Appendix No. 2b
to Application for admittance to a post-doctoral habilitation procedure
Kraków, 07.12.2016

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

(English version)

1. Name and surname

Zenon Nieckarz

2. Diplomas obtained and academic titles, including their names, and the place/year where/when they were received, and the title of the Ph.D. dissertation.

Doctor of Earth Sciences Major: physical geography 2009	Jagiellonian University in Cracow, Faculty of Biology and Earth Sciences, Doctoral dissertation: *"Assessing the activity of tropical storm areas on the basis of the lightning discharge intensity index"* Supervisor: Prof. Janina Trepińska PhD, Reviewer: Professor Joanna Wibig PhD (Łódź University), Professor Szymon Malinowski (University of Warsaw), Professor Zbigniew Ustrnul PhD (Jagiellonian University in Kraków) Date when the title was received: 15 December 2009
M.Sc. Eng. Major: technical physics 1996	AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Master's thesis: *„Identification of the rated parameters of a pulse transformer"* Supervisor: Professor Kazimierz Korbel PhD Date when the title was received: 15 November 1997

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3. Previous employment with research units/ artistic institutions

From 1996	Jagiellonian University in Kraków, Faculty of Physics, Astronomy and Applied Computer Science, Experimental Computer Physics Department, Position: science technician
From 2000	Jagiellonian University Medical College, Kraków, Department of Biophysics, Chair of Physiology Position: science technician (part-time)
From January 2011 to June 2015	University of Physical Education in Kraków Section of Physiology of Muscles Position: senior lecturer (part-time)

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4. **Indication of the accomplishment, as defined in Article 16(2) of the Act of 14 March 2003 on academic degrees and titles and on academic degrees and titles in art (Journal of Laws [Dz. U.] No. 65, Item 595, as amended):**

1. **Title of the academic/ artistic accomplishment;**

   Methods for assessing and analysing electrical storm activity at various spatial scales

2. **Author/authors, title/titles of publication/publications, year of publication, name of publisher;**

   Chronological list of publications

[P1] **Nieckarz Z.,** A. Kułak, S. Zieba, A. Odzimek (2011) Cloud-to-ground lightning dipole moment from simultaneous observations by ELF receiver and combined direction finding and time-of-arrival lightning detection system, *Journal of Geophysical Research*, 116, D08107, doi:10.1029/2010JD014736, **IF= 3.021,**
I estimate my percentage share at 80%.

[P2] Kułak A., J. Kubisz, S. Micek, A. Michalec, **Z. Nieckarz**, M. Ostrowski, S. Zięba (2012-2104), Sposób i urządzenie do monitorowania aktywności burzowej na powierzchni Ziemi w czasie rzeczywistym;
Patent granted in the following countries:
European Patent Office (Poland, The Netherlands, Germany, Spain, The United Kingdom, Italy, 2012) EP 2165223, Mexico (2012) MX 29512, Russia (2012) RU 2470332, United States (2012) US 8,332,150 B2, China (2013) CN 101802650 B, Canada (2014) CA 2690085, Japan (2014) JP 5562237, South Korea (2014) 1357434.
My percentage share is estimated at 16%. The authors' percentage shares were determined earlier for the needs of the patent application (Kułak A. – 18%, J. Kubisz – 16 %, Z. Nieckarz – 16 %, A. Michalec – 15 %, S. Zięba – 15 %, S. Micek – 10 %, M. Ostrowski – 10 %)

[P3] **Nieckarz Z.,** S. Zięba (2013) Variability of daily thunderstorm surface in Poland and Europe in years 1980-2010, *Atmospheric Research*, (127) 77–89, **IF= 2.421,**
I estimate my percentage share at 95%.

[P4] **Nieckarz, Z.,** P. Barański, J. Młynarczyk, A. Kułak, J. Wiszniowski, (2015) Comparison of the charge moment change calculated from electrostatic analysis and from ELF radio observations, *Journal of Geophysical Research Atmosphere*, 120, doi:10.1002/2014JD022289. **IF=3.318**,
I estimate my percentage share at 66%.

[P5] **Nieckarz, Z.,** (2016) Imprints of natural phenomena and human activity observed during 10 years of ELF magnetic measurements at the Hylaty geophysical station in Poland, *Acta Geophysica*, vol. 64, no. 6, pp. 2591 – 2608, **IF_{2015}=0.945**,
My percentage share is 100%.

The summative IF of the publications submitted as the academic accomplishment amounts to 9.705. The co-authors' statements on their contributions to the above publications are attached in Appendix No. 4.

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3. Description of the academic/ artistic objective of the above publications and of their outcomes, including their potential use.

The research activity I have pursued for years is dedicated to assessing, in a reliable way, electrical storm activity at various spatial scales. My efforts have focused on two methods for measuring and assessing thunderstorm activity:

A) terrestrial observations of days with a thunderstorm,

B) terrestrial measurement of Extremely Low Frequency (ELF) electromagnetic waves (3-3000 Hz).

Re A)

Terrestrial observations of days with a thunderstorm are among the longest observation series offering information about electrical activity of the atmosphere. With the earliest of them dating back to the late 17th century, such observations have been used in a number of studies, mainly climatological ones. When I was analysing literature concerning thunderstorm occurrence in Poland and Europe, I noticed that no investigations had been carried out on diurnal variations in simultaneous spatial occurrence of thunderstorms within the above areas.

In my paper **(P3)** entitled **„Variability of daily thunderstorm surface in Poland and Europe in years 1980-2010"**, I proposed my own method for calculating two indicators of daily thunderstorm activity, and then analysed thunderstorm activity in Poland and Europe using them. My research was based on terrestrial meteorological observations of days with a thunderstorm in the years 1980-2010. The study describes in detail the methodology for calculating two indices of daily thunderstorm activity: a static one (*Ms*) and one based on Voronoi diagrams (*Mv*) (Voronoi 1908). The *Mv* calculation method was based on the Thiessen method used in hydrology to calculate mean precipitation within a catchment area. The method I developed is based on the conversion of daily qualitative observations into quantitative indices describing the daily surface area covered by a thunderstorm. The paper also presents the results of numerical simulations I devised using the Monte Carlo method to test both index calculation methods and to estimate the error associated with them. I presented a comparative analysis of the two indicators based both on simulation data and data from within Poland. The comparison proved that the Voronoi method is a better one since errors for the *Mv* index are significantly lower than for the *Ms* index when assessing the surface area of both convective and frontal thunderstorms. Based on an analysis of data for Poland from the years 1980-2010, I demonstrated that the average number of days with thunderstorms spanning extremely large areas of Poland (over 30%) has increased in the last 30 years by 4±1 days per decade. For Europe, using the *Ms* indicator, I showed that the mean frequency of the occurrence of days with a thunderstorm spanning large areas (over 10%) decreased in the study period by 9±2 days per decade, while their mean frequency expressed as a percentage decreased by 0.5% per decade. I financed the paper with my **own scholarship (NCN 0390/B/P01/2011/40)** entitled **"Assessing the variability of the surface area of thunderstorms over Poland compared to Europe in the years 1980-2009**."

Re B) Terrestrial measurements of extremely low frequency (ELF) electromagnetic waves (3-3000 Hz) has been a central focus of my research since 2000. At the time, I started to collaborate with a group of astronomers from the Jagiellonian University Astronomical Observatory (OA UJ) who conducted occasional observations of

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ELF waves in the Bieszczady Mountains as part of their astronomical and geophysical studies. The research resulted in **study papers (Kułak et al. 2003a, 2003b, 2006) which I co-authored**.

In recent decades, ELF waves have become increasingly popular among researchers representing a range of disciplines, including astronomers, physicists, geophysicists, meteorologists and climatologists. The behaviour of ELF waves in the Earth's atmosphere was investigated for the first time by W. O. Schumann (1952). He demonstrated in theory that extremely low frequency electromagnetic waves (3-3000Hz) would be very poorly absorbed by the atmosphere and, at the same time, would be reflected very well both from the Earth's surface and from the lower layer of the ionosphere. Thus, both surfaces will create a closed space between them, referred to as the Earth-ionosphere resonant cavity (E-i). Schumann demonstrated that inside the E-i cavity ELF waves may circulate along orthodromic distances in various directions and interfere with each other. This means that waves of certain frequencies will weaken while others will strengthen each other, creating within the power spectrum of the recorded EM waves characteristic peaks spaced at 6.2 Hz on average. The first three peaks (also referred to as modes) of the Schuman resonances (SchR) occur at the following frequencies: 7.8, 14.0, 20.1 Hz. Schumann also declared that such ELF waves within the E-i cavity can be caused by lightning discharges. ELF waves were successfully observed for the first time by Balser and Wagner (1960), who confirmed Schumann's theory. The interest in ELF grew considerably after Williams published a study (1992) in which he demonstrated a clear correlation between the amplitude of the first peak of Schumann resonances and air temperatures in tropical areas.

Analyses of the global balance of electrical thunderstorm activity based on ELF electromagnetic waves rely on power spectra. Until recently, it was commonly assumed – based on Williams study (1992) – that the best indicator of thunderstorm activity is the amplitude of the first SchR mode (Nickolaenko and Rabinowicz 1995, Williams and Satori 2004). It must be pointed out that according to Schumann's analytical formula (Schumann 1952), the amplitude of each SchR mode is proportional to the product of three factors influencing their value. The first one is the lightning discharge frequency, i.e. the number of lightning flashes per unit of time. The other is the value of the mean dipole moment of the lightning strokes observed. The third factor is the associated Legendre function whose argument is the distance between the lightning stroke and the ELF wave receiver (source-receiver distance). It must also be noted that each SchR mode exhibits this dependence on a polynomial of a different degree.

As is shown by my research and analyses of the problem, the third of the above factors, i.e. the correlation between the amplitude of the SchR modes and the source-receiver distance, is incorrectly taken into account by researchers. As a result of my further research, I proposed a new method for assessing thunderstorm activity based on the I_{RS} index. The method I proposed for calculating the index is based on calculating the mean value of the amplitudes of the first 7 modes of Schumann resonances. I described this aspect of research in my doctoral dissertation, which I defended in 2009.

What proved to be extremely interesting was using the I_{RS} index for comparative studies with another method for assessing global thunderstorm activity frequently used in atmospheric physics – i.e. assessing it as an element of the Global Electric Circuit (GEC), which consists in measuring electric field intensity close to the Earth's surface. The comparison is presented in my paper **(Nieckarz et al 2009a, IF=1.811)** entitled **"Comparison of global storm activity rate calculated from Schumann resonance background components to electric field intensity E_{0Z}"**. Later on, I used the I_{RS} index to

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investigate changes in the electrical activity of three major continental thunderstorm centres on Earth. I published the results of those analyses in my paper **(Nieckarz et al. 2009b, IF=2.238)** entitled **„Study of the periodicities of lightning activity in three main thunderstorm centers based on Schumann resonance measurements"**. Neither of the above studies is included in the present academic accomplishment because they were published in the calendar year when I received the PhD title. The analyses and outcomes presented in the above study (**Nieckarz et al. 2009a**) and most of the results presented in another study (**Nieckarz et al. 2009b**) are not relevant for the subject matter of my doctoral dissertation.

My further research addressed ways of mapping the distribution of electrical thunderstorm activity on Earth, and significantly contributed to the development of the patent **(P2)** named **„Method and apparatus for monitoring storm activity on Earth's surface in real time,"** which is submitted as part of this accomplishment. In the years 2012-2014, the patent was registered by the European Patent Office and patent offices of 7 economically important countries of the world. The choice of the countries was based on their economic potential since assessing global electrical thunderstorm activity in a reliable way allows the introduction of information that cannot be obtained by other measurement methods into numerical meteorological models. The market research performed for the needs of the patent procedure by competent units of the Jagiellonian University demonstrated that weather forecasts based on such modelling are mainly prepared by countries with a large economic potential.

Based on simultaneous analysis of a number of Schumann resonance modes, my associates and I developed a method for mapping electrical activity on Earth in real time. The method permits the modelling of the electrical activity of the so-called tropical continental chimneys, present over Africa, America and the Maritime Continent, which covers the Indian Peninsula, south-east Asia, and Australia (Ramage 1968). They are the 3 areas on Earth that show the highest electrical storm activity (Chalmers 1967, Christian et al. 2003). Currently, the areas are under close scrutiny and observation by researchers, e.g. in the context of climate change (Brooks 2013). The documents attached to the patent file contain detailed descriptions of both the components of the measuring apparatus which was designed and constructed for the needs of investigating thunderstorm activity and the method for mapping global thunderstorm activity in real time. The dossier describing the apparatus components contains drawings which offer a better understanding of the idea underlying the measurements and diagrams of the measurement stations built. Meanwhile, the part dedicated to the method for mapping global electrical thunderstorm activity presents the theoretical assumptions of the method, the description of the invention, and the method of implementing it.

According to literature on analytical solutions (Schumann 1952, Galejs 1961), the amplitude of the n-th mode of the resonance power spectrum for a signal emitted by a constant-amplitude source point changes with the source-receiver distance as described by the associated Legendre polynomials of the n-th degree. On the other hand, the results of some analyses **I co-authored (Kułak et. al. 2006)**, obtained from numerical studies of a strongly dampened resonator using the finite-difference time-domain method, show that the power spectra for a strongly dampened resonator do not take the shape of classical Lorentzian curves, but instead take that of clearly asymmetrical resonance curves, which had already been observed earlier in other phenomena, e.g. neutron scattering in nuclear physics (Breit and Wigner 1936, Fano 1961) . Therefore using classical resonance curves in the process of matching theoretical formula to asymmetrical spectra observed in nature does

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not yield correct results and leads to errors when determining the amplitudes and other parameters of the Schumann resonances. The method I have created with my fellow researchers, where the matching of the theoretical curve to observed spectra is based on an asymmetrical resonance curve model, is named the decomposition method (DECOMP). Using the power spectrum decomposition method permits the obtaining of non-distorted resonance mode amplitudes. Knowing the amplitudes is a key requirement of the patented method. The accuracy of the DECOMP method was confirmed in a study paper **I co-authored (Dyrda et al. 2014)**. The literature postulates methods for mapping global electrical storm activity using the full SchR spectrum (Heckman et al. 1998) or the FDTD method (Shvets et al. 2009, Yang and Pasko 2006). In my opinion, these solutions have a serious drawback attributable to the methods and approaches they rely on, i.e. direct or indirect use of symmetric Lerentzian curves.

The exceptional qualities of the E-i resonator allow researchers to investigate electrical storm activity at various spatial scales. Such research is exemplified by my study **(Nieckarz et al. 2009c) entitled "Day-to-Day Variation of the Angular Distribution of Lightning Activity Calculated from ELF Magnetic Measurements,"** where I use ELF measurements to analyse the electrical storm activity of a cyclone moving above the Mediterranean Sea in 2006, as a complement of satellite observations obtained from a Lightning Imaging Sensor (LIS) and Full Disk Meteosat InfraRed Images. For formal reasons, the above study is not included in this academic accomplishment either since it was published in the year I defended by doctoral dissertation. The subject of the study is not consistent with the problems discussed in the dissertation. In my subsequent academic paper, I investigated the relationship between the parameters of electric lightning activity determined on the basis of ELF waves and those obtained by other established measurement methods and techniques available to scientists. Therefore I undertook work designed to compare lightning dipole moments calculated on the basis of ELF wave parameters to the discharge peak current determined on the basis of measurements of a terrestrial lightning detection network. In my publication **(P1)** entitled **"Cloud-to-ground lightning dipole moment from simultaneous observations by ELF receiver and combined direction finding and time-of-arrival lightning detection system,"** I investigated the relation by analysing two 48-hour periods: 28–29 July and 6–7 September 2005. The research was based on data sets of the French lightning detection network Meteorage, and covered the territory of France and parts of neighbouring countries. In both study periods, the discharges originated in frontal thunderstorms moving from the west eastward – from the Iberian Peninsula inland. To obtain results with the highest confidence levels, I needed to ensure an optimal sample of ELF measurements with the highest signal-to-noise ratio. To achieve this, I narrowed down my analysis to cloud-to-ground (CG) strokes with positive polarisation (CG+) and negative polarisation (CG-) because their presence in the ELF signal is nearly always clearly observable. In addition, I adopted additional amplitude-related criteria which allowed me to reject signals characterised by low confidence. All in all, I studied over 60 thousand positive lightning discharges and 20 thousand negative ones. The mean distance of the lightning discharges from the Halaty ELF measuring station, the Bieszczady Mountains, Poland, was approx. 1500 km, and the average dipole moment (p) for CG- and CG+ discharges was approx -200 Ckm and +400 Ckm. Based on an analysis of the above data, I found that the relation between the peak current of a discharge (I_{max}) and its dipole moment (p) is expressed by the following formula: $p=7.5*I_{max}$. I demonstrated in my paper that the information collected by European commercial and academic lightning detection and location networks can be supplemented with another parameter, which cannot be determined by other methods on such a spatial scale. Even though the average detection effectiveness (*EI*) was only 25%, which means that only every fourth discharge was discernible in the ELF observations, it nevertheless exceeded the thresholds I adopted in the amplitude criterion. However, it must be remembered that the discharges were located more than 1000 km away from the ELF measuring station. With discharges located near the ELF station, the *EI* parameter is nearly 100%, which I indirectly proved in my later publication **(P4).**

In some situations, the same correctly defined electric parameters of lightning discharges can be obtained using two completely different measurement methods and techniques. One example is the electric dipole moment (*p*), also known as the charge moment change (CMC). Thus, an important question arose whether using different methods leads to the determination of the same CMC values? Therefore, my later research efforts were focused on comparing CMC values obtained by means of two completely different and independent methods. The first CMC determination method relies on measuring electric field intensity changes detected by VLF receivers working as a local lightning detection system (Warsaw area), whereas the other determines the CMC on the basis of ELF radio observations made by a single station (Hylaty). My study **(P4)** entitled "**Comparison of the charge moment change calculated from electrostatic analysis and from ELF radio observations** compared CMCs obtained by means of both methods. The first method uses multistation ground-based measurements of the E field change. Theoretically, measuring CMC by a sensor network consisting of at least four points should permit calculating the Q charge neutralised in the discharge and its coordinates (x,y,z). The product with $*Q$ is referred to as the electric dipole moment, which I marked in the study as CMC_{ES}, and the correlations used in this method are based on the laws of electrostatics. In reality, the measurements are recorded by a higher number of stations to be able to determine the error of the parameters. The study was based on measurements of a local lightning detection network consisting of 6 stations active in the summer of 2009 in Warsaw (Barański et al. 2012). The second method is based on measurements of the horizontal magnetic field components of electromagnetic waves generated by atmospheric discharges in the ELF (extremely low frequency) range and analytical formulae for wave propagation in the E-i cavity, and can be used to determine CMC_{ELF}. The amplitude of magnetic field impulses recorded by the receiver depends on the CMC of the source and on the signal transfer function. The value of the function can be calculated on the basis of the source-receiver distance, the signal transfer function in the E-i cavity, and the transfer function of the receiver. Using the ELF measurements, I calculated the amplitudes of magnetic field impulses B. I computed the distance between the signal source (lightning discharge) and the receiver (ELF station) on the basis of their known coordinates. The average distance between the ELF station and the recorded lightning discharges in the Warsaw area was 350 km. Furthermore, the characteristics of the ELF receiver are also very well known, with its 3-dB bandwidth ranging between 0.03 Hz and 52 Hz. Knowing the above correlations and magnitudes I calculated the dipole moment of the source CMC_{ELF}. The theoretical assumptions of the method were described in a study **I co-authored (Kułak i in. 2010)**. In another study **(P4)**, I conducted a comparative analysis of the CMC_{ES} and CMC_{ELF} values for 26 cases of negative cloud-to-ground lightning discharges (CG-) recorded by means of both measuring methods. The 26 lightning discharges consisted of 10 return strokes (RS) and 16 return strokes with continuous current (RS&CC), in which the return stroke phase (RS) was directly followed by a continuous current phase (CC). The analyses showed that for RS&CC discharges, the electrostatic method yields underestimated CMC_{ES} values more

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often than for $CMC_{ELF.}$ Meanwhile, for RSs, static analysis demonstrated that both methods give the same CMC value (for *p-value*=0.05). The CMCs I obtained are similar to those described in the literature, among others, by Lu et al (2012).

When long-term measurements and observations are pursued, it is important and desirable that they are uniform. The measurements made by the Hylaty ELF station are used to determine the character of electrical storm activity across a range of spatial scales. Therefore in my paper **(P5)** entitled **"Imprints of natural phenomena and human activity observed during 10 years of ELF magnetic measurements at the Hylaty geophysical station in Poland,"** I analysed the quality of the data sets collected by the Hylaty ELF station. I used data gathered by the station over a 10-year period (2005-2014). One of the anthropogenic factors I investigated was the impact of the intensity of the magnetic fields generated by 50 Hz power lines on the quality of the observations and analyses performed using this spectrum range. Schumann resonances are an example of a natural phenomenon observed within this bandwith. I demonstrate in my paper **(P5)** that the location of the Hylaty station, which lies just outside the border of the Bieszczady National Park, is a good choice. This is evidenced by the low level of anthropogenic EM distortions, which have not increased significantly in the last decade, during which the station has conducted continuous ELF observations. This means that the indexes of electrical storm activity calculated on the basis of its measurements are characterised by an invariably high quality. The additional discussion and analysis of the impact of cities and urban areas on the quality of the measurement of natural magnetic fields introduced in paper (**Nieckarz 2016**).

5. Other academic/ artistic accomplishments.

Most of my papers not included in the academic accomplishment are publications which are directly or indirectly related to the subject matter of the accomplishment. The publications include, among other works, studies of the impact of the sun as a key determinant of the propagation of electromagnetic waves in the Earth-ionosphere cavity (A1, A2), while papers (A10, A15) address the method for assessing and describing the sun's activity and possibilities of predicting it. Study (A4) presents a new method for "decomposing" the electromagnetic spectra of the Earth-ionosphere resonator, which was applied both to numerical data and observed data. Study (A9) presents an analytic formula describing lightning as an antenna. The paper took into account both standard lightning discharges of the CG type comprising short RSs and long-lasting CC discharges, and established a correlation between the maximum amplitude of a recorded magnetic field impulse and the dipole moment of the discharge. Study (A14) describes in detail the design and operation of the Hylaty station, as well as the methods used for analysing the data gathered by the station. Publication (A16) describes how the decomposition method (DECOMP) was applied to recorded Schuman Resonance spectra to describe the activity of an African thunderstorm centre.

The research conducted by the habilitation candidate on electrical storm activity is also inherently related with the problems of torrential rainfall and extreme phenomena in hydrology, as well as their underlying causes, such as the occurrence of specific air mass types, the direction of their advection, as well as large-scale meteorological phenomena. The hydrological aspects of Carpathian rivers, in particular extreme flows, are analysed in studies (D4, D9, D10, E1), which investigate, among other phenomena, the occurrence trends of high flows and extreme flows in the Dunajec catchment area. An analysis of the water surface level in Morskie Oko lake and the results of research into the periodicity of the parameter are presented in publication (E2). Predicting hydrological extremes based on air circulation indicators are

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discussed in paper (D3), and the results of research of the impact of the North Atlantic oscillation on the flows of Carpathian rivers are presented in studies (D1, D2). Study (A12) investigates the occurrence frequency and duration of mass types in southern Poland.

The measurements and analysis of the electrical parameters of the atmosphere encouraged me to study the impact of these factors – both natural and anthropogenic ones – on living organisms. Investigating the impact of electromagnetic waves on living organisms has become one of my additional interests. The interdisciplinary studies I was engaged in resulted in study papers (A13, A17, D5) addressing the impact of electromagnetic fields on the growth of chicken embryos, especially on heart action. To measure the heart rhythm, use was made of non-invasive ballistocardiographic measurements. Study (D11) addressed the impact of magnetic fields on the behaviour of U937 cancer cells.

Another group of scientific publications in which I have participated are papers (D7, D8) dedicated to researching the human heart as a source of a magnetic field generated by the currents in cardiac muscle cells. The papers present a numerical method for solving the inverse problem in magnetocardiography. The analysis also comprised signals recorded by a set of multiple Siemens SQUID detectors arranged in a single plane. It was proven that the method may be useful for early diagnosis of cardiac conduction changes.

Thanks to my extensive experience in the design of electronics used in measuring apparatus and in data analysis, I have been invited to collaborate on and participate in many interesting research projects, which have resulted in a number of scientific and academic publications. Publications (A3, D6) are dedicated to the design of apparatus and are aimed at improving the possibilities of ultrasound scanners in ophthalmology and refining the methods for analysing data provided by those scanners. Study paper (A5) addresses non-linear oxygen consumption processes in skeletal muscles of animals, while publications (A11, A18) extend the research to comprise human muscles, and contain a detailed analysis of the heart rate during exercise in healthy youths. Paper (A16) describes a new fractal-based approach to assessing the system of blood vessel imprints in the human skull using topographic adjustment based on skull shape, which can be useful in anthropological studies.

Cited literature

A1..., D1..., E1... - these indicate publications listed in Appendix entitled "List of published academic papers".

Barański, P., M. Łoboda, J. Wiszniowski, and M. Morawski (2012), Evaluation of multiple ground flash charge structure from electric field measurements using the local lightning detection network in the region of Warsaw, *Atmospheric Research*, 117, 99–110.

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Dyrda, M., A. Kulak, J. Mlynarczyk, M. Ostrowski, J. Kubisz, A. Michalec, and **Z. Nieckarz** (2014), Application of the Schumann resonance spectral decomposition in characterizing the main African thunderstorm center, *J. Geophys. Res. Atmos.*, 119, 13,338–13,349, doi:10.1002/2014JD022613.(**IF=3.426**)

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Kułak, A., J. Młynarczyk, S. Zięba, S. Micek, and **Z. Nieckarz** (2006) Studies of ELF propagation in the spherical shell cavity using a field decomposition method based on asymmetry of Schumann resonance curves, *Journal of Geophysical Research*, 111, A10304, doi:10.1029/2005JA011429 (**IF=2.800**).

Lu, G., S. A. Cummer, R. J. Blakeslee, S. Weiss, and W. H. Beasley (2012) Lightning morphology and impulse charge moment change of high peak current negative strokes, *J. Geophys. Res.*, 117, D04212, doi:10.1029/2011JD016890.

Nickolaenko, A. P., and L. M. Rabinowicz (1995) Study of the annual changes of global lightning distribution and frequency variations of the first Schumann resonance mode, *J. Atmos. Terr. Phys.*, 57, 1345–1348.

Nieckarz Z., A. Kułak, S. Zięba, M. Kubicki, S. Michnowski, and P. Barański (2009a) Global Storm Activity Rate Calculating from Schumann Resonance Background Component with Electric Field Intensity E0Z, *Atmospheric Research*, Vol. 91, pp. 184-187 (**IF=1.811**);

Nieckarz Z., S. Zięba, A. Kułak, and A. Michalec (2009b) Study of the Periodicities of Lightning Activity in Three Main Thunderstorm Centers Based on Schumann Resonance Measurements, *Monthly Weather Review*, Vol. 137, No. 12 : pp. 4401-4409 (**IF=2.238**).

Nieckarz Z., A. Kułak, S. Zięba, and A. Michalec (2009c) Day-to-Day Variation of the Angular Distribution of Lightning Activity Calculated from ELF Magnetic Measurements, *AIP Conf. Proc.*, 1118, 28, 2009, DOI:10.1063/1.3137709;

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