





**Climate, Climate Change  
Nuclear Power and the  
Alternatives**

**PHYC 40050**

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School of Mathematical Sciences  
University College Dublin



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**Lecture 6**

**EdGCM**

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A Global Climate Model for Research and Education  
The EdGCM Cooperative Project, Columbia University



Support provided by: NSF Paleoclimate Program and NASA High-Performance Computing Program

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**EdGCM Project Goal**

To improve the teaching and learning of climate change science by providing the education community with access to:

- 1) A research quality global climate model (GCM)
- 2) A user-friendly interface to operate the GCM and organize the results
- 3) Educational materials to make the GCM a useful tool for learning about the climate system

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**What is EdGCM?**

**Educational Global Climate Model**

- A Global Climate Model
- Computer-based modelling program
- Relational Database
- Graphical User Interface
- Post-Processing Software
- Scientific Visualization Tools (EVA)
- Software for constructing scientific manuscripts and publishing them to the web.

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## What is a GCM?

General Circulation Model  
Global Climate Model

And why should we be interested in it?



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Climate change is in the news



It's in the science news!



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CAUSE → EFFECT

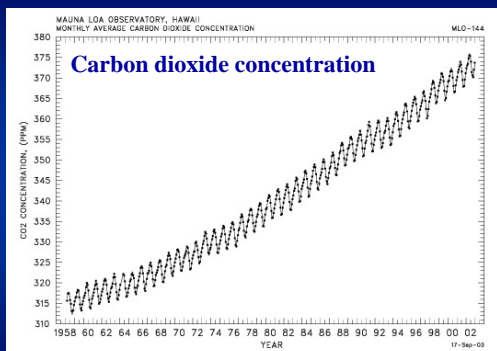
Recent Climate Change:  
Observed forcings and results.



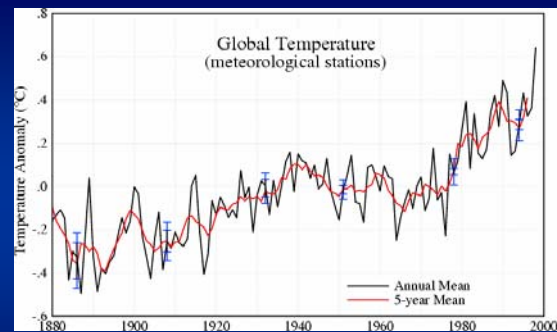
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## The Keeling curve (Charles Keeling)



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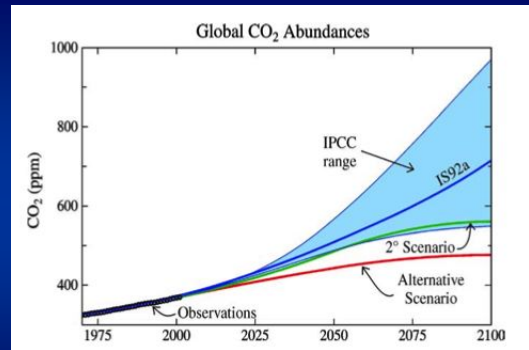


**CAUSE** → **EFFECT**

Future Climate Change:  
Uncertainty of forcing.



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Hansen, 2004



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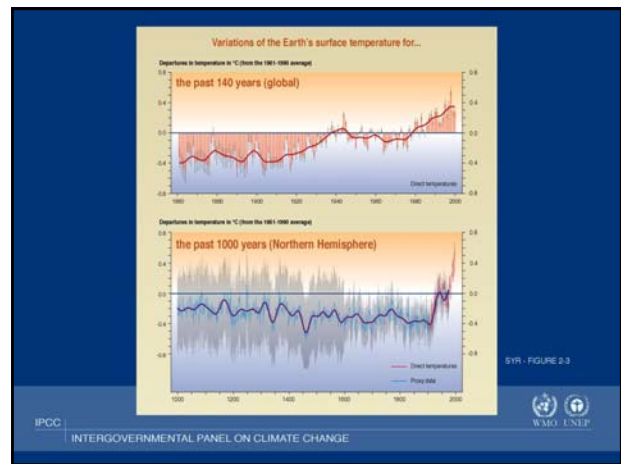


**CAUSE** ← **EFFECT**

Past Climate Change:  
Observed results. Uncertain forcings.



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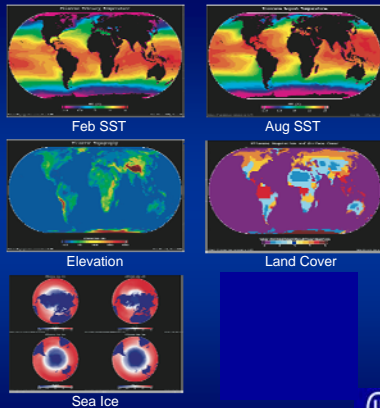


SIIR - FIGURE 2.3

IPCC  
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



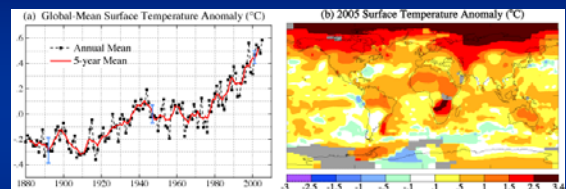
**Pliocene Research,  
Interpretation  
and  
Synoptic  
Mapping**



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**2005 - Warmest Year on Record**

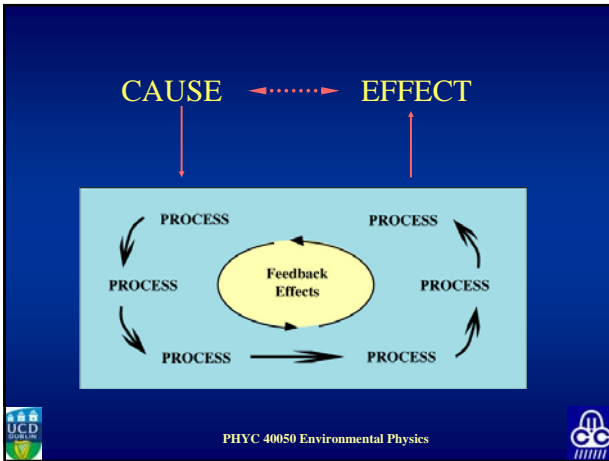


<http://data.giss.nasa.gov/gistemp/2005/>



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### Climate Sceptics (from BBC website)

While I am prepared to accept that there may be global warming, nothing I have seen shows a causal connection. Tim, UK

One of the most persistent arguments made by those who do not believe that climate change is caused by human activity is that there is "no consensus" amongst climatologists about this. Tim Dennell, Sheffield, United Kingdom

Five hundred years ago the scientific consensus was that the world was flat. Thirty years ago, we were about to enter another ice age. Twenty years from now we will all have a good laugh about "global warming". Thumper31

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### The GCM in EdGCM: GISS Model II

#### Cartesian Grid General Circulation Models

(Henderson-Sellers, 1985)

##### Basic Equations

**Conservation of momentum:**  

$$\frac{d\vec{v}}{dt} = -(\vec{v} \cdot \nabla)\vec{v} - \frac{1}{\rho} \nabla p - \vec{g} - 2\vec{\Omega} \times \vec{v} + \nabla \cdot (\mathbf{K}\nabla\vec{v}) - \vec{F}_v$$

**Conservation of energy:**  

$$\rho c_p \frac{dT}{dt} = -\rho c_p \vec{v} \cdot \nabla T - \nabla \cdot \vec{F}_r + \nabla \cdot (\mathbf{K}\nabla T) + C - E$$

**Conservation of mass:**  

$$\frac{d\rho}{dt} = -\rho \nabla \cdot \vec{v} + \rho \nabla \cdot \vec{v}$$

**Conservation of H<sub>2</sub>O (vapor, liquid, solid):**  

$$\frac{dq}{dt} = -\rho \nabla \cdot \vec{v} q + \nabla \cdot (\mathbf{K}\nabla q) - S_v + E$$

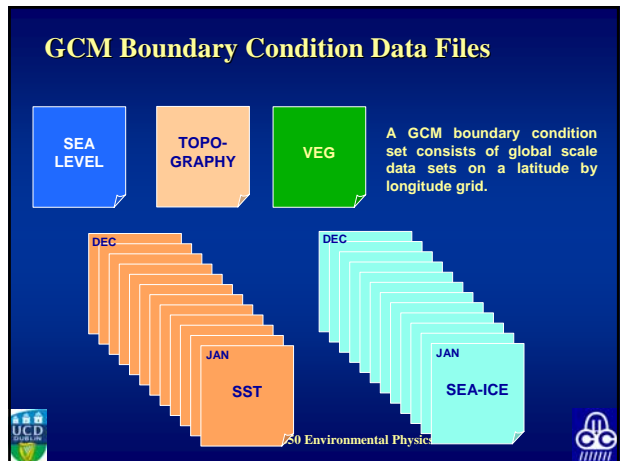
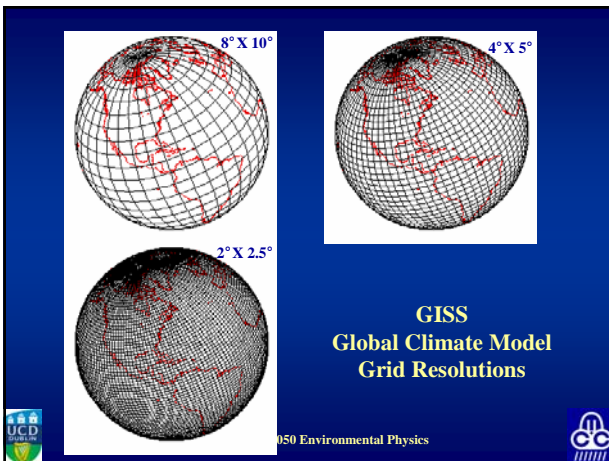
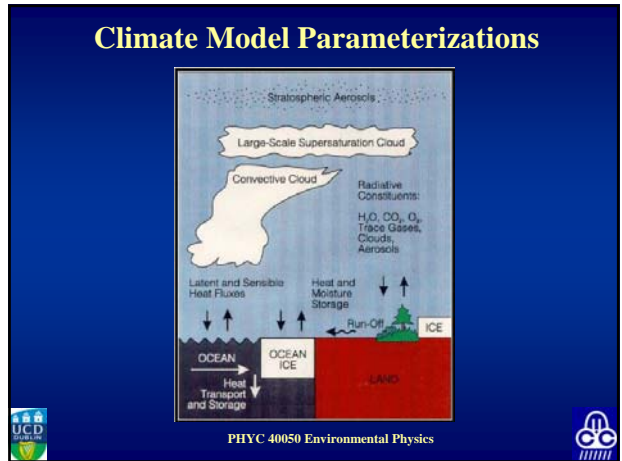
**Equation of state:**  

$$p = \rho R T$$

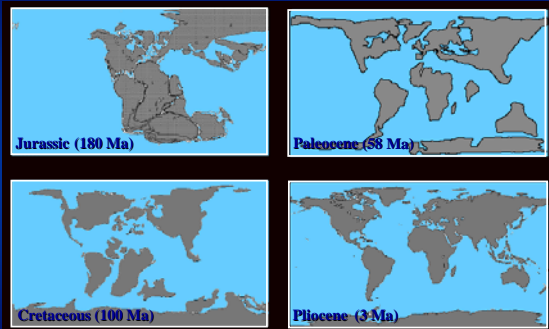
$\vec{v}$  = velocity  
 $T$  = temperature  
 $p$  = pressure  
 $\rho$  = density  
 $q$  = specific humidity  
 $\vec{g}$  = gravity  
 $\Omega$  = rotation of earth  
 $\vec{F}_v$  = drag force of earth  
 $\vec{F}_r$  = radiation vector  
 $\mathbf{K}$  = radiative heating  
 $C$  = conductive heating  
 $E$  = evaporation  
 $S_v$  = latent heating  
 $S_s$  = phase change source  
 $\mathbf{K}_v$  = diffusion coefficient  
 $K_s$  = dry air gas constant

(Hansen et al., 1983)

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## Paleogeography Throughout Earth History



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## Prescribed Climate Forcings

- Solar Luminosity
- Orbital Parameters
- Radiatively Significant Trace Gases
- Volcanic Aerosols
- Other Natural and Anthropogenic Aerosols



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## Ed GCM Project Objectives

- 1) Allow teachers to run a NASA global climate model on a desktop computer, *encouraging students to participate in the full scientific process* including: experiment design, running simulations, analyzing data and reporting results.



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## Ed GCM Project Objectives

- 1) Allow teachers to run a NASA global climate model on a desktop computer, *encouraging students to participate in the full scientific process* including: experiment design, running simulations, analyzing data and reporting results.
- 2) Facilitate collaborations between the education community and research institutions and among universities. In this way, *students will become familiar with the role that teamwork plays in scientific research.*



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## Scientific Research Involves Teamwork



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## Organizing and Designing Scientific Experiments

### Step 1: Setting Up Climate Model Simulations



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```

Snowball_sim2.R Model II 8/24/2000

Owner: Dr. Mark Chandler, chandler@jise.nasa.gov
Group: Paleoclimata Group
This experiment simulates a time period approximately 600 million years ago. There is
evidence that a "super" ice age occurred that affected even tropical continents. Did the
Earth freeze over entirely???

Object modules:
MainC9
DiagC9
RadC9
FFRC9
UTILC9

Data input files:
7=08X10_600Ma
9=NOV1910.ref_snowball
15=08X10_600Ma
17=
25=Modern_OceanTransports
19=08X10_600Ma
23=v8X10_600Ma
26=28X101_600Ma
21=WRAN_02515
22=RPLX25
29=snowball_Earth_Regions

Label and Namelist:
Snowball_sim2 (Snowball Earth Experiment: 600 million years ago)

&INPUTE
  TAU1=10176.,TYEAR=1900,
  KOCAN=1.,SRCOR= 95489638151,
  SOR=1.,COR= 317403174631,
  USEV=0.,TADE=35040.,
  USESLP= 12.,
  ISTRAN=1.,KOCVP=2.,NDPRNT=-1.,TAIR=10177.,TAIP=95616.,
&END

```

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Scarsdale Teachers Institute, March 3 and 4, 2006

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## Analyzing the Results of Scientific Experiments

Step 2: Post-processing of raw GCM output

Step 3: Visualization of climate model variables

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## Reporting Results of Scientific Experiments

Step 4: Generating scientific-style manuscripts

Step 5: "Publishing" and presenting results

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eJournals

Image Libraries

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**Snowball Earth: Superglacials of the Neoproterozoic Era (580 Ma)**  
Linda Sold and Mark Chandler

**Figure 1:** Advanced satellite imaging of an ice cover in the modern Arctic Ocean. During the Pleistocene, glaciation, sea ice would have extended farther to roughly the same latitude as the southern tip of Greenland and southern Scandinavia. The maximum extent of ice cover during the Snowball Earth glaciations of the Neoproterozoic Era is one of the questions that researchers have tried to address through climate simulations (Image courtesy of NASA/JPL/Propulsion Laboratory)

**Figure 2:** This image taken by the Voyager 1 spacecraft is a false-color composite of Europa, one of Jupiter's larger moons. Europa is thought to have a solid global ice cover over a liquid ocean which could harbor life. Proposals of "hard snowball" glaciations have suggested that Europa is an appropriate model to consider for how life could have survived extreme glaciation here on Earth, perhaps even suggesting evolutionary changes that led to life as we know it. Earth's "Snowball" to this idea, however, noting that the existing level of ice is not good enough to support this hypothesis (Image courtesy of NASA/JPL/Propulsion Laboratory)

**Introduction**  
With the debate over global warming capturing the attention of many, it is not surprising that a great deal of current climate research is aimed at understanding the causes and effects of warmer climates. However, despite the likelihood that the 21st century will be an exceptionally warm century we are technically still in the middle of an ice age - the Pleistocene - that has persisted for nearly two million years. The Pleistocene ice age has been the focus of many climate studies that have helped us to better understand not only cold climates, but the Earth's climate system in general. However, just as there have been periods in Earth history that were warmer even than what we expect from global warming, the Earth has experienced ice ages that were far colder than the Pleistocene.

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**EdGCM Educational Global Climate Modeling**

Welcome to the EdGCM Website!

**EdGCM: The Project**  
The EdGCM Project is a collaboration between the Center for Global Change Science and the Center for Earth and Environmental Science at Columbia University. The project is focused on developing educational resources for teaching climate science in K-12 schools and universities.

**EdGCM: The Software**  
The EdGCM software is a free, open-source climate model designed for educational use. It is available for download and use on a variety of operating systems.

Downloads  
Technical Manual  
Community Showcase  
Educational Standards  
Events

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The EdGCM website is a focal point for collaborations, which will allow for:

- Downloads of EdGCM software, materials, and updates
- Simulation exchanges
- Discussion groups
- A location to publish results
- Development work
- News, EdGCM Exercises, and Community Showcases

## A Few Final Points

1. EdGCM is designed to support a broad range of National and State Science Education Standards

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## A Few Final Points

1. EdGCM is designed to support a broad range of National and State Science Education Standards
2. On-line Materials:
  - Technical manual
  - Software downloads
  - Quicktime video tutorials - coming soon

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## A Few Final Points

1. EdGCM is designed to support a broad range of National and State Science Education Standards
2. On-line Materials:
  - Technical manual
  - Software downloads
  - Quicktime video tutorials - coming soon
3. Information Resources and Educational Materials
  - Electronic Support Forums
  - Frequently Asked Questions Guide
  - Community Showcase
  - Simulation and eJournal Exchanges
  - Climate Science in Action - EdGCM Exercises

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<http://edgcm.columbia.edu>

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## End of Lecture 6



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