UNIT 8 PREDICTING FUTURE CLIMATES

Structure

8.1 INTRODUCTION

In recent years, there has been a growing concern about climate change all across the globe. The increasing average global temperatures, the rising of sea level and submerging of low-lying islands, the loss of biodiversity and shrinking of hotspots all over the world have led to increasing distress about the changing climate. Historically speaking, ever since the origin of the

Earth, it is not the first time that the climate is changing; however, the enhanced anthropogenic contribution to climate change is what makes the entire scenario worrisome. As a result, scientists all over the world are thinking of various strategies to understand the phenomenon of climate change, to gain an insight about its implications and also to quantify the changing climate by means of models. It is where the role of climate models comes into picture. These models attempt to quantify the changing climate by using physical laws of radiation and energy; and studying the radiation behaviour and flux at the surface of the Earth. So, there may be regional or global climate models to quantify the extent of change that the Earth is undergoing in terms of climate; and also include clouds and aerosols in more complex models for understanding their dual role in radiative forcing of the Earth, that eventually leads to climate change. Various emission scenarios of greenhouse gases are also discussed in this unit that have been reported by the Intergovernmental Panel on Climate Change (IPCC).

8.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the analogues from past climate;
- classify the different types of climate models; and
- explain the emission scenarios.

8.3 ANALOGUES FROM PAST CLIMATE

As per IPCC Report (2007), rapid climate changes have been observed in the recent past and are further expected to increase in the near future. The analogues approach is a novel method of testing the ground realities to the outputs of climate models. In this approach, the analogues tool connects the sites that are analogous (similar) to climates at sites across other geographic locations, implying climates across space as well as time (means with respect to historical or projected future climates). For example, if any place in the world has the present climate that is similar to the future predicted climate elsewhere; then these two sites can provide interesting observations on adaptation strategies to be followed for mitigating or at least minimizing the adverse effects of predicted climate change in future. This approach is usually helpful for complex systems that face difficulty in climate models. But this approach holds true only if climate is the driving force behind the observations in differences at the two sites. In a holistic way, the analogues approach can help to relate global models with targeted field studies (Ramírez-Villegas et al., 2011) to explore mechanism of adaptation. Such comparisons between sites can be used to enable farmers to develop a knowledge framework for realising the future of site-specific agricultural output. The analogues tool, coupled with field studies link mathematical climate models with existing farm technologies. The analogues methodology can use historical data to understand the case studies where the success or failure of adaptation mechanism can be identified.

In this approach, users specify a location known as the 'reference' location'; variables such as rainfall and temperature; and, one or more climate scenarios for future-related analyses (e.g., 2020, 2030, or 2050), an SRES emissions scenario (IPCC 2000, Moss et al. 2010), and a global climate model (GCM) (IPCC 2007, PCMDI 2007). The temporal data for variables ranges from hourly to yearly basis including daily or monthly data. When the tool finds suitable global present-day analogues for the 2050 climate of a given reference site A, the analogues tool would first use the forecast the climate scenario and then compare the present-day climate for all sites where data exist with A's projected climate. The result is then compared using dissimilarity index. Not only climatic, but other variables such as soils, crops, and socioeconomic characteristics are also considered. The outputs are generated for any geographic region at any resolution equal to or above 1 km, depending on the amount of data, the computational power and the spatial resolution of the data.

8.4 CLIMATE MODELS

A model is a qualitative and/or quantitative representation of objects or phenomenon. Computer models that simulate Earth's climate are called as General Circulation Models (GCMs). Climate models use physical parameters and processes as input to simulate past climate and predict future climatic conditions. Various workers call climate models as an extension of weather forecasting; except that the primary focus on time duration lies on decades, rather than hours. These models represent mathematically the five components of climate system- atmosphere, hydrosphere, lithosphere, cryosphere and biosphere based on physical and chemical principles of thermodynamics, fluid dynamics, radiative transfer and biological interactions. In recent years, inclusion of clouds and carbon cycle in climate models has also been emphasized. Thus, these models can be used to simulate changes in temperature, rainfall, winds and oceanic circulations over long periods. However, these models being based on assumptions and mathematical algorithms have certain limitations in simulating the Earth's climate which is complex and in dynamic state of flux. Nevertheless, these models have improved greatly in the last few years to provide better insight into future climate. The accuracy of these models can be tested by assessing their ability to simulate past or present climates. The climate models are an important tool for understanding how climate might change, rather than will change, based on quantitative and scientific measurements. Normally, *"scientists validate their models by comparing them against real-world observations or testing against past changes in the Earth's climate ('hindcasts') such as temperature, rainfall, snow, hurricane formation, sea ice extent and many other climate variables. Also, it has been observed that the average of all models can be more accurate than most individual models* *in terms of higher reliability and consistency when several independent models are combined"* (https://www.carbonbrief.org/qa-how-do-climate-models-work).

8.5 TYPES OF CLIMATE MODELS

The best models of climate change have been used by Intergovernmental Panel on Climate Change (IPCC) to develop climate change scenarios. The two primary models used to project changes in climate were developed at Canadian Climate Centre, and Hadley Centre in United Kingdom.

Other climate models have been developed at:

A) National Centre for Atmospheric Research

B) NOAA's Geophysical Fluid Dynamics Laboratory

C) NASA's Goddard Institute for Space Studies

D) Max Planck Institute for Meteorology in Germany

Although these models work on similar principles; however, the output from these models vary based on inputs provided for these models as well as the uncertainties in emissions of greenhouse gases. For example, the Hadley model projects wetter climate than Canadian model; while the latter projects higher temperatures over US. In general, almost all climate models predict higher increase in temperature at regions in middle to high latitudes since the melted ice and snow in these regions decrease reflectance; thus, allowing for greater absorption of heat in these regions. These models predict that the net effect of adding greenhouse gases and fossil fuel combustion results in producing a warmer climate. IPCC anticipates a warming of 1.1°C to 6.4°C between 1900 and 2100. Thus, it becomes imperative to understand the differences in model projections for interpreting the results from the models. Some models have been discussed below:

8.5.1 Energy Balance Models (EBMs)

These models calculate surface temperature as a variable for climate by considering the balance between incoming solar energy and outgoing solar energy in the form of heat released back to space.

8.5.2 Zero-dimensional Models

These models considerthe entire Earth as a whole unit; essentially, as a single point. For example, a simple radiant heat transfer model that treats the earth as a single point and averages outgoing energy.

8.5.3 One-dimensional Models

Besides treating Earth as a one unit, these models includethe transfer of energy across different latitudes of the Earth's surface. Further, one-dimensional model can be represented by the following equation:

$$(1-\alpha)S\pi r^2 = 4\pi r^2 esT^4$$

where,

$(1-\alpha)S\pi r^2$refers to the incoming energy from the sun

$4\pi r^2 esT^4$represents the outgoing energy from the sun calculated from Stefan Boltzman's constant using constant radiative temperature T

S is the solar constant = 1367W/m^2

$\alpha$is Earth's average albedo (~ 0.3)

r is the Earth's radius, approximately 6.371×10^6m

e is effective emissivity of earth, about 0.612

s is Stefan Boltzman's Constant, approximately $5.67\times10^{-8}JK^{-4}m^{-2}s^{-1}$

T is the Radiative temperature (K).

If we factor out πr^2, then

$$(1-\alpha)S = 4esT^4$$

The above equation represents the effective radiative temperature of the Earth and yields an average Earth temperature of 288K. This model determines the effect of changes in solar output or albedo or earth's emissivity on surface temperature. However, these one-dimensional models do not look into the issue of temperature distribution on Earth or the factors responsible for circulation of energy about the Earth.

8.5.4 Radiative Convective Models

These models are refinement of one-dimensional model that they can determine the effects of varying concentrations of greenhouse gases on emissivity and hence the surface temperature. Further, these models simulate the transfer of energy through the altitudes of the atmosphere by Radiative transfer or convection for transport of heat. Radiative Convective Models can calculate the temperature and humidity of different layers of the atmosphere.

8.5.5 General Circulation Models (GCMs)

These models are also called Global Climate Models, and are four – dimensional (4-D) models (including time as a parameter) which simulate the climate based on physical laws, the flows of air and water in the atmosphere and/or the oceans, as well as the transfer of heat. Earlier GCMs focussed on only one component of atmosphere, may be only atmosphere or oceans.

The first general circulation climate model combining both atmospheric and oceanic processes was developed by NOAA Geophysical Fluid Dynamics Laboratory in 1960s. Early GCMs only simulated one aspect of the Earth system – such as in "atmosphere-only" or "ocean-only" models – but they did this in three dimensions, incorporating many kilometres of height in the atmosphere or depth of the oceans in dozens of model layers.

A global climate model (GCM) is a complex mathematical representation of the major climate system components mentioned below:

A) The atmospheric component- simulates clouds and aerosols.

B) The land surface component- vegetation, snow cover, and water bodies.

C) The ocean component- simulates current movement and biogeochemistry

D) The sea ice component- It modulates solar radiation absorption and air-sea heat and water exchanges.

These climate models divide the globe into a three-dimensional grid of cells, and equations for each component (atmosphere, land surface, ocean, and sea ice) are calculated on the global grid for a set of climate variables such as temperature; as well as exchange fluxes of heat, water, and momentum. The grid size is dependent upon the computing power and the capability of the computer to solve these equations. If the resolution is fine, that means higher number of grid cells are required; while for farther spaced grid cells, lesser calculations are required; but even the details are less comprehensive.

Further, there are two types of processes within climate models - simulated and parameterized. Simulated processes are larger than grid-scale and based on principles such as conservation of energy, mass, and momentum. An example of a simulated process is the model representing tropical cyclones and storm activity. Parameterized processes represent processes that are smaller than grid scale, and use both scientific principles as well as use of observational data. An example of a parameterized process is model that represents cloud and aerosol composition.

For parameterisation of climate models, the Earth is divided into grid cells and the average climate for each grid cell is calculated. However, various processes such as height of landscape or presence of clouds occur at much smaller scale than the size of grid, and hence may be overlooked. To rectify such errors in a model, these variables are "parameterised", implying that their values are defined in the computer code rather than being calculated by the model itself. A few examples include scattering by aerosols, snow cover, evaporation, condensation, soil properties, rain, surface roughness and so on.

In many cases, it is not possible to narrow down parameterised variables into a single value, so the model needs to include estimation. Scientists run tests with the model to find the value – or range of values – that allows the model to give the best representation of the climate. Examples for the same include tuning model for albedo, sea ice extent and absolute temperatures.

After tuning, the next important step in a climate model is reducing the 'biases' generated as a result of deviations of simulations from the observed climate. These biases occur because models are a simplification of the climate system and the large-scale grid cells that global models use can miss the detail of the local climate. This generally occurs in case of regional or local simulations. Typically, bias correction is applied only to model output, but in the past, it has also been used within runs of models.

As such, GCMs are critical tools to improve the understanding and prediction of climate change. The uses for climate modelling include diagnosis and prognosis.

8.5.5.1 Diagnostic Climate modelling

It includes detection and attribution.

a) Detection

It is the process of demonstrating that climate has changed in some defined sense without providing a reason for that change.

b) Attribution

It is the process of establishing the most likely causes for the detected change with some defined level of confidence.

An example of diagnostic climate modelling is the role of anthropogenic forcing in 20th century climate change.

8.5.5.2 Prognostic climate modelling

It predicts future climate, such as global warming trends, using current or historic data (ocean structure, radiative forcing, etc.) as a basis. Timescales for projection include seasonal/inter-annual variability, decadal prediction, and 21st century scenarios.

Thus, although we are well aware of the fact the computation of climate modelling is very intensive; however, complex algorithms and increased computing power would help in better simulations and parameterized processes, as well as reliable climate change projections.

8.5.6 Coupled atmosphere-ocean general circulation models

The coupled models are sophisticated as they factor in multiple models. The purpose of the coupled models is to represent the functioning of climate system in an inclusive manner. For instance, the coupled atmosphere-ocean general circulation models (or "AOGCMs") can at best simulate the exchange of heat and freshwater between the land and ocean surface and the air above.

A major concern with climate models is that with the diversity of climate models, it becomes difficult to compare the results of different models since the approach of each model is difficult. As a result, Coupled Model Inter-comparison Project ("CMIP") has been developed as a framework for climate model experiments, to analyse and validate GCMs. These are coupled atmosphere-ocean GCMs that aim to bring an improvement and homogeneity into all the climate models. Earlier, CMIP focused on modelling atmospheric CO_2 concentrations; later it incorporated more detailed Representative Concentration Pathways ('RCPs'). To rule out the differences in the output using different models, the results of various models are loaded on a central web portal, managed by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) that can be freely accessed by scientists all over the world. The Working Group on Coupled Modelling committee is responsible for CMIP. It is a constituent of the World Climate Research Programme (WCRP) based at the World Meteorological Organization in Geneva. Currently, CMIP6 is underway that comprises of 21 individual Model Intercomparison Projects, or "MIPs".

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What are zero-dimensional Models?

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2) What is the objective of CMIP?

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8.6 GREENHOUSE GAS EMISSION SCENARIOS

Different climate models project different values for rise in temperature, by next decade or next 50 to 100 years. This extreme gap between various climate models could be attributed to two factors:

- Climate models are unable to factor in the effects of clouds. The clouds are composed of an important greenhouse gas called water vapour, that traps the heat; as well as exert cooling effect by blocking sun's rays from reaching the earth's surface. Therefore, it is not clear as to which of the dual role these clouds play in modifying the climate. Thus, inclusion of these clouds generates some error in results, which may amount to 1 to 2°C error on a prediction for 2100.

- Further, a second aspect that needs to be taken into account is not only the current amount of greenhouse gases; but also, the amount of greenhouse gases that would be added to the atmosphere due to anthropogenic inputs.

Since such an impact of clouds and greenhouse gases would vary according to different human inputs; therefore, scientists are using the term "**emission scenarios"**, to describe the behaviour of greenhouse gases emissions. The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to "assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change". Since its inception, the IPCC has produced a series of comprehensive Assessment Reports on the state of understanding of causes of climate change, its potential impacts and options for response strategies. It prepared also Special Reports, Technical Papers, methodologies and guidelines. These IPCC publications have become standard work of reference, widely used by policymakers, scientists and other experts. In 1992, the IPCC released emission scenarios to be used for driving global circulation models to develop climate change scenarios. IPCC has developed emission scenarios for long term in 1990 and 1992. The Special Report on Emissions Scenarios (SRES) was published by the Intergovernmental Panel on Climate Change (IPCC) in 2000. The greenhouse gas emissions scenarios described in the Report have been used to make projections of possible future climate change. IPCC has in fact described about 40 scenarios which are grouped mainly into four main families - A1, A2, B1, B2; and they reflect a particular trajectory (evolution) of humanity, and the important hypothesis (concerning demography, agricultural practices, technology spreading, etc.) are then turned into "food production" and "consumption of energy" using models.

The IS92 scenarios were the first global scenarios to provide estimates for the greenhouse gases. Therefore, the IPCC decided in 1996 to develop a new set of emissions scenarios which will be of broader use than the IS92 scenarios. The new scenarios provide also input for evaluating climatic and environmental consequences of future greenhouse gas emissions and for assessing alternative mitigation and adaptation strategies.

8.6.1 The A1 family

The A1 family is based on the following hypothesis:

- Increased economic growth;
- the world population that peaks in mid-century and declines thereafter;
- introduction of new and efficient technologies;
- underlying theme converge between regions;

- social and cultural interactions increase rapidly;
- A1 scenario family describes alternative directions of technological change in the energy system; that are distinguished by their technological emphasis:
- fossil intensive (A1FI),
- non-fossil energy sources (A1T), or
- Balance across all sources (A1B).

This A1 family scenario explains that there would be increased energy consumption and exhausting of limits for fossil fuels (except coal). Besides, the atmospheric CO_2 concentration in 2100 comes close to 1100 ppm.

8.6.2 The A2 family

The A2 family is based on the following hypothesis:

- Continuously increasing world population;
- Evolution of the world in a heterogeneous manner;
- economic growth is region oriented;
- spreading of new efficient technologies is slower and are very different depending on the region of the world;
- The underlying theme is self-reliance and preservation of local identities.

8.6.3 The B1 family

The B1 family is based on the following hypothesis:

- the world peaks in mid-century and declines thereafter;
- the economic structures directed towards service and information technologies;
- rapid dissemination of new, clean and efficient technologies; and
- addressing economic, social and environmental problems without any supplementary climate initiative.

Hence, this scenario suggests significant additional resources in oil and gas compared to present times, and development of nuclear energy. Also, it predicts the atmospheric concentration of CO_2 in 2100 near about 450 ppm.

8.6.4 The B2 family

The B2 family exemplifies a world where:

- World population reaches 10 billion people by 2100.
- In this family of scenarios, the sustainability from the spheres of economic, social and environmental perspectives are emphasised through local solutions;

- Economic development is intermediate;
- Oriented towards environmental protection and social equity, it focuses on local and regional levels; and
- Development and transfer of efficient technologies in B2 family is quite uneven.

The atmospheric carbon dioxide concentration in this scenario reaches about 740 ppm.

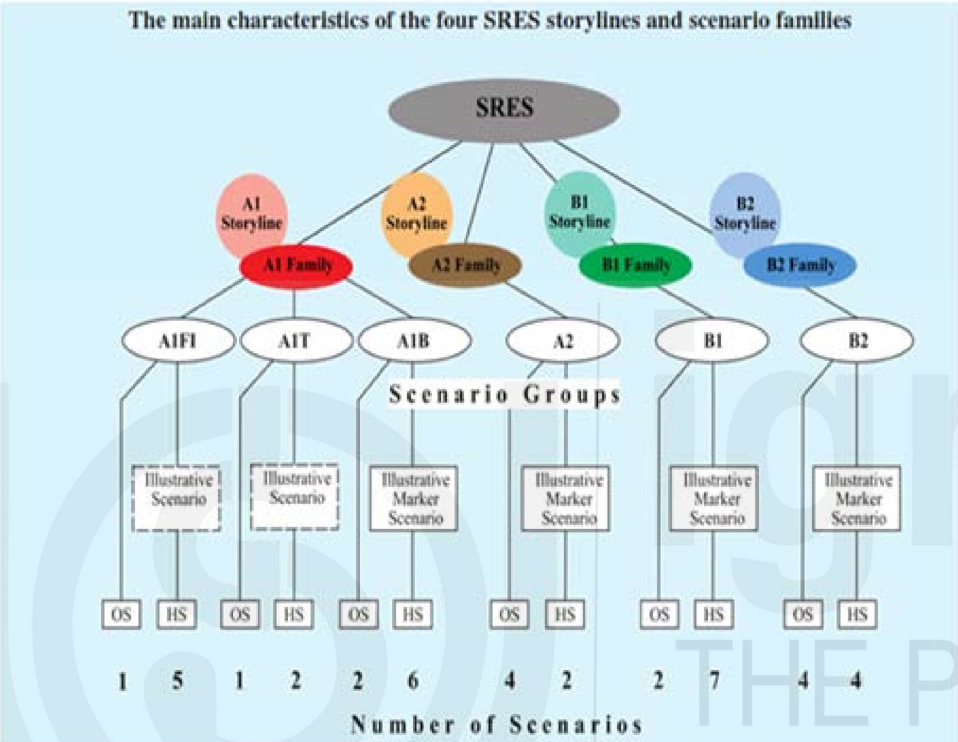

Fig. 8.1 Schematic illustration of SRES scenarios (A Special Report of IPCC Working Group III, IPCC, 2000)

8.7 TIME DEPENDENT MODELS

The emissions and radiative forcing scenarios described include a component of time: i.e., by what quantity would the climate change and what would be the time duration for the same. However, the magnitude of human-induced climate change depends more on the net carbon emitted into the atmosphere rather than average annual emissions.

Analysing all the above scenarios reveals that none of them account for extreme events such as nuclear war or a massive outbreak. Further, though they are in limited numbers, these scenarios lead to very different patterns for the greenhouse gases emissions and concentrations during the coming century. *The IS92a scenario is an older scenario that was used for the 1995* IPCC *report.* For a given emission scenario, the various models do not differ by more than 1 to 2 °C for the predicted temperature increase in 2100.

In effect, different social, economic and technological developments have a strong impact on emission trends, and the scenarios provide important understanding about relationship between environmental quality and development choices. This will greatly aid policy builders and decision makers for appropriate climate interventions.

8.8 REPRESENTATIVE CONCENTRATION PATHWAYS (RCPs)

Representative Concentration Pathways (RCPs) are a set of scenarios that have been used in IPCC Fifth Assessment Report (AR5) for predicting future climate scenario based on climate models. Since these models were developed to represent possible future concentration of greenhouse gas emissions by including a pathway that represents the trajectory of GHG emissions to reach a particular radiative forcing by 2100; hence the name Representative Concentration Pathways. Radiative forcing is a measure of the energy that is absorbed and retained in the atmosphere by greenhouse gases and aerosols. Thus, it can be positive (heating) or negative (cooling) and is affected by concentration of greenhouse gases and aerosols, changes in land cover and total solar irradiance. RCP was adopted by IPCC in its Fifth Assessment Report (AR5) that superseded Special Report on Emissions Scenarios (SRES) projections based on socio-economic scenarios that were used in Third and Fourth IPCC Assessment Reports. The basic difference lies in the fact that RCPs fix the emissions trajectory and resultant radiative forcing rather than the socio-economic circumstances. Thus, these RCPs can then be used to test policy decisions on mitigation and adaptation to climate change. There are the following four pathways based on the amount of radiative forcing produced by greenhouse gases till 2100 (https://www.environment.gov.au/system/files/resources/492978e6-d26b-4202-ae51-5eba10c0b51a/files/wa-rcp-fact-sheet.pdf).

8.8.1 RCP8.5

- According to this pathway, the radiative forcing reaches greater than 8.5 W/m^2 by 2100.
- Atmospheric carbon dioxide concentrations in 2100 would be 936 ppm (used as input in most model simulations).
- The average temperature increase for 2081-2100, relative to 1850-1900 baseline as per this model is 4.3°C while the likely range of temperature increase is 3.2-5.4°C.
- The average global mean sea level rise for 2081-2100, relative to 1986-2005 is 0.63 m while the probable range is 0.45-0.82m.
- It is based on minimum efforts to reduce emissions.

8.8.2 RCP6

- In this intermediate stabilisation pathway, the radiative forcing is stabilised at approximately 6 W/m² after 2100.

- Atmospheric carbon dioxide concentrations in 2100 would be 670 ppm (used as input in most model simulations).
- The average temperature increase for 2081-2100 relative to 1850-1900 baseline as per this model is 2.8°C while the likely range of temperature is 2.0-3.7°C.
- The average global mean sea level rise for 2081-2100 relative to 1986-2005 is 0.48 m while the probable range is 0.33-0.63m
- It requires strong mitigation efforts, with early participation from all emitters followed by active removal of atmospheric carbon dioxide.

8.8.3 RCP4.5

- In this intermediate stabilisation pathway, the radiative forcing is stabilised at approximately 4.5 W/m² after 2100.
- Atmospheric carbon dioxide concentrations in 2100 would be 538 ppm (used as input in most model simulations).
- The average temperature increase for 2081-2100 relative to 1850-1900 baseline as per this model is 2.4°C while the likely range of temperature is 1.7-3.2°C.
- The average global mean sea level rise for 2081-2100 relative to 1986-2005 is 0.47 m while the probable range is 0.32-0.63m.

8.8.4 RCP2.6

- In this pathway, the radiative forcing peaks at approximately 3 W m^{-2} before 2100 and then declines.
- Atmospheric carbon dioxide concentrations in 2100 would be 421ppm (used as input in most model simulations).
- The average temperature increase for 2081-2100 relative to 1850-1900 baseline as per this model is 1.6°C while the likely range of temperature is 0.9-2.3°C
- The average global mean sea level rise for 2081-2100 relative to 1986-2005 is 0.40m while the probable range is 0.26-0.55m.
- It is also referred to as RCP3-PD. (PD stands for Peak and Decline).
- RCP2.6 aims to keep warming likely below 2°C above pre-industrial temperatures.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What is emission scenario?

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2) What are the four main families of emission scenario?

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8.9 LET US SUM UP

The increasing average global temperatures, the rising of sea level and submerging of low-lying islands, the loss of biodiversity and shrinking of hotspots all over the world have led to increasing distress about the changing climate. The complexity in the climate change issue compelled the scientists all over the world to device strategies to understand the phenomenon of climate change, to gain an insight about its implications and also to quantify the changing climate by means of models. In this regard, the climate models are very important. The climate models attempt to quantify the changing climate by using physical laws of radiation and energy; and studying the radiation behaviour and flux at the surface of the Earth. There are variety of models that include regional or global climate models to quantify the extent of change that the Earth is undergoing in terms of climate.

We have studied in this unit about the role of climate models in predicting the future climate. Further, we have discussed the importance of climate analogues in climate change studies, and emission scenarios.

Acronyms

IPCC: Intergovernmental Panel on Climate Change

SRES: Special Report on Emissions Scenarios

GCMs: General Circulation Models

EBMs: Energy Balance Models

GFDL: Geophysical Fluid Dynamics Laboratory

AOGCMs: Atmosphere-ocean general circulation models

CMIP: Model Inter-comparison Project

RCPs: Representative Concentration Pathways

WCRP: World Climate Research Programme

UNEP: United Nations Environment Programme

8.10 KEY WORDS

Climate Models: A model is a qualitative and/or quantitative representation of objects or phenomenon. Computer models that simulate Earth's climate are called as General Circulation Models (GCMs). Climate models use physical parameters and processes as input to simulate past climate and predict future climatic conditions.

Energy Balance Models (EBMs): Energy Balance Modelscalculate surface temperature as a variable for climate by considering the balance between incoming solar energy and outgoing solar energy in the form of heat released back to space.

Detection: Detection of change is defined as the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change.

Attribution: Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence.

Emission scenario: A plausible representation of the future development of emissions of substances that are potentially radiatively active based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections.

Representative Concentration Pathways (RCPs): Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover.

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Web Links

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https://science2017.globalchange.gov/chapter/4/

https://www.environment.gov.au/system/files/resources/492978e6-d26b-4202-ae51-5eba10c0b51a/files/wa-rcp-fact-sheet.pdf

https://www.gfdl.noaa.gov/blog_held/time-dependent-climate-sensitivity/

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8.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) These models considerthe entire Earth as a whole unit; or as a single point. For example, a simple radiant heat transfer model that treats the

earth as a single point and averages outgoing energy

2) Coupled Model Intercomparison Project (CMIP) has been developed as a framework for climate model experiments, to analyse and validate GCMs; and bring an improvement and homogeneity into all the climate models.

Check Your Progress 2

1) The behaviour of greenhouse gases as modelled by climate models is emission scenario.

2) The four main families of emission scenario are A1, A2, B1, B2; and reflects a particular evolution of humanity, and the main hypothesis concerning demography, agricultural practices and technology spreading.