Data-enhanced Investigations for Climate Change Education

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Overview

The paper describes the ongoing development, piloting, and dissemination of Data-enhanced Investigations for Climate Change Education (DICCE). DICCE is making high school classroom use of the Goddard Interactive Online Visualization and Analysis Infrastructure (GIOVANNI) more tenable. GIOVANNI is a powerful portal of Earth observation data to high school classrooms that provides access to over 75 data products on Earth system phenomena covering the land biosphere, physical land, ocean biosphere, physical ocean, physical atmosphere, atmospheric gases, and energy and radiation system. The various data products are derived from remote-sensing instruments on satellites, plus from ground stations and data assimilation models. DICCE is creating high school teacher and student access to some of these data to enable student investigations of their local climates. Teachers can query the Giovanni data archive, then save the results as map images, time series plots, vertical profiles and data tables. The map images can also be imported to appear as layers in geographic information systems. DICCE-GIOVANNI (DICCE-G) is the name of this high school user-friendly access to the data. The project has also produced DICCE-Learning Environment (DICCE-LE), a tool for teachers to author student data investigation activities centered around representations they choose to make available to their students via DICCE-G. DICCE-LE will also support teacher selection of assessment items about the climate of a different place.

The DICCE approach is rooted in the perspective that powerful data and tools that build knowledge about the Earth system are likely to be out of reach to typical high school teachers and students due to the challenges of navigating data access and making sense of the parameters of data available to them. We are testing the theory that by providing a scaffolded technology supported curriculum authoring process and a wiki with supporting professional development resources, teachers will become capable of making such instructional decisions and follow up with effective classroom implementation. We are researching how well DICCE-G, DICCE-LE, and the DICCE wiki build teacher capacity to understand fundamental content about climate change and make effective instructional decisions given the breadth of data and visualization options made available to them through the project. Our driving research question is, will the scaffolded DICCE data querying and curriculum authoring process build greater teacher capacity to understand fundamental content about climate change and make effective instructional decisions when the teachers have wide ranging place-based data sets and representations to choose from?

The paper describes access challenges that the project is trying to address for novice or other relatively unseasoned users of the complex geospatial data in GIOVANNI. Such users would include most high school teachers and students as well as other people besides professional scientists, geospatial data technicians, post-secondary faculty, and graduate students in the geosciences. Novices may lack adequate geospatial data literacy, technology mastery, and understanding of the complex topic of climate change at the regional level. The paper also describes what the project is trying to do to meet these challenges, and how some participating teachers are responding with plans for using the data in their curricula.

Challenges

Building critical thinking about climate change at the regional level. Regional climate change does not tell a simple story that simply echoes global summary trends. There are many meteorological, oceanographic, and biological factors that influence regional climate change outcomes. The danger is that when unsophisticated audiences do not find obvious patterns that reinforce simplistic conceptions of global warming that they have only learned about at the global level, they may come to the wrong conclusions. The project team created two supports to help users think critically about trends and non-trends evident in the regional data. First, to support the users' broad conceptual understanding of how the phenomena represented by the data parameters fit into the broad schema of what is happening to the climate and the Earth system in general from human population growth and environmental degradation, a schema was created consisting of three overlapping slides. The first slide shows certainties about what is happening to the Earth system from anthropogenic influences. The second slide superimposes negative feedbacks and the third slide superimposes uncertainties. Embedded within each phenomenon identified in the schema are the specific data parameters in the DICCE G Basic Set that can be used to investigate it.

Second, to support the users' decision-making about what data parameter to examine and how to interpret whatever trends they may notice, the team authored a "Trend Guide," a spreadsheet about how to interpret increases or decreases of each data parameter at the regional level. For any given data parameter, the following information is provided in the cells of the guide: (1) what a trend of higher or lower values signifies, (2) what the trend could be a sign of, (3) whether the trend could be an effect of climate warming, (4) whether the trend could be contributing to more climate warming, (5) whether the trend could be contributing to less warming, and (6) whether there may be other reasons for the trend. The following is an example. Higher values of the data parameter "Normalized Difference Vegetation Index" are identified in the trend guide as indicating in most cases more coverage of the landscape by green plants, which could be a sign of a more nourishing climate for photosynthesis. As to a relationship between the greater greenness and climate warming, it is stated that the trend could be an effect because some areas may become warmer and wetter, resulting in more extensive vegetation. However, an alternative hypothesis is also posed, that the increased greenness could be due to the presence of new nature preserves or other environmental restoration efforts. Finally, it is stated that greater greenness is more likely to contribute to less greenhouse gas-induced climate warming rather than more because plants take in more atmospheric carbon than they give off.

Thinking critically about what can be concluded from the different data representations that the learners are examining. Data sets from NASA missions are powerful yet limited by the short ranges of recent years' data they provide, by their spatial resolution, and by the extent to which most of them summarize the measured phenomena in monthly averages. The project is addressing this challenge by providing in the Learning Environment a template known as a Trend Table, which supports student reasoning about different types of data by pushing them to think critically about whether the data on the particular representation they are examining is showing a trend, how strong of a trend, and why; and in the process, to differentiate random or seasonal fluctuations from trend evidence.

Understanding enough about how the data are derived and represented to be able to query the data informatively, interpret the data and draw reasonable conclusions. Some missions produce data from ground stations, hence procedures for the collection of those types of data are relatively easy for a novice to understand. However many of the missions' data come from remote-sensing procedures and from data assimilation models, which are more difficult to understand. To address this challenge, there is a table in DICCE-G providing summary information about each mission data parameter that we have made available in our basic set. This table contains columns identifying the source of data (i.e. remote sensing, ground station, or assimilation model) plus measurement units, approximate spatial resolution, and map palette characteristics. There is also a file of extended help about the data parameters which provides overview information about what defines each data parameter, plus its possible connections to current climate warming. For help in interpreting the different visualization forms (maps, time series graphs, atmospheric vertical profiles) there are short tutorials that the teacher can make available to the students in the learning activities that she constructs in DICCE. Lastly, there is support for making good decisions regarding appropriate ranges of time and ranges of values to be displayed on the different data visualizations. For example, support is provided to help users make decisions about refining queries so that the greatest contrast between variances in the data can be discerned from the query output. Specifically, users are helped with identifying when a default range of values being depicted on a map needs to be customized to show more precisely noteworthy differences in values in the selected region.

There are many data sets that are useful for scientific research but likely to be beyond comprehension for most high school students. Hence, the project team has isolated 27 data parameters that it calls the "basic set" and has delineated them by Earth system domain (physical ocean, ocean biosphere, physical atmosphere, atmospheric gases, energy and radiation system, physical land, land biosphere). The criteria used to select for the basic set were (1) whether the data parameter could be adequately understood by the targeted learners using their prior knowledge, (2) be explainable to them without requiring prohibitive knowledge of chemistry or physics or math and (3) have a clear relationship to current global climate change.

Confusing output. Data output on maps or graphs can be puzzling due to occasional mission instrument malfunctions, missing data, the way some of the data appear in square grids, varying spatial resolutions and mid-mission decisions to change data collection and scaling protocols. To address the challenge of keeping these features from being a roadblock, the team created a "troubleshooting guide" that identifies each type of data representation problem, explains why the problem may be occurring, and finally explains how the user should respond to it.

Technical Performance. On the Giovanni server, there is occasional yet unpredictable slowness when user queries are being processed. Such slowness has to do with traffic on the site and it is beyond the users' control. It can be particularly intimidating to a teacher if the teacher is expecting the students to conduct their own queries. The project is addressing this challenge by setting up the teacher tools in a way that makes it unnecessary for anybody but the teacher to go on to DICCE-G to query the data. The DICCE LE curriculum authoring tool is designed to enable the teacher to present static visualizations of her own prior query results. Nevertheless, there is nothing to preclude a teacher from allowing students to use DICCE-G to query data themselves provided they understand that software performance problems occasionally arise.

User interface constraints. The project team has always been constrained to design novice user pathways within the existing Giovanni website infrastructure because creation of a completely new infrastructure to support novice use has not been an option under the current funding and mission stakeholder structure. To create the pathway, the project team designed the DICCE-G home page to bring up the query map from which users select regions of the world about which to generate visualizations within specified time ranges. This is in contrast to the usual Giovanni portal, where many clicks through individual idiosyncratic mission information are usually needed to bring the user to the same querying tool. The team also embedded into the DICCE G data pathway additional help through links from specific data parameters to extended help texts about those parameters, and navigation to the help text is made aware to the DICCE G user through special DICCE icons. The team has also put created tutorial videos teaching users how to do the core technology tasks in DICCE G, including how to generate the various visualization options (e.g., time series graphs and maps), and how to change the palette colors and data ranges displayed on map output. Two additional videos are in progress about how to make a vertical profile and how to import data table output from DICCE G time series graphs into tab-delimited Excel worksheets for data manipulation and graphing. Soon, these videos will be available on YouTube.

School technology access constraints. Some teachers are would like to engage their students with the data but lack access to sufficient numbers of sufficiently high performance computers. To address this challenge, the team designed the DICCE LE curriculum authoring and delivery tool to not require students to respond to questions on the computer, yet they can read and see the content on the computer or read, see, and respond to on printouts.

Professional community building. It is easy for teachers doing innovative practices to feel isolated from their peers. To address this challenge the project team created a project wiki. The wiki contains (1) a tutorial about how to use the DICCE Learning Environment and the wiki itself, (2) an overview document providing access information to DICCE G, DICCE LE, and the wiki, plus information about NASA glossaries linked to DICCE LE, and (3) access to related climate-related scientific overviews about the key climate change-related topics (atmosphere, carbon cycle, energy budget, land surfaces, ocean, weather, and societal debate about global warming), and (4) sample data images that the team produced from Giovanni about each teacher's region, about the whole world, and about a section of Northern Alaska that is discussed in Education Development Center's Foundations Earth Science curriculum. A General Resources folder on the wiki contains all additional documents that the teachers need access to, such as articles about the different climate change related Earth system phenomena addressed in the DICCE-G basic data parameters, and to files of the various supports for students.

Additional student support. Students may not be able to complete DICCE data-centered activities if they lack the prerequisite knowledge. Hence, the project team identified broad comprehension needs then developed a set of help texts that teachers can make available in DICCE- LE to their students when doing their DICCE learning activities. The help texts address (1) how to interpret the data on the different data visualization options (2) unfamiliar technical vocabulary and (3) the converting of less familiar units of measurement presented in Giovanni output (such as Kelvin) to more familiar metrics (such as Farenheit).

Teacher outcomes so far

Development work advanced far enough along by February 2012 to launch DICCE use with participating teachers. Each teacher had already participated in two meetings designed to get their feedback on early designs and development decisions. Starting in February, each teacher was trained individually by project research team members, including the principal investigator and a senior researcher. Training consisted of the teachers examining printouts of data visualizations that the researchers created of their local areas in conjunction with the climate change schema and trend guide documents. This procedure was carried out as the first step in the training agenda because the researchers concluded that it would be most useful for the teachers to first think conceptually about the data before getting immersed in how to use the software. Hence, the researchers acquainted the teachers with data output and asked them to (1) brainstorm about what patterns they noticed, (2) ponder what potential student learning opportunities existed if the students were also to study the output, and (3) ponder what activities and questions and they could devise to prompt these student learnings. Teachers varied on what types of regional data they took note of. For example, a teacher from New Mexico focused on trends in air temperature and forms of precipitation, a teacher from San Jose California focused on western Pacific sea surface temperatures, and a teacher from San Diego California focused on atmospheric data parameters signifying human influences on the troposphere over the region (ozone, CO2 fraction, and aerosol optical depth). A critical part of the training was to get the teachers to think about what types of questions about their regions are best addressed by examining map output as opposed to output from time series plots and vertical profiles.

Several weeks after the training, an external evaluator conducted interviews with participating teachers to gauge their reaction to the training and ask them their current thinking about how they will use DICCE with their students. Examples of thoughts that the teachers expressed to the evaluator include using DICCE...

- to teach about other science topics in addition to climate change; for example, studying variables about motion or air density in physics, water density in chemistry plus other environmental science topics such as biome diversity and whether the vegetation is changing in the region
- to study the characteristics and effects of sea surface temperature changes during the El Nino years and have students measure the breadth of those changes
- to teach students how to interpret graphs in conjunction with having the students graph counts of familiar objects themselves, such as different types of cars in the parking lot, and in the process think about what should go on the axes and what are the dependent and independent variables.

- to make connections to the carbon and water cycles and to how these cycles affect the students and the local environment
- to connect the data to the Farmer's Almanac and to the students' everyday lives, since many of the students live on ranches., hence very dependent on the weather and climate
- in a culminating activity that would bring in what the students have been learning about increasing CO2 in the atmosphere and its effects
- to teach about how the climate affects the biomes and their biodiversities and how global warming may not mean that every local area is getting warmer
- to reinforce learnings from the curriculum about the oceans, weather and climate, factors affecting climate change, albedo, the Earth system, water cycle, carbon cycle, air currents, and water currents

DICCE is in the middle of the second year of its three-year funding cycle. Participating teachers are finding opportunities to develop and implement their own DICCE activities during the 2011-12 and 2012-13 academic years. On a different NICE grant, DICCE will soon be used among teams of science teachers in several high schools in a large school district in Southern California. The development team is now turning its attention to formulating a bank of assessment items that teachers can select to administer to their students depending on which data parameters they have their students investigate.

Conclusion

THE DICCE project has been dedicated to formulating appropriate technical structures, learning resources, instructional supports, and teacher professional development strategies that make possible fulfillment of the goal of making the data from Giovanni more accessible to high school teachers and students. We believe that critical thinking about the characteristics of climate change through the study of real data is a worthy learning goal and that Giovanni provides a powerful vehicle for doing so. When students know how to look at data output critically against what we know and do not know about climate change and the Earth system in general, they become independent minded informed citizens capable of seeing through the public rhetoric surrounding climate change. So far, results are showing that teachers are capable of being educated about the data and the software and trained to use the DICCE resources in their instructional planning. The next step is to see how well this translates into effective classroom practice. Hence, as the project proceeds into classroom implementation and assessment phases, additional data will be gathered to look at student impacts.