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Educating the Public about Light Pollution

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Abstract. Using low-gain DMSP data, we obtained absolute values of light energy loss ejected to space from different cities. Showing these data to local people in each city encourages them to try to reduce light energy loss. This educational approach is very effective in reducing light pollution.

1. Introduction

It is true that the public need and enjoy illuminating light. However, outdoor lighting is producing light pollution. We professional and amateur astronomers have a tendency to request light reduction from the public with arguments that star fields are beautiful and that scientific outputs are important for human-beings. Sometimes we succeed in making the public turn down the lights, especially for astronomically interesting events such as Comet Hyakutake, Comet Hale-Bopp and the Leonid showers.

It is also true that the fraction of people enjoying astronomical observations and star-watching is not large, that is, only one tenth or one hundredth of the total population. In order to get the support of the majority of people, we have to develop a clear way to educate the public. Since we have the DMSP (Defense Meteorological Satellite Program) data, we are trying to develop a new way to reduce light pollution.

2. Energy Loss

Electrical engineering has been much developed in the 20th century, especially in these last decades, during which people have enjoyed a much brighter night-time environment. However, the public and also lighting designers want to have lighting fixtures which are well decorated, especially in day time. Then they most easily use lighting fixtures which eject a large fraction of light towards the sky (Kawakami & Isobe 1998), and this light becomes energy loss.

Light pollution of astronomical observations is mainly produced by light ejected in directions with elevation angles of 0° to 45°. As an example, such an effect was studied by Osman et al. (2001) for the case of Kottamia Observatory in Egypt. City light ejected directly in near-zenith directions is only energy loss but does not create much light pollution of nearby observatories.

3. DMSP Data

The US Air Force started the DMSP in 1972 and made continuous observations using a series of satellites. However, after the US Air Force had used those data, they had no interest in keeping the data in digital form and just kept photographic prints. Using those prints Sullivan (1991) produced a famous map of Earth at Night and later Nakayama (1992) read the brightness distributions of all the photographic prints into a computer, corrected the projection effects and obtained a better map of the Earth at Night.

Fortunately, since 1993 the National Geographic Data Center receive digital data from the US Air Force and keep all the data in the form of 8-mm tapes. Through some communications with a leader on this programme, Dr. Elvidge of NGDC, we also get the data interesting for us as a collaborative project with NGDC.

The DMSP data from 1993 to 1996 were obtained using a high-gain mode which can detect light levels within the range 8×10^{-11}W/cm^2/sr/μm to 7×10^{-9} W/cm^2/sr/μm (Elvidge et al. 1999), but a large fraction of the area of big cities was usually saturated. Therefore, we cannot measure absolute values of light energy detected. However, we can still obtain a reasonable result for small cities and we have demonstrated increases of light energy loss from 1993 to 1997 in the cities of Akita, Shizuoka, Hiroshima, Matsuyama, and Tokushima in Japan (Isobe & Hamamura 2000).

By a strong request of Dr. C. Elvidge, the US Air Force made several observations with low gain. Gain number is different from time to time, but in most cases we could get non-saturated data, except for the central parts of very big cites such as Tokyo.

Table 1 shows all the results that we could reduce to date. Although we have a much larger amount of data, we have reduced only a small part of them because of a shortage of manpower. However, we will extend our efforts. Figures 1 and 2 show two maps of the brightness distribution. Further results of this ongoing work, tables and a picture gallery, can be viewed at the following web site, http://neowg.mtk.nao.ac.jp/ .

Fortunately, in 1999 the US Air Force plan to observe with low-gain much more frequently and then we will be able to compare values of light energy loss at different years.

4. Discussion

In Table 1, column 2, the observed value is just for observed total intensity in each area. Light energy loss per year is estimated assuming that the amount of energy lost to space is constant for 10 hours per night for each night of one year. Then light energy loss/km^2/year is calculated. Since the dynamic range of the detector is not so large, the resulted light energy loss/km^2/year estimated for most of the cities has values spanning only a factor of 20.

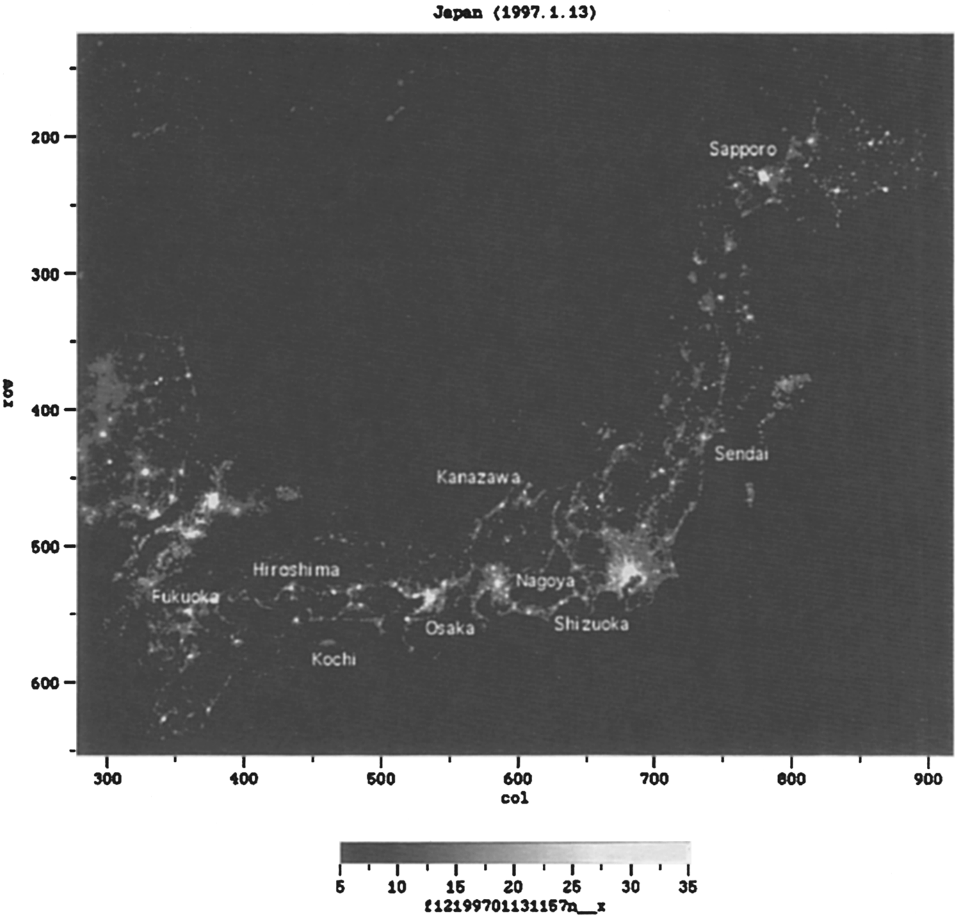

Figure 1. Brightness distribution of Japan on 13 January 1997.

There are fairly high values for cities in Canada, which may be caused by light reflection from snow on the roads. We see a similar effect for the Japanese city of Sapporo. To escape this snow effect, we should use low-gain data obtained in a season other than winter. However, only winter data are available in 1997 and therefore we have to wait to make a definite conclusion.

Although our data have still a problem to be resolved, we have now a fairly large number of light energy loss values for cities. In Japan, the Environmental Agency set a guideline to protect light pollution and assigned six cities to work on this. Then, if some city tries to reduce upward light, we can detect a decrease of light energy loss. Local people can see that their effort is directly linked to reduced energy loss and get a triggering motivation to consider the conservation of energy for future generations.

This kind of work is not a direct method to reduce a light pollution, but a certain method for making it happen.

Table 1. Energy detected by the DMSP and values estimated from it.

	Observed Value $(10^{-8}\mathrm{W/cm^2/st/\mu m})$	Light Energy Loss/Year $(10^6\mathrm{kWh})$	Area (km^2)	Light Energy Loss/Area/Year $(10^6\mathrm{kWh/km^2})$
Japan (1997.1.13)				
Sapporo	2.47×10^{3}	14.8	1046	1.41×10^{-2}
Sendai	7.40×10^{2}	4.43	463	9.57×10^{-3}
Kanazawa	5.18×10^{2}	3.10	543	5.71×10^{-3}
Shizuoka	4.56×10^{2}	2.73	528	5.17×10^{-3}
Nagoya	3.83×10^{3}	22.9	1519	1.51×10^{-2}
Osaka	5.85×10^{3}	35.1	1896	1.85×10^{-2}
Hiroshima	8.72×10^{2}	5.22	1001	5.21×10^{-3}
Kochi	2.39×10^{2}	1.43	729	1.96×10^{-3}
Fukuoka	1.56×10^{3}	9.35	1026	9.11×10^{-3}
Korea (1997.2.27)				
Seoul	7.07×10^{3}	42.4	2266	1.87×10^{-2}
Pusan	1.49×10^{3}	8.96	910	9.85×10^{-3}
Pyongyang	2.38	0.0143	133	1.08×10^{-4}
Europe (1997.1.13)				
London	4.84×10^{3}	29.0	2030	1.43×10^{-2}
Amsterdam	1.07×10^{3}	6.43	367	1.75×10^{-2}
Leiden	2.16×10^{2}	1.29	138	9.35×10^{-3}
Bruxelles	9.64×10^{2}	5.78	536	1.08×10^{-2}
Paris	6.33×10^{3}	37.9	2091	1.81×10^{-2}
Europe (1997.2.3)				
Wein	1.20×10^{3}	7.19	1080	6.66×10^{-3}
Budapest	1.58×10^{3}	9.44	1331	7.09×10^{-3}
Praha	1.26×10^{3}	7.55	1020	7.40×10^{-3}
Bratislava	4.25×10^{3}	2.55	389	6.56×10^{-3}
Warszawa	1.47×10^{3}	8.81	950	9.27×10^{-3}
Dresden	9.23×10^{2}	5.53	1162	4.76×10^{-3}
Brno	4.02×10^{2}	2.41	384	6.28×10^{-3}
Krakow	7.35×10^{2}	4.40	592	7.43×10^{-3}
Milano	2.32×10^{3}	13.9	1434	9.69×10^{-3}
Zagreb	4.78×10^{2}	2.86	380	7.53×10^{-3}
Greece (1997.2.5)				
Athinai	2.49×10^{3}	14.9	1837	8.11×10^{-3}
Tessaloniki	6.67×10^{2}	4.00	711	5.63×10^{-3}
Larisa	1.13×10^{2}	0.674	219	3.08×10^{-3}
Volos	1.25×10^{2}	0.749	210	3.57×10^{-3}
Lamia	65.6	0.393	148	2.66×10^{-3}
Iraklion	1.06×10^{2}	0.637	273	2.33×10^{-3}
Middle East (1997.1.9)				
Tel Aviv-Yafo	1.72×10^{3}	10.3	813	1.27×10^{-2}
Jerusalem	7.40×10^{2}	4.43	511	8.67×10^{-3}
Amman	8.77×10^{2}	5.25	478	1.10×10^{-2}
Haifa	5.53×10^{2}	3.31	253	1.31×10^{-2}
Damascus	4.98×10^{2}	2.98	320	9.31×10^{-3}
Beirut	6.48×10^{2}	3.88	464	8.36×10^{-3}
Baghdad	9.39×10^{2}	5.62	1510	3.72×10^{-3}
Egypt (1997.2.5)				
Cairo	4.51×10^{3}	27.0	1968	1.37×10^{-2}
Alexandria	6.52×10^{2}	3.90	818	4.77×10^{-3}
Ismailiya	2.88×10^{2}	1.73	273	6.34×10^{-3}
Suez	3.38×10^{2}	2.02	264	7.65×10^{-3}

Table 1. continued

	Observed Value (10^{-8}W/cm^2/st/μm)	Light Energy Loss/Year (10^6kWh)	Area (km^2)	Light Energy Loss/Area/Year (10^6kWh/km^2)
Canada (1997.1.12)				
Quebec	6.13×10^{3}	36.7	1767	2.08×10^{-2}
Trois Riviere	1.23×10^{3}	7.37	36	0.205
Montreal	2.32×10^{4}	139	4039	3.44×10^{-2}
Ottawa	5.44×10^{3}	32.6	1612	2.02×10^{-2}
Toronto	2.29×10^{4}	137	4330	3.16×10^{-2}
Sudbury	1.41×10^{3}	8.45	603	1.40×10^{-2}
Chicoutimi	1.28×10^{3}	7.65	400	1.91×10^{-2}
Calgary	1.39×10^{4}	83.4	1901	4.39×10^{-2}
Edmonton	9.83×10^{3}	58.9	1819	3.24×10^{-2}
U.S.A. (1997.2.4)				
New York (Long Is.)	2.26×10^{4}	136	9095	1.50×10^{-2}
Philadelphia	8.10×10^{3}	148.5	2690	1.80×10^{-2}
Boston	2.51×10^{3}	15.0	1122	1.34×10^{-2}
Baltimore	4.88×10^{3}	29.2	1854	1.57×10^{-2}
Washington D.C.	6.98×10^{3}	41.8	3087	1.35×10^{-2}
Buffalo	3.34×10^{3}	20.0	1250	1.60×10^{-2}
U.S.A. (1997.1.12)				
Mineapolis	2.04×10^{4}	122	4329	2.82×10^{-2}
St. Louis	1.55×10^{4}	93.0	4061	2.29×10^{-2}
Kansas City	1.19×10^{4}	71.5	4611	1.55×10^{-2}
Las Vegas	6.35×10^{3}	38.0	1552	2.45×10^{-2}
Phoenix	9.18×10^{3}	55.0	4782	1.15×10^{-2}
Tuscon	2.20×10^{3}	13.2	1804	7.32×10^{-3}
Middle America (1997.2.8)				
Mexico City	9.82×10^{3}	58.8	4015	1.46×10^{-2}
Monterrey	1.63×10^{3}	9.79	1701	5.76×10^{-3}
Guadalajara	2.56×10^{3}	15.3	1260	1.21×10^{-2}
Guatemala	7.23×10^{2}	4.33	1184	3.66×10^{-3}
San Salvador	4.57×10^{2}	2.74	1038	2.64×10^{-3}
Tegucigalpa	3.23×10^{2}	1.93	489	3.95×10^{-3}
Managua	2.75×10^{2}	1.65	630	2.62×10^{-3}
San Jose	8.64×10^{2}	5.17	1141	4.53×10^{-2}
Panama	5.35×10^{2}	3.21	891	3.60×10^{-3}
Habana	3.61×10^{2}	2.16	706	3.06×10^{-3}
Kingston	7.33×10^{2}	4.39	891	4.93×10^{-3}

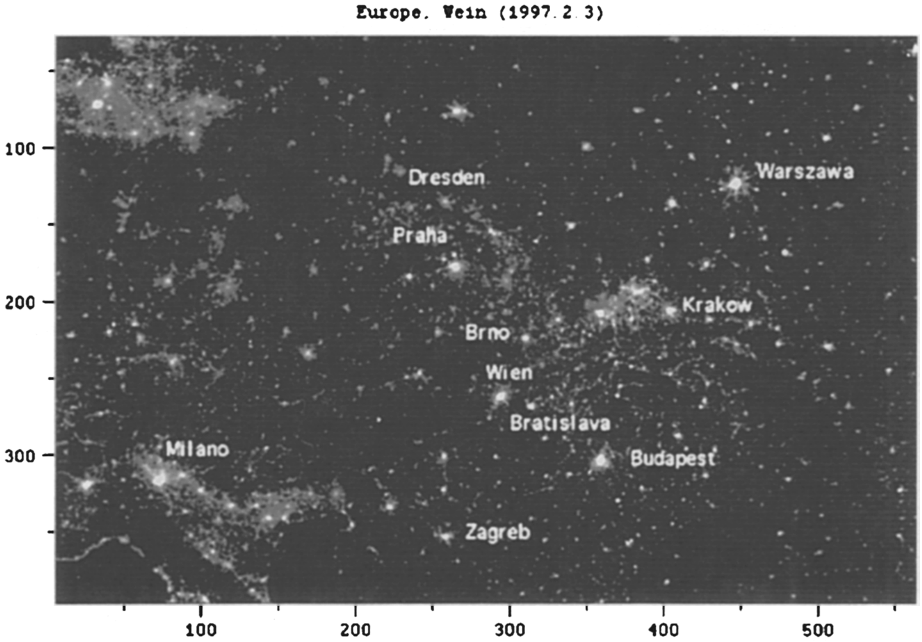

Figure 2. Brightness distribution of Europe on 3 February 1997.

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