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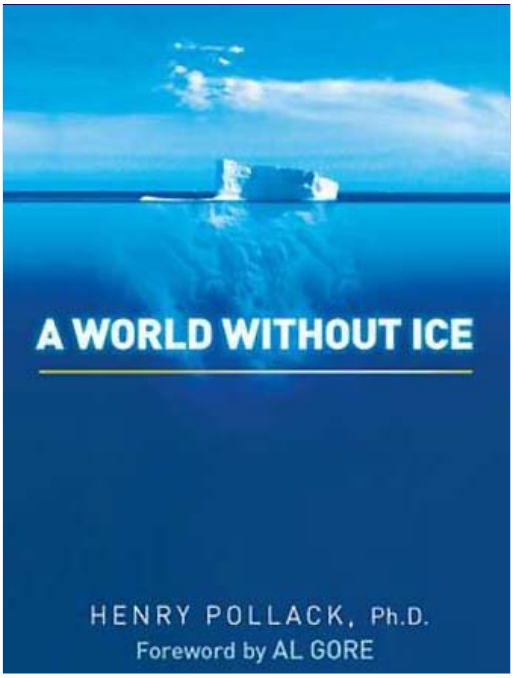
Last Time Earth Without Ice: 55 Million Years Ago

"Ice asks no questions, presents no arguments, reads no newspapers, listens to no debates. It is not burdened by ideology and carries no political baggage as it changes from solid to liquid. It just melts."
- Henry Pollack, Ph.D., Geophysicist and Author, *A World Without Ice*

Click for podcast.

Sea ice melt in the Arctic, Greenland, and elsewhere is likely to affect future temperatures in the regions because ice reflects much of the sun's radiation back into space while dark ocean water absorbs more of the sun's energy. As ice melts, more exposed ocean water changes the Earth's albedo, or fraction of energy reflected away from the planet. This leads to increased absorption of energy that further warms the planet in what is called ice-albedo feedback and Earth gets warmer. Illustration by NASA.

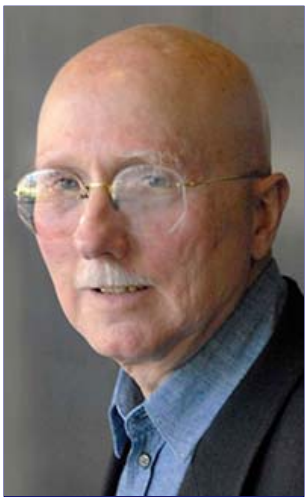
December 5, 2009 Albuquerque, New Mexico - This week 2007 Nobel Peace Prize participant and Professor Emeritus Geophysicist Henry Pollack, Ph.D., was in Albuquerque to speak at the University of New Mexico about his new book, *A World Without Ice*, released in October 2009. I was able to interview him before his presentation about the recent leaked climate data scandal, the upcoming December 7 to 18, 2009, Copenhagen global climate conference that Dr. Pollack will attend and his perspective on Earth's climate past, present and future. According to the United Nation's Inter-Governmental Panel on Climate Change (IPCC), Earth will warm up between 1.4 degrees Celsius and 5.8 degrees Celsius (roughly 2 degrees Fahrenheit to 10 degrees Fahrenheit) by the end of this century.



A World Without Ice © 2009 by Henry Pollack, Ph.D., with Foreword by Al Gore, both participants with the United Nation's Inter-Governmental Panel on Climate Change (IPCC) in the 2007 Nobel Peace Prize. **Click to Amazon.com.**

Interview:

Henry Pollack, Ph.D., Prof. Emeritus, University of Michigan, and Contributing Author to the Inter-Governmental Panel On Climate Change (IPPC) 2007 research report that shared the 2007 Nobel Peace Prize with former American Vice President Al Gore, Ann Arbor, Michigan:



Henry Pollack, Ph.D., Prof. Emeritus, University of Michigan, and Participant, 2007 Nobel Peace Prize. Image by Jens Zorn.

“WHAT IMPACT DO YOU THINK THE STEPPING DOWN OF DR. PHIL JONES FROM THE UNIVERSITY OF EAST ANGLIA IN THE U. K., AMID THE LEAKS OF ALL OF THESE EMAILS THAT SEEM TO SUGGEST THAT SCIENTISTS IN THE GLOBAL CLIMATE AREA HAVE BEEN CONCERNED ABOUT MANIPULATING DATA OR PRESENTING DATA THAT WOULD FAVOR AN AVERAGE MEAN GLOBAL TEMPERATURE INCREASE VERSUS THE PLATEAU IN TEMPERATURE THE PAST DECADE?

The University of East Anglia has been a climate data center and a center for climate research for most of a century. It’s one of the better-known climate research units in academia around the world. But they are not the only one that do similar types of research on constructing temperature changes over the globe over the past century from weather station records and temperature sensors in buoys that float around in the ocean and such.

The same type of work is done by NASA in the United States, by NOAA in the U. S., by the British Meteorological Service called the Hadley Centre in the U. K., by other institutions in Germany and Japan. They do the research independently. They all use more or less the same data and they all make their own decisions as to which data are reliable and which are less reliable. They all make their own decisions about how to make corrections to thermometer readings over the years. But this research goes on independently at many different places.

The important result of comparing the independent exercises of constructing the temperature history of Earth over the past century is that all of the constructions, all of the assemblies of data, tell the very same story (of a warming planet). So, even if the University of East Anglia had been doctoring or fudging or manipulating data – and I'm not accusing them of that – but even if they had and the entire research output were discarded from that climate unit, there would still be the same results from half a dozen different institutions done independently by independent scientists making their own scientific judgments.

So, I don't think it (East Anglia situation and leaked emails) should have a big effect at all because the data itself is so persuasive that you can't erase climate change from the record, nor can you put it in. This is Nature speaking and it is a story that the 20th Century has been one of warming over the long term.

The predictions of the climate scientists in projecting future temperatures, they don't predict there will be an incremental temperature increase year by year. They are saying there is a long-term trend upward, but the natural variability of the Earth's temperature due to changes in ocean currents, the El Nino events, the Arctic Oscillation of the Northern Hemisphere ocean waters – a lot of phenomena like that – superimposes ups and downs on a long-term upward trend (of warming).

And so climate scientists do not say that every year you are going to see an increase in average global mean temperature of the Earth. Some years we know there are even decreases. But as has been pointed out over the last year, the temperatures have kind of plateaued, but I might note that they have plateaued at a very high temperature.

The temperatures over the past decade, even though they have not been climbing year-by-year, they still comprise the hottest decade in the entire instrumental record. So, it's not as if the Earth has suddenly started to cool. It has plateaued for a decade [since around 1999] in its upward climb.

But that kind of pausing or ups and downs that we see on shorter time scales – that's not climate. We're looking at climate as the long-term trend and to any eye that looks at a century worth of data, the trend is upward and there is nothing in the last decade that will negate that.

So, my assessment of what has come out of the Univ. of East Anglia situation is that it does not undermine the fact that the Earth is warming. It might say something about a particular group of scientists, but that is far from representing the whole scientific community.

Water Vapor As Important As CO2?

DO YOU THINK CO2 BUILD UP IS AS IMPORTANT AS WATER VAPOR?

CO2 is a greenhouse gas and water vapor is also a greenhouse gas. The two are actually interlinked because if the atmosphere were to warm from the greenhouse effect of carbon dioxide, it would be able to hold more water vapor because a warmer atmosphere can hold more water vapor. So, then there is an increase in evaporation and more water vapor joins the atmosphere as well. With that amplification by two greenhouse gases, it is simply getting warmer faster.

I don't think water vapor has been ignored. All the climate models that I'm aware of recognize that water vapor will grow in the atmosphere as the atmosphere warms and the models all take that into account.

IS THERE ANY REASON WHY WATER VAPOR HAS BEEN EXCLUDED FROM THE DISCUSSIONS IN COPENHAGEN?

I think the so-called exclusion is not only of water vapor. It's the whole hydrological cycle and the different environmental signatures in different parts of the globe that affect the hydrological cycle. That is what has been set aside as a discussion in Copenhagen because Copenhagen is dealing principally with ways to slow down climate change and the

perturbations to the hydrological cycle are some of the changes in climate change. In choosing to focus on the causes as opposed to the consequences that have been the conscious choice to focus strongly on the causes of climate change and their mitigation. That's not to say that the consequences and impacts on hydrological cycle are not important. It's just that that's not the focus of this particular conference.

Is Earth Headed for Another Iceless Age?

Ice is a very sensitive indicator of climate change because it is very close to its melting point over large regions of the Earth. So, with very small changes in temperature, you'll see big changes in the distribution of ice. I like ice in that context because I call it Nature's best thermometer. It doesn't read the newspapers. It doesn't listen to debates. It has no ideological baggage. Just when it gets warm enough, it melts.

So, it's a natural thermometer and it is talking to us. Places that are more accessible to most people are mountaintops such as the high tops of the Himalayas or the Andes in South America or even in Glacier National Park in the U. S. A. The ice in those mountainous regions in the mid-latitudes and tropical latitudes is receding in the valleys and thinning in the thickness of the ice very dramatically. If that continues over the next few decades, we will see the loss of most mountain ice by mid-century. The consequences of that are very significant because the melt water provides water for agriculture. About one-quarter of Earth's population is drawing their water in part from the high ice in the Himalayas and other mountains. So, losing that ice has a big impact on large numbers of people.

The second component of ice that is changing is the Arctic sea ice. Usually the Arctic Ocean freezes and for most of human history it's been frozen. But every summer, it tends to break up a little bit and the re-freezes again in the winter. So, the Arctic has basically been a big frozen sheet of seawater.

But in the last few decades, more and more of that has been breaking up in the summertime and exposing the dark ocean water that absorbs the sunshine. Therefore, the ocean gets warmer. Then it's harder to freeze it again in the fall and it doesn't freeze as thick over the winter and it begins to break up earlier in the spring. It's a feedback cycle that is quickly destroying the sea ice in the summertime in the Arctic Ocean.

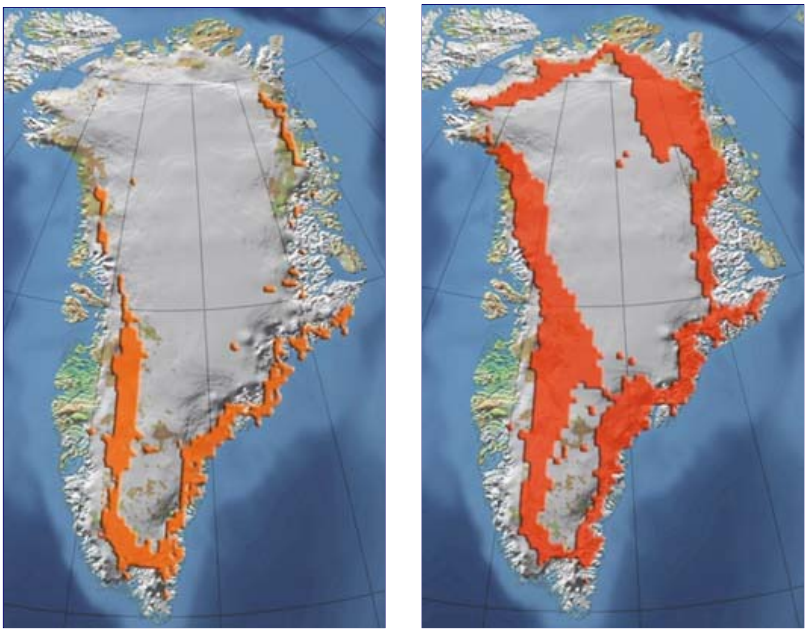
If the rate of loss of summertime sea ice continues, we'll see an ice-free Arctic ocean by mid century as well with big consequences for the territory around the Arctic Ocean – the largely frozen areas of northern Alaska and northern Canada and Siberia. There the permafrost is beginning to melt.

More Arctic ocean ice melt will also open up more political tensions in the Arctic as people compete for the fishery resources. There will certainly be more exploration for oil and gas. There will be increased commerce through the Northwest and Northeast passages – the shortcut to Asia from Europe and North America. So, we'll see the Arctic ocean turning into a beehive of activity when effectively, it's been off limits to human activity since before humans have been on Earth.

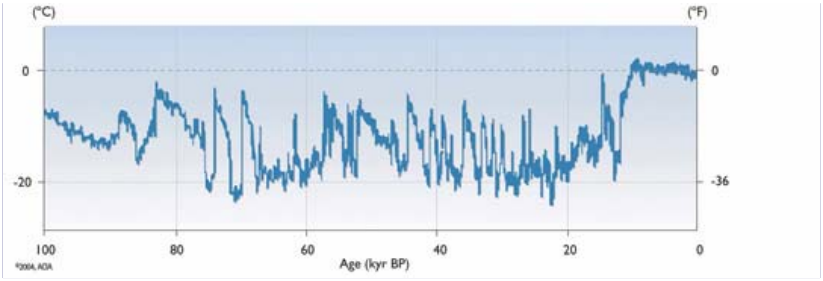
One climate scientist I know has said that an ice-free Arctic ocean in the summer will be the biggest change Earth's landscape that people have ever seen.

A third effect is the creeping melting of Greenland and West Antarctica where there are big piles of ice sitting on those pieces of land. Summertime melting in Greenland is creeping higher and higher onto the Greenland ice sheet and the melt water is plunging into deep crevasses and down deep to the base of the ice sheet and lubricating the bottom of the ice. The consequence of that is that glaciers that are chipping ice off Greenland to the sea are now moving faster and delivering their ice more rapidly.

So Greenland is actually losing ice mass every year at an ever-faster pace as well as West Antarctica experiencing the same thing.



Greenland ice decline in 1992 (left) versus ice decline ten years later in 2002 (right). Greenland is a self-governing Danish province located between the Arctic and Atlantic Oceans. Though geographically and ethnically an Arctic island nation associated with the continent of North America, politically and historically Greenland is closely tied to Europe, specifically Iceland, Norway and Denmark. It is the largest island in the world that is not also considered a continent. Source: *Arctic Council, Impacts of a Warming Climate: Arctic Climate Impact Assessment*, Cambridge Univ. Press, Cambridge, Massachusetts, 2004.



Greenland temperatures over the last 100,000 years. This chart is based on ice cores, taken from: *Arctic Council, Impacts of a Warming Climate: Arctic Climate Impact Assessment*, Cambridge Univ. Press, Cambridge, Massachusetts, 2004.

We're seeing what I call a sleeping giant being awakened. Ice that has been with us for most of human history is now being de-stabilized and being returned to the sea. Ultimately the consequences will result in rising sea levels as well because every time you send melt water back to the sea you are adding to the seawater. But even just dropping ice into sea (from land) raises the water right away, just as dropping an ice cube into a beverage glass does.

So, we're seeing a lot of action in the cryosphere, the world of ice that shows it is responding to climate change in ways that will have great impact on the human population everywhere around the world.

AND CONTINUES TO MELT REGARDLESS OF HUMAN ARGUMENTS.

Indeed! Nature is talking to us and if we don't listen, we're doing so at our own peril. The effects of rising sea levels, the effects of changes in our hydrological cycle, greater rainfall in some places and greater dryness of the soil in other places – Nature is sending us a strong message and if we don't pay attention to it, it will be adverse consequence for us.

Arctic Ocean Summers Ice-Free by 2050

HOW LONG DO YOU THINK IT WILL BE BEFORE THE ARCTIC IS ICE-FREE IN SUMMERS?

I think by mid-century, the Arctic Ocean will be ice-free in the summertime. It will of course re-freeze in the winter, but it will be a much thinner ice sheet and much more vulnerable to break up. I think we'll see ice-free summers in the Arctic Ocean within the

first half of this century.

We'll see the loss of the mountain ice probably even sooner over most of the lower latitude and tropical mountain glaciers.

Sea Level Rise by 2100 - 6 Feet?

The de-stabilization of Greenland and West Antarctica is a longer term process, but we actually could see enough ice lost from those two areas to have a sea level change by the end of the 21st Century by as much as six feet.

In the very long term, if we lose all the ice from Antarctica and from Greenland – I'm not predicting that in an immediate future, but on a millennial time scale – if we lose all of that ice, sea levels will rise by perhaps as much as 250 feet.

WHICH WOULD FLOOD MOST EVERYWHERE!

Most everywhere. Even more modest sea level changes in the 21st century, which are probably going to be in the range of 3 to 6 feet – a 3 foot rise in sea level will displace 100 million people around the globe. That's how many people live very near the seashores within 3 feet above sea level. That includes people who live on atolls in the Pacific; it includes people on the Maldives Islands in the Indian Ocean; it includes the people who live in the low-lying land of the Ganges River and the Nile River. We're going to see large-scale displacement of human populations on a scale that humanity has never dealt with before. There will be great political and social instability occurring and amplified year-by-year for every year that slips by without people addressing this issue.

55 Million Years Ago Was Last Time Earth Was Without Ice

> *" ... there was a large exhalation of methane gas from the ocean floor ... for some unknown reason."* - Henry Pollack, Ph.D.

WHEN WAS THE LAST TIME PERIOD THAT THE ARCTIC WAS COMPLETELY OPEN?

I think the last time period that we can be certain that the Arctic ocean was open was 55 million years ago when the Earth probably had no ice at all. That was perhaps the last time that Earth was totally ice free.

IS IT TRUE THAT SCIENTISTS REALLY DON'T UNDERSTAND THE MECHANISM FOR WHY THE EARTH GOES IN AND OUT OF ICY PERIODS?

We know that the last time the Earth was totally without ice 55 million years ago that there was a large exhalation of methane gas from the ocean floor. There is a lot of methane stored beneath the ocean floor. For some unknown reason, that was destabilized. Methane is a powerful greenhouse gas and it went into the atmosphere and raised temperatures significantly for a fairly long period of time. The consequence was that Earth warmed up and lost its ice.

> **[** Editor's Note: *ScienceDaily* on December 27, 2007, reported: "There are new findings regarding a phase of rapid global greenhouse warming that took place 55 million years ago. This period of climate change is regarded as the best fossil analogue to current and future greenhouse warming.
>
> Analogous to the Earth's current situation, greenhouse warming 55 million years ago was caused by a relatively rapid increase of CO2 concentrations in the atmosphere. This phase, known as the Paleocene-Eocene thermal maximum (PETM), was studied using sediments that accumulated 55 million years ago on the ocean floor in what is now New Jersey.
>
> The new study shows that a large proportion of the greenhouse gases was released as a result of a chain-reaction of events. Probably due to intense volcanic activity, CO2 concentrations in the atmosphere became higher and the ensuing greenhouse effect warmed the Earth. As a result, submarine methane hydrates (ice-like structures in which massive amounts of methane are stored) melted and released large amounts of methane into the atmosphere.

> This further amplified the magnitude of global warming, which comprised about 6 degrees Celsius in total. According to the IPCC, Earth will warm up between 1.4 degrees Celsius and 5.8 degrees Celsius (roughly 2 degrees Fahrenheit to 10 degrees Fahrenheit) by the end of this century.
>
> The new research confirms that global warming can stimulate mechanisms that release massive amounts of stored carbon into the atmosphere. Current and future warming will likely see similar effects, such as methane hydrate dissociation, adding additional greenhouse gases to those resulting from fossil fuel burning.
> Last year, the same group of researchers showed in *Nature* that tropical algae migrated into the Arctic Ocean during the PETM, when temperatures rose to 24 degrees C. Current climate models are not capable of simulating such high temperatures in the Arctic."]

DO YOU HAVE A HYPOTHESIS ABOUT WHAT WOULD HAVE RELEASED SO MUCH METHANE 55 MILLION YEARS AGO?

My hunch is that all you have to do is raise the temperature of the deep ocean water a few degrees and you can destabilize it. It may well be that in some parts of the globe, there was a situation of ocean currents that maybe led to warming of the deep ocean and release of methane locally. But once that reaches the atmosphere, the methane becomes a global greenhouse blanket and it warms the seas everywhere else and you destabilize some more. So, it's like a runaway process that led to large-scale loss of methane from the ocean floor.

Could Warming Deep Oceans Suddenly Release Methane in 21st Century?

PROF. POLLACK, IF THAT HAPPENED 55 MILLION YEARS AGO AND A COMBINATION OF INDUSTRY AND OTHER FACTORS ARE INCREASING GLOBAL WARMING NOW, THEN WHAT ARE THE CHANCES THAT WE COULD HAVE A MASSIVE RELEASE OF METHANE FROM THE OCEANS SOME TIME THIS CENTURY BECAUSE THE OCEANS ARE WARMING?

That's a good question. Currently we have a lot of temperature measurements down through the ocean columns. The water is warming, but the warming so far has been confined to about the upper two miles. Warming has not penetrated to the deepest ocean levels. So, it's going to take some time to warm that body of water mass. I don't think that warming (deeply) can take place in this 21st century, but an uncontrolled greenhouse and increase of global temperatures that will eventually penetrate into the deep ocean water and could conceivably destabilize the methane in the deep ocean floor.

WHAT IS THE DEPTH OF OUR DEEPEST OCEANS?

The average depth of the ocean is about 2.5 miles. There are deeper places and shallower on the continental shelves. We've seen warming measured down to about 1.5 miles right now.

> [Editor's Note: Challenger Deep in the Mariana Trench is the deepest point in Earth's oceans. The bottom there is 35,840 feet or 6 miles (10,924 meters) below sea level. If Mount Everest, the highest mountain on Earth, were placed at this location it would be covered by over one mile of water. The Challenger Deep is named after the British survey ship Challenger II, which discovered this deepest location in 1951. It was first explored by the deep-sea robotic vehicle, Nererus, designed by scientists at the Woods Hole Oceanographic Institution in 2009.]

We don't know how long it has taken to warm up because we have been measuring oceans over large areas and at great depths for maybe half a century. So, we can see the warming has taken place, but we only have computer models to theorize how long it has taken to mix the ocean from the warming that takes place at the surface to circulating that heat down to greater depths. But the heating processes so far have not distributed heat to the deep ocean bottom in any great amount yet. [Ocean temperature monitoring by NOAA.]

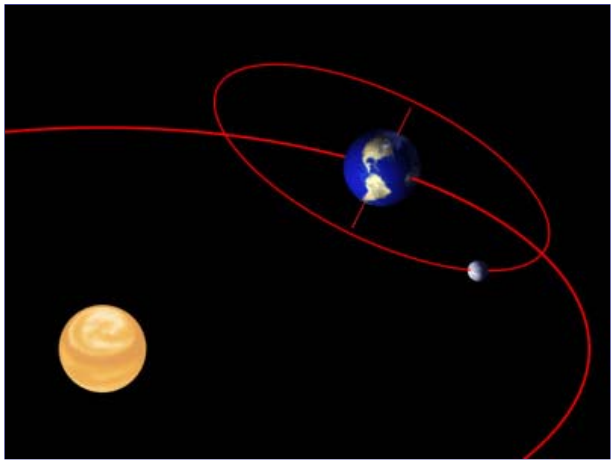
Earth Oceans Were 100 Feet Higher 3 Million Years Ago

There was a period of time only 3 million years ago when sea levels were about 100 feet

higher than now. It's not quite so clear what caused that, but it might have been a time when Greenland lost its ice and Antarctica had lost some of its ice, not all, but some. So, only 3 million years ago, sea levels were 100 feet higher than now and that shows you the magnitude of change that can occur in the context of the modern climate system.

What Causes Earth's Ice Ages?

The issue of what causes ice ages coming and going in a rhythmic or periodic pattern, we think has to do with the orbit of the Earth around the sun and the orientation of the Earth to the sun.



Earth tilted on its axis about 23.5 degrees and orbiting moon, both in revolution around the sun. Over a 40,000 year period, the Earth oscillates on its axis between 21 degrees and 24 degrees. The more the Earth is tilted, the more seasonal variability there is. Source: **North Carolina State University Earthinspace.**

There are 3 important factors:

1) One is the shape of the Earth's orbit around the sun. It is elliptical. But the ellipse sometimes gets more elongated more like a cigar and sometimes much less so and more like a circle. That effect determines how uniformly over a year how the sunshine that reaches the Earth warms our planet. If you come very close and then very far in a yearly excursion around the sun, then the distance effect means you get much less sunshine. So, there is an amplification of the seasons due to that changing orbital shape. That shape changes in a period of about 100,000 years.

2) The tilt of the Earth's axis currently is about 23.5 degrees, but that oscillates between 21 degrees and 24 degrees with a period of a little over 40,000 years. The more the Earth is tilted, the more seasonal variability there is.

3) Then the third effect is the orientation of Earth's rotational axis that goes about in a big processional circle – kind of like a spinning top will slowly wobble. That determines whether the elliptical effect and the tilt effect reinforce each other or work against each other in one hemisphere or another.

The summary of all that is the orbital effects of tens of thousands of years of periods that create effects where it can promote a lot of snowfall at high latitudes and that's the start of an ice age. The effects themselves would have to be amplified in other ways, which we don't understand and puzzle about. But it's clear in the timing of the ice ages that these orbital effects are the pacemaker of past glaciations.

HOW MUCH IMPACT COULD THE SUN HAVE?

The sun, of course, is a big player in what I've just described because the orientation and distance of the Earth from the sun determines how sunshine falls on the Earth. In terms of shorter-term climate change, there are variations of energy from the sun that occur on all time scales from daily to monthly to yearly and even longer periods. But in examining those variabilities in the context of the current warming of the Earth, the measurement of radiation from the sun indicates that the sun has actually been in slight decline in the last half of the 20th century. If that were the only factor playing a role, Earth would have cooled slightly. But in fact, Earth warmed dramatically, so we know there are other factors besides the sun.

Worst Case in A Melting World?

WHAT IS THE WORST CASE IF THE PLANET CONTINUES TO WARM AND THE ICE CONTINUES TO MELT?

The worst case in global consequence is rising sea level. It will have many affects that are different from place to place, but rising sea level is a major consequence that will have the biggest social and political consequences because it will displace hundreds of millions of people. So, sea level rise is at the top of my list and my own guess as to what we'll see in this century is anywhere from 3 to 6 feet.

IS ONE OF THE IRONIES THAT AS ICE MELTS AND CHANGING TO WATER THAT A CONSEQUENCE OF THE FUTURE COULD BE THERE IS MORE DROUGHT EVEN WITH THE MELTING WATER?

That's true. We'll have an acceleration of the hydrological cycle, which means we will evaporate more water from the surface of the oceans and continents, so you'll see soil moisture loss, drought, but you'll also more intense rainfall as that moisture rains down again elsewhere. So, you'll have both intense droughts and intense rainfalls. It's an acceleration of the hydrological cycle that will have extreme perturbations.

MORE DROUGHT IN SOME PLACES AND MORE WATER IN OTHERS.

Yes.

IN COPENHAGEN, ARE YOU EXPECTING ANY DISCUSSION ABOUT GOVERNMENTS AROUND THE WORLD HAVING ANY PLANNING OR MECHANISMS NOW FOR HANDLING THE HUGE CHALLENGE OF WHAT DO YOU DO WHEN ISLAND NATIONS GO UNDER WATER AND WHAT DO YOU DO AS LARGER NATIONS HAVE WATER COMING OVER THEIR SHORES THIS CENTURY?

It will always be in the (Copenhagen) background, but the principal discussions and debates is how to slow the greenhouse blanket from getting thicker and better at trapping Earth's heat. That has to be slowed down and reversed and that's the central focus at the Copenhagen conference.

WHAT DO YOU PERSONALLY THINK WOULD BE THE FASTEST AND MOST EFFICIENT WAY OF GETTING A HANDLE ON CONTROLLING CO2 EMISSIONS?

There is no silver bullet. But t he lowest hanging fruit is simply using less energy. It's conservation and efficiency. The cost of that energy is effectively zero. If you don't use it, you don't pay for it and it's not produced.

What Can December 2009 Copenhagen Climate Meeting Accomplish?

IF CHINA AND INDIA DON'T GO ALONG WITH THAT AS THE GOAL, WHAT DO YOU THINK THE CONSEQUENCES ARE OVER THE NEXT DECADES?

China and India are still burning coal as is the U.S.A. But the country that learns how to break way from coal and petroleum and utilize renewable energy is going to be the leading economy of the 21st Century and you can be certain that China wants that to be in China. They are already leading the way in wind energy. Europe is also leading in wind energy. The U. S. is lagging.

All of the big energy users want to be the industrial leaders that lead us out of the carbon based age. We're going to see a lot of competition – NOT to see who will burn more coal. It will be competition to see who leads the industrial revolution of the 21st Century that will take us into a new energy environment.

WHEN YOU THINK ABOUT WHERE THE FUTURE OF THIS EARTH IS HEADED AND YOU'VE WRITTEN A BOOK THAT IS CALLED 'A WORLD WITHOUT ICE,' WHAT IS YOUR GREATEST WORRY ABOUT WHERE WE ARE ALL HEADED?

My greatest worry is that people don't recognize the urgency of what needs to be done. There's little question in my mind that rising sea levels and climate change and drought are going to catch peoples' attention sooner or later. But we need to have it be sooner. So, it's my biggest worry that the slowness of the developing awareness that this is a real problem and it has very severe consequences.

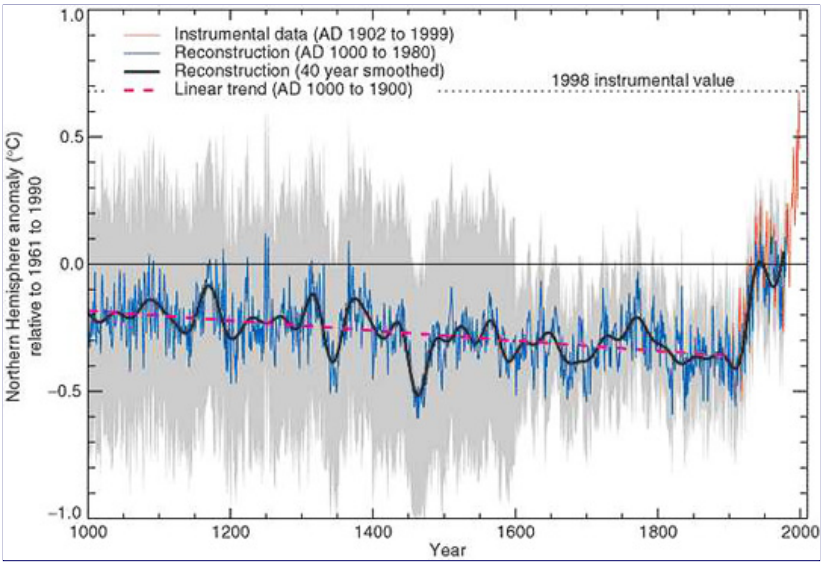
I would like to see things addressed right away and I worry there will only be baby steps taken and wait and see attitude. That will lead to situations that grow out of control and we won't be able to mitigate the problems.

ALREADY NO ONE IS EXPECTING ANYTHING PRODUCTIVE OUT OF COPENHAGEN.

Well, I'm expecting something productive out of Copenhagen. I'm expecting that the broad framework will be established and that the details of a new climate treaty will be worked out in the next six months.

So, while the original hope was that the Copenhagen conference would actually write the treaty, that's not going to happen. But I don't think Copenhagen will be unproductive."

Temperature in Northern Hemisphere Over Last 1000 Years



Source: Millennial Northern Hemisphere temperature reconstruction, adapted from Mann, Bradley and Hughes by the Intergovernmental Panel on Climate Change (IPCC) for their report *Climate Change 2001: The Scientific Basis.*

More Information:

For further information about global warming, please see **Earthfiles Archive** (partial list below):

- 11/20/2009 — Red List of Earth Life Facing Extinction Keeps Growing
- 10/30/2009 — How Long Will Our Sun Remain Quiet and Cosmic Rays Increase?
- 10/06/2009 — Cosmic Rays Reaching Earth At Highest Level in 50 Years
- 06/26/2009 — Mysterious Northeast Bat Deaths Now in 9 States
- 02/26/2009 — Unprecedented Northeast Bat Die-off Spreading Rapidly
- 10/24/2008 — Rapidly Changing Earth
- 08/15/2008 — Amphibian Warning Bell of Mass Extinctions
- 06/21/2008 — Updated June 25, 2008: Increasingly Acidic Pacific Coast Waters Threaten Marine Life
- 03/27/2008 — Ice Block Size of Northern Ireland Has Broken From Wilkins Ice Shelf in West Antarctic Peninsula
- 02/29/2008 — Mysterious Bat Deaths in New York, Vermont and Massachusetts
- 01/18/2008 — Amphibians Dying Out At Alarming Rate
- 12/13/2007 — Update: As CO2 Increases, Carbonic Acid Build Up in Oceans Expected to Kill Off Coral Reefs by 2050
- 05/18/2007 — Antarctica: Unprecedented Western Ice Melt and CO2-Saturated Southern Ocean
- 02/23/2007 — Scientists Hope "Amphibian Arks" Can Save Frogs and Toads
- 02/23/2007 — Part 1: Earth Life Threats - Alarming Disappearance of Honey Bees
- 02/23/2007 — Part 2: Earth Life Threats - "Noah's Ark" for World's Seeds
- 02/02/2007 — Updated: New U. N. Global Climate Change Report: Earth Could Warm Up 3.2 to 11.52 Degrees Fahrenheit by 2100
- 01/13/2007 — Confusing Sun: Will Solar Cycle 24 Be Most Intense On Record?
- 01/10/2007 — 2006: USA's Warmest Year On Record
- 12/16/2006 — Updated: Unprecedented Die-Off of 2,500 Mallard Ducks in Idaho
- 12/07/2006 — Earth Headed for Warmest Period in 55 Million Years?
- 11/09/2006 — Outer Space Sunshade to Cool Earth in Global Warming?

Websites:

University of East Anglia Climatic Research Unit (CRU):
http://www.cru.uea.ac.uk/

NASA Gravity Recovery and Climate Experiment (GRACE satellites):
http://www.csr.utexas.edu/grace/

Arctic Sea Ice Melt: **http://www.nasa.gov/vision/earth/environment/arcticice_decline.html**

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Credits