P2.30 DIRECTMET® GIS : REAL-TIME INTEGRATION OF METEOROLOGICAL SATELLITE DATA INTO THE WORLD OF GIS.

George Schwenke*, Global Science & Technology, Inc. (Greenbelt, MD) and Broadneck Senior High School (Annapolis, MD); and Ron Boyd, Paul Gifford, Eduardo Valente Jr., Eugene Shaffer, and Chris Dobbins, Global Science & Technology (Greenbelt, MD)

Abstract

Meteorologists have used satellite imagery to understand weather events and patterns for many years. These images typically have a "base map" merged into them, providing basic geo-referencing. GIS technologies and data have matured in the last decade as well, and highly-interactive programs allow users to display, manipulate and analyze many types of data. The authors have developed a new Java-based application called DirectMet®GIS which integrates the display and manipulation of GEO meteorological satellite data within the capabilities of a GIS environment. This system provides visualization of all standard GIS formatted data, including meteorological information, and presents users with an intuitive GUI which facilitates the use and understanding of the information.

DirectMet®GIS is already in use in K-12 education, university-level instruction, and several government and private organizations. The presentation provides information about these applications, lessons-learned from application development, and challenges for future work.

1. Introduction

Meteorological satellite imagery has been used in operational meteorology and oceanography since shortly after the April 1960 launch of the TIROS 1 satellite. Since that time, numerous satellites with ever increasing capabilities and sophistication have been developed and deployed. “Weather” satellites provide valuable real-time cloud images, and they also can image areas not covered by clouds and sense such meteorological variables as water vapor or surface temperature. Most importantly, coverage includes the 70 percent of the earth's surface covered by water where few surface observations can be made.

Almost as soon as the first fuzzy images began to appear on television weather broadcasts and in newspapers, educators saw uses for these “pictures of the Earth”.

Corresponding author address: George W. Schwenke 7855 Walker Drive, Greenbelt MD 20770 e-mail: schwenke@gst .com

Students, especially in the kindergarten through 12th grades (often referred to as “K-12”) learn much better if they can see a picture. Lessons on Earth Science and weather became more interesting and more understandable when the cold front was not just a concept on the blackboard, but a line of big thunderstorms on a picture taken just minutes ago!

The pictures are just as exciting and interesting to professional meteorologists and other scientists who use them in their daily operational work or research. Present day uses of meteorological satellites would have seemed unthinkable just a decade ago - we now routinely sense or derive from sensed data information about a wide range of important meteorological and oceanographic parameters such as:

- Aerosols
- Surface vegetation
- Snow and Ice (land & sea)
- Photosynthetic activity Ozone
- Atmospheric soundings
- Precipitable water
- Rainfall rates Surface winds over water
- Thin cirrus
- Atmospheric chemistry
- CO_2, Methane

2. Background

Prior to looking at the applications of meteorological satellite imagery to education, it is best to briefly review *how* people learn. This will help understand how satellite imagery and GIS data can enhance the learning process.

Many educators and psychologists identify three distinct types of learning:

- Visual Learners – learn through seeing
- Auditory Learners – learn through hearing
- Kinesthetic Learners – learn through moving, doing and touching

The needs of each of these types of learners have to be addressed in an effective classroom. Many students employ more than one learning style at once, but most tend to have a predominate mode for their learning. In the K-12 environment, many more students learn effectively through “hands-on” or kinesthetic learning than either of the other two; thus many well-structured curricula incorporate a variety of kinesthetic activities. These are often accomplished in a group activity, a process generally referred to as *cooperative learning*. It's enjoyable to watch a group of students engaged in an interesting cooperative learning activity – they will work together, as a team, and individual students will assume the different roles required to make the task work. For example, one student may operate the computer, another may record results, a third may be talented in drawing and design and prepare the report or presentation, and a fourth may feel comfortable actually giving the presentation of results.

Another important consideration for choosing a learning tool (such as a meteorological satellite image) is the structure in which the tool will be employed. In a general sense this structure is the curriculum for the given course, which specifies the particular topics to be taught as well as the order in which they will be discussed. Curricula are developed in response to the various national and state standards which provide high level direction for the content.

A popular teaching strategy is called the "5-E's". This approach uses a series of steps to interest the students, investigate the content, and assess the results. Steps in one version of the "5-E" are:

- **Engage** – get the students interested in the content.
- **Explore** – explore the material. Teacher-initiated, student-accomplished exploration is best.
- **Explain** – explain what is being observed and why it is happening, based on what has been learned.
- **Extend** – apply the knowledge to other areas of study, other phenomena, or other places.
- **Evaluate** – see what has been learned. Review weak areas.

Topics related to Earth and Space Sciences are especially amenable to the "5-E" approach. Images of hurricanes, tornadoes, blizzards, floods, earthquakes quickly catch the attention and interest of all students, and they are usually well motivated to learn more.

Real-time GOES imagery and GIS data easily provides this "hook". It also provides the tools to explore, explain and extend. The lead author teaches a high-school level (10th grade) course called "**Earth and Space Systems Science**", developed through a collaboration of Anne Arundel and Montgomery counties (Maryland) and NASA's Goddard Space Flight Center Education Office. The DirectMet®GIS meteorological satellite imagery system has been evaluated in support of part of this course as taught by the author in his classroom (specifically, the "atmosphere" and "geosphere" units). Please note DirectMet® is not specified as a necessary component of this course – its use by the author was only an evaluation of how well it could provide support for the course and meet the needs of his students.

3. Earth and Space Systems Science

The course mentioned above was developed in recognition of a growing national movement towards a "systems" approach to the Earth sciences. Recent changes in national standards reflect this change. The curriculum documents for the course used in the author's county (Anne Arundel County, Maryland) provide a definition for Earth/Space Systems Science:

" ***Earth/Space Systems Science emphasizes the dynamic interrelationships between the atmosphere, the geosphere, the hydrosphere, the biosphere and the earth-universe system. There is a strong emphasis on internet-based and technology activities, and laboratory activities. Science skills and processes learned in this course prepare for continued development of scientific inquiry in other science disciplines. A partnership with the Goddard Space Flight Center and collaboration with Montgomery and Anne Arundel County Public Schools provides enhanced richness to the learning activities. This is a core course and prepares students for the upcoming high school assessment test in earth/space science. This course is recommended for all students.*** " (underlining added)

The underlined words are the key to how a "hands-on", real-time, system for data acquisition, processing and display like DirectMet®GIS can add so much to the success of both students and teachers.

Meteorological satellite imagery has thus found its way into the Earth science/weather curricula being taught in many K-12 schools, especially in grades 6-12. The images are frequently used as a starting point (the "Engage" step!) in a lesson about the structure of synoptic scale and mesoscale weather systems. A teacher might show a current image of a mid-latitude cyclone, and then focus on the surface and upper air features associated with it. Hurricane images are excellent engagement devices when starting a lesson. The data used for this purpose is generally a GOES image, because of its consistent coverage areas and more frequent updates (as compared to polar orbiting satellites). NASA data from research satellites and sensors like Terra, SeaWiFS, MODIS or TOMS is used for "special cases", with images taken from such excellent sources as NASA's Earth Observatory. These images are rarely used "real time" in schools because of greater difficulty in obtaining them quickly.

GIS software is fairly new to schools. Companies such as ESRI have made available introductory products like Arc Voyager, Intergraph has a similar but more limited product called GeoMedia, and NASA/GSFC's Image 2000 performs many similar functions. GIS software requires fairly robust computers, a factor which has limited their installation in all but the newest school computer laboratories. However, students are generally very interested in GIS-type applications, from simple steps like finding their home or school in a county street GIS file, to more complex studies involving vegetation and soil types, land use, and census data interpretation. K-12 students learn software applications intuitively, much like younger children frequently learn foreign languages faster than adults.

DirectMet®GIS merges these two "high-interest" areas for K-12 education. For example, if students were able to analyze information detailing soil porosity, land elevation and land development using GIS data, and then combine these in the same application with current enhanced infrared (IR) GOES imagery and Doppler weather radar precipitation intensity and history, they could predict areas subject to flooding. Even more importantly, they could analyze the areas which DID experience flooding, and learn how their analysis methodology worked. This is "real world" learning, and ties together many important curriculum disciplines and technologies, and learning processes. DirectMet®GIS draws upon the heritage of earlier (non-GIS enabled) DirectMet® systems, a full appreciation of the new technologies finally available for use in a classroom, and careful consideration of how a classroom actually *works*.

Table 1 show below summarizes selected areas from newly-revised state and national standards for Earth and space science education, and shows how capabilities built into DirectMet®GIS address them through capabilities built into the program:

Science Content Standard	**DirectMet®GIS *Capability***
Students will analyze geophysical data form hypotheses about natural events they see occurring in the data	Image visualization and looping; image enhancement for cloud or surface temperatures
Students will employ technology in the analysis of scientific data	Multiple correspondences
Students will use GIS images and software to visualize Earth science data sets	Use of GIS layers merged with raster meteorological satellite data
Students will employ real-time data in the study of Plate Tectonics	Use of GIS (National Earthquake Center) data plotted on a US map

Table 1: Correspondence matrix between Earth/Space standards and DirectMet® GIS

4. Overview of DirectMet®GIS

DirectMet®GIS is a Java based multi-platform capable application. It draws from the heritage of the earlier DirectMet® "classic" application[5], but has many more capabilities and functions. DirectMet® "classic", which is still sold and in use around the world, provided basic background maps from the World Data Base data set, and allowed users to add cities or locations of interest. It did not allow the use of standard GIS data sets, and it was more limited in terms of the enhancements which could be applied to the images, and in terms of how easily these enhancements could be added.

A schematic of DirectMet®GIS is show below in figure in figure (1):

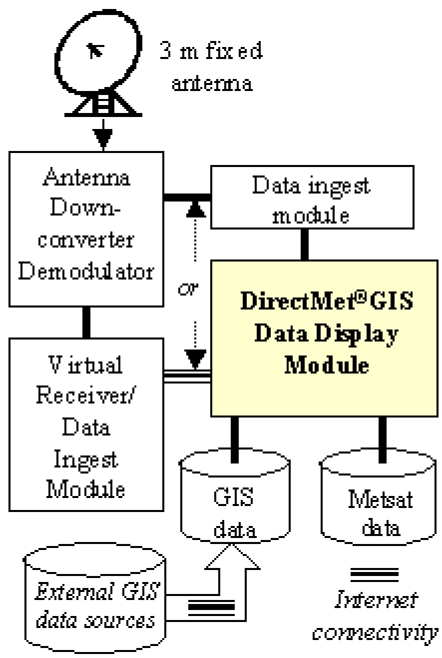

Figure 1: Simplified DirectMet® GIS Schematic

There are two ways DirectMet® GIS can receive its input signal. The system can be used with an installed Parabolic mesh dish antenna (2° bandwidth) and associated electronics, or it can receive the data from a remote computer itself connected to a antenna and receiving system. This second configuration is called the Virtual Receiver. The first configuration is a complete "stand-alone" system which does not require an internet connection and provides greater customization; the second requires internet connectivity but has the advantage of allowing one antenna to support multiple display systems.

DirectMet®GIS is engineered to receive the signals from GOES-East, GOES-West, or GMS. The receiving system must be configured for the desired satellite, and must be aligned for optimum signal. The signal is processed through a down converter and demodulator, and then input into the DirectMet®GIS Data Ingest module or server providing Virtual Rreceiver support. The data management functions within DirectMet®GIS build databases of all available GIS data and all satellite images which have been received. The user specifies the areas of coverage desired (ranging from full disk to a small subset for local area interest) and the desired bands (Vis, IR1, IR2, NIR, Water Vapor), and the data are automatically acquired. This high degree of automation makes the system ideal for an educational environment where students and teachers may not wish to deal with system configuration issues – they just want to use the data!

Once GOES data have been received and automatically placed in the database, it can be combined with GIS data to produce displays useful in the classroom.

5. DirectMet® GIS in the Classroom

Science standards dictate the content of the curriculum, as was discussed above. DirectMet® GIS allows the teacher (and the student) to perform many functions that would have required a professional meteorological workstation just a few years ago. Some of these operations, like downloading a GOES image that includes a particular geographic area, can be accomplished by simply using a web browser and connecting to a NOAA, NASA or commercial weather site (such as "AccuWeather" or the "Weather Channel"). The capability of DirectMet®GIS comes into play when the teacher wishes to enhance the image to show additional structure in the image. The most popular enhancement is to "colorize" the cloud tops by temperature on an IR image. This points out the important relationship between cloud height and cloud temperature (and thus some secondary information about the temperature structure in the atmosphere). It can also help identify a weather system. In the images below, **Tropical Storm Lili** in September 2002 is shown in gray shade IR (figure 2), and then with selected enhancements to show the cloud structure (figure 3). The enhancement tool is so intuitive that students can easily "play" with it, discovering different things about their image as they do so. This is hands-on learning that cannot be accomplished with static pictures from NOAA, NASA or web-based commercial web sites.

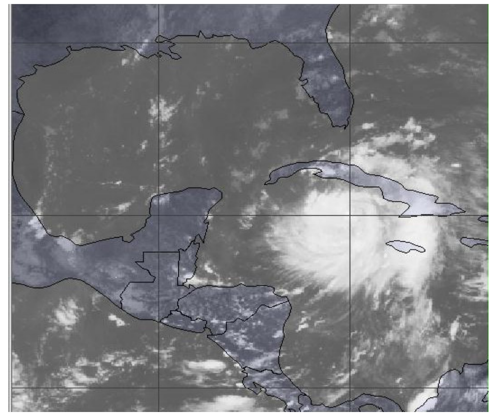

Figure 2: IR1 image of Hurricane Lili on 30 Sep 2002

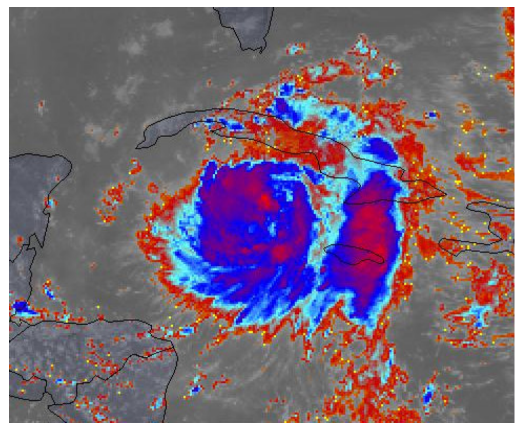

Figure 3: Enhanced IR image of Hurricane Lili (30 Sep 2002)

Another powerful tool built into DirectMet®GIS is the ability to read latitude, longitude and temperature directly off the image in an interactive mode.

The image below (Figure 4) is an IR1 taken on the morning of 29 September 2002, showing the Atlantic to the southeast of Cape Cod, MA. There were few clouds and thus the temperature structure of the water is evident from the gray shades. In this case, a warm eddy in the Gulf Stream is nearly separated from the main flow and is extending at the surface northward on top of cooler shelf waters. Point A on the image is the cool waters – the readout from the DirectMet® system is shown below the image, and it tells the student the latitude is 40.43N, the longitude 66.57W, and the surface water temperature 16.1°C. Less than 50 miles to the west at point B, the latitude is still 40.43N, the longitude 67.19W, and the surface water temperature over five degrees warmer at 21.4°C! This observation, conducted *by* students, can lead to a discussion of Gulf Stream support for cyclogenesis, or the thermal structure of the North Atlantic!

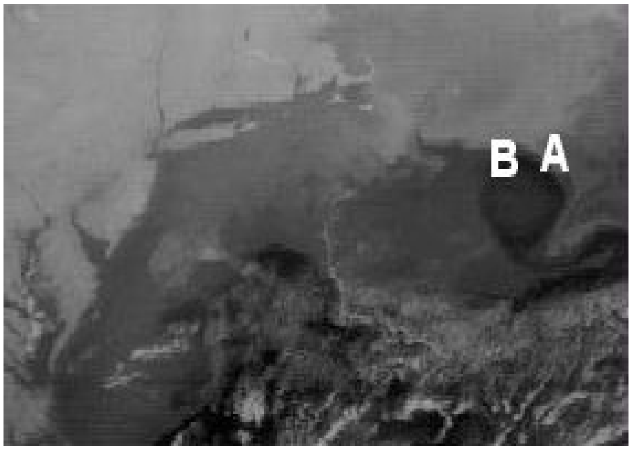

Figure 4 – IR2 image on 29 Sep 2000 for areas east of New England

X: 519 Y: 353 Lat: 40.43 Lon: -66.57 Pix:113 Tc:16.1

Figure 5 – DirectMet® readout at point A

X: 504 Y: 353 Lat: 40.43 Lon: -67.19 Pix:100 Tc:21.4

Figure 6 – DirectMet® readout at point B

DirectMet®GIS also incorporates the ability to display and manipulate GIS data files. This capability is unique among meteorological imagery display systems, and allows students to bring together data sets which naturally "go together". For example, in September of 2002, Tropical Storm "Kyle" displayed an unusual northeast to southwest track over a five day period of time. Student questions about this track, and "where is the storm likely to go next" could be answered with a look at storm track climatology, but a more interesting answer was easy to build with DirectMet® GIS.

Students downloaded an IR image of "Kyle", then overlaid two GIS data sets onto the satellite imagery – a map of the U.S. counties (from census data), and a map of historical hurricane/tropical storm tracks for September. The resulting image (figure 7 below) showed not only where Kyle was, but where it might go. The interesting thing is that this image was developed and built by the students who posed the question – not by the teacher!

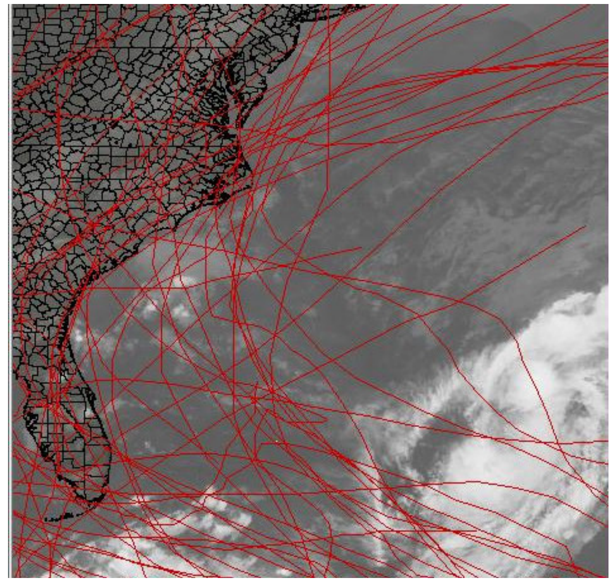

Figure 7 – Tropical Storm Kyle (30 Sep 2002) and GIS data sets for counties and historical hurricane tracks

6. Conclusion

DirectMetGIS® is unique among meteorological satellite imagery programs in its ability to integrate GIS data with meteorological satellite images and other types of meteorological data. It is also a powerful satellite imagery processor in its own right, providing novice users with a standards set of data acquisition, processing and display tools while allowing more experienced or professional users. Its ability for configuration with a "Virtual Receiver" which can provide satellite data for an entire school (or school district!) from one receiving antenna makes it economical for use in science classes from upper elementary through college. Some school districts have worked with their local community colleges to have them provide the receiver and data servers, as well as providing teacher training in the use of satellite imagery and GIS data in their classrooms. There are many benefits to both institutions with this arrangement.

Experiences in the author's 10th grade Earth and Space Systems Science classroom have shown that students at all levels enjoy "hands-on" learning activities, and do well with the technology to support them. DirectMet®GIS is one tool that has been very beneficial in bringing together the worlds of satellite meteorology and GIS data into a system that students (and teachers!) can use, understand, and learn from.

References

Anne Arundel County Public Schools/NASA Goddard Space Flight Center, cited 2002: Earth and Space Systems Science. [Available online at http://edmall.gsfc.nasa.gov/aacps/index.html]

Bogod, E, 2002: *Learning Styles & Multiple Intelligences*, Vancouver Island Invisible Disability Association's (VIDA) {Available online at http://www.ldpride.net/learningstyles.MI.htm#What%20are]

National Academy of Sciences, cited 1995: National Science Education Standards: An Overview. [Available online at http://books.nap.edu/html/nses/html/overview.html#content]

National Academy of Sciences, cited 2001: *What are* the National Science Education Standards? [Available online at http://stills.nap.edu/readingroom/books/intronses/1]