# Review egusphere-2023-522

Investigation of meteorological conditions and BrO during Ozone Depletion Events in Ny-Ålesund between 2010 and 2021

## 1 general comments

`evaluating the overall quality of the discussion paper`

The paper investigates the importance of polar cyclones and associated meteorological condition on ozone depleting events (ODEs) observed in the proximity of Ny-Ålesund. The authors apply complementary datasets of both ozone ($O_3$) and BrO (e.g. in situ observations and various remote sensing products) and combine these with Lagrangian (FLEXPART) and Eulerian (WRF) modeling techniques. Though, no Chemistry Transport Model (CTM) or process modeling were applied in this study. Overall, the paper is

- well-structured,
- comprehensible in its application of the composite data analysis.

The language is

- comprehensive
- and for most parts only minor corrections may apply.

Though this paper was, overall, a real pleasure to read, a major shortcoming emerges from the distinction between background (no ODE) state of the atmosphere and ODE state. The authors define *no ODE*, in principle, by $Y_{\mathrm{noODE}} = Y_{\mathrm{tot}} - Y_{\mathrm{gap\,O_3\,data}} - Y_{[\mathrm{O_3}]<15\,\mathrm{ppb}}$, where $Y$ in this case refers to one record in 1-hourly meteorological data (e.g. $Y_{\mathrm{tot}}$ would correspond to 744 records in March). Applying this definition of the background state of the atmosphere most likely reduces the explanatory power of the anomaly analysis because ODE conditions are likely to be contained in the *no ODE* data records. This clearly emerges from the sensitivity analysis in Section 3.2.1 where a lower threshold (20 ppb) was applied. This weakened the found dipole structure. The anomaly analysis could potentially benefit from stronger constraints on the background state, however, the general outcome of the study will probably not change significantly. Hence, either the authors, unconstrained by computational and human resources, repeat the anomaly analysis with a more clear-cut background state or discuss the implications more thoroughly in Section 3.2.1.

## 2 specific comments

`individual scientific questions/issues`

- p4 l116: "[...] not necessarily capture all ODEs at sea level.": Could you possibly give an estimate based on your composite analysis? Or give a number of coincident events?

- p5 l121: "[...] ODEs occur mainly in polar spring [...]": Is there evidence that they do occur in, e.g., fall?
- p5 Table 1: Would it make more sense to differentiate between ODEs and total number of ascents in the respective month?
- p6 Table 2 (and respective paragraphs in the text): How is "ODE" count exactly defined here? It seems as if you count consecutive hours of below threshold $O_3$ as one event each. An ODE can, in fact, as your correctly wrote and showed (Fig 7), last for several days. Hence, your definition of ODE in this Table is not consistent with, e.g., Section 3.3. In any case, no ODE and ODE [hours with $O_3$ below threshold] do not add up to the total number of hours in each month, e.g., 744 h in March. It is not clear if this is caused by gaps in data. Could you clarify this?
- p5 l122: How did you define the 15 ppb threshold? Is it possible to clearly separate populations in a histogram of $O_3$ monitoring (bi-modal distribution)?
- p5 l129: How like do you detect "fake" ODEs due to low hemispheric $O_3$ background especially at higher thresholds?
- p7 l154–177: "From 2010 until 2017 [...]": Too specific and technical. You may summarize the technical information about the different satellite products in a table and keep only additional information in the text.
- p8 l195–196: "[...] two domains were used in a two-way nested run, i.e. the values of the coarse domain are overwritten by values of the higher resolution [...]": That's not entirely correct, as changes in the inner and outer domain influence field information of one another in a two-way coupled model system. Either explain the coupling in detail or drop the second half of the sentence starting with "i.e.".
- p9 l219-223; eq (1): $Y_{ODEanom} = \overline{Y}_{ODE} - \overline{Y}_{noODE}$: This method is slightly problematic in the sense that you may have erroneously detected ODEs / noODEs in both data sets (even more so in the data sets with the lowered threshold of 20 ppb). These will blur the signal you are after. In this context, the definition of ODE that you apply to the ozone monitoring data is not sound (see also comment regarding Table 2). Consecutive hours of below threshold ozone concentrations are a necessity to identify an "event", hence the number of hours of ODE is misleading with respect to ODE statistics. The lag analysis that you apply in the following should be associated to the onset/end of an individual ODE. In summary, if you use times of "no ODE" you have to make sure that these really **do not contain any ODE** which I currently cannot see satisfied in your analysis. Another threshold, e.g. for *normal* ozone concentrations, could do the trick.
- p10 Fig 2: Regarding the shown data, where does the "white" area south of Svalbard come from? Did you use some kind of "sea ice edge" filtering to exclude these data or are there no data due to retrieval constraints?
- p11 l274: "long computing times": On which kind of system? Personal computer, HPC? If former is the case an application of other computational resources should have been considered for this analysis, perhaps?

- p13 Section 3.2.1: How did you derive the different threshold values? Are they "random" choices or were the derived from a bi-modal analysis of ozone concentration distributions if that is even possible? As you show in this section, the choice of threshold is crucial for identifying a causal signal. Have you analyzed coincident ODEs in both sounding and monitoring data with respect to the meteorological and BrO conditions? Or are there too few coincident ODEs?
- p14 l309: "Overall, the anomalies are slightly less pronounced when using the 20 ppb threshold.": This doesn't really come as surprise. By lowering the threshold you'd allow for more "false positive" ODEs that can originate from both transport and mixing of air parcels with different trace gas concentrations, as well as the inclusion of subsiding ODEs where the actual cause is not present in your time lag analysis.
- p17 l361–370: "Several years [...] show strong anomalies [...] other years still show similar patterns [...]": Let's turn this around: If you'd find similar patterns in your meteorological fields but no ODE, wouldn't that mean that these meteorological conditions do not suffice as cause of ODEs?
- p17 l385–387: "[...] the amount of BrO is not fully captured by the satellite observations." Could this be due to the algorithm used to separate tropospheric and stratospheric columns?
- p21 l452: "Due to a decrease of sea ice extend less source area for BEE will be available." Without taking the processes associated with BEE and ODE into account, this remains highly speculative. Given blowing snow on first year sea ice and brine on (young) sea ice is among the major sources of Br in the polar spring boundary layer (see e.g. `10.5194/acp-12-6237-2012` for a review of processes), the extent of the sea ice is probably less important compared to the structure and dynamics of the sea ice, higher wind speeds, and a change in frequency in the occurrence of polar lows. Dynamics of sea ice formation have been notoriously hard to detect with passive sounding satellite-born instruments, but advances might have been made in recent years.

## 3 technical corrections

`purely technical corrections`

- p2 l24: "during sunlight": term?
- p2 R1–R6: Typesetting of chemical formulas: $Br_2 \rightarrow \mathrm{Br_2}$, asf.
- p6 Fig 1: (left) Maybe indicate altitude of Zeppelin observatory?
- p7 l154 ff: "From 2010 until 2017 [...]": Duplicate of paragraph "To analyse [...]" (p7 l146 ff). Please condense the two paragraphs.
- p8 l183–185: "Additionally, to analyse [...]": This sentence might be grammatically incorrect. Maybe better: *Daily AMSR (...) sea ice concentration (SIC) observations on a* $25 \times 25$ $\mathrm{km^2}$ *grid have been used to analyse the SIC [...].*

- p8 l184, l191, l190: Style! "was used" is used in each of these consecutive sentences. You may want to rephrase.
- p8 l196–198 and Fig 9: Definition of WRF domains: Which projections were used? Does the clipping shown in Fig 9 represent the boundaries of the outer domain? Would it be possible to indicate the location of the inner domain in the WRF related plots in Fig 9?
- p9 l213, l214, l225, and others: "time points" Incorrect term. Rephrase → *times*.
- p9 l215–216: "To separate the ozone data [...]": Repetition of Section 2.1. Remove or rephrase: *From the ozone data (see Section 2.1), we found 14 ODEs and 228 no ODEs in ozone sonde data records and [...].*
- p9 l219 ff: Typesetting of formulas. If not defined otherwise in the journal's style guide, non-indexing subscripts should not be set in italic font: $\overline{Y}_{ODE} \rightarrow \overline{Y}_{\mathrm{ODE}}$.
- p10 Fig 2: "BrO VCD anomalies for ODE and no ODE" Caption text confusing? I would assume, you should drop "for ODE and no ODE" here. Regarding the shown data, were does the "white" area south of Svalbard come from? Did you use some kind of "sea ice edge" filtering to exclude these data or are there no data?
- p10 l235: Typo: "Ny-Alesund" → Ny-Ålesund
- p10 l242: Typo: "the the" remove one "the"; Missing comma after adverb?: "Normally the Icelandic low [...]"
- p10 l243: "Due to the lower pressure [...]": Perhaps *low pressure system*? (But I'm not firm in weather synoptics.)
- p15 l314–345: "[...] a more pronounced lower pressure anomalies [...]": Mismatching singular article and plural noun.
- p17 l378: "As shown in the blue line": preposition?: *As shown by the blue line*
- p17 l379: "in the same altitude": preposition?: *at the same altitude*
- p21 l452: "extend" → *extent*
- p27: Empty → Fig C1 should have appeared here.
- p25: Fig A5 is not referenced in the text.