Response to suggestions technical corrections by Report #1

The revision and reply addressed my comments. Thanks!

It is very interesting to see in the added test case a nice log scaling of water vapour radiative forcing. As far as I know, no one else has shown this behaviour in the microwave frequency in any paper. This looks to me a meaningful science result to include and discuss in this paper.

It would also be useful to list the other (available) test cases in the paper.

Following the reviewer invitation, we added the following Section 4.6 to the manuscript. In addition, Sections 4 and 6 now provide the link to the gallery of PyRTlib examples, which are continuously upgraded. We thank the reviewer for the insightful advices and the valuable time dedicated to our manuscript.

4.6 Radiative forcing versus water vapour concentration

The last example presents an interesting feature of the radiative forcing (i.e., radiance change at the top of the atmosphere) caused by greenhouse gases. It has been demonstrated that such a radiative forcing has a logarithmic dependency on the concentration of some greenhouse gases (e.g., CO_2 and H_2O), and thus logarithmic scaling of e.g. CO_2 radiative forcing are often used (IPCC, 2021). This feature is partially attributed to spectrally averaged absorption that saturates logarithmically with the absorber amount (Huang & Bani Shahabadi, 2014), but it was found valid also for infrared monochromatic radiance calculations (Bani Shahabadi and Huang, 2014). To explain that, Huang & Bani Shahabadi (2014) proposed the emission layer displacement (ELD) model, based on the vertical displacement of the most contributing layers, which effectively resolves the radiance change as proportional to the logarithm of the gas concentration. However, assumptions underlying the ELD model do not hold for low-opacity frequencies (e.g., window region). In particular, Bani Shahabadi and Huang (2014) indicate that the logarithmic scaling is valid for relatively opaque frequencies (optical depth >1), while linear scaling is more appropriate for relatively transparent frequencies (optical depth ≤1). To our knowledge, this has not been verified at microwave frequencies yet, though it can be easily tested with PyRTlib as follows. Considering the standard tropical atmosphere and nadir viewing, brightness temperatures are computed at two frequencies corresponding to relatively weak and strong H_2O absorption lines (i.e. 22.235 and 183.0 GHz). For each frequency, T_B are computed seven times by multiplying the water vapor mixing ratio by the following scaling factors ($SF_{q_{H_2O}}$): 1/8, 1/4, 1/2, 1, 2, 4, 8. Figure 12 shows the brightness temperatures difference (ΔT_B) with respect to the unperturbed tropical profile plotted against the binary logarithm of the scaling factor. The logarithmic relationship between ΔT_B and water vapor concentration is evident for high atmospheric absorption at 183 GHz (opacity ~6 to 262). Conversely, for the relative weak absorption at 22.2 GHz, the relationship changes from linear to logarithmic as the opacity increases from 0.05 to 1.86, showing a knee at ~1 Np.

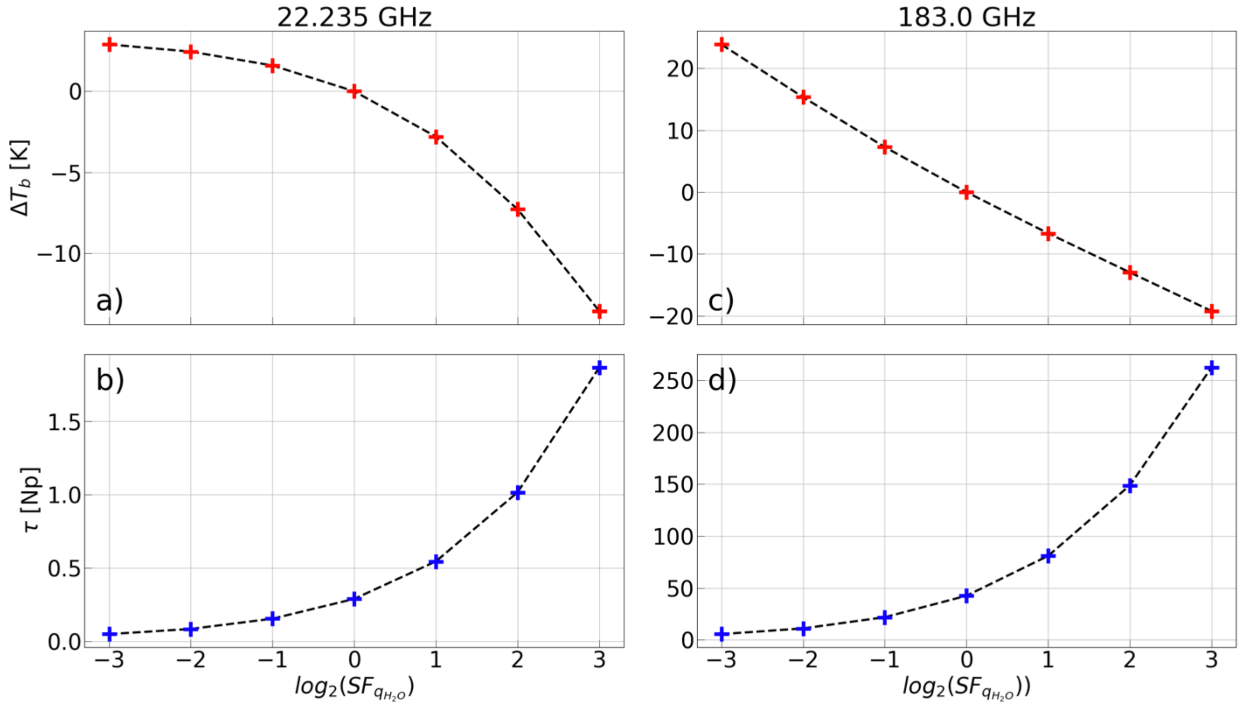

Figure 12. Bottom: Atmospheric opacity τ at 22.235 (b) and 183.0 GHz (d) vs. $\log_2$ of water vapor concentration scaling factor ($SF_{q_{H_2O}}$). Top: Corresponding change of zenith upwelling monochromatic T_B (ΔT_B) for relatively low opacity at 22.235 GHz (a) and high opacity at 183.0 GHz (c).

Added references:

Bani Shahabadi, M., and Y. Huang, Logarithmic radiative effect of water vapor and spectral kernels, J. Geophys. Res. Atmos., 119, 6000–6008, https://doi.org/10.1002/2014JD021623, 2014.

Huang, Y., and M. Bani Shahabadi, Why logarithmic? A note on the dependence of radiative forcing on gas concentration, J. Geophys. Res. Atmos., 119, 13,683–13,689, https://doi.org/10.1002/ 2014JD022466, 2014.

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896.