

Opponent's report on a doctoral thesis of Jan Zählava:
“Lightning-Related Electromagnetic Wave Phenomena in the Earth's Magnetosphere”

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The presented doctoral thesis focuses on lightning-related electromagnetic wave phenomena observed by DEMETER and Van Allen Probes in the Earth's inner magnetosphere. The thesis has two main topics: 1) lightning contribution to the electromagnetic wave power in the magnetosphere, and 2) special events with banded structures observed in the ionosphere. Both topics are relevant and well-focused in the thesis. It was shown that during nights the total wave intensity observed in the plasmasphere is strongly correlated with lightning activity. The second topic is a good start for further studies.

The work has divided into five numbered chapters and one non-numbered chapter for Conclusion. It has 12 pages long bibliography, which contains 139 references. There is the list of publications appended to the work containing 5 original papers published in JGR Space Physics in the end of the thesis. The actual text of the work, including the content and the bibliography, is 78 pages long. While total length of the thesis is 162 pages almost a half of it is reserved for reprints of original papers in which Mr. Zählava has always been the first author. The first chapter of the thesis is devoted to the theoretical introduction to the studied problems, i.e., plasmasphere, whistlers, lightnings, and Earth-ionosphere waveguide. The second chapter is just one page and it tells the aims of the thesis. The third chapter introduces DEMETER and Van Allen Probes spacecrafts, their instruments and data sets that are relevant for this thesis, as well as lightning detection systems LIS/OTD and WWLLN. The main studies of the thesis are in chapters 4 and 5. Chapter 4 is presenting the first of the main topics. It is divided into two subtopics, i.e., whistler detection analysis and longitudinal dependence of intensity of whistler-mode waves. Main results are summarized in the last paragraph of each subtopic. Chapter 5 is presenting the second of the main topics. It is also divided into two subtopics, i.e., VLF attenuation events and ELF attenuation events. Similarly to Chapter 4, main results are summarized in the last paragraph of each subtopic. The quality of all Figures is very good throughout the thesis.

Introduction chapter is presenting reasonable theory of magnetosphere and plasmasphere. The theory of whistlers are dealt mostly with their propagation properties. In this work, the most important understanding is required with whistler propagation from the ground to top part of ionosphere. As far as this thesis is studying lightning signals observed onboard the spacecrafts very detailed theory of different types of lightnings is not needed. The understanding of signal propagation in Earth-ionosphere waveguide and in the ionosphere is much more important.

Chapter 3 is presenting used spacecrafts and their instruments, which are needed for this study. Figure 3.2 shown clearly the coverage of DEMETER data both in survey and burst modes. It would have been nice to have similar map for Van Allen Probes. The following chapters have nice summary paragraphs in the end of each subchapter. This could have been made also for chapter 3.

Chapter 4 is considering the scientific results about wave power from ground-based lightnings to the

magnetosphere. So far, all the whistlers are lightning originated that allows us to use e.g., DEMETER observations of fractional hop whistlers as power input to the magnetosphere. Difference between day and night is very clear. Mr. Záhlava has explained well this discrepancy. However, it would have been elucidated to show also DEMETER survey mode data, especially because it has been the main data for this study. This chapter is based on original papers A2 and A3.

- 1) Question of day and night data sets of DEMETER: DEMETER was quasi-Sun-synchronous satellite and practically all data is observed neat 10 MLT and near 21 MLT. How well these two times are representing day and night (see Fig. 3.1)?**
- 2) Question: Why there is no geographical explanation of dashed lines in Figs. 4.7 – 4.14? Only explanation has been given on the top text on page 37.**
- 3) Question: What is amount of events in each Figs. 4.7 – 4.10?**

Chapter 5 presents totally different type of VLF and ELF events. The text related to events on VLF frequencies is mostly from original paper A1. Altogether 1601 VLF events with bands of enhanced and reduced wave intensities were identified. Most probable source for these structures is based on the propagation of lightning-generated waves in Earth-ionosphere waveguide and waveguide mode interference. The events at ELF range were studied in original paper A4. Altogether 263 events have been studied, and a possible formation mechanism proposed to be a modal interference in a waveguide at altitudes around 110 km.

- 4) Question: What is the white arrow in Fig. 5.1?**
- 5) Question: Figs. 5.9d and 5.10d show nicely most of the structures seen in Figs. 5.9c and 5.10c. Why this model spectrograms were explained much better in original paper A1 on page 9790 than in subchapter 5.1?**
- 6) Question: The studied ELF events seemed to resemble very much so called Ionospheric Alfvén Resonator (IAR), which can be observed by induction magnetometers during nighttime especially in the minimum phase of solar activity. Have you been thinking any kind of relation to IAR?**

- 7) Question: Is there any idea if these kind of events could be observed on the ground?**

The presented doctoral thesis is a collection of five studies published in international impacted journal, *J. Geophys. Res., Space Physics*, with Jan Záhlava being their main (first) author. As such, I believe that the thesis clearly demonstrates the author's ability of independent scientific work and his deep understanding of the analyzed phenomena. I thus highly appreciate the presented doctoral thesis and fully recommend it for the defense.

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