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WHY SPACE-BASED OBSERVATION IS ESSENTIAL FOR CLIMATE CHANGE MITIGATION

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Space exploration and spacecraft's role in earth observation is well established. Climate change has been closely monitored for decades as part of earth surface observation. In recent times, climate change has been of greater concern because of one of its visible effects, the global increase in temperatures year after year. A comparative visualisation of the increase in global temperatures (Fig 1) clearly indicates major anomalies in the Polar regions.[1]

All Earth observations are predominantly undertaken in the visible, infrared (IR), and microwave regions of the Electromagnetic (EM) Spectrum. Satellite sensors which greatly contribute to monitoring the Earth's surface temperatures are IR sensors, specifically thermal IR sensors.

Spacecraft play a major role in analysing the causes and effects of the change in temperature variations around the globe. Spacecraft also measure the activities in the atmosphere like the carbon dioxide layer, ozone layer, UV radiation and water vapour concentration.

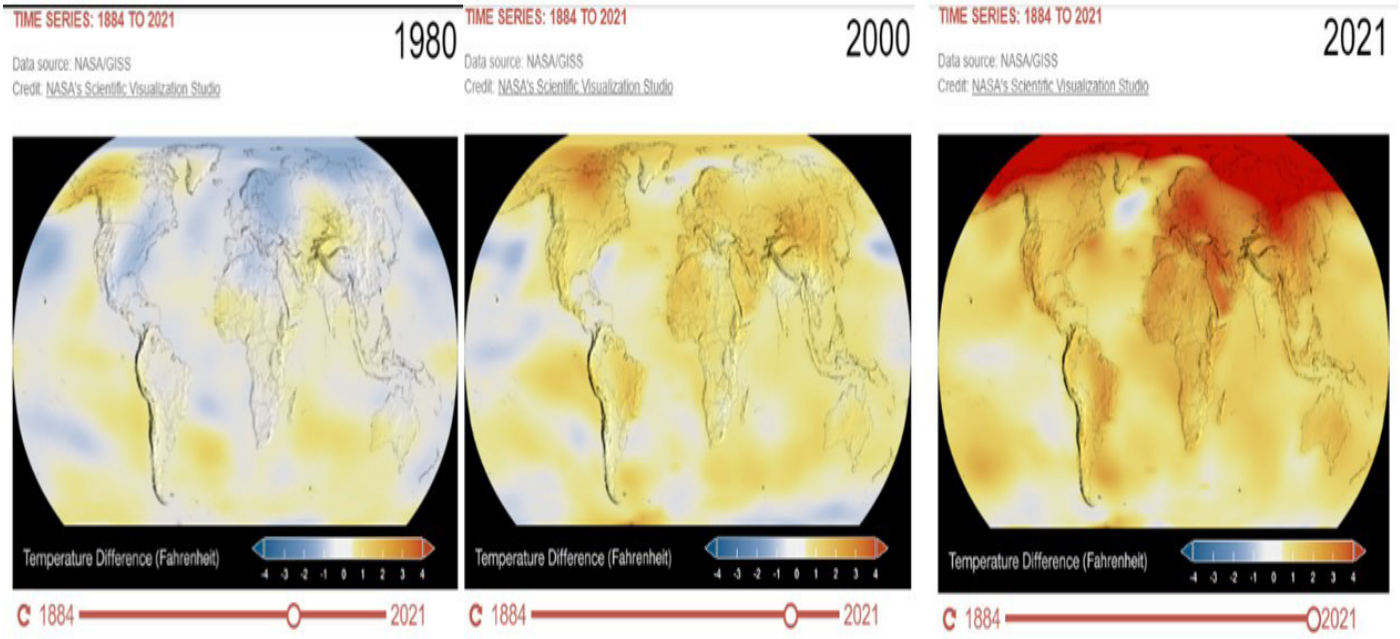
Earth Observation

Energy from the sun is received at the Earth's surface and interacts with the satellite sensor by way of emission, reflection, or transmission from the object. All Earth observations are predominantly undertaken in the visible, infrared (IR), and microwave regions of the Electromagnetic (EM) spectrum. Satellite sensors which greatly contribute to monitoring the Earth's surface temperatures are IR sensors, specifically thermal IR sensors.[2] IR radiation is termed as the emission from all objects that have a temperature above absolute zero. The human eye is not designed to differentiate between thermal radiation as it is accustomed to the visible range of the EM spectrum. These sensors

measure radiation from the Earth's surface, and the processed data from these sensors is analysed and utilised for the detection and mitigation of climate change.

The land and sea surface and the Earth's atmosphere behave differently in the EM spectrum. The visible region corresponds to the frequencies and observations that are easy to analyse and are conducted in daylight. The IR region corresponds to frequencies and observations which are difficult to analyse and can be conducted in the day or night or even in poor visibility conditions. These observations are largely dependent on the peculiar qualities of the materials or substances on the Earth's surface and in the atmosphere.[3] Microwave regions correspond to frequencies which are called 'active monitoring' in nature and are performed as radar or radio observations. These observations are very difficult to analyse and not easily comprehensible to the human eye, although they are taken as all-weather observation technology. Fig 2 describes the full EM spectrum and its relevant imaging bands.

Figure 1: Comparison of Global Temperatures



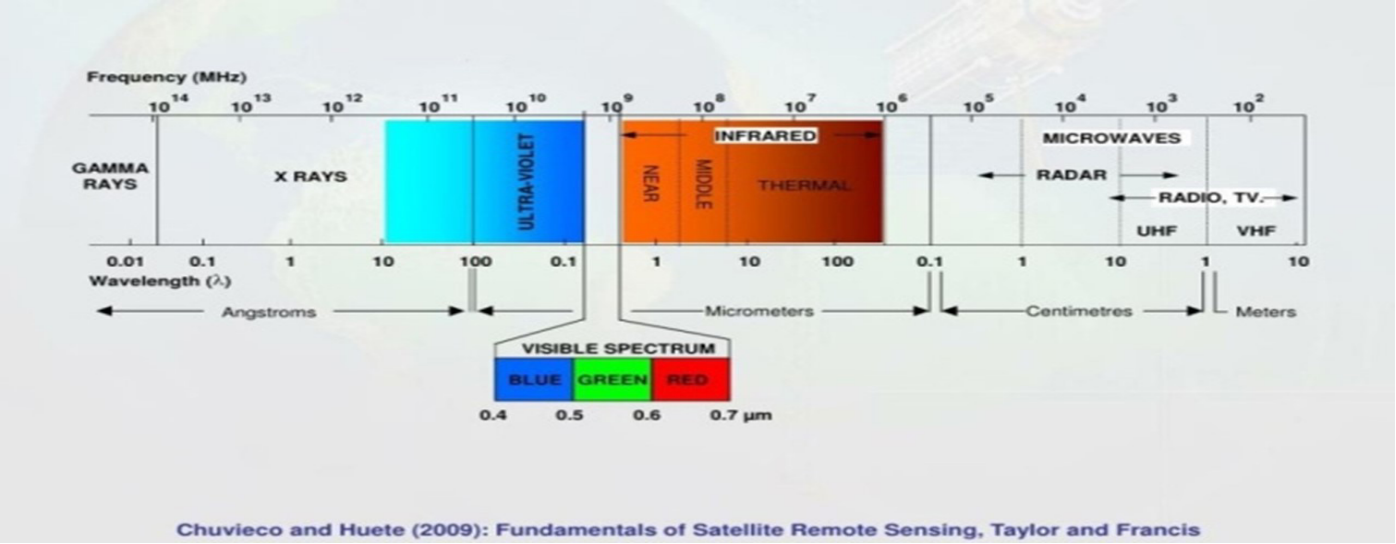
Source: "Vital Signs - Global temperature," *Global Climate Change* – NASA, https://climate.nasa.gov/vital-signs/global-temperature/. Accessed on September 10, 2022.

Data captured by IR sensors is often called 'thermal images' or 'heat maps' due to the impression caused by the radiation. These nomenclatures can have variable understandings by the researchers involved in climate change monitoring. A great advantage of IR sensing over others is the day and night capability of detection by sensors, as land surfaces and ocean surfaces behave differently during the day and night. This is due to the specific ability and peculiarity of different materials on the Earth's surface while sending the energy back to the atmosphere. IR has the peculiar advantage of monitoring in poor visibility conditions due to different weather phenomena which hinder the propagation of energy.

Visible and microwave regions are also extensively utilised for Earth observations, and the utilisation of captured data is purely dependent on the applications. There are instances when a fusion of visible and IR or visible and microwave images is performed for better understanding and analysis.

A very important use is climate modelling, wherein the archived data is used to project future climate change, which further provides a road map for mitigating such changes. All projections and future references are to be backed up with data modelling. Several studies are undertaken for different cases of climate change, such as the CO2 layer, ozone layer, global warming, etc. One such projection states that if global temperatures continue to rise at the same pace, by the end of the century global temperatures will rise by 5° Celsius.

Figure 2: Electromagnetic Spectrum



Source: Emilio Chuvieco and Alfredo Huete, "Fundamentals of Satellite Remote Sensing – Chapter 2," August 21, 2014, https://www.slideserve.com/elon/fundamentals-of-satellite-remote-sensing-chapter-2. Accessed on September 10, 2022.

Climate Change Variables

Climate change monitoring[4] involves several factors and has different ingredients to monitor as they continue to affect mankind at large. Some of them are enumerated:

Land Surface Observables

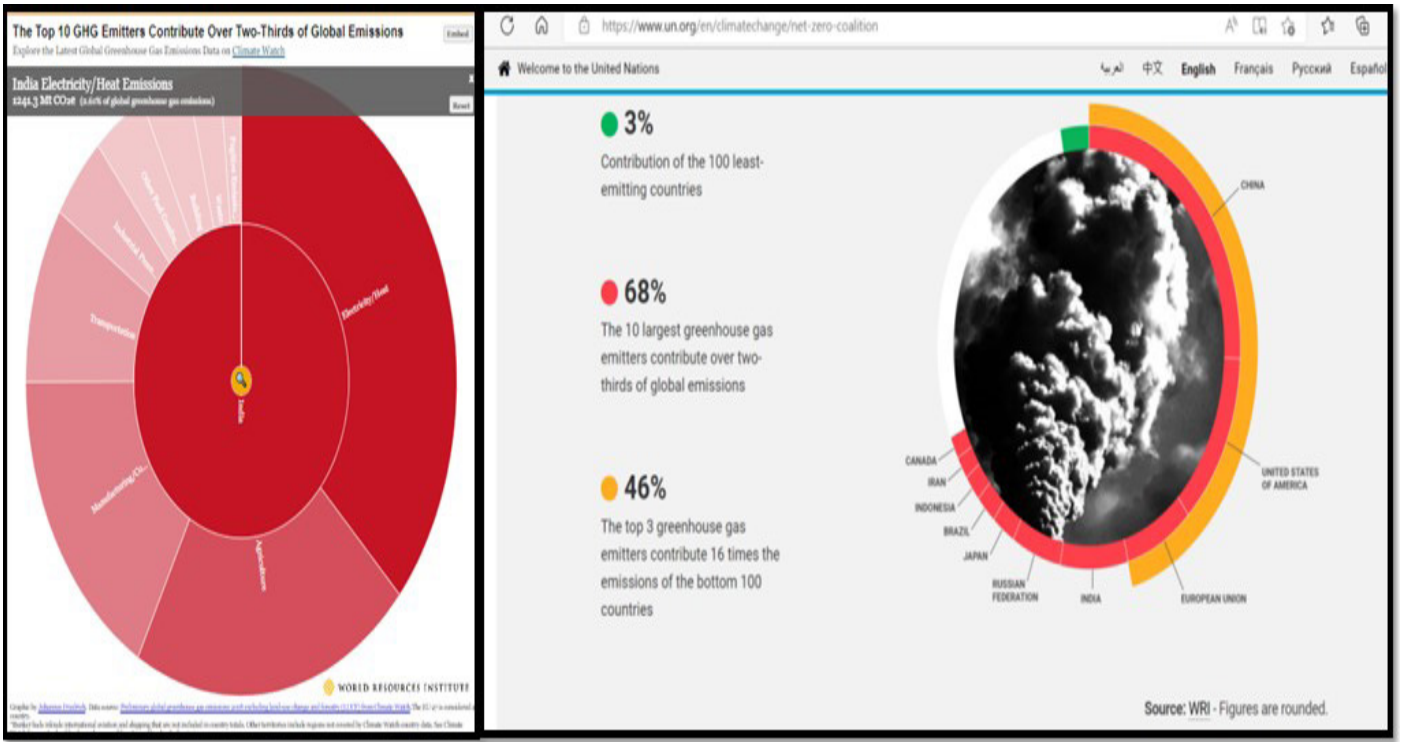
Space-based observation is best to monitor surface activities like surface temperature, soil moisture content and vegetation content discrimination for detection of drought outbreaks, forest area fires identification for disaster mitigation, urban heat mapping for population density, etc. It has been found that fossil fuel burning plays a major role in the increase in global temperatures the world over and causes various health issues. Alternatives to fossil fuels are finding ways to mitigate the effects. All these activities are interrelated to each other and contribute to global warming. It requires the nuances of each activity to be processed and analysed for current action, and, if required, modelling to be undertaken for future references.

Water Surface Observables

Space-based observation is best to monitor surface activities like surface temperature, soil moisture content and vegetation content discrimination for detection of drought outbreaks, forest area fires identification for disaster mitigation, urban heat mapping for population density, etc.

Space-based observation is best to monitor sea surface temperature and its role in global warming. It is well understood that the ocean serves as a reservoir for heat absorption and helps in cooling down the Earth's temperatures. It also measures ice status and snow coverage in designated areas, maps coastal areas for erosion likelihood, monitors rivers' overflow for flooding, and monitors lakes for inundation for their status. Any change can be distinguished by the analysis of data over a period of time and is termed 'time series analysis.' Modelling also helps in all these areas to understand the severity in the future, which guides the community in the proposed action. A study finds that sea levels could rise by 10 to 12 inches by the year 2050, which is a great threat to coastal cities and infrastructure.

Figure 3: Chart of Countries responsible for Global Emissions



Source: "For a livable climate: Net-zero commitments must be backed by credible action," United Nation Climate Action, https://www.un.org/en/climatechange/net-zero-coalition . Accessed on September 12, 2022.

Earth Atmosphere Monitoring

A lot of activities take place in the atmosphere, and all of these are required to be monitored. Some of the activities are the creation of the carbon dioxide layer, the study of the ozone layer, the monitoring of methane emissions, the quantity of water vapours and the role of clouds in temperature reduction. Greenhouse gases include all

emissions which contribute towards the increase in global temperature and several methods are employed to monitor them. A very interesting study conducted by NASA titled 'A satellite's view of ship pollution,' finds pollution caused by shipping vessels in shipping lanes across Asia, which indicates an increase in nitrogen dioxide levels exclusively in those regions.[5] A common feature which is daily viewed by all is the weather reporting on news channels, and weather channels, which is of interest to everyone due to its effect on their daily routine.

Indian Geo Platform of ISRO-BHUVAN is contributing towards climate action and is providing necessary actionable insights to the Indian and global community.

Volcanic Eruption

Volcanic plumes indicate a threat to climate change and their detection provides the data for the amount of sulphur dioxide and thermal ash in the atmosphere. This facilitates insight into disaster management due to any onslaught of tsunami or threat due to volcanic ash and is way ahead for further climate change mitigation.

Disaster Management

Several surface and sub-surface activities result in disasters induced by natural calamities. Data generated by these sensors is also used by disaster management authorities for management and rescue purposes. Flooding and landslides are the most common events that occur in our case every year. In the Indian context, a disaster management authority has been set up for mitigation and management. There is a need for optimum utilisation of satellite data for modelling and advance warning of these calamities.

Way Ahead for Climate Action

Observation or detection of the causes is the first step towards climate change mitigation. The second step is the identification of the extent of damage which can be caused by different variables. The next step is the series of actions which are required to be taken by the global community at different levels for mitigation of the effects. Modelling is undertaken on a regular basis to understand if the steps taken are sufficient. Several spacecraft operated by advanced space-faring nations are involved in the monitoring of the Earth and its atmosphere. The USA is a prime nation among space-faring nations, and its several agencies, both government and private, are involved in space exploration. Globally, NASA is the leading agency with several methods to monitor climate change. Sensors in the International Space Station, operated by NASA in collaboration with other national space organisations, are one of the major contributors to climate data capture in this domain.

India's Role in Climate Action

India is contributing towards Earth observation by means of several spacecraft controlled by the Indian Space Research Organization (ISRO). The Indian Geo Platform of ISRO-BHUVAN is contributing towards climate action and is providing necessary actionable insights to the Indian and global community. The major fields in which the data is being generated are land and sea monitoring, forestry, agriculture, weather monitoring, urban planning, and disaster management. There is a further need to disseminate this data to the field level through state remote sensing agencies for better analysis, evaluation, and action. A study by the UN suggests that India is fourth in the list of countries after China, the USA, and the European Union (Fig 3), in contribution towards emissions and global warming.[6] It becomes incumbent on India to act and chalk out a plan for net zero. Most of the emissions are from electricity and heat generation, agriculture, and construction, thus pointing towards corrective action to be taken in these areas.

Global Coordination for Net Zero

The United Nation General Assembly adopted the '2030 Agenda for Sustainable Development' resolution in September 2015. It states 17 sustainable development goals (SDGs) for the world to follow. This was further shaped in December 2015 through the 'Paris Agreement on Climate Change.' In these 17 SDGs, there are three goals which correspond to climate action and its dependents. Goal number 13, corresponds to climate action; goal number 14 is relating to life below water and goal number 15 talks about life on land. All these 17 SDGs describe a path to be followed by all nations. The 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC – COP 27) to be hosted by Egypt in November 2022 will determine affirmative steps to be taken in this regards so that the first target is achieved in 2030.

Notes:

[1] "Vital Signs - Global temperature," *Global Climate Change* – NASA, https://climate.nasa.gov/vital-signs/global-temperature/. Accessed on September 10, 2022.

[2] Naresh Jayakumar, "How is Thermal Imaging Used in Climate Change Research?," *Azo Optics,* April 20,2022, https://www.azooptics.com/Article.aspx?ArticleID=2207. Accessed on September 10, 2022.

[3] Chris Miwa, Mousa Diabat, "How Thermal Infrared Mapping is Monitoring Our World", *Directions Magazine*, May 25, 2022. https://www.directionsmag.com/article/11536. Accessed on September 12, 2022.

[4] D Michael Cai, "Satellite image analysis for surveillance, vegetation and climate change," *U.S. Department of Energy Office of Scientific and Technical Information*, January 18, 2011https://www.osti.gov/biblio/1047143; and "What is climate change," *United Nations Climate Action*, https://www.un.org/en/climatechange/what-is-climate-change. Accessed on September 12, 2022.

[5] "A satellite's view of ship pollution," Global Climate Change – *NASA*, February 10, 2013, https://climate.nasa.gov/news/860/a-satellites-view-of-ship-pollution/. Accessed on September 12, 2022.

[6] "For a livable climate: Net-zero commitments must be backed by credible action," *United Nation Climate Action*, https://www.un.org/en/climatechange/net-zero-coalition . Accessed on September 12, 2022.

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