Empirical depth-time parameters of investigation of a GPR experiment

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1 Common offset two-way time

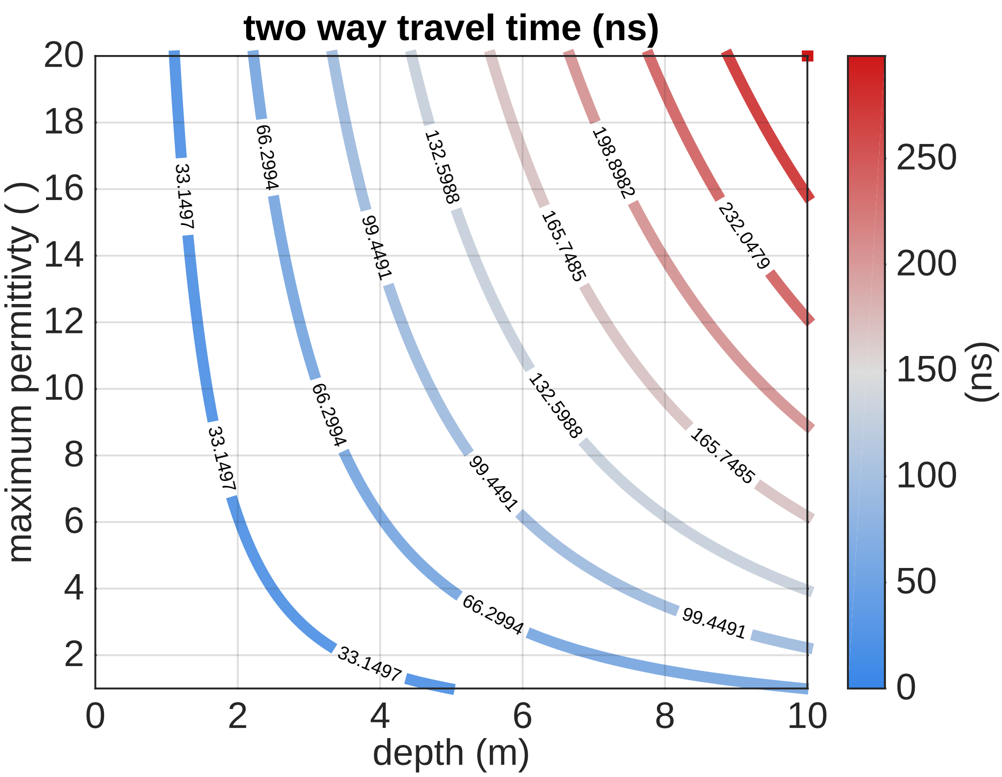

Figure 1: Two-way travel time as a function of relative permittivity and depth of investigation.

2 Common shot gather depth of investigation

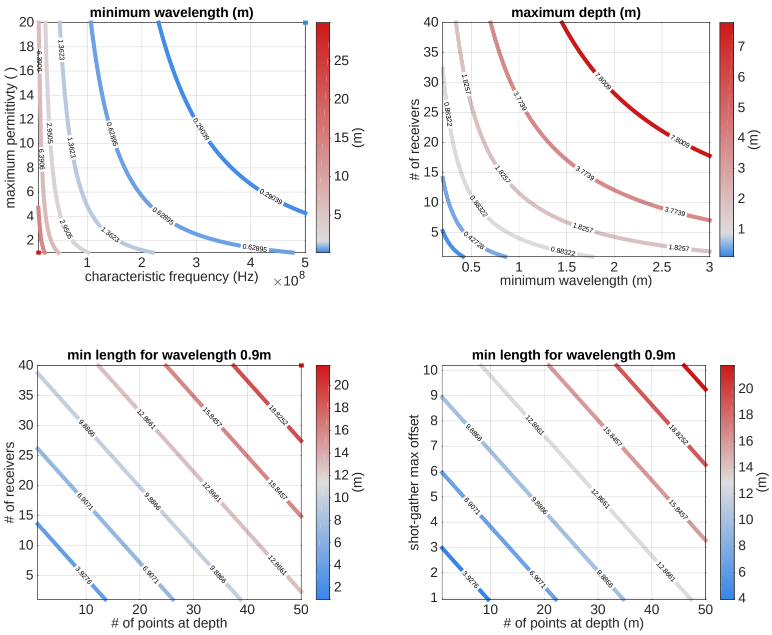

Figure 2: Plots are read top-bottom, left-right (like reading a book). **b)** and **d)** are specific examples for a fixed frequency and chosen minimum wavelength.

Follow this recipe for determining the depth of investigation and the length of your survey:

1. See Figure 2-**a)** and choose the target minimum wavelength as a function of the maximum target permittivity and the characteristic frequency of your system.
2. See 2-**c)** and choose how deep you want to probe to get the # of receivers needed for that minimum wavelength and that depth.
3. Run `w_depth_arrays.m` and plot similar Figures 2-**b)** and **d)** for your chosen minimum wavelength.
4. See Figure 2-**b)** and determine how many image points at depth you want (this is an empirical computation of the # of points), and see how many receivers you need for that.
5. Figure 2-**d)** is one-to-one with Figure 2-**b)**, so for that # of receivers you now have a distance in meters for maximum shot-gather offset and the total length of the survey.

3 Explanation

Let c be the speed of light in vacuum and f_o be the characteristic frequency of your GPR system,

$$\begin{aligned} v &= \frac{c}{\sqrt{\varepsilon}}, \\ \lambda_o &= \frac{v_{min}}{f_o} = \frac{c}{f_o\sqrt{\varepsilon_{max}}}, \end{aligned} \tag{1}$$

where λ_o is the minimum target wavelength.

3.1 Two-way traveltime

For the two-way travel time we have,

$$t = \frac{z}{2 \cdot v} = \frac{z\sqrt{\varepsilon}}{2 \cdot c}, \tag{2}$$

where t is two-way travel time and z is depth of investigation with a constant velocity v.

3.2 Depth of investigation and length of common source survey

Let n_r be the # of receivers and n_i the # of illuminated points at depth z, where z denotes the maximum depth of sensitivity for the given array. Empirically,

$$\begin{aligned} 2z = x_{sr} &= \Delta sr + (n_r - 1)\Delta r, \\ x &= x_{sr} + (n_i - 1)\Delta r, \end{aligned} \tag{3}$$

where x_{sr} is the maximum length between source and receiver of a common source gather, and x is the total length of the survey. Our linear array assumes to have distance between source and first receiver $\Delta sr = \lambda_o$, receiver-receiver spacing $\Delta r = \lambda_o/4$, and source-source spacing Δr.

4 Assumptions

- Plane wave
- Homogeneous velocity model
- No intrinsic or geometric attenuation
- No dispersion