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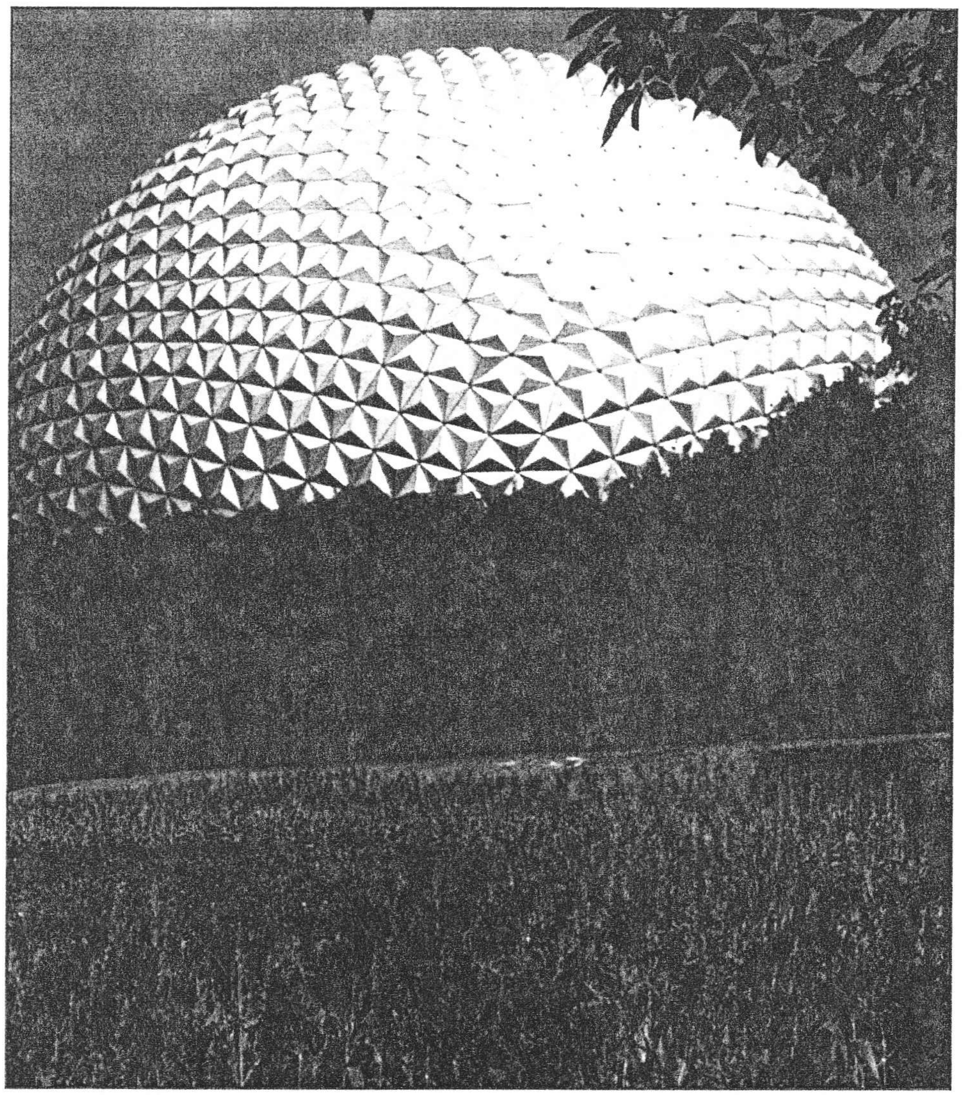

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SESSION G: CROP MODELING AND INFORMATION TECHNOLOGIES

STORAGE AND VISUALIZATION OF OZONE LAYER THICKNESS DATA* **

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ABSTRACT

The High Performance Database Research Center (HPDRC) at Florida International University (FIU) has been involved in the research, storage, and visualization of several remotely sensed data sets including Ozone Layer Thickness data. This paper describes the storage and visualization of the Ozone (Total Ozone Mapping Spectrometer, TOMS) Layer data from three different satellites: Nimbus-7, Meteor-3, and Earth Probe. A Semantic Database has been designed and created. All the textual data including instrument, satellite, frequency and date, as well as the spatial Ozone layer thickness data for about twenty years have been loaded into the database using the Semantic Database Management System's (DBMS) Binary Database Interface that has been developed at the HPDRC. A friendly graphical user interface has been created together with the main system areas: display process, data manipulation, and data retrieval. All these components are tightly integrated to form a practical interactive system that facilitates the interpretation, manipulation, visualization, analysis, and display of the Ozone data through different platforms including Solaris, Windows, and the Internet. At the same time, during the development of the system, several storage methods and data transfer techniques were tested.

1.0 INTRODUCTION

Remote sensed data such as Ozone Layer Thickness has become very important in the research, forestry, agricultural, and environmental communities. Over the past several years, a reduction in the thickness of the Ozone layer has been detected during certain seasons over various areas of the world. This reduction would allow more ultraviolet radiation to penetrate to the Earth's surface, which could affect natural resources, harm crops, and interfere with wildlife habitats. If the Ozone Layer continues to shrink over some regions of the Earth, the effect could include a dramatic change in the environment.

At the HPDRC, we have a wide variety of spatial data sets from several sources including Ozone data deployed by NASA's Goddard Space Flight Center. Thus, due to the large amount of data inherent in this data set and the interest from the research point of view, we found the need for a computer-based system able to efficiently store, manipulate, analyze, and display the Ozone data. This paper will describe the design and implementation of a semantic database for the storage of the Ozone data and a practical interactive system that will facilitate the visualization and interpretation of the Ozone data by providing a good set of analysis tools and a friendly graphical user interface. By building this system using a high performance DBMS, efficient storage, manipulation, analysis, visualization, and retrieval of both conventional and spatial data sets is provided. This semantic database will provide protection and security for the data and at the same time, enforce consistency of the stored data. It will also provide efficient simultaneous retrieval of massive amount of data to multiple users, and ensure better logical properties such as a comprehensive enforcement of integrity constraints, greater flexibility, and substantially shorter application programs (Rishe, 1992a).

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2.0 BACKGROUND

2.1 WHAT IS OZONE?

Ozone (O_3) is an unstable, pale blue trace gas at room temperature, but it condenses to a deep blue liquid at –112 degrees Celsius. Its density is about 1 ½ times that of Oxygen (O_2) and it is a very strong oxidizing agent. Even small amounts of Ozone at the surface of the Earth decompose rubber and plastic products (Whitter, 1992).

Ozone is formed and mainly found in the stratosphere. This layer of Ozone filters or blocks harmful ultraviolet (UV) radiation. Ozone is also found in the troposphere but, as shown in Figure 1, in very low concentrations. In all about 90% of the total amount of Ozone in the atmosphere resides in the stratosphere with the remaining 10% in the troposphere.

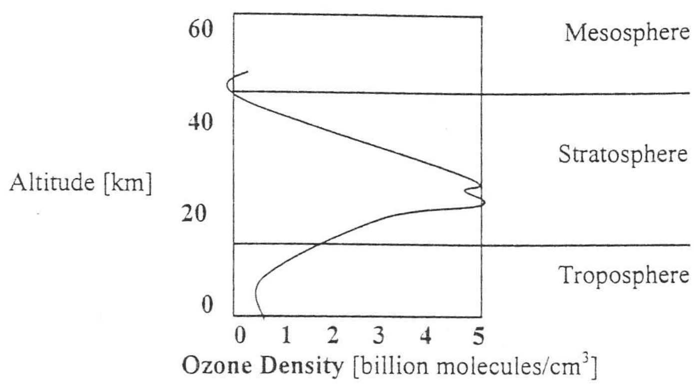

Figure 1. Ozone vs. Altitude

Ozone is naturally formed in the upper atmosphere as O_2 molecules and absorbs high-energy electromagnetic radiation from the sun. In this region oxygen molecules (O_2) absorb wavelengths less than 240 nanometers and produce O atoms. These Oxygen atoms combine with other Oxygen molecule (O_2) to form Ozone (O_3) (Whitter, 1992).

2.2 MEASURING OZONE

Ozone has been measured using spectrometers from the ground, aircraft, balloons, satellites, space shuttle missions and Dobson networks. Ozone was first measured in 1956 at Halley Bay using a ground based instrument called the Dobson spectrometer (Dobson, 1968). Then, in the early 1970's, satellite measurements began. In 1978, NASA launched the first TOMS instrument aboard the Nimbus-7 polar orbiting satellite. Since then several other aircraft, satellite and space shuttles have carried several instruments into space to measure, study, and analyze Ozone values and data. The primary instruments used have been TOMS (Total Ozone Mapping Spectrometer), TOPS (Total Ozone Portable Spectrometer), TOVS (TIROS Operational Vertical Sounder), and SSBUV (Shuttle Solar Backscatter UltraViolet) (Dobson, 1968) (Mims, 1993).

All those instruments measure the thickness of the Ozone Layer in a convenient scale called a Dobson Unit (DU). Dobson Units indicate the thickness of the Ozone layer if it were measure at 0 degree Celsius and at standard atmospheric pressure (1 atm) (Asker, 1993). More specifically, 0.01mm thickness of Ozone at 0 degrees Celsius and standard atmospheric pressure is defined to be 1DU. Ozone levels of values about 200DU or less are considered extremely low. Areas where the Ozone level is very low are referred to as the "ozone hole". Some areas of the world have reported values as low as 90 DU. Ozone levels of about 450 DU or more are considered very high.

2.3 SEMANTIC DATABASE MANAGEMENT SYSTEM

Under NASA sponsorship, the HPDRC is presently developing a High Performance Semantic Database Management System (DBMS). This semantic DBMS has been developed with an object-oriented approach and is based on the Semantic Binary Model. Thus it satisfies the three essential needs of many database applications: strong semantics embedded in the database to handle the complexity of the information, storage of multi-dimensional spatial, images, scientific and other non-conventional data, and very high performance that allows rapid flow of massive amounts of data. The semantic parallel architecture of this database system provides efficient and flexible access to a large collection of data stored on various physical devices. Further, data reference transparency is an inherent property of the semantic binary model system (Rishe, 1992a) (Rishe, 1994).

The Semantic Database model is potentially more efficient than conventional models for two main reasons. First, all the physical aspects of the representation of the information are invisible to the users. This additionally creates a potential for optimization by allowing more changes to the database without affecting the users' programs. Second, the semantic system knows more about the meaning of the user's data and about meaningful connections between such data. This allows that knowledge to be used to organize the data in such as way that meaningful operation can be performed faster. (Rishe, 1992b).

3.0 OZONE DATABASE

A Semantic Database schema is a set of categories, relations, and database types. A category is a specification for database abstract objects that belong to that category. Each category may have several relations with other categories and data types. A relation from a category to a data type is called an attribute, and a relation from category to a category is called an abstract relation (Rishe, 1992a).

3.1 SCHEMA DESIGN

The database used for this application has to store the spatial and semantic data together in the same database. This is a feature that most DBMS systems lack. They store the spatial data separately from the textual data (Waugh, 1987) which makes the system inefficient and difficult to use (Rishe, 1994). This database also has to store several types of information from the data set. For example, the following information needs to be stored: satellite name, instrument used, a color table (containing values, colors, and a short description), observational program (including date and frequency) and the data files. In addition, the database schema needs to be generic so it can be used to store some other types of spatial data sets. Based on this requirements, the following semantic database schema was designed and implemented:

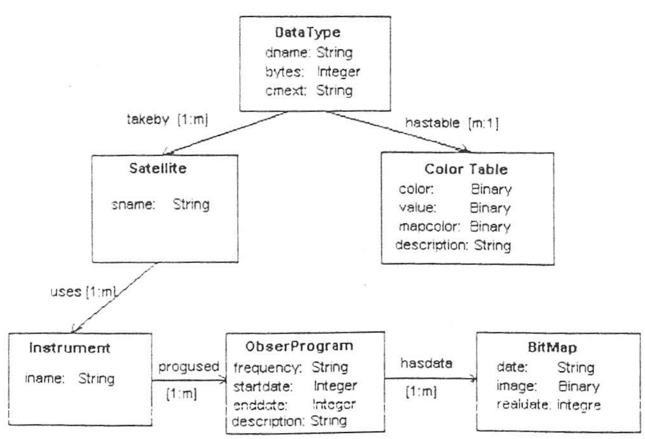

Figure 2: Semantic Schema for the Ozone database

4.0 OZONE INTERACTIVE SYSTEM

This system is completed independent from the data upon which it operates. It retrieves all necessary information (data) from the semantic database, making this interactive system a generic one that works for a variety of data sets. In addition, this is a client-server application that is portable across several platforms including Windows, Soralis, and the Internet. The Java based client program consists of a graphical interface, manipulation techniques, and display process. The sever part, on the other hand, handles the data retrieval (database queries) and the data transfer. All these components are tightly integrated to achieve the system's goals.

4.1 GRAPHICAL INTERFACE

We endeavored to develop a friendly graphical user interface that is simple to use while maintaining a high level of flexibility and advanced data manipulation techniques. The main features of the interface are a top bar, drop-down menus, buttons, and text-boxes. These allow users to easily manipulate the data, navigate through the semantic database schema and retrieve the desired information. Initially users can use the menu options to open the database and view a display of the semantic database schema as shown in Figure 2. Then, by clicking on the categories or relations, users can get a window from where they can make queries to the database and retrieve textual and spatial data.

Before viewing the Ozone map users can/should specify the satellite and the instrument that they want, as well as the frequency (daily, or monthly) and the date range. Some of the menu options that the users have to manipulate and analyze the map are:

- Projection: current available views include Orthographic, Orthogonal, Sinusoidal, Stereographic, Homolographic and Polar View. Figure 3 depicts a projection sequence of ozone data maps in the above mention sequence.

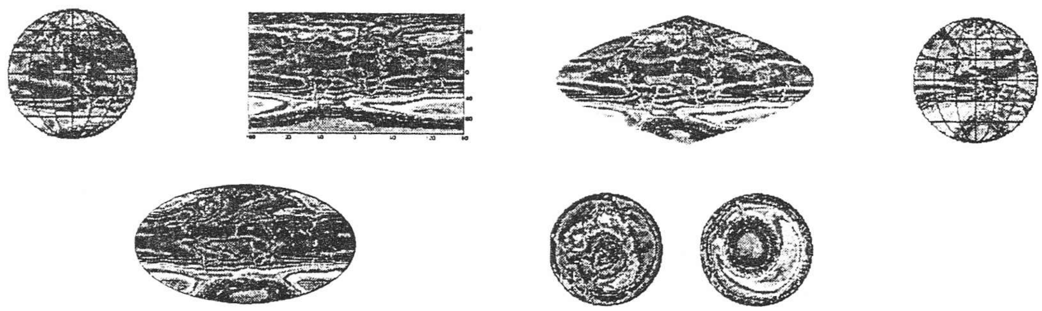

Figure 3. Ozone data maps in different projections

- View: allows the users to view the 'Next Frame', 'Previous Frame' or an Animation of the data. Every time a new frame or image is displayed, the corresponding measured date is also displayed on the lower portion of the screen.
- Zoom: allows the users to zoom in to a particular geographical location. For each selected area, a new window is opened displaying the magnified area. Magnification can range from 20% to 120%. An addition option in this menu is 'Magnify'. If this option is set, an area of about 50x50 pixels is magnified around the mouse position by merely rolling the mouse over the image area. This allows the users to view more details about the data by only rolling the mouse within it.
- Options (Date): has two date options: 'Enter date' and 'View date' allowing the users to enter a specific date. The query is submitted to the database and the data image for the best match is displayed on the window. This is very useful if users are only interested on specific dates.

Another feature of this system is the color table. Every time that a data set is displayed on the screen, a color chart (color, value) is also displayed next to the map to aid in the interpretation of the colors. For Ozone, values are given in Dobson Units.

4.2 DISPLAY PROCESS

This system displays the spatial data images in static and dynamic modes. During the static display process, a data file for one particular date is retrieved from the database and placed in a buffer. Then, it is sent through a TCP/IP connection to the client program running on the user's computer. Once the client program gets this data buffer, it begins the display process. The frame containing the outlines of the continents is superimposed over the Ozone data frame resulting in two different frames being displayed at the same time. Thus, in order to get the right image, the program needs to "remember" the location of the outline of the continents. Once this process is done, the data buffer is passed to the Frame class where the whole data file is processed and displayed depending upon the projection. For instance, if the active projection is Homolographic, the following mathematical computations need to be performed to display the image.

```
for(int y = 0;  y < 180;  y++)
    for(int x = 0;  x < 360; x++)
    {
        Color colors = new Color (map[ind], map[ind+1], map[ind+2]);          //RGB color
        g.setColor(colors);
        bx=(int) (180+(x+180)*Math.sqrt(1.0-((yh-90.0)*(yh-90.0))/8100.0));    //compute projection
        by = 340 – y;
        g.fillRect(bx, by, 1, 1);
    }
```

When the frame is finally displayed on the screen, users view the Ozone data and the continents outline all in one frame. This overlaying process is done to give users a better geographical orientation of the ozone layer values.

4.3 DATA RETRIEVAL

This application is constantly retrieving information from the semantic database. Each time that users press the 'Query', 'Next', or 'Previous' bottom to get the textual information about the data or when a New, Next or Previous data map is requested on the client program, a message is sent to the server program to get the data. For example, when the satellite name is requested, the following source code is executed on the server to retrieve the data from the database:

```
Var S = RangeQuery(TheRelation("DATATYPE::dname", DB), dtname);
SetQuery Satel = S(TheRelation("DATATYPE::takeby", DB);
while( Satel.GetVarInc(sateln))                          // get the name of all available satellite
{
    Var SName = sateln["Satellite::sname"];
    sprintf(satel_name[i++], "%s", pChar(SName));
}
```

Once this is completed, the information is sent to the client program for displaying. As can be have seen from this source code listing, retrieving data to get a list of possible menu options is very simple. However, when a different data set is selected, and the user has already chosen all the options for a particular satellite, instrument, and frequency that he or she desires to view, more complicated queries are done to the database to extract the correct information and start the displaying process.

4.4 DATA TRANSFER

Image processing systems like this and their related databases usually run on different computers. In this case, the database (server) is stored in a computer called Miami, and the interactive system (client) can run on several computers selected by the user. This is a typical homogeneous system (Webster, 1988) which has a single database stored centrally at Miami and several clients' computers spread through out the network from which the database can be accessed.

For testing the system, both a high-speed data transfer device and the regular Ethernet was used. A ForeRunner ASX-200 switch based on ATM (Asynchronous Transfer Mode) technology was used for the high-speed data transfer. This switch delivers high-performance ATM connectivity. It has an interface speed from 1.5 MB/sec to 155 MB/sec and it provides 2.5 GB/sec to 10 GB/sec of switching capacity. Therefore, this ATM switch played an important role in achieving fast data transfer during the test.

4.5 DATA COMPRESSION

While building this system and the database, several tests were performed using compressed and uncompressed data to define the best way to store the data. For the compression experiments, the spatial data was stored compressed on the database and decompressed on the fly as requests to the database were performed. Unix g-zip, a compression program based on the Lempel-Ziv algorithm (Ziv, 1977), was used for this test. Minor changes were made to the g-zip programs to write the output to memory instead of a file. In this way, we have memory to memory compression that is useful to get the data file compressed and then write it to the database.

5.0 DATA

5.1 SEMANTIC DATA

Several megabytes of semantic and spatial data were used to test this application. As was stated previously, this system does not merely display spatial data. It provides users with information about the data including color tables, satellites, instruments, dates, data descriptions and observation programs including frequencies, starting dates and ending dates. In order to achieve this, all the textual information is combined with the spatial data in the same database. This is needed to better meet all requests coming from the users and allows users to view information about the spatial data at the same time that they are looking at the images

5.2 SPATIAL DATA

The spatial data currently stored in the database is mainly in a raster format. It includes Ozone data for a period of up to 20 years (1978-1997) involving three different satellites and two different frequencies (monthly and daily). Each of these files is approximately 103680 bytes. Ozone data is grided into 1-degree latitude by 1.25 degree longitude zones. Latitudes range from -90 degrees (the South Pole) to 0 degrees (the equator) to +90 degrees (the North Pole) in 1-degree steps. Thus, there are 180 latitude zones. The first few lines of a data file looks like this:

Day: 182 June 30, 1992 Real Time Meteor-3 TOMS LECT: 12:00 PM
Longitudes: 288 bins centered on 179.375 W to 179.375 E (1.25 degree stp)
Latitudes: 180 bins centered on 89.5 S to 89.5 N (1.00 degree stp)
317317317317317317317317317317317317317317317317317317317318318318318318318318318318318 0 0 0
317317317317317317317317317317317317317163163163163163163163163163163163163143143143143 1... ... .
At the end of the first 288 zone readings, the data file will state "lat. = -89.5".

The first three lines are header information specifying the data format. Then the 288 longitude values for one latitude zone, centered at -89.5 are given followed by the next 288, and so on. The zeroes denote flagged data, i.e., data that could not be collected due to satellite or instrument problems. All measurements are given in Dobson Units.

6.0 APPLICATION RESULTS

6.1 ADVANTAGES

This system has facilitated the manipulation, study, analysis and interpretation of Ozone data sets. This has been achieved by providing advanced data manipulation techniques, high levels of flexibility and observation capability, fully documented images and a database navigator interface.

- This system provides users with advanced data manipulation techniques that allow them to analyze, study and observe the data in great detail. With the available menu options, users can view different data maps at different magnification levels and at different projections.
- Another feature of this system is its high level of flexibility. It is completed independent of the database upon which it operates. The system retrieves all necessary information including the data format from the database. Thus, different data sets can be displayed without having to change the system itself. The application's flexibility is further illustrated in that users can click on a pull-down menu option, button or icon at any time and a variety of operations will be performed instantly.
- A high level of observation capability is an additional feature of this system. All of the windows containing selected zoomed frames and the whole original map can be displayed on the screen at the same time. This greatly increases a user's observation and analysis capability since different geographical locations can be viewed on several windows at the same time at different magnifications and projections. Moreover, users can view the data from different a viewpoint by just selecting the projections of interest from the list of possible options.
- Every displayed image is fully documented in this system. The data type, name, frequency, instrument, and satellite are given in the windows. Additional documentation includes a color table giving the relationship between colors and the values of the displayed data, a description of the color table, and the date for each frame.
- The semantic schema diagram allows clients to become familiar with the schema and to navigate through the semantic database. Users do not need to have knowledge about semantic databases or the information stored on the database to retrieve data. By just clicking on the Category or Relation that they want to query, a window is displayed giving the list of attributes under that category and some query buttons for easy data retrieval. By this simple process they can retrieve all the desired semantic and spatial data at any time during the program execution.

This application could also be considered an intelligent system. It is able to "remember" distinctive geographical information such as continents and then display this information in other projections as a point of reference for data precession or omit it for data clarity. In addition, this system works with a semantic DBMS, which makes it efficient and reliable. Another major advantage of this application is its portability. It is portable across several platforms including Windows NT, Windows 95, and Solaris. The client part of this system, as was stated previous, is a Java applet, so it can be accessed and run through the Internet from any remote client computer.

6.2 STORAGE AND PERFORMANCE

The overall performance of this system is very good. The retrieval and transfer time is almost instantaneous for textual information. For the spatial data, after performing some tests, we conclude that the best way to store the data is uncompressed. The compressed database is about 151MB, but the display time is longer than for the uncompressed database. Data needs to be retrieved, uncompressed and processed before display it. The uncompressed database is about 379MB, but the response time (time from when the user click on the query button to get the image to the time the image is display on the window) is faster. The added uncompressed step (algorithm) for the compressed database delays the response time. Data files are only 64KB, so compression does not improve the transfer and display time nor the storage efficiency. This system was tested with both the ATM switch and the regular Ethernet. As expected, the Ethernet took a few more milliseconds.

6.3 DATA ANALYSIS

This system has also allowed us to analyze, interpret and study the data currently stored in the database. The development of the ozone hole (regions where the total ozone column is less than 200 DU) has been monitored. And graphical sequence of the Antarctic ozone hole formation taken from monthly readings from the Nimbus-7 Satellite has been studied. We have observed how the ozone layers at the beginning of the year have values greater than 230 DU. On the other hand, during a different season (September-November), Dodson Unit values less than 100 DU has been found over the South Pole (Antarctic). These values were recorded by NASA's TOMS instrument flying on Russia's Meteor-3 satellite in October 1993. It was during this time that the ozone hole was 9 million square miles, slightly smaller than 1992 ozone hole of 9.4 million square miles. On this day, a balloon sensor flown by NOAA measured 90 DU while a spectrophotometer on the surface measured 88 DU (Gregg, 1994). This shows how variable ozone layer values can be from one month to the other.

7.0 CONCLUSION

The design and implementation of this interactive system covered several areas. First, its Semantic Database was designed and created, and all the textual and spatial data was loaded into the database. Then the main areas of the system – the user interface, displaying process, data retrieval and data transfer - were implemented with the help of some tools and devices. Finally, all these components were tightly integrated to form an innovative and practical system.

The resulting system has facilitated the interpretation, storage, manipulation, analysis and display of the Ozone data. At the same time, storage mechanisms (i.e., compressed and uncompressed data) have been tested. With the help of this system, the Ozone Layer has been tracked for a period of more than 20 years. When did the TOMS instrument first detect the ozone hole? During which weather seasons is the ozone layer thinner and over what regions? These are only a few of the questions that can be answered using this application as the main tool for data examination, interpretation and manipulation. This system guides users in retrieving all the desired information from the database and helps them to better analyze and observe the spatial data using a wide variety of menu options. In addition, retrieval and transfer time has been checked while running the system using an ATM switch and Ethernet. Finally, data stored in the database has been periodically checked to ensure that the DBMS has been maintaining protection, security and consistency.

8.0 REFERENCES

J. R. Asker, "U.S./Russian satellite maps worst Antarctic ozone hole", Aviation Week & Space Technology, vol. 139, No. 17, 1993.

G.M.B. Dobson, Exploring the Atmosphere, 2nd Edition, Oxford, 1968.

W. Gregg, et. al. SeaWiFS Technical Report Series. NASA Technical Memorandum 104566. Vol. 15, January 1994.

Forrest M. Mims, III, "Satellite Ozone monitoring error", Nature, Vol. 361, No.6412, 1993.

N. Rishe, "A Database Design: The Semantic Modeling Approach. McGraw-Hill, 1992, pp.528.

N. Rishe, Q. Li, "Storage of spatial data in Semantic Databases", Computer in Engineering 1994, (Preceding of the 1994 ASME International Computer in Engineering Conference, Minneapolis, MN, Sept 11-14, 1994) ASME, pp. 793-800.

N. Rishe, Accepted grants proposal to NASA. Grant NAGW-4080. 1992.

T. C. Waugh, R. G. Healey, "The GEOVIEW design: A relational database approach to geographical data handling", International Journal of Geographical Information System, Vol. 1 No. 2 1987, pp. 101-118.

C. Webster, "Desegregated GIS architecture: Lessons from recent developments in multi-site database Management systems", International Journal of Geographical Information Systems, vol. 2, no. 1, 1988

K. W. Whitter, K. D. Gailey, and R. E. Davis, General Chemistry with Qualitative Analysis. 4th edition, 1992.

J. Ziv, and A. A. Lempel, Universal Algorithm for sequential Data Compression, IEEE transactions of Information Theory. Vol. IF23, No. 3, May 1977.