

Episode – 14

Historical Evidence of Climate change

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Abani	College teacher (45 years)
Raja	Student (20 years)
Gita	Student (19 years)
Rohan	Student (20 years)
Mala	Student (20 years)
Neha	Daughter of Abani (10 years)

(A group of students going on a study tour to a hilly area, it was winter, they were discussing with their teacher, bus sound)

Raja: It is already November, but we cannot feel it.

Rohan: Earlier in October during Durga Puja we used to listen Chandi Path in radio early in the morning. I remember we used to cover ourselves with thick quilt.

Mala: Yes these days we don't have 6 seasons any more, we have only two seasons – summer and rainy.

Neha: Rainy season also is very erratic, sometime come very late, sometimes heavy rains, other time it is very little rain.

Gita: Really everything has become very irregular.

Abani: Yes climate is changing.

Raja: Sir, this is happening these days or earlier also it has happened?

Abani: Earlier also we had this.

Raja: When we first realized about this?

Abani: People started thinking about the climate change first in 19th century when ice age and other natural changes in paleoclimate were first suspected. At that time natural greenhouse effect was identified for the first time.

Neha: What is a greenhouse papa? Is it a green coloured house?

Abani: A greenhouse is a house made of glass. It has glass walls and a glass roof. People grow tomatoes and flowers and other plants in them. A greenhouse stays warm inside, even during winter. Sunlight shines in and warms the plants and air inside. But the heat is trapped by the glass and can't escape. So during the daylight hours, it gets warmer and warmer inside a greenhouse, and stays pretty warm at night too.

- Neha:** What is greenhouse effect Papa?
- Abani:** The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases.
- Gita:** The absorbed energy warms the atmosphere and the surface of the Earth. This process maintains the Earth's temperature at around 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.
- Neha:** What are the greenhouse gases?
- Raja:** Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons, it is also called CFCs
- Rohan:** Earth's atmosphere does the same thing as the greenhouse. Gases in the atmosphere such as carbon dioxide do what the roof of a greenhouse does. During the day, the Sun shines through the atmosphere. Earth's surface warms up in the sunlight. At night, Earth's surface cools, releasing the heat back into the air. But some of the heat is trapped by the greenhouse gases in the atmosphere. That's what keeps our Earth a warm and cosy 59 degrees Fahrenheit, on average.
- Abani:** Water in the atmosphere also acts as a greenhouse gas. The atmosphere contains a lot of water. This water can be in the form of a gas—water vapour—or in the form of a liquid—clouds. Clouds are water vapour that has cooled and condensed back into tiny droplets of liquid water.
- Gita:** Water in the clouds holds in some of the heat from Earth's surface. But the bright white tops of clouds also reflect some of the sunlight back to space. So with clouds, some energy from the Sun never even reaches Earth's surface.
- Rohan:** But sir how greenhouse effect change the climate?
- Abani:** It was in late 19th century scientists first argued the human emissions of greenhouse gases could change climate. Many other theories of climate change involve volcanic eruption and solar variation.
- Raja:** Yes, I have read that in 1960s warming effect of carbon dioxide gas became increasingly convincing. Some scientists also pointed out that human activity that generated atmospheric aerosols could have cooling effects as well.
- Abani:** Yes, During the 1970s, scientific opinion increasingly favoured the warming viewpoint. By the 1990s, as a result of improving fidelity of computer models and observational work confirming the Milankovitch theory of the ice ages.
- Rohan:** a consensus position formed: greenhouse gases were deeply involved in most climate changes and human-caused emissions were bringing discernible global warming. Since the 1990s, scientific research on climate change has included multiple disciplines and has expanded.

- Abani:** Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions such as more or fewer extreme weather events.
- Gita:** Sir, since when people started thinking about climate change?
- Abani:** From ancient times, people suspected that the climate of a region could change over the course of centuries. For example, Theophrastus, a pupil of Aristotle, told how the draining of marshes had made a particular locality more susceptible to freezing, and speculated that lands became warmer when the clearing of forests exposed them to sunlight.
- Mala:** Renaissance and later scholars saw that deforestation, irrigation, and grazing had altered the lands around the Mediterranean since ancient times; they thought it plausible that these human interventions had affected the local weather. Vitruvius, in the first century BC, wrote about climate in relation to housing architecture and how to choose locations for cities.
- Raja:** But sir, when did people thought on this seriously?
- Abani:** The most striking change came in the 18th and 19th centuries, obvious within a single lifetime: the conversion of Eastern North America from forest to croplands. By the early 19th century many believed the transformation was altering the region's climate—probably for the better.
- Rohan:** Some experts reported that deforestation not only caused rainwater to run off rapidly in useless floods, but reduced rainfall itself. European professors claimed that the Orientals of the Ancient Near East had heedlessly converted their once lush lands into impoverished deserts.
- Gita:** Prior to the 18th century, scientists had not suspected that prehistoric climates were different from the modern period. By the late 18th century, geologists found evidence of a succession of geological ages with changes in climate.
- Abani:** There were various competing theories about these changes, and James Hutton, whose ideas of cyclic change over huge periods of time was among those who found signs of past glacial activity in places too warm for glaciers in modern times
- Raja:** Sir I have read that In 1815 Jean-Pierre Perraudin described for the first time how glaciers might be responsible for the giant boulders seen in alpine valleys.
- Abani:** Yes, as he hiked in the Val de Bagnes, he noticed giant granite rocks that were scattered around the narrow valley. He knew that it would take an exceptional force to move such large rocks. He also noticed how glaciers left stripes on the land, and concluded that it was the ice that had carried the boulders down into the valleys.

- Rohan:** But sir, his idea was initially met with disbelief. It was thought that his hypothesis was so extraordinary and even so extravagant that it was considered to be not worth examining or even considering.
- Abani:** Then scientists developed a theory what is named as Ice age. It was the time when glaciers covered Europe and much of North America. In 1837 Agassiz was the first to scientifically propose that the Earth had been subject to a past ice age.
- Raja:** A field trip was organised to Alps and it was supported the ice age theory.
- Gita:** But sir during that period only scientist found that Earth's atmosphere kept the planet warmer than would be the case in a vacuum.
- Abani:** Yes. it was accepted then that the atmosphere transmitted visible light waves to the earth's surface. Then earth absorbs visible light and emitted infrared radiation in response. But the atmosphere did not transmit infrared efficiently, which therefore increased surface temperatures.
- Rohan:** Also it was suspected that human activities could influence climate.
- Gita:** Sir, is there any other reasons for climate change?
- Abani:** Some scientists suggested that ice ages and other great climate changes were due to changes in the amount of gases emitted in volcanism. But that was only one of many possible causes.
- Rohan:** Another obvious possibility was solar variation. Shifts in ocean currents also might explain many climate changes
- Abani:** For changes over millions of years, the raising and lowering of mountain ranges would change patterns of both winds and ocean currents. Or perhaps the climate of a continent had not changed at all, but it had grown warmer or cooler because of polar wander (the North Pole shifting to where the Equator had been or the like). There were dozens of theories.
- Neha:** For such a long time I'm hearing the word climate and climate change. But I don't know what is climate?
- Raja:** Let me answer this. Do you know what weather is?
- Neha:** Yes, in TV news they give weather news. When it will be rain and when will not rain etc.
- Raja:** Yes you are right. Weather is what the forecasters on the TV news predict each day. They tell people about the temperature, cloudiness, humidity, and whether a storm is likely in the next few days. That's weather! It is the mix of events that happens each day in our atmosphere.
- Abani:** But remember, Weather is not the same everywhere. It may be hot and sunny in one part of the world, but freezing and snowy in another.

- Neha:** Ok, but what is climate?
- Mala:** Now you know what weather is. Weather is the changes we see and feel outside from day to day. It might rain one day and be sunny the next. Sometimes it is cold. Sometimes it is hot. Weather also changes from place to place. People in one place might be wearing shorts and playing outside. At the same time, people far away might be shovelling snow.
- Raja:** Climate is the usual weather of a place. Climate can be different for different seasons. A place might be mostly warm and dry in the summer. The same place may be cool and wet in the winter. Different places can have different climates. You might live where it snows all the time. And some people live where it is always warm enough to swim outside!
- Gita:** There's also Earth's climate. Earth's climate is what you get when you combine all the climates around the world together.
- Neha:** If it is the weather of a place, then it changes everyday. Then why everybody is worried for climate change? What actually is climate change?
- Mala:** Climate change is a change in the usual weather found in a place. This could be a change in how much rain a place usually gets in a year. Or it could be a change in a place's usual temperature for a month or season.
- Rohan:** Climate change is also a change in Earth's climate. This could be a change in Earth's usual temperature. Or it could be a change in where rain and snow usually fall on Earth. Weather can change in just a few hours. Climate takes hundreds or even millions of years to change.
- Neha:** Is Earth's Climate Changing?
- Rohan:** Earth's climate is always changing. There have been times when Earth's climate has been warmer than it is now. There have been times when it has been cooler. These times can last thousands or millions of years.
- Raja:** People who study Earth see that Earth's climate is getting warmer. Earth's temperature has gone up about one degree Fahrenheit in the last 100 years. This may not seem like much. But small changes in Earth's temperature can have big effects.
- Gita:** Some effects are already happening. Warming of Earth's climate has caused some snow and ice to melt. The warming also has caused oceans to rise. And it has changed the timing of when certain plants grow.
- Abani:** Now we will come to our main discussion. Prior to the 18th century, scientists had not suspected that prehistoric climates were different from the modern period. By the late 18th century, geologists found evidence of a succession of geological ages with changes in climate.
- Rohan:** Yes, there were various competing theories about these changes.

Abani: You are right Rohan, a scientist named James Hutton was there. His idea of cyclic change over huge periods of time was one of them. It was later named as uniformitarianism.

Gita: What was his observation?

Abani: He was among those who found signs of past glacial activity in places too warm for glaciers in modern times.

Rohan: Sir, what about the giant boulders seen in alpine valleys?

Abani: In 1815 for the first time it was found that how glaciers might be responsible for the giant boulders seen in alpine valleys. As he hiked in the valleys, he noticed giant granite rocks that were scattered around the narrow valley.

Raja: He knew that it would take an exceptional force to move such large rocks. He also noticed how glaciers left stripes on the land, and concluded that it was the ice that had carried the boulders down into the valleys.

Mala: His idea was not accepted initially. People thought his hypothesis so extraordinary and even so extravagant that they were neither interested to examine it nor considering it.

Abani: But after a lot of persuasion and trial, the famous scientist Louis Agassiz was convinced. Agassiz developed a theory called Ice age.

Gita: What is ice age?

Abani: An ice age is a long period of reduction in the temperature of the Earth's surface and atmosphere, resulting in the presence or expansion of continental and polar ice sheets and alpine glaciers.

Neha: Ice every where? That means you can have ice cream and chuski whenever you want? What a great fun!!

Raja: But Neha, it will be very cold, in this cold you have to get up and go to school early in the morning.

Neha: No! No! Then I don't want ice age or ice cream either.

Rohan: Within a long-term ice age, individual pulses of cold climate are termed "glacial periods"

Mala: These are also known as glacials.

Abani: In between ice age there were warmer period also. These intermittent warm periods are called "interglacial".

Neha: Papa, please explain ice age.

Abani: Ice age implies the presence of extensive ice sheets in both northern and southern hemispheres.

Raja: Sir, what is Holocene?

Abani: The Holocene is the current geological epoch. It began approximately 11,650 cal years before present, after the last glacial period, which concluded with the Holocene glacial retreat.

Rohan: The Holocene has been identified with the current warm period. Some considered it as to be an interglacial period within the Pleistocene Epoch.

Mala: How many ice ages was there Sir?

Abani: There have been at least five major ice ages in the Earth's history. They are the Huronian, Cryogenian, Andean-Saharan, Karoo Ice Age, and the current Quaternary Ice Age). Outside these ages, the Earth seems to have been ice free even in high latitudes.

Raja: What could be the time period of these ages?

Abani: The earliest ice age is the Huronian ice age. Rocks formed in this period are 2.4 to 2.1 billion years ago, it was the early prozoic era.

Gita: What is the next one, sir?

Rohan: The next well-documented ice age, and probably the most severe of the last billion years, occurred from 850 to 630 million years ago.

Abani: Yes, it was cryogenian period. During this time earth had become a snowball in which glacial ice sheet reached upto equator.

Rohan: Possibly being ended by the accumulation of greenhouse gases such as CO₂ produced by volcanoes. "The presence of ice on the continents and pack ice on the oceans would inhibit both silicate weathering and photosynthesis, which are the two major sinks for CO₂ at present.

Raja: Sir I think the third ice age was the Andean-Saharan occurred from 460 to 420 million years ago, during the Late Ordovician and the Silurian period.

Abani: Very good Raja, You are correct.

Mala: And what about the fourth one sir?

Abani: The fourth one is very interesting. The evolution of land plants at the onset of the Devonian period caused a long term increase in planetary oxygen levels and reduction of CO₂ levels, which resulted in the Karoo Ice Age. It is named after the glacial tills found in the Karoo region of South Africa, where evidence for this ice age was first clearly identified.

- Rohan:** There were extensive polar ice caps at intervals from 360 to 260 million years ago in South Africa during the Carboniferous and early Permian Periods.
- Abani:** The Quaternary Glaciations / Quaternary Ice Age started about 2.58 million years ago at the beginning of the Quaternary Period when the spread of ice sheets in the Northern Hemisphere began. Since then, the world has seen cycles of glaciation with ice sheets advancing and retreating on 40,000- and 100,000-year time scales called glacial periods, and interglacial periods.
- Gita:** Sir, what is glacial and interglacial period please explain.
- Abani:** Within the ice ages (or at least within the current one), more temperate and more severe periods occur. The colder periods are called glacial periods, the warmer periods interglacials,
- Rohan:** Glacial are characterized by cooler and drier climates over most of the earth and large land and sea ice masses extending outward from the poles.
- Mala:** Sir, why this ice age happens?
- Abani:** The causes of ice ages are not fully understood for either the large-scale ice age periods or the smaller ebb and flow of glacial–interglacial periods within an ice age. The consensus is that several factors are important: atmospheric composition, such as the concentrations of carbon dioxide and methane.
- Raja:** changes in the earth's orbit around the Sun known as Milankovitch cycles; the motion of tectonic plates resulting in changes in the relative location and amount of continental and oceanic crust on the earth's surface, which affect wind and ocean currents; variations in solar output, the impact of relatively large meteorites and volcanic eruptions etc. are also some of the other reasons.
- Gita:** Sir, does it affect the earth's atmosphere.
- Abani:** There is evidence that greenhouse gas levels fell at the start of ice ages and rose during the retreat of the ice sheets, but it is difficult to establish cause and effect.
- Rohan:** Greenhouse gas levels may also have been affected by other factors which have been proposed as causes of ice ages, such as the movement of continents and volcanism.
- Raja:** The Snowball Earth hypothesis maintains that the severe freezing in the late Proterozoic was ended by an increase in CO₂ levels in the atmosphere, mainly from volcanoes, and some supporters of Snowball Earth argue that it was caused in the first place by a reduction in atmospheric CO₂. The hypothesis also warns of future Snowball Earths.
- Abani:** In 2009, further evidence was provided that changes in solar insolation provide the initial trigger for the earth to warm after an Ice Age, with secondary factors like increases in greenhouse gases accounting for the magnitude of the change.

- Mala:** Does the human activity have any role in this?
- Rohan:** Yes, of course! There is considerable evidence that over the very recent period of the last 100–1000 years, the sharp increases in human activity, especially the burning of fossil fuels, has caused increase in atmospheric greenhouse gases which trap the sun's heat.
- Abani:** A 2012 investigation finds that dinosaurs released methane through digestion in a similar amount to humanity's as the current methane release, which could have been a key factor to the very warm climate 150 million years ago.
- Raja:** The positions of the continents also play a role in it.
- Gita:** How?
- Raja:** The geological record appears to show that ice ages start when the continents are in positions which block or reduce the flow of warm water from the equator to the poles and thus allow ice sheets to form. The ice sheets increase Earth's reflectivity and thus reduce the absorption of solar radiation.
- Gita:** So what happens?
- Rohan:** With less radiation absorbed the atmosphere cools; the cooling allows the ice sheets to grow, which further increases reflectivity. The ice age continues until the reduction in weathering causes an increase in the greenhouse effect.
- Raja:** There are three main contributors from the layout of the continents that obstruct the movement of warm water to the poles.
- Mala:** Such as...
- Abani:** A continent sits on top of a pole, as Antarctica does today, A polar sea is almost land-locked, as the Arctic Ocean is today and A supercontinent covers most of the equator, as Rodinia did during the Cryogenian period.
- Rohan:** The danger is since today's Earth has a continent over the South Pole and an almost land-locked ocean over the North Pole, geologists believe that Earth will continue to experience glacial periods in the geologically near future.
- Raja:** Some scientists believe that the Himalayas are a major factor in the current ice age, because these mountains have increased Earth's total rainfall and therefore the rate at which carbon dioxide is washed out of the atmosphere, decreasing the greenhouse effect.
- Neha:** So the greenhouse effect is good for earth also.
- Rohan:** Yes Neha, everything has a good and bad side, but excess of both are bad.
- Neha:** I know Himalaya was formed by collision of two lands mass.

- Abani:** Yes, The Himalayas' formation started about 70 million years ago when the Indo-Australian Plate collided with the Eurasian Plate, and the Himalayas are still rising by about 5 mm per year because the Indo-Australian plate is still moving at 67 mm/year. The history of the Himalayas broadly fits the long-term decrease in Earth's average temperature since the mid-Eocene, 40 million years ago.
- Raja:** Another cause may be the fluctuations in ocean currents.
- Mala:** What are fluctuations in ocean current?
- Abani:** Another important contribution to ancient climate regimes is the variation of ocean currents, which are modified by continent position, sea levels and salinity, as well as other factors. They have the ability to cool, aiding the creation of Antarctic ice and the ability to warm that is giving the British Isles a temperate as opposed to arboreal climate.
- Rohan:** Analyses suggest that ocean current fluctuations can adequately account for recent glacial oscillations. During the last glacial period the sea-level has fluctuated 20–30 m as water was sequestered, primarily in the Northern Hemisphere ice sheets.
- Mala:** Sir, I have read that milankovitch cycle affect the glacial period.
- Abani:** There is strong evidence that the Milankovitch cycles affect the occurrence of glacial and interglacial periods within an ice age. The present ice age is the most studied and best understood, particularly the last 400,000 years.
- Raja:** But Sir, what is milankovitch cycle?
- Rohan:** The Milankovitch cycles are a set of cyclic variations in characteristics of the Earth's orbit around the Sun. Each cycle has a different length, so at some times their effects reinforce each other and at other times they (partially) cancel each other.
- Raja:** Does volcanoes have any relation with glaciation?
- Gita:** Volcanic eruptions may have contributed to the inception and/or the end of ice age periods. At times during the paleoclimate, carbon dioxide levels were two or three times greater than today.
- Abani:** Yes, you are right Gita. Volcanoes and movements in continental plates contributed to high amounts of CO₂ in the atmosphere. Carbon dioxide from volcanoes probably contributed to periods with highest overall temperatures.
- Rohan:** One suggested explanation of the Palaeocene-Eocene Thermal Maximum is that undersea volcanoes released methane from catharses and thus caused a large and rapid increase in the greenhouse effect.
- Mala:** There appears to be no geological evidence for such eruptions at the right time.

- Raja:** But this does not prove they did not happen.
- Neha:** Now I have heard a lot about the glaciations that is the earth is covered by ice. But what was its effect?
- Mala:** Are wah! You have understood a lot. Good. Although the last glacial period ended more than 8,000 years ago, its effects can still be felt today.
- Gita:** For example, the moving ice carved out the landscape in Canada (See Canadian Arctic Archipelago), Greenland, northern Eurasia and Antarctica.
- Rohan:** The weight of the ice sheets was so great that they deformed the Earth's crust and mantle. After the ice sheets melted, the ice-covered land rebounded. Due to the high viscosity of the Earth's mantle, the flow of mantle rocks which controls the rebound process is very slow—at a rate of about 1 cm/year near the center of rebound area today.
- Gita:** During glaciations, water was taken from the oceans to form the ice at high latitudes, thus global sea level dropped by about 110 meters, exposing the continental shelves and forming land-bridges between land-masses for animals to migrate.
- Abani:** Yes, during deglaciation, the melted ice-water returned to the oceans, causing sea level to rise. This process can cause sudden shifts in coastlines and hydration systems resulting in newly submerged lands, emerging lands, collapsed ice dams resulting in salination of lakes, new ice dams creating vast areas of freshwater, and a general alteration in regional weather patterns on a large but temporary scale. It can even cause temporary reglaciation.
- Rohan:** This type of chaotic pattern of rapidly changing land, ice, saltwater and freshwater has been proposed as the likely model for the Baltic and Scandinavian regions, as well as much of central North America at the end of the last glacial maximum.
- Neha:** What is woolly mammoth papa? Our teacher was saying they were living when it was very cold.
- Mala:** Woolly mammoths are extinct relatives of today's elephants. They lived during the last ice age, and they may have died off when the weather became warmer and their food supply changed.
- Raja:** Humans may also be partly responsible for their disappearance due to hunting.
- Abani:** Although the word "mammoth" has come to mean "huge," woolly mammoths were probably about the size of African elephants. Their ears were smaller than those of today's elephants. This was probably an adaptation to the cold climate that kept their ears closer to their heads and kept them warmer.
- Rohan:** Their tusks were very long, about 15 feet (5 meters) and were used for fighting and digging in the deep snow. Mammoths were herbivores and ate mostly grass, but also ate other types of plants and flowers.

- Neha:** How big were these animals?
- Gita:** They were roughly about the size of modern African elephants. A male woolly mammoth's shoulder height was 9 to 11 feet tall and weighed around 6 tons. Its cousin the Steppe mammoth was perhaps the largest one in the family — growing up to 13 to 15 feet tall.
- Neha:** When did these animals died finally?
- Abani:** Although, most of the woolly mammoth population died out by 10,000 years ago, a small population of 500-1000 woolly mammoths lived on Wrangel Island until 1650 BC. That's only about 4,000 years ago!
- Mala:** Although the jury is still about exactly how the large-bodied mammals disappeared from our planet, one of the major culprits had to have been climate change.
- Gita:** The giant ground sloth is just about the last survivor of the large-bodied mammal extinctions. Its story is one of survival through climate change, only to be overwhelmed by human predation.
- Rohan:** You now Neha, As massive as they were (about 13 feet long and five to seven tons), Woolly Mammoths figured on the lunch menu of early Homo sapiens, who coveted these beasts for their warm pelts (which could presumably keep an entire family comfy on bitterly cold nights) as well as their tasty, fatty meat.
- Neha:** So sad papa, just for meat and the fur people killed these huge animals!
- Mala:** But interestingly, they love this animal also. From about 30,000 to 12,000 years ago, the Woolly Mammoth was one of the most popular subjects of neolithic artists, who daubed images of this shaggy beast on the walls of numerous western European caves.
- Neha:** How fun it could be to have a mammoth here in our city.
- Abani:** Looking deep into time, anatomically modern humans lived during three epochs: Pleistocene, Holocene, and now Anthropocene. Earth during the Pleistocene was very different from today; the epoch was characterized by a harsh climate, strong winds and storms, and large ice sheets. Climate was highly variable and humans survived in small nomadic groups for around 190,000 years through this period.
- Rohan:** 18,000 years ago, the ice caps began to melt and approximately 11,000 years ago we entered a period of unusually stable climate called the Holocene. Everything we know and recognize as human civilization dates to this epoch: agriculture, cities, and complex societies.

Raja: These hallmarks of civilization originate from a period of relative climatic stability that is less than 6% of our time on Earth. Our species has been fortunate, perhaps more than we realise. The stability of the Holocene climate allowed our species to thrive.

Abani: We have walked a lot, everybody must be very hungry. Let us have our food. Neha, do you have your food with you.

Neha: Yes papa, otherwise I would have disappeared like woolly mammoth.

Raja: We had a nice discussion Sir, I always was worried how ice age affected our climate? Today I became clear on this. Thank you very much sir.

Neha: After listening so much on ice we should eat ice cream, am I right papa?

(everybody laughs)