Report for COST Action CA15211 “ElectroNet”
Short-Term Scientific Missions (STSM)

This report is submitted for approval by the STSM applicant to the STSM coordinator

STSM title: Investigation of the lake-effect on the local thunderstorm activity in Hungary and in Armenia

1. **APPLICANT**

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2. **HOST**

Last name: Veronika
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3. STSM PERIOD: **23/09/2019 to 03/10/2019**

PURPOSE OF THE STSM:

Overall context and objectives of this proposal

Natural and artificial lakes are able to change the climate of their surroundings. These modifications are collectively known as lake effects and range from microscale to synoptic scale. The climatic effects of the Great Lakes of North America (Wilson (1977), Moore and Orville (1990), Kristovich and Steve (1995) etc.) have been thoroughly studied, as well as the influence of Balaton in Hungary (Bell 1974), Baikal in Russia (Kornienko1969) and Masurian Lakes in Poland (Parczewski W., 1965, Bielec-Bąkowska Z., 2002). Additional studies have examined changes made in many other lakes in the world, including artificial lakes, such as Nassar and Karimba in Africa (Eichenlaub V.L. (1987)). The so called Lake-Effect Thunderstorms are of particular interest because they occur during outbursts of cold air when the air above the ground is stable and thunderstorms are not expected (Steiger et al, 2009).

Lakes affect weather and climate by impacting the basin’s energy and water cycles. Lake effect has a significant influence on regional climate by absorbing, storing and moving heat and water. The charge structure of typical summertime thunderstorms can be described as a tripole [weak positive charge centre near cloud base, main negative charge region above, and main positive charge centre near the top of the storm]. However, very little is known about the electric field of wintertime storms such as lake-effect storms (MacGorman and Rust 1998, p. 288). In addition, any association between snowfall rate and lightning occurrence is inconclusive (MacGorman and Rust 1998, p. 290).

For this research, we will use Electric Field Mill (BOLTEK 100) instrument of Geodetic and Geophysical Institute (Hungary). The atmospheric electricity measurement site is in the Nagycenk Geophysical Observatory, which is situated next to the lake Fertő. Alikhanyan National Laboratory (Yerevan Physics Institute) have installed the same Electric Field Mill (BOLTEK) instrument at 6 stations, two of them have a lake nearby. We will use data measured by international lightning detection networks (Blitzortung, WWLLN, NOAA) as well. We will use this data for understanding lake effect relation with local thunderstorm activity. First we will create maps showing the distribution of lightning activity above the lake and compare with lightning activity above land area. Furthermore, we would like to use meteorological data measured at different distances from the lakes in order to look for the impact of the local meteorological circumstances on the efficiency of the lake.

The objectives of the present proposal

The main objective of the STSM is to investigate thunderstorm activity relation with lake effect, by applying statistical data analysis on meteorological parameters and lightning distribution.

1.) We will select events for the case studies from recent years when thunderstorm activity was detected close to the Lake Fertő. We will analyze the lightning distribution (Blitzortung data) during the selected events. We will separate the events into two groups, when thunderstorm went directly through the territory of the lake and when they keep off from the lake. We will investigate the lightning activity during these two separate groups. Furthermore, we will compare the measured meteorological data for the events of the two groups to investigate the impact of the meteorological circumstances on the lake-effect. We will compare data measured by Field Mill at Nagycenk, Hungary and we will try to find connections with thunderstorm generation and precipitation activity.
2.) Another goal of the STSM is to study lake effect of the Lake Fertő on the lightning activity using meteorological and lightning data detected around the lake. We will analyze the lightning distribution (Blitzortung data) during summertime (April - October) of three consecutive years (2015-2017).
3.) We will continue the study at my home institute, which has a station near Sevan lake. In the end, we will compare **results from** these two studies and will understand more about lake effect.

Reason for choosing the host institute

The Geodetic and Geophysical Institute (Sopron, Hungary) is chosen to host this project for a number of reasons:
The PI of this project, Dr Veronika Barta is working at Geodetic and Geophysical Institute. She is the responsible person of the Potential Gradient measurement (BOLTEK EFM 100) at the Nagycenk Geophysical Observatory, Hungary. Dr Barta is an excellent advisor and provided guidance and expertise on the field mill measurements and dataset proceeding as well as input on the wider subject of atmospheric electricity and the GEC. Dr Barta supervised a BSc student who has done a study on lake-effect. The topic of the thesis was the Fertő lake effect on the local thunderstorm activity. Therefore, she has experience also in this particular topic. Moreover, she has excellent experience in science education in secondary schools, she used to give informative presentations in high schools and in public events regularly. The expertise from Dr Barta will be utilized during the STSM visit to provide training which will help me to make deeper understanding in investigations and analyzing of lightning data and electric field measurements. The atmospheric electricity measurement site in the Nagycenk Geophysical Observatory is situated next to the lake Fertő. Therefore, it is making an excellent condition for the above-mentioned studies.

Description of the work carried out during the STSM

1. Overview of STSM visit

I attended at the Cost action CA15211 Management Committee 5th meeting during the first four days of STSM. Participating in the Cost action meeting was a great opportunity for me to meet the leading scientists of this field. Moreover, the meeting with Karen Aplin motivated me a lot, we discussed the historical journal and the possibility of applying for a PhD at the University of Bristol. Discussions with the Serbian group gives more information about lightning data sources and one of the suggested sources was used for this study. The talk of C. Price was really interesting, a lot of things came into my mind after his presentation. The most useful talk for STSM fellow was Stefan Chindea's talk about new devices for measuring the electric field, and during the conversation he tells a lot of information about the device and suggestions for creating a new experimental field mill for students.
During Cost action period STSM fellow looked over the literature focusing on the positive and negative influence from lake on thunderstorm generation and made a summary report about the past results of what was found in the literature.

In the first day after the cost meeting the STSM fellow became familiar with the Geodetic and Geophysical observatory measurements and the format of the Blitzortung lightning data files with the help of the host. The next following days the STSM fellow created algorithms for analysing and plotting lightning and meteorological data.
Each day in the STSM period, discussions were held with the Dr Veronika Barta, current results were discussed, and further steps were planned. This way of working was very useful and the research focused on the most important issues.

The following important points were taken from the literature:

1. Physical considerations suggest that major effects of the lakes are:
   a. moderate maximum and minimum temperatures of the region at all times of the year (possibly with a slight net effect on average temperatures),
   b. an increase in cloud cover and precipitation above and just downwind of the lakes during the winter due to the relatively large number of sources of heat and moisture
   c. a decrease in summer convective clouds and precipitation over lakes due to the greater stability of the atmosphere created on the surface by relative the lakes, and existely colder water (Scott, 1996).
   d. Deep convection is not often formed in summer aboing storms dissipate significantly when moving above the lakes due to the greater stability created by the lower atmosphere and the colder surfaces of the lake (Lyons, 1966).
2. Positive effects from lake for thundercloud generation:

   a. In cloud temperature profiles closer to 0 C are more favourable for graupel formation, and charge separation occurs with the help of graupel (Reynolds et al. 1957, Takahashi 1978, 1984).
   b. When the water temperature is higher than air temperature, there is a high probability of thundercloud generation
   c. When the temperature difference between air in 850 mb height and near earth's surface is more than 13 C it can make instability in the atmosphere and generate thundercloud (Wilson, 1977).
3. Negative effects from lake for thundercloud generation
   a. It is believed that collisions between graupel and ice crystals with the presence of supercooled water droplets are crucial for charge separation in the cloud. If the air is too cold (for example, the isotherm -10 ° C <1 km AGL), then the cloud will not contain graupel or supercooled water, necessary for the separation of charge inside the cloud (Steiger et al. 2009).

References:

1. Bell, B., and T. Lajos, (eds.),. Climate of Lake Balaton, Hungary (in Hungarian), vol. 40. Országos Meteorológiai Szolgálat Budapest, Hivatalos Kiadványai, Budapest.(1974)
2. Bielec-Bąkowska Z.,: Spatial differentiation and long-term variability of thunderstorms occurrence in Poland 1949–1998. Wyd. Uniw. Śląskiego (2002)
3. Changnon, S. A., Jr., : Precipitation climatology of Lake Michigan basin. Bull. 52, Illinois State Water Survey, Urbana, 44 pp.(1968)
4. Eichenlaub V.L. Lakes, effects on climate. In: Climatology. Encyclopedia of Earth Science. Springer, Boston, MA. (1987)
5. Kornienko, V. I.,. The effect of evaporation from Lake Baikal on precipitation in adjacent regions, Glavnaya .(1969)
6. Kristovich, D.A.R., and R. Steve.. A Satellite Study of Cloud Band Frequencies of the Great Lakes. Journal of Applied Meteorology, 34:2083-2090. Geofizicheskaia Observatorija, Trudy 247, 122–126.(1995)
7. MacGorman, D. R., and W. D. Rust,: The Electrical Nature of Storms. Oxford University Press, 422 pp.(1998)

8. Moore, P. K., and R. E. Orville,: Lightning characteristics in lake-effect thunderstorms. Mon. Wea. Rev., 118,1767–1782.(1990)
9. Parczewski W.,: Atmospheric fronts over Poland. Wiadomości Służby Hydrologicznej i Meteorologicznej, Wyd. Komunikacji i Łączności, Warszawa, 59, 20–36.(1965)
10. Scott, R. W., & Huff, F. A. . Impacts of the Great Lakes on Regional Climate Conditions. Journal of Great Lakes Research, 22(4), 845–863. doi:10.1016/s0380-1330(96)71006-7 ((1996))
11. Scott M., Steiger S., Hamilton R. , ,Lake-Effect Thunderstorms in the Lower Great Lakes,,Journal of Applied Meteorology and Climatology(2009)
12. Wilson, J. W. : Effect of Lake Ontario on precipitation. Mon. Wea. Rev. 105, 207–214.(1977)

In the following days the STSM fellow begin to analyze data for summertime (April-October) of 3 years from 2015 to 2017. At the first stage, the days were separated into two groups, when the air temperature is higher than the water temperature, and vice versa. The number of lightning have been analysed for these two groups. Furthermore, the lightning distribution around and above the lake have been analyzed for these two groups separately. Therefore, maps about monthly activity with a radius of 50 km from the lake have been produced for each year.

Based on the first results, the STSM fellow and the host decided to perform the same analysis for larger lakes eg. Lake Balaton in Hungary, Lake Sevan in Armenia and the Caspian Sea to see the difference or similarity of the lake effect of a larger lake. The comparison will help to understand the lake-effect in details and to determine the size of the lake when the impact of the lake on the lightning activity can be considerable.

On the last day of STSM, a discussion seminar was held with the former president of the COST Association, Sierd Cloetingh at the Geodetic and Geophysical Institute. Prof. Cloetingh mentioned the applicant talking about STSM of COST Actions and gives many good suggestions for the future.

Data and Methods

For data analysis, Python libraries were used and a new Python module was written to create lightning frequency graphs on the map. Using the longitude and latitude data of the satellite, the lake and the surrounding area were divided into 16 km square parts and the number of lightning was calculated in those parts.

Results

Because most lake-effect thunderstorms occur early in the cool season, a warmer lake surface and convective boundary layer are critical in the development of these storms.

As it was hypothesized when the water temperature is higher than air temperature there can be instability in the atmosphere and near the lake will generate thundercloud.

We calculate the temperature difference between the water surface temperature and air temperature measured near the lake Fertő for 3-year data and compared the lightning activity of the two groups (when water temperature is warmer than air temperature W_T > A_T and vice versa).

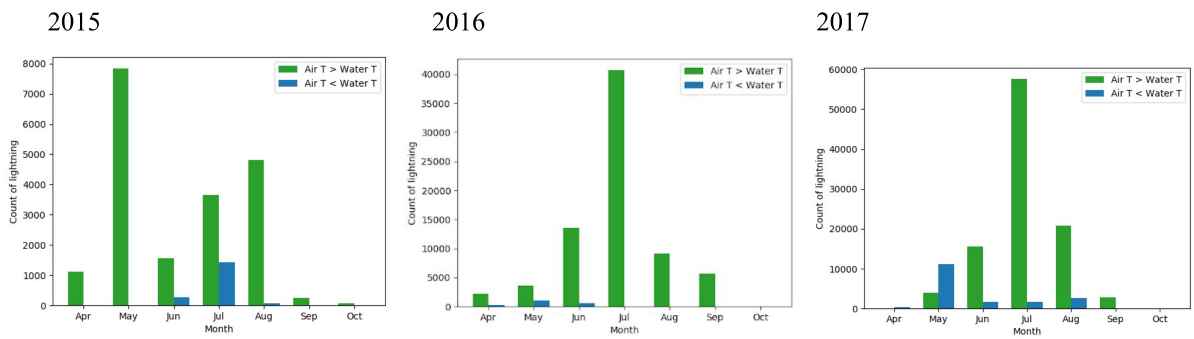

Figure 1: Lightning monthly activity when air temperature was higher than water temperature (green) and when water temperature was higher than air temperature (blue) in the territory with 50 km radius around the Lake Fertő.

Monthly lightning activity investigations show that the activity is high in May (in 2015) and July (2016 and 2017), especially in 2017 when it almost reached 60 000 count/ month.We can generally state that the lightning activity is higher taking into account the whole territory when the air temperature is higher than the water temperature. The water temperature was higher than air temperature in 2015 from June to August, the total number of registered lightning was more than 2000 during this period, in 2016th activity took from April to June and in 2017 there was thunderstorm activity from April to August when the water temperature was higher than air temperature.In May 2017 the number of registered lightning was more than 10.000 when water temperature was higher, which is two times more than count of lightning when air temperature was higher (Figure 1).

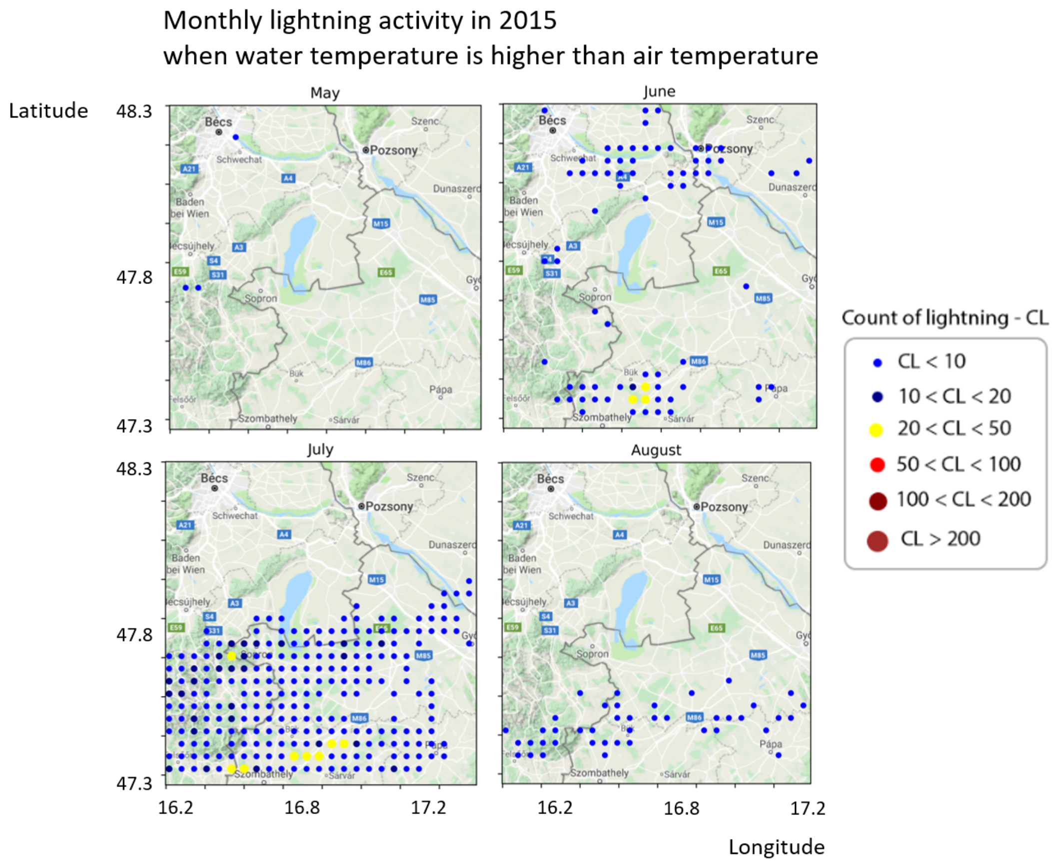

Figure 2: Lightning frequency when water temperature was higher than air temperature 2015

In 2015, when the water temperature was higher than the air temperature, lightning were registered from May to August. Lightning was far from the lake, except in July, when major discharges were recorded in the southern part of the lake, according to the observations of the geodetic and geophysical institute, there were few local small thunderstorms during this period, so activity in the southern part of the lake can be associated with lake effect to local thunderstorm generation(Figure2).

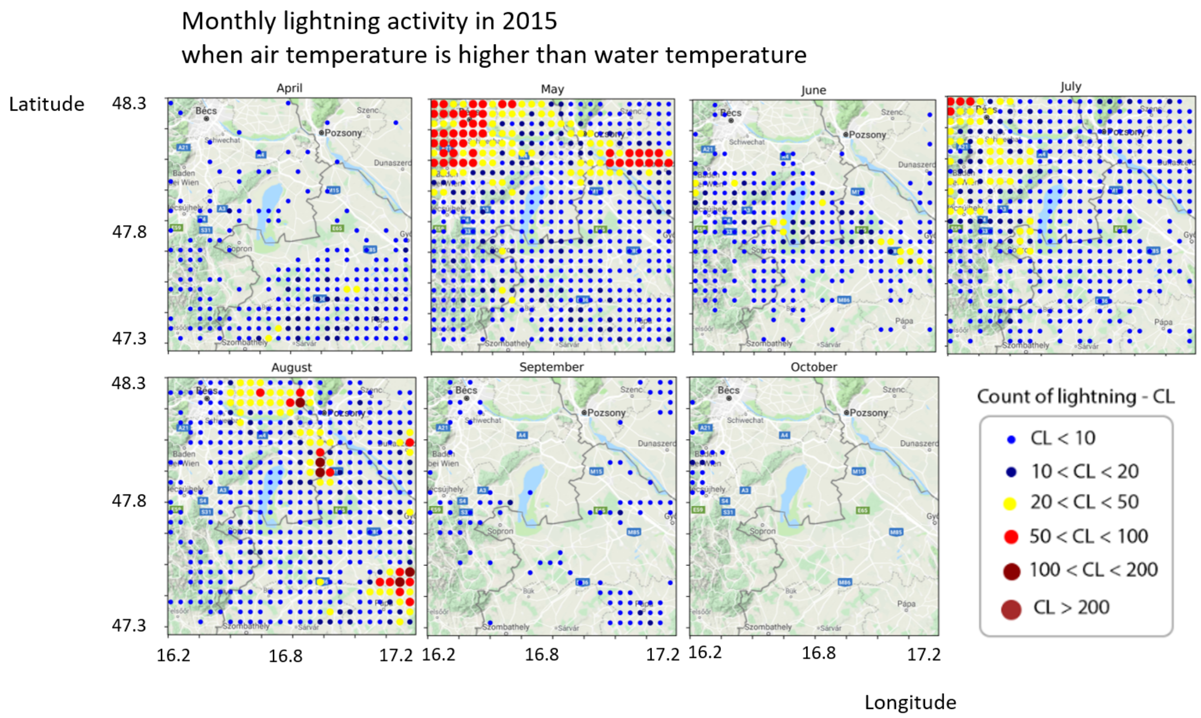

Figure 3: Lightning frequency when air temperature was higher than water temperature 2015

Lightning activity was higher in May, July and August 2015. The most active front comes from the northwest, and less than 10 lightning were recorded for every 16 km of the area to the lake(Figure3).

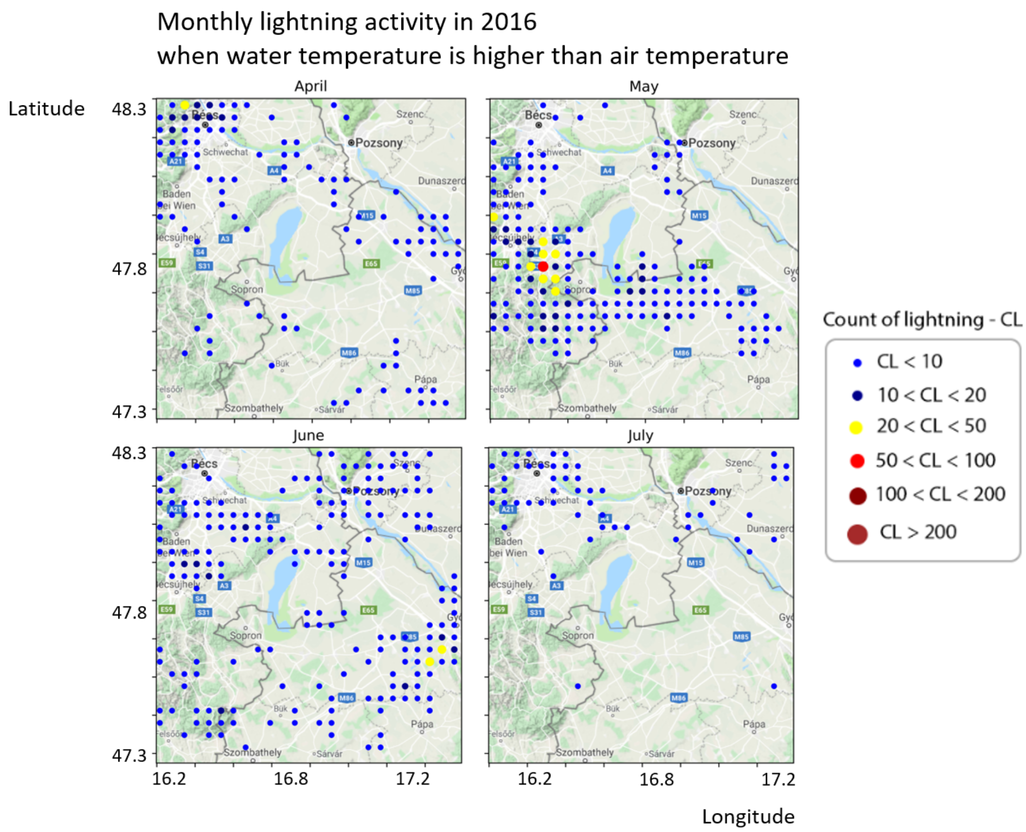

Figure 4: Lightning frequency when water temperature was higher than air temperature 2016

In May in 2016 there was local thunderstorms in the beginning of the month and in the middle, satellite data shows lightning activity very close to lake area in that period(Figure 4).

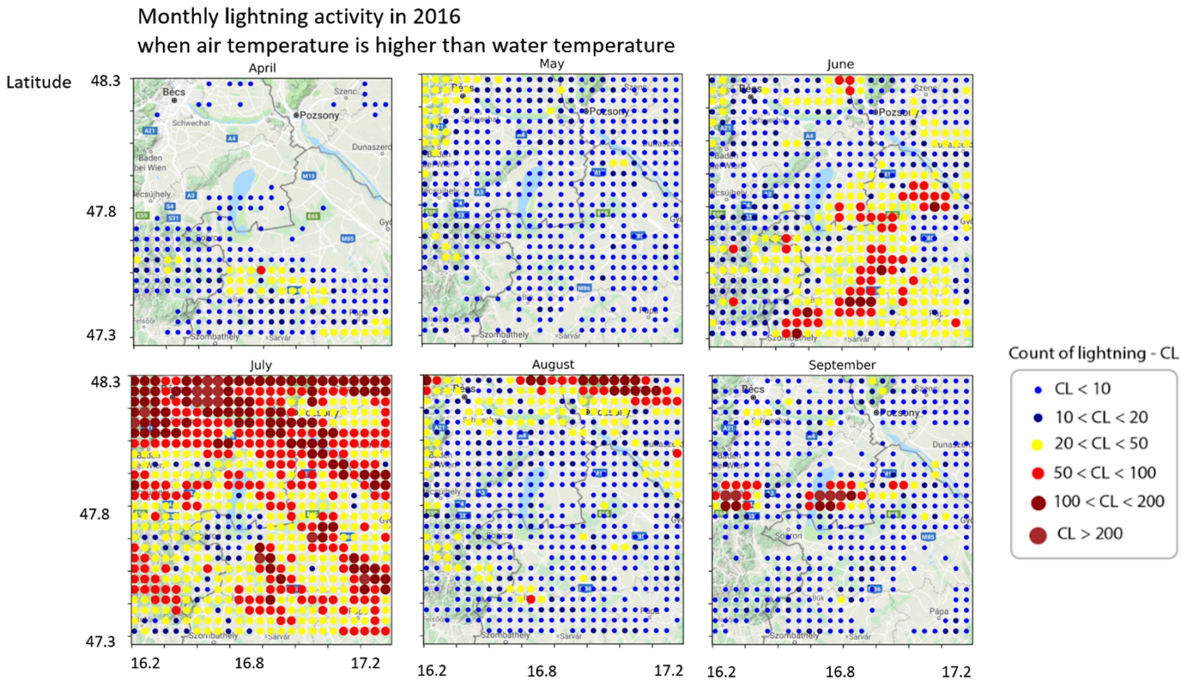

Figure 5. Lightning frequency when air temperature was higher than water temperature 2016

Lightning activity was very high in July 2016, the main active part was in the northern waste, more than 200 lightning was recorded on 16 km square of the area..(Figure 5)

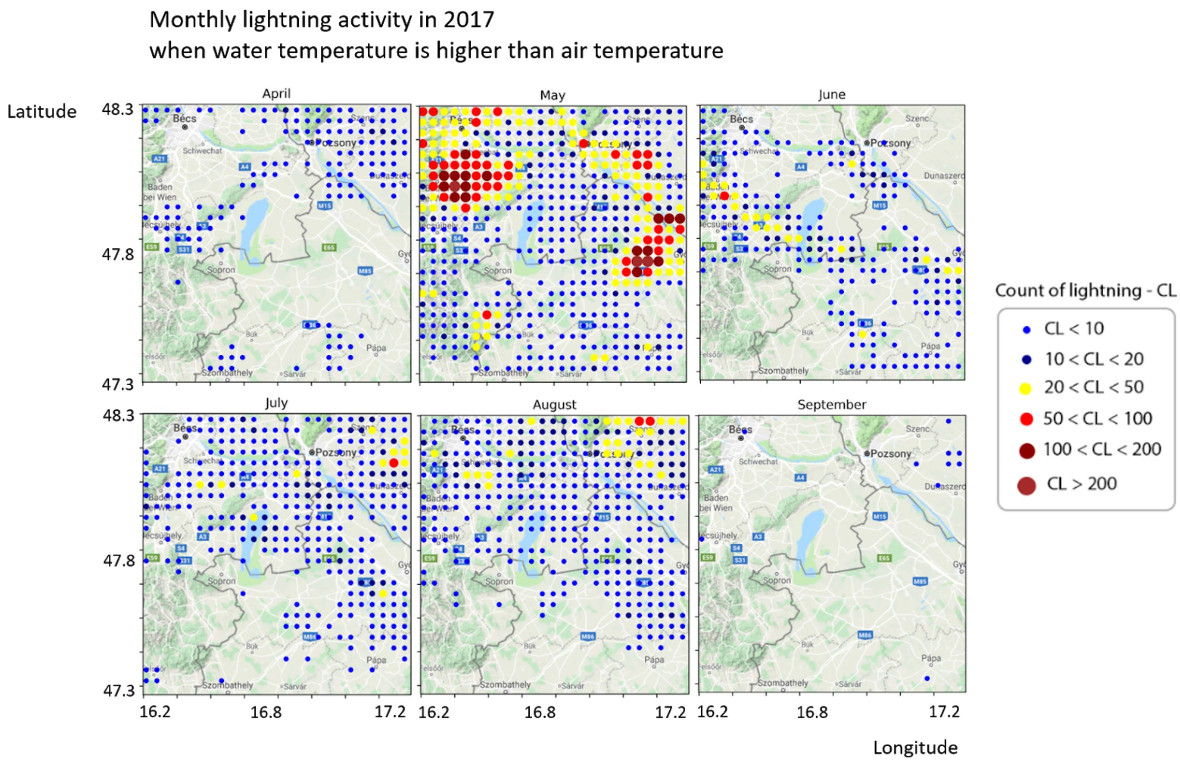

Figure 6: Lightning frequency when air temperature was higher than water temperature 2017

More than 10 lightning per 16 km square was registered close to lake area in June and July when the water temperature was higher than air temperature in 2017(Figure 6).

Summary

Based on the lightning distribution maps when water temperature was higher than the air temperature we can not observe any positive impact of the lake on the lightning activity. Therefore, the hypothesis that the Lake Fertő can have a positive effect on the thundercloud generation and the lightning activity when the water temperature is higher than the air temperature has not been strengthened.
Furthermore, we can not conclude that there is a clear negative effect of the lake on the lightning activity according to the lightning distribution maps when the air temperature is higher than the water temperature. Nevertheless, there are some months when it seems a clear border in the lightning activity map between the surface of the lake and the coast (eg. in June and July 2015, June 2016). This seems to strengthen the hypothesis that "Deep convection is not often formed in summer above the lakes, and existing storms dissipate significantly when moving above the lakes due to the greater stability created by the lower atmosphere and the colder surfaces of the lake" (Lyons, 1966). However, this effect is not clear in every case based on our results.

FUTURE COLLABORATIONS (if applicable)

The possible further steps of the current research, what I would like to implement collaborating with the host, are the following:
- We would like to analyse the day- and nighttime thunderstorms occurred during the investigated period separately. We would like to separate the nighttime thunderstorms (from 20 UTC to 05 UTC) into two groups, when water temperature is larger than the air temperature and vice versa based on the night time temperature measurements and produce the lightning distribution maps for the two groups.
- We would like to check the lightning distribution around the lake during small, local thunderstorms as case studies. We have already chose candidates for this analysis from the investigated 3 years.
- According to Wilson (1977) when the temperature difference between air in 850 mb height and the water surface temperature is more than 13 C it can make instability in the atmosphere and generate thundercloud (Wilson, 1977). Thus, we would like to separate the thunderstorms into two groups, when this condition is true and when it is not. Then we would like to produce the lightning distribution maps for the two groups.
- We would like to compare the number of lightning estimated by the vertical component of the atmospheric electrical field (Ez) measured at the Nagycenk Geophysical Observatory with the lightning activity detected by the Blitzortung network.
- Finally, we would like to repeat the same analysis for the lightning activity measured above and around larger lakes (e.g. Lake Balaton (Hungary), Seven Lake (Armenia) and Caspian Sea) in order to investigate the lake-effect dependence on the spatial scale of the lake.