Overview of the CBERS-2

Gyanesh Chander, SAIC

Contract employee under U.S. Geological Survey contract 03CRCN0001

U.S. Department of the Interior

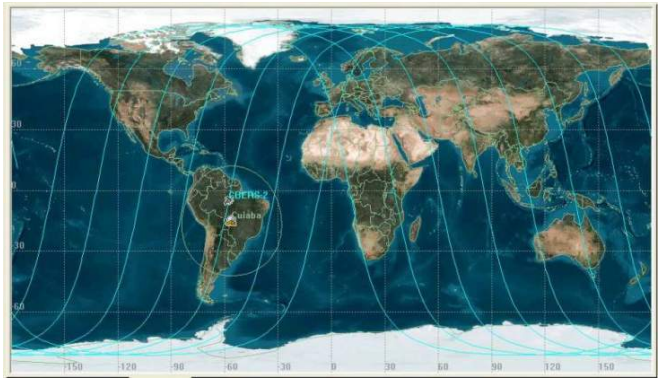
U.S. Geological Survey

Outline

- Background
- Orbit and Payload
- Sensor Overview
- RSR Profiles comparison
- Data Products
- Conversion to Radiance
- References

China Brazil Earth Resources Satellite - CBERS

- **CBERS-1, was launched on Oct. 14, 1999**
  - The spacecraft was operational for almost 4 years
  - The CBERS-1 images were not used by user community
  - On Aug. 13, 2003, CBERS-1 experienced an X-band malfunction causing an end of all image data transmissions
- **CBERS-2 (or ZY-1B) was launched successfully on Oct. 21, 2003 from the Taiyuan Satellite Launch Center**
  - The spacecraft carries the identical payload as CBERS-1
- **CBERS Orbit**
  - Sun synchronous
  - Height: 778 km
  - Inclination: 98.48 degrees
  - Period: 100.26 min
  - Equator crossing time: 10:30 AM
  - Revisit: 26 days
  - Distance between adjacent tracks: 107 km



CBERS- Sensor Compliment

- **CBERS satellite carries on-board a multi sensor payload with different spatial resolutions & collection frequencies**
  - HRCCD (High Resolution CCD Camera)
  - IRMSS (Infrared Multispectral Scanner)
  - WFI (Wide-Field Imager)
- **The CCD & the WFI camera operate in the VNIR regions, while the IRMSS operates in SWIR and thermal region**
- **In addition to the imaging payload, the satellite carries a Data Collection System (DCS) and Space Environment Monitor (SEM)**

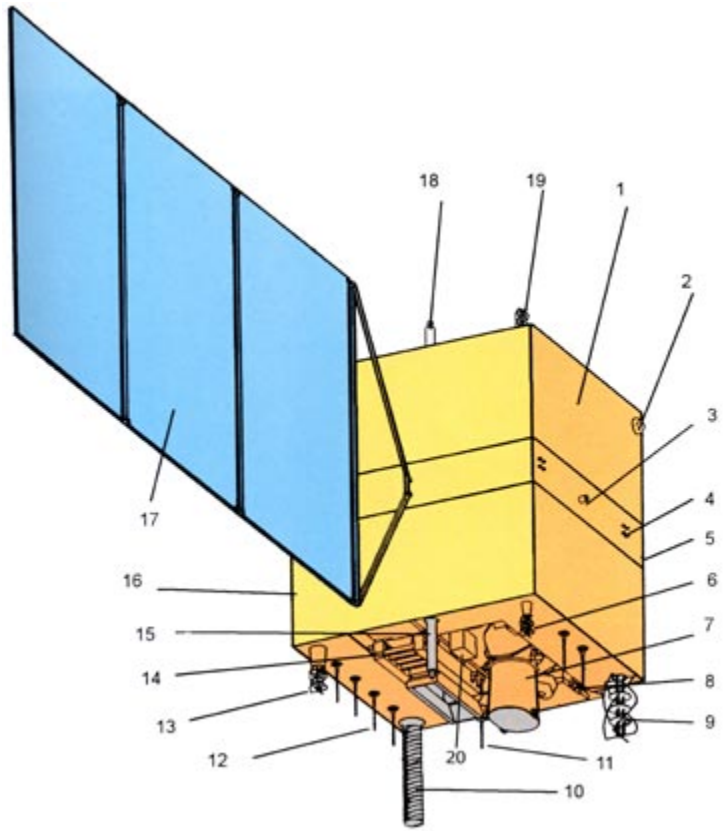
Work Share (70% China, 30% Brazil)

Pay load Module (16)

CCD (14)	China
IRMSS (7)	China
WFI (20)	Brasil
Data Transmission	China
Data collection	Brasil

Service Module (1)

Structure	Brasil
Thermal Control	China
Attitude and Orbit Control	China
Power supply	Brasil
On-board computer	China
Telemetry	Brasil



High Resolution CCD (HRCCD)

- **The HRCCD is the highest-resolution sensor offering a GSD of 20m at nadir (Pushbroom scanner)**
- **Quantization: 8 bits**
- **Ground swath is 113 km with 26 days repeat cycle**
  - Steerable upto +/- 32^{o} across track to obtain stereoscopic imagery
- **Operates in five spectral bands - one pan & four VNIR**
  - CCD has one focal plane assembly
  - The signal acquisition system operates in two channels
    - Channel 1 has Bands 2, 3, 4
    - Channel 2 has Bands 1,3,5
    - Four possible gain settings are 0.59, **1.0**, 1.69 & 2.86

HRCCD Detector Arrangment

- Focal plane has five spectral bands with three staggered CCD arrays, each with 2048 detectors
  - 2048 x 3 = 6144
- 14 pixels in the third array are not received by the station
  - 6144 – 14 = 6130
  - 6130 bytes are received in each line of the image
- There is a superposition region of 154 detectors
  - 154 x 2 = 308
- There is a dark current region of 8 detectors in each array
  - 8 pixels are dark (8 x 3 = 24)
- The final image contains 5798 pixels in a line
  - 6130-308-24=5798

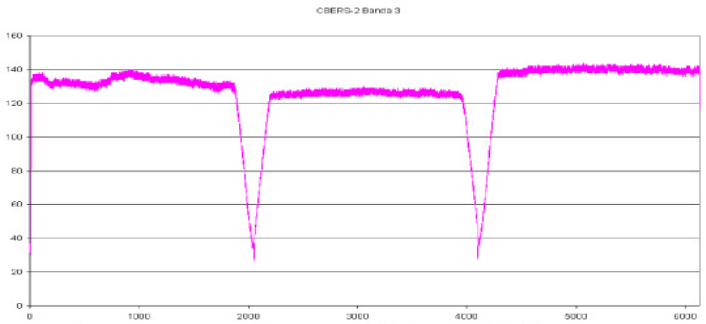
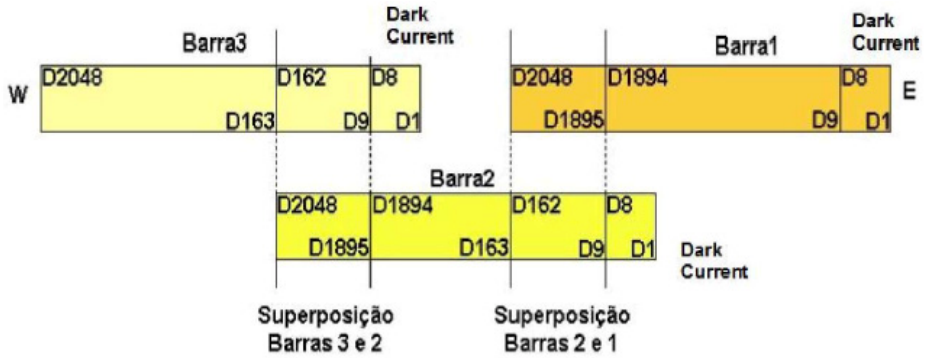


Figure 1.5.1 – CBERS2-CCD: Responses of the detectors in the three arrays.



Calibration issues with CCD camera

- **Spectral range for band 2 is broader than specs**
  - Specification = 0.52 – 0.59 um / Measurement = 0.515 – 0.635 um
    - Technical difficulties in meeting the project specification by CAST
  - The wider the spectral band the greater the radiance seen by detector
    - Decreases the instrument dynamic range in the spectral band
    - Thus, saturation is reached much lower than expected
- **Signal to Noise Ratio (SNR)**
  - Bands 1,3,4 has SNR 4 db, 2 db and 1 db lower than specifications
  - Max spectral radiance values for all bands are lower than specs
  - The random noise level measured was 2.7mV (equivalent to 0.7DN)
  - Therefore, saturation level is reached lower than expected
- **CCD images (band 4) has high saturation problem**
  - Due to high gain determined during prelaunch

Infrared Multispectral Scanner (IRMSS)

- **The IRMSS is a moderate-resolution sensor offering a GSD of 80m (pan/SWIR) & 160m (thermal)**
- **Quantization: 8 bits**
- **Ground swath is 120 km with 26 days repeat cycle**
- **Operates in four spectral bands - one pan, two SWIR & one thermal**
  - The four spectral bands has eight detector staggered arrays mounted along track
  - IRMSS has three focal plane assemblies
    - The Pan band (Si photodiodes detectors) is located on the warm focal plane
    - The SWIR bands & the thermal band (HgCdTe detectors) are located on cold focal planes with cryogenic temps of 148K & 101K respectively
    - Four of eight thermal detectors are spare

IRMSS On-board Calibrator

- **The IRMSS incorporates an onboard radiometric calibration system**
- **Internal Calibrator (IC) and a Solar calibrator**
  - The IC includes cal lamp & blackbody that acquire real time cal data during the scan-turn around interval
    - During that time a rotating shutter is driven to prevent the Earth flux from being incident on the focal plane and the flux from calibration lamp and blackbody is reflected to the focal plane
    - The lamp calibrator has 4 operation states corresponding to different flux output (each state lasts about 16 seconds)
  - The solar calibrator is designed to provide cal reference with the Sun upon ground command
    - As the satellite passes over the north polar regions, the solar cal collects the solar flux & reflects it onto the Pan/SWIR band detectors
    - The solar calibration also provides a check on the stability of the on-board lamp calibration (It is performed once every 13 day)

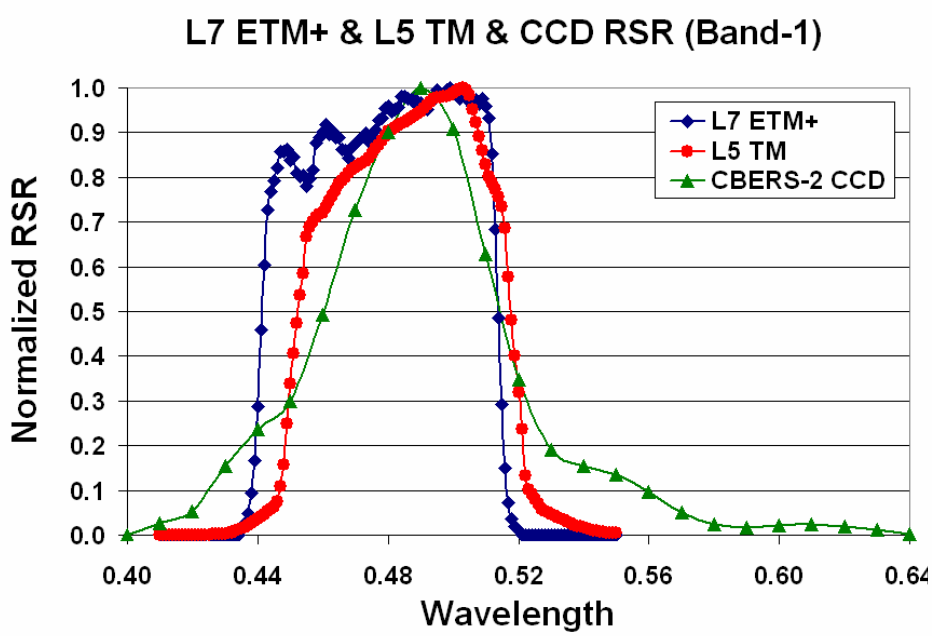
Wide-Field Imager (WFI)

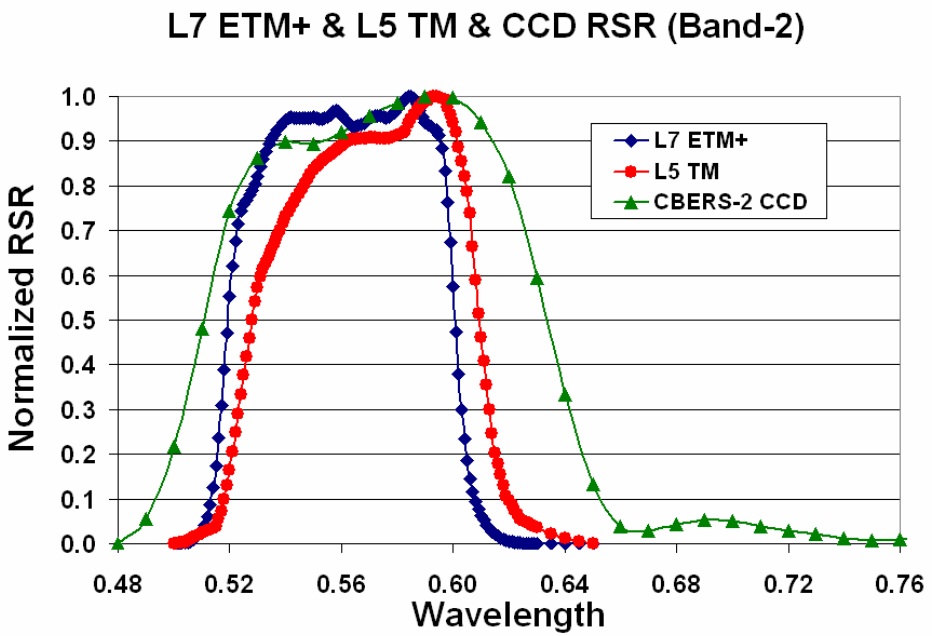
- **The WFI camera provides a synoptic view with spatial resolution of 260m**
- **Ground swath is 885km with 3-5 days repeat cycle**
- **Operates in two spectral bands – (Band 3 & 4)**
  - 0.63 - 0.69 µm (red) and 0.77 - 0.89 µm (infrared)
  - Similar bands are also present in the CCD camera providing complementary data

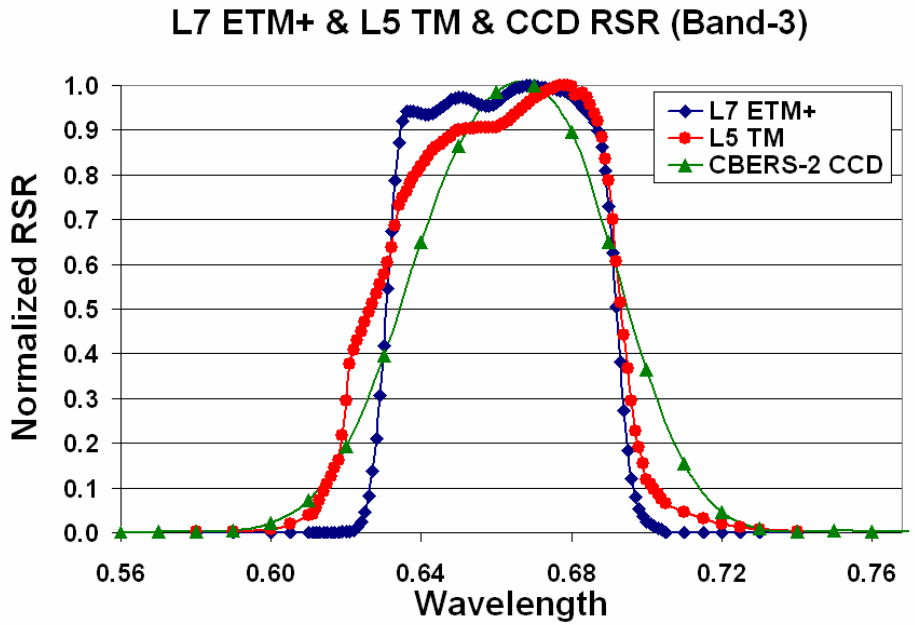
Overview of the CBERS instruments

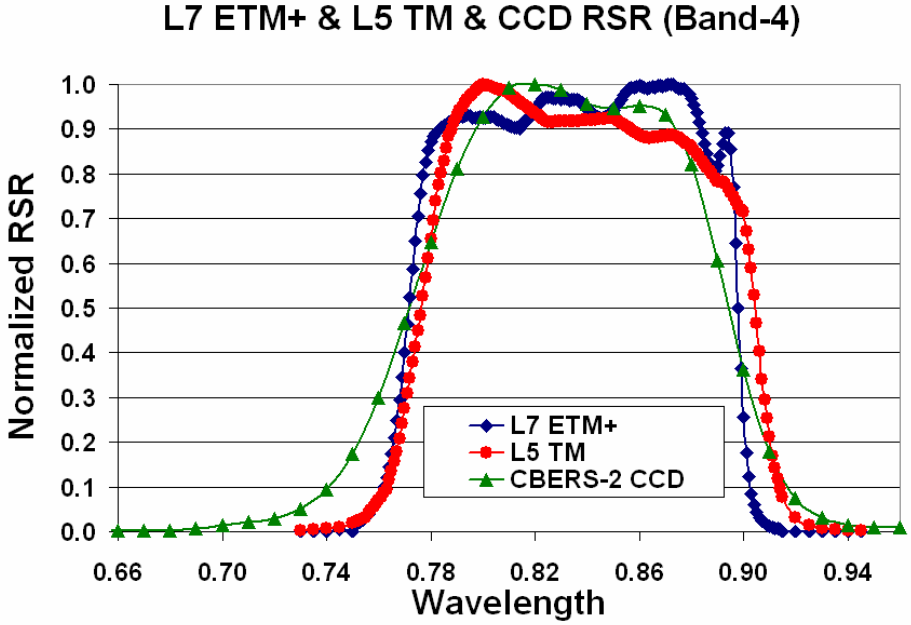
Parameter	HRCC	IRMSS	WFI
Spectral Bands (µm)	0.51 - 0.73 (PAN)	0.50 - 1.10 (PAN)	0.63 - 0.69
	0.45 - 0.52	1.55 - 1.75 (SWIR)	0.76 - 0.90
	0.52 - 0.59	2.08 - 2.35 (SWIR)	
	0.63 - 0.69	10.4 - 12.5 (TIR)	
	0.77 - 0.89		
Spatial Resolution	20 m	80 m (PAN & SWIR) 160 m (TIR)	260 m
Swath Width (FOV)	113 km (8.32°)	120 km (8.78°)	885 km (60°)
Temporal Resolution	26 days	26 days	3-5 days
Cross-Track Pointing	±32°		
Data Rate	2 x 53 Mbit/s	6.13 Mbit/s	1.1 Mbit/s
Carrier Frequency (X-band)	8.103 and 8.321 GHz	8.216 GHz	8.203 GHz
EIRP	43 dBm	39.2 dBm	31.8 dBm
Modulation	QPSK	BPSK	QPSK
Tracking Beam Frequency	8.196 GHz	8.196 GHz	8.196 GHz

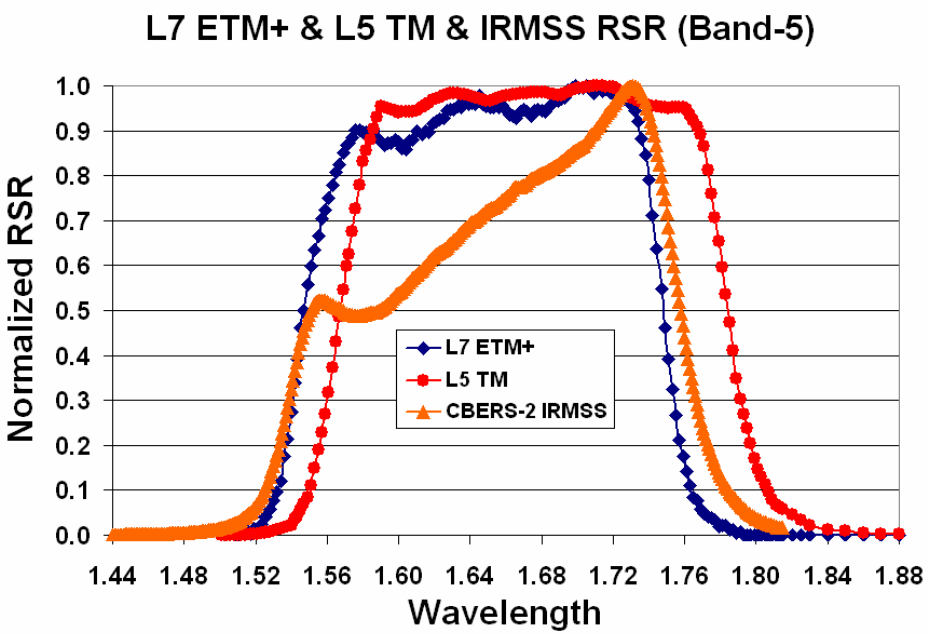
Spectral Range (um) and Ground Sample Distance (m)							
	Landsat		CBERS			SPOT-4	IRS-P6
Band	L5 TM	L7 ETM+	HRCC	IRMSS	WFI		LISS-III
RC	16	16	26	26	5	26	24
1	0.450-0.520 (30)	0.450-0.515 (30)	0.45-0.52 (20)				
2	0.520-0.600 (30)	0.525-0.605 (30)	0.52-0.59 (20)			0.50-0.59 (20)	0.52-0.59 (23.5)
3	0.630-0.690 (30)	0.630-0.690 (30)	0.63-0.69 (20)		0.63-0.69 (260)	0.61-0.68 (20)	0.62-0.68 (23.5)
4	0.760-0.900 (30)	0.775-0.900 (30)	0.77-0.89 (20)		0.76-0.90 (260)	0.79-0.89 (20)	0.77-0.86 (23.5)
5	1.550-1.750 (30)	1.550-1.750 (30)		1.55-1.75 (80)		1.58-1.75 (20)	1.55-1.70 (23.5)
6	10.40-12.50 (120)	10.40-12.50 (60)		10.4-12.5 (160)			
7	2.080-2.350 (30)	2.090-2.350 (30)		2.08-2.35 (80)			
Pan		0.520-0.900 (15)	0.51-0.73 (20)	0.50-1.10 (80)		0.51-0.73 (10)	0.50-0.75 (5.8)

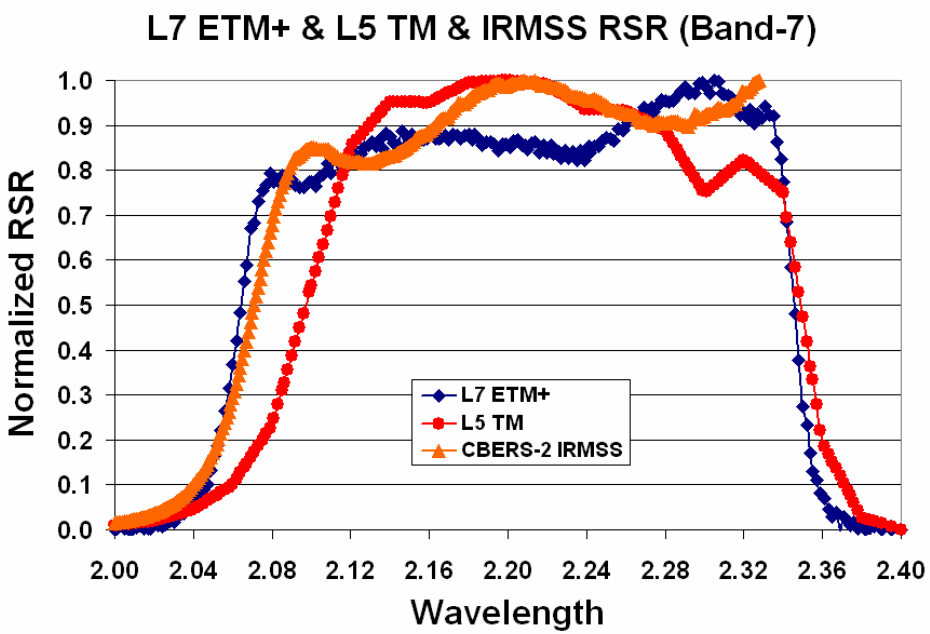

L7 ETM+ & L5 TM & CCD RSR (Band-1)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
CBERS-2 CCD
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64

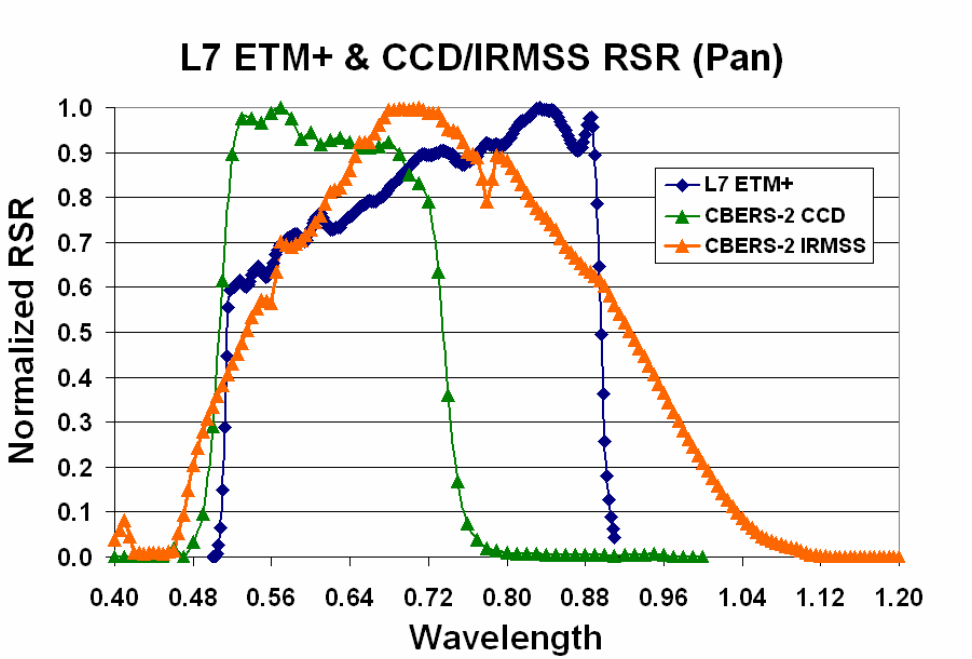

L7 ETM+ & L5 TM & CCD RSR (Band-2)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
CBERS-2 CCD
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.48
0.52
0.56
0.60
0.64
0.68
0.72
0.76


L7 ETM+ & L5 TM & CCD RSR (Band-3)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
CBERS-2 CCD
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.56
0.60
0.64
0.68
0.72
0.76

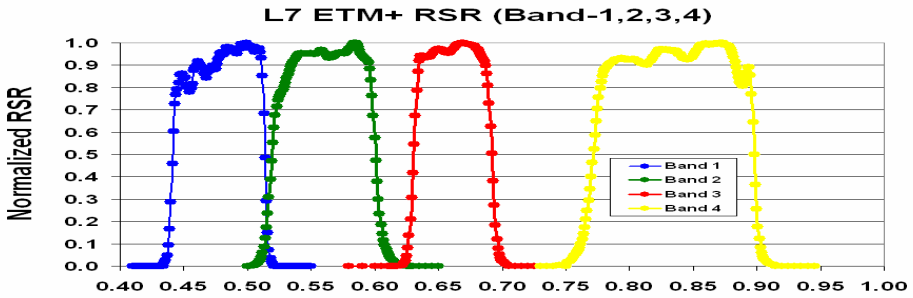

L7 ETM+ & L5 TM & CCD RSR (Band-4)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
CBERS-2 CCD
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.66
0.70
0.74
0.78
0.82
0.86
0.90
0.94

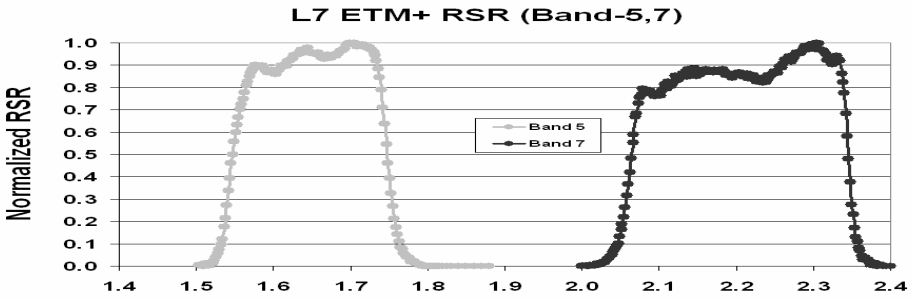

L7 ETM+ & L5 TM & IRMSS RSR (Band-5)
Normalized RSR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1.44 1.48 1.52 1.56 1.60 1.64 1.68 1.72 1.76 1.80 1.84 1.88
Wavelength
L7 ETM+
L5 TM
CBERS-2 IRMSS

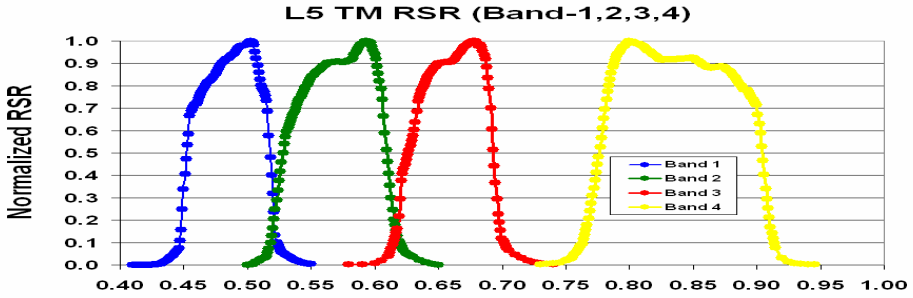

L7 ETM+ & L5 TM & IRMSS RSR (Band-7)
Normalized RSR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.00 2.04 2.08 2.12 2.16 2.20 2.24 2.28 2.32 2.36 2.40
Wavelength
L7 ETM+
L5 TM
CBERS-2 IRMSS

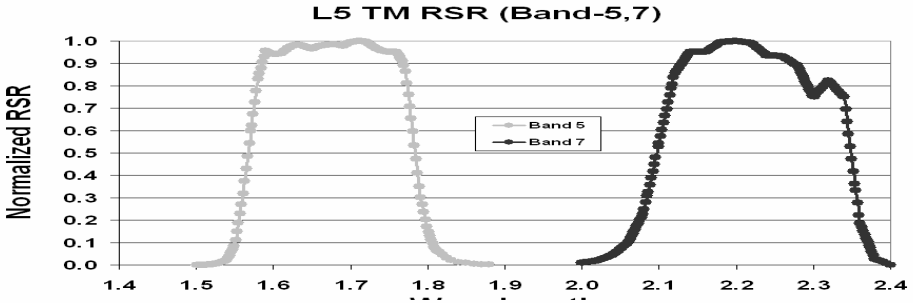

L7 ETM+ & CCD/IRMSS RSR (Pan)
Normalized RSR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40 0.48 0.56 0.64 0.72 0.80 0.88 0.96 1.04 1.12 1.20
Wavelength
L7 ETM+
CBERS-2 CCD
CBERS-2 IRMSS

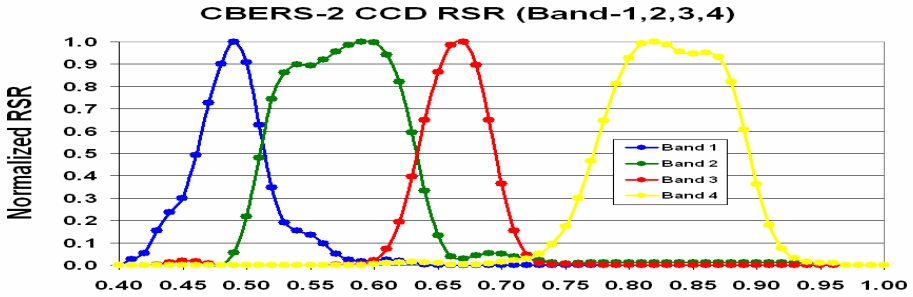
Relative Spectral Response (RSR) Profiles

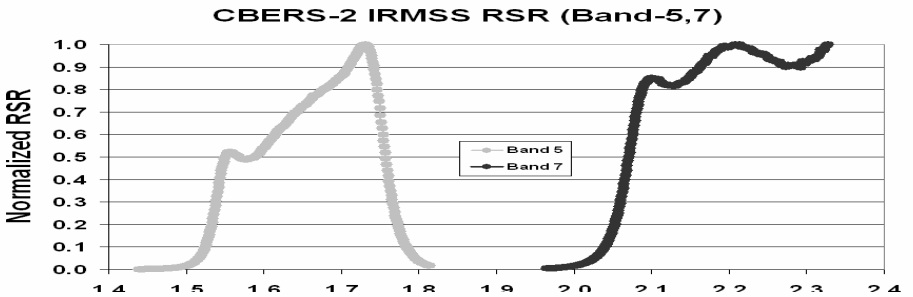


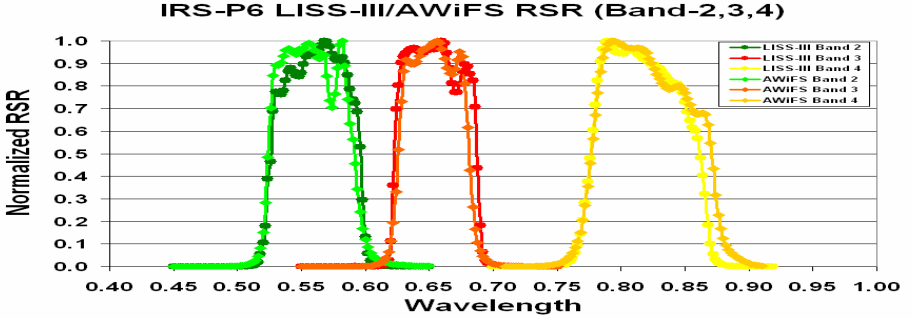


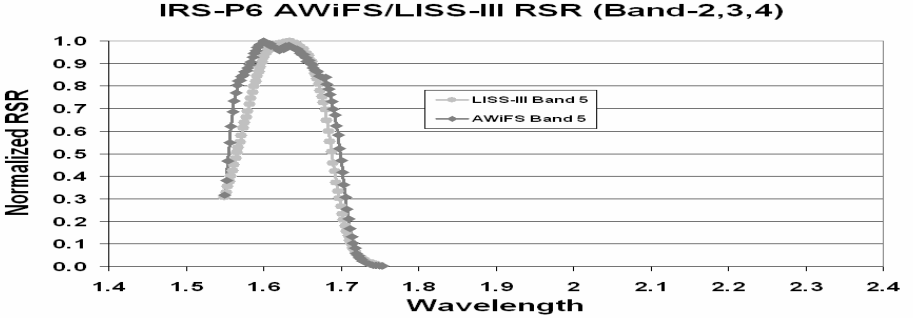












CBERS-2 Data Product Levels

Product Level	Product Level Explanation
Level 0	Not corrected raw data
Level 1	Radiometrically corrected and geometrically raw data
Level 2	Radiometrically and geometrically corrected using system model
Level 3	Radiometrically and geometrically corrected using Ground Control Points (GCPS)
Level 4	Radiometrically and geometrically corrected using GCPS and Digital terrain Model (DTM) for terrain
Level 5	Deeply processed remote sensing thematic mapper and image
Output Media	4-mm tape, 8-mm tape, 9-track CCT, CD-ROW

Absolute Calibration Coefficients

- **Independent studies are carried out by INPE & CRESDA**
  - INPE used calibration sites in the west part of State Bahia
  - CRESDA used Gobi desert (Dunhuang) test site in China

L* = DNn / CCn

Where

L* = spectral radiance at the sensors aperture W/(m2.sr.um)

DN = Digital number extracted from the image in band n

CCn = absolute calibration coefficient for band n

CBERS-2 CCD Vicarious Absolute Calibration Coefficients (CCn)						
	Test-Site	**CCD_1**	**CCD_2**	**CCD_3**	**CCD_4**	**CCD_Pan**
Pre-launch		0.9800	1.5900	1.2000	2.2900	1.2500
Brazil						
25th June 2004	Bahia	1.228	2.357	1.215	2.553	1.628
16th August 2004		1.0090	1.9300	1.1540	2.1270	1.4830
Oct_3th New		0.862	1.544	0.874	1.933	0.995
Oct_3th Old		0.978	1.721	1.057	1.936	1.223
Oct_6th New		0.84	1.558	0.89	2.095	1.03
Oct_6th Old		0.97	1.74	1.083	2.105	1.263
China						
19th August 2004		0.9917	1.6761	1.0096	2.0613	
25th August 2004	Dunhuang	1.0292	1.7254	1.0356	2.1515	
24th August 2005	Dunhuang	1.0288	1.8096	1.1079	2.2783	

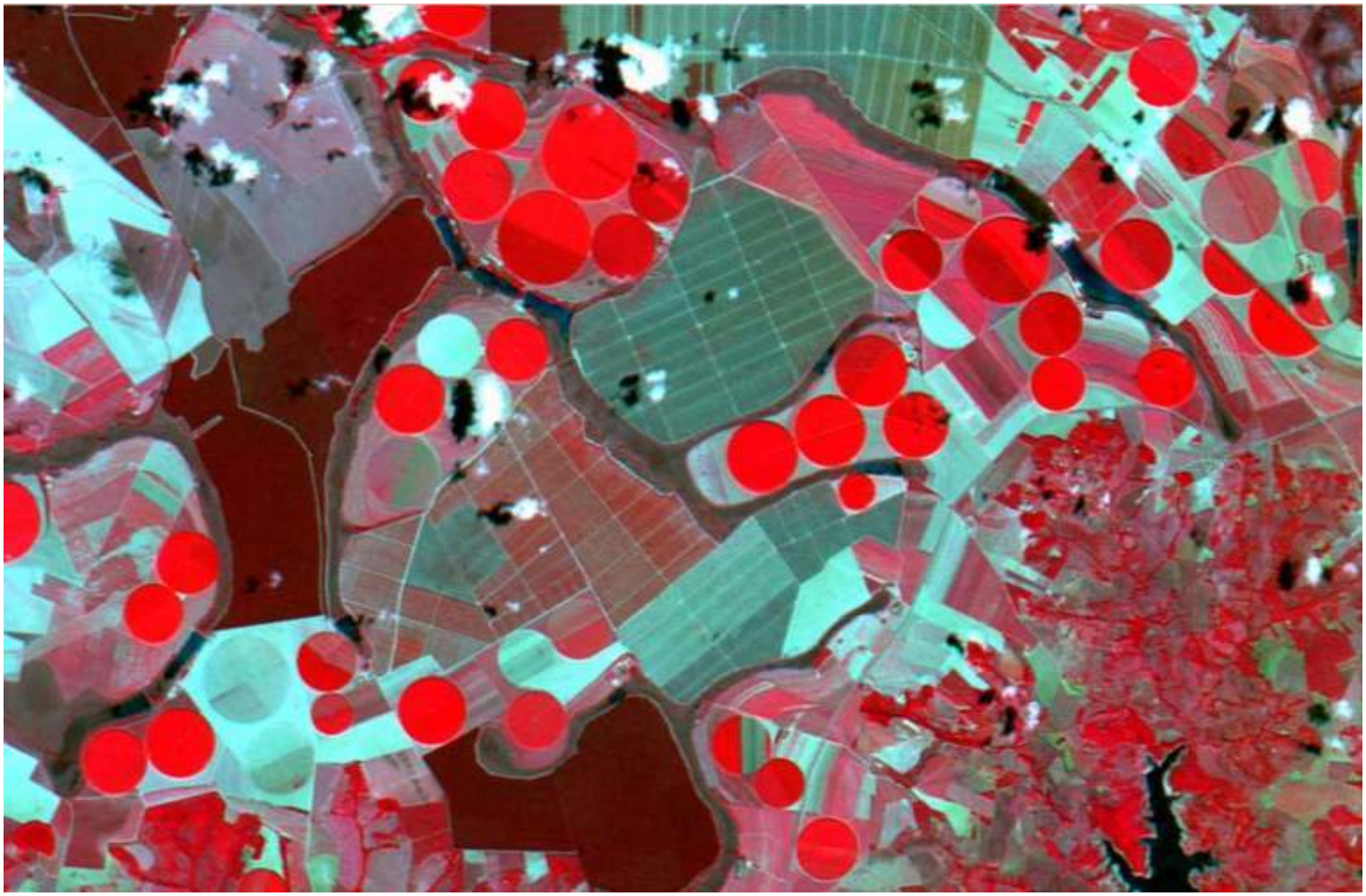
Radiance to TOA Reflectance

$$\rho_p = \frac{\Pi \bullet L_\lambda \bullet d^2}{ESUN_\lambda \bullet \cos\theta_s}$$

ESUN Units = W/(m^2.um) from INPE				
CCD_1	CCD_2	CCD_3	CCD_4	CCD_Pan
1934,03	1787,10	1548,97	1069,21	1664,33
IRMSS_1	IRMSS_2	IRMSS_3		
1347,75	222,32	83,46		
WFI_1	WFI_2			
1563,95	1068,25			

Solar Exoatmospheric Spectral Irradiances										
Units:	ESUN = W/(m^2.um)									
Model :	Neckel and Labs		Chance Spectrum CHKUR (MODTRAN 4.0)							
Band	L4 TM	L5 TM	L4 TM	L5 TM	L7 ETM+	E0-1 ALI	HRCCD	IRMSS	LISS-III	AWiFS
1	1958	1957	1957	1957	1969	1967.6	1928.18			
2	1828	1829	1825	1826	1840	1837.2	1799.51		1846.77	1849.82
3	1559	1557	1557	1554	1551	1551.47	1535.35		1575.5	1579.37
4	1045	1047	1033	1036	1044	1164.53	1053.38		1087.34	1075.11
5	219.1	219.3	214.9	215.0	225.7	230.03		220.11	270.66	254.24
7	74.57	74.52	80.72	80.67	82.07	79.61		83.3		
Pan					1368	1747.86				
1P						1851.8				
4P						957.46				
5P						451.37				

CBERS-2 CCD, Minas Gerais, Brazil



CBERS-2 CCD image, Louisiania

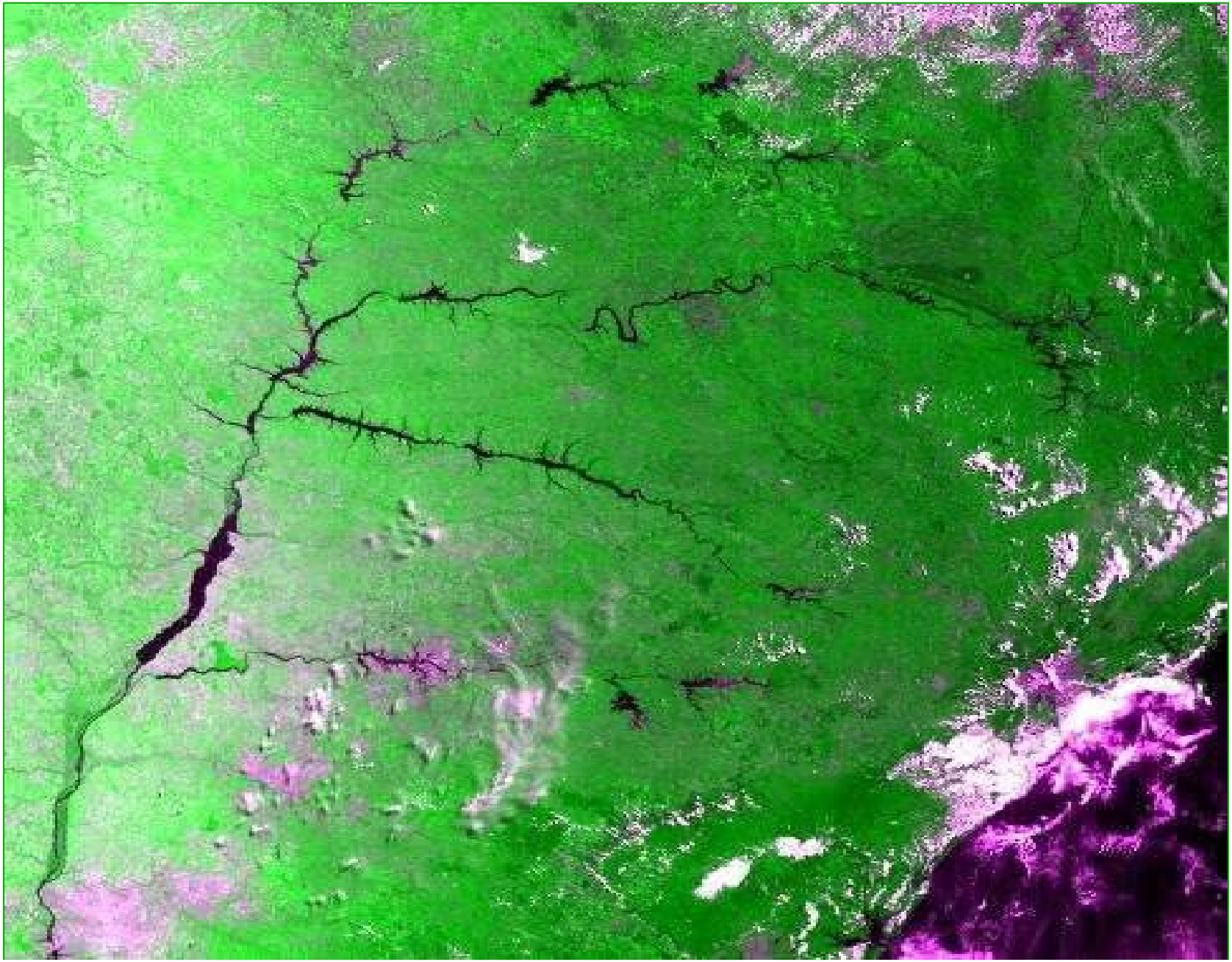
Obtained from on-board data recorder

IRMSS sensor

CB2-IRM-157/124, 24/3/2004, Catanduva (Brazil)

WFI sensor

CBERS2-WFI – 157/124, 18/01/2004, São Paulo



Minutes from USGS-INPE meeting

São José dos Campos, April 22nd 2005 (XII BRSS)

- INPE and USGS jointly agreed to pursue the below three actions in the spirit of GEOSS and to hold further discussions that are directed towards long-term and open data exchange agreements
  - Trial data reception at Sioux Falls: USGS and INPE agreed on a trial reception of CBERS data at USGS ground station. INPE will provide the prototype data ingest system and data production software for this test
    - USGS received the bit-synch from INPE
    - Dr. Gilberto Camara is the new Director of INPE
  - USGS and INPE agreed on a joint calibration campaign
  - General information on CBERS program and data policy: INPE will provide further information to USGS on aspects related to CBERS data availability and ground station infrastructure

Potential use for applications

- ✓ **Crop evapotranspiration and other agricultural applications**

  (G. Senay, S. Maxwell, J. Verdin) – Early Warning & Environmental Monitoring
- ✓ **Landcover and fire fuels; perhaps imperviousness mapping**

  (M. Crane) – Land Characterization
- ✓ **NLCD project for trending purposes**

  (C. Homer) – Land Characterization
- ✓ **Water consumption and energy balance algorithms**

  (J. Milliken) – US Bureau of Reclamation
- ✓ **Mapping agricultural lands and occasional mapping of natural vegetation, and surface water quality in large reservoirs**

  (D. Eckhardt) – US Bureau of Reclamation

Comments from the user community

- **From the Richard Allen (University of Idaho):** These satellites provide resolution on the order of Landsat including the thermal band. I'm sure that the quality is not as good as Landsat, but we are interested in learning more about the system. Our understanding is that CBERS only downlinks over S. America and Asia at the present time. Do you know if there is any "talk" within NASA or EROS to establish a ground link for N. America for CBERS and to work with the CBERS mission? The use of CBERS may provide our high resolution energy balance and ET mapping a "way out" of the future evaporation of Landsat imagery availability. From our perspective it would be worth a substantial investment in the downlink and even some flow of cash to China and Brazil. We would be pleased to encourage our congressmen to push for something like this. I was curious to know if you knew of any discussions or study on the CBERS missions.

- **From Jeff Milliken (USBR):** Briefly, I believe the USBR would be very interested in access to both CBERS data and SPOT data (reduced price). Currently our Lower Colorado region routinely monitors approximately 1 million acres of agricultural land for water consumptive use applications as well as other applications. We purchase approximately 12 to 14 Landsat scenes per year as part of this monitoring effort. Our classification accuracies are enhanced by also using bands 5 and 7 (mid IR) in the Landsat sensor. We have gotten by with no Mid IR using IRS data when cloud cover prevented us from acquiring Landsat, data but our accuracies dropped around 5%. Even though the CBERS mid IR is coarser (80 meters I believe) resolution, I don't think this would be a problem since we tend to have fairly large agricultural fields in this area. SPOT 2 and 4 could also be used in place of Landsat though I don't believe these have operational Mid IR bands (?).

  The USBR is also currently conducting a study with the Alliance University group to test and validate energy balance algorithms that utilize Band 6 (thermal) from the Landsat sensor. These algorithms produce Evapotranspiration data - also critical to meeting a variety USBR needs. There are fewer alternatives (if any?) to Landsat for the routine availability of higher resolution thermal data. The CBERS thermal band (160 meter?), would still be a much better alternative than others I am aware of at present, depending on the cost of course.

- **From David Eckardt (USBR):** My office uses TM data routinely for mapping agricultural lands in the West, and for occasional mapping of natural vegetation on Reclamation Lands and surface water quality in large Reclamation reservoirs. In the coming years, my office will probably purchase on the order of 35 to 50 TM scenes (or similar) either yearly, or every other year. Having access to CBERS 2 data after L5 dies would be very useful to us.

References

- **Personal communication**
  - Flavio Ponzoni (INPE)
  - Fu Qiaoyan (CRESDA)
- **World Wide Web (WWW)**
  - http://www.cbers.inpe.br/
  - http://www.cresda.com/
- **Documents**
  - **Radiometric Quality Assessment of CBERS-2**
  - **The CCD & IRMSS for CBERS**
  - **CALIBRAÇÃO ABSOLUTA DOS SENSORES CBERS-2**
  - **In-flight absolute calibration of the CCD/CBERS-2 sensor**