WORLD DATA CENTER A
for
Solid Earth Geophysics

Global Change Data Base

Training Exercise Manual

Exploring Earth's Environment
. . . Africa as an Example

World Data Center A for Solid Earth Geophysics Publication SE-48
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NATIONAL GEOPHYSICAL DATA CENTER

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How to Contact Us

We invite anyone to propose corrections or volunteer additions to the data base, documentation, or this workbook. We do not guarantee that we will be able to incorporate these changes. Nevertheless, we will endeavor to make corrections where appropriate, and where our resources allow us to do so. Comments may be addressed to:

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PREFACE

Welcome! By following this manual, you will learn how to see the world in a new and fascinating way. You will be able to explore possible relationships between characteristics of the Earth. You will be able to study the impact of the environment on a region, such as the effect of poor soils and low precipitation on vegetation.

This manual of exercises is designed for self-study. It will take you from a brief introduction to the data base, through actual analysis examples using the data for Africa from the Global Change Data Base (GCDB). This manual does not cover basic concepts of computers, the DOS operating system environment, any particular scientific discipline, nor the full range of capabilities of geographic information systems (GIS).

This manual is structured around a series of introductory exercises that are designed to stimulate "thinking in GIS." That is, to provide a basis from which you can begin to have a "feel" for how data are handled and the various kinds of analytical operations that can be performed. With luck, you will never complete this work, for you may be drawn into a quest to continually learn more about Earth's environment

Materials have been created by people with experience in teaching at the middle-school, secondary school, U. S. junior college, university undergraduate and postgraduate levels. These exercises should be adaptable to your own teaching or learning environment, using the exercises themselves as examples, and your creativity.

Likewise, these exercises may give you ideas for developing your own new exercises. If you do develop new exercises, we would like to hear from you. We would like to review your developments for possible inclusion in subsequent versions or supplements to this manual, with appropriate credit to the authors of the new materials.

This manual was developed using IDRISI, a low-cost educational GIS. These exercises, and the data themselves, can be used in a variety of other software packages. See Appendix B for guidelines for using the materials in some GIS other than IDRISI.

For users of IDRISI, a more detailed introduction to the IDRISI GIS software is provided by the IDRISI reference manual, which contains a tutorial section that focuses specifically on the use and applications of IDRISI. The tutorial in the IDRISI reference manual may be useful to users of other GISs besides IDRISI.

Please note that this manual was written for users of IDRISI 3.X. IDRISI 4.0, just released, has some minor changes. For example, you now press the ESC key to exit COLOR, rather than the

ENTER key. IDRISI 4's .DOC files are slightly different from DIRISI 3.X's. Users of IDRISI 4.0 and future editions may want to convert their .doc files, remembering that the reference system (projection) of these data is latitude-longitude. The documentation for the Global Change Data Base, Pilot (Diskette) Project for Africa contains information to ease this conversion.

ACKNOWLEDGEMENTS TO CONTRIBUTORS

This workbook is the result of many contributions, most notably by the Graduate School of Geography of Clark University (Worcester, Massachusetts), the National Center for Geographic Information and Analysis (University of California, Santa Barbara), WDC-A for Solid Earth Geophysics operated by the National Geophysical Data Center of NOAA, the United Nations Institute for Training and Research (Geneva, Switzerland), the United Nations Environment Programme Global Resources Information Database (Nairobi, Kenya), and participants in UNITAR/UNEP training workshops in Accra (Ghana) and Dakar (Senegal).

Individual components of the data base have been developed by numerous scientific laboratories and individual scientists. Specific credits are made in the documentation to the data base. The data have been compiled and integrated at the World Data Center - A for Solid Earth Geophysics.

Funding support for this project came from NOAA's National Geophysical Data Center, the Interagency Working Group on Data Management for Global Change, the International Geophere-Biosphere Programme's Working Group on Data and Information Systems, the International Council of Scientific Unions' Panel on World Data Centers, and the United Nations Institute for Training and Research.

The final version of the workbook was edited by Michelle Fulk of Clark University and David Hastings of NOAA's National Geophysical Data Center.

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INTRODUCTION

This manual attempts to provide economical and convenient ways for researchers and schools to explore the global environment, and to analyze phenomena of global change. The complete package includes the data base (extracted from the Global Change Data Base, supplemented with selected data sets for Africa), documentation for the data base, this workshop manual, and the user's choice of raster Geographic Information System (GIS) including its own documentation and training materials.

Up to the present, most research on the global environment has focused on either localized detailed studies (such as with high-resolution satellite imagery), or very coarse-scale (2.5 to 5 degree resolution) regional and global modeling studies primarily of the oceans or atmosphere. In contrast, relatively little has been done at medium scales ranging from 1/4 to 100 km (approximately .3 to 60 arc-minutes), with the exception of pioneering work with the satellite-derived "vegetation index" and other products derived from NOAA's AVHRR sensor. Other existing data sets at these medium scales are sketchily developed and inadequately accessable in usable form. Yet information at this scale can reveal interesting phenomena that may be significant over nations, regions, continents, and the world. It can provide a useful context for high resolution studies of internal interest to many countries. Thus it is with the goal of furthering research at this medium resolution, and linking it with work at the two extremes, that the Global Change Data Base has been inspired.

The source data sets available for this project were often not complete, well documented, or as reliable as desired. However, much work has already been done to improve this situation, to provide the best data sets that are readily available in digital form. Appendix A describes the development of the data base.

You may want to follow developments in the overall Global Change Data Base, being compiled at the World Data Center - A for Solid Earth Geophysics, in cooperation with numerous laboratories and individual scientists. As that project progresses, additions and improvements to the global data base can be windowed out for Africa, to supplement/improve data used for these exercises. You will also be able to design your own investigations of Africa, or elsewhere in the world, with the full Global Change Data Base.

You may wish to place yourself on the mailing list to receive future announcements about the Global Change Data Base, by contacting the World Data Center - A for Solid Earth Geophysics, at the address, phone, or FAX number given on the page ii of this manual.

BRIEF OVERVIEW OF THE DATA

The next two sections offer a very brief summary of data upon which this manual is based. A full description of the data is given in the documentation manual that accompanies the data base. The two sections given here provide a simpler review, designed for the classroom. If enough interest is developed, we may create a collection of 35mm slides to illustrate some of these issues for use in the classroom and lecture hall.

Derivation of the Global Vegetation Index from Satellite Observations

Since 1978, the Polar Orbiting Environmental Satellites of the USA's National Oceanic and Atmospheric Administration (NOAA) have carried an instrument called the Advanced Very High Resolution Radiometer (AVHRR). Besides measuring the temperature of the Earth's surface with its thermal infrared channels, AVHRR has been used by several scientists to study the vegetation of the land surface.

AVHRR has proven to be the most practical way to monitor Earth's surface regularly, at a resolution that is adequate for many medium- to large-scale studies. While the high-resolution satellites (e.g. Landsat) provide resolution of an order of magnitude or better, they do not offer adequate time resolution for such study.

AVHRR has a field of view on the ground of about one kilometer. However, such detail produces a lot of data, far beyond the capacity of the satellite's on-board tape recorders to store. In order to produce daily coverage of Earth, the data must be sampled to lower resolution. Thus, an onboard processor samples the 1-km data to obtain a 4-km product which is then stored for transmission to designated ground stations. The result is one sixteenth (1/4 x 1/4) the data, allowing complete daily coverage of Earth with 4-km AVHRR imagery.

Widespread cloud cover obscures the Earth's surface. Thus the 4-km data are saved and processed to produce a composite containing minimal cloud cover. If cloud-free coverage exists for any given area during the sampling period, such imagery is used in the final composites. Cloud-free global coverage usually requires at least five days. Sometimes even 14 days of samples do not provide completely cloud-free imagery. Of course there are regions of very low cloudiness, but these also tend to have low vigor of vegetative growth.

The Satellite Data Services Division (SDSD) of NOAA's National Climatic Data Center distributes daily and weekly global composited Global Vegetation Indices. For this project, we have composited and regridded these data to monthly images on a 10-minute spatial grid (about 16 x 16 km near the equator).

You may wish to read the chapter in the documentation that discusses the Global Vegetation Index. It describes how the data are computed, and gives references and an example of how the data can be used.

If one desires higher resolution than provided by the Global Vegetation Index, one must process the individual 1-km or 4-km scenes. These must be geometrically corrected to reduce distortions inherent in the original data from sensor characteristics, and roll, pitch, yaw, and variation of altitude of the spacecraft. Many more corrections should be made. These include corrections for different intensities of illumination at different latitudes on the Earth, dust, haze, and other obstacles in the atmosphere, etc. All these corrections must be performed perfectly to obtain a high-quality image. Current technology does not enable us to make all these corrections to the level that we would like. The result is a valuable but imperfect view of the world.

Derivation of Additional Thematic Data Sets From Available Sources

A major part of this data base has been derived by digitizing maps, or by placing into digital form information that traditionally would be printed out as hardcopy maps.

The data are regional data sets, available for the whole world, or at least for Africa. None of these data sets is perfect, as our knowledge of the world is uneven and incomplete. We don't even know what categories to use when designing data for digital processing. Soil groupings or rock-type classifcations were originally developed for people to think about qualitatively, not for the numerical rigor of digital processing. These classifications have not been optimized for digital processing. It is likely that we will substantially change our methods of describing soils, vegetation, and other topics, as we learn more about how to handle digital environmental data.

Even if the data currently in the data base are less than ideal, they are pioneers in the attempt to digitally represent Earth. We can discover much useful information in these data sets. The key to providing a truly usable data base is to use a coherent and commonly registered data structure (as required by geographic information systems) and complete documentation that will allow the user to assess the value and limitations of the data set.

This project attempts to provide an educational version of such data. The data include:

- NOAA monthly 10-min. normalized difference vegetation index (April 1985-December 1988)
- Olson world ecosystems (WE1.4)
- Holdridge life zones
- Matthews vegetation, land-use, and seasonal albedo
- Zobler soil type, soil texture, surface slope, and other properties
- FAO soil units

- UNEP-GRID/FAO Africa GIS data base (wind, rain, crop, vegetation, desertification hazard)
- Legates and Willmott average monthly air temperature and precipitation
- Revised FNOC elevation, terrain, and surface characteristics
- Integrated elevation and bathymetry
- Micro World Data Bank II: coastlines, country boundaries, islands, lakes, and rivers
- World Data Bank II: nations (polygonized) and rivers

Sources for these data sets are credited in the documentation.

Development of Appropriate GIS Software

All data sets in the project have been quality-checked and registered to a common origin, projection, and format. Most of the environmental data provided to us have been in gridded format, with the exception of line work such as national boundaries.

This structure makes the data base suitable for use in raster-based GISs. The data can be converted to vector format for use in vector-based GISs. However, many vector-based systems lack many capabilities needed to carry out the exercises, or to perform some other types of analysis. This is not an inherent deficiency in vector technology, just a result of the current state of development of many vector-based systems.

IDRISI, the GIS used most heavily in this project, is a raster-based Geographic Analysis and Image Processing system with vector overlay and database management capabilities which runs on widely available, IBM-compatible microcomputers. It has been significantly modified for this project, and has been adopted by UNEP/GRID and UNITAR for their training program.

If you are planning to use a GIS other than IDRISI, you should become familiar with Appendix B of this manual.

For cultural perspective, you may wish to read Appendix A, which describes the goal of the UNEP/UNITAR training program in GIS. Appendix A contains a brief sketch of the development of the data base and accompanying materials. This will let you appreciate some of the problems that your colleagues face around the world, as they try to explore the global environment with less-than-ideal facilities.

GETTING STARTED

To get started, we will install the data, and the GIS that you have chosen to explore the data. Then we will learn the basic skills necessary to use our GIS with the data. If you've already had some experience with a GIS software package, you will then be ready to explore the data base on your own. We recommend, however, that even if you've had such experience, you go through the exercise section of this workbook.

Installation

If the data base is already installed on your computer, go directly to "A Look at Your GIS and Data Base" (page 10). **If you are using a GIS other than IDRISI, read Appendix B before proceeding.** Installation of the Global Change Data Base (GCDB) must be undertaken in several steps:

1. **Install your GIS.** Follow the instructions in your software manual.

2. **Install the Data Needed for the Exercises.**

   General instructions for installation of the Global Change Data Base are included in the Data Set Documentation. You should read these before installing the data. The full data base contains almost 70 megabytes. If you have enough disk space this will not present a problem. If disk space is limited, you can perform the exercises with the specially marked Workshop Exercise Disks. These require about 30 megabytes of data plus some work space. Ideally, you should have about 50 megabytes of free disk space.

   The Global Change Data Base is provided three sets of floppy diskettes, labelled "Global Change Data Base: Africa," "Workshop Exercise Disk," and "Supplemental Data Disk." To install only the minimum required to complete the exercises:

   A. Create a directory to hold the data. For the purposes of these instructions we will assume it is called "d:\gcdb". Use the DOS "make directory" command from the d: prompt:

   ```
   md gcdb
   cd gcdb
   ```

B. Place each disk of the series "Workshop Exercise Disk" into Drive A. For each disk enter the following command:

copy a:*.*

C. When all "Workshop Exercise Disks" are copied onto your hard disk, enter the command:

load

"Load" executes a batch file named "load.bat." This runs the program "pkunzip.exe" on the disk, which decompresses the included ".zip" file into several data sets. "Load" then deletes the compressed file. If something goes wrong, such as your having insufficient space on your hard disk, files may not have been converted completely or correctly. If your GIS cannot read them, repeat the installation process, making sure that you have sufficient space on your hard disk. APPENDIX F gives a list of the data sets contained on each floppy diskette, to help you find a file on the original floppies.

3. Optional Installation of Other Data From the Global Change Data Base.

At some time, you may want to look at the rest of the data base for Africa. You may be curious about what other environmental data may exist, or you may want to develop additional workshop exercises.

NOTE: If you DO develop additional exercises, and wish to share them with other educators, remember that the data and this manual are in the public domain, so may be freely copied. Also, please remember that your GIS is probably NOT in the public domain, not legally copyable. If you develop exercises that you believe might interest the wider educational community, and you would like us to distribute them in an expanded workshop manual, please contact us at (303) 497-6125, or at the address given on the inside front cover of this manual.

Look at APPENDIX F to see the names of types of data included in the floppy diskettes. Look at the documentation manual for the data base, to learn about these types of data. Make a note of each file name that you are interested in, and note the Global Change Data Base or Supplemental Data disk that each file is on.

A Make a temporary subdirectory, for example:

md gcdbtemp
cd gcdbtemp

B. Place each Global Change Data Base disk holding data that you want to use in Drive A. For each disk, enter the following command:

copy a:*.*

C. When all such disks have been copied into your temporary directory gcdbtemp, run:

load

Run "DIR *.img" on directory gcdbtemp, to see what files are there. You may find extra data sets that you don't want. You can delete these, remembering to delete both the .img and the .doc file for a data set. Copy the files that you want to your main directory for the Africa data base (in our example, directory "gcdb"), and delete them from directory gcdbtemp.

4. Copy the Palette Files to the Correct Location.

If you are using IDRISI, you may know about palette files. During your installation, you have copied some .pal files into your data directory. They need to be transferred to your program directory.

(If you are using another GIS, you may be able to translate these palette files for your use. Alternately, you may ignore them.)

C. Now change to your IDRISI program directory and copy the files using the commands:

cd \idrisi
copy d:\gcdb*.pal

D. Finally, check that your CONFIG.SYS file has an entry that reads FILES=30 (or any larger amount). The exercises make extensive use of a Microsoft-compatible mouse. Be sure that your mouse driver software is automatically loaded by either your CONFIG.SYS file (eg. "device=mouse.sys") or by your AUTOEXEC.BAT file.

This completes the installation process. If you have any trouble with this process, please contact the NOAA National Geophysical Data Center at (303) 497-6125. If you are using IDRISI, and your problem is with software characteristics or installation, call the IDRISI Technical Assistance Line at (508) 793-7526.

A Look at Your GIS and Data Base

Let's take a look at the GIS that you will be using, and at the data base. Depending on your proficiency with your GIS, you may want to follow different itineraries when reading this section:

1. If you are expert on your GIS, and merely want to learn about the Global Change Data Base for use in the exercises, you will want to skim lightly over parts of this text that are irrelevant to you. Don't skim too quickly, however. Some of the text, though geared to familiarizing users of IDRISI, can be adapted to your GIS.

2. If you will be using IDRISI, you will want to read this entire section at varying rates of speed, depending on your expertise with IDRISI. However, don't read so quickly that you miss material that will be useful to you in the exercises.

In this section you'll learn the basic skills that you will use in the exercises, and in exploring the data base on your own. Take your time as you are going through, and be sure you understand the operations you are performing before you continue.

IDRISI FUNDAMENTALS

If you are new to IDRISI, and plan to use it for these exercises, you may want to read this section in detail. If you are an experienced user of IDRISI, or if you are going to use another GIS with these exercises, you may only want to skim over this section, to glean from it information that will help you with the exercises.

The first thing we need to do is get into the directory where you installed IDRISI. For example, if you installed IDRISI into a directory on Drive C named "idrisi," your command sequence would be:

c:	change to Drive C
cd\idrisi	change to the IDRISI directory

You should then see the line "C:\IDRISI>" followed by a blinking underline, known as the cursor. You are now in the IDRISI directory, and can run any of IDRISI's commands from here. There is, however, a menu system also available. Access the IDRISI menu by typing "idrisi" and pressing return.

If you use IDRISI a lot, you may find it convenient to create a DOS batch file that saves all these manual directory changes and gets you quickly to IDRISI. Place such batch files in a \BAT directory, if you have one, or in any other directory that is in your normal DOS path. An example:

c:	changes the system to Drive C
cd\IDRISI	changes the system to the IDRISI directory
environ	starts the IDRISI "environ" command that lets you set the location of your data base (in our example, you would want line "1" of the environ command to read "c:" and line 2 to read \gcdb.)

You might call this IDRISI.BAT.

Another example, which you could call idrisi.bat if you never use the batch file noted above, or which you might alternatively call menu.bat, might be:

c:	changes the system to Drive C
cd\IDRISI	changes the system to the IDRISI directory
idrisi	starts the IDRISI menu system (This is convenient if you use the menu a lot.)

OK. Back to the IDRISI menu.

The menu system provides a main menu which lists the major program groups in IDRISI and submenus which list individual program modules. To move around the menus, use either your mouse (if you have one attached) or the arrow keys. The menu system will also allow you to type commands directly as if you were at the operating system (DOS) prompt. In fact, all the menu system really does for you is type the keystrokes that you would otherwise have to type yourself at the operating system prompt. As you become familiar with IDRISI commands, you may find that typing commands in at the DOS prompt is faster than using the menu.

With the menu on the screen, use your mouse or the arrow keys to move the highlighted box over DISPLAY MODULES, then press ENTER. All of the commands belonging to the DISPLAY group of commands will then be shown in the submenu on the right side of the screen. Notice how at this point, the mouse and arrow keys move you around in the submenu, and the DISPLAY MODULES box in the main menu is fixed. To get out of the submenu and back over to the main menu, press the ESC key.

Note that the line "Idrisi >>" appears in the lower left part of the screen. This looks similar to the operating system prompt you saw earlier, and in fact, works the same way. Any IDRISI command can be executed directly from here, just by typing in the command.

Pressing ESC again will take you out of the menu system entirely. You are now back at the operating system prompt within the IDRISI directory. To get back into the menu system, simply type IDRISI.

Practice going back and forth from the operating system prompt to the menu a few times. Be sure you are comfortable with this before proceeding. The rest of the workbook will be written as if you are typing in commands from the operating system prompt. If the menu system seems more comfortable to you, feel free to use it. Which method you choose to use is completely up to you, and won't affect your results in any way. Whenever the instructions tell you to run or use a command, either type the command in at the prompt, or, if you are using the menu system, look through the commands until you find the correct one, position the highlight box over it, then press return.

For example, if the instructions tell you to use COLOR, if you are using the menu, you would look at the main menu categories, decide which was likely to contain the command COLOR (in this case DISPLAY MODULES) highlight that main menu category, press return, find COLOR in the submenu, highlight it, and press return. This will get you to the same point as if you had typed in COLOR at the operating system prompt.

Use either method to run COLOR. IDRISI will then ask you for the name of the file to be displayed. Since we haven't looked at the files in the data base yet, enter q (for quit) and press return. You can get out of many of IDRISI's commands in this way.

SETTING THE ENVIRONMENT

The first step in any session with IDRISI is to check that the "environment" is correctly set. The "environment" refers to the various settings that IDRISI uses to determine where your data can be found, the measurement units you're using, and the like. The environment is set by a program module named ENVIRON. Run ENVIRON.

ENVIRON will show how the system is currently set up, and will allow you to change any of the items that are not correct for your session. To change any item, first enter the number of the item you wish to change, and press return. You will be prompted by a line at the bottom of the display to give the new value. Try this with number 1, the default data disk drive option (even if it's set correctly, just to try it). Enter a 1 and press return. Then enter the name of the disk drive that contains the Global Change Data Base (ask your instructor if you're not sure). If you make a mistake and need to change the drive to something else, do so. When you have the drive you want listed, press return. Now you are ready to choose another item to change.

Make sure that the default data path is set to the directory that contains the GCDB data base (eg. "\gcdb"). Note that the default data path must always begin with a backslash "\". The only remaining option we need to change is the cell measurement units. This item tells IDRISI in what units (meters, miles, degrees, etc.) to measure things. For all the files in the GCDB data base, the unit of measurement is degrees ("deg"). Therefore select the cell measurement unit item and change it to read "deg."

The remaining items can be left at their default values. In particular, you should not alter the various naming conventions for file extensions that are listed. The GCDB uses the default extensions. Other options may be changed if you wish. You will see that some options allow you to change the colors of the text displays in IDRISI. Experiment with these if you like. (If you want to go back to the usual (default) colors and don't remember which they are, simply choose the item number and press return without giving a number.)

Items 13 and 14 of ENVIRON give the addresses of the digitizer and plotter. We won't be using either of these pieces of equipment in this manual, so don't worry about these settings in the "environment."

Now that all of the items are set to their correct value, press return to exit ENVIRON. The settings will now remain in effect for the rest of this session and for any subsequent session (even if you turn off the power) until you intentionally change the settings at a later date. It is always a good idea to check the environment each time you start a new session, particularly if others are working on the same computer-someone else may have changed the settings.

BROWSING THROUGH THE DATA BASE WITH YOUR GIS

Before using the data from within your GIS, you should familiarize yourself with them. Study your data base manual. You will learn about the history of development of each data set, and about some applications that have been made of the data. You will be able to develop an appreciation for the pioneering efforts that have developed the data, and something of the diverse philosophies of the individual groups that developed the data. Take a moment to note the widespread locations and the variety of backgrounds of the developers.

Also note that there is a naming convention to the data. This naming convention may initially seem a bit cryptic, but is somewhat forced this way because of the 8-character file naming limitation in DOS. The naming convention is apparent from the documentation, and will become familiar to you as you work with the data.

If you are using a GIS other than IDRISI, check Appendix B for hints on converting IDRISI naming conventions to those of your GIS. Appendix C and D contain lists of IDRISI functions, that should help you to translate the "dialect" of IDRISI to that of your GIS.

IDRISI allows us to browse through the files in the default data directory with the module LIST. (Commands in IDRISI are often referred to as modules.) Run LIST. You will notice that the file names and the titles of the files are listed, and that the files are listed in order according to type (image files first, then vector, then attribute values files). IDRISI knows where to find these files since you set the directory and path information with ENVIRON. Keep pressing return to see all of the files. (If there are no IDRISI files to be listed, check the environment again. If it is correct, and you are still not getting a list of files, the data base may have been incorrectly installed.)

The GCDB contains many files. If you are in the middle of a long listing like this and you wish to stop, press Ctrl-Break (ie., hold down the control key and press the break key). Most IDRISI operations can be stopped, or "broken," in this way. (This is very useful when you are running a module and realize you have made a mistake and need to start over!) Try "breaking" LIST by running it again, but this time press Ctrl-Break after you have seen one or two screens.

GETTING MORE INFORMATION ABOUT A FILE

We were able to see the names and titles of all the data files in the data base using LIST. Now suppose we wanted to know more about a particular file, such as how many rows and columns it contains, what the maximum and minimum data values are, or if it has a legend. To find this information, we will use the module DESCRIBE.

As the name suggests, DESCRIBE gives you additional information about a data file. Run DESCRIBE. When it asks for the name of the file to be described, answer AFMVEG. DESCRIBE will then list the characteristics of that image, including its legend.

Run LIST again and write down the names of two images that interest you. Then use DESCRIBE to find out more about them. Fill in the following:

Filename:
Title:
Maximum data value:
Minimum data value:
Number of rows:
Number of columns:
What kind of data is in the file?

Filename:
Title:
Maximum data value:
Minimum data value:
Number of rows:
Number of columns:
What kind of data is in the file?

We will learn more about the meaning of various items listed by DESCRIBE as we go through the exercises.

Every image and every vector file in the IDRISI system is actually made up of two files. The first is the main file that contains the data, and the second is a smaller documentation file that describes the contents of the main file. It is this second file that we see when we run DESCRIBE.

Let's verify this by using a couple of DOS commands. Whether you are using the menu or typing at the DOS prompt, type the following:

dir c:\gcdb\afmveg.*

(If your default data drive and directory are different, type in the correct drive and directory.)

This is an operating system command asking the computer to list all the files in the gcdb directory on Drive C with the name AFMVEG. You see that there are two files— AFMVEG.IMG, the main data file, and AFMVEG.DOC, the image documentation file. Now do the same for the vector file COASTS. Type:

dir c:\gcdb\coasts.*

Again you see two files—COASTS.VEC, the main data file, and COASTS.DVC, the vector documentation file. When you use IDRISI you never need to worry about file extensions—it will keep track of these automatically. However, if you ever try to access a data file outside of an IDRISI module, you will need to refer to the extensions. For example, if you wanted to use the DOS command COPY to copy an image to a diskette, you would have to specify the three letter extension. And if you were planning on using the image with IDRISI on another machine, you would need to take both the .IMG and the .DOC files with you.

DISPLAYING DATA FILES WITH COLOR

In this section we will explore the most commonly used IDRISI module, COLOR, which displays image files on the screen. If you have an IDRISI software manual, open it to the section on the COLOR module.

The first image we will examine is named EXVEG. This is a simplified version of the image AFVEGX, a vegetation map for Africa, which is also in the data base. Run COLOR, and give EXVEG as the file to be displayed. When you are asked which palette to use, answer 1 to choose the IDRISI default palette. When asked whether to display a legend answer 1 for yes. When asked whether to set display factors by hand answer "no." COLOR will then display EXVEG on the screen. EXVEG will remain on the screen until you press return.

The legend captions at the right tell us which vegetation classes the different colors stand for.

0-1. What are the major vegetation classes in Kenya? In Mali?

If you had difficulty answering these questions, there is good reason! It is difficult to distinguish some of the classes because they are nearly the same color. It is also difficult to find where specific countries are without the political boundaries on the image. Fortunately, IDRISI provides solutions to both problems.

The legend categories on the right of the screen show us the different colors used on the image, but the image data file is filled with numbers, not colors. When we chose the IDRISI palette, we chose a specific set of colors which are arranged in a specific order. In the IDRISI palette, black is always color number 0, dark blue is color number 1, and so forth. (Color number 0 in any palette is always the background color surrounding the image.) When COLOR displays EXVEG, every time it sees the value 15, for example, it puts the color green on the screen.

Whatever operations we do with EXVEG will be done with the numeric data, not the colors. (The computer doesn't understand green plus blue, but has no problem with 14 + 2.)

If you have a mouse, you can examine the numeric data. With EXVEG still on the screen, press the c key (don't press return) to activate the cursor. A small cross will appear on the screen. Now look at the lower left corner of the screen. A message comes up that tells you the row and column position of the cursor. Move the cursor around with the mouse and watch the row and column position numbers change.

Now stop the cursor and press the left mouse button. The "z" value displayed at the bottom of the screen is the data value of that place, in this case the category number of the vegetation type. Press the left mouse button again to release the cursor. Move around the image and check a few "z" values. Note that if you move the cursor off the image, the row and column message will change colors and you won't see a "z" value when you click the left mouse button. Verify that the data values match the color numbers. (Color numbers start at the top of the legend with color 0, which is black in the IDRISI palette.) De-activate the cursor by pressing the right mouse button.

So, now we are able to know whether an area that is colored blue has value 2 or 3, but we still don't know exactly where to look for Kenya or Mali. With EXVEG still displayed on the screen, press the v key to use the vector overlay utility in COLOR. Give COASTS as the vector file name and 12 as the color code. COASTS will now be overlayed using color number 12 of the palette you used in displaying the image. Press v again, and display COUNTRY with color code 15. Now you are able to locate any country. (If you are not familiar with the countries of Africa, consult your paper map to match country names to locations and shapes on the image.)

Find Kenya on the image. Let's zoom in and look more closely at the data in EXVEG for Kenya. There are two ways to do this in IDRISI. The first requires a mouse. Therefore if you do not have one, read but do not try to execute the instructions in the next paragraph.

While you are viewing the EXVEG image (repeat the above procedure if you pressed return and it disappeared), press the letter "w" without pressing return. This invokes the "window" utility of COLOR. You will notice that a cursor again pops up in the middle of the screen. Move it to the upper left corner of Kenya, then press the left mouse button to "lock" this corner. Now move the mouse to the diagonally opposite corner of the window region. You will notice a window box form as you move the mouse. When the window is set where you want, press the right mouse button. You will now see the display zoom in on your windowed region. The vector overlays, COASTS and COUNTRY, do not appear on the zoomed image unless you use v to overlay them again.

0-2. What happens to the "smoothness" of the appearance of the data when you zoom in? Why do you think this happens?

You can zoom in further by pressing w again and repeating the above procedure. Zoom in far enough so that you can distinguish the individual cells that make up the image. Activate the cursor and move it around in the zoomed display. Note that the row and column numbers don't change unless you move the cursor into another cell. These cells, known as pixels, are the basis of all images. When COLOR is displaying many pixels, our eyes don't pick up the cell-by-cell nature of the image. It's only when the image being displayed has few pixels, or we zoom in, that we actually see the underlying structure of the image.

To zoom out, press the "w" key again without pressing return. When the cursor comes up, press the right button first without having locked a corner. COLOR will respond by choosing a window that can display the entire image on the screen. Try this.

If you don't have a mouse, you can still zoom in by setting the display parameters by hand when you run COLOR. If you still have a graphic image on the screen, press return to exit COLOR. Now run COLOR again and specify the same options except answer yes when asked if you wish to set display factors by hand. First it will ask for the expansion factor — specify 5. This indicates that you wish to "zoom up" by a factor of 5 (i.e., pixels will be displayed five times their normal size). You can also specify negative expansion factors. For example, an expansion of -2 would cause it to display only every second pixel on every other line causing it to look like it was reduced in size.

It will then tell you that it cannot fit all of the image onto the screen with that degree of expansion and will start asking a sequence of questions about the start and end columns and rows for the display. Let's start at column 100. You will notice that when you specify a start column of 100 it will indicate to you the maximum end column you can fit onto the screen. To accept this suggestion press return—IDRISI modules almost always have defaults built into questions like this that you can accept by simply pressing return. When it asks for the start row, type 50 and then press return to accept the suggested end row. You will now see the expanded display. If you wanted to zoom in on a particular region using this method, you would have to estimate the row and column numbers of the corner points of the area in which you were interested and specify these when setting the display parameters. The only way to zoom back out with this method is to hit return, and re-display the image using COLOR.

Now that you know about overlaying vector files, using the cursor, and zooming in COLOR, you are ready to answer the questions that we started with:

0-3. What are the predominant vegetation classes in EXVEG for Mali and Kenya?

We've learned several ways to enhance COLOR, but there is more to come!

Display AFFAOSOL using COLOR and the IBM palette (number 3). Simply press return for the rest of the questions. By doing this, you are choosing the "default" answers. Defaults in IDRISI are set to the first choice in a list, or the most likely answer if there is no list.

0-4. What is different about this display? [Hint: Examine the legend.]

Press the page down key and watch what happens. When there are more than 16 values in an image (up to 255) COLOR shows the first 15 categories, then shows everything higher than that as color 16. When you press Page Down, you get the next 15 values. When you reach the end of the values, you see that everything lower than the values displayed is displayed with color number 0. You can also use Home to move directly to the beginning and End to go directly to the end of the legend.

0-5. How many categories are in the legend of AFFAOSOL?

The other thing you should have noticed is that distinguishing between adjacent values is not a problem with the IBM palette as it was with the IDRISI palette. Even so, suppose that you don't like some of the colors in the palette. COLOR has a color change utility so that you can customize your palettes. Press the Home key. With AFFAOSOL still on the screen press k. Enter the color number of a color in the palette you would like to change (remember that the numbering starts at the top with number 0).

What happens now depends on the type of monitor you have. If you have an EGA monitor, skip to the paragraph after question #. If you are still reading this paragraph, you must have a VGA or 8514/A display. Every color is made by mixing different amounts of red, green and blue. You can now change the amount of red in the color you chose by pressing r, then using the up and down arrow keys. You can hold down the arrow keys to change the numbers quickly. To change the amount of green in the color, press g, then the arrow keys. Do the same with b for blue.

The possible range for each of the three colors is 0 to 63, making possible 262,144 (64 x 64 x 64) combinations. When you have mixed exactly the color you want, press return. You are now ready to activate any of COLOR's utilities, including k again. Answer the following questions, then skip the next paragraph, which describes the EGA display.

Activate K again and choose any color to experiment with in answering the following questions. Be sure to change the color back to one you like when you have answered all the questions.

0-6. What color is produced with equal amounts of red, green, and blue...

when the values are high (near 63)?

when the values are low (near 0)?

0-7. Use K to make the following colors. What values for Red, Green, and Blue did you choose?

	R	*G*	*B*
Black			
White			
Yellow			
Purple			

Many more advanced display systems than current DOS PC video displays use a scale of 0-255 rather than 0-63.

If you have an EGA adaptor you will now see in the lower-left corner a color index number. The EGA adaptor has a total range of 64 possible colors. These are given index numbers from 0-63. What you are seeing is the color index for the color number you chose. To alter it to another color, press either the up or down arrow keys. You can hold down the arrow key to get the color to continuously change. Try it. When you have finished altering a color, press the return key and you will return to the normal display. Alter a few colors.

0-8. What color numbers correspond to the following colors:

White:

Black:

Yellow:

Light Blue:

When you are finished working with AFFAOSOL, press return. When you exit COLOR by pressing return, you will be asked for a name for the new palette you created. Entering a name here will save the palette you've created for future use. Give the palette you've just created the name QUAL. IDRISI will save QUAL so that you can use it later on. Often we create palettes in order to look at something on the screen, but don't want to save them. In these cases entering q instead of a palette name will quit without saving the palette.

Now run LISTPAL. You should see the names of all the palette files already in the IDRISI directory on your computer, including the one you just created, QUAL.

Now use COLOR to display EXVEG again, only this time choose the "User Defined Palette" option and give the name QUAL when asked. Default through the other questions.

0-9. Making a distinction between soil and vegetation categories is certainly easier when we used the IBM or QUAL palettes. Is there a type of data that would be better displayed by a palette in which the colors change gradually from low to high, such as the IDRISI palette?

There are two basic types of data. The images we have been viewing are qualitative because the categories in them are different due to their quality rather than quantity. In EXVEG, Forest has value 1, and Tree Savanna has value 2, but the numbers only tell us that the categories are different, not that Tree Savanna is twice as much as Forest. In fact, we could have given Tree Savanna the number 1 and Forest the number 2. The order is not important, we are only interested in the fact that they are different.

The second basic type of data is quantitative. With quantitative data, we are interested in the quantity of something. Let's look at a few examples of quantitative data from the data base.

Run COLOR A (the A will be explained shortly) and specify the filename AFELBA. Choose the default palette, and default through the remaining questions. AFELBA is an image showing elevation and bathymetry (water depth). The lowest values (deepest water—water depth is expressed as negative numbers) are displayed with the lowest color numbers (blues), and the highest values (mountains) are displayed with the highest color numbers (greens). In contrast to qualitative data, with quantitative data, a value of 4 really does indicate twice as much as the value 2. (For example, an elevation of 500 feet in AFELBA is twice as high as an elevation of 250 feet.)

Let's look at AFELBA again, but this time use simply COLOR rather than COLOR A. Default through the rest of the questions. On its own, COLOR expects an image containing only integer numeric values within a range from 0 to 15. If a number is less than 0 it gives it the same color as 0 anyway, and if it is greater than 15 it gives it the color assigned to 15. If the highest number is less than 255, it will then allow you to scan through all colors with the PgUp/PgDn feature. However, if there are more (as in this case), it will only show the first 15. This is what we see when we use COLOR to display AFELBA. color 0 (black in the IDRISI default palette) is used for all values less than 1. Color number 15 (green) is used for all values that are greater than or equal to 15. The other colors we see represent pixels which have elevations of 1-14 feet.

To get our limited display system of 16 color display all of the data, we must go through a process of scaling in order to assign to each color a range of data values. (We will do this ourselves in one of the exercises using the STRETCH module.) Fortunately COLOR has an automatic scaling utility that we can use by running COLOR A, for autoscaling, rather than COLOR.

COLOR A looks at the minimum and maximum values stored in the documentation file and then divides all data values in between the min and max evenly among the available 16 colors. In this way, COLOR A lets us see the whole range of values, even if the range is extremely large. Many of the quantitative files in the data base, such as AFELBA, have legends which are for use only with COLOR A.

0-10. Use LIST once again to browse through the files in the data base. By looking at the titles, find and write down the names of five files which have qualitative data, and five which have quantitative data.

QUALITATIVE	*QUANTITATIVE*
1.	*1.*
2.	*2.*
3.	*3.*
4.	*4.*
5.	*5.*

Experiment with COLOR and COLOR A, and the various palettes available. You should become familiar with figuring out when to choose COLOR or COLOR A, and which palette type, qualitative or quantitative, will give the most meaningful display.

OTHER WAYS OF DISPLAYING DATA

Finally, let's look briefly at three other ways to display data—VIEW, HISTO, and ORTHO. Use VIEW S to display the actual values of AFELBA. (The S sends the output to the screen, rather than to the printer. VIEW S is not on the menu. You must type it in.) Choose a field width of 7 and 0 decimal places. Default through the other questions by pressing return. VIEW will now print the actual values in the data file to the screen. When we display AFELBA in COLOR, the colors on the screen are representing these data values. To stop the display, press the pause key. To continue, press return. To quit displaying, break out of VIEW by pressing CTRL BREAK.

Run the module HISTO to create a histogram of AFELBA. A histogram is a chart or graph that tells us how often a value occurs in the data file. HISTO first tells us the max and min, then asks if we want to change these for the display. Changing the max and min is useful when we are only interested in a certain range of values in the data file. In this case, answer "no," since we are interested in the entire image. For class width, enter 100. Have HISTO create a Graphic output. (Don't worry about the warning—HISTO is simply informing you that the range of values doesn't divide evenly by 100, so the last class goes beyond the maximum value in the image.) This will take several seconds to calculate.

The histogram shows us how many pixels fall into each class of values. Pressing return will exit the display of the histogram and a few summary statistics will be given. Run HISTO again, keeping everything the same except ask for a numeric output. Frequency tells you how many pixels fall within the upper and lower limits given. Proportion tells you what proportion of the entire image falls within that class. Cumulative Frequency tells you how many pixels are in that class or lower, and cumulative proportion tells you what proportion of the image is in that class or lower.

Now run ORTHO with AFELBA. Read, then default through all the other questions. ORTHO will then begin to draw AFELBA, one row at a time on the screen. This will take a while. When the display is finished, you will see a three dimensional view of Africa, sticking up out of the ocean.

Take some time to look at the various images in the data base and experiment with the IDRISI commands you have learned. You should get a feeling not only for how to run the various commands, but also for when each might be useful.

0-11. Now, to help you review what you have learned in the GETTING STARTED section, write a brief description of what the following modules and options do:

ENVIRON

LIST

DESCRIBE

COLOR

COLOR A

options in COLOR and COLOR A

- *c*
- *v*
- *w*
- *k*

LISTPAL

VIEW

HISTO

ORTHO

IF YOU USE A GIS OTHER THAN IDRISI
(whether or not for these exercises)

How would you perform similar functions in your GIS? Write a "translation dictionary" between IDRISI and your GIS. You may want to make a thorough "translation dictionary" using either Appendix C or Appendix D, to ease your use of your GIS for the rest of this manual.

Where To Go From Here

The next section of this manual contains a series of exercises specifically related to the Global Change Data Base. The text gives step by step instructions for completing the exercises. You should try to answer all the questions (marked with a # at the left edge of the text column) as completely as possible.

Sections entitled FOR FURTHER EXPLORATION give a fairly complete outline of the procedure to be followed, but do not give literal step-by-step instructions for exploring another aspect, or expanding upon an exercise.

Sections entitled ON YOUR OWN give suggestions and some hints for other investigations that you might want to undertake. You will be expected to come up with the steps for these on your own (or in groups).

We encourage you to explore the environment of Africa with these tools.

And remember, if you want to look at any other part of the world, a global version of the Global change Data Base is available from the National Geophysical Data Center on digital compact disc (CD-ROM), for use on your computer, if it is equipped with a CD-ROM drive.

Enjoy!

THE EXERCISES

EXPLORING THE DATA BASE

EXERCISE 1: Finding Your Way Around

In the Getting Started section, you were introduced to the data base and to the GIS tools necessary to explore it. The data base, when used in conjunction with a geographic information system (GIS), enables you to visualize and analyze spatial information in a variety of ways. In fact, one of the most powerful features of GIS is its ability to easily combine and manipulate layers of information and to use this new information in modeling and decision making.

In order to fully understand the results of GIS data manipulation and analysis, it is essential to have a knowledge of the underlying data—how they are stored in the computer, their limitations, their accuracy, their currentness, etc. For example, on a screen display of vegetation types, the areas which are "tropical rain forest" to you are only fields of numbers to the computer. When this vegetation layer is combined with other data to create output layers, the numbers can be manipulated in inappropriate ways and eventually lead to misleading or invalid conclusions. Or the data, while manipulated correctly, might themselves be ill-suited for answering the questions directed at them.

Analysis in GIS, regardless of the validity and complexity of the methods, is only as good as your input data. By thoroughly understanding and assessing the data, the GIS output is more easily and accurately interpreted. This exercise is designed to give a closer, more detailed look at the data in order to gain insight and confidence in evaluating GIS output. It will also give you the opportunity to discover which GIS tools are most useful in examining various types of data.

Use COLOR A to view AFMPRANN, the average annual precipitation layer. Using the cursor, find the value of Dakar's average annual precipitation in millimeters. [Hint: Overlay the vector files COASTS and COUNTRY using v, and use a paper map of Africa to help you locate the city of Dakar, Senegal.]

1-1. What are the row/column coordinates of the location you found for Dakar?

1-2. What is the average annual precipitation (the Z-value) for this location?

Figure 1.1. Here is an outline map of Africa, created by using INITIAL to create a blank image with 438 rows, 480 columns, and data value 0. Then COLOR was used to display the image (which shows up as a blank screen), and the "v" option was used to overlay several vector files in sequence: COAST, ISLAND, COUNTRY, RIVER, and LAKE. Try this!

How many countries in Africa can you identify without looking at a map? What do you know about these countries? Look in an almanac, encyclopedia, or other reference (such as the CIA *World Factbook*, available to anyone from the U. S. Government Printing Office Bookstore nearest to you, or by mail). Look at information such as per-capita income, infant mortality, etc. Look at data within the Global Change Data Base. Can you now better understand why some countries are relatively developed and prosperous, why some countries can produce most of their own food, etc.?

Deactivate the cursor and press return to exit COLOR A. We will now "zoom in" on the northwest portion of Africa by extracting a window of the original image. (This is different from the interactive zooming we did using the mouse or display parameters in Getting Started. Here we are actually creating a new image that is a copy of a small piece of the full image.) Use IDRISI's WINDOW command to do this. The name of the original file is AFMPRANN. Call the new window image NWZOOM. Enter the following information:

```
Column number of upper-left window corner     : 0
Row number of upper-left window corner        : 0
Column number of lower-right window corner    : 200
Row number of lower-right window corner       : 200
```

Display NWZOOM with COLOR A. Show the coastlines by overlaying the vector file NWZ. (The vector files COASTS & COUNTRY will not correctly overlay the windowed image.) Note the change in scale from the previous image. This image also fills the screen, but it shows only a fraction of the African continent displayed in AFMPRANN.

1-3. Do you think this larger-scale image gives more detailed information on African rainfall than the image of the entire continent? Why or why not?

Using the cursor, go to the row/column coordinates you found for Dakar above. How does the Z-value at this location compare with the one you found earlier?

Although the windowed image of northwestern Africa is of a larger scale and might appear to contain more detailed information, it actually contains exactly the same information as the corresponding portion of its source image, AFMPRANN. The data themselves were not changed.

1-4. Why would you want to extract a window of a larger image?

The process of windowing out a portion of a data layer is useful in masking out areas which are not of interest and also in speeding up the computer's processing time by working on a small area within the large data base.

In IDRISI, as in most raster-based GISs, data are stored as numbers assigned to PIXELS or GRID CELLS. The reason Dakar's precipitation value didn't change in # above is that by looking at the same row/column location each time, we were examining the same grid cell. The underlying data (the pixel values) were not altered.

A pixel represents some data value over an area of Earth's surface. The size of the area covered by a pixel determines the RESOLUTION of an image. An image with a large number of pixels which each cover a small area on Earth is said to have HIGH RESOLUTION, whereas an image with fewer pixels covering large areas is said to have LOW or COARSE RESOLUTION.

1-5. *Think of a paper map that you are familiar with. What features are shown on the map? What area of land does it cover? How does its resolution compare to the resolution of this data base?*

1-6. *Suppose we have two images, each with the same number of rows and columns. One image covers the state of Massachusetts, the other covers all of North America. Which image has the higher resolution?*

1-7. *Is there a relationship between the resolution of an image and the total ground coverage of the image?*

Images which span a large ground area and at the same time have very high resolution tend to be extremely large. Very large data files use up valuable computer storage space and are time-consuming to process and manipulate. This is why, generally, the more land area an image covers, the coarser the resolution.

Pixels are often of a fixed size, for example 30 by 30 meters of ground distance on a side. The African data base, however, uses pixels which are 10 minutes of latitude by 10 minutes of longitude (1 degree = 60 minutes). (Remember that latitude measures distance north and south of the equator, while longitude measures distance east and west of the prime meridian.) Ten minutes of latitude cover essentially the same distance anywhere on Earth (not exactly the same distance since Earth is not perfectly spherical). Ten minutes of longitude, however, does not cover a constant distance. Since Earth's meridians converge at the poles, 10 minutes of longitude represents a variable distance which is greatest at the equator and smallest at the poles.

Use COLOR A to display AFMPRANN. Overlay COASTS and COUNTRY. Looking at this display, along with your paper map, answer the following questions:

1-8. *What effect does the convergence of the meridians have on the relative ground coverage of the pixels in the African data base as you move north to south?*

1-9. *In which African nations is the ground area covered by the pixels the largest? The smallest?*

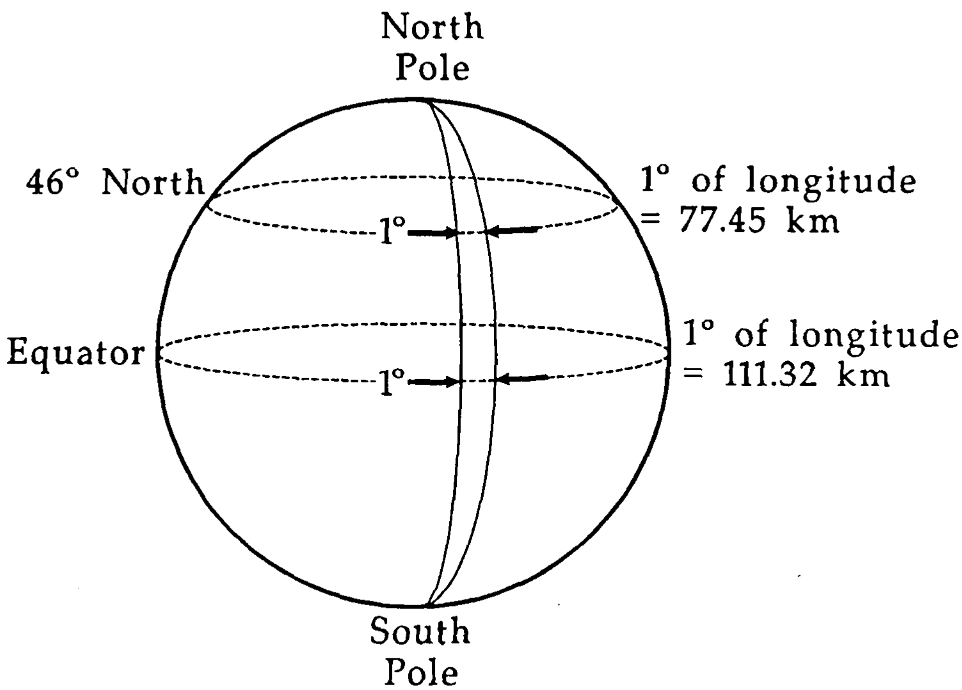

Figure 1.2. Variable length of one degree of longitude.

One degree of latitude on Earth varies from 110.6 km at the equator to 111.7 km at the poles. Assuming an average value of 111.15 km, what is the length in the North-South distance of a 10-minute pixel? (60 minutes = 1 degree)

1-10. Using the information provided in the following table and your map of Africa, calculate the ground coverage area of a pixel at the equator and a pixel at the northernmost part of Africa.

Latitude in Degrees	Length of One Degree Longitude in Kilometers
0	111.32
10	111.17
20	104.65
30	96.49
40	85.40
46	77.85

Equator:______________ Northern Africa:______________

1-11. Given the pixel areas you just calculated, how does pixel size regulate an image of roads and highways in this data base?

The African data base has variable resolution in the sense that the 10-minute pixels do not cover constant areas. Yet another type of variable resolution exists in the data base.

Use COLOR to look at AFZSOILS, the Zobler soil classifications, and AFFAOSOL, the FAO soil classifications.

1-12. Do you notice a difference in the appearance of the two soil images? Which one appears to have the higher resolution?

Now examine the data in a more direct way. Use VIEW S (remember the S sends the output to the screen rather than the printer) on the same two layers to display the numeric values of the grid cells. Since the screen is not capable of displaying the entire image at once in this mode, you will have to examine a smaller portion of the image. VIEW will prompt for additional information—use the following:

```
Field width:                  3
# of decimal places:          0
First column:               245
Last column:                270
```

1-13. Do you think AFZSOILS and AFFAOSOL have the same resolution? Why or why not?

All grid cells in the African data base have dimensions of 10 minutes by 10 minutes, yet not all of the data were actually collected at this resolution. The AFZSOILS data, for example, were gathered at one degree resolution (that is, the cell dimensions are one degree of latitude by one degree of longitude).

1-14. A one-degree grid cell in Africa covers approximately 10,000 to 12,000 km^2. How well do you think a single soil type describes an area of this size?

1-15. Think about areas or types of data that are relatively consistent over space, or which are perhaps not well known for Africa. Could such data be shown by one-degree gridding, rather than a finer grid?

In order for the low resolution soil layer, AFZSOILS, to be compatible with the rest of the data base, the one-degree cells were "chopped up" (resampled) into 36 ten-minute cells, each holding the value of the original one-degree cell. Don't let the cell size lead you to believe that the data are of 10-minute resolution. When in doubt, refer to your data documentation. It is essential to be fully aware of the limitations of the data. Always question the data.

Each pixel in the data base is a generalized representation of some ground truth. Taking elevation as an example, imagine a 300 km^2 area in the mountains of Morocco. Clearly a wide range of elevations are present, yet given the constraint of 10-minute resolution, the elevation for that 300 km^2 area must be generalized and represented by a single number. Various ways exist to represent this information.

1-16. How many ways can you think of to represent elevation within raster grid cells using a single number? (In other words, what are some different ways to generalize the varying elevations within a cell into one number?)

Examine the ELEV_3 image with COLOR A. ELEV_3 is actually three separate elevation layers concatenated together to permit viewing them on the screen at one time. This image presents the same theme (elevation) in three different ways:

The **minimum**—each pixel contains the minimum elevation found on its ground area.

The **maximum**—each pixel contains the maximum elevation found on its ground area.

The **mode**—each pixel contains the elevation which is most common on its ground area.

Another common way for a pixel to represent information is the mean. A mean elevation layer (which is not included in the African data base) would contain the mean or average elevation value for its ground area.

Using the cursor, find the elevation for the same pixel on each of the three images. Use the following coordinates since the concatenation process altered the row/column values of the original images:

Image	Column	Row	Z-value
min	100	100	_______
max	340	100	_______
mode	340	319	_______

1-17. What can you infer about the topography of Africa by looking at two or more of the elevation layers that would not be apparent or discernible by looking at one layer alone?

1-18. For what purpose might each type of elevation information be most useful? In which type would you think an airline pilot would be most interested? Why?

Often one feature clearly dominates a given ground area. However, especially at coarse resolutions, several categories of features can exist within a single pixel, often making it difficult to determine what value a pixel should be given. Look at the vegetation layer AFVEGX with COLOR. Press "page down" to view the last legend item, water.

1-19. Do you think this layer accurately represents all water features (rivers, lakes, marshes, etc.) in Africa? Why or why not?

1-20. Why don't you see the Nile River on the image?

1-21. Imagine a pixel covering an area which is 33.3% lakes, 33.3% forest, and 33.3% grassland. If lakes were category number 1, forest was category number 4 and grassland was category number 33, what value should be assigned to the pixel?

The above question illustrates a common dilemma: there is no right answer. When assigning categorical data groups to a pixel, especially at coarse resolutions, often no single category will stand out as dominant. Since the pixel usually must be assigned to only one category, some information will be lost. The reason you don't see the Nile on the AFVEGX image is that the Nile's water does not occupy enough area to dominate a ten-minute pixel.

Now view the AFWATER layer with COLOR A. The pixel values of AFWATER are percentages of water found within each pixel's ground area.

1-22. Does AFWATER give you more information about water in Africa than AFVEGX?

1-23. Does AFVEGX contain information about water in Africa which AFWATER does not?

Many methods exist for representing reality within a pixel: the mean, minimum, maximum, mode, and the percentage of occurrence. None of the methods can preserve all the information within the cell coverage—there will always be generalizations, omissions, and inaccuracies. Thus it is important to be concerned with the quality of the data: how well does the data answer the questions asked of it?

ARE THE DATA APPROPRIATE?

We saw ORTHO briefly in Getting Started. We used it to display AFELBA, and saw the continent of Africa in three dimensions. This time let's use ORTHO to display a perspective view of AFVEGX. Default through the rest of the questions.

1-24. Describe what you see. Is this an appropriate way to view this particular data layer? Why or why not?

1-25. Would it make sense to use ORTHO to view a temperature layer? a precipitation layer? a soil type layer? Recalling the two data types discussed in the previous exercise, which type, qualitative or quantitative, is appropriate for view with ORTHO?

In general a perspective view of qualitative data does not produce a meaningful image. For example, on a soil image, soil type 35 appears as a tall plateau while type 7 appears as a low area. Yet this does not mean that soil type 35 is larger or greater than type 7. The category numbers are arbitrary. On a quantitative data layer such as temperature, high values are indeed greater than low values. A perspective view of temperature data provides a meaningful surface in which peaks are areas of high temperatures and pits are areas of low temperatures.

1-26. Suppose you were interested in finding flat, non-forested areas suitable for siting an airstrip. Which images in the data base would be most useful to you? Which would allow you to identify flat areas? Which would allow you to find forested areas? Are the available data appropriate for solving this problem? [Hint: Think particularly about the resolution of the data in relation to the problem. How critical is slope for the building of an airstrip? Is an average slope value for a pixel that is one degree on each side useful for siting an airstrip?]

MANIPULATING DATA TO GET MORE INFORMATION

Use COLOR A to view AFMALBFA, the Matthews average fall albedo in hundredths of a percent. Albedo refers to the percentage of light reflected by a surface. Snow and ice reflect a lot of light, while dense forest reflects less. Albedo is a piecewise continuous variable—although albedo has sharp breaks in many satellite images, in AFMALBFA it tends to vary smoothly across the landscape without sharp breaks.

1-27. What do you notice on the albedo image? Do you see sharp breaks or a smoothly varying surface with AFMALBFA?

AFMALBFA was created at one-degree resolution and resampled to ten-minute resolution to match the rest of the data base. The resampling process leaves blocks of 36 identical pixels, which often results in sharp, unnatural breaks at the boundaries of the original one-degree cells.

We can use IDRISI to "smooth" the data to create an image with less obvious breaks, which we believe will be a truer representation of reality. Run the module FILTER and choose the Mean filter type. AFMALBFA is the image to be filtered and we will call the new image FILTFALB (for filtered fall albedo). Give FILTFALB the title "Filtered AFMALBFA". The filtering operation will smooth the data by replacing each pixel's value with the average value of the pixels occurring within every 3 pixel by 3 pixel array in the original image.

Look at FILTFALB with COLOR A. Use the cursor to examine pixel values at boundary areas.

1-28. Do you notice a difference? Do you think this new image better reflects reality than the original image? Would it make sense to run FILTER again on FILTFALB?

1-29. Can you think of some examples of sharp breaks in albedo that could be found in reality? [Hint: sand has a relatively high albedo, while water often has a very low albedo.]

1-30. Would you ever want to run such a filter on qualitative data?

COMPARING DATA FROM DIFFERENT SOURCES

1-31. Would you expect two data sets from different sources but covering the same data type to agree completely? What might cause them to differ?

Use DESCRIBE to look at the legends of AFMVEG (Matthews vegetation type) and AFVEGX (UNEP vegetation type). Compare the representation of "grassland" on each of these images. Which categories on each image correspond to "grassland?" Write these down. Now use the module CONCAT to join the main image, AFMVEG, and the other image, AFVEGX, to create the new image VEG2. Join AFVEGX to the right of AFMVEG. Give the new image the title "AFMVEG (left), AFVEGX (right)."

If you have a printer, print out the documentation files for AFMVEG and for AFVEGX by changing to the directory that contains the data, and typing:

```
PRINT AFMVEG.DOC
PRINT AFVEGX.DOC
```

Have these two printouts handy to work on the question that follows.

CONCAT simply joins images together, so that we can look at more than one image at a time on the screen. Display VEG2 with COLOR and the IDRISI palette. You will need to "zoom out" in order to see the entire image. Do this by setting the display factor in COLOR to -2, or after the image is on the screen, by pressing w then the right mouse button. Use the cursor to locate the areas on each image that are grassland (they will be different colors because grassland belongs to different category numbers in each image).

1-32. Do the two source layers agree for the most part? What factors might have caused any discrepancies? What about the definition of "grassland"? What about the date each data set was compiled?

Remember that your screen shows two maps with different legends that you have printed out. A particular class number on one data set may not coincide with the number for the corresponding class number on the other data set. On your screen, you should pay particular attention to the colors on the images, the class numbers associated with these colors, and the actual types of vegetation shown by these class numbers (which you should read from your printed documentation files).

In the next exercise we will learn some methods that will make such comparisons easier and more accurate.

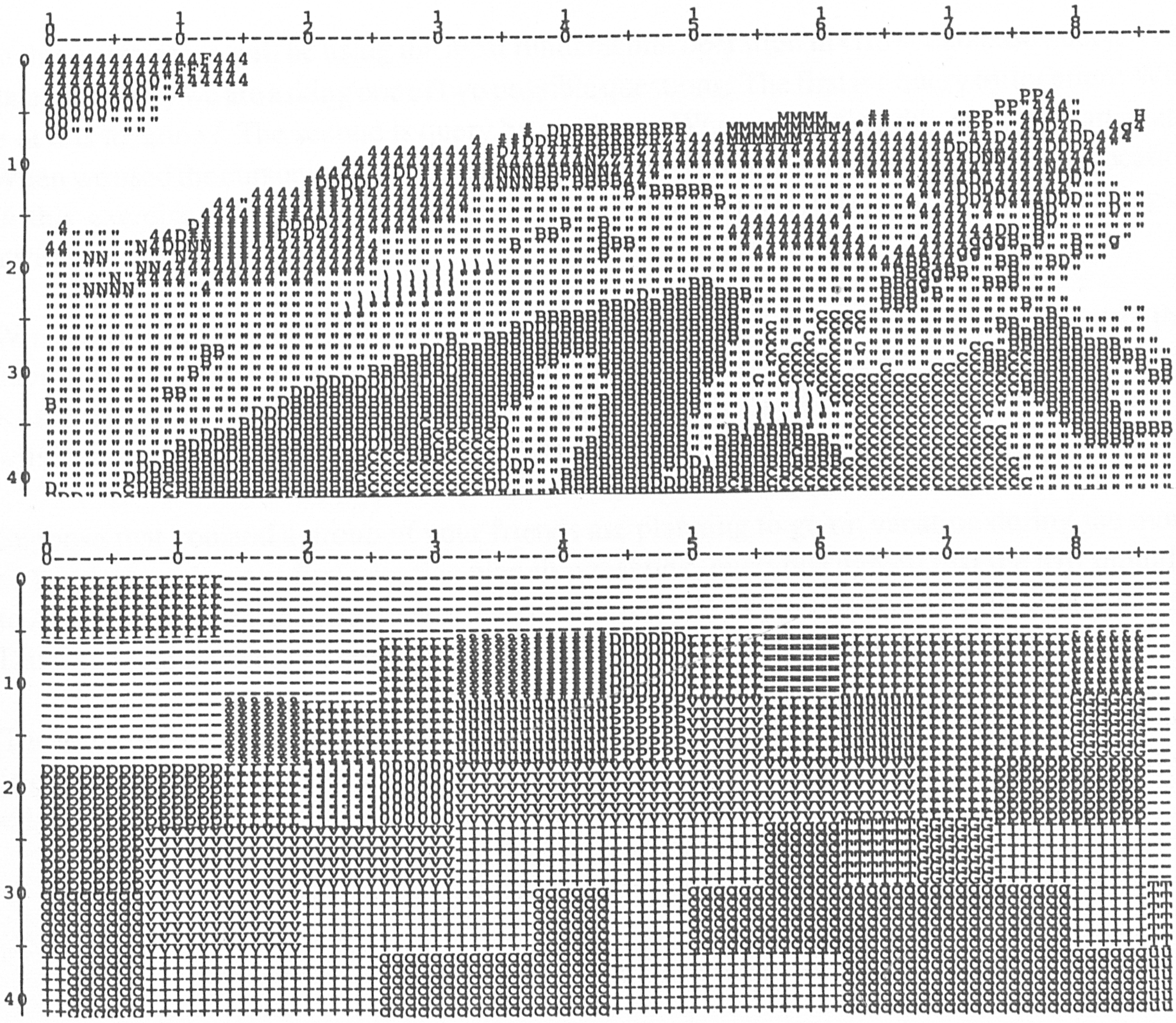

Figure 1.3. This image is a printer plot of AFFAOSOL. It shows an area bounded by columns 100 and 187, and by lines 1 and 41 on the Africa data base. You can produce a somewhat similar image on your screen with COLOR A (a more exact image with COLOR85, if you have 8514/A compatible graphics), by specifying these columns and rows for your area of interest, and choosing your scale factor to fill the screen.

To locate yourself, notice that the top left corner of the plot shows southeastern Spain, while the top right corner shows Tunisia.

The lower image shows the same area, but from AFZSOILS. Notice the difference in level of detail? Why is this? You may wish to review what you did on page 35.

EXERCISE 2: Data Base Query

In this exercise we will be using the most fundamental operation in GIS—database query. With database query we are asking one of two possible questions. The first is a query by location: What is at this location? The second is query by attribute: Where can I find this particular attribute? When we used the cursor in COLOR in the previous exercises, we were doing queries by location. In this exercise we will learn how to perform the very important operation of querying by attribute.

When we query by attribute, we tell the computer the conditions in which we are interested, then have it show us all the pixels that conform to those conditions. If the query is very simple, RECLASS or ASSIGN will be enough to complete the query. If the query is more complex, we will have to use OVERLAY, along with the concepts of Boolean algebra to complete the query.

Suppose that you and a group of your friends are planning to go on vacation during the month of December. In your first vacation planning meeting, everyone agreed that the trip should be to Africa, but beyond that, no one had any specific ideas. You, having access to the Global Change Data Base for Africa, volunteer to narrow down the search using GIS.

The group decided that one of the most important conditions that an ideal vacation spot must meet is good weather—warm but not too hot, and not much rain. The group decided on the following climatic conditions that the chosen destination must meet:

Mean Temperature for December: 75 to 85 degrees Fahrenheit

Mean Measured Precipitation for December: less than 0.5 inches

Your job is to find all the places in Africa that meet both of these conditions, and to present the results to the rest of the group at your next meeting.

Use LIST to browse through the data base. Which images do you find that are suitable for solving this problem?

2-1. Write the name of the file next to the attribute:

December Temperature:
December Precipitation:

Let's begin with temperature. Use DESCRIBE with AFTMPDEC.

2-2. In what unit of measurement is AFTMPDEC given?

What are the minimum and maximum values?

There are two things we must take notice of here. The first is that the maximum and minimum tell us that there are many values in the data file, yet there is a legend with only 15 categories. This is common in the data base, and happens because of the way in which the data base was put together. Whenever the actual values in the image do not correspond to the category number, but only to the category label, the legend is meant to be used only with COLOR A, not with COLOR. If you display AFTMPDEC without autoscaling in COLOR, the legend will not be accurate.

The second item to notice is that AFTMPDEC, like most of the files in the data base, uses metric units of measurement. Our friends, how ever, have specified the range of temperature that is acceptable in Fahrenheit. We have the choice of converting the entire data file to Fahrenheit by using SCALAR, or by simply converting the range of acceptable values our friends have identified to Celsius. The latter is easier, so let's choose that option.

The formula for converting temperature in Fahrenheit to Celsius is:

(Degrees F - 32) / 1.8 = Degrees Celsius

Using this formula to convert our endpoints to Celsius, then rounding to one decimal place we get:

```
(75 - 32) / 1.8 = 23.9
(85 - 32) / 1.8 = 29.4
```

Now, to convert to tenths of degrees Celsius, which is the unit of measurement for AFTMPDEC, we must multiply each endpoint by 10.

```
23.9 x 10 = 239
29.4 x 10 = 294
```

Any pixel in AFTMPDEC which has a value between 239 and 294 is a potential vacation site, as far as temperature is concerned. Let's make an image in which only the pixels with acceptable temperatures are shown. We no longer care about the actual temperature of each pixel, but only whether each is acceptable or unacceptable. Because of this, we will use the quantitative temperature data to create a qualitative image in which all the acceptable pixels have the value

1, and all the unacceptable pixels have the value 0.

Use RECLASS on AFTMPDEC to create the new image VACTMP (for vacation temperature). Choose the User Defined Classification option. Give a new value of 0 to old values ranging from 0 to those just less than 239. Give a new value of 1 to old values ranging from 239 to those just less than 295 (since we want 294 to be included). Give a new value of 0 to old values ranging from 295 to those just less than 400 (this could be any number, as long as it is larger than the maximum value in the file.) Finally, finish the reclassification by entering -1, then giving the new image the title "Temperature Between 75 and 85 Degrees F".

Look at VACTMP with COLOR. (Remember that you can always overlay the COASTS and COUNTRY vector files by using "v" in COLOR.) What we have created here is often referred to as a binary or Boolean image be cause it contains only 1's and 0's. The areas that meet the specified conditions have value 1, while those that don't have value 0. The term "mask" is also used to describe such images. In creating VACTMP, we have "masked out" the areas that have temperatures higher than 85 degrees F, or lower than 75 degrees F.

Now let's make a mask for precipitation. We'll follow the same procedure as with temperature.

2-3. What is the unit of measurement in AFMPRDEC? [Hint: Look at the title using DESCRIBE.]

What are the max and min values?

Is the legend for use with COLOR or COLOR A?

The formula for converting inches to millimeters is simply:

inches x 254 = mm.

2-4. What is the acceptable range of precipitation in mm?

Now we'll use RECLASS with AFMPRDEC to create VACPR. Remember that in the mask, we want the areas of interest (those pixels with values within our acceptable range) to have value 1, and everything else to have value 0.

2-5. Fill in the following as you are running RECLASS:

Give new value of:
To old values ranging from :
To those just less than:

Give new value of:
To old values ranging from :
To those just less than:

Finish RECLASS by entering -1 and giving the new image the title "Precipitation Less Than 0.5 Inches". Look at the precipitation mask we just created with COLOR.

Now we need to be able to combine the temperature and precipitation masks to show us only the areas that are acceptable for both attributes. To do this we will use OVERLAY.

OVERLAY allows us to perform mathematical operations on two images. If we were to choose the addition option in OVERLAY, for example, each pixel in the first image would be added to its corresponding pixel in the second image and the result would be written to a new image. (Because of this, OVERLAY can only be used with two images that have exactly the same number of rows and columns.)

In our case, since we want to produce a new image showing where both conditions are acceptable, we will use the Multiply option in OVERLAY. For all the possible combinations, we will get the following results:

VACTMP	x	VACPR	=	Result
0	x	0	=	0
0	x	1	=	0
1	x	0	=	0
1	x	1	=	1

Run OVERLAY, choosing the Multiply option. Give VACTMP and VACPR as the first and second images (the order doesn't matter with multiplication) and give VACTP as the name of the output image. Give the new image an appropriate title.

2-6. *If we wanted an image in which pixels having acceptable values for EITHER temperature OR precipitation, which OVERLAY option would we use? Make a table similar to the one above showing all the possible results.*

Look at VACTP with COLOR and overlay the COASTS and COUNTRY vector files. A considerable amount of the area we have identified as suitable is actually in the ocean! Let's take one more step to get rid of these ocean areas.

Use list to find the Ocean Mask file in the data base. Look at AFOCEAN with COLOR and confirm that the land areas have value 1 and the water areas have value 0. Now OVERLAY using Multiply, VACTP and AFOCEAN to create the output image VACTPO, and give it a title.

The image is now ready to present to the group at the next meeting.

2-7. *Think about some of the issues raised in the last exercise and the data we have used in this exercise. Would you promise your friends that if they went to a place falling within the area you've identified as suitable they would definitely find suitable climatic conditions? What information about temperature and precipitation, in addition to monthly means, would enable you to identify suitable areas with a greater chance of success?*

2-8. *What other factors do you think should be taken into account in choosing a vacation spot? Can any of these be identified by using files in the data base?*

FOR FURTHER EXPLORATION

Suppose your vacation group decided to further narrow its choices by choosing a particular vegetation type for the area. You decide that you want to visit an area of forests, but since you are trying to avoid rain, you'll visit only areas identified as dry forests. Use DESCRIBE with the Holdridge Life Zones image, AFHOLD, to look at the legend categories and write down which of the 37 category numbers correspond to dry forests (there are three).

2-9. *Is the legend of AFHOLD meant to be used with COLOR or COLOR A?*

We now need to make another mask, as before. This time, however, let's use ASSIGN rather than RECLASS. The two are often inter changeable, but one will usually be easier than the other for any particular situation. ASSIGN is used only with whole numbers (integers), and is often faster than RECLASS when only a few of the old values are being changed and the rest are being masked out (changed to zero), and when the old values being changed are not in sequential order.

To use ASSIGN, we first must make a values attribute file. Use EDIT, and option 1, attribute values file. Call the file DRYFOR. EDIT looks for a file with that name, and since there isn't one, gives you a blank file to write on. An attribute values file is made up of two columns of numbers. The first column has the old values, followed by a space, then the new values.

Make the attribute values file by typing in the following lines. Use the arrow, backspace, and delete keys to move around and make corrections.

```
20 1
27 1
35 1
```

Any old value not appearing in the attribute values file will be automatically assigned the new value zero.

Press escape and answer yes to save the file. Now run ASSIGN. The feature definition file is AFHOLD. Call the resulting image DRYFOR and give it an appropriate title. (We can use DRYFOR for the file name without overwriting the values file, DRYFOR, because IDRISI gives image files and values files different extensions. The values file is DRYFOR.VAL, and the ASSIGN process has created DRYFOR.IMG, the data file, and DRYFOR.DOC, the documentation file.) Look at DRYFOR with COLOR.

Once more, use OVERLAY to create an image that includes the condition that the vegetation type in the vacation area be dry forest in addition to the temperature, precipitation, and ocean conditions specified above. Look at your final image.

2-10. Which files did you OVERLAY?

2-11. Which countries have areas that are suitable according to all our conditions?

ON YOUR OWN

A. Use a World Almanac, Encyclopedia, or other reference materials to create an attribute values file (using EDIT) for official languages for all of the African nations in AFNATION. DESCRIBE will give you the country number codes. You will need to decide on a numbering scheme (Arabic = 1, English = 2, etc.), and think of a way to handle countries with more than one official language. Use ASSIGN with AFNATION to create a new image that shows official languages. Suppose you and your friends decided to vacation in a country which has French as the official language. Make a new image to showing the suitable areas, taking into account all of the conditions we've identified so far. Which countries are left to choose from?

B. Now that you know about making masks and overlaying them, choose one type of vegetation (such as desert, or forest) and compare two sources of vegetation data. Give an outline of the steps you took. Describe to what extent the two images match and to what extent they differ. What are some possible explanations for the differences you found?

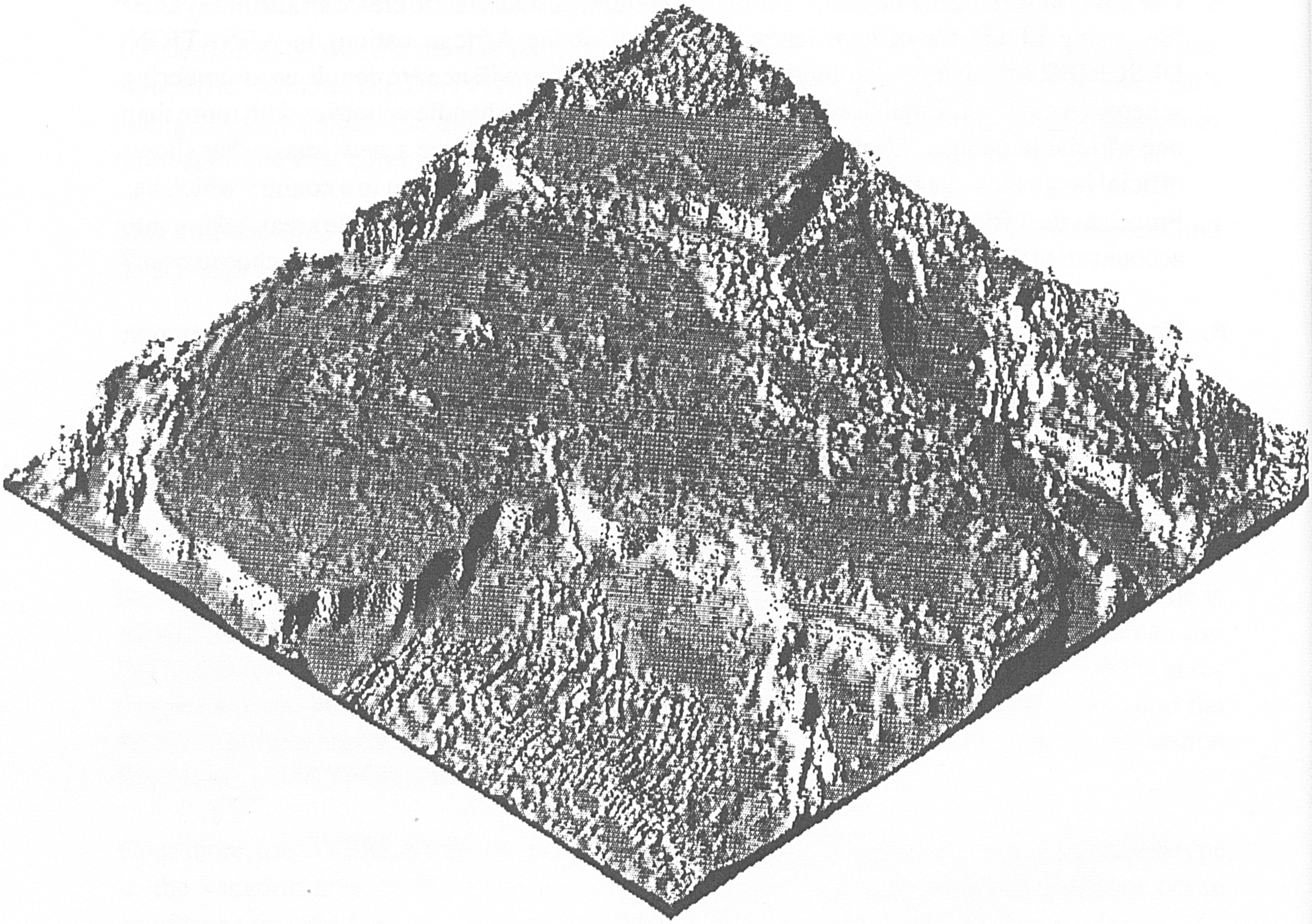

Figure 2.1. Here is a perspective shaded relief image of Africa. It was created by first running SURFACE with option 4 (analytical hill shading) on AFELBA, which contains elevations and bathymetry (ocean depths). The resultant image was run through ORTHO to produce a draped image. If you have IDRISI, try using ORTHO to drape a global vegetation index (your choice of dates) over AFELBA. If you are using another GIS, find the equivalent function. (Many GISs have such functions, though they may give them different names.)

EXERCISE 3: Determining Rainfall Regimes

Rainfall regime tells us when, during the course of the year, an area receives rain. There is a big difference, for example, between a place which receives its total annual rainfall in a few months during the summer and another place that gets small but frequent showers throughout the year, even though the total annual precipitation for both places might be exactly the same. Information about rainfall regime is important in determining which plants can grow in a place, when tourism should be promoted, when roads should be scheduled for repair, etc.

There are many ways of characterizing rainfall regimes. A simple way is to assign all areas to three regimes: summer, winter, and uniform. A place is said to have a summer rainfall regime when the summer rainfall is at least 30% greater than winter rainfall. Likewise, a winter rainfall regime is one in which winter rainfall is at least 30% greater than summer rainfall. If neither of these conditions applies, it is assumed to be a uniform rainfall regime. This way of classifying rainfall regimes helps us know about the relationship between rainfall and temperature. A summer rainfall regime, for example, indicates that more of the annual precipitation falls when the temperatures are warm than when they are cold.

We will create a map which identifies these three categories of rainfall regimes for Africa. First, lets think about what we mean by the words "summer" and "winter." If we think of summer as the warm part of the year and winter as the cold part of the year, then we know that in the United States, summer is May through October and winter is November through April. But is this the case all over the world?

In fact, because of the tilt of the earth, the Northern Hemisphere has summer while the Southern Hemisphere is having winter, and vice versa. Since the equator runs through Africa, we will need to be very careful about what we call summer and what we call winter here!

3-1. Before reading on, try to outline the steps you think we must take to make a map of rainfall regimes. [Hint: We'll be starting with monthly rainfall data.]

The first step we will take is to make a map showing the total rainfall from May through October. We will do this by adding the separate monthly images from the data base with the OVERLAY command, using the addition option.

Use OVERLAY and choose the addition option with AFMPRMAY and AFMPRJUN to make the output file TEMP. Run OVERLAY again, this time adding TEMP and AFMPRJUL to make the output file TEMP2. The values in TEMP2 are now the sum of May, June and July. Run OVERLAY again, adding TEMP2 and AFMPRAUG, and calling the output file TEMP.

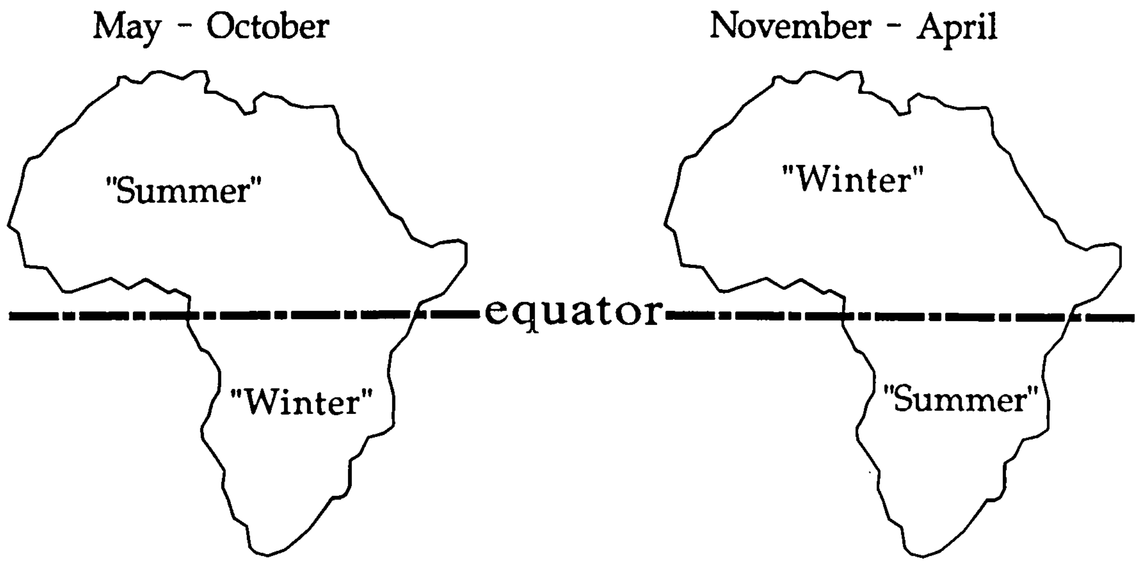

Figure 3.1. The terms "Winter" and "Summer" do not have a common meaning in Africa. To a Southern African, winter may mean July, while to an Egyptian, winter may mean January. In Equatorial Africa, the terms "Winter" and "Summer" may be based on temperatures, which may be based on monsoonal rainy seasons. This figure shows the conventions that we will use in these exercises.

We can use this filename again because IDRISI will simply over write the old file, which we don't need anymore. OVERLAY add TEMP and AFMPRSEP to make TEMP2. Finally, use OVERLAY to add TEMP2 and AFMPROCT to make AFMAYOCT, the sum of the monthly precipitation values for May through October.

Use COLOR A to look at AFMAYOCT. With the image displayed on the screen, press "v" to overlay the vector file COASTS in any color you like. Press "v" again and overlay COUNTRY. (These outline files can be overlaid whenever you have displayed an image in COLOR. Use them at any time during the exercises when you need to get an idea of where things are.)

3-2. Summer precipitation is highest in what region of Africa? What is the maximum amount?

Now we need to do the same thing for November through April. While the above procedure didn't take all that long, it was pretty dull after the first couple of overlays. This time let's take advantage of something called a "batch file" to accomplish the same thing.

Usually when we use the computer, we give it one command and it executes that command, then comes back and waits for us to give it the next command. With a batch file, we are able to put all of our commands together in a file, then tell the computer to execute all of them, in the order they've been written. We are then free to sit back and watch, or take a break.

Type OVERLAY ?. (Including the "?".) The information that comes up on the screen tells you about the format that the OVERLAY command must take if it is to be used in a batch file. This is called command line format. Make a note of the format. Note that the second item in the line is the letter "x", not a multiplication sign.

Now we are ready to create the batch file. We will do this with the IDRISI text editor. Type EDIT. Choose option 8, other file not in data directory, give the pathname: C:\IDRISI\ADDER.BAT, and press return. Batch files must have the .BAT extension and must be in the IDRISI program directory rather than the data directory.

EDIT searches for a file with that path and name and if none exist, allows you to create a new file. Type the following commands into the new file, one on each line:

```
OVERLAY x 1 AFMPRNOV AFMPRDEC TEMP1
OVERLAY x 1 TEMP1 AFMPRJAN TEMP2
OVERLAY x 1 TEMP2 AFMPRFEB TEMP1
OVERLAY x 1 TEMP1 AFMPRMAR TEMP2
OVERLAY x 1 TEMP2 AFMPRAPR AFNOVAPR
```

Press the escape key when you are finished, and answer "y" to save the file. To run the batch file, at the prompt in the IDRISI directory (where you have been running all of the IDRISI modules), type ADDER and press return.

Watch as the batch file is executed. If there are any mistakes, you will hear a beep or see an error message. If there were no errors, skip to the next question. If there was a beep or an error message, use EDIT again, giving the same pathname as before, and use the arrow and delete keys to correct your mistake. Run the batch file over. Repeat this process until the batch file runs without error.

3-3. *Did it take you longer to make AFMAYOCT or AFNOVAPR? If you were summing 30 images instead of six, which method would you use? What about for three images?*

3-4. *Look at AFNOVAPR with COLOR A. Note where rainfall is highest and lowest. How does it compare to AFMAYOCT?*

Now that we have these two images, we are a step closer to determining the rainfall regimes. According to our definitions of summer, winter and uniform rainfall regimes, we need to find the relationship between summer and winter rainfall. In other words, a certain amount of rain in the summer or winter doesn't determine which rainfall regime a pixel belongs to, but rather the **ratio** of rain falling in summer to that falling in winter. To make this image we will have to divide using OVERLAY and the ratio option.

Before dividing, we must deal with another small problem. Use DESCRIBE to look at the minimum values in AFMAYOCT and AFNOVAPR. Dividing by zero is mathematically impossible. This problem will come up again in later exercises and we will see that there are a few ways to handle it. This time, let's just get rid of the zeros by adding a small number, such as 1, to all the values. This won't change the values significantly—only 1 mm of precipitation over 6 months—but it will solve our division by zero problem.

Zero values in the numerator don't pose a problem mathematically, but they would cause us to lose information about the comparison between the summer and winter rainfall. Since zero divided by any number is still zero, we wouldn't see a difference between a pixel which has zero precipitation in summer and 400 mm in winter and another pixel which has zero precipitation in summer and 1000 mm in winter. By adding 1 to the numerator as well as the denominator, we will be able to make this distinction since 1/400 (0.0025) is different from 1/1000 (0.001).

Whenever we want to add the same number to all the pixels in an image, we use SCALAR. SCALAR is also used to subtract, multiply, divide, and exponentiate an image by a single number. Run SCALAR and add 1 to AFMAYOCT. Call the resulting image MAYOCT1. Do the same with AFNOVAPR, calling the output NOVAPR1. Now use OVERLAY with the ratio option to divide MAYOCT1 by NOVAPR1, and call the result AFRATIO. Look at AFRATIO with

COLOR A and the IDRISI palette. Use the cursor to examine the values of several pixels.

You didn't make a mistake! The image should be mostly black, with some colored areas in the Sahara Desert. The values are so much higher in these areas, all of the lower values get assigned to the same color—black.

3-5. *Why do these colored areas have such high values? [Hint: Use the cursor to find the row and column one of the pixels with the highest values. Then find the values of the same pixel in MAYOCT1 and NOVAPR1.]*

Think carefully about how AFRATIO was created, then complete the following questions.

What do values greater than 1 represent?

In the northern hemisphere: The value for AFMAYOCT was larger than the value for AFNOVAPR.

In the southern hemisphere:

What do values less than 1 represent?

North:

South:

What do values equal to 1 represent?

North:

South:

Remember, however, we are not concerned only with whether the winter rainfall is higher than the summer rainfall and vice versa. We are concerned with whether one is 30% or more higher than the other.

When we divided MAYOCT1 by NOVAPR1 in the Northern Hemisphere, we divided summer by winter. Therefore, for that hemisphere, all values that are >1.30 will be considered a summer rainfall regime (1 + 30% = 1.30). Using the same reasoning, since a winter rainfall regime is defined as winter rainfall exceeding summer rainfall by at least 30%, all values in the Northern Hemisphere which are < 0.77 will be considered winter rainfall regime (1 / 1.30 = 0.77). All values which are between 1.30 and .77 will be considered uniform rainfall regimes.

3-6. What will be the case in the Southern Hemisphere? Fill in the chart:

Hemisphere	*Northern Hemisphere*	*Southern Hemisphere*
Summer =	*> 1.30*	
Winter =	*< 0.77*	
Uniform =	*0.77 < z < 1.30*	

Now we are presented with another dilemma. We would like to have a map in which all the summer regime pixels have the same value. The problem is that summer regime pixels in the northern part of the image have one range of values while those in the southern part have another range of values. If we try to reclassify pixels in the Northern Hemisphere which are summer regime, the winter regime pixels in the Southern Hemisphere will also be reclassified to the same value!

As usual, there is more than one way to get around this problem. We could cut the image in half along the equator using WINDOW, RECLASS the halves separately, then join them back together with CONCAT. We could make a copy of the image and blank out the northern half on one image, the southern half on the other image using UPDATE, RECLASS them, then rejoin them with OVERLAY addition or cover. We could also make a new image to OVERLAY with the old image which would result in changing the values in one half of the image to different values.

You can come back later and try the different methods mentioned here and any others you have thought of. For now let's use the last one described. We'll create an image in which the Northern Hemisphere all has the value 1 and the Southern Hemisphere all has the value -1, then we'll multiply this image with AFRATIO.

3-7. What will happen to the values in the Northern Hemisphere? The Southern Hemisphere? Would this method be appropriate if AFRATIO had positive and negative values in both hemispheres?

3.8 Use DESCRIBE to find how many rows and columns are in AFRATIO, and what the cell dimensions in X and Y are. Write these down.

Rows:
Columns:
Cell dimension in X:
Cell dimension in Y:

The cell dimensions are written in scientific notation. You can consult any mathematics text for the details, but essentially, all you have to do is move the decimal point according to the number following the E. The decimal point should be moved left if the number following the E is negative, and to the right if the number following the E is positive.

```
1.66667E-01 = 0.166667
7.235E03 = 723.5
```

To create the new image we will use the module INITIAL. INITIAL creates an image with the file format, number of rows and columns, and the cell dimensions we specify. All the pixels in the new image will have the same initial value. Run INITIAL to make the image CHANGER. We want an integer binary file, with the same cell dimensions and number of rows and columns as AFRATIO. Give CHANGER an initial value of 1.

At this point CHANGER has the value 1 in every pixel. Now we want to change the Southern Hemisphere to have the value -1 in all its pixels. Before we can change the Southern Hemisphere, however, we need to know where it is! We will need to find out between which rows the equator lies.

Display CHANGER with COLOR. (You won't see much because all the pixels have the same value.) Now overlay the vector files COUNTRY, COASTS, and LAKES using any color codes you like. Compare the boundaries with those on the paper map you have and, using the cursor, try to determine between which rows the equator should lie. This will be easier if you "zoom in" on the equatorial region using the "w" window command, then overlay the vector files again.

3-9. According to your best estimate, the equator should pass between which two rows in the image? Label these row numbers on Figure 3.2 (next page).

Run UPDATE on CHANGER. Refer to Figure 3.2. We are going to update the Southern Hemisphere in our image to have the new value -1. The first row is the row you identified just below the equator. The last row is the bottom row of the image, number 437. The first column is number 0, and the last is 479. Enter -1 as the new value to be placed in these cells.

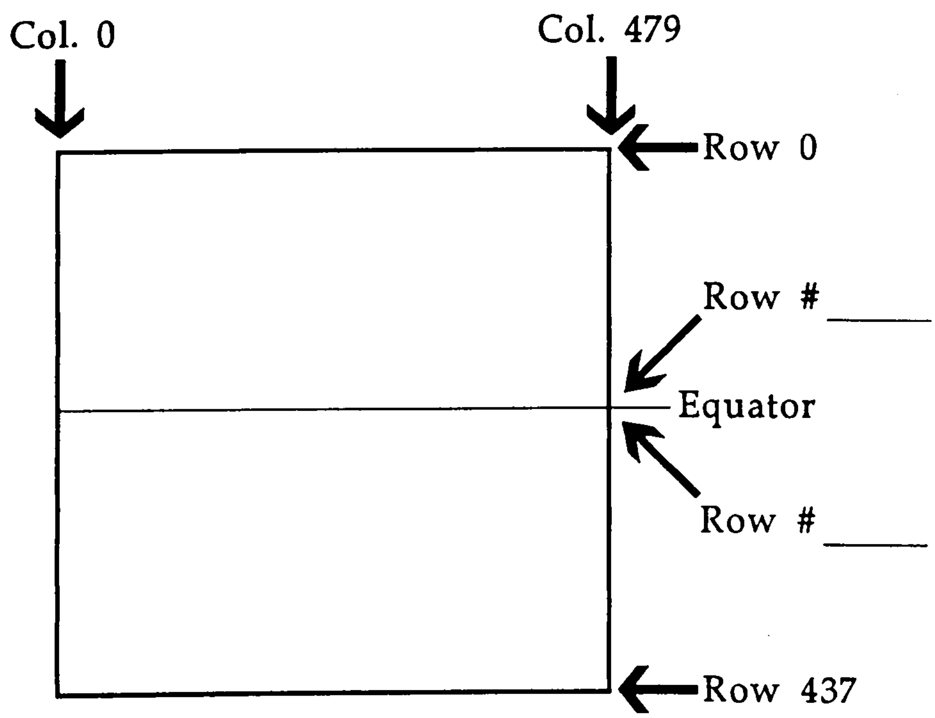

Figure 3.2. Figure to use in exercise questions 3-8 and 3-9.

Now look at CHANGER with COLOR A. Use the cursor to confirm that the pixels in the Northern Hemisphere have the value 1 and those in the Southern Hemisphere have the value -1.

Now OVERLAY (multiply option) CHANGER and AFRATIO. Call the resulting image NSRATIO (for North-South ratio). Use DESCRIBE to see the new maximum and minimum values of NSRATIO.

3-10. A Southern Hemisphere pixel with value 0.77 in AFRATIO has what new value in NSRATIO? A Northern Hemisphere pixel with value of 0.77 in AFRATIO has what value in NSRATIO?

Now we're ready to RECLASS NSRATIO into three classes: summer, winter and uniform rain regimes. We want these classes to have the following new values in the resulting image:

Winter Rainfall Regime = 1
Uniform Rainfall Regime = 2
Summer Rainfall Regime = 3

3-11. Think about how we created NSRATIO, and fill in the following table:

		NEW VALUE	OLD VALUE RANGE
Northern Hemisphere	*a.*		*1.3 to 500*
(summer/winter)	*b.*		*0.77 to 1.30*
	c.		*0 to 0.77*
Southern Hemisphere	*d.*		*-0.77 to 0*
(winter/summer)	*e.*		*-1.30 to -0.77*
	f.		*-100 to -1.30*

(If you are uncertain about your table, before proceeding, check it against the list of new values given just before the ON YOUR OWN section on the next page.)

Run RECLASS with NSRATIO using the above table as your guide. Name the resulting image REGIMES. You will notice that there are two options with RECLASS. You want to use option [2] "USER-DEFINED CLASSIFICATION." Then follow the instructions carefully to input the values you have just chosen. Be patient, the RECLASS takes a few minutes.

Look at REGIMES with COLOR and the IBM palette. This is the final rainfall regime map. Let's put the finishing touches on this map by adding a legend.

With REGIMES still on the screen in COLOR, press "l" to activate the legend category update utility. You will see a message in the lower left hand part of the screen. Give the appropriate legend labels to each category.

3-12. What can you say about the distribution of summer, winter and uniform rainfall regimes in Africa?

3-13. What do you notice along the equator? What causes this? Can you think of a way to produce REGIMES without having this problem?

Don't delete REGIMES, as we will be using it in the next exercise. The new values for RECLASS in question 3-11 are: a-3, b-2, c-1, d-3, e-2, f-1.

ON YOUR OWN

A. Some people say that the terms summer and winter don't really mean anything within 5 degrees north and south of the equator. Create a new map in which all rainfall regimes in this band are labeled as uniform. [Hint: You don't have to start at the beginning! Think about how you could do this starting with REGIMES.]

B. Make a computer "slide show" showing the steps you took to create the REGIME image. (It will be a "slide show" in the sense that the images will automatically display themselves on the computer screen.) You will use the command line format of COLOR in a batch file. (You can find the command line format of any IDRISI module by typing the module name, followed by a space and a question mark. If the module proceeds rather than showing you command line information, that module is not capable of being used in this way.) You can make a cassette recording of narration to go along with the "slide show," adjusting the pauses in the command lines to fit the narration.

EXERCISE 4: Suitability Analysis

Deforestation has received much public attention in the past few years. Depletion of forest resources can have very adverse effects on humans, wildlife, and whole ecosystems. When forest resources are lost, it becomes more difficult for humans to supply their fuel needs, erosion can become more severe and the climate of an area may actually become drier.

Attempts to replant trees have met with varying degrees of success. Many factors must be considered when planning a reforestation project if it is to be successful. A species must be selected which will suit the needs of the people in the area. The species must also be suited to the physical conditions of the area, such as temperature, rainfall, slope, and soil depth and type.

In this exercise we will use GIS to determine where, in Africa, the climatic conditions are suitable for the planting of the tree species Eucalyptus grandis. We will only examine the climatic factors, so our result will be only a part of what might be a complete suitability analysis.

Eucalyptus grandis, which we will call E. grandis for short, has been used in forestry projects around the world. Scientists have observed the conditions under which E. grandis grows well, and have found that the species likes the following climatic conditions:

Mean annual rainfall	700 - 2500 mm
Rainfall regime	summer or uniform
Maximum monthly mean temp.	31° C
Minimum monthly mean temp.	-1° C
Mean annual temp.	14 - 22° C

We must now decide what data we will need to use in order to identify the suitable areas for E. grandis in Africa.

Use LIST to examine the images available in our data base.

4-1. For each of the conditions listed, write down the name of a file or files which might give us the required data.

Condition	*Filename*
annual rainfall-	
regime-	
monthly mean temp.	
monthly mean temp.	
annual temp.	

4-2. Now that we think we have identified all the necessary data to complete our climatic suitability map for Eucalyptus grandis, let's use DESCRIBE with each of the files to find the maximum and minimum data values and the units of measurement.

Climatic Factor	Suitable Range	Image	Max	Min	Units
Mean Annual Rainfall	700 - 2500 mm	AFMPRANN			
Rainfall Regime	Summer,Uniform	REGIMES			
Max. Monthly Mean Temp.	31° C or lower	MAXHOT			
Min. Monthly Mean Temp.	-1° C or higher	MINCOLD			
Mean Annual Temp.	14 - 22° C	AFTMPANN			

For each of the five files, we need to make a new image showing where the conditions for that particular climatic factor are suitable for E. grandis. We will be reclassifying the images so that the suitable areas all have the value 1 and those that are unsuitable have the value zero. Images in which the areas of interest have the value 1 and those not of interest have the value 0 are very commonly used in GIS analyses. They are sometimes referred to as "Boolean masks." Using the values 0 and 1 will make the later combination of various images easier.

Use RECLASS with AFMPRANN to make the new image AFMPRANR (for reclassified). Give a new value of 0 to old values ranging from 0 to those just less than 700. Give a new value of 1 to old values ranging from 700 to those just less than 2500. And give a new value of 0 to those values ranging from 2500 to those just less than 5292 (this could be any value as long as it is larger than the maximum value in AFMPRANN.) Type in -1 to finish the reclassifying. Now use DESCRIBE with AFMPRANR to make sure the max is 1 and the min is 0.

Now let's make the Boolean mask for the rainfall regimes. This time we are only interested in summer and uniform regimes. All the pixels in these two categories (values 2 and 3 according to the image legend) should have the value 1 in the mask. Those belonging to the winter regime category are not of interest to us, and will therefore be reclassified to have the value 0. RECLASS REGIMES to produce the new image REGIMESR. Give a new value of 0 to old values ranging from 1 to 1, and a new value of 1 to old values ranging from 2 to those just less than 3.1.

4-3. Why did we use 1 to 1 rather than 1 to 1.1 in the first case? [Hint: Read the text that appears on the screen when you run RECLASS.]

Consult the above table for the max and min values, units, and the range of suitabilities, and RECLASS the three temperature images in the same manner. (BEWARE! The suitable ranges are given in degrees C, but the data in the images is in tenths of degrees C. You need to multiply the suitable range numbers by 10 and use these new values in RECLASS.)

Call the resulting images MAXHOTR, MINCOLDR, and AFTMPANR. Check each result with DESCRIBE or COLOR A and the cursor to make sure there are only 1's and 0's in the image.

4-4. *If there are only 1's and 0's, does that mean the reclass was done correctly? How might an error be made that wouldn't be caught by checking the 1's and 0's?*

Now you have five separate images, each showing where one climatic factor is suitable for E. grandis. We now want to find the places where ALL FIVE factors are suitable. To do this we will use OVERLAY.

OVERLAY all five files using the multiply option. This must be done as in the preceding exercise, using temporary files along with the data files since only two images can be used in OVERLAY each time. You may make and use a batch file, such as we did to produce AFNOVAPR in the last exercise if you like. (Remember, however, that this time we are multiplying rather than adding, so that command line parameter will be 3 rather than 1!) Name the final image SUITABLE.

Look at SUITABLE with COLOR. Overlay the vector files COASTS and COUNTRY.

4-5. *How would you describe the distribution of the suitable areas? Are the pixels which are suitable spread out or grouped together? Are there more suitable areas to the north or south of the equator? Why do you think this is the case?*

FOR FURTHER EXPLORATION

Suppose that scientists have determined that as long as a place falls within the suitable range for annual precipitation, only three of the other four climatic conditions must be within the suitable range for successful growth of E. grandis. Let's make a new map representing these new criteria.

Since the suitable ranges for each climatic factor have not changed, we can use the Boolean masks we used before. The OVERLAY process is going to be different, however.

4-6. *What overlay procedure can we use to show how many conditions are met for each pixel? Should we include Minimum Monthly Mean Temperature in this overlay operation with the other four factors?*

Use OVERLAY and the addition operation to add climatic factors MAXHOTR, MINCOLDR, AFTMPANR, AND REGIMESR. Call the resulting image FACTORS.

4-7. *Looking at what you have computed for the input data sets to FACTORS, what are the possible values in FACTORS? If a pixel has the value two, what does that mean? Does this tell us anything about* ***which*** *two factors are suitable for this pixel?*

Now use OVERLAY to multiply FACTORS and your Boolean mask for minimum monthly mean temperature (that is, MINCOLDR). Call the resulting image FACTORS2.

Is FACTORS2 the final map? Look at the documentation file for FACTORS2 with the command DESCRIBE FACTORS2. What is the range of values? Run HISTO on FACTORS2, using the default options. How many classes are there?

Let's use DOCUMENT to edit a legend for FACTORS2. First type DOCUMENT, and hit the "ENTER" key. When DOCUMENT asks you for the map name, answer with FACTORS2. DOCUMENT then gives you a screen to edit. Press the "L" key, to edit a legend. Then, following prompts on the screen, press "1" to edit legend category 1. Enter text (perhaps "1 favorable factor") to label category 1. Add consistent legends for categories 2, 3, and 4. Follow the instructions of DOCUMENT to exit the function.

Now, look at FACTORS2 with COLOR, using the IBM palette. Does this map show us every place where the annual temperature is suitable and AT LEAST 3 of the other four climatic factors are also within their suitable limits?

To create the final image, RECLASS FACTORS2 so that the pixels which only meet 1 or 2 of the climatic criteria are changed to zeros. Call the output image FINAL and give it an appropriate title. Label the legend categories.

ON YOUR OWN

A. Make a map in which we know for each pixel precisely which of the five climatic factors are suitable.

B. Take one of the vegetation maps in the data base and choose one of the vegetation classes from it. Try to determine the range of suitability for the five climatic factors used in this exercise for that vegetation class. When you think you have defined the suitabilities, make the appropriate masks and overlays, then check the distribution of the areas you determined were suitable for this vegetation type against the distribution of the vegetation type on the original map. Discuss any differences you see. What factors other than those we used seem to be important in determining the distribution of the vegetation class you chose? [Hint: You may want to consider using the following modules that we haven't used in any of the exercises so far: EXTRACT, CROSSTAB, AREA.]

CHANGE DETECTION AND ANALYSIS TECHNIQUES

Earth scientists are often concerned with the way things change. Change can occur over space and over time, can be caused by man or nature, and can be relatively permanent or simply part of a normal pattern of variation. Several techniques for analyzing changes in satellite imagery have been developed over the years. Each has its strengths and weaknesses, depending on the changes of interest to the investigator. In the following exercises, we will explore the various ways in which environmental change can be analyzed, through the use of satellite data for the continent of Africa.

The data we will use was gathered by the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) satellite. As the sensor passes over Earth, it records information about the amount of energy that is either being reflected, in the case of light, or radiated, in the case of heat, by Earth. AVHRR data is used in a wide variety of studies. One of the most common uses of AVHRR data at a global scale is in studying how much living matter (biomass) is present in any particular place. Plants absorb visible red light (which is why our eyes don't detect red when we look at plants) and reflect infrared energy. We use this characteristic of green plants to calculate the Normalized Difference Vegetation Index (NDVI), commonly known as the "Green Index." The NDVI is calculated with the following equation:

$$\text{NDVI} = (\text{Infrared} - \text{Red}) / (\text{Infrared} + \text{Red})$$

Imagine a case where the satellite sensed a lot of infrared energy being reflected and hardly any visible red energy being reflected. Would this yield a high or low NDVI value?

This would, in fact, yield a high value and would indicate that there was a lot of healthy green vegetation in that area. Clouds, water and snow.reflect more red than infrared, and thus have a negative NDVI value. Bare soil and rock reflect about the same amount of red as infrared, so they have NDVI values near zero.

EXERCISE 5: Simple Differencing

We begin with a very simple question—what differences can we detect between the NDVI images for Africa of December, 1987, and December, 1988 ? We follow this by asking if the differences we are able to detect represent significant change, or are simply the products of normal variation. (Note that a more meaningful comparison might be made on a seasonal, rather than monthly basis. We are using the monthly images for illustration of the change analysis techniques.)

We will be working with two images—AFDEC87 and AFDEC88. NOAA has already calculated the monthly average NDVI values for us, and to make the data easier to store and work with, they have converted it to a range of 0 - 175. The legend that goes with these images is accurate only when used with COLOR A, not with COLOR.

Use COLOR A to look at each of the images. If you have a VGA or 8514a display, use the "user defined palette" option, and give NDVI as the name of the palette. This palette has been created for use with NDVI images. Note that the green colors represent high NDVI values and therefore represent areas on the earth where there are many green plants. The browns and reds in the palette represent areas of little vegetation.

Display AFDEC88 with COLOR A. Overlay COASTS and COUNTRY using the V option.

5-1. Use the cursor to determine in what countries the lowest NDVI values are found? The highest?

The first technique we will use to compare the two images is simple differencing. We will take the NDVI value of each pixel in the 1988 image and subtract the corresponding pixel in the 1987 image. We will use the result of this subtraction to create a new image which shows the simple difference.

Run OVERLAY with the SUBTRACT option to subtract AFDEC87 from AFDEC88 and call the result DIF88-87. Look at DIF88-87 with COLOR A and the IDRISI palette. Use the cursor to find which color represents values closest to zero. The palette colors going from that color to the top of the screen represent negative values. Those going from that color to the bottom of the screen represent positive values.

5-2. *If the value of a pixel in DIF88-87 is positive, does AFDEC87 or AFDEC88 have a higher NDVI value? Where are most of the pixels located which have the highest values in DIF88-87? Where are those with the lowest (most negative) values? Sketch a map showing the areas with positive values and those with negative values.*

The simple difference image, DIF88-87, shows us the changes in the NDVI values from one December to the next, but it doesn't tell us anything about the significance of the change, that is, what is true change and what is normal variation. To try to establish the limits of "normal variation," we will make a histogram of the simple difference image, then using some simple statistics we will define "thresholds," beyond which we consider that true change has occurred.

Run HISTO on DIF88-87. We (1) want a graphic histogram, (2) don't want to change the maximum or minimum values, and (3) want a class width of 1. With the histogram on the screen, press "p" on the keyboard if you have a supported printer hooked up to your computer to print the histogram, or make a sketch of the histogram if you don't have a printer.

5-3. *Are there more values to the left of the peak or to the right? Does this mean, generally, that December of 1987 was greener or less green than December of 1988?*

When you have finished looking at the histogram, hit return to see the summary statistics. The only statistics we are concerned with at this time are the mean and the standard deviation. Make a note of these values.

The mean, also known as the average, is the sum of the values of all the pixels, divided by the number of pixels. The standard deviation is a measure of the distribution of the data around the mean. It is only useful when the data follow a "normal" distribution, sometimes referred to as a "bell-shaped curve". If a data set forms a "normal" distribution, the histogram would have the shape shown in Figure 5.1.

In a normal distribution, 68% of the data values are within one standard deviation of the mean, 95% are within two standard deviations and 99% are within three standard deviations. Thus, anything outside 3 standard deviations is very unusual.

As you already noted, the histogram of DIF88-87 did not show a perfectly "normal" shaped curve. Still, since there was a peak at the mean and tails in either direction, we can use the standard deviation to approximate our threshold values. We will assume that the 99% of the pixels of DIF88-87 which fall within 3 standard deviations from the mean are showing normal variation, while the 1% that are outside of that are showing significant change.

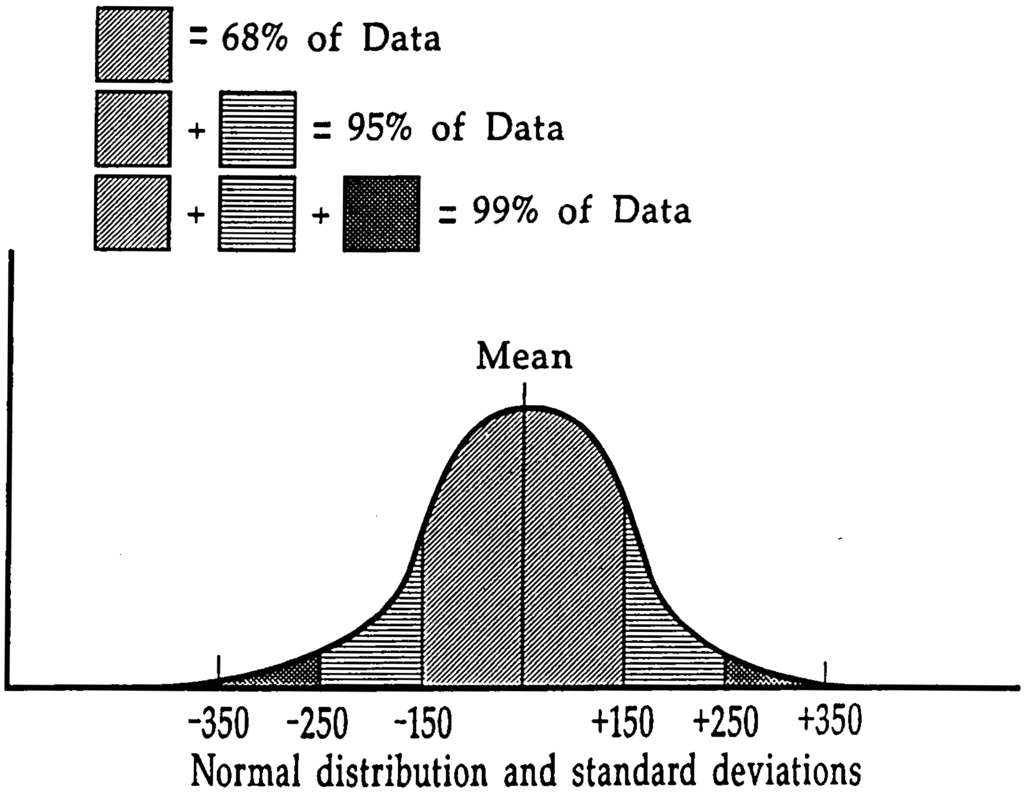

Figure 5.1. Graphical depiction of a normal distribution. See text on pages 70 and 72.

Now we need to identify our threshold values. To do this we will add three standard deviations to the mean (which you wrote down from the histogram summary) to get the upper threshold, and will subtract 3 standard deviations from the mean to get the lower threshold.

5-4. Mean:

Standard Deviation:

3 times the Standard Deviation:

Mean + 3 S.D. (this is the upper threshold):

Mean - 3 S.D. (this is the lower threshold):

Now we want to look only at the pixels which we consider to be showing significant change. To do this we will reclassify the simple difference image so that all the unusual positive values have one value, the unusual negative values another value, and everything else has value 0 (is masked out).

Run RECLASS on DIF88-87. Call the resulting image CHG8887, and specify User-Defined Classification. Use the information in the following table:

New Value	Old Value Ranging From	To Those Just Less Than
0	-44.565	41.3256
1	-100.	-44.565
2	41.3256	200.

Look at CHG8887 with Color and the IDRISI palette. The colors for classes 1 and 2 are not easy to distinguish. With the image on the screen, press "k" on the keyboard. Change the colors of category 1 and 2 to be very distinct. (Refer back to IDRISI FUNDAMENTALS if you've forgotten how to use k.) When the colors are as you want them, type "l" for legend update. Update category 1 to read "Greener 87" and category 2 to read "Greener 88".

5-5. Compare this image with your answers for question 3. Having "masked out" the changes which we are considering to be normal, do you get a different impression of where positive and negative changes have been detected? Are there more pixels showing that 87 was greener or that 88 was greener?

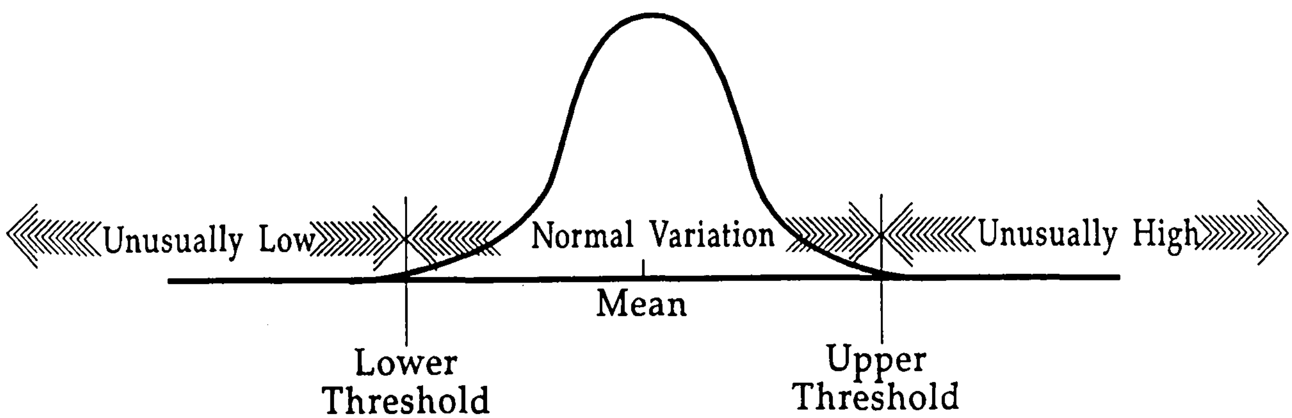

Figure 5.2. Graphical depiction of mean, normal variation, and upper and lower thresholding. See text on page 72.

EXERCISE 6: Image Regression

You probably noticed that the mean value of GHG8887 is not 0, but *is* very close to zero. You also probably noticed that there were regions of Africa that had higher values NDVI for 1987, and other areas with higher values for 1988. This suggests that there is an overall change between the two dates in these regions. One possibility is that, on average, December of the year of the lower NDVI was not as wet as December of the year of higher NDVI in these regions, and therefore not as green. This is the kind of change we are hoping to detect.

Unfortunately, there are other possible sources for the change which have nothing to do with actual conditions on the ground. It is possible that the sensor on the satellite was not working identically over the two years. There also may have been differences in atmospheric conditions or illumination by the sun which would make the two data sets non-comparable.

We need to be concerned not only about a change in the mean, but also a change in the variation of the data. To correct for changes in the mean and variation, a technique known as image regression can be used. Regression is a statistical tool which defines the relationship between two variables. We could run a regression, for example on the heights and weights of children in a primary school, and find the average relationship between the two. Then, when given the height of a child, we could predict his weight. Of course there will be some children whose weights are far from the predicted weight for their height, but most would be close.

We are going to use the two December images as variables in a simple linear regression. When we use this technique, we are saying that we believe there is a relationship between the value of each pixel in AFDEC87 and its corresponding pixel in AFDEC88. That is, we assume that the image at time 2 is a function of that at time 1 (i.e., that it is the way it is largely because of the way it was in the past). The time 1 image is thus the "independent" variable — that which can account for values at time 2. The time 2 image is then the "dependent" variable. REGRESS then calculates the linear relationship between the two images and plots a graph of individual pixel values. This graph is sometimes called a scatter plot.

If we drew this graph by hand, we would follow the x axis to the NDVI value of pixel 1 in AFDEC88, then go up in the Y direction to the NDVI value of pixel 1 in AFDEC87 and make a point, then do the same for all the other pixels in the image. (See Figure 6.1., next page.)

6-1. If the values in AFDEC87 were exactly the same as the values for AFDEC88, what would the regression scatter plot look like? Make a sketch. On your sketch, indicate where you would find: a) the point for a pixel in which AFDEC87 was higher than AFDEC88, and b) the point for a pixel in which AFDEC87 was lower than AFDEC88.

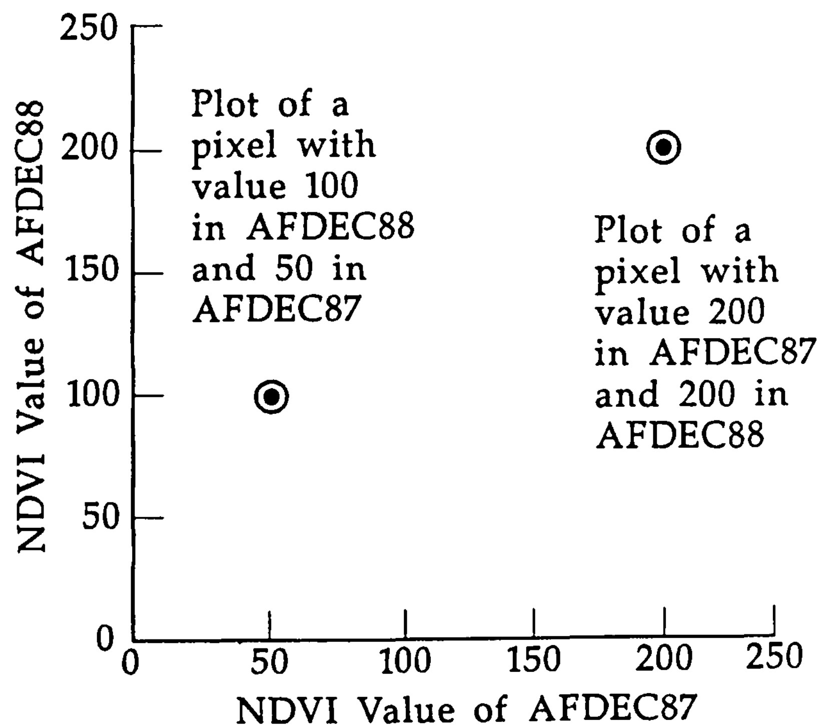

Figure 6.1. Scatter plot illustrating discussion on page 75.

REGRESS will draw a best fit trend line and give the equation of that line, along with the scatter plot. The best-fit trend line is calculated to pass as close as possible to the points in the scatter plot. There is a mathematical formula to derive this line, but if you were estimating it by eye, you would take a ruler, lay it down on the scatter plot, and move it around until the edge came as close as possible to passing through as many points as possible, then you would draw the line.

The equation defining the line, also known as the regression equation, is given in the form: $Y = b + mX$. Y is the dependent variable, in our case AFDEC88, X is the independent variable, AFDEC87, b is the value on the Y axis where the line crosses, and m is the slope of the line, that is, the change in Y divided by the change in X. This means that if we know the value of X, we can find the value of Y by multiplying X by m, then adding b.

We will use the regression equation with SCALAR to create a "predicted" image for time 2 based on the data for time 1. That is, we will use the data we have for DEC87 and will create an imaginary, or predicted DEC88 based on the relationship between the two real images that we derived with REGRESS. Then by subtracting our predicted DEC88 from the actual DEC88, we will get a difference image which we will threshold using the steps we used before. We use this method to get rid of, or mask out, changes which are due to overall changes in the mean and variation which may be due to conditions discussed before.

Let's give this method a try with our data.

Now run REGRESS. When it asks, indicate that you will be computing a regression between images and specify AFDEC87 as the independent variable and AFDEC88 as the dependent variable. Be patient, this operation will take a few minutes.

6-2. What is the regression equation? (It's across the top of the screen when the scatter plot is displayed.)

Hit return to see the summary statistics. Write down the correlation coefficient, r, and the coefficient of determination, r2. (We won't be using any of the other statistics given, but if you are curious about them, you can consult any statistics textbook.)

You should have found that the equation is Y = -1.1823E+01 + 1.2226E+00 X, and the coefficient of determination is 89.48 %. This means that the value in December 1988 is equal to -11.2 plus 1.2226 times the value in December 1987, and that 89.48% of the variability in December 1988 can be explained by the variability in 1987. This means that 10.52% of the variability cannot be explained by 1987. We can also see that the slope of the regression line is 1.2226. If the slope were exactly 1, we could conclude that there is no difference in the variability of the two data sets.

Let's use the regression equation, then, to create the predicted December 1988 image from AFDEC87. We will then compare the actual and predicted 88 data sets, and analyze the differences.

Use SCALAR to multiply AFDEC87 by 1.2226. Call the result TMP. Run SCALAR again to subtract 11.823 from TMP and call the resulting image PRDEC88 (for predicted December 1988).

The predicted image for 1988 represents what the 1988 values would have been if the relationship between 1987 and 1988 were perfect, that is, if all the pixels had plotted exactly on the line in the scatter plot. This would indicate that the only difference between the two Decembers was the slope of the line, known as the gain, and the place where it crosses the Y axis, known as the offset. We have seen that this was not the case. While the points certainly clustered around the line, there were some higher and some lower.

This means that there are some differences between the images in addition to offset and gain.

To analyze the difference between the predicted and actual 1988 data, use OVERLAY to subtract PRDEC88 from AFDEC88. Call the result DIFPRED. Display DIFPRED with COLOR A and use the cursor to examine some of the values.

6-3. *What does a negative value in DIFPRED tell you about the NDVI values for that pixel in AFDEC87 and AFDEC88? A positive value?*

Now use HISTO on DIFPRED. Change the minimum and maximum to new values of -96 and 116, and create a graphic output with a class width of 1.

6-4. *Make a sketch of the histogram (or print it out if your computer is connected to a supported printer). How does it compare to the histogram created in the previous exercise? What are the mean and standard deviation? How do these compare with those for the simple difference histogram? Try to explain why we see these differences.*

Recall the procedure we used in Exercise 5 to identify threshold values and reclass an image to show only change, not normal variation.

We'll use the same procedure again here with DIFPRED.

6-5. Mean:

Standard Deviation:

Three Standard Deviations:

Mean + 3 SD:

Mean - 3 SD:

Now that you've identified the upper and lower threshold values, run RECLASS as we did in exercise 5. Call the result CHGPRED.

6-6. Give a new value of:

to old values ranging from:

to those just less than:

Give a new value of:

to old values ranging from:

to those just less than:

Give a new value of:

to old values ranging from:

to those just less than:

Examine CHGPRED with COLOR and the special palette you created before.

Let's visually compare CHGPRED and CHG8887. Use CONCAT to make a new image called COMPARE. Use CHG8887 as the main image and join CHGPRED to it on the right side. Title the new image "Change from Simple Differencing (left) and Image Regression (right). Look at COMPARE in COLOR with your special change palette. (You will have to zoom out to see the entire image.)

6-7. Describe any differences or similarities you notice between the two images. Try to explain why the different techniques produce the differences you see.

Image regression is a very effective technique for getting around "offset and gain" effects between images. However, both simple image differencing and image regression consider differences of a given quantity to be equivalent no matter where they occur on the measurement scale. Sometimes this is not desired. In some instances a researcher may wish to give more emphasis to differences at the low end of the scale. Let's imagine, for example, that a researcher is more concerned about change in arid areas than those with a lot of vegetation. A change of 20 in the NDVI scale might not be noticed on the ground in a lush area, but the same change of 20 in a desert would be very noticeable on the ground. In such instances a relative scaling of differences is required, and we achieve this through our third technique, called image ratioing.

EXERCISE 7: Image Ratioing

Image ratioing is accomplished in OVERLAY by using the ratio (divide) option.

If we divided the 88 image by the 87 image, what would be the result for pixels with identical values? Could a pixel in the result have a negative value? If the 88 NDVI value is larger than the 87 value, what can you say about the result? What if the 87 value is larger?

The image that then results will often look quite different from one produced by image differencing, with progressively more weight given to differences the closer they are to zero. Note the ratios resulting from the following values:

IMAGE 1	IMAGE 2	RESULTING RATIO
5	10	0.50
10	5	2.0
95	100	0.95
100	95	1.05

The ratios resulting from 5 units of change near the lower end of the scale are further from 1.0 (no change) than those with 5 units of change at the higher end of the scale, thus emphasizing change at the low end.

There are, however, a few problems with the image ratioing technique. First, the presence of zeros in the images being compared presents a variety of problems. Division by zero is undefined, that is, we have no way to deal with it mathematically. IDRISI does give us a way around this, however. In OVERLAY, 0/0 is evaluated as 1.0 (i.e., no change), a positive number divided by 0 is evaluated as positive infinity which is represented by a very large number (1 times 10 to the power of 18), and similarly, a negative number divided by zero is evaluated as negative infinity. These "make-believe" values then become part of the resulting image and the analyst must decide how to treat them.

One solution is to add a small number to all the values in the images as we did in Exercise 3. Whether or not that method is acceptable depends upon the data and the purpose of the analysis. Another option is to simply mask out of the final analysis all of the cells that contained zeros in the original images. Since IDRISI will allow division by zero to occur (without crashing the machine), this kind of processing "after-the-fact" can be done. In the NDVI images, zero values tend to be concentrated on the ocean, and since we're not concerned with changes in the ocean, we will use this second option.

Besides division by 0, there is another problem with image ratioing. The resulting numeric scale is not linear, nor symmetric. That is, it isn't in the form of a straight line nor does it look the same on both sides of 1. For example, while 1.0 indicates no change and 2.0 indicates twice as much change in time 2, 0.5 represents twice as much at time 1 — a distance only half that when the sequence is reversed.

To correct this problem we can use the TRANSFORM module in IDRISI to convert the ratio scale to a logarithmic ratio scale (look at any mathematics text to find out about logarithms). The result will then be linear and symmetrical about zero. For example, ratios of 0.5, 1 and 2 will produce log ratios of -0.69, 0, and +0.69.

Lets explore image ratioing with our data. Use OVERLAY with the ratio option to divide AFDEC88 by AFDEC87 and call the resulting image RATIO. Look at RATIO with COLOR A. Use DESCRIBE to find the maximum and minimum of RATIO. Make a note of these values.

Use HISTO with the image RATIO. Change the max and min values to 10 and 0, and use a class width of 0.1, so we will have 100 classes. When asked to choose between graphic and numeric output, reply "G" for graphic output. If you have a printer connected to your computer, press "p" to print out the histogram while it is displayed on the screen. If you don't have a printer connected, make a sketch of the histogram. Press return to see the summary statistics and make a note of the mean and standard deviation of RATIO.

7-1. Match the condition described in the left hand column with the resulting value that we observed in the histogram of RATIO in the right hand column.

CONDITION	*RESULT*
A. AFDEC88 > AFDEC87	*a. 0*
B. AFDEC88 = AFDEC87, including 0=0	*b. 1*
C. AFDEC88 = 0, AFDEC87 <> 0	*c. 0 to 1*
D. AFDEC88 < AFDEC87	*d. > 1*
E. AFDEC88 <> 0, AFDEC87 = 0	*e. very lg. positive number*

A.______ B.______ C.______ D.______ E.______

Now let's look at the problem of the histogram not being symmetrical about the mean. This is a common problem in spatial analysis with GIS. Use the module TRANSFORM on RATIO to produce the output image LOGRATIO. Choose the natural logarithm option.

If you are not familiar with logarithms, you should consult any basic mathematics text book. When we asked IDRISI to TRANSFORM RATIO into the natural logarithm, for each value in RATIO, IDRISI asked the question, "Ten raised to what exponent gives me this number?" For example, the value 100 in RATIO would be transformed to the value 2 in LOGRATIO because 10^2 equals 100.

7-2. What would be the transformed value in LOGRATIO for the following values in RATIO:

a. 10

b. 1000

Exponents don't have to be whole numbers. While the number $10^{2.5}$ is difficult for us to calculate, it is no problem for the computer. Let's see what TRANSFORM has done.

First run DESCRIBE on LOGRATIO to find the max and min values. Make a note of these. Next, run HISTO on LOGRATIO and specify new max and min values of 4 and -4, and a class width of 0.1. Again, make a print out if you can, otherwise, make a sketch. Note that now the histogram is roughly symmetrical about 0, which is what we wanted. Make a note of the mean and standard deviation.

The histogram looks good between -4 and 4, but we know from the max and min listed in DESCRIBE that there are values which fall outside this range. Where did these values come from? Are there other values between the maxima and minima of our histogram and those for the entire image (as displayed by DESCRIBE)?

Let's go back to the values we discussed in question 7-2, and think about what TRANSFORM has done to them.

VALUE IN RATIO	VALUE IN LOGRATIO
0	The logarithm of 0 is undefined, so this probably produced an unpredictable result in LOGRATIO. We know the minimum is a large negative number, so was probably the result of this undefined operation.
1	We ask the question, 10 raised to what exponent gives the result 1? The answer is 0. If this doesn't make sense, check with a math teacher or textbook.
0 to 1	Again, 10 raised to what power gives a positive result less than 1? Here the exponent must be a negative number. For example, $10^{-2} = 0.01$.

(table continued next page)

> 1	These are the positive numbers we saw in the histogram.
very large positive number	We would have to raise 10 to a fairly large exponent to get this very large number. We saw in DESCRIBE that 85.195 is the maximum in LOGRATIO. Is 10^{85} a very large number? It certainly is! It is a 1 with 85 zeros after it! So we know that the very large positive numbers in RATIO have been transformed to 85.195 in LOGRATIO.

Finally, we're ready to mask out the pixels that had values of 0 in our original images, AFDEC87 and AFDEC88. We want to make a mask that has 0's wherever *either* file had a zero.

To make the zero mask, RECLASS AFDEC87 so that pixels with values ranging from 1 to 176 have new value 1. (We don't need to do anything with the 0s, since they are already 0.) Call the resulting image ZERO87. Do the same for AFDEC88 and call the result ZERO88.

Use OVERLAY, multiply, with ZERO87 and ZERO88 to make the image ZEROMASK. Any pixel that had a value of 0 in either ZERO87 *or* ZERO88 will have the value 0 in ZEROMASK. Only those pixels with non-zero values in both images will have the value 1 in ZEROMASK.

OVERLAY, multiply, ZEROMASK and LOGRATIO, to create LOGRATZ.

Use HISTO on LOGRATZ, change the max and min to 4 and -4, and specify a class width of 0.1. Make a note of the mean and standard deviation.

7-3. There are slightly more values to the left of zero than to the right. Does this mean that 1987 was greener than 1988, or the opposite?

Now that we've gotten rid of the problem zero cases, we have a histogram which is linear and symmetrical about zero. We are ready to do the thresholding in the usual way to produce a change image.

As we did with the first two methodologies, we will assume that any values falling within 3 standard deviations from the mean represent normal variation. We will assume that all values falling outside 3 standard deviations represents true change.

First multiply the standard deviation by 3. Add it to the mean to get the upper threshold of normal variation. Subtract it from the mean to get the lower threshold of normal variation.

7-4. What are the values you calculated for the upper and lower thresholds?

Now RECLASS LOGRATZ so that everything we have decided to call normal variation has the value 0. Everything with values less than the lower threshold has value 1, and everything with values greater than the upper threshold has value 2. Call the resulting image LOGRCHNG.

Look at LOGRCHNG with COLOR and your special change palette. Use the "l" key to update the legend categories as you did before.

Remember that we chose the ratio methodology in order to accentuate changes at the low end of the NDVI scale.

7-5. Describe the changes shown in LOGRCHNG.

We have used three different methods for looking at change between two images. To summarize this section, let's compare the three change images we produced by putting all three images on the screen at once. You already created the image COMPARE from the simple difference image, DIF88-87, and the regression change image, DIFPRED. We just need to add the ratio difference image.

First, we will need to make a blank image so that the four images will fill a rectangular screen.

Use DESCRIBE with LOGRCHNG to see the file format, number of rows and columns, and cell dimensions. Then use INITIAL to create an image called BLANK that has the same specifications. Use CONCAT with LOGRCHNG and BLANK to make the image TEMP. Finally, to join the two concatted images, use CONCAT again with COMPARE and TEMP to make the final image called ALLTHREE.

Look at ALLTHREE with COLOR and your change palette.

7-6. What can you say about the three methods and the changes that show up in each? Which method identified the most change pixels? Did all three methodologies identify more pixels showing "87 greener than 88"?

ON YOUR OWN

Choose a month you consider to be very different from December. Follow the same steps for one or more of the change detection and analysis techniques in comparing the 1987 and 1988 NDVI images for the month you chose. How do the results compare to those for December? Can you explain the differences?

EXERCISE 8: Comparing Two Qualitative Images

In the last exercise we created three new images which showed areas of significant change, CHG8887 (simple differencing), CHGPRED (image regression) and CHGRATIO (image ratioing). We started with the same images in making all three of these, AFDEC87 and AFDEC88. These original images had as values NDVI index numbers between 0 and 175. These images were quantitative, meaning that the numbers indicate a quantity of something—in this case NDVI or "greenness." A pixel with value 50 has less "greenness" than a pixel with value 200.

But what about the change images? Are the values in these three images still quantitative? Does the value 2, which we have given to those pixels which were "Greener 88" indicate a quantity of something? These three change images now show qualitative rather than quantitative data. Qualitative data show differences in the quality, or character of pixels instead of amounts of something. (Refer to an earlier discussion of qualitative versus quantitative data in the IDRISI FUNDAMENTALS section.)

We want to be able to compare CHG8887 and CHGPRED. We were able to compare the quantitative images by subtracting, regressing, ratioing, etc. These mathematical operations don't make sense with data which is qualitative, however. To compare qualitative images, such as our change images, we must have a different technique.

Whenever we have qualitative categories on maps, the only way to compare them is to overlay the two maps and tabulate the extent to which the various combinations of the two appear. This is called cross-tabulation and is provided in IDRISI by the module named CROSSTAB. Figure 8.1. illustrates a very simple example of CROSSTAB.

Run CROSSTAB with CHG8887 and CHGPRED. When it presents the list of output options, choose 3 if you have a printer or 1 if you do not. When it asks, specify CROSS as the name of the cross-correlation image.

If you have a printer, option 3 will provide two forms of output. The first is a cross-tabulation table showing the categories of one of the images along the columns and the categories of the other along the rows. This then forms a grid with cell entries showing the total number of pixels falling into each combination. The second output is a cross-correlation image with categories illustrating each of these combinations.

If you do not have a printer and chose option 1, you will only get the cross-correlation image, CROSS, because IDRISI doesn't print the table to the screen. You can get all of the information in the table, however, by running HISTO on CROSS. Indicate that you want a numeric histogram, don't want to change the maximum or minimum values, and want a class width of 1.

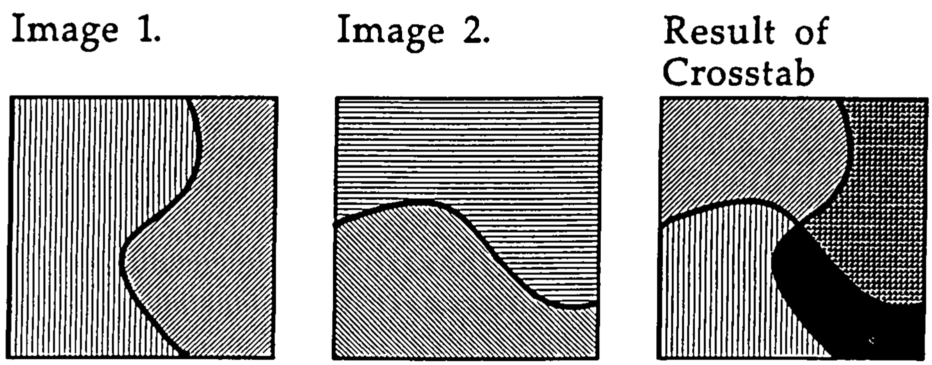

Figure 8.1. Simple graphical illustration of cross-tabulation (see p. 87).

Copy down the upper and lower bounds and the frequency for each class. To see which class represents which combinations, use DESCRIBE with CROSS and look at the legend captions. The first number is the class from the first image you named when running CROSSTAB. The second number is the class from the second image you named. Use the values you found with HISTO to fill in the number of pixels for each combination in the following table (which looks exactly like what the printer produced).

Use COLOR along with the IBM palette to examine CROSS. You will notice that each category already has a caption indicating the various combinations of the original images they represent (in the same order as they are indicated in the title). Now use the "k" option to change to black the color of all of the categories in which the original images had the same values (0|0, 1|1, 2|2). In this way, the only colors on the screen will be for those pixels which had different classes in CHG8887 and CHGPRED. You may wish to change the other colors to something bright and distinctly different from each other.

Table 1. Cross-correlation output from process described.

Cross-Tabulation of chg8887 (columns) against chgpred

	0	1	2	Total
0	206643	0	643	207277
1	1096	110	0	1206
2	223	0	1534	1757
Total	207962	110	2168	210240

Chi Square = 148305.13
df = 4
Cramer's V = 0.59
Kappa = 0.62

8-1. Does CROSS illustrate your earlier comments about the comparison between the simple differencing and image regression differencing techniques? Can you add to or modify any of your earlier statements?.

At the bottom of the printed table there are some statistics given. The Chi Square and degrees of freedom (df) entries can be used to assess whether or not there is any significant association between the two images (consult an introductory statistics text for this). Cramer's V is related to this and measures the strength of this relationship using a form of correlation coefficient. Cramer's V varies from 0 (no association) to 1 (perfect correlation). In addition, whenever there are exactly the same number of categories on both maps, CROSSTAB also prints out the Kappa coefficient (also known as KHAT). Kappa also is a measure of correlation but requires that the categories on the two maps really mean exactly same thing to be interpretable (as they do in our case). As we can see, Kappa and V are both fairly similar and indicate a good association. However, there is still a considerable amount of disagreement, suggesting that the two techniques did lead to some significant differences.

FOR FURTHER EXPLORATION

Use CROSSTAB to compare two other maps of qualitative data, such as vegetation from different sources, and discuss the results. (Remember that in this case category 1 on one image may mean something very different from category 1 on the other image.)

MULTIPLE COMPARISONS

From the above exercises we can see that there are a variety of ways in which we can compare two images. Sometimes instead of having only two images, however, we have a whole sequence of images to study, such as the monthly NDVI images in the data base. (A series of images which show the same thing as it varies over time is known as a "time series.") Then the process becomes more difficult. We will look at three techniques for studying a time series—time sequencing, time profiling, and principal components analysis.

EXERCISE 9: Time Sequencing

With time sequencing, we prepare a time series file which we will use with COLOR so that each image in the sequence is displayed automatically, one after the other. We want to make a time series file that will show each month of NDVI data for 1988.

A time series can only be displayed using COLOR, not COLOR A. Use COLOR and the IDRISI palette to look at AFJAN88. Without autoscaling, only the values 0-14 show up and everything else is displayed in color number 15 (green in the IDRISI palette). Use the cursor to check the values of several green pixels. The values are still there, but the image doesn't look nice using COLOR. (The legend is only accurate when used with COLOR A.)

Now display AFJAN88 with COLOR A and the NDVI palette. This is what we would like the time series images to look like when they display. How can we accomplish this without using COLOR A?

We can do the same thing that the "A" (autoscaling) function does in COLOR A by using the STRETCH module. STRETCH takes all the data values in the image and regroups them into 16 levels, keeping the basic relationships the same. Imagine taking the histogram of an image which has a minimum value of 0 and maximum of 175, picking up the tail on the right side, and moving it all the way down to 16. In effect we would be squashing the pixels which used to take up 175 levels into 16 levels. (The module is called STRETCH rather than "SQUASH" because we more often go the other way—picking up the tail and stretching the histogram out to 255 levels from an original 175, for example.)

Run STRETCH with AFJAN88 and call the output file JAN88ST (for stretched). Choose the linear stretch, min for the minimum, and max for the maximum (since we want to keep all of our values). Answer "no" to the question about treating the 0's as background, and stretch to 16 levels. Look at JAN88ST with COLOR. Use the cursor to check the values of a few pixels.

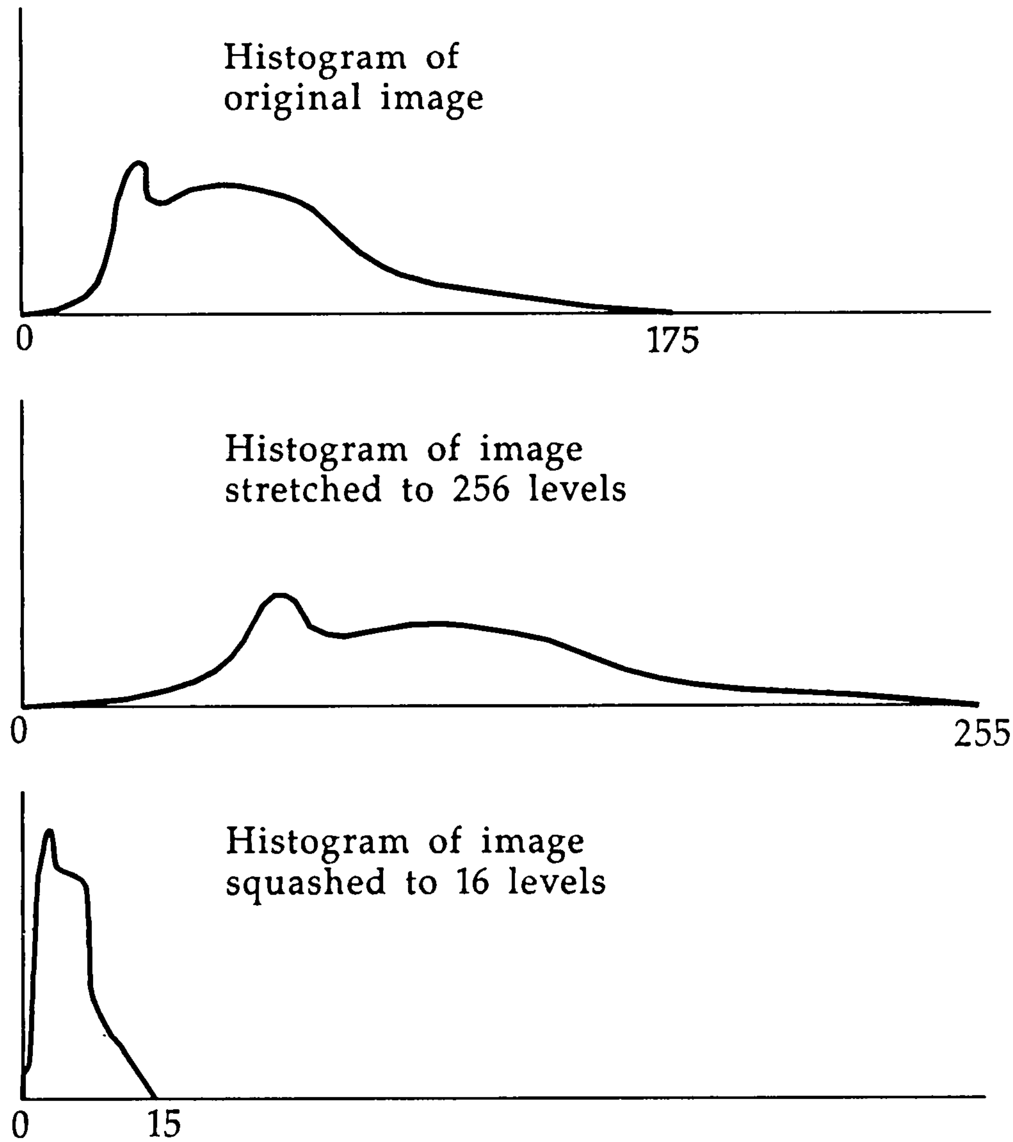

Figure 9.1. Simplified histograms illustrating the changes in distributions in data values from stretching.

9-1. What are the maximum and minimum values in the new image?

We could use STRETCH with the remaining eleven months to produce images that we could then use in the time series. Because the process is rather tedious (and the people who prepared this workbook are so nice!) we have included a set of stretched images in the data base. These images are called JAN88C, FEB88C, etc., and in addition to being stretched, have had the ocean masked out and legends added.

We'll use these twelve images to make our time sequence. Our first step is to create a time series file. A time series file simply tells COLOR how many files will be displayed, how many seconds to wait between each file, then lists the images in the order to be shown. To create this, run EDIT and select "time series file" from the list of options. Give the name NDVI88. When the edit window opens, type onto the first line the numbers "12 0" (i.e., with one space between them). This indicates that there will be 12 images in the sequence and no time delay (i.e., it should display the next image immediately after finishing the one before). On the next line type JAN88C, go down one line and type FEB88C, and continue like this until you have listed all twelve filenames, one on each line. Check at the end that you have exactly 13 lines and that there are no empty lines within this group. Then press the "ESC" key to quit and indicate that you wish to save the file.

Now type COLOR T, to tell COLOR to look for a time series file rather than an image. The time series file name is NDVI88. When it asks for a palette, indicate "ndvi". Then simply press return for all other options. The time series will then appear.

If you wish to pause the display at any time, press the "PAUSE" key on the keyboard (and then press return to have it continue). The last image will remain on the screen until you press return.

9-2. After watching the time series a couple of times, how can you best summarize the change in NDVI values for Africa over the course of 1988?

ON YOUR OWN

A Make a similar time series for another year in the data base, or for the same month from several years.

B. Make a batch file using the command line for COLOR and autoscaling to display the unstretched monthly NDVI images for 1988. Is there any advantage to using a time series rather than a batch file?

C. There is an annual average NDVI value for each pixel. We could take this average to represent the "background". Make a time series file which shows how the changes in NDVI through the year without the "background". [Big Hint: To do this, first find the mean NDVI for the whole year (add all the images (OVERLAY) then divide by 12 (SCALAR)). Subtract this mean value from each month (SCALAR). Find the minimum and maximum values in the whole series (DESCRIBE), then decide on meaningful classes that will include all the values. RECLASS each image using exactly the same classes. Create and display the time series file. Note: We don't use stretch here because each file will have a different max and min, and we want the final classes to mean the same thing on each image. For example, if class 1 for the April image is -10 through 0, class 1 for November should also be -10 through 0, even if there are no pixels in that class for some images.]

EXERCISE 10: Time Profiling

The time sequence was fun to watch, and we could get a general sense of how the NDVI values change through the year. But it would be difficult to study in detail how the values were changing over time in a particular area just by visually examining the time sequence. We can use a time series file, however, with another module, PROFILE, to get a more detailed look at the series of images for certain areas.

With time profiling we can create a profile over time of how data values change at a particular site. The site might be a single pixel, or a whole group of pixels forming a larger polygon, or perhaps even several polygons. PROFILE will allow us to monitor up to 15 sites simultaneously in this manner.

In this exercise we will use PROFILE to monitor the average NDVI over the 12 months of 1988 for 5 countries. Since PROFILE doesn't care about displaying the images, we can use the original images rather than the stretched images.

10-1. Why would we rather use the original files with values ranging from 0 to 175 than the stretched files with values ranging from 0 to 15?

Create a new time series file named PROF88 using EDIT. Again, your first line should read "12 0". The next 12 lines should read AFJAN88, AFFEB88, etc. Make sure that PROF88 has 13 lines and no blank lines in between.

Use COLOR A to display the image AFNATION. This is an image in which each country has a different value. Overlay the vector files COASTS and COUNTRY. Choose five countries that you would be interested in profiling. It will be more interesting if you choose countries from different parts of Africa rather than from the same region. Use the cursor to find the values of these five countries and write them down. Now use DESCRIBE with AFNATION and examine the legend to find out (or verify if you already know) which countries you chose.

We need to have an image in which the five selected countries have the values 1 through 5 and everything else is 0. There are two ways to do this. One is to run RECLASS, and the other is to use ASSIGN. Let's use ASSIGN. ASSIGN needs a values file which has two columns of numbers separated by a space. The left column contains the old numbers we are interested in, the right column contains the new number we are assigning to the old number. Any old number that doesn't appear in the values file will automatically be assigned the new value 0.

Use EDIT to create a values file named NEWVALS. Type in the old value of your first country, then a space, then 1. This will change the value of that country to value 1. Go to the next line and type in the old value of the second country, a space, and 2. Complete the remaining 3 lines. Fill out the following table for future reference:

COUNTRY NAME	ORIGINAL VALUE	NEW VALUE

Now run ASSIGN. Our geographic definition file is AFNATION. Name the new image PROSITES. The values file is called NEWVALS. Use COLOR to look at the PROSITES image. Use the cursor to confirm that the countries you chose have their new values.

Now run PROFILE. We are interested in a profile over time. When it asks for the name of the image defining the profile sample spots specify PROSITES. The time series file it should use is PROF88. PROFILE will then calculate the average NDVI for each country for each month and then draw out the profiles.

10-2. Study the profiles. Given that NDVI is largely a response to rains, describe the general precipitation regime of the five countries you chose over the 12 months of 1988. Include in your descriptions which were the wettest months and driest months, and if the rainfall varied widely over the year or was pretty much the same each month.

10-3. Now compare the five profiles to each other. Which countries show similar patterns? Which are the most different?

FOR FURTHER EXPLORATION

We determined rainfall regimes for Africa in an earlier exercise. This was based on rainfall data that had been gathered over many years then averaged. We don't have rainfall data for 1988, but since NDVI is an indicator of rain, let's try to check if the NDVI profile we found for each country roughly matches the rain regime category we assigned to it in Exercise 3.

We will use EXTRACT to pick out the dominant rainfall regime assigned to each country. Run EXTRACT (use EXTRACT S if you don't have a printer connected) with PROSITES as the geographic definition file and REGIMES as the file to be processed. We want to have the results in a table. We will choose average as the type of summary.

Look at the table and round the value for each country to the nearest whole number. Remember that we classed value 1 as winter, 2 as uniform and 3 as summer. What is the average rainfall regime for each country?

Do the profiles for NDVI in 1988 generally support the rainfall regime classification for your 5 countries? (Refer back to Exercise 3 if you don't recall the conditions used in the rainfall regime classification.)

ON YOUR OWN

A. Choose 5 countries which are close together and run PROFILE for them. Describe the variation you see (if any), and try to explain what might be the cause.

B. Choose several countries (up to 15) which are roughly in a line running west-east (or north south) and run PROFILE on them. Describe the general change in rainfall pattern you see when moving from west to east (or north to south).

EXERCISE 11: Temporal/Spatial Analysis with Principal Components Techniques

Both of the multiple comparison techniques we have looked at so far are descriptive in character. The technique we will look at in this exercise is more analytical. It should also be recognized that it is more experimental as well. This technique has not received much previous research, but does appear to be quite promising in the abstraction of change from a sequence of images.

Principal Components Analysis is closely related to Factor Analysis and is used extensively in remote sensing as a data compression technique. With Principal Components, a set of original image bands are used to create a new set of "components" such that these new components contain all of the original information but each is uncorrelated with all of the others. This is not the case with the original images where significant correlation often exists. The components are also ordered by how much they explain the variation in the original images. It is often the case that the first few components are in fact able to describe almost all the information in a much larger set of original bands—hence the data compression.

In our application we will use this technique for a very different purpose. First we will use a variant on the normal technique by using standardized variables (in remote sensing, unstandardized are more often used). With standardized variables we will calculate the components based upon the correlation matrix between bands rather than the usual variance/covariance matrix (thus giving equal weight to all images). Second, we will be using a set of bands that actually display exactly the same thing (or at least should be) except that they differ in time. As a result, the inter-image correlations will be extremely high.

To explore this technique, we will again use the 1988 NDVI images (AFJAN88, AFFEB88, and so on up to AFDEC88). We will then use Principal Components Analysis to see what it does with this time series.

Run PRINCOMP. When it asks, indicate that you wish to calculate covariances directly and that you wish to use standardized variables (this is very important — if you make a mistake in asking for this, use CTRL-BREAK to exit and start again). Then when it asks for the number of bands and components, specify 12 bands and 12 components. Then list the 12 raw images for 1988. When it asks for a 3-letter prefix for the components, indicate A88. The components will then be calculated and written (be patient, this will take some time) after which a series of screen displays will be produced. If you have a printer attached, use your PRINTSCREEN key to create copies of each of these displays. If you do not have a printer, copy down the amount of variance explained by each component and then the entire display listing the "loadings" on the components.

Now use COLOR A to examine the first component using the ndvi palette. The name of this first component is A88CMP1.

11-1. How much of the variance in the original bands does this component contain? Describe the nature of the "loadings" (i.e., correlations) between each of the original bands and this image (refer to the module description sheet for PRINCOMP in the IDRISI manual if you are having trouble extracting these items or information).

Note that the first component looks very much like the original images. Clearly this explains most of the variance and is highly correlated with all of the original images. This image thus contains the "typical" or "characteristic" vegetation pattern regardless of the season. It also suggests that the majority of the variation between images is that which occurs spatially (not unreasonably).

Now use COLOR A to examine the second component but use the default IDRISI palette. The second component is called A88CMP2.

11-2. How much variation does this component explain? What pattern do you see in the loadings?

11-3. Remember that each component is perfectly uncorrelated with each other. If the first component describes the "most typical" pattern, what would be perfectly uncorrelated with the typical?

The second component is thus the first change component. Since the components are ordered in terms of the variance explained, it thus explains the greatest degree of difference between the images as a group. Interestingly, the loadings indicate a winter/summer split. It would appear, then, that the greatest difference from the typical pattern shown in component 1 is that produced by summer or winter.

To confirm this interpretation, use COLOR A to examine one of the summer images. Notice how the second component has the zone of active vegetation in the northern hemisphere.

Now use COLOR A to examine one of the winter images.

11-4. Based upon what you see here, how do you feel the negative loadings should be interpreted for the second component?

Now use COLOR A to look at the third component.

11-5. What proportion of total variance does this component explain? What pattern do you see in the loadings for this component?

Component 3, then, would appear to represent spring/fall. It is suggesting, then, that the second major change in 1988 was produced by spring and fall. Given our understanding of seasons, this would appear, then, to be making sense.

The remaining components each explain some aspect of variability from one pixel to the next — however, with progressively less weight. Components are not always easy to explain. In this case we could rely upon our knowledge of the seasons and cyclic sun patterns to provide a useful interpretation. However, in most instances you will have little to guide you. Probably the best use for Standardized Principal Components Analysis is to abstract from the group as a whole the most dominant change. The loadings then suggest when this pattern was most prevalent. This is one of the few techniques we can use to "filter" out change in this manner — the first component always represents the "typical" while the second represents the most dominant change.

FOR FURTHER EXPLORATION

Now run the same procedure on the four December images for 1985-88 : AFDEC85, AFDEC86, AFDEC87, and AFDEC88. Extract out four components using the standardized variable option.

11-6. What do you feel is the largest "change" or "anomaly" that occurred in December over these four years? Where did it happen? When?

EXERCISES DEVELOPED FOR MIDDLE SCHOOL STUDENTS

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BACKGROUND:

The following exercises were developed by Bonnie J. McClain while in temporary residence at the National Geophysical Data Center in Boulder, Colorado. The lessons are designed to illustrate the applicability of research data for classroom use. The lessons represent the very beginning of possibilities that creative teachers can explore and incorporate into a curriculum. The focus is threefold. 1) There will be increased awareness of the interdependence of technology, and understanding of our Earth's systems and space exploration. 2) Students and teachers will have hands-on experience with the same data available for scientific and technical analysis. 3) By incorporating research data into topics of study, teachers and students will be exploring a very relevant approach to learning.

GRADE LEVEL: Middle level to high school

OBJECTIVES:

- To use technological, scientific, and communication skills and information in inquiry-based learning experiences
- To acquaint students with scientific data and their applications
- To involve students in cooperative learning activities
- To access sources of scientific and technological information for a specific purpose
- To think critically and reflectively in examing interactions and concepts

- To analyze natural and technological systems
- To revise conclusions when additional valid information is presented
- To explain the relationship between physical and cultural features of Earth's surface
- To apply reading skills relevant to a specific type of context and purpose
- To adapt presentations skills to particular audiences, situations, and purposes
- To develop active listening skills
- To be able to communicate scientific and technological information in a variety of formats.

TEACHER'S NOTES:

Satellite images and other data have been used to explore topography, land features, climate, resources, and related living conditions of Africa. Extension activities can allow correlation of this information to the inhabitants of this land. The population of Africa responds culturally, economically, and intellectually to their particular land, just as each of us does to our own unique land space. Delving more deeply with comparison, research, and communication, we can begin to understand what is meant by the term "global community" and develop respectful empathy and insight of our neighbors. Indeed, we are all one family, and this Earth is homeland to each and every individual.

"Exercise 12: Introduction to African Studies," beginning on page 107, is designed in a space exploration motif in order to teach students how to use a geographic information system to answer scientific questions. The fact that the study area is Africa is not emphasized. However, the exercises in this workbook may also be linked with an overall unit on African studies. Many extension activities are possible:

Literature/Reading. Study African folk tales, books by Basil Davidson and others on African culture and history, literary selections and poems found in literature texts, Alex Haley's *Roots*. Compile a bibliography of well-known African-based stories and/or authors. Play some African music; discuss its features and influence on American music.

Science. Study and model African biomass. Trace interrelations of soil to vegetation to ecosystems; relate this information to the effects of animal and plant life in Africa. Complete an analysis of population, land use, and African endangered species.

History. Compare African features to those of students' State. Understand the interdependence of agricultural, economic, and political developments. Produce a visual history profile of the continent.

Social Studies. In the exercise, students will choose spacecraft landing sites based on much information. It is assumed they would consider those sites to be the better places to survive. It may be interesting to compare their sites with the actual population distribution via an image of urban coverage. Discussing reasons for a match or mismatch could prove worthwhile. (The image name is **AFURBAN**. Adding a coastline, as shown on #3 of page 118, is helpful. Use color code **6** for the overlay of coasts. There are a total of five images in the display file. Notice there are very few major cities, but their population figures are quite high. What are the implications of that fact?)

Political Science. Study famous or infamous leaders and the impact that their leadership had or is having on the specific country, continent, or world.

Economics. Have a symposium on the term "Third World Countries." Discuss the implications of the term to those countries as well as to the world in general. Discuss different points of view towards technology, and global concerns such as the greenhouse effect and ozone depeletion. Invite speakers from these countries to share experiences and information about their homeland with students.

Geography. Use the image named **AFNATION** to identify African countries. This display has a total of five images, each identifying a section of Africa. The legend provides the names which were correct at that date. This exercise provides an alternate method of transferring country identification to a paper map. Students may then choose sections of Africa for discovery. The students will become information specialists on that section's flags, governments, history, population facts, cultural customs, monetary systems, economic dependencies, greatest problems, possible solutions, etc.

General. A celebration at the end of an African Studies Unit could include: 1) a student-organized cultural fair open to the school and/or public, 2) a creative skit demonstrating learnings based on whatever topic or topics the skit groups had chosen, and/or, 3) a wall (or paper wall) mural displayed in the school's media center depicting learned concepts.

EXERCISE 12: Introduction to African Studies

TEACHER'S NOTES:

Major Concepts: Using an inquiry-based approach, students will interpret relationships between atmospheric conditions, temperature, topographic features, and vegetation locations to the population's culture and living conditions. Using technical skills, students will analyze and interpret images. Using cooperative learning groups, students will practice group discussion and decision-making skills.

Key Words: Legend, analysis, vegetation, satellite images, topography, elevation, bathymetry, culture, atmosphere, accessing images, sites, scientific data

Materials Needed: IBM-PC compatible computer(s), pocket folders or other organizing materials, paper, pencils or pens. *Optional:* transparencies, grease pens, paper maps outlining Africa, colored pencils, a printer for capturing images from the screen, poster paper for charts, rewards such as stickers or other surprises.

This lesson is designed for cooperative learning groups working as spacecraft crews. The following roles and responsibilities are offered as an organizational suggestion. Role responsibilities can easily be combined into the ideal number of four crew members, but for larger classes you may prefer the cooperative groupings of six:

Commander
Discussion leader, decision maker, directly responsible for group interaction updates to Mission Control (the teacher)

Pilot
Navigator (computer controller), second in command

Mission Specialist #1
Paper map coder/colorer

Mission Specialist #2
Records all decisions, summarizes daily activities for commander and Mission Control

Payload Specialist #1
Inventories all supplies on a daily basis

Payload Specialist #2
Anticipates, requisitions, and obtains all needed supplies (creativity encouraged)

Once students are organized in their cooperative groupings, they may wish to develope scenarios about Mission Control and their own spacecraft crew. This could involve creating code names, crew identifiers like logos, spacecraft design, and histories of aliens and planets already encountered. Activities such as these could be used as extensions of art units or writing units relating to this specific computer/science module.

Provide the Commander with a folder or mission packet, which includs the pages: "Your Mission," "Duty Roster," "Report to Mission Control—Crew Observations, Comments, Decisions," and "A First Look at the Planet."

Discuss the first page—"Your Mission." Answer any questions which may come up.

Have students complete the "Duty Roster." Then direct them to the page(s) labelled "Report to Mission Control—Crew Observations, Comments, Decisions." Explain that these forms may be used to record answers, and for crew observations, comments, and decisions.

"A First Look at the Planet" is the first activity that the crews do on their own. This is an overview of the surface and will allow crews to get used to a few of the nuances of the IDRISI geographic information system. Students are asked to record their first impressions of the planet. After this, the crews are told to report back to Mission Control for the next part of the lesson.

Distribute the page titled, "Determining a Landing Site." The purpose of this small group discussion is to logically come to conclusions about important factors in choosing a landing site. The five computer images which will be created later by the crews include information on these factors:

1. The temperature

2. The atmosphere (precipitation will be studied)

3. Land/surface features (rocky, spongy, plains, lakes, rivers, etc. Water availability and topography will be studied.)

4. Areas of life or vegetation

Students may have thought of more than these. That is fine as long as they have included these four. It is suggested that they also list reasons why they feel the information they have identified would be useful. If they have not focused on the four listed areas, direct them to continue their discussion and report to you again.

Once they have achieved success, provide the Commander with the rest of the exercises. (Optional: Include a survival packet of star stickers, Starburst or Starlight mint candies, or other rewards.)

The crews will now begin "Analyzing Planetary Images." Notice that directions ask each cooperative group to access five images, but the order in which the images are accessed and analyzed does not change the end result. Therefore, groups may be working with differing information at their own rate of discovery.

As Mission Control, you may wish to announce a time limitation for the project as a whole, or divide the procedure into smaller segments with mandatory reporting of progress. Mission Control's basic responsibility is to function as a resource person and encourager during this part of the lesson.

Exercise pages may be freely reproduced or embellished. Have fun!

Blank page retained for pagination

Your Mission

You have become interplanetary travelers and explorers. In fact, your government has recently assigned you to crews whose mission it is to explore a newly discovered planet. Your crew consists of ___ members, each having a very specific and important job to assure the success of this mission.

Driven by plasma power, your spacecraft has been traveling at the speed of light for 14 days. According to your scientific documentation you should be nearing the new planet. Once the land area is visible on your navigation screen, you, as a crew, must determine three alternate landing sites. The commander will then prioritize the sites into #1, #2, and #3.

Good luck and "May the force be with you!"

Duty Roster

Today's Star Date: ____________________

Crew Names	Scientific Title
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________

Team Name: ______________________________

Report to Mission Control

Crew Observations—Comments—Decisions

A First Look at the Planet

Type **IDRISI** and press **RETURN** or **ENTER**.

SCREEN ONE

You are now looking at the **MAIN MENU**.

Using the arrow keys, move the highlighting bar to **DISPLAY MODULES**, and press **RETURN** or **ENTER**.

Again, using the arrow keys, move the highlighting bar to **COLOR** and press **RETURN**.

SCREEN TWO

Enter the name of the file to be displayed: Type **AFSURF**

Enter the palette desired: Type **1**

SCREEN THREE

Image selected: **AFSURF**

Do you wish a legend: Select **1**

Do you wish to set display factors by hand (default = "n" which means no): press **RETURN** and it will set automatically. The image now on your screen will remain there until you press **RETURN**.

** If your navigator indicates an emergency exists and you need to begin procedures again, press **ESCAPE** or press the **CTRL and BREAK** key at the same time. If you do not return to the **MAIN MENU** type **IDRISI** and you will return to SCREEN ONE.

Congratulations!

You are viewing the very first image we have had of land on this planet. What are your impressions?

For historical record keeping purposes, some of your remarks should be written down by your mission specialist. Include the remark, the date, and who uttered the words. These will be used in textbooks for centuries to come!

When you have completed this part, report to Mission Control, who will give you further instructions.

Determining a Landing Site

What do you need to know about the planet before you land your spacecraft there?

Remembering your long, hard training at Space Academy, discuss and agree on the types of information needed to help you determine landing sites. Mission Control has assured you of the following:

1. An exporatory probe has indicated that the land surface will support the weight of your spacecraft.
2. Your spacecraft will serve as your shelter on the planet.
3. You have enough food to supply your needs for 30 days.
4. Your exploration suits will protect you from the planetary environment.

Once you have reached agreement, record your conclusions. Report to Mission Control and request further instructions.

Analyzing Planetary Images

Images of this new land are available for annual temperature, average monthly rainfall, elevation (this will reveal land features), river locations, water sources, and vegetation.

To display an image, you will use the same sequence of steps given to display AFSURF. Some of the images will have further instructions to direct you in discovering additional ways of using these images.

It makes no difference which of the images you display first. The order is the choice of your crew.

Keep in mind that your goal is to come up with three possible landing sites. Discuss what supplies you may need and collect those from Mission Control. For example, you may wish to have paper maps or transparencies on which to duplicate specific details from the navigator's screen. Decide the best procedure to use for each image.

Part of the success of this mission will depend upon your crew's observation skills. Remember to record vital information for each image in a manner that will allow you to review all information later and come to logical conclusions.

As you complete the instructions for each image, your Commander and Mission Control both need to initial and date the form on the **ANALYSIS COMPLETED** line.

IMAGE AFVEGX (Vegetation)

1. Display **AFVEGX**

2. This display is comprised of 2 images. Notice that the last legend category reads **Press PgDn**. Try pressing the **PAGE DOWN** key. Your second image will appear.

3. Adding a coastal outline may make the image more meaningful. To add this, press **v** without pressing **return**. A message will appear in the bottom left-hand corner of the screen asking for the name of a file to display. Type the word **COASTS**. A second question will ask for a color code. Type the number **3**.

4. As you can see by looking at the legend, abbreviations and colors indicate specific types of vegetation growing on this strange land. Analysis will help you decide which types would not interfere with landing and which would be prohibitive.

5. List three types of vegetation for each category below. Be sure to list reasoning for the decision of placement.

NO PROBLEM	REASONS
1. ______________________	______________________
2. ______________________	______________________
3. ______________________	______________________

HAZARDOUS LANDING HERE!	REASONS
1. ______________________	______________________
2. ______________________	______________________
3. ______________________	______________________

You may or may not be familiar with all of the listed vegetation types. Record two vegetations for which you checked definitions. Please include the definitions.

VEGETATION TYPE:

Definition:

VEGETATION TYPE:

Definition:

ANALYSIS COMPLETED

Commander ______________________________

Mission Control ______________________________

Date ____________

IMAGE - AFTMPANN (TEMPERATURE)

1. Display **AFTMPANN**.

2. Adding a coastal outline will make this image more meaningful. To do this, press **v** without pressing **RETURN**. A message will appear in the bottom left-hand corner of the screen asking for the name of a file to display. Type in the word **COASTS**. A second question will ask you for a color code. Type in the number **1**.

3. If you wish to find the temperature for an exact landing possibility, and you have a mouse, follow these steps.

4. Press the letter **c** without pressing **RETURN**. A cursor will appear on the screen. Using the mouse, move the cursor to any location you wish. Press the **LEFT** mouse button. The temperature for that point will be displayed in the lower left-hand corner of the screen. The cursor is locked at this point until your press the **LEFT** mouse button again. To exit the cursor mode or remove it from the screen, press the **RIGHT** mouse button.

5. Discuss and decide upon some landing sites based on temperature. Record the sites and the temperatures.

ANALYSIS COMPLETED

Commander ______________________________

Mission Control ______________________________

Date ____________

IMAGE - AFRAINX (PRECIPITATION)

1. Display **AFRAINX.**

2. Information given is the average monthly rainfall measured in millimeters.

3. Look carefully at the legend. Notice that the darkest green color is labeled **PgDn**. That means that this specific image does not show you rainfall for the darkest green area. This display is comprised of a total of 3 images. The other images will give you the correct coloring for the darkest green area.

4. To access images 2 and 3, simply press the key labeled **Page Down. PgDn** indicates there are more images to follow in the total display. You may also access the images in reverse, i.e. 3 then 2 then 1 by pressing the key **Page Up.** Try it!

5. As you access each image you will notice the old information will be blackened out. Only the new will be easy to analyze. You may wish to view these images several time to understand all of the information.

6. What is the least amount of rainfall measurement?

7. What is the highest measurement of monthly rainfall?

8. Convert answer #7 to inches. (Use the space below to figure this out.)

9. Locate areas having about 825 mm monthly rainfall. This is approximately the amount of rainfall for an **entire year** for mid-western states! Estimate what portion of this land has as much or more rainfall than a mid-western state.

10. In addition to choosing landing sites, record 3 or 4 conclusions about this land based on information from these images.

    A.

    B.

    C.

    D.

ANALYSIS COMPLETED

Commander ______________________________

Mission Control ______________________________

Date _______________

IMAGE - AFWATER & AFRIVERS (WATER AVAILABILITY)

1. Your crew may wish to discuss the importance of water sources to your selection site. What reasons, relating to water, would make it a poor site? Why might you want to land beside water? How much or what kind of water sources would be best?

2. There are two types of information available for your analysis. One display is **AFWATER**; a second is **AFRIVERS**. The first display will show you water coverage in terms of percentage. The second display will show you locations of rivers.

3. Display **AFWATER.**

4. Notice the legend gives water coverage in terms of percentage. The last listing in the legend is **PgDn**. This tells you that if you press the key **PAGE DOWN** you will access a second **AFWATER** image. There are a total of 8 images in this display. **PAGE DOWN** indicates there are more images to follow. You may also access the images in reverse order by pressing the key **PAGE UP**.

5. It is important to notice that with each new image in the display, the information shown on the previous image is blackened out. You may view only the new information.

6. Determine which areas would not be advisable for landing sites and which areas could be considered.

7. Display **AFRIVERS**.

8. Adding a coastline to this image will make it more meaningful. To do this, press **v** without pressing **RETURN**. A message will appear in the bottom left-hand corner of the screen asking for the name of a file to display. Type in the word **COASTS**. A second question will ask you for a color code. Type in the number **13**.

9. Record your crew's decision regarding the importance of water to a landing site.

10. Review your answer to #6. If you wish to make any changes, do so now.

ANALYSIS COMPLETED

Commander ______________________

Mission Control ______________________

Date ____________

IMAGE - AFMODE & AFELBA (ELEVATION & BATHYMETRY)

1. This image presents a true challenge for analysis and methods of accessing information. Follow directions carefully and if something doesn't seem to work, just give it a second try! When your crew is ready for this data sheet to be initialed you have achieved a true accomplishment. You might try hinting to Mission Control that your energy reserves are depleted and in need of immediate replenishment!

2. Display **AFMODE.** Elevation is shown. The legend gives you measurement of the height of land above sea level.

3. By viewing this information you probably know areas where you would not want to land. Why not? Are high elevations always rocky surfaces? What additional information would help you in understanding the land surface?

4. When we look at a paper map or one with a flat perspective, we are limited to that view of the data. Computer capabilities and special programs, in this case geographic information systems (GIS), allow us to view data in new formats. Applying a new method to elevation may give a better understanding of land features. Let's explore that possibility.

5. Type **IDRISI** to return to the **MAIN MENU.**

6. Choose **DISPLAY MODULES** in the left-hand column and **ORTHO** in the right-hand column of **SCREEN ONE.**

7. You will be asked questions on several screen displays. Type in these answers.

   Image to be displayed: **AFELBA**
   Do you wish to drape an image: **NO**
   Do you wish to make changes: **NO**
   Viewing direction: **0**
   Viewing angle: **50**
   Vertical exaggeration factor: **1**

   Although it takes longer than normal for this process to complete, most find it intersting to watch the image appearing on the screen.

8. Does it take some time to adjust to this new perspective? Do you see the outline of this new land? Is the view useful for your purposes? Explain why you feel this method of looking at land features **is** or **is not** helpful in interpreting image data.

9. Using these topographic information images, mark possible landing sites on a paper map or transparency. Be able and ready to explain your reasons.

ANALYSIS COMPLETED

Commander ______________________

Mission Control ______________________

Date ______________

Analysis Summary and Conclusions

Your crew has gathered all required analytical data. Review and discuss all information. Reach a crew agreement on three possible landing sites for your spacecraft. Prepare a map highlighting these sites. Provide written reasons for each. The Commander's responsibility is to prioritize the sites based on the crew's logic and reasoning.

Check with Misison Control on the date, location, and time of an all-crew meeting. Be organized and ready to present and defend your crew's top selection site.

SUMMARY, CONCLUSIONS, REMARKS:

At this point, you should be able to design your own exercises. In fact, let's try this! Your next assignment is to design your own exercise. Is there anything that you would like to explore? Does your teacher have suggestions? Write your own exercise, and help your teacher by carrying out this exercise (that you will write), to explain to your teacher something that interests you about the environment.

APPENDICES

APPENDIX A
Some Background on the Development of These Materials

A Brief History of This Compilation

By using this manual, you are building upon an international cooperative effort in data compilation and distribution, to use an experimental scientific data base for educational development. You are pioneering a new method of exploring the environment.

This effort is the result of the merging of several different but compatible interests of many organizations and people.

Let's picture ourselves in Stockholm, Sweden, in October 1988. The International Geosphere-Biosphere Programme (IGBP) of the International Council of Scientific Unions (ICSU) is having a meeting of its Scientific Advisory Council. The IGBP is an effort at getting scientists and the public to view the Earth as a complete system, with interdependence across traditional scientific disciplines. It is an effort to get us to think more broadly about the Earth, and about the ramifications of our actions. ICSU is a "league" of national scientific bodies, such as the USA's National Academy of Sciences.

At this meeting, a plan was developed that included the creation of a pilot project to assemble global environmental data and analytical tools, to make them available to the broadest possible audience via the most widely used medium—the floppy diskette read by IBM-compatible computers (and, through extensions, by other computers such as the Apple Macintosh).

Refinements to this plan emphasized digital "Global Vegetation Indices" computed from satellite data and associated data. It was decided to limit the coverage of the initial pilot data set to a single continent, to reduce the data base to a reasonable number of diskettes. It was decided that monthly average values of Global Vegetation Index should be provided for a few years. The monthly averages were adequate to illustrate the general points of change over the period of data availability. Seasonal and inter-annual study could be attempted with such data.

Representatives of the United Nations Environment Programme's (UNEP's) Global Resource Information Database (GRID) and the United Nations Institute for Training and Research (UNITAR) expressed interest in using the pilot data base in a training program in Africa to introduce GIS technology to developing countries.

The recommendations of the IGBP plan were compatible with efforts already underway at the World Data Center-A for Solid Earth Geophysics, operated by the National Geophysical Data Center of the U.S.A.'s National Oceanic and Atmospheric Administration. This Center, in

Boulder, Colorado, had been working for several years to design and construct a global scientific data base. NOAA/NGDC, through its World Data Center affiliation, agreed to lead the development of the Global Change Database Project in cooperation with the IGBP and the ICSU Panel on World Data Centers.

NOAA produces a Global Vegetation Index from data collected by its satellites (see elsewhere in this manual). NGDC recompiled weekly GVI data to monthly averages, to reduce the data volume. It took these data, plus a wide variety of other data sets produced by laboratories around the U.S.A. and other countries, and studied them. Most of these data sets, though pioneering attempts to understand specific aspects of the global environment, had not been designed for integration with other data sets for multidisciplinary digital study. Different projections, misregistration, internal inconsistencies, and other problems cropped up in some of the data. The staff at NGDC were able to correct some of these problems. Others remain in the data for members of the public to find and correct.

The resultant Global Change Database Project (GCDP) Diskette Pilot Project for Africa included monthly vegetation index data for 1985-1988, along with related thematic data sets (topography and geographical information, soil classifications, land cover and ecosystem classifications, average monthly climate data, and others.

The GCDP is not only an effort to provide researchers with needed information, it is an experiment in large-scale data management aimed at:

1. improving the quality, integration, documentation, and applicability of global and regional data sets,

2. involving the scientist-user in the data management process through peer review;

3. improving the delivery of information to users; and,

4. stimulating innovative research and development in data base design and geographic information system (GIS) functionality.

The creators of this project believed that such experimental developments, leading to improved quality control, information exchange, and cooperation among users, are necessary to cope with the large data streams and information demands expected in the next century. The projects were considered necessary to have for global change studies, but daunting to manage without a well developed service and user infrastructure. These developments were part of an overall program at NOAA/NGDC and the World Data Center-A for Solid Earth Geophysics to create an environment for publication and distribution of digital data similar to that for hardcopy scientific publications.

In the course of developing the data base, NGDC/WDC-A selected software for the project that was readily available on a non-profit basis from the Graduate School of Geography of Clark University. This software was the GIS known as IDRISI, and an agreement was made with its developer for continuing support to the GCDP with specific software modifications and enhancements, training materials, and other forms of participation. A year later, the National Center for Geographic Information and Analysis (NCGIA) at the University of California in Santa Barbara, also joined the project to assist with training materials and evaluation. The data diskettes, GIS package, and training materials are being distributed to African scientists through a series of 2-day seminars conducted jointly with UNEP/GRID and UNITAR GIS training workshops. The first workshop was held in the fall of 1989 in Accra, Ghana. During the summer of 1990 approximately 32 Beta Test and Research Development Facilities were established worldwide to provide peer review and lead applications and the development of training exercises.

NOAA/NGDC Staff have continued development of these materials, in cooperation with the people and organizations credited in several parts of this manual (and in the documentation manual for the data). These materials are the result of this significant combination of people and events.

Associated International Activity

UNEP/UNITAR TRAINING PROGRAM IN GEOGRAPHIC INFORMATION SYSTEMS

It is imperative that scientists from developing countries be involved in all forms of research relevant to both the causes and effects of global change. Without special efforts in this direction by the scientific community, multi- and bilateral organizations, research institutions and developing country governments themselves, these scientists will be left behind in the process of understanding global change issues. In addition, without global input to such study, the groups that have the resources to conduct such study will have biased data, unnecessarily lacking at least some credibility in their design and content.

In order to make such involvement possible, training and research programs for scientists from developing countries should be part of a long-term commitment that would include institutional build-up and support, transfer of capabilities, support for project and applications-oriented activities, and finally, support in establishing a formal and informal network of scientific and scholarly exchange. The workshop and training program is based on experiences gained during several years of UNEP/UNITAR training in GIS and Imaging Processing Systems technology for the management of natural resources and the environment for scientists from developing countries.

The UNEP/UNITAR training programs were initially designed to last three to six months: three months for high-level scientists and civil-servants, six months for mid-level scientists. Very soon it became obvious that there were not many scientists in developing countries who were already familiar with the technology and its possible applications, and the shorter course was postponed indefinitely. The core of the programs evolved around the fundamentals of environmental monitoring and hands-on training in GIS, with considerable emphasis on image processing. From the very start, the program was designed to be problem-oriented and indeed a total of almost three months, out of the six-month-long program, was devoted to project work with a GRID analyst. It was this very involvement in project work that incited the organizers to perpetually evaluate the real impacts of the training programs in a problem-oriented context. The combination of two very different UN agencies—UNEP with its catalytic mandate and UNITAR with its research-oriented approach—was a fruitful combination for the training program in general. From 1986 through 1990, 47 scientists from 28 developing countries have been trained. The UNEP/UNITAR training program has four principal aims:

1. to train scientists and planners from developing countries to operate and benefit from GIS technology;

2. to guide trainees through their first GIS research projects;

3. to encourage and assist trainees to set up GIS in their own countries which can benefit from GRID technology and data base support;

4. to enable trainees to train others in GIS technology when they return to their own countries.

The first training programs were conducted in Switzerland and around GRID's European node. In 1989, a first pilot regional program was organized in Nairobi around the African node. Since then, the decentralization of the training program has continued following the development of the regional GRID nodes. In 1990, there was one training program around the GRID Asian node, in Bangkok (May 1990); two training programs around the GRID African node in Nairobi (June and September 1990); and one is planned for Latin America. After this the regional expansion of the training program should stop for a few years as the GRID regional nodes consolidate themselves, with the exception of a possible program for West Asia.

The Swiss program will remain the main training program and become increasingly geared toward high-level training and project work. The proximity of Switzerland to the UNITAR cooperating centers of excellence, such as Swiss and other European universities, will allow a gradual return to UNITAR's initial plans, which were to direct the Swiss-based part of the program to high level scientists and managers of natural resources, to thematic training, and to short-term refresher training and/or research sessions for former trainees.

In Africa, the lack of existing infrastructure and institutional support have prompted reflection on the content and aims of the program. Last year, a breakthrough allowed UNITAR to conceive of programs that were more "holistic" in approach. IBM donated fifteen IBM PS/2 Model 80's and peripheral equipment to the GRID project for distribution in Africa. Around these systems, UNEP and UNITAR then planned a program that would include identifying host agencies in African countries, training, technology transfer, in-country project work and follow-up after training. The whole program covers almost a year, at the end of which a national seminar is held to launch the projects and assist the national agency to actively seek support of other possible donors. Yearly regional or subregional workshops present GIS technology and application to policy-makers and scientists. In 1989, UNEP and UNITAR organized a workshop in Accra for English-speaking West Africa, in cooperation with Ghana's Environmental Protection Council. In 1990, a similar workshop was held in Senegal for CILSS member-countries in cooperation with the United Nations Sudano Sahelian Office (UNSO) and the Centre de Suivi Ecologique (CSE) in Dakar.

Each year the UNEP/UNITAR program has gone through many changes, both in content and in form. At a very early stage it became obvious to UNEP and UNITAR that the program could not dissociate itself from the trainees at the end of the courses. A long-term association should be the very essence of training programs which are designed for professionals. It became evident that after a scientist from a given developing country had received training in the use of GIS technology, our job was just starting. Would he/she return to the same job, and if yes, were the necessary systems available? What about the data? Was there support from their managers for them to continue? If funds were available to purchase the required hardware and software, who would assist them to set up a rational configuration, or to find their way about in the labyrinth of available systems? What if the external funding was from a source that insisted on the acquisition of systems not at all compatible with what the training had been done on? What about peer-exchange? How to avoid intellectual isolation for a former trainee? What are the indicators of success for a programs, and after how long? Would the number of courses organized be a real indication of success? And how could we continue supplying the tools for those scientists capable and willing to continue research and application projects?

When many young scientists in developed countries have a hard time acquiring sufficient grants in order to afford satellite imagery for example, the significance of the costs of a Landsat TM or SPOT scene to the budget of a developing country institution could be overwhelming. Unless training programs insert the on-going costs of the transfer of technology into their budgets, or unless there are international funds set up to assist in this domain, there seems to be no way that scientists from developing countries can be at a level with their colleagues from developed nations. The necessity of access to at least the minimum tools was very clear.

UNITAR TRAINING AND THE IGBP GLOBAL CHANGE DATABASE PROJECT

In joining forces with the Global Change Database Project, the UNEP/UNITAR training program has become an integral part of a more global need. To summarize this larger context:

1. There now exist substantial programs for the capture of timely data of demonstrated relevance to global change studies (e.g., NDVI derived from AVHRR, the future Earth Observing System, etc.). However, access to those data remains in the hands of a small proportion of the scientific community—largely because of the absence of a broad program of data dissemination using widely accessible formats.

2. Inexpensive microcomputer technology now possesses the processing, storage, and graphics power to handle global and regional environmental data sets. In addition, the installed user base of such systems reaches all sectors of the scientific community.

3. Microcomputer-based image analysis and GIS software has now developed to the point where very sophisticated analytical procedures can be brought to bear on environmental data. However, GIS are poorly developed in procedures for the analysis of dynamic change, spatial statistics, and links with theoretical/mathematical models of environmental and ecosystem processes.

4. It is becoming clear that a much broader group of scientists needs to become involved in the analysis and monitoring of environmental change phenomena—particularly in the developing world, where the impact of many of these changes is so profound. And yet there are currently no coordinated, long-term programs for an introduction of digital analysis in ecosystem studies for students, environmental managers and scientists from developing countries.

The objectives of the program can be stated as:

1. to develop a program of data dissemination using standardized digital products on inexpensive media that are compatible with available computer-based analysis systems;

2. to develop an inexpensive analytical software system by enhancing the capabilities of a widely-used and non-profit GIS and image processing system to meet the needs of ecosystem modeling; and,

3. to foster a program for training and education in the use of digital data for the examination of global change phenomena by developing training data sets, exercises and workshops with particular attention to the needs and means of scientists from developing countries.

The combined interests of these organizations has influenced the development of this workbook and associated materials.

APPENDIX B
Using the Data and Exercises with Your GIS

Support of Education

If you read Appendix A, you will know that this workbook, and the associated data base, is the culmination of efforts by a large number of organizations around the world.

A common bond to these efforts is our interest in education and improved research capabilities in global environmental (including global change) studies using spatial data bases and geographic information systems.

Developed Primarily in IDRISI . . .

The data base has been developed using three GISs: IDRISI (from Clark University), GRASS (from the U. S. Army Corps of Engineers), and ARC/INFO (from the Environmental Sciences Research Institute). IDRISI was the dominant development environment. The exercises are developed entirely around IDRISI. This is because of the low cost, substantial functionality, and educational/research emphasis of IDRISI, and because of support from the developers of IDRISI for this work.

. . . But Designed to Support Other Systems

This frequent mention of IDRISI should not prevent you from using the data with another GIS. The relatively generic data structures enable you to convert the data to many other GISs. We have worked with several developers of other GISs to confirm this convertibility.

We invite developers of any GIS to contact us for suggestions on implementing ingest procedures for this data base, and for other compatible global change data being integrated and distributed by NGDC. We will also maintain a list of GISs (and conversion procedures for those GISs) that warrant capability of ingesting these data and performing most of the scientific analyses in this exercise manual, that inform us that they want to be so listed, and that provide us with written conversion procedures.

If you are new to Geographic Information Systems

IDRISI was developed largely to educate people about GIS. Fully half of the IDRISI manual is a self-contained tutorial about GIS. If you are unfamiliar with GIS, IDRISI or one of the other educational GISs (such as OSU Map-for-the-PC from Ohio State University) may help you to pick up skills in the general aspects of GIS. Such skills are useful precursors to learning how to use GIS to study the global environment. Geography (or other) departments in many colleges also teach GIS, should you be interested in formal instruction.

If You Are an Advanced User of GIS

If your interests in GIS are more high-powered, you may want to work with an open development environment. Although less frequently advertised, public domain GISs offer access to source code, programming guides, and a large base of users that happily share ideas about development and application of completely accountable and shareable GIS environments. The Map Overlay and Statistical System (MOSS) is perhaps the most heavily used public-domain GIS, whereas the Geographical Resources Analysis Support System (GRASS) is a more recent development, designed to overcome a deficiency in scientific GISs conceived and developed primarily for environmental analysis. The users groups for GRASS and MOSS usually provide short courses, demonstrations, professional papers and interactions that will accelerate your development of expertise in these systems. IDRISI is not a completely open system. You do not have access to source code. However, its modularity is designed to make enhancement relatively easy.

Not All GISs Have Sufficient Capabilities in Scientific Analysis

Some GISs were developed upon the technology of computer-based cartography. A main current use of such GISs is planning. Many such GISs are currently incompatible with the scientific analysis demonstrated by these exercises. Such GISs are not inherently incompatible with many of these functions. Indeed, many of the most fundamental functions, such as reclassification and area calculations, can usually be performed in such systems. But the scientific market has yet to exert sufficient influence on some planning-oriented GISs. If you use such a GIS, you may want to acquire an inexpensive alternative, such as IDRISI, GRASS, or OSU-Map-for-the-PC (although the latter will take some creativity to import these data).

Using Another GIS

You will need to do two, perhaps three things to use these materials in another GIS:

1. Convert the data to your GIS,

2. Find the functional equivalents in your GIS for each IDRISI function used in the exercises. Also learn to translate the optional features used in the exercises for your GIS,

3. In some cases, your GIS may not have exact functional equivalents to those used in the exercises. If your GIS is sufficiently substantial, and you are an experienced user, you may be able to find a workaround. If not, perhaps you can still adapt the exercise to suit your interests, and the capabilities of your GIS.

The remainder of this Appendix should help you to make these translations to your GIS.

Converting These Data to Another GIS

Appendix E of this manual gives the structures of IDRISI data. To summarize, the structures used here are extremely simple, and are based partly on de-facto standards of data exchange. **The following guidelines may be confusing to non-users of a particular GIS. They are designed to be representative, and to be easy-to-follow, for users of the particular GISs.**

RASTER FILES

The raster data provided consist of a grid file (with .img DOS extension) and a separate header file (with DOS extension .doc). IDRISI raster data files can be in ASCII, unpacked binary, or packed binary. However, for this data base, only unpacked binary files are provided. These are just about the simplest raster data structure possible. 8-bit raster grid files are merely a string of byte pixel values. The first byte is for the top left-hand corner of the gridfile. The second byte is for the next pixel to the right. Successive bytes correspond to successive pixels to the right until the top line of pixels is completed. The next byte is for the left end of the second-from-top scan line. The last byte is for the bottom scan line, last pixel to the right. The data base used here has 438 lines (rows) by 480 samples (columns); an 8-bit data file has exactly 438 x 480 = 201,480 bytes.

Most data in the data base are such files. The files for elevation are 16-bit files, which require two bytes for each pixel. The elevations thus have exactly 402,960 bytes.

Most substantial GISs can import such grid files. If you use such a GIS, you should be familiar with these procedures. If your GIS lacks such a procedure, contact the developer. Lack of such an ingest procedure for a generic binary raster grid would be a deficiency in a GIS.

Example 1. Importing into GRASS. An 8-bit GRASS grid file is identical to the .img files provided here. Merely remove the .img extension, move the files to the CELL file subdirectory for your new GRASS AFRICA data base, and run the GRASS command that completes the ingest of a data layer (in GRASS 4.0 this is r.support). Edit the cell header by providing 480 and 438 for columns and rows. You will want to set consistent figures for grid spacings in X and Y (these can be units of your convenience—however, you will probably prefer to use "1.0" if you want to work in dimensions of pixels, or 0.16666666667 if working in degrees of latitude and longitude. Run r.compress (compress in GRASS 3.X) to compress the files. In most cases, this will make a more compact file in GRASS. If r.compress tells you that the compressed file is actually larger than the uncompressed file, run r.compress again with the decompress option (decompress in GRASS 3.X) to reverse the process.

The 16-bit files are imported with virtually the identical procedure. However, you may have to swap byte order (using the dd command in your UNIX workstation). Then run r.support to create the header (remembering that these are 2-byte rather than 1-byte data). Finally, checking with g.region (in GRASS 4.0, or with window in GRASS 3.X) to ensure that you are working on the entire file in full resolution, you run r.mapcalc (in GRASS4.0, Gmapcalc in Grass3.X) with the following syntax:

r.mapcalc afelba = if(temp-32768,temp-65536,temp,temp)

You will now have converted a 16-bit integer file (**afelba.img** in the data base, but you have copied it as **temp**) into GRASS's multibyte format. In this example, the new file has been called **afelba**. Of course, you can name the output file anything that you would like, not necessarily "**afelba.**" However, we encourage you to keep original file names (less the .img), so save confusion in reading this exercise manual. You should check this output to confirm that **afelba** has a range of -5953 to +3524. If so, you can remove **temp** from your data base.

This procedure may not work for some UNIX workstations. Refer to the "Reminder" box on page 142 if you have trouble.

Example 2. Importing into ERDAS. Copy the .img files into the subdirectory for your new ERDAS data base. Rename all the .img files to .gis. Run FIXHEAD to add a header, and run BSTATS to add the statistical information that will complete your ingest of a file into ERDAS.

Example 3. Importing into Arc/INFO. A beta test site for this data base noted that it could not get simple binary grid files into ARC/INFO. ARC/INFO's vector environment has only a nominal capability to handle some gridded data. However, the new ARC/INFO GRID module promises to have much more substantial raster capabilities and the ability to import GRASS files. If the import procedure for GRASS files is sufficiently flexible, ARC/INFO

GRID should be able to import the data for these exercises. If you are not successful, work with ESRI to develop capabilities of ingesting simple binary gridded data into ARC/INFO GRID.

Example 4. Importing into SPANS. Run the normal procedures for adding header information, and converting a straight raster grid into SPANS' quadtree format.

Example 5. Importing into an unspecified GIS of your choice. Copy the data, without the .img extension, into the subdirectory that you will work in. Using the information on the corresponding .doc file, run the support program that creates the header (file or record) and whatever else is necessary, following the instructions provided by your GIS. If you cannot figure out how to do this, contact the developer of your GIS.

VECTOR FILES

The vector data provided here are in .vec files, with .dvc header files. The .vec files are in ASCII, and are akin to the files produced by digitizers. As such, they should be easily modifiable in a word processor, or in a data base management system. Converting the data in this way, you should be able to match an ASCII vector file or digitizer file format, if your GIS handles vector or digitized data. We have converted these files to GRASS, and to OSU MAP-for-the-PC format using a full-fledged word processor, such as Word Star. GRASS takes ASCII data in a well-documented format and converts them to binary vector files. These files can be rasterized, or used in GRASS in their vector format. OSU MAP-for-the-PC takes ASCII digitizer files and rasterizes them.

A word of caution: Idrisi vector files use the bottom-left corner as the origin, whereas Idrisi raster files use the top-left corner as the origin. You therefore may need to subtract 1080 from the Y coordinate, then multiply the Y coordinate by -1 to convert the coordinates. This can be done with a word processor that permits mathematical operations on numerical data, and which has a column mode. Otherwise, a word processor can reconfigure the vector file format (from its two inter-fingered line formats to a uniform four-column format), and a data base management system can convert the coordinates (with a reconversion to your GISs vector file format in the DBMS or word processor).

If you have difficulties converting the vector files, contact NGDC support. The telephone number appears on page ii. Though the low cost and public domain nature of these data preclude commercial (e.g. costly) support, we will try to help you if you obtained the data and exercise manual directly from us. Please have a copy of our paperwork that came with your purchase, as we may have to verify this. (The data and exercise manual are not copyright. You are free to copy them. However, we can only attempt to support people who obtained the materials directly from us.)

TRANSLATING IDRISI FUNCTIONS TO THOSE OF YOUR GIS

This manual was partially edited at Clark University, in the laboratory that develops IDRISI. Subsequent editing has been performed to make the manual more generalized. Nevertheless, it is still strongly based on IDRISI. This makes it relatively easy for someone to use the materials with IDRISI, but less so for users of other GISs.

However, this barrier is more apparent than real for users of other GISs, if they are sufficiently capable in their functionality. The following guidelines should simplify the adaptation to another GIS.

Many of the most basic GIS functions have similar, but not identical, names in different systems. For example, the IDRISI "Color" module is actually a color or monochrome raster display function, with a few enhancements enabling the change of a color table, the creation of new color tables, vector overlay, zooming (in some new versions of Color), finding locations and data values. Many other GISs contain the basic display capabilities in functions called, "display," "show," or the like.

Two lists of abbreviated descriptions of Idrisi functions are provided as Appendix C and D. Appendix C sorts the functions by topic, Appendix D sorts the functions in alphabetical order. These should help you to develop a strategy for converting IDRISI functions to your GIS.

A Reminder

If you have trouble getting these data to work in your GIS, please try the following:

1. **Reread this appendix, and Appendix A, with a colleague that knows the GIS.** Perhaps the colleague will see something that you may have overlooked.

2. **Contact the group that supports your GIS.** If you are not the first caller with this problem, the support group may have an answer for you. If you ARE the first to call your support group about this problem, you will give them a chance to develop ingest procedures for this standardized data format.

3. **If you have tried these avenues, and you obtained the data and exercise manual directly from us, call our support people.** We may have the answer; in other cases we may not have the answer immediately. But we want to know if there are any problems. Our address, telephone and FAXimile number are listed on page ii. Please have handy the paperwork that came with your order. We may need to confirm that you received the materials directly from us.

We hope you enjoy these materials!

APPENDIX C
Translation Guide from IDRISI-Speak to the Lingo of Your GIS (Part I)

This glossary of selected IDRISI functions lists all functions referred to in this workbook, plus several others, sorted by type of function. This may help you to find the IDRISI equivalent to a function in another geographic information system. Appendix D provides the same list of functions, sorted in alphabetical order. Appendix D may make it easier for you to find the description of an IDRISI function. This may be useful if you are trying to translate an exercise in this manual to work in another GIS.

This material was modified from the IDRISI software manual, produced by Clark University.

A. System Operation Module

DESCRIBE	Describes the contents of any image, vector (e.g. LIST V) or values file.
ENVIRON	Changes the prevailing IDRISI operating environment (directory paths, etc).
IDRISI	The Main IDRISI menu system.
LIST	Lists the names and titles of all image, vector and values files.
LISTPAL	Lists color palette files in the active data directory.
LISTSCR	Lists vector script files used with PLOT.
LISTSIG	Lists supervised classification signature files.

B. Data Entry Modules

DIGITIZE	A vector digitizing module (Summagraphics MM Series digitizers).
EDIT	A simple ASCII text editor.
INITIAL	Initializes a new image with a constant value.
INTERCON	Interpolates a surface from a set of contours by linear interpolation.
INTERPOL	Interpolates a surface from point data using either a weighted-distance of potential surface model.
LINERAS	Line-to-Raster conversion.
POINTRAS	Point-to-Raster conversion.
POLYRAS	Polygon-to-Raster conversion.
POLYVEC	Raster-to-Polygon conversion.
UPDATE	Keyboard entry / update of image data.

C. Data Storage and Management Modules

CONCAT	Concatenates two images to produce a larger image.
CONTRACT	Reduces an image by pixel aggregation or thinning.
CONVERT	Converts between all of the image storage formats supported by IDRISI. Files may be converted to any combination of the byte, integer, and real (floating point) data types and the ASCII, binary, and packed (run-length encoded) file structures.
DOCUMENT	Creates a documentation file for a new imported data file, or allows editing existing documentation file.
EXPAND	Enlarges an image by pixel duplication.
QUERY	Extracts pixels designated by an independent mask into a sequential file for subsequent statistical analysis.
RESAMPLE	Determines the data values for a rectangular grid by interpolation of the values in a different (and possibly warped) grid. Linear, quadratic, and cubic mappings between the grids are provided, along with nearest-neighbour and bilinear interpolations. Vector files may also be transformed with this "rubber sheet" procedure.
TRANSPOS	Image transposition by row or column reversal or by rotation.
WINDOW	Extracts a rectangular sub-image.

D. Data Retrieval and Display Modules

COLOR	Produces color output of images on selected display hardware. Allows autoscaling of the full range of data values to a EGA/VGA screen ("a" option). Other options include inquiring about data values marked with the curser ("c" option), digitizing on-screen ("d" option), zoom ("w" option), vector overlay ("v" option), and modifying a color palette ("k" option)
COLOR85	8514/A display high-resolution version of COLOR
DISPLAY	A "universal" display routine using ASCII characters. Legends are produced using the image documentation file, and area statistics are given for each category.
HISTO	Produces histograms of image file values. Graphic or numeric output.
IMAGE	Produces a grey-scale image (up to 32 levels) using a half-tone procedure on dot-matrix printers (or color on some printers.
ORTHO	Produces a three-dimensional orthographic perspective plot of surface data, with optional draping of a second color image.
PLOT	Produces vector plots on screen and to HPGL plotters.
STRETCH	Linear contrast stretch of data values in an image.
VIEW	Allows direct examination of the data values in any portion of an image. Output precision is user-specified.

E. The GIS Ring Modules

ALLOCATE	Performs spatial allocation using either DISTANCE or COST surfaces.
AREA	Creates a new image by giving each output pixel the value of the area of the class to which the input pixel belonged.
COST	Generates a distance/proximity surface where distance is measured as the least cost distance in moving over a friction surface.
DISTANCE	Calculates the distance (proximity) of each pixel to the nearest of a set of target pixels.
GROUP	Classifies pixels according to contiguous groups.
HNTRLAND	Determines the supply areas dominated by (ie., the hinterlands of) point demand centers.
OVERLAY	Performs mathematical operations between map layers. Adds, subtracts, multiplies, divides, performs normalized difference calculations, exponentiates, takes the maximum or minimum value of images. Also covers one image with another, except when the second image has values of zero.
PATHWAY	Finds the shortest path between one or more specified points and a destination specified as the lowest point on a cost surface.
PERIM	Creates a new image by giving each output pixel the value of the perimeter of the class to which the input pixel belongs.
RECLASS	Reclassifies pixels by equal intervals or user-defined schemes.
SCALAR	Adds, subtracts, multiplies, divides, and exponentiates pixels by a constant value.
SURFACE	Produces slope and aspect images from a surface image.
TRANSFOR	Transforms the attributes of images (eg. log transformation) using any of 14 operations.
VIEWSHED	Creates an image of all points visible from one or more viewpoints over a given surface.
WATERSHED	Determines the watersheds of one or more specified locations.

F. The Spatial Statistic Ring Modules

AUTOCORR	Computes Moran's "I" first lag auto-correlation statistic for an image, along with confidence tests.
CENTER	Computes the mean center (weighted or not) of a point distribution and standard radius (the two-dimensional equivalent of a standard deviation).
CRATIO	Computes the compactness ratio of polygons given corresponding area and perimeter images.
CROSSTAB	Performs image cross-tabulation and cross-correlation.
PROFILE	Creates profiles over space or over time.
QUADRAT	Computes the density, variance and variance-mean ratio of quadrat cell counts.
RANDOM	Creates random images of specified mean and standard deviation for simulation studies.
REGRESS	Performs regression analysis on images or attribute values files.
THIESSEN	Produces Thiessen polygons (a Voronoi Tessellation) about a set of irregularly distributed points.
TREND	Calculates the best fit linear, quadratic, or cubic trend surface to a set of irregular cell control points by least-square procedures. Produces new images of the trend surfaces in addition to surface statistics.

G. Image Processing Ring Modules

CLUSTER	Performs unsupervised classification
COLSPACE	Performs HIS/RGB color space transformations.
COMPOSIT	Produces color composite images.
DESTRIPE	Removes band striping due to variable detector output.
EDITSIG	Allows on to edit signatures creates with MAKESIG.
FILTER	Convolves (strictly correlates) an image with a digital filter. Mean, median, mode, edge-enhancement, low-pass, high-pass, and user-defined filters are accommodated.
LANDSAT	Facilitates the downloading of Landsat CCT-X data.
LISTSIG	Lists signature files created using MAKESIG.
MAKESIG	Creates signatures from training sites delineated with COLOR or UPDATE.
MAXLIKE	A Maximum Likelihood classifier.
MINDIST	A Minimum Distance to Means classifier.
PIPED	A Parallelepiped classifier.
PRINCOMP	Principal Components Analysis (standardized and unstandardized).
RADIANCE	Converts raw values to calibrated radiances for Landsat images.
RESAMPLE	See entry in the Core Modules section.
SIGCOMP	A signature comparison utility.
STRETCH	Performs contrast manipulation. See entry in the Core Modules.

H. The Vector/DBMS Ring Modules

ASSIGN	Creates an image from an attribute values file by assigning the data values contained in the attribute values file to the cells belonging to defined regions. ASSIGN can also be used to reclassify integer images (see RECLASS below).
DBIDRIS	DBIDRISI is used to import dBASE files into IDRISI values files, and move IDRISI values files back into dBASE format.
EXTRACT	Creates an attribute values file from an image by extracting a summary of data values found within defined regions. The summary (minimum, maximum, range, total, mean, or standard deviation) may also be output as a table.
LINERAS	Line-to-Raster conversion.
PLOT	Produces vector plots on screen and to HPGL plotters. Use of script files provides for multiple vector files and attributes files to be combined in a single plot.
POINTRAS	Point-to-Raster conversion.
POLYRAS	Polygon-to Raster conversion.
POLYRAS	Polygon-to Raster conversion.
POLYVEC	Raster-to-Polygon conversion.

APPENDIX D

Translation Guide from IDRISI-Speak to the Lingo of Your GIS (Part II)

This glossary of selected IDRISI functions lists all functions referred to in this workbook, plus several others, sorted by alphabetical order. This may make it easier for you to find the description of an IDRISI function. This may be useful if you are trying to translate an exercise in this manual to work in another GIS. Appendix C provides a listing of IDRISI commands by their type of GIS functionality. Appendix C may help you to find the IDRISI equivalent to a function in another Geographic Information System.

This material was modified from the IDRISI software manual, produced by Clark University.

ALLOCATE	Performs spatial allocation using either DISTANCE or COST surfaces.
AREA	Creates a new image by giving each output pixel the value of the area of the class to which the input pixel belonged.
ASSIGN	Creates an image from an attribute values file by assigning the data values contained in the attribute values file to the cells belonging to defined regions. ASSIGN can also be used to reclassify integer images (see RECLASS below).
AUTOCORR	Computes Moran's "I" first lag auto-correlation statistic for an image, along with confidence tests.
CENTER	Computes the mean center (weighted or not) of a point distribution and standard radius (the two-dimensional equivalent of a standard deviation).
CLUSTER	Performs unsupervised classification
COLOR	Produces color output of images on selected display hardware. Allows autoscaling of the full range of data values to a EGA/VGA screen ("a" option). Other options include inquiring about data values marked with the curser ("c" option), digitizing on-screen ("d" option), zoom ("w" option), vector overlay ("v" option), and modifying a color palette ("k" option)
COLOR85	8514/A display high-resolution version of COLOR
COLSPACE	Performs HIS/RGB color space transformations.
COMPOSIT	Produces color composite images.
CONCAT	Concatenates two images to produce a larger image.
CONTRACT	Reduces an image by pixel aggregation or thinning.
CONVERT	Converts between all of the image storage formats supported by IDRISI. Files may be converted to any combination of the byte, integer, and real (floating point) data types and the ASCII, binary, and packed (run-length encoded) file structures.

COST	Generates a distance/proximity surface where distance is measured as the least cost distance in moving over a friction surface.
CRATIO	Computes the compactness ratio of polygons given corresponding area and perimeter images.
CROSSTAB	Performs image cross-tabulation and cross-correlation.
DBIDRIS	DBIDRISI is used to import dBASE files into IDRISI values files, and move IDRISI values files back into dBASE format.
DESCRIBE	Describes the contents of any image, vector (e.g. LIST V) or values file.
DESTRIPE	Removes band striping due to variable detector output.
DIGITIZE	A vector digitizing module (Summagraphics MM Series digitizers).
DISPLAY	A "universal" display routine using ASCII characters. Legends are produced using the image documentation file, and area statistics are given for each category.
DISTANCE	Calculates the distance (proximity) of each pixel to the nearest of a set of target pixels.
DOCUMENT	Creates a documentation file for a new imported data file, or allows editing existing documentation file.
EDIT	A simple ASCII text editor.
EDITSIG	Allows on to edit signatures creates with MAKESIG.
ENVIRON	Changes the prevailing IDRISI operating environment (directory paths, etc).
EXPAND	Enlarges an image by pixel duplication.
EXTRACT	Creates an attribute values file from an image by extracting a summary of data values found within defined regions. The summary (minimum, maximum, range, total, mean, or standard deviation) may also be output as a table.
FILTER	Convolves (strictly correlates) an image with a digital filter. Mean, median, mode, edge-enhancement, low-pass, high-pass, and user-defined filters are accommodated.
GROUP	Classifies pixels according to contiguous groups.
HISTO	Produces histograms of image file values. Graphic or numeric output.
HNTRLAND	Determines the supply areas dominated by (ie., the hinterlands of) point demand centers.
IDRISI	The Main IDRISI menu system.
IMAGE	Produces a grey-scale image (up to 32 levels) using a half-tone procedure on dot-matrix printers (or color on some printers.
INITIAL	Initializes a new image with a constant value.
INTERCON	Interpolates a surface from a set of contours by linear interpolation.
INTERPOL	Interpolates a surface from point data using either a weighted-distance of potential surface model.
LANDSAT	Facilitates the downloading of Landsat CCT-X data.
LINERAS	Line-to-Raster conversion.
LIST	Lists the names and titles of all image, vector and values files.
LISTPAL	Lists color palette files in the active data directory.
LISTSCR	Lists vector script files used with PLOT.

LISTSIG	Lists supervised classification signature files.
MAKESIG	Creates signatures from training sites delineated with COLOR or UPDATE.
MAXLIKE	A Maximum Likelihood classifier.
MINDIST	A Minimum Distance to Means classifier.
ORTHO	Produces a three-dimensional orthographic perspective plot of surface data, with optional draping of a second color image.
OVERLAY	Performs mathematical operations between map layers. Adds, subtracts, multiplies, divides, performs normalized difference calculations, exponentiates, takes the maximum or minimum value of images. Also covers one image with another, except when the second image has values of zero.
PATHWAY	Finds the shortest path between one or more specified points and a destination specified as the lowest point on a cost surface.
PERIM	Creates a new image by giving each output pixel the value of the perimeter of the class to which the input pixel belongs.
PIPED	A Parallelepiped classifier.
PLOT	Produces vector plots on screen and to HPGL plotters.
PLOT	Produces vector plots on screen and to HPGL plotters. Use of script files provides for multiple vector files and attributes files to be combined in a single plot.
POINTRAS	Point-to-Raster conversion.
POLYRAS	Polygon-to Raster conversion.
POLYRAS	Polygon-to-Raster conversion.
POLYVEC	Raster-to-Polygon conversion.
WINDOW	Extracts a rectangular subimage.
PRINCOMP	Principal Components Analysis (standardized and unstandardized).
PROFILE	Creates profiles over space or over time.
QUADRAT	Computes the density, variance and variance-mean ratio of quadrat cell counts.
QUERY	Extracts pixels designated by an independent mask into a sequential file for subsequent statistical analysis.
RADIANCE	Converts raw values to calibrated radiances for Landsat images.
RANDOM	Creates random images of specified mean and standard deviation for simulation studies.
RECLASS	Reclassifies pixels by equal intervals or user-defined schemes.
REGRESS	Performs regression analysis on images or attribute values files.
RESAMPLE	Determines the data values for a rectangular grid by interpolation of the values in a different (and possibly warped) grid. Linear, quadratic and cubic mappings between the grids are provided, along with nearest-neighbour and bilinear interpolations. Vector files may also be transformed with this "rubber sheet" procedure.
SCALAR	Adds, subtracts, multiplies, divides, and exponentiates pixels by a constant value.
SIGCOMP	A signature comparison utility.

STRETCH	Linear contrast stretch of data values in an image.
SURFACE	Produces slope and aspect images from a surface image.
THIESSEN	Produces Thiessen polygons (a Voronoi Tessellation) about a set of irregularly distributed points.
TRANSFOR	Transforms the attributes of images (eg. log transformation) using any of 14 operations.
TRANSPOS	Image transposition by row or column reversal or by rotation.
TREND	Calculates the best fit linear, quadratic, or cubic trend surface to a set of irregular cell control points by least-square procedures. Produces new images of the trend surfaces in addition to surface statistics.
UPDATE	Keyboard entry / update of image data.
VIEW	Allows direct examination of the data values in any portion of an image. Output precision is user-specified.
VIEWSHED	Creates an image of all points visible from one or more viewpoints over a given surface.
WATERSHED	Determines the watersheds of one or more specified locations.
WINDOW	Extracts a rectangular sub-image.

APPENDIX E

Guide to the Structure of the Data Base

The data base structure was chosen to coincide with that of IDRISI. This decision was taken for two resons:

1. The IDRISI data format is relatively generic, and has been designed to be highly compatible with conversion to other GISs. IDRISI itself has conversion utilities for several GISs.

2. Because of its cost, portability, wide distribution, and its emphasis on education, IDRISI is the most likely single GIS to be used for this project.

If you are planning to use a GIS other than IDRISI, this information, and that of Appendix B, should help you to convert the data. This section describes the formats of the data base, while Appendix B outlines methods for converting the data to other GISs.

This Appendix is modified from the IDRISI software manual. The basic text of this part of the IDRISI manual was provided by the IDRISI Project at Clark University specifically for this purpose. We have modified the text to make it slightly more generally useful to users of this data base.

Format of Individual Data Sets

Data files are of three basic types—grid (also called image or raster) files, vector files, and attribute values files (also called values files). In the Global Change Data Base, image files are the primary means by which spatial phenomena are described and analyzed. Vector files are used for data input, and also with vector functions such as IDRISI's PLOT and DBIDRIS. Attribute values files describe only the quality or character of features, and not their locations.

In raster GIS, spatial data are stored as a fine rectangular matrix of data values. Although the data we store in these grid cells do not necessarily refer to phenomena that can be seen in the environment, the data grids themselves can be thought of as "images" — images of some aspect of the environment that can be made visible through the use of a raster display. In a raster display, such as the screen on your computer, there is also a grid, of small cells called pixels. Pixel is a contraction of the term "picture element." Pixels can be made to vary in their color, shape or gray tone. To make an image, the cell values in our data grid must be defined and in this way regulate the graphic appearance of their corresponding pixels. Thus the data control the visible form we see and we will refer to gridded data sets as images.

Images are representations of space, in a grid-cell or raster structure. A given area of space is divided into a set of rows and columns, producing grid cells that are typically but not necessarily square in shape. Each cell is given an identifier or attribute that is stored as a numeric value. The value stored may represent a feature identifier, a qualitative attribute code or a quantitative attribute value. For example, a cell could have the value "6" to indicate that it belongs to District 6 (a feature identifier), or that it is covered by soil type 6 (a qualitative attribute), or that it is 6 meters above sea level (a quantitative attribute value).

In addition to images, many GISs allow you to store map data in what is known as a "vector" format. With a vector representation, features are described by the coordinates of a series of points that, when joined, define the point location, course of the feature or its outermost boundary. GISs based on a vector structure are common and have strengths quite different from raster systems.

The third type of data used in GIS is non-spatial, known as an "attribute values file" or "values file." This file is unusual for a grid-based system, but common for vector based systems. In a vector system, vector data files only describe the geography of features and their boundaries, with the features themselves identified by feature codes. The attributes of those features are stored in a separate data file as a relational table. For example, a data file for the United States might contain 50 rows, one for each state, and a series of columns, one for each attribute, with the first column listing the feature identifier codes. The advantage of such a system is that with 100 variables relating to the states it is not necessary to store 100 maps. Instead, only a single map that defines the regions is saved and the more compact attribute values files.

In raster, the attributes of features are normally stored directly within the raster grid. Although data compaction techniques greatly reduce the volume of data required to store a grid, a separate image must be stored for each data variable.

In the Global Change Data Base, the attribute values file concept has been extended to raster processing as well as vector, because it is an efficient means of storing data for identifiable features. For instance, it is possible to have a single raster image that contains feature identifiers such as district codes, and a series of attribute values files that list the attributes of those features. Modules exist for the creation of a new image from the combination of an image containing feature identifiers and an attribute values file and to reverse the process to extract an attribute values file from an image. Separate attribute files are not provided with the current version of the Africa data base. However, the attribute data structure is supported; and such data are likely to be available for the full Global Change Data Base sometime in the future.

The attribute file structure allows one to manipulate tabular data in a data base management system, then edit them for output to the attribute data format. Of course, the data in the DBMS must have thematic pointers or other information that can be associated with the spatial data base.

Nomenclature of File Names in the Data Base

Data file names in PC-DOS can be up to 8 characters in length. The upper- and lower-case characters are ignored, and no spaces are allowed. DOS allows the use of a three-letter "extension" on file names to help distinguish their contents or purpose. In this version of the Global Change Data Base, image files have ".IMG" extensions, vector files have ".VEC" extensions and values files have ".VAL" extensions. In IDRISI you do not need to worry about file extensions since all data files are referred to by their simple names. Thus, you might have an image that contains data on soil types. If it is called SOILS, you would refer to it as SOILS, even though the actual name, as it is stored on disk, is SOILS.IMG. The same applies to vector and values files. In GISs other than IDRISI, you may need to modify the DOS extension. For example, in ERDAS, you would probably use the .GIS extension, and would not have a .DOC file (as FIXHEAD would attach header information to your .GIS file.) In brief, each GIS has different conventions for handling filenames. You should modify your filenames to suit your GIS.

Documentation Files

When you specify image, vector or values files with the data base, you may (depending on your GIS) always use these simple names, and it appears that you are interacting with a single data file.

However, in the original format of the data base, there are in fact two files simultaneously. Each data file is paired with a documentation file that has a ".DOC", ".DVC" or ".DVL" extension, depending upon whether it applies to an image file, a vector file, or a values file respectively. The documentation file contains information about the data file in question. For example, in the case of an image file, the documentation file contains information on the number of rows and columns, the title, legend data and scale. If you specify an image named SOILS in an IDRISI module, the module first looks for a file named SOILS.DOC and reads the information needed to run, particularly the number of rows and columns and the file and data formats. The module then opens up the main data file, SOILS.IMG, and processes that information.

If you are using IDRISI, you do not need to worry about maintaining documentation files. Whenever a new image is created within IDRISI, an appropriate documentation file is created for it. However, when a foreign file is imported into the IDRISI system, a documentation file must be created. A program module named DOCUMENT exists to create the documentation file for a new file regardless of type. Once a documentation file is created, it is maintained automatically when the file is modified. DOCUMENT can also be used to update or change the information in a documentation file to correct an error, or to add or change the legend, or title.

If you are using another GIS, your software may handle header information differently from the default in the Global Change Data Base. Some GISs use embedded headers, others use separate header files. The information contained in the data base's header files should help you to build appropriate header information for the GIS of your choice.

Default Drives and Data Paths

Each GIS has its own preferred form of directory structures. Some GISs put all data into one directory for each study area. Other GISs put header information, attributes, vector files, raster files, each into different subdirectories within an overall directory for the study area. Read your software manual and copy the files from the floppy diskettes into your GIS in the appropriate way.

Raster Grid Files

In the grid-cell structure used by the Global Change Data Base, cells are numbered left-to-right as you might expect, but rows are numbered top-to-bottom. This is common with most raster systems because of the directionality of many output devices, particularly printers that print from top to bottom. Also, since raster systems are derived from image processing systems, and this is the nomenclature of image processing systems, this format should not be surprising.

While the logical structure of an image file is a grid, the actual structure, as it is stored, is a single long column of numbers. For instance, an image consisting of 3 rows by 4 columns is stored as a single column of 12 numbers. It is the documentation file that allows the raster GIS to reconstruct the grid from this list.

An image that looks like this:

10	15	9	10	1
11	14	10	11	13
14	13	11	10	12

has an image file that looks like this:

10
15
9
10
1
11
14
10
11
13
14
13
11
10
12

The documentation file or header, containing the number of rows and columns, allows the image to be correctly recreated for display and analysis.

The numbers in a grid file may be integer, byte, or real. Integers are numbers having no fractional part, within the range of -32768 to +32767 (plus or minus 215,or the number representable using two 8 bit bytes of data). Byte values are positive integer numbers ranging from 0 to 255 (28, the number representable using one 8 bit byte). Real numbers have a fractional part such as 3.14. Integer or byte values can be used to represent actual numbers or be used as codes for categorical data types. For example, a soils map may record three soil types in a particular region.

Many GISs do not handle real (floating point) values. This is a series impediment to scientific analysis, as the scientist must be convinced that the GIS hasn't wrecked the scientific content of the data by translating them to integers or byte class values. Unfortunately, in some cases, some scientific content is lost in the translation, and some errors are propagated at explosive rates if high levels of floating point precision are absent. The Global Change Data Base allows data to be in any of these formats, respecting the scientific credibility of the data as originally created by their authors.

The .DOC file records the file data type. When a new image is created, it maintains the prevailing data type of the input image, or it produces a data type that is logical based upon standard mixed arithmetic rules. Thus, dividing one integer data image by a second integer data image should yield a real data image as a result.

The byte data type deserves special mention. Byte values are integer values within the restricted range of 0-255. Integers within this range require only a single byte of disk storage, as opposed to the two bytes required for standard integers. Most categorical map data can be stored in a byte format, requiring half as much storage space as the integer type. The byte data type is used for data compression, as is the packed binary file type to be discussed below. Data compression is an important issue in raster processing, and is achieved in IDRISI by use of the CONVERT module. CONVERT can be used at any time to convert an integer or real file to byte, providing the range falls between 0-255. In the case of real numbers, CONVERT offers the option of converting to byte integers by rounding or truncation.

IDRISI can store files in ASCII, binary, or packed binary formats. File format is recorded in the documentation file. The ASCII format is also referred to as a "text" file, and can be viewed directly from your operating system using the TYPE command. It is also suitable for transferring files to and from other programs, since the coding system is a recognized standard (ASCII = American Standard Code for Information Interchange). ASCII files are not the most efficient means of storing data. You may wish to convert any ASCII files that you might have to binary format before getting too involved with your analyses.

The IDRISI module CONVERT converts ASCII to binary or binary to ASCII. Binary files cannot be examined directly, however IDRISI provides strong data examination facilities beyond the TYPE command, so you do not need to be intimidated by this structure.

Many GISs do not handle binary data. NGDC uses utilities in IDRISI, as well as custom-written utilities to convert ASCII data to binary form, and vice versa. The Global Change Data Base favors unpacked binary data, though there are a few specific exceptions (that you will not have to worry about with the educational package created for this manual).

The packed binary format is a special data compression format for binary integer or byte data. Virtually all IDRISI modules support the packed binary data type, though you should be careful, as some bugs have been reported in some modules that might occasionally corrupt an output file when working with packed binary data. We recommend that you work only with unpacked binary files until this reported bug is put to rest.

Image Documentation Files

Documentation files in the Global Change Data Base are always stored in ASCII format, and can be viewed using the IDRISI DESCRIBE utility. Issuing the command "C>DESCRIBE soils" prints out the contents of the documentation file for the SOILS image. You do not need to specify the drive and data path.

Similarly, you can issue the DOS command "C>TYPE DRIVE:\PATH\soils.doc /p" to read the description of the map layer "soils" contained in the documentation file.

The documentation file consists of a series of lines containing vital information about the corresponding image file. The first 14 characters describe the contents of the line, while the remaining characters contain the actual data. For example, the documentation file SOILS.DOC looks like this:

```
image title   :  Major Soil Groups
data type     :  integer
file type     :  binary
rows          :  480
columns       :  640
minimum       :  1.0000000000E+00
maximum       :  3.0000000000E+00
cell x        :  250
cell y        :  250
legend        :  3
category 1    :  Podzol Soils
category 2    :  Brown Podzolic Soils
category 3    :  Gray-Brown Podzolic Soils
```

This file contains information on major soil groups, and is in integer format stored as a binary file. The image contains 480 rows and 640 columns, for a total of 307,200 values stored as a single column of numbers. The next two entries are stored in floating point "power of ten" format. If you are unfamiliar with this notation, the minimum in this example is 1 (1 times 10 to the power of zero) and the maximum is 3.

The "cell x" and "cell y" entries refer to the size of each grid cell in the x and y directions. In IDRISI, the units of measure are specified in the environment file. In this example, both dimensions read 250, indicating a square cell. If the units specified in the environment file are meters, then the cell is 250 meters by 250 meters. These values are important for those modules that calculate area, slope or distance.

The legend entry indicates the maximum number of legend captions. A zero indicates that no legend has been stored for this image. In this example, the entry reads 3 indicating that three legend captions follow. The IDRISI module DOCUMENT is used to enter and update legend category descriptions.

Vector Files

All geographical data is not best served by a raster format. Raster digitizing is currently difficult and expensive, so digitizing is generally done in a vector format. Polygons associated with aggregated data such as census tracts and state and national boundaries are best saved in a vector format, as is information for discrete geographic entities such as parcels in a town. For this reason, the Global Change Data Base uses IDRISI's vector format in addition to the various types of raster files described above. This format is a single uniform vector file structure for points, lines and polygons. For all feature types (point, line, polygon), the file consists of a sequence of numbers indicating:

1. a feature identifier,
2. the number of points that define that feature, and
3. the X and Y coordinates for each point.

The following shows the contents of a simple point file:

```
5      1
34.5   76.3
3      1
57.3   12.8
0      0
```

This file contains two points. The first has an identifier of 5 at location 34.5 in X and 76.3 in Y, and the second has an identifier of 3 at 57.3 in X and 12.8 in Y. The final pair of zeros mark the end of the file. Note that in a point file, the second entry for each feature always reads 1 because there is only one point per feature. For lines and polygons, this number is greater than one. The following shows the contents of a line file containing two lines:

```
300  4
21.5 18.1
22.3 21.5
34.1 24.6
45.9 29.8
500  3
34.5 76.3
64.3 52.1
22.0 12.0
0    0
```

This file contains two lines. The first has an identifier of 300 and contains four points. The second line has an identifier of 500 and contains 3 points. The final zeros mark the end of the file.

The following shows a polygon file containing a single polygon:

```
110  4
12.2 14.6
56.5 15.3
62.4 85.9
12.2 14.6
0    0
```

Here is a polygon with the identifier value of 110. It says it has 4 points, but you can see that in fact it has three — the last point is a duplicate of the first. The difference between a line and a polygon ın is that a polygon's first and last points are identical. This is necessary to "close" the polygons, and is a convention that must be followed in digitizing.

NOTE!

Unlike the numbering for grid rows, the coordinate system for vector files has the 0,0 point in the lower-left corner. In the example above, X,Y coordinates of 0.5,0.5 would fall in the very center of the bottom left-most cell (0,0). Similarly, X,Y coordinates of 49.5,99.5 would fall in the very center of the top right-most cell. This is the usual orientation for most vector digitizing devices, which typically have their origins in the lower left-hand corner. This is consistent with IDRISI's format.

When we convert vector representations to raster format, it is necessary to transpose the Y-axis to maintain the image "right side up." IDRISI provides two mechanisms for transposing the Y axis. The first is to answer "yes" when any of the rasterizing routines ask if you would like to have the Y axis transposed. If you do so, the systems will be matched automatically.

Alternatively, it is possible to do the Y-axis inversion at a later stage. Create the vector file in a normal plane coordinate system, and undertake the vector-to-raster conversion process desired. Then use the TRANSPOS module to reverse the rows and thus invert the Y dimension. This module is discussed further in the next section.

If you use a system other than DIGITIZE to create your vector files, you may need to write a small program to transform your vector data into the required format. If the file is in ASCII format you may use either real or integer values for each entry. However, if your file is in binary, it must contain Turbo Pascal 6-byte reals. Do not forget to place a pair of zeros at the end of the file.

NGDC regularly translates vector files between IDRISI and, say, GRASS, by editing them in a powerful word processor and/or data base management system. Both IDRISI and GRASS use slightly different ASCII text formats for input vector data, which can be created by anyone familiar with such procedures in a word processor or DBMS. See Appendix B for more information on this translation.

Vector Documentation Files

As with image files, all vector files are paired with documentation files with the ".DVC" extension by default.

A vector documentation file is shown here:

```
title         :  Land Use / Land Cover
data type     :  integer
file type     :  ASCII
object type   :  polygon
coord. span   :  1.0000000000E+03
coord. unit   :  m
min X         :  2.9600000000E+02
max X         :  3.1600000000E+02
min Y         :  4.7640000000E+03
max Y         :  4.7750000000E+03
```

The title entry is self-evident. The data type refers to the data type of the feature identifiers in the vector file. The coordinates are always stored as real numbers. The file type may be ASCII or binary. If it is ASCII, you can read the data file using an ASCII text editor or the TYPE command from the operating system. The object type may read "point," "line," "polygon," or "chain." The chain type is not used in the current version, but will be in future releases. The coordinate span refers to the ground distance represented by a coordinate difference of 1. In this example, each coordinate unit represents 1000 meters. The measurement unit is recorded on the next line, and entry options are the same as in the environment file—m, ft, mi, km, deg or rad.

The coordinate span and coordinate unit entries provide a statement of scale. Finally, the minimum and maximum X and Y entries refer to the limits of the rectangular area digitized. Typically, these values form a "window", also known as the world coordinate window, which frames all digitized files relating to a single study region. In this particular example, UTM coordinates are given for a study region in Wisconsin.

It is important to recognize that the minimum and maximum X and Y values recorded in the documentation file do not refer to the minimum and maximum coordinates associated with any feature, but to the boundary or "limits" of the study area. Thus they correspond to the BND (boundary) coordinates in vector systems such as Arc/INFO.

Attribute Values File

An attribute values file lists the attributes for a set of labeled or named features, where the "names" are in the form of integer numbers. For example, the following is an illustration of an attribute values file listing the populations of the 10 provinces of Canada:

```
1    570
2    860
3    120
4    715
5    6440
6    8585
7    1050
8    955
9    1905
10   2575
```

where 1 = Newfoundland, 2 = Nova Scotia, 3 = Prince Edward Island, and so forth. Values files always consist of two columns of data. The left column is always a set of integer feature codes. The right column may contain either integer numbers, real numbers, or character strings. It is possible to create a second values file listing the "name" attribute for our province codes as follows:

```
1 Newfoundland
2 Nova Scotia
3 Prince Edward Island
4 New Brunswick
5 Quebec
6 Ontario
7 Manitoba
8 Saskatchewan
9 Alberta
10 British Columbia
```

In the current version of the data base, all values files are planned for storage as ASCII files. It is easy to create them with a simple text editor or word processor. Values files in ASCII format can be loaded, modified and saved with a "spreadsheet" program such as Lotus Corporation's "Lotus 1-2-3" or Borland International's "Quattro". Many analyses can be performed by a spreadsheet or data base management program, and subsequently exported to ASCII values files.

Values files are not maps. Instead they contain information that can be used to create maps with the aid of a module like IDRISI's ASSIGN and an image of feature codes showing where each of the features is located, referred to as a geographic definition file. For example, to create a map of population by province in Canada, we need the values file illustrated above and an image where each cell contains the feature code of the province in which it is located. Zeros are used to indicate the cells that are not within any province. The ASSIGN module creates a new image in which each cell is assigned the population of the province to which it belongs. With a population "image", a population density map can be produced by dividing the population image by a map of areas. The division is done with the OVERLAY module, and the calculation of areas is done with the AREA module.

ASSIGN converts values files into image files through the use of a geographic definition file. A geographic definition file must exist to define the features listed in any values file. It is likely that there are many values files for a single geographic definition file, just as there are many files of statistical data about the Canadian provinces. It is possible to create a values file from an image so long as a geographic definition file exists. The modules named AREA and PERIM, for example, can create values files of the areas and perimeters of defined regions. The module named EXTRACT can extract a values file from any image, by summarizing the data values within each defined region. These summaries can take the form of totals, means, minima, maxima, standard deviations, ranges, and the like. EXTRACT and ASSIGN are thus the complements of each other in moving data between images and values files.

Attribute Values Documentation Files

The current version of the data base follows IDRISI's format of accepting values files with or without a documentation file. A function like IDRISI's ASSIGN procedure can also be used as a rapid method of reclassification, and it is often desirable to be able to create a values file with minimal fuss. Similarly, a spreadsheet program such as Lotus 1-2-3 or Quattro does not automatically create a documentation file when exporting an ASCII values file. As a result, the current version of IDRISI will work with values files that do not have accompanying documentation files. They are useful as a means of documenting the data in a values file. It is strongly suggested that you get into the habit of creating documentation files for all of your attribute values files.

The structure of values files is as follows:

```
title          :  Population of Canada
subtitle       :  by Provinces (1980)
description    :  thousands of persons
data format    :  integer
no. classes    :  0
class. type    :  none
records        :  10
minimum        :  1.2000000000E+02
maximum        :  8.5850000000E+03
legend         :  0
```

As with the other documentation files in the data base, those for values files are stored in ASCII format with the first 14 characters used purely for descriptive purposes. The title and subtitle are obvious. The description may not be— it records information that might be used to describe the measurement units. In this example, our Canadian population data was recorded in thousands. The data format may read "integer," "real," or "string," where string indicates a string of characters. The number of classes entry reads 0 if the data are unclassified (raw), or greater than 0 if a classification procedure has been used. If the latter is the case, the data values indicate class numbers and the "class. type" entry indicates the name of the classification technique used such as "equal intervals," or "quantiles." If the data are raw values, the classification type is recorded as "none." The records entry indicates the number of features listed in the file, while the minimum and maximum entries record the highest and lowest values occurring. Finally, the legend entry serves the same purpose as it does with images; it identifies the values recorded in the data file. In the case of classified data, the legend entries record the class intervals associated with each class: "10-19", "20-29", etc. As with image files, the category descriptions may contain any text that is useful. Logically, only values files containing integers will have legend captions. For more information on legend captions, see the section on image documentation files above.

APPENDIX F

Inventory of Data Files on Each Diskette

The Workshop Exercise Diskettes accompanying this manual contain the files listed below. Individual files may be extracted by:

1. Copying to an empty directory on your hard disk the entire contents of diskettes containing desired files,
2. From within this directory on your hard disk, run "PKUNZIP *.ZIP."
3. Delete the files that you DO NOT want.
4. Copy the remaining desired files to the directory that contains your working data base.

All diskettes have pkunzip.EXE = 21,440 bytes

Disk 1 file: EXDISK1

name		size
AFAPR88	DOC	616
AFAPR88	IMG	210240
AFDEC86	DOC	619
AFDEC86	IMG	210240
AFDEC87	DOC	619
AFDEC87	IMG	210240
AFDEC88	DOC	619
AFDEC88	IMG	210240
AFELBA	DOC	716
AFELBA	IMG	420480
AFFAOSOL	DOC	5986
AFFAOSOL	IMG	210240
AFFEB88	DOC	619
AFFEB88	IMG	210240
AFHOLD	DOC	2103
AFHOLD	IMG	210240
16 FILES		1904057

Disk 2 file: EXDISK2

name		size
AFJAN88	DOC	618
AFJAN88	IMG	210240
AFJUL88	DOC	615
AFJUL88	IMG	210240
AFJUN88	DOC	615
AFJUN88	IMG	210240
AFMALBFA	DOC	694
AFMALBFA	IMG	420480
AFMALBSP	DOC	696
AFMALBSP	IMG	420480
AFMAR88	DOC	616
AFMAR88	IMG	210240
AFMAY88	DOC	614
AFMAY88	IMG	210240
AFMAYOCT	DOC	308
AFMAYOCT	IMG	420480
AFMPRAUG	DOC	697
AFMPRAUG	IMG	420480
18 FILES		4427257

Disk 3 file: EXDISK3

name		size
AFMPRDEC	DOC	699
AFMPRDEC	IMG	420480
AFMPRFEB	DOC	699
AFMPRFEB	IMG	420480
AFMPRJAN	DOC	698
AFMPRJAN	IMG	420480
AFMPRJUN	DOC	695
AFMPRJUN	IMG	420480
AFMPRMAR	DOC	696
AFMPRMAR	IMG	420480
AFMPRMAY	DOC	694
AFMPRMAY	IMG	420480
AFMPRNOV	DOC	699
AFMPRNOV	IMG	420480
AFMPROCT	DOC	698
AFMPROCT	IMG	420480
AFMVEG	DOC	2565
AFMVEG	IMG	210240
AFNATION	DOC	3142
AFNATION	IMG	210240
AFNOV88	DOC	619
AFNOV88	IMG	210240
AFNOVAPR	DOC	313
AFNOVAPR	IMG	420480
24 FILES		4427257

Disk 4 file: EXDISK4

name		size
AFOCEAN	DOC	314
AFOCEAN	IMG	210240
AFOCT88	DOC	618
AFOCT88	IMG	210240
AFRAINX	DOC	1334
AFRAINX	IMG	210240
AFRIVERS	DOC	294
AFRIVERS	IMG	210240
AFSEP88	DOC	620
AFSEP88	IMG	210240
AFSURF	DOC	269
AFSURF	IMG	307200
AFTMPANN	DOC	690
AFTMPANN	IMG	1261440
AFTMPDEC	DOC	686
AFTMPDEC	IMG	420480
AFURBAN	DOC	1483
AFURBAN	IMG	210240
AFVEGX	DOC	1097
AFVEGX	IMG	210240
AFWATER	DOC	2390
AFWATER	IMG	420480
22 FILES		3891075

Disk 5 file: EXDISK5

name		size
AFZSOILS	DOC	3103
AFZSOILS	IMG	210240
COASTS	DVC	299
COASTS	VEC	95202
COUNTRY	DVC	302
COUNTRY	VEC	82120
ELEV_3	DOC	298
ELEV_3	IMG	420480
EXVEG	DOC	513
EXVEG	IMG	210240
FEB88C	DOC	573
FEB88C	IMG	70526
ISLANDS	DVC	300
ISLANDS	VEC	4467
JAN88C	DOC	571
JAN88C	IMG	63368
LAKES	DVC	298
LAKES	VEC	32359
MAXHOT	DOC	294
MAXHOT	IMG	420480
MINCOLD	DOC	294
MINCOLD	IMG	420480
NDVI	PAL	223
NWZ	DVC	281
NWZ	VEC	15683
RIVERS	DVC	299
RIVERS	VEC	57579
27 FILES		2110872

SUPPLEMENTARY DATA DISK

name		size
AFFALL	DOC	295
AFFALL	IMG	92108
AFJANTMP	DOC	567
AFJANTMP	IMG	210240
AFSPRG	DOC	297
AFSPRG	IMG	97046
AFSUMM	DOC	297
AFSUMM	IMG	86196
AFVEGX2	DOC	700
AFVEGX2	IMG	210240
AFWINT	DOC	297
AFWINT	IMG	91984
NDVI	PAL	223
NWZ	DVC	281
NWZ	VEC	15683
SEASONS	TS	37
VEG	PAL	224
VIFILES	TS	133
18 FILES		806848

APPENDIX G

The World Data Center System

Description of World Data Centers

The World Data Centers (WDCs) were created in 1957 to provide archiving for the observational data resulting from the International Geophysical Year (IGY). In the years following the IGY, the International Council of Scientific Unions (ICSU) recommended that the WDCs continue to collect, archive, and redistribute data. This new system for exchanging geophysical data was found to be very effective, and the operations of the WDCs were extended by ICSU on a continuing basis to other international programs. The WDCs were under the supervision of the Comite International de Geophysique for the period 1960 through 1967 and are now supervised by the ICSU Panel on World Data Centres.

World Data Centers have been established in a variety of countries: WDC-A is located in the USA; WDC-B in the USSR; WDC-C in western Europe, Australia, and Japan; and WDC-D in the People's Republic of China. The Centers collect and distribute data for a number of disciplines:

- meteorology
- oceanography
- astronomy
- rockets and satellites
- solar-terrestrial physics: solar and interplanetary phenomena, ionospheric phenomena, flare-associated events, geomagnetic phenomena, aurora, cosmic rays, airglow
- nuclear radiation
- glaciology (snow and ice) and geocryology
- marine geology and geophysics: gravity, magnetics, bathymetry, seismic profiles, marine sediment, rock analyses
- solid earth geology and geophysics: seismology, tsunamis, gravimetry, Earth tides, recent movements of Earth's crust, Earth's rotation, magnetic measurements, paleomagnetism and archeomagnetism, volcanology, geothermics
- renewable resources and environment

In each discipline, the scientific community determines the nature and form of data exchange, based on research needs. Thus, the type and amount of data in the WDCs differ from discipline to discipline. However, each WDC is responsible for:

- collecting data in the field or discipline for which it is responsible
- protecting the incoming data

- copying and reproducing data, maintaining adequate standards of clarity and durability
- supplying copies of data to other WDCs
- preparing catalogs of data
- making data available to the scientific community.

All the Centers are staffed, funded, and maintained exclusively by the countries in which they are located. The WDCs catalog the data and make them available to scientists in all countries upon written request or personal visit. Minimal charges may be requested to cover costs of processing the requested data.

World Data Center A

World Data Center A was established in the United States under the auspices of the National Academy of Sciences. WDC-A is operated with national resources, but follows ICSU guidelines. The National Academy of Sciences has overall responsibility through the Geophysics Research Forum and its Committee on Geophysical Data. WDC-A consists of a Coordination Office and nine subcenters at scientific institutions in various parts of the United States. Most WDC-A subcenters are at corresponding national data centers, whose large national collections are available through the WDC-A subcenters.

Organizations wishing to contribute data or establish exchange agreements should contact the appropriate World Data Center A.

WORLD DATA CENTER A
COORDINATION OFFICE
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, DC 20418, USA
Telephone: 202-334-3368

WORLD DATA CENTER A: GLACIOLOGY (SNOW AND ICE)
Cooperative Institute for Research in Environmental Sciences
University of Colorado
Boulder, Colorado 80309, U.S.A.
Telephone: 303-492-5171

WORLD DATA CENTER A FOR MARINE GEOLOGY AND GEOPHYSICS
National Geophysical Data Center
NOAA, E/GC3
325 Broadway
Boulder, Colorado 80303-3328, U.S.A.
Telephone: 303-497-6487

WORLD DATA CENTER A: METEOROLOGY
National Climatic Data Center
NOAA, E/CC
Federal Building
Asheville, North Carolina 28801, U.S.A.
Telephone: 704-259-0682

WORLD DATA CENTER A: OCEANOGRAPHY
National Oceanographic Data Center
NOAA, E/OC
1825 Connecticut Avenue, NW
Universal Building, Room 406
Washington, DC 20235, U.S.A.
Telephone: 202-673-5594

WORLD DATA CENTER A: ROCKETS AND SATELLITES
NASA/Goddard Space Flight Center
Code 630.2
Greenbelt, Maryland 20771, U.S.A.
Telephone: 301-286-7354

WORLD DATA CENTER A: ROTATION OF THE EARTH
U.S. Naval Observatory
Washington, DC 20392-5100, U.S.A.
Telephone: 202-653-1529 or 1527

WORLD DATA CENTER A: SEISMOLOGY
U.S. Geological Survey
Branch of Global Seismology and Geomagnetism
Box 250436, Mail Stop 967
Denver Federal Center
Denver, Colorado 80225, U.S.A.
Telephone: 303-236-1500

WORLD DATA CENTER A FOR SOLAR-TERRESTRIAL PHYSICS
National Geophysical Data Center
NOAA, E/GC2
325 Broadway
Boulder, Colorado 80303-3328, U.S.A.
Telephone: 303-497-6324

WORLD DATA CENTER A FOR SOLID EARTH GEOPHYSICS
National Geophysical Data Center
NOAA, E/GC1
325 Broadway
Boulder, Colorado 80303-3328, U.S.A.
Telephone: 303-497-6521

WDC-A for Solid Earth Geophysics Reports

World Data Center A for Solid Earth Geophysics has a variety of reports related to its activities. This publication, SE-45, *A Report on Geomagnetic Observatory Operations*, is one in a series. To obtain ordering information about the other publications (listed below), call 303-497-6277, fax 303-497-6513, telex 592811 NOAA MASC BDR, or write to:

WORLD DATA CENTER-A FOR SOLID EARTH GEOPHYSICS
NATIONAL GEOPHYSICAL DATA CENTER
NOAA, CODE E/GC1
325 BROADWAY
BOULDER, COLORADO 80303-3328, U.S.A.

SE-1 Catalog of Tsunamis in Alaska
SE-2 Geodynamics International-9
SE-3 Summary of Earthquake Focal Mechanisms for the Western Pacific-Indonesian Region, 1929-1973
SE-4 Catalog of Tsunamis in Hawaii
SE-5 Geodynamics International-10

SE-6 Catalog of Seismograms and Strong-Motion Records
SE-7 Directory of Seismograph Stations
SE-8 Survey of Practice in Determining Magnitudes of Near Earthquakes, Part 2: Europe, Asia, Africa, Australia, the Pacific
SE-9 Survey of Practice in Determining Magnitudes of Near Earthquakes, Part 1: North, Central, and South America
SE-10 Geodynamics International-11

SE-11 The Information Explosion and Its Consequences for Data Acquisition, Documentation, and Processing: An Additional Aspect of the Limits to Growth
SE-12 Geodynamics International-12
SE-13 Bibliography of Statistical Aspects of Seismicity
SE-14 Directory of U.S. Data Repositories Supporting the International Geodynamics Project
SE-15 Geodynamics International-13

SE-16 Geodynamics International-14
SE-17 Annual Mean Values of Geomagnetic Components for Selected Observatories, 1940-1973
SE-18 Homogenous Magnitude System of the Eurasian Continent: P-Waves
SE-19 Geodynamics International-15
SE-20 Manual of Seismological Practice

SE-21 Geomagnetic Observatories, 1978
SE-22 Historical Seismogram Filming Project: First Progress Report
SE-23 Geodynamics International-16
SE-24 Historical Seismogram Filming Project: Second Progress Report
SE-25 Directory of World Seismograph Stations, Volume 1. The Americas—Part 1. United States, Canada, Bermuda

SE-26 Geodynamics International-17: Final Report
SE-27 Catalog of Significant Earthquakes, 2000 B.C.-1979
SE-28 Historical Seismogram Filming Project: Third Progress Report
SE-29 Strong-Motion Data from Japanese Earthquakes
SE-30 Progress Report on Selected Geophysical Activities of the United States, 1977-1981

SE-31 New Catalog of Strong Earthquakes in the U.S.S.R. from Ancient Times Through 1977
SE-32 Directory of World Digital Seismic Stations
SE-33 Historical Seismogram Filming Project: Fourth Progress Report
SE-34 Homogeneous Magnitude System of the Eurasian Continent: S and L Waves
SE-35 Documentation of Earthquake Algorithms

SE-36 Catalog of Submarine Volcanoes and Hydrological Phenomena Associated with Volcanic Events: 1500 B.C. to December 31, 1899
SE-37 Inventory of Filmed Historical Seismograms and Station Bulletins at World Data Center A
SE-38 Catalog of Strong-Motion Accelerograph Records
SE-39 Tsunamis in Peru-Chile
SE-40 Earthquake Catalog for the Middle East Countries 1900-1983

SE-41 Directory of World Seismograph Stations, Volume II. East Asia—China, Japan, Korea, and Mongolia

SE-42 Catalog of Submarine Volcanoes and Hydrological Phenomena Associated with Volcanic Events: January 1, 1900 to December 31, 1959

SE-43 A Directory of Geomagnetic Observatories with Digital Recording Magnetometers, 1987

SE-44 Directory of Data Sources for Lithospheric Investigations, Volume 1

SE-45 A Report on Geomagnetic Observatory Operations, 1990

SE-46 Enhancement of Earth Science Research and Educational Capabilities in the Developing Nations Through the Use of Compact Disc Technology; Report on the Pilot Project

SE-47 Global Change Data Base: Pilot (Diskette) Project for Africa; Data Base Documentation, Version 1.1

SE-48 Global Change Data Base: Training Exercise Manual; Exploring Earth's Environment, Africa as an Example

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