Answer to Reviewer #2:
Thank you very much for your comments and corrections.
Following are our answer (in black) to each of your comments (in red).

General comments:
The manuscript reports on HF wave propagations with respect to different conditions of internal magnetic field. Especially, the manuscript presents the propagation effects including the reflection from the lower ionosphere using ray tracing analysis. The contents may be interesting to the community for ionospheric dynamics during dipole field decrease. However, I find a serious problem that the manuscript does not deal with the effects of wave propagation by the irregularity of electron density in the ionosphere.

You are right in that we do not deal with the significant effects of electron density variations on ray tracing (neither regular nor irregular), since the main idea of this work is to isolate the main Earth's magnetic field effect, which is a long-term as well as large-scale effect.
We will include in the revised version a thorough discussion of HF ray path effects due to ionospheric irregularities, and we will also explain why we are not considering these effects.

From equations (1) to (7), I would like to point out that the effects of wave propagation by the irregularity of electron density in the ionosphere not addressing in this manuscript are dominant rather than them by geomagnetic field change focusing in this manuscript. I think that the results are not well discussed due to no discussion on the effects causing by irregularity of electron density. The author must address the advantages on this study for neglecting the wave propagation effects from the irregularity of electron density in the ionosphere.

Indeed electron density irregularities (TIDs for example, or latitudinal variation at low latitudes) have stronger effects on HF ray paths than the Earth's magnetic field, even considering field reversal scenarios. However, the idea of the present work is to analyze the magnetic field effect, which is important for three main reasons:

1. from a theoretical point of view.
2. electron density is characterized by large amplitude high frequency variations (days, annual, decadal), whereas the magnetic field is characterized by low amplitude lower frequency variations. Our study reveals the ground range variability over a timescale of several thousand years of a reversal.
3. The Spitze angle depends only on the internal magnetic field morphology, not on the electron density.

As you suggest, and as mentioned in our answer to your first comment, we will add to the text a thorough comparison between the effects of electron density irregularities and magnetic field morphology on the ground range.

Comment 1 (in Section of "Theory") Most of texts and equations in this section are general talk. It looks like only equations (8) and (9) are important in this manuscript. The authors must improve making an important summary of related theory and mostly rewrite.

You are right. We could cite the works were the ionosphere refractive index is explained. We decided to include equations (1) to (7) thinking on the community that studies paleomagnetism, who probably is not familiar with these concepts. But if you insist, we can delete them and just cite some papers.

Comment 2 (line 242) The authors should address why the calculation took different resolution for latitudes and longitudes. I think the irregularity of electron density is smaller than the spatial resolution used in this ray tracing.

The resolution of R space-variation is 5° in latitude and 10° in longitude. This was chosen according to the space-scale of the Earth's magnetic field variation, for which the chosen resolution is more than enough, even under a field reversal with a dominant multipolar configuration. The values were chosen in order to have well defined patterns with the least calculations. We set higher resolution in latitude because the seasonal variability of the atmosphere is more pronounced in latitude than in longitude. We tested a higher resolution, like 5°x5° and the results are almost identical. However, each ray-tracing performed at each grid point is totally different. Hamilton's equations given in Equations (15) to (20) are integrated using a Fortran subroutine which computes the numerical solutions of the system of six simultaneous first-order differential equations over a specified interval with given initial conditions applying the Adams-Moulton procedure. This is a multi-step method that requires a self-starter, in this case a fourth order Runge-Kutta method, together with a predictor given by Adams-Bashforth formula. With this method we get steps of much less than a kilometer. So, if we would analyze a TIDs effect on a ray path, it is very well resolved with our ray tracing code.

Hoping to meet all your requirements,

Mariano Fagre, Bruno S. Zossi, Erdal Yigit, Hagay Amit and Ana G. Elias