

APPLIED CLIMATOLOGY

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**UNIVERSITY DEPARTMENT OF GEOGRAPHY,
DR. SHYMA PRASAD MUKHERJEE UNIVERSITY, RANCHI.**

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INTRODUCTION: -

In this course, so far you have learnt about the processes and factors that shape the climate of a place ranging from a micro-scale to global or planetary scale. You have studied about progress in climatology and other contemporary issues related to climate change and its effects, rural and urban climatology, etc. You have also studied about weather forecasting methods and its importance. In this module, you will learn about applied aspects of climatology. So here we deal with the effects of climate rather than its causes.

Any subject of study should have an applied aspect so as to benefit the society and so should not be purely academic. Since weather and climate of a particular place is a major determinant in shaping our activities and life style, climatology as a subject matter has immense practical utility and there is a need to study the applied aspects of climatology with greater sincerity.

DEFINITION: -

In simple words, we can define applied climatology as the study of the effects of climate on natural and social systems. Let us also examine a few definitions given by some leading scholars.

According to H. Landsberg and W.C. Jacobs (1951), applied climatology is the scientific analysis of climatic data in the light of useful applications for an operational purpose.

As per K. Smith (1987), applied climatology may be defined as the use of achieved and real-time climatic information to solve a variety of social, economic and environmental problems for clients and managers in fields such as agriculture, industry and energy.

Another definition was given by G.A. Marotz (1989), who defined applied climatology as the scientific use of climatic data and theoretical constructs for the solution of particular problems.

MEANING AND IMPORTANCE

Any subject cannot survive if it is purely academic. It should make some practical contributions to the society. These days a considerable amount of work is being done by climatologists considering its applied aspects. However, the field of applied climatology is of recent origin, and has probably emerged during 1940-50. By 1951-1960, the scope of applied climatology further widened when the impact of climate was studied in relation to human activities. It is also true that climate has a lot of bearing on our life style. It determines the type of food we eat, type of clothes we wear and the type of houses we live in. These three things are the basic necessity of human beings. Take for example the snow-houses or *igloo* built by the Eskimos of Tundra region because of the sub-zero temperatures prevailing there which prevents the house from melting and also keep the inside warm due to insulating property of snow. These igloo are quite different from house built in tropical regions which are quite open and aerated having lots of windows for wind and sunlight to enter the house.

Similarly, we all know that vegetation is the index of climate. So the type of crops we grow, has a lot of bearing on the climatic conditions of a place. Take for example, people living in the extremely cold conditions say in Tundra region cannot grow crops for major time in a year as the sub-soil remains frozen in those areas and whatever grows is nothing more than mosses and lichen. So these are eaten by the local people through food gathering, who also resort to other means like hunting to supplement their food needs. On the other hand, in the humid tropical regions climatic conditions are favourable to grow a wide range of crops. So, agriculture and allied activities serve as a major portion of livelihood and food needs of the people of the tropics.

You may now reason out why people in warm tropics wear cotton clothes and people in the cold regions wear warm and well insulated clothes. Of course, in warm areas people wear light cotton clothes to keep themselves cool and prevent themselves from excessive sweating while in cold regions people wear warm or insulated clothes in order to retain their body temperature from excessively cold temperatures and winds. Today technology has enabled us to survive in adversely warm and cold conditions with the help of air-conditioners and other items of comfort. Still, the impact of climate cannot be ignored. Therefore, while planning our economic and social policies, elements of weather and climate should be given utmost importance.

In the coming sections of this module, you will study about the applied aspects of climatology in greater detail. First of all, let us get acquainted with different sources of climatic data.

SOURCES OF CLIMATOLOGICAL DATA:-

Recently there is greater dissemination of climatological data due to the services provided by several weather agencies and meteorological departments. This has enabled the climatologists to get access to climatic data for their studies. Some relevant climatic data are also on the internet either free of cost or at a marginal fee. So far as sources of collection of climatic data is concerned, it is broadly divided into two types:

- Primary Sources
- Secondary Sources

PRIMARY SOURCES

Primary sources of climatic data collection include the processes where the investigator himself/herself goes to the field and collects climatic data using various instruments like thermometers, radiometers, moisture sensors *etc.*

SECONDARY SOURCES

Secondary sources of data are the data collected elsewhere and then compiled and quality checked which then gets ready for the climatologists and researchers for use. So the climatologists in this case do not collect the data themselves but rely on external sources, agencies or various meteorological departments spread across the world like World Meteorological Organisation (WMO), National Centre for Atmospheric Research, National Oceanic and Atmospheric Administration (NOAA), India Meteorological Department (IMD), *etc.* Now-a-days, meteorological data is also available on the internet. The data is finally reanalysed by the climatologists and various atmospheric variables are segregated for use in research or other climate related studies.

Let us now focus our attention on direct and indirect impacts of elements of weather and climate on human beings and their activities. We start off with the discussion on the impact of climate on natural systems.

CLIMATE AND NATURAL SYSTEMS

Our natural system comprises of all the five spheres, viz., lithosphere, atmosphere, hydrosphere, biosphere and cryosphere. There is a continuous interaction between these spheres and climate plays a major role in affecting different processes that occurs within these systems. Processes in the atmosphere inherently affect other spheres. First of all, let us study the impact of climate on lithosphere.

LITHOSPHERE

You should be knowing that, lithosphere comprises of the rigid, outermost crust and the upper portion of mantle of the earth. Various geomorphological processes take place in the lithosphere and climate happens to be a major driving factor that have direct impact on these processes. Exogenetic processes includes denudational processes of weathering and erosion which basically originates due to climate factors. These days the field of climatic geomorphology is an emerging field and researchers study how temperature and moisture affects the rate of weathering, soil formation, sub-surface freeze and thaw *etc.* It was started as a distinct branch of geomorphology in the 20th century in France and Germany.

Elements of climate like temperature, humidity, wind circulation *etc.* affect various erosional processes like fluvial, aeolian, marine, groundwater, glacial, peri-glacial *etc.* It is also a well-known fact that spatial variations in climatic parameters like temperature, humidity,

precipitation, etc. leads to variations in the landforms in different climatic regions. For example, a region with high mean annual temperature and humidity favours deep chemical weathering and the steep slopes in these regions would have the presence of gullies. Also high temperature and humidity favours dense vegetation on such slopes. So soil erosion, sheetwash and other erosional activities are reduced to a great extent in slopes having dense vegetation. Contrary to this, the slopes which have been cleared of natural vegetation would experience active erosion.

Humidity also leads to the events like landslides, soil creep and other mass wasting activities along the slopes. Glaciers and winds also shape the landforms. These are well established research frontiers for climatic geomorphologist.

ATMOSPHERE

Atmosphere is a gaseous envelope surrounding the earth and contains several gases as well as minute suspended solid and liquid particles (aerosols). These are held by earth's force of gravity and support life. Nitrogen and oxygen are two major constituent gases that make up about 99% of dry air in lower atmosphere. The remaining one percent is constituted by argon, carbon dioxide, helium, methane, hydrogen, nitrous oxide, ozone etc. Out of this one percent gas, few are greenhouse gases like carbon dioxide, methane, nitrous oxide, water vapour etc. Due to human activities like burning of fossil fuels, gases emanating from industries etc., the percentage of greenhouse gases has increased. This has in-turn increased the temperature of the atmosphere as these gases are transparent to incoming solar radiation but traps the outgoing longwave terrestrial radiation and creates a warming effect. A change in temperature would affect other climatic elements like humidity, pressure etc. and have an adverse effect on all the other spheres. It would bring change in landscape, water bodies, ice sheets, as well as biogeochemical cycles.

HYDROSPHERE

Hydrosphere is the discontinuous layer of water at or near the earth's surface and includes all liquid and frozen waters on surface and underground, in rocks and soil as well as atmospheric water vapour. The processes operating in hydrosphere are hydrological processes due to which water is in a constant state of motion and gets transferred from one realm and form to other in a hydrological cycle. Climate is also a major determinant of hydrological processes.

Temperature and precipitation are the two important climatic parameters that directly affect the amount, seasonality and distribution of water available in different realms of hydrosphere like surface run-off, overland flow, soil water retention or infiltration of rainwater, channel flow, storage etc. If there is any change in global climate system, it affects the water on earth's surface and this changes the water balance in different realms. This also affects the human systems like agriculture, fisheries, environmental management etc.

Changes in climatic parameters affect the salinity which also affects the hydrosphere. They also have an impact on fisheries and coastal and marine ecosystem. Climate change also affects the deep water circulation in the oceans by altering the thermohaline circulation. The hydrological processes also get affected due to human activities like deforestation, urbanization,

industrialization, concretization etc. which results into a change of climatic parameters either directly or indirectly.

BIOSPHERE

Biosphere is the life supporting layer which surrounds our planet earth and consists of all living organisms (the biotic component), energy (the energy component) and physical environment (abiotic component). Climatological impacts are felt in biosphere in a number of ways and it affects the interactions between living organisms themselves and also between living organisms and physical environment. These interactions can be in the form of predator-prey relationships, disease and insect infestations etc.

The atmospheric processes are also responsible for these large scale input-output mechanisms through biogeochemical cycles. They also have impact on the soil composition, its vertical profile, soil moisture and its erosion.

CRYOSPHERE

You may also be familiar with the term *cryosphere*. Cryosphere is the frozen part of the earth's system. It includes ice and snow on land as well as that found on water bodies. Snow covered areas on land includes continental ice sheets found in Greenland, Antarctica as well as other areas of snow and permafrost. The other part of cryosphere found on water bodies includes the frozen parts of oceans near polar regions and also includes frozen rivers and lakes. Climate has a lot of effect on the cryosphere.

You must have read in a previous module of this course that snow has very high albedo or reflectivity of the incident shortwave solar radiation. This means that it reflects about 90% of the incident light or it can be said that it has an albedo of 90%. A slightest increase in temperature conditions would melt some snow and this would decrease the albedo of that part of the cryosphere which increases the rate of melting of snow further. The conditions are just the reverse when there is a decrease in temperature conditions of the cryosphere.

Refer to Figure 1 to get a clear picture of the effect of climate on different natural systems.

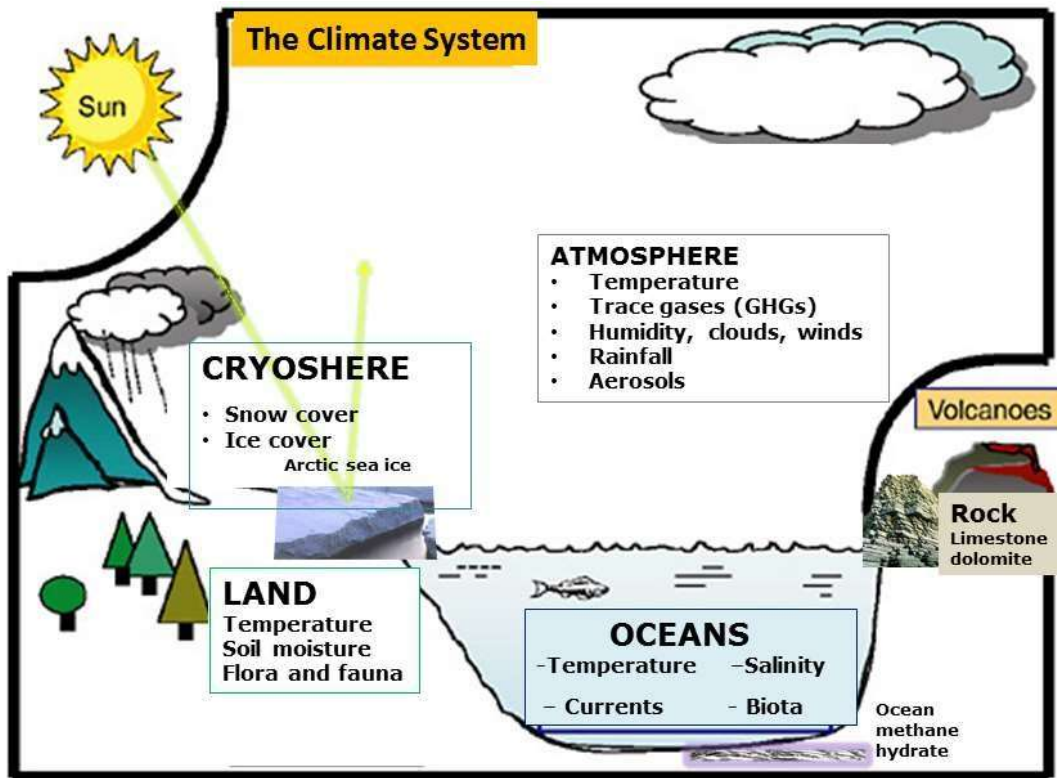


Fig.1: Climate and Natural Systems

Let us now study about the impact of climate on societal systems.

CLIMATE AND SOCIETAL SYSTEMS

Climate has a lot of impact on our societal systems. Some of them are impacted directly or in a primary manner while others are affected in an indirect manner or secondary manner. Let us first acquaint ourselves with the impact of climate on societal systems like agriculture, transport sector, recreational activities, energy or power requirement and insurance sector which are affected directly by climatic parameters.

CLIMATE AND AGRICULTURE

Agriculture is the most primary occupation of human beings and marks the beginning of their sedentary life. Prior to agriculture, human beings spent a nomadic life wandering about from one place to another and practised hunting and food gathering for their sustenance. Climatic elements like temperature, humidity, precipitation etc. determines the type of crops that are grown in a particular area and also determines their distribution at places having similar climatic conditions. It also determines the farming practices.

Today in the technological era, a lot of advances have been made in the field of agriculture and it has been possible to grow crops in quite adverse conditions. However, the impact of climate cannot be ignored. Take for example, temperature, which acts as one of the major climatic parameter and affects the crops at different successive stages of their development right from sowing and germination to their maturity. An optimum temperature is required at every stages of development of crops, otherwise the quality and yield of crops are affected. For example, in India, a sudden increase in temperature from the beginning of March speeds up the ripening of wheat which also reduces its yield.

Similarly, frosts and hailstorms are also very dangerous for crops. Frosts are responsible for damaging certain crops like potatoes, tomatoes, oil seeds, peas etc. In the same way, fruit orchards in the mountain valleys are also damaged due to frosts which results due to temperature inversion. Hailstorms associated with western disturbances, also pose a serious threat to the standing crops of wheat, vegetables, oilseeds and other *rabi* (winter) crops.

Moisture is another important climatic parameter that affects the cultivation of crops. As plants derive their nutrients from the soil, so soil moisture is very important for plants. The amount of soil moisture varies from being in saturated stage to field capacity stage to wilting stage. ***Saturated stage*** refers to the stage when all voids and pores of soil are filled with water and such conditions are preferred by crops like paddy and sugarcane which are water intensive crops. In ***field capacity stage*** about 50% of the total voids and pore spaces are filled with water and the rest is occupied by air. Such a soil condition is favourable for millets, maize, wheat, mustard seeds, etc. Lastly the ***wilting stage***, as the name suggests refers to the stage when soil water is lost through continuous evaporation and the crop wilts. So such type of soil is not conducive for any crops.

Apart from soil moisture, atmospheric moisture and precipitation also affects agricultural productivity. There are normally three types of droughts resulting due to rainfall deficiency. First is the ***permanent drought*** which is a characteristic of arid regions. Second is the ***seasonal drought*** which is associated with two distinct periods of wet and dry seasons and the third is the ***occasional drought*** which is associated with rainfall variability.

Besides moisture, incoming solar radiant energy is also an important parameter which is controlled by climate. Productivity of any crop depends on the efficiency of plants to convert solar energy into chemical energy. Solar energy also regulates the temperature conditions of a particular place and decreases from equator to poles. So it is also a major determinant of the types of crops grown at a particular place as well as its productivity.

CLIMATE AND TRANSPORTATION

Transportation is another societal sector which is impacted by climate. Transportation system forms the backbone of any country as on it depends the movement of raw materials, finished products, food grains, commodities, people etc. Machine or fossil fuel based transportation system includes air transport, water transport and land transport (roads and railways). Air transportation makes tremendous use of weather conditions like temperature at varying altitudes, snowfall, winds and turbulence, overcast sky and low visibility, heavy rainfall, etc. The field is also known as *aviation climatology*, which includes average weather at different altitudes and over different locations on the earth. Air transport uses climatic data at all stages like take-off stage, flying stage and landing stage.

Similarly, we have *highway meteorology* or *highway climatology* which studies the relationship between weather and climate and road transport. Temperature is an important climatic parameter which impacts road transport. Freezing temperatures cause frosting of road materials while increasing temperatures (greater than 35°C) causes the non-concrete roads to melt. A dip in temperature below -20°C also brings about waxing of diesel which makes the vehicular movement impossible. Cyclonic winds also block the roads by uprooting trees along the roadsides or bringing other debris and accumulating them on the roads. Sandstorms and dust storms also play havoc to the road traffic as visibility becomes very low. Excessive rainfall also causes flooding of the roads which brings a lot of inconvenience to the roads traffic and sometimes even halts it completely.

Elements of weather like temperature, rainfall and conditions leading to fog, snow etc. also affect the rail transport. Rail tracks are severely affected due to seasonal variations in temperature conditions. Freezing temperatures sometimes bring about fractures in the tracks, the condition being more prevalent in the states of Punjab, Haryana, Western Uttar Pradesh, Jammu and Kashmir, Rajasthan, etc. in India. Fog creates severe visibility problems and delays the trains as they move about very slowly. Heavy rainfall also causes flooding along the railway tracks and also damages them.

Weather induced oceanic phenomenon of tides, waves etc. affect the oceanic transport or shipping. Weather elements like air temperature, precipitation and atmospheric disturbances like cyclones, hurricanes, tornadoes etc. badly affect the water transport along oceans and seas. Dense fogs also reduces visibility and creates hassles in the water transport. Temperatures below the freezing point leads to the formation of icebergs which creates obstacles in water navigation.

CLIMATE AND RECREATIONAL ACTIVITIES AND TOURISM

Climate affects several forms of recreation and tourism industry. Some of the recreational activities like skiing as you know directly depends on sub-freezing temperatures and snowfall. Similarly sports events especially outdoor ones also depends on good weather. So activities like hill tracking, skiing, gliding, surfing etc. are *weather dependent sports*. On the other hand, sports like football, cricket, rugby, volley ball etc. are *weather-interference sports* as they are interfered or interrupted by weather activities like rainfall, thunderstorms, duststorms, fog etc.

Now it must be obvious for you that climatic factors affecting tourism and recreation are air temperature, sunshine, humidity, cloudiness, wind speed etc. Based on these tourism can be grouped into two categories, viz, ***climate-dependent tourism*** and ***attractiveness-dependent tourism***. Visits to hill stations during summers are examples of climate dependent tourism while visits to Sahastra dhara falls in Dehradun is an example of attractiveness based tourism. Refer to Figure 2 and Figure 3 to get a clear picture of climate-dependent tourism and attractiveness-dependent tourism respectively.

RELIGIOUS TOURISM is also dependent on weather and climatic conditions as quite a number of religious places are situated on high altitudes which are landslide prone. Figure 4 shows the path that leads to Vaishno Devi shrine which is landslide prone. Usually rainy seasons are avoided by tourists as landslides are more frequent due to rains. Besides, some religious places situated at high elevations are open only for a limited duration during the summers to avoid extreme freezing temperatures prevailing there. An example of this can be cited as the visit to “*Char Dham*” (Kedarnath, Badrinath, Yamunotri, Gangotri), Kailash Maansarovar etc.

Figure 2: Climate Dependent Tourism (A View of Hill Station of Kullu in Himachal Pradesh)



Figure 3: Attractiveness Dependent Tourism (Sahastra Dhara Falls in Dehradun)



Figure 4: Landslide Prone Route of Vaishno Devi Shrine, Jammu and Kashmir



Let us now get acquainted how climate is directly related to energy requirement of the society and also the insurance sector.

CLIMATE AND ENERGY REQUIREMENT

Climate has a direct impact on the amount of energy consumed. You can easily reason this out as extremes of temperatures lead to greater consumption of energy. Our body needs an optimum amount of temperature. If the temperature rises to an intolerable extent, then power is needed to

run air-conditioners to cool the room to an optimum level so that it becomes comfortable. Reverse is the condition if a place experiences freezing temperatures. In that case extra power is required to operate blowers and air-conditioners that produce a warming effect in the room. Power companies often take suggestions from climatologists so as to get an estimate of the power needed for a particular season based on climatic forecasts. Climatologists also give suggestions regarding feasibility of exploring the use of non-conventional sources of energy for a particular place which could in fact reduce burden on fossils fuels and also save environment by providing green energy.

CLIMATE AND INSURANCE SECTOR

The insurance and risk management sector is also directly influenced by weather and climate. Disasters do happen when people settle in areas vulnerable to hazards. You know that these days a lot of developmental activities have come up in hazard prone areas. This has led to greater inhabitation or settlement of those areas compared to the past. Sometimes even the carrying capacity of those regions have exceeded and any hazard would result in severe loss of life and property. A very good example of this can be seen in Figure 5 which shows Kedarnath area in 1882 and 2011. You must have noticed that so many settlements have come up in these years around the temple area which is landslide prone especially during the rainy season. This was one of the main reasons why so many people lost their lives in the heavy rains of June 2013, when the area experienced multiple landslides and also breach of Chorabari Lake which washed away the entire settled area around the Kedarnath temple.

Figure 5: Settlements around Kedarnath Temple Area in the year 1882 and 2011



Source: A Report on Kedarnath Devastation, Wadia Institute of Himalayan Geology, December, 2013,

So again, consultancy of atmospheric scientists are taken by insurance and risk management companies as well as National Disaster management agencies of government in the form of pre-warning given by them. This helps in prior evacuation of the areas and save life and to some extent curtail the loss of property too.

SECONDARY SOCIETAL IMPACTS

So far, you have studied about the societal systems which are affected primarily by weather and climatic elements. Now let us get acquainted with the indirect or secondary impact of climate on societal systems in brief.

Climatic parameters have direct influence on agriculture which in turn affects the food prices. If the crop fails, the shortage leads to a soar in the prices of affected crops. Similar situation is also reached during extreme weather events which make even bare sustenance almost impossible for those affected. This also affects the economic as well as political conditions of the place. Sometimes failure of the government to handle price rise of essential commodities leads to a kind of unrest amongst the affected people. In India and a few other places in the world have witnessed the downfall or even change in the government due to these factors.

With the above discussion, it is evident that climate plays a major role on the societal sector. Let us now study the impact of climatic elements on human health which is emerging as an important area of research now-a-days.

CLIMATE AND HEALTH

We have already discussed that human body can survive in certain suites of climatic conditions. We require an optimum amount of light, sunshine, temperature, humidity, precipitation and above all a requisite amount of oxygen. If any of these parameters, are above or below an optimum level, there is an adverse effect on human health. We all know that at high altitudes, that is, in mountainous regions, there is lack of oxygen, due to low air pressure in those regions. You might have noticed that while travelling towards higher altitudes, you often get nausea feeling or experience bleeding from the nose. This is also called *mountain sickness*. This happens because body pressure is high compared to the surrounding atmospheric pressure in the regions and in order to maintain a balance between body and the environment, things like nausea and bleeding occurs and create a lot of discomfort. At extremely high altitudes, breathing might be even impossible without the aid of oxygen cylinders. You might have seen that mountaineers going for higher expeditions like Mt. Everest are often armed with oxygen cylinders and wear proper insulated dresses so as to combat the extremely cold winds. Refer to Figure 6 to get an idea of the mountaineers on an expedition to Mt. Everest.

Figure 6: Mountaineers on an Expedition to Mt. Everest

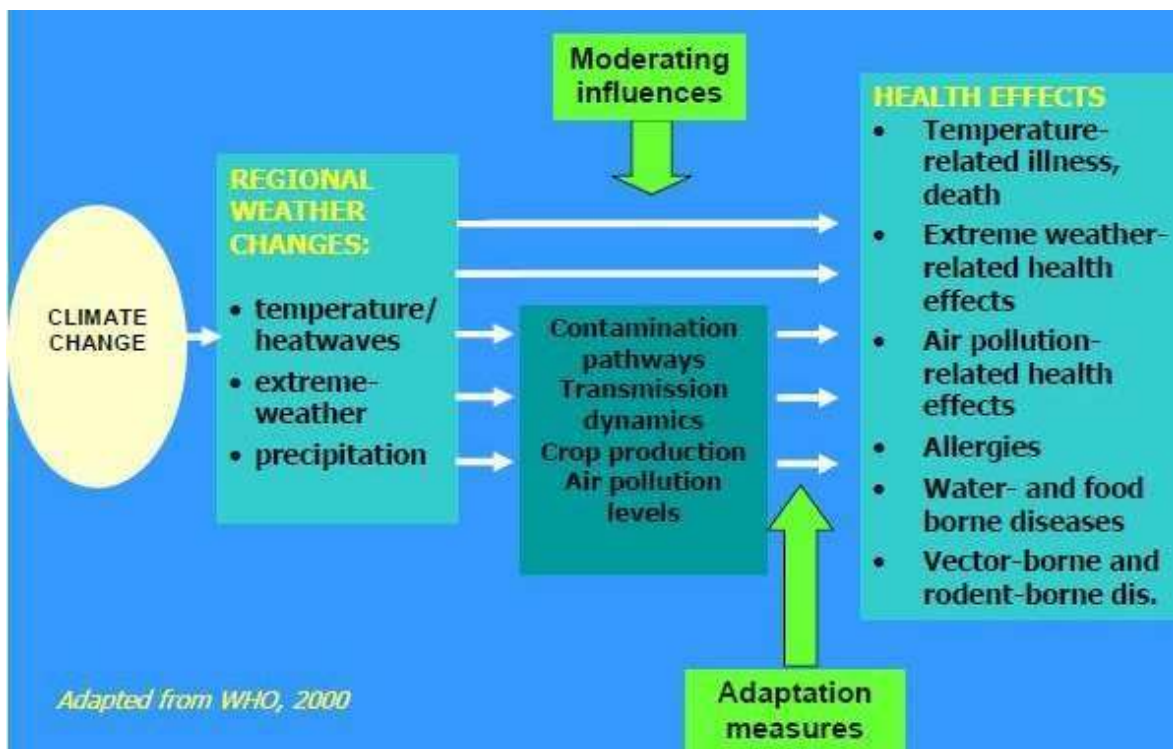


Normal body temperature of human beings is 98.6° F (37° C). Body metabolism helps to maintain a balance between incoming and outgoing heat. When the surrounding air temperature is above the human body temperature, body gains heat and vice versa. The skin acts as a primary source of heat exchange from body to the environment and vice versa. This gives rise to two extreme conditions, namely *hypothermia* and *hyperthermia*. Hypothermia is a condition that happens in extremely cold environmental conditions when the body temperature falls much below the normal level and causes severe frost bites and in acute cases leads to death of human beings due to freezing of tissues and destruction of cells. On the other hand hyperthermia is a condition which happens in extremely hot environment and the human body temperature rises and blood vessels dilate. A lot of sweating occurs as moisture escapes from skin in an attempt to

reduce the body temperature by evaporation. Both the conditions of hypothermia and hyperthermia brings a lot of discomfort to human body and is also fatal in some cases. It is obvious that the comfort zone of human beings exists when normal body temperature is maintained. Based on this a few comfort indices have been devised known as *physioclimate indices*. These include the heat index stress, standard effective temperature, apparent temperature, comfort clothing etc.

Now-a-days, the effect of weather and climate on human health is studied under an upcoming branch of climatology which is called *medical climatology*. Certain diseases are related to climate. For example global warming and humidity may increase the cases of vector borne diseases like malaria, dengue etc. to areas beyond their normal locations. So, we can conclude that, climate has a role to play on human health and comfort.

Figure 7: Climate and Health



CONCLUSIONS

Applied climatology is the study of the effects of climate on natural and social systems. Sources of climatic data is broadly divided into two types, that is, primary and secondary sources. We have studied the effect on climate on natural systems which consists of five spheres. There is a continuous interaction between these spheres and climate plays a major role in affecting different

processes that occurs within these systems. Processes in the atmosphere inherently affect other spheres. Climate also has a huge impact on our societal systems like agriculture, transportation, tourism, energy requirement, insurance sector etc. Climate also has a lot of bearing on human health as human body can survive well only in certain suites of climatic conditions.