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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Seventeen years of ozone sounding at L'Aquila, Italy: evidence of mid-latitude stratospheric ozone recovery and tropospheric profile changes" *by* Daniele Visioni et al.

Anonymous Referee #2

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Review of acp-2020-525

Seventeen years of ozone soundings at L'Aquila, Italy: evidence of mid-latitude stratospheric ozone recovery and tropospheric profile changes by Daniele Visioni et al.

The paper by Visioni et al. presents 17 years of ozone profile measurements at the station of L'Aquila (Italy), which are used for trend analyses of partial columns ranging from the boundary layer up to the middle stratosphere. The results are discussed in the light of enhanced greenhouse gas concentrations and the corresponding changes

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of dynamical and chemical processes in recent years, for instance the acceleration of the Brewer-Dobson circulation and the slowing down of ozone destroying gas-phase reactions due to stratospheric cooling. Results of Chemistry-Climate Models (CCMs) are consulted to point out the role of the most important dynamical and chemical processes. The manuscript in its present form cannot be published in ACP. Currently it contains several (interesting) points, but which are not matching well with each other, in other words, the "red thread" cannot be seen in this paper. I am missing concrete scientific results and further pointing out the advantages of this new, long-term ozone time series of L'Aquila (for instance with respect to local tropospheric ozone changes, i.e. differences between the other mid-latitude ozone stations in the Northern hemisphere). The presented draft needs major revisions, not only with respect to the structure of the scientific paper, but also regarding the scientific content including the interpretation and the discussion of results. Moreover, the used methods of analyses are not adequately explained or they are not referring to the respective literature. So far the scientific significance of this study is low, the scientific quality is fair and the presentation quality of the paper is good.

The scientific content of this paper should focus on what have been promised in the title: first, provide evidence for mid-latitude ozone recovery and second, explanation of changes of tropospheric ozone profiles. In a first step (section) you should introduce in more detail the presented new ozone data set of L'Aquila (which "have never been published before in the scientific literature", page 3, line 68), by describing (briefly) the used measurement system. How do you organize the quality check of the ozone data, and how does the data set compare with other (Northern mid-latitude) ozone stations (for instance more detailed discussions of deviations and the range of uncertainty are needed). In a next step (section) you should describe the methods of data analyses, which are used in the paper. Afterwards you can present the results of your trend analysis, which should be compared in more detail to the findings at other Northern mid-latitude stations (based on your discussion about Figs 2 and 3; and possibly a comparison with satellite measurements would be nice). This will help to classify much

better the measurements at L'Aquila in comparison with other stations, i.e. showing that the data of L'Aquila are (more or less) in line with other respective ozone data sets. Finally, for the interpretation of the trend analyses, results of specific CCM simulations can help to explain the role important atmospheric processes, which are responsible for the observed changes. At the end the major (new) findings of this study should be summarized (or at least say that your results are in agreement with recent (other) investigations). Currently in the available manuscript I cannot see results or conclusions, which have not been published before.

Here are, in more detail, my major points:

- It would be helpful to present first the (new) ozone data set of L'Aquila including a more detailed description of the measurements (including the technical description of the used instruments) and how you have verified and validated your measurements. And some words about the long-term stability of the 17-year time series of ozone data would be helpful. In another section you should (briefly) describe your method of trend analyses and explain your statistical analysis (which is the foundation of your investigations). At least the corresponding literature should be cited. And then, in a next section, you can present the results of your trend analyses and discuss how robust the ozone trends at Northern mid-latitudes are. Here it would be highly desirable to have a comparison with the trends of the different partial columns at the different Northern mid-latitude ozone sonde stations. It would be nice to see if the L'Aquila station shows similar or different trends, or which other stations show most obvious "differences". At the end of the trend section it would be nice to get an overview of the mid-latitude ozone trends and a statement about the robustness of the "sign of ozone recovery" in the Northern hemisphere. A more detailed trend analysis (I am hoping for an "improved" statements about ozone recovery at Northern mid-latitudes) would guarantee a significant upgrade of this study. In case of a consistent picture, in a next step results of specific CCM simulations may be used to explain the identified trends. I like very much the idea using the results of CCM simulations, but I think that you have used the

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wrong set of CCM-simulations (see my next comment below) for the analysis of the recent ozone trends (2000 to 2016).

- For the discussion of CCM results you are using the refC2 simulation, which is the reference forecast simulation (the phrase “historical simulations (refC2)”, page 3, line 73, is misleading). Although refC2 is running from 1960 (until 2100), it does contain boundary conditions for the past, which are not based on observations (e.g. observed sea-surface temperature (SST) and sea-ice cover (SIC), concentrations of greenhouse gases and other chemical compounds and emissions). To make a consistent future simulation refC2 (without a break when switching from the past into the future), for instance the SST field is taken from an ocean model or the greenhouse gas concentrations are following the RCP6.0 scenario. I think that for the comparison with the L’Aquila ozone data (and other Northern mid-latitude ozone stations) it would be better to use the available CCM results of the refC1SD (specified dynamics) or the refC1 (free running climate) simulations, which are both focusing on the recent past (e.g. from 1980 to 2017). Concentrating your investigations on the Northern mid-latitudes, a comparison with respective observation (mean conditions) with results of CCMs (multi-model means of refC1SD and refC1) would be much better. And in a last step you can in particular analyze the results of L’Aquila together with the results of other single ozone stations, and checking the importance of relevant atmospheric processes, which are influencing the ozone trends (profiles) in Northern mid-latitudes. My point is that you should look in more detail into the results (e.g., ozone fluxes from the stratosphere to the troposphere) of your analyses. So far the discussion regarding the CCMI model results is in larger parts superficial. Finally, in addition a look into the future (based on refC2, up to 2100) would make sense, also in combination with the sensitivity simulations (e.g., senC2-fGHG or -fODS).

- The role of the strengthening of the Brewer-Dobson circulation (BDC) (due to enhanced greenhouse gases) is mentioned and discussed. So far, this is a result of simulations (with enhanced greenhouse gas concentrations) with global circulation models

(including CCMs), but so far studies based on measurements in recent years (e.g., Engel et al., Nature, 2008; Fu et al., Environmental Research Letters, 2019) did not find an increase of the BDC (or a decrease of the mean age of stratospheric air), in particular after year 2000. Since you are looking in the time period from 2000 to 2016 there is an obvious discrepancy between assessments based on observations and model simulations (e.g., Butchart, Review of Geophysics, 2014). This point must be mentioned not only in the Abstract (page 2, lines 38-39) and Introduction (page 2, lines 57-58), but also in detail in the discussion-section (with respect to the ozone fluxes, especially the downward transport from the stratosphere into the troposphere) and also in the Conclusions (page 18, paragraph beginning in line 336). In particular, your findings regarding the refC2 ULAQ-CCM simulation (page 15, line 280), indicating enhanced stratospheric influx, need further discussions with respect to the observations. In general, so far the discussions of results regarding the relevant atmospheric processes are mostly qualitative. If the analyses of the CCM simulations would be intensified in this study, concrete results with more quantitative statements can be expected.

Some minor points:

- Page 3, line 67 and line 81: The lat/lon coordinates of the L'Aquila station should be the same. Please check it regarding consistent information in the manuscript.

- Page 3, line 68 and page 4, line 102/103: "... have never been published before..." is in contradiction to the statement "... L'Aquila ozone-sounding data were used in the validation ... retrieved by MIPAS...". This should be clarified.

- Page 6, lines 129 to 138: This paragraph is hard to read; it is difficult to get the message of it. Please try to give a clearer statement.

- Page 11, line 200 and line 205: is the altitude range (mid-upper stratosphere and upper stratosphere) here the same? Are the estimated trend values comparable?

- As an example, page 11, line 210: if you are referring to the ozone assessments,

it would be helpful to cite also the respecting Chapter, where the information can be found.

- Page 12 and 13, lines 240 to 245: wrong Figure numbers in the text; Fig 7d should be Fig 8a (?!), Fig 9 should be Fig 8 and Fig 10 should be Fig 9. In the following the numbering of the figures is okay again.

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