Climate change: Is it for the first time?

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Introduction

The phrases CLIMATE CHANGE and GLOBAL WARMING and off late GLOBAL COOLING are now part of our lives and rarely does a day go by without a mention in the press of the possible causes of climate change and its consequences. This climate change has come upon in a relatively short span of time and is accelerating with alarming speed. Is this for the first time in the history of Earth's climate? No, paleoclimatologists claims that in the past also climate change was there. Then why should we be worried about this? The cause is nothing but its nature of source and speed of change. The entire past climate changes happened before the start of anthropogenic intensive activities which means 'Climate Change' phenomena is not newly born but it was there in nature. But today it is perhaps the most serious problem that the civilised world is facing. So let's have a look over those factors which were behind this problem when anthropogenic activities were insignificant.

Causes of Climate Change:

Climate change one of the most spoken topic in this era is an effect of not only any one factor but it is the result of interaction of many factors.Changes in the state of this system can occur externally (from extraterrestrial systems) or internally (from ocean, atmosphere and land systems) or through the complex interaction of the described components. For example, an external change may involve a variation in the Sun's output which would externally vary the amount of solar radiation received by the Earth's atmosphere and surface. Internal variations in the Earth's climatic system may be caused by changes in the concentrations of atmospheric gases, mountain building, volcanic activity, and changes in surface or atmosphericalbedo.

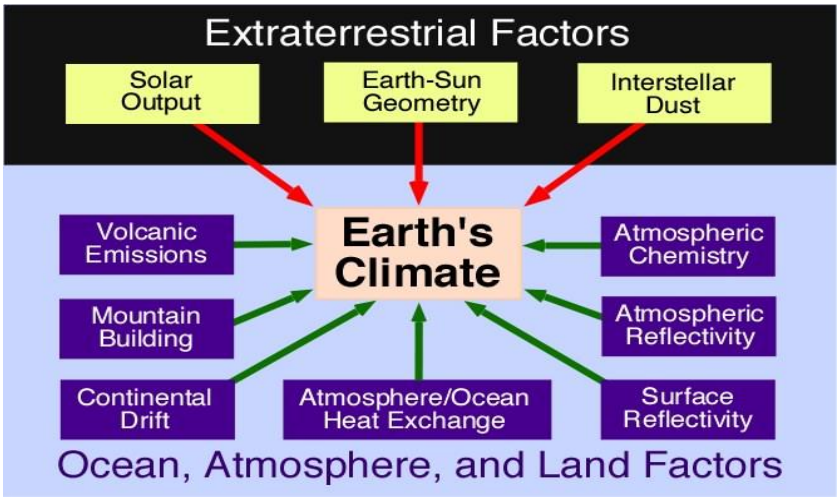

Fig 1: Factors that influence the earth's climate.

The work of climatologists has found evidence to suggest that only a limited number of factors are primarily responsible for most of the past episodes of climate change on the Earth. These factors include:

- Variation in Earth's orbital characteristics
- Volcanic eruptions
- Solar Activity, Cosmic Ray
- Movement of Solar System and Earth's Climate
- Asteroids and Earth's Climate

Variations in Earth's orbital characteristics:

Computation of the orbital solution of the Earth is complex because the Earth's motion is perturbed by Moon and all the other planets of the Solar system. Milankovitch, based on mathematical computations, calculated the amount of solar radiation for each latitude for different times of the year and came up with the ideas which could have caused the change in the solar insolation leading to the climate change (Milankovitch, 1941).

Eccentricity:

It controls the shape of the Earth's orbit around the Sun. The Earth's orbit around the sun is an ellipse in which Sun is roughly located in one of its two loci. The orbit gradually changes from being elliptical to being nearly circular and then back to elliptical in a period of about 100,000 years (fig 2). The current eccentricity is 0.0167 but in the past hundred million years eccentricity has varied from about 0.0669 to almost 0.0001; that is a near circular orbit (Laskar et al, 2004). The greater the eccentricity of the orbit (i.e., the more elliptical it is), the greater the variation in solar energy received at the top of the atmosphere between the Earth's closest (perihelion) and farthest (aphelion) approach to the Sun. Currently, the Earth is experiencing a period of low eccentricity. The difference in the Earth's distance from the Sun between perihelion and aphelion (which is only about 3%) is responsible for approximately a 7% variation in the amount of solar energy received at the top of the atmosphere. When the difference in this distance is at its maximum (9%) i.e. the eccentricity is maximum, the difference in solar energy received is as high as about 20%.

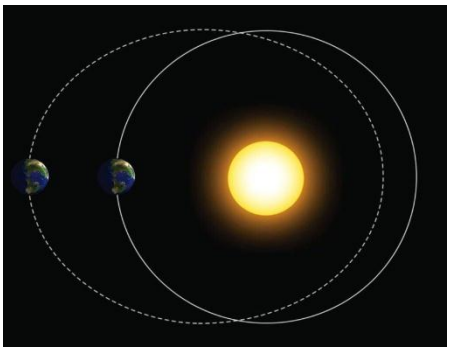

Fig 2: Eccentricity of earth's orbit.

Precession:

Precession originates from the fact that, as the Earth rotates on its polar axis; it wobbles like a spinning top changing the orbital timing of the equinoxes and solstices. This effect is also known as the precession of equinox. The *precession of the equinox* has a cycle of approximately 23,000 years (Fig-3). At the present time the Earth is closer to the Sun in January (perihelion) and farther away in July (aphelion) (Fig-2).So the Southern Hemisphere summer happens at the time of perihelion for which at that time earth receives about 4% more solar radiation than Northern hemisphere summer. Besides this increased solar radiation the change of temperature in southern hemisphere is not that much significantmainly due to the presence of more oceans in the Southern Hemisphere. Because of precession, the reverse will be true after 13,000 years and the Earth will then be closer to the Sun in July (Fig-2). At that time in time of perihelion Northern Hemisphere will be closer to the Sun. So it will receive about 4% more solar radiation than what it is receiving now. But due to the presence of more land masses this amount of excess solar radiation will increase the temperature of Northern Hemisphere at an enhanced rate than what it is doing for Southern Hemisphere. This means, of course, that if everything else remains constant, 12,000 years from now seasonal variations in the Northern Hemisphere should be greater than at present (colder winters and warmer summers) because of the closer proximity of the Earth to the Sun.

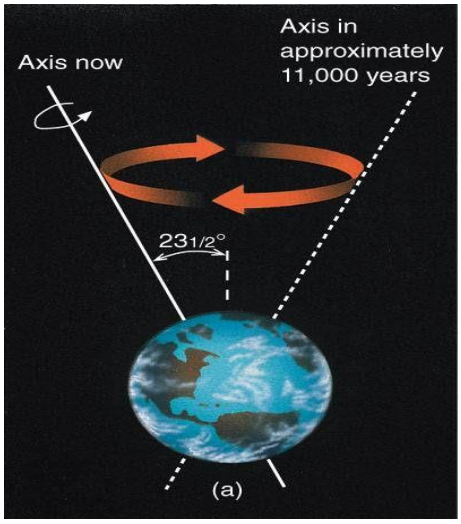

Fig 3: Precession of the earth.

Obliquity:

The inclination of the earth relative to its plane of travel about the sun is called ‘Obliquity’ or ‘Tilt’. And, this is the main reason of seasons to occur in our Earth. The hemisphere "pointing toward" the sun is in summer, while the opposite hemisphere is in winter. The earth makes one full orbit around the sun each year. If the earth's axis were "straight up and down" relative to the orbital planethere would be no seasons, since any given point at the top of the atmosphere would receive the same amount of sun each day of the year.

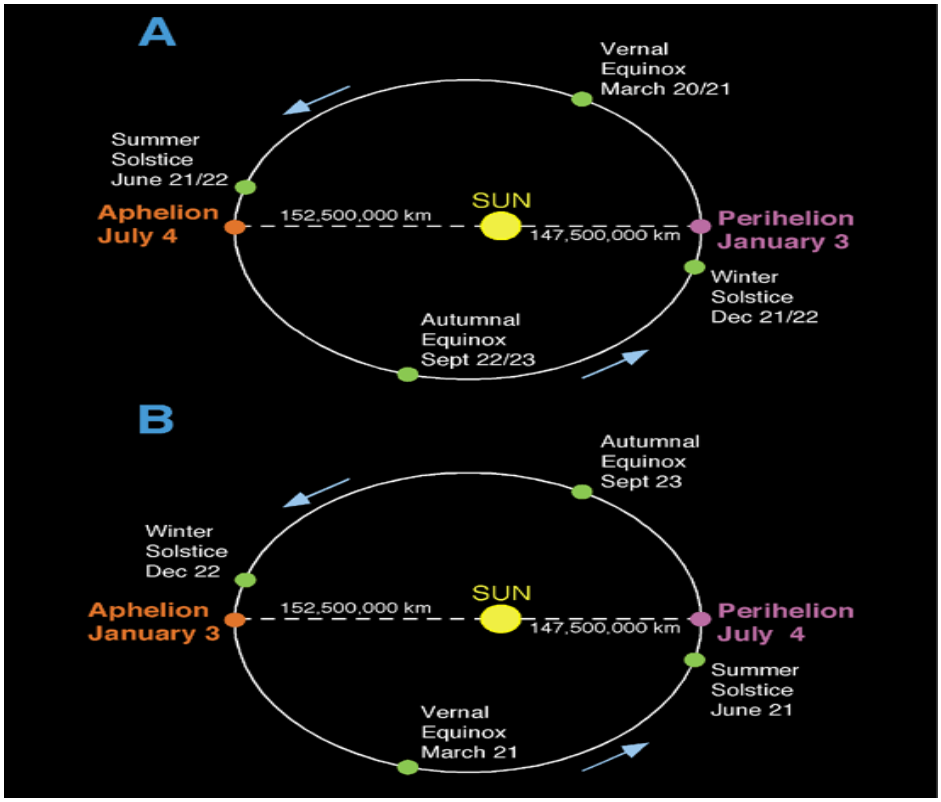

Fig-4; Modification of the timing of aphelion and perihelion over time (A = today; B = 13,000 years into the future).

So, Changes in the "tilt" of the earth can change the severity of the seasons - more "tilt" means more severe seasons - warmer summers and colder winters; less "tilt" means less severe seasons - cooler summers and milder winters.

The earth wobbles in space so that its tilt changes between about 22 and 24.5 degrees (Fig-3) during the period of about 40,000 years (Fig-3). The current value of this 'Obliquity' is about 23.44° and it is decreasing.

Volcanic Eruptions:

Volcanic activity is an important natural cause of climate variations because tracer constituents of volcanic origin impact the atmospheric chemical compositions and optical properties. The effect of volcanoes in the change of climatic parameters is highly time dependent. Volcanic ashes have short term influence on the insolation while aerosols created after eruptions have quite long tern influence. Volcanic eruptions also have strong but slow influence on atmospheric circulation, sea ice and ocean current.

Volcanic Aerosol and Climate:

Volcanic emissions comprised of gases (H_2O, CO_2, N_2, SO_2, H_2S) and solid (mostly silicate) particles commonly called as volcanic ash. These ash particles are relatively large, exceeding 2μm in diameter, and therefore deposit relatively quickly within few weeks. So they are responsible for short term regional perturbations of the Earth's radiative balance and

weather parameters. A weak volcanic eruption only erupts gases and ashes in the troposphere but strong eruptions of Volcanic Explosivity Index (VEI) equal to or greater than four could inject volcanic ash and sulphur rich gases (SO2 & H2S) into the clean lower stratosphere at an altitude of about 25-30 Km(Simkin, 1993). These gases quickly oxidizes to form sulphuric acid and which forms aerosol in the stratosphere. It reflects more amount of shortwave radiation coming from the sun to the space creating a negative radiative balance in the atmosphere. At the same time it absorbs the infrared radiation emitted from the earth and as a result stratospheric temperature increases (Gerstell et al, 1995). After the Mt. Pinatubo eruption after 1991, with global visible optical depth maximizing at about 0.15, cause perturbation of the global radiative balance at the top of the atmosphere reaching -3 W. m^{-2} and cause a reduction in global surface temperature by 0.5K (Stenchikov,et al, 2004).

Solar Activity:

Until recently, many scientists thought that the Sun's output of radiation only varied by a fraction of a percent over many years. However, measurements made by satellites equipped with radiometers in the 1980s and 1990s suggested that the sun's energy output may be more variable than was once thought. Measurements made during the early 1980s showed an increase of 0.1 percent in the total amount of solar energy reaching the Earth (Frohlich et al, 1998). If this trend were to extend over several decades, it could influence global climate. Numerical climatic models predict that a change in solar output of only 1 percent per century would alter the Earth's average temperature by between 0.5 to 1.0° Celsius. Scientists have long tried to also link sunspots to climatic change. Sunspots are huge magnetic storms that are seen as dark (cooler) areas on the Sun's surface. The number and size of sunspots show cyclical patterns, reaching a maximum about every 11, 90, and 180 years.

Cosmic Ray: Its impact on Cloud Coverage, Rainfall and Temperature

Recent research has shown that the Earth’s cloud coverage (from Satellite) is strongly influenced by Cosmic Ray (CR) intensity (Swenamark, 2000). The reason is that due to the increase in CR intensity the number of condensation nuclei generated is more (due to more ionisation) and these facilitate the formation of more amount of clouds. These cloud influences the radiative properties of the atmosphere by both cooling through reflection of incoming short wave radiation and heating through trapping of outgoing long wave radiation (the Greenhouse effect).Hartmann showed that high optically thin clouds tend to heat while low optically thick clouds tend to cool. So to know the relationship between the type of cloud and the CR intensity variation Marsh &Swensmark conducted an experiment and came up with the results that the CR intensity was having highest correlation with the lower level clouds i.e. more the CR intensity more the lower level clouds lesser will be the temperature. According to Swensmark the increase of air temperature by 0.3°c corresponds to a decrease of CR intensity by 3.5% and a decrease of global cloudiness by 3% which is equivalent to an increase of solar radiance of 1.5 $W.m^{-2}$, is five times bigger than the solar cycle change in solar irradiance.

Asteroids and Earth's Climate:

It is well known fact that in past asteroids has struck Earth with ample energy to force the major climatic changes (the famous dinosaur-killing mass extinction at the end of the Cretaceous) (Hut et al, 2000). However it is unlikely that our present climate change is due to any way to such events. But today with modern methods of Astronomy, the trajectory of dangerous asteroids can be determined correctly and can be deflected with modern rocket power.

Conclusion:

Numerous factors both extraterrestrial and anthropogenic can influence the Earth's climate. As we have seen from the above discussion, that space factors are mainly of two types 'Gradual' type, related to changes on long time scales such as variation of Earth's orbital characteristic, plate tectonics, etc producing effects that could be greater than that produced from anthropogenic factors and 'Sudden' type such as supernova explosions & asteroid impacts, but this also may indeed be catastrophic to our civilisation. Solar Activity, Volcanic and anthropogenic factors are also 'Sudden' factors in their effect on climate change. The prediction of climate change due to only variation of Earth's orbital parameters is the decrease in the Earth's air temperature for the next 50,000 years. But in the present century the rate of increase in concentration of green house gases in the atmosphere has also increased. In the past history also temperature increase was more or less coupled with the increase in the concentration of GHGs in the atmosphere. But in the past times that were due to different natural causes discussed above and this present day increase in concentration of GHGs is mainly anthropogenic in nature. It is also showed that the volcanoes have negative effect on the atmospheric temperature and the present rate of volcanic eruption is reducing the rate expression of warming caused by the anthropogenic and other factors. So it is clear that all the factors influencing the climate system is not working in the same direction to cause this change but this change is due to the complex interaction of all those factors. All these factors always force the climate, but the magnitude of this force is most important. As in the past times the anthropogenic factor was not present so people could relate past climate changes with Milankovitch cycle with little difficulty, but in today's situation all the forces are present. And, discussion shows that probably at this time anthropogenic force is dominating thus making this change directed by it.

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