International Conference on Lightning Protection
33rd International Conference on Lightning Protection
25 - 30 September 2016
Estoril, Portugal

About 100 Years Survey of the Surface Temperatures of Japan Sea and Lightning Days along the Coast

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***Abstract*— On the website of the Japan Meteorological Agency, various weather data are shown. This paper has surveyed the hundred years data of the surface temperatures of Japan Sea and the number of lightning days in cities along the Japan Sea coast. The sea surface temperatures have increased by 1.2 °C to 2.2 °C in the last hundred years, and correspondingly the number of lightning days has increased by 20 to 45 days in the last hundred years. The correlation coefficient for winter lightning shows rather high dependence of the lightning days on the sea temperature in the cities located in a high latitude.**

Keywords- lightning days per year , sea surface temperature , correlation , Japan Sea, winter lightning

I. INTRODUCTION

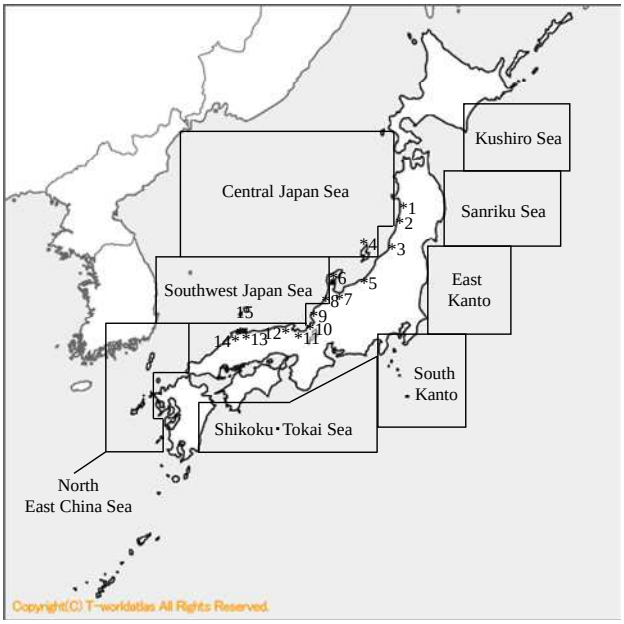
It has been reported that the number of lightning days in USA may be increased by 50 % towards the end of this century [1]. A similar trend is also reported in Japan, especially in the area of Japan Sea [2]-[4]. Further it was informed that the amplitude of the lightning current was increasing year by year [5]. The lightning is, in general, local phenomena and is significantly influenced by atmospheric conditions in that local area or by the local climate. However, it is estimated that variation of the lightning phenomena, for example the number of lightning days per year for a long time period, say 100 years, is influenced by the world-wide climate change. Winter lightning in the area along Japan Sea coast is generated when Siberia cold air flows across Japan Sea, where warm Tsushima current is going to north, and reaches the coast. Therefore it is expected that the surface temperature of Japan Sea influences the winter lightning phenomena [6].

A number of weather data such as the air pressure, temperature, humidity and precipitation, have been collected, measured and published in the home page of the Japanese Meteorological Agency (JMA) [7]. Measured results of lightning days per year and the sea surface temperature around Japan are also included in the JMA data.

In this paper, data for about one hundred years of the sea surface temperatures and lightning days per year along Japan Sea are surveyed, and the correlation between the temperature and the number of lightning days per year is investigated. Measured results of the sea surface temperature since 1920 are described in Chapter II. The number of lightning days in twelve cities along Japan Sea coast are presented in Chapter III. In Chapter IV, the correlation between the temperature and lightning days are estimated and the results are discussed. Chapter V summarizes the surveyed and investigated results in the paper.

II. MEASURED SURFACE TEMPERATURE OF JAPAN SEA FOR ABOUT 100 YEARS SINCE 1920

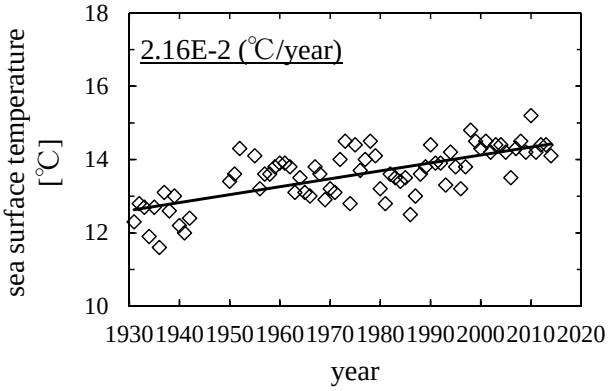
Fig.1 illustrates sea divisions around Japan of which the average surface temperatures have been calculated by the JMA [8]. The JMA calculate the average surface temperatures from the data measured in 1x1 degree resolution from January 1891 up to the latest month [9]. The measuring method for the sea surface temperature is shown in Ref. [10].



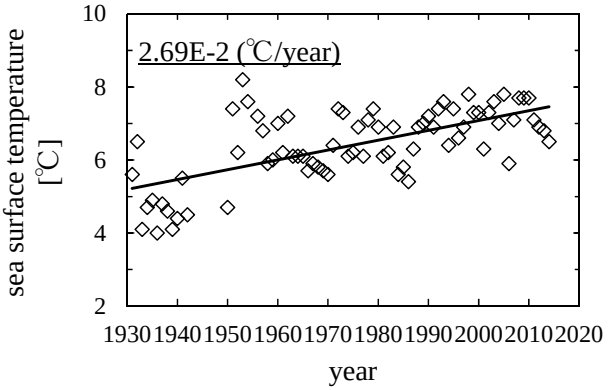
*1:Akita, *2:Sakata, *3:Ngata, *4:Aikawa, *5:Takada, *6:Wajima, *7:Toyama*8:Kanazawa, *9:Fukui, *10:Tsuruga, *11:Maizuru, *12:Toyooka, *13:Yonago*14:Matsue, *15:Sakai

Fig. 1 Divisions of the sea area surrounding Japan

In this paper we focus the divisions along Japan Sea coast, i.e. “Central Japan Sea” and “Southeast Japan Sea” in Fig.1. Figs. 2 and 3 show (a) the average sea surface temperature in a year, and (b) the average temperature in winter for 3 months from December for 100 years from 1930. Lozenge symbols in the figures indicate measured results, and a bold line is a linearly approximated temperature as a function of year evaluated by a least squaring method. The numeric value given at the left top of the figures is a slope (C /year) of the curve.

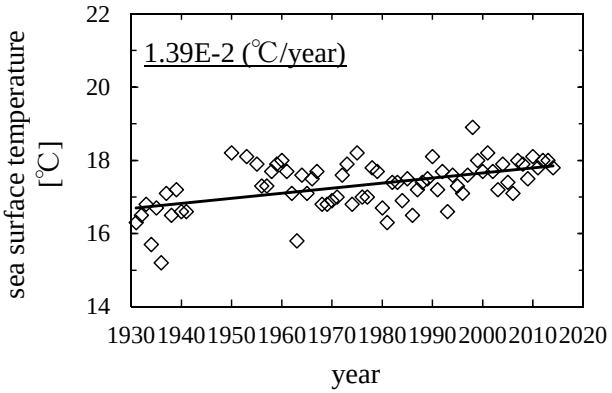


(a) Annual average

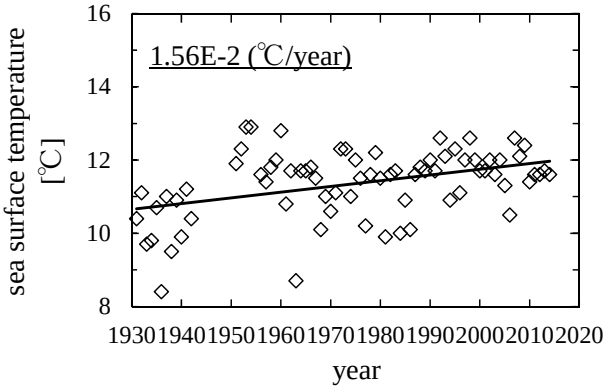


(b) Winter average

Fig. 2 Trend of the sea surface temperature in the central Japan sea area



(a) Annual average



(b) Winter average

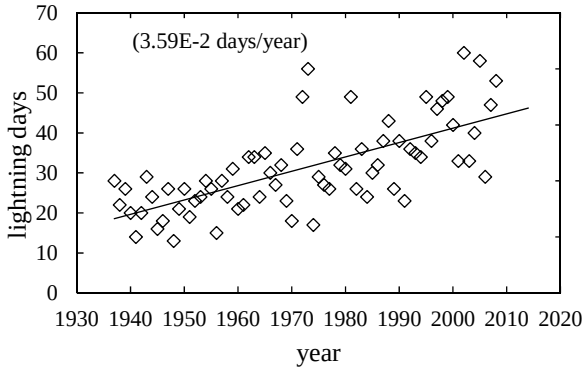
Fig. 3 Trend of the sea surface temperature in the southwest Japan sea area

It is clear that the surface temperature tends to increase as year passes. The increase is in the range from 1.2 °C to 2 °C since 1930. The increase is more noticeable in Fig.2 of Central Japan Sea, especially in (b) Winter, than in Fig.3 of Southeast Japan Sea. If we assume the number of lightning days is strongly correlated to the temperature, it is estimated a larger number of lightning days in winter in the Central Japan Sea area than that in the Southeast area.

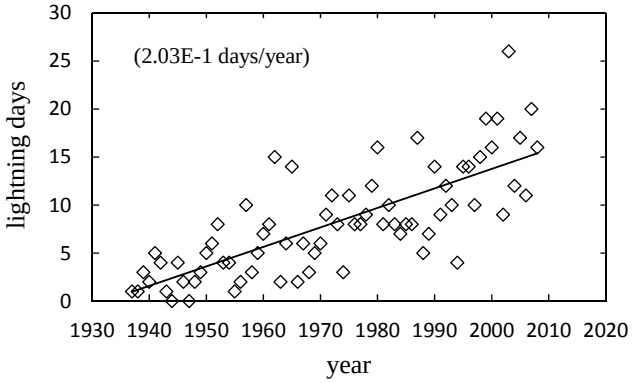
III. MEASURED LIGHTNING DAYS

Figs. 4 and 5 show the number of lightning days (a) in a year, and (b) in Winter in the cities of Sakata located at latitude: north 38°55’16” and Matsue at north 35°24’85” respectively. The lightning days have been counted by staffs at each meteorological weather station. They did not use any instruments to count it. When they hear thunder or watch lightning, they count it.

It is clear that the number of lightning days tends to increase as year passes somehow dependent on the temperature increase as observed in the previous chapter. The increase is the same in every city as explained in the next chapter.

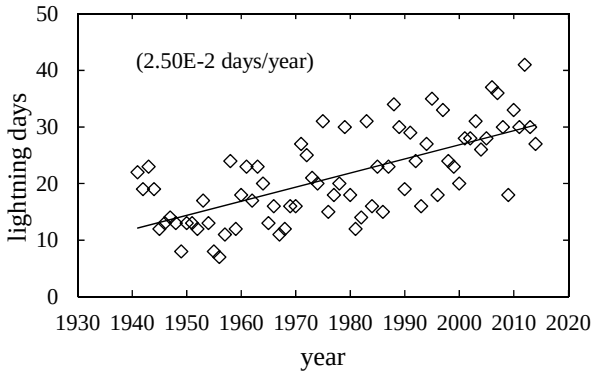


(a) Annual average

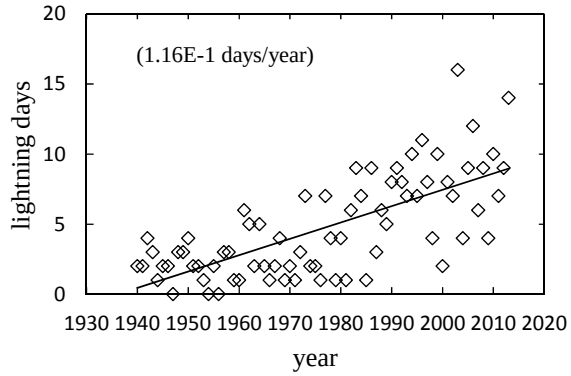


(b) Average in winter

Fig. 4 Trend of the average lightning days in the city of Sakata.



(a) Annual average



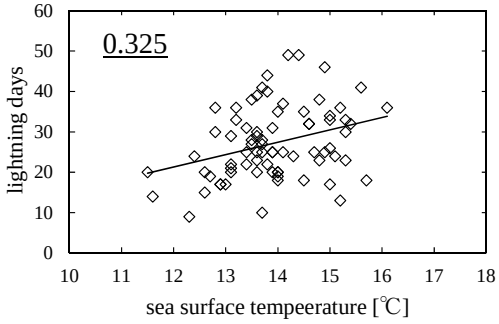
(b) Average in winter

Fig. 5 Trend of the average lightning days in the city of Matsue.

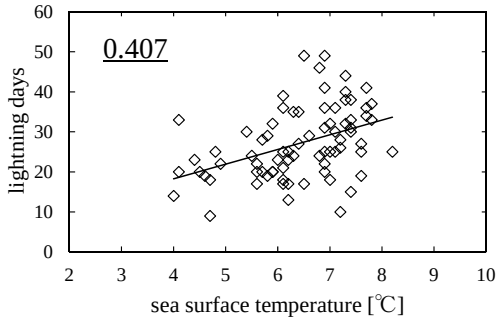
IV. Correlation between Lightning Days and Sea Temperature

Figs. 6 and 14 show correlation between the number of lightning days per year and the sea temperature in twelve cities along the Japan Sea coast. (a) is the lightning days per year, and (b) is for 3 months in winter from December. The bold line is a regression line evaluated by the sea surface temperature shown in Figs.2 and 3 and the number of days shown in Figs. 4 and 5 as an example in the previous chapter. The numeric value given at the top left in a figure is the correlation coefficient. Table 1 summarizes the coefficient in each city.

It is observed in the figures and the table that the correlation coefficient in winter is higher than 0.4 in the cities of Akita, Sakata, Aikawa and Niigata. Thus, the lightning days in winter in the cities can be said highly correlated to the sea temperature. Also in the cities, the coefficient in winter is much higher than that in a year. However the coefficient in winter is not so high in the other cities, and also it is not easy to find a noticeable difference between in winter and in a year. It should be noted that the cities with a higher correlation coefficient in winter locate in a higher latitude than that in the other cities.

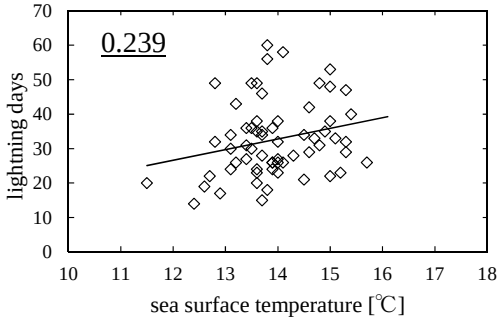


(a) Per year

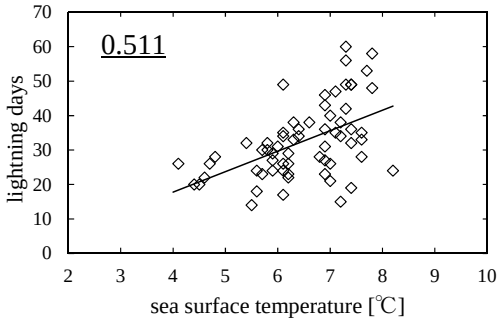


(b) Three months in winter

Fig. 6 Correlation between the number of lightning days and the sea surface temperature in Akita

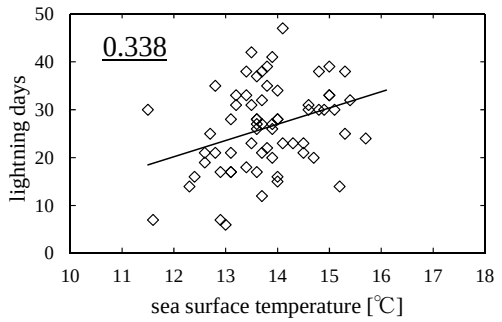


(a) Per year

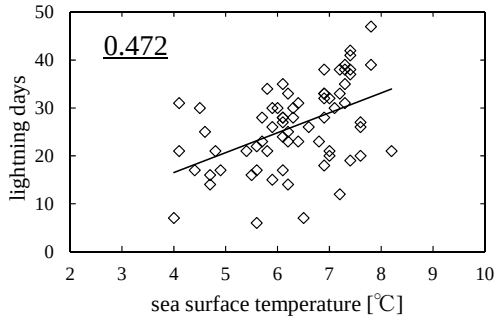


(b) Three months in winter

Fig. 7 Correlation between the number of lightning days and the sea surface temperature in Sakata

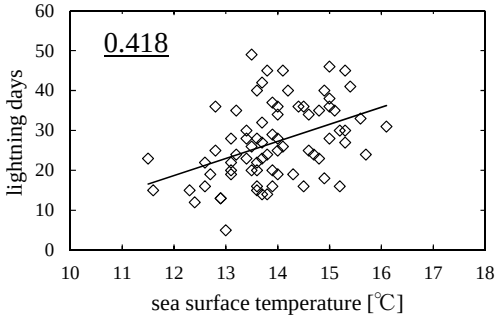


(a) Per year

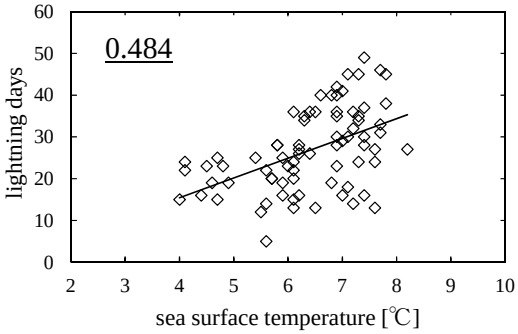


(b) Three months in winter

Fig. 8 Correlation between the number of lightning days and the sea surface temperature in Aikawa

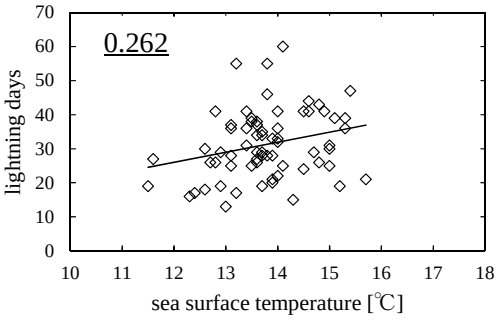


(a) Per year

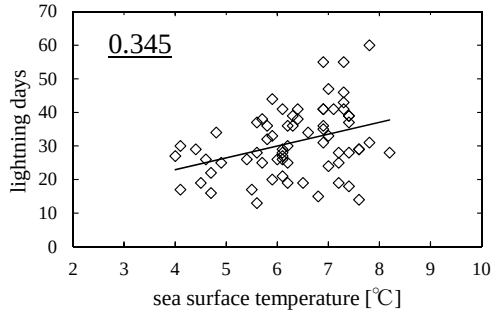


(b) Three months in winter

Fig. 9 Correlation between the number of annual lightning days and the winter average sea surface temperature in Niigata

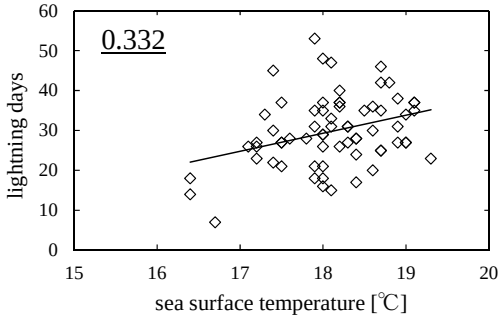


(a) Per year

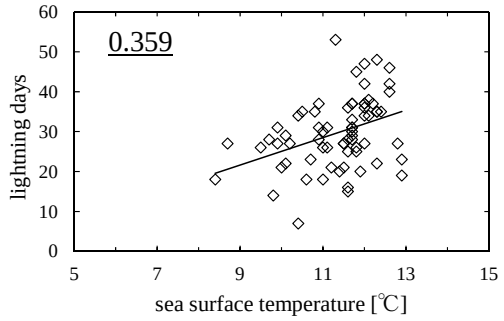


(b) Three months in winter

Fig. 10 Correlation between the number of annual lightning days and the winter average sea surface temperature in Takada

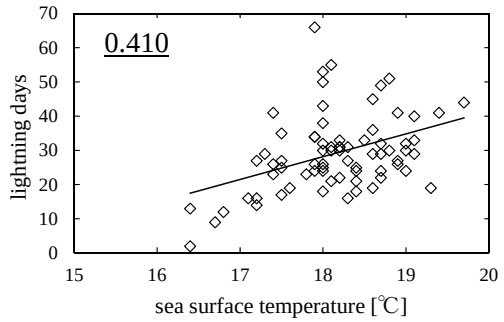


(a) Per year

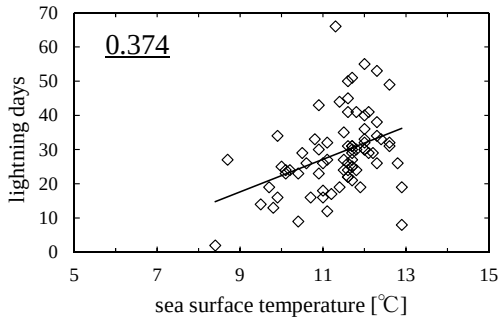


(b) Winter

Fig. 11 Correlation between the number of annual lightning days and the winter average sea surface temperature in Wajima

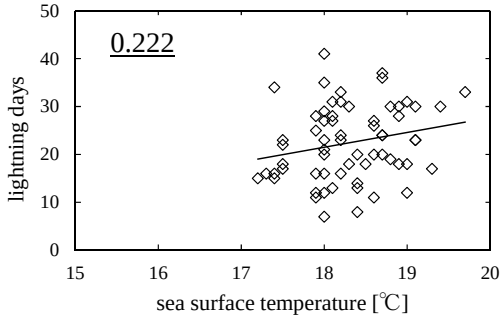


(a) Per year

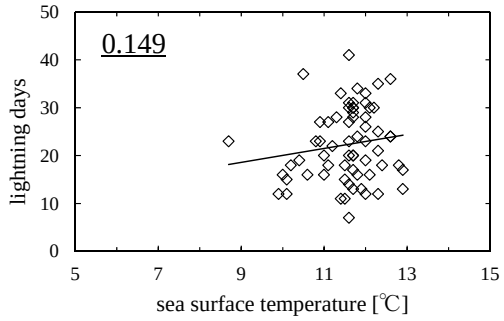


(b) Winter

Fig. 12 Correlation between the number of annual lightning days and the winter average sea surface temperature in Fukui

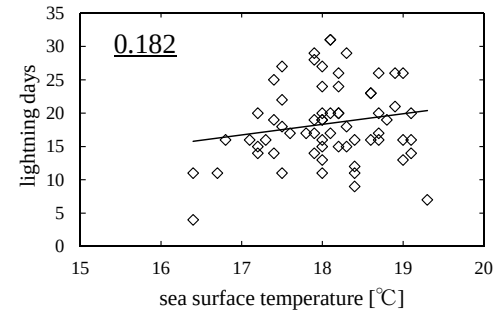


(a) Per year

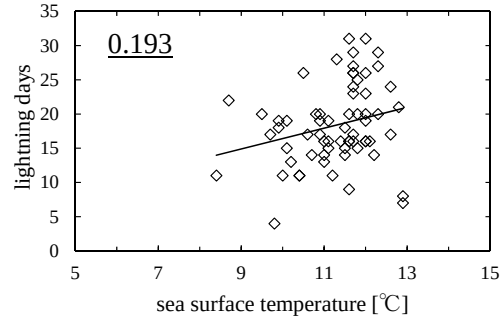


(b) Winter

Fig. 13 Correlation between the number of annual lightning days and the winter average sea surface temperature in Matsue



(a) Per year



(b) Winter

Fig. 14 Correlation between the number of annual lightning days and the winter average sea surface temperature in Hamada

Table. 1 Correlation coefficient between the number of lightning days and the sea surface temperature

Point	Annual	Winter
Akita	0.325	0.407
Sakata	0.239	0.511
Aikawa	0.338	0.472
Nigata	0.418	0.484
Takada	0.262	0.345
Toyama	0.220	0.217
Wajima	0.332	0.359
Kanazawa	0.335	0.250
Fukui	0.410	0.374
Tsuruga	0.250	0.192
Maizuru	0.187	0.256
Toyooka	0.294	0.240
Tottori	0.305	0.205
Yonago	0.213	0.221
Sakai	0.309	0.251
Matsue	0.222	0.149
Hamada	0.182	0.193

V. CONCLUSIONS

Measured results of the surface temperatures of Japan Sea and the number of lightning days in the cities located along Japan Sea coast are surveyed for one hundred years since 1930 based on the data collected by the Japanese Meteorological Agency. From the investigations of the data and evaluated correlation coefficient, the following remarks are obtained.

The surface temperature of Japan Sea has increased by 1.2 to 2.2 °C in the last hundred years since 1930. The number of lightning days in the area has also increased by 20 to 45 days in the last hundred years since 1930. A rather high correlation coefficient is observed between the number of lightning days in the cities located in the high latitude and the surface temperature of Japan Sea. However in the cities in a lower latitude, no clear correlation is observed.

The sea temperature used in this paper covers too wide area to discuss the correlation between the sea temperature and the number of lightning days. Therefore, a further survey is required to discuss the correlation in detail.

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