# The Origin of the Ozone Hole – Natural or Anthropological

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## Introduction

The Earth is surrounded by a thin layer of ozone in the middle atmosphere (stratosphere) about 25 kilometers above the Earth's surface. Ozone is a minor constituent of the stratosphere (1-10 ppm). Ozone and oxygen molecules in the stratosphere absorb ultraviolet light from the Sun, providing a filter that prevents this radiation from passing to the Earth's surface. While both oxygen and ozone together absorb 95 to 99.9% of the Sun's ultraviolet radiation, only ozone effectively absorbs the most energetic ultraviolet light (UV), known as UV-C (220-290 nm) and UV-B (290-320 nm). Energetic ultraviolet radiation at the Earth's surface is a health concern because it is believed to cause biological damage in the form of skin cancer (malignant melanoma), tissue damage to eyes, plant tissue damage and destruction of plankton populations in the ocean. An approximate 5 percent reduction of ozone in the stratosphere was observed from 1979-1990. Ozone depletion varies both by season and geographically. Ozone holes are areas where the reduction of ozone is dramatic; leaving voids in the ozone layer. The ozone holes occur in the Polar Regions (70% over Antarctica and 30% over the Arctic). The ozone losses occur annually each spring in the Polar Regions but recover by the summer.

Two theories exist that explain ozone depletion and the formation of an ozone holes. One theory postulates the cause is anthropological (release of man-made chemicals). The other theory postulates the cause is natural (a weakening of Earth's magnetic field).

## Anthropological Theory

Under the anthropological theory, the depletion of ozone is due to release of man-made chemicals, chlorofluorocarbon (CFC) compounds and ozone depleting substances (ODS) such as carbon tetrachloride, methyl bromide and methyl chloroform. Over time these released chemicals are believed to work their way up into the stratosphere. CFC and ODS break apart under UV radiation releasing chlorine atoms, halons and bromine atoms that destroy ozone.

Assuming the anthropological theory on the origin of the ozone hole is correct, one would expect that the area most affected would be the mid-Latitude Northern Hemisphere (the industry and population centers in the U.S., Canada, Europe, India, Asia, Russia, China and Japan). This band should correspond to the most industrialized and polluted area of the world and the site of major CFC and ODS releases. Therefore, one would expect an ozone hole (depletion band) to occur regularly over this region. But instead, we are observing an annual ozone hole in one of the most pristine places left on the planet, located in the Southern Hemisphere, in a place called Antarctica.

## Natural Theory

Earth's atmosphere is composed of approximately 21% molecular oxygen ($O_2$) and 78% molecular nitrogen ($N_2$). These two molecules are the principal constituents in the Stratosphere. A number of minor constituents are present which includes nitric oxide (NO), atomic oxygen (O), ozone ($O_3$) and water vapor. Ozone is produced in the stratosphere through a natural process of photodissociation of $O_2$ by ultraviolet light (UV).

$$3O_2 + UV \longrightarrow 2O_3$$

Nitric oxide is produced through a natural process when solar and galactic cosmic rays (high-energy protons), collide with nitrogen and oxygen molecules unbinding the atoms allowing them to freely recombine to form nitric oxide. Nitric oxide is a natural ozone-depleting chemical.

$$\mathbf{NO + O_3 \longrightarrow NO_2 + O_2}$$

$$\mathbf{O + NO_2 \longrightarrow NO + O_2}$$

The sun routinely generates violent explosions that produce burst of high-energy protons. These events are known as Solar Proton Events (SPE's). Ozone layer density on Earth can be dramatically affected by SPE's, which can locally decrease ozone content in the stratosphere 10-15%.[1]

Cosmic ray production of nitric oxide in the atmosphere leaves behind a chemical signature, which is visible in ice core records. The history of past SPE's and supernovas that produce cosmic rays are recorded as nitrate spikes. Nitrate-ions ($NO_2^-$ and $NO_3^-$) are generated in Earth's atmosphere in a chain of chemical reactions with nitric oxide. The nitrate-ions are captured by aerosols, fall down with precipitation and become fixed in polar ice. A strong correlation has been observed between nitrate spikes captured in ice core records and the timing and intensity of solar cosmic rays produced by Solar Proton Events and Galactic Cosmic Rays (GCR's) produced by nearby supernova events.

| Nitrate Spike Signature | Ice Core | Reference |
|---|---|---|
| SPE of September 1, 1859 | Arctic | 2 |
| SPE of July 15, 1892 | Summit, Greenland | 3 |
| 25 SPE's (1888-1995 AD) | Law Dome, Antarctica | 4 |
| Multiple SPE's (1576-1991 AD) | Central Greenland | 5 |
| 125 SPE's (1561-1994 AD) | Greenland | 6 |
| 62 SPE's (1840-1950 AD) | Arctic | 7 |
| 4 Supernova (1150-1990 AD) | South Pole, Antarctica | 8 |

In general, this natural destruction of ozone is held in check by Earth's magnetic field. On the Earth's surface, the field varies from being horizontal and of magnitude ~ 30,000 nanoTesla (nT) near the equator to vertical and ~ 60,000 nT near the poles. Charged particles are deflected by the horizontal component of the Earth's magnetic field. Therefore the magnetic shielding of charged particles is strongest above the equator and weakest above the poles.

One would expect the highest concentration of nitric oxide production to occur at the magnetic pole because at this location the field in general has only a vertical component. And indeed that is the case. ISCAT & NCAR scientists observed atmospheric nitric oxide levels at the South Pole that are 10 times higher than in other areas of Antarctica. The levels at the South Pole exceeded 550 parts per trillion by volume of air (pptv). This would help to explain why the ozone holes appear in the Polar Regions over Antarctic and the Arctic.

The strength of the Earth's magnetic field has been declining. Scientific analysis of ancient pottery has shown that the overall magnetic field strength has declined 50% in the last 4,000 years. This decline in field strength has intensified recently. But the decline is not applied uniformly across the Earth's surface. The South Pole in Antarctica has experienced a magnetic field decline of 13.0% during the past 100 years.

(Geomag program, IGRF dataset, latitude $90^{O}$ S, longitude $0^{O}$ W, years 1905-2005, a decline from 63,876 to 55,565 nT). http://www.ngdc.noaa.gov/seg/geomag/models.shtml

When the Earth's magnetic field is strong, it is characterized as a dipole with a north and south magnetic pole on opposite sides of the Earth. As the Earth's magnetic field weakens, it does not do this uniformly, rather the magnetic field breaks down into quadrupoles, octupoles and local magnetic field reversals. The appearance of this complex structure allows minipoles to effectively cancel out the Earth's magnetic field reducing the overall magnetic field strength to 10% or below.

A South Atlantic Anomaly (SAA) is a region with a major depression in Earth's magnetic field strength. This region is located in the South Atlantic Ocean centered just to the East of Brazil. The horizontal intensity of the magnetic field (the component that shields against proton penetration) has declined dramatically at this location falling from 22,553 nT down to 14,827 nT during the past 100 years. This is a drop of 34.3% in horizontal field intensity. (Geomag program, IGRF dataset, latitude $30^{O}$ S, longitude $30^{O}$ W, altitude 50 km [top of stratosphere], years 1905-2005).

As the Earth's magnetic field weakens, less energetic protons in solar and galactic cosmic rays become capable of penetrating the upper atmosphere and driving deep into the stratosphere, producing an increase in the ozone depleting chemical, nitric oxide. SPE's and supernovas that produce cosmic rays have left behind an observable fingerprint (nitrate spike) as a proxy in the ice cores. The Earth's magnetic field protects the planet from ozone destroying cosmic rays. But the Earth's magnetic field has been weakening significantly; the field is currently asymmetric; and local magnetic field reversals have begun to appear. The recent decline in ozone layer density is a natural process and is due to the weakening in the Earth's magnetic field strength.

## Predictive Future

It is very likely that Earth's magnetic field strength will continue to decline and the decline may become more rapid. It is also likely that as the field strength declines other local magnetic field reversals will materialize. If the reduction of stratospheric ozone is primarily due to natural processes (changing Earth's magnetic field strength) then one would expect that as the field strength declines, the size of the ozone hole will expand. In general, this expansion will be primarily limited to the low population density Polar Regions. But the creation of local magnetic field reversal is a different matter because these local areas can extend into mid-latitude and equatorial regions, resulting in thinning of the ozone layer above highly populated regions.

SPE events follow the ~ 80-100 year Gleissberg cycle. The Earth is currently at the minimum of the Gleissberg cycle. The coming solar cycles will show an increasing number of large SEP events.[2] Ozone depletion during these SEP events will be amplified by a weakening magnetic field strength on Earth.

## References


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