GEOMETRIC QUALITY ASSESSMENT OF CBERS-2 IMAGES

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ABSTRACT

CBERS-2, the second satellite of the China-Brazil Earth Resources Satellite Program, was successfully launched in October, 2003. After a period of extensive tests at the INPE processing ground station, images of the three CBERS-2 instruments – CCD (20m), IRMSS (80m), and WFI (260m) cameras – are now available for download on the Internet. This work describes the geometric assessment procedure and presents results regarding the geometric quality of CBERS-2 images. Four elements are controlled in the evaluation process: changes in the geographic position of scene centers, band-to-band registration accuracy, internal accuracy, and positioning accuracy. Although raw images could have been used to evaluate both changes in geographic position of scene centers and band-to-band registration accuracy, this geometric assessment was accomplished with system-corrected images, as they represent the entry-level product for most remote sensing users. Changes in the geographic position of scene centers are investigated by comparing nominal WRS positions to actual geographic positions. Changes in the geographic position of scene centers do not meet the specification of 10% of a CCD scene width for the period of investigation. Band-to-band registration accuracy is determined by an intensity interpolation method that maximizes correlation and establishes similarity measurements. Visual inspections are also used. Band-to-band registration accuracy is within the specification of 0.3 pixels. The internal accuracy is calculated by means of a similarity transformation that is applied to tie CBERS-2 system-corrected images to ground control points. The internal accuracy is the root mean square error of the remaining residuals. An affine transformation is also used to test image registration possibilities. The internal accuracy is around 80m for CCD images, 250m for IRMSS images, and 700m for WFI images. If an affine transformation is used to refine the geometric correction process, internal accuracy improves to 28m for CCD images, 112m for IRMSS images, and 380m for WFI images. The positioning accuracy is determined by the average difference between reference geographic positions and geographic positions determined by the geometric correction process. CBERS-2 positioning accuracy is about 14km, thus indicating a considerable difference between the satellite real position and the position being transmitted to ground stations.

1. INTRODUCTION

The geometric quality assessment procedure is used to determine and validate the relationship between terrain points and their positions in CBERS-2 images. It provides the necessary information on the possibilities of integrating images and other spatially referenced data sources. The evaluation process monitors changes in the geographic positions of scene centers, band-to-band registration accuracy, positioning accuracy, and internal accuracy.

Changes in the geographic position of scene centers are computed by subtracting real geographic positions, which result from the geometric correction process, from the corresponding nominal positions, which are obtained from CBERS-2 World Reference System (WRS).

Multispectral bands must conform, by construction, to a subpixel band-to-band registration accuracy. This ensures the registration, for each instrument and from each spectral band, of images viewed under the same geometric conditions.

The internal accuracy is the root mean square error of the remaining residuals after an orthogonal or a similarity transformation is applied to tie a system-corrected image to the map projection reference system used in the geometric correction process. The internal accuracy defines the possibilities of integrating system-corrected images, maps, and other geographic measurements.

The positioning accuracy is the computed translation of an orthogonal or a similarity transformation that is applied to tie a system-corrected image to the map projection reference system used in the geometric correction process. The positioning accuracy determines how far a system-corrected image is from its true position.

2. IMAGES USED IN THE ASSESSMENT

CBERS-2 CCD, IRMSS, and WFI system-corrected images, in GeoTIFF format, are directly evaluated against ortho-rectified LANDSAT ETM images, also in GeoTIFF format. The assessment procedure includes the following images:

- Four system-corrected CCD scenes, WRS 159/121, UTM projection, SAD69 planimetric datum (December 17, 2003, March 30, 2004, May 21, 2004, July 12, 2004).
- Four system-corrected IRMSS scenes, WRS 159/121, UTM projection, SAD69 planimetric datum (December 17, 2003, March 30, 2004, May 21, 2004, July 12, 2004).
- One system-corrected WFI scene, WRS 159/124, Lambert Conformal Conic projection, SAD69 planimetric datum (November 04, 2003).
- Two ortho-rectified ETM images, UTM projection, WGS84 planimetric datum, downloaded from NASA/ESAD (Circa 2000).

Figures 1, 2, 3, and 4 show CBERS-2 CCD, IRMSS, WFI, and LANDSAT ETM, respectively.

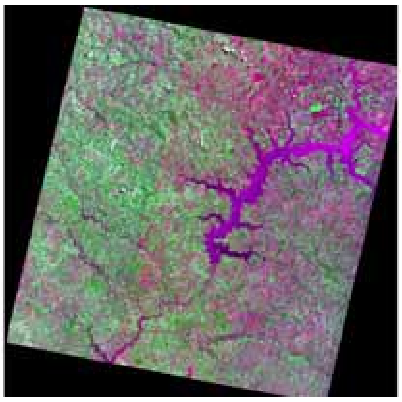


FIGURE 1 – CCD R(3)G(4)B(2)

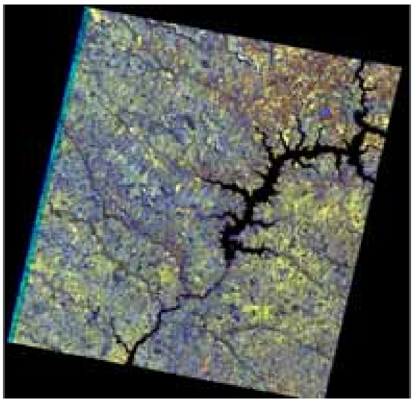


FIGURE 2 – IRMSS R(3)G(2)B(1)

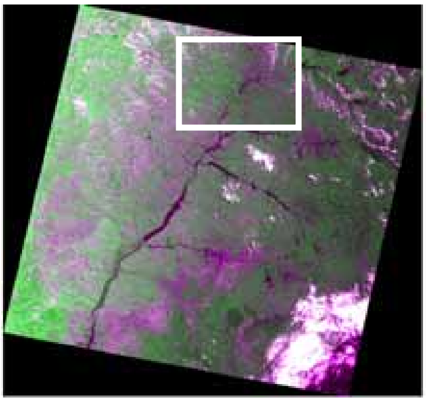


FIGURE 3 – WFI R(1)G(2)B(1)

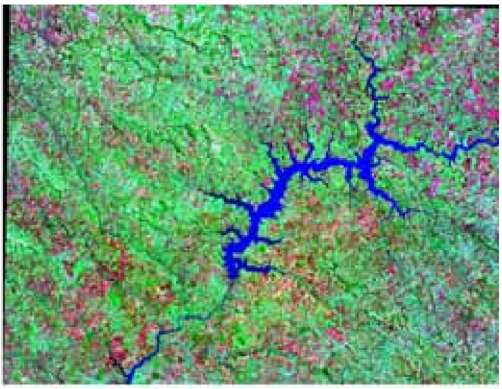


FIGURE 4 – ETM R(7)G(4)B(2)

3. METHODOLOGY

The assessment procedure begins by establishing a common GIS database that comprises all images. Because of its comprehensive image processing capabilities, SPRING, a GIS developed at the Image Processing Division of the National Institute for Space Research (INPE), is used to create such a database. Since WFI images cover 890km on the earth surface and UTM is unsuitable to map such large areas, all other images are remapped to the Lambert Conformal Conic projection referred to the SAD69 planimetric datum. Image remapping is part of SPRING GeoTIFF import function.

3.1 GEOGRAPHIC POSITION OF SCENE CENTER

Real geographic positions of scene centers are directly compared to the corresponding nominal positions. A set of routines is used to transform WRS path and row into nominal geographic coordinates (longitude and latitude) of scene center, and vice-versa. Real geographic coordinates are obtained by applying the geometric correction process to the image coordinates (column and row) of the pixel located at scene center.

3.2 BAND-TO-BAND RESGISTRATION

The task of band-to-band misregistration estimation is performed by means of an intensity interpolation approach that is supposed to be applied on relatively calibrated (both inter-array and inter-detector) images.

It is necessary to have an image window extracted from each of the two bands, one called ‘reference window’ and the other ‘search window’ (the later bigger in size than the former). The task consists in overlaying the reference and search windows in all possible positions in order to evaluate similarity between image data for each position. The matching position is defined as the one that corresponds to the maximum among similarity values.

3.3 INTERNAL ACCURACY

The internal accuracy refers to the relative position of pixels with respect to the map projection reference system selected in the geometric correction procedure. Therefore, the internal accuracy defines the possibilities of integrating images and maps. Given a set of manually chosen control points, an orthogonal transformation is applied to establish a relation between image coordinates and map projection coordinates of ground control points. Actually, the transformation is more easily determined if image coordinates are substituted by the map projection coordinates that result from the geometric correction process. Map projection coordinates of ground control points can be obtained from large scale maps, from GPS measurements, or from any reliable georeferenced digital data, like the ortho-rectified LANDSAT ETM images used here. The orthogonal transformation accounts for three parameters: a global rotation and two displacements (ΔX and ΔY). These parameters are calculated by means of a least-square adjustment. As a result, a root mean square error is computed from the observation residuals of the adjustment. The root mean square error responds for the internal accuracy of the image. For the sake of unbiased estimations, the set of control points is usually split into two subsets: one is used in the least-square adjustment and the other is used to compute the differences between reference map projection coordinates and map projection coordinates that result from the least-square adjustment.

Alternatively, a similarity transformation may also be used. This introduces a fourth parameter, a global scale factor, which accounts for variations in the pixel size and, consequently, defines the length distortion. An orthogonal-affine transformation may also be applied in the sense that different scale factors along the X and Y directions can indicate distinct scale problems along these directions during image acquisition, allowing the computation of the anisomorphism.

3.4 POSITIONING ACCURACY

The positioning accuracy defines how far a system-corrected image is from its true position. Given a set of manually chosen control points, an orthogonal transformation is applied to establish a relation between image coordinates and map projection coordinates of ground control points. Actually, the transformation is more easily determined if image coordinates are substituted by the map projection coordinates that result from the geometric correction process. Map projection coordinates of ground control points can be obtained from large scale maps, from GPS measurements, or from any reliable georeferenced digital data, like the ortho-rectified LANDSAT ETM images used here. The orthogonal transformation accounts for three parameters: a global rotation and two displacements (ΔX and ΔY). The positioning accuracy is then computed as the resultant of the displacements ΔX and ΔY.

The positioning accuracy is computed in the same way when a similarity or an orthogonal-affine transformation is used instead.

4. RESULTS OF THE GEOMETRIC QUALITY ASSESSMENT

4.1 GEOGRAPHIC POSITION OF SCENE CENTER

Changes in the geographic position of scene centers were monitored through the four CCD scenes available to the evaluation process. Results are presented in Table 1:

TABLE 1 – Geographic position of scene center

CCD SCENE	DISPLACEMENT
December 17, 2003	-28km (to the west)
March 30, 2004	-39km (to the west)
May 21, 2004	-21km (to the west)
July 12, 2004	+4km (to the east)

It is interesting to note that these displacements agree with the longitudinal drift at equator that is being constantly monitored by the Satellite Control Center Facility at INPE, as shown in Figure 5.

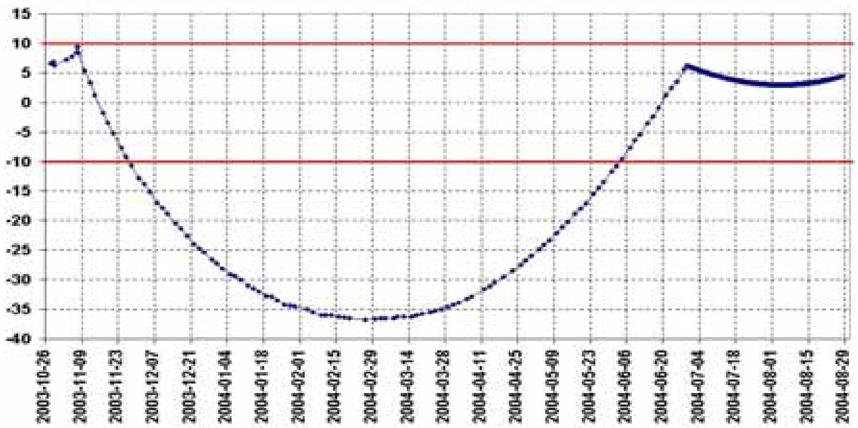
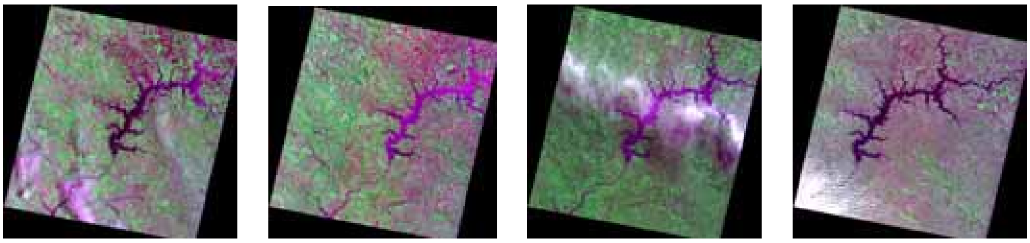


FIGURE 5 – CBERS-2 longitudinal drift at equator

Figure 6 presents the four CCD scenes used to test changes in the geographic position of scene centers. Note how the reservoir position changes.



2003-12-17 2004-03-30 2004-05-21 2004-07-12

FIGURE 6 – Monitoring the geographic position of scene centers

4.2 BAND-TO-BAND REGISTRATION

Estimation of the band-to-band registration accuracy on CCD images was mainly accomplished by means of the intensity interpolation method described in section 3.2. Visual inspection was also applied on CCD, IRMSS, and WFI images. It is important to state that band-to-band registration is controlled by CBERS-2 processing station, where a configuration file can be easily edited in order to account for any mismatch problem between CCD, IRMSS, and WFI bands that might have been detected.

Figure 7 shows a noticeable vertical band-to-band mismatch between CCD bands 2 and 4. This test was performed with the original parameters transmitted along with CCD image data. Note that red and green do not coincide perfectly in most horizontal linear features. Figure 8 depicts a notorious mismatch between IRMSS bands 1 and 2.

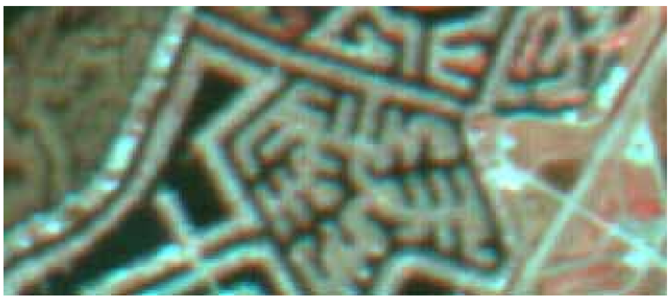


FIGURE 7 – Mismatch between CCD bands 2 and 4

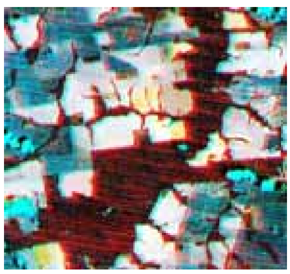


FIGURE 8 – Mismatch between IRMSS bands 1 and 2

After the band-to-band configuration file has been properly set up and arranged, the mismatch problem is solved. Figure 9 shows CCD bands 2 (in red) and 3 (in green), figure 10 shows IRMSS bands 1 (in red) and 3 (in green), and figure 11 shows WFI bands 1 (in red) and 2 (in green).

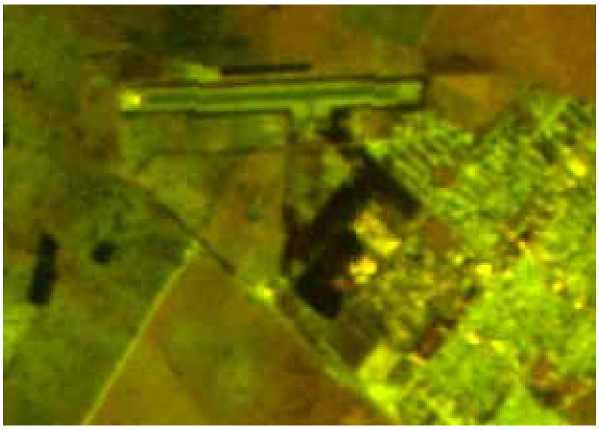


FIGURE 9 – CCD bands 2 (red) and 3 (green)

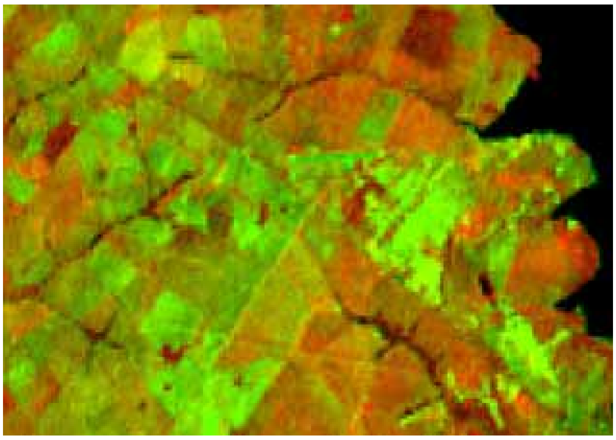


FIGURE 10 – IRMSS bands 1 (red) and 3 (green)

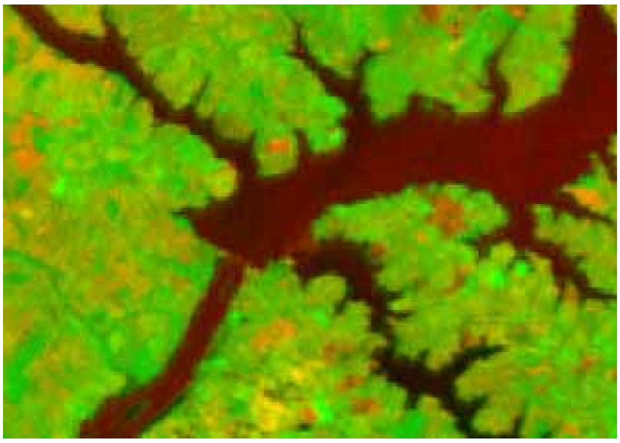


FIGURE 11 – WFI bands 1 (red) and 2 (green)

4.3 INTERNAL ACCURACY

Table 2 presents results of the internal accuracy for CCD, IRMSS, and WFI images. A similarity transformation was used to determine the root mean square error that responds for the internal accuracy. An orthogonal-affine and an affine transformation were also applied to investigate the possibilities of image registration.

TABLE 2 – Internal accuracy

INSTRUMENT / TRANSFORMATION	RMSE
CCD – Similarity	110m
CCD – Orthogonal-affine	67m
CCD – Affine	32m
IRMSS – Similarity	170m
IRMSS – Orthogonal-affine	154m
IRMSS – Affine	33m
WFI – Similarity	973m
WFI – Orthogonal-affine	733m
WFI - Affine	675m

4.4 POSITIONING ACCURACY

The positioning accuracy depends only on the satellite orbit and the attitude data used in the geometric correction process. Therefore the positioning accuracy is the same for all instruments. Table 3 shows the values computed along both the north-south east-west directions.

TABLE 3 – Positioning accuracy

DIRECTION	ERROR
North-south	-4km
East-west	-11km

5. CONCLUSION

Changes in the geographic position of scene centers must be continuously monitored by the CBERS-2 control center facilities in Brazil and China to avoid situations in which WRS scenes would cover a completely different portion of the earth surface.

INPE is currently deepening the investigation of the band-to-band registration issue through a more comprehensive analysis of CCD images. As of today, results indicate the problems have been detected and corrected accordingly.

The internal accuracy of 110m, 170m, and 973m for CCD, IRMSS, and WFI images, respectively, do not follow the standards set by LANDSAT TM/ETM and also SPOT HRV images. Typical internal accuracy for TM/ETM and HRV is about 1.5 pixel. Therefore, there is a need to improve the internal accuracy of CBERS-2 images, possibly by enhancing the attitude control in the next satellites of the CBERS series. On the other hand, results obtained by applying an affine transformation ensure that image registration is definitely feasible, mainly for CCD and IRMSS images. Based on simple cartographic rules, these results indicate that CCD images can be used at 1:100,000 and IRMSS images can be used at 1:250,000. WFI images, nevertheless, still require improvement to be used at 1:1,000,000

The positioning accuracy also does not follow LANDSAT and SPOT standards, suggesting that a more reliable orbit control must be established for the next CBERS satellites. However, it is important to note that a positioning error, whether it is 350m or 20km, will always imply an external registration procedure for system-corrected images in order to ensure proper integration with other sources.

6. REFERENCES

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