

**GSA-5859**

**SISTEMAS DE INFORMAÇÃO GEOGRÁFICA  
EM SOFTWARE LIVRE**

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INSTITUTO DE ENERGIA E AMBIENTE - USP

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**Sensoriamento Remoto**

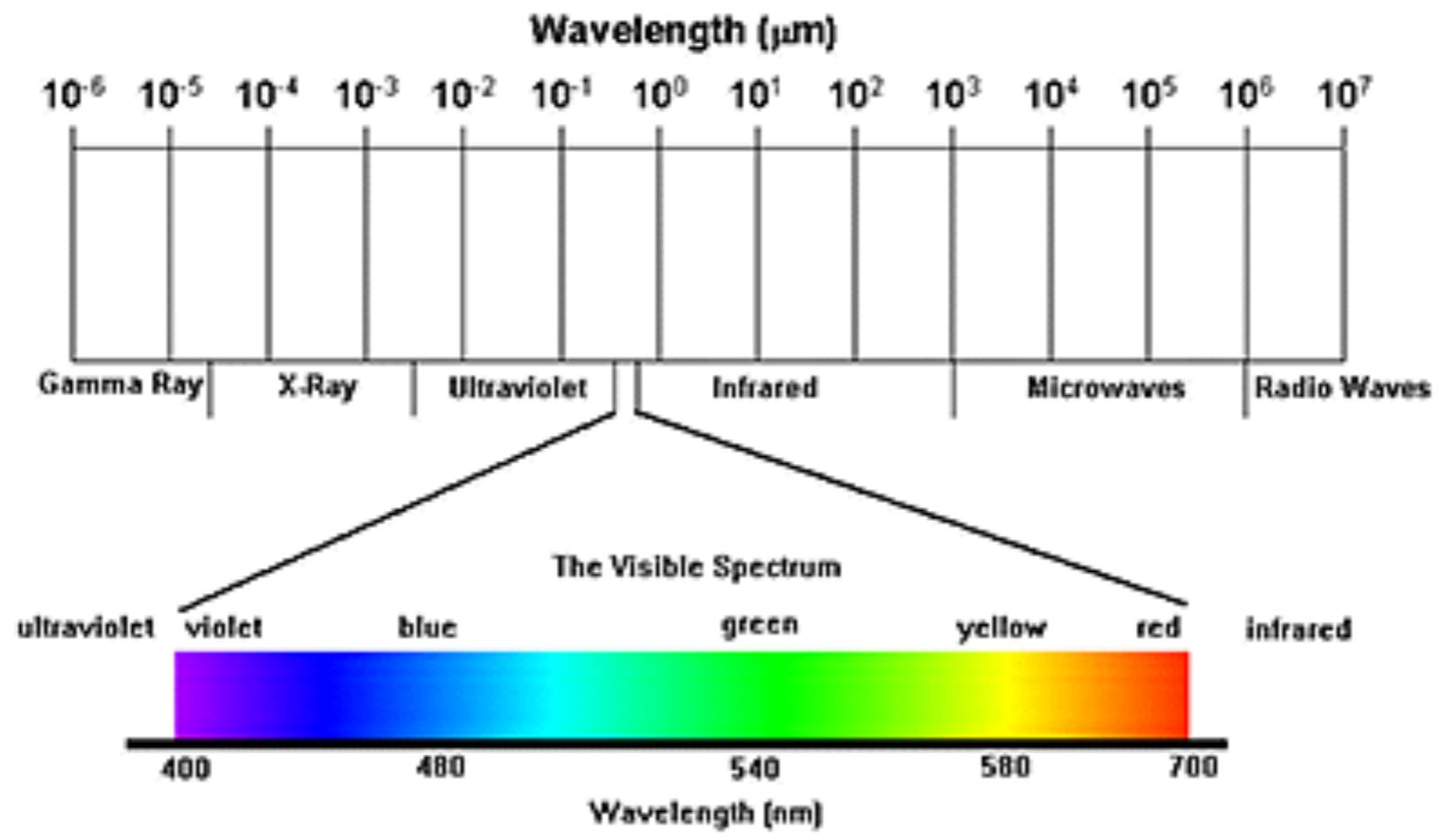
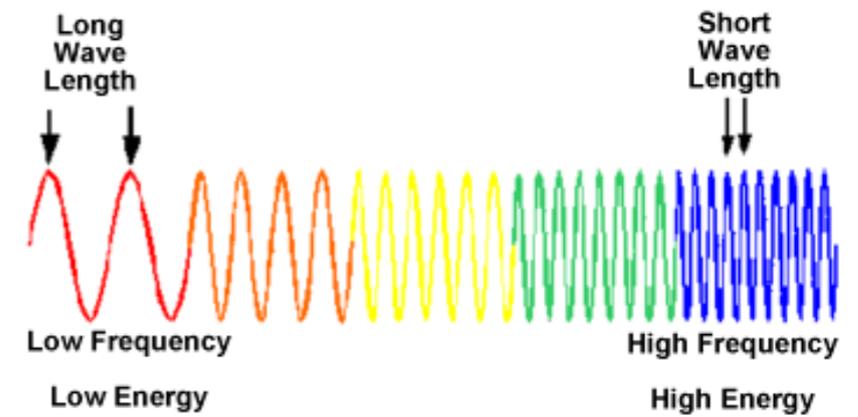
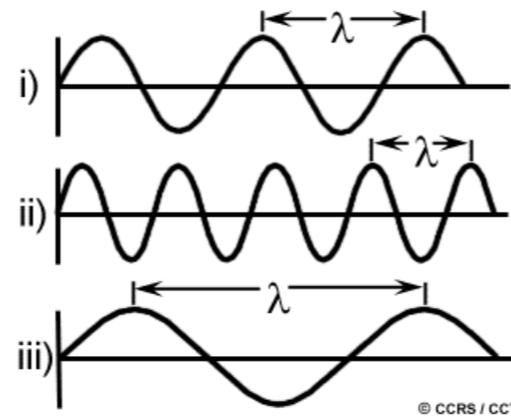
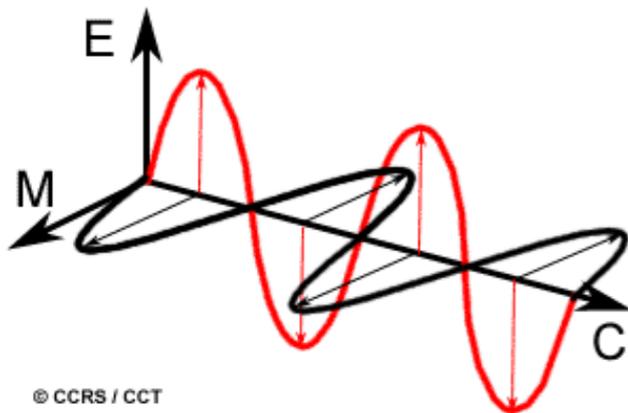
## DEFINIÇÃO 1 (INPE)

- ▶ "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.

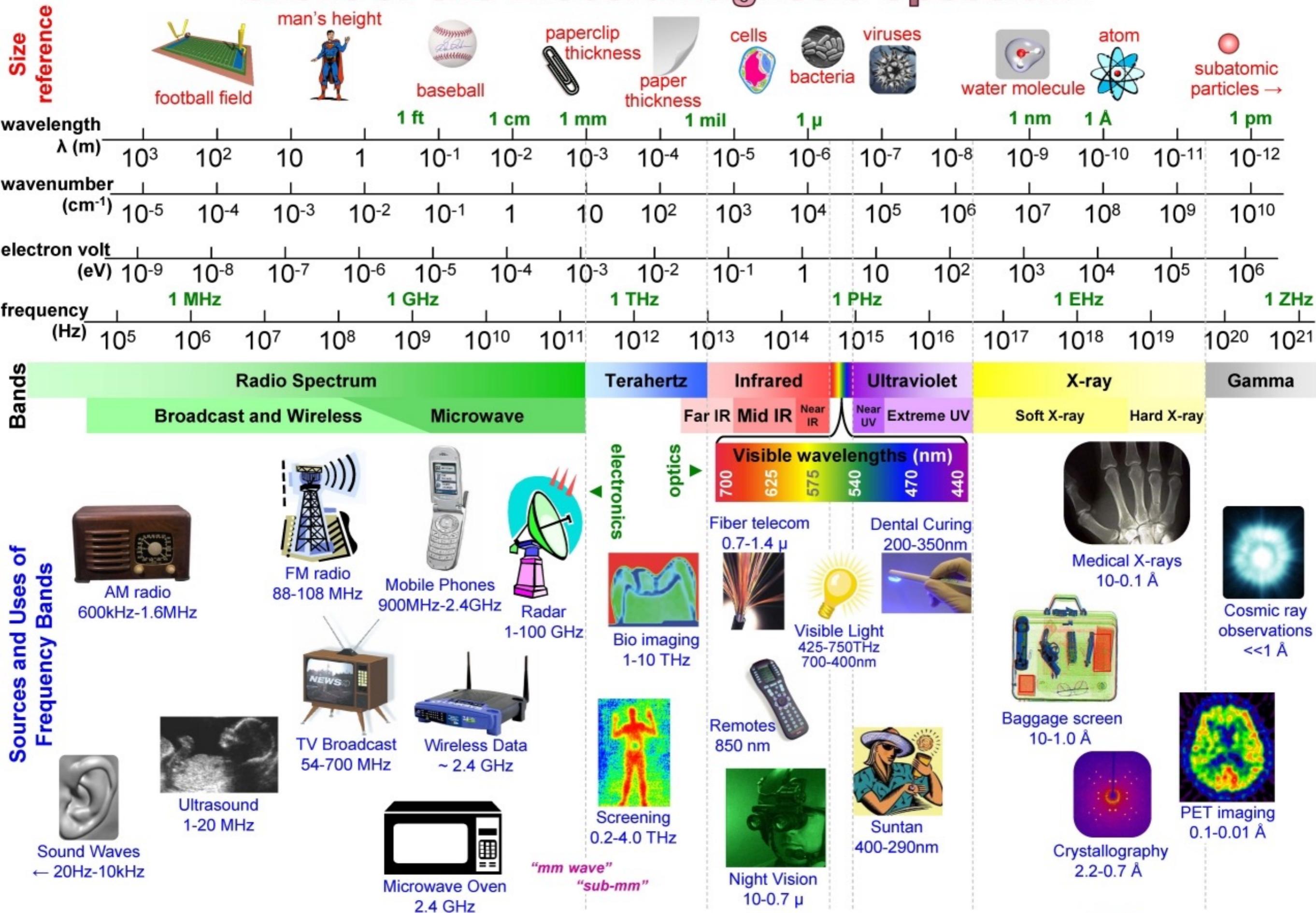
## DEFINIÇÃO 1 (INPE)

- ▶ "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



$$\lambda = 3 \times 10^8 / \text{freq} = 1 / (\text{wn} * 100) = 1.24 \times 10^{-6} / \text{eV}$$

# SISTEMA VISUAL HUMANO

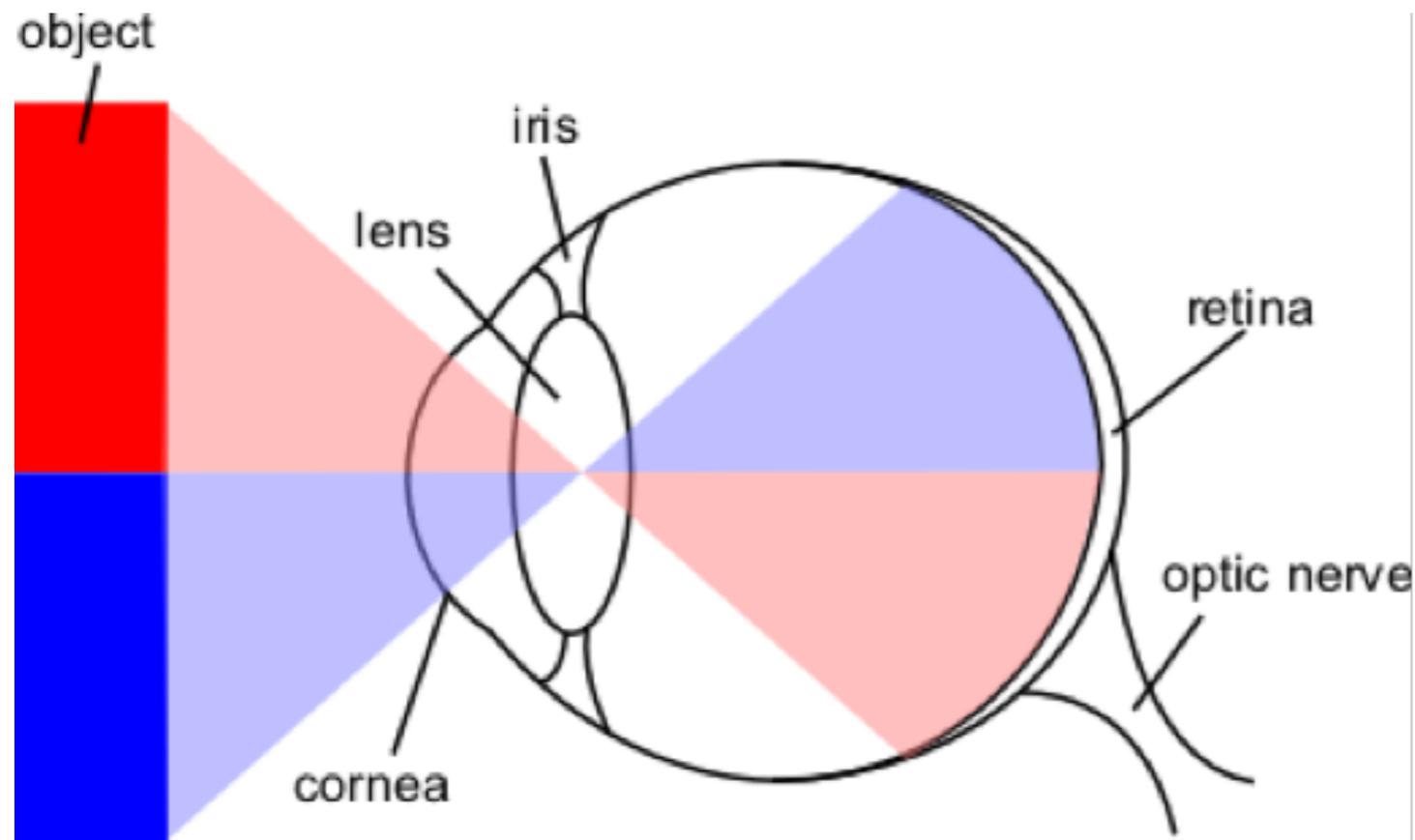
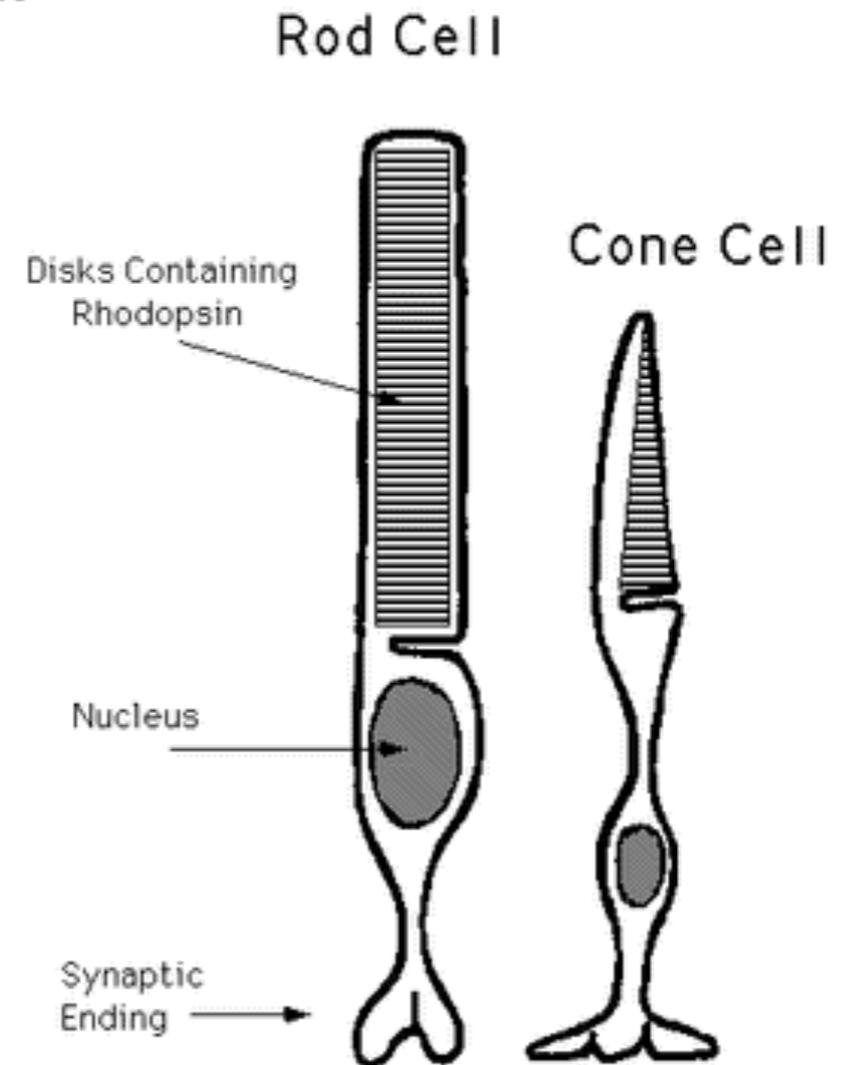


Figure 2

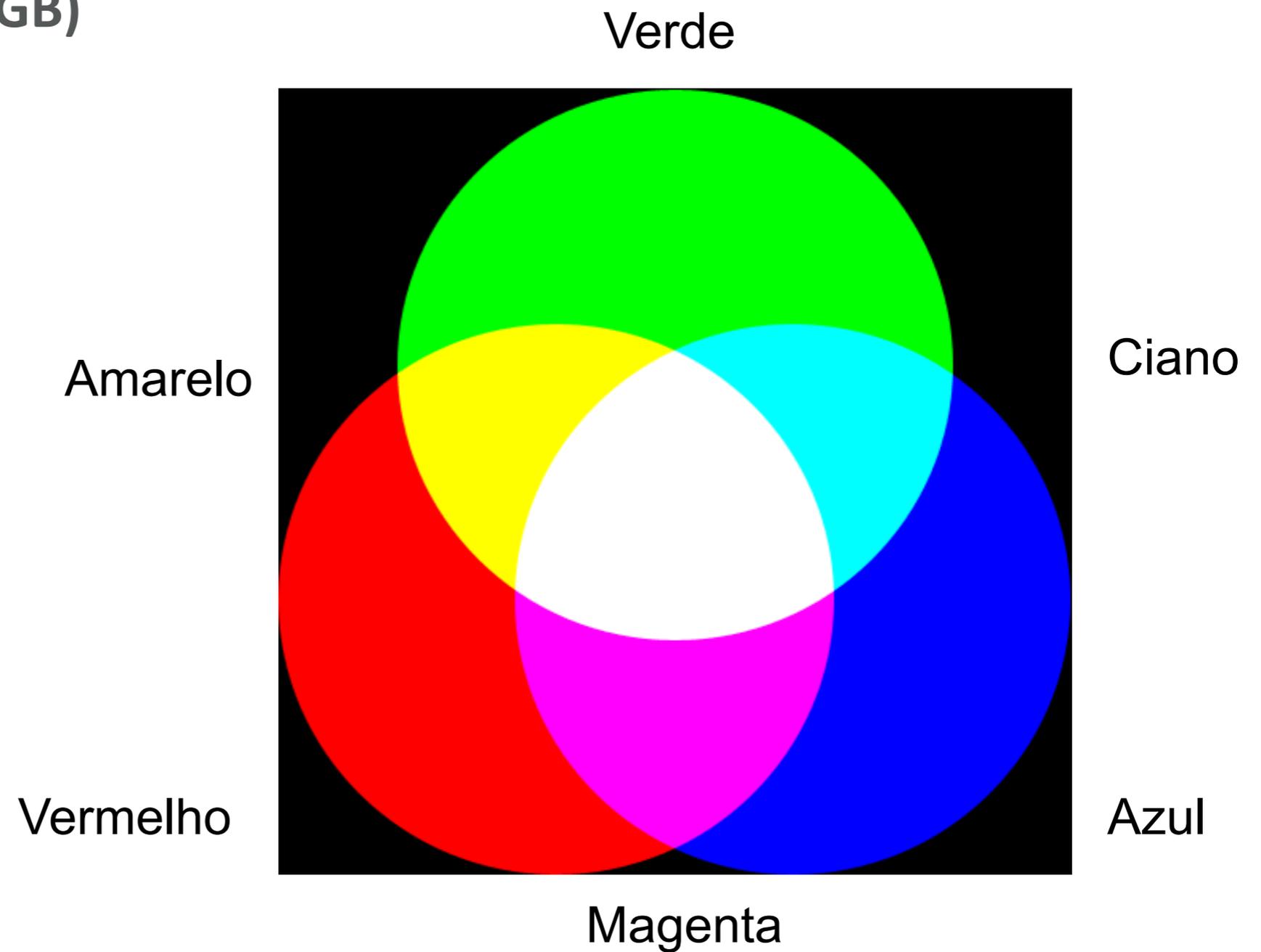


# SISTEMA VISUAL HUMANO

- ▶ **Bastonetes:**  $\sim 100 \cdot 10^6$  por toda a retina, exceto no centro, onde a visão é mais acurada
  - ▶ para distinguir a variação no tom de cinza:  $\sim 1\%$
  - ▶ aprox. 100 tons de cinza (idealmente)
- ▶ **Cones:**  $\sim 6-7 \cdot 10^6$  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 =  $\sim 1.000.000$  cores !!
  - ▶ Somos seres Tricromáticos – enxergamos a partir de 3 cores

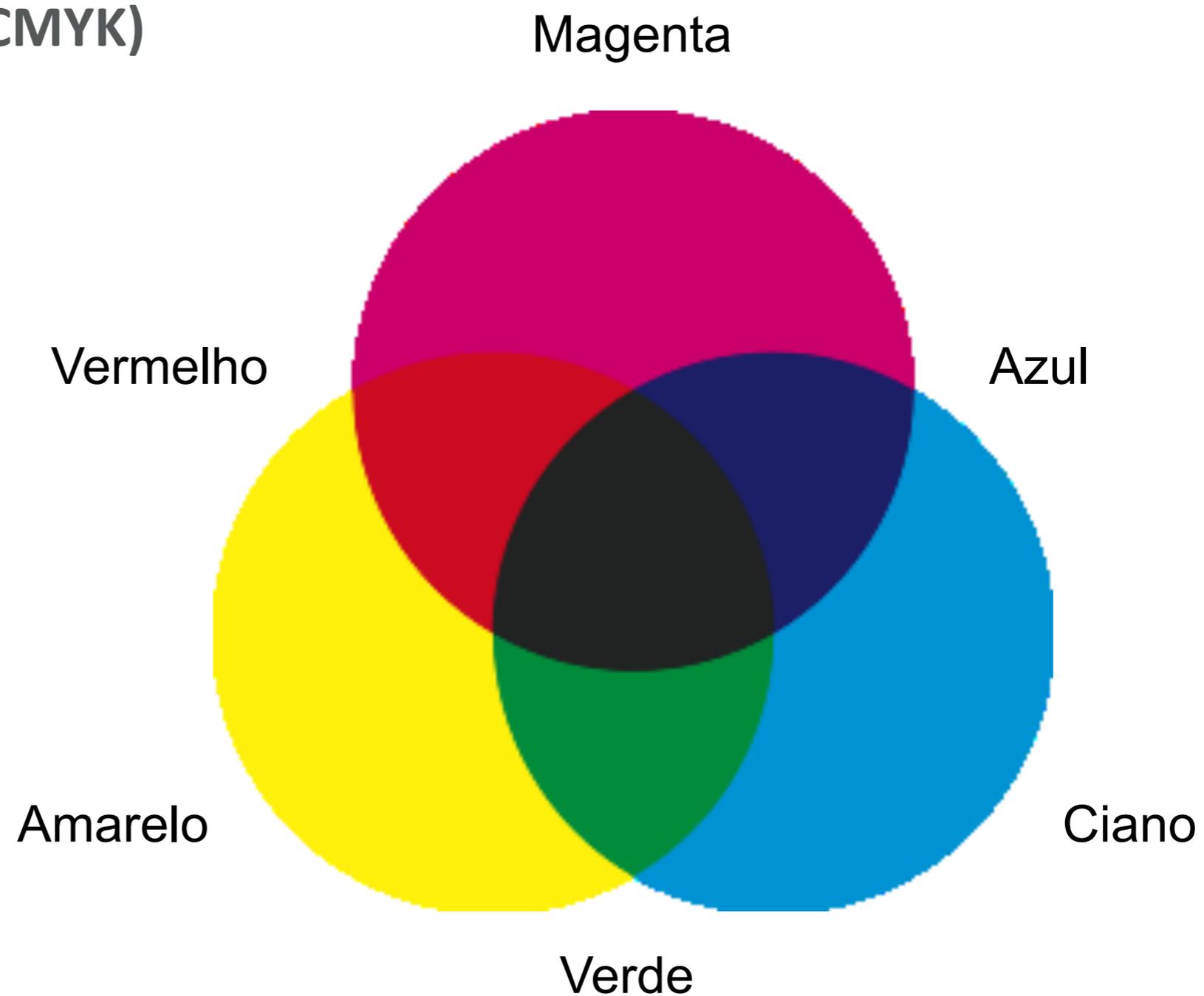
# SISTEMAS DE CORES

## ▶ Sistema Aditivo (RGB)



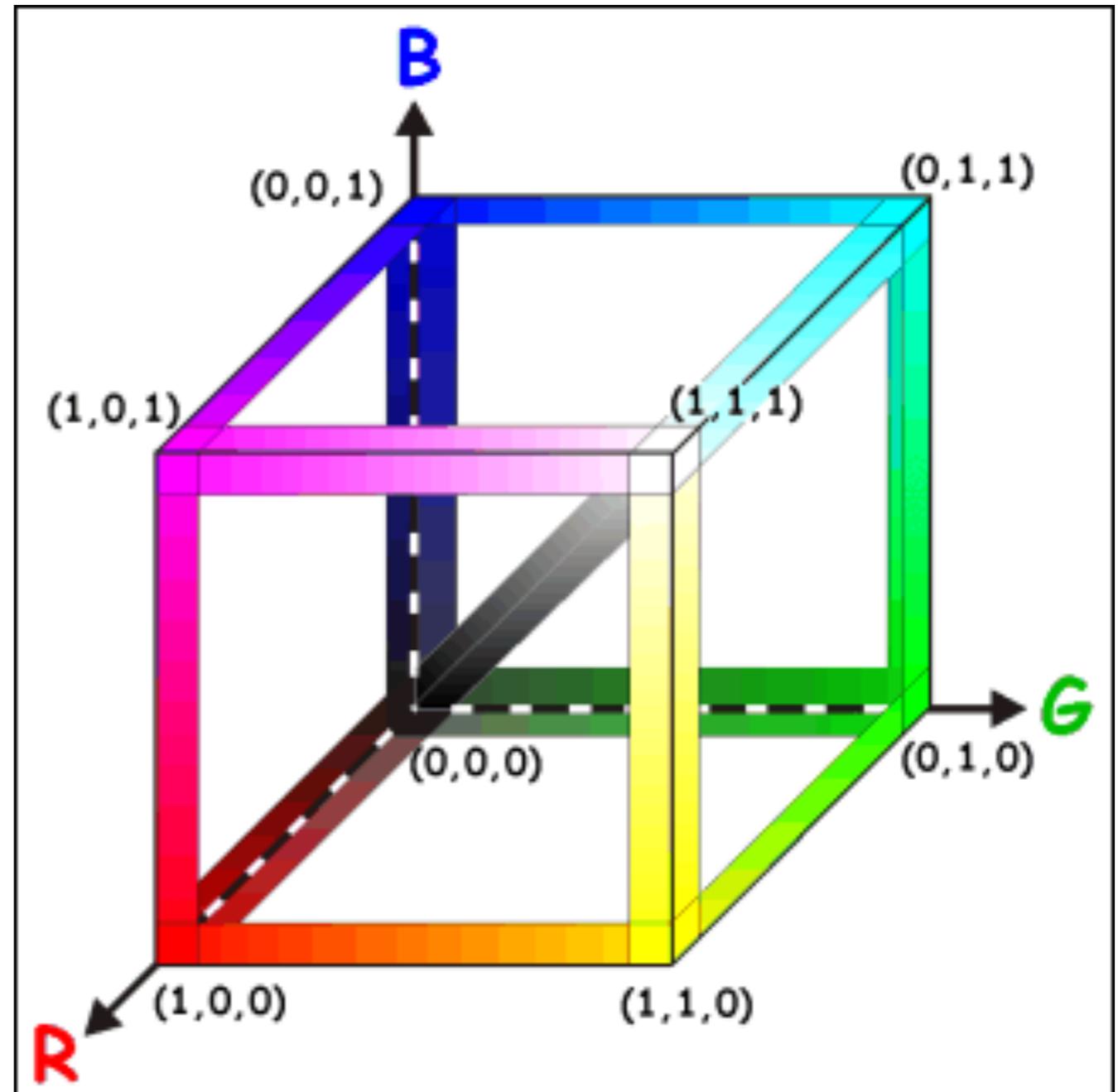
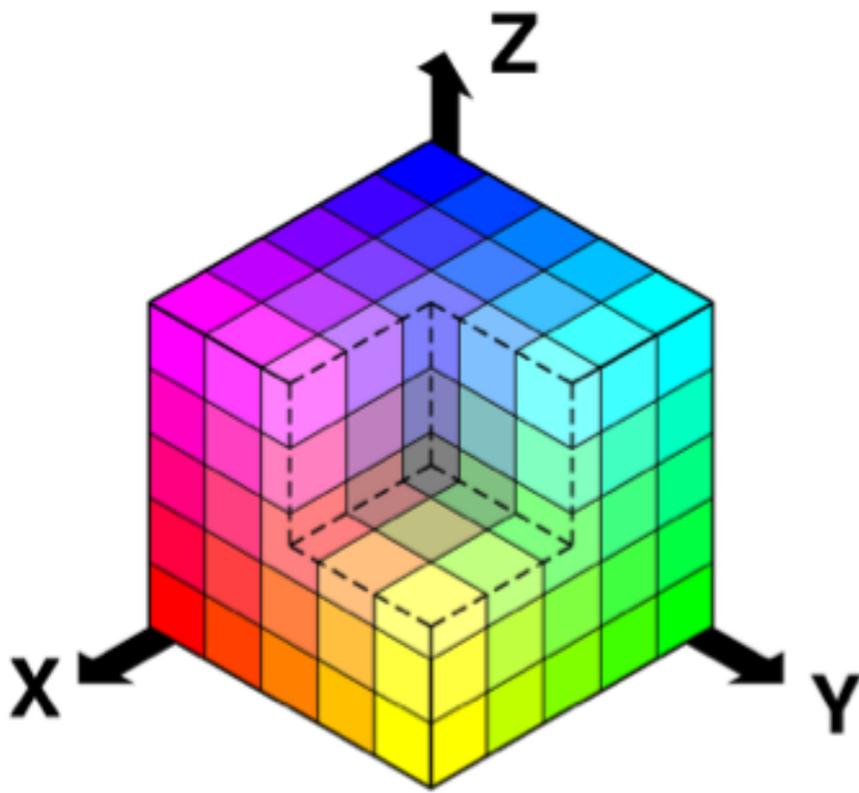
# SISTEMAS DE CORES

## ▶ Sistema Subtrativo (CMYK)



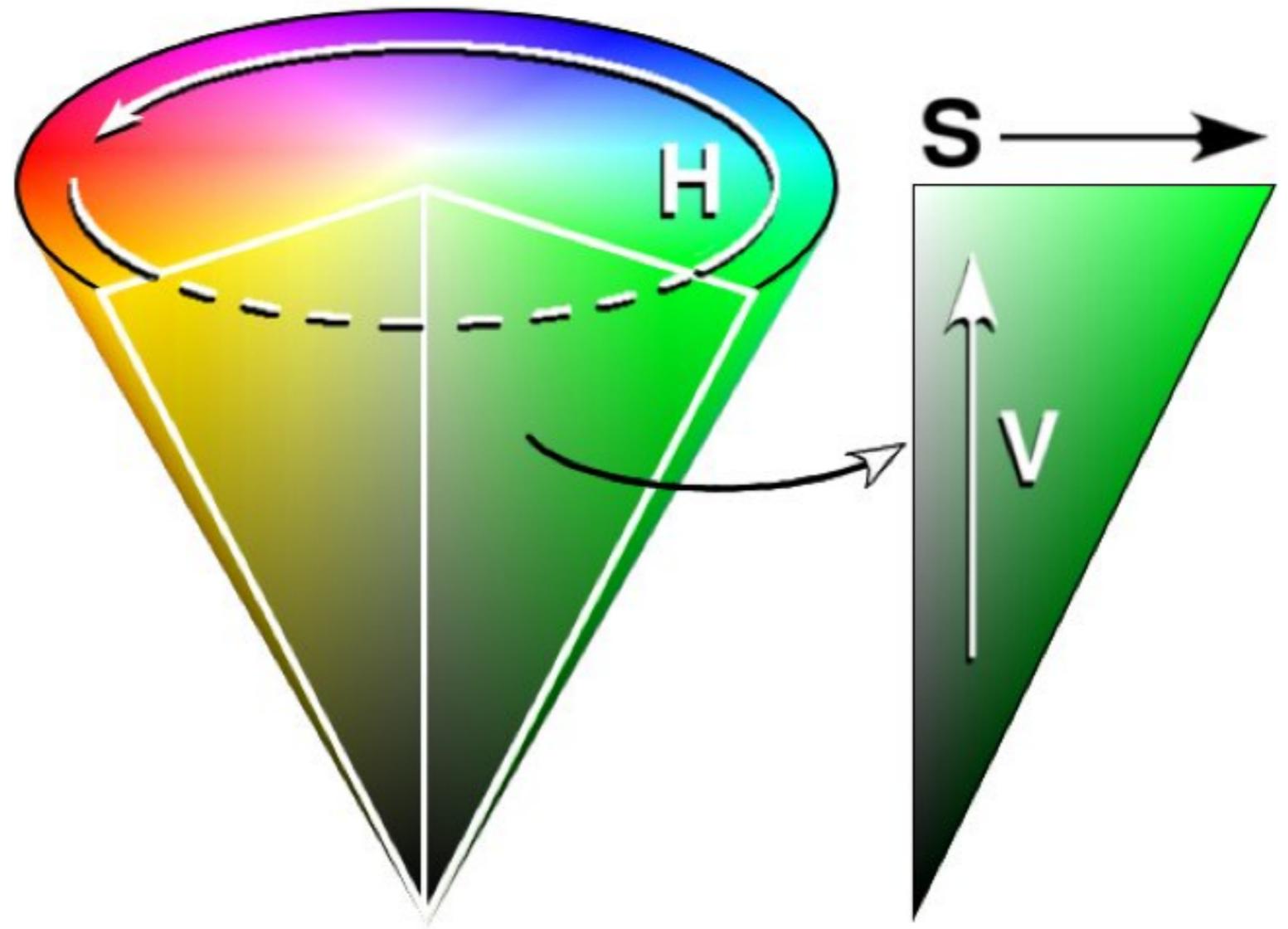
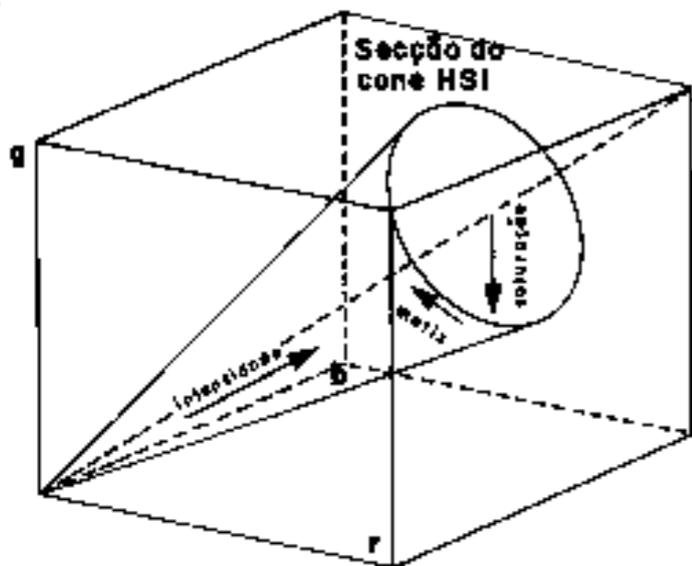
# SISTEMAS DE CORES

## ► Cubo RGB



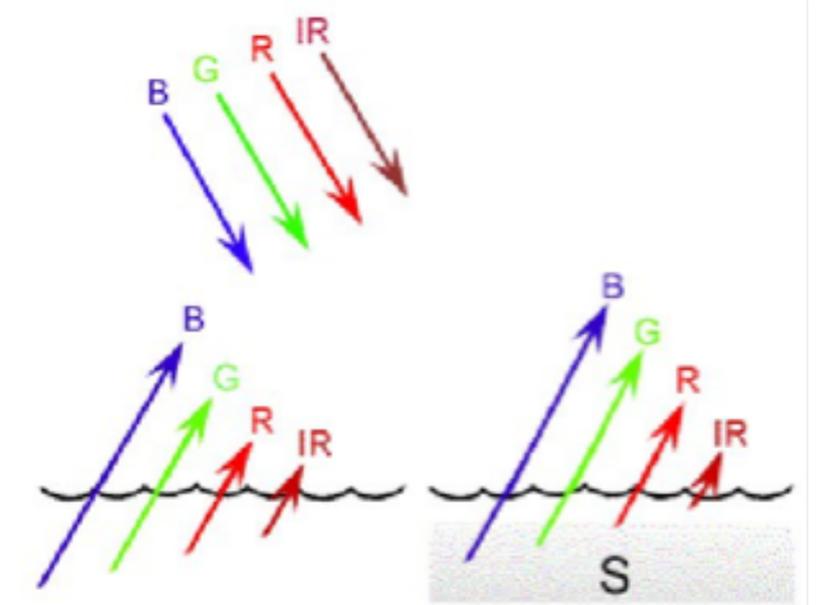
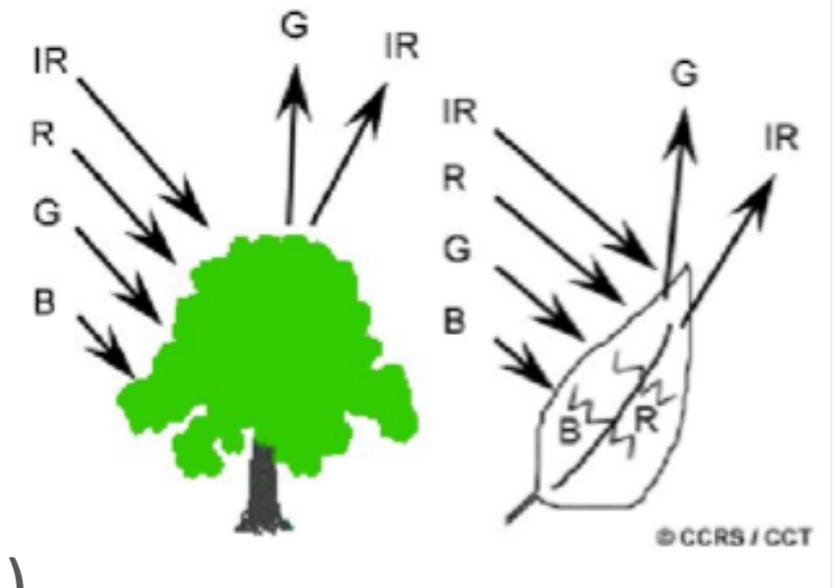
# SISTEMAS DE CORES

## ► Cone IHS



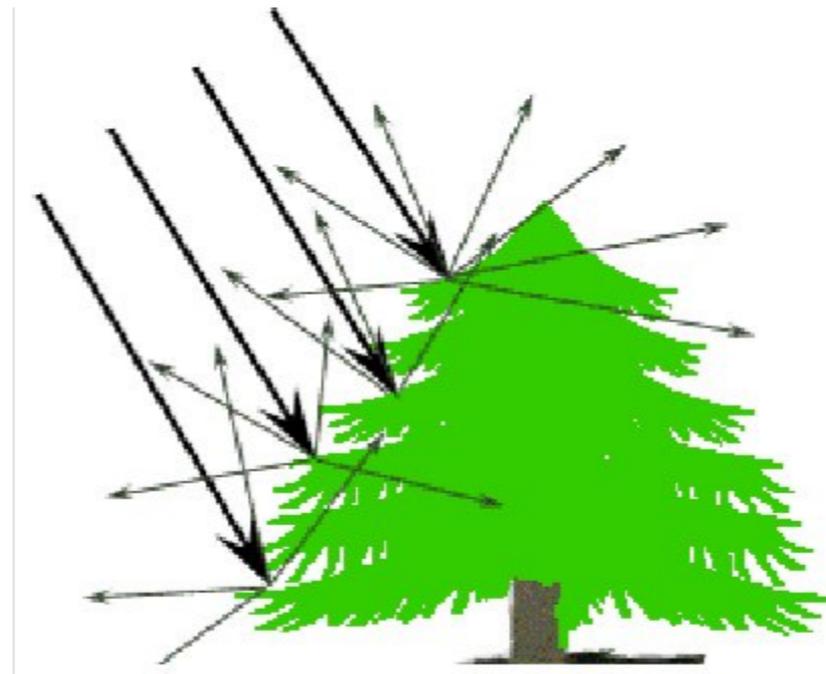
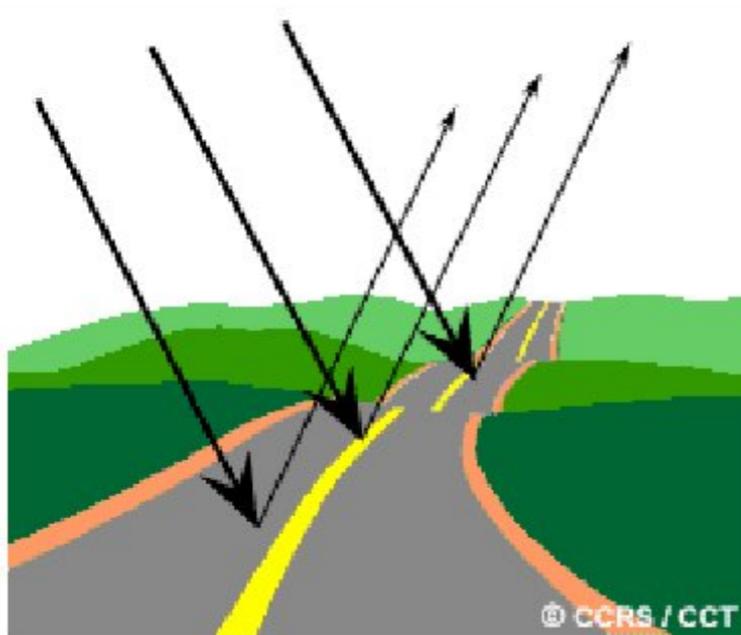
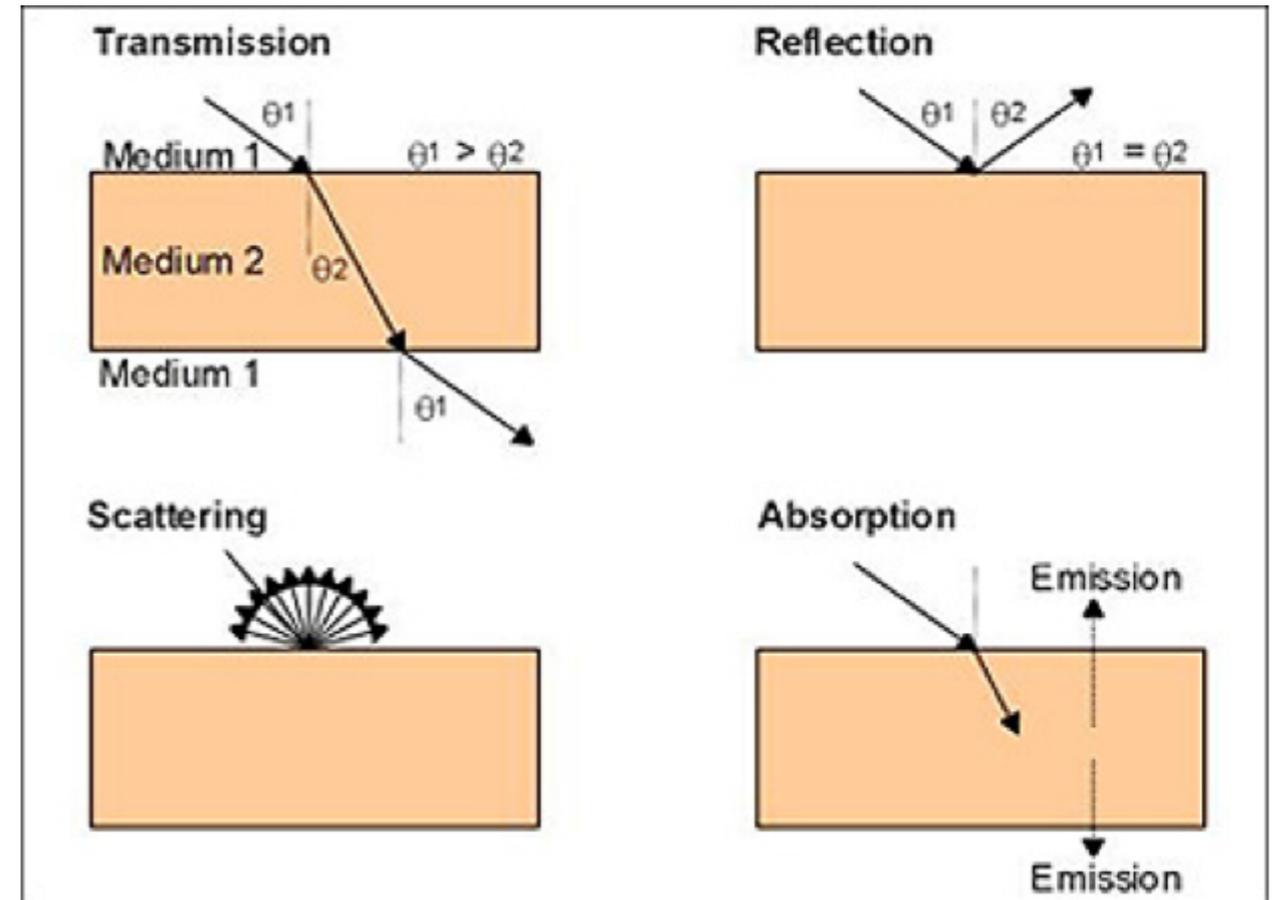
# CORES

- ▶ 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...



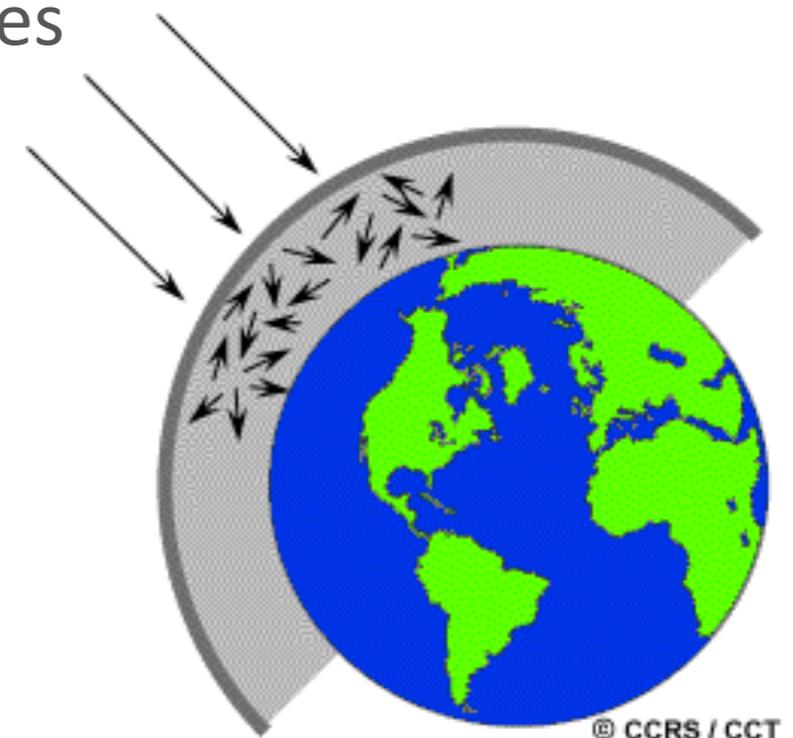
# COMPORTAMENTO DA REM

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



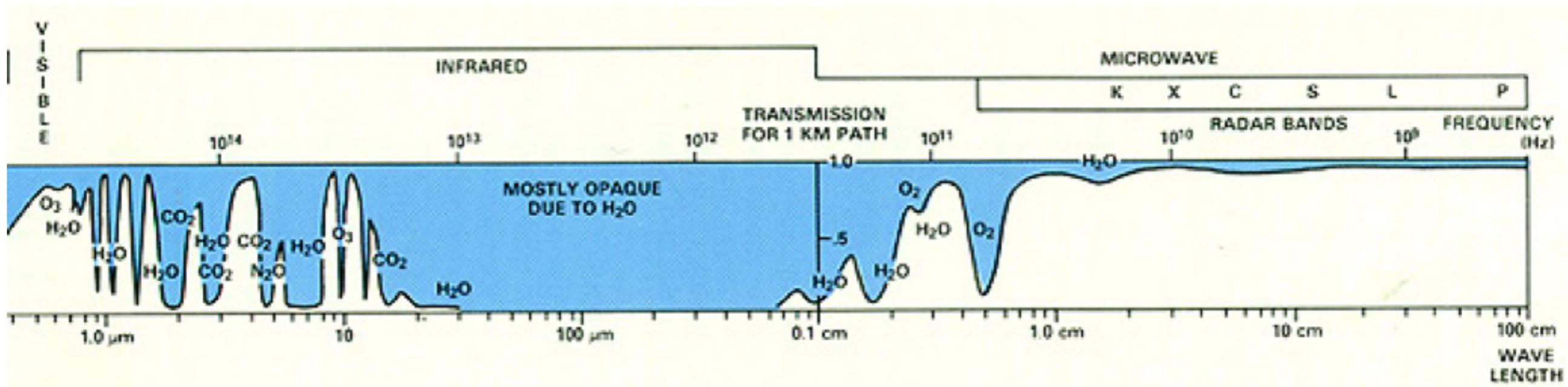
# ESPALHAMENTO ATMOSFÉRICO

- ▶ Espalhamento de Rayleigh
  - ▶ principal efeito de espalhamento atmosférico
  - ▶ partículas dispersas são muito menores que o comprimento de onda da REM (poeira, O<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>O)
  - ▶ 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



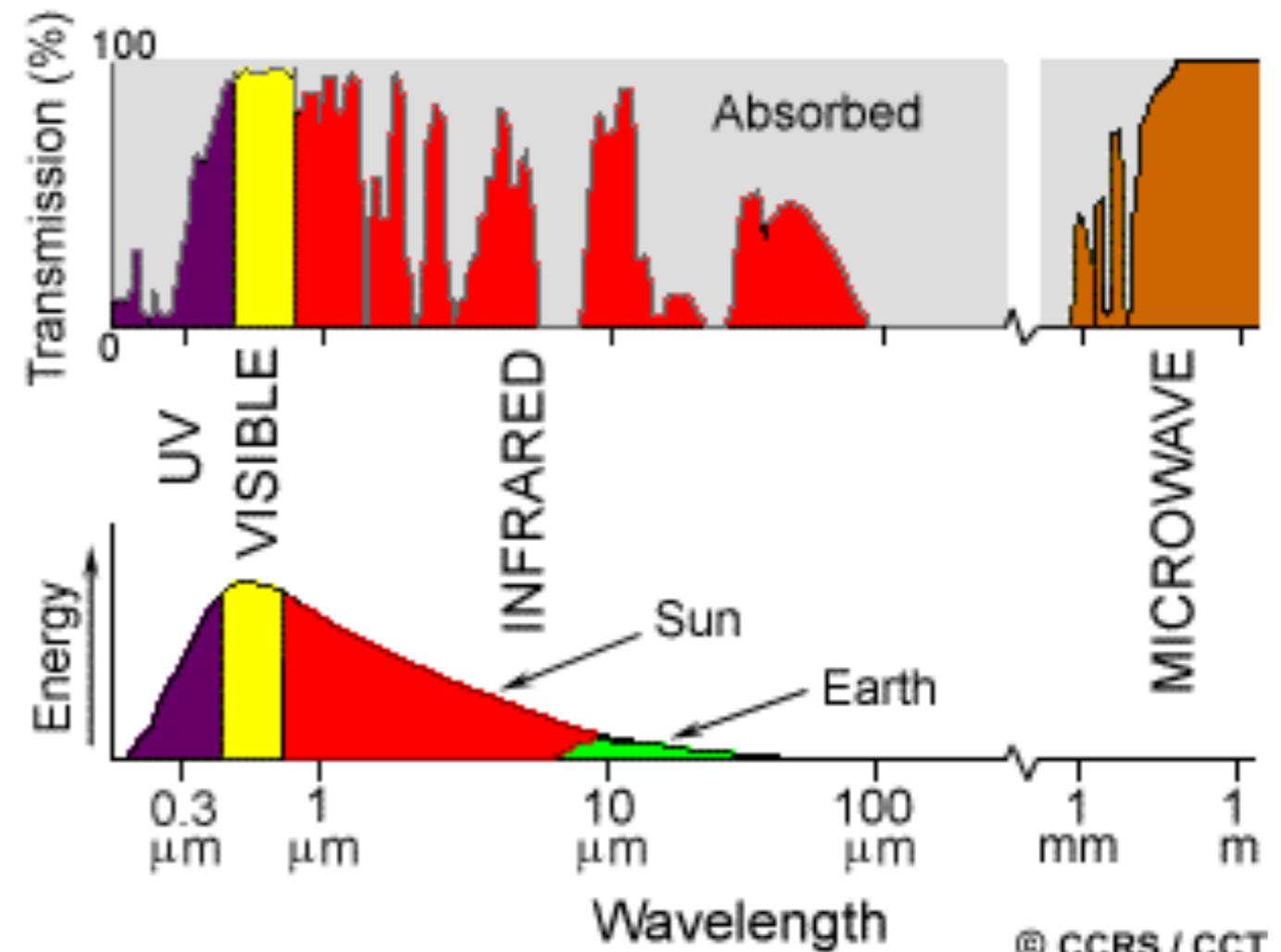
# COMPORTAMENTO DA REM

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



# COMPORTAMENTO DA REM

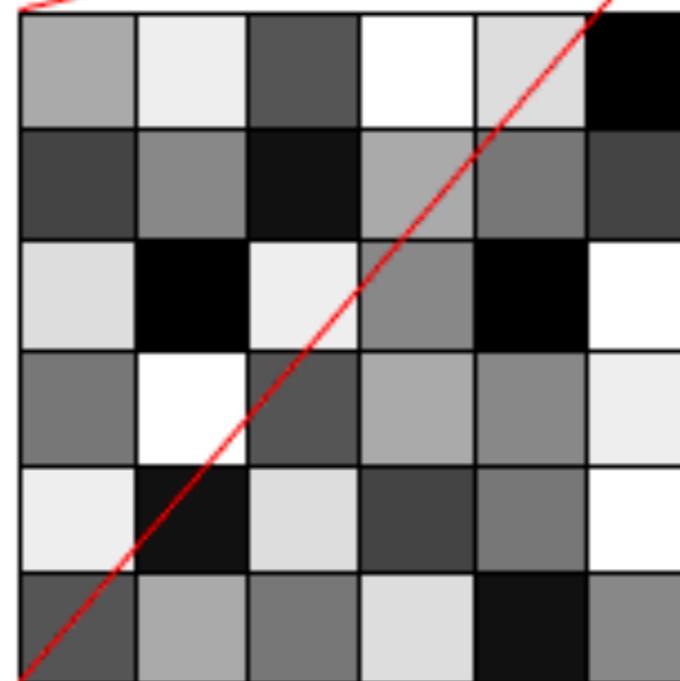
- ▶ Energia das fontes (Sol, Terra) x janelas atm.
  - ▶ determinar os melhores comp. onda para SR
- ▶ Visível: janela + pico de energia solar



# 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

© CCRS / CCT



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

# IMAGENS MULTIESPECTRAIS

- ▶ Sensores captam diferentes faixas do espectro
- ▶ Cada faixa é 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

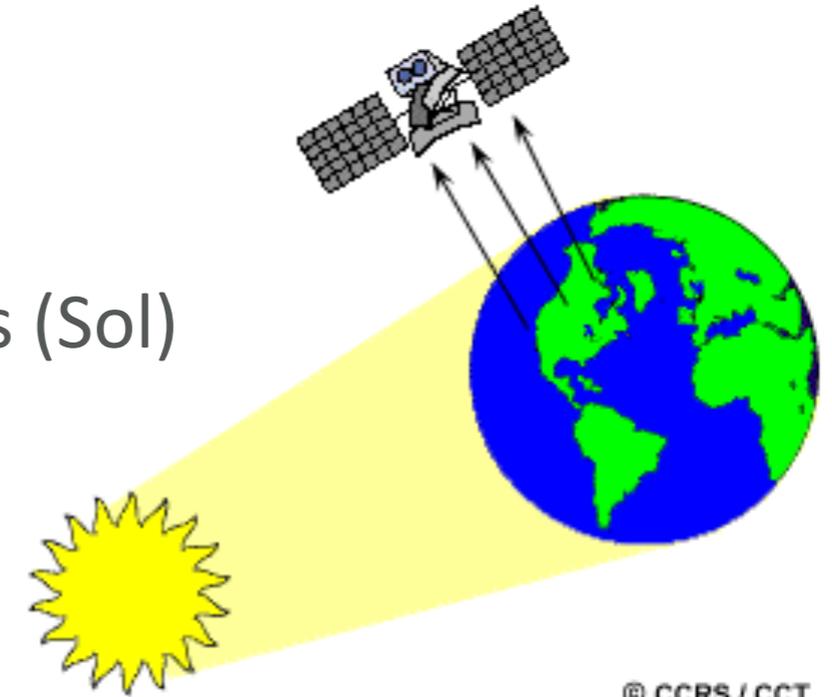
- ▶ **Fotográficos**
  - ▶ imagem é capturada de uma só vez
- ▶ **Não-fotográficos**
  - ▶ imagem capturada pixel a pixel (scanner)



# TIPOS DE SENSORES

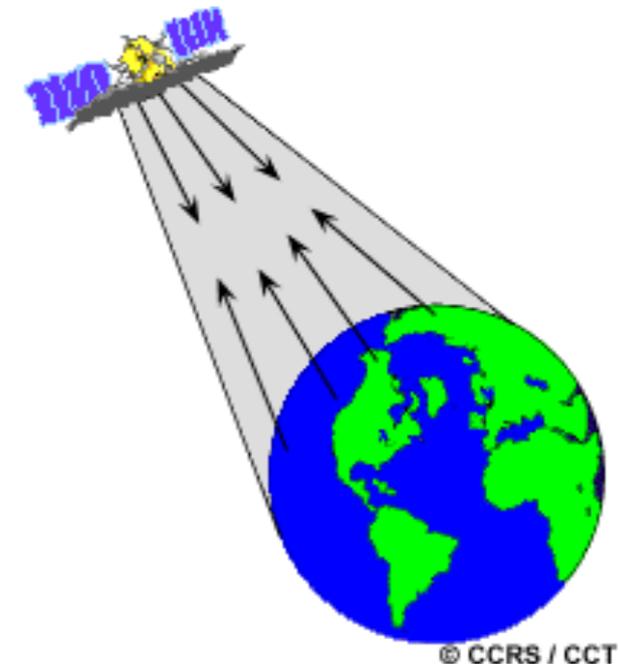
## ▶ Sensores Passivos

- ▶ 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



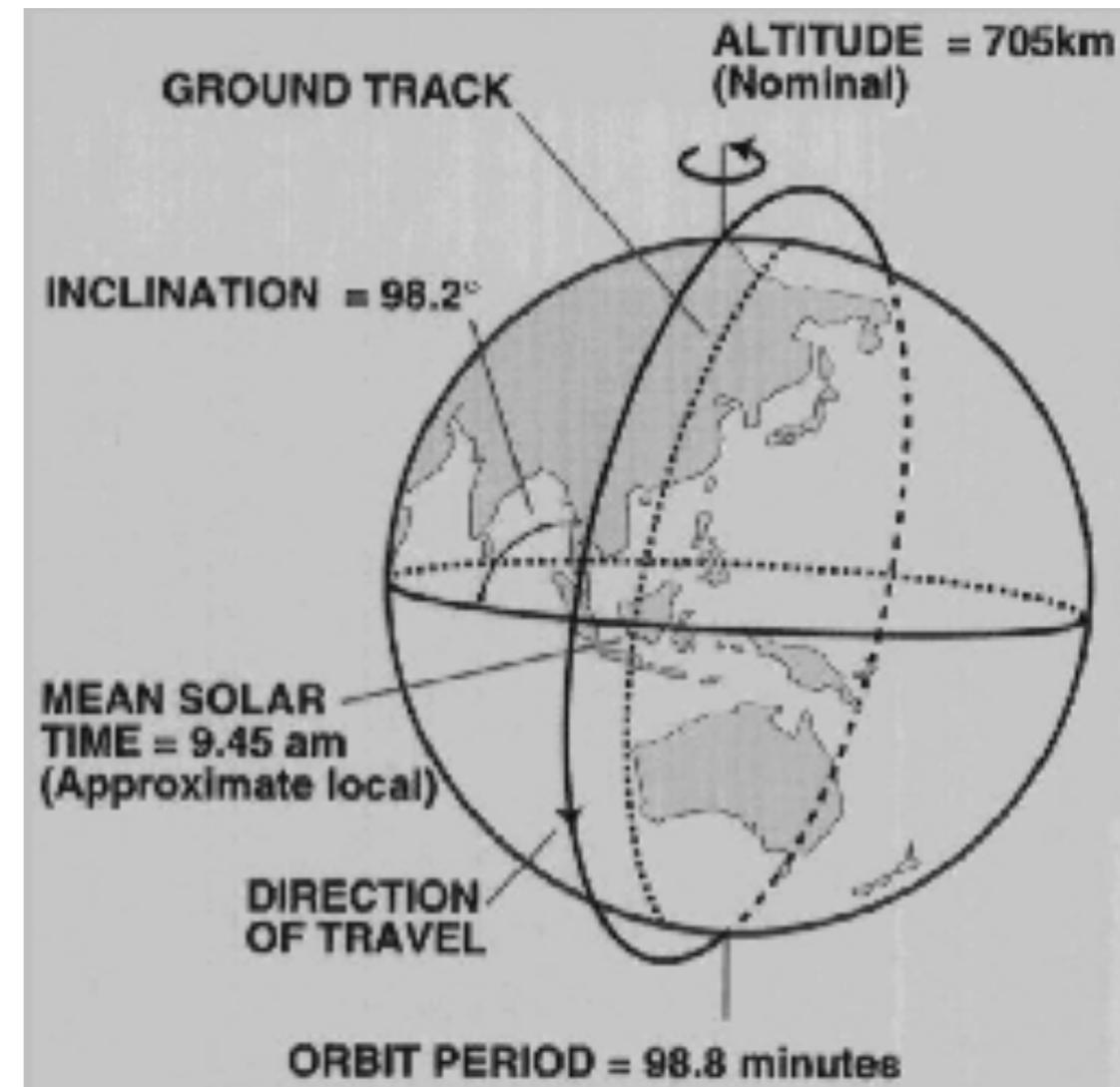
# TIPOS DE SENSORES

- ▶ Terrestre
- ▶ Aeroportado
- ▶ Orbital (Satélite, Ônibus espacial, OVNI...)

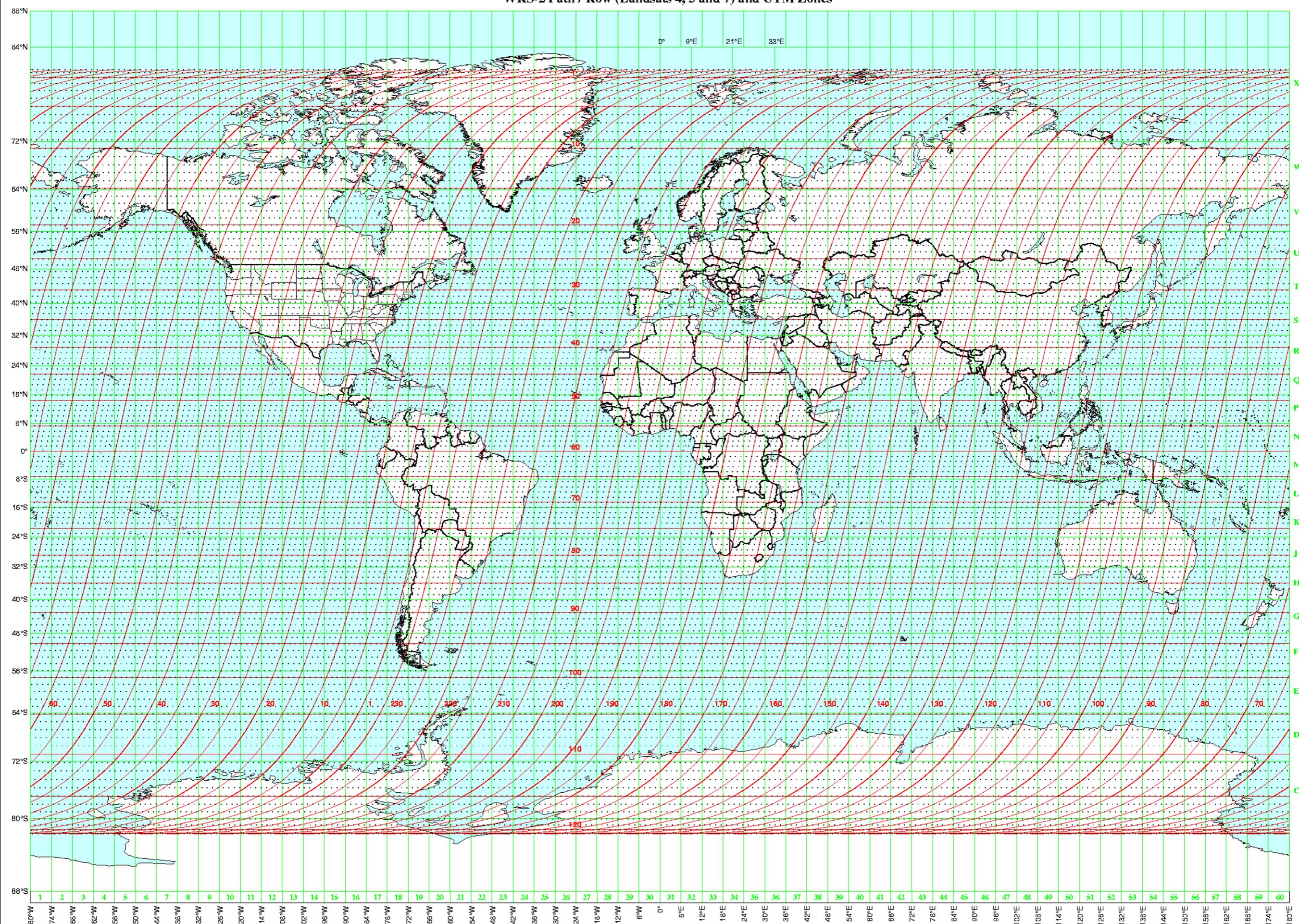


# SATÉLITES

- ▶ 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

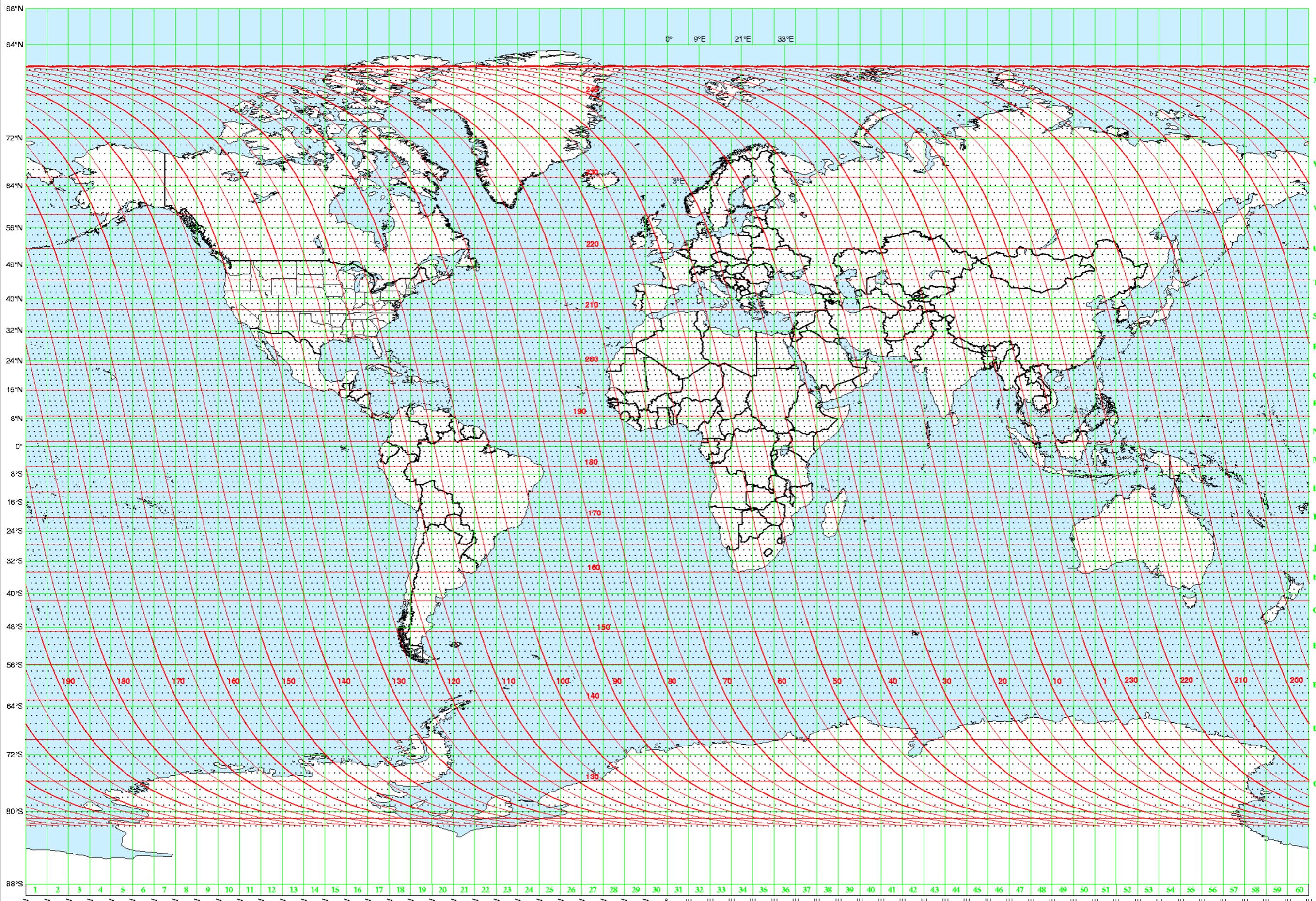


WRS-2 Path / Row — Red line  
UTM Zones — Green line

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

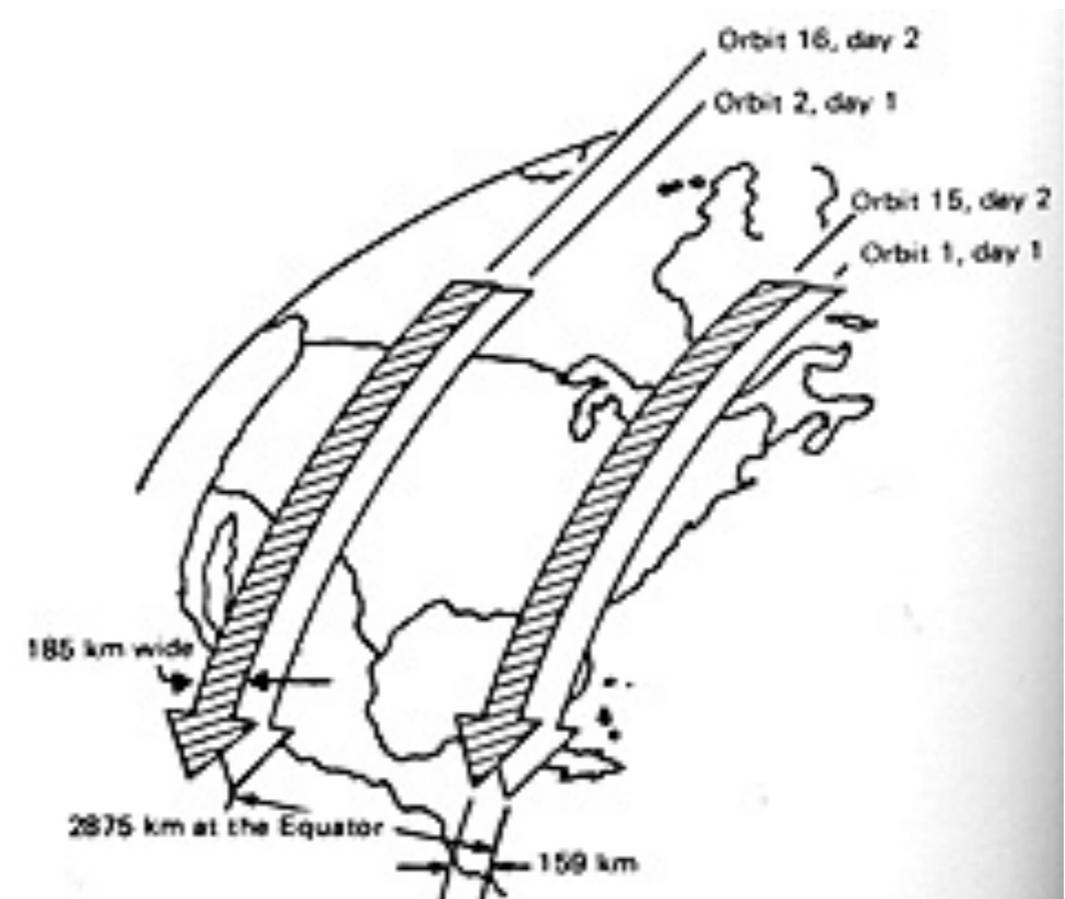
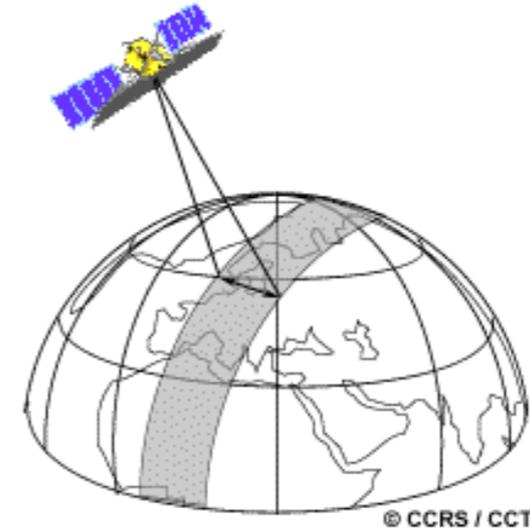


WRS-2 Path / Row ————  
UTM Zones ————  
Black dots --- Intermediate Path / Row  
Miller cylindrical projection

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

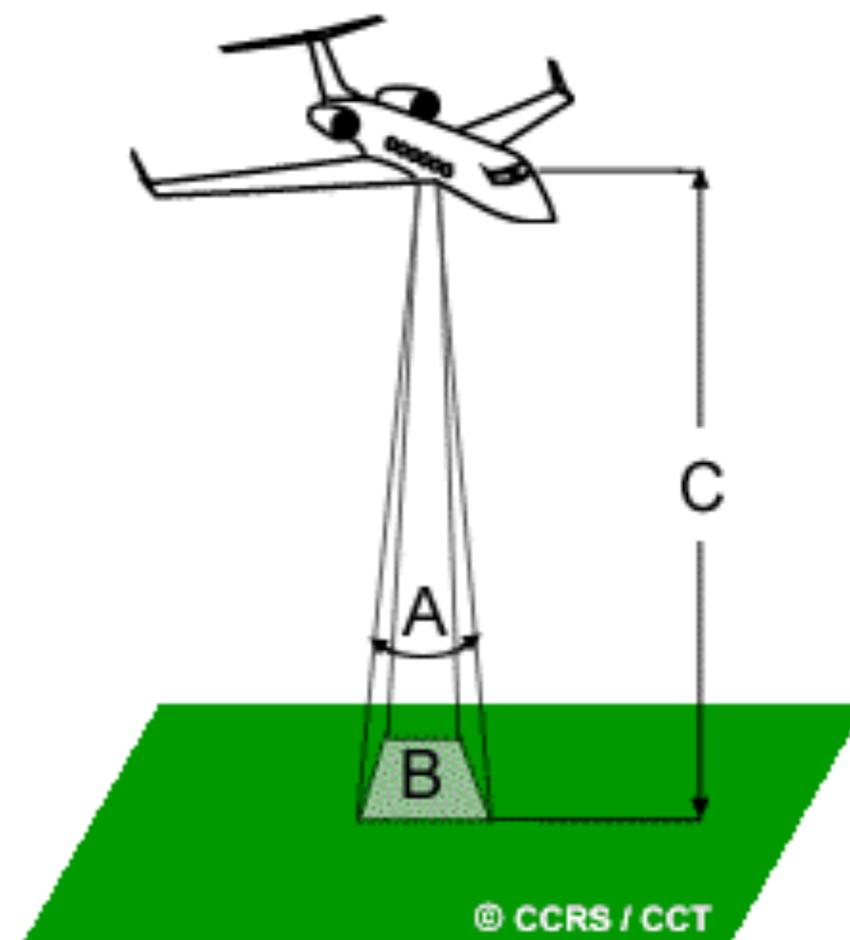
# SATÉLITES

- ▶ swath - faixa imageada
- ▶ largura de dezenas a centenas de km
- ▶ período de revisita:
- ▶ tempo para imagear a mesma área (nadir) duas vezes
- ▶ overlap – área próximas dos pólos são imageadas mais frequentemente



# 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



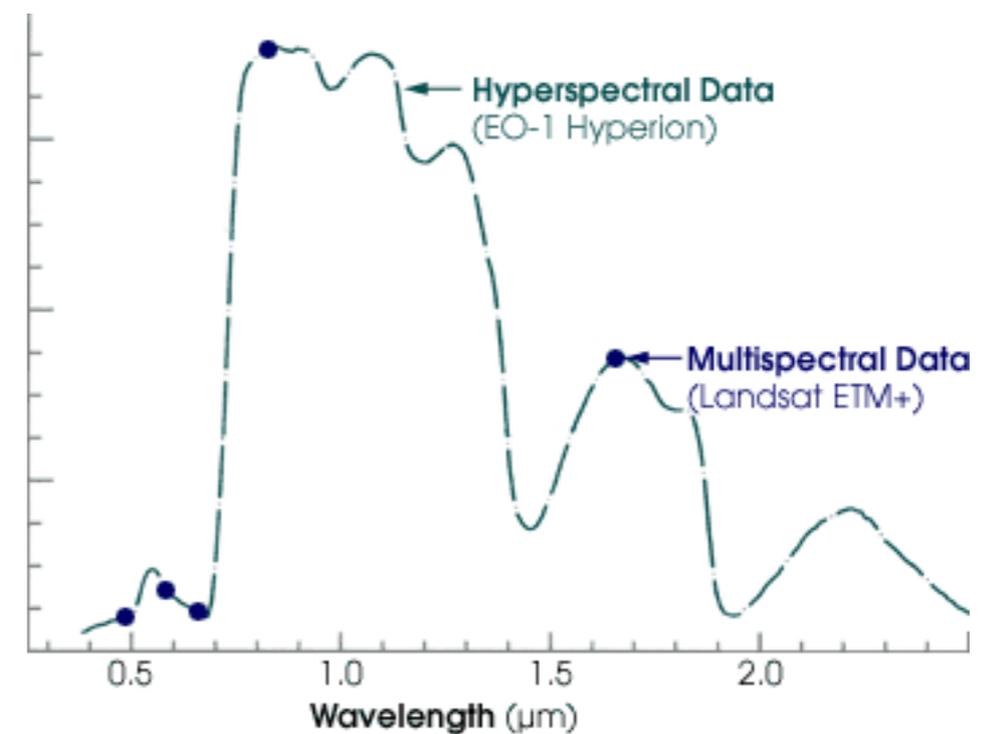
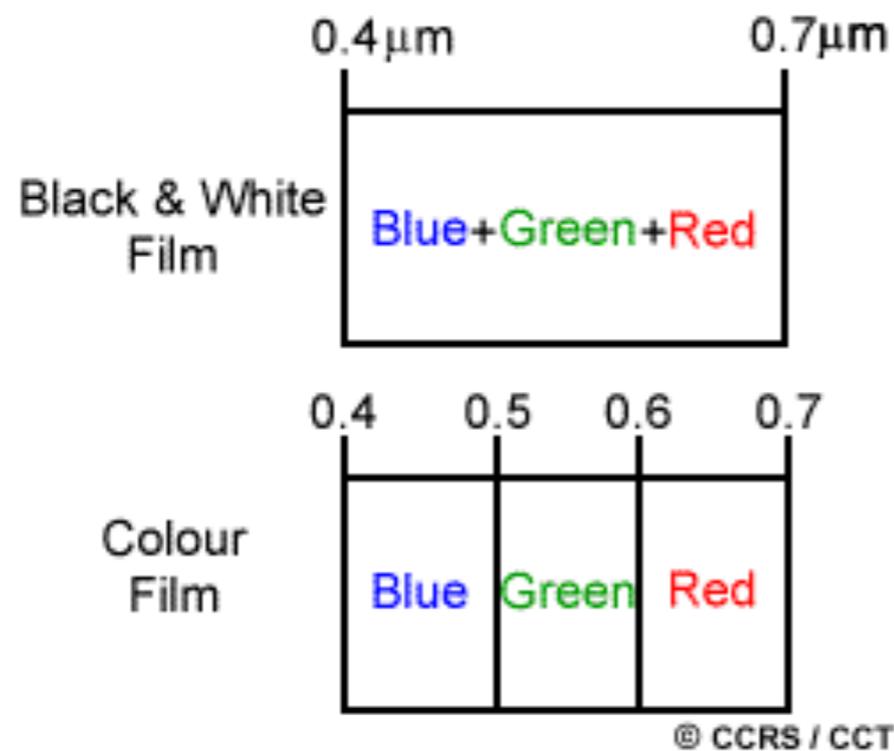
baixa



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

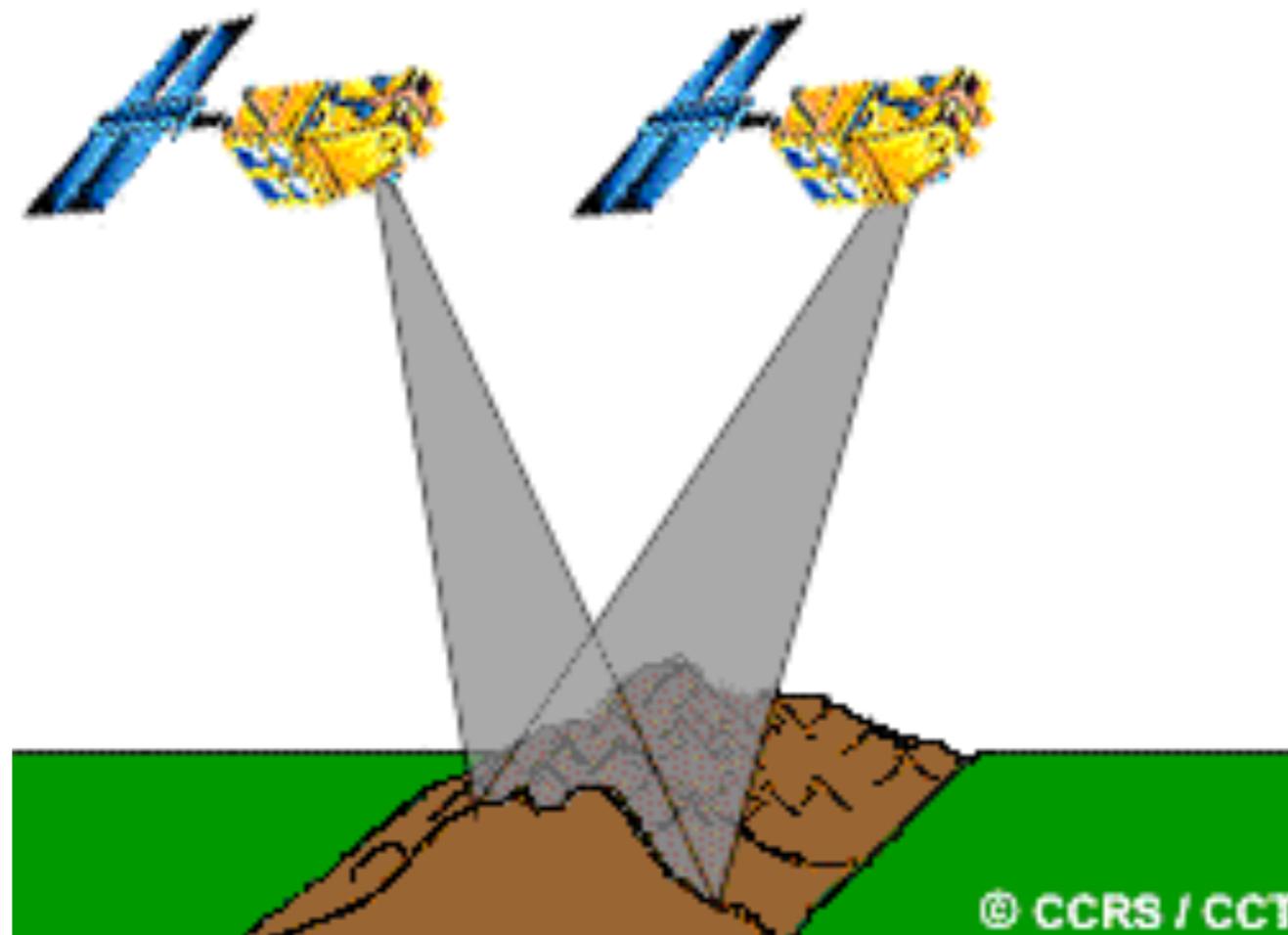


8 bits  
256 tons de cinza



# RESOLUÇÕES

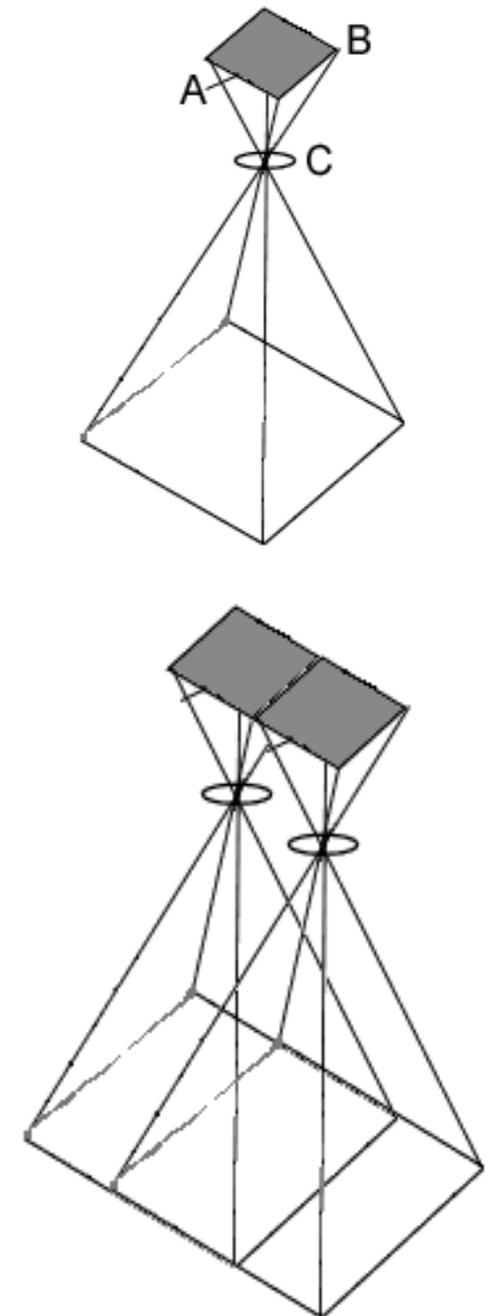
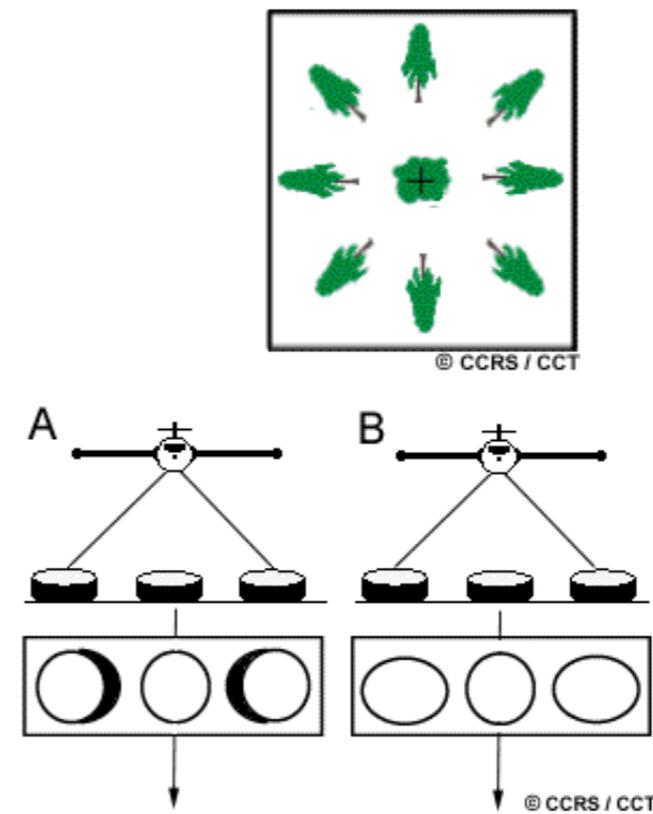
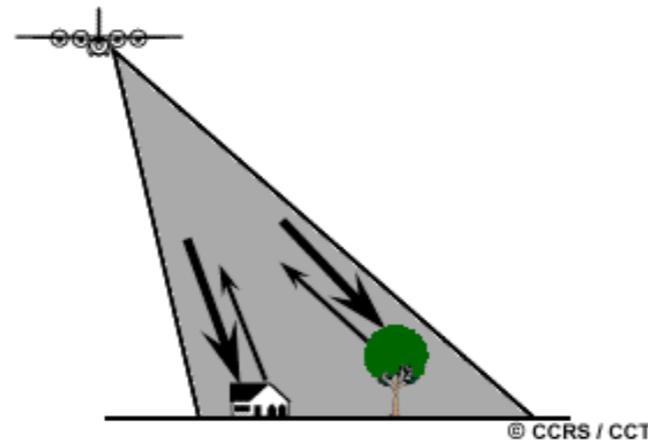
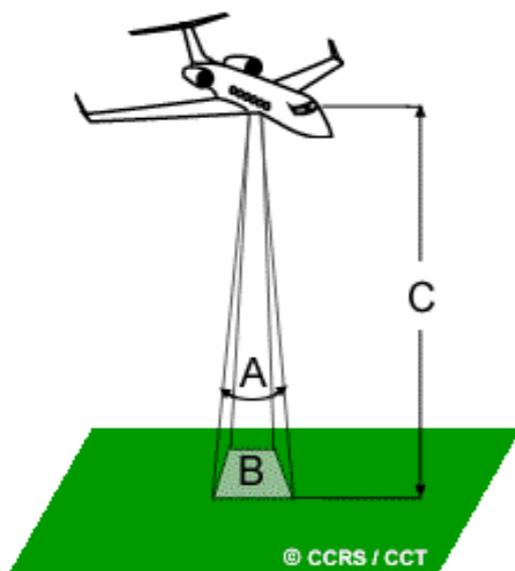
- ▶ **Resolução temporal** - Período de revisita
  - ▶ varia com a latitude, sobreposição entre faixas adjacentes e capacidade do sensor em *off-nadir*



# SISTEMAS DE IMAGEAMENTO

## ▶ Fotografias Aéreas

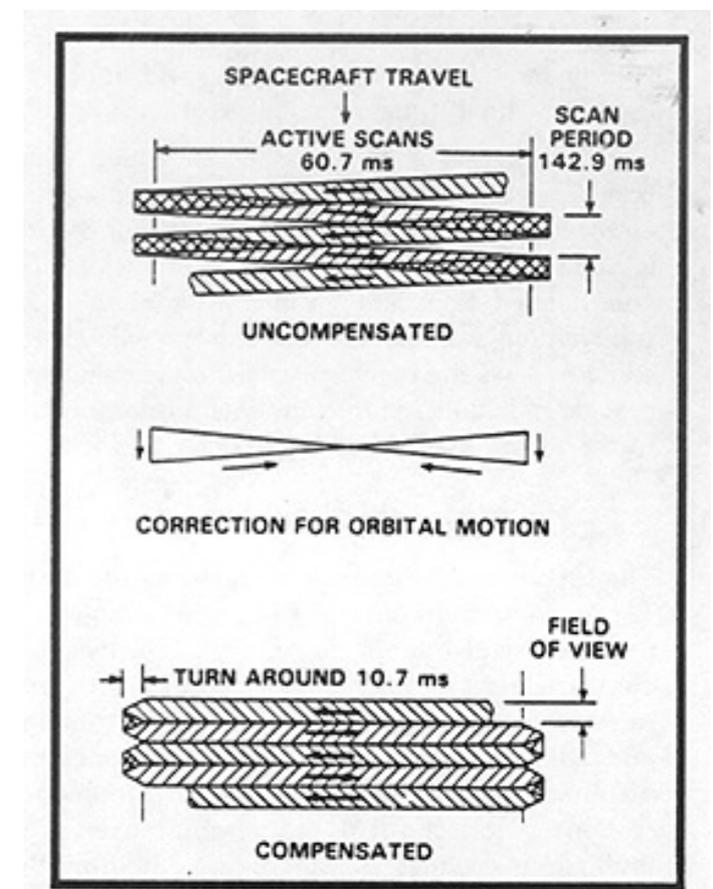
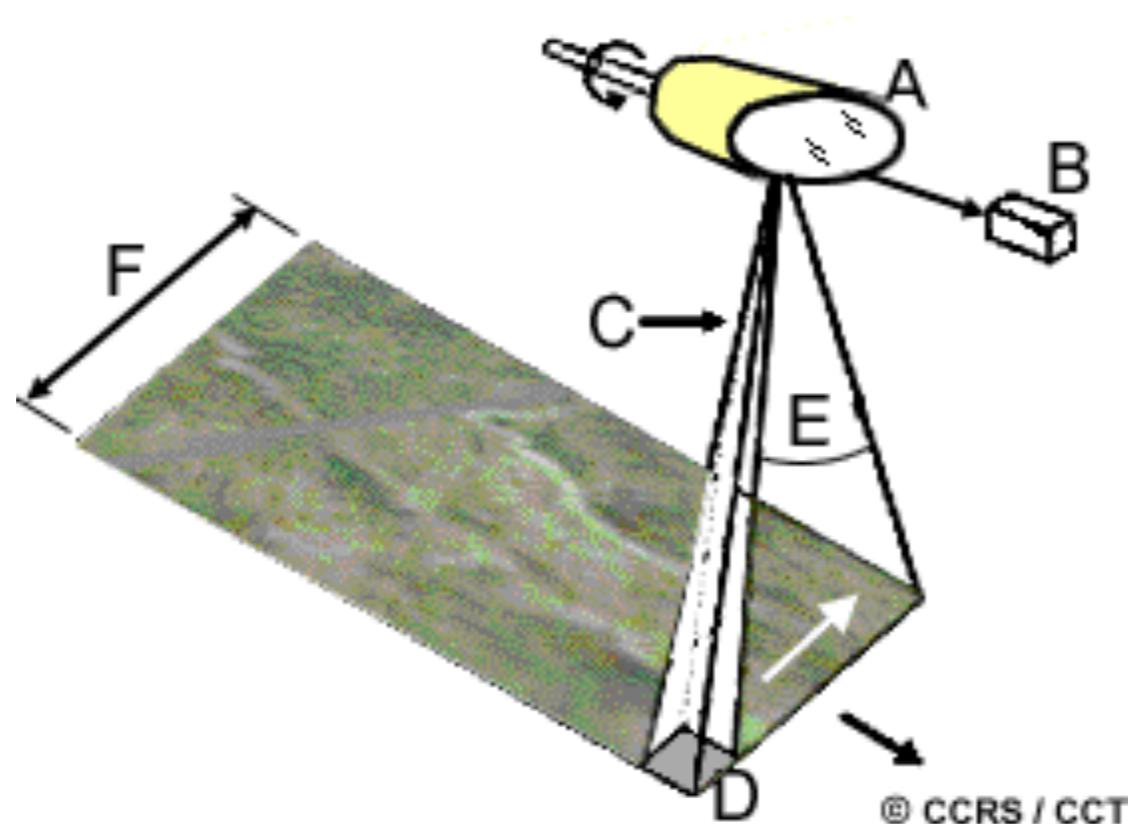
- ▶ alta resolução espacial
- ▶ efeitos de distorção nas bordas
- ▶ sobreposição: estereoscopia
- ▶ fotografias digitais



# SISTEMAS DE IMAGEAMENTO

## ▶ Sensores Multiespectrais (MSS)

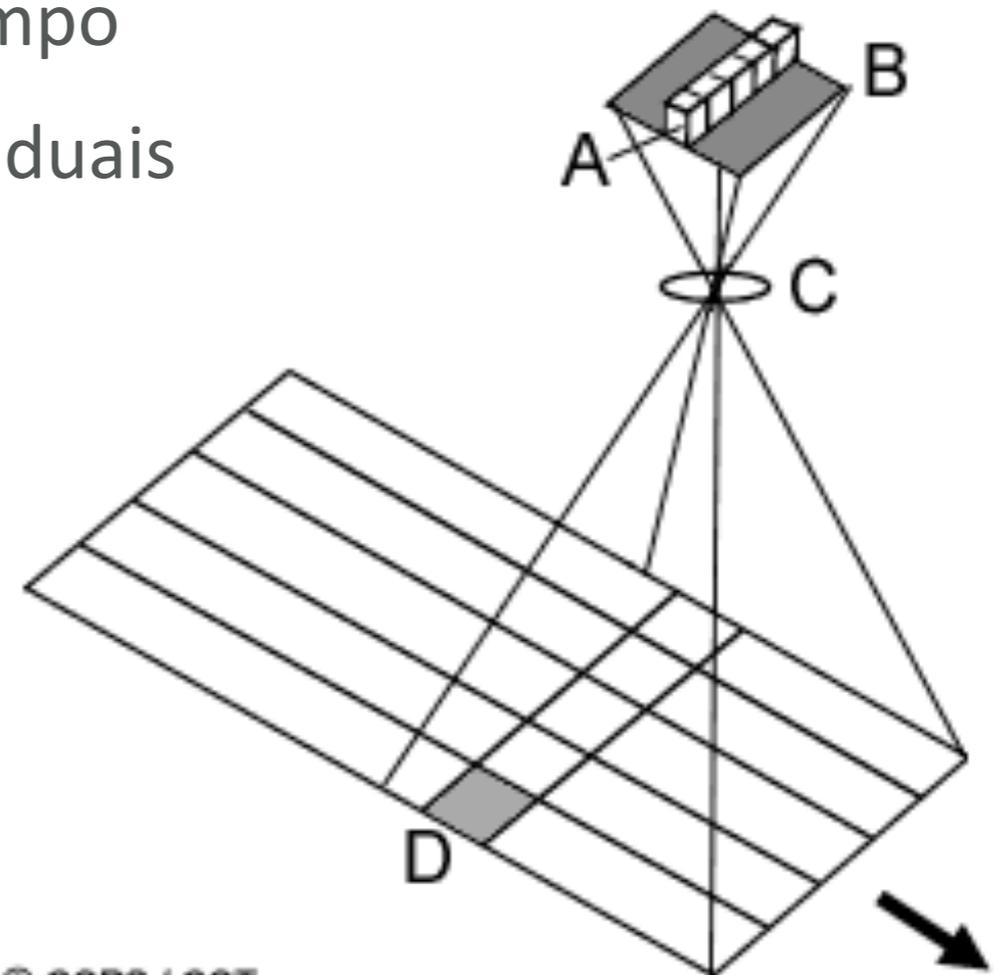
- ▶ *across-track scanners*
- ▶ série de linhas perpendiculares ao movimento do sensor
- ▶ espelho rotativo



# 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

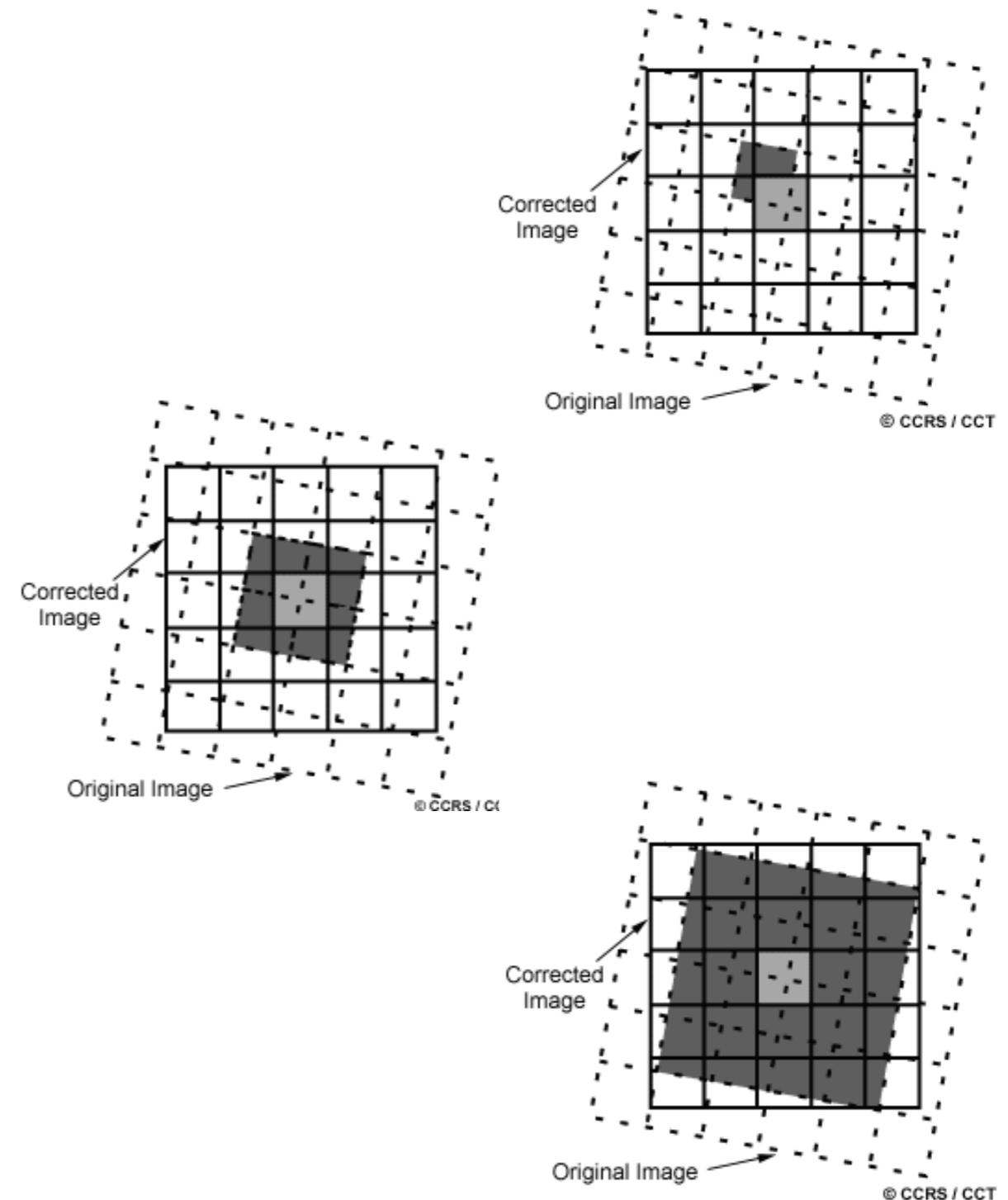


# OPERAÇÕES EM SR

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

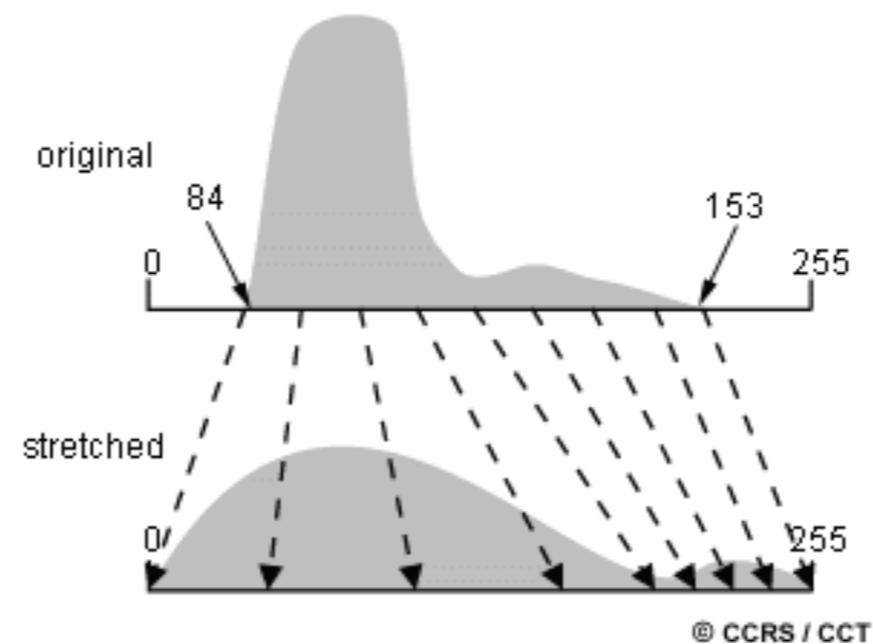
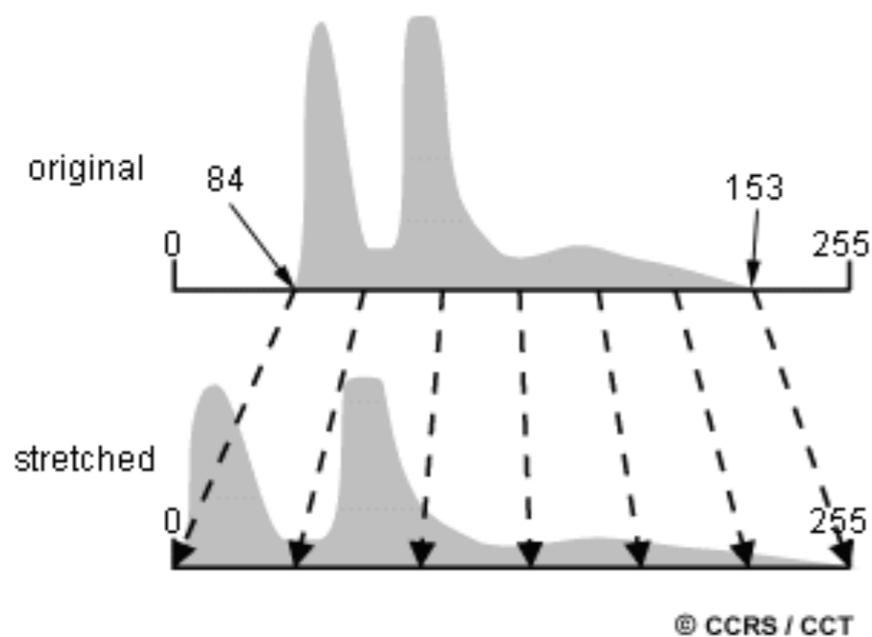
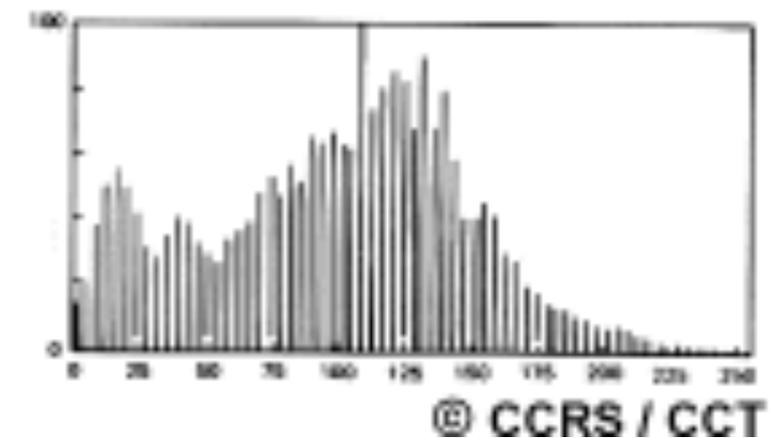
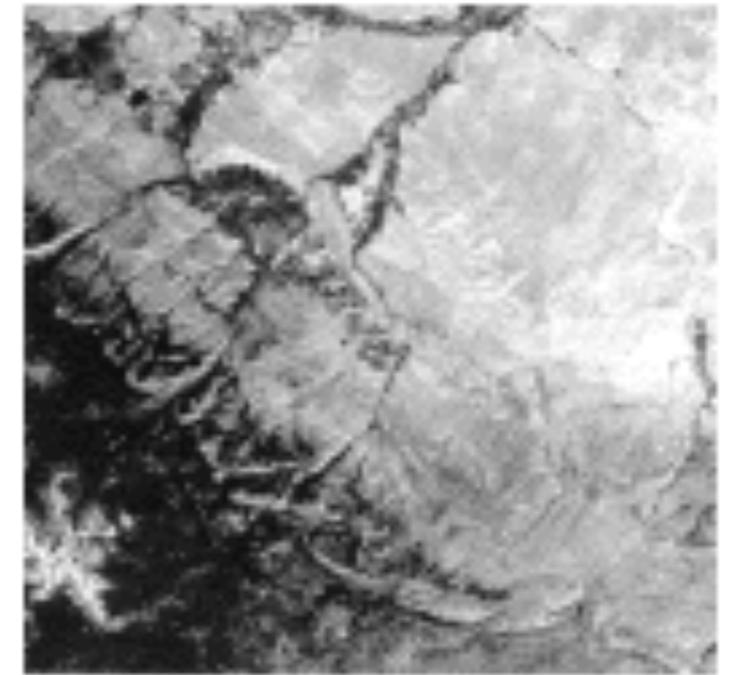
# OPERAÇÕES EM SR

- ▶ **Registro** (Georreferenciamento)
- ▶ Correção geométrica
- ▶ Projeção cartográfica
- ▶ Ground Control Points (GCPs)
- ▶ image-to-map / image-to-image
- ▶ Vizinho mais próximo
- ▶ Interpolação bilinear
- ▶ Convolução cúbica



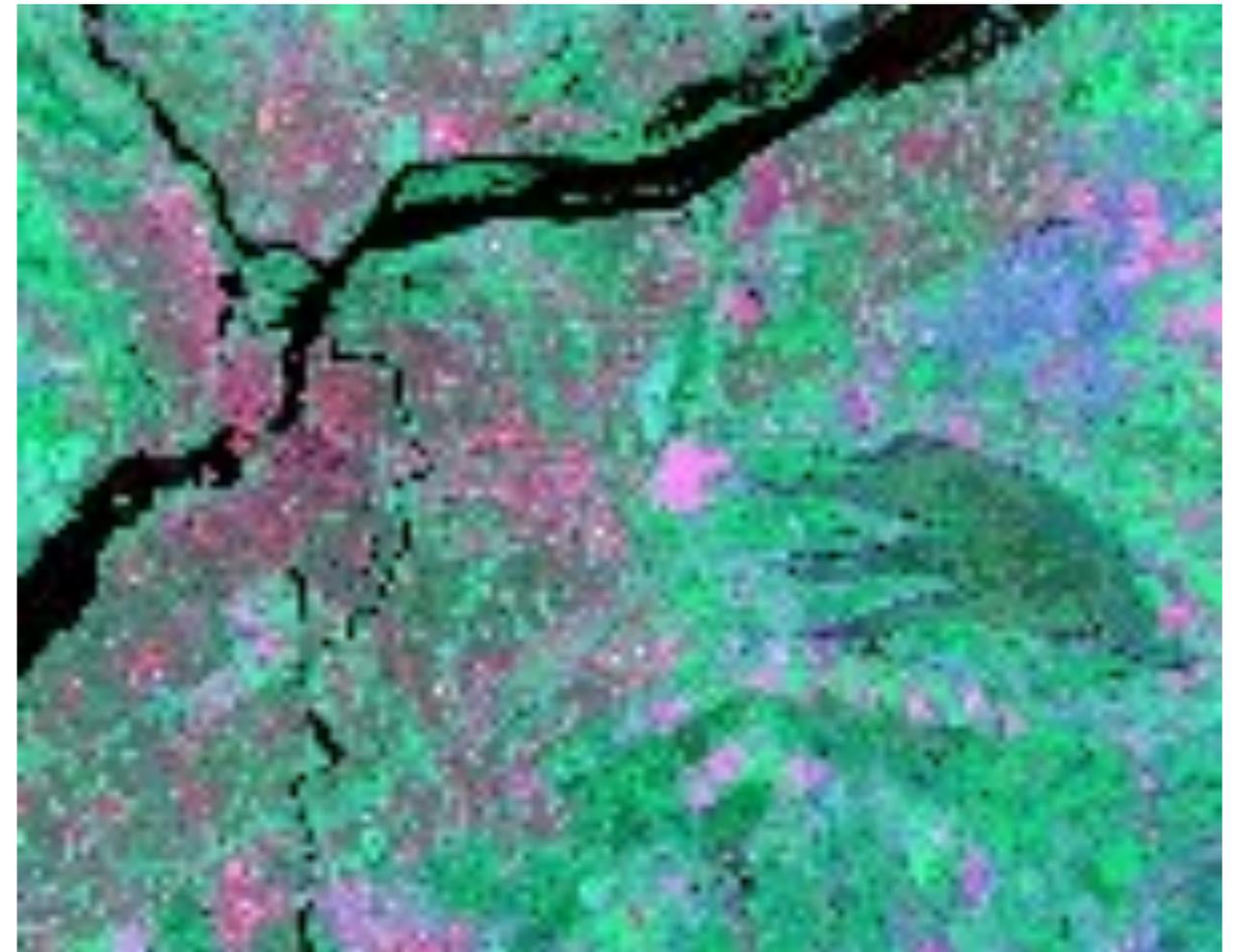
# OPERAÇÕES EM SR

- ▶ **Realce**
- ▶ Histograma – representação dos DN's
- ▶ Função de transferência de contraste (stretch)
  - ▶ linear
  - ▶ equalizada



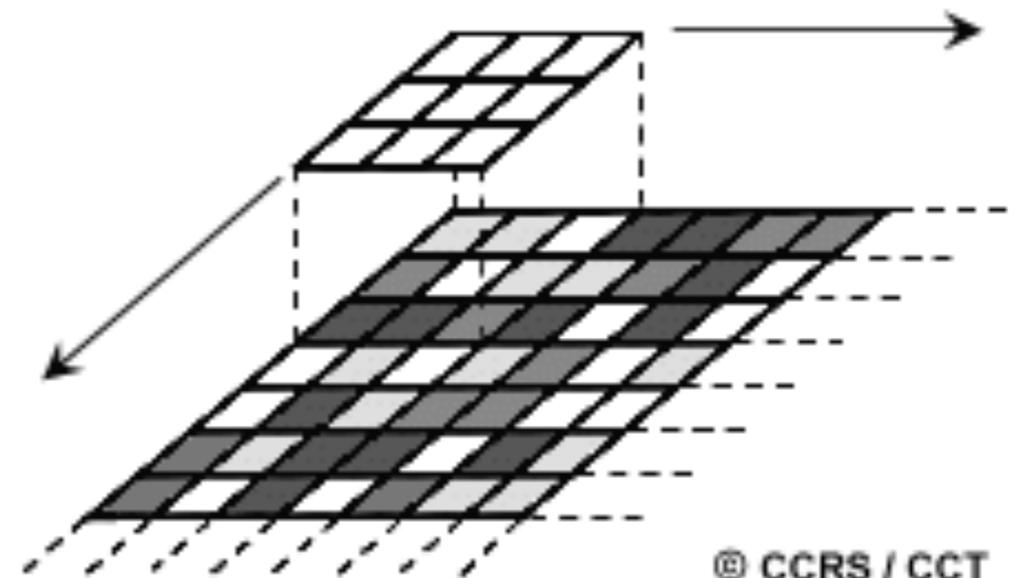
# OPERAÇÕES EM SR

## ► 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)

2 5	2 7	3 2	2 0	2 1	1 9	2 4
2 3	2 7	1 9	2 5	2 2	1 8	2 5
2 7	2 6	2 4	2 6	2 2	2 2	2 6
2 3	2 5	2 8	3 0	2 7	2 5	2 7
1 9	2 2	2 8	3 2	2 9	2 7	2 5
1 7	1 9	2 5	2 7	3 0	3 1	2 2
2 0	2 1	2 5	2 3	2 1	1 9	1 7

Imagem original

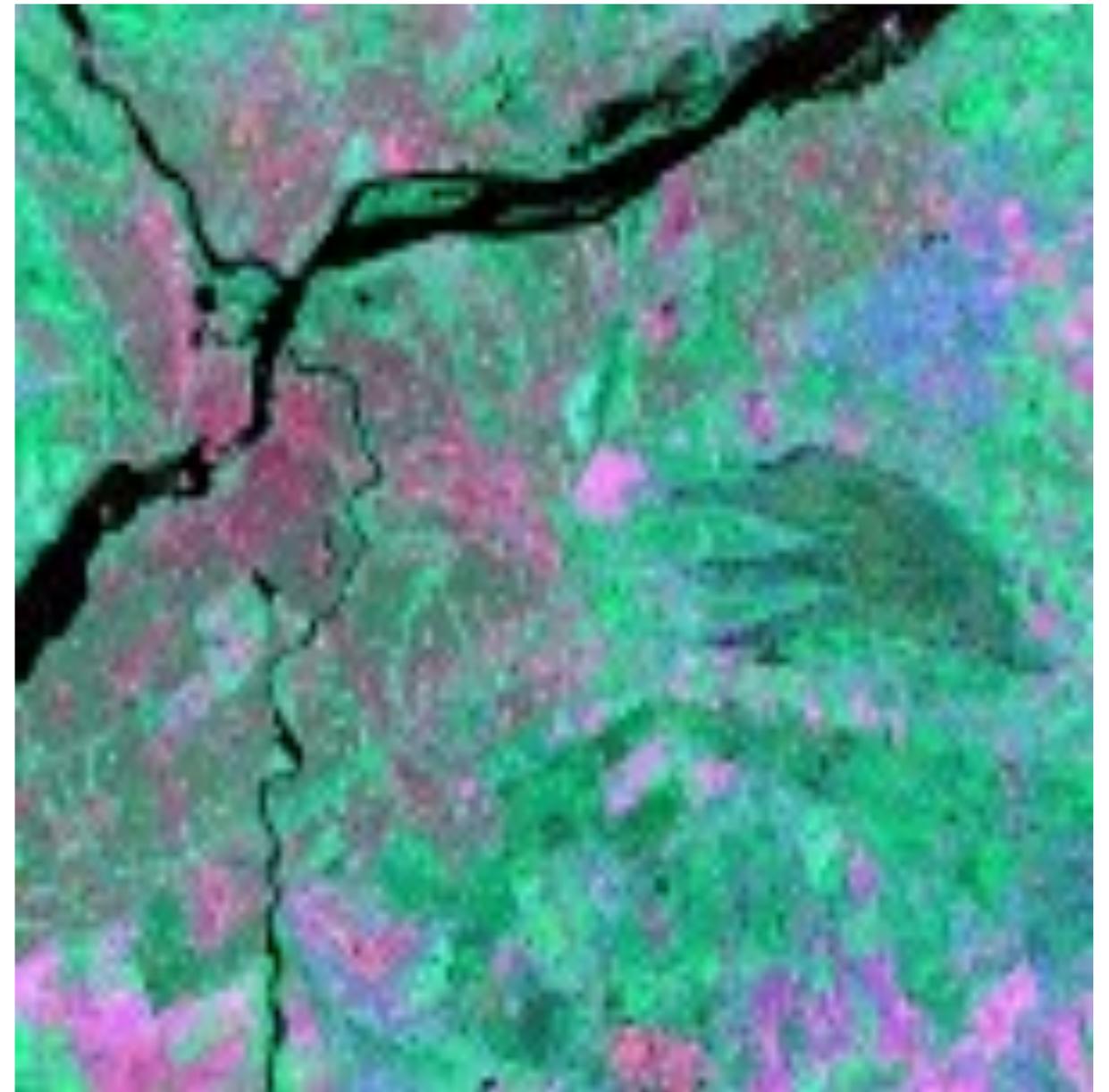
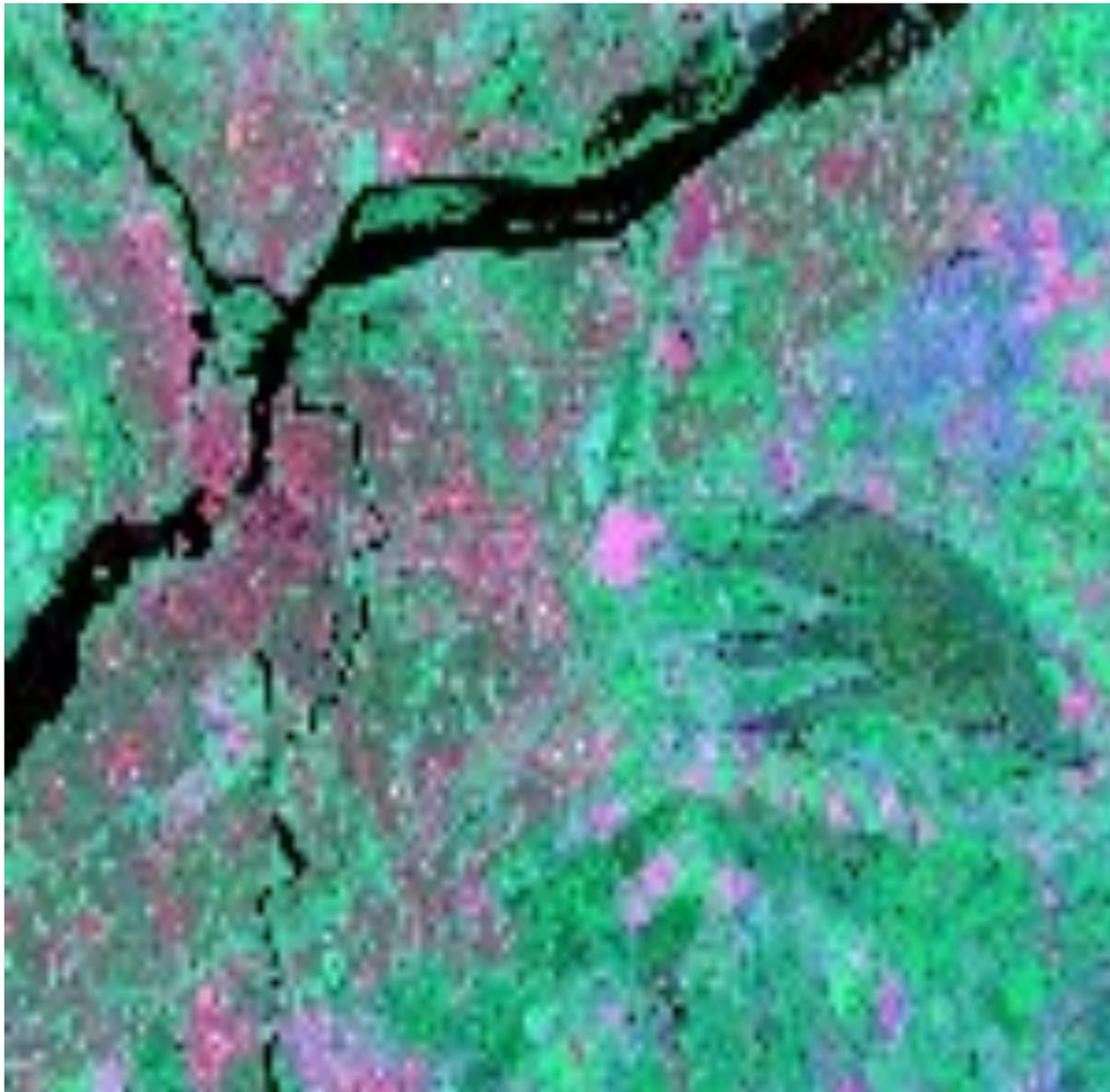
	2 6	2 5	2 3	2 2	2 2	
	2 5	2 6	2 5	2 4	2 6	
	2 5	2 7	2 7	2 7	2 6	
	2 3	2 6	2 8	2 9	2 7	
	2 2	2 5	2 7	2 7	2 5	

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

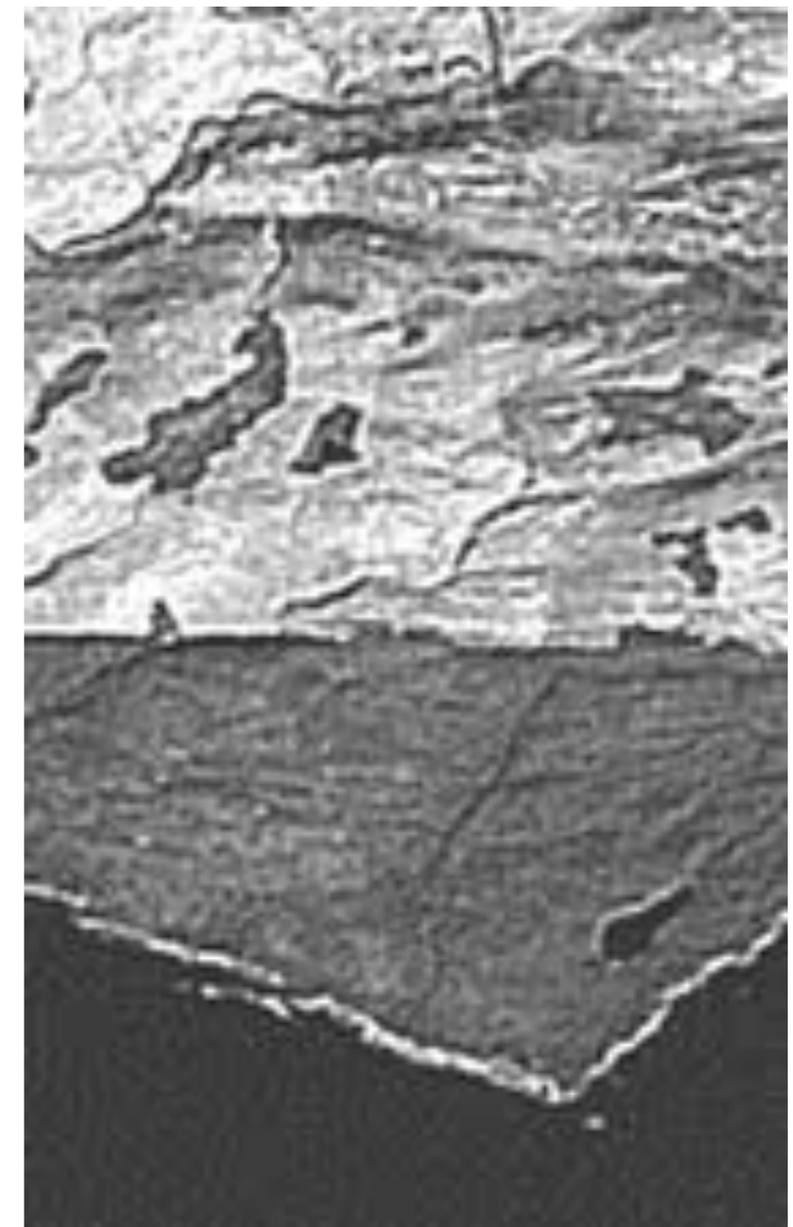
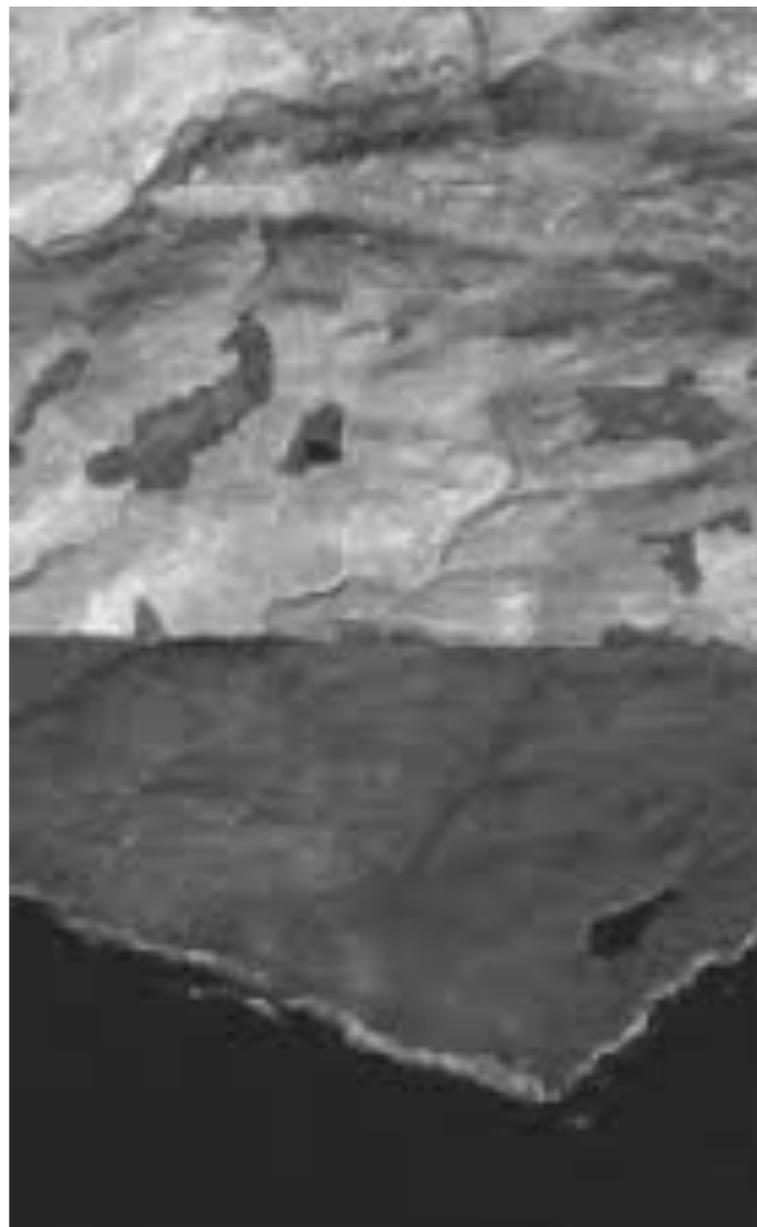
## ► Filtro passa-altas

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

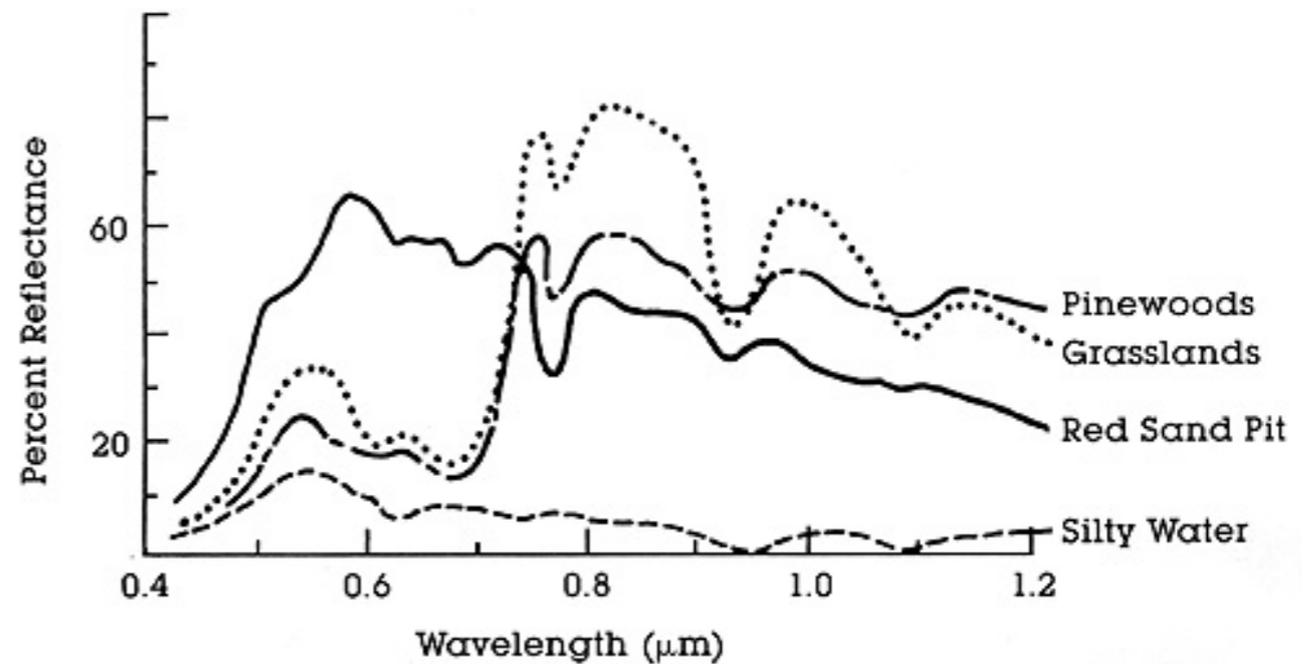
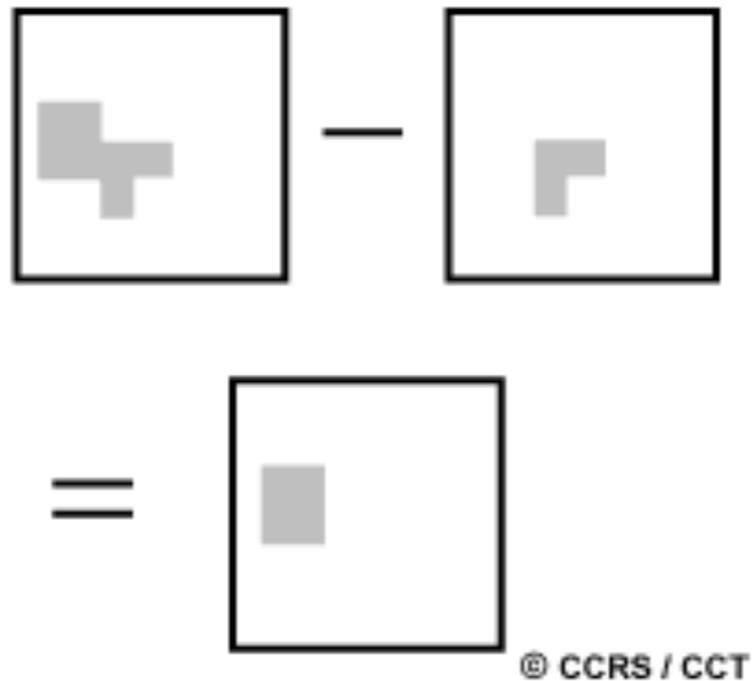
Exemplos de filtros Laplacianos + Original

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



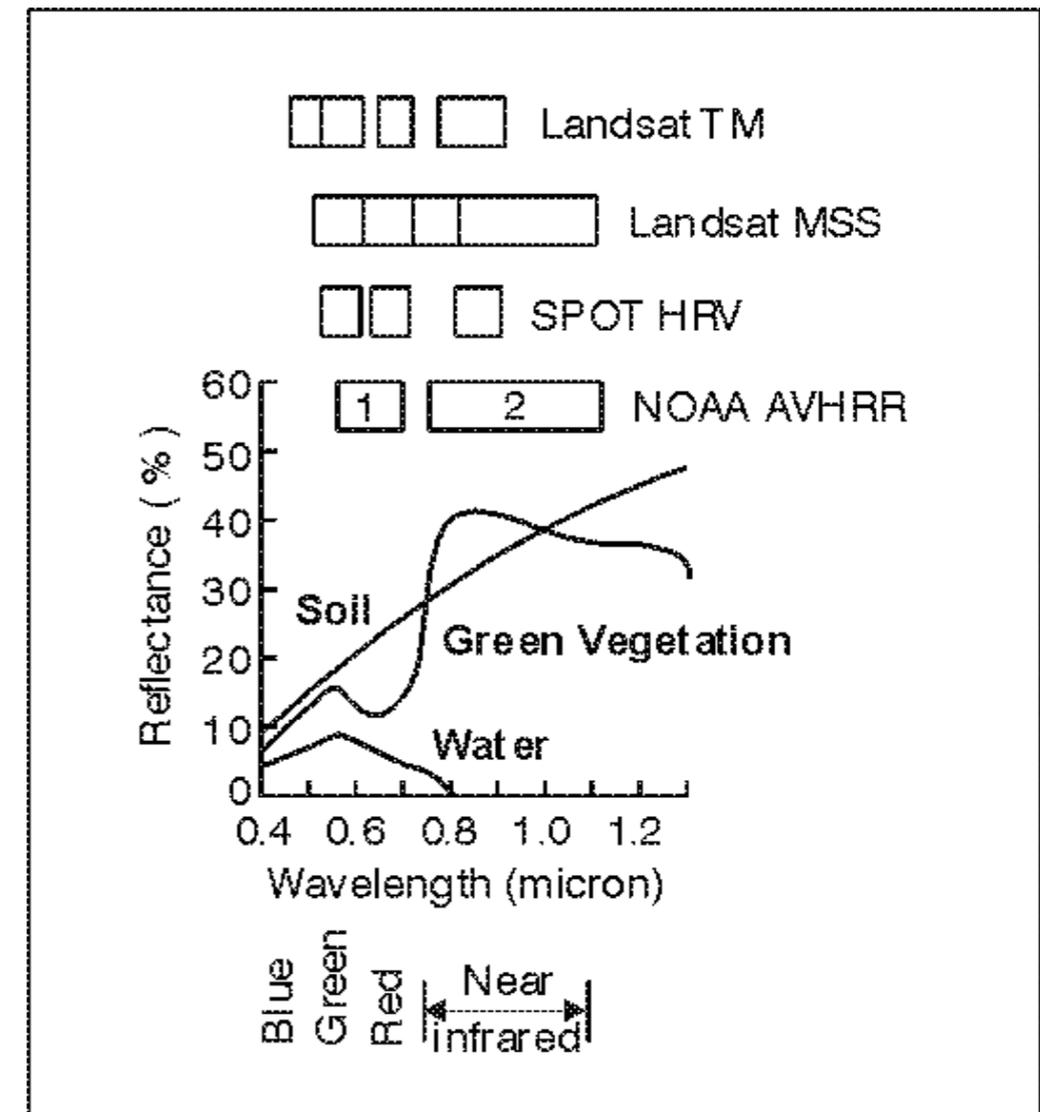
# OPERAÇÕES EM SR

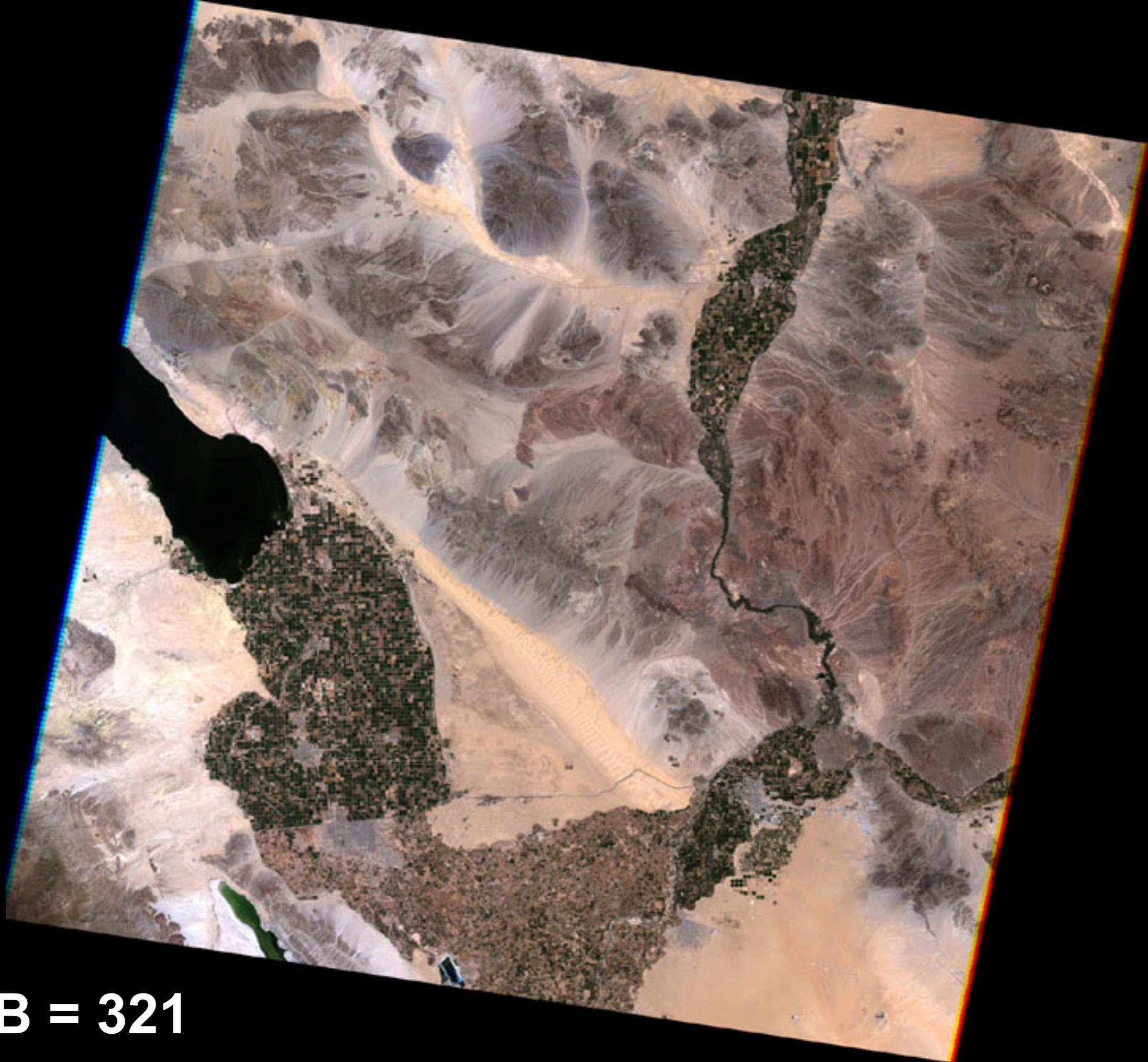
- ▶ Operações aritméticas
- ▶ Subtração: mais usada em análise temporal
- ▶ Razão: realça diferenças de comportamentos espectrais



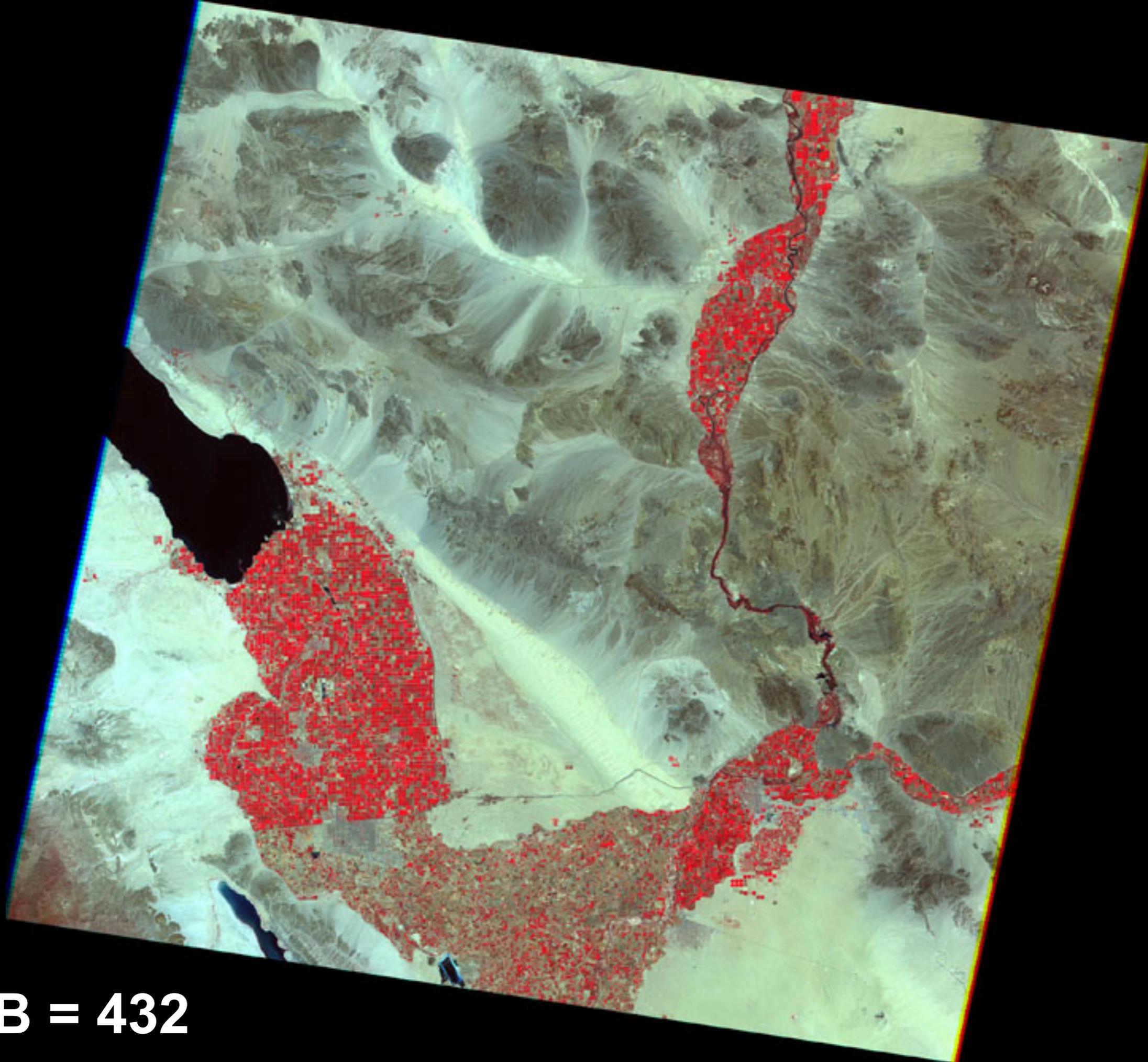
# OPERAÇÕES EM SR

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

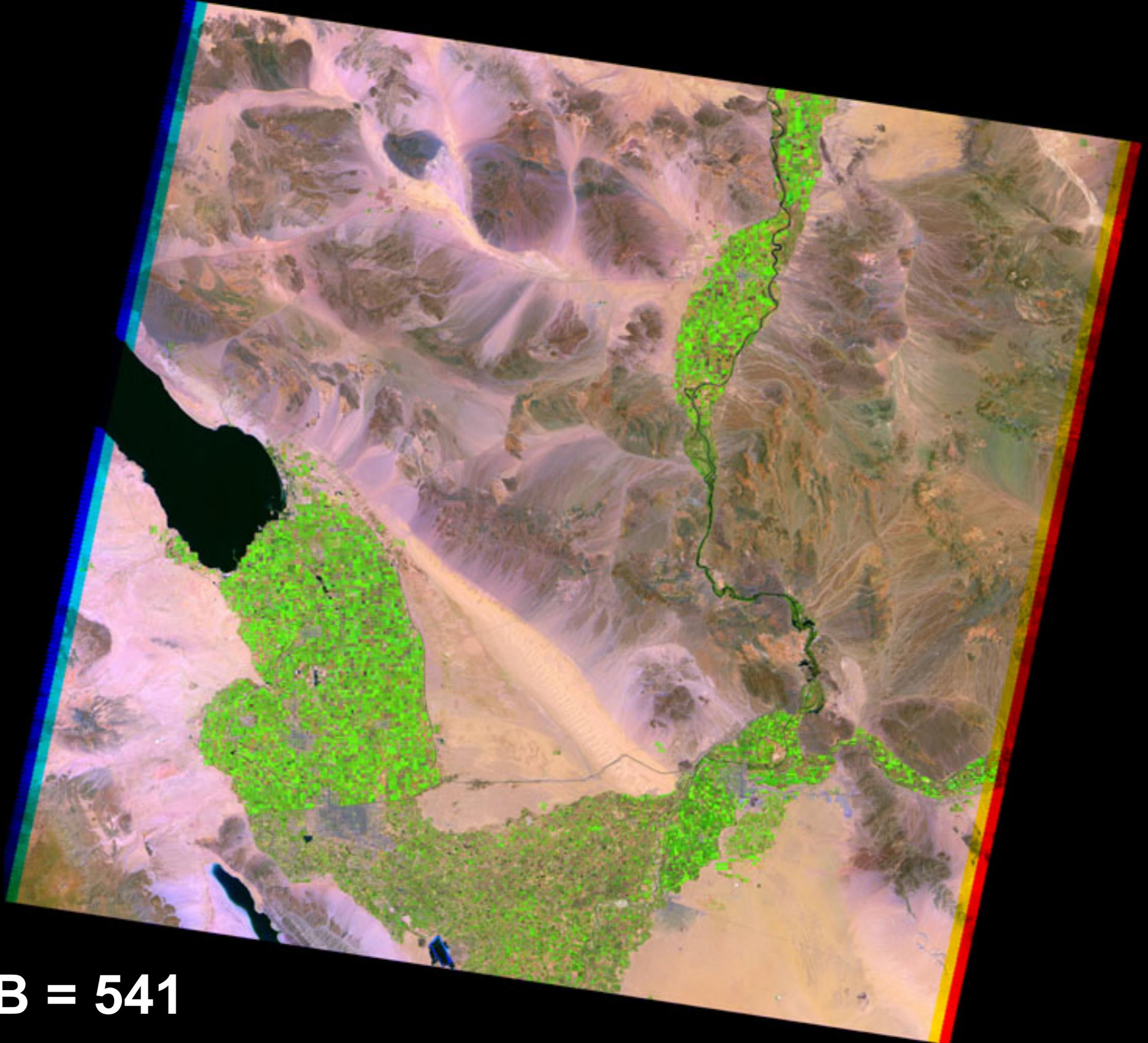




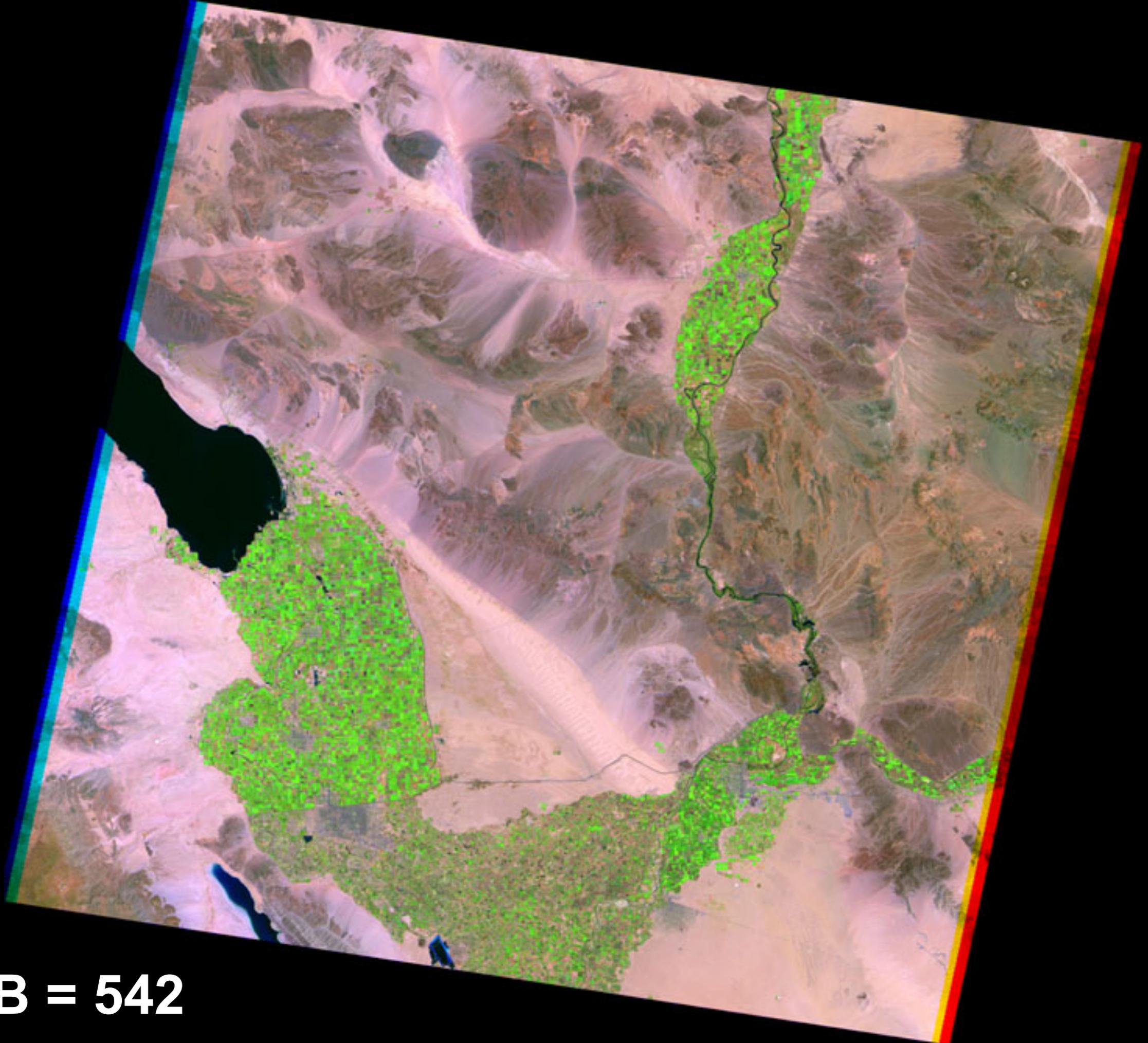
**RGB = 321**



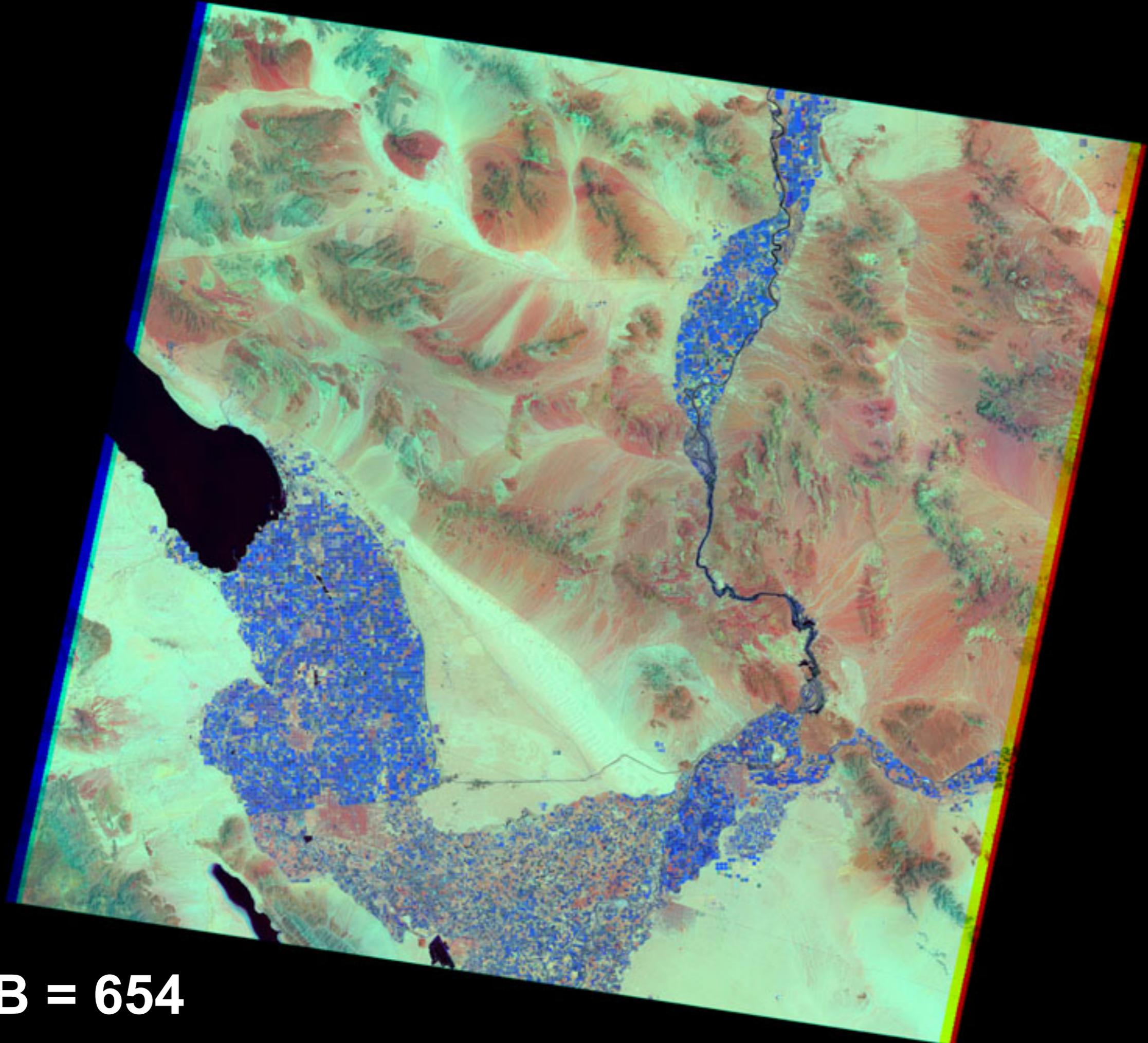
**RGB = 432**



**RGB = 541**



**RGB = 542**



**RGB = 654**

# OPERAÇÕES EM SR

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

- ▶  $NDVI = (NIR - R) / (NIR + R)$

- ▶ **ETM**

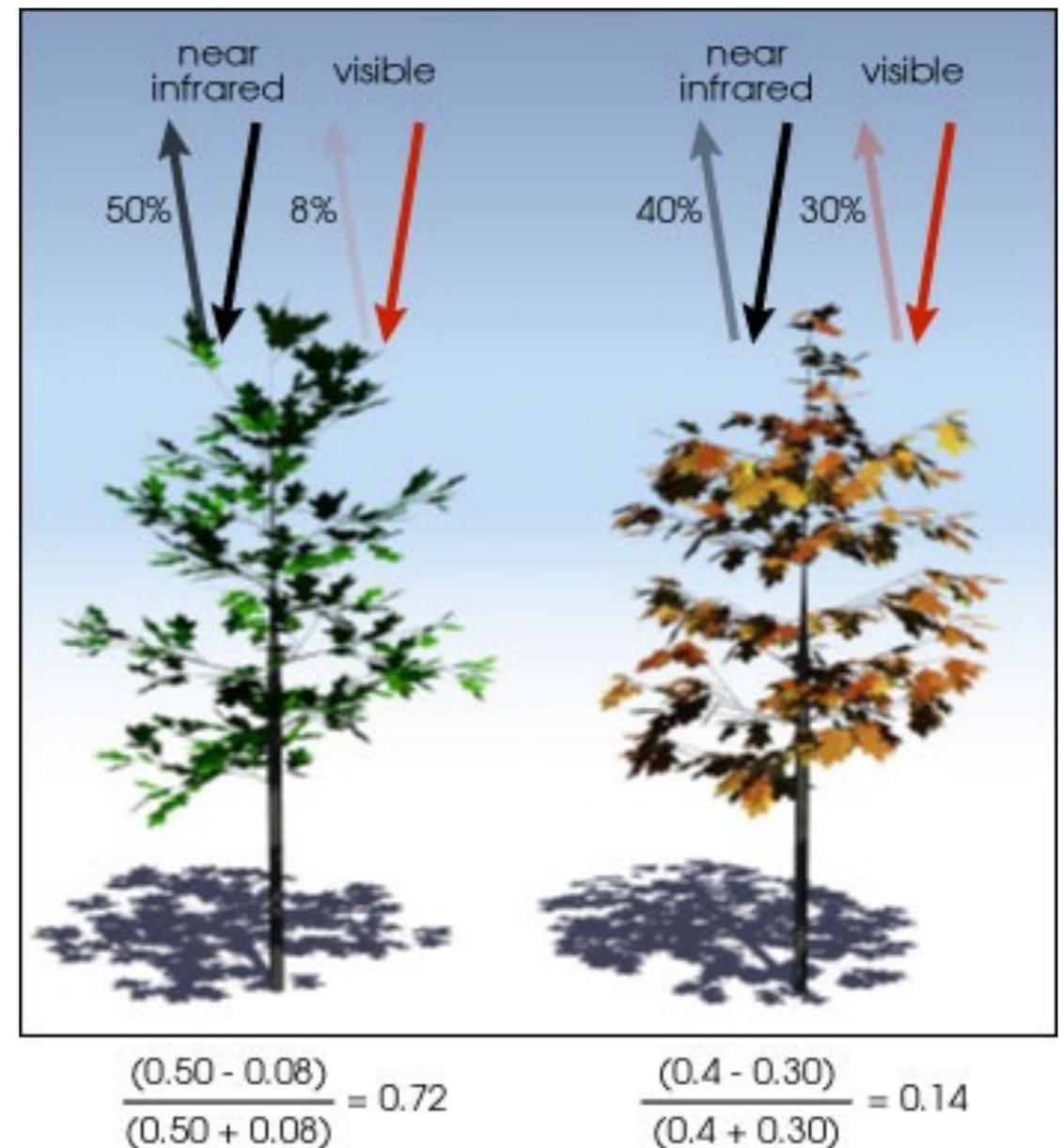
- ▶  $NDVI = (4 - 3) / (4 + 3)$

- ▶ **AVHRR**

- ▶  $NDVI = (2 - 1) / (2 + 1)$

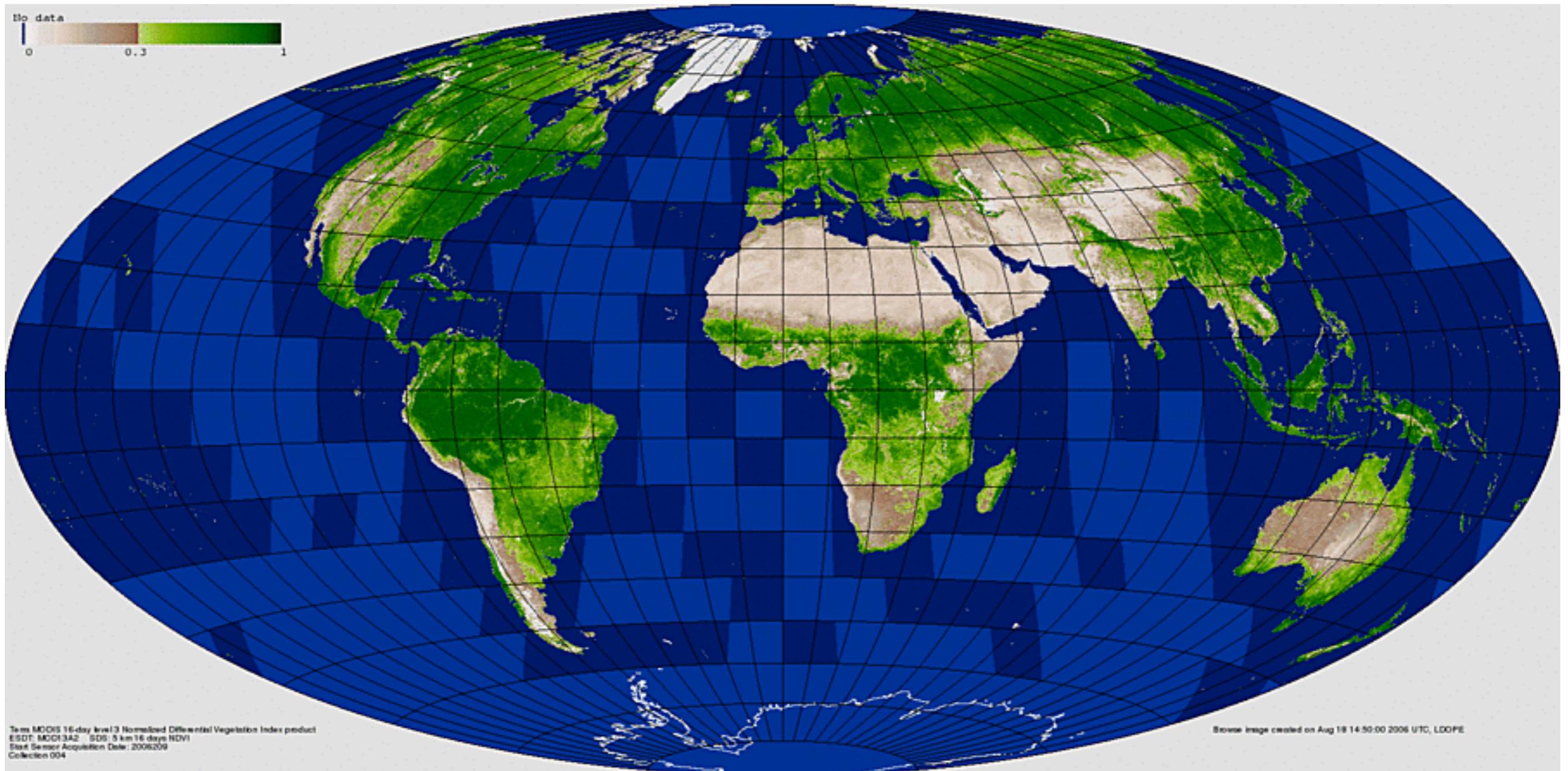
- ▶ **MODIS**

- ▶  $NDVI = (2 - 1) / (2 + 1)$



# OPERAÇÕES EM SR

- ▶ Normalized Difference Vegetation Index (NDVI)

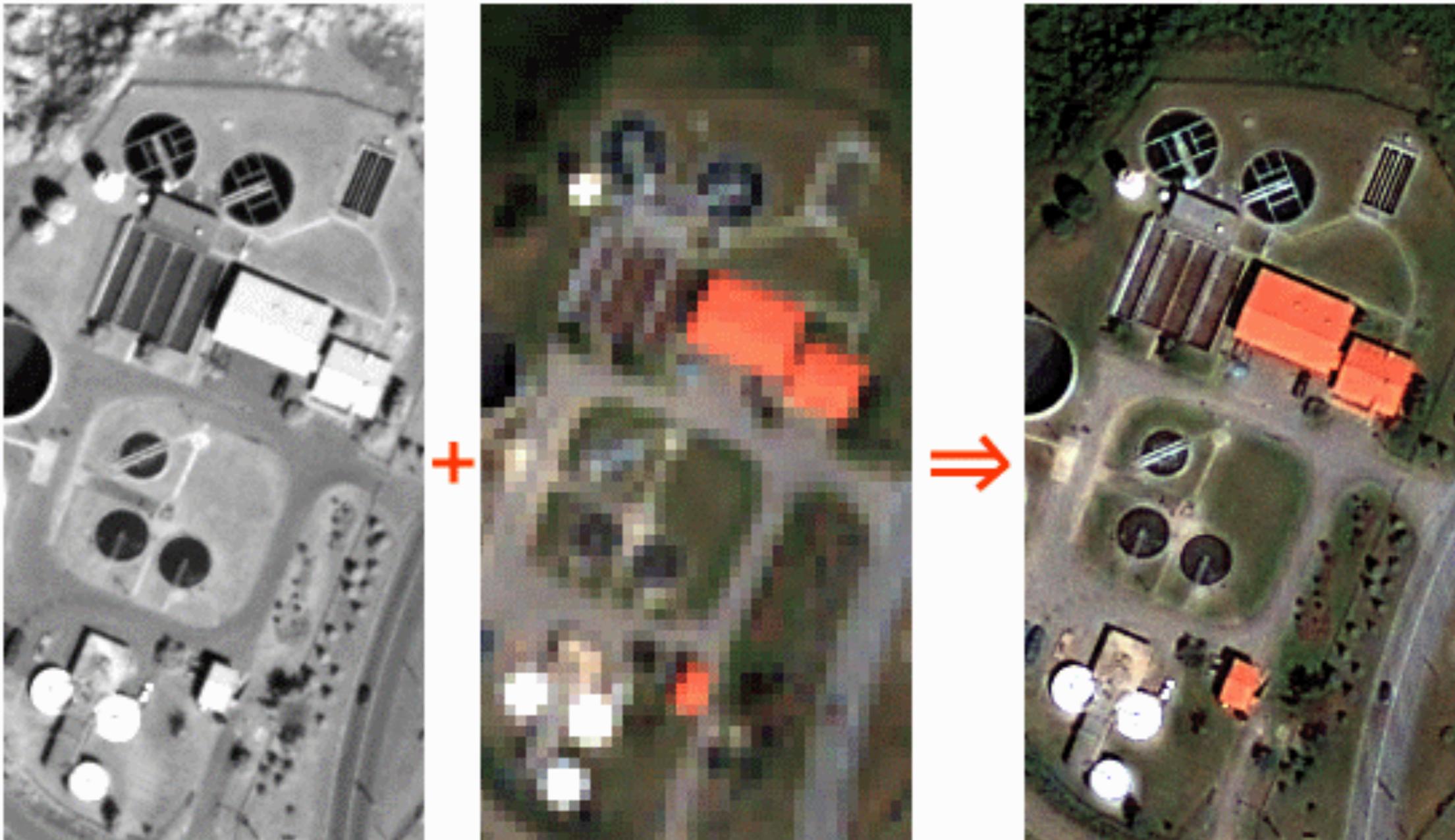


## OPERAÇÕES EM SR

- ▶ **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 Terrestres
  - ▶ Landsat, SPOT, CBERS, ASTER
  - ▶ RADAR – Radarsat, JERS, SRTM
- ▶ Alta Resolução
  - ▶ Ikonos, QuickBird
- ▶ Hiperespectrais
  - ▶ Hyperion

# SATÉLITES METEOROLÓGICOS

- ▶ GOES - Geostationary Operational Environmental Satellite

Band	Wavelength Range ( $\mu\text{m}$ )	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

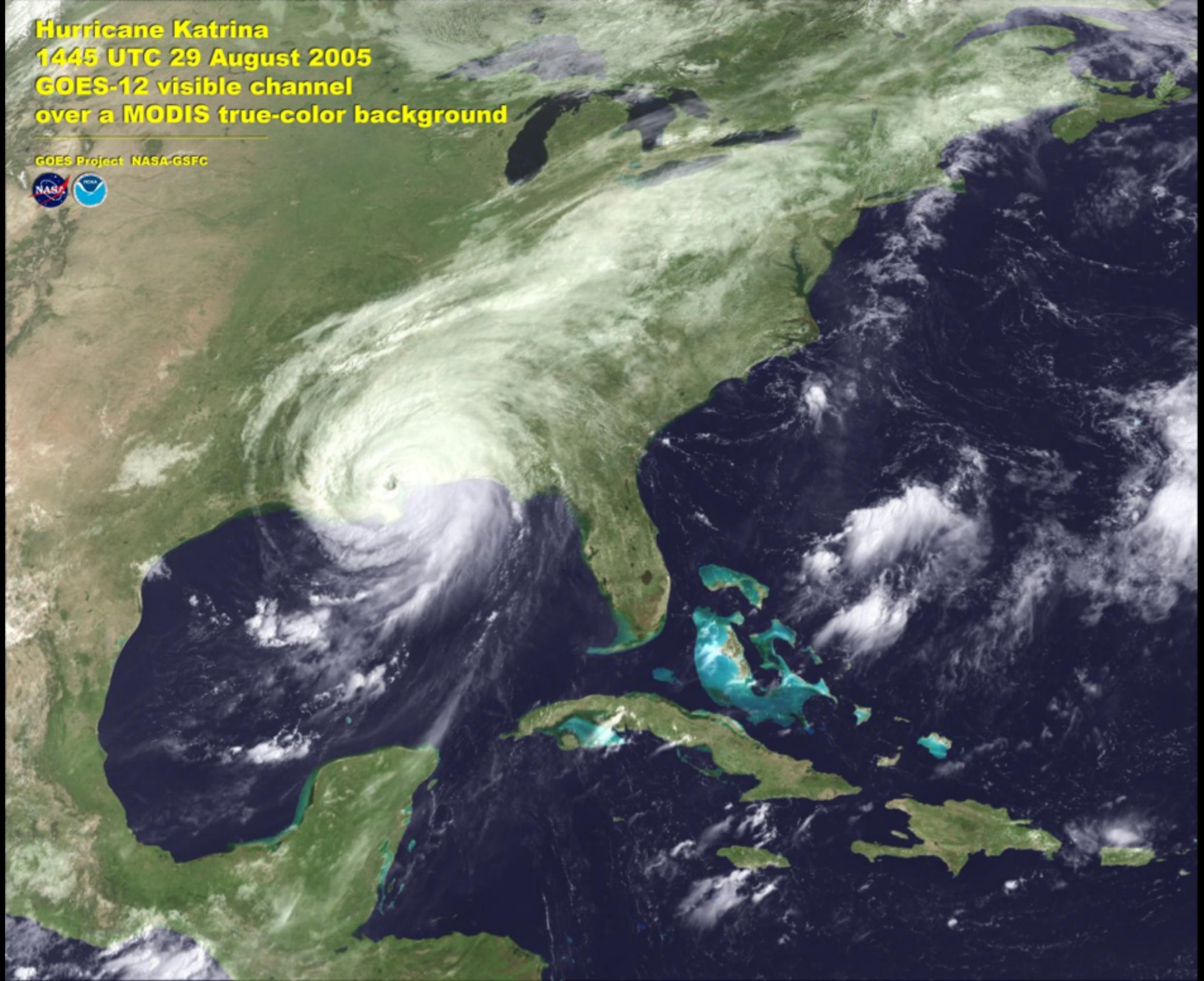
# SATÉLITES METEOROLÓGICOS

- ▶ NOAA AVHRR (Advanced Very High Resolution Radiometer)

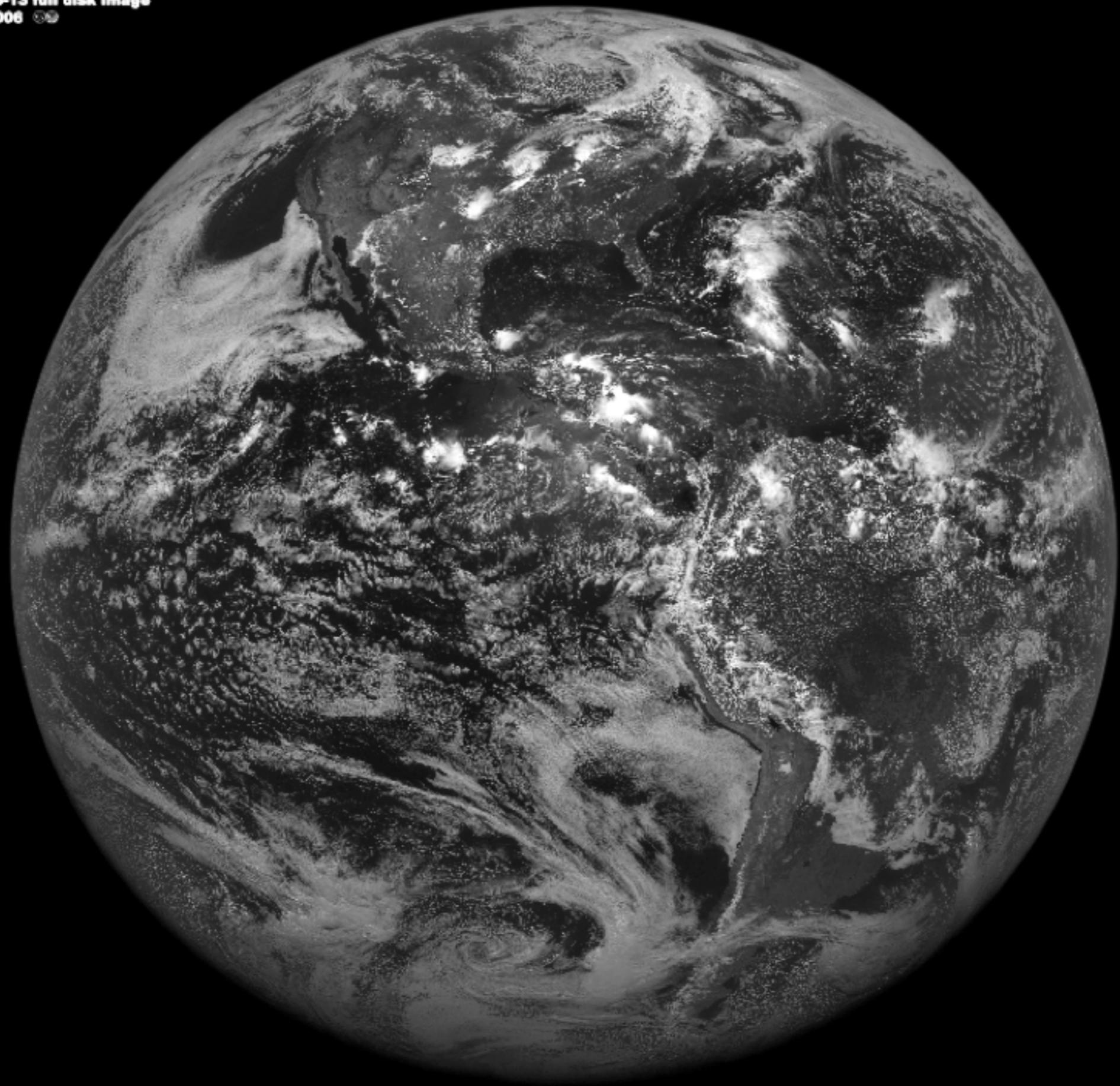
<b>Band</b>	<b>Wavelength Range (μm)</b>	<b>Spatial Resolution</b>	<b>Application</b>
1	0.58 - 0.68 (red)	1.1 km	cloud, snow, and ice monitoring
2	0.725 - 1.1 (near IR)	1.1 km	water, vegetation, and agriculture surveys
3	3.55 -3.93 (mid IR)	1.1 km	sea surface temperature, volcanoes, and forest fire activity
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

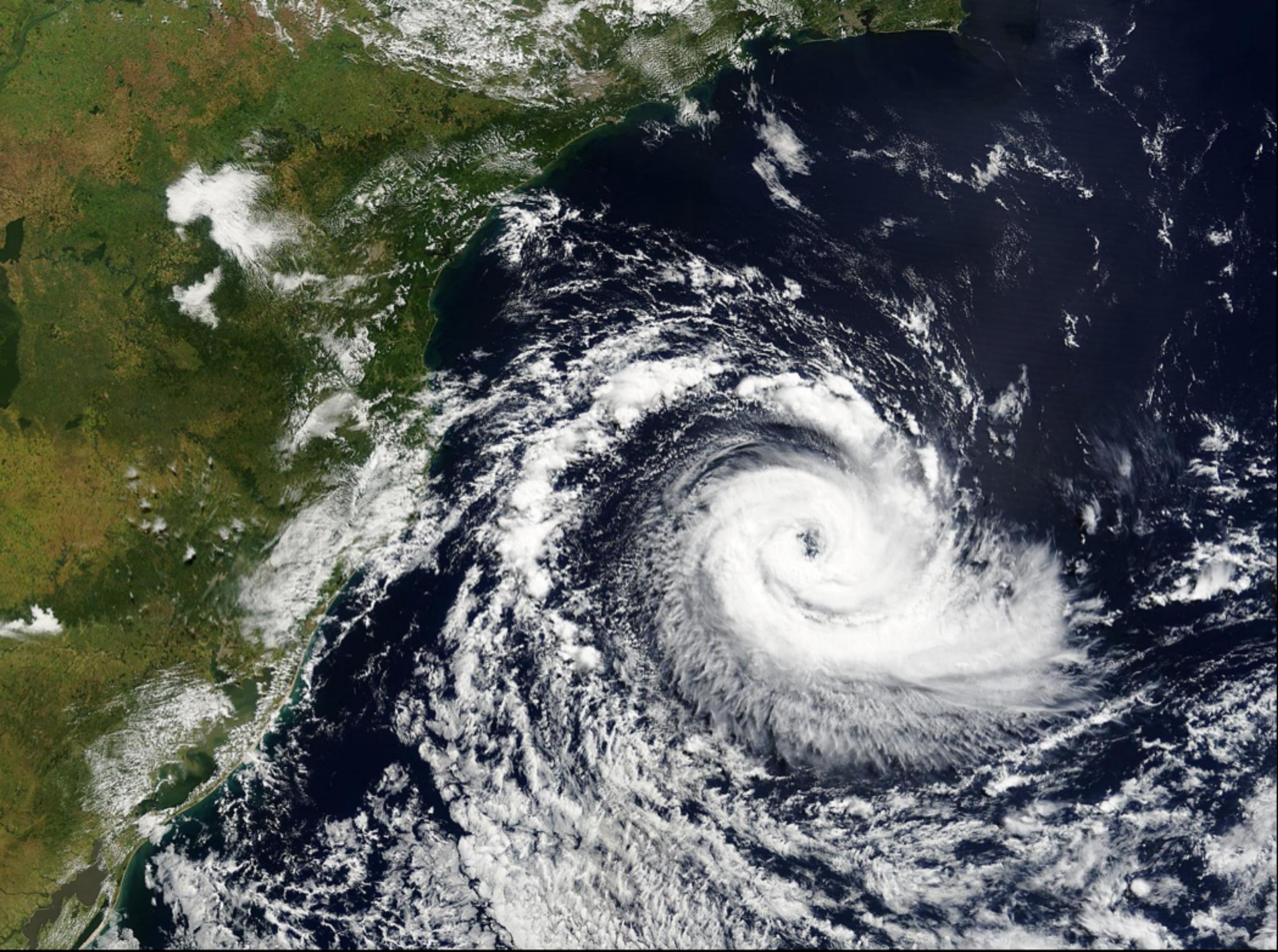
**Hurricane Katrina**  
**1445 UTC 29 August 2005**  
**GOES-12 visible channel**  
**over a MODIS true-color background**

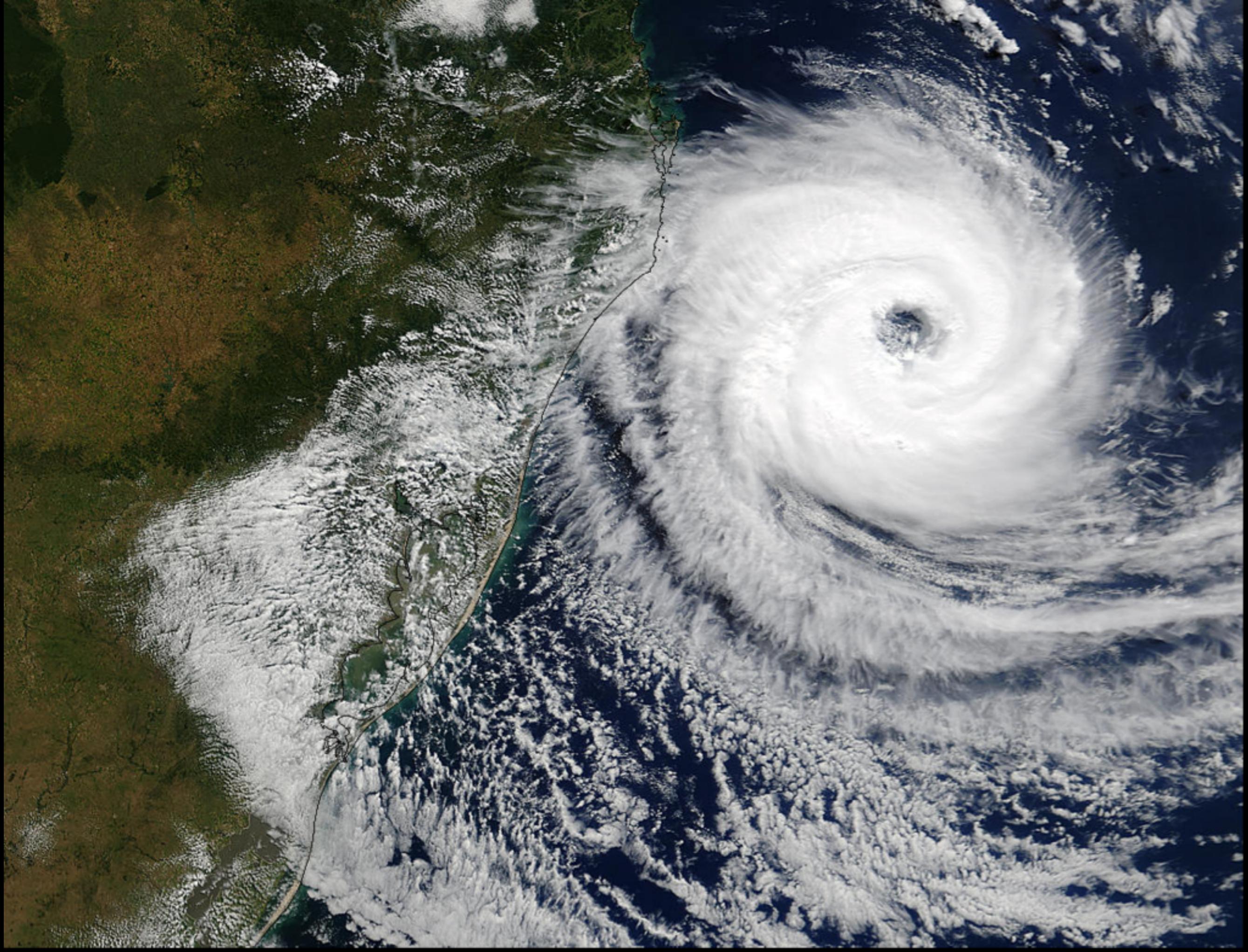
GOES Project NASA-GSFC



First GOES-13 full disk image  
22 June 2006 ©

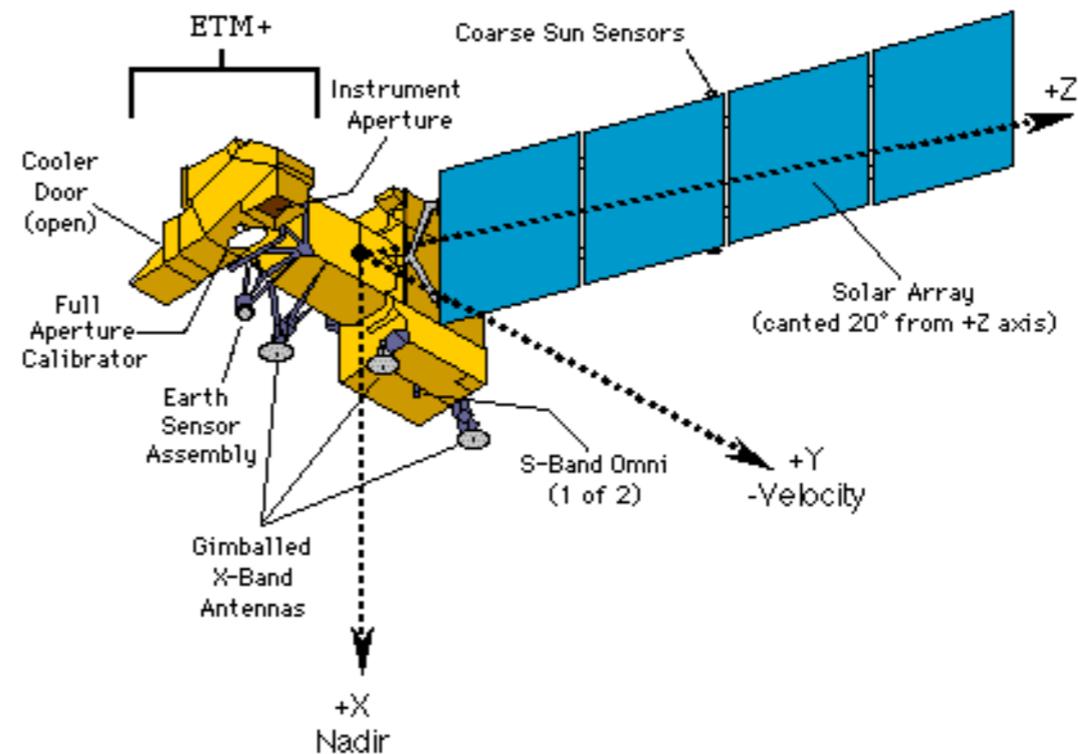
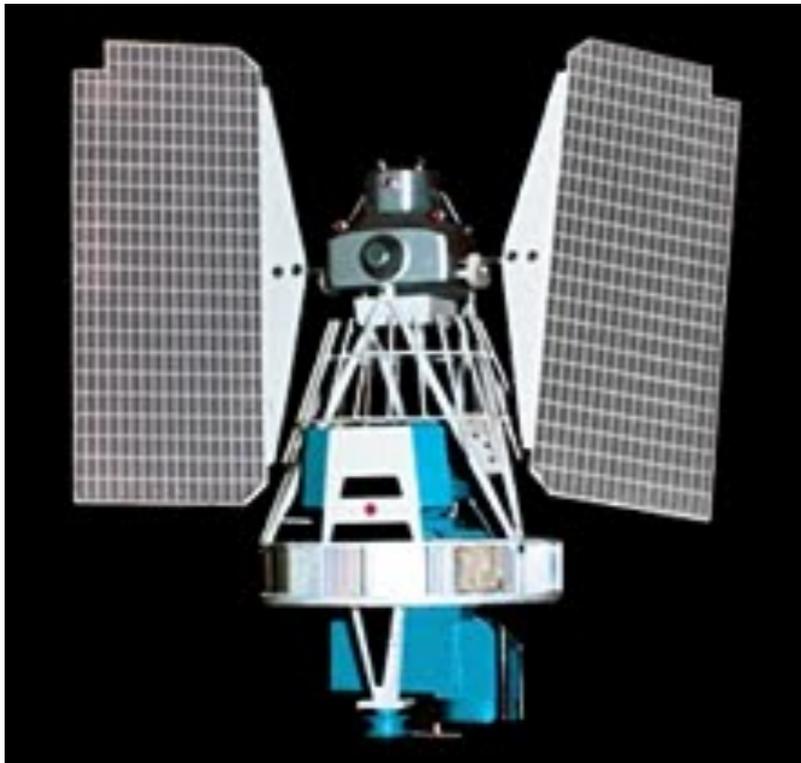






# SATÉLITES DE RECURSOS TERRESTRES

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



# LANDSAT TM

Channel	Wavelength Range ( $\mu\text{m}$ )	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

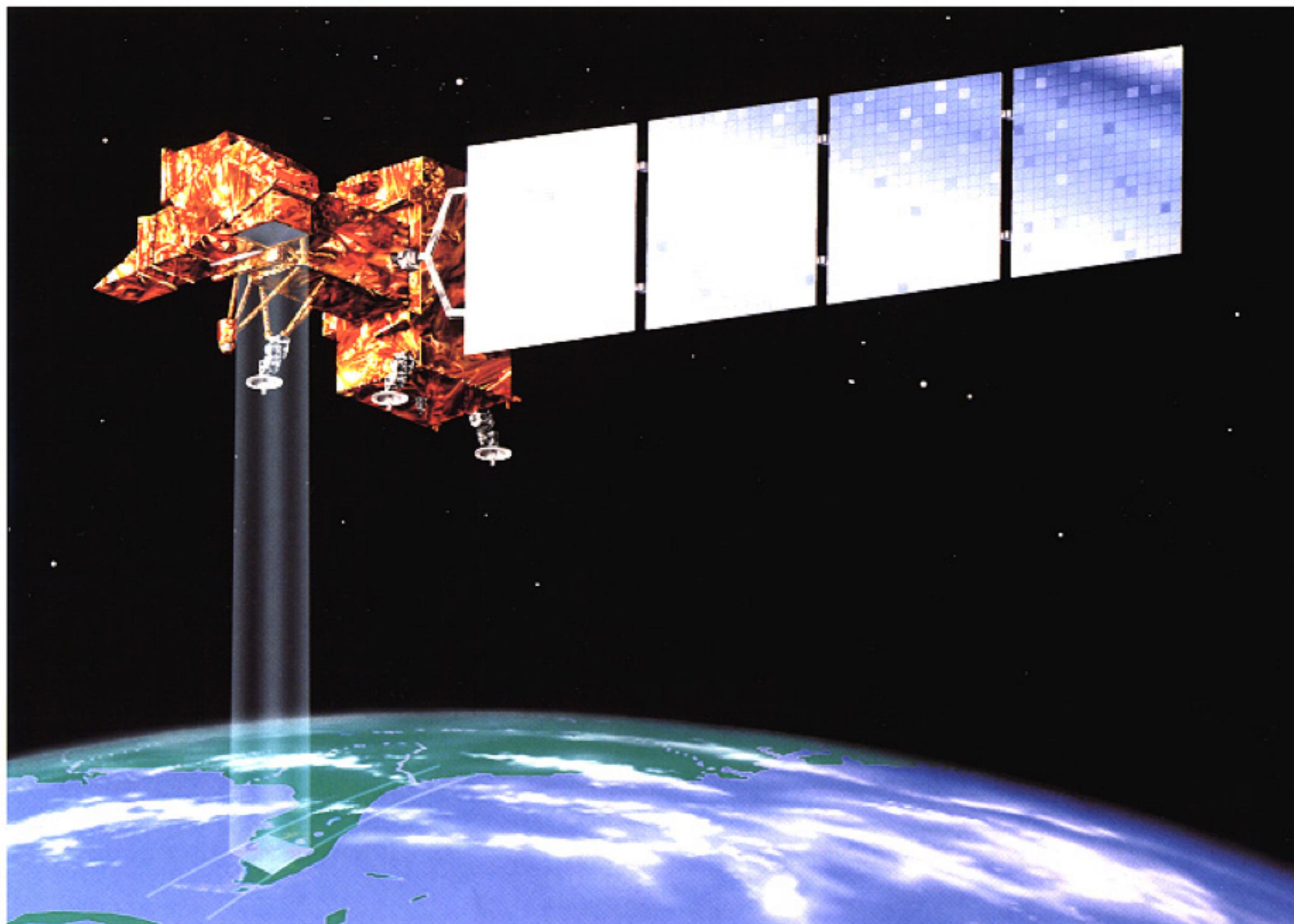


National Aeronautics and  
Space Administration  
Goddard Space Flight Center

# LANDSAT 7

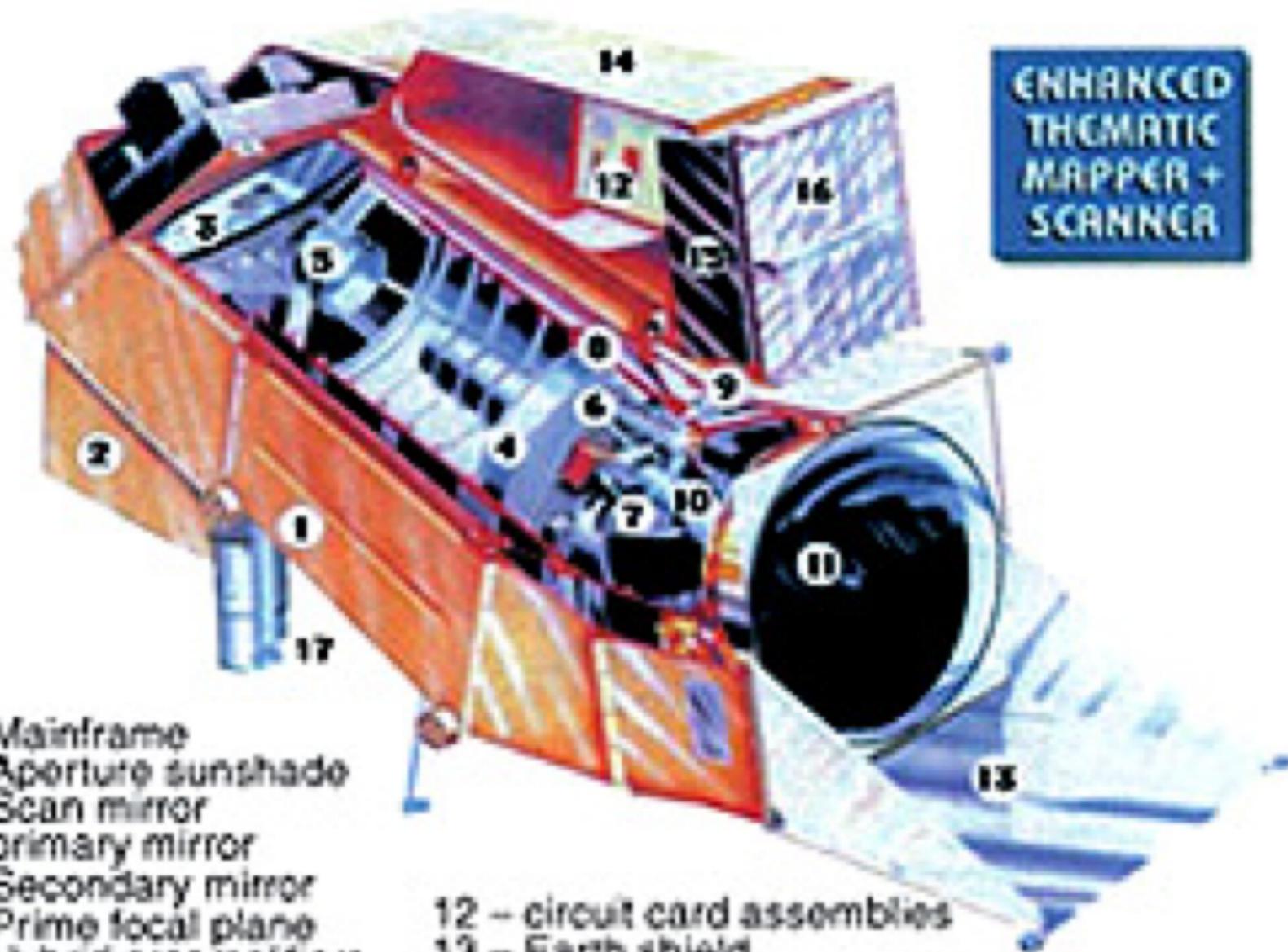


science for a changing world U. S. Geological Survey



# Landsat-7 ETM+

## ENHANCED THEMATIC MAPPER + SCANNER



- 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

- 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





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

<b>Mode/Band</b>	<b>Wavelength Range (<math>\mu\text{m}</math>)</b>
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)

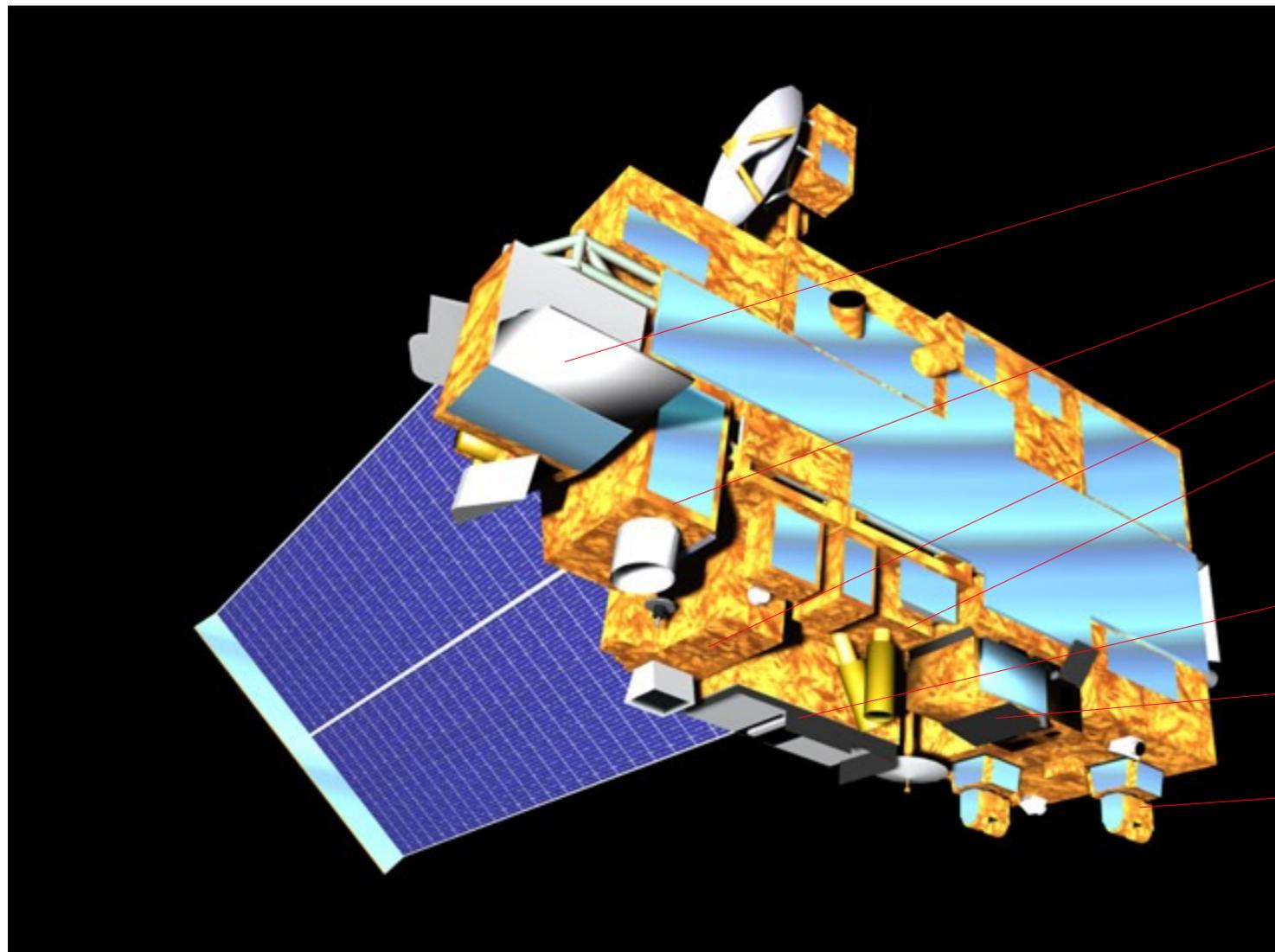
# TERRA

- ▶ 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!***



MODIS

***ASTER*** (TIR)

***ASTER*** (SWIR)

***ASTER*** (VNIR)

MISR

MOPITT

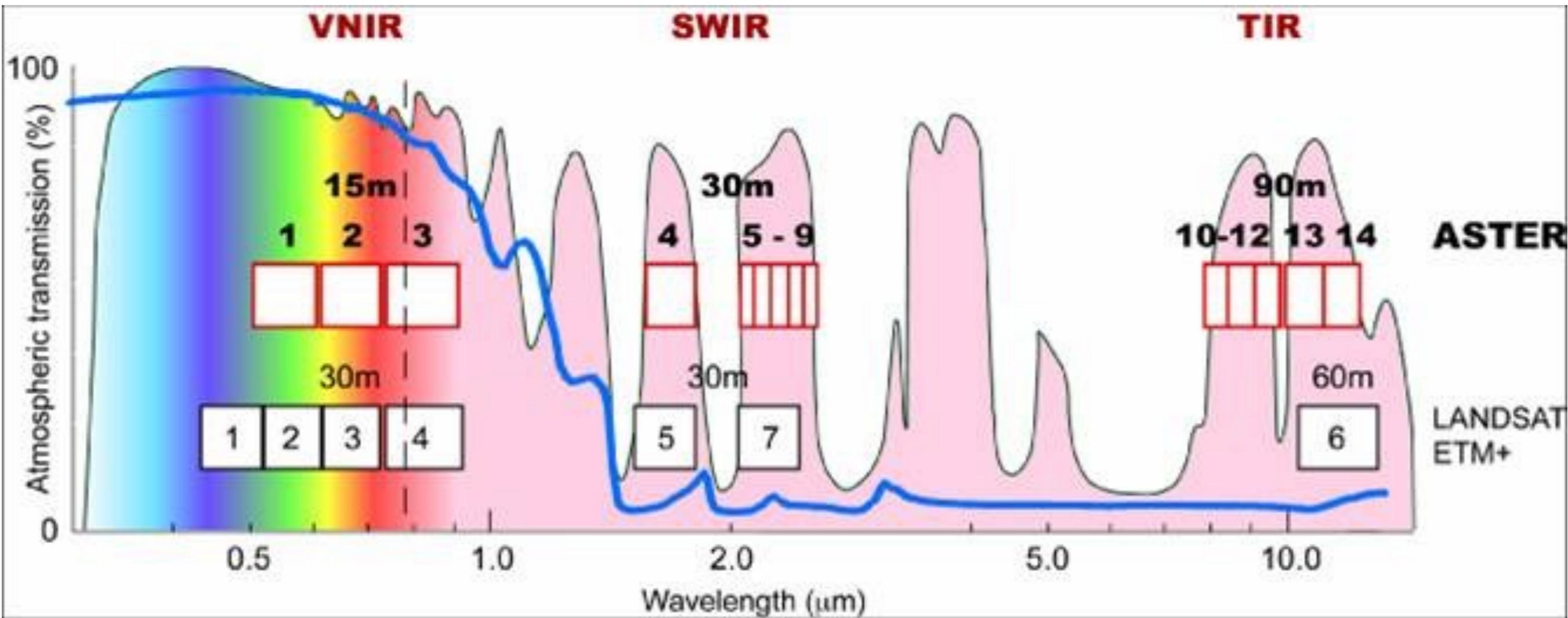
CERES

# ASTER

- ▶ Advanced Spaceborne Thermal and Emitted Radiometer

Subsystem	Band No.	Spectral Range ( $\mu\text{m}$ )	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		

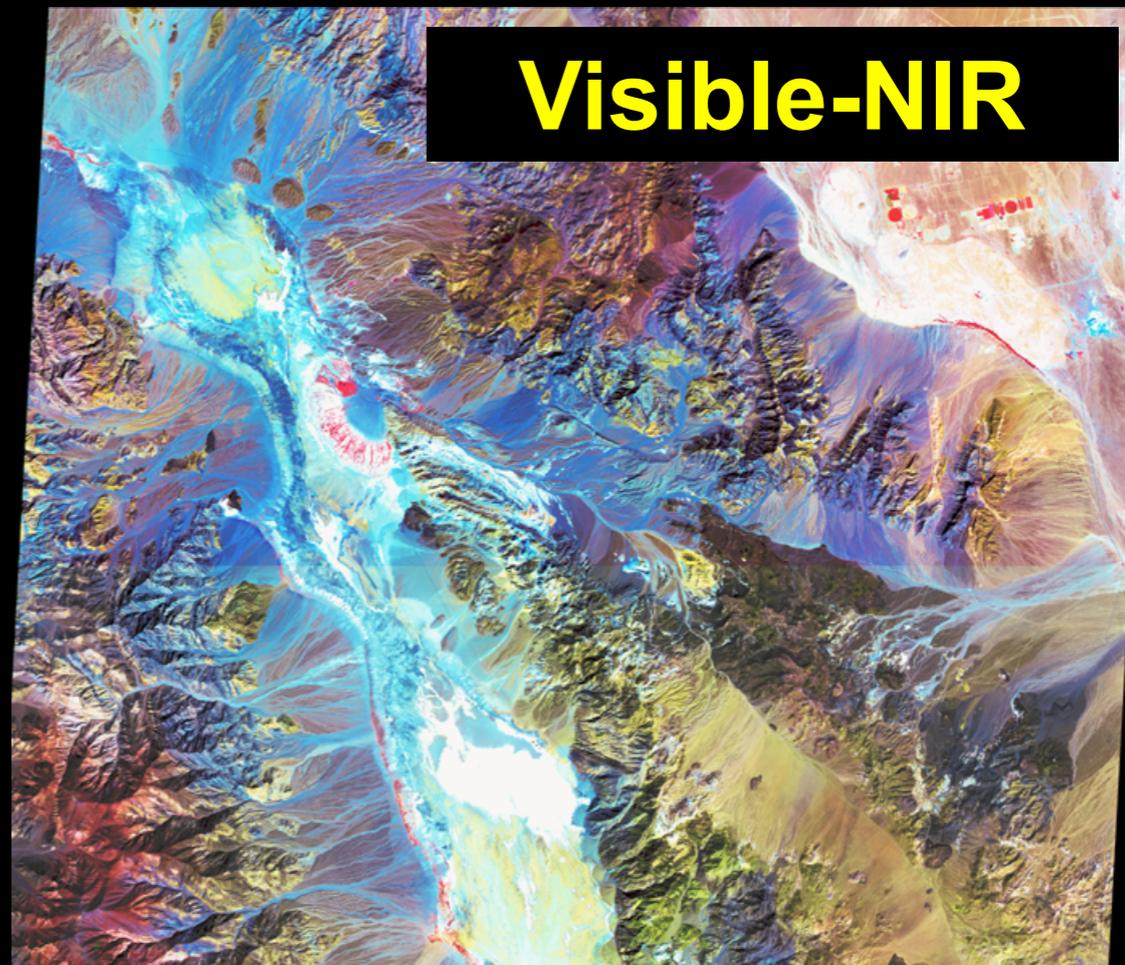
# ASTER



**Visible-NIR**



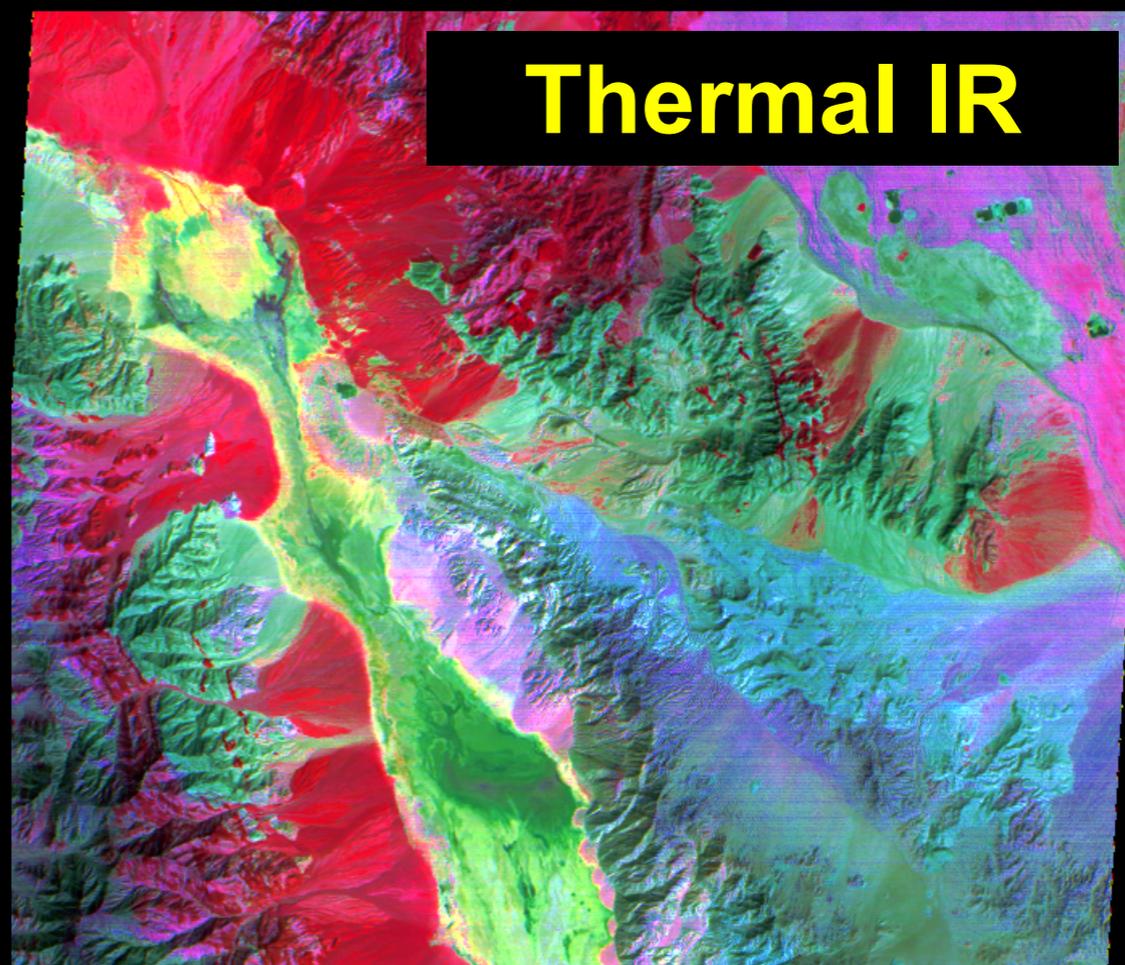
**Visible-NIR**



**Short Wave IR**

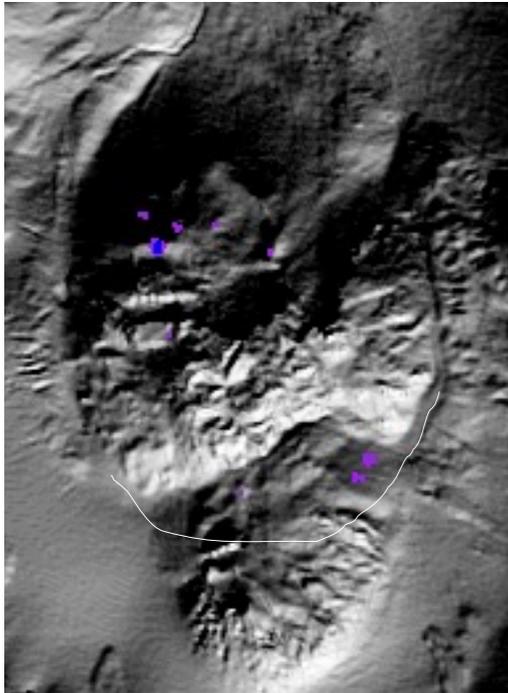


**Thermal IR**



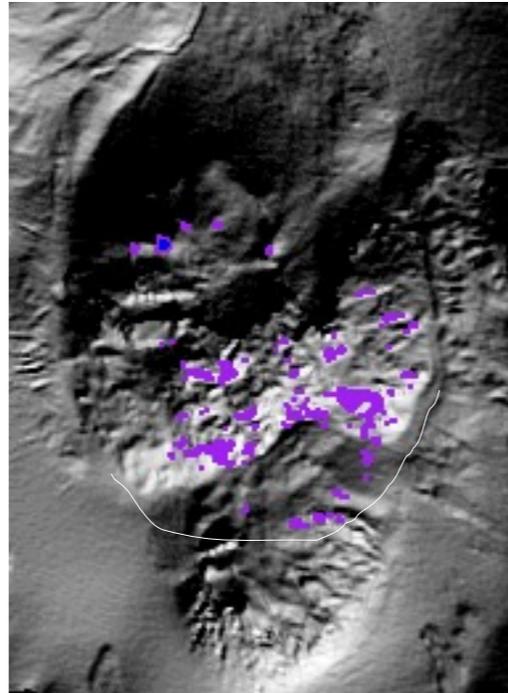
# MONITORAMENTO DE VULCÕES

09-24-2004 – 4:30pm



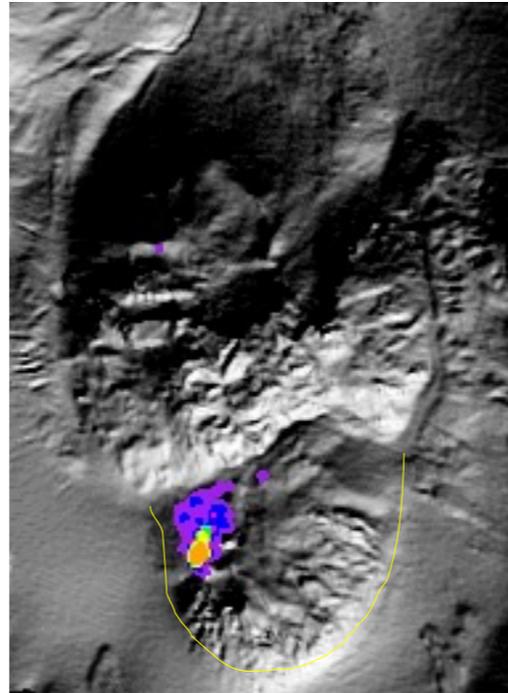
Boundary of Old Dome

09-30-2004 – 1:30pm



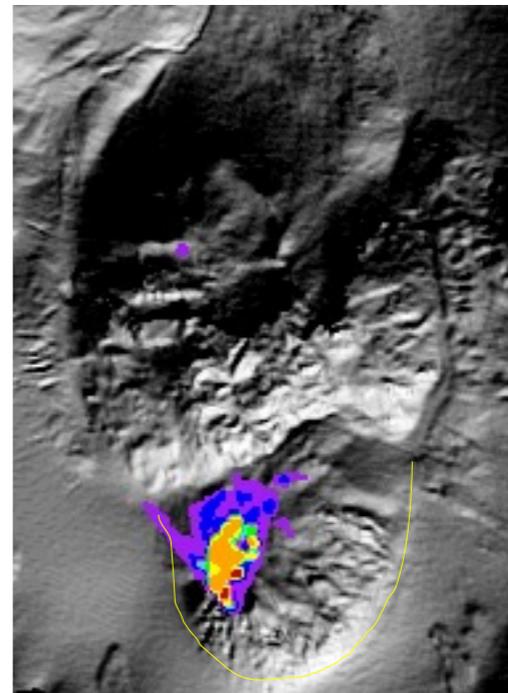
Boundary of Old Dome

10-12-2004 – 8:00am



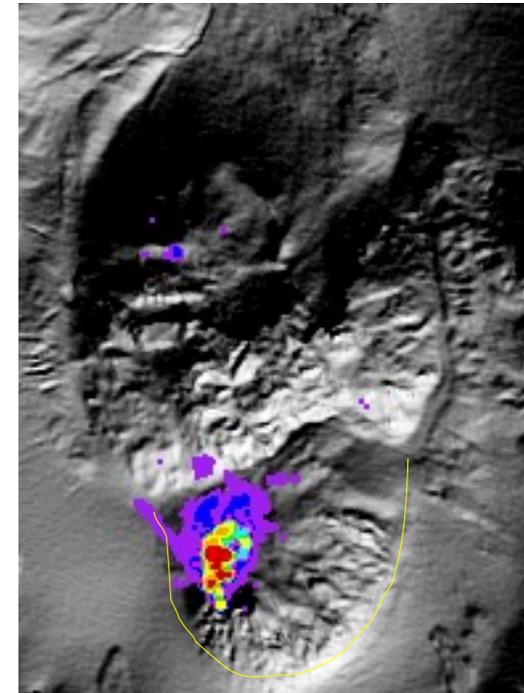
Boundary of New Dome

10-14-2004 – 8:00am



Boundary of New Dome

10-14-2004 – 12:45pm



Boundary of New Dome

High = 51 °C

High = 54 °C

High = 181 °C

High = 250 °C

High = 330 °C

60-75 °C

45-60 °C

30-45 °C

105-150 °C

90-105 °C

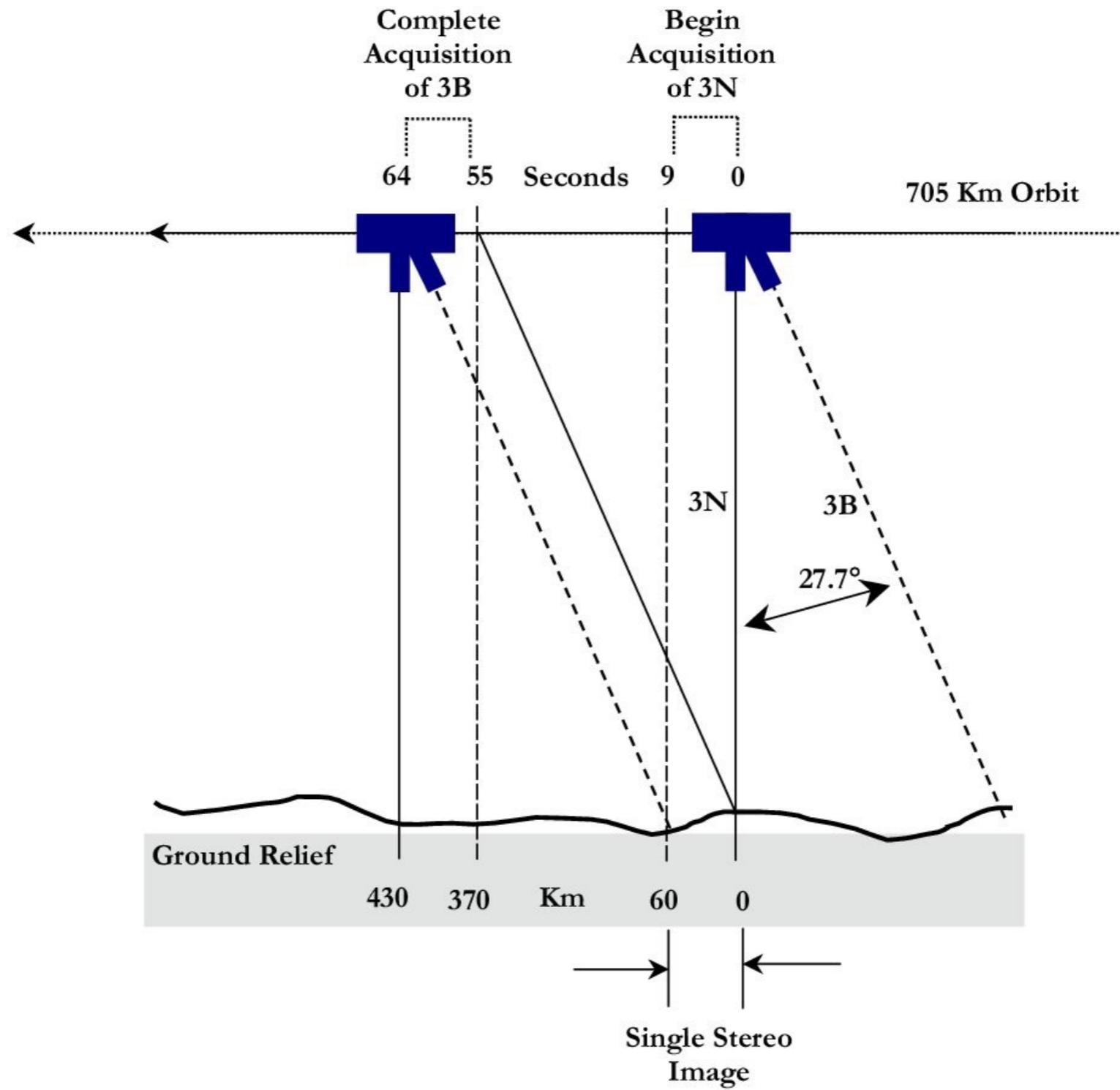
75-90 °C

> 300 °C

200-300 °C

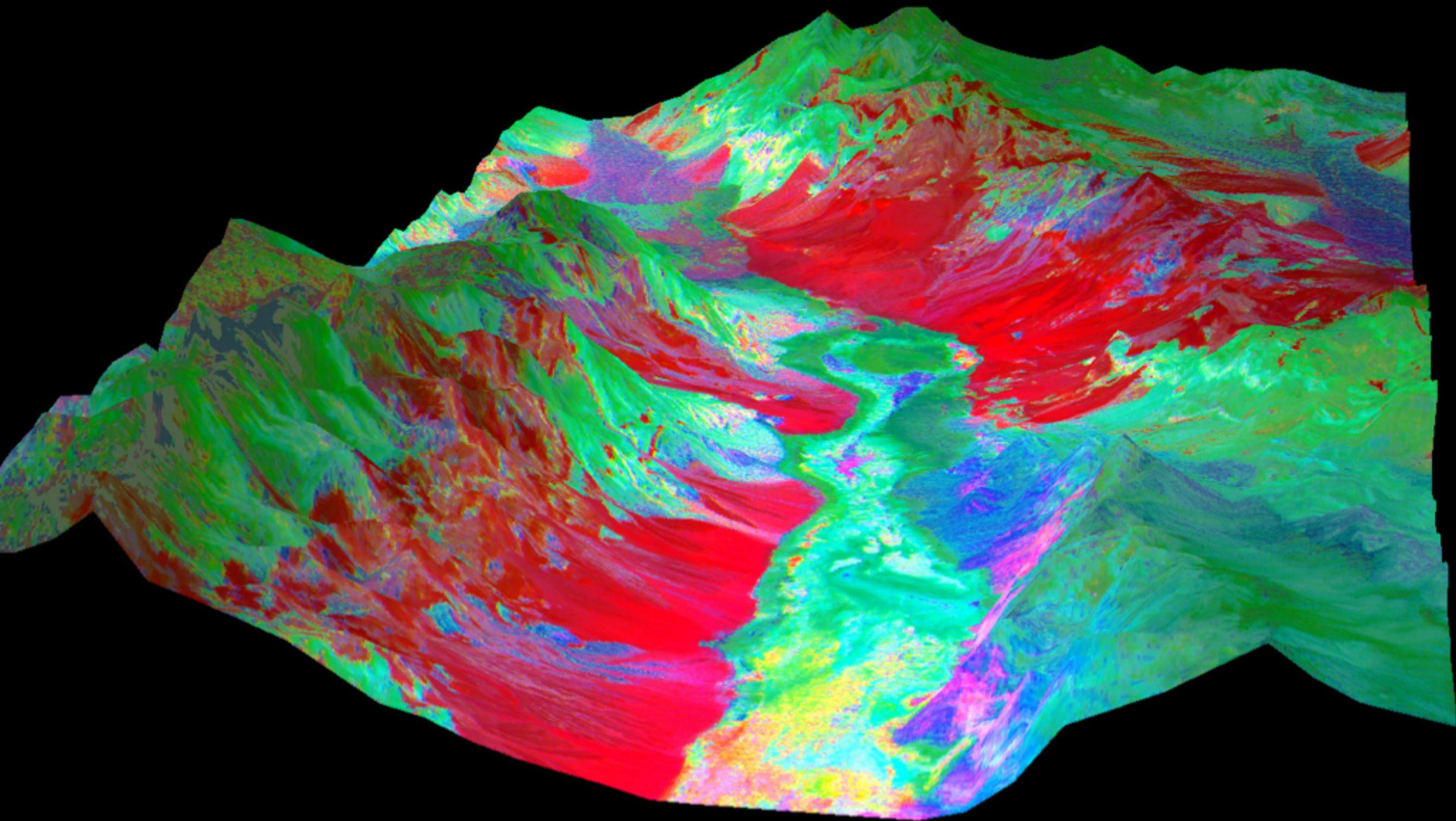
150-200 °C

# ASTER DEM



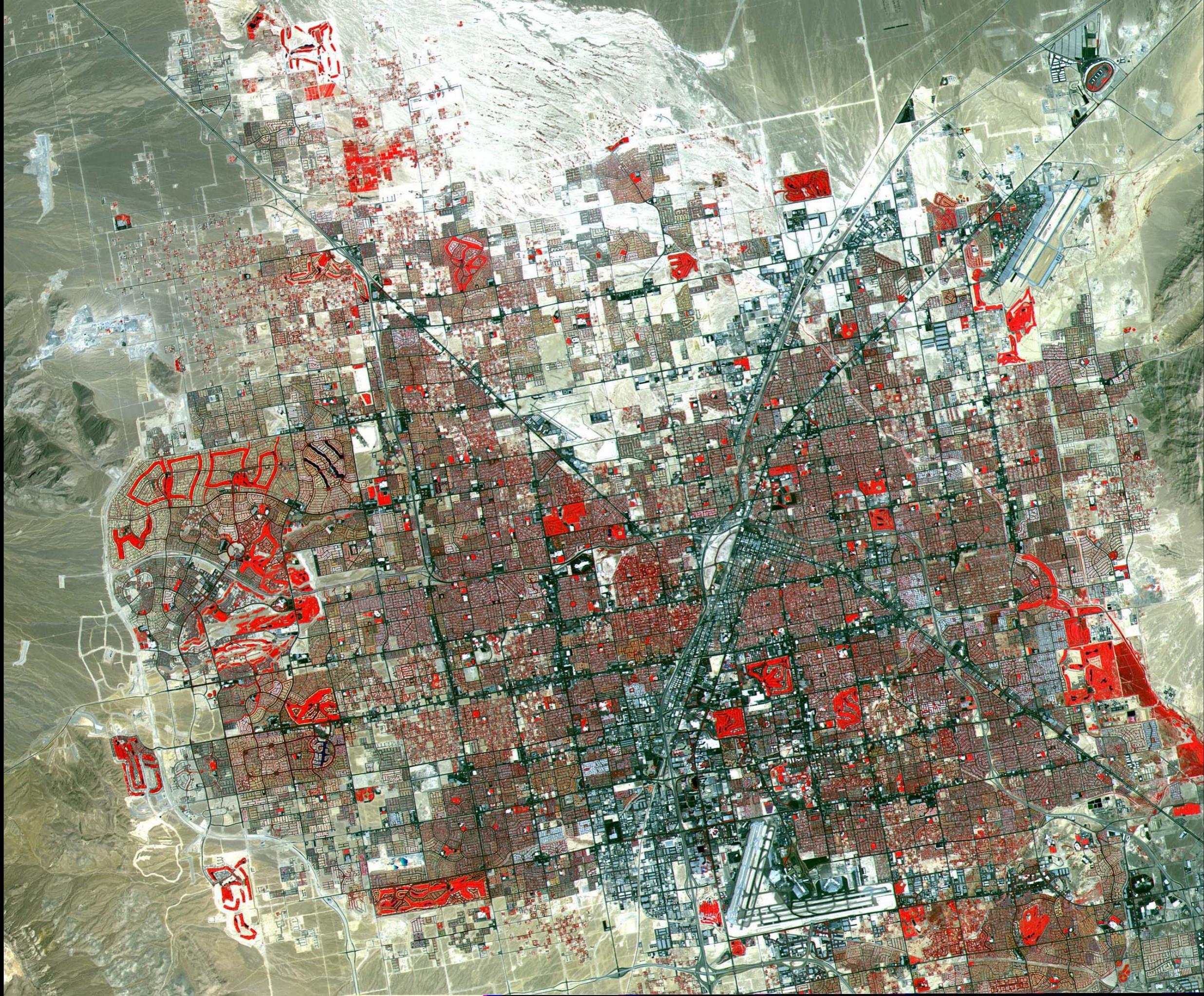


**Estrutura Richat, Mauritânia**





**Fronteira México - EUA**



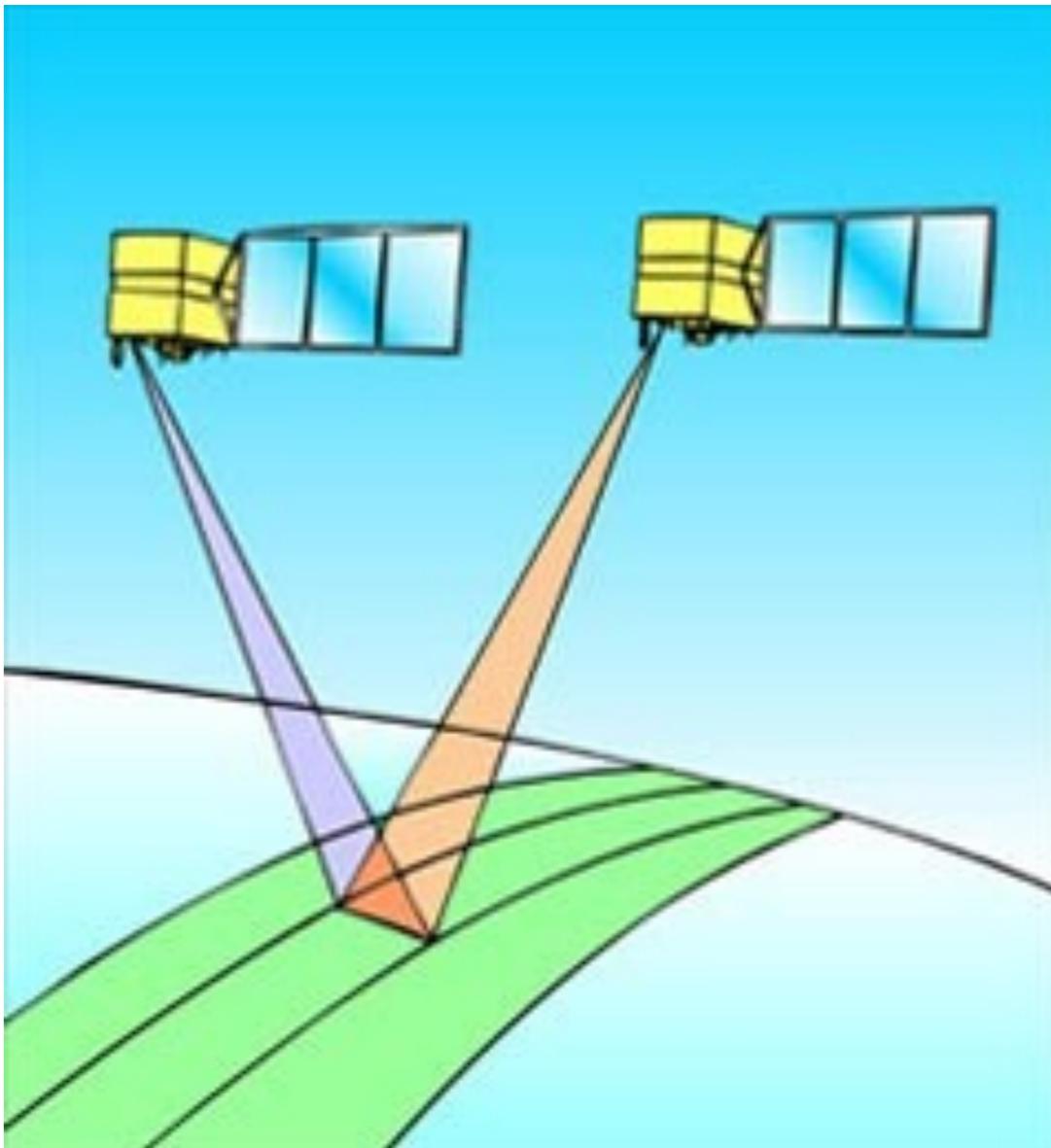


# CBERS

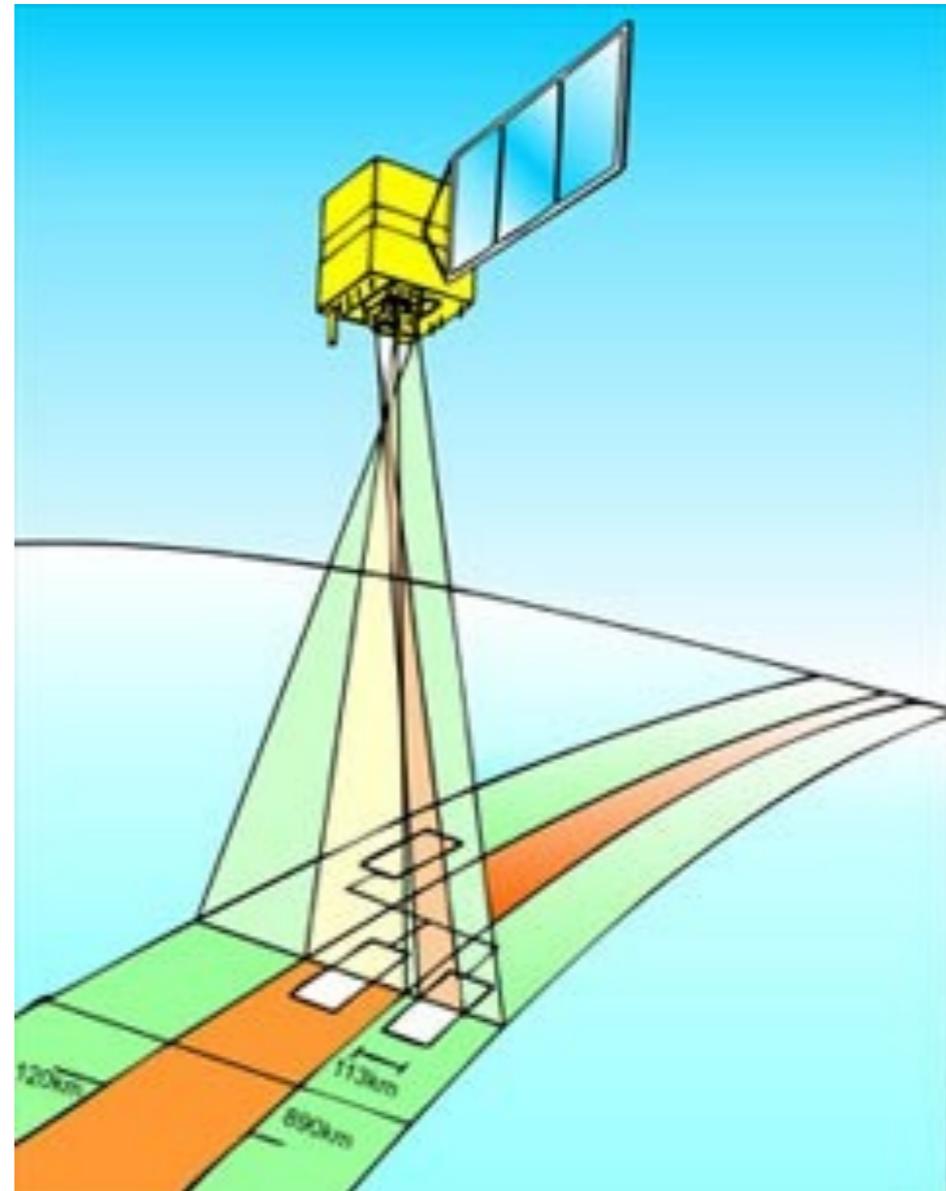
- ▶ China-Brazil Earth Resources Satellite
- ▶ Imagens gratuitas
- ▶ Câmeras
  - ▶ WFI (Wide Field Imager)
  - ▶ IRMSS - Infrared Multispectral Scanner
  - ▶ CCD - High Resolution CCD Camera
  - ▶ HRC – High Resolution Camera (2B)



# CBERS 1 E 2



Estereoscopia



Diferentes campos de visada

**Características do Imageador de Amplo Campo de Visada WFI**

Bandas espectrais	0,63 - 0,69 $\mu\text{m}$ (vermelho) 0,77 - 0,89 $\mu\text{m}$ (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 $\mu\text{m}$ (pan) 0,45 - 0,52 $\mu\text{m}$ (azul) 0,52 - 0,59 $\mu\text{m}$ (verde) 0,63 - 0,69 $\mu\text{m}$ (vermelho) 0,77 - 0,89 $\mu\text{m}$ (infravermelho próximo)
Campo de Visada	8,3°
Resolução espacial	20 x 20 m
Largura da faixa imageada	113 km
Capacidade de apontamento do espelho	$\pm 32^\circ$
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 $\mu\text{m}$ (pancromática) 1,55 - 1,75 $\mu\text{m}$ (infravermelho médio) 2,08 - 2,35 $\mu\text{m}$ (infravermelho médio) 10,40 - 12,50 $\mu\text{m}$ (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

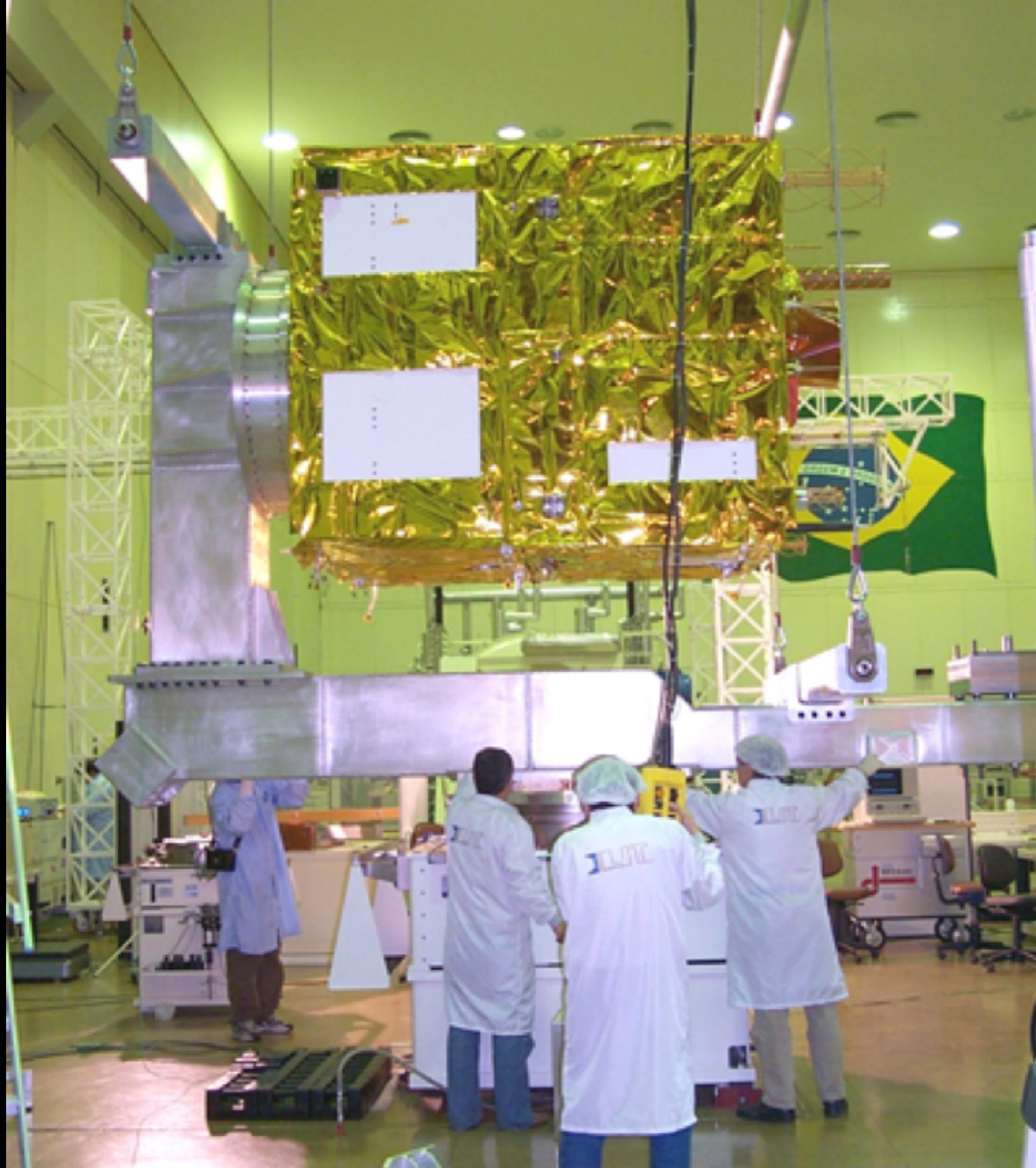
Características das câmaras do CBERS-3 e 4

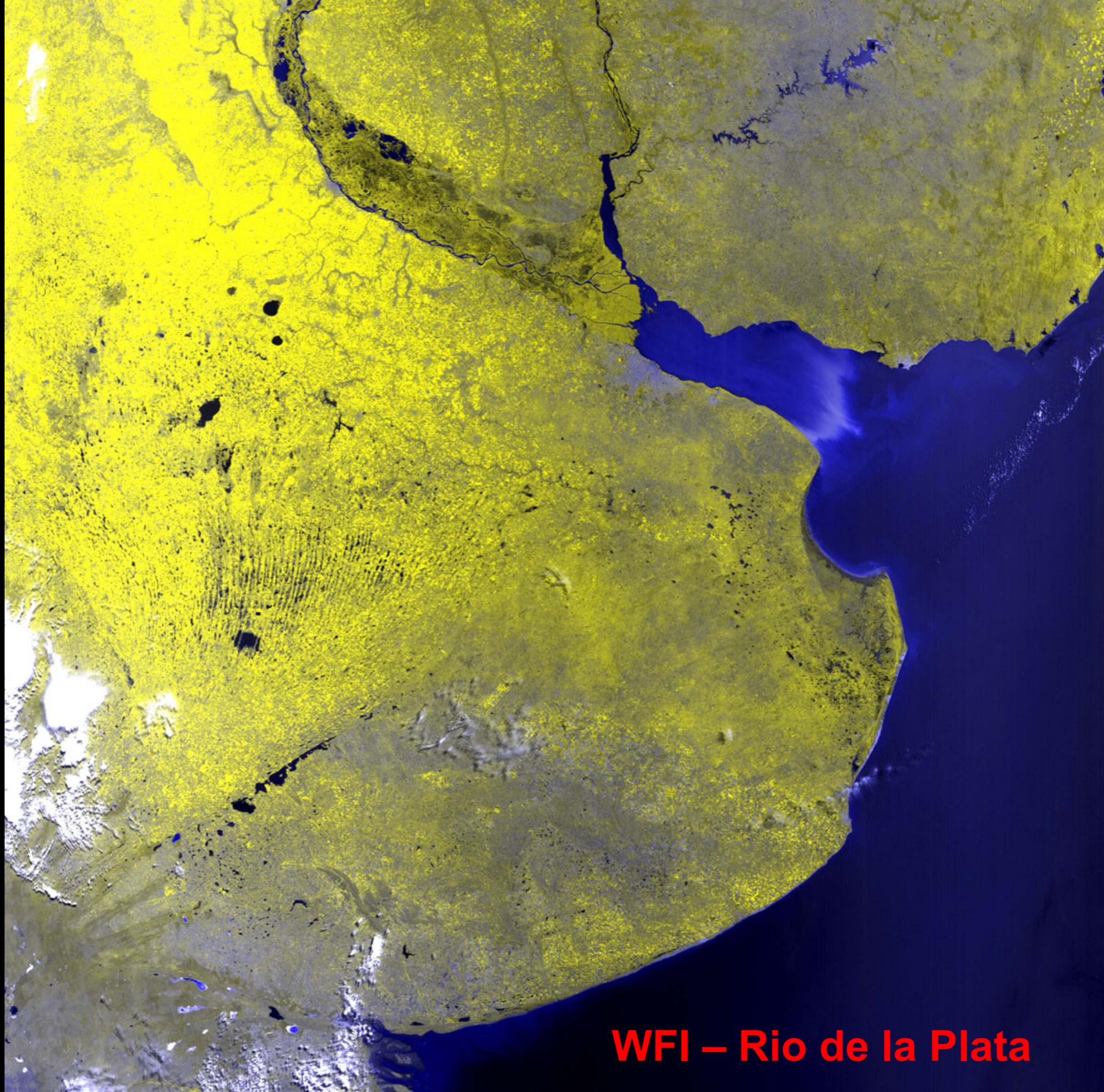
	<b>MUXCAM</b>	<b>PANMUX</b>	<b>IRMSS</b>	<b>WFI</b>
<i>Bandas espectrais</i>	0,45 - 0,52 $\mu\text{m}$ 1,55 - 1,75 $\mu\text{m}$ (TBC) 0,52 - 0,59 $\mu\text{m}$ (G) 0,63 - 0,69 $\mu\text{m}$ (R) 0,77 - 0,89 $\mu\text{m}$ (NIR)	0,51 - 0,75 $\mu\text{m}$ 0,51 - 0,85 $\mu\text{m}$ (TBC) 0,52 - 0,59 $\mu\text{m}$ (G) 0,63 - 0,69 $\mu\text{m}$ (R) 0,77 - 0,89 $\mu\text{m}$ (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)
<i>Resolução</i>	20 m	5 m/10 m	40 m/ 80 m (TH)	73 m
<i>Largura da faixa Imageada</i>	120 km	60 km	120 km	866 km
<i>Apontamento</i>	$\pm 32^\circ$ /Não (TBC)	$\pm 32^\circ$	não	não
<i>Revisita</i>	3 dias (TBC)	5 dias		
<i>Revisita real</i>	26 dias	não	26 dias	5 dias
<i>Quantização</i>	8 bits	8 bits	8 bits	10 bits
<i>Taxa de Dados Bruta</i>	68 Mbit/s	140 Mbit/s 100 Mbit/s	16 Mbit/s	50 Mbit/s

CBERS 2B – 2007

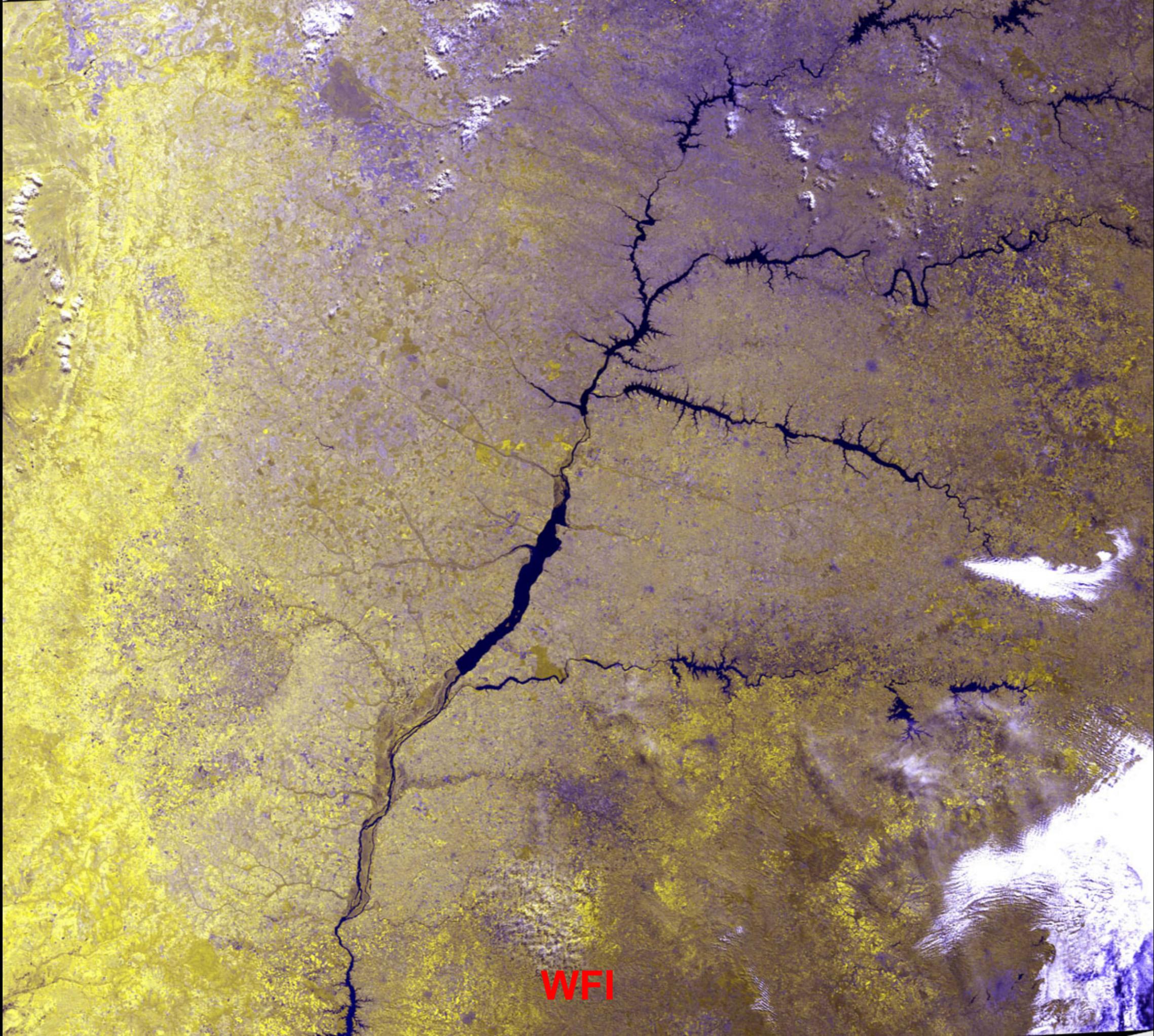
CBERS 3 – 2011

CBERS 4 – 2013

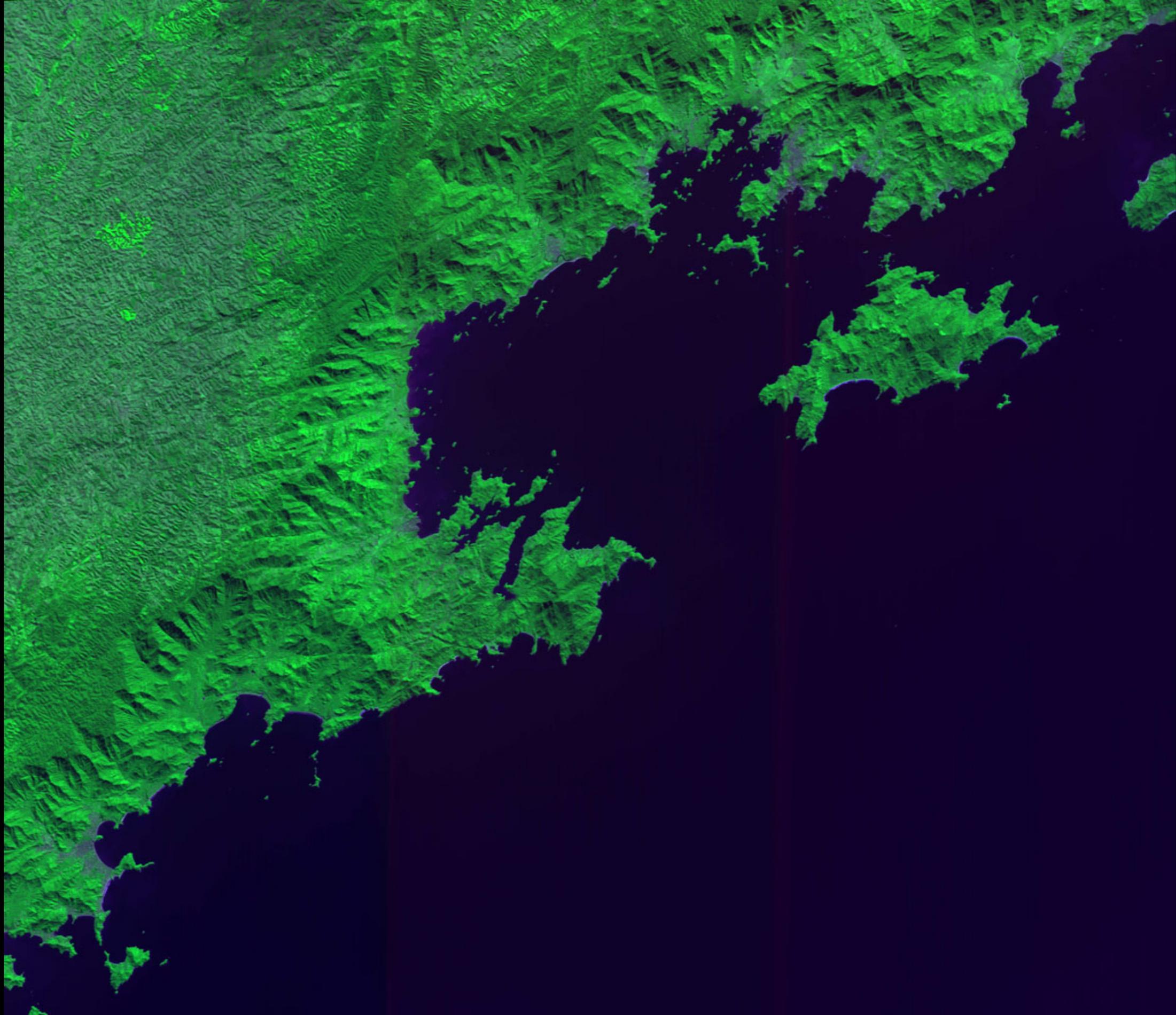




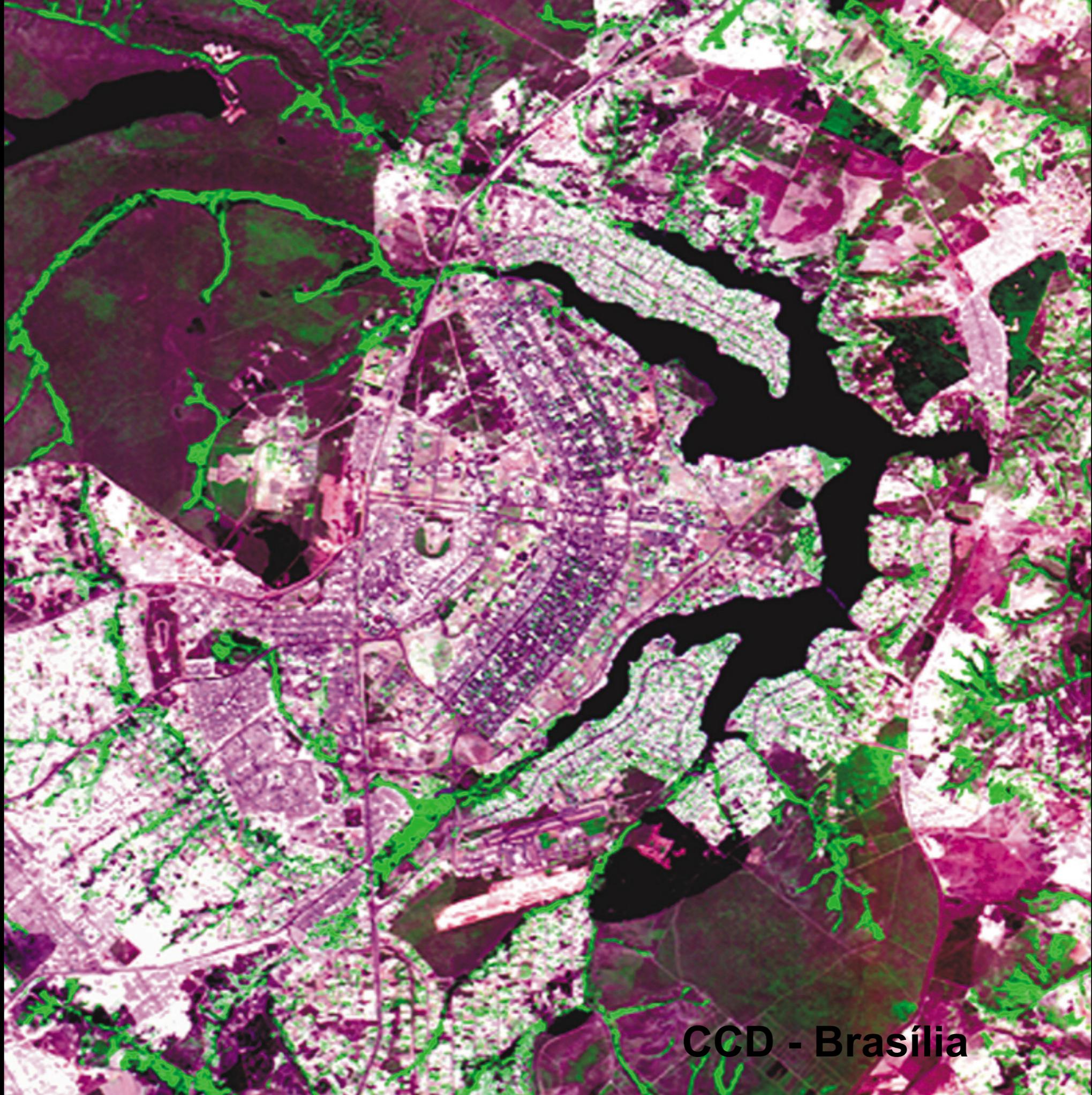
**WFI – Rio de la Plata**



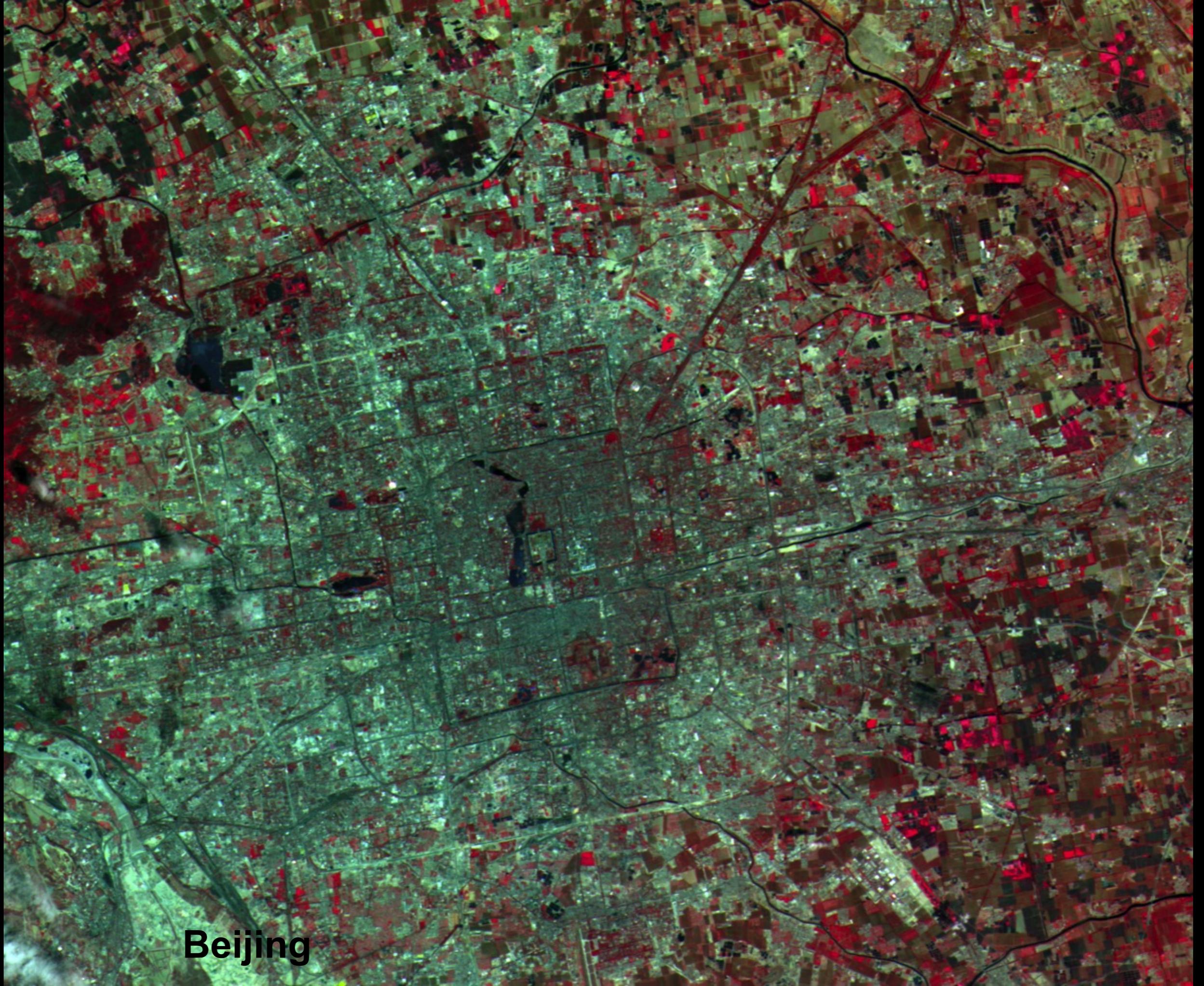
WFI



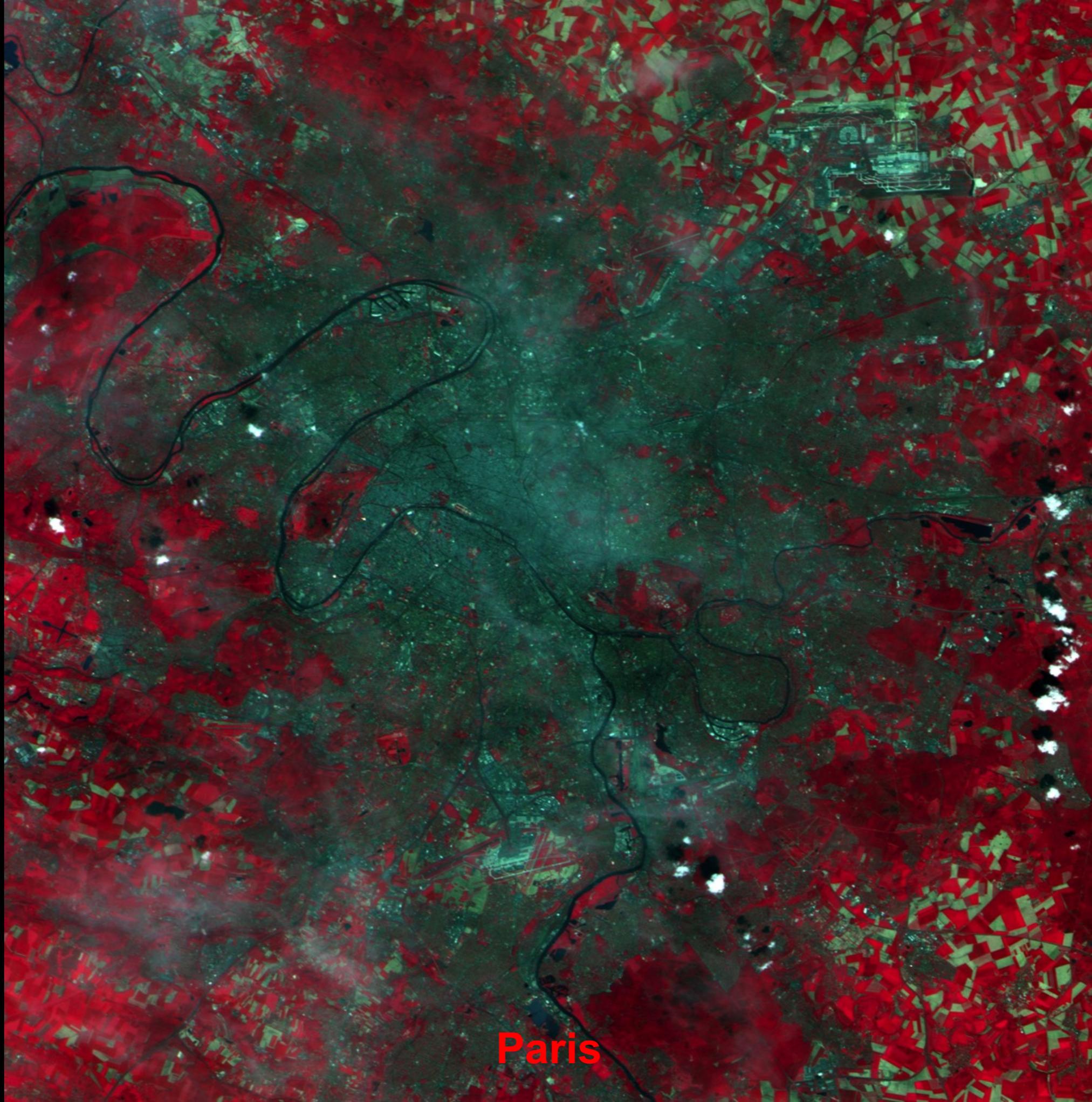
**IRMSS**



**CCD - Brasília**



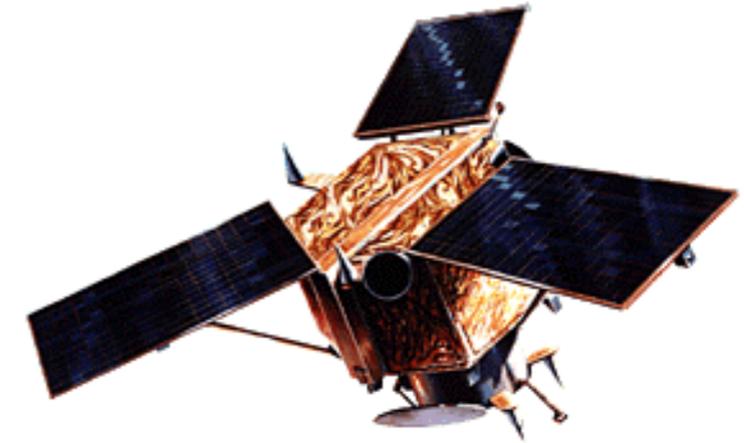
**Beijing**



Paris

# IKONOS

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



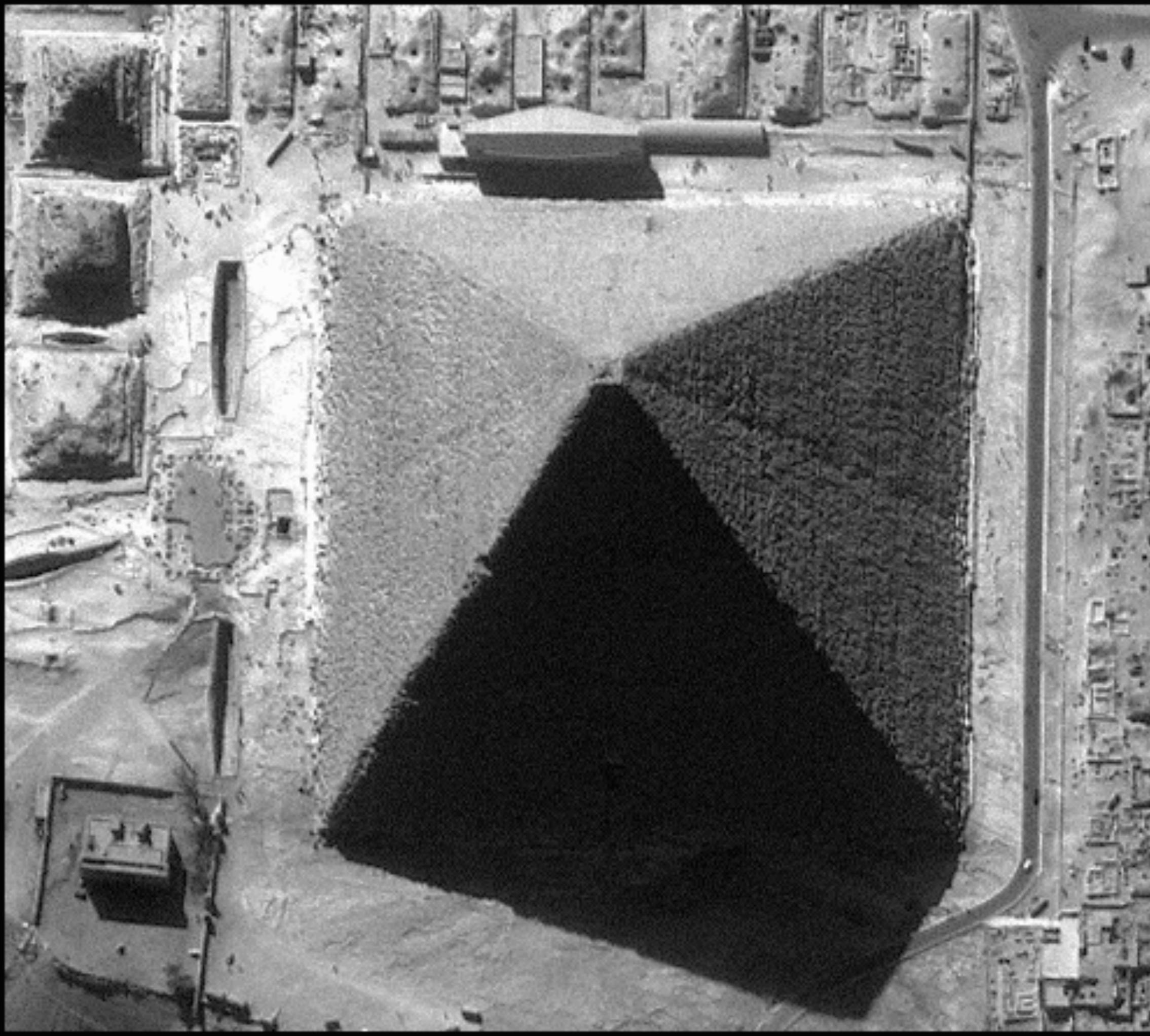
<b>Band</b>	<b>1-m PAN</b>	<b>4-m MS &amp; 1-m PS</b>
1 (Blue)	0.45-0.90 $\mu\text{m}$	0.445-0.516 $\mu\text{m}$
2 (Green)	*	0.506-0.595 $\mu\text{m}$
3 (Red)	*	0.632-0.698 $\mu\text{m}$
4 (Near IR)	*	0.757-0.853 $\mu\text{m}$









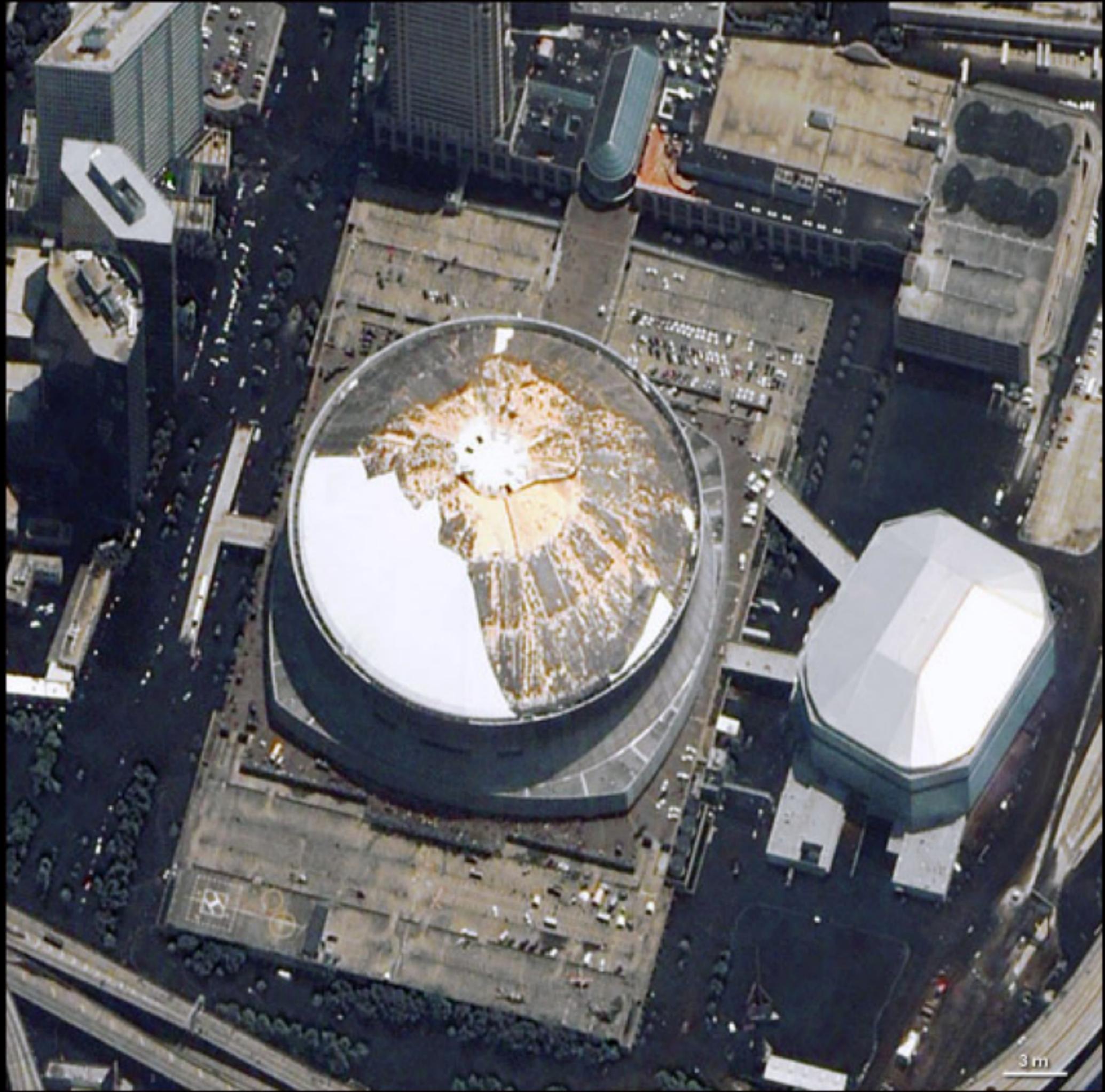


# QUICKBIRD

- ▶ Revisita: 3-7 dias dependendo da latitude



<b>Sensor Resolution &amp; Spectral Bandwidth</b>	Panchromatic	Multispectral
	<ul style="list-style-type: none"><li>● 60-centimeter GSD (Ground Sample Distance) at nadir</li><li>● Black &amp; White: 445 to 900 nanometers</li></ul>	<ul style="list-style-type: none"><li>● 2.4-meter GSD at nadir</li><li>● Blue: 450 to 520 nanometers</li><li>● Green: 520 to 600 nanometers</li><li>● Red: 630 to 690 nanometers</li><li>● Near-IR: 760 to 900 nanometers</li></ul>



3 m

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





# 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

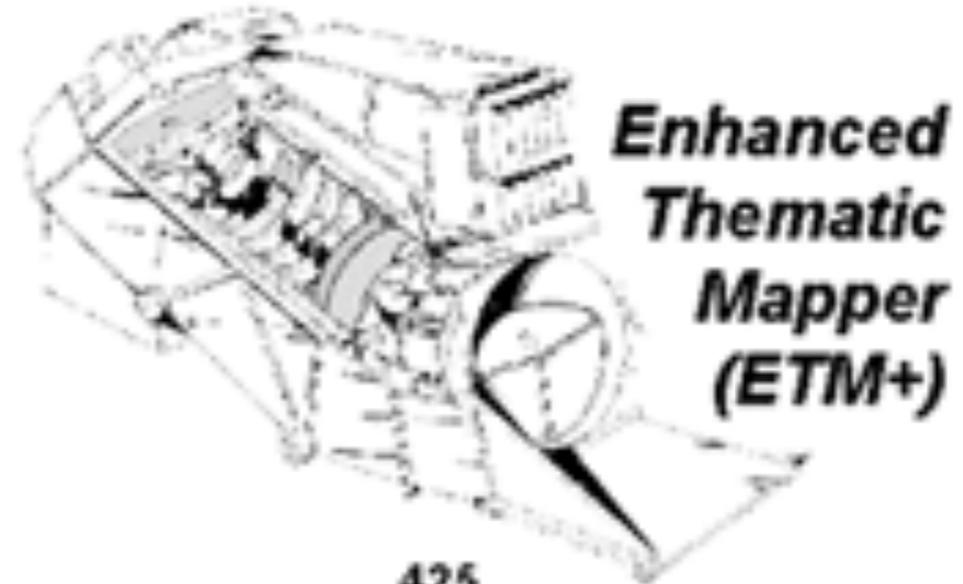
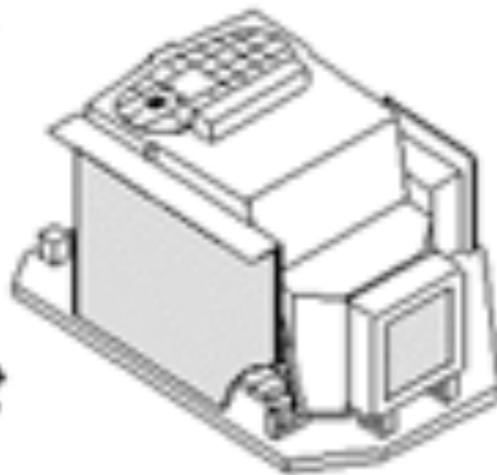
## *EO-1 ALI Spectral Coverage*

<b>Band</b>	<b>Wavelength (<math>\mu\text{m}</math>)</b>	<b>Ground Sample Distance (m)</b>
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**

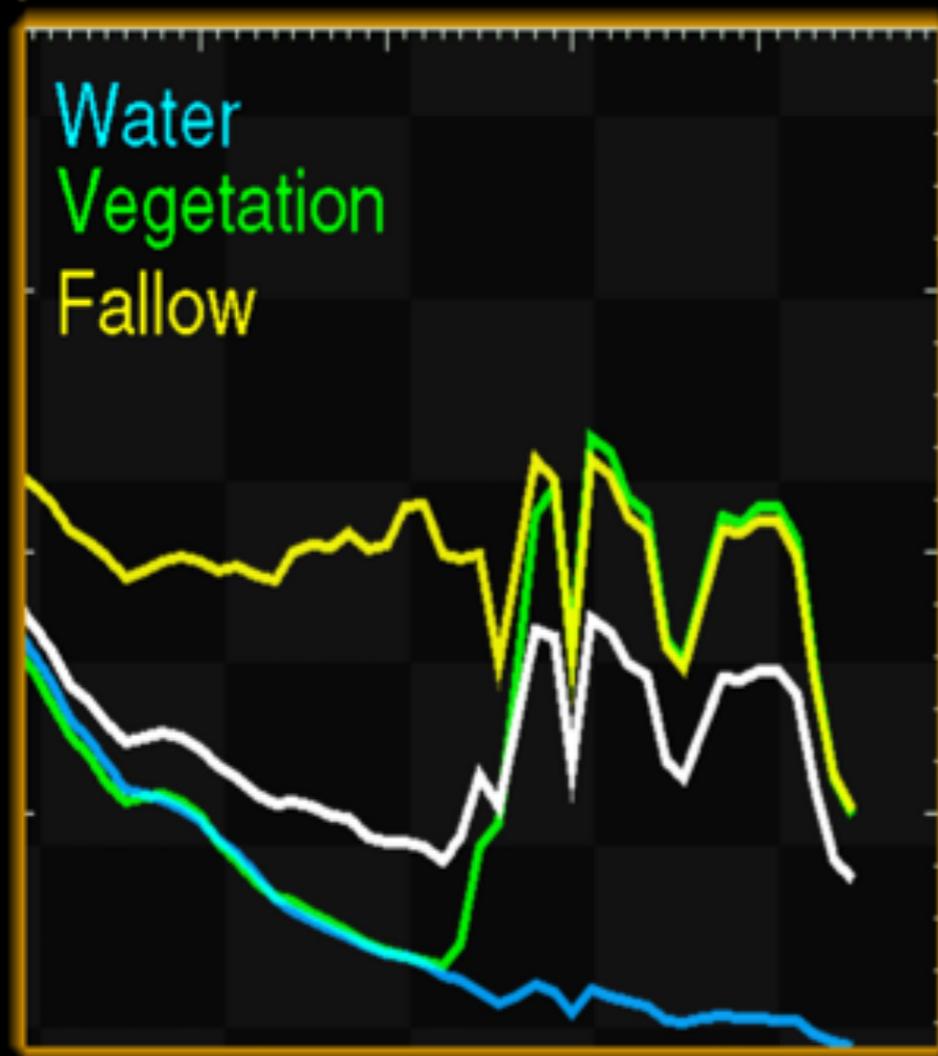


**Enhanced  
Thematic  
Mapper  
(ETM+)**

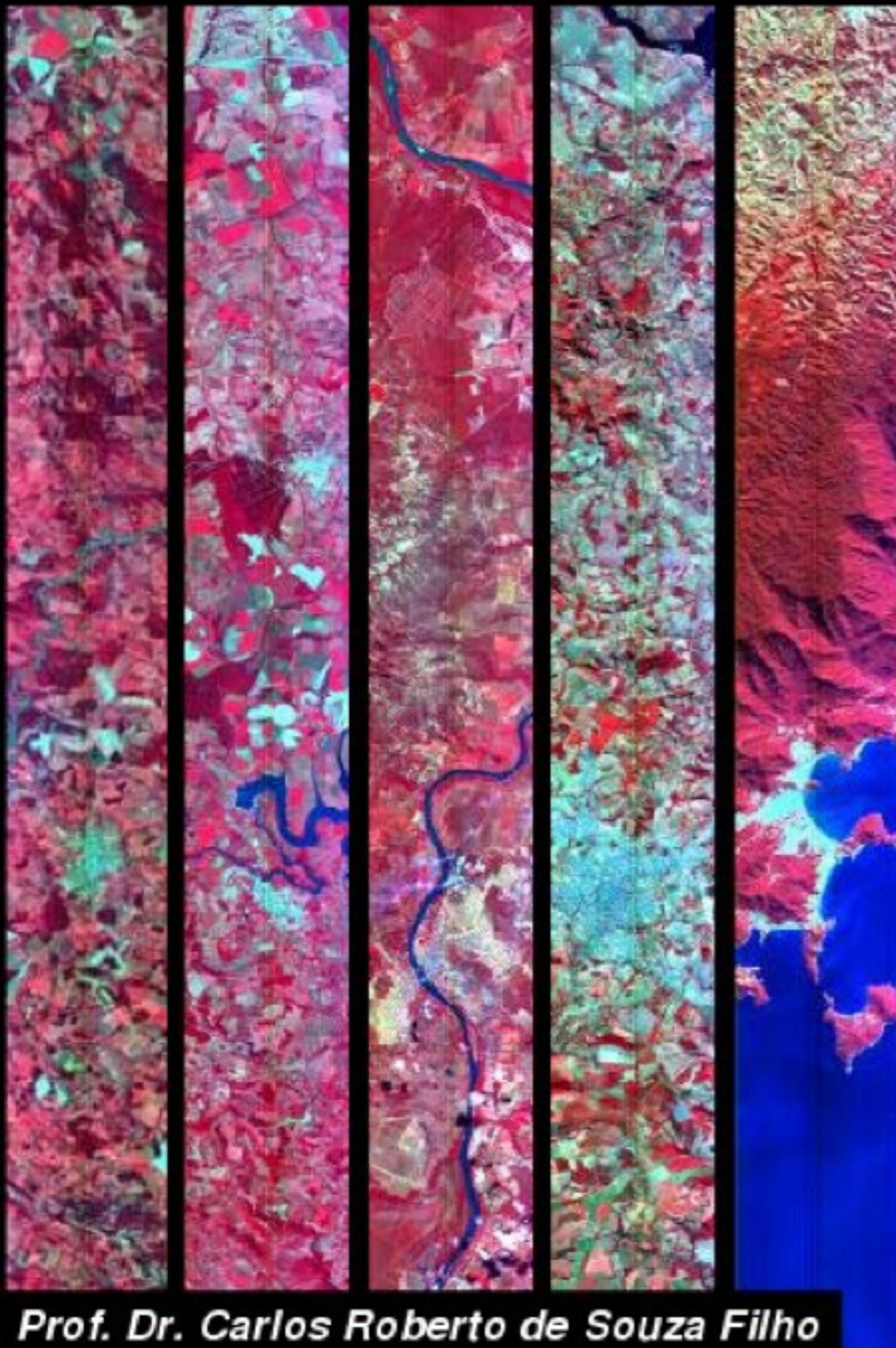
100	Mass (kg)	425
100	Power (W)	545
0.2	Size (m <sup>3</sup> )	1.4
10	VNIR / SWIR Bands	7
6200	Detectors Per Band	16
None	Thermal Bands	1
300	Data Rate (Mbps)	150
10	Pan Resolution (m)	15
4x	Relative SNR	1x

# E0-1/Hyperion

## Analysis



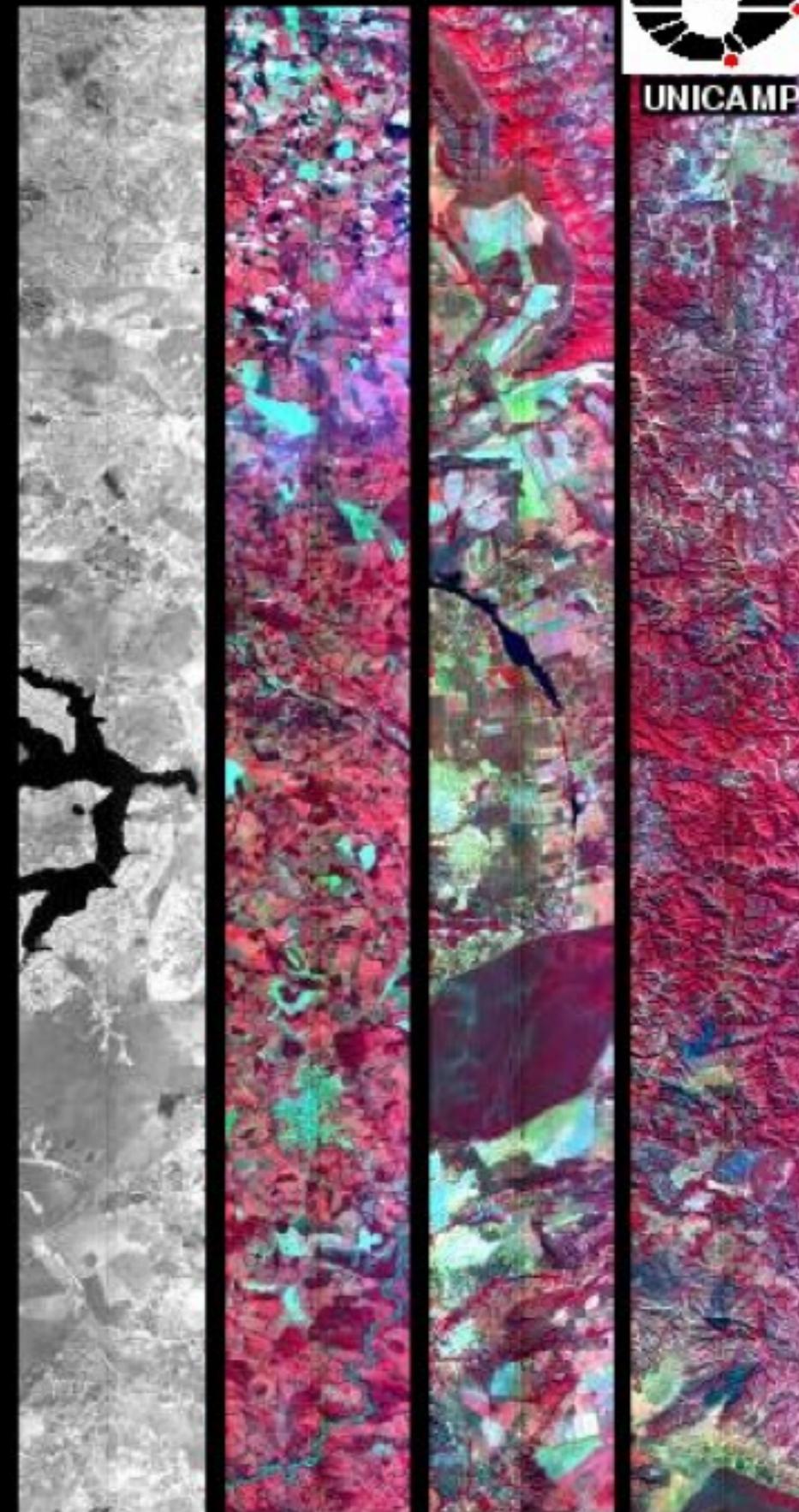
São Paulo



BH



Brasília



UNICAMP

# 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

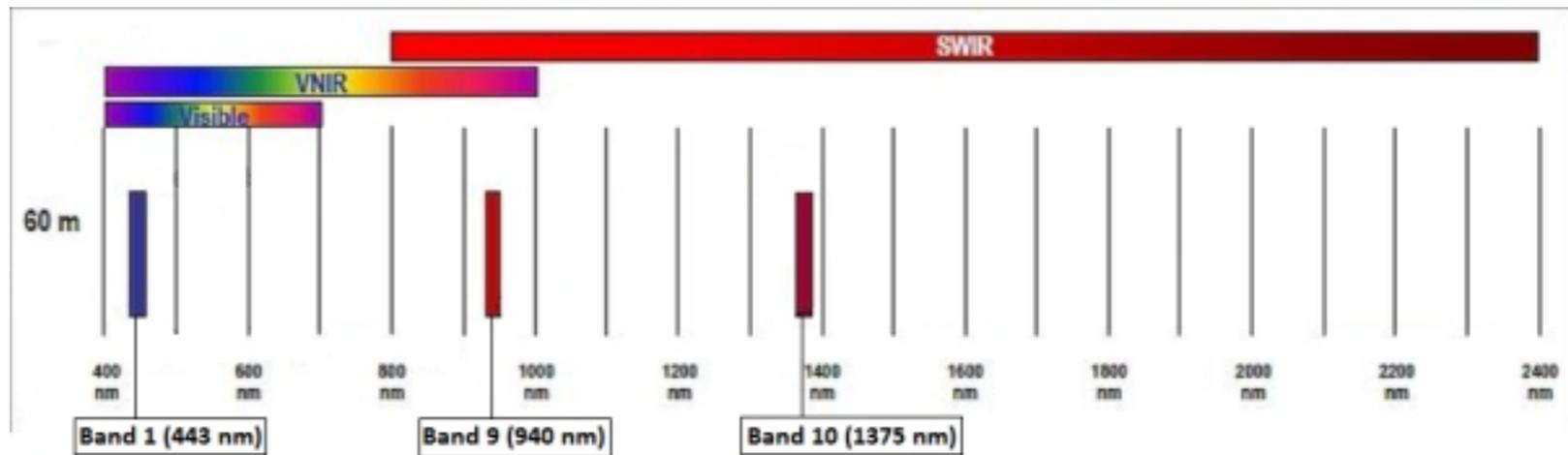
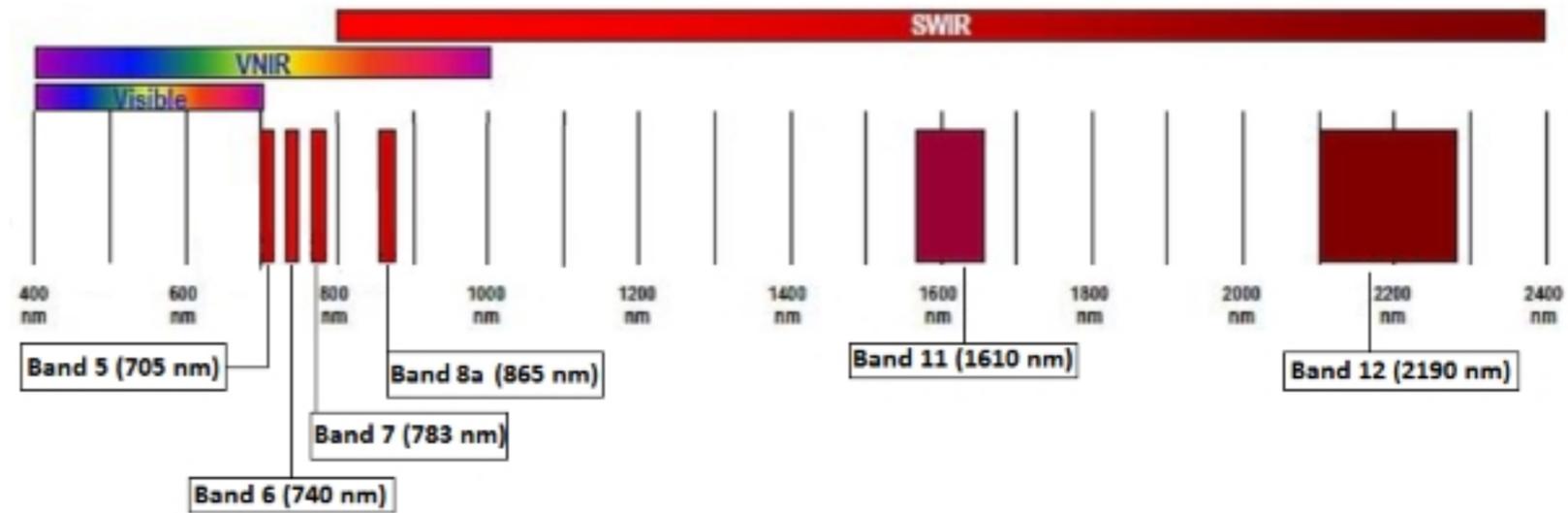
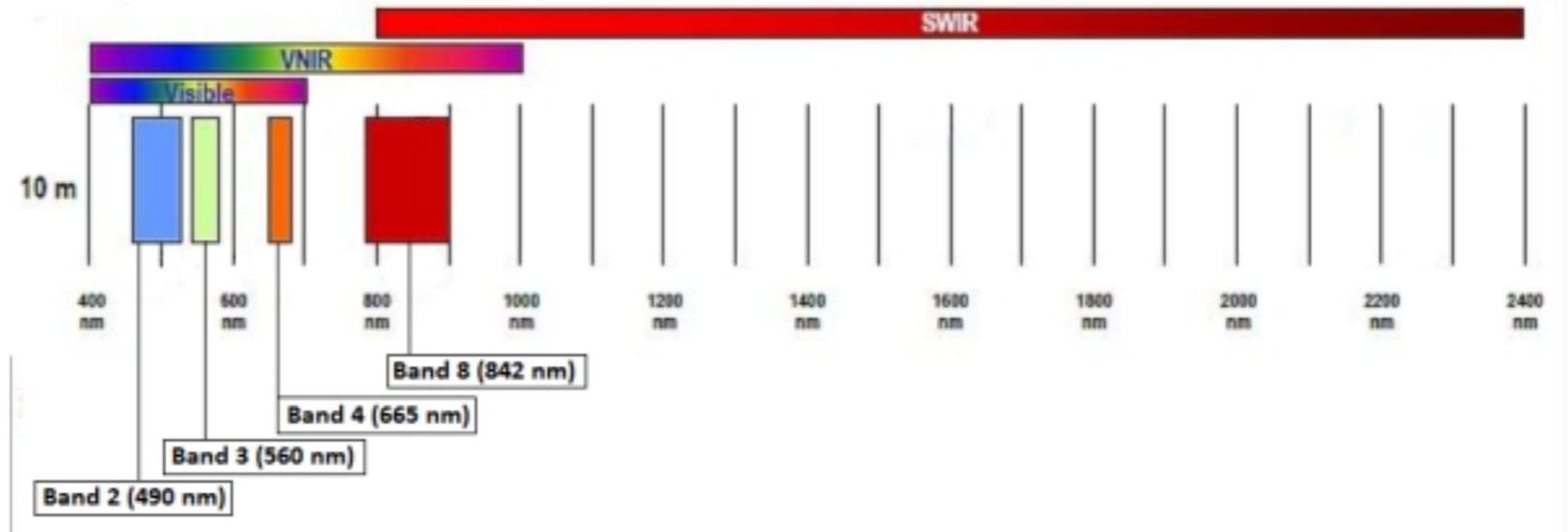
# SENTINEL-2

▶ ESA

▶ 10m

▶ 20m

▶ 60m



# LANDSAT-8

Comparison of Landsat 7 and 8 bands with Sentinel-2

