Atmospheric Chemistry and Physics
Discussions

Atmos. Chem. Phys. Discuss., referee comment RC1
https://doi.org/10.5194/acp-2021-331-RC1, 2021

Comment on acp-2021-331

Anonymous Referee #3

Referee comment on "Self-consistent global transport of metallic ions with WACCM-X" by Jianfei Wu et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-331-RC1, 2021

Understanding the global metallic ions transport in the thermosphere is important for the field. There is no doubt that WACCM-X is one of the excellent global-scale models to study metallic ions' transport. Overall, the work on this subject is worthy for publication. However, there are a few points that are not clear enough in the manuscript. I would like to suggest to the authors do a minor revision to clarify all the comments. Here are the detailed comments,

Major Comments:

First and foremost, the ambipolar diffusion velocity in equation 2 of the ion velocity equation adopts the equations (5.54) and (5.70) in Schunk and Nagy (2000), which include the effects of the neutral collision, the number density gradient, and temperature gradient, the gravity force, and the viscous stress along with the magnetic field line. Since the equation 5.54 is derived from the momentum equations 5.51 and 5.52, the neutral-ion momentum transform has been already taken into account. If the authors directly use equation 5.54 in Schunk and Nagy (2000), that could lead to double counting neutral wind effects in equation 2 in the manuscript. The ambipolar diffusion equation shows up as different formulas in various literature. It has to be careful to use them directly, and a strict mathematical derivation is required.

In section 3.1, the peak altitude of Mg^+ is ~10 km higher in the summer hemisphere, and the authors suggest that it is caused by the summer to winter neutral wind that transports the metallic ions along with the magnetic field line. Although the vertical drift velocity is provided, the evidence is not enough to support this inference. Firstly, the authors need to clarify the contributions of electric field and neutral wind to the upward drift velocity of ~5 m/s in line 98. Does it mean the ~5 m/s upward drift velocity is only driven by neutral wind? Secondly, since the magnetic field line is roughly symmetric on both sides of the dip equator, we would expect the downward drift velocity on the other side. Some features in Figure 1 may indicate the downward drift, however, more clear evidence should be provided. Thirdly, due to lack of collision, the weak ion-neutral collision may lead to less effect of neutral wind in higher altitudes, but the upward drift velocity somehow increases with respect to altitude in Figure 1. If it is caused by the increasing winds, related evidence should be provided.

Compared with Figure 1, Figure 2 shows the Mg+ is barely above 100 km at 10 LT for all months, and much lower than those in Figure 1. It is skeptical because the wind and electric field show no upward effects at all, especially, the diurnal variations of Mg+ in section 3.2 show the Mg+ ions are easily transported to higher altitudes by the fountain effect around the local noon. Is there any explanation, and further investigation on this feature?

In section 3.3, sentence "…, the ions at subtropical latitude (orange line) are transported upward to a small extent at midday, but transported downward to a lower height (☐1 cm−3 at ☐100 km) at March …, which is in reasonable agreement with the downward drift of the fountain effect along the magnetic field lines at midnight." is questionable. The dynamo effect originates from the strong ion-neutral coupling in the lower E region, and the electric field produced by the dynamo effect could have substantial effects on the vertical transport of ions in higher altitudes. In the mid and low latitude region, the electric field may not be that important below 120 km, compared with neutral winds. In other words, neutral winds could be the dominant factor that determines in the vertical motion below 120 km in the mid and low latitude region. I would like to suggest the author examine the wind and electric field at March Equinox and June Solstice, and calculate the vertical drift velocities driven by neutral wind and electric field, respectively. In addition, it is hard to judge what factors determine the Fe+ profile shape for the orange and green lines. It's better to extend the discussion on the role of electric field and neutral winds.

In section 3.4, what are the initial global number densities and distributions of Fe+, Mg+, and Na+? The studies in Huba et al (2019) show that there is not much difference between the transports Fe+ and Mg+, please refer to Figures 1 and 2 in Hube et al (2019). To clarify this issue, it's better to compare the vertical drift velocities of Fe+ and Mg+.

Minor Comments:

Line 35, "thermospheric metal atom" -> "the thermospheric metal atom"

Line 43, "affects of ion" -> "effects of ion"

Line 80, "a major sources" -> "a major source"

Line 86, “Na^+, Fe^+ and Mg^+”->” Na^+, Fe^+ , and
Mg^+”

Line 102, “which shows a minimum” -> “which show a minimum”

Line 115, “The modelled” -> “The modeled”

Line 120, “Diurnal variation of” -> “Diurnal variations of”

Caption Figure 3. “… The white dashed lines indicates the position of the the dip equator.” -> “… The white dashed lines indicate the position of the dip equator.”

In Figure 4, the caption says the time is UT, but the titles of all subplots are LT. It is confusing. Please make a consistent statement.

Line 170, “is thought to be related” -> “are thought to be related”

Line 173, “Figure 7 and 8 compares” -> “Figure 7 and 8 compare”

Line 184, “charge transfer of” -> “the charge transfer of”

The axes of all figures are not friendly. Please add minor ticks in y-axis. Please add ticks from the low limit to the up limit of every axis.

The x-axis of Figure 4 and Figure 8 better shows from 0 to 24 with 2 or 4 hours step.