Critical turning point can trigger abrupt climate change

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Ice ages are the greatest natural climate changes in recent geological times. Their rise and fall are caused by slight changes in the Earth's orbit around the Sun due to the influence of the other planets. But we do not know the exact relationship between the changes in the Earth's orbit and the changes in climate. New research from the Niels Bohr Institute indicates that there can be changes in the CO_2 levels in the atmosphere that suddenly reach a critical turning point and with that trigger the dramatic climate changes. The results are published in the American journal *Paleoceanography*.

The Earth's climate is essentially contolled by three different cycles (Milankovitch). All three cycles are caused by the pull of the other planets in the solar system on the Earth, and one could say that they control the Earth's climate by causing changes in the Sun's radiation.

1: The Earth's orbit around the sun is not completely circular, but slightly elliptical. The orbit is 'elastic' and contracts and expands in a cycle of 100.000 years. And the closer we are to the Sun, the more solar radiation and the more heat we receive.

2: The Earth's axis has a tilt in relation to the Sun and that is why we have summer and winter. But the tilt is not constant, it swings between 22 degrees and 24 degrees, and the greater the tilt, the greater the difference between summer and winter. This cycle takes 40.000 years.

3: The Earth rotates around on its axis like a top - this gives day and night. But due to the tilt of the Earth and the elliptical orbit the direction changes with a cycle of 20.000 years. This results in varation in to whether the Earth is nearest the Sun during the summer or during the winter.

Solar radiation varies in the two hemispheres during the summer due to these cycles in the Earth's tilt and the elliptical orbit and this has profound implications for whether ice caps can build up in the northern hemisphere, where the largest land areas are.

Mysterious changes in ice ages

The ice ages have come and gone the last 20 million years and for the last few million years we know with reasonable accuracy how often they come. In the period before about 1 million years ago the ice ages occured around every 40.000 years, then it happened suddenly that the period changed so that it became circa 100.000 years between ice ages. It is a mystery because nothing changed in the behaviour of the Earth's orbit 1 million years ago. It is therefore due to a change that comes from the climate itself.

The conventional wisdom around the 100.000 year cycle of the last 10 ice ages is that the 100.000 years variation in the Earth's orbital eccentricity (the measure for how elliptical the orbit is and the half-yearly variation in the Earth's distance from the sun). This variation is still weaker than the variation that occurs with the 40.000 year cycle, so that in itself is a mystery.

Warm, half cold, ice cold

With completely new research results geophysicist Peter Ditlevsen, Centre for Ice and Climate at the Niels Bohr Institute, has found part of the explanation for the mystery of the sudden change of the ice ages. He has made model calculations of the climate of the past and compared it to the concrete data from seabed cores, which tell us about the climatic fluctuations of the past.

From the results he has been able to construct a diagram over the possible climatic conditions resulting from the variation in solar radiation. It appears that the ice ages and interglacial periods are not a gradual fluctuation between cold and warm climates.

What happened 1 million years ago was that the climate system went from a situation where it fluctuated between two states (cold and warm) with a 40.000 year cycle, corresponding to the dominant change in the Sun's radiation. After this period the dynamic changed so that the climate jumped between 3 states, that is to say between a warm interglacial climate like our present climate, a colder climate and a very cold ice age climate. It is still the 40.000 year variation in solar radiation which controls our current fluctuations, but it results in changing climate periods of 80.000 and 120.000 years.

Chaotic dynamic climate The climate does not become gradually colder or warmer - it jumps from the one state to the other. That which gets the climate to jump is that when the solar radiation changes and reaches a certain threshold - a 'tipping point', the existing climate state, e.g. an ice age, is no longer viable and so the climate jumps over into another state, e.g. a warm interglacial period. In chaos dynamics this phenomenon is called a bifurcation or a 'catastrophe'.

In addition to the change in solar radiation there can be random changes in the Earth's weather variations, that contribute to triggering the bifurcation or the 'catastrophe'. Such variations are called 'noise', and a theory is, that the atmosphere's CO_2 level can be an important noise-factor. This means that there is the possibility that the 'noise' is a decisive factor for very large climate changes, which can therefore be unpredictable.

There is still no explanation for the change in the climate system 1 million years ago, but one theory is that the atmosphere's CO_2-level fell to the lowest level ever. If so, the manmade increase in CO_2 may result in a return to 40.000 year ice age cycles.

"The new results are an important piece of the puzzle for understanding the ice ages and their climate dynamics. In the manmade climate changes, that we are possibly in the middle of now, one worries a lot about the possible so-called 'tipping points'. The bifurcations that are now identified in the natural climate fluctuations are tipping points, so this is of course an important step in our understanding of climate changes", explains Peter Ditlevsen.

More information: "The bifurcation structure and noise assisted transitions in the Pleistocene glacial cycles": www.agu.org/journals/pa/papers … shtml#id2008PA001673

Source: University of Copenhagen

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