Application of GIS Technology for Agrometeorological Bulletins

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Abstract

U.S. Department of Agriculture World Agricultural Outlook Board meteorologists recently implemented a geographic information system to analyze the impact of weather on domestic and international crop progress and conditions. Sample products are presented demonstrating the effectiveness of this system in preparing agrometeorological analyses. A significant capability of this system is the ability to develop customized applications that automate data processing and display. Staff meteorologists are currently developing an application to automatically generate black and white contour maps for the U.S. Department of Agriculture *Weekly Weather and Crop Bulletin*.

Introduction

The U.S. Department of Agriculture (USDA), World Agricultural Outlook Board (WAOB) provides official government forecasts of agricultural commodities. These forecasts are prepared by staff economists, which are responsible for estimating domestic and international crop production, supply, and trade. The impact of weather on crop progress, condition, and ultimately production is well documented. For example, timely rainfall and seasonable temperatures can significantly enhance crop production. In contrast, untimely precipitation and temperature extremes can significantly reduce crop production. Given the influence of weather on crop progress and conditions, WAOB meteorologists monitor weather conditions worldwide to help staff economists to improve forecasts of changes in agricultural commodities.

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WAOB meteorologists employ various techniques to monitor and analyze global weather conditions. Time series analyses are used frequently to diagnose the timing and cumulative affects of weather through the various stages of crop development. These analyses help analysts determine the vulnerability of crops to weather extremes at point locations or within small regions. Analog comparisons are used often to identify similarities among recent and historical weather data. These analyses enable meteorologists to estimate the likely impact of weather on current crop production based on crop production figures from those years when similar weather patterns were observed. Spatial analyses are employed regularly to plot and analyze meteorological data relative to geographically important features. Such features may include political boundaries, terrain, or crop growing regions. Recently, WAOB meteorologists implemented operationally a geographic information system to monitor changes in the weather relative to major crop producing regions worldwide. Several applications were developed to facilitate and automate data processing and display, improving meteorologist capabilities to identify and delineate crop areas of concern. Following is a brief introduction to geographic information systems and a description of how WAOB meteorologists are implementing such a system to prepare agrometeorological products.

Geographic Information Systems

Definition

Geographic Information Systems (GIS) are used to display and overlay layers of spatial data. In contrast to basic computer programs that can be used to draw simple maps or import static images, GIS import, manage, and display raw spatial data. This GIS capability is significant, enabling users to develop accurate and precise maps based on quantitative data. Because quantitative data are incorporated into GIS the associated maps can be modified easily, changing with changes in the underlying spatial data. Furthermore, this quantitative data handling capability enables users to overlay numerous spatial data sets and statistically analyze these data, developing quantitative relationships not achievable using simple map drawing or graphics display programs.

Components

A GIS consists of three key components: hardware, software, and data. A simple GIS can be developed by loading basic GIS software on a desktop personal computer and using it to display and analyze any spatial data accessible through that computer. A more robust GIS can be developed by loading advanced GIS software on multiple desktop computers, linking these computers through local area networks (LAN), and using a database management system (DBMS) to archive spatial data. Although the second GIS described offers the most options and flexibility in performing agrometeorological analyses, quality analyses can still be achieved using the first GIS described. Furthermore, the former often requires much less maintenance than the latter, and is therefore much easier to manage.

WAOB GIS

Hardware and software

WAOB meteorologists developed an agency GIS using Environmental Systems Research Institute (ESRI) Inc. ArcView 3.2 software installed on desktop personal computers and the WAOB LAN. Each desktop computer has a Pentium III processor, a processing speed between 450 and 900 MHz, between 256 and 512 MB of RAM, and is equipped with the Microsoft Windows 98 operating system. ESRI's Spatial Analyst 2.0 extension is installed on several desktop computers and the LAN, enhancing the functionality of the ArcView 3.2 software. Given this configuration, multiple people within WAOB have access to the GIS. Nevertheless, the majority of the GIS products regularly produced by WAOB are created using just one computer, demonstrating that advanced systems and networks are not necessary to produce quality products.

Data

Several meteorological data sets are examined regularly to assess the impact of weather on global crop production. International crop progress and conditions are estimated using World Meteorological Organization (WMO) temperature and precipitation data. Similarly, domestic crop development is monitored using synoptic and cooperative observer data obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA). All of these data are archived in the WAOB agricultural weather DBMS. Other meteorological data sets are examined less frequently, however, these data often play a significant role in assessing crop progress and conditions when extreme or severe weather is observed. Such data includes tropical cyclone coordinate data and data from various meso-networks. Because these data are used irregularly, these data are not typically stored in the WAOB DBMS.

Another important group of data examined by WAOB meteorologists is various agricultural data. International and domestic crop production data are used to identify major and minor crop producing areas worldwide. These data help meteorologists focus crop weather monitoring efforts on only those regions that are agriculturally important. Additionally, domestic crop progress and condition data obtained from the USDA National Agricultural Statistics Service (NASS) are often examined to help augment these assessments.

Sample Analyses

Following are examples of how WAOB meteorologists have used GIS to display and analyze agrometeorological data.

Analysis of WMO data

Figure 1 shows a sample text file containing comma-delimited WMO temperature and precipitation data. Note that information on the latitude and longitude of each reporting station is included in this file. Such data are necessary for the GIS to plot the weather observations in the correct locations. Figure 2 depicts these data after they have been imported into ArcView 3.2. This data table looks similar to those seen in spreadsheets, however, unlike spreadsheets; GIS are designed specifically to display and analyze spatial data. Figure 3 illustrates how ArcView 3.2 can be used to display the raw meteorological data and overlay these data on other data such as political boundaries. This map was created using the graphical user interface (GUI), commanding the software to generate a map of maximum temperatures at point locations. Finally, figure 4 shows how GIS can be used to further analyze spatial data. A shaded contour map of maximum temperatures was created using the ArcView Spatial Analyst extension to interpolate among point values. In addition to serving as an effective tool for displaying and analyzing meteorological data, GIS is also an effective tool for displaying and analyzing crop data.

Analysis of crop production data

Figure 5 shows U.S. county-level crop production data for corn as viewed on the USDA NASS web site. Data tables for a variety of crops, including corn, cotton, soybeans, wheat, and barley, were downloaded from this web site to a desktop computer. Similar to the WMO data, the downloaded data were imported into ArcView 3.2 and displayed, as demonstrated in figure 6. Major and minor crop production areas in the United States are delineated based on the underlying quantitative crop production data imported into the GIS. Note that latitude and longitude data are not included in the crop data table. In this case, crop production data were mapped by joining the crop data file to a county data file that contained the necessary spatial data to map county locations. These examples combined demonstrate how GIS can be used to display and analyze a wide variety of data. Significantly, these data layers can be overlaid and analyzed simultaneously to obtain even more information.

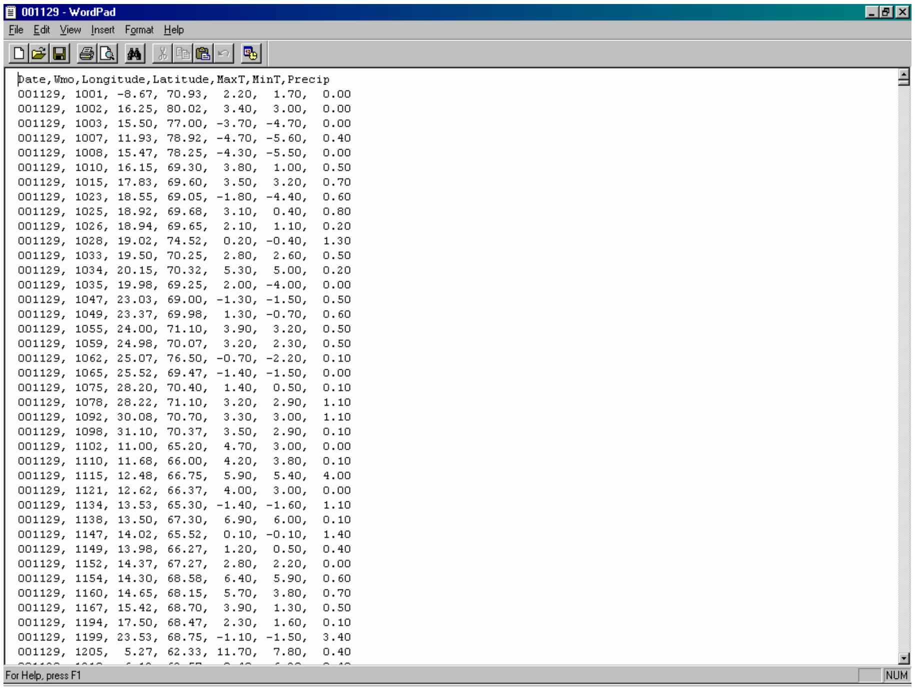


Figure 1. Sample text file containing WMO temperature and precipitation data.

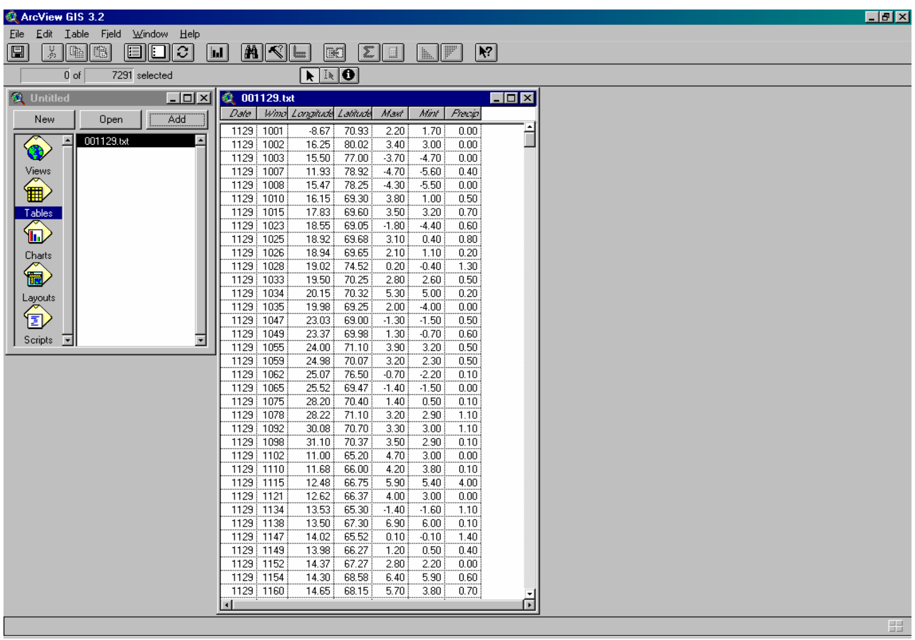


Figure 2. WMO data imported into ArcView.

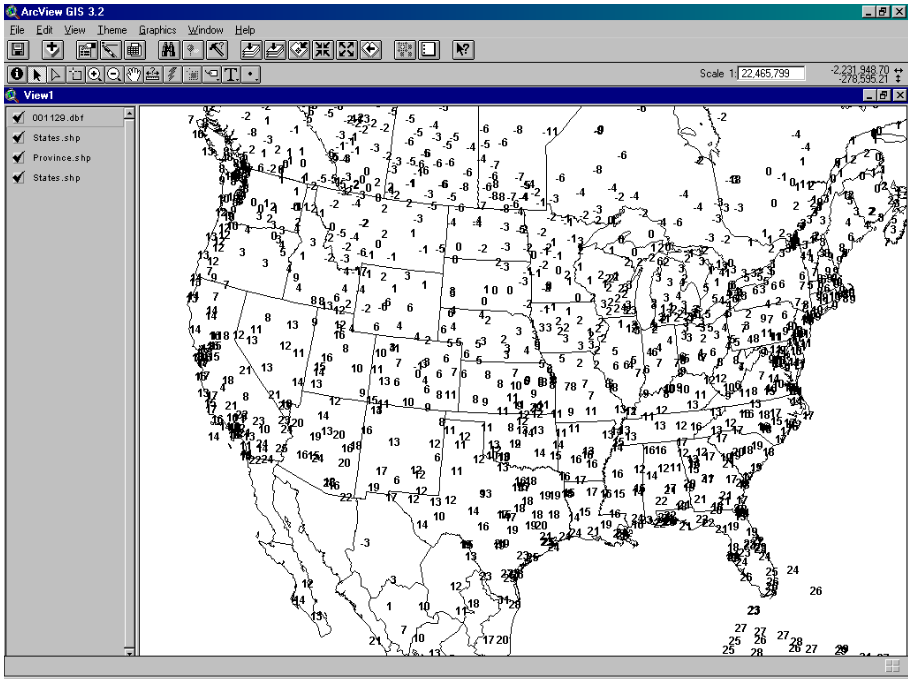


Figure 3. Raw WMO maximum temperature data plotted in ArcView.

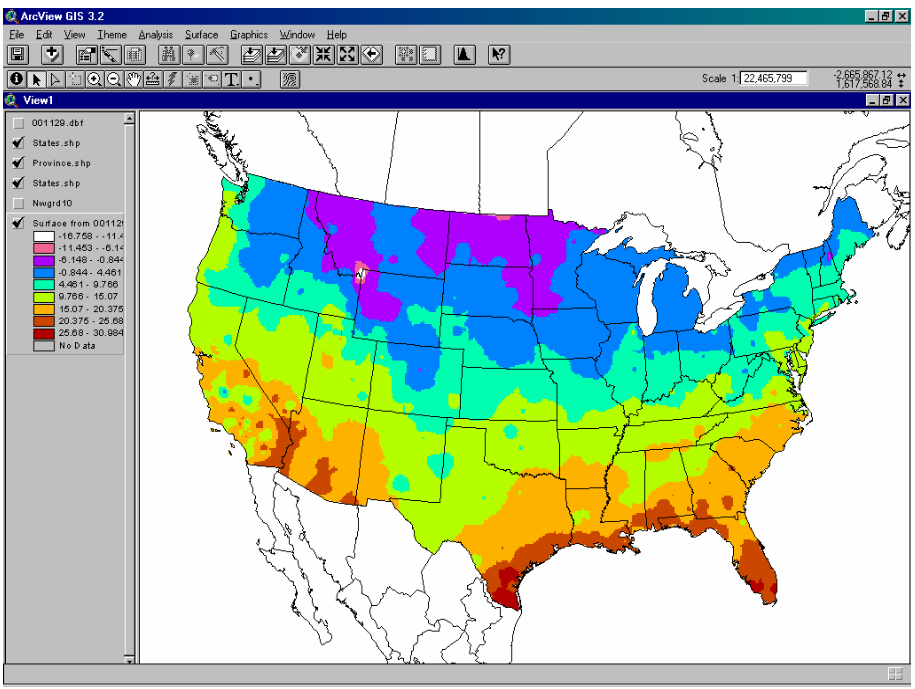


Figure 4. Interpolated analysis of maximum temperatures in ArcView.

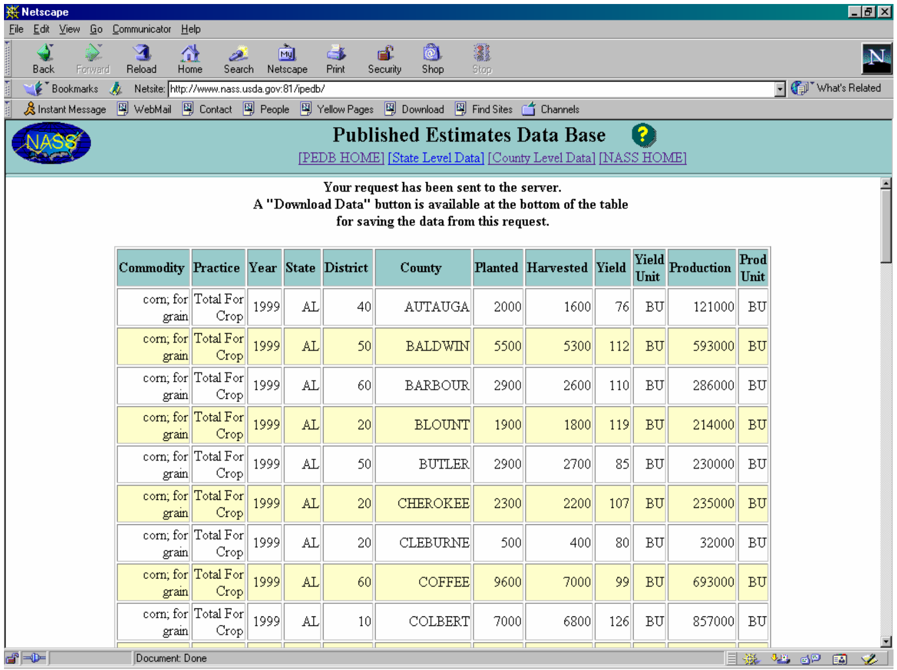


Figure 5. County-level corn production data on the USDA NASS web site.

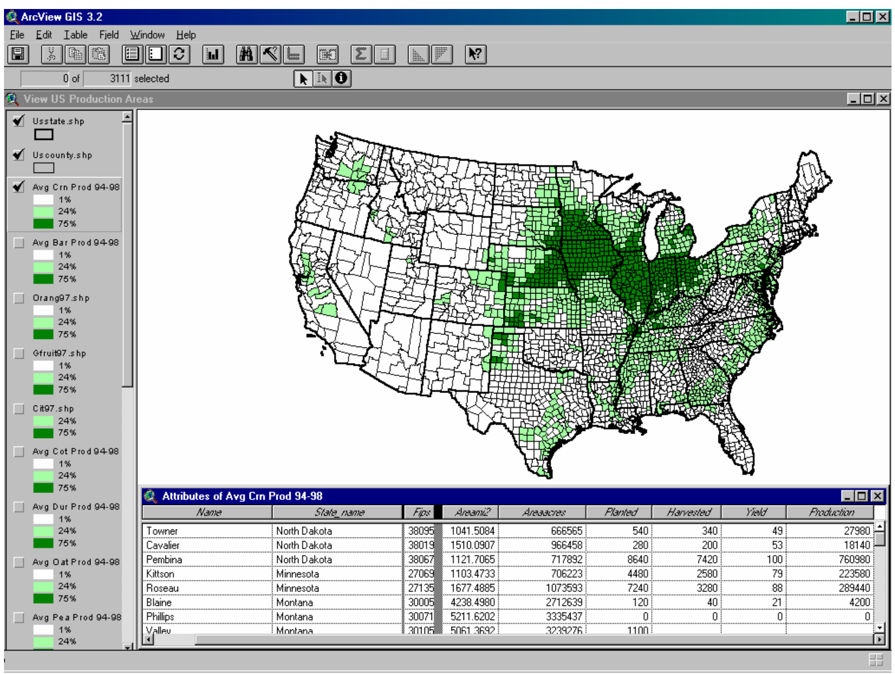


Figure 6. Corn data imported into ArcView and displayed.

WMO data overlaid crop production data

In September 2000 tropical storm Gordon made landfall in the southeastern U.S., producing heavy rain in major cotton-producing areas. WAOB meteorologists were requested to assess the likely impact of the heavy rain on cotton production in this area. This task was accomplished by overlaying numerous data sets in the WAOB GIS. Figure 7 depicts the major and minor cotton-producing areas in the southeastern U.S. as shown in ArcView. Tropical storm coordinate data were downloaded from the Internet and imported into ArcView to show the track of the storm, as shown in figure 8. Similarly, rainfall data were obtained from NOAA and imported into the GIS. These data were contoured and overlaid the other data layers for further analysis, as shown in figure 9. Finally, the percent of cotton in each state that was in the critical open-boll stage of development was plotted on the map to identify the fraction of the crop most susceptible to heavy rainfall. The final map, shown in figure 10, was exported as a JPEG image and distributed to WAOB economists to assist them in preparing commodities estimates. Similar products have been prepared to assess the temporal and spatial extent of flooding rains during summer crop harvesting, to analyze the likely impact of drought on corn production, and to determine the impact of freezing temperatures on citrus production.

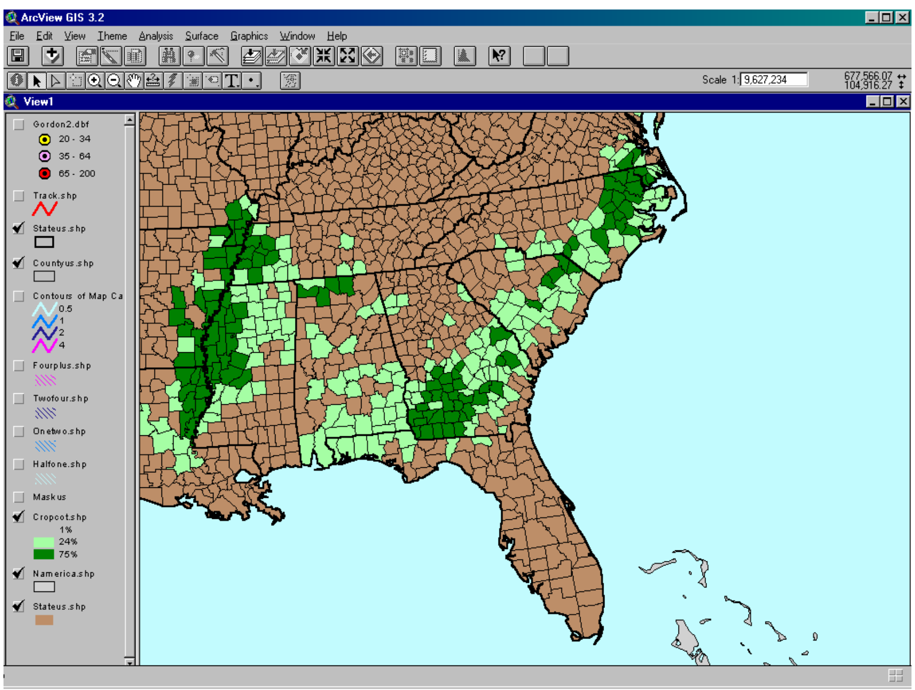


Figure 7. Cotton-producing areas in the southeastern U.S. displayed in ArcView.

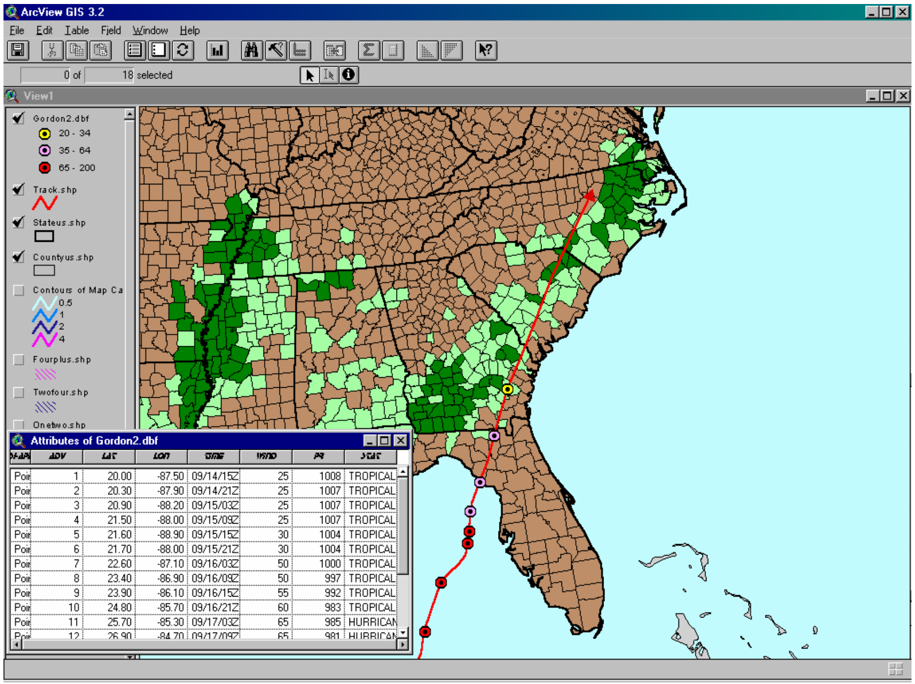


Figure 8. Tropical storm coordinate data imported into ArcView and overlaid crop data.

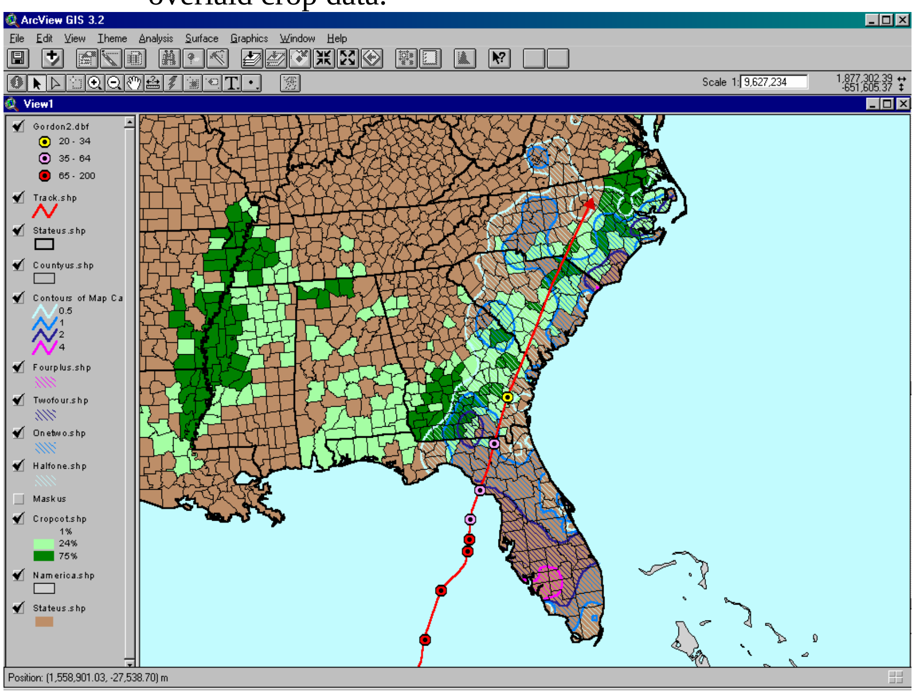


Figure 9. Rainfall data contoured and overlaid crop and tropical cyclone data.

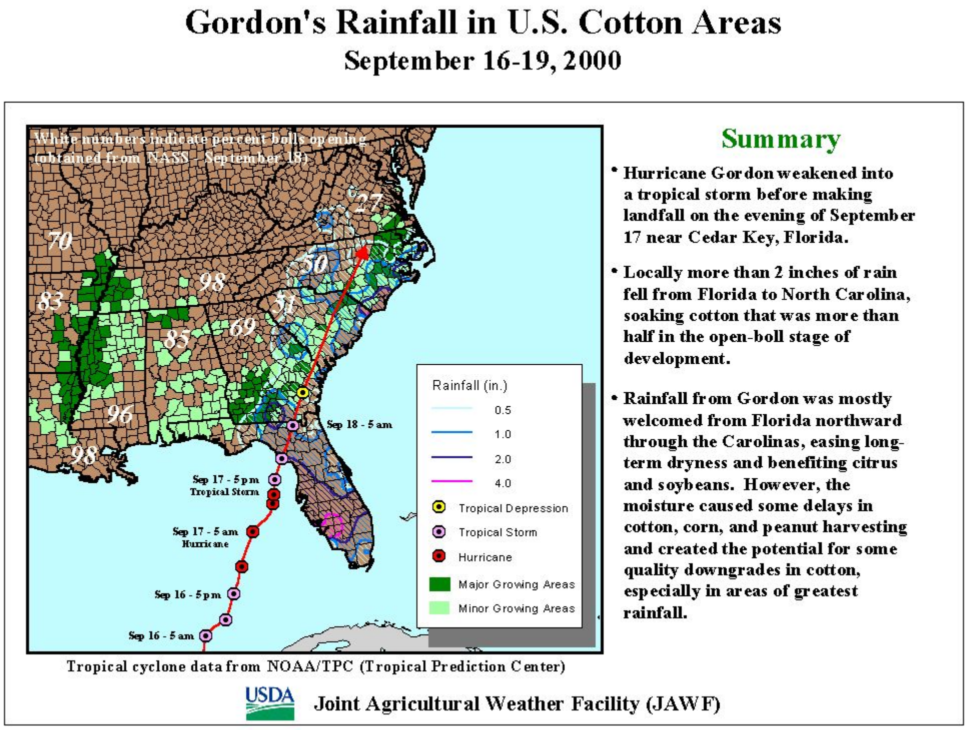


Figure 10. Final product resulting from several data layers overlaid in GIS.

Customization and Automation

Programming

Similar to other commercially available Windows products, ArcView 3.2 has a user-friendly, menu-driven architecture that simplifies user interactions with the GIS. Nevertheless, creating several similar, but relatively simple maps, or one map with numerous data layers, can be time consuming. An important feature of ArcView 3.2 that has significantly benefited WAOB meteorologists is the ability to customize and automate ArcView processes using the Avenue programming (i.e., scripting) language. WAOB meteorologists produce hundreds of maps each month using the WAOB GIS. Such maps include daily and weekly plots of maximum and minimum temperatures and precipitation for approximately 20 regions worldwide and crop progress and condition maps for several major domestic crops. Producing these maps without automation capabilities would be enormously labor intensive and time consuming. For these reasons, Avenue scripts were developed to automate numerous tasks, including importing data, processing and analyzing data, and exporting maps.

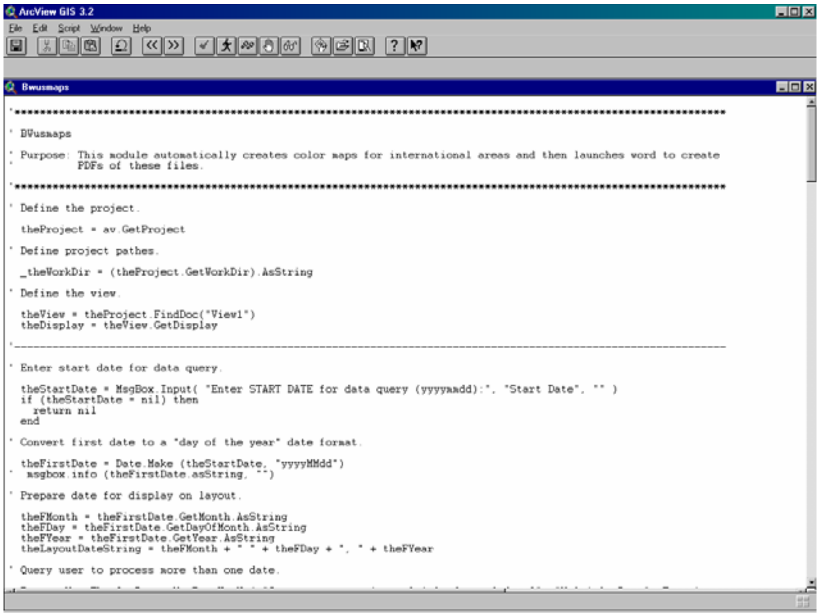
The Avenue programming language is an object-oriented programming language that is similar to Visual Basic or Visual Basic for Applications. The language is considered object-oriented because the code interacts with windows, menus, buttons, text boxes, and other objects within ArcView. For example, GIS users can develop routines that respond to such actions as button pushes or menu clicks. Conversely, code can be written that causes points to be plotted, text to be written, or maps to be exported automatically. Using Avenue, WAOB meteorologists have significantly improved operational efficiency by creating custom menus, buttons, and tools that are tailored to specific user needs and automate numerous time consuming and redundant tasks. If such programming capabilities were not available, many of the maps produced by WAOB could not be produced operationally.

Weekly Weather and Crop Bulleting maps

WAOB meteorologists developed several scripts that automatically produce color maps using the WAOB GIS. Although color maps are often easier to interpret, printing and copying costs prevent distribution of these maps via the *Weekly Weather and Crop Bulletin* publication. As a result, WAOB meteorologists recently began developing scripts to produce black and white versions of these maps for publication. Given that these maps must be produced in black and white, these maps necessitate the use of labels to delineate temperature and precipitation gradients. Figure 11 shows sample code developed for this project. This code is similar in structure to that of the Visual Basic programming language. Figure 12 shows a sample map generated using this code. Note that many of the properties of this map are controlled through this code. Such features include, but are not limited to, contour spacing, label size and spacing, line thickness, shaded areas, and the map projection.

Discussion

These examples show that GIS is a convenient method for displaying and analyzing agrometeorological and other data sets. An important feature of GIS, however, is the ability to overlay and analyze data sets simultaneously. This capability enables users to statistically evaluate and quantify relationships, such as the percentage of a corn-producing area that is experiencing severe drought. Another important feature of ArcView GIS is the ability to customize and automate tasks by programming in Avenue. This programming language enables users to automate repetitive tasks and thereby improve operational efficiency. Such automation is necessary to create rapidly multiple maps. Given that a wide variety of dissimilar data sets can be displayed and analyzed in GIS, and that quality maps can be produced using this technology, GIS offers an attractive means for producing maps for agrometeorological bulletins.



```
ArcView GIS 3.2
File  Edit  Script  Window  Help

Bwusmaps

'*****************************************************************************************
' BWusmaps
' Purpose: This module automatically creates color maps for international areas and then launches word to create
'          PDFs of these files.
'*****************************************************************************************
' Define the project.

  theProject = av.GetProject

' Define project pathes.

  _theWorkDir = (theProject.GetWorkDir).AsString

' Define the view.

  theView = theProject.FindDoc("View1")
  theDisplay = theView.GetDisplay
'-----------------------------------------------------------------------------------------

' Enter start date for data query.

  theStartDate = MsgBox.Input( "Enter START DATE for data query (yyyymmdd):", "Start Date", "" )
  if (theStartDate = nil) then
    return nil
  end

' Convert first date to a "day of the year" date format.

  theFirstDate = Date.Make (theStartDate, "yyyyMMdd")
'  msgbox.info (theFirstDate.asString, "")

' Prepare date for display on layout.

  theFMonth = theFirstDate.GetMonth.AsString
  theFDay = theFirstDate.GetDayOfMonth.AsString
  theFYear = theFirstDate.GetYear.AsString
  theLayoutDateString = theFMonth + " " + theFDay + ", " + theFYear

' Query user to process more than one date.
```

Figure 11. Sample Avenue code that creates black and white contour maps.

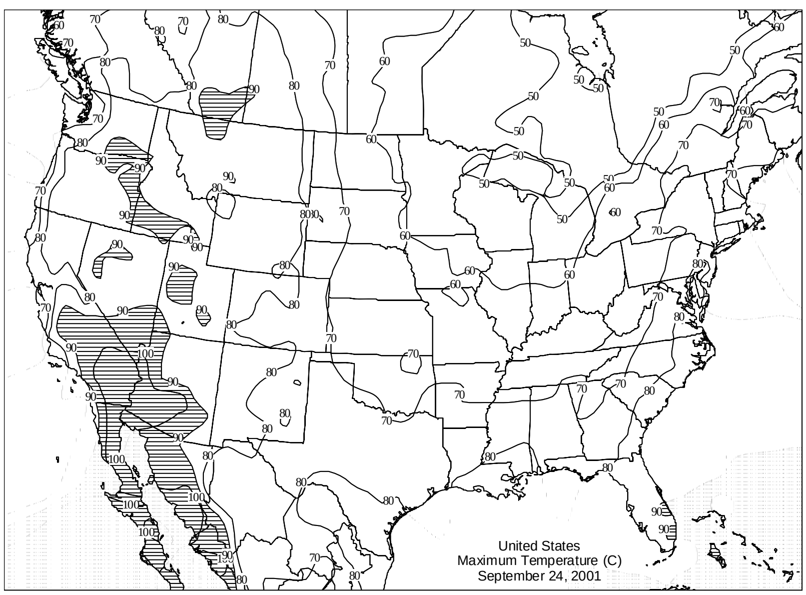


Figure 12. Example black and white contour map generated from the above code.