Studying the propagation of ELF waves in the Martian ground-ionosphere waveguide using an FDTD method with application to the ground tomography

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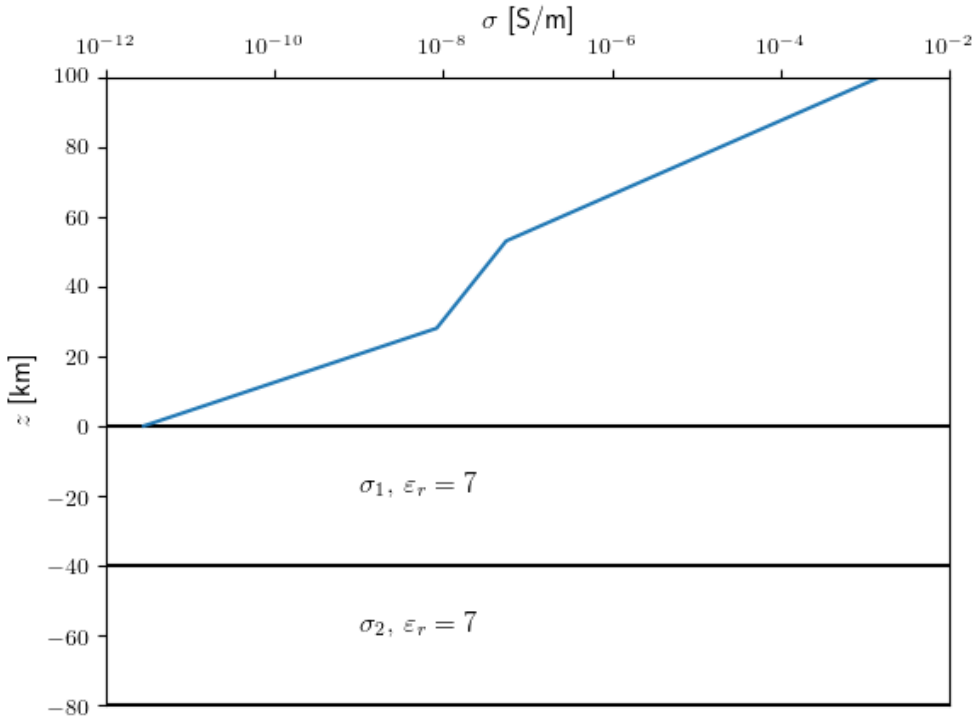
Mars ground-ionosphere waveguide and the idea of ground tomography

- Short pulses are generated by dust-devils / dust storms
- Ground surface on Mars is very (extremely) dry
- ELF waves can penetrate ground much deeper than on Earth
- Reconstruction of wave propagation can be useful for development of inverse methods and therefore allow measurements of subsurface properties
- Martian ELF stations are currently under development in our team

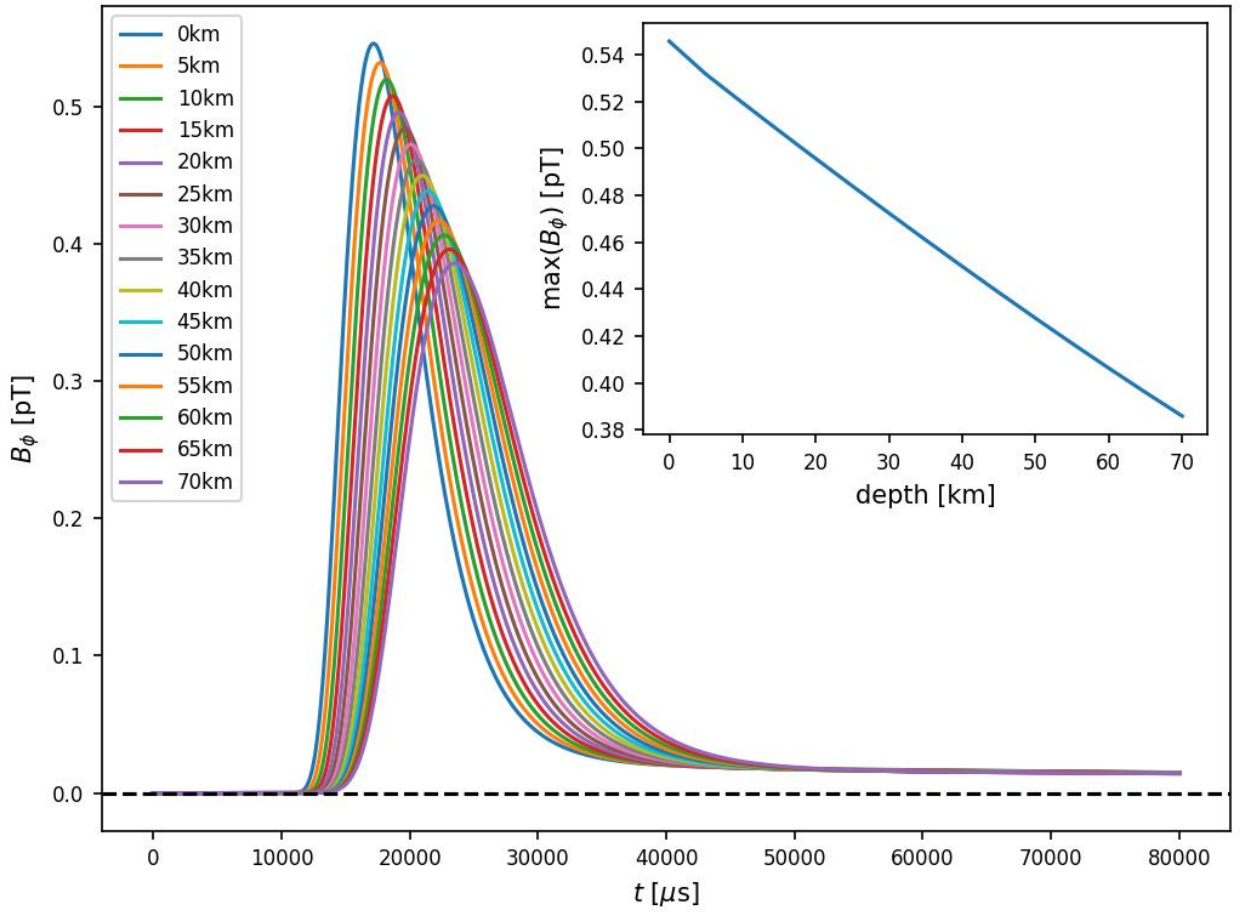
Numerical model

- Time domain simulation
- Cylindrical coordinates centered around the event and scaled via focusing factor
- Large scale grid ($\mathrm{d}\rho = 10\mathrm{km}$, $\mathrm{d}z = 1\mathrm{km}$)
- Measurements at large distances (3 Mm)
- Current source – Short VED with a cutoff at 450 Hz
- Double-‘‘knee’’ daytime ionosphere profile [Pechony and Price 2004]
- Multilayer ground [Kulak and Mlynarczyk 2013]



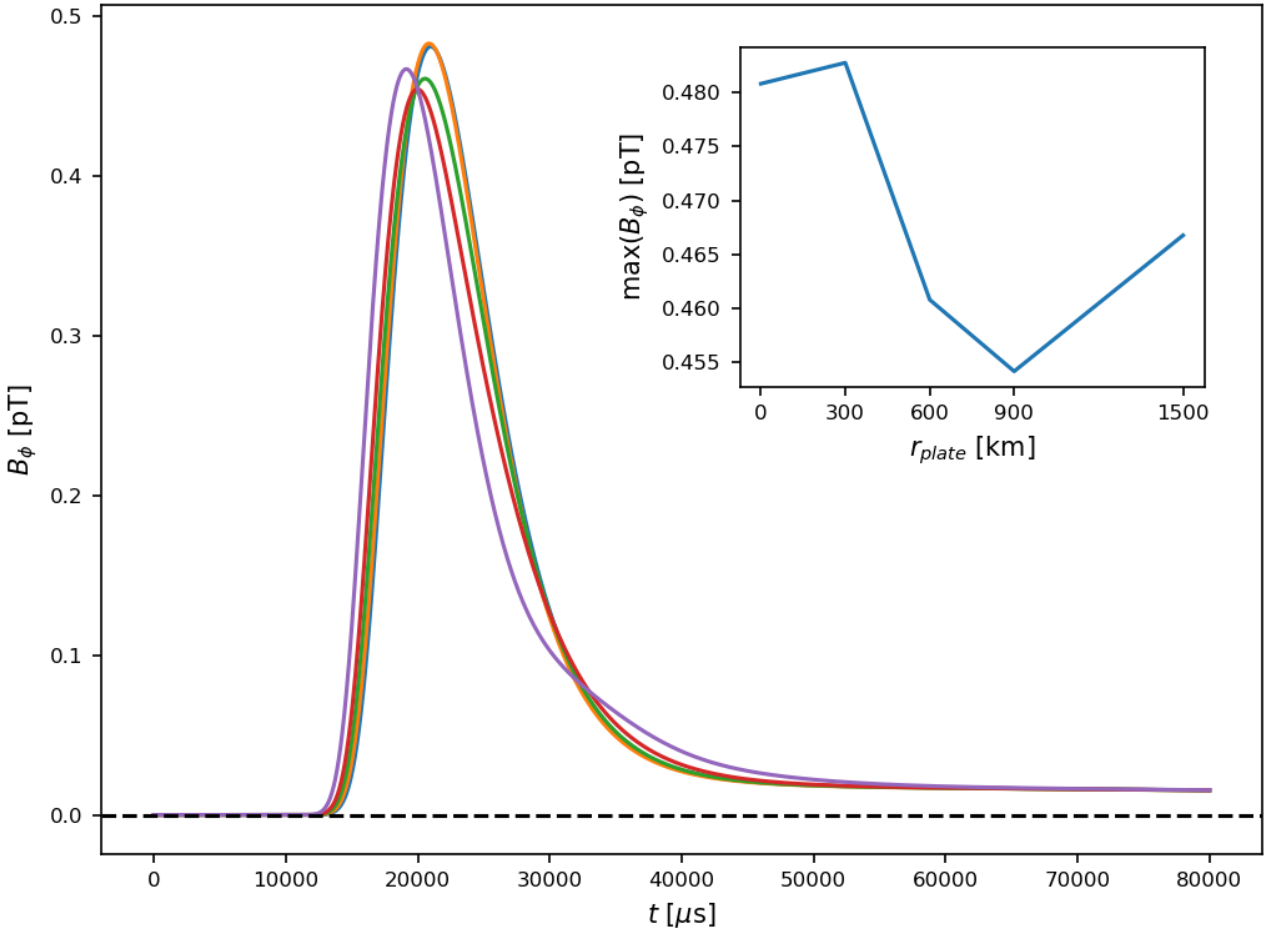
Results

- First layer - small conductivity ($\sigma_1 = 10^{-6}$ S/m), second layer - high conductivity ($\sigma_2 = 10^{-2}$ S/m)
- Pulse source with $p = 1\ \mathrm{C} \cdot \mathrm{km}$ dipole moment
- Measured amplitude at the distance of 3 Mm from the source for various depths of the first layer



Results

- Same environment + highly conducting plane (diameter = $2r_{plane}$) with source located in the center
- Small conducting plane – almost no impact
- Possible resonance on some plane size relative to antenna location



Conclusions

- Amplitude of the electromagnetic field at large distances from the source strongly depends on the ground structure
- This approach allows measurement of waveforms and enables identification of ground structure and its components.
- Possibilities of further studies:
  - local distortions of ionospheric profile
  - impact of the solar terminator