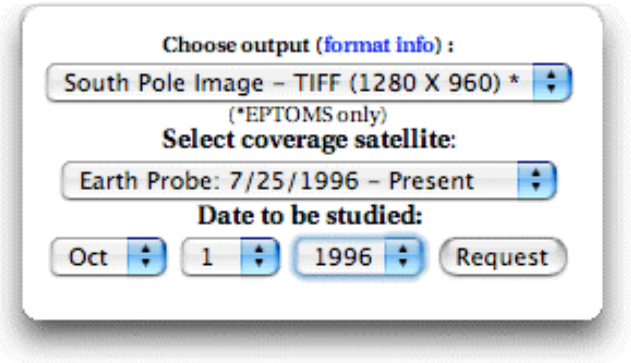
Analyzing the Antarctic Ozone Hole

http://serc.carleton.edu/eet/ozonehole/index.html

Part 1-Download Images and Software

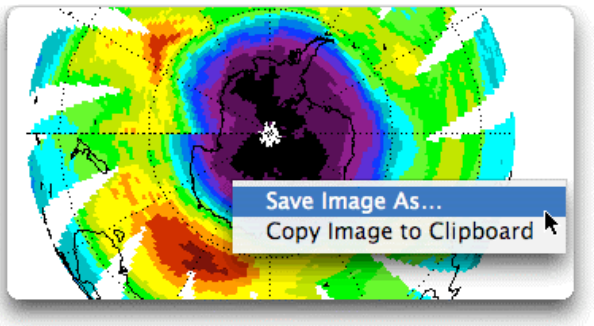
Step 1-Request and Download Ozone Images

Go to the Total Ozone Mapping Spectrometer (TOMS) site (http://toms.gsfc.nasa.gov.ozone.ozone.html) to download ozone images.



1. Near the bottom of the TOMS page, under "Choose output," click the drop-down menu and choose **South Pole Image - TIFF (1280 x 960)**.
2. Under "Select coverage satellite," click the drop-down menu and choose **Earth Probe: 7/25/1996-Present**.
3. Under "Date to be studied," set the fields to **Oct 1, 1996**.
4. Click the **Request** button.
5. When the image appears in your browser window, right-click it (or ctrl-click on Macs) and select the "Save image as" option. Save the image in a new folder named "TOMS Images" on your hard drive. Keep the default name for the image, or give it a name that includes the date it represents.

Show me how



- Right-click the image (Mac users-hold down the ctrl key and click) to display a menu of choices. Select the **Save Image As...** or **Download Image to Disk** option to store the image on your computer.
- When prompted for a location to store the image, make a new folder named TOMS Images. Keep the default image name (it tells the date), and click **Save**.
- A TROUBLESHOOTING NOTE: Some browsers appear to display TIFF images within Quicktime, and Save as... is not an option. If

this is the case for you, go to http://serc.carleton.edu/files/eet/ozonehole/ozone_tiffs_z.zip to download a zipped file that contains all the images. If the zipped file does not decompress automatically, double-click the file to invoke your computer's decompression software.

6. After you've downloaded the first image, click your browser's **Back** button. Under "Date to be studied," change the year to 1997. Click the Request button again, then save the next image to your hard drive.
7. Repeat step 6 until you've requested and saved TOMS images of October 1 for every year from 1996 through 2004.

Show me some troubleshooting tips

- Seeing the images in your browser window isn't sufficient. You must download and save each of the images to your hard drive. This is necessary so you will be able to open the image files within the image processing software in Part 2.

Step 2-Download and Install ImageJ Software

The ImageJ program is in the public domain. It can be freely downloaded and installed on any computer including those at schools, homes, and businesses.

Open the ImageJ download page (http://rsb.info.nih.gov/ij/download.html) in a new window. Download the file for your computer's operating system and install the software on your hard drive.

Show me how

1. Click the link above to open the ImageJ. Download page in a new window.
2. On the ImageJ download page, click the link that appears directly below the name of your computer's operating system (Mac, Windows, Linux). This action will transfer a compressed file of the software to your computer. Your browser should automatically expand the file, creating an ImageJ folder on your computer's hard drive.

For more detailed instructions from the ImageJ website, click Installation Instructions (http://rsb.info.nih.gov/ij/docs/install) then select your operating system.

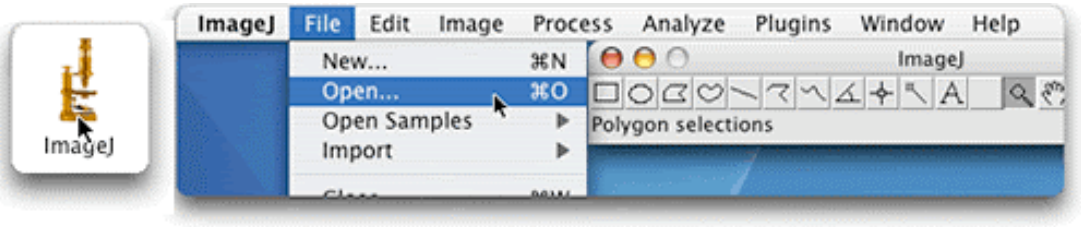
Part 2-Open and Explore Ozone Images .

Step 1-Open Images in ImageJ

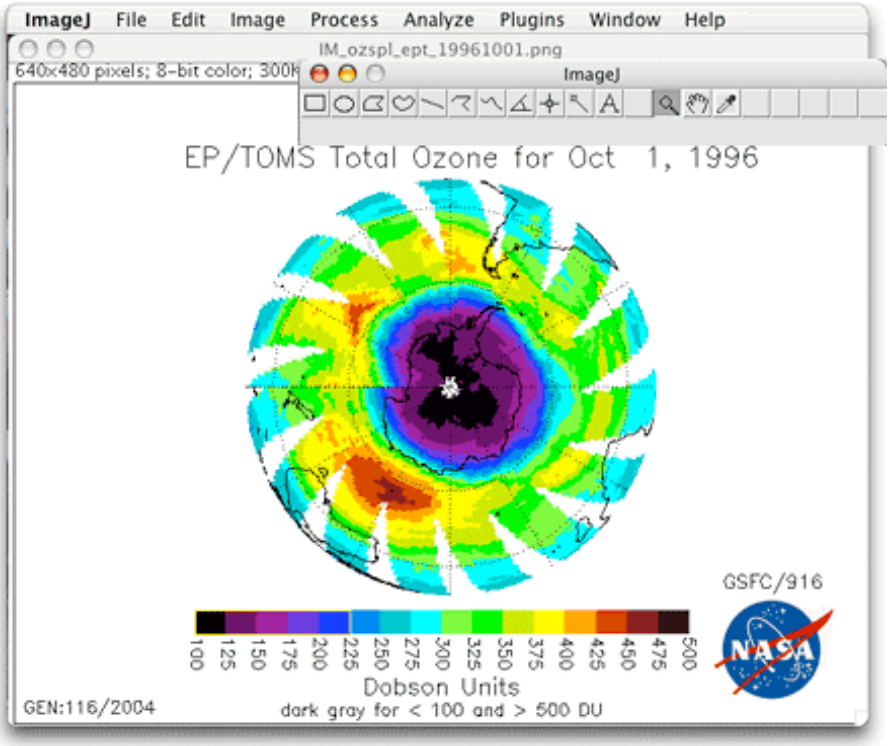
Start ImageJ, choose **File > Open...** then select the first image. Open all the images in chronological order.

Show me how

1. Open the ImageJ folder and double-click ImageJ's application icon (looks like a microscope) to start the image processing software.
2. From ImageJ's menu bar, choose **File > Open...** then navigate to the folder where you stored the downloaded TOMS images. Select the es961001 image, then click **Open**.



3. When images are open, you should have the tools of ImageJ available.

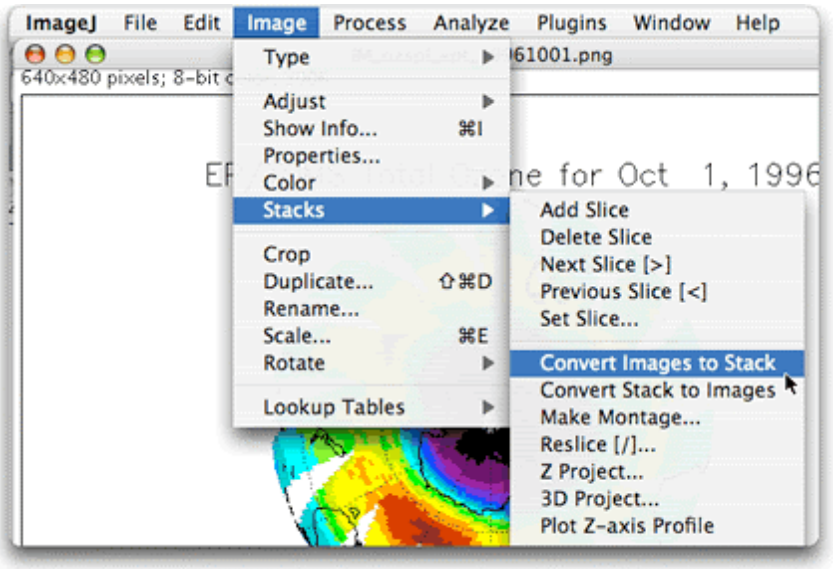


4. Repeat to open all 9 images in chronological order.

Step 2-Convert Images to a Stack and Save

1. From ImageJ's menu bar, select **Images > Stacks > Convert to Stack**.

   Show me how



   NOTE: This step puts all nine images into a single window named Stack. You can flip between the images by dragging the slider button along the bottom of the stack window, or by pressing the greater than ">" or less than "<" keys on your keyboard.

2. Save the resulting stack as a TIFF file.

   Show me how

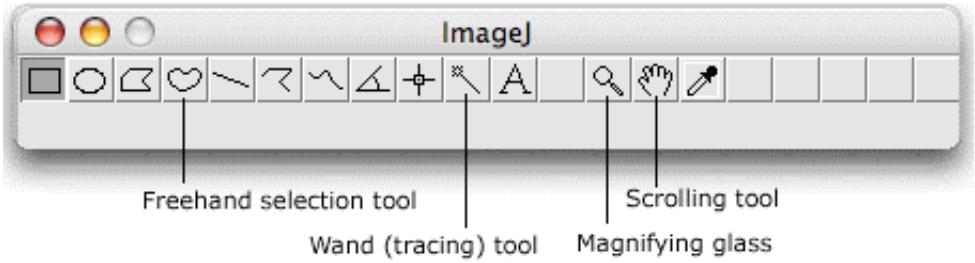
   - Choose **File > Save As > TIFF...**
   - Select a place on your computer to store the stack (for instance, in your TOMS images folder)
   - Give the stack a new name or use the default name.

Step 3-Explore the Images

The images you've opened show the amount of ozone overhead, measured in Dobson Units. The measurements can be thought of as showing the "thickness" of the ozone layer: if all of the ozone molecules overhead could be brought down to Earth's surface, the "layer" of ozone would only be about 3 millimeters thick—about the same height as two stacked pennies. This amount of ozone has a Dobson Unit value of 300 DU. The ozone "hole" is defined as the area where the total amount of ozone is less than 220 DU.

1. Look at the color scale below the first image to figure out where ozone is "thickest" and "thinnest." Can you identify the area that would be considered as part of the ozone hole?
2. Use the **<** and **>** keys to flip through the stack of images and examine them. Watch how the ozone levels and the size of the low-ozone area changed through the nine years.

Show me some information about ImageJ's tools



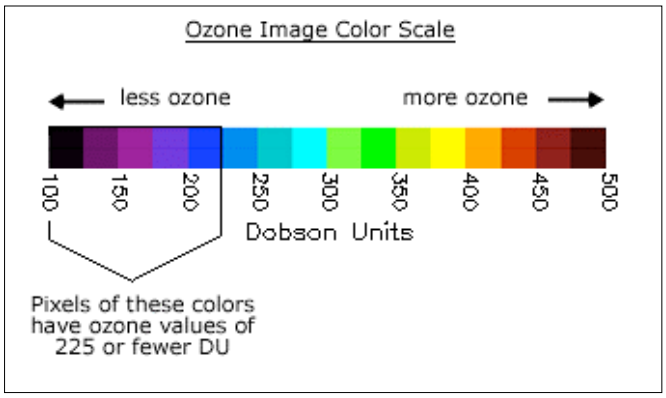
- To **zoom in** on the image, select the magnifying glass on the tool bar, then click any location on the image.
- To **zoom out**, double-click the magnifying glass on the tool bar.
- To **scroll around** the image while it is enlarged, select the scrolling tool (the hand) on the tool bar, then click and drag on the image.
- To **read the x,y location** or the value of the pixel under your cursor, look just below the tools in the status bar.
- To **animate** the stack of images, choose **Image>Stacks>Start Animation**. Choose **Image>Stacks>Animation Options...** to control the animation speed.

Images centered on the South Pole allow us to see the shape and size of the ozone hole in comparison with the rest of the globe. The surface area represented by each pixel in the images is not equal, but as all the yearly images use the same viewpoint, we can measure changes the hole by counting the number of pixels that are part of the hole each year. You won't have to count the pixels by hand—ImageJ gives you a convenient way to highlight and measure the number of pixels that represent the hole each year.

Part 3-Highlight and Measure the Ozone Hole

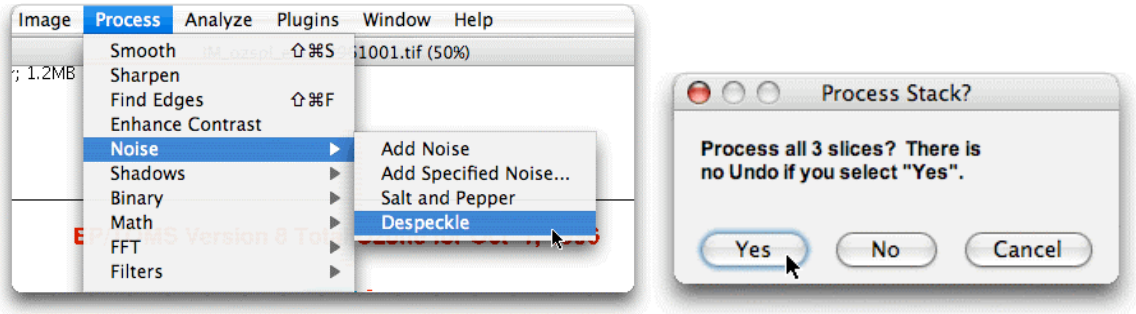
Step 1-Highlight and Outline the Ozone Hole

Scientists who study the atmosphere consider areas with less than 220 Dobson Units (DU) of ozone to be part of the ozone hole. The TOMS images show ozone in increments of 25 DU, so we'll count pixels (picture elements) with 225 DU or fewer to estimate the area of the hole. In this step, you'll highlight and automatically outline the pixels with these values to measure the ozone hole in each yearly image.



1. If you made any changes to the images during your exploration, you may need to close the stack (don't save any changes) and reopen it. Within ImageJ, choose File > Open... and navigate to the location where you stored the stack.
2. To remove the continent outlines that can interfere with the highlighting, select Process > Noise > Despeckle. When queried to process all the slices, choose Yes.

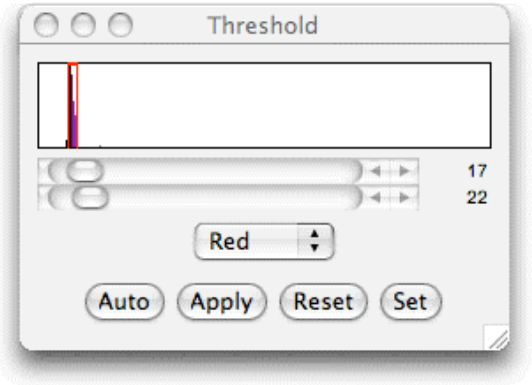
Show me how



3. Select Image > Adjust >Threshold…Threshold allows you to specify a range of pixel values (the ones that represent the ozone hole, for instance) and highlight them in the image.
4. In the Threshold dialog box, below the two horizontal sliders, set the drop down menu to "Red"
5. Drag the top and bottom sliders (or use the arrow buttons to move them) so that pixels representing ozone measurements of 225 and lower are red and pixels of higher ozone levels remain unchanged.

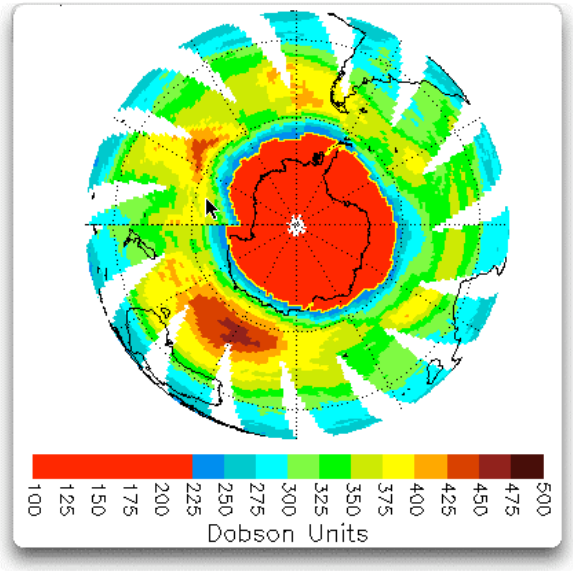
Show me how to highlight the ozone hole

Start with the top and bottom sliders at 0 (zero). Move the bottom slider slowly to the right to increase the range of pixel values that are highlighted. Watch how the colors representing different ozone measurements turn red as the slider reaches their value. You can click the arrows at the right end of the bottom slider to adjust the highlighted range one unit at a time. Stop when pixels representing the ozone hole are red, but the rest of the image is unchanged. You don't need to click any of the buttons below the sliders.



6. From ImageJ's toolbar, select the wand (tracing) tool and click it just to the left of the group of red pixels that represent the ozone hole. This will automatically trace a yellow selection line around the red pixels.

Show me an example



Step 2-Measure Area of Ozone Hole

1. Once the hole area is outlined, select **Analyze > Measure**.
2. The area (in pixels) you selected and measured is displayed in the Results window. To bring the Results window forward, select **Windows > Results**.
3. Click the right arrow button that is at the bottom right corner of the stack window to advance to the next image.
4. Click the wand tool to the left of the ozone hole again to trace the new outline.
5. Choose **Analyze > Measure** to record each measurement to the Results window.
6. Repeat the previous 3 steps until you have measured the area of the ozone hole for all nine years.

NOTE: If you record an incorrect measurement, try selecting it in the Results window then choose **Edit > Delete**. If you cannot delete single measurements, you can choose **Analyze > Clear Results** to start over, or you can plan to delete bad measurements once you bring the results in to your spreadsheet application.

7. When you're done, the Results window should have 9 measurements corresponding to the years 1996 through 2004.
8. Save the Results file by choosing Windows > Results , then choose File > Save As.... On a Windows computer, you'll need to choose Text... to complete the save. Store the Results file in the same place as your TOMS images, with the file name of Results.txt.

Part 4-Import and Graph the Data

Step 1-Import Results into a Spreadsheet Program

Any spreadsheet program that can produce graphs can be used for this part. The instructions here refer to using Microsoft Excel.

1. Start Excel, choose **File > Open...**, navigate to where you stored your Results file, and click **Open**.
2. When the Text Import Wizard opens, go with the default selections, simply clicking Next >, Next >, and Finish to open the file.

Step 2-Graph the Data

1. Select (highlight) the nine pixel measurements in column 2 of your spreadsheet.
2. Activate the Chart Wizard by clicking its icon in the Excel toolbar—the icon looks like sparks coming from the end of a wand in front of a document.
3. In the list of Chart Types, choose **Area** and click **Next**.
4. In the next dialog box, you'll see the cell address for the data you selected and the **Columns** option checked under Series. Click **Next >**.
5. On the next page, enter a title for your graph plus appropriate names for each axis. You may also want to customize other options such as gridlines or data labels.
6. When you are pleased with your chart display, click **Next >**.
7. On the last dialog box of the Wizard, place the chart as an object in your Results.txt file and click **Finish**.
8. Save your results file with the chart.

Step 3-Analyze the Data

Examine the graph you produced. Consider the following questions and choose one for follow up study.

- Did the size of the ozone hole increase, decrease, or stay the same over the nine years you analyzed? What might account for the changes?
- How might you go about discovering why one of the years holes was much smaller than the others? Outline a plan for finding out how that year might have been different than other years.
- Does an ozone hole ever form over the Artic Region? Outline a plan for using TOMS images to look for a hole in the Northern Hemisphere.