



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS



CBERS-2

Attitude Control and its Effects on Image Geometric Correction



Topics for discussion

- Image positioning errors change depending on which country controls the satellite
- Known issues about CBERS-2 attitude data
 - Attitude angles transmitted in X-band (to the image receiving station) and S-band (to the TT&C station) are exactly the same
 - Transmitted attitude angles are too small
 - IRES output data are significant
 - IRES output data change according to the controlling side
- Use of attitude post-processed on ground
 - Attitude data computed from IRES and DSS data
 - Attitude data computed from the integration of angular velocities estimated onboard



Topics for discussion

■ Attitude issues that require further analysis

- Transmitted attitude angles do not match the values estimated on ground from IRES and DSS data
- Definition of the best attitude data for image processing of CBERS-2 and CBERS-2B
- What is the influence of ephemeris data sets uploaded from Brazil and China on the onboard determination of attitude?
- What are the impacts of a similar attitude control on the time-delay integration of CBERS-2B HRC camera?



How did we come up with this?

- Systematic evaluation of CBERS-2 images by INPE
 - Presentation to CRESDA in Beijing (October, 2004)
 - Presentation in the Brazilian Remote Sensing Symposium (April, 2005)
 - Presentation to CRESDA in São José dos Campos (June, 2005)
 - Continuous interaction with CBERS users in Brazil
- Cooperative investigation among CBERS segments at INPE
 - Application
 - Control
 - Space



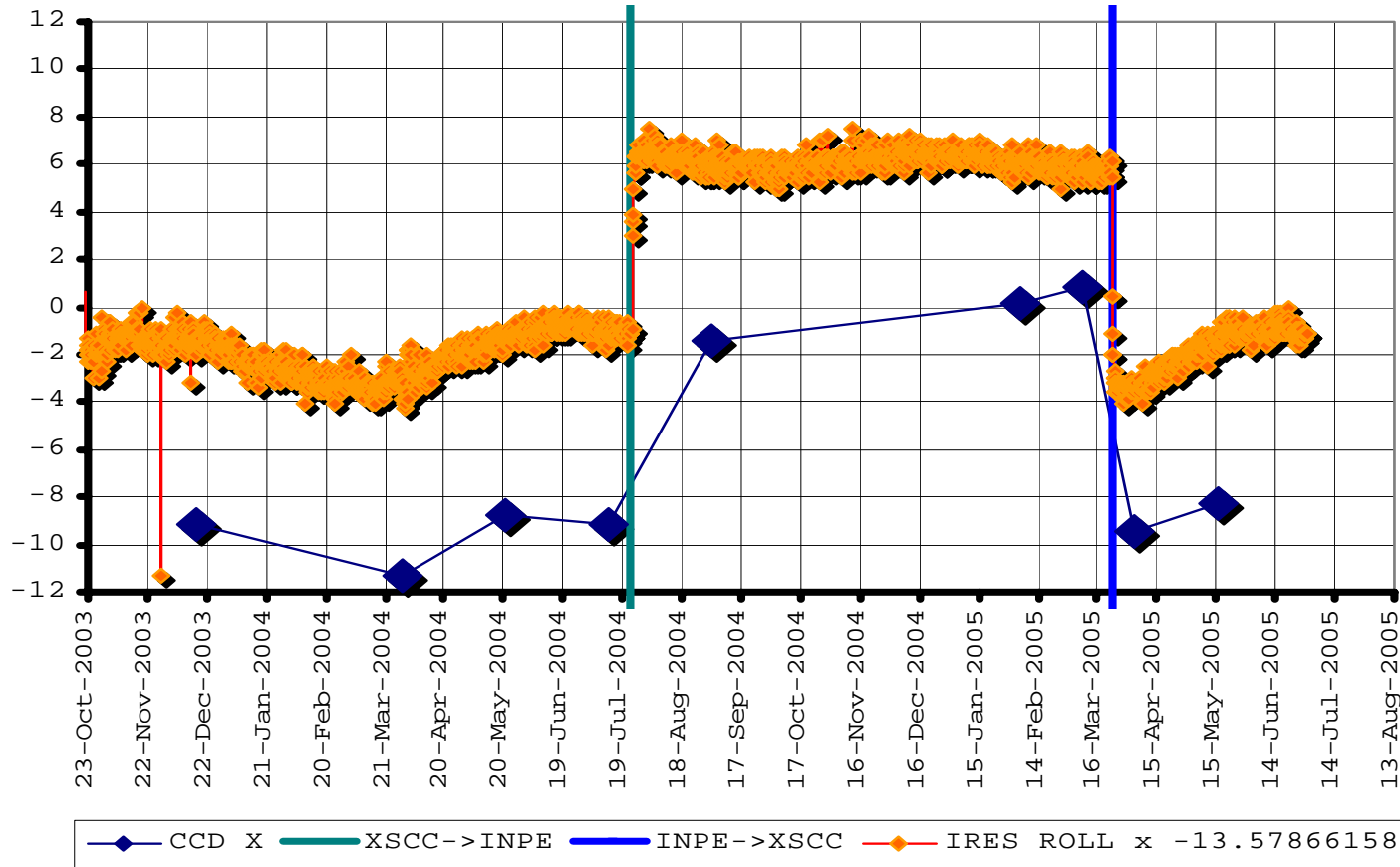
Background

- Previous geometric evaluations of CBERS-2 positioning error

DATE	ΔX (km)	ΔY (km)	RESULTANT (km)
17-Dec-2003	-7.4	+7.7	10.7
30-Mar-2004	-11.8	+5.0	12.8
21-May-2004	-9.7	+4.3	10.6
12-Jul-2004	-10.0	+3.7	10.7
02-Sep-2004	-2.5	+4.1	4.8
05-Feb-2005	+0.7	+4.2	4.3
29-Mar-2005	-8.4	+8.2	11.7
20-May-2005	-7.6	+3.2	8.2

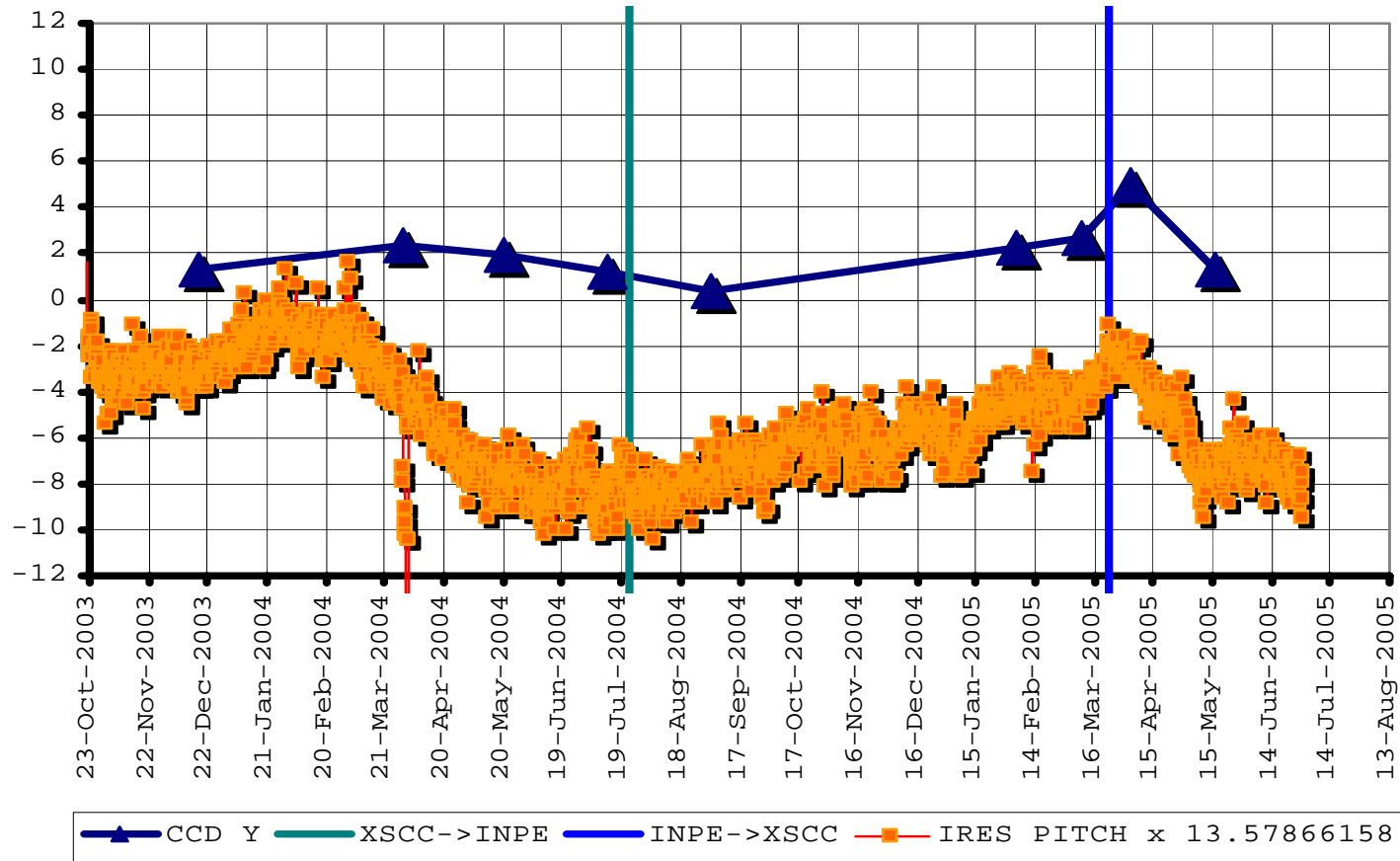
Background

■ Correlation between Δx error and roll angle from IRES



Background

- Correlation between Δy error and pitch angle from IRES





Attitude investigation

- Attitude was tested around the last control transition from Brazil to China
 - March 20, 21, 23, 25, and 26, 2005
 - CCD 153/111, 160/101, 162/102, 169/105, 187/116
 - Bore-sight(x) = bore-sight(z) = 0; bore-sight(y) = $-1.923e-2$ radians
- Test 1
 - Transmitted attitude and ephemeris data computed from TLEs
- Test 2
 - Post-processed attitude (computed from IRES and DSS data) and ephemeris data computed from TLEs

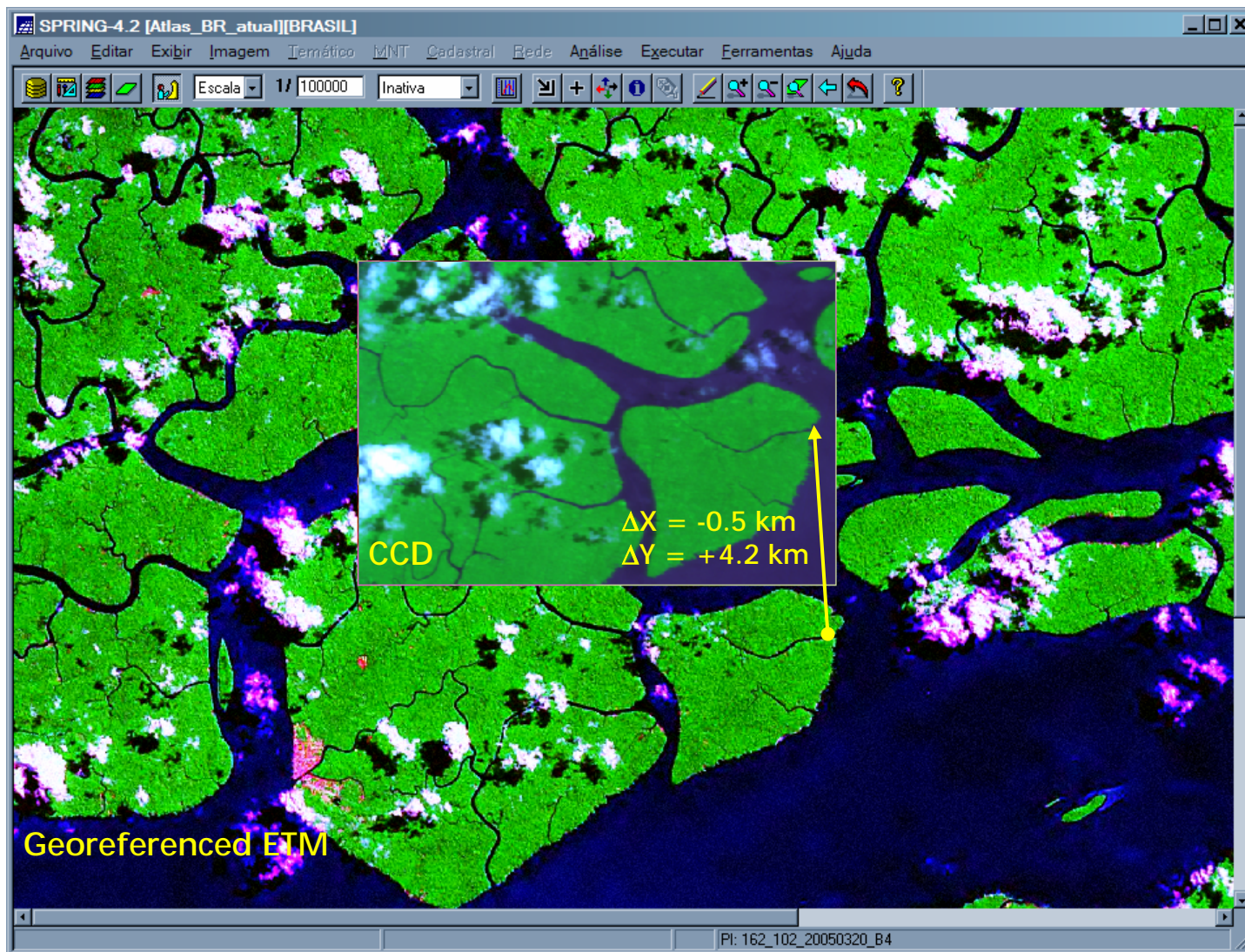


Test 1

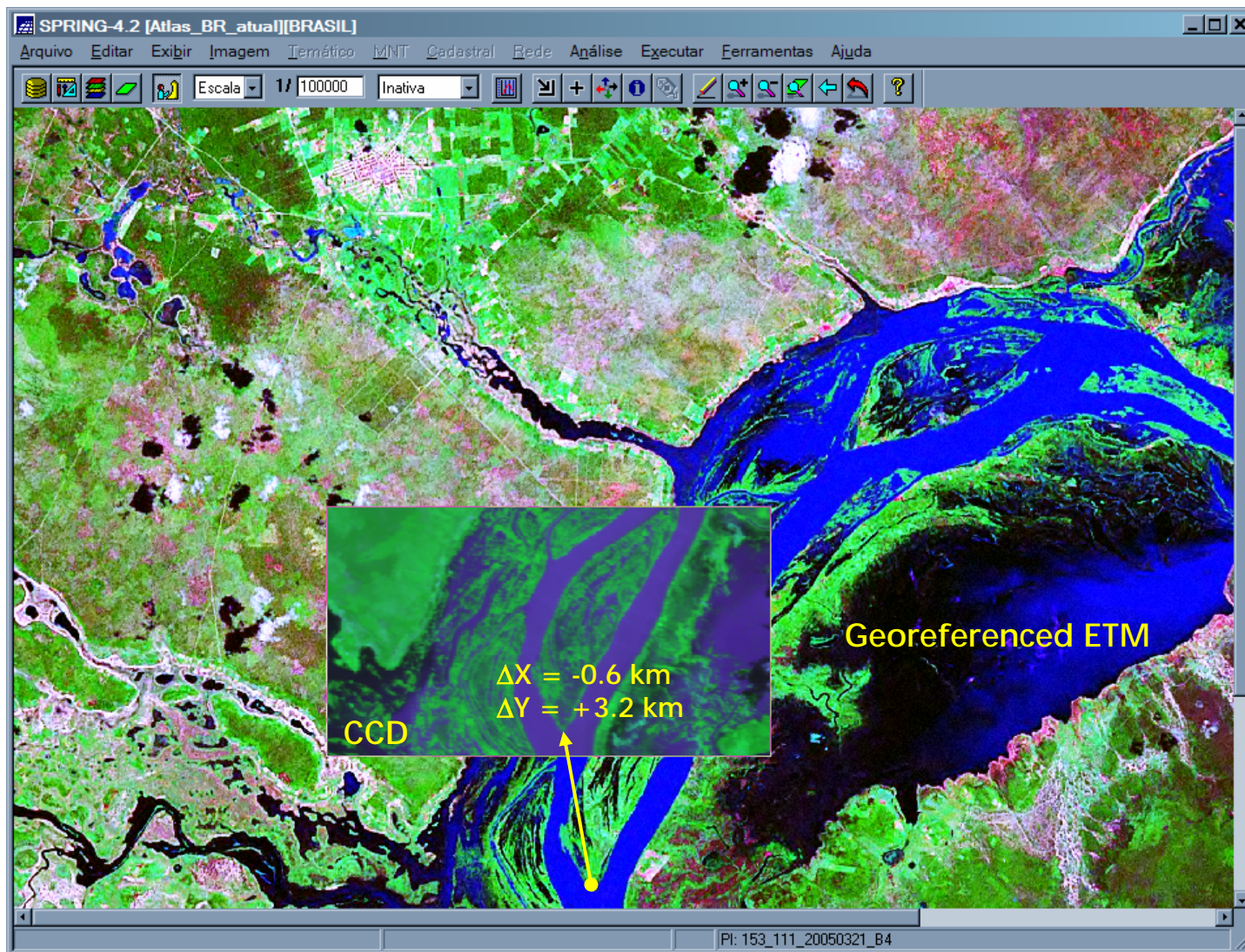
- Positioning error with transmitted attitude and ephemeris data computed from TLEs

DATE	ΔX (km)	ΔY (km)	RESULTANT (km)
20-Mar-2005	-0.5	+ 4.2	4.2
21-Mar-2005	-0.6	+ 3.2	3.3
23-Mar-2005	-7.5	+ 4.8	8.9
25-Mar-2005	-9.1	+ 7.4	11.7
26-Mar-2005	-10.3	+ 6.7	12.3

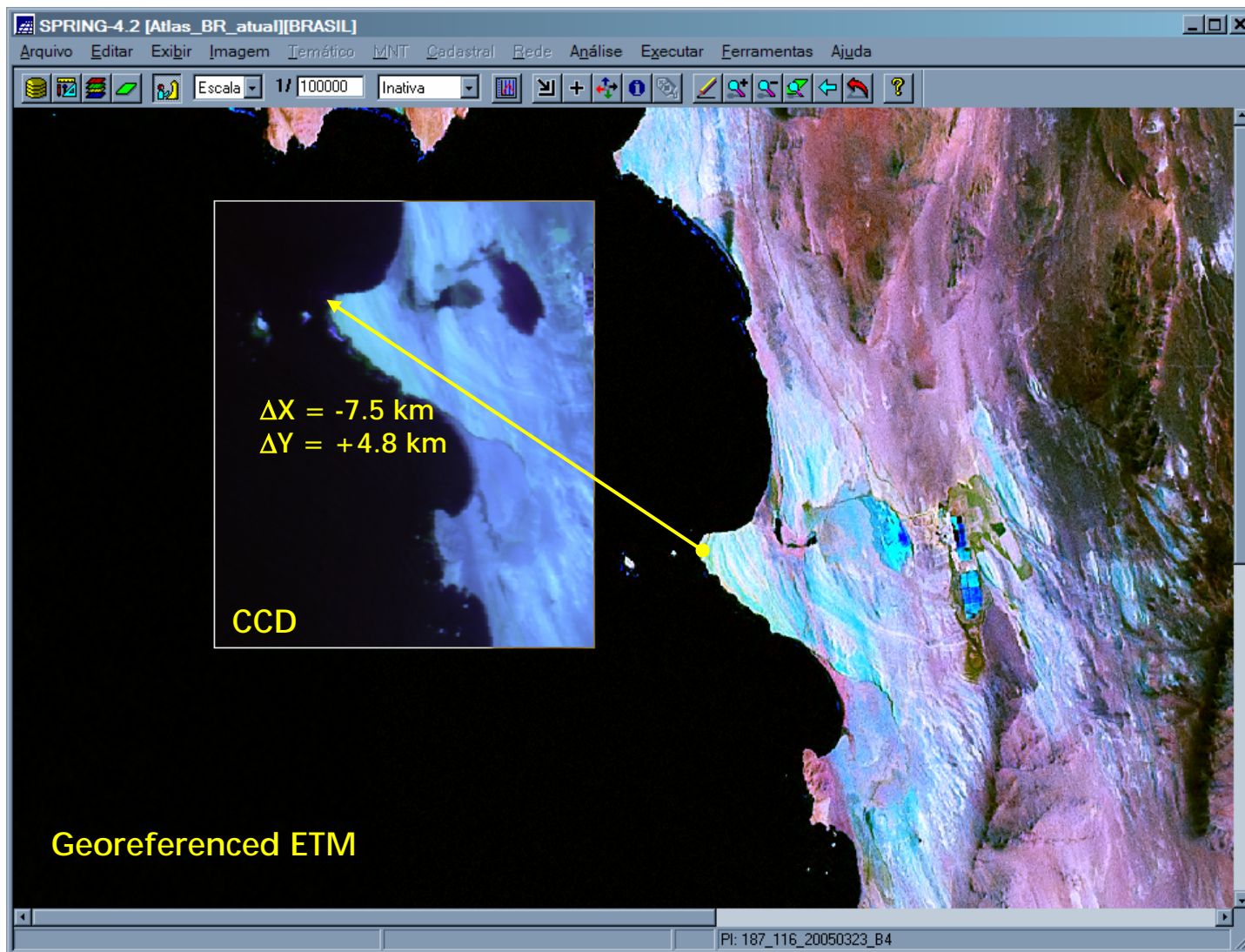
Test 1 on March 20, 2005



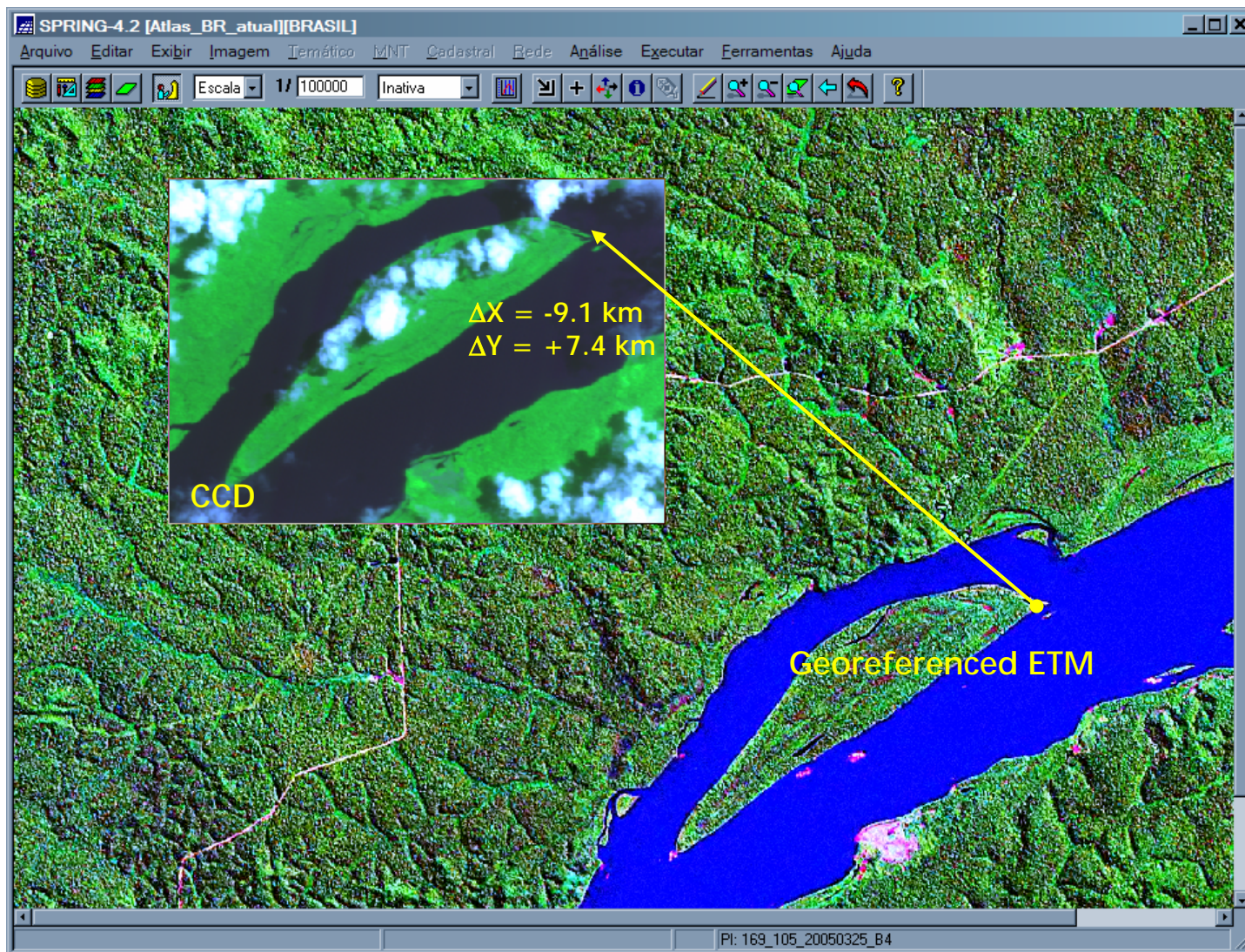
Test 1 on March 21, 2005



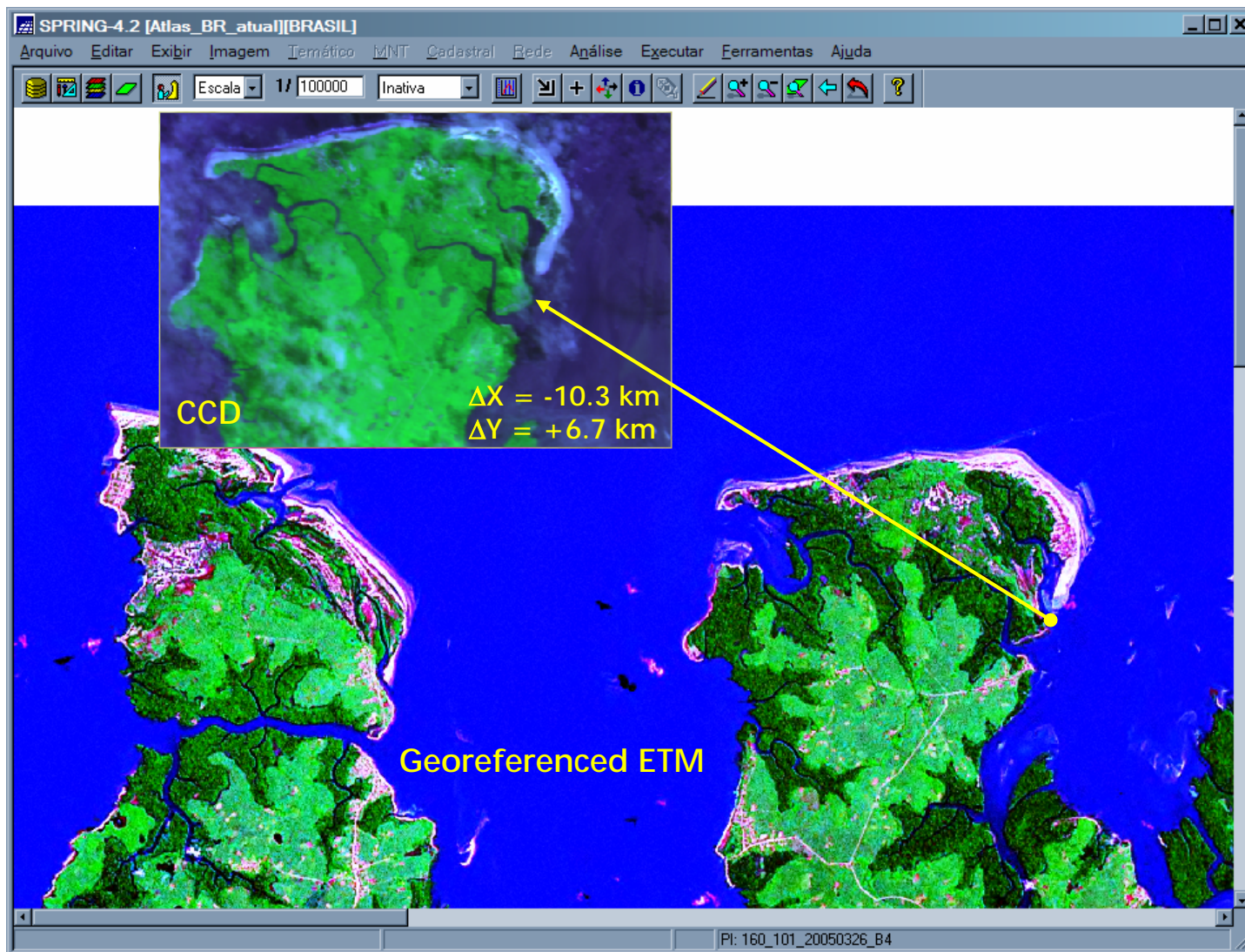
Test 1 on March 23, 2005



Test 1 on March 25, 2005



Test 1 on March 26, 2005

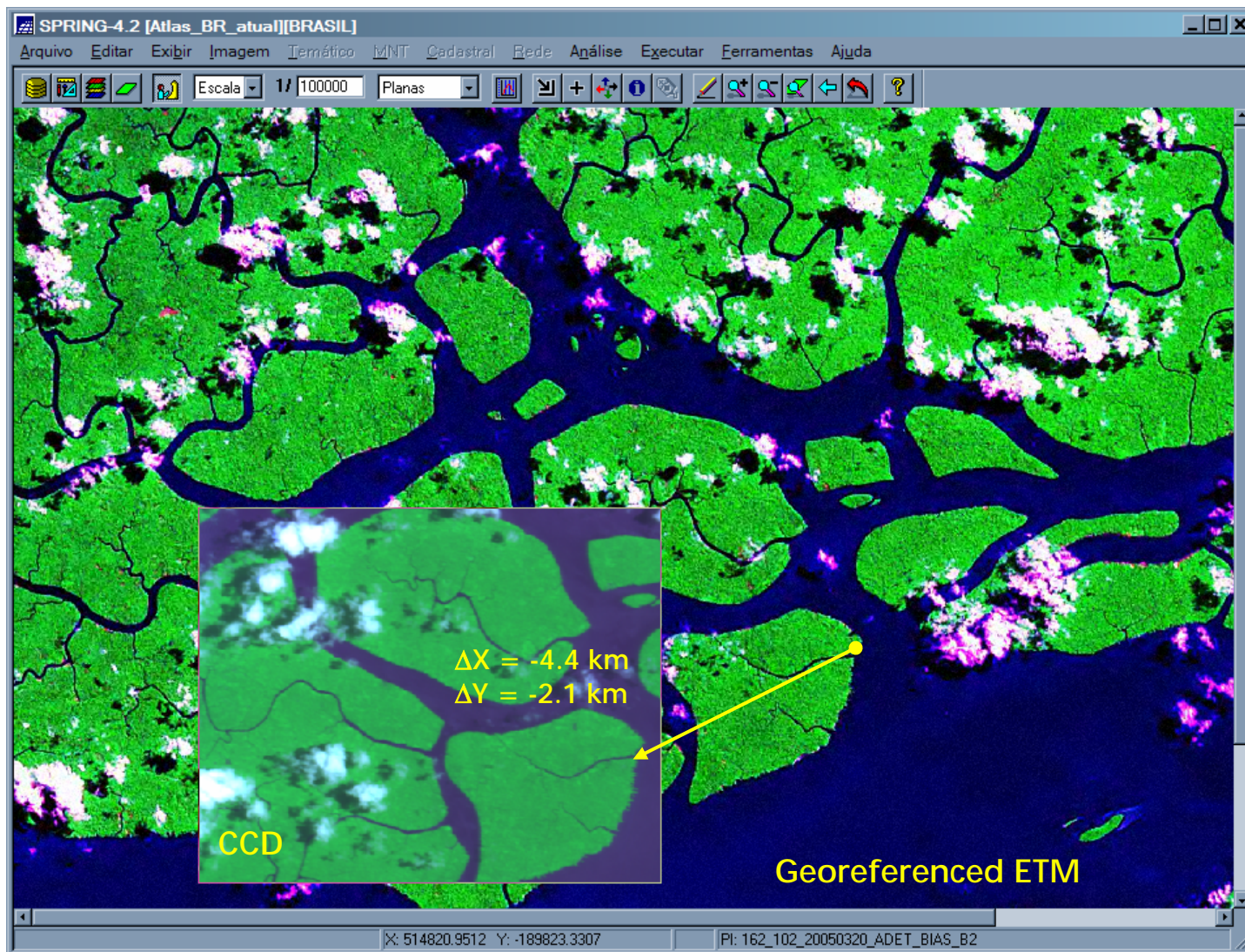


Test 2

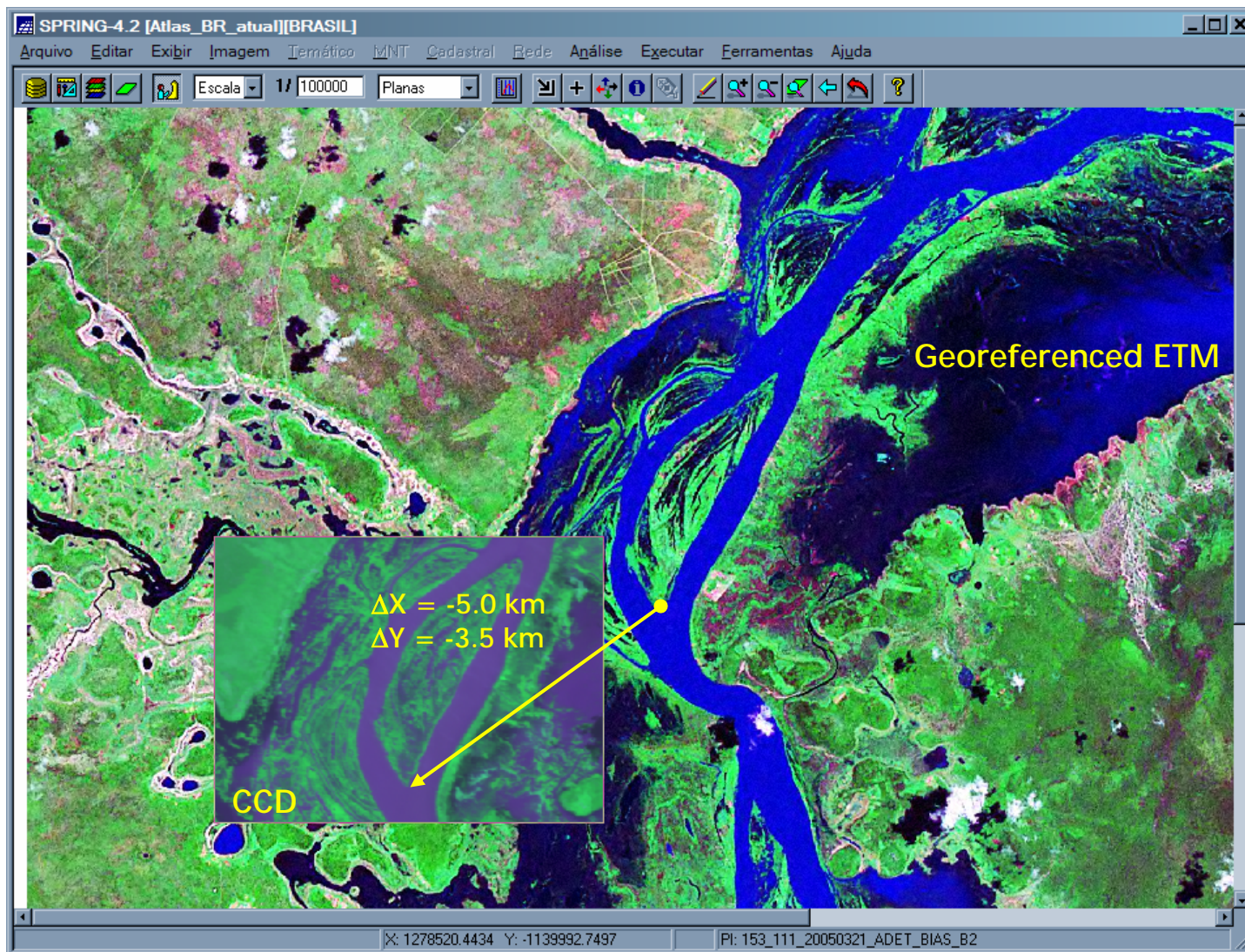
- Positioning error with post-processed attitude and ephemeris data computed from TLEs

DATE	ΔX (km)	ΔY (km)	RESULTANT (km)
20-Mar-2005	-4.4	-2.1	4.9
21-Mar-2005	-5.0	-3.5	6.1
23-Mar-2005	-6.0	-2.6	6.5
25-Mar-2005	-4.7	-2.9	5.4
26-Mar-2005	-5.6	-1.5	5.8

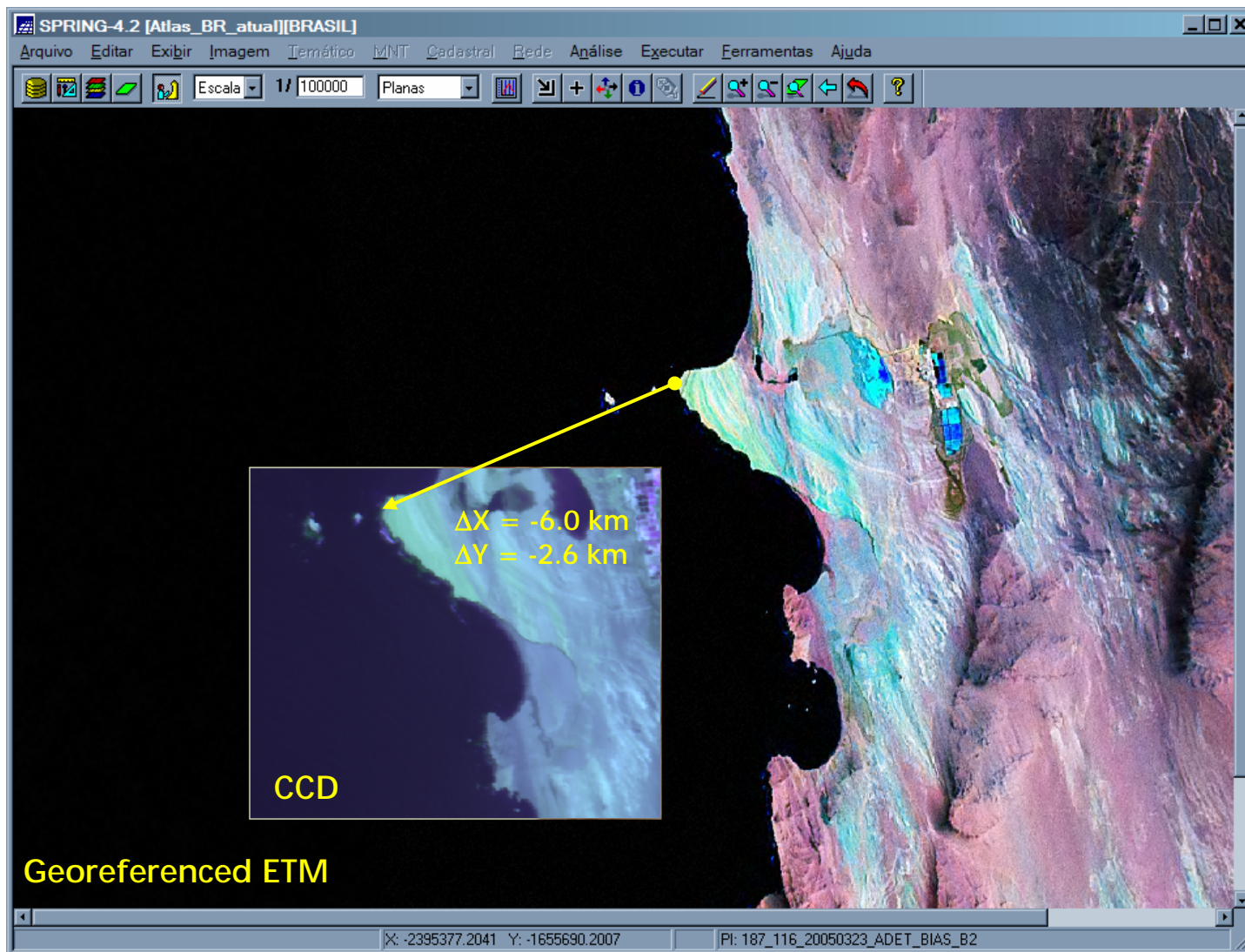
Test 2 on March 20, 2005



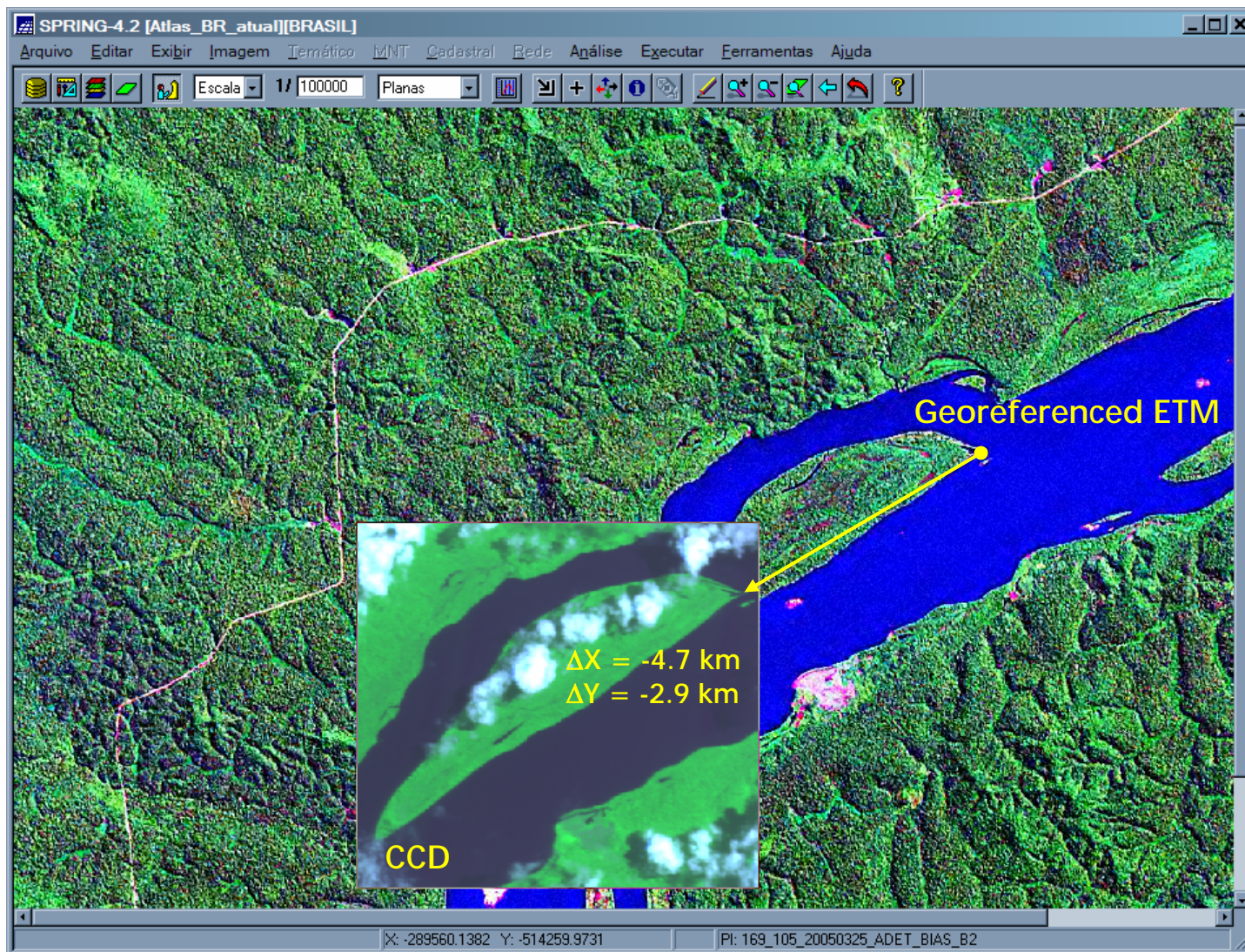
Test 2 on March 21, 2005



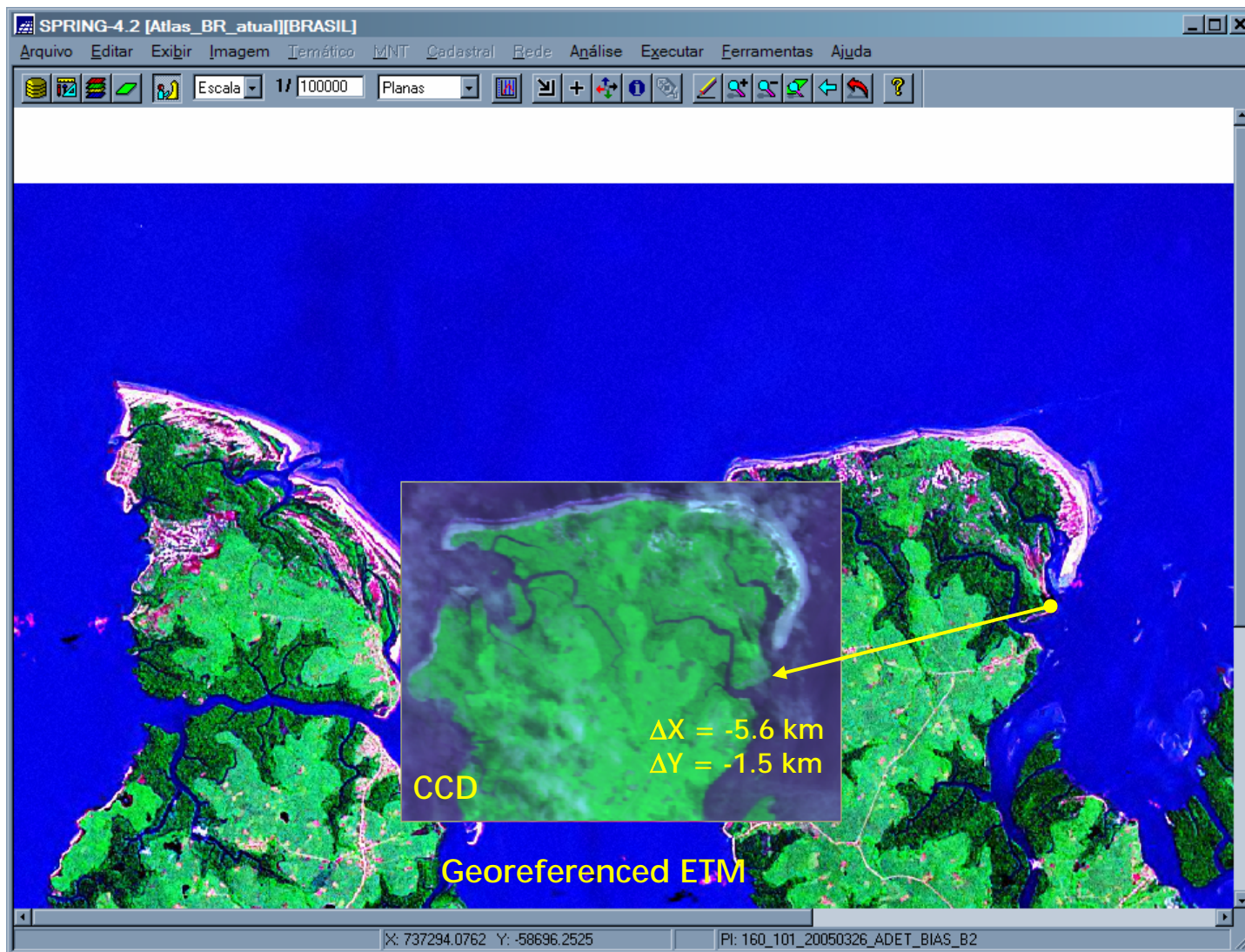
Test 2 on March 23, 2005



Test 2 on March 25, 2005



Test 2 on March 26, 2005

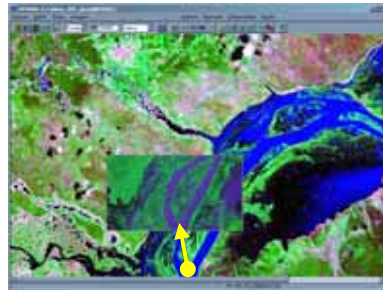


Synthesis of attitude tests

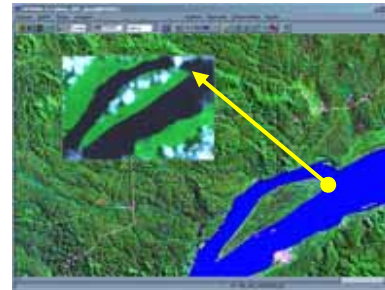
■ Test 1 – transmitted attitude



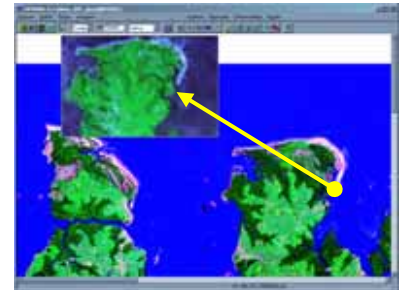
March 20, 2005



March 21, 2005



March 25, 2005

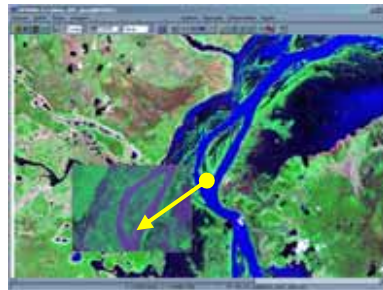


March 26, 2005

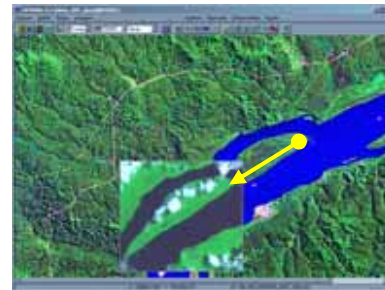
■ Test 2 – post-processed attitude



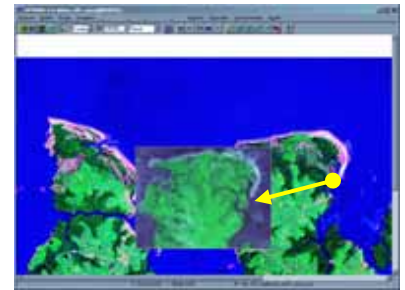
March 20, 2005



March 21, 2005



March 25, 2005



March 26, 2005



Telemetry data analysis

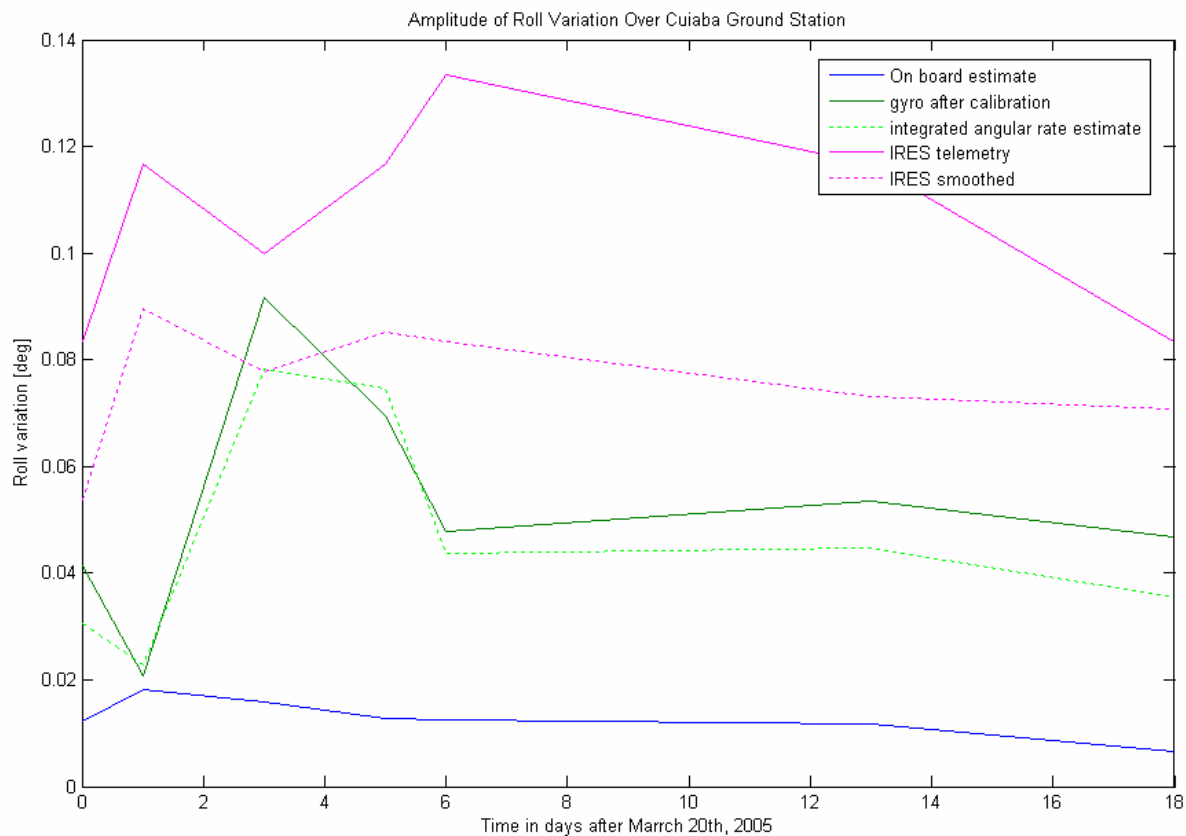
- **Statement 1: Apparently the attitude telemetry data have discrepancies**
 - Telemetry data inform that the attitude angles are (most of the time) smaller than 0.05 degree
 - Image positioning errors indicate that the attitude angles might be bigger than the telemetry data
 - The IRES show angles of different magnitude when the control is handed over between China and Brazil
 - The integration of angular velocity telemetry is not consistent with the attitude angle telemetry



Telemetry data analysis

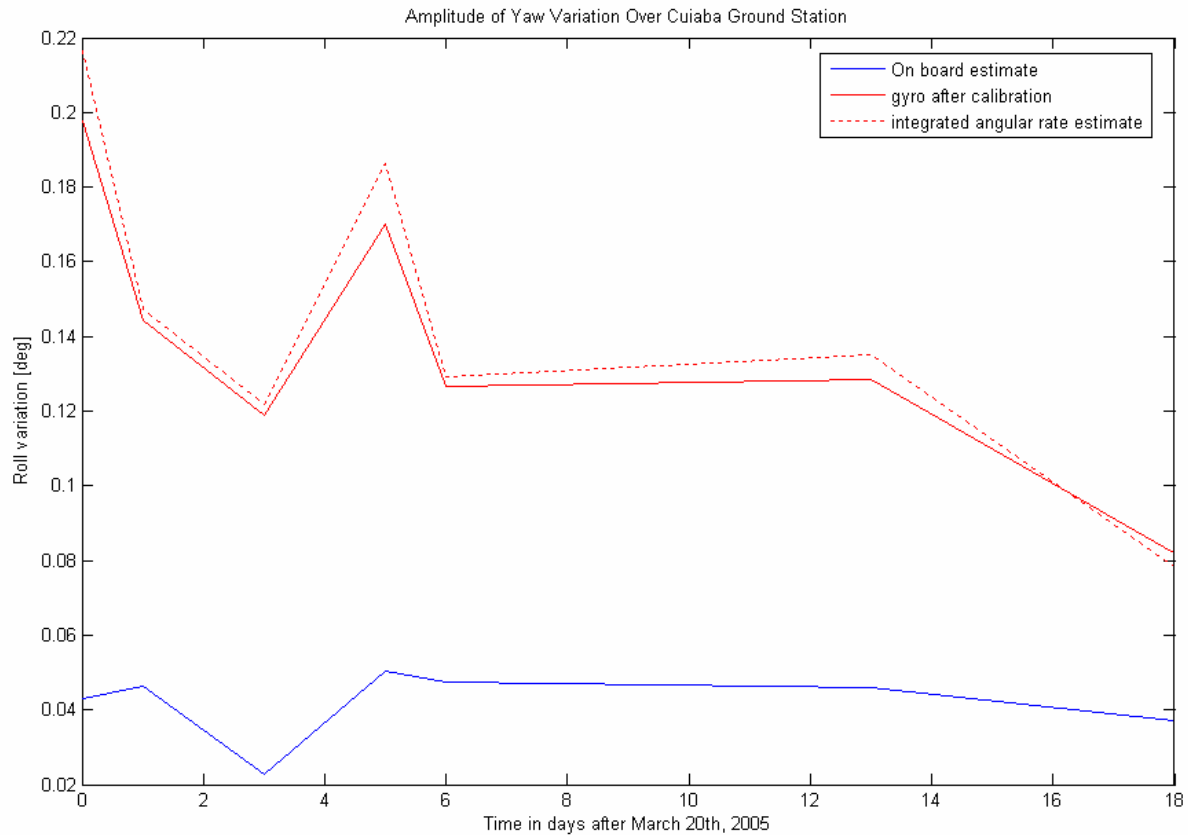
- **Statement 2:** The pointing errors may be out of specification
 - The image location analysis shows errors ranging from 0.5 to 10 km
 - Image location errors around 5 km correspond to the specified pointing accuracy of 0.3 degree
 - The IRES data show absolute values close to 0.8 degree which are compatible to the image location errors
 - The IRES output “changes” after control center handover
 - The IRES bias (installation error) “changes” after control center handover

Attitude behavior



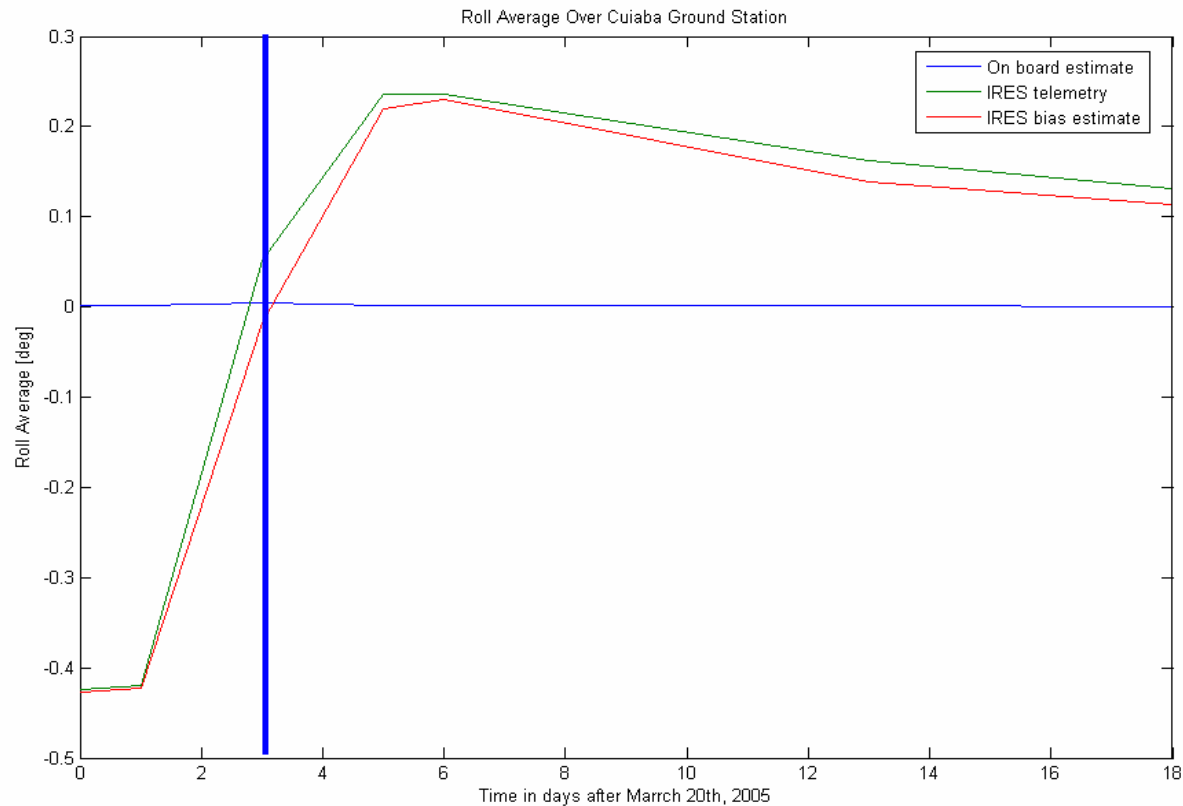
Discrepancy between roll and roll-rate estimates and other telemetry

Attitude behavior



Discrepancy between yaw and yaw-rate estimates and other telemetry

Attitude behavior



IRES roll-axis bias before and after switching the control handover on March 23rd

Image effects

Image Positioning Error

	Test 1: OB-OrbAt		Test 2: Ground-OrbAt estimating IRES Bias		Test 3: Ground-OrbAt considering zero bias		Test 4: test 3 + rate integration	
Date	ΔX (km)	ΔY (km)	ΔX (km)	ΔY (km)	ΔX (km)	ΔY (km)	ΔX (km)	ΔY (km)
20/03/2005	-0.5	4.2	-4.4	-2.1	-6.1	8.4	-5.5	9.7
21/03/2005	-0.6	3.2	-5.0	-3.5	-5.8	7.8	-5.5	10.0
23/03/2005	-7.5	4.8	-6.0	-2.6	-6.8	7.3	-7.3	7.6
25/03/2005	-9.1	7.4	-4.7	-2.9	-6.0	8.1	-6.3	10.3
26/03/2005	-10.3	6.7	-5.6	-1.5	-6.7	8.4	-7.0	9.6

Image effects

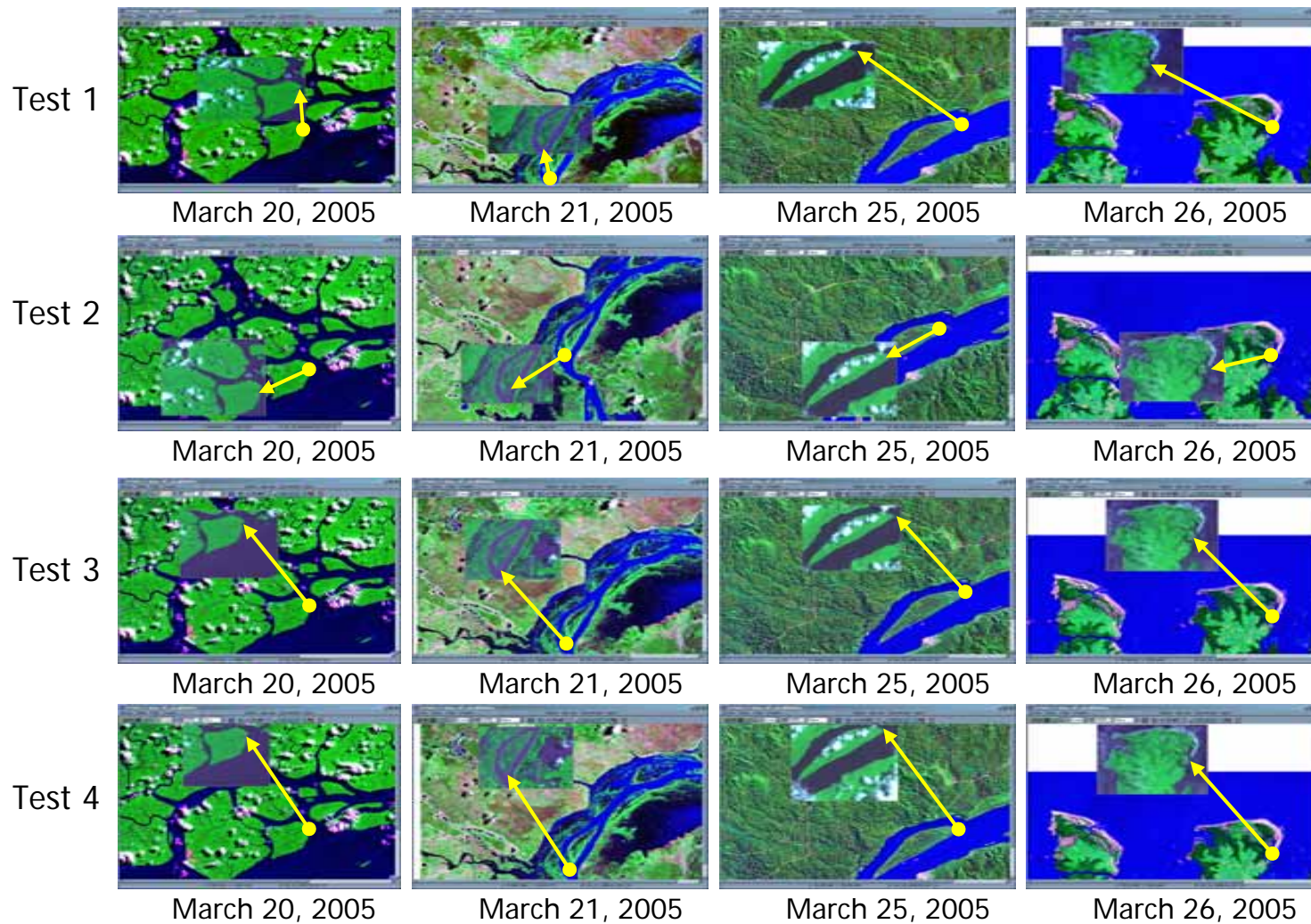


Image effects

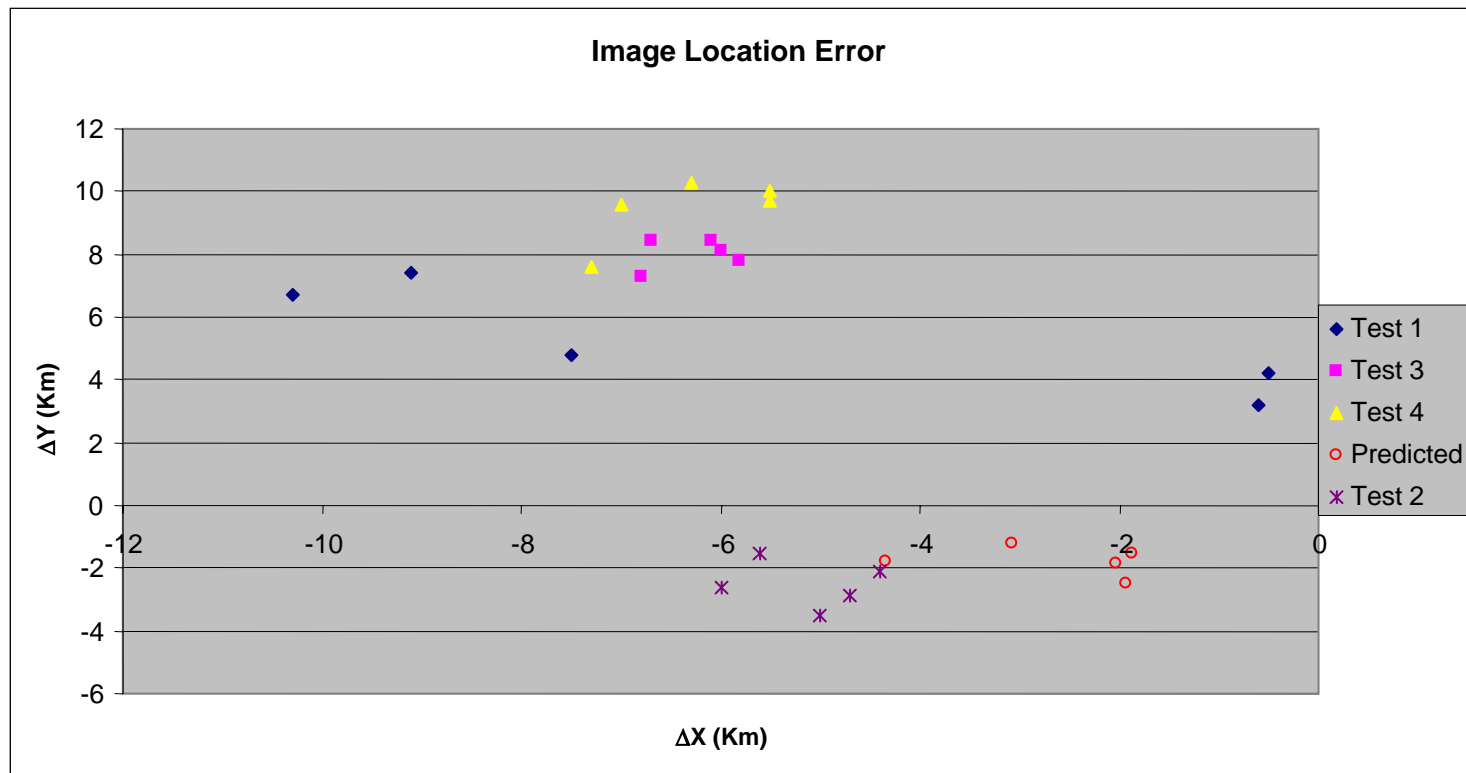


Image Location Error

Image effects

Predicted errors due to Bias

Date	Bias		Longitude Error		Latitude Error		Angular Error		Linear Error	
	roll (.)	pitch (.)	roll (.)	pitch (.)	roll (.)	pitch (.)	Long (.)	Lat (.)	Long (km)	Lat (km)
20/03/2005	-0.20	-0.77	-0.198	-0.114	-0.030	0.762	-0.312	0.732	-4.2	9.9
21/03/2005	-0.17	-0.79	-0.168	-0.117	-0.025	0.781	-0.285	0.756	-3.9	10.3
23/03/2005	-0.08	-0.69	-0.079	-0.102	-0.012	0.682	-0.181	0.671	-2.5	9.1
25/03/2005	-0.18	-0.77	-0.178	-0.114	-0.027	0.762	-0.292	0.735	-4.0	10.0
26/03/2005	-0.16	-0.74	-0.158	-0.109	-0.024	0.732	-0.268	0.708	-3.6	9.6

Image effects

■ On ground roll estimation

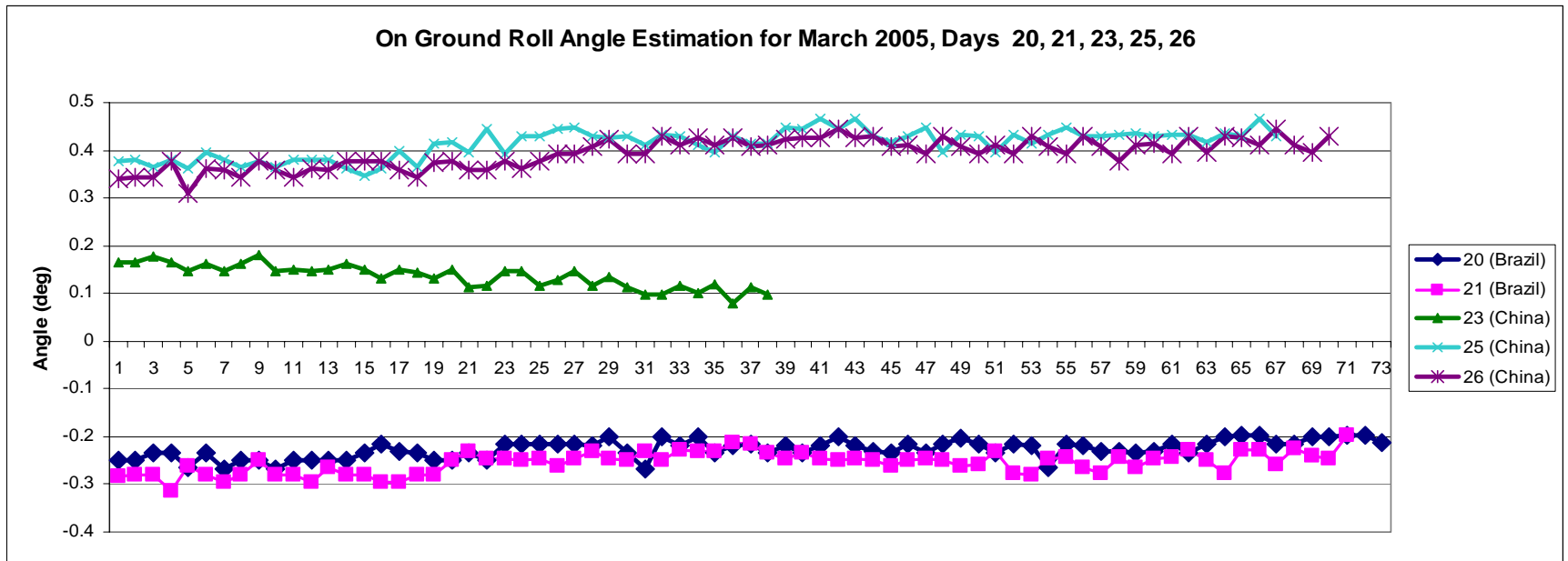


Image effects

■ On ground pitch estimation

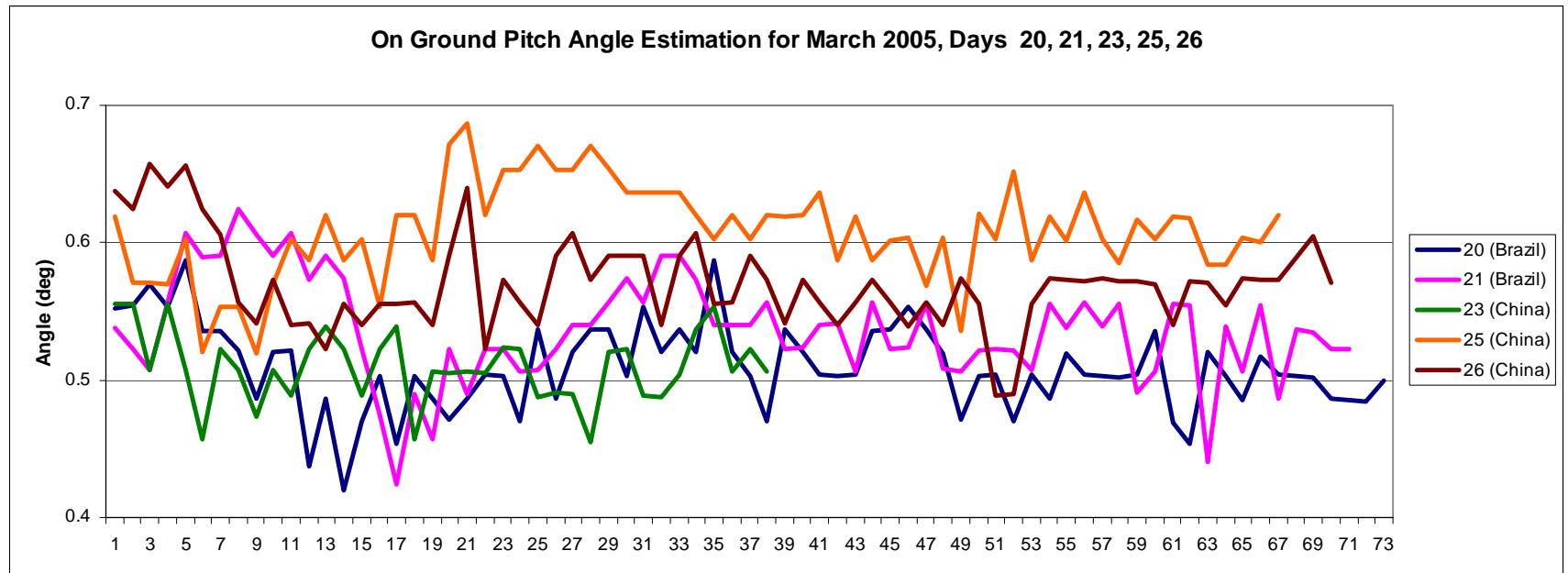




Image effects

■ On ground yaw estimation

- Not relevant in the present analysis
- The quantization of DSS telemetry is only 2 bytes
- The accuracy of yaw attitude determination is worse than the accuracy of roll and pitch attitude determination



Final comments

- The analysis is based on
 - Image positioning errors
 - On ground attitude determination
- Image positioning errors using attitude telemetry
 - Longitude errors from 0.5 km to 10.3 km ($\Delta = 9.8$ km)
 - Latitude errors from 3.2 km to 7.4 km ($\Delta = 4.2$ km)
- Image positioning errors using on ground attitude estimates
 - Longitude errors from 4.4 km to 6.0 km ($\Delta = 1.6$ km)
 - Latitude errors from 1.5 km to 3.5 km ($\Delta = 2.0$ km)



Final comments

■ On ground attitude determination

- Roll angle values ranging from -0.3 to +0.4 degree
- Pitch angle values ranging from 0.4 to +0.65 degree

■ Suggested actions

- Ensure consistency between ephemeris data uploaded from both control centers
- Analyze the impact on CBERS-2B
- Analyze the possibility of improving attitude sensors telemetry data accuracy



Obrigado

Thank you