Evaluation Method for Geometric Correction Accuracy of Geostationary Environment Monitoring Spectrometer Images

Choi S.[1], Ban S.[2] and Kim T.[3*]

[1]Master Student, Department of Geoinformatic Engineering, Inha University, Republic of Korea

[2]PhD Student, Department of Geoinformatic Engineering, Inha University, Republic of Korea

[3]Professor, Department of Geoinformatic Engineering, Inha University, Republic of Korea

*tezid@inha.ac.kr

1. Introduction

Geostationary Environment Monitoring Spectrometer(GEMS) is the world's first geostationary hyperspectral sensor and is currently operating on GEO-KOMPSAT-2B satellite. The GEMS has a spatial resolution of 7 km x 8 km, an imaging area of 5,000 km x 5,000 km, and 1,033 spectral bands (Kim et al., 2020). It plays a crucial role in the analysis and monitoring of climate and atmospheric conditions in the East Asian region. To ensure accurate observation of the satellite images, geometric correction is essential to eliminate positional errors. Additionally, to enhance the reliability of the analysis, verifying the accuracy of the geometric correction is necessary. However, due to the GEMS' low spatial resolution, spectral characteristics, and factors such as clouds, traditional geometric accuracy verification methods using landmarks are difficult to apply. Therefore, this study aims to establish an efficient method for evaluating the geometric correction accuracy of GEMS images. Experiments utilized Advanced Meteorological Imager (AMI) images from GEO-KOMPSAT-2A, a meteorological geostationary satellite. The AMI images are being captured at similar times as the GEMS images. Geometric correction accuracy was evaluated by comparing the two images at three scales: global, regional, and local. At the global scale, GEMS images were shifted by -5 to 5 pixels on AMI images, and correlation coefficient values between the two images over the same area were calculated to analyze positional accuracy. The experiment results indicated that when GEMS images were shifted vertically by less than 2 pixels, the correlation between the two images was highest. However, while the general trend of GEMS' geometric accuracy was identifiable, factors such as rotational errors were difficult to assess. At the regional and local scales, normalized cross-correlation based matching was used to analyze the direction and magnitude of positional errors within subregions and local areas. The results showed that the root mean square error(RMSE) between the matched pixel positions was less than 2 pixels on average.

As a result, we were able to confirm the direction and magnitude of positional errors in the images. Based on these geometric accuracy evaluation results, we confirmed that the regional geometric accuracy evaluation method was more suitable for future improvements in geometric correction accuracy and can be applied to such assessments.

2. Materials and Methods

In this study, GEMS Level 1C data from June 1, 2023, to June 21, 2024, with a 10-day interval, were used. For periods where geometric errors occurred, additional daily images were analyzed. Additionally, for AMI images, three Level 1B images captured on the same day as GEMS images were utilized. Specifications for each satellite image are shown in Table 1.

Table 1: Specifications of Satellite Image.

	Spatial Resolution	**Imaging Area**	**Wavelength Range**	**Acquisition Time**
GEMS	7 km x 8 km	East Asia	300-500 nm	Imaging for 30 min
AMI	1 km	Full Disk	470 nm	Imaging for 10 min

To evaluate geometric accuracy among two geostationary satellite images, a collocation process is performed to ensure that GEMS and AMI images, which have different imaging characteristics, are spatiotemporally and spectrally aligned. First, an AMI image captured within 5 minutes of GEMS acquisition time is selected, and AMI pixel values within the latitude and longitude range of GEMS pixels are averaged to perform spatiotemporal collocation between the two images. And GEMS pixel values on channels 200 are weighted using the spectral response function of the AMI VI004 band to match the spectral characteristics of two images.

Comparison is performed through matching at three scales: global, regional, and local, using the two spatiotemporally and spectrally collocated images. The matching process for each scale is described in the following section.

2.1 Global Scale Matching

First, the whole GEMS image extent is shifted in the N-S direction by -5 to 5 pixels. For each shift, correlation coefficients between the shifted GEMS image and corresponding AMI image extent are calculated. The same process is then repeated for shifts in the E-W direction. To analyze temporal trends, this procedure is repeated for images acquired at different time. Finally, the calculated correlation coefficient values are normalized and displayed to facilitate interpretation in graphs. This process enables determining the direction and the amount of positional errors of GEMS images.

2.2 Regional Scale Matching

During the spatiotemporal collocation of GEMS and AMI images, the time frame of AMI images used for collocation varies depending on the acquisition time. Therefore, this study aims to analyze the differences in geometric accuracy across different regions based on varying acquisition times. First, the collocated GEMS and AMI image columns are divided into three sections, considering the total 30-minute acquisition time of GEMS images. Then, within each divided section, pixel errors between the two images are calculated using normalized cross-correlation based matching, and the errors are displayed with different colors based on their magnitude. This approach enables a more detailed analysis of geometric accuracy differences according to the image acquisition times.

2.3 Local Scale Matching

At the local scale, the entire collocated images are not divided into subregions. Instead, small patches are defined across the entire images and location of highest correlation coefficients are searched for at each small patch. Position errors between the two images are calculated and displayed using normalized cross-correlation based matching. This allows for an evaluation of the geometric accuracy across the entire GEMS image.

3. Results

Global scale matching results from June 1, 2023, to July 17, 2023, showed a tendency for a high correlation between the two images when the shift of GEMS image was less than 1 pixel. Additionally, on July 18, 2023, and December 11, 2023, the results differed significantly from the trends before and after. After investigation, the analysis revealed that errors occurred on these dates due to a reboot of the GEMS. From July 19, 2023, to June

21, 2024, the results indicated that the correlation was highest when GEMS images were shifted upwards by 1 to 2 pixels. Below, Figure 1 shows the geometric accuracy trend represented through a graph.

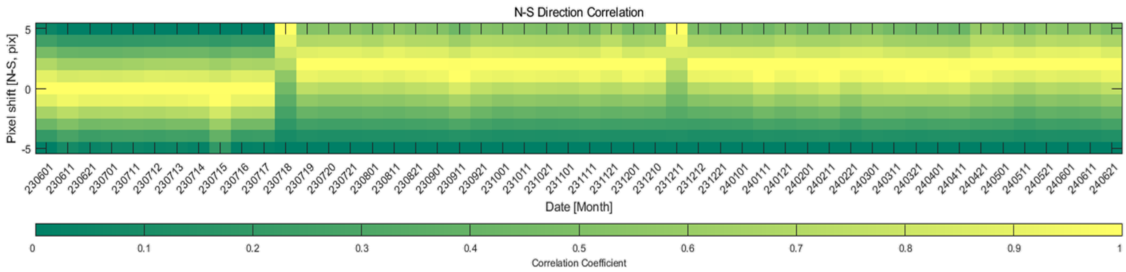
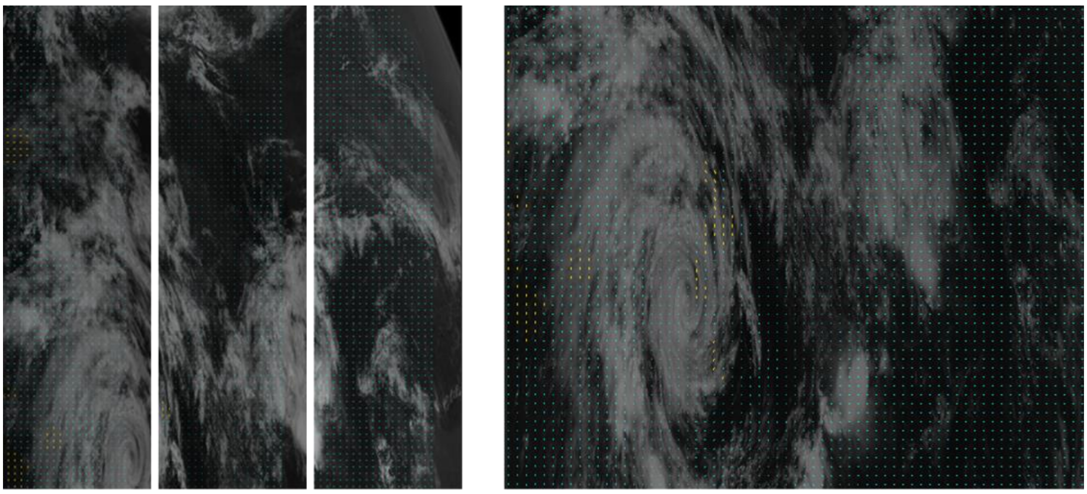


Figure 1: Correlation Results through Global Scale Matching.

The results of matching GEMS images at the regional scale showed RMSE values of 0.72 pixels in the first section, 0.86 pixels in the second section, and 1.04 pixels in the last section. We confirmed that there was a larger error in the matching during the final time period. When the same GEMS image was analyzed using local matching, the RMSE of the entire image was 0.88 pixels, with an error of less than 1 pixel. Additionally, the geometric accuracy evaluation of GEMS images from different time periods revealed that the average error from June 1, 2023, to July 17, 2023, was less than 1 pixel, while from July 18, 2023, to June 21, 2024, the average error increased to around 2 pixels. Figure 2 shows example results of the regional and local scale matching.



(a) (b)

Figure 2: Geometric Accuracy Results. (a) Regional Scale (b) Local Scale

4. Conclusion

In this study, the geometric accuracy of GEMS images was evaluated by comparing them with AMI images using three different matching methods, and the most efficient evaluation method was analyzed. The analysis using the global matching method allowed for the geometric accuracy trends of GEMS time-series data to be intuitively understood at a glance. However, while shifts in errors were identified, factors like rotational elements were difficult to assess. In contrast, the analysis using regional and local matching methods enabled identification of the direction and magnitude of the errors within the images. However, these methods were sensitive to the influence of clouds caused by time differences. Therefore, to achieve a more accurate evaluation of the geometric accuracy of GEMS images, matching and evaluating within regional patches, where the time difference between the two images is significantly reduced, is considered more appropriate.

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References

Kim, J., Jeong, U., Ahn, M., Kim, J. H., Park, R. J., Lee, H. et al., 2020. New era of air quality monitoring from space: Geostationary Environment Monitoring Spectrometer (GEMS). *Bulletin of the American Meteorological Society*, 101(1), E1 – E22. https://doi.org/10.1175/BAMS-D-18-0013.1