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

Mark Chandler (mchandler@giss.nasa.gov), Michael Shopsin and Steve Richards NASA/GISS at Columbia University, 2880 Broadway, New York, New York 10025

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 o 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

End 01/01/2000

Global_Warming

GreenhouseEffect_CH4

GreenhouseEffect_CO2

Ice_Age_Climate

Modern2_sC9

Modern_pC9

Pliocene_01a_sC9

Pliocene_02a_sC9

Snowball_Earth

Sturtian_01m_p2C9

Sturtian_01m_pC9

Sturtian_01m_sC9

Sturtian_02m_sC9

V2A04dPC9new

V2A04ePC9.IS5

V2A05apC9.IS

V2A05bpC9.IS

V2A05cPC9.IS

Varanger.002.s2C9

Varanger_002_sC9

Varanger_01m_p2C9

Varanger.002.sC9

Varanger_003_sC9

Varanger_01m_pC9

Varanger_01m_sC9

Varanger_02m_sC9

Varanger_03m_pC9

▼ Setup Simulation

Duplicate

View Rundeck

Make Scenario

Open All Sections

Close All Sections

Link to eJournals

View Links

Delete

Sturtian.002.sC9

Pliocene_03a_sC9

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, chart 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 the visualization utilities that are an important part of the EdGCM suite of software

4

Setup Simulation: Cretaceous 1. Toolbar: The EdGCM Control Panel

Run label: This is the longest realisitic string with MEGAMAMOUTS to

Project ID: Mark's Class

_ Input files

Ocean model

Diagnostic output

_ N2O trend

_ CH4 trend

_ CFC11 trend

_ CFC12 trend

_ Solar trend

Luminosity: 1366.61 W/m^2

use old SOX code test test test

Ocean mode: Specify SST

Ocean surface file: O8X10.250MLD

Max mixed layer: Z10MAX.8X10.250M

Date: 01/02/2000

CO2: 600 ppm N2O: 0.3456 ppm CH4: 1.51 ppm CFC11: 0.2646 ppt CFC12: 0.5367 ppt

Owner: Michael Shopsin

Collect ocean/atmosphere fluxes

Collect fluxes every: 24 hours

Collect fluxes from: 1901 year

Use observed values for year: 1950 Set

Use observed values from year: 2100 Set

Use observed values from year: 0 Set

From: 1915 To: 1975

Use observed values from year: 0 Set

Ocean basins file: kbasin

Traditionally, a global climate model is controlled and started (initialized) through a combination of computer Sort by: Run ID programs and Unix shell scripts. EdGCM removes this layer of complexity by placing all control of the climat model into a graphical user interface (GUI). As with man modern desktop computer applications, EdGCM uses 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 simulation 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 (se

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 thi 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



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 Cretaceous 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 Modern2_sC9 eeds. It also frees researchers and educators to spend more time analyzing experiments and Modern_sc9 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 as experiments) or around administrative criteria (e.g. course title or student working groups)

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 textbased information.

Cretaceous: Climate in the time of the dinosaurs

The warm central Pacific portion of the ENSO even

Global Warming Simulation with increasing CO2 only

The cool central Pacific portion of the ENSO event

iocene 3MYA w/Maximum Peak PRISM SSTs

Sturtian, 750Ma: w/Rodinian Paleocontinents

Find Show All

Global warming simulation using carbon dioxide as forcing

Simulation Library

Number of sections: 7 Delete eJournal Snowball Earth: Evolution of a Hypothesis Instructor Notes Link to Simulations eJournal to web

EdGCM 4D File Edit Use eJournal Go Window Help

AIII

Start 12/01/1900

▼ Run List

Sort by: Creation Date

El_Niño

Global_Warming

GreenhouseEffect_CH4 GreenhouseEffect_CO2

Ice_Age_Climate

La_Niña

Pliocene_02a_sC9

Pliocene_03a_sC9

Pliocene_01a_sC9

Varanger_03m_pC9

Sturtian_01m_p2C9

Sturtian_01m_pC9

Varanger_01m_p2C9

Varanger_01m_pC9 Sturtian_01m_sC9

Sturtian_02m_sC9

Varanger_01m_sC9

/aranger_02m_sC9 Modern_pC9

Modern2_sC9

Varanger_002_sC9 Varanger_003_sC9

Varanger_sC9

/aranger.002.s2C9

Sturtian.002.sC9

Varanger.002.sC9

Global Warming Report

reenhouse Effect: CO2 Fa...

Ms. Smith's Class Report

Specify 00/00/00 Michael Shopsin Mark's Class

Specify 01/01/1911 Mark Chandler

Specify 00/00/00 Mark Chandler Climate Modeling 1

00/00/00 Michael Shopsin Mark's Class

End 12/31/1910

Status 01/01/1

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 eling does present some unique challenges not posed by climate studies of the 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.

Y5: anger_01m_p2C9-Ocean Ice Light Gr...

Snowball Earth: Simulations of the Precambrian Climate that the 21st century will be an exceptionally warm century we are technically still in the midst of an ice age - the Pleistocene - that has persisted for nearly two million years. The Pleistocene ice age has been the focus of many general. However, just as there have been periods in Earth history that were warmer even than what we expect from e are technically still in the midst 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 global warming, the Earth has experienced ice ages that were far colder than the Pleistocene. SUPER GLACIALS OF THE NEOPROTEROZOIC ERA tween 543 million and 1 billion years ago, during the Neoproterozoic Era, the Earth twice dipped into deep freezes at most geologists consider to have been among the coldest climates in the history of our planet. A variety of evidence suggests that Earth experienced two broad intervals of widespread glaciation: the first around 750 million ears ago (the Sturtian glaciation) and another at approximately 580 million years before present (the Varanger of Marinoan glaciation; see Figure 1). One of the more remarkable features of these glaciations is the determination, based sheets existed at sea level within 10 degrees of the equator – equivalent to the modern-day latitude of Costa Rica Because the extreme cold conditions are thought to have produced snow and ice cover over much of the Earth's surface, the Sturtian and Varanger glaciations have become known as "snowball Earth" intervals. he possible occurrence of ice sheets in the tropics was a controversial topic until fairly recently, when data clearly upporting their existence came to light (Sohl et al., 1999). Still controversial is the question of whether the tropical oceans were also totally covered with sea ice during these extreme glacial intervals. Proponents of total or near-total reeze-over of the tropical oceans have argued that such occurrences had an enormous impact of the subsequent volution of multicellular life on Earth, and in fact may have been the trigger for the "Cambrian explosion" of life forms that were the ancestors of much of modern multicellular life. The broader ramifications of the glaciations' effects controversy over the possible occurrence of extreme glaciation in the Neoproterozoic has a ng history. Brian Harland (1964) was the first scientist to propose a "worldwide glaciation" nearly have thus provoked a great deal of interest in understanding just what climatic conditions might have been like during 40 years ago, by combining observations about the widespread distribution of glacial deposits with the glacial intervals, and what climate forcings may have been reponsible for producing such extremely cold conditions. sheets at low latitudes could be accounted for if large areas of land were ted in mid- to low latitudes; so from his perspective, the ice sheets simply grew n available surface with sufficient snow accumulation. A concentration of land

Linda Sohl, Mark Chandler



Figure 2: Sea Surface Temperatures (SSTs) used to from

modern to derive paleo SSTs

7. Publishing eJournals to the Web

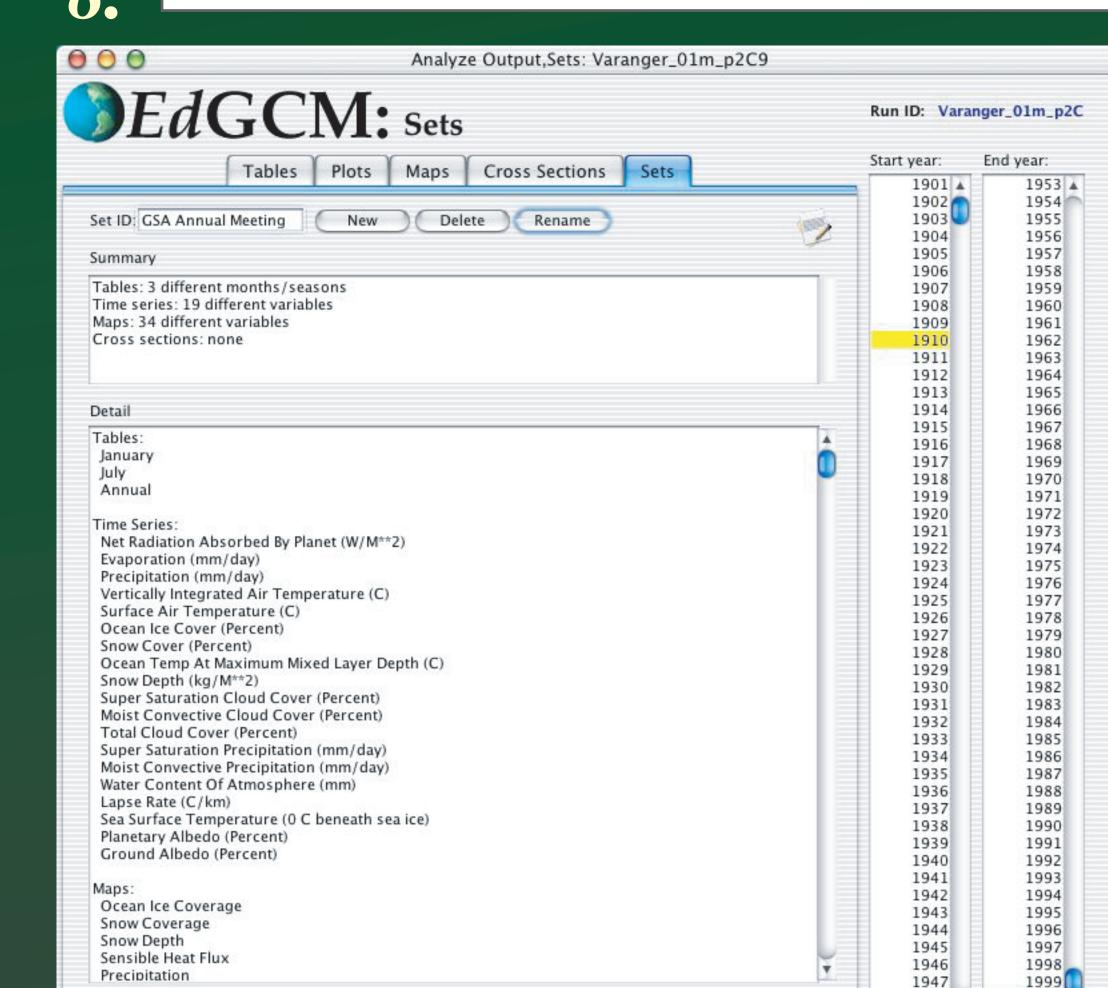
With a click of a button any eJournal produced in EdGCM can be published to the world wide web. EdGCM converts eJournals to html, formats all text and images appropriately, attaches figure numbers and captions, and embeds thumbnails of each image into the document (the later is done to make the documents 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.

8. Sets: Teacher Selected Variables

Because GCMs produce so much output - too much for almost any individual to analyze in an

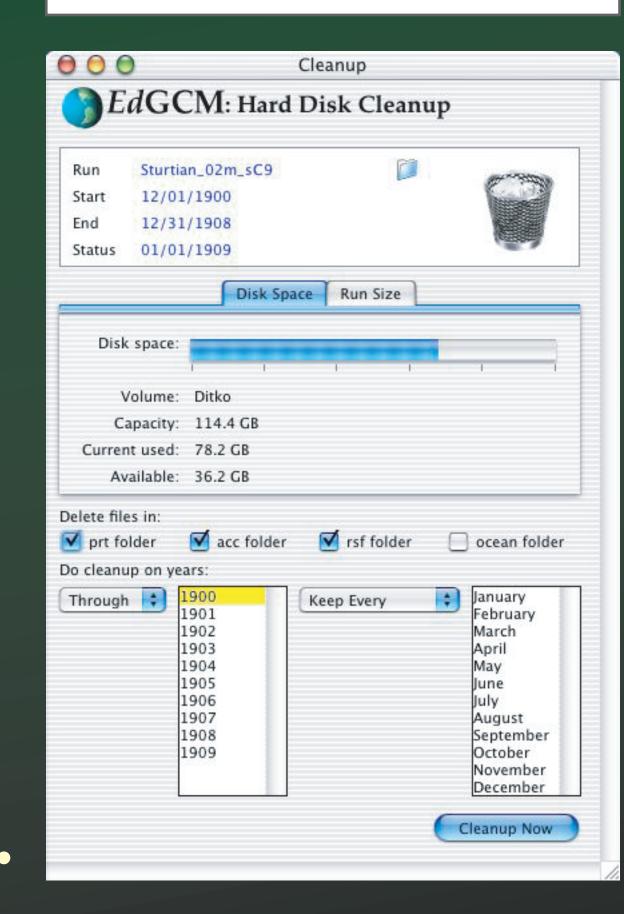
shone roughly 4-6% less brightly than at present, as well as a radically different

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 entify critical variables that should be analyzed in classroom projects.



9. Cleanup: Saving Schools' Hard Disks

n addition to simulating global climate, another thing that GCMs are good at is chewing up huge amounts of nard 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



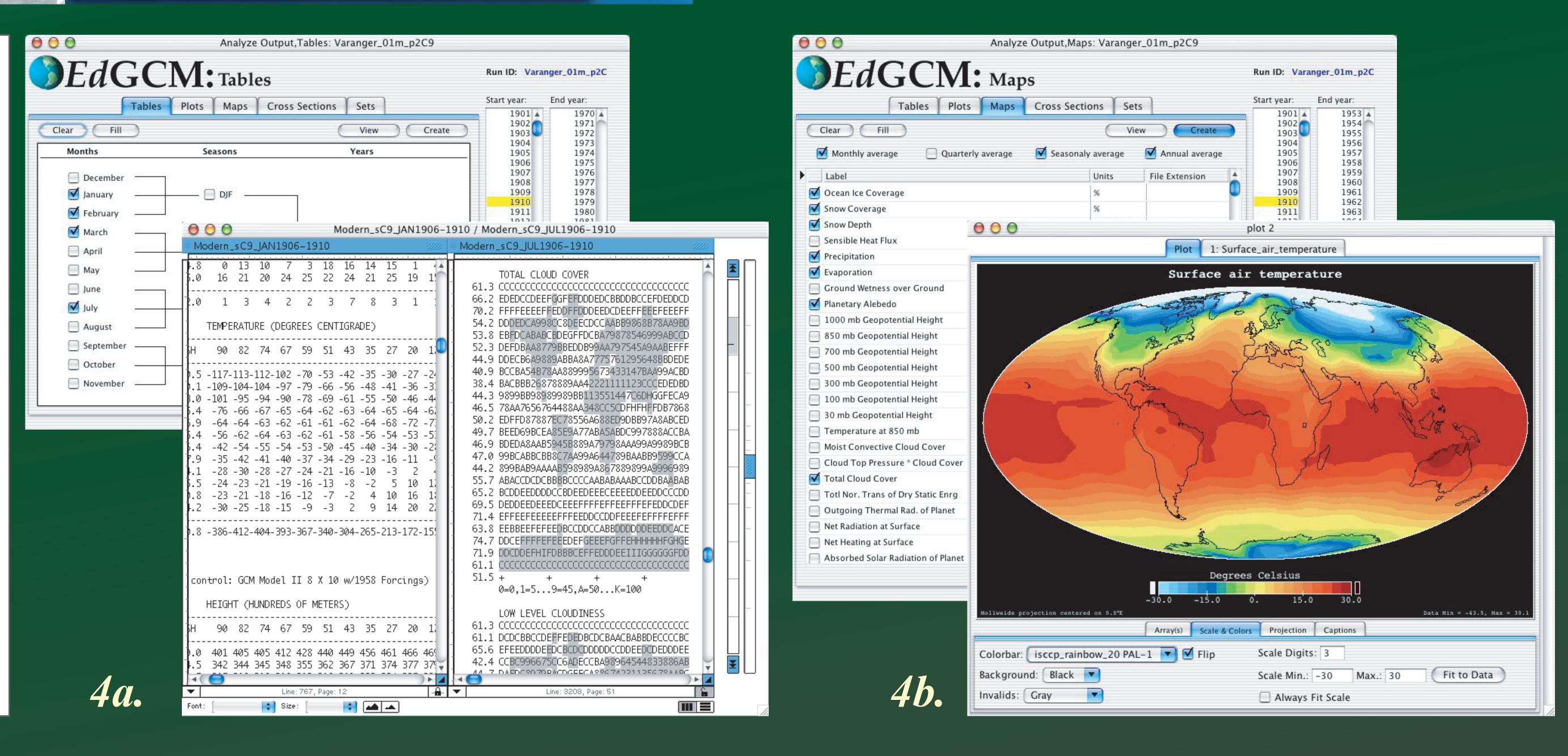
4. Analyze Output: Processing Model Results

The most important aspect of any climate modeling project is the analysis of results once the simulations are complete. As it turns out, 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

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





Analyze Output, Plots: Varanger_01m_p2C9