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INTEGRATING LEAD RESEARCH IN UNDERGRADUATE EDUCATION

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1. INTRODUCTION

Linked Environments for Atmospheric Discovery (LEAD) is making meteorological data, forecast models, and analysis and visualization tools available to anyone who wants to interactively explore the weather as it evolves. LEAD evolves through the development and beta-deployment of Integrated Test Beds (ITBs), which are technology build-outs that are the fruition of collaborative IT and meteorological research. As the ITBs mature, opportunities emerge for the integration of this new technological capability into education.

The LEAD Education and Outreach (E&O) initiative is aimed at bringing new capabilities into classroom from the middle school level to graduate education and beyond. One of the principal goals of LEAD is to democratize the availability of advanced weather technologies for research and education. The degree of democratization is tied to the growth of student knowledge and skills, and is correlated with education level (though not for every student in the same way). The average high school student may experience LEAD through an environment that is more controlled by the instructor than an undergraduate student. This is necessary to accommodate not only differences in knowledge and skills, but to assure that the "teachable moment" is not lost.

Undergraduates will have the opportunity to query observation data and model output, explore and discover relationships through concept mapping using an ontology service, select domains of interest based on current weather, and employ an experiment builder within the LEAD portal as an interface to configure, launch the WRF model, monitor the workflow, and visualize results using Unidata's Integrated Data Viewer (IDV), whether it be on a local server or across the TeraGrid. Such a robust and comprehensive suite of tools and services can create new paradigms for embedding students in an authentic, contextualized environment where the knowledge domain is an extension, yet integral supplement, to the classroom experience.

This presentation describes two different approaches for the use of LEAD in undergraduate education: 1) a use-cases for integrating LEAD technology into undergraduate subject material; and 2) making LEAD capability available to a select group of students participating in a collegiate forecasting contest. The use-cases (1) are embedded in learning modules designed to have students explore a particular weather phenomenon (e.g., a frontal boundary, jet streak, or lake effect snow event) through self-guided inquiry, and are intended as a supplement to classroom instruction.

Toward the goal of democratization and putting new tools and services into the hands of many would-be users, efforts are underway to bring LEAD to a broader community of 10 institutions through a competitive forecasting challenge. The contest would be a pilot program, which if successful, will be expanded in the 2006-07 academic year. A plan is being implemented in spring 2007 that will provide LEAD accessibility to a limited number of participating institutions with the specific goal of quantifying the value added to both the forecasts and the decision making process.

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2. USE CASES FOR UNDERGRADUATES

LEAD-to-LEARN modules were created specifically to build conceptual knowledge of the phenomenon, adjoin germane terminology, explore relationships between concepts and similar phenomena using the LEAD ontology, and guide them through the experiment builder and workflow orchestration process in order to establish a high-resolution WRF run over a region that exhibits the characteristics of the phenomenon they wish to study. Several learning modules have been developed by the LEAD E&O team around case studies that focus on a set of atmospheric phenomena. The learning modules are pedagogically structured, complete with learning objectives, content within the context of the phenomenon, a glossary with pop-up definitions, and tools for self-assessment. So far the LEAD team has developed nine modules that can be accessed via the LEAD portal > Education > LEAD-to-LEARN (http://portal.leadproject.org). Figure 1 provides a screen shot of the modules page. The student is guided through the module through a sequence of descriptions and visualizations of the meteorological conditions that would be associated with the particular weather event.

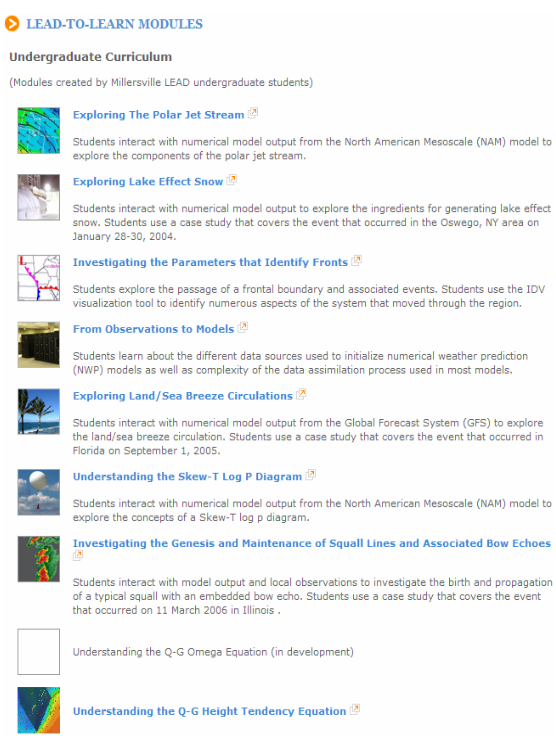

Fig. 1: Current List of LEAD-to-LEARN Modules.

Some modules contain the partial differential equations that serve as the mathematical underpinning for an in-depth treatment of the subject, and were designed for use in junior and senior undergraduate meteorology courses. For example, the module on "Understanding the Quasi-Geostrophic Height Tendency Equation" comes with a full mathematic description of the equation and its individual terms, and content and visualizations that illustrate how each term plays a role in influencing the Q-G height tendency (Figs. 2 and 3).

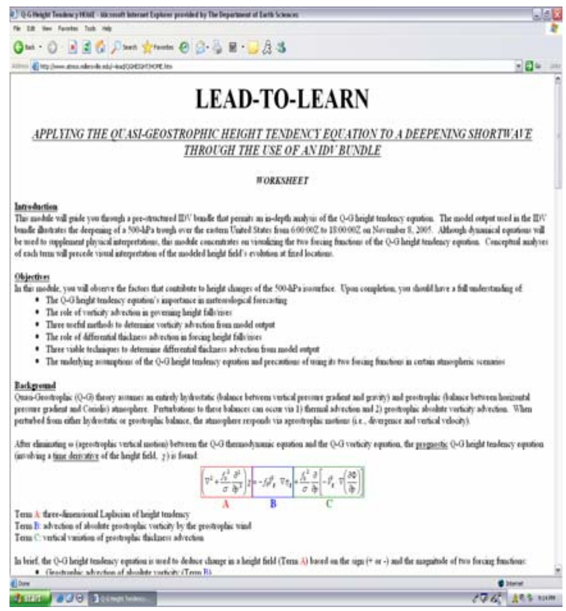

Fig. 2. The introductory page to the Q-G height tendency module.

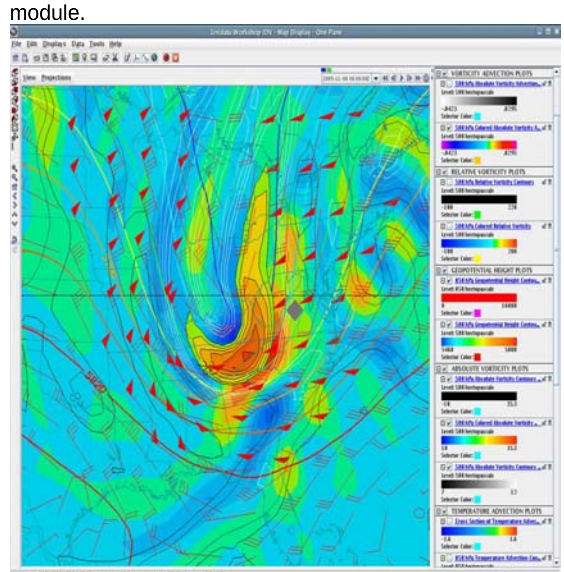

Fig. 3. Visualization in IDV from the Q-G height tendency module.

Other modules use a more descriptive approach. For instance, the module on “Exploring Lake Effect Snow” events was designed with discussions and visualizations of observational data and model output to explore the atmospheric condition leading to lake-effect snowfalls. The module is suitable as a lake-effect primer or for meteorology students enrolled in their first course in the major sequence.

The modules also contain links to archived data sets that the student can download in Unidata’s 3-D Integrated Data Viewer (IDV) by importing XML bundles that have pointers to the data, and can either explore the data volume using the module’s approach to guided inquiry, or discover for themselves or with guidance from their instructor, the features related to the phenomenon. At Millersville, course instructors incorporating these modules to supplement their instruction either in class or given as an assignment have found them to be useful, and students have commented that they gain a better understanding of the phenomenon by having the content and visual materials in the form of guided inquiry.

However, LEAD technologies allow the learning process to be much more than one of guided inquiry; they enable the student in an authentic way that exposes the same process of investigation, and many of the same tools, that are used by researchers to study a phenomenon. Moreover, this comes at a time when undergraduates are no longer satisfied to only look at model products. Students want to investigate the model itself, understand the physical core, parameterizations, boundary conditions, and data assimilation techniques. They want to create the workflow themselves, launch a high-resolution WRF run over a domain of their choosing, and have their own space to store, retrieve, visualize, analyze, and interpret the atmospheric features characteristic of their investigation. And this is exactly what the LEAD developers having been challenged to create – an integrated, scalable framework for identifying, accessing, decoding, assimilating, predicting, managing, analyzing, mining, and visualizing a broad array of meteorological data and model output, independent of format and physical location in a democratized environment that is friendly and intuitive to the end-user.

3. ENHANCED USE CASES

The LEAD project is now at a period of development when some of the fundamental IT research challenges have been met and are ready for testing and integration into other LEAD thrusts. The first effort involved the LEAD E&O thrust is to build into the learning modules use-cases that enable the student to query real-time observations and model output for atmospheric signatures that are similar to those described in the module about a particular phenomenon. The concept is simple but powerful. Once the student has been introduced to lake-effect snowfall events (for instance) and the atmospheric conditions and features that favor those events, *what if the student could use the LEAD data query service to investigate in real-time similar conditions playing out across the U.S., use the experiment builder to define a domain over the region of interest (Fig. 4), compose an automated workflow (i.e. a sequencing of steps or programs that go into the realization of a meteorological analysis or experimentation) that includes choosing the model’s physical core, boundary layer parameterization, initialization field for the assimilation service, launch a high-resolution WRF run (Fig. 5), and store the output in the student’s MyLEAD workspace for visualization and analysis (Fig. 6)?* The student becomes the researcher in an authentic scientific investigation. As functional components of this technology become hardened and available from the LEAD development team, they are being incorporated as features in the learning modules for students use.

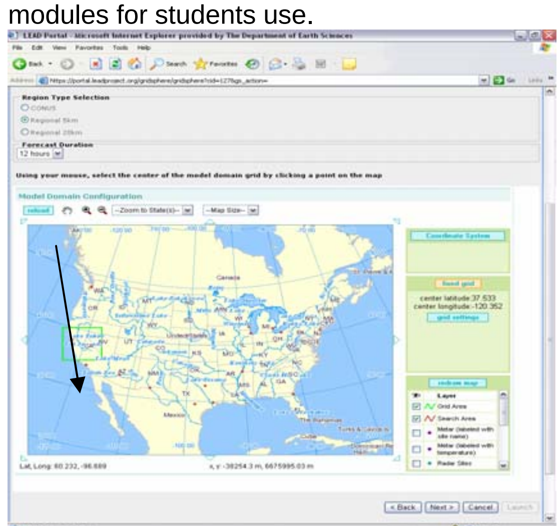

Fig. 4. Choosing a model domain over a region of interest within the LEAD portal.

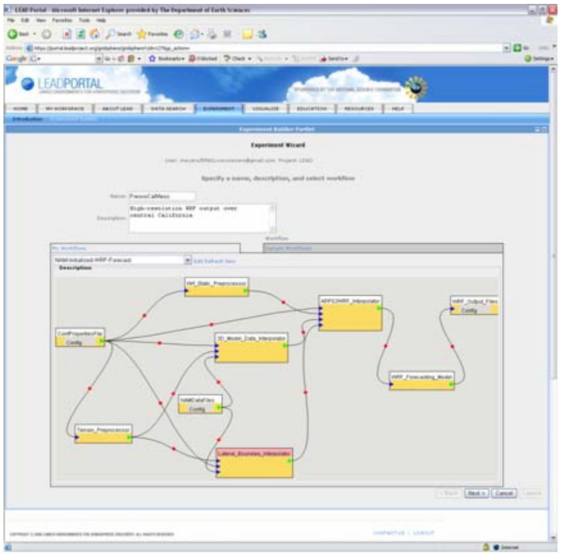

Fig. 5. Composing a workflow and launching a WRF run.

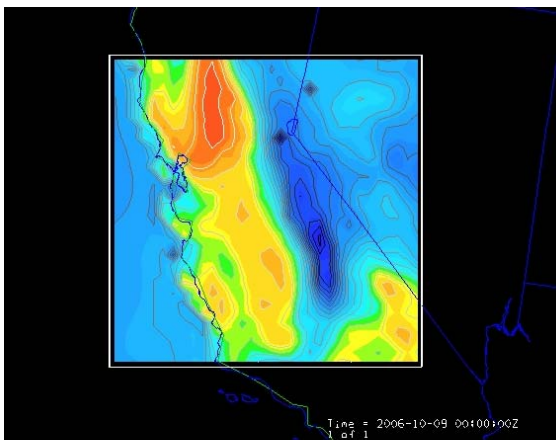

Fig. 6. Visualizing data stored in MyLEAD workspace.

To-date, a few of the learning modules allow students to position a domain over a region of interest, select the model resolution, acquire NAM or ADAS (CAPS atmospheric data assimilation system) initialization fields, choose from a few workflow templates, launch a WRF model run using external resources, and store the data in MyLEAD workspace, which can be imported to IDV for analysis and visualization. The student can enter the experiment builder from the learning module or by going directly to the experiment builder through the LEAD portal.

4. LEAD FORECAST COMPETITION

The LEAD goal is to begin ushering in a paradigm change in how experiments are conceived and performed, in the structure of user application tools and middleware, and in methodologies used to observe the atmosphere. Moreover, LEAD seeks to democratize the availability of advances in weather technologies for research and education, lowering the barrier to entry, and empowering a new generation of scientists through the development of complex end-to-end weather analysis and forecasting tools.

One way of empowering a generation of scientists is to engage them as students in the process of fundamental change. Toward this end, LEAD plans make a set of capabilities available at 10 institutions across the U.S. to participate in a collegiate forecasting competition. These institutions will form a pilot program during the spring 2007 forecasting period that uses the capabilities that were described above for the use cases, but instead will apply this functionality to forecasting for specific cities that are on the formal list of stations selected by the *Wx Challenge*, the national collegiate forecasting contest. The number of participants will be limited for this pilot so that LEAD developers can monitor the status of resources that will be made available for specifically for this program.

A student at each institution will be selected and given authorization to access a current release of the LEAD IT framework for building experiments, composing workflows, and launching WRF runs. The student will be expected to enter a description of the experimental design and process by which certain workflow tasks and WRF name list files were configured into a password protected LEAD blog, along with the forecast for the particular station. While a set of rules will govern the overall procedure, the configuration will remain open–ended and user-driven to allow the student maximum flexibility. The LEAD competition will not have a formal association with *Wx Challenge* in spring 2007, but scores will be given in a manner according to the procedure used by *Wx Challenge*, i.e. by verifying against the actual observations for that station, and the regular *Wx Challenge* student forecasters will serve as a control group. Moreover, the pilot program is not intended to primarily emphasize the advantages or disadvantages of LEAD capabilities in forecasting, but to work out the details, test the resources, and refine the plan for a larger experiment that is tentatively scheduled for fall 2007 through spring 2008 as a formal part of the *Wx Challenge* national collegiate forecast contest.

Academic programs at the 10 institutions involved in this competition will be encouraged to provide opportunities for students to receive Independent Study credits for their effort.

During the spring 2007 pilot experiment and in cooperation with the *Wx Challenge*, a project design will be developed for the following year's forecast competition. This design will include a component to address the sociology of decision making under pressure. In addition to the plethora of existing forecasting resources, student forecasters will have available the suite of tools and services developed by LEAD to produce high-resolution mesoscale forecasts over the station of interest and determine whether these capabilities result in better forecast scores and in more effective forecast decision trees.

5. ACKNOWLEGEMENTS

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