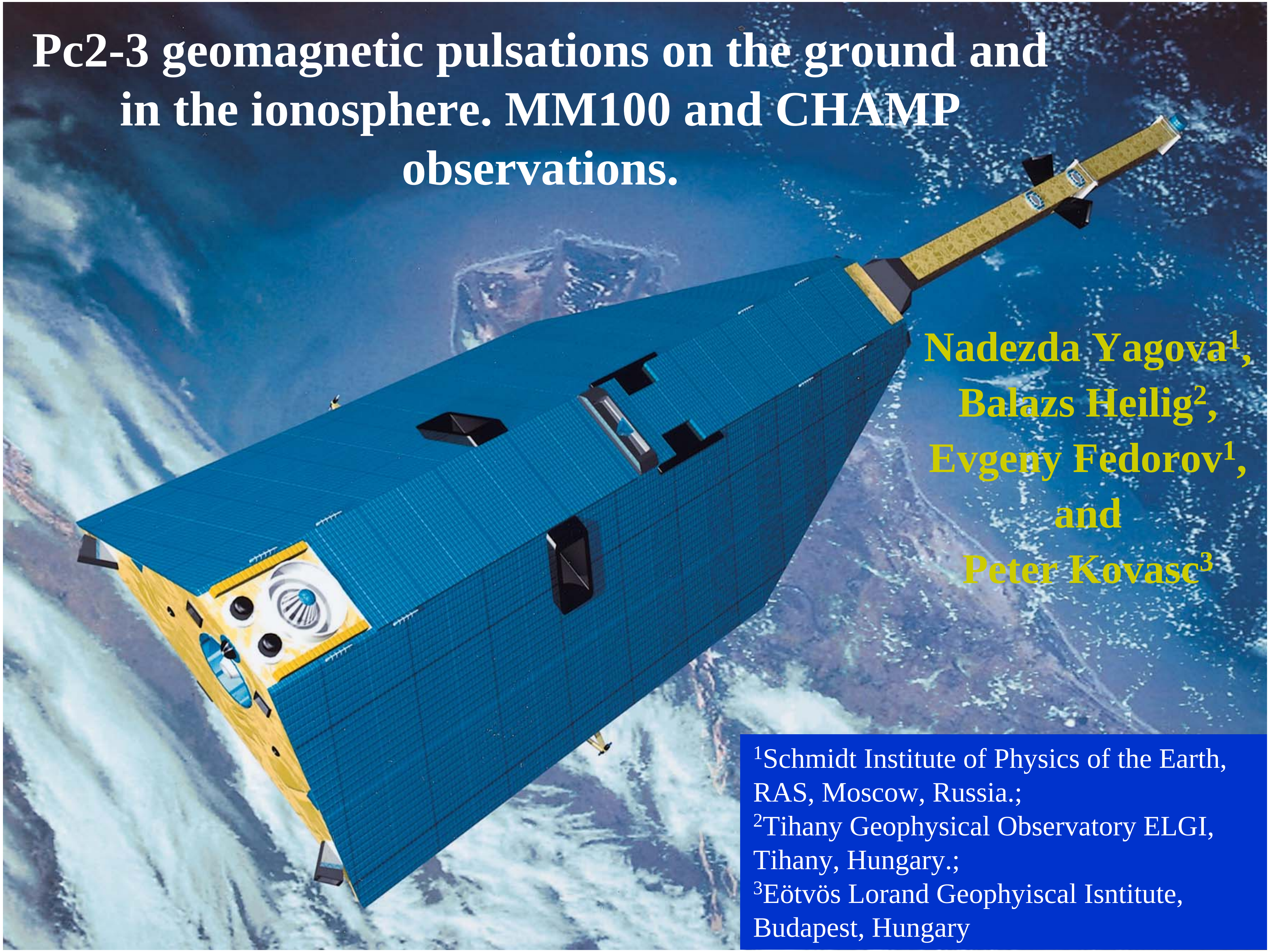
# Pc2-3 geomagnetic pulsations on the ground and in the ionosphere. MM100 and CHAMP observations.

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# Abstract


- Pc2-3 Pulsations are studied at the meridional magnetometer chain MM110 and in the ionosphere at CHAMP satellite. Ionospheric pulsations are characterized by high, in comparison with ground measurements, contribution of high (>80 mHz) frequencies. The cross-spectral analysis of CHAMP and ground data has shown that the observed disturbances are pulsations, but not the result of satellite pass through spatial structures in the ionosphere. Although the amplitudes of geomagnetic disturbances in this frequency range is low on the ground surface, a clear maximum in spectral coherence between CHAMP and MM100 signal is often seen simultaneously with Pc2-3 at CHAMP. The polarization of pulsations supports their Alfven nature: the azimuthal component dominates in the ionosphere, and the coherence is higher between the azimuthal component in the ionosphere and the meridional component on the ground. Pc2-3 in the ionosphere and the magnetosphere may be generated by the ion-cyclotron instability on oxygen, and effective ionospheric screening at small transversal scales leads to low amplitudes of these pulsations on the ground.

# Introduction

The main morphgological features of ground pulsations in frequency range from 0.01 to 1 Hz (Pc1-3) were formulated as a result of early studies at magnetometer networks. The most important difference between Pc3-s and Pc1-s is the mostly extra-magnetospheric control of Pc3 spectra and intra-magnetospheric – of Pc1. Actually, both types of pulsations are generated by ion-cyclotron instability, and difference in main frequencies results from different magnetic field amplitude in the foreshock and in the magnetosphere. Both types of pulsations are also influenced by the Alfvenic resonance in the magnetosphere-ionosphere system, but the frequencies of mid-latitude Pc3s correspond to first harmonic of magnteospheric resonator, while for Pc1 it coincides with first harmonic of Ionospheric Alfven resonator (IAR).

Pulsations in the intermediate frequency range, Pc2 (periods 3-15 s) are not often observed on the ground surface at middle-latitudes. This frequency range correspond to higher harmonics of magnetospheric Alfven resonance and to ion-cyclotron resonance on heavy ions, which are effectively damped by the ionospheric E-layer. However, no reason exists for lower Pc2 amplitudes in the upper ionosphere. The other expected feature  is the simultaneous existence of several Alfvenic harmonics above the ionospheric E-layer.

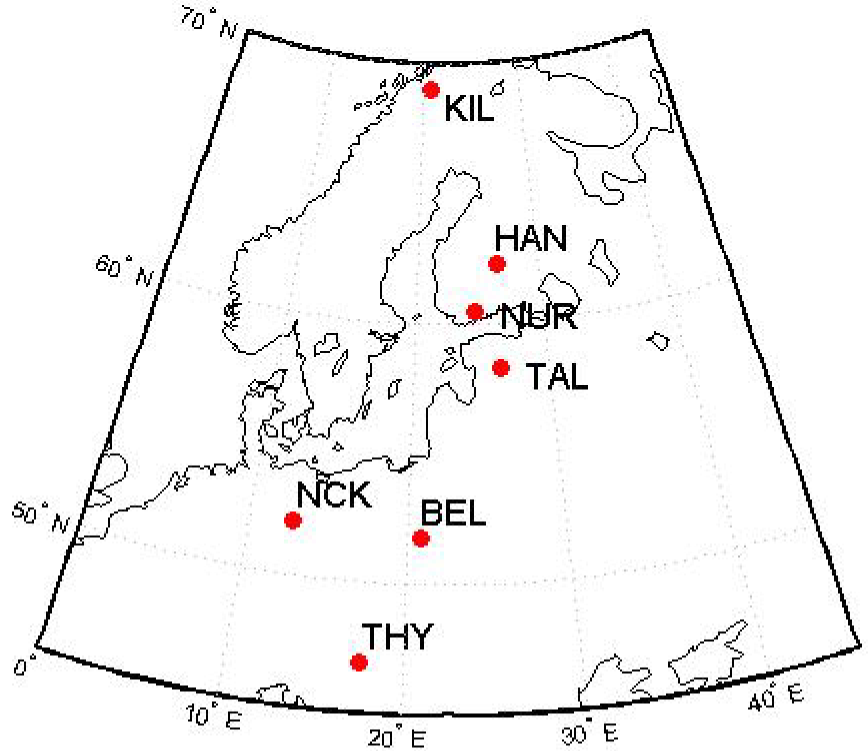
# Observational data

| Station | Geographic | | CGM | | L | MLT midnight |
|---|---|---|---|---|---|---|
| | Lat | Lon | Lat | Lon | | |
| KIL | 69.02 | 20.79 | 65.94 | 103.73 | 6.11 | 21:20 |
| HAN | 62.25 | 26.60 | 58.73 | 104.56 | 3.77 | 21:16 |
| NUR | 60.50 | 24.65 | 56.95 | 102.18 | 3.42 | 21:25 |
| TAR | 58.26 | 26.46 | 54.54 | 102.91 | 3.02 | 21:22 |
| NCK | 47.63 | 17.62 | 42.74 | 91.52 | 1.88 | 22:07 |
| BEL | 51.8 | 20.8 | 47.57 | 96.04 | 2.23 | 21:50 |
| THY | 46.90 | 17.54 | 41.92 | 92.01 | 1.83 | 22: 6 |

Coordinates of MM100 stations are given in the Table. Segments of CHAMP orbit with footprint in the vicinity of MM100 are taken for analysis.

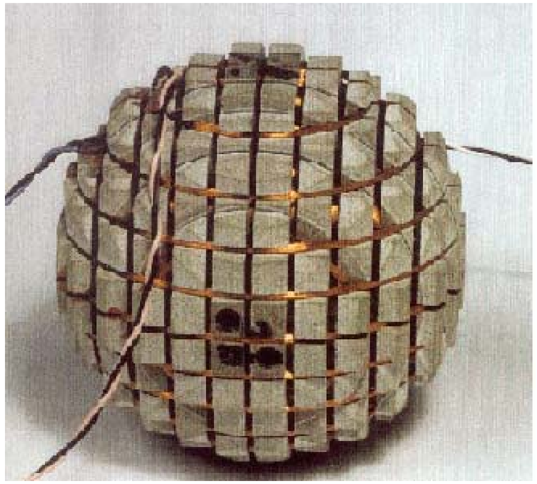
# MM100 stations

MM100 stations are equipped with 3-component flux-gate magnetometers, oriented along geographic coordinates with 1s sampling. Typical Pc3 amplitudes are about several nT and device sensitivity is enough for all the pulsations. Levels of industrial interference differs from station to station. We have selected for the analysis stations THY, NCK, HAN and NUR with low industrial interference and high quality of data.

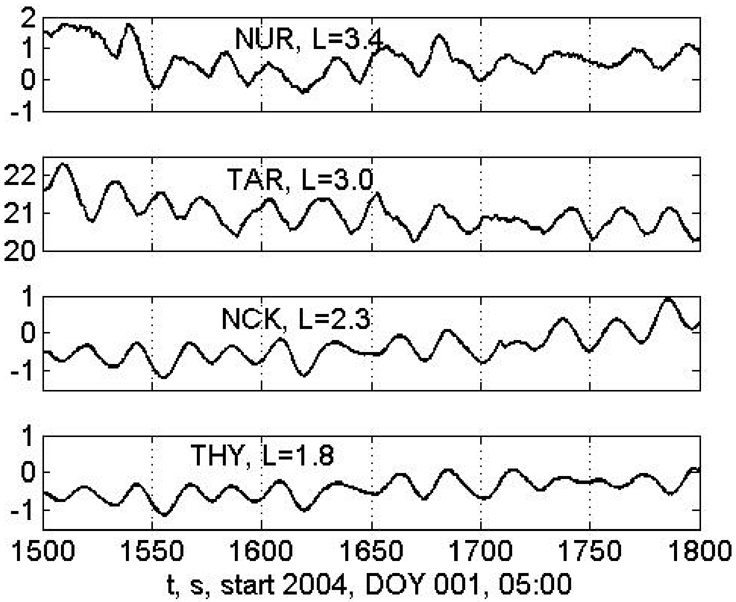


# CHAMP data

- **Fluxgate Magnetometer Characteristics (see the full description in http://www-app2.gfz-potsdam.de/pb1/op/champ)**
- The FGMs cover the full ±65000 nT range of the Earth's field in all three components. The analogue outputs are digitised by 24 bit ADCs achieving a quantisation step size of 10 pT uncompressed and 125 pT compressed.
- Deviations from linearity are found to be in the range of ±100 pT and the overall noise level is of the order of 50 pT (rms). In nominal operation mode the field vector is sampled at a rate of 50 Hz providing a spatial resolution along the orbit of approximately 150 m.
- In order to reduce data rates and thus the demands on data storage and transmission, a compression mode and/or lower sampling rates can be selected.
- Sensors are oriended along geographical north, east and down directions



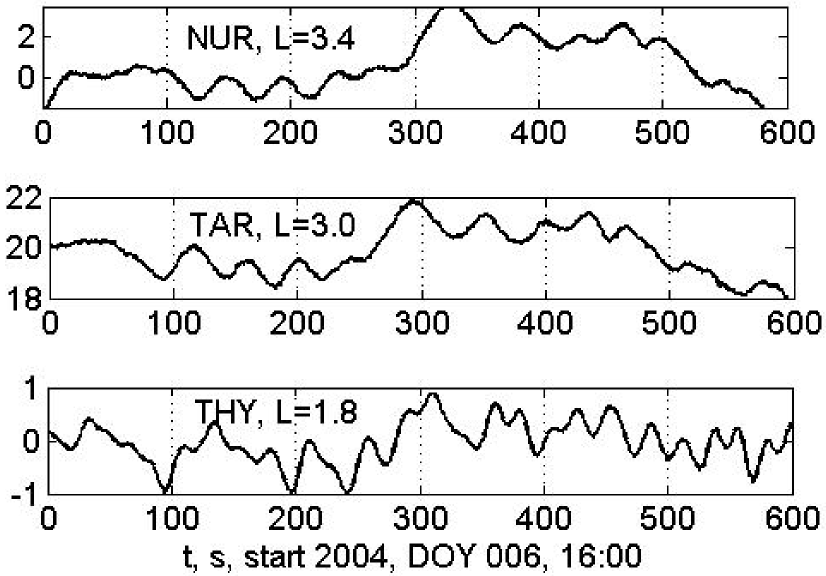
# Pc3-4 at MM100




An example of a highly coherent event with almost idendical spectral content along meridional chain is shown in the Figure. Pulsations’ dominating period is about 20 s, phase difference becomes sufficient at about 5$^{o}$ in latitude. Pulsations’ period is determined by extra-magnetospheric sources.

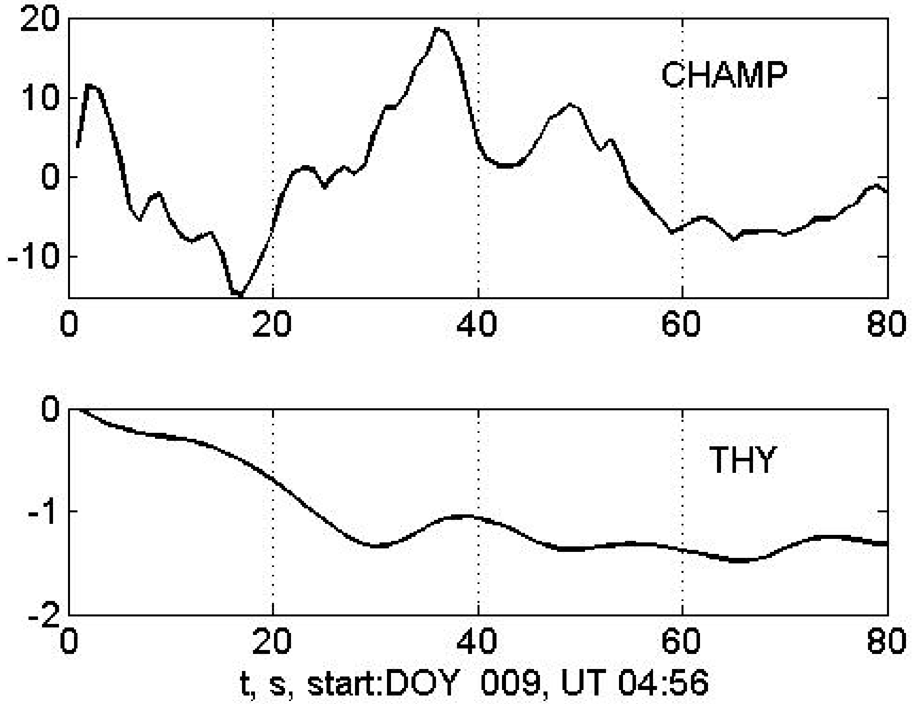
- Parameters of mid-latitude Pc3 are intensively studied for many years and known perfectly well. However, we show here several pictures of typical activity in this frequency range, because level of industrial and natural interference varies from one observational point to another and quality of data can differ severely at different stations. Generally, MM100 data are of high quality and Pc3 are seen without any interference.
- Different combinations of external sources and local resonance effects give different pictures in distribution of pulsations’ amplitude and phase in space and frequency. The main question of the present work is how different types of ground pulsations are seen in the ionosphere and vice versa.

# FLR effects at MM100



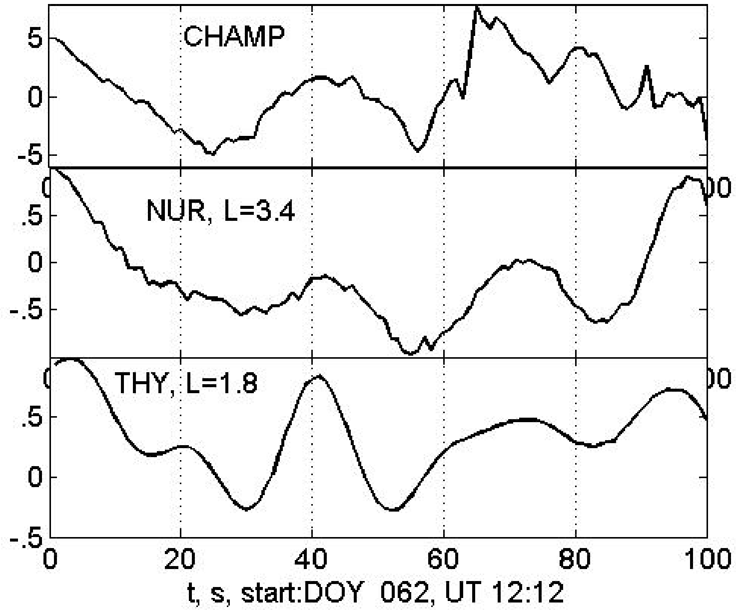

- In dependence on spectral content of external source FLR reveals itself either only in amplitude distribution or also in frequency dependence on latitude. An example of clear latitude dependemnce of Pc3 frequency is shown in the Figure. Pulsations' frequency decreases about two times from L=1.8 (THY) to L=3 (TAR). Statistically frequency dependence is seen better in H component than in D, and, best of all in H/D spectral ratio.

# Decoupled pulsations on ground and in the ionosphere




- Pc2 range (3-8 s) pulsations are very typical for upper ionosphere, while for ground stations no regular activity in this frequency range is registered. An example of pre-morning Pc2 at CHAMP, decoupled from ULF activity at MM100 is shown in the Figure.

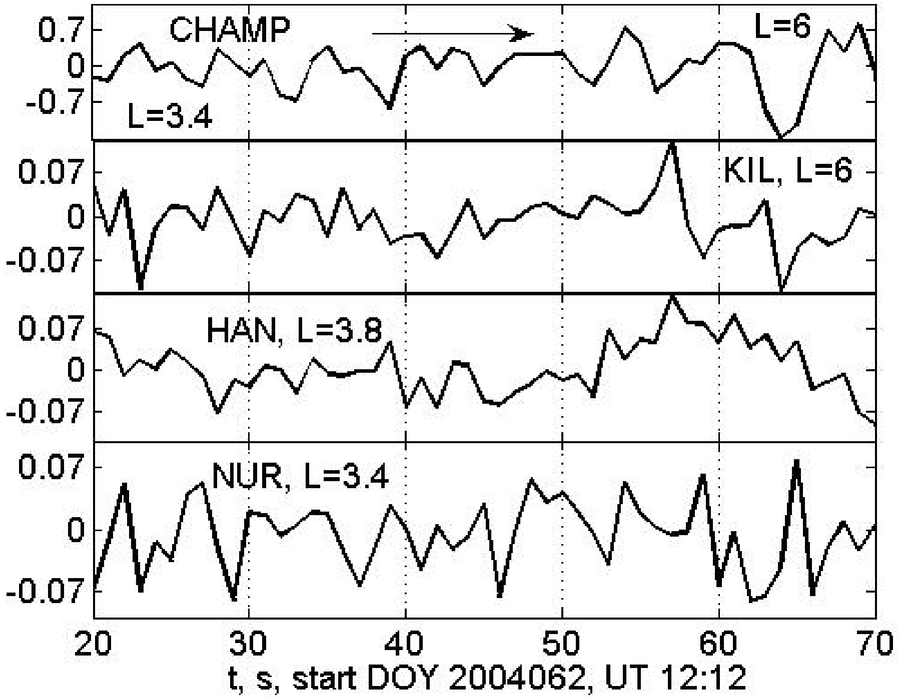
# Coherent Pc3 on the ground and in the ionosphere




Two important features should be mentioned for this event. 20 s Pc3 Are seen with almost zero phase difference, throughout MM100 and at CHAMP, ant 4s Pc2 are locally seen at champ and at NUR.

- It is natural to expect that Pc3, highly coherent on the ground surface will be seen with the same period in the ionosphere. However, it is not so as a rule, and there are situations when even big-scale pulsations are decoupled on the ground and in the ionosphere, but the events, seen with no distortion. The afternoon event at day 2004062 illustrates such a possibility. CHAMP orbit is well conjugated with the MM100 chain from L=3.3 (NUR) in the beginning of the interval to L=6 (KIL) in the end.

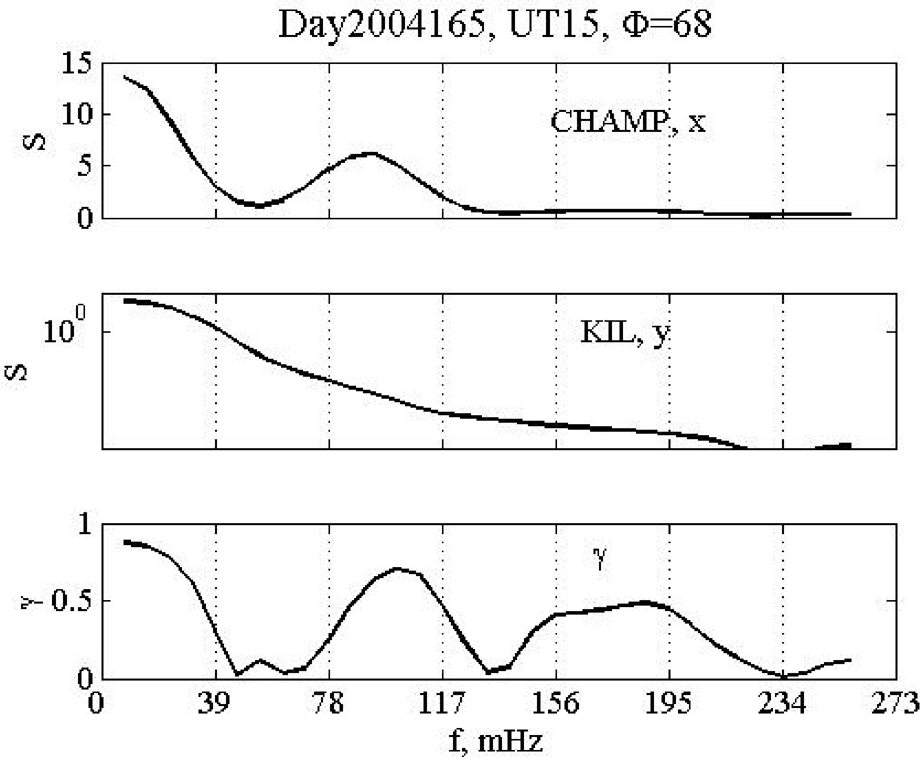
# Local high frequency (Pc2/Pi1) pulsations in the ionosphere and on the ground




Pc2 range pulsations at CHAMP and three MM100 stations. High-pass filter f>20 mHz

High frequency (Pc2 range) pulsations are seen at CHAMP with peak-to peak amplitude about 1 nT, and is 5-10 times lower at high-latitude segment of M100 (L>3.4). The correspondence of ground and ionospheric pulsations is better at conjugated points. During the interval CHAMP moves from L=3.3 to L=6 and in the beginning of the interval the CHAMP's pulsations repeat one at NUR, and in the end at KIL.

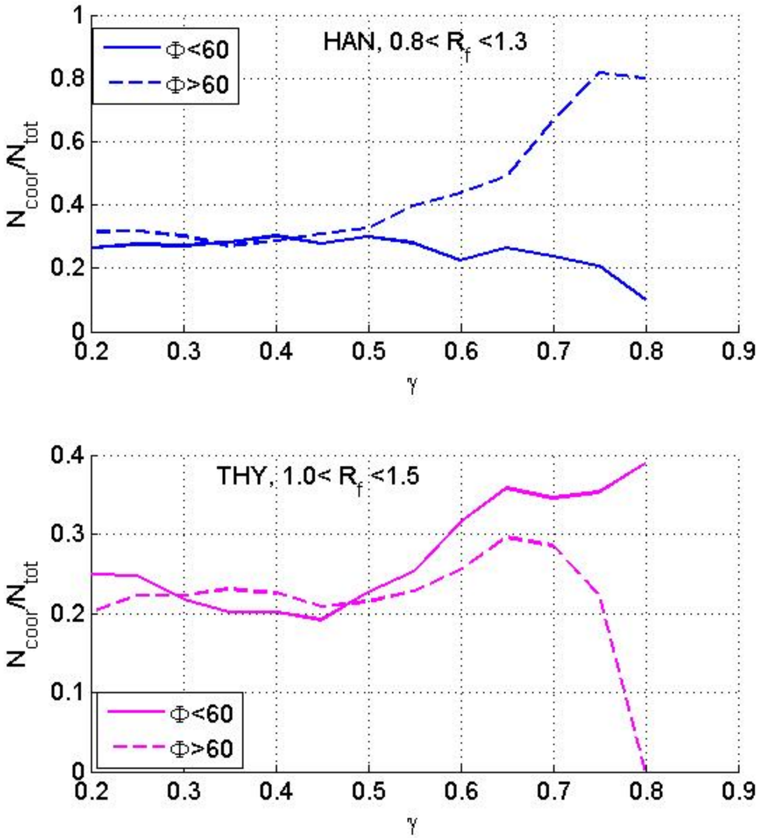
# Spectral coherence, example




- Spectra at CHAMP and KIL (approximately conjugated point) and spectral cohrence. Note that CHAMP spectral maximum is seen clearly in spectral coherence at a somewhat higher frequency

Disturbances, seen at CHAMP as Pc2-3, can be of both spatial and temporal nature. To discriminate these possibilities, we analyze spectral coherence between ionospheric and ground data. The events are selected according to existence of pronounced spectral maximum at CHAMP in the frequency range 70-200 mHz. The time window was 128 points (~2 minutes) .

# Spectral coherence, statistics




Results, averaged over 2004.

A higher coherence at HAN is found at high-latitude segment of CHAMP orbit, and for THY – at its low latitude segment.

The optimal interval for $R_f=f_\gamma/f_{CHAMP}$ ratio, where $f_\gamma$ ($f_{CHAMP}$) are the frequencies of γ (CHAMP spectrum) maxima, respectively, is higher at THY when the satellite angle velocity in CGM $d\Phi/dt$ is higher, than for HAN.

Statistical analysis confirms the results of case studies. Selecting events, for which the maximum of γ (between y-component at CHAMP and y – at the ground) lies in a close vicinity of spectral maximum at CHAMP we find that the coherence averaged over these intervals is higher than for the general sample.

# Discussion

Pc2-3 pulsations in the upper ionosphere are characterized by higher contribution of higher frequencies (upper frequency bound of Pc3 range and Pc2) in comparison with ground pulsations.

Spectral maxima in the frequency range 70-200 mHz are only rarely seen in the spectral power density of ground pulsations, and much better in the spectral coherence.

The frequency of $\gamma$ maximum is averagely higher than the frequency of corresponding spectral maximum at CHAMP.

The coherence is higher between azimuthal component in the ionosphere and meridional on the ground.

Higher coherence is found at nearly conjugated segments of CHAMP orbit and M100 magnetometer chain.

Not all Pc2-3 events in the ionosphere are seen on the ground. For them additional analysis is necessary to discriminate spatial structures and specific ionospheric pulsations with small spatial scales. Such waves are effectively damped by the E-layer and are not seen on the ground.

# References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