MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

BRASIL UM PAÍS DE TODOS

Geometric Quality Assessment of CBERS-2

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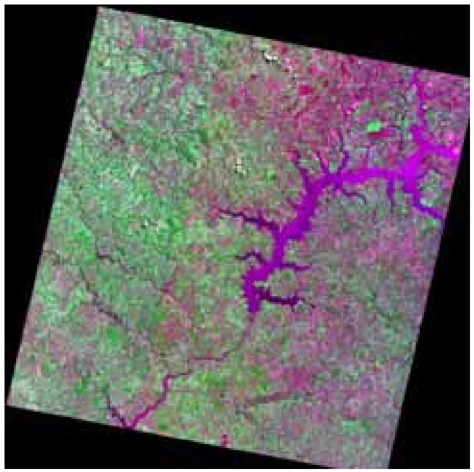
Contents

- Monitoring CBERS-2 scene centers
  - Satellite orbit control
- Band-to-band registration accuracy
  - Detection and control
- System-corrected images (level 2)
  - What to expect of such images?
  - Internal error … attitude data
  - Positioning error … ephemerides and attitude data
- Geometric quality of CBERS-2 images

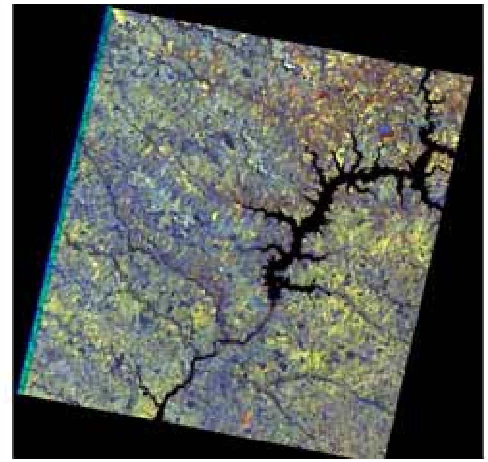
Images used in the assessment

- 6 CCD scenes, 159/121, UTM, SAD69
  - December 17, 2003; March 30, 2004; May 21, 2004; July 12, 2004; September 02, 2004; February 05, 2005
- 6 IRMSS scenes, 159/121, UTM, SAD69
  - December 17, 2003; March 30, 2004; May 21, 2004; July 12, 2004; September 02, 2004; February 05, 2005
- 3 WFI scenes, 159/124, Lambert Conformal Conic, SAD69
  - November 04, 2003; March 30, 2004; September 02, 2004
- 2 ortho-rectified ETM images, UTM/WGS84
  - Circa 2000

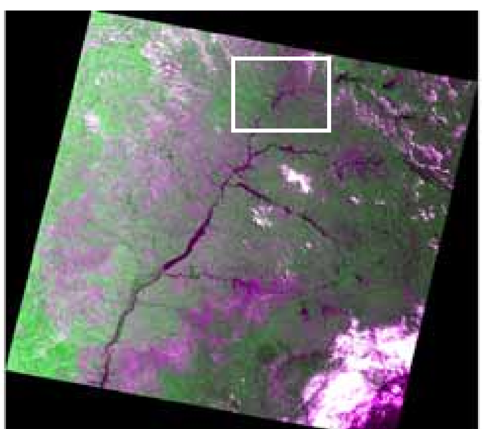
Images used in the assessment



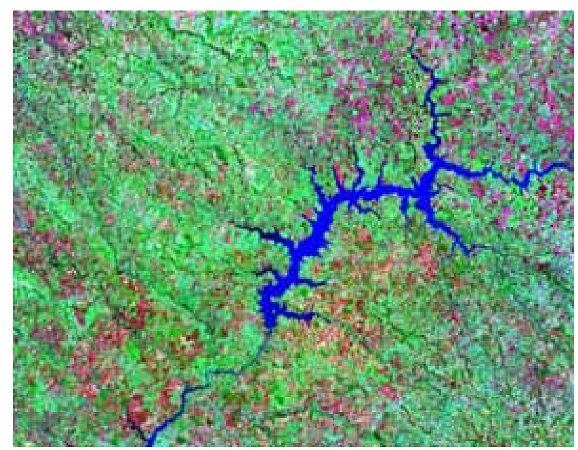
CCD



IRMSS



WFI



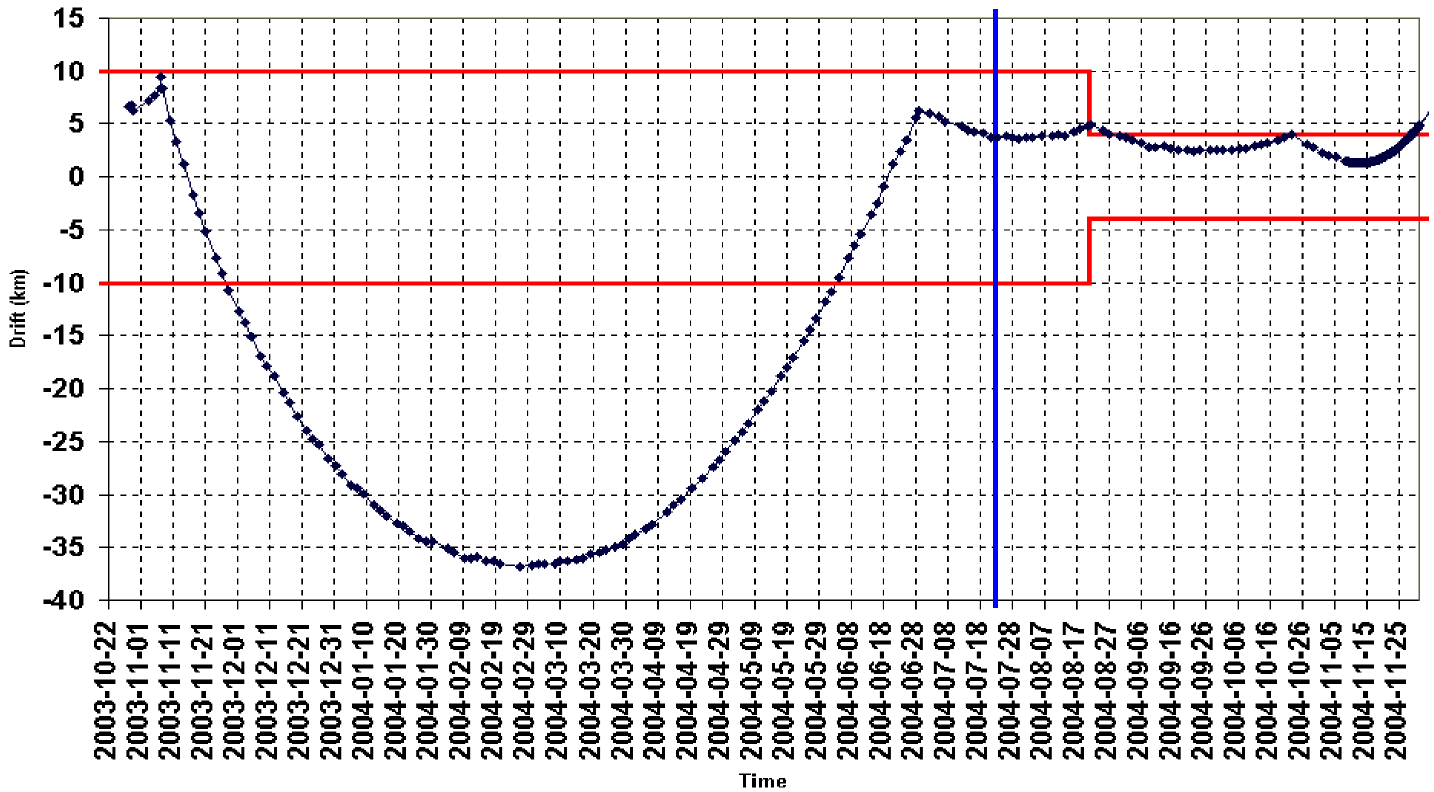
ETM

Monitoring CBERS-2 scene centers

- Geographic position of scene centers
  - WRS path and row are transformed into nominal geographic coordinates
  - Geographic coordinates of scene centers are computed through the geometric correction process
  - Differences between real and nominal geographic coordinates are calculated
    - December 17, 2003 …….. -28km (to west)
    - March 30, 2004 ………….. -39km (to west)
    - May 21, 2004 ……………. -21km (to west)
    - July 12, 2004 ……………… +5km (to east)
    - September 02, 2004 ……. +4km (to east)
    - February 05, 2005 ………. +2km (to east)
  - Orbit control and longitudinal drift at equator

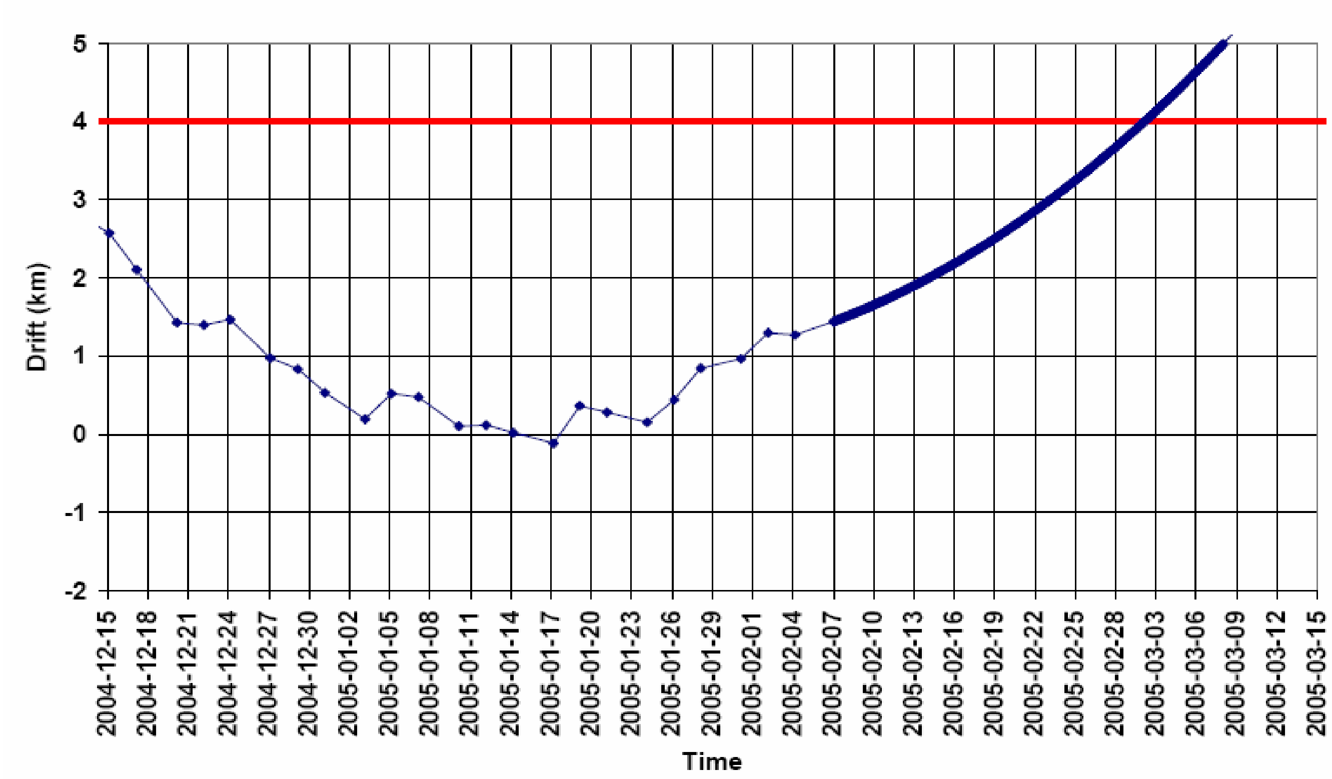
Monitoring CBERS-2 scene centers

- Longitudinal drift at equator computed in the CBERS-2 Control Center Facility at INPE

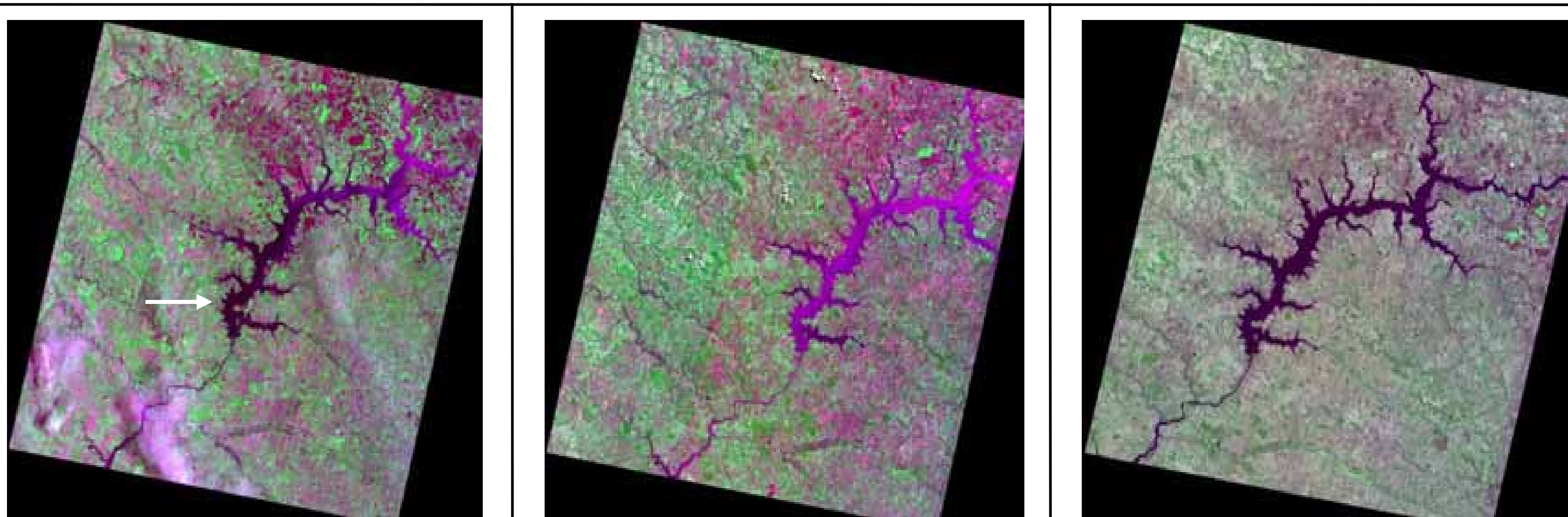


Monitoring CBERS-2 scene centers

- Longitudinal drift at equator computed in the CBERS-2 Control Center Facility at INPE



Monitoring CBERS-2 scene centers



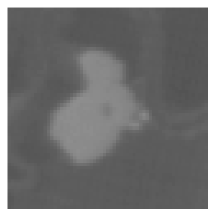
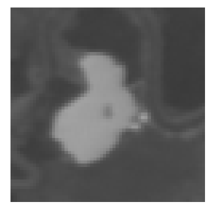
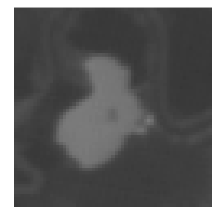
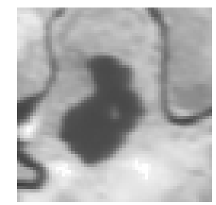
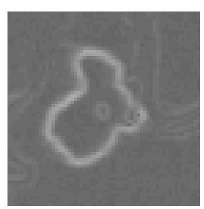
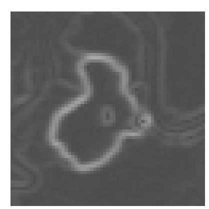
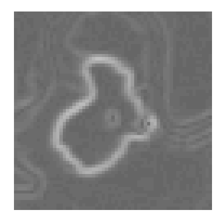
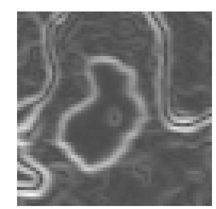
December, 2003	March, 2004	September, 2004

Band-to-band registration accuracy

- Band-to-band mismatch is estimated by an intensity interpolation method
  - Reference and search windows are defined by sub-images that are resampled to 1/11 of the original pixel size
    - Cubic convolution interpolation function (α = -0.5)
  - Reference and search windows are overlaid in all possible positions to determine similarity on selected control points
    - Normalized cross-correlation
  - Matching position at each control point is determined by the maximum similarity value
  - Spatial distance between any reference window and the corresponding matching position defines the band-to-band mismatch

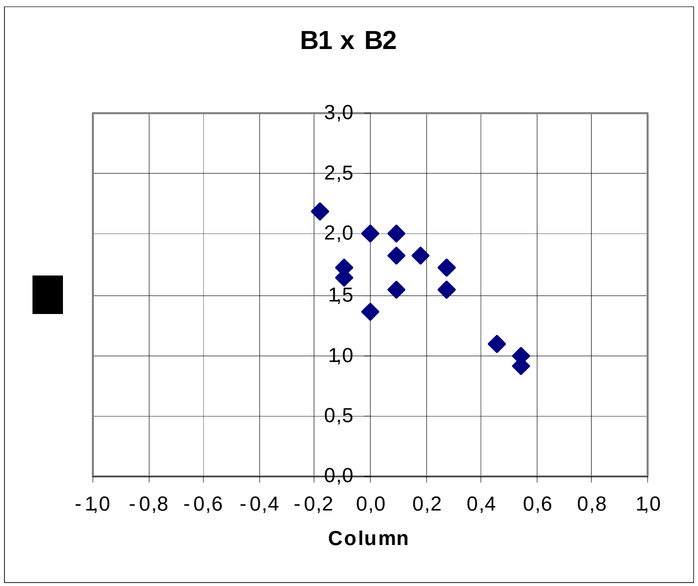
Band-to-band registration accuracy

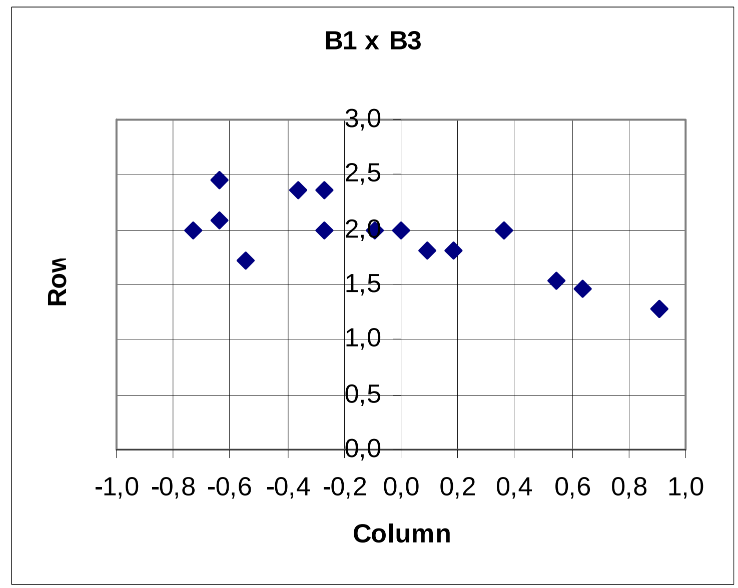
- Example of control points

CCD IMAGE	BAND 1	BAND 2	BAND 3	BAND 4
GRAY LEVEL				
GRADIENT (Sobel operator)				

Band-to-band registration accuracy

- Estimation of CCD band-to-band registration





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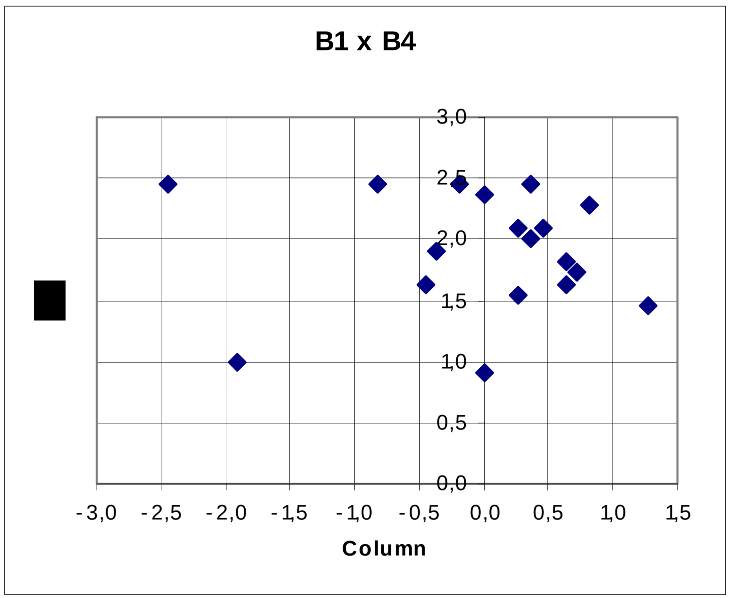
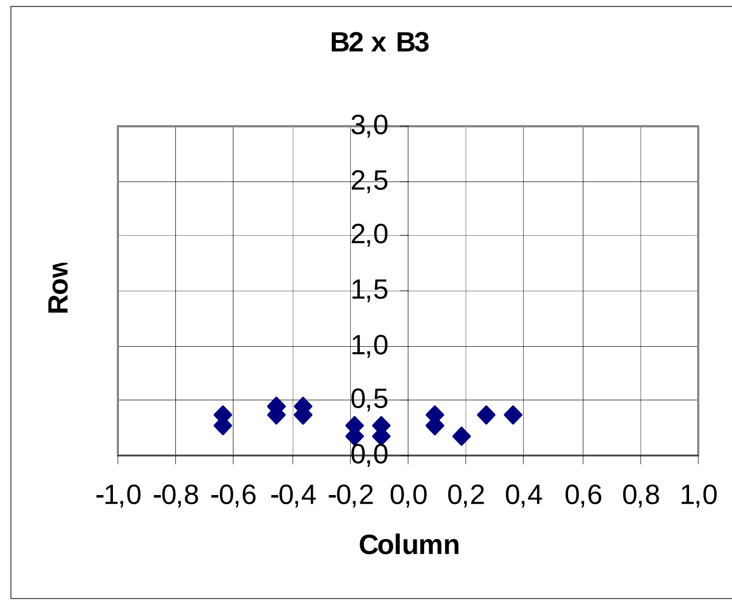
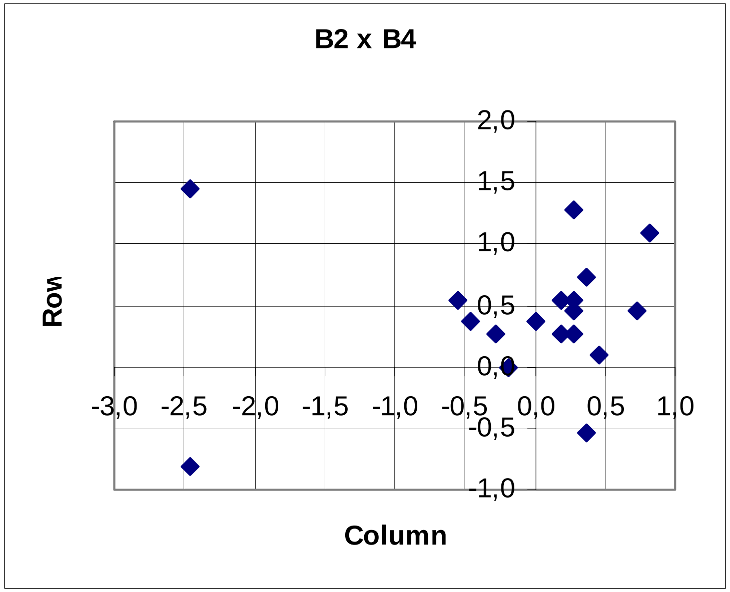
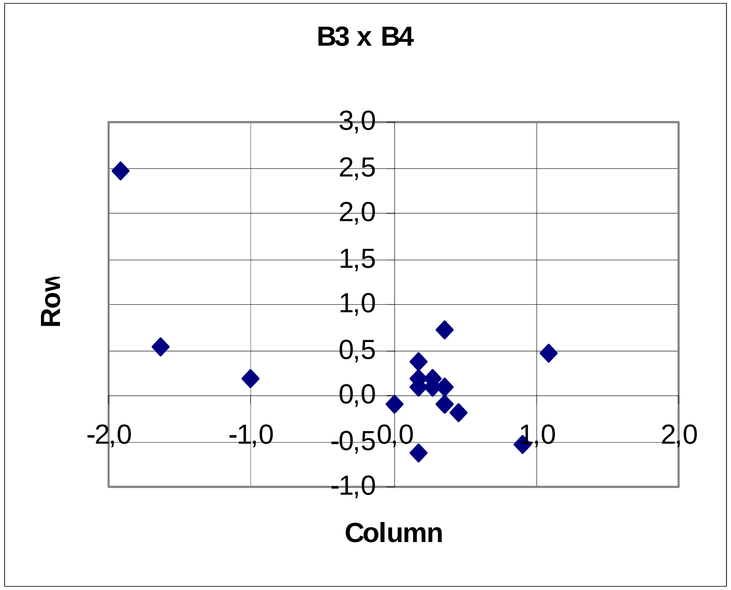




Band-to-band registration accuracy

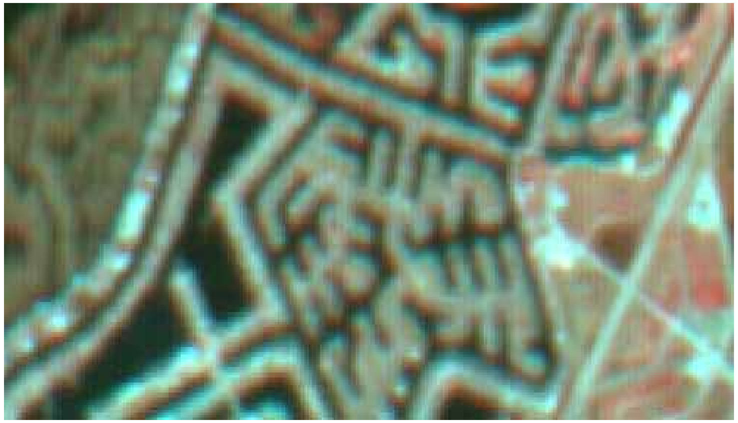
- Estimation of CCD band-to-band registration



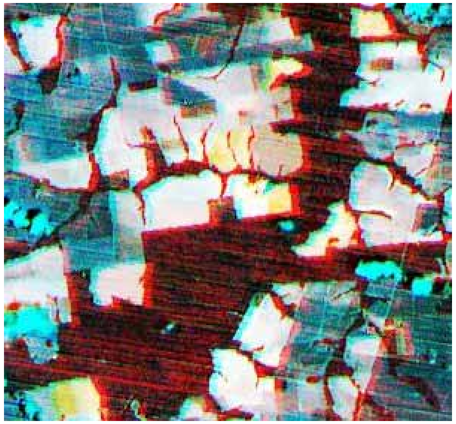


Band-to-band registration accuracy

- Visual estimation of band-to-band registration



CCD bands 1 and 4



IRMSS bands 1 and 2

- Estimated mismatches are corrected in the CBERS Processing Station

System-corrected images (level 2)

- Ephemerides
  - Satellite position and velocity on time t
- Attitude data and instrument
  - Viewing direction on time t
- Intersection with earth reference ellipsoid
  - Geographic coordinates of pixel acquired on time t
- Image remapping to a map projection reference system

System-corrected images (level 2)

- Internal accuracy
  - Relative position of pixels with respect to a map projection system
  - LANDSAT TM/ETM and SPOT HRV/HRG have established the standards
    - Mean error of 1.5 pixel
  - Accurate attitude data
- A good internal accuracy allows users to easily integrate images, maps, and other geographic data sources

System-corrected images (level 2)

- Positioning accuracy
  - Global displacement of the image with respect to the earth surface
  - LANDSAT TM/ETM and SPOT HRV/HRG have established the standards
    - Mean error of 1,500m for LANDSAT-5
    - Mean error of less than 350m for SPOT-5
    - Mean error of less than 200m for LANDSAT-7
  - Accurate ephemerides and attitude data
- The positioning accuracy defines how far an image is from its true position

Internal and positioning accuracy

- System-corrected CCD, IRMSS, and WFI images were imported to a common GIS database
- NASA (ESAD) ortho-rectified ETM images were imported to the same GIS database
  - GeoTIFF converted from MrSID
  - UTM, WGS84
- CBERS-2 and LANDSAT-7 images were remapped to a common reference system
  - Lambert Conformal Conic, WGS84

Internal and positioning accuracy

- Internal accuracy estimation
  - Measurement of control points
    - Control points were selected manually (automatic selection is under development)
    - Map projection coordinates were measured on both CBERS-2 and LANDSAT-7 images
  - Geometric transformations
    - Similarity and orthogonal-affine transformations were used in the assessment
    - Affine transformation was used to investigate image registration possibilities
  - Coordinates calculated through the transformations were compared to the coordinates provided by the reference LANDSAT ETM image
  - Differences were used to compute the internal accuracy

Internal and positioning accuracy

- Positioning accuracy estimation
  - Measurement of control points
    - Control points were selected manually (automatic selection is under development)
    - Map projection coordinates were measured on both CBERS-2 and LANDSAT-7 images
  - Displacements along north-south and east-west directions were calculated by subtracting CBERS-2 coordinates from the reference LANDSAT ETM coordinates
    - Average north-south displacement (ΔY)
    - Average east-west displacement (ΔX)
  - The resultant of average displacements defines the positioning accuracy
    - $[(\Delta X)^2 + (\Delta Y)^2]^{0.5}$

Internal accuracy estimation

INSTRUMENT	TRANSFORMATION	RMSE_X (m)	RMSE_Y (m)	RMSE (m)
CCD	Similarity	79	77	110
	Orthogonal-affine	50	45	67
	Affine	24	20	31
IRMSS	Similarity	115	126	170
	Orthogonal-affine	108	110	154
	Affine	28	17	33
WFI	Similarity	708	668	973
	Orthogonal-affine	661	316	733
	Affine	618	272	676

Internal accuracy estimation

INSTRUMENT	LENGTH DISTORTION	ANISOMORPHISM
CCD	0.998	0.996
IRMSS	0.999	1.003
WFI	1.008	1.008

Positioning accuracy estimation

DATE	ΔX (km)	ΔY (km)	RESULTANT (km)
December 17, 2003	← -7.4	↑ +7.7	10.7
March 30, 2004	← -11.8	↑ +5.0	12.8
May 21, 2004	← -9.7	↑ +4.3	10.6
July 12, 2004	← -10.0	↑ +3.7	10.7
September 02, 2004	← -2.5	↑ +4.1	4.8
February 05, 2005	→ +0.7	↑ +4.2	4.3

Comments and discussion

- Changes in the geographic position of scene centers must be continuously monitored by the CBERS-2 Control Center Facilities in Brazil and China
- A certain WRS scene should always cover the same portion of the earth surface
- CBERS-2 WRS must be a reliable image search tool for remote sensing users

Comments and discussion

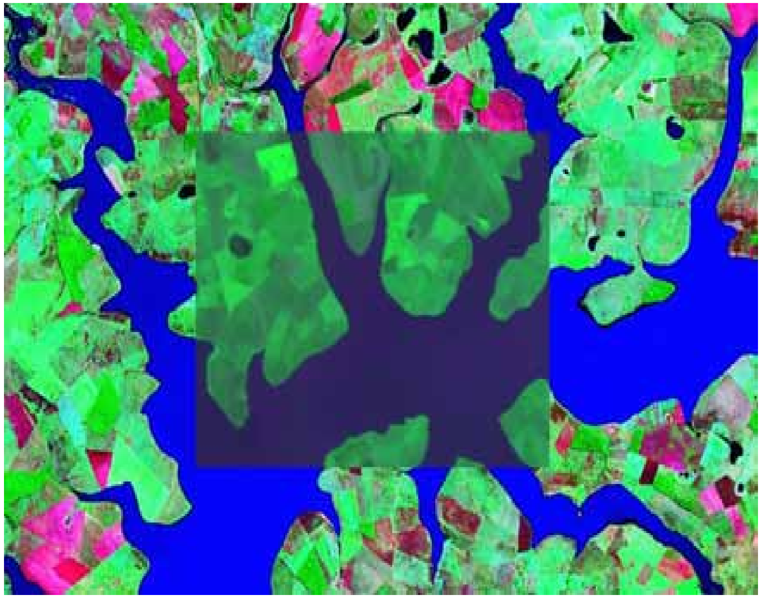
- INPE is investigating the band-to-band registration issue through a more comprehensive analysis of CCD images
- Band-to-band mismatches have been detected and corrected accordingly in the CBERS station at INPE
- Additional study is also required to verify the occurrence of displacements between arrays of detectors

Comments and discussion

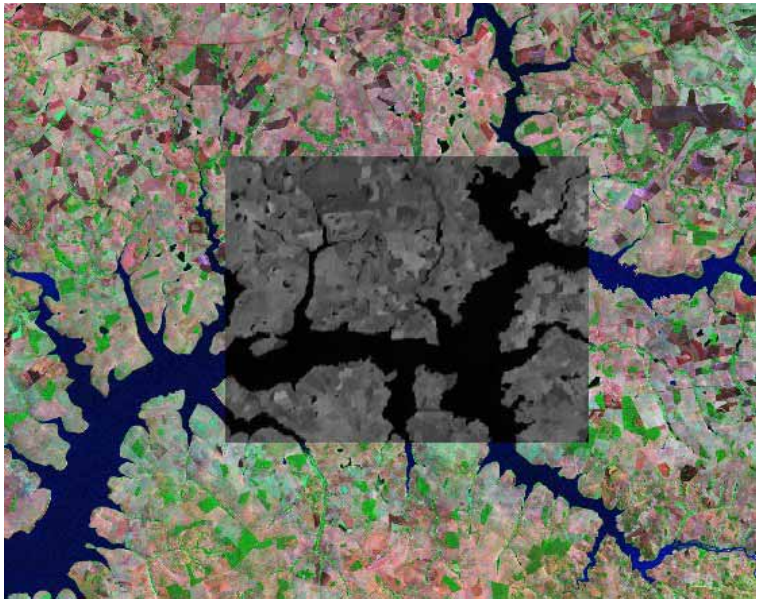
- Internal accuracies of 110m for CCD, 170m for IRMSS, and 973m for WFI images do not follow the standards set by TM/ETM and HRV/HRG images
- But ... results of the affine transformation indicate that image registration is feasible
  - Suggested maximum scale for CCD is 1:100,000
  - Suggested maximum scale for IRMSS is 1:250,000
  - Suggested maximum scale for WFI is 1:1,500,000
  - An error still remains along the east-west direction after WFI images have been registered by an affine transformation

Comments and discussion

- INPE is investigating the generation of fully corrected images by automatic registration with ETM ortho-rectified image data



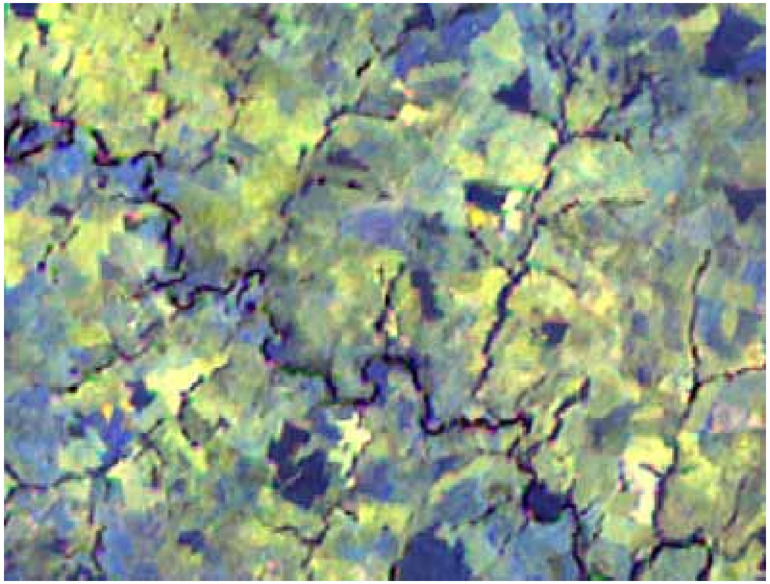
CCD registered with ETM



IRMSS registered with ETM

Comments and discussion

- IRMSS forward and reverse scans
  - Mismatch between forward and reverse scans on the extremities of the images
  - Current behavior of IRMSS mirror profile is different from the expected nominal profile?

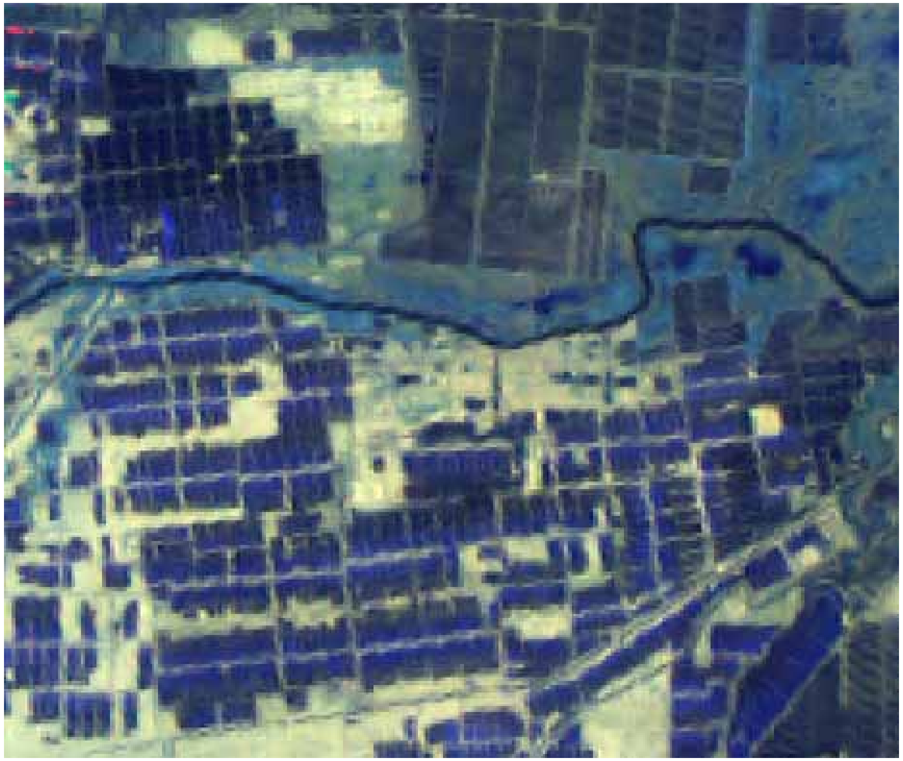


Comments and discussion

- CRESDA (China) has proposed an adjustment method that slightly changes time for each segment of the scan mirror profile
  - Read some lines of image raw data, get number of pixels in each segment, and compute scan time for each segment
  - Fit the scan mirror profile to the relative mirror angles of the instrument using a third order polynomial
  - Readjust the scan mirror angles for each segment
  - Offset is about $(4.4/1536)^{o}$ per pixel
  - Forward mirror profile after adjustment
    - $f(t) = -2.19448 + 59.85849t - 27.15604t^2 + 222.16511t^3$
  - Reverse mirror profile after adjustment
    - $f(t) = 2.19388 - 59.3667t + 1.65016t^2 - 38.1988t^3$

Comments and discussion

- IRMSS forward and reverse scans after adjustment by the CRESDA method



Comments and discussion

- Image orientation to the north
  - True north direction and the north direction calculated by the geometric correction process should be the same
  - All tests detected a little misalignment (2 ~ 6 pixels) between the axes of the map projection system that is computed in the geometric correction process and the axes of the reference map projection system
  - Presence of bore-sight angles?
  - Inaccurate attitude data (yaw)?
  - INPE is investigating the problem
- However … image registration by an affine transformation fixes the problem

Comments and discussion

- Positioning accuracy between 4 and 12km does not follow standards set by LANDSAT and SPOT
- However ... a positioning error, no matter it is 10km or 350m, always implies an external registration procedure

Comments and discussion

- Positioning accuracy can be improved by the use of post-processed ephemerides
- Tests have been made that account for:
  - Presence of unexpected bore-sight and attitude angles
  - Computation of a bias-matrix

Conclusion

- Current developments towards ensuring a good geometric quality for CBERS-2 images
  - Careful control of satellite orbit to avoid unacceptable longitudinal drifts
  - Systematic verification of the band-to-band registration accuracy
  - Use of post-processed ephemerides generated at a regular basis in the CBERS-2 Control Center Facility at INPE
  - Refinement of attitude data by using control points
  - Computation of bore-sight angles by using control points
  - Use of automatic registration techniques to generate fully corrected images