

Stratospheric Ozone:

An Online Learning Module

Using your favorite browser open [Ozone/index.htm](http://cs.clark.edu/~mac/Geol390/StratosphericOzone/StartOzoneActivity.html) or go to <http://cs.clark.edu/~mac/Geol390/StratosphericOzone/StartOzoneActivity.html>

Work through the web pages (shown in bold) below and answer the questions related to each page.

Open **EarthsAtmosAndO3**

Objective: Become familiar with the structure of the atmosphere.

What are the lowest two layers in the atmosphere? _____

Knowing that 99.9% of the atmosphere is in these lowest two layers we can look at the picture on the left side of the web page and can also say that 99.9% of the atmosphere is below what altitude? Express your answer in kilometers and miles. _____ km
_____ miles

The exercise within this box may be done at anytime before turning in this assignment. However, make sure you look and marvel at the thin blue veil image towards the bottom of EarthsAtmos&O3 page):

Objective: To obtain a feeling of just how thin is the atmospheric "Blue Veil" compared to the Earth?

On a separate sheet of paper draw the Earth's surface and its atmosphere as concentric circles to scale. Use a scale of 2.0cm = 1000 km (or 1.0 mm = 50 km). Earth's radius is 6400 km. With this scale the complete Earth circle may not fit completely onto your sheet of paper but do the best you can. Within the empty space on Earth circle page comment on the concept of the thin blue veil. (See image near bottom of this web page) Turn this in with your lab sheet.

Which is the atmospheric layer in which we live?

About how high is the top of the lowest atmospheric layer? ___ km

Which atmospheric layer contains most of the atmospheric ozone?

Describe how the temperature changes with height in the troposphere.

What causes the stratosphere to warm?

Open Ozone Basics (Ozone\OzoneBasics.htm)

Acknowledgement: Video Clips used in this learning module are from a [UARS](#) video tape create by NASA's [Scientific Visualization Studio](#). Courtesy of Dr. Charles Jackman.

Objective: *Learn about stratospheric ozone, how it's produce and destroyed, where it is located, why it is important, and how it is changing.*

Click to view each video clip below and then answer the related questions. It may help to read the questions first and then view (and review) the clip.

Introduction (QT movie 4.3 MegaBytes)

What aspects of the atmosphere help sustain life on Earth?

From what does the ozone layer shield our planet?

Approximately when do paleontologists believe that complex life forms began to evolve on our planet?

What happened at this time that allowed complex life to form?

What type of activities can change the ozone layer? (**human, natural, or both**)

Ozone Hole first discovered (QT movie 4.8 MegaBytes)

When did British Researchers (British Antarctic Survey) first announce dramatic changes in the ozone layer?

This finding was based on measurements from what type of instrument?

The British Antarctic Survey found that as much as _____ percent of the ozone over Antarctica was rapidly disappearing each spring.

Careful analysis of ozone records by NASA scientists verified the British Antarctic Survey results and also showed that similar but smaller depletions were taking place over the _____ as well.

Globally ozone amounts have decreased by _____ percent from 1979 to 1993.

Scientists had been predicting significant changes in the ozone layer since the _____.

Why did NASA construct UARS? (give initial motivation and usefulness of UARS)

What do the initials UARS stand for?

What is Ozone & how is ozone produced in the stratosphere. (QT movie 1.2 MB)

High energy ultraviolet radiation from the sun breaks apart the _____ to create single atoms of _____. A single atom of _____ then combines with _____ producing a molecule with [1, 2, or 3?] _____ atoms of _____ (ozone).

Ozone Destruction

Click to view each video clip (bold italics) below and then answer the related questions. Click back navigator arrow to leave video clip.

1. Photo Destruction of Ozone (QT movie 1.2 MB)

When ozone absorbs ultraviolet radiation what happens to the ozone bonds?
When this happens what is released from ozone?

2. Ozone is present throughout the atmosphere. (QT movie 1.5 MB)

At about what altitude is the greatest concentration of ozone is found?
At this location of greatest ozone concentration there are fewer than _____ ozone molecules per million molecules of air.
Ozone absorbs nearly all of the biologically _____ radiation from the sun.

3. So why is ozone under threat? (QT movie 1.7 MB)

Ozone easily loses its third oxygen atom in the presence of other highly reactive compounds called _____, which contain _____, _____, _____, or _____.

Minute quantities of these radical can cause large decreases in ozone because they are not consumed in the reaction. This is called a _____.

4. Where do Ozone destroying radicals come from? (QT movie 4.7 MB)

Most hydrogen radicals come from _____.
Nitrogen radicals come from nitrous oxide which increases when we use _____. Nitrogen radicals are also formed in _____.
Examples of where naturally produced chlorine radicals come from are _____ and _____.
Most of the stratospheric chlorine comes from _____.
In the video clip there is a CFC molecule F-12 shown. This molecule has a central carbon atom with several chlorine and fluorine atoms bonded to it. How many chlorine atoms are in CFC F-12 molecule? _____ How many Fluorine atoms are in the

CFC F-12 molecule? _____ **Bonus:** write out the chemical formula for CFC F-12.

The CFC molecule is very stable. What finally breaks the CFC molecule apart?

Where do CFC molecules break apart?

FYI. A major source of Bromine radicals is fire retardant commonly used in fire extinguishers.

5. Montreal protocol (QT movie 1.6 MB)

When did governments from around the world initially agreed to restrict the production of chlorofluorocarbons.

6. CFCs and Stratospheric circulation (QT movie 1.8 MB)

CLEAS measurements show that beyond a doubt significant levels of _____ reach the stratosphere.

The decrease in CFC concentration at higher altitudes in the stratosphere indicates that CFC molecules are _____ by ultra-violet radiation.

7. CFCs and Reservoir Gases (QT movie 2.8 MB)

UARS measurements have confirmed that CFCs enter the stratosphere in the _____. Chlorine nitrate and hydrogen chloride are called reservoir gases for the chlorine radical. These reservoir gases usually contain more than _____ percent of the chlorine in the stratosphere.

8. Are CFCs changing in Stratosphere? (QT movie 3.6 MB)

When UARS was first launched measurements by HALOE showed that CFC byproducts were still _____ in the stratosphere.

But the newest HALOE measurements show that the CFC byproducts are no longer _____.

9. Water vapor and Stratospheric circulation (QT movie 2.4 MB)

By measuring water vapor amounts HALOE measurements have also shown us that it takes about _____ years for CFCs to reach the upper stratosphere.

10. Reactions on Polar Stratospheric Clouds (PSCs) (QT movie 2.9 MB)

On the surface of the cloud particles chlorine nitrate and hydrogen chloride react and release _____. The _____ then reacts with ozone forming chlorine monoxide and starting the catalytic ozone destruction cycle. The mass of ozone loss over Antarctica forms the Antarctic _____.

11. *What about the Arctic? (QT movie 1.4 MB)*

Key to understanding the chlorine chemistry in the polar stratosphere is the measurement of _____, _____, and the reservoir gas _____.

Go back to **ozoneBasics** or Home and open

OzoneVerticalProfile

Objective: Learn about the average vertical distribution of ozone and the vertical location of the ozone hole.

Earlier we learned that on average the greatest ozone concentration is typically at an altitude of 15 miles (about 22 km). Click on the graph on the **OzoneVerticalProfile** web page to enlarge it for easy reading. This shows the vertical ozone profile over the south pole. Answer the following questions by carefully reading the graph.

For the south pole:

At what altitude (in km) is July 8 (pre ozone hole) ozone concentration greatest?

For the Oct 8, 2001 profile, between what altitudes is the ozone concentration essentially zero? _____ and _____.

What is the minimum temperature for the Oct 8, 2001 profile? _____ degrees C

Is the location of this minimum temperature near the ozone hole location or far away from the ozone hole location?

Would you describe the ozone hole as a hole through the atmosphere (like a hole through your pants) or a hole in the atmosphere (like a hole inside a loaf of bread)? Explain.

Return to the Main page (home)

OzoneMeasurements

Objective: To learn about ozone measurement and measurement units appropriate for ozone concentrations.

What does ppm stand for and explain what an ozone concentration of 15 ppm means.

What is a Dobson Unit?

What does TOMS stand for?

In which units would the TOMS instrument likely express ozone concentrations?

What is an ozonesonde?

How is an ozonesonde typically deployed?

In which units would an ozonesonde likely express ozone concentrations?

Return to home

Go back to Home and then to **Ozone Data**

O3Climatology (Note: In all of these images the solid white regions near the poles is where no data is available because of no sunlight)

Objective: Learn how the average total ozone amounts in Dobson Units above a location depend on the latitude and season.

Click on the TOMS total Ozone 1979-1992 averages Global image so it is easy to read. Ozone concentrations are typically lower/higher in the tropical regions (around the equator) than near the poles.

What is an approximate average ozone column amount over the tropics?

For the 1979-1992 period the approximate average ozone column amount over the high Northern hemisphere latitudes (above 50 degrees North) is? _____

Is there typically more or less ozone over the Northern hemisphere than the southern hemisphere?

Go Back and then Click on the TOMS total Ozone 1979-1992 averages by Latitude (zonal) and Month image (4th image from top) so it is easy to read.

During What Month(s) is the total ozone column amounts over the high Northern hemisphere greatest? _____ Smallest? _____

During What Month(s) is the total ozone column amounts over the high Southern hemisphere greatest? _____ Smallest? _____

The dark blue region on this image near the South pole is the ozone hole.

Return to home.

Go back to Home and then to **Trends**

Objective: *Learn how ozone amounts have been changing over the past 40 years.*

Click on the image 1960 to 2001 South Pole Spring-time total ozone column amount to enlarge it.

What is the approximate SP Spring-time total ozone average for the first three years of data (1961, 1962, 1963)?_____

What is the approximate SP Spring-time total ozone average for the last three years of data (1999, 2000, 2001)?_____

What is the approximate percent decrease in SP Spring-time total ozone column amount from 1962 to 2000? (The link [%ChangeCalculation](#) on Home page can help you if you're not sure about this calculation)

Go back to Home and then to **MonthlyOzone**

Objective: *The goal here is to be able to answer the question: Does the ozone hole persist all year or for only several months each year?*

Select the video showing 2001 Monthly values by clicking on the image and step through the slides to answer the questions below. The SP vertical profile slide show can also be helpful since the TOMS instrument does not work when the sun isn't shining over Antarctica but the ozone sondes do. The Jan and Dec slides have exit buttons on them to get you back.

For what month(s) is the 2001 Antarctic total ozone smallest?

About how long (in months) does the 2001 Antarctic ozone hole persist?

What is the approximate minimum total ozone column amount over Antarctica in 2001?

Does the ozone hole persist all year or for only several months each year?

Go back to Home and then to **1980to2002OzHole**

Objective: *For the past 20 years, determine when the October Antarctic Hole was most severe and how it has changed.*

Click on the image to watch the *1980 to 2002 Oct Ozone* video.

Which years have a minimum Average October ozone value between:

100 to 125 DU? _____

125 to 150 DU? _____

150 to 175 DU? _____

175 to 200 DU? _____

200 to 225 DU? _____

225 to 250 DU? _____

From this information would you say that the ozone hole got better or worse during the 1990s?

Which two years were the worst (lowest ozone values and largest ozone hole area) holes on record?

Which five years were the worst (lowest ozone values and largest ozone hole area) holes on record?

Which five years were the best (highest ozone values and smallest ozone hole area) holes on record?

Go back to Home and then to **DailyOzHole**

Objectives: *explore the time development of the ozone hole.*

2001 and 2002 ozone hole movies and view the two graphs, 1979-2002 Ozone Hole & 2001 and 2002 compared with 1990s to answer the following questions.

Describe the general similarities and differences between the time development and structure of the 2001 and 2002 ozone holes.

General shape. *(two movie movies)*

When they began to form *(2001 and 2002 compared with 1990s Graph).*

how big they got. *(2001 and 2002 compared with 1990s Graph).*

how long they lasted *(2001 and 2002 compared with 1990s Graph).*

How low the ozone amounts got. *(1979-2002 Ozone Hole)*

Go back to Home and then to **OzoneRecovery**

Objectives: *Learn about factors that may influence the timing of the ozone hole recovery.*

After looking through **OzoneRecovery** Be prepared to discuss in class whether the Antarctic ozone hole is recovering now or not.

Notes related to what you learn about ozone recovery: