Radar Sounding of Temperate Permafrost in Alaska: Analogy to the Martian Mid-Lattitude ice-rich Terrains

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Study of the distribution and state of the Martian subsurface water is one of the priority goals of the Mars Exploration Program, as it has important implications on the hydrogeologic and climatic evolution of Mars and on the possible development of life on the red planet.

In order to constrain the ambiguities regarding the distribution and state of subsurface water, two low-frequency sounding radars, MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) [1] and SHARAD (SHAllow subsurface sounding RADar) [2] are probing the Martian subsurface.

The identification of volatiles signatures in the GPR data is constrained by our understanding of both dielectric and scattering losses mechanisms that are generated by the dielectric complexity and the heterogeneities of the Martian subsurface. Although some GPR investigations have examined Mars analogs volcanic terrains [3,4,5], radar sounding on Mars analog frozen terrains (like permafrost) remain poorly investigated.

To address this issue, we conducted ground penetrating radar and resistivity investigations on Mars analog permafrost terrain [3], in the area of Fairbanks (Alaska, USA). We used four frequencies antennas (40, 270, 400 and 900 MHz) along a same profile allowing us to study the frequency dependence of attenuation mechanisms over a wide frequency band.

Location & Geology

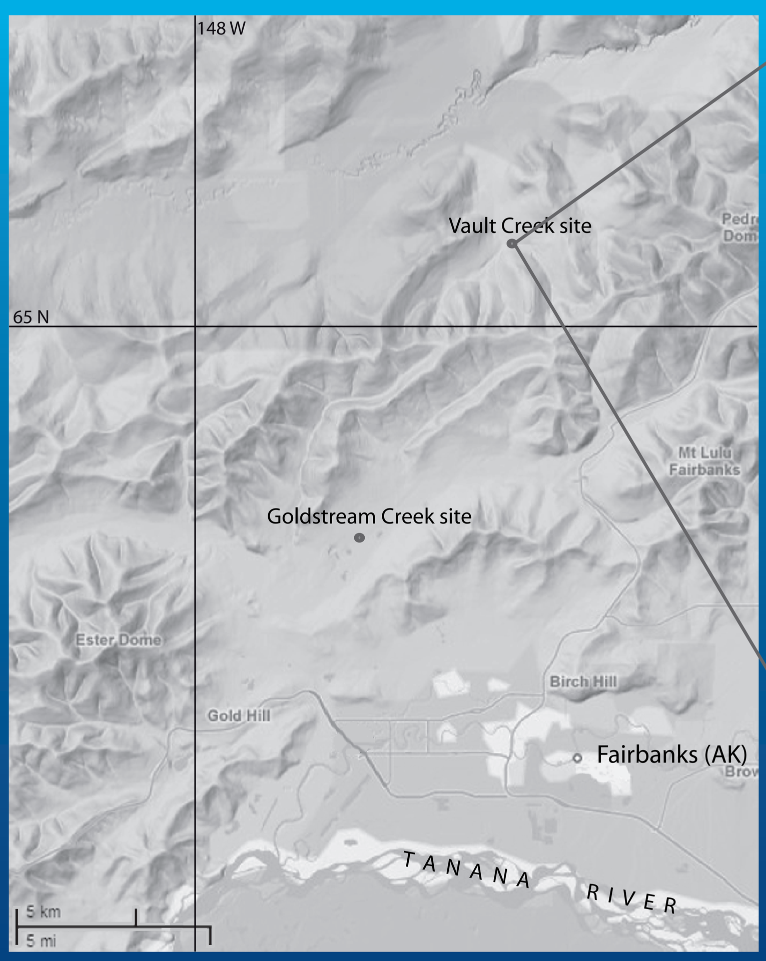


Figure 1 : Location of the investigation site (Vault Creek site), ~20 km North of Fairbanks. The area of Fairbanks is located in the middle interior region of Alaska (USA), at 200km Northeast of the Denali National Park.

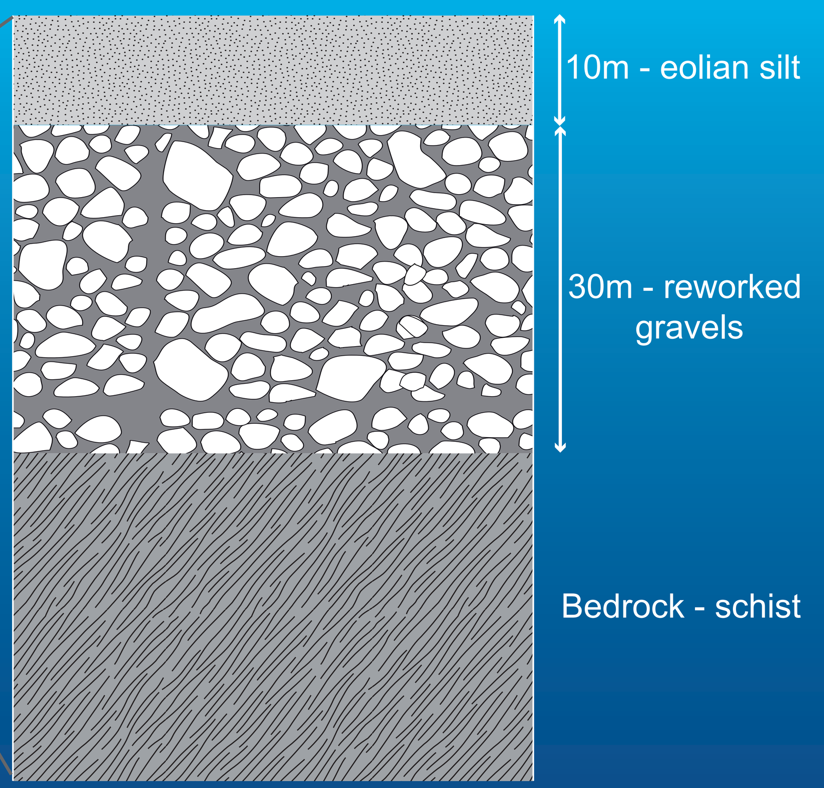


Figure 2 : Geological cross-section of the Vault creek site subsurface observed in the 40m deep tunnel. The subsurface is composed of eclogite-bearing schist amphibolites overlain by reworked creek gravels (~30 m thick) and eolian silt deposits perennially frozen with large mass of ground ice (~10 m thick) [6]. The subsurface is perennially frozen (up to ~120m deep) with large mass of ground ice (except the active layer in the upper 1 to 2 m).

Resistivity sounding

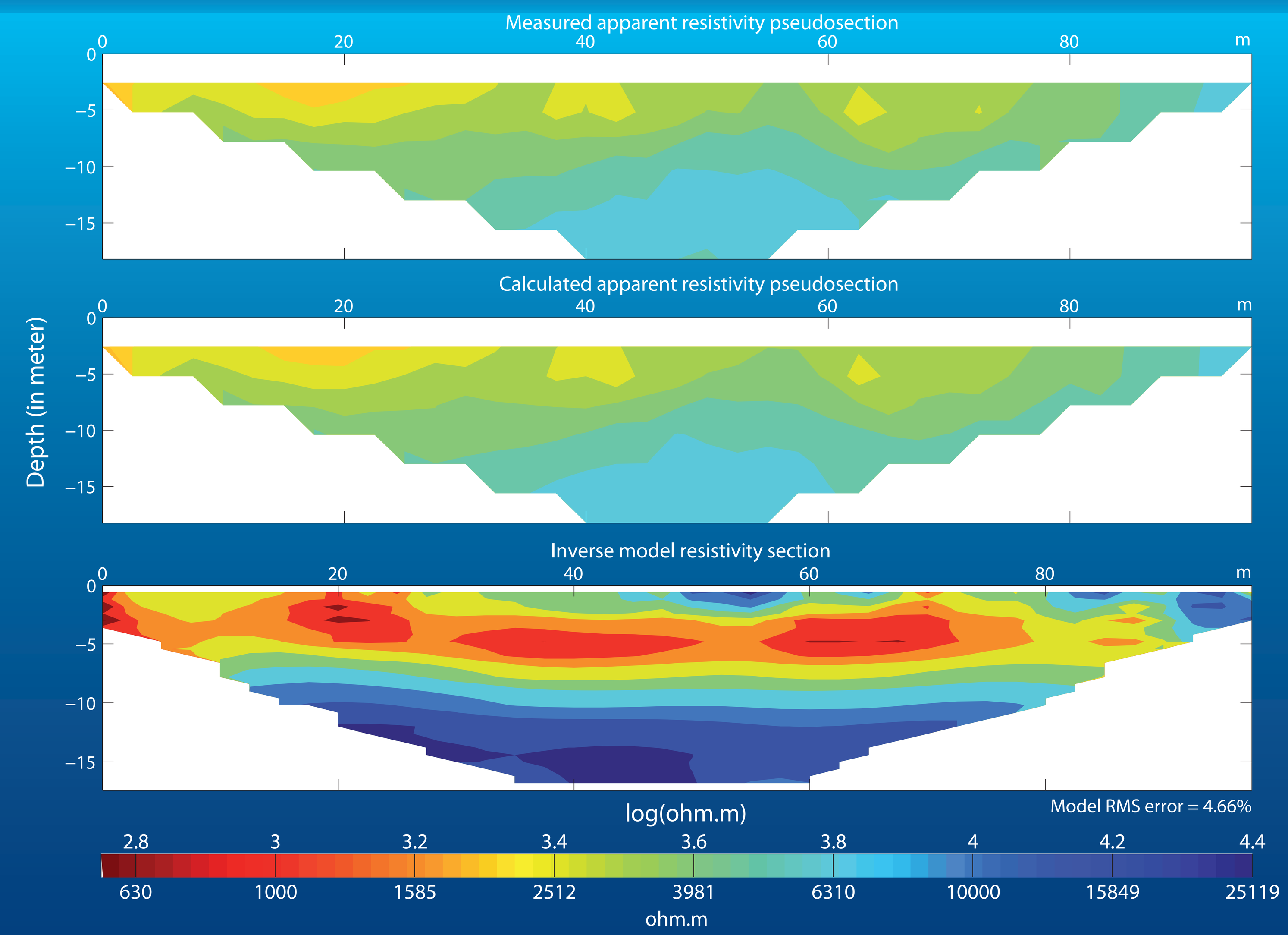


Figure 3 : Measured (top) and calculated (middle) apparent resistivity pseudosections (in ohm.m) of the Wenner electrical survey (Vault creek site). The lowest pseudosection is the result of a least-square inverse inversion of the ERT data after 8 iterations (RMS error of 4.66%). The contrast between the more conductive layer and the resistive layer (~8 to 10m deep) corresponds to the silt/gravels interface. We used the software RES2DINV (Geotomo Software [7]).

Ground penetrating radar sounding

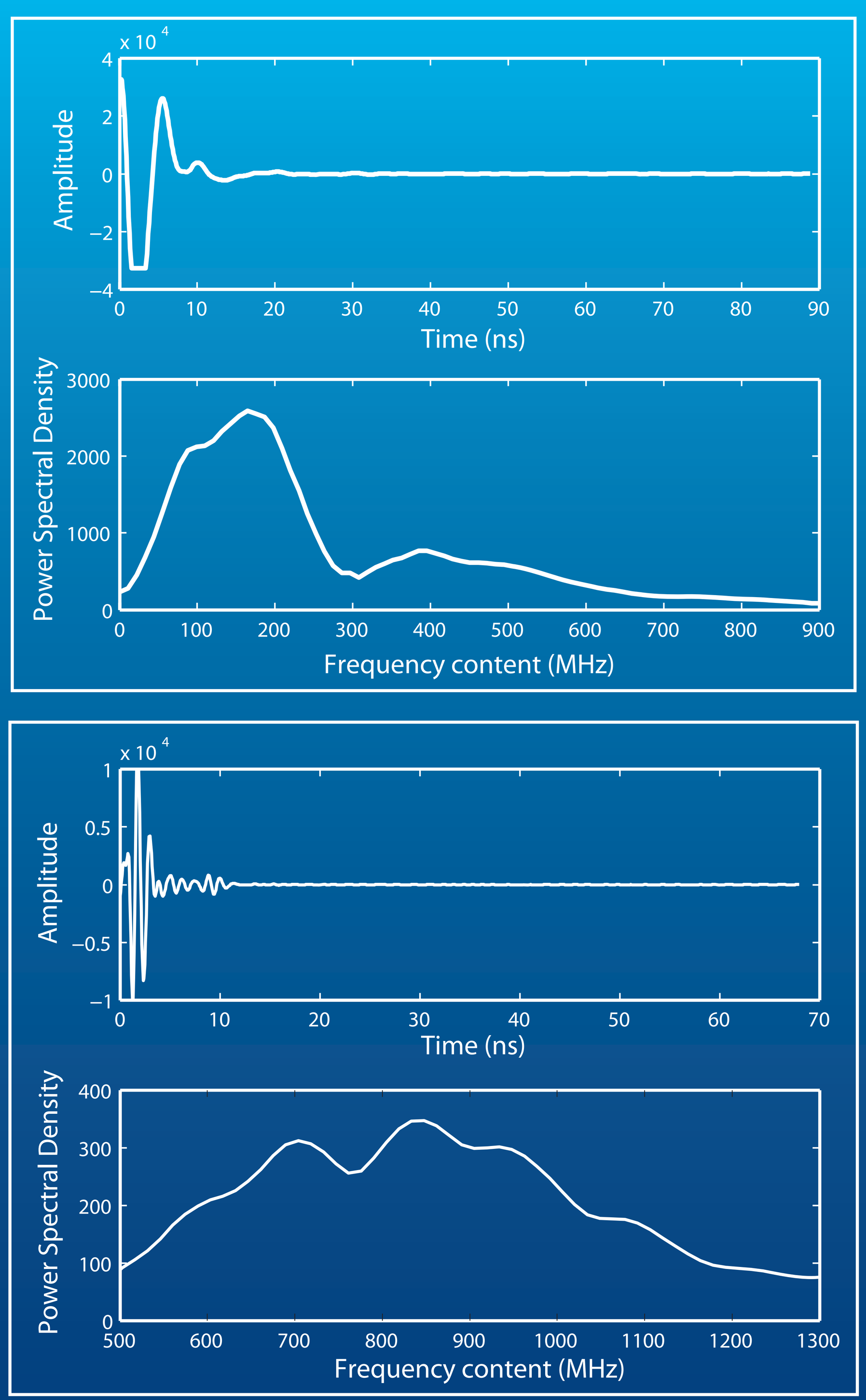
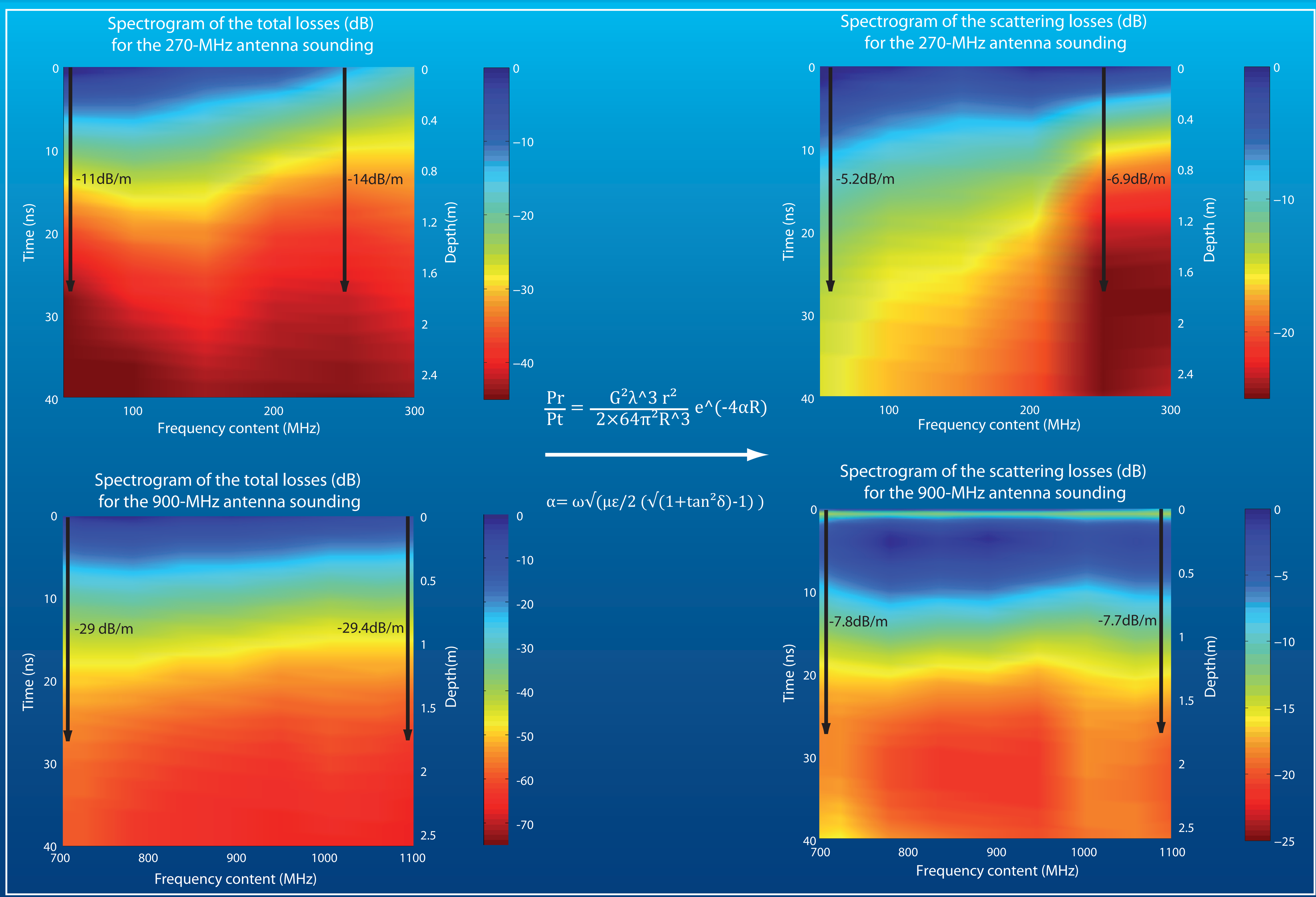


Figure 4 : Amplitude and power spectral density of the radar signal echo for the 270 MHz-antenna sounding (top) and the 900 MHz-antenna sounding (bottom) (Vault Creek site). The central frequency is , for both, shifted to lower frequencies. This is generated byt the contact between the antenna and the ground.



$$\frac{Pr}{Pt} = \frac{G^2 \lambda^3 r^2}{2\times 64 \pi^2 R^3} e^{(-4\alpha R)}$$

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+\tan^2\delta}-1\right)}$$

Figure 5: Spectrograms of the 270 MHz-antenna signal (top) and the 900 MHz-antenna signal (bottom). We fisrt calculated the spectrogram of the total losses (left). We then deduced the scattering losses (right) applying the radar equation above [3]. The first term represents the geometric spreading losses and the second is the dielectric losses. Here, we apply the radar equation formula for the case of an infinite planar target in the Fresnel zone [8].

Références

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Conclusion

This study allows to better understand and quantify the frequency behaviour of the signal losses. It is well known that the ground acts as a low-pass filter (as the low wavelenghts = high frequencies will interact with the subsurface heterogeneities). This phenomenon can be observed, particularly, on the spectrograms of the 270MHz antenna sounding (from -11 to -14 dB/m for the total losses and from -5.2 to -6.9 dB/m for the scattering losses). This investigations will allow to better constrain the different losses observed in the Martian radar data acquired over Martian frozen terrains and thus to access to the subsurface heterogeneity informations.