Reply to comments from Referee #2

> *This short paper presents some simple estimates for what is described as the residence timescale for energy in a planetary atmosphere, as applied to the atmospheres of Venus, Mars and Titan. The calculations are relatively crude, “back of the envelope” estimates based on data derived from the published literature with insufficient detailed explanation or discussion/critique of how accurate or appropriate these are for the purpose described.*
>
> *The motivation for the calculations is also not well developed and the authors seem unaware of the considerable literature on energy storage and transfer in planetary atmospheres.*
>
> *Although this is mentioned in Section 4, how does the proposed timescale differ from the well known radiative relaxation timescale in atmospheric physics (e.g. see J. T. Houghton “The Physics of Atmospheres” Chapter 2 - which is similar to the timescale in Wells 2012)? Such timescales have been computed for many years for all three planets in question as well as for the Earth - e.g. see P Gierasch & R Goody, A study of the thermal and dynamical structure of the Martian lower atmosphere, Plan. Space Sci., 16, 615-646 (1968) for Mars; Pollack JB, Young RE (1975) Calculations of the radiative and dynamical state of the Venus atmosphere. J Atmos Sci 32:1025–1037 for Venus; F. M. Flasar, R. E. Samuelson & B. J. Conrath Titan's atmosphere: temperature and dynamics, Nature, 292, 693-698 (1981) for Titan. For Earth’s climate, energetic adjustment timescales have been computed using more sophisticated models - e.g. see T. W. Cronin & K. A. Emanuel, The climate time scale in the approach to radiative-convective equilibrium, JAMES, 5, 843-849 (2013), which takes into account the adjustment timescale for the surface as well as the atmosphere - which seems more appropriate when comparing with the Kelvin-Helmholtz timescale for the Sun. These may not be computing quite the same quantities as what the authors have in mind here, but why not compare them quantitatively with the residence timescale computed here?*

The concept of residence time of energy in a planetary atmosphere, τ, is simple; it is the timescale for the energy transport, and is computed using published data of energy and energy fluxes. Logically its accuracy depends on that of the current experimental data used in the computation.

From a likely comparison with solar physics, we say that if τ is a timescale similar to the solar KH, we conclude that, after a global thermal perturbation, τ is also the time that an atmosphere would take to come back to equilibrium.

The well known radiative relaxation time, τ_R which is explained in a number of texts, is deduced for small perturbations in the temperature, i. e. it is assumed that the equilibrium has been slightly perturbed. Furthermore, τ_R depends on the values of p and T where it is computed. This is illustrated, for example, in Flasar et al. (1981) Table 3, where radiative times are calculated for several pressures. Other clear example is in Venus, where $\tau_R$varies from 116 days at 40 Km (lower cloud deck) to 0.5 hr at 100 Km (Sanchez-Lavega et. al. (2017)).

On the contrary, in the computation of τ , the only dependence is on globally averaged planetary parameters.
So, the difference between τ_R and τ is clear; $\tau_R$is the relaxation time for small or moderate radiative perturbations, whilst τ is related to global perturbations.
It is important to keep in mind that the departures from equilibrium in the troposphere are damped by convection. At these pressures τ_R is very high, which makes radiative transfer inefficient. See for example Houghton's book, page 15.
Following your suggestion, a new section dealing the radiative timescale has been added.
We acknowledge your comments and dedication.

Detailed comments:

> *P.2 Eq (7) - This assumes a simple integration with height, but atmospheres also vary in structure horizontally. Won't this make a difference?*

We have tested the accuracy of Eq (7) to reproduce the values of S shown in the literature (Peixoto and Oort (1992)). The agreement is excellent.

> *Section 2 - By focusing on E or S as the main measures of energy you focus on essentially the dry static energy, which is dominated by internal energy. But much of this energy will be unchanged by internal dynamical adjustments and would be unlikely to vary unless the global thermal perturbation was to be fairly cataclysmic. Why is this the most significant quantity to calculate?*

We agree, if S is not much bigger than K+L, our result would be just a poor lower bound. Future observations could settle this result.

Let us remember 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 K/S ≈ 0.2.

Knowing that wind speeds in Titan decrease steadily as altitude decreases (see Bird el al. (2005)) we are confident that K/S is everywhere very small and the same can be said of Mars.

> *Table 2 - It is mentioned that most of these figures for fluxes originate from the Trenberth diagrams published by Read et al. (2016). But the fluxes quoted appear to represent either the upward or downward IR fluxes between the atmosphere and surface. Would it not be more meaningful to compute the net flux entering or leaving the atmosphere? For Venus this would look more like 22 W/m^2 at the surface. The corresponding figure for Mars would be nearer 26 W/m^2 and 0.26 W/m^2 for Titan, based on the information in Read et al. (2016). These figures definitely need more explanation and justification.*

In Section 3, we have added a new clarifying paragraph showing how the fluxes F_i and F_o are calculated for Venus.