Stratospheric Ozone:

An Online Learning Module

Answers

Instructors Notes: The UARS video (17 minutes) is an excellent introduction to this lab. 20 sec to 1 minute video clips from this video are used to outline the basics of the stratospheric ozone problem. Each video clip comes with several questions that should be easy to answer after listening to the clip. To help students get started so they can smoothly sail through this activity it would be helpful to do the first page or two in class. Answers to questions are provided here in Bold Blue.

Using your favorite browser open Ozone3/index.htm. Work through the web pages (shown in bold on this sheet) below and answer the questions related to each page.

Open **EarthsAtmos&O3**

What are the lowest two layers in the atmosphere? **the troposphere and stratosphere**

Knowing that 99.9% of the atmosphere is in the 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. ____**50**__ km ____**30** __ miles

The exercise within this box may be done at anytime. 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 note 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.

With this scale the Earth's radius is 12.8 cm and the atmosphere is 0.1 cm above it (less than a pencil line).

Which is the atmospheric layer in which we live? **The troposphere**

About how high is the top of the lowest atmospheric layer? __ **about 12**_ km

Which atmospheric layer contains most of the atmospheric ozone? **The stratosphere**

Describe how the temperature changes with height in the troposphere. **The temperature in the troposphere drops gradually (by about 6 C/km)**

What causes the stratosphere to warm? **The heating in the stratosphere is primarily of strong absorption of solar energy by ozone.**

Open Ozone Basics (Ozone3\OzoneBasics.htm)

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)

What aspects of the atmosphere help sustain life on Earth?
The atmosphere provides oxygen, moisture and shields us from the harsh environment of space.
From what does the ozone layer shield our planet?
The ozone layer shields our planet from the sun's intense ultraviolet radiation.

Approximately when do paleontologists believe that complex life forms began to evolve on our planet? **Paleontologists believe that complex life evolved on our planet one and a half to two billion years ago.** What happened at this time which allowed complex life to form? **the ozone layer formed**

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

Ozone Hole first discovered (QT movie)

When did British Researchers (British Antarctic Survey) first announce dramatic changes in the ozone layer? **1985**

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

The British Antarctic Survey found that as much as __**60%**_____ 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 _____ **Northern hemisphere** _____ as well.

Globally ozone amounts have decreased by ___**about 5%**_____ percent from 1979 to 1993.

Scientists had been predicting significant changes in the ozone layer since the _____**1970s**_____.

Why did NASA construct UARS? (give initial motivation and usefulness of UARS)
In response to public concern about ozone depletion to study the chemistry and dynamics of stratospheric ozone.

What do the initials UARS stand for? **Upper Atmosphere Research Satellite**

What is Ozone & how is ozone produced in the stratosphere.

High energy ultraviolet radiation from the sun breaks apart the ___**molecular oxygen**_____ to create single atoms of _____**Oxygen**_____. A single atom of _____ **Oxygen** ____ then combines with __ **molecular oxygen**_____ producing a molecule with __**three**_____ atoms of ___ **Oxygen** _____ (**ozone**).

Ozone Destruction

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

1. Photo Destruction of Ozone
When ozone absorbs ultraviolet radiation what happens to the ozone bonds? **It breaks**
When this happens what is released from ozone? **A single oxygen atom**

2. Ozone is present throughout the atmosphere.
At about what altitude is the greatest concentration of ozone is found? **15 miles**
At this location of greatest ozone concentration there are fewer than __15_____ozone molecules per million molecules of air.
Ozone absorbs nearly all of the biologically __**damaging**___ radiation from the sun.

3. So why is ozone under threat?
Ozone easily looses its third oxygen atom in the presence of other highly reactive compounds called _**radicals**___, which contain ___**hydrogen**_, __**chlorine**____, _____**nitrogen**_____, or ___bromine____.

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

4. Where do Ozone destroying radicals come from?
Most hydrogen radicals come from ___**methane**_____.
Nitrogen radicals come from nitrous oxide which increases when we use _**chemical fertilizers**_____**.** Nitrogen radicals are also formed in __**Aircraft Exhaust**_____.
Examples of where naturally produced chlorine radicals come from are_**volcanic gases**_____ and ___**biological decay**_____.

Most of the stratospheric chlorine comes from __**man made CFCs**_____.
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? _____**two**_____ How many Fluorine atmos are in the CFC F-12 molecule?_____ **two** _____ **Bonus:** write out the chemical formula for CFC F-12. **CCl_2F_2**

The CFC molecule is very stable. What finally breaks the CFC molecule apart? **UV solar radiation**

Where do CFC molecules break apart? **In the stratosphere**

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

5. Montreal protocal
When did governments from around the world initially agreed to restrict the production of chlorofluorocarbons. **1987**

6. CFCs and Stratospheric circulation
CLEAS measurements show that beyond a doubt significant levels of ___**CFCs**_____ reach the stratosphere.
The decrease in CFC concentration at higher altitudes in the stratosphere indicates that CFC molecules are __**being broken up**_____ by ultra-violet radiation.

7. CFCs and Reservoir Gases
UARS measurements have confirmed that CFCs enter the stratosphere in the_**tropics**___.
Chlorine nitrate and hydrogen chloride are called reservoir gases for the chlorine radical. These reservoir gases usually contain more than _____**90**_____ percent of the chlorine in the stratosphere.

8. Are CFCs changing in Stratosphere?
When UARS was first launched measurements by HALOE showed that CFC byproducts were still _____**increasing**_____in the stratosphere.
But the newest HALOE measurements show that the CFC byproducts are no longer _____ **increasing** _____.

9. Water vapor and Stratospheric circulation
By measuring water vapor amounts HALOE measurements have also shown us that it takes about _____5_____ years for CFCs to reach the upper stratosphere.

10. Reactions on Polar Stratospheric Clouds (PSCs)
On the surface of the cloud particles chlorine nitrate and hydrogen chloride react and release _____ **chlorine** _____. The ____ **chlorine** _____ then reacts

with ozone forming chlorine monoxide and starting the catalytic ozone destruction cycle. The mass of ozone loss over Antarctica forms the Antarctic _**Ozone Hole**___.

11. What about the Arctic?

Key to understanding the chlorine chemistry in the polar stratosphere is the measurement of ____**polar stratospheric clouds**_____, ___**chlorine monoxide**_____, and the reservoir gas ____**chlorine nitrate**_____**.**

Go back to ozoneBasics or Home and open

OzoneVerticalProfile (Ozone3\ozoneverticalprofile.htm)

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 so its easy to read. 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? **15 km**

For the Oct 8, 2001 profile, between what altitudes is the ozone concentration essentially zero? _____**14 km**_____ and _____**21 km**_____.

What is the minimum temperature for the Oct 8, 2001 profile? __**about -85**_____ degrees C

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

~ 1 hr

Return to the Main page (home)

OzoneMeasurements

What does ppm stand for and explain what an ozone concentration of 15 ppm means. **Parts per million 15 ppm means that there are 15 ozone molecules for every million air molecules. Or when one take a sample of one million air molecules 15 of these are ozone.**

What is a Dobson Unit? **A measure of total ozone amount in a vertical column. 1 Dobson unit equals 0.01 mm thickness of pure ozone when compressed to STP.**

What does TOMS stand for? **Total Ozone Mapping Spectrometer**

In which units would the TOMS instrument likely express ozone concentrations? **Dobson units (DU)**

What is an ozone sonde? **An instrument that measures ozone concentrations in the atmosphere.**

How is an ozone sonde typically deployed? **With a balloon or rocket.**

In which units would an ozone sonde likely express ozone concentrations? **ppm or molecules per cc**

Return to home
1 hr 10 minutes

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)

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? **250 Dobson** Units

For the 1979-1992 period the approximate average ozone column amount over the high Northern hemisphere latitudes (above 50 degrees North) is?____**400 Dobson**_____

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

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? __**March-April**_____ Smallest ? _____**Sept-Oct**__

During What Month(s) is the total ozone column amounts over the high Southern hemisphere greatest? ____**Dec**_____ Smallest ?___**Sept-Oct**_____

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**

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)?____**300 DU** ____
What is the approximate SP Spring-time total ozone average for the last three years of data (1999, 2000, 2001)?____**160 DU** ____

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

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

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 slide show 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? **Oct & Sept**

About how long (in months) does the 2001 Antarctic ozone hole persist? **2 or 3 months**

What is the approximate minimum total ozone column amount over Antarctica in 2001? **100 DU**

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

Go back to Home and then to **1980to2002OzHole**
Click on the image to watch the ***1980 to 2002 Oct Ozone*** video.
Which years have a minimum Average October ozone value between: Be careful because the 2001 and 2002 images use a different color scale.
100 to 125 DU? 1998 (students may miss this because this low ozone region is so small)

125 to 150 DU? 1987, 1992, 1996, 1997, 1999, 2000, 2001

150 to 175 DU? 1985, 1989, 1990, 1991

175 to 200 DU? 1983, 1984 , 1986

200 to 225 DU? 1982, 1988, 2002

225 to 250 DU? 1980, 1981

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

Which two years were the worst (lowest ozone values and largest ozone hole area) holes on record? **1998 and 2001**

Which five years were the worst (lowest ozone values and largest ozone hole area) holes on record? **1998 and 2001, 1999, 1997, 1996**

Which five years were the best (highest ozone values and smallest ozone hole area) holes on record? **1980, 1981, 1982, 1988, 2002**

Go back to Home and then to **DailyOzHole**
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. **The 2001 Antarctic Ozone Holes (AOH) developed and stay in one large central region whereas the 2002 AOH developed and then broke apart into two distinct smaller regions**

When they began to form **The 2001 and 2002 AOHs started out much the same in the middle of August**
how big they got. **By 1 Sept the 2001 was much larger than the 2002 AOH and stayed that way through the AOH season.**
how long they lasted **The 2001 AOH persisted from the middle of August to Late November where the 2002 AOH seemed to break up significantly in late September , stay small, and had completely disappeared by Early November *(see right hand figure below which is fully accessible from OzoneRecovery page)*.**
How low the ozone amounts got. **2001 average (Sept7-Oct.13)AOH column amount was 25 million square kilometers with a high of 27 and a low of 23 million kilometers. 2002 average (Sept7-Oct.13)AOH column amount was much smaller 9 million square kilometers with a high of 18 and a low of 3 million kilometers. *(see left hand figure below which is fully accessible from OzoneRecovery page)*.**

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

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

Other Options/directions or extra credit activities

Be prepared to discuss:

Good ozone and bad ozone
Ozone and Health
Possible Arctic ozone hole
Ozone history