Large-area Measurements of the Night Sky Brightness Using the Sky Quality Meter: 2010-2018 Data

Nobuaki Ochi*

Abstract

The night sky brightness is a good indicator of the light pollution level of a location. While various methods and tools are available for the measurement of the night sky brightness, here we used the Sky Quality Meter by Unihedron as the most widely-used and easy method. Nine areas in Japan were investigated and compared. The resulting maps show that some parts of these areas have the brightness of ≥21.0 mag/arcsec^2. This means, even though Japan is well known as one of the brightest countries, some parts like remote islands still preserve near-pristine night skies. However, very dark skies can be destroyed very easily by the artificial outdoor lighting, so it is important to do actions for keeping dark skies and raising awareness about light pollution.

Keywords：Night sky brightness, Light pollution, Sky Quality Meter, Environmental monitoring

1. Introduction

Light pollution is one of global environmental issues, which is especially serious in populated cities. It is not well-known among the public yet, though it seems to be ubiquitous. Light pollution can cause the change of behavior of animals and insects, adverse effects on human health, a waste of energy, brighter night skies and more (International Dark-Sky Association(2012)). To reduce light pollution, we should diminish the use of 'bad outdoor lighting', that is, the light shining to unnecessary direction or in unnecessary time, excessive light, or unnatural color light (especially, blue-rich light in nighttime). By adapting 'good outdoor lighting', we can reduce light pollution and energy waste while the safe and comfortable lighting environment is kept. However, most of ordinary people do not know about light pollution nor what the bad (or good) lighting is. As a result, the bad lighting is still being installed more and more in cities all over the world.

* Natural Science Laboratory, Toyo University, 5-28-20 Hakusan, Bunkyo-ku, Tokyo 112-8606, Japan

To tackle the problem of light pollution, it is important to know the current situation. A good indicator for evaluating the light pollution level at a location is the night sky brightness. Lights directly going upward from an outdoor lighting cause a glow of the night sky through the scattering process with floating particles in the air. The author reported a result of long-term variations of the night sky brightness measured by the lightmeter before (Ochi, 2014). In this paper, the Sky Quality Meter by Unihedron is employed for measuring the night sky brightness at various sites in Japan, because it is the most widely-used and easy way (Unihedron, 2018).

In 2016, Falchi showed an updated World Atlas of Light Pollution, which was composed mainly by the Suomi NPP satellite data (Falchi (2016) and Falchi et al. (2016)). The map indicated that more than one-third of humanity, including 60% of Europeans and 70% of Japanese, cannot see the Milky Way from their places. Their result implies that it is an urgent task for our modern cities to do actions for keeping dark skies and raising awareness about light pollution.

2. Measurement

2.1 Sky Quality Meter (SQM)

SQM is a handheld-size device developed by Unihedron (Unihedron (2018), Cinzano (2005)). It measures the night sky brightness in magnitudes per square arcsecond (mag/arcsec^2) and has high sensitivity enough to evaluate and compare the brightness quantitatively. There are several models and the SQM-L (SQM with lens, Fig. 1) model was employed in this research. The half width half maximum (HWHM) of the angular sensitivity of SQM-L is about 10 degrees, thus it can precisely measure the brightness of a restricted area like the zenith.

Fig. 1 : Sky Quality Meter (SQM-L)

The SQM-L outputs a measured value of the night sky brightness in unit of mag/arcsec^2. The larger values mean the darker night sky. Fig. 2 shows the conversion of various night sky brightness scales. As shown in this figure, the Milky Way can be seen from around 20 mag/arcsec^2. A natural unpolluted starry sky corresponds to about 21.7 mag/arcsec^2.

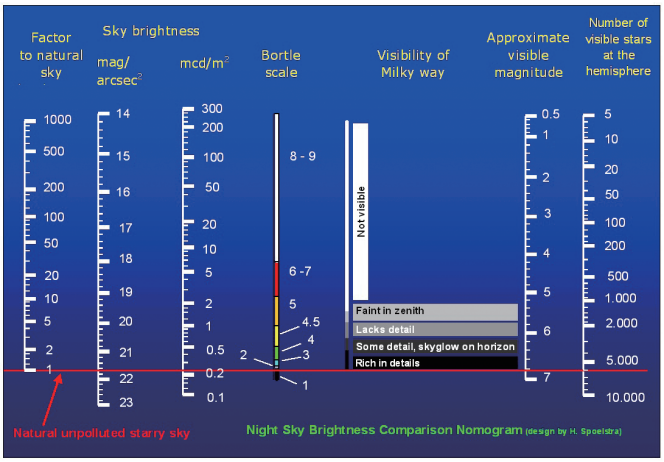

Fig. 2 : Night sky brightness comparison nomogram (Spoelstra, 2012)

2.2 How to measure the night sky brightness

To measure the night sky brightness at a location, SQM-L aimed at the zenith when no clouds existed around it. Moonless nights were selected for the observation periods in order to avoid the brightness of the moon light. Five measurement values were obtained with interval of several seconds and the average of middle three measurements (the minimum and the maximum values were omitted) was recorded as the brightness value of the location. It should be noted that brightness values can vary on time (human activities), air conditions, sky conditions and so on. Locations as far from artificial light sources as possible were chosen for the measurements while driving or walking along roads or paths.

3. Results

Here we show results of SQM measurements at nine areas in Japan. Details of measured data (date, local time, latitude, longitude and SQM-L value) are shown in Appendix.

3.1 Yonago-Daisen

An area over Yonago city, Sakaiminato city, Hiezu village, Daisen town, Houki town and Nambu town in Tottori prefecture was investigated on May 1–5, 2010. The main source of light pollution in this area is the center of Yonago city (population~150k, density~1.1k/km^2). The weather was fine throughout the period and the sky was very clear. They were also moonless nights. The result is shown as Fig. 3. The darkest areas

were in Daisen town and Houki town, which recorded ≥20.8 mag/arcsec^2, while the values were <18.5 mag/arcsec^2 around the center of Yonago city, the brightest area.

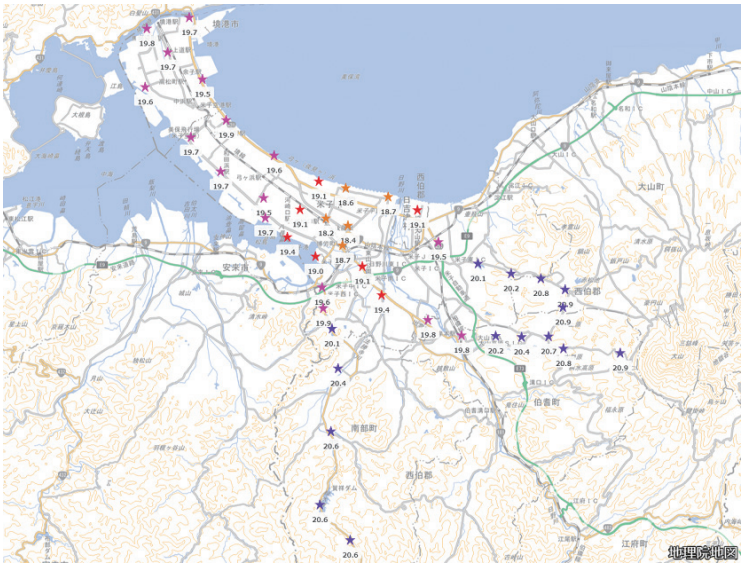

Fig. 3 : SQM-L measurements in Yonago-Daisen area

3.2 Bisei-Yonago

From Bisei Observatory in Bisei town, Okayama prefecture to Yonago city, Tottori prefecture, the night sky brightness was continuously measured with interval of about 2–5 km. The measurement was started at 23:43, August 20, 2010 at Bisei observatory and ended at 3:56, August 21 at Yonago city. The moon set time was 2:00, so the first part of measurements were affected by moon light. Also, thin fog slightly affected the values in the first part of measurements.

The population density of Bisei town, Ibara city (population~42k, density~0.2k/km^2), Okayama Prefecture is very low. Surrounded by mountains, the night sky is very dark. An interesting fact is that Bisei town enacted a light pollution prevention ordinance in 1989, the first one

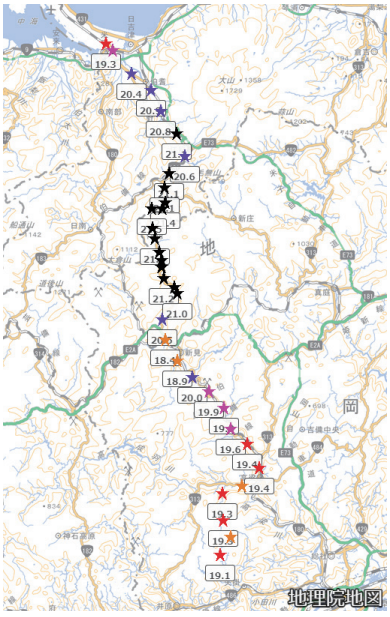

Fig. 4 : SQM-L measurements in Bisei-Yonago area

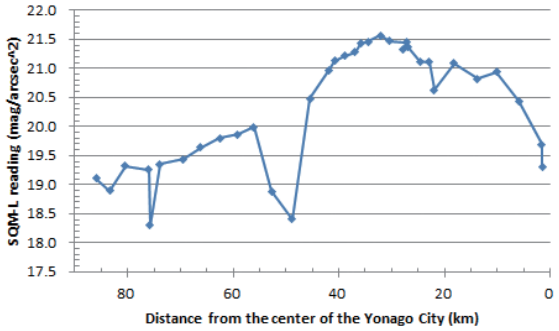

Fig. 5 : Relationship between the night sky brightness and the distance from Yonago city

of such regulations by municipalities in Japan (Sugihara, 1995). In the ordinance, it is prohibited to use outdoor lighting fixtures which emit light above the horizontal and it is recommended to turn off outdoor lighting between 10 p.m. and dawn. This town is popular among Japanese stargazers.

The result is shown as Fig. 4. The measured area is partly overlapped with Fig. 3. The darkest area was around the border between Niimi city (Okayama) and Hino town (Tottori) and it had very dark values of ≥21.5 mag/arcsec^2. In Fig. 5 we also show the relationship between the night sky brightness and the distance from the center of Yonago city. It is clear that the effect of city lights from Yonago city reaches 20–30 km.

3.3 Hiruzen-Kurayoshi

Along the peripheral road of Mt. Daisen (1,729m), the night sky brightness was measured on December 5–6, 2010. Hiruzen plateau area (Okayama prefecture) and Kurayoshi city (Tottori prefecture, population~51k) are on the route. The measured road is partly overlapped with Fig. 4. The sky was fine and moonless. The result is shown as Fig. 6. The darkest areas were Kofu town (Tottori) and Hiruzen (Okayama), which recorded ≥21.0 mag/arcsec^2.

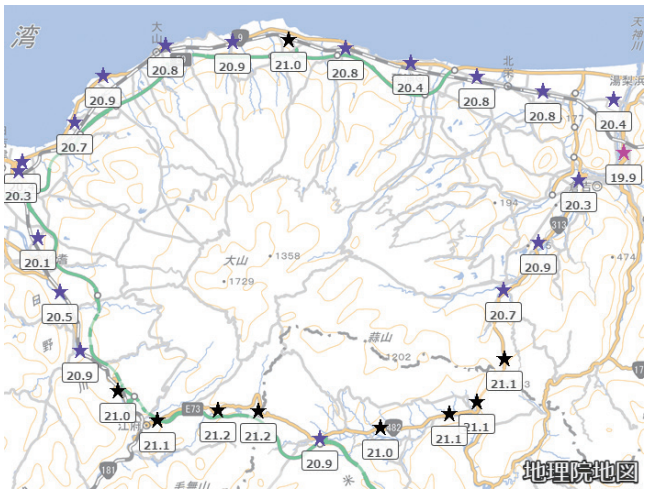

Fig. 6 : SQM-L measurements in Hiruzen-Kurayoshi area

3.4 Sakaiminato-Matsue

An area over Sakaiminato city , Matsue city and Yonago city was investigated on December 10, 2010. Matsue city in Shimane prefecture has a population of ~192k, but the measured area is far from the city center. The measured area is partly overlapped with Fig. 3. The sky was fine and moonless. The result is shown as Fig. 7. This area yielded rather bright data with the darkest value of 20.5 mag/arcsec^2 in Matsue city on this night.

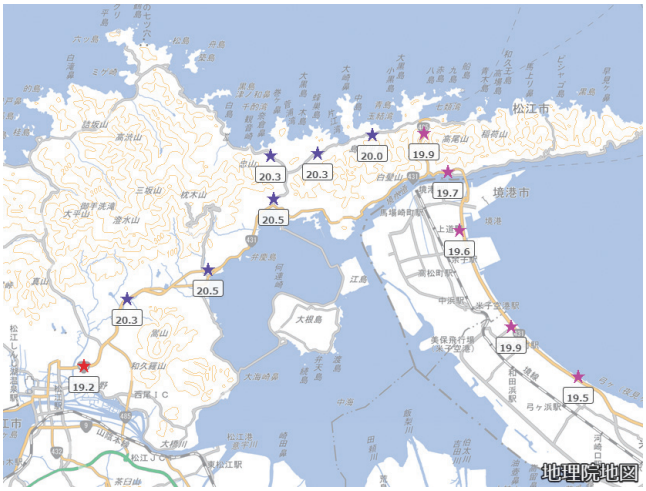

Fig. 7 : SQM-L measurements in Sakaiminato-Matsue area

3.5 Chichijima

Chichijima is a remote, small island in the Pacific Ocean. To reach the island, it is needed to ride a ferry from the Tokyo Port bounding south for about 25 hours, because the island does not have an airport. The distance from Tokyo Metropolitan area is about 990 km. This situation keeps the island almost free from city lights. The island itself has a small population of ~ 2 k and belongs to Tokyo. The measurement was done on August 28 and 29, 2013. The sky was fine and moonless in both nights. The resulting map is shown as Fig. 8. Even the village center (the north-western part of the island) city lights and street lights are very limited, resulting in the sky brightness ~20.0 mag/arcsec^2. In all other area, the values reach ≥21.0 and in some places ≥21.5 mag/arcsec^2. We can safely say Chichijima

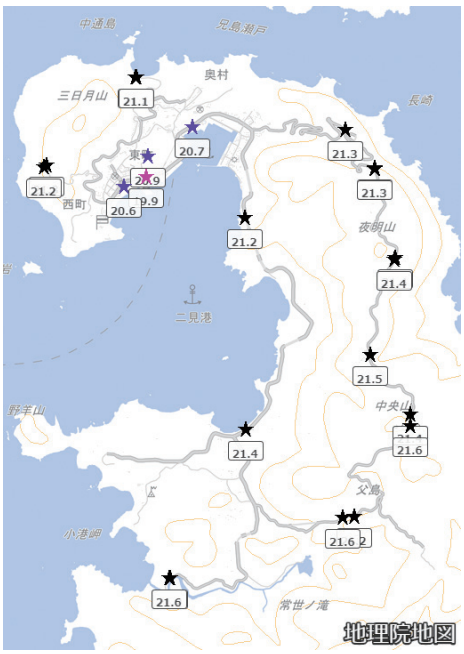

Fig. 8 : SQM-L measurements in Chichijima

has one of the top quality dark skies in Japan.

3.6 Yaeyama Islands

Yaeyama islands locate at the most south-western part of Japan. The area is one of the most popular destinations of tourists thanks to the beautiful sea, nature and starry sky. The area was designated as an 'international dark-sky park' by International Dark-Sky Association, the first one in Japan (International Dark-Sky Association, 2018). In the preparation process for obtaining the designation, local municipalities (Ishigaki city and Taketomi town) enacted the "light-scape management plan" to reduce light pollution.

The measurement was executed on February 28, March 2 and 3, 2014. The sky was clear and moonless, but it was humid. The resulting map is shown as Fig. 9. The values were ≥21.0 mag/arcsec^2 in most part of islands (except the center of Ishigaki city), confirming near-pristine dark skies in this area.

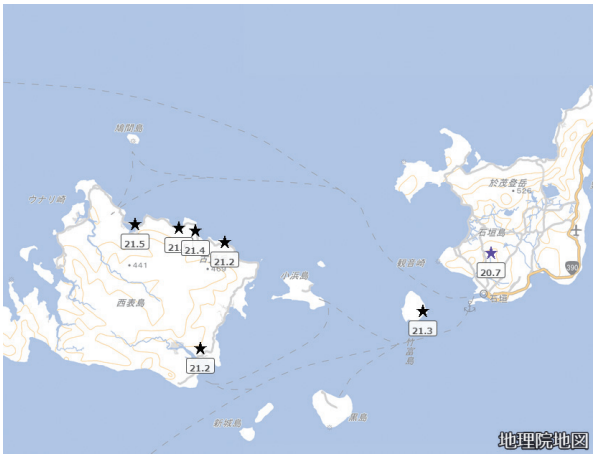

Fig. 9：SQM-L measurements in Yaeyama Islands

3.7 Izuoshima

Izuoshima is a remote island in the Pacific Ocean and nearer from mainland Tokyo than Chichijima. The distance from Tokyo Metropolitan area is about 110 km. It takes about two hours from the Tokyo Port to the island by a ferry, and enough to avoid influential city lights. The population is ~ 8 k and the island belongs to Tokyo. The measurement was performed on March 30, 2016. The sky was clear. The time of moon rise on the night was 23:58 and the last measurements could be slightly affected by moon lights. The resulting map is shown as Fig. 10. In the town center the value was 20.1 mag/arcsec^2, while other parts yielded ≥21.0 mag/arcsec^2. The island can be reached easily from Tokyo Metro-

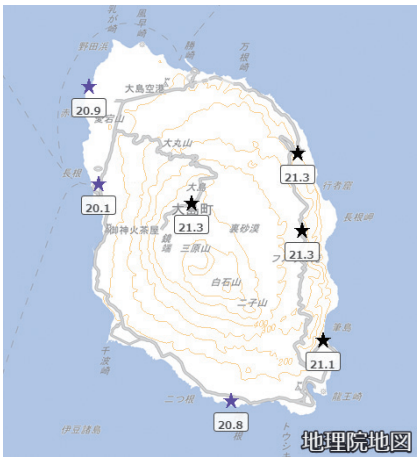

Fig. 10：SQM-L measurements in Izuoshima

politan area but the night sky is being kept very dark.

3.8 Aogashima

Aogashima is another remote small island in the Pacific Ocean and between Izuoshima and Chichijima. The distance from Tokyo Metropolitan area is about 360 km. It can be reached by airplane (Tokyo-Hachijojima) followed by helicopter (Hachijojima-Aogashima). The population is only about 160. However, there are bright street lights and road lights in some parts of the island.

Fig. 11 : SQM-L measurements in Aogashima

The measurement was done on February 25, 2017, and it was an extremely unique night because the electricity of the whole island was shut down at 24:10 due to the maintenance work by the electric company. Fig. 11 shows the resulting map. Before the blackout, the darkest value was 21.4 mag/arcsec^2. The value dropped to 21.7 mag/arcsec^2 after the blackout at the same place. This clearly shows the effect of outdoor lighting to the brightness of the night sky.

3.9 Takayama

Takayama village belongs to Gunma prefecture. Since the village has a large astronomical observatory, a light pollution prevention legislation, similar to that of Bisei, was enacted in 1998. However, some street lights have been replaced by LED lamps which emit upward light a lot in recent years.

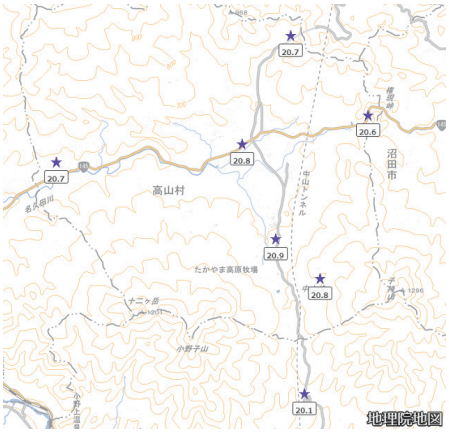

Fig. 12 : SQM-L measurements in Takayama

The measurement was performed on March 14, 2018, moonless night. There were no clouds but it was foggy a little. The resulting map is shown as Fig. 12. No measurement points showed values of ≥21.0 mag/arcsec^2. However, it is far darker than city areas around it and should be preserved by the legislation.

4. Discussion

According to Falchi et al. (2016), the percentage of land area in Japan where people cannot see the Milky Way is only 7.1%, but 70.4% of Japanese population live there. Most parts of the nine areas investigated in this paper belong to darker and sparse areas. By comparing our resulting maps with the detailed maps by Falchi (2016) it turned out that both maps are consistent. By our maps people can know where night skies are very dark (or bright) in more detail, which should be useful information for stargazers, photographers, educators and so on. From Fig. 5 we can know the effect of city lights of ~150k population can reach as far as 20–30 km, which is also helpful to search for stargazing places in other parts of Japan.

As a conclusion, the night sky brightness was measured at nine areas in Japan to study the current situation of light pollution. From 2010-2018 data, it was found that the night sky brightness at some parts (especially remote islands) is very dark with the value of more than 21 mag/arcsec^2. However, very dark skies can be destroyed very easily by artificial outdoor lighting, so it is important to do actions for keeping dark skies and raising awareness about light pollution.

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Appendix

Here we tabulate date, local time, latitude (N), longitude (E) and SQM-L value (mag/arcsec^2) of all data points used in the maps shown in this paper. Values of local time, latitude and longitude were obtained by a GPS device. SQM-L values shown in these tables are the average of three values, which were obtained by omitting the minimum and maximum values from five measurements repeated with time interval of several seconds at a point.

Yonago-Daisen (Year: 2010)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	05/01	20:30	35.456	133.289	19.5		24	05/02	23:20	35.282	133.343	20.6
2	05/01	21:10	35.477	133.295	19.6		25	05/02	23:40	35.390	133.331	20.1
3	05/01	21:19	35.495	133.265	19.9		26	05/02	23:44	35.400	133.326	19.9
4	05/01	21:37	35.547	133.242	19.7		27	05/02	23:59	35.432	133.338	18.7
5	05/01	21:43	35.542	133.216	19.7		1	05/04	22:40	35.456	133.289	19.3
6	05/01	21:51	35.512	133.215	19.6		2	05/04	22:48	35.477	133.295	19.4
7	05/01	22:03	35.530	133.229	19.7		11	05/04	23:01	35.464	133.323	19.1
8	05/01	22:16	35.516	133.251	19.5		28	05/04	23:14	35.450	133.385	19.1
9	05/01	22:27	35.487	133.244	19.7		29	05/04	23:22	35.433	133.398	19.5
10	05/01	22:34	35.469	133.262	19.7		30	05/04	23:31	35.423	133.422	20.1
1	05/02	20:30	35.456	133.289	19.3		31	05/04	23:44	35.418	133.443	20.2
2	05/02	21:11	35.477	133.295	19.6		32	05/04	23:51	35.415	133.462	20.8
11	05/02	21:22	35.464	133.323	19.1		33	05/04	23:55	35.409	133.477	20.9
12	05/02	21:29	35.461	133.340	18.6		34	05/05	00:15	35.401	133.475	20.9
13	05/02	21:37	35.456	133.367	18.7		35	05/05	00:20	35.386	133.466	20.7
14	05/02	21:47	35.442	133.342	18.3		36	05/05	00:25	35.380	133.476	20.8
15	05/02	21:55	35.446	133.328	18.2		37	05/05	00:33	35.377	133.511	20.9
16	05/02	22:02	35.450	133.312	19.1		38	05/05	00:53	35.385	133.449	20.4
17	05/02	22:10	35.436	133.304	19.4		39	05/05	01:03	35.386	133.433	20.2
18	05/02	22:17	35.446	133.290	19.7		40	05/05	01:08	35.386	133.412	19.8
19	05/02	22:32	35.426	133.321	19.0		41	05/05	01:13	35.394	133.391	19.8
20	05/02	22:44	35.411	133.325	19.6		42	05/05	01:22	35.407	133.362	19.4
21	05/02	22:55	35.369	133.335	20.4		43	05/05	01:28	35.421	133.350	19.1
22	05/02	23:03	35.337	133.331	20.6		11	05/05	01:46	35.464	133.323	19.2
23	05/02	23:14	35.300	133.324	20.6							

Bisei-Yonago (Year: 2010)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	08/20	23:43	34.674	133.545	19.1		18	08/21	02:07	35.107	133.437	21.3
2	08/20	23:54	34.701	133.563	18.9		19	08/21	02:10	35.116	133.438	21.4
3	08/21	00:03	34.726	133.550	19.3		20	08/21	02:15	35.129	133.432	21.5

4	08/21	00:11	34.767	133.549	19.3		21	08/21	02:22	35.149	133.425	21.6
5	08/21	00:21	34.778	133.584	18.3		22	08/21	02:28	35.164	133.421	21.5
6	08/21	00:32	34.805	133.616	19.4		23	08/21	02:36	35.194	133.420	21.5
7	08/21	00:45	34.841	133.594	19.4		24	08/21	02:45	35.194	133.439	21.3
8	08/21	00:52	34.863	133.563	19.6		25	08/21	02:49	35.203	133.444	21.4
9	08/21	00:58	34.895	133.551	19.8		26	08/21	02:55	35.226	133.443	21.1
10	08/21	01:05	34.920	133.524	19.9		27	08/21	03:02	35.247	133.451	21.1
11	08/21	01:14	34.941	133.493	20.0		28	08/21	03:07	35.272	133.480	20.6
12	08/21	01:24	34.966	133.465	18.9		29	08/21	03:15	35.306	133.465	21.1
13	08/21	01:36	34.998	133.444	18.4		30	08/21	03:26	35.340	133.436	20.8
14	08/21	01:42	35.028	133.439	20.5		31	08/21	03:32	35.371	133.418	20.9
15	08/21	01:52	35.067	133.466	21.0		32	08/21	03:40	35.396	133.382	20.4
16	08/21	01:56	35.076	133.460	21.1		33	08/21	03:50	35.431	133.348	19.7
17	08/21	02:02	35.089	133.441	21.2		34	08/21	03:56	35.440	133.336	19.3

Hiruzen-Kurayoshi (Year: 2010)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	12/05	22:24	35.438	133.393	19.7		16	12/06	00:19	35.433	133.812	20.3
2	12/05	22:35	35.398	133.407	20.1		17	12/06	00:28	35.449	133.846	19.9
3	12/05	22:43	35.365	133.424	20.5		18	12/06	00:35	35.482	133.838	20.4
4	12/05	22:50	35.329	133.439	20.9		19	12/06	00:43	35.487	133.786	20.8
5	12/05	22:58	35.304	133.468	21.0		20	12/06	00:49	35.496	133.736	20.8
6	12/05	23:10	35.286	133.497	21.1		21	12/06	00:56	35.504	133.687	20.4
7	12/05	23:18	35.292	133.542	21.1		22	12/06	01:04	35.513	133.638	20.8
8	12/05	23:26	35.292	133.572	21.2		23	12/06	01:12	35.518	133.595	21.0
9	12/05	23:33	35.275	133.618	20.9		24	12/06	01:19	35.517	133.553	20.9
10	12/05	23:40	35.281	133.664	21.0		25	12/06	01:26	35.515	133.503	20.8
11	12/05	23:47	35.290	133.715	21.1		26	12/06	01:34	35.497	133.456	20.9
12	12/05	23:53	35.297	133.736	21.1		27	12/06	01:40	35.468	133.435	20.7
13	12/05	23:58	35.323	133.756	21.1		28	12/06	01:48	35.444	133.396	20.4
14	12/06	00:04	35.365	133.756	20.7		1	12/06	01:53	35.438	133.393	20.3
15	12/06	00:11	35.395	133.782	20.9		29	12/06	02:04	35.464	133.323	20.0

Sakaiminato-Matsue (Year: 2010)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	12/10	21:41	35.477	133.295	19.5		7	12/10	22:40	35.558	133.179	20.3
2	12/10	21:49	35.495	133.265	19.9		8	12/10	22:46	35.557	133.158	20.3
3	12/10	22:11	35.530	133.242	19.6		9	12/10	22:51	35.542	133.159	20.5
4	12/10	22:18	35.551	133.237	19.7		10	12/10	23:01	35.516	133.130	20.5
5	12/10	22:23	35.566	133.227	19.9		11	12/10	23:07	35.505	133.094	20.3
6	12/10	22:33	35.565	133.203	20.0		12	12/10	23:13	35.481	133.075	19.2

Chichijima (Year: 2013)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	08/28	22:13	27.096	142.185	21.2		14	08/29	21:58	27.099	142.199	20.7
2	08/28	22:24	27.103	142.194	21.2		15	08/29	22:07	27.099	142.214	21.3
3	08/28	22:39	27.099	142.214	21.4		16	08/29	22:13	27.096	142.217	21.3
4	08/28	22:45	27.096	142.217	21.4		17	08/29	22:28	27.088	142.219	21.4
5	08/28	22:52	27.088	142.219	21.4		18	08/29	23:03	27.080	142.216	21.5
6	08/28	22:58	27.074	142.220	21.3		19	08/29	23:08	27.073	142.220	21.6

7	08/28	23:09	27.060	142.197	21.2		20	08/29	23:15	27.066	142.214	21.6
8	08/28	23:21	27.066	142.215	21.2		21	08/29	23:23	27.060	142.197	21.6
9	08/28	23:39	27.094	142.192	20.6		22	08/29	23:33	27.073	142.204	21.4
10	08/29	20:57	27.097	142.195	20.9		23	08/29	23:42	27.091	142.204	21.2
11	08/29	21:15	27.095	142.195	19.9		14	08/29	23:51	27.099	142.199	20.5
12	08/29	21:31	27.096	142.185	21.3		11	08/29	23:55	27.095	142.195	20.0
13	08/29	21:46	27.103	142.194	21.1							

Yaeyama Islands (Year: 2014)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	02/28	22:15	24.397	123.822	21.5		5	02/28	23:15	24.290	123.884	21.2
2	02/28	22:24	24.395	123.864	21.5		6	03/02	2 :05	24.322	124.097	21.3
3	02/28	22:35	24.392	123.880	21.4		7	03/03	21:40	24.373	124.163	20.7
4	02/28	22:42	24.382	123.908	21.2							

Izuoshima (Year: 2016)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	03/30	20:11	34.784	139.352	20.9		5	03/31	0 :05	34.737	139.435	21.3
2	03/30	20:46	34.752	139.355	20.1		6	03/31	0 :20	34.702	139.443	21.1
3	03/30	22:11	34.762	139.433	21.3		7	03/31	0 :39	34.683	139.407	20.8
4	03/30	22:31	34.746	139.392	21.3							

Aogashima (Year: 2017)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	02/25	19:24	32.461	139.763	21.2		4	02/25	21:20	32.451	139.771	21.4
2	02/25	20:01	32.471	139.759	21.3		5	02/25	21:36	32.453	139.765	21.4
3	02/25	21:04	32.457	139.778	21.4		5	02/26	00:52	32.453	139.765	21.7

Takayama (Year: 2018)												
No.	mm/dd	L. Time	Lati.	Longi.	SQM-L		No.	mm/dd	L. Time	Lati.	Longi.	SQM-L
1	03/14	20:04	36.568	138.970	20.1		6	03/14	22:27	36.632	138.988	20.6
2	03/14	20:22	36.595	138.974	20.3		2	03/14	22:44	36.595	138.974	20.8
3	03/14	21:31	36.625	138.952	20.5		7	03/14	23:33	36.604	138.961	20.9
4	03/14	21:49	36.621	138.899	20.7		3	03/15	00:08	36.625	138.952	20.8
5	03/14	22:13	36.650	138.966	20.7							

The base maps of Fig. 3, 4, 6–12 are the Digital Map by Geospatial Information Authority of Japan. (https://maps.gsi.go.jp/)

要 旨

スカイクオリティメーターを用いた夜空の明るさの広域測定：2010-2018年データ

越 智 信 彰

夜空の明るさは、ある地点での光害進度を定量的に評価するのに有効な指標である。夜空の明るさの測定方法やツールはいろいろなものがあるが、本論文では最も簡便で広く利用されている、ユニヘドロン社のスカイクオリティメーターを使用した。日本国内９つのエリアで広域測定を行い、比較した。その結果、いくつかの地域では21.0 mag/arcsec^{2}を上回る暗さであった。日本は世界で最も夜の明るい国の一つとして知られるが、部分的には（特に離島など）まだほぼ自然の状態に近い暗い夜空が残されていることが直接測定により明らかとなった。しかしながら、暗い夜空は不適切な人工光の使用により簡単に破壊され得るものであり、意識的に保護・啓発することが重要である。