

Response to anonymous reviewer #2

We thank the reviewer for providing helpful comments on our manuscript. We address all issues raised (blue text) as follows:

The paper is well structured and written. However, it is quite long and the authors could consider shorten the text and add some summarizing figures or statistics.

This article is long because of the breadth of material we cover. We have structured the article in a consistent, accessible way, so that individual subject areas e.g., historical aspects, or mercury etc. can be found by specialist readers. Meanwhile, we have kept each individual section concise. We do not believe that adding additional figures, metadata, and tables will shorten the manuscript. Shortening the article would require removing sections, which would then mean the paper was no longer comprehensive. We also note that reviewer #1 suggests the length is justified for this type of article.

We do agree that some statistics on the impact of the site would be useful and add these to the revised manuscript in the introduction, e.g. "The Zeppelin Observatory is now a leading global background measurement site (Tørseth et al., 2012). Google scholar finds at least 280 publications including the search term "Zeppelin Observatory" and, for example, greenhouse gas data/ meta data (CO₂, CO, CH₄) have been downloaded at least 4439 times from the ICOS carbon portal (<https://www.icos-cp.eu/observations/carbon-portal>)."

line 53: how the decision of the Swedish parliament accepted for a Swedish monitoring program in connected to the Norwegian approach. Please clarify.

We reformulate this sentence to "Meanwhile in Sweden in the same year, the Swedish parliament accepted the proposal for a Swedish monitoring programme ('program för övervakning av miljö kvalitet', PMK) one part of which was to be long-term monitoring at Ny-Ålesund by Stockholm University of changes in atmospheric composition with an emphasis on aerosols and carbon dioxide in collaboration with NILU in Norway."

line 842: History; you could add the time line figure demonstrating the different atmospheric composition measurements at different locations. This would also provide a general overview on the development and availability of long term measurements and address the role of Zeppelin measurements.

We have added a timeline figure to the revised manuscript.

line 113: add "full stop" after parenthesis.

This has been corrected in the revised manuscript.

lines 195-199: please add references for the location climate / vegetation classification.

A reference to (Bliss, 2000) has been added for 'Arctic Tundra Zone'. 'Northern' does not need a reference as the high latitude has been stated previously in the manuscript but should not be capitalized, i.e. "northern Arctic Tundra Zone". This has now been corrected.

line 224: please add a reference if possible.

A reference to (Hov and Holtet, 1987) has been added.

line 255: you could use ["/sios-svalbard.org/](https://sios-svalbard.org/)"

This has been corrected in the revised manuscript.

line 285: open the acronym FLEXPART particle dispersion model:>>> “FLEXible PARTicle dispersion model”. Please re-check all the acronyms in the text and open the acronym when mentioned for the first time

This, and other undefined acronyms in the text have been defined in the revised manuscript.

Fig 3: improve quality (resolution) of the figure

The figure quality has been improved in the revised manuscript.

line 316: Aitken mode particles, please add size

This has been added to the revised manuscript: “At the same time there is usually a shift in the aerosol size distribution from dominant accumulation mode towards smaller Aitken mode particles (particle diameter typically <60 nm, e.g. Tunved et al., 2013) indicating a very different origin of the chemical load observed. “

Fig 4 please improve quality (resolution) of the figure

The figure quality has been improved in the revised manuscript.

line 340: you could add a short overall (meta) description / table of all measurements which would better describe the overall measurement capacity of the station. And give some general statistics of the measurements.

Tables 1-4 already list the instruments and capability of the Zeppelin Observatory. General numbers are given in the main text where relevant to the discussion, while we feel that adding more complexity to the tables without context (which would otherwise increase the length of the paper) would not provide the reader with a better overview of the history of the station or long-term developments in the Arctic atmosphere.

line 350-365: (4.1) this is very detailed description of the samplings and filters, you could consider a schematic figure of the process or an annex.

A small part of the discussion on filter sampling has been removed to keep this method description more consistent in length with the other methods sections.

line 366: add the reference for Mann-Kendall Test/Sen’s slope.

The references (Mann, 1945; Kendall, 1948; Sen, 1968) have been added to the revised manuscript at appropriate locations.

Fig 6., 7., 8. technical quality of the fig should be improved

The figure resolutions have been improved in the revised manuscript.

line 439: “With this set-up the Zeppelin Observatory is now one of the first global aerosol observatories with semi-continuous in-situ cloud sampling”. What are the other stations ?

We have modified this sentence as follows: “With the current set up, including cloud condensation nuclei counters (CCNC), cloud residual properties and cloud and precipitation microphysical properties the Zeppelin Observatory is now (to the best of our knowledge) the first global aerosol observatory with continuous in-situ observations of atmospheric aerosol, cloud residuals, clouds and precipitation (e.g., Koike et al., 2019).”

line 839, 865: some error with the reference (Error! Not a valid bookmark self-reference)

This has been corrected in the revised manuscript.

line(s) 925 & 962 please check, add the reference Petäjä et al. 2020 Overview: Integrative and Comprehensive Understanding on Polar Environments (iCUPE) – concept and initial results, *Atmos. Chem. Phys.*, 20, 8551–8592, <https://doi.org/10.5194/acp-20-8551-2020>, 2020.

This reference has been added to the revised manuscript.

line 1074: please add some specification for the acronyms “POLARCAT” “TOPSE”

The acronyms Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport (POLARCAT) and Tropospheric Ozone Production about the Spring Equinox (TOPSE) have been added to the revised manuscript

line 1172: “strengthen the position of the Zeppelin Observatory as a leading global measurement platform, perhaps” one of the ? / Arctic ?

Since the Zeppelin observatory is defined as a global background site, e.g. (Tørseth et al., 2012), we have changed this to “strengthening the position of the Zeppelin Observatory as a leading global background measurement site”

line 1200: Refer to “open access”, how is the data access to Zeppelin measurements currently organized ?

Data access is already described in Section 9. “Most data are publicly available on ebas.nilu.no or else on request via the responsible institutions listed in Tables 1-4.”

line 1227: “Changes in the Arctic aerosol burden will in turn influence climate via direct and indirect aerosol effects, i.e. via increased absorption and scattering, and changes in CCN and ice nucleating particles (INP), respectively.” - add reference

We have added a reference to (Schmale et al., 2021) in the revised manuscript.

line 1228: “Another important non-CO₂ greenhouse gas is N₂O, with a global warming potential 265–298 times that of CO₂.” - add reference

References to Montzka et al. 2011 and Hodnebrog et al., 2013 have been added to the revised manuscript.

References

- Bliss, L. C.: Arctic tundra and polar desert biome, *North American terrestrial vegetation*, 2, 1-40, 2000.
- Hov, Ø., and Holtet, J., A.: Prosjektering av atmosfærekjemisk forskningsstasjon I Ny-Ålesund på Svalbard. NILU OR 67/87. Lillestrøm, Norway., 1987.
- Kendall, M. G.: Rank correlation methods, 1948.
- Koike, M., Ukita, J., Ström, J., Tunved, P., Shiobara, M., Vitale, V., Lupi, A., Baumgardner, D., Ritter, C., and Hermansen, O.: Year-round in situ measurements of Arctic low-level clouds: Microphysical properties and their relationships with aerosols, *Journal of Geophysical Research: Atmospheres*, 124, 1798-1822, 2019.
- Mann, H. B.: Nonparametric tests against trend, *Econometrica: Journal of the econometric society*, 245-259, 1945.
- Schmale, J., Zieger, P., and Ekman, A. M.: Aerosols in current and future Arctic climate, *Nature Climate Change*, 11, 95-105, 2021.
- Sen, P. K.: Estimates of the regression coefficient based on Kendall's tau, *Journal of the American statistical association*, 63, 1379-1389, 1968.

Tørseth, K., Aas, W., Breivik, K., Fjæraa, A. M., Fiebig, M., Hjellbrekke, A.-G., Lund Myhre, C., Solberg, S., and Yttri, K. E.: Introduction to the European Monitoring and Evaluation Programme (EMEP) and observed atmospheric composition change during 1972–2009, *Atmospheric Chemistry and Physics*, 12, 5447-5481, 2012.