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INTRODUCTION TO CLIMATE CHANGE STUDIES

KEYWORDS: climate change, IPCC, climate change models

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ABSTRACT The present study is concerned with the climate change. Earth's climate system can be separated into four components: the atmosphere, the oceans, the cryosphere (ice) and the biosphere. Physical processes, such as radiation, circulation and precipitation, interact with biological processes, such as carbon uptake by growing plants, and chemical transformations to form a complex and dynamic system. This report deals with the causes of climate changes with respect to time, which occurs due to the change in the sun's energy received on Earth. Brief explanation has been given about the mechanisms causing climate change. Different types of models for climate change studies have been explained. Also, a downscaling technique, which is an effective tool, is used in modeling. IPCC (Intergovernmental Panel on Climate Change) Scenario reports relating to the climate change is presented at the end of the report, emphasizing on Globalization and Regionalization.

I. INTRODUCTON

Climate change refers to alterations in weather patterns or a climate system over a period of time resulting from natural processes or activities by human and other organisms. Global warming is currently the greatest trigger of climate change and it results from depletion of the ozone layer by carbon emissions.

Scientists actively work to understand past and future climate by using observations and theoretical models. Even with drastic advances in technology and scientific knowledge, climatologists still have to make many compromises in terms of realistically representing the Earth. For example, until recently most models focused only on atmospheric circulation (AGC models) whereas we now know that the oceans, cryosphere (glaciers, ice sheets, sea ice, snow cover), and land surface play extremely important roles in shaping our climate. Today, most models contain a separate or self-contained oceanic component that actively interacts with the model atmosphere. These are called Atmosphere-Ocean coupled models or AOGCMs

II. CAUSES OF CLIMATE CHANGE

The climate varies naturally on all time-scale. Variations may occur due to forces such as changes in the sun's output of energy. This energy is distributed around the globe by winds, ocean currents and other mechanisms to affect the climates of different regions. Factors that can shape climate are called climate forcing or "forcing mechanisms".. Some parts of the climate system, such as the oceans and ice caps, respond slowly to climate forcing, while others respond more quickly. Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself. External forcing mechanisms can be either natural or anthropogenic. Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast, slow, or a combination. Therefore, the climate system can respond abruptly but, the full response to forcing mechanisms might not be fully developed for centuries or even longer.

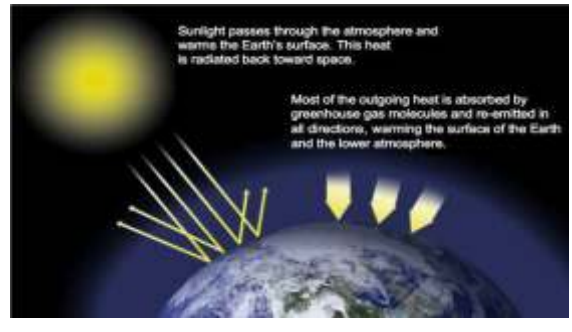

Fig 1 A Schematic of modern thermo-heline circulation

III. Modeling of Climate change

Climate change modeling presents the most current thinking on the environmental mechanisms that contribute to global climate changes and explores scientifically grounded steps to reduce the buildup of greenhouse gases in the atmosphere. The important components to be considered in constructing or understanding a model of the climate system are:

1. **Radiation** – the way in which the input and absorption of solar radiation and the emission of infrared radiation are handled;
2. Dynamics – the movement of energy around the globe by winds and oceans currents and vertical movements;
3. Surface process – inclusion of the effect of sea and land-ice, snow, vegetation and the resultant change in albedo, emissivity and surface atmosphere energy and moisture interchanges;
4. Chemistry – the chemical composition of the atmosphere and the interaction with other components, for example carbon exchanges between ocean, land and atmosphere;
5. Resolution in both time and space – the time step of the model and the horizontal and vertical scales resolved.

Various methods used for modeling of climate change are as follows:
General circulation model (GCM)

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A General circulation model (a type of climate model) is a mathematical model of the general circulation of a planetary atmosphere or ocean and is based on the Navier–Stokes equations on a rotating sphere with thermodynamic terms for various energy sources (radiation, latent heat). These computationally intensive numerical models are based on the integration of a variety of fluid's dynamic, chemical, and sometimes biological equations.

A typical GCM in the fourth IPCC assessment report models the atmosphere using grid-boxes that are about 2 degrees latitude by 2 degrees longitude by 1 km height. At the equator, the base of this box, which represents a single "pixel" in the global climate system, will cover forty-nine-thousand square kilometres (about 1/5 area of Gujarat).
The challenge is to make substantial progress toward a mathematical theory which will unlock the secrets hidden in the Navier-Stokes equations. Fluids are important and hard to understand. There are many fascinating problems and conjectures about the behaviour of solutions of the Navier-Stokes equations as in eq. (1). Standard methods from PDE appear inadequate to settle the problem. Instead, we probably need some deep, new ideas.

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t}+\mathbf{v}\cdot\nabla\mathbf{v}\right)=-\nabla p+\nabla\cdot\mathbf{T}+\mathbf{f} \quad \ldots\ldots \quad (1)$$

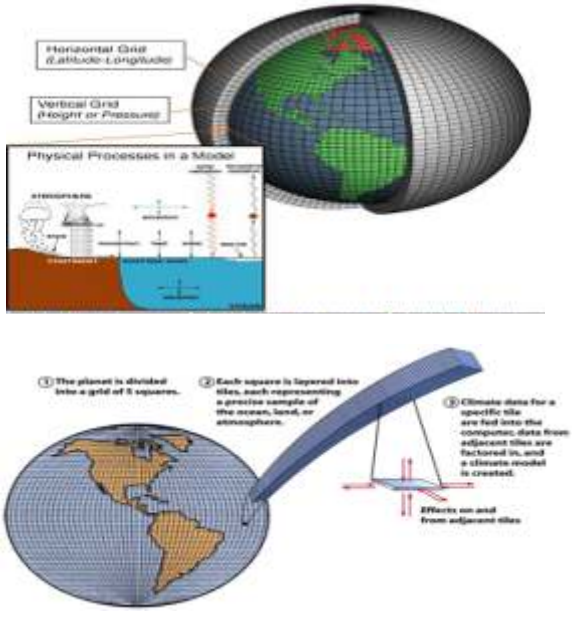

Fig 2(a, b): General Circulation model

Global Climate Model
Global Climate Model (GCMs) have been used for a range of applications, including investigating interactions between processes of the climate system, simulating evolution of the climate system and providing projections of future climate states under scenarios that might alter the evolution of the climate system.

There are both atmospheric GCMs (AGCMs) and ocean GCMs (OGCMs). An AGCM and an OGCM can be coupled together to form an atmosphere-ocean coupled general circulation model (AOGCM). Weather models represent a subset of climate models in which, the basic framework of all scales of weather models is presented.

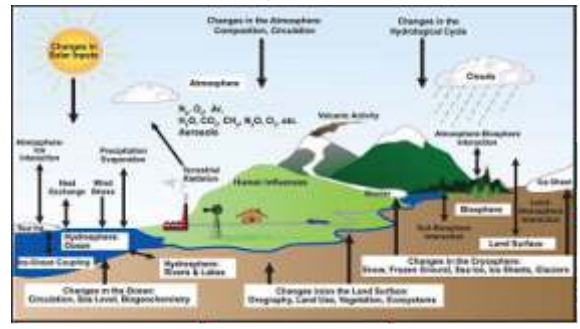

Fig 3 global climate model

Regional climate model
The RCMs have shown significant improvements over the global models in depicting the surface climate over the Indian region, enabling the development of climate change scenarios with substantially more regional detail. Some of the major findings concerning water resources are:
The rainfall scenarios are dependent on climate scenarios.
There are substantial spatial differences in the projected rain fall changes. The maximum expected increase in rainfall (10 to 30%) is for central India.
There is no clear evidence of any substantial change in the year-to-year variability of rainfall over the next century.

Energy Balance climate model
These models have been instrumental in increasing our understanding of the climate system and in the development of new parameterizations and methods of evaluating sensitivity for more complex and realistic models.
Energy balance models are generally 'one-dimensional', the dimension in which they vary being latitude. Since the energy balance is allowed to vary from latitude to latitude, a horizontal energy transfer term must be introduced, so that the basic equation for the energy balance at each latitude is
a Cm [$^{\triangle}$T (φ)/ t] = R↓(φ) - R↑(φ) + transport into zone
Where, Cm is the heat capacity of the system and can be thought of as the system's 'thermal inertia', and R and R are the incoming and outgoing radiations fluxes respectively. When using the model for annual average calculations, the surface albedo can be regarded as constant for given latitude. This type of model, however, can also be used for seasonal calculations.

One dimensional radioactive - convective climate model
One dimensional RC model represents an alternative approach to relatively simple modelling of the climate and they also occur at the bottom of the modelling pyramid. In this case 'one dimension' in the name refers to altitude, although temperature at various levels in the atmosphere can be obtained.
Radioactive- convective models can be constructed either as equilibrium models or in a time- dependent form. The main use of radioactive-convective models is to study the effects of changing atmospheric composition and to investigate the likely relative influences of different external and internal forcing. They are the basic for the 'column' models that have recently begun to be used to evaluate aspects of the parameterizations of the atmospheric 'columns' in more complex GCMs.

Two- dimensional climate model
Two – dimensional climate models can represent either the two horizontal dimensions or the vertical and one horizontal

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dimension. In such models the general circulation is assumed to be composed mainly of a cellular flow between latitudes, which is characterized using a combination of empirical and theoretical formulations. These models typically involve the modelling of tens to hundreds of chemical species and many hundreds of different reactions, and are much more demanding of computer time than 'atmosphere-only' 2D models.

Downscaling

Downscaling is the general name for a procedure to take information known at large scales to make predictions at local scales. The two main approaches to downscaling climate information are dynamical and statistical.

Dynamical downscaling: Dynamic downscaling requires running high-resolution climate models on a regional sub-domain, using observational data or lower-resolution climate model output as a boundary condition.

Statistical downscaling: Statistical downscaling is a two-step process consisting of

i) The development of statistical relationships between local climate variables (e.g., surface air temperature and precipitation) and large-scale predictors (e.g., pressure fields), and

ii) The application of such relationships to the output of global climate model experiments to simulate local climate characteristics in the future.

IPCC Scenarios:

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. It produced four major assessments of climate change in 1990, 1991, 2001 and 2007.

The IPCC SRES (Special Reports on Emission Scenarios - SRES) scenarios contain various driving forces of climate change, including population growth and socio-economic development.

The SRES team defined four narrative storylines (Fig .4) labeled A1, A2, B1 and B2, describing the relationships between the forces driving greenhouse gas and aerosol emissions and their evolution during the 21st century for large world regions and globally.



Fig. 4 IPCC SRES scenarios

A1: globalization, emphasis on human wealth Globalized, intensive (market forces). The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources.

A2: regionalization, emphasis on human wealth Regional, intensive (clash of civilizations). The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities.

Key messages from IPCC reports

* Coming years will see more extreme weather events (floods, cyclones, cloud bursts, unseasonal excessive rains and drought etc) in most parts of the globe

* Maldives, China, India, Pakistan, Bangladesh and Sri Lanka will be among the most affected countries in Asia

* Climate change may be a determining factor in national security policies.

* Decline in food grain production (wheat in India/Pakistan and wheat and maize in China).

* Big coastal cities like Mumbai and Kolkata will be affected by sea-level rise in 21st century.

* Some fish and other marine animals will face extinction by 2050, affecting fishing community.

Table-1: Difference between climate change and climate variability

Climate change	Climate variability
It occurs because of changes to earth's environment	Climate varies on all time scale of a few years to a few decades.
It is weather averaged over many days and large special scales	It varies over season and years instead of day-to-day like weather.
It can be detected by long term trend analysis considering many factors.	It can be detected by trend analysis of individual factors.
Attributed to both natural variability and human activities.	Attributed to the only natural variability such as temperature, precipitation, etc.

Conclusions

Climate Change (CC) may reduce poor people's livelihood assets, for example health, access to water, homes and infrastructure. It may also alter the path and rate of economic growth due to changes in natural systems and resources. And it is likely to directly impact children and pregnant women because they are particularly susceptible to vector- and water-borne diseases, e.g., malaria is currently responsible for a quarter of maternal mortality.

Direct impacts:

Climate change may alter the quality and productivity of natural resources and ecosystems, some of which may be irreversibly damaged, and these changes may also decrease biological diversity and compound existing environmental degradation.

Climate change would alter the ecosystem-human

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interfaces and interactions that may lead to loss of biodiversity and hence erode the basic support systems for the livelihood of many people

Indirect impacts:

- Loss of livelihood assets (natural, health, financial and physical capital) may reduce opportunities for full time education in numerous ways.
- Natural disasters and drought reduce children's available time (which may be diverted to household tasks), while displacement and migration can reduce access to education opportunities.
- Many impacts can be avoided, reduced or delayed by mitigation for that we will need a mix of adaptation and mitigation measures to meet the challenge of climate change, but this is hampered by a lack of information on the costs and benefits of adaptation
- The IPCC Fourth Assessment Report concluded, with increased confidence over the Third Assessment, that some weather events such as heat waves, storms and droughts that can have large impacts, are likely to become more frequent and widespread in the future and, in some cases, more intense.
- The main use of radioactive-convective models is to study the effects of changing atmospheric composition and to investigate the likely relative influences of different external and internal forcing.

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