Reply on RC1:

This is interesting and useful article, which deserves publication after minor revision. This article reports for the first time simulation of climatic changes in the upper atmosphere over the whole Holocene.

Thank you for your recognition of our work. We are very grateful for your detailed comments. We have made minor revision to the manuscript accordingly.

Comments:

I would like to see comparison of results of authors with the results of Qian et al. (2021, https://doi.org/10.1029/2020JA029067) over the 1960s – 2010s.

Qian et al. (2021) indicated that, at 300 km, the change of the greenhouse gas (GHG) concentrations caused a global mean neutral temperature trend with a magnitude of ∼−2 to −3 K/decade, while the change due to the magnetic field driver was overall much smaller in magnitude compared to that due to the GHG driver. The GHG driver caused a global-scale decrease of the mass density at 400 km, on the order of ∼−4%/decade on a global average basis. The change of the magnetic field had a very minor impact on the mass density trend, <10% compared to the impact by the GHG driver. Contributions of the magnetic field driver to the global average trends of the neutral temperature and density were negligible on shorter timescales.

Our results show the global mean neutral temperature trend is −0.341 K/ppm at 400 km, considering an increase in CO2 of ~90 ppm from 1945 to 2015. Therefore, the trend is also ∼−3 K/decade in the last 100 years. For the global mean neutral density, the trend due to the increase of CO2 is about ∼−2%/decade at 400 km. The trends in both global mean neutral density and temperature due to magnetic field changes are negligible.

In addition, Qian et al. (2021) suggested that the magnitude of the neutral temperature trend caused by the change of the GHG concentrations increased with altitude, transitioning to a nearly uniform cooling on the order of ∼−20 K from the 1960s to 2010s, which is generally consistent with our results that the uniform cooling on the order of ∼−26 K from 1945 to 2015, see Figure 1.
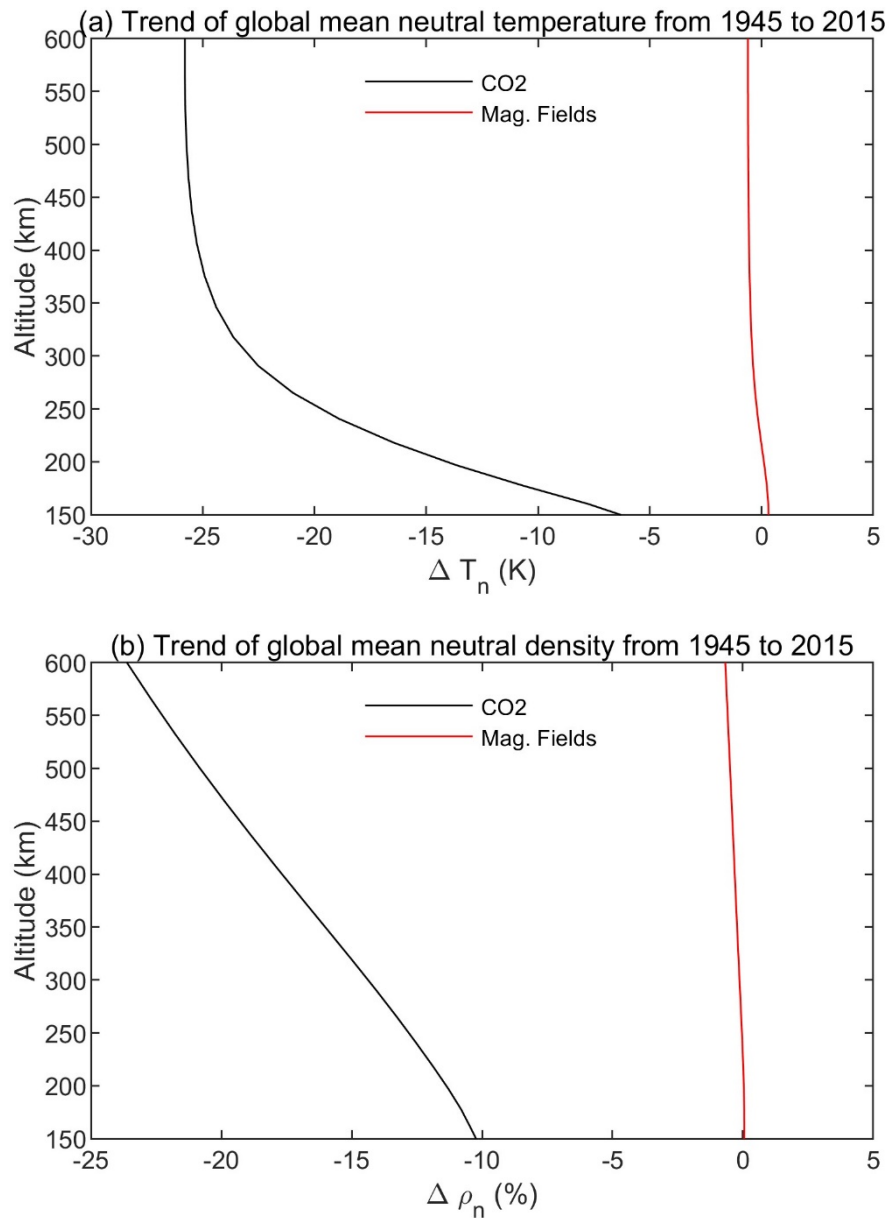
Figure 1. The altitude variation of the trend of global mean neutral (a) temperature and (b) density from 1945 to 2015 caused by (black line) CO_2 and (red line) magnetic fields.

Overall, our results are generally consistent with the results of Qian et al. (2021), especially in the trend of global mean neutral temperature and the negligible contributions of magnetic field changes on shorter timescales. However, the trend of global mean neutral density in our results is half that of Qian et al. (2021), which may be due to the fact that we consider a much longer time scale than Qian et al. (2021) and that we use the high-latitude convection model of Weimer (1996) rather than Heelis et al. (1982).

Lines 136 and 137: Both weakening (line 136) and increase (line 137) of dipole moment make increase of neutral density???

Figure 3 shows that when the dipole moment increases beyond~3×10^{22} Am^2 (in ~7500 BC and from ~1500 BC to ~1000 AD), the density will in turn decrease. A small increase in dipole moment is not sufficient to decrease the density.

Wording and misprints:

- Line 47: delete comma – "concentrations," should be "concentration"
- Line 58: delete "in detail" – claim that you understand the evolution over 10,000 years is too strong; you report only the first simulation, which does not include motion of magnetic poles (at present important factor)
- Line 65: "as Yue" should be "as that used by Yue"
- "1990" – 1990 or 1900?
- Line 77: delete "that"
- Line 117: "(Afraimovich et al., 2008)" should be "Afraimovich et al. (2008)"
- Line 121: "clear" – better is "clearly visible"
- Lines 204 and 206: "greater" should be "larger"
- Line 213: "an altitude" should be "altitude"

Thanks for your detailed comments. These comments are very useful for our manuscript. It should be 1900 in line 75. We have corrected other wording and misprints in the corresponding lines.