Recent Arctic Ozone Depletion

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ABSTRACT: The Arctic stratospheric reductions in ozone in up to 38 percent were recorded in the winter of 2010-11. In the winter of 2015-16, there was yet another significant decline of 27 percent. The record low temperatures below TICE, a threshold of formation of the PSC polar stratosphere cloud persisted during the winter polar vortex for one month, an occurrence never seen before which caused the polar vortex to dehydrate/denitrify unprecedentedly. Chemistry-climate-modeling (CCMs) generally predict lower stratosphere cooling with an increase in greenhouse gas (GHG) atmospheric concentrations, although there are considerable variations between them which imply relative great uncertainty in predictions. A strong interpretation of the interaction in-between ozone depletion and stratospheric temperature is made of findings from (CTMs) chemical transport models. The great seasonal instability in the Arctic ensures, though, that major events of ozone loss like those of 2010-11 and 2015-16 will occur before the ozone-depleting material concentrations revert to their 1960s. It is possible, however, that the originally expected stratospheric ozone recovery in the mid-2030s will be postponed. The key cause of doubt in the existence of Arctic ozone was therefore the meteorological fluctuations and its possible development. To ensure that Arctic ozone recovers, high-quality soil-based measurements, including SAOZ (System of Study by Zénithale Observation) and satellite ozone column tests around the Arctic in winter and continuous modeling efforts, are necessary to evaluate and recognize trends in the coming decades.

KEYWORDS: Artic, Modeling, Ozone, Stratospheric reduction, Temperature, Global Warming.

INTRODUCTION

A historic thirty eight percent ozone loss of approx. 160 DU was recorded in the Arctic winter of 2011, in comparison to magnitude of the Antarctic. In the last 68 years, the highest and coldest polar vortex was reported while a time of low (PW) planetary wave amplitude. In the winter of 2015-16, when a loss of 27 percent, the third-largest after SAOZ (System d'Analyse Par Observation Zénithale, Pommereau et Goutail) started in 1990. Such unprecedented low temperatures, as represented by the Aura Microwave Limb Sounder (MLS), culminated in exceptional turbulent dehydration between 410 K and 520 K possible temperatures, which has never before been seen in the Arctic. Denitrification is also remarkable and widespread triggering of chlorine & chemical ozone depletion occurred before all but the last season [1]. Nevertheless, the scale of chemical ozone loss was reduced at the beginning of March by the first significant final warming (Manney and Lawrence 2016).

Therefore, the issue is whether an episode of such chemical ozone depletion may occur more regularly after the stratosphere is cooled by growing greenhouse gaseous concentrations (GHGs), delaying the ozone recovery currently predicted in the Arctic by the mid-2030s (WMO 2014) or if only with anomalous cold and sporadic occurrences [2]. Langematz recently proposed that future of Arctic stratosphere will cool dramatically in early winter, with ECHAM / MESSy Atmospheric Chemistry (EMAC) model for chemical/climate conditions. Bednarz et al. (2016) using the UK Met Office, UKCA, which verified the predicted mid and upper stratosphere cooling to a degree, and illustrated poor confidence in estimated lower stratosphere temperature patterns. Like Langematz et al. (2014), they have reported that the large, inter-annual structural variation of the Arctic atmosphere may contribute to a major, episodic reduction of broad ozone columns [3].

Throughout the 1990s, when the Arctic climate became extremely dry, scientists reported significant ozone reductions across the Arctic, warning about incidents of severe ozone depletion. Scientists were also uneasy because, because of the mixture of air masses, ozone losses in the Arctic would decrease the amount of ozone over central latitudes. The problem was that at the end of the 20th century the amounts of chlorine-depleting chemicals or bromine atoms were near peaks and the freezing of the Arctic stratosphere, resulting from changes in the atmospheric concentration of carbon dioxide, would produce more desirable conditions than ever for ozone depletion [4]. In other terms, the Arctic was predicted to be exposed to a massive loss of ozone over the next 20 years at the end of the 20th century.

However, since 2000 scientists have observed shifts in the Northern Hemisphere's minimum ozone and temperatures. The Northern Hemisphere's global ozone rates reversed their declining trend in 2000 and were higher than predicted as a consequence of the improvements in the ambient amount of ozon-depleting compounds. In the same period, during abnormally cold years, serious episodes of Arctic ozone depletion continued to occur, but the intensity of the cold years declined (Fioletov 2008). And if the Arctic climate is indeed impacted by ozone loss, it has not been equivalent since 2000. That is because the stratospheric atmosphere is improved because the concentration of stratospheric ozone has been raised in the Arctic and the Arctic stratosphere is hot. This transition could be partly due to enhanced stratosphere energy movement, predicted greenhouse gas reaction or part of the natural variability [5]. Work has shown that substantial rise in UV radiation on the surface of the planet arising from extreme ozone loss is very dangerous to vulnerable types. Arctic existence. In the spring Arctic ozone rates were 30 to 60% below average during abnormally cold years, resulting in a rise in the ultraviolet radiation at ground level, which is similar, but somewhat significantly greater.

Although in the Arctic ultraviolet radiation rates in the spring are usually very small, the rise in ultraviolet radiation has become a source of human and environmental issues, such as increased sunburns and snow blindness, which has never before been reported. The strengthening of the northern atmosphere in the polar and sub-polar regions followed a decline in the quantity of ice and snow cover. Although the intrusion of the water layer of ice and snow is significantly decreased, the drastic reduction in the sea ice and snow cover that resulted in late summer 2007 and 2008 altered water-borne radiation exposure. There has been a rise of ultra-violet radiation of unhealthy species live near to the water surface during early life stages. Different meteorological events arise in winter and in early spring in polar areas culminating in severe ozone declines in both the Arctic and the Antarctic [6]. Once in the winter a vortex of wind is created in each hemisphere around the poles and the polar stratosphere separated. Air within the vortex is very cold without a milder air circulating from the lower latitude even without the sunshine. Clouds of ice, nitric acid & sulfuric acid continue to form in the stratosphere at temperatures of –78 °C or below. Polar stratographic clouds (PSCs) are considered to create a variety of chemical reactions and are often easier to remove ozone than colder air reactions. The loss of ozone starts after PSCs are produced in the spring with the release of sunlight. This ends a sequence of chemical reactions to photolysis free chlorine. The degradation proceeds rapidly until the ozone becomes destroyed. The Vortex dissipates, and warmer temperatures avoid more PSCs from developing, as the atmosphere warms gradually in spring. Related processes take place every spring in the Arctic, however, ozone concentrations have not decreased to the very small Antarctic levels. This is primarily that in late winter and spring the Arctic has a higher ozone concentration [7]. It is also a result of the northern hemisphere's complex air circulation, which reduces the integrity of the Artic vortex. As a consequence, incursions from southern air are always too warm for PSCs in the Arctic stratosphere.

LITERATURE REVIEW

1. *The Discovery of the Antarctic Ozone Hole:*

In early 1980s, the initial declines in gross ozone layer in research stations on the Antarctic peninsula were recorded. Absolute Dobson spectrophotometers were taken to calculate the performance. In winter season and early spring season between September to November, measurements revealed exceptionally weak overall ozone. In these months, gross ozone was smaller than previous statements from 1957. The early studies were issued by the JMA and the British Antarctic Survey. Since three British Antarctic Survey scientists in 1985 reported their findings in the science journal Nature, the results were well-known to the world and hypothesized that CFCs are causal. Early in the winter / early spring season from the early 1980s, satellite observations reported spring ozone depletion and further revealed that the loss occurred over a wide region centered close to the South Pole. The word "ozone crater" was used as a metaphor for several weeks with very small overall ozone levels covering the Antarctic continent.

Every year, a mixture of balloon, ground and satellite measurements is actually recorded in the creation and extent of the Antarctic ozone hole. Ozone measures quite early in the Antarctic. Throughout the 1950s, after intensive steps in the Northern Hemisphere and Arctic, a first number of ozone measurements were carried out in Antarctica, using Dobson spectrophotometers. The average ozone concentrations during spring were in and around 300 DU, which were significantly lower than in the Arctic season, as the two polar-regions were thought to contain comparable amounts at the moment. We now know also that Antarctic overall ozone levels are smaller systemically in earlier spring relative to Arctic values, as the polar vortex is much greater and, thus, slightly more efficient in minimizing ozone-rich air transport from medium to polar latitudes [8]. Measuring the minimum ozone in 1958, utilizing an empirical plating process to measure the emission of solar ultraviolet energy as it moves through an ozone amount at Dumont d'Urville station in location (66.7 °S, 140 °E) in Antarctica. The measurements recorded in September and October were anomally low, hitting DU 110–120. Which are close to minimum ozone hole levels, which are now regularly found in the same months in the Antarctic. Few have hypothesized that these small observations suggest that an ozone hole existed in existence until the ODS pollution became sufficiently high to induce depletion [9].

2. Ozone loss in 2015-16 and 2016-17:

Table 1 displays a table, latitude & date of first observations at each station from the SAOZ column measurements at 8 stations in the Arctic mentioned in Table 1. Table 1 includes a number, the dates of the first observations of SAOZ and SZAs at two measurements at solar zenith angles (SZAs) between 86 °C and 91 °C twice a day, hence permanently to the polar pole [10].

Table 1: SAOZ Arctic stations, latitude, longitude and date of start.

Eureka and Nunavut	80° N - 86° W	2006
Ny-Alesund and Svalbard	78° N - 12° E	1991
Thule and Greenland	76° N - 69° W	1991
Scoresbysund and Greenland	71° N - 22° W	1991
Sodankyla and Finland	67° N - 27° E	1990
Salekhard and Russia	67° N - 67° E	1998
Zhigansk and Russia	67° N - 123° E	1992
Harestua and Norway	60° N - 11° E	1994

Every station has a passive method of measuring the ozone depletion. The columns of calculated columns, as defined in Goutail et al. (1999) compared to those of the Chemical Transport Models (CTM). The diurnal variability in nitrogen dioxide, suggested by chlorine activation, was also calculated since NOx was transformed in $ClONO_2$ and thus lost NO_2 at midday with still active chlorine (Pommereau et al., 2013). Figure 1 indicates depletion of ozone and NO_2 in the winters of 2015-16 and 2016-17. The 0.5%/day ozone loss average in 2016 was 27±3% at March 20, although it was slower (0.2%/day), shorter (as of February 27, 2017, and smaller (16±3%) in total in 2017. Chlorine stayed disabled and NO_2 was therefore not available until 10 February 2016 in the afternoon just 10 January 2017.

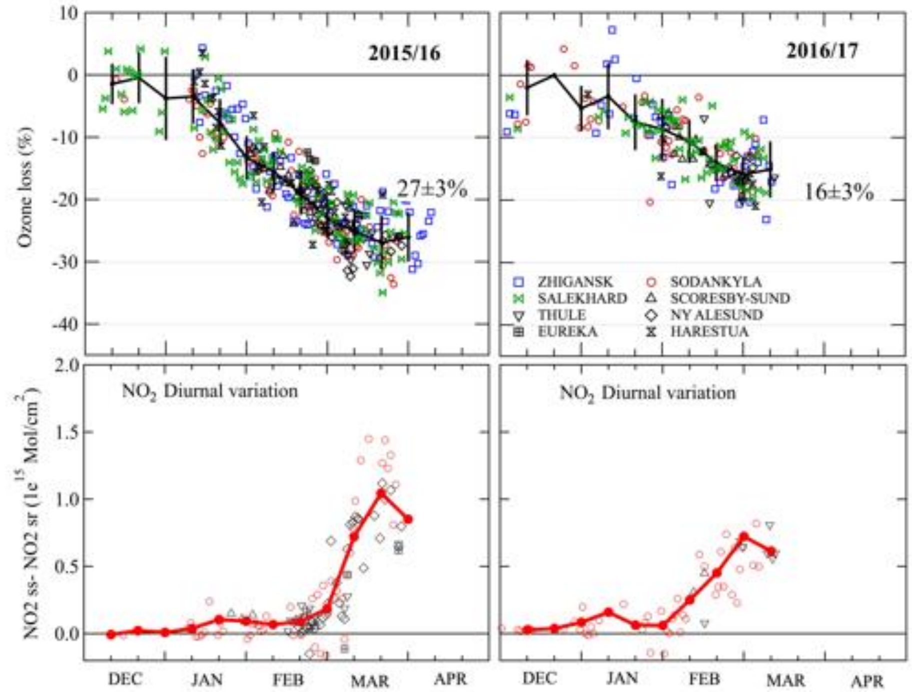

Figure 1 : Time series of observed ozane loss (%) inside vortex (top penals) and NO_2 diurnal variation amplitude (bottom panels), above each SAOZ station in winter 2015-16 (left) and in winter 2016-17 (right)

Figure 2 displays the long-term ozone depletion trend since SAOZ measurements of network started in 1990 and the outcome of CTMs REPROBUS and SLIMCAT. While the main warming was halted at the beginning of mars, after the high of 1995-96 and the record-breaking failure of 2010-11, the 2015-16 decline became the third highest.

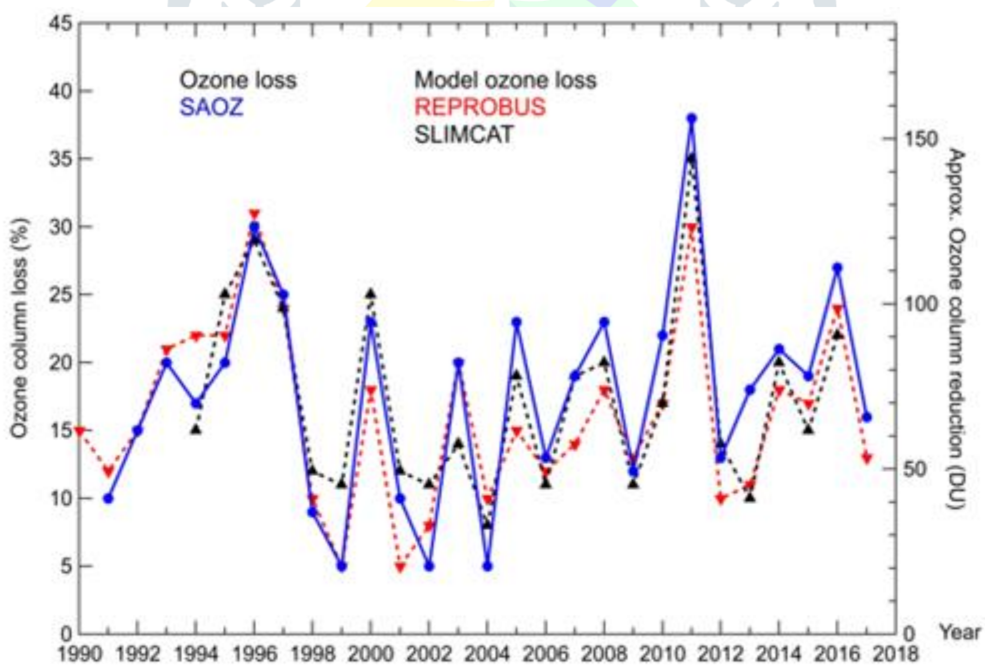

Figure 2: Ozone Loss Magnitude reported each year by the SAOZ network since 1990 and calculated by the two models REPROBUS and SLIMCAT.

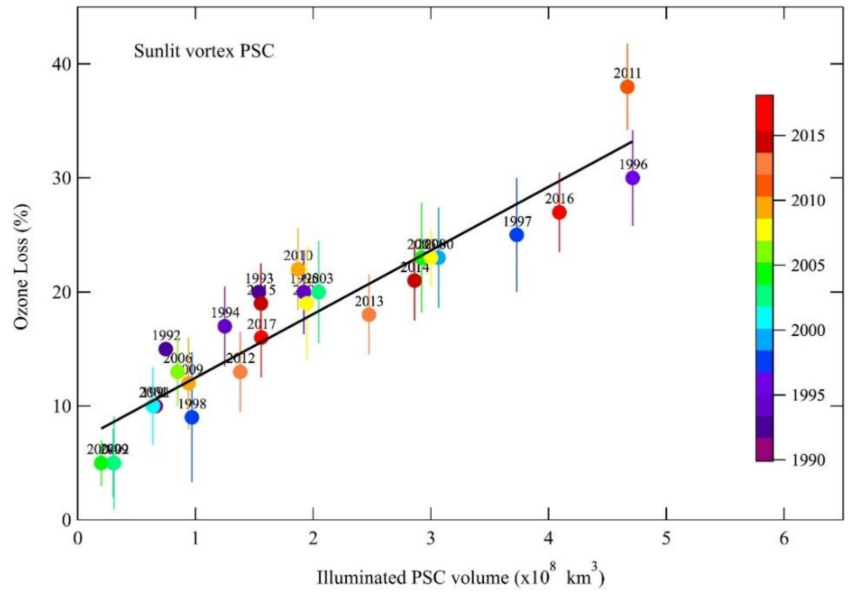

Figure 3 : SAOZ ozone loss magnitude versus nitric acid trihydrate (NAT) PSC sunlit volume (VPSC) between 400-675K levels.

Significant, ozone depletions since 1998 and 2005 are not regularly detected after 2005 because early warmth in late December and early January. The EMAC model predicts that the stratosphere below TNAT would cool in the early winter of each year after 2005, contributing to an ozone loss of at least 12-15% each year. The reported depletion values are quite strong for REPROBUS and REPROBUS respectively of 24, 3±1.9% and 13±2% and 25±2% and SLIMCAT of 11±3%, with the exception of 2012-13 because all simulations underestimated the ozone loss reported. The declining levels are 29±3% in 2016-17. Figure 3 indicates the connection of the magnitude of SAOZ ozone depletion to the illuminated amount of nitric trihydrate acid (NAT). Within the lower stratosphere between 400 - 675 K, the illuminated quantity of NAT PSC is measured (Pommereau et al. 2013). The episodes 2015-16 and 2016-17 were fully compatible and established the longitudinal association between the amount of ozone depletion and NAT PSC sun-light, suggesting the activation of chlorine.

CONCLUSION

In summary, both model forecasts conclude that the lower stratosphere of the Arctic will get cooler as GHG rates rise. However, there are major variations among these, e.g. freezing in early winter, freezing in mid- or upper stratosphere, increasing or weakening of Brewer-Dobson circulation, extra cooling after ice melting in the sea, etc. Considerable variations occur between them. In general, model predictions are in line with the observed winter cooling of the lower stratosphere, aligned with, for example, the latest 2015-16 trend for lower temperatures. CCMI models often reflect on the correlation between ozone depletion and temperature, where measurements are well represented by models of chemical transport. The strong Arctic meteorological variation means that incidents like 2010-11 and 2015-16 tend to occur in broad chemical ozone loss before the ODS concentration falls to its 1960 rate. It will greatly postpone the recovery of Arctic stratospheric ozone projection for mid-2030. The persistence of high-quality land-based and satellite columns in the arctic in winter would allow for annual ozone depletion assessments in the long terms, which is most important for the estimation of potential Arctic ozone production and minimizing variability in the timing of its reconstruction.

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