The Effect of Altitude on Atmospheric Ozone

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Objective: The objective of this experiment is to measure the ozone concentration in the troposphere and the stratosphere.

Theory: In this experiment an ozonesonde will be flown in a foam box on a weather balloon to collect data about the Earth's ozone concentration above Montana.

Many experiments have proven that ozone levels are present in the troposphere, which is 10 kilometers high from the Earth's surface, and the stratosphere, this is from 10 kilometers to 50 kilometers from the Earth's surface.

Ozone is three oxygen molecules put together. Out of the ten million air molecules, 2 million are oxygen and only 3 are ozone! These ozone molecules shield the Earth from the sun's harmful UV rays. CFCs are chemicals that are very harmful to ozone. These chemicals are emitted by commercial, industrial, and household applications (such as refrigerators and vehicles). When these chemicals are released into our troposphere and stratosphere they are broken down into chlorine and bromine molecules. One of these molecules can destroy 100,000 ozone molecules until they are removed from the stratosphere. This was not a problem because ozone was being created at the same rate it was being decreased, but a few decades ago CFCs began to increase their levels of occurrence in the stratosphere. Today these chlorofluorocarbons are creating holes in the ozone layer. This has become an increasing worry for the citizens of the Earth because the ozone layer is a major part in keeping people safe from skin cancer and other diseases dealing with the sun's rays.

After collecting and analyzing the data from the ozonesonde, the expectation is to see approximately 10-75 nanobars of ozone partial pressure in the troposphere and a range of about 1-100 nanobars of pressure in the stratosphere. The ozonesonde uses the viscosity of the anode and cathode solutions to calculate a voltage corresponding to the partial pressure of ozone. (See figure 1 on page for the graph of pressure in nanobars.)

Apparatus: Electrochemical Concentration Ozonesonde

The device used in this experiment is an ozonesonde created by the EN-SCI Corporation. The ozonesonde uses the chemical reaction of ozone and iodide to measure ozone concentration in the air.

This is how it works: Air is sucked into the ozonesonde through a Teflon tube attached to the cathode solution chamber. When the air enters the chamber, the ozone in the air reacts with the iodide in the cathode solution creating iodine. The iodine then flows across an ion bridge. This ion bridge runs from the cathode solution to the anode solution. Connected to this ion bridge is a sensor that sends a voltage reading due to the viscosity of the solution to a circuit board, where the information is stored to a 4-channel HOBO. The higher the viscosity of the solution the higher the reading on the HOBO. Back in the anode solution, there is another chemical reaction that turns the iodine back into iodide. The air is then released back into the atmosphere through an exhaust tube in the anode solution chamber. This process is repeated every four seconds until the flight of the weather balloon is completed. A 12volt lithium battery (which lasts a long time because it is rechargeable) powers the ozonesonde.

The ECC ozonesonde was flown in a 10inX10inX12in deep box. This box is then covered by a red nylon slipcover. Then it is attached to a parachute by nylon string and four carabineers on the top corners. This brightly colored parachute is then attached to a latex balloon with the use of duct tape and one carabineer at the top of the parachute. (Apparatus shown in figure 2).

Procedure:

1. Acquire an ECC Ozonesonde
2. Begin conditioning the sonde one week prior to flight
3. The first conditioning test is to clean the cathode and anode cells with distilled water
4. Allow to dry thoroughly
5. Using a plastic syringe with a Teflon spaghetti tubing on the end, cleaned with distilled water, fill the cathode cell with 3.0 milliliters of cathode solution
6. Using another syringe of the same kind fill the anode solution with 1.5 milliliters anode solution *Make sure to label these syringes “Cathode” and “Anode” legibly and do not store them together and rinse with distilled water after changes of solutions
7. Allow the solutions to settle for 24 hours *Directions on how to make anode and cathode solutions are shown in figure 3 below
8. Empty out the solutions and refill with same amount of anode and cathode

Background current test:

9. Now begin the background current tests which will tell if the ozonesonde is reading ozone levels properly
10. Hook the 12v lithium batteries to the ozonesonde using the power supply chord
11. Attach the an Ozone-destruction filter to the intake tube attached to the cathode cell through the motor
12. Attach a voltmeter to the ozonesonde using red and black banana clips hooking to the HOBO circuit board , black to ground and red to red probe
13. Set the voltmeter to the lowest setting, which is micro-amps
14. Run for 10 minutes
15. Record amp reading after the 10 minutes is done *Note: make sure to record this data somewhere where to be accessed again
16. Disconnect the ozone-destruction filter from the ozonesonde
17. Run for another 10 minutes and record the last amp reading when the time is up

The Pump Flow Rate Test:

18. Attach the small Teflon tube of the 100mL glass burette to the exhaust tube on the anode cell
19. Attach the 12v lithium batteries to the ozonesonde as specified above
20. Also, acquire a stopwatch
21. Fill the burette with soap solution until the solution is just below the connector tube
22. Now create a bubble by squeezing the rubber bulb a few times *Make sure not to squirt the solution out of the burette
23. Turn the ozonesonde on and time how long it takes to make the bubble travel 100mL

24. Repeat this process 5 times and take the average *Make sure to write down the findings of this process somewhere where it can be found again for computations
25. Disconnect sonde from burette
26. Empty the contents of the cathode and anode solutions with the same syringes used above
27. Change solutions again using process described above
28. Short sensor cell leads on circuit board with a small wire

Day of Flight:

1. Disconnect the short of the sensor leads
2. Change anode and cathode solutions with process described above *Make sure syringes are cleaned with distilled water before use
3. Connect 12v lithium batteries to ozonesonde
4. Run on ozone-destruction filter for 10 minutes and record
5. Run without destruction filter for 10 minutes then record (should be less than .05micro amps)
6. Disconnect voltmeter
7. Attach 4-channel HOBO to the circuit board
8. Attach the circuit board to the ozonesonde
9. Insert the ozonesonde into the box and secure the bottom of the sonde with velcro to the box
10. Make sure that the intake tube connected to the cathode is outside of the box so that the sonde can take in the air

Also in the box:

1. In the box there should also be a STXe GPS transmitter. This device uses two or more satellites to triangulate the box's position using latitude and longitude.
2. A HAM radio is also inside the box as a way to track the box on its flight if the STXe fails
3. Seal the box with duct tape (the slipcover is already on)
4. Attach four carabineers to the top four corners of the box and run the nylon string through the carabineers
5. Attach the string to the parachute lines, making sure that the lines are not tangled
6. Now attach the parachute to the already inflated latex balloon using string, a carabineer on the top of the parachute, and duct tape
7. Launch the balloon!!! *Make sure all systems are a "go" before launching of course
8. Using the STXe and the HAM follow the balloon using the coordinates that these devices give and tracking them on a map of the area
9. When box is found, open and turn off ozonesonde and other devices
10. Disconnect HOBO from sonde and off-load using Boxcar software for data analysis

After Flight:

1. If ozonesonde will be used in another flight change cathode solution ONLY and store until one week before flight
2. If ozonesonde will not be used again empty solutions and put away in the Styrofoam box that it came in

Figure 3: Sensing Solutions

Cathode Solution

To 500 ml distilled water add:

5.00 g		**KI**
12.50 g		**KBr**
0.63 g		**$NaH_2PO_4.H_2O$**
2.50 g		**$Na_2HPO_4.12H_2O$**
	or	
1.87 g		**$Na_2HPO_4.7H_2O$**

Shake vigorously to dissolve the chemicals, then add distilled water to make up 1000 ml of cathode sensing solution.

Anode Solution

Fill a 100-ml plastic bottle one-half full with 50 ml cathode solution (prepared as described above). Add 70 g KI crystals to the solution, and shake vigorously to dissolve the crystals. Some crystals will remain undissolved, indicating that the solution is saturated.

Storage

Store the cathode and anode sensing solutions in a dark place at 20° to 25° C. After several months of storage old solution should be discarded and new solution prepared for use.

Data and Computations:

The data from the ECC Ozonesonde is pictured in figure 4 below. There will be about 8000 of these data points if the sonde is set to take readings every 4 seconds.

The first five columns were offloaded from the HOBO on the computer with the Boxcar software. Then copy and paste into Microsoft Excel.

Column1: Time of day in hours: min: sec
Column2: Voltage 1- sensor cell current output (microamperes) “red”
Column 3: Voltage 2- pump motor current “green”
Column 4: Voltage 3- pump temperature “white”
Column 5: Voltage 4- battery voltage “black”

These voltages will be used to calculate the categories listed above. The calculations are as follows:

Cell Current, 1_{ECC}

$$1_{ECC} \text{ (microamps)} = \text{Voltage measured} \times 4.0000$$

Battery Voltage, V_{batt}

$$V_{Battery} \text{ (volts)} = \text{Voltage measured}.(8.675)$$

Pump Motor Current, l_{motor}

$$l_{motor} \text{ (milliamps)} = \text{Voltage measured}(100)$$

Pump Temperature T_{pump}

$$T_{pump}\ (^\circ C) = ((A+B\ (\ln R) + (\ln R)^{2} + D\ (\ln R)^{3})^{-1})-273.15$$

A= 1.119715 e-3
B= 2.355755 e-4
C= 0.000
D= 8.266238 e-8
R (ohms) = Thermistor resistance

$$= \frac{V_{meas}\ (20{,}000)}{2.500\text{-Vmeas}}$$

Note 1: ln= $\log_e$
Note 2: Thermistor is Fenwal Unicurve, P/N 192-103 LET-A01 (10.0 kΩ at 25.0°C).
Note 3: Kelvin is to be used in the partial pressure calculations, just + 273.15.

Use the voltages in the columns of Excel to complete the calculations above. Types in the equation on the formula bar in excel. Then drag the bottom right corner of the cell down until the gray box is on the last data point. All of the cells in that column are now formatted to calculate that equation with the given voltage in the corresponding row.

Now acquire the data from a pressure or temperature HOBO with altitude and ambient air pressure readings. Make sure that the data from the sonde and the data from the HOBO are synced in the time the readings were taken

There might be some deleting of cells if necessary.

When the times are synced, then use the data calculations from above to calculate partial pressure of ozone using the equation below.

$$p_3 = 4.307 \times 10^{-3}(i_m - i_b)\ T_p t$$

where p_3 is the ozone partial pressure (in nanobars), i_m is the measured sensor output current (in microamps), i_b is sensor background current in microamps (which is the current reading that was taken when the sonde was run on the ozone destruction filter), T_p is the pump temperature in kelvins, and t is the time in seconds that the ozonesonde took to force the bubble in the flow rate test 100mL.
There should be another column in the spreadsheet on Excel.

Now, with the ozone partial pressure, the calculation of Ozone in parts per million can be done using the formula below.

$$O_3\ (\text{ppmv}) = 1000p_3/\ P = 4.307(i_m - i_b)\ T_p t/P$$

where O3 (ppmv) = the measured ozone in parts per billion by volume and P is the ambient air pressure in milibars.

Note 4: There should be a column for each of these calculations on the spreadsheet.

Graphs:

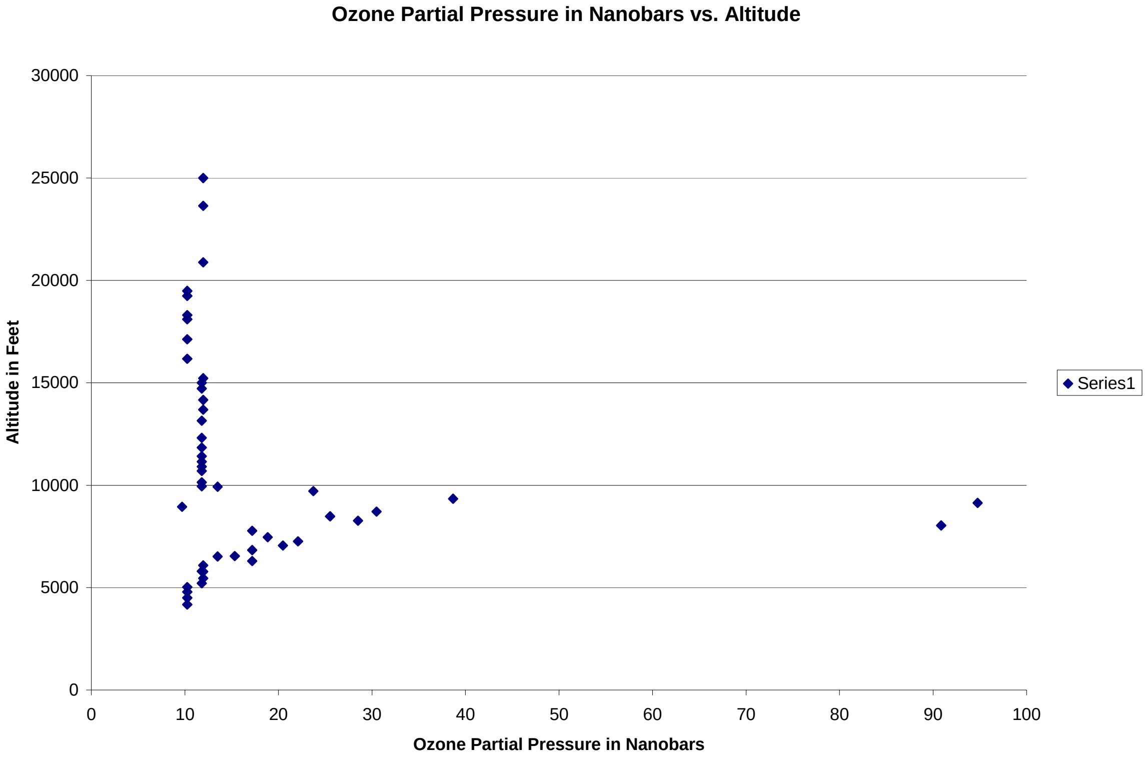
Ozone parts per million can be graphed vs. Altitude in meters or whatever altitude reading that is preferred. The data from this flight was graphed using the partial pressure of ozone vs. altitude from the STXe in feet on Excel.
An example is shown in figure 5.
There is also a graph of the sensor cell current vs. time.

Conclusion:

After conducting this experiment, it was found that ozone concentrations do depend on the altitude at which these chemicals reside. The hypothesis about there being10-75 nanobars in the troposphere, but there could not be a sufficient conclusion if there actually were 1-100 nanobars in the stratosphere because the ozonesonde stopped functioning properly after thirty minutes into the flight. The data required for ozone parts per million couldn't be calculated because the pressure HOBO also had a malfunction. If another source of ambient air pressure could have been acquired, then there could be more information about the ozone parts per million measured on this flight.

Next time that this experiment is conducted, there should be extra precautions to make sure that the connections between the ozonesonde to the lithium batteries, the ozonesonde to the intake tubing, and the HOBO cables to the circuit board. These connections could have been the problem with the malfunction of the HOBO and the ozonesonde.

Figure 5


Ozone Partial Pressure in Nanobars vs. Altitude
30000
25000
20000
15000
10000
5000
0
Altitude in Feet
0
10
20
30
40
50
60
70
80
90
100
Ozone Partial Pressure in Nanobars
◆ Series1

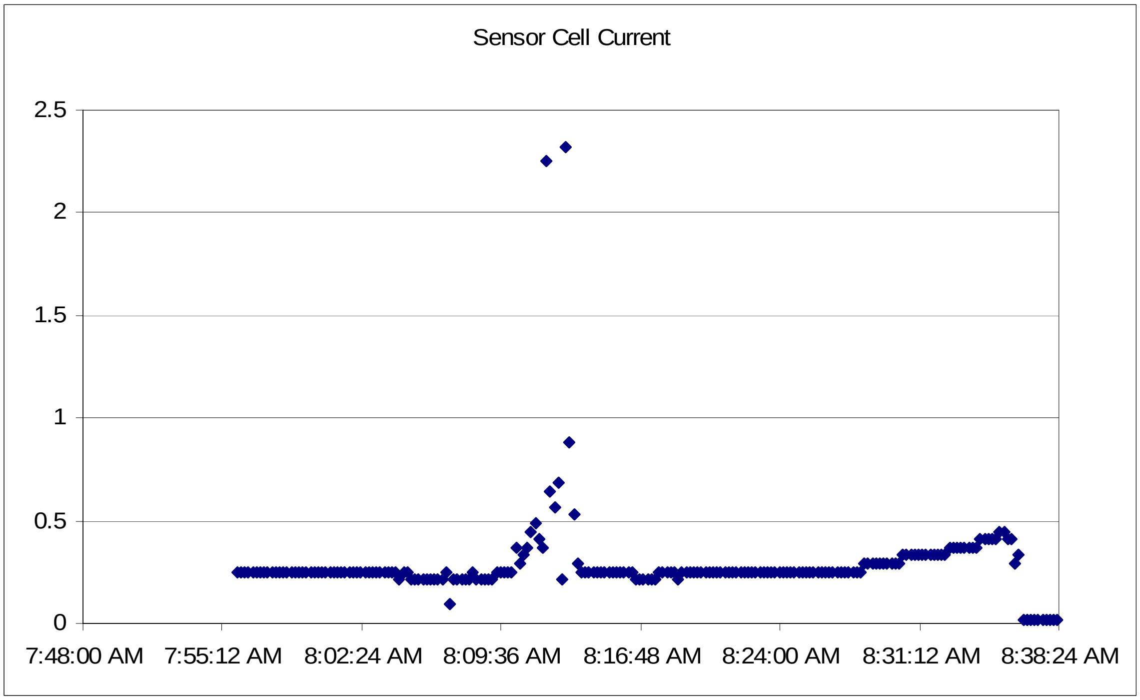

Sensor Cell Current
2.5
2
1.5
1
0.5
0
7:48:00 AM
7:55:12 AM
8:02:24 AM
8:09:36 AM
8:16:48 AM
8:24:00 AM
8:31:12 AM
8:38:24 AM

Figure 1: x-axis Partial Pressure of Ozone (nanobars)
y-axis Altitude in Meters

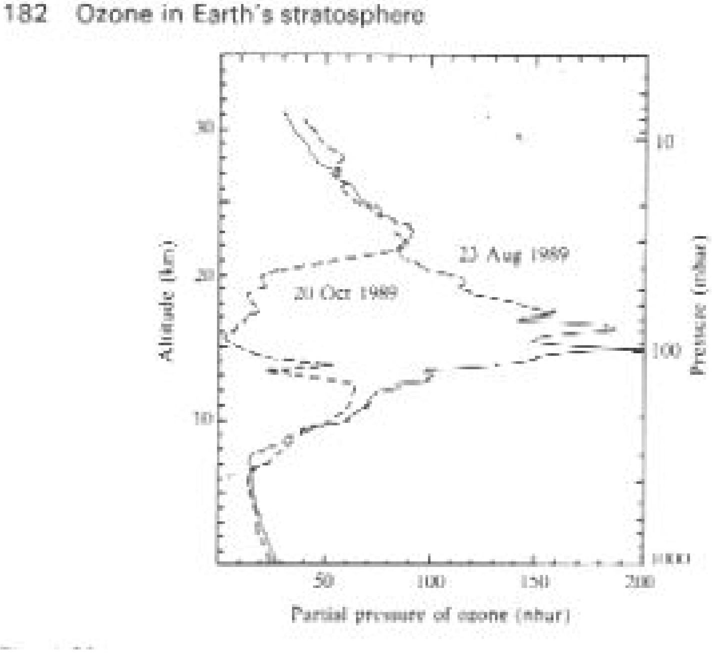


Figure2: