in the ionosphere. The results concerning gravity waves in the ionosphere have been reported in (Altadill et al., 2004; Boška and Šauli, 2001; Boška et al., 2003; Bošková and Laštovička, 2001; Laštovička, 2001b; Šauli and Boška, 2001). We have proved that the activity of these waves culminates in the lower ionosphere in summer, and that in the upper ionosphere the period of these waves depends on the intensity of the geomagnetic disturbance. We also found that the intensity of gravity waves in the ionosphere is affected by the passage of meteorological fronts, in particular strong cold fronts. To satisfy the interest of customers, we produced overview papers concerning the propagation of radio waves (Altadill et al., 2004), the physics of the lower ionosphere (Laštovička, 2001b), the physics of ionospheric layer F and the vertical coupling of the atmosphere-ionosphere system.

The studies of planetary waves (Laštovička et al., 2003a, 2003b) we carried out have shown that the effects of these waves could be predicted with a user usable accuracy only when such measurements, suitable as predicators, can be made in a neutral atmosphere. The results, concerning planetary waves in the ionosphere, have been reported in (Altadill et al., 2004; Laštovička, 2001b; Laštovička et al., 2003a, 2003b). The research was focused namely on their duration. We found that this period is not a function of geographic longitude, that it was practically the same in the upper and lower ionosphere, and that it decreased with increasing period of these waves. As in the case of gravity waves, overview papers were focused on prediction of the effects of planetary waves, on the radio waves propagation (Altadill et al., 2004), on the physics of the lower ionosphere (Laštovička, 2001b) and on the vertical coupling of the atmosphere-ionosphere system.

3. SEISMICITY, EARTHQUAKE AND GEODYNAMIC HAZARDS

In the project, the staff of the Institute of Rock Structure and Mechanics, AS CR (IRSM) concentrated on two tasks: (a) compilation of a map of seismic zones for the national application document EUROCODE –8 (CSN P ENV, 2005), and (b) assessment of the earthquake hazard. The results of both tasks can be applied directly in earthquake engineering to designing earthquake-resistant structures, and in land or urban development of larger regions.

For the purposes of constructing the map of seismic zones for the national application document Eurocode-8, geological materials and geophysical data were collected, in particular experimental data on the dynamics of seismic waves and macroseismic effects in relation to local geology. Since a sufficient set of acceleration records is not available from the territory of the Czech Republic, the method of determining the reference peak ground acceleration a_{gR} was tested on the acceleration records of Central Greece that were joined with directly observed macroseismic intensities I (Schenková et al., 2003; Kalogeras et al., 2004). These analyses allowed the values of a_{gR} and I for main structural geological blocks of the Bohemian Massif to be assessed.

The standard maps of earthquake hazard for the territory of the CR use the mean dependence of the attenuation of seismic waves with distance, which corresponds, more or less, to the granitoid rocks. Changes in attenuation occur only in the near-surface parts of the Earth's crust formed by sedimentary rocks of various consolidation ranging up to unconsolidated sediments. For the purpose of determining the dependence of the attenuation in the CR and the regions of Central Europe (Schenk et al., 2001; Giardini et al., 2003) macroseismic data observed in densely populated regions of Central Europe were used as well as observations of macroseismic intensities and particle ground accelerations from moderate to destructive Greek earthquakes of the recent fifty years (Kalogeras et al., 2004).

The map of seismic zones of the CR was compiled so that one value of a_{gR} was defined for each administrative district. In future it is assumed that for the districts with $a_{gR} \geq 0.05$ g informative standards will be produced, which will specify selected localities of the district in dependence on the type of underlying rocks in more detail. At present, the national application document EUROCODE-8 is being updated, and the map will have to be judged by a specialist committee before it is included in the application document.

Apart from a compilation of the map of seismic zones for the CR in particle accelerations given in gravity [g] (Figure 4), the seismic hazard assessment due to short-term release of energy during earthquake shocks accumulated by geodynamic processes was begun within the scope of the project on assessment of the long-term effects of these geodynamic processes near the Earth's surface, that led to the deformation and stress field assessment of the region being monitored and to delimiting geodynamic terrains (Schenk et al., 2002, 2003a, 2003b). Long-term displacement trends, responsible for local deformations of the uppermost parts of the Earth's crust, were detected by the staff of the IRSM from directly measured geodetic GPS data. Ear-marking knowledge of exposed locations or zones is important from designing elongated structures to minimise or eliminate the long-term effects of geodynamic processes on their operation. This involves motorway or railway constructions, oil and gas pipelines, lifelines or aqueducts, dams, bridges, etc.

The staff of the IRSM devoted their attention to contact area of the Lugicum and Silesicum, to the thrust structural zones (the Červená hora Saddle, the

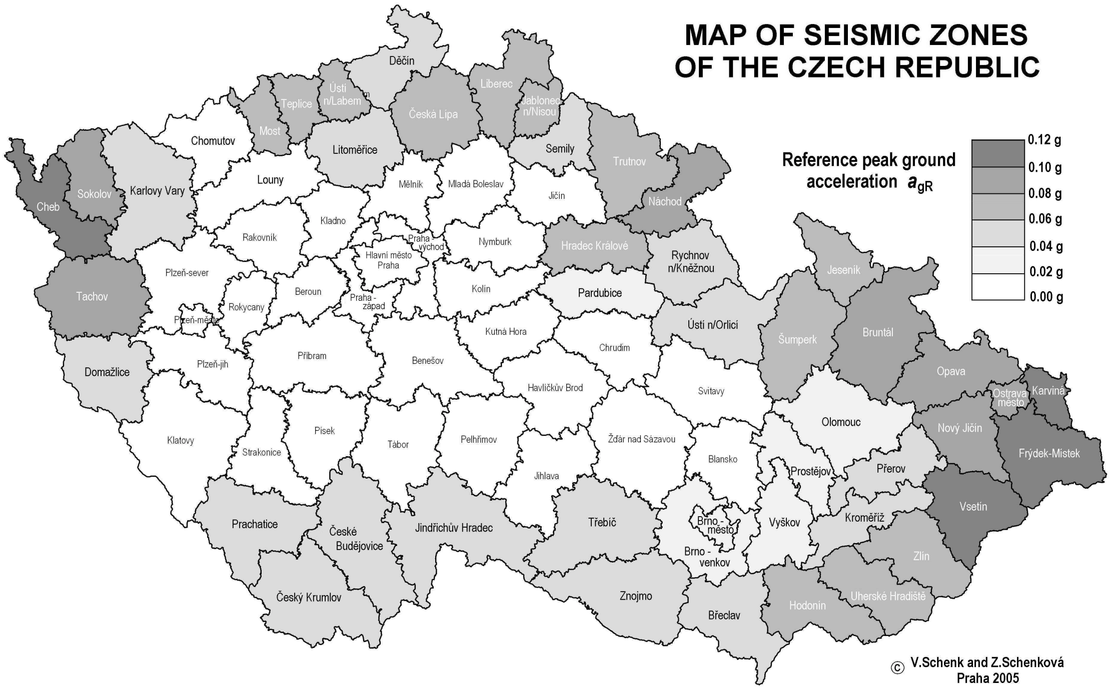

Fig. 4 Map of seismic zones for the Czech Republic expressed in the reference peak ground acceleration a_{gR}

Ramzová Saddle, etc.) and their interaction with faults of the Sudetic direction, because a motorway passing under the Červená hora Saddle is planned in North Moravia and Silesia. Observed GPS data were used to assess this geodynamic hazard and to construct possible strain and stress fields (Schenk et al. 2003a, 2004). General procedures for limiting the destructive impact of geodynamic hazard on long-range structures were suggested.

The Geophysical Institute (GI) established a virtual seismic network, which consists of permanent seismic observatories of the GI and other seismic stations in Central Europe. The data are transmitted to the GI and processed in real time on a high-performance computer, bought with project funds. The Program packages Antelope and SeedLink ensure the collection, analysis and international exchange of seismic data. The GI virtual network provides rapid and quality localisations and estimates of the magnitudes of regional earthquakes in Central Europe. Up-dated catalogues of regional seismic events are published on the http://www.ig.cas.cz/.

The quick determination of the position and magnitude of seismic events felt on the territory of the CR is very important to give prompt information to government authorities, the media, the public and Civil Protection authorities to apply rescue means in case of destructive earthquakes in Europe and the Mediterranean (e.g., Algiers, May 21, 2003, M = 6.7). The increased detection capability and sensitivity of the virtual GI network is significant also for timely assessment of arising seismic activity in regions of potential strong shocks on the territory of the CR: in the region of earthquake swarms in West Bohemia, in the foothills of the Orlické hory Mts along the Hronov-Poříčí fault, and in North Moravia and Silesia.

ACKNOWLEDGEMENTS

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GEOFYZIKÁLNÍ POZOROVÁNÍ A PŘEDPOVĚĎ GEOFYZIKÁLNÍCH POLÍ PRO POTŘEBY PRAXE

Josef Bochníček, Jan Laštovička, Vladimír Schenk, Josef Boška, Dalia Burešová, Pavel Hejda, Josef Horáček, Pavel Kottnauer, Peter Křižan, Jaroslava Nejedlá, Bohuslav Růžek, Zdeňka Schenková, Petra Šauli a Jan Zedník

ABSTRAKT:
Pravidelně byly vypracovávány denní a týdenní předpovědi geomagnetické aktivity, které byly předávány do zpravodajství České televise a do ústředí mezinárodní organizace ISES (International Space Environmental Service). Detailnější předpovědi geomagnetické aktivity byly využívány firmou IMPULS při letecké prospekci. Společnosti MERO byl vysvětlen důvod, proč dochází během geomagnetických bouří k indukci napětí a proudu v ropovodech. Byla analyzována přesnost předpovědí geomagnetické aktivity. Ve spolupráci s ústředím ISES, Boulder (USA), byla průběžně inovována internetová stránka ISES RWC Praha. Projekt pomohl realizovat nejen ionosférickou službu a tvorbu pravidelných ionosférických předpovědí v ÚFA AV ČR, ale podpořil i aktivity ISES RWC Praha. Ionosférické předpovědi byly pravidelně zasílány spojovacímu pracovišti Armády ČR. K vyřešení krátkodobých předpovědí byly posílány real-time ionogramy do datového a předpovědního centra RAL ve Velké Británii. Podrobně byly studovány účinky geomagnetických bouří, planetárních a gravitačních vln na procesy v ionosféře.

Byly spočítány standardní mapy zemětřesného ohrožení v jednotkách makroseismické intenzity a špičkového zrychlení pro Českou republiku, Polsko a Slovensko. Pro národní aplikační dokument EUROCODE-8 byla vypracována mapa seismických zón v jednotkách referenčního špičkového zrychlení. Z přímo měřených GPS dat byly určeny dlouhodobé pohybové trendy vyvolávající lokální deformace. Byly navrženy obecné postupy ocenění geodynamického ohrožení, které byly aplikovány na širší území Červenohorského sedla. Byla vybudována virtuální seismická síť, která poskytuje rychlé lokalizace a odhady velikosti zemětřesení, což jsou klíčové informace pro vládu, orgány Civilní obrany, média a veřejnost při výskytu zemětřesení. Aktualizovaný katalog regionálních seismických jevů je zveřejňován na internetových stránkách GFÚ AV ČR.

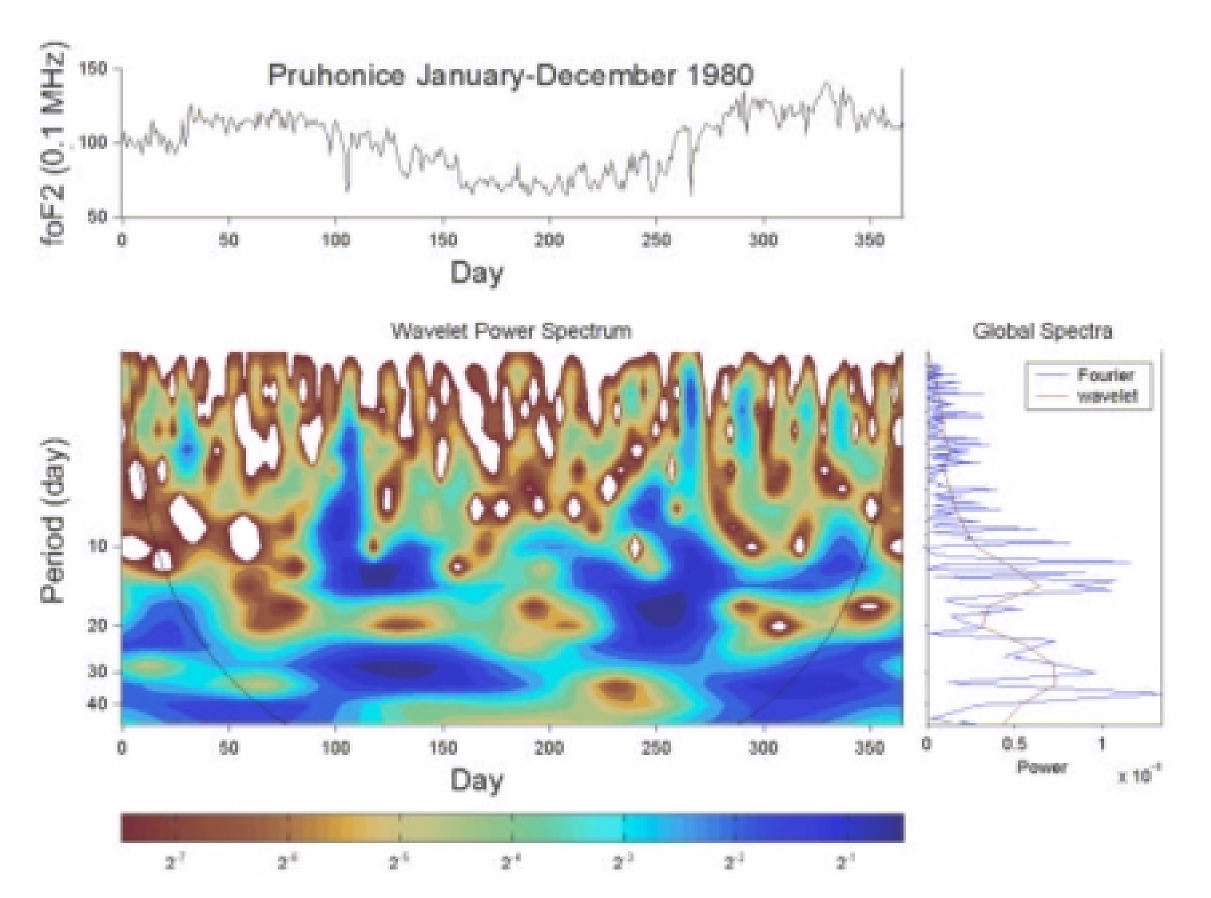

Fig. 3 Planetary wave activity inferred from foF2 for Průhonice, January – December 1980, Morlet wavelet transform (Laštovička et al., 2003a). Top panel – time series of raw foF2 data. Bottom left panel – wavelet transform power spectrum of the planetary wave activity changing by colour from white and black-blue (minimum values) through green to red and black-red (maximum values). Power spectrum is normalized to 1. Bottom right panel – global (over 365 days) Morlet wavelet and Fourier spectrum; horizontal axis – power; vertical axis - period of oscillations in days.