Atmospheric and Climate Sciences, 2022, 12, 564-587
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

Ice Sheet Melt and Ozone Hole Variations on Three Solar Cycles Possible Anthropogenic Interactions

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How to cite this paper: Hagen, M. and Azevedo, A. (2022) Ice Sheet Melt and Ozone Hole Variations on Three Solar Cycles Possible Anthropogenic Interactions. *Atmospheric and Climate Sciences*, **12**, 564-587.
https://doi.org/10.4236/acs.2022.123032

Received: May 8, 2022
Accepted: July 2, 2022
Published: July 5, 2022

Abstract

This paper investigated the information about Ice sheet melt and Ozone hole variations during three solar cycles. After performing the inquiry on the data, the final results pointed out that both phenomena varying accord with Earth's seasonality. The sea melt extension depends on the season and if the ocean waters are warmer around the polar caps. We checked the suggestion that anthropogenic perturbations could influence the variations in both phenomena.

Keywords

Sun-Earth Connections, Sea Melt, Ozone Hole, Anthropogenic Disturbances

1. Introduction

This study focuses on the pole disturbances, one on the sea melt in the Arctic and on a minor scale in Antarctica; the other is the Ozone hole disturbances where the southern is most sensitive. These regions have higher responses to solar geomagnetic storms and other sun disturbances. Firstly, we must explain how the Sun interacts with the Earth, which is electromagnetically or mechanical. Mechanical forces depend on Newton's law and are inversely proportional to the square distance between the two bodies.

Then, the forces are strong electromagnetically, and the interplanetary magnetic field is double the Earth's dipolar field. The connections Sun-Earth affect events on Earth's surface; however, finding out the impacts on the lower magnetosphere layers is more complicated. The connection Sun-Earth is significant and necessary to explain before any other step as the human disturbances. Previously, the authors conducted a study on solar and anthropogenic interactions in the terrestrial climate [1].

The study was made during several solar cycles in the last 20 years and compared the significance of the Sun-Earth relationship to human disturbances and how it changes during solar cycles. We have seasons, solar flares, and several electromagnetic activities from the solar wind influencing the Earth's climate.

The Sun's disturbances on Earth are solar flares, electromagnetic events, and seasons. Solar cycles are happening for 11 - 12 years, and their connections with Earth are discussed in another previously mentioned article. The Earth's poles have stronger interactions with the Interplanetary Magnetic Field (IMF) due to the dipolar shape of Earth's magnetic field lines being stronger in these regions.

The paper aims to comprehend the electromagnetic interactions from the Sun to Earth. We also need to understand how anthropogenic activities could increase the greenhouse gases and other pollutants in the troposphere, improving the disruptions in the climate. Finally, we examine how greenhouse gases moving vertically to the troposphere could affect regions located close to the Earth's surface and if there is a chance that the pollution moves from the Northern Hemisphere to the Southern Hemisphere.
(https://en.wikipedia.org/wiki/Northern_Hemisphere).

A large part of the total land is in the Northern Hemisphere regarding the Earth. Therefore, the characteristics of the Northern Hemisphere and Southern are essential in this study, not only for the interactions with the anthropogenic emissions but also for the geography, population distribution, stage's development of each nation, the sources of exploitation, the oceans currents, the Earth's position concerning the Sun, the solar cycles.

The winds make the connections linking the Earth's surface and the atmosphere. All the greenhouse gases travel to the troposphere in vertical movements and are trapped in the wind cells. There are three kinds of those cells, distributed by latitude, Polar easterlies, westerlies, and trade winds. They are approximately circular and moving according to the Coriolis effect. The names are Hadley cells, Ferrell cells, and Polar cells.

Hadley cell—The Equator receives more heat as compared to other regions. As a result, the air at the Equator becomes warm and moist. The air rises at the Equator till near tropopause (10 - 15 km) and then moves towards the poles on either side of the Equator. As the air moves towards the poles, it cools and collides with a colder air mass coming from the poles and sinks. Those events happen at about 30 degrees latitude, creating a high-pressure zone (**Figure 1**).

As the air moves towards the Equator, it deviates towards the west due to the Coriolis force. This occurrence gives rise to the trade winds or Easterlies of the tropics.

Ferrell cell—Air in the Ferrell cell moves towards the poles near the surface. This is a part of sinking air mass at 30˚ latitude. At about 60˚ latitude, this air mass collides with another front from the poles. The air rises after collision and

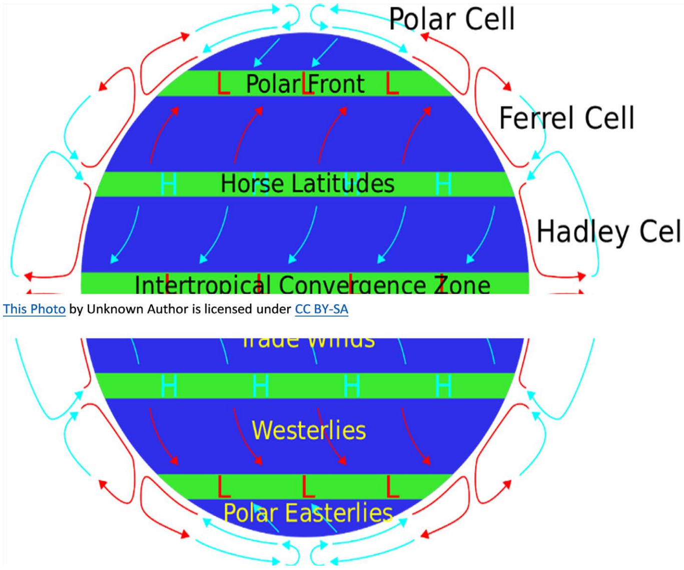

Figure 1. The three wind waves on Earth's troposphere. Three atmospheric cells are traveling from Earth's surface through the troposphere. The red lines mean hot gas ascends, and the blue (cold) gas descends. Those cells are Hadley cell, Ferrel cell, and Polar cell. The explanation and description are in the text.

returns at 30˚ latitude to complete the Ferrell cell. Westerly winds found near the surface in the Ferrell cell are due to the Coriolis force.

Polar cell is the smallest and the weakest cell. The frigid air from the poles (near the surface) moves towards the lower latitudes and interacts with the Ferrell cell. The air rises after interaction and again sinks at the poles, thus completing the polar cell.

As the Earth rotates from west to east, the Coriolis effect kicks in the winds on the Northern Hemisphere curve to the right and the Southern Hemisphere curve to the left. Prevailing wind patterns worldwide are westerly means going from west to east. The first air current moves from 90˚ (the North Pole and the South Pole) and heats up at 60˚—the air expands, rises, and cycles back in a counterclockwise loop. The trade winds occur between the Equator line and 30˚ and 60˚; a new convection current takes shape in a clockwise mode (**Figure 2**).

The rising air creates a Hadley cell in which the air rises and cools at high altitudes and moves toward the poles. Since the Earth rotates, the Hadley cells cause winds to be deflected to the right in the Northern Hemisphere and the left in the Southern due to the Coriolis effect. Therefore, there is a poor atmospheric wind interaction between the two hemispheres. The winds are essential to understanding the conduction of greenhouse gases on the Earth's surface. Those cells are driven vertically, and the interaction North and South Hemispheres is impossible from such patterns.

Summer in the Northern occurs from the summer solstice until the autumn equinox. The Winter happens from the winter solstice until the vernal equinox. The Earth's axial tilt of 23.439˚ is responsible for the seasons. Summer in the Southern happens between December 22 and March 20, and Winter from June

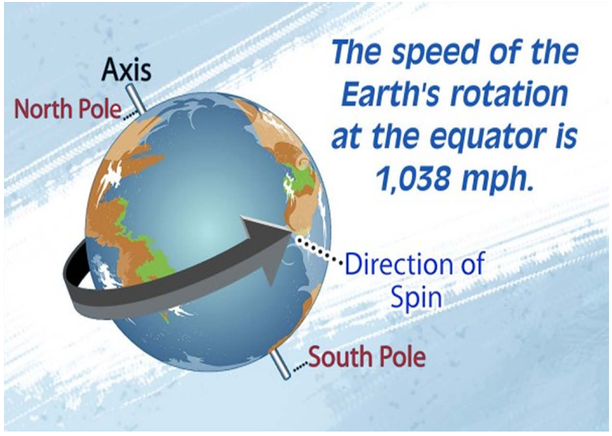

Figure 2. The direction of the wind around the Equator by the Coriolis effect, following the Earth's rotation. The direction is from west to east; it also shows rotation speed.

21 to September 21.

The Sun rises to its maximum point during the Northern Hemisphere at a southerly position. In the Southern Hemisphere, the opposite situation takes place. Storm movement comparison is explained in the next section. An estimated 90% of the population of the Earth lives in the Northern Hemisphere. It means approximately 6.6 billion people from 7.3 billion on the entire Earth.

The Northern Hemisphere includes Europe and North America, most of Africa and Asia, and parts of South America [2] [3].

There is a significantly lesser amount of industrialization and pollution in the Southern Hemisphere compared to the northern. The Northern is 60.7%water, compared with 80.9%water in the case of the Southern Hemisphere. Europe and North America are entirely on Earth's Northern Hemisphere.

Southern climates tend to be slightly milder than those at similar latitudes in Northern Antarctica, colder than the Arctic. The Arctic is the region around the North pole; its climate is characterized by cold winters and cool summers.

Our later study examined anthropogenic activity during ten years in the USA, mainly three hazard events, wildfires, floods, and droughts. Our results in the USA (the location chosen) showed that wildfires are 85% due to anthropogenic reasons, which may influence the occurrence of the two other events. Pollutants are thrown into the troposphere and trapped in this lower layer of the atmosphere, creating a blanket keeping impossible the escape of greenhouse gases from the region.

Humans are one of the leading causes of three natural hazards: wildfires, floods, and droughts [3] [4].

All the greenhouse gases can naturally be recovered. However, it is slow compared to the pace they are emitted from the ground. Therefore, we conclude that the climate changes over the USA, observed in some locations, are due to the trapped pollutants in the Hadley Cells that cannot recycle faster, disturb the climate, and provoke sudden effects such as droughts and floods.

There are other issues of climate variability: the space around the Earth, the atmosphere layers, troposphere, stratosphere, mesosphere, thermosphere, and exosphere. Still, the influences from the Sun on the Earth cannot disturb much of the layers closest to the ground.

The troposphere and the stratosphere form the lower atmosphere. Both are dense compared to the upper atmospheric layers. The troposphere has a negative temperature gradient, constant convection, and abundant clouds and moisture. The stratosphere has a positive temperature gradient, has stable layers of air, no clouds except at the poles, and is dry.

Greenhouse gases climb to the troposphere in vertical paths. The pollutants are not fast recycled; they are trapped in this low layer, eventually warming the Earth's surface below. Advances in technology also enhance the total of contaminants dragged to the troposphere. Since the three cells identified in the atmosphere, make upward, and cyclical movements, most pollution created in the Northern does not escape or cross the Equator. The Southern produces just 10% of the pollutants transferred to the troposphere. Our investigation range is 1979 (when the satellite records started) to 2021; the time corresponds to three solar cycles. The aim here is to search for a possible connection between the solar variability and the evolution of events occurring on Earth's surface during this period.

There is a chance that better results could be found for more extended periods; however, it was better to keep on the records by satellites for coherence.

2. The Disturbances in the Arctic and Antarctic Seas' Extent

The Northern Hemisphere is the half of the Earth located north of the Equator. Trade winds blow from east to west just above the Equator. The winds pull water with them, creating currents, which drive westward due to the Coriolis effect. Then, at about 30˚ north latitudes, the westerlies, a different set of winds, push the currents back to the east, producing a closed clockwise loop.

In the region we are studying, the Arctic, the ice is primarily formed from the frozen sea and contained by the surrounding landmasses. Greenland is the largest ice cap in the Arctic; other than this, permanent ice is rare and minor. Icebergs form when the edges of the Greenland ice sheet reach the ridge; most of the ice in the Arctic remains ice even in the Summer. The Arctic is not as cold as Antarctica for two main reasons; firstly, the sea's temperature does not fall below −2˚C means that the whole of the arctic polar region and coastal regions are kept warm even though the sea is covered by ice.

The Southern Hemisphere is located half below South the Equator. Its surface is 80.9% water, and it contains 32.3% of Earth's land. Southern Hemisphere climates tend to be slightly milder than those at similar latitudes in the Northern. The Sun passes from east to west through the north in the southern. The Sun follows a right to left trajectory through the northern sky. The Coriolis effect causes cyclones and tropical storms to spin clockwise in the Southern and anticlockwise in the Northern. The southern temperate zone, a subsection of the

Southern Hemisphere, is primarily oceanic.

Arctic and Antarctica differ in many aspects; the Arctic is a semi-enclosed ocean almost surrounded by land. Some Arctic Sea ice remains through the Summer and grows following Autumn. The Antarctica ice is 1 to 2 meters thick, while the Arctic is covered by 2 to 3 meters thick. The Antarctic maximum sea ice pattern is symmetric around the pole, forming a circle around Antarctica. The Arctic is asymmetric with thickness in some longitudes than others.

In the Antarctic, the ocean currents and wind tend to flow without interruption around the continent in a west-east direction, acting as a barricade to warmer air and water to the north.

Each year, Arctic Sea ice follows the same general trajectory: growth from late September through March or April and melt from mid-April through mid-September. It means the melt occurs most during Spring-Summer. The melt's shape or yearly trajectory did not change but has experienced lower extents. Antarctic sea ice follows the opposite general pattern each year, declining from January to mid-April. The melt happens during the end of Summer-Fall and grows from August to November.

Zwally *et al.* [5] concluded that Antarctica was acquiring ice on the Eastside. It was gaining more mass than offset losses elsewhere. Differences between Antarctica's maximum sea ice are the currents. The winds flow without interruption around the continent from west to east, acting as a barricade to warm air and water to the north. In contrast, the Arctic region, located in the Northern Hemisphere, is susceptible to the warmer waters from the South because of how the Ocean current flows. In addition, precipitation is rare; snowfall tends to be low, except near the ice edge.

Antarctica sea ice is covered by thicker snow, which may accumulate to the point that the weight of snow pushes the ice below sea level. In addition, Southern Hemisphere circulation is different from the Northern Hemisphere. The Southern is more regular and zonal, and the atmosphere wave activity is lower than the Northern. Therefore, there is an implication in the total zone response regarding the geomagnetic storms Northern and Southern [6].

Differences are observed between Arctic and Antarctica sea ice resulting from the polar regions' diverse land and ocean configurations. The seasonal extremes in the two poles are due to geographic differences. The Arctic Sea is an ocean basin surrounded by land. The Antarctic is a continent encircled by a vast ocean. Sea ice expands freely across the Southern Ocean in Winter; it can get no closer to the South Pole than the Antarctic coastline will allow. Natural variability in the Southern Ocean and atmospheric circulation patterns significantly influence Antarctica's sea ice extent more than climate change. The ice extent in the Arctic and Antarctica varies with seasons. In the Arctic, the maximum extent is January-March (Winter) and the minimum end August-November (end of Summer to end of Fall). In the Arctic Sea, ice expands to 6 million square miles. The National Snow Data Center estimates that the overall extent of the Arctic Sea in 2009 dropped by 5.1 million square kilometers, which was below the average minimum recorded in the period 1979-2000. The 2022 extent was 690,000 square kilometers below the 1981 to 2010 average [7] [8].

The ice in Antarctica has sea ice concentration sometime in late September. The Antarctic Sea extends seven million squares in Winter. The Antarctica summer minimum is around 1 million square miles and 2.5 million square miles in the Arctic.

Sea ice expands freely across the Southern Ocean in Winter. Therefore, natural variability in the Southern Ocean and atmospheric patterns exert a more considerable influence on Antarctica's sea extent than anthropogenic disturbances. As told, the Arctic's maximum extent is January-March (end of Winter to Spring), and the minimum is August-November (late Summer to Fall). In Antarctica, the minimum is January-April (late Summer-Fall), and the maximum is August-November (End Winter to Spring).

As observed, the ice in Antarctica has sea ice concentration sometimes late in September. Antarctica sea extends about 11,265.408 square km. In the Arctic, the area in kilometers during Winter, sea ice extends to 9656.064 squares km.

The Summer minimum in Antarctica is about 1609.344 square km; in the Arctic is 2.5 million square miles. In 2009 sea ice in the Arctic reached the third-lowest level ever recorded from satellite records since 1979. Sea ice reflects sunlight which keeps the Arctic region cool and plays a significant role in moderating the global climate. The lowest ice consumption occurs around September, the beginning of the Fall after sea ice melts through the warm summer months. As a result, the Arctic Sea ice extent declined over the past. The National Snow Data Center estimates that the overall extent of the Arctic Sea in 2009 dropped by 5.1 million square kilometers, which was below the average entire period 1979-2000. The 2022 extent was 690,000 square kilometers below the 1981 to 2010 average. In the Arctic, it was a maximum in 1979, around 16,427million km^2, and in 2014 with 14,602 million km^2. The Arctic and Antarctica sea ice plots, **Figure 3** and **Figure 4**, show the most critical aspect of this issue: the seasons.

The ice extent varies with the seasons for each pole, and the ice rises in the Winter and vice-versa during the Summer. Therefore, the ice extent is inversely proportional if we compare hemispheres, as verified in plots 3 and 4. When the melt is a maximum in the Arctic (Summer), it is a minimum in Antarctica (Winter).

Comparing **Figure 5** and **Figure 6**, notice the Arctic ice extent can drop by 3435 million km^2 (2012), in Antarctica by 1937 million km^2 (2021) which is slightly below 2017 (record minimum) with 2186 million km^2.

Somehow Arctic Sea ice minimum follows the years of solar maxima. Southern presented a maximum of 20,043 million km^2 in 2014 (solar maximum). Other years of solar maxima did not show these peaks; they were 1979, 1989, 2001. There was only an average variation of ice melt for the solar minimum in the following year of minima 1986, 2008, 2019.

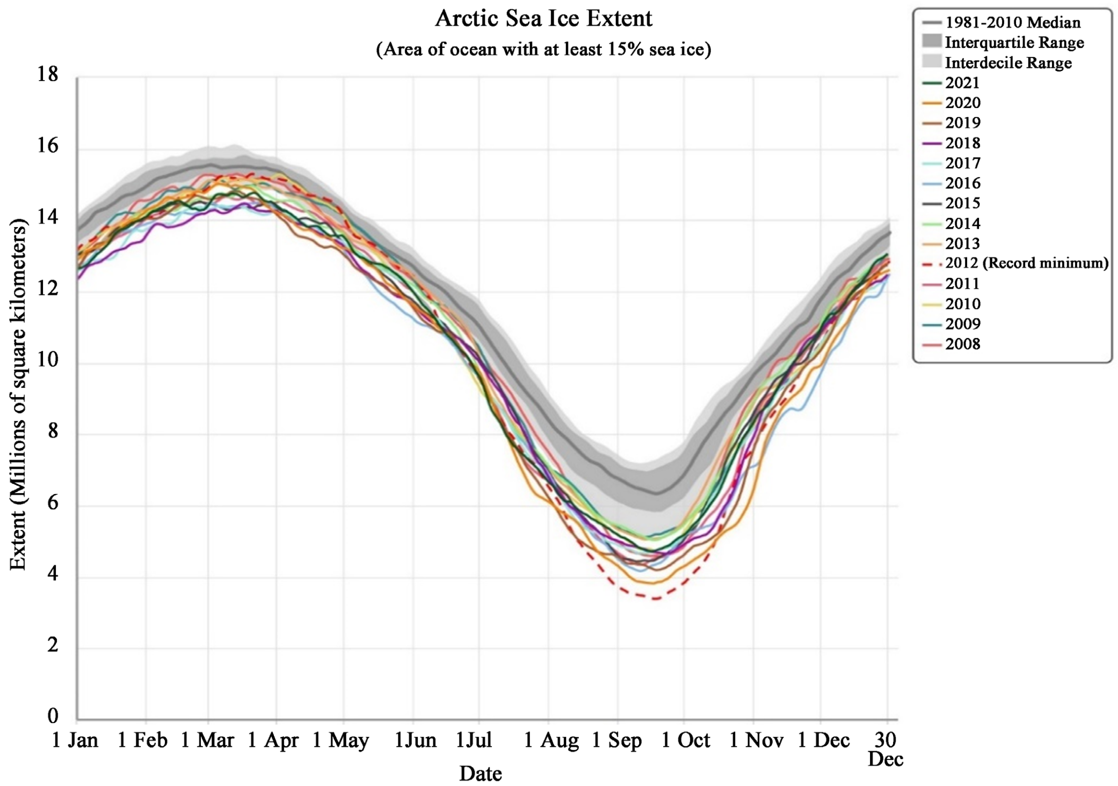

Figure 3. The sea ice extent in the Arctic during a solar cycle (2008-2021). The minimum was in 2012; however, the maximum was in 2012 in the first months. It happened two years before the solar maximum https://nsidc.org/arcticseaicenews.

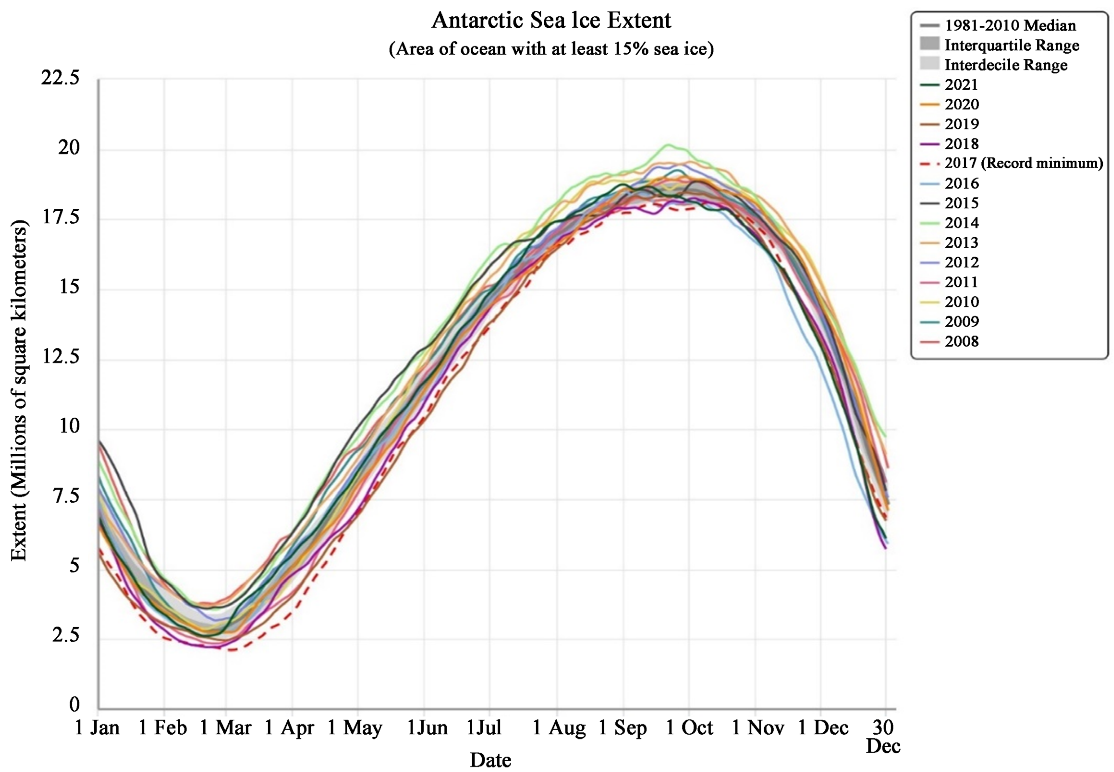

Figure 4. Antarctic Sea extent during one solar cycle (2008-2021); the minimum was in 2017. The maximum coincident with the solar maximum in 2014. https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph.

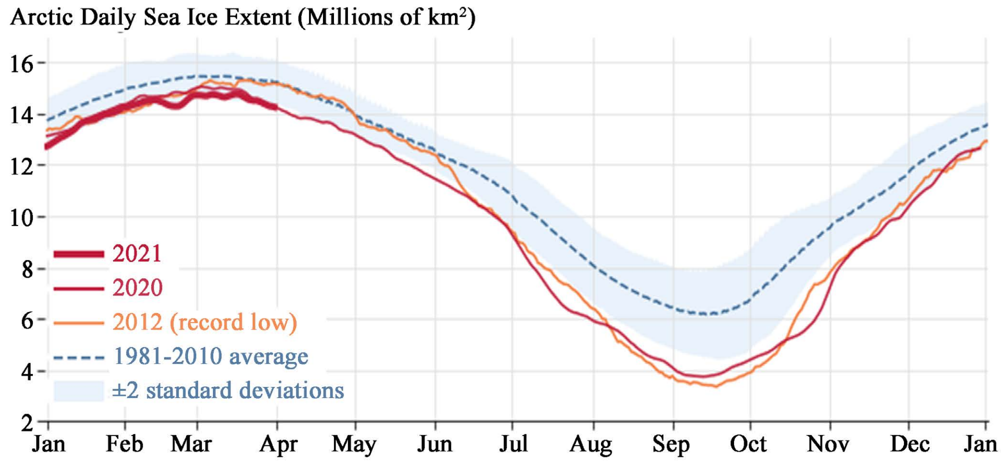

Figure 5. The evolution of ice melt in the Arctic Sea Ice extent shown during the period 1979-2021 with a minimum in 2012 is considered a record low (National Snow and Ice Data Center-//nsidc.org).

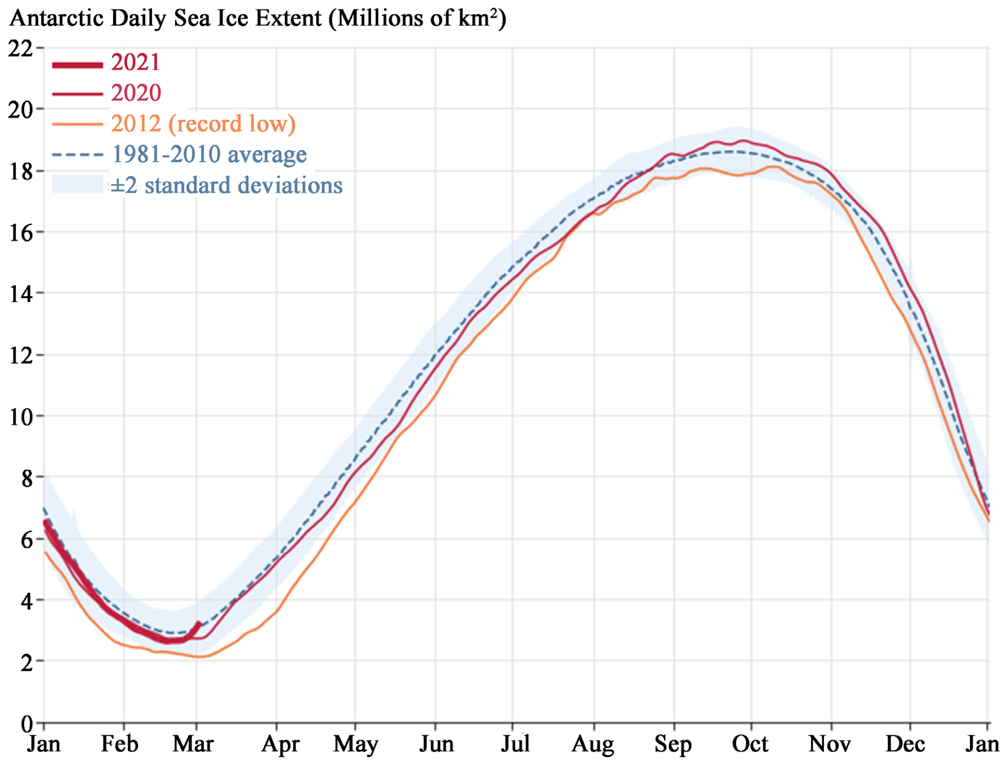

Figure 6. The evolution of ice melt in the Antarctic in the period 1979-2021 with ice extent minimum in 2017 (National Snow and Ice Data Center-//nsidc.org).

3. Comparisons of Arctic, Antarctica Sea Ice Sheet

Over decades, the Arctic Sea has declined in extent and thickness. Antarctica sea ice has shown little overall change with sizeable regional variability [6] [7]. The impact of natural variability on the ice cover is significant at both poles. So modeled ice trends are not entirely inconsistent with natural variability and anthropogenic forcing contributions. The decline in the Arctic was maximum in 2007. This record was surpassed in 2012, two years before the solar maximum (2014).

The record low in Antarctica was in 2017. **Figure 4** shows it happened three years after the solar maximum. Arctic sea cover is constrained by land. In Antarctica, the ice grows unbounded by land at its northern edge in Winter and retreats close to the coast in Summer, resulting in twice the seasonal cycle of growth and retreat in ice extent compared with the Arctic.

The ocean's interactions with the west side of Antarctica accelerate the melting in West Antarctica. Upper-ocean temperatures to the West of the Antarctica Peninsula have increased by over 1˚C since 1955. The consistently Arctic change is a substantial decline in all regions except the Bering Sea.

Table 1 shows that the Arctic Sea ice extent with the minimum area was in 2017, followed by 2018; though, there was a recovery in the following years. However, although the last decade displayed a gradual decrease in the sea ice, it does not mean a permanent change.

The data center does not have a similar table since the behavior of the Southern Pole is different. The melt depends on the region examined. This research investigates a possible connection with the Sun events.

Ice sheets depend on ocean conditions; as ocean currents vary, accumulated pollution in the water around the pole. Therefore, connecting ice melting with solar variability or greenhouse emissions is complicated.

One aspect of the solar variability is the seasons; as indicated in **Figure 5** and **Figure 6**, our examination points out that from middle August (Summer) to middle October (Fall), when the Arctic Sea ice extent reaches a minimum.

In Antarctica, the occurrences happen from January (Summer) to the middle

Table 1. Fourteen lowest maximum Arctic Sea ice extents (satellite record, 1979 to present). Values within 40,000 square kilometers are considered tied. The 2019 value changed from 4.15 to 4.19 million square kilometers when the final analysis data was updated from near-real-time data (National Snow and Ice Data Center).

		IN MILLIONS OF SQUARE KILOMETERS	Date
1	2012	3.39	Sept. 17
2	2020	3.74	Sept. 15
3	2007	4.16	Sept. 18
	2016	4.17	Sept. 18
	2019	4.19	Sept. 10
6	2011	4.34	Sept. 11
7	2015	4.43	Sept. 9
8	2008	4.59	Sept. 19
	2010	4.62	Sept. 21
10	2018	4.66	Sept. 23
	2017	4.67	Sept. 13
12	2014	5.03	Sept. 17
	2013	5.05	Sept. 13
14	2009	5.12	Sept. 13

of April (Fall); consequently, the sea ice in both poles is susceptible to Summer and Fall. Therefore, the difference observed during the months in both hemispheres corresponds to the seasonality in each Hemisphere.

The record minimum in Antarctica was 2017, as shown in **Figure 5**, and the Arctic minimum was in 2012, as displayed in **Figure 6**. From 1979 to 2017, Antarctic-wide Sea ice extent showed a slightly positive trend overall, although some regions experienced declines. Those exceptions have occurred around the Antarctic Peninsula. The region south and west of the Antarctic Peninsula has shown a persistent decline. However, this downward trend is slight compared to the high variability of Antarctic sea ice overall. In the Weddell Sea, another region near the northern tip of the Peninsula showed substantial sea ice declines until 2006. However, the ice in that region has rebounded in recent years. The eastern Ross Sea region has shown a modest increase in ice extent over the same period [8].

There is no evidence of a mechanism to explain the greenhouse emissions from the Northern can affect the sea ice extent in the Antarctic region.

Remember that the greenhouse gas emissions travel vertically to the troposphere with the poison gases trapped in the atmospheric cells over the pollutants' locations [9].

Harmful emissions occur 90% in the Northern Hemisphere. It was impossible to find any connection between the troposphere, stratosphere, and the transport of the polluted gases among Hemispheres. The Ozone displacement occurs from the Equator to higher or lower latitudes, Northern or Southern [10].

The pollutants are vertically pulled upwards into the troposphere, moving into an atmospheric cell—the leader in pulling harmful emissions in the Northern Hemisphere. It is absolutely no evidence that those harmful emissions are carried to the Southern since the Hadley and other similar cells have a path that moves harmful emissions vertically back toward Earth's surface, as formerly discussed.

4. Study the Ozone Layer in the Troposphere and Stratosphere

Ozone is a molecule made up of three oxygen atoms called O_3. Ozone is formed when heat and sunlight cause chemical reactions between nitrogen oxides (NO_x) and Volatile Organic Compounds (VOC), also known as Hydrocarbons. Stratospheric Ozone is formed 16 - 48 km above the Earth's surface and forms a protective layer called the ozone layer. Ozone levels are maximum during the afternoon hours of the Summer months when the influence of direct sunlight is the highest [11].

The natural processes of formation and breakdown are balanced: only in recent decades have supposed human activities led to the Ozone being destroyed much faster than it can be formed, thereby creating the ozone hole that exists today. Furthermore, theoretical models ignore that the Northern Hemisphere is responsible for most greenhouse gases, including Ozone, and there is no evidence that harmful gases are transported to Antarctica's stratosphere, where ozone depletion occurs.

Ozone can also be formed at the ground level producing 'photochemical smog'; as the Ozone is a toxic gas, there is a health hazard when the Ozone reaches superior levels. This problem occurs primarily in the Summer in cities with high traffic when sunlight interacts with car exhaust fumes containing nitrogen oxides [11].

These gases have a moderately short stay in the troposphere, between a few hours and several weeks. Ozone production also occurs in the vicinity of the pollution sources. The harmful emissions are dragged into Hadley cells to higher altitudes, eventually going to the stratosphere. Tropospheric ozone—ozone above the Earth's surface around 12 to 15 kilometers is a greenhouse gas and air pollutant. At basic levels, it can harm people's lungs and damage plants.

Gaudel's team found an overall increase in ozone levels above the Northern Hemisphere. Gaudel [12] and her co-authors, CIRES scientists in NOAA, and international colleagues found the most striking increases in areas where ozone levels were once lowest: Malaysia/Indonesia, Southeast Asia, and India, for example. Those regions had shallow ozone values between 1994 and 2004 and extremely significant levels in recent years, between 2011 and 2016. Previous studies could not draw firm conclusions on Northern Hemisphere ozone trends, according to Gaudel, because there are too few long-term monitoring locations, and new satellites with near-global coverage have provided conflicting results on ozone trends. The highest ozone levels increase occurred above Malaysia, Indonesia, Southeast Asia, and India, followed by Northeast China and Korea, and the Persian Gulf. The warm season from April to September exhibited the highest levels recorded in these regions. Though increases above the United States and Germany were relatively weak compared with those above Asia in recent years, surprising, researchers found that much of Asia showed shallow ozone values between 1994 and 2004. They employed global atmospheric chemistry models to quantify long-term changes in the troposphere, situated at about 11 miles except at the poles. The thickness of the ozone layer varies worldwide and is thinner near the Equator and thicker near the poles. Thickness refers to how much Ozone is in a column over a given area and varies from season to season. The reasons for these variations are atmospheric circulation patterns and solar intensity.

Stratospheric Ozone is formed 16 - 48 km above the Earth's surface and forms a protective layer called the ozone layer. Nitrogen oxides catalyze ozone formation in the troposphere. The Global Ozone Monitoring Experimental (GOME) satellite data display a maximum of NO_x over the Northern Hemisphere, as North America, Europe, and Asia. The anthropogenic source of NO_x is fossil fuel combustion, with 40% from the transportation sector.

The stratospheric ozone influx into the troposphere is difficult to quantify; the ozone concentrations in some regions have decreased in the stratosphere over the last decades. For example, the influx was reduced by 30% from early 1970 to mid-1990.

An analysis of ozonesonde data in the mid-troposphere (around 5 km altitude) showed the Northern Hemisphere seasonal variations have similarities spatially, with a maximum in Ozone between April and September. The maximum had several causes, including efficient photochemical ozone formation during Summer [13] [14].

NO_x emission from lightning is more effective over the continents in Summer. All this investigation led to the following results.

Most stratospheric Ozone is produced at tropical latitudes, but high-altitude winds spread it over the planet. As a result, it is continually forming and breaking down. Its distribution over the planet is not uniform or constant. Instead, there are seasonal and longer-term variations in the quantity of stratospheric Ozone in various parts of the world.

When Ozone is produced by solar UV radiation in the tropics, it is done by circulation lifting ozone-poor air out of the troposphere and into the stratosphere, where the Sun photolyzes oxygen molecules and turns them into Ozone. Then, the ozone-rich air is carried to higher latitudes and drops into lower layers of the atmosphere.

Research has found that the ozone levels in the United States are highest in the spring months of April and May and lowest in October. However, weather patterns, especially during the late Fall through early spring months, can also be influenced by changes in the atmosphere from above—*i.e.*, by changes in the circulation of the stratosphere. One of these changes comes from alterations in the stratospheric polar vortex [14].

Scientists studied extratropical stratosphere-troposphere coupling (*i.e.*, poleward coupling at about 35˚N)—the troposphere talks to the stratosphere via vertical Rossby wave propagation at these latitudes [15].

Once these waves move into parts of the lower and middle stratosphere, they will eventually break and deposit the heat and momentum they carry back to the stratosphere, thus dynamically changing the circulation. As the stratospheric circulation changes, these variations are communicated downwards through the column. They can impact the circulation in the troposphere (*i.e.*, alter the strength and position of the jet stream). Because this communication occurs only during the cold season, using the stratosphere to advance predictions of tropospheric weather is a natural move forward to improve winter weather forecasts across the middle and high latitudes [16] [17]. The total amount of Ozone increases, moving from the tropics to higher latitudes.

The concentrations are more formidable at the northern pole than in the southern pole, with spring ozone columns in extreme northern latitudes occasionally exceeding 600 DU and averaging 450 DU, whereas 400 DU constituted a usual maximum in the Antarctic before the ozone depletion. This difference occurs naturally because of the weaker polar vortex and the presence of Brewer-Dobson circulation in the Northern Hemisphere, owing to that Hemisphere's large mountain ranges and significant contrasts between land and ocean temperatures. In addition, the difference between high northern and southern latitudes has increased since the 1970s due to the ozone hole phenomenon. The highest amounts of Ozone are found over the Arctic during the spring months of March and April. However, the Antarctic has the lowest amounts of Ozone during the spring months of September and October.

The ozone layer can be depleted by free radical catalysts, including nitric oxide (NO), nitrous oxide (N_2O), hydroxyl (OH), atomic chlorine (Cl), and atomic bromine (Br).

While there are natural sources for all of these species, the concentrations of chlorine and bromine increased markedly in recent decades because of the release of large quantities of manufactured organ halogen compounds, especially (CFCs) bromofluorocarbons. These highly stable compounds can survive the rise to the stratosphere, where Cl and Br radicals are liberated by the action of ultraviolet light. Each radical is free to initiate and catalyze a chain reaction capable of breaking down over 100,000 ozone molecules. By 2009, nitrous oxide was the most prominent ozone-depleting substance (ODS) emitted through human activities. The breakdown of Ozone in the stratosphere results in reduced absorption of ultraviolet radiation [16] [17].

Consequently, unabsorbed and dangerous ultraviolet radiation can reach the Earth's surface at a higher intensity. As a result, ozone levels have dropped by about 4 % since the late 1970s. In addition, for approximately 5 % of the Earth's surface, much more significant seasonal declines have been seen around the north and south poles.

5. Antarctica and Arctic Ozone Layer Seasonal Variations

Severe Ozone depletion happens over Antarctica. The destruction of the Ozone happens during the Winter when stratospheric clouds (PSCs) rise a series of chemical reactions that destroy the Ozone more effectively than the reactions in warmer air. Once PSCs are created, the destruction of Ozone starts with the return of sunlight in the Spring.

Figure 7 and **Figure 8** show the Ozone variation in the Southern Hemisphere (SH), the hole minimum occurring between September (Spring) to November (end of Spring). In the period studied 1979-2022, is described as a black line average, the year 2021 is blue and 2022 is red (just the first months of the year).

Figure 7 shows the ozone variation in DU (Dobson Units) for several years as an average between 1979 and 2021. However, 2021 presented a deeper variation in the minimum in the Southern Hemisphere. Nevertheless, it shows that the minimum Ozone is periodical and always happens during the same months.

Figure 8 shows the Ozone depletion in terms of periods versus the Ozone area in millions of km^2 (area). The 2021 showed a maximum of approximately 25 million km^2. The year 2022 just began at this moment. Both plots concern the

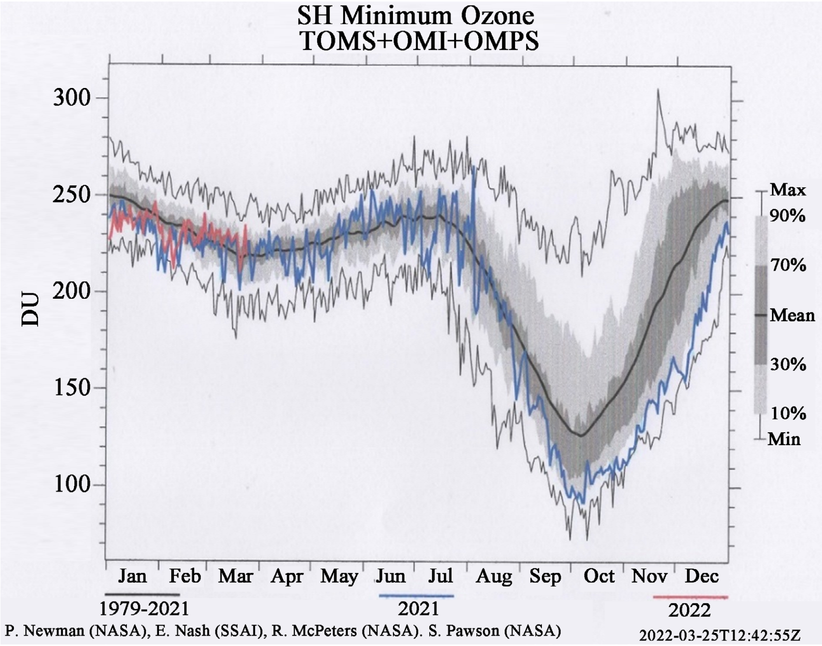

Figure 7. Ozone variation in a year minimum September-November, Southern Hemisphere. Observe the differences for each period, first 1979-2021, the blue line is 2021, and partial 2022 in red https://ozonewatch.gsfc.nasa.gov/meteorology/.

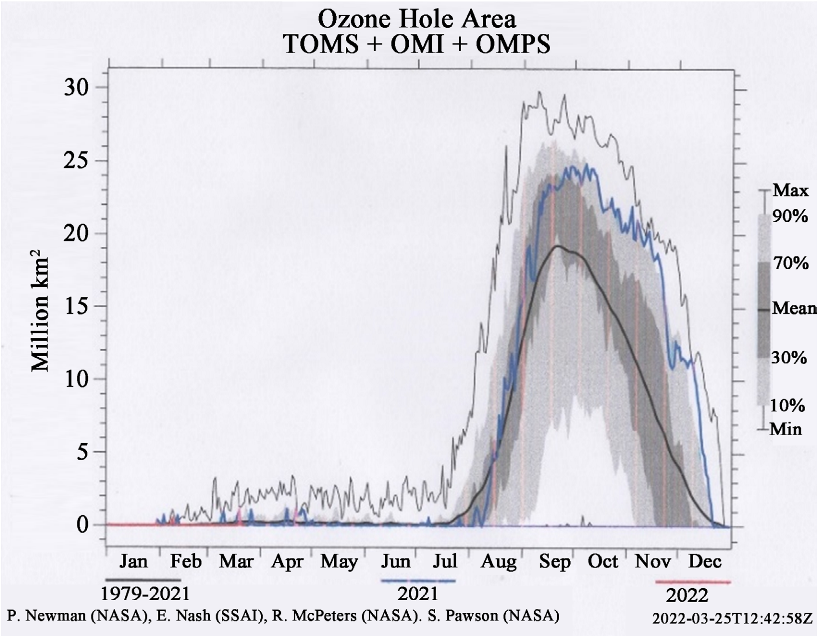

Figure 8. Southern Hemisphere area losses occurring August-October of each year.

Southern Hemisphere, where the ozone hole appears.

Comparing Figure 7 shows that a minimum of Ozone in DU units corresponds to a maximum of area losses in Figure 8.

The following section compares other characteristics of Ozone loss and the influence of the solar cycles, focusing on two different months, January, and September, in both hemispheres. The main reason for the choice is that the heaviest changes in the Southern occur most from the middle of August until November.

6. Maximum and Minimum Ozone Hole Variations during Three Solar Cycles

To analyze the behavior of the Ozone layer, we examine the data available during three solar cycles. Figure 9 shows how the Ozone layer explicitly varied in the period with satellite records 1979-2021. It is a general view about the loss in million tons, 1979-2022.

The next pictures considered two months corresponding to Summer and Spring in the Southern Hemisphere, where the Ozone depletion is deeply affected.

At the Southern cap, we took January (Summer) and September (Spring); September is supposed to show the deep variation in the hole with Ozone units. Pictures show three solar cycles; cycle 22 displays a minimum polar cap zone (January); for the next cycle, 23, there is no data in 1995 (possible fail in the satellite instruments); therefore, evaluating cap ozone value is impossible. The last cycle 24 analyzed pointed out 2008 as a minimum, and it has the same DU units observed in cycle 22. In the solar maximum 2014, there was an enhancement in the polar cap with the same minimum as in cycle 22. Overall, the Ozone in January around the Southern Hemisphere decreased after 1995. It has slightly recovered in 2020 but is still lower than the values in 1980. Figure 10 illustrates the Ozone variation in DU units between 1979-2021 in the Southern Hemisphere in the month of January (Summer) observe after the gap occurred in 1995. Notice that the sudden gap is followed by a decrease 2000-2001 with a lower peak in

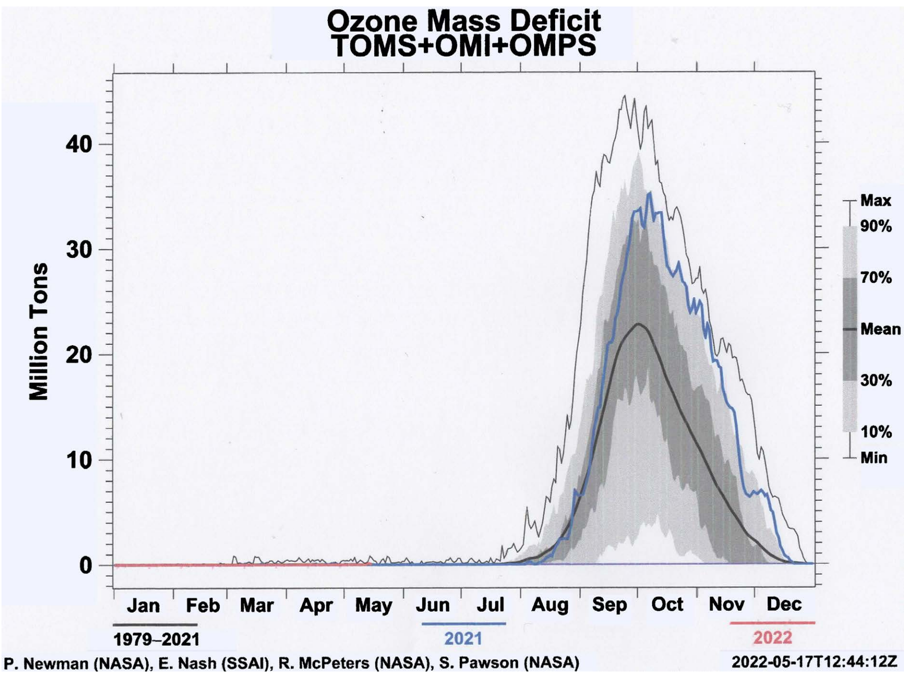

Figure 9. It shows how the Ozone Mass Deficit in million tons in the period 1979-2021, the data for 2022 is until May displayed in million tons.

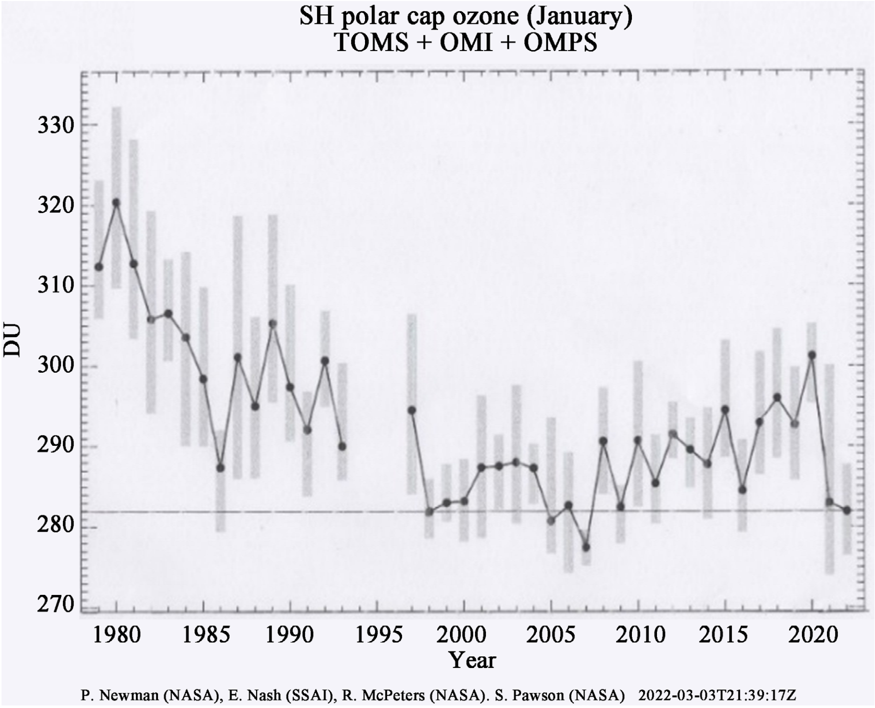

Figure 10. The picture shows the variation of Ozone in the Southern Hemisphere during January.

2005, after a slight increase until a more significant enhancement in 2019.

Observe that the sudden gap in 1995 is followed by a decrease 2000-2001 with a low peak in 2005, after a slight increase until a more significant value in 2019. There are two peaks, 1989 (solar maximum) and 2019 (solar minimum). Those two years have been increasing the Ozone hole in DU units. Figure 11 displays the month of September also in DU units in the same period as Figure 10. In this particular month, the plot configuration showed enhancement activity in the three years 1989, 2001 and 2019.

It is important to remember that the seasonality in the Southern is opposite to the one in the Northern; this project examines and compares what happens in both poles along the years or months; the period remains 1979-2021.

Let us examine what is happening in the Northern Hemisphere; Figure 12 shows what occurred from January 1979 to 2021. The first remark is that the ozone loss in the region reached a value above 400 DU this month. The gap occurred in 1995; later, the Ozone layer's recovery in DU back to the same values as before with some enhancements in 2014 and 2018. It is Summer in the Southern and Winter in the Northern in January. On the other hand, September is the beginning of the Spring in the Southern and Fall in the Northern.

Figure 12 shows what occurred in January (Winter) during the period 1979-2021. Figure 13 considered the September in the Northern Hemisphere and the year average is around 400 DU for all months between 2019-2021. Next, Figure 13 reveals that in September (Fall) the maximum Ozone depletion is on average around 400 units, still with a gap in 1995. Both figures reveal that in the

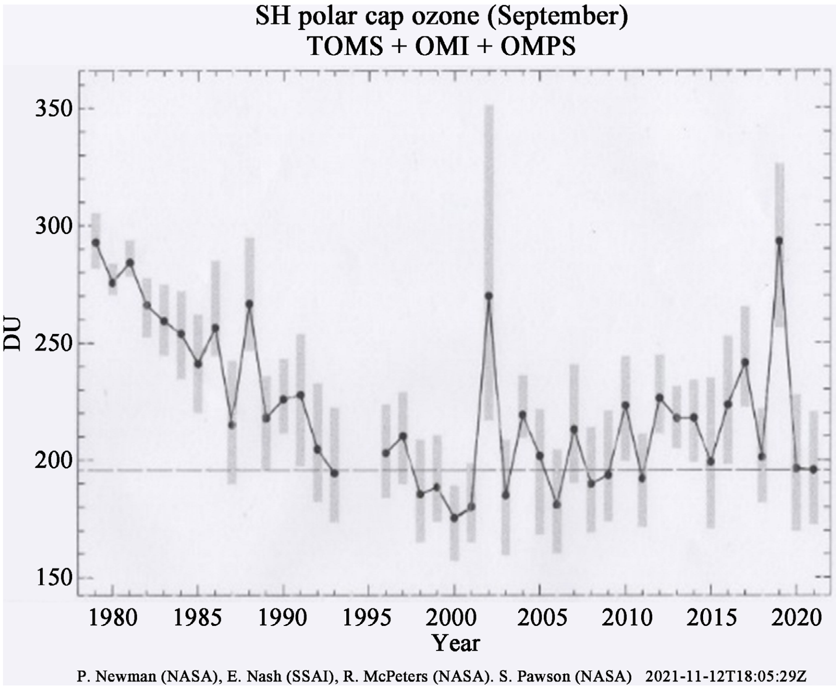

Figure 11. The picture shows the Polar cap Ozone variations in September in the Southern Hemisphere.

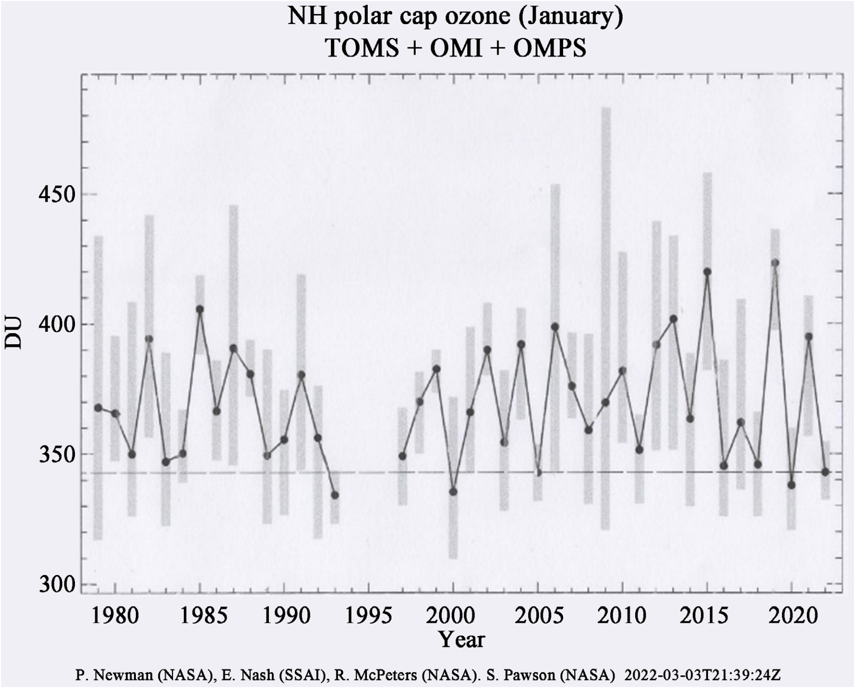

Figure 12. January in the Northern Hemisphere, maximum Ozone amount variation in DU units during the period 1980-2021. The gap in1995 is the absence of data. https://ozonewatch.gsfc.nasa.gov/meteorology/.

Northern Hemisphere, the season makes minor differences in the behave of the Ozone hole. It reveals that in the Northern Hemisphere, the seasons make minor differences in the behavior of the ozone hole. However, it seems more affected

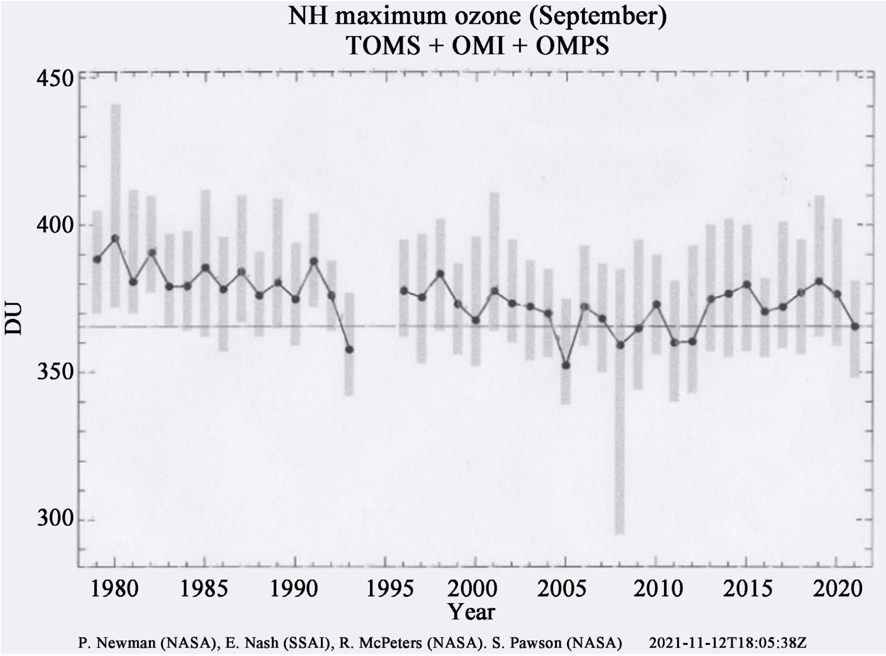

Figure 13. There is a maximum Ozone depletion in September (North Hemisphere).

by the solar maximum than other parameters. Therefore, we must enhance the knowledge by running the data in January and September in the same range 1979-2021.

The outcomes showed that the Northern Hemisphere is more connected to solar cycles than the Southern. There is another essential aspect of our calculations during the three solar cycles. Observations data do not vary much year by year; see the former figures, the variation of each year is minimal compared to the total number of years; however, they all depend on seasons.

Let examines what happens among the global ozone layer by geographic locations. Figure 14 shows what happened globally for the Ozone varying the latitudes. The time interval is the same as 1979-2021 used for the Ozone in DU units. Results demonstrate the lowest ozone values happening to 10˚S - 10˚N, 30˚S - 10˚S, and 10˚N - 30˚N. The gap observed in 1995 is due to a failure in the satellite instruments detecting the variations in the Ozone hole in the Antarctic region during this time. For example, the location 90˚S - 60˚S reached values above 300 DU, but after a gap in 1995, it decreased below 260 DU.

The analysis concerning solar cycle maxima indicated that the tendency of Ozone in DU is minimum for most locations during Solar maximum. The exceptions occurred where the locations were 60˚S - 30˚S, 10˚N - 30˚N, and 30˚S - 60˚S in 1986; in 2008, only 10˚S - 10˚N increased. Finally, in 2019, 60˚N - 90˚N, the amount of DU was enhanced. Let us check some solar maxima; in 1989; the DU amount enhanced in the locations 30˚S - 10˚S, 10˚N - 30˚N in 2000, 10˚N - 30˚N, 30˚S - 10˚S, 90˚S - 60˚S. In 2014, 30˚S - 10˚S, 60˚S - 30˚S, 30˚N - 60˚N. In 2014, 30˚S - 10˚S, 30˚N - 60˚N.

Globally, the Ozone depletions are more significant for the latitudes 60˚N -

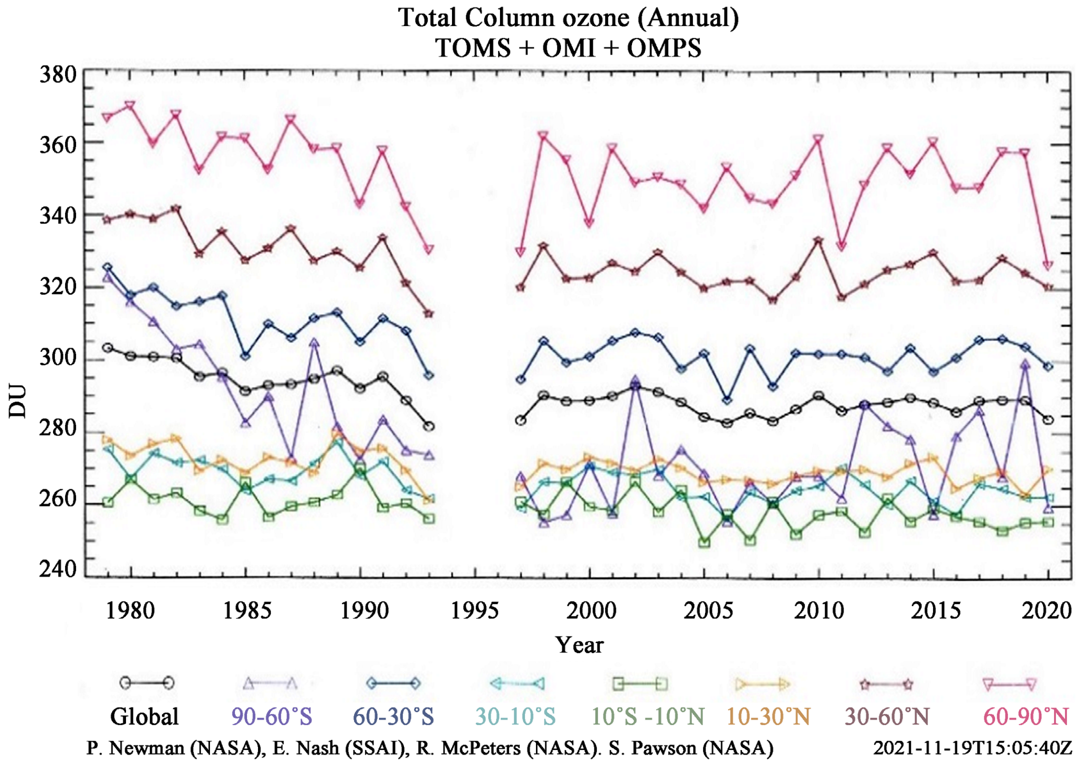

Figure 14. The annual- and monthly-mean Ozone for eight latitude bands: 90˚S - 90˚N (global), 90˚S - 60˚S, 60˚S - 30˚S, 30˚S - 10˚S, 10˚S - 10˚N, 10˚N - 30˚N, 30˚N - 60˚N, 60˚N - 90˚N. No interpolation of missing values is performed. The instruments only work and measure in sunlight.

90˚N and 10˚S - 10˚N, which are more perturbed when there is a Solar event maxima or minima.

The Worldwide column ozone shows some variation in higher and lower latitudes during the solar maxima and minima; we consider the range picked (1979-2021) small compared to the total number of solar cycles.

Here is essential to mention two years, 1991 and 2010, when a peak in the Ozone hole was recorded for all latitudes; in both years were observed powerful solar storms.

The Northern Hemisphere is heavily influenced by anthropogenic activity, the ice sea melt, and the ozone variations in both events. It does not occur in the Southern. Some anthropogenic production may feed our data-informed the Arctic Ozone Layer since many greenhouse emissions become O_3. Also, the atmospheric cells in Figure 1 can lift the gases to the troposphere, where some of the particles would reach the stratosphere. It adds a probability that the Ozone in the Arctic would enhance with anthropogenic help. There is no such possibility in Southern Hemisphere since few humans are around the location. Overall, the emission in the Southern is just 1/6 of the worldwide amount. As described above, the Arctic's Ozone may increase by anthropogenic interference. On the other hand, there is no evidence that the same is occurring in Antarctica. The results point out that the depletion observed in the Southern is due to the seasonal variations, geography, and other natural causes.

7. Similarities and Differences between Antarctica and Arctic Events

Our study pointed out that seasonality is the main similarity between Antarctica and Arctic events; when the weather is warmer, the ice melt event, or the ozone depletion increase, still the ozone variation has other factors to consider for each cap.

The Arctic Sea ice extent reaches a minimum from middle August (Summer) to middle October (Fall). On the other hand, in Antarctica, the occurrences happening January (Summer) to the middle of April (Fall); hence, the sea ice in both poles is extremely sensitive to Summer and Fall. Therefore, the difference in months observed for each location corresponds to the seasonality of each Hemisphere. In Antarctica, Ozone layer depletion is happening more from August to November (maximum).

In the Northern, a theoretical Ozone depletion would happen from the end of Summer to the end of Fall, corresponding to the Southern end of Fall to the end of Spring.

This pattern is repeated year by year though it is a strong attachment for the seasons to the phenomena observed. The global ozone layer has higher variations annually, most to 60˚N - 90˚N and 90˚S - 60˚S.

Our data shows that the Ozone hole variation is crucial around Antarctica and is mild around the Arctic. There is another crucial aspect of our calculations of the three solar cycles. The data does not change much year by year; if you look at the plots, the variation of each year is tiny compared with other years. All the increase or decrease in ozone depletion is seasonal, and the same occurs with the ice sea melt. Our results indicate that the significant rule for those variations involves the seasons. No data indicate anthropogenic disturbances as a cause of the depletion around the Southern cap.

Both events researched in this paper, Sea ice melt and Ozone depletion could be influenced by anthropogenic interference nevertheless, in a different way that is considered now.

In the Southern, there is only 10% of polluted gases. Therefore, the supposition that greenhouse gases could be carried from the Northern to the Southern, affecting Antarctica has no technical or scientific support. All greenhouse gas transportation is done vertically over the region that creates them; it is trapped in the atmospheric cells. Once reach the stratosphere, they will be dragged back to the Earth's surface, see **Figure 1**.

8. Conclusions

This paper researched two different phenomena which are happening on the poles. The first part is about the Ice Sea melting around the polar regions. The second is the Ozone hole depletion that is happening in Antarctica. The fluctuations observed are strongly dependent on the seasons. The maximum events occur during the transitions from Spring to Summer and Summer to Fall in the

Arctic and Antarctica. The pollution in the Northern Hemisphere is 90% of the total discharges on the troposphere driven vertically from the Earth's surface. Regarding the Ice melt in the Arctic and Antarctica, there are some natural occurrences such as seasonal variations in both caps. Atmospheric cells uphold the winds that dislocate perpendicular to the Earth's surface, those chambers keeping the greenhouse gases trapped. It occurred in each Hemisphere and the connection between both Hemispheres does not happen. This means that the pollution created by anthropogenic reasons in the Northern Hemisphere is unable to be transported to the Southern.

Regarding the Ice melt in the Arctic and Antarctica, there are some natural occurrences such as seasonal; vertical winds occurring in the cells are perpendicular to Earth's surface for upholding the pollution gases into the atmospheric cells, keeping them in separate Hemispheres. Individually the Hemisphere settles greenhouse gases into atmospheric cells see **Figure 1**, in a cycle that starts and ends on the Earth's surface. The Arctic's ice sea melt had a maximum in 2012, and for Antarctica, a maximum occurred in 2017.

Hence, oceans pollution and greenhouse gases could be affecting the ice melt. Our question here was if the greenhouse gases could be transported to Antarctica, if the pollution would move from Northern to Southern, crossing the Equator.

However, the authors did not find any evidence of such an occurrence. There is another point: Ozone created by humans in the Northern probably could reach the Arctic leading and helping to construct the Ozone shield.

In the Southern Hemisphere, the area around Antarctica is barely populated, and technology and pollution by greenhouse gases are at a minimum. Therefore, it is impossible to detect anthropogenic perturbations significantly active over the location. However, analyzing the possible connections between Ozone depletion and the poles, the evidence pointed out that greenhouse gases and pollutants eventually would mess up the layer in the Northern. But then, in the Southern, the Ozone depletion is affected mainly through natural means, independent of human perturbations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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