Initial and boundary conditions in the Mars Multifluid Magnetohydrodynamic Model (M^4)

The atmospheric profiles of ion, electron, and neutral densities, pressures, and temperatures, which are used for the simulations presented in this work, have been presented in *Riousset et al.* [2013]. This validation study develops the hypotheses and methods used to produce Figure S1. The small size of the simulation domain in this work supports the assumption of small horizontal variations, which permits the use of horizontally uniform profiles. The domain used for the present modeling studies does not extent more than a few hundred kilometers in the horizontal dimensions. Consequently, we use the same horizontally uniform profiles as in our previous work.

We also maintain the use of Neumann boundary conditions at all the boundaries of the simulation domain. In *Riousset et al.* [2013], we demonstrated that moderate magnetic fields ∼20 nT yield a dynamo region extending down to ∼150 km, and up to ∼225 km. Increasing the magnetic field by a factor a hundred lowers it down to 110 km. In the present work, the magnetic field (which is maximum at the lower boundary at z=100 km) never exceeds a magnitude greater than 1250 nT. Therefore, the dynamo region is not expected to reach altitudes lower than 110–120 km. Below the dynamo region, electrons and ions are completely decoupled from the magnetic field, therefore no current can flow and the motion of the charge carriers is completely determined by the neutral wind. With a vertical resolution of 4 km in this part of the simulation domain, this corresponds to a buffer of a several grid points, ensuring that the dynamics of the dynamo region are not contaminated by spurious numerical effects that could happen at the lower boundary. Figure S2 shows how the dynamo current forming around a magnetic cusp (see Figure 1b) is essentially contained between the altitudes z=110 km and z=150 km. At $t\approx 27$ s into the simulation, corresponding the snapshot time of Figure 1, the current density at the lower boundary (Panel (c) of Figure S2) remains quasi-null.

Reference

Riousset, J. A., C. S. Paty, R. J. Lillis, M. O. Fillingim, S. L. England, P. G. Withers, and J. P. M. Hale (2013), Three-dimensional multifluid modeling of atmospheric electrodynamics in Mars' dynamo region, *J. Geophys Res.*, *118*(6), 3647--3659, doi:10.1002/jgra.50328.