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Making Earth Science Data Accessible and Usable in Education

The Earth Exploration Toolbook provides instructions on accessing and analyzing Earth science data to explore scientific concepts and issues.

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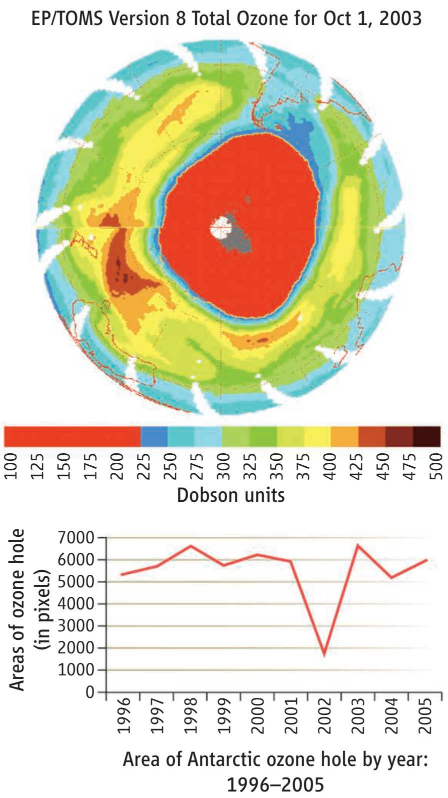
To enable responsible decision-making in the future and to ensure the development of the next generation of scientists, students must develop the skills that enable them to explore scientific questions, assess the results of scientific research, and draw and communicate conclusions to others. These skills are essential as society faces science and engineering challenges, including the need to understand and respond to the impacts of changes in Earth's climate.

One way to help students develop these skills is to involve them in exploring scientific questions using the same data and data analysis tools that scientists use. The Earth Exploration Toolbook (EET, http://serc.carleton.edu/eet) is a freely available online resource made up of investigations or "chapters" that help teachers and their students become competent data users (*1*).

Each stand-alone chapter in the EET addresses a different topic (e.g., hydrologic cycle, weather, climate, environmental quality, or natural hazards), data set (e.g., global temperatures, sea ice extent, ocean core records, or stream flow data), or analysis tool [e.g., spreadsheets, image-processing software, or geographic information system (GIS)]. Chapters are designed for use by teachers of grades 6 through 12, undergraduate faculty, and/or their students. By working through a chapter, users gain experience and knowledge of the data set and analysis tool so that they can use them for their own investigations, investigate other aspects of the Earth system, and/or apply the techniques in other contexts or disciplines. In particular, educators can adapt them to their classrooms. This flexibility allows teachers and students to use the featured data sets and tools across a range of learning activities, from prepared demonstrations to open-ended inquiry projects.

The EET chapters have a common structure with six basic elements: (i) a Chapter Overview providing a brief description of the content; (ii) Teaching Notes providing extensive curricular and pedagogic details about the chapter; (iii) the Case Study presenting a relevant and interesting context that draws users in via a question or problem to explore; (iv) Step-by-Step Instructions guiding users through the process of navigating to the pertinent Web sites, downloading the data and analysis tools, formatting and importing the data, conducting an analysis, and interpreting the results; (v) Tools and Data providing full details about each tool and data set used; and (vi) Going Further, which includes suggestions for users who want to extend the investigation or apply it to new situations.



Antarctic ozone hole image data from NASA. The area of the ozone hole was outlined and measured by means of the ImageJ image-processing software. The graph of the changing size of the ozone hole between 1996 and 2005 was produced in the spreadsheet application using measurements made in ImageJ.

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Most chapters use freely or commonly available tools and data sets such as earthquake and stream flow data from the U.S. Geological Survey, weather data from National Oceanic and Atmospheric Administration (NOAA), and satellite data from National Aeronautics and Space Administration (NASA) (see the first figure). The EET chapter, "Analyzing the Antarctic Ozone Hole," uses ImageJ, a public-domain image-analysis program from the National Institutes of Health, and Excel, a commonly available spreadsheet application, to animate, measure, and graph the changes in the Antarctic ozone hole over 10 years. Students can then consider why the observed variations have occurred.

In general, as the EET chapter is written, there is one result for each activity, although teachers might approach activities at different levels. However, teachers and students could do different kinds of analysis. For example, in the "Analyzing the Antarctic Ozone Hole" chapter, users get the ozone data from 1 October each year, create an animation of the evolving size of the ozone hole on that date each year, and measure how its size changes over a number of years. Alternatively, they could get the data for every day through a year and animate the evolution of the ozone hole over the course of a year. A more advanced activity would be to do a similar analysis of ozone over the North Pole and compare the results with an analysis of ozone over Antarctica.

Effective communication between scientists, educators, and curriculum developers can be a challenge. Some scientists find it difficult to translate their technical terminology into language that educators and students can understand. Compounding this challenge is the scientists' unfamiliarity with what educators need to effectively teach the complex scientific concepts inherent in Earth system science. At the same time, educators and curriculum developers are not always aware of what scientific data or information they need to effectively convey specific scientific concepts, and even if they are aware, they often lack the time to obtain and prepare the data or

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Local environmental awareness. Students who participated in a summer workshop discuss data from their local community displayed in GIS software.

information into a form they can use.

The EET serves as a locus of activities to address these issues. The process we use to make scientific data sets accessible and usable in educational contexts supports effective communication between the scientific and educational communities (*2*). EET also has been featured in professional development programs that help teachers learn to use the resources (including the science content and inquiry skills they feature) and to integrate them into their curricula (*3*, *4*).

We brought together the scientific and educational communities to create new EET chapters during our AccessData workshops (http://serc.carleton.edu/usingdata/accessdata). These 2½-day workshops, run annually between 2004 and 2009, each facilitated ~10 teams, with each team focused on identifying a data set, data analysis tool, and a compelling scenario for investigating the data. Each team had five to seven members representing the expertise of the data provider, analysis tool specialist, scientist, curriculum developer, and educator. After the workshop, a curriculum developer completed the EET chapter. During breakout sessions, both the scientific and educational community participants had time to get to know the needs and capabilities of team members from other communities. That interaction affected not only how the EET chapter evolved but also how individuals conducted their own work. For example, in the longitudinal evaluation in 2010 (*5*), in response to the question—"How has your participation … [affected] how you think about and put in practice providing data to educators and students?"—a data provider said, "It has changed how we document our software; how we implement middleware [software and services that connect user application programs with possibly remote computer operating system functions]; and what metadata schemas to adopt and support; [and] what formats to use and make available for data transfer, storage, and visualization." Simply providing access over the Internet was not enough to effect such changes.

Teachers involved in professional development programs that feature EET investigations report that the EET has changed their approach to teaching science by enabling them to use scientific data to address authentic situations. We have some anecdotal evidence that the integration of analysis of scientific data sets in middle-school classrooms has a positive impact on standardized test scores. Teachers also find that the EET chapters provide a mechanism for them to learn and relearn data analysis skills so that they can help their students address scientific questions using Earth science data.

In summary, learning experiences based on EET chapters prepare students to inquire about complex real-world problems, such as how to deal with environmental issues in their communities resulting from climate change (see the second figure) teach them to critically evaluate the integrity and robustness of data; and provide them training in scientific, technical, quantitative, and communication skills. To more fully integrate research and education, however, it is necessary to bring members of the scientific and educational communities together to work through the technological and pedagogical obstacles to effective use of data in education.

About the authors

Tamara Shapiro Ledley is a senior scientist and chair of the Center for Science Teaching and Learning at TERC and is the principal investigator of the Earth Exploration Toolbook and AccessData projects. **LuAnn Dahlman**, formerly at TERC, works as an educational specialist in NOAA's Climate Program Office. **Carla McAuliffe**, **Nick Haddad**, and **Marian Grogan** are also at TERC. McAuliffe leads professional development efforts, develops curricular materials, and conducts educational research and evaluation. Haddad is a senior curriculum developer who manages curriculum and professional development projects. Grogan is a project manager. **Michael Taber** is associate professor of Science Education and Chair of the Education Department at Colorado College. **Ben Domenico** is outreach coordinator at the Unidata/UCAR Program Center, University Corporation for Atmospheric Research. **Susan Lynds** is a program evaluator and associate scientist at CIRES at the University of Colorado at Boulder. Haddad, Ledley, Dahlman, and McAuliffe (pictured from left to right) were the initial EET team and are authors on numerous EET chapters. Ledley, Dahlman, Taber, Domenico, Lynds, and Grogan make up the AccessData team.

References and Notes

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