Replies to referee comments (RC2) on the scientific article "New Routine NLTE15µmCool-E v1.0 for Calculating the non-LTE CO_2 15 µm Cooling in GCMs of Earth's atmosphere" by A. Kutepov and A. Feofilov

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Below we reproduce the referee comments in normal font followed by our comments in italic.

OVERVIEW

The solid knowledge on the spatial-temporal distributions of CO_2 cooling/heating are desirable for modelling of dynamics and temperature in General Circulation Models. A number of parameterizations are used for this purpose. All of them are characterized by either lack of accuracy or high numerical and time costs. This article describes a model that is devoid of these disadvantages.

The research is scientifically valuable. The theoretical part is presented in the paper very convincingly. The methods and approaches are correct. On my opinion this work brings deep insights on modelling of MLT region and new model essential for precise and efficient calculations. On my opinion this work should be accepted in Geoscientific Model Development after minor revision.

We are very grateful to this referee for recognizing the importance for MLT GCMs of a new routine we present, and for very interesting comments, which stimulated us to improve the manuscript text to make it more informative.

Comments.

1. The ODF technique is explained only briefly, the authors refer to their previous works on the implementation of the ODF to the radiative transfer in molecular bands in the planetary atmospheres. But they say no word about the limitation of this technique - is it 100% equivalent to line-by-line in terms of accuracy? If not, what are the errors introduced by this technique? Do these errors depend on the pressure-temperature profile or on CO_2 concentration or both?

We agree that the limitations of the ODF technique were not discussed in the paper. Indeed, the ODF is a very useful technical approach, which is not 100% equivalent to line-by-line in terms of accuracy. However, it introduces very small errors in the 15-micron cooling calculations. For current CO2 density (~400 ppm in the lower atmosphere), these errors do not exceed 0.3 K/Day in a broad range of temperature variations, see Figure 18 of Feofilov and Kutepov, 2012. They increase roughly linearly with the CO2 increase if the pressure is fixed. Additionally, with the pressure increase line overlapping needs to be accounted. We added corresponding paragraph in the revised text.

Since our current ODF approach is developed for the non-overlapping lines, we do not recommend using our routine below 20 km where overlapping becomes important.

*We are preparing the paper about the ODF technique, where we describe in detail how it works applied to various problems. We do not show in this technical paper all accuracy tests, which will overload it. Instead, we show **cumulative** errors caused by ODF approach, plus reduced set of levels and bands, etc, since they are most important for the end user.*

2. Additionally, the authors wrote that they apply ODF exceptionally for the band branches. It looks more reasonable to apply it directly to the entire band. May the authors explain why they do not do this?

We do not apply ODF to the entire bands because our tests show that it reduces the accuracy of calculations, and there's a physical reason for this, which we describe in the paper in preparation. We show in it that the accuracy cannot be restored even if we double or triple the number of frequency points describing the ODF profile of entire band.

3. How the final result is sensitive to the completeness of the spectral database used for an input? I understand that the code uses a pre-formatted HITRAN dataset, but does one need to reprocess this dataset for each new version of HITRAN?

It is correct, we do not apply directly the HITRAN data, but, use, as we call it the "mini-HITRAN" data set. This set comes from the pre-calculated A and B Einstein coefficients for band branches. These coefficients were calculated as described by Kutepov et, al, 1998 and Gusev and Kutepov, 2003, using HITRAN-2016. We also compared them with those calculated for 3 earlier HITRAN versions and found the differences less than 0.1-0.2% for bands included in our CO2 night time model. For some hot 15, 4.3-micron, and combinational bands included in the daytime model, these differences are of the order of 0.5%, since data for these bands slightly vary from one HITRAN version to another. We do not believe that any further version of HITRAN or any other spectral database will significantly affect these values. Addressing this question, we added the information about the accuracy of spectral data we use.

4. When authors write that the "accuracy is not sacrificed", when they change their conversion criterion from 1e-4 to 1e-2, what exactly do they mean? Could you, please, be more specific and provide actual numbers and indicate the test conditions?

First of all, we define the convergence at each iteration as a ratio of the level's population change to the level's population, checked over all altitudes and all vibrational levels. For a given iteration, the worst converged level/altitude defines the convergence value. The non-LTE iterations stop and we consider the problem to be converged when the convergence value is below the convergence threshold. Answering the question we'd like to explain that we performed a series of test calculations, varying the non-LTE problem convergence threshold, and did not see a significant change in cooling/heating accuracy for any of the atmospheric profiles we used if the convergence criterion changes from 1e-4 to 1e-2.

5. The model is supposed to work in a plane-parallel approach. What are the errors associated with abandoning spherical geometry? Are they different for the nighttime and daytime?

Lopez-Puertas and Taylor, 2003 stated that plane-parallel geometry is a very good approximation approach for the middle and upper atmosphere by the solution of the non-LTE problem. Perhaps only one concern related to the sphericity of the atmosphere is the absorption of solar radiation and related heating. However, we took explicitly the sphericity by calculating the solar radiation impact in our routine.

References

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