Booklet of Theses

Studying the system of electrical interactions among environmental processes in the near-Earth space based on atmospheric electric potential gradient measurements

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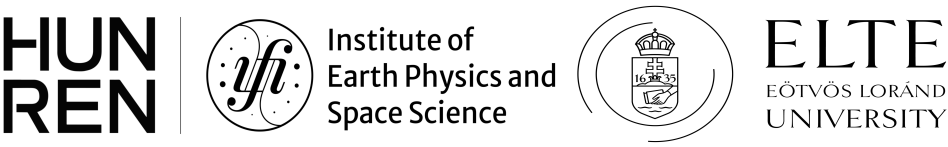

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1. Introduction

In Earth's atmosphere, even without the presence of nearby lightning or any overpassing clouds, there is a ubiquitous quasi-static vertical electric field of natural origin all the time. The main source of this electric field is the global thunderstorm activity. The atmospheric electric field is an important constituent of the Global Electric Circuit (GEC), which is a global system of currents connecting the ionosphere and the ground. In the GEC, far away from any lightning strokes, the return current maintains the fair weather electric field. The reverse of this electric field is called atmospheric electric potential gradient (PG). The PG is a readily measurable and versatile diagnostic tool in Earth sciences and it is the main topic of my PhD thesis.

2. Motivation and objectives

Nowadays, there is a growing interest towards the measurement of PG all around the globe with an ever increasing number of geophysical observatories that host PG measurements. One of the causes of this trend is that the PG can be measured in a relatively cost-effective way and a wide spectrum of environmental phenomena can be studied with it not only via its continuous monitoring but via occasional measurement campaigns as well.

PG research is greatly facilitated by the fact that there are multiple long-term PG records available from different observatories which span over decades. One such site is the István Széchenyi Geophysical Observatory of the HUN–REN Institute of Earth Physics and Space Science at Nagycenk (NCK) where quasi-continuous recording of the PG commenced in 1962 and still lasts to date. Furthermore, beside the PG time series of single observatories, there are more and more international networks which coordinate and integrate PG measurements from around the world. An excellent illustration of one such network is the so-called GloCAEM (Global Coordination of Atmospheric Electricity Measurements) project lead by the University of Reading (United Kingdom).

One of the main motivations behind my PhD research is to demonstrate how the PG can contribute to the study of different electrical interactions among environmental processes in the near-Earth space, and to introduce the concept of PG to the national professional community of Earth sciences experts in Hungary. A perfect opportunity for my research was that I had access to the long-term PG dataset measured at NCK and to PG data stored on the GloCAEM servers. In my PhD thesis, I show how I performed the correction and the trend analysis of the PG time series recorded at NCK based on on-site measurements, careful ca-

libration of the instruments, and numerical modeling, thus eliminating the time-dependent electrostatic shielding effect caused by nearby trees from the data. Moreover, I present how I quantified the impact of cutting down of the trees at NCK in 2020, which was a sudden and powerful effect on the PG data. Ultimately, I demonstrate how PG measurements can be used in cutting-edge geophysical research supported by a concrete example, namely, the study of the eruption of the Hunga Tonga–Hunga Ha'apai volcano in 2022.

3. My theses

I. thesis **Based on numerical modeling, on-site measurements, and instrument calibration, I developed a method to take into account and correct for the impact of the electrostatic shielding effect of nearby conducting objects on PG measurements. The shielding effect poses a serious problem in PG measurements as in the case of many observatories where the ideally flat and open area with a proper dimension can not be provided. With the aid of this method, I assessed the shielding effect at NCK.**

Supporting publications: [1], [2], [5].

II. thesis **By correcting for the time-dependent electrostatic shielding effect of nearby trees at NCK which led to a significant distortion of the recorded values, I produced a long-term PG dataset with which the decadal variations of the GEC can be studied more reliably, thus, solving a long-standing scientific debate. I published this dataset in an internationally recognized, professionally reviewed data repository and performed its trend analysis.**

Supporting publications: [1], [2], [5], [7], [8].

III. thesis **Based on numerical modeling and on-site measurements, I determined a new correction factor after a group of trees have been cut down at NCK in 2020 causing a sudden and significant change in the environment of the PG measurements. I have shown how an abrupt change in the environment of the measurements can cause dramatic variations in PG data. Using this approach, I proposed a method to quantify the sudden changes in the PG that show a high variability, taking into account the natural variations in the PG too.**

Supporting publications: [4].

IV. thesis **In order to study the impact of the Hunga Tonga–Hunga Ha'apai volcanic eruption in 2022, I used PG data from six stations around the world. I found that in the main phase of the eruption (15. jan. 2022 04:15–06:20 UTC) the PG records displayed a distinct increase. The mean enhancement in the PG records (+21–25%) was significantly greater than that of the globally-representative natural diurnal variation of the PG (+7,4%) or of the enhancement derived from parallel lightning detections (+15,6%).**

Supporting publications: [3], [6].

4. My publications

4.1. Publications supporting my theses

✣ *Peer-reviewed papers*

[1] **Buzás, A.**, Barta, V., Horváth, T., & Bór, J.: Revisiting the long-term decreasing trend of atmospheric electric potential gradient measured at Nagycenk, Hungary, Central Europe. *Anna-*

les Geophysicae, 39(4): 627–640, 2021. DOI: 10.5194/angeo-39-627-2021.

[2] Bór, J., Sátori, G., Barta, V., Szabóné-André, K., Szendrői, J., Wesztergom, V., Bozóki, T., **Buzás, A.**, & Koronczay, D.: Measurements of atmospheric electricity in the Széchenyi István Geophysical Observatory, Hungary. *History of Geo- and Space Sciences*, 11(1): 53–70, 2020. DOI: 10.5194/hgss-11-53-2020.

[3] Bór, J., Bozóki, T., Sátori, G., Williams, E., Behnke, S. A., Rycroft, M. J., **Buzás, A.**, Silva, H. G., Kubicki, M., Said, R., Vagasky, C., Steinbach, P., Szabóné-André, K., & Atkinson, M.: Responses of the AC/DC Global Electric Circuit to Volcanic Electrical Activity in the Hunga Tonga–Hunga Ha'apai Eruption on 15 January 2022. *Journal of Geophysical Research: Atmospheres*, 128(8): e2022JD038238, 2023. DOI: 10.1029/2022JD038238.

✣ *Other papers, conference proceedings*

[4] **Buzás, A.**, & Bór, J.: Investigating the impact of cutting down nearby trees on measured values of the atmospheric electric potential gradient data.

Geophysical Observatory Reports 2020, pp. 6–13, 2021. DOI: 10.55855/gor2020.1.

[5] **Buzás, A.**, Bozóki, T., & Bór, J.: A nagycenki Széchenyi István Geofizikai Obszervatóriumban folyó, hat évtizednyi légköri elektromos térerősség mérések bemutatása. In *Bacsárdi László: Magyar Űrkutatási Fórum 2021 - Válogatott közlemények*, pp. 7–12, MŰF2021-K-02, 2023. ISBN: 9789637367335.

[6] Bór, J., Bozóki, T., Sátori, G., **Buzás, A.**, Steinbach, P., Szabóné-André, K., Williams, E. R., Behnke, S. A., Rycroft, M. J., Silva, H. G., Kubicki, M., Said, R., Vagasky, C., & Atkinson, M.: A globális légköri elektromos áramkör egyenáramú és váltóáramú komponenseinek kvázi-azonnali változásai a Hunga Tonga-Hunga Ha'apai vulkán 2022. január 15-i kitörésének hatására. In *Bacsárdi László: Magyar Űrkutatási Fórum 2023 – Válogatott közlemények*, pp. 17–23, MŰF2023-K-02, 2023. ISBN: 9789637367335.

✣ *Data publications*

[7] **Buzás, A.**, Szabóné-André, K., & Bór, J.: Atmospheric electric potential gradient data and

measured as well as reanalyzed meteorological parameters at the Széchenyi István Geophysical Observatory, Hungary, from the years 1962–2009. *PANGAEA*, 2022. DOI: 10.1594/PANGAEA.942036.

[8] Magos, L., **Buzás, A.**, Tacza, J., Bozóki, T., Bozsó, I., Kuslits, L., Timkó, M., Horváth, A., & Bór, J.: Atmospheric electric potential gradient data at the Széchenyi István Geophysical Observatory, Hungary, digitized from photographical records from the years 1999–2009. *PANGAEA*, 2022. DOI: 10.1594/PANGAEA.950160.

4.2. Other publications of mine

✣ *Peer-reviewed papers*

[9] **Buzás, A.**, Kouba, D., Mielich, J., Burešová, D., Mošna, Z., Koucká Knížová, P., & Barta, V.: Investigating the effect of large solar flares on the ionosphere based on novel Digisonde data comparing three different methods. *Front. Astron. Space. Sci.*, 10:1201625, 2023. DOI: 10.3389/fspas.2023.1201625.

[10] Barta, V., Bozóki, T., Süle, D. P., Kouba, D., Mielich, J., Raita, T., & **Buzás, A.**: Ionosphe-

ric Absorption Variation Based on Ionosonde and Riometer Data and the NOAA D-RAP Model over Europe During Intense Solar Flares in September 2017. *Remote Sens.*, 16(21): 3975, 2024. DOI: https://doi.org/10.3390/rs16213975.

[11] Koucká Knížová, P., Potužníková, K., Podolská, K., Šindelářová, T., Bozóki, T., Setvák, M., Pásztor, M., Szárnya, Cs., Mošna, Z., Kouba, D., Chum, J., Zacharov, P., **Buzás, A.**, Hanzlíková, H., Kozubek, M., Burešová, D., Bozsó, I., Berényi, K. A., & Barta, V.: Impacts of Storm "Zyprian" on Middle and Upper Atmosphere Observed from Central European Stations. *Remote Sens.*, 16(22): 4338, 2024. DOI: https://doi.org/10.3390/rs16224338.

✣ *Other papers, conference proceedings*

[9] **Buzás, A.**, Kouba, D., Mielich, J., Burešová, D., Mošna, Z., Koucká Knížová, P., & Barta, V.: Flerek vizsgálata új generációs ionoszonda adatok alapján három különböző módszer segítségével. In *Bacsárdi László: Magyar Űrkutatási Fórum 2023 - Válogatott közlemények*, pp. 24–29, MŰF2023-K-03, 2023. ISBN: 9789637367335.

[10] Barta, V., Berényi, K., **Buzás, A.**, Kiszely, M., Szabóné-André, K., & Szárnya, Cs.: Földrengések nyomai a felsőlégkörben? *Fizikai Szemle*, 73(10): 338–342, 2023. URL: https://real-j.mtak.hu/24989/49/FizSzem_2023-10-PDFA.pdf#page=8 (u.m.: 2025.04.25.).