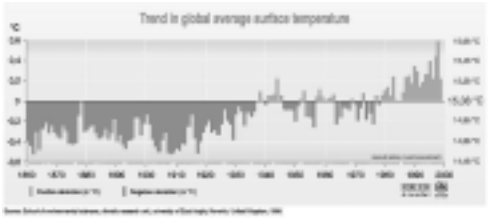
Lecture 1: Is Our Planet Fragile or Robust?

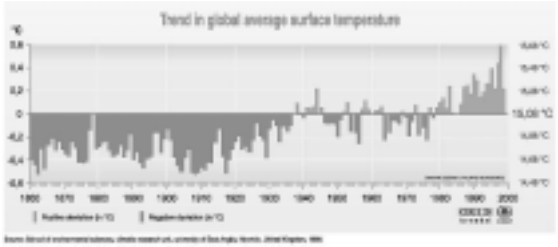


- What Do We Know About the Global Warming
- Uncertainties in Science
- How Policy Cope with the Uncertainties in Science
- Controversy of the Gaia Hypothesis

What is Climate Change?

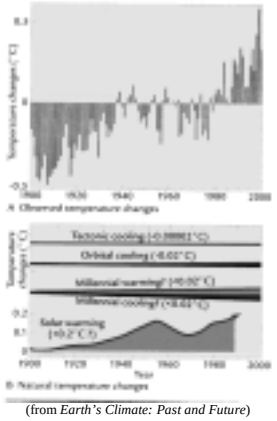
- Climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (from United Nation's Framework Convention on Climate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

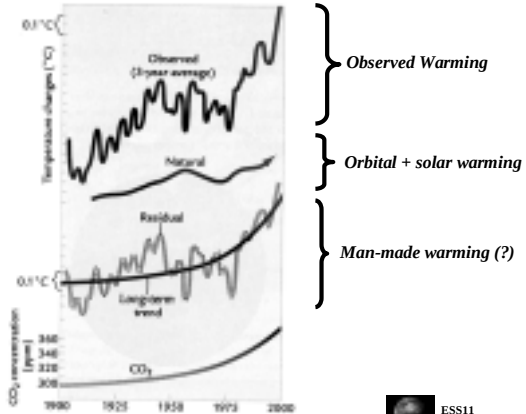
Global Warming: Natural or Man Made?



(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?



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

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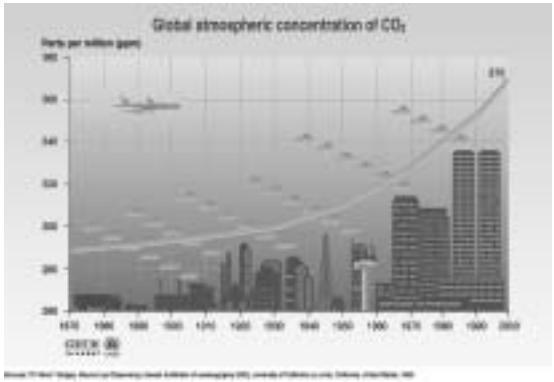
Increase of CO2 in the Atmosphere



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Human Injection of Carbon

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

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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.

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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

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.

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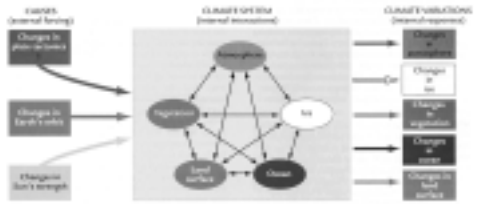
Why Uncertainties In Climate Prediction?



(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.

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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.

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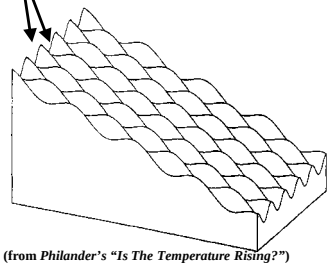
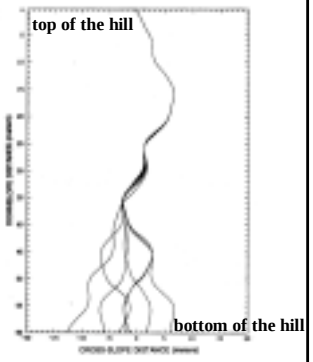
An Example of Chaos

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



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



- 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.

A Successful Case of the Adaptive Approach

- In 1987, the world agreed in the Montreal Protocol that each country would limit its production of the chlorofluorocarbons (CFCs) that contribute to the depletion of the ozone hole.
- This decision was made before clear evidence that CFCs are harmful to the ozone layer.
- The regulations were agreed in subject to periodic reviews to accommodate new scientific results.

How Soon Should We Make A Decision?

(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

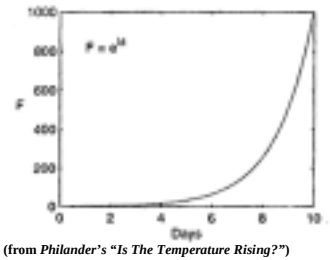
Explosive Growth Events

- 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: Day 99

Global Change – An Explosive Growth Event

Exponential Growth | Global Warming



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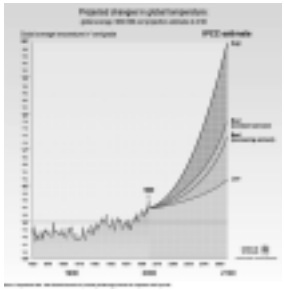


Consequence of Late Response

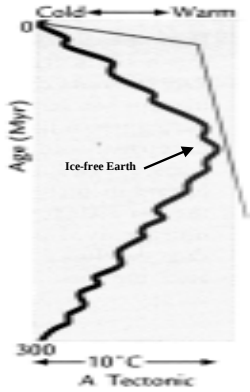
- Suppose the gardener, once he realizes what is happening, quickly ***enlarge the pond to twice its size. On what day will the new pond be completely filled?***

ANSWER: Day 101

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.

Is Global Warming Really A Catastrophe?



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

- Global temperatures have been much higher and much lower than they are today.
- Many factors have kept temperature extremes of our planet from approaching those prevail on Venus and Mars.
- Life has been on Earth for more than three billion years.
- From the perspective of the entire biosphere, ***our planet may seem robust.***

Faint Young Sun Paradox

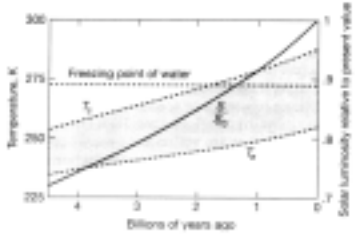


FIGURE 8-8
The faint young Sun paradox. The scale on the right applies to the solar luminosity curve, labeled S/S_0; the scale on the left applies to temperature curves. The shaded area represents the magnitude of the atmospheric greenhouse effect. (From J.F. Kasting et al., How Climate Evolved on the Terrestrial Planets, Scientific American 256(2): 90–97, 1988. Used with permission. © George V. Kelvin/Scientific American.

(from *The Earth System*)

- Solar luminosity was much weaker (~30%) in the early part of Earth's history (a faint young Sun).
- If Earth's albedo and greenhouse effect remained unchanged at that time, Earth's mean surface temperature would be well below the freezing point of water during a large portion of its 4.5 Byr history.
- That would result in a "snowball" Earth, which was not evident in geologic record.

The Gaia Hypothesis

- The Gaia hypothesis argues that life itself has been responsible for regulating Earth's climate.
- This hypothesis states that the biosphere acts as an organism that maintains conditions that are favor to life.

A White Daisy World

- When the intensity of sunshine increase
  - ➔ increase global temperature
  - ➔ favor the growth of daisy
  - ➔ increase the number of white daisies
  - ➔ daisies reflect more sunshine back to space
  - ➔ global temperatures stop to increase
  - ➔ daisy acts as a thermostat to control global temperature
  - ➔ support the Gaia hypothesis.

Controversy About the Gaia Hypothesis

- However, if there is threshold temperature beyond which the white daisy would die, then the Gaia hypothesis won't work.

- When the intensity of sunshine increase
  - ➔ increase global temperature ***TOO MUCH***
  - ➔ decrease the number of white daisies
  - ➔ daisies reflect less sunshine back to space
  - ➔ global temperatures continue to increase
  - ➔ white daisies distinct
  - ➔ against the Gaia hypothesis.

Controversy About the Gaia Hypothesis

- There is no doubt that life can affect global climate.

- But it is controversy whether the biosphere is capable of controlling the global environment to its own benefit.

- Our planet may seem robust from the perspective of the entire biosphere, but it can appear fragile from the perspective of individual species, specially for us.

Lessons Learned

- Uncertainties in science are inevitable.

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

- Over tens of thousands of years, we are unlikely to do great harm to our planet as a whole.

- We can, however, cause inconvenience to ourselves in the next several decades by continually perturbing the global climate.