EdGCM: REAL-TIME GLOBAL CLIMATE MODELING RESEARCH FOR THE CLASSROOM

Educational Global Climate Model

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Most climate researchers believe that climate change will impact our planet's environment and the world's economy profoundly in the coming decades. Thus, everyone should have a basic knowledge of the Earth's climate system so that informed judgments may be shaped with regard to critical issues. Teachers need to be provided with resources to engage students in the scientific and technological processes scientists use to forecast climate change. In so doing, students will become knowledgeable about a topic that will surely affect their lives and we will better prepare the next generation of scientists who will grapple with a myriad of complex climate issues. ***Computer-driven global climate models (GCMs) are one of the primary tools used today in climate research.*** Unfortunately, few educators have access to GCMs, which have generally required supercomputing facilities and skilled programmers to run. In addition, the lack of familiarity with climate modeling techniques often engenders public distrust of important scientific findings based on such methodologies. In the end, graduate-level programs end up teaching fundamental techniques that could be taught much sooner and younger students miss out on excellent opportunities to participate in real-world research projects.

Our goal is to improve the quality of teaching and learning of climate-change science through broader access to GCMs and to provide appropriate technology and materials to help teachers use these models effectively. With research-quality resources in place, linking classrooms to actual research projects is not only possible, it can be beneficial to both educators and scientists. To fulfill our goal we have created EdGCM, software that allows teachers and students to run a 4-D climate model on desktop computers. The GCM at the core of EdGCM was developed at NASA and is currently in use by researchers to study climates of the past, present and future. To operate the GCM in the classroom EdGCM has a user-friendly interface that simplifies management of simulations. Experiments are automatically archived in a searchable database and easy-to-use utilities for mapping, plotting, and data analysis are integrated with the software. Finally, the software allows teachers to produce their own instructional materials (text, charts, images) and allows teachers and students to easily export research reports to the web.

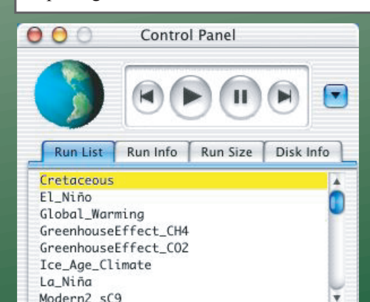
EdGCM permits teachers and students to explore the fundamentals of climate science utilizing tools identical to those used in major climate research programs. Many simple climate experiments are possible (e.g. How does the sun warm the planet?), but, it is also possible to conduct in-depth investigations of current events, in near real-time, as they are being studied by climate scientists. EdGCM comes with some pre-prepared scenarios for investigating a variety of interesting climate issues (global warming, ice ages), but teachers can, also, easily construct their own scenarios to satisfy curricular requirements. EdGCM easily scales for use at levels from middle school to graduate school, making it a unique tool for linking research to the classroom. Our future plans involve the creation of the EdGCM Cooperative, a network of researchers and educators actively collaborating on climate research projects.

The EdGCM Project is supported by the National Science Foundation, Division of Undergraduate Education and the Division of Atmospheric Sciences, Paleoclimate Program. We gratefully acknowledge the help of the scientists and programmers at NASA's Goddard Institute for Space Studies who have worked for decades developing GCMs, including the model at the core of EdGCM. Model development at GISS is supported by NASA's Climate Program. Special thanks to Robert Schmunk, Matthew Shopsin, and David Hirschfield, who wrote the visualization utilities that are an important part of the EdGCM suite of software.

1. Toolbar: The EdGCM Control Panel

Traditionally, a global climate model is controlled and started (initialized) through a combination of computer programs and Unix shell scripts. EdGCM removes this layer of complexity by placing all control of the climate model into a graphical user interface (GUI). As with many modern desktop computer applications, EdGCM uses a *toolbar palette* to access the various components of the software. The toolbar contains controls, similar to those on a VCR or CD player, that start, stop, pause, rewind and extend simulations. It also contains a list of all simulations in the database, which allows the user to conveniently select an experiment to work with. Additional controls appear in the toolbar dependent upon which windows are currently open in EdGCM. In this way the toolbar is kept uncluttered, yet useful controls are always available (see example in section 5).

Finally, the toolbar can be "minimized" to the point that it contains only the most basic controls and info about available GCM simulations (see image, below). In this mode the toolbar is called, simply, the "Control Panel". The Control Panel comes in handy when one wants use the computer to work on other things, but still wants to keep tabs on simulations that are in progress, or if the user wants to periodically pause and restart a simulation without opening the more elaborate EdGCM controls.



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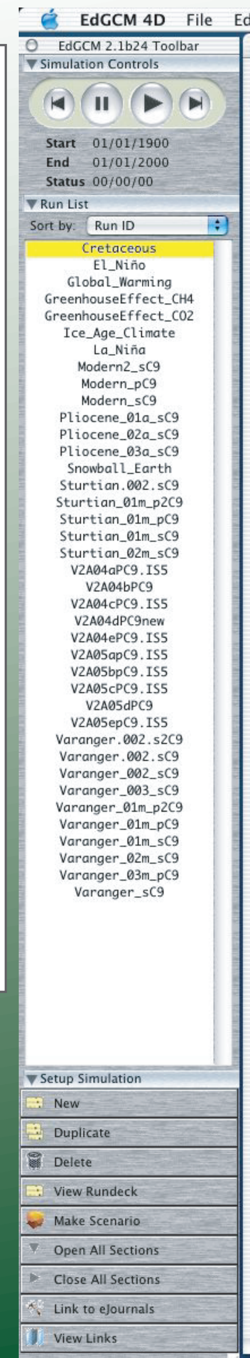

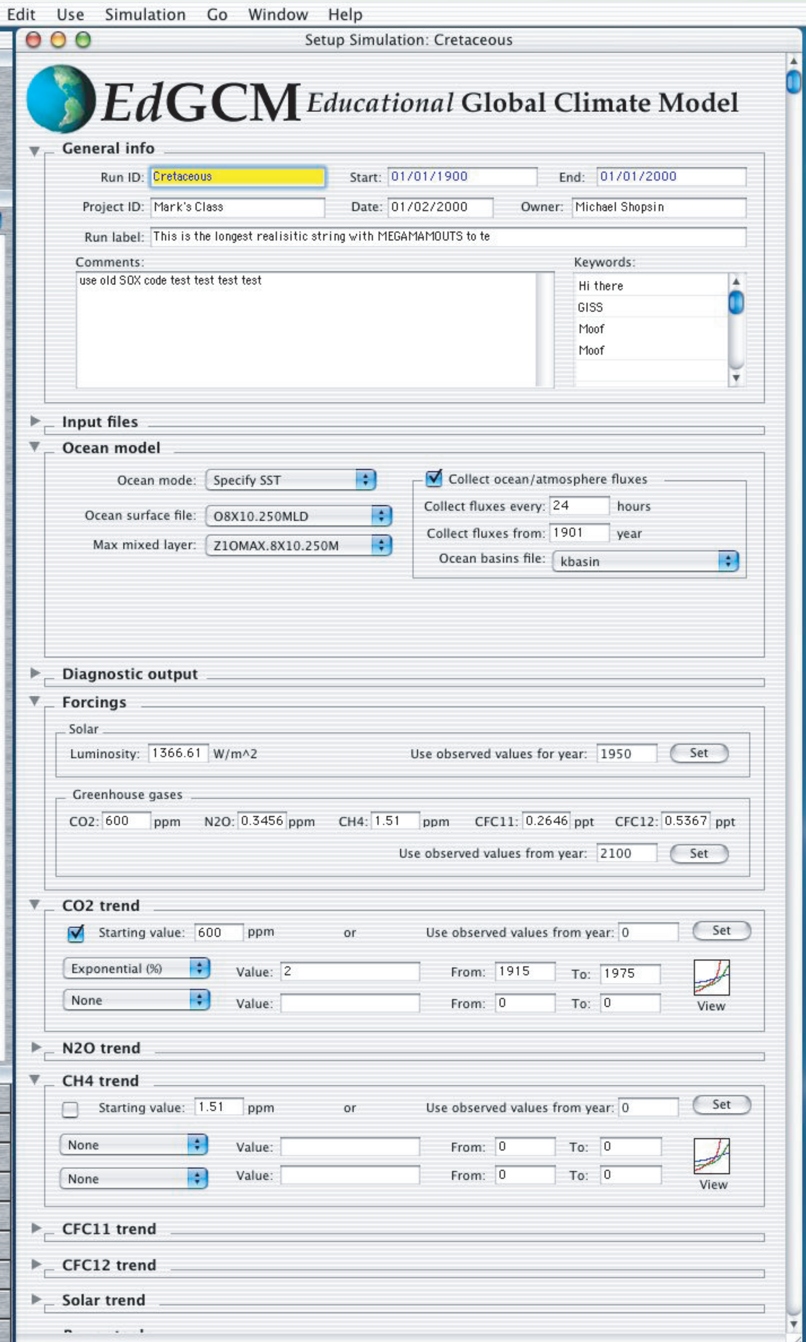

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2. Setup Simulations: Designing Simulations Using EdGCM

Traditionally, a global climate model is controlled and started (initialized) through a combination of computer programs and Unix shell scripts. EdGCM removes this layer of complexity by placing all control of the climate model into a graphical user interface (GUI). Designing experiments is done in "Setup Simulations" using an interface with well-defined fields for entering the names of input files, and with easily manipulated "point and click" controls for choosing a variety of climate modeling options (e.g. length of experiment, the quantity of greenhouse gases in the atmosphere, vegetation distributions, paleocontinental configurations, etc.). The interface is divided into several logical sections, each of which the teacher can show or hide depending upon which components of the GCM they want to be the focus of study.

Using EdGCM teachers and students can easily create experiments that simulate a wide variety of climates of the past, present and future. In this way the teacher can supplement textbook-based lessons on the fundamentals of the climate system with experiential learning, which involves students in the method that scientists themselves are using to study the Earth's climate system. Teachers can simulate climates of various periods in geologic history, for example, the Cretaceous Period or the Last Glacial Maximum. They can simulate climate changes that may occur in the future, such as global warming or the effects of deforestation. And, they can simulate the impacts of modern climate events such as El Niño/La Niña cycles or volcanic eruptions. The new interface allows such detailed control over model functions that EdGCM arguably has more user-definable capabilities than does the research-only version.

3. The EdGCM 4D Database

EdGCM is built using a database as an underpinning because, in our experience, the volume of information produced by any global climate model can easily exceed the manageable level. The database structure removes the need for the teacher or researcher to spend time organizing large volumes of data, model output and supplementary information. This frees the teacher to spend more time organizing lesson plans that better utilize the information for specific class needs. It also frees researchers and educators to spend more time analyzing experiments and less time organizing them. The database engine of EdGCM also makes it simple to search, sort and access information from several different classes or from one semester to the next. Teachers can choose to organize sets of experiments around physical criteria (e.g. greenhouse gas experiments) or around administrative criteria (e.g. course title or student working groups).

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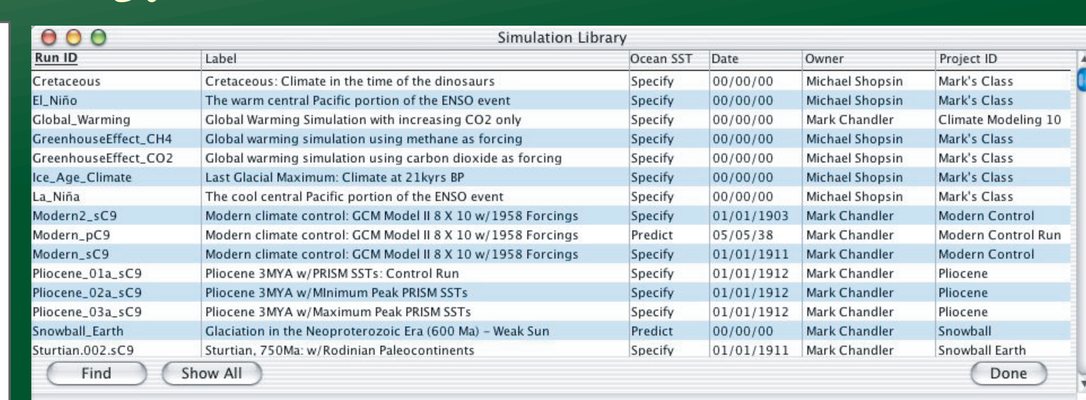
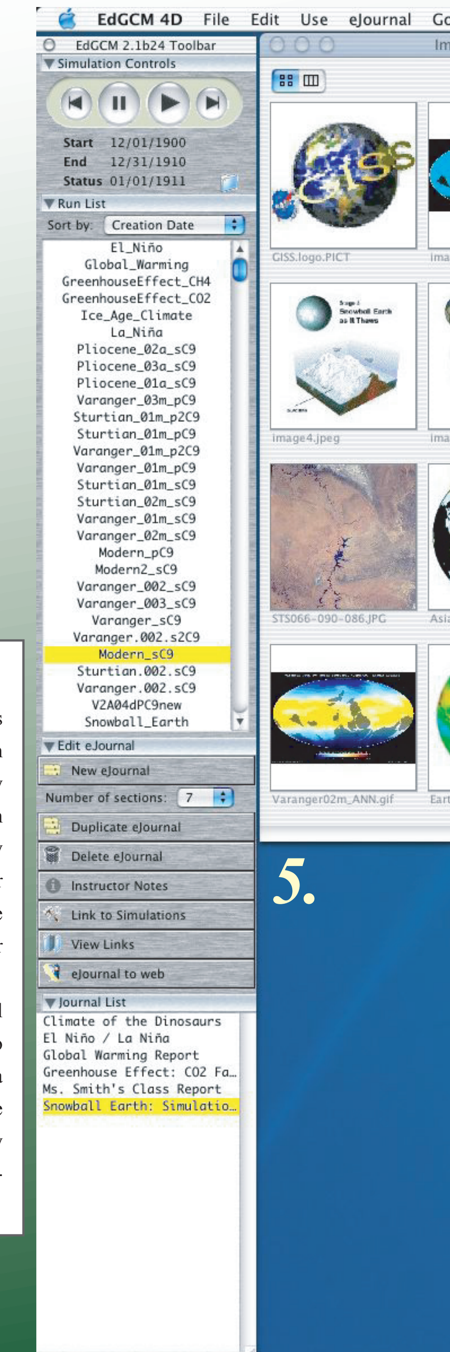


5. Image Browser

EdGCM contains an image browsing tool that allows teachers and students to collect images for use in reporting the results of experiments. Images are easily imported into the image browser, either by placing them into the "Images" folder on the hard drive or by individually importing them using a button on the toolbar (not shown in this view). Numerous graphics formats are supported and EdGCM will convert each to JPEGs for use on web sites if desired.

Importantly, all images can have attached textual information so that teachers can add learning material to each image. In addition, if a class is collaborating with a scientist, which is an important component of the EdGCM Cooperative Project, the scientist may supply images to the teachers and students with attached text-based information.



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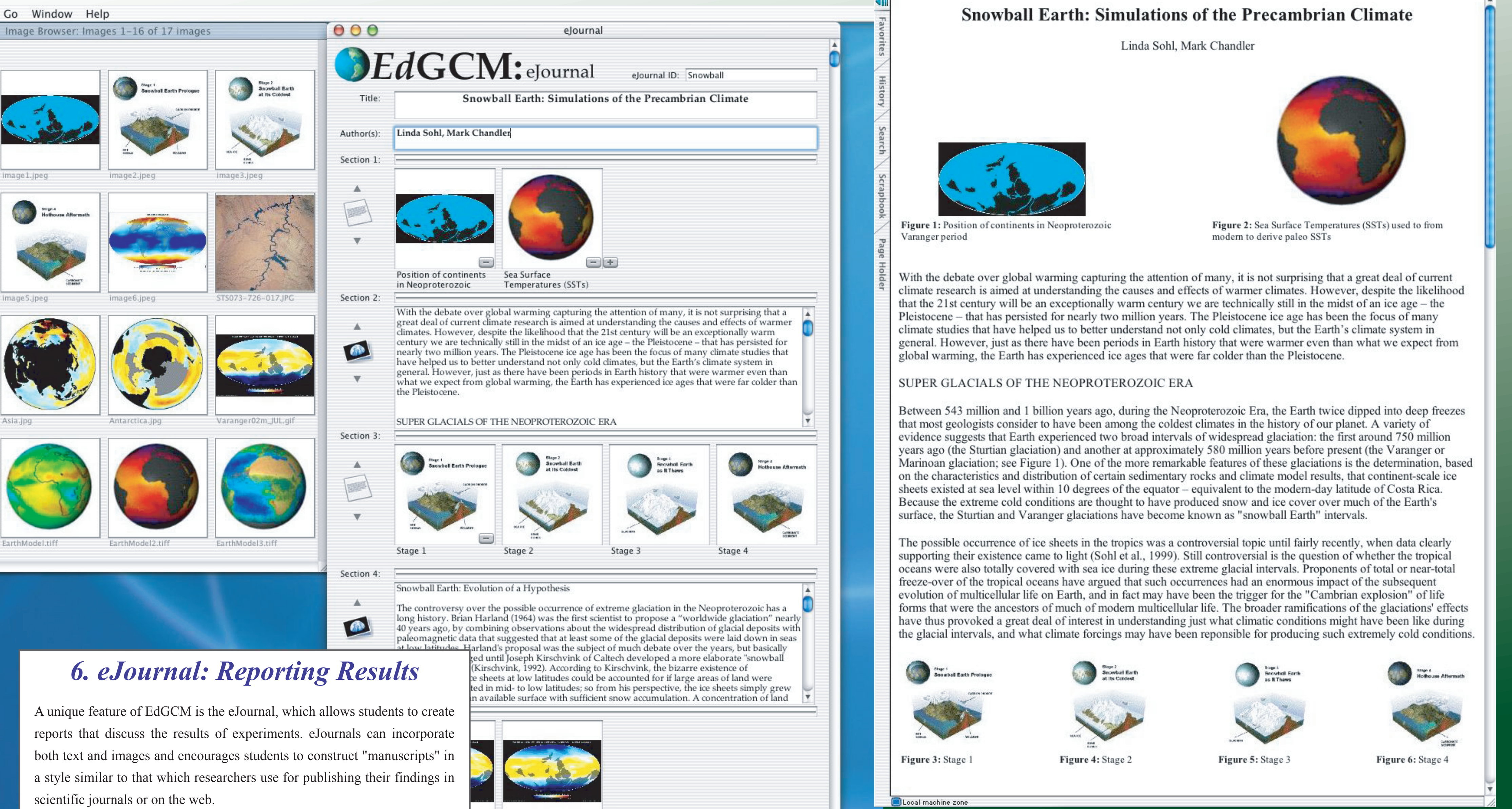
6. eJournal: Reporting Results

A unique feature of EdGCM is the eJournal, which allows students to create reports that discuss the results of experiments. eJournals can incorporate both text and images and encourages students to construct "manuscripts" in a style similar to that which researchers use for publishing their findings in scientific journals or on the web.

eJournals contain up to 20 text and image sections. Sections can be added or rearranged at anytime during the creation of the report. eJournals are closely integrated with the Image Browser and with GCM simulations. Images can be cut and pasted (or use drag and drop) from the Image Browser into an eJournal report. The attached text information is also transferred to the report as a figure caption, but figure captions are also editable so that students can point out specific information pertinent to their analyses. Links can also be established (linking interface not shown) between eJournal reports and individual simulations so that the database establishes a relationship between simulations and their analyses. The relational database then keeps track of situations where many students are analyzing and reporting on one experiment or when one student analyzes and reports on many experiments.



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7. Publishing eJournals to the Web

With a click of a button any eJournal produced in EdGCM can be published to the world wide web. EdGCM converts eJournals to html, formats all text and images appropriately, attaches figure numbers and captions, and embeds thumbnails of each image into the document (the later is done to make the documents small enough for easy transfer over the internet). The original full-sized images can also be accessed from the web page simply by clicking on any thumbnail image in the report.

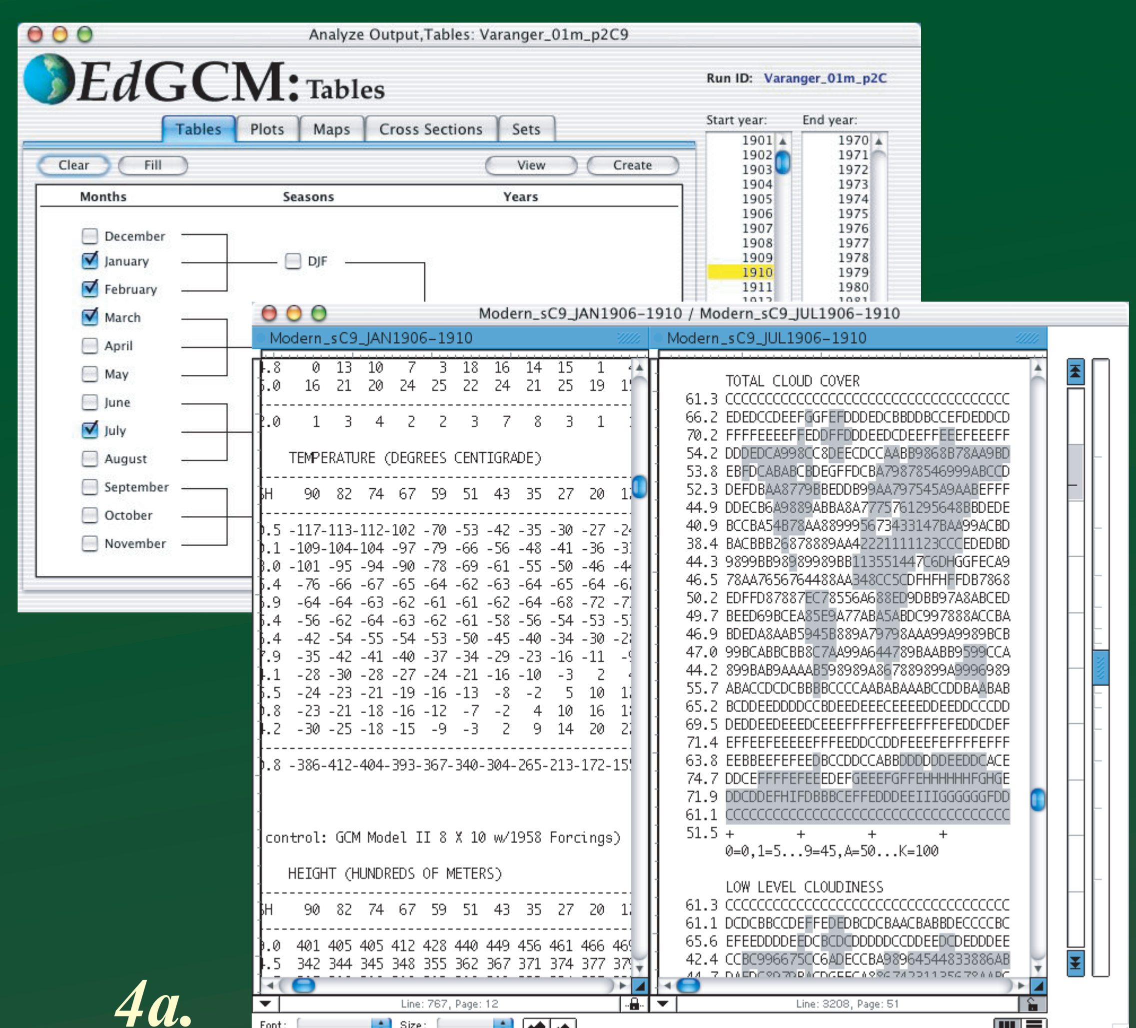
4. Analyze Output: Processing Model Results

The most important aspect of any climate modeling project is the analysis of results once the simulations are complete. As it turns out, for most global climate models, processing model output can be as involved as running the simulation in the first place. Key variables of interest must be extracted from binary output files, averaged, scaled, and converted to formats that can be usefully analyzed. Much of this work is performed by professional programmers at most climate modeling labs because the task can be so time consuming it eats into the time available for the analysis of results. While this might be a "limitation" for many research programs it is probably an insurmountable obstacle at most high schools and many undergraduate institutions.

In order to tackle this problem we converted a number of our most-used post-processing programs to the desktop environment and have added user-friendly interfaces to EdGCM for running the programs. To date we have adapted three key programs to help clear the path for analyzing model results. These include utilities that:

- 4a. Generate summary ***Tables*** of all diagnostic variables produced by the GCM (around 400 variables!) averaged over months, seasons, or years for any portion of a simulation
- 4b. Create global ***Maps*** of about 80 different climate variables.
- 4c. Produce time series ***Plots*** of up to 80 climate variables Such plots are used to track climate changes that occur during an experiment.

Examples of the interfaces that run these programs and samples of the mapping, plotting and data viewing utilities are shown at the right.



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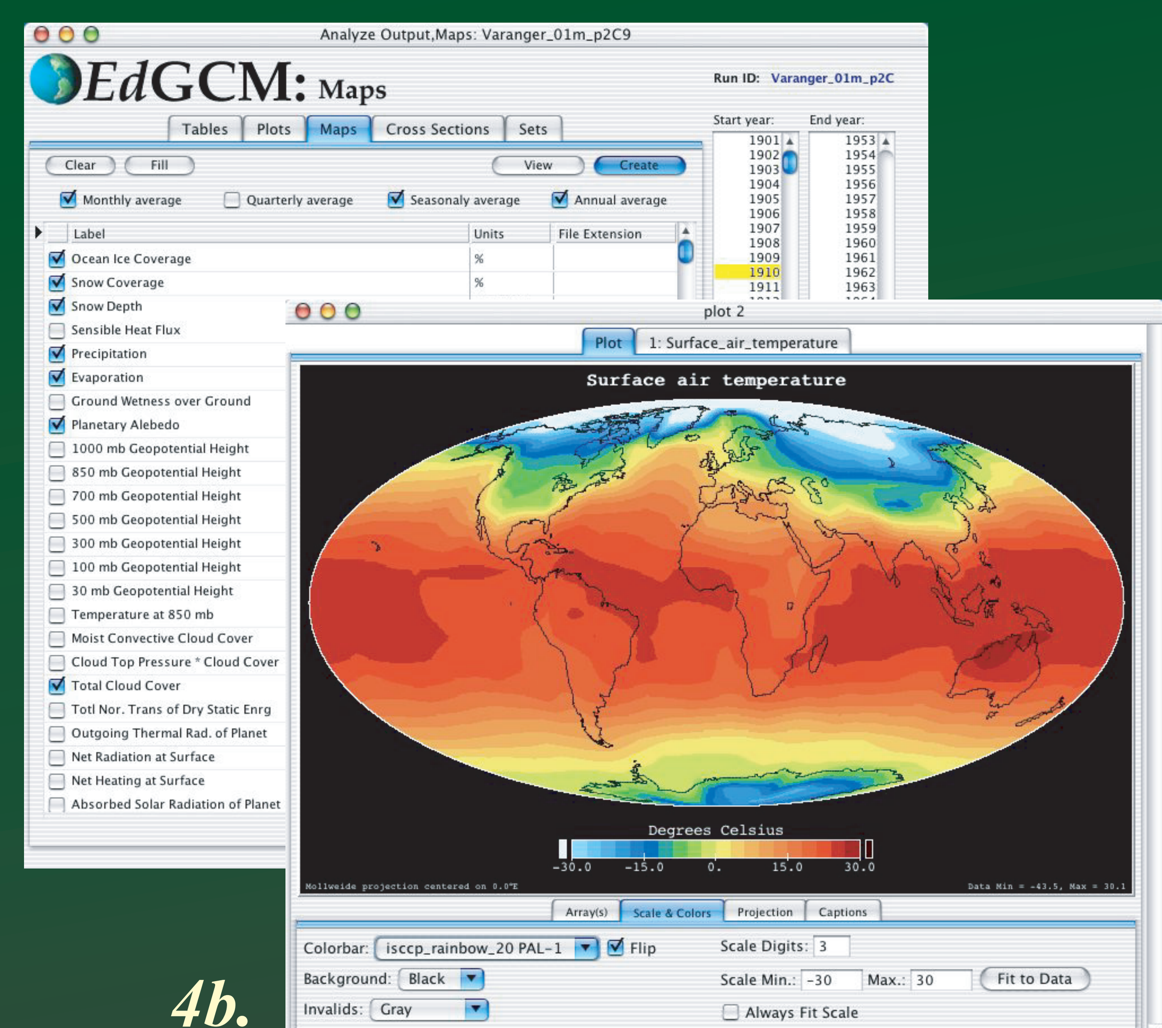

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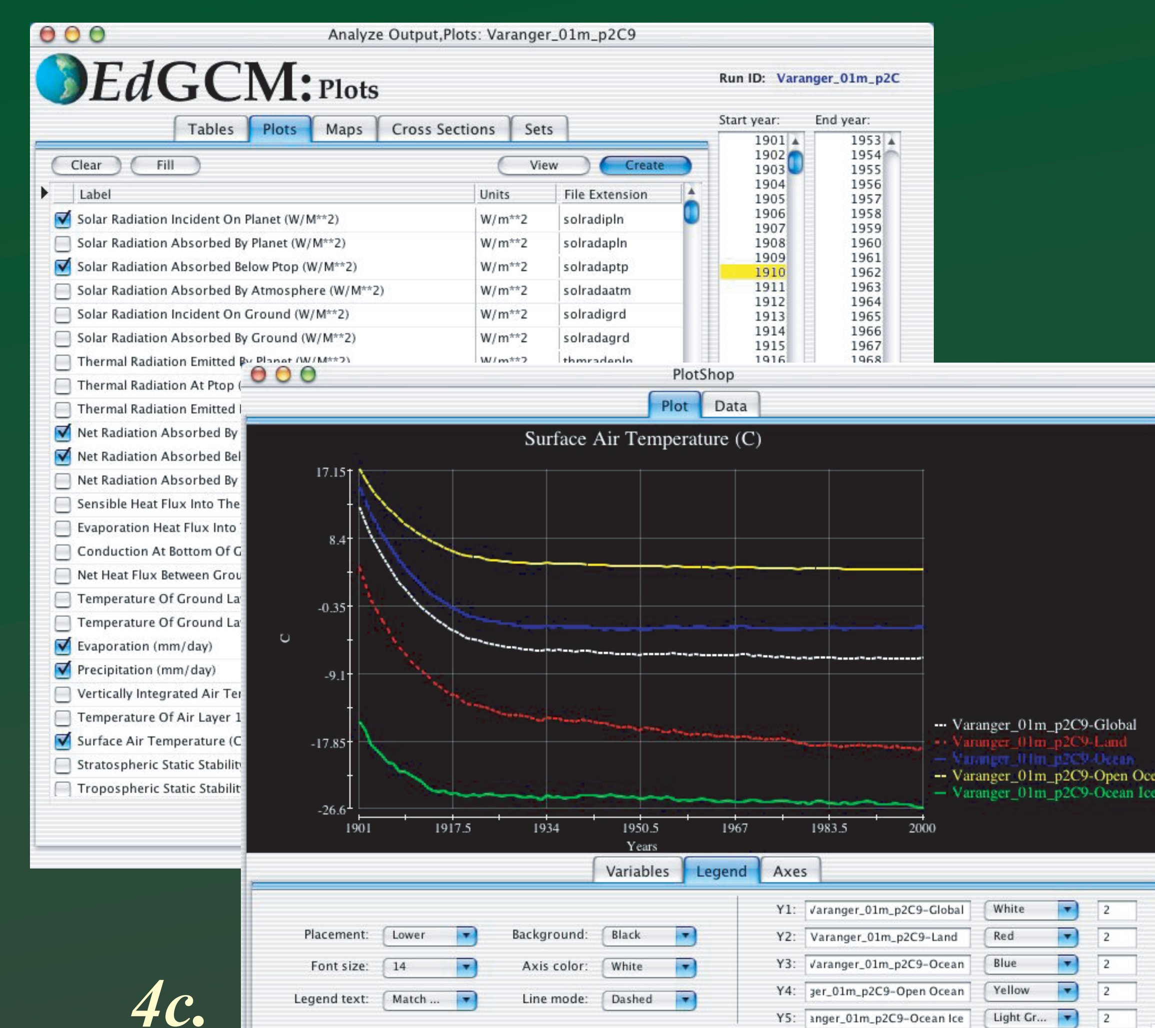

4c.

8. Sets: Teacher Selected Variables

Because GCMs produce so much output - too much for almost any individual to analyze in an efficient manner - EdGCM has a built-in utility that allows the teacher to specify, ahead of time, which climate variables students are allowed to access. This means that teachers can tailor EdGCM's interface to match the level of the students or they can create project-specific sets of variables to better focus students on key values that apply to individual lesson plans. A summary of the "set" information is shown above, and summaries can be written out and printed for handy reference. In collaborative education/research projects "Sets" can also be used to let the scientist identify critical variables that should be analyzed in classroom projects.

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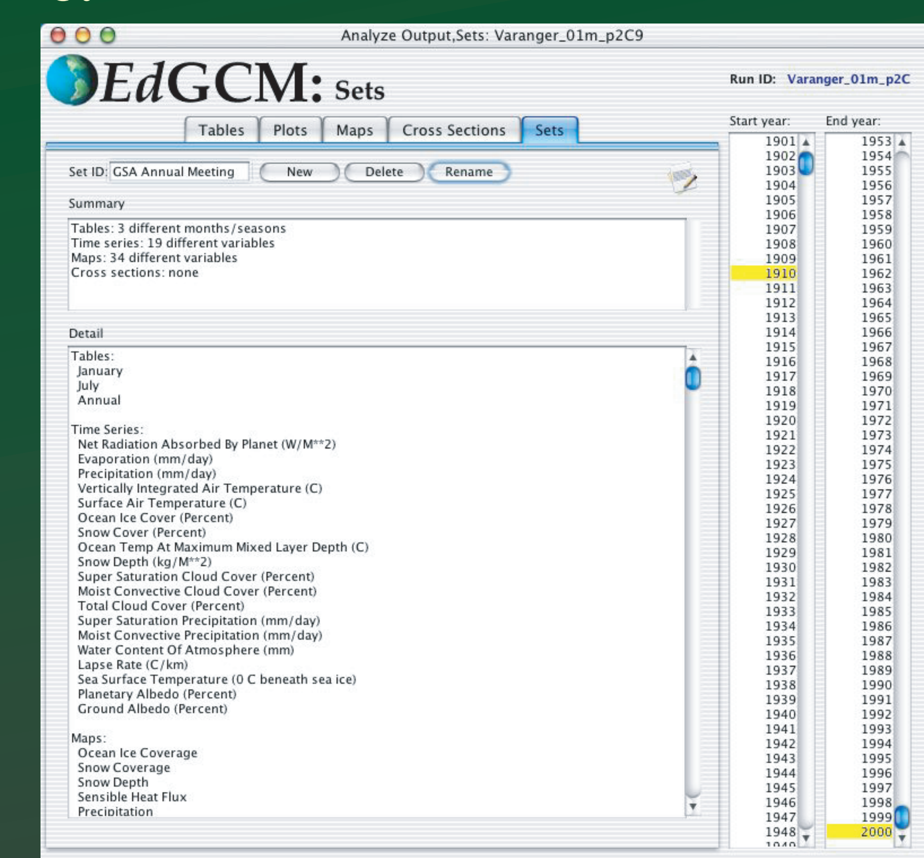
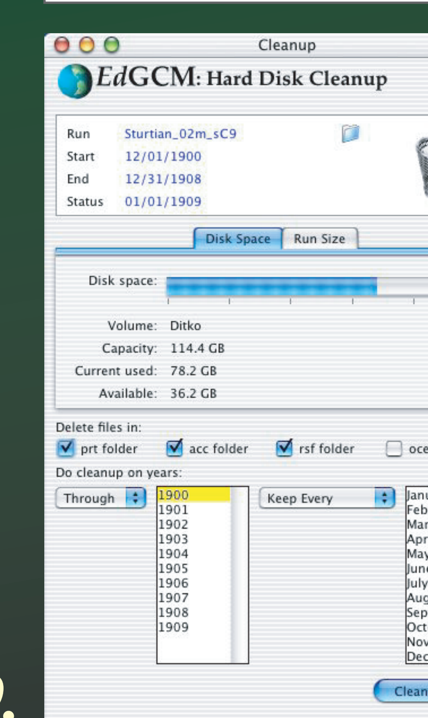


9. Cleanup: Saving Schools' Hard Disks

In addition to simulating global climate, another thing that GCMs are good at is chewing up huge amounts of hard disk space. Most research institutions use large arrays of disk drives to store these massive amounts of GCM output, but that is a luxury few schools will have. As a solution, EdGCM contains a "smart" Cleanup utility. Cleanup allows users to keep track of disk space, including the amount occupied by GCM simulation output. If storage space becomes short the Cleanup utility allows teachers to intelligently clean up the disk (meaning without damaging the ability to later use simulations) by removing the least important files first.



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