1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Influence of thermodynamic instability of the atmosphere on the variability of the cloud-to-ground lightning in Poland in the years 2002-2020

1.1. Project goals

The aim of the research is to detect the relationship between thermodynamic instability of the atmosphere and the circulation of the atmosphere and their influence on the formation of storm clouds and cloud-to-ground (CG) flashes in Poland. The analysis will cover:
- spatial distribution of thunderstorm days and CG lightning in Poland;
- annual and daily courses of CG flashes;
- main severe storm cells tracks direction;
- variability and trend of the incidence of thunder storm days and CG flashes in Poland in the years 2002-2020;
- analysis of instability conditions of the atmosphere (CAPE - convective available potential energy) in Poland;
- impact of atmospheric circulation and CAPE on storm cloud formation and occurrence of CG flashes in Poland;
- case study of days with the highest values of CG flashes in Poland.

1.2. Outline

As global climate is constantly changing and air temperatures are rising, there is an increase in potential energy in the atmosphere, which results in higher incidence of severe thunderstorms (McMichael et al. 2005). Preliminary results from climate projections for Europe indicate that an increase in the most unstable CAPE (convective available potential energy) values and a slight in shear are expected in the next 100 years (Púčik 2017). To sum up, thunderstorms capable of producing severe and extremely severe phenomena may become more frequent. Consequently, we all should take this into consideration and be prepared for this phenomenon as it may occur again in the near future. Therefore it is necessary to predict the impending threat and understand its strength.

Previous studies on the frequency of storms in Poland have not shown an increase in their incidence (Bielec 1998). However, only visual observations were used in these studies. Launching the lightning detection system (PERUN) in 2002 enables the analysis of their spatial distribution and variability in time. The main aim of this study is to detect areas particularly vulnerable to lightning. It will be necessary to create maps of the distribution of storms and lightning. Factors conducive to the formation of storm clouds (especially supercells), types of synoptic citation and atmospheric instability (CAPE) will be investigated. The results of this research will be supported by weather forecasting and a warning system against dangerous meteorological phenomena, such as storms and accompanying dangerous atmospheric phenomena. In Poland, there are numerous dangerous storm related phenomena, such as hail, severe squalls and tornadoes. In recent years, the multicellular storm has done considerable damage on August 11, 2017 (Taszarek et al. 2019).

1.3. Work plan

1. Review of the literature related to the formation of storms and atmospheric discharges in Poland and other countries.
2. Collection of data from 2002-2020:
   - atmospheric discharges in Poland - PERUN lightning detection system;
   - data from vertical atmosphere surveys in Poland – the University of Wyoming;
   - synoptic maps (the Institute of Meteorology and Water Management – National Research Institute) and satellite images (Meteosat).
   - SYNOP data (the Institute of Meteorology and Water Management – National Research Institute)
3. Performing statistical calculations - hourly, daily, monthly and annual averages in 10 x 10 km grids cells in Poland.
4. Analysis of the spatial distribution of cloud-to-ground in Poland in individual months and years (maps).
5. Analysis of daily and annual information about lightning (peak current, polarization).
6. Analysis of atmosphere thermodynamic variability (CAPE) in Poland.
7. Analysis of CAPE correlation and frequency of storms and lightning.
8. Variability and trends of days with thunderstorms and lightning strikes in the years 2002-2020 and their relationship with atmospheric circulation and CAPE.
9. Case study of extreme storm phenomena at 2002-2020 period.

1.4. Literature

This type of research has not been conducted for the area of Poland. The subject of atmospheric discharges for Poland has not been studied thoroughly, hence few studies are available. In international research, this issue is more advanced and, consequently, publications were created for various countries or Europe linking discharges to other factors.

Allen, 2018, Climate change and severe thunderstorms. In: Von Storch H, et al. (eds) *Oxford Research Encyclopedia of Climate Science.*, Oxford University Press: 1–37, https://doi.org/10.1093/acrefore/9780190228620.013.62.

Barczyk M, 2013, The use of meteorological radar to detect and forecast meteorological phenomena, Instytut Meteorologii i Gospodarki Wodnej, Warszawa: 4–24.

Bielec-Bąkowska Z, 2013, Burze i grady w Polsce. *Prace Geograficzne Instytutu Geografii i Gospodarki Przestrzennej*, Uniwersytet Jagielloński 132: 99-132.

Brooks HE, 2013, Severe thunderstorms and climate change. *Atmospheric Research*, 123: 129–138, https://doi.org/10.1016/j.atmosres.2012.04.002.

Celiński-Mysław D., and Łoboda Ł, 2019, Kinematic and thermodynamic conditions related to convective systems with a bow echo in Poland. *Theoretical and Applied Climatology*,137: 2109–2123.

Dotzek N, European Severe Weather Database, https://eswd.eu/cgi-bin/eswd.cgi?&lang=pl_27 (access: 15.11.2019).

Mäkelä A., Rossi P., 2011, The daily cloud-to-ground lightning flash density in the contiguous United States and Finland. Monthly Weather Review, 139 (5), 1323-1337.

Nag A., Rakov V.A., 2012, Positive lighting: An overview, new observation and inferences. Journal of Geophysical Research, 117, doi:10.1029/2012JD017545.

Santos, J. A., M. A. Reis, J. Sousa, S. M. Leite, S. Correia, M. Janeira, and M. Fragoso, 2012: Cloud-to-ground lightning in Portugal: Patterns and dynamical forcing. Nat. Hazards Earth Syst. Sci., 12, 639–649, doi:10.5194/nhess-12-639-2012.

1.5. Required initial knowledge and skills of the PhD candidate

- analytical thinking,
- eager to learn,
- open for challenging tasks,
- understanding of meteorology and climatology,
- knowledge of GIS programs,
- knowledge of English (B+ level),
- ready to go abroad for traineeship or study (Erasmus + or other program).

1.6. Expected development of the PhD candidate's knowledge and skills

- the ability to ask research questions and independently search for answers,
- knowledge of statistical programs and the ability to analyze data (big data),
- the use of GIS software in the spatial analysis of phenomena,
- ability to write scientific articles,
- ability to deliver papers and conduct scientific discussions.