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A GIS Interface for Environmental System Analysis:
Application to the South Florida Ecosystem

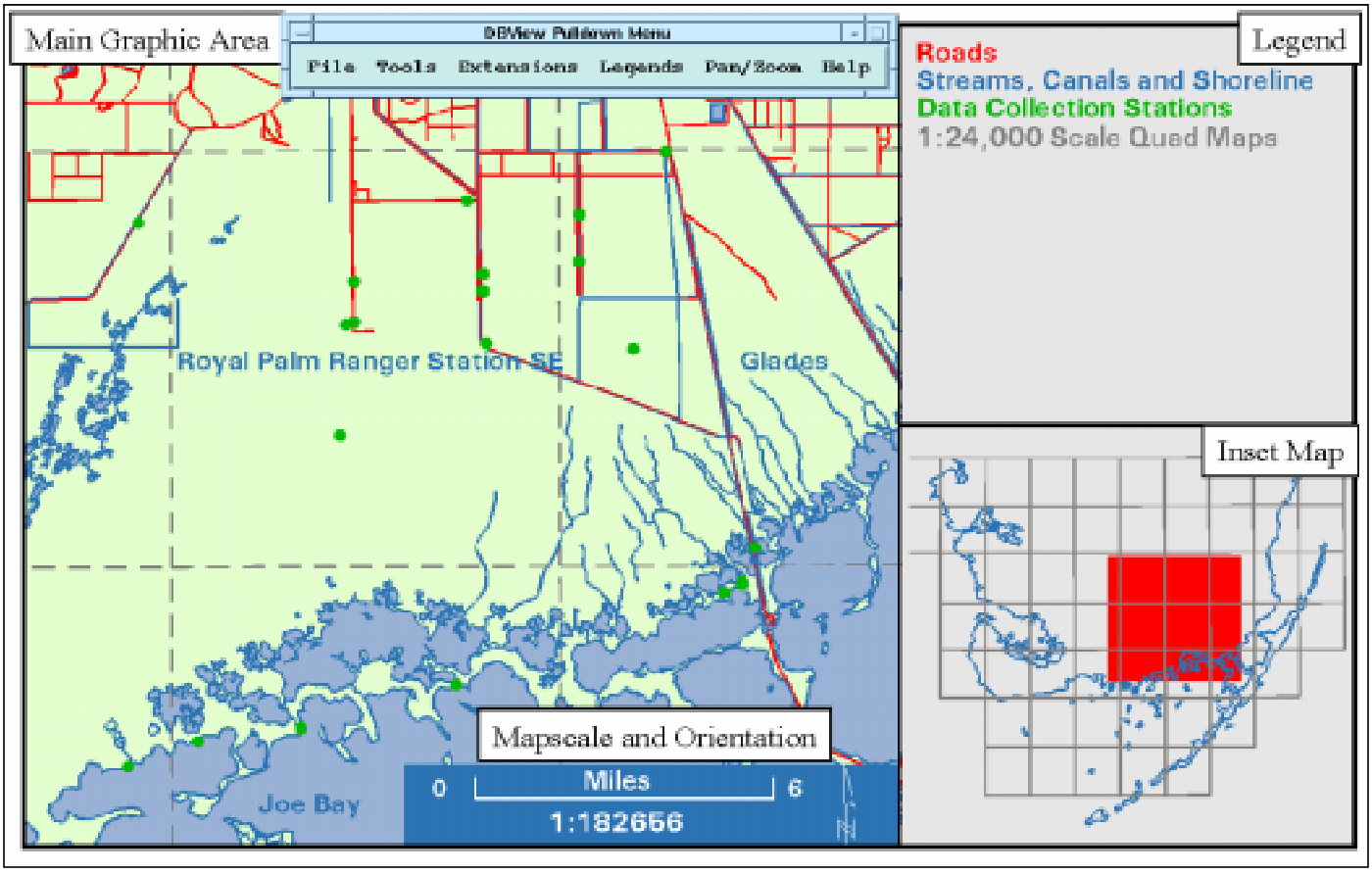

Figure 1. Map graphic of a portion of South Florida showing the main graphics area, map scale and orientation box, legend information area and overview inset map generated by a GIS interface developed by the U.S. Geological Survey (USGS). This illustrates the framework of what a user sees on the computer screen when running the GIS graphical user interface called DBView.

Introduction

Environmental investigations typically involve the collection of extensive sets of data that describe hydrological, geochemical, and biological processes, as well as terrestrial and ecological conditions, occurring within a geographic region. Because of their common spatial attributes, these data are particularly suitable for analysis and interpretation within a geographic information system (GIS). A GIS stores and manages diverse information according to its common spatial attributes. It uses points, lines, areas, and grids to represent features. A GIS can also accommodate time-varying data by relating sequences of this temporal information to their spatial location(s).

Vast amounts of spatial and temporal data are currently being collected and compiled by the U.S. Geological Survey (USGS) and other State and Federal agencies in support of the ecosystem restoration efforts in South Florida. Spatial data that are being "mapped" include vegetation characteristics, aquifer properties, soil conditions and types, land-surface elevations, physical features, and embayment bathymetry. Temporal data depicting seasonal changes in the distribution and abundance of species, constituent concentrations, water levels, wetland flows, and canal discharges, as well as meteorological data, such as precipitation, wind speed and direction, temperature, and solar radiation, are also being collected. A GIS-based tool has been developed within the USGS and is being used to assimilate, interpret and analyze the spatial and temporal data in support of the development of hydrologic, hydrodynamic/transport, and ecological models of the South Florida ecosystem.

Until recently, GIS users have been relatively few in number due to the inherent need for both an extensive knowledge of, and facility with, the complex programming language required to interact with the various GIS functions. Now, a graphical user interface (GUI) has been developed and incorporated into a GIS framework as illustrated in figure 1. The GUI insulates a user from underlying GIS complexities. A user can now create a GIS

working environment that does not require any prior programming-language knowledge or GIS experience. A properly designed GUI can automate GIS tasks, can be customized to reflect the science of the user, can employ terminology that the user readily understands, and thus, ease the use of a GIS. By means of pre-defined investigative paths, a GUI can guide a user through a sequence of GIS functions and thereby enable the investigator to more easily and comprehensively analyze a particular set--or several sets--of environmental data.

The objective of this project has been to develop a user-friendly, interactive GUI to enable scientists to easily and readily analyze and assess comprehensive data that describe complex environmental systems, such as the South Florida ecosystem. The GUI described here provides a GIS interface to comprehensive databases that anyone can use, and allows a user to browse and manipulate with ease their own spatial data, called "coverages", as well as, coverages that have been compiled by others. This GIS database viewing tool, called DBView, uses ARC/INFO's[1] Arc Macro Language (AML) to maintain computer hardware and operating system portability with many computer platforms. DBView consists of a number of general-purpose GIS tools that offer an intuitive means for assessing GIS databases, and can display and identify mapped features and their attributes. DBView is a GIS interface that provides a fast, yet powerful means-of-access to a variety of environmental databases, such as those maintained for the South Florida ecosystem by the Everglades National Park, the South Florida Water Management District, and other State and Federal agencies. Although DBView is proving to be useful in conducting the South Florida ecosystem investigation as illustrated herein, it is a portable generic tool that also can be useful in other environmental studies.

DBView Overview

Certain design principles guided the development of this GIS interface. The objectives were to provide users with: 1) an intuitive, easy-to-use tool with comprehensive GIS functionality, 2) an ability to convey a general overview, yet capable of providing detailed information when requested, and 3) the flexibility to Pan and Zoom to any geographic area of interest. Consistent button placement within the DBView framework, as well as consistent terminology and behavior, makes the interface easy to learn. Knowledge gained in executing one menu of the interface readily transfers to other menus. A graphic overview of the region of interest provides the ability to readily visualize and maintain the spatial relevance of the data. Pan and zoom options allow the user to select and display an area of particular interest and to magnify such areas where more specific details are needed. Specific information about the characteristics of the spatial and temporal data can be readily requested and displayed. For example, users can determine which types of data, if any, are available for a particular location. Users also can determining the sampling frequency and temporal extent of the data. These features significantly reduce the burden of data compilation and permit investigators to focus more directly on their analyses.

Spatial Data Characteristics

DBView features the ability to use spatial coverages that are in vector, raster, and image formats. Vector coverages represent features as points, lines and areas, such as the USGS digital line graphs (DLG) map products. Raster format pertains to data represented in rows and columns of cells that make up a rectangular grid of values. Each cell contains attributes about the geographic area that it represents, such as elevations in USGS digital elevation model (DEM) grids. Image data include digital satellite photographs or map products such as USGS digital orthophoto quadrangles (DOQ) and digital raster graphics (DRG).

Interface Framework

Spatial data are displayed by DBView in a map graphics framework (fig. 1) that consists of a main map-graphic area, map scale and orientation box, overview inset map, and a legend information area. The map scale and orientation box, which consists of a scale bar and a north arrow, and the inset map are recalculated to correspond to the geographic area currently being displayed. The legend information is also updated to always reflect the map-information layers selected by the user. The USGS 1:100,000-scale DLG layers (hydrography in blue and transportation in red) for a portion of South Florida are illustrated in the main graphic area of figure 1. Also displayed are data-collection stations (green dots) and 1:24,000-scale topographic quadrangle map boundaries (dark gray dashed lines). Quadrangle names are indicated in blue text.

Using DBView

A typical DBView user scenario would be to define a geographic area, select the desired map-information layers and map features to be displayed, and then utilize the provided GIS tools and extensions to analyze the available temporal and spatial data. The functional components of the **Tools**, **Extensions** and **Pan/Zoom** options of DBView are offered in pulldown menus from the toolbar (fig. 1).

Defining the Geographic Area

The **Pan/Zoom** options, included on the main pulldown menu bar, offer the user a number of ways to define and display a geographic area of particular interest. *Zoom-in* options permit the user to magnify an area of interest by 1) defining a rectangle on the screen using the mouse, 2) keying in latitude/longitude coordinates, 3) specifying cover features, 4) identifying a particular 1:24,000-scale topographic quadrangle map, and 5) selecting data-collection sites. Three pre-defined *zoom-out* options enlarge both x and y dimensions of the currently displayed region by 10, 30, or 80 thousand meters or feet, depending on the units of the map projection. A fourth *zoom-out* option allows the user to specify the enlarging dimensions using units of their choice of feet, meters, or miles. The *Pan* option provides the ability to display the region adjacent to the one currently displayed. A *Previous*

[1] Use of this product name is for descriptive purposes only and does not imply endorsement by the U.S. Government.

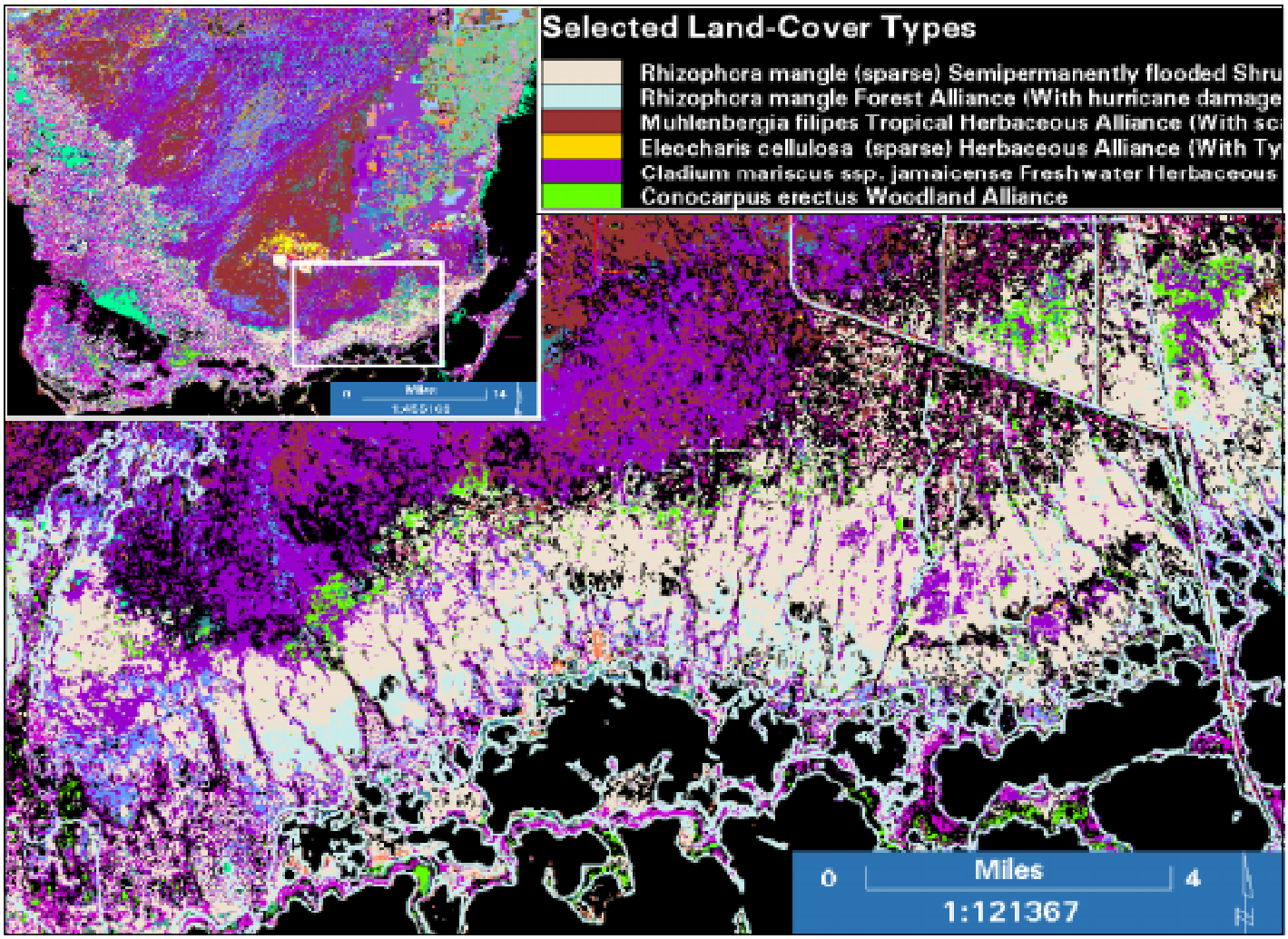

Figure 2. Vegetation image grids of South Florida displayed in DBView. The top-left image displays all vegetation types for the entire South Florida area. The region within the white box is expanded in the lower image, which displays only the selected mangrove, sawgrass, cattail and rush communities as partially identified in the top-right graphic area. (Vegetation grid, consisting of more than 80 million 28.5-meter-square cells of vegetation classified into 68 different types using the Nature Conservancy southeastern classification scheme, compiled from 1993/1994 Landsat thematic imagery by the former National Biological Service and the University of Florida.)

option permits the user to re-display the area that was previously displayed. This enables the user to readily zoom in and then zoom back to the original area with ease.

DBView Tools and Extensions

DBView consists of several general purpose tools and extensions that automate specific GIS functions to help users compile, analyze, and interpret their data. These tools allow the user to find, display, and identify mapped features by listing their attributes. Most menu tools within DBView contain a *Help* option that briefly describes how to use the menu and what the tool expects as input. The **Tools** and **Extensions** options, also located on the main pulldown menu bar, contain the following:

Identify Menu - provides the capability to point and click on a displayed map feature and have DBView present the feature's attributes in either a popup window or as annotation in the map-graphic area, depending on the identification presentation option (*List* or *Annotate*) selected by the user.

Select Sites - contains a number of options that provide the capability to select data-collection sites that meet user-specified criteria. DBView will highlight and display sites that meet a user's criteria -- for instance, sites that are in a specified area and at which desired parameters were collected during a specified time period. The functional capability to access the actual temporal data that are associated with the selected sites is currently being developed. (For the South Florida Ecosystem Program, the temporal database is currently under development and will be maintained by the USGS office in Miami, Fla. DBView will provide users remote access to this database.)

Select Land-Cover Types - provides the capability to specify land-cover types to be displayed. Once the land-cover types have been specified, DBView will calculate a statistical summary identifying the number of acres, square meters or square miles, and percent of each selected land-cover type. This summary information is presented to the user in a popup window. This tool can be used, for instance, with the vegetation map of the South Florida region (fig. 2) and with other USGS products such as the 1:250,000-scale land-use digital data.

Grid Data Points - provides the capability to select data points using a variety of methods and to create contour maps using one of the attributes of the data. A gray-scale contour map

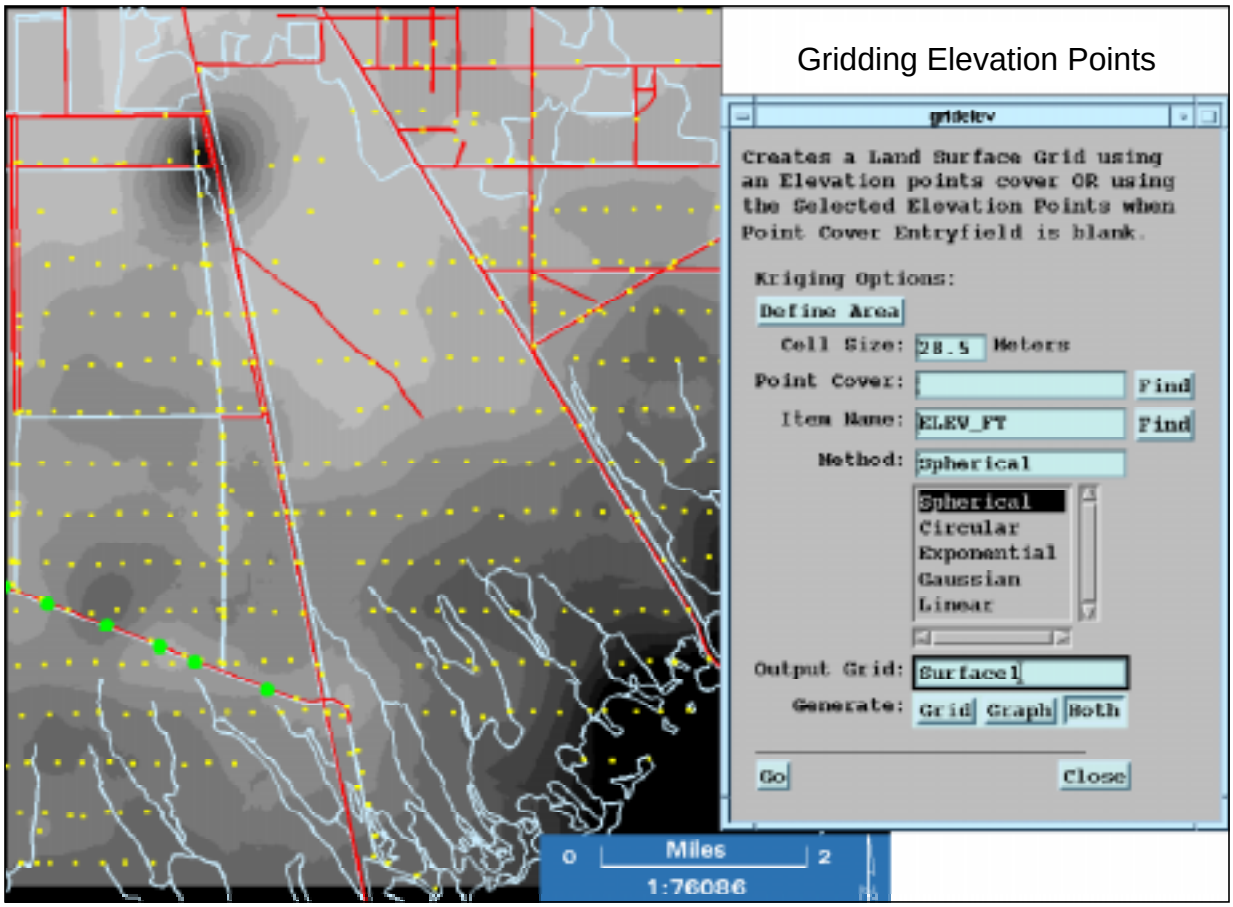

Figure 3. Contour map generated and displayed by DBView showing roads (red lines), elevation data points (yellow dots), and streams, canals, and shoreline (blue lines). Lighter colored areas indicate higher land-surface elevations whereas darker colored areas indicate lower elevations.

of land-surface elevations created using high-accuracy, Global Positioning System (GPS) derived data, that have been collected in the South Florida region by the USGS, is illustrated in figure 3. A number of interpolation options, including kriging, are offered for grid generation. The user also can specify the cell size of the grid to be generated and have the newly generated contour map added to DBView as a map layer.

Grid Generation

The grid generation capabilities of DBView are currently being expanded in support of a variety of numerical simulation models. Existing grid editing functions provide the capability to use vector map layers to adjust and modify (add, subtract, multiply, or divide) cell elevation values. For example, a “roads layer” can be used to add a specified value to the cells that are intersected in an elevation grid, and/or a “hydrography layer” could be used to subtract a specified value -- the resultant elevation grid would then more accurately reflect the physically mapped features and produce a better representation of the land surface. Grids generated by DBView can be saved to text files and used in other applications, such as hydrologic simulation models. The grid generation functionality is currently being enhanced and extended in support of implementation of the USGS two-dimensional surface water integrated flow and transport (SWIFT2D) model for a portion of the South Florida ecosystem.

Ongoing Developments

Extension of DBView’s functional capabilities is an ongoing effort within the USGS. Some of the developmental work currently being conducted includes:

- enhancing grid editing capabilities
- generating hardcopy graphic output plots
- plotting hydrographs of retrieved data
- integrating a variety of simulation models.

It is anticipated that continued development and enhancement of GIS interface capabilities, such as those provided by DBView, will contribute to an increase in the thoroughness of scientific investigations by providing a robust tool for the synthesis of a wide variety of environmental data. This additional capability should facilitate environmental decisions based on the analysis of such comprehensive interrelated data.

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