1.5 EDGCM: ENHANCING CLIMATE SCIENCE EDUCATION THROUGH CLIMATE MODELING RESEARCH PROJECTS

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1. INTRODUCTION

Global climate models (GCMs) are one of the primary tools of climate research today. Unfortunately, few educators have access to such models. The primary goal of the EdGCM (Educational Global Climate Model) Project is to enhance the quality of climate-change science teaching and learning at the high school level through broader access to actual GCMs, and to assist teachers by providing the appropriate technology, materials and support to use these research-quality climate models effectively in the classroom.

2. EDGCM PROGRAM OBJECTIVES

The main objectives of the EdGCM project are two-fold:

1) Provide training to educators in the use of a GCM that operates on desktop computers through a graphical educator/student-friendly interface. The training encourages educators to involve students in the full scientific process by including: hypothesis development, experiment design, running simulations, visualization and analysis of data, and reporting results.

2) Facilitate collaborations between universities, the K-12 community and research scientists so that students can become familiar with the critical role that teamwork plays in climate science today.

In order to accomplish its objectives, the EdGCM project, currently funded by National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF), has created a suite of software, which includes a desktop version of the NASA Goddard Institute for Space Studies GCM, which is currently used by researchers to investigate the climates of the past, present and future. EdGCM, a closely integrated suite of software, simplifies the management of a research-quality climate model by using a traditional point-and-click interface (Fig. 1 and Fig. 2). Experiments are automatically archived in a searchable database and easy-to-use utilities are included for analysis and visualization (Fig. 3). The software is also flexible enough to allow teachers to configure the interface for different levels or topics and to incorporate their own instructional materials (text, charts, images). Moreover, the software allows teachers, students and others to produce reports (text and images) and export them to the web in the format of a scientific manuscript that will be available for viewing by others at the EdGCM web site, http://www.edgcm.org.

With research-quality resources in place, it becomes possible to link student research projects in the classroom to actual research projects at climate-science research facilities and at universities, to the benefit of both educators and scientists.

The EdGCM project strongly encourages and facilitates such collaborations through its web site-based, on-line Forum, eJournal, SimExchange (simulation exchange) and web-publishing components. These on-going communications between pre-college teachers and students, undergraduate students and faculty, and active research scientists will allow remote groups of students to work together on similar projects and to share their experimental ideas, educational materials, and scientific findings.

3. EDGCM STUDENT RESEARCH PROJECTS

The EdGCM Project is specifically designed to allow teachers and students to explore the fundamentals of climate science utilizing the tools identical to those used in major climate-change research programs. Many basic experiments are possible (e.g., how does the sun warm the earth?). It is also possible, however, to conduct in-depth, research quality investigations of climate change on a time frame similar to that of ongoing climate research.

EdGCM will include some pre-prepared scenarios for investigating a variety of interesting climate issues (e.g., global warming, snowball earth) but teachers can easily construct their own research scenarios in order to satisfy the curricular requirements of their state and/or local education agencies.

4. EDGCM ADDRESSES NATIONAL EDUCATION STANDARDS

The National Research Council's publication of the National Science Education Standards (NSES) in 1996 emphasizes that all students should acquire the skills needed to design and conduct scientific investigations and to understand the nature of scientific inquiry. Many state standards actually require that high school students understand a variety of Earth System concepts and processes, including fundamental issues relating to climate and global change, such as "Energy in the Earth System" and the "Origin and Evolution of the Earth System." Although the NSES standards were developed

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for the K-12 levels, these directives apply equally to most undergraduate curricula in the United States. High school students and undergraduates alike do not regularly participate in the type of real-world scientific research that is expected in most graduate programs, and which reflects the day-to-day routine for most scientists. It is striking that in a nation in which every person is increasingly dependent upon technology and science, too few of its citizens are cognizant of the scientific process. The framers of the NSES were clearly mindful of some of the challenges facing teachers, who must deal directly with this issue.

Documents have been produced that illustrate in detail the numerous correlations between EdGCM research project outcomes and the following additional formalized science standards: the Project 2061 Benchmarks for Science Literacy (American Association for the Advancement of Science), the National Educational Technology Standards (NETS) and Performance Indicators For Teachers (International Society for Technology in Education) and the National Geography Standards (National Council for Geographic Education).

A compilation of correlations of EdGCM activities to each of the sets of standards cited above is available for perusal at the EdGCM web site, at the following URL: http://www.edgcm.org/standards.php.

5. EdGCM INITIAL PROGRAM UNITS

The first EdGCM climate-science units planned for the classroom are "CO_2 and Global Warming", "The Water Cycle", and "Paleoclimate." Each module will address the basic climate science of the topic area. In addition, these units will provide teachers and students with the instructional materials and procedural directions required for creating research portfolios which, when completed, will contain the authentic products of a complete scientific research project.

Through assessment of these portfolios, students will be evaluated not only on their knowledge of the subject matter, but also on the demonstration of their ability to accurately conduct and comprehend each stage of a scientific research project.

Future plans include the development of an in-depth instructional "Immersion Unit in Climatology," which will be developed in collaboration with the SCALE (System-wide Change for All Learners and Educators http://scalemsp.wceruw.org/) program, an NSF-sponsored project that holds as one of its objectives the creation of state-of–the-art science immersion projects and implementing these system-wide in a number of city school districts including Los Angeles and Denver.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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American Association for the Advancement of Science (AAAS), (1997): Benchmarks for Science Literacy, AAAS Project 2061, Washington, DC, http://www.project2061.org/

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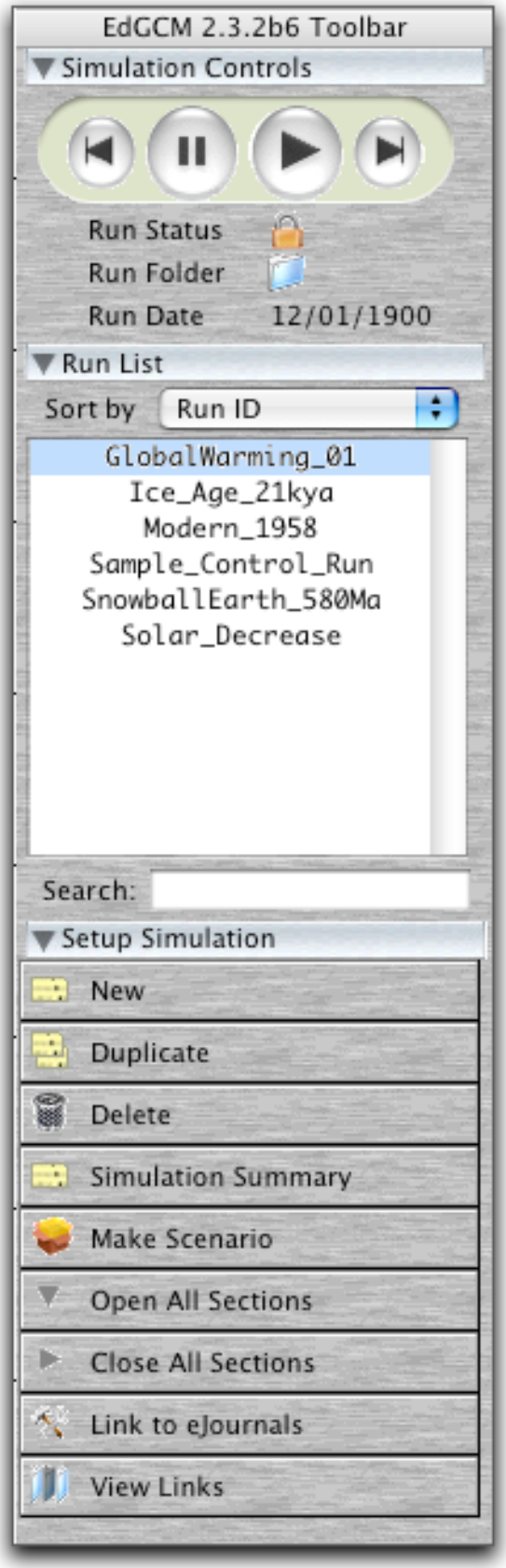


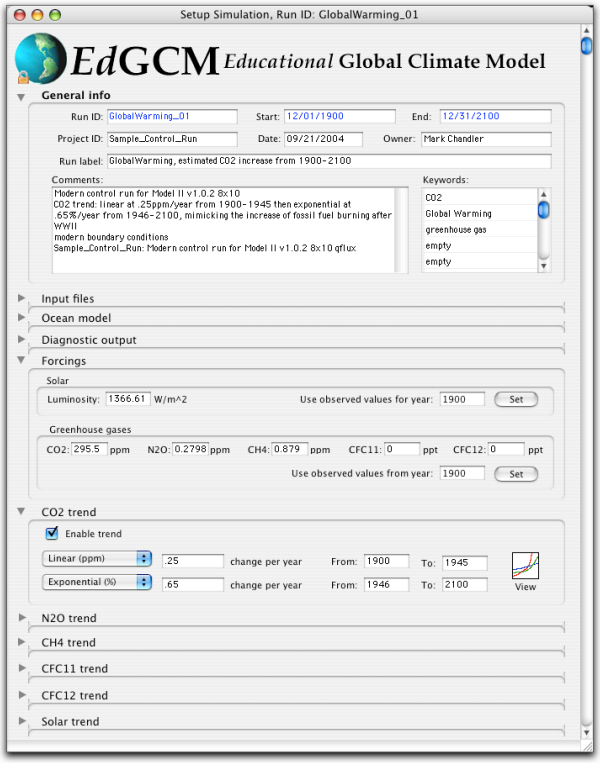
FIGURE 1. THE EDGCM TOOLBAR PALLETTE

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 DVD player, which start, stop, pause, rewind and extend simulations.

The Toolbar also contains a list of all simulations in the database, thus allowing the user to conveniently select an experiment to work with. Additional controls (buttons, lists, pop-up menus, etc.) appear in the toolbar depending upon which windows are currently open in EdGCM. In this way the toolbar is kept uncluttered, yet useful controls are always available.

FIGURE 2. SETTING UP SIMULATIONS

Designing experiments is done 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, quantity of greenhouse gases, vegetation, paleoclimate scenarios, etc.). The interface is divided into 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.



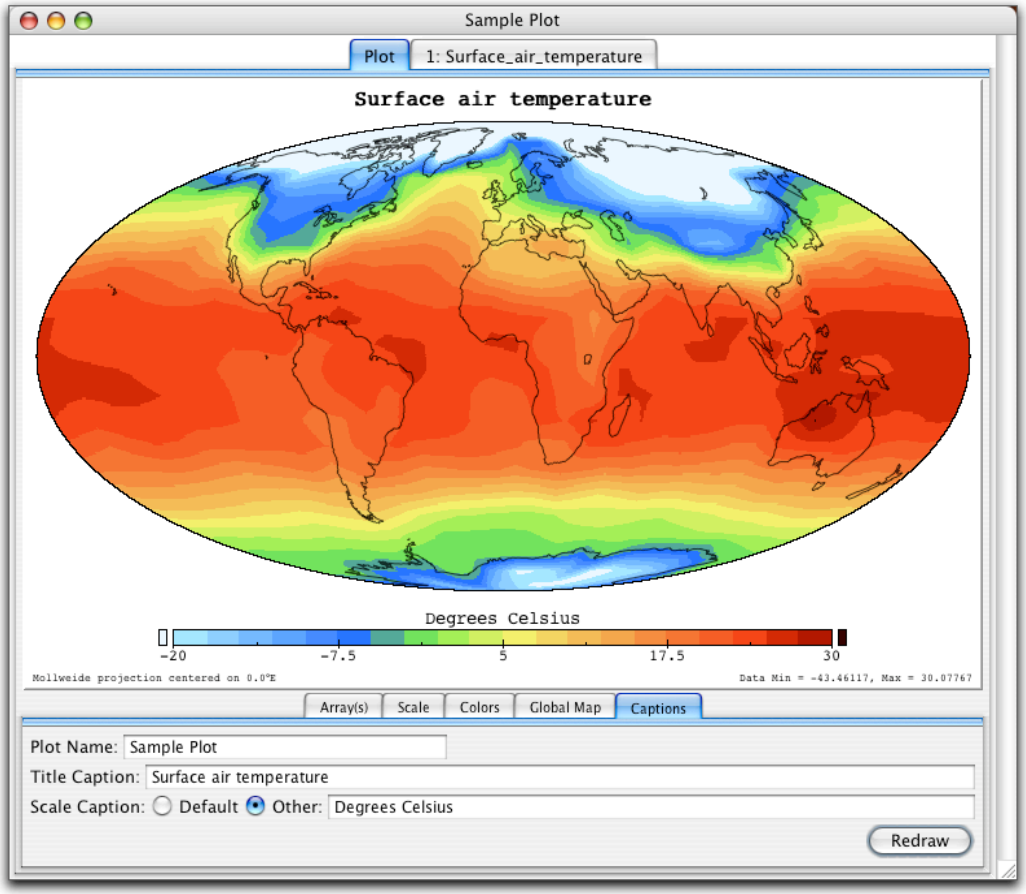


FIGURE 3. THE EDGCM ANALYSIS AND VISUALIZATION TOOLS

The most important aspect of any climate modeling project is the analysis, including visualization, of results once the simulations are complete. As it turns out, for most global climate models, preparing model output for analysis can be as involved as setting up the simulation in the first place. This preparation of model output for analysis is referred to as "post-processing" and it involves several steps (most of which are hidden from the user in EdGCM): Variables of interest must first be extracted from the large binary files that are a GCM's raw output, next data are averaged over meaningful time periods or geographic areas. For example, a "summer temperature" or "precipitation over land areas", Finally, the values are scaled to standard meteorological units (e.g. degrees Celsius) and are then converted to formats that can be usefully analyzed by desktop software. 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 performing post-processing can be a "limitation" for many research programs it is probably an "insurmountable obstacle" for most high schools and undergraduate institutions.

In order to tackle this problem EdGCM automates the most-used post-processing programs and have added user-friendly interfaces to perform steps that can't, or shouldn't, be entirely hidden. To date, we have adapted three key programs to help clear the path for analyzing model results. These include utilities that:

1. Generate summary Tables of all diagnostic variables produced by the global climate model (over 400 variables!) averaged over months, seasons, and years for any portion of a simulation.
2. Create global Maps of around 80 different climate variables, which can be used to analyze geographic patterns of climate change.
3. Produce time series Plots of around 80 climate variables, which can be used to track climate changes that occur throughout the duration of a simulation.

Examples of the interfaces that run these programs and samples of the mapping, plotting and data viewing utilities are available at:

http://www.edgcm.org/EdGCM/Tables.php
http://www.edgcm.org/EdGCM/Maps.php
http://www.edgcm.org/EdGCM/Plots.php