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Atmospheric Measurement Techniques Discussions

Interactive comment on "Measurement of horizontal wind profiles in the polar stratosphere and mesosphere using ground based observations of ozone and carbon monoxide lines in the 230–250 GHz region: Proof of concept" *by* D. A. Newnham et al.

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We thank Dr Rufenacht for his short comment (Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-406, 2016) on our manuscript. We are pleased that he found the manuscript very interesting. Our discussion response, and proposed minor changes to the manuscript to address the two points raised in his short comment, are given below.

1. 'It is particularly notable how you benefit from the dry Antarctic atmosphere to push the upper limit of your measurement range to very high altitudes by using CO (in this context it might also be interesting to explain to the reader how you can retrieve at altitudes where Doppler broadening is dominating over pressure broadening).'

Dr Rufenacht is correct in pointing out that, at the high altitudes where we demonstrate the wind retrievals that would be possible using CO, the linewidth is dominated by Doppler (thermal) broadening rather than pressure broadening. Calculated Doppler- and pressure- broadened full-width half-maxima (FWHM) linewidths for the CO 230 GHz line in mean winter (JJA) and mean summer (DJF) conditions at Halley, Antarctica are shown in Figure 1. Pressure and temperature profiles used in the calculations are taken from the SD-WACCM model data used in the simulated wind retrievals, and the pressure broadening coefficients are from the HITRAN spectroscopic database (http://hitran.org/). The dotted horizontal lines in the figure show the altitudes above which the Doppler contribution to the linewidth exceeds pressure broadening, i.e. above 62 km in winter and above 69 km in summer. Doppler broadening increases rapidly above 100 km as temperature rises in the thermosphere (e.g., see Figure 4e in the manuscript). We retrieve the horizontal wind over a 24 km altitude range between 73 km and 97 km (shown by the green shaded panel in the figure) where the linewidth, dominated by Doppler broadening, is at a minimum.

We propose explaining this in the manuscript by adding the following text on page 11, line 27 after the sentence ending '...ultraviolet photo-dissociation of carbon dioxide (CO_2).'

At the retrieval altitudes the CO linewidth is dominated by Doppler (thermal) broadening. However the Doppler FWHM linewidth is at a minimum with a reasonably constant value of 440+/-10 MHz between 70 km and 97 km. Doppler broadening increases above 97 km due to higher temperatures in the lower thermosphere. Pressure broadening dominates, and the CO linewidth rapidly increases, below 62 km in winter and below 69 km in summer. Thus the wind retrieval is possible at high altitudes where

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the minimum in the Doppler broadening characterises the altitude and where the CO mixing ratio is sufficiently high, but the height resolution of the retrieval is limited by the uniformity of the Doppler linewidth at these altitudes.

2. 'on page 4, line 27 I found a statement that disturbs me: You cite our paper (Rüfenacht et al., 2014) of wind retrievals with the wind radiometer WIRA as reference for your statement that baseline issues which can arise from standing waves or other sources are uncritical for wind retrievals from observations with Doppler microwave radiometers. However, it should be noted that in the cited paper we have only analysed the effect of a baseline ripple with a period and amplitude similar the one found in the data acquired with the wind radiometer WIRA. Such a baseline is indeed uncritical. Nevertheless one could imagine that other baselines (e.g. with faster oscillations) can influence wind retrievals. I would be grateful if you could modify your manuscript in this sense.'

We accept that the original wording in the manuscript, describing the potential impact of standing waves and other baseline artefacts on millimetre-wave wind retrievals, could be misleading. We propose amending the manuscript to briefly discuss possible strategies for minimising and characterising such baseline effects, by replacing the sentence on page 4, line 27 starting 'The effects of frequency errors arising from reference oscillator instabilities and spectrum baseline artefacts...' as follows.

Rufenacht et al. (2014) showed for the WIRA instrument that frequency errors arising from reference oscillator instabilities and spectrum baseline artefacts such as standing waves are either small or can be adequately characterised to minimise their impact on the wind retrievals. However for other wind radiometers these effects could make a larger contribution to the measurement uncertainty, that is not considered in the simulations here. For example, with instruments using a SIS mixer there is the potential for significant interfering reflections between cryostat windows and other optical components. The potential sources of such artefacts need to be identified at the instrument design and build stages and steps taken to reduce them to an acceptable level, e.g.

through anti-reflection machining of optical surfaces and path-length modulation aimed at minimising standing wave amplitudes.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-406, 2016.

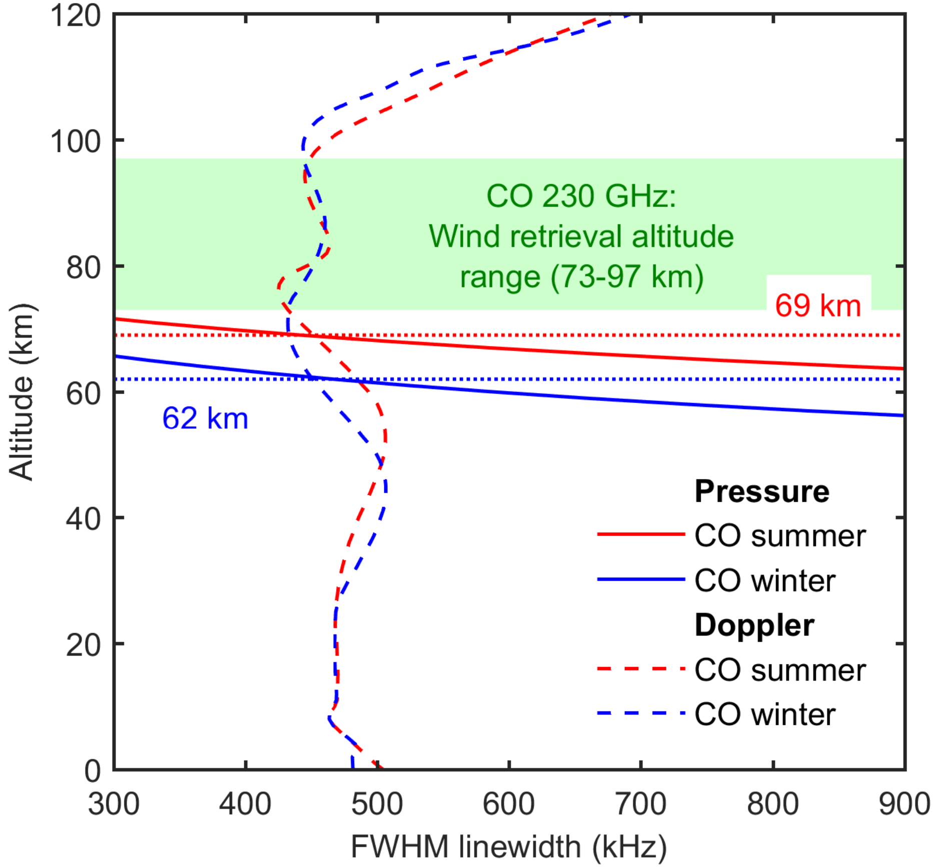

Fig. 1. Pressure (air) and Doppler broadened full width half maximum (FWHM) linewidths for the CO 230.54 GHz emission line above Halley station, Antarctica in summer (DJF) and winter (JJA).

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