졸업논문청구논문

SeaWiFS 해색 자료를 이용한 동해에서의 chlorophyll-a 농도 분석 : LAC 자료와 GAC 자료의 비교

Analysis of the chlorophyll-a concentration in the Korean East Sea using SeaWiFS ocean color data : comparison between the LAC data and the GAC data

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1. 이 논문은 내가 직접 연구하고 작성한 것이다. □
2. 인용한 모든 자료(책, 논문, 인터넷자료 등)의 인용표시를 바르게 하였다. □
3. 인용한 자료의 표현이나 내용을 왜곡하지 않았다. □
4. 정확한 출처제시 없이 다른 사람의 글이나 아이디어를 가져오지 않았다. □
5. 논문 작성 중 도표나 데이터를 조작(위조 혹은 변조)하지 않았다. □
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A thesis submitted to the Gyeonggi Science High School in partial fulfillment of the requirements for the graduation. The study was conducted in accordance with Code of Research Ethics.*

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*Declaration of Ethical Conduct in Research: I, as a graduate student of GSHS, hereby declare that I have not committed any acts that may damage the credibility of my research. These include, but are not limited to: falsification, thesis written by someone else, distortion of research findings or plagiarism. I affirm that my thesis contains honest conclusions based on my own careful research under the guidance of my thesis advisor.

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Analysis of the chlorophyll-a concentration in the Korean East Sea using SeaWiFS ocean color data : comparison between the LAC data and the GAC data

Abstract

다시 번역 The seasonal variability chlorophyll-a concentration in the Korean East Sea had been obtained by processing SeaWiFS Local Area Coverage(LAC) and Global Area Coverage(GAC) oceancolor data from January 2003 to December 2006. Both data showed similarities in the tendency showing peaks on spring(April) and fall(November). However, the value of chlorophyll-a concentration was different, the maximum/minimum value of LAC and GAC data each being 1.61 mg/m3 / 0.28 mg/m3, and 1.72 mg/m3 / 0.32 mg/m3. Comparing the pixel histogram of LAC and GAC data showed GAC data had more speckle errors. The pixel analysis of chlorophyll-a concentration data on April, 2003 also showed it is more accurate to use LAC data because of its high resolution.

SeaWiFS 해색 자료를 이용한 동해에서의 chlorophyll-a 농도 분석 : LAC 자료와 GAC 자료의 비교

초 록

SeaWiFS LAC (Local Area Coverage) 및 GAC (Global Area Coverage) 자료를 이용하여 2003년 1월부터 2006년 12월까지 동해의 chlorophyll-a 월평균 농도를 산출하였다. 두 자료 모두 봄철(4월)과 가을철(11월)에 월평균 농도가 높게 산출되어 전체적인 경향은 비슷하게 나타났다. 그러나 LAC와 GAC 자료로 산출한 chlorophyll-a 월평균 농도의 최대값/최소값은 각각 1.61 mg/m^3 / 0.28 mg/m^3 과 1.72 mg/m^3 / 0.32 mg/m^3 으로 차이가 나타났다. 차이를 구체적으로 분석하기 위하여 LAC와 GAC 데이터의 픽셀 히스토그램을 비교한 결과 GAC 데이터에서 스펙클 오류가 더 크게 나타남을 확인하였다. Chlorophyll-a 월평균 농도가 높았던 2003년 4월 이미지 픽셀을 분석해 본 결과 해상도가 높은 LAC 자료를 이용하는 것이 GAC 자료를 이용하는 것 보다 더 정확함을 확인하였다.

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I. Introduction

Algae is an important factor in the marine ecosystem. It adds oxygen to water by photosynthesis, and it also determines the water transparency. However, when nutrients are oversupplied, eutrophication occurs causing overgrowth of algae in water. Such phenomenon is called as algal bloom. It blocks sunlight and also consumes lot of oxygen when it dies and decomposes, causing a negative effect on the marine environment. In addition, measuring the amount of algae in the water is crucial.

Ocean color remote sensing allows us to indirectly measure various matters in the ocean. The Coastal Zone Color Scanner (CZCS) that is the first ocean colour sensor, operated from 1978 to 1986 and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) has observed global ocean colour distributions for about a decade, from 1998 to 2010, and has provided the scientific community with abundant information for a variety of oceanic application research [1, 2].

It collects several bands of reflected light from the ocean, which can be calculated to amount of matters using developed algorithms. The data we obtain from such methods is called ocean color data. Ocean color data is important in understanding the temporal and spatial distribution of algae [3].

Chlorophyll-a concentration can be calculated using ocean color remote sensing. Since chlorophyll-a is a pigment that is required for photosynthesis, it is also found in algae. Additionally, chlorophyll-a concentration is used as a determinant for the amount of algae in ocean [4].

There have been several studies about chlorophyll-a concentration in the Korean East Sea, using ocean color remote sensing. Spring bloom and fall bloom were observed, showing a seasonal pattern. The chlorophyll-a concentration was also found to be related with wind, sea surface temperature, and many other variables of the ocean [5]. SeaWiFS(Sea-Viewing Wide

Field-of-View Sensor) satellite is often used for studying the chlorophyll-a concentration in the Korean East Sea. It was found to have small areas with abnormally high concentration of chlorophyll-a compared to the areas nearby, which is called speckles. There had been studies to correct this error [6].

SeaWiFS creates two types of level 1 data with different spatial resolutions, Local-Area Coverage(LAC) data and Global-Area Coverage(GAC) data. Level-1 data is a data that had gone through radiometric and geometric calibration. LAC is created with full-resolution(1.1km) for local area while GAC is created with low resolution(4.5km) for a global area. They both use the OC4 algorithm and the color index algorithm to be converted to level-2 chlorophyll-a concentration data. Level-2 data is a data of geophysical variables processed from level-1 data.

(LAC와 GAC 차이를 좀 더 자세히 적고 인용표시)

Although many scientists used SeaWiFS LAC data and GAC data for research, they did not found which is more suitable. There is also no proof that applying same algorithms will give both accurate results.

The goal of this research are the followings. First, observing the chlorophyll-a concentration variability in the Korean East Sea from 2003 to 2006 using SeaWiFS ocean color data. Second, comparing the chlorophyll-a concentration data of LAC and GAC to find the effect of spatial resolution.

II. Methodology

2.1 Acquiring SeaWiFS data

This research used SeaWiFS ocean color data to derive chlorophyll-a concentration since SeaWiFS is a satellite that was created to collect global ocean biological data. Moreover, SeaWiFS creates data with two different resolutions that can be compared. However, research on recent years is not possible since SeaWiFS had been activating from September 1997 to December 2010. Table 1. shows the mission charactoristics of SeaWiFS and Table 2 shows the Cahracteristics of the SeaWiFS ocean color sensor [2].

Table 1. The mission characteristics of SeaWiFS.

. Orbit Type	Sun Synchronous at 705 km
Equator Crossing	Noon +20 min, descending
Orbital Period	99 minutes
Swath Width	2,801 km LAC/HRPT (58.3 degrees)
Swath Width	1,502 km GAC (45 degrees)
Spatial Resolution	1.1 km LAC, 4.5 km GAC
Real-Time Data Rate	665 kbps
Revisit Time	1 day
Digitization	10 bits

Table 2. Cahracteristics of the DeaWiFS ocean color sensor.

. Band	Wavelength FWHM[nm]	Saturation Radiance	Input Radiance	SNR
1	402-422	13.63	9.10	499
2	433-453	13.25	8.41	674
3	480-500	10.50	6.56	667
4	500-520	9.08	5.64	640
5	545-565	7.44	4.57	596
6	660-680	4.20	2.46	442
7	745-785	3.00	1.61	455
8	845-885	2.13	1.09	467

The SeaWiFS Level 2 data of chlorophyll-a was downloaded from NASA Ocean Color Web. Processing Level 1 data to Level 2 data was done by NASA, using NASA SeaDAS program. NASA SeaDAS uses two algorithms to create chlorophyll-a concentration data from the Level 1 data of remote sensing reflectance(R_{rs}); these algorithms are the OCx band ratio algorithm and the color index(CI) algorithm of Hu. The OCx band ratio algorithm use the ratio of two bands in a fourth-order polynomial equation in a relation with chlorophyll-a It can be expressed as the following equation 1.

$$\log_{10}(\mathrm{chlor_a}) = a_0 + \sum_{i=1}^{4} a_i \log_{10}\left(\frac{(R_{rs}(\lambda_{blue})}{(R_{rs}(\lambda_{green})}\right)^{i} \tag{1}$$

The coefficients a_0 - a_4 are values for each sensor acquired from experiments. The OCx algorithm was proved to be accurate by O'Reilly et. al [4]. The CI algorithm uses three bands and can be expressed as the following equation. The λ_{blue}, λ_{green}, λ_{red} are wavelengths closest to 443 nm, 555 nm and 670 nm, different for each sensor. According to Hu, C., Lee, Z., and Franz, B., for the lower concentration of chlorophyll-a (less than 0.25 mg/m^3), it is more accurate to use CI algorithm [7]. The NASA SeaDAS software uses CI algorithm for chlorophyll retrievals below 0.15 mg/m^3, and OCx band ratio algorithm for retrievals above 0.2 mg/m^3. For the concentration between 0.15 mg/m^3 and 0.2 mg/m^3, it blends both algorithm. The area of interest was chosen as 32.31°N - 45.00°N, 126.74°E - 135.00°E which covers the whole East Sea near Korea. The Yellow Sea is not covered in this research because it is too shallow for the algorithms to be applied. The dates of the data were chosen from the year 2003 to 2006. This is because from 2007, the number of data files decreases significantly due to the errors generated in the satellite.

2.2 Deriving Chlorophyll-a Concentration using LAC data and GAC data

NASA SeaDAS is used to process the level 2 data of chlorophyll-a to level 3 data of monthly-mean/ 8-day-mean of chlorophyll-a concentration data. Monthly-mean data is created to show the overall tendency, while 8-day-mean data is created to see more specific tendency. Simple average method had been used to create the mean files. This method sum pixel values of chlorophyll-a at the same location and divide it by the number of data that has been compiled. This process also gives latitude longitude value to the pixels, creating a Standard Mapped Image(SMI). Chae, H. J., & Park, K. (2009) used weighted average method to process data. However, according to Park, K. A., Park, J. E., Lee, M. S., & Kang, C. K. (2012), both the weighted average method and the simple average method are suitable for processing SeaWiFS data in East Sea. In addition, we use the more general method which is the simple average method. Since running each process using SeaDAS is inconvenient, so we automate the process by using python batch processing. This commands SeaDAS to repeat the process. Python can also create png files from the SMI. We use the obtained monthly-mean and 8-day-mean data to find the annual variability of chlorophyll-a concentration. The effect of spatial resolution on the data was also progressed. The histograms for chlorophyll-a concentration were compared between LAC data and GAC data. Then, the SMI data itself was enlarged to find the difference between them.

III. Results

3.1 The Annual Variability of Chlorophyll-a Concentration in the Korean East Sea

The annual variability of chlorophyll-a concentration in the Korean East Sea from 2003 - 2006 is shown in Figure 1, Figure 2. Both the LAC data and the GAC data has similar tendency, showing peaks on spring(April) and fall(November). The maximum/minimum value of LAC and GAC data was each 1.61 mg/m^3 / 0.28 mg/m^3, and 1.72 mg/m^3 / 0.32 mg/m^3. The difference between the two data was not ignorable. This infer that the effect of spatial resolution on the data has to be considered.

The annual variability of 8-day-mean chlorophyll-a concentration in the Korean East Sea from 2003 to 2006 is shown in Figure 3, Figure 4. This result allowed more concrete analysis of the data. The spring peak had 1.2 - 1.3 mg/m^3 of chlorophyll-a concentration and was higher than the fall peak which had the value of 0.9 - 1.0 mg/m^3. Winter had a higher concentration (0.6 mg/m^3) compared to summer (0.4 mg/m^3). The chlorophyll-a concentration in the Korean East Sea had clear seasonal differences. Both the LAC data and the GAC data was sufficient to show the seasonal differences. However, even though the 8-day-mean data was created using average of 4 years, the time of maximum concentration was different.

Part of the LAC data (2004 46th 8-day-mean, 2005 11th 8-day-mean, 2005 31th 8-day-mean) had been lost due to satellite failures. The data for these dates were substituted with the average of the adjacent data. This did not have a significant effect on the tendency, so the error was ignorable.

Figure 1. The annual variability of monthly-mean chlorophyll-a concentration in the Korean East Sea from 2003 to 2006, (a) LAC (b) GAC.

The monthly-mean chlorophyll-a concentration of LAC from 2003 to 2006 is shown in Figure 3 and Figure4. The monthly-mean chlorophyll-a concentration of GAC from 2003 to 2006 is shown in Figure5 and Figure6. The grey area is land showing Korea at the west and Japan at the southeast. Red means high concentration than the blue as it can be told from the color bar. Spring (March, April, May) and fall (October, November) show high concentration. The black area is part with no data due to cloud coverage or satellite failures.

Figure 2. The annual variability of 8-day-mean chlorophyll-a concentration in the Korean East Sea, (a) LAC (b) GAC. Each 8-day-mean data is average of data from 2003 to 2006.

3.2 The Effect of Spatial Resolution on the Data

To find the effect of spatial resolution on the data, we compare the histograms of LAC data and the GAC data of April, 2003. We find that the histogram of GAC data shows more discontinuous shape compared to the LAC data in Figure9. From the fact that a histogram of real data has continuous shape, it can be inferred that using LAC data is more accurate than using GAC data. The histogram of GAC data also shows more pixels with over $\mathrm{mg/m^3}$ of chlorophyll-a concentration with sporadic distribution. These pixels are the speckles from previous researches (Chae, H. J., and Park, K., 2009; Hu, C., Carder, K. L., and Muller-Karger, F. E., 2001) also showing that LAC data is more appropriate for studying chlorophyll-a concentration.

In Figure10, part of the data with high chlorophyll-a concentration is enlarged to compare between LAC data and GAC data. LAC data has 6 pixels over $\mathrm{mg/m^3}$, while GAC data has more than 100 pixels over 10 $\mathrm{mg/m^3}$. Such result occurs since one high-concentration value in GAC data affects a large area compared to LAC because of its low resolution. In Figure11, part of the data with speckles is enlarged to compare between LAC data and GAC data. GAC data has a larger size of speckle because it has low resolution. In other words, it has more errors. Even if the speckles of the GAC data has been corrected, it will correct larger area compared to LAC causing a larger gap between the real value. In addition, even with the speckle correction applied using corrected LAC data will be more accurate.

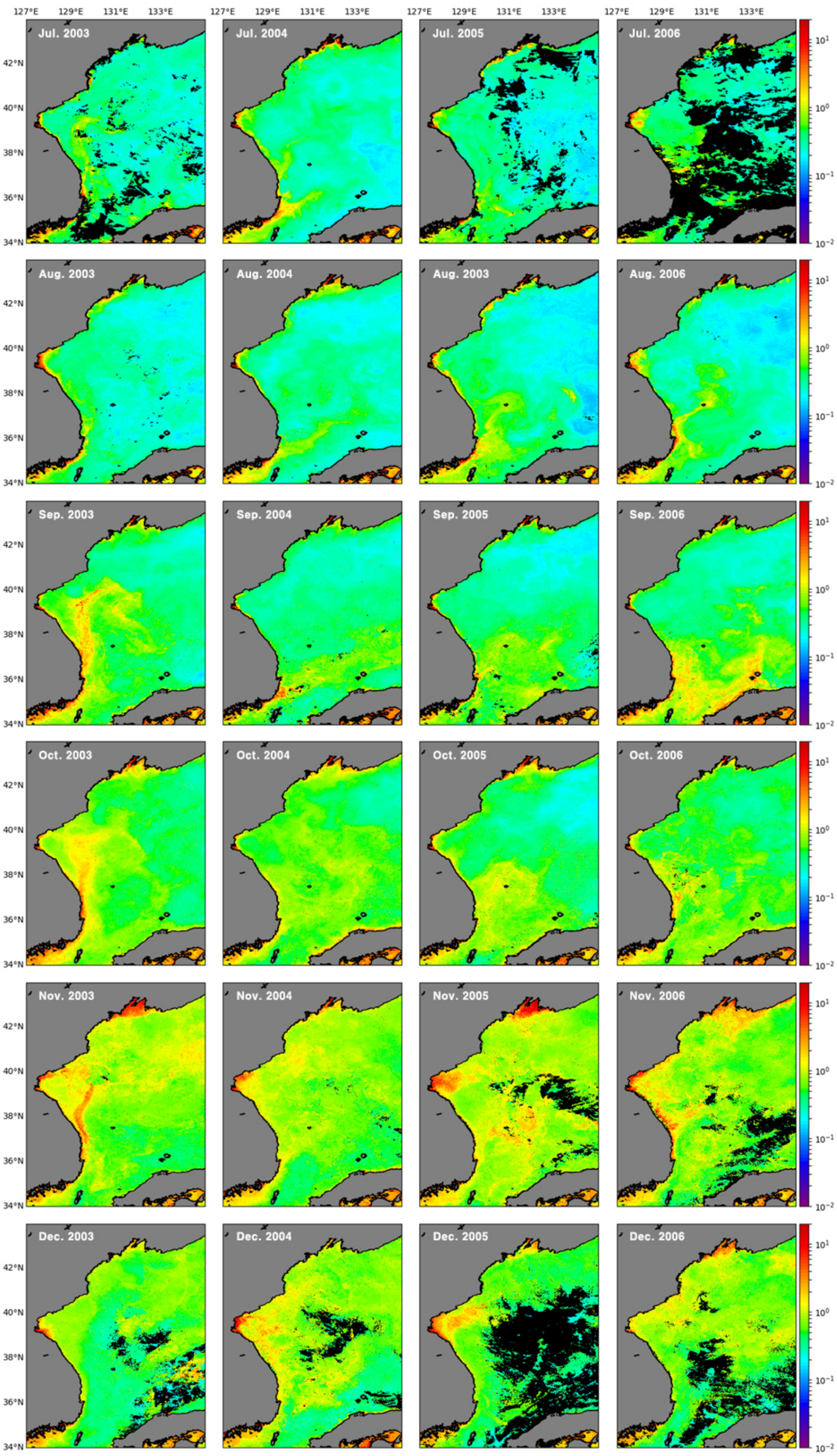

Figure 3. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

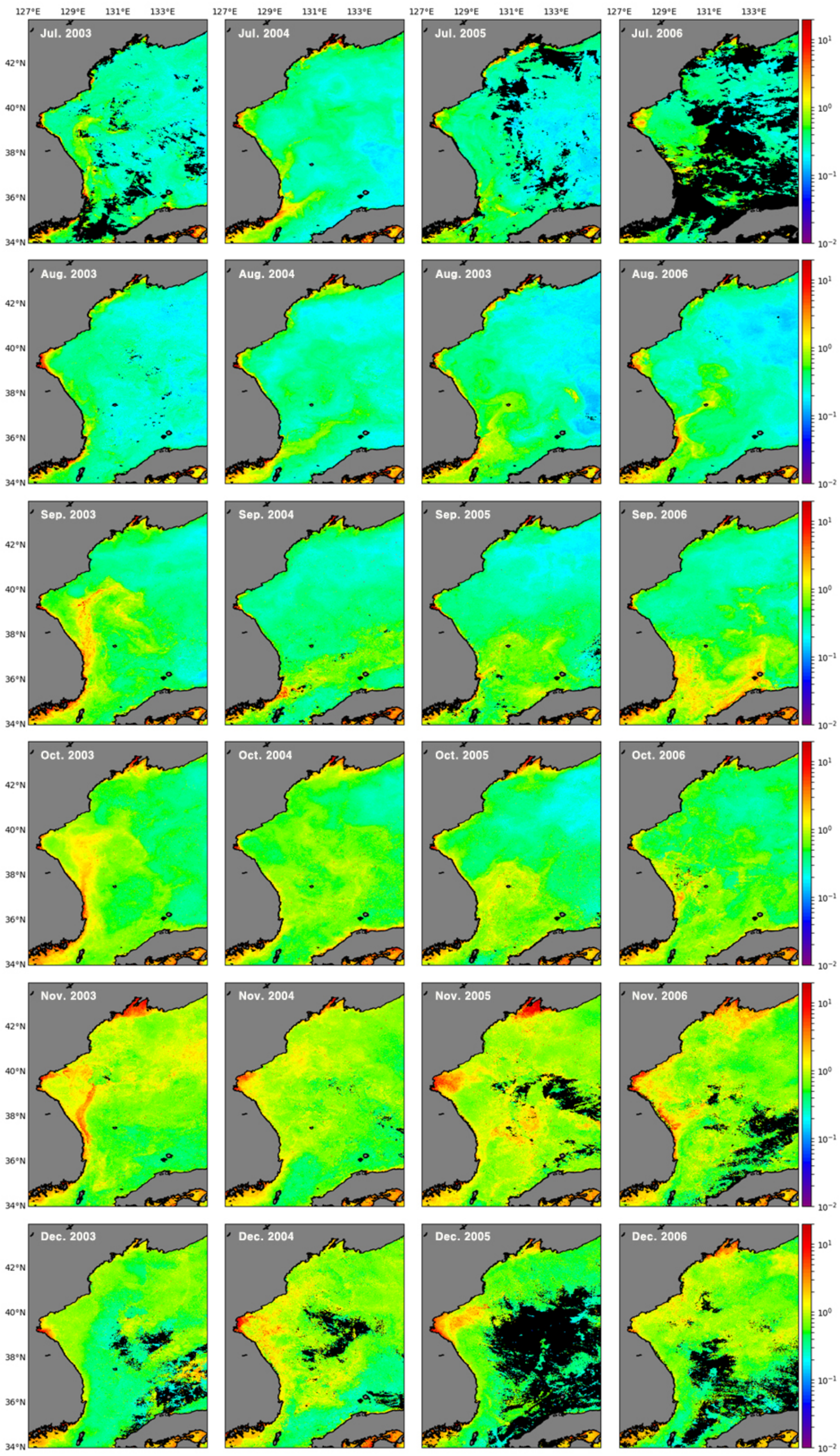

Figure 4. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

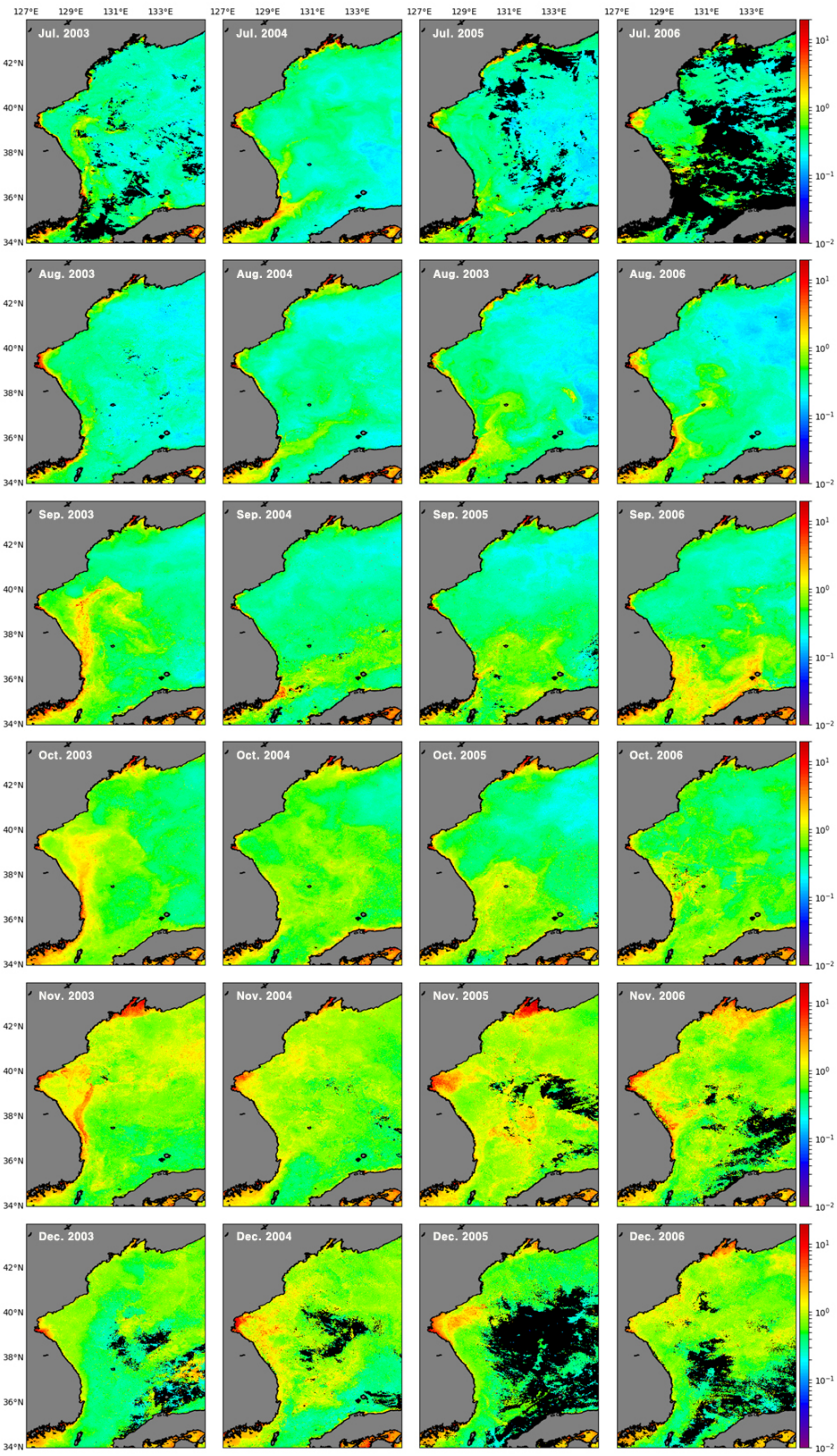

Figure 5. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

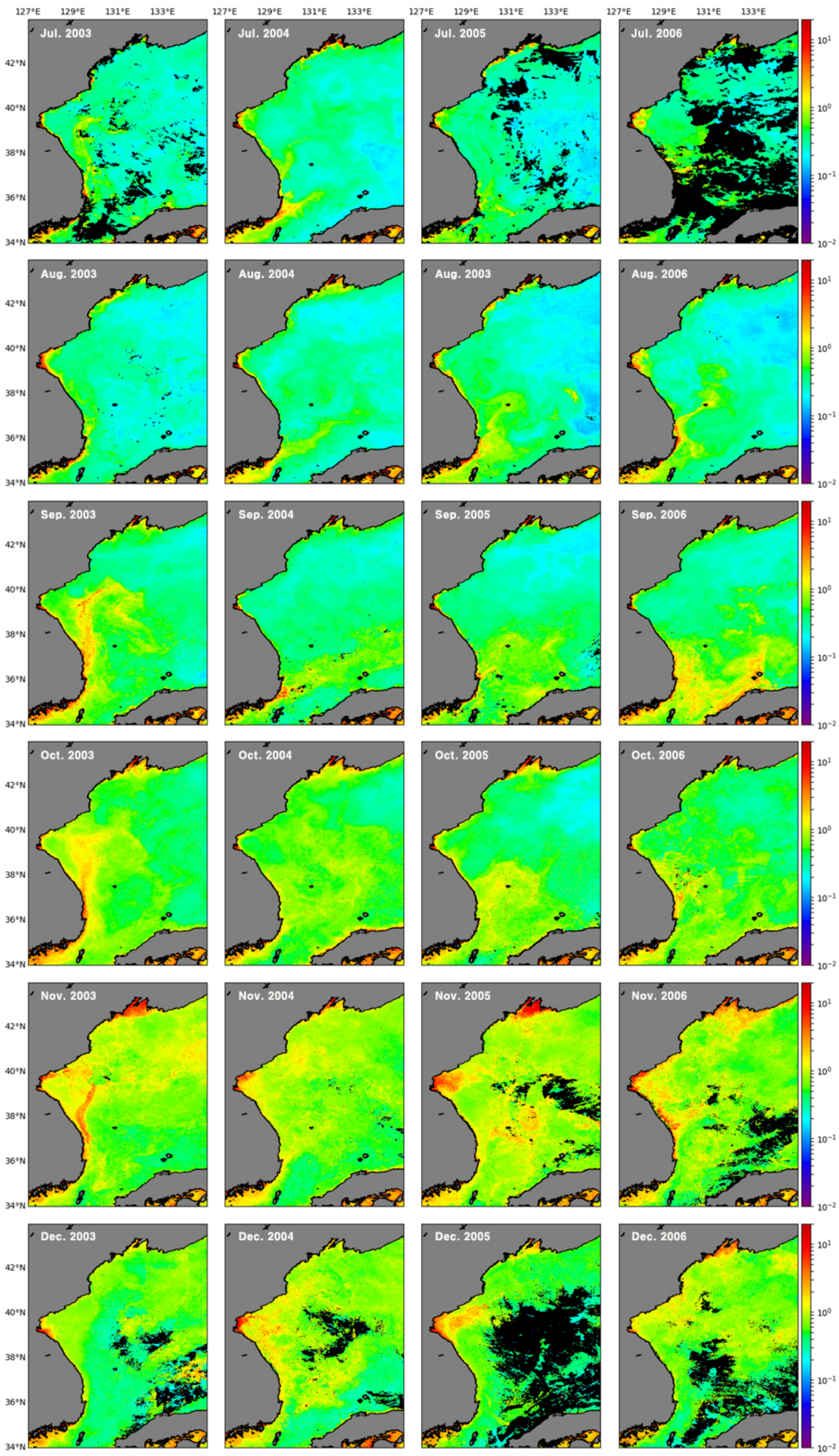

Figure 6. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

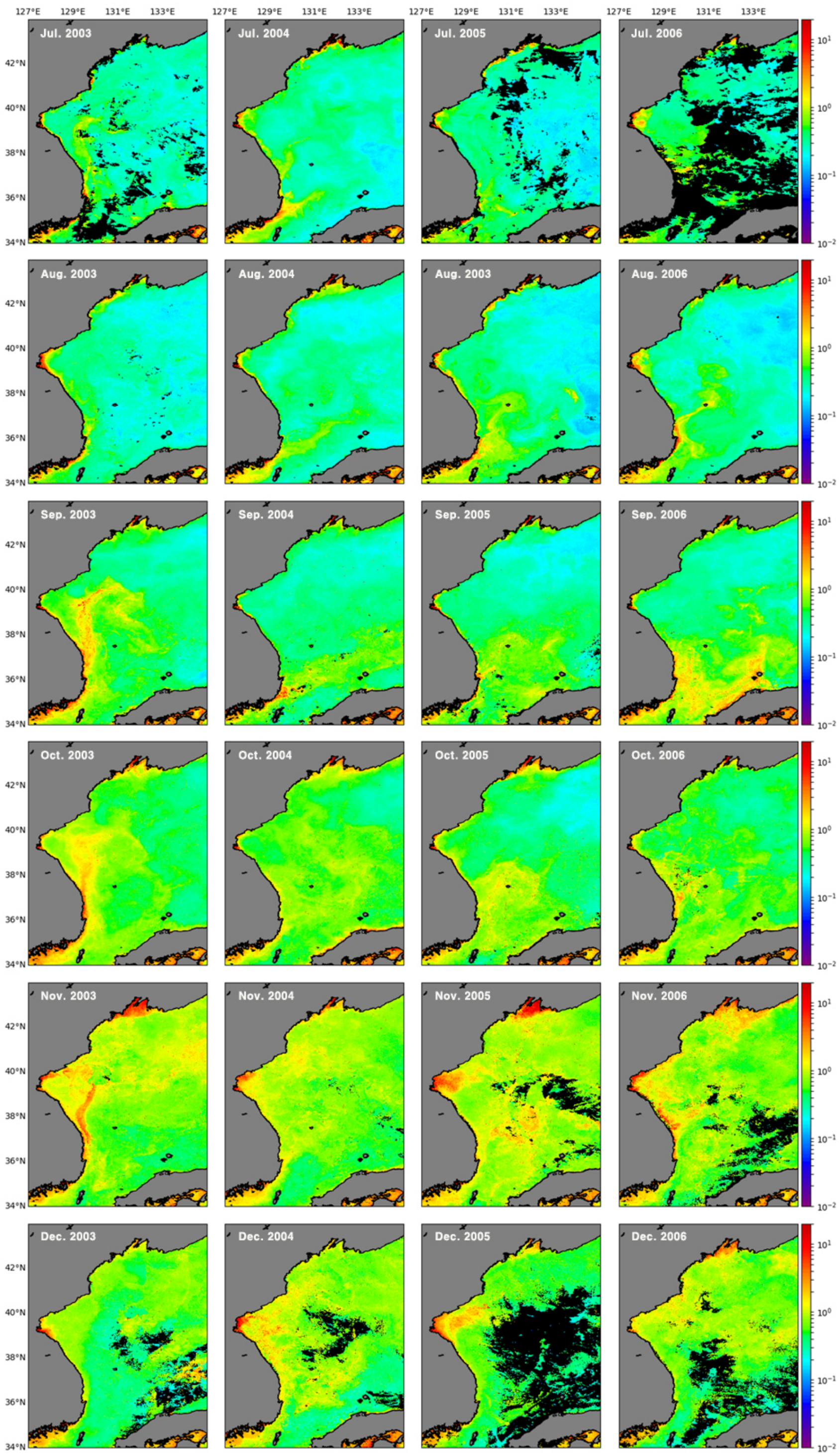

Figure 7. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

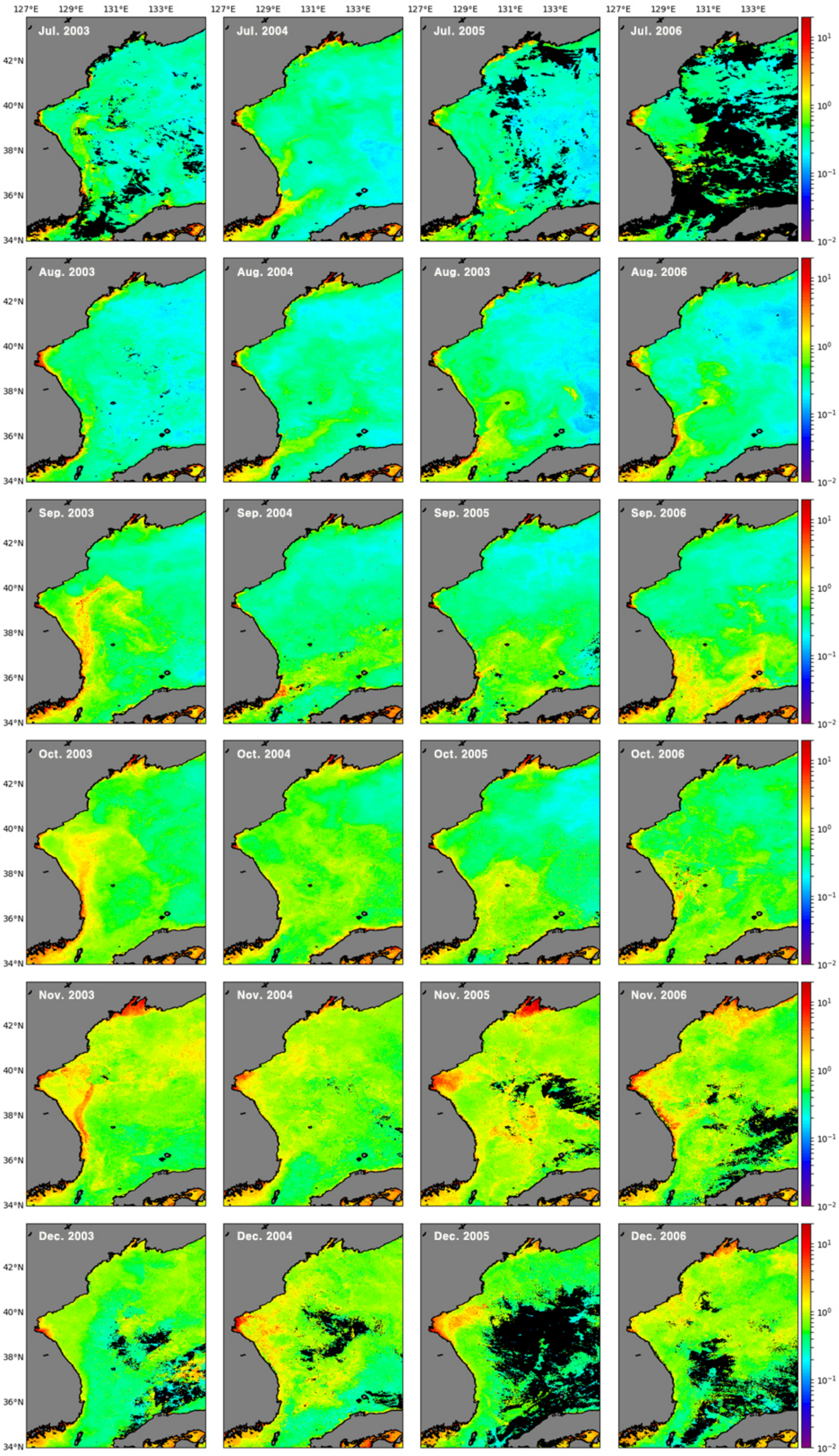

Figure 8. The monthly-mean chlorophyll-a distribution in the Korean East Sea, LAC. From 2003 to 2006, January to June. The unit of the color bar is mg/m^3.

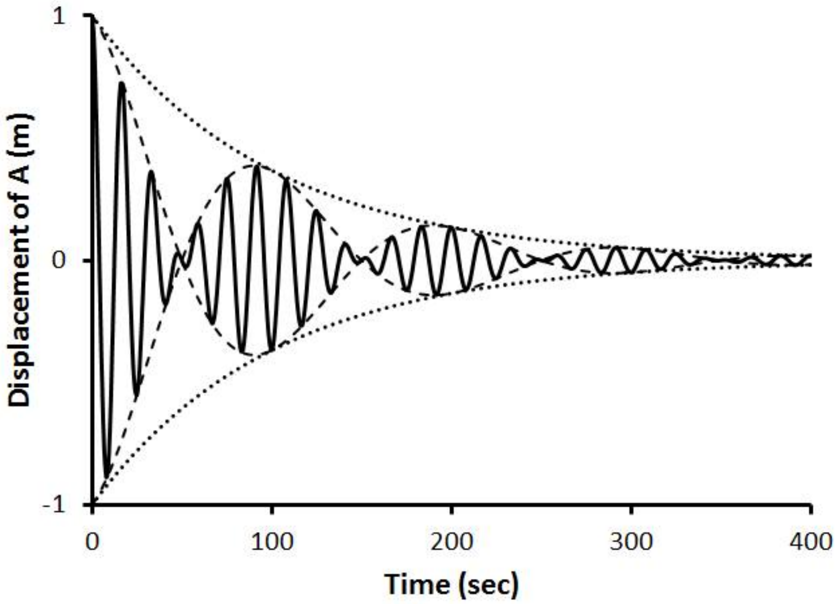

Figure 9. The monthly chlorophyll-a mean histogram in the Korean East Sea on April, 2003, (a) LAC (b) GAC.

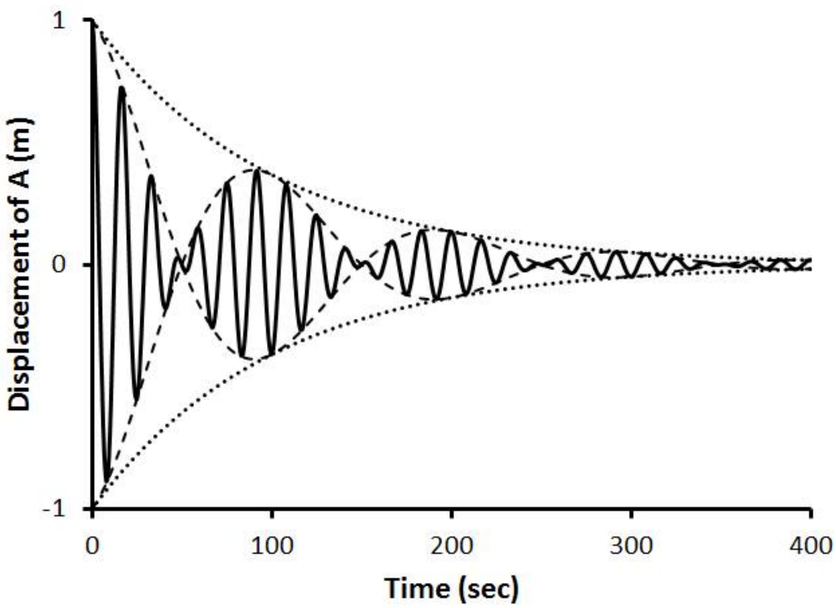

Figure 10. The monthly chlorophyll-a mean distribution in the Korean East Sea on April, 2003, (a) LAC (b) GAC. Enlarged an area with high concentrations of chlorophyll-a.

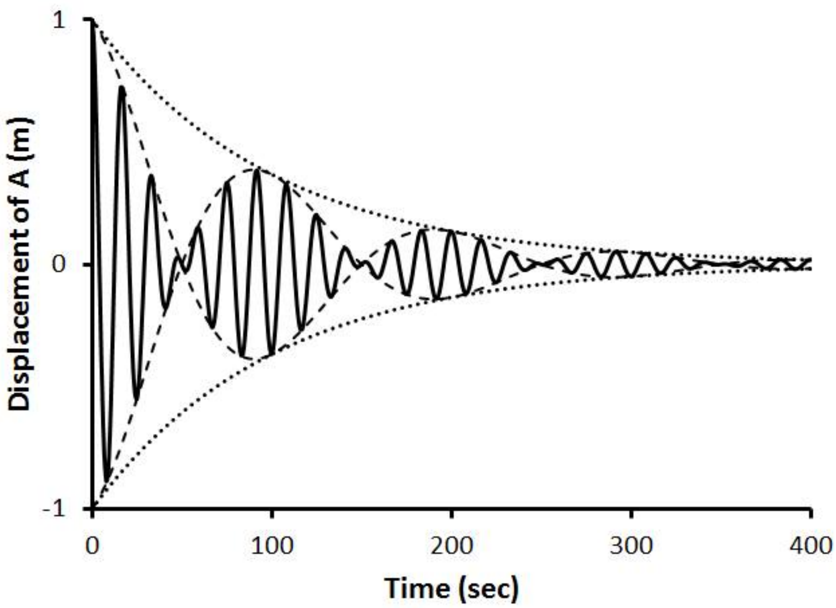

Figure 11. The monthly chlorophyll-a mean distribution in the Korean East Sea on April, 2003, (a) LAC (b) GAC. Enlarged an area with speckles.

IV. Discussion

Spring(April) and fall(November) each had 1.2 - 1.3 mg/m^3, 0.9 - 1.0 mg/m^3 of chlorophyll-a concentrations which was higher than the other seasons showing similarities with the result of Yamada, K., Ishizaka, J., Yoo, S., Kim, H. C. and Chiba, S. [5]. Analysis of annual variability with the temporal resolution increased to 8-day-mean data showed winter (December, January, February) had higher concentration compared to summer (June, July, August), each with the values of 0.6 mg/m^3 and mg/m^3. This conclude that the Korean East Sea shows clear seasonal differences.

In a perspective of spatial resolution, both the LAC data and the GAC data were suitable for research on the chlorophyll-a concentration variability in the Korean East Sea. However, histogram analysis showed that GAC data had more speckles compared to LAC data. The pixel analysis of chlorophyll-a concentration data on April, 2003 also showed that even with the speckle correction it is more accurate to use LAC data because of its high resolution.

The limit of this research is that speckle errors were not corrected causing the concentration values to be higher than the in-situ data. Moreover, the in-situ data of the area of interest was not measured in this research so it could not directly show whether the LAC data or the GAC data is more accurate. Further research will compare the processed data of LAC and GAC with the in-situ data from previous researches.

References

[1] Kyung-Ae Park, Hwa-Jeong Chae, J.-E. P. (2013). Characteristics of satellite chlorophyll-a concentration speckles and a removal method in a composite process in the east/japan sea. *International Journal of Remote Sensing*, *34*(13), 635–651.

[2] (1992). *An Overview of SeaWiFS and Ocean Color*.

[3] Kim, H.-c. (2006). (a) study of surface chlorophyll variation in the korean east sea using ocean color remote sensing data.

[4] O'Reilly, J. E., Maritorena, S., Siegel, D. A., O'Brien, M. C., Toole, D., Mitchell, B. G., . . . et al. (2000). Ocean color chlorophyll a algorithms for seawifs, oc2, and oc4: Version 4. *SeaWiFS postlaunch calibration and validation analyses, Part*, *3*, 9–23.

[5] Yamada, K., Ishizaka, J., Yoo, S., Kim, H.-c., & Chiba, S. (2004). Seasonal and interannual variability of sea surface chlorophyll a concentration in the japan/east sea (jes). *Progress in oceanography*, *61*(2), 193–211.

[6] Chae, H.-J., & Park, K. (2009). Characteristics of speckle errors of seawifs chlorophyll-α concentration in the east sea. *Journal of the Korean earth science society*, *30*(2), 234–246.

[7] Hu, C., Lee, Z., & Franz, B. (2012). Chlorophyll aalgorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference. *Journal of Geophysical Research: Oceans*, *117*(C1).

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