Studying Earth's Environment

From Space

Module 1:
Computer Lab
Exercises

EXPLORING
STRATOSPHERIC
OZONE USING NASA
SATELLITE DATA

Release: December 2002

**NASA Goddard Space Flight Center,
Earth Sciences Directorate**

Stratospheric Ozone Module written, edited and produced by

Barbara Gage and Diana Sunday

1998

Scientific & Educational Endeavors (SEE)

NASA Goddard Space Flight Center

Revised for NASA-Image2000 by

Rachel Campbell

2002

Advanced Automation and Architectures Branch

NASA Goddard Space Flight Center

List of Exercises

Studying Earth's Environment From Space

Introduction to Module 1: Stratospheric Ozone Computer Lab Exercises

Overview

The set of exercises that follow were designed to explore characteristics of stratospheric ozone distributions using satellite data for the whole globe collected by the Total Ozone Mapping Spectrometer (TOMS) from 1978 to 1993. Students will use *NASA Image2000* to display and analyze the data sets. The exercises are inquiry based and designed for advanced high school or college level classes. Additional background information can be found on the SEE website at http://see.gsfc.nasa.gov/edu/SEES/; the Classroom Resources include an electronic textbook on stratospheric ozone, which contains supporting scientific information that may be used to answer and explain the distribution and dynamics of stratospheric ozone that the students will be observing.

Before You Begin

These exercises assume that the *NASA Image2000* software and the Exercise Data are correctly installed on your system. Refer to the *NASA Image2000 Users Guide: Basic Operations* for assistance in installing the software.

NASA-Image2000

NASA Image2000 is an image processing software package available on multiple platforms, designed to bring high-end scientific image processing capabilities to the standard desktop computer. Developed to meet the needs of educators, *NASA Image2000* supports the display, analysis and processing of satellite imagery.

In the past, users have been forced to choose between software designed for expensive high-end computer systems, and software that lacked many of the tools necessary for performing analysis of satellite images. *NASA Image2000* is designed to provide those tools in a system that is suitable for simple applications, such as would be used in a classroom, but is powerful enough to support research.

The functionality built into *NASA Image2000* was designed to provide the capability for the display and analysis of geo-coded satellite imagery. The breadth of functionality, however, goes well beyond this scope, and most types of images can be used. Users can perform standard image processing tasks, similar to those available in general graphics packages. In addition, the system provides other less common functions, which are specifically intended for use with scientific images. These exercises provide an introduction both to image processing in general, and to the specific use of *NASA Image2000*.

Why Study Stratospheric Ozone

Most of the earth's atmosphere is composed of nitrogen and oxygen, but small amounts (or "trace" amounts) of other gases are also present, such as water vapor, argon, carbon dioxide, neon, helium, methane, carbon monoxide, and ozone. The presence and concentrations of some

of these trace gases have important implications because of their various interactions with the radiation coming into and leaving the Earth atmosphere system. Ozone is one of the more important trace gases in the atmosphere, and changes in its atmospheric concentrations brought about by human activities have led to considerable publicity about atmospheric ozone since the mid-1980s.[1]

Ozone is a molecule consisting of three oxygen atoms. Its chemical notation is O_3. Breathing ozone is lethal at dosage levels of a few molecules per million air molecules. This is why ozone at the surface is referred to as a pollutant. Yet ozone high in the atmosphere screens out biologically harmful solar ultraviolet radiation, keeping it from reaching the surface. Such ultraviolet radiation is destructive of genetic cellular material in plants and animals, as well as human beings. Without the "ozone layer" high up in the atmosphere, life on the he surface of the Earth would not be possible, as we know it.

Chlorofluorocarbons (CFCs) are a family of chemical compounds developed back in the 1920's as a safe, nontoxic, nonflammable alternative to dangerous substances like ammonia for purposes of refrigerations and spray can propellants. Their usage grew enormously over the years. One of the elements that make up CFCs is chlorine. Very little chlorine exists naturally in the atmosphere. But it turns out that CFCs are an excellent way of introducing chlorine into the ozone layer. The ultraviolet radiation at this altitude breaks down CFCs, freeing the chlorine. Under the proper conditions, this chlorine has the potential to destroy large amounts of ozone. This has indeed been observed, especially over Antarctica. As a consequence, levels of genetically harmful ultraviolet radiations have increased. [2]

Loading the Data

All the images and software required for using these lessons are included in the *NASA Image2000 CD* (v.1.1 or higher). Simply install the software as indicated in the Read Me file on the DC or in the *NASA-Image2000 Basic Users Guide (Section 2)*, located in the doc folder.

Important Notes On Presentation

Because there are multiple data source possibilities, navigational paths for moving through the hierarchical directory structure of your

---

[1] Parkinson, Claire, 1997, Atmospheric Ozone and the Antarctic Ozone Hole, *Earth from Above, Using Color-Coded Satellite Images to Examine the Global Environment,* Ch. 3, University Science Books

[2] Newman, Paul, Stratospheric Ozone, *Studying the Earth's Environment from Space electronic textbook,* Ch. 1-1, (http://see.gsfc.nasa.gov/edu/SEES).

Studying Earth's Environment From Space

EXAMPLE

...Title of procedure...

1. Insert ...

2. Select ...

3. Go to:

    <i2kinstalled>| *data* | *SEES* | Ozone | ozex1 | GA801001.N7T

4—Click on ...

---

computer and *NASA Image2000* materials are referenced from the location of your *NASA Image2000* installation. The path is depicted as follows:

> *<i2kinstalled>*| data | SEES | <module> | <exercise name> | <file name>

In addition, notes, specific tasks and exercises are presented in the left column (see example at left).

For Further Research:

Total Ozone Mapping Spectrometer (TOMS) Data Set for 1978-1993

TOMS ozone data in ASCII format is available from the TOMS website:

> http://toms.gsfc.nasa.gov/ozone/ozone01.html

Nimbus-7 TOMS 0_3 Gridded Data:1978-1993is available on a 2CD-ROM set which contains tthe latest version (version 7) of ozone data from the TOMS (Total Ozone Mapping Spectrometer) instrument onboard the Nimbus-7 spacecraft. Data covering the entire Nimbus-7 TOMS lifetime, November 1, 1978 through May 6, 1993 are given as daily files of gridded data, as zonal means, and as monthly averages.

How to use the SEES electronic text to support inquiry based exercises

In several of the computer lab exercises, questions will be asked of the user that can not be directly answered through the image analysis software and activites. These questions can be directed to the SEES electronic textbook. This electronic textbook is organized like a printed textbook. It also contains digital files for the graphics that you may either view directly on screen or obtain high-resolution versions for sending to a printer to make color view graphs for overhead projectors. A glossary for each module is also provided. The electronic textbook for each module can also be used to support lecture materials, independant student investigations, or other applications that may require more detailed scientific background.

Accessing the SEES electronic textbook

The SEES electronic textbook is available in two locations:

1) On the web at http://see.gsfc.nasa.gov/edu/SEES. From the home page, find the link "Class Resources" under the module you

Studying Earth's Environment From Space

are interested in. This will pull up the textbook homepage for that module. Links to each chapter are listed here, leading you to the detailed etext, digital files, and graphics you are searching for.

2)   On the CD "Studying Earth's Environment from Space, educational materials for students and teachers grades 11-16," available from the NASA CORE (Central Operation of Resources for Education), at http://core.nasa.gov or toll free 866-776-CORE. Once the CD is loaded on your computer, you can access the home page for the etext by going to sees_v1/htmlpages/index.html for ozone and global land vegetation modules and sees_v2/htmlpages/index.html for polar sea ice and oceanography modules.

If you have comments, problems, or suggestions, please e-mail helpdesk@see.gsfc.nasa.gov.

Studying Earth's Environment From Space

Exercise 1: Investigating Characteristics and the Display of TOMS Ozone Data

Before Beginning

- Make sure you have read through the Introduction to Module 1: Exploring Stratospheric Ozone Computer Lab Exercises document.

- Start *NASA Image2000*, or if it is already running close any open images

Overview

Before working with any set of data it is important to understand the characteristics of the data set. A knowledge of the data format, missing data, and data processing is critical to ensure correct scientific interpretation. In this activity you will investigate the way the TOMS Ozone data were formatted, problems that may arise when using the data set, and ways in which the data can be displayed using *NASA-Image2000*.

Investigating the TOMS Ozone Data Set Format

We will start by having you open the data files to see how the files are named, organized, and formatted. The header file contains information about each data set and is located in the first three lines of the data file.

E-TEXT Refer to etext on Nimbus 7 TOMS Ozone Gridded Data.

➡ Exercise 1.A

Open a TOMS ozone data file as a text file:

1. Pull down the **File** menu and choose **Open** or click on the Open icon on the toolbar.

    The Open window is displayed.

2. Locate and select the file:

    <i2kinstalled>| data | SEES | Ozone |ozex1 | GA801001.N7T

3. Check the **Open as Text** checkbox.

4. Click the **Open** button.

    The Text window is displayed with the data from file GA801001.N7T

➡ Do Exercise 1.A now.

Answer These Questions:

1. Supply the following information for the GA801001.N7T data set from the header information located in the first few lines.

    a. Day (out of 365) _____

       Date_____

    b. Time of day the satellite passed over the equator at local equator crossing time (LECT) ascending _____

    c. Longitude:

       starting to ending range _____

       center value _____

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

        degrees between values _____

    d. Latitude:

        starting to ending range _____

        center value _____

        degrees between values _____

2.   Which of these values (a–d) above will change with each data set?

3.   Scroll down the file to look at the data values. Periodically you will see a "lat= " with a value. This marks the end of a row of data for a particular latitude.

    a. Based on the longitude range and degrees between values, how many pixels (data values) are in a row?
        * The number of pixels in a row or column are notated in the header as "bins".

    b. How many rows will there be?

4.   a. What are the units of the measurements? _____

    b. Define this unit for STP (Standard Temperature and Pressure) conditions?_____

    c. What is the range of values?_____

5.   When you look at the gridded data you will notice zero values.

    a. What do the zero values represent?

    b. Give two possible reasons for zero value data.

Close the text window by clicking OK.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Displaying TOMS Data Using NASA-Image 2000

Overview

Now lets display a gridded daily (GA) TOMS data set as a gray-scale image, using the Image2000 software.

Do Exercise 1.B now.

Exercise 1.B

Open a TOMS ozone data file as an image file:

1. Pull down the **File** menu and choose **Open** OR

   Click on the **Open** icon on the toolbar.

   The **Open** window is displayed.

2. Deselct the **Open as Text** checkbox.

3. Locate and select the file you wish to open:

   <I2KInstalled> | data | SEES | Ozone |ozex1 | GA801001.N7T

4. Click on the **Open** button.

   The data are displayed as a greyscale image.

You should now see a window with an image in shades of gray. You can view more information about the image and the specific pixel values using the **ImageInfo** window.

Move the cursor over the image. The information in the Image Info window updates as you move the cursor. Place the cursor at the center of the image. The Image Info window appears as seen in Figure 1.1
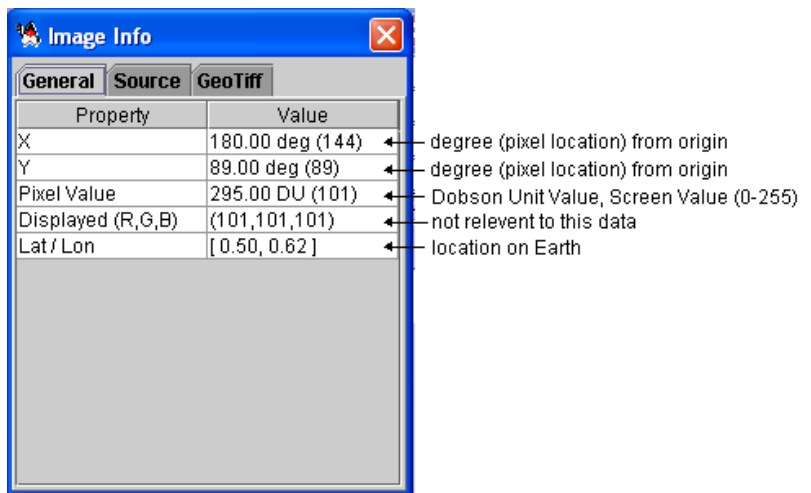
Figure 1.1: The Image Info window.

The coordinates of the image start at the origin, pixel 0,0 in the upper left corner. The image is 288 pixels wide (x) and 180 pixels tall (y). The degree value next to x and y corresponds to degrees from the origen. Since this is a global image it is 360 degress wide (circle) and 180 degrees tall (1/2 circle from North to South pole).

0°,0°
0,0

lat/lon 89.50, -179.38

359.75°,0°
287,0
89.50, 179.37

0°,179°
0,179
89.50,-179.38

358.75°,179.00°
287, 179
-89.50,179.37
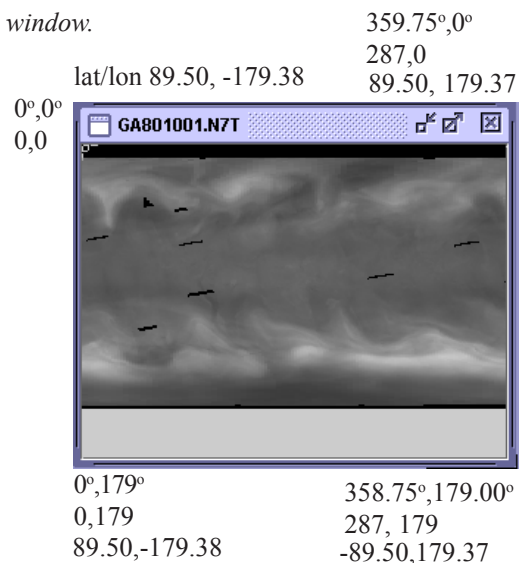
Figure 1.2: Image coordinates.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

In the next few steps you will be applying a color LUT and an overlay that will help you visualize this global data set.

To better distinguish value differences we can apply color to the image using a color table (or look-up table, LUT) that assigns a value or range of values to each color.

Exercise 1.C

Color the TOMS image using a Look Up Table (LUT):

1.   In the LUT window, click on the **Load** button.

     The Open window is displayed.

2.   Select "TOMS.lut"

4.   Click on the **Open** button.

     The LUT is displayed in the LUT window. The image is also updated to display the new colors.

5.   Select the **Use as Default** checkbox to keep this LUT active during your session.

Do Exercise 1.C now.

The image is now displayed in color.

Move the cursor over the LUT window. The Index value and the RGB values for each color definition are displayed. Now move your cursor over the actual image, and look at the number associated with Pixel Value in the Info window. These are the ozone values associated with each color.

Answer These Questions:

1.   Move the cursor to the bottom of the LUT window. What value is associated with black?_____

Actually, all values less than 93 will be displayed in black.

Move the cursor over the image and monitor the Value in the Image Info window. The value at each pixel corresponds to a data value in the data file you viewed earlier.

2.   What approximate range of values (excluding zero) is displayed on this image?

Investigating Potential Problems With TOMS Ozone Data Sets

Repeat Exercise 1.B:

Open the June 12, 1979 (GA790612), and the June 19, 1979 (GA790619), images:

>   *<I2KInstalled>* | data | SEES | Ozone | ozex1 | GA790612.N7T
>   *<I2KInstalled>* | data | SEES | Ozone | ozex1 | GA790619.N7T

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

---

Note:

The data files will open with the TOMS LUT applied if you perfomed step 1.C.5, as long as the LUT window remains open.

Answer These Questions:

E-TEXT   Refer to Nimbus–7 TOMS O 3 Gridded Data: 1978–1992 for information to help answer the following questions.

3.   a.   What do the black areas in all three images represent?

      b.   Explain the possible cause(s) for the large black region on the GA790619.N7T image.

      c.   What is the reason for the band of black at the top and bottom of GA801001.N7T and the bottom of GA790612.N7T and GA790619.N7T?

      d.   What caused the cigar shape black areas for GA790612.N7T?

Close only the GA790612.N7T and GA790619.N7T images when you are finished.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Adding Overlays and Viewing Different Map Projections

Overview

TOMS images have geocoded information, which allows you to apply various map projections.

In interpreting images it helps to have overlays that will aid you in locating yourself geographically on the image. For example, we can apply an overlay with the continental boundaries and longitude and latitude lines onto a TOMS image.

Graphic overlay in *NASA Image2000* is done in a non-destructive manner. In other words, when a graphic (i.e., lines, text, continental boundaries) is overlaid on an image the value of the pixels under the graphic are preserved. As a result, you can still perform image analysis after you have added text or graphics in the image window.

Exercise 1.D

Overlay the Continents On a TOMS Image:

1. On the Image Layers window, click the **Add…** button.

   The Open window is displayed.

2. Enter the following pixel value as the transparent pixel in the **Transparency** text field: **<255>**

2. Locate and select this file:

   <i2kinstalled> | data | SEES | Ozone | LATLONG.TIF

4. Click on the **Open** button.

   A grid of lat/long lines and the outline of major continents is displayed on top of the image.

5. In the Image Layers window, click on Layer 1 to activate the ozone data image.

Do Exercise 1.D now.

Place your cursor at x=144 and y=90. Where are you? You are as close to lat/lon=0,0 where the Greenwich Meridian (Longitude 0°) crosses the Equator. A grid of lat/lon lines and the outline of major continents is displayed on top of the image. Map Projections are used to represent a spherical object like the Earth on a flat surface such as paper or a computer screen. The overlay image of the continents is very distorted which is obvious when you look at the outline of certain countries on the image.

The surface area of a pixel on the equator ($\sim$15400 km 2) is much greater than the surface area of a pixel near the poles ($\sim$100km 2).

Using different map projections, we can greatly reduce these distortions.

Do Exercise 1.E now.

Answer these Questions:

1. Using the images and the section on "Working with map projections" in the *NASA Image2000 Users Guide*, explain the advantages and disadvantages of each projection.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Exercise 1.E

Generating Map Projections of TOMS Images

1   Click inside the window with the October 1, 1980, image (GM801001.N7T).

2.   Pull down the **Image** menu, select **Geometric Transformations> Projections>**, and choose the projections:

- Select **Goode.** No further parameters are necessary.

    The image is updated, with the Goode projection applied.

- Select **Hammer,** then enter <–100> for a reference longitude. (This is so the image will be centered on the U.S.) Click **OK**.

    You will see that the Hammer projection transforms the globe into a football shape.

- Select **Polar,** and choose the radio button for either the North or South Pole. Click **OK**.

    The image is updated, with the Polar projection applied.

Map Projection	Advantage	Disadvantage
Original		
Goode		
Hammer		
Polar		

Close all images when you are finished.

End of Exercise 1: Stratospheric Ozone Computer Lab Exercise 1

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

Exercise 2: Comparing Daily Ozone Values Over the Globe to the Daily Average and Investigating Ozone Distribution Patterns

Before Beginning

- Make sure you have read through the Introduction to Module 1: Computer Lab Exercises document.
- Start *NASA Image2000*, or if it is already running close any open images

Exercise 2.A

Open the September 1, 1991 image:

1. Pull down the **File** menu and choose **Open** OR

    Click on the **Open** icon on the toolbar.

    The **Open** window is displayed.

2. Locate and select the file you wish to open:

    <i2kinstalled>| data | SEES | Ozone | ozex2 | GA910901.N7T

3. Click on the **Open** button to open the image.

    The data are displayed as a greyscale image.

Exercise 2.B

Color the TOMS image using a Look Up Table (LUT):

1. In the LUT window, click on the **Load** button.

    The Open window is displayed.

2. Select "TOMS.lut"

4. Click on the **Open** button.

    The LUT is displayed in the LUT window. The image is also updated to display the new colors.

5. Select the **Use as Default** checkbox to keep this LUT active during your session.

Overview

There is variation in ozone values across the globe at any given time. In this exercise we will work with a single date TOMS image to investigate this variation. We will start by calculating the global average ozone for September 1, 1991. This global average ozone value will be used as a reference to compare with several ozone values in the image. We will then use a gridded monthly image to investigate some general characteristics of ozone distribution.

Do Exercises 2.A and 2.B now.

Calculating Global Average Ozone for September 1, 1991

A daily global average ozone value for an image is a single value that is the average of all the ozone values in that image. We can perform this calculation with the *NASA Image2000* Measure operation. When performing measurements to determine an average, all pixel values are treated as representing equal areas. Because this is not an equal area image (the surface area of a pixel on the equator (~15400 km 2) is much greater than the surface area of a pixel near the poles (~100 km 2), some error is introduced into the calculation of the global average ozone value. We will not try to correct for this during this exercise since we are interested in relative values and patterns of ozone distribution. All pixels with no-data values are ignored when using this operation so they do not add error.

Would you expect significant changes in daily global ozone values within a year or between years? Explain.

Normally, the daily global average ozone value would not be expected to change significantly on any given day throughout the year or between different years.

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

Exercise 2.C

Calculating An Average:

1. Select the GA910901.N7T image (September 1, 1991).

2. Pull down the **Image menu** and choose **Analysis>Measure**, or select the Measure icon from the icon bar.

   The image mean and standard deviation are displayed in the Image Info window.

3. Record the mean value.

Exercise 2.D

Add an overlay of continents on the image:

1. On the Image Layers window, click the **Add…** button.

   The Open window is displayed.

2. Enter the following pixel value as the transparent pixel in the **Transparency** text field: **<255>**

3. Locate and select this file:

   <i2kinstalled> | data | SEES | Ozone | LATLONG.TIF

4. Click on the **Open** button to apply the overlay to the image.

5. In the Image Layer window, select Layer 1 to activate the information associated with the image layer.

TIP

If you are only seeing values of 0 or 255 you misssed step 2.D.5 that allows you to view the image pixel values.

Do Exercise 2.C now.

Global Average Ozone Value_____

Comparing Individual Pixels to theDaily Global Ozone Average

The value generated above is the daily global average ozone value for this day. We can compare this value with individual ozone values at various locations to see if they are greater than or less than the global average.

To add points of reference we will apply an overlay to the image before continuing.

Do Exercise 2.D now.

On this overlay latitude lines appear at 30° intervals; lines of longitude appear at 60° intervals. For purposes of this exercise we will define the region from 60–90° latitude as polar, 30–60° as midlatitude, and 0–30° as tropical.

Answer These Questions:

1. Move the cursor onto the colored portion of the image and look at the Info window for the number after Pixel Value. This number is the ozone value in Dobson Units (DU) for the pixel under the cursor. What do areas of black represent?

2. Compare the values of individual pixels at different locations with the global average. Record the general latitudinal region the pixel falls in (north or south polar, north or south mid-latitude, north or south tropical), the associated ozone value in Dobson Units (DU), and whether the value for the pixel is above, below or roughly comparable (± 10 DU) to the daily global average value for the same day. *(Complete table on following page..)*

Comparing Daily Ozone Values Over the Globe to the Daily Average and Investigating Ozone Distribution Patterns   Exercise 2, page 3

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

TIP

You can simplify the process of locating specific pixel locations by using the "Go To" tool from the Tools Window.

1. Select the Fine Cursor Movement tool from the Tools Window.

2. Double-click on the image.

   The Go-To (X,Y) window is displayed.

3. Enter the desired pixel locations in the X and Y text fields, then click the **Go To** button.

   The cursor is placed at the specified location, allowing you to refer to the Image Info window to determine pixel information.

Pixel Location (X,Y)	Latitudinal Region	Ozone Value (DU)	Comparison to Global Value (higher, lower, same)
10,15			
125,20			
50,75			
62,72			
15,95			
230,100			
20,130			
100, 145			
185,145			

3a. What color or color ranges are associated with the following.

daily global average (± 10) _____

values above the global average _____

values below the global average _____

3b. Is there a pattern of distribution for the ozone values? Explain.

3c. Where are the areas containing the highest and lowest values located? Is this expected? Explain.

Close the GoTo window, and then close the GA910901.N7T image when you are finished.

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

Observing Patterns in Ozone Distribution

Exercise 2.E

Open the September monthly image, and apply the LUT:

1. Pull down the **File** menu and choose **Open** OR

    Click on the **Open** icon on the toolbar.

      The **Open** window is displayed.

2. Locate and select the file you wish to open:

    <i2kinstalled>| data | SEES | Ozone | ozex2 | GM9109.N7T

3. Click on the **Open** button to open the image.

4. If you do not have the TOMS LUT active please do Exercise 2.B now.

You probably noticed some patterns in the ozone distribution from the September 1, 1991 image. To investigate this further we will use a gridded monthly image for September 1991 that is generated from the September 1991 daily images. We will interpret the image with an overlay.

Do Exercise 2.E now.

Observe the September 1991 image with overlay (GM9109.N7T)

Because we will need to use the September 1991 image without an overlay later in this exercise, we will make a copy of it before applying the overlay.

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

EXERCISE 2.F

Making a copy of the September 1991 image

1   Select the September 1991 image (GM9109.N7T)

2.   Pull down the **Edit** menu and choose **Duplicate Image**.

> This will duplicate the image and will append "Copy" to the title in the new image window.

EXERCISE 2.G

Adding an overlay of continents on an image:

1.   Make sure the original image is selected, and on the Layers window, click the **Add…** button.

> The Open Layer window is displayed.

2.   Enter the following pixel value as the transparent pixel in the **Transparency** text field: **<255>**

3.   Locate and select this file:

> *<i2kinstalled>* | data | SEES | Ozone | LATLONG.TIF

4.   Click on the **Open** button.

> The overlay is applied to the image.

5.   To restore the image info and the LUT, click on Layer 1 in the Image Layers window.

TIP

To see features better, select the **Zoom In** Tool .

Click once inside the GM9109.N7T image. You will now see an image twice as large as the original.

You can return the image to its normal size by using the **Zoom Out** Tool.

Do Exercises 2.F and 2.G now.

Answer These Questions:

1a.   Do you see a pattern of distribution of ozone values in a north-south or east-west direction?

1b.   What is the basis for the pattern?

To enhance any patterns we can highlight a range of ozone values using density slicing tool. Density slicing allows the user to take a range of values (block of values) and assign a color to them. The default color is red. The LUT Tool can be used to manipulate the density slice when density slicing is enabled.

First we will define a range of 50 values by moving the upper and lower boundaries of the density slice. The boundaries can be monitored in the Info window. We will use the default color red for the color block. Then we will move the density slice block up and down the LUT window, which will change the upper and lower boundaries of the values that we are interested in highlighting in red.

EXERCISE 2.H

To perform density slicing on a LUT:

1. While viewing the LUT, click on the Slice button.

    The Density Slice Editor window is displayed.

2. Identify the range of pixels you wish to edit, either by editing the Start Index (enter <100>) and End Index (enter <150>) text fields, or by moving the range sliders in the LUT window.

3. Close the Density Slice Editor window when you are satisfied with the changes.

Do Exercise 2.H now.

Move the density slice color block to the top of the LUT window by clicking on the block of red and holding the mouse button down (you will see a hand). Slowly drag it toward the bottom. As you drag the density slice region down the color bar, you will highlight regions with ozone values within a range of 50 DU. The Density Slice Editor shows you the changing starting DU values and ending DU values.
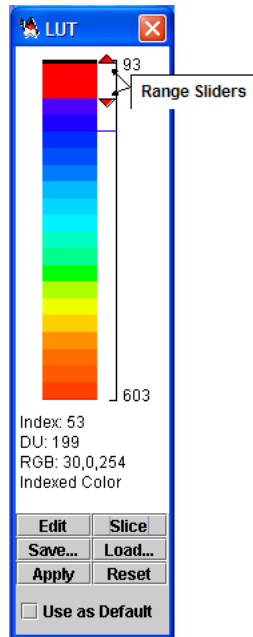
Answer These Questions:

2a.   Record the range of ozone values in Dobson Units for the regions with the following characteristics.

    highest DU values (last appearance of red)_____

    lowest DU values (first appearance of red)_____

    most area highlighted (greatest amount of red) _____

2b.   Does the range of values for the areas with the most highlighting correspond to the global average ozone value? Explain.

2c.   How do the ozone values in the tropical regions compare to northern high latitude values? to southern high latitudes? to the polar regions?

Observing Ozone Values Over Areas of High Elevation

Would you expect the ozone values to be higher over mountains or valleys? Explain.

To investigate possible differences, we can use the density slice tool.

Select the GM9109.N7T image. Delete the current density slice (in the density slice editor) and change the width of the density slice color block as you did in procedure 2.H so that the difference between the upper and lower limit is 20. (Use 100 for the start DU and 120 for the end DU.) Move the density slice color block to the top of the LUT window and then slowly drag it toward the bottom.

Observe the LUT display. When the lower slice value reaches about 251 you will notice an oblong shape north of India.

Answer These Questions

3a.   Are the ozone values for this area higher or lower than the surrounding areas?

3b.   What Earth surface feature(s) might this correspond to?

Drag the color block until the start DU is about 237 and you will you will notice a banana shaped object at the northwest coast of South America.

4a.   Are the ozone values for this object higher or lower than the surrounding areas?

4b.   What does this feature represent?

5.   What general statement can you make regarding the ozone values over high topographic regions compared to lower elevations? Why might this be true?

Observing a Phenomenon Related to Continental Margins

The TOMS LUT displays a range of ozone values (25 DU) with a single color. We can display the TOMS data with a color table that utilizes more hues such as "Spectrum". In this table each color represents a narrower range (2 DU) of ozone values.

Exploring Stratospheric Ozone using TOMS ozone data—Computer Lab Exercises

EXERCISE 2.I

Apply a new Look Up Table:

1. Select the image Copy you made in Exercise 2.F. Pull down the **View** menu and select **Lookup Table (LUT)**

    The LUT window is displayed.

2. Click on the **Load** button.

    The Open File window is displayed.

3. Select "Spectrum.lut"

4. Click on the **Open** button.

    The new LUT is displayed in the LUT window and the image is also updated to display the new colors.

Do Exercise 2.I now.

Select the GM9109.N7T image and return it to normal size if necessary with the Magnifying Glass Tool. Place the image next to the "GM9109.N7T Copy" image for land mass reference.

Answer These Qustions:

6.   Examine the "GM9109.N7T Copy" image. Can you see any patterns in ozone distribution that follow land masses? Why might they exist?

International ozone researchers have noticed that when they apply a rich color palette (more than 500 hues) to monthly mean (average) global data they can see the contours of continents appear as "ghost" images. You can see some of this effect using the Spectrum LUT. In fact, researchers call this the GHOST (Global Hidden Ozone Structures from TOMS) effect. They are still trying to determine the causes for this effect.

Close all images when you are finished.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Exercise 3: Comparing Polar and the Tropical Monthly Ozone Distributions Through Histograms

Before Beginning

- Make sure you have read through the Introduction to Module 1: Computer Lab Exercises document.

- Start *NASA Image2000*, or if it is already running close any open images

Exercise 3.A

Open the June, 1991 image:

1. Pull down the **File** menu and choose **Open** OR

   Click on the **Open** icon on the toolbar.

   The **Open** window is displayed.

2. Locate and select the file you wish to open:

   <i2kinstalled>| data | SEES | Ozone | ozex3 | GM9106.N7T

3. Click on the **Open** button.

   The data are displayed as a greyscale image

Exercise 3.B

Color the TOMS image using a Look Up Table (LUT):

1. In the LUT window, click on the **Load** button.

   The Open window is displayed.

2. Select "TOMS.lut"

4. Click on the **Open** button.

   The TOMS LUT is displayed in the LUT window. The image is also updated to display the new colors.

5. Select the **Use as Default** checkbox to keep this LUT active during your session.

Overview

Patterns of ozone distribution differ between the polar and tropical regions. One way to analyze this difference is to compare histograms from each region. In this exercise we will define an area within the tropics and an area within the north polar region and compare histograms to look at differences and similarities in ozone distribution.

A histogram is a plot of the frequency of occurrence of a value (y axis) against the value (x axis). If we generate a histogram for a TOMS image, it provides the number of pixels in a image for specific values in Dobson Units (DU).

For this exercise we will define the polar region within the Arctic circle, and the tropical region as the area between the Tropic of Cancer and the Tropic of Capricorn and generate histograms for each region. Some error will be introduced because the pixels in the image we are using do not represent the same area on Earth. However, since we are looking at relative distributions of values, we will not correct for this distortion for this exercise.

Do Exercises 3.A and 3.B now.

NASA Image2000 automatically opens TOMS images using geographic properties so that the Image Info window indicates the latitudes and longitude. We will use this information to determine pixel boundaries for each region on the image and will use the Rectangle Selection Tool to outline the region. It is useful to know that the upper left corner of an image has a pixel value of 0,0, and the TOMS images are 288 pixels wide by 180 pixels tall.

The Tropic of Cancer and Tropic of Capricorn correspond with latitudes of 23.5° N and 23.5° S respectively. The latitude for the Arctic circle is 66.7° N. Since these features span the globe we can use any longitude to pinpoint them but we will use a longitude of −180° to locate where the features begin at the left side of the image.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

EXERCISE 3.C

Locate regions on an image:

1. Pull down the **View** menu and select **Image Info.**

    The Image Info window is displayed.

2. Move your cursor over the image until the latitude = 66.7 and the longitude = −180.

3. Enter the X and Y values from the Info window for the Arctic circle.

4. Repeat 1–3 using latitude = 23.5 and longitude = −180 for the Tropic of Cancer.

5. Repeat 1–3 using latitude = −23.5 and longitude = −180 for the Tropic of Capricorn.

EXERCISE 3.D

Define an Arctic region of interest using the rectangle selection tool:

1. Select the Rectangle Selection Tool (dashed rectangle in the Tools window).

2. Move the cursor to X=0, Y=0 and click and hold the mouse button. While holding the mouse button down, move the mouse until the Width and Height are 288 and 23 respectively then release the mouse button. If a "marching ants" style rectangle was not drawn, repeat the procedure.

EXERCISE 3.E

Generating a histogram for the Arctic region

1. Pull down the **Image** menu and select **Analysis> Histogram**.

    The Generate Histogram Operation window opens.

Do Exercise 3.C now.

Arctic circle   X= _____   Y= _____

Tropic of Cancer   X= _____   Y= _____

Tropic of Capricorn   X= _____   Y= _____

The width and height of the Arctic circle region on the image will be set at 288 wide and 23 pixels high respectively. The region between the Tropics of Cancer and Capricorn will be 288 pixels wide and 48 pixels high.

Do Exercise 3.D now.

Now that we have defined the Arctic region we can generate a histogram for the values within that region.

Do Exercise 3.E now.

The X-axis contains the ozone values and the Y-axis contains the number of pixels for a particular ozone value. To read the histogram information, select the histogram window. Move the cursor into the histogram window and move it over the black regions of the histogram. The histogram values are displayed. The first value indicates the ozone value and the second shows how many pixels there are for that Level. You can print this histogram by selecting **File>Print** .

Important Notes:

While you can open multiple histogram windows at a given time, these windows are only distinguished by the name of the image referenced. Therefore, if you generate a histogram for a second region of a given image, both histogram windows will be displayed with the same name.

You may wish to save the histogram as an image file with your own file name. Note that you will not be able to access the Count and DU values from that image file. Be sure to record any data you need from the histogram before saving it as an image.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

EXERCISE 3.E, cont...

2. Accept the default values in the Histogram and click **OK**.

3. Move the cursor over the histogram to view the DU value and pixel count.

EXERCISE 3.F

Defining a tropics region of interest using the rectangle selection tool

1. Select the Rectangle Selection Tool (dashed rectangle in the Tools menu).

2. Move the cursor to X=0, Y=66 and click and hold the mouse button. While holding the mouse button down, move the mouse until the Width and Height value in the Info window equal 287 and 48 respectively then release the mouse button.

EXERCISE 3.G

Generate a histogram for the tropics region:

1. Pull down the Image menu and select **Analysis>Histogram**.

2. Accept the default values and click **OK**.

Answer These Questions:

1. Sketch the histogram here or attach a print. On the histogram label: the minimum and maximum DU values; the DU value and Count for distinct peaks that characterize the shape.

Do Exercises 3.F and 3.G now.

2. Sketch the tropics histogram here or attach a print. On the sketch label: the minimum and maximum DU values; the DU value and count for the three largest peaks.

3. Why would the Antarctic region be a poor choice for study using this particular TOMS image (GM9106.N7T)?

Comparing Histograms of the Tropics and Polar Regions

Place the Arctic and Tropics histogram images side by side on the desktop. Use these and the data you recorded from them earlier:

Answer These Questions:

4a. Ozone value that has the greatest frequency for the

    Tropics_____   Arctic_____

4b. Range of ozone values for the

    Tropics_____   Arctic_____

4c. What are the major differences between the two histograms?

4d. What general observations can you make about the ozone values in the tropical region compared to the north polar region for this month?

Close all images when finished.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Exercise 4:Observing Global Seasonal Variations In Total Column Ozone Values Using Monthly Average Images

Before Beginning

- Make sure you have read through the Introduction to Module 1: Computer Lab Exercises document.
- Start *NASA Image2000*, or if it is already running close any open images

⬛➡ EXERCISE 4.A

Open a stack of daily images for January 1979, and color

1. Pull down the **File** menu and choose **Open** OR Click on the Open icon on the toolbar.

    The Open window is displayed.

2. Locate and select:

    <i2kinstalled> | data | SEES | Ozone | ozex4 | M7901

3. Click on the **Open** button to open the images in a stack.

    The Open Directory dialog opens.

4. Select the **Stack** radio button to open all 31 images.

5. Click on the **OK** button to continue.

    All 31 images are opened in a stack.

6. Pull down the **View** menu and select **Lookup Table (LUT)**.

    The LUT window is displayed.

7. Click on the **Load** button.

    The Open window is displayed.

8. Select "TOMS.LUT".

9. Click on the **Open** button.

10. Select the Use as Default checkbox to keep the LUT active during your session.

Overview

Do ozone values vary as the seasons change? To answer this question, we will compare total column ozone values at different times of the year. We will examine monthly average images for 1979 to observe global seasonal variations. We will finish the exercise by animating the images to visually observe the distribution of ozone values across the globe throughout the year.

To look at seasonal changes in ozone values it is useful to use monthly average images of TOMS data. The monthly average image is generated by averaging the value of each pixel for all days in a month. You can obtain this average image from a gridded monthly TOMS data set (a pixel must have a value recorded for at least 20 days within that month to be included) or use a *NASA Image2000* feature that can perform this operation. We will generate a monthly average first and compare it to the TOMS monthly average (GM) image.

Comparing Two Monthly Average Ozone Images And Daily Images

⬛➡ Do Exercises 4.A, 4.B, and 4.C now.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

EXERCISE 4.B

Calculate the Monthly Average of the January images:

1. Pull down the **Stack** menu and select **Statistics> Mean**.

    The Results Options window opens.

2. Select the radio button for **Maintain Current Calibration** and click **OK**.

    The new mean image for the stack is displayed (Mean from M7901)

EXERCISE 4.C

Open a TOMS monthly averaged image:

1. Pull down the **File** menu and choose **Open** OR Click on the **Open** icon on the toolbar.

    The **Open** window is displayed.

2. Locate and select:

    <I2KInstalled> | data | SEES | Ozone | ozex4 | GM79 | GM7901.N7T

3. Click on the **Open** button to open the image.

    The GM7901.N7T image is displayed.

Answer These Questions

1. Place the two monthly average images (Mean from M7901 and GM7901.N7T) next to each other. How well do the two images compare? What variations can you note?

Select the stack of images (M7901 1/31).

You can view the images in the stack sequentially by using the "slider" on the bottom of the stack image.

Move forward and backward through the stack observing the images. Compare the global monthly average images with the daily images. Ignore the no-data sections on the daily images.

2a.   What is the major difference evident in the monthly averages when compared to the daily images?

2b.   Based on your comparison, what do you think are the advantages and disadvantages of using monthly averaged data? (Consider global regions and smaller localized areas.)

Close all images and stacks of images before continuing.

Now that you have had experience calculating monthly average ozone images we will save time and use the TOMS monthly average images for the rest of this exercise.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Investigating Ozone Values from a Montage

EXERCISE 4.D

Open a stack of monthly images for January 1979:

1. Pull down the **File** menu and choose **Open**. The Open window is displayed.

2. Locate and select:

    <i2kinstalled>| data | SEES | Ozone | ozex4 | GM79

3. Click on the **Open** button.

    The Open window is displayed.

4. Select the **Stack** radio button to open the 12 images in a stack.

5. Click on the **OK** button.

    The images open in a stack named GM79 1/12.

EXERCISE 4.E

Color the stack of images a LUT :

1. Pull down the **View** menu and select **Lookup Table (LUT)**

    The LUT window is displayed.

2. Click on the **Load** button.

    The Open window is displayed.

3. Select "TOMS.lut"

4. Click on the **Open** button.

    The TOMS LUT is displayed in the LUT window and all of the images in the stack are updated with the new colors.

5. Select the **Use as Default** checkbox to keep this LUT active during your session.

EXERCISE 4.F

Applying an overlay to a stack of images:

1. Pull down the **Stack** menu and select **Overlays>Choose Overlays Transparent Pixel Value.**

    The Transparent Pixel Value dialog is displayed.

2. Enter <255> for the pixel value and click on the **OK** button.

Overview

You can create a montage of images from a stack, allowing you to compare each image to one another.

Do Exercises 4.D, 4.E, 4.F, and 4.G now.

Visually examine the montag of images. You will notice that in all of the images there are no-data areas that are black. Ignore these for the following questions.

Answer These Questions:

1a. What general statement can you make about the global distribution of ozone for any one of the images?

1b. Is a distribution pattern more prominent vertically (longitudinally) or horizontally (latitudinally)? Why do you think this is so?

As you move the cursor over areas in any of the images you will see an ozone Value (in Dobson Units) displayed in the Image Info window. You can determine the range of values associated with any color by moving the cursor over the desired color in the LUT window and reading the Value in the Image Info window.

2a. Determine the approximate maximum and minimum ozone values that occur for the year and note the associated image color.

    maximum_____   minimum _____

    color _____   color _____

2b. For purposes of this exercise we will define the region from 60–90° latitude as polar, 30–60° as midlatitude, and 0–30° as tropical. Which geographic regions show maximum change over the year? Why do you think this is so?

2c. Make a general statement about seasonal changes in ozone value for this year based on your observations of the montage.

Close the montage image window when finished.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

---

EXERCISE 4.F, con't...

3. Pull down the **Stack** menu and select **Overlays>Overlay from File**.

4. Locate and select the following overlay:

    <i2kinstalled> | data | SEES | Ozone | latlong.tif

EXERCISE 4.G

To create a montage from a stack and display the Image Info window:

1. Pull down the **Stack** menu and select **Montage…** .

    The Create Montage window is displayed.

2. Accept the defaults and click on the **OK** button:

    A new untitled montage image window opens.

3. Pull down the **View** menu and choose **Image Info**.

    The Image Info window is displayed.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Investigating Seasonal Ozone Changes Through an Animation

Overview

Animating the stack allows you to easily see changes to the ozone over time.

EXERCISE 4.H

To animate an open stack:

1. Pull down the **Stack** menu and select **Animate**…

   The Animate Stack window is displayed.
2. Keep the default setting and click on the **Start** button to start the animation.
3. To change the speed of the animatio, click the **Stop** button and change the settings. To restart the animation, click on the **Start** button.

Do Exercise 4.H now.

Answer These Questions:

1. After you have had a chance to look at the animation and move through the stack one by one, make a statement about whether your answers to seasonal changes are verified or if you wish to make changes after viewing the stack.

   See Stratospheric Ozone chapters 3 and 6 for further support to your conclusions.

Close all stacks and images when finished.

Exploring Stratospheric Ozone Using TOMS Ozone Data—Computer Lab Exercises

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Exercise 5: Comparing Spring Antarctic (14 Octobers) Ozone Values And Spring Arctic (15 Marches) Ozone Values

Before Beginning

•   Make sure you have read through the Introduction to Module 1: Computer Lab Exercises document.

•   Start *NASA Image2000*, or if it is already running close any open images

Exercise 5.A

Open a stack of images:

1   Pull down the **File** menu and choose **Open.**

2   Locate and select the directory you wish to use for the stack:

    <i2kinstalled> | data | SEES | Ozone | ozex5 | 14Octobers

3. Click **Open**. Be sure you do not enter the "14Octobers" directory.

    The "Open Directory" window opens.

4. Click on **Stack**, then click **OK**.

    All the images are displayed as a stack named 14 Octobers 1/14.

Exercise 5.B

Color the stack of images a LUT :

1. Pull down the **View** menu and select **Lookup Table (LUT)**

    The LUT window is displayed.

2. Click on the **Load** button.

    The Open window is displayed.

3. Select "TOMS.lut"

4. Click on the **Open** button.

    The TOMS LUT is displayed.

5. Select the **Use as Default** checkbox to keep this LUT active during your session.

Overview

There has been a significant amount of discussion of the variations in the size and extent of the Antarctic "ozone hole". By viewing a sequence of TOMS monthly averages for the spring Antarctic phenomena from October 1979 to October 1992, we will be able to observe how the size and shape of the ozone hole over the South Pole has varied. Then we will observe the Spring Arctic fluctuations in ozone for the monthly average data from March 1979 to March 1993 and compare it to Antarctic Spring ozone distributions.

Investigating Antarctic springs from a montage

October is a spring month for the southern hemisphere where seasons are reversed compared to the northern hemisphere. Observe the ozone distribution patterns in the southern hemisphere. Use the cursor to move over various pixels on the images to view ozone Values displayed in the Info window. Remember that black has a value of 93 and represents the no-data value—it should not be considered a minimum value.

Do Exercises 5.A, 5.B, 5.C and 5.D now.

Answer These Questions

1a.   What is the highest ozone value recorded on any image?

1b.   Where are the highest values concentrated on any of the images?

1c.   What is the lowest ozone value displayed on any image?

1d.   Where are the lowest values concentrated on any of the images?

E-TEXT   Stratospheric Ozone, Chapters 10 and 11.

1e.   Explain why you might expect to see this ozone distribution pattern.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Exercise 5.C

Applying an overlay to a stack of images:

1. Pull down the **Stack** menu and select **Overlays>Choose Overlays Transparent Pixel Value.**

    The Transparent Pixel Value dialog is displayed.

2. Enter <255> for the pixel value and click on the **OK** button.

3. Pull down the **Stack** menu and select **Overlays>Overlay from File**.

4. Locate and select the following overlay:

    <i2kinstalled> | data | SEES | Ozone | latlong.tif

Exercise 5.D

Create a montage of the 14 images

1   Pull down the **Stack** menu and choose **Montage**.

2   Enter 4 for columns, 4 for rows, and leave the rest at the default settings. Click **OK**.

2a.   Is there an obvious pattern or trend in the maximum and minimum values you observe while examining the montage of images? Explain.

2b.   What does this imply about southern polar spring ozone values during the period from 1979 to 1992?

2c.   What factors may be responsible for the changes with time? Explain.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Investigating Antarctic Spring Ozone Values From A Montage Of South Polar Map Projected Images

Overview

We can often see the patterns in data for a particular region more clearly by generating a projection that places the location we are interested in at the center of an image. In the next procedures we will generate and explore a South Polar map projection (placing the South Pole at the center) using the ozone data for Antarctic spring.

Exercise 5.E

Generate a South Pole map projection:

1   Close the montage and click on the stack of 14Octobers to activate that window.

2   Pull down the **Stack** menu and select **Project Stack>Polar**.

>   The Polar Projection window is displayed.

3   Enter "2" to select a South Pole projection and click OK.

Note:

If you plan to continue this exercise, please keep this stack of polar projected images open.

Exercise 5.F

Generate a montage of the stack of 14 projected images

1   Pull down the **Stacks** menu and choose **Montage**.

>   The Create Montage dialog window opens.

2   Leave the default settings and click **OK**

>   The montage image is displayed.

Do Exercises 5.E and 5.F now.

1a.   Would you say that there is a latitudinal distribution of ozone values? Explain.

1b.   What are the basic shapes of the most prominent features on a majority of the images?

1c.   What is the approximate range of ozone values associated with each feature?

1d.   Based on your answers above, what are these features?

1e.   Which year shows the lowest values of ozone along with largest circular feature size? Recall that you have sequential images for 1979 to 1992 displayed.

E-TEXT   See Chapter 11.

1f.   What is the cause of these features? Explain.

Investigating Ozone Feature Symmetry

We can use another tool of *NASA Image2000*, Profile (horizontal, vertical or segment), to investigate the symmetry of features on the individual images in this montage. In ozone studies the word "profile" refers to a plot of ozone as a function of altitude. For that reason we will call the selections we make "slices" to avoid confusion.

Do Exercise 5.G now.

Select the 1987 (#9) image on the montage and generate a horizontal slice across the prominent circular feature.

Answer These Questions

2a.   What is the source of the downward spikes on the profile? Should you consider them when interpreting the plot? Explain.

2b.   Is the feature reasonably symmetrical based on the horizontal slice? Explain.

2c.   Generate slice plots for the same feature with lines at varying angles. Try to keep each line passing through the same central point (approximate position of the South Pole). What can you say in general about the longitudinal symmetry of this feature based on this image?

2d.   Try the same technique for the same feature for several different years. Can you make a general statement about the symmetry of this feature?

Exercise 5.G

Plotting values for a slice across an Antarctic spring ozone feature

1   In the Tools window, click on the **Segment Profile Plot** tool (slanted line highlighted in yellow with an arrow pointing at the bottom end of the line).

2   Position the cursor at the start point where you want the profile line to be drawn, hold the mouse down and move to the end of where you want your profile. Release the mouse and the profile is drawn.

> When you release the mouse button the plot will appear showing the Dobson unit value for each pixel under the profile line.

Note

When you are done plotting profiles, in the tools window, click the arrow to return to the cursor mode.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Investigating The South Pole Projections Through Animation

We can investigate the ozone values at the South Pole through animating the projected stack.

➡️ Do Exercise 5.H now.

➡️ Exercise 5.H

Stack and animate the images

1. Click on the stack 14 Octobers to activate.

2. Pull down the **Stack** menu and select **Animate**…

    The Animate Stack window is displayed.

3. Enter "1" in the "Frames/Second(1-30) text box and make sure htere is a check-mark next to "Loop". Click on "Start" to begin the animation. To speed up the animation, click on "Stop", and then increase the number in the "Frames/Second(1-30) text box and click "Start" again.

Note:

To view the stack, image by image, stop the animation and close the animation window. Now press the left or right arrows on the lower left and right corners of the stack window. Each time you press these arrows the next (if you press the right arrow) or previous (if you press the left arrow) is displayed.

View it through several cycles. Stop the animation and use the "slider" tool at the bottom of the stack screen to move sequentially through the stacked images. Repeat these operations as necessary to answer the following questions. The title will be too long to display on the projected image stack so if you need know what year you are observing you should go to the top (1979) or bottom (1992) of the stack and count from there (or save the stack with a very short title).

Answer These Questions

Describe what happens to the following characteristics of the central circular feature in October from 1979 to 1992.

1a.   Size

1b.   Shape

1c.   Position with respect to Antarctica

2.   Do you see the same pattern of change with the banana shaped feature? Explain.

Investigating Ozone During Arctic Spring

Overview

A logical question is, "Can we see the same features or patterns in the northern polar regions during Arctic spring (March)?"

Answer These Questions

1. Do you think the features and patterns will be the same? Explain.

To uncover the answer to this question we need to repeat some of the same procedures using data from March while concentrating on the northern hemisphere

Repeat Exercises 5.A–5.C using the 15 images for March 1979–1993.

   <i2kinstalled> | data | SEES | ozone | ozex5 | 15Marches

2a.   What color represents the highest values of ozone in the northern hemisphere during Arctic spring?

   What range of values is associated with this color?

2b.   What year appears to have sustained the highest values over the largest area?

   What year shows the lowest values for ozone in the north polar region?

2c.   Is there an obvious pattern or trend in the ozone values you observe in the northern hemisphere while examining the montage of images for Arctic spring? Explain.

To see if features similar to the ones we saw in Antarctica during October exist during Arctic spring (March) we can generate a north polar map projection.

Activate the stack of March images.

Repeat Exercises 5.D and 5.E but enter "1" to generate a North Polar projection.

Simply select the radio button for North in the **Stacks** menu under

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

NOTE:

For comparison you may select the montoage of images for October, "South Polar 14 Octobers." You will have to move the montages to compare them. If you have a small screen you can reduce the size of the montages by selecting 'Edit/ Scale and Rotate' and entering 0.5 for the horizontal scale. Be sure that the Create New Window box is checked.

Project Stack>Polar.

3a.   Is a there a latitudinal distribution of ozone apparent from the images in the montage? Explain.

3b.   Are there prominent ozone distribution features comparable to the ones in the Antarctic? Explain based on size and shape.

3c.   How would you characterize the symmetry of the March ozone distribution? You can generate slices through the North Pole as you did in Exercise F for a number of the images to support your response. Be sure the line extends an equal distance in both directions from the pole. Because you will cross many no-data points, the slices will be noisier than before. Look at the general trend from one side of the resulting plot to the other to assess symmetry.

Close all montage windows.

Repeat Exercise 5.H.

Animate the North Pole 15 Marches stack and watch it through several cycles.

4a.   Is there a clear pattern to the ozone distribution that is more obvious from the animation? Explain.

Refer to Chapters 6 and 10.

4b.   Why do you think there is a difference in the ozone distribution in the northern and southern polar regions during their respective springs?

Close all images and stacks when finished.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Further Examination Of Differences Between Spring Arctic And Spring Antarctic Ozone Distributions

Before Beginning

- Make sure you have read through the Introduction to Module 1: Computer Lab Exercises document.
- Start *NASA Image2000*, or if it is already running close any open images

Exercise 6.A

Open and color multiple TOMS images

1   Pull down the **File** menu and select **Open**.

> The Open dialog is displayed.

2   Locate and select:

> *<i2kinstalled>*| data | SEES | Ozone | ozex6

3.   Click **Open**.

> The open window is displayed.

4.   Select **Stack** and click **OK**.

> The stack of images is displayed.

5.   Pull down the **View** menu and select **Look up Table (LUT)**

> The LUT window is displayed.

6.   Select the Use as Default checkbox to keep the TOMS LUT active.

7.   Pull down the **Stack** menu and select **Stack to Widnows>Image Alone**.

8.   Move the image windows so you can see each one.

Exercise 6.B

Generate histograms of global ozone data;

1.   Select the March 1979 image (GM7903.N7T) by clicking on it.

> *Continued on following page...*

Overview

To demonstrate how ozone is distributed and varies in the spring for either the North or South Pole we will compare March and October monthly images from 1979 and 1992. We will use histograms and profiles to look at distribution patterns and will generate ratio images to enhance regions of change between March and October of each year.

To explore seasonal distributions in total column ozone we can apply a valuable mathematical analysis tool called the histogram. A histogram is a plot of the frequency of occurrence of a value against the value. For TOMS images, it provides the number of pixels in a image with a given Dobson Unit (DU) value.

Investigating The March And October Histograms

Do Exercises 6.A and 6.B now.

This draws a histogram of the ozone values. The X axis contains the ozone values and the Y axis contains the number of pixels for a particular ozone value. To read the histogram information, move the cursor into the histogram window and view the results in the Info window. Level shows the ozone value and Count lists how many pixels there are for that Level. This histogram can be printed by selecting **File>Print**.

Answer These Questions:

1.   Sketch the histogram for March 1979 (or attach the printed histogram) below labeling the lowest and highest values and the values for any significant peaks. Supply the requested information in the table on the following page. Ignore the spike at 95 on the histograms. This represents the no-data or black areas on the image.

2.   Repeat Exercise 6.B and complete Question 1 for October 1979 (GM7910.N7T), March 1992 (GM9203.N7T), and October 1992 (GM9210.N7T). (Sketch or attach histograms)

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Exercise 6.B, con't...

2. Pull down the **Image** menu and choose **Analysis > Histogram**.

    The Generate Histogram Operation window is displayed.

3   Keep all of the settings as is (X-Period = 1, Y-Period=1, Number of bins = 256, Lowest value=0.0, and Highest value=256.0) and click **OK**.

4   Moving the mouse over the histogram will display the pixel value in DU on the x axis and the number of pixels with that value on the y axis.

Image	Most Frequent Ozone Value	Lowest Ozone Value	Highest Ozone Value	Range for ~75% of Pixels
March 1979 "GM7903.N7T"				
October 1979 "GM7910.N7T"				
March 1992 "GM9203.N7T"				
October 1992 "GM9210.N7T"				

3a.   Look at the sketches and data you recorded for the March and October 1979 histograms. What are the major similarities and differences between the two histograms?

3b.   Would you expect the histograms to be the same or different? Explain.

3c.   Does there appear to be a general spring pattern to the ozone value distributions? Explain.

3d.   Compare the March and October 1992 histograms. Is the pattern of distribution for 1992 similar to 1979? Explain.

3e.   Compare the two October histograms. What is the major difference between these two? What might account for this difference?

Close the Histogram windows when finished.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Comparing The March And October Profiles

Overview

We can plot pixel values for any line segment on the image we select using the profile tool. This can be useful for looking at latitudinal differences in ozone values on a TOMS image. In ozone studies the word "profile" refers to a plot of ozone as a function of altitude. For that reason we will call the selections we make "slices" to avoid confusion.

Exercise 6.C

Draw N-S ozone profiles

1 Select the March 1979 image (GM7903.N7T) by clicking on it.

2 In the Tools window click on the Profile Plot tool (vertical line highlighted in yellow with an arrow pointing at the right end of the line).

3 Position the cursor at the point the number 170 appears (the represents 170 pixels in from the left side of the image) and then click.

> When you release the mouse button the plot will appear showing latitude on the x axis and the DU value for each pixel on the y axis.

> This plot can be printed if desired by selecting **File > Print** or click on the Printer icon at the top of the NASA-Image2000 window.

Do Exercise 6.C now.

Answer These Questions:

1. Sketch the resulting plot or attach a print of the plot. Label the axes.

2. Repeat Exercise 6.C to generate plots for the following images.GM7910.N7T; GM9203.N7T; GM9210.N7T. Sketch the plots.

[E-TEXT] Refer to Stratospheric Ozone Chapters 6 and 11.

3a. Why is there a steep rise at the beginning and end of each plot? Should it be considered when interpreting the plot? Explain.

3b. Compare the two March slice plots. Are they similar in shape. Is this expected? Explain.

3c. Explain why the maximum values fall where they do on both March plots.

4a. Are the plots for the two Octobers the same? Explain.

4b. What is evident on the October 1992 plot that is not present in October 1979?

FYI

The plot profile window can also be save as an image by selecting **File > Save As** and entering a file name.

TIP

When you are done with the profile tool you may select the arrow tool to get back into cursor mode.

Close the Plot window when finished.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Investigating A Ratio Image

Exercise 6.D

Produce a ratio of two images to visualize seasonal change:

1   Pull down the **Image** menu and choose **Math >Calculator**.

2   Select the March image (GM7903.N7T) from the upper most ("Image 1") drop-down menu. Select the October image (GM7910.N7T) from the second ("Image 2") drop-down menu.

3   Enter the following values/choices:

   • Select "Divide" from the "Operation" drop-down menu.

   • Enter "1" in the box next to the three "Scale" ("Scale 1", "Scale 2", and "Scale 3") text-boxes since we do not want to multiply the result by a constant.

   • Enter "0" in the "Offset" text-box next to the plus sign (+) since we don't want to add a constant to the resulting image.

   • Type "March/October 1979" in the "Result Name" text-box next to the equal sign (=). This will be the name of the output image.

   • Select the Real Result check box (click on the box to put a check-mark in the box) since the resulting image pixel values will be outside the 1–254 range.

   • Click **Execute** to perform the division.

   A new image window is displayed.

4   Pull down the **View** menu and select **Look-Up Table** to view this image with a color table that will enhance differences.   Load the SpecialRatio.lut

Overview

Another image processing technique used to visualize the difference between two images involves determining the ratio of the images. Since each pixel represents a value, we can compute a ratio of each corresponding pixel to produce another image. The result is an image where numbers greater than one indicate areas where the numerator image had a higher value and numbers less than one indicate areas where the denominator image had a higher value. The further the resulting value is from one, the greater the difference between the two images.

We will ratio the March and October 1979 images.

E-TEXT   Refer to Chapters 6 and 11.

Do Exercise 6.D now.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

To determine the approximate latitude ranges for certain values we can apply an overlay that has latitude and longitude lines.

Exercise 6.E

Apply a latitude/longitude overlay

1   Click on the "March/October 1979" image to select it.

2   In the "Image Layers" window click on **Add**.

    The Open dialog window opens.

3   Enter "255" in the "Transparency" text-box then

4. Locate the following file:

    <i2kinstalled> | data | SEES | Ozone | LATLONG.tif

5. Click **Open**.

    The continents overlay will overlay the TOMS image.

Do Exercise 6.E now.

Move the cursor over the pixels in the ratio image March/October 1979 and note the values in the Info window. Each value is the ratio for that pixel.

Answer These Questions:

1a.   What color range represents values greater than 1?

1b.   What color range represents values less than 1?

1c.   What latitude range (north or south polar, north or south midlatitude, tropical) shows values higher than 1?

      Why would you expect this?

1d.   What latitude range shows the least difference in ozone values from March to October? Explain why.

Keep the ratio image open.

Comparing Ozone Values In March 1992 To October 1992

Would you expect the same ratio values if you compared March and October data from 1992? Explain why or why not.

To test your hypothesis do the comparison of the March and October 1992 images.

Repeat Exercises 6.D and 6.E using March 1992 (GM9203.N7T) and October 1992 (GM9210.N7T).

2.   Do you see the same latitudinal trend in the 1992 ratio image as in the 1979 ratio image? Explain.

3a.   Where are the most significant changes in the ratio values from 1979 to 1992?

3b.   What is responsible for these changes?

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

4.   Suggest another ratio that might provide useful information using the images in this exercise and try it out. Explain what you expected, did, and what the results were in the space below.

Close all images when finished.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Using Monthly And Annual Averages To Monitor Seasonal Changes In Total Column Ozone For 1979 And 1992

Before Beginning

• Make sure you have read through the Introduction to Module 1: Stratospheric Ozone Computer Lab Exercises document.

• Start *NASA Image2000*, or if it is already running close any open images

Exercise 7.A

Open a stack of images:

1. Pull down the **File** menu and choose **Open.**

2. Locate and select the directory you wish to use for the stack:

   <i2kinstalled> | data | SEES | Ozone | ozex7 | GM92

3. Click **Open**. Be sure you do not enter the "GM92" directory.

   The "Open Directory" window opens.

4. Click on **Stack**, then click **OK**.

   All the images are displayed as a stack named GM92 1/14.

Exercise 7.B

Color the stack of images a LUT :

1. Pull down the **View** menu and select **Lookup Table (LUT)**

   The LUT window is displayed.

2. Click on the **Load** button.

   The Open window is displayed.

3. Select "TOMS.lut"

4. Click on the **Open** button.

   The TOMS LUT is displayed.

5. Select the **Use as Default** checkbox to keep this LUT active during your session.

Overview

In Exercise 4 we used the monthly average images of TOMS total column ozone values from 1979 to observe the seasonal fluctuations of atmospheric ozone values. In this exercise we will observe seasonal changes in the monthly average images for 1992 and compare these to 1979.

Do Exercises 7.A, 7.B, 7.C and 7.D now.

Investigating Average Monthly Ozone Values For 1992 Through Animation

Animate or move sequentially through the GM92 stack and observe the monthly average images.

Answer These Questions:

1. Do the same seasonal changes appear to be happening in the northern and southern polar regions? Use the colors (or ozone values) to justify your answer.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

Exercise 5.C

Applying an overlay to a stack of images:

1. Pull down the **Stack** menu and select **Overlays>Choose Overlays Transparent Pixel Value.**

    The Transparent Pixel Value dialog is displayed.

2. Enter <255> for the pixel value and click on the **OK** button.

3. Pull down the **Stack** menu and select **Overlays>Overlay from File**.

4. Locate and select the following overlay:

    <i2kinstalled> | data | SEES | Ozone | LATLONG.tif

Exercise 7.D

Stack and animate the images

1. Pull down the **Stack** menu and select **Animate**…

    The Animate Stack window is displayed.

2. Keep the default setting and click on the **Start** button to start the animation.

3. To change the speed of the animatio, click the **Stop** button and change the settings. To restart the animation, click on the **Start** button.

Investigating Ozone Values From A Montage

To compare seasonal distributions of ozone in 1992 to 1979 it will be useful to generate a montage of the 12 images and compare this to the montage you saved for the 1979 images in a previous exercise.

→ Do Exercise 7.E now.

Visually examine the 1992 montage images. You will notice that in all of the images there are no-data areas, which are black. Ignore these for the following questions.

Answer These Questions:

[E-TEXT]   Refer to Stratospheric Ozone chapter 3.

2a.   What general statement can you make about the pattern of global ozone distribution for any one of the images?

2b.   Is a distribution pattern more prominent zonally (east-west along a line of latitude) or meridionally (north-south along a line of longitude)?

Why is this so?

As you move the cursor over areas in any of the images you will see an ozone value (in Dobson Units) displayed in the Info window.

3a.   Determine the approximate maximum and minimum ozone values that appear for the year and note the associated image color. You may wish to record the minimum and maximum values for several month to help determine the yearly low and high values.

(1 = January, 2 = February, 3 = March...)

maximum _____   minimum _____

color _____   color _____

Which geographic regions (north or south polar, north or south

---

→ Exercise 7.E

Making a montage of the images

1   Pull down the **Stacks** menu and choose **Make Montage**.

2   Enter '3" for columns, "4" for rows, "1" for increment and leave the rest at the default settings. Click **OK**.

3   Pull down the **File** menu and choose **Save**.

   The Save File dialog is displayed.

4.   Select TIFF format and save the image in the following location, as "Montage92".

   <i2kinstalled> | data | SEES | Ozone | Ozone_Answers

FYI:

Open the View>Image Info window to display the DU values as you examine the images.

Using Monthly And Annual Averages To Monitor Seasonal Changes In Total Column Ozone For 1979 And 1992   Exercise 7, page 4

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises

midlatitudes, tropics) show maximum change over 1992? Why do you think this is so?

3b.   Make a general statement about seasonal changes in ozone values for this year based on your observations of the montage.

Comparing 1992 To 1979 Monthly Average Ozone Values From Montages

➡️ **Do Exercise 7.E now.**

Depending on the size of your display monitor, you may have to move the two montage images for comparison as you answer the next questions.

Answer These Questions:

4.   Compare the first four months in the northern hemisphere on both montages. What can you say about the change in ozone values from 1979 to 1992 for this region?

5.   Look at all the months on both montages for the tropical regions. Has there been a change in the ozone values?

      Explain.

6.   Move the cursor over various regions on both montages and look at the corresponding ozone values in the Info window. Remember that the value will have meaning only if the window you are investigating with the cursor is selected. What region has experienced the most significant change from 1979 to 1992?

      Explain your answer based on ozone values.

Exercise 7.F

Opening the 1979 montage image

1.   Pull down the **File** menu and choose **Open**.

      The Open dialog is displayed.

2.   Locate the following file and click **Open**:

      <i2kinstalled> | data | SEES | Ozone | ozex7 | Montage79

      The montage image is displayed.

Close both montages when you are finished but keep the stack (GM92) open. Do not save changes unless directed by your instructor.

Investigating Monthly Average Images And A Yearly Average Ozone Image

7.   It is possible to compute a yearly average image using the monthly average images. Based on what you have generated previously, what might you expect to see on an image that represents a yearly average? Explain.

↱ Exercise 7.F

Create a yearly average image from the monthly averaged images:

1   Select the GM92 stack by clicking on the stack.

2   Pull down the **Stack** menu and choose **Statistics > Mean**.

      If the color LUT is not active, repeat Exercise 7.B

      The Results Options window is displayed.

3.   Select the "**Maintain Current Calibration**" radio button and click **OK**.

Note:

Although the procedure in Exercise 7.F does calculate an average of the 12 monthly averages, it does not calculate the "true" yearly average. The result of this calculation is sufficient for our purpose to illustrate differences in average yearly ozone from year to year. The "true" yearly average would need to be calculated using all of the daily images for a particular year. This is possible using Image2000; however, the memory requirements are quite high.

↱ Do Exercise 7. F now.

Using the "slider", move through the 1992 monthly average stack (GM92) Compare each monthly image with the yearly average image (GlobalAve92).

Answer These Questions:

8a.   How does the GlobalAve92 image compare to the monthly images? Explain.

8b.   How did your prediction of what the yearly average image would look like compare to the actual image? Explain.

8c.   In general, how do the yearly average ozone values vary over the globe? Do significant hemispheric differences exist? Explain.

Close all stacks and images when finished.

Exploring Stratospheric Ozone Using Toms Ozone Data—Computer Lab Exercises