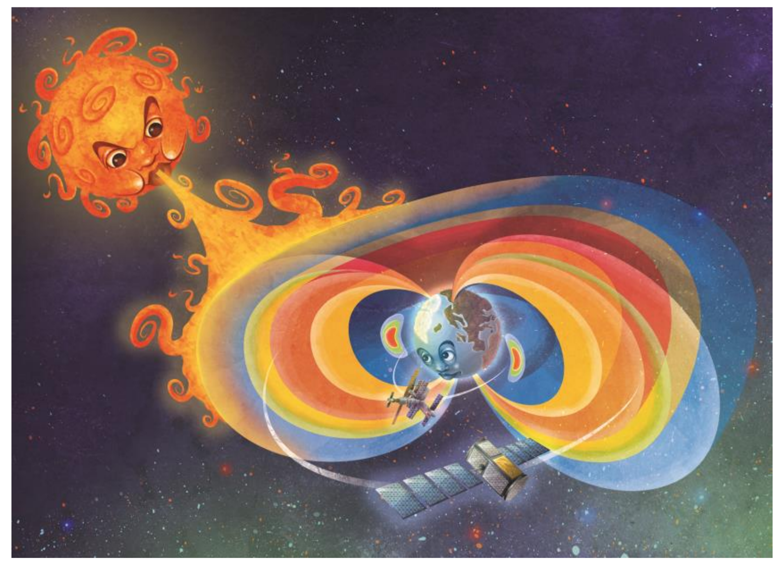
ST2.4/PS5.4: EGU2014-5841. B1034

ULF wave-power databases inferred from space-borne and ground-based magnetic field observations



C. Papadimitriou(1), (2), G. Balasis(1), I. A. Daglis(2), (1), S. Dimitrakoudis(1), M. Georgiou(1), (2) & Y. Khotyaintsev (3)

IAASARS

(1) Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Athens, Greece

(2) Department of Astrophysics, Astronomy & Mechanics, Faculty of Physics, University of Athens, Athens, Greece; (3) Swedish Institute of Space Physics, Uppsala, Sweden

ABSTRACT: ULF waves are important in radiation belt dynamics, playing a critical role both in local acceleration and in the radial diffusion of energetic electrons. The focus of the present work is a statistical study of ULF waves as observed by the CHAMP satellite and the IMAGE ground magnetometer array, both of them being European initiatives in the realm of geomagnetism and geospace physics. The CHAMP (Challenging Minisatellite Payload) was a German LEO satellite, which flew for more than 10 years (from July 2000 to September 2010) on a polar orbit of initial altitude of 454 km, providing among others high quality measurements of the Earth's magnetic field. The IMAGE (International Monitor for Auroral Geomagnetic Effects) array consists of 31 magnetometer stations in central and northern Europe.

In the framework of the MAARBLE project, we have developed a set of tools based on the wavelet transform, which enable us to detect ultra low frequency (ULF) wave activity through both in situ and ground magnetometer observations. The application of these tools, on data from the CHAMP satellite mission and selected stations of the IMAGE ground magnetometer array, enabled us to create a database of wave power spectral density (PSD), for the entire first decade of the new millennium, spanning years from 2001 to 2010. Our focus here is on the lowest bands of the ULF waves, with frequencies lower than 100 mHz and down to a few mHz.

For the case of the CHAMP satellite, the creation of such a database with the inclusion of additional data, enable us to derive valuable statistics for many important physical properties relating to the spatio-temporal location of these waves, the wave power and frequency, as well as other parameters and can be used as a starting point in the launch of further investigations on the correlation of low frequency ULF waves with solar wind conditions, magnetospheric indices, electron density data, ring current decay and radiation belt enhancements.

From the wave PSD database of the IMAGE network arises the additional opportunity to calculate radial diffusion coefficients, which in turn can be used to improve radiation belt modeling.

Radial diffusion, generated by ULF waves, plays an important role in the transport of electrons in the outer radiation belt. Modeling that process requires reliable calculations of the diffusion coefficient from the ULF waves' electric and magnetic field power spectral densities (PSD), which must also be reliably measured, either directly or by inference from other measurements. Brautigam and Albert (2000) demonstrated how PSD measurements by ground-based magnetometers can be mapped to the equatorial plane in space, thus translating to PSD values there and, from those, to the electromagnetic and electrostatic diffusion coefficients in space. Ozeke et al. (2012) greatly expanded on the set of ground magnetometer data, using 15 years of measurements from the CARISMA and SAMNET magnetometer stations, from which they derived a diffusion coefficient due to electric field fluctuations (D_{LL}^E), and used in situ measurements to derive a diffusion coefficient due to the compressional magnetic field fluctuations (D_{LL}^B). A significant result of the latter work was the observation that D_{LL}^E is dominant over D_{LL}^B for all relevant values of the parameter space.

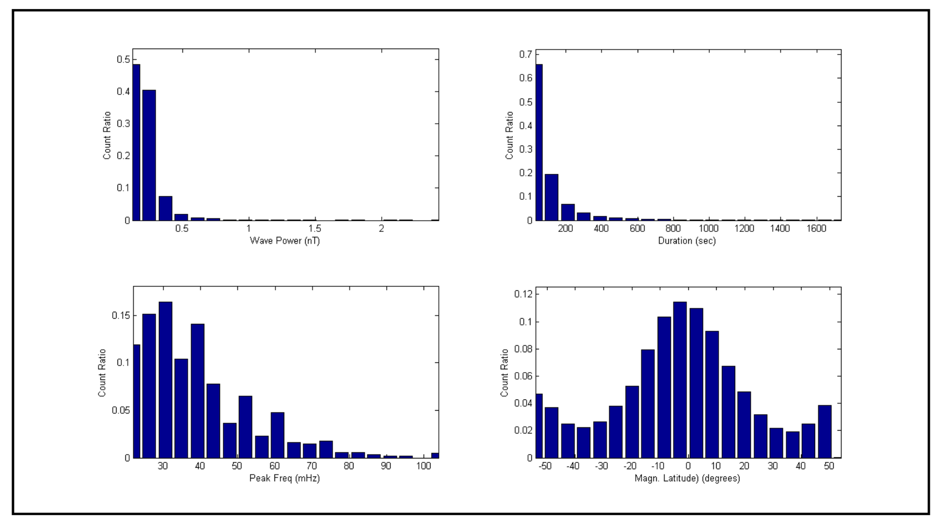
Building on that work, we proceeded to make our own calculations of D_{LL}^E using 11 years of ground magnetometer data from nine IMAGE stations, namely Uppsala (UPS), Nurmijärvi (NUR), Dombås (DOB), Oulujärvi (OUJ), Rørvik (RVK), Sodankylä (SOD), Kiruna (KIR), Kevo (KEV) and Tromsø (TRO). We find that our results agree with those of Ozeke et al. (2012) for low values of Kp but show a divergence for higher values of Kp. However, when plotting the upper and lower quartiles of each calculated PSD and of the resulting diffusion coefficients, we find that the Ozeke et al. (2012) values lie within those bounds.

Future work will expand upon the present study to explore the effects of binning our PSD values by geomagnetic or solar indexes other than Kp.

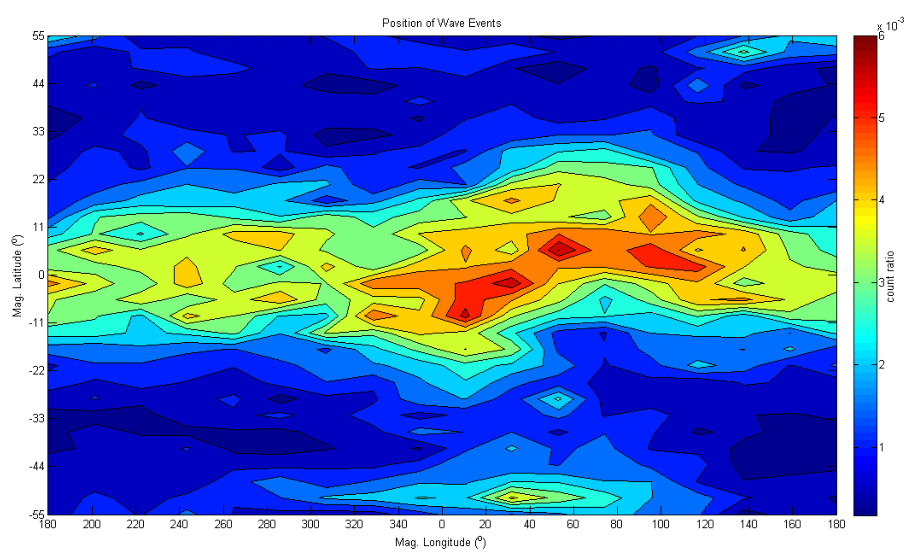
Statistical Analysis of CHAMP data

For a statistical analysis we employ our automated wave detection routines on data from the CHAMP mission. We apply the wavelet analysis on each track (half-orbit) of the satellite, limiting it further to measurements performed when the satellite's position was within +/- 55 degrees in magnetic latitude, in order to avoid perturbations due to the auroral currents and the polar cusps. After that, the algorithm detects parts of the spectra that exhibit enhanced power and performs a series of tests. If such a candidate signal is tested successfully against all criteria, it is considered a valid wave event and its characteristics are saved in an event catalogue, from which useful statistics can be extracted. If not, the algorithm classifies the candidate event into two other categories, namely Non-Events (if the candidate was too short, or too weak to pass the corresponding criteria) or False Positives (spikes, gaps in the data and/or preprocessing errors). For more details see Balasis et al. (2013).

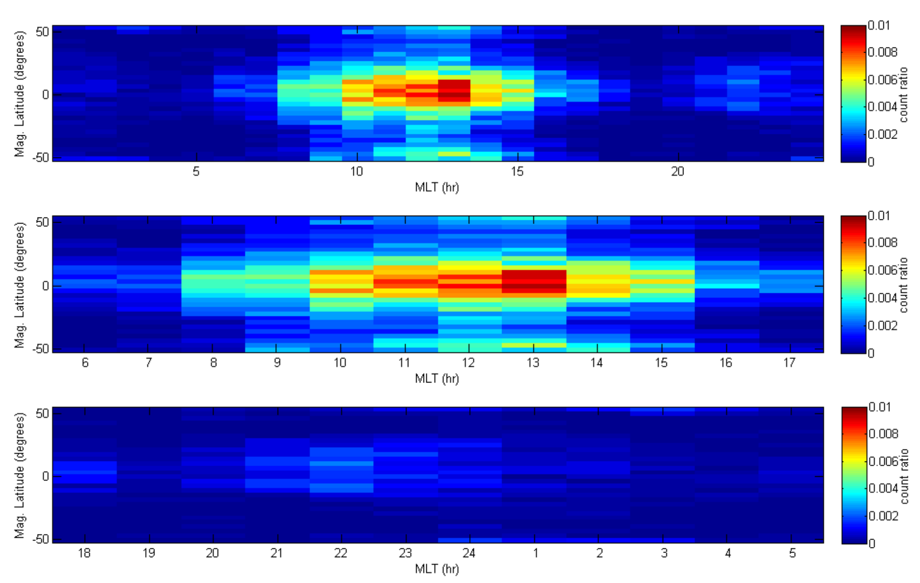
Analysis of wave events observed by CHAMP for the years 2003 – 2005



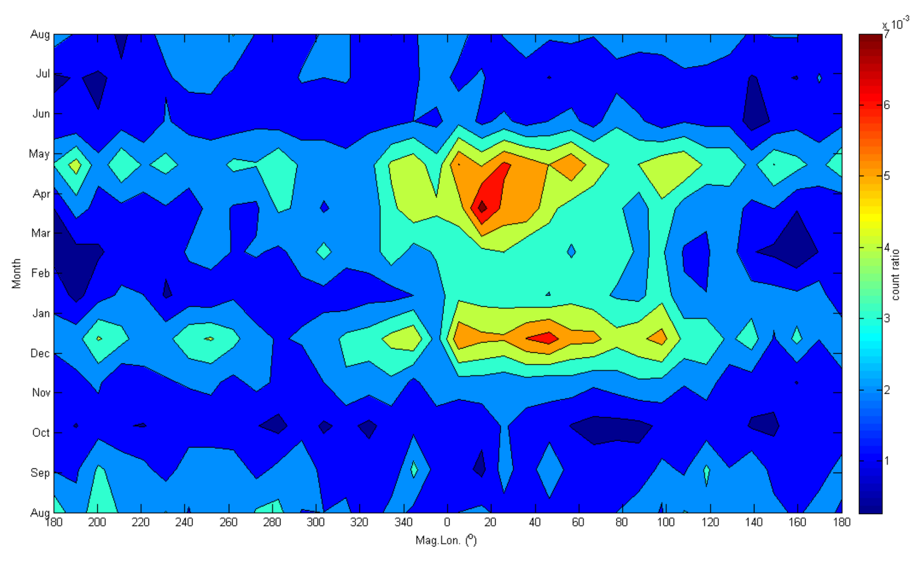
Distributions of Wave Power, Duration, Peak Frequency and Magnetic Latitude



Position of wave events in magnetic coordinates

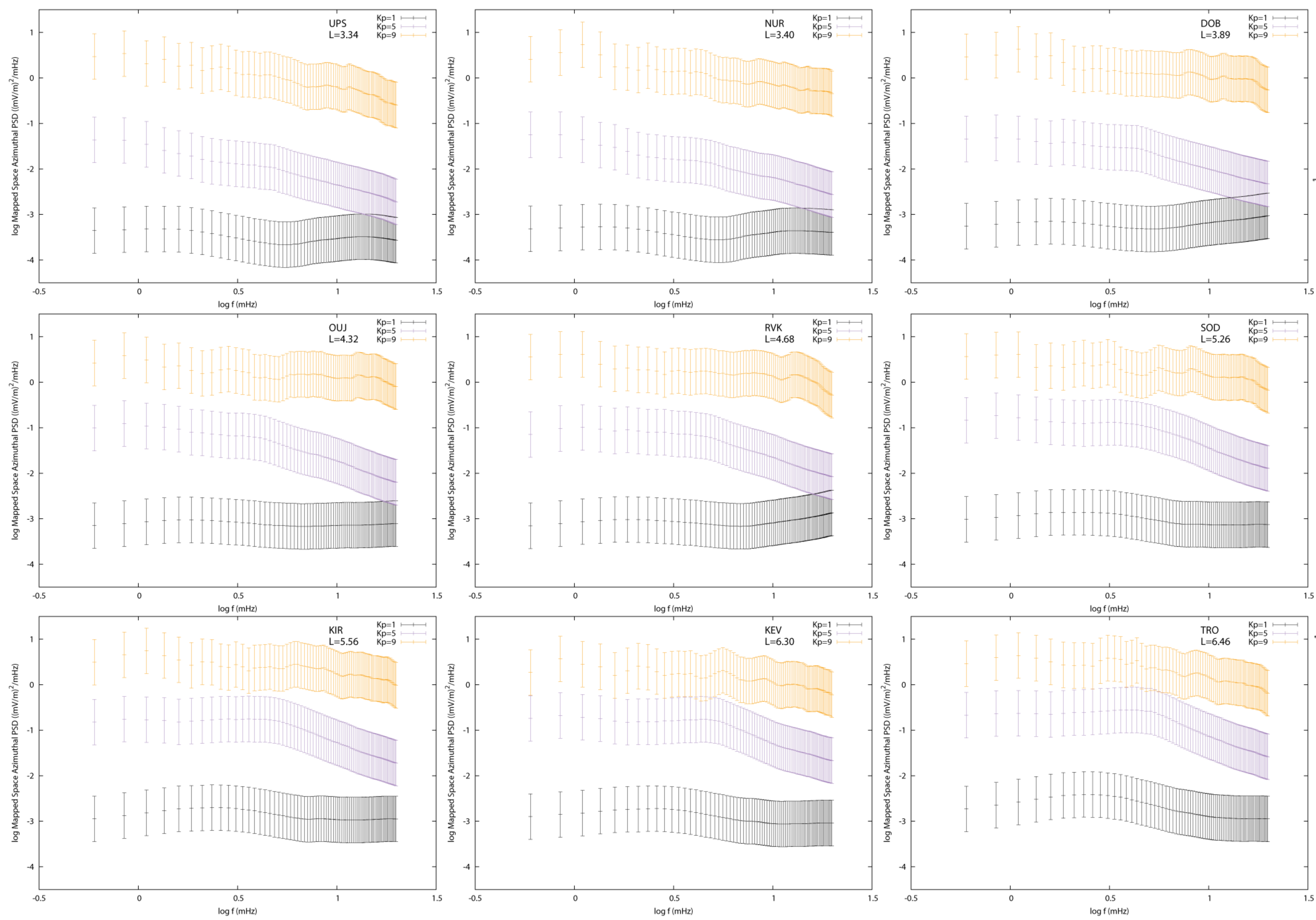


Top Panel: All events – Middle: Daytime Only – Bottom: Nighttime Only

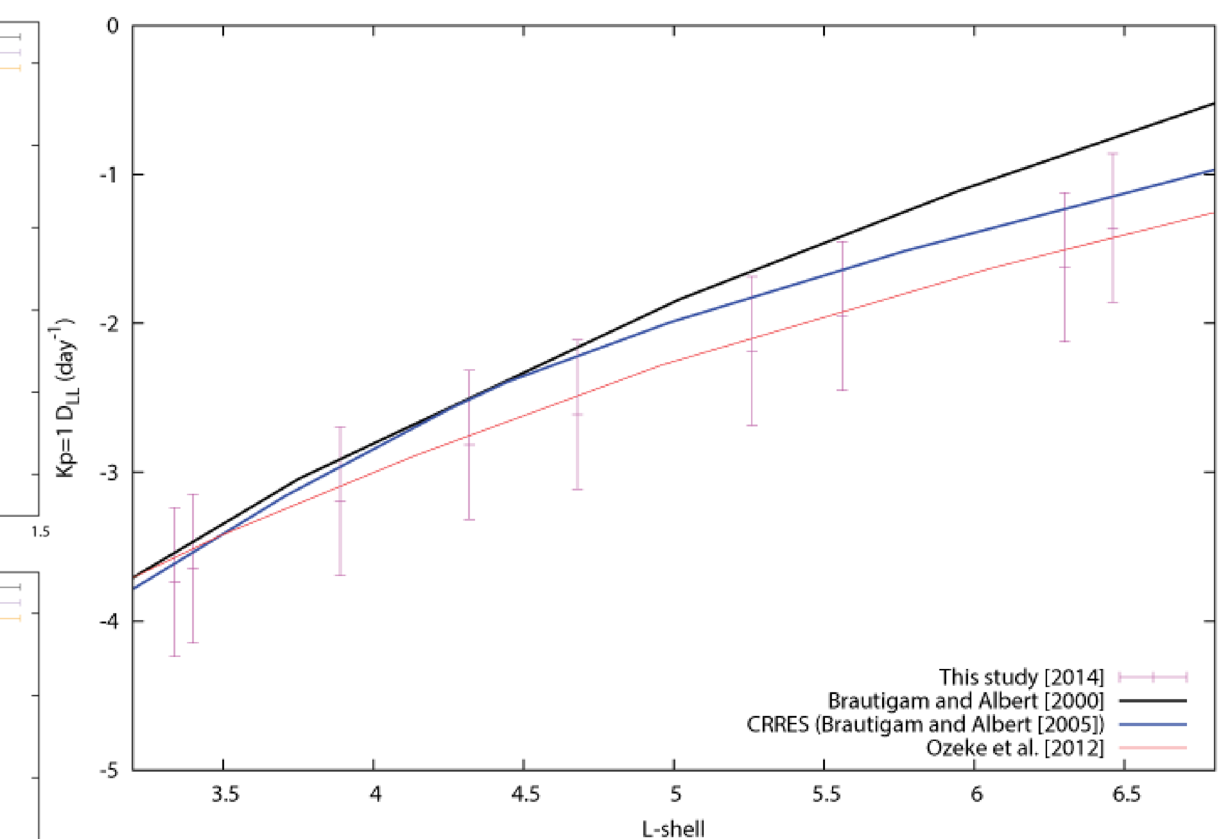


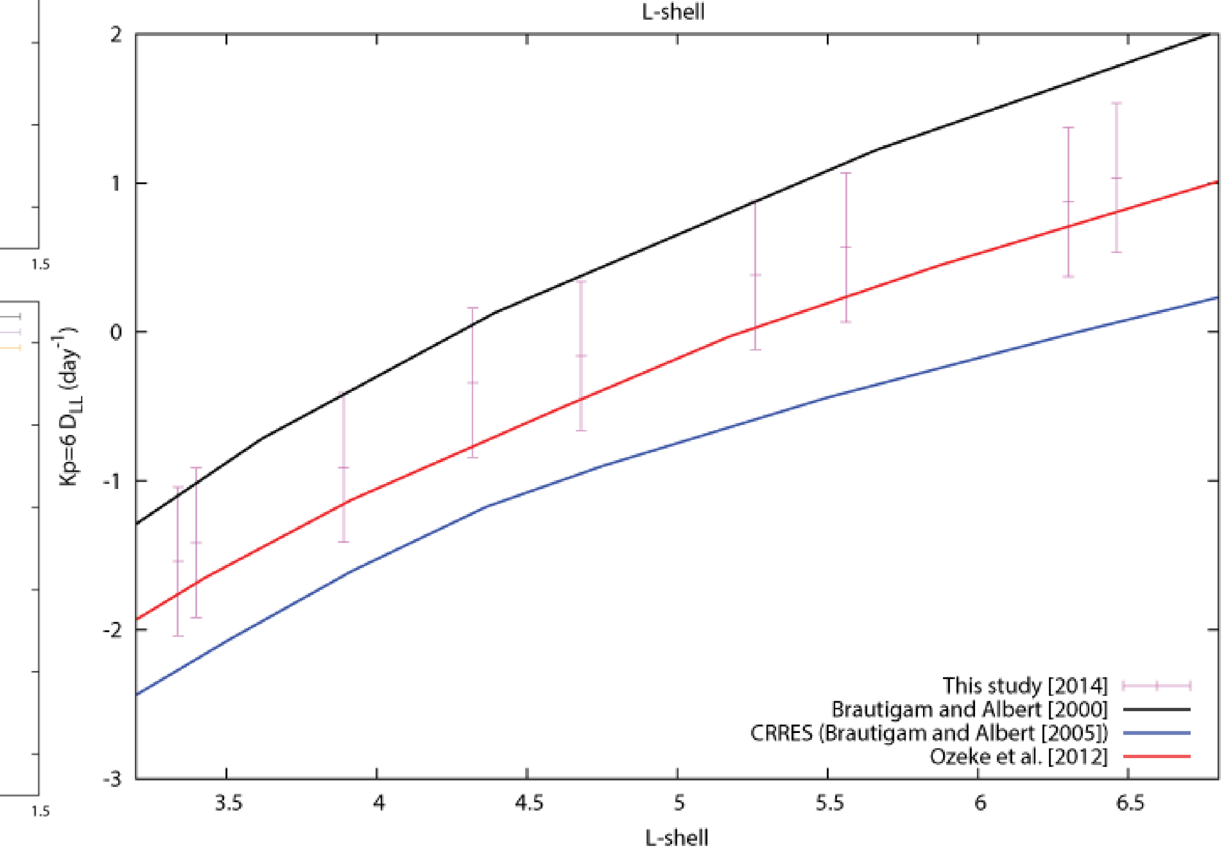
Monthly variations on the occurrence rates for wave events location

Mapped Spectra for Equatorial E_ϕ



Diffusion Coefficients for 500 MeV/G





Conclusions

We have developed a set of tools, based on wavelet analysis, that enable us to detect magnetic wave activity by both space-borne and ground magnetometers. Our tools are able to perform wave event detection for long time intervals, thus enabling the creation of event catalogues which facilitate statistical studies on ULF waves and their physical properties. Furthermore, by applying analogous wavelet methodologies to data from ground based stations we can compute the power spectra at the Ultra Low Frequency range and from them derive important parameters that govern the dynamics of the Radiation Belts, such as the diffusion coefficients. By applying additional statistical analysis we will strive to estimate the dependence of these coefficients to indices of magnetospheric activity and parameters of the solar wind and try to quantify the effect of these to the diffusion of Radiation Belt particles.

References

Balasis, G., I. A. Daglis, M. Georgiou, C. Papadimitriou and R. Haagmans (2013), Magnetospheric ULF wave studies in the frame of Swarm mission: a time-frequency analysis tool for automated detection of pulsations in magnetic and electric field observations, Earth Planets Space, 65, 1385-1398, 2013

Brautigam, D. H., and J. M. Albert (2000), Radial diffusion analysis of outer radiation belt electrons during the October 9, 1990, magnetic storm, J. Geophys. Res. , 105(A1), 291-309, 2000

Brautigam, D. H., G. P. Ginet, J. M. Albert, J. R. Wygant, D. E. Rowland, A. Ling, and J. Bass (2005), CRRES electric field power spectra and radial diffusion coefficients, J. Geophys. Res., 110, A02214

Heilig, B., H. Luehr, and M. Rother: Comprehensive study of ULF upstream waves observed in the topside ionosphere by CHAMP and on the ground, Ann. Geophys., 25, 737-754, 2007

Ozeke, L. G., I. R. Mann, K. R. Murphy, I. J. Rae, D. K. Milling, S. R. Elkington, A. A. Chan, and H. J. Singer (2012), ULF wave derived radiation belt radial diffusion coefficients, J. Geophys. Res., 117, A04222, 2012

Acknowledgment

The work leading to this paper has received funding from the European Union's Seventh Framework Programme (FP7-SPACE-2011-1) under grant agreement no. 284520 for the MAARBLE (Monitoring, Analyzing and Assessing Radiation Belt Energization and Loss) collaborative research project. This paper reflects only the authors' views and the Union is not liable for any use that may be made of the information contained therein.

We gratefully acknowledge Helmholtz Centre Potsdam GFZ - German Research Centre for Geosciences, and the institutes who maintain the IMAGE Magnetometer Array for providing data used in this study.

SEVENTH FRAMEWORK PROGRAMME