UNIT 13 CLIMATE, ENVIRONMENT AND DISASTER MANAGEMENT

Structure

13.1 INTRODUCTION

In the previous two units, you have studied about natural resources studies and management, land use planning, infrastructure and e-governance. In this unit, we will study about applications of geoinformatics for climate and environment related studies, such as global warming, climate change, air pollution monitoring and natural hazards monitoring and management. Our existence, lifestyles and economy depend completely on the sun and the Earth's natural resources, such as water, soil, forests, grasslands, wetlands, oceans, lakes, wildlife and minerals. They form our life support system. The term environment is often used to describe this life support system of the Earth.

Remote sensing and Geographic Information Systems (GIS) provide appropriate technologies and methodologies to acquire and analyse information about the environment and provides accurate information of the Earth's terrain over diverse scales and time periods.

Objectives

After reading this unit, you should be able to:

- recognise how satellites and their sensors observe the atmosphere, hydrosphere and the lithosphere thus lending them to various environmental applications;
- describe the capabilities and limitations of remote sensing systems available for climate, environmental related applications;
- discuss the scope and application of geoinformatics for natural hazard studies; and
- explain the role of the combined use of remote sensing, in-situ measurements (i.e. ground truthing) and modeling to answer specific research questions.

13.2 STRUCTURE OF THE EARTH

To understand the applications of geoinformatics in environment related studies, it is essential to first understand the structure of the Earth. Earth consists of three layers, namely atmosphere, hydrosphere and lithosphere. The part of the Earth, i.e. the atmosphere, hydrosphere and lithosphere in which living organisms exist, or that is capable of supporting life, is called as the *biosphere*. Now we will discuss about atmosphere, hydrosphere and lithosphere under three sub sections.

13.2.1 Overview of the Atmosphere

The atmosphere is a thin layer of life-sustaining gases surrounding the Earth which is zoned into several subdivisions (based on altitude and on composition and physical properties) and on differences in the absorption of incoming solar energy as shown in Fig. 13.1. The atmosphere consists of four major zones: troposphere, stratosphere, mesosphere and thermosphere.

The first is the ***troposphere*** which is the innermost layer and extends up to 17 kilometers above sea level at the equator and about 8 kilometers over the poles. 99% of the volume of clean, dry air in the troposphere consists of 78% nitrogen, 21% oxygen with the remaining being composed of less than 1% argon, 0.036% carbon dioxide and trace amounts of neon, helium, methane, krypton, hydrogen, xenon water vapours. Temperature decreases with altitude in the troposphere. The *tropopause* is the transition layer between the troposphere and stratosphere (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

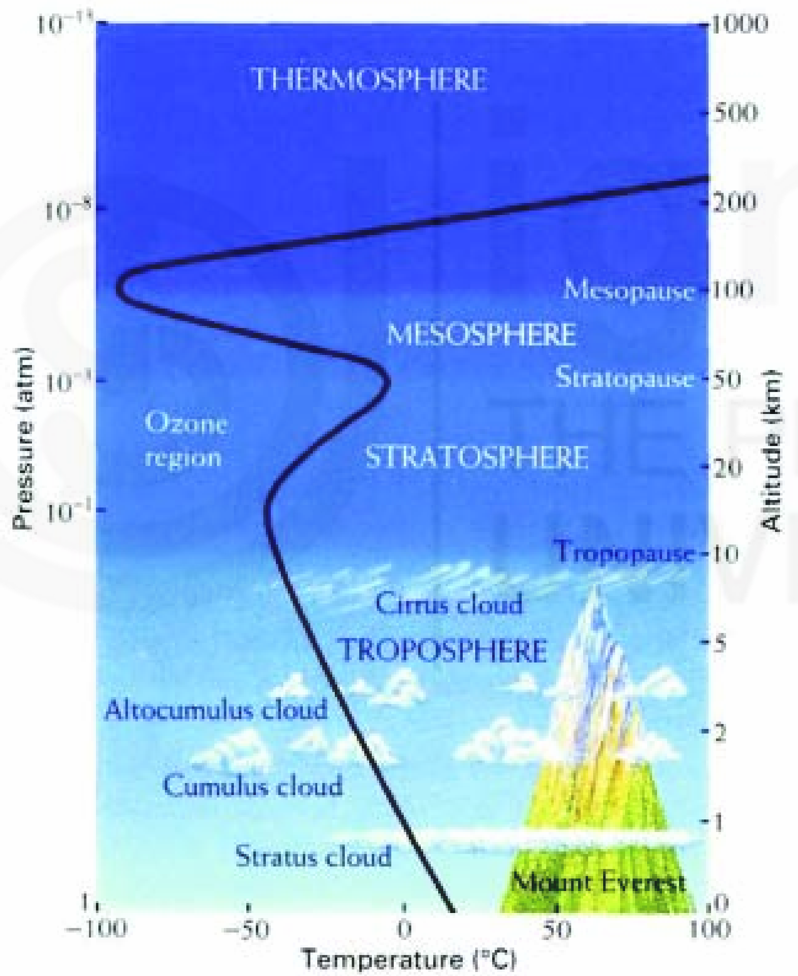
The next layer is the ***stratosphere*** which extends from 17 to 48 kilometers above the Earth's surface. Its composition is more or less similar to the troposphere with two exceptions:

- the volume of water vapour here is 1000 times less and
- the volume of ozone is 1000 times greater making it the '*global sunscreen*'.

The presence of ozone in the stratosphere protects human beings, plants and animals from sun's harmful ultraviolet radiation by preventing them from reaching the Earth's surface thus protecting us from skin and eye cancers and damage to the immune systems. Unlike the troposphere, temperature rises with altitude in the stratosphere till there is a reversal at the stratopause, which marks the end of the stratosphere and the beginning of the atmosphere's next layer.

The layer above the stratosphere at the height of around 50 kilometers is ***mesosphere.*** In this layer, temperature decreases with increasing altitude because of decreasing solar heating and increasing cooling by carbondioxide radiative emission. Temperature in the upper mesosphere has been reported as low as –100°C (–158°F). The upper boundary of the mesosphere is *mesopause* which is believed to be the coldest place on Earth.

Thermosphere is located above the mesosphere where temperature generally increases with altitude reaching 600°F to 3000°F (600-2000°K) depending on solar activity. The ***exosphere,*** a zone of free helium atoms, is the most distant atmospheric region from the Earth's surface.



The variation of atmospheric pressure and temperature with altitude above Earth's surface. The regions of the atmosphere are noted, and the Himalayas are drawn in for perspective.

Fig. 13.1: Structure of the atmosphere (source www.ic.ucsc.edu)

13.2.2 Overview of the Hydrosphere

About 71% of the Earth's surface is covered with water. Out of which around 97% is found in the ocean (salty water). The remaining 3% is fresh water of which 2.997% is locked up in ice caps or glaciers and in underground reservoirs. This means that only 0.003% is available for our direct use. However, oceans are the source of most of the precipitation that constantly recycle water. The world's oceans help regulate the planet's climate, dilute and degrade some of our wastes and are a major habitat for many of the planet's living inhabitants (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

13.2.3 Overview of the Lithosphere

The lithosphere consists of three layers: the inner core, the mantle and the crust. The **core** is approximately 7000 kilometers in diameter, and is located at the Earth's center. The **mantle,** which surrounds the core has a thickness of about 2900 kilometers and comprises 83% of the Earth's volume. It is composed of the upper mantle from the base of the crust downward to a depth of about 670 kilometers. The top layer of the upper mantle, 100 to 200 kilometers below surface, is called the ***asthenosphere***. Below the upper mantle is the lower mantle that extends from 670 to 2900 kilometers below the Earth's surface. The **crust** floats on top of the mantle. The lithosphere is a layer that includes the crust and the upper most portion of the asthenosphere. This layer is about 100 kilometers thick and has the ability to glide over the rest of the upper mantle. The lithosphere is also the zone of earthquakes, mountain building, volcanoes, and continental drift (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

Fig. 13.2: Structure of the Earth (source: Miller and Spoolman, 2007)

Spend 5 mins

Check Your Progress I

1) List out the three layers of the Earth.

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2) The gas that protects us from harmful ultraviolet radiation from sun is known as

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In the next two sub sections, we will discuss about scope and application of geoinformatics for studying atmosphere, hydrosphere and related processes.

13.3 GEOINFORMATICS FOR ATMOSPHERIC STUDIES

The advent of satellite remote sensing has opened new horizons in directly observing atmospheric properties, weather systems, oceanographic conditions and water runoff enabling global coverage on a daily basis. Some of the common applications are:

- air pollution monitoring
- wind speed and direction monitoring
- weather forecast
- cyclone/storm tracking and providing early warnings
- solar radiation studies, etc.

In next two sub sections, we will discuss about air pollution monitoring and meteorological applications.

13.3.1 Air Pollution Monitoring

Air pollution has always existed in the form of volcanic eruptions, wildfires and dust storms with their associated emissions of sulfur dioxide, carbon monoxide and particulate matter. Air pollution accelerated dramatically due to the increase of emissions since the industrial revolution to reach very alarming proportions today in most countries around the world.

Air pollution emission sources are chiefly man-made and can be categorised into the followings:

- transportation sources (such as vehicles, planes, trains and ships)
- agricultural sources (such as livestock, rice farming and land cultivation)
- industrial sources (such as by-products of manufacturing processes, plants and industries) and
- construction activities and landfill activities

Chlorofluorocarbon (**CFC**) is an organic compound that contains carbon, chlorine, and fluorine, produced as a volatile derivative of methane and ethane.

Apart from the devastating long term effects on human health, plants and materials, air pollution has disastrous effects on the stratosphere. The presence of chlorofluorocarbons (CFCs) accelerates the breakdown of ozone leading to

The **greenhouse effect** is a naturally occurring process that aids in heating the Earth's surface and atmosphere. It results from the fact that certain atmospheric gases, such as carbon dioxide, water vapour, and methane, are able to change the energy balance of the planet by absorbing longwave radiation emitted from the Earth's surface.

Spectrometer is an instrument used to measure properties of light over a specific portion of the electromagnetic spectrum.

Radiometer is a device for measuring the radiant flux (power) of electro-magnetic radiation.

the formation of the 'ozone hole' a phenomena discovered in 1985. Increase in concentration of certain gases, such as carbon dioxide, nitrogen oxides, methane and CFCs trap heat in the form of infrared radiation near the Earth's surface leading to a 'greenhouse effect', a phenomenon similar to what happens inside a greenhouse where heat is trapped. This is today leading to a warmer Earth, a phenomenon known as 'global climate change' with several disastrous consequences, such as melting of polar ice caps, rise in sea level, flooding of coastal areas, changes in weather and climate affecting agricultural production and biodiversity.

Once it was realised that man-made CFCs being released into the atmosphere are destroying large amounts of ozone in the stratosphere, National Aeronautics and Space Agency (NASA) and National Oceanic and Atmospheric Agency (NOAA) developed the capability to measure tropospheric composition from space using ultraviolet and visible spectroscopy. These include measurements of atmospheric pollutant gases which help in predicting air quality. Since 1979, several satellites have been equipped with sensors that collect data on ozone, as well as other atmospheric constituents that affect the amounts of ozone present. The Total Ozone Mapping Spectrometer (TOMS) is one such sensor (Fig. 13.3 and Fig. 13.4). The satellites that have flown TOMS have included Meteor-3, Nimbus-7, and most recently ADEOS (Advanced Earth Observing Satellite) and Earth Probe.

Over the last decade, the capabilities of satellite instruments for remote sensing of the lower troposphere have strongly increased. New space borne radiometers make it possible to determine aerosol parameters on spatial scales of a few kilometres, whereas the new generation of spectrometers can detect nitrogen dioxide and other trace gases on urban scales.

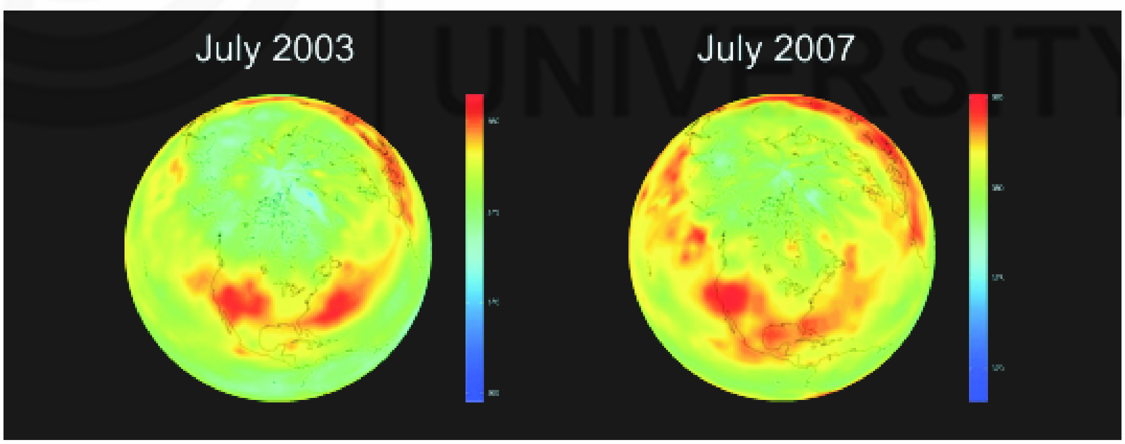

Fig. 13.3: Images from the Atmospheric Infrared Sounder (AIRS) instrument onboard NASA's Aqua spacecraft. The above images show that the carbon dioxide levels in our atmosphere are rising. Both images show the spreading of carbon dioxide around the globe as it follows large-scale patterns of circulation in the atmosphere. The colour codes used in these two pictures are different in order to account for the carbon dioxide increase from 2003 to 2007. If the colour bar for 2003 were to be used for 2007, the resulting 2007 map would be saturated with reddish colours, and the fine structure of the distribution of carbon dioxide obscured (source: NASA/JPL)

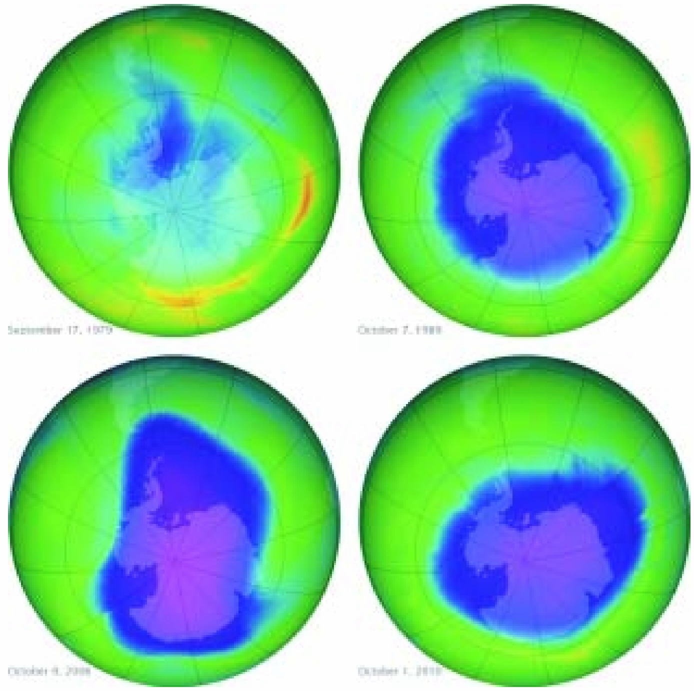

Fig.13.4: This series of images above shows the Antarctic ozone hole on the day of its maximum depletion in four different years; that is, the days with the thinnest ozone layer as measured in Dobson Units (DU). The measurements were made by NASA's Total Ozone Mapping Spectrometer (TOMS) instruments from 1979-2003 and by the Royal Netherlands Meteorological Institute (RNMI) zone Monitoring Instrument (OMI) from 2004–present. Purple and dark blue areas are part of the ozone hole (source: NASA)

A **Dobson Units (DU)** is the most basic measure used in ozone research. The unit is named after G.M.B. Dobson, one of the first scientists to investigate atmospheric ozone (1920 - 1960).

While satellite observations have the advantage of global coverage and homogeneous quality, they also have disadvantages as they cannot provide information on large scale features and phenomenon. To benefit the most from the space borne observations, the air quality community combines satellite data with information from ground based sensors and models.

13.3.2 Meteorological Studies

As you watch in daily news channels, meteorological applications, particularly the weather forecasts, have become part of our daily lives. The first ever United States satellite in Earth orbit designed specifically to image and monitor conditions on and above the surface, was the meteorological satellite, called TIROS-1, launched on April 1, 1960 soon after NASA came into existence. The TIROS program provided the first accurate weather forecasts based on data from space, demonstrating that it was possible to use satellites to observe weather. Following this, several meteorological satellites, including India's INSAT series were launched to provide current timely data for weather system monitoring and forecasting but also for communication purposes.

Meteorological satellites are of two types, i.e. polar orbiting and geostationary. Polar orbiting satellites can provide global coverage twice in 24 hours. Examples of the polar orbiting are NOAA, ERS-1, ERS-2, TRMM, DMSP, etc. Examples of Indian satellites include IRSP-4, Oceansat-1and 2, etc. Geostationary satellites remain over the same location on the equator and can provide coverage every half an hour. Examples of geostationary satellites are GMS, GOES, METEOSAT -5, METEOSAT-6, etc. Examples of India satellites include INSAT Series of satellites and KALPANA-1.

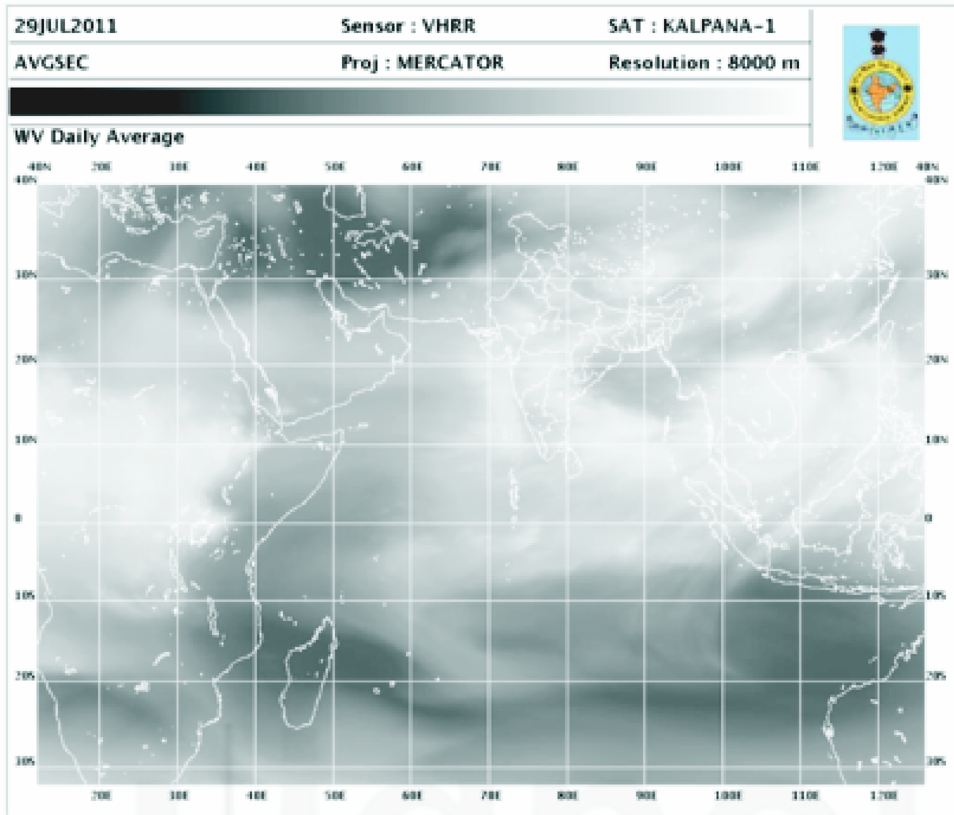

Fig. 13.5: Daily average water vapour image from KALPANA-1 satellite for 28 July 2011 (source: http://www.imd.gov.in/section/satmet/dynamic/compositewv.htm)

The meteorological sensors are classified based on their ability to collect spatial or spectral information. Spatial information includes the extent and the temperature of sea surface, clouds, vegetation, soil moisture, etc. Spectral information includes interaction of objects of interest with sun's radiation. The AVHRR (Advanced Very High Resolution Radiometer) which has been on the NOAA series for the last thirty years is used for global measurement of cloud coverage, sea surface temperature and vegetation. Other important sensors for meteorological applications include the Total Ozone Mapping Spectrometer (TOMS) for measuring the amount of ozone in the atmosphere.

Meteorological satellites are generally used to collect following information-

- rainfall
- atmospheric water vapour
- sea surface temperature
- wind
- cloud coverage
- aerosols, etc.

As discussed earlier, the commonest example is the weather forecast as shown in Fig. 13.5 which shows water vapour image from KALPANA-1 satellite for 28 July 2011. Another useful example of meteorological satellites is tracking and forecast of cyclone and its behaviour. Satellites have greatly enhanced the ability to detect and track severe storms and also to understand the mechanisms of cyclone formation and development. Meteorologists work to constantly monitor cyclones as they move, issuing cyclone warnings. Earlier coastal residents had very little or no time to prepare or evacuate their homes from an oncoming cyclone. Today they can receive warnings to evacuate one to two days in advance.

Cyclones are characterised as tornadoes, hurricanes and typhoons. A *tornado* is a smaller kind of cyclone. When a cyclone forms over tropical waters in the North Atlantic or Eastern North Pacific oceans and has high winds of 119 km/hr or more it is called as a *hurricane*. If the cyclone forms in the Western Pacific with winds of 119 km/hr or more it is called as a *typhoon*. All of these storms are generally accompanied by high winds, heavy rains, severe thunder and lightning. In the north Indian Ocean they are simply called as *tropical cyclones*.

A typical mature tropical cyclone is a warm core vortex in the atmosphere, (anti-clockwise **vortex** rotation in the northern hemisphere and clockwise in the southern), cyclonic in the lower troposphere and anti-cyclonic in the upper troposphere. The circulation extends horizontally up to 1000 km from the centre and vertically to about 15 km above sea level. The cyclone has an 'eye' at the centre of radius 5 to 50 km and is rain-free with light winds and is surrounded by a 'wall cloud' made of tall **cumulonimbus** clouds riding up to an altitude of 15-18 km with the wall cloud thickness being about 10-15 km radially. Beyond the wall cloud, surface winds speeds decrease gradually with the radial distance from the center.

A **vortex** is a spinning, often turbulent, flow of fluid. Any spiral motion with closed streamlines is vortex flow. The motion of the fluid swirling rapidly around a center is called a vortex.

Cumulonimbus is a towering vertical cloud that is very tall, dense, and involved in thunderstorms and other inclement weather. Cumulonimbus originates from Latin: Cumulus "accumulated" and nimbus "rain". It is a result of atmospheric instability.

NASA's Quick Scatterometer (QuikSCAT) spacecraft launched in June 1999 carries the SeaWinds scatterometer, a specialised microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over the Earth's oceans. Data from the SeaWinds scatterometer augments traditional satellite images of clouds by providing direct measurements of surface winds. Comparison of winds with the observed cloud patterns helps in better determination of a cyclones location, direction of motion, structure, and strength. This data thus helps meteorologists to identify accurately the extent of the winds associated with a storm, while supplying inputs to numerical models that provide forecasts.

The Tropical Rainfall Measuring Mission (TRMM) is the first space mission dedicated to studying tropical and subtropical rainfall. The Precipitation Radar and the Microwave Imager on TRMM enables scientists to peer inside the tropical thunderstorms associated with hurricanes and cyclones giving them a three dimensional view to understand organisation of precipitation in hurricanes and its relation to storm intensity and environmental effects. This information can improve computer-based weather models enabling precise prediction of the path and intensity of hurricanes and cyclones. Together, QuikSCAT and TRMM provide opportunity to observe a hurricane's/cyclones wind and rain before it makes landfall.

One of the greatest values of meteorological satellites lies in both their real time tracking capabilities and in their acquisition of data helpful in forecasting their future paths. Cyclone Nargis in the Indian Ocean which passed over Myanmar (Burma) on May 2 and 3, 2008, and has been the most disastrous in recent time. It is a classic example of real time tracking as shown in Fig. 13.6. The Indian Meteorological Department (IMD) is the nodal agency for providing operational cyclone forecast to Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand. INSAT imagery is used to identify and locate the various stages of the cyclone.

Fig. 13.6: The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite acquired this image of Cyclone Nargis at 4:40 UTC on May 2, 2008. In this image, the sprawling storm spirals over the bay, between India in the west and Burma in the east. Bangladesh lies directly north of the storm

Thus satellite, field observations and models developed to understand the phenomena are adding to our knowledge of the structure and mechanism of cyclones and the large-scale climate patterns that influence them.

Spend 5 mins

Check Your Progress II

1) Name 5 different sensors used in meteorological studies.

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2) List atleast three different applications of geospatial technology associated with the atmosphere.

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13.4 GEOINFORMATICS FOR THE STUDY OF HYDROSPHERE

There are evidences to prove that though natural warming of the Earth takes place, human actions have accelerated this process manifold. This and other related phenomena are addressed as 'global climate change' problems. The threats are not only from the gradual rise in global temperature and sea level but the redistribution of heat over Earth's surface. Some spots will warm while others will cool. These changes, and the accompanying shifts in rainfall patterns, could relocate agricultural regions across the planet affecting people and global biodiversity.

Satellite observations of the oceans over the past three decades have revolutionised our understanding of global climate change through global measurements and modeling of the ocean-atmosphere climate system. Global data sets available on time scales of days to years (and, looking ahead, to decades) have been and will be a vital resource for scientists and policy makers in fields from ocean commerce to disaster mitigation. Key social and economic benefits of satellite ocean data include:

- *Climate Research:* Scientists study the evolution of weather patterns by modeling changes in the distribution of the oceans' heat
- *Hurricane/Cyclone Forecasting:* Altimeter and scatterometer data are incorporated into atmospheric models for hurricane/cyclone season forecasting and individual storm severity
- *El Nino and La Nina Prediction:* Understanding the pattern and effects of climate cycles such as El Nino helps us to predict and mitigate the disastrous effects of floods and drought
- *Fisheries Management:* Satellite data are used to identify ocean eddies as well as plankton concentrations, which bring an increase in organisms that comprise the marine food web and attract fish and fishermen
- *Marine Mammal Research:* Sperm whales, fur seals and other marine mammals are tracked and studied around ocean eddies, where nutrients and plankton are abundant
- *Coral Reef Research:* Remotely sensed data are used to monitor and assess coral reef ecosystems, which are sensitive to changes in ocean temperature

El Nino/La Nina is a quasiperiodic climate pattern that occurs across the tropical Pacific Ocean roughly every five years. It is characterised by variations in the temperature of the surface of the tropical eastern Pacific Ocean-warming or cooling known as *El Nino* and *La Nina* respectively.

A number of satellites, such as SeaSat, TOPEX/Poseidon, ERX-1, ERX-2, Jason, Quicksat, etc., dedicated to gathering oceanic data have significantly increased our understanding of the behaviour of large bodies of water. The key to measuring ocean currents from space is ocean-surface topography through the use of radar altimeters, a microwave sensor which map the height of the sea surface at all points on the globe.

Scatterometer data has wide coverage, and thus contributes to improving the forecast accuracy of weather forecasting models. Launched in 1999 on the QuikSCAT satellite, the SeaWinds scatterometer has provided information on changes in the polar sea-ice masses besides providing the longest continuous, global view of ocean-surface winds to date, including the detailed structure of hurricanes, wind-driven circulation.

A radiometer is used to measure sea surface temperature, wind speed, salinity, soil moisture, sea ice, precipitation, integrated water vapour and liquid water content of the atmosphere. They operate in the visible, infrared and microwave range thus lending themselves to a wide range of environmental applications. We will discuss here about one of the common applications i.e. flood forecasting.

Applications in Flood Forecasting

Being a tropical country India is prone to floods. Traditionally gathering and analysing hydraulic and hydrologic data related to floodplains and river catchments has been a time consuming effort requiring extensive field observations and calculations. With the development of remote sensing and computer analysis techniques, traditional techniques can be supplemented with these new methods of acquiring quantitative and qualitative flood hazard information. Most of the flood prone rivers in India change their course frequently after every flood causing enormous damage. It is, thus, essential to understand the behaviour of the river and its latest configuration to plan flood control measures, it is also important to monitor the existing flood control structures periodically to avoid breaches in view of the frequent changes in river configuration. In such cases, it is important to monitor the river both in time and space which cannot be done by conventional. In this regard satellite remote sensing provides an excellent source of information and coupled with GIS is an effective tool for river/flood monitoring (Fig. 13.7).

Topography of the river catchment is a basic need for flood forecasting. Remote sensing provides quantitative topographic information that is extremely valuable for model inputs. Satellite remote sensing can play a major role in rainfall runoff modeling which is a part of the flood forecasting model. The real time rainfall data provided by meteorological satellites is used as an input in the flood forecast models.

Today urban flooding is an inevitable problem in many cities, and is on the rise. Wetlands have been reclaimed effectively annihilating flood buffers due to the increased demand for land for various developmental purposes. This has led to a substantial decrease in the proportion of rainfall that infiltrates into the ground and a consequent increase in surface runoff, in terms of both volume and flow rate. Urbanisation has changed natural run-off pattern and accelerated transport of water, pollutants and sediment from the urban areas. One of the typical features of urban flooding is shortening the runoff travel time making it a flash event. The continuous development of urban settlements necessitates data on flow rates, physical and topographical settings for more periodic assessment, and monitoring to cope up with storm water flooding. Recent advances have greatly enhanced the satellite remote sensing data capabilities in supplementing the data needs for management of urban flooding.

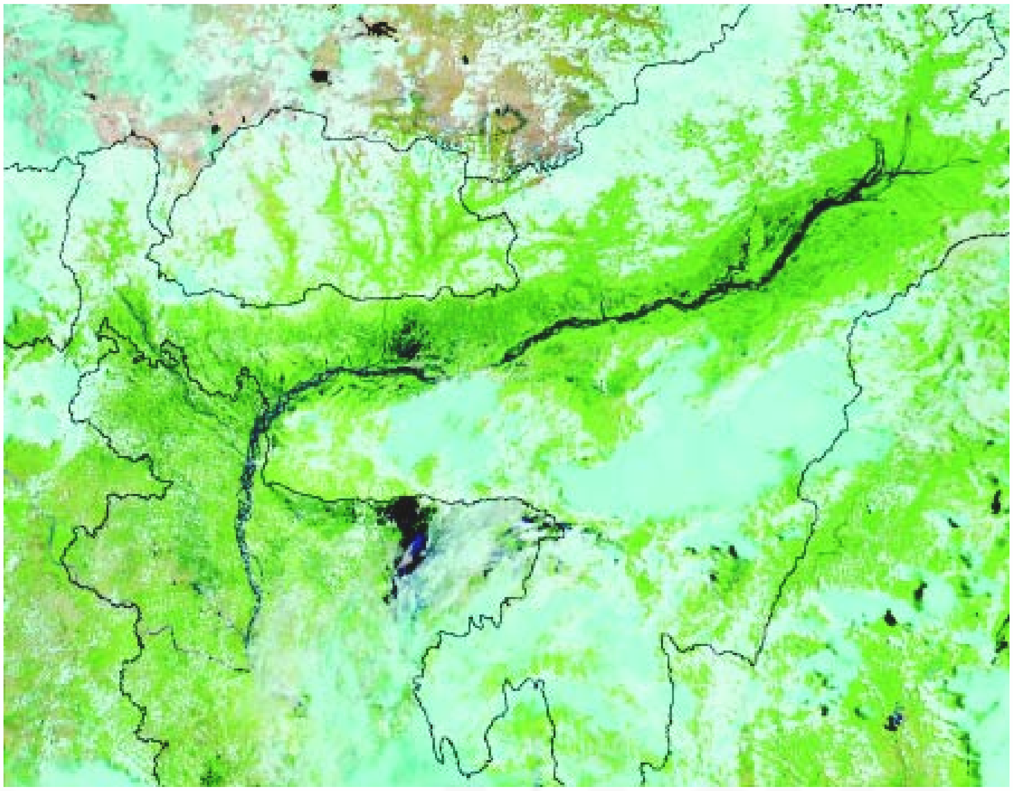

Fig. 13.7: This image was acquired by MODIS on the Aqua satellite during the floods in Assam highlights the standing water, which appears dark blue or black. The river makes a thin line through the pale tan flood plain, which contrasts against the green vegetation. Flooded areas are seen along the foothills of the Himalayas, which run across the top of the images (source: http://visibleearth.nasa.gov/view.php?id=66805)

Check Your Progress III

1) Match the following

A	B
Radar images	Measures sea surface temperature
Radiometer	Measures height of the sea surface
Scatterometer	Used to assess flood extent
Radar altimeters	Identifies potential fishing zones
Ocean colour monitor	Measures sea surface roughness

13.5 GEOINFORMATICS IN NATURAL AND MAN-MADE DISASTERS

India has traditionally been vulnerable to natural disasters on account of its unique geo-climatic conditions. Floods, droughts, cyclones, earthquakes and landslides have been recurrent phenomena. About 60% of the landmass is prone to earthquakes of various intensities, over 40 million hectares is prone to floods, about 8% of the total area is prone to cyclones and 68% of the area is susceptible to drought (www.ndmindia.nic.in/GoIUNDP/ReportPub/DM-Statu-%20Report.pdf).

Although natural disasters cannot be controlled, they can be reduced through a proper disaster management plan including disaster prevention (hazard and risk assessment, land use planning and legislation, building codes), disaster preparedness (forecasts, warning, prediction) and rapid and adequate disaster relief. Mitigation of natural disasters can be successful only when adequate knowledge is obtained about the expected frequency, character and magnitude of hazardous events. The use of Earth observation methods has proven to be especially suitable in the field of disaster management. In a number of countries, where warning systems and building codes are more advanced, remote sensing of the Earth has been found to successfully predict the occurrence of disastrous phenomena and to provide early warning to people. Natural disaster includes flooding, volcanoes, forest fire, earthquake, landslide, etc., Human induced disaster includes mine subsidence, oil spills, etc. Here we will discuss about the application of geoinformatics in monitoring volcanoes, forest fire, earthquake and landslides. We will also discuss about the oil spills which is not a natural disaster but a man-made.

13.5.1 Monitoring Volcanoes

When we think of volcanoes, the first image that comes to mind is probably a tall, conical mountain with orange lava spewing out the top. There are certainly many volcanoes of this type. But the term volcano actually describes a much wider range of geological phenomena. Generally speaking, a volcano is any place on a planet where some material from the inside of the planet makes its way through to the planet's surface. This material is its magma, fluid molten rock which is partially liquid, partially solid and partially gaseous.

More than 1,500 potentially active volcanoes dot the Earth's landscape, of which approximately 500 are active at any given time. Satellite technology now makes it possible to monitor volcanic activity in even the most isolated corners of the globe and to routinely observe changes in the Earth's surface that may signal an impending eruption. In addition, remote sensing data offer scientists the chance to prevent catastrophic damage to life and property by determining how and where volcanic debris spreads after an eruption. Fig. 13.8 provides concentration of sulphur dioxide erupted from the Sarychev Peak Volcano on Matua Island.

The MODIS Thermal Alert System, known as MODVOLC, now enables scientists to detect volcanic activity anywhere in the world within hours of its occurrence (http://earthobservatory.nasa.gov/Features/monvoc). MODVOLC uses data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors, which fly aboard NASA's Terra and Aqua satellites. A developed algorithm scans each 1-kilometer pixel within every MODIS image to see if it contains high-temperature heat sources or hot spots. MODIS achieves complete global coverage every 48 hours, which means that this system checks every square kilometer of the globe for volcanic activity once every two days. Using this system, remote volcanoes that would normally not have been detected even for weeks can now be monitored. For each hot spot identified, MODVOLC records the date and time at which it was observed and its geographic coordinates. Since active lava flows or growing lava domes emit vast amounts of energy, these hot spots are relatively easy to detect in MODIS imagery. Because of its global coverage every alternate day MODIS data are useful for quickly providing researchers with information about new eruptions.

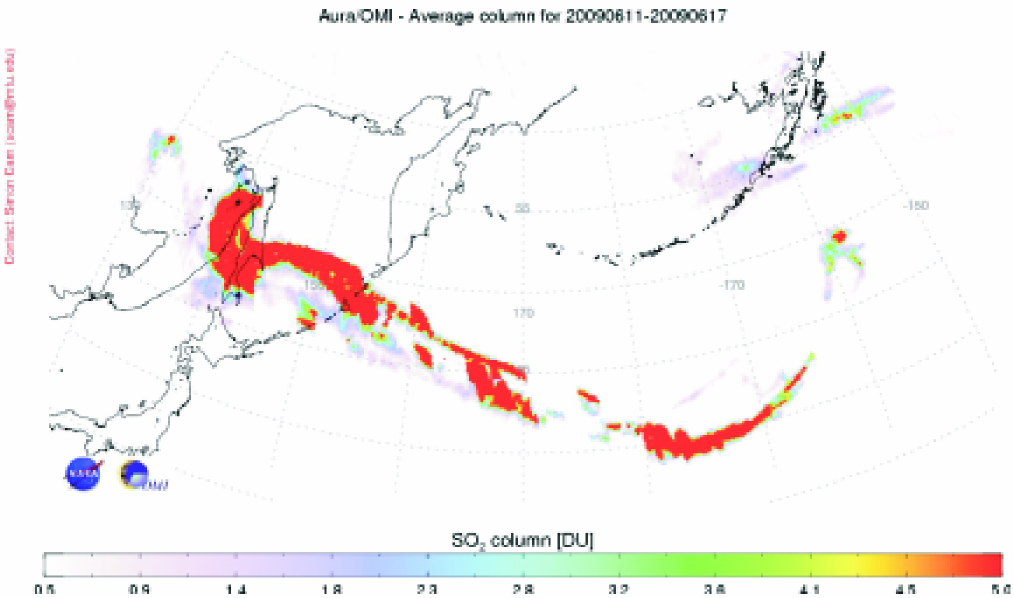

Fig. 13.8: This image shows average column sulfur dioxide concentrations between June 10 and 17, 2009, from the Sarychev Peak Volcano on Matua Island in the northwest Pacific based on data from Ozone Monitoring Instrument (OMI). High concentrations of sulfur dioxide stretched westward from the volcano as far as Sakhalin Island and mainland Russia and eastward as far as Alaska (source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=38975)

Other types of satellite data, such as Synthetic Aperture Radar (SAR), are better suited to look at the changes that often precede an eruption and provide the coverage necessary to see how the ground surface is deforming over a broad region.

Although scientists will continue to use ground-monitoring techniques to keep an eye on the Earth's volcanoes, satellite data will increasingly allow scientists to see 'the big picture' and, as a result, better predict volcanic activity.

13.5.2 Forest Fire Monitoring

Fire is part of the natural reproductive cycle of many forests revitalising growth by opening seeds and releasing nutrients from the soil. However, fires can also spread quickly and threaten settlements and wildlife, eliminate timber supplies and temporarily damage conservation areas. In tropical deciduous forests, fire is a natural phenomenon due to the high levels of water stress during summer. Fires are also deliberately lit by local people to elicit a fresh flush of grass for their cattle during the dry summer months. Forest fires can have large impacts on both ecosystems and economy. Thus the cause of fires may be both intentional and unintentional.

Forest fires have tremendous impacts on the physical environment, including land cover, land use, biodiversity, climate change and forest ecosystem as well as on human health and socio-economic system of the affected countries. The more pronounced consequences of forest fires are their potential effects on climate change. Biomass burning contributes to the global budgets of many radioactively and chemically active gases, such as carbon dioxide, carbon monoxide, tropospheric ozone, etc. It is recognised as a significant global source of emission contributing as much as 40% of gross carbon dioxide and 30% of tropospheric ozone. This has sparked a renewed interest in detection, monitoring and assessment of forest fires.

Traditionally forest fires have been detected using fire lookout towers located at high points in a forested area. Today however advanced forest fire detection systems are based on satellite imagery. AVHRR, MODIS, IRS-WIFS sensors are being used for active forest fire detection.

Remote sensing can be used to detect and monitor forest fires and the regrowth following a fire as a surveillance tool for routine sensing facilitates observing remote and inaccessible areas as well as alerting monitoring agencies to the presence and extent of a fire. NOAA AVHRR thermal data and GOES meteorological data can be used to delineate active fires and remaining 'hot-spots' when optical sensors are hindered by smoke, haze, and /or darkness. Comparing burned areas to active fire areas provides information about the rate and direction of movement of the fire. Remote sensing data can also facilitate route planning for both access to and escape from a fire. Information about the behaviour of the forest after a forest fire event can also be obtained from remote sensing data.

While thermal data is best for detecting and mapping ongoing fires, multispectral (optical and near-infrared) data are preferred for observing stages of growth and phenology in a previous burn area. Moderate spatial coverage, high to moderate resolution and a low turnaround time are required for burn mapping. On the other hand, fire detection and monitoring requires a large spatial coverage, moderate resolution and a very quick turnaround to facilitate response.

India has developed a forest fire response and assessment system, named as INFFRAS (Indian Forest Fire Response and Management System), to facilitate forest fire management (http://applications.nrsc.gov.in/fire/). INFFRAS integrates multisensor satellite data with GIS databases to address forest fire management at following three levels:

- **Pre fire:** Preparatory planning for fire control
- **During fire:** Near real time active fire detection and monitoring and
- **Post fire:** Damage and recovery assessment and mitigation planning

With the advent of a series of satellite onboard, it is possible to detect active fires to a minimum of four times in a day (i.e. MODIS-Terra/Aqua, NOAA-17/ 18, IRS P6) and at least two times during the night by DMSP-OLS (F15 and F16). In an integrated approach, daytime fire signals using MODIS Terra/ Aqua and night-time fire signals using DMSP-OLS are disseminated to the user (State Forest Department), through INFFRAS. Different spatial and temporal satellite data i.e. IRS 1D/P6, MODIS are analysed for fire monitoring and burnt area assessment on the basis of daily fire alert or based on special request from any user and are made available at INFFRAS for the users.

13.5.3 Earthquake Related Studies

Among the natural disasters, earthquakes cause immense damage to life and property. Occurrences of earthquakes are quite uncertain. An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. Remote sensing data can be used for earthquake monitoring, prediction, hazard zonation and damage assessment.

Although researchers relentlessly work on earthquake prediction; operationally earthquakes are difficult to predict or forecast. Researchers have used following information for monitoring and prediction of earthquakes-

- ground movement
- thermal and
- ionspheric changes.

Remote sensing based studies are being attempted to detect thermal anomaly associated with earthquake to demonstrate its potentials in earthquake-related studies. Generally, intensity and magnitude of earthquake is known only after the Earthquake has actually occurred in a region and causes immense destruction and loss of life and property. This requires all time preparedness for the authorities and the people. The use of high resolution satellite data with short revisit satellite imagery plays a vital role in post-earthquake management. The integrated analysis of geologic and seismologic data, field observations, lineament data, derived from satellite radar images, if integrated with historical data on earthquake, demographic data, soil type, soil deformation analysis, etc., would help to generate seismic hazard zonation map of an area. This can help evaluate the potential of occurrences of earthquake in an area enabling pre-earthquake management/engineering practices to be chalked out.

While no earthquakes have been predicted based on remote sensing alone, it has proved to be very useful in detecting active faults and thus delineating these zones for establishing the seismic stations. Today extensive research has resulted in the identification of many precursors to earthquakes. One of the important ones is thermal anomaly, i.e. a sudden rise in land surface temperature (LST) a few days or weeks before the occurrence of the earthquake. Prior to the earthquake various physical and electrical changes along with a change in the thermal regime of the epicentre region occur. This can be detected by space borne sensors, like Advanced Very High Resolution Radiometer (AVHRR) and MODIS.

Remote sensing can thus play an important role in earthquake prediction, seismic micro-zonation and post-earthquake disaster management-related studies. The major limitations of remote sensing based earthquake studies are ascribed to rare validation of satellite based measurement with ground data.

13.5.4 Landslide Studies

Landslide is a downward movement of mass of rock, soil, down a slope. Factors, such as terrain slope, lithology, geological structure, land use, lineament density, geomorphology, etc., can induce a landslide. Landslides can be triggered by rainfall, undercutting of slopes due to flooding or excavation, earthquakes, snowmelt and other natural as well as human-made causes, such as over grazing by cattle, terrain cutting and filling and excessive development. Rainfall increases the pore water pressure decreasing the shear strength of the rock, leading to landslides in an area. In India, most of the landslides occur during rainy season due to heavy downpour in a short period of time. Geoinformatics can be used to prepare landslide inventory, landslide hazard zonation map and for assessment of damages.

Comprehensive landslide inventory is a prerequisite for landslide hazard and risk analysis. A landslide inventory map not only shows the time and date of occurrence but also the types of landslide.

Lidar data have been used to prepare landslide inventory under forest areas in hilly regions and to refine the boundaries of landslides prepared during field investigations. This data is not only useful for mapping old landslides but also can improve field survey based investigations in regions with subdued morphology.

SAR has all weather monitoring ability and the images are useful in identifying critical terrain elements such as faults and slope characteristics. Also subtle movements due to landslides can be picked up from interferograms generated from SAR images.

Very high resolution imagery (QuickBird, IKONOS, CARTOSAT-1 and 2) has become the best option now for landslide mapping, and the numbers of operational sensors with similar characteristics are growing year by year. Other remote sensing approaches of landslide inventory mapping include shaded relief images produced from Light Detection and Ranging (LIDAR) DEM and Synthetic Aperture Radar (SAR) interferometry. In India, different agencies, such as ISRO, DRDO, DST, etc., have prepared landslide hazard zonation maps and landslide information system for different parts of the country utilising geoinformatic technology.

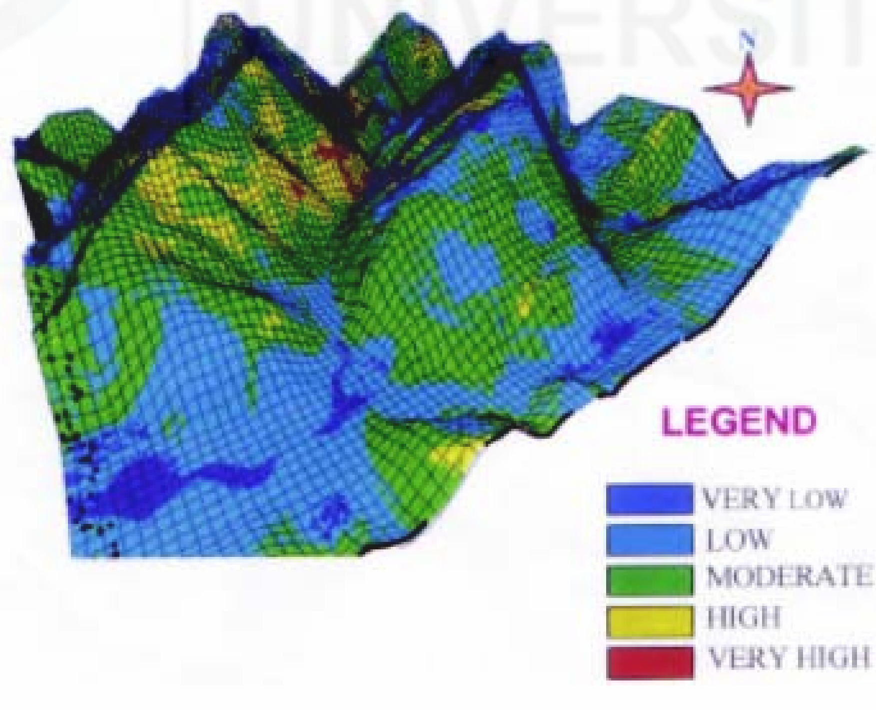

Fig. 13.9: 3D visualisation of landslide hazard zonation map of Kelani area in Uttarakhand (source: www.ias.ac.in/currsci/jul252000/RESEARCH %20COMMUNICATIONS2.pdf)

13.5.5 Monitoring Oil Spills

Petroleum products play an important role in modern society, particularly in the transportation, plastics and the fertilizer industry. There are typically ten to fifteen transfers involved in moving oil from the oil field to the final consumer. Oil spills can occur during oil transportation or storage, and spillage can occur in water, ice or on land. Marine oil spills can be highly dangerous since wind, waves and currents can scatter a large oil spill over a wide area within a short span of time. Thus uncontrolled leakage of oil from and around a well drilling site or a tanker accident as that which happened recently in the Gulf of Mexico in 2010 is a dreaded ecological disaster.

There are many sensors available to detect marine oil spills on various types of water surfaces and multiple sea-states and they can provide the following information for oil spill contingency planning:

- detection, location and spread of oil spill over both large and small areas
- thickness distribution of an oil spill to estimate the quantity of spilled oil
- classification of the oil type in order to estimate environmental damage and to take appropriate response action
- timely and valuable information to assist in response and clean-up operations
- stored and time-stamped, real-time data on any spills and response efforts

Oil spill remote sensing is invaluable in organising cleanup operations and controlling the oil spill response but perhaps most importantly, for the early and rapid detection of the actual oil spills themselves.

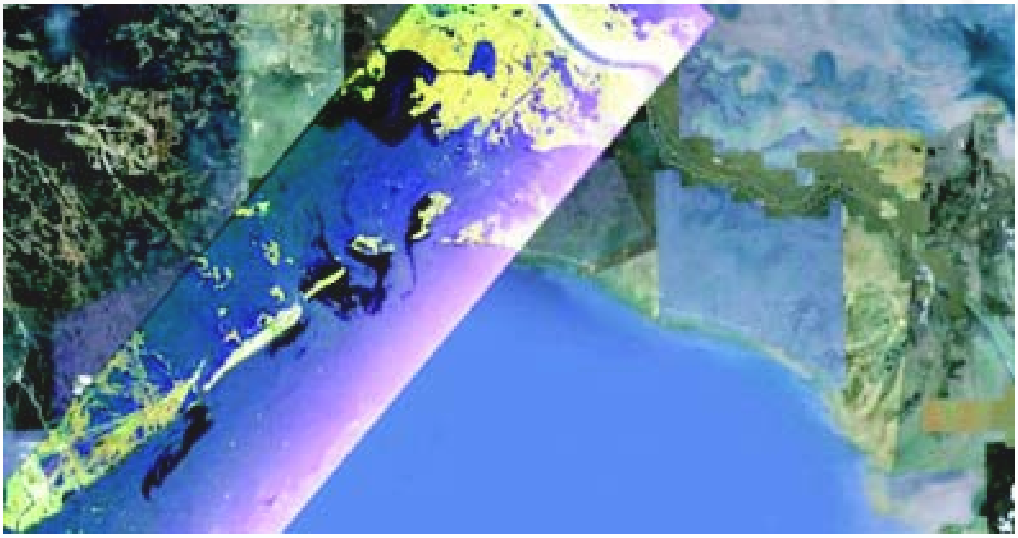

Fig. 13.10: NASA's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) over Gulf of Mexico to image the deepwater horizon oil spill on June 2010 took this image (source: www.nasa.gov/topics/earth/features/oilspill/pia13233.html)

Researchers have used variety of techniques, such as radar, infrared, optical and laser for oil spill detection and monitoring. Radar can be used to detect oil over a large area and at long distances, making it an effective tool for a detection and assessment in determining the possible location of an oil spill. SAR (Synthetic Aperture Radar) and SLAR (Side- Looking Airborne Radar) are the two most common types of radar which can be used for oil spill studies.

Infrared/Ultraviolet (IR/UV) line-scanners capture the infrared and ultraviolet radiation reflected by the sea surface. The ultraviolet images can be overlaid with infrared images to generate an oil spill relative thickness map. UV images are based on the reflected sunlight, and hence cannot operate in the night.

A laser fluorosensor is the most useful and reliable instrument to detect oil on various backgrounds including water, soil, weeds, ice and snow. The disadvantage is that laser fluorosensors cannot measure oil thickness greater than 10-20 microns as the UV laser light is completely absorbed by oil and cannot reach the underlying water.

Optical and multi-spectral imaging systems are widely used in oil spill remote sensing. Visible sensors are useful only for close-range detection and documentation purposes as there are no methods to ensure the positive detection of an oil spill at longer distances.

Satellite remote sensing is most effective when the position of the oil spill is already established. The limitations with using satellite remote sensing are that it has a lower spatial resolution than airborne remote sensing and very few sensors except visible detection and radar can be used on a space-borne platform.

13.6 ACTIVITY

Identify one case study each in the fields of assessment of global climate change, air pollution modeling, oil pollution mitigation, management of cyclones, earthquakes and volcanoes or any other environmental application from research papers (You could access research papers from Google scholar). From the case study assess the following:

- What has been the remote sensing input? Identify the sensor used, its properties and role.
- What has been other in-situ/ancillary data used?
- What have been the possible analytical steps?
- Present the methodology as a flow chart.

13.7 SUMMARY

Geospatial technology today is a very vital tool that has opened new horizons in directly observing atmospheric properties, weather systems, oceanographic conditions, water runoff, natural hazards, etc., enabling global coverage on a daily basis. In this unit, we have studied that:

- Applications such as weather monitoring has brought geospatial technology into our homes. Meteorologists use satellites to track and forecast cyclone behaviour, detect and track storms. The greatest value of meteorological satellites lies in both their real time tracking capabilities and in their acquisition of data helpful in forecasting their future paths.

- Today satellite data is useful for climate research, hurricane/cyclone forecasting, El Nino and La Nina prediction, fisheries management, coral reef research, etc.
- Geoinformatics provides reliable information and is an effective tool for river/flood monitoring. Meteorological satellites also provide the real time rainfall data that is used as an input in the flood forecast models.
- Geoinformatics is used to monitor natural disaster such as volcanic activity, forest fire, earthquakes, landsides, etc., and prepare hazard zonation plan and also enabling disaster management.
- Geoinformatics has also been used for detecting human induced disaster, such as oil spills.

13.8 UNIT END QUESTIONS

Spend 30 mins

1) What according to you have been the benefits of the space program for environment conservation?
2) Highlight the role of geospatial technology in mitigating global climate change.
3) What is the role of geospatial technology in oil spill monitoring, prevention and management?

13.9 REFERENCES

- Miller, G.T. and Spoolman, S. (2007), *Environmental Science*, Thompson, Brooks/Cole, 551p.
- http://applications.nrsc.gov.in/fire.
- http://earthobservatory.nasa.gov/Features/monvoc.
- http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=38975.
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Data from links was retrieved between 29th July to 7th December 2011.

13.10 FURTHER/SUGGESTED READING

- Jensen, J.R. (2008), *Remote Sensing of the Environment: An Earth Resources Perspective*, 2nd Ed., Pearson, 608p.
- Lillesand, T.M., Kiefer, R.W. and Chipman, J.W. (2011), *Remote Sensing and Image Interpretation*, 6th Ed., Wiley India Pvt. Ltd., 772p.
- Roy, P.S. (2000), *Natural Disaster and their mitigation*, Published by Indian Institute of Remote Sensing (IIRS).

- Barry, R.G. and Chorley, R.J. (2003) *Atmosphere, weather and climate*, 8th Ed., Routledge: Taylor and Francis, 472p.

13.11 ANSWERS

Check Your Progress I

1) Atmosphere, hydrosphere and lithosphere.

2) Ozone.

Check Your Progress II

1) Meteorological sensors : High Resolution Infrared Sounder (HIRS), Total Ozone mapping Spectrometer (TOMS), Moderate Resolution Imaging Spectroradiometer (MODIS), Synthetic Aperture Radar (SAR), Advanced High Resolution Radiometer (AVHRR).

2) Geospatial applications associated with the atmosphere are measurement of ozone, prediction of cyclones, measurement of air pollution.

Check Your Progress III

1) Information of location of oil spill, size and extent of the spill, direction and magnitude of oil movement, wind, current and waves are needed for controlling an oil spill.

2)

A	B
Radar images	Used to assess flood extent
Radiometer	Measures sea surface temperature
Scatterometer	Measures sea surface roughness
Radar altimeters	Measures height of the sea surface
Ocean colour monitor	Identifies potential fishing zones

Unit End Questions

1) The answer to this question should provide a brief overview of the various applications in ozone monitoring, climate change studies, monitoring and management of disasters highlighting the sensors used and process in brief. Role of remote sensing, in-situ data collection, modelling should be highlighted.

2) The answer to this question should provide an overview of process of global climate change, its causes and the role of geospatial technology highlighting sensors and the various parameters they measure.

3) This answer should provide an overview of the causes of oil pollution, parameters needed for oil spill detection, role of remote sensing data long with pros and cons of sensors and need for insitu measurements.