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Interactive comment on "Terrestrial ion circulation in space" *by* Masatoshi Yamauchi

Anonymous Referee #2

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This paper is interesting in many aspects, it puts into perspective the importance of terrestrial ion outflow and dynamics in various parts of the earth's magnetosphere and examines the consequences of O+ escape into space, now and on geological scale. This paper deserves a quick publication in Annales Geophysicae after some revisions as indicated below:

Geotail, Cluster, Themis and later MMS have revealed Âń cold Âż ionospheric ions hidden by the spacecraft potential almost everywhere into the outer magnetosphere. This should be more clearly emphasized. For example, Seki used periods when Geotail was into eclipse and therefore was losing its positive charge to detect low energy ions in the anti-solar tail. This work is quoted in the paper, however Hirahara (2004), using the same spacecraft, evidenced the periodic emergence of multi composition cold ions modulated by geomagnetic field line oscillations in the dawn, near-Earth (10 Re), magnetosphere (Hirahara et al., JGR, 2004) and this work is not quoted. Similarly, Sauvaud

(2001) using Cluster showed the appearance, close to the dayside magnetopause, of a cold ion population of ionospheric origin when the magnetopause is put into motion by pressure changes (Sauvaud et al., Annales Geophysicae, 2001). The ionospheric ions can be very abundant, with densities up to 100 cm^{-3} and these cold ions mass load the magnetosphere, changing global parameters of magnetic reconnection, like the Alfvén speed or the reconnection rate. In addition, they introduce a new length-scale related to their gyroradius and kinetic effects which must be accounted for (André and Cully, GRL, 2012; Toledo-Redondo et al., GRL, 2016). These findings exemplified the importance of independent density measurement devices, i.e. relaxation sounder, electric field, waves. . .for spacecraft orbiting in the outer magnetosphere.

About the energy dependence of ion drift in the inner magnetosphere and related effects, several observations and interpretations have been made from missions before Cluster. For example, the ion gap resulting from the drift and residence time allowing charge exchange with neutrals close to the mirror points have been studied by Kovrazhkin et al. (Annales Geophysicae, 1998), and two types of ion gaps were reported by Buzulukova et al. (Annales Geophysicae, 2002).

The dynamics of hot ions injected from the tail plasma sheet is presented with a bias toward the inner magnetosphere. There are numerous studies concerning sporadic injections of hot magnetospheric H+ and O+ ions into the auroral bulge with accompanying strong ejections of ionospheric ions from the poleward border of the active auroral oval. Some of these works performed with Akebono, Interball and Cluster should be quoted (e.g., Hirahara, JGR, 1997, Sauvaud et al., JGR, 1999, Sergeev et al., JGR, 2000, etc.).

Finally, the author states correctly that the shadowing effect of the magnetopause and charge exchanges with the atmospheric neutrals close to the mirror points are two main loss mechanisms in the inner magnetosphere. Some words should be added on the losses occurring from plasmoid ejection during substorms which lead to the detection of escaping molecular and atomic ions in the far tail, as seen onboard Geotail and

STEREO (Christon et al., GRL, 1998; Kistler et al., JGR, 2010; Opitz et al., JGR, 2014, etc.)

Altogether the suggested corrections should not modify the structure of the paper.

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