Reply to Reviewer 2

In this work, the authors present a statistical model to evaluate the existence period of Polar Stratospheric Clouds (PSCs) from global gridded stratospheric temperature datasets. The model parameterization is derived from PSC-observations performed by the CALIOP lidar on the CALIPSO satellite between 2006 and 2020. Subsequently this model is used to analyse the trend of the PSC season length over Antarctica at different stratospheric pressure levels over an extended period from 1980 to 2020 based on the MERRA2 reanalysis dataset.

In general, the manuscript is well written albeit a bit lengthy in some places where the material could be presented more compressed with less repetitions. I would suggest to really concentrate only on the really necessary parts and move some of the less significant items in the appendix. Content wise the manuscript fits into the scope of ACP and I would support its publication after consideration/implementation of the following comments.

We thank the reviewers for their constructive comments which helped us to improve the quality of the paper. Following these comments and similar ones from the other reviewer, we made an effort in the revision to clarify and summarize the repetitive and long Sections. We have considerably reduced the length of the text, the number of steps to present results, the number of figures (from 16 to 10), and the Appendix. We answer below point-by-point to all comments.

- ***Chapter 2.1:***

  Seems too long with information not needed in the following. Please concentrate on describing the dataset which is used within the study and put references for further reading.

The reviewer suggests shortening Section 2.1. Following this comment and a similar one from the other reviewer, we have shortened Section 2.1 by trying to keep only information relevant to the paper.

- ***Chapter 2.2:***

  Here (or later in the discussion section) a discussion on the reliability of MERRA2 would be valuable to be able to judge on the conclusions drawn on the pre-CALIPSO periods. As an example, one may refer to the "SPARC Reanalysis Intercomparison Project (S-RIP) Final Report" or other work, especially comparing temperatures with ERA-5.

We thank the reviewer for this extremely useful SPARC reference. Based on its contents, we added a discussion about the reliability of MERRA2 temperatures in the polar lower stratosphere in Sect 2.2 and Sect. 5 to discuss the significance of trends found over different timescales.

- ***193: 'fits the best for most of the plots is a polynomial of degree 2'***

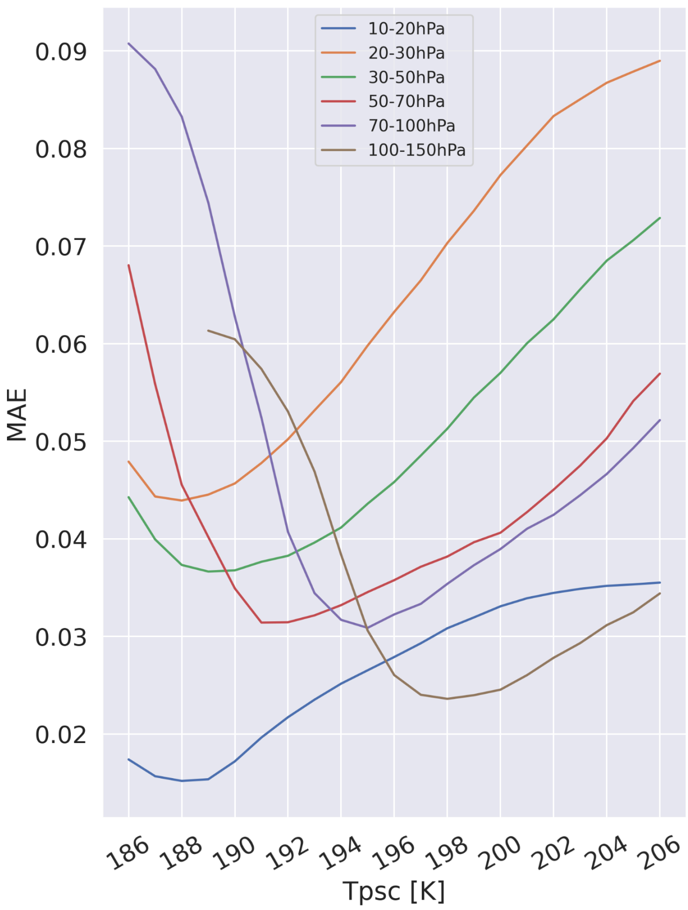
  What is the criterion for the statement 'best'? A higher-order polynomial would mathematically fit better but there might be other reasons (e.g. simplicity) to choose 2nd order. What is the norm which is minimized for the fit (RMS)?

We have performed tests with polynomials of different orders and found that degree 2 is the smallest order giving good performance (ie small determination coefficients). We have modified the text to explain that. Our python code uses from numpy the polyfit function, which indeed minimizes the squared error as the reviewer suggests.

- ***218: 'The** $Tpsc$ **and parameters which lead to the smallest MAE are selected for the month and pressure level considered'***

  How well defined is this minimum? A plot of MAE as f(Tpsc) would be helpful to judge on the uniqueness of the result. Further, the choice to use monthly changing threshold temperatures seems a bit arbitrary. Have you tried to perform some kind of 'smooth' transition between the monthly Tpsc values or what is your argument to use such a 'coarse' binning.

In our study, we calculated the MAE for each Tpsc and chose the Tpsc which gives the smallest MAE. This is now clarified in the text. To investigate how well the minimum is defined, the plot below presents for each pressure level in June the MAE as a function of Tpsc. Minimas appear well-defined enough to specify Tpsc with a precision of 1-2 Kelvin.



Mean absolute error (MAE) between observed and evaluated PSC densities depending on the temperature threshold TPSC at different pressure levels

Defining Tpsc using monthly timescales makes it possible to take into account changes in chemical species available for the formation of PSCs. As a given Tpsc provides a set of (a,b,c) coefficients from the polynomial regressions which estimate the PSC densities, we cannot interpolate the Tpsc (since we cannot interpolate the regression coefficients). Our tests have shown it is possible to calculate threshold temperatures on sub-monthly scales (for instance 15 days), this does not change the results significantly. Shorter timescales do not provide enough data points to the regressions.

- ***238: 'The difference is particularly important at lower altitudes'***

  This finding should be supported by references to previous publications.

- ***248: 'there is often a large difference between the temperature threshold*** T_{NAT} ***at'***

  Can you support this statement by pointing to papers describing these obvious differences based on CALIOP observations?

We address these two comments as one as they relate to the same issue. The noted sentences (lines 238 and 248) describe Tpsc in Figure 3. Tpsc is a temperature threshold that we defined in the paper and is required to apply our methodology. It is therefore not referenced in existing literature, and we cannot rely on the literature to explain the differences between TNAT and Tpsc. We do not expect Tpsc to be necessarily equivalent to TNAT. We apologize for the confusion, and tried to clarify the text to avoid misunderstandings.

- ***Chapter 4:***

    Here only the simulated PSC densities on basis of monthly temperature thresholds for the related year are shown. I think the results obtained with the multi-year derived T-thresholds are much more relevant. Thus, I would strongly suggest to show and discuss also those. In principle this is shown in Figs. 6-8 in chapter 5, albeit so squeezed that the curves cannot be distinguished.

Following this suggestion and a similar one from the other reviewer, the original section 4 (2009 and 2010 PSC seasons) was removed. Consistent with this comment, the new section 4 now focuses on the results obtained with the multi-year derived T-thresholds. In order to facilitate the reading of the squeezed Figures 8a, Appendix C now describes for the pressure level 50-70 hPa, each PSC densities observed and estimated by our model for each year from 2007 to 2020.

- ***551: 'This longer period can be attributed to the gridded dataset including latitudes south of 82°S, absent from the CALIPSO dataset.'***

    This statement can easily (and should) be substantiated by performing the respective analysis only down to 82S.

We thank the reviewer for this appropriate suggestion, also noted by the other reviewer. We updated what is now Section 5 (previously Section 6) by presenting results restricted to the 60°S-82°S region. The new results confirm that the considerably longer PSC seasons are indeed due to the inclusion of the region poleward 82°S.

- ***Chapter 6:***

    These findings strongly depend on the accuracy of the MERRA2 analysis, esp. on their trends. Please discuss the influence of related uncertainties on your findings and, if possible, point to supporting material.

Following this comment and a similar one on Section 2.2, Section 5 now includes a discussion of the accuracy and biases of MERRA2 stratospheric temperatures and their relation to the trends we found in the PSC season duration over the 1980-2021 period.

- ***Data availability :***

  The data used for the model calculations (e.g. Tpsc, polynomial coefficients) have to be made publicly available in digital form.

Following this comment, a CSV file (data_statistical_model.txt) describing for each pressure level and month the Tpsc and associated regression coefficients has been uploaded as supplementary data on ACP.