Reply to comments from Referee #1

> *This short communication calculates (for some lower bounds) the residence timescale of an atmosphere for Venus, Earth, Mars, and Titan. The authors use the comparability of the residence timescale and the KH timescale to argue that both have the same meaning, i.e., both express the time needed to return to equilibrium after a thermal perturbation. This article can be considered for publication after addressing some concerns listed below.*
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> *Major comments*
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> *1 I am Not sure I am convinced that the residence timescale is equivalent to the time needed to return to equilibrium after a thermal perturbation. This claim is from the comparability between the residence timescale and the KH timescale for the Sun. However, this can be a mere coincidence. By definition, the residence timescale is the time that takes, in this case, energy, from entering the system until it goes out. Although it can be, this is not necessary the time to return to equilibrium, other processes, such as radiative, transport, and turbulence, can act to make the equilibration either faster or slower.*

In the new version of the paper, some of the main modifications are:

1.- From the very beginning it is said that the residence time of energy in a planetary atmosphere , is the time scale of the transport of energy across the atmosphere.
2.- A new distribution of sections has been made.
3.- In the new section 5 it is explained what the Radiative Relaxation Timescale is.
4.- It is remarked that only if the analogy between τ and the solar Kelvin–Helmholtz scale is assumed, then τ would also be the time the atmosphere needs to return to equilibrium after a global perturbation. And it would be the longest timescale because the perturbation had been global.
5.-The analogy between τ and KH seems likely and attractive but in no way is a proof.
They have been inspired, in part, by your criticism to the first version of the paper.
We acknowledge your comments and dedication.

> *2 Lines 22-35: The transition to the Sun is unclear and not motivated. After reading Osacar et al. 2020, it became clear that it is for claiming the residence time as an equilibration timescale. You should give a motivating sentence before this discussion and emphasise the point you want to say.*

A new Section on the residence time of energy in the Sun has been added for clarifying the analogy we assume between KH timescale and τ. See lines 4 and 5 of the first block of the answer. Stix (2003) made the equivalence between residence time and global recovery timescale.

> *3 Line 71: "The longest of these scales corresponds to the residence time as computed in Section 3." - Is this statement correct? Can you show or reference this?*

In solar physics -Spruit (2000)- it is shown that KH is the longest timescale. By analogy, in planetary atmospheres, τ will also be the longest timescale.

4 The radiative timescale discussion is important but feels detached from the rest of the manuscript. You should give a connecting sentence at the beginning of the discussion and a summarising sentence at the end.

A new Section about the radiative timescale discussion has been added.

5 The parameters you chose are motivated; however, they are not unique. First, the radiative timescale is manifested in our daily living. Consider Earth's seasonal cycle, there is a time-lag of about a month between solstice and the warmest day of the year, resulting from the radiative timescale. Also, Mitchell and Lora (2016) estimate 200 Earth years for the tropospheric radiative timescale of Titan. This radiative timescale is about five times longer than the residence timescale you have calculated. Also, note that there they consider the effect of the atmospheric opacity.

This time lag between the solstice and the warmest day of the year in a given city depends on the distance between the city and the sea. For this reason, in our opinion, the ocean should be a partner of the model and τ_R would not be the unique parameter.

The calculation by Mitchell and Lora is done for the Titan's troposphere. By using the formula of Wells (2012) with $p_s = 37.9$ mb, $g = 1.35$ m s^{-2}, $T_e = 80$ K, we obtain a radiative timescale of 0.8 years. This computation of τ_R has been carried out at the pressure where temperature is equal to the blackbody temperature of the planet (T_{eff}), where most of the longwave radiation is emitted to space.

Minor comments

1 Line 21: "Harte (1988) uses this concept to estimate the anomalous temperature in urban heat islands." - Adding this line is a bit confusing. Consider elaborating on this point or remove that line.

We had cited Harte at the beginning of the paper just to show skepticals that the residence time for energy was a valid concept. But, in the same paragraph, we had remarked that the type of problems addressed in this paper was different to that of the temperature of the anomalous heat islands. Though, in a private mail, Prof. J. Harte of Berkeley, expressed his positive opinion about our first paper, we have followed your suggestion and removed that line.

2 Line 48: "It is important to remark that S is much bigger than the sum K + L. For example, for the Earth" - This is probably true, but on other planets, like Mars (or Pluto and Triton) where the atmosphere is thin, or Titan, where it is cold, but still has strong winds, these terms might be comparable. So maybe not be so decisive.

Yes, if S is not much bigger than K+L, our result would be just a poor lower bound.
Let us remember that K/S ≈ (wind speed / sound speed)^2. By using the highest wind speed recorded in Titan of 120 m/s at an altitude of 120 km (see for example Bird, M., Allison, M., Asmar, S. et al. The vertical profile of winds on Titan. Nature 438, 800–802 (2005) https://doi.org/10.1038/nature04060), one obtains that K/S ≈ 0.2.
As wind speeds in Titan decrease steadily as altitude decreases (see Bird et al. (2005)) we are confident that K/S is very small everywhere.

3 Line 72: "The residence time of energy in a planetary atmosphere characterises the planet, and is computed in a model independent way." - This sentence is unclear. What do you mean by characterises the planet? In what form?

The usual radiative timescales τ_R presented by several authors (e.g. Houghton (2002), Wells (2012), Sanchez-Lavega (2011)) are calculated assuming that a small perturbation is produced in the temperature, i.e. it is a perturbative calculus. Furthermore, τ_R depends on the values of pressure and temperature where it is computed.

On the contrary, in the computation of the residence time of energy $\tau = E/F$ in planetary atmospheres, the unique dependence is on global planetary parameters. It is a property of the whole atmosphere because it is calculated from global averaged parameters.