Atmospheric Chemistry and Physics Discussions

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Review of acp-2020-1313

Anonymous Referee #1

Referee comment on "Exceptional loss in ozone in the Arctic winter/spring of 2019/2020" by Jayanarayanan Kuttippurath et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1313-RC2, 2021

In their manuscript, Kuttippurath et al. investigate Arctic stratospheric ozone loss during the exceptional winter 2019/2020 from a range of satellite and ground-based observations. Their analysis is thorough and the results are sound. It is, however, less clear to me, what the main message of this paper is. Previous studies, correctly cited in this manuscript, have already come to similar results. So it would be good, if Kuttippurath et al. could spell out a bit clearer what this study adds, that is not already known from these previous studies.

I have one concern with the claims made here that the exceptional ozone loss in 2019/2020 is a sign of climate change. As far as I am aware of the current literature, most climate models do not show any increase in Arctic ozone loss due to climate change. Can the authors rule out that 2020 was not just an extreme winter within the current range of variability? And related to that point: the Arctic did experience in March 2020 ozone hole conditions, as this study demonstrates. Is there evidence of an "exposure of nearly 650 million people and ecosystem to unhealthy ultra-violet radiation levels" (quoting from the first sentence of the abstract)? Or do the authors suggest that future Arctic winters could show even larger ozone depletion? And if so, on which basis? The authors should try to make these points clearer.

The paper is overall generally well written, but could be made clearer at several points. See my specific comments below. I recommend the manuscript for publication in Atmos. Chem. Phys. if the authors can address my general and specific comments.

Specific comments:

P1, l13: "Severe vortex-wide ozone loss in the Arctic would expose nearly 650 million people and ecosystem to unhealthy ultra-violet radiation levels." The number of 650 million people does not appear in the body of the manuscript and is not backed-up by any citation. So I suggest removing this explicit statement here from the abstract.

p1, l22: "the very colder Arctic winters in the near future will experience even more ozone loss": do you mean Arctic winters in the near future will become colder? On what basis is

this claim made? Or do you mean the coldest Arctic winters in the near future within the current range of variability? But why should they experience very likely even larger losses?

p1, l22: language: "Our study suggests that the very colder Arctic winters in near future would also very likely to experience even more ozone loss and encounter ozone hole situations, provided the stratospheric chlorine levels still stay high there." -> "Our study suggests that colder Arctic winters in the near future would likely experience even more ozone loss and encounter ozone hole situations, as long as stratospheric chlorine levels remain high."

p1, l30: why did the Antarctic ozone loss peak in the late 1980s when polar stratospheric chlorine loading peaked around the early 2000s?

p2, l42: "e.g., > 1.5ppmv of loss" seems arbitrary. Please motivate this value

p2,l43: 25-30% in which metric? The statement on 1.5ppmv above clearly refers to loss at a certain altitude. On a given altitude, previous Arctic winters (such as 1999/2000 or 2010/11) experienced losses far greater than 25-30% (e.g., Sinnhuber et al., 2000; Sinnhuber et al., 2011). Please be specific which metric this refers to: column loss with the vortex, column loss poleward of a certain latitude, local loss, …

p2, l46: "short-lived" is what sense?

P2, l50: "ozone loss is found to be proportional to the timing of the major warmings": I think I know what you mean, but this statement is not very clear

P2,l53: "The occurrence of extreme events is a signature of climate change and so are the extreme cold winters with large loss in ozone (e.g. IPCC, 2007)" Sorry, it may be true that under a changing climate the occurrence of extreme cold winters may increase, but it is not at all clear if there is a trend towards more extreme events in Arctic stratospheric temperatures and whether or not it is related to climate change! This statement is not backed-up by IPCC, 2007.

p2,l62: would be good to have references for the data sets

p2,l64: latitude and longitudes swapped for Alert

p2,l65: Do the 5-10% refer only to the sondes, or also to the satellite profile data?

p3, l70: GOME -> GOME-2 ?

p3, l74: "and other trace gas profiles": which?

p3,l75: does OMPS provide temperature profiles?

p3, l80: what is poisson_grid_fill ? Reference?

p3, l84: if the precision varies so strongly, maybe better to give percentage uncertainty?

p3, l87: not clear to me how well justified this extrapolation is. Does this extrapolation takes into account the tropospheric N2O VMR?

p4, l114: "longest winters"? You mean latest vortex break-up? Or coldest winters?

p4, l129: "PSC area" -> "potential PSC area". Please make clear, that this is not area of

observed PSCs but area of temperatures cold enough for formation of PSCs.

p5 ,l133: "in 40 years": where there colder temperatures before, or are these the coldest ever observed?

p5, l133: "the largest ice PSC ": This is likely not a single cloud, but an area of temperatures cold enough for the formation of ice PSCs

p5, l143-150: This general discussion of the relation between wave activity and vortex strength can be moved to the introduction.

p5, l159: "occupied the entire polar region": how do you define polar region? North of 60N? Or entire vortex?

p6, l165-168: can be removed, redundant

p6, l188: didn't Rex define APSC and VPSC as the temporal integral of PSC area and volume, respectively?

p7, l196: From Fig. 3: I don't see a gradual descent of loss from the middle stratosphere to the lower stratosphere: I see some (small) loss above 600K in December and much larger losses in the lower stratosphere (below 600K) beginning in December as well and intensifying during January. Or does this statement refer to earlier winters?

p7, l200: chlorine activation does not require sunlight, but high levels of ClO do

p7, l216: the high levels of ClO in airmasses with low PV are very surprising. The high ClO suggests that the reductions are not only "dynamically driven"? Would be great to have a bit more discussion at this point.

p7, l220: citations seem out of place

p9, l264: "chlorine activation and ozone loss is limited to the winters with very low temperatures in December–February" this statement is somewhat incorrect

p9, l268: "ozone loss in the winter 2011 was about 1.0 ppmv (or 30–40 DU),": I don't understand what these numbers refer to. E.g., Sinnhuber et al., 2011, derived maximum ozone loss in Arctic winter 2010/11 of more than 2ppm at 19km and more than 120 DU column loss. Is this what is meant in the next sentence: "which is higher than that of other Arctic winters (about 2.1–2.3 ppmv or 100–100 DU)"? (100-100DU is a typo anyway, I guess.) Is the first sentence then referring to loss before February only?

p9, l77: "undoubtedly" is a strong word. I suggest to remove.

Fig. 5: I couldn't find for which period in the given years the ClO profiles are shown. Are these maximum values or temporal averages? Any idea why ClO is so much higher above 550K in the Antarctic in 2019 compared to 2015 – keeping in mind that 2019 was a rather warm and disturbed Antarctic spring?

Section 3.5, Fig. 6: When discussing the maximum ClO amounts in the past winters, it would be interesting to put this into context of the EESC (or similar metric): By how much has total chlorine (or EESC, …) decreased between 2005 and 2020?

p11, l346: how exactly is saturation ("complete loss of ozone") defined here? In reality ozone is of course never completely gone. Okay, I see further down at l359 that you define this as below 200ppbv with a reference to Smit et al. (2007). I believe it would be

good to include a brief justification here, why this is a useful definition for loss saturation.

p11, l347: Again, I don't understand the meaning of "ozone loss normally happens only up to 25–30% in the Arctic winters". Local loss in previous cold Arctic winters was clearly larger than 30%.

Fig. 5: Please indicate the dates for the sonde profiles.

p12, l362: "the loss saturation suggests that the Arctic has entered an exigent climate change scenario": again, it is not self-evident, why this is a sign of climate change and not just an extreme winter within the range of variability. Same comment applies to l403.

p12, l380: Just for curiosity: why are GOME measurements more restricted in latitude than OMI or OMPS? I thought all three use similar wavelengths ranges?

p12, l389: contradiction: in the previous sentence it is stated that a column loss of about 90-120 DU occurs in extreme winters such as 2005 and 2011 and in the next, the largest observed loss was 100 DU in 2011. Sorry, but these small contradictions are very confusing and make for a tiresome reading.

P14, l437: "Extreme weather events are harbingers of climate change": See comments above on extremes and climate change.

Technical corrections

p2, l61: ->"We have used two satellite ozone profile datasets."

p2, l77: ER5 -> ERA5

p2,l78/79: active and passive voice changes

p6, l186: ozone AND N2O

p7, l227: present IN all

p9, l286: Wohltmann

p12, l369: by Nash et al.

p13, l404: not present continuously