“If you can’t measure it,
you can’t manage it”

How Satellite Data Helps Us Understand Climate Change

- **INTRODUCTION**
- **Remote sensing** is the science and art of acquiring information about an object, area or phenomena without actually being in contact with it.
- **The sensor** is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure or any number of other environmental phenomenais, usually mounted on moving platforms such as balloons, aircraft and satellites
- **Platforms of remote sensing are:**
  - Land based (surface or ground observation)
  - Airborne based (from 100 m to 40 km)
  - Space based (from 150 km to 36000 km)

What are Satellites?

- **A satellite is an object (moon) that orbits another large object like planet.**
- **A satellite is a station in space that is used for**
- ❑ **telecommunication,**
- ❑ **radio and television signals .**
- Sputnik 1 was the first satellite in space. The Soviet Union launched it in 1957.
- Satellites come in many shapes and sizes.
- But most have at least two parts in common - an antenna and a power source. The antenna sends and receives information, often to and from Earth. The power source can be a solar panel or battery. Solar panels make power by turning sunlight into electricity.
- **Satellite subsystems attend many tasks such as thermal control, telemetry, attitude control and orbit control.**

Many types of satellites have been launched for various purposes.

Traditionally

- **Radio and TV broadcast satellites**
- **Military satellites**
- **Satellites for navigation and localization (e.g GPS)**

Telecommunications

- **Global telephone connections**
- **Backbone for global networks**
- **Connections for communication in remote places**
- **Global mobile communication**

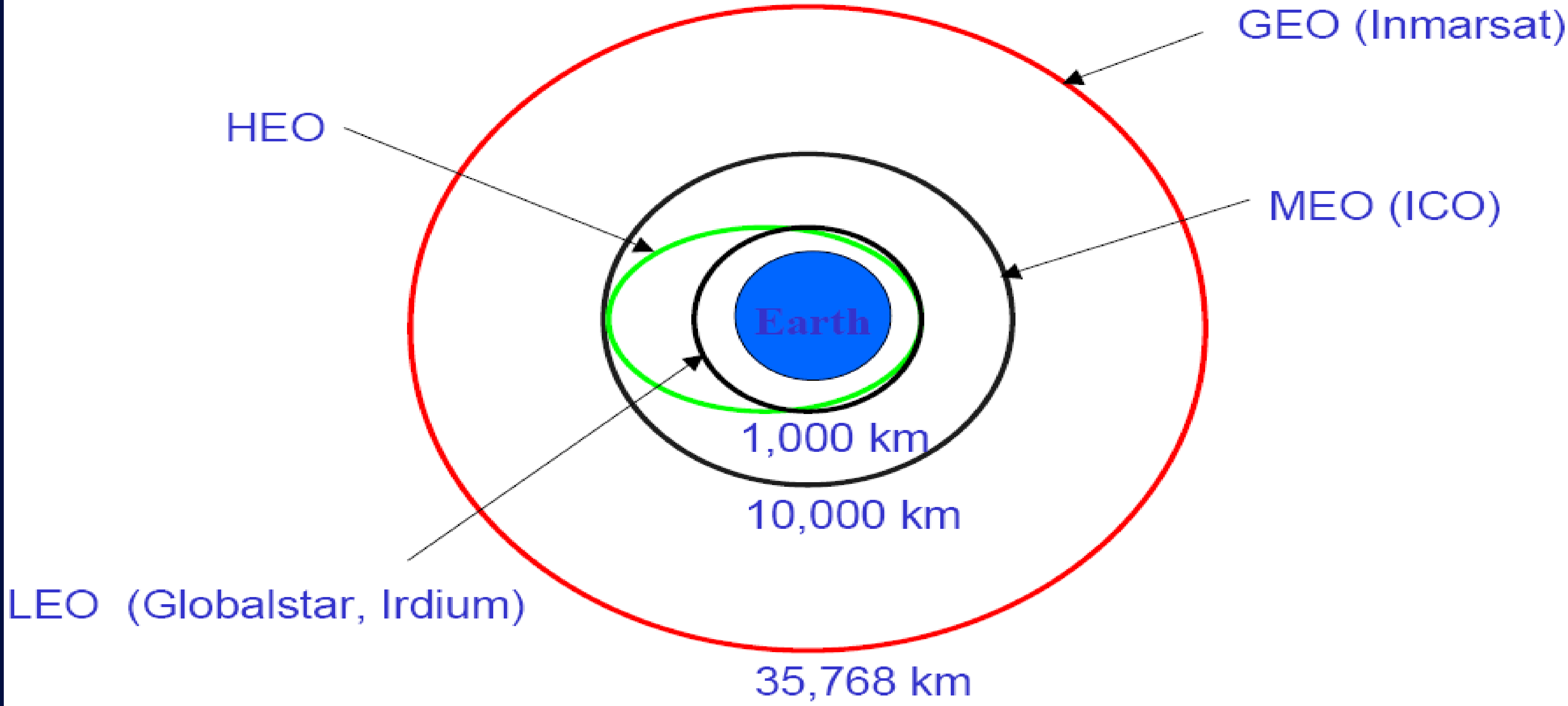
For monitoring the environment

- – **Meteorological (weather) satellites**
- – **Earth Resource satellites (ERS)**
- – **Research and Development satellites (R&D).**

- **Types of Satellite Systems**

Four different types of satellite orbits have been identified depending on the shape and diameter of each orbit:

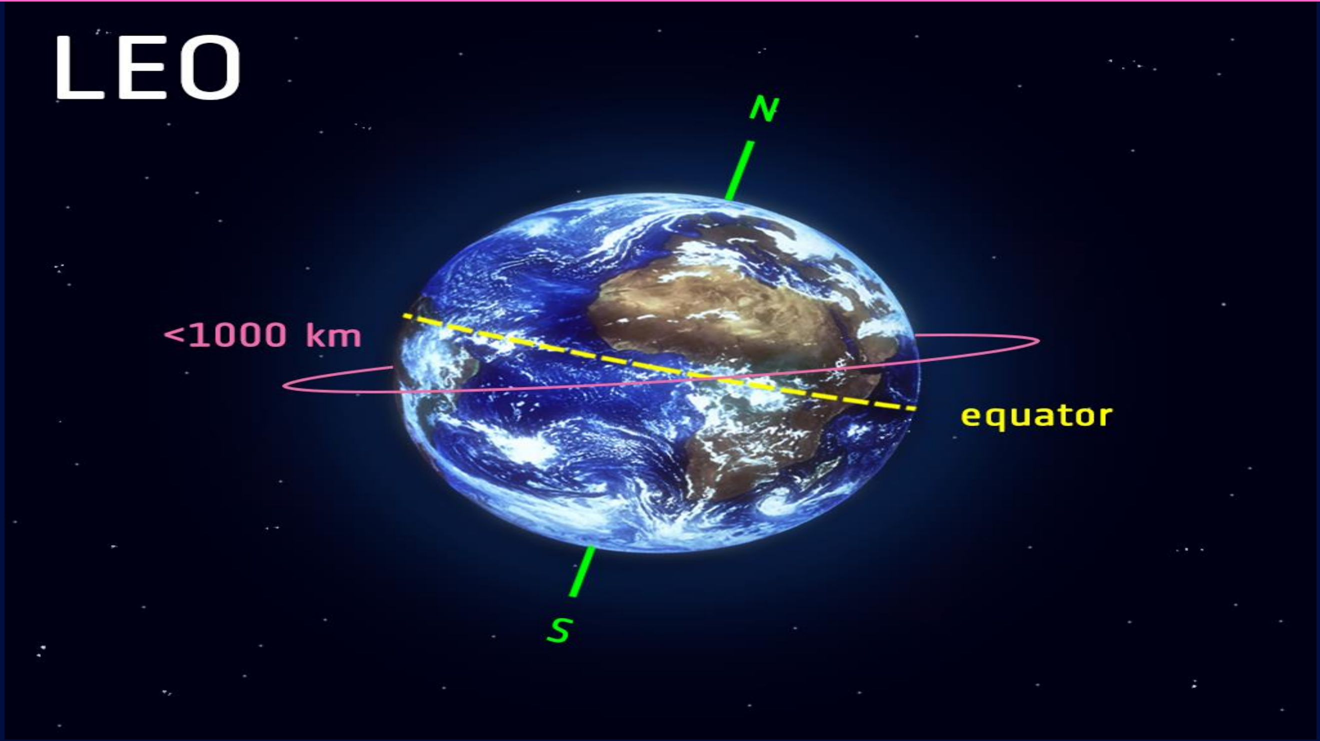
- **GEO (Geostationary Earth Orbit) at 36,000 kms above earth's surface.**
- **LEO (Low Earth Orbit) at 200-1500 kms above earth's surface.**
- **MEO (Medium Earth Orbit) or ICO (Intermediate Circular Orbit) at 6000-20000 kms above earth's surface.**
- **HEO (Highly Elliptical Orbit) is between MEO and LEO.**



Orbits of different satellites

LEO (Low Earth Orbit)

Typically LEO satellites have an orbit time of around 90 to 120 minutes. The ability to get close to Earth for reconnaissance, the high speed of orbit and the fast transfer of data makes this the most popular area of satellites with over 72% of satellites in this space.

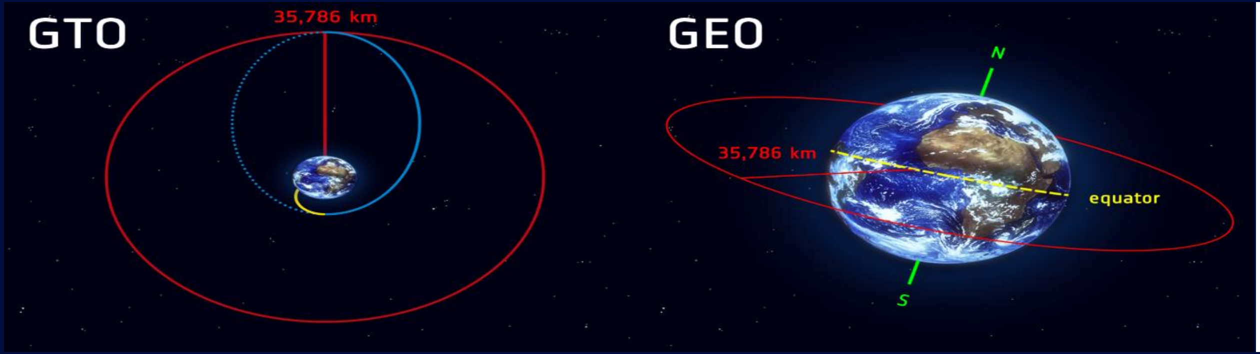


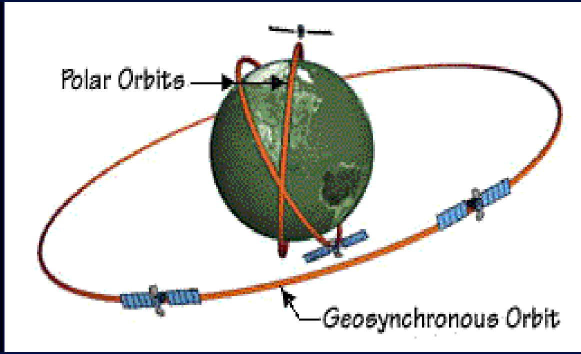
Geostationary satellites

Geostationary satellites orbit around the Earth over the equator and of speed should be about 3 km per second **at a height of about 35 800 km.**

A Geo-stationary satellite is used in

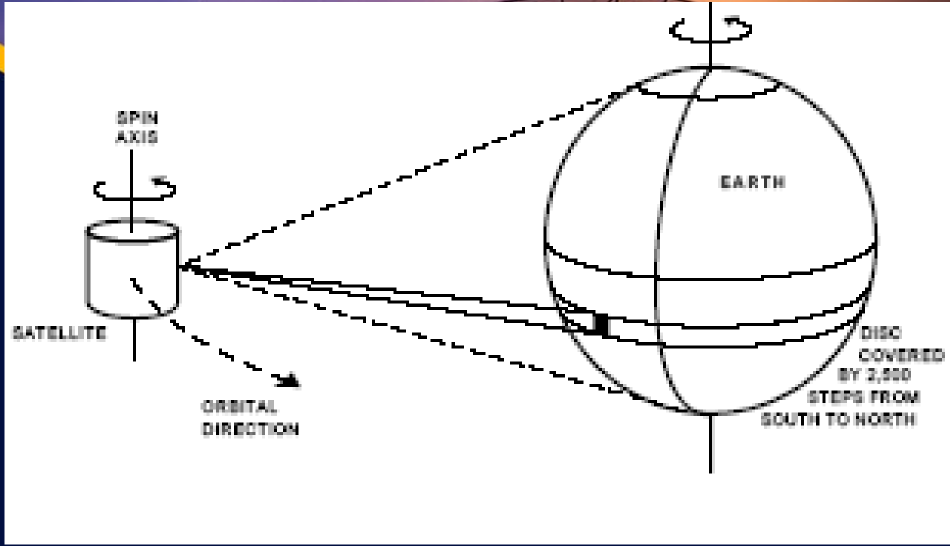
- **radio and telephone communications.**
- **live television program.**
- **weather monitoring.**





[Launch and ascent to space (yellow line) becomes the geostationary transfer orbit (blue line) when the rocket releases the satellite in space on a path to geostationary orbit (red line).]()

- The main advantage of geostationary satellites lies in the high temporal resolution of their data. It takes about 5 minutes to scan the full Earth's disc.

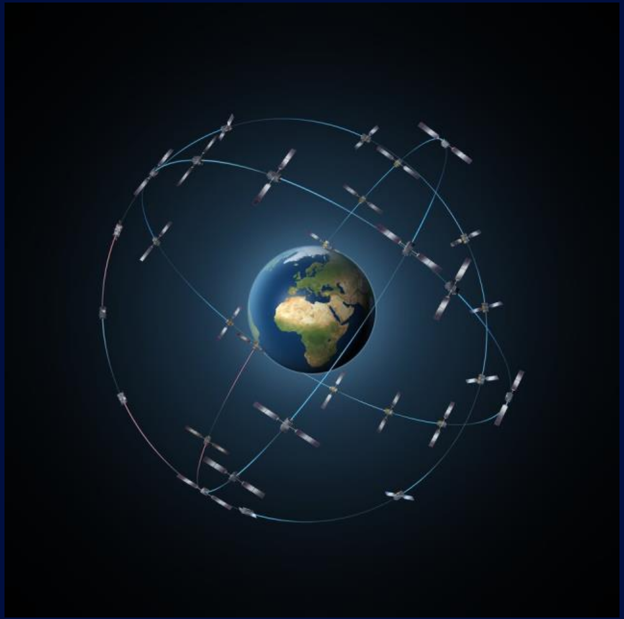


- The main disadvantage of many geostationary satellites is their limited spatial resolution, which is a consequence of their distance from the Earth.
- Useful information is restricted to the belt between 70° N and 70° S.

2. Geostationary satellites

MEO (Medium Earth Orbit)

MEO refers to satellites between the LEO ad GEO orbits yet, despite the huge range distances only 5% of satellites operate in this space. This area is used largely by navigation satellites from tracking large jumbo jets to getting directions to your smartphone like the European Galileo system.

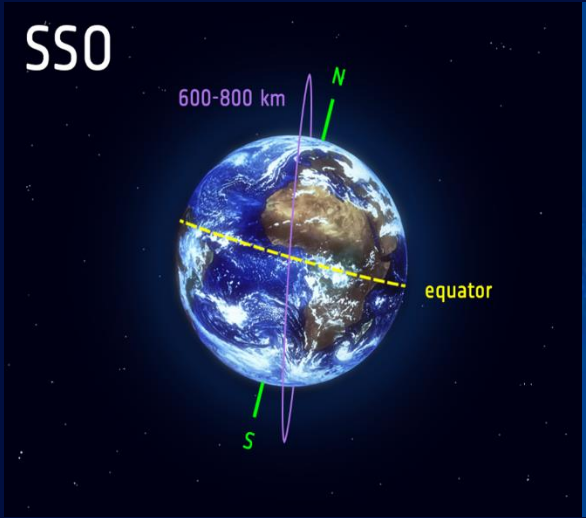


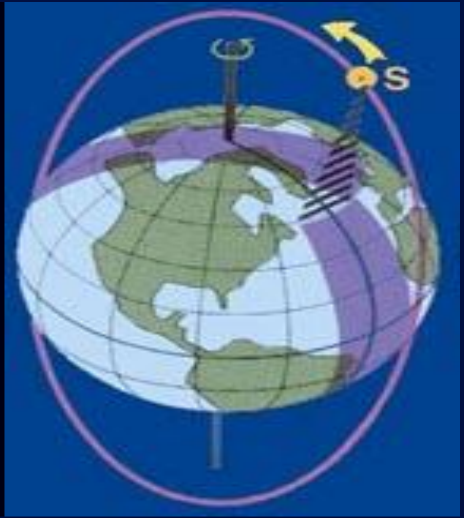
Galileo Constellation for Navigation – Image by ESA

Polar-orbiting satellites

- The orbits of these satellites pass approximately over the poles, usually at a height of about 700 to 850 km and always make an angle of 90o with respect to its equator. Satellites in a polar orbit do not have to pass the North and South Pole precisely; even a deviation within 20 to 30 degrees is still classed as a polar orbit. Polar orbits are a type of low Earth orbit, as they are at low altitudes between 200 to 1000 km.

Polar and Sun-synchronous orbit





The swaths are usually about 2600 km wide, and by completing 14 orbits per day one satellite can provide a complete cover of the globe twice every 24 hours.

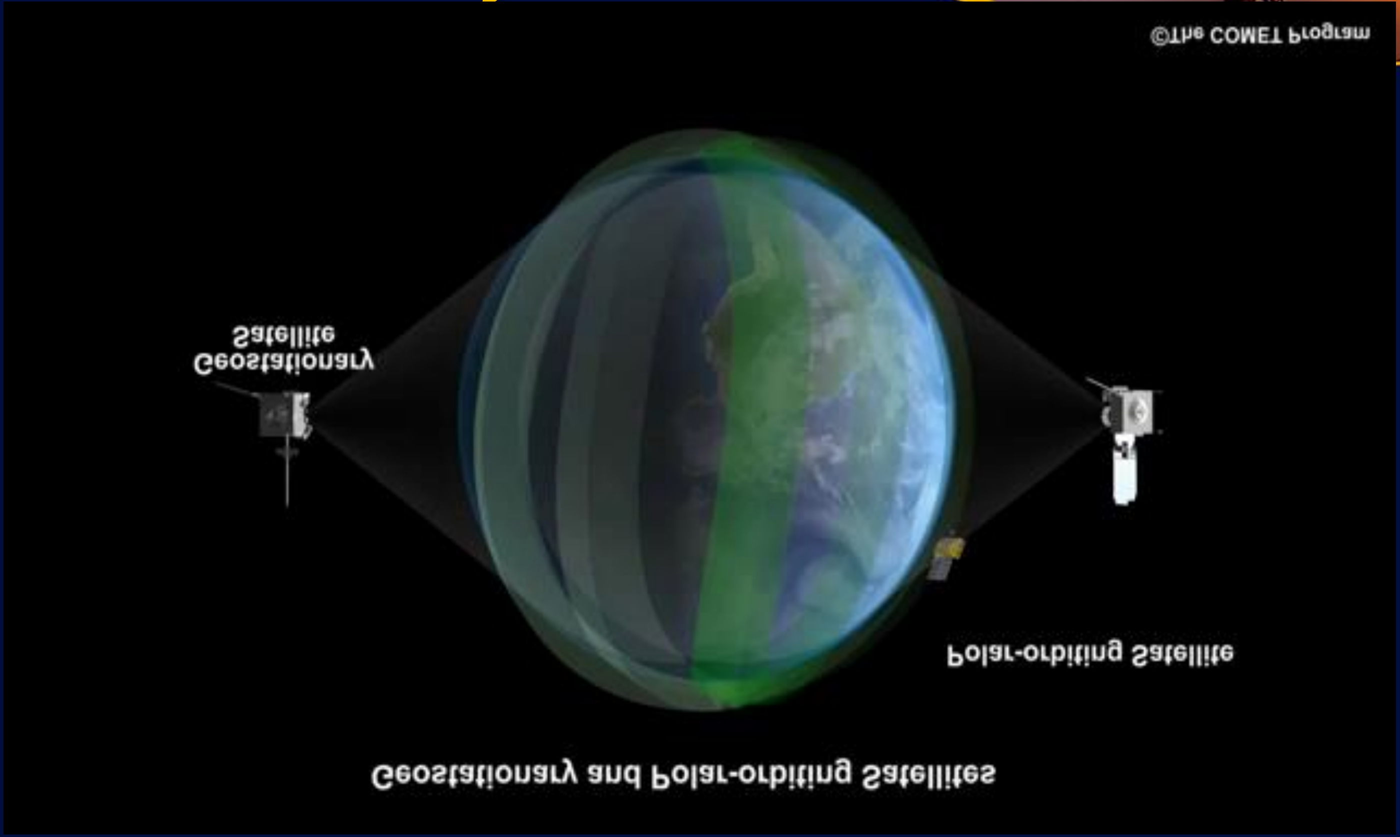
Polar-orbiting satellites are normally used for providing telecommunicatin services and weather.

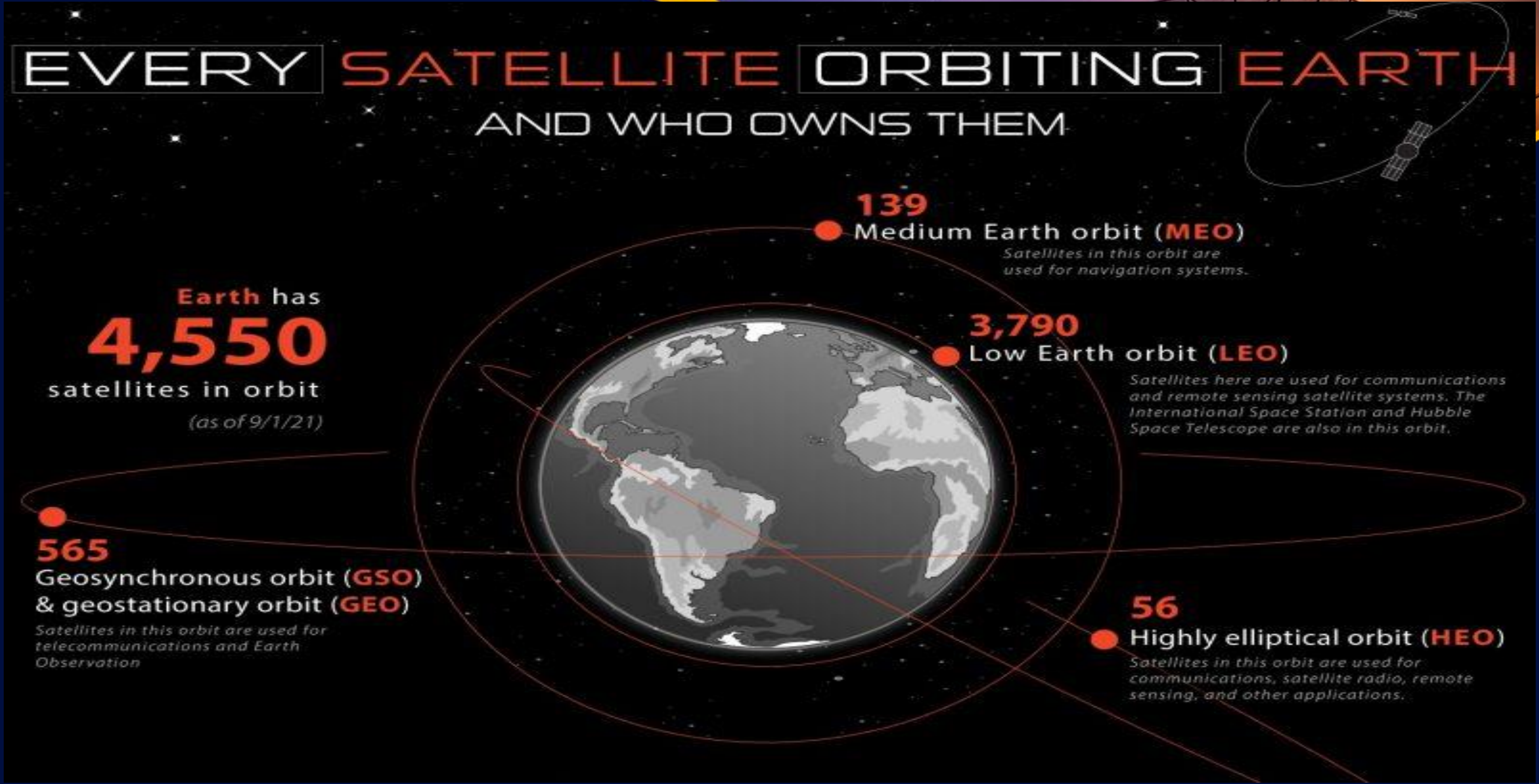
Types of meteorological satellite:

Polar-orbiting satellites

Geostationary satellites

Polar-orbiting satellites and Geostationary satellite





Approximately 50% of the satellites in space are communications satellites

THE COUNTRIES WITH THE MOST SATELLITES

Rank	Country	Total Number of Satellites	Rank	Country	Total Number of Satellites
1	USA	2,804	16	Brazil	16
2	China	467	16	Netherlands	16
3	United Kingdom	349	18	Finland	15
4	Russia	168	19	Australia	14
5	Japan	93	20	Saudi Arabia	13
6	India	61	20	Taiwan	13
7	Canada	57	20	United Arab Emirates	13
8	Germany	47	20	Switzerland	13
9	Luxembourg	40	24	Singapore	11
10	Argentina	34	25	Turkey	9
11	France	31	26	Indonesia	8
12	Spain	24	26	Norway	8
13	Italy	21	26	Mexico	8
14	Israel	19	29	Thailand	7
15	South Korea	18	30	Kazakhstan	6

Countries With 5 Satellites: Algeria, Belgium, Greece, and Sweden

Countries With 4 Satellites: Denmark, Egypt, Malaysia, and Vietnam

Countries With 3 Satellites: Czechia, Morocco, Nigeria, Pakistan, and South Africa

Countries With 2 Satellites: Azerbaijan, Belarus, Ethiopia, Lithuania, Slovenia, and Venezuela

Countries With 1 Satellite: Austria, Bangladesh, Bolivia, Bulgaria, Chile, Colombia, Ecuador, Estonia, Hungary, Iran, Iraq, Jordan, Kuwait, Laos, Mauritius, Monaco, Nepal, New Zealand, Paraguay, Peru, Qatar, Sri Lanka, Sudan, Tunisia, Turkmenistan, and Ukraine

SOURCES:

https://www.ucsusa.org/resources/satellite-database

https://maps.esri.com/rc/sat2/index.html

https://www.spacefoundation.org/space_brief/types-of-orbits/

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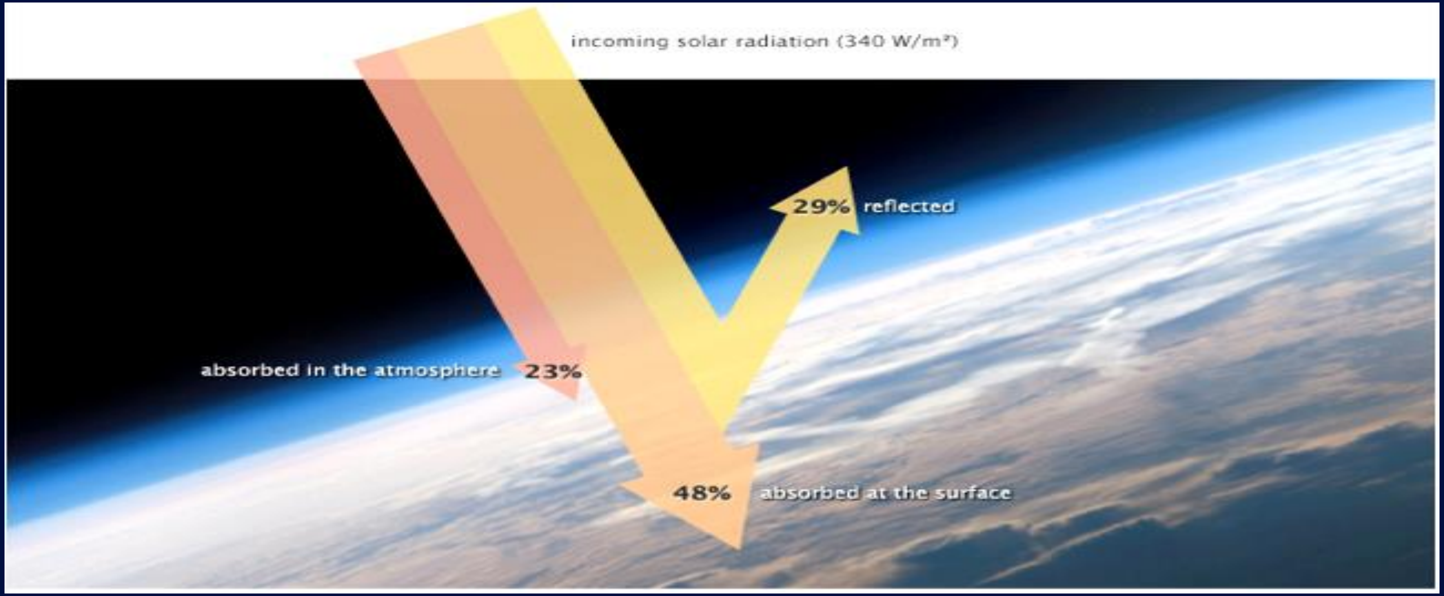
Satellite images

- To understand more about how satellites sensors work, it helps to remember that –
- As sunlight strikes Earth's surface, some of it is absorbed, and some of it is reflected back into space.



NASA illustration by Robert Simmon. Astronaut photograph ISS013-E-8948

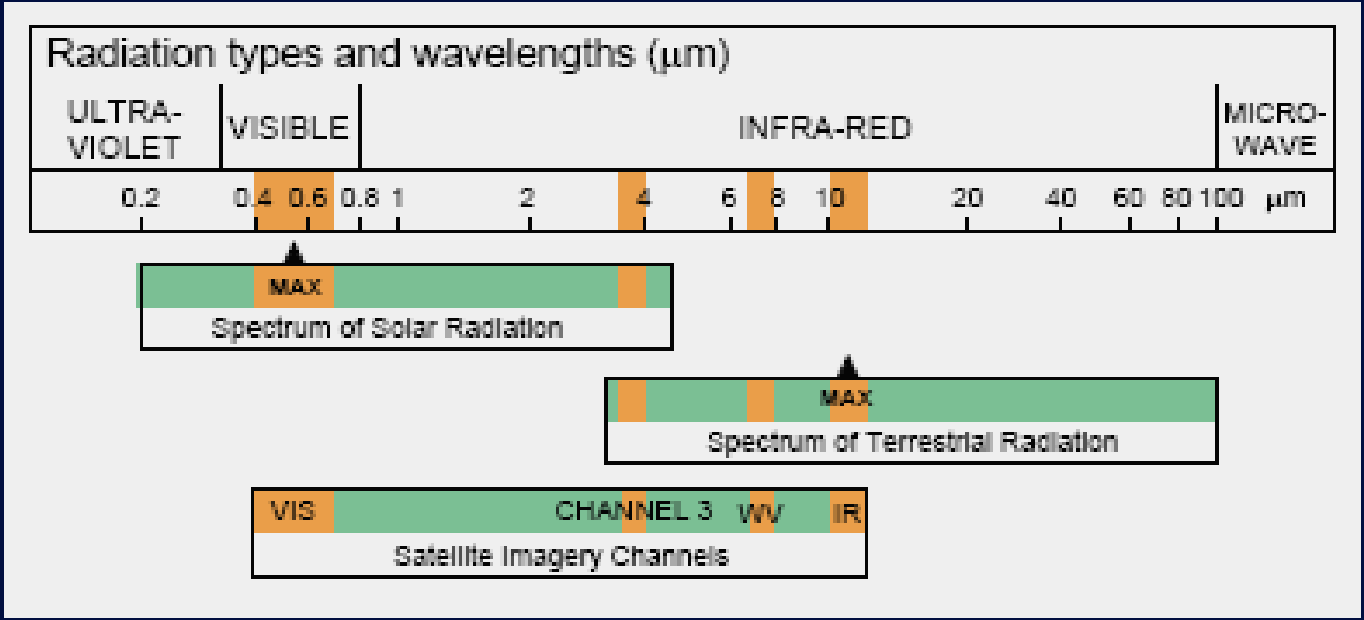
- Sunlight has visible light *and* infrared light,as well light of other wavelengths.
- Sunlight interacts with the objects it hits. Some of it is *absorbed* and some of it is *reflected* by those objects.

Satellite imagery

All solids, liquids and gases emit electromagnetic

Satellite imagery: is obtained from radiometers that measure the scattered electromagnetic radiation emitted from the sun, Earth and atmosphere radiation.

Fig shows the wavelengths of some common types of radiation. It also indicates the spectra of radiation emitted by the sun (at a temperature of about 6000 K)(solar radiation) and by the Earth and its atmosphere (at temperatures between 200 and 300 K)(terrestrial radiation)



Satellite imagery

(a) **VIS — imagery derived from reflected sunlight at visible and near-infrared wavelengths (0.4–1.1 µm);**

(b) **IR — imagery derived from emissions by the Earth and its atmosphere at thermal-infrared wavelengths (10–12 µm);**

(c) **WV — imagery derived from water vapor emissions (6–7 µm);**

(d) **3.7— µm (often referred to as ‘channel 3’) Imagery from this specific wavelength, which is in the overlap region between solar and terrestrial radiation, is sometimes called the ‘near IR’.**

- Climate change is arguably the most existential threat facing humanity.
- Its effects can be observed and experienced every day—fires, floods, droughts, melting glaciers, hotter summers, snowless winters, and unexpected hurricane-force winds are just a few examples.

- we understand that climate change is real
- and how do we measure it, using satellites and other data sources?

Satellite measurements of Earth's

- temperature,
- greenhouse gas emissions,
- sea levels,
- atmospheric gases,
- dwindling ice
- and forest cover etc,

are essential for improving the understanding of Climate change and predicting future of the Earth.

- Currently, there are around 162 satellites in-orbit that measure the various indicators related to climate change.
- Within the next five years, many new satellite missions will be launched, including Eumetsat’s second-generation polar-orbiting satellites, third-generation Meteosats and Chinese satellites.
- Satellite data provides information about more than half of the 50 crucial climate change variables, gives us precise information about sea levels, Atmospheric chemical composition and greenhouses gases like Methane.

Climate change variables

Atmosphere

Surface

- Precipitation
- Pressure
- Radiation budget
- Temperature
- Water vapour
- Wind speed and direction

Upper-air

- Earth radiation budget
- Lightning
- Temperature
- Water vapor
- Wind speed and direction

Atmospheric Composition

- Aerosols
- Carbon dioxide, methane and other greenhouse gases
- Clouds
- Ozone
- Precursors for aerosols and ozone

Land

Hydrosphere

- Groundwater
- Lakes
- River discharge

Cryosphere

- Glaciers
- Ice sheets and ice shelves
- Permafrost
- Snow

Biosphere

- Above-ground biomass
- Albedo
- Evaporation from land
- Fire
- Fraction of absorbed photosynthetically active radiation (FAPAR)
- Land cover
- Land surface temperature
- Leaf area index
- Soil carbon
- Soil moisture

Anthroposphere

- Anthropogenic Greenhouse gas fluxes
- Anthropogenic water use

Ocean

Physical

- Ocean surface heat flux
- Sea ice
- Sea level
- Sea state
- Sea surface currents
- Sea surface salinity
- Sea surface stress
- Sea surface temperature
- Subsurface currents
- Subsurface salinity
- Subsurface temperature

Biogeochemical

- Inorganic carbon
- Nitrous oxide
- Nutrients
- Ocean colour
- Oxygen
- Transient tracers

Biological/ecosystems

- Marine habitats
- Plankton

Dwindling ice covers

- the biggest news came in 2017 when a huge iceberg broke away from the Antarctica landmass. This changed the map of the world forever.
- NASA satellites ASTER and Landsat, the Copernicus Sentinel-3 mission and the ICESat-2 are mainly for applications for

the ocean and coastal monitoring,

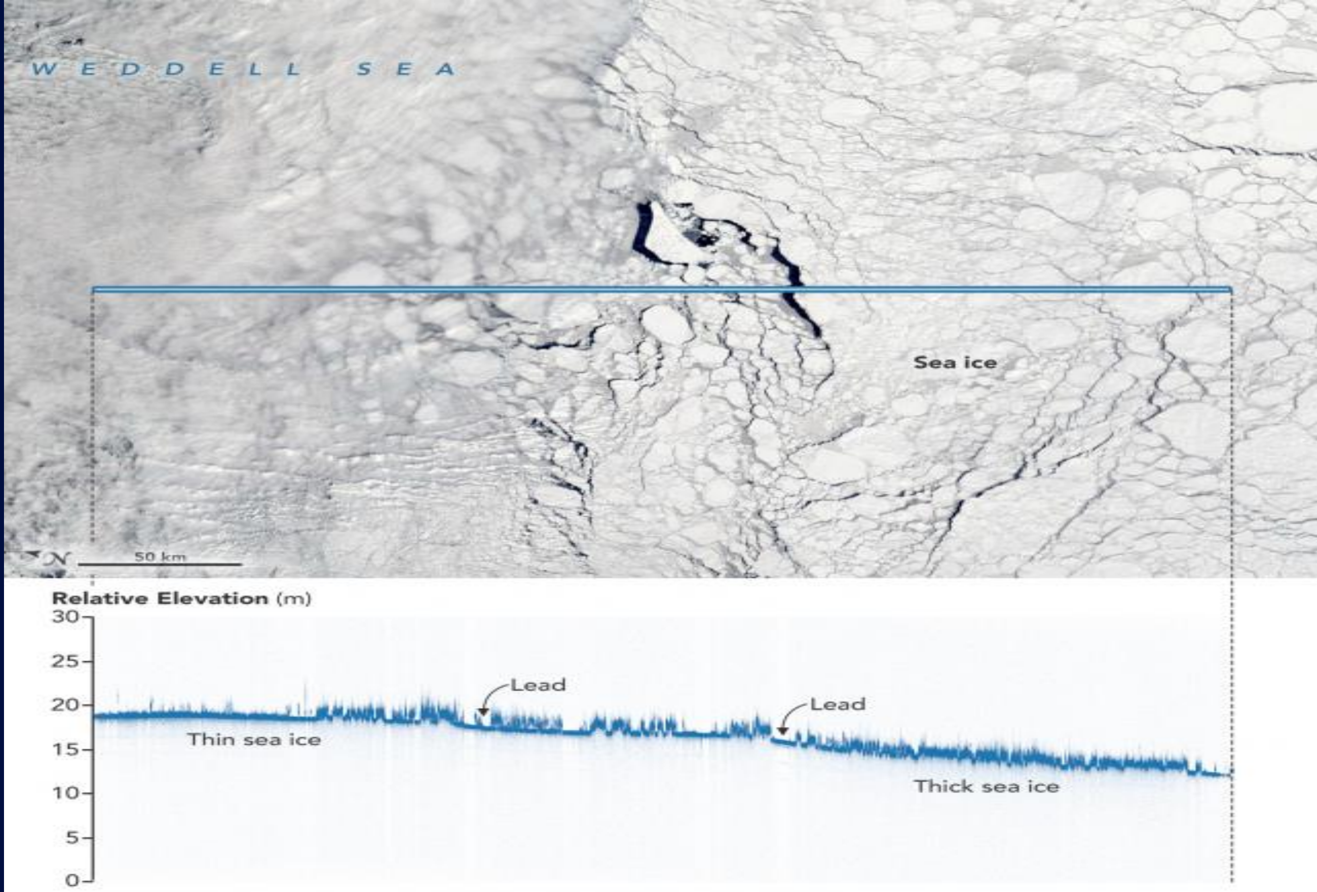
numerical weather and ocean prediction,

sea-level change and sea-surface topography monitoring,

land-cover change mapping,

also provide information about vanishing ice caps in the two polar regions of the Earth.

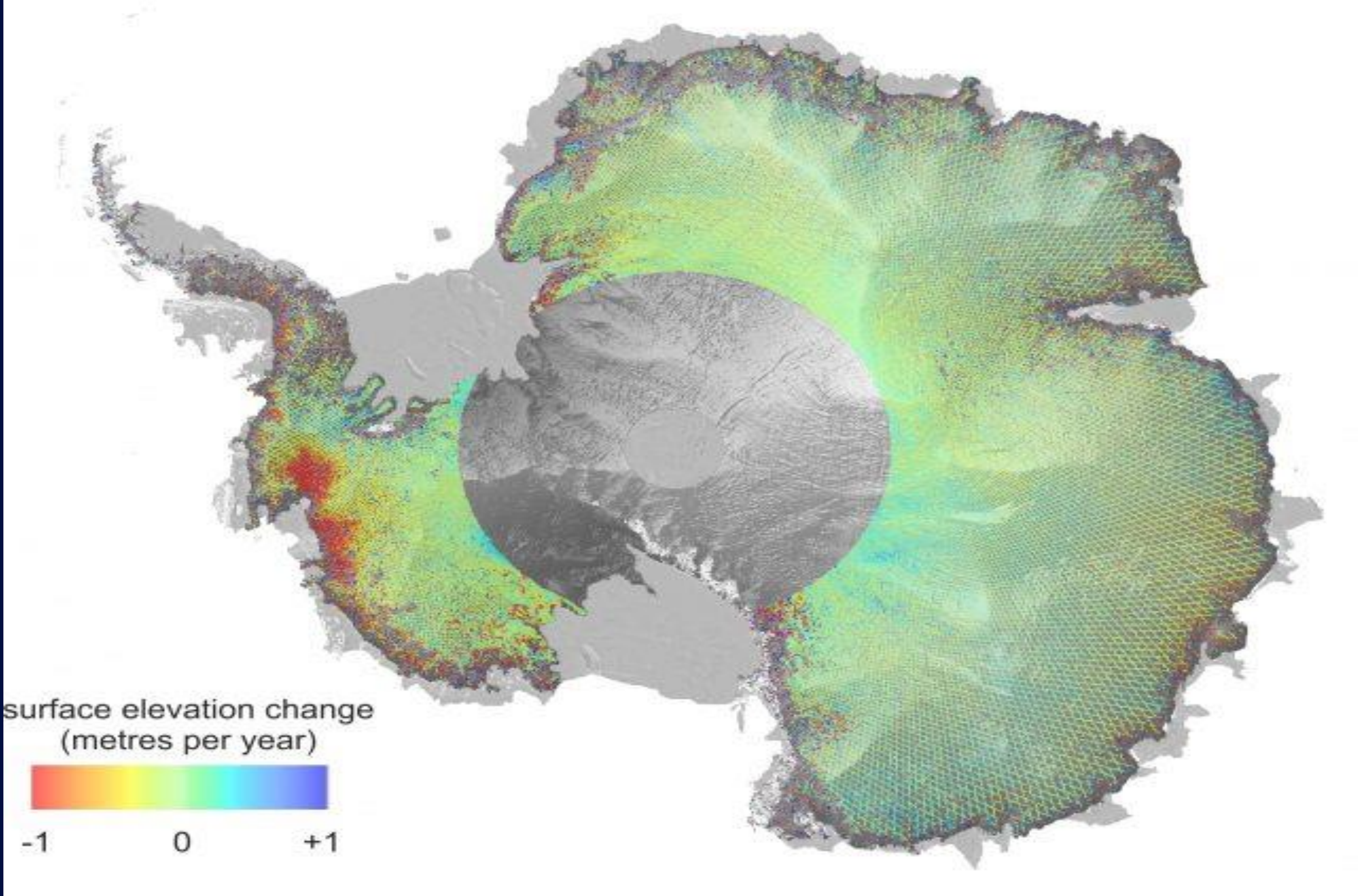
Satellite imagery shows the decrease in ice caps in Antarctica. In Greenland, the ice sheet is melting six times faster as compared to 1980s.



Sea ice of different thickness and bumpiness is broken up by the cracks between floes, called leads, in this graph of photon returns from ICESat-2 as it orbits over the Weddell Sea in Antarctica. Image Courtesy: NASA Earth Observatory/Joshua Stevens.


February 4
February 13
Melt
ponds
2 km
Foto: NASA's Earth Observatory

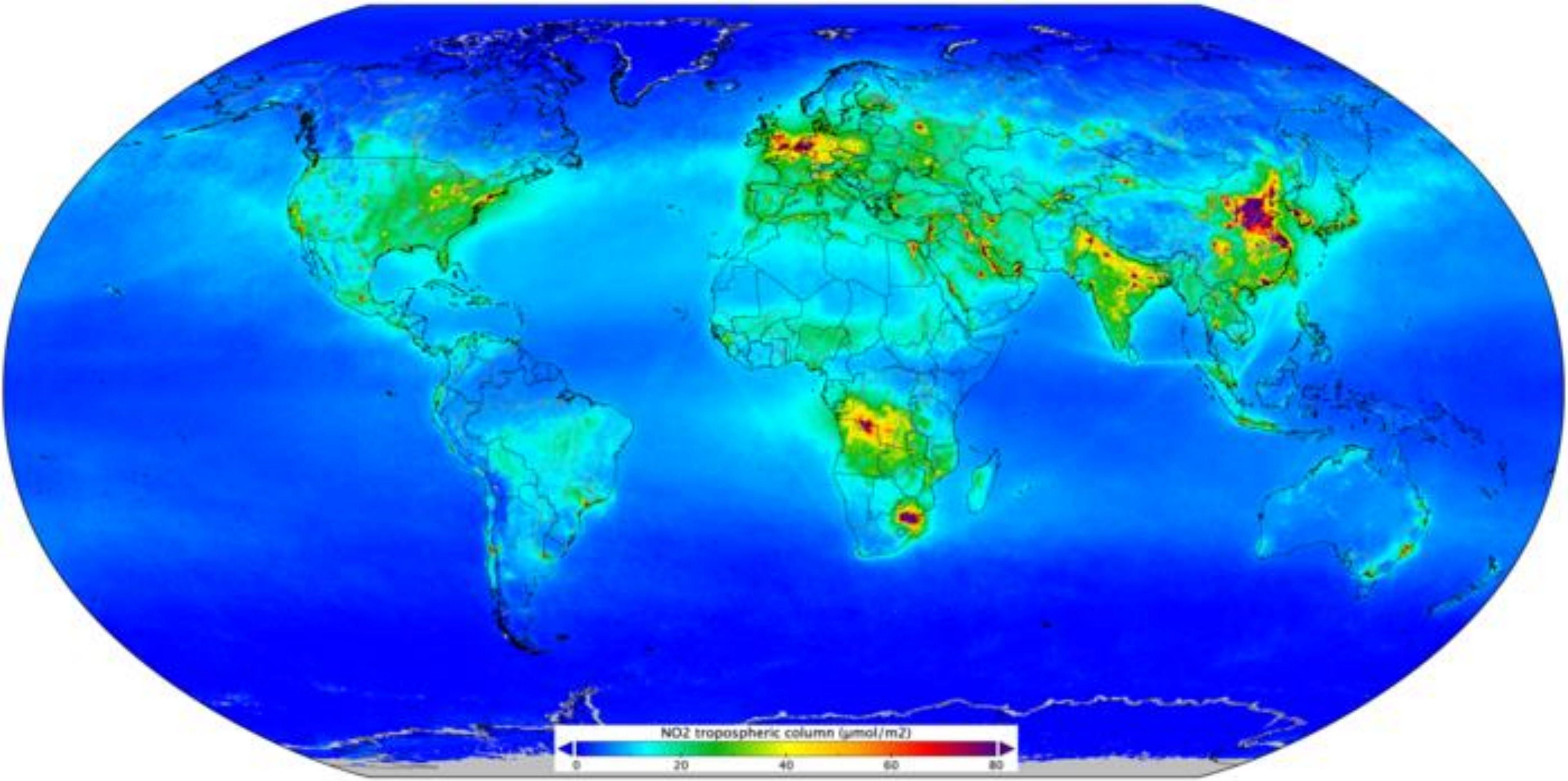
Copernicus Sentinel-3 maps Antarctic Ice Sheet elevation change



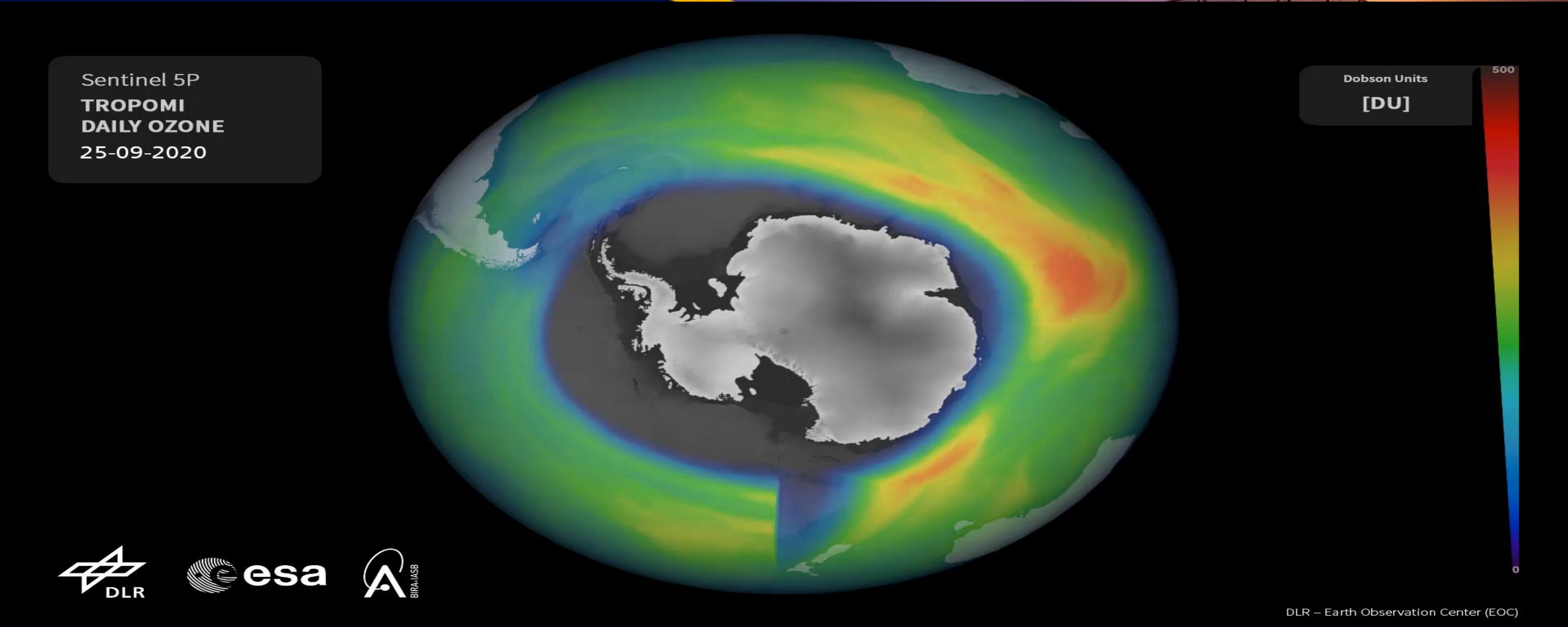
Satellite images help in mapping the changes caused by climate change. Right image - Greenland glaciers from a Landsat 8 image dated August 2019. Left Image- composite image from Landsat 1 dated September 1972. Source: NASA/Christopher Shuman.

Pinpointing emissions and pollution

- In January 2009, Japan launched the world's first satellite dedicated to greenhouse monitoring — Greenhouse Gases Observing Satellite (GOSAT). It measures CO2 and methane densities from 56,000 locations around the world. In October 2019, the Japan Aerospace Exploration Agency (JAXA) launched GOSAT-2 to generate even more precise data.
- in October 2017, ESA (European Space Agency) launched Copernicus Sentinel-5P, is said to be the most advanced pollution monitoring satellite in the world. It tracks carbon monoxide, nitrogen dioxide, and ozone, along with aerosol. It also monitors formaldehyde, which is one of the sources of carbon monoxide.
- By early 2024, US is scheduled to launch the Geostationary Carbon Observatory (GeoCarb) to track global carbon cycle from a geostationary orbit, making it the first NASA satellite to measure methane near Earth's surface. GeoCarb will gather 10 million daily observations of the concentrations of carbon monoxide, carbon dioxide, methane and solar-induced fluorescence (SIF) at a spatial resolution of about 3 to 6 miles (5 to 10 kilometers).



Sentinel-5P image shoes NO2 concenteration worldwide



- According to ESA, in 2020, the hole in the ozone layer over Antarctica reached a size of 25 million km^2, has expanded rapidly since mid-August and covers most of the Antarctic continent. It was one of the largest and deepest seen in recent years and shows record low ozone values reached nearly 100 Dobson units on October 2.

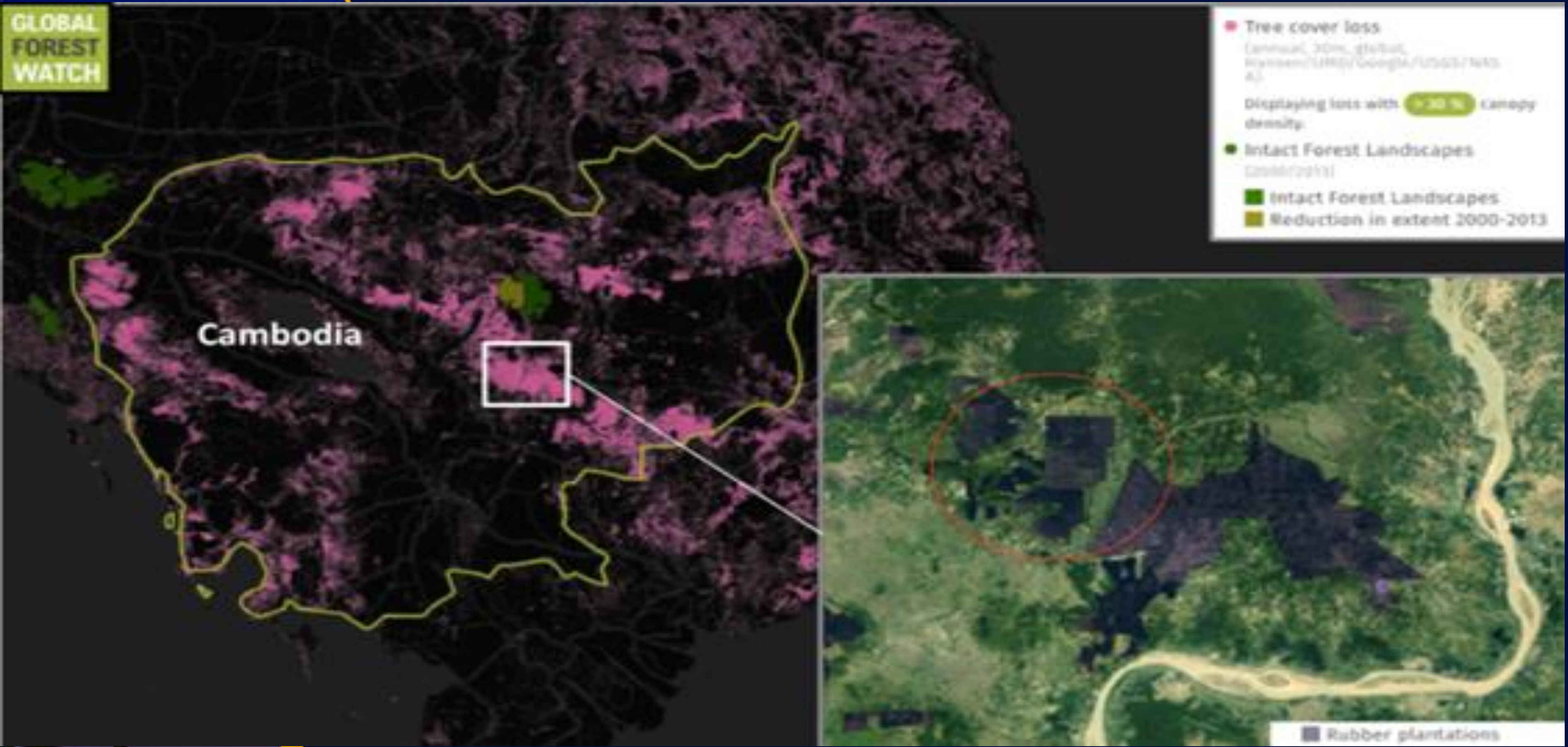
Deforestation

- Deforestation in tropical rainforests In countries like Brazil and Indonesia is among the leading causes of global warming, accounting for around a quarter of global greenhouse gas emissions especially carbon dioxide.
- The state of Rondônia in western Brazil, which was once home to 208,000 square kilometers of forest (about 51.4 million acres), now has become one of the most deforested parts of the Amazon, according to the NASA Earth Observatory.

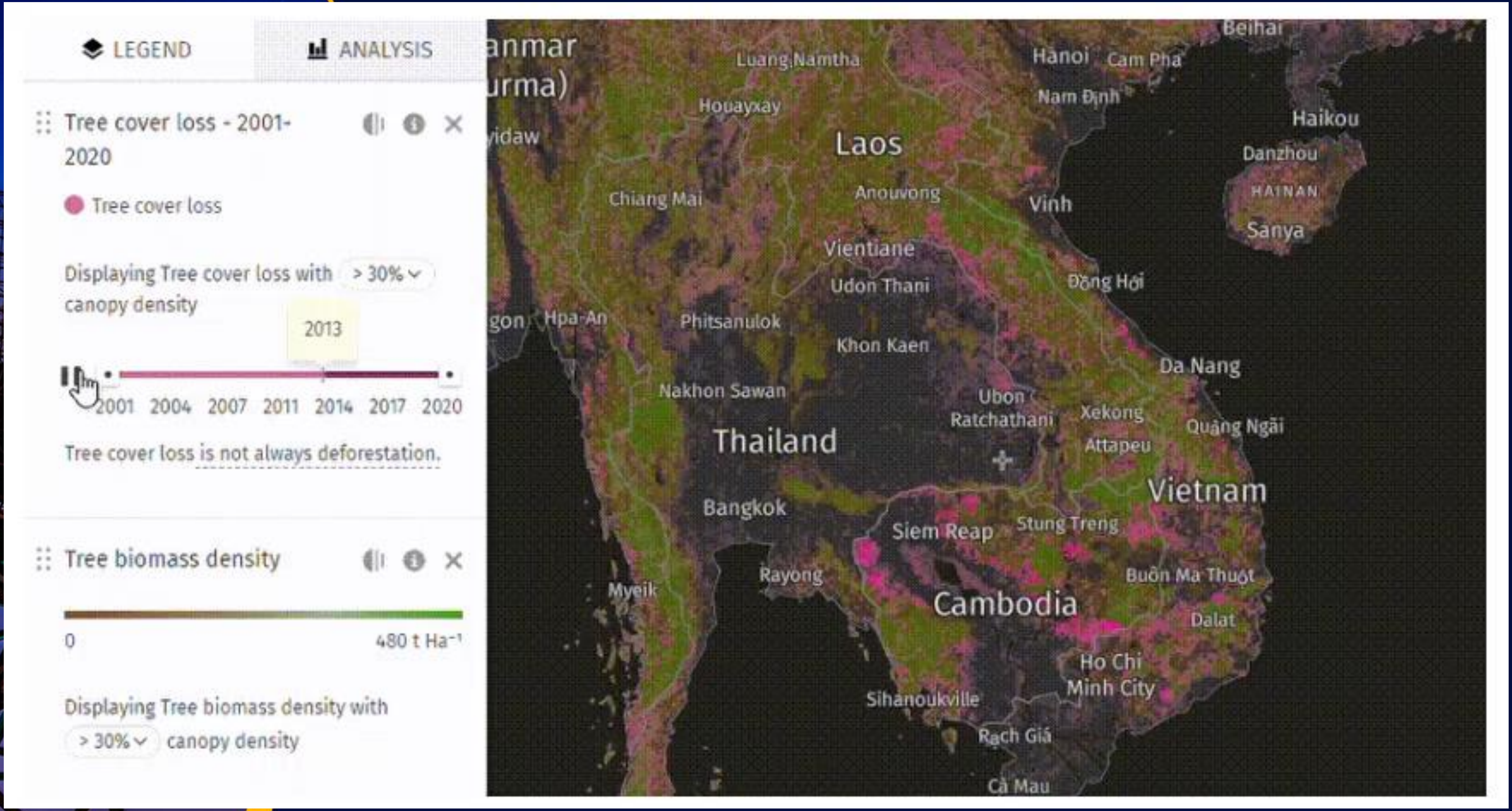
On September 5, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Aqua satellite acquired a natural-color image (above) of smoke over parts of Bolivia and Brazil..

Deforestation

- a major consequence of large-scale deforestation is the release of huge amounts of CO_2. in Cambodia alone Global Forest Watch Climate data shows that the loss of 1.59 million hectares of forest, over 14 years, has resulted in the emission of about 533 million metric tons of carbon dioxide.
- In contrast, Canada’s energy consumption in 2011—which ranks ninth highest in the world—contributed to 552.5 million metric tons of CO_2 emissions. A frightening comparison.



Progressive deforestation in Cambodia shown in Global Forest Watch app


LEGEND
ANALYSIS
Tree cover loss - 2001-2020
Tree cover loss
Displaying Tree cover loss with > 30% canopy density
2013
2001 2004 2007 2011 2014 2017 2020
Tree cover loss is not always deforestation.
Tree biomass density
0
480 t Ha⁻¹
Displaying Tree biomass density with > 30% canopy density
Luang Namtha
Hanoi
Cam Pha
Beihai
Nam Định
Houayxay
Haikou
Laos
Danzhou
HAINAN
Sanya
Chiang Mai
Anouvong
Vinh
Vientiane
Udon Thani
Đồng Hới
Hpa-An
Phitsanulok
Khon Kaen
Da Nang
Nakhon Sawan
Ubon Ratchathani
Xekong
Quảng Ngãi
Thailand
Attapeu
Vietnam
Bangkok
Siem Reap
Stung Treng
Rayong
Buôn Ma Thuột
Myeik
Cambodia
Dalat
Ho Chi Minh City
Sihanoukville
Rạch Giá
Cà Mau

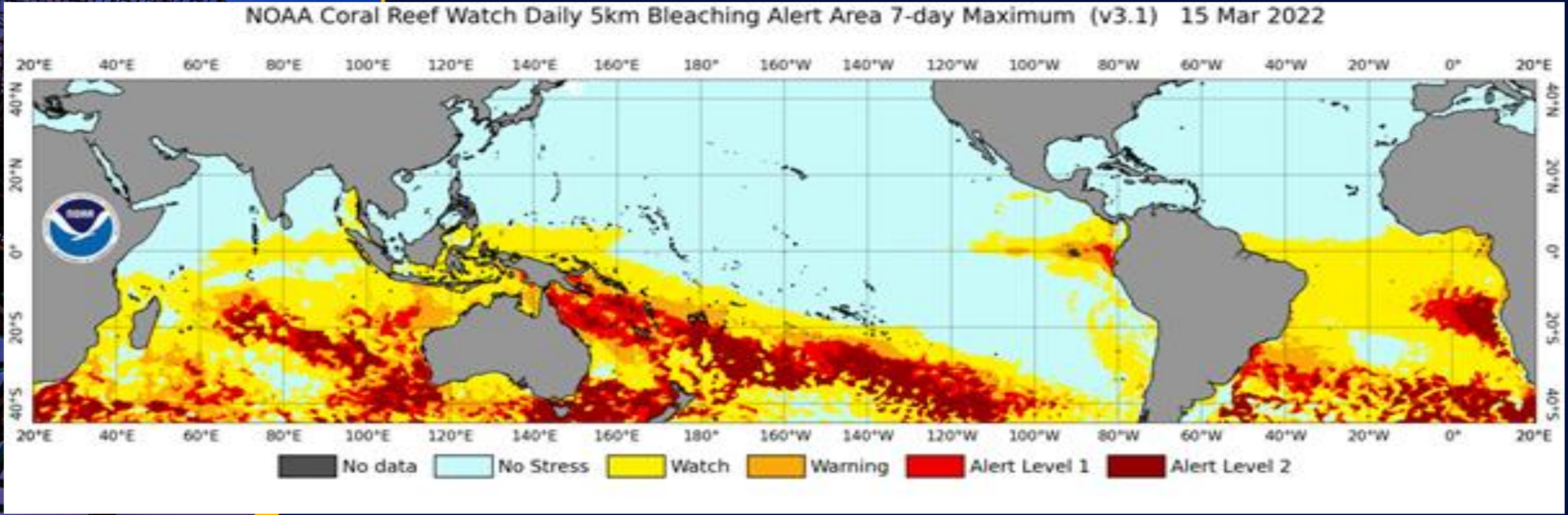
Ocean pollution

Oceans too are bearing the brunt of human activities and water pollution is leading to the death of many aquatic species. Satellites are used to monitor the discharge of plastic in the ocean. It is estimated that around eight million tones of plastic is dumped into the sea every year. Satellite imagery shows the havoc unleashed by plastic dumping.

NASA's Landsat-8 satellite image showing pollutants and organic matter flowing into the Atlantic Ocean

Coral Reefs

Coral reefs support Around 25% of marine life but in the past 30 years, more than half of the world's corals have been destroyed. It is being estimated that going by the current alarming rate, more than 90% of the world's corals will cease to exist in the next 50 years. Coral Reefs are threatened due to massive global warming and greenhouse gas emissions



Satellite imagery shows the extent of coral reef bleaching.

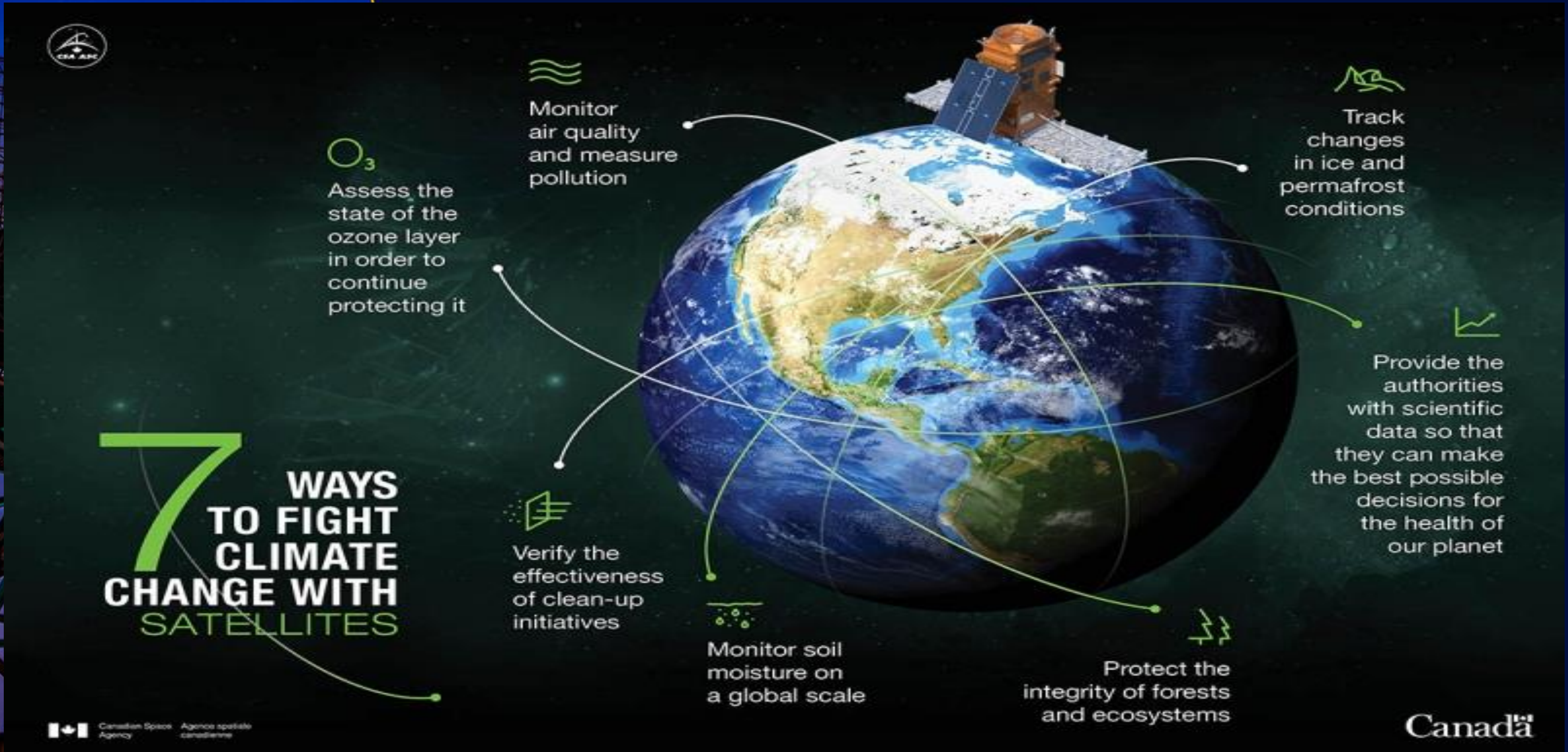
Desertification

Desertification is a type of degradation of land due to which land becomes more arid because of global warming. Each year around 12 million hectares of productive land become barren due to desertification and drought

NASA imagery showing desertification in Mali

Lake Poopó, Bolivia, photo shows the progressive disappearance of the lake.

7 ways Satellites Help Fight Climate Change



Despite the value space-based instruments provide for climate monitoring, policymakers have yet to address two key issues. First, climate-monitoring satellites contribute to the proliferation of objects in Earth’s immediate orbit. Dozens of states operate satellites for research, communications, and intelligence. Adding new climate satellites will increase the risk of collisions that create clouds of space junk. Second, increased attention to melting sea ice contributes to questions of access to satellite data, with climate watchdogs and scientific communities lobbying for access to government-collected data.

References

1. **Satellite Systems ,chapter 11,**Dr. Dharma P. Agrawal and Dr. Qing-An Zeng, 2002.
2. https://www.geospatialworld.net/blogs/satellites-for-monitoring-climate-change/
3. https://geoawesomeness.com/eo-hub/
4. National Aeronautics and Space Administration http://www.nasa.gov
5. https://earthsky.org/space/who-owns-satellites-company-country/
6. https://hsat.space/satellites-types-of-orbit/

Thank you