Climate Change and Causes

Introduction to the lecture

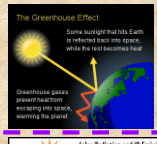
- This lecture introduces the factors that control the global climate change.
- It provide an overview on the fundamental concept of climate change, role of atmospheric gases, role of surface solar radiation, role of space weather and cosmic ray effects, role of volcanic activity, role of variations of the earth's orbital characteristics i.e. eccentricity, precession and obliquity and insolation.
- This lecture provides a geological history of the climate change through geological period.

Aim and Learning outcomes

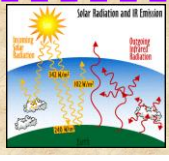
- The aim is to introduce students to the reason for climate change (natural and anthropogenic).
- On completion of lecture "Climate change and causes", students will be able to:
  - Examine basic causes of climate change.
  - Describe the components, drivers, and interactions of climate.
  - Explain the relationship between human activities and climate change

Talk outline

Introduction

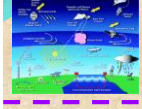


Role of atmospheric gases

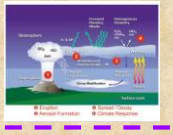


Surface solar radiation

Talk outline



Space weather and cosmic ray effects

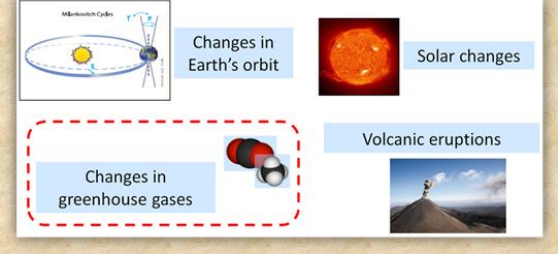


Role of volcanic activity

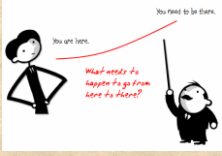
Variation of the earth's orbit

Talk outline

A Geological history of climate change



Learning Objectives



- Explain various causes of climate change.
- Explore the key scientific concepts of global climate change.
- understand the physical basis of the natural greenhouse effect, including the meaning of the term radiative forcing, compounds and particles.
- Analyze the causes of climate change and see how human activities affect the climate.

Introduction -

- The phrases CLIMATE CHANGE and GLOBAL WARMING and more recently GLOBAL COOLING are now part of our lives and rarely does a day go by without a mention in the press or on the radio of the possible causes of climate change and its consequences.
- Climate change has come upon us in a relatively short space of time and is accelerating with alarming speed.
- It is perhaps the most serious problem that the civilized world has had to face

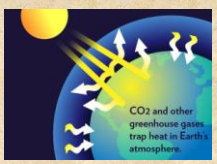
Introduction -

- The changes in the climate over the last millennium have been found by studying tree rings, ice cores and corals. The results are consistent, which confirms their accuracy.
- During the last forty years more extensive data have been obtained by instruments carried aloft by balloons and by satellites.
- The most important long-term effects are changes in the average temperature and in the sea level.
- Climate is one of the determining features of civilization, so any change in the climate can have momentous consequences.

Role of atmospheric gases

- If the general public in the developed world is confused about
  - what the greenhouse effect is,
  - what the important greenhouse gases are, and
  - whether greenhouse gases really are the predominant cause of the recent rise in temperature of the earth's atmosphere, it is hardly surprising.

Role of atmospheric gases



- It is necessary to understand the origin of the greenhouse effects: primary and secondary effects.
- Physical chemistry properties of greenhouse gases
- Lifetime of a greenhouse gas in the Earth's atmosphere.
- Long-lived greenhouse gases.

Role of atmospheric gases

- The earth is a planet in dynamic equilibrium, in that it continually absorbs and emits electromagnetic radiation.
- It receives ultra-violet and visible radiation from the sun, it emits infra-red radiation and energy balance says that 'energy in' must equal 'energy out' for the temperature of the planet to be constant.
- Evidence for the presence of greenhouse gases absorbing infra-red radiation in the atmosphere comes from satellite data.

Role of atmospheric gases

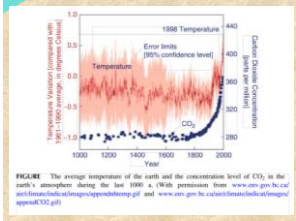
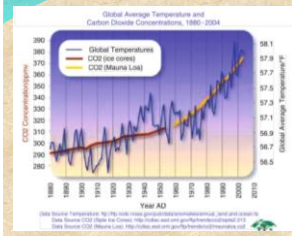


FIGURE The average temperature of the earth and the concentration level of CO_2 in the earth's atmosphere during the last 1000 a. (With permission from www.cmc.gov.bc.ca/arc/climate/indicat/images/appendtmtemp.gif and www.cmc.gov.bc.ca/arc/climate/indicat/images/appendCO2.gif)

- There is no doubt that the concentration of CO2 in our atmosphere has risen from ca. 280 parts per million by volume (ppmv) to current levels of ca. 380 ppmv over the last 260 a.

- It is also not in doubt that the average temperature of our planet has risen by ca. 0.5–0.8 K over this same time window.

Role of atmospheric gases



- Even more recent data of the last 100a, where the correlation seems to be better established will not convince the sceptic.

- That said, as demonstrated most clearly by the recent IPCC 2007report, the consensus of world scientists, and certainly physical scientists, is that a strong correlation does exist.

Role of atmospheric gases

- Data suggest that the temperature of the earth actually decreased between 1750 and ca. 1920 whilst the CO2 concentration increased from 280 to ca. 310 ppm over this time window.

- The drop in temperature around 1480 AD in the 'little ice age' is not mirrored by a similar drop in CO2 concentration.

- All that said, however, the apparent 'agreement' between rises of both CO2 levels and Te over the last 50 a is very striking.

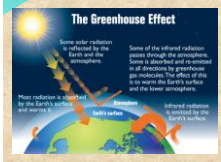
- The most likely explanation surely is that there are a multitude of effects, one of which is the concentrations of greenhouse gases in the atmosphere, contributing to the temperature of the planet.

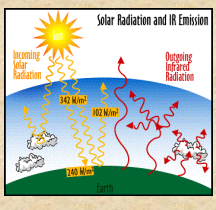
Role of atmospheric gases

- CO2 and CH4 currently contribute ca. 81% of the total radiative forcing of long-lived greenhouse gases, but it is too simplistic to say that control of CO2 levels will be the complete solution, as is often implied by politicians and the media.

- It is certainly true that concentration levels of CO2 in the earth's atmosphere are a very serious cause for concern, and many countries are now putting in place targets and policies to reduce them.

Role of surface solar radiation





- The flux density and wavelength of electro-magnetic radiation emitted from a body depend on its temperature.

- On the earth's surface the wavebands that contain the most energy, and are therefore of prime interest in the context of climate influences, are those emitted by the sun and the earth.

Role of surface solar radiation

- Global radiation decreased significantly (i.e. dimming) from the beginning of widespread measurements in the 1950s to the late 1980s over large parts of the globe and then partly recovered (i.e. brightening) in many places.

- The areal extent of these changes is not certain because of the large spatial variability, but the mean trends are evident in satellite estimates of global radiation.

- The trends are apparently caused by anthropogenic aerosols which reduce surface short wave radiation directly and indirectly through their influence on cloud properties.

Role of surface solar radiation

- Changes in radiation have played a part in regional and global changes in daily temp. range (positively correlated) as well as soil moisture (negatively correlated) and potential evaporation rates (positively correlated).

- Dimming may have offset global warming between the 1950s and 1980s while the more recent brightening may have unmasked the full extent of global warming, as seen in the accelerated temperature increase since the early1990s.

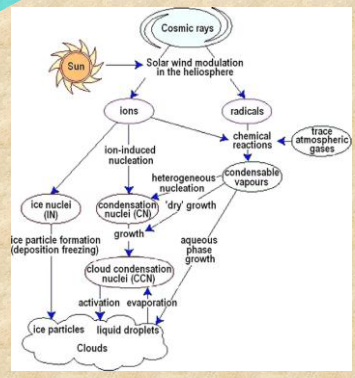
Role of space weather and cosmic ray

- There are a number of space phenomena that influence the Earth's climate and determined its long-term and short-term changes. These include:
  - the variability of the Sun's irradiation flux energy
  - the variations of the Earth's orbital characteristics;
  - the variable solar activity
  - the precipitation of energetic electrons and protons from the Earth's magnetosphere during magnetic disturbances
  - the variable Earth's magnetic field's

Role of space weather and cosmic ray

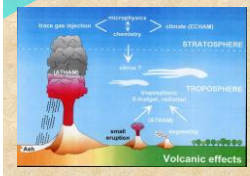
- There are a number of space phenomena that influence the Earth's climate and determined its long-term and short-term changes. These include:
  - the moving of the solar system around the galactic centre and crossing the Galaxy arms
  - the impacts of the solar system with galactic molecular dust cloud
  - the impacts of the solar system with interplanetary zodiac dust cloud
  - asteroid impacts and nearby supernova explosion

Role of space weather and cosmic ray



Possible paths of solar modulated CR influence on different processes in the atmosphere leading to the formation of clouds and their influence on climate.

Role of volcanic activity in climate



- Volcanic activity is an important natural cause of climate variations because tracer constituents of volcanic origin impact the atmospheric chemical composition and optical properties.

- This study focuses on the recent period of the Earth's history and does not consider a cumulative effect of the ancient volcanic degassing that formed the core of the Earth's atmosphere billions of years ago.

Role of volcanic activity in climate

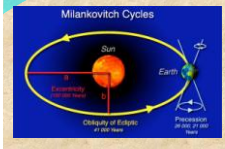
- At present, a weak volcanic activity results in gas and particle effusions in the troposphere (lower part of atmosphere), which constitute, on an average, the larger portion of volcanic mass flux into the atmosphere.

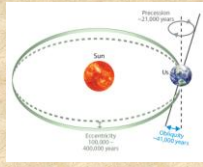
- However, the products of tropospheric volcanic emissions are short-lived and contribute only moderately to the emissions from large anthropogenic and natural tropospheric sources.

Role of volcanic activity in climate

- Volcanic emissions comprised of gases (H_2O, CO_2, N_2, SO_2, H_2S) and solid (mostly silicate) particles, that are usually referred to as volcanic ash.
- Volcanic ash particles are relatively large, exceeding 2 mm in diameter, and therefore deposit relatively quickly, that is, within a few weeks.
- They are responsible for short-term regional-to-continental perturbations of the Earth's radiative balance and meteorological parameters.
- Volcanic eruption has impacts on the tropospheric cooling and stratospheric warming, effects on hydrologic cycle, atmospheric circulation, ocean heat and sea level and sea ice.

Role of variation: Earth's orbit



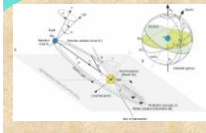


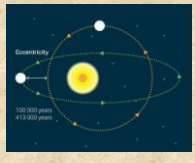
- The climate of the Earth is characterised by trends, aberrations and quasiperiodic oscillations varying over a broad range of time-scales .
- The trends are largely controlled by plate tectonics, and thus tend to change gradually on a million year (Ma) time scale. Aberrations occur when certain thresholds are passed and are manifested in the geological record as unusually rapid (less than a few thousand of years) or extreme changes in climate.

Role of variation: Earth's orbit

- The quasiperiodic oscillations are mostly astronomically paced; they are driven by astronomical perturbations that affect the Earth's orbit around the Sun and the orientation of the Earth's rotation axis with respect to its orbital plane.
- These perturbations are described by three main astronomical cycles: eccentricity (shape of the Earth's orbit), precession (date of perihelion) and obliquity (angle between the equator and orbital plane), which together determine the spatial and seasonal pattern of insolation received by the Earth, eventually resulting in climatic oscillations of tens to hundreds of thousands of years.
- The expression of these astronomical-induced climate oscillations is found in geological archives of widely different ages and environments.

Role of variation: Earth's orbit



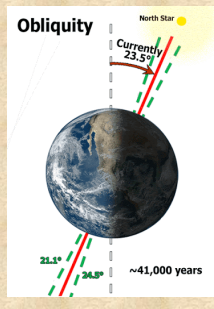


- Role of variation of the earth's orbital characteristic has effects on global climate change through eccentricity, precession and obliquity, insolation.
- The role of orbital forcing in climate change has been unequivocally shown by their characteristic patterns in sedimentary archives, ice cores and proxy records.
- Although our knowledge of orbital forcing is concerned with longterm natural climate cycles, it is of fundamental importance to assess and remediate global climate change problems on short-term periods.

Role of variation: Earth's orbit

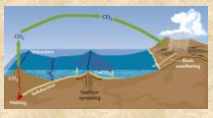
- In particular, the integration of climate modelling experiments with geological observations will provide these insights required for a better understanding of climate change in the past and near future.
- Considerable challenges will have to be addressed before the full spectrum of orbital-induced climatic variability has been unravelled, including the phase behaviour of different parts of the climate system, feedback mechanisms and the impact on ecosystem dynamics.

Role of variation: Earth's orbit



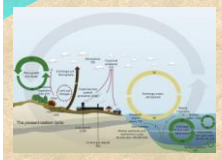
- From all the evidence, it is most likely that the climate change that we are currently experiencing is not due to variations of the Earth's orbital movements.
- With the fast rising CO_2 concentrations in the atmosphere, general orbital theories dealing with the icehouse world conditions will probably not account for future predictions.
- Integrating our knowledge of geological times when greenhouse gas conditions were those as being predicted, we might be able to decipher the role of orbital forcing in future climate change scenarios.

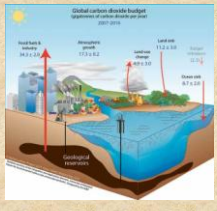
A geological history of climate change



- Earth's climate is now changing in response to an array of anthropogenic perturbations, notably the release of greenhouse gases; an understanding of the rate, mode and scale of this change is now of literally vital importance to society.
- There is presently intense study of current and historical (i.e. measured) changes in both perceived climate drivers and the Earth system response.
- Such studies typically lead to climate models that, in linking proposed causes and effects, are aimed at allowing prediction of climate evolution over an annual to centennial scale.

A geological history of climate change



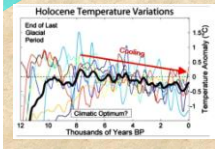


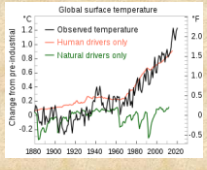
- Anthropogenic climate change is probably the largest experiment humanity has ever conducted.
- One of the major goals of climate science is to understand the system so we can predict how it will respond. But we are also interested in understanding and reconstructing past climate so we can study the geologic past.
- Our discussion in one lecture will only scratch the surface, and will be focused on the geologic controls on, and record of, past climates.

A geological history of climate change

- The history of Earth's climate system, as deduced from forensic examination of strata, has shown a general very long-term stability, which has probably been maintained by a complex interaction between the biosphere, atmosphere, hydrosphere, cryosphere and lithosphere.
- Superimposed on this overall stability has been a variety of climate perturbations on timescales ranging from multi-million year to sub-decadal, inferred to have been driven, amongst others, by variations in palaeogeography, greenhouse gas concentrations, astronomically forced insolation and inter-regional heat transport.

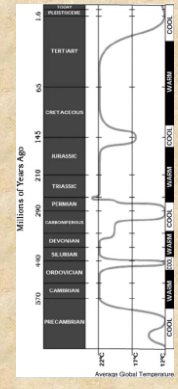
A geological history of climate change





- Current anthropogenic changes to the Earth system, particularly as regards changes to the carbon cycle, are geologically significant.
- Their effects may likely include the onset of climate conditions of broadly pre-Quaternary style such as those of the 'mid-Pliocene warm period', with higher temperatures (particularly at high latitudes), substantially reduced polar ice cover, and modified precipitation and biotic patterns.

A geological history of climate change



A graph showing estimated changes in global Earth temperature during geological time and alternating cold and warm periods (modified from Scotese 2008).