Evaluation of the gradient method with ULF waves in a MHD simulation

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Methods called `gradient methods' [e.g., Baransky et al., PSS, p859, 1989] are designed to extract information on field-line eigenoscillations (FLEs below) from actually observed ground magnetometer data, which is a mixture of perturbations coming from many sources; simply looking at the ground magnetometer data does not reveal FLEs. If we can identify an FLE, we can obtain the field-line eigenfrequency, which can be used to remote-sense the plasma density along the field line from the ground.

The gradient methods take a difference between the magnetometer data from two adjacent stations (separated in latitude); by doing so the methods cancel out perturbations coming from non-FLE sources, which usually have weaker latitude dependence than FLE. There exist many papers in literature showing that the gradient methods actually work.

However, although cases of success do confirm that there existed FLE then, cases of failure do not confirm that there did not exist FLE then: That is, there might exist FLEs which are not identified by the gradient methods.

To explore this aspect, we apply the gradient methods to outputs of an MHD simulation: Since we can clearly identify ULF waves in the simulated data in an independent manner from applying the gradient methods, we can test if the gradient methods can actually identify the ULF waves in the simulation.

The MHD simulation code used in this paper is that a little modified from the code by Lee and Lysak [JGR, 1999, p28691]. We have confirmed that there do exist cases in which the gradient methods actually succeed in extracting FLEs from the simulation data; this supports the meaningfulness of applying the gradient methods to the simulated data.
We have also found a possible area where the gradient methods fail but there exist FLEs: Which area exists when the ionospheric damping is taken into account. It exists where the field-line eigenfrequency is close to a discrete and uniform frequency of the compressional-type wave, which one may call the cavity-mode wave.