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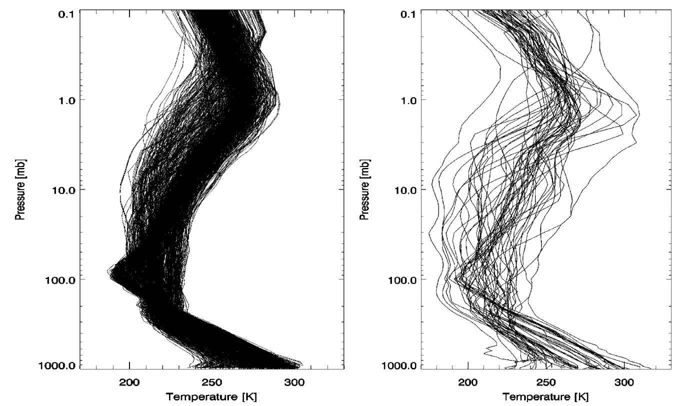

Fig. 1. Two sets of atmospheric temperature profiles, sampled from (left) a NOAA set of radiosondes and (right) a representative set of 52 ECMWF profiles, showing the natural variability of atmospheric temperature at the 1000-mbar pressure level.

Reply to the Comment on "Uncertainties in the Temperature Dependence of the Line-Coupling Parameters of the Microwave Oxygen Band: Impact Study"

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The impact study described in [1] is, in essence, a theoretical sensitivity analysis of the temperature dependence of the line coupling coefficients in the microwave Oxygen absorption band as accounted for in the millimeter-wave propagation model (MPM). The study was driven by emerging highly demanding requirements in terms of accuracy of the brightness temperatures measurements and therefore equally demanding requirements for models that simulate them. The main conclusions of the study are twofold: 1) the need to extend experimental measurements to the lower range of the atmospheric temperatures and 2) that errors due to uncertainties in the temperature dependence, are not necessarily entirely removable by a bias correction. The spectral region, where most of the impact was found, is located at the edge of the absorption band, especially in dry conditions. The MPM absorption model is widely used in the microwave remote sensing community because it is accurate for current applications and uses for its spectroscopy the extensive work of Liebe *et al.* [2]. To the best of our knowledge, no serious deviations exceeding the estimated calculation uncertainty, were found comparing available experimental data and simulations performed with MPM. Nevertheless, as shown in the study, MPM (as well as other atmospheric absorption models) could benefit from extending the experiments to cover the lower end of the atmospheric temperature range in deriving the main factors including the line coupling coefficients. As described in the study, these overlapping factors (and line widths indeed) were derived in [2] using available measurements in the range 279–327 K. This represents roughly the third of the whole atmospheric range, approximately between 183 and 328 K.

The variation of the individual line coupling coefficient shown in the impact study [1, Fig. 2] consisted of considering a single layer with a constant pressure of 1000 mbar. It was tested at other pressures but these were not shown. For the modeling of the oxygen absorption, the two driving inputs to MPM are the pressure P and temperature T. To assess the impact of the temperature dependence on the absorption, the pressure was held constant and a varying temperature was used. The combination of the two variables (P, T) is realistic to a large extent. Fig. 1 shows two representative sets of atmospheric profiles where temperature at the level corresponding to 1000 mbar, covers the range between 235–300 K for the NOAA set and between 220–320 K for the ECMWF set. The temperature range used in the study was 200–320 K. The study has been performed as a function of temperature for fixed pressures, for the reasons stated above. As Dr. Rosenkranz has suggested, an analysis performed for fixed densities would have provided a more physical approach. The line coupling and collisional broadening are taken to result from binary collisions with the effects inversely proportional to the time between collisions, i.e., proportional to density.

Because the fitting of the coefficients in [2] was performed using the high end of the temperature range, it was the aim of the study to assess the impact on the lower end. By plotting the coefficients for the whole range, we noticed a nonmonotonic variation only at the 7– transition line. Because the formulation relies on a unique temperature dependence exponent (for all frequencies) and because the parameter was determined using just a portion of the temperature full range, it could be that the nonmonotonic variation seen in the 7– line is numerical, due to the two-term expansion formalism used to fit the limited range of temperature data available when deriving the MPM coefficients. Liebe *et al.* [2] had actually warned that this formalism could fail outside the temperature range that they used.

Another feature that could be noticed in [1, Fig. 2] is that any theoretical error in the X exponent (shown by three curves in each plot) is hardly detectable by fitting the 279–327-K range only. But the same error has a large impact in the lower range of temperature, especially at certain lines including the 7– transition one.

In the sensitivity study, the widths were purposefully held known in order to perform an impact study of the uncertainty on the line coupling coefficients themselves. An uncertainty in the line coupling could of course be hidden by another compensating uncertainty in the width (as well as by uncertainty in the line intensity) and therefore not be noticed. Although they would more likely impact the standard deviation metric. By holding the width constant, it is easier to assess the

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impact of a theoretical uncertainty in the line coupling parameters. There are certainly better ways to come up with more realistic estimates of uncertainties in the line coupling coefficients. For simplicity however, we chose to apply a 10% error across the band but only for line coupling coefficients outside the temperature range covered by experiments that served for deriving the model parameterization. Such unrealistic change of mixings leads nevertheless to mean differences similar to those noticed in [4] (also mentioned in the comment), between measurements and simulations using MPM92 at six AMSU frequencies. These means could be deduced from the impact study [1, Fig. 4] where a 10% error was applied to the line coupling coefficients at temperatures below 279 K (note that above 279 K, these parameters were unchanged). Their values are approximately 0.4 K at 52.8 GHz, -0.4 K at 53.6 GHz, -0.4 K at 54.4 GHz, -0.25 K at 54.94 GHz, -0.12 K at 55.5 GHz, and were negligible at 57.29 GHz. These values are roughly consistent with the values reported in the comment (from -0.42 to 0.23 K). Beyond the mean biases (always correctable), what is thought to be more important is the scatter around the mean (between 0.05 and 0.2 K). In conclusion, what the impact study showed, and it is thought that the comment concurs with, is that it would be beneficial for microwave absorption models to extend the temperature range of the measurements to the low end in order to: 1) potentially improve and 2) at least increase our confidence in, the absorption modeling in the subfreezing temperatures.

We agree with what the comment rightfully points out to indirectly, which is that any revision of the temperature dependence formalism of the line coupling parameters, based on updated measurements, should be carried out simultaneously with a revision to the line widths estimation.

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