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Interactive comment on "Strato-mesospheric carbon monoxide profiles above Kiruna since 2008" *by* Niall J. Ryan et al.

Anonymous Referee #1

General comments

The paper describes a new atmospheric dataset which comprises a time series of carbon monoxide (CO) vertical profiles above Kiruna, northern Sweden. It carefully details the derivation of CO volume mixing ratio profiles from ground based microwave radiometer measurements during 2008 to 2015. The methodology uses well-established atmospheric radiative transfer and retrieval codes and builds on previously reported work by the group on ozone profile measurements using the same radiometer instrument. The effect of a priori temperature on such retrievals can be important, and this is investigated using temperature profiles constructed from various observed and modelled (or reanalysis?) datasets. As well as describing how the profiles were determined and validated the paper indicates how they should be used e.g. applying the supplied averaging kernels to smooth other data-sets when making comparisons. Measure-

ments such as these are important, providing insights into atmospheric dynamics and chemical transport in the polar middle atmosphere and having applications in climate modelling and 'ground-truthing' of satellite data.

Overall the paper is well structured and presented with adequate description of the methodology, discussion of the results, and citing of prior work. However some sections are somewhat challenging to follow, for example the discussion of differences between data-sets where it can be unclear which dataset is positively biased in comparisons with other data. I've highlighted a number of other areas in the text and figures where clarifications and improved presentation are needed. I recommend that the authors address these points before the revised paper is accepted for publication in Earth System Science Data.

Specific comments

Title. A date range of 2008–2015 would be better as 'since 2008' is ambiguous. It would be clearer if a more complete description of the measurement location was given in the title, e.g. Kiruna, Sweden including the geographic co ordinates.

Page 1, Line 15. 'CO concentrations' should be 'CO volume mixing ratio (VMR, in ppmv)' here and throughout the manuscript.

Page 2, Line 23. 'Leading to a bias of > 5 ppm at 80 km'. Here and throughout the paper it should be made clear what data the biases are between and which of the compared data-sets has the higher values. Also the units of VMR should be ppmv.

Page 2, Line 34–35. 'The timespan of continuing KIMRA measurements will generally surpass the lifetime of any satellite instrument'. This is an important point that could be expanded on, e.g. indicating what timespans / lifetimes are typically achieved by ground based and satellite instruments. What factors allow KIMRA, and other ground based instruments to make measurements that surpass those by individual, or overlapping, satellite missions. Why are long term datasets such as these important?

Page 3, Line 13. 'So the pointing angle changes from one measurement to another'. Does this mean that both the elevation and azimuthal angles are changed? If the azimuth is kept fixed while elevation is changed, as I suspect, then the azimuthal angle should be stated. Is the optimum pointing angle checked and, if necessary, changed after each calibration cycle measurement from which a brightness temperature spectrum can be calculated or after a longer time interval? What is the range of pointing angles?

Page 3, Lines 12–14. Please clarify whether 'individual spectra' and 'each spectrum' means those calculated from one calibration cycle, or integrated measurements over a longer period.

Page 3, Lines 20–23. Which version of WACCM is used, for which year is WACCM winter-time output used, and what are the WACCM grid points? If only one winter of WACCM data is used to generate the a priori CO profile is that representative for the years 2008–2015? Is an average profile for winter (presumably December, January, and February) appropriate for all of the months September to May where the CO profile will differ considerably?

Page 3, Lines 23–28. The source of the CO a priori data is given but not for the other atmospheric gases included in the forward model. How are the ozone, water vapour, molecular oxygen, nitrogen, and nitric acid a priori profiles constructed?

Page 3, Line 32. In this type of microwave measurement baseline errors include, and may be dominated by, those arising from standing waves. However there will be contributions to baseline error from imperfect radiometric calibration, non-linearity, and other instrumental artefacts introduced in the signal down-conversion and spectrometric analysis. While a detailed study of these errors, and their impact on the CO retrieval, is beyond the scope of this paper it would be helpful to indicate them here and later on in the discussion section. The contribution of baseline noise will also depend on the system noise temperature ($\sim$1800 K according to Table 1), spectrometer channel

bandwidth, and the integration time.

Page 4, Line 3. 'in case some changes in the baseline with time became evident.' Did any changes in the baseline become evident in processing this dataset?

Page 4, Line 5. How do the estimated uncertainties (0.5 K, 0.3 K, and 0.5 K) in the standing wave amplitudes compare with the baseline noise of the spectra? Are the standing waves being effectively fitted to the baseline noise level?

Page 4, Lines 19–20. Why are the KIMRA CO profiles most sensitive to temperature information between approximately 40 km and 90 km? Although the CO line profile will be dominated by thermal Doppler broadening in the upper mesosphere, at lower altitudes pressure broadening will dominate. This could also be discussed in the context of the averaging kernels of the CO retrieval and estimated altitude resolution (Figure 1 and Page 5, Lines 7–20).

Page 7, Line 6–7. MLS values at 82 km and 84 km are stated as often unusable for scientific work. Are MLS data with the warning flag at these altitudes included in the analysis and, if so, how might that affect the results?

Page 9, Line 4. Do you really mean the data from 2015/16 are presently unavailable? This suggests the data might become available in future, whereas my understanding of 'failure of the KIMRA cooling system' is that measurements were not collected during this period.

Page 9, Lines 10–13. What is happening to the CO during and after SSWs? What is the difference between major and minor SSWs and is the observed CO behave as would be expected for these events. What might be causing large decreases in CO abundance above $\sim$65 km during December 2013 (12/13 on Figure 7), that is not assigned to a SSW?

Technical comments

Page 1, Lines 17–18. 'This dataset is compared...' It should be made clear which

dataset is being referred to here.

Page 1, Line 24. 'at all altitudes below 82.5 km'. The exact altitude range should be given as this could be misinterpreted as meaning 0–82.5 km.

Page 2, Line10. 'study the composition of Arctic winter' should probably be 'study the composition of the Arctic winter atmosphere' or similar wording.

Page 2, Line 11. 'Sudden Stratospheric Warming' should be all lowercase.

Page 2, Line 20. 'Atmopsheric' should be 'Atmospheric'. This spelling mistake is also made numerous times in the data supplement (https://doi.pangaea.de/10.1594/PANGAEA.861730).

Page 2, Line 31. 'European Centre for Medium Range Weather Forecasts' should be 'European Centre for Medium Range Weather Forecasting'.

Page 5, Lines 27. 'compared with the ACE satellite' should be 'compared with measurements by the ACE-FTS satellite instrument' and the abbreviation ACE (-FTS) defined.

Page 6, Line 10. 'The position relative to the vortex...' The position of what?

Page 6, Lines 10–28. In the text the partial columns are stated as over altitudes 40–60 km and 60–80 km whereas in Figure 2 they are 46–66 km and 66–86 km.

Page 7, Line 23. 'X (MLS) and Y (KIMRA)'. The 'X' and 'Y' should probably be replaced by 'abscissa' and 'ordinate' respectively.

Page 9, Line 7. 'movement of higher CO concentrations to lower altitudes' should be 'movement of CO to lower altitudes' or 'CO concentrations (or, more correctly, volume mixing ratio) increased at lower altitudes'.

Figure 1. The subplots should be labelled (a), (b), (c), and (d) and 'n' in the left-hand plot defined. Does the residual plot show measurement minus fit or fit minus

measurement? The axis label '[VMR/VMR]' is confusing as the other axes show units in square brackets (VMR is a quantity); probably the label should be 'Averaging kernel'.

Figure 3. The different curves would be clearer if plotted using different solid / dashed lines with different symbols for each line. What are the units of VMR?

Figure 4. The different curves in (a) would be clearer if they were all plotted using different solid / dashed lines. The differences shown in panel (b) might be clearer if shown as percentages (as is done for temperature in Figure 5(b)).

Figures 5 and 6. The ranges of the horizontal axes in panels (c) and (d) should be adjusted to show the data more clearly.

Figure 7. It would be helpful to mark the occurrence of SSW's. The colorbar label should include 'CO VMR' as well as '[ppmv]'.