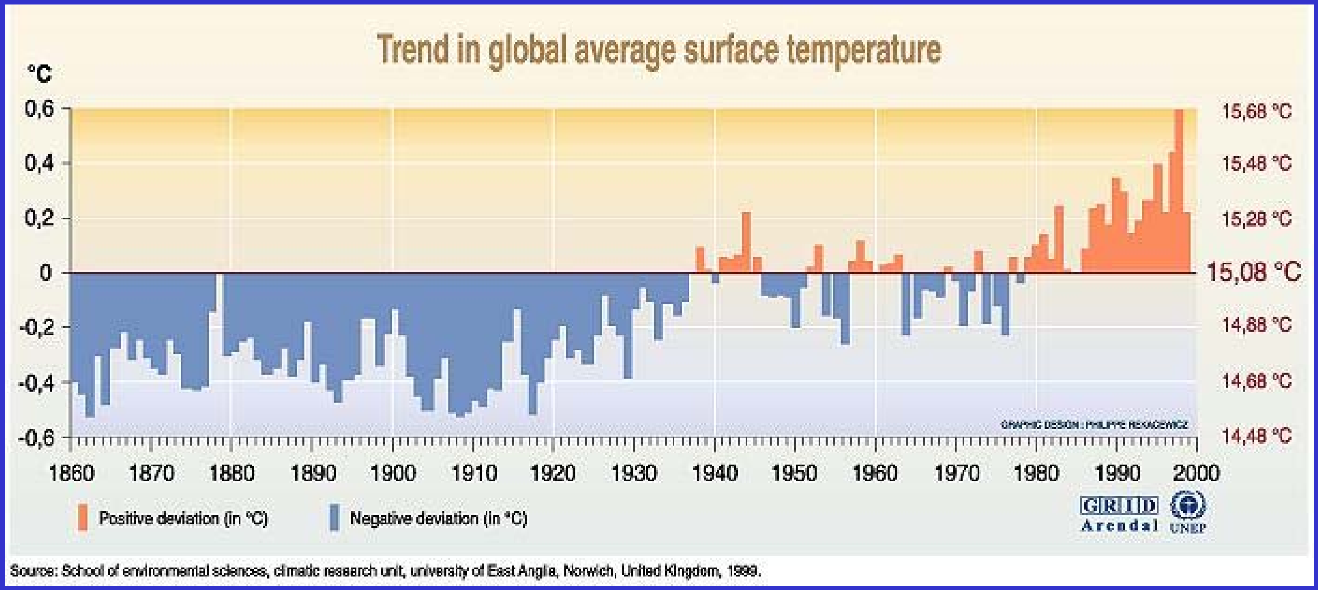
Lecture 1: An Overview of the Issue of Climate Change

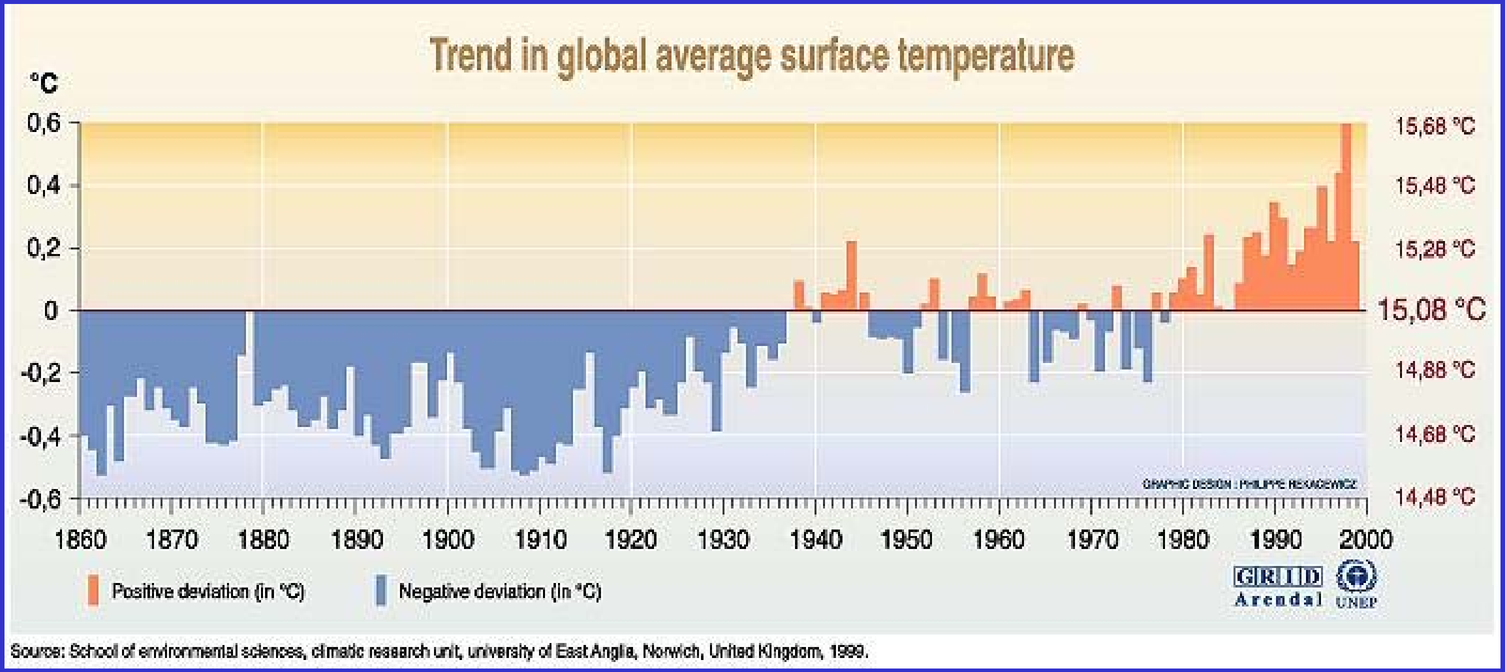


- ❑ What do we know about the global warming
- ❑ Uncertainties in science
- ❑ How policy cope with the uncertainties in science

What is Climate Change?

- Climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (from United Nation's Framework Convention on Climate Change)

Global Warming in the Past 100 Years



The mean global surface temperature has increased by about 0.3 to 0.6°C since the late 19th century and by about 0.2 to 0.3°C over the last 40 years.

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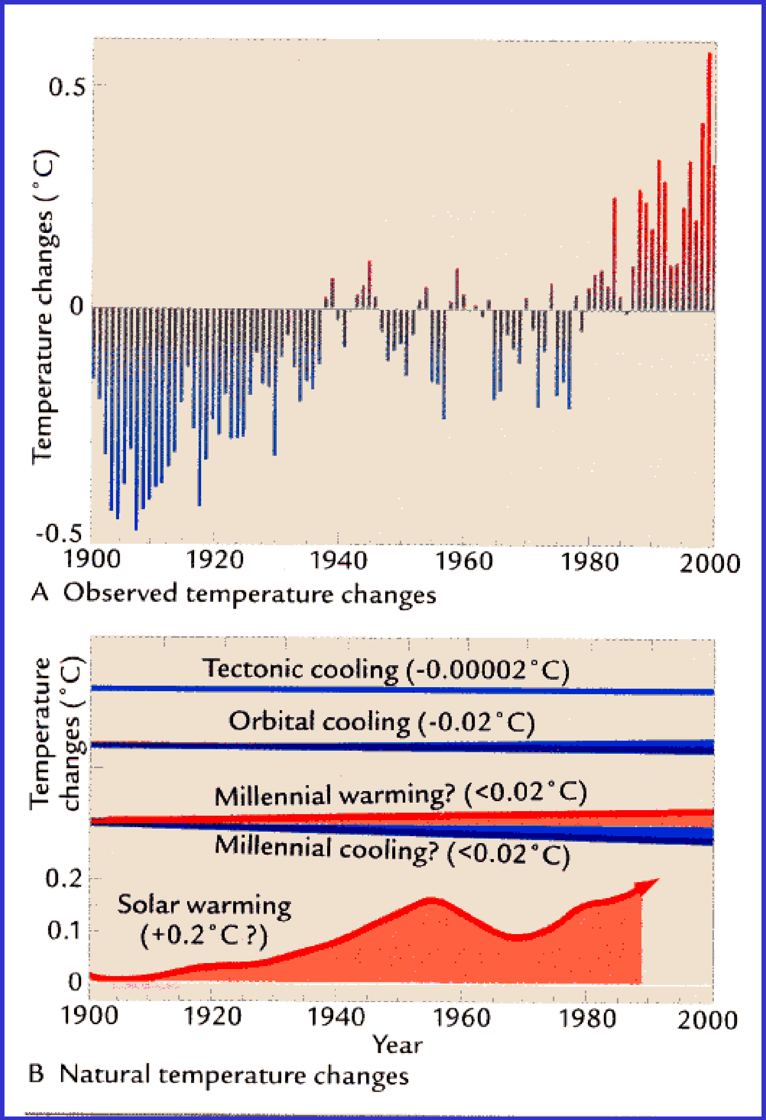
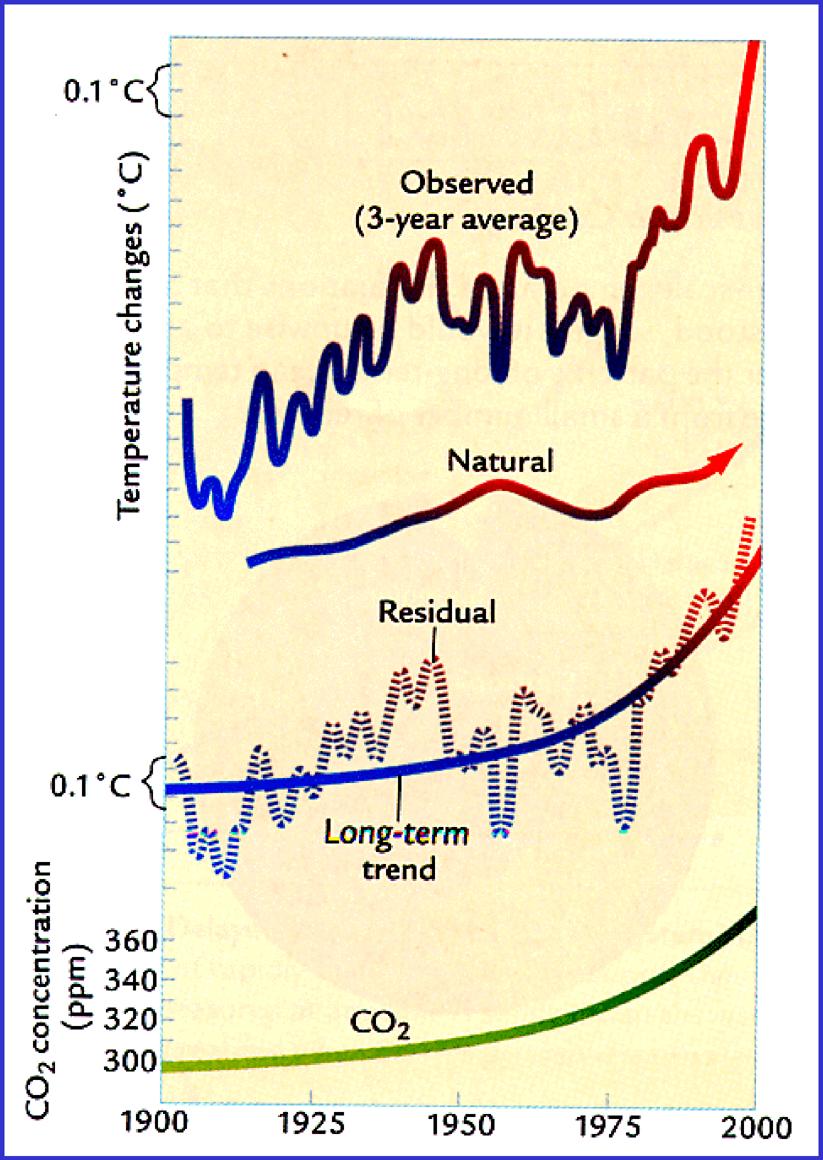
Global Warming: Natural or Man Made?



(from *Earth's Climate: Past and Future*)

- **Observed warming**
  0.6°C in the last 100 years.
- **Tectonic Scale**
  Cooling by 0.00002°C within 100 years
- **Orbital Scale**
  Cooling by 0.02°C within 100 years
- **Millennial Scale**
  Uncertain, but probably on the order of 0.02°C (such as the net cooling into the Little Ice Age)
- **Solar Activities**
  May cause 0.2°C warming

Global Warming: Is it Man-mad?



Observed Warming

Orbital + solar warming

Man-made warming (?)

(from *Earth's Climate: Past and Future*)

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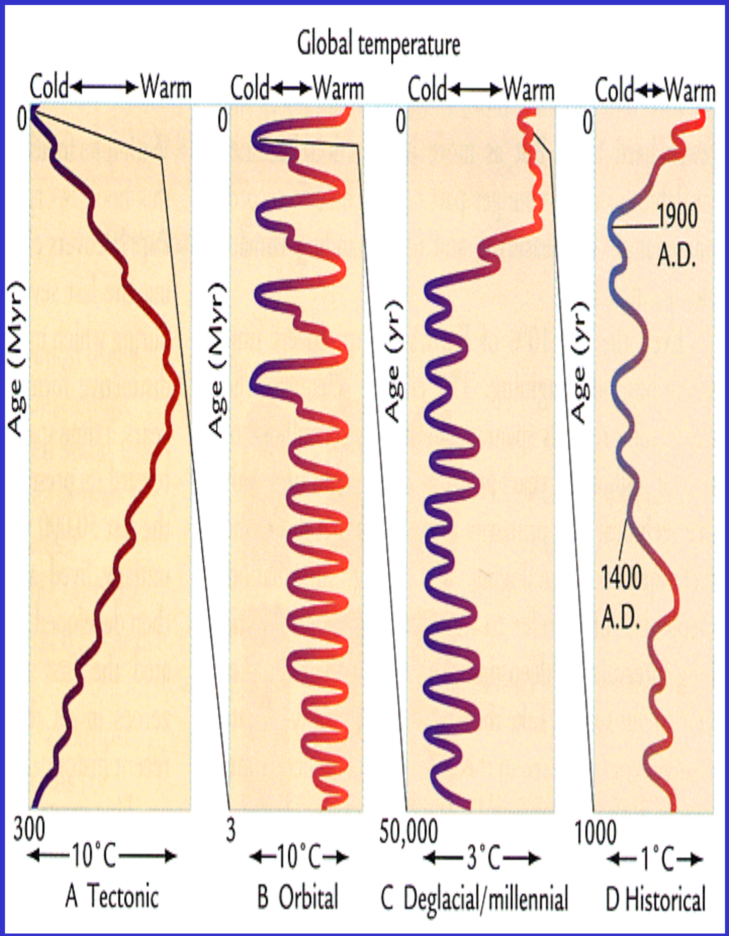
Climate System Change - Sources



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- ❑ Tectonic-Scale Climate Changes
- ❑ Orbital-Scale Climate Changes
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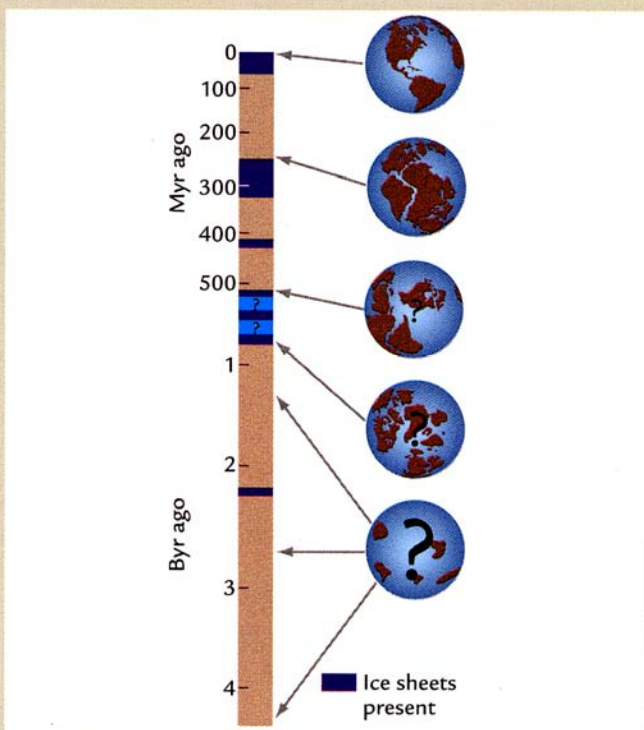
- ❑ Historical Climate Change
- ❑ Anthropogenic Climate Changes

Tectonic Scale

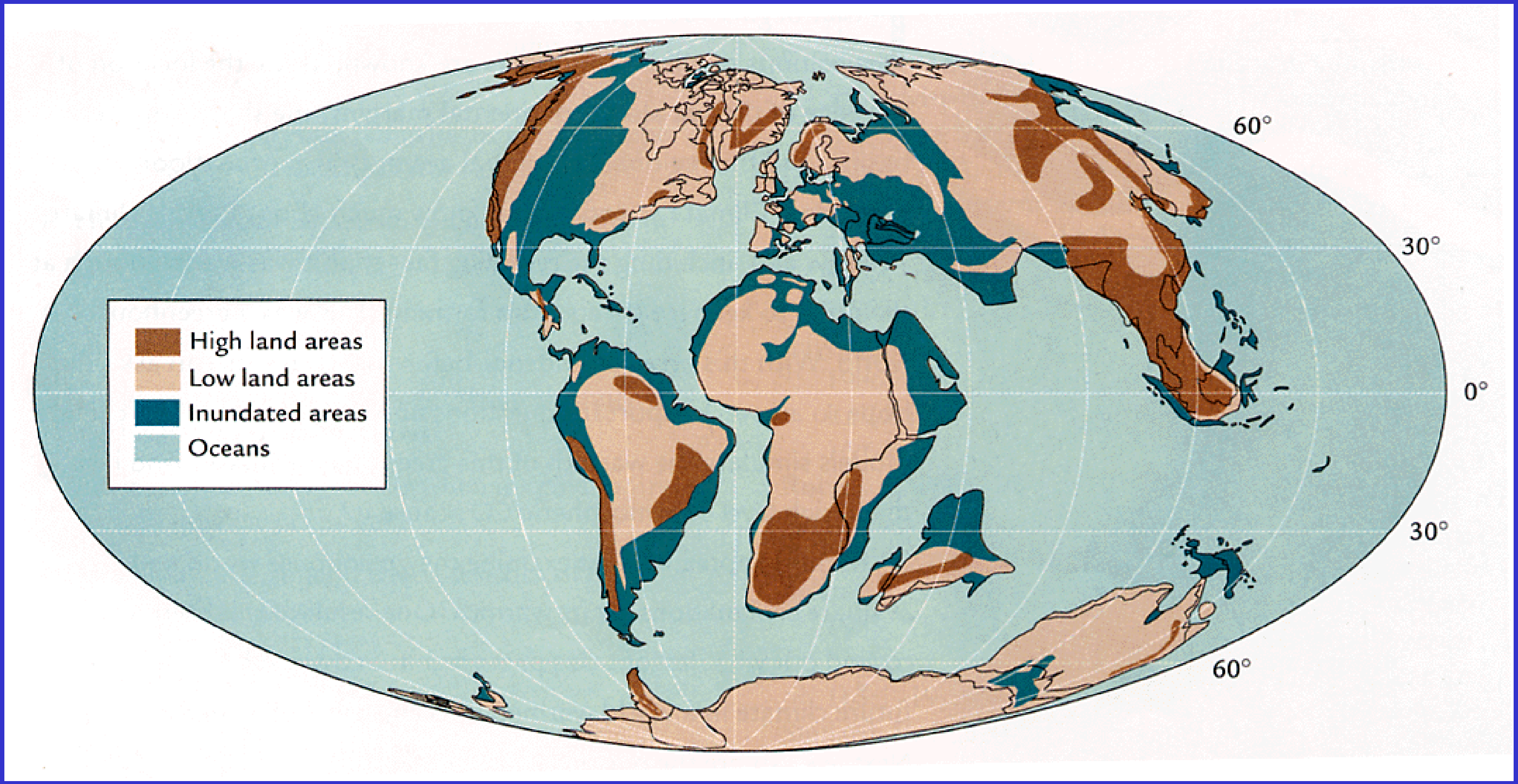


Past glaciations and continental positions. During Earth's 4.55-billion-year history, intervals when large continental ice sheets were present alternated with times when they were not (left). The earliest history of these changes is poorly defined because few ancient records are preserved. The movements of continents in relation to ocean basins are well known only for the last several hundred million years (right). (Globes adapted from D. Merritts et al., *Environmental Geology*, © 1997 by W. H. Freeman and Company.)

- Tectonic Scale: the longest time scale of climate change on Earth, which encompasses most of Earth's 4.55-billion years of history.
- Tectonic processes driven by Earth's internal heat alter Earth's geography and affect climate over intervals of millions of years.
- On this time scale, Earth's climate has oscillated between times when ice sheets were presented somewhere on Earth (such as today) and times when no ice sheets were presented.

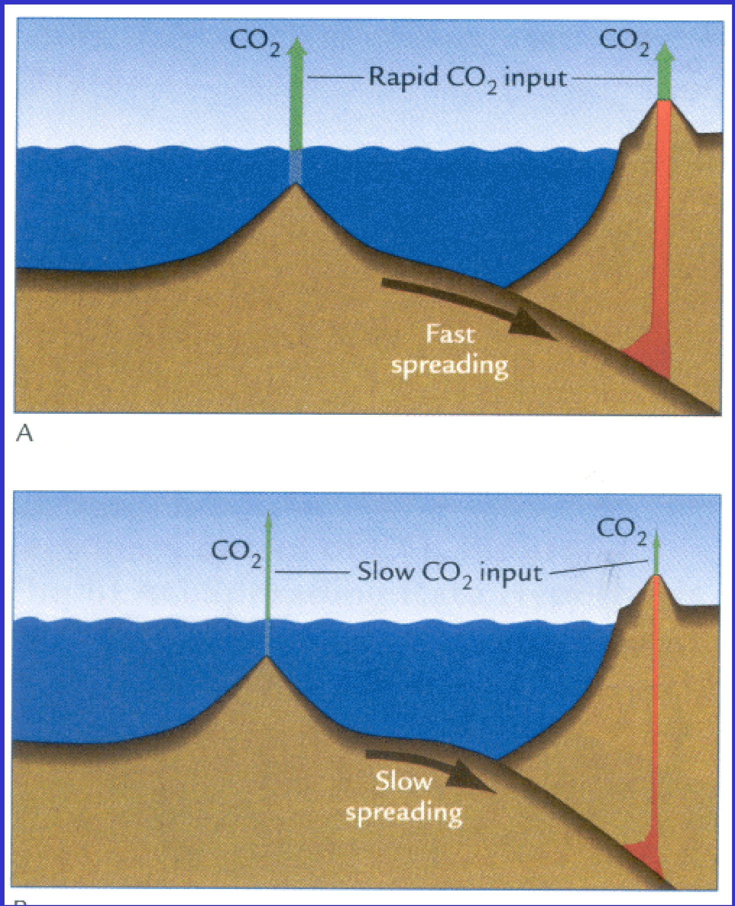
(from *Earth's Climate: Past and Future*)

The World 100 Myr Ago



(from *Earth's Climate: Past and Future*)

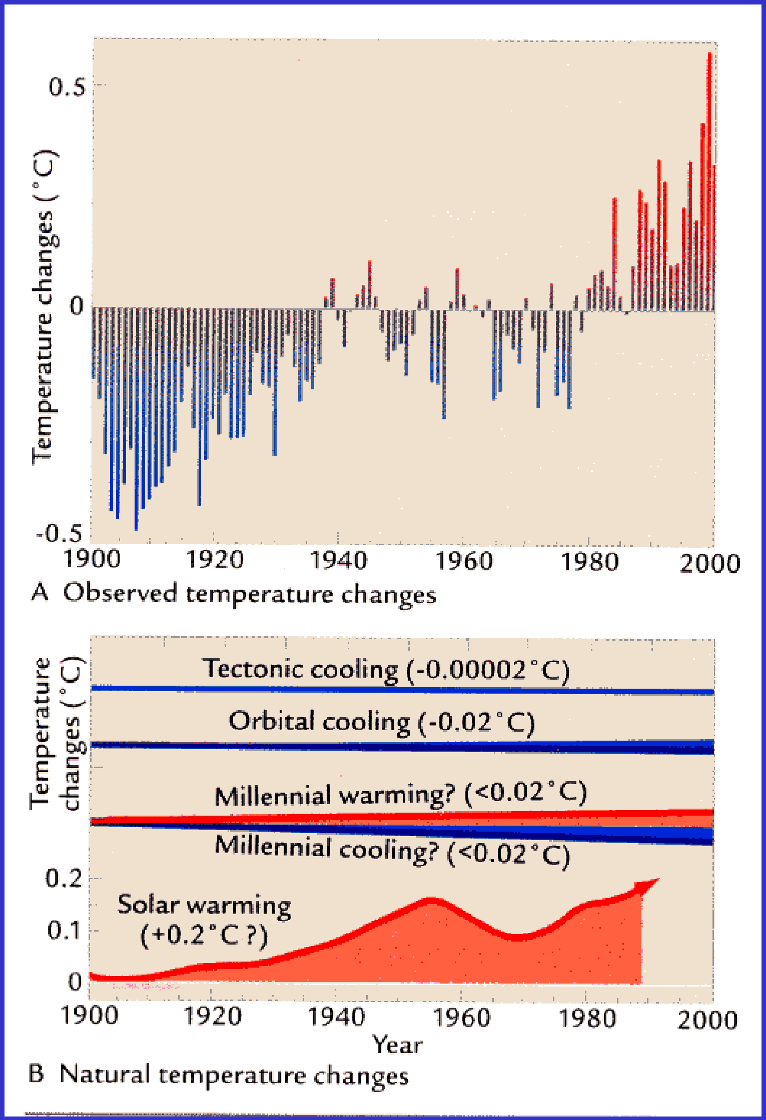
Tectonic Control of CO_2 *Input* – The Seafloor Spreading Rate Hypothesis



(from *Earth's Climate: Past and Future*)

- During active plate tectonic processes, carbon cycles constantly between Earth's interior and its surface.
- The carbon moves from deep rock reservoirs to the surface mainly as CO_2 gas associated with volcanic activity along the margins of Earth's tectonic plates.
- The centerpiece of the seafloor spreading hypothesis is the concept that changes in the rate of seafloor spreading over millions of years control the rate of delivery of CO_2 to the atmosphere from the large rock reservoir of carbon, with the resulting changes in atmospheric CO_2 concentrations controlling Earth's climate.

Global Warming: Natural or Man Made?



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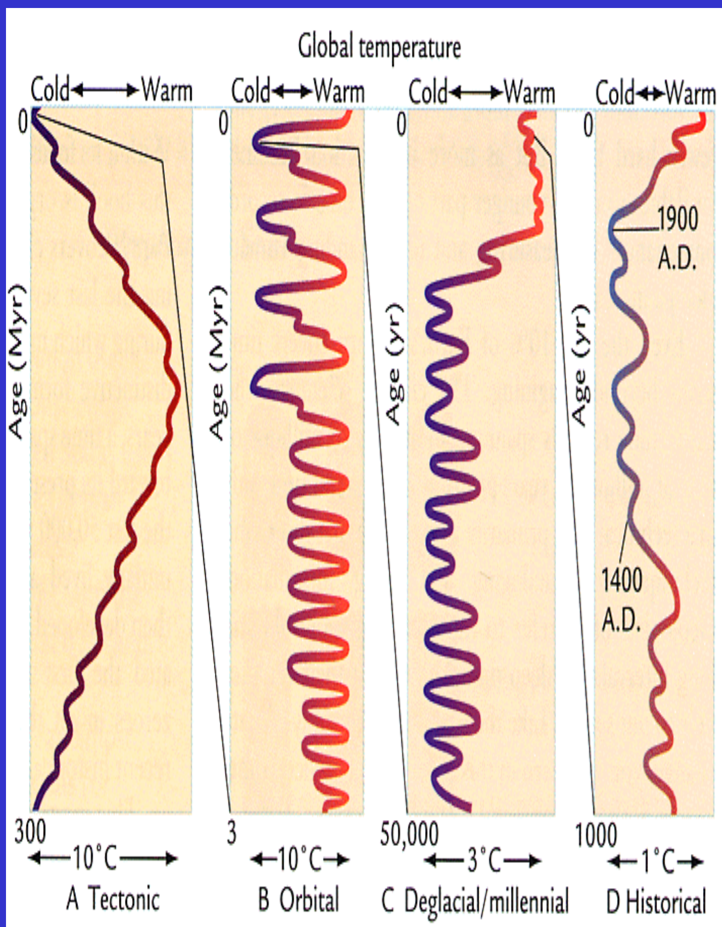

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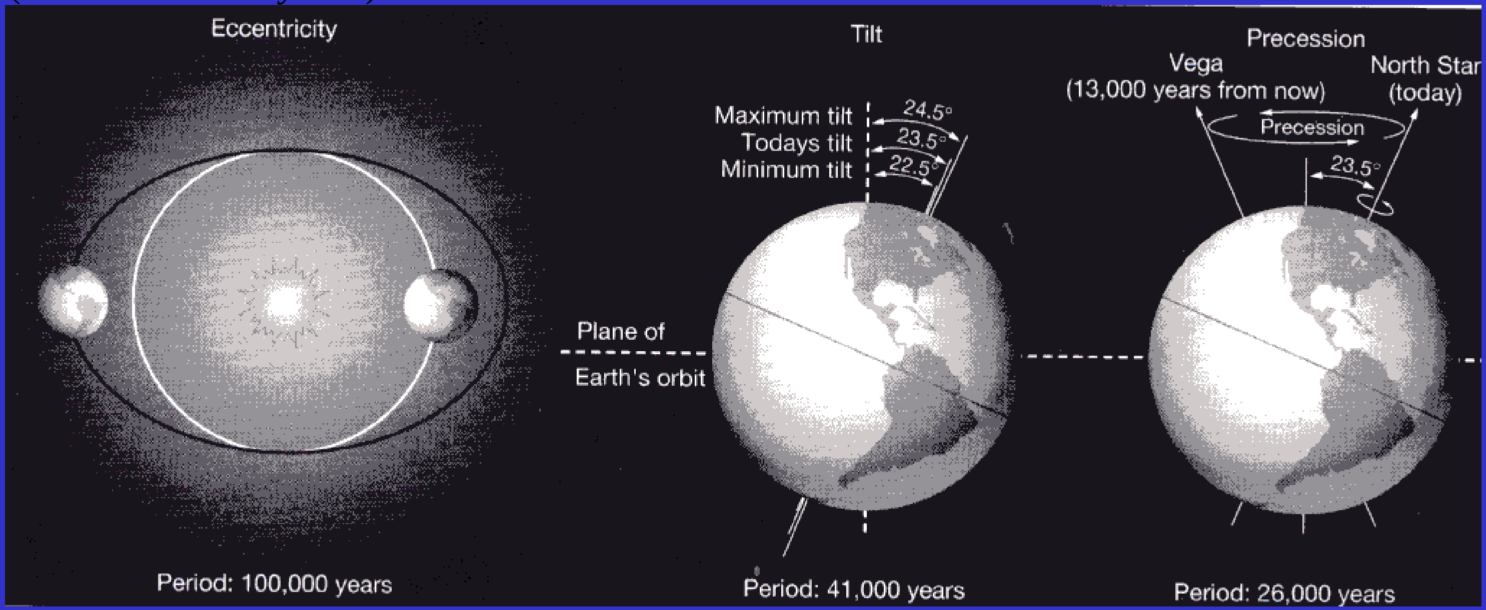
Orbital Scale

(from *The Earth System*)

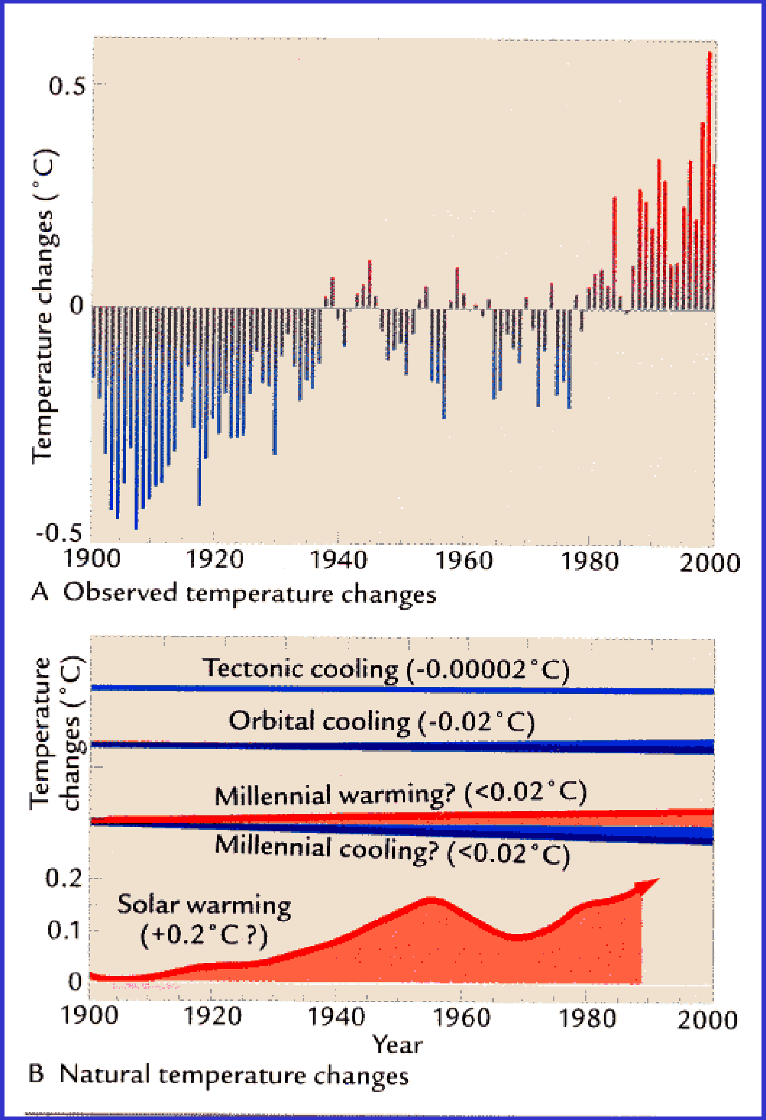


- ❑ Orbital-scale climate changes are caused by subtle shifts in Earth's orbit.

- ❑ Three features of Earth's orbit around the Sun have changed over time:
  (1) the tilt of Earth's axis,
  (2) the shape of its yearly path of revolution around the Sun
  (3) the changing positions of the seasons along the path.

- ❑ Orbital-scale climate changes have typical cycles from 20,000 to 400,000 years.

Global Warming: Natural or Man Made?



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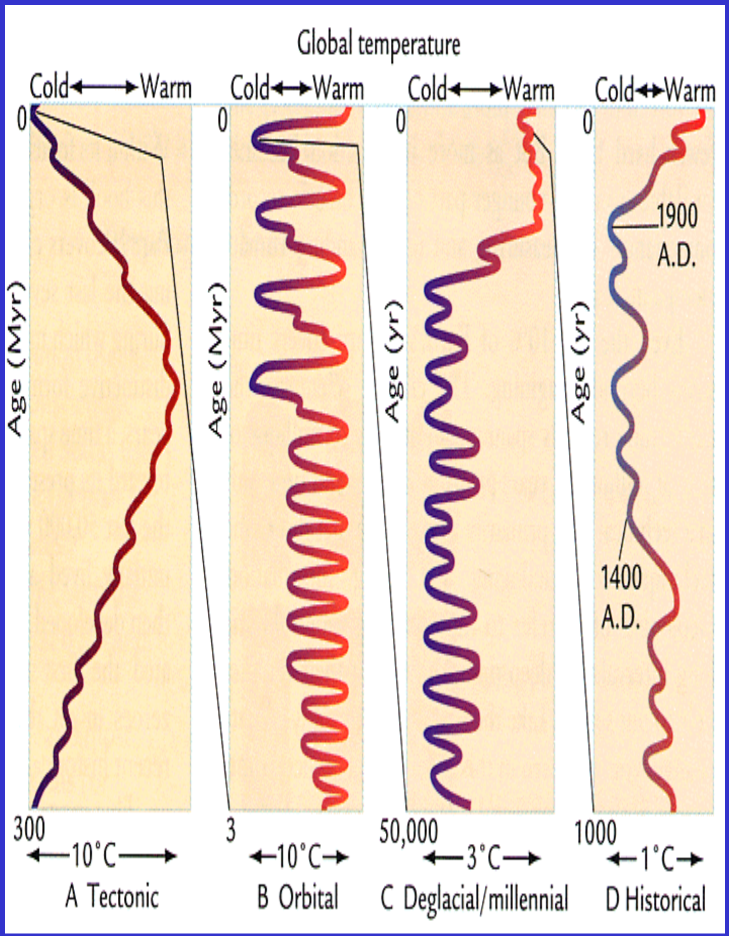

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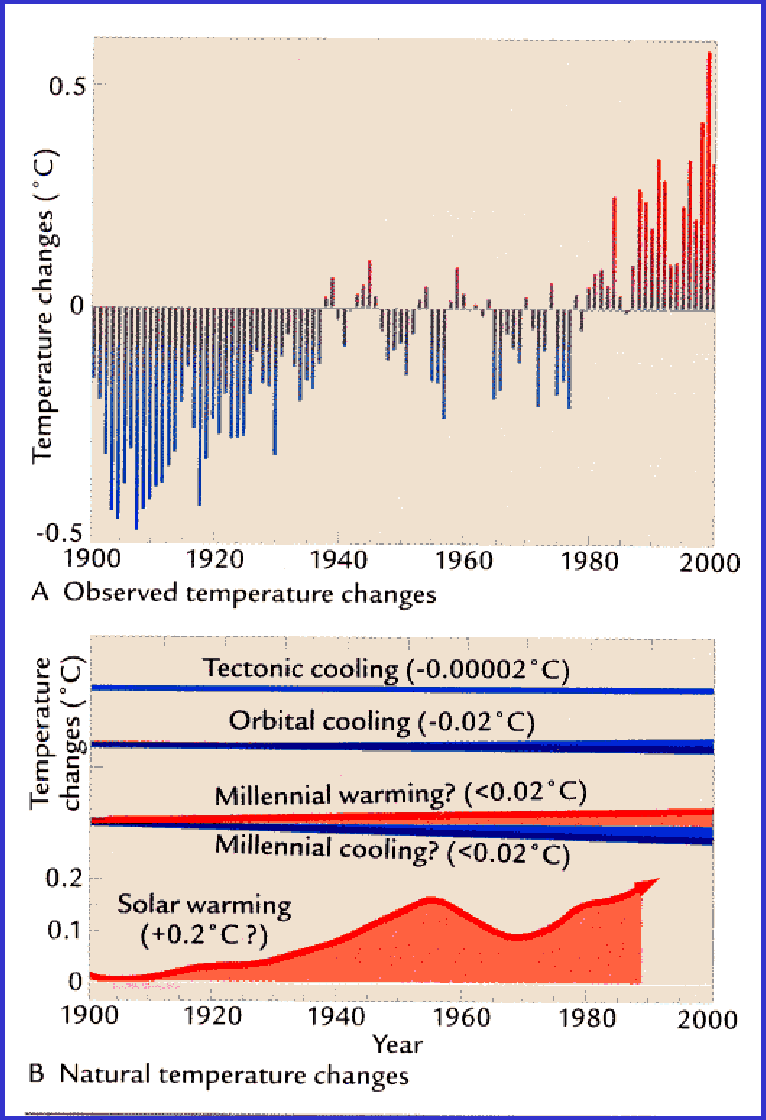

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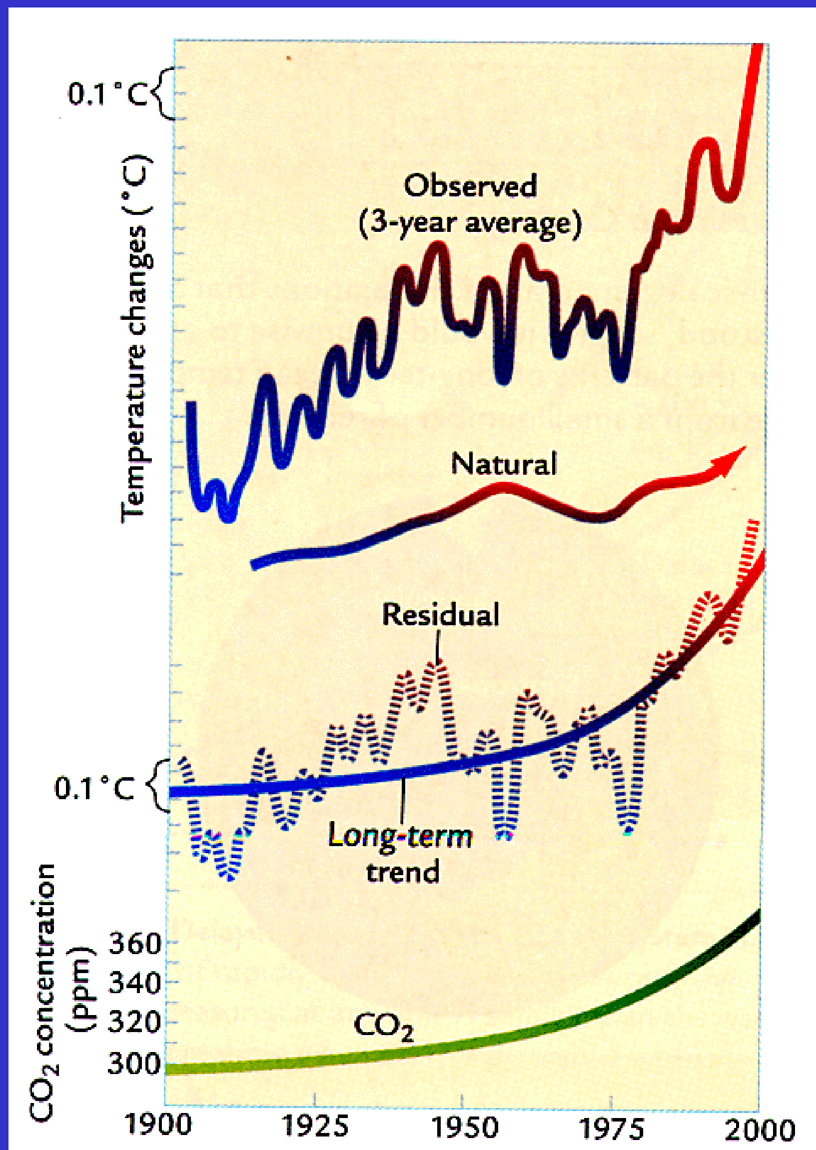

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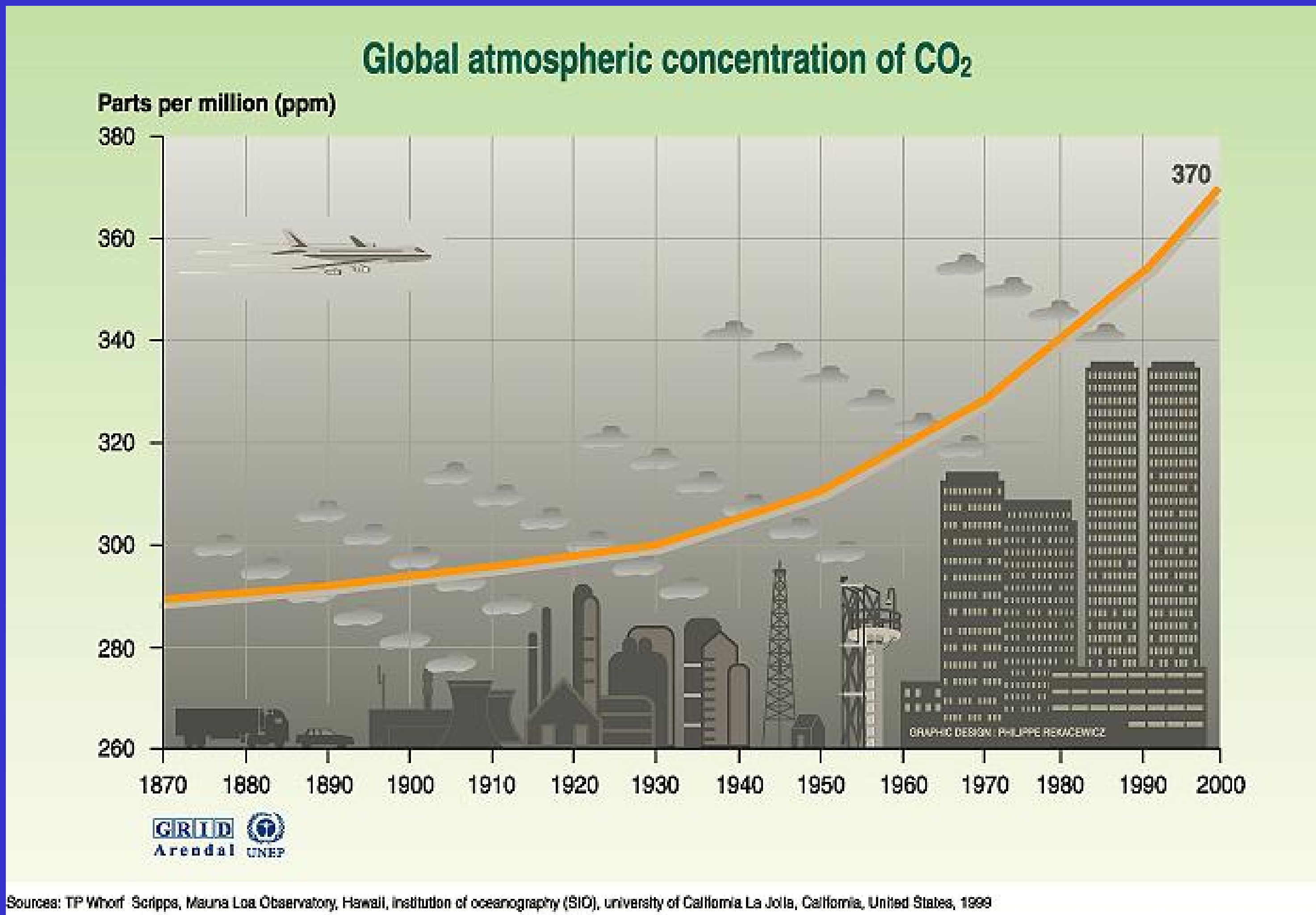
Increase of CO2 in the Atmosphere



Dilemma for Policy Makers

- How do we weight the possible harm of our actions against the advantage of economic growth?

➔ Policy makers want scientists to make precise predictions of the *timing* and *magnitude* of the future global warming.

Gliding Down A River Toward A Waterfall

(1) How far away are we from the waterfall?

➔ A scientific question.

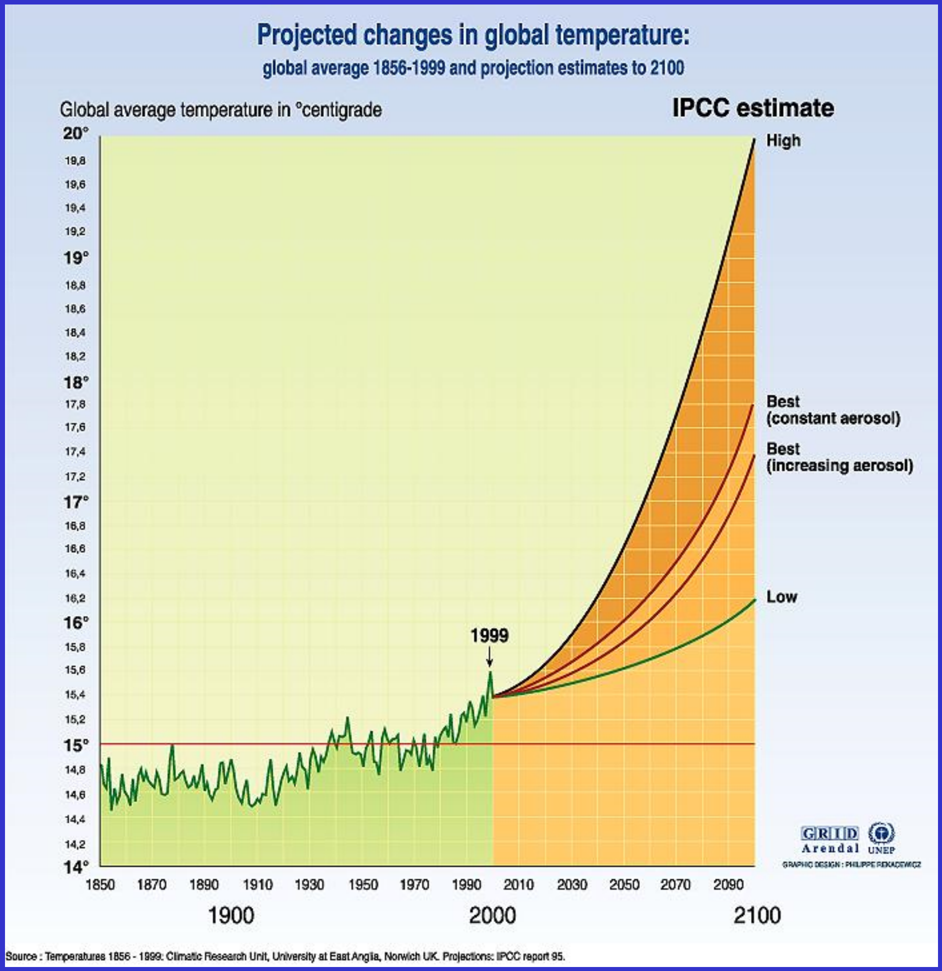
(2) When should we get out of the boat?

➔ A political decision.

30 minutes
Or
30±10 minutes

A catastrophe waiting ahead!

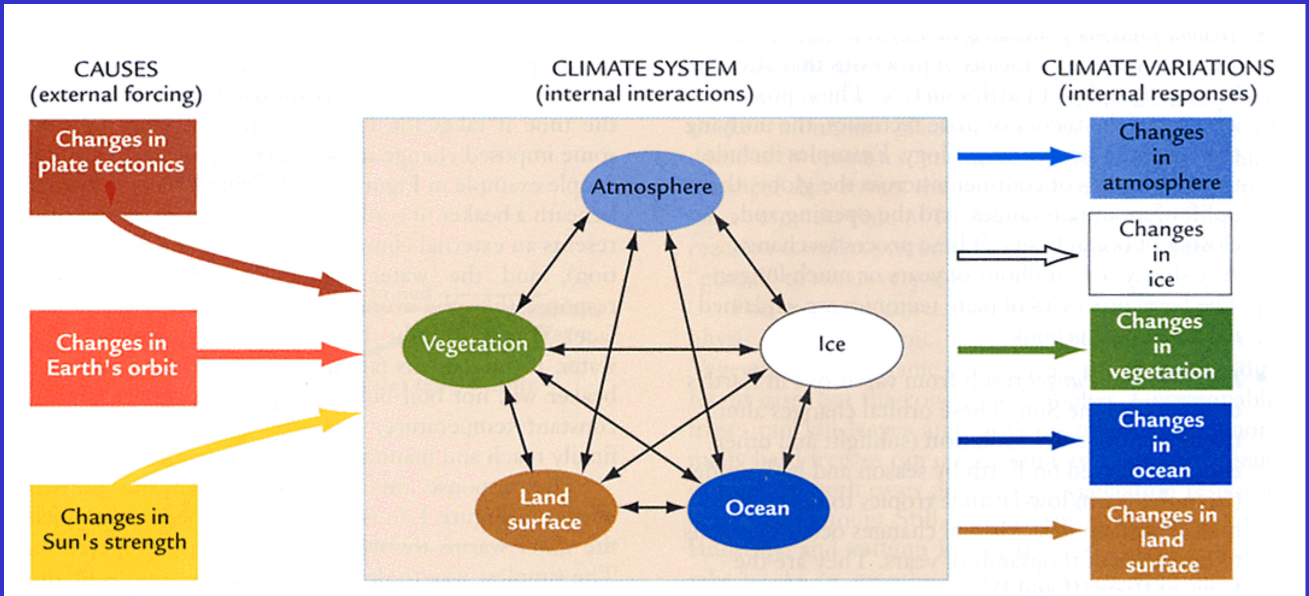
Can Scientists Predict Future Warming?



- ***YES.*** Our understandings of the climate system and the recent advancements in computer climate modeling have allowed us to predict the future global warming and its impacts.

- ***But with uncertainties.*** There are still significant uncertainties in predicting the timing and magnitude of the warming.

Why Uncertainties In Climate Prediction?



(from *Earth's Climate: Past and Future*)

- Earth's climate is determined by enormously complex interactions among the atmosphere, ocean, land surface, vegetation, ice …..

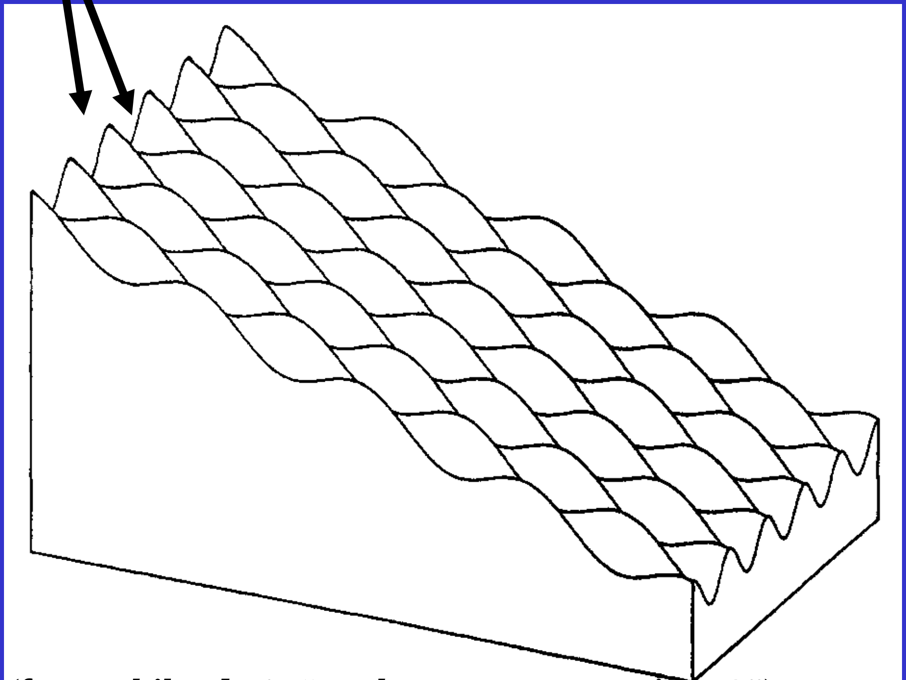
- The complexity of the Earth climate system leads to ***inevitable uncertainties*** in scientific predictions of the impacts of human activities.

Climate – A Chaotic System

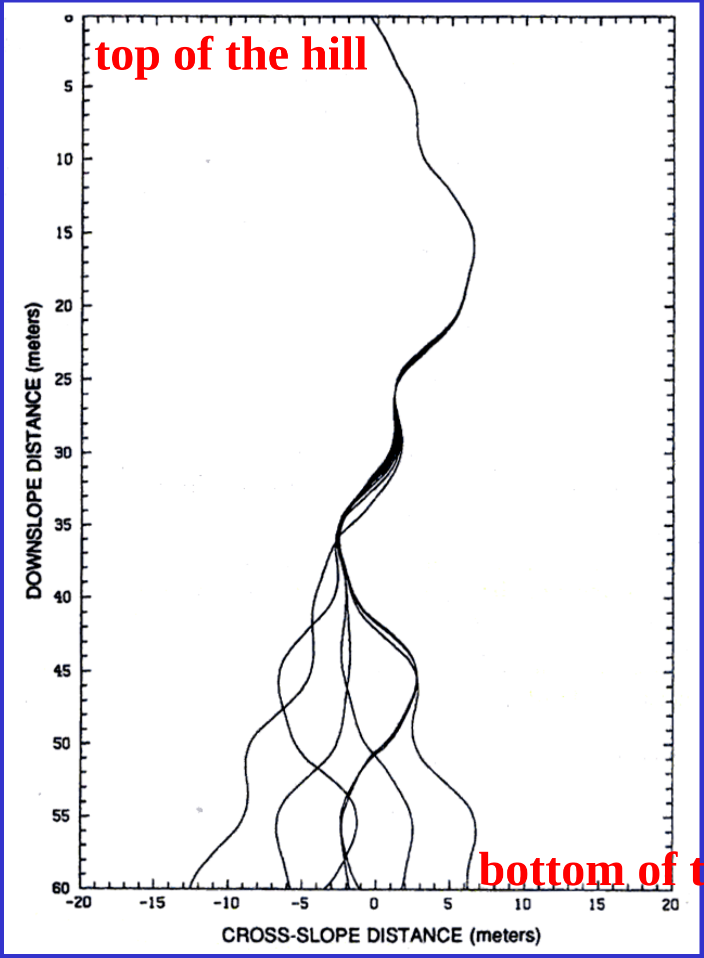
- In an effort to study the predictability of weather, Edward Lorenz (a meteorology professor at MIT) started the study of “chaos” systems.
- The weather/climate system is a nonlinear system. A small change in its initial condition can be amplified to a huge disproportionate effect on the whole system.
- For example, the small change caused by the flapping of the butterfly's wings in the Far East may causes massive changes in the eventual overall behavior of the storm in the North America.

An Example of Chaos

Dropping a wallet on the top of a snow hill…..



(from *Philander's "Is The Temperature Rising?"*)



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- It is important to accept that fact that *"..although accurate predictions are, in principle, possible on the basis of the laws of physics, such forecasts may be impossible in practice.."* because the complexity of our climate system.

How Should Policy Makers Cope with the Uncertainties in Science?

- Rather than implement ***comprehensive programs*** that decree a rigid course of action to reach grand and final solution,
- We should promote ***adaptive programs*** whose evolution is determined by the results of these programs and by the new scientific results that become available.

How Soon Should We Make A Decision?

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➔ A scientific question.

(2) When should we get out of the boat?

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30 minutes
Or
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Explosive Growth Events

- A gardener finds that his pond has one lily pad on a certain day, two the next day, four the subsequent day and so on. After 100 days the pond is completely filled with lily pads. *On what day was the pond half full?*

ANSWER: (A) Day 20; (b) Day 50; (C) Day 80; (D) Day 90; (E) Day 99

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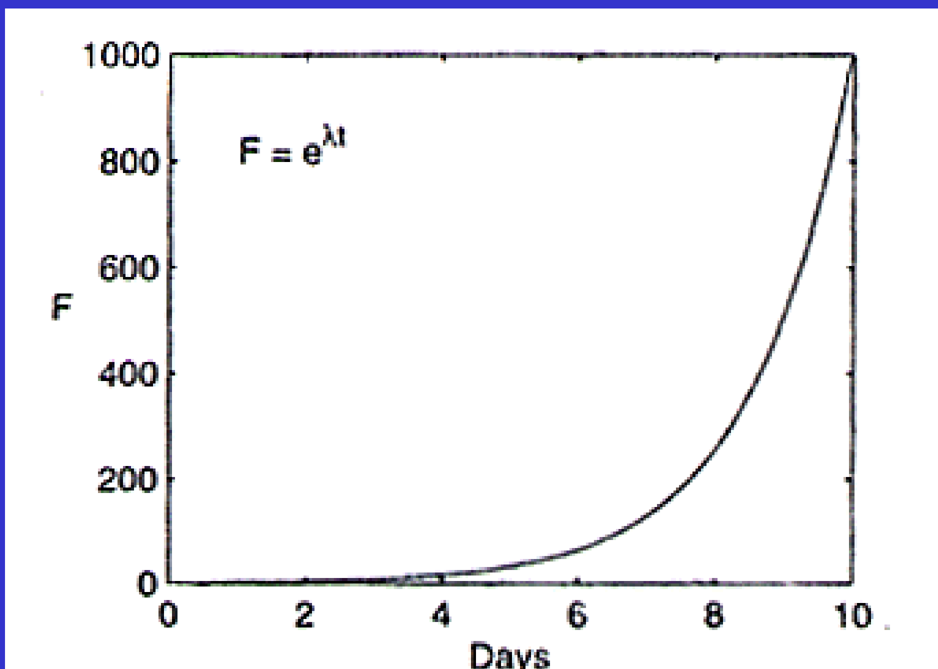
Global Change – An Explosive Growth Event

Exponential Growth



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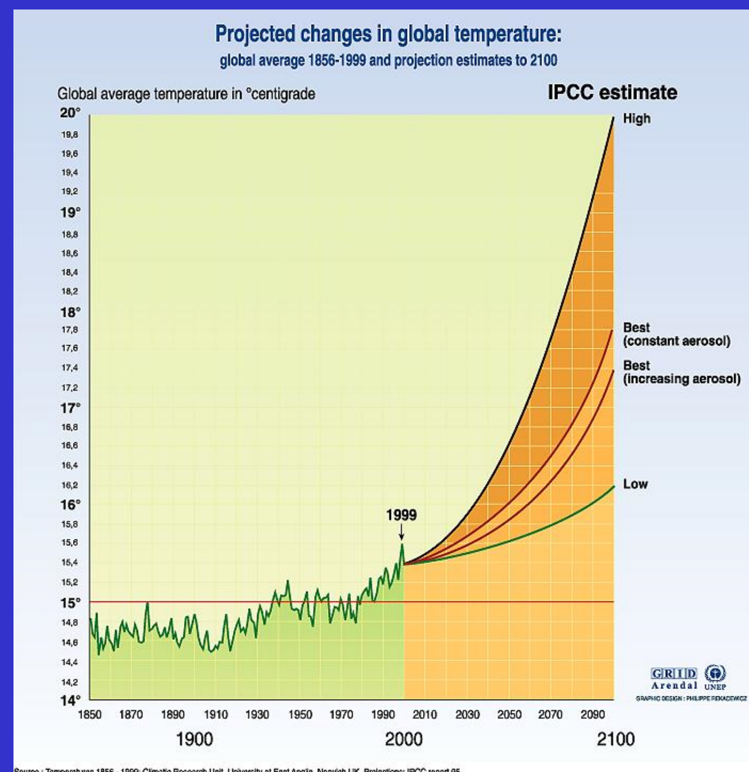
Global Warming



Consequence of Late Response

- Suppose the gardener, once he realizes what is happening, quickly ***enlarge the pond to twice its size.*** ***On what day will the new pond be completely filled?***

ANSWER: (A) Day 101; (B) Day 120; (C) Day 150; (D) Day 200

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Sooner Is Better Than Later

- Is our global warming problem close to Day 1 or Day 100?
- In stead of waiting for a precise answer to end this debate, it is more important to recognize the explosive-growth nature of the global warming problem.
- It is wiser to act sooner than later.

Lessons Learned

(1) Uncertainties in science are inevitable.

➔ We should not expect a precise prediction of the timing and magnitude of the future warming.

(2) Global change is an explosive growth event.

➔ We need to act sooner than later.

❑ We need to familiarize ourselves with the processes that determine the climate of this planet and the sensitivity of these processes to perturbations.