OZONE HOLE RECOVERY

A RESEARCH PAPER
PRESENTED BY

DAVID STEPHEN
Research Associate
Theoretical Research Place
davids@hush.ai
http://stephaz.webs.com

MAY 2011

SYNOPSIS

The procedure in this paper approaches ozone depletion from the stratosphere, a layer of the earth's atmosphere. The ozone layer protects planet earth from dangerous ultraviolet (UV) radiation (or rays) emanating from the sun. Ozone layer as named is made up of ozone gas; it is formed in chemical reactions involving UV rays and oxygen molecules in the stratosphere. When sunlight breaks an oxygen molecule into two oxygen atoms, the atoms react separately with two oxygen molecules to produce two ozone molecules. These ozone molecules are dissociated by UV rays; the process of dissociation and combination in the presence of sunlight prevents planet earth from harmful UV rays. Man’s use of certain gases (called ozone depleting substances) reacts with ozone molecules when at that level of the atmosphere to produce compounds that cannot prevent harmful UV rays from reaching planet Earth. Dangers with harmful UV rays to man includes skin cancer and cataract. This paper presents a procedure to repair depleted part of the ozone layer by injecting oxygen gas under high pressure to replace lost molecules and join in reactions. Aerodynamic objects will be used to convey oxygen to low stratospheric altitude where it will be discharged.

1.0 INTRODUCTION

Ozone is a triatomic form of oxygen; it is available in the earth's atmosphere but predominant in a part of the atmosphere called the stratosphere roughly between 19 and 48km above sea level. Most ozone in the atmosphere resides in lower stratosphere in what is known as the ozone layer, having about 90% of ozone. The remaining 10% is found in the troposphere, the lowest part of the Earth's atmosphere. [1]

The ozone layer is a protective shield; it prevents harmful Ultra Violet (UV) rays from reaching the Earth surface. UV rays have wavelengths shorter than light but longer than X-rays lying outside the visible spectrum at its violet end. UV etymology comes from the theory that the color with the highest frequency humans can see is violet, and ultra- means far beyond normal, so being undetectable to the human eye, it is ultraviolet.

Ultraviolet radiation is measured in wavelength, with units in nanometers (nm) or electron volts (eV). The amount of UV rays that reaches the ground is mainly controlled by cloud cover, pollution and amount of atmospheric ozone. With other factors same, UV at the Earth's surface increases as the amount of total ozone decreases because ozone absorbs UV radiation. [1]

Electromagnetic spectrum of UV rays can be subdivided by their wavelength range; UV-A measures between (400 nm - 315nm); UV-B measures between (315nm - 280nm); UV-C measures between (280nm - 100nm). UV-B and UV-C are screened out by the ozone layer while UV-A reaches the Earth surface. [1]

This paper presents repairing depleted parts of the ozone layer artificially; the ozone layer is expected to be repaired naturally in the middle of the 21st Century, this maybe longer if Ozone Depleting Substances (ODSs) are not phased out as agreed assuming other factors remain constant. This procedure requires further scientific and technical review to save it for future use as necessary.

Feasibility of this procedure is quite high since the method of approach tackles possible impediments. An aerodyne (heavier than-air-craft) or aerostat (lighter-than-air-craft) will carry liquid oxygen to the stratosphere because more volume of the same mass of oxygen can be carried as liquid than as gas. It will be discharged through a hull under high pressure; carrier aircraft should hover around depleted area where ozone depletion is observed, and wind & turbulence is bearable.

2.0 THEORETICAL DEVELOPMENT

Long-term fluxes have had natural balance of ozone creation and destruction in the stratosphere; with reduced use of ozone depleting substances by man, the ozone layer will not be fully repaired until the middle of this century. This is many years away even as effects of harmful UV rays are noticed. [2]

The photochemical process leading to creation and destruction of ozone molecules in the ozone layer favors this artificial approach. Atomic oxygen (O), oxygen molecule (O_2) and ozone molecule (O_3) are some allotropes of oxygen; these are structurally different forms of oxygen with different physical and chemical properties.

In the ozone layer, UV light {<242nm} dissociates an oxygen molecule to form two atoms of oxygen, these atoms separately react with two other oxygen molecules to form two ozone molecules. UV rays {300-210nm} dissociate ozone molecules formed in this process.

The overall process of dissociation and combination in presence of UV rays makes the ozone layer protect man and the environment from harmful UV rays. UV rays with wavelength {enclosed} are absorbed by oxygen and ozone molecules thus prevent UV rays of harmful range from reaching the earth surface.

Oxygen gas to be injected in this Ozone Layer Geoengineering (OLG) procedure can be useful in at least two ways; it can react with oxygen atoms to create more ozone molecules or can possibly be dissociated by UV rays to form oxygen atoms that will continue in photochemical reactions described.

Ozone gas, O_3 itself is unstable and dissociates to diatomic oxygen, O_2 at high concentrations in about half an hour under atmospheric conditions.

$2\ O_3 \rightarrow 3\ O_2$

Heat intensity in the stratosphere dissociates Oxygen molecule to atomic oxygen,

$O_2 \rightarrow O + O$

O_2 + solar energy of wavelength less than 242nm $\rightarrow 2\ O_2$

$O + O_2 \rightarrow O_3$
$O + O_3 \rightarrow 2\ O_2$

O_3 + solar energy of wavelength less than 336nm $\rightarrow O^* + O_2$

O* is an exited state of oxygen. It can be de-excited through thermal collisions and become a single oxygen atom. It can be seen that light with wavelength from 336nm down will be absorbed. Only the lowest-energy UV radiation will reach the surface. All these transformations are encapsulated in what is called the Chapman cycle. [3]

A large percentage of ozone is formed over the equator where sunshine (heat) amount are preeminent. It is transported by moving air towards the South Pole and North Pole. At high latitudes, very high amounts of ozone are found in the upper atmosphere; its thickness is subject to change with season and geographical location.

Injecting oxygen gas to lower stratospheric altitude will mitigate the depletion. This will be noticed by re-observing the hole after time. This process can be used recover thinned ozone over Antarctica during its spring & lessen fractional melting of glaciers caused by increased intensity during that period. [4]

ODSs are chemical elements or combination of elements of natural and artificial sources; they find their way to the stratosphere and react with ozone molecules reducing them to oxygen molecules that may never successfully return for protection reactions. Natural ODSs have been existent for hundreds of years but the cumulative effect artificial ODS (of the last 30-40years) on the ozone layer have been massive.

Chlorofluorocarbons (CFC's) used as refrigerants for refrigerators and propellants in aerosols are examples of artificial ODSs. CFC's contain mainly chlorine, fluorine and carbon. CFC's for example, once at the stratosphere gets dissociated by sunlight releasing chlorine, Cl^-, this Cl^- react with ozone molecule, O_3 to produce chlorine monoxide, ClO and one oxygen molecule, O_2; see equation (i)

$Cl^- + O_3 \rightarrow ClO + O_2$ --- equation (i)
$ClO + O_3 \rightarrow Cl^- + 2\,O_2$ --- equation (ii)

The monoxide reacts with another ozone molecule to release two oxygen molecules, $2O_2$ and chlorine, Cl^-; this Cl^- continues to react with ozone molecules as in equation (i) and occurs thousands of times more. [3]

This summarizes how ozone gets depleted in the stratosphere; chlorine, bromine from man-made sources adds to the molecules in the stratosphere making oxygen allotropes available for UV rays protection reduced.

When oxygen gas is injected as in this OLG experiment, it will increase the total volume of oxygen in the ozone layer. Some injected oxygen molecules will form 'new' ozone molecules by absorbing UV rays and proceeding further in reactions for protection against harmful UV rays.

$^*O_2 \rightarrow O + O$
$O + {}^{'}O_2 \rightarrow O_3$
$O + {}^{'}O_2 \rightarrow O_3$

$^*O_2$ is one of injected oxygen molecule split by UV rays to oxygen atoms; ${}^{'}O_2$ is one of injected oxygen molecules in reaction with already split oxygen atom to form an ozone molecule.

With this, injected oxygen molecules can solely form ozone molecules without reaction with existing oxygen molecules. Injected oxygen molecules can also enter reaction with naturally existing oxygen atoms to increase the number of ozone molecules in the stratosphere.

OLG will not be for total depleted space estimated to be about 3% of the whole; it will be used for parts it will impact to be known from various measurements before a decision. Amounts of ODSs are usually calculated, amount of depletion over an area is calculated too, the season and geographical location is also necessary; these will determine when and how to carry out this experiment.

With these measurements and checks in place, this experiment for repair will give expected result; this will be relevant for the atmosphere over Arctic and Antarctica for recovery of lost ozone.

This geoengineering experiment should not have harsh effects on the environment because gases to be added will be within the range of ozone/oxygen available in the atmosphere over that area. This should cover lost place and join in sustaining planet earth's natural process for protection against harmful UV rays.

Testing of this procedure can come in the atmosphere over Arctic and Antarctica since they don't have permanent human inhabitants and also experience recurrent ozone loss for polar vortex and other reasons. OLG can be used for recovery of the ozone layer should Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) geoengineering experiments cause attrition of the ozone layer.

Modeling and studies through this decade can bring about a report that will form a background for this experiment for use anytime from next decade if necessary.

3.0 EXPERIMENTAL PROCEDURE

Method of delivery for oxygen comes from a number of options amongst objects known to fly to stratospheric height; this heading presents sections relevant to achieve the objective.

3.1 Oxygen Tank

Liquid oxygen will be carried to the stratosphere but will be released as gas because more volume of oxygen is stored as liquid than as gas. The tank capacity should be able to hold around 300m^3 of liquid oxygen per aircraft; the liquid will be made to vaporize in the next chamber before discharge as gas. It will be ejected under high pressure to trigger reactions in the stratosphere immediately.

A non-reactive pressurized gas like nitrogen may be held above the oxygen storage tank to force the oxygen gas to a vaporization chamber before discharge. The oxygen gas will join naturally existing molecules and let natural process of creation and collapse of ozone molecules occur as it were.

Depending on the extent of depletion, more volume may be carried by one flight to reduce continuous flights. Oxygen is preferred for OLG because production and storage of a large volume of ozone gas (unstable under normal atmospheric conditions) for transportation up high is practically impossible and financially guzzling. Oxygen gas discharged will escape destruction by CFC's likely to immediately destroy ozone if injected.

Protection from harmful UV rays is a process where from oxygen ozone is formed, ozone formed to be later dissociated 'possibly understands' the dynamics of the process; freshly injected ozone molecules may not understand this on entry to the ozone layer and may falter by not protecting planet earth or lost after encountering ODSs.

3.2 Aerodynamic use

To get to the stratosphere with a liquefied oxygen tank an aerodynamic object will be used; examples are of likely aerodynamic objects are: airships, rotorcrafts, drone, rocket and jumbo jet. The one with little or no aftereffect to the ozone layer, large storage capacity for the oxygen tank, high altitude capability and speed will be considered.

The problem of pollution especially to that region may hamper the use of jet engine or rocket engine. This gives light to airships but altitude and load capacity questions their ability to convey oxygen for discharge.

Aerodynes and aerostats have their disadvantages, but a way to discharge the oxygen gas to depleted areas of the ozone layer is a novel objective; achieving it should be possible.

3.2.1 Airship

Recent developments in airship industry especially for defense systems submit the possibility of airship use for this objective. Hybrid configuration used for flying high altitude airships and cargo airships gives aerostats the advantage to get this done.

Airships also called blimps or dirigibles are self-propelled lighter-than-air craft with directional control surfaces or steering systems. Airships can also be defined as powered, gas-filled balloon which can be steered not requiring movement through surrounding air. They were used for transportation many years ago; they have been modernized lately for high altitude and better transport capability. [5]

Operating capability of airships used in space defense system gives it an advantage to deliver oxygen to the ozone layer. The oxygen gas to be discharged is expected to pass through a hull and should pass through it without causing critical loss of helium in the airship. The internal hull pressure will be maintained around 1-2% above surrounding air pressure.

Previously developed stratospheric airships flew at 22km where wind and turbulence is bearable. The oxygen gas will be discharged at relatively low stratospheric altitude (20-22km). The discharged oxygen cum ozone is expected go higher in the stratosphere by wind and other air motion.

The HiSentinel Airship, a United States Army Space and Missile Defense Command project to demonstrate powered stratospheric airship at high altitudes was tested for five hours in 2005 and could carry medium weight between 9-90kg; it flew around 18km above sea level. [6]

This example presents two barriers for the ozone replacement purpose: timing (depending on the tank capacity could discharge oxygen gas in a few hours) and its load capacity. There are cargo airships not reaching 20km that stay longer in air and carry more tons. The airship to be used will have an equipment pod; a propulsion system and a liquid oxygen tank; it is required to discharge oxygen gas at hypersonic speed, spending few hours hovering ozone depleted space.

The airship once at the desired altitude will be programmed to immediately release the gas from the chamber at high pressure to the stratosphere; this should make the airship stay there in a short time. The airship will also release gas as it comes down steadily from its maximum altitude within the stratosphere.

Airships should be designed specifically for this procedure; there may be twin airship design that will have both fly simultaneously and reliant to achieve this goal.

Recent technologies have hybrid airships that can fly around 26km above sea level, stay longer in air and carry more tons. With this or special purpose airships built for OLG, Man can be at ease for harmful UV rays effects knowing that airships can discharge oxygen emitting little or negligible pollution.

3.2.2 Unmanned Aerial Vehicle

An unmanned aerial vehicle also called Unmanned Aircraft System or drone is defined as a powered, aerial vehicle that does not carry a human operator, it uses aerodynamic forces for lift, can fly autonomously or be piloted remotely. [7]

An unmanned aerial vehicle can help deliver oxygen gas to the ozone hole since existing ones have been successfully used for reconnaissance and defense discharge at stratospheric height with load capacity far exceeding 500kg. [8]

The design, performance, flight altitude, load capacity, integrated system and sensor packages gives a vertex mark for expected outcome for OLG. This flight presents two drawbacks, cost and pollution. We are trying to recover depleted ozone in the stratosphere but taking a flight to that level that will eject some gases that may react with naturally produced ozone and further deplete them, this is not so nice.

Tank containing liquid oxygen with weight of about 900kg can be carried by the RQ-4 Global Hawk. The Northrop Grumman RQ-4 Global Hawk was used by the United States Air Force as a surveillance aircraft; a high altitude (21km), long-endurance unmanned aerial reconnaissance system with an integrated sensor suite provided military field commanders with high resolution, near real-time imagery of large geographic areas. [9]

A more recent Unmanned Aircraft is the Boeing X-37B, operated by the United States Air Force for space experimentation, risk reduction and a concept of operations development for reusable space vehicle technologies. It can carry a reasonable amount of load and is powered by Gallium Arsenide Solar Cells with Lithium-Ion batteries. [10] No pollution fears if this aircraft is used for this ozone objective; it can spend desired time and more in the stratosphere but it is extremely expensive to build and run.

The liquid oxygen tank will be connected to a chamber where it is expected to vaporize and released under pressure through a hull; the hull will also prevent gases from space to enter the tank. High cost is the key disadvantage of UAV’s for this objective. Since this research is preliminary, chances exist to extemporize for UAV usage.

4.0 RESULTS AND DISCUSSION

Using either of the two aerodynamic systems, oxygen will be discharged to places where ozone depletion is observed. After discharge, wind is expected to carry discharged oxygen gas or emanated ozone gas higher. The airship will linger depleted area during discharge to ensure that spread is even and reactions are triggered for high pressure of discharge.

This research is not oxygen recovery, it is ozone recovery but oxygen is used because of processes that lead to ozone molecule formation in the stratosphere, discharged oxygen will add to the total volume of oxygen at depleted places and join in reactions.

This method is injection of oxygen gas to the stratosphere not ozone gas because injecting ozone is practically impossible; that will be delivering a large volume of gas to that altitude. Injecting oxygen gas is not expected to upset existing balance since there is a range of ozone molecule amount in the stratosphere, incoming oxygen molecules should not exceed that range.

This approach is suggested for depleted parts of the layer not everywhere in the stratosphere, discharged gas from a number of flights should protectively cover. It also should not be continuous since it will recover lost ozone molecules to a good extent, natural recovery will definitely be continuous not artificial recovery.

Amounts of ozone are often described in terms of the thickness of ozone in a column of air that stretched from the Earth's surface to the top of the atmosphere. The most common measurement of total ozone values in the column are called Dobson's unit (DU). [1]

One DU is equal to the number of molecules of ozone that will be needed to create a layer of pure ozone 0.01millimeter thick. Typical amounts vary between 200 and 500 DU worldwide. Total ozone value of the ozone hole is around 100DU. This is equivalent to a layer of pure ozone gas on the earth surface having a thickness of only 1millimeter. [1]

4.1 CONCLUSION

Ozone layer geoengineering is feasible from the procedure detailed in this research work, as we await natural repair in time to come, we should skillfully do by having this research analyzed and developed.

Development in science is beyond staying at a corner of impossibility; it is with scientists, institutions and nations to use every technology, procedure and research to save our world. This research is an option for protection, further scientific and technical review will have it on hand.

APPENDIX

Global Warming

The concept of global warming started with observed and measured rise in temperature in the 20th Century. Global warming is usually caused by the heat trapping actions of Greenhouse Gases (GHGs). GHGs are heat trapping gases that absorb heat within the thermal infra-red range to planet earth. [11]

Sunlight shines on the earth emitting radiations in all direction including infrared radiation, some of the infrared radiation passes through the atmosphere; some are absorbed and re-emitted in all directions by GHGs. The effect is to warm the Earth's surface and lower atmosphere.

GHG in upper atmosphere is on the rise because they are emitted mostly by human activities. Examples of GHG are water vapor, carbon (IV) oxide, methane, Nitrous oxide and ozone gas, (Ozone is a GHG when at the troposphere; it is also responsible for photochemical smog and poor visibility in the near atmosphere). Some of these gases grow from processes like burning fossil fuel and deforestation.

Each GHG contribution to Green House effect depends on its characteristics and abundance, in the upper atmosphere. Normally without GHG, planet Earth will be colder on average than what is obtainable.

Other dangerous substances that make it to the upper atmosphere are halogens (chlorine family of element) released when sun dissociates chlorofluorocarbons compounds used in freezers, aerosols, fire extinguishers and air conditioners. These gases once at the ozone layer react with ozone molecules and form monoxides that cannot protect us from UV radiation.

GHGs trap heat for the earth in the troposphere; about 10 - 18 km above sea level, with more amounts of GHGs due to anthropogenic activities, less heat gets to the ozone layer because they will trap more heat than re-emit making the stratosphere colder.

Usually, re-emitted heat supports ozone molecule formation and dissociation, a process that prevents harmful UV rays. A colder stratosphere results in a weaker ozone layer which can make harmful UV rays to reach the earth surface. Cutting and capping GHG emissions will stay recovery whether natural or artificial.

ACKNOWLEDGEMENT

Many thanks to all whose works, views and comments have contributed to development of this research paper, you are sincerely appreciated.

REFERENCES

1. U.S. Climate Change Science Program, (2008) Trends in Emissions of Ozone-Depleting substances, Ozone Layer Recovery and Implications for Ultra Violet Radiation Exposure. Synthesis and Assessment Product 2.4.

2. Australian Academy of Science, (2008) Enhanced Greenhouse effect - a hot international topic: nova 016 / 016 key.

3. Wilkins J, (2006) How the Earth got its ozone layer. Energy, publication of Department of Physics, Ohio State University, E01.1 .

4. McKenzie, R., B. Connor, and G. Bodeker, (1999) Increased summertime UV observed in New Zealand in response to ozone loss. Science 285 (10 September): 1709-1711.

5. John M, Introduction of Airships. Article Alley Publications 1437412_31.

6. Smith S Jr., and L. Michael, (2007) The HiSentinel Airship, presented paper at the 7th AIAA Aviation Technology, Integration and Operation (ATIO) 2nd C, Belfast, Northern Ireland.

7. Wagner. W, (1982) Lightning Bugs and other Reconnaissance Drones, Armed Forces International Journal Page XI.

8. Axe, D, (2009) Strategist: Killer Drone Level Extremist Advantage, Wired.

9. United States Air Force, (2009) RQ-4 Global Hawk, Fact Sheet by the Air combat command, Public Affairs office, Virginia Unites States Of America.

10. United States Air Force, (2010) X-37B Orbital Test Vehicle, Fact Sheet from the Office of the Secretary of the Air Force (Public Affairs), Washington, USA.

11. United States National Academy of Sciences, (2008) “Understanding and Responding to Climate Change”.