


# EdGCM: Global Climate Modeling In The Classroom

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[edgcm.columbia.edu](http://edgcm.columbia.edu)

# EdGCM Project Objectives

- Allow educational institutions and individuals to run a global climate model on desktop computers
  - Encourage students to participate in the full scientific process
    - Experiment design
    - Running simulations
    - Analyzing data
    - Reporting on results
  - Facilitate collaborations between schools, universities, national labs, and the private sector *so students become familiar with the role of teamwork in scientific research.*
  - Demystify how scientists forecast future climate change as a way to deal with public skepticism about global warming.
- 

# GCM: Global Climate Model

Atmosphere



Oceans



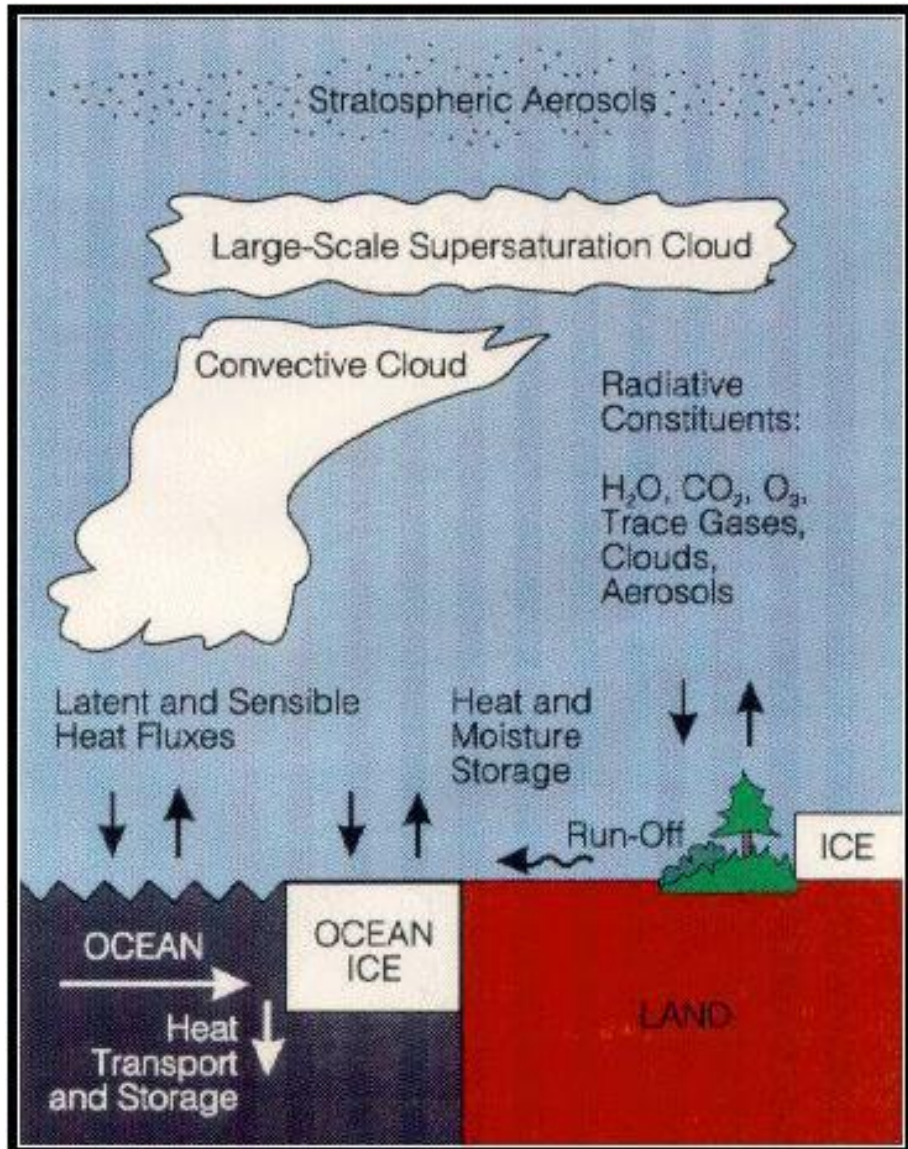
Cryosphere



Vegetation

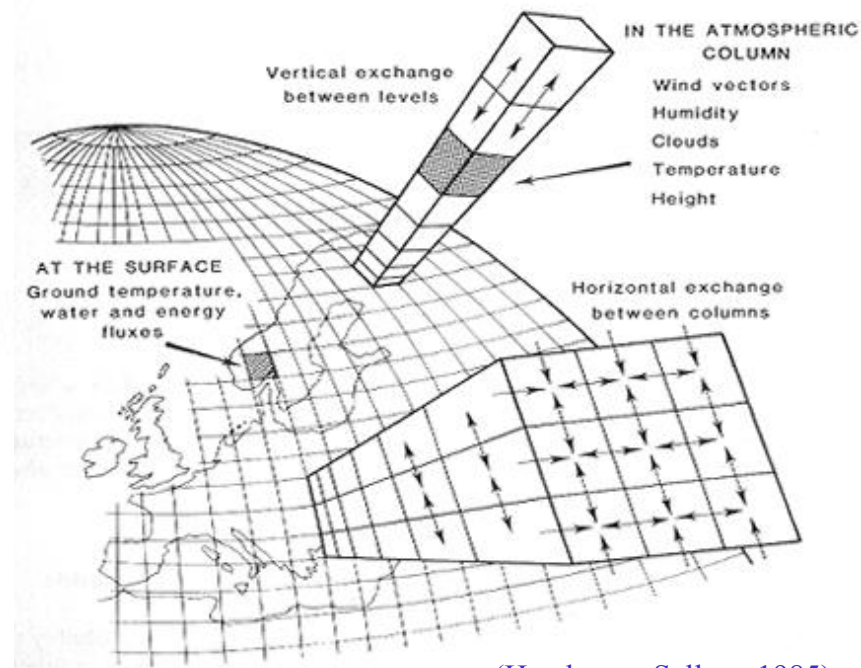
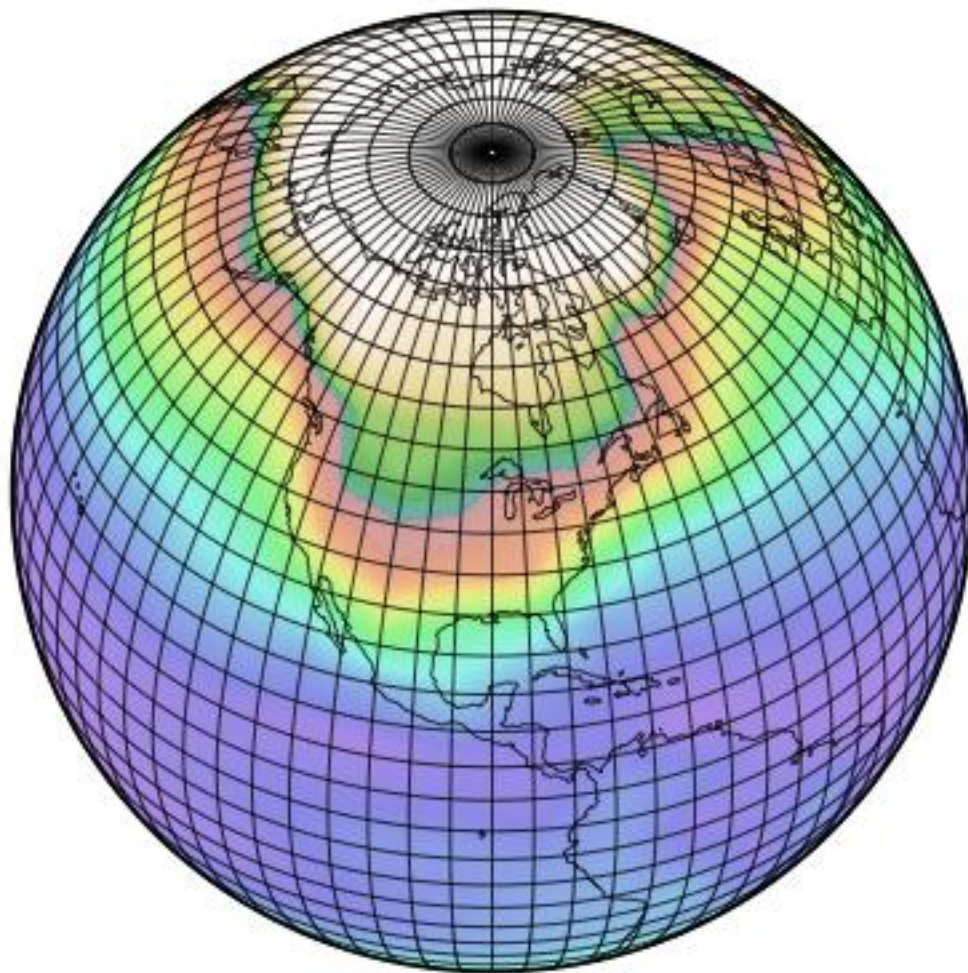


# Physical Processes Simulated by GCMs



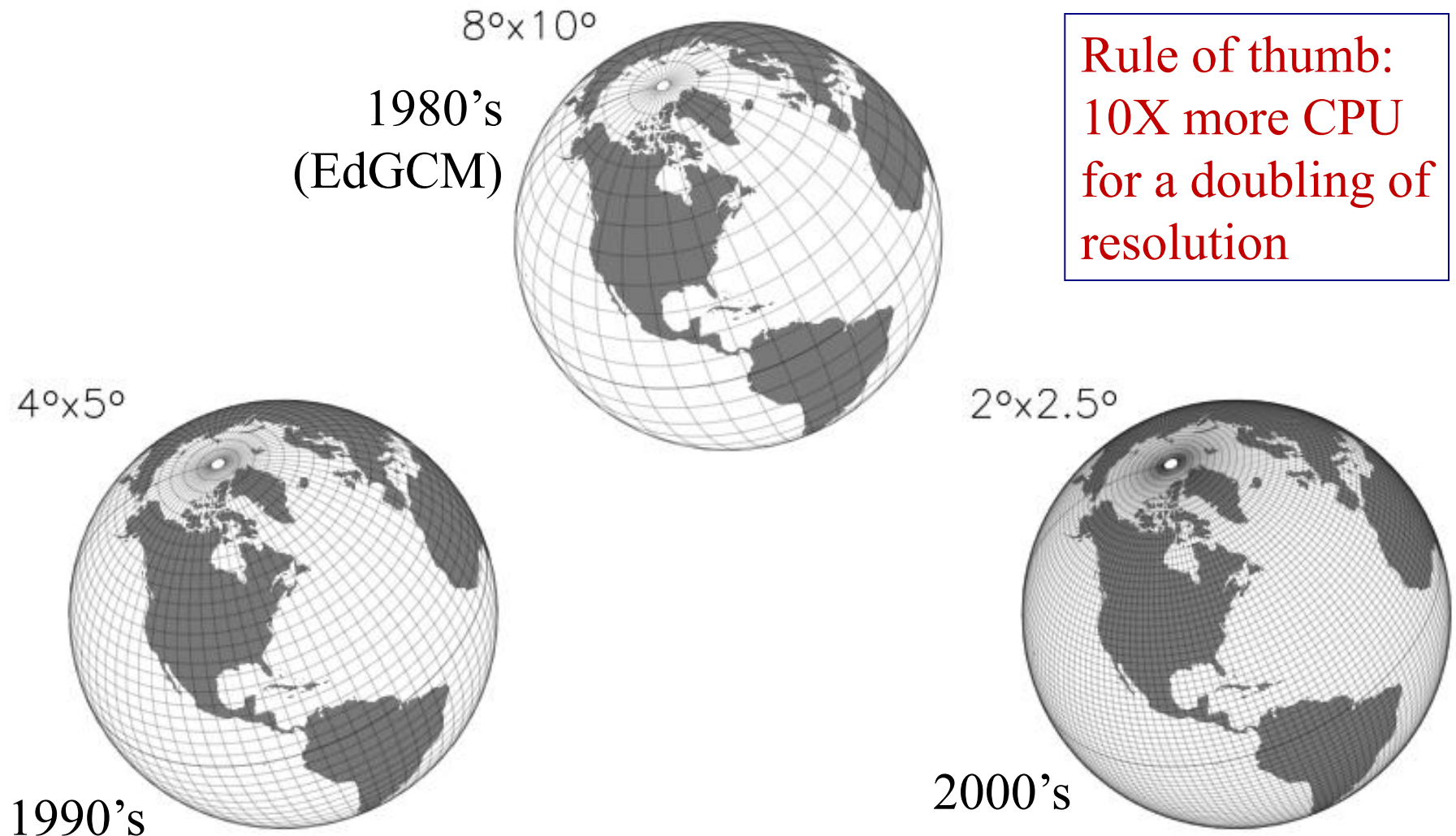
- Seasonal and Diurnal Cycles
- Latent and Sensible Heat Fluxes
- Clouds and Convection
- Planetary Boundary Layer
- Greenhouse Gases
- Aerosols
- Sea Ice
- Ground Hydrology
- Ocean Heat Transport
- Ocean Circulation*
- Dynamic Vegetation*
- Dynamic Ice Sheets*
- Carbon Cycle Chemistry*

# Grid Point Models



(Henderson-Sellers, 1985)

# Increased Resolution Requires Increased Computing Resources



# Fundamental Physical Quantities & Equations

At every grid cell GCMs calculate:

- Temperature (T)
- Pressure (P)
- Winds (U, V)
- Humidity (Q)

- Conservation of momentum

$$\frac{\partial \vec{V}}{\partial t} = -(\vec{V} \cdot \nabla) \vec{V} - \frac{1}{\rho} \nabla p - \vec{g} - 2\vec{\Omega} \times \vec{V} + \nabla \cdot (k_m \nabla \vec{V}) - \vec{F}_d$$

- Conservation of energy

$$\rho c_V \frac{\partial T}{\partial t} = -\rho c_V (\vec{V} \cdot \nabla) T - \nabla \cdot \vec{R} + \nabla \cdot (k_T \nabla T) + C + S$$

- Conservation of mass

$$\frac{\partial \rho}{\partial t} = -(\vec{V} \cdot \nabla) \rho - \rho (\nabla \cdot \vec{V})$$

- Conservation of  $H_2O$  (vapor, liquid, solid)

$$\frac{\partial q}{\partial t} = -(\vec{V} \cdot \nabla) q + \nabla \cdot (k_q \nabla q) + S_q + E$$

- Equation of state

$$p = \rho R_d T$$

# But, What Is a GCM *really*?: A Computer Program

Global\_Warming\_Sim2.R Model II 8/24/2000

Owner: Dr. Mark Chandler, chandler@giss.nasa.gov  
Group: Paleoclimate Group  
This experiment simulates climate change based on a  
1 percent/year increase in CO2

Object modules:  
MainC9 DiagC9 RadC9  
FFTC9  
UTILC9

Data input files:

21=RTAU.G25L15  
22=RPLK25  
29=Snowball\_Earth\_Regions

Label and Namelist:  
Global\_Warming\_Sim2 (Transient increase in CO2)

```
&INPUTZ
TAUI=10176.,IYEAR=1900,
KOCEAN=1, SRCOR=.95485638151,
S0X=1.,CO2=.31746031746031,
USET=0.,TAUE=35040.,
USESLP=-12.,
ISTART=3,KCOPY=2,NDPRNT=-1,TAUE=10177.,TAUP=95616.,
```

```
C** INITIALIZE SOME ARRAYS AT THE BEGINNING OF SPECIFIED DAYS
```

```
fName = './prt'//JMINTH0(1:3)//CYEAR//'.prt'//LABEL1(
```

```
IF(JDAY.NE.32) GO TO 294
```

```
JEQ=1+JM/2
```

```
DO 292 J=JEQ,JM
```

```
DO 292 I=1,IM
```

```
292 TSFREQ(I,J,1)=JDAY
```

```
JEQM1=JEQ-1
```

```
DO 293 J=1,JEQM1
```

```
DO 293 I=1,IM
```

```
293 TSFREQ(I,J,2)=JDAY
```

```
GO TO 296
```

```
296 DO 297 J=1,JM
DO 297 I=1,IM
```

```
TDIURN(I,J,1)=1000.
```

```
TDIURN(I,J,2)=-1000.
```

```
TDIURN(I,J,6)=-1000.
```

```
PEARTH=FDATA(I,J,2)*(1.-FDATA(I,J,3))
```

```
IF(PEARTH.GT.0.) GO TO 297
```

```
TSFREQ(I,J,1)=365.
```

```
TSFREQ(I,J,2)=365.
```

```
297 CONTINUE
```

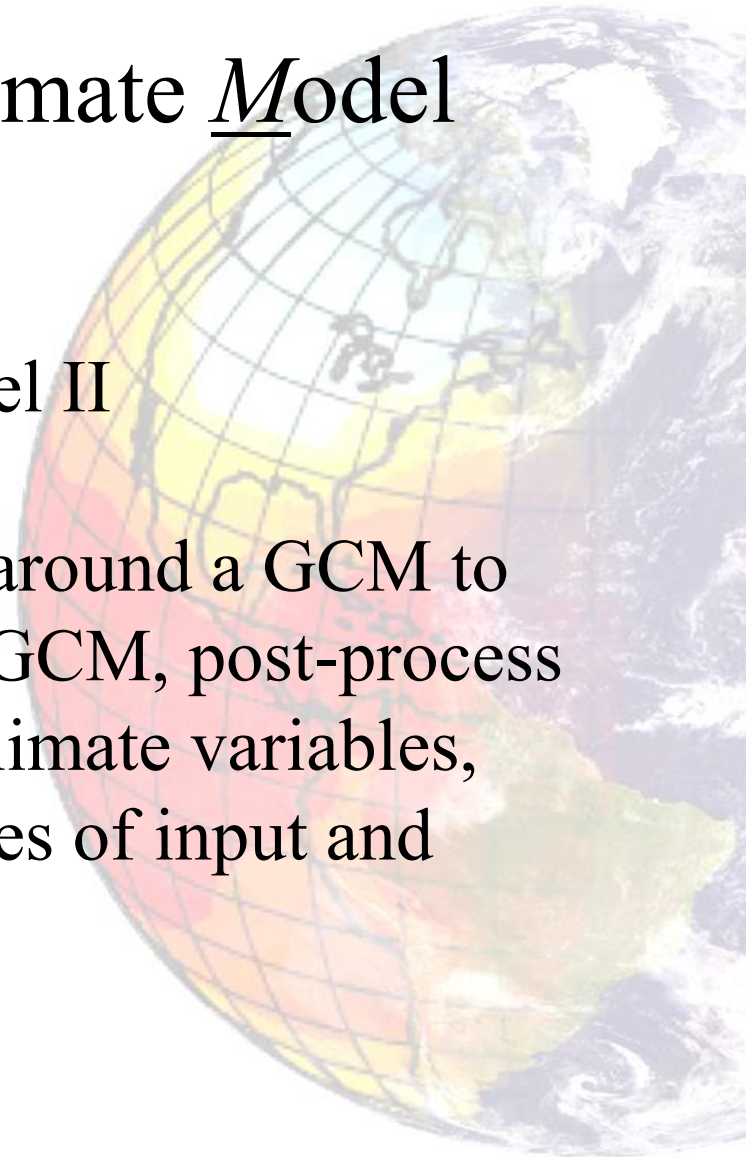
## Unix scripts and Fortran Code

### Requiring significant programming skills to operate

# What is *Ed*GCM?

## Educational Global Climate Model


- A Global Climate Model
  - NASA/GISS Model II
- A suite of software wrapped around a GCM to make it easier to operate the GCM, post-process and visualize the simulated climate variables, and organize the large volumes of input and output data.



# Design, Run, Organize Experiments

EdGCM 3.1 (706) Toolbar

Simulation Controls

Run Folder  Run Date 01/01/2101

Run List

Sort by: Run ID

- ☐ 331\_tutorial
- ☐ Doubled\_CO2
- ☒ Global\_Warming\_01
- ☐ Ice\_Age\_21kya
- ☐ Modern\_PredictedSST
- ☐ Modern\_SpecifiedSST
- ☐ Pliocene\_3mya
- ☐ Pliocene\_sSST
- ☐ RunID178
- ☐ Sample\_Control\_Run
- ☐ SnowballEarth\_750Ma
- ☐ Solar\_Decrease

Search by:

Setup Simulation

New

Duplicate

Delete

Simulation Summary

Make Scenario

Open All Sections

Close All Sections

Link to eJournals

View Links

Setup Simulation, Run ID: Global\_Warming\_01

EdGCM Setup Simulations

General info

Run ID: Global\_Warming\_01 Start on Jan. 1: 1958 End on Dec. 31: 2100

Project ID: Global Warming Date: 02/11/2005 Owner: Mark Chandler

Run label: Global Warming: CO2 gradually increases, doubling by 2069

Comments:

based on Modern control run using Model II v1.06  
uses predicted SST with deep ocean diffusion  
Initial CO2 = 315.4  
increasing CO2 trend is linear with 0.5 ppm increase per year through 2000 then an additional 1.0% per year exponential increase from 2000 through 2100. This yields a doubled-CO2 (i.e. double the 1958 value = 629.8ppm) around the year 2062.  
All other greenhouse gases are held fixed at 1958 values to match the control run

Permissions:

Input files

Ocean model

Diagnostic output

Forcings

Greenhouse gases

CO2: 314.9 ppm N2O: 0.2908 ppm CH4: 1.224 ppm CFC11: 0.0076 ppt CFC12: 0.0296 ppt

Solar

Luminosity: 1366.619 W/m

Orbit

Eccentricity: 0.0167

CO2 trend

☒ Enable trend

Linear (ppm) 0.5

Exponential (%) 1

N2O trend

EdGCM 3.1 (706) Toolbar

Simulation Controls

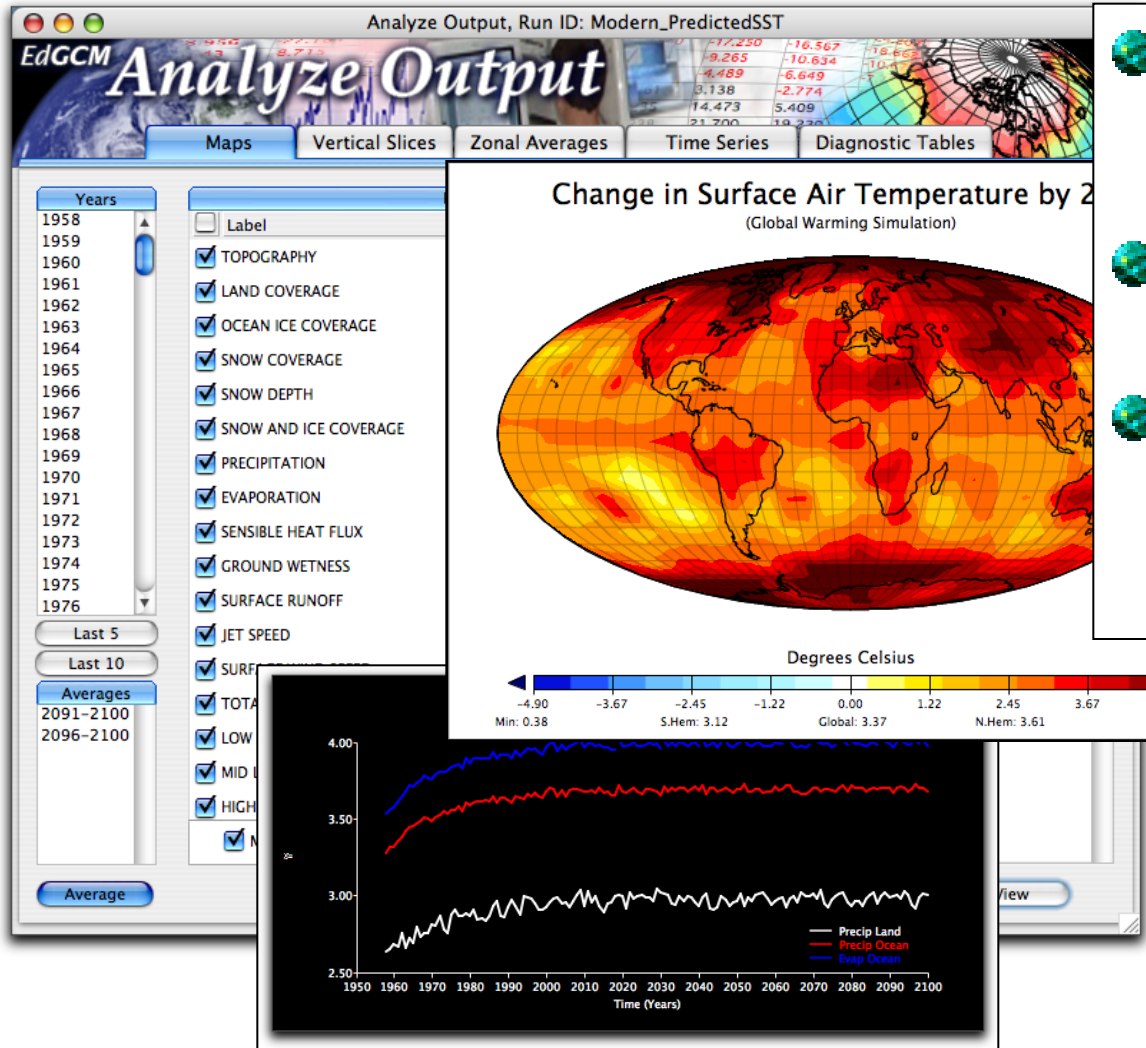
Run Folder  Run Date 01/01/2101

Simulation Library

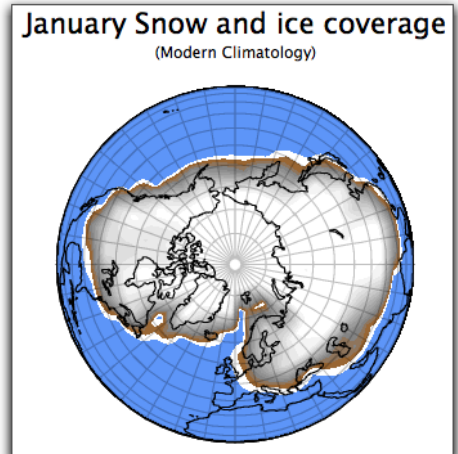
Run ID	Label	Date	Owner	Project ID
331_tutorial	Sample for geography 331	09/18/07	Dave Rice	Modern_PredictedSST
Doubled_CO2	Global Warming from doubling CO2 instantaneously	02/11/05	Mark Chandler	Doubled_CO2
Global_Warming_01	Global Warming: CO2 gradually increases, doubling by 2069	02/11/05	Mark Chandler	Global Warming
Ice_Age_21kya	Ice Age 21kya, LGM trace gases, modern orbit	02/11/05	Mark Chandler	Ice Age - LGM
Modern_PredictedSST	Modern Control Run, 1958 forcings with predicted SSTs	02/11/05	Mark Chandler	Modern_PredictedSST
Modern_SpecifiedSST	Modern Control Run, 1958 forcings with Specified SSTs	02/11/05	Mark Chandler	Modern Climate
Pliocene_3mya	Pliocene simulation using PRISM2 Data	09/26/07	Mark Chandler	Paleoclimate
Pliocene_sSST	Pliocene with PRISM2 data collecting vertflux	10/18/07	Mark Chandler	Modern Climate
RunID178	Copy of : Modern Control Run, 1958 forcings with Specified S	09/26/07	mac	Modern Climate
Sample_Control_Run	Modern control run for Model II v1.0.6 8x10 qflux	05/14/05	Mark Chandler	Sample_Control_Run
SnowballEarth_750Ma	Neoproterozoic Sturtian 750Ma, reduced solar, CO2, OHT	03/29/06	Mark Chandler	Neoproterozoic
Solar_Decrease	Decrease Solar Luminosity by 2%	02/11/05	Mark Chandler	Solar Change

Delete Find Show All Cleanup Permissions Import Export

# Analysis and Visualization



- Post-process *all* of the binary GCM output (hundreds of climate variables)
- Allow teachers to define variable sets
- Scientific Visualization
  - Color and contour maps
  - Line plots
  - Data spreadsheets



# Creating Reports and Publishing

## eJournals

EdGCM eJournal

eJournal ID: Pliocend

**The Climate of the Pliocene: Simulating Earth's Last Great Warm**

Mark A. Chandler  
Columbia University

**Abstract:** The Mid-Pliocene (ca. 3.0 Myr) is the most recent time in Earth's history when mean global temperatures were substantially warmer (estimated by GCMs to be 2 oC to 3 oC above pre-industrial), providing an accessible example of a world that is similar in many respects to what models estimate will be the Earth of the late 21st century. The Pliocene is also recent enough that the continents and ocean basins had nearly reached their present geographic configuration. Taken together, the average of the warm middle Pliocene presents us with a view of the equilibrium state of a globally warmer world in which CO2 concentrations were higher (between 360-400 ppm) and geologic evidence and isotopes agree that sea level was at least 15-25 m above modern (Dowsett and Cronin, 1990; Shackleton et al., 1995), with correspondingly reduced ice sheets.

**Section 1:**

Figure 1. During the Pliocene, global temperatures, particularly at high latitudes, are believed to have been significantly warmer than today. This figure

Figure 2. This image taken by the Galileo

Figure 3. EVAlogo

**Section 2:**

**Introduction**

Much of the research conducted by scientists at the Goddard Institute for Space Studies is aimed at developing tools for simulating future climate change. The ultimate objective is to help anticipate the changes that will have on society and the environment. The development of computer model efforts, and global climate models (GCMs), in particular, are the primary tool we use to environment and the forces that affect it. Among those forces are many which are anthropogenic, or human-caused, including increased greenhouse gases and aerosols, ozone depletion, and deforestation.

**Section 3:**

## Image Libraries

Image Browser: Images 1-16 of 19 images

View: Snowball Earth

Map of annual average surface air temperature

Continent-scale ice sheets have tremendous

This graph shows the increase in the Sun's

Difference map showing the deviation of annual

Map of annual average surface air temperature

Map of annual average snow and ice cover for

Timeline of some key events and intervals in

Advanced radar imaging of sea ice cover in the

The Climate of the Pliocene: Simulating Earth's Last Great Warm Period

Mark A. Chandler  
Columbia University

The Mid-Pliocene (ca. 3.0 Myr) is the most recent time in Earth's history when mean global temperatures were substantially warmer (estimated by GCMs to be 2 oC to 3 oC above pre-industrial), providing an accessible example of a world that is similar in many respects to what models estimate will be the Earth of the late 21st century. The Pliocene is also recent enough that the continents and ocean basins had nearly reached their present geographic configuration. Taken together, the average of the warm phases during the middle Pliocene presents us with a view of the equilibrium state of a globally warmer world, in which CO2 concentrations were higher (between 360-400 ppm) and geologic evidence and isotopes agree that sea level was at least 15-25 m above modern (Dowsett and Cronin, 1990; Shackleton et al., 1995), with correspondingly reduced ice sheets.

**Figure 1:** During the Pliocene, global temperatures, particularly at high latitudes, are believed to have been significantly warmer than today. This figure

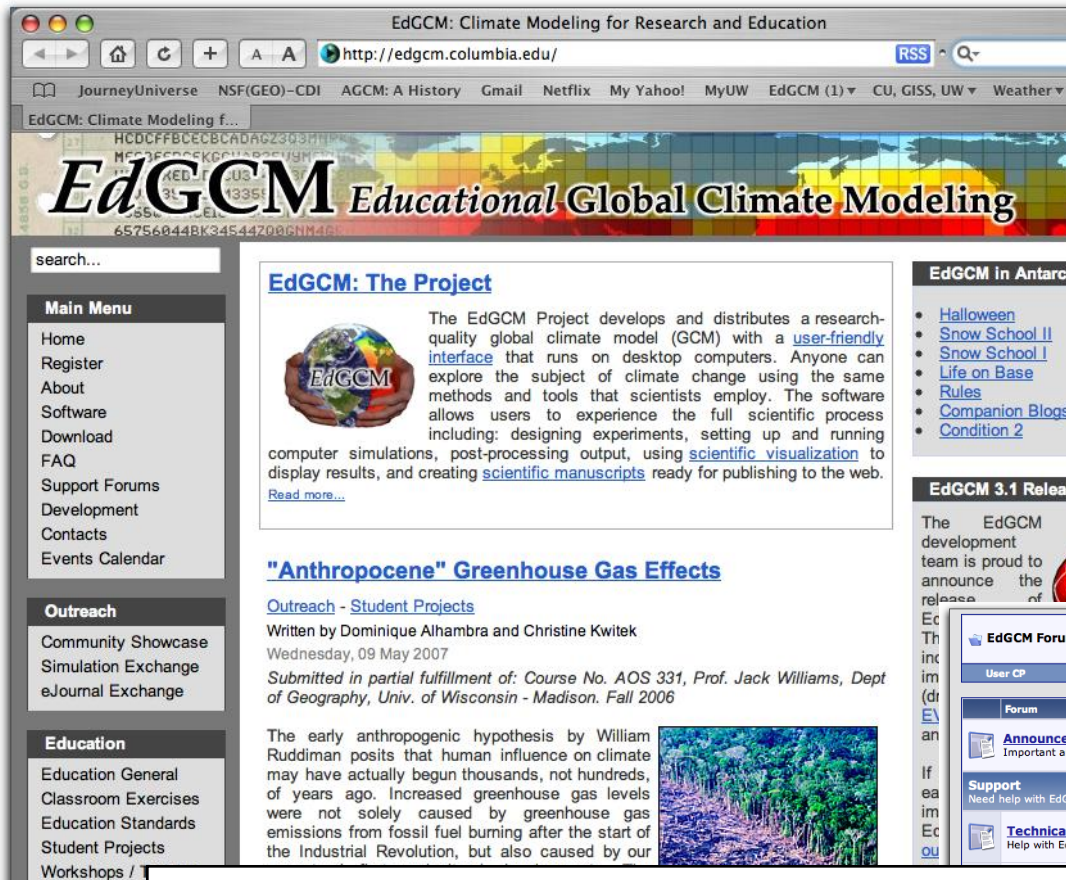
**Figure 2:** Cap Carbonates overlying glacial diamictite.

**Introduction**

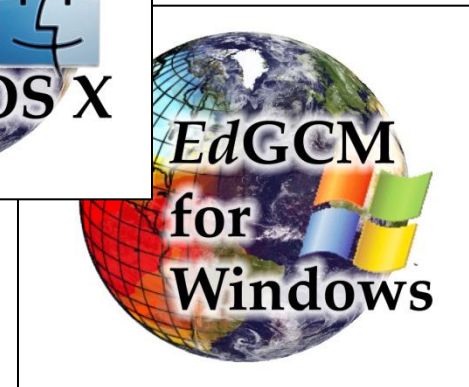
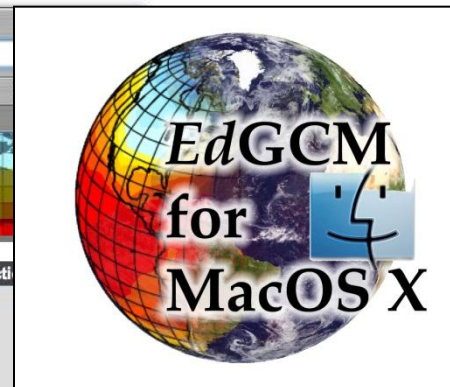
Much of the research conducted by scientists at the Goddard Institute for Space Studies is aimed at developing tools for simulating future climate change. The ultimate objective is to help anticipate the impact that those changes will have on society and the environment. The development of computer models is central to our efforts, and global climate models (GCMs), in particular, are the primary tool we use to simulate the Earth's environment and the forces that affect it. Among those forces are many which are anthropogenic, or human-caused, including increased greenhouse gases and aerosols, ozone depletion, and deforestation.

## Web-based Publishing

# The EdGCM Cooperative Website



The screenshot shows the EdGCM website homepage. The browser address bar displays "http://edgcm.columbia.edu/". The main header features the "EdGCM Educational Global Climate Modeling" logo over a world map. A left sidebar contains a "Main Menu" with links like Home, Register, About, Software, Download, FAQ, Support Forums, Development, Contacts, and Events Calendar. Below this is an "Outreach" section with links to Community Showcase, Simulation Exchange, and eJournal Exchange. Further down is an "Education" section with links to Education General, Classroom Exercises, Education Standards, Student Projects, and Workshops. A "Polls" section is at the bottom. The main content area includes "EdGCM: The Project" with a description of the research-quality global climate model and a "user-friendly interface". It also features "EdGCM in Antarctica" with a list of links (Halloween, Snow School II, Snow School I, Life on Base, Rules, Companion Blogs, Condition 2) and "EdGCM 3.1 Release" with a description of the development team's announcement. A section titled "Anthropocene Greenhouse Gas Effects" includes a quote from Dominique Alhambra and Christine Kwitek dated Wednesday, 09 May 2007, and a photograph of a forest.



- Download Software and Materials
- Support and Discussion Forums
- Community and Student Showcases
- Video Tutorials and Manuals



The screenshot shows the EdGCM Forums page. It includes a welcome message for "mchandler" and a table of forum threads. The table has columns for "Forum", "Last Post", "Threads", and "Posts".

Forum	Last Post	Threads	Posts
<b>Announcements</b> (1 Viewing) Important announcements regarding the EdGCM project and software.	<b>EdGCM goes to Antarctica</b> by mankoff July 13th, 2007 21:45	24	38
<b>Support</b> Need help with EdGCM? Post in the appropriate forum below...			
<b>Technical Support</b> (1 Viewing) Help with EdGCM: downloads, installation, interface, disk management, etc.	<b>Changed permissions/flags...</b> by mchandler Today 10:26	53	349
<b>Application</b> (1 Viewing) Climate model.	<b>Why does the SLP in EdGCM's...</b> by Patrick LEE October 6th, 2007 00:31	52	385
	<b>Reinstalling or Updating EVA...</b> by mchandler October 3rd, 2007 23:25	14	74
	<b>EdGCM Icon</b> by mchandler April 2nd, 2006 14:06	7	33
	<b>Dirt snow</b> by mchandler June 20th, 2007 11:07	5	80
	<b>EdGCM in Italy</b> by mchandler December 4th, 2006 20:06	6	8

# Student Research Projects

- The "Anthropocene" Greenhouse Gas Effect
- Snowball Earth: The Effects of Obliquity
- Global Climate Change Effects on Agriculture in the Midwest
- Examining the Effectiveness of the Kyoto Protocol
- Effects of Varying Rates of Methane Emission on Global Climate

# Distribution, Training, and Development

- Over 40,000 copies in distribution, on 7 continents



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