Exploiting the Capabilities of NASA's Giovanni System for Oceanographic Education

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ABSTRACT: The NASA Goddard Earth Science Data and Information Services Center (GES DISC) Giovanni system [GES DISC Interactive Online Visualization ANd aNalysis Infrastructure] has significant capabilities for oceanographic education and independent research utilizing ocean color radiometry data products. Giovanni allows Web-based data discovery and basic analyses, and can be used both for guided illustration of a variety of marine processes and phenomena, and for independent research investigations. Giovanni's capabilities are particularly suited for advanced secondary school science and undergraduate (college) education. This presentation will describe a variety of ways that Giovanni can be used for oceanographic education. Auxiliary information resources that can be utilized will also be described. Several testimonies of Giovanni usage for instruction will be provided, and a recent case history of Giovanni utilization for instruction and research at the undergraduate level is highlighted.

1 INTRODUCTION

The primary challenge of oceanographic education in the 21st century is to integrate fundamental oceanographic concepts, and observations acquired historically in this scientific field, with the increasing amount of observational data that is currently being obtained by researchers and observational programs. Whereas in the past researchers were required to interpolate, extrapolate, and blend data points from single sampling points which were characteristically discrete, and which could be widely separated spatially and temporally, the modern era of increasing sensor coverage and remote sensing provides a much better synoptic overview of dynamic processes.

Oceanographic educators are challenged to adequately cover oceanographic fundamentals in classroom instruction while providing an enironment which allows students to both appreciate the research process and to undertake investigational learning. As many times it is difficult to provide students with more than a brief "hands-on" shipboard research experience (particularly in the context of undergraduate education) the ability to investigate oceanic processes interactively with oceanographic data becomes vital. The widespread availability of computing systems with data analysis capabilities unthinkably powerful a decade ago, combined with a ballooning volume of online oceanographic data, allows new strategic methods to be implemented in oceanographic education.

The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) now proposes that teachers and instructors should consider the remarkable capabilities of "Giovanni" (the GES DISC Online Interactive Visualization ANd aNalysis Infrastructure) for oceanographic education. Giovanni is a system which enables rapid visualization and analysis of remote-sensing data: for the oceans, Giovanni's data consists primarily of biology-related and ocean optical parameters, with some physical data available as well. In the following paper, the advantages of Giovanni, and the areas where it will be most effective, will be described. After evaluating comments of educators who have already utilized Giovanni for oceanographic education, and including examination of an initial dedicated pedagogical example, effective strategies for the utilization of Giovanni in oceanographic education, and a route to encourage such strategies, will be described.

2 THE GOALS OF OCEANOGRAPHIC EDUCATION

The basic goals of oceanographic education have been previously mentioned in the Introduction. Oceanography has a rich history of discovery, and this history should be a thematic element of this field. The ability of early researchers to analyze and determine the principal factors in dynamic oceanic processes, many times based on severely limited observational data, possesses high instructional value.

Traditionally, oceanographic education can be divided into four sub-disciplines: Biological, Physical, Geological, and Chemical. Biological oceanography is concerned with organisms that inhabit the oceans; physical oceanography with the characteristics of water masses and water mass movement, and the physical factors which influence both; geological oceanography studies the setting of the oceans in Earth's geological framework, as well as seafloor and coastal geology; and chemical oceanography analyzes the chemical species which are found in seawater and the chemical reactions that change the concentration and composition of seawater constituents.

It is an obvious statement that these sub-disciplines can overlap. For example, seafloor tectonic processes can introduce heated geothermal fluids into the overlying water, affecting the chemical characteristics in the local environment. Furthermore, these volcanic events feature unique biological realms.

Although Giovanni's oceanographic data is characterized as primarily biological, the nature of this data does not provide significant information about the flora and fauna inhabiting the oceans. Instead, it shows biological patterns in the ocean. These patterns are strongly influenced by physical oceanographic processes – but Giovanni does not show what causes these processes. (Because Giovanni features remote sensing data, it is not widely applicable to the geological and chemical sub-disciplines.) Giovanni is therefore most applicable to the understanding of how physical oceanographic processes influence biological activity in the ocean, an excellent stepping stone from oceanographic basics to more complex oceanographic interactions.

3 THE GIOVANNI SYSTEM

The full (current) Giovanni system is covered by Acker & Leptoukh 2007. Giovanni is described as a World Wide Web-based data exploration system that enables rapid data access, analysis, and visualization online. Researchers are not required to download data files to their own system before initiating analysis and research – a paradigm of the classic data archival system which is currently in flux. By allowing researchers to conduct basic data explorations and analyses without having to first acquire significant auxiliary knowledge, scientific utilization and progress is accelerated.

Giovanni consists of the following basic elements: a) an interactive map for region-of-interest selection; b) a menu of available data products; c) a calendar menu for time-period selection; d) a menu of visualization options; e) visualization-specific options (color palette, axis values); and f) a menu of output options.

The current Ocean Color Giovanni utilizes data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) mission and the Moderate Resolution Imaging Spectroradiometer (MODIS) mission

on the Aqua satellite. All of the observational data products are mission data products or derived products (the NASA Ocean Biogeochemical Model includes some climatological input data fields. The following data products are available:

- Chlorophyll concentration
- Diffuse attenuation coefficient at 490 nm
- Normalized water-leaving radiance (nLw) at 555 nm (SeaWiFS) or 551 nm (MODIS)
- Absorption coefficient of dissolved and detrital matter at 443 nm
- Particulate backscatter coefficient at 443 nm
- Sea surface temperature (MODIS)
- Assimilated chlorophyll and other output fields from the NASA Ocean Biogeochemical Model (NOBM)

Giovanni visualizations include area plots, time-series of area-averaged data, Hovmöller latitude vs. time or longitude vs. time plots, and simple animations. The Multi-Dataset Intercomparison System available in Ocean Color Giovanni provides, in addition, multiple data product area plots and time-series, X-Y scatter plots, and correlation plots. In the current Giovanni system, ASCII text output can be obtained, and access to higher resolution daily swath data is provided. In the next-generation "Giovanni-3", Hierarchical Data Format output will also be available.

4 CURRENT USAGE OF GIOVANNI IN OCEANOGRAPHIC EDUCATION

4.1 *Examples from Oceanographic Educators*

Educators from the University of Plymouth (UK), the University of South Carolina (USA) and Bigelow Laboratory for Oceanic Sciences (Maine, USA) have described Giovanni as a very useful tool for their educational efforts. Giovanni was described as research/exploratory tool at the University of Plymouth and Bigelow, allowing students to investigate regions and processes of interest with remarkable ease. At the University of South Carolina, undergraduate instruction included the generation of designated Giovanni output types for specific regions to illustrate oceanic processes in those regions. In all cases, the educators noted that the ease-of-use and the capability that it provides to students with limited computer experience was clearly advantageous. The experience of these researchers indicates that Giovanni can be easily added as a research tool to oceanographic classrooms.

4.2 *A dedicated pedagogical example at the United States Naval Academy*

In the first months of 2007, a remote-sensing class at the United States Naval Academy (USNA) participated in an initial pedagogical test of Giovanni usage in oceanographic education. The students were first administered an oceanographic "knowledge survey" consisting of questions answerable with Giovanni, and were then provided with an interactive lecture demonstration of Giovanni. Following the demonstration, the students briefly described their impressions of the system and their expectations of it.

Subsequent to the demonstration, the class instructor created a collaborative research project which utilized Giovanni as the investigative tool. The environment of the Taiwan Strait and Luzon Strait, influenced by monsoonal circulation, was selected for investigation. Four research areas were designated: the "North Box" north of Taiwan; the "East Box" (analyzed by the instructor) east o f Taiwan, the "West Box" in the Taiwan Strait west of Taiwan, and the "South Box" south of Taiwan. The students were instructed to generate multiple data product time-series plots of chlorophyll *a* concentration, nLw(551), and K490, and SST, examine correlations, and to provide initial interpretations. Student groups provided a demonstration of their research results when the project was completed. All of the visualizations were reportedly generated during a single laboratory period.

An example of a student-generated figure from the "West Box" is shown in Figure 1.

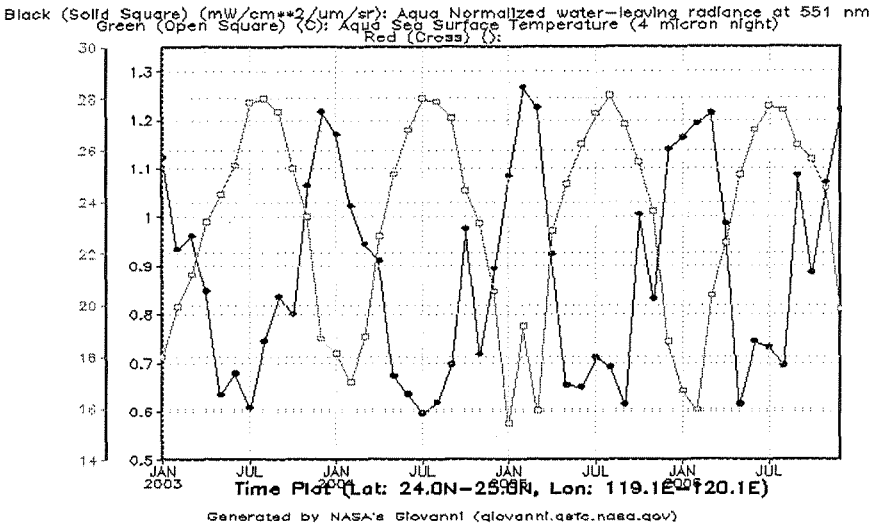

Figure 1. Time-series plot of nLw(551) (black) and SST (green) in the "West Box" located in the Taiwan Strait. A significant negative correlation is noted, calculated by Giovanni to be -0.80.

This particular figure shows the significant negative correlation between nLw(551) and SST in the West Box, where strong winter monsoonal winds transport coastal sediments southwest along g the coast of mainland China. nLw (551) is particularly useful for observing reflection from inorganic particles (as opposed to absorption by chlorophyll in phytoplankton in the 443 nm band).

Student conclusions from this research project were insightful. Examples:

- "Monsoonal variability in SST observed at all four locations. Greater range in SSTs in Taiwan Strait and north of Taiwan, with much colder SSTs during winter monsoon."
- "nLw551 is relatively high and negatively correlated with SST in the North and West boxes, much weaker and more variable in the East and South boxes."
- "In Taiwan Strait, K490 is also strongly correlated with nLw551. Chl *a* algorithm in Taiwan Strait may be inaccurate due to presence of suspended sediments, likely advected southward from the Yellow Sea during the winter monsoon."
- West Box: Moderate negative correlation between SST & Chl *a*, strong negative correlation between SST & nLw 551"

In the research presentations, unusual patterns were observed and discussed, providing opportunities for more detailed examination (if instructional and laboratory time permit).

Following the research project presentations, the students were shown how to use Giovanni to address the questions in the knowledge survey, and all students answered a greater number of questions on the survey correctly following the use of Giovanni. At the end of this exercise, the students completed a brief survey regarding their use of Giovanni, and evaluated their expectations. All of the students indicated that Giovanni met or exceeded their expectations regarding ease-of-use and facility of visualization generation and analytical capability. (These results will be preserved until additional classroom experience can be obtained, to fully demonstrate and evaluate Giovanni usage in this setting.)

5 DETERMINING EFFECTIVE USAGE METHODOLOGIES FOR GIOVANNI IN OCEANOGRAPHIC EDUCATION

The descriptions from oceanographic educators, and our initial pedagogical trial in the USNA remote sensing class, provide strong indications that Giovanni can be an effective educational tool in

this field. It is therefore useful to consider what the most effective usage methodologies will be. Four basic usage methodologies for Giovanni can be described:

I. **Guided answering of questions.** Provide a question, and show students stepwise how to utilize Giovanni to answer it.
II. **Unguided answering of questions.** Provide a question, let students figure out how to use Giovanni to answer it.
III. **Guided research**. Provide a research topic or area; tell students what functions to perform for analysis.
IV. **Unguided research.** Provide a research topic or area; let students utilize Giovanni as they wish to investigate it.

We advocate Guided Research (if time permits) as the most effective methodology. Giovanni can certainly be used to answer questions, but this does not fully demonstrate its usefulness for research. Using Giovanni in the Guided Research methodology can illustrate concepts and regional oceanographic processes with the student performing their own investigative process. This method reinforces knowledge better than fact acquisition, and also increases awareness of how remote-sensing research is conducted, in addition to providing basic practice in the conduct of general scientific research.

Unguided Research is also an excellent methodology for Giovanni in oceanographic education, provided that fundamental concept knowledge has already been attained. As has been demonstrated in several oceanography programs, students can quickly and easily assemble research projects with Giovanni visualizations and analyses, following a "learning by doing" (emphasis on student understanding through inquiry) scientific education model that is strongly advocated by the Science Education Standards authored by the National Research Council (National Committee on Science Education Standards and Assessment, 1996).

6 AN EFFECTIVE STRATEGY FOR IMPLEMENTING GIOVANNI IN OCEANOGRAPHIC EDUCATION

Skilled teachers in all disciplines must strike a balance between the time spent teaching students to use a research tool and the instructional requirements of an entire course of study. Furthermore, teachers will always need time to learn how to use a research tool with sufficient skill to be able to instruct students in its use. Time and course demands limit the ability of teachers to incorporate new technology into a course, even if such incorporation is advantageous.

In terms of oceanographic education, we have discussed previously that Giovanni's capabilities do not fit neatly into the core disciplines of oceanography. It is most applicable to demonstrating how physical oceanography influences biological patterns and dynamics – an intermediate knowledge level of this field. Thus, it is important that students have a sufficient grasp of oceanographic fundamentals to be able to fully comprehend and interpret the data visualizations and analyses that Giovanni so easily creates.

An established and successful curriculum in an oceanographic course (or any scientific field) will also stand as a barrier to the implementation of new technology like Giovanni. teachers who have taught courses for many years know what works – and they cover the material they have determined to be necessary. Adding a new instructional element such as Giovanni usually requires replacing an instructional element that has functioned well in the past with something which functions as good, or better, than the element being replaced. And if the element being added is only as good as the element being replaced, there is little value to the teacher to make the required effort for the change.

In order to foster a greater use of Giovanni in oceanographic education (or other Giovanni interfaces applicable to other fields of earth science) it should be a relatively effortless process for the teacher to incorporate Giovanni into a course of study. To make this possible, we recognize that what is needed is a Giovanni "cookbook" – providing "recipes" for the investigation of a multitude of regions and oceanographic processes. Once such a cookbook is available, a skilled chef – the classroom instructor – can select the appropriate recipes which meet the educational requirements of a particular course, and "flavoring" the instructional process with their own skill and expertise. A recipe would indicate the data products, visualizations, regions, time periods, etc. to produce the desired output – *which the student interprets*. This is the Guided Research mode of instruction which we feel best exploits Giovanni's capabilities for oceanographic education.

7 CONCLUSION

Giovanni has reached a level of maturity and acceptance in the scientific and educational community that the creation of a Giovanni "cookbook" should now become a recognized goal, to facilitate wide use for education and to fully exploit the capabilities of this remarkable system. However, forward-thinking instructors and educators can (and will) begin to develop such recipes on their own. The staff of the GES DISC will assist any educators attempting to utilize Giovanni as we work toward providing more resources devoted to the use of Giovanni for oceanographic and earth science education.

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URLs

Goddard Earth Sciences Data and Information Services Center (GES DISC)
http://disc.gsfc.nasa.gov/

Giovanni: http://giovanni.gsfc.nasa.gov/

Ocean Color Giovanni: http://reason.gsfc.nasa.gov/Giovanni/

Laboratory for Ocean Color Users: http://disc.sci.gsfc.nasa.gov/oceancolor/locus/index.shtml