MONITORING LIGHT ENERGY LOSS ESTIMATED BY THE DMSP SATELLITES

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ABSTRACT. Data obtained by US DMSP satellites were analyzed to obtain light energy loss in order to monitor light pollution in Japan. From data of 1993-1996, we found 10 to 20 percent increase of light energy loss at all the 5 cities for which our measurements had been carried out. We will proceed our measurements for the other cities in Japan and also in the other countries. Data at 3 specific days in 1997, which were observed at a low gain mode and have practically no saturation points, gave absolute values of light energy loss and we got values around 900 GW x hour and 20 billion yen of its loss in a year assuming 10 hour light-on and electric energy cost of 25 yen per 1 kW x hour (currently 1 US dollar is equal to 130 yen).

1. Introduction

It is clear that a condition for astronomical observations is becoming worse and worse owing to light pollution. However, it is inevitable that society produce light from lamps in order to make human life convenient, and don't take care much on astronomical observations. Astronomers can directly oppose people producing useless light, but it is usually hard work since many people like bright lighting. A way to minimize light pollution is to make people realize what they are loosing (Isobe 1998). The US Defense Meteorological Satellite Program (DMSP) started to produce night-time terrestrial images in 1972, but till 1992 those images were available in a form of photographic prints. Fortunately, digital data became available from 1993. Those data containing clear views were obtained from the US National Geographic Data Center (NGDC) and were used to estimate the energy loss of city light into space. Isobe and Hamamura (1998) showed some preliminary results using the data in a period of 1993 to 1996. In this paper, we will show the further results including the total light energy loss into space in a year.

2. Data analysis

The DMSP has a sensitive detector with different gain mode. Since it is a defense satellite, it is usually used at a high-gain mode. Its current detection level is within 2×10^{-9} Watt/cm^2/st/μm - 2×10^{-8} Watt/cm^2/st/μm which is too much sensitive, and therefore, most of the cities in Japan have saturated images (Isobe and Hamamura, 1998). Because of a strong request by the NGDC, the US Air force tried to reduce its gain on January 7, 13, and February 9, 1997 and fortunately it was mostly cloudless in these 3 nights. This detection level is within $4x10^{-9}$ Watt/cm^2/st/μm - $3x10^{-7}$

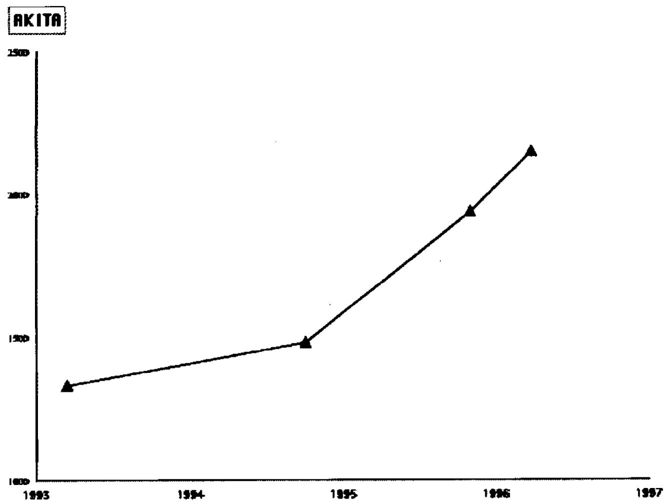


Fig. 1. Time dependent relative index of light loss at Akita city from 1993 to 1996.

Watt/cm^2/st/μm. Then, we can estimate the total energy loss into space in these 3 nights. An energy flux, F, ejected in a wavelength range of 0.4 - 0.7 μm to its telescope (its aperture of 20 cm) from an area (1.2 km x 1.2 km) corresponding to a detector pixel at an altitude of 835 km is given by

$$F = 4.56 \times 10^7 \times E \quad Watt \tag{1}$$

Here, E is energy flux detected. Therefore, its detection limits is 9.12×10^{-2} Watt. Assuming that an amount of light energy loss into space is constant in 10 hours of night through a year, one can estimate the total amount of light energy loss per year. Then, taking a typical price of electrically usage in Japan (25 yen/KW x hour), an amount of money lost by light energy per year can be estimated.

3. Results

In a paper (Isobe and Hamamura 1998), we show a time dependence of relative light energy loss from 1993 to 1996 at the 5 cities (Akita city, Shizuoka city, Hiroshima city, Tokushima city, and Matsuyama city). Here, we will show a reliable example of Akita city (figure 1) where number of saturated pixel is relatively small. One should remind that we can not measure its absolute value because of an inclusion of saturated pixel. Under this limited condition, an increase of light energy loss in an order of 40 % can be easily identified. Since a bullet train line had been expected to reach the city in 1997, it was just a period that its commercial activities became higher and higher. Figure 2

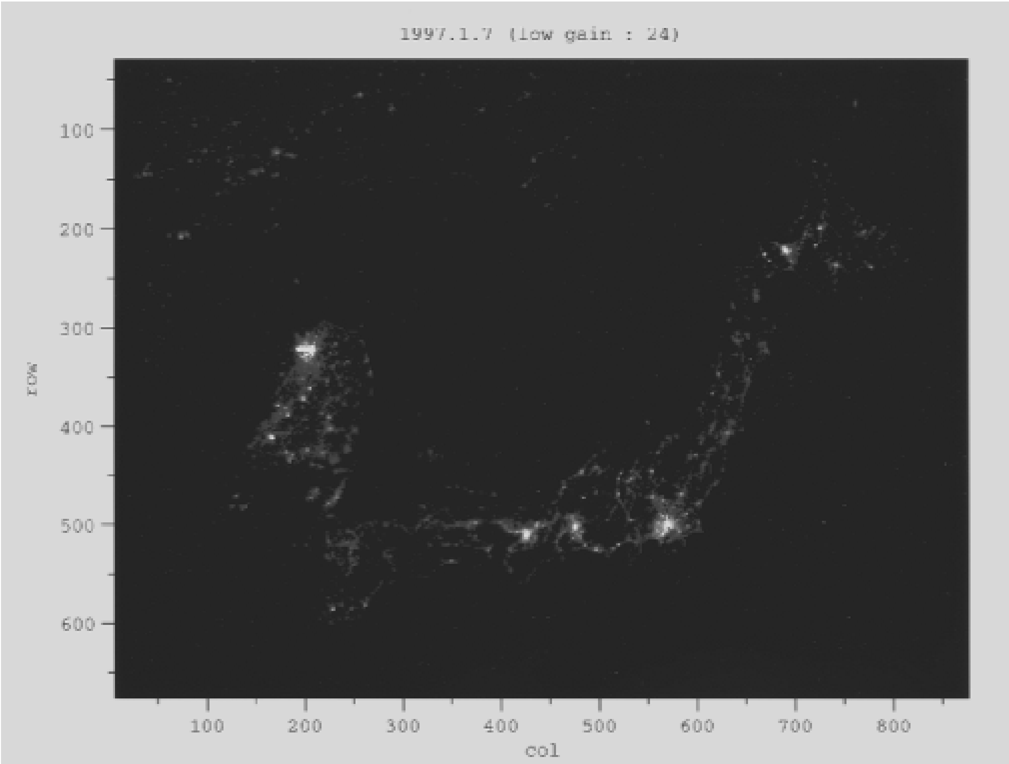


Fig. 2. Night time brightness distribution of Japan on January 7, 1997.

shows a night time brightness distribution of Japan obtained from the low gain data of January 7, 1997, and Figure 3 shows its enlarged map of Kanto plain including the capital of Tokyo which has still some number of saturated pixels. In this map, one can easily identify all the cities within the map as well as skiing resorts. Although the DMSP data are obtained at midnight, one tries to make those skiing areas by machines and need much light for those activities. We tentatively measured light energy loss within 30 km, 60 km, 90 km, 120 km, and 150 km square areas centered at the center of Tokyo and calculated those in each area between two consecutive areas (table 1). It is clear that the nearer the area is the more the light energy is lost. Only Tokyo city lost about 10 % of light energy loss in the whole Japan. The total light energy loss of Japan per year estimated from the data of January 7, 13, and February 9 are shown in table 1. There is 15 % fluctuation. Since Japan is a very long country (∼3,000 km), it is rare to have a clear weather all over the country. When we see its infrared data, some thin cloud can be seen from place to place. This is one of causes of error. There are many working fishing boats surrounding Japan, which eject much light to sea surfaces to collect fishes. This reflected light becomes bright light source detected by the DMSP satellites. This light fluctuation is also a cause of error. Therefore, our estimates in table 1 are reasonably

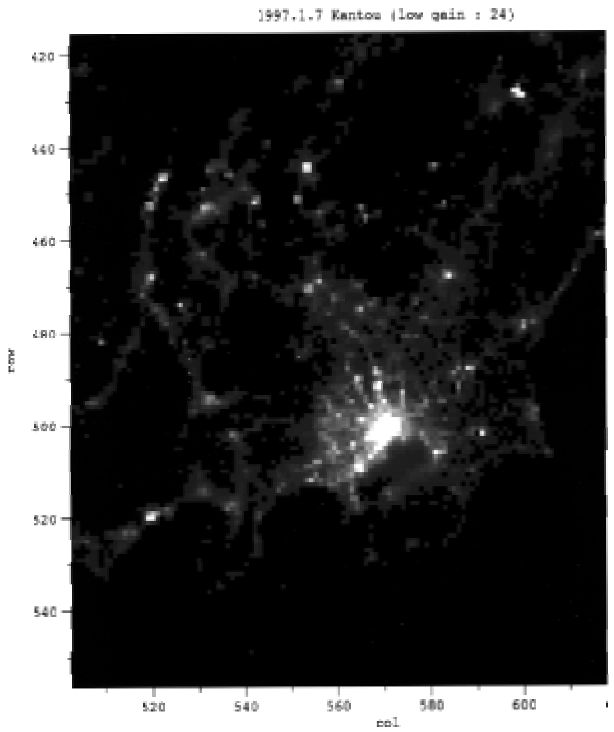


Fig. 3. A map of Kanto plain enlarged from figure 2.

coincident with each other. In future, we will measured an area to the others a where we can not find any cloud from data of different days and sum up through the country. Then, much reliable data will be obtained.

4. Conclusion

There were no monitoring methods for light pollution except an effort of some specific observatories. Now, we found from our study in this paper that data of the DMSP satellites can give a global monitoring method for light pollution. When people see they are loosing so much energy and money, I believe they will join our activities to reduce light pollution. Finally, I will say that the Japan Environmental Agency produced a guideline against light pollution in March, 1998, after two year study within a committee where I was one of the members, and is requesting to each local government to follow this guideline. I believe this is the first governmental effort in the would.

Table 1. Measured loss in energy and in yen

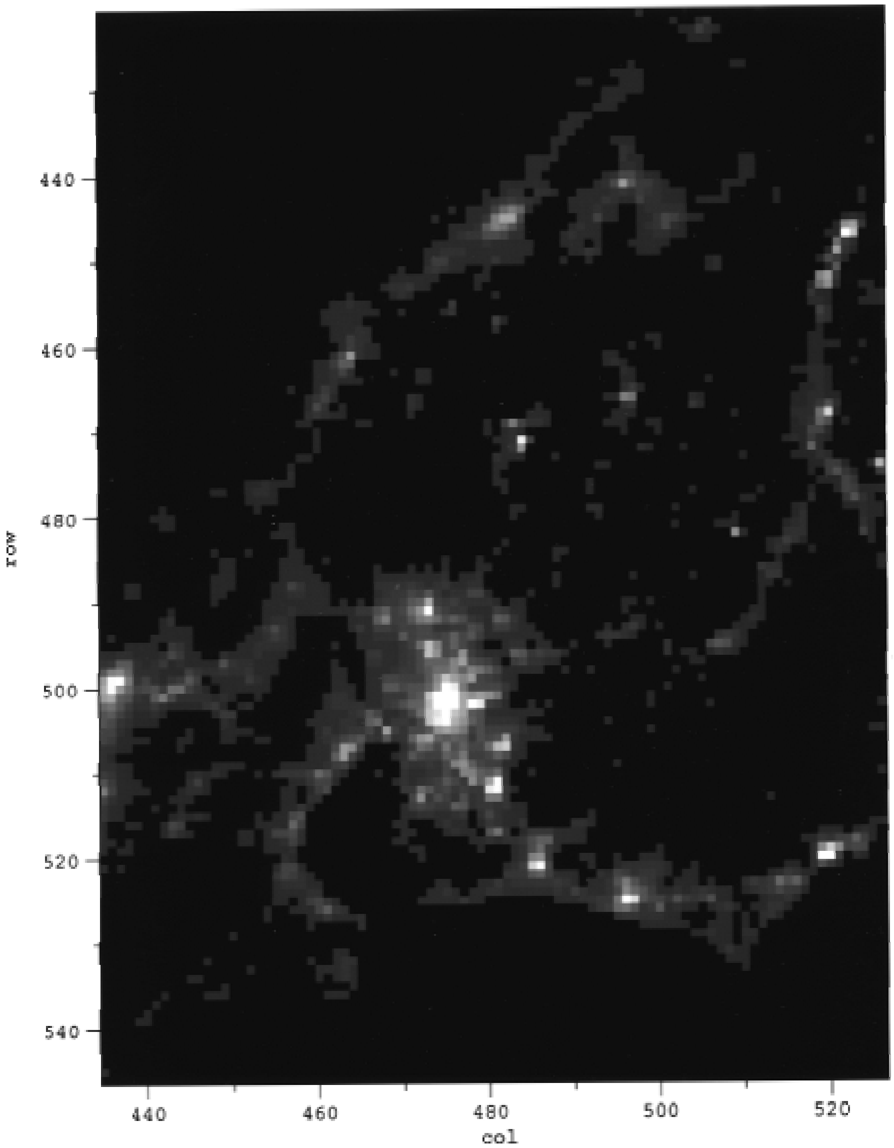
	Total observed energy 10^{-8} Watt/cm²/st/μm	Total energy loss 10^{6} kW·h	Total loss in yen 100 million yen
Akita city	410	2.47	0.62
Kanto plane 1997. 1. 7			
30km×30km	1.17×10^{4}	70.2 (70.2)	17.6
60km×60km	2.46×10^{4}	147 (25.6)	36.8
90km×90km	3.15×10^{4}	189 (8.4)	47.3
120km×120km	3.40×10^{4}	204 (2.1)	51.0
150km×150km	3.41×10^{4}	213 (1.0)	53.2
Japan			
1997. 1. 7	1.38×10^{5}	826	207
1997. 1. 13	1.44×10^{5}	866	217
1997. 2. 9	1.60×10^{5}	961	240

References

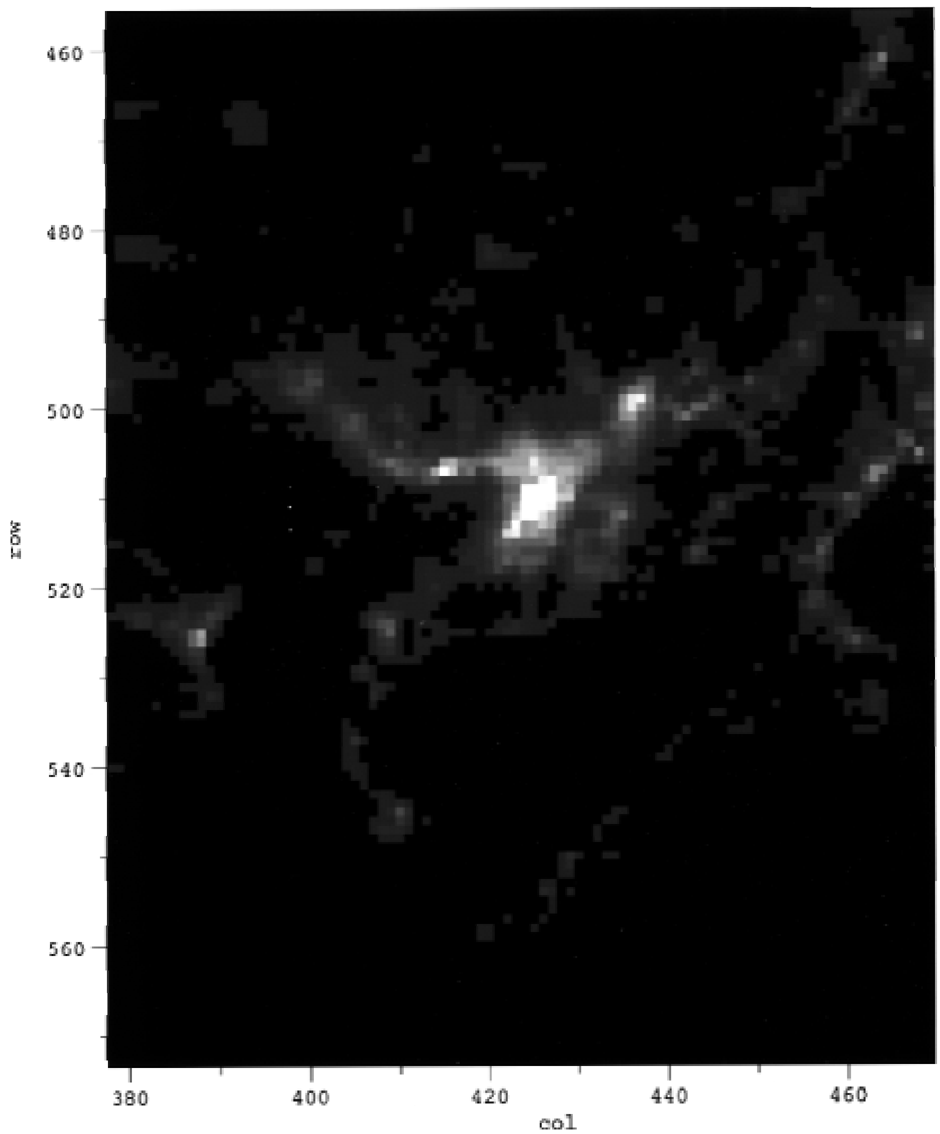
Isobe, S. 1998, Bilateral agreements, zoning, international protocol to preserve astronomical windows, in Preserving the Astronomical Windows : Astronomical Society of Pacific Conference Series, pp.119-123.

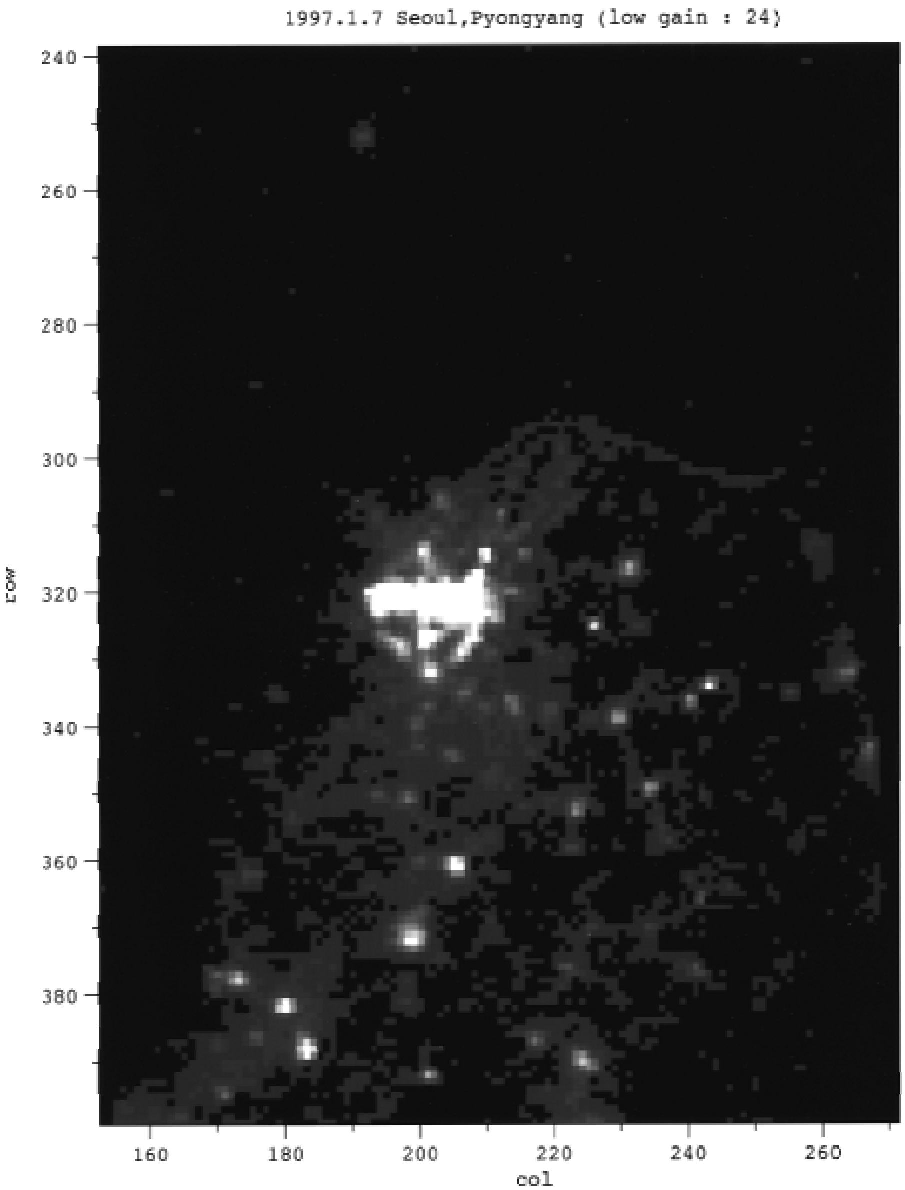
Isobe, S. and Hamamura, S. 1998, Ejected city light of Japan observed by a defense meteorological satellite program : Astronomical Society of Pacific Conference Series, pp.191-199.

1997.1.7 Nagoya,Kanazawa (low gain : 24)



1997.1.7 Osaka (low gain : 24)




1997.1.7 Seoul,Pyongyang (low gain : 24)
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