Exploring Visualization in the Geosciences - EXPLORES!

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EXPLORES! Imagery Applications

In this new and improved version of EXPLORES!, which has existed since 1991 (Ruscher et al. 1993), we will expand greatly the work that has been accomplished to date in EXPLORES!, by performing the following tasks:

- Develop new instructional methods for teaching imagery (content and how did we get it?) from the following scientific platforms: NOAA (polar orbiting weather satellite), GOES (geostationary weather satellite), Landsat (earth resource) satellite, MODIS (Moderate-Resolution Imaging Spectro-radiometer), TRMM (Tropical Rainfall Measurement Mission), and QuikSCAT.
- Develop necessary linkages between radar and satellite imagery, since radar imagery is now ubiquitous on the WWW, and since two of the satellites used are actually radars (one for precipitation, one for wind).
- Select a cadre of 20 teachers to participate in the two-year project.
- Develop and teach a distance-learning course entitled "Geoscience Imagery in the Classroom" for these teachers.
- Adapt materials previously used in the EXPLORES! program for this new project.
- Involve new teachers in collaborative instructional methods and action research with their students.

In addition to alignment with the national (NSES) and state (SSES) science education standards, the proposed project will seek alignment with various competencies and objectives of the science portion of the Miami-Dade county Competency-Based Curriculum (CBC)[2]. Several of the competencies include, at the elementary (5th grade) level for example, describing the various aspects of the water cycle as well as, at the middle and high level, describing how earth/space science interacts with technology and society. Some of the objectives, which relate directly to the competencies, include relating how technological problems often create a demand for new scientific knowledge and that new technologies make it possible for scientists to extend their research in a way that advances science, as well as describing how technological devices (satellites, submersibles, sonar, decompression chambers, etc.) have enabled scientists to gather data and formulate hypotheses concerning oceanography, respectively.

a. Satellite and Radar Platforms

In this section we describe examples of how imagery from the six meteorological observation systems have been used in previous projects, and/or how they will be used in this project. Imagery from both NOAA polar-orbiting and geostationary satellites are used in the EXPLORES! program, and imagery from the Landsat satellites are used in the GLOBE program; we also propose ways in which teachers can use imagery from three other important satellites, as well.

i. <u>NOAA</u>

Weather satellite ground receiving stations are designed to receive either Automatic Picture Transmission (APT) imagery from polar-orbiting weather satellites or Weather Facsimile (WEFAX) imagery from geostationary (GOES) weather satellites. Direct readout ground stations are built by adding radio-receiving components to existing personal computers. The NOAA polar-orbiting satellites provide infrared and daytime visible images twice per day at any location at a resolution of 4 km (infrared and visible). Because the polar orbiters can be easily tracked, it is recommended that beginning and novice students using a ground station begin with a basic station capable of accessing images from these satellites (Taggart 1990). This system, called the APT system, will expose students and teachers to the basics of satellite tracking, image transmission, and ground station receiver capabilities. High resolution visible imagery from APT systems have proven useful in the interpretation and analysis of weather phenomena on the scale of sea-breeze circulations and thunderstorms up to the scales of phenomena such as mid-latitude cyclones and hurricanes. A more advanced, higher resolution (1.1 km) system is also available, called High-Resolution Picture Transmission (HRPT), but its cost is upwards of $10,000. In the EXPLORES! Program, we have provided each of our participating schools with APT ground stations, and much of our prototype curricula are based on these image types, an example of which is shown in Figure 1. We propose to continue supporting APT direct readout, since this image type will continue to be supported by NOAA through at least 2010. Using the FSU HRPT satellite receiving station (installed successfully in April 2002), NOAA, and other HRPT data servers, however, we will develop learning activities that illustrate the effect of satellite image resolution on our ability to discern features. In this way, we will integrate knowledge of scale, a fundamental idea present in teaching standards, into lessons. We will start with very blocky pixels on the order of 100 km and move progressively to smaller scales (down to 1 km) in our treatment of satellite imagery; we will be able to resolve much finer scales on radar, MODIS, and Landsat imagery.

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[2] http://portal.dadeschools.net/cbc/index.htm

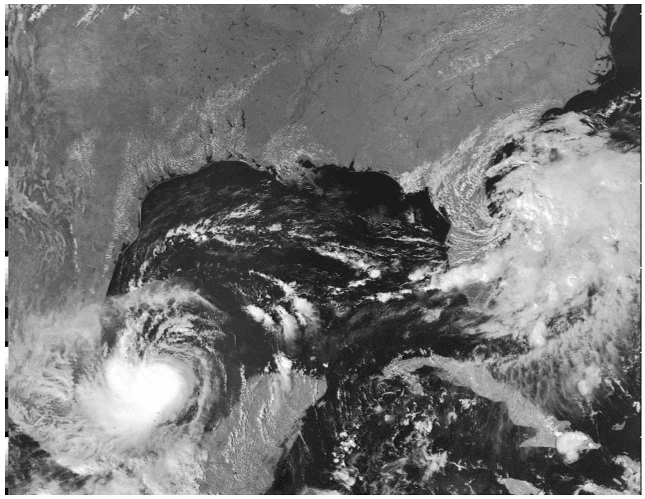

Figure 1. *Example of APT image received from a EXPLORES! Ground-station. This is one of the first images sent from the NOAA 16 satellite. Image pixels are 4 km. Hurricane Keith (near Texas) and Tropical Storm Leslie (near Florida) are shown in this image, from 4 October 2000.*

ii. GOES

An adaptation of a school-based satellite ground station with broader educational appeal includes the ability to receive and animate data from the series of satellites known as GOES (Geostationary Operational Environmental Satellites). GOES-East (GOES 8) is currently positioned approximately at an altitude of 38,000 km above the equator at 75°W longitude; it will be replaced by GOES-12 on April 1, 2003. GOES-West (GOES 10) is located at 135°W at the same altitude. Both these satellites carry the weather facsimile (abbreviated WEFAX) instrument which processes daytime visible and infrared satellite images (continental US imaged at a resolution of 4 km in both visible and infrared channels) sectored by quadrant of the visible earth, tropical sectors, polar-orbiter composite images, weather charts, and informational bulletins. WEFAX capability requires a special antenna configuration that is added to the existing APT ground station. In addition to imagery received by the satellite itself, GOES East also transmits imagery from the Meteosat satellite, operated by the European Meteorological and Satellite Agency (Eumetsat), which includes daily imagery from Europe and Africa. GOES-West (GOES 10) also transmits imagery from the Japanese GMS satellite, covering the Pacific Ocean and East Asia. This capability allows users to receive and process weather satellite imagery on a global scale.

In the EXPLORES! program, we have typically begun our installations by providing the APT equipment to teachers from participating schools, and we upgrade in the second or later year to the WEFAX capability, upon evaluation of the use of the ground station in the school. This is how the program has worked, very successfully (Tebo 1993; Taggard 1995; Graham 1995) for many years in Florida. Beginning in 1998, we have invited teachers to join the program from other states, and we now serve teachers in Alaska, Montana, Michigan, and Georgia as well as Florida. In 2003, however, NOAA will begin to drop support for the WEFAX broadcast in favor of direct readout of the high resolution GOES variable resolution (GVAR) imagery, which has a resolution of 1 km for visible and 4 km for infrared wavelengths. Very successful web-based imagery servers have been established (e.g., Arnold et al. 2000) which enable the user to selectively navigate their region and then produce animations. However, very little is available online to help teachers to build their self-confidence in helping students to interpret what they see. Towards this end, EXPLORES! Will continue to provide weather satellite image interpretations, only focused on broader areas across the nation, not just in the southeastern U. S., as has been our practice for our statewide effort. Such interpretations were standard products issued by NOAA until the early 1990s, when federal budget cuts forced closure of the NOAA satellite field service offices. These interpretations[3] are among the most widely visited pages on the EXPLORES! WWW site. Figure 2 illustrates an example GOES 8 image from Florida from the new FSU GVAR station, which would be utilized in the project.

[3] Available at http://www.met.fsu.edu/explores/imagery/

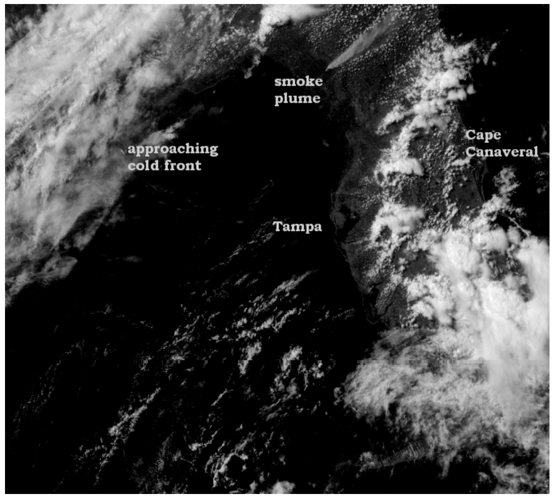

Figure 2. *A weak trough of low pressure is present over south Florida, producing clouds and precipitation as shown in this GOES 8 visible image from February 2002, from the FSU GVAR ground station. Image pixel resolution is 1 km. A cold front is draped across the panhandle of the state, and smoke from a forest fire is being blown by southwesterly winds aloft.*

iii. Landsat

Landsat is a series of satellites designed and launched by NASA and the U. S. Geological Survey (USGS), respectively, to image the earth's surface and monitor its changes. The GLOBE program has been using geographic information systems (GIS) software to examine Landsat photographs in their training and Land Cover assessment protocols for some time, with great success. Schools receive a 15 km × 15 km image from the Landsat 5 satellite centered on their school, with pixel resolution of 30 m. These photographs are used to help students and teachers monitor land cover and land use in their GLOBE study area, defined as the area covered in their Landsat image. A Landsat 7 image of Miami, Florida is shown in Figure 3. This picture was taken in 2000; the *false color* image is one way of examining areas that are dominated by healthy vegetation, shown as bright red pixels.

Figure 3. *Image of Miami as observed from the Landsat 7 satellite. Bands 4, 3, 2 are used here to develop a false color image that shows vegetated areas as red with healthy vegetation bright red. Miami is one of the locations where the FSU GLOBE training team conducted statewide workshops for GLOBE in 2002.*

We propose to develop learning strategies based on the imagery centered at each of the 20 participating project teachers' schools. As a certified GLOBE training team, we will use the GLOBE model as a means to introduce Landsat imagery and GIS software to schools. Many excellent resources have already been developed for this purpose by GLOBE and are available online in the GLOBE Training and Resource Room[4]. We will extend this work by examining changes

[4] http://www.globe.gov/

over time, and by correlating these changes to soil moisture and drought indices such as the Keetch-Byram Drought Index (KBDI) or the Palmer Drought Severity Index, both of which are available online[5]. We will acquire the imagery for each school necessary for them to observe and understand the effects of drought on vegetation health, and have them develop research investigations that will enable them to examine how drought evolves. Using GLOBE, NOAA, and USGS data, they will initiate this research project through the web-based course mentioned previously, which will include enough GLOBE training to certify participating teachers in GLOBE.

iv. Radar – WSR 88D NEXRAD

As part of its modernization program of the 1990s, the National Weather Service (NWS) established a network of over 100 Doppler Next Generation (NEXRAD) WSR 88 D weather radars. Data from this network of radars became available free of charge to anyone on the WWW in 2001, and we propose to exploit the freely available data for all users. We will use materials developed by groups such as the University Cooperation for Atmospheric Research (UCAR) / Cooperative Program for operational Meteorology (COMET)[6] (e.g., Wetzel and Ruscher 1996), the National Weather Service, and University of Oklahoma's radar team to tailor a series of activities for teachers to learn how to use radar in their classes, in particular how radar works and how to distinguish among the various image types (e.g., reflectivity, velocity, echo tops, precipitation, etc.). We will also tie radar and satellite imagery together for teachers when NOAA conducts Rapid Scan Operations (RSO) with GOES 8 and 10 (the satellite images every 7.5 minutes as opposed to the normal 15 minutes) or Super Rapid Scan Operations (SRSO – the satellite images every 1 minute) modes (received in real-time by FSU), which will enable us to merge satellite and radar imagery into superimposed loops which are quite informative in terms of the types of structures that one can (and *cannot*) see from one type of image or another. A sample reflectivity image from Twin Lakes, Oklahoma during the severe tornado event of May 1999 is shown in Figure 4. Some types of images available have resolution of 125 m. Treatments of radar data for educators are weak at best. Notably, the best-selling college-level introductory meteorology text (Ahrens, 2000) has several errors in figures and captions that purport to describe radar velocities from WSR 88D interrogations of severe thunderstorms. In fact all of the figures are actually showing reflectivity! Our access to WSR 88D raw data will be made available through our co-location with the NWS office in Tallahassee, which is now located in our building on the FSU campus.

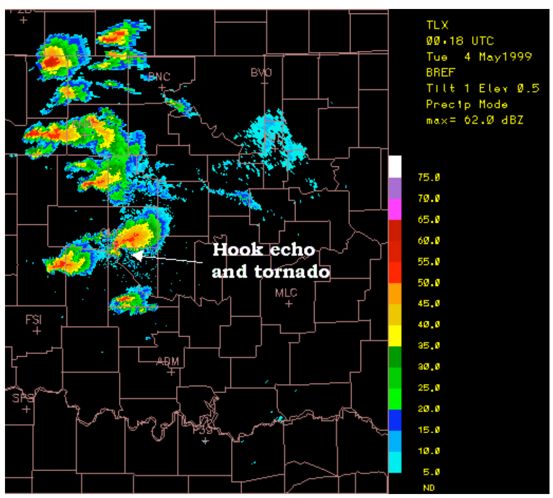

Figure 4. *Doppler WSR 88D reflectivity image from Twin Lakes, Oklahoma NWS office at 0018 UTC, 4 May 1999. A very strong tornado is indicated on radar by the presence of a "hook echo" and other reflectivity signatures as indicated. Image provided by the Oklahoma Climatological Survey to the OUN NWS office. Image from* *http://www.srh.noaa.gov/oun/storms/19990503/intro.html*

v. MODIS

The Terra satellite was launched by and for NASA in late 1999, and its principal scientific payload is the Moderate-Resolution Imaging Spectroradiometer (MODIS)[7]. Terra flies in polar-orbiting sun-synchronous orbit and scans the entire Earth every two days. Imagery from MODIS is available at resolutions up to 250 m and many special types of images have already started showing up on the WWW. Its partner satellite, Aqua, is scheduled to be launched

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5 http://flame.fl-dof.com/fire_weather/kbdi/

6 http://www.comet.ucar.edu

7 http://modis.gsfc.nasa.gov/about/index.html

later this spring, providing two imagery sources for this high resolution capability to image Earth's surface and cloudy atmosphere. An example (Figure 5) shows far greater detail than is available from conventional NOAA or GOES satellite imagery, and prompts many questions on the resulting structures.

vi. Other Imagery Sources

By introducing ground-based radar systems with our WSR 88D materials, we will have a natural means to establish activities that will allow teachers to use imagery from the geostationary Tropical Rainfall Measuring Mission (TRMM), which carries a radar instrument[8]. TRMM is a joint U. S. /Japan program launched in 1997 which is still providing outstanding imagery of clouds, precipitation, and lightning. By using space-based radar, meteorologists are able to discern those clouds that are actively precipitating from those which are not. This is particularly helpful in remote areas or in areas where meteorological radars do not exist.

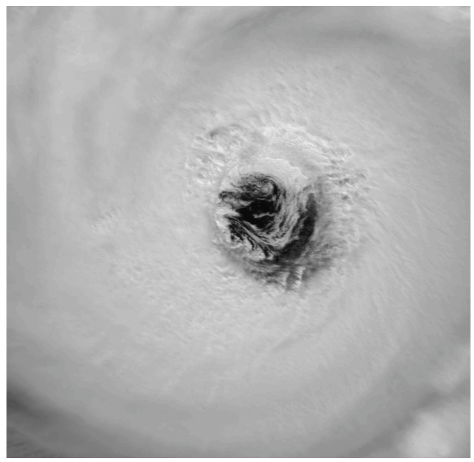

Figure 5. *A close-up of the eye of Hurricane Erin on 9 September 2001. Note the small-scale vortices present in the eye in this high-resolution image (resolution 250 m). This might motivate the question: Which one (if any) of the apparent vortices represents the center of the storm? Courtesy University of Wisconsin, from http://www.ssec.wisc.edu/media/spotlight/Erin_modis-1.html*

QuikSCAT

Another space-borne radar instrument is the SeaWinds instrument aboard the QuikSCAT satellite, which was launched in 1999[9]. NASA's Jet Propulsion Laboratory (JPL) manages this project. With this instrument, surface wind information is extracted by a powerful 13.4 GHz radar examining the ocean surface for roughness; variations in roughness change the way in which radar waves are reflected from the ocean surface, which can be related to wind detection. We will develop new materials for the WWW that will teach how QuikSCAT imagery is different from other types of imagery used in the project. This can be very confusing for teachers who have not had a great deal of training in the geosciences or in remote sensing, according to our experiences with teachers working with only two types of weather satellite imagery. Figure 7 shows QuickSCAT surface winds over the Atlantic Ocean as observed by the SeaWinds instrument.

b. Utilization of Imagery in the Classroom

Although meteorology is not traditionally considered a core academic subject, it is clearly a part of everyday life which affects all students in terms of what they will wear to school, and in many cases, it affects their parents' livelihood (e.g., in Florida, some of the job classifications which are weather-sensitive include outdoor contractors, fisherman, travel and tourism industry workers, electric utility workers, water management personnel, natural resources personnel, etc.). Furthermore, meteorology and climatology are integrally related to social studies curricula at the elementary school level,

[8] http://trmm.gsfc.nasa.gov/images_dir/images.html

[9] http://winds.jpl.nasa.gov/missions/quikscat/quikindex.html

earth/physical science at the middle school level, and earth science at the high school level. Aspects of meteorology such as ozone depletion and acid rain also fall into the area of chemistry, actions of forces are applicable to physics classes, technical aspects of practical meteorology are often used in mathematics problems, and aspects of physical oceanography as viewed from satellites (such as the Gulf Stream or Loop Current) are often taught in a marine biology component of a traditional biology course.

In a relatively recent summary of nationwide educational standards, Kendall and Marzano (1996) document no less than 40 specific references to weather and climate as being critical parts of pre-college curricula and understanding. The staff and participating teachers in the EXPLORES! program have over ten years of experience developing tailored and general curricula for use at all levels and in a multitude of class types for the pre-college teacher. The proposed project will serve the needs of the interactive distance learner using a particular type of educational technology to improve their students understanding of complex scientific ideas. At the same time, weather satellite imagery can be used to improve interactions at local schools with business and government partnership programs, sometimes bringing local private and public sector professionals into the schools to assist teachers when needed. Distance learning strategies are also used as a direct instruction and support mechanism in this project, and it is one that our teachers say sets us apart from most workshops or projects they have participated in. Our support system is focused on ensuring that the technology works, is useful to the teacher, and we offer continued good information about its uses, and offer opportunities to meet with staff and other teachers throughout the school year.

By using imagery from six different types of satellite and radar platforms, we believe we will provide ample opportunity for students and teachers to understand how a large portion of the electromagnetic spectrum (visible through microwave) is used to explore the planet Earth and its atmosphere. Since many of the satellite platforms are NASA-based, substantial educational materials already exist to help teachers understand these individual missions. We do not propose to duplicate these fine materials, which are generally mission-specific. Our materials will be developed with tie-ins to the other imagery types throughout, so that teachers have a great support system for understanding the various differences and capabilities of platforms.

Acknowledgements

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