EdGCM: Global Climate Modeling In The Classroom

Mark Chandler, Ken Mankoff, Linda Sohl and Steven Richards
NASA Goddard Institute for Space Studies, Columbia University

edgcm.columbia.edu

EdGCM Project Objectives

- Allow educational institutions and individuals to run a global climate model on desktop computers

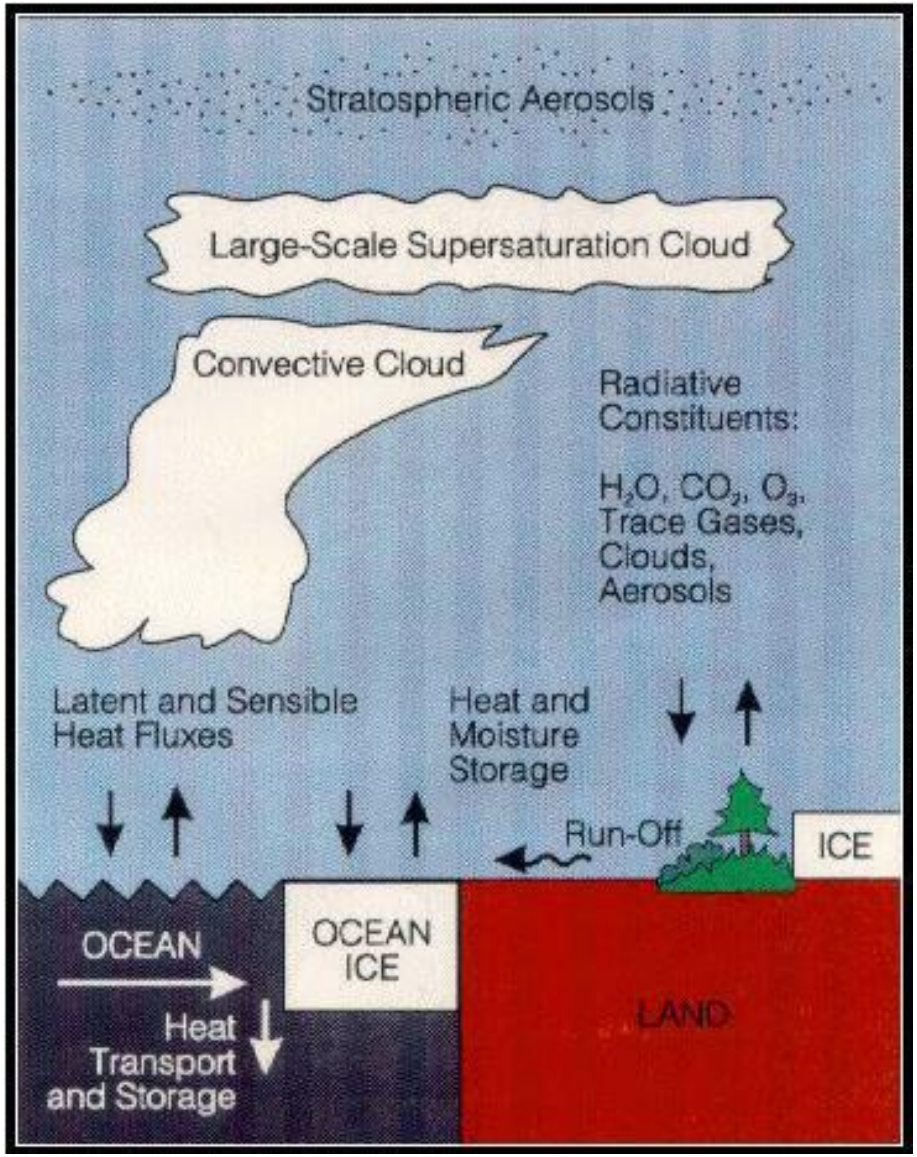
- Encourage students to participate in the full scientific process
  - Experiment design
  - Running simulations
  - Analyzing data
  - Reporting on results

- 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.

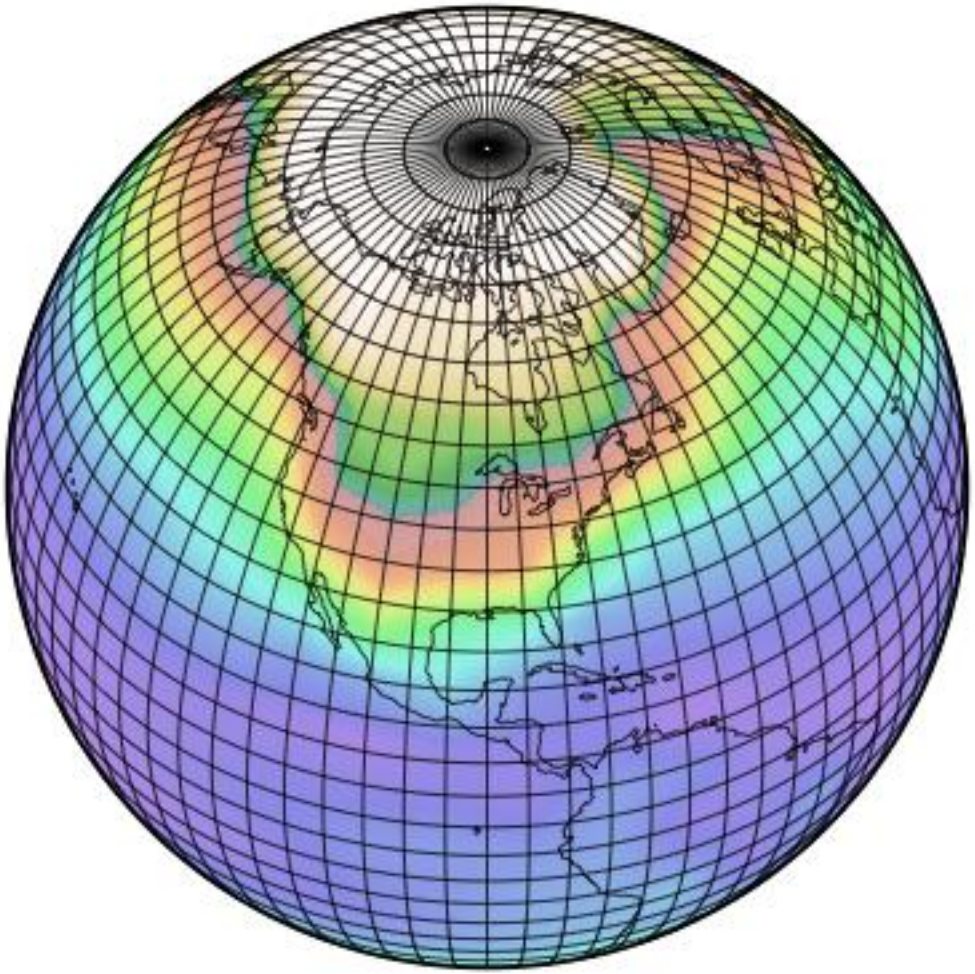
GCM: Global Climate Model

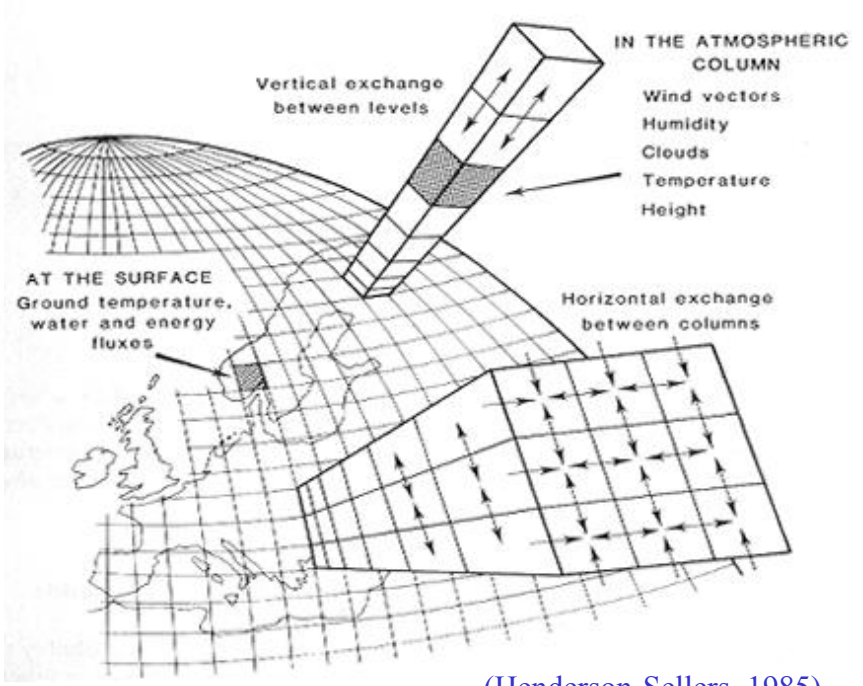
Physical Processes Simulated by GCMs



- 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



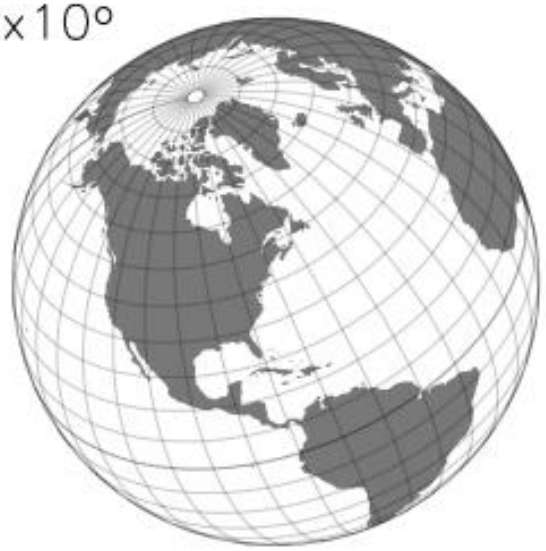


(Henderson-Sellers, 1985)

Increased Resolution Requires Increased Computing Resources

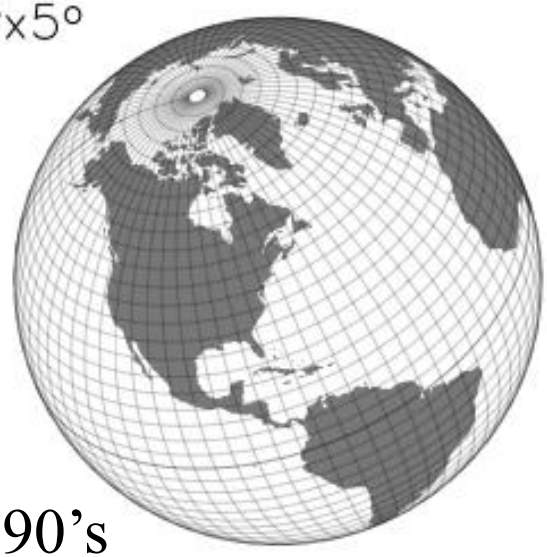
8°x10°

1980's
(EdGCM)



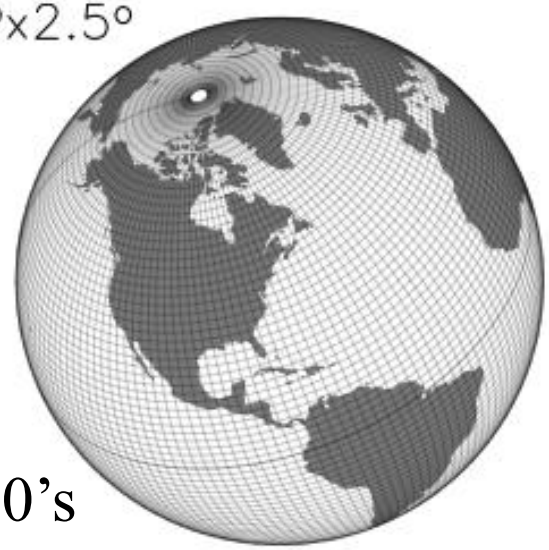
Rule of thumb:
10X more CPU
for a doubling of
resolution

4°x5°



1990's

2°x2.5°



2000's

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

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

- 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/'//JMNTH0(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    TSFREZ(I,J,1)=JDAY
       JEQM1=JEQ-1
       DO 293 J=1,JEQM1
       DO 293 I=1,IM
  293    TSFREZ(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
       TSFREZ(I,J,1)=365.
       TSFREZ(I,J,2)=365.
  297    CONTINUE
```

Unix scripts and Fortran Code
Requiring significant programming skills to operate

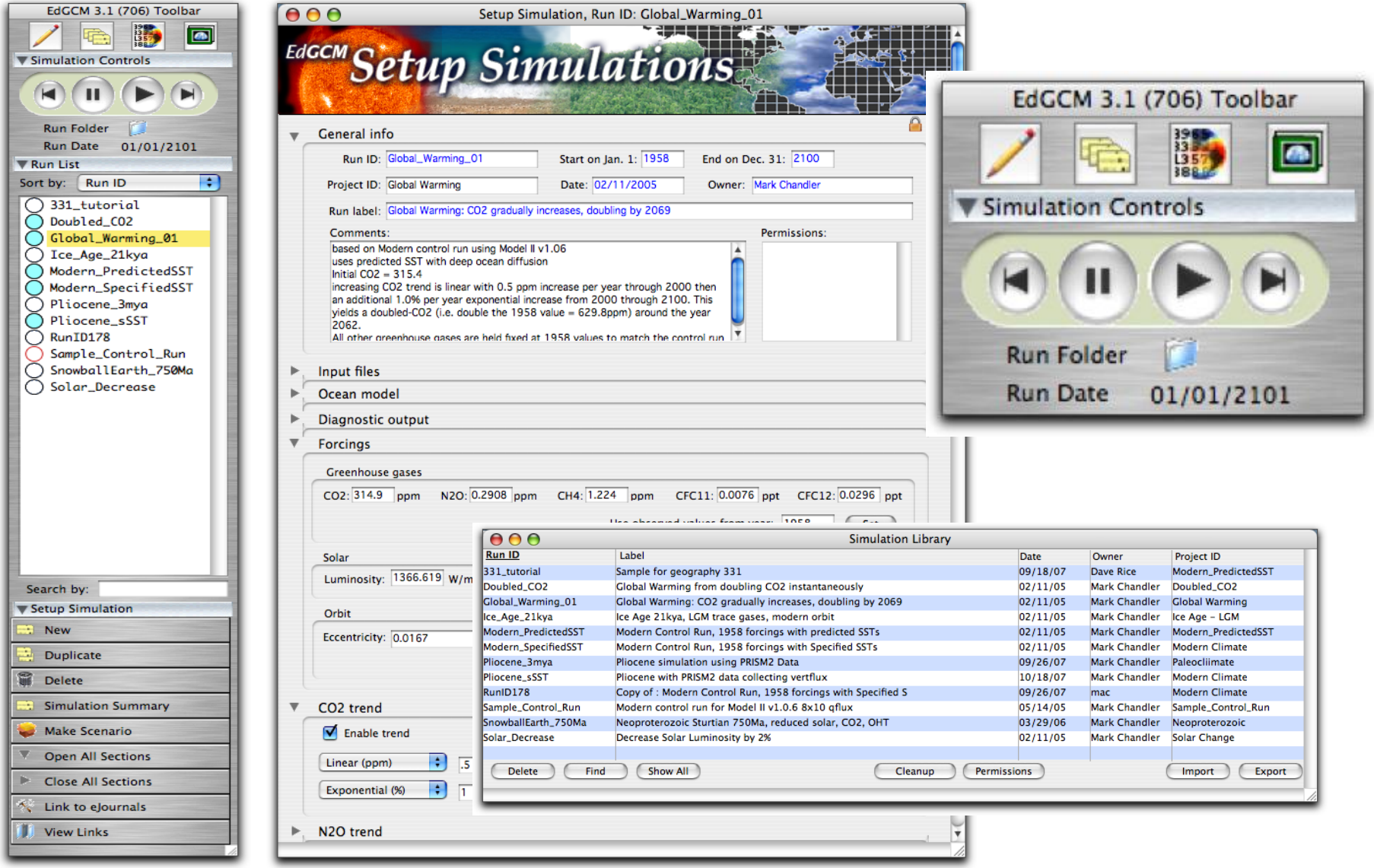
What is *Ed*GCM?

*Ed*ucational *G*lobal *C*limate *M*odel

- 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.

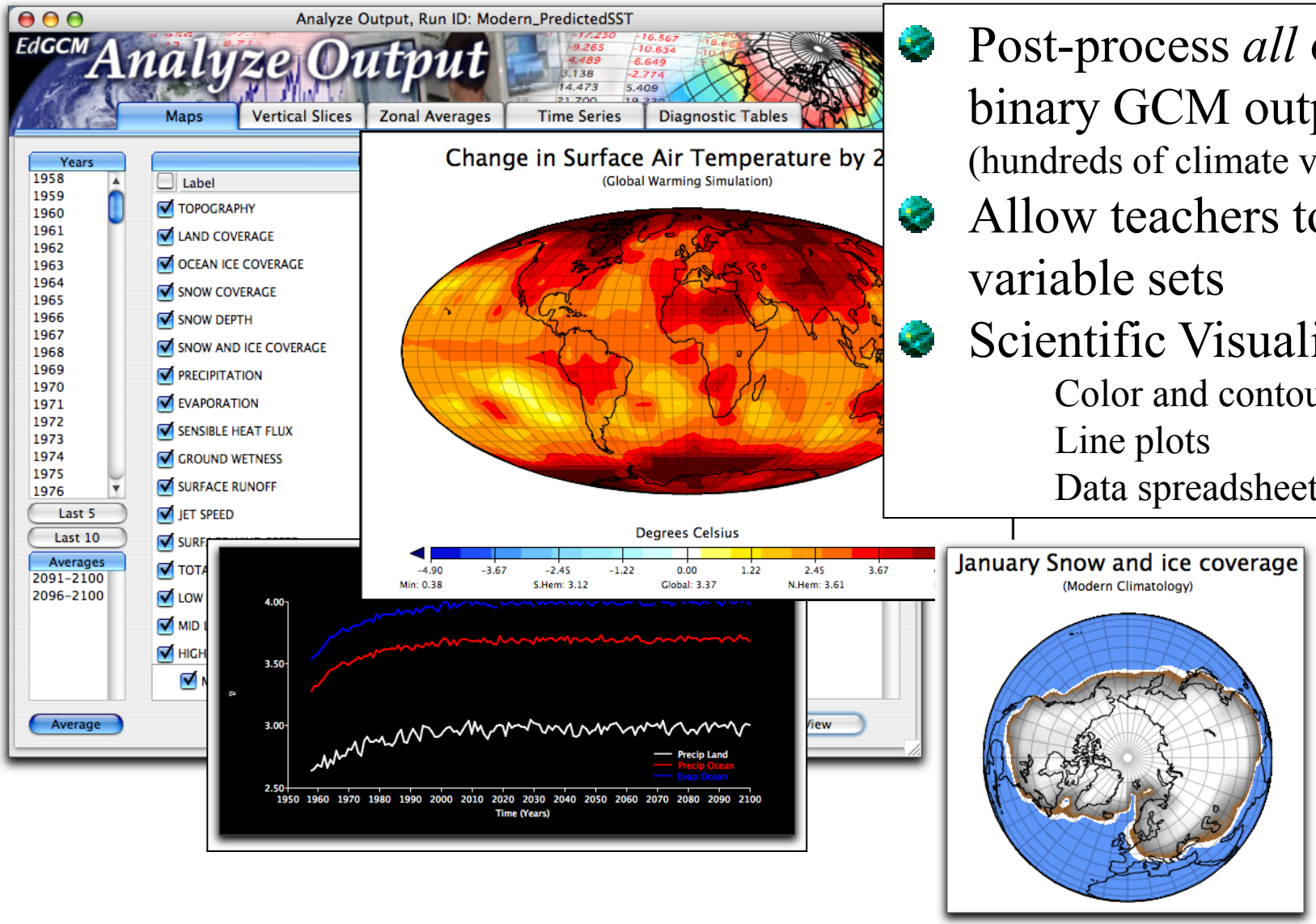
*Ed*GCM

Design, Run, Organize Experiments



*Ed*GCM

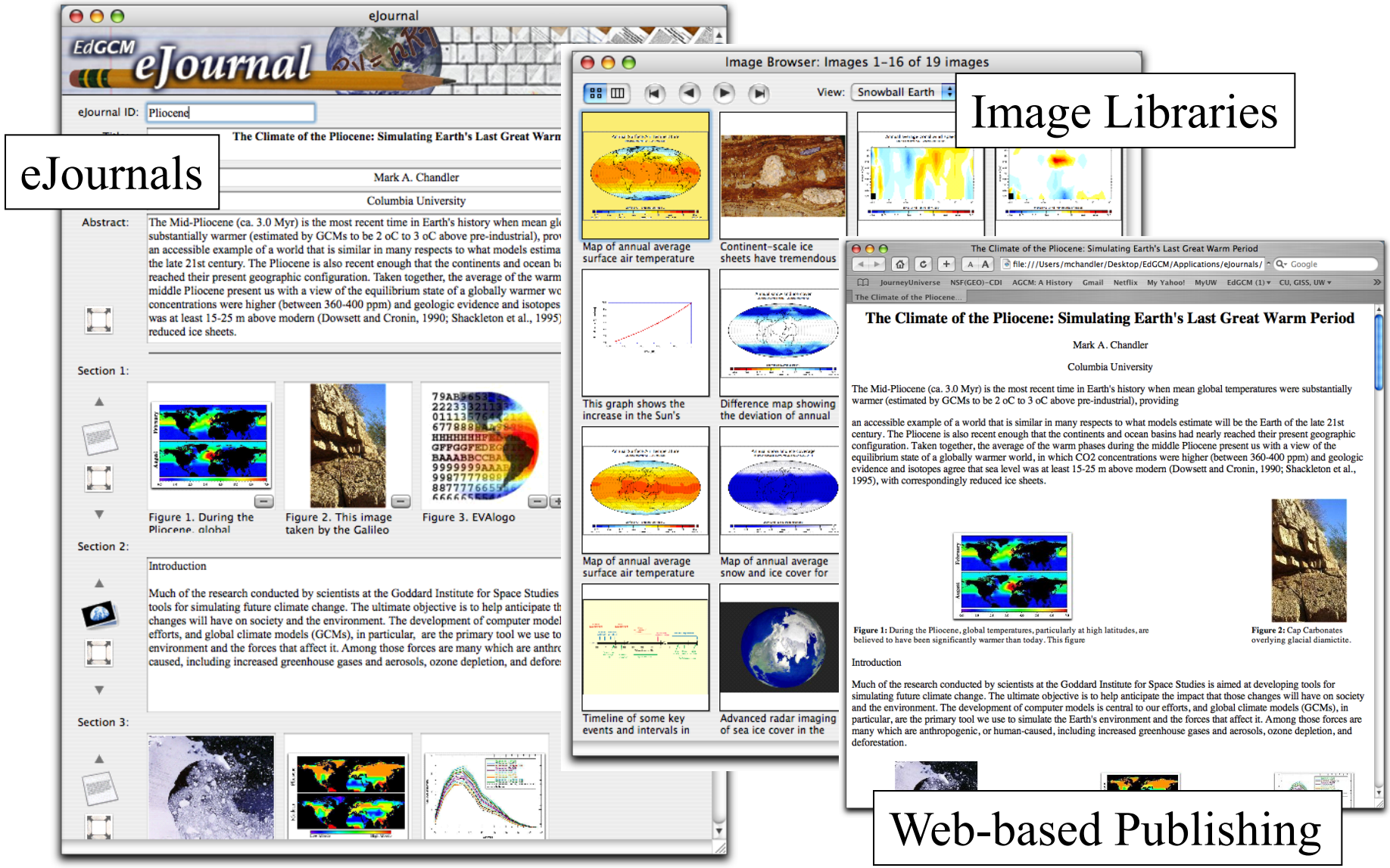
Analysis and Visualization



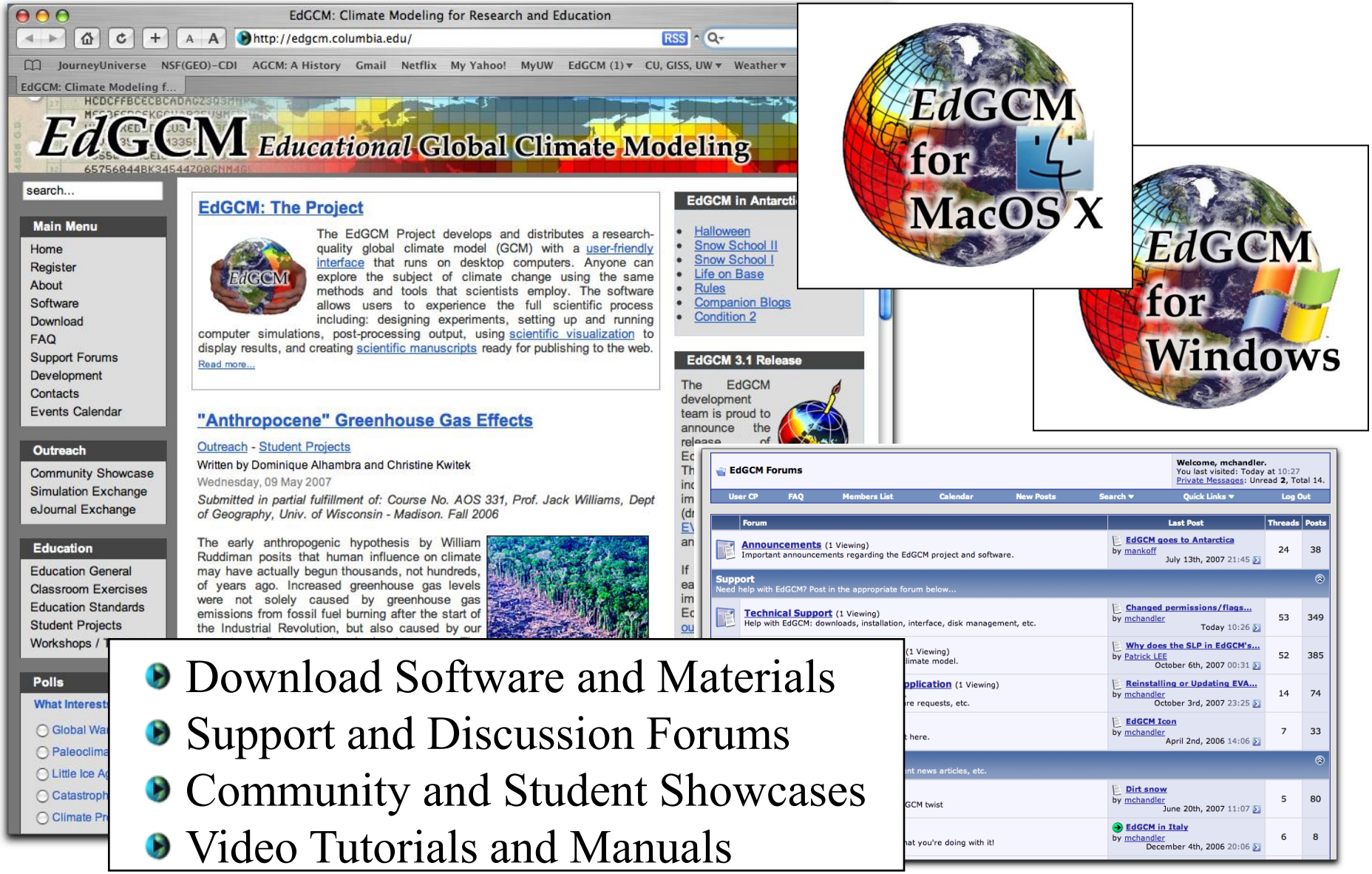
- Post-process *all* of the binary GCM output (hundreds of climate variables)
- Allow teachers to define variable sets
- Scientific Visualization
  - Color and contour maps
  - Line plots
  - Data spreadsheets

*Ed*GCM

Creating Reports and Publishing



The EdGCM Cooperative Website



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

Student Research Projects

- The "Anthropocene" Greenhouse Gas Effect
- Snowball Earth: The Effects of Obliquity
- Global Climate Change Effects on Agriculture in the Midwest
- Examing 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