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## 1. INTRODUCTION

Visualizations are a useful and powerful tool for researchers in earth sciences and are used for both real-time forecasting and for detailed scientific studies of particular geophysical events like hurricanes or thunderstorms. Visualizations are often used to isolate individual processes within large complex systems for study or to view otherwise non-viewable phenomena. Visualization can also make large, detailed and unwieldy data sets tractable.

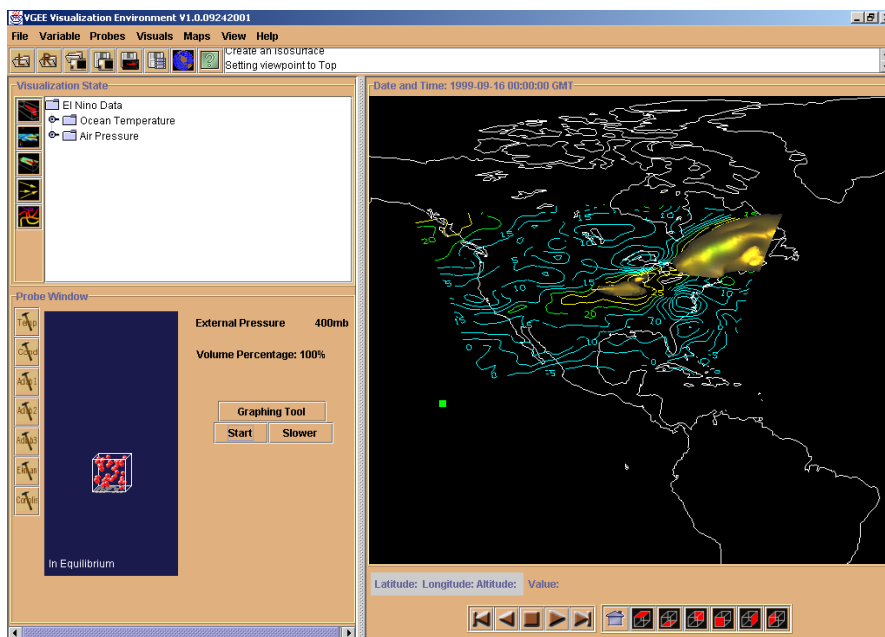


Fig. 1. VGEE Visualization Environment with Dry Adiabatic Probe

## 2. CHALLENGE

If visualizations could be brought to the college undergraduate level, primarily into an introductory science elective course, students could also benefit. However, there are challenges. Visualization environments are difficult to navigate, and are sometimes even more so to interpret the results. Also, the knowledge that guides fruitful exploration of a visualization, the knowledge of where to look and what to look for, maybe much more than can be expected of a student at this level. Finally, introductory students normally do not possess the same analytic abilities as a scientist, which may hinder their ability to interpret visualization.

## 3. VISUAL GEOPHYSICAL EXPLORATION ENVIRONMENT (VGEE)

An effort focused on overcoming these challenges is called The Visual Geophysical Exploration Environment (VGEE), and it uses the visualization process and exploration to teach undergraduate students geophysical concepts and phenomena. The VGEE offers a more tractable environment as well as guidance needed to understand and extract useful information from student-constructed visualizations.

### 3.1 VGEE Graphical User Interface (GUI)

A primary focus of VGEE is the development of a learner friendly Graphical User Interface (GUI). A picture of the GUI can be seen in Fig. 1. The GUI's primary goal is to deliver an interactive graphical environment for exploring 3D geophysical datasets. The GUI provides the same functions available to professional researchers,

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but they have been tailored for use at the undergraduate survey level. Its primary components consist of the main display, the visualization state, and the probe window and can be seen in Fig. 1. The main display is on the right side of the GUI, the visualization state is found in the upper-left portion, and the probe window is in the lower left. Geophysical datasets can be viewed and interactively manipulated in 3D in the main display, while the visualization state displays dynamic information about the current content in the main display. The probe window contains probes that display environmental relationships of variables (e.g. temperature, humidity, pressure, etc.) based on the current position of the main display's 3D mouse cursor and the corresponding variable values.

### 3.1.1 Main Display

The main display houses the visualization, and provides an environment for interactive manipulation (zoom, pan, and rotate) of visualization objects (contour slices, maps, isosurface, trajectories, and streamlines). The visualization objects represent phenomena taken from input data that can be local to the system or remotely served from a DODS server. Users are provided with specially prepared datasets, but they can also supply their own geolocated gridded data in netCDF format conforming to COARDS, GDV, NUWG, and CSM netCDF conventions. This expands the user base beyond just meteorology or even geoscience to any other discipline that takes advantage of visualizations.

### 3.1.2 Visualization State

Users interact with the Visualization State window to track, update, and change the parameters (isosurface values, colors, plane levels, etc.) of the objects in the main display. This window also provides a graphical mechanism for instantiating all the visual objects available to the user. The initial release of this software includes support for isosurfaces and horizontal and vertical contour slices. The software will eventually support streamlines, vectors, and trajectories for exploring 3D flow fields in the data.

### 3.1.3 Probe Window

The probe window allows users to interrogate the data set. A probe can be placed over the main display and extract specific information into the probe window -- isolating a

specific process occurring in the data set. By isolating an individual process within the overall system, the information delivered to the student at one time is reduced, helping them to more easily understand that isolated piece. They can then return to the larger dataset with new knowledge that will ultimately help them understand the entire visualization.

## 3.2 Web Content

Further guidance is lent to the learner in the form of web content. In the VGEE's first example, students work their way through the El Niño phenomena. El Niño and the processes leading to its development are partitioned into topics, and each topic contains multiple activities that challenge them to look at specific aspects of the environment. By breaking down a complex system into short focused activities, the students can more easily learn about El Niño. An example activity is shown in Fig. 2.

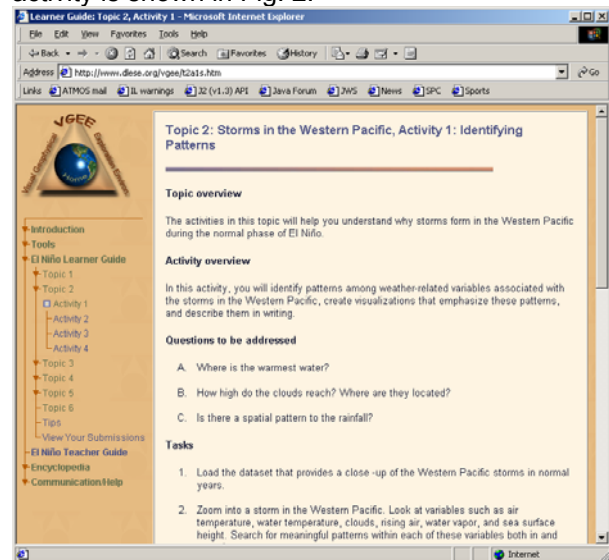


Fig. 2. Example VGEE web activity page

## 3.3 Concept Models

Before a student is expected to be able to understand both how a probe works as well as what can be learned from it, they are able to look at these probes outside of the three-dimensional environment as concept models. They operate similarly to the probes, but allow the user to freely change the environment themselves. Idealized concept models help students learn and conceptualize fundamental physical processes (Pandya, *et al.*, 2002). Concept models are so

named because their chief focus is to teach one or two simple relationships (i.e., how condensation is affected by atmospheric temperature or how volume, pressure, and temperature are all interrelated). As an example; the Moist Adiabatic Concept Model is shown in Fig. 3.

#### 4. Student use of the VGEE

In an example of how the elements of the VGEE come together, consider the following scenario: students may begin an activity about storms and their development. They use the evaporation probe and are able to work with the evaporation concept model to understand the relationship between higher oceanic temperatures and the presence of clouds in the air. Then, the students open and view a data set of ocean temperatures and cloud cover and move through the three-dimensional environment to locate areas of interest. They can probe these areas to verify that the relationship between clouds and temperature from the concept model holds and applies to the complexity of real systems.

#### 5. JAVA / VISAD

Both the GUI and the probes/concept models are written in Java, offering the flexibility of an extensible object-oriented language. It also allows for an easy interface between the two. Information learned from the probe stems directly from changes in the dataset. The underlying technology of the 3D visualization environment was heavily leveraged from the Gridded Data Viewer (GDV) software developed as part of UNIDATA's MetApps project ([www.unidata.ucar.edu/projects/metapps/index.html](http://www.unidata.ucar.edu/projects/metapps/index.html)) and VisAD ([www.ssec.wisc.edu/~billh/visad.html](http://www.ssec.wisc.edu/~billh/visad.html)), a Java component library for interactive and collaborative visualization and analysis of numerical data. The Java-VisAD-MetApps development environment was chosen because of its platform independence, easy integration with other components of the VGEE, ready implementation of client-server architecture, and the easy extensibility provided by its open architecture and vigorous development community (Pandya, *et al.*, 2002).

#### 6. CONCLUSION

There are a number of benefits for scientists associated with the use of visualizations. For the power of visualization to be brought to the undergraduate survey course level, steps would have to be made to simplify their use – especially

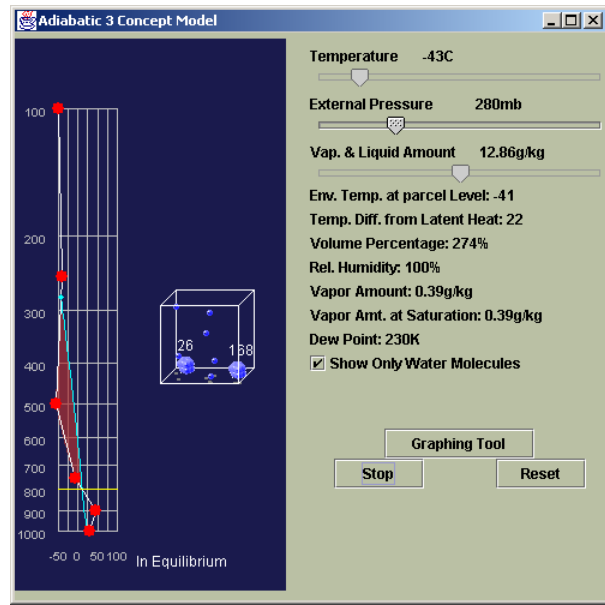


Fig. 3. Adiabatic 3 (Buoyancy) Concept Model

when working with students who are not necessarily interested in science or scientific thought. The VGEE presents a real effort in this direction by providing a powerful visualization environment, while providing help in the form of concept models, probes, and traditional content.

#### 8. ACKNOWLEDGEMENT

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#### 9. SEE ALSO

Bramer, D., *et al.*, 2000: The Technology Behind a Virtual Exploratorium: A Resource for Discovery-Based Learning in the Geosciences. Proceedings of the Ninth Symposium on Education, Long Beach, CA, American Meteorological Society.

Pandya, R. *et al.*, 2002: An Inquiry-Based Learning Strategy from the VGEE. Proceedings of the Eleventh Symposium on Education, Orlando, FL, American Meteorological Society.

Pandya, R., *et al.*, 2001: Using the Virtual Exploratorium to Support Inquiry-Based Learning in Introductory Geoscience Courses: An ENSO Example. Proceedings of the Tenth Symposium on Education, Albuquerque, NM, American Meteorological Society.