# Environmental Hazards and Global Warming

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## 1.1 Introduction

Natural hazards are extreme events and disasters are potential risks to these events. Hazards are defined as phenomena that pose a threat to people, structure, environmental resources and economic assets and which may cause a disaster. The term disaster owes its origin to the French word ‘disastre’ which is the combination of two words ‘des’ meaning ‘bad or evil’ and ‘astre’ meaning a ‘star’. The combined expression is ‘bad or evil star’. Disaster is defined as “… a serious disruption of the functioning of a society, causing widespread human, material, or environmental losses which exceed the ability of the affected society to cope using its own resources.” The United Nations defines disaster as “…the occurrence of a sudden or major misfortune which disrupts the basic fabric and normal functioning of a society (or community). It is an event or a series of events which gives rise to casualties and/or loss of property, infrastructure, essential services or means of livelihood on a scale that is beyond the normal capacity of the affected communities to cope with unaided. Disaster is sometimes also used to describe a “catastrophic situation in which the normal patterns of life (or eco-systems) have been disrupted and extraordinary emergency interventions are required to save and preserve human lives and / or the environment”.

Disaster mitigation is a “collective term used to encompass all activities undertaken in anticipation of the occurrence of a potentially disastrous event including preparedness and long term risk reduction measures (UNDP, 1994)”. Mitigation involves reducing the actual or probable effects of extreme disaster on man and environment.

***“Today, about three-quarters of all natural disasters are related to weather, climate and water and their extremes…. Progress in the meteorological and hydrological sciences shows that the impacts of natural hazards can be reduced through prevention and preparedness,”***

***“In order to be prepared and to take action to meet the risk posed by disasters, it is imperative to be informed of the risks involved, and of possible options to mitigate the risk.”***

***“It is WMO's ambition to halve the number of deaths due to natural disasters of***

***meteorological, hydrological and climatic origin over the next 15 years."*** **Michel Jarraud,** Secretary-General of WMO, Message on the occasion of World Water Day on 22 March 2004.

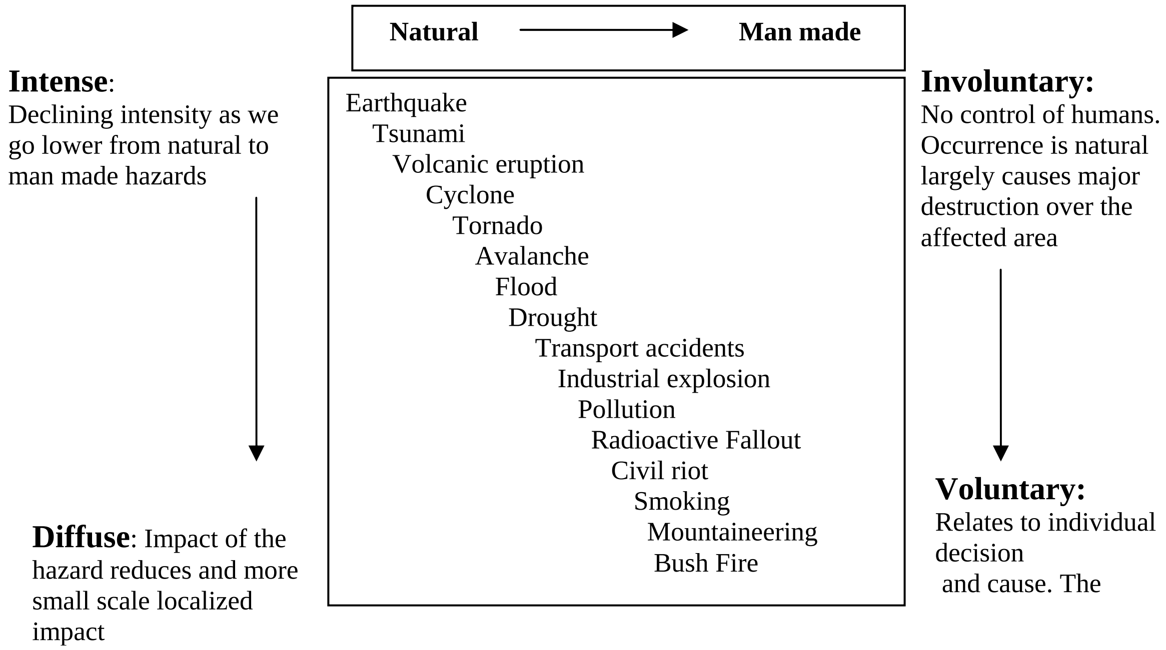
People face complex combination of vulnerability and hazard. A disaster is a result of the interaction of both if, there are no hazards but there is vulnerable population, if there is hazard but no vulnerable population there is any risk. Disasters claim a large proportion of life and property loss all over the world. Disaster can simply be defined as 'unfortunate' or 'adverse event'.

The Indian subcontinent has a highly diversified range of natural features. The Himalayas, which are the young fold mountain and where the phenomena of stress release is very common together with the uncertain monsoon winds make the region highly prone to natural disasters. The region being the most populous in the world further adds to the damage caused by the natural disasters.

The United Nations General Assembly adopted resolution 42/169 in December 1987 and subsequent resolutions which proclaimed the 1990's as the 'International Decade for Natural Disaster Reduction' (IDNDR, 1989). Resolutions 43/202 (1988) and 44/236 (1989) is illustrated by the statement that purpose of IDNDR is to:
"Introduce through concerted international actions, especially in developing countries, loss of life, property damage and social economic disruption caused by natural disasters such as earthquakes, windstorms (Cyclones, hurricanes, tornadoes, typhoons), tsunamis, floods, landslides, volcanic eruptions, wild fires, grasshopper and locust infections, drought and desertification and other calamities of natural origin."

The term environmental hazard has the advantage of including a wide variety of hazard types ranging from 'natural' (geophysical) events, through 'technological' (man-made) events to 'social' (human behaviour) events (Fig 1)  The extent to which hazards are voluntary or involuntary is particularly important. The degree of individual human responsibility for disaster increases greatly from accidental  geophysical hazards like earthquakes, tsunamis etc to the largely self induced social hazards like smoking mountaineering etc

**Fig 1 -A General spectrum of environmental hazards from geophysical to human activities**



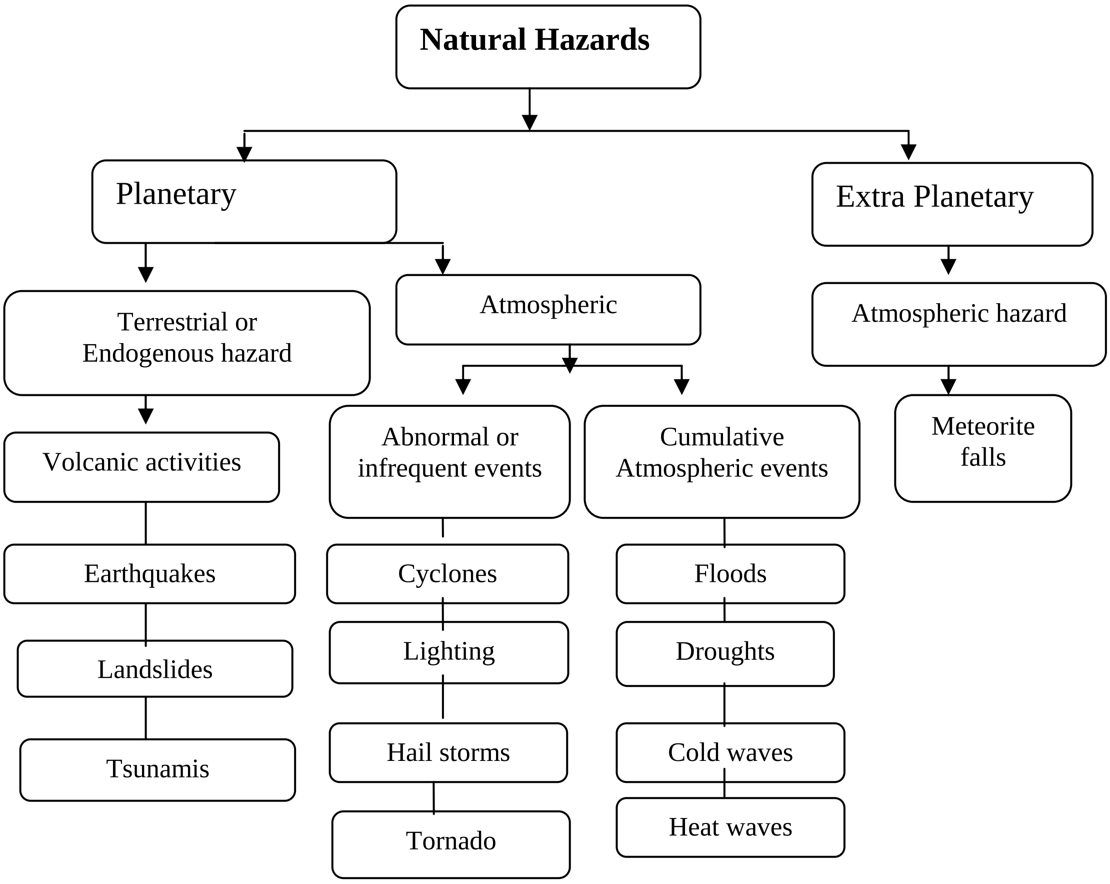

*Source: Adapted from Smith, Keith, (3rd ed), 2001*

### 1.2 Various kinds of Natural Hazards

Disasters can be broadly divided into two categories of natural and man-made. Natural Disasters are those which occur in nature, either of geological origin in form of terrestrial origin, climatic/meteorological origin or of atmospheric origin and extra planetary (Fig 2). Man-made or man induced disasters are largely either in form of physical, chemical or biological; most of them are part of environmental disasters like pollution, deforestation and road construction leading to landslides, desertification, other form of environmental disaster are pest infection. Epidemics are caused by poor living conditions, either caused by water borne diseases or plague caused by rodents etc. Industrial accidents constitute a big portion of man made disasters whether it is Bhopal gas tragedy in India or Chernobyl nuclear disaster in Russia.

Drought, floods, cyclones, landslides and earthquakes are the major types of disaster phenomena occurring in the region, and the recent in the list is tsunamis. Almost all parts of India experience one or more of these disasters. Based on the frequency of occurrence and vulnerability to natural disasters, the entire country may be classified into three broad categories. The first is the Himalayan region spreading over 5,00,000 square km. This region is prone mainly to Earthquakes, Landslides, Avalanche and Bush fire. The second category is the north and central Indian Plains. This region has some great river systems and a rich source of water for drinking and irrigation. However, these rivers during the monsoon period usually carry water in excess to their capacity causing flood phenomena. The same region also experiences droughts when the rainfall is less. The third category is the coastline of India which is prone to devastating cyclonic winds emerging in the oceans and tsunami waves. Under NRDMS Programme, thrust is being given to incorporate studies on landslides, drought and flood.

**Fig 2- Major Natural Hazards**

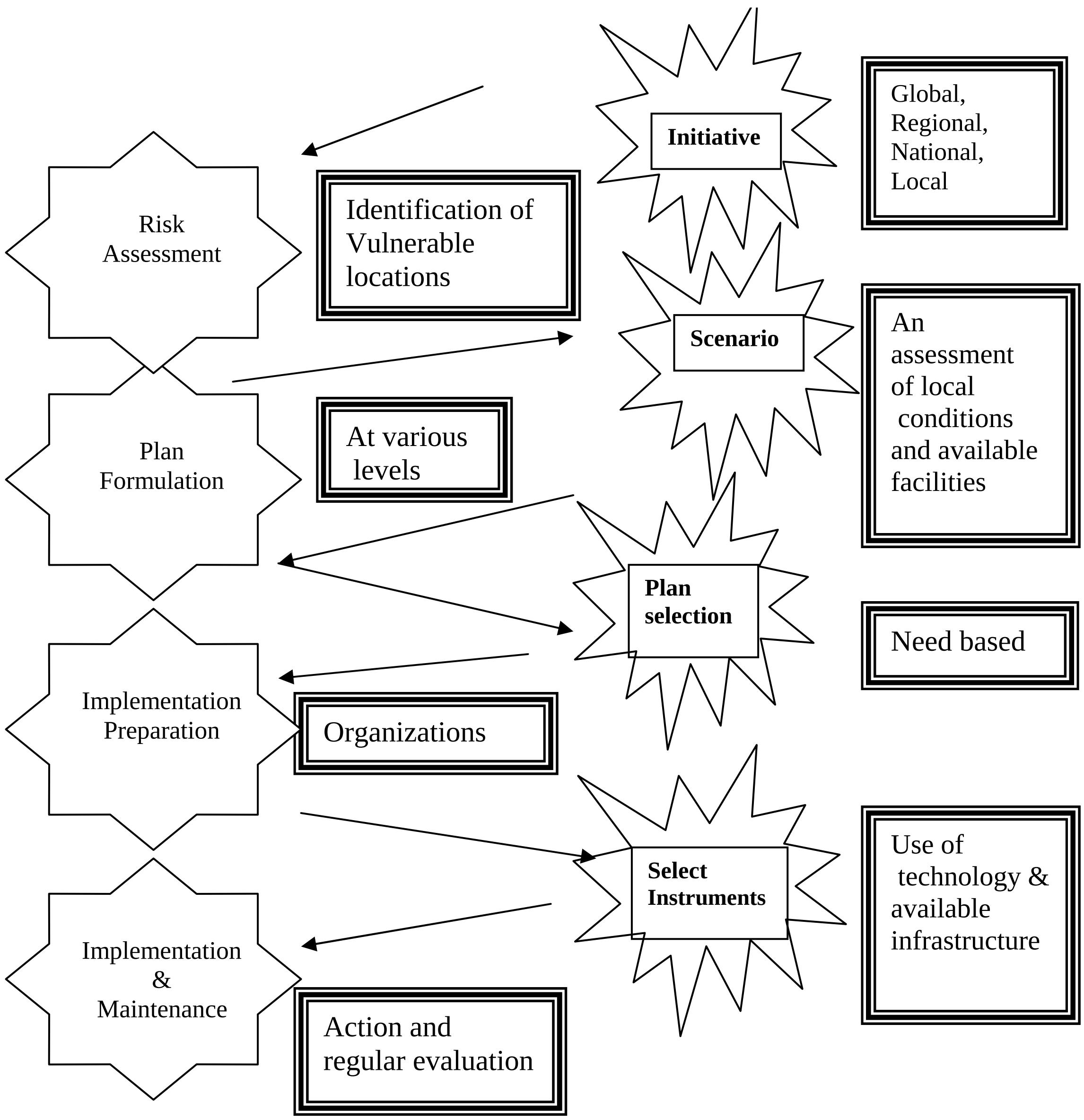



**Source: Illustration by Author**

### 1.3 Natural Disaster Mitigation

Generally mitigation process is described in four basic steps that are risk analysis, plan formulation, preparation for implementation and implementation and maintenance. The disaster mitigation process is interactive, running through successive steps (Fig 3). *Risk analysis* provides a basis for different options of planned interventions to reduce the risks from natural hazards on settlements and for preparation of the risk profile of a settlement, area or region.

**Fig 3 Disaster Mitigation Process**




Source: Illustration by Author

These processes consist of successive steps of hazard assessment, vulnerability analysis, risk assessment and risk appraisal. *Plan formulation is* to improve the risk of profile a settlement. It does not limit itself to physical planning measures only but extends to engineering, functional and adaptation to institutional measures as well. Disaster mitigation planning needs to be comprehensive and will have to review a range of alternative strategies against clearly laid down criteria so that the objectives can be met and performance evaluated. The selection of the plan for implementation is a policy decision and requires the involvement of decision makers. There is need is for suitable legislative and insurance programs for disaster prone areas. The preparation of the *implementation phase* is the next step. The instruments of implementation are identified and attuned to the plan proposals and local conditions. These may relate to legal, financial, land tenure and community participation aspects of the plan implementation. The final step is implementation and maintenance. This applies itself to details of project management, phasing, resources, maintenance aspects etc.

Amongst the hazards, floods have occurred maximum number of times, i.e. 888, whereas incidents of major avalanches and landslides have been least, at 173, in the last decade globally. A brief review of the major natural hazards, number of episodes, people affected and financial losses in million dollars between 1991-2000 is shown in Table 1

**Table 1- Numbers and Impact major natural hazards (1991- 2000)**

| **Disaster** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Avalanches/ Landslides** | 11 | 14 | 22 | 8 | 15 | 24 | 13 | 22 | 15 | 29 | **173** |
| Life loss | 781 | 1,070 | 1,548 | 280 | 1,497 | 1,129 | 801 | 994 | 351 | 1,099 | **9,550** |
| People affected (millions) | 89 | 79 | 80 | 298 | 1,122 | 9 | 34 | 214 | 15 | 208 | **2,150** |
| Loss in US$ (million) | 19.4 | 531.5 | 845.8 | 72. 3 | 11.6 | 0 | 17.4 | 0 | 0 | 168.4 | **1,666.5** |
| **Drought / Famines** | 19 | 30 | 13 | 9 | 15 | 9 | 18 | 34 | 30 | 46 | **223** |
| Life loss | 2,632 | 2,571 | 0 | 0 | 54,000 | 54,000 | 54,530 | 57,875 | 54,029 | 370 | **2,80,007** |
| People affected | 27,118 | 39,944 | 12,132 | 15,515 | 30,431 | 8,536 | 8,450 | 24,647 | 38,372 | 1,76,457 | **3,81,602** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (millions) | | | | | | | | | | | |
| Loss in US$ (millions) | 2,612.0 | 3,066.4 | 1,315.2 | 1,419.6 | 6,527.5 | 1,320.0 | 437.6 | 475.9 | 7056.5 | 6305.1 | **3,05,357** |
| **Floods** | 82 | 57 | 82 | 80 | 86 | 69 | 77 | 90 | 112 | 153 | **888** |
| Life loss | 5,920 | 5,367 | 5,930 | 6,504 | 7,25 | 8,040 | 6,602 | 1,186 | 34,366 | 6,307 | **97,747** |
| People affected (millions) | 2,27,529 | 23,421 | 1,49,341 | 1,29,688 | 1,84,726 | 1,80,113 | 43,700 | 2,91,725 | 1,50,167 | 62,111 | **1,442,521** |
| Loss in US$ (millions) | 90,684.6 | 6,892.7 | 29,083.4 | 22,315.7 | 29,019.7 | 26,045.8 | 12,432.0 | 31,961.0 | 13,712.9 | 10,670.0 | **2,72,818.9** |
| **Earthquake** | 26 | 24 | 14 | 22 | 25 | 11 | 14 | 16 | 33 | 26 | **211** |
| Life loss | 2,863 | 3,936 | 10,113 | 1,242 | 7,966 | 582 | 3,076 | 7,412 | 21,870 | 189 | **59,249** |
| People affected (millions) | 1,391 | 787 | 270 | 731 | 3,029 | 1,996 | 593 | 1,878 | 3,893 | 2,455 | **17,023** |
| Loss in US$ (millions) | 2,912 | 804 | 2,294 | 44,222 | 1,50,598 | 581 | 5,208 | 400 | 32,435 | 142 | **2,39,601** |

*Source: World Disaster Report, International Federation of Red Cross, 2001*

### 1.4 Major Environmental Hazards in India

Indian sub continent experiences various environmental hazards whether they are earthquakes, landslides, cyclones, tsunamis, floods and droughts etc. Interestingly, many zones are multi hazard prone like north eastern hills which experience earthquakes, landslides and floods; northern and western Himalayas witness landslides, earthquakes, cloud bursts causing flash floods and avalanches. Coastal areas are affected by cyclones, floods, and tsunamis, and adjacent to coastal zones in Andhra Pradesh there are zones of severe droughts in Rayalseema and Telengana region. The desert areas of Rajasthan experience drought and desertification; while neighboring semi arid areas occasionally witness flash floods because of sudden rains along the canal areas, some areas experiencing water logging and salination and alkanisation of soil.

**2.0 Cyclone**

A "Cyclonic Storm" or a "Cyclone" is an intense vortex or a whirl in the atmosphere with very strong winds circulating around it in anti-clockwise direction in the Northern Hemisphere and in clockwise direction in the Southern Hemisphere.

The word "Cyclone" is derived from the Greek, word "Cyclos" or “Kyclos” meaning the coils of a snake. Henry Peddington, to whom the tropical storms in the Bay of Bengal and in the Arabian Sea appeared like the coiled serpents of the sea, named these storms as "Cyclones".

Cyclones are intense low pressure areas, from the centre of which pressure increases outwards. The amount of the pressure drop in the centre and the rate at which it increases outwards gives the intensity of the cyclones and the strength of winds. Sudden, unpredictable, violent storms which bring widespread devastation to coastal lines and islands lying in their erratic paths is experienced almost every year. They are very dangerous as they are coupled with high speed winds measuring more than 120 kmph, heavy rainfall and storm surges. A full-grown cyclone is a violent whirl in the atmosphere 150 to 1000 km across and 10 to 15 km high. Gale winds of 150 to 250 kmph or more spiral around the center of very low pressure area with 30 to 100 hPa below the normal sea level pressure. The central calm region of the storm is called the "Eye". The diameter of the eye varies between 30 and 50 km and is a region free of clouds and has light winds. Around this calm and clear eye, there is the "Wall Cloud Region" of the storm about 50 km in extent, where the gale winds, thick clouds with torrential rain, thunder and lightning prevail. Away from the "Wall Cloud Region", the wind speed gradually decreases. However, in severe cyclonic storms, wind speeds of 50 to 60 kmph can occur even at a distance of 600 km from the storm centre. The gales give rise to a confused sea with waves as high as 20 metres, swells that travel a thousand miles. Torrential rains, occasional thunder and lightning flashes join these under an overcast black canopy. Through these churned chaotic sea and atmosphere, the cyclone moves 300 to 500 km in a day to hit or skirt along a coast, bringing with it storm surges as high as 3 to 12 metres, as if splashing a part of the sea sometimes up to 30 km inland leaving behind death and destructions.

### 2.1 Cyclones in the Indian Seas

Cyclones form in certain favourable atmospheric and oceanic conditions. There are marked seasonal variations in their places of origin, tracks and attainment of intensities. These behaviors help in predicting their movements.

Cyclones affect both the Bay of Bengal and the Arabian Sea. They are rare in Bay of Bengal from January to March. Isolated ones forming in the south Bay of Bengal move west north westwards and hit Tamil Nadu and Sri Lanka coasts. In April and May, these form in the south and adjoining central Bay of Bengal and move initially northwest, north and then recurve to the northeast striking the Arakan coasts in April and Andhra-Orissa-West Bengal-Bangladesh coasts in May. Most of the monsoon (June - September) storms develop in the central and in the north Bay of Bengal and move west-north-westwards affecting Andhra-Orissa-West Bengal coasts. Post monsoon (October-December) storms form mostly in the south and the central Bay, recurve between $15^0$ and $18^O$ N affecting Tamil Nadu-Andhra Orissa-West Bengal-Bangladesh coasts.

Cyclones do not form in Arabian Sea during the months of January, February and March and are rare in April, July, August and September. They generally form in southeast Arabian Sea and adjoining central Arabian Sea in the months of May, October, November and December and in east central Arabian Sea in the month of June. Some of the cyclones that originate in the Bay of Bengal travel across the peninsula, weaken and emerge into Arabian Sea as low pressure areas. These may again intensify into cyclonic storms. Most of the storms in Arabian Sea move in west-north-westerly direction towards Arabian Coast in the month of May and in a northerly direction towards Gujarat Coast in the month of June. In other months, they generally move northwest north and then recurve northeast affecting Gujarat-Maharashtra coasts; a few, however, also move west north westwards towards Arabian coast.

Pre and Post-monsoon storms are more violent than the storms of the monsoon season. Life span of a severe cyclonic storm in the Indian seas averages about 4 days from the time it forms until the time it enters the land.

### 2.2 Destruction caused by Cyclones

There are three elements associated with a cyclone, which cause destruction. They are explained in the following paragraphs:

1. Cyclones are associated with high-pressure gradients and consequent strong winds. These, in turn, generate storm surges. A storm surge is an abnormal rise of sea level near the coast caused by a severe tropical cyclone; as a result, sea water inundates low lying areas of coastal regions drowning human beings and livestock, eroding beaches and embankments, destroying vegetation and reducing soil fertility.
2. Very strong winds may damage installations, dwellings, communication systems, trees etc. resulting in loss of life and property.
3. Heavy and prolonged rains due to cyclones may cause river floods and submergence of low lying areas by rain causing loss of life and property. Floods and coastal inundation due to storm surges pollute drinking water sources causing outbreak of epidemics.

It may be mentioned that all the three factors mentioned above occur simultaneously and, therefore, relief operations for distress mitigation become difficult. So it is imperative that advance action is taken for relief measures before the commencement of adverse weather conditions due to cyclones.

The most destructive element associated with an intense cyclone is storm surge. Past history indicates that loss of life is significant when surge magnitude is 3 metres or more and catastrophic when 5 metres and above.

**2.3 Effective Cyclone Disaster Prevention and Mitigation Plan requires:**

- A Cyclone Forecast and Warning Service.
- Rapid dissemination of warnings to the Government Agencies, marine interests like the ports, fisheries and shipping and to general public.
- Organizations to construct Cyclone Shelters in the cyclone-prone areas and ready machinery for evacuation of people to safer areas.
- Community preparedness at all levels to meet the exigencies.

Tropical cyclones, or typhoons, are common in the Asia-Pacific region. They occur most frequently over the north-west Pacific, just east of the Philippines, during June and November with an average of 30 typhoons a year, i.e. about 38 per cent of the world total (ESCAP, *Economic and Social Commission for Asia and the Pacific, 1995a*). Tropical cyclones usually form over the southern end of the Bay of Bengal during April–December and then move to the east coast of India and Bangladesh causing severe flooding and often devastating tidal surges. The cyclones generated in the South Pacific Ocean frequently cause devastation in small island countries such as Fiji, Tonga, Vanuatu, Solomon Islands and Samoa. Overall, the Philippines, Bangladesh and Vietnam suffer most frequently from major events.

## 2.4 Cyclone Operation in India

For cyclone forecast and advance warning, Government has strengthened the Meteorological Department, by providing Cyclone Surveillance Radars at Kolkata, Paradip, Visakhapatnam, Machilipatnam, Chennai and Karaikal in the east coast and at Cochin, Goa, Mumbai and Bhuj in the west coast. Satellite picture receiving (APT -Automatic Picture Transmission) equipments at Delhi, Mumbai, Pune, Chennai, Visakhapatnam, Kolkata and Guwahati are receiving satellite pictures of the cyclones from the polar-orbiting satellites of the U.S.A. and Russia since April 1982. An A.V.H.R.R. (Advance Very High Resolution Radiometer) ground receiving equipment is operative at New Delhi. At this centre, Very High Resolution Cloud pictures (Resolution 1.1 km) in 5 channels as also T.I.P. data (Tiros Information Processor) are being regularly received and are being archived in Magnetic Tapes. Hard copies of the pictures in 2 or 3 channels are being obtained regularly. Distinct advantage of these pictures is due to their very High Resolution in all the 5 channels. Further improvements in the cyclone tracking and forecasting have taken place after the meteorological application programme of the Indian Geo-Stationary Satellite INSAT-IB has become operational since October 1983. Monitoring of the cyclone by taking hourly pictures has helped the forecaster to improve his skill in issuing the timely warnings to the public. Satellite pictures received by the Meteorological Data Utilisation Centre (M.D.U.C.) at New Delhi are further disseminated to all the forecasting Offices through Radio Facsimile.

Cyclone operations are being done by the Meteorological Department through the Area Cyclone Warning Centres (ACWC) and the Cyclone Warning Centres (CWC). ACWC at Kolkata and Chennai and the CWC at Bhubaneswar and Visakhapatnam are responsible for cyclone forecasting in the Bay of Bengal, ACWC at Chennai and Mumbai and CWC at Ahemdabad are responsible for the cyclones in the Arabian Sea - the National Forecast Centre or the Weather Centre at Pune being the coordinator. Computerized Operational

Advisory Forecasts on cyclone movements are issued by the Numerical Weather Prediction (NWP) division of the Department at the H.Q. Office at New Delhi. Storm surge advisories are being issued to the ACWC/CWC by the Northern Hemispheric Analysis Centre (NHAC) at the H.Q. Office at New Delhi. Researches on scientific and operational aspects of Cyclones are being carried out at the Cyclone Warning Research Centre (CWRC) at Chennai. Specialized researches on storm surges relating to surge height to storm intensity are done at the H.Q. Office at New Delhi.

It may be mentioned here that with the present knowledge about the cyclones and with the available aids, the average error in the predictions of the storm centre for a 24-hour forecast is about 200 km.

Cyclone warnings in appropriate formats are being disseminated to the various warnees. Cyclone warnings issued to the Chief Secretaries, the Relief Commissioners and the District Collectors of the maritime states are the very basic information for cyclone distress prevention and mitigation. These are disseminated under "Two Stage Warning Scheme" i.e., in two stages whenever any coastal belt is expected to experience heavy rains, gales and tidal waves in association with a cyclonic storm or depression expected to intensify into a cyclonic storm. The first stage warning known as the "Cyclone Alert" is issued 48 hours in advance of the expected commencement of the adverse weather over the coastal areas. The second stage warning known as the "Cyclone Warning" is issued 24 hours in advance. Both cyclone "Alert" and "Warning" messages are passed to the AIR (All India Radio) stations for repeated broadcast. However, they are requested to broadcast cyclone warnings at hourly or half-hourly intervals, when the cyclone is nearer to the coast. It will be seen from the table that for dissemination of cyclone warnings, the Meteorological Department has to depend mostly on the telecommunication channels of the Post and Telegraph Department consisting of landline telegrams, tele-printer, telex, telephone, etc. Indian Meteorological Department has been including some of the vital information like port signal advices in the cyclone warning bulletin issued to the AIR. Concerned warnees have also been advised to monitor the cyclone-warning bulletin on the AIR during cyclone seasons, which would help them to take appropriate action even in the case of not receiving the addressed warnings due to delay or failure of communications. During 1987, INSAT based Cyclone Warning Dissemination System (CWDS) for south Andhra and north Tamil Nadu coasts was made operational, which is capable of circumventing failure of traditional communication Systems. Under this scheme, the cyclone warnings are directly sent to the users through INSAT. Such facilities have now been extended to all other cyclone prone areas.

**2.5 Disaster Prevention and Preparedness**

In 1969, the Govt. of India suggested to the governments of the maritime states to set up "Cyclone Distress Mitigation Committee" (CDMC) in the respective states with the objective of preventing loss of life and minimising damage to properties. CDMCs are to plan the communication systems in the state for quick dissemination of meteorological warnings and prevention measures. Prevention measures include construction of storm shelters, connecting roads for evacuation of people, construction of wind breaks, dykes, bunds, flood storage reservoirs, afforestation along the coastal belts and improvement of drainage facilities. An advance warning will not be effective unless the public is enlightened about the destructive features and the actions to be taken by them to avoid sufferings. CDMCs have also, therefore, programmes for generating public awareness through information pamphlets, brochures, audiovisual materials, cyclone preparedness meetings, talks and discussions over the radio and television.

**3.0 Tsunami**

Tsunami is a wave generated by seismic activity that is potentially the most catastrophic of all ocean waves. They are also called seismic sea waves, or erroneously sized tidal waves. Barely discernible in the open ocean, the amplitude of a tsunami may increase greatly as it approaches shallow coastal waters. Tsunami is a Japanese word meaning “harbour wave”. The pronunciation for tsunami is "soo-nah-mee", and comes from Japanese tsu (port) + nami (wave). It is generated by tectonic displacement a volcano, landslide or of the seafloor, which in turn causes a sudden displacement of the water above and the formation of a small group of water waves having wavelength equal to the water depth (up to several thousand meters) at the point of origin. Sea water is displaced into violent motion and swells up, ultimately breaking over land with great destructive power devastating to low-lying coastal areas.

Tsunamis affect many of the coastal areas of the region, including those of Japan, Indonesia and the Philippines. The infamous Krakatao volcanic eruption during 1883 in Sunda Straits, Indonesia, generated a 35 metre high tsunami which caused 36,000 deaths and the tsunami of 17 August 1976 in the Moro Gulf area of the Philippines claimed another 8,000 lives

(*ESCAP*, *1995a*). In the Indian Ocean region, more recently, the tsunami of 26th December 2004 caused the death of over 270,000 people in 11 countries in Asia and Africa.

**3.1 Approaches toward Tsunami Safety Measures In Coastal Areas**

**3.1 a) General Measures**

Adoption of integrated multi-hazard approach with emphasis on cyclone and tsunami risk mitigation in coastal areas includes implementation of early warning system for cyclones and tsunamis, stream lining relief distribution system in disaster affected areas, design, practice and implementation of evacuation plans with emphasis on self reliance for sustenance with the locals (coastal community) and planning for reconstruction and rehabilitation. Emphasis on mental health and to socio-psychological issues should be accorded in every plan. Identification and strengthening of existing academic centers in order to improve disaster prevention, reduction and mitigation capabilities and capacity building programmes needs to be taken up on priority basis, public awareness programmes, enhancing capabilities of the institutes working in field of disaster mitigation and management.

**3.1 b) Specific Measures**

(i) Structural measures including:

- Construction of cyclone shelters, plantation of mangroves and coastal forests along the coast line;
- Development of a network of local knowledge centers (rural/urban) along the coast lines to provide necessary training and emergency communication during crisis time (e.g. centers developed by M.S. Swaminathan Foundation in Pondicherry);
- Construction of location specific sea walls and coral reefs in consultation with experts;
- Development of break waters along the coast to provide necessary cushion against cyclone and tsunami hazards;
- Development of tsunami detection, forecasting and warning dissemination centres;

- Development of a “Bio-Shield” - a narrow strip of land along coastline. Permanent structures should come up in this zone with strict implementation of suggested norms. Bio-Shield can be developed as coastal zone disaster management sanctuary, which must have thick plantation and public spaces for public awareness, dissemination and demonstration;
- Identification of vulnerable structures and appropriate retrofitting for tsunami/cyclone resistance of all such buildings as well as appropriate planning, designing, construction of new facilities like critical infrastructures e.g. power stations, warehouses, oil and other storage tanks etc. located along the coastline, all other infrastructure facilities located in the coastal areas, public buildings and private houses, all marine structures, construction and maintenance of national and state highways and other coastal roads.

(ii) Non-Structural Measures including:

- Strict implementation of the coastal zone regulations (within 500 m of the high tide line with elevation of less than 10 m above m.s.l.). A proposed Damage Risk Zone classification on sea coast for consideration, for e.g., Sea Coasts 0-1 m above high tide level (Very High Damage Risk Zone); 1-3 m above high tide level (High Damage Risk Zone); 3-5 m above high tide level (Moderate Damage Risk Zone); 5-10 m above high tide level (Low Damage Risk Zone); 10 m or more above high tide level (No Damage Risk Zone).
- Mapping the coastal area for multiple hazards, vulnerability and risk analysis upto taluka/ village level. Need for development of Disaster Information Management System (DIMS) in all the coastal states.
- Aggressive capacity building requirements for the local people and the administration for facing the disasters in wake of tsunami and cyclone.
- Developing tools and techniques for risk transfer in highly vulnerable areas.
- Launching a series of public awareness campaign throughout the coastal area by various means including AIR, Doordarshan & other media.
- Training of local administration in forecasting warning dissemination and evacuation techniques.
- Awareness generation and training among the fishermen, coast guards, officials from fisheries department and port authorities and local district

officials etc., in connection with evacuation and post tsunami storm surge management activities. Regular drills should be conducted to test the efficacy of the DM plans.

- Studies focusing on the tsunami risk in India may be taken under Natural Calamity Relief Management project.

**3.1 c) Actions Required in Coastal Areas for Protection against Tsunami / cyclone mitigation**

To achieve satisfactory level of disaster mitigation in coastal areas, following activities need to be carried out.

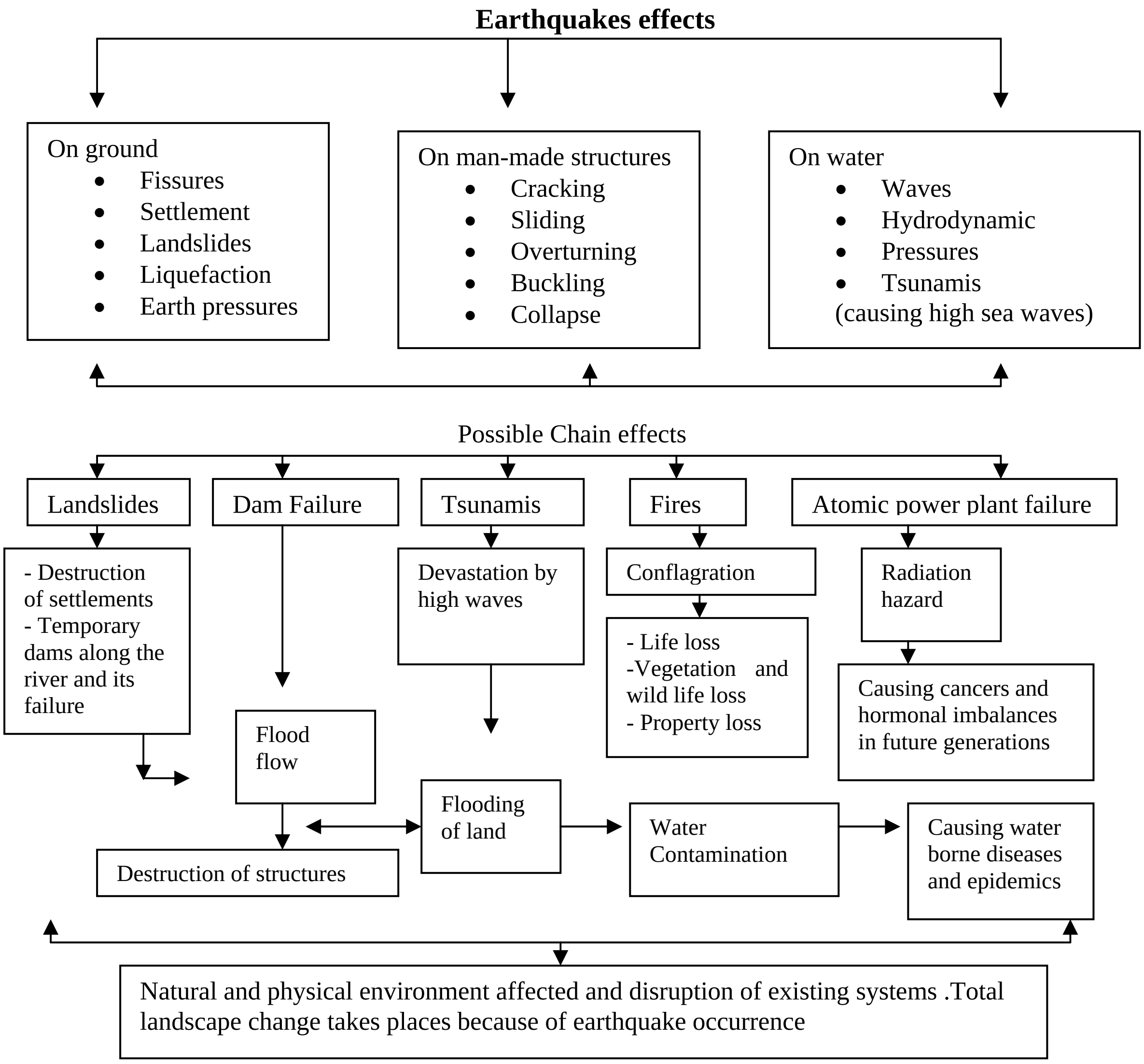
- Revision of Coastal Zone Regulation Act in wake of tsunami storm surge hazards and strict implementation of the same. This responsibility may be given to respective state disaster management authorities. A special task force for this purpose may be constituted comprising the representatives from various departments of the government and other relevant organizations (e.g. Departments of Forestry, Fisheries, Soil Conservation, Town and Country Planning Organization, Navy, Coast Guard, IMD, ISRO/DOS etc.).
- A state of the art EOC may be established with the authority of monitoring disaster watch (bay watch) safety measures along important beaches in the country, providing round the clock monitoring, warning, lifeguard facilities & creation of website for missing personnel etc.
- Organization of sensitization workshops on cyclone/tsunami risk mitigation in various states for senior bureaucrats / politicians for these states.
- Organizing drills on regular basis to check the viability of all plans and to check the readiness of all concerned. Training of professionals, policy planners and others involved with disaster mitigation and management programmes in the states.
- Retrofitting of important buildings like fire stations, police stations, army structures, hospitals; VIP residences, offices, railways, airport; schools/colleges; hazardous industries; other critical structures (i.e. power stations, warehouses, oil and other storage tanks etc)

- Designing incentives: Providing legislative back up to encourage people to adopt cyclone, tsunami resistant features in their homes e.g. tax rebate in terms of house tax and/or income tax and developing public-private partnerships.

**4.0 Earthquake**

Earthquakes are caused by sudden movement of the Earth's lithosphere (its crust and upper mantle). An earthquake releases the built-up stress within rocks along geologic faults or by the movement of magma in volcanic areas. They are usually followed by aftershocks. It is sudden shift of earth’s crust below or at surface that results in ground vibration and potential collapse of buildings and possible destruction of life and property if the quake is of sufficient magnitude. Earthquakes are considered to one of the most disastrous phenomenon, is usually sudden with no or little warning. Earthquakes are multi dimensional features which results in some direct and chain effects over the occurrence area the effects are felt over ground, water and man- made structures. There are possible chain reactions which causes other hazards like landslides, Tsunamis, dam failure etc. (Fig 4).

**Fig 4 - Direct and Chain effects of Earthquakes**




**Source: Illustration by Author**

## 4.1 Earthquake Zones in India

Based on seismic data and different geological and geophysical parameters, the country is divided into five seismic zones. Of the five zones, zone one is least seismic activity where as zone five shows maximum seismic activity. The entire north eastern region falls in zone five. In fact in the last 100 years, as much as five major earthquakes with a magnitude of 7.0 or above on Richter scale occurred in this region - Assam in July 1918, July 1930 and October

1943, Arunachal Pradesh-China border in August 1950 and Manipur-Myanmar border in August 1988.

Other states in this zone are Jammu & Kashmir, Himachal Pradesh, Uttrakhand, Rann of Kutch in Gujarat, northern Bihar and Andaman & Nicobar islands. The major reason, especially for the northern states, is that there is young fold Mountain range (Himalayan range), which frequently witnesses tectonic activities/ movements. The zone four includes states of Sikkim, Delhi, parts of Jammu & Kashmir, Himachal Pradesh, Bihar, northern parts of UP, parts of Gujarat and small parts of Maharashtra near western coast. In the last 15 years, number of cyclones have occurred in Uttrakhand in October 1991, Latur-Osmanabad in Maharashtra in September 1993, Jabalpur (MP) in May 1997, Chamoli in March 1999 and most recent in Bhuj in Gujarat in 2001. They were all above 6 on the Richter scale. Zone three comprises states of Kerala, Goa, Lakshadweep, and remaining parts of Uttar Pradesh, West Bengal, parts of Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Orissa, Andhra Pradesh and Karnataka. The remaining states with lesser activity fall in zones one and two.

### 4.2 Earthquake Disaster Mitigation Programme

a) **Preventive Phase before Disaster** include i) Preparation of earthquake categories and epicentral & geologic-tectonic maps; ii) Analysis of seismic risk and seismic zoning for general purposes; iii) Development of anti-seismic codes of design and construction of various structures; iv) Education & training of engineer and architects in earthquake engineering principles and use of codes; v) Promulgation of laws and bye-laws for providing earthquake resistance features in all new construction according to codes; vi) Development of methods for seismic strengthening of existing structures, particularly in the structures considered critical for the community; vii) Development of simple methods for upgrading the seismic resistance of the traditional non-engineered construction and their dissemination to the common builders and owners by mass communication techniques, demonstration, extension work etc.; viii) Earthquake assurance for the buildings and structures to reduce the economic impact on individuals; and ix) Installation of seismological observations for monitoring seismic activity with a variety of instruments capable of recording and locating all earthquakes bigger than a selected magnitude.

The construction of dams in some of the tectonically active areas has not led to more earthquakes, and the best practical use of this information would be to attempt to reduce a threatened earthquake by lowering the water level in a reservoir. The release of stored water would also minimize the risk of dam failure and downstream failure.

Another possibility exists in the manipulation of groundwater levels. There is already evidence that the disposal of liquid waste into boreholes has created such an effect and it may be that the injection of water into fault lines could help to control the build-up of hazardous tectonic strain.

**b) Hazard Resistant Design**: The solution lies in seismic-resistant construction methods, some of which have a long history. The temple of Hephaistes in Athens, Greece, is contemporary with Parthenon. The column blocks which make up the pillars are tied together by lead pins and may constitute the earliest example of earthquake resistant houses. Some traditional societies have employed 'weak' structures as a defence against earthquakes. In Japan, most city dwellers used to live in wooden houses of apparently flimsy design with woven matting ceiling and partition walls consisting of no more than white cotton stretched across wooden frames etc.

**c) Community Preparedness**: Community preparedness and recovery planning is a key factor in mitigating earthquake impact. It is best developed at the local level within a framework provided by the state or national government. The basic checklist provides a useful indication of wide ranging of pre-planning which is required. Emergency response is most efficient when there is a clearly prioritized identification of tasks to be done and it is also established beforehand who is responsible for each job. Better traffic management, through limiting non-essential vehicles and redirecting emergency support, was clearly necessary after this event, together with heavy lifting equipment to clear the streets of rubble. Training in basic first-aid, search and rescue and firefighting techniques is helpful if imparted to the urban survivors of the earthquake. In the immediate aftermath of disaster, public behaviour is usually rational and supportive.

**d) Insurance**: Private insurance against landslides and other mass movement hazards is not generally available in many countries of the world. New Zealand in contrast has a complete landslide insurance protection available under the Earthquake and War Damage Act of 1944.

e) The **stability of the slope** may be improved by a variety of engineering techniques / other measures, including (i) Excavation and filling methods can be used to produce a more stable average slope. Specific techniques include unloading the head of a slide and loading the toe, with the replacement to failed material with lighter loads; (ii) Drainage: Drainage methods range from the removal of surface water and the drainage of the tension cracks to the insertion of trenches filled with gravel or horizontal drains. Properly designed and constructed drainage systems work well but others soon become clogged by fine particles; (iii) Re-vegetation: Plant roots help to bind the soil particles together, the vegetation canopy protects the soil surface from rain splash impact and transpiration processes aid in drying out the slope; (iv) Restraining structures, such as piles, buttresses and retaining walls can be helpful for slides covering limited area. Guiding structures near the base of the slope, such as diversion walls, can deflect small debris flows effectively; (v) Other methods include chemical stabilization of slopes and the use of grouting to reduce soil permeability and increase its strength. On some construction sites, the freezing of a mass of moving soil has been successfully accomplished, the freezing plant being left in operation unit the soil retaining structures are completed; (vi) Slope stabilization, along with hazard-resistant construction techniques appear to be the most effective preventive strategy for controlling new development. Landslide control is most successful if combined with land use planning. Mitigation has been pursued through construction of check dams, drainage systems and other physical controls in combination with development restrictions.

## 5.0 Landslides

A landslide is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes and shallow debris flows. Landslides generally occur as secondary effects of heavy rainfall, storms, earthquakes and volcanic eruptions. It occurs as a result of changes, either sudden or gradual, in the composition, structure, hydrology or vegetation on a slope. It covers a wide variety of land forms and process involving the movement of soil under the influence of gravity. Landslides are much widespread and over time cause more property loss than any other geological event.

The landslide hazard causes severe loss of life, injury, damage to property, destruction of communication networks and loss of precious soil and land. Although the occurrence of landslides is declining all over the world due to greater scientific understanding and public awareness, in many areas the mounting pressure of population at the base of slopes, canyons and unstable borders of plateau have led to an increase in dangers due to landslides. Landslides are universal phenomena, but more than being ‘natural hazards’, they are induced by human activity. Although gravity's action on an over-steepened slope is the primary reason for a landslide, there are other contributing factors affecting the original slope stability. The term, ‘landslide’ encompasses falling, toppling, sliding, flowing and subsidence of soil and rock materials under the strong influence of gravity and other factors. Some geomorphologists thus prefer to use the term mass movement instead of landslides. The resultant landforms produced by mass movements are termed mass wasting**.** Mass movement occurs when the slope gradient exceeds its threshold angle of stability.

M.A. Carson and M.J. Kirkby (1972) divided hill slopes into (i) weathering-limited slopes and (ii) transport-limited slopes. In the former case, rock disintegrates in situ, whereas, in the latter case, slopes are covered by thick soil or disintegrated rock materials, known as regolith. Due to the presence of regolith, transport-limited slopes experience frequent landslides.

### 5.1 Factors responsible for Landslides

Slope instability may be caused by removal of lateral or underlying support, mainly by river erosion and road cuts, landfill dumping, faulting, tectonic movement or the creation of artificial slopes by constructional activities.

Weathering involves rock disintegration, causing weakening of soil and decreased resistance to shearing. A significant cause of landslide is related to increased water infiltration which causes saturation of soil. It may be due to ploughing or poor organisation of drainage on a sloping area that has undergone modification due to deforestation and urbanization. Pore water pressure is increased by soil saturation which results in a positive force on the slope.

Landslides due to slumping may occur due to construction of settlement built on filled up land that suffers from poor compaction or engineering. In forests, timber harvesting may negatively affect slope stability. Tractors, in general, cause immense damage as runoff follows the wheeling. Apart from the above-mentioned forces, the causes of slope failure may be distinguished as (i) immediate causes such as vibrations, earth-quake tremors, heavy precipitation and freezing and thawing; and (ii) long-term causes such as the slow and progressive steepening of the slope. R.U. Cooke and J.C. Doornkamp (1974) suggested a few factors that contribute to landslides.

(i) Factors leading to accelerated shear stress - Surcharge i.e., loading of the crest of slopes with an additional load; undermining of slope; lateral pressure exerted on cracks due to factors like freezing.
(ii) Factors that cause reduced shear strength - Characteristic of some soil particles like clay to swell and shrink alternatively in wet and dry periods; rock structure such as faults, joints, bedding etc.; pore-pressure effects; drying and desiccation; loss of capillary action; crumbling soil structure that leads to reduced cohesion in soil.

According to Crooke and Doornkamp, the process of movement which follows planes is called shear. Applied forces are called stresses. Slope failure takes place as a result of shear stresse**s** operational along straight or curved shear planes. Strain is the deformation caused by movement. If it is the result of shear stresses it is called shear strain. The amount of resistance offered by the slope to movement is measured by the strength of the slope. The component of this which is directed against shear stresses is termed the shear strength.

**5.2 Types of Landslides**

Landslides are extremely complicated and varied phenomena. They differ in terms of sliding, flowing, creeping, toppling or speed of movement so markedly that it is extremely difficult to combine all these diagnostic phenomena into a standard taxonomy. Classifications of landslides have been attempted by T.H. Nilsen (1979), R.J. Blong (1973), A.J. Nemcock (1972), A.W. Skempton and J.N. Hutchinson (1964), and D.J. Varnes (1978). The scheme advanced by Varnes has received widest acceptance.

- **a.** Rotational slide: It is a classic form of landslide. Some cases produce multiple regressive phenomena when continued instability produces new head carps to develop progressively up the slope.
- **b.** Translational slide: It involves relatively flat, planar movement following the surface. This type of movement is found in bedding planes made of sedimentary or metamorphic rocks dipping in the direction of slope.

- **c.** Roto-translational slide: It is a complex type where a combination of slip along a circular arc and a flat plane is found.
- **d.** Soil-slab failure: In this case, a slab of saturated regolith is converted into a thick liquid. So the speed of landslide accelerated to as high as 10m/sec.
- **e.** Debris slide or avalanche: It occurs in surface deposits of granular materials. The surface of rupture is almost parallel to the inclination of bedrock.
- ***f.*** Debris flow: It occurs when debris is saturated with water. When rigid solid also falls alongwith the sliding mass, the phenomenon is called plug flow.
- **g.** Falls: These take place through air; for example, jointed weathered rock falls from vertical cliffs.
- **h.** Topples: After detachment from cliffs the outward rotation of angular blocks and rock columns cause toppling.
- **i.** Mudflow: It contains 20 to 80 per cent fine sediments saturated with water. Friction is caused by viscous movement that generates enough power to carry even large boulders.
- **j.** Soil creep: It is the least destructive of landslide phenomena. Creep is slow and superficial.

P.E.Kent (1966) proposed a hypothesis based on fluidization of rock mass. He said that accumulated stress within rock particles causes compression of air in the pore spaces. This results in fast-moving streams of debris. A. Heim (1932) held elastic-mechanical collisions responsible for landslides. His emphasis was on exchange of stresses between solid particles rather than fluids.

## 5.3 Landslides in India

The Himalayas are prone to landslides, especially during the monsoon months, from June to October. The types of landslides include block slumping, debris fall, debris slide, rock fall, rotational slip and slumping. The pressure of population and the economic exploitation of the mountain region have been major causes for landslides. Turning forest land into orchards (apple growing being a lucrative activity), the increased construction and road building activities, and grazing by cattle are some of the activities that have led to increased chances of landslides. Factors such as deforestation by the timber industry and shifting agriculture have also contributed to the removal of valuable vegetation cover, leading to soil erosion and frequent landslides. Efforts are, however, being made to lessen the impact of landslides.

Of late, several thematic maps depicting geology, slope, drainage, land use, relief and landslide hazard comprising about 2,500 sq km of Alaknanda valley from Devaprayag to Nandaprayag have already been prepared. A criterion for zoning for landslide hazard has also been developed by the Central Building Research Institute (CBRI). Theses maps are useful because they enable the concerned authorities to take decisions on techno-economic feasibility of land use, geographical location of dams, construction of bridges and housing complexes, alignment of roads, and in undertaking suitable measures to combat hazards and preserve the ecology of the Himalayas. An innovative and cost-effective technology for designing and building rigid masonry retaining walls characterised by reinforced back fill has been developed. The new expertise has been successfully tested by constructing a retaining wall, 11 metre high, located on the Hardwar Badrinath road in collaboration with the Border Road Organisation. The CBRI has take up a project related to the engineering behaviour of joints, discontinuities, slip surfaces and shear zones with specific emphasis on landslides and hazard assessment.

Engineering methods such as building underground wells or tunnels and surface channels by pumping out groundwater are useful in preventing landslides. Since the methods of checking landslides are prohibitively expensive, it seems to be more rational to concentrate on the prevention of the consequences of landslides. Prior knowledge of landslide may enable authorities to evacuate people before the loss of lives and property; but this requires vigilance, forecasting and constant monitoring.

Landslides, which are very common in the hills and mountainous parts of the Asia-Pacific region, occur frequently in India, China, Nepal, Thailand and the Philippines. In addition to the influence of topography, landslides are aggravated by human activities, such as deforestation, cultivation and construction, which destabilize the already fragile slopes. As a result of the combined actions of natural (mostly heavy rainfall) and human-induced factors, as many as 12,000 landslides occur in Nepal each year (*ESCAP, 1995a*).

### 5.4 Methods to Minimize Damage

R.U. Crooke (1984) and W.J. Kochelman (1986) have proposed some methods for reducing the land-slide hazard.

(i) Avoidance: One way to avoid land-slides is by controlling the location, timing and nature of development. The measures include bypassing unstable areas; putting restrictions on land use; mapping of hazard-prone areas and land use zoning; acquiring and restructuring of public property; spreading social awareness among people; disclosing the nature of hazard to prospective property buyers; promoting insurance against hazard; giving financial assistance such as loans, tax credits, etc. to promote the reduction of the hazard.

(ii) Reducing shear stress: One could reduce shear stress by limit or reduce angels of slope, cut and fill; limit or reduce unit lengths of slope; remove unstable material.

(iii) Reducing shear stress and augmenting shear resistance**.** This could be achieved through an improved drainage system which involves improving surface drainage that covers terrace drains and other drains; improving subsurface drainage; controlling unsustainable agriculture.

(iv) Increasing shear resistance. This would be through retaining structures such as cribs or building retaining walls; adoption of engineering methods by piling, tie-rods, anchors etc.; building hard surface e.g., concrete surface; controlling fill compaction.

Landslides occur in the hilly terrain. The Himalayas being geologically young and susceptible to earthquakes and intensive soil erosion, are highly prone to occurrences of landslides. Landslides also occur in Western Ghats, Eastern Ghats and Nilgiri hills with lesser frequency and intensity. Over the years, due to increasing cultural activity, the incidences of landslides have shown a disturbing tend of occurrence with higher damage to life and property. In 1998, some of the worst occurrences of landslides were witnessed. International experience, e.g. Japan, Hong Kong, and USA, has shown that proper management of slopes on sound scientific principles can lead to mitigation of landslide hazard to a large extent. In India, landslide studies are conducted by a number of institutions, research and academic. However, there is a need for better coordination among a various research groups so that a focused thrust can be provided to some critical aspects of landslide studies, for example geotechnical characterization, soil mechanics and land use zonation. The Department of Science & Technology has initiated a coordinated programmed on the Study of Landslides which is being carried out in a multi-institutional mode. The various topics of research on which some projects have been initiated are: Database, Development, Zonation, Monitoring and instrumentation, Modeling and up gradation of technology, Documentation and dissemination, and Training.

*Intensive test areas*

Detailed investigations of geological studies have been undertaken in the parts of Satluj Beas Valley, H.P., South Sikkim, Parts of Garhwal and Kumaon Himalaya, Western Ghats, Nilgiri Hills, Lungeli District, Mizoram and Guwahati, Assam during the last years. Recently, five more critical slopes/landslides have been identified by the task force of landslides for detailed geological sand geotechnical investigations. The identified landslides will also be monitored with a suitable set of instrument. The names of the new landslides are: Chanmari (Sikkim), Sher-ka-Danda (Nainital), Nathpa (H.P.), Powari (H.P.) and Karsingsa (Arunachal Pradesh).

*Present Status:* A few of the important outputs of the programme are:

1. Landslide Hazard Zonation Methodology: Identification of areas prone to landslide and their categorization as per the intensity of the disaster are the key elements in suggesting mitigation measures for minimizing the losses caused by landslides. Experience gained during the studies undertaken by WIHG (Wadia Institute of Himalayan Geology), CBRI (Central Building Research Institute), CRRI (Central Road Research Institute) and Roorkee University in different selected test areas have helped in evolving a landslide hazard zonation methodology. Based on this methodology, landslide hazard zonation mapping has been completed in parts of the Satluj-Beas Valley, H.P., Garhwal Himalaya, Kumaon Himalaya, Sikkim, Nilgiris, Lungeli, Guwahati and Western Ghats on 1:50,000 scale. Also, micro zonation on 1:10,000 scale was carried out in parts of Srinagar-Badrinath Road in Garhwal Himalayas.

2. Mass Movement Model: In order to quantitatively assess the extent of mass movement and predict the deposition profile in case of a landslide, it is necessary to model the process of the mass movement and analyse the slope stability. Digital terrain models were used in a study undertaken by IIT, Mumbai to prepare the sections of the unstable slopes and determine the failure surfaces. The mass movement was modelled to predict the motion parameters and deposition profile.

3. Control measures: A state-of-the-art report on landslide control measures was prepared. The other work such as stablisation of landslide through soil nailing techniques in progress.

4. Dissemination and training: In order to create awareness among the potential users, four training courses/workshops have been conducted during the last five years.

5. Future Thrust: Responding to the incidences of landslides in Himalayan region during the month of August, 1998, in which major damage to life and property occurred, the DST reviewed the scientific status of the landslides studies in the country. Noting the inputs provided by various institutions, the following Task Forces were suggested to be constituted:

- Landslides Hazard Zonation- By *Geological Survey of India*
- Geotechnical Investigations - by *Department of Science and Technology*
- Landuse Zoning and Regulations - by *Department of Environment. & Forests*

Following up the above recommendation, DST constituted a Task Force on "Geotechnical Investigations on Landslides" in November 1998. This task force has held four meetings. Five landslide sites have been selected for detailed geological and geotechnical investigations. The names of the selected landslides are: Powari (H.P.), Sher-ka-Danda Slide (Nainital, U.P.) Chanmari (Sikkim), Karsingsa (Arunachal Pradesh) and Nathpa Landslide (H.P). All the slide areas are proposed to be suitably instrumented for monitoring of the landslide movements.

**6.0 Floods**

Flood, a cumulative atmospheric hazard, simply means inundation of extensive area by water for several days at a stretch, or say a flood is a state of high water level along a river channel or on the coast that leads to inundation of land which is not normally submerged. A flood is a discharge that exceeds the channels capacity of the river (it is bigger than the bank full discharge), so it inundates the adjacent floodplain. When this happens the channel and the floodplain together allow passage of floodwaters. In other words it is natural process, over bank flows that may construct a flood plain adjacent to a stream channel or higher than normal levels along a coast that extends inland beyond the beach. Floods is a natural phenomenon and is response to rainfall (important component of hydrological cycle) from the hazard perspective, high water levels in a stream, lake or ocean that may damage human facilities causes large scale loss of life and property. Flood is also a rise of water levels which is abnormally high inundating neighboring areas of water channels because of heavy precipitation, dam failures, rapid snow melts, storm surges, cloud burst etc. Floods can broadly divided into three types - flash floods, river floods and coastal floods. Most of the floods may result in physical damage, deaths and injuries, problems in availability of drinking water and food shortages. It is usually due to the volume of water within a body of water, such as a river or lake, exceeding the total capacity of the body, and as a result some of the water flows or sits outside of the normal perimeter of the body. It can also occur in rivers, when the strength of the river is so high it flows right out of the river channel, usually at corners or meanders. These of course, are not applicable in such instances as sea flooding. The word comes from the old English word ‘flod’, a word common to Teutonic languages, compare German *Flut*, Dutch *vloed* from the same root as is seen in *flow*, *float*.

### 6.1 a) Primary effects

- Physical damage- Structures such as buildings get damaged due to flood water. Landslides can also take place.
- Casualties- People and livestock die due to drowning. It can also lead to epidemics and diseases.

### 6.1 b) Secondary effects

- Water supplies- Contamination of water. Clean drinking water becomes scarce.
- Diseases- Unhygienic conditions. Spread of water-borne diseases
- Crops and food supplies- Shortage of food crops can be caused due to loss of entire harvest.

### 6.1 c) Tertiary/long-term effects

- Economic- Economic hardship, due to e.g. temporary decline in tourism, rebuilding costs, food shortage leading to price increase etc, especially to the poor.
- Psychological- Loss of loved ones etc.

## 6.2 Flood factors and causes

The degree and type of flooding is influenced by many climatologically, hydrological and environmental and local geomorphological factors (Fig 5), such as:

(a) Heavy continued rainfall over a long period is the root cause of river floods as the immense volume of runoff results in overtopping of the river bank;

(b) Large scale deforestation in the upper catchments is the most important anthropogenic factor in river bank;

(c) Bare and open basin accelerates soil erosion thereby increases siltation load in the river channel. This reduce cross sectional area of the channel leading to spill over;

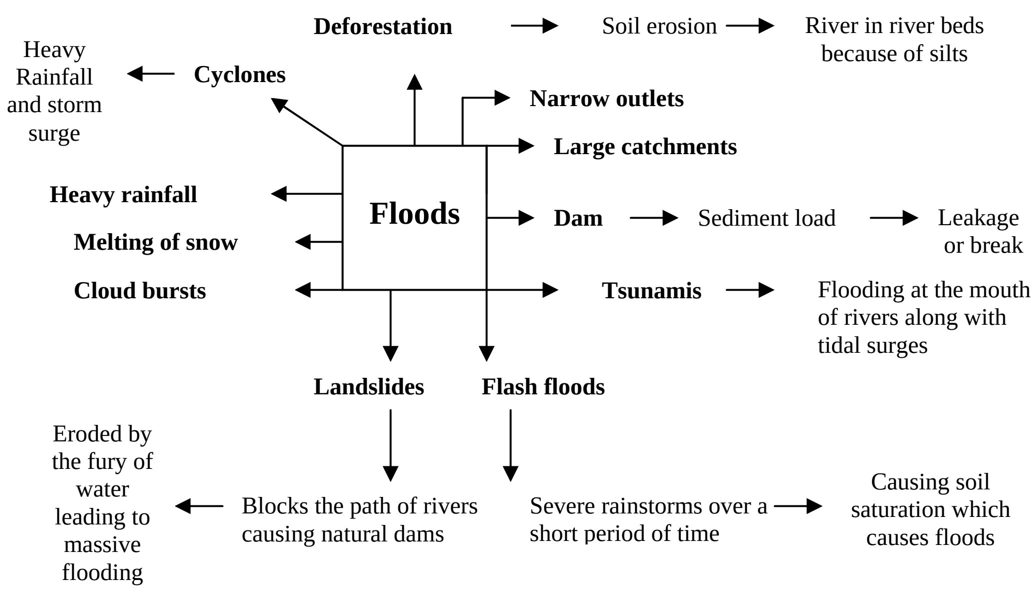
(d) Due to heavy siltation the bed level is elevated, which reduces channels depth causing spill over;

(e) Dams capture steady flow of sediment from the upper catchments reducing the water holding capacity of the reservoir. As a result, excess water due to heavy down pour needs immediate release causing floods in the lower catchments;

(f) Highly sinuous and meandering courses of the river obstruct the normal flow of water resulting in low velocity. With flooding the meandering valleys are immediately overflowed and the meander loops are inundated;

(g) Change of slope is another cause of flood. For example, low slope with flat surface supports oscillating channels, sluggish flow, low bank height and low velocity;

**Fig 5- Major factors and causes of floods**



Source: Illustration by the Author

(h) The earthen embankments entropy the river, which disturb its normal behavior and hinder natural land building processes;

(i) Increasing floodplain encroachment for residential and agricultural purposes increases the flood damage; and

(j) Unchecked urbanization increases the frequency and dimension of floods in the rivers, as the concrete ground surface and masonry drains reduce rainwater infiltration rate substantially increase runoff.

Flooding tends to be most frequent during the wet and/ or the melt seasons. In some parts of the world, including Britain, intense convection storms can produce flooding during the summers. Floods are the most common climate-related disaster in the region and include seasonal floods, flash floods, urban floods due to inadequate drainage facilities and floods associated with tidal events induced by typhoons in coastal areas. In Bangladesh, one of the most flood-prone countries in the region, as many as 80 million people are vulnerable to flooding each year (*ESCAP*, *1995a*). In India, where a total of 40 million hectares is at risk from flooding each year, the average annual direct damage has been estimated at US$ 240 million, although this figure can increase to over US$ 1.5 billion with severe flood events (*ESCAP*, *1995a*).

**6.3 Spatial Pattern of Floods in India**

Most of the flood affected area lie in the Ganges Basin; the Brahmaputra basin comprising the Barak, the Teesta, the Torso, the Subansiri, the Sankosh, the Jaldhaka, the Dibang, the Dihang and the Luhit; the north-western river basin comprising of the Jhelum, the Sutlej, the Beas, the Chenab and the Ravi and the Ghagger; the peninsular river basin comprising the Tapi, and the Narmada, the Mahanadi, the Baitarni, the Godavari and Krishna, the Pennar and the Cauvery and coastal regions of Andhra Pradesh, Tamil Nadu, Orissa and Kerala. The most flood-prone basins are those of Ganges in Uttar Pradesh, Uttarakhand, Bihar and West Bengal, the Brahmaputra in West Bengal and Assam, followed by the Baitarni, the Brahmani and the Subarnarekha basin in Orissa. The floods are also experienced in Andhra Pradesh, Rajasthan, Haryana and Gujarat. The area under chronically flood prone Uttar Pradesh and

Bihar is increasing. The profile of major damage caused by floods in India between 1953-2002 is shown in the Table 2.

**Table 2-Flood Affected Areas and flood Damages in India (1953 to 2002)**

| Item | Unit | Flood damage (average) | Maximum damage (with year) |
|---|---|---|---|
| Area affected | Million ha | 7.38 | 17.50 (1978) |
| Population affected | Million | 32.97 | 70.45 (1978) |
| Human lives lost | Numbers | 1560 | 11,316 (1977) |
| Cattle lost | Numbers | 91,555 | 6,18,248 (1979) |
| Cropped area affected | Million ha | 3.48 | 10.15 (1988) |
| Value of damage to crops | Million Rs. | 5,969.65 | 25,109.00 (1988) |
| Houses damaged | Million | 1.19 | 3.51 (1978) |
| Value of damage to Houses | Million Rs | 1,891.02 | 13,078.94 (1988) |
| Value of damage to public utilities | Million Rs | 5,662.36 | 31,714.03(1998) |
| Total value of damage | Million Rs | 13,760.84 | 58,459.80 (1998) |

*Source: Singh R.B, 2006*

### 6.4 Mitigation of Floods

Flooding is a natural process of renewal fertile alluvial soil; but with their increasing intensity and occupancy of flood prone areas by humans and their activities it is important to institute mitigation measures and manage flood prone areas to reduce life loss and structural property loss. Following measures could be adopted:

a) Reduction of runoff by inducing and increasing infiltration into the ground in the catchments area. Large scale afforestation with trees that generate lot of litter; b) Reduction of water volume and water peaks with help of engineering approaches such as construction of reservoirs, which impound enormous amount of water during flood periods; c) Reduction of flood levels can be achieved by protection against inundation, flood plain zoning and forecasting; d) Methods like stream canalization, channel improvement and flood diversion; e) Flood forecasting and warning plays a pivotal role in flood mitigation. It helps in a faster and smothers evacuation, provided safe routes maps are identified and placed in hazard prone site. Exit routes should be in good condition and maintained properly; f) Flood alleviation and training programmes; g) Flood proofing; h) Flood relief channels; i) Flood abatement schemes; and j) Flood storage and reservoirs.

**7.0 Droughts**

Droughts have disastrous impact on the economy and can affect a large segment of society which may last for months and in some cases several years. Generally, drought situation may be defined as a temporary reduction in water or moisture availability significantly below the normal or excepted amount for a specific period. Droughts are of three broad types - Meteorological droughts, Hydrological droughts and Agricultural droughts.

In meteorological terms, a drought is “a sustained and regionally extensive deficiency in precipitation”. According to IMD a drought is a situation when the deficiency of rainfall is at a meteorological sub- division level. According to the definition of meteorological drought adopted by the Indian meteorological Department (IMD), a drought is a situation when the deficiency of rainfall at a meteorological sub-division level is 25% more of the long-term average (LTA) of that sub-division for a given period. If the deficiency is between 26% and 50%, the drought is considered ‘moderate’ and if the deficiency is over 50%, the drought is termed ‘severe’.

In India, the south-west monsoon accounts for most (about 70%-80%) of the rainfall and is the main source of water. The monsoon rainfall above 19% of the normal value is termed as excess rain. When the rainfall departure is within 19%, it is known as normal rain; below 19% it is deficient rain; and it is scanty if the rainfall is below 59%.

The meteorological drought is only a representation of the rainfall distribution pattern and statistics. The hydrological drought is the manifestation of critically low groundwater tables and a marked reduced river and stream flow, causing severe shortage of water for livestock and human needs. An agricultural drought results when soil moisture and rainfall are inadequate during the crop growing season to support healthy crop growth to maturity. The National Commission on Agriculture has defined an agricultural drought as a period of four consecutive weeks (of severe meteorological drought) with a rainfall deficiency of more than 50% of the LTA (Long term average) or with a weekly rainfall of 5 cm or less during the period from mid-May to mid-October (the kharif season) when 80% of the country’s total crop is planted, or six such consecutive weeks during the rest of the year. The intensity of drought is guided by several factors, viz., the degree of rainfall deficiency, the length of dry periods, the size of the affected area, and the availability of various facilities including irrigation. Of late the "Palmer Drought Severity Index" is commonly brought into use for expressing the severity of drought. The index measures the relative dryness of local weather within successive periodic intervals. It considers the differences of actual precipitation from the minimum amount of precipitation required in normal conditions to sustain evapo-transpiration, run off and storage of moisture in a given climate region.

In India, drought remains a recurrent phenomena in spite of its vast water resources. India has several major, medium, and minor rivers. The annual rainfall and snowfall is about 114 cm which creates 4000 cu km of water per annum. Even after evaporation and other losses, about 1860 cu km of water should remain as excess. But, in reality, only 700 cu km surface water reserve remains usable owing to topographical and hydrological bottlenecks. Out of about 6 million villages of India, about 2,31,000 are called 'problem villages'. In these 'problem villages', water is not available within a 1.6 km radius. Almost 68% of the sown area is dependent upon rainfall. Rain fall distribution grossly varies in more than 35 meteorological subdivisions of India. For example, Cherrapunji receives about 118.70 cm of rainfall in comparison to about 10 mm or less rain received in the western part of Rajasthan. The most drought-prone regions is located in West Rajasthan, Gujarat, Saurashtra and Kutch, Maharashtra, Telengana, Rayalaseema, Bihar and some parts of Orissa, such as Kalahandi, Bolangir and Koraput.

It has been observed that the impact of droughts differs widely between developed and developing countries because of the influence of such factors as water supply and water-use efficiency. The majority of the estimated 500 million rural poor in the Asia-Pacific region are subsistence farmers occupying mainly rain-fed land (*ESCAP*, *1995a*). The drought-prone countries in this region are Afghanistan, Iran, Myanmar, Pakistan, Nepal, India, Sri Lanka and parts of Bangladesh. In India, about 33% of the arable land is considered to be drought-prone (i.e. about 14% of the total land area of the country) and a further 35% can also be affected if rainfall is exceptionally low for extended periods (*ESCAP*, *1995a*). Nepal has been subjected to severe droughts in the past. The Philippines, Thailand, Australia and the Pacific islands of Fiji, Vanuatu and Samoa also contain drought-prone areas.

### 7.1 Major Incidences of Drought in India

The worst drought experienced by India occurred in 1877. The rainfall departure in 1877 was -79%, which had a spread of over 66.8% of the area. In recent times droughts have occurred in 1979, 1982, and as close as 2000. The drought of 1979 had an adverse impact on about 200 million people of Rajasthan, Punjab and Himachal Pradesh. A 'phenomenal' drought took place in 1987 when the departure of rainfall was -19.3% and the area suffering from deficient rainfall was 64.3%. Among the victims were about 285 million people and 168 million cattle in 15 States and 6 Union Territories. Saurashtra, Kutch, Diu, western part of Rajasthan, Delhi and Haryana suffered tremendously. The occurrence of drought does not always have a link with the occurrence of rainfall in a particular region. In recent years, Cherrapunji which receives the highest amount of rainfall in the world was also facing drought conditions due to lack of water harvesting methods.

In the first quarter of 2000, large parts of the country were hit by another drought. Some 14 states reported drought or drought-like conditions of varying magnitude. The worst hit were Rajasthan (in which 26 million people in 23,000 villages in 26 districts were affected), Andhra Pradesh (30 million people in 17,000 villages in 18 districts) and Gujarat (25 million people in 8,000 villages in 17 districts). Parts of Madhya Pradesh, Orissa, Maharashtra, Manipur, Mizoram and Tripura also came under some stress, as did some districts of Himachal Pradesh, Jammu and Kashmir, Karnataka and West Bengal which reported severe scarcity of water. Over 15% of the Indian population, i.e. 130 million people were affected. Because droughts are a regular feature in India, the Government of India had developed contingency plans. One of its major activities was to establish relief camps where families were provided with work, shelter, food and health care. Protection and care for women and children were a priority. Local and international NGOs were also actively involved in relief programmes.

While UNICEF released immediate assistance through its state offices, it also decided to focus on long-term assistance to help prevent such situations. The Government of Gujarat requested UNICEF to assist in the development of a White Paper on water management policies. Support was received from Australian Aid (US$ 576,000) and the Dutch Government (US$ 2.8 million) for Gujarat and Rajasthan.

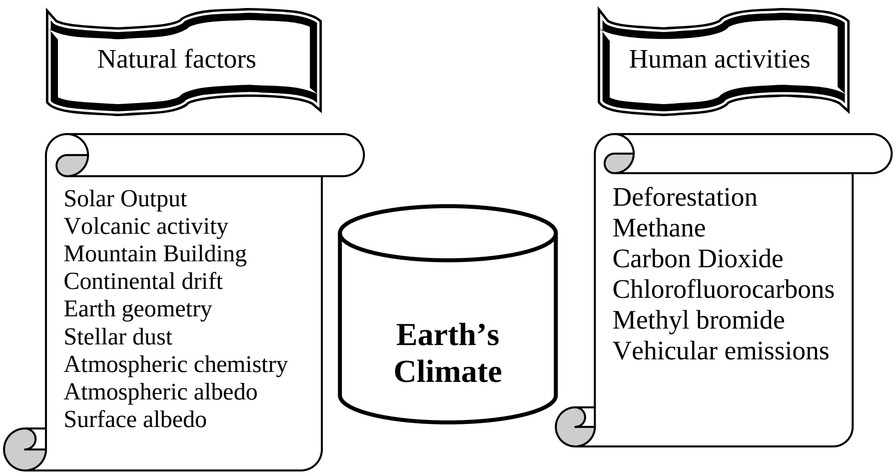
### 7.2 Drought insurance

Drought mitigation schemes need to take note of indigenous strategies for coping with drought, including crop and livestock insurance, fodder, fuel and seed reserves, permanent breeding stocks of animals, refugee pasture areas and stockpiles of tools for relief employment. Regional movements of people across frontiers should be encouraged during severe drought.

## 8.0 Global Warming

Global warming is a potential increase in the amounts of greenhouse gases such as Carbon Dioxide ($CO_2$) in the atmosphere. Models referenced by the Intergovernmental Panel on Climate Change (IPCC) predict that global temperatures are likely to increase by 1.1 to 6.4 °C (2.0 to 11.5 °F) between 1990 and 2100. The uncertainty in this range results from two factors: differing future greenhouse gas emission scenarios, and uncertainties regarding climate sensitivity. There is great concern that global warming will lead to the destruction of ecosystems due to sudden temperature changes and weather anomalies such as heavy rain, drought, and extreme heat, as well as the submersion of low-lying regions due to rising sea levels.

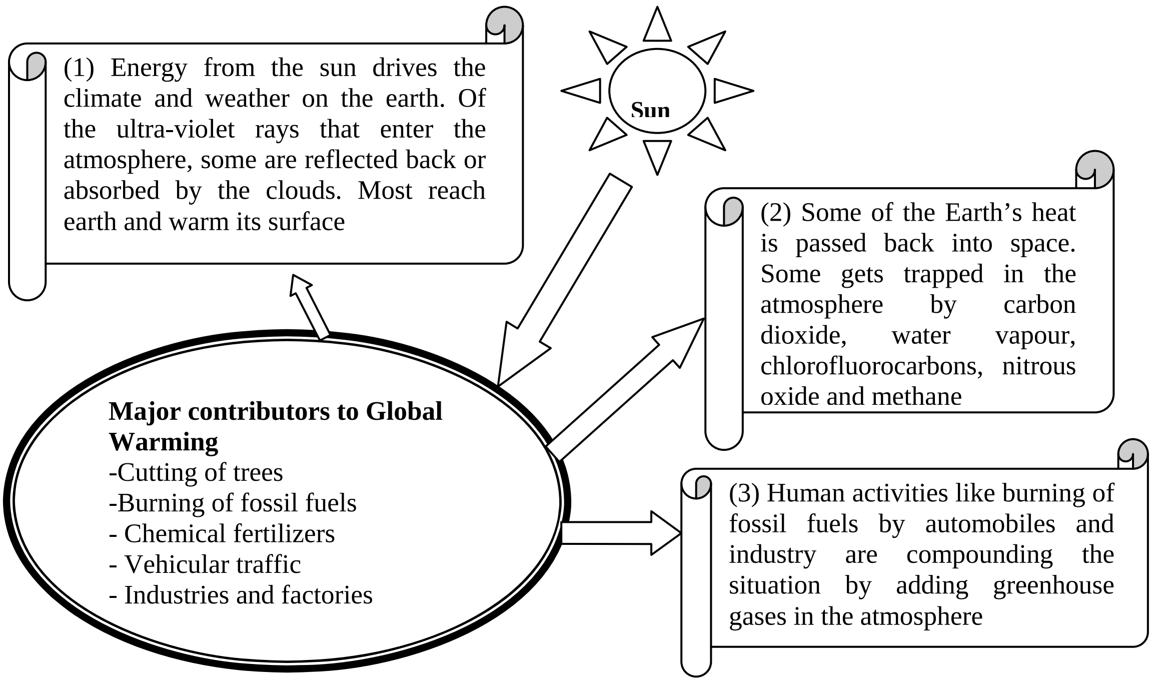
**Fig. 6: Natural factors affecting climate change and human induced activities causing global warming**




Source: Illustration by the Author

For millions of years, gases in the Earth's atmosphere have trapped sufficient heat from solar radiation to sustain life. However, an increase in human activity is now raising levels of greenhouse gases such as $CO_2$, so that excess heat is trapped in the atmosphere. The burning of fossil fuels, forest cover change and use of chemical fertilizers etc. are increasing the amount of green house gases as the atmosphere becomes a better insulator, retaining more heat which is provided by sun - this phenomenon is called 'Global Warming' (Fig. 6 and Fig. 7). Global warming is occurring faster than predicted because rapid economic growth has resulted in higher than expected greenhouse emissions since 2000.

**Fig. 7: The Green house Effect**

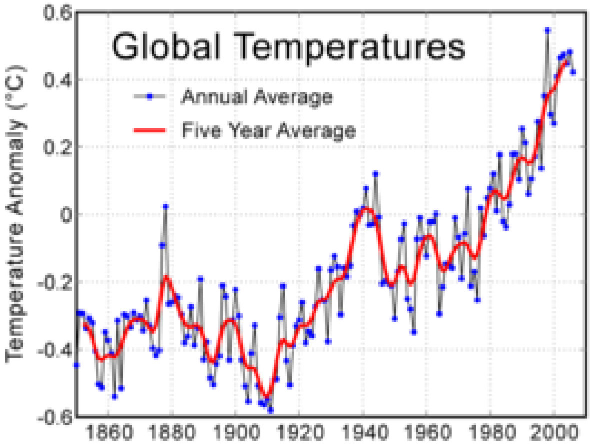



Source: Illustration by the Author

Ice holds large fresh water supplies and is a vital part of the ecosystem. Melting ice and climate change thus demands urgent attention by decision makers and the public worldwide. Global warming is also wiping out creatures – it is suspected that every hour 3 species disappear, every day up to 150 species are lost, every year between 18,000 and 55,000 species become extinct. If warming continues, more than a million species worldwide would be extinct by 2050. Global sea levels could rise by more than 20ft., devastating coastal areas. Deaths from global warming will double in just 25 years to 3 lakh people a year. The recent tsunami that claimed more than 270,000 lives, sprouting of grasses in the Antarctica and snowfall in Dubai are all warning signals of global warming.

**Fig. 8 – Increase in Global Temperatures in the Last Century**

*Source:*

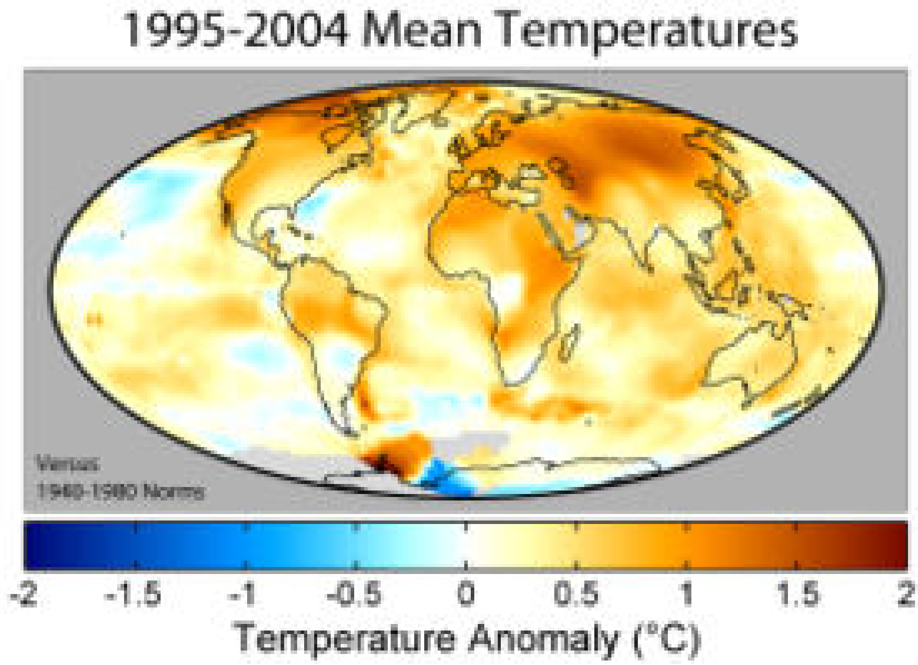



*http://www.agregatepros.com/parts.html*

Global average near-surface atmospheric temperature rose 0.74 ± 0.18 °Celsius (1.3 ± 0.32 °Fahrenheit) in the last century (Fig. 8 and Fig. 9). The prevailing scientific opinion on climate change is that "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations," which leads to warming of the surface and lower atmosphere by increasing the greenhouse effect. Greenhouse gases are released by activities such as the burning of fossil fuels, land clearing, and agriculture.

The term global warming is a specific example of the broader term climate change, which can also refer to global cooling. In principle, global warming is neutral as to the period or causes, but in both common and scientific usage the term generally refers to recent warming and implies a human influence. The UNFCCC (United Nations Framework Convention on Climate Change) uses the term "climate change" for human-caused change, and "climate variability" for other changes. Some organizations use the term "anthropogenic climate change" for human-induced changes.

**Fig. 9: Temperature Anomaly in the Past Decade**




*Source:* *http://www.agregatepros.com/parts.html*

**8.1 The Impact of Global Warming**

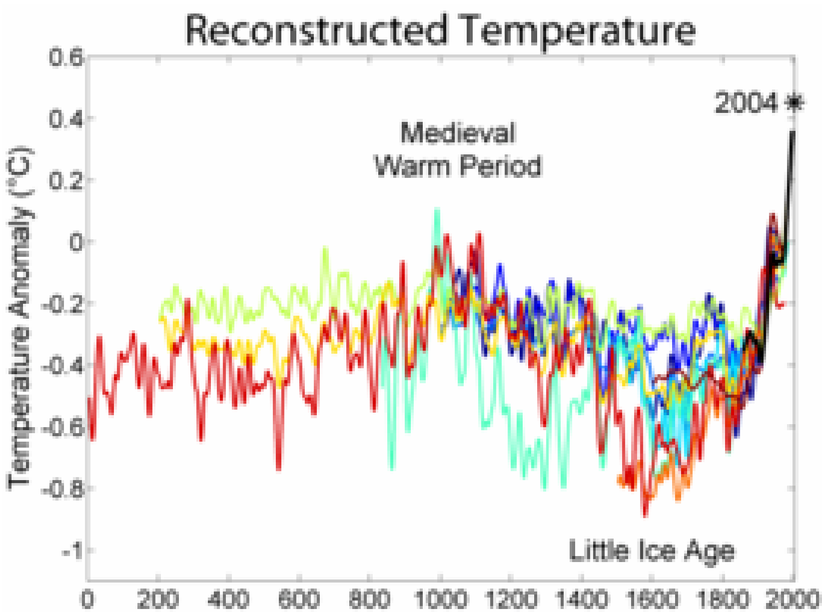
An increase in global temperatures can in turn cause other changes, including a rising sea level and changes in the amount and pattern of precipitation. These changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes, and tornadoes. Other consequences include higher or lower agricultural yields, glacier retreat, reduced summer streamflows, species extinctions and increases in the ranges of disease vectors. Warming is expected to affect the number and magnitude of these events; however, it is difficult to connect particular events to global warming. Although most studies focus on the period up to 2100, even if no further greenhouse gases were released after this date, warming (and sea level) would be expected to continue to rise for more than a millennium, since $CO_2$ has a long average atmospheric lifetime.

The impact of global warming will cause sea level rise by half a meter by 2100, and glacial melt downs. Himalayan glaciers are retreating at a record pace - the Gangotri glacier is retreating 98 feet every year. Erosion of coral reefs is occurring in Andaman, Seychelles, Malaysia, Madagascar, Sri Lanka, Somalia, Maldives and Indonesia. Flooding is also causing havoc in coastal areas, like in Sunderbans area, where 18,500 hectares have been flooded in past 30 years. 1 m rise could mean extinction of the Royal Bengal Tiger in the Sunderbans. If the sea level rises by 2 m, half of Bangladesh will be submerged.

**8.2 History of warming / Temperature record:**

Relative to the period 1860–1900, global temperatures on both land and sea have increased by 0.75 °C (1.4 °F), according to the instrumental temperature record; the urban heat island is not believed to be significant. Since 1979, land temperatures have increased about twice as fast as ocean temperatures (0.25 °C/decade against 0.13 °C/decade) (*Smith, 2005*). Temperatures in the lower troposphere have increased between 0.12 and 0.22 °C (0.22 and 0.4 °F) per decade since 1979, according to satellite temperature measurements. Over the one or two thousand years before 1850, temperature is believed to have been relatively stable, with possibly regional fluctuations such as the Medieval Warm Period or the Little Ice Age (Fig. 10).

**Fig. 10 Temperature Movement over the Ages**




*Source:* *http://www.agregatepros.com/parts.html*

Although 1999 was not a record breaker, it was the fifth warmest year in the recorded history. The overall warmth of the decade would have been even greater were it not for the eruption of Mt Pinatubo in the Philippines in 1991. Stratospheric aerosols from the eruption reduced the amount of solar radiation reaching the surface of the northern hemisphere during 1992-1993, making them the 2 coolest years of the decade (though still warmer than the long-term average) and, although we don't have reliable records for the years prior to 1880, a recent analysis using techniques by using complex computer programs called general calculation model (GCM) estimates the global distribution of temperature & precipitation that would result from hypothesized changes in the atmosphere. It describes that 5 of the years in 1990s were probably the warmest for North America over the last six centuries. Interestingly, though land and ocean temperature both increased significantly in the 1990s, they were not perfectly in sync with each other.

Human health threats due to rise in temperature, may be more serious than temperature data alone would suggest. This is important because experts believe that the most dangerous health threat occurs not from very high day time temperature for several days but without intervening cool nights. The results of the study are even more noteworthy when one takes into account that data from the record warm years of 1997 through 1999 were not included. (Aguado Edward and Burt E. James, 2001)

A study done in the US between 1949-1995 found that the incidence of extreme apparent temperature has increased more dramatically. To make matters worse, the increase in night time apparent temperature has been greater than the increase in day time apparent temperature, and instead of dropping at sunset, it has persisted overnight.

**8.3 Effects of Global Warming**

Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming. Glacier retreat, ice shelf disruption such as the Larsen Ice Shelf, sea level rise, changes in rainfall patterns, increased intensity and frequency of hurricanes and extreme weather events, are being attributed at least in part to global warming. While changes are expected for overall patterns, intensity, and frequencies, it is difficult or impossible to attribute specific events (such as Hurricane Katrina) to global warming.

Some anticipated effects include sea level rise of 110 to 770 mm (0.36 to 2.5 feet) by 2100, repercussions to agriculture, possible slowing of the thermohaline circulation, reductions in the ozone layer, increased intensity and frequency of hurricanes and extreme weather events, lowering of ocean pH, the spread of diseases such as malaria and dengue fever, and mass extinction events.

Increasing extreme weather catastrophes are due to increasing severe weather and an increase in population densities. The World Meteorological Organization and the U.S. Environmental Protection Agency have linked increasing extreme weather events to global warming, as have Hoyos et al. (2006), writing that the increasing number of category 4 and 5 hurricanes is directly linked to increasing temperatures.

## 8.4 How Climate Change will affect World Regions

The UN climate report looks at the impact on eight world regions, with the Arctic, southern Africa, Pacific islands and Asian Coastal regions worst hit:

| **(1) North America** | **(2) South & Central America** | **(3) Small Pacific islands** | **(4) Africa** | **(5) Europe** | **(6) Polar areas** | **(7) Asia** | **(8) Australia, New Zealand** |
|---|---|---|---|---|---|---|---|
| (a) More heat waves<br>(b) More forest fires<br>(c) Year-round snow melts in western mountains<br>(d) Coastal regions threatened by floods | (a) Reduction of rain forest<br>(b) Dispersion of savannah<br>(c) Sea level rise threatens cities on the Atlantic coast | (a) Increased threat due to rising sea level and storms<br>(b) Drinking water reservoirs reduced<br>(c) Tourism affected | (a) droughts, water shortages<br>(b) Fishing tourism threatened<br>(c) Crops, feed affected | (a) Increased risk for floods, especially in central and Eastern Europe<br>**Southern Europe**<br>(a) More heat waves<br>(b) Forest fires<br>(c) Water shortages<br>(d) Crops at risk<br>**Northern Europe**<br>(a) Improved crops<br>(b) Increased Hydro-Power production | (a) Rising temperatures, glacier and ice melt affect flora and fauna<br>(b) Change in perma-frost situation affects infra-structure | (a) Himalayan glacier melting<br>(b) Rising water levels increasing the risk of flooding<br>(c) Decrease of precipitation affects crops and feed | (a) water shortage worsens<br>(b) more threatened species in Great Barrier Reef and other reservations<br>(c) Coastal regions are more threatened by more storms and floods<br>(d) Moderate global temperatures rise gives New Zealand better conditions for agriculture |

*Source: Complied from The Times of India, New Delhi ed., Dated: Wednesday, April 4, 2007*

The Intergovernmental Panel on Climate Change (IPCC), giving the most authoritative study on the on the regional impact of climate change since 2001, also warns that the poorest nations are likely to suffer the most. The report warns that the temperature rises of 2-3 degrees Celsius predicted by 2050 spell disaster for both humanity and environment. By 2050, the report warns, more than 200 million people could be forced to leave their lands by rising sea levels, floods and droughts with many more facing early deaths from mal nutrition and heat stress. According to UN Environment Programme "We are talking about a potentially catastrophic set of developments" and "Even a half-metre rise in the sea level would have catastrophic effects in Bangladesh and some island states". The report predicts that Himalayan glaciers will melt away, affecting hundreds of millions of people. If current warming is maintained, Himalayan glaciers could decay at very rapid rates, shrinking from the present 500,000 sq km by 2030 according to draft technical summary (*The Times of India, New Delhi ed., Dated: Tuesday, April 2, 2007*)

United Nations Convention on Climate Change highlighted needs and duties of developing and developing countries as follows:

a) Developed countries shall help developing nations deal with requirements of the convention and the effects of climate change by-
   - Providing money and technological assistance to help these nations measures flow of green house gases.
   - Assisting countries that are particularly vulnerable to harmful effects of climate change to meet the costs of adoption
   - Providing environmentally sound technologies within these nations

b) All nations to
   - Provide information on the quantities of green house gases they release, and how much is absorbed by their sinks.
   - Publish regular updates on programmes to control emissions, and to adopt to climate change.
   - Promote the sound management and conservation of such green house gas sinks as plants, forests and oceans.
   - Cooperate in planning for the impact of climate change on coastal zones, water resources and agriculture
   - Cooperate in the protection of areas prone to floods or droughts, particularly in Africa.
   - Inform the public about climate change and its effects, and promote and facilitate public participation in developing responses.

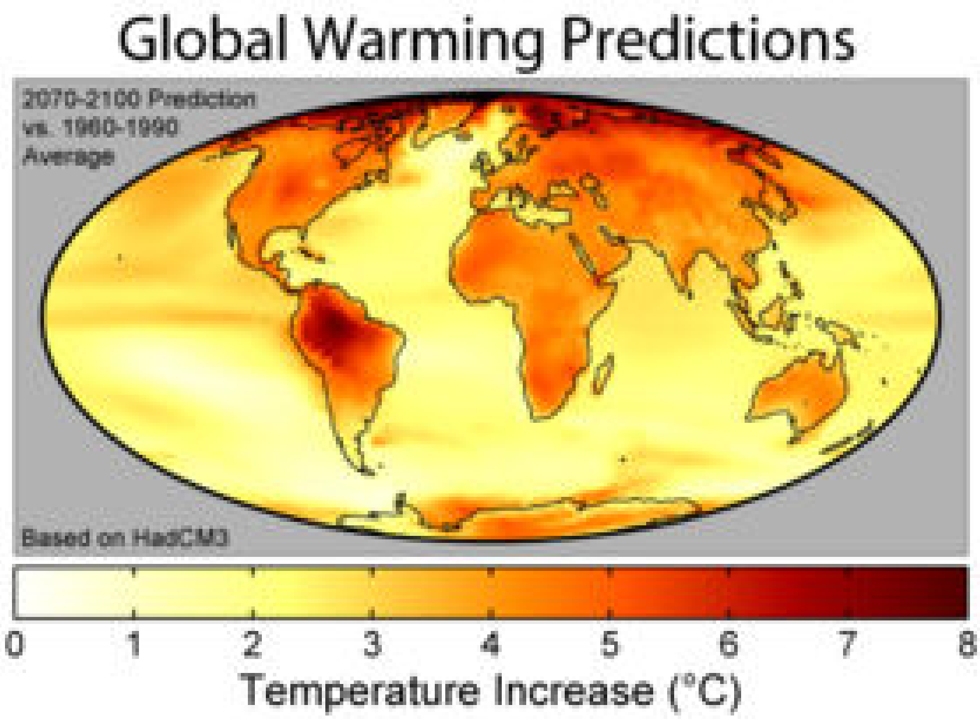
## 8.5 Mitigation of Global Warming and Adaptation to Global Warming

The broad agreement among climate scientists that global temperatures will continue to increase has led nations, states, corporations and individuals to implement actions to try to curtail global warming. Some of the strategies that have been proposed for mitigation of global warming include development of new technologies; carbon offsets; renewable energy such as wind power, and solar power; nuclear power; electric or plug-in hybrid electric vehicles; non-fossil fuel cells; energy conservation; carbon taxes; improving natural carbon dioxide sinks; deliberate production of sulfate aerosols, which produce a cooling effect on the Earth; population control; carbon capture and storage; and nanotechnology. Many environmental groups encourage individual action against global warming, often aimed at the consumer, and there has been business action on climate change.

## 8.6 Kyoto Protocol

The world's primary international agreement on combating global warming is the Kyoto Protocol. The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. Developing countries are exempt from meeting emission standards under Kyoto Protocol. This includes China and India, the second and third largest emitters of $CO_2$, behind the United States.

**Fig. 11 Global Warming Predictions in 21st Century Based on HadCM3 Model**




*Source: http://www.agregatepros.com/parts.html*

## 8.7 Global climate

**model**

The geographic distribution of surface warming during the 21st century is calculated by the HadCM3 climate model, if a business as usual scenario is assumed for economic growth and greenhouse gas emissions. In this figure (Fig. 11), the globally averaged warming corresponds to 3.0 °C (5.4°F).

Scientists have studied global warming with computer models of the climate. These models predict that the net effect of adding greenhouse gases will be a warmer climate in the future. However, even when the same assumptions of fossil fuel consumption and $CO_2$ emission are used, the amount of predicted warming varies between models and there still remains a considerable range of climate sensitivity.

Climate models have produced a good proxy to observations of global temperature changes over the last century. While these models do not unambiguously attribute the warming that occurred from 1910 to 1945 to either natural variation or human effects; however, they suggest that the warming since 1975 is dominated by man-made greenhouse gas emissions.

## 9.0 Conclusions

A hazard only becomes a disaster when it comes in contact with vulnerable population or location. Natural disasters cannot be stopped but with better mitigation we can reduce the loss they incur on life and property and reduce it to bare minimum. Techniques of risk assessment, vulnerability analysis, structural and non structural measures including building codes, resistant structures, warning and forecasting etc. can reduce the impact of disaster.

In regard to global warming the big question is whether it is largely result of human activities or natural variations. While the answer is not known for certain, each new warmer year lands further support to the predictions of a warmer atmosphere in response to increased concentrations of greenhouse gases.

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