IOP Conf. Series: Earth and Environmental Science **37** (2016) 012004 doi:10.1088/1755-1315/37/1/012004

Assessment of geometric errors of Advanced Himawari-8 Imager (AHI) over one year operation

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Abstract. This paper presents an approach to check a geometric performance of Advanced Himawari-8 imager (AHI) and demonstrate and evaluate a new approach to ensure more geometric accurately focusing on visible imagery in 500 meters. A series of processing is supplemented by ground control points of shore lines, land mark locations and digital elevation model. Firstly, a template matching technique is conducted to find a best matching point by simply moving the center of AHI sub-image over each point in a reference image of shore lines and calculating the sum of products between the coefficients and the corresponding neighbourhood pixels in the area spanned by the filter mask. Secondly, ortho-rectification processing is carried out to compensate for the geodetical distortions with respect to the acquisition condition including viewing geometry and so on. As a result, an average of root mean square sum of residual errors with system correction and that of precise geometric correction are shown. Overall geometric accuracy is about 1 to 1.5 pixels from 2015 March to July and it also gradually decreased down to 0.2 to 0.8 from 2015 September to 2016 February. AHI is officially open to public for operational use as of July 1, 2015 and after that operation date geometric errors are reasonably satisfied within one pixels of errors.

1. Introduction

Advanced Himawari-8 Imager (AHI) is a Japanese weather satellite for geosynchronous with a three-axis stabilized spacecraft with a meteorological mission. The Japan Meteorological Agency (JMA) contracted for AHI as a successor to MTSAT and GMS series, in cooperation with the Civil Aviation Bureau (CAB), of the Ministry of Transport of Japan [1].

Geostationary satellites such as Meteosat, MTSAT and Geostationary Operational Environmental Satellite (GOES) were designed for meteorological applications. As a consequence, the onboard sensors have very low geometric, radiometric and spectral resolution. Despite these characteristics, during recent years, several studies have used geostationary satellite data for land surface remote sensing application. In most of them, these data have been used to retrieve geophysical parameters used as an input for models GMS data and are very effective to detect burned areas in different tropical environments as well [2].

AHI breaks through limitations of earlier three-axis stabilized GEO instruments with significant improvements in many areas, including spatial sampling, radiometric sensitivity, calibration and performance around local midnight. The process for the automatic detection of Landmarks and Earth Edges has been working operationally for the first image open to public via JMA. The ability to use these data as the basis to determine the satellite orbit and attitude has also been demonstrated [3]. In this sense, it is necessary to have a continuous accurate and timely determination of the satellite orbit and attitude in order to perform geometric correction of Earth images acquired by geostationary meteorological satellites [4].

The objective of this study is to check a geometric performance of AHI imagery and demonstrate and evaluate a new approach to ensure more geometric accuracy focusing on visible imagery in 500 meters from 2015 March to 2016 February.

2. Methodology

2.1. Framework and data used in this study

Figure 1 shows a framework of precise geometric correction of AHI. A time-series of AHI images from March 2015 to February 2016 at 03:00 (UTC) were collected for evaluation and band 3 (red, 0.64μm) with 500-meters footprint was calibrated to a top-of-atmosphere (TOA) reflectance for further processing.

A series of processing is supplemented by ground control points (GCPs) from MODIS MOD44W land-sea mask (LSM), land mark locations (LML) developed for GMS and digital elevation model from shuttle radar topographic mission (SRTM3). LMLs consists of a collection of land marks developed for a geometric correction of Japanese geostationary meteorological satellite (GMS) which was a predecessor of AHI [5]. It consists of 792 locations with latitude and longitude values and are expected to have a sufficient performance on AHI as well which has the same spatial coverage with MTSAT and GMS [6].

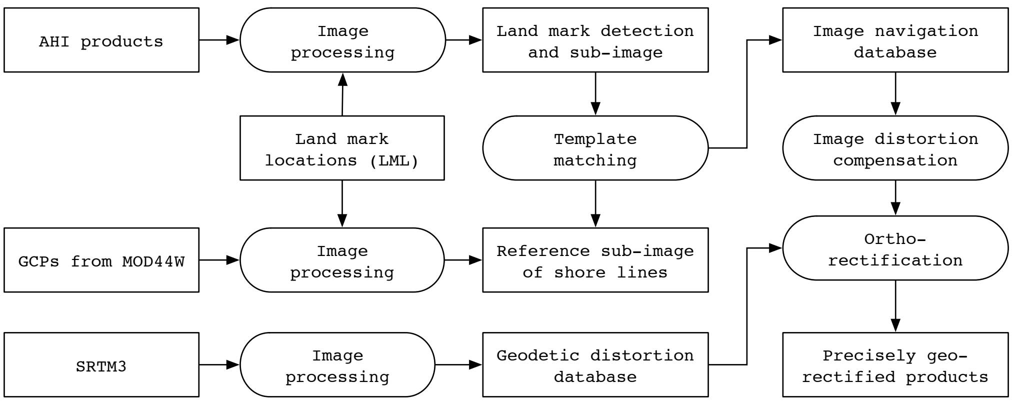

Figure 1. Flowchart of a precise geometric correction of AHI using a template matching technique.

2.2. Sub-image generation and template matching technique

Firstly, a AHI visible image was clipped out into 64 × 64 sub-images centered on 792 LML. Secondly, a suit of sub-images was digitized into a land-sea mask image using a discriminant analysis which enables a dynamic thresholding [7]. Thirdy, shore lines were extracted from LSM database and they were digitized into 128 × 128 sub-images centered on 792 LMLs used as a reference. Finally, a template matching technique was conducted to find a best matching point by simply moving the center of 64 × 64 sub-image over each point in a reference image and calculating the sum of products between the coefficients and the corresponding neighbourhood pixels in the area spanned by the filter mask [8].

2.3. Image distortion compensation and ortho-rectification
Image distortion compensation is conducted by an affine transformation shown as following formula;

$$\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} \quad (1)$$

where x and y values are defined in image coordinates of AHI image and Δx and Δy values are measured by a template matching technique between a AHI sub-image and a reference sub-image derived from shore lines. Then a_{ij} and b_i are computed by a least-squres method over selected cloud-free sub-images by minimizing the sum of the residuals squared. Finally, orthorectification processing is carried out to compensate for the geodetical distortions with respect to the acquisition condition including viewing geometry, platform attitude, Earth rotation and of the relief effects (parallax). It is based on the intersection of viewing direction and the WGS-84 earth ellipsoid using SRTM3 digital elevation model with sufficient accuracy in 500-meters.

3. Results and discussions
Figure 3-(a) shows the number of fine pixels among 796 LSLs which are identified as cloud free and used to detect land mark and generate sub-image from Band 3. It ranges from 5 to 25 LSLs from 2015 March to 2016 February. The number of fine pixels are relatively lower from May to August because of rainy season in monsoon Asian region whereas 20 to 25 LSLs are available from September to October which guarantees higher geometric error compensation reliability. A series of template processing is carried out by using those fine LSLs for the further analysis.

Figure3-(b) shows geometric errors in east-west direction which is obtained from template matching results. Overall geometric accuracy is about 0.7 to 1.2 pixels from 2015 March to July and it gradually decreased down to 0.2 to 0.5 from 2015 September to 2016 February. In July and November, a relatively higher errors more than 2.0 pixels are often found because of less fine GCP's are available for processing as shown in Figure3-(a).

Figure3-(c) shows geometric errors in north-south direction which is obtained from template matching results. Overall geometric accuracy is about 0.2 to 0.5 pixels from 2015 March to July and it also gradually decreased down to -0.2 to 0.2 from 2015 September to 2016 February. In July and November, a relatively higher errors more than 2.0 pixels are often found like those in east-west direction because of less fine GCP's are available for processing as shown in Figure3-(a).

Figure3-(d) shows overall geometric errors which is obtained from root mean square errors from east-west and north-south directions. Overall geometric accuracy is about 1 to 1.5 pixels from 2015 March to July and it also gradually decreased down to 0.2 to 0.8 from 2015 September to 2016 February. AHI is officially open to public for operational use as of July 1, 2015 and after that operation date geometric errors are reasonably satisfied within one pixels of errors.

4. Conclusions and future works
This study was carried out to check a geometric performance of AHI imagery and demonstrate and evaluate a new approach to ensure it more accurately focusing on visible imagery in 500 meters. The ability to use these data as the basis to determine the satellite orbit and attitude has also been demonstrated. Overall geometric accuracy is about 1 to 1.5 pixels from 2015 March to July and it also gradually decreased down to 0.2 to 0.8 from 2015 September to 2016 February. AHI is officially open to public for operational use as of July 1, 2015 and after that operation date geometric errors are reasonably satisfied within one pixels of errors. Extensive modeling and analysis work over one year has shown that good correlation with the true orbit and attitude can be achieved.

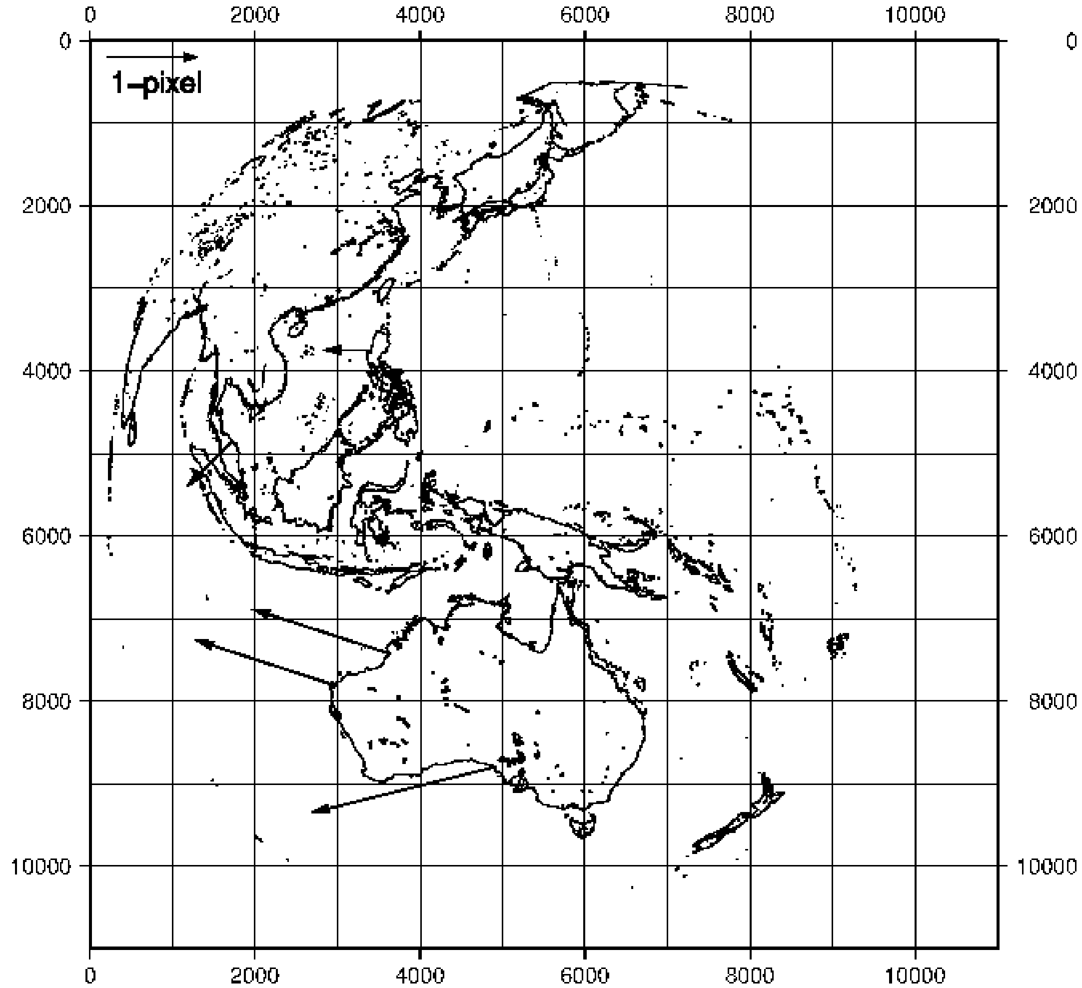

Figure 2. Error vector map of geometric correction on Dec. 18, 2014.

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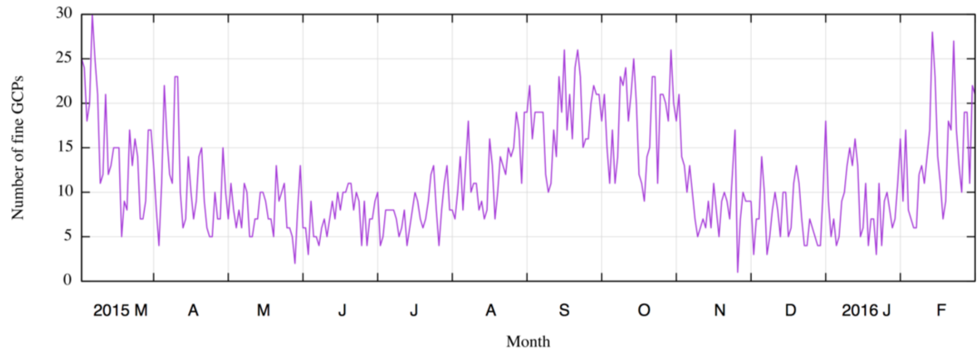
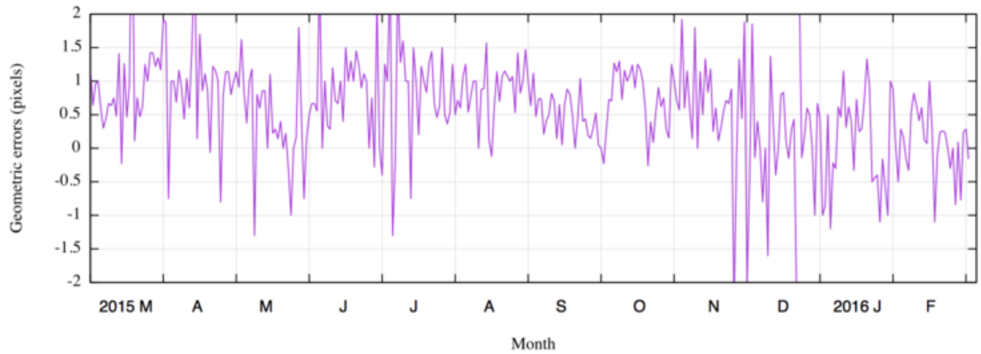
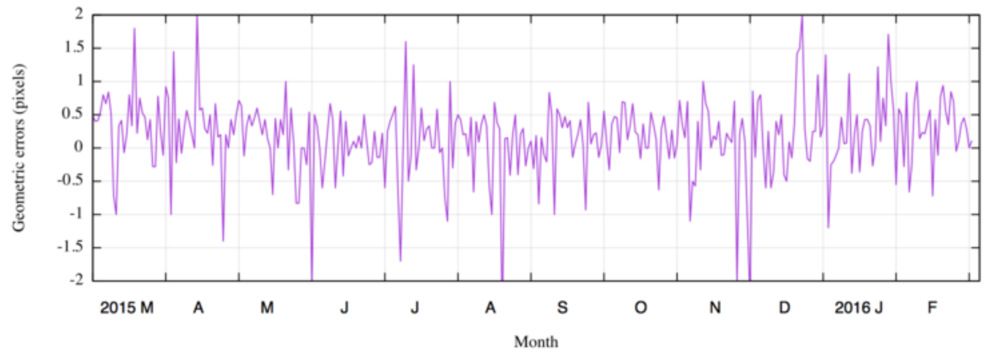


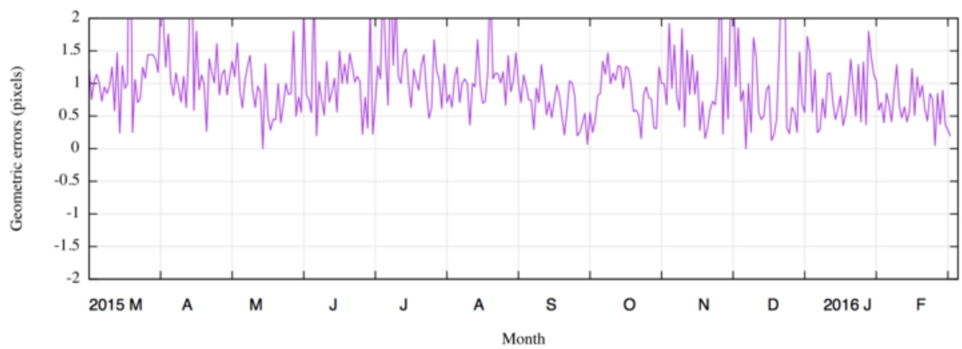
(a) The number of fine GCPs



(b) Geometric errors in east-west direction



(c) Geometric errors in north-south direction



(d) Overall geometric errors

Figure 3. The number of fine GCPs selected for template matching and geometric errors.