A methodology to create DMSP-OLS night-time mosaic image for monitoring fishing boats

Izumi Nagatani*

*Agriculture, Forestry and Fisheries Research Information Technology Center / 2-1-9 Kannondai, Tsukuba, Ibaraki 305-8601, Japan; Tel +81-29-838-7341, Fax +81-29-838-7364
E-Mail: nagatani@affrc.go.jp

Abstract: A methodology to create the DMSP-OLS nighttime mosaic image was developed for monitoring fishing boats. It is a simple and fast processing methodology to be implemented in the operational database system. The main features of this methodology are selecting night orbit’s files and calculating sun zenith angle to eliminate the sun illumination for each pixel. The product image shows the earth surface lights without sun illumination. The threshold of sun elevation of central pixel was set -8.0 degree and the threshold of sun zenith angle was set -0.15 in cosine. The sun zenith angle threshold could be set between -0.15 to -0.25 depending on use purpose.

Keywords: DMSP-OLS; nighttime lights; SIDaB, nighttime light mosaic.

1. Introduction

Monitoring Fishing boats using satellite data is required to grasp fishing grounds and to manage fisheries. The night time light image of the Defense Meteorological Satellite Program’s Operational Linescan System (DMSP-OLS) is useful for this purpose (Elvidge,C.D. 2009, Kiyofuji, H. 2004).

The DMSP-OLS is designed as a cloud imager with two spectral band observations, which are visible-near infrared (0.40 to 1.10 μm) and thermal infrared (10.5 – 12.6 μm), and using a photomultiplier tube (PMT), the OLS can detect faint lights at night which are not only moonlit cloud but also human settlements, gas flares, fires and even fishing boats (Elvidge,C.D. 1997 and 2001, Imhoff M.L. 1997)
The Agriculture, Forestry and Fisheries Research Information Technology Center (AFFRIT) of the Japan’s Ministry of Agriculture, Forestry and Fisheries (MAFF) has operated the satellite image database system (SIDaB) since 2000 (Kodama, M. 2000, Song, X. 2000) and it has distributed the DMSP-OLS night time image collaborating with the National Oceanic and Atmospheric Administration’s National Geophysical Data Center (NOAA/NGDC). The one of the popular SIDaB products among the users is the semi real-time OLS night time mosaic image which has been generated operationally using TeraScan® commercial software (SeaSpace Corp.).

DMSP-OLS data files have been transmitted from the NOAA/NGDC to the SIDaB using high performance network of the Asia Pacific Advanced Network (APAN) consortium. As soon as received the data files, the SIDaB generates a nighttime mosaic image automatically. However, unfortunately some of the products are inappropriate because of their simple overlay methodology which may generates sun illuminated image with fishing boats lights interrupted.

In this paper, new methodology is described for mitigating this problem. It is to create a DMSP night time mosaic image in real-time without missing fishing boats lights. The main features of this methodology are selecting night orbit files using sun elevation and calculating sun zenith angle to eliminate sun illumination for each pixels. The output image shows the latest Earth’s surface lights without sun illumination. We explored and determined the angle thresholds from DMSP-OLS dataset of January 2009 observations, and the methodology were applied to other observations which are of each April in 1995, 1999, 2001, 2005 and 2008.

2. Methods

2.1. SIDaB system and DMSP-OLS

The SIDaB is a fast and real-time processing database system for satellite remote sensing data such as, NOAA, DMSP, MTSAT and TERRA/AQUA-MODIS. It consists of data reception, processing, archiving and distributing systems (Figure 1). The TeraScan® software is used for the data reception and processing systems which generates the level 3 products automatically from raw received data. As for DMSP-OLS, the raw data which are formatted in the OLS Interleaved Smooth data file (OIS) and selected for East and Southeast Asia region (Latitude: 10S-60N, Longitude: 90E-160E) by NOAA/NGDC in advance, are transmitted from the NGDC to the SIDaB in semi real-time after three hours holding control. The received data are converted to TeraScan Data Format (TDF) in real time processing system and their Level 1 and one-night mosaic image product are generated. These products are immediately registered to the PostgreSQL database and archived into disk storage, so that users can download the semi real-time products from the web interface.
2.2. DMSP-OLS mosaic image

One night mosaic image is created from night time orbit images. The orbit images of DMSP-OLS are showed in Figure 2. It shows a night time orbit (a), a day time orbit (b) and a dawn-dusk orbit (c) images with grid line in red and coastline in green. In the night time orbit image, city lights and fishing boats lights at sea are looking white in a dark background, meanwhile in the day time orbit image, clouds and lands are depicted in gray scale. The night time orbit image consists of mostly night observation pixels and the dawn-dusk orbit image has both night and day time observation pixels. In summer season, even night time orbit image has day time pixels around Japan according to sun elevation condition. In the proposed methodology in this paper, the day time pixels are not used and just night time pixels are picked up to create one night mosaic image.
The proposed methodology consists of five processing steps (Figure 3). The first step is choosing night orbit files. The sun elevation angle at the central pixel of image is used and the threshold of sun elevation angle should be set in advance. The files whose sun elevation is below the threshold are identified as night orbit. TDF format file has the orbital and geometrical information in their file header and the sun elevation angle can be calculated easily using one TeraScan command. This step is effective to distinguish night time orbit files from day time orbit files.

The second step is geolocation. The latitude-longitude coordinate system is used. The location of image center is 20N and 100E in latitude and longitude, and 3000 lines and 5000 samples in image size.

The next step is calculating sun zenith angle and making a mask of the day time pixels. The sun zenith angle is used in this step instead of sun elevation angle depending on the TeraScan command usage. The sun elevation angle is measured from the horizon meanwhile the sun zenith angle is measured from the zenith of each pixel position. The threshold of sun zenith angle should be set in advance. The pixel whose sun zenith angle is above the threshold is identified as sun illuminated pixel or day time pixel, and such pixel is masked and not used as output. The sun zenith angle calculation is performed by one TeraScan command which is derived from pixel location (lat-lon) and observation time.

The fourth step is sorting files by satellite and observation time, and they are overlaid on an output image. The output image will show a latest light perspective by newer satellite observation.
2.3. Threshold definition

The thresholds of sun elevation and sun zenith angle were statistically determined. Firstly, from some sun elevation angle images, we assumed that the angle under -10.0 degrees was identified as night pixel, the angle above -5.0 degrees was identified as day pixel, and the angle between -10.0 and -5.0 degrees was transitional. Figure 4 shows an example. The image (a) is an OLS visible band image, and (b) is those sun zenith angle image colored with black-white gradient which means black shows lower zenith angle of sun and white shows higher zenith angle of sun. The image (c) is an identified image which white color identified as day pixels and dark gray identified as night pixels. Using the number of night pixels and day pixels, the night coverage for each image of from January 1st to 31st, 2009 was calculated by following equation,

\[ \text{Night coverage (\%)} = 100 \times \frac{N_{\text{night}}}{N_{\text{night}} + N_{\text{day}}} \]
where $N_{night}$ and $N_{day}$ are the number of night pixels and day pixels respectively. The relationship between the night coverage and sun elevation angle of image center was analyzed, and the threshold of sun elevation angle was determined for process step 1.

To explore the sun zenith angle threshold for the process step 3, sample dataset of January 2009 were created with each five sun zenith angle thresholds, -0.15, -0.17, -0.2, -0.25 and -0.3 in cosines. The Number of Sun Illuminated Pixels (NSIP) was counted for each created images. The NGDC’s stable light product, which is the 2009’s version 4, was used to distinguish Sun Illuminated Pixels (SIP) from city light pixels. The stable light product was downloaded from NOAA-NGDC DMSP web site. If the stable light’s pixel value was less than 5 and OLS visible value was greater than 9, such pixel was identified as SIP. The relationship between the sun zenith angles and NSIP was statistically analyzed.

3. Results and Discussion

Figure 5 shows the relationship between the sun elevation of central pixel of image and night coverage. It shows that the sun elevation angle is decreasing with increasing night coverage. The sun elevation angle is -7.7 degrees at night coverage 50%. Thus, the sun elevation threshold was defined as -8 degrees approximately.
Figure 6 shows the relationship between the NSIP and sun zenith angles threshold in cosine. This graph was created from statistical average of dark night images of from 1st - 3rd and 14th – 31st January 2009 except moonlit cloudy images, 4th - 13th January. This figure shows that if the sun zenith threshold is increase more than -0.2, the NSIP increased exponentially. The sun zenith threshold -0.3 was too below and led to eliminate day pixels with even meaningful night pixels. Thus the sun zenith threshold was defined as -0.25 to create perfect dark night image. However, some fishing boats lights could be found within the sun illumination (Figure 7.), thus for this practical use, the sun zenith threshold was determined as -0.15.

Another mosaic datasets were created for checking the applicability of the thresholds, the sun elevation threshold was -8.0 degrees and the sun zenith was -0.25. The April’s datasets of 1995, 1999, 2001, 2005 and 2008 were created and output mosaic image was checked visually. The April’s orbit had partially illuminated by sun, so it was checked if these sun illuminated pixels were eliminated well. Meanwhile, the remains of sun glare pixels which occurred by scattered sunlight entered OLS telescope were found and were highly visible in the images. The result is showed in Table. The sun glares were found in F12 and F15 satellite images and could not be removed by sun zenith threshold method. Thus, to improve the methodology, to remove the sun glare is the future challenge.

![Graph](image)

Figure 5. The relationship between sun elevation and night coverage from statistics of January 2009 OLS data

<table>
<thead>
<tr>
<th>sun_elevation(degrees)</th>
<th>night coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
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<table>
<thead>
<tr>
<th>Num. of averaged SIP</th>
<th>sun zenith threshold (cos)</th>
</tr>
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<tbody>
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<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

\[
y = -7E-05x^3 + 0.0113x^2 - 0.7356x + 9.537
\]

\[
R^2 = 0.9869
\]
Table 7. Yearly mosaic results of F12 and F12, F14, F15, F16, and F17 satellites. Image quality:

<table>
<thead>
<tr>
<th>dates</th>
<th>year</th>
<th>used satellites</th>
<th>Image quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 1–30</td>
<td>1995</td>
<td>F12</td>
<td>existing sun glare of F12</td>
</tr>
<tr>
<td>Apr. 1–30</td>
<td>1999</td>
<td>F12,F14</td>
<td>fine image (dark night with lights)</td>
</tr>
<tr>
<td>Apr. 1–30</td>
<td>2001</td>
<td>F12,F14,F15</td>
<td>existing sun glare of F15</td>
</tr>
<tr>
<td>Apr. 1–30</td>
<td>2005</td>
<td>F14,F15,F16</td>
<td>fine image (dark night with lights)</td>
</tr>
<tr>
<td>Apr. 1–30</td>
<td>2008</td>
<td>F15,F16,F17</td>
<td>sun glare appearing partially</td>
</tr>
</tbody>
</table>
4. Conclusions

A methodology to create the DMSP-OLS nighttime mosaic image was developed for monitoring fishing boats. For this purpose, near real-time processing is important. This methodology is a simple and fast processing to generate operational products using the TeraScan system. The main feature of this method is selecting night orbit files using sun elevation of the image center and eliminating the sun illumination using sun zenith angles for each pixel. The output image shows Earth surface lights without sun illumination. The threshold angles were
defined as -8.0 and -0.15 in sun elevation and sun zenith respectively. The sun illumination could not be eliminated enough but we set these thresholds, because some fishing boat lights are found in sun illuminated area. The sun zenith angle threshold could be set between -0.15 to -0.25 depending on their use purpose. The sun glare removal is remained as a future challenge.

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References


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