GSA-5859
SISTEMAS DE INFORMAÇÃO GEOGRÁFICA EM SOFTWARE LIVRE

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Sensoriamento Remoto

DEFINIÇÃO 1 (INPE)

- "Utilização de sensores para aquisição de informações sobre objetos ou fenômenos sem que haja contato direto entre eles"

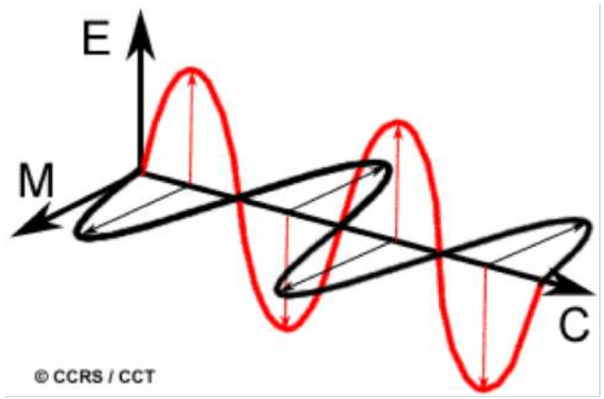
    - Sensores: são equipamentos capazes de coletar energia proveniente do objeto, convertê-la em sinal passível de ser registrado e apresentá-lo em forma adequada à extração de informações.

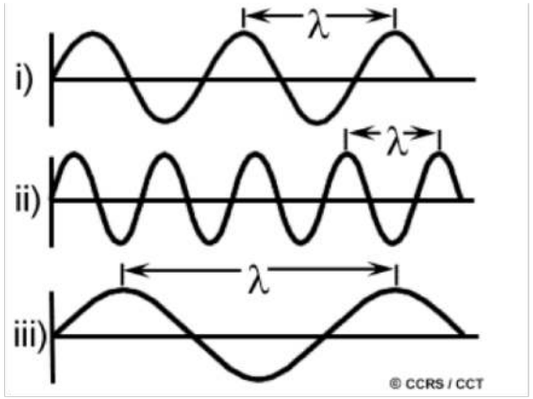
    - Energia: na grande maioria das vezes é a energia eletromagnética ou radiação eletromagnética.

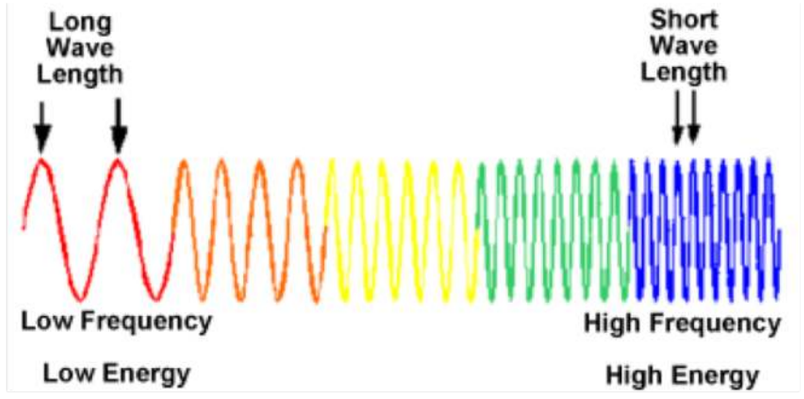
DEFINIÇÃO 1 (INPE)

- "Conjunto das atividades relacionadas à aquisição e a análise de dados de sensores remotos"
    - Sensores remotos: sistemas fotográficos ou óptico-eletrônicos capazes de detectar e registrar, sob a forma de imagens ou não, o fluxo de energia radiante refletido ou emitido por objetos distantes.

RADIAÇÃO ELETROMAGNÉTICA (REM)







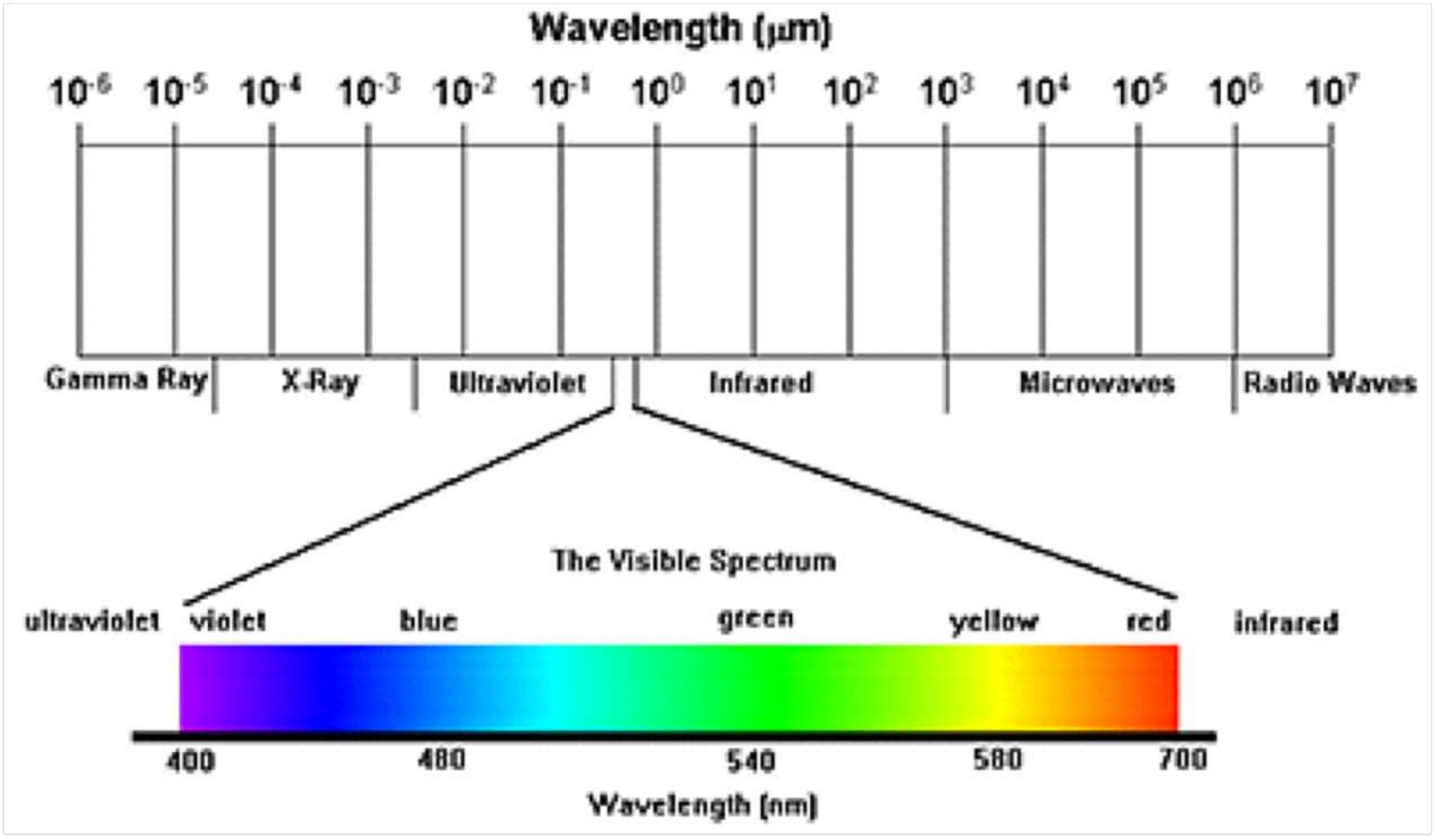
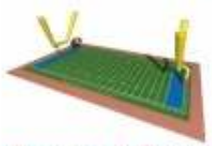


Chart of the Electromagnetic Spectrum

Size reference


football field

man's height


baseball


paperclip thickness


paper thickness


cells


bacteria


viruses


water molecule


atom


subatomic particles →

wavelength λ (m)

1 ft | 1 cm | 1 mm | 1 mil | 1 µ | 1 nm | 1 Å | 1 pm

10^{3} 10^{2} 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}

wavenumber (cm^{-1})

10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10}

electron volt (eV)

10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}

frequency (Hz)

1 MHz | 1 GHz | 1 THz | 1 PHz | 1 EHz | 1 ZHz

10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21}

Bands

Radio Spectrum | Terahertz | Infrared | Ultraviolet | X-ray | Gamma

Broadcast and Wireless | Microwave | Far IR | Mid IR | Near IR | Near UV | Extreme UV | Soft X-ray | Hard X-ray

electronics ◄ ► optics

Visible wavelengths (nm)

700 625 575 540 470 440

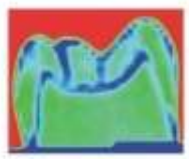
Sources and Uses of Frequency Bands


AM radio
600kHz-1.6MHz


FM radio
88-108 MHz


Mobile Phones
900MHz-2.4GHz


Radar
1-100 GHz


Bio imaging
1-10 THz

Fiber telecom
0.7-1.4 µ


Visible Light
425-750THz
700-400nm

Dental Curing
200-350nm


Medical X-rays
10-0.1 Å

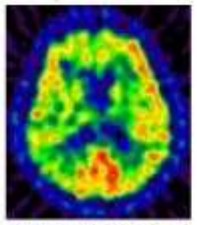

Cosmic ray observations
<<1 Å


Baggage screen
10-1.0 Å


Remotes
850 nm


Suntan
400-290nm


Crystallography
2.2-0.7 Å


PET imaging
0.1-0.01 Å


Screening
0.2-4.0 THz


Night Vision
10-0.7 µ


Sound Waves
← 20Hz-10kHz


Ultrasound
1-20 MHz

TV Broadcast
54-700 MHz


Wireless Data
~ 2.4 GHz


Microwave Oven
2.4 GHz

"mm wave"
"sub-mm"

$\lambda = 3x10^{8}/freq = 1/(wn*100) = 1.24x10^{-6}/eV$

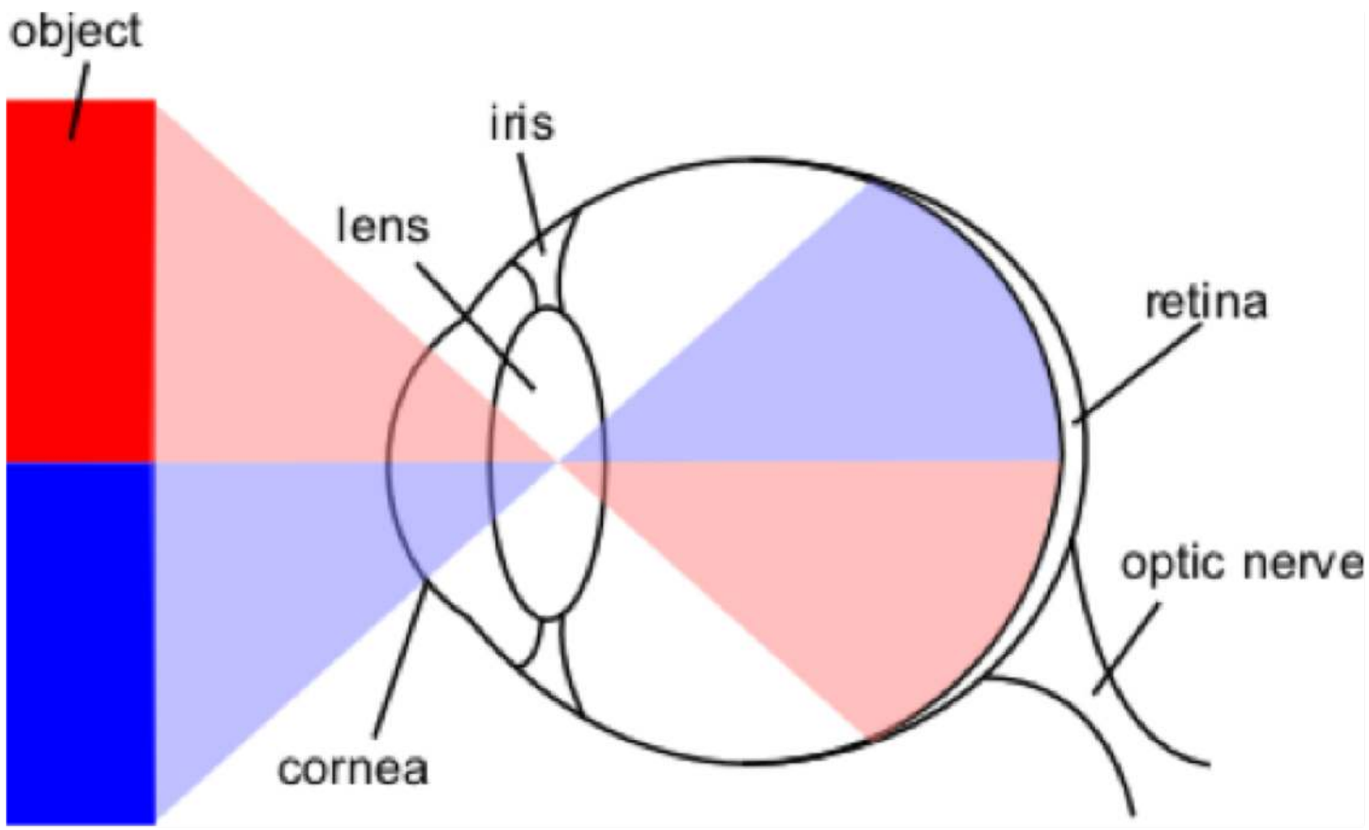
SURA Southeastern Universities Research Association ®

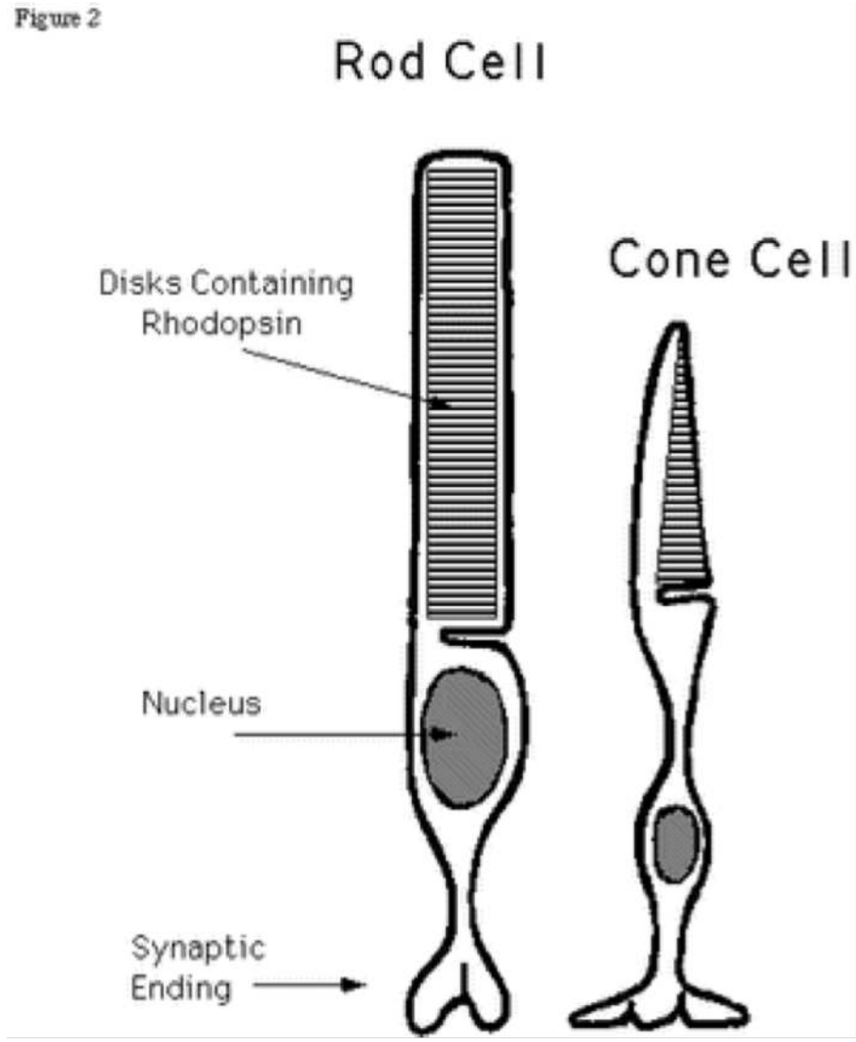
SISTEMA VISUAL HUMANO

- **Bastonetes**: ~$100*10^6$ por toda a retina, exceto no centro, onde a visão é mais acurada
  - para distinguir a variação no tom de cinza: ~1%
  - aprox. 100 tons de cinza (idealmente)

- **Cones**: ~$6\text{-}7*10^6$ principalmente no centro da retina
  - só funcionam com luminosidade
    - com pouca luz, enxergamos em tons de cinza
  - aprox. 100 tonalidades cada tipo
  - 3 tipos: Vermelho, Verde, Azul = ~1.000.000 cores !!
  - Somos seres Tricromáticos – exergamos a partir de 3 cores

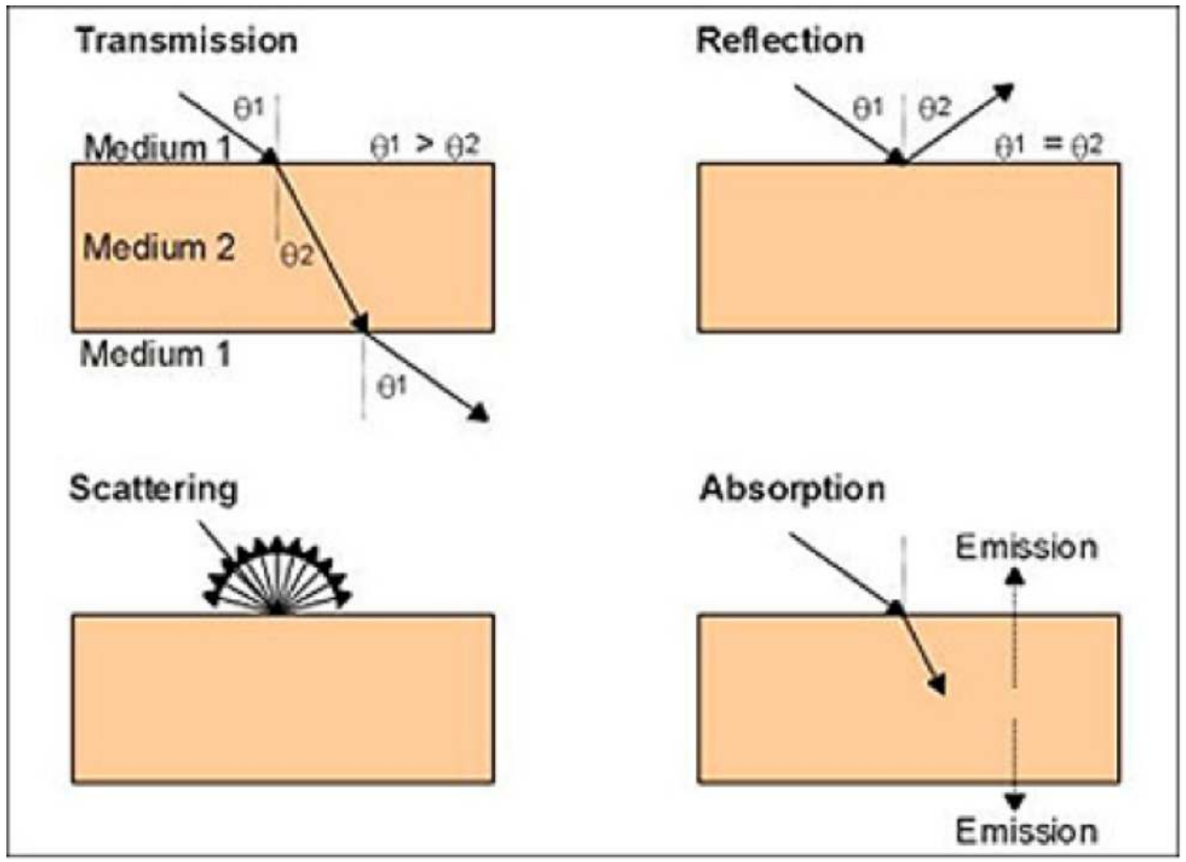
SISTEMA VISUAL HUMANO

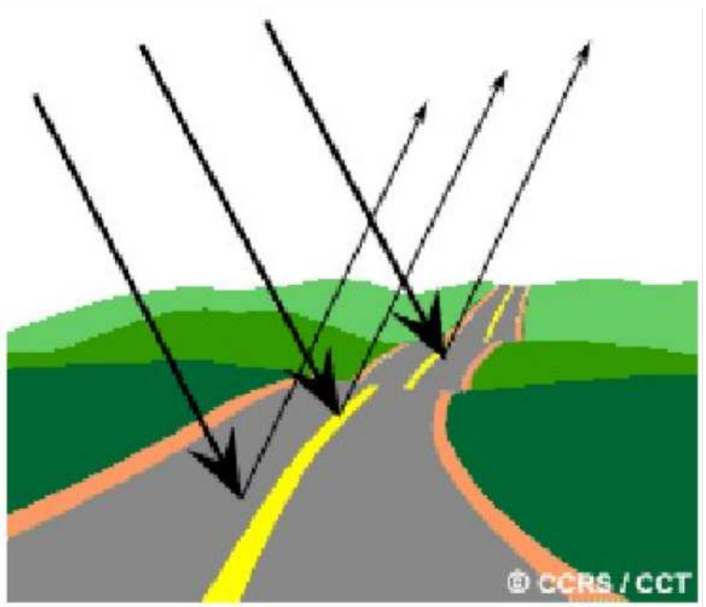


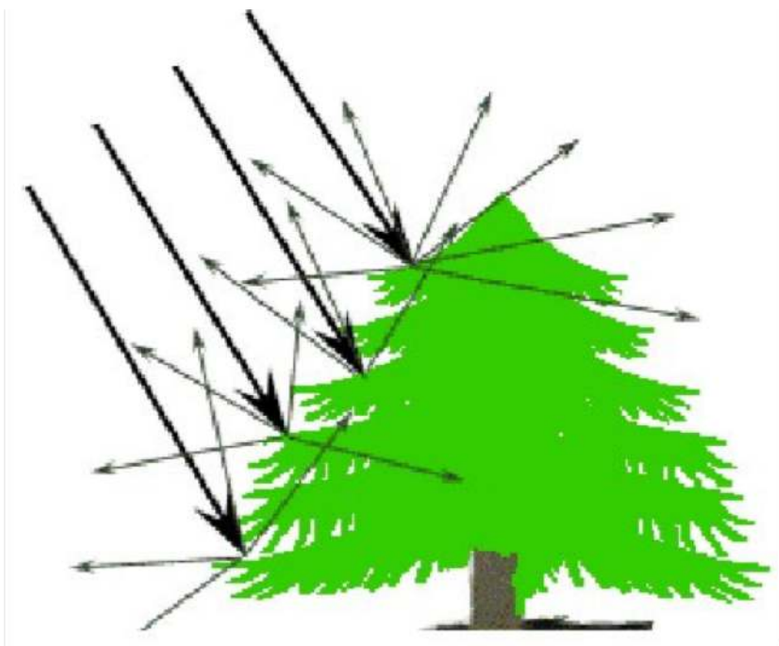


COMPORTAMENTO DA REM

- Transmissão
- **Reflexão** (especular/difusa)
- **Espalhamento**
- Absorção

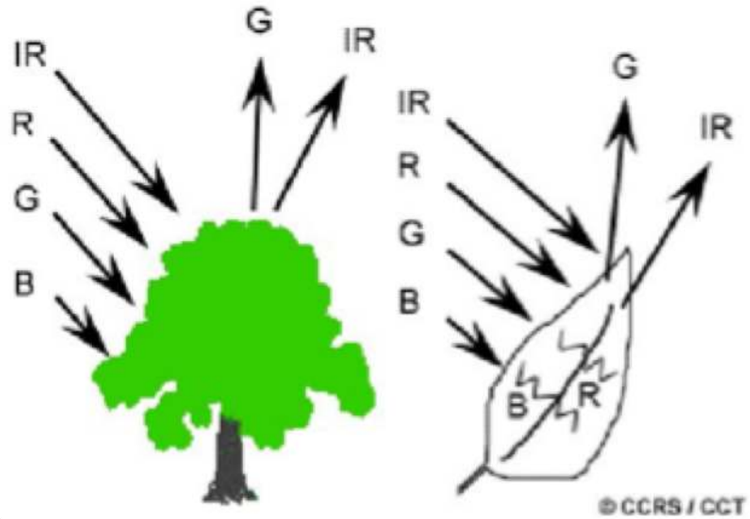


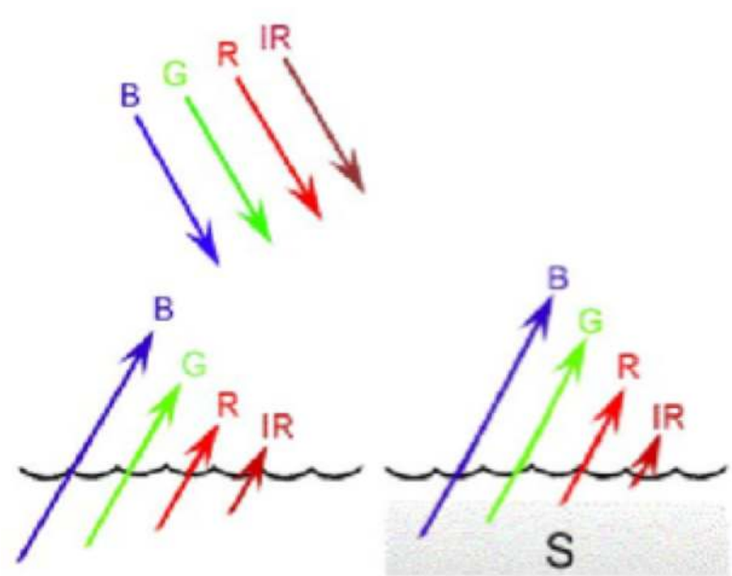




CORES

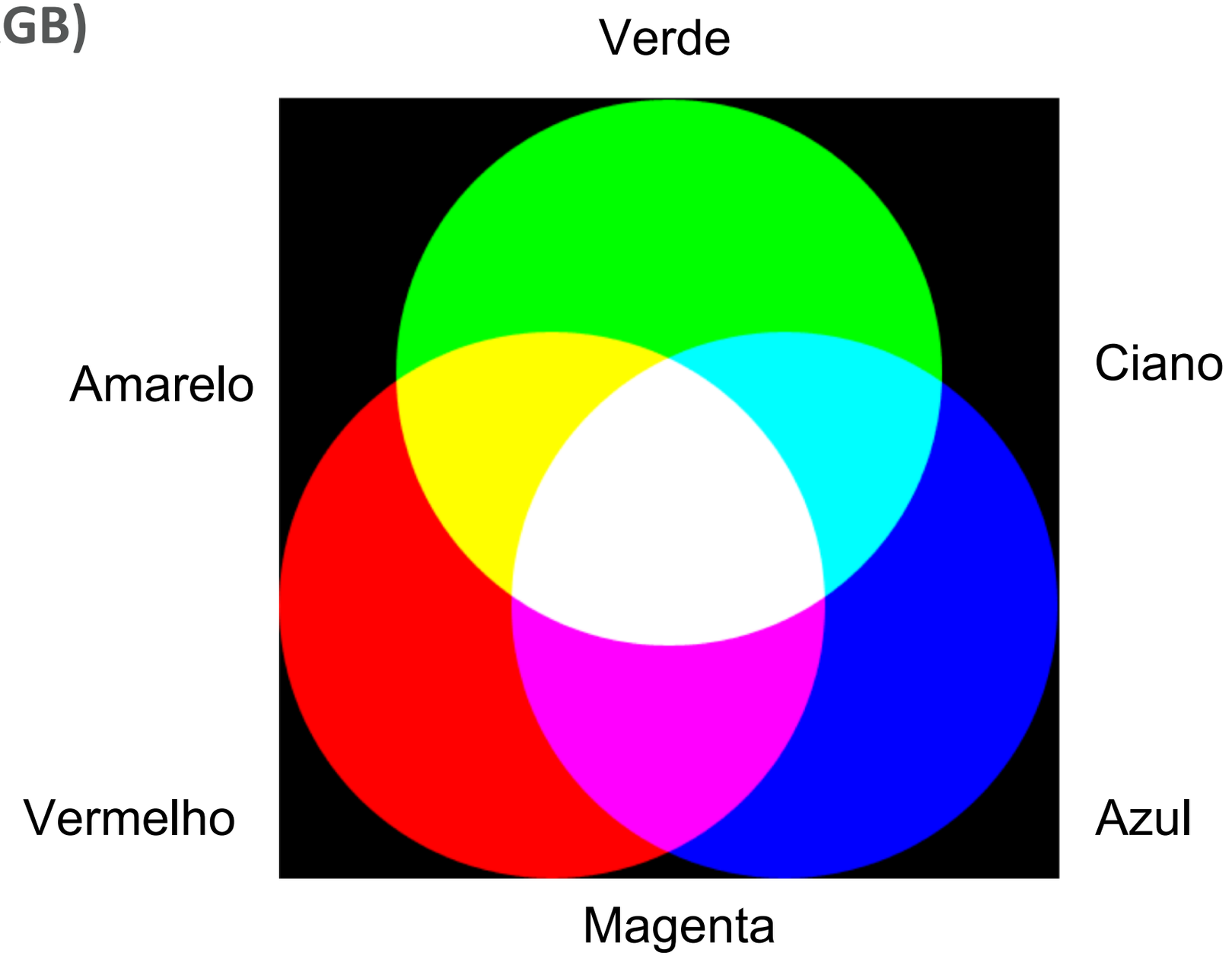
- Cor do objeto depende do comprimento de onda refletido
- folhas: clorofila
  - absorve R e B
  - reflete G e NIR
- água
  - absorve G+R+NIR (comp. onda longos do visível)
  - presença de algas ou sedimentos...





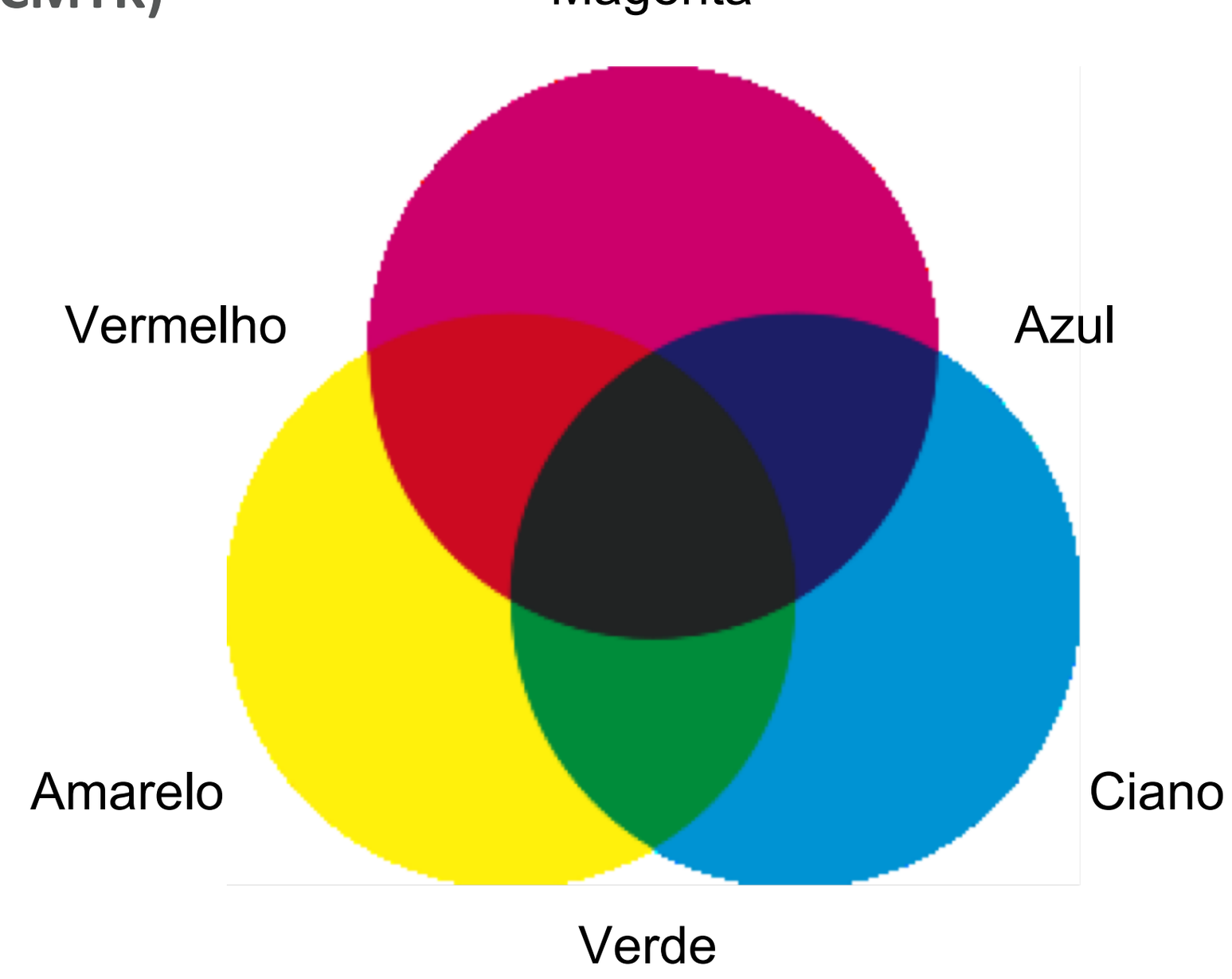
SISTEMAS DE CORES

- **Sistema Aditivo (RGB)**



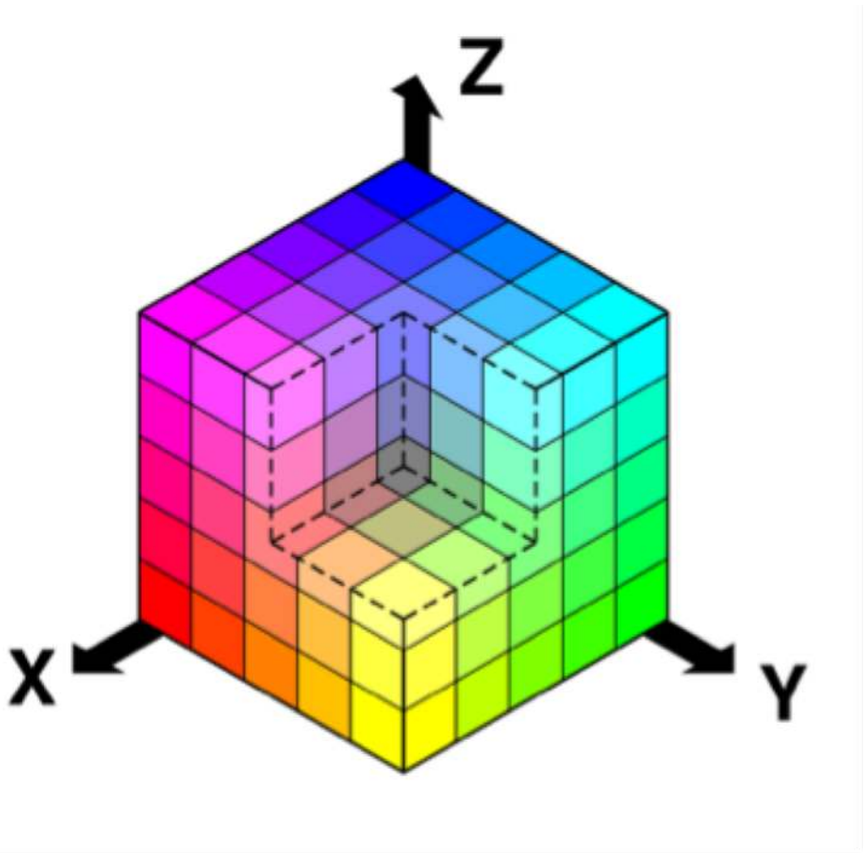
SISTEMAS DE CORES

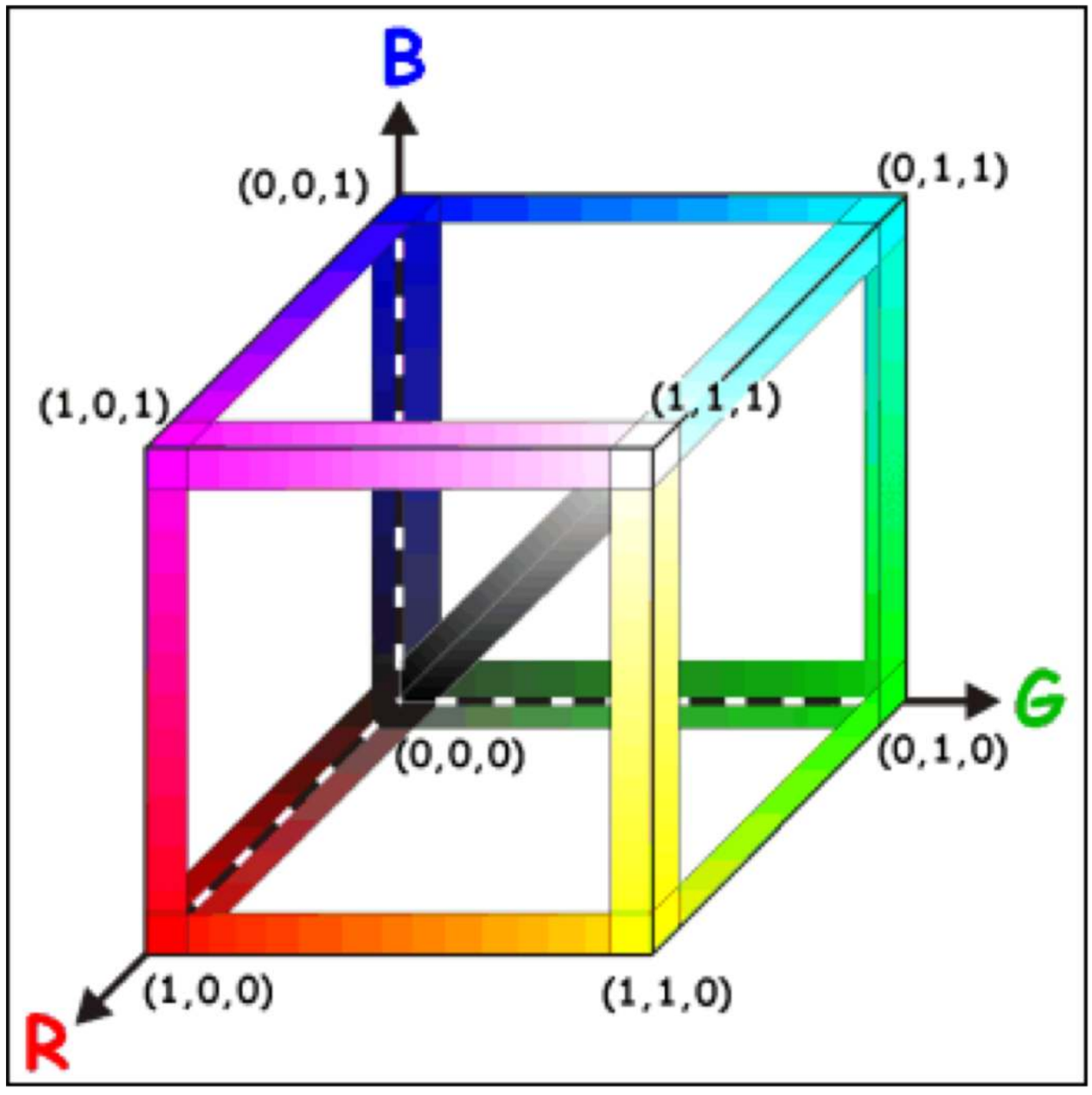
- **Sistema Subtrativo (CMYK)**



SISTEMAS DE CORES

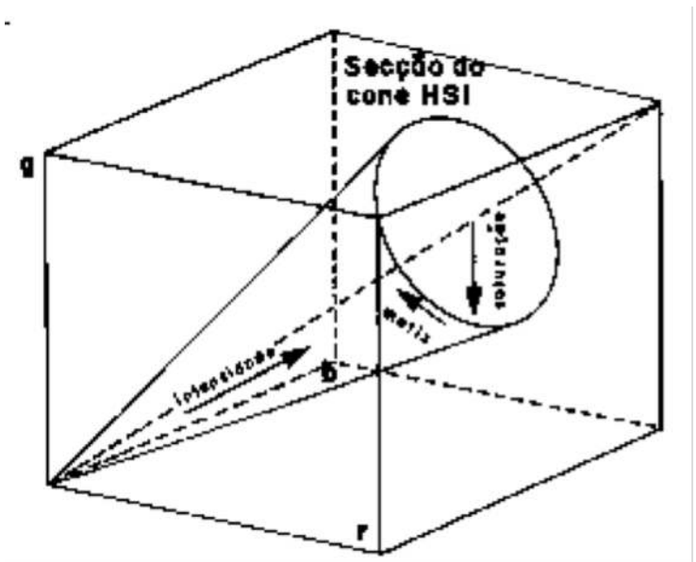
- **Cubo RGB**

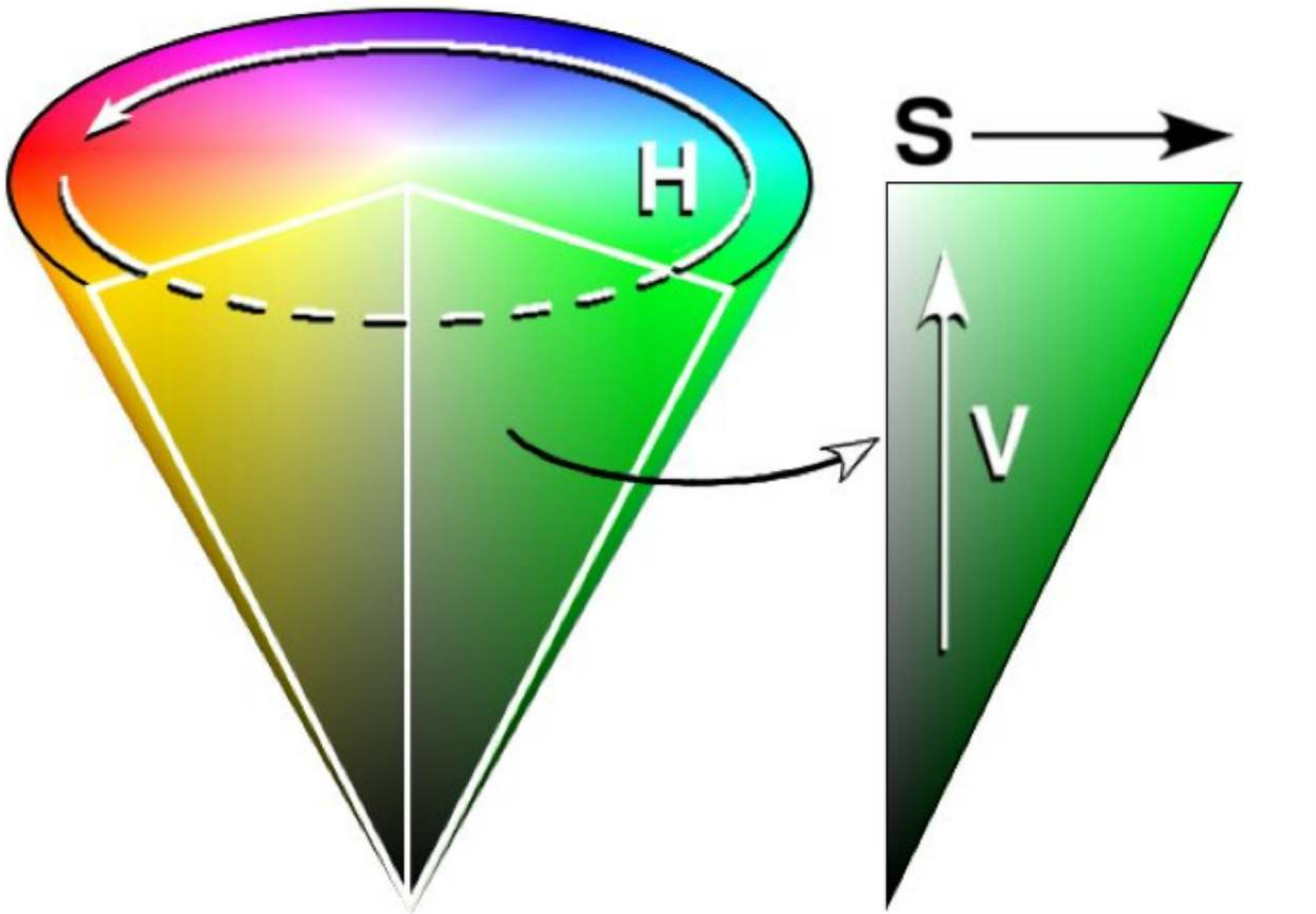




SISTEMAS DE CORES

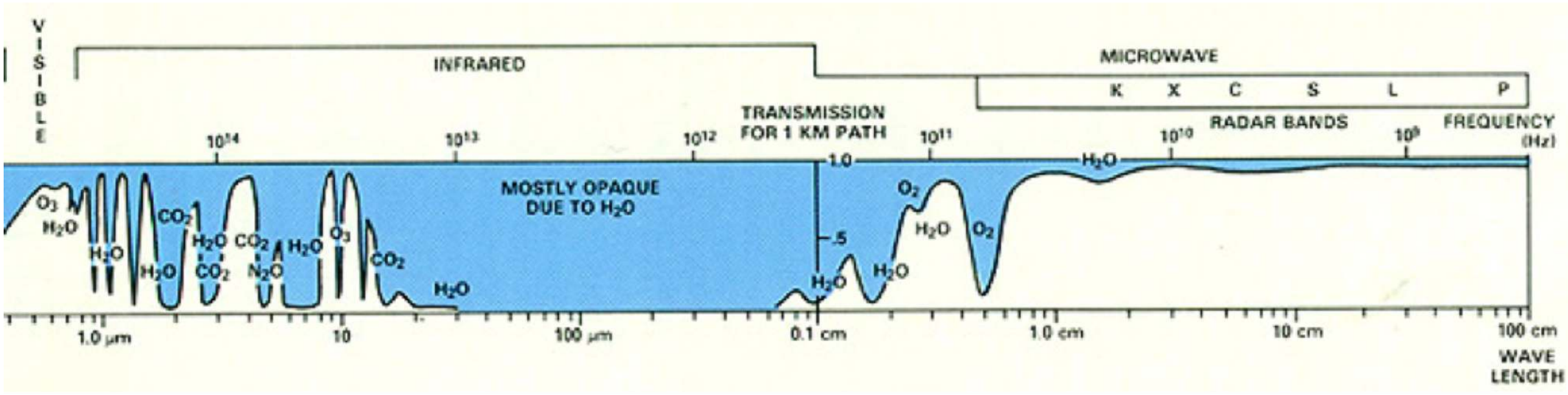
- **Cone IHS**





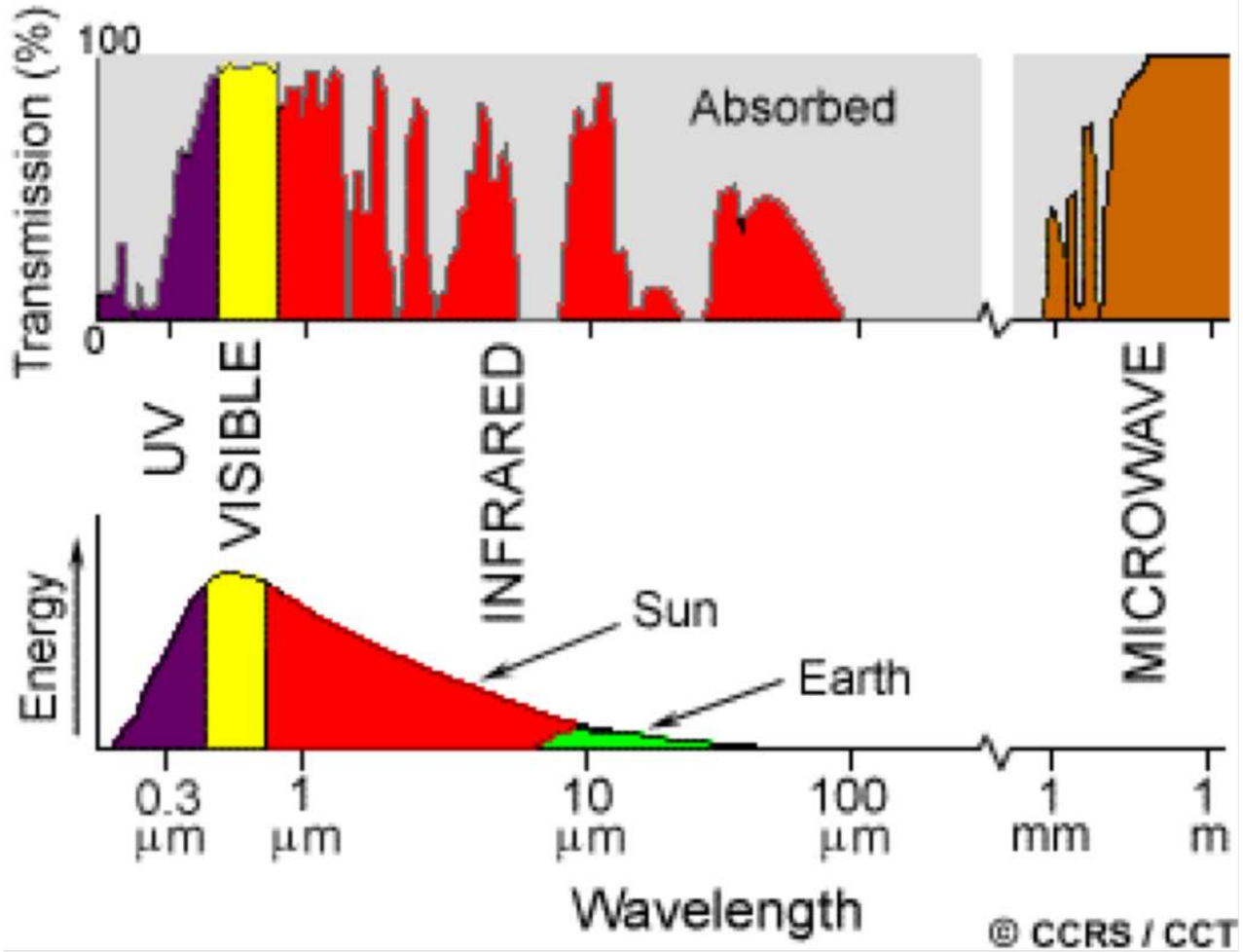
COMPORTAMENTO DA REM

- Transmissão da REM pela atmosfera não é contínua.
- Existem “janelas” criadas pela absorção da REM, principalmente pela água.



COMPORTAMENTO DA REM

- Energia das fontes (Sol, Terra) x janelas atm.
  - determinar os melhores comp. onda para SR
- Visível: janela + pico de energia solar



ESPALHAMENTO ATMOSFÉRICO

- Espalhamento de Rayleight
  - principal efeito de espalhamento atmosférico
  - partículas dispersas são muito menores que o comprimento de onda da REM (poeira, O2, N2, H2O)
  - comprimentos de onda pequenos (UV, azul) sofrem muito mais espalhamento que comprimentos de onda maiores

- Espalhamento Não-Seletivo
  - afeta todos os comprimentos de onda
  - nuvens brancas

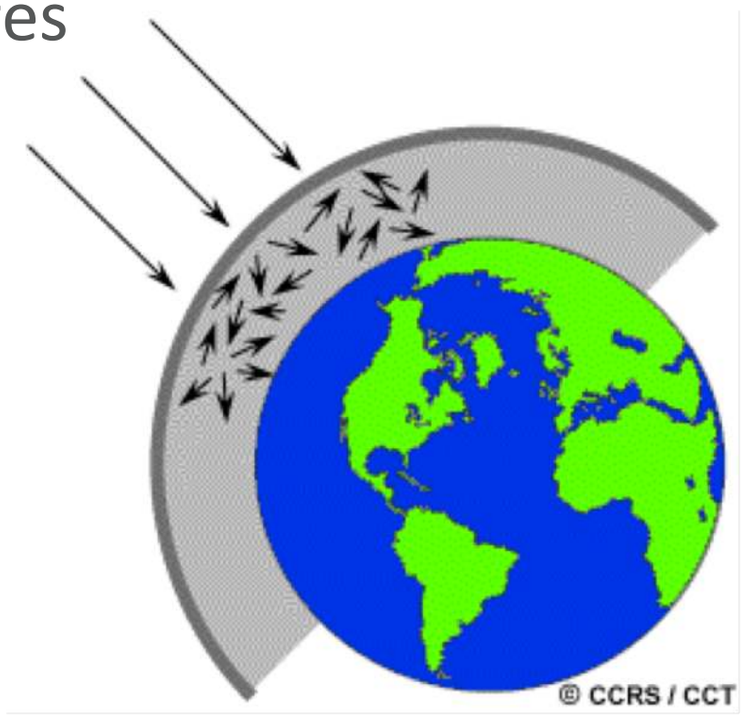
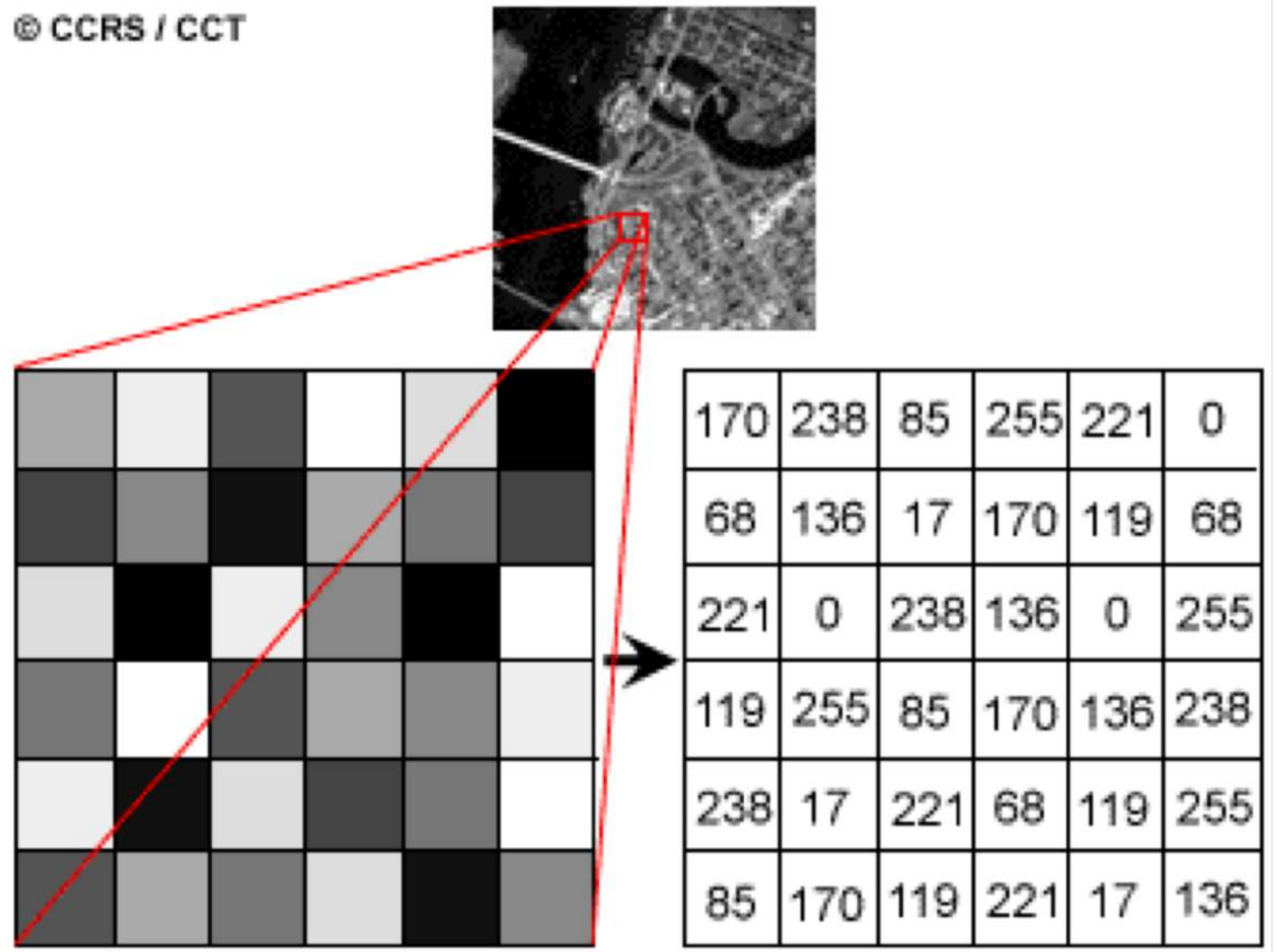


IMAGEM DIGITAL

- matriz de pixels (raster)
- valor do pixel – digital number (DN)
- radiância no sensor
- imagem 8bits
  - 2^8=256 (0-255)
  - 256 tons de cinza
  - 0 = preto
  - 255 = branco



IMAGENS MULTIESPECTRAIS

- Sensores captam diferentes faixas do espectro

- Cada faixa á armazenada em uma **banda**

- Cada banda é representada em tons de cinza

- A fusão das bandas gera a imagem colorida

- pixel = picture element

IMAGEM RGB

BANDA R

BANDA G

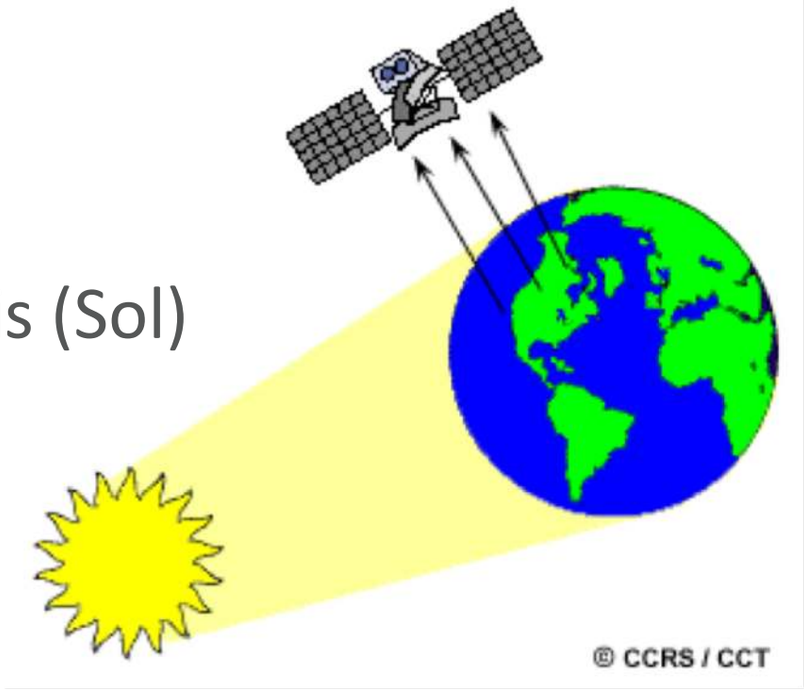
BANDA B

TIPOS DE SENSORES

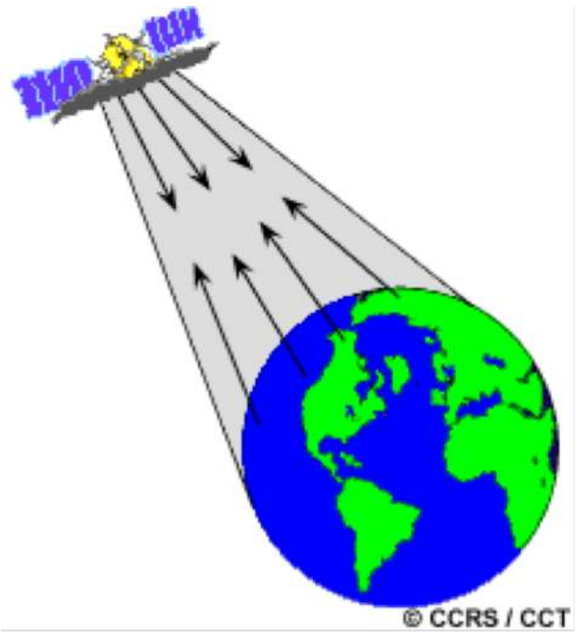
- **Fotográficos**
  - imagem é capturada de uma só vez
- Não-**fotográficos**
  - imagem capturada pixel a pixel (scanner)

TIPOS DE SENSORES

- **Sensores Passivos**
  - registram energia refletida por fontes naturais (Sol)
  - maioria



- **Sensores Ativos**
  - emitem sua própria energia e registram o sinal refletido
  - RADAR, LiDAR
  - podem ser usados à noite

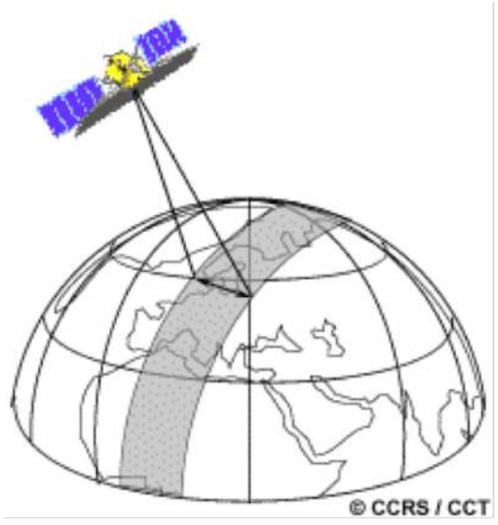


TIPOS DE SENSORES

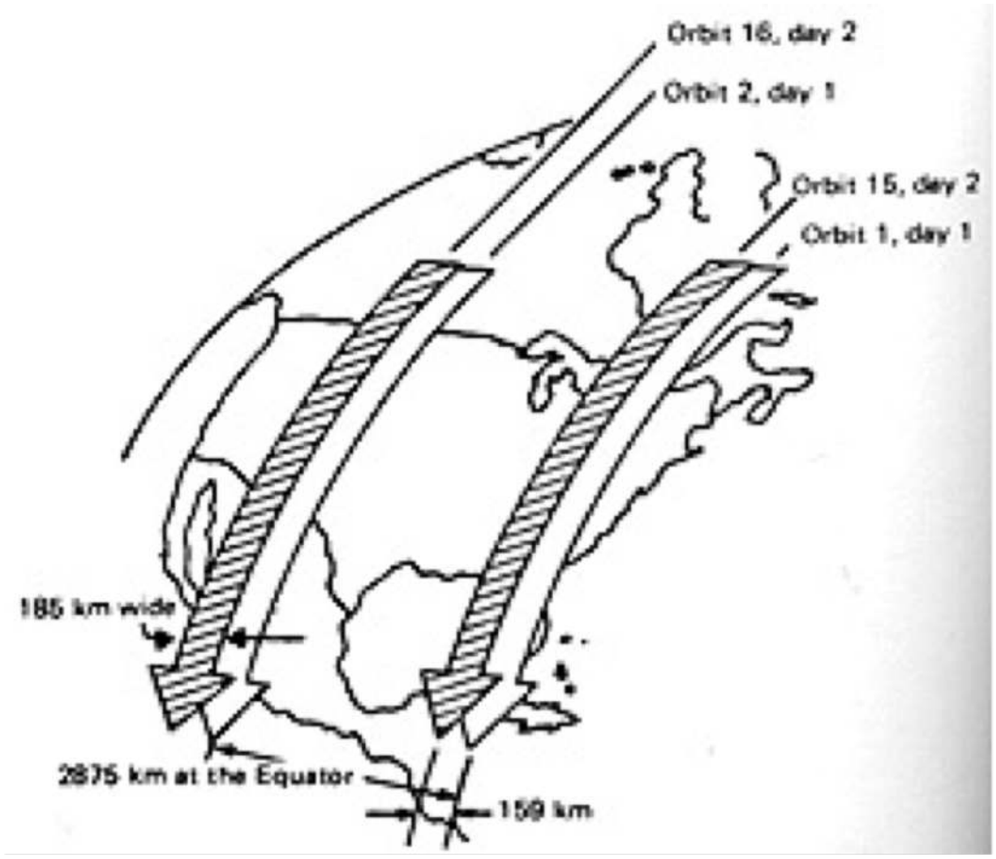
- Terrestre
- Aeroportado
- Orbital (Satélite, Ônibus espacial, OVNI…)

SATÉLITES

- swath - faixa imageada
- largura de dezenas a centenas de km



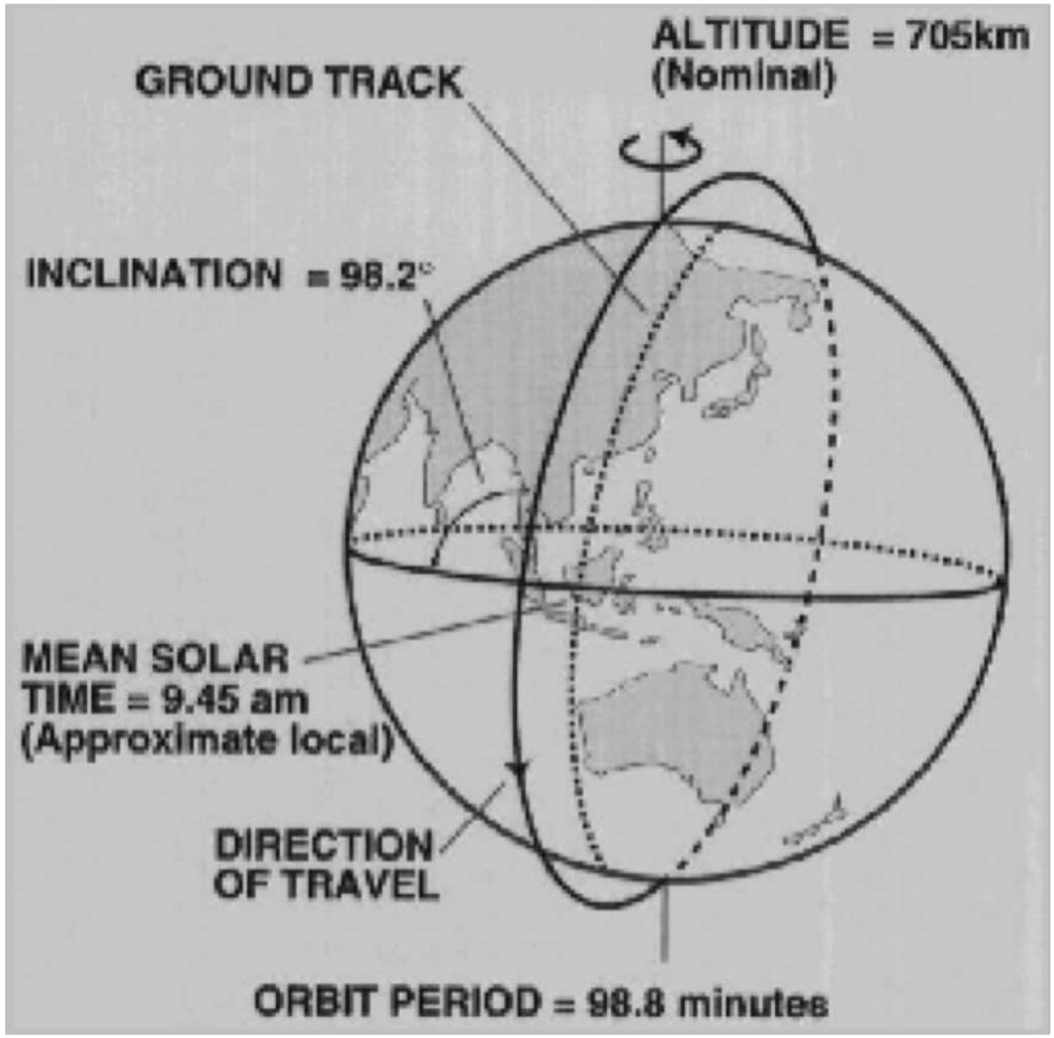
- período de revisita:
- tempo para imagear a mesma área (nadir) duas vezes



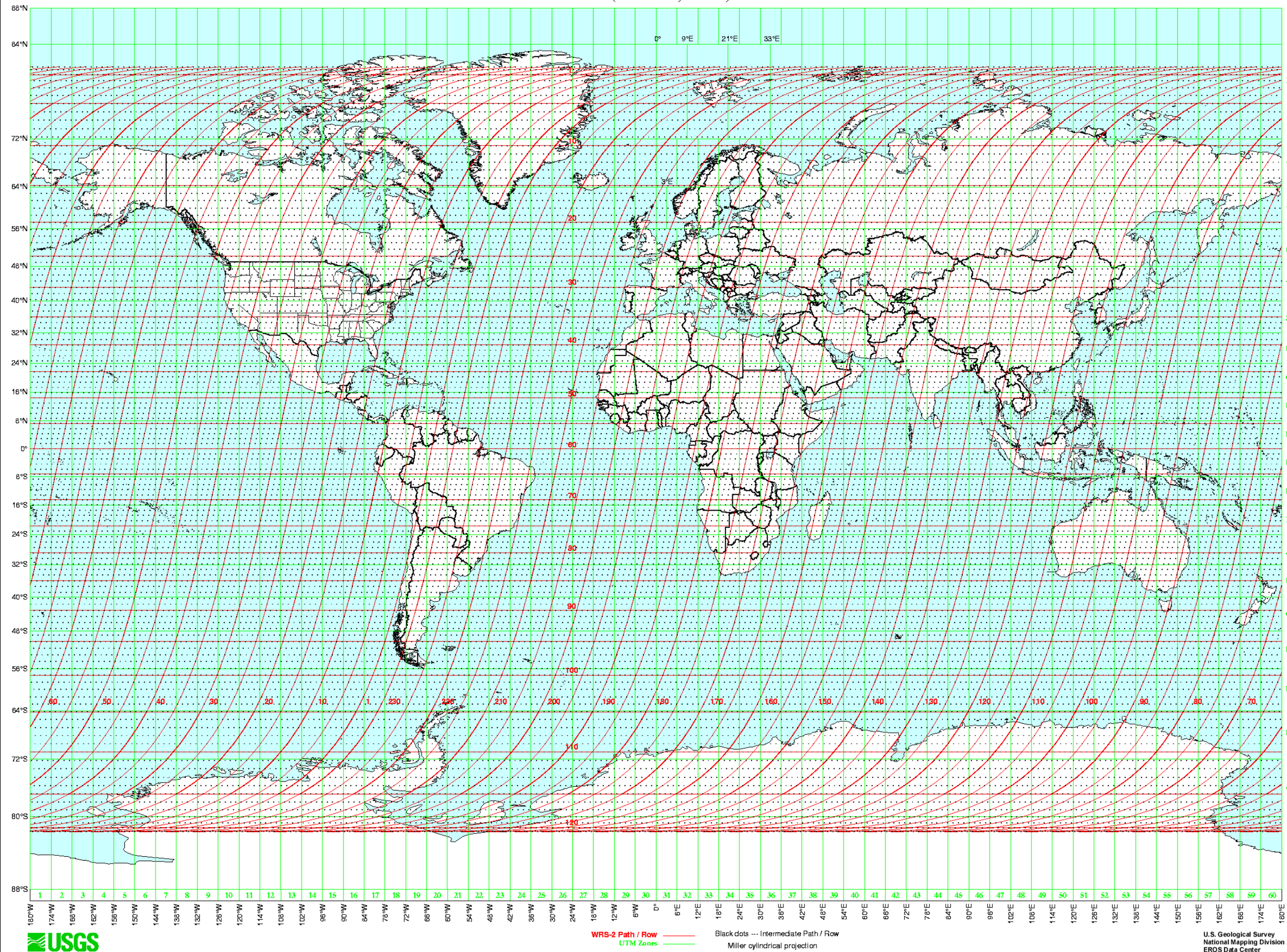
- overlap – aŕea próximas dos pólos são imageadas mais frequentemente

SATÉLITES

- Órbita – altitude da órbita determina campo de visão e período de revisita
- Geoestacionários - 36.000km altitude
- Heliossincrônicos - órbita acompanha horário local do sol
  - órbitas:
    - descendente – dia
    - ascendente – noite
- Worldwide Reference System 2 (WRS2)



WRS-2 Path / Row (Landsats 4, 5 and 7) and UTM Zones



USGS
science for a changing world

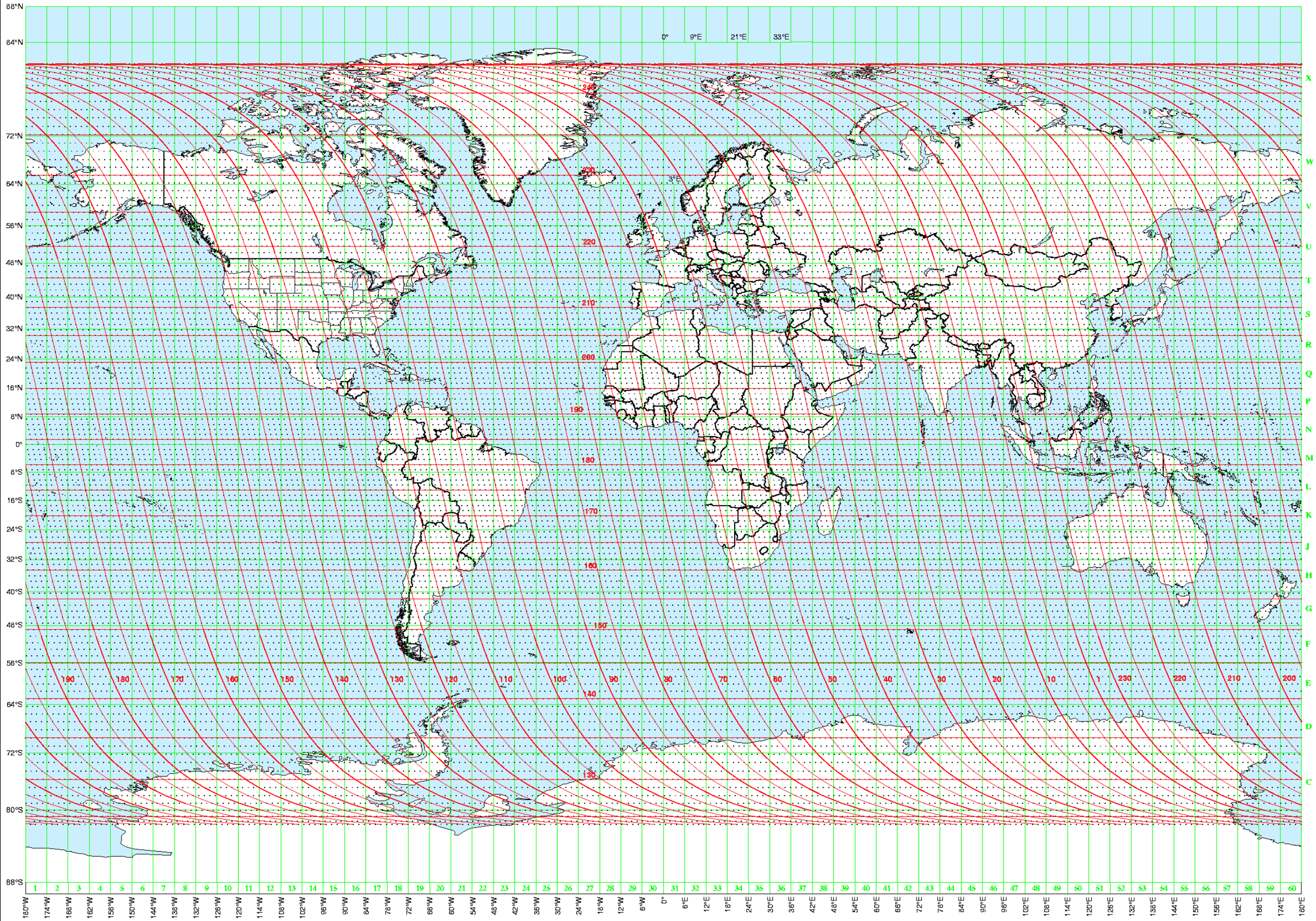
WRS-2 Path / Row
UTM Zones

Black dots --- Intermediate Path / Row

Miller cylindrical projection

U.S. Geological Survey
National Mapping Division
EROS Data Center
Sioux Falls, SD

WRS-2 Night-time Ascending Path / Row (Landsats 4, 5 and 7) and UTM Zones



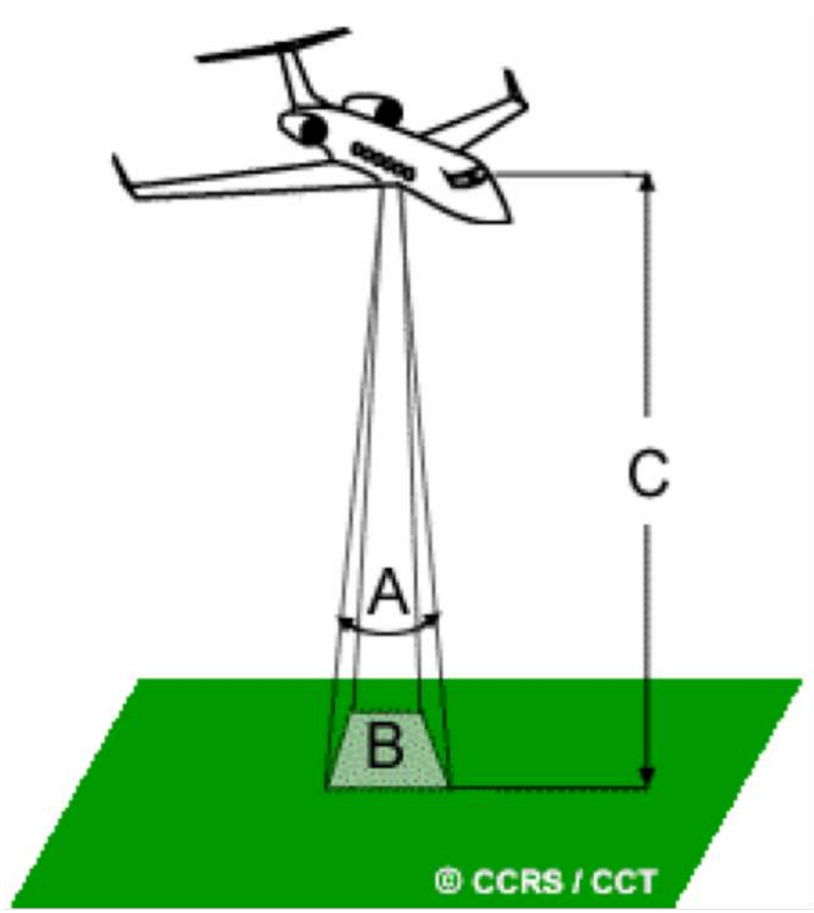
USGS
science for a changing world

WRS-2 Path / Row
UTM Zones
Black dots --- Intermediate Path / Row
Miller cylindrical projection

U.S. Geological Survey
National Mapping Division
EROS Data Center
Sioux Falls, SD

RESOLUÇÕES

- **Resolução espacial** – determina o tamanho do menor objeto que podemos reconhecer em uma imagem (tamanho do pixel)
- IFOV (Instantaneous Field Of View) – cone de visibilidade do sensor
- Altitude do sensor
- B=C*A



RESOLUÇÕES

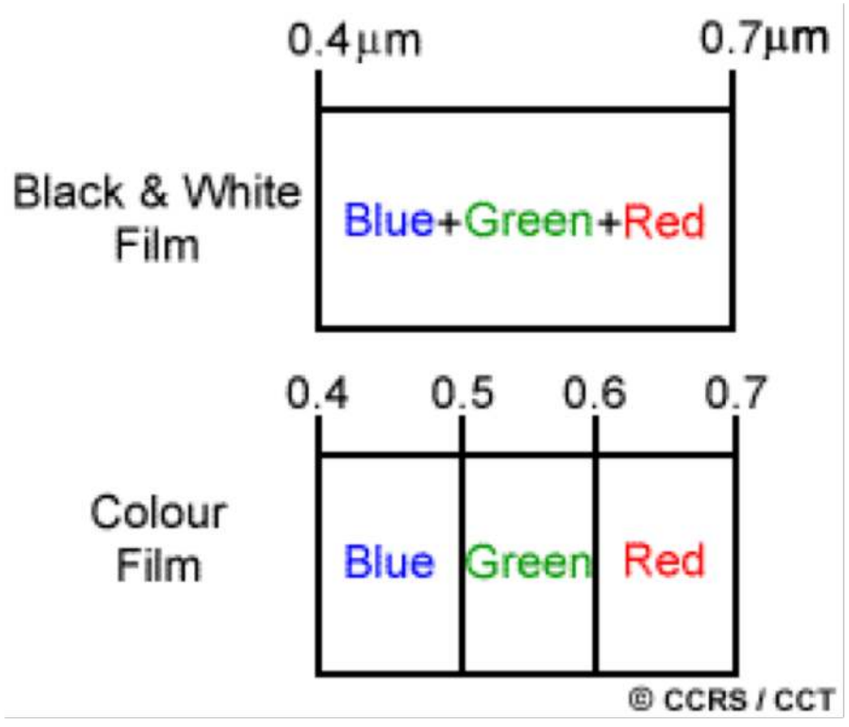
- **Resolução espacial**

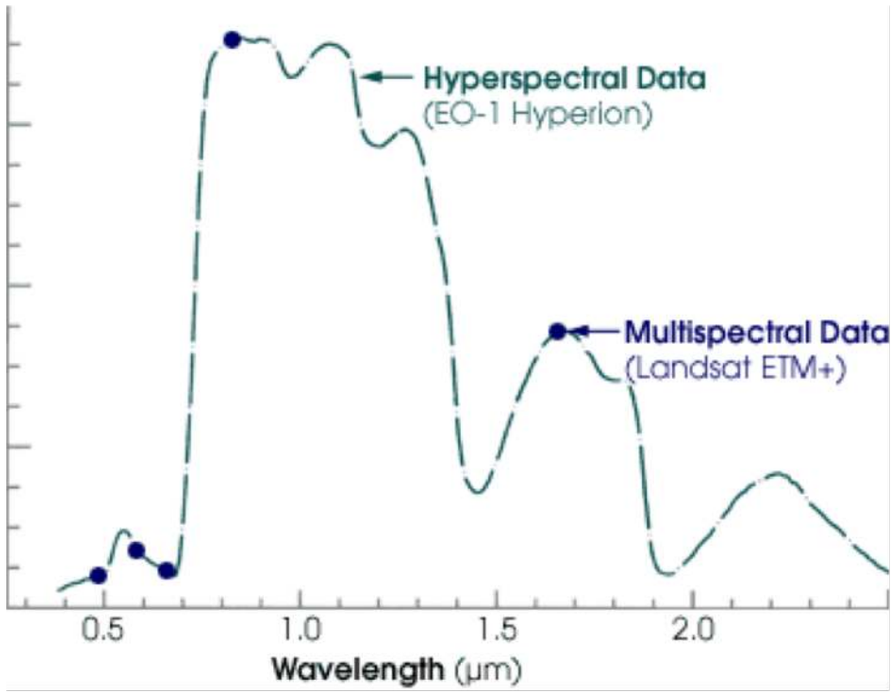
baixa

alta

RESOLUÇÕES

- **Resolução espectral** - Capacidade do sensor em separar faixas no espectro EM
- Sensores Multiespectrais – 3...20 bandas
- Sensores Hiperespectrais – centenas !!





RESOLUÇÕES

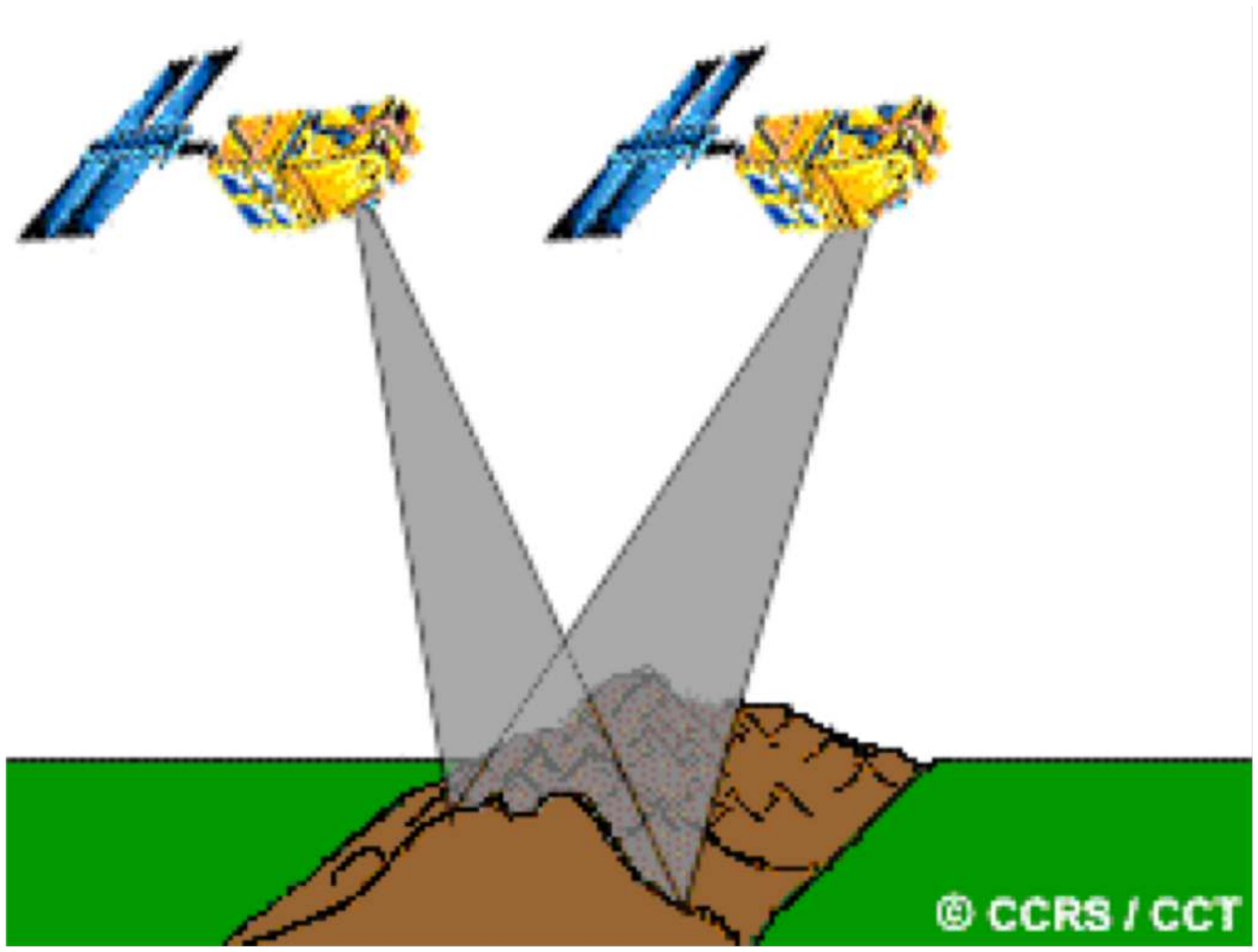
- **Resolução radiométrica** - Capacidade do sensor em diferenciar variação na intensidade de energia

2 bits
4 tons de cinza

8 bits
256 tons de cinza

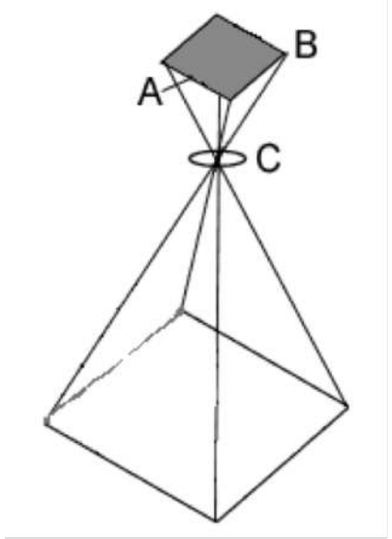
RESOLUÇÕES

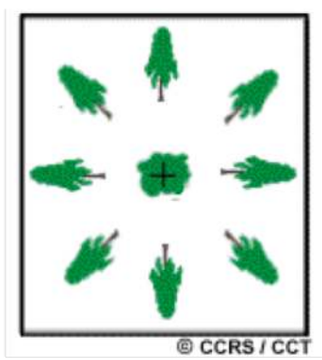
- **Resolução temporal** - Período de revisita
  - varia com a latitude, sobreposição entre faixas adjacentes e capacidade do sensor em *off-nadir*

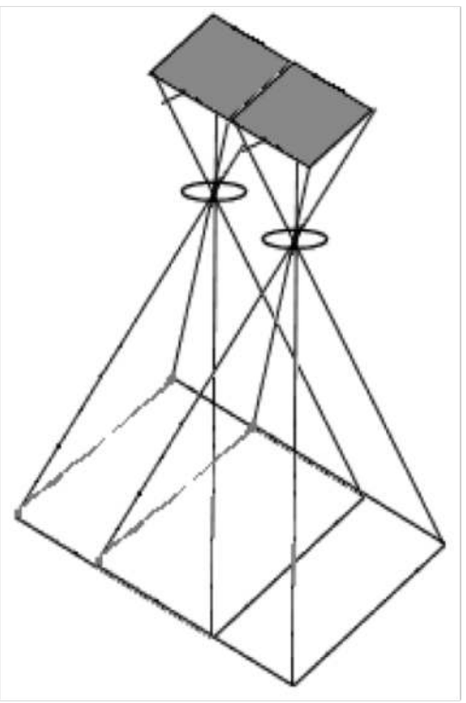


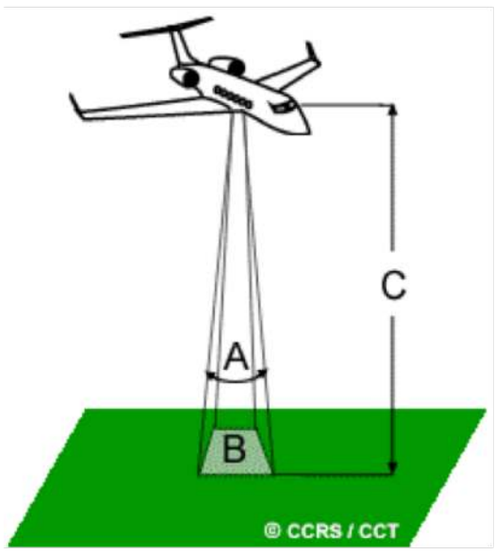
SISTEMAS DE IMAGEAMENTO

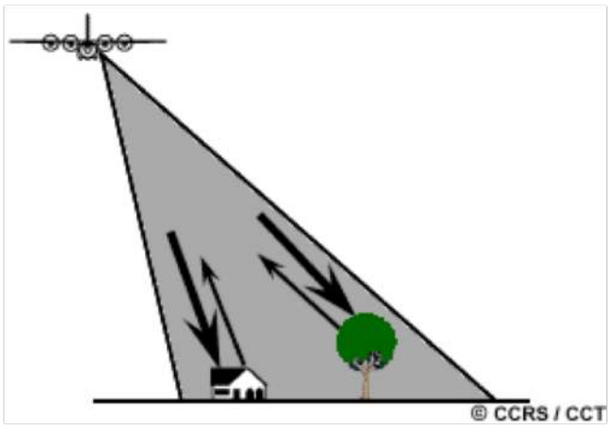
- **Fotografias Aéreas**
  - alta resolução espacial
  - efeitos de distorção nas bordas
  - sobreposição: estereoscopia
  - fotografias digitais

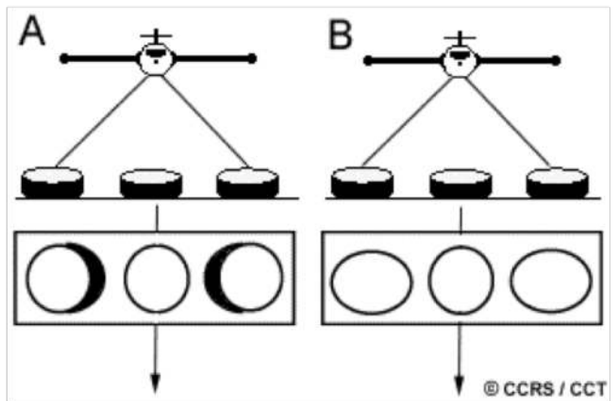






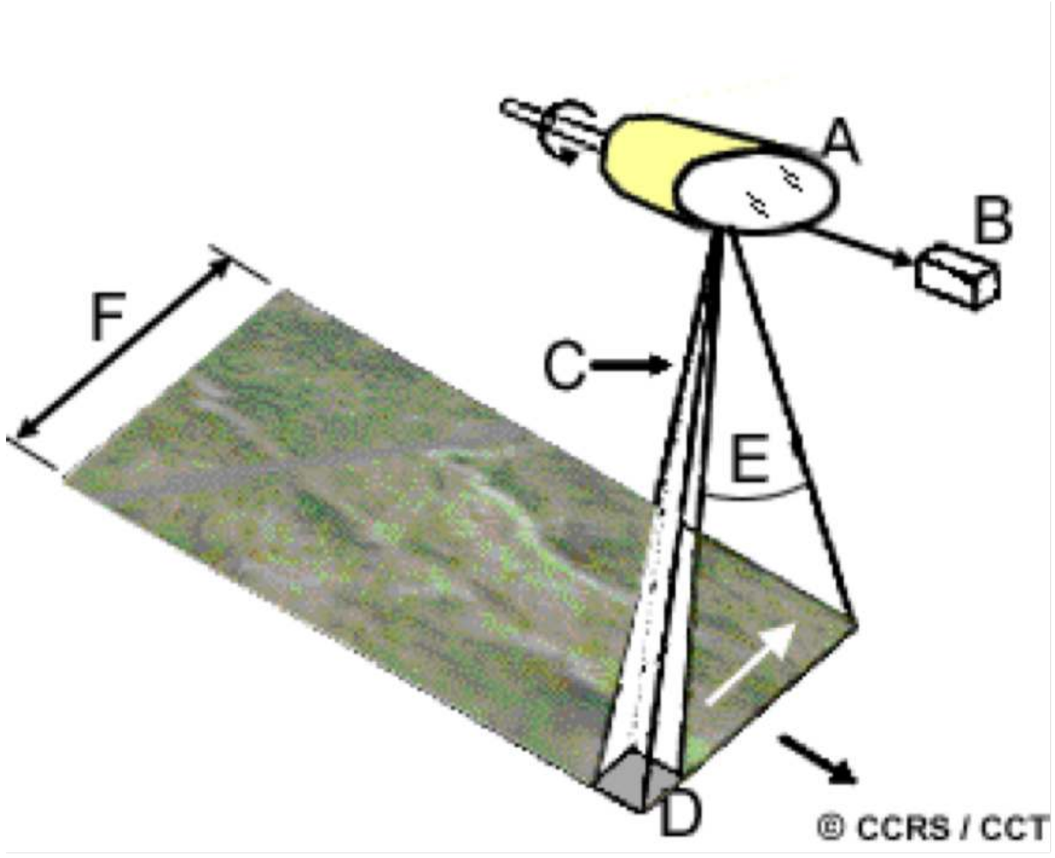


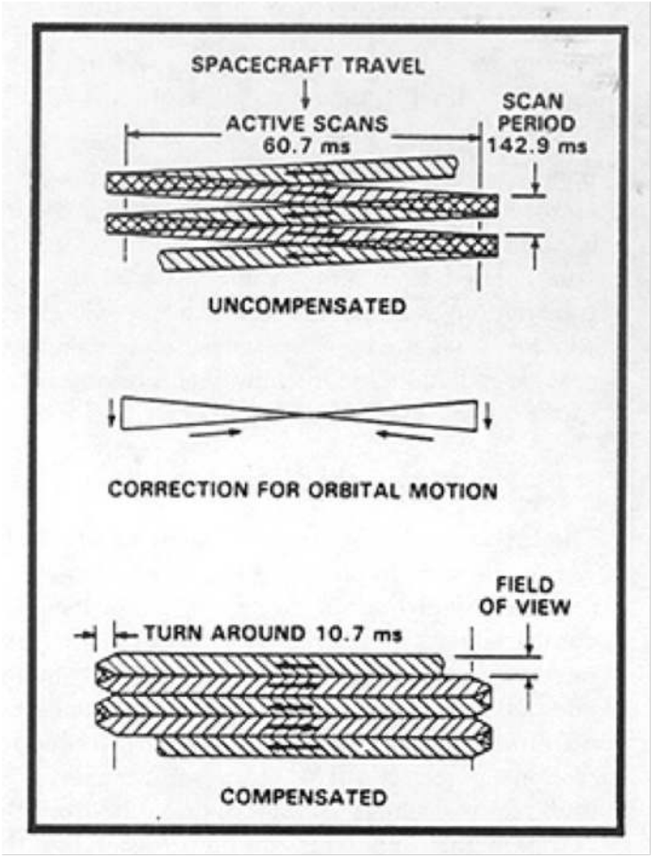




SISTEMAS DE IMAGEAMENTO

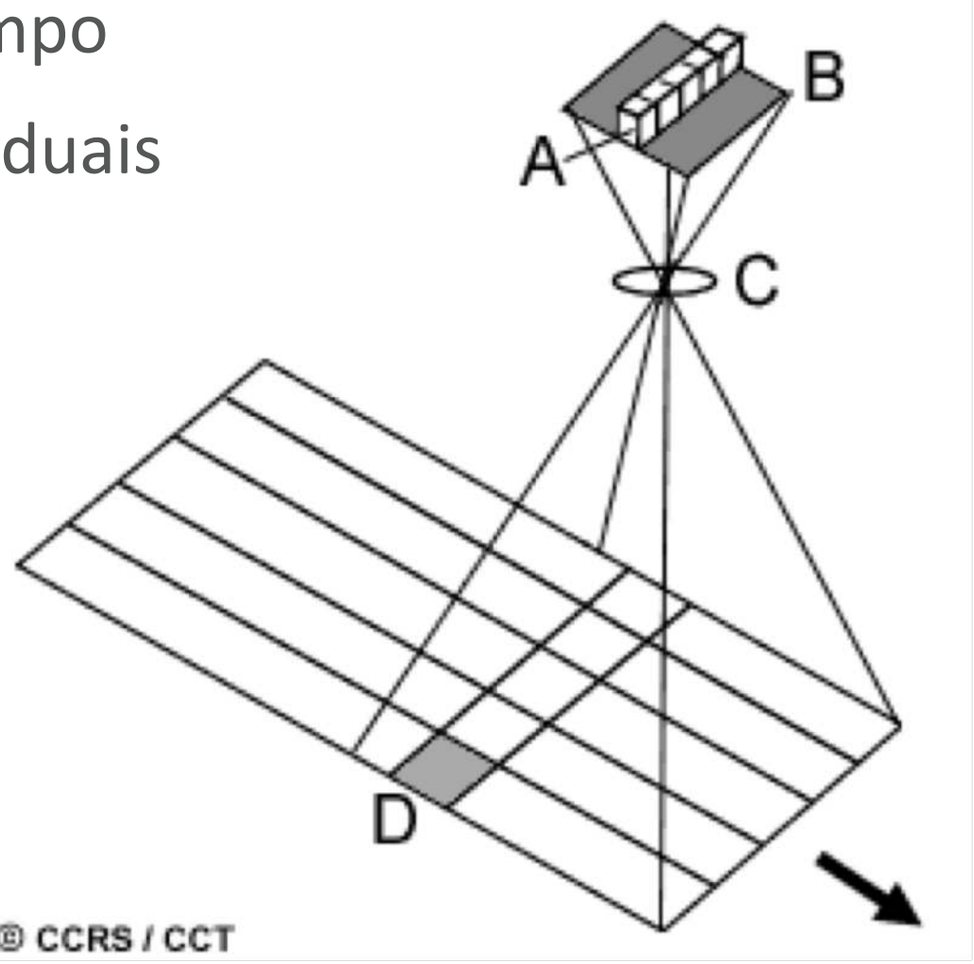
- **Sensores Multiespectrais (MSS)**
  - *across-track scanners*
  - série de linhas perpendiculares ao movimento do sensor
  - espelho rotativo





SISTEMAS DE IMAGEAMENTO

- **Sensores Multiespectrais (MSS)**
  - *along-track scanners (pushbroom scanners)*
  - *array* linear de sensores “empurrados” na direção do movimento
  - sensores “vêem” os objetos por mais tempo
  - calibração de centenas de sensores individuais



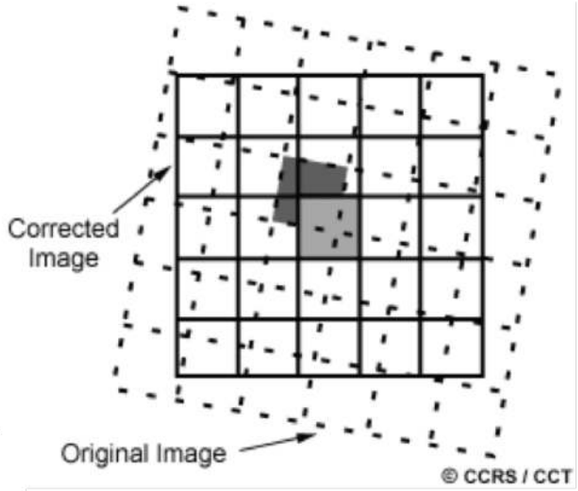
OPERAÇÕES EM SR

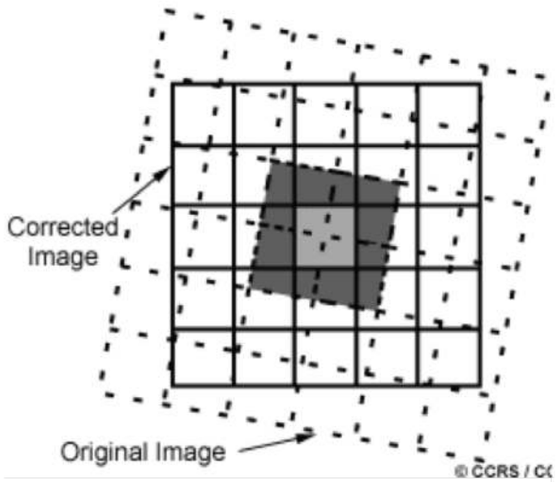
- Pré-Processamento
  - Conversão radiância-reflectância
  - Correção Atmosférica
- Registro
- Realce
- Filtragem
- Composições
  - RBG
  - IHS

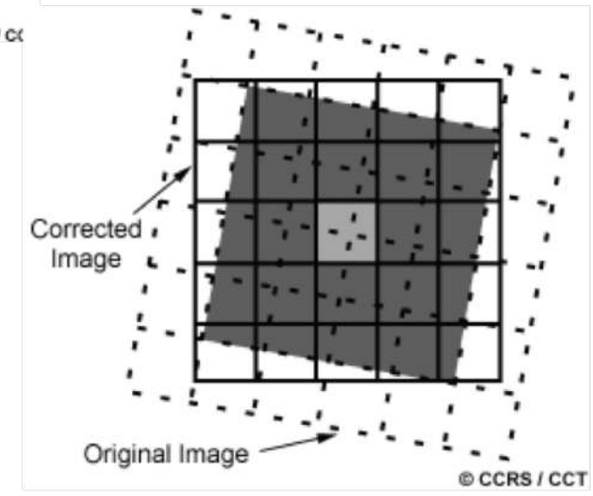
OPERAÇÕES EM SR

- **Registro** (Georreferenciamento)
- Correção geométrica
- Projeção cartográfica
- Ground Control Points (GCPs)
- image-to-map / image-to-image

- Vizinho mais próximo
- Interpolação bilinear
- Convolução cúbica

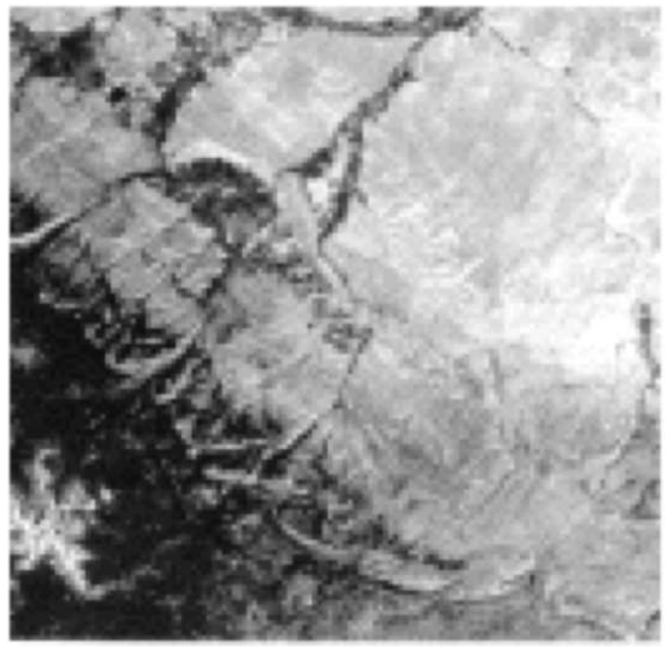


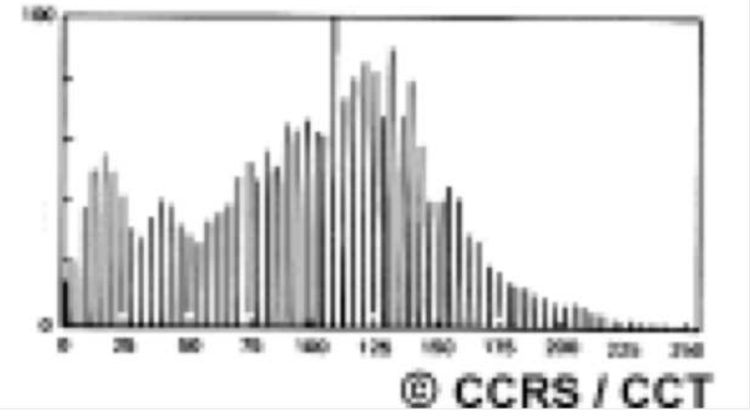


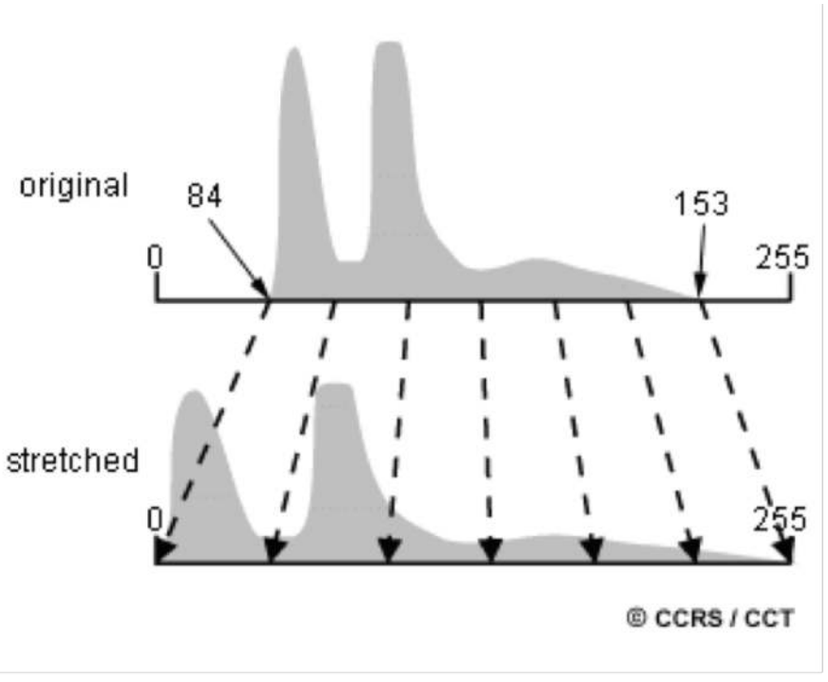


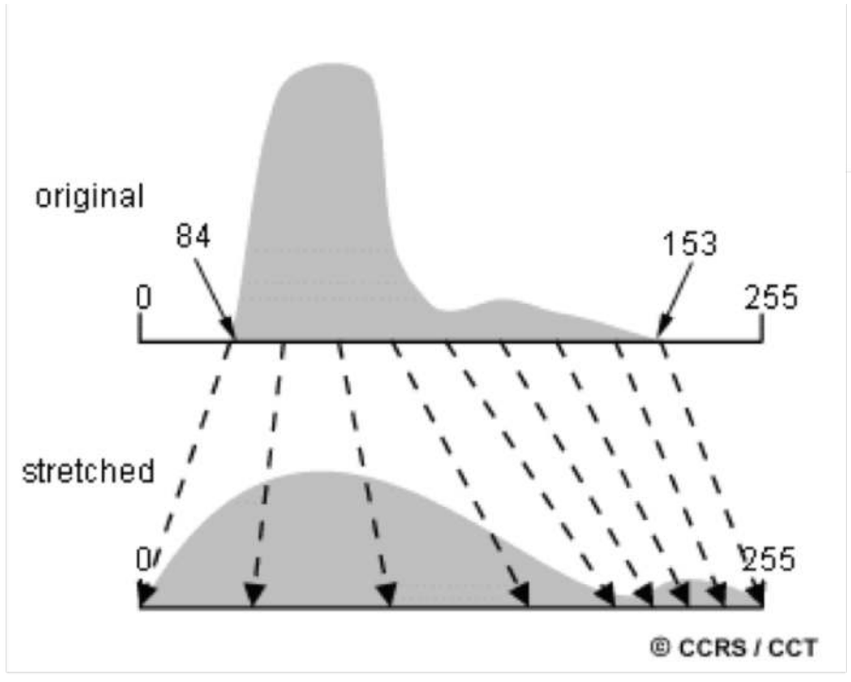
OPERAÇÕES EM SR

- **Realce**
- Histograma – representação dos DNs
- Função de transferência de contraste (stretch)
  - linear
  - equalizada



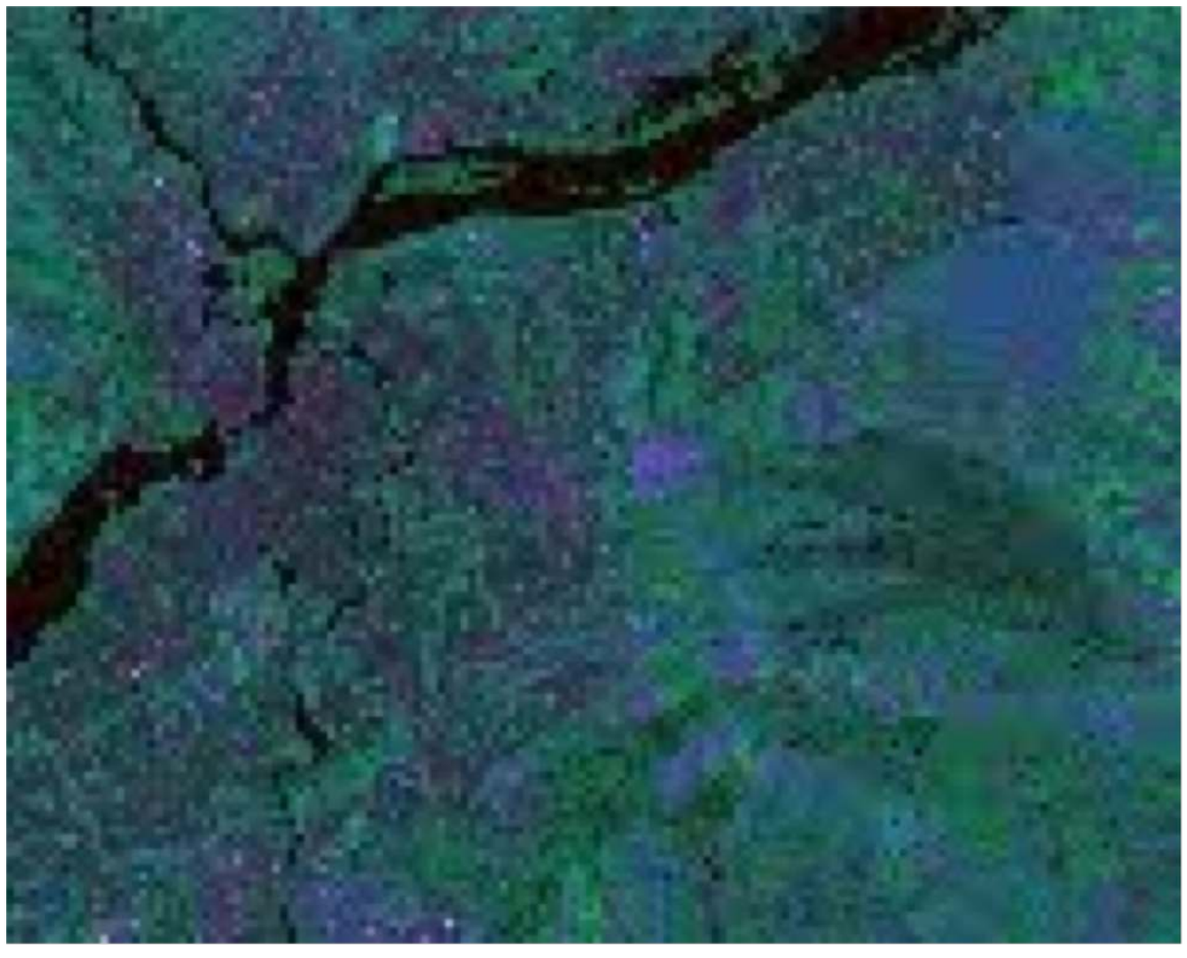


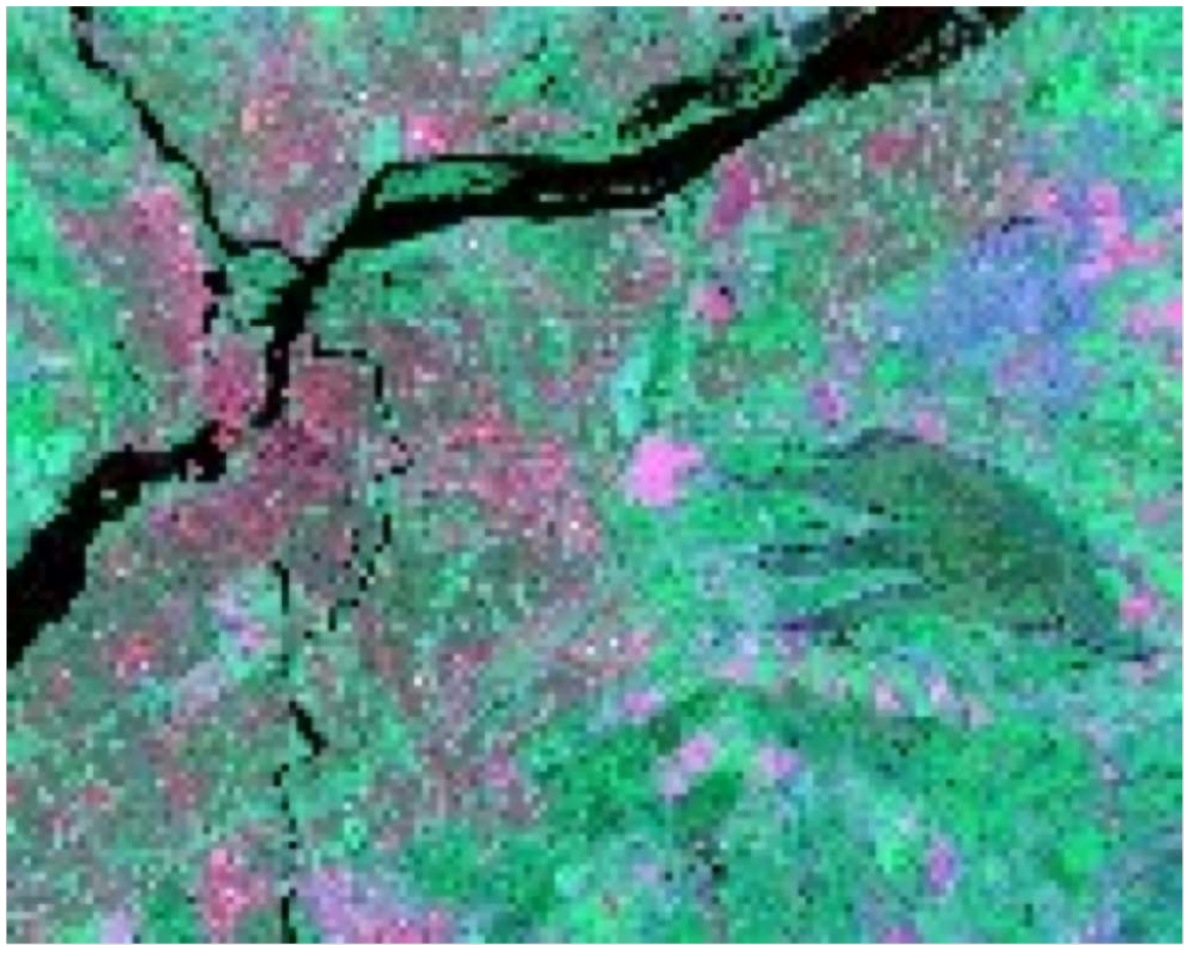




OPERAÇÕES EM SR

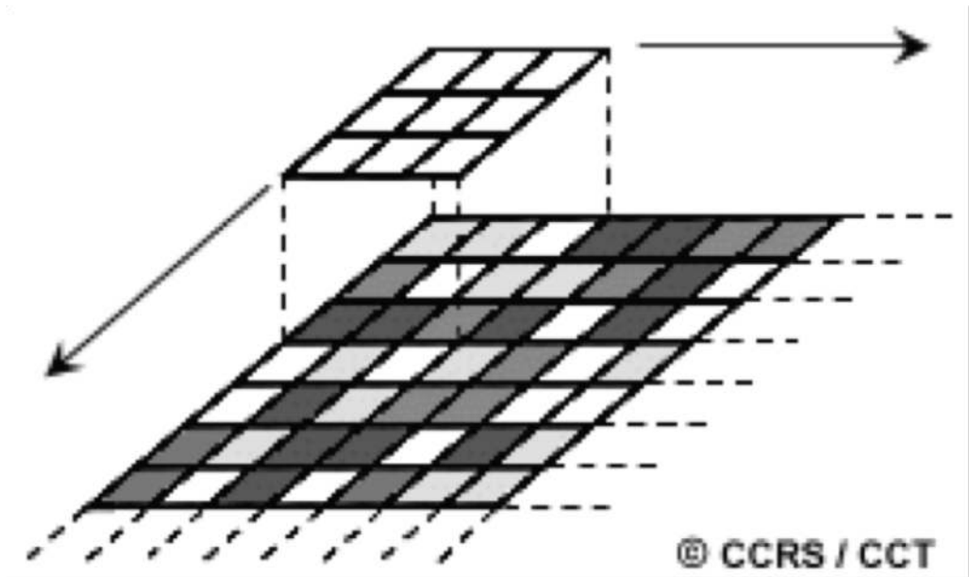
- **Realce Linear**





OPERAÇÕES EM SR

- **Filtragem espacial** - Janela móvel (3x3, 5x5...)
- Freqüência espacial
  - alta freqüência: rodovias, bordas
  - baixa freqüência: áreas homogêneas
- Passa-baixas: média, moda
- Passa-altas: laplacianos
- Direcionais



OPERAÇÕES EM SR

- **Filtro de média (passa-baixas)**

25	27	32	20	21	19	24
23	27	19	25	22	18	25
27	26	24	26	22	22	26
23	25	28	30	27	25	27
19	22	28	32	29	27	25
17	19	25	27	30	31	22
20	21	25	23	21	19	17

Imagem original

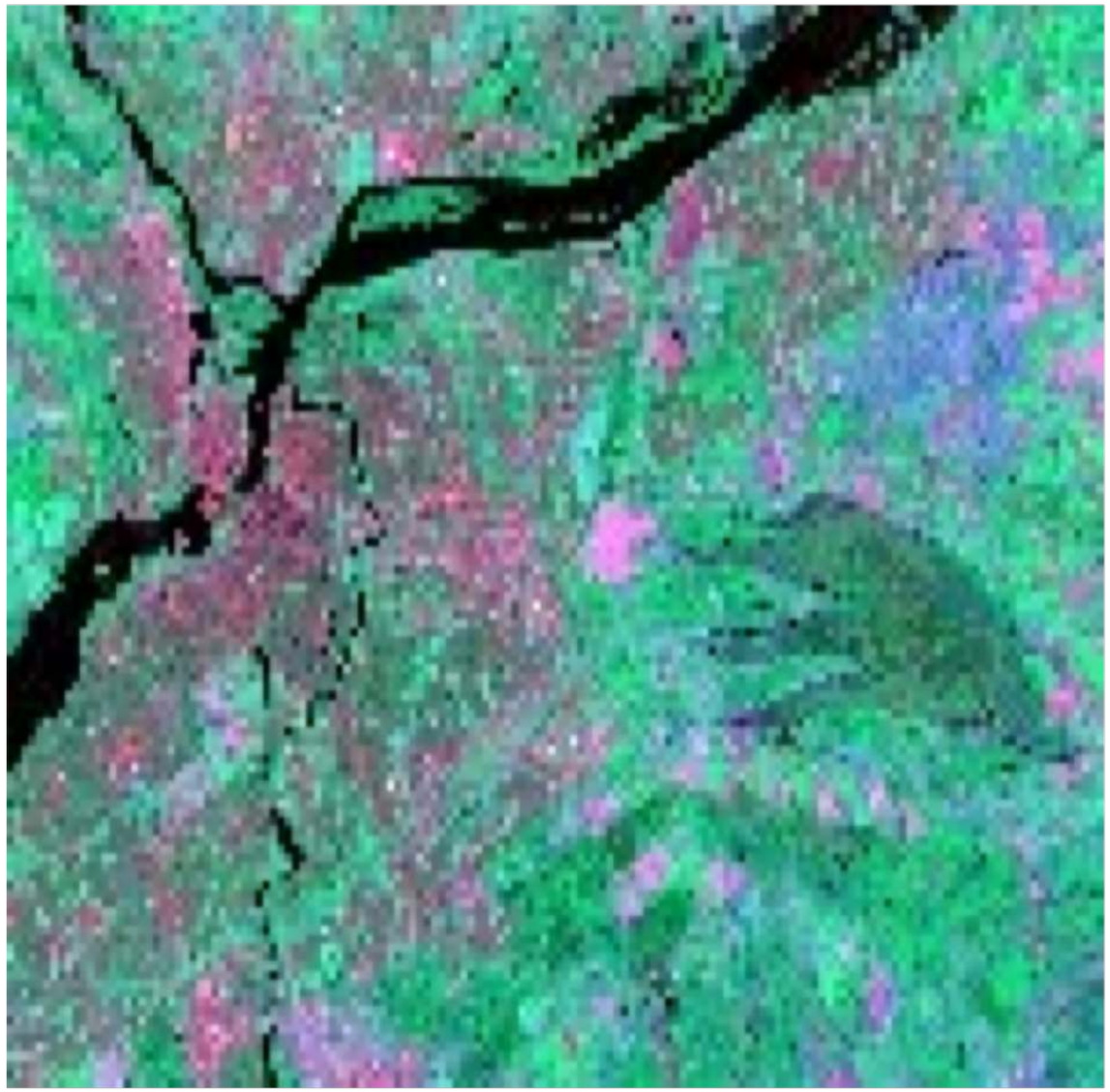
	26	25	23	22	22	
	25	26	25	24	26	
	25	27	27	27	26	
	23	26	28	29	27	
	22	25	27	27	25	

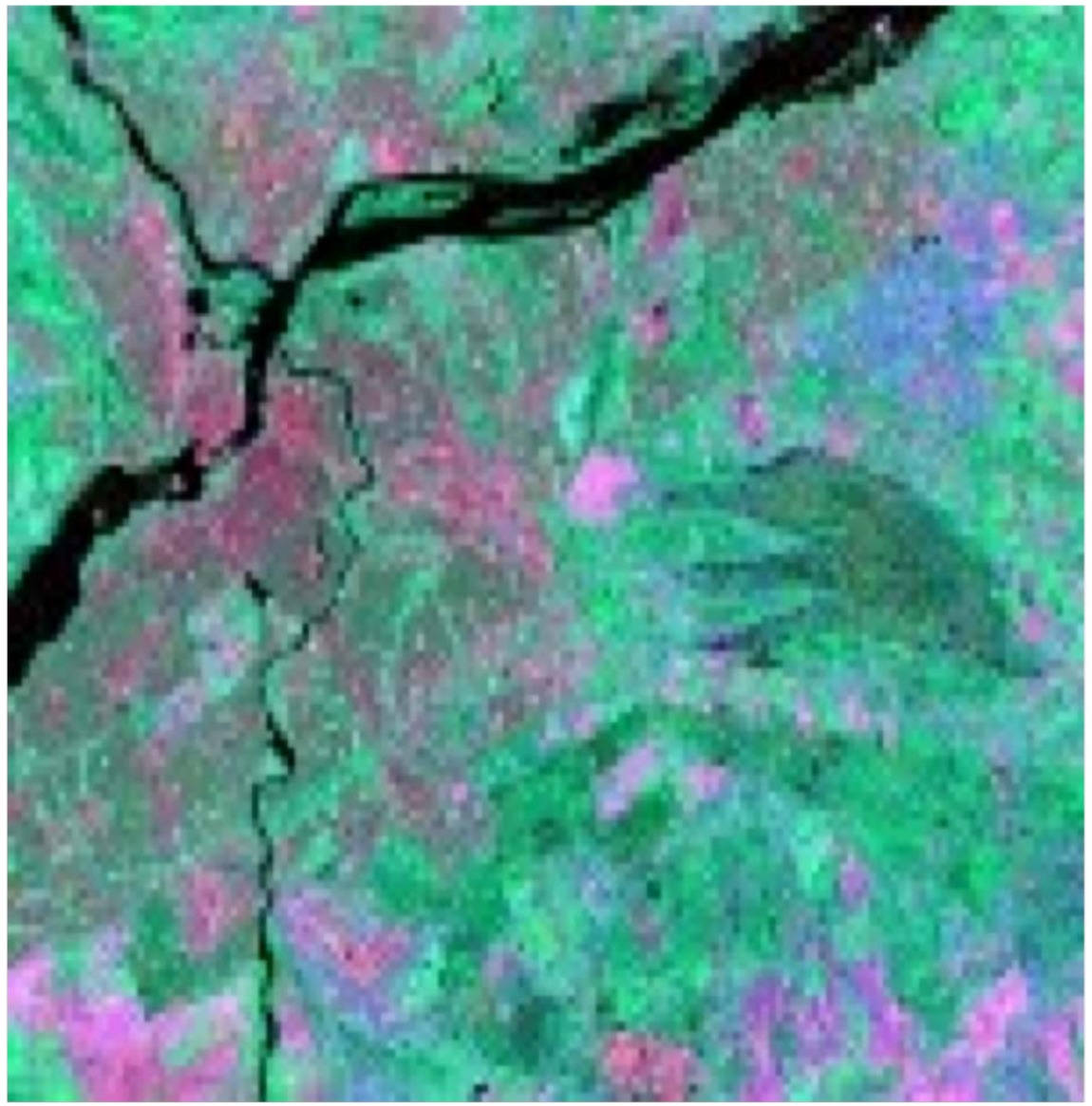
Imagem filtrada

$$\text{Pixel central} = 1/9 \begin{bmatrix} 24+26+22 \\ +28+30+27 \\ +28+32+29 \end{bmatrix} = 27$$

OPERAÇÕES EM SR

- **Filtro de média (passa-baixas)**





OPERAÇÕES EM SR

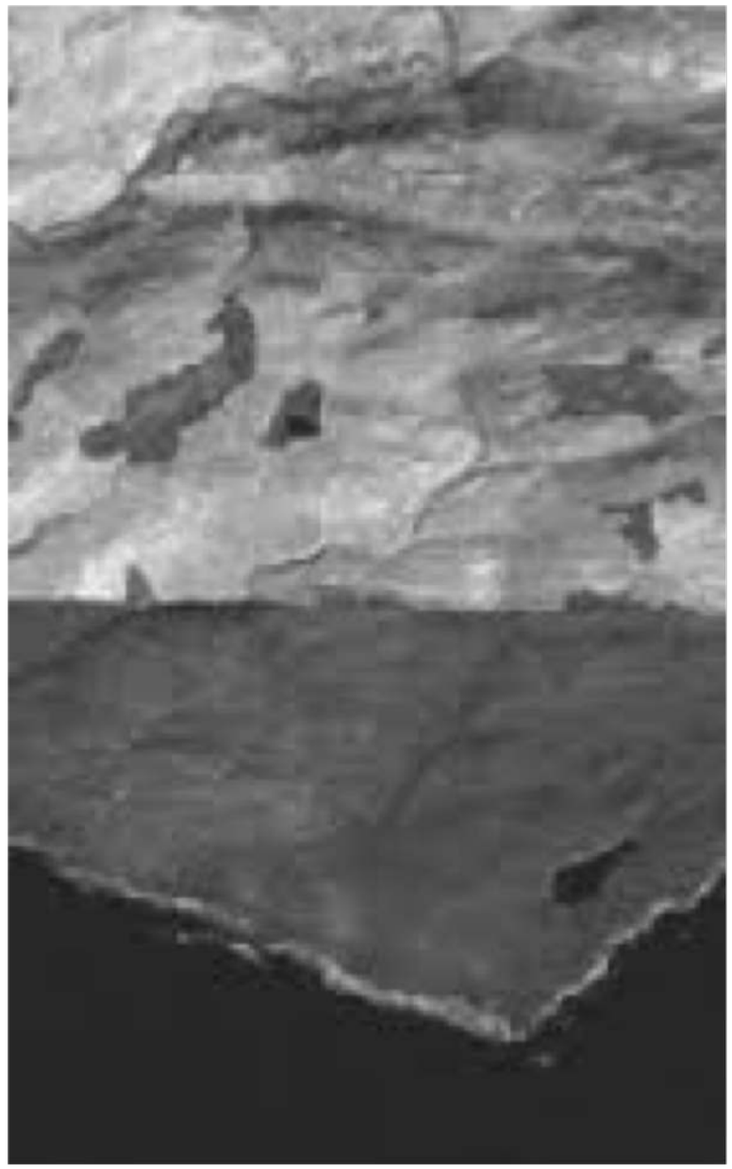
- **Filtro passa-altas**

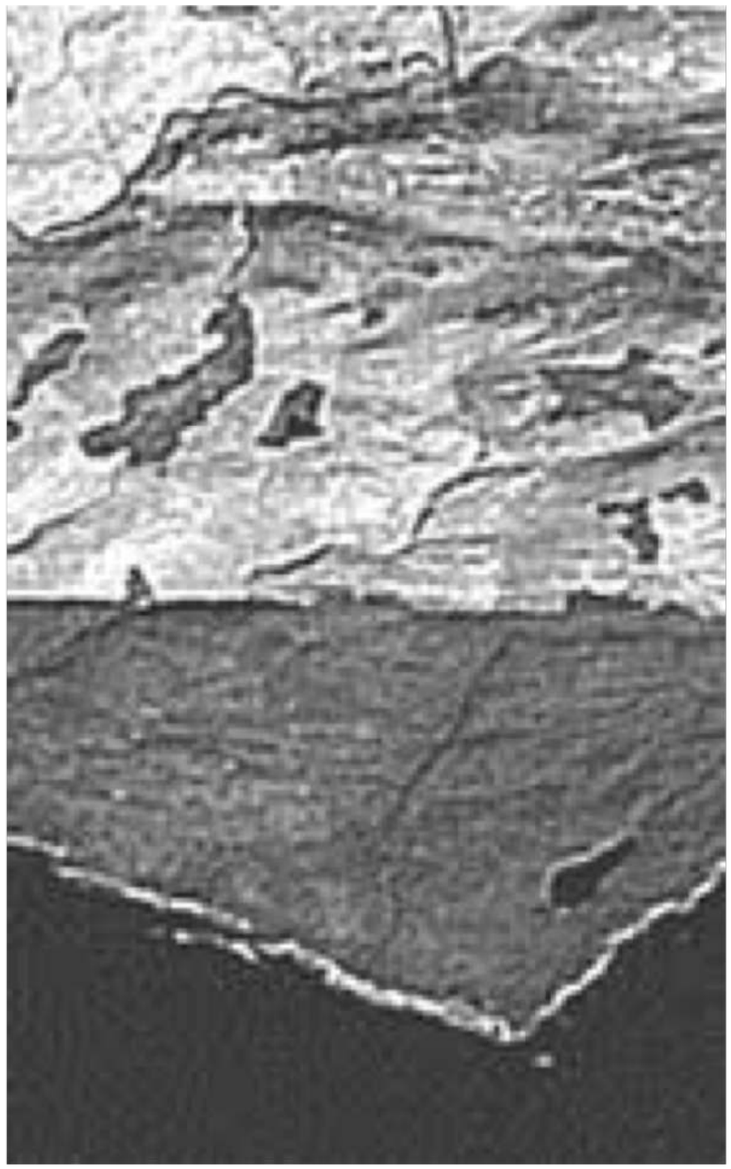
Exemplos de filtros Laplacianos:

0	-1	0	-1	-1	-1	1	-2	1
-1	4	-1	-1	8	-1	-2	4	-2
0	-1	0	-1	-1	-1	1	-2	1

Exemplos de filtros Lapacianos + Original

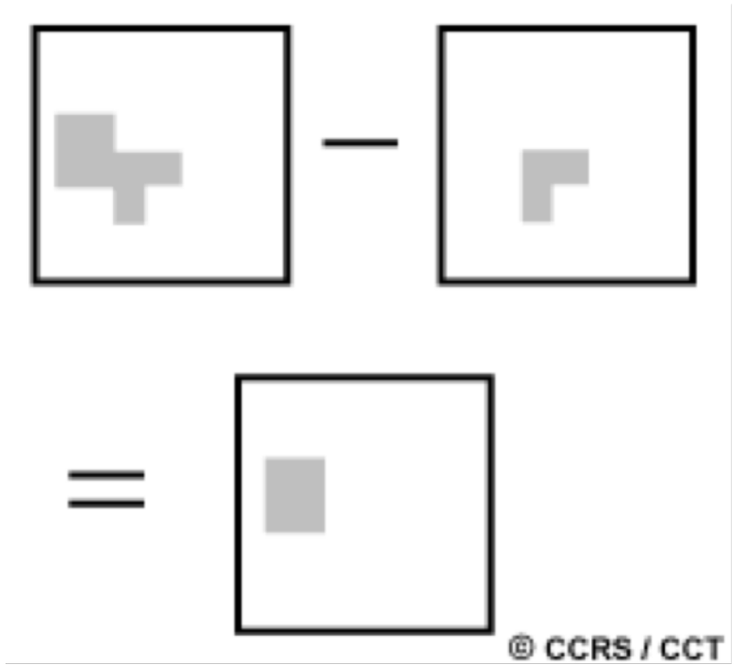
0	-1	0	-1	-1	-1	1	-2	1
-1	5	-1	-1	9	-1	-2	5	-2
0	-1	0	-1	-1	-1	1	-2	1

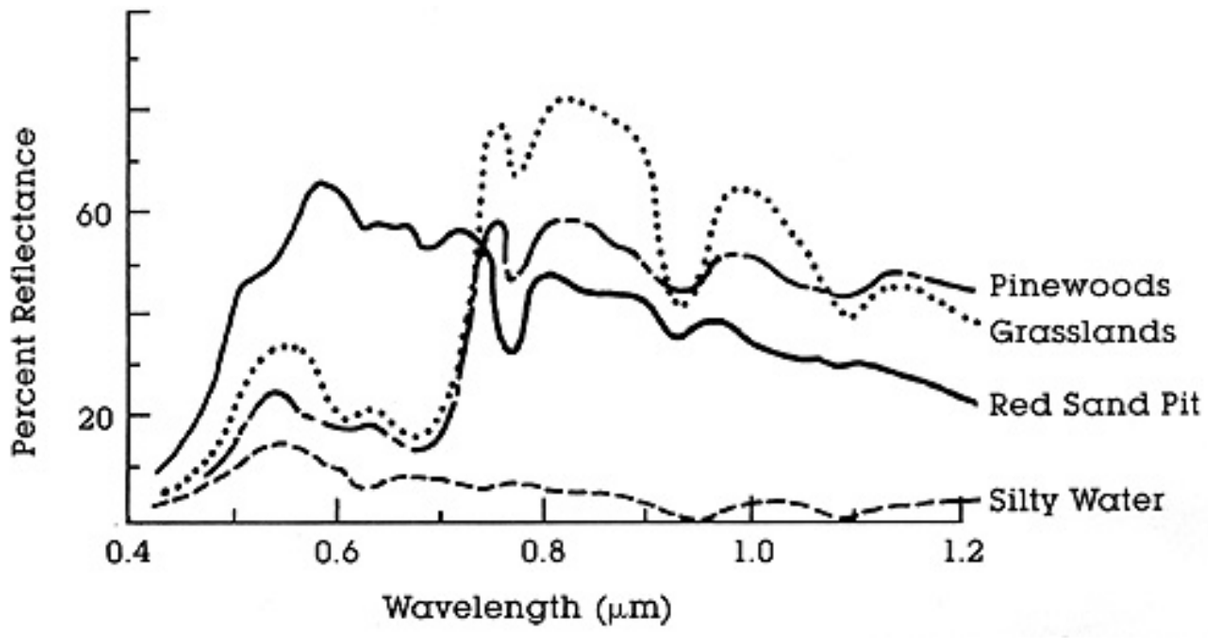




OPERAÇÕES EM SR

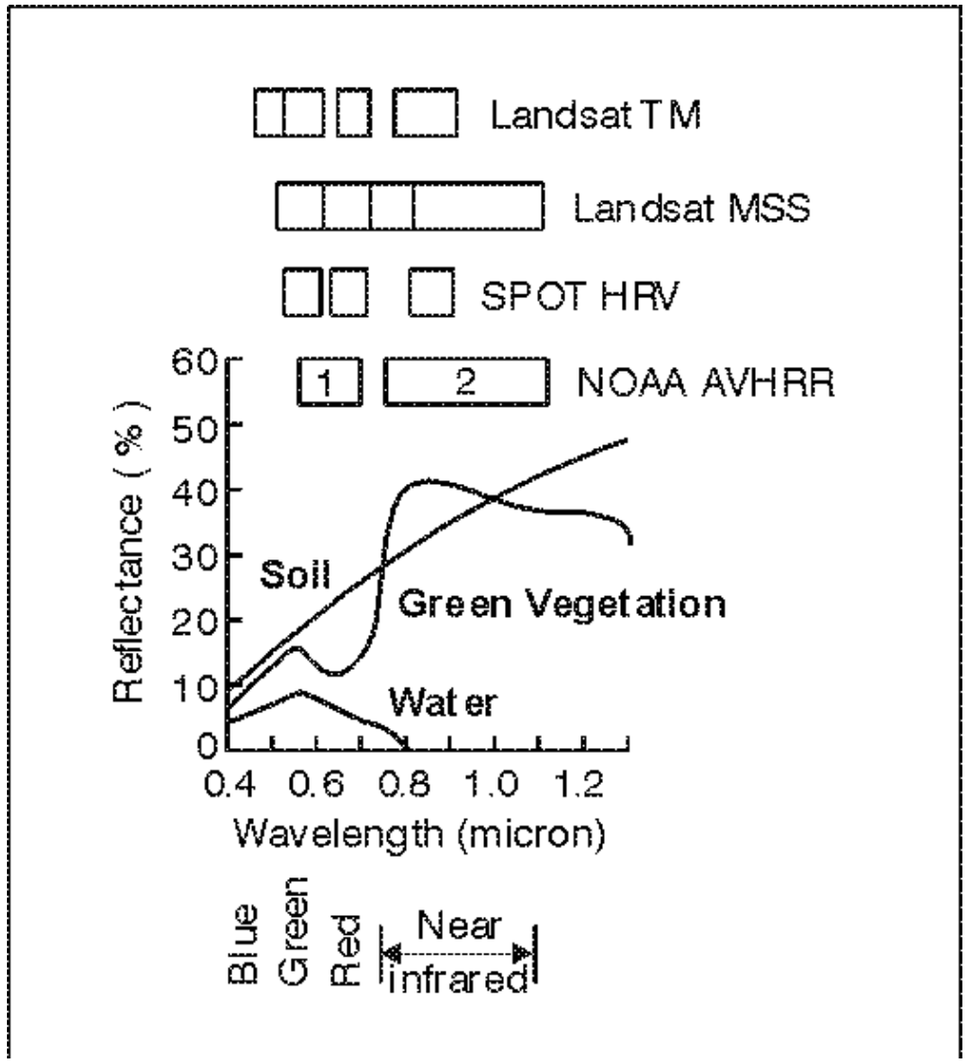
- **Operações aritméticas**
- Subtração: mais usada em análise temporal
- Razão: realça diferenças de comportamentos espectrais



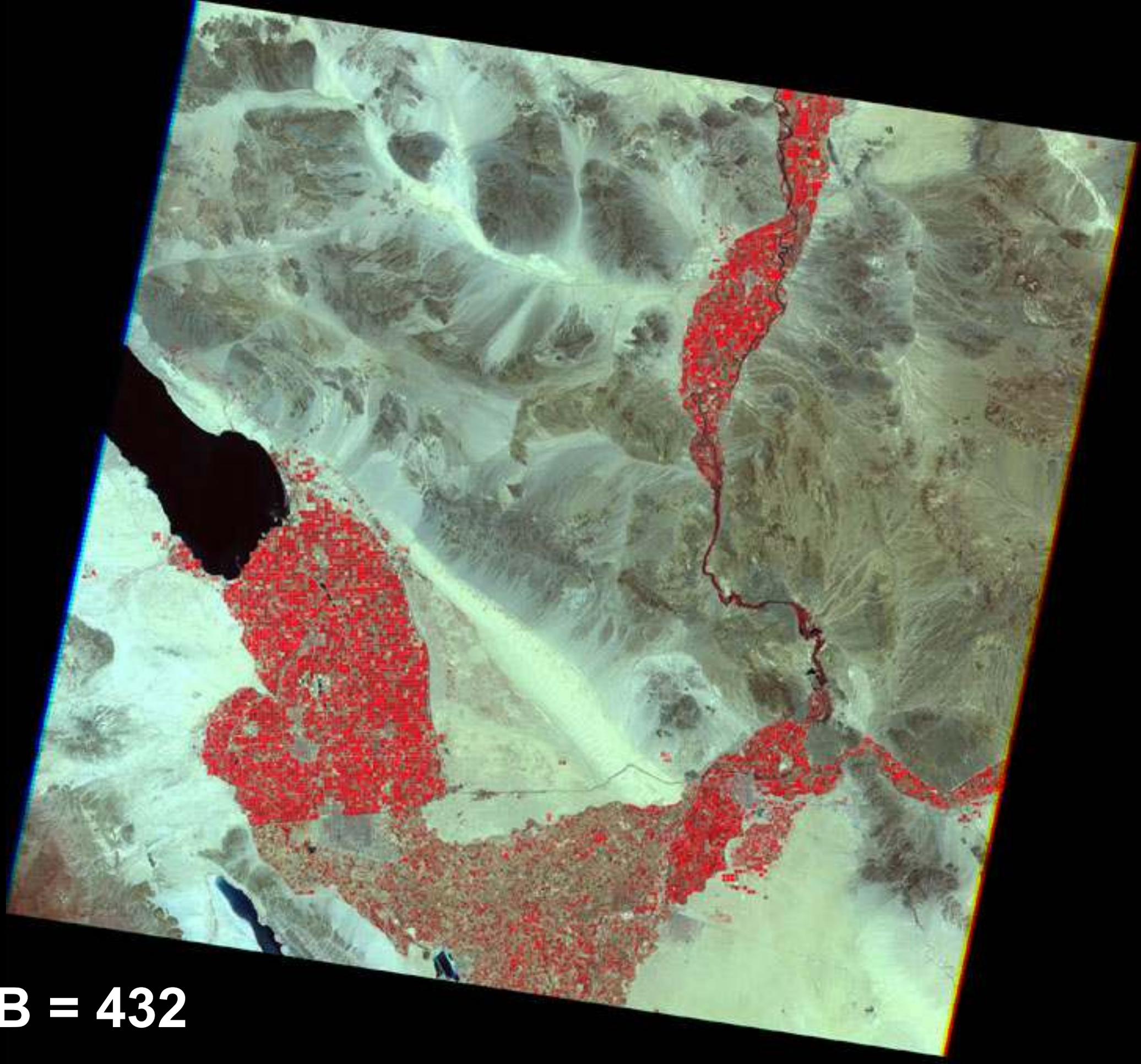


OPERAÇÕES EM SR

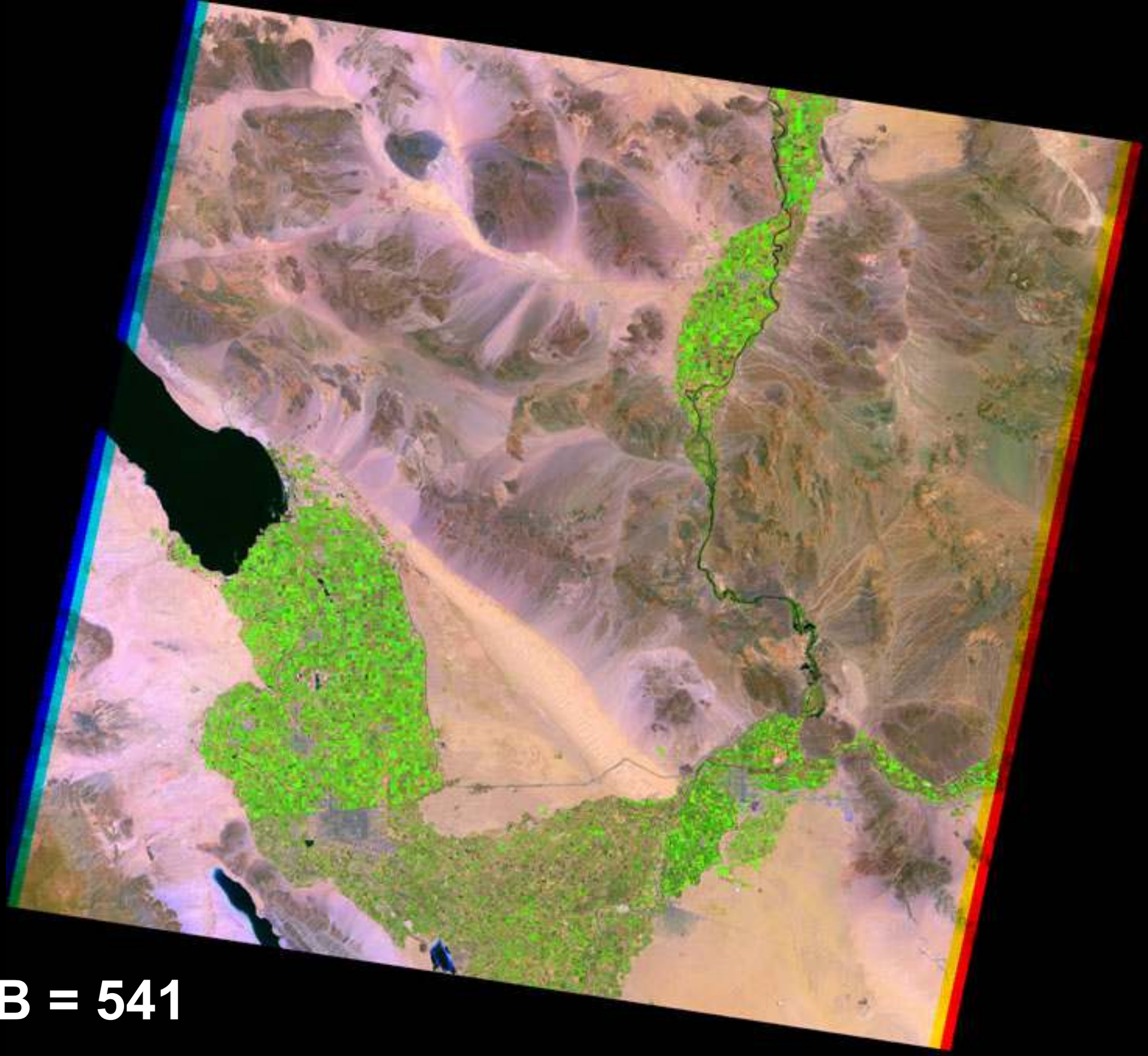
- **Composições RGB**
- Ressaltar diferentes respostas espectrais
- feição de interesse: vermelho



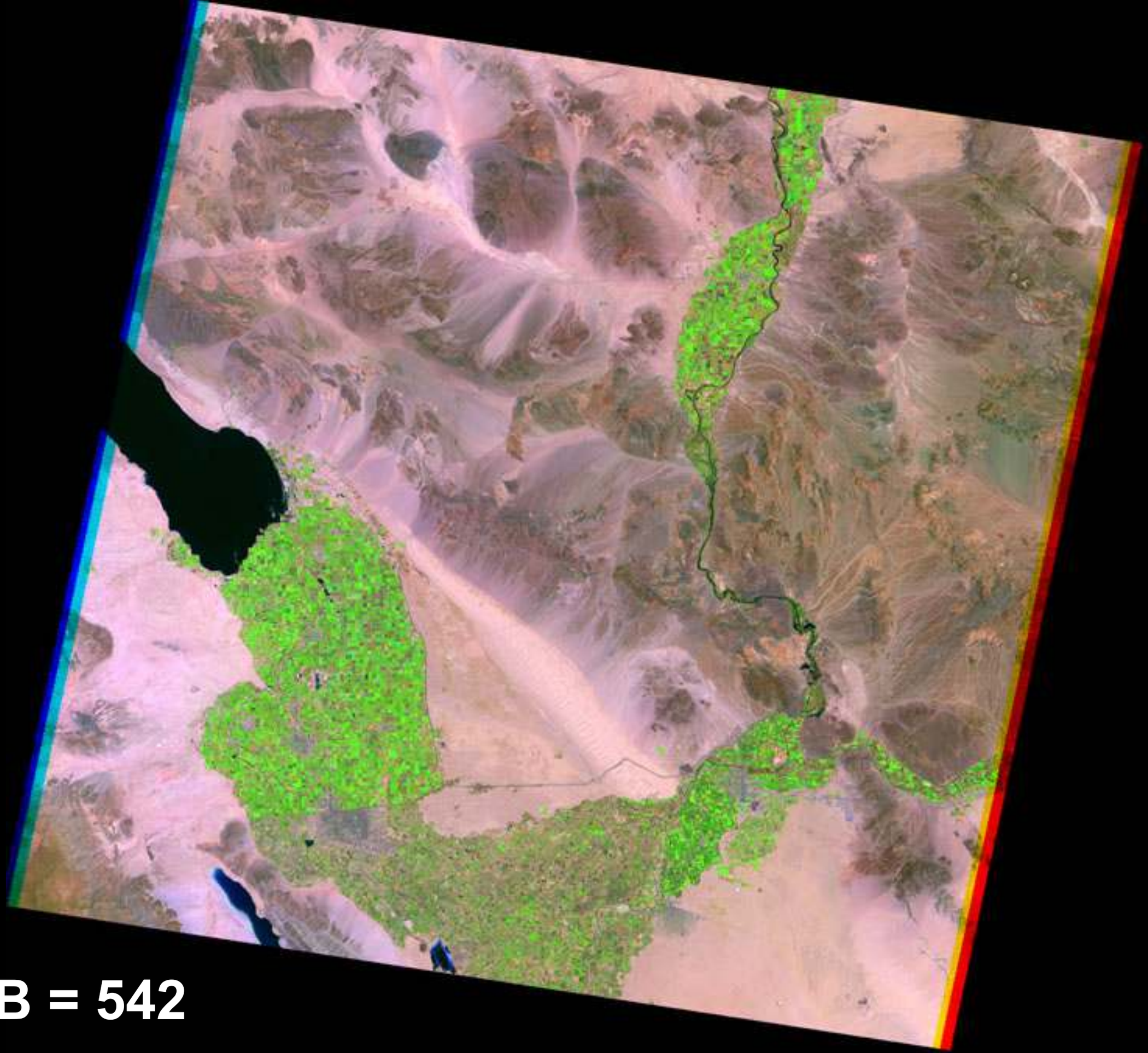
RGB = 321



RGB = 432



RGB = 541

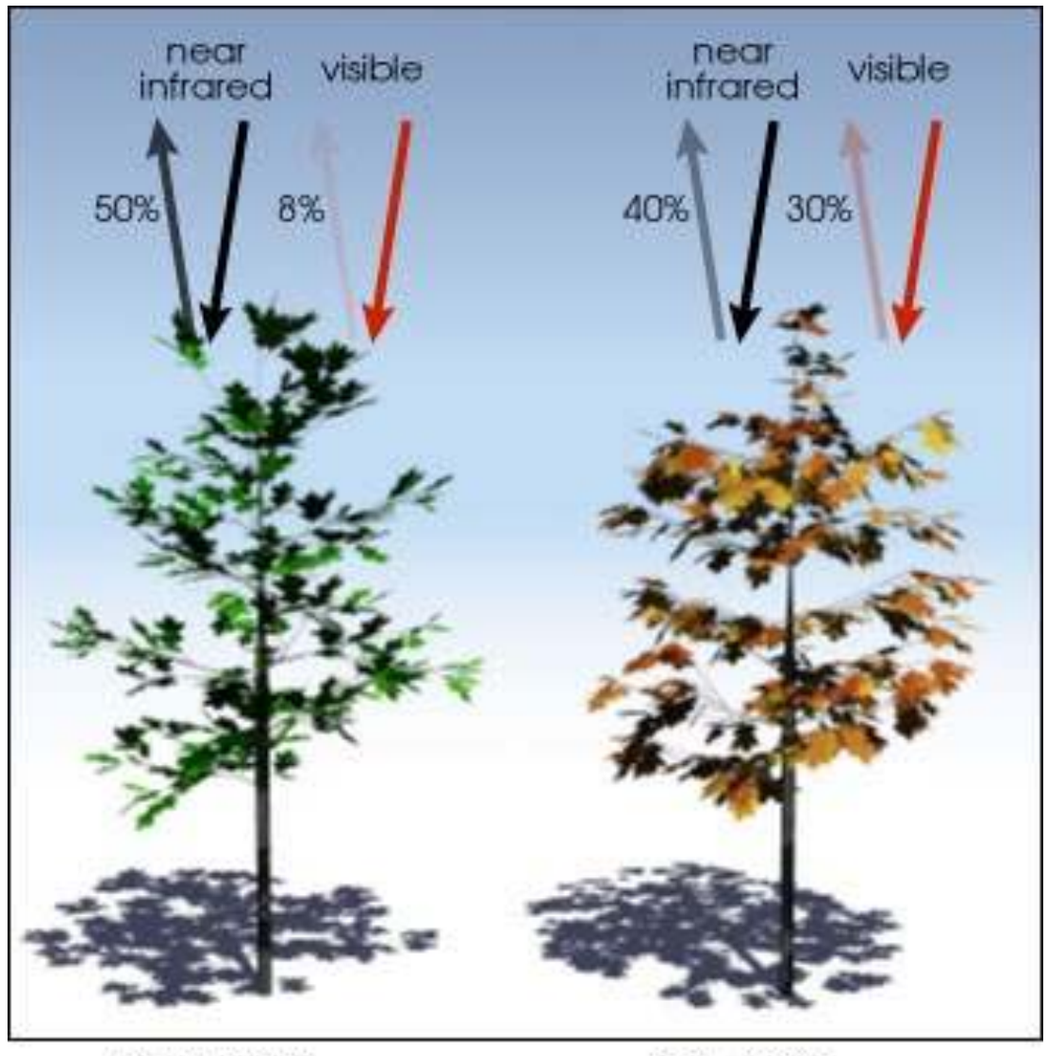


RGB = 542

RGB = 654

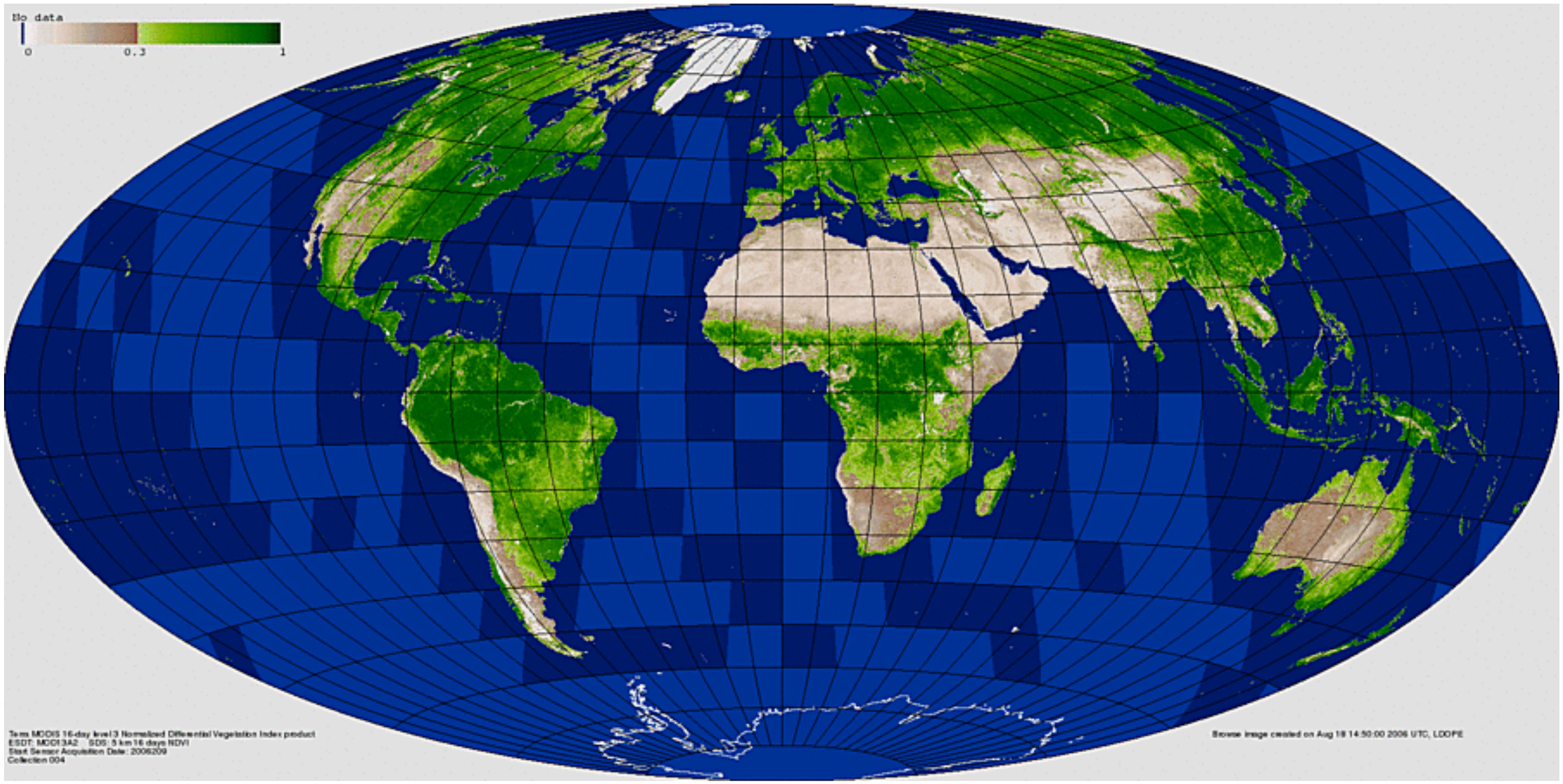
OPERAÇÕES EM SR

- **Normalized Difference Vegetation Index (NDVI)**
- NDVI = (NIR-R)/(NIR+R)
- ETM
  - NDVI=(4-3)/(4+3)
- AVHRR
  - NDVI=(2-1)/(2+1)
- MODIS
  - NDVI=(2-1)/(2+1)



OPERAÇÕES EM SR

- **Normalized Difference Vegetation Index (NDVI)**



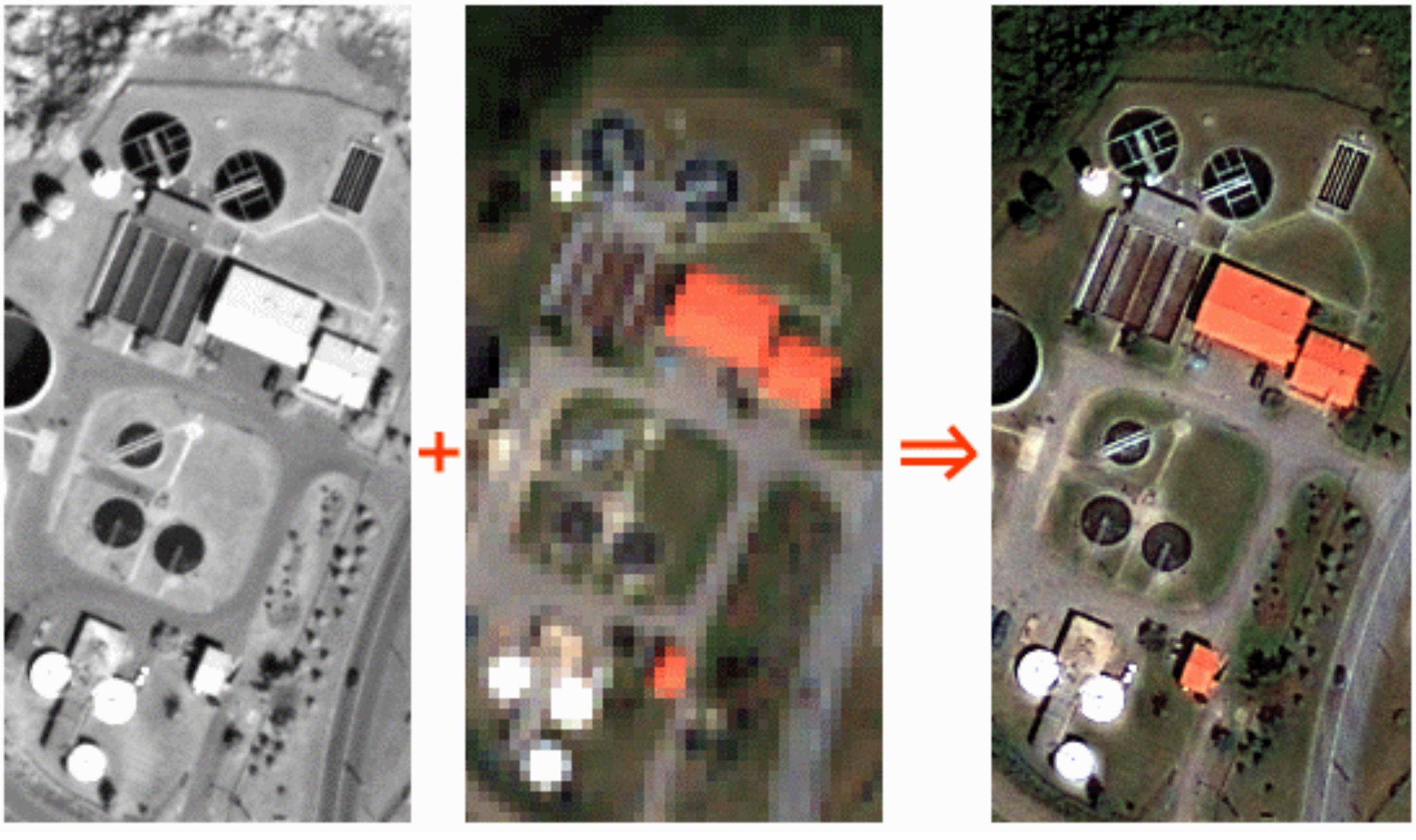
OPERAÇÕES EM SR

- **Composições IHS (ou HSV, HSB..)**
- Pan-sharpening
- Adicionar informação textural da banda pan à informação textural das bandas multiespectrais

- RGB p/ IHS
- substitui o canal de Intensidade pela banda Pan
- IHS p/ RGB

OPERAÇÕES EM SR

- Pan-sharpening



OPERAÇÕES EM SR

- Pan-sharpening

PRINCIPAIS SATÉLITES E SENSORES

- Meteorológicos
  - GOES, AVHRR
- Recursos Terretres
  - Landsat, SPOT, CBERS, ASTER
  - RADAR – Radarsat, JERS, SRTM
- Alta Resolução
  - Ikonos, QuickBird
- Hiperespectrais
  - Hyperion

SATÉLITES METEOROLÓGICOS

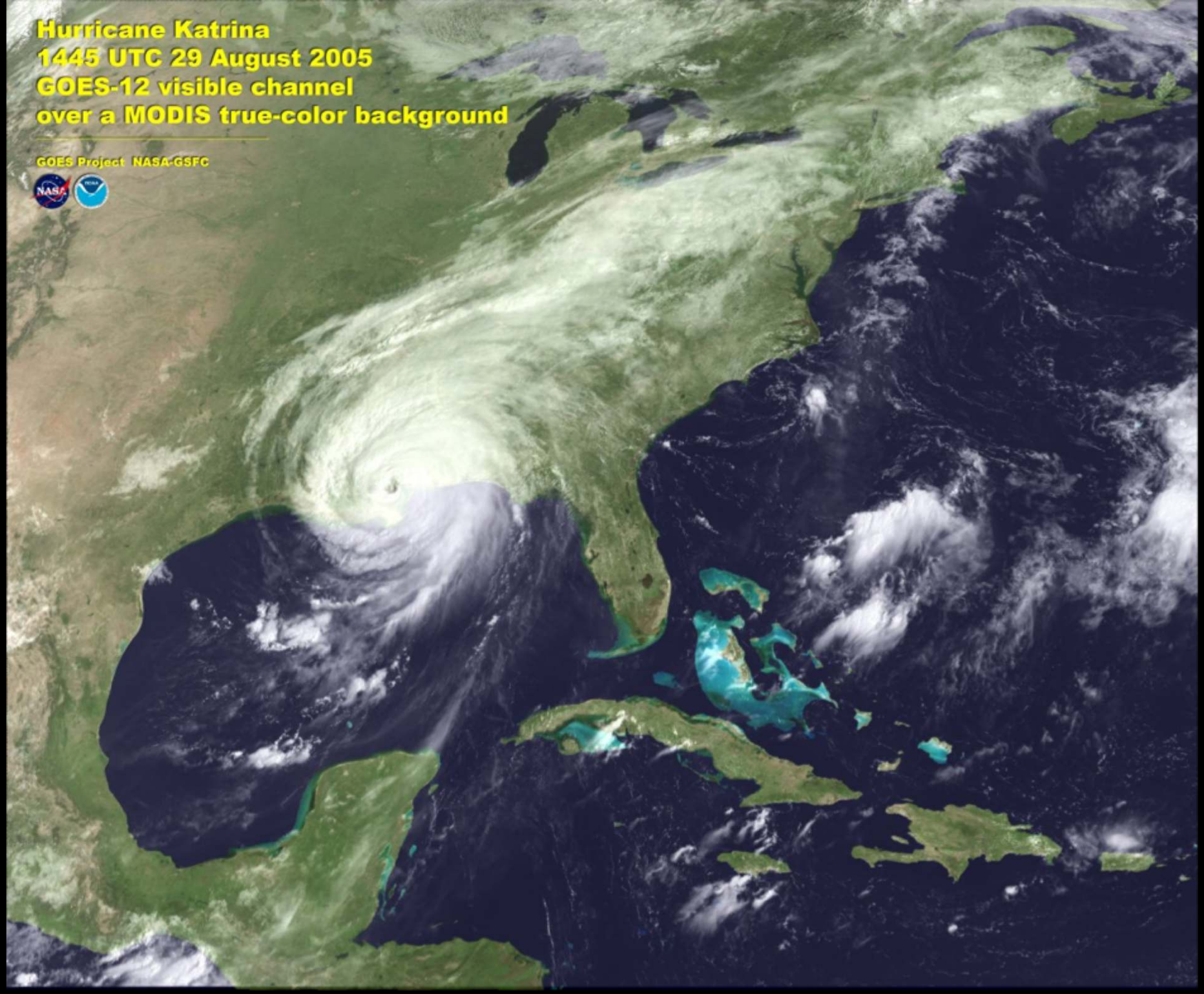
- GOES - Geostationary Operational Environmental Satellite

Band	Wavelength Range (>μm)	Spatial Resolution	Application
1	0.52 - 0.72 (visible)	1 km	cloud, pollution, and haze detection; severe storm identification
2	3.78 - 4.03 (shortwave IR)	4 km	identification of fog at night; discriminating water clouds and snow or ice clouds during daytime; detecting fires and volcanoes; night time determination of sea surface temperatures
3	6.47 - 7.02 (upper level water vapour)	4 km	estimating regions of mid-level moisture content and advection; tracking mid-level atmospheric motion
4	10.2 - 11.2 (longwave IR)	4 km	identifying cloud-drift winds, severe storms, and heavy rainfall
5	11.5 - 12.5 (IR window sensitive to water vapour)	4 km	identification of low-level moisture; determination of sea surface temperature; detection of airborne dust and volcanic ash

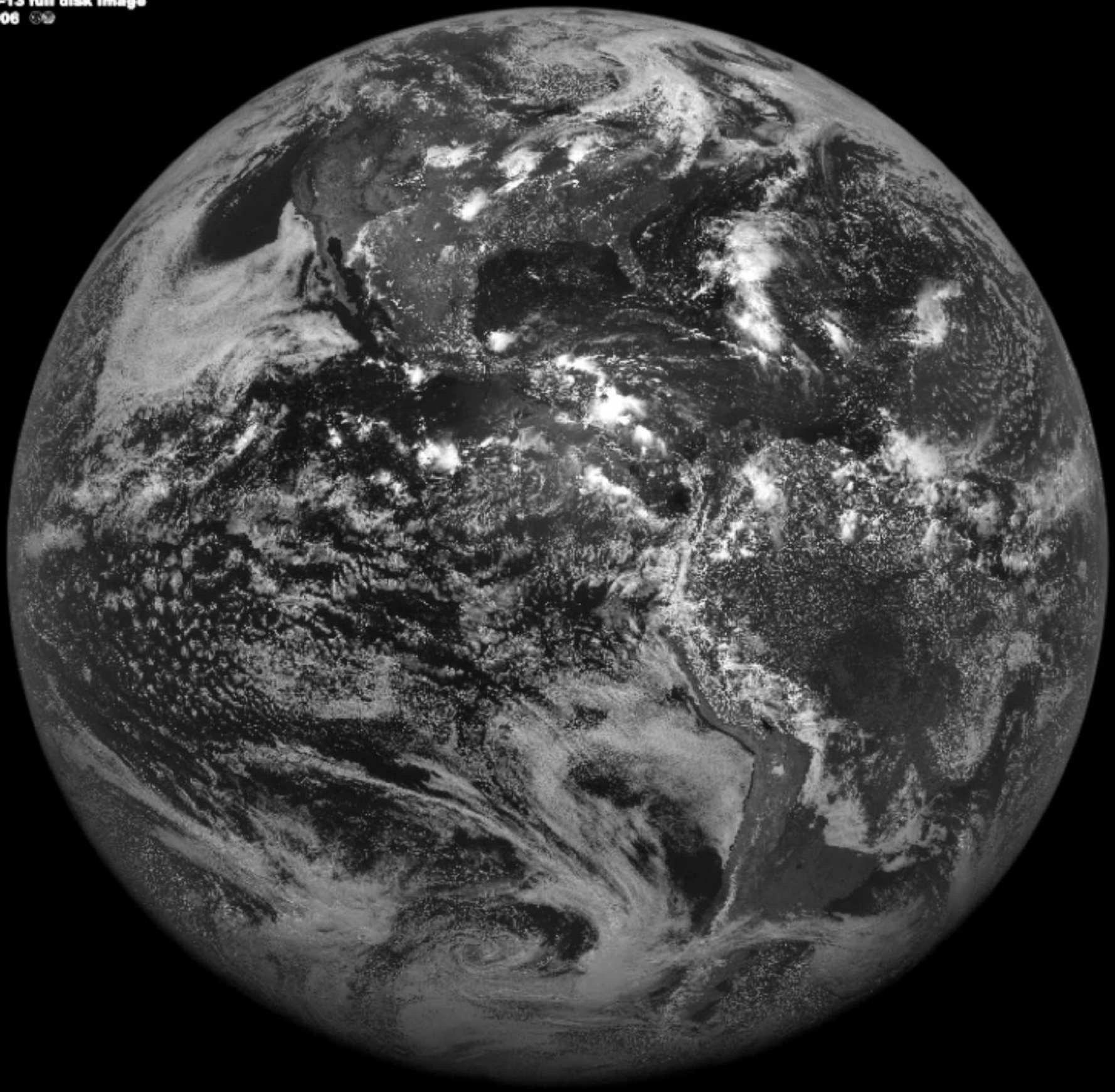
SATÉLITES METEOROLÓGICOS

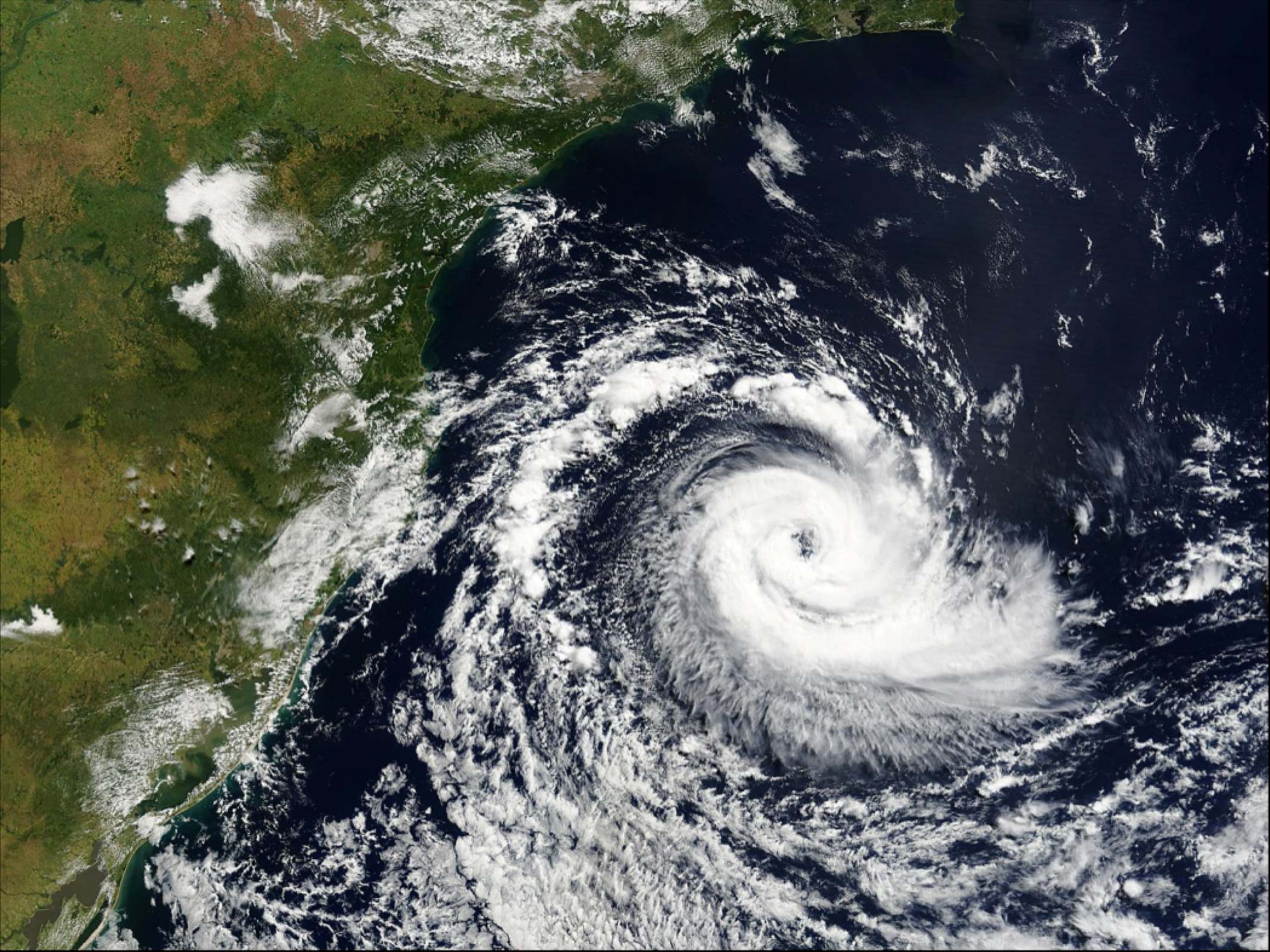
- NOAA AVHRR (Advanced Very High Resolution Radiometer)

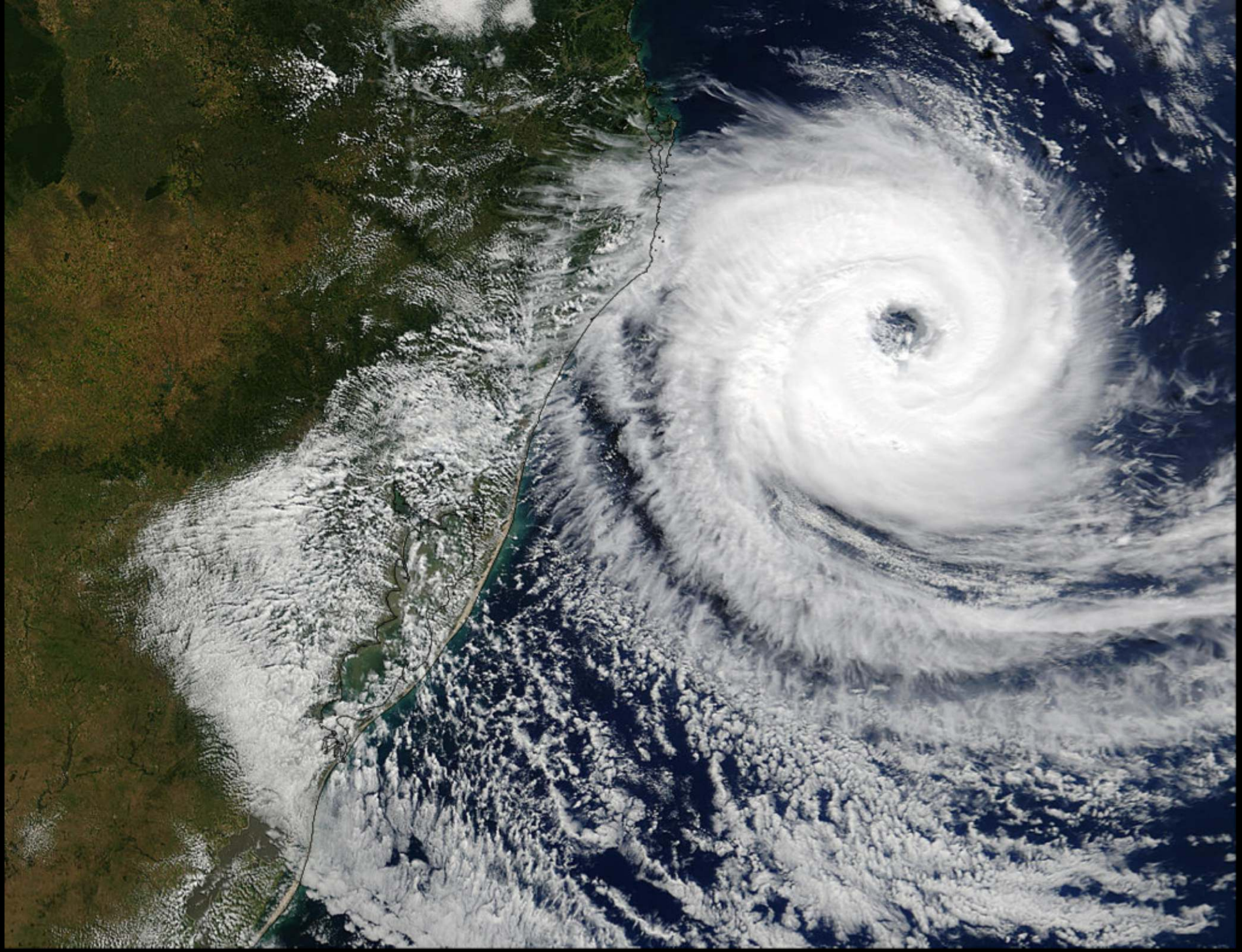
Band	Wavelength Range (μm)	Spatial Resolution	Application
1	0.58 - 0.68 (red)	1.1 km	cloud, snow, and ice monitoring
2	0.725 - 1.1 (near IR)	1.1 km	water, vegetation, and agriculture surveys
3	3.55 -3.93 (mid IR)	1.1 km	sea surface temperature, volcanoes, and forest fire activity
4	10.3 - 11.3 (thermal IR)	1.1 km	sea surface temperature, soil moisture
5	11.5 - 12.5 (thermal IR)	1.1 km	sea surface temperature, soil moisture


Hurricane Katrina
1445 UTC 29 August 2005
GOES-12 visible channel
over a MODIS true-color background
GOES Project NASA-GSFC

First GOES-13 full disk image
22 June 2006

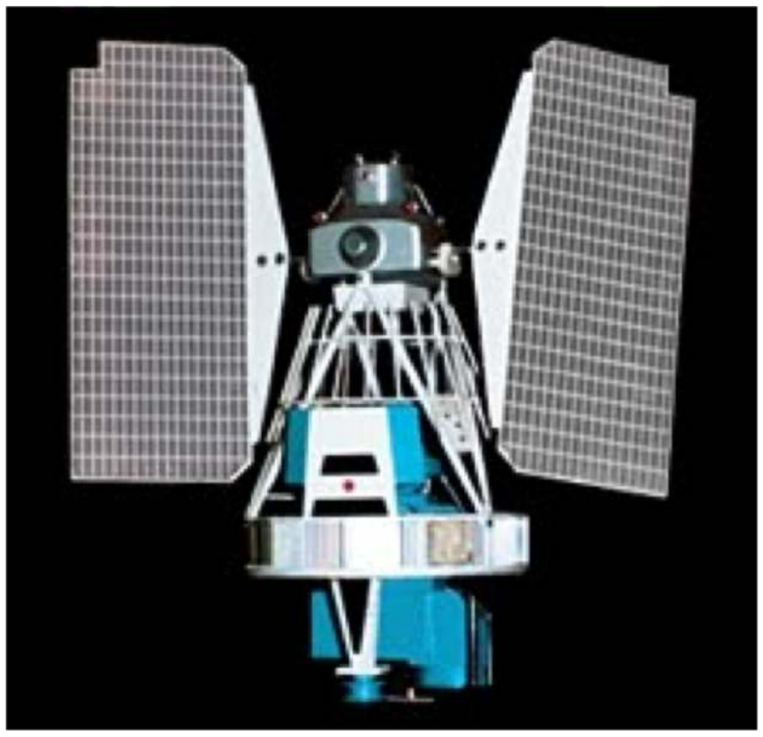


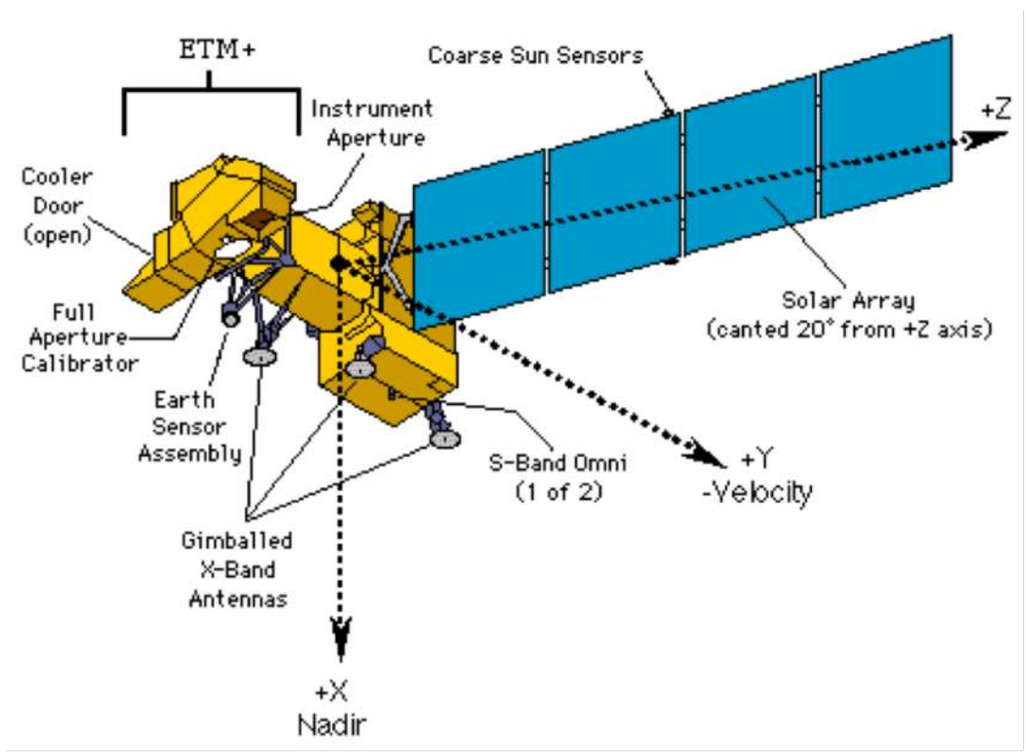




SATÉLITES DE RECURSOS TERRESTRES

- Landsat
- Landsat 1 (ERTS-1) – 1972
- Landsat 7 – 1999
  - sensor ETM+ (Enhanced Thematic Mapper plus)





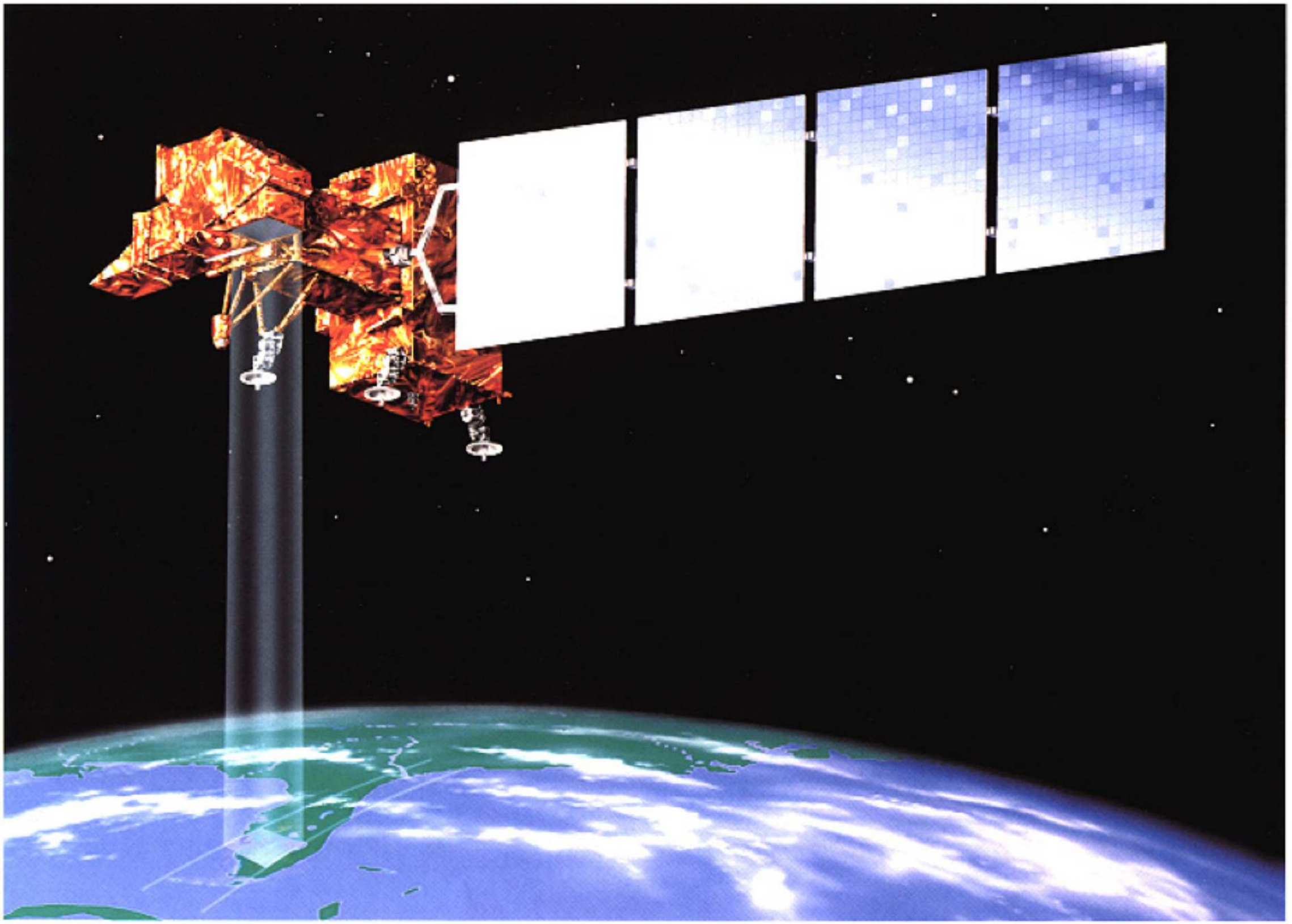
LANDSAT TM

Channel	Wavelength Range (μm)	Application
TM 1	0.45 - 0.52 (blue)	soil/vegetation discrimination; bathymetry/coastal mapping; cultural/urban feature identification
TM 2	0.52 - 0.60 (green)	green vegetation mapping (measures reflectance peak); cultural/urban feature identification
TM 3	0.63 - 0.69 (red)	vegetated vs. non-vegetated and plant species discrimination (plant chlorophyll absorption); cultural/urban feature identification
TM 4	0.76 - 0.90 (near IR)	identification of plant/vegetation types, health, and biomass content; water body delineation; soil moisture
TM 5	1.55 - 1.75 (short wave IR)	sensitive to moisture in soil and vegetation; discriminating snow and cloud-covered areas
TM 6	10.4 - 12.5 (thermal IR)	vegetation stress and soil moisture discrimination related to thermal radiation; thermal mapping (urban, water)
TM 7	2.08 - 2.35 (short wave IR)	discrimination of mineral and rock types; sensitive to vegetation moisture content

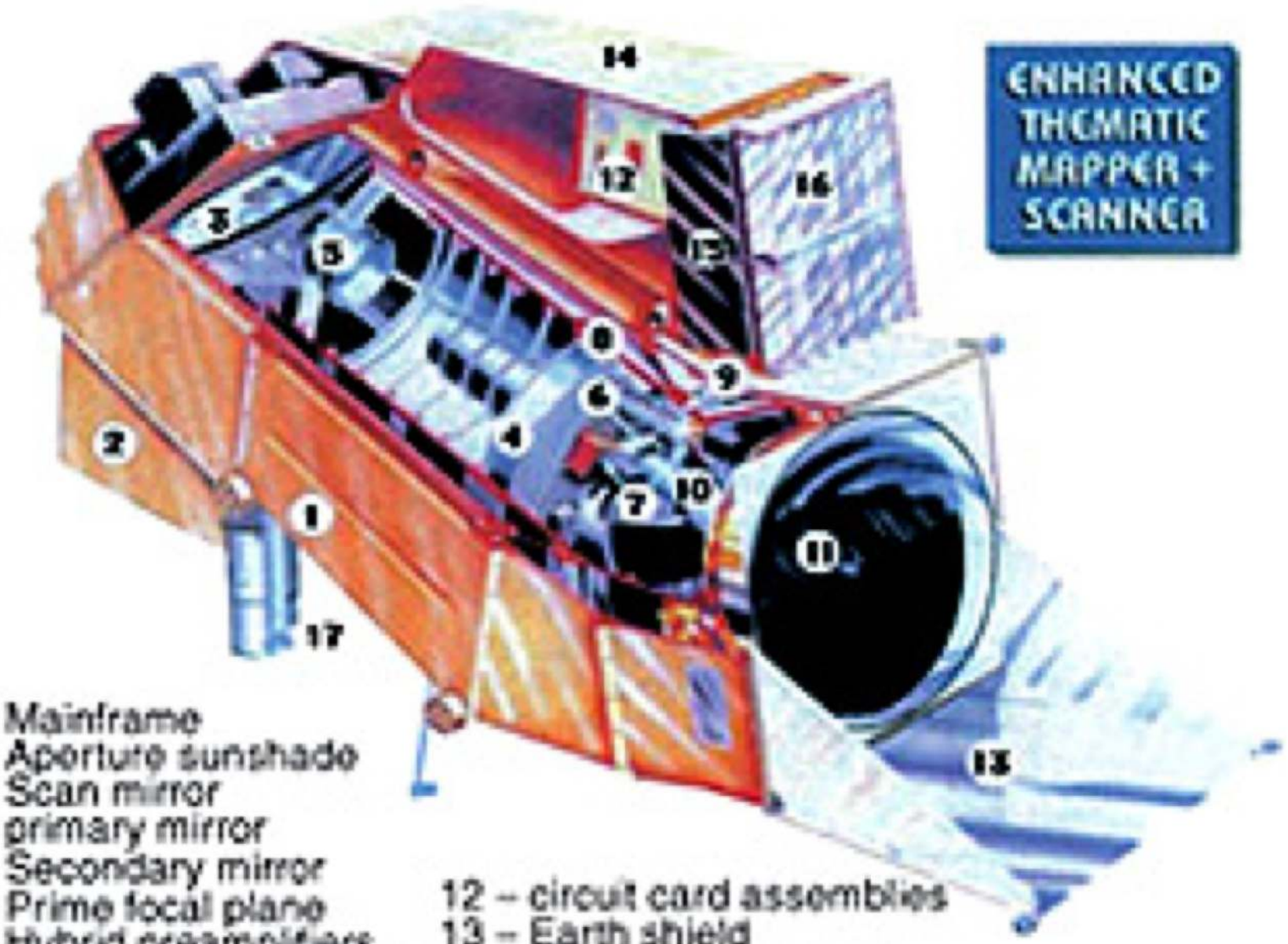
National Aeronautics and Space Administration
Goddard Space Flight Center

LANDSAT 7

USGS science for a changing world
U. S. Geological Survey



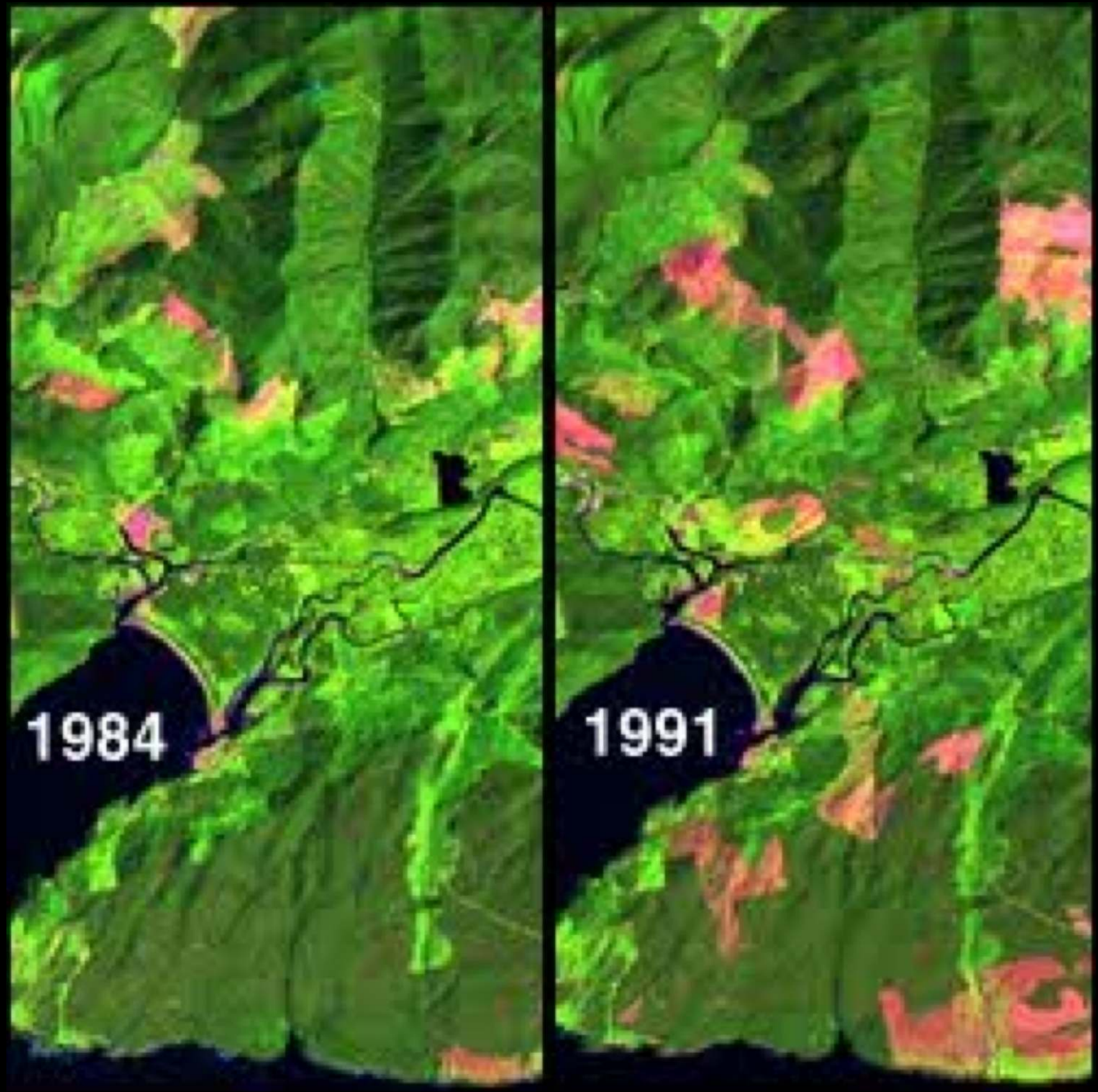
Landsat-7 ETM+



ENHANCED THEMATIC MAPPER + SCANNER

- Multispectral scanning radiometer with 8-bands (visible, near-infrared, short-wave, and thermal infrared)
- Capable of providing high-resolution image information of the Earth's surface.
  - Bands 1-5, 7: 30m resolution
  - Band 6: 60m resolution
  - Band 8: 15m resolution
- Ground swath is approximately 185 km wide

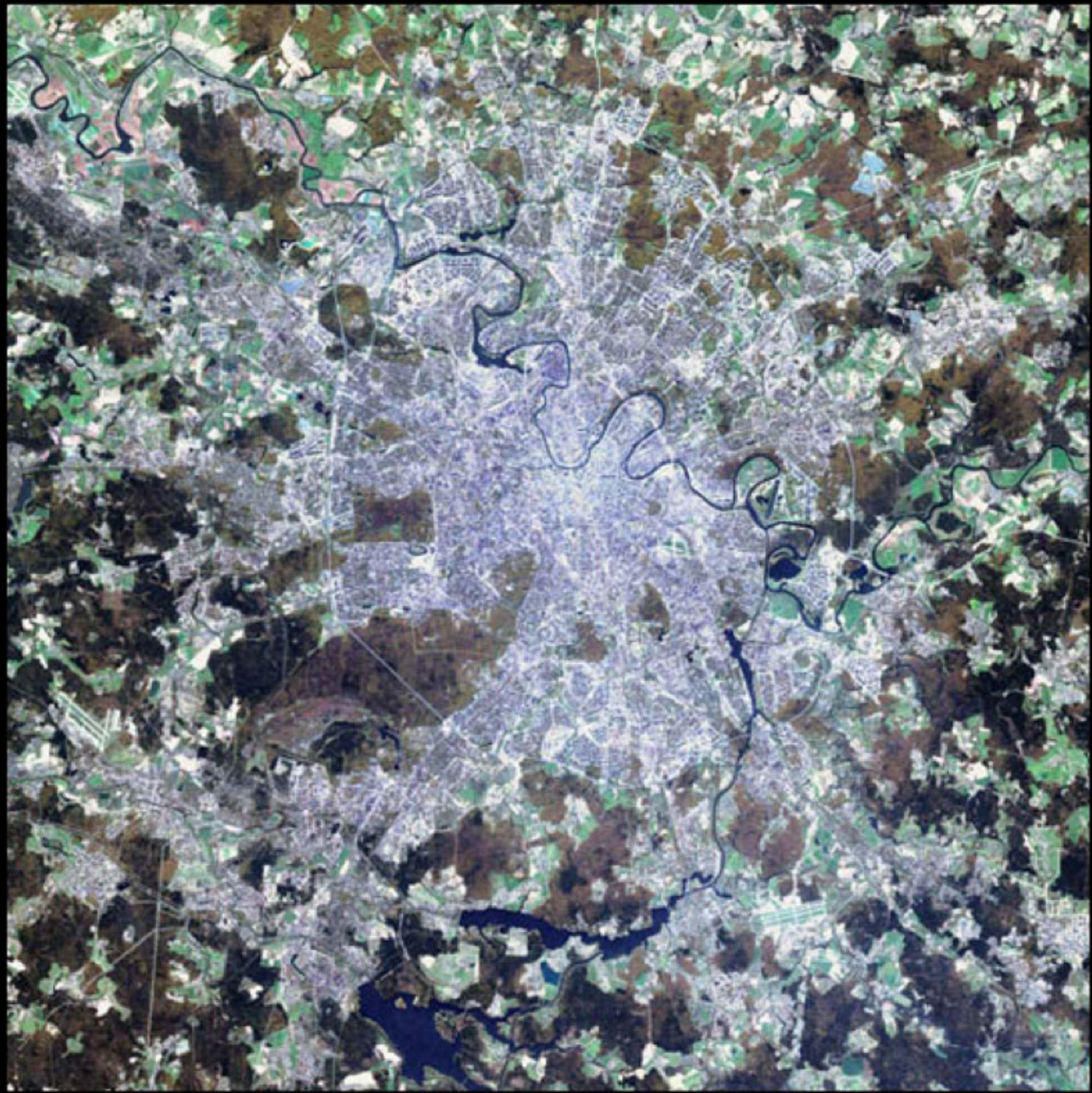
1 – Mainframe
2 – Aperture sunshade
3 – Scan mirror
4 – primary mirror
5 – Secondary mirror
6 – Prime focal plane
7 – Hybrid preamplifiers
8 – Calibration shutter
9 – Black body
10 – Relay optics assembly
11 – Radiative cooler
12 – circuit card assemblies
13 – Earth shield
14 – Electronics module
15 – Power supplies
16 – Thermal control louvers
17– Full aperture calibrator assembly


1984
1991

Lago Carnegie, Austrália

Dragon Lake, Sibéria


Encontro dos Rios Negro e Solimões



SPOT

- Système Pour l'Observation de la Terre
- SPOT 5 – PAN 2.5m resolução

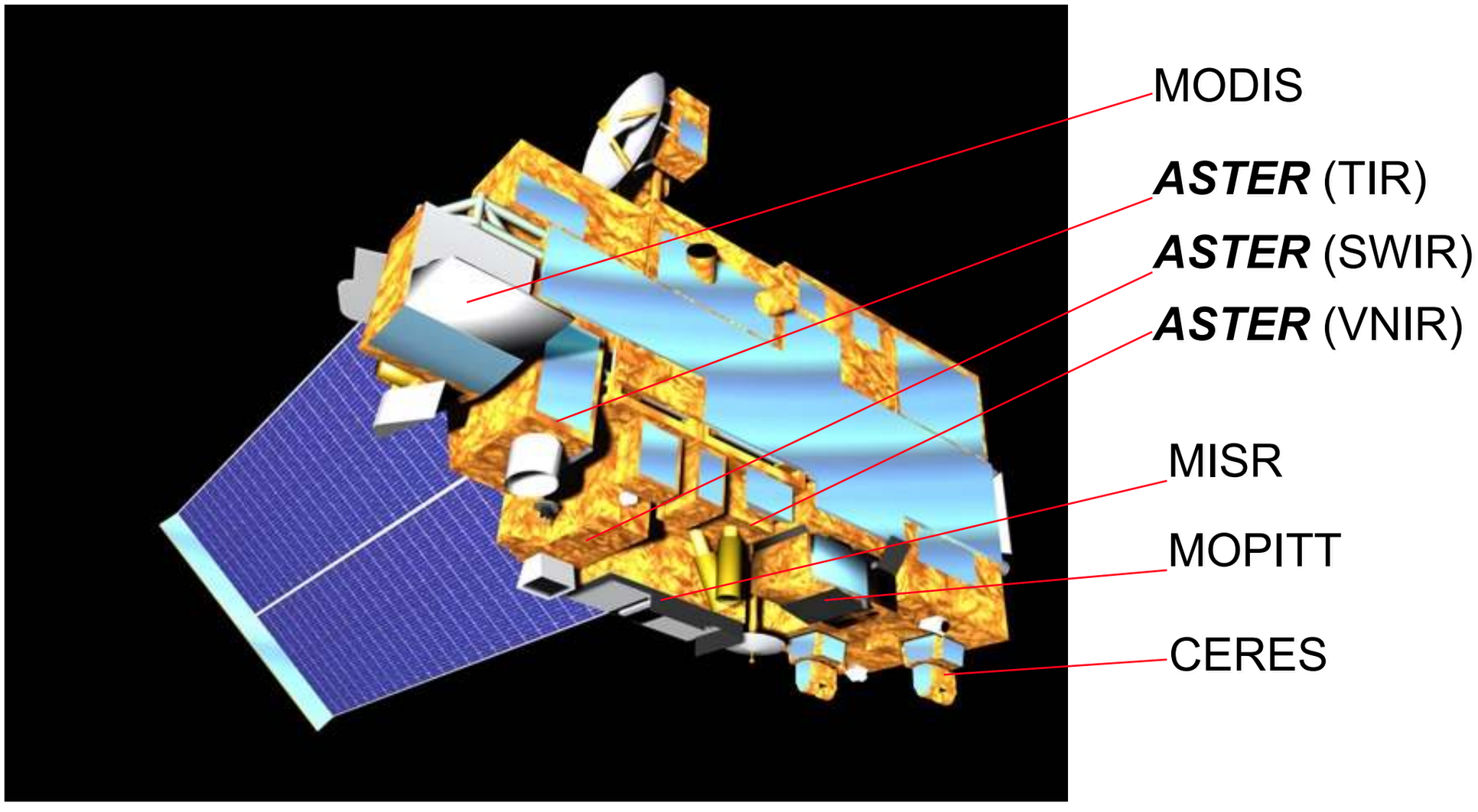
Mode/Band	Wavelength Range (μm)
Panchromatic (PLA)	0.51 - 0.73 (blue-green-red)
Multispectral (MLA)	
Band 1	0.50 - 0.59 (green)
Band 2	0.61 - 0.68 (red)
Band 3	0.79 - 0.89 (near infrared)

TERRA

- EOS AM-1
  - ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer
  - CERES - Clouds and the Earth's Radiant Energy System
  - MISR - Multi-angle Imaging SpectroRadiometer
  - MODIS - Moderate-resolution Imaging Spectroradiometer
  - MOPITT - Measurements of Pollution in the Troposphere

Terra is the flagship of NASA's ESE (Earth Science Enterprise).

ASTER is the zoom lens of Terra!

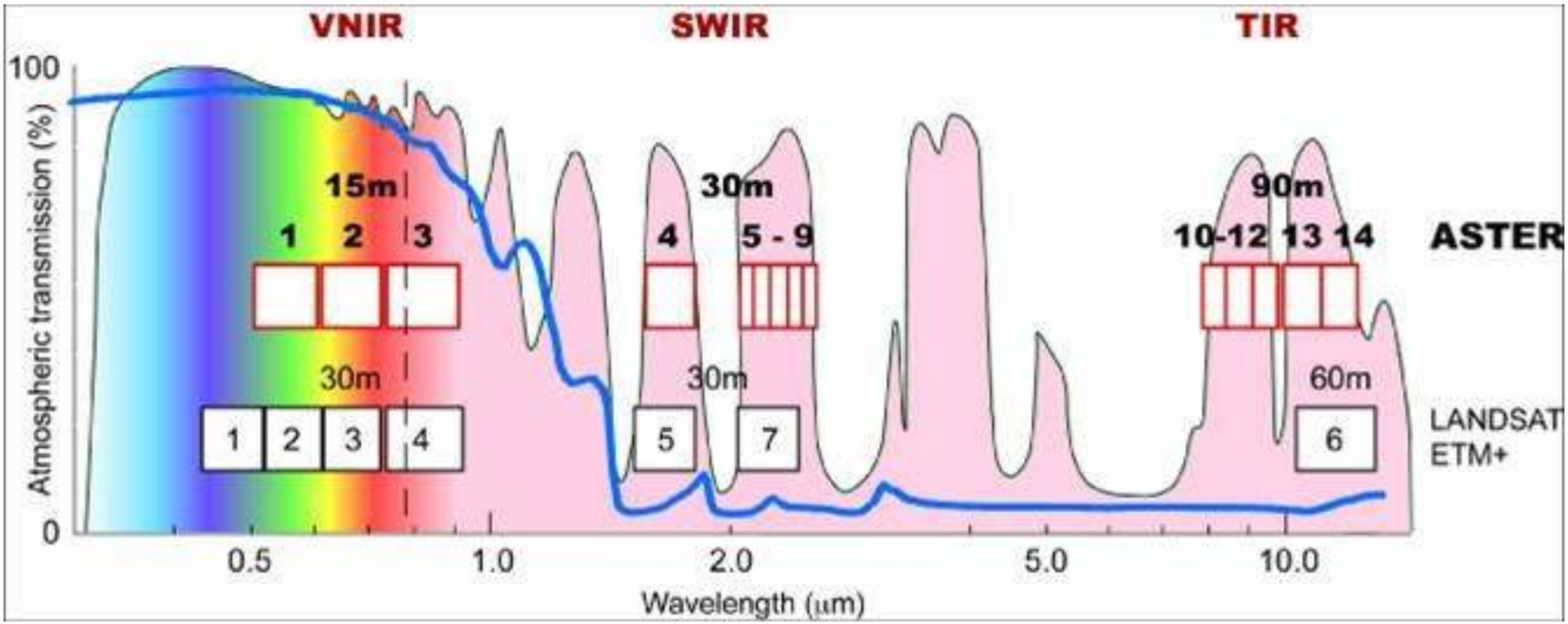


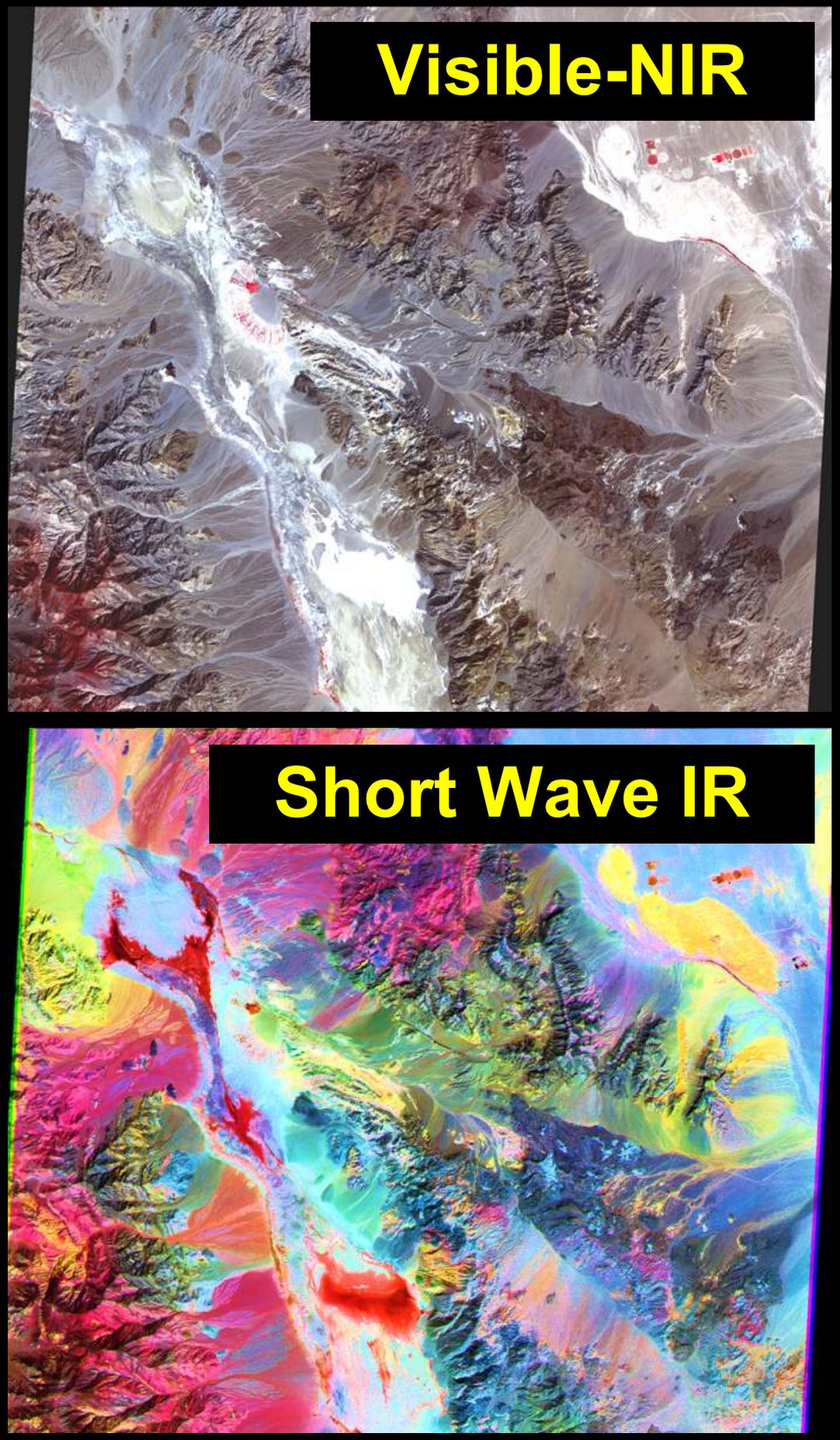
ASTER

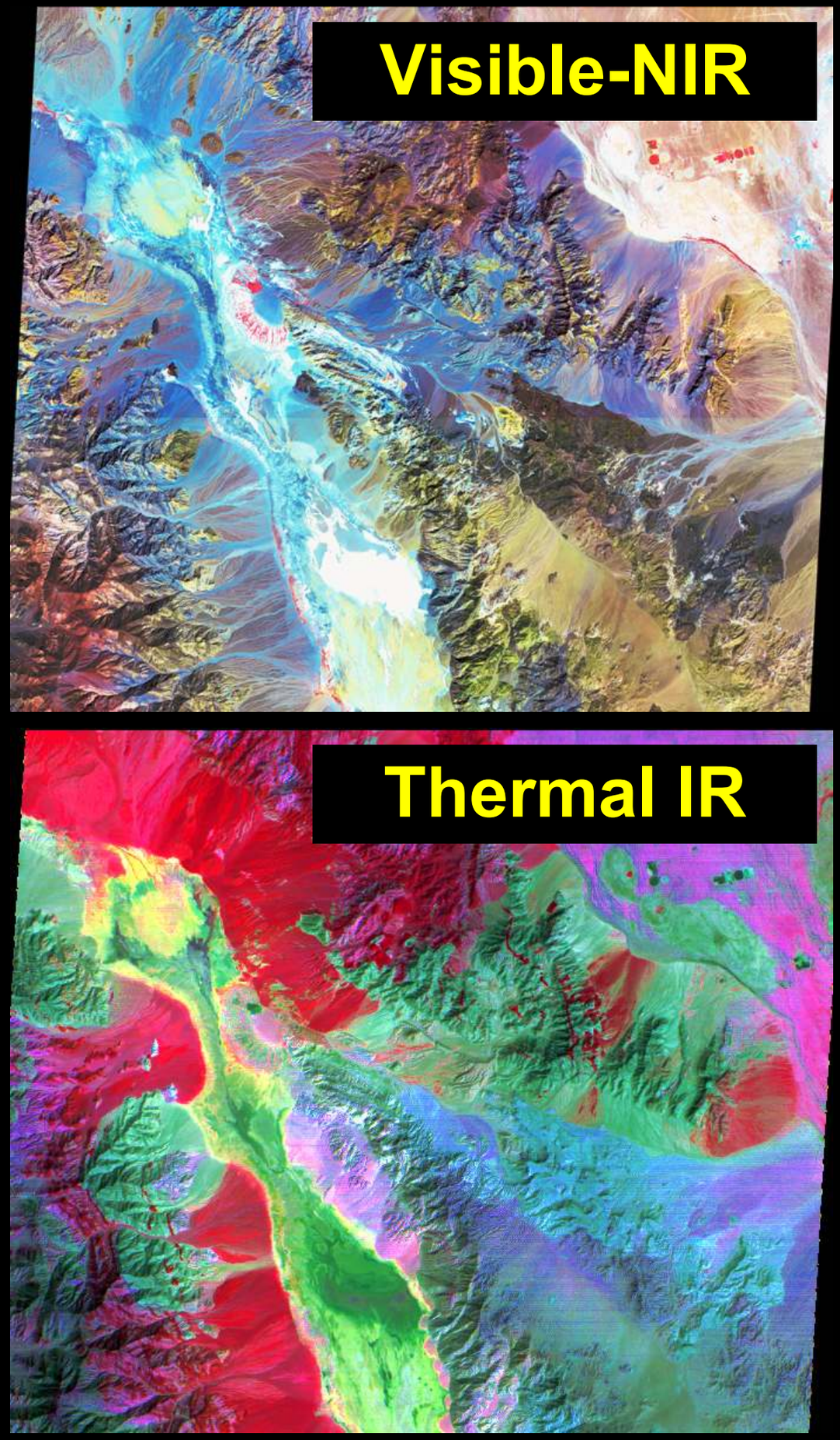
- Advanced Spaceborne Thermal and Emitted Radiometer

Subsystem	Band No.	Spectral Range (μm)	Spatial Resolution, m	Quantization Levels
VNIR	1	0.52-0.60	15	8 bits
	2	0.63-0.69		
	3N	0.78-0.86		
	3B	0.78-0.86		
SWIR	4	1.60-1.70	30	8 bits
	5	2.145-2.185		
	6	2.185-2.225		
	7	2.235-2.285		
	8	2.295-2.365		
	9	2.360-2.430		
TIR	10	8.125-8.475	90	12 bits
	11	8.475-8.825		
	12	8.925-9.275		
	13	10.25-10.95		
	14	10.95-11.65		

ASTER


VNIR
SWIR
TIR
100
0
Atmospheric transmission (%)
15m
30m
90m
1
2
3
4
5 - 9
10-12
13
14
ASTER
30m
30m
60m
1
2
3
4
5
7
6
LANDSAT
ETM+
0.5
1.0
2.0
5.0
10.0
Wavelength (μm)


Visible-NIR

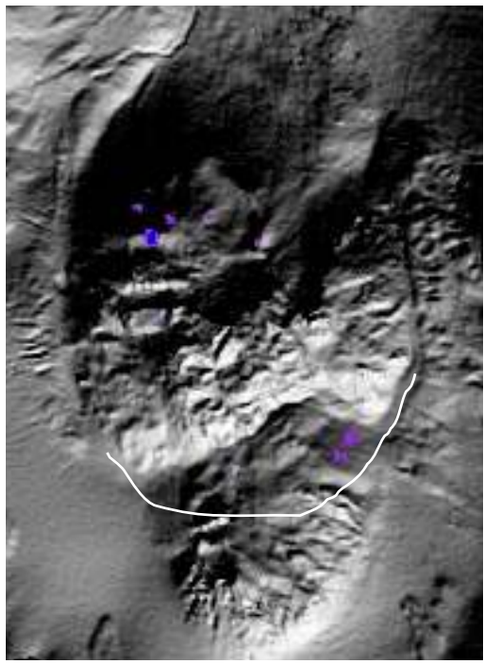

Visible-NIR

Short Wave IR

Thermal IR

MONITORAMENTO DE VULCÕES

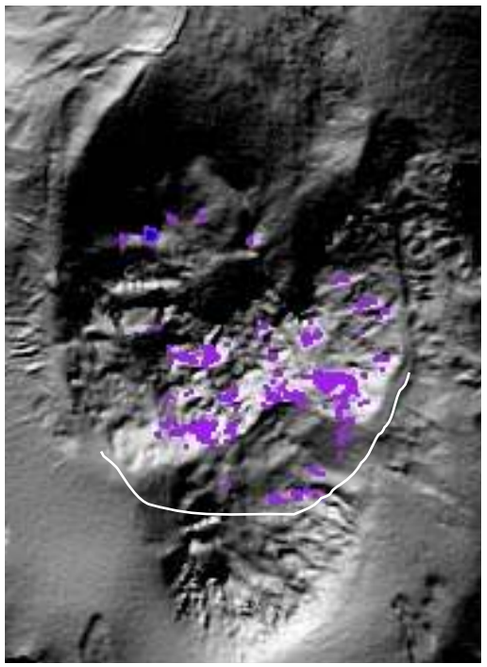
09-24-2004 – 4:30pm



Boundary of Old Dome

High = 51 ºC

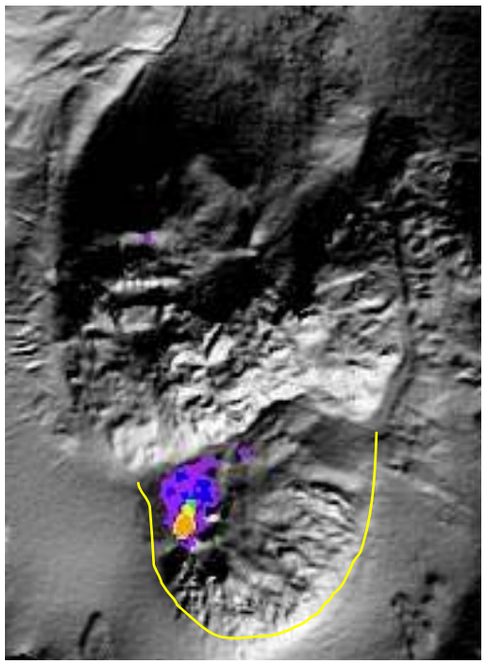
09-30-2004 – 1:30pm



Boundary of Old Dome

High = 54 ºC

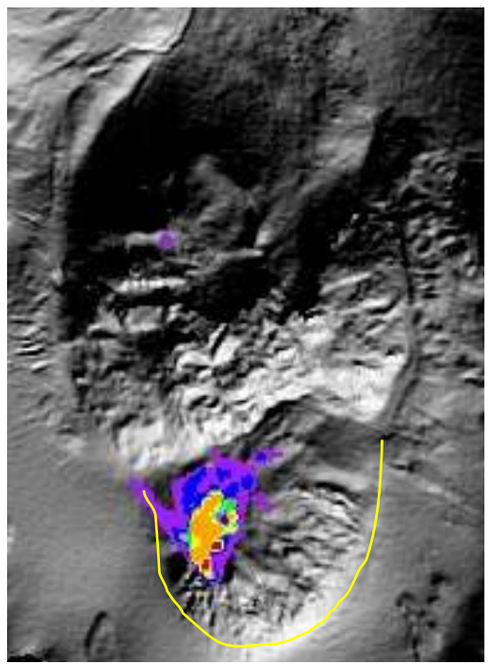
10-12-2004 – 8:00am



Boundary of New Dome

High = 181 ºC

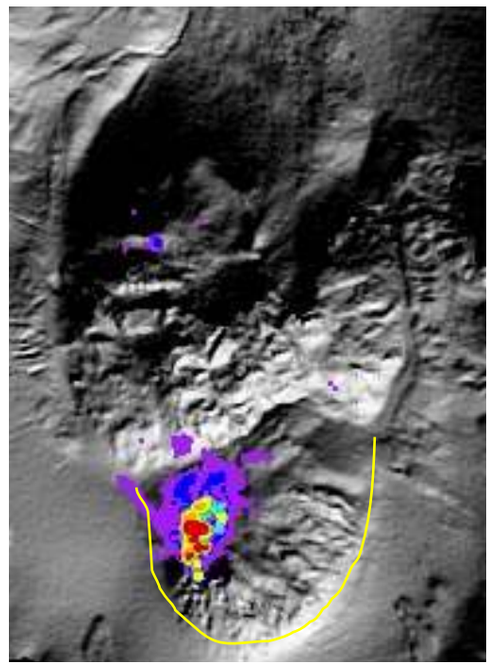
10-14-2004 – 8:00am



Boundary of New Dome

High = 250 ºC

10-14-2004 – 12:45pm



Boundary of New Dome

High = 330 ºC

60-75 ºC

45-60 ºC

30-45 ºC

105-150 ºC

90-105 ºC

75-90 ºC

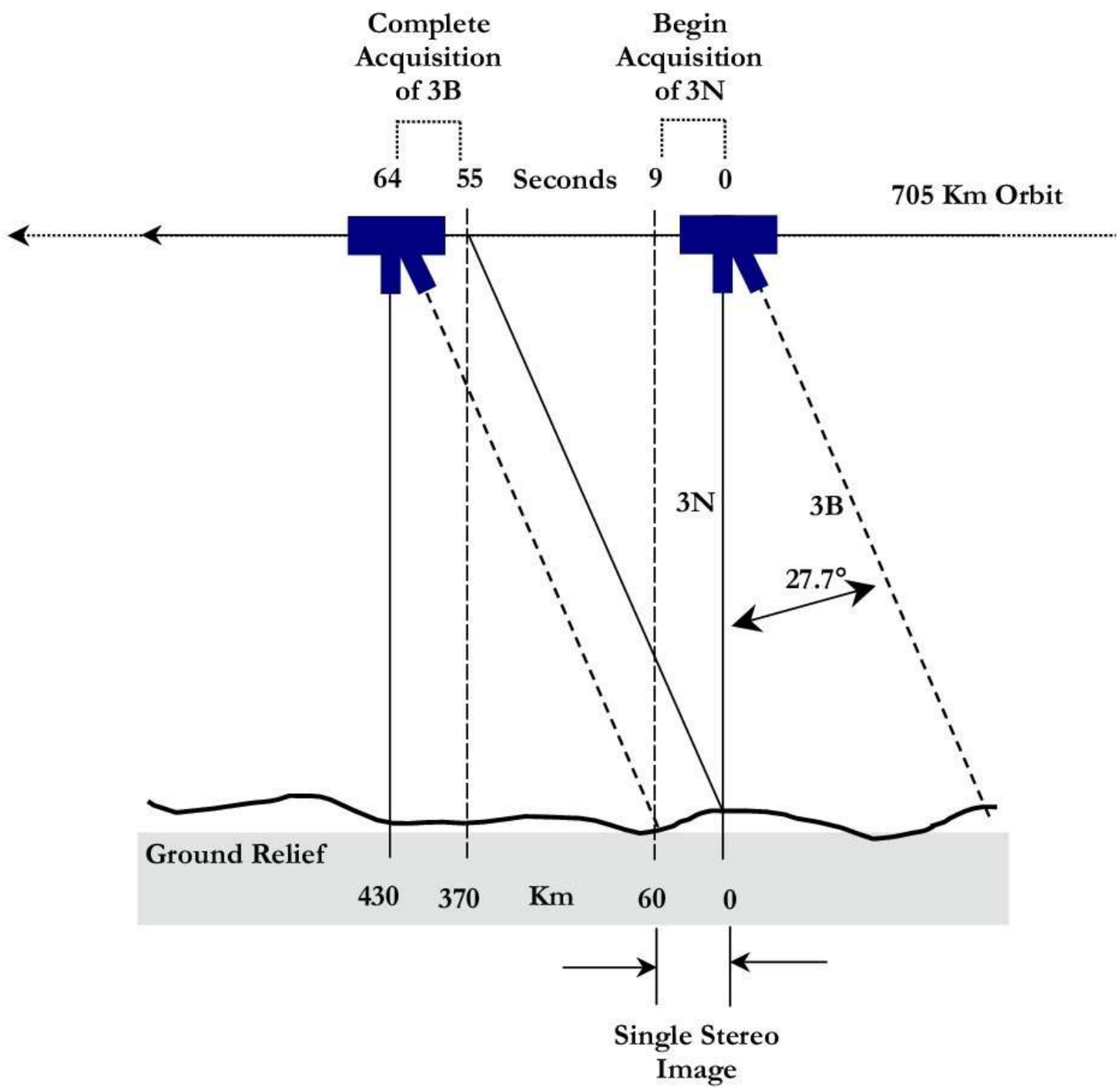
> 300 ºC

200-300 ºC

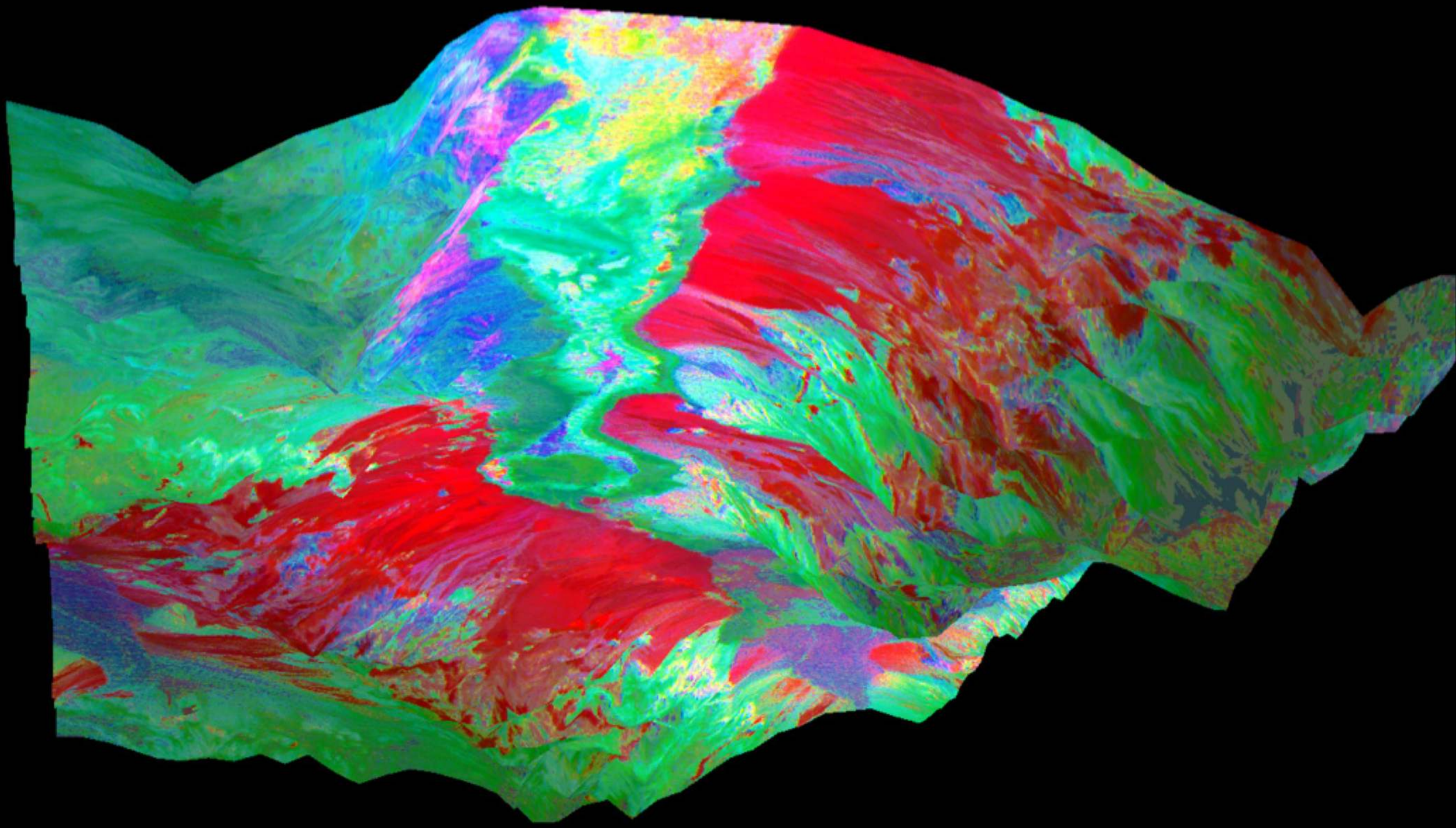
150-200 ºC

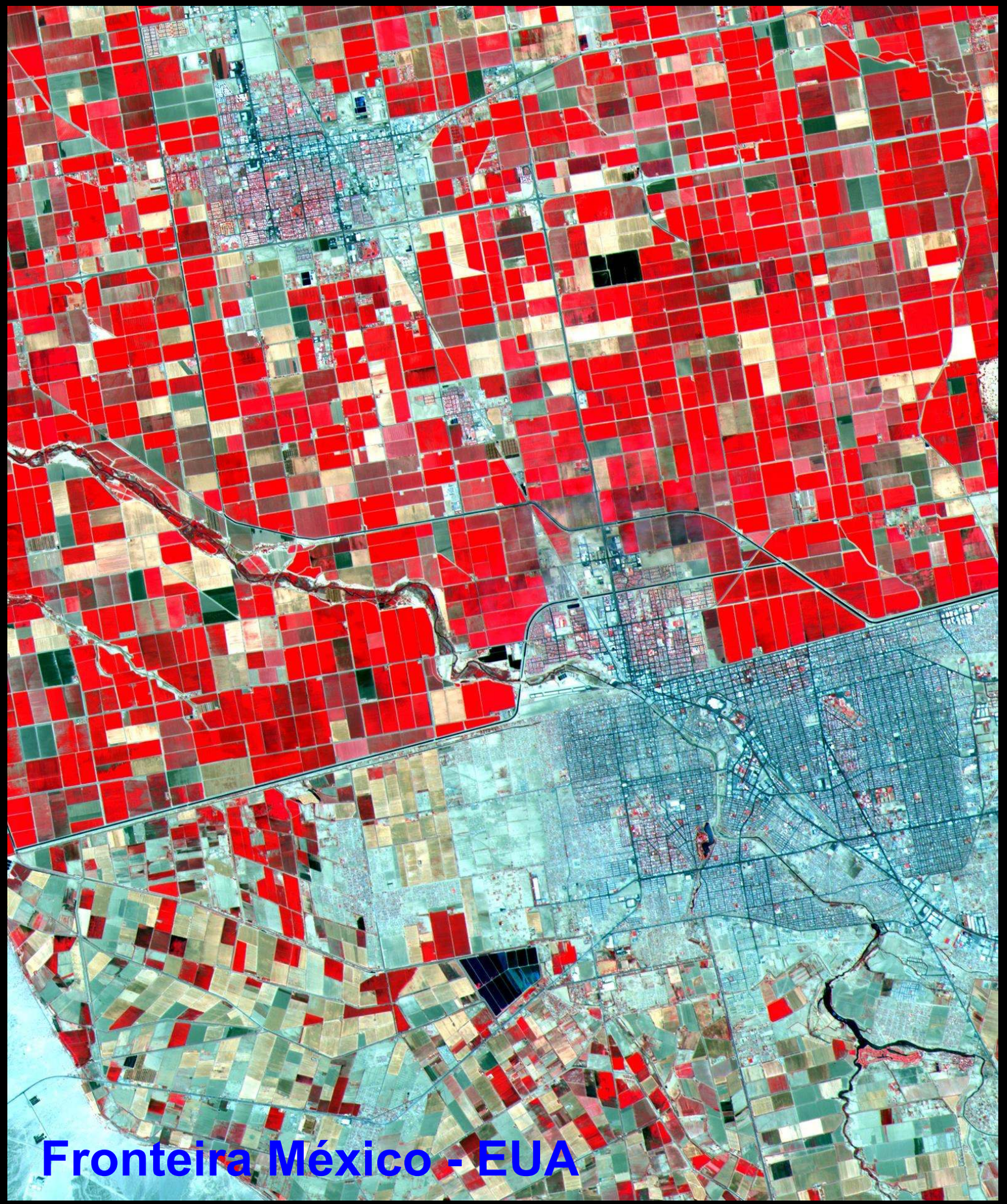
Courtesy of Greg Vaughan, JPL

ASTER DEM


Complete Acquisition of 3B
Begin Acquisition of 3N
64
55
Seconds
9
0
705 Km Orbit
3N
3B
27.7°
Ground Relief
430
370
Km
60
0
Single Stereo Image

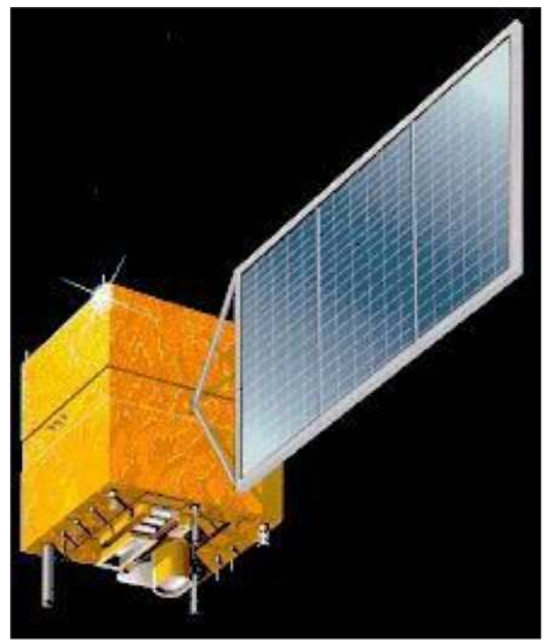
Estrutura Richat, Mauritânia



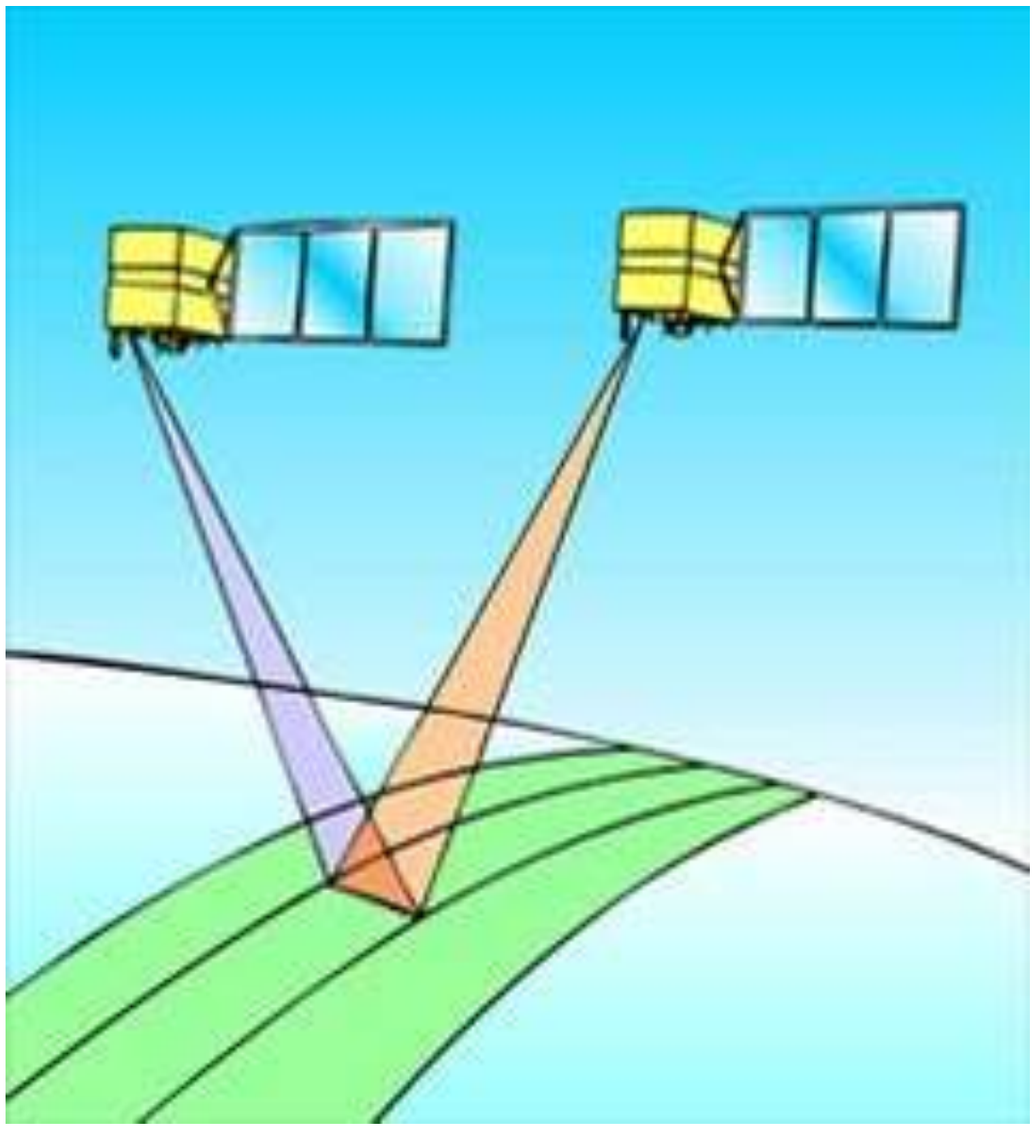

Fronteira México - EUA

CBERS

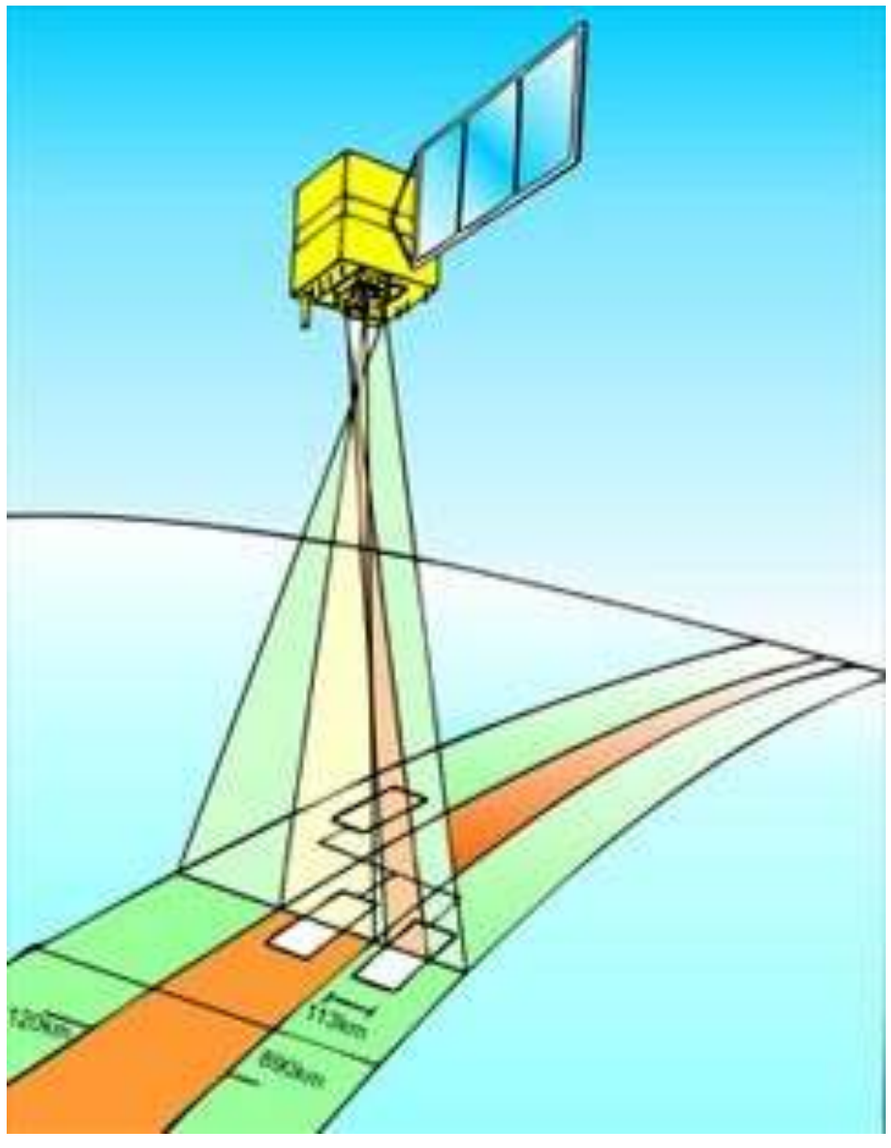
- China-Brazil Earth Resources Satellite
- Imagens gratuitas
- Câmeras
- WFI (Wide Field Imager)
- IRMSS - Infrared Multispectral Scanner
- CCD - High Resolution CCD Camera
- HRC – High Resolution Camera (2B)



CBERS 1 E 2



Estereoscopia



Diferentes campos de visada

Características do Imageador de Amplo Campo de Visada WFI	
Bandas espectrais	0,63 - 0,69 µm (vermelho) 0,77 - 0,89 µm (infra-vermelho)
Campo de Visada	60°
Resolução espacial	260 x 260 m
Largura da faixa imageada	890 km
Resolução temporal	5 dias
Frequência da portadora de RF	8203,35 MHz
Taxa de dados da imagem	1,1 Mbit/s
Potência Efetiva Isotrópica Irradiada	31,8 dBm

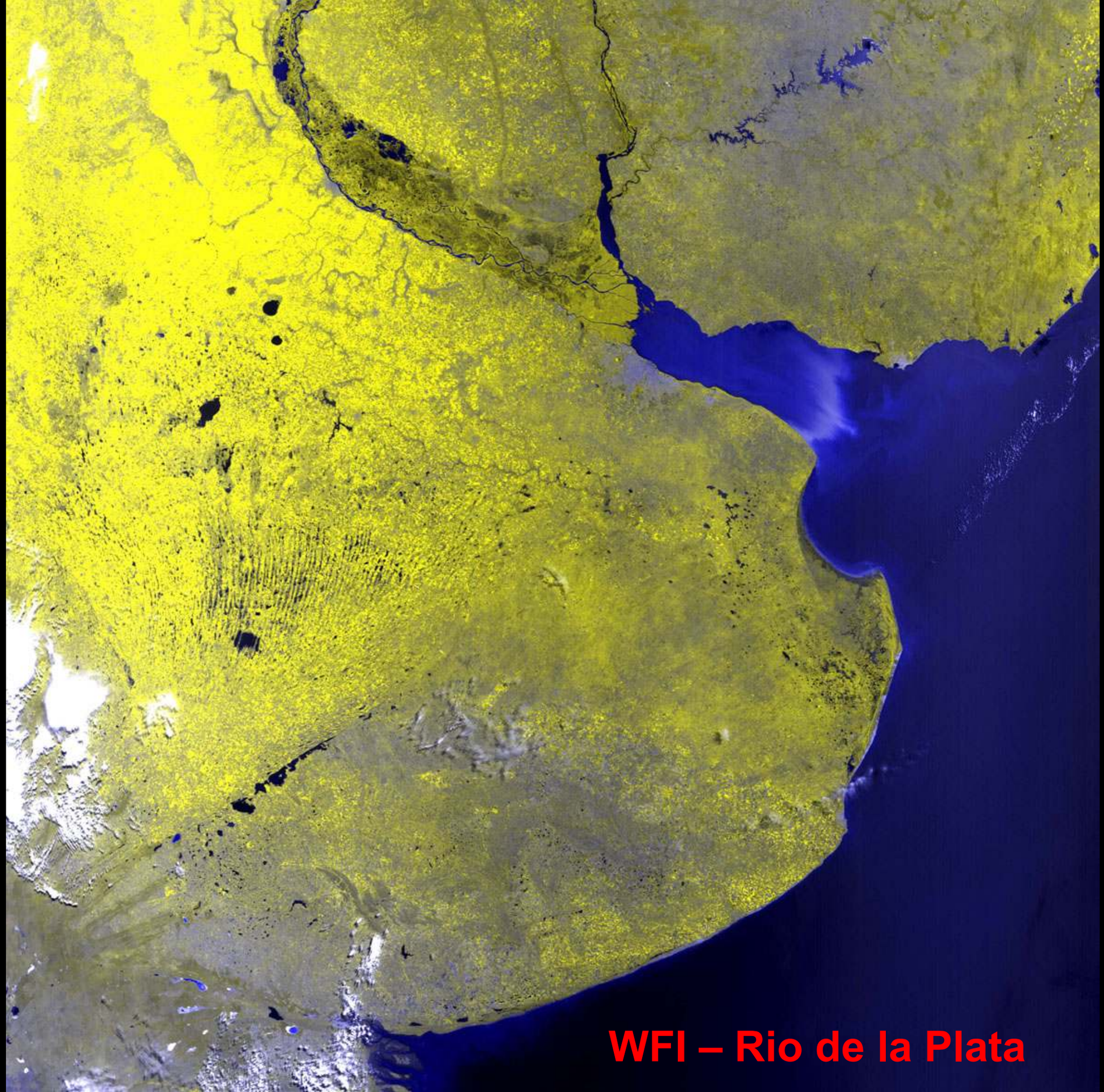
Características da Câmera Imageadora de Alta Resolução CCD	
Bandas espectrais	0,51 - 0,73 µm (pan) 0,45 - 0,52 µm (azul) 0,52 - 0,59 µm (verde) 0,63 - 0,69 µm (vermelho) 0,77 - 0,89 µm (infravermelho próximo)
Campo de Visada	8,3°
Resolução espacial	20 x 20 m
Largura da faixa imageada	113 km
Capacidade de apontamento do espelho	±32°
Resolução temporal	26 dias com visada vertical (3 dias com visada lateral)
Frequência da portadora de RF	8103 MHz e 8321 MHz
Taxa de dados da imagem	2 x 53 Mbit/s
Potência Efetiva Isotrópica Irradiada	43 dBm

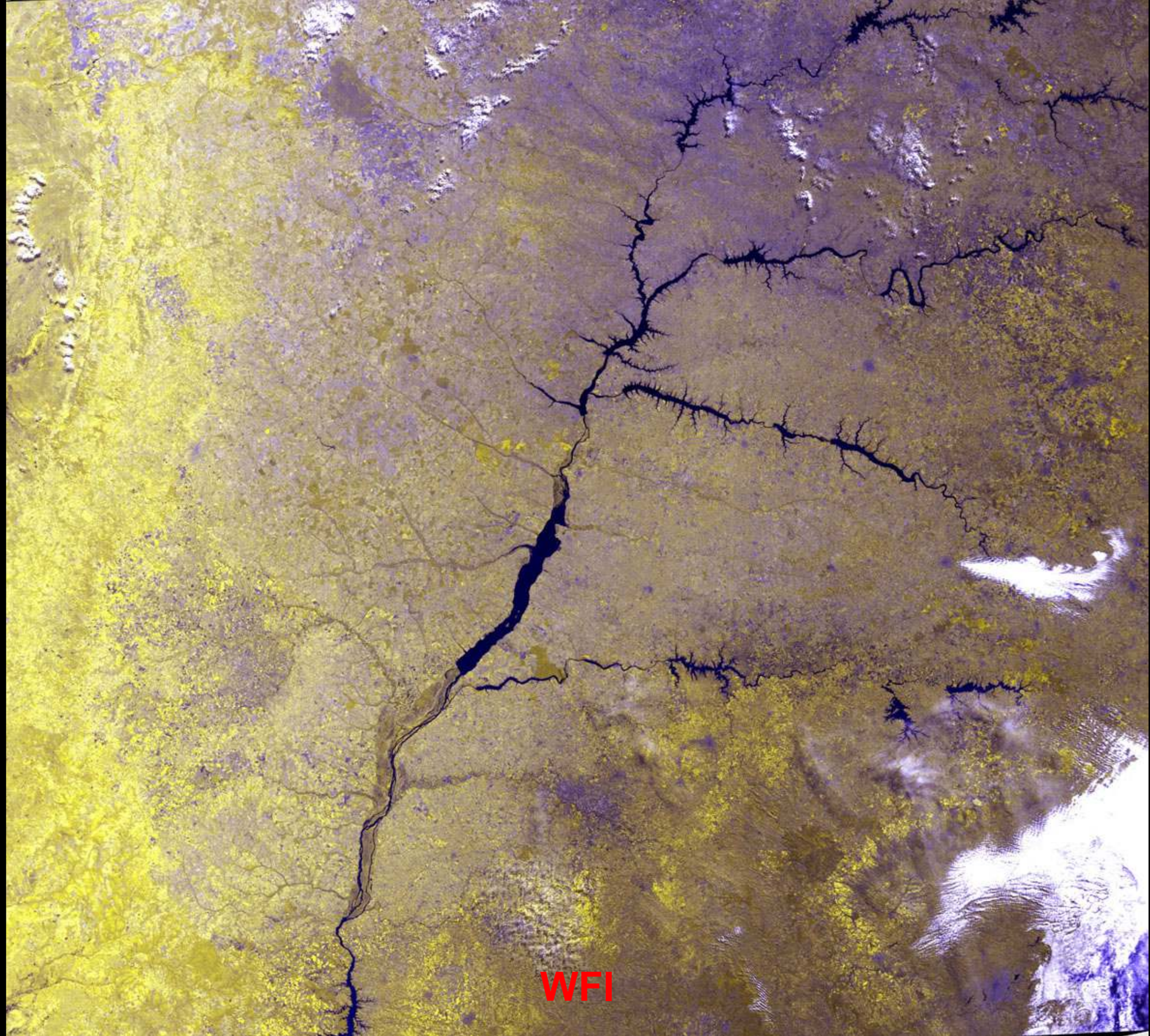
Características do Imageador por Varredura de Média Resolução IRMSS	
Bandas espectrais	0,50 - 1,10 µm (pancromática) 1,55 - 1,75 µm (infravermelho médio) 2,08 - 2,35 µm (infravermelho médio) 10,40 - 12,50 µm (infravermelho termal)
Campo de Visada	8,8°
Resolução espacial	80 x 80 m (160 x 160 m termal)
Largura da faixa imageada	120 km
Resolução temporal	26 dias
Frequência da portadora de RF	8216,84 MHz
Taxa de dados da imagem	6,13 Mbit/s
Potência Efetiva Isotrópica Irradiada	39,2 dBm

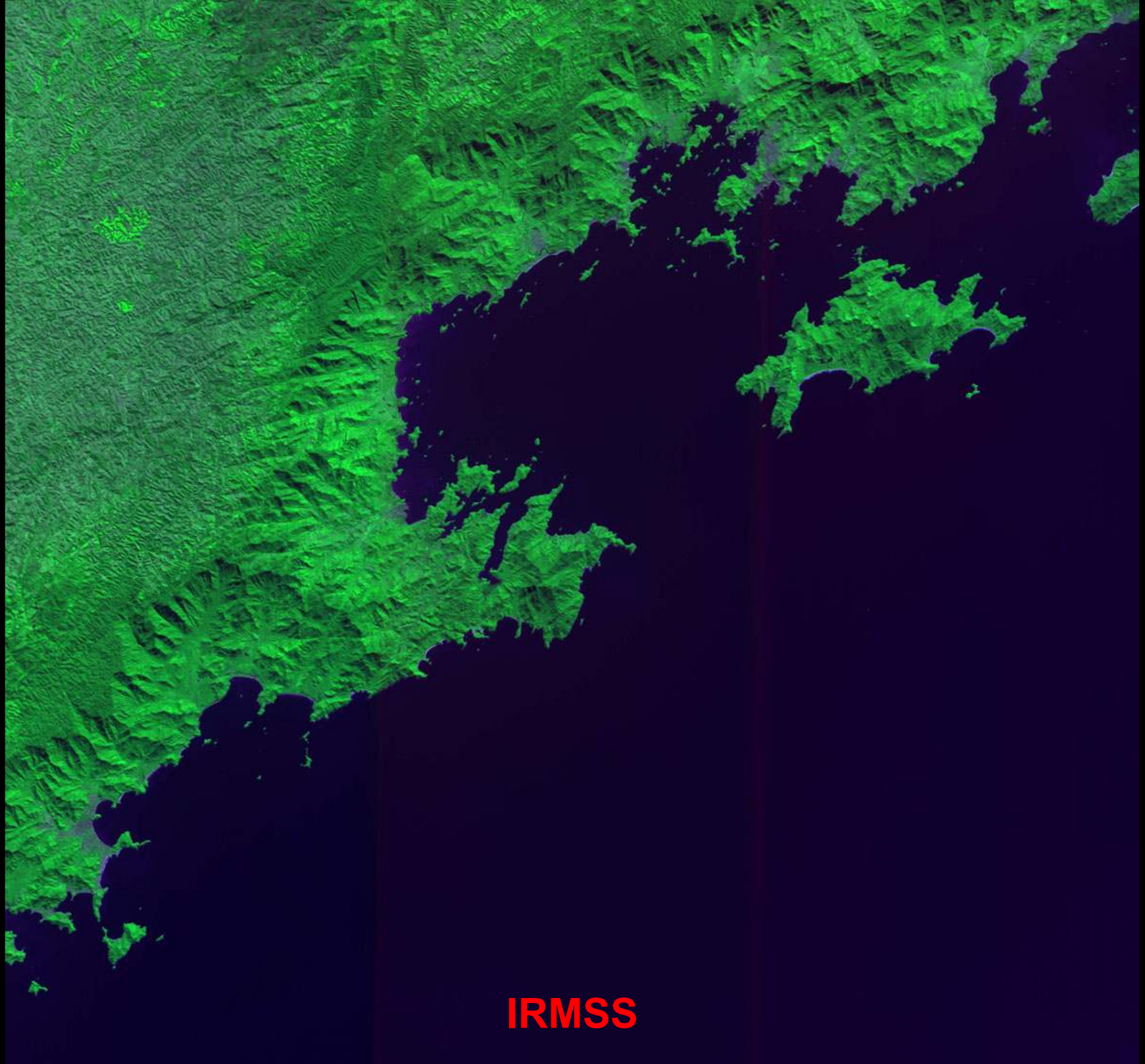
CBERS 3 E 4

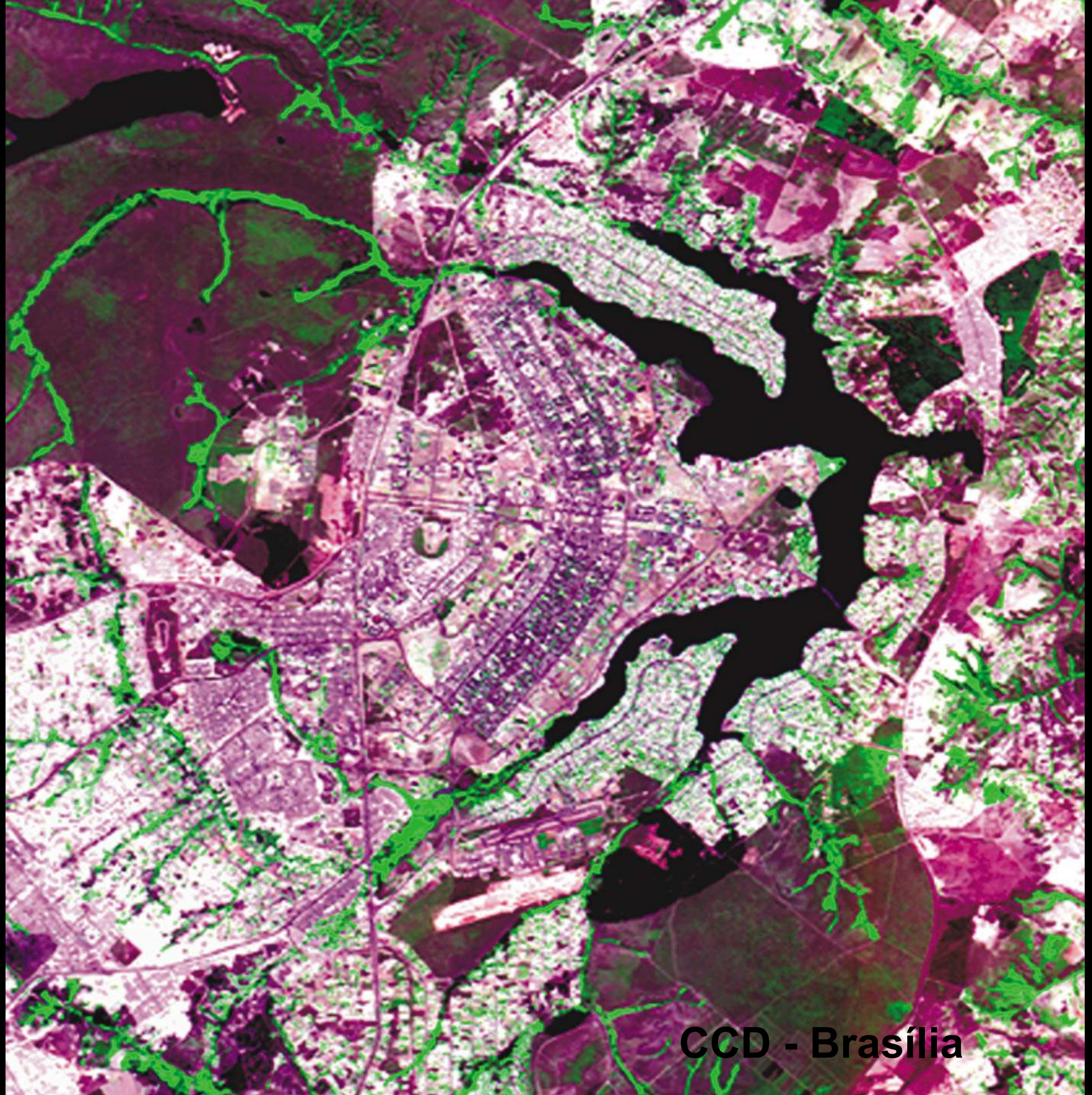
Características das câmaras do CBERS-3 e 4				
	MUXCAM	**PANMUX**	**IRMSS**	**WFI**
Bandas espectrais	0,45 - 0,52 µm 1,55 - 1,75 µm (TBC) 0,52 - 0,59 µm (G) 0,63 - 0,69 µm (R) 0,77 - 0,89 µm (NIR)	0,51 - 0,75 µm 0,51 - 0,85 µm (TBC) 0,52 - 0,59 µm (G) 0,63 - 0,69 µm (R) 0,77 - 0,89 µm (NIR)	0,76 - 0,90; 0,76 - 1,10 (C) 1,55 - 1,75 (MIR) 2,08 - 2,35 (SWIR) 10,40 - 12,50 (TH)	0,52 - 0,59 (G) 0,63 - 0,69 (R) 0,77 - 0,89 (NIR) 1,55 - 1,75 (MIR)
Resolução	20 m	5 m/10 m	40 m/ 80 m (TH)	73 m
Largura da faixa Imageada	120 km	60 km	120 km	866 km
Apontamento	±32º/Não (TBC)	±32º	não	não
Revisita	3 dias (TBC)	5 dias		
Revisita real	26 dias	não	26 dias	5 dias
Quantização	8 bits	8 bits	8 bits	10 bits
Taxa de Dados Bruta	68 Mbit/s	140 Mbit/s 100 Mbit/s	16 Mbit/s	50 Mbit/s

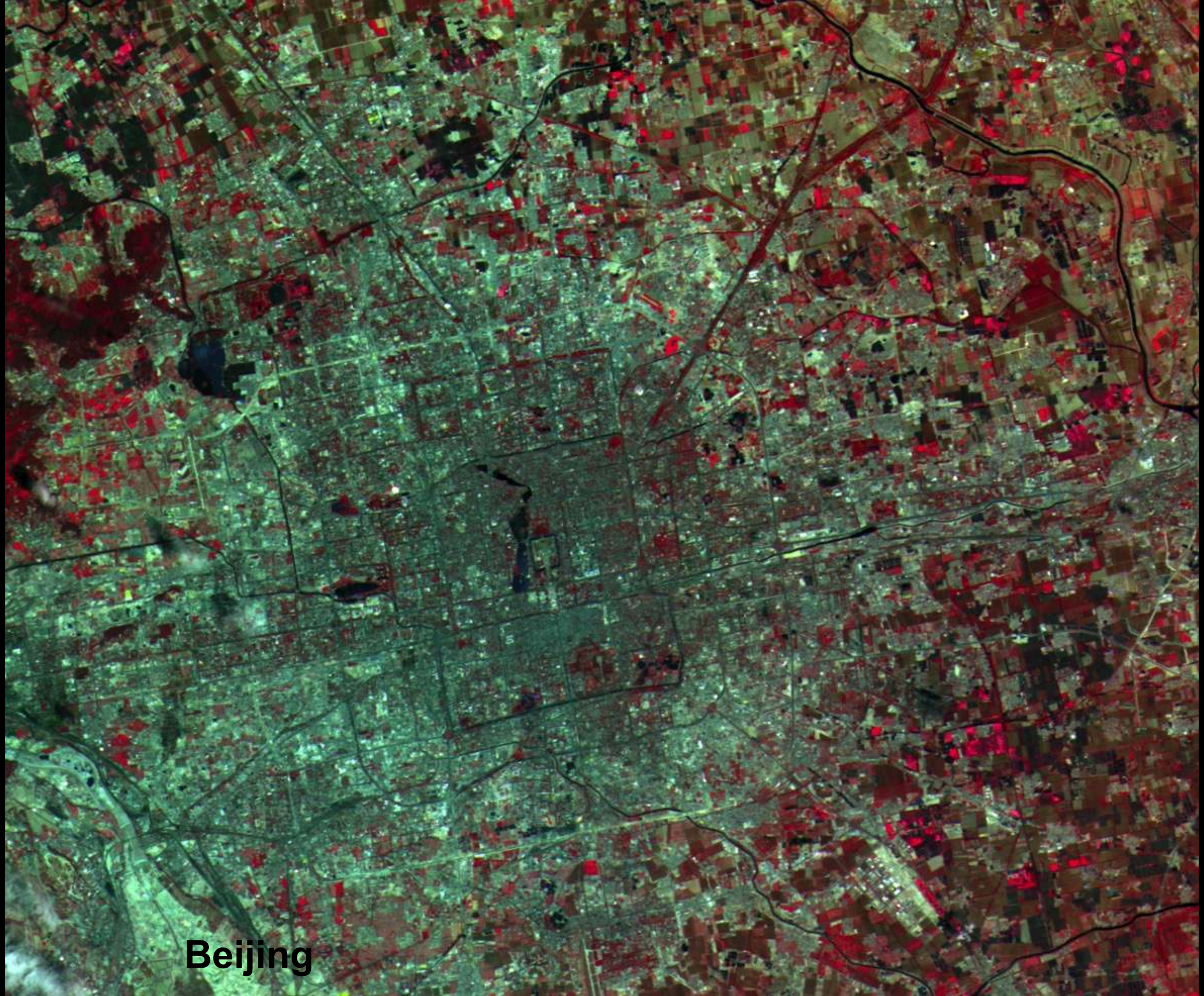
CBERS 2B – 2007
CBERS 3 – 2011
CBERS 4 – 2013

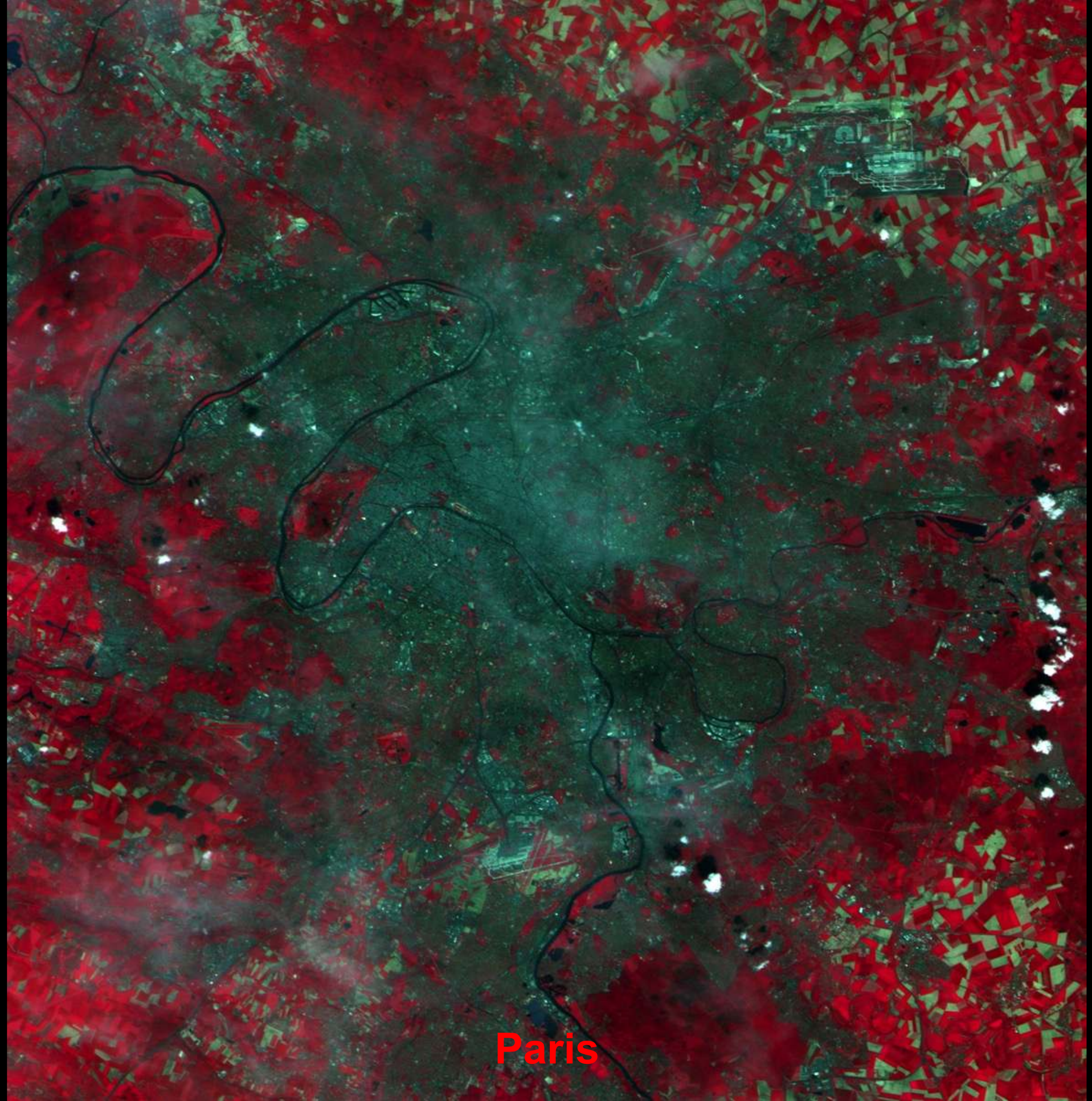

WFI – Rio de la Plata


WFI


IRMSS

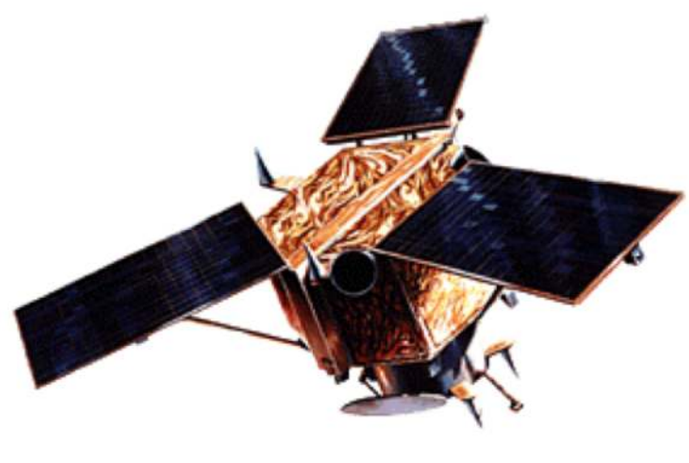

CCD - Brasília


Beijing

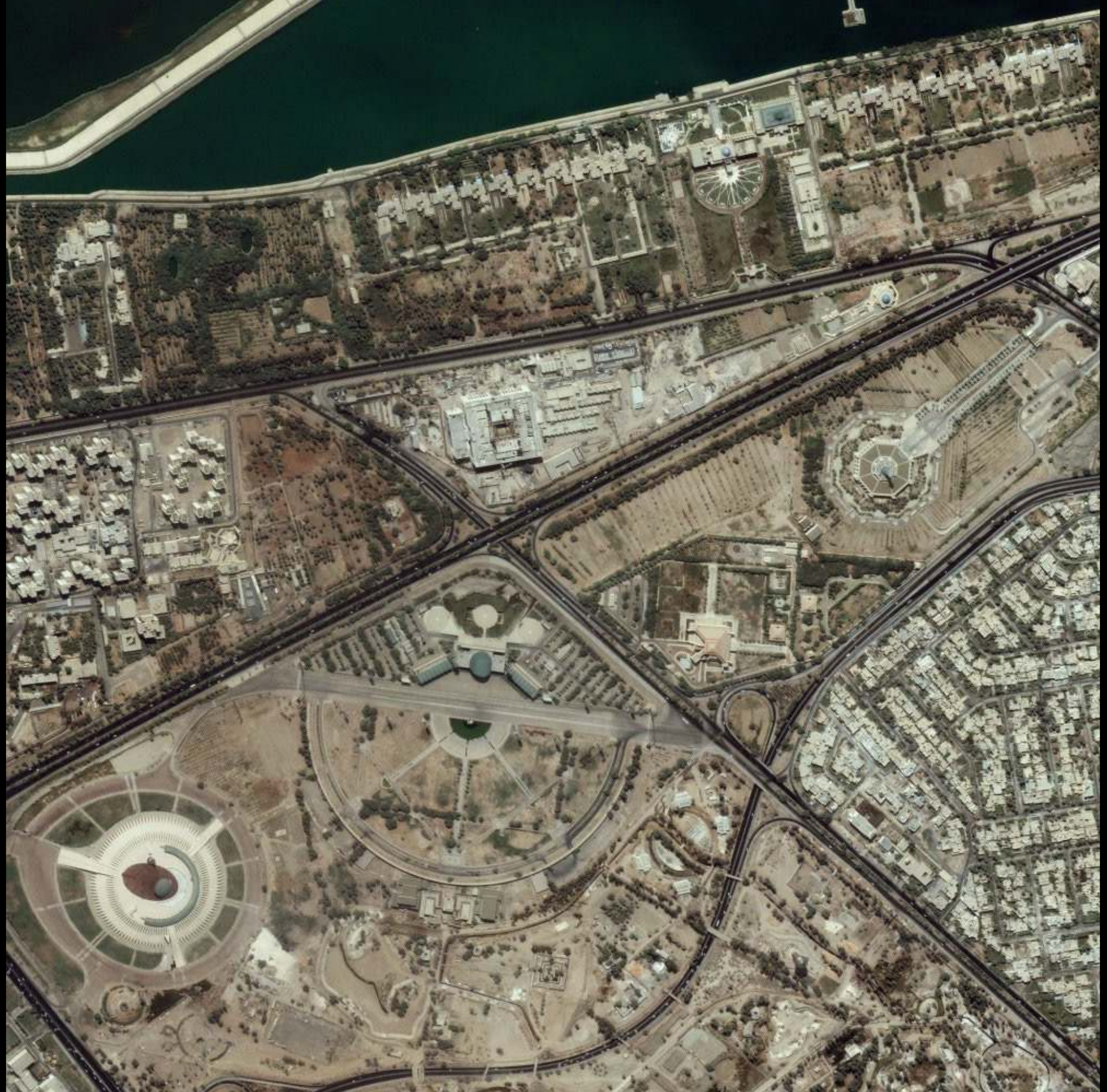

Paris

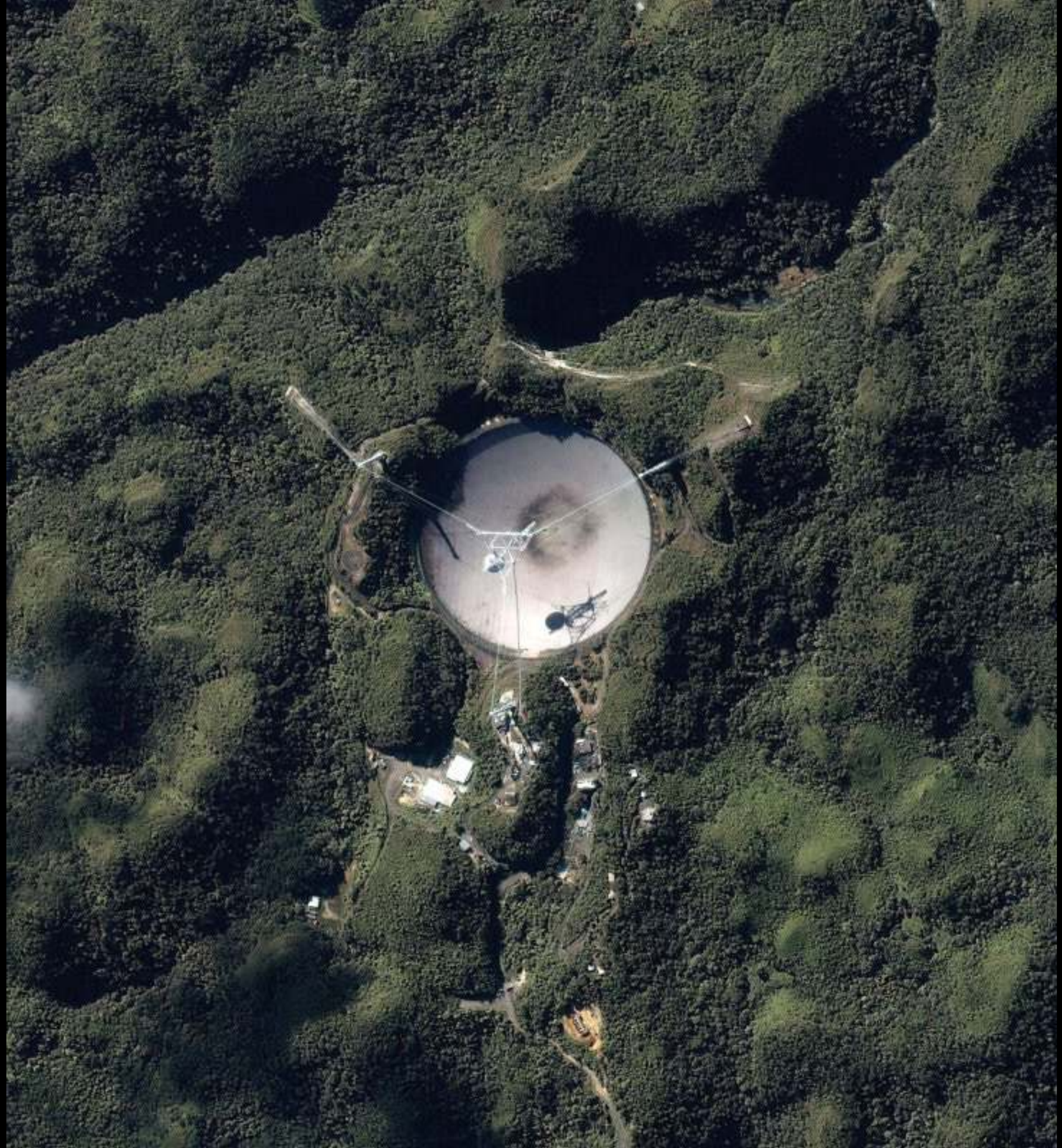
IKONOS

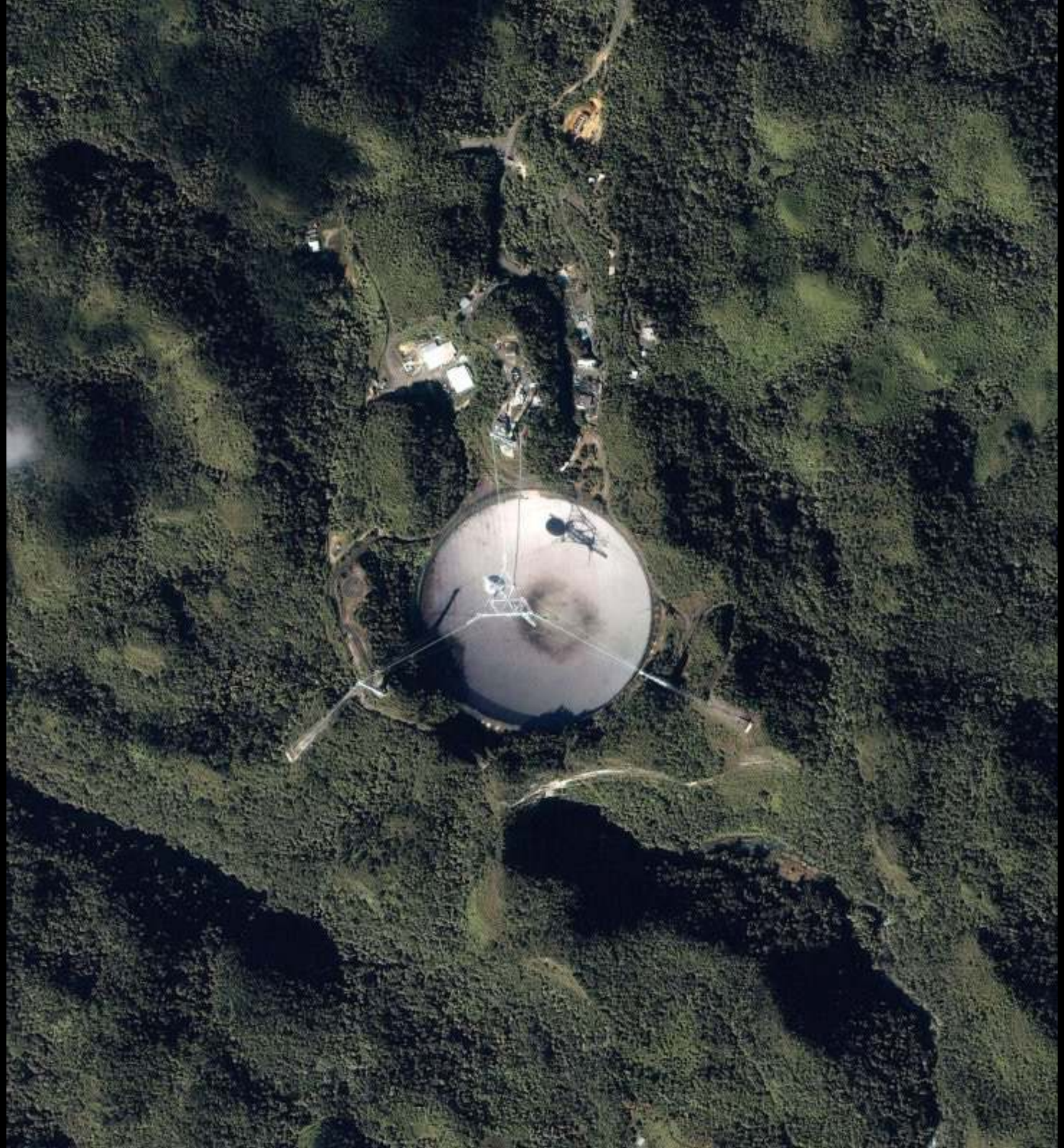
- Revisita
  - 3-5 dias off-nadir
  - 144 dias nadir

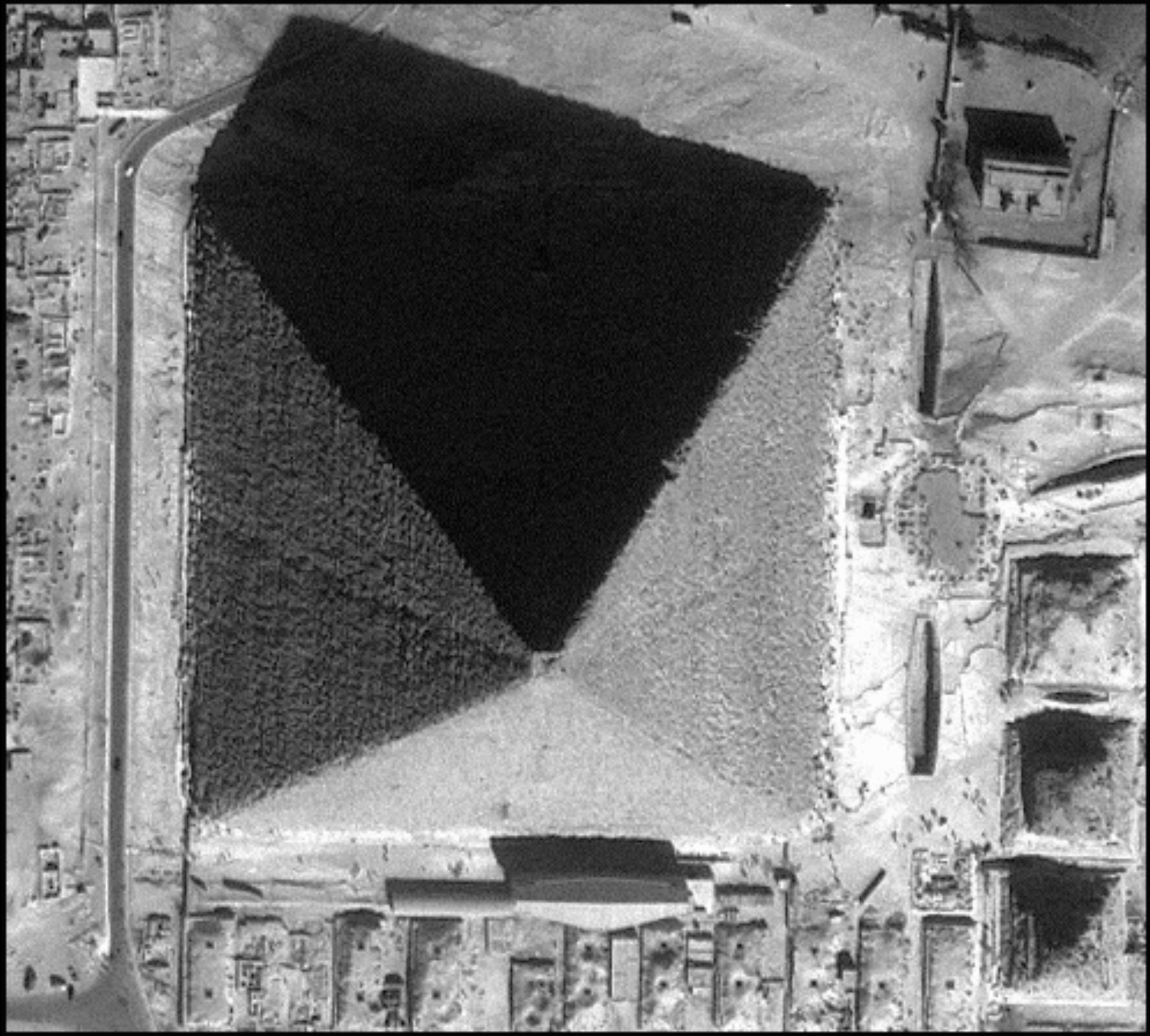


Band	1-m PAN	4-m MS & 1-m PS
1 (Blue)	0.45-0.90 µm	0.445-0.516 µm
2 (Green)	*	0.506-0.595 µm
3 (Red)	*	0.632-0.698 µm
4 (Near IR)	*	0.757-0.853 µm





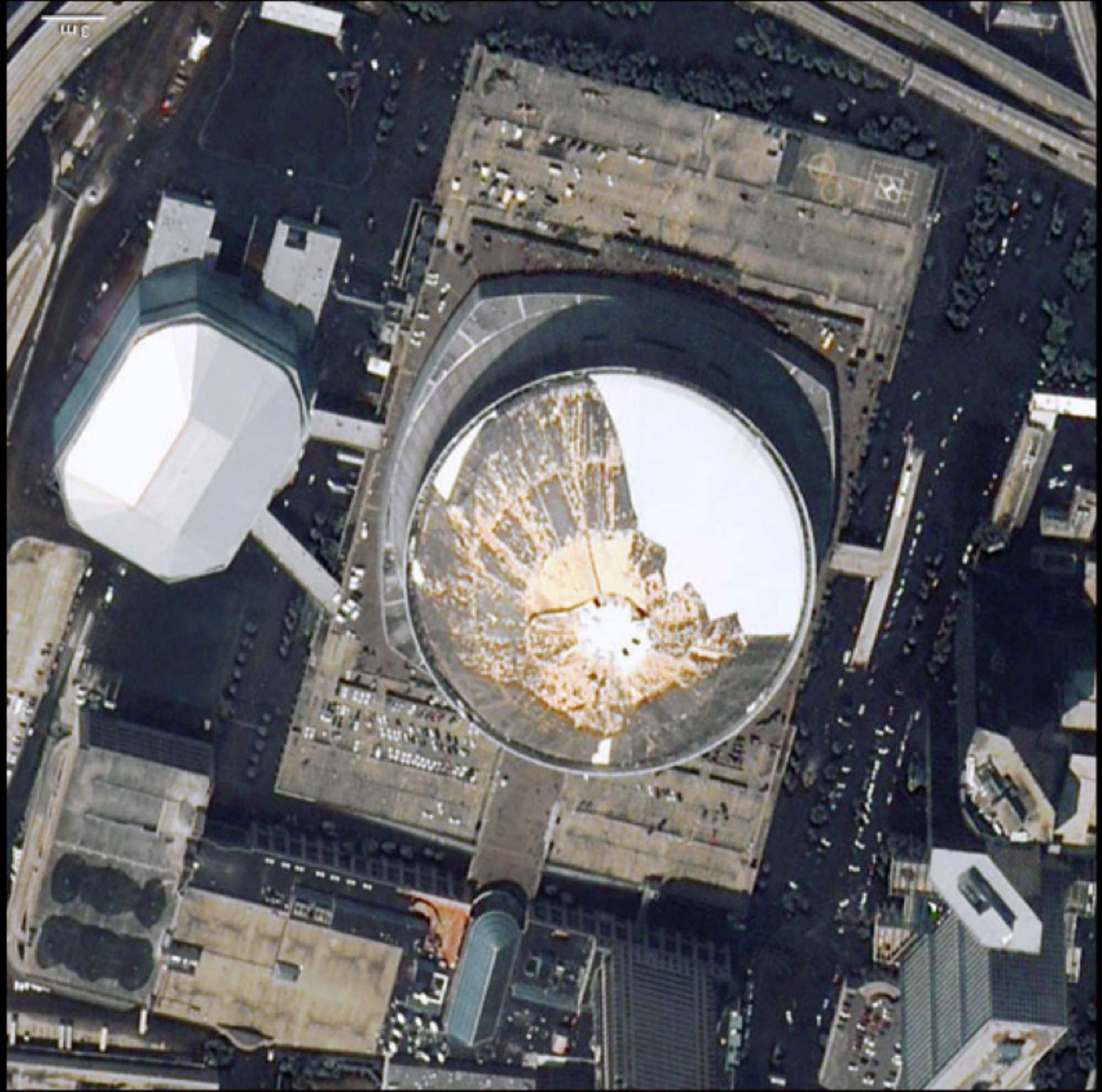




QUICKBIRD

- Revisita: 3-7 dias dependendo da latitude

Sensor Resolution & Spectral Bandwidth	Panchromatic ● 60-centimeter GSD (Ground Sample Distance) at nadir ● Black & White: 445 to 900 nanometers	Multispectral ● 2.4-meter GSD at nadir ● Blue: 450 to 520 nanometers ● Green: 520 to 600 nanometers ● Red: 630 to 690 nanometers ● Near-IR: 760 to 900 nanometers


3m

SPACE SHUTTLE - DISCOVERY - 2005

Launch Pad 39B - NASA Kennedy Space Center in Florida, USA

QuickBird Satellite Image at 0.6m Resolution

Acquired on: 21-APR-2005

www.satimagingcorp.com

SATELLITE IMAGING CORPORATION
12777 JONES ROAD, SUITE 370
HOUSTON, TEXAS 77070-4649 USA
TEL: 1.832.237.2900
FAX: 1.832.237.2910
WEB: WWW.SATIMAGINGCORP.COM
E-MAIL: INFO@SATIMAGINGCORP.COM


www.satimagingcorp.com
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EO-1

- Hyperion
  - 220 bandas
  - 30m res.espacial
  - faixa 7.5 x 100 km
- ALI (Advanced Land Imager)
  - teste de tecnologia
  - provável sucessor do ETM+

ALI

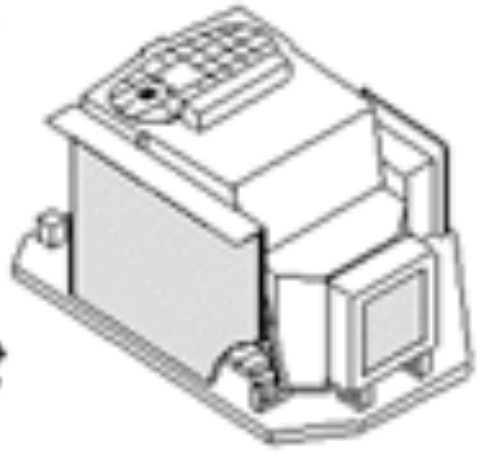
EO-1 ALI Spectral Coverage

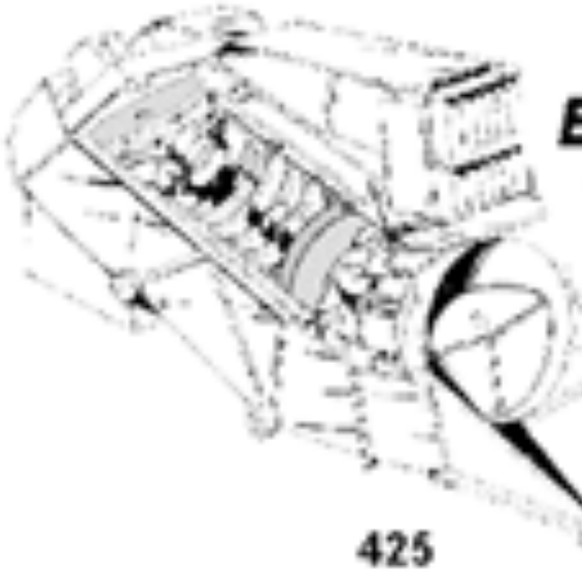
Band	Wavelength (μm)	Ground Sample Distance (m)
Pan	0.48 - 0.69	10
MS-1'	0.433 - 0.453	30
MS-1	0.45 - 0.515	30
MS-2	0.525 - 0.605	30
MS-3	0.63 - 0.69	30
MS-4	0.775 - 0.805	30
MS-4'	0.845 - 0.89	30
MS-5'	1.2 - 1.3	30
MS-5	1.55 - 1.75	30
MS-7	2.08 - 2.35	30

ETM X ALI

EO-1/Landsat Instrument Comparison

ALI Based Concept for Future Landsat Instrument



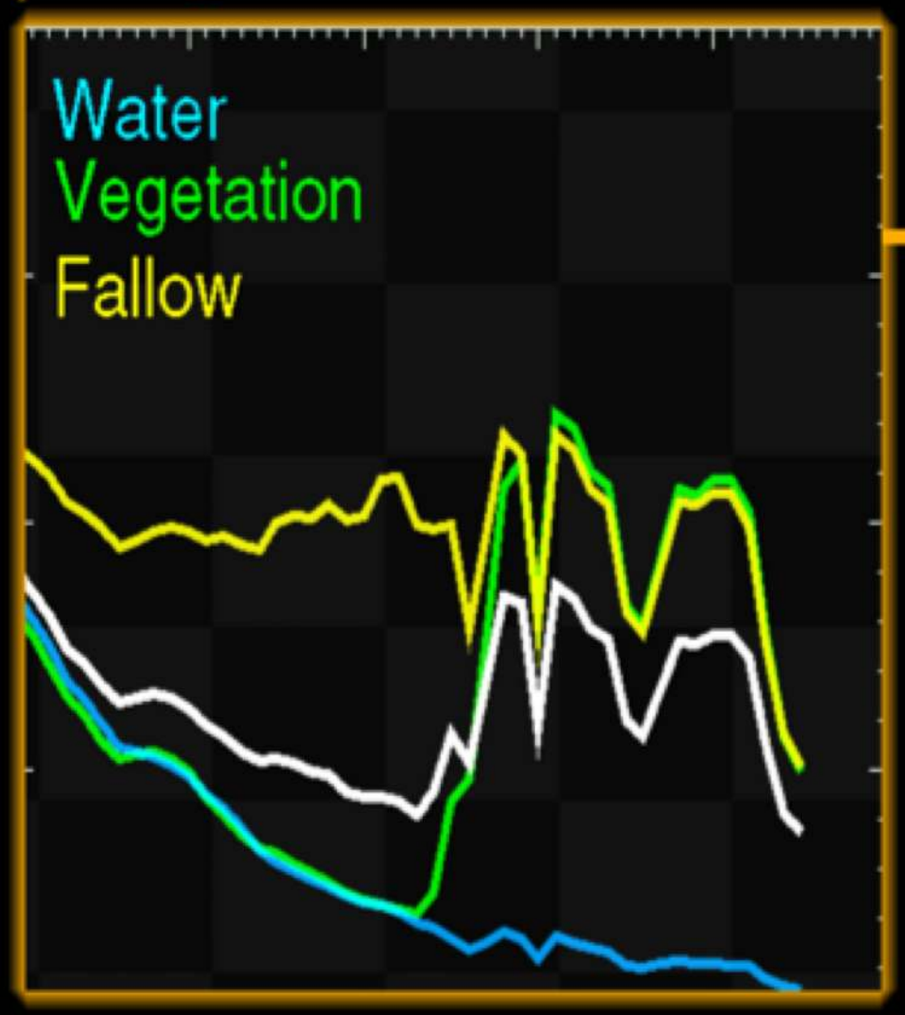


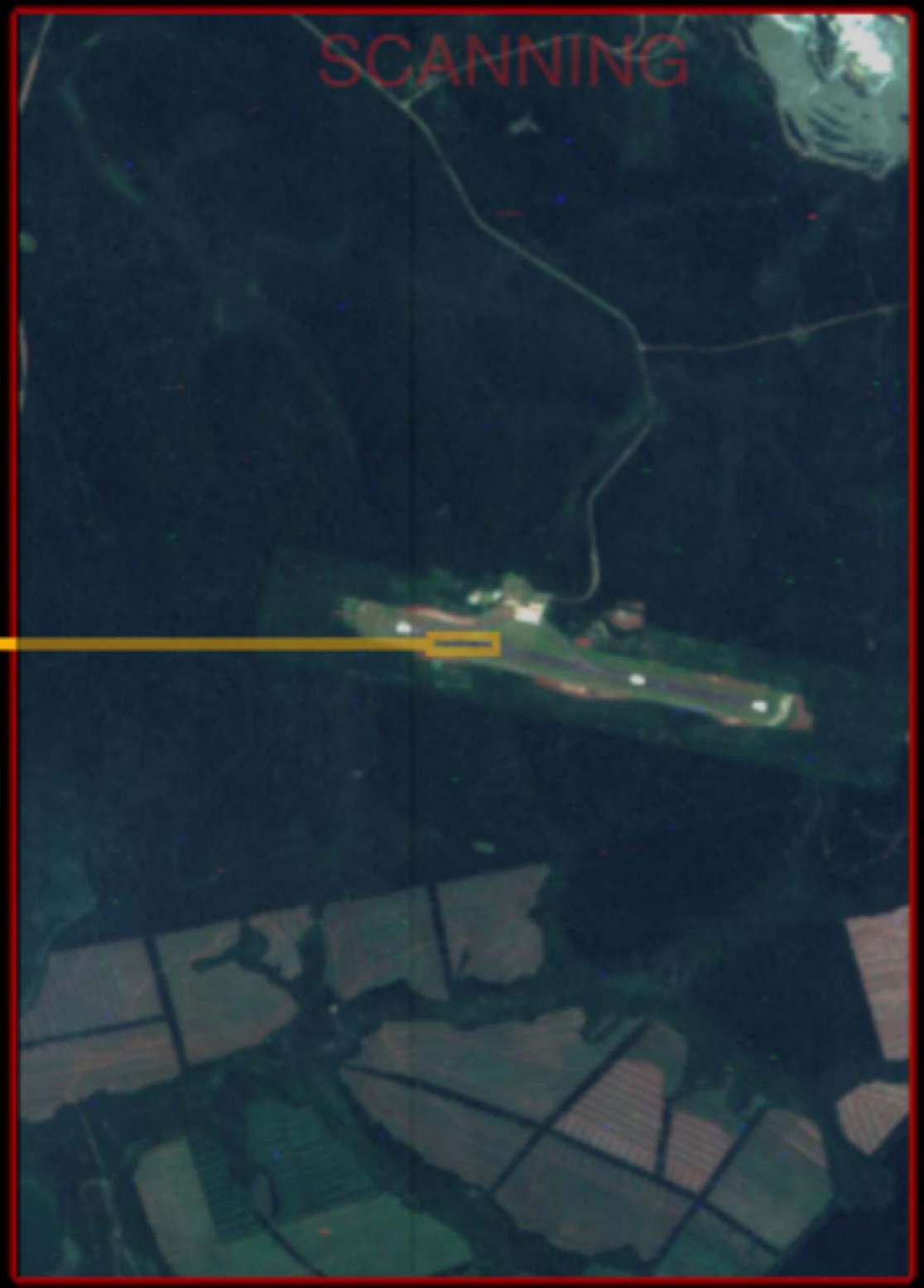
Enhanced Thematic Mapper (ETM+)

100	Mass (kg)	425
100	Power (W)	545
0.2	Size (m^3)	1.4
10	VNIR / SWIR Bands	7
6200	Detectors Per Band	16
None	Thermal Bands	1
300	Data Rate (Mbps)	150
10	Pan Resolution (m)	15
4x	Relative SNR	1x

EO-1/Hyperion

Analysis



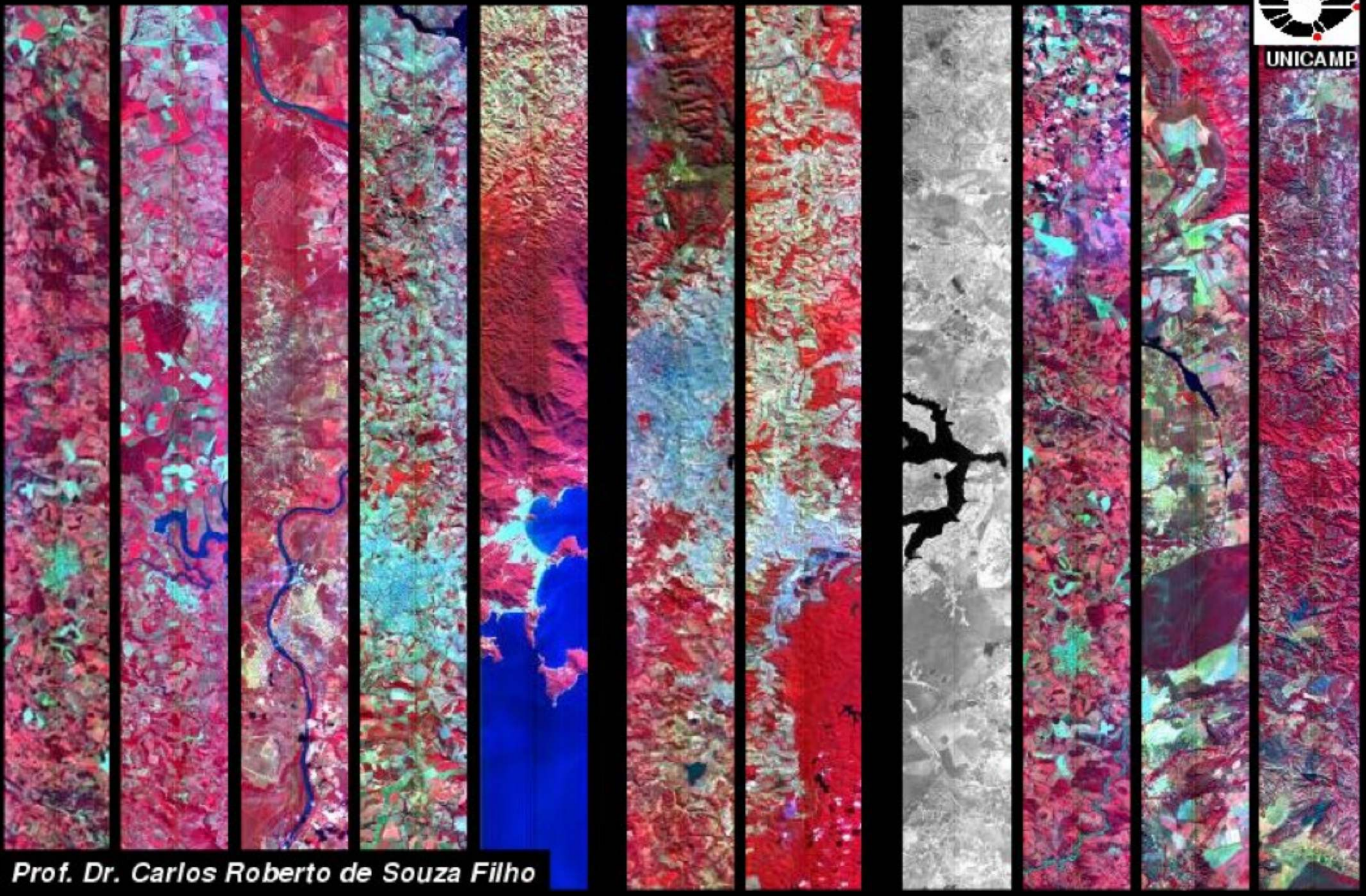


São Paulo

BH

Brasília

UNICAMP



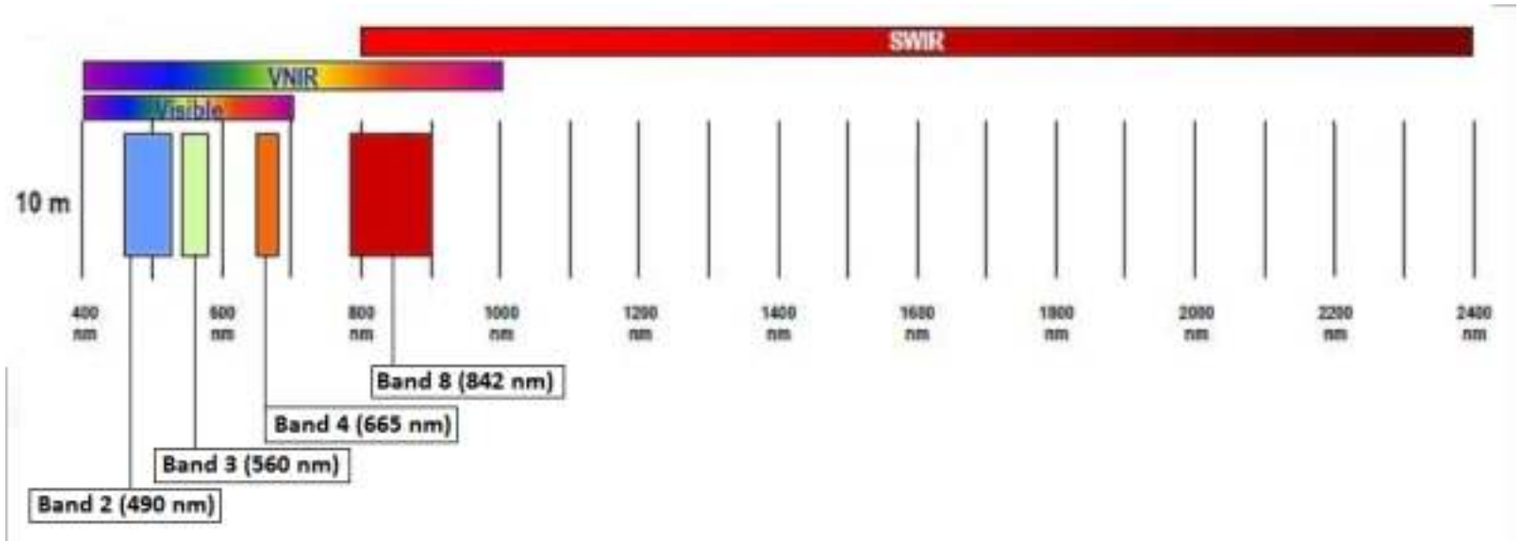
Prof. Dr. Carlos Roberto de Souza Filho

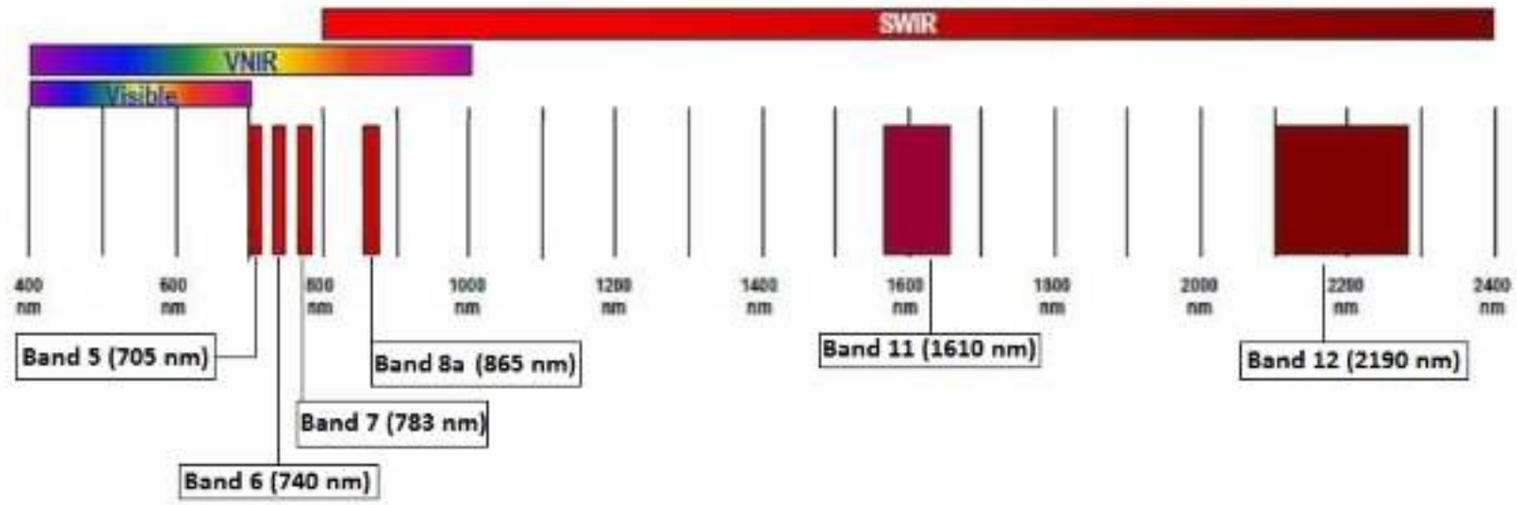
LANDSAT-8

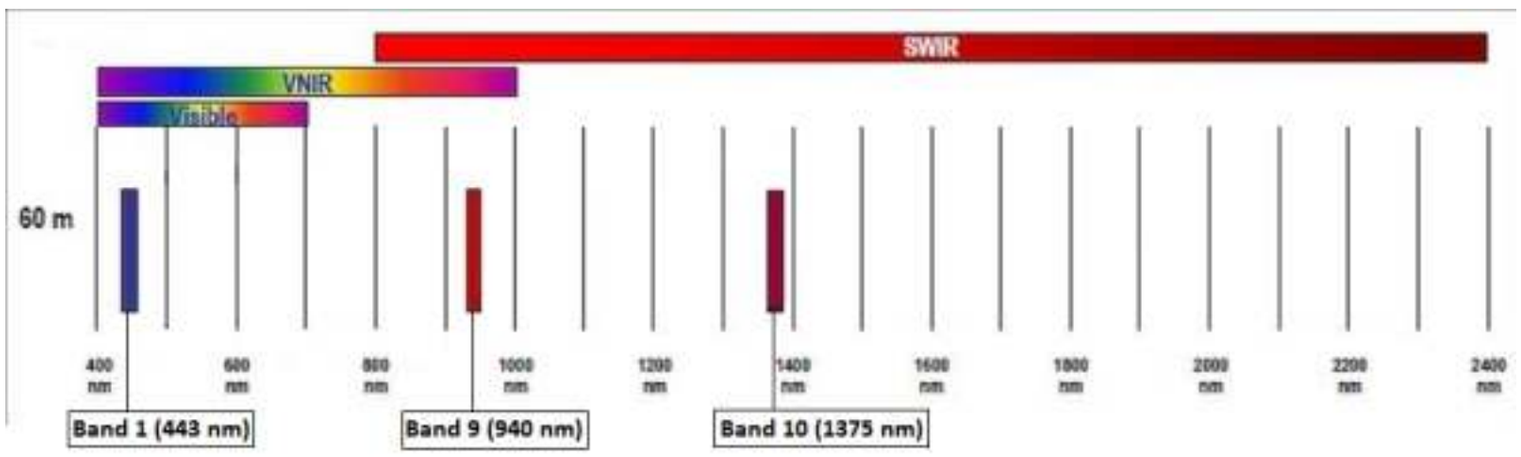
- **OLI - Operational Land Imager**
- Pixel Size:
  - OLI multispectral bands 1-7,9: 30-meters
  - OLI panchromatic band 8: 15-meters
  - TIRS bands 10-11: collected at 100 meters but resampled to 30 meters to match OLI multispectral bands
- 16-bit pixel values

SENTINEL-2

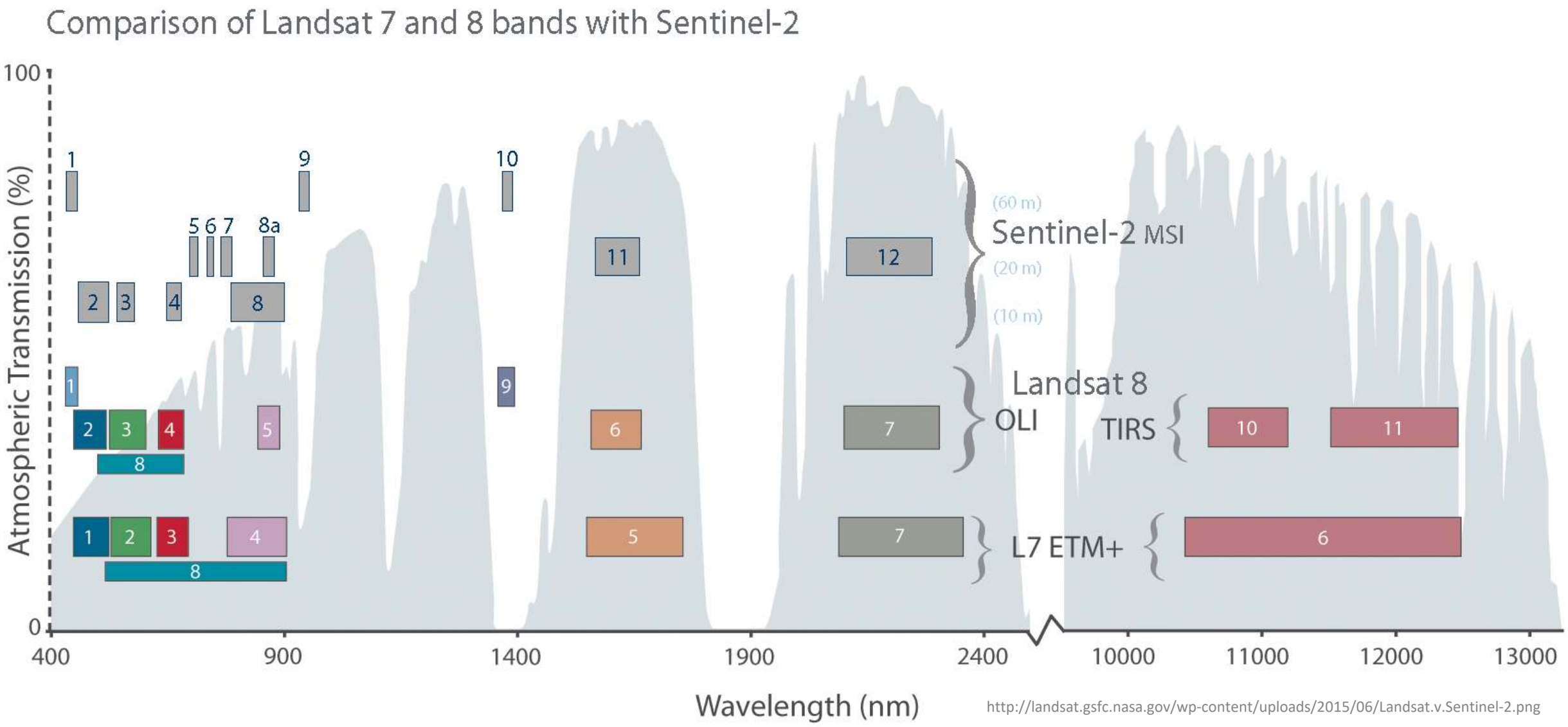
- ESA
  - 10m
  - 20m
  - 60m







LANDSAT-8



http://landsat.gsfc.nasa.gov/wp-content/uploads/2015/06/Landsat.v.Sentinel-2.png