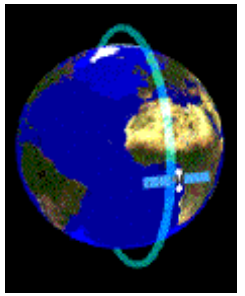
Introduction to Remote Sensing of Earth and Planetary Bodies

R.P. Singh

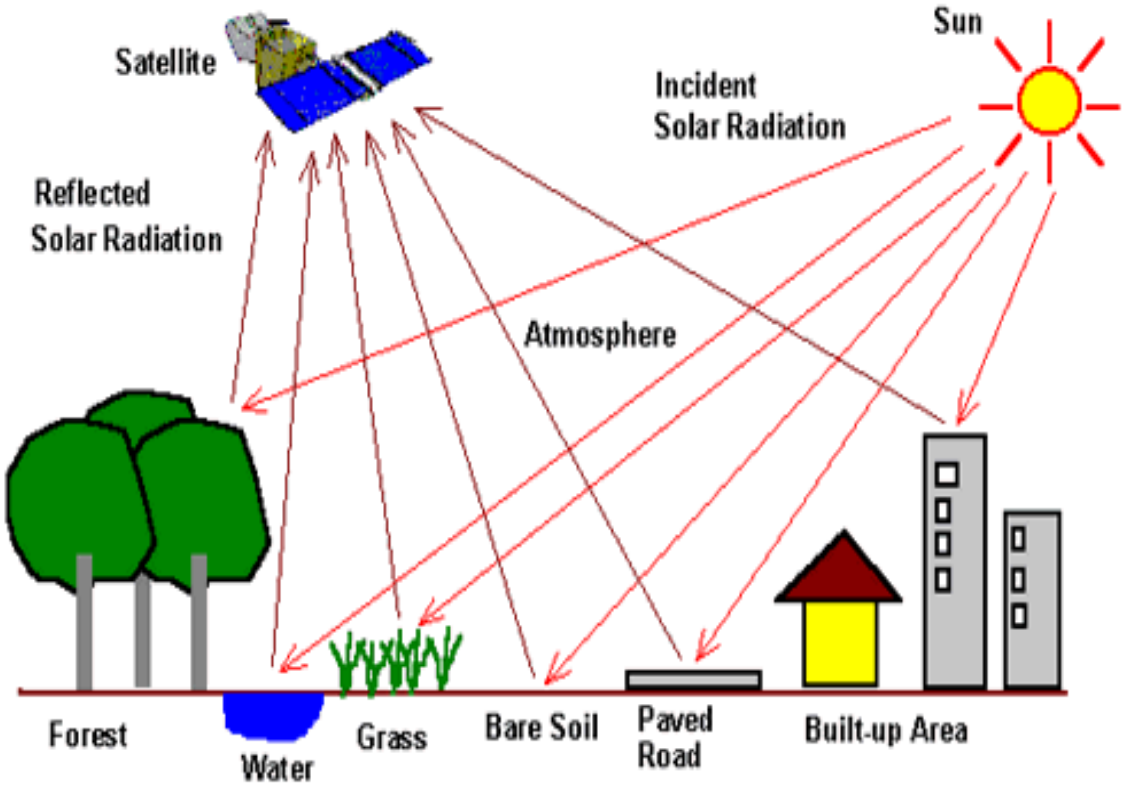
Indian Institute of Remote Sensing
Dehradun, India

Remote Sensing



- Remote sensing is the science of making inference about material objects from measurements made at distance without coming into physical contact with the objects understudy.

- It usually refers to the technology of acquiring information about the earth's environment using sensors onboard airborne (aircraft, balloons) or space borne (satellites, space shuttles) platforms.



Physical basis and applications of Earth Observation

Imaging System

Optical	Thermal	Microwave
Reflectance (ρ)	Brightness Temp B(T)	Backscatter, B(T)
Spectral signature	Planck's law	Dielectric property
$\rho(\lambda) = \frac{\pi . L_{sensor}}{E_0 . \cos\theta_s}$	$B(\lambda,T) = \frac{2\pi . h . c^2}{\lambda^5 . (e^{\frac{hc}{\lambda kT}} - 1)}$	$P_r = \frac{P_t . G_t . G_r . \lambda^2 . \sigma}{(4\pi)^3 . R^4}$

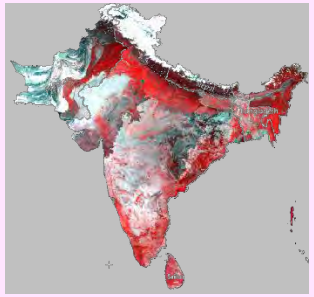
Physical Basis

Measurements

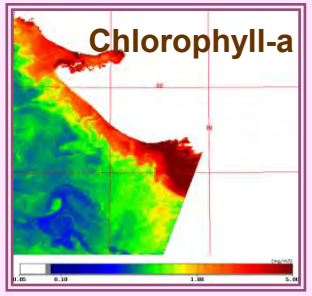
Modeling

Image Processing | RT model | Parameter retrieval | Process model

Applications



Land



Ocean

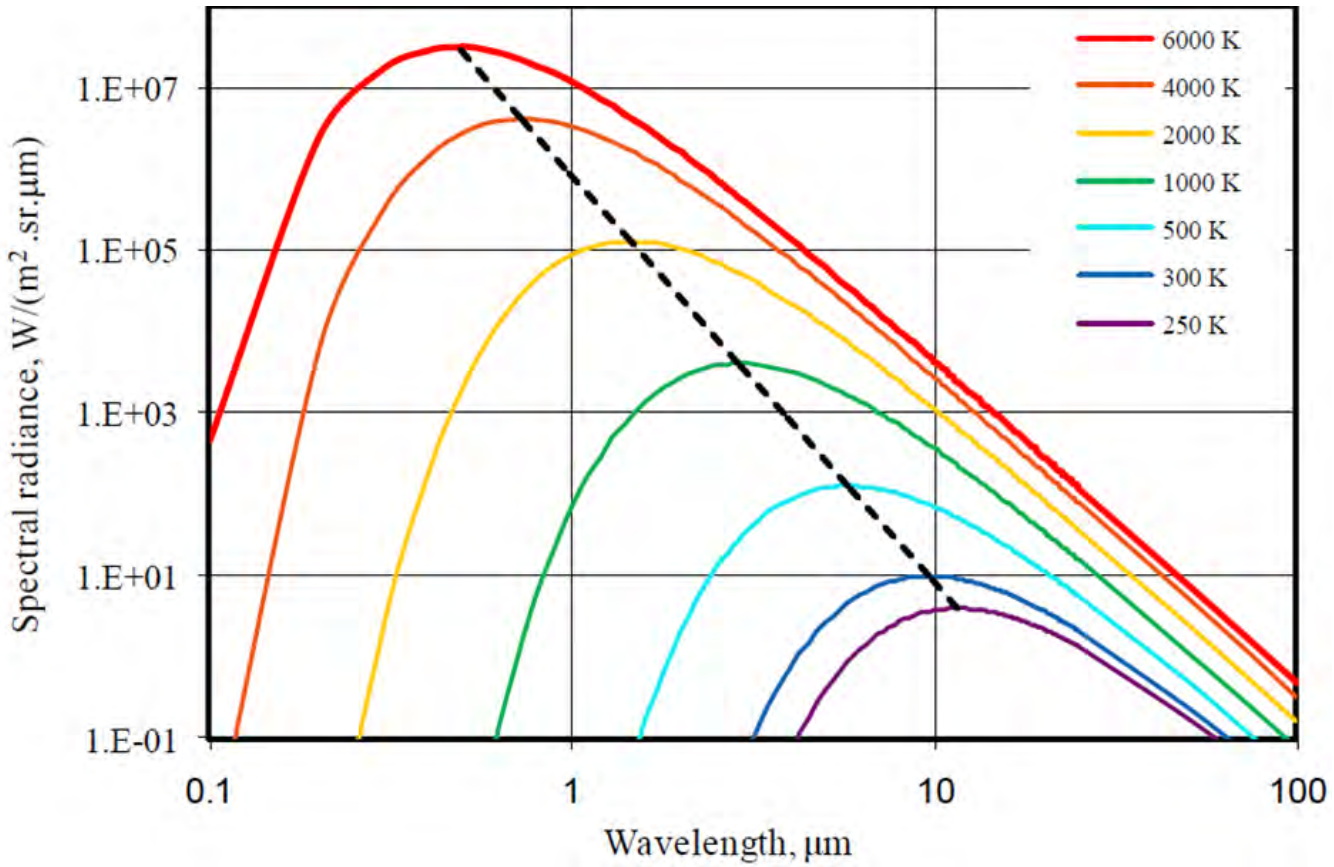
Atmosphere

Planetary Sciences

Blackbody Radiation

All things emit radiation. The "perfect emitter" of radiation is called a blackbody. It emits radiation according to the Planck function:

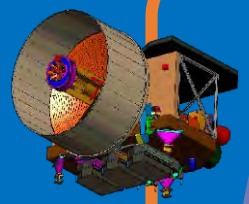
$$M_\lambda = \frac{2\pi hc^2}{\lambda^5[\exp(hc/\lambda kT) - 1]}$$



SENSORS

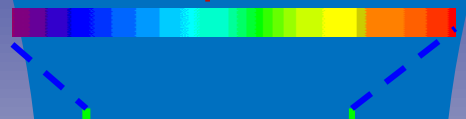
Active

Passive

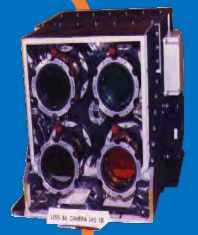


LIDAR

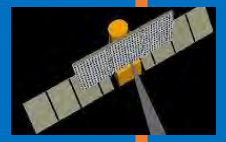
Optical



- Radiometers (in visible, near & thermal infrared)
- Imaging spectrometer



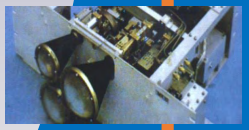
UV | Visible | NIR SWIR | Thermal IR



- Synthetic Aperture RADAR (SAR)
- Scatterometer
- Altimeter

Microwave

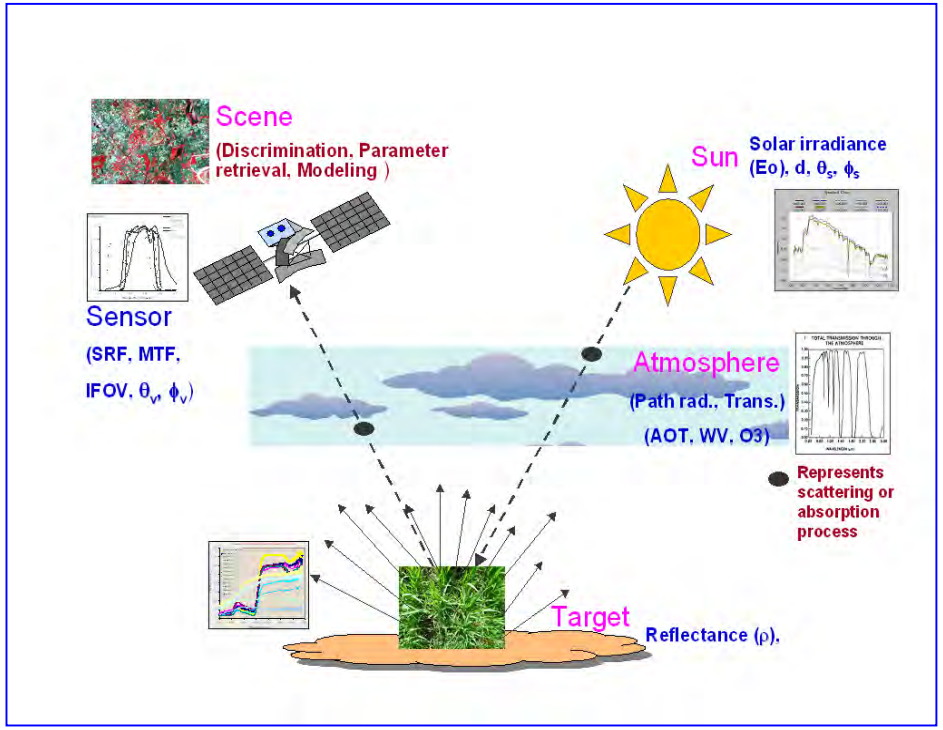
Multi-frequency Microwave Radiometer



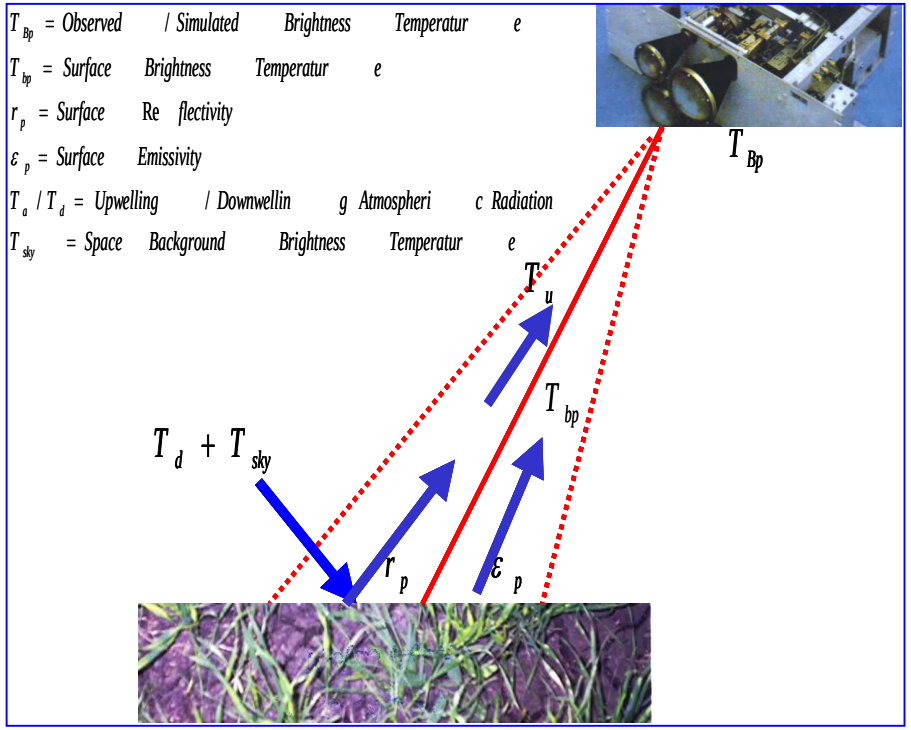
Ka | K | Ku | X | C | S | L | P

Passive Remote Sensing

Remote sensing of energy naturally reflected / radiated from the terrain.



Optical

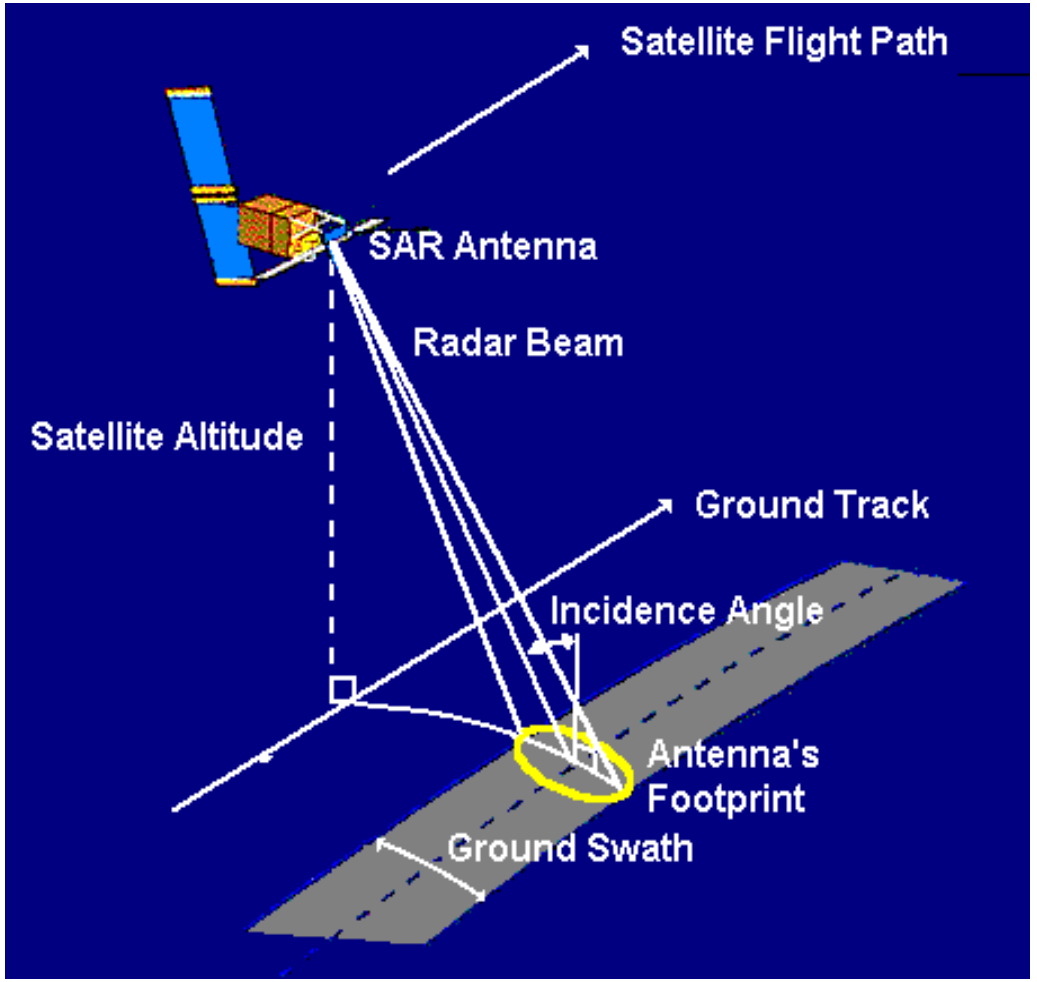


Thermal/Microwave

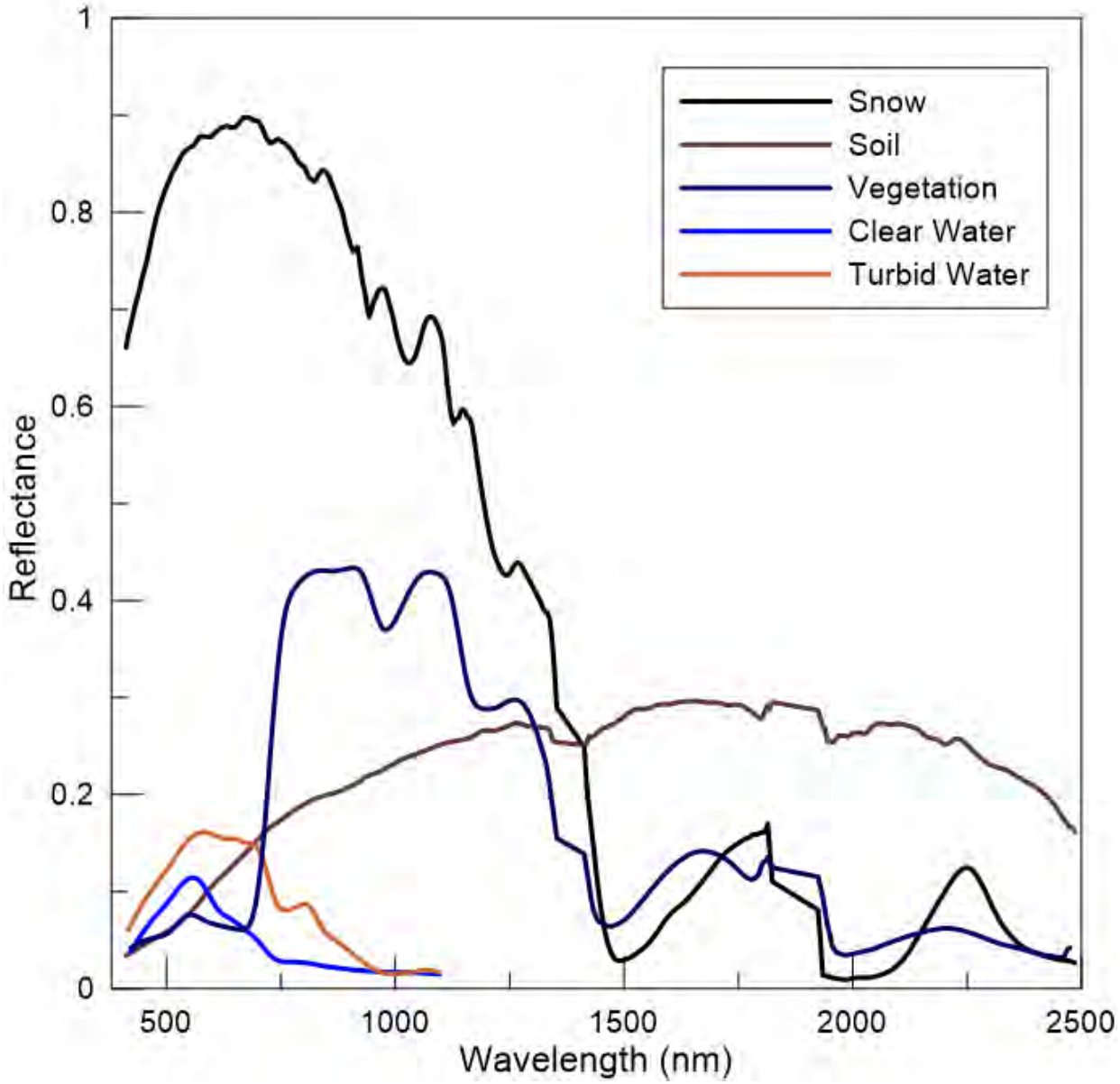
Active Remote Sensing

Remote sensing method that provide their own source of electromagnetic radiation to illuminate the terrain.

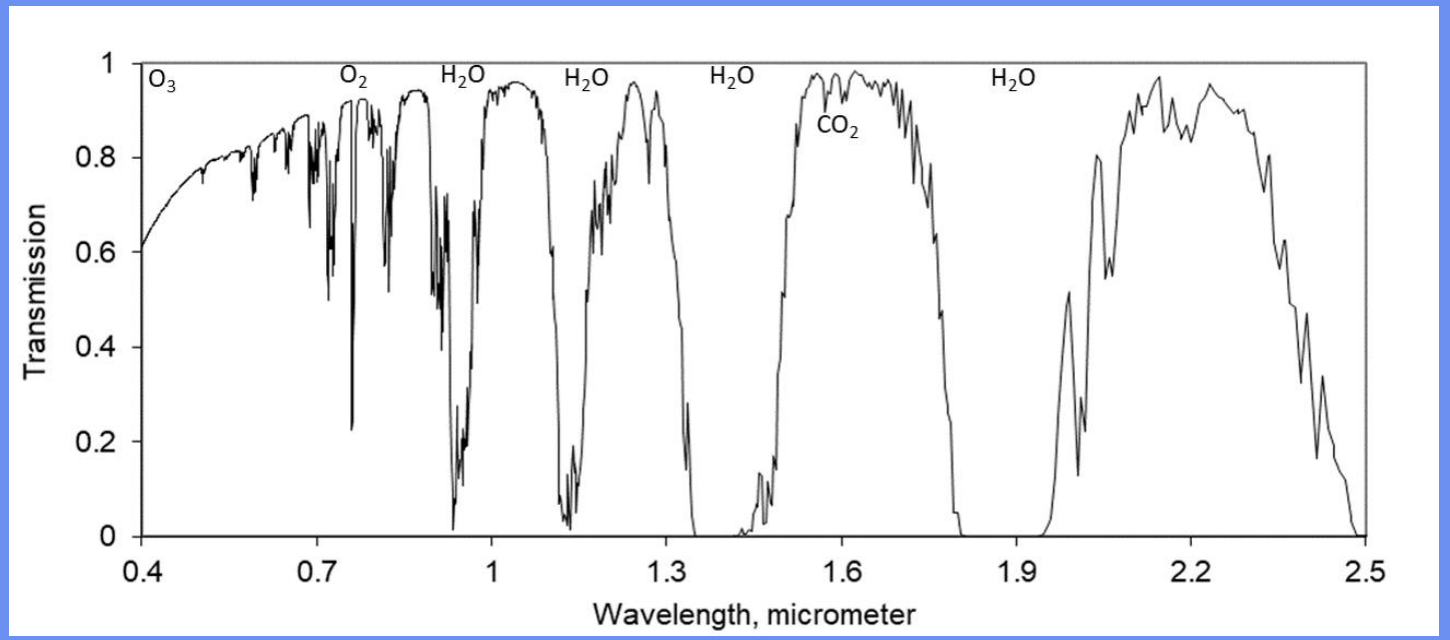
Radar/Scatterometer/Lidar is one example.



Scientific Rationale of Detection



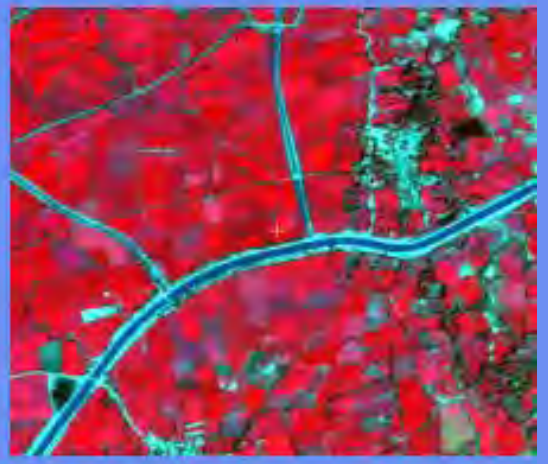
Multi Spectral Imaging



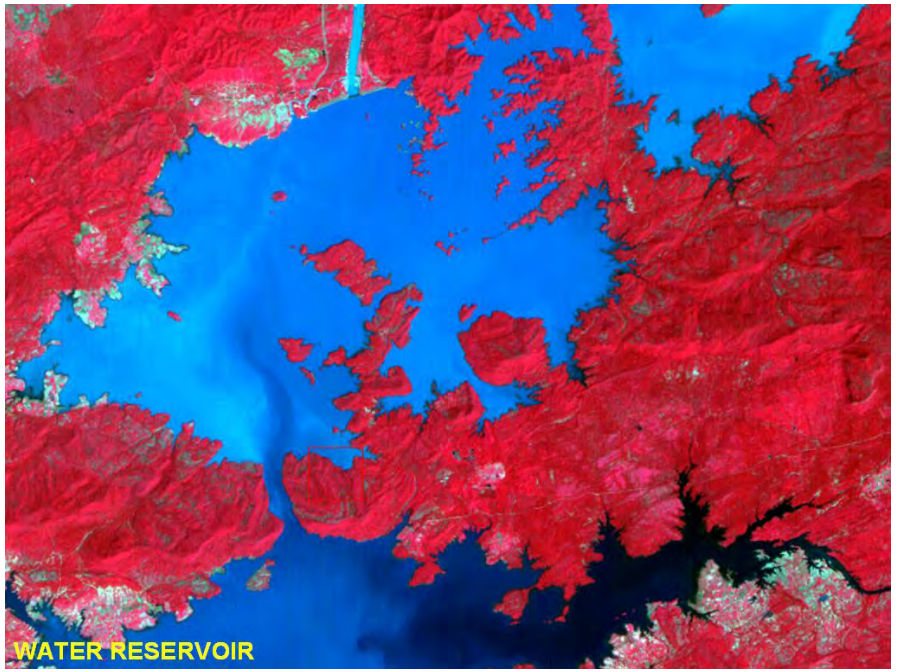
Green

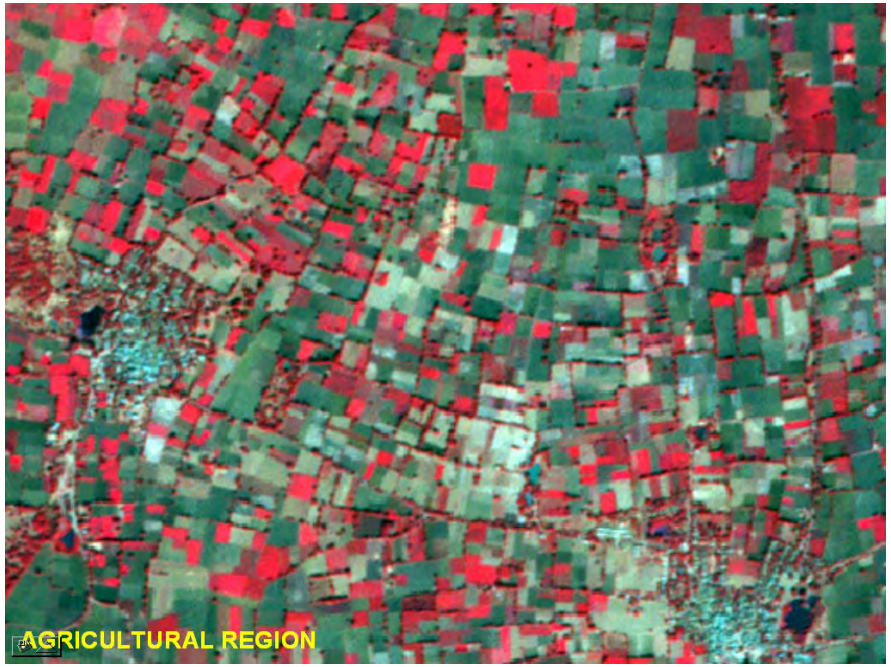
Red

NIR

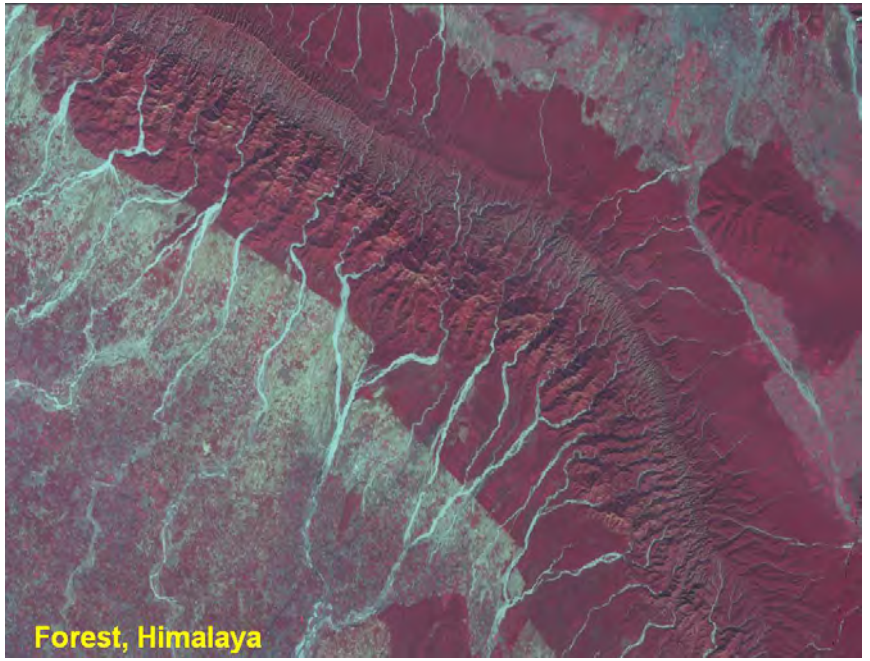


FCC


WATER RESERVOIR

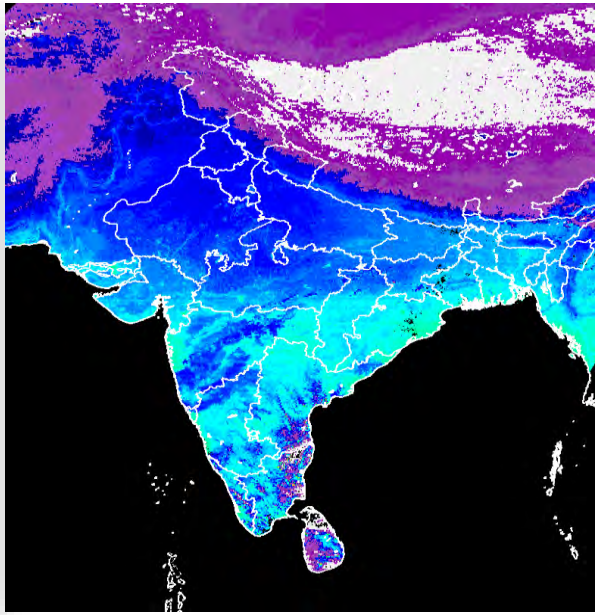

AGRICULTURAL REGION


South Coast of India

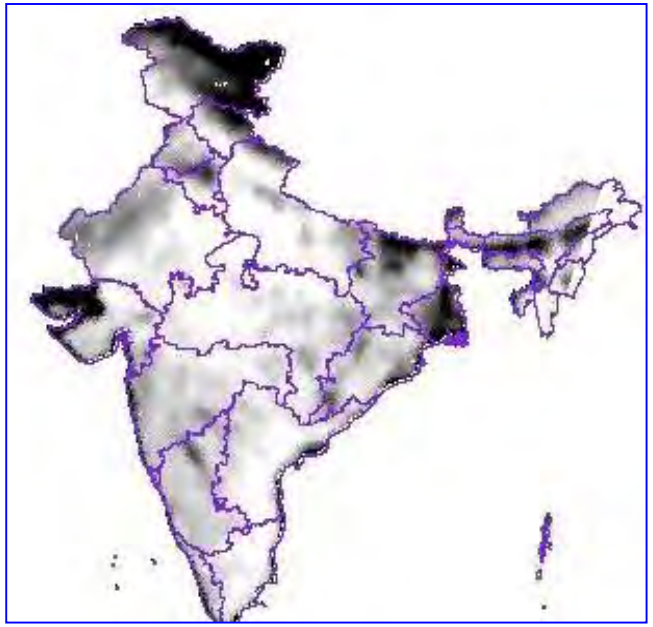

Forest, Himalaya

Observations in Different Electromagnetic Wavelengths

Visible(Reflection)

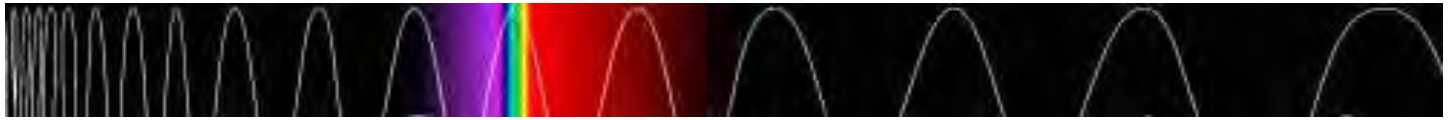


Infrared (Emission)

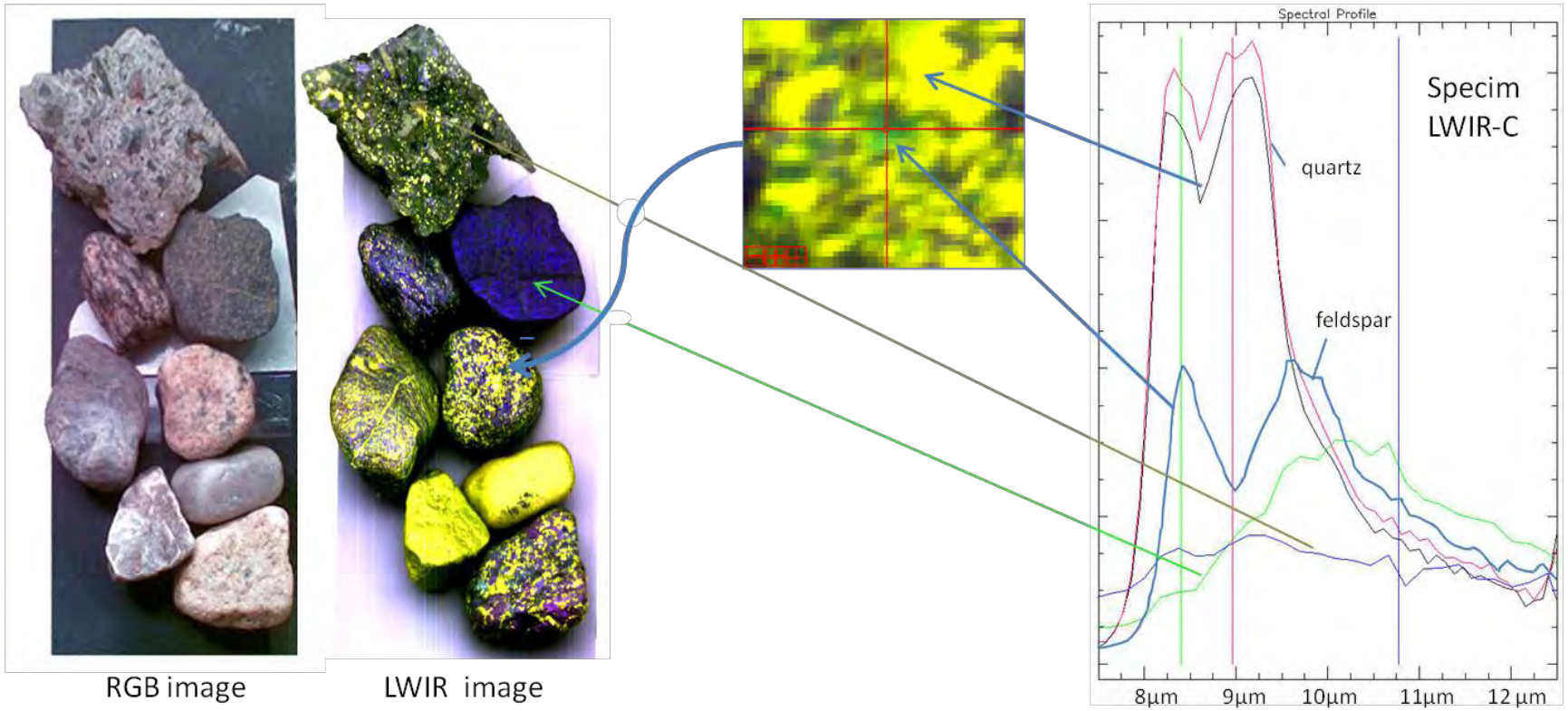


Microwave (Emission)

Microwave (Backscattering)

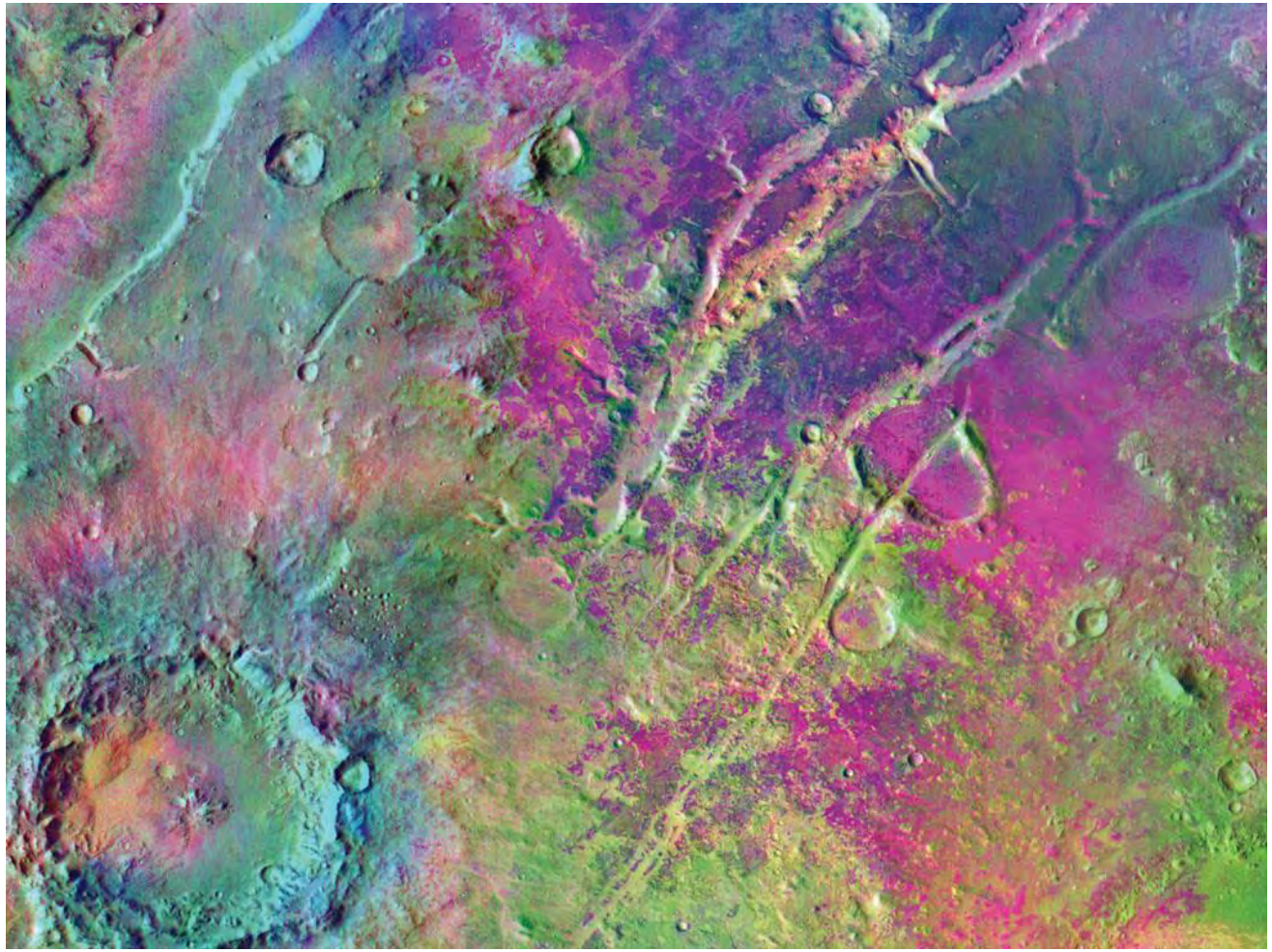


Scientific Rationale of Detection



Source: Holma, H., (2011), Thermische Hyperspektralbildgebung im langwelligen Infrarot, Photonik

Evidence for extensive, olivine-rich bedrock on Nili Fossae, Mars



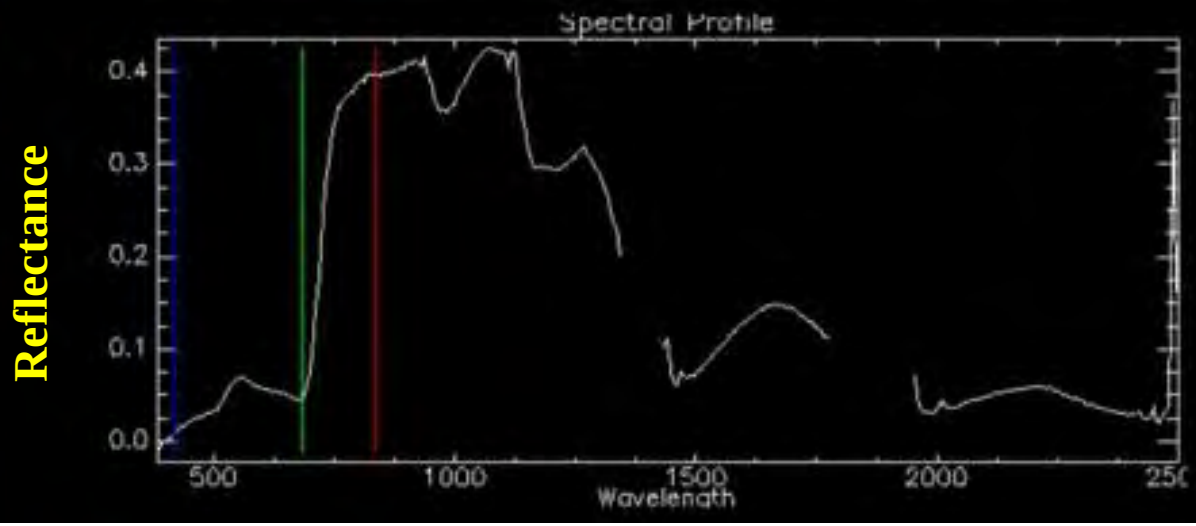
NASA's Mars Odyssey Thermal Emission Imaging System (THEMIS) Data

FCC
Infrared bands
B5 : 9.35 um,
B7 : 11.04 um,
B9: 12.57 um

Olivine

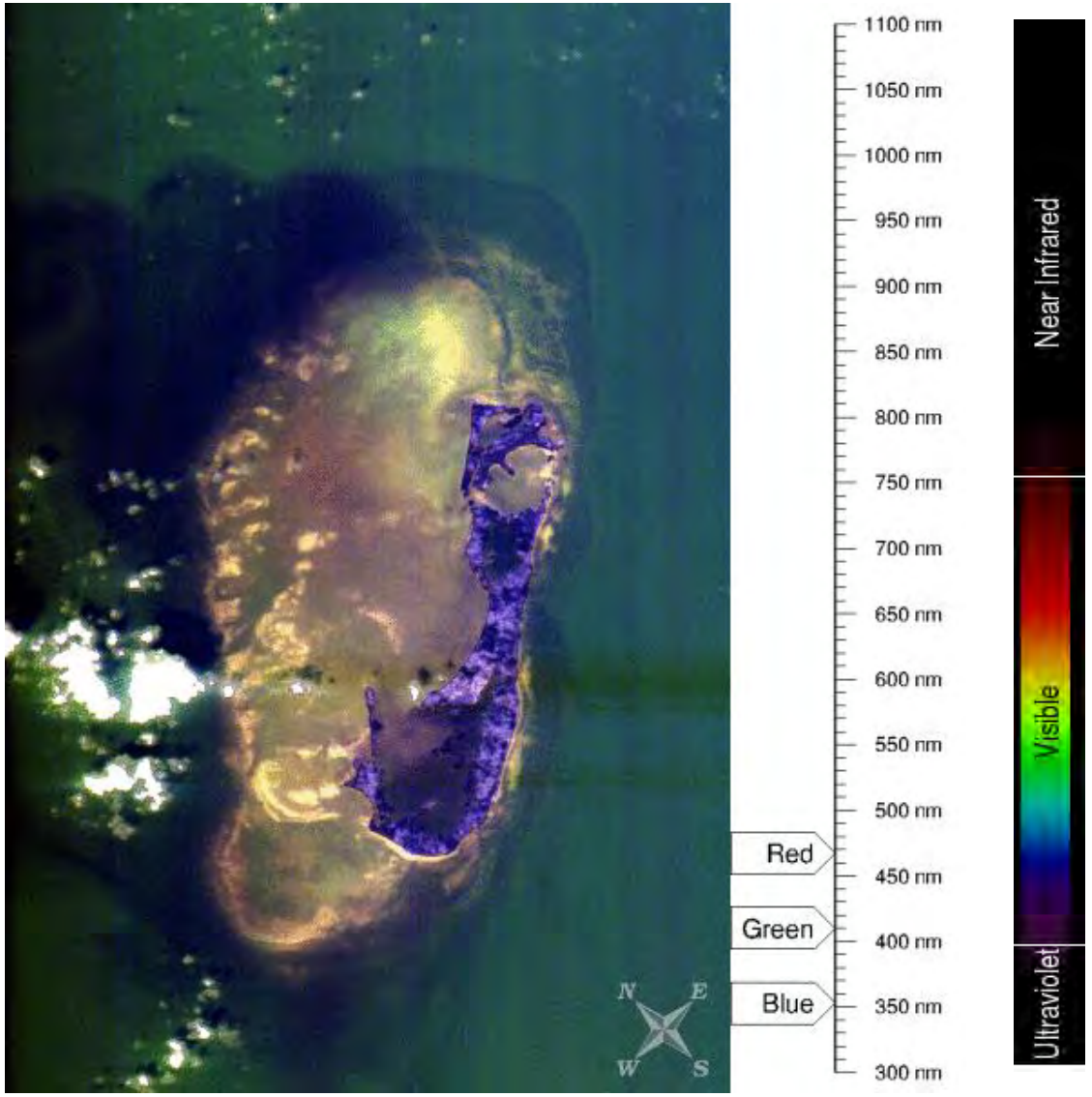
Scientific Rationale of Detection

Spectral Signatures of Crops



AVIRIS-NG SPECTROMETER DATA

Scientific Rationale of Detection



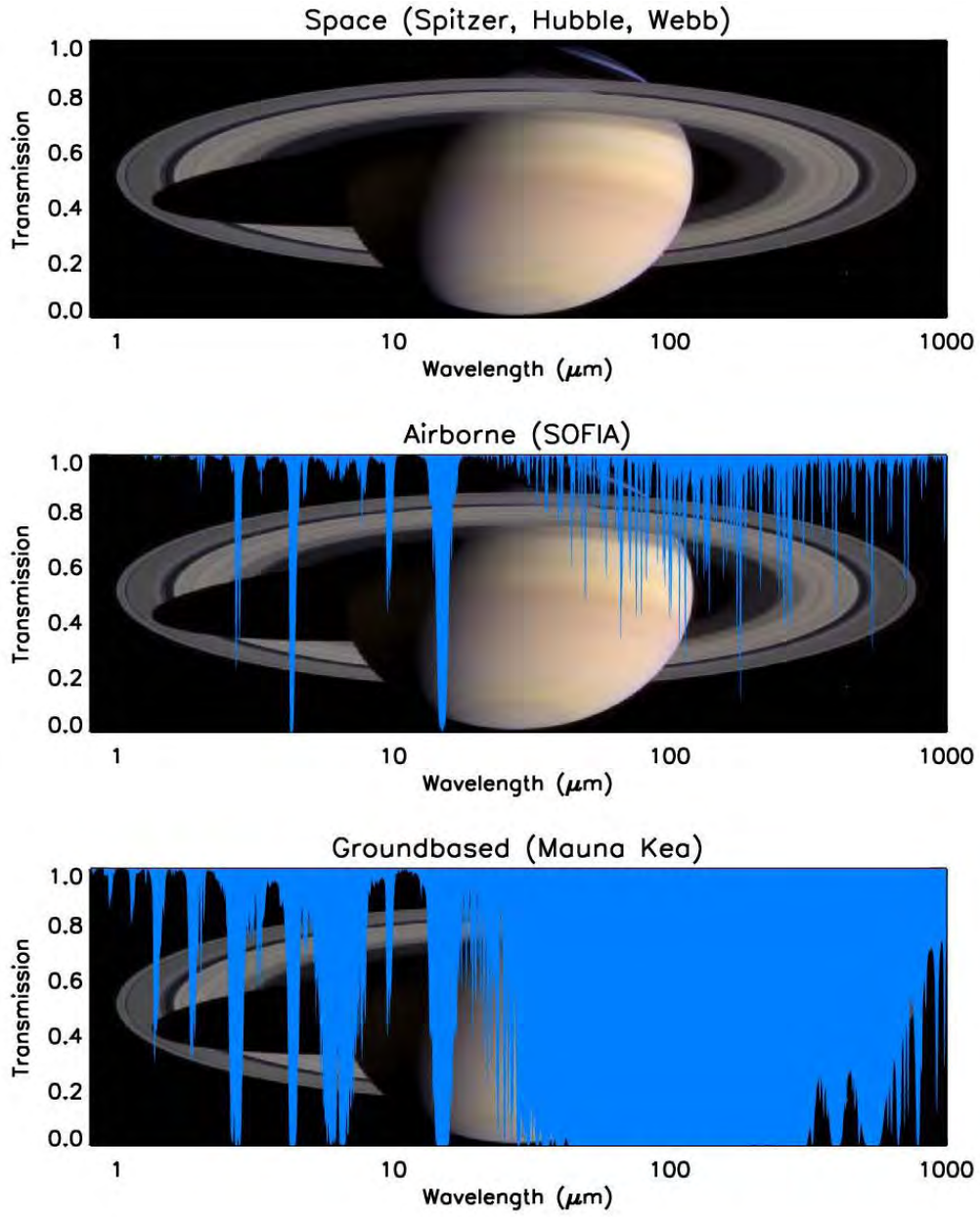
Source: HICO Data
(128 bands)

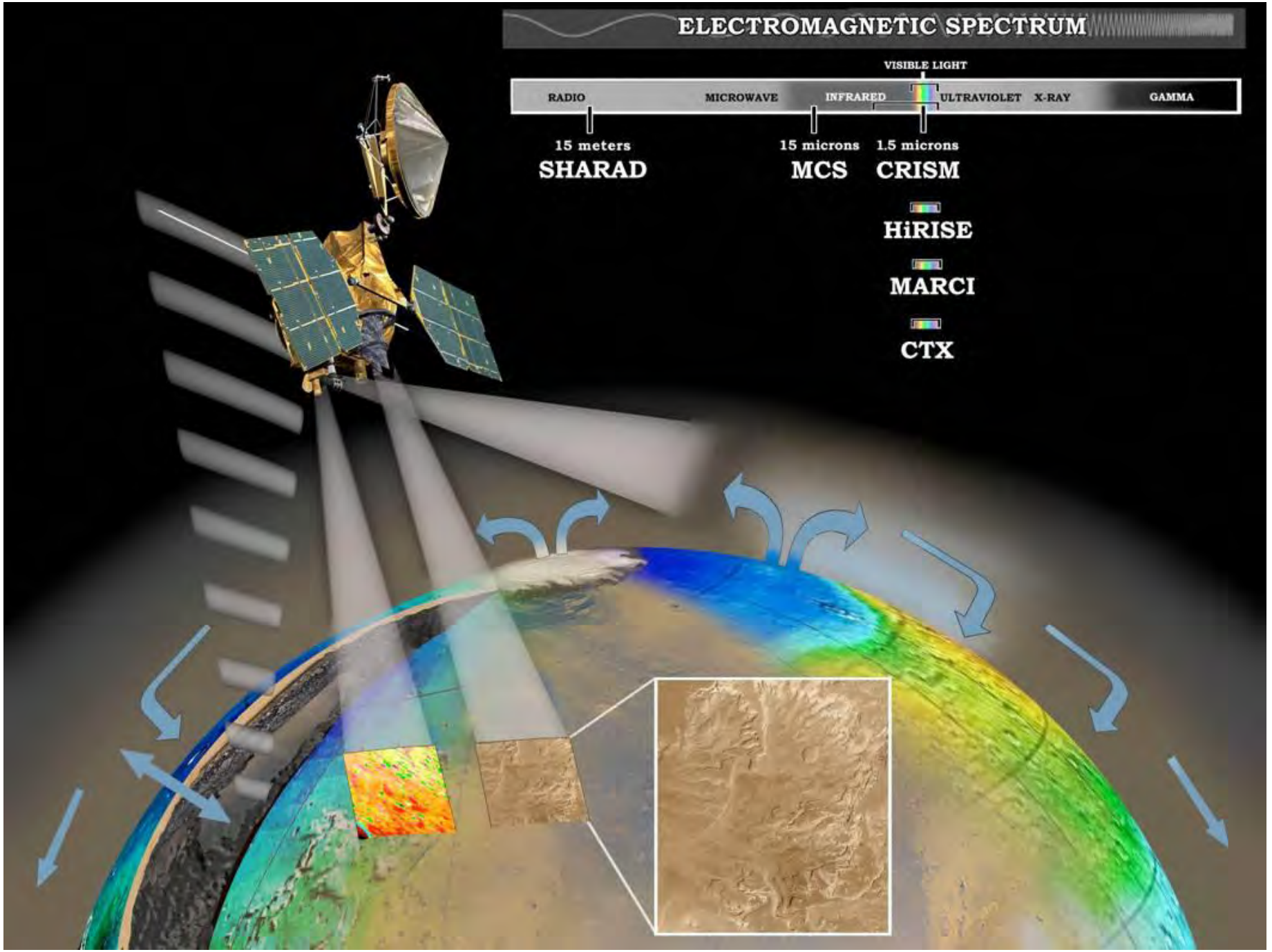
Scientific Rationale of Detection

Single Date FCC
(31 Jan. 2023)

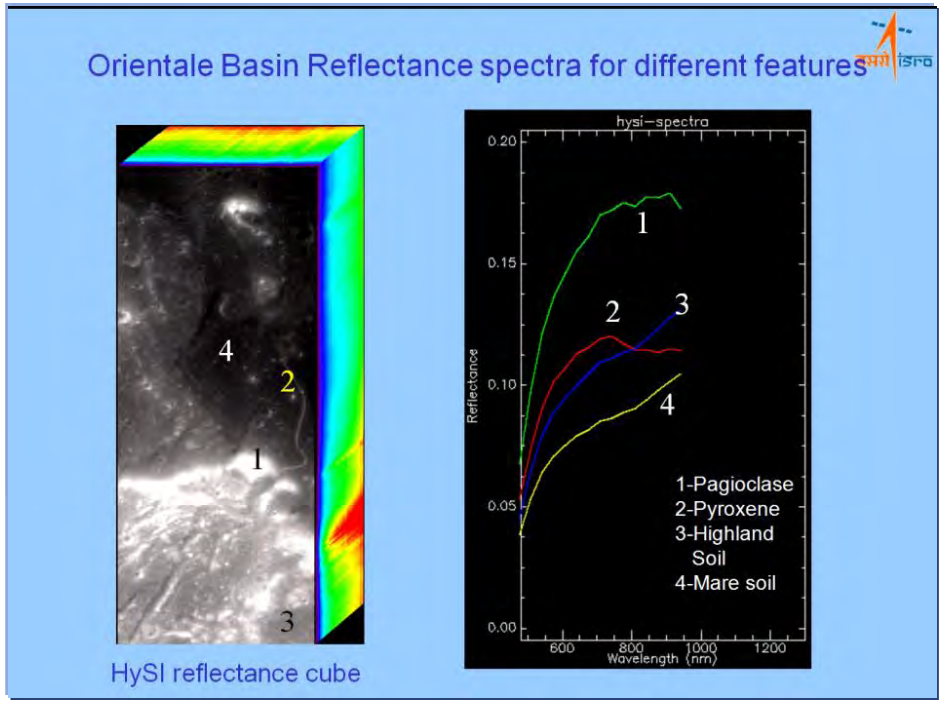
Multi Date NDVI
(25 Jan. 2023, 5 Dec. 2022, 5 Nov.2022)

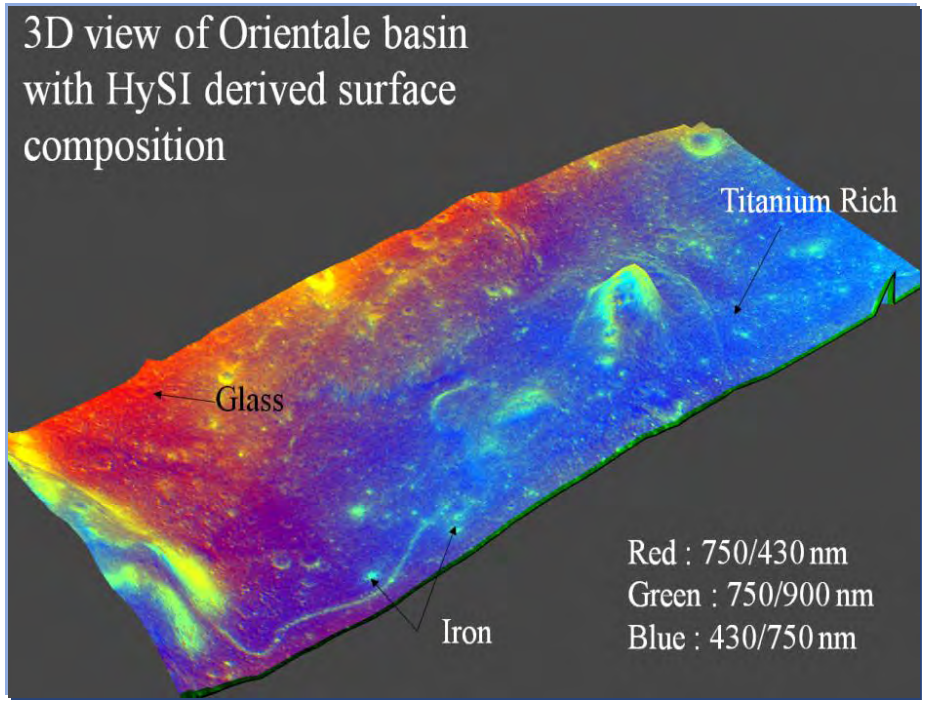
Benefits of Space based Planetary Observation



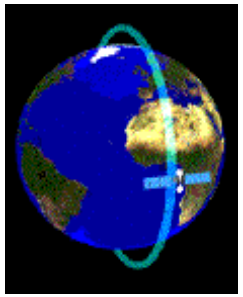

ELECTROMAGNETIC SPECTRUM
VISIBLE LIGHT
RADIO
MICROWAVE
INFRARED
ULTRAVIOLET
X-RAY
GAMMA
15 meters
SHARAD
15 microns
MCS
1.5 microns
CRISM
HiRISE
MARCI
CTX

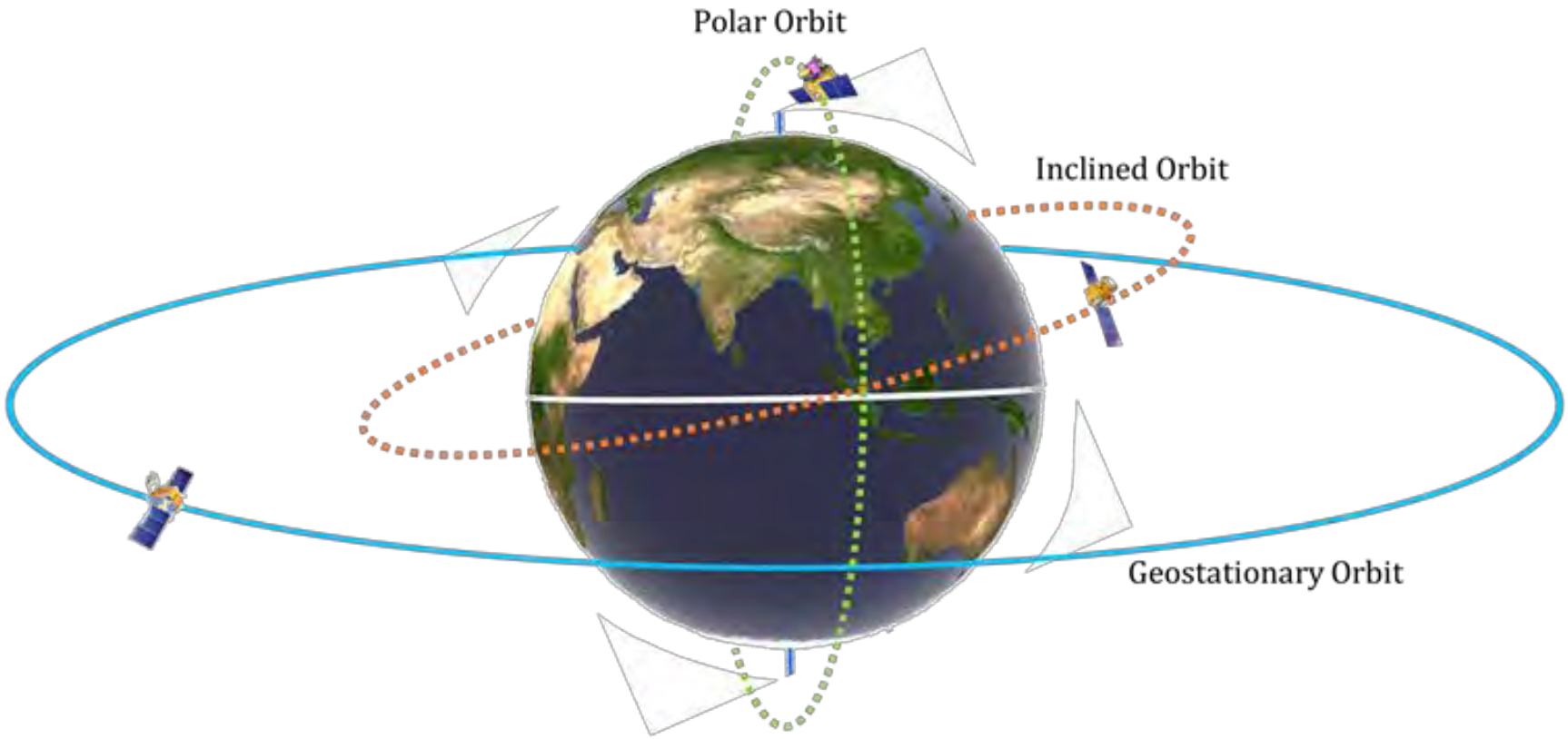
Detection of Minerals using Remote Sensing





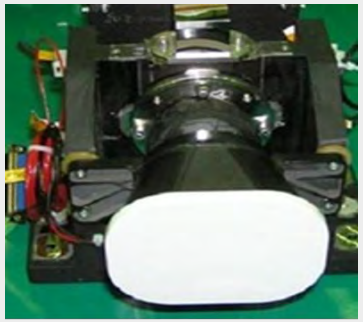
Source: Chauhan et al.





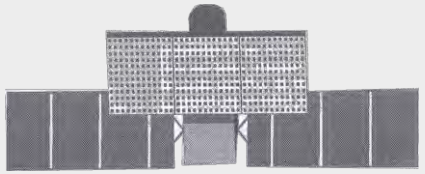
TV Payload

Multi Spectral

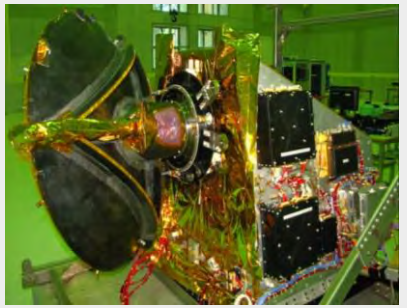


Spectrometer

Altimeter

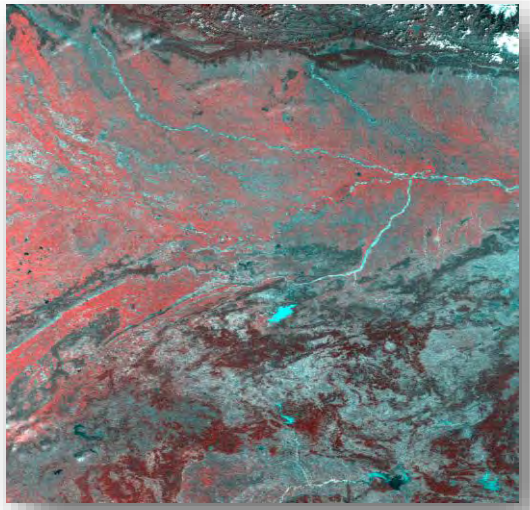


SAR

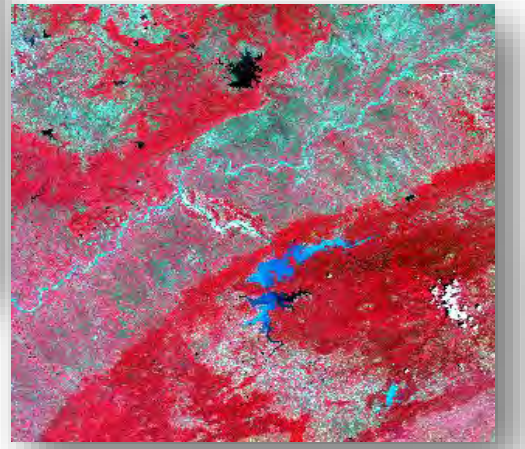


Scatterometer

Images from Polar Orbits

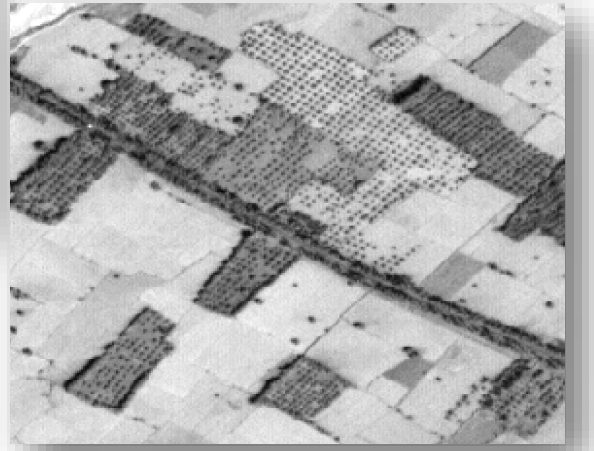


Wide Field Sensor



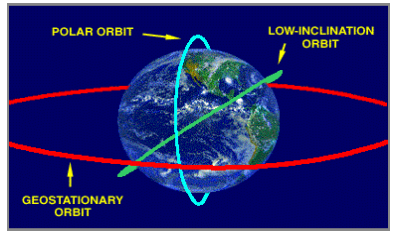
LISS-III

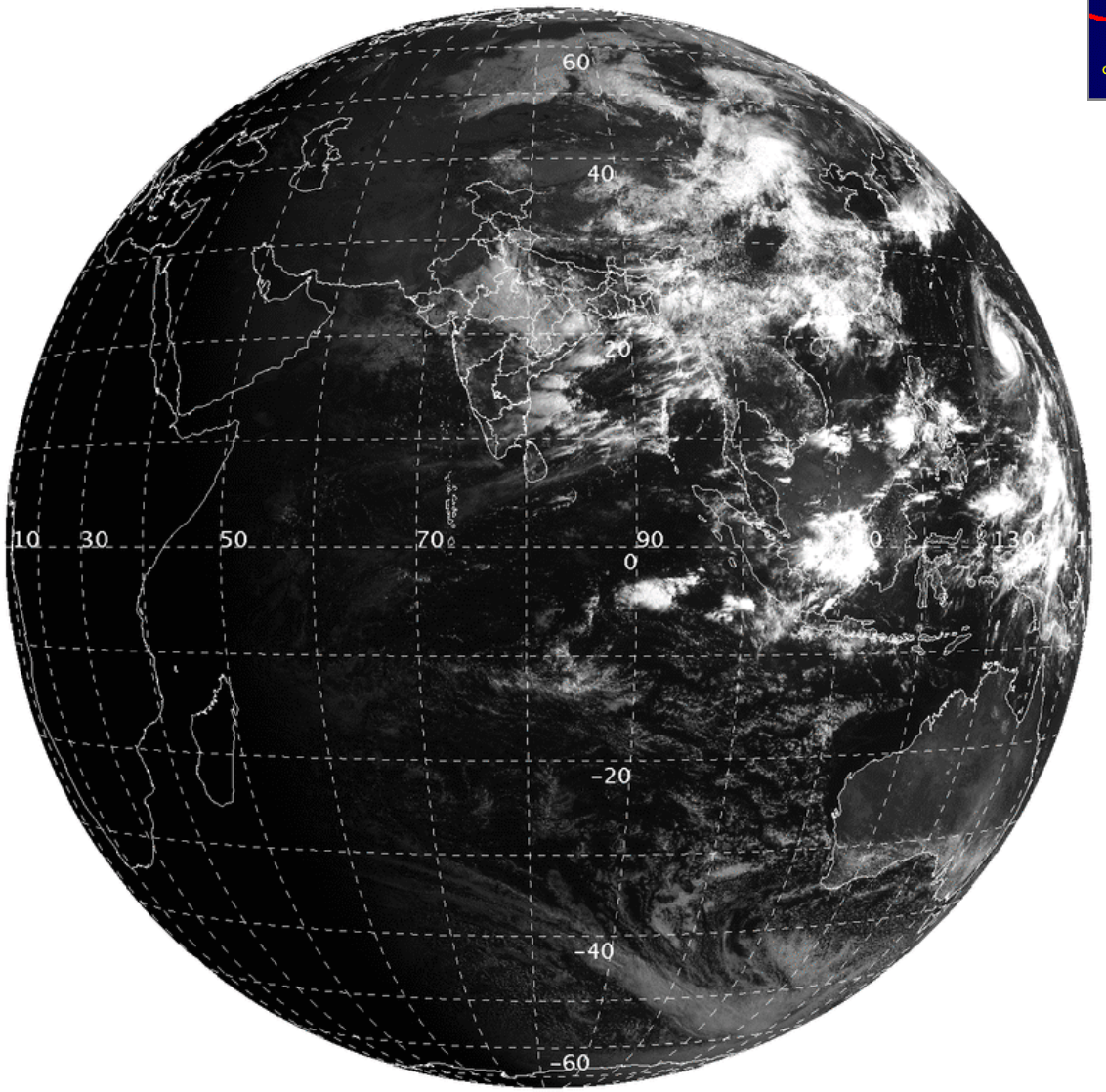
LISS-IV



CARTOSAT

Eyes in Space





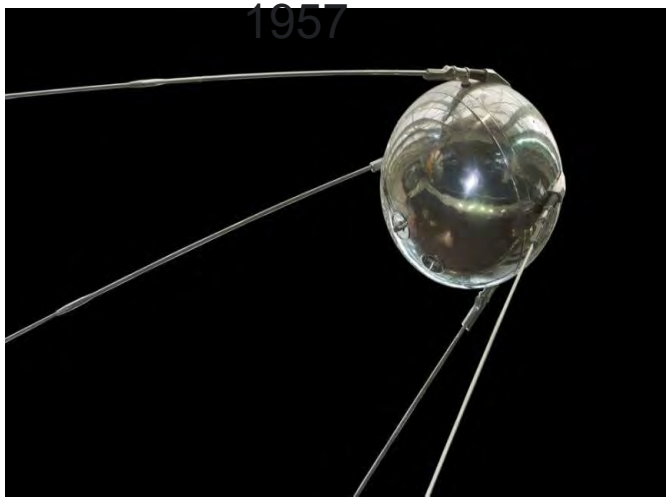
Geostationary Platform

Source: INSAT-3D Camera Obs..
Distance: 36000 km
1-2 Sept. 2018

Earth Observations

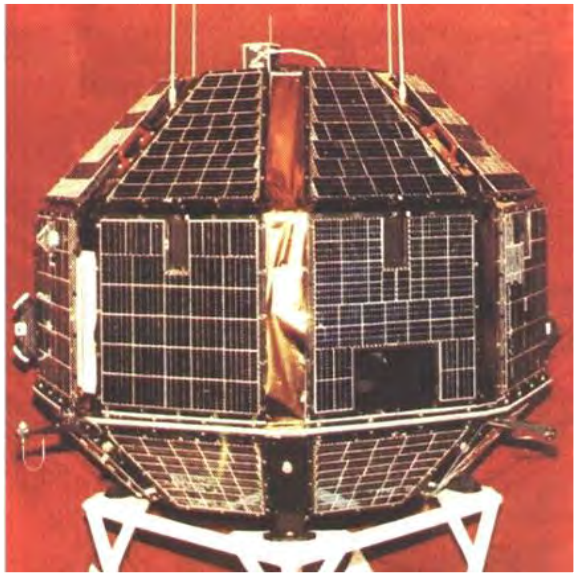
Balloon

Sputnik
1957



Aryabhatta (1975)

Bhaskara (1979)

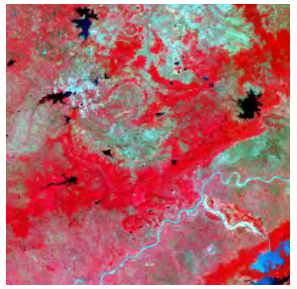


Nike-Apache on the launch pad.

Dimensions of Space Technology

Data reception

Data Product Generation



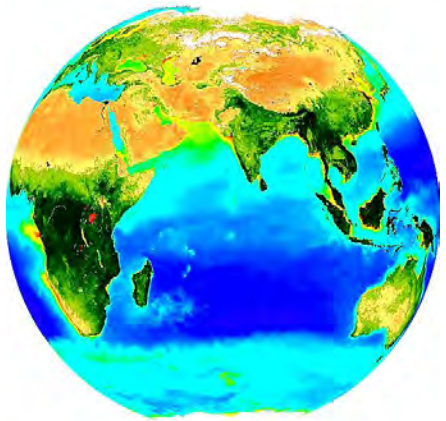
Application

Water Resource

Launch

Development of Sensor

EO Observations



INDIA: RESOURCES & CHALLENGES

Geography:
3.27 M km^2

Glaciers:
8500 km^2

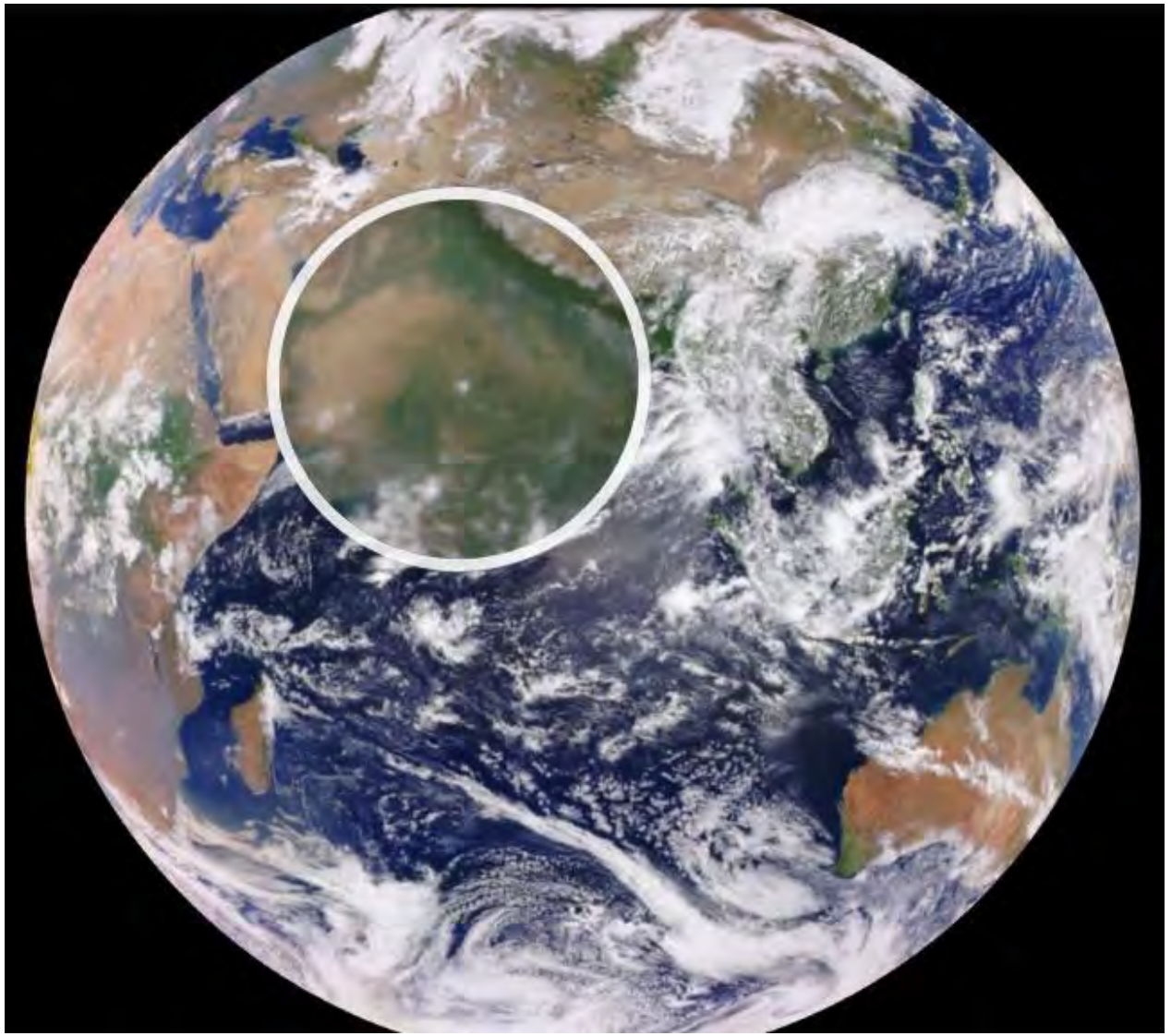
Biodiversity
> 7% of World

Coastline
7516 km

Wetland
7.6 M ha

Forest cover
21.54 %

Population
1.32 B



Declining Water

Land Degradation

Reduced Forest Cover and Biodiversity

Glacier Retreat

Disaster and Extreme Weather Prone

INDIA'S PRIORITIES

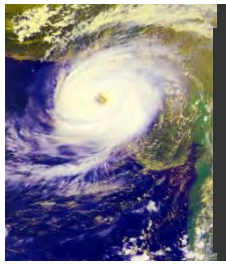
- Surface Water Resources
- Ground Water Prospecting
- Snow & Glaciers

- Sustainable Agriculture
- Inland & Marine Fisheries
- Horticulture

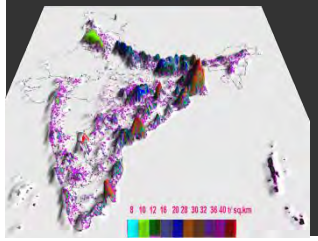
- Weather Forecasting
- Ocean State Forecasting

- Forest Status
- Biodiversity
- Coastal Zone
- Environmental Impact

- Urban Planning
- Rural Roads
- Infrastructure Development



- Disaster Monitoring & Mitigation



- Global change Indicators
- Regional Climate Model
- Impact Assessment

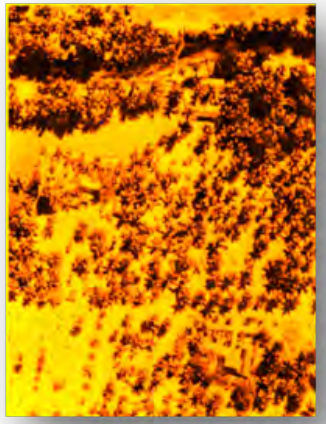
Early Phase

1968

Remote Sensing proposed as a tool for national development

1970

Detecting Coconut Root Wilt Disease Study



1974-76

Crop Yield Assessment Anantapur, AP Patiala, Punjab

Agricultural
Resources
Inventory &
Survey
Experiment

1979

LANDSAT Data Reception Centre

Demonstration studies using LANDSAT-1 &2 Data.

First Decade: Experimental Phase

1979-1990

Bhaskara-1/2 (1979/81)

IRS-1A (1988)

Bhaskara-I	**TV Camera, SAMIR**	**7 June 1979**
Bhaskara-II	TV Camera, SAMIR	20 Nov. 1981
IRS-1A	LISS-I and LISS-II	17 March 1988

Bhaskara Satellite (1979)


INDIAN EXPRESS

CJs seek abolition of second appeal

Move to reduce arrears in courts

Banarsi Das Gupta bows to farmers' lobby for survival

Desai plans to visit S-E Asia this year

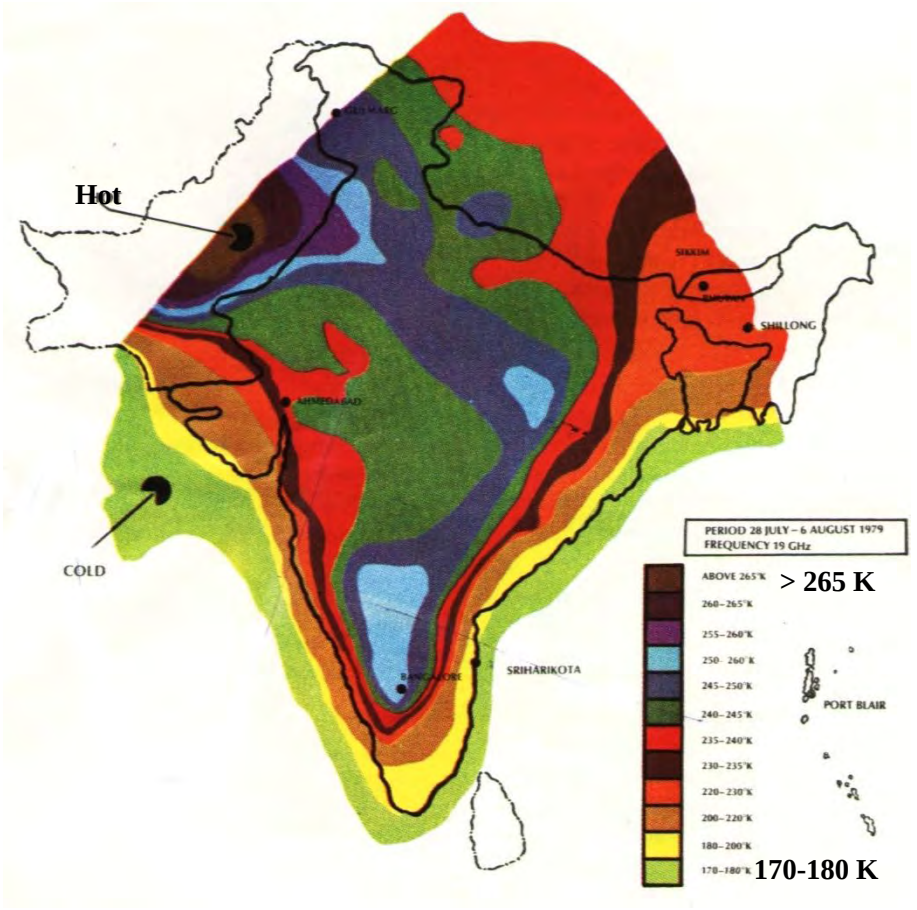
27 killed as IAF Avro crashes near Leh

Bid for compromise in Karnataka tangle

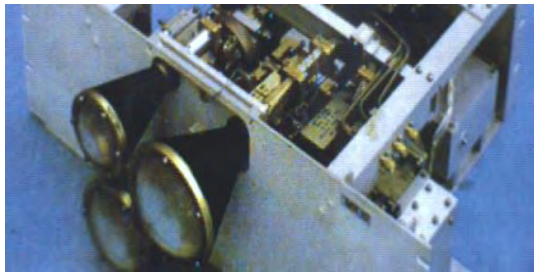
Devi Lal claims majority support

Neutrals meet skirts Kampuchea issue

Second Indian satellite launched

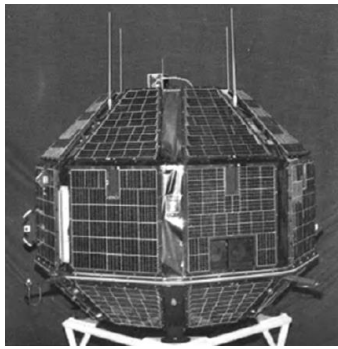


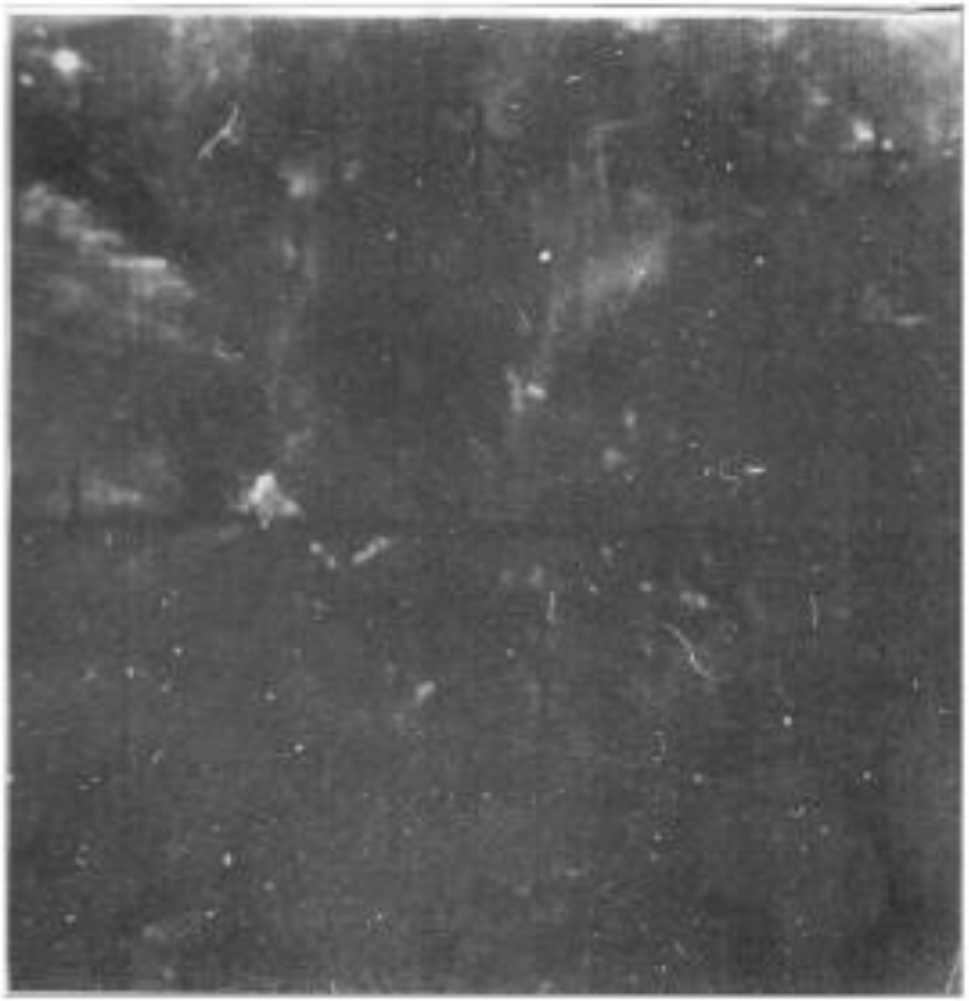
SAMIR 19 GHz BT
(July 28 – August 6 1979)



Microwave Radiometer
(19.24, 22.235, 31.4 GHz)

Bhaskara Satellite (1979)





The Pearl (Doha) by Cartosat-2S

Second Decade: Developmental Phase

1991-2000

IRS-1B (1991)

IRS-1C/1D (1995/1997)

INSAT-2E (1999)

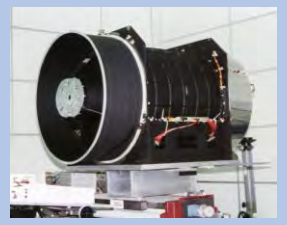
OCM-1 (1999)

IRS-1B	LISS-I and LISS-II	29 Aug. 1991
IRS-P2	LISS-II	15 Oct. 1994
IRS-1C	LISS-III, PAN and WiFS	28 Dec. 1995
IRS-P3	MOS-A,B, C and WiFS	21 Mar. 1996
IRS-1D	LISS-III, PAN and WiFS	29 Sept. 1997
INSAT-2E	CCD,VHRR	03 Apr.1999
IRS-P4 (Oceansat-1)	OCM, MSMR	26 May 1999

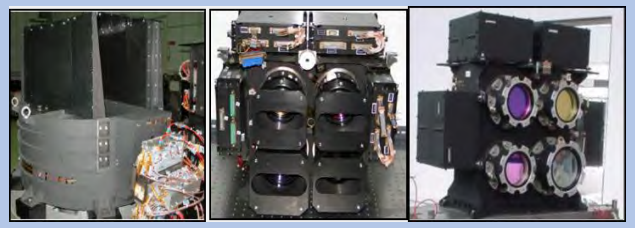
Third Decade: Operational Phase

2001-2010

Kalpana (2002)

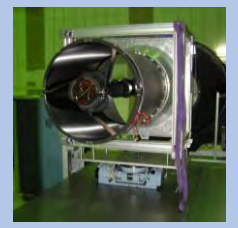


INSAT-3A (2003)

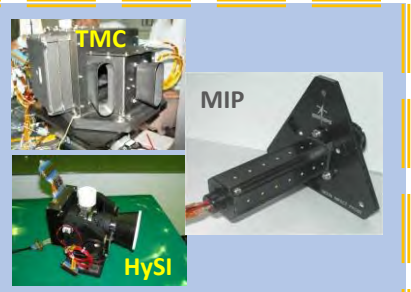


Resourcesat-1 (2003)

Cartosat-1 (2005)



Cartosat-2 (2007)



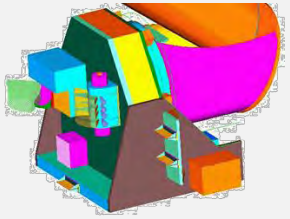
Chandrayaan-1 (2008)

Kalpana-1	VHRR	12 Sept. 2002
INSAT-3A	CCD, VHRR	10 Apr. 2003
IRS-P6 (Resourcesat-1)	LISS-III, LISS-IV, AWiFs	17 Oct. 2003
IRS-P5 (Cartosat-1)	PAN (Fore and Aft)	5 May 2005
Cartosat-2	PAN	10 Jan. 2007
Cartosat-2A	PAN	28 Apr. 2008
IMS-1	HySI and MX	28 Apr. 2008
Oceansat-2	OCM, Scatterometer, ROSA	23 Sept. 2009
Cartosat-2B	PAN	12 July 2010

Fourth Decade: Advanced and Scientific Exploration Phase

2011-2020

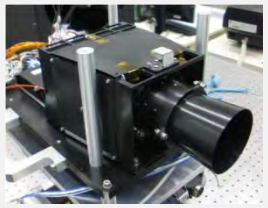
RS-2/2A (2011/16)

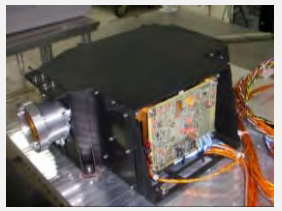


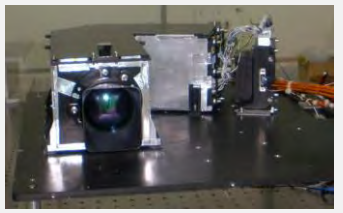
MT (2011)

RISAT-1 (2012)

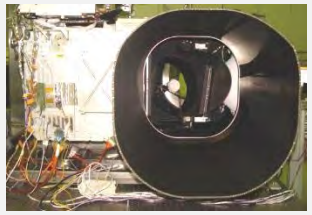
SARAL-ALTIKA (2013)



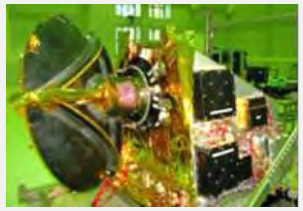




Mars Orbiter Mission (2013)

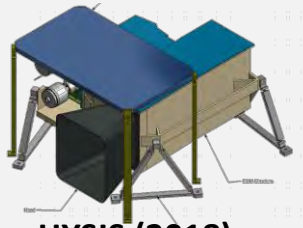


INSAT-3D/3DR (2013/16)

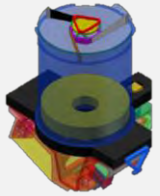


SCATSAT-1 (2016)

Cartosat-2S (2016/17/18)



HYSIS (2018)

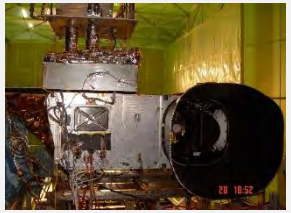


Cartosat-3 (2019)

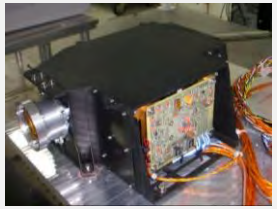
Resourcesat-2	**LISS-III, LISS-IV, AWiFs**	**20 Apr. 2011**
Megha Tropique	MADRAS, ScaRaB, SAPHIR	12 Oct. 2011
RISAT-1	C-Band SAR	26 April 2012
SARAl Altika	Ka Band Altimeter	25 Feb. 2013
INSAT-3D	Imager and Sounder	26 July 2013
Cartosat-2S	PAN, MX	22 June 2016
INSAT-3DR	Imager and Sounder	8 Sept. 2016
SCATSAT-1	Scatterometer	26 Sept.2016
Resourcest-2A	LISS-III, LISS-IV, AWiFs	07 Dec.2016
Cartosat-2S	PAN, MX	15 Feb. 2017,23 June 2017,12 Jan. 2018
HYSIS	Hyper Spectral Spectrometer	29 Nov. 2018
Cartosat-3	PAN, MX	27 Nov. 2019

Fifth Decade

2021-2030

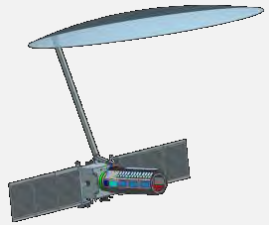


RISAT-1A/1B

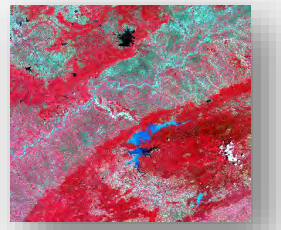


Oceanat-3

GISAT

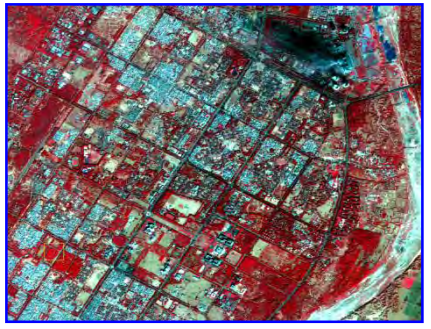


NISAR

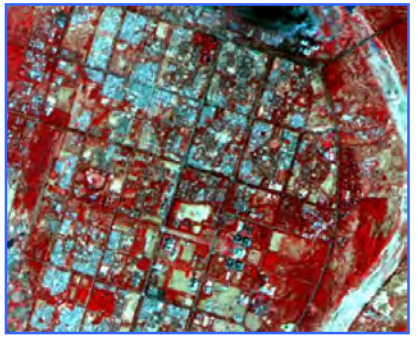


TRISHNA

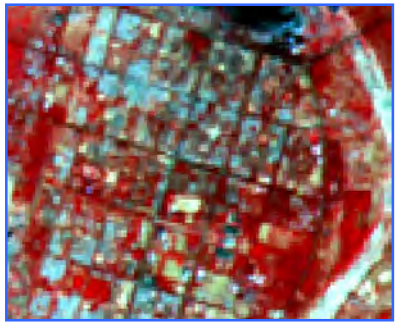
Resourcesat Series Satellites



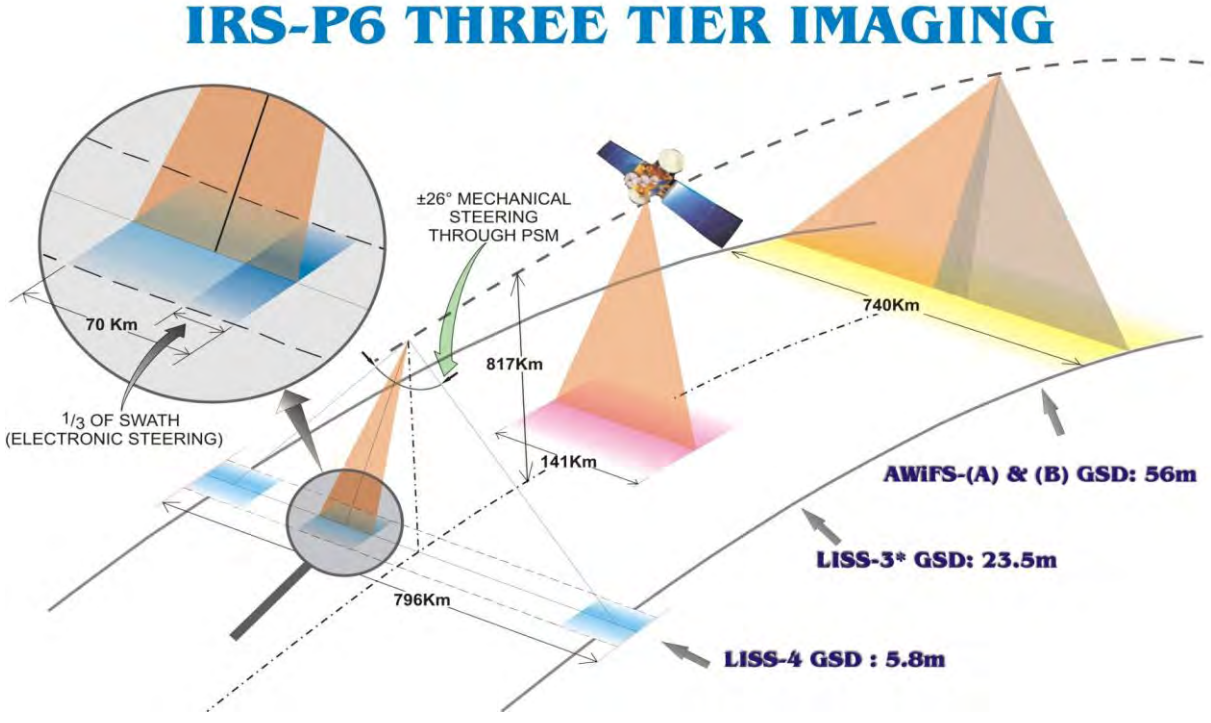
LISS-IV



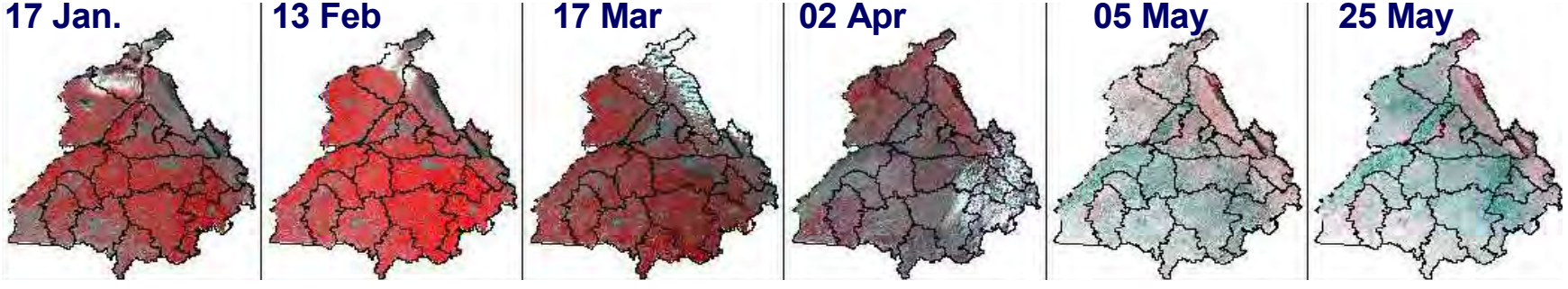
LISS-III



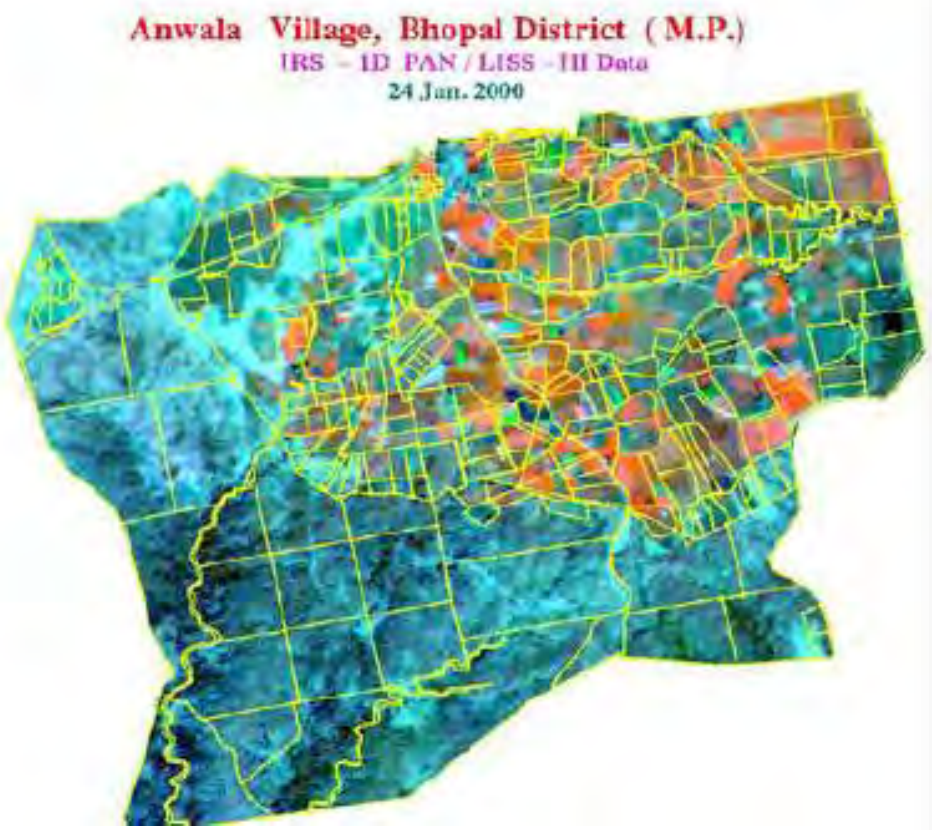
AWiFS

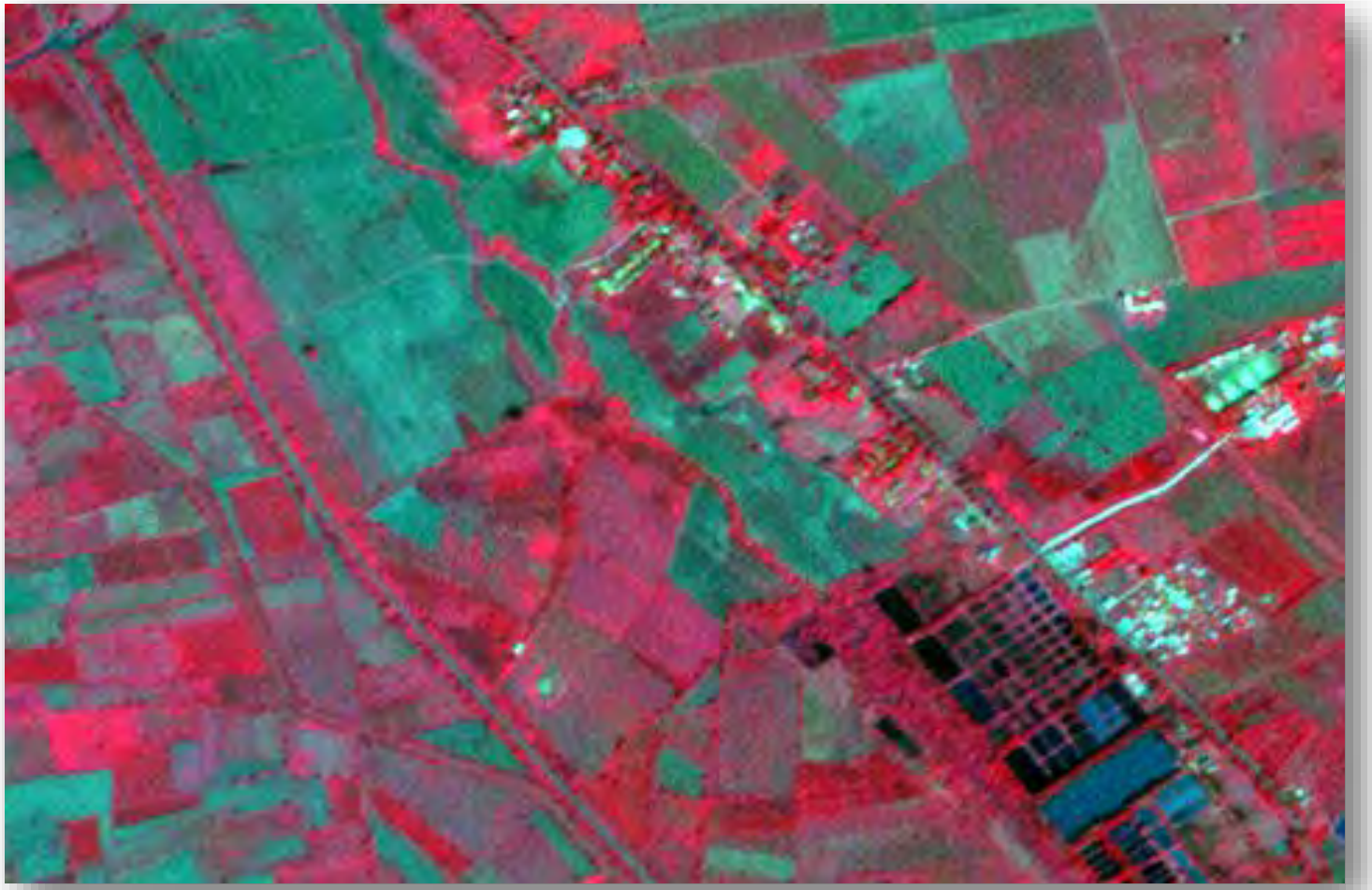


Temporal Crop Growth Dynamics

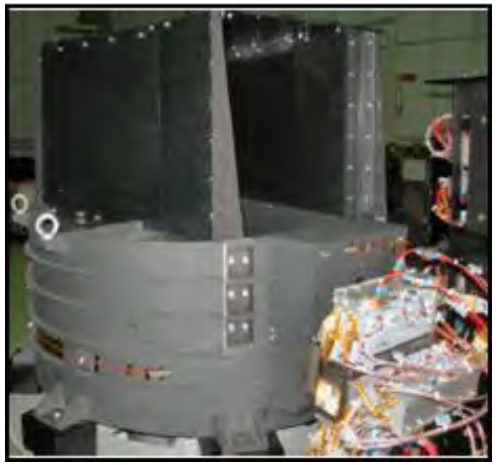


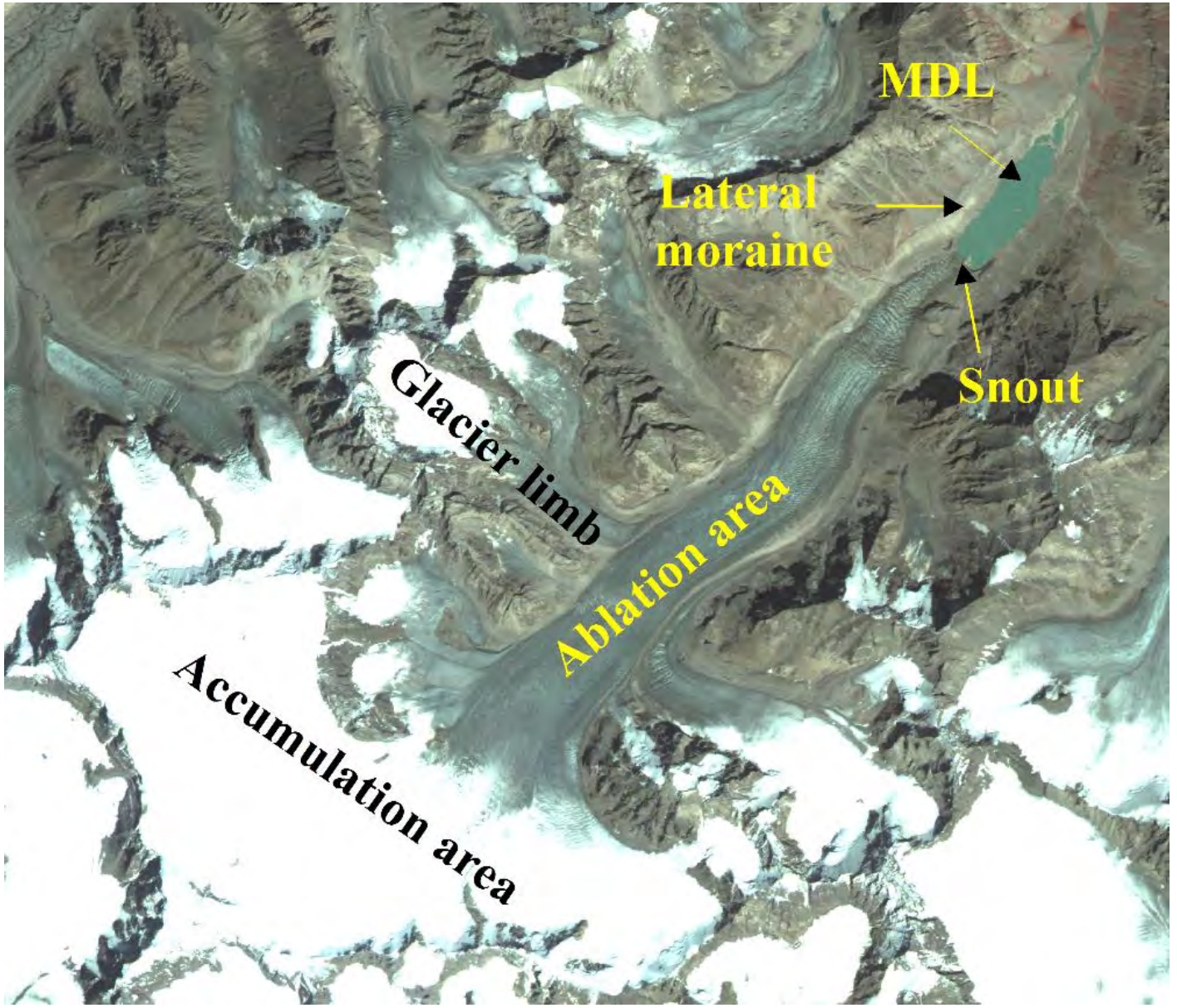
Agriculture



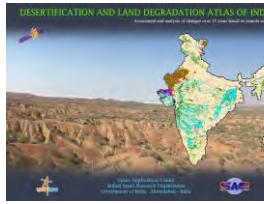


Glaciers Seen by Resourcesat Satellite

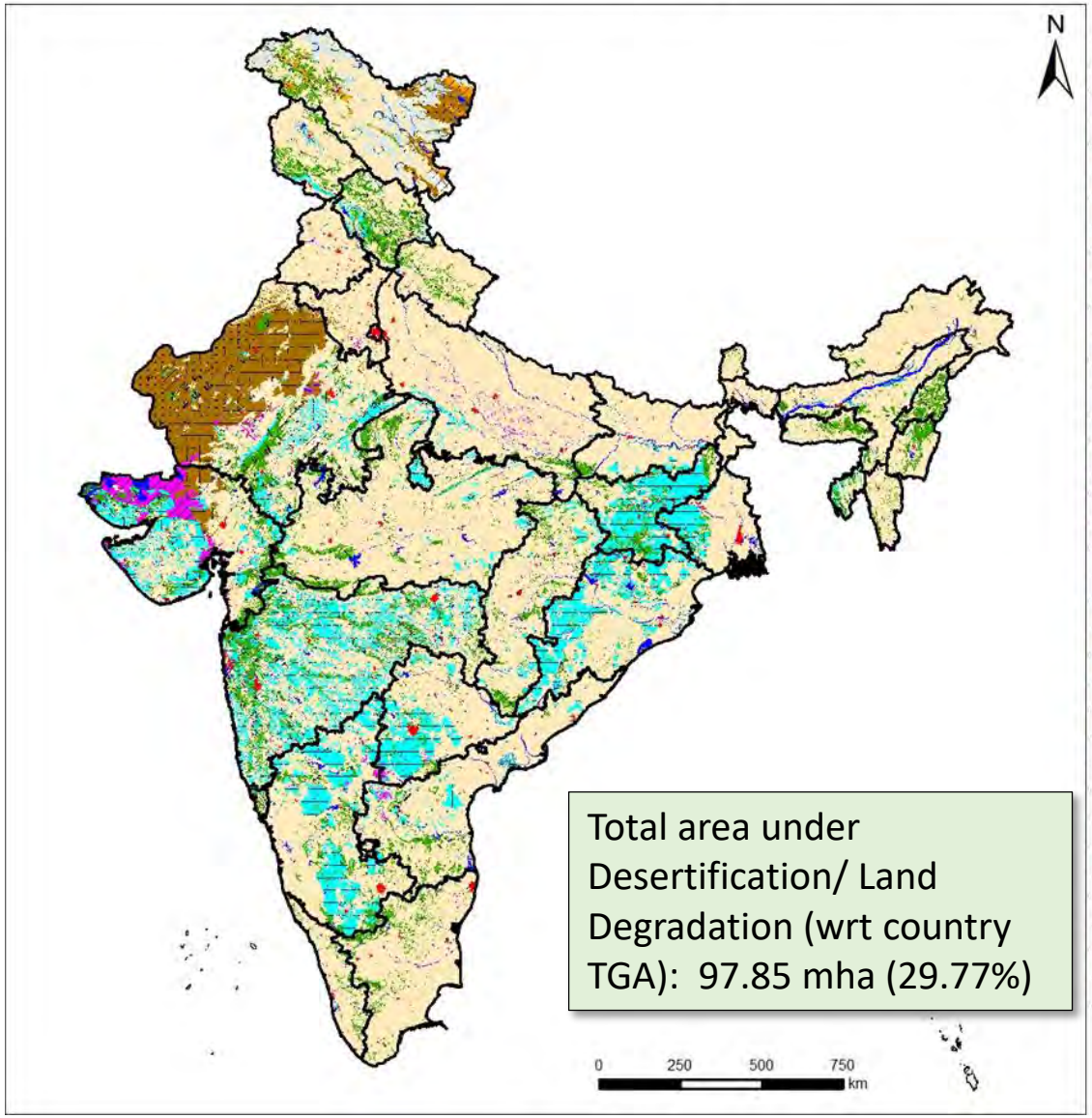




Desertification and Land Degradation (DLD)



DESERTIFICATION / LAND DEGRADATION STATUS MAP OF INDIA - 2018-19



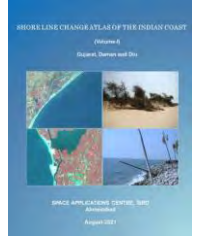
Total area under Desertification/ Land Degradation (wrt country TGA): 97.85 mha (29.77%)

Legend		
Symbol	Code	Description
	Fv1,2	Forest, vegetation degradation
	Gv1,2	Grassland / Grazing land, vegetation degradation
	Sv1,2	Land with scrub, vegetation degradation
	Iw1,2	Agriculture irrigated, water erosion
	Dw1,2	Agriculture unirrigated, water erosion
	Fw1,2	Forest, water erosion
	Sw1,2	Land with scrub, water erosion
	Bw1	Barren, water erosion
	Ew1	Dune / Sandy area, water erosion
	Ie1,2	Agriculture irrigated, wind erosion
	De1,2	Agriculture unirrigated, wind erosion
	Se1,2	Land with scrub, wind erosion
	Be1	Barren, wind erosion
	Ee1,2	Dune / Sandy area, wind erosion
	Is1,2	Agriculture irrigated, salinity / alkalinity
	Ds1,2	Agriculture unirrigated, salinity / alkalinity
	Gs1,2	Grassland / Grazing land, salinity / alkalinity
	Ss1,2	Land with scrub, salinity / alkalinity
	Bs1,2	Barren, salinity / alkalinity
	Il1,2	Agriculture irrigated, water logging
	Dl1,2	Agriculture unirrigated, water logging
	Fl1	Forest, water logging
	Gl2	Grassland / Grazing land, water logging
	Sl1,2	Land with scrub, water logging
	El1,2	Dune / Sandy area, water logging
	Bg2	Barren, mass movement
	Rf1	Rocky, frost shattering
	Lf1,2	Periglacial, frost shattering
	Fm1,2	Forest, man made
	Tm1,2	Others, man made
	B	Barren
	R	Rocky
	S	Settlement
	W	Water body/ Drainage
	NAD	No Apparent Degradation

Data Source: IRS AWiFS (2018-19), Ancillary Information

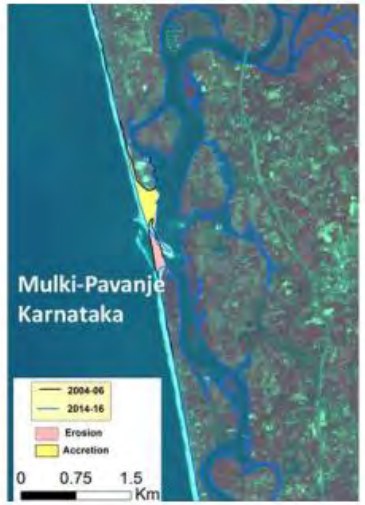
Prepared by:
Space Applications Centre,ISRO, Ahmedabad

Shoreline Change Atlas of the Indian Coast



Some Hot Spots of Shoreline Changes

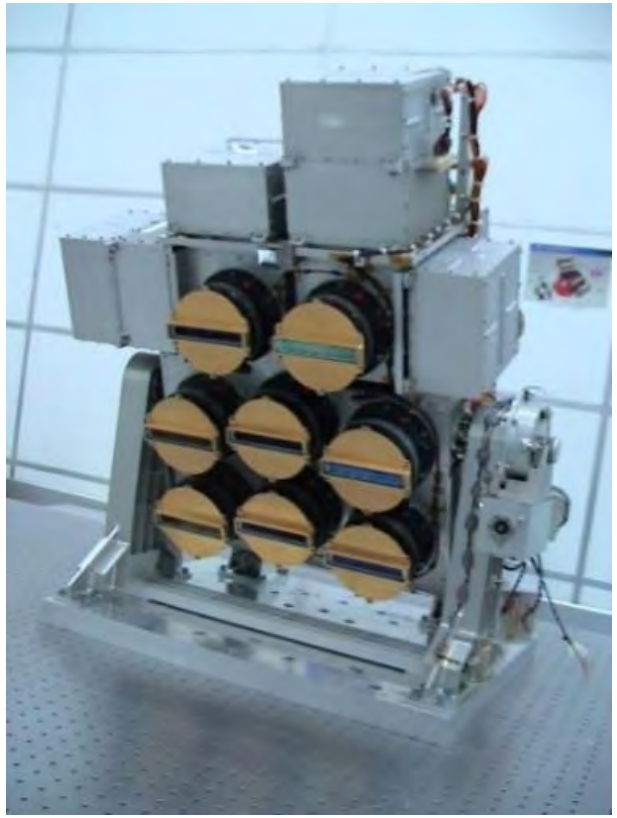
River mouth/Alongshore bar migration

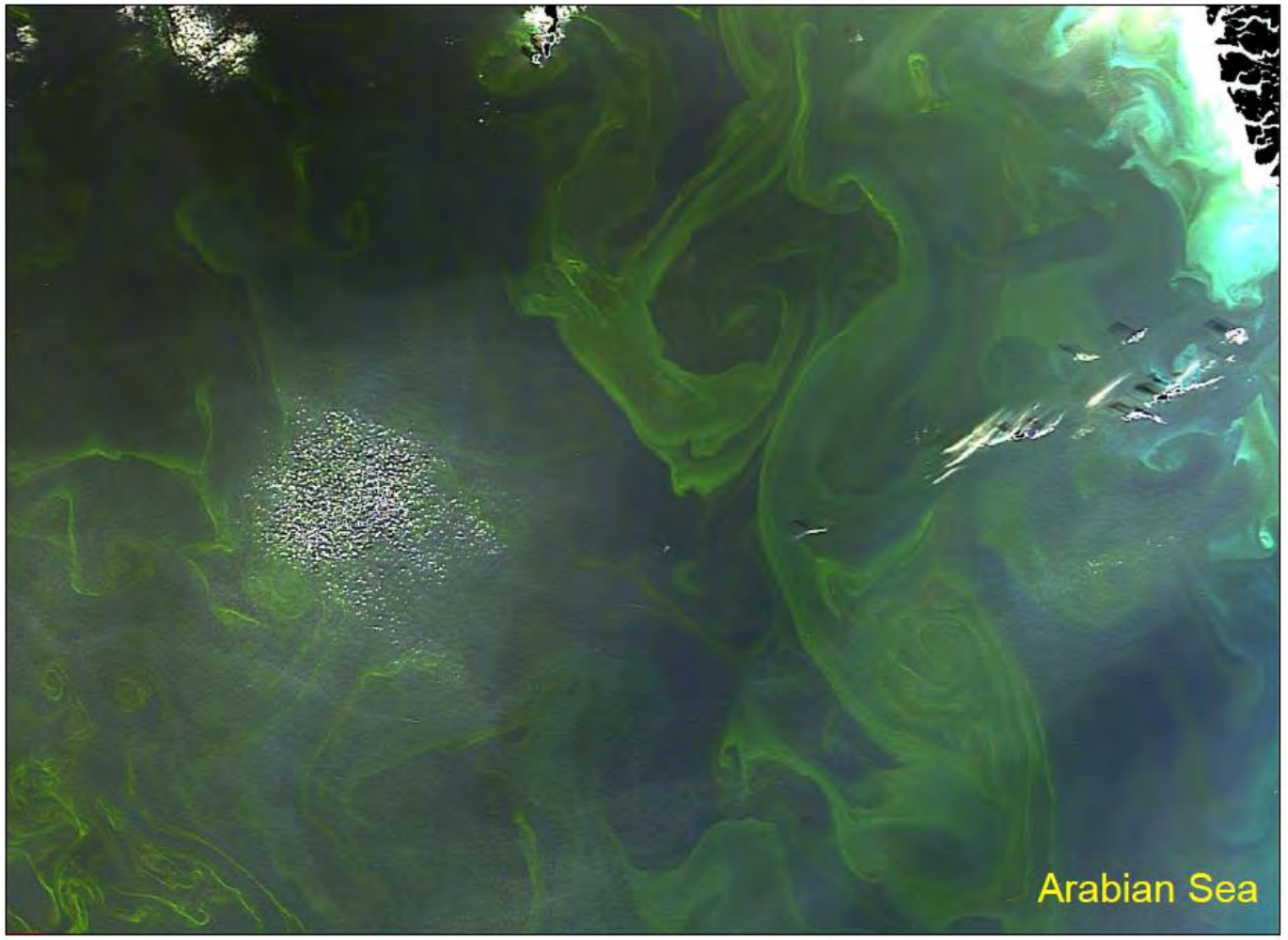


Natural Processes

Total length of the Indian shoreline is 7549 km. Around 5321 km of the coast is stable, 1144 km of the coast shows erosion and 1084 km is accreting.

Ocean Colour from Oceansat Satellite

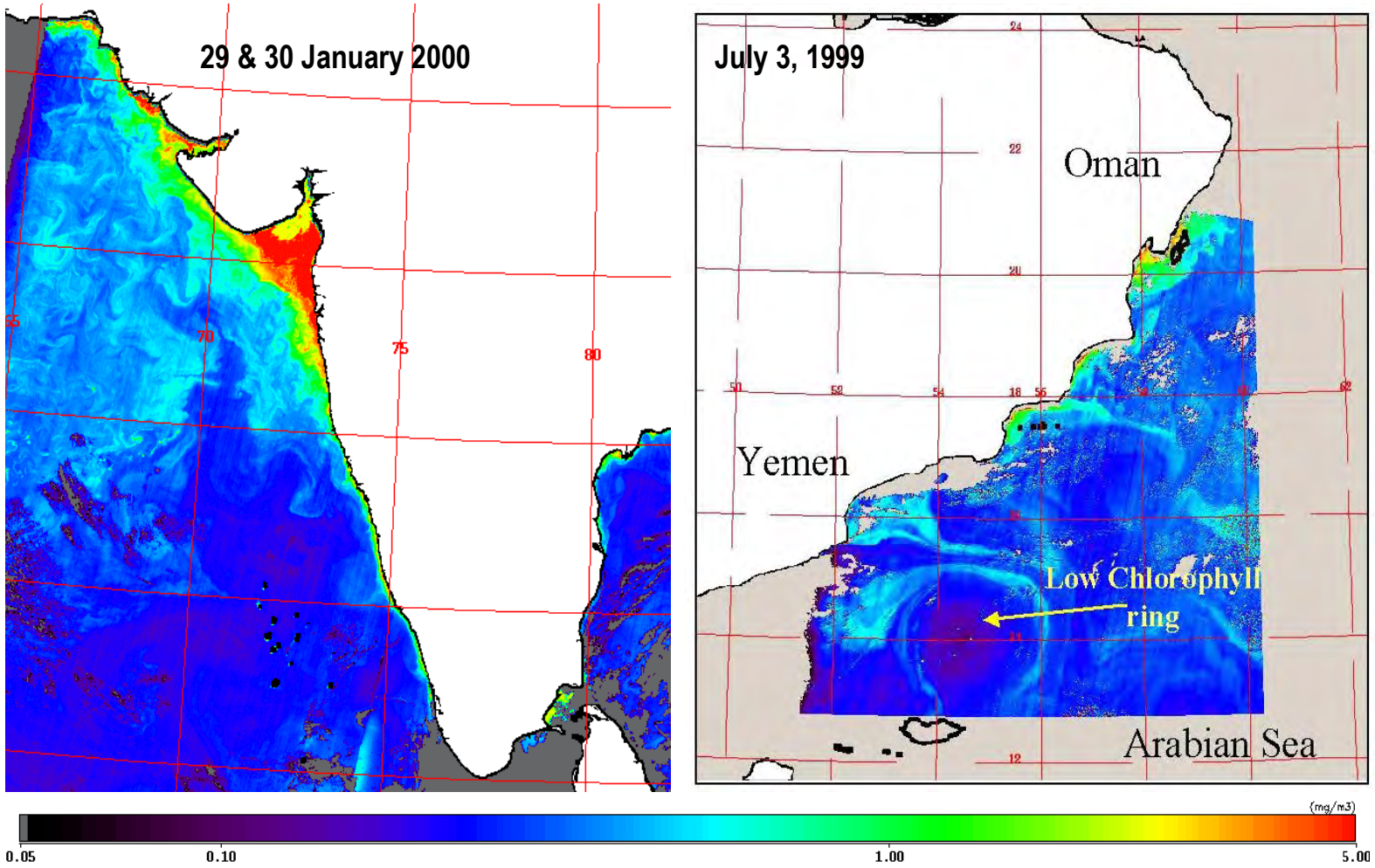


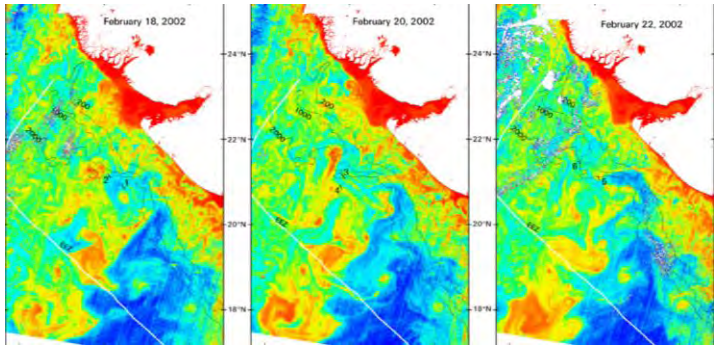


Forest of the Sea : Massive Outbreak of Noctiluca algal blooms in green colour in the Arabian Sea as captured by OCEANSAT-2 OCM on Feb 8, 2018

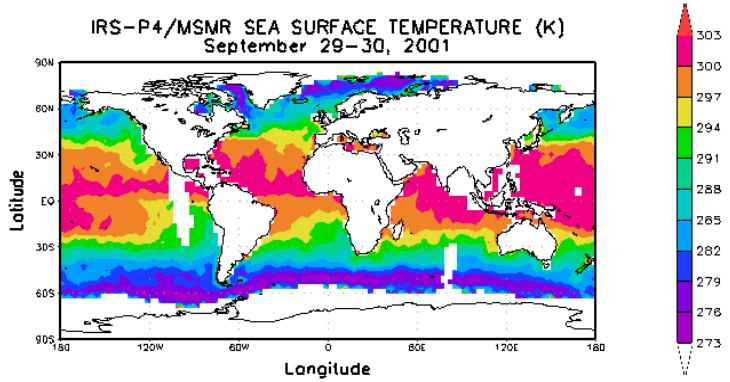
OCEANSAT-1 APPLICATIONS

Chlorophyll-a distribution in Arabian Sea





Potential Fishing Zone Forecast



Global coverage from Oceansat-3 OCM

Microwave Instruments

1979-81

BHASKARA-1
BHASKARA-2
(SAMIR)

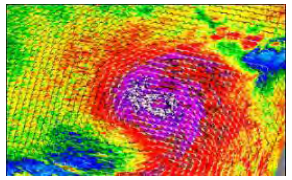
1985-90

Airborne SLAR
(20- 100 m
Res.)

1991-02

ASAR
(6 m Res.)
IRSP4-MSMR

2007-2010



DMSAR
RISAT-2 SAR
Oceansat-2
(Scatterometer)

2011-2017

RISAT-1 (SAR)
Megha
Tropique
(Madras,
ScaRab,
SAPHIR,
GPS Occ.)
SARAL
SCATSAT-1

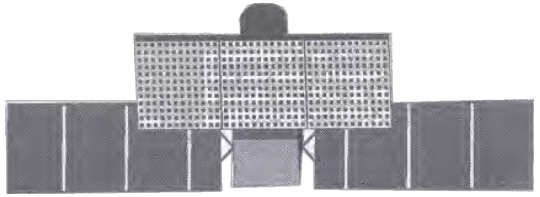
2020-2025

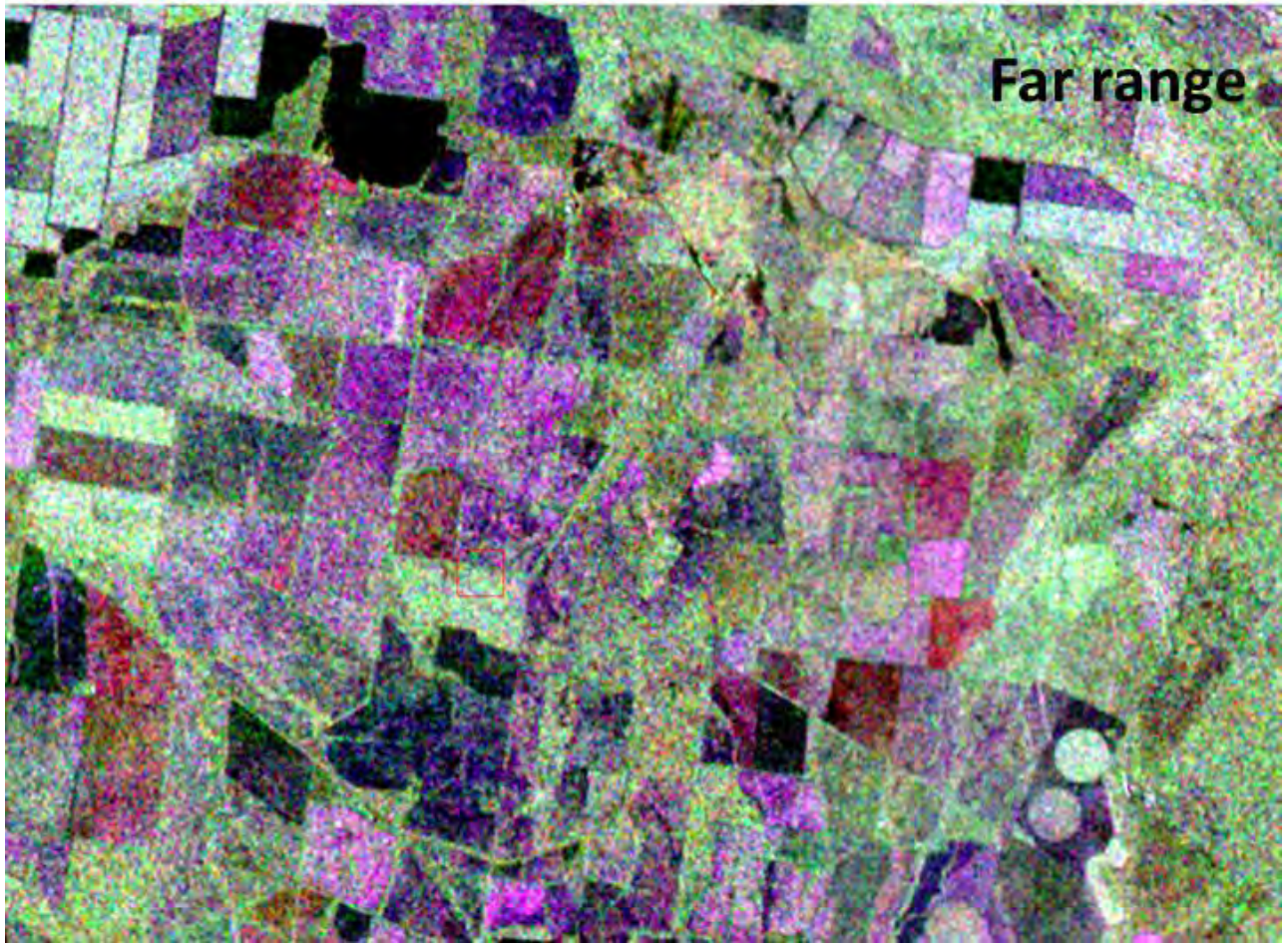
RISAT-1A (SAR)

RISAT-1B (SAR)

O3-Scatterometer

Radar Imaging From RISAT Satellite





Space borne SAR in C-band at 5.35 GHz

ATMOSPHERIC AND OCEANIC OBSERVATIONS

1979-81

BHASKARA-1
BHASKARA-2
(SAMIR)

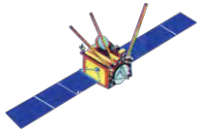
1982-90

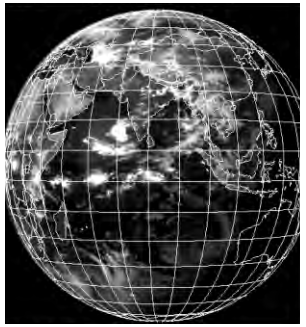
INSAT
(1A/1B/1C/1D)
(VHRR)

1991-95

INSAT
(2A/2B/2C)
(VHRR)

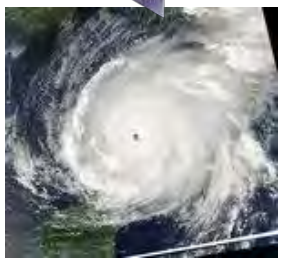
1996-2000





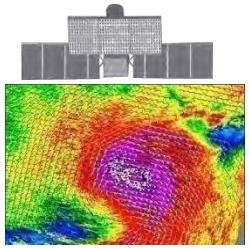
IRS-P3 (MOS)
INSAT-2D (VHRR)
INSAT-2E (VHRR,CCD)
IRS-P4 (OCM,MSMR)

2001-2005



KALPANA (VHRR)
INSAT-3A
(VHRR,CCD)

2007……

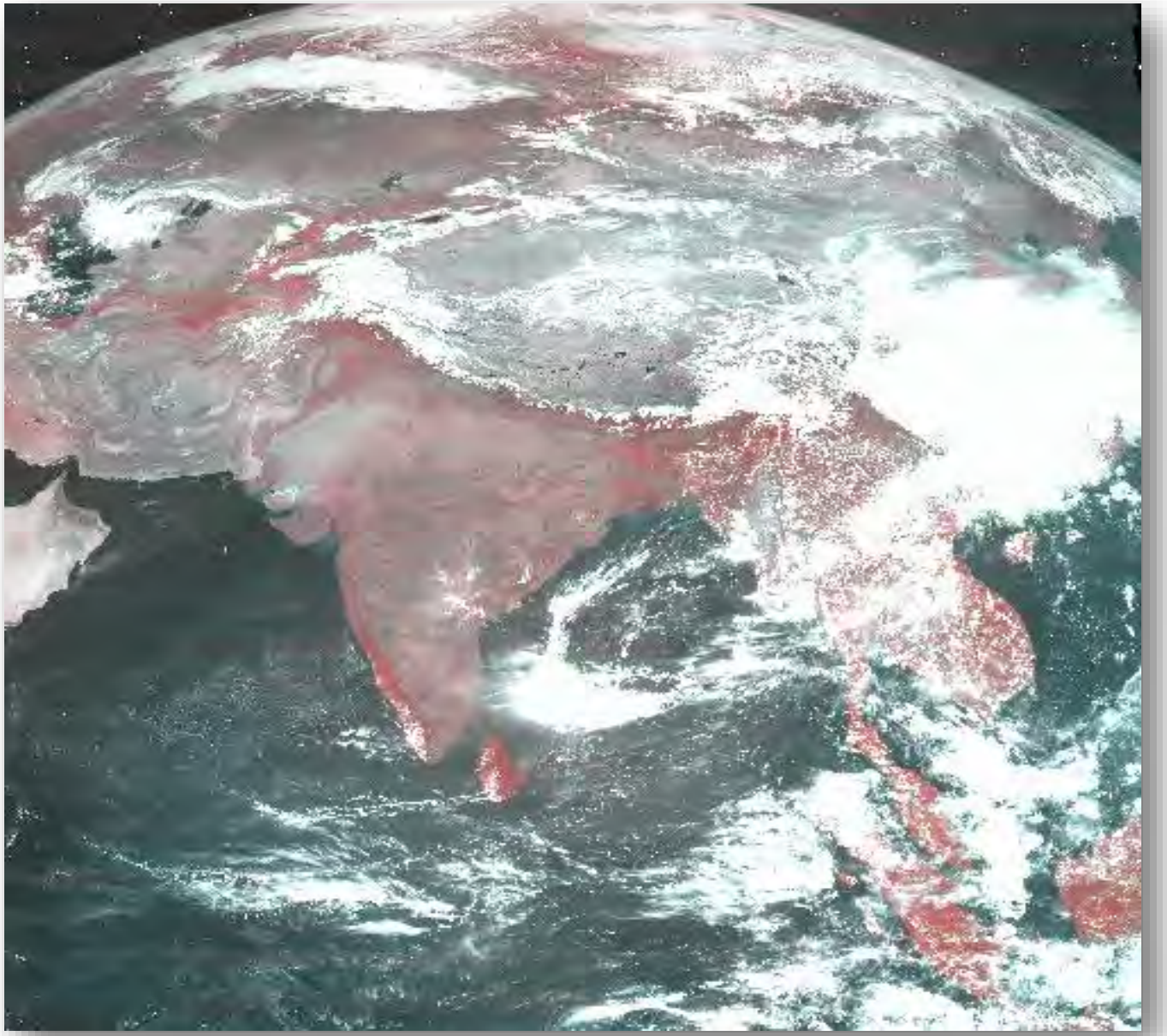


Oceansat-2,
INSAT-3D/3DR,
Megha Tropiques,
SARAL

VHRR
2.75 km
Vis
11 km IR

VHRR
2.0 km Vis
8 km IR WV
CCD
1 km MS

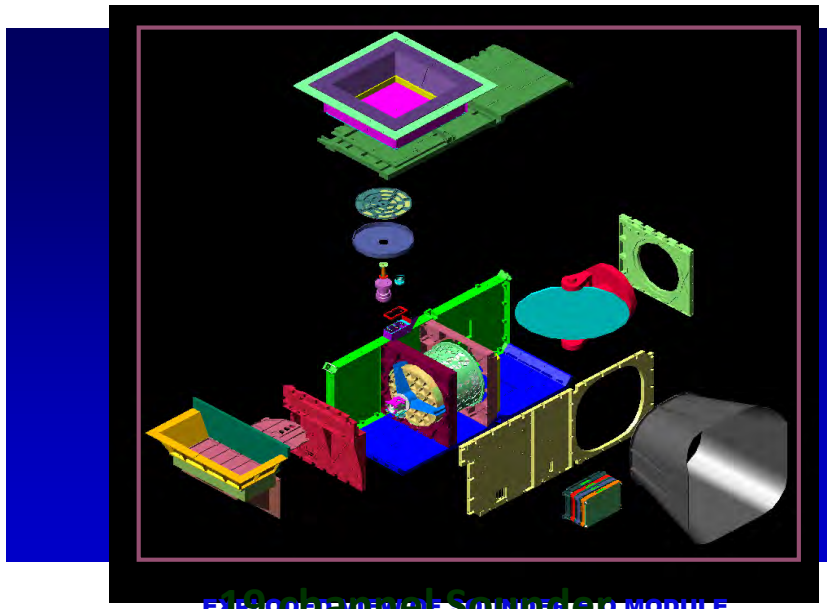
INSAT-3A CCD CAMERA



First of its kind imaging at 1 km (NDVI) from Geo Platform in world.

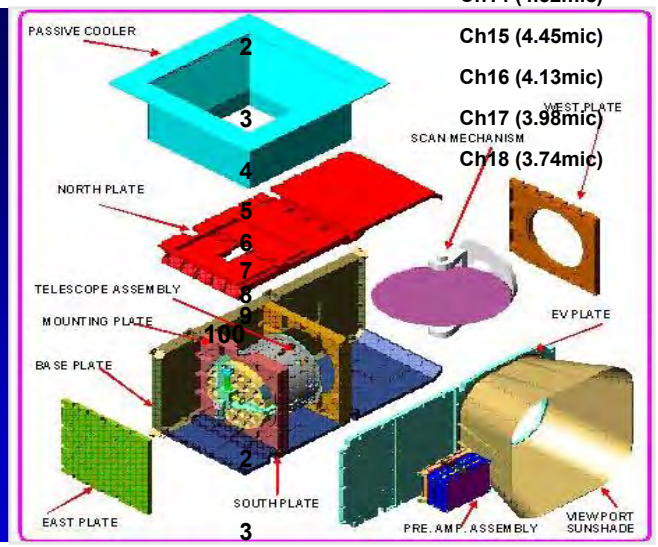
INSAT 3D Met Imaging

Sounder



19channel Sounder

Imager



Advanced 6-channel imager

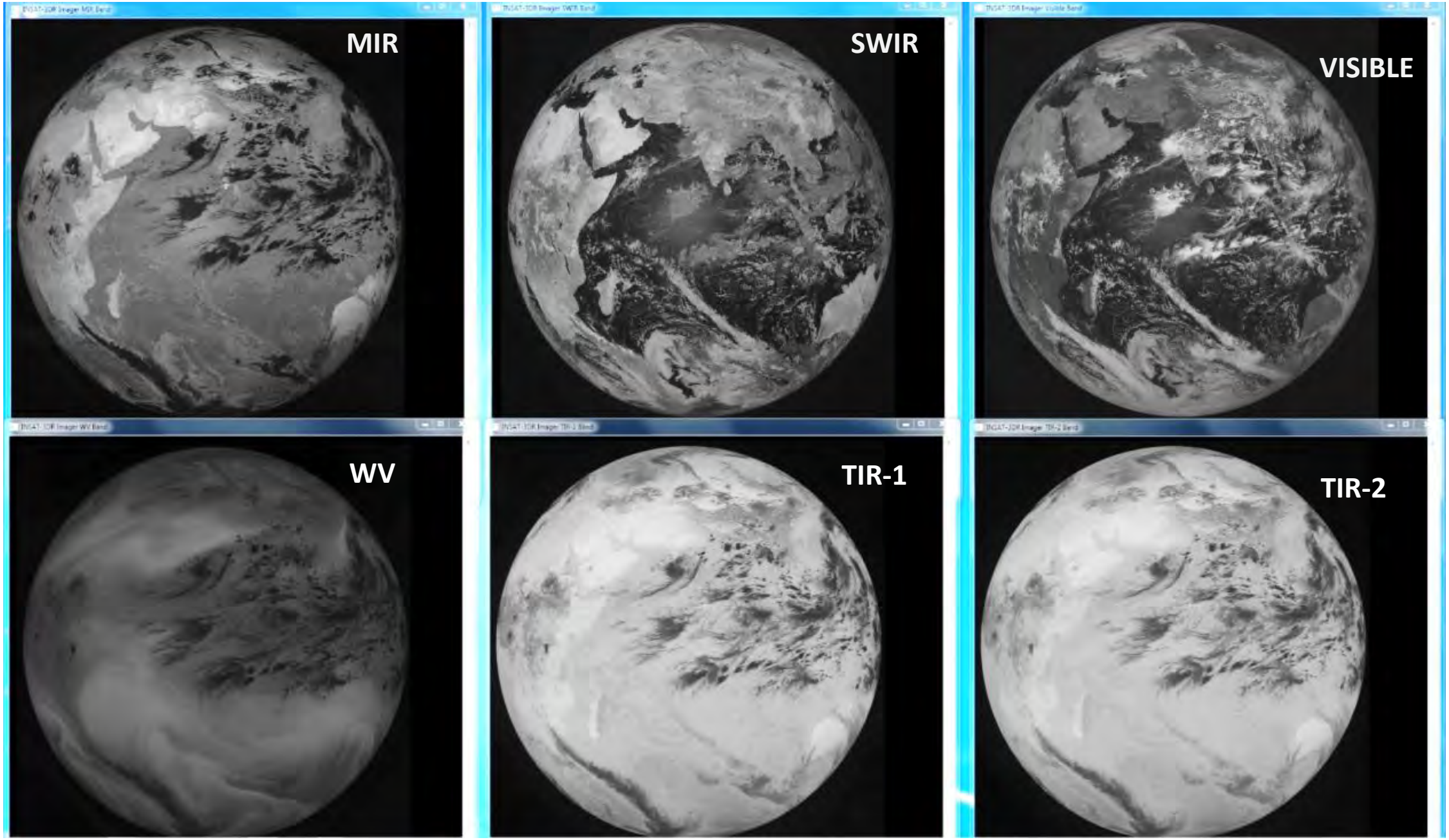
Sounder: 19 channels with spatial resolution of 10 km

Imager: 6 channel with spatial resolution of 1 km to 8 km

Applications: Improved estimation of water vapour content, cloud, wind vector, upper tropospheric humidity, sea surface temperature and surface insolation

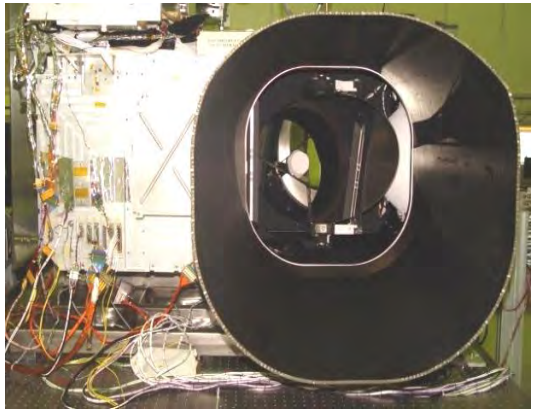
INSAT-3D Weighting Function over Indian Region (

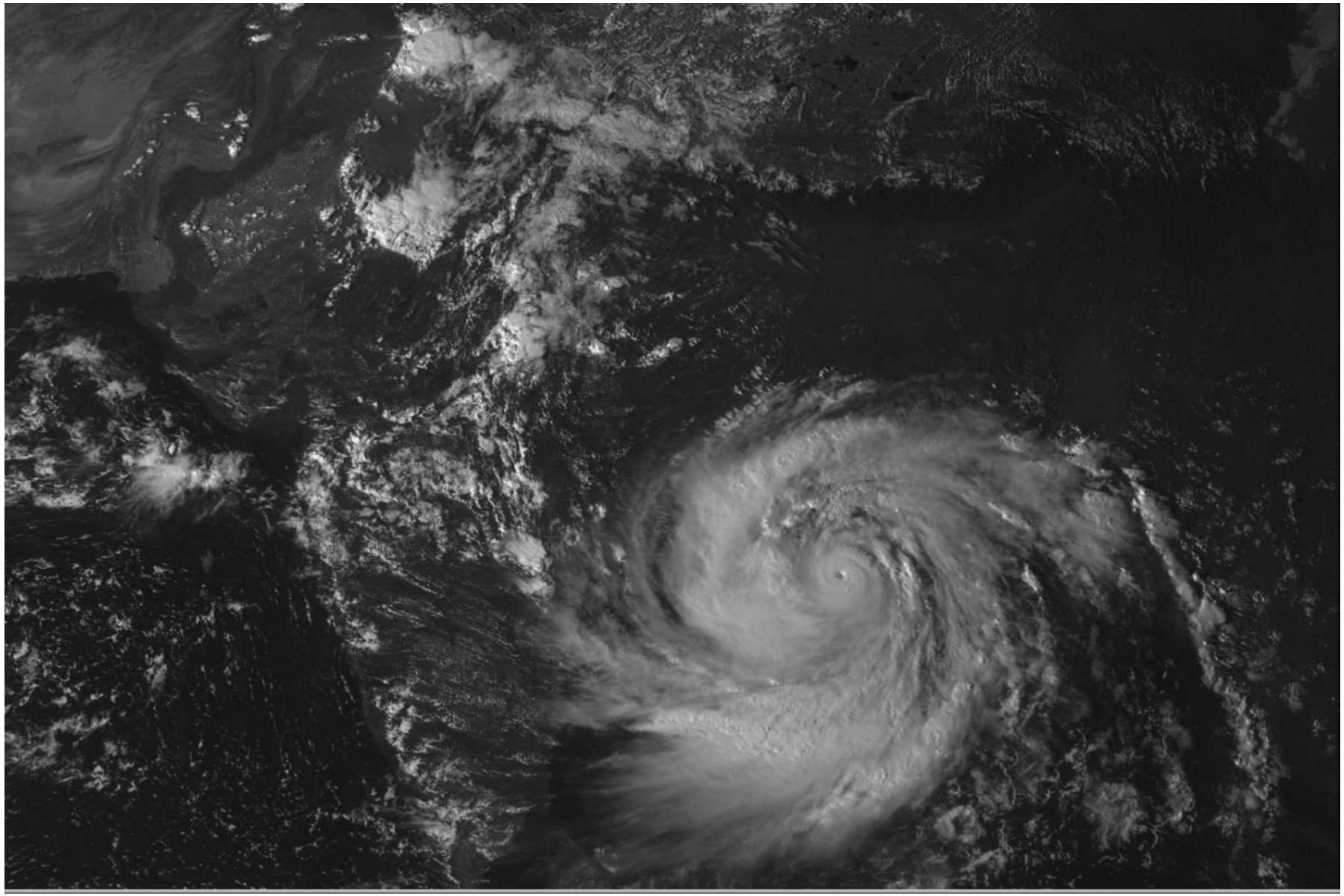
INSAT-3D Weighting Function over Indian Region (July)



First Day Screenshot of 6-Channel Imager (INSAT-3DR)

Cyclone Monitoring Using INSAT Satellites





Chandrayaan-1 India's First Mission to Moon

Objectives

- High Resolution Mapping of Topographic features in 3D, Distribution of Various Minerals & Elemental chemical species.
- Realize the mission goal of harnessing the science payloads, lunar craft & launch vehicle with suitable ground support system.

UK: Low Energy X-Ray Spect.

Germany: Infrared Spect. (SIR-2)

Sweden: Sub KeV Atom reflect. Analyser

Bulgaria: Radiation Dose Monitor

USA: Miniature SAR

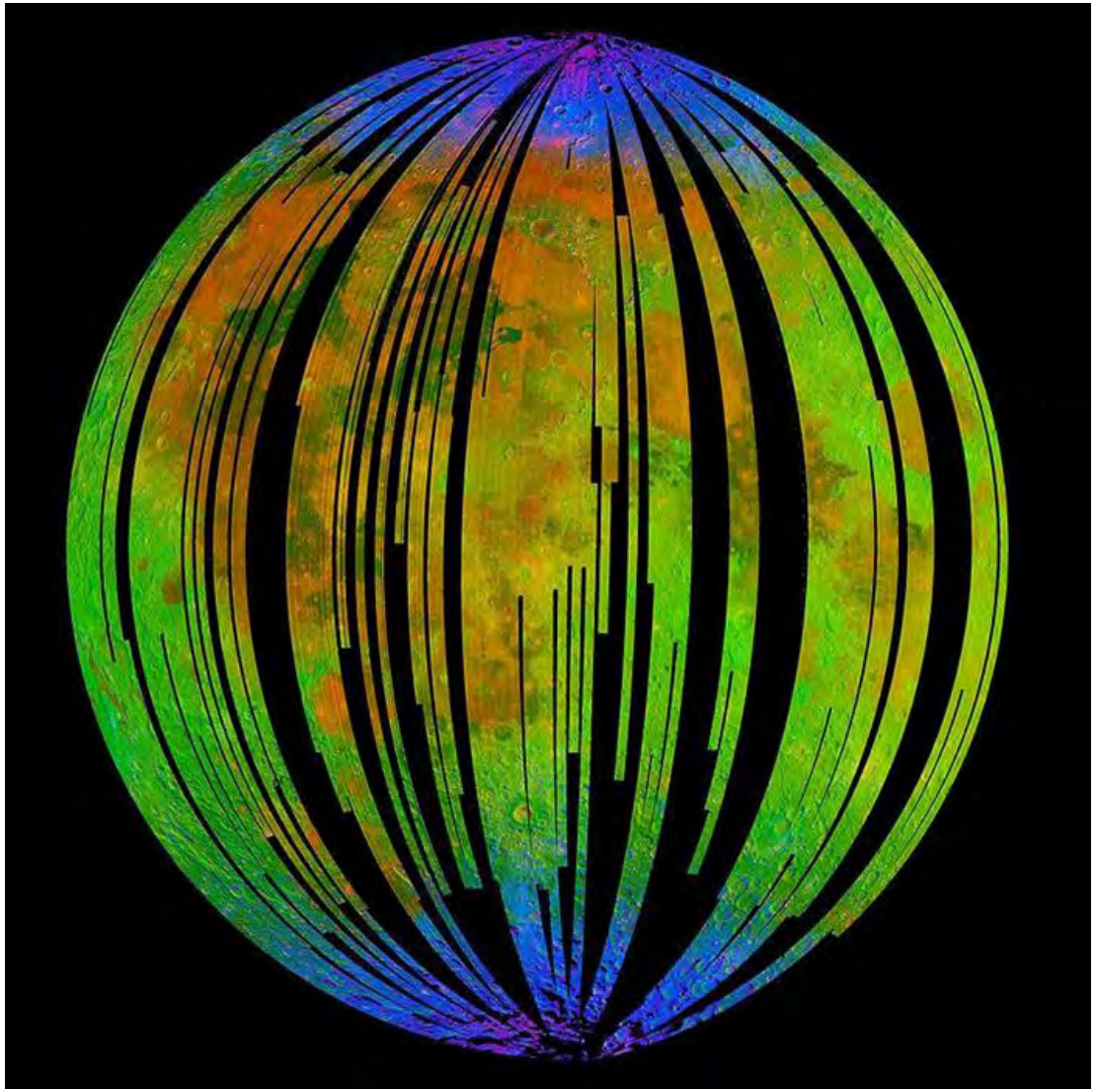
USA: Moon Mineralogy Mapper

Chandrayaan-1

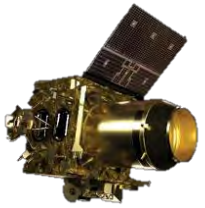
Indian Payloads

- Terrain Mapping Stereo Camera (TMC) in Panchromatic band (R- 5 m & S-40 Km)
- Hyperspectral Imager (HySI) (400-900nm) for mineralogical mapping (Sp R-15nm, R-80 m & S-40 Km).
- Lunar Laser Ranging Instrument (LLRI) to determine altitude of spacecraft above lunar surface.
- Collimated Low Energy X-ray Spectrometer (LEX) for measuring the fluorescent X-Rays to Map Si, Al, Mg, Cal, Fe, Ti.
- High Energy X-ray / g-ray Spectrometer (HEX) for measuring Pb, Rn, U, Th etc.
- Solar X-ray Monitor (SXM)

Discovery of water
Chandrayan-1 Spacecraft



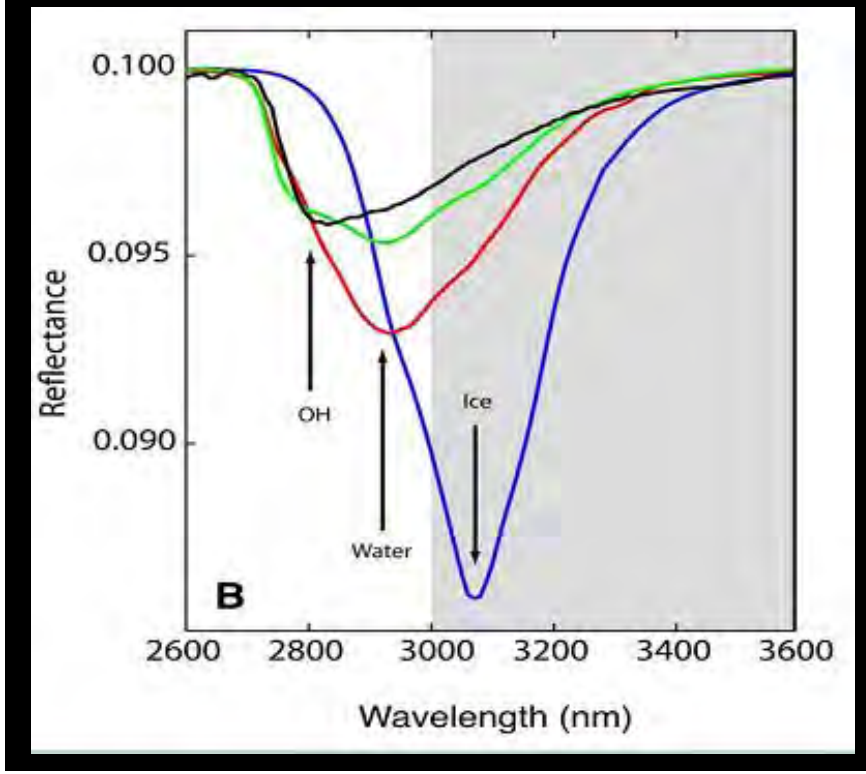
Far side of Moon seen from
Chandrayan-2 Spacecraft



CHANDRAYAAN 2

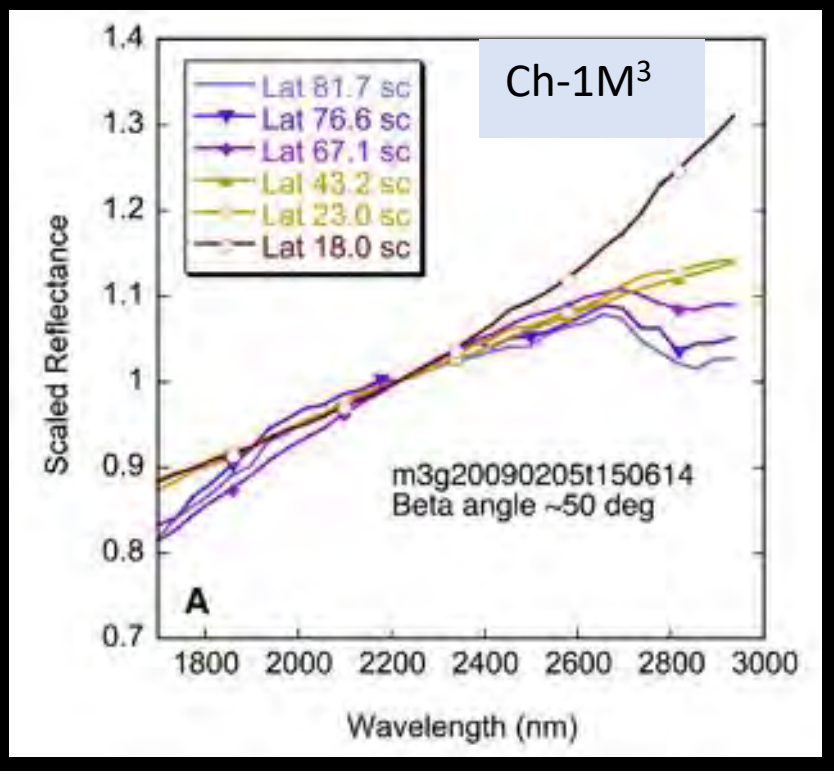
Complete picture
Clear and unambiguous detection

Lunar Water



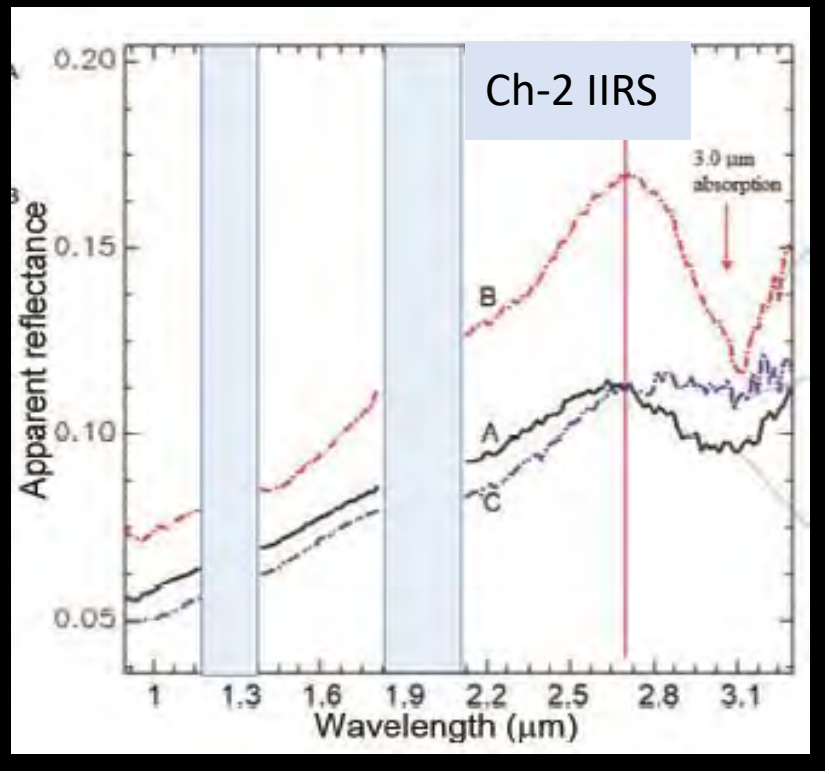
OH/H2O (2.8-3.1μm)

Chandrayaan-1



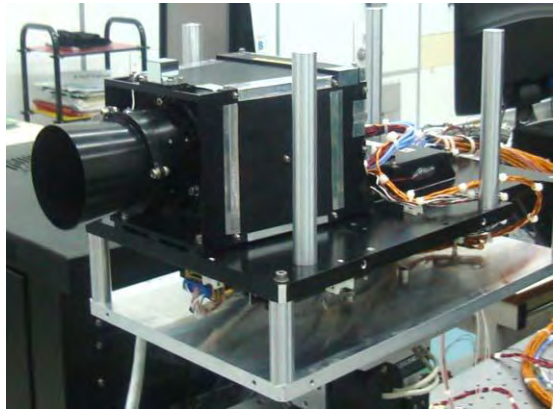
0.5-3 μm

Chandrayaan-2



0.8-5 μm

Mars Orbiter Mission



Paleo Rivers on Mars seen through Mars Colour Camera

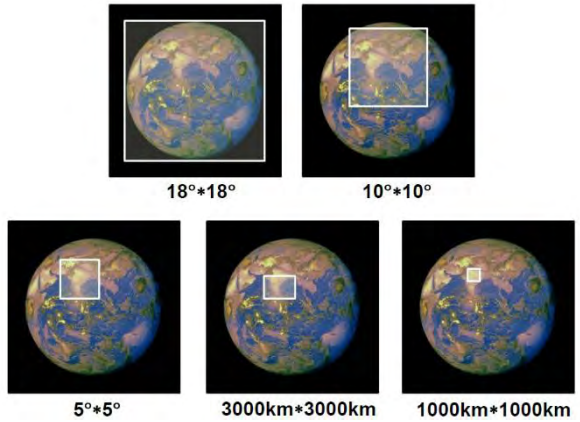
Launch of Mars Orbiter Mission

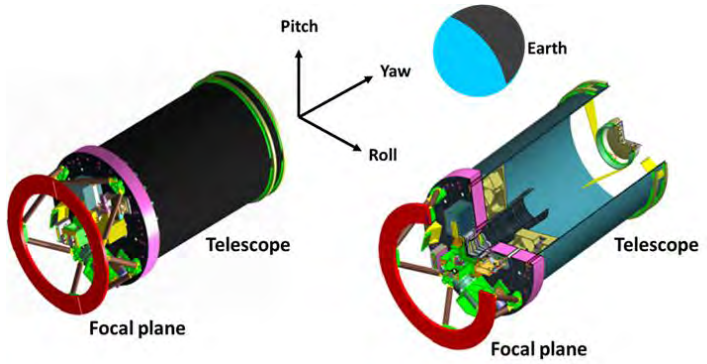
Geostationary Imaging Satellite (GISAT)

Simultaneous and integrated observations of Land, Ocean and Atmosphere at relatively high resolution using hyper spectral technique.

GISAT Payload Features

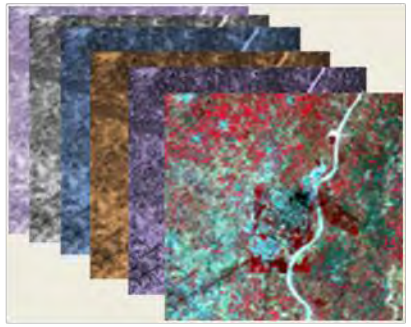
Sensors	Spectral Bands	Spectral Region (um)	Spatial Res. (m)	Swath (km)	Remarks
MX- VNIR	6	0.45 – 0.875	42	470	MX-Optical
HySI- VNIR	158	0.38 – 1.0	320	160	Hyperspectral (5 nm)
HySI- SWIR	256	0.90 – 2.5	191	190	Hyperspectral (10 nm)





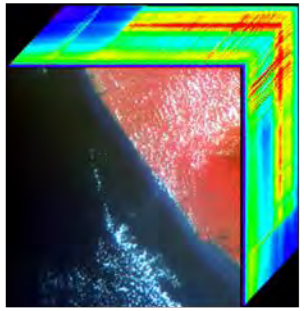
MX

- Blue
- Red Edge
- Split NIR



AWiFS Like Capability

HYSI

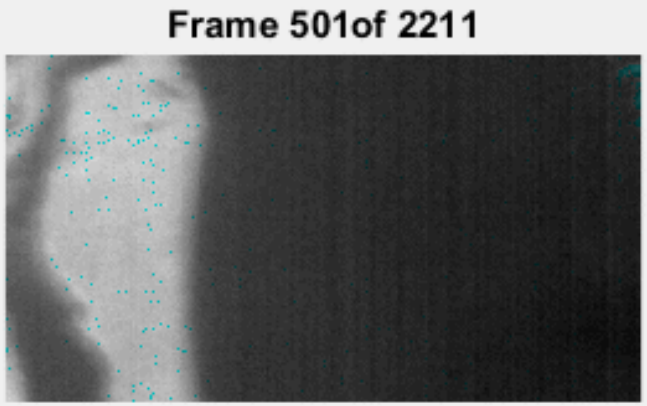


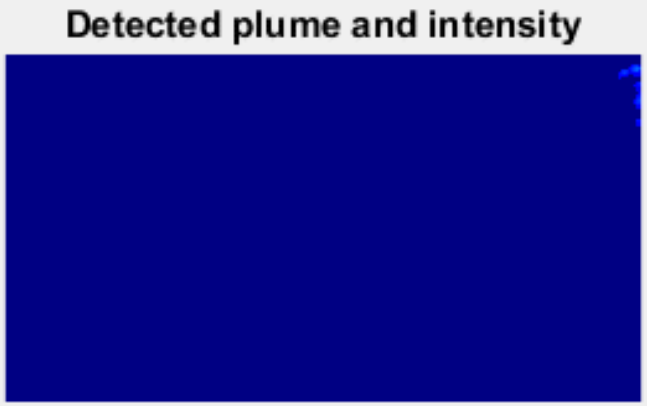
OCM Like Capability

India Mosaic

INSAT-CCD Like Capability

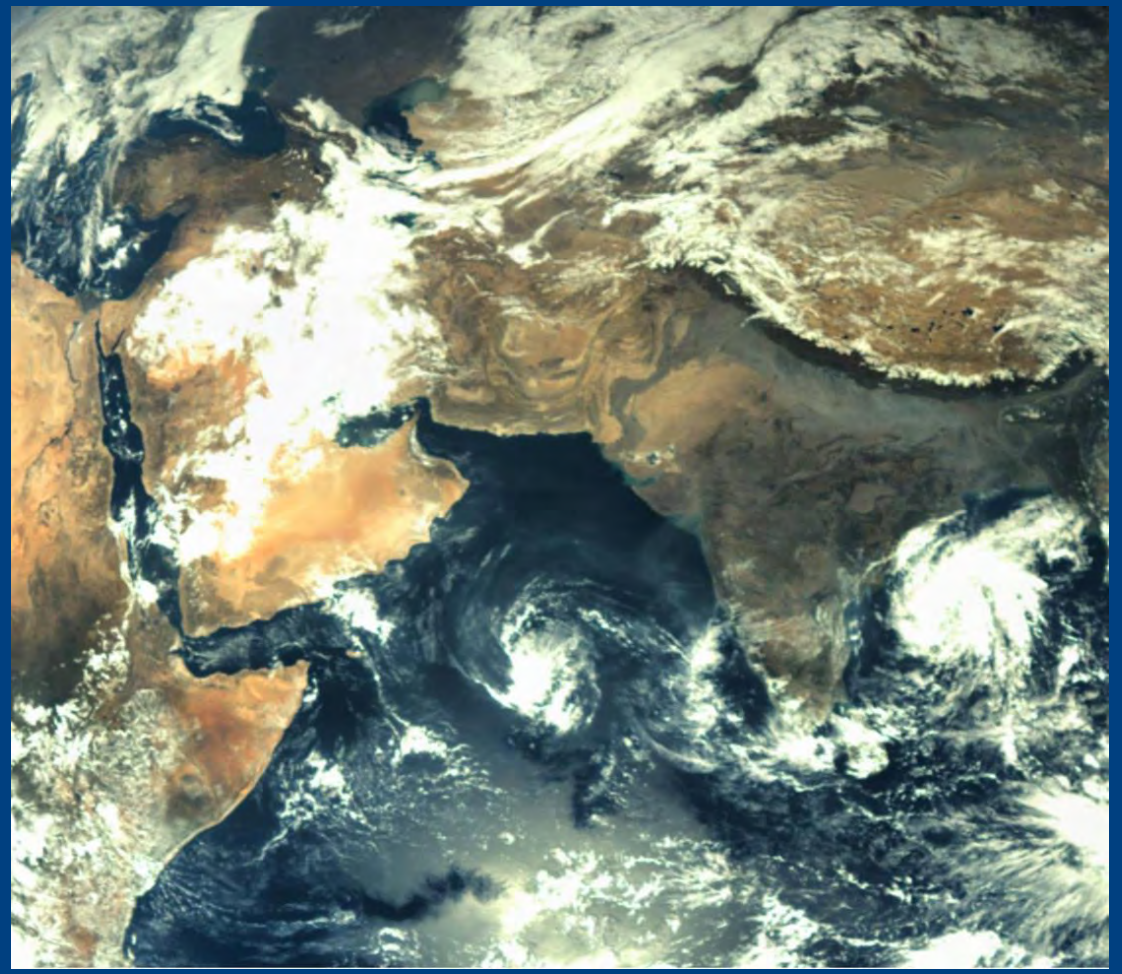
Observations from GHRC Instrument





Future Direction

- Development of dedicated constellation of satellites.
- Improved methodologies for retrieval of various hydrological parameters from satellite data.
- Assimilate the information in physically based distributed hydrological models
- Near Real time Monitoring and Forecast of extreme events and Web based Data dissemination.



Thank You !