Geometric Accuracy Improvement of Geostationary Environment Monitoring Spectrometer by Pixel Offset Adjustment

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Abstract: In this study, we propose a method of improving the geometric accuracy of Geostationary Environment Monitoring Spectrometer (GEMS). We propose to apply a shift offset, whose value is derived using Advanced Meteorological Imager (AMI) data as a reference. After performing collocation processes to align spatiotemporal and spectral characteristics of GEMS and AMI images, GEMS images were shifted within a ±5-pixel range in both vertical and horizontal directions. Correlation coefficients were then calculated through matching shifted GEMS images with collocated AMI images. The shift value at which the correlation coefficient reached its maximum was defined as the optimal offset. This value was then applied to GEMS images to compare geometric accuracy before and after adjustment. Using GEMS data acquired from January 2023 to July 2025, experiment results showed that geometric errors occurred mainly in the north–south direction, with a magnitude of about one pixel. After applying optimal offset, geometric errors were reduced to within one pixel in most cases. These results demonstrate that the proposed shift offset correction method can effectively improve the geometric accuracy of GEMS image.

Keywords: Satellite Image; Geometric Correction; GEMS; AMI; Image Matching

1. Introduction

As environmental issues, such as air pollution and climate change caused by greenhouse gases, continue to grow, the importance of monitoring systems has also increased. In South Korea, Geostationary Environment Monitoring Spectrometer (GEMS), the world's first hyperspectral sensor, was successfully launched aboard the GEO-KOMPSAT-2B in 2020 and is currently in operation (Kim et al., 2020). GEMS provides essential data to support environmental policies and research by observing air pollutants such as NO_2, SO_2, ozone, and formaldehyde on an hourly basis over the East Asia and Southeast Asia regions (Choi et al., 2018). While geostationary satellites like GEMS offer advantage of continuously observing the Earth from an altitude of about 36,000 km, issues such as satellite attitude instability, misalignment between satellite and payload, and thermal deformation can result in positional errors in observed images. If these position errors accumulate, they can reduce the reliability of products and complicate the integration of data from other satellites, making it crucial to remove such errors.

This study proposes a method to evaluate and correct the geometric accuracy of GEMS images using the Advanced Meteorological Imager (AMI) images from another geostationary satellite as a reference. First, to compare the geometric accuracy of GEMS and AMI images with different acquisition characteristics, images are collocated to align their spatiotemporal and spectral properties. The GEMS images are then shifted within a ±5-pixel range in both vertical and horizontal directions and matching between shifted GEMS images and collocated AMI images is performed. For each shift condition, correlation coefficients between the two images are calculated. Pixel shift value that maximizes the correlation coefficient is defined as optimal offset and applied to the GEMS image. Finally, the correlation coefficient is recalculated for the adjusted image, and the geometric accuracy trends before and after correction are evaluated.

Experiment results show that in most cases, the geometric error was reduced to within the target accuracy of one pixel. This confirms that the geometric accuracy of GEMS images can be effectively improved through optimal pixel shift offset adjustment.

2. Methodology

2-1. Collocation Processes

In this study, AMI image was used as reference to evaluate geometric accuracy of GEMS image, and preprocessing was performed to correct acquisition characteristic differences between the two images. Detailed specifications of each sensor are summarized in Table 1.

Table 1: Characteristics of GEMS and AMI images.

Payload	Spatial Resolution	Field of Regard	Spectral Range	Scan Duration
GEMS	7 km x 8 km	East Asia	300-500 nm	30 min
AMI	1 km	Full Disk	440-500 nm	10 min

First, acquisition times recorded in GEMS and AMI image are considered, and only pixels with time difference less than 5 minutes are selected for temporal collocation. Then, since spatial resolution of GEMS and AMI image differs by the factor of 7, multiple AMI pixel values within latitude–longitude extent of one GEMS pixel are averaged to construct corresponding pixel value. Finally, GEMS image is spectrally adjusted to AMI image by applying weighted sum using spectral response function of AMI visible blue band. Through this process, GEMS and AMI image spatiotemporally and spectrally collocated are used for subsequent geometric accuracy evaluation.

2-2. Matching

Through matching, overall trends in geometric accuracy of GEMS images are evaluated, and optimal pixel offset with highest correlation to AMI images is derived. For this purpose, GEMS images are shifted within ±5-pixel range in north–south and east–west directions at 1-pixel intervals. Correlation coefficient is repeatedly calculated for each shift. Correlation is computed only for overlapping area within common extent of two images, excluding edge regions. Shift value at which correlation between images reaches maximum is defined as geometric error. Calculated correlation coefficients for each shift are normalized to range 0–1, allowing evaluation of direction and number of pixels at which similarity between two images is maximized. This analysis enables identification of spatial pattern of GEMS geometric accuracy, as well as intuitive observation of its temporal trend through time-series analysis.

Optimal offset derived for each date is then applied to GEMS images for correction. Afterward, same procedure is repeated to recalculate correlation coefficient, thereby evaluating geometric accuracy before and after correction.

3. Results

Global matching was performed on GEMS data collected daily from 1 January 2023 to 31 July 2025. Analysis showed that geometric error of GEMS images was mainly about one pixel in north–south direction, while remaining stable in east–west direction. In addition, variation was observed where trend of geometric accuracy reversed from +1 pixel to −1 pixel around system reboot events. Nevertheless, throughout entire period, geometric error was generally maintained within 1-pixel range. Figure 1 below shows global matching results before applying pixel shift offset.

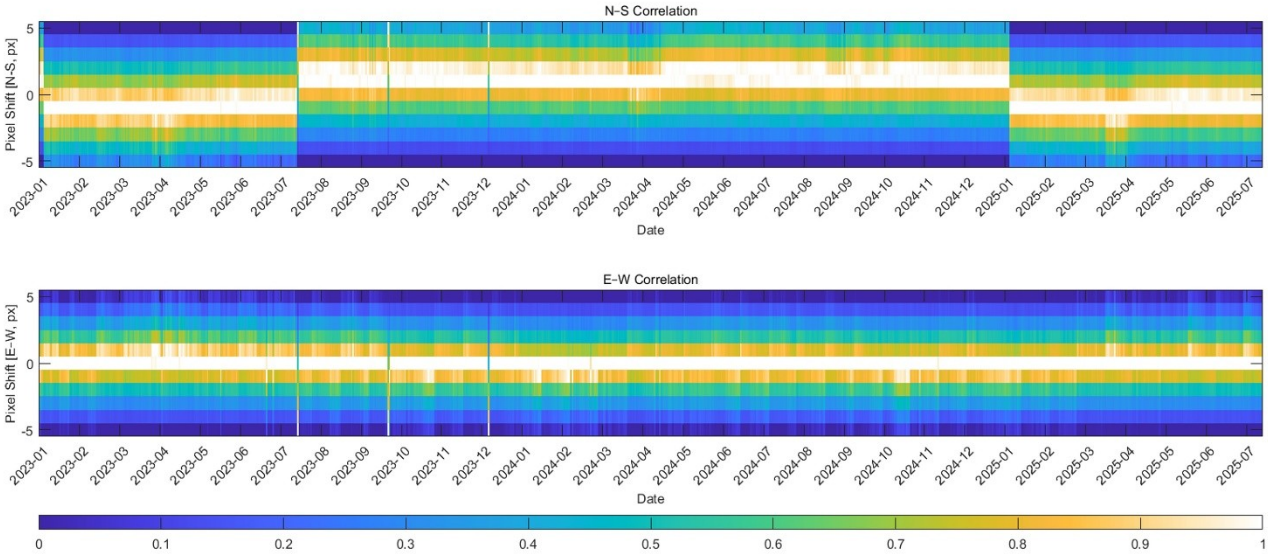

Figure 1: Global matching results before shift offset adjustment.

Optimal pixel shift offsets derived from global matching were applied for each date to correct GEMS images. The offsets were mainly about one pixel in north–south direction. After correction, global matching between corrected GEMS images and AMI images was performed again to re-evaluate geometric accuracy. Recalculated results showed that 1-pixel geometric error repeatedly observed in north–south direction was eliminated, with correlation consistently maximized at zero shift after correction. Geometric error in east–west direction, which had been stable before correction, also remained stable. Figure 2 shows global matching results after pixel shift offset correction.

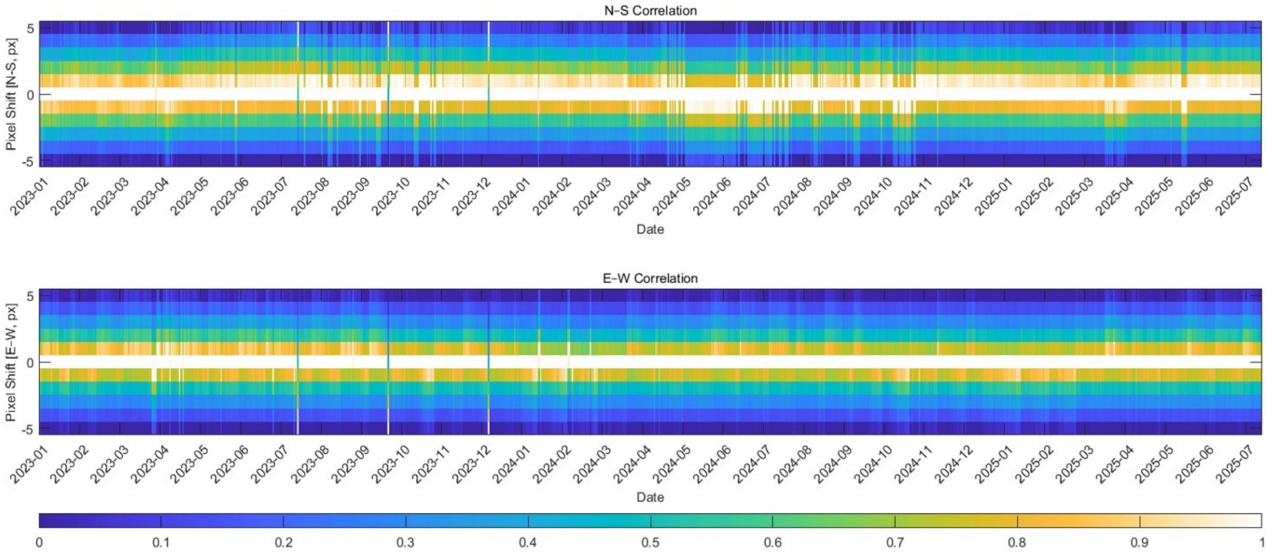

Figure 2: Global matching results after shift offset adjustment.

4. Conclusion

In this study, a shift offset correction method based on global matching results was proposed to improve geometric accuracy of GEMS images using AMI images as reference. After performing spatial, temporal, and spectral collocation between GEMS and AMI images, correlation coefficients were calculated within ±5-pixel range to derive optimal pixel shift offset. Experiment results showed that geometric error of GEMS images was mainly about one pixel in north–south direction, with temporary variations observed after system reboot. However, after applying pixel shift offset for correction, geometric error was improved to within one pixel in most cases. These findings confirm that the proposed shift offset correction method can effectively improve geometric accuracy of GEMS images. It is expected that the proposed method can be practically applied to improve geometric accuracy in future.

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