

卫星遥感技术的应用

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Basics of Remote Sensing

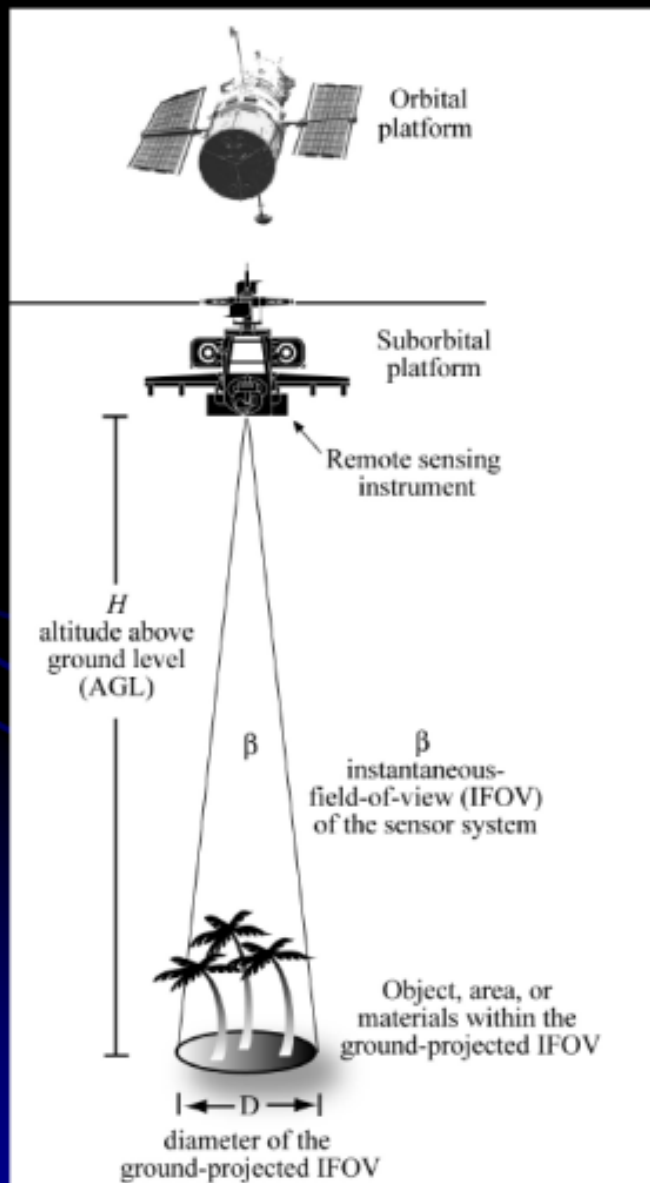
Remote Sensing

- **Remote sensing** is the acquisition of information about an object or phenomenon without making physical contact with the object



Remote sensing generally refers to the use of satellite- or aircraft-based sensor technologies to detect, classify and measure objects on Earth, including on the surface and in the atmosphere and oceans, based on propagated signals (e.g. electromagnetic radiation)

Remote Sensing



A remote sensing instrument collects information about an object or phenomenon within the instantaneous-field-of-view (IFOV) of the sensor system without being in direct physical contact with it. The sensor is located on a suborbital or satellite platform.

Remote Sensing Sensors (1)

- Sophisticated devices that are frequently used to detect and respond to electrical or optical signals
- Converts physical parameter into a signal that can be measured electrically

Remote Sensing Sensors (2)

- According to source of energy
 - Active remote sensing
 - Passive remote sensing

Active Remote Sensing

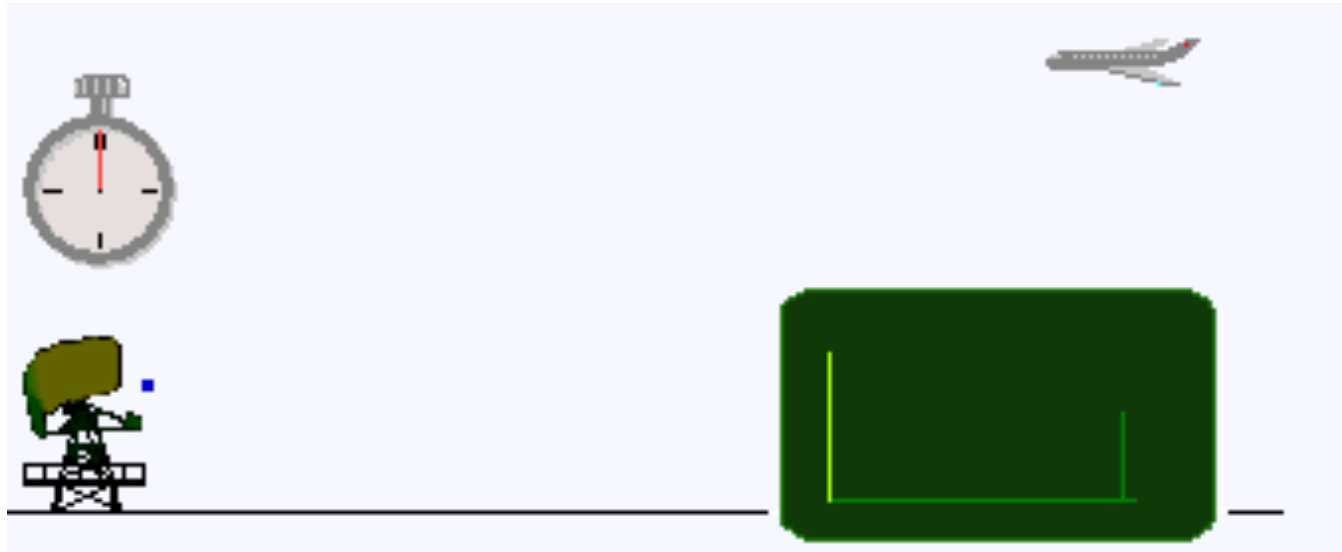
A signal is emitted by a satellite or aircraft and its reflection by the object is detected by the sensor



Active Remote Sensing

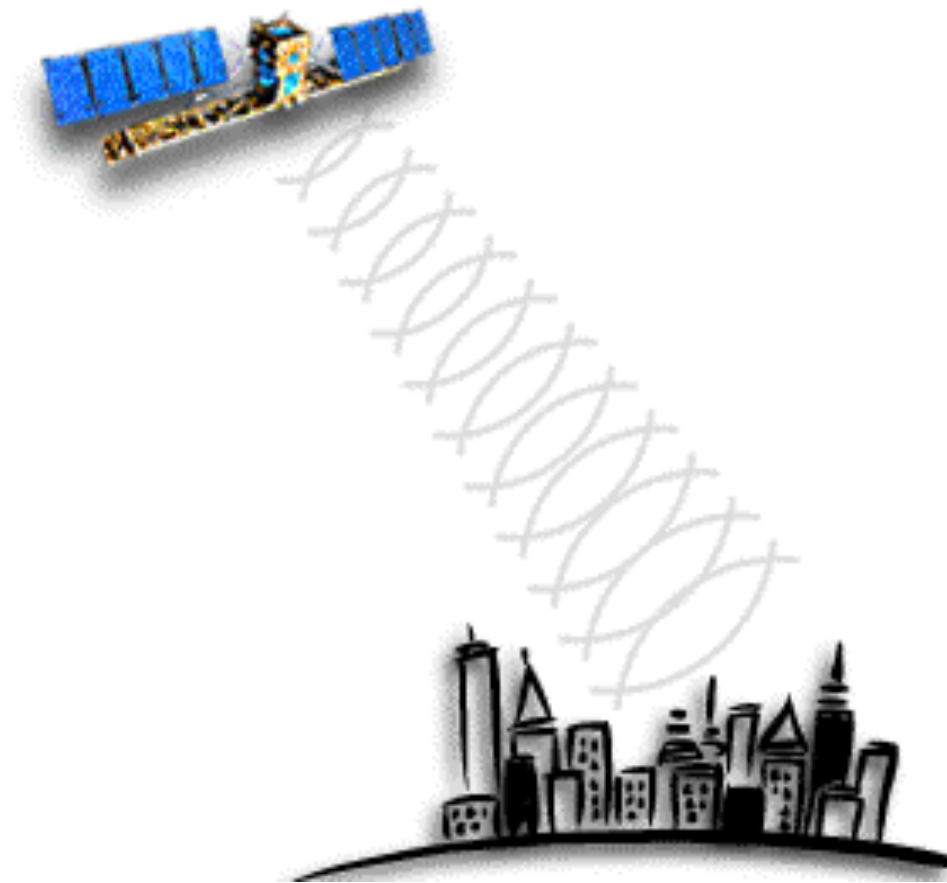
Examples of Active Sensors

Radar (RAdio Detection And Ranging)



Examples of Active Sensors

Radar (RAdio Detection And Ranging)



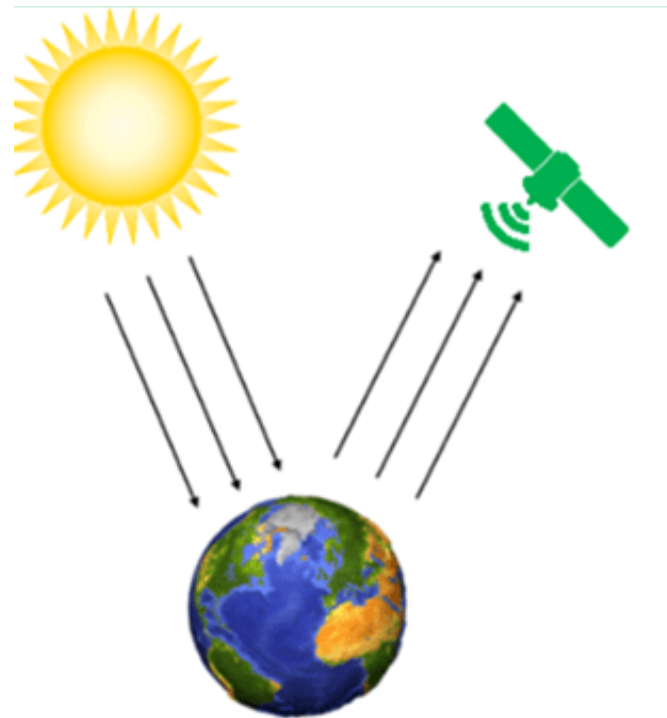
Examples of Active Sensors

LiDAR (Light Detection And Ranging)



Passive Remote Sensing

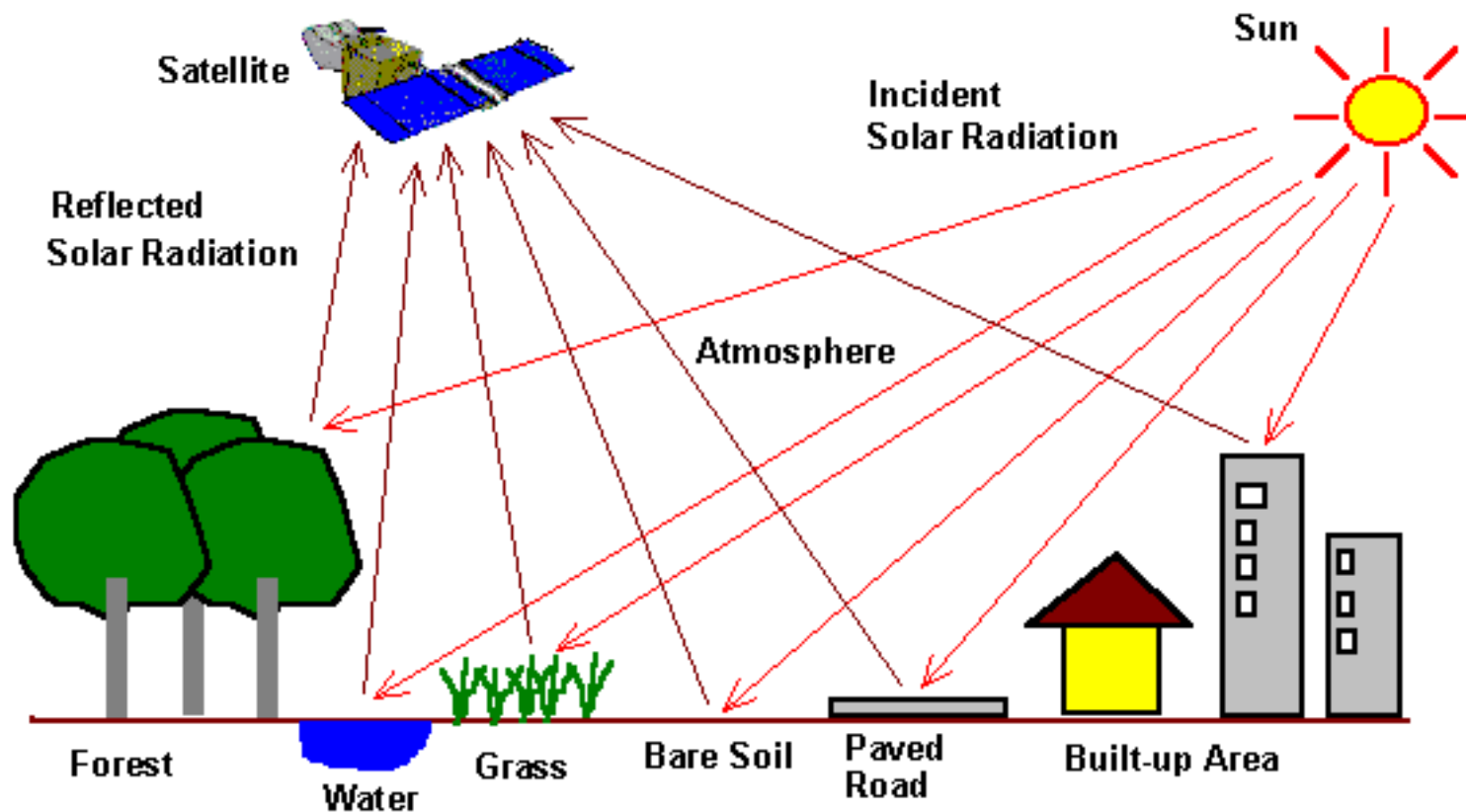
The reflection of sunlight is detected by the sensor



Passive Remote Sensing

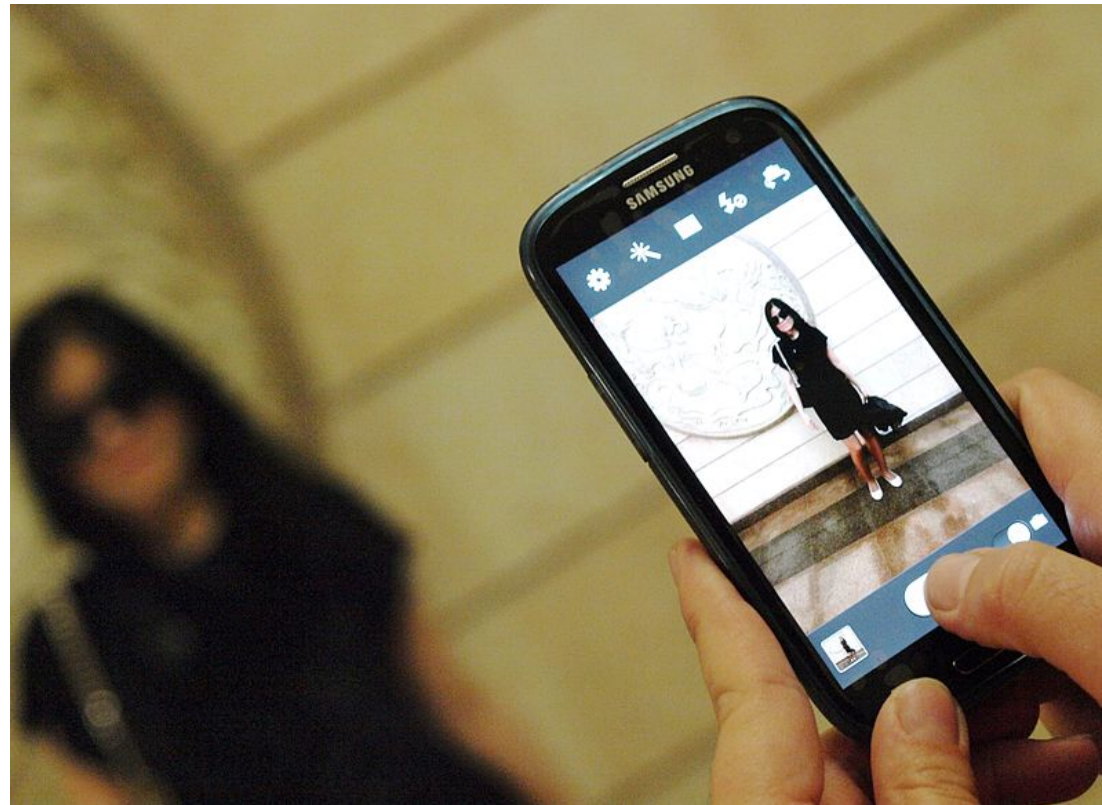
Examples of Passive Sensors

Optical Remote Sensing



Examples of Passive Sensors

Photography



Examples of Passive Sensors

Infrared Sensor



Infrared (IR) is invisible radiant energy. Most of the thermal radiation emitted by objects near room temperature is infrared.

Remote Sensing Sensors (3)

- According to spectral bands
 - Panchromatic
 - Multispectral
 - Superspectral
 - Hyperspectral

Panchromatic Imaging Systems

- The sensor is a single channel detector sensitive to radiation within a broad wavelength range.
- If the wavelength range coincide with the visible range, then the resulting image resembles a "black-and-white" photograph taken from space.
- The physical quantity being measured is the apparent brightness of the targets. The spectral information or "colour" of the targets is lost
- Examples: IKONOS PAN, SPOT HRV-PAN



Portion of a 1-meter resolution panchromatic image of Washington, DC produced by the Ikonos

Multispectral Imaging Systems

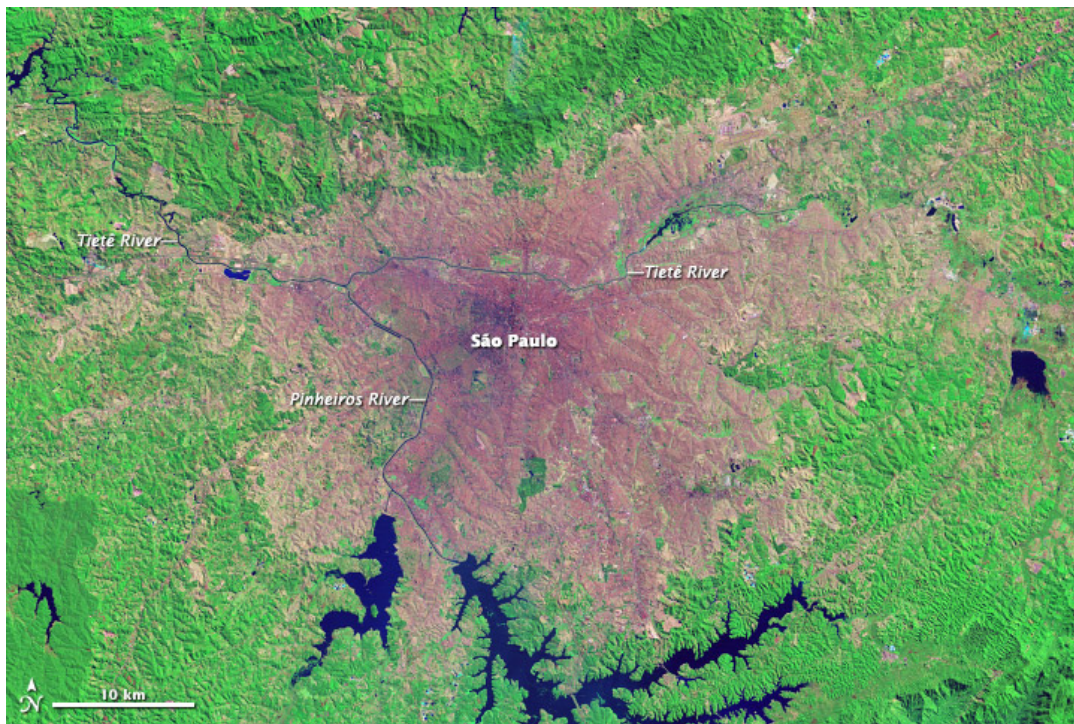
- The sensor is a multichannel detector with a few spectral bands.
- Each channel is sensitive to radiation within a narrow wavelength band.
- The resulting image is a multilayer image which contains both the brightness and spectral (colour) information of the targets being observed.
- Examples: LANDSAT MSS, LANDSAT TM, SPOT HRV-XS, IKONOS MS

LANDSAT 4,5 MSS Sensor Characteristics

	Band	Wavelength (μm)	Resolution (m)
Green	1	0.5 - 0.6	82
Red	2	0.6 - 0.7	82
Near IR	3	0.7 - 0.8	82
Near IR	4	0.8 - 1.1	82

LANDSAT 8

Band Number	μm	Resolution
1	0.433–0.453	30 m
2	0.450–0.515	30 m
3	0.525–0.600	30 m
4	0.630–0.680	30 m
5	0.845–0.885	30 m
6	1.560–1.660	30 m
7	2.100–2.300	30 m
8	0.500–0.680	15 m
9	1.360–1.390	30 m
10	10.6–11.2	100 m
11	11.5–12.5	100 m



The Landsat satellites captured this change in these two false-color images. Landsat 5 acquired the top image on August 6, 1986; the lower image is from Landsat 8 on September 1, 2013. In both images, urban areas range from tan in the suburbs to pink and purple in the most densely built areas. Plant-covered land is green, and exposed earth is tan (like the urban areas).



<http://landsat.visibleearth.nasa.gov/view.php?id=83987>

Superspectral Imaging Systems

- A superspectral imaging sensor has many more spectral channels (typically >10) than a multispectral sensor.
- The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor.
- Examples: MODIS, MERIS

Spectral Bands of MODIS

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required SNR ³
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1.0	110
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21.0	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric Water Vapor	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required NE[delta]T(K) ⁴
Surface/Cloud Temperature	20	3.660 - 3.840	0.45(300K)	0.05
	21	3.929 - 3.989	2.38(335K)	2.00
	22	3.929 - 3.989	0.67(300K)	0.07
	23	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17(250K)	0.25
	25	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16(240K)	0.25
	28	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55(300K)	0.05
	32	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52(260K)	0.25
	34	13.485 - 13.785	3.76(250K)	0.25
	35	13.785 - 14.085	3.11(240K)	0.25
	36	14.085 - 14.385	2.08(220K)	0.35
¹ Bands 1 to 19 are in nm; Bands 20 to 36 are in μm ² Spectral Radiance values are $(\text{W}/\text{m}^2 \cdot \mu\text{m}\cdot\text{sr})$ ³ SNR = Signal-to-noise ratio ⁴ NE(delta)T = Noise-equivalent temperature difference Note: Performance goal is 30-40% better than required				



MODIS

Web

+ ABOUT MODIS

+ NEWS

+ DATA

+ IMAGES

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+ Home

About MODIS

+ DESIGN CONCEPT

+ COMPONENTS

- SPECIFICATIONS

+ MEDIA

SPECIFICATIONS

Orbit:	705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular
Scan Rate:	20.3 rpm, cross track
Swath Dimensions:	2330 km (cross track) by 10 km (along track at nadir)
Telescope:	17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop
Size:	1.0 x 1.6 x 1.0 m
Weight:	228.7 kg
Power:	162.5 W (single orbit average)
Data Rate:	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization:	12 bits
Spatial Resolution:	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36)
Design Life:	6 years

+ Home

Images

+ IMAGE GALLERY

+ IMAGES OF THE DAY

July 14, 2014

July 13, 2014

July 12, 2014

July 11, 2014

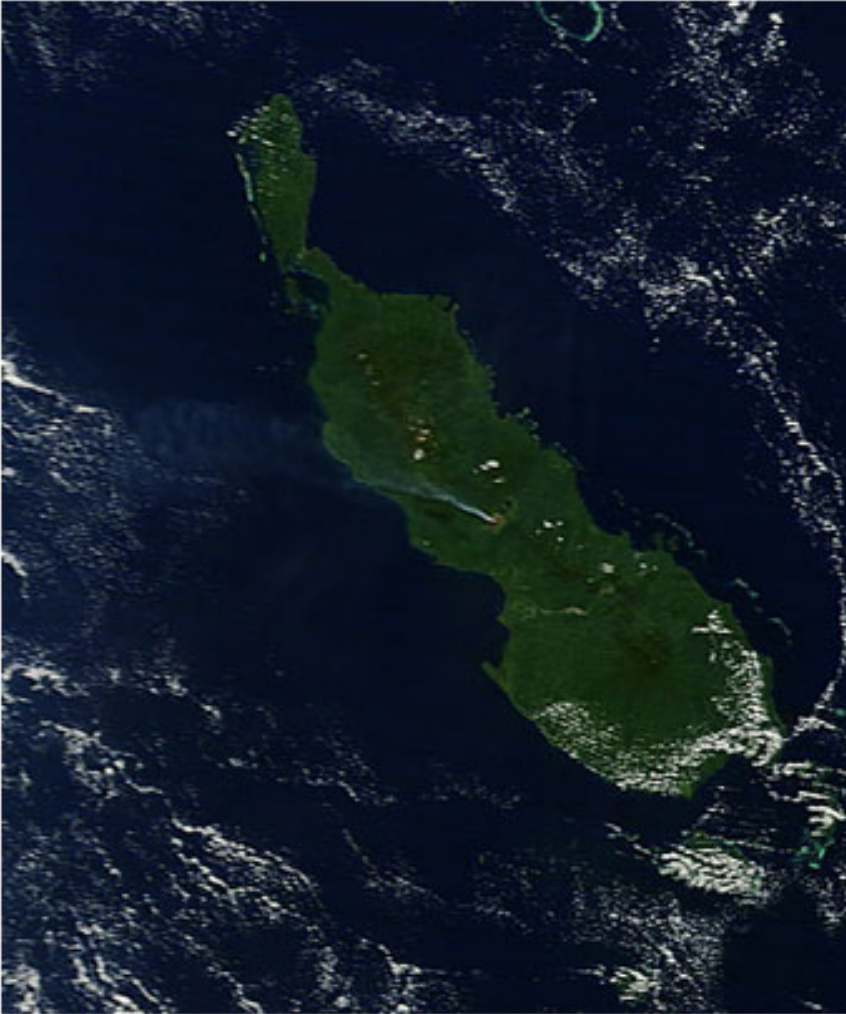
July 10, 2014

July 9, 2014

July 8, 2014

IMAGES OF THE DAY

July 14, 2014 - Plume from Bagana, Bougainville Island



Satellite:

Terra

Date Acquired:

7/6/2014

Resolutions:

500m (67.9 KB)

250m (156.8 KB)

Bands Used:

1,4,3

Credit:

Jeff Schmaltz

MODIS Land Rapid

Response Team,

NASA GSFC

http://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2014-07-14

Hyperspectral Imaging Systems

- A hyperspectral imaging system is also known as an "imaging spectrometer".
- It acquires images in about a hundred or more contiguous spectral bands.
- The precise spectral information contained in a hyperspectral image enables better characterisation and identification of targets.
- Hyperspectral images have potential applications in such fields as precision agriculture (e.g. monitoring the types, health, moisture status and maturity of crops), coastal management (e.g. monitoring of phytoplanktons, pollution, bathymetry changes).
- Example: Hyperion on EO1 satellite

The Hyperion provides a high resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 μm) with a 30-meter resolution. The instrument can image a 7.5 km by 100 km land area per image, and provide detailed spectral mapping across all 220 channels with high radiometric accuracy.

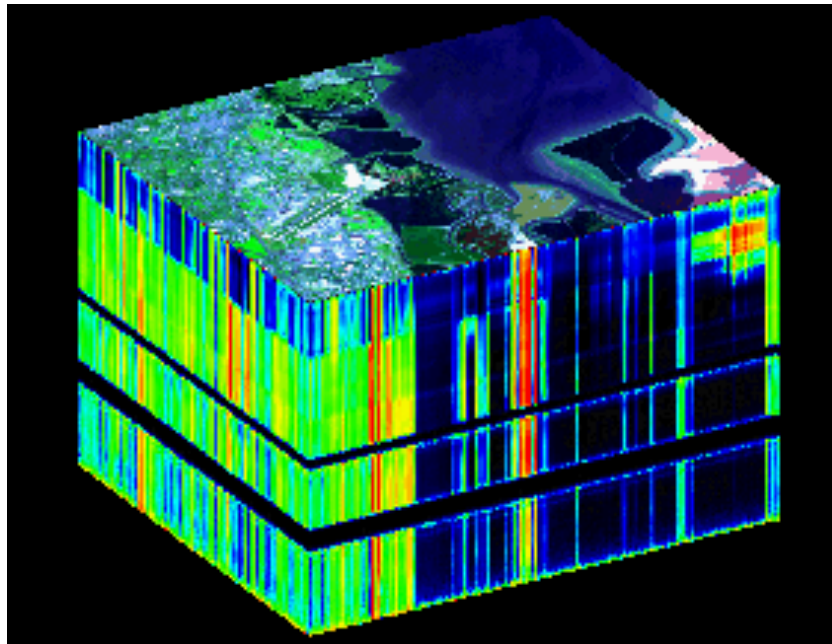


Hyperspectral Imaging Systems

- Applications of hyperspectral imagery:
 - **Atmosphere:** water vapor, cloud properties, aerosols
 - **Ecology:** chlorophyll, leaf water, cellulose, pigments, lignin
 - **Geology:** mineral and soil types
 - **Coastal Waters:** chlorophyll, phytoplankton, dissolved organic materials, suspended sediments
 - **Snow/Ice:** snow cover fraction, grainsize, melting
 - **Biomass Burning:** subpixel temperatures, smoke
 - **Commercial:** mineral exploration, agriculture and forest production

Hyperspectral Imaging Systems

- Hyperspectral imagery is typically collected (and represented) as a data cube with spatial information collected in the X-Y plane, and spectral information represented in the Z-direction.



Atmospheric Windows

- Some types of electromagnetic radiation easily pass through the atmosphere, while other types do not.
- The ability of the atmosphere to allow radiation to pass through it is referred to as its transmissivity, and varies with the wavelength/type of the radiation.
- The areas of the EM spectrum that are absorbed by atmospheric gases such as water vapor, carbon dioxide, and ozone are known as absorption bands.

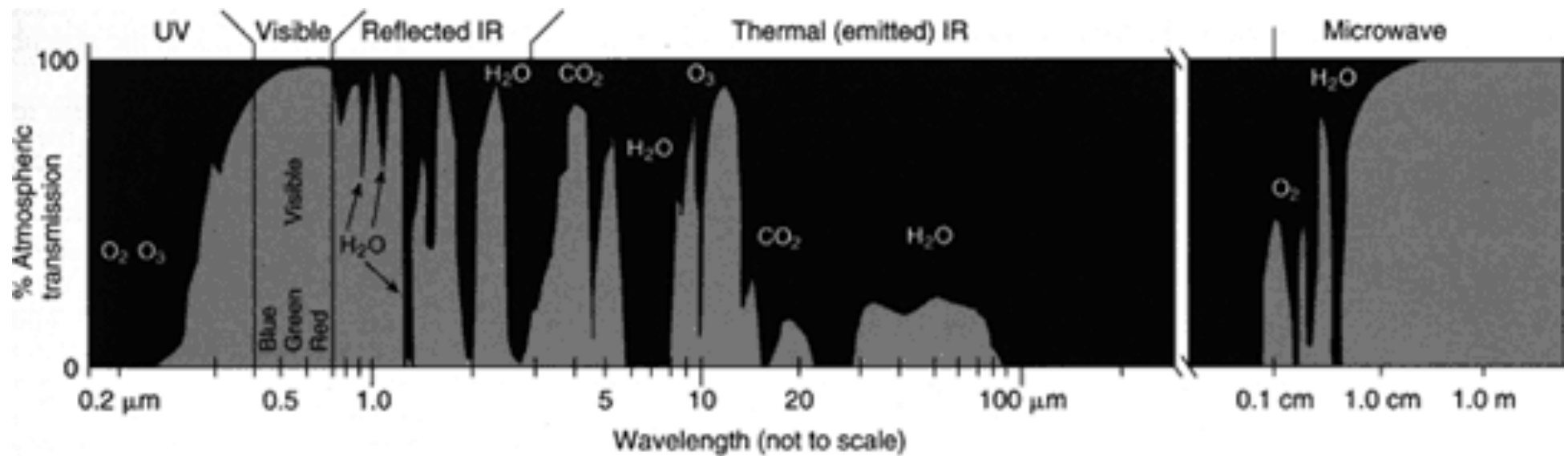


Diagram of atmospheric windows—wavelengths at which electromagnetic radiation will penetrate the Earth's atmosphere. Chemical notation (CO_2 , O_3) indicates the gas responsible for blocking sunlight at a particular wavelength.

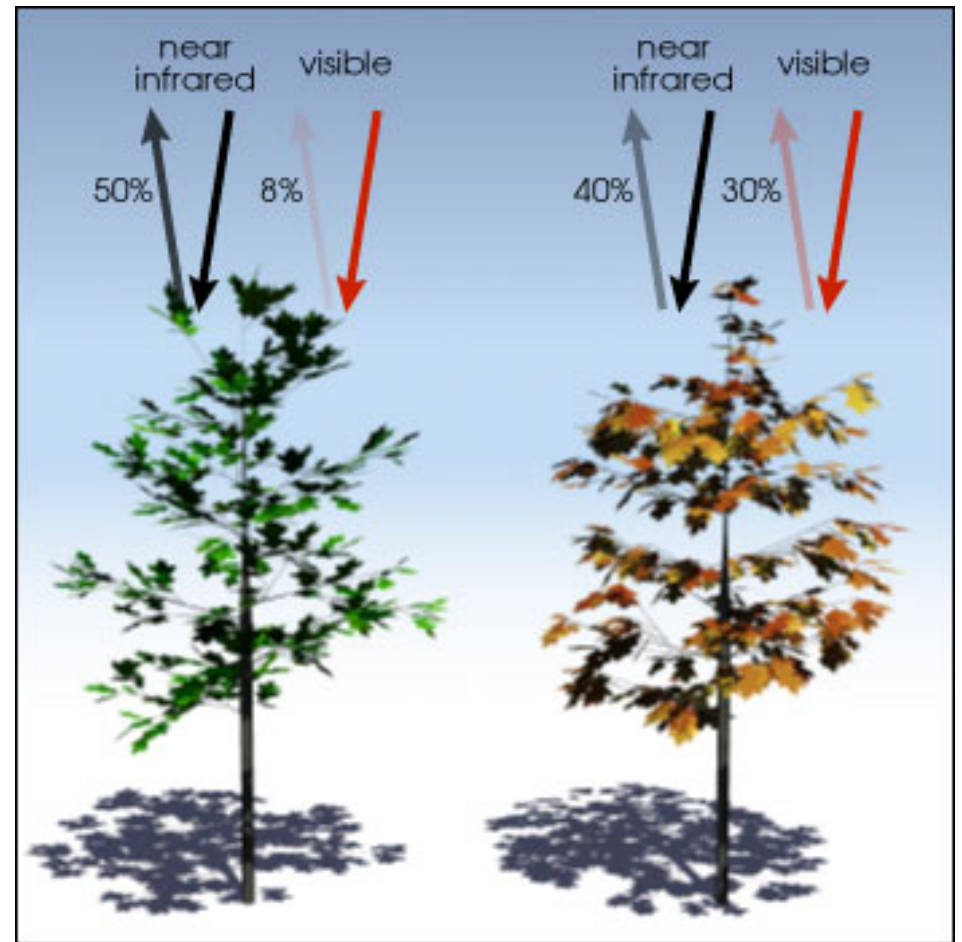
http://earthobservatory.nasa.gov/Features/RemoteSensing/remote_04.php

How Remote Sensing Works

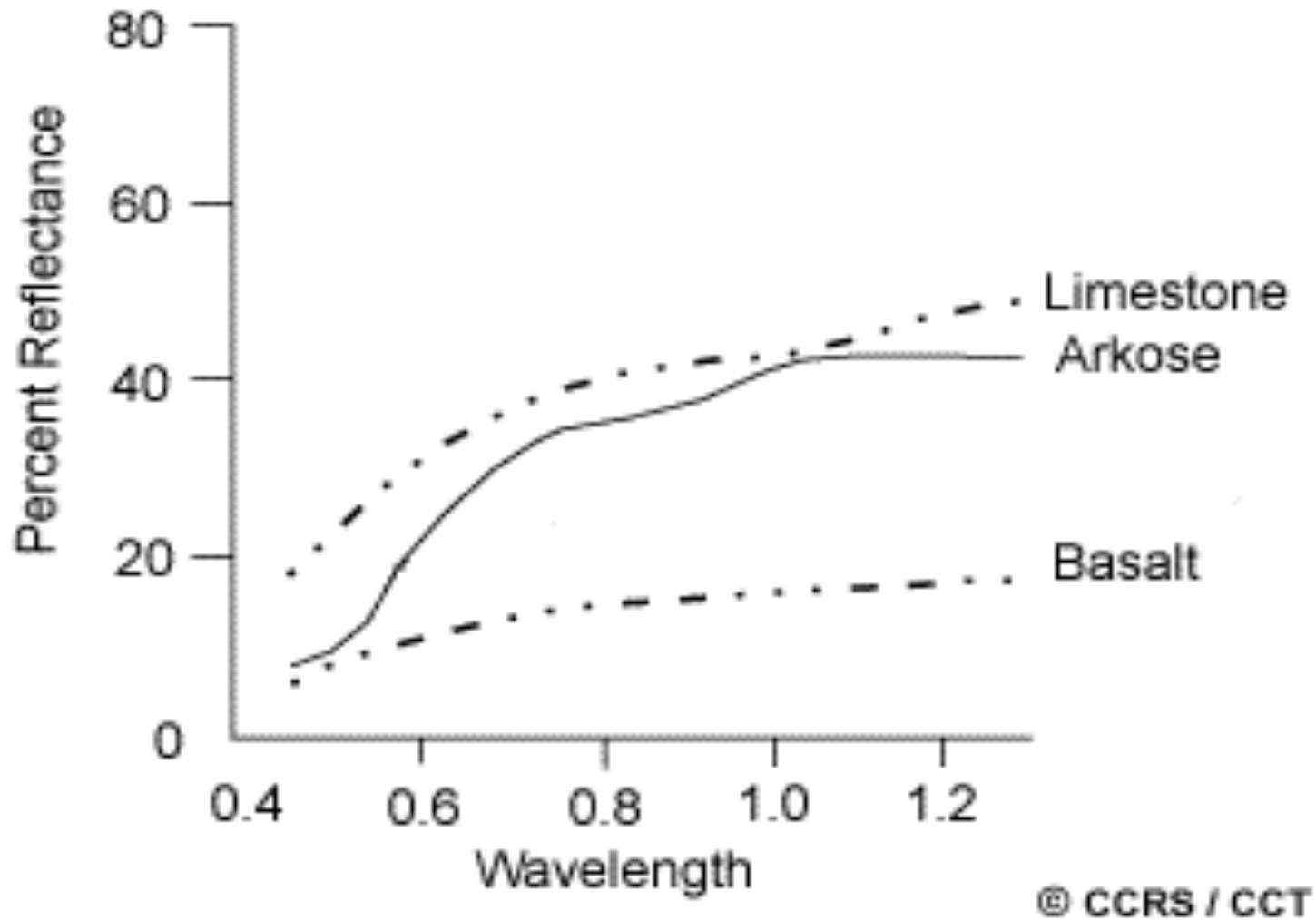
- The key is to establish relationship between the signals/images and the properties of the observed objects

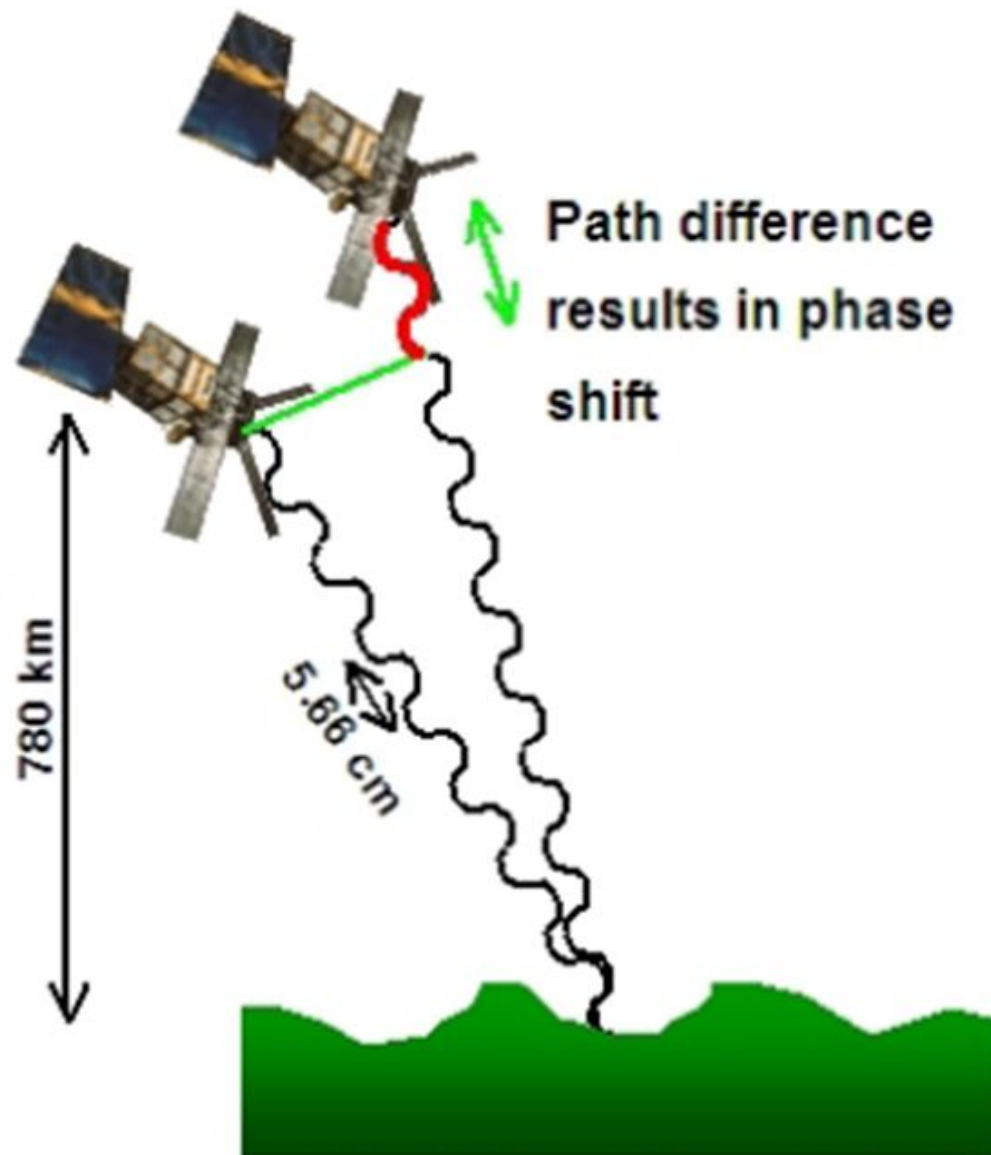
Examples: How Remote Sensing Works

- Different surface materials absorb and reflect energy of certain wavelengths of EMR differently
- One can distinguish one surface material from another by the differences in reflectance.

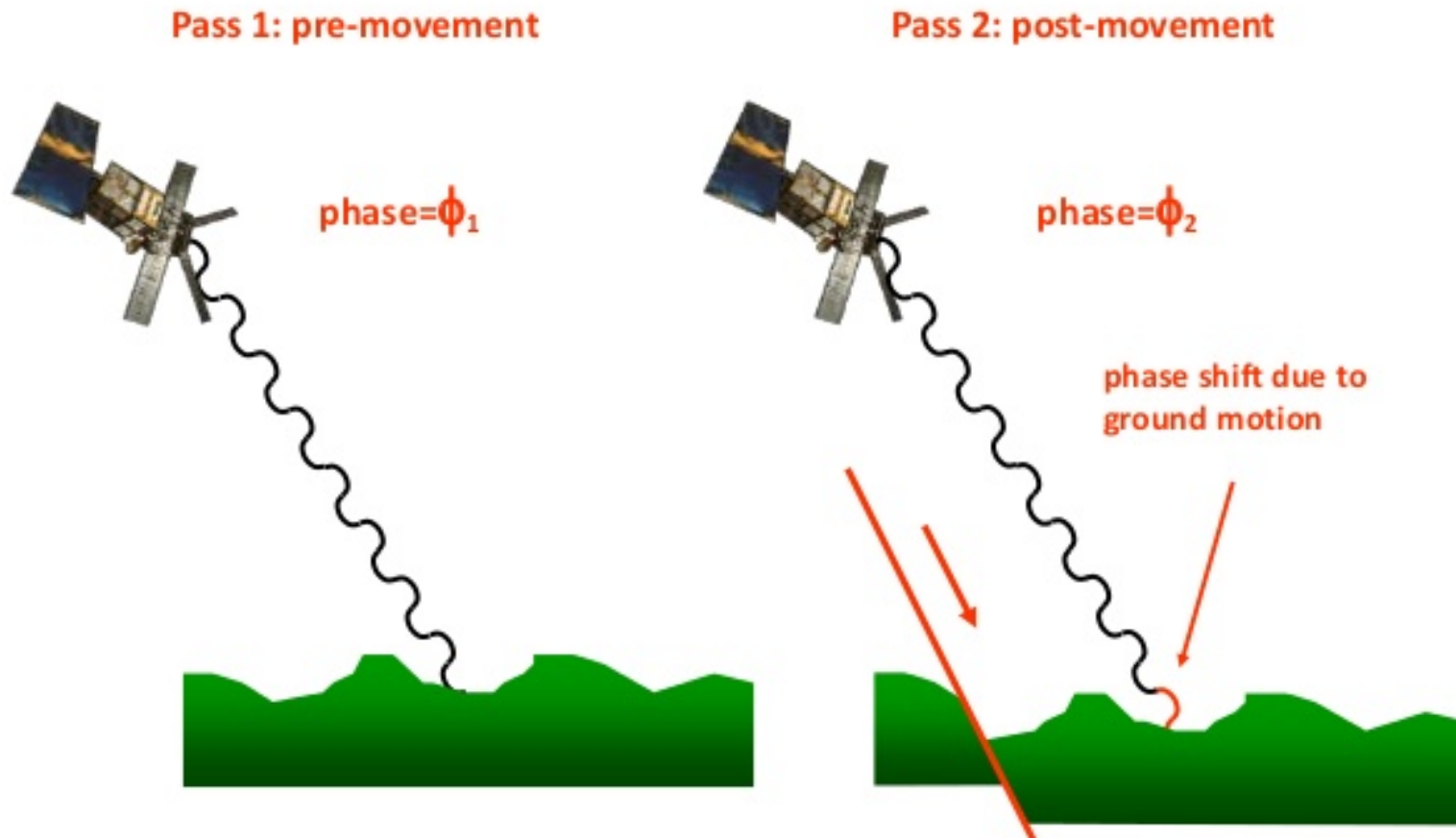


Examples: How Remote Sensing Works

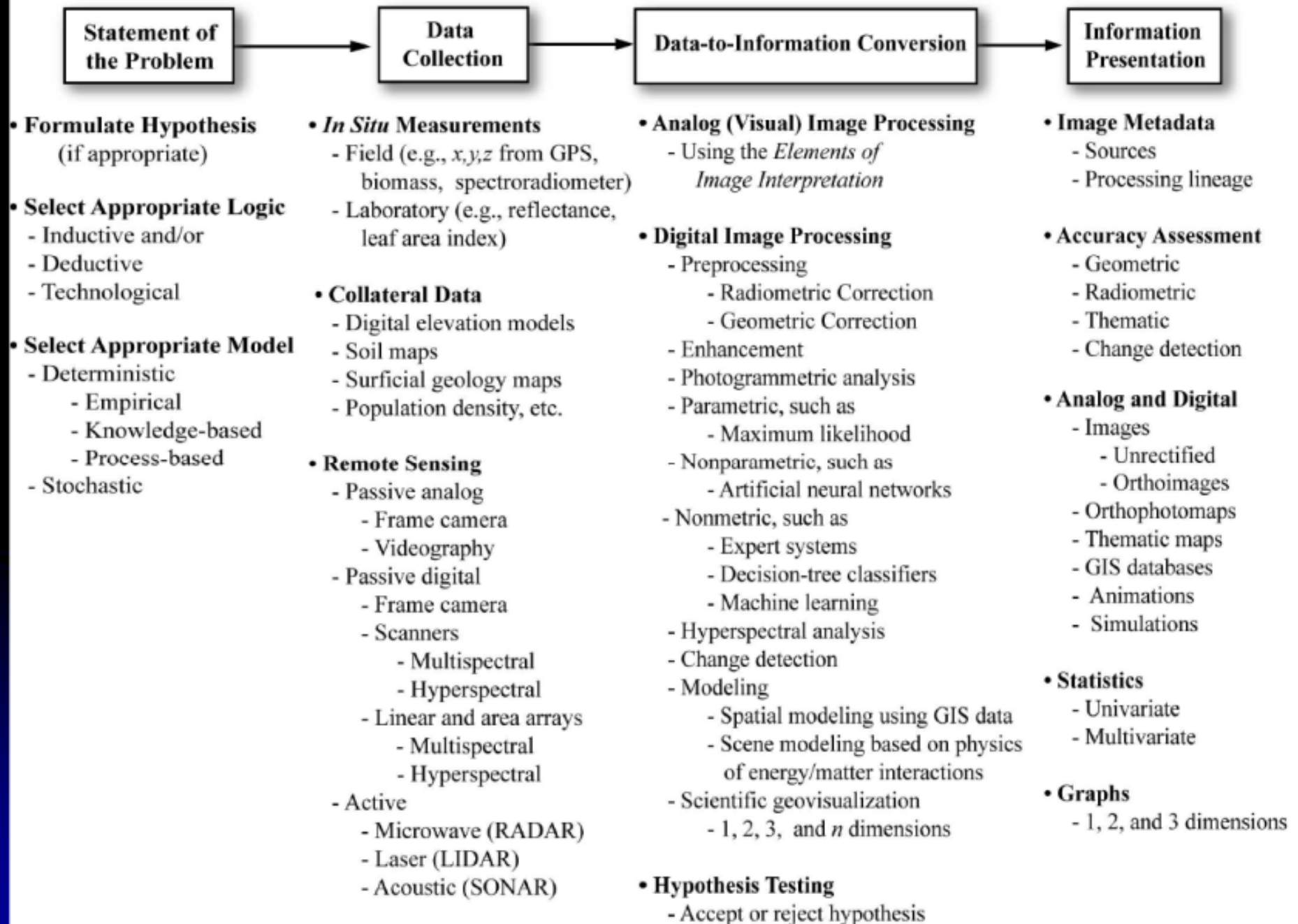




InSAR: How it works



The Remote Sensing Process



Satellites

Satellite

A **satellite** is an artificial object which has been intentionally placed into orbit.



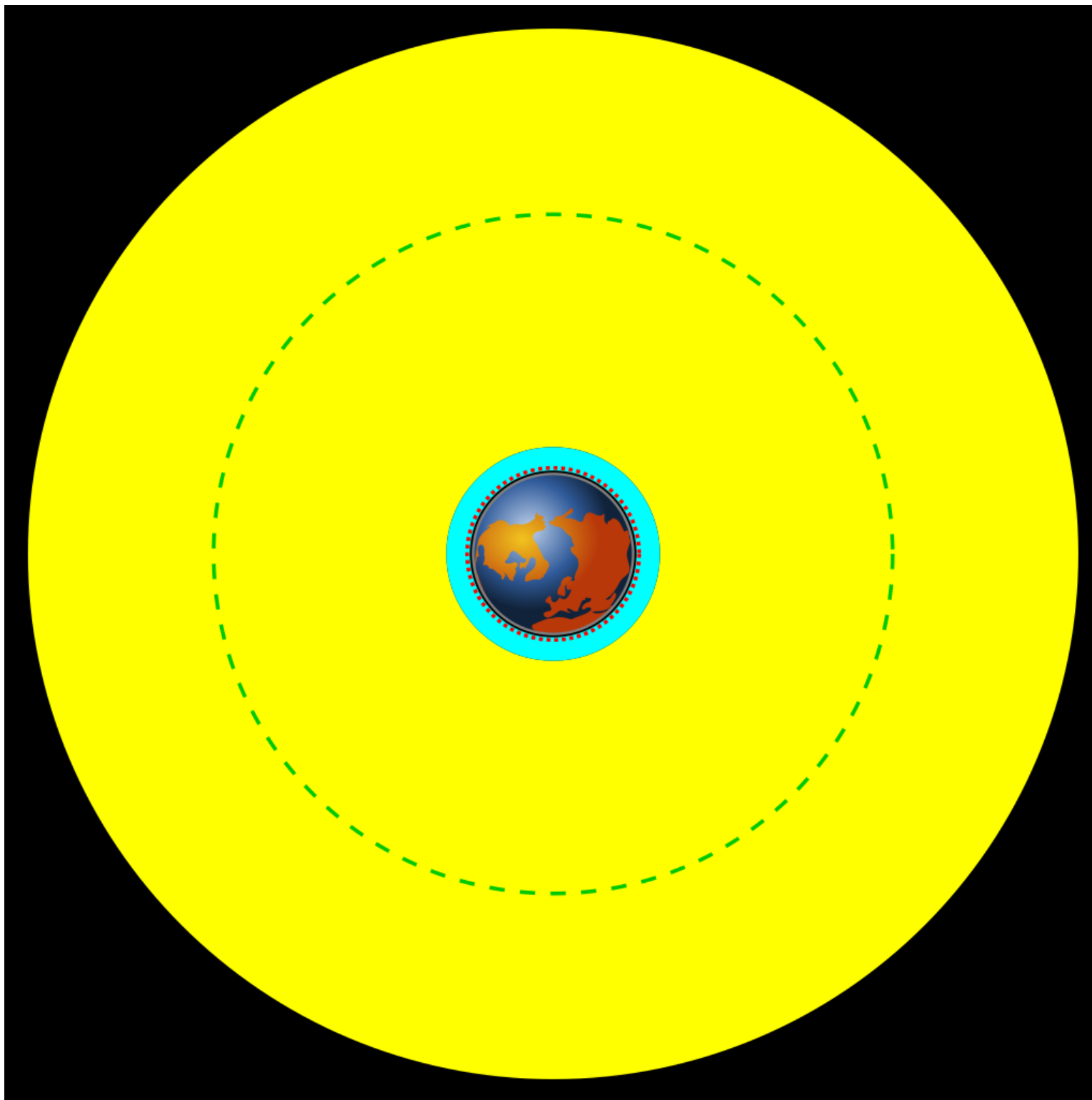
卫星结构

人造卫星一般由有效载荷（payload）和卫星平台两部分构成。

- 有效载荷（不同類型衛星均不同，共同的有：）
 - 對地相機
 - 恆星相機
 - 搭載的有效载荷
- 衛星平台（為有效载荷的操作提供環境及技術條件，包括：）服務系統
 - 熱控分系統
 - 姿態和軌道控制分系統
 - 程序控制分系統
 - 遙測分系統
 - 遙控分系統
 - 跟蹤和測試分系統
 - 供配電分系統
 - 返回分系統（限於返回式衛星）
- 衛星結構平台

Altitude Classifications

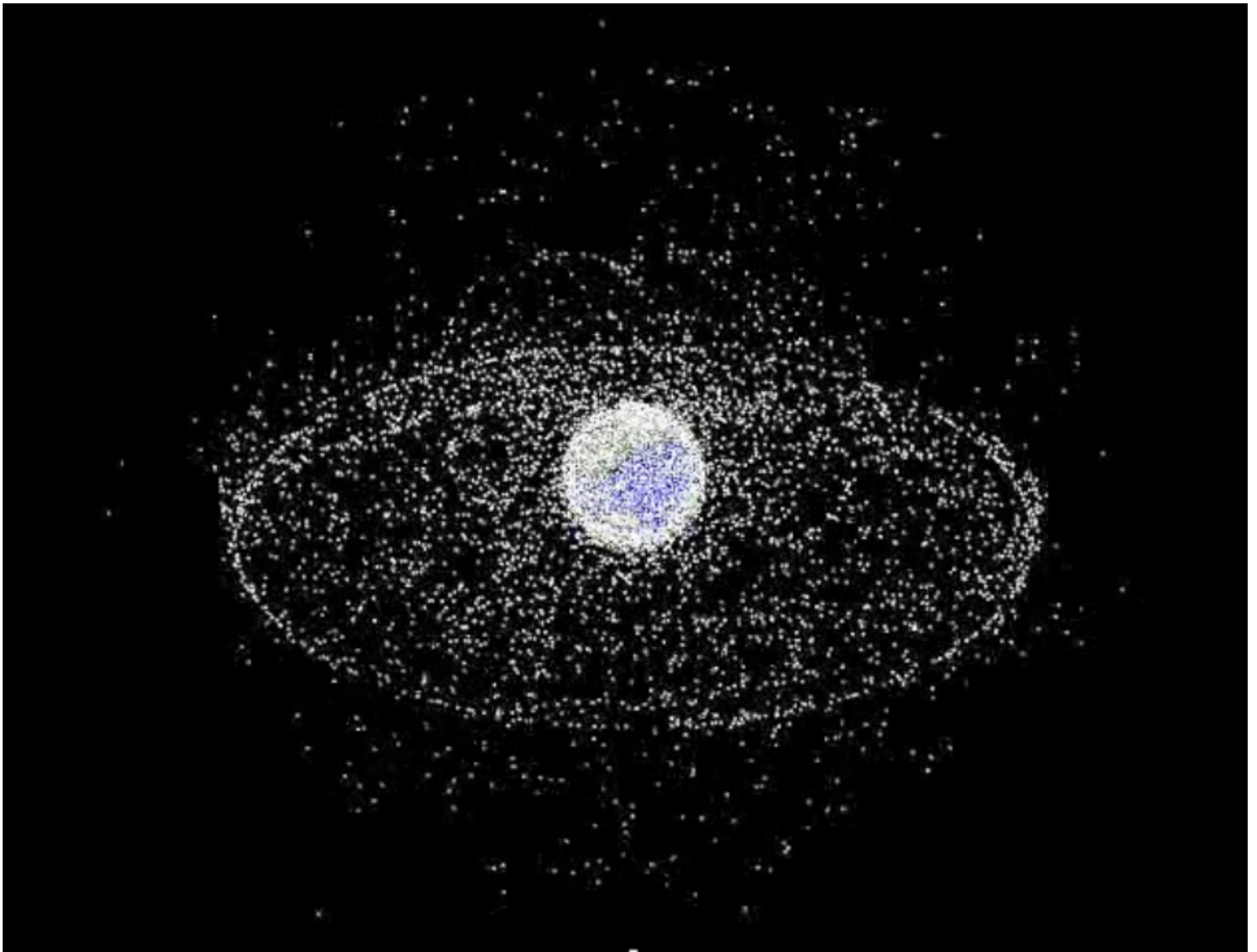
- **Low Earth orbit (LEO):** Geocentric orbits ranging in altitude from 180 km - 2,000 km
- **Medium Earth orbit (MEO):** Geocentric orbits ranging in altitude from 2,000 km - 35,786 km.
- **Geosynchronous orbit (GEO):** Geocentric circular orbit with an altitude of 35,786 kilometres. The period of the orbit equals one sidereal day, coinciding with the rotation period of the Earth. The speed is approximately 3,000 metres per second.
- **High Earth orbit (HEO):** Geocentric orbits above the altitude of geosynchronous orbit 35,786 km (22,236 mi).



By Image of earth: Gringer. Scale
orbits: Mike1024 - Created by
Commons user Mike1024, Earth
based on File:Worldmap
northern.svg, Public Domain,
[https://commons.wikimedia.org/
w/index.php?curid=3406139](https://commons.wikimedia.org/w/index.php?curid=3406139)

按衛星重量區分

- 大型衛星：大於1000kg（1噸）。
- 中型衛星：界於500到1000kg（半噸）。
- 小型衛星：不到500kg的都叫小型衛星，其中分類如下：
 - 迷你型衛星：500到100kg
 - 微衛星：小於100kg
 - 奈米衛星：10kg或更低
 - 方塊衛星：按國際標準約1.3kg
 - 米粒衛星：僅以公克為單位



First launch by country

Order	Country	Date of first launch	Rocket	Satellite(s)
1	Soviet Union	4 October 1957	Sputnik-PS	Sputnik 1
2	United States	1 February 1958	Juno I	Explorer 1
3	France 	26 November 1965	Diamant-A	Astérix
4	Japan	11 February 1970	Lambda-4S	Ohsumi
5	China	24 April 1970	Long March 1	Dong Fang Hong I
6	United Kingdom	28 October 1971	Black Arrow	Prospero
7	India	18 July 1980	SLV	Rohini D1
8	Israel	19 September 1988	Shavit	Ofeq 1
- [1]	Russia	21 January 1992	Soyuz-U	Kosmos 2175
- [1]	Ukraine	13 July 1992	Tsyklon-3	Strela
9	Iran	2 February 2009	Safir-1	Omid
10	North Korea	12 December 2012	Unha-3	Kwangmyŏngsŏn g-3 Unit 2
11	New Zealand	21 January 2018	Electron	Dove Pioneer , Lemur-2

First satellites of countries including those launched indigenously or with the help of others^[33]

Country ↕	Year of first launch ↕	First satellite ↕	Payloads in orbit as of April 2016 ^[34] [needs up]
 Soviet Union ( Russia)	1957 (1992)	Sputnik 1 (Kosmos 2175)	1457
 United States	1958	Explorer 1	1252
 United Kingdom	1962	Ariel 1	40
 Canada	1962	Alouette 1	43
 Italy	1964	San Marco 1	22
 France	1965	Astérix	60
 Australia	1967	WRESAT	14
 Germany	1969	Azur	49
 Japan	1970	Ohsumi	153
 China	1970	Dong Fang Hong I	210
 Netherlands	1974	ANS	5
 Spain	1974	Intasat	9
 India	1975	Aryabhata	173
 Indonesia	1976	Palapa A1	13
 Czechoslovakia	1978	Magion 1	5
 Bulgaria	1981	Intercosmos Bulgaria 1300	1
 Saudi Arabia	1985	Arabsat-1A	12
 Brazil	1985	Brasilsat-A1	15
 Mexico	1985	Morelos 1	9
 Sweden	1986	Viking	11
 Israel	1988	Ofeq 1	11

A Bit History of Satellite and Remote Sensing

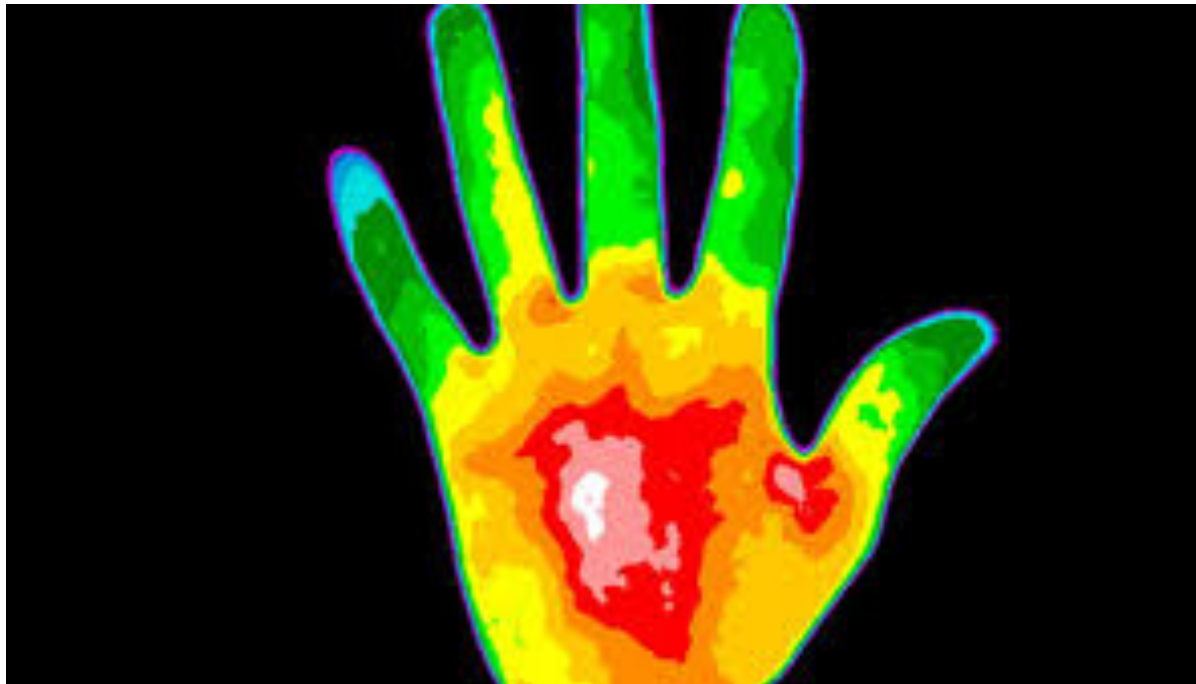
Ability of Our Eyes Is Limited

1. Viewing perspectives dictated by the location of our bodies



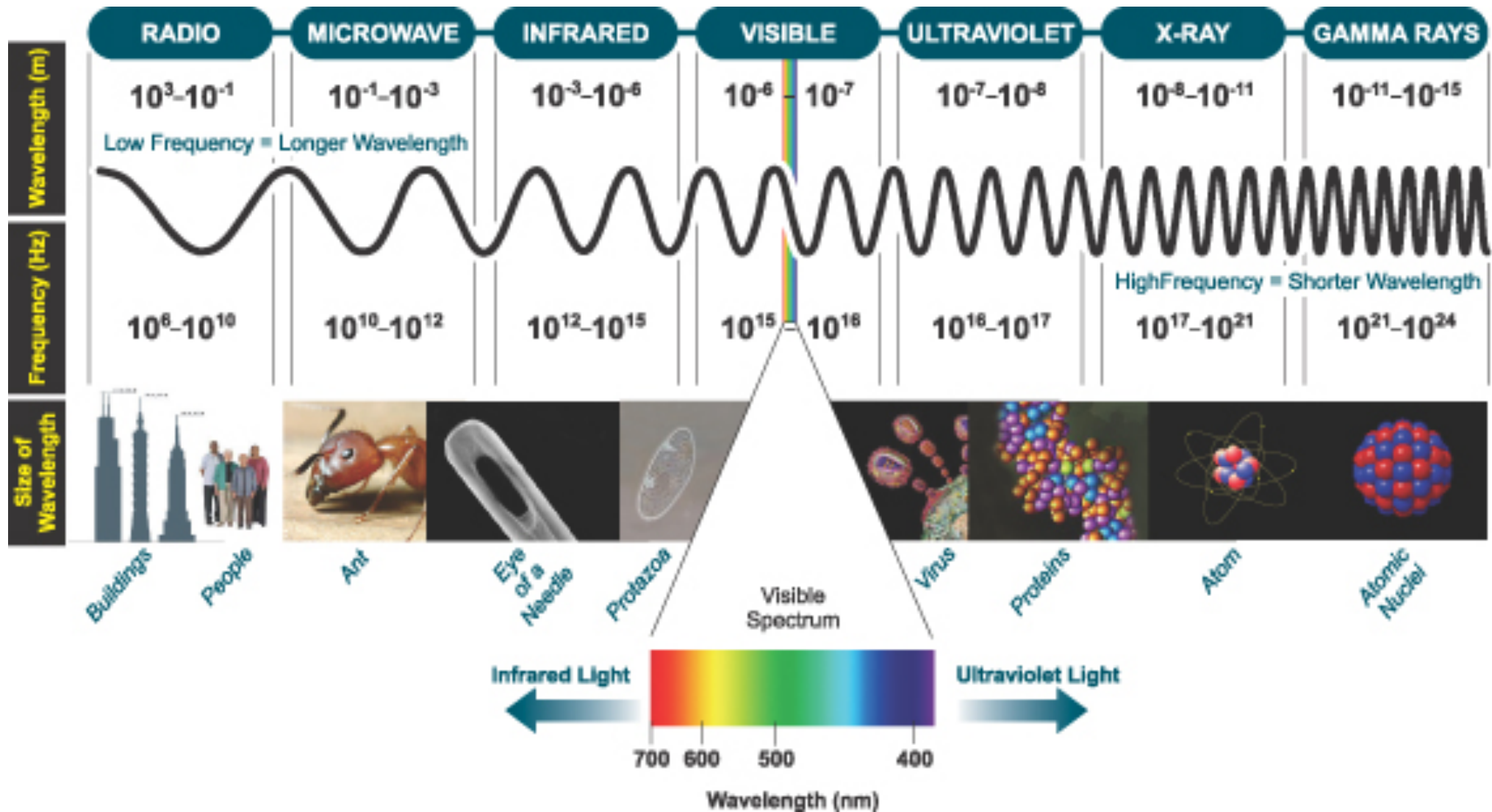
Ability of Our Eyes Is Limited

2. Sensitive to only the visible range of electromagnetic energy





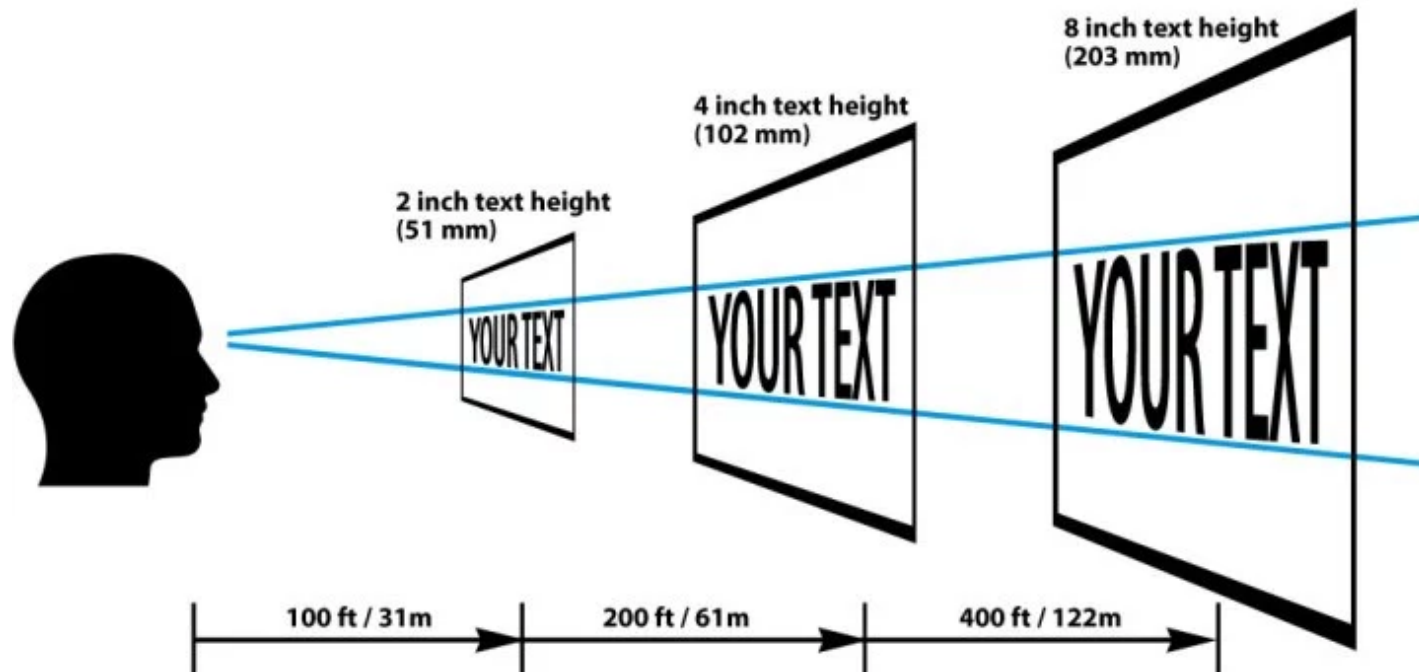
Electromagnetic Spectrum



Ability of Our Eyes Is Limited

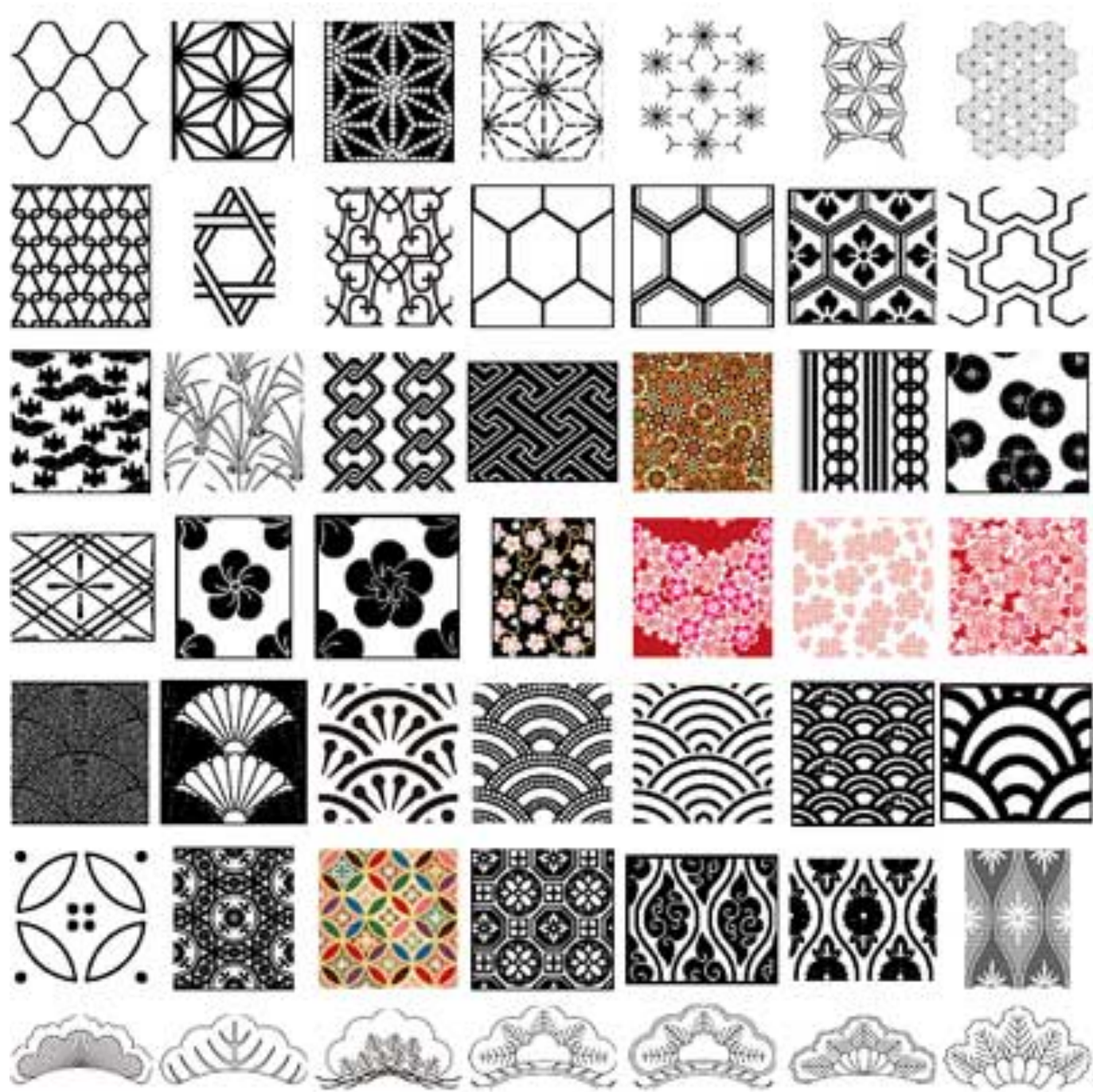
3. Viewing distance limited

TEXT SIGHT DISTANCE



Ability of Our Eyes Is Limited

4. Inability to form a lasting record of what we view

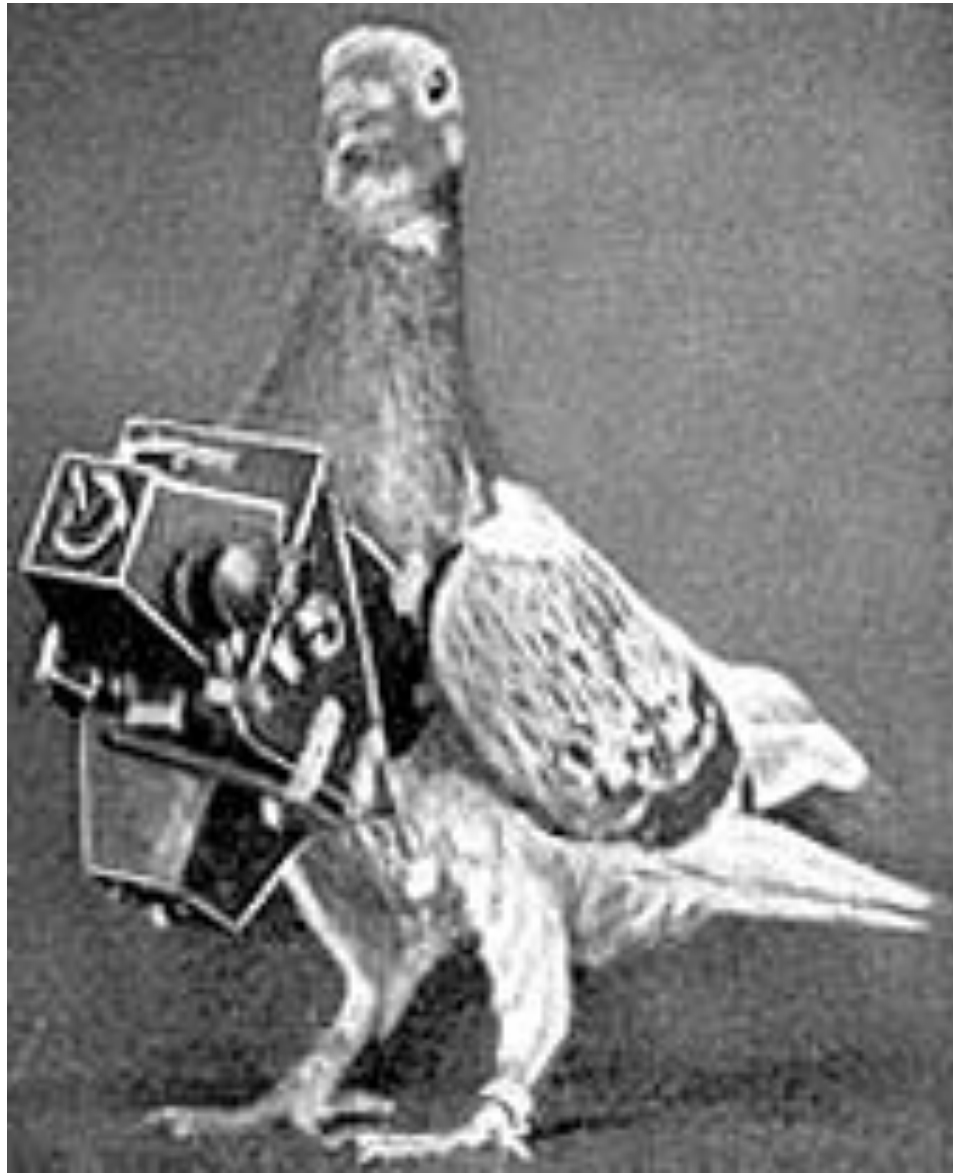


Humans have continuously sought to develop the technological means to increase our ability to see and record the physical properties of our environment.



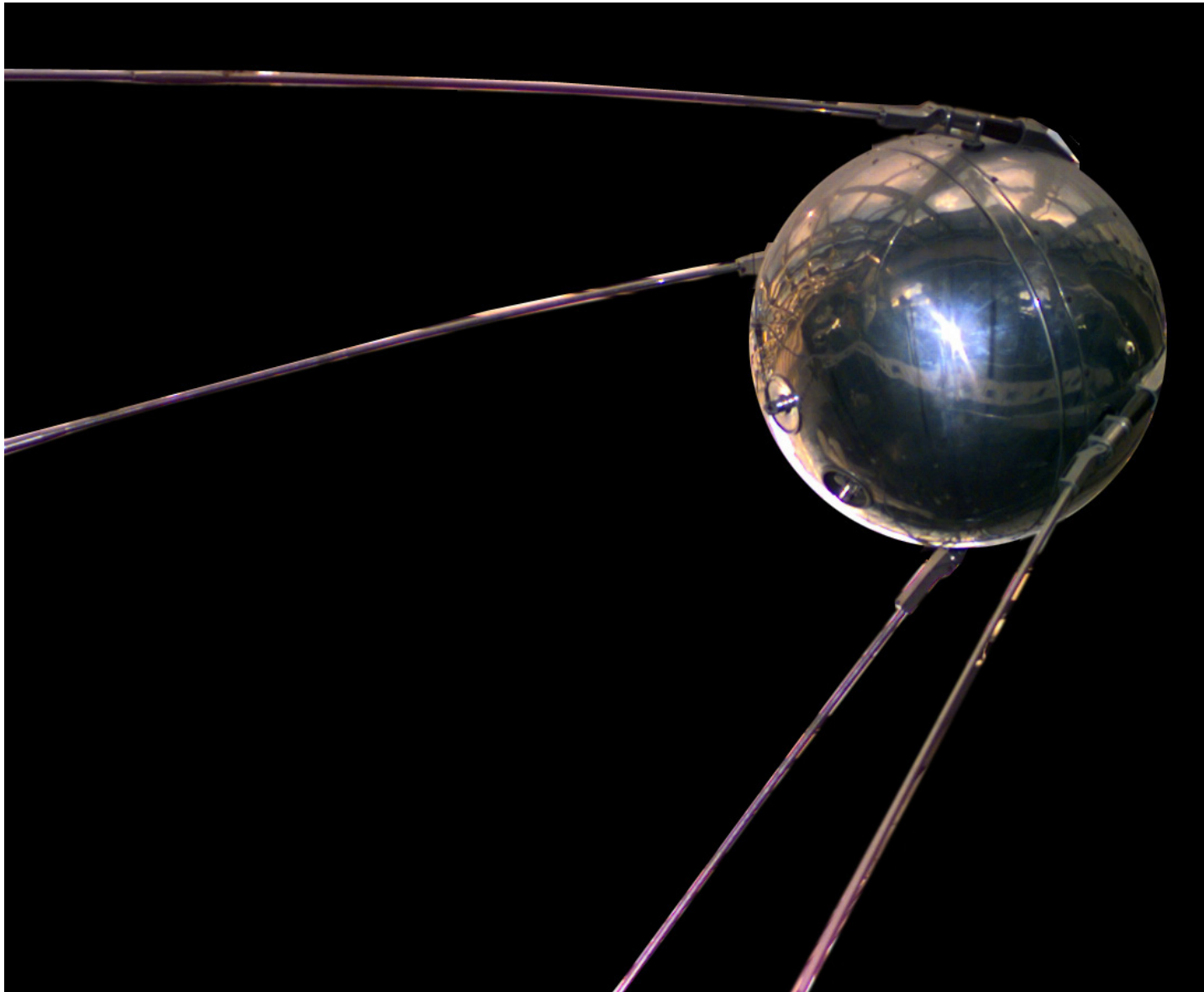


Photographing
Paris from a
balloon, 1862.
Honoré Daumier



Pigeonparadise.com

Camera mounted on a bird for pictures from behind enemy lines in WWII.



By NSSDC, NASA[1] - <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1957-001B>, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=1129363>



U-2 Aircraft Reconnaissance Program

After World War II and through the 1950s, the Cold War with the Soviet Union created a need for the United States to know about the military strength of the Soviet Union, especially with respect to the number of long range bombers and intercontinental ballistic missiles (ICBMs) that it possessed.

<https://www.oneonta.edu/faculty/baumanpr/geosat2/RS%20History%20II/RS-History-Part-2.html>



<https://newsela.com/read/gl-history-essay-cold-war/id/21580/>

U-2 Aircraft Reconnaissance Program



Reconnaissance planes were being sent across the borders into the Soviet Union and its allied nations. However, these planes could only penetrate the edges of the country and the information needed was in the middle of the Soviet Union's large land mass. Many of these planes and their crews never returned.

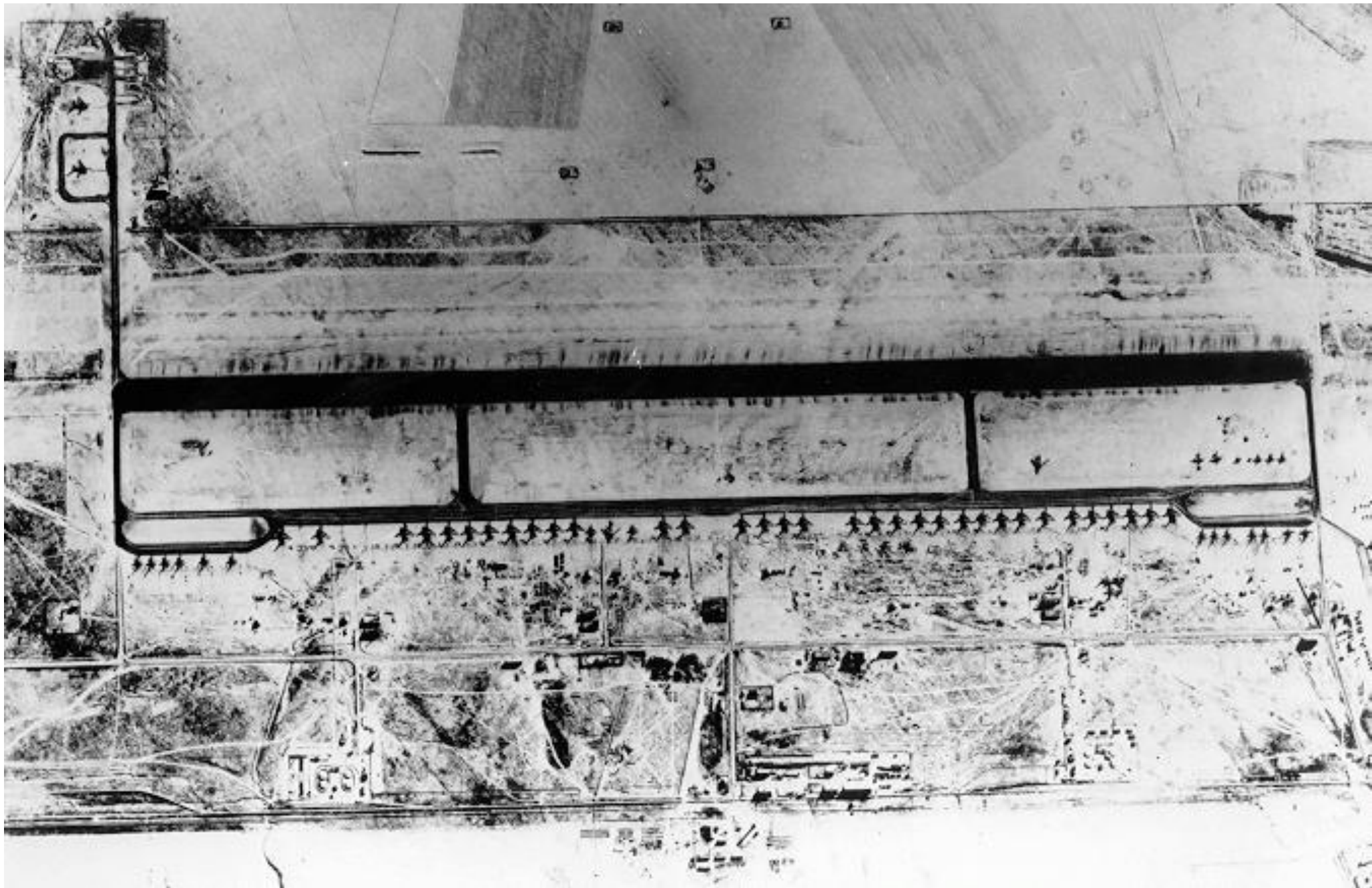
U-2 Aircraft Reconnaissance Program

In 1954, the U.S. developed the U-2. It flew at 70,000 feet, about 25,000 feet higher than any other plane could fly at the time.



<https://www.oneonta.edu/faculty/baumanpr/geosat2/RS%20History%20II/RS-History-Part-2.html>

The first overflight of the Soviet Union by a U-2 occurred on July 4, 1956. It took off from West Germany and flew over Poland, Belorussia, Moscow, Leningrad, and the Soviet Baltic states. It exposed 3,600 feet of film per mission using two high-resolution cameras. One camera had a long focal length allowing it to spot items that were two to three feet across.



U-2 aerial photograph of an airfield in the Soviet Union

These flights occurred several times over the next few years followed each time by formal protests by the Soviet Union.

Finally, on May 1, 1960, using a cluster of 14 SA-2 missiles, the Soviet Union was able to shoot down a U-2 over its territory.

The plane's pilot, Francis Gary Powers, survived, and in August 1960 the Soviets staged a highly publicized trial to embarrass the United States.

The United States agreed never to fly a reconnaissance plane across the Soviet Union again.

First remote sensing satellite ?

CORONA Program

The CORONA Program occurred between 1959 and 1972 but the American public did not know about the project until 1995 when President Bill Clinton ordered the declassification of the imagery.

Thus, the United States embarked in 1956, about the time of the first flight of a U-2 over the Soviet Union, to develop a reconnaissance system based on orbiting satellites.

The satellite had made seven passes over the denied territory and 17 orbits of the Earth.

From this imagery 64 Soviet airfields and 26 new surface-to-air (SAM) sites were identified.

Satellite capsule being captured

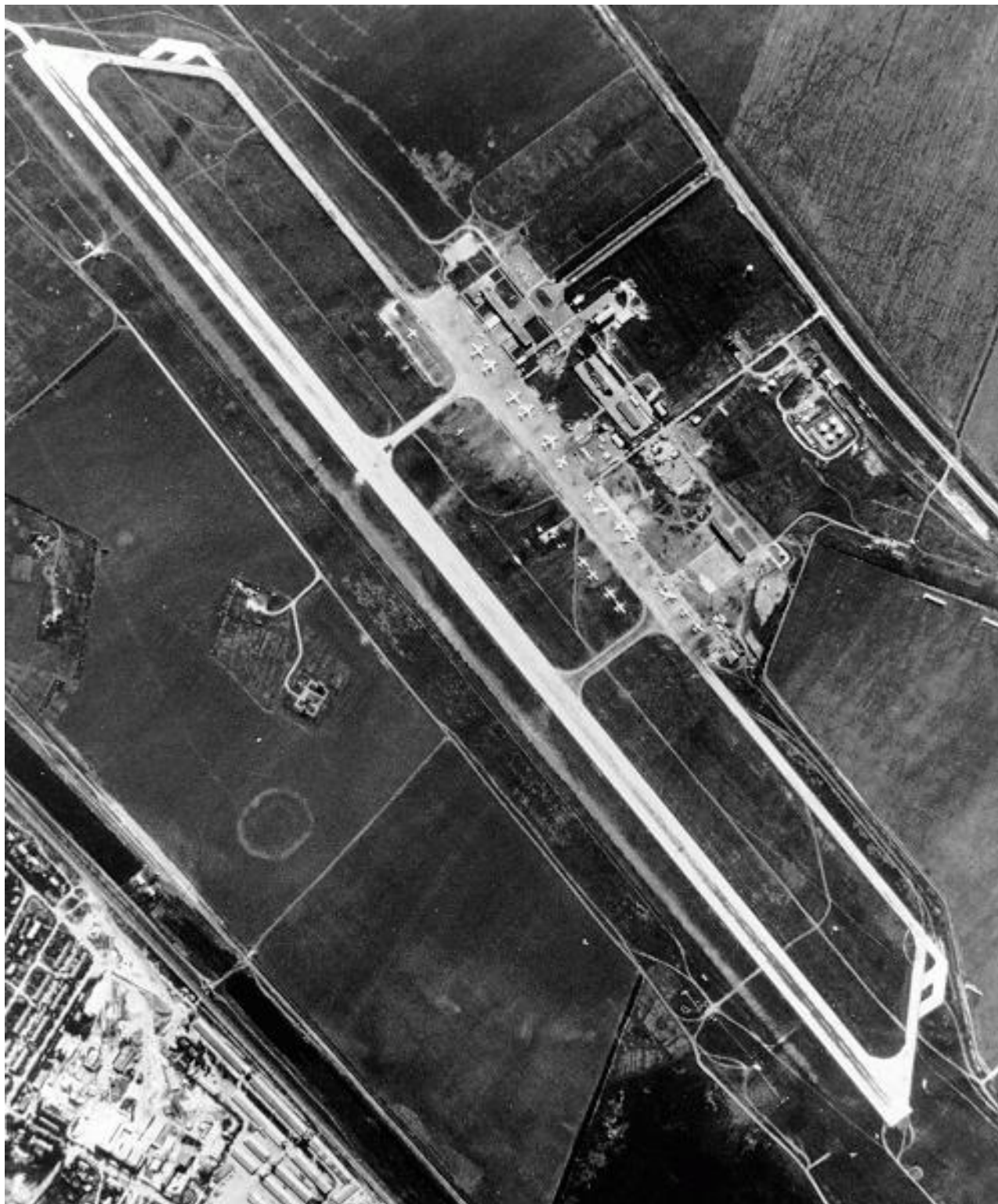


When the first successful CORONA satellite system occurred in 1960 it started the age of space reconnaissance and revolutionized remote sensing.

First CORONA photograph



<https://www.oneonta.edu/faculty/baumanpr/geosat2/RS%20History%20II/RS-History-Part-2.html>



CORONA 4 photograph of Soviet airfield

<https://www.oneonta.edu/faculty/baumanpr/geosat2/RS%20History%20II/RS-History-Part-2.html>

Table 1: Summary of CORONA Program – 1959 to 1972

	Camera	Launches	Recoveries	Time Period
KH-1		10	1	1959-1960
KH-2	C'(C Prime)	10	4	1960-1961
KH-3	C''' (C Triple Prime)	6	5	1961-1962
KH-4	M (Mural)	26	20	1962-1963
KH-4A	J (J-1)	52	94	1964-1969
KH-4B	J-3	17	32	1967-1972

While the United States has been recording events over the Soviet Union from space, the Soviets were doing the same thing over the United States. The Soviet Union launched its reconnaissance satellite system in 1961 with the Zenit-2 program. Designed differently from the CORONA Program, it also obtained good imagery.



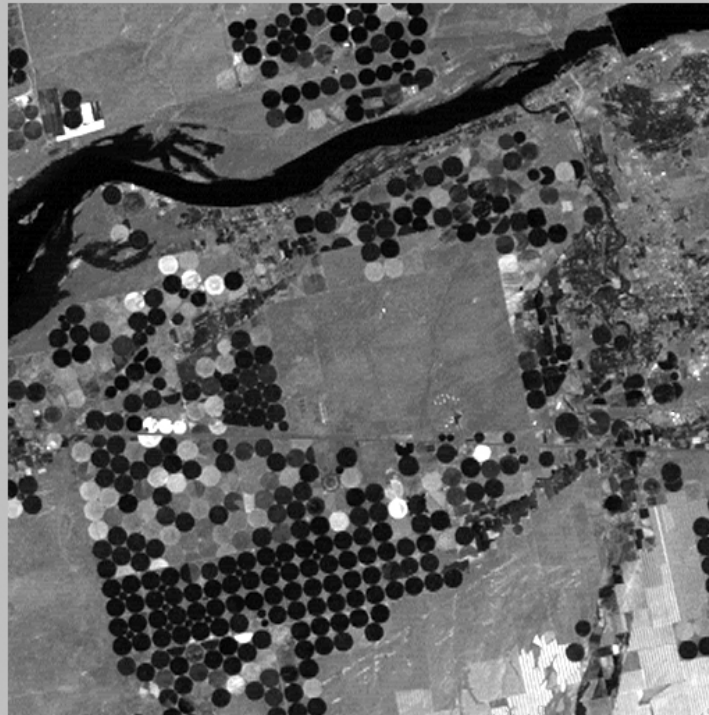
Artist's view of Landsat 1

Launched on July 23, 1972, Landsat 1, initially named ERTS (Earth Resources Technology Satellite), was the first satellite designed to study and to monitor the Earth's surface, more specifically its landmasses.

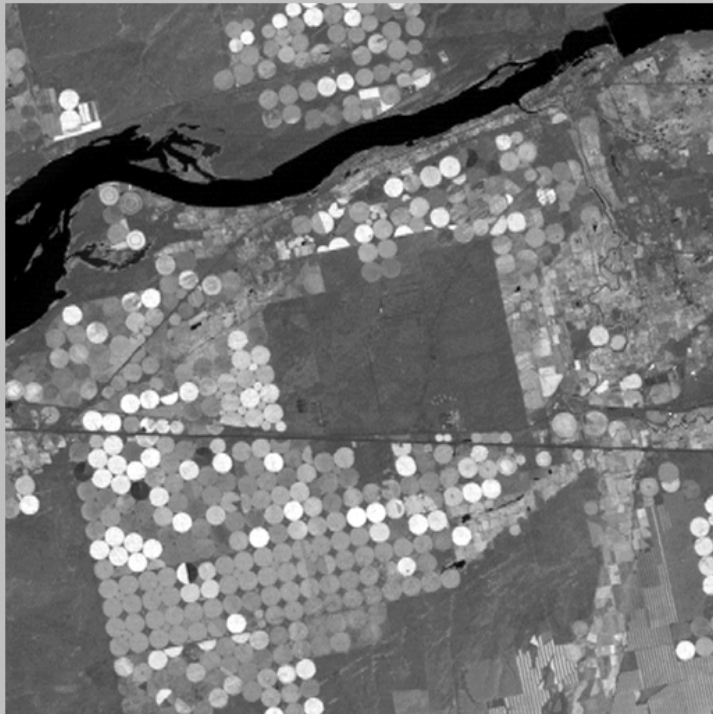
Landsat 1's two image sensor systems were the Return Beam Vidicon (RBV) built by the Radio Corporation of America (RCA) and the Multispectral Scanner System (MSS) built by General Electric. The RBV was supposed to be the primary instrument and the MSS, a highly experimental instrument, the secondary. However, the MSS imagery was found to be superior to the RBV imagery. In addition, the RBV instrument electronically interfered at times with the satellite's altitude control functions; thus, it had to be shut down after recording only a few images. In comparison, the MSS acquired over 300,000 images before the operation of Landsat 1 was terminated in January 1978.



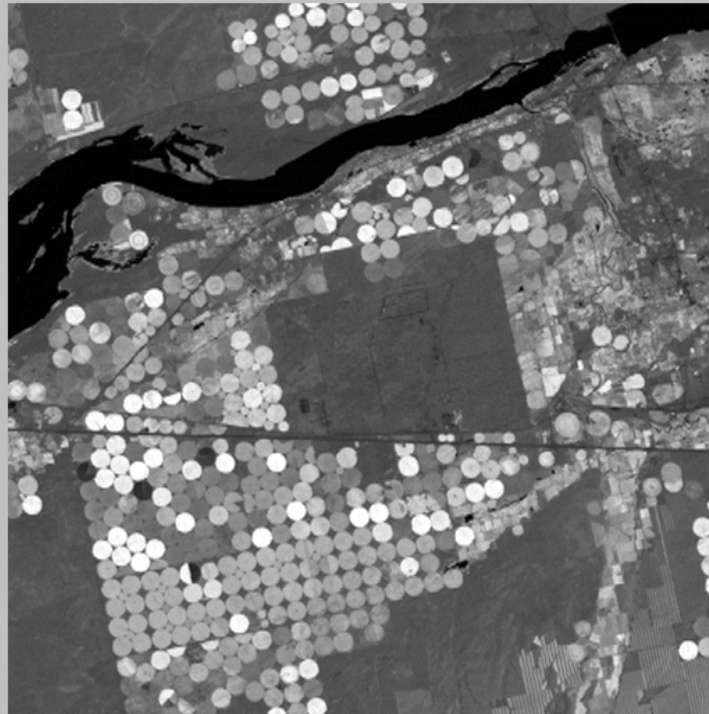
Band 4



Band 5



Band 6



Band 7

**MSS bands
showing
center
pivotal
irrigation
fields near
the
Columbia
River in
Oregon**



SeaSat, the first ever civilian spaceborne imaging radar instrument (SAR) was launched in 1978.

During its brief 110-day lifetime, SeaSat collected more information about the oceans than what had been acquired in the previous 100 years of shipboard research.

Examples of Remote Sensing Missions



+ ABOUT LANDSAT

+ NEWS & FEATURES

+ IMAGES

+ DATA

+ EDUCATION

+ REFERENCES



landsat
data



so
what?



digital
media



landsat
data
continuity
mission

The Landsat Program

The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Since 1972, Landsat satellites have collected information about Earth from space. This science, known as remote sensing, has matured with the Landsat Program.

Landsat satellites have taken specialized digital photographs of Earth's continents and surrounding coastal regions for over three decades, enabling people to study many aspects of our planet and to evaluate the dynamic changes caused by both natural processes and human practices.

[:: learn more ::](#) [search site ::](#)



Tahiti, French Polynesia

Important News

Landsat & the Chesapeake

June 19 • Big changes are happening to the Chesapeake Bay
[+ more](#)

Earth as Art contest ...

Landsat 5 update ...

[+ All Current News](#)



featured
bio



Landsat

- Since the early 1970s, the Landsat program has collected spectral information from Earth's surface, creating a historical archive unmatched in quality, detail, coverage, and length.
- Landsat sensors have a moderate spatial-resolution. This is an important spatial resolution because it is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as urban growth.

Landsat 1

THE DETAILS

Launch Date: July 23, 1972

Status: expired, January 6, 1978

Sensors: RBV, MSS

Altitude: nominally 900 km

Inclination: 99.2°

Orbit: polar, sun-synchronous

Equatorial Crossing Time: nominally 9:42 AM mean local time (descending node)

Period of Revolution : 103 minutes; ~14 orbits/day

Repeat Coverage : 18 days

Landsat 7

THE DETAILS

Launch Date: April 15, 1999

Status: operational despite Scan Line Corrector (SLC) failure May 31, 2003

Sensors: ETM+

Altitude: 705 km

Inclination: 98.2°

Orbit: polar, sun-synchronous

Equatorial Crossing Time: nominally 10 AM (± 15 min.) local time (descending node)

Period of Revolution : 99 minutes; ~14.5 orbits/day

Repeat Coverage : 16 days

The Thematic Mapper

TM Bands

Band Number	μm	Resolution
1	0.45-0.52	30 m
2	0.52-0.60	30 m
3	0.63-0.69	30 m
4	0.76-0.90	30 m
5	1.55-1.75	30 m
6	10.4-12.5	120 m
7	2.08-2.35	30 m

TM TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**

Spatial Resolution: **30 m (120 m - thermal)**

Spectral Range: **0.45 - 12.5 μm**

Number of Bands: **7**

Temporal Resolution: **16 days**

Image Size: **185 km X 172 km**

Swath: **185 km**

Programmable: **yes**

The Multispectral Scanner System

MSS Bands

Band Number (L1-L3)	Band Number(L4-L5)	μm	Resolution*
4	~ 2 (0.52–0.60 μm)	0.5-0.6	68 m X 83 m
5	~ 3 (0.63–0.69 μm)	0.6-0.7	68 m X 83 m
6	~ 4 (0.76–0.90 μm)	0.7-0.8	68 m X 83 m
7	~ 4	0.8-1.1	68 m X 83 m
8	~ 6 (2.08–2.35 μm)	10.41-12.6	68 m X 83 m

MSS TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**

*Spatial Resolution: **68 m X 83 m (commonly resampled to 57 m, or 60 m)**

Spectral Range: **0.5 - 1.1 μm**

Number of Bands: **4, 5 (Landsat 3 only)**

Temporal Resolution: **18 days (L1-L3), 16 days (L4 & L5)**

Image Size: **185 km X 185 km**

Swath: **185 km**

Programmable: **no**

The Enhanced Thematic Mapper Plus

ETM+ Bands

Band Number	μm	Resolution
1	0.45-0.515	30 m
2	0.525-0.605	30 m
3	0.63-0.69	30 m
4	0.75-0.90	30 m
5	1.55-1.75	30 m
6	10.4-12.5	60 m
7	2.09-2.35	30 m
8	0.52-0.9	15 m

ETM+ TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**

Spatial Resolution: **30 m (60 m - thermal, 15-m pan)**

Spectral Range: **0.45 - 12.5 μm**

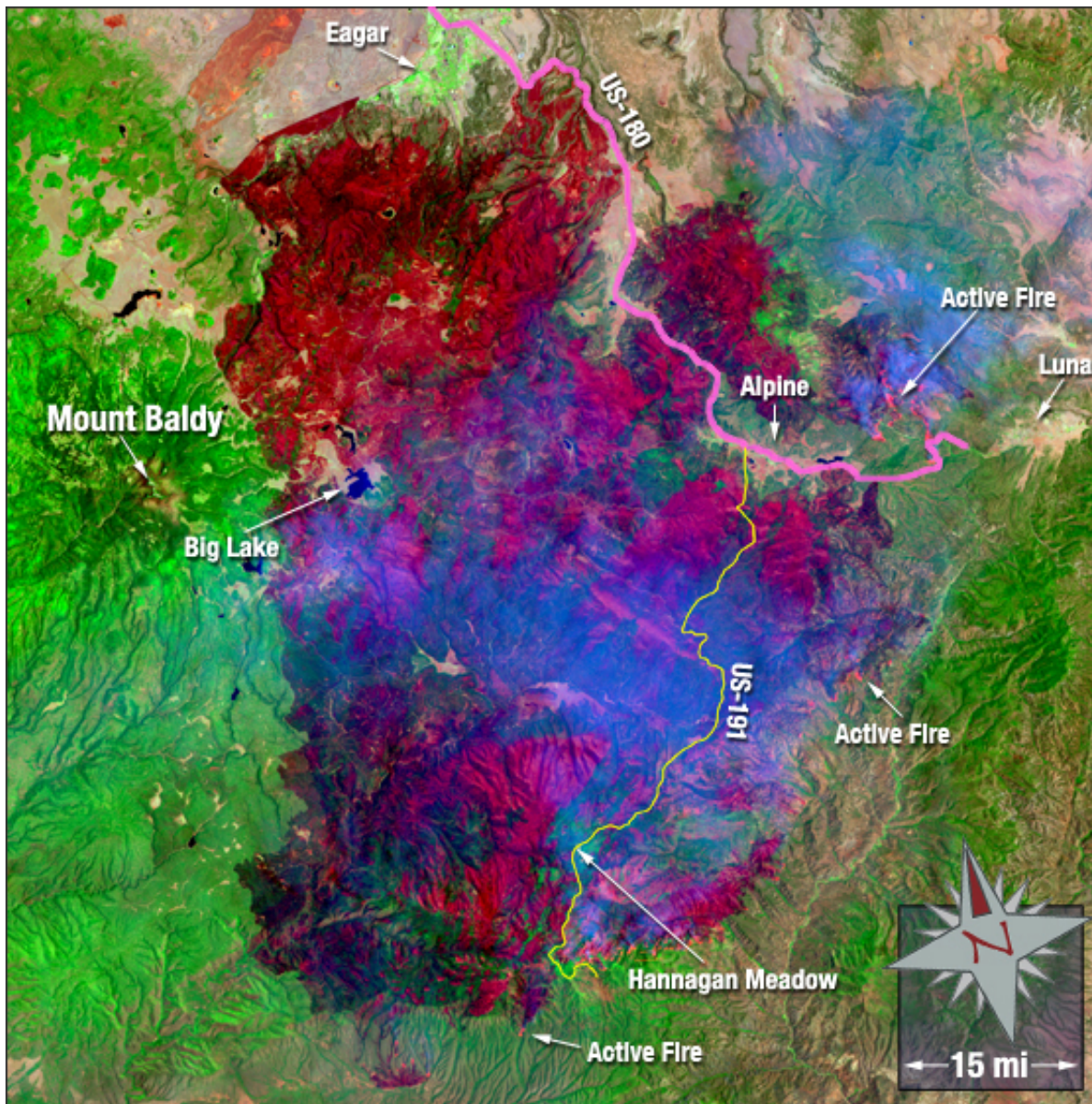
Number of Bands: **8**

Temporal Resolution: **16 days**

Image Size: **183 km X 170 km**

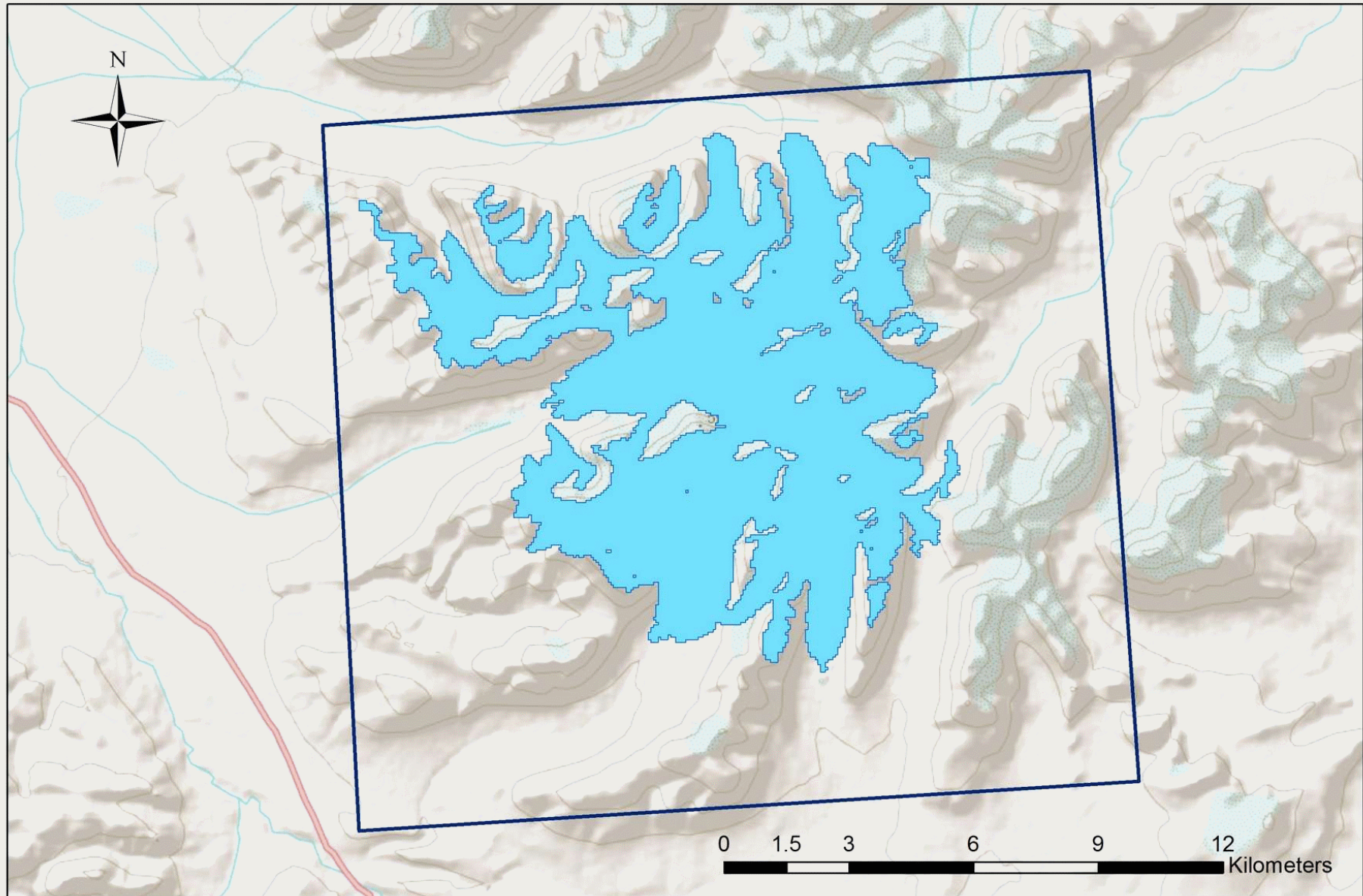
Swath: **183 km**

Programmable: **yes**



The Wallow fire began May 29, 2011 in the Bear Wallow Wilderness area located in eastern Arizona. High winds and low humidity combined to turn the the Wallow Fire into Arizona's largest wildfire to date by June 14, 2011 with over 733 square miles burned.

1976-11-11



Copernics Program

- This initiative is headed by the European Commission (EC) in partnership with the European Space Agency (ESA).
- Consists of 30+ satellites, the most ambitious Earth observation programme to date.
- Provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

Sentinel Satellites

- ESA is developing a new family of satellites, called Sentinels, specifically for the Copernicus programme.
- Six main categories of services: land management, the marine environment, atmosphere, emergency response, security and climate change.



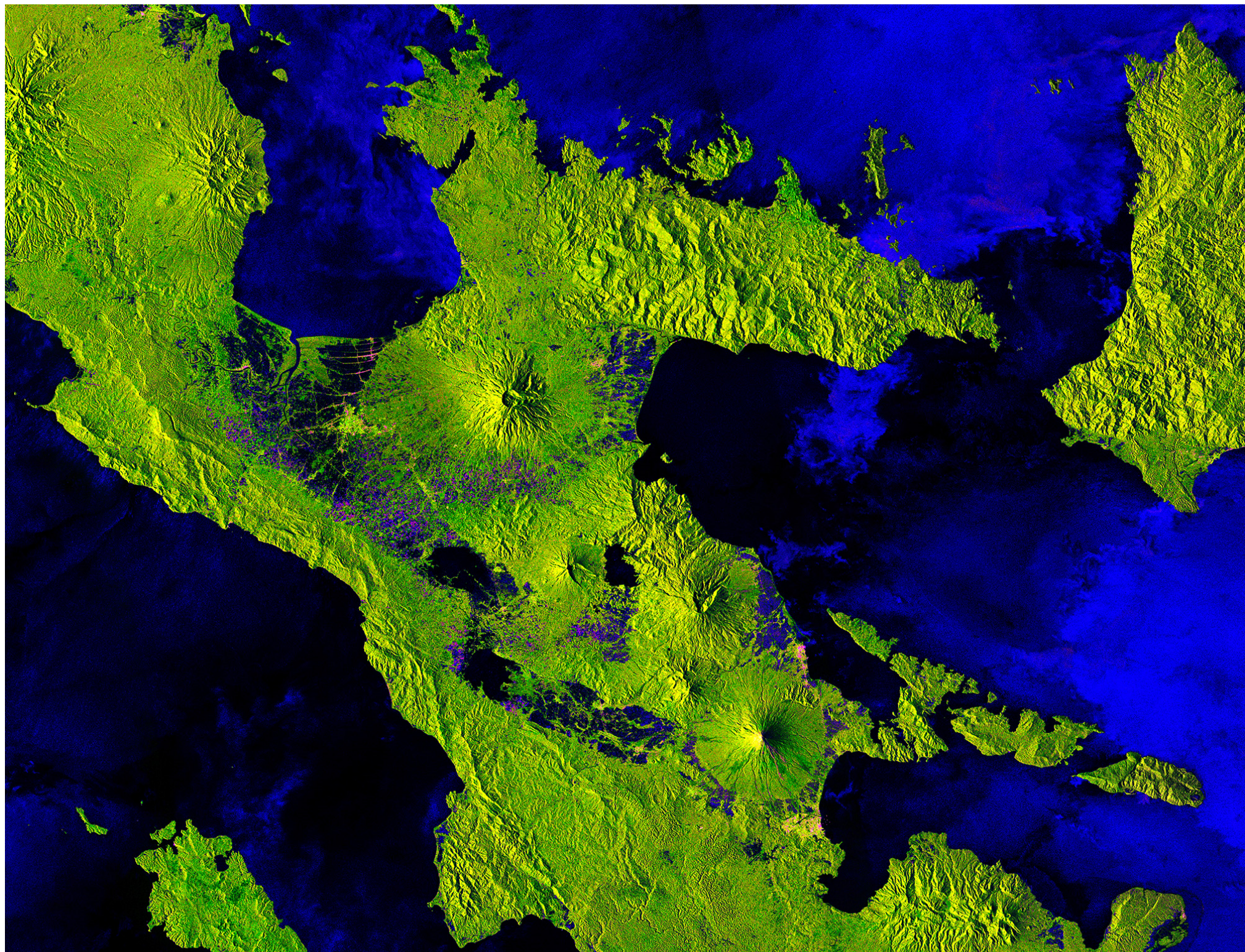
- The Sentinel missions mark a new era in Earth observation for decades to come.

http://www.esa.int/spaceinimages/Images/2009/03/Global_Monitoring_for_Environment_and_Security

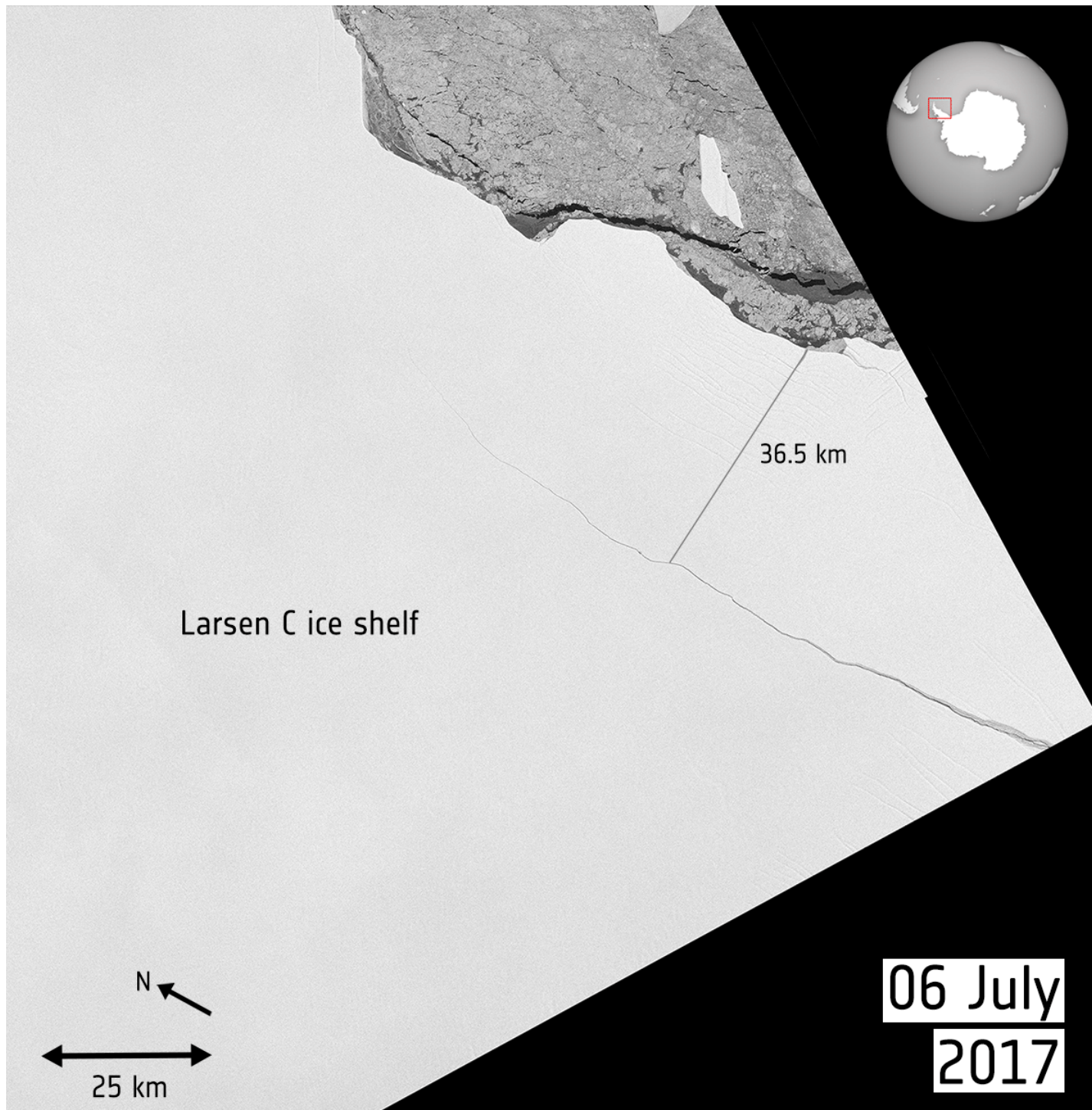
Sentinel Satellites

- **Sentinel-1** is a polar-orbiting, all-weather, day-and-night radar imaging mission for land and ocean services. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B on 25 April 2016. Both were taken into orbit on a Soyuz rocket from Europe's Spaceport in French Guiana.





Giant berg on the move (Courtesy of ESA)



Sentinel Satellites



<http://www.esa-sen2agri.org/SitePages/EODData.aspx>

- **Sentinel-2** is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring to provide, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 can also deliver information for emergency services. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B on 7 March 2017.

23 May 2018

Restless
Kilauea
(courtesy of
ESA)



This land monitoring mission consists of a pair of satellites, carrying each one an optical payload with **visible, near infrared and shortwave infrared sensors**, providing continuity for the former Spot and Landsat missions. Both sensors will include **13 spectral bands** (4 bands at 10 m, 6 at 20 m and 3 at 60 m) with a **290 km swath**, providing continuity for the current Spot and Landsat missions.

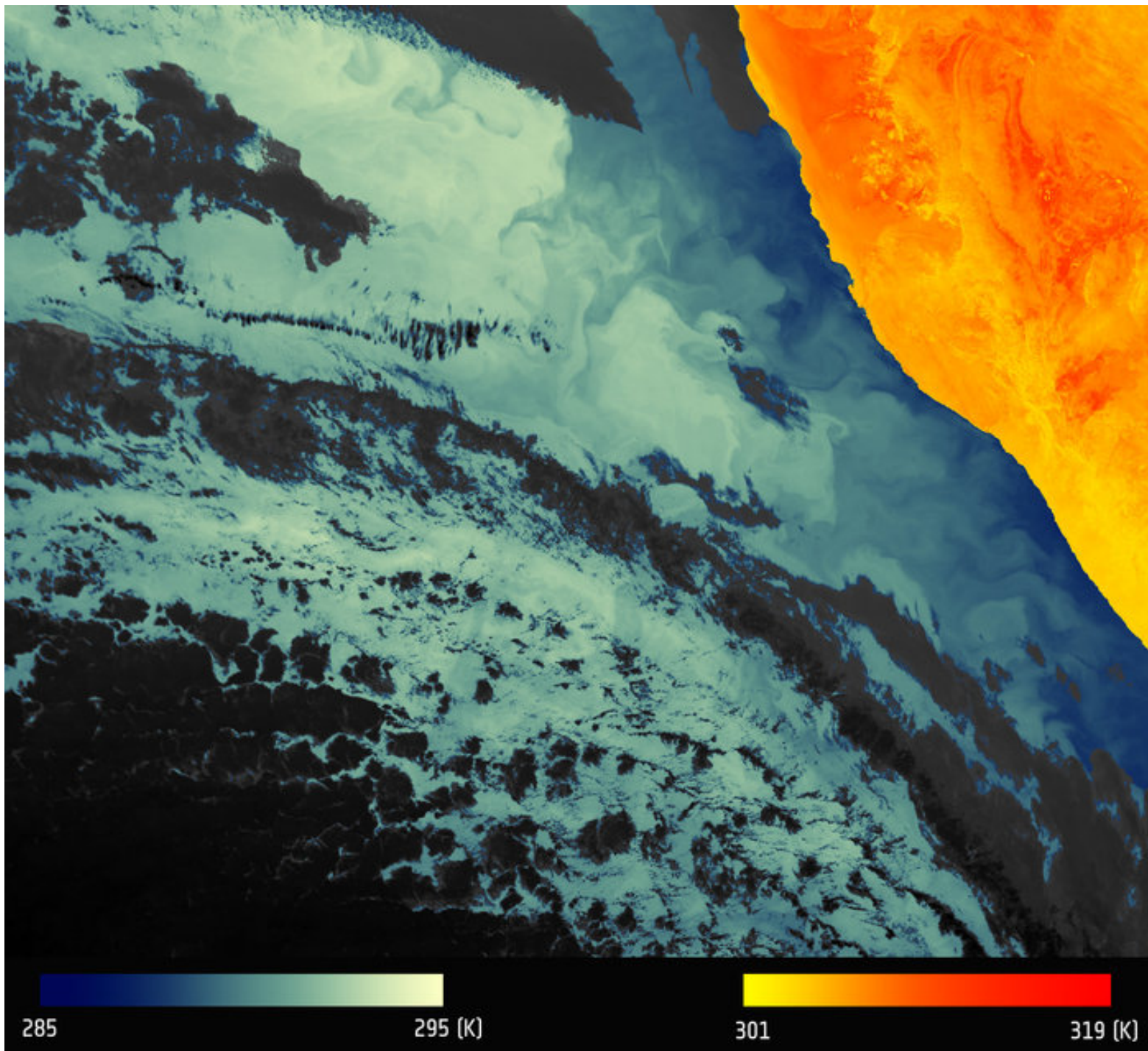
Sentinel-2, with its final two units in operation, will reach a **revisit time of 5 days at the equator and 2–3 days at mid-latitudes**. The first of them, Sentinel-2A, was launched on 23 June 2015, whereas Sentinel-2B is planned for mid-2016.

Sentinel Satellites

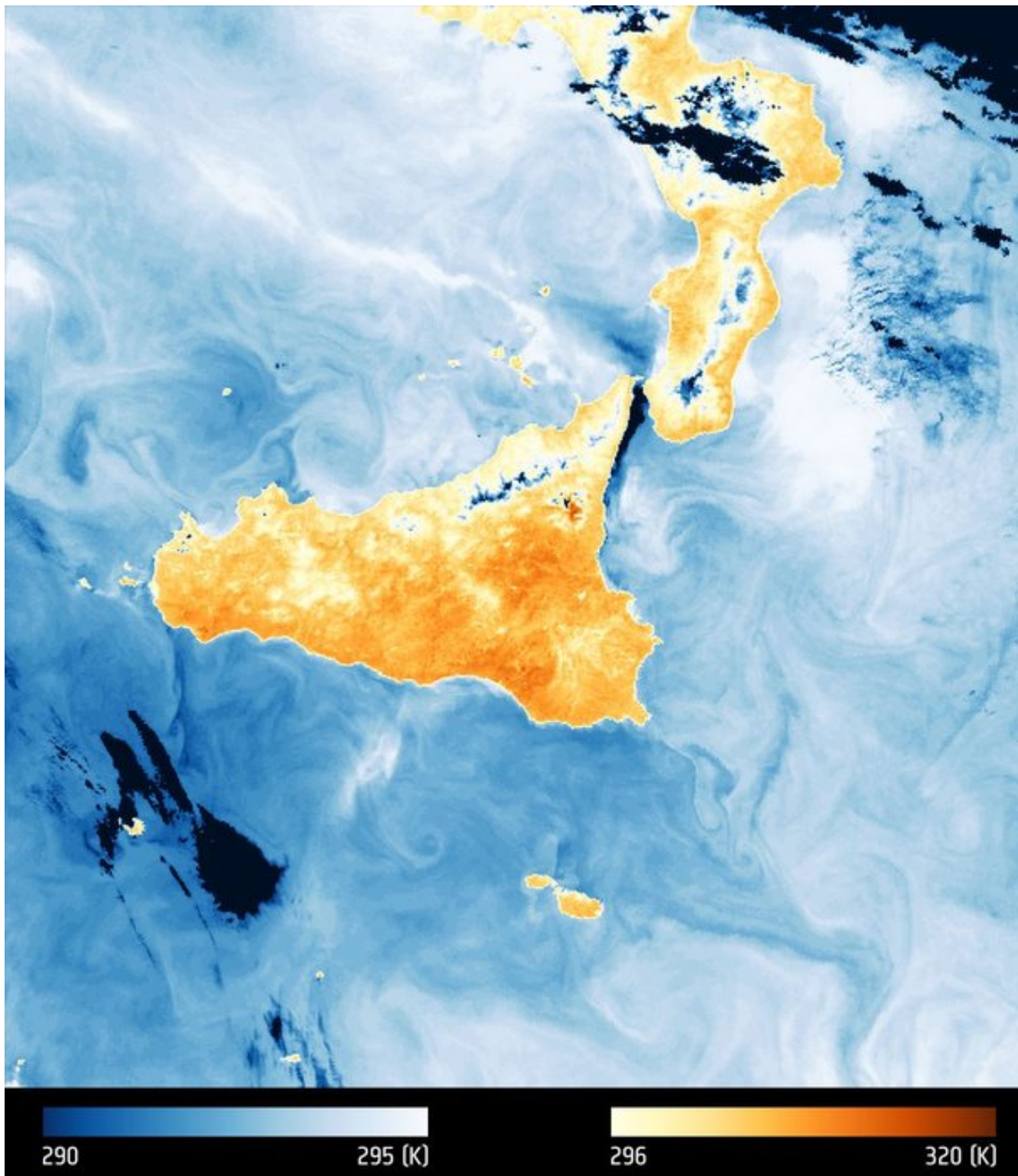
- The primary objective of SENTINEL-3 is marine observation, and it will study sea-surface topography, sea and land surface temperature, ocean and land colour.



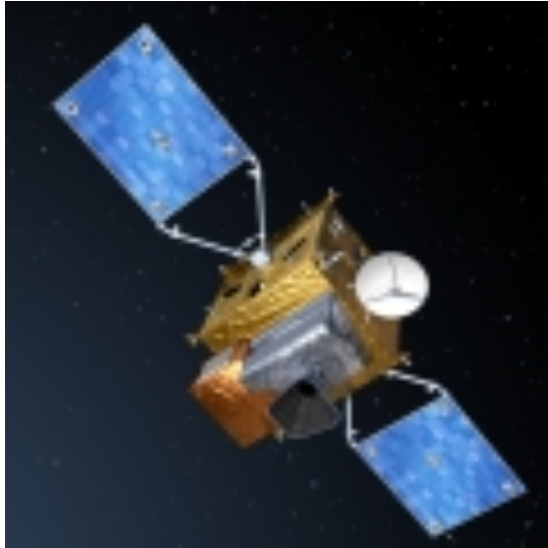
Sentinel-3A
was launched
on 16
February 2016.
Sentinel-3B
followed on 25
April 2018.



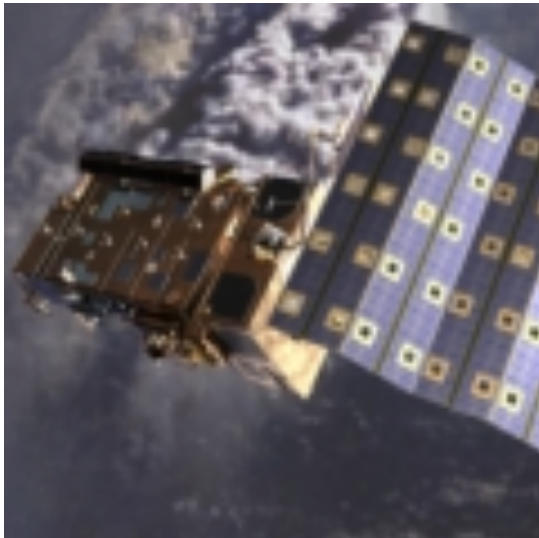
Sicily hotspot (courtesy of ESA)



Sentinel Satellites

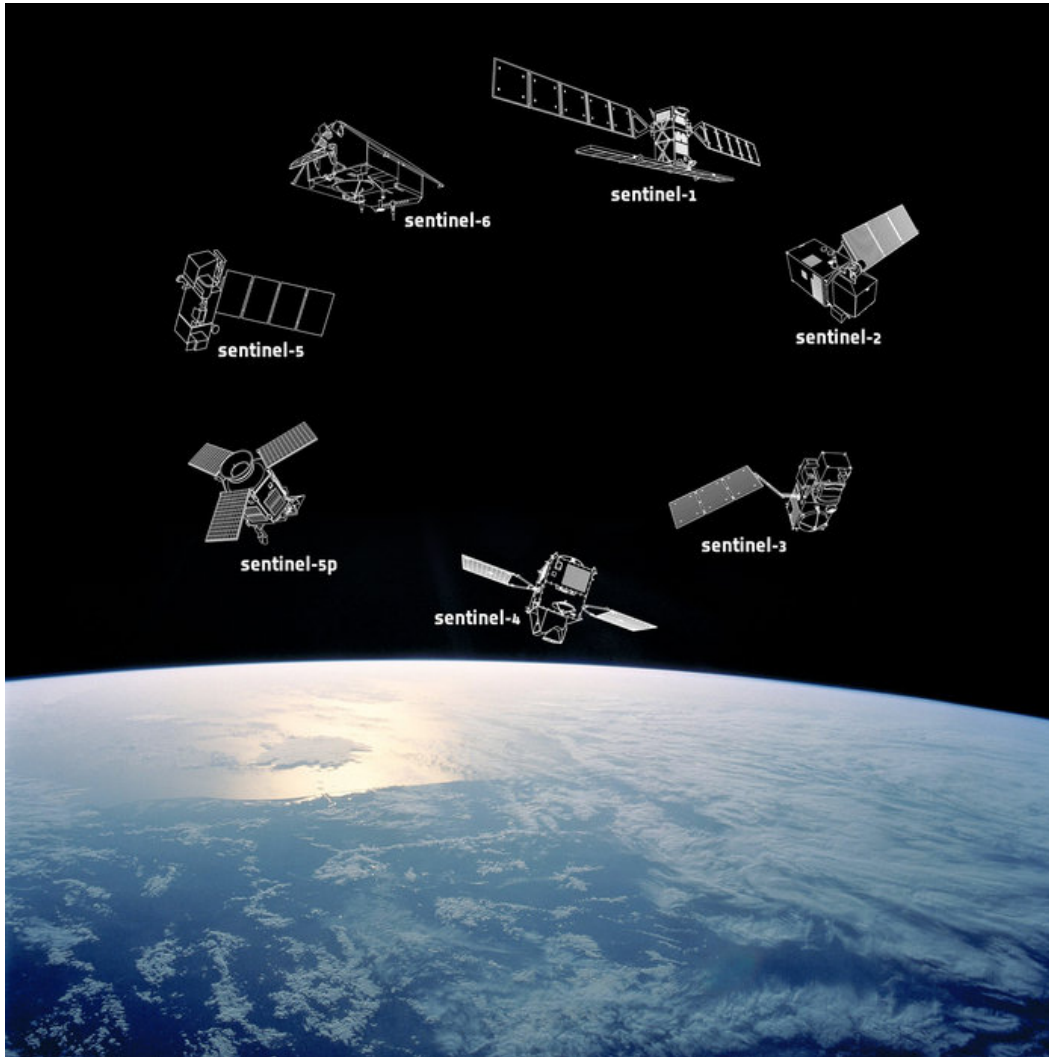


- Sentinel-4 and -5 will provide data for atmospheric composition monitoring from geostationary and polar orbits, respectively.



<https://sentinel.esa.int/web/sentinel/missions>

Sentinel Satellites



- Sentinel-5P
Precursor mission
is being
developed to
reduce data gaps
between Envisat,
in particular the
Sciamachy
instrument, and
the launch of
Sentinel-5.

Sentinel Satellites

- Sentinel-6 will carry a radar altimeter to measure global sea-surface height, primarily for operational oceanography and for climate studies.

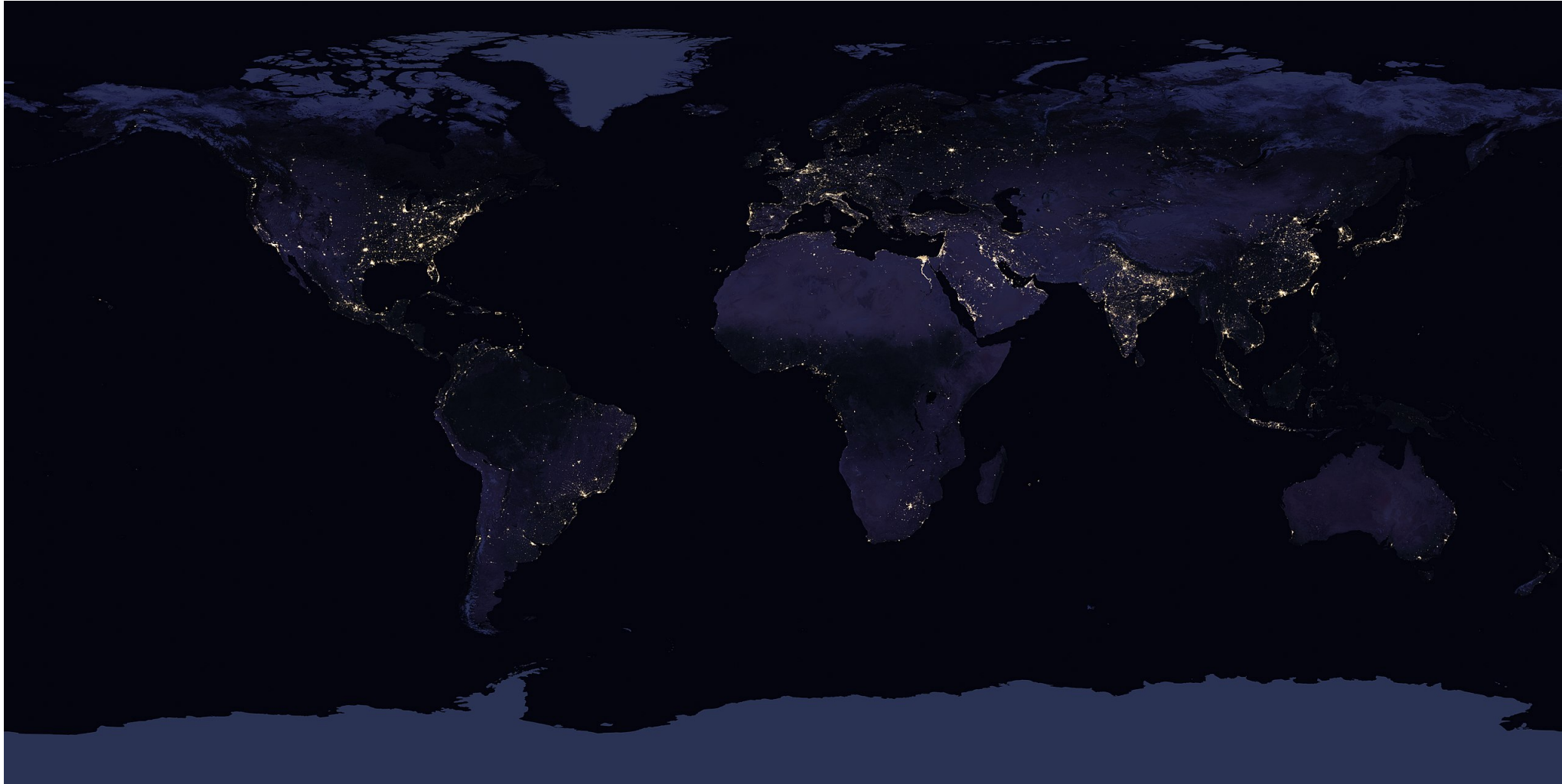


Remote Sensing Applications – Global Change

Global Change

- The atmosphere, oceans, and land change at a variety of spatial and temporal scales

Example: Human Activities

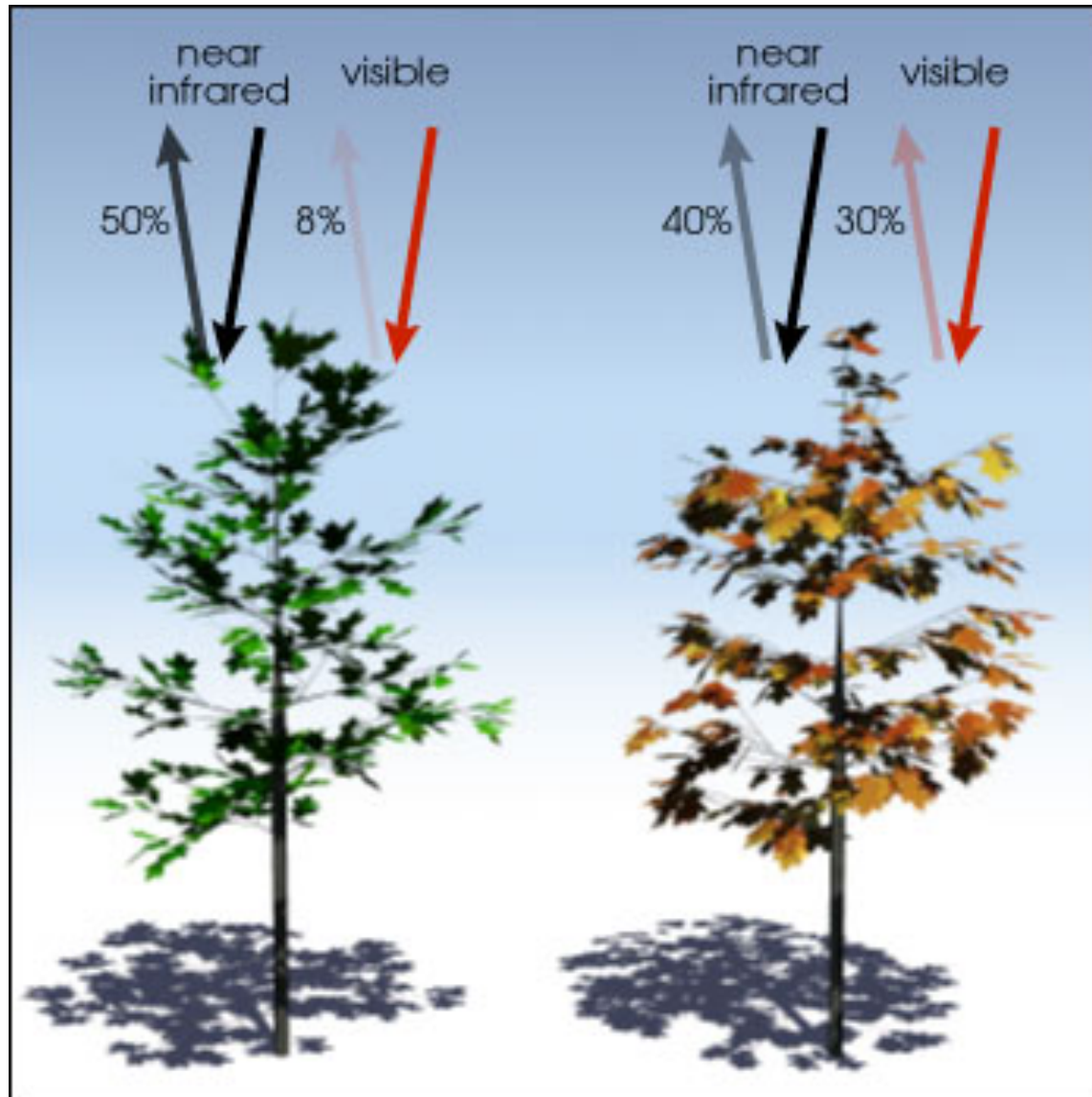


https://en.wikipedia.org/wiki/Visible_Infrared_Imaging_Radiometer_Suite

Example: Vegetation Monitoring

- Patterns of vegetation reflect climate and environmental changes as well as human activities
- Photosynthesis plays a big role in removing carbon dioxide from the atmosphere and storing it in wood and soils
- Mapping vegetation is a key for studying the carbon cycle

Normalized Difference Vegetation Index (NDVI)



Normalized Difference Vegetation Index (NDVI)

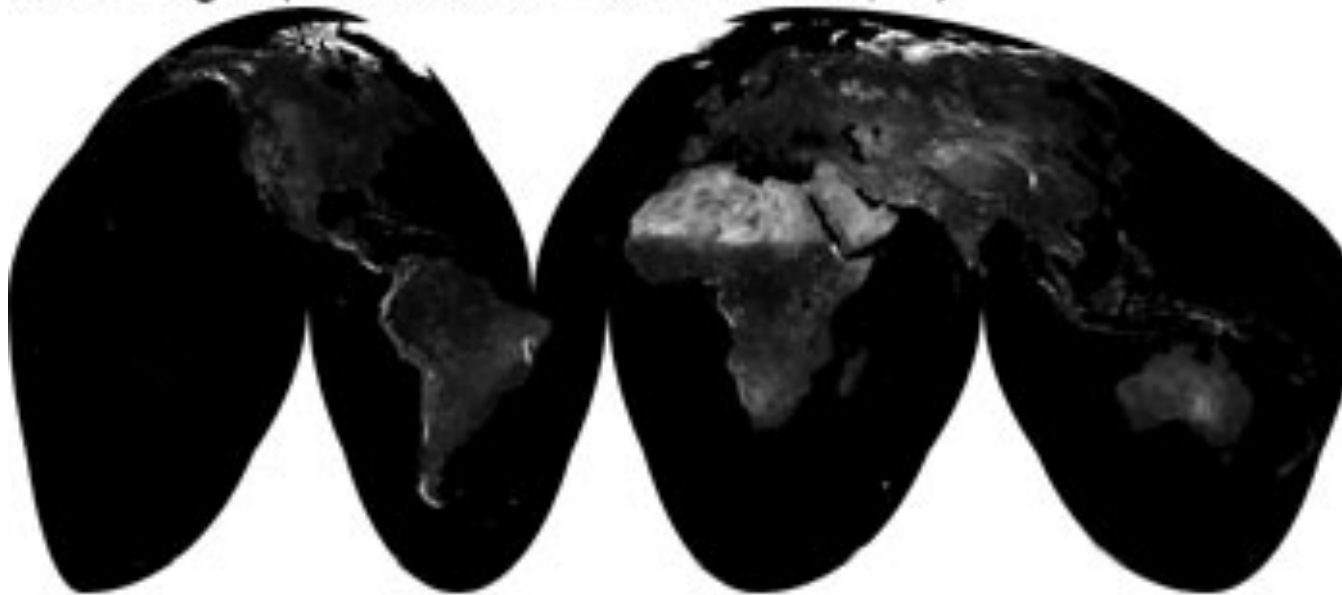
- The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis.
- The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm).
- The more leaves a plant has, the more these wavelengths of light are affected, respectively.

Normalized Difference Vegetation Index (NDVI)

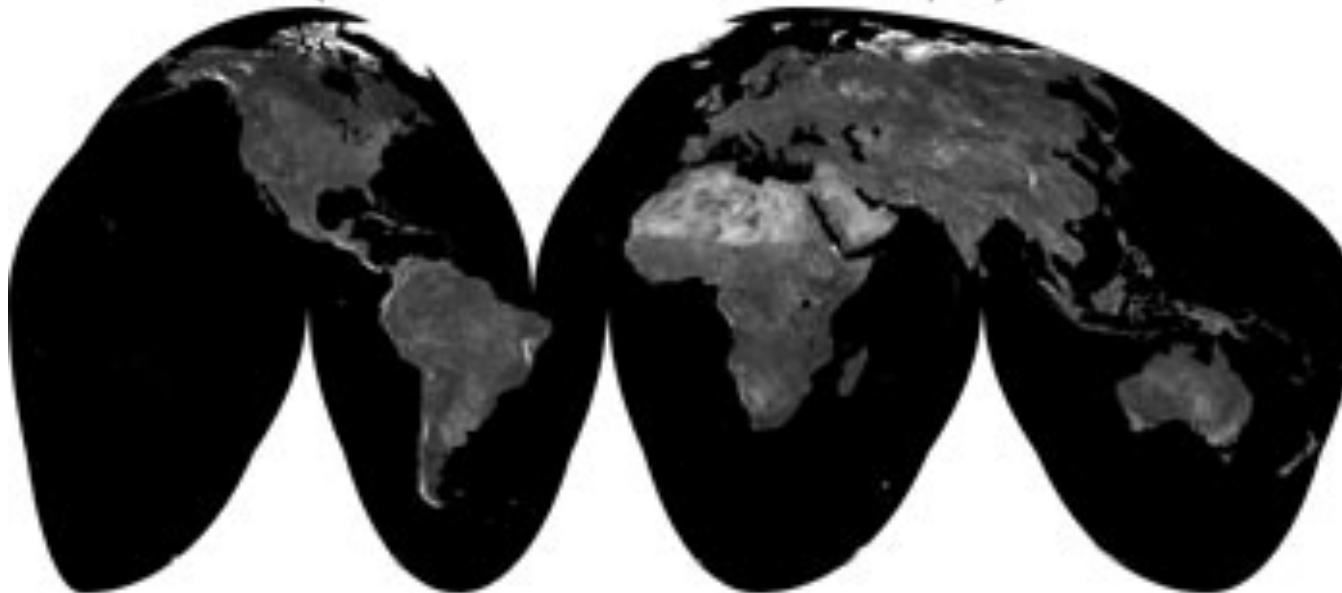
$$\text{NDVI} = (\text{NIR} - \text{VIS}) / (\text{NIR} + \text{VIS})$$

- $\text{NDVI} = -1 \sim +1$
- No green leaves gives a value close to zero.
- Close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

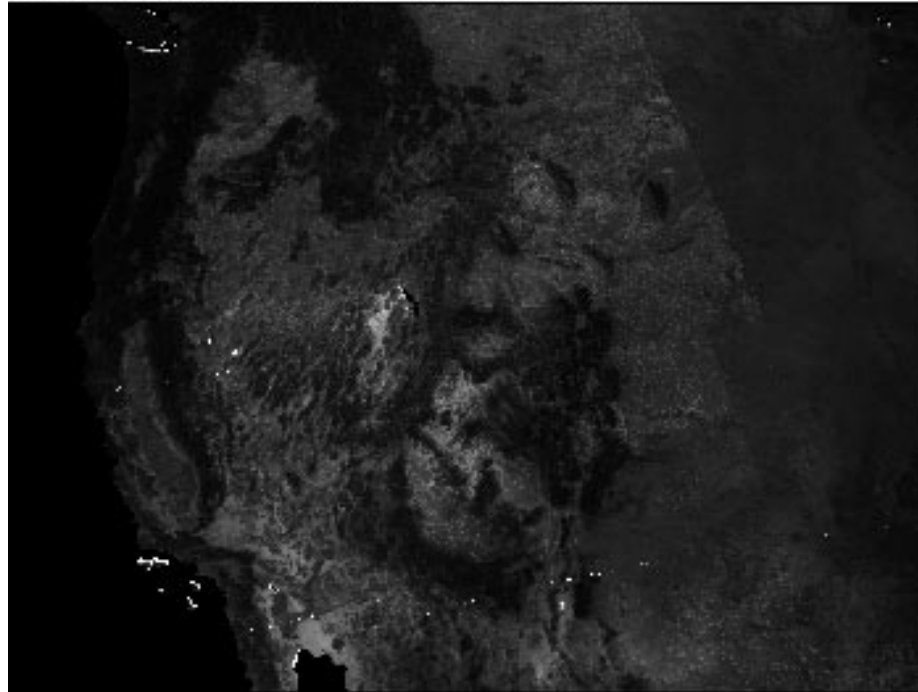
Visible Light (AVHRR Channel 1, .58–.68 μm)



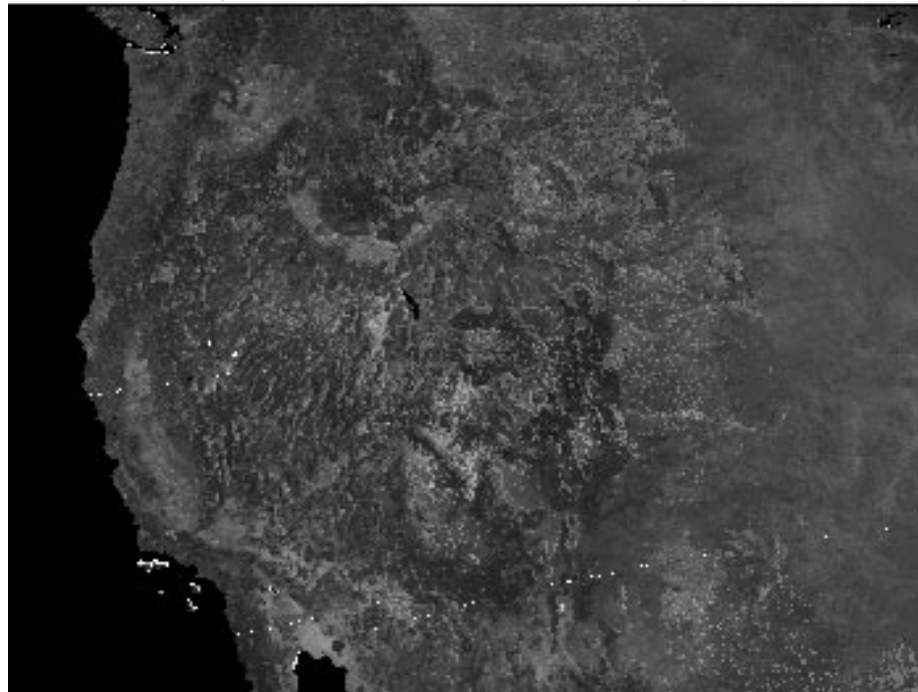
Near Infrared (AVHRR Channel 2, .725–1.1 μm)

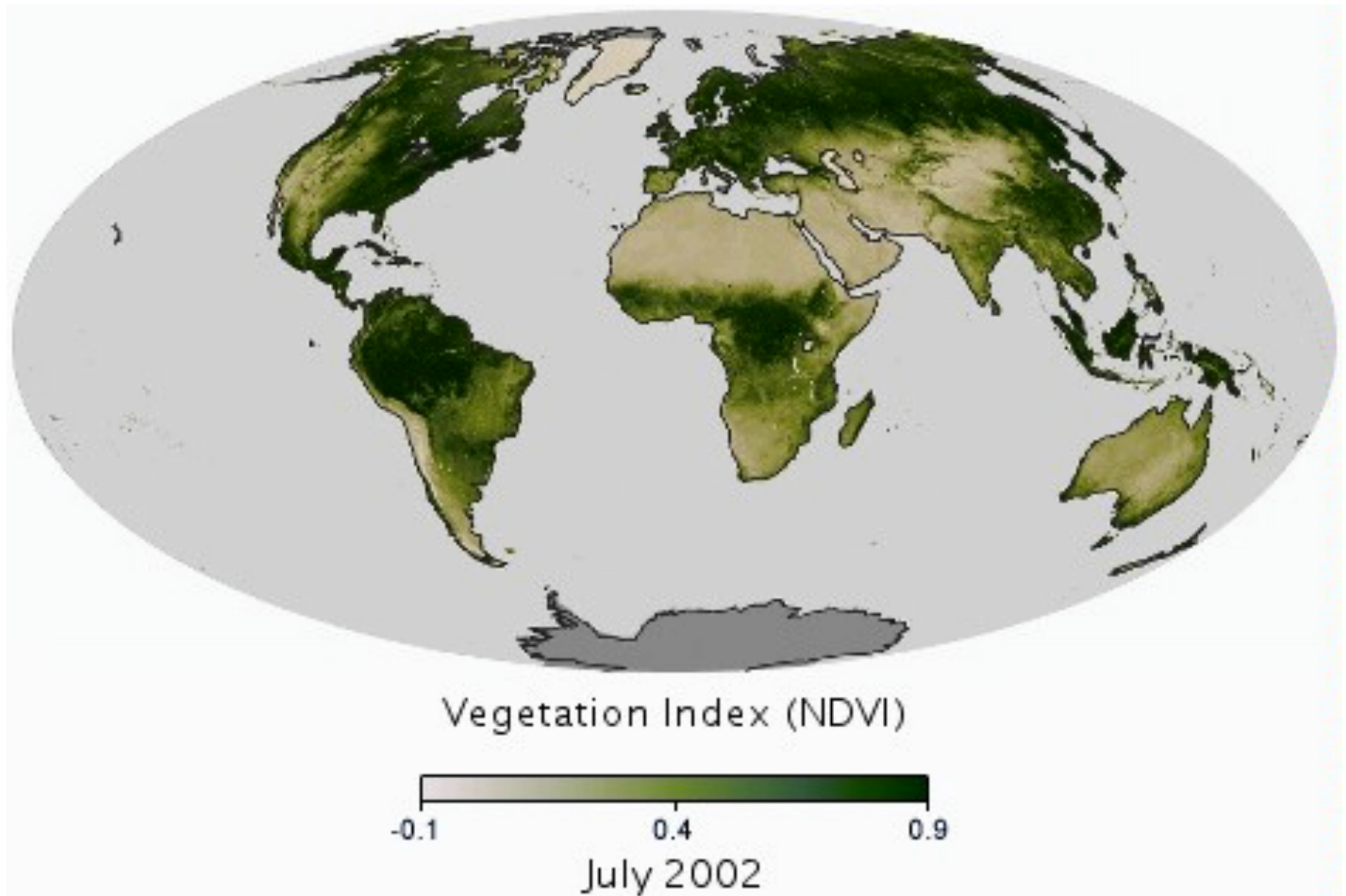


Visible Light (AVHRR Channel 1, .58-.68 μm)



Near Infrared (AVHRR Channel 2, .725-1.1 μm)





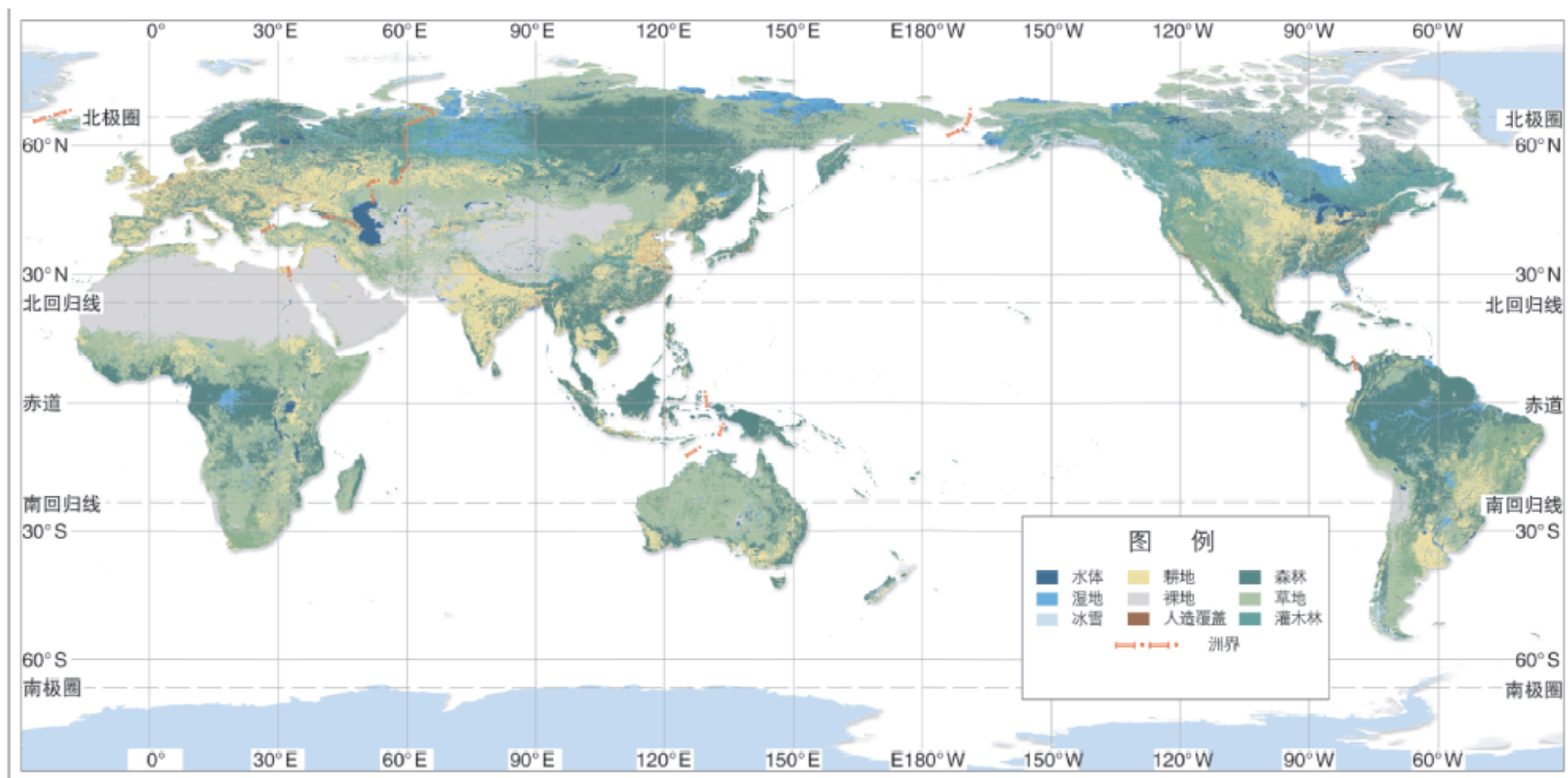


图 3 全球 30 m 地表覆盖分布总示意图

Fig.3 30 m global land cover map

引文格式: CHEN Jun, CHEN Jin, LIAO Anping, et al. Concepts and Key Techniques for 30 m Global Land Cover Mapping[J]. Acta Geodaetica et Cartographica Sinica, 2014, 43(6): 551-557. (陈军, 陈晋, 廖安平, 等. 全球 30 m 地表覆盖遥感制图的总体技术[J]. 测绘学报, 2014, 43(6): 551-557.) DOI: 10.13485/j.cnki.11-2089.2014.0089

全球 30 m 地表覆盖遥感制图的总体技术

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Concepts and Key Techniques for 30 m Global Land Cover Mapping

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HAN Gang¹, ZHANG Hongwei¹, HE Chaoying¹, WU Hao¹, LU Miao¹

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摘 要:针对全球 30 m 分辨率地表覆盖遥感制图这一世界性难题,提出了以多源影像最优化处理、参考资料服务化整合、覆盖类型精细化提取、产品质量多元化检核为主线的总体研究思路,研发了影像几何与辐射重建、异质异构服务化集成、对象化分层分类、知识化检核处理等主体技术方法;用于制定了相应数据产品规范、生产技术规范,研发了多项生产型软件,用于研制了 2000 和 2010 两个基准年的全球 30 m 地表覆盖数据产品,将空间分辨率提高了 1 个数量级。

关键词:全球地表覆盖;遥感制图;30 m 分辨率;对象化分层分类;服务化集成

中图分类号:P282

文献标识码:A

文章编号:1001-1595(2014)06-0551-07

基金项目:国家 863 计划重点项目“全球地表覆盖遥感制图与关键技术研究”(2009AA122001; 2009AA122003)

1 概 述

地表覆盖及其变化是环境变化研究、地理国情(世)监测、可持续发展规划等不可或缺的重要基础信息和关键参量^[1-5]。国内外主要是利用航

天、航空遥感影像中蕴含的丰富光谱和纹理及时相特征,结合各种参考资料和知识,采用数理统计、交互解译等方法,提取类型分布及变化信息,进行地表覆盖制图^[6-9]。20 世纪 90 年代以来,国际科学界一直高度关注全球地表覆盖遥感制图问题^[10-12]。

Example: Glaciers/Ice Sheets Studies

- Glaciers are directly affected by global warming
- Melting of glaciers contributes to global sea level rise



<http://www.glogster.com/coolsuperstar/how-glaciers-are-formed/g-6n993b2o5e8ba7ssmk6rma0>

Glaciers Studies

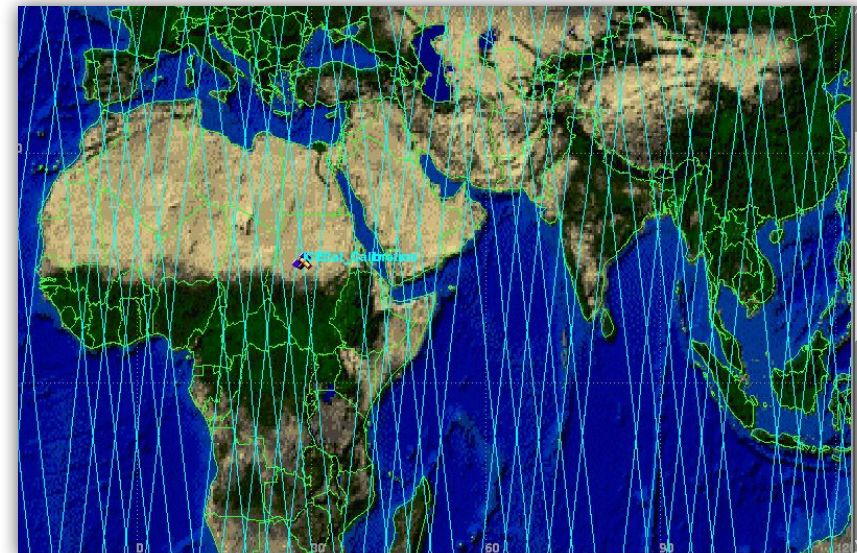
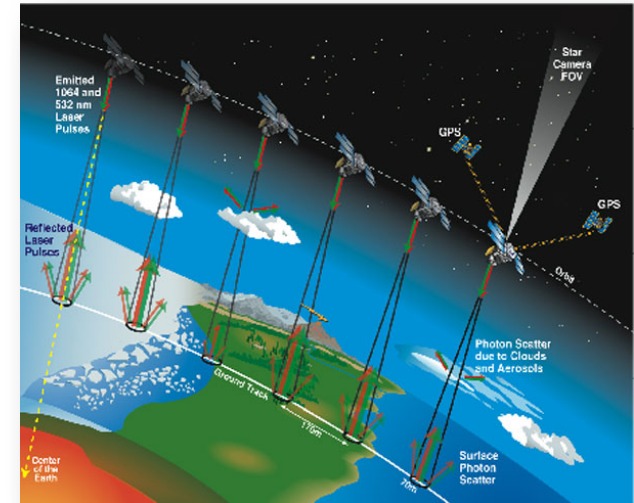
- Glaciers can be studied from different angles, e.g.,
 - Measurement of volume/mass/extent changes
 - Measurement of ice flow
 - Study of dynamics
- Sensors used
 - Optical
 - SAR
 - LiDAR
 - Altimeter
 - GPS
 - ...



<http://en.wikipedia.org/wiki/File:Glaciereaston.jpg>

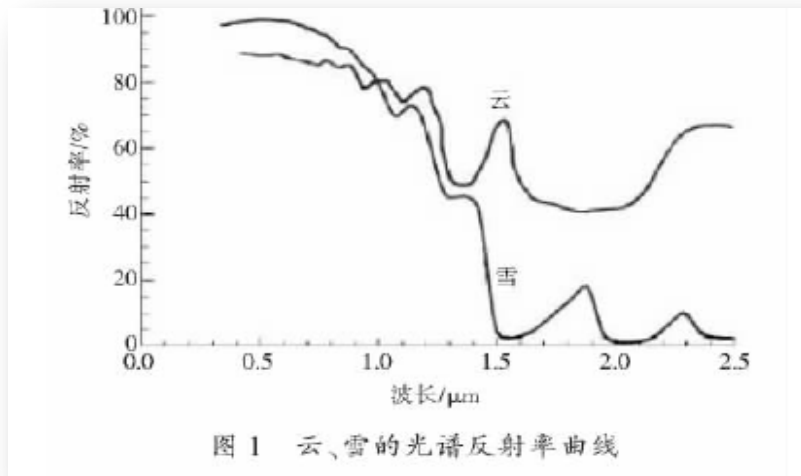
Laser Altimetry

- Laser altimeter- GLAS/ICESat:
 - Lunch time: January 2003
 - Decommissioned: 14 Aug 2010
 - Orbital altitude: 600 km
 - Orbital inclination: 94 degrees
 - Laser footprint size: 70 m in diameter
 - Distance between footprints along track: 170m
 - Distance between adjacent tracks :
 - along Equator: 15 km
 - at 80 degree: 2.5 km
 - Repeat cycle:
 - Calibration Orbit : 8 days
 - Mission Orbit: 91 days



Tracks of ICESat

Methods for Retrieving Glaciers



Characteristics of spectral reflectance of snow:

visible spectrum (0.4-0.7 μm) : high reflectivity

Near-infrared (0.8-2.5 μm): medium reflectivity

Thermal-infrared (2.5-14μm): low reflectivity and high emissivity

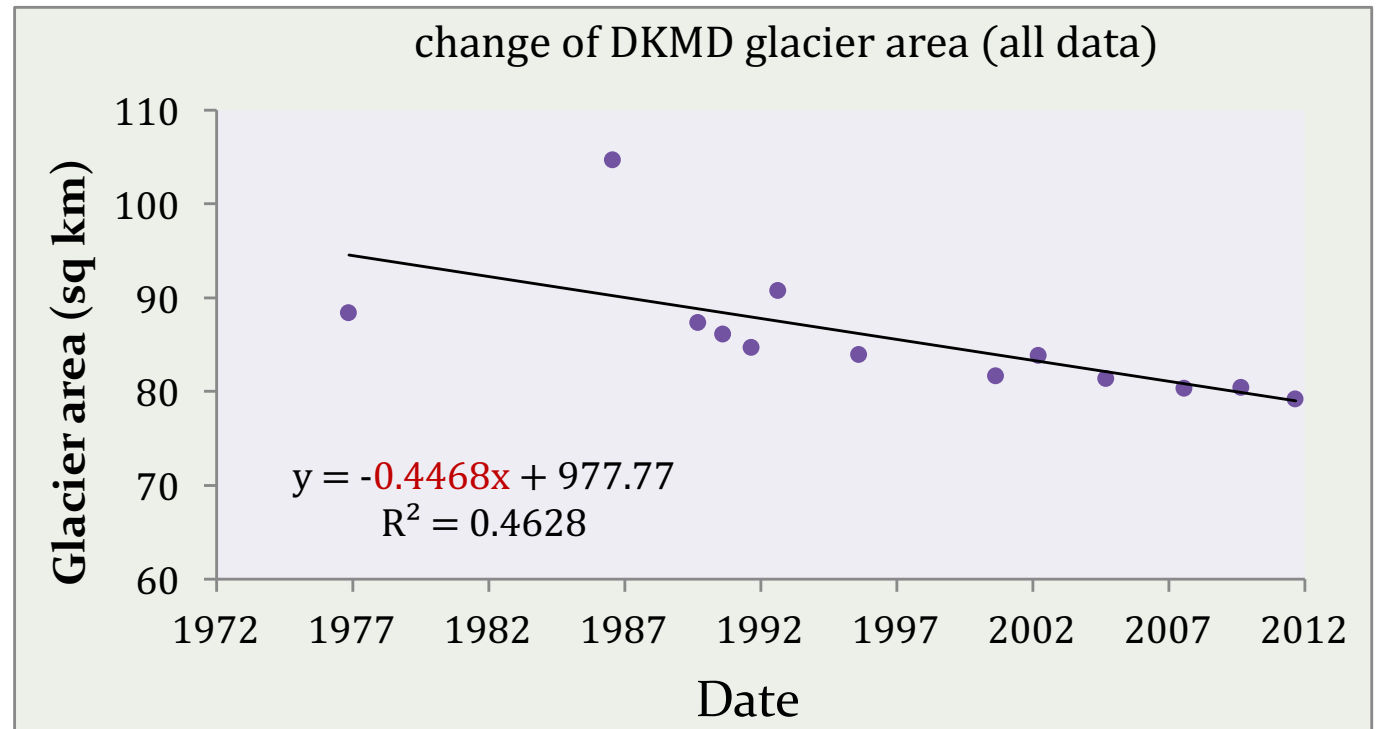
Absorption increase with wavelength greater than 2.5μm

Decision rule:	$NDSI = (\rho_{TM2} - \rho_{TM5}) / (\rho_{TM2} + \rho_{TM5})$
	ρ_{TM2} : surface reflectance at band 2
$NDSI \geq 0.4$ (a)	(a) Can discriminate snow from surrounding surface
$\rho_{TM2} > 0.10$ (b)	(b) distinguish snow&Ice from certain vegetation (Spruce)
$\rho_{TM4} > 0.15$ (c)	(c) Distinguish snow&Ice from water surface

Traits of this method: highly automated; consistent over a series of images; flexible threshold to tackle with different area ; Topographic effect (shade) and atmospheric effect can be mitigated to a very low level.

Results: Glacier Area Change

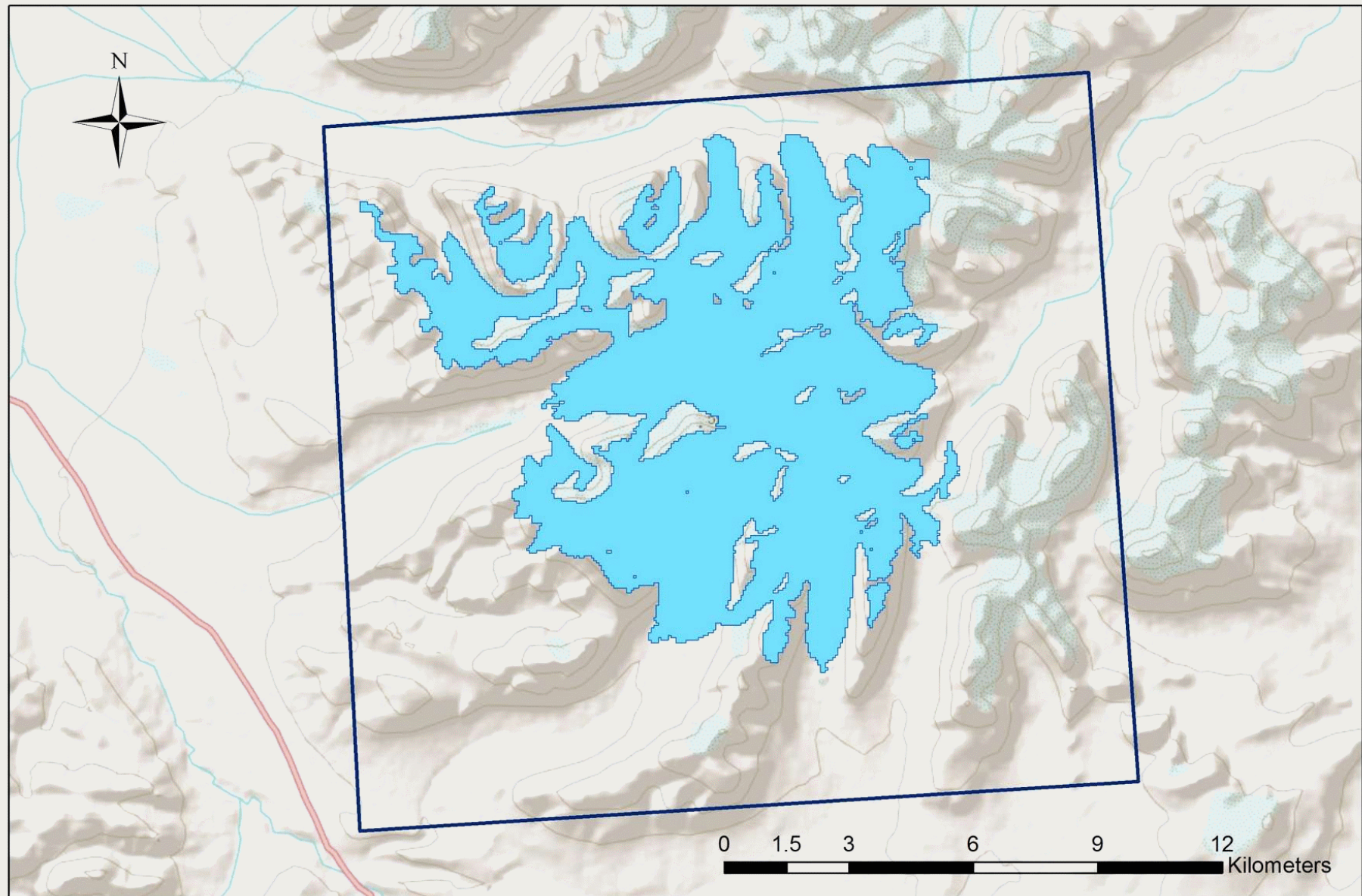
Date	Area (km ²)	Area change ratio/ 100%
1976_11_11	88.3476	0
1986_7_30	104.67	18.4752
1989_9_17	87.3531	-1.12567
1990_8_19	86.1165	-2.52537
1991_8_29	84.6369	-4.20011
1992_8_31	90.7497	2.718919
1995_8_17	83.8764	-5.06092
2000_8_30	81.675	-7.55267
2002_3_21	83.84996	-5.09085
2004_9_10	81.3789	-7.88782
2007_8_2	80.3232	-9.08276
2009_8_30	80.4483	-8.94116
2011_8_29	79.2162	-10.3358



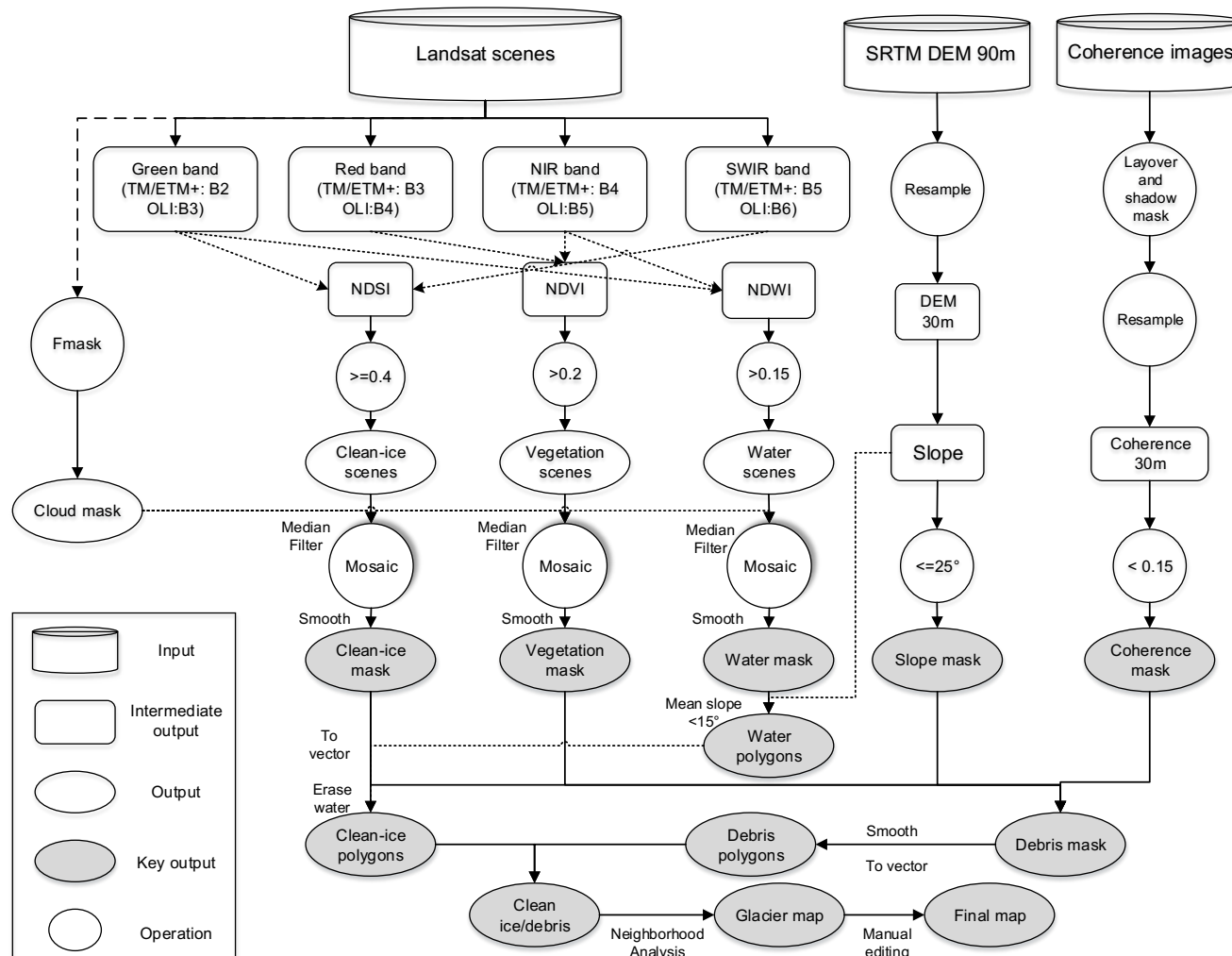
The area of DKMD glacier has decreased by **10.3%** from 1976 to 2011.

During the 35 years, about 9.13 km² glacier area has been lost. That equals to an average shrinkage rate of **0.26 km²/a.**

1976-11-11



Combining Landsat, SAR and SRTM DEM for Mapping Glaciers



A mapping clean-ice :

- 1) generation of clean-ice masks;
- 2) Cloud masking ;
- 3) Overlay of multi-temperate scenes;
- 4) Water masking ;
- 5) spatial filtering

B mapping debris-covered glacier tongues

- 1) Segmenting coherence maps ;
- 2) vegetation mask;
- 3) Slope mask ;
- 4) overlay of all masks ;
- 5) neighborhood analysis

C post process: manual check and editing

September/March (minimum/maximum)	September Average Extent (millions of square kilometers)	March Average Extent (millions of square kilometers)
1979–2000 mean	7.0	15.7
1999/2000	6.2	15.3
2000/2001	6.3	15.6
2001/2002	6.8	15.4
2002/2003	6.0	15.5
2003/2004	6.2	15.1
2004/2005	6.1	14.7
2005/2006	5.6	14.4
2006/2007	5.9	14.7
2007/2008	4.3	15.2
2008/2009	4.7	15.2
2009/2010	5.4	15.1
2010/2011	4.9	14.6
2011/2012	4.6	15.2

A solid orange rectangular box with a slight gradient and a thin black border, centered on the page.

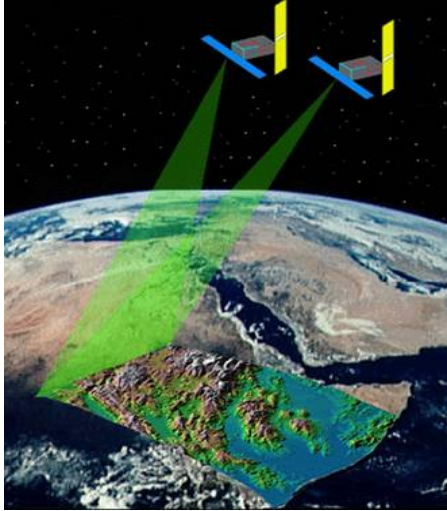
InSAR

InSAR

Interferometric Synthetic Aerture Radar
(=IfSAR)

**A radar remote sensing technology,
capable of measuring large-area
deformations with high resolution
and accuracy**

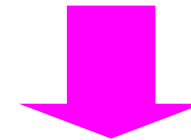
Working Process of InSAR



SAR images



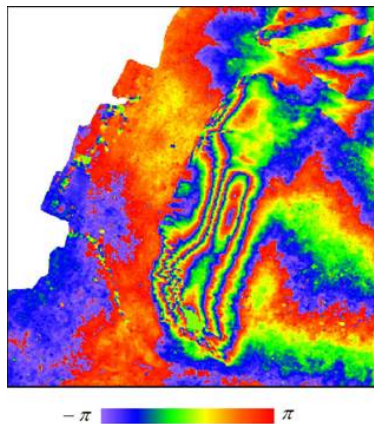
Ground station



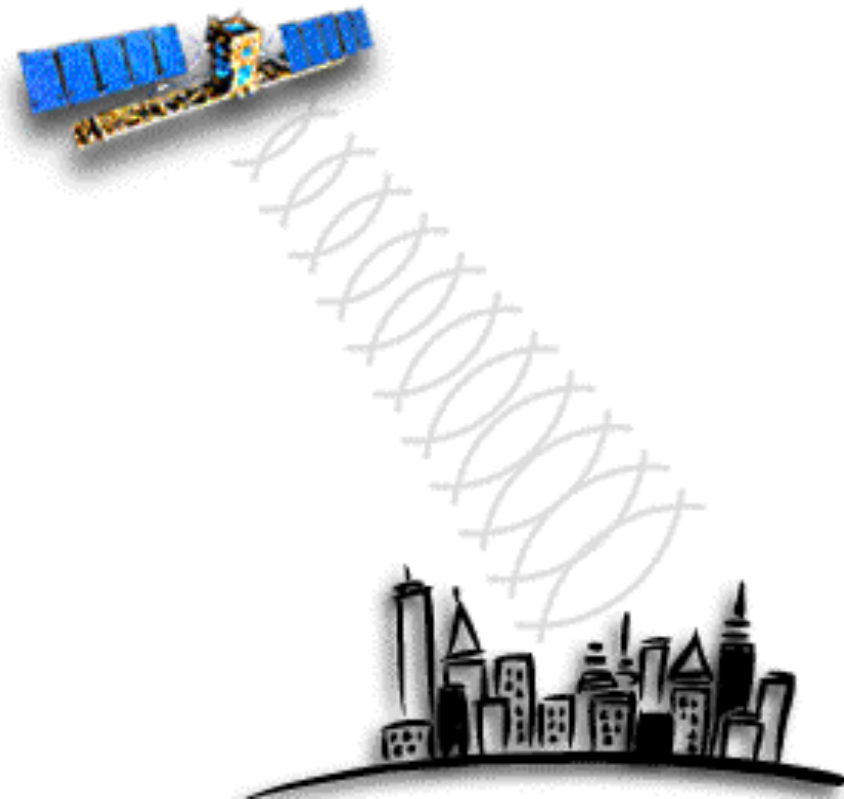
Users



Deformation measurements



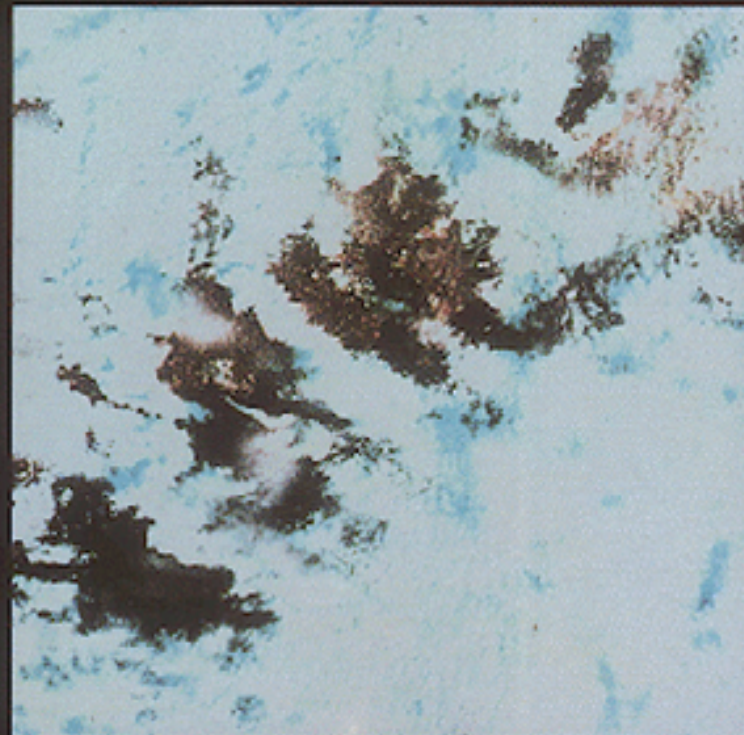
SAR Imaging



- Active remote sensing
- Some ability of penetration
- Two components of results: amplitude and phase

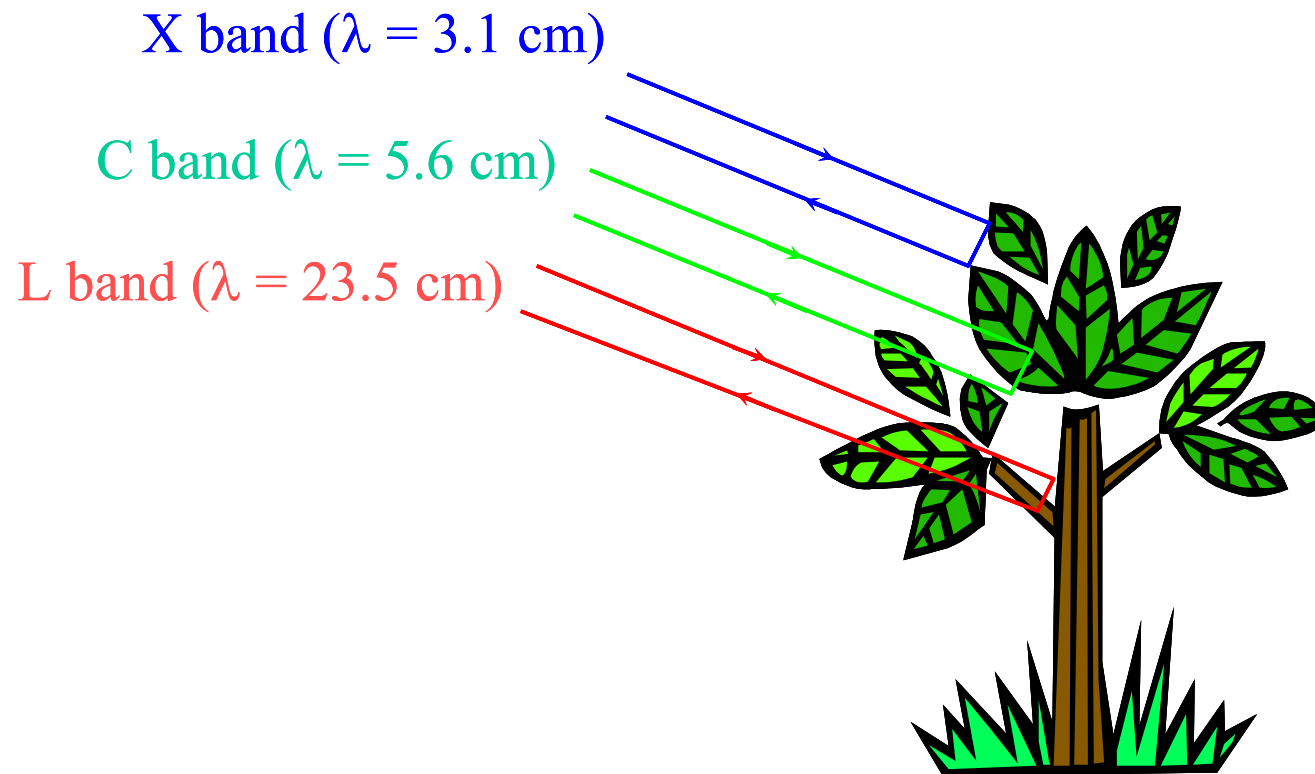


ERS-1



LANDSAT

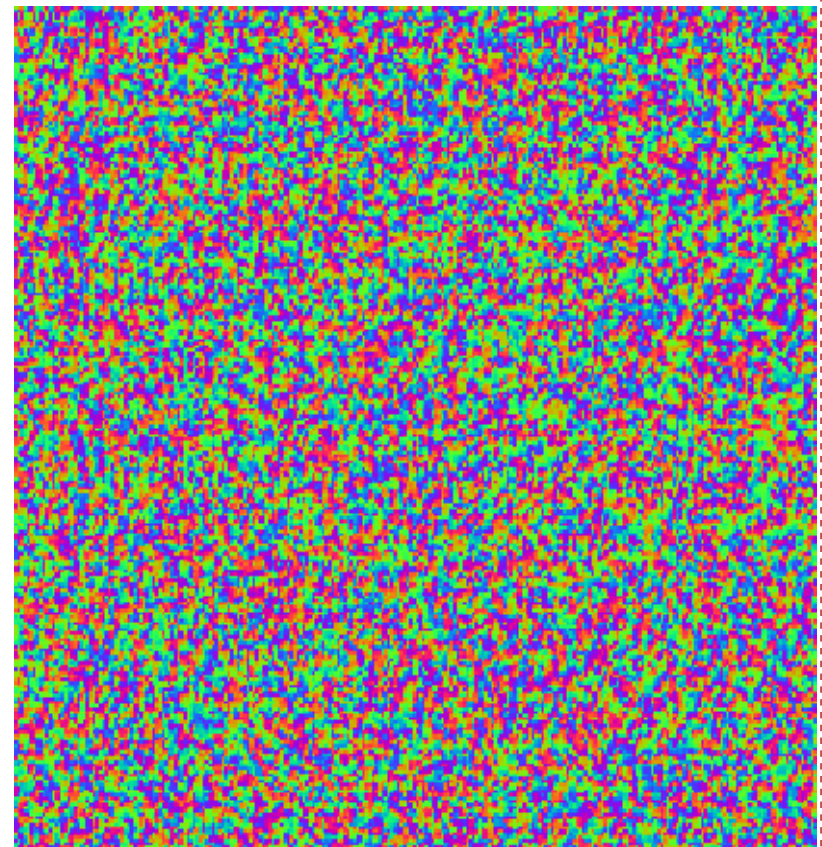
9/8/91 ERS-1 (11.25 am), Landsat (10.43 am)



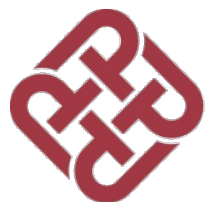
Ability of penetration of radar signals depends on the wavelength of the signals

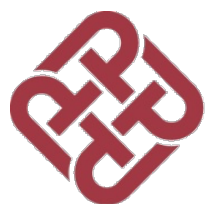
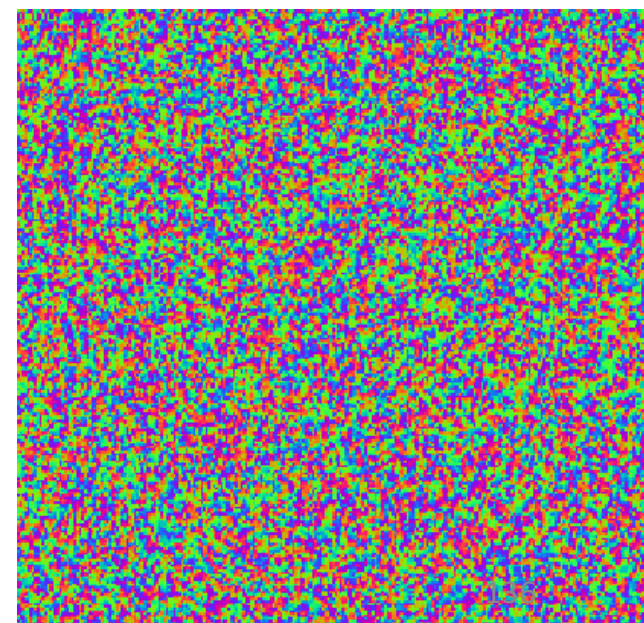
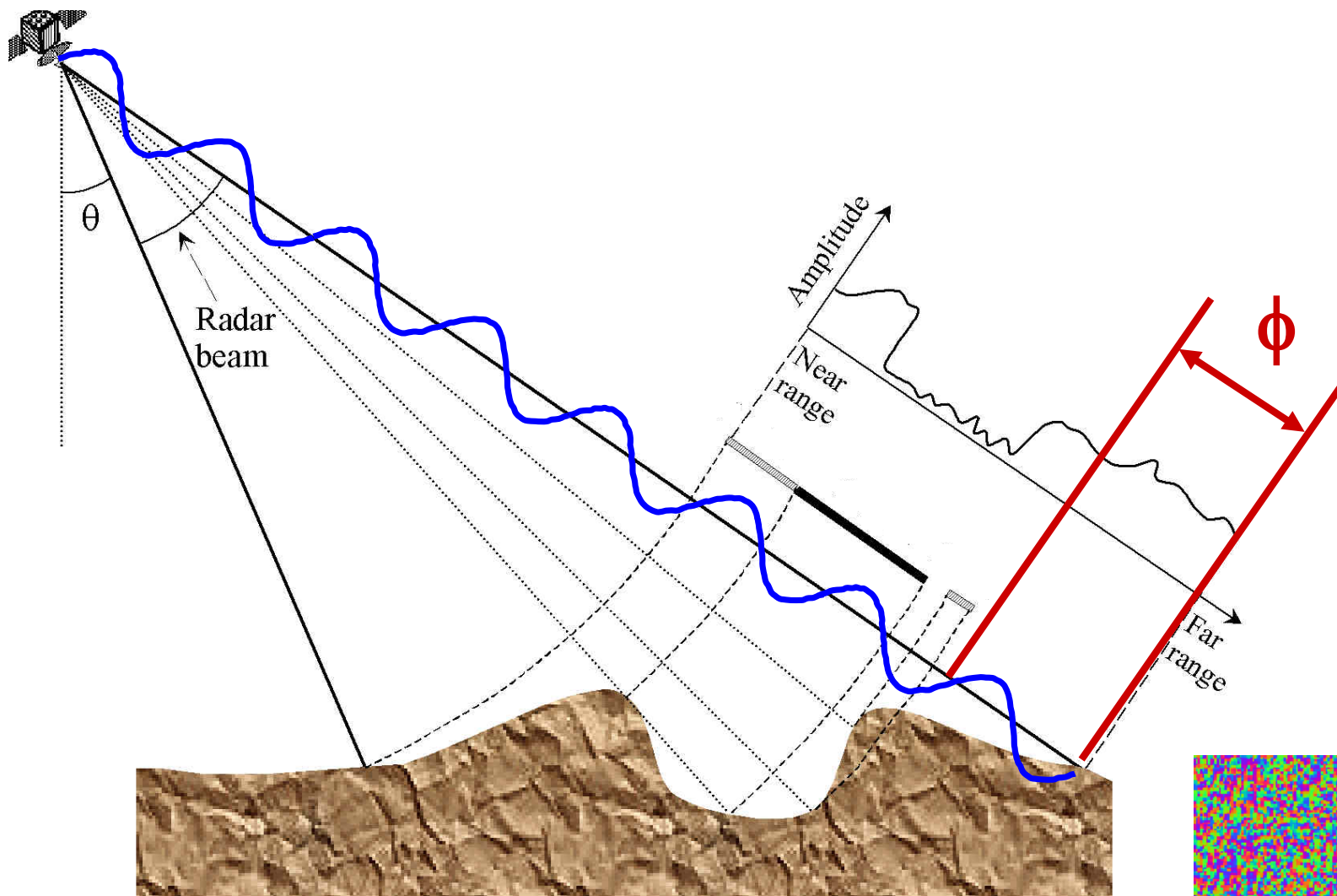


Amplitude component



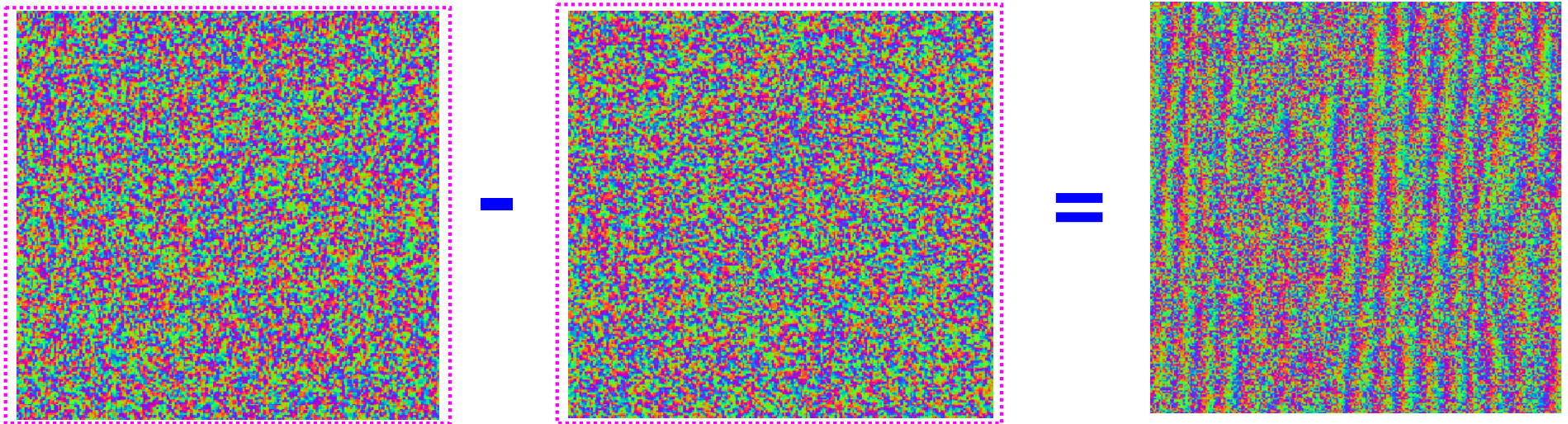
Phase component



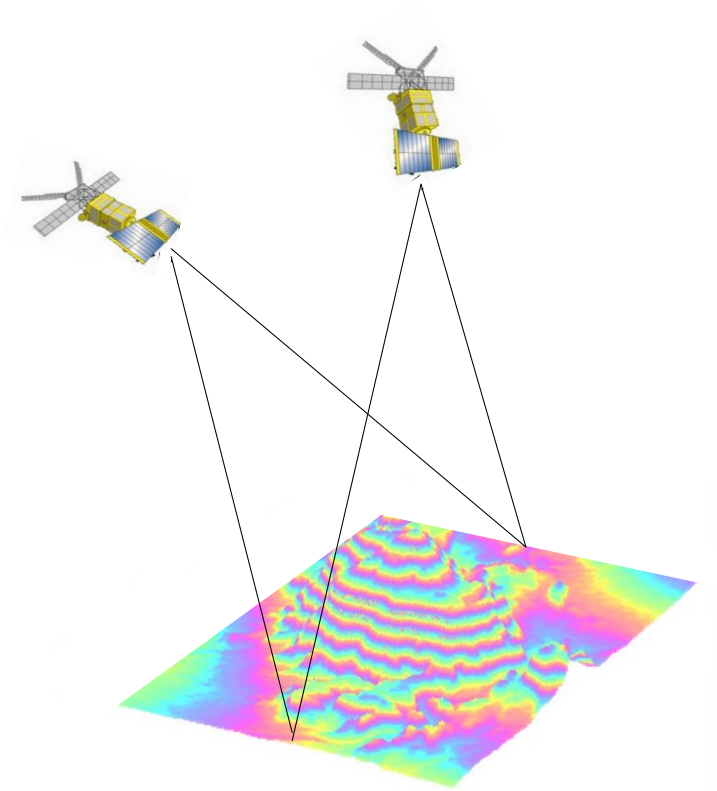
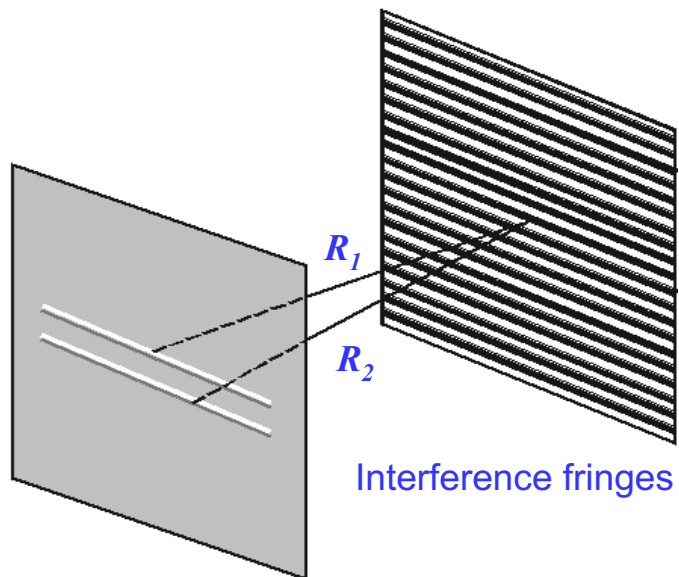


SAR Interferometry

Interferogram



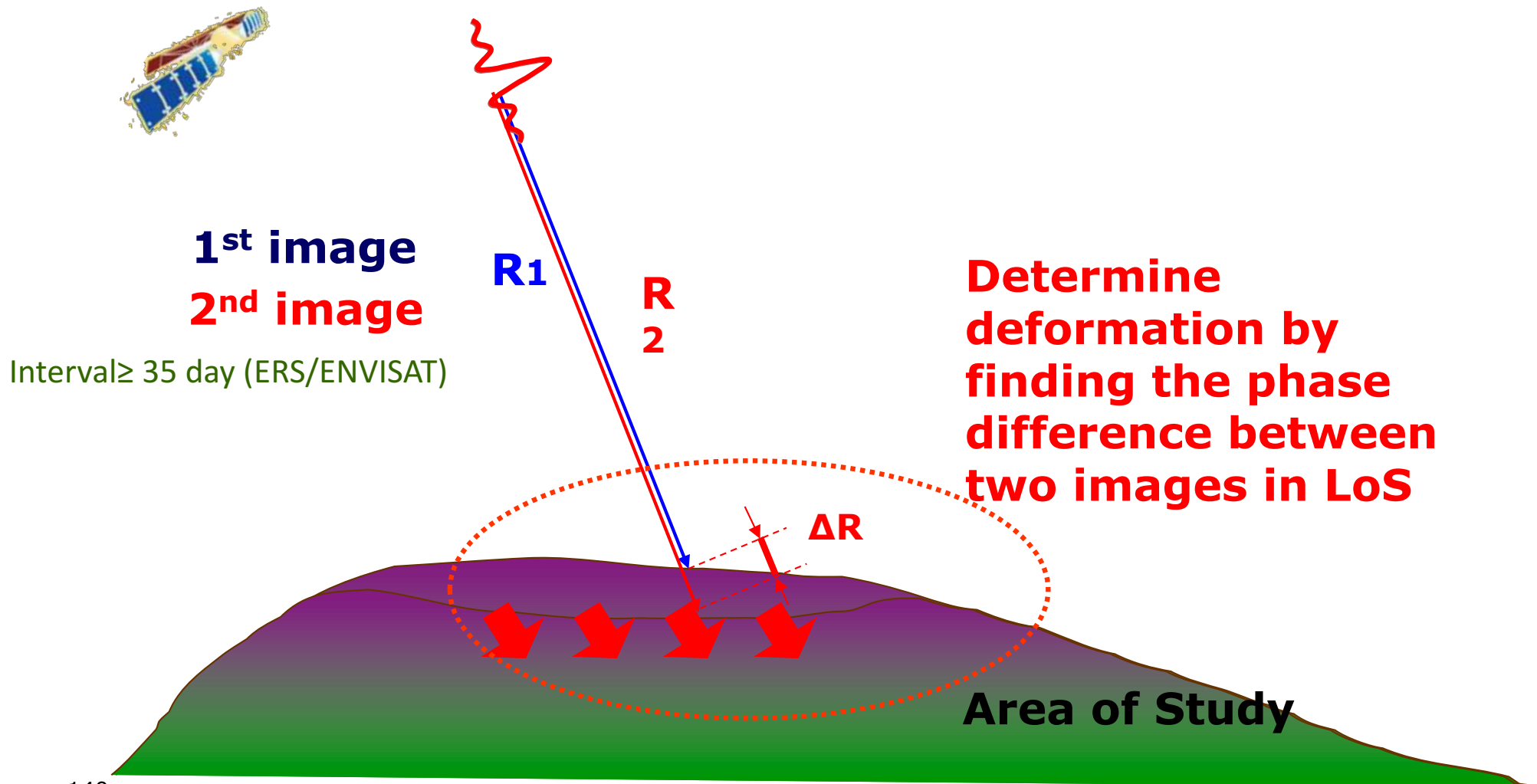
Concept of InSAR



SAR Interferogram

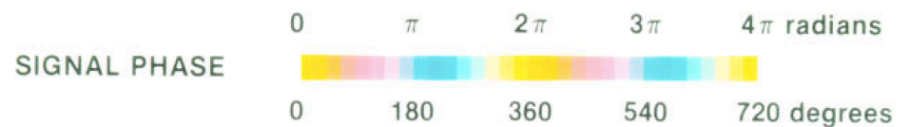
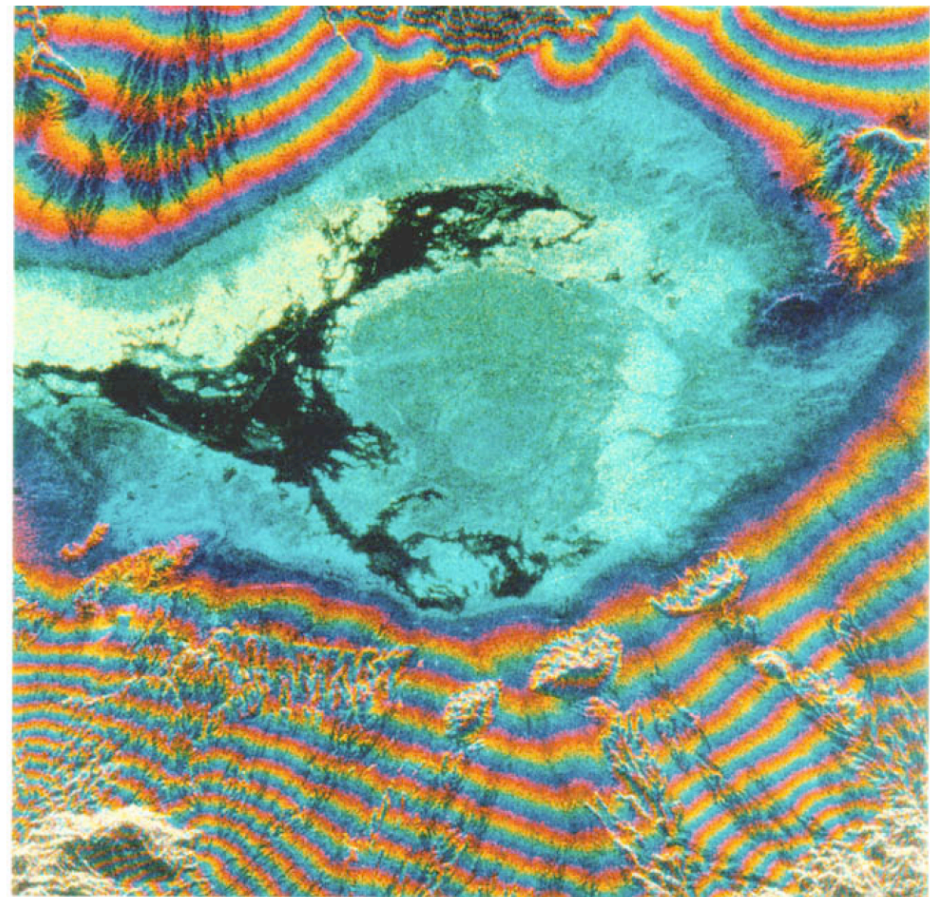
- Contains information on
 - Topography
 - Surface deformation
 - Systematic errors
 - Noises
- Traditional InSAR method has been explored for many applications since about 30 years ago

InSAR Deformation Measurement



1st Spaceborne InSAR DEM Result

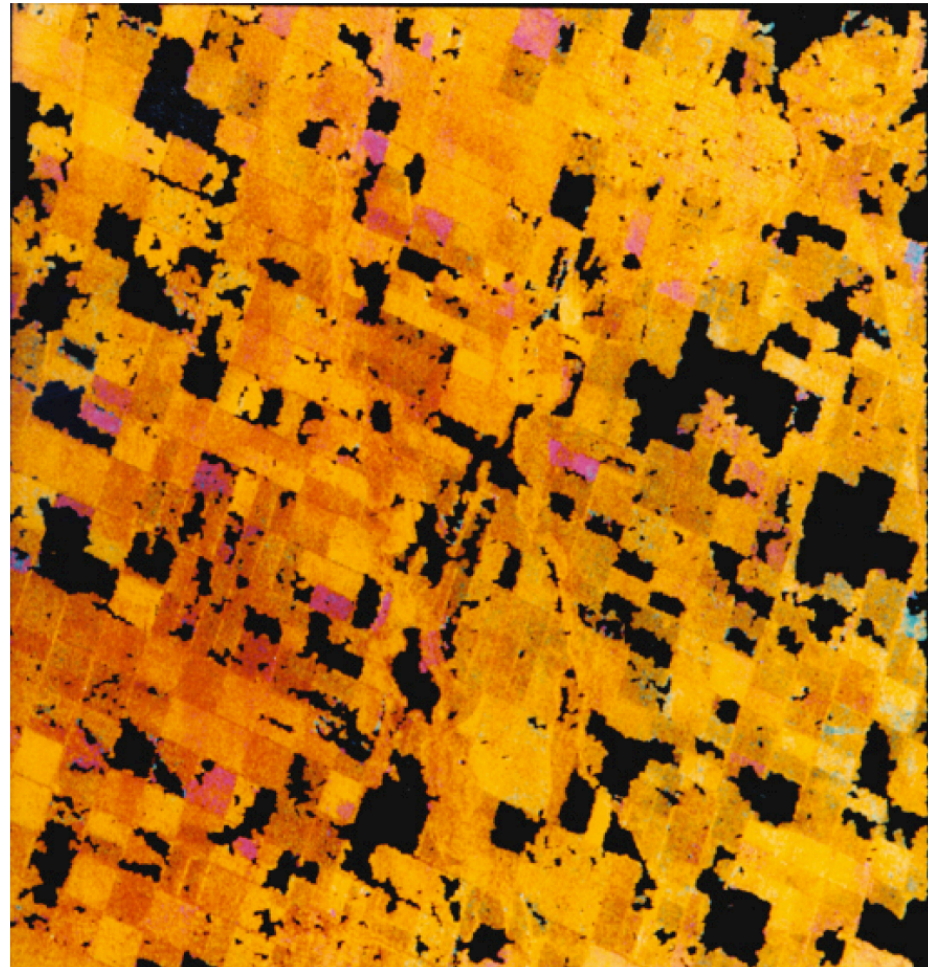
Topographic map
of Cottonball Basin
in Death Valley
(Zebker et al., 1988)



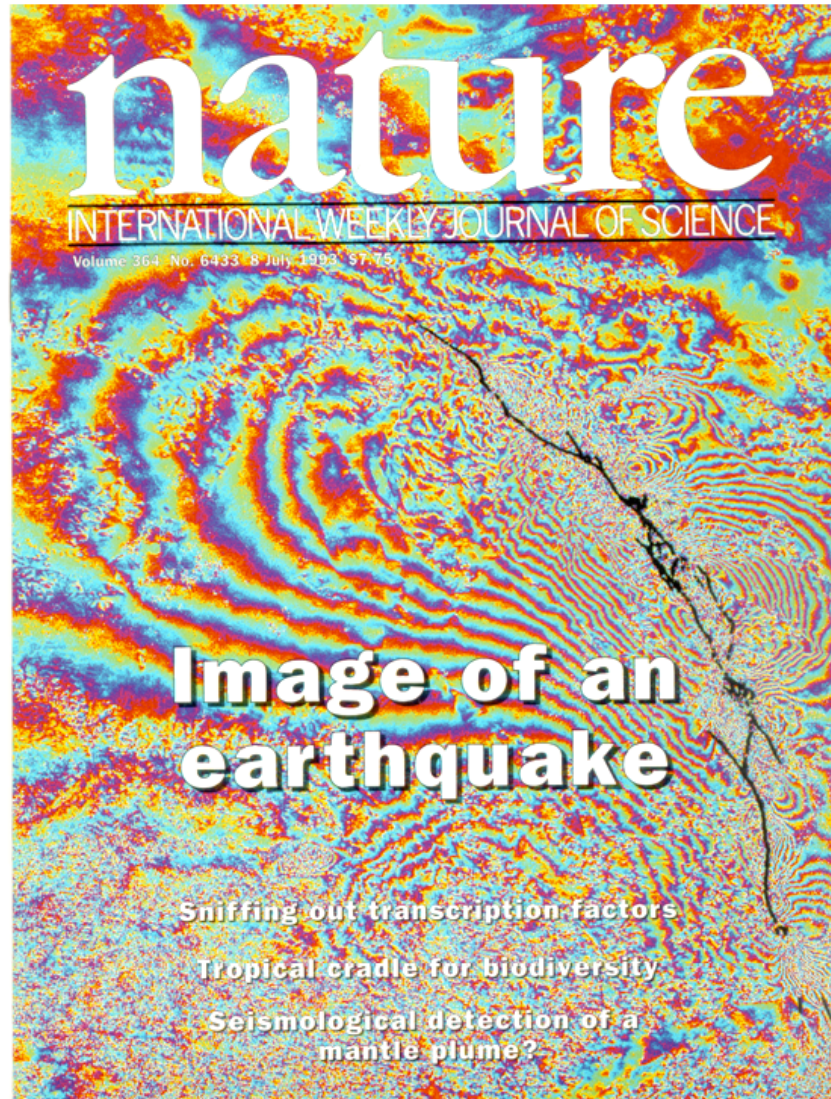
1st InSAR Deformation Measurement

Salton Sea area, south
California

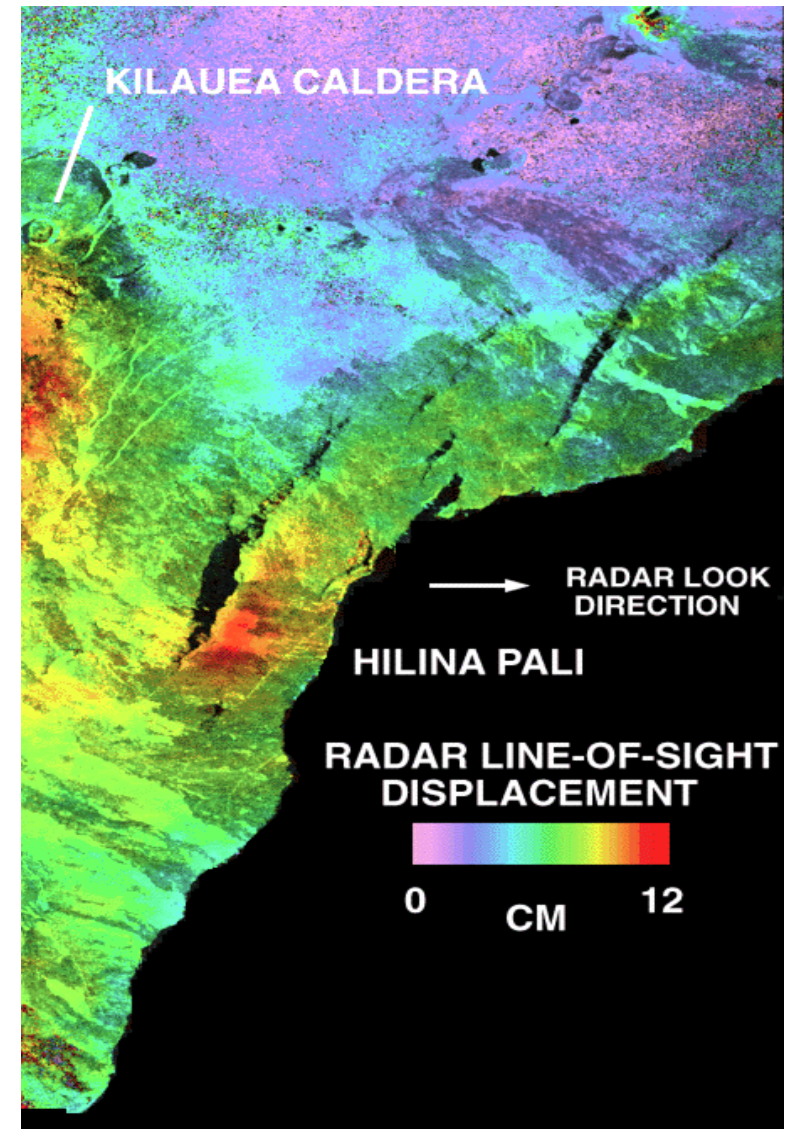
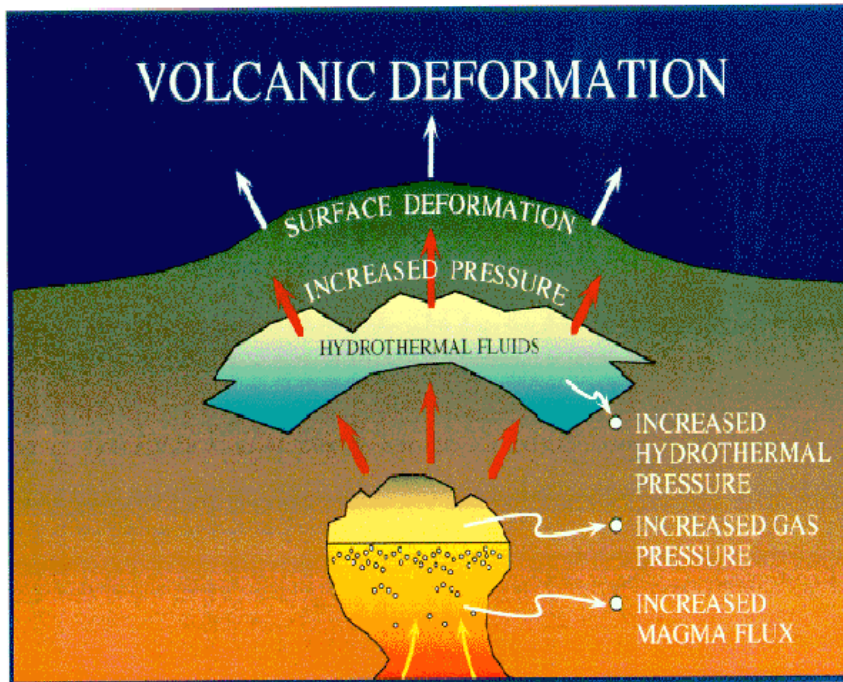
(Zebker et al, 1989)



1st InSAR Earthquake Study

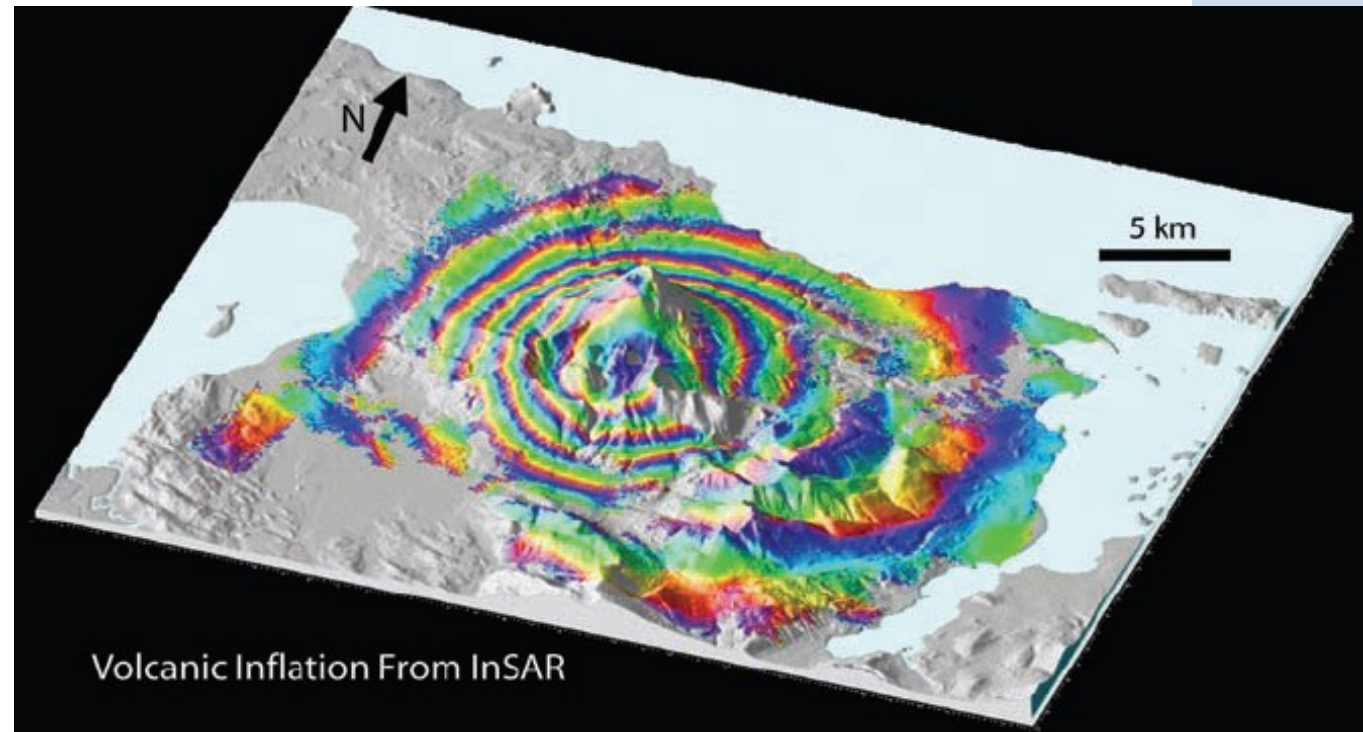


The displacement field of
Landers earthquake
(Massonnet et al., 1993)



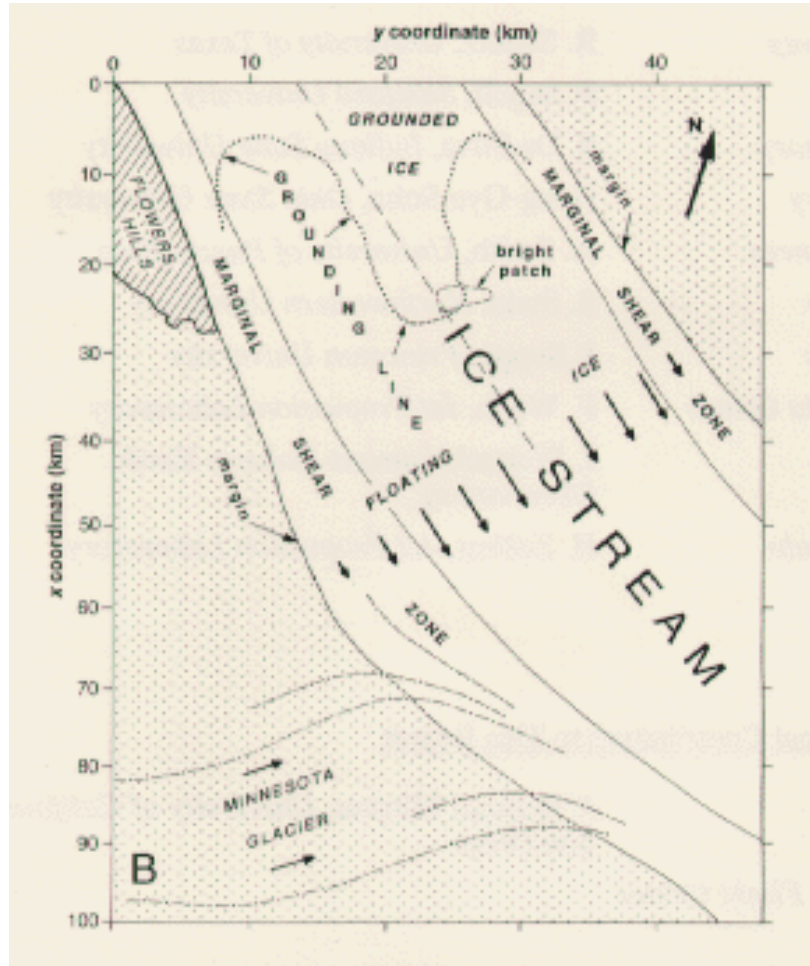
(Courtesy NASA/JPL)

In the late 1990s, InSAR was used to map the deformation of volcanoes during quiescent periods. InSAR-derived surface deformation patterns shed important insights into the structure, plumbing, and state of restless volcanoes

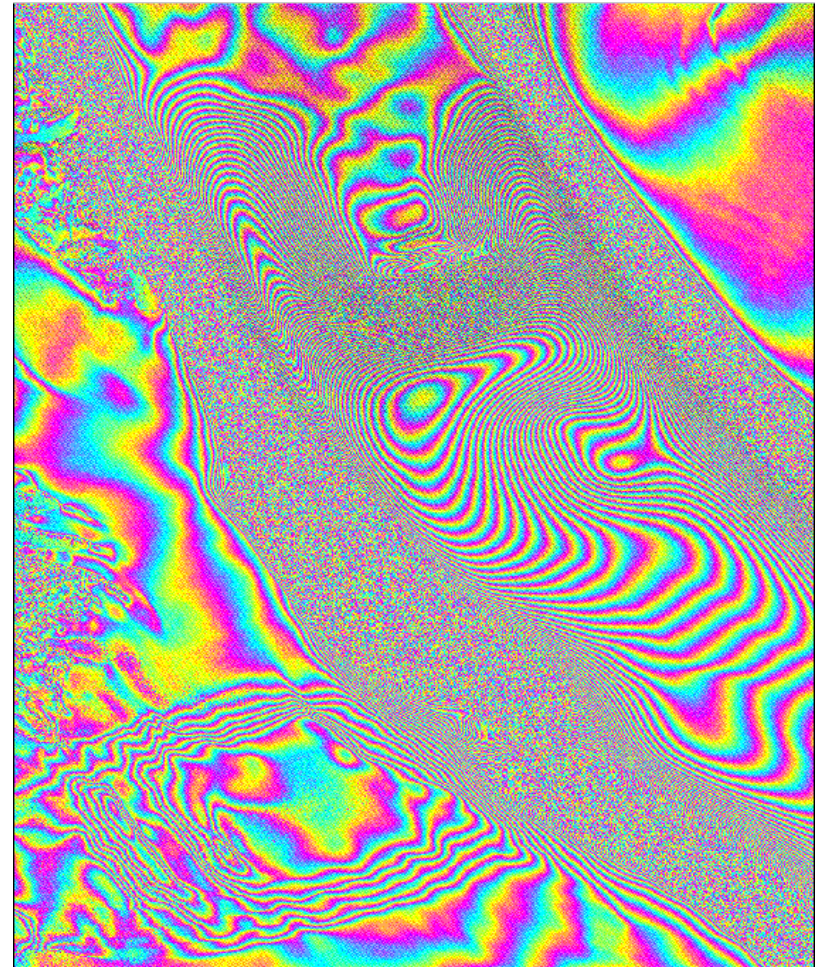


(Lu, 2007)

Ice-Sheet Motion

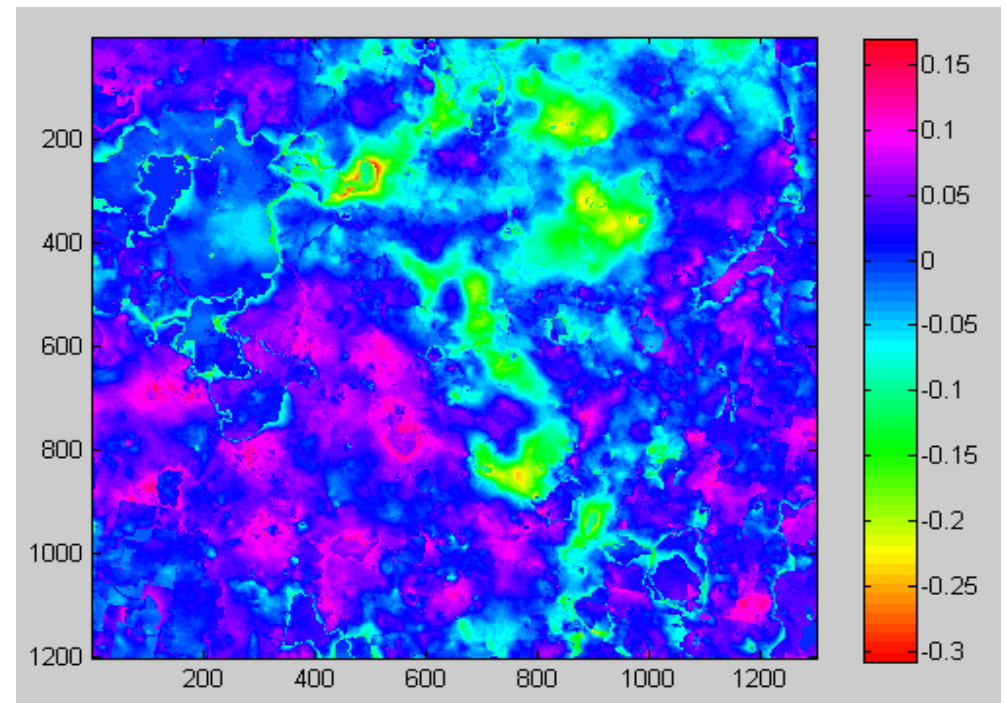


Goldstein *et al.*, 1993, JPL

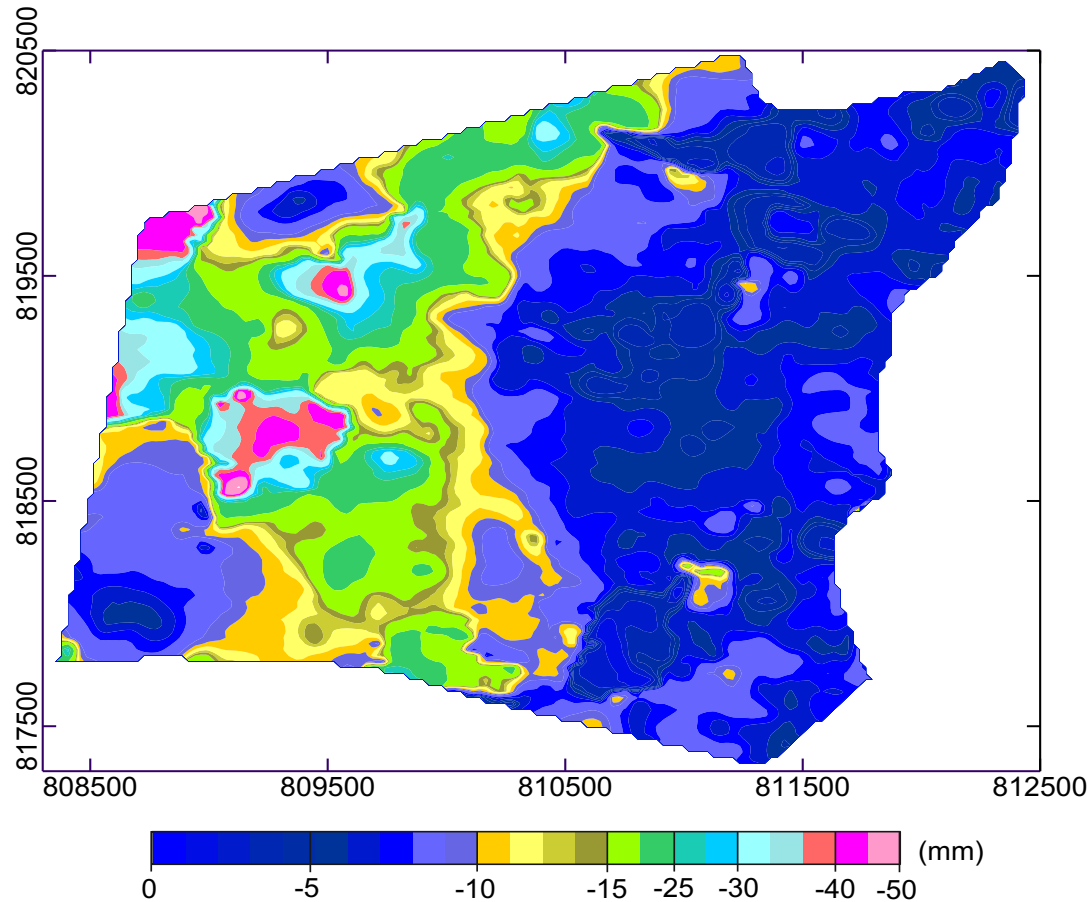


Rutford, Antarctic

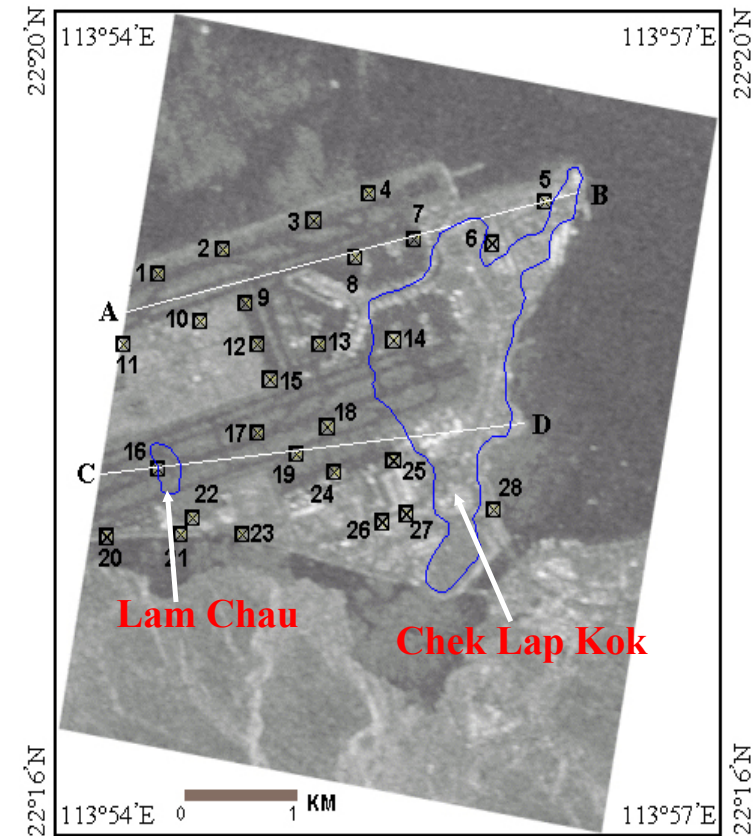
Accumulative Subsidence in Shanghai 1992.10-1998.01



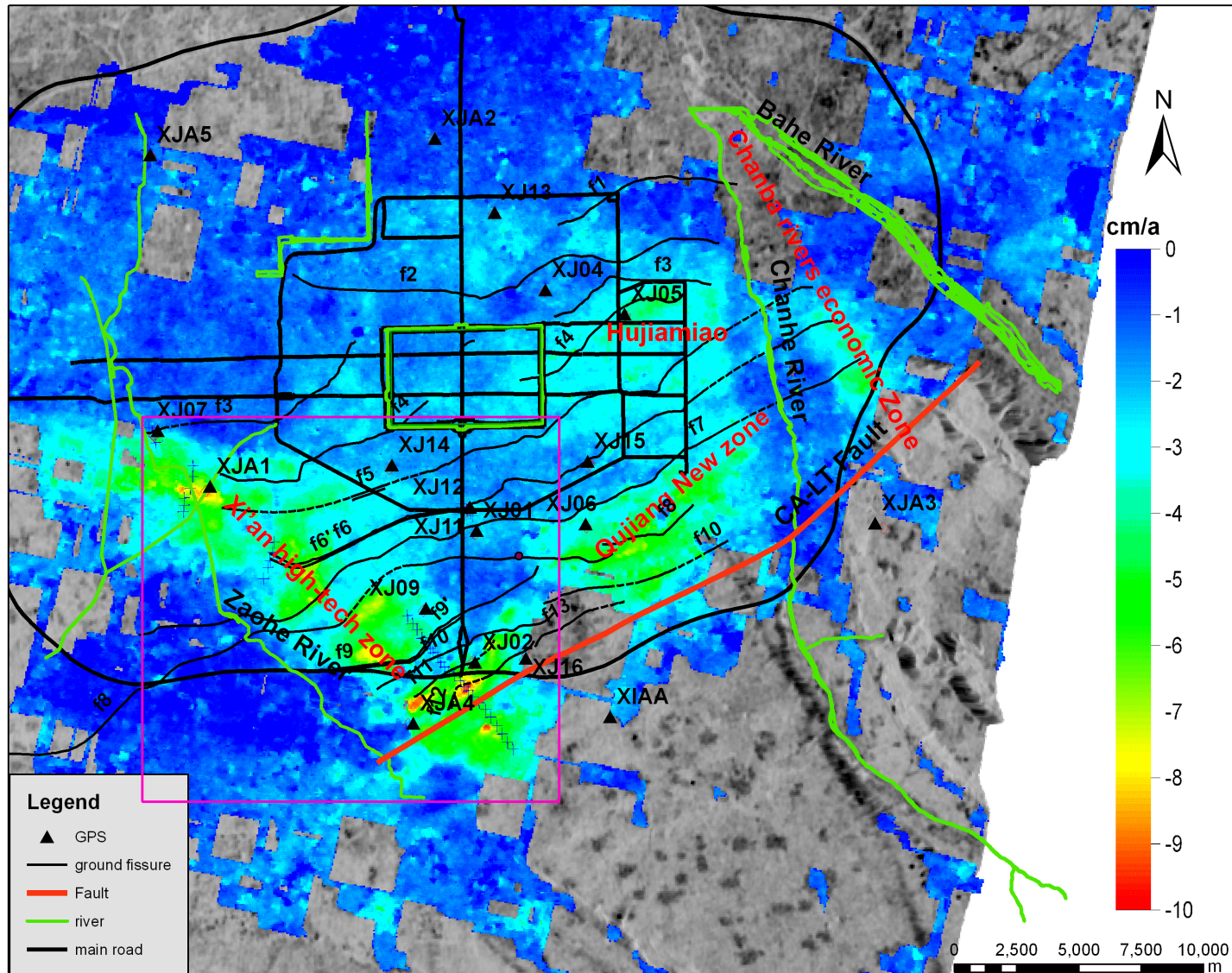
Settlement of HK Airport



Settlement map near 1 year (1999)



Ground Subsidence in Xi'an in 05-06



Current Remote Sensing Research

- Further developing techniques, e.g., to better interpret data
- Develop new platforms and sensors
- New science and results based on remote sensing studies

THANK YOU

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