Seasonal distribution of lightning over Bulgaria and Black Sea and its relationship with sea surface temperature

S. PETROVA [1], R. MITZEVA [1], V.KOTRONI [2] and E.PENEVA [1]*

1. Faculty of Physics, University of Sofia, Sofia, Bulgaria
2. Institute for Environmental Research, National Observatory of Athens, Athens, Greece

*email: asavita@phys.uni-sofia.bg

AIM:

- Analysis of seasonal variations of lightning in two different areas: continental (Bulgaria) and maritime (Black Sea), based on 10-year data set
- To study if there is a relationship between lightning activity and sea-surface temperature (SST) of the Black sea during autumn.

2. DATA

The lightning data during **winter, spring, summer and autumn** for 10 years (**March 2005-February 2015**) are analyzed. Lightning data are provided by the ZEUS lightning detection network operated by the National Observatory of Athens. The number of recorded flashes and the flash density at different time intervals (annual, seasonal, monthly and 3-hours) in grid boxes of 0.25x0.25 degrees over land and sea are determined. Each grid box is characterized as continental or maritime depending on the underlying surface of the area it represents.

Bulgaria - the **continental domain** of the analysis is confined within 22,5° to 28,5°E and 41,25° to 44,25°N.

Black sea -the **maritime domain** of the analysis is confined within 27 ° to 42°E and 41° to 47°N.

The maritime area is approximately **3 times** larger than the continental area and for this reason in the present study the **flash density** (number of detected flashes during analyzed period divided by the corresponding surface area: [flashes/km2]) are used.

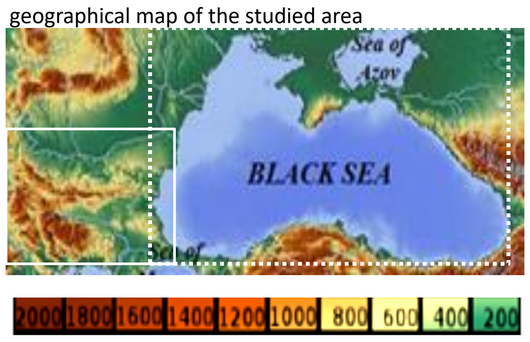
Data of sea surface temperature (SST) is retrieved from the ERA5 reanalysis of the European Centre for Medium-Range Weather Forecasts, downloaded for the hours 0000UTC, 0600UTC, 1200UTC, 1800UTC for each day of September (2005-2014). The SST is compared with lightning number for each time interval ((00:00-03:00)UTC, (06:00-09:00)UTC, (12:00-15:00)UTC, (18:00-21:00)UTC) of the September days and at grid boxes of 0.25°×0.25°. Data is grouped into two samples – cases with flashes and cases without flashes. Cases with flashes are formed by each box (0.25°x0.25°) of the grid, where at least one flash had been registered in the studied 3-hour intervals.

Local time: LT= EET = UTC+2hours.

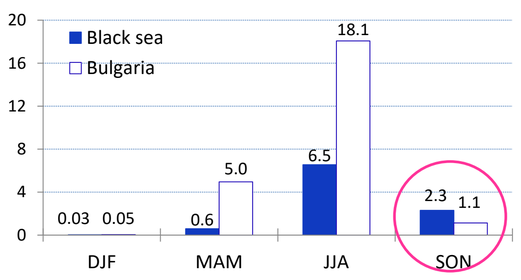
3. RESULTS

Lightning activity in winter, spring and summer is in accordance with the annual global distribution - the flash density over land surface (Bulgaria) is higher than over the maritime area (Black Sea). However in the autumn the flash density is higher over the Black Sea than over the land surface (Bulgaria).

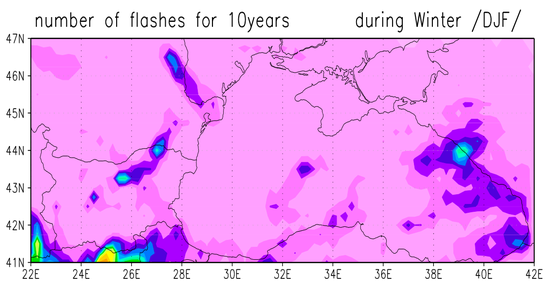
geographical map of the studied area

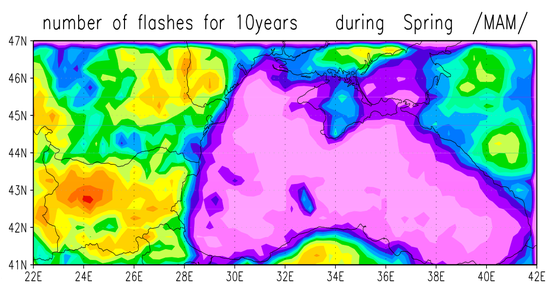


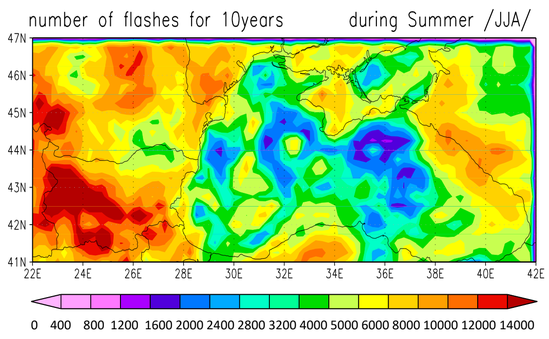
Flash density [flashes/km²] during winter (DJF), spring (MAM) ,summer (JJA) and autumn(SON)

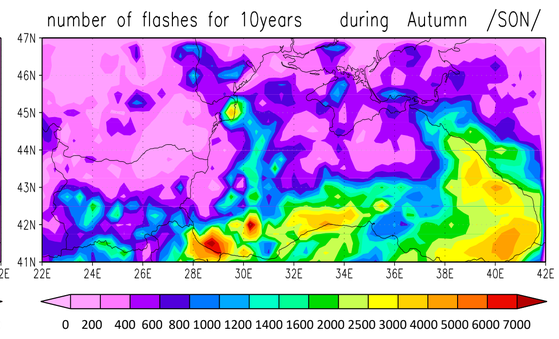


Seasonal-spatial distribution of the number of flashes for 10 years (March 2005-February 2015) /the scales are different for each season **/**

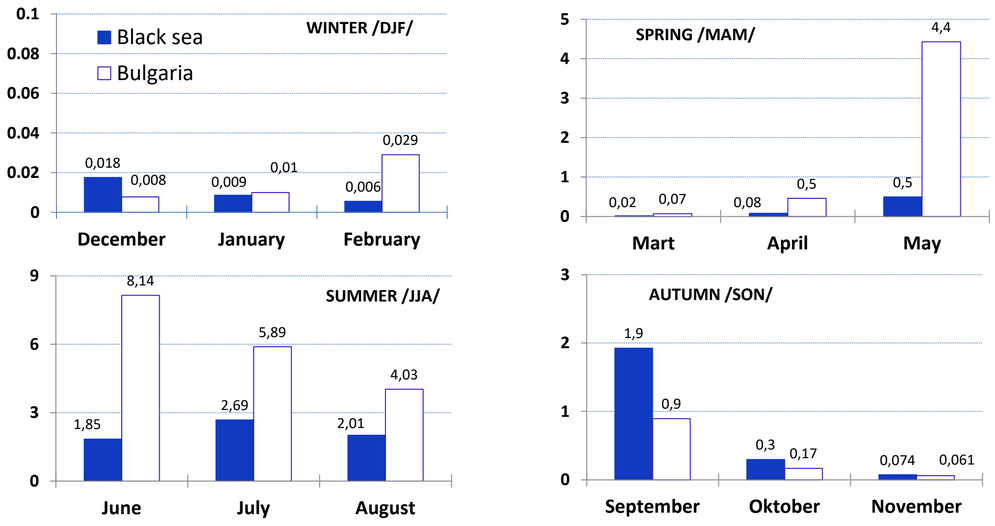








Flash density for each month over the Black Sea and over Bulgaria (data set-10 years)



Maximum number of flashes over Bulgaria and over the Black Sea is registered during the **summer** period (with a maximum over Bulgaria in June and over the Black Sea in July), and a **minimum** number of flashes is registered in **winter** over both surface types (with a minimum over Bulgaria in December and minimum over the Black sea in February). The maximum flash density during **spring** period is over Bulgaria (in **May**), but during the **autumn** period is over the Black Sea (in **September**).

These results lead to the next question and the following task in the present work:

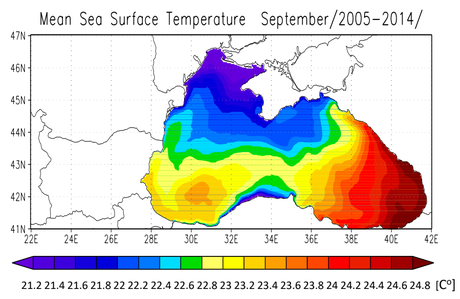
? What are the reasons for the higher flash density over sea compared to over land during the autumn season?

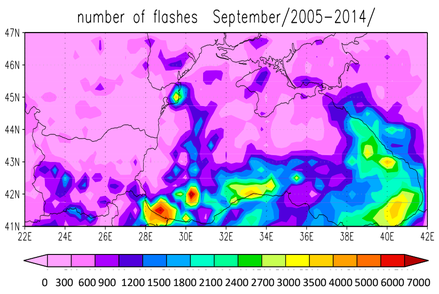
! One possible reason could be that the sea surface temperature (SST) in autumn is higher than the land surface temperature.

First step: To investigate if there is a relationship between lightning activity and sea-surface temperature (SST) of the Black sea in autumn.

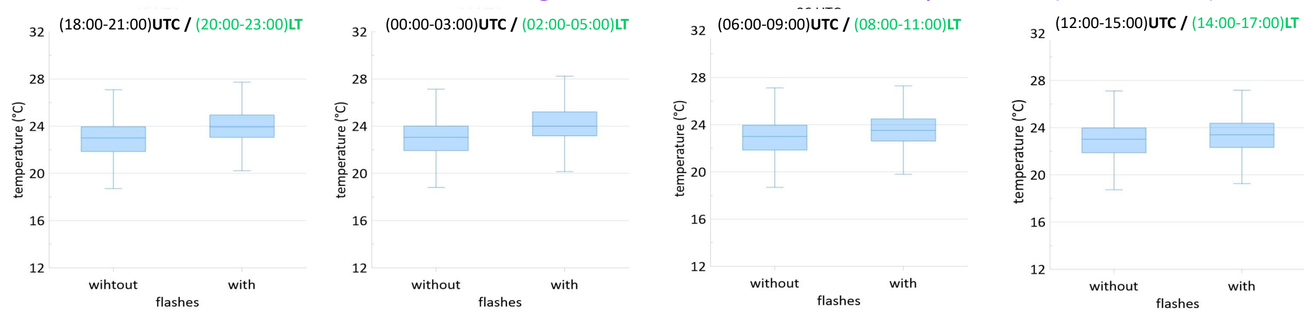
In the autumn, 84 % of lightning was observed in September of the studied 10 year period. A combined analysis of SST and lightning activity is presented using data from September (2005-2014).

The spatial distribution of number of lightning and mean SST in September (2005-2014) shows that the warm waters of the southern part of the Black Sea are associated with a higher number of lightning, compared to the relatively colder waters of the northern part of the basin, which are associated with a much lower number of lightning.





Box and whisker plot of the sea-surface temperature (**SST**) distribution for the cases **without** and **with** flashes for all four investigated time-intervals from September (2005-2014).

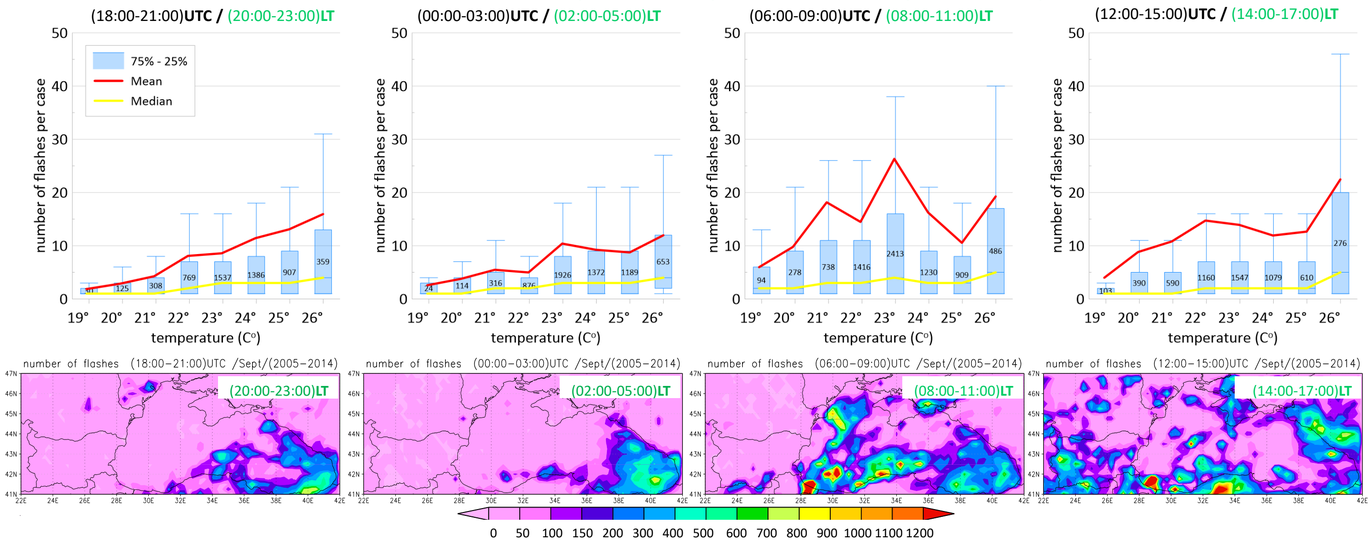


median–blue line; **box**:25% and 75% ; **upper whisker**: P(75%) + 1,5*IQR; **bottom whisker:** P(25%) – 1,5*IQR; **interquartile range:** IQR = P(75%) – P(25%)

The mean and median of SST are higher in the cases with flashes compared to the corresponding values in the cases without flashes. The differences are more pronounced in the night intervals: (20:00-23:00)LT and (02:00-05:00)LT.

Box and whisker diagram of the **flash frequency (number of lightning per case)** as a function of sea-surface temperature**(SST)**

At **nigh**t, in the investigated intervals (20:00-23:00)LT and (02:00-05:00)LT, there is a clear trend of the increase of mean flash frequency per case with the SST increase. The established linear correlation coefficients for these night intervals are very high, respectively R=0.99 and R = 0.92. During the **daily** intervals (08:00-11:00)LT and (14:00-17:00)LT, this trend is not well pronounced especially in the (08:00-11:00)LT, with visible fluctuations of the mean frequency per case with the SST increase. The correlation coefficients are lower – R=0.47 for (08:00-11:00) LT and R=0.83 at (14:00-17:00)LT.



The analysis indirectly shows that the influence of the SST on the formation of thunderclouds is different depending on the diurnal time interval. The results indicate that during the day there are, also, other favorable atmospheric processes for the formation of thunderstorm clouds with greater significance than the influence of sea-surface temperature. However in the night the higher SST values probably play a more significant role in thunderstorm clouds formation at particular orographic conditions. From the spatial distribution of the flashes for these night time-intervals ((21:00-24:00) LT and (03:00-06:00) LT), one can see that the largest number of flashes is detected over the southeastern part of Black sea. This part of the Black sea is located between mountains and one can assume that the combination between warm sea surface and mountain sea breeze (slope winds and sea breeze) during night intervals create favorable conditions for cloud formation. These conditions are associated with a bigger temperature gradient between the warmer air, located just above the "warm" sea surface, and the colder air, cooling faster due to the closeness of the mountains, above it.

CONCLUSION:

- In winter, spring and summer the flash density is higher over land (Bulgaria) than over the Black sea, while in autumn - vice versa.
- Over land (Bulgaria), 92% of the total number of lightning for the studied 10-year period are detected in May, June, July and August. Over the Black Sea, 90% of the total number of lightning occur in June, July, August and September.
- The mean and median of SST over the Black Sea in autumn are higher for the cases when lightning occurred than when it is absent. This difference is more pronounced during the night intervals.
- For the investigated night intervals when the mean sea-surface temperature increases, the mean values of the flash frequency also increases, while for the daytime hours such tendency is not clearly evident.
- The results indirectly show that the influence of SST on the formation of thunderclouds is more significant during the night than during the day.

ACKNOWLEDGMENTS:

The present work is partially supported by the Science Foundation of Sofia University (grant 80-10-21/2022).

The ZEUS lightning data were provided by the National Observatory of Athens.

Data on the spatial distribution of Sea Surface Temperature is provided by the E.U. Copernicus Marine Service (https://doi.org/10.25423/CMCC/BLKSEA_MULTIYEAR_PHY_007_004)