

Implementation of Hagedoorn's plus-minus method in Matlab GUI

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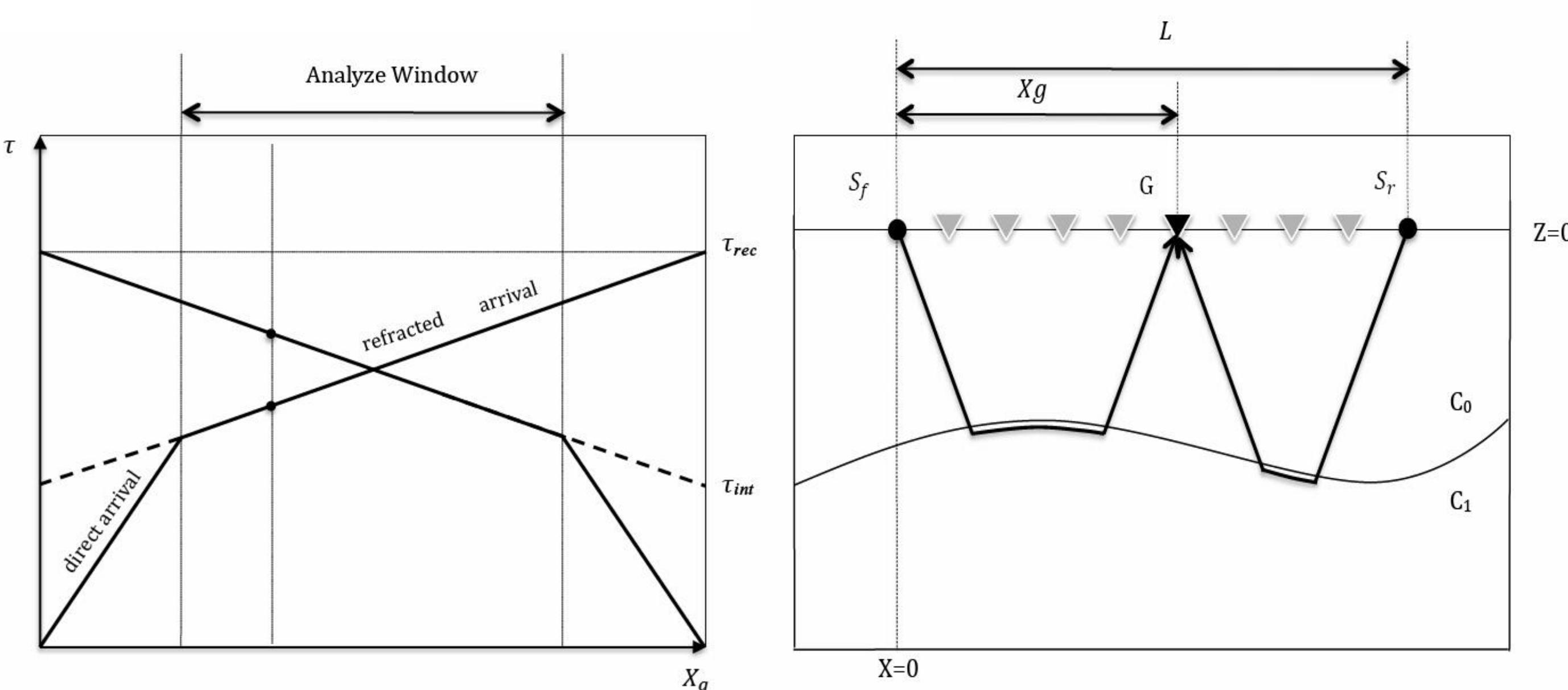
ABSTRACT

The basic theory of seismic refraction and one of the most popular refraction methods---plus-minus are elaborated in this paper. Despite of the limitations of plus-minus method, geophysicists benefit by its convenience to roughly explore the subsurface structure and acquire significant information of layers. This method is realized in Matlab as a graphical user interface (GUI), as a more approachable tool for beginners. From finite-difference model and field data tests, usability of the tool is proved.

Plus-Minus method

The plus-minus method is a geophysical principle raised by J.G.Hagedoorn (1959), it appeared as an improvement to Thornburgh's wave-front theory (Thornburgh,1930) in regions that subsurface velocity distribution is unascertained.

Plus-minus interprets seismic refraction profiles from symmetrical shot points over irregular strata with single interface whose slope angles are less than 10° . The result is correct only in region that is covered by reversed directions' refraction, in other words, in the "analyze window".



forward and reverse shots. Their travel-time expressions in *delay time* format are

$$\tau_{Rf}(X_g) = \frac{X_g}{C_1} + \delta_{sf} + \delta_g$$

$$\tau_{Rr}(X_g) = \frac{L - X_g}{C_1} + \delta_{sr} + \delta_g$$

Define "minus" time as

$$\tau^-(X_g) = \tau_{Rf} - \tau_{Rr} - \tau_{rec} = \frac{2X_g}{C_1} + (\delta_{sf} - \delta_{sr} - \frac{L}{C_1} - \tau_{rec})$$

and "plus" time as

$$\tau^+(X_g) = \tau_{Rf} + \tau_{Rr} - \tau_{rec} = 2\delta_g$$

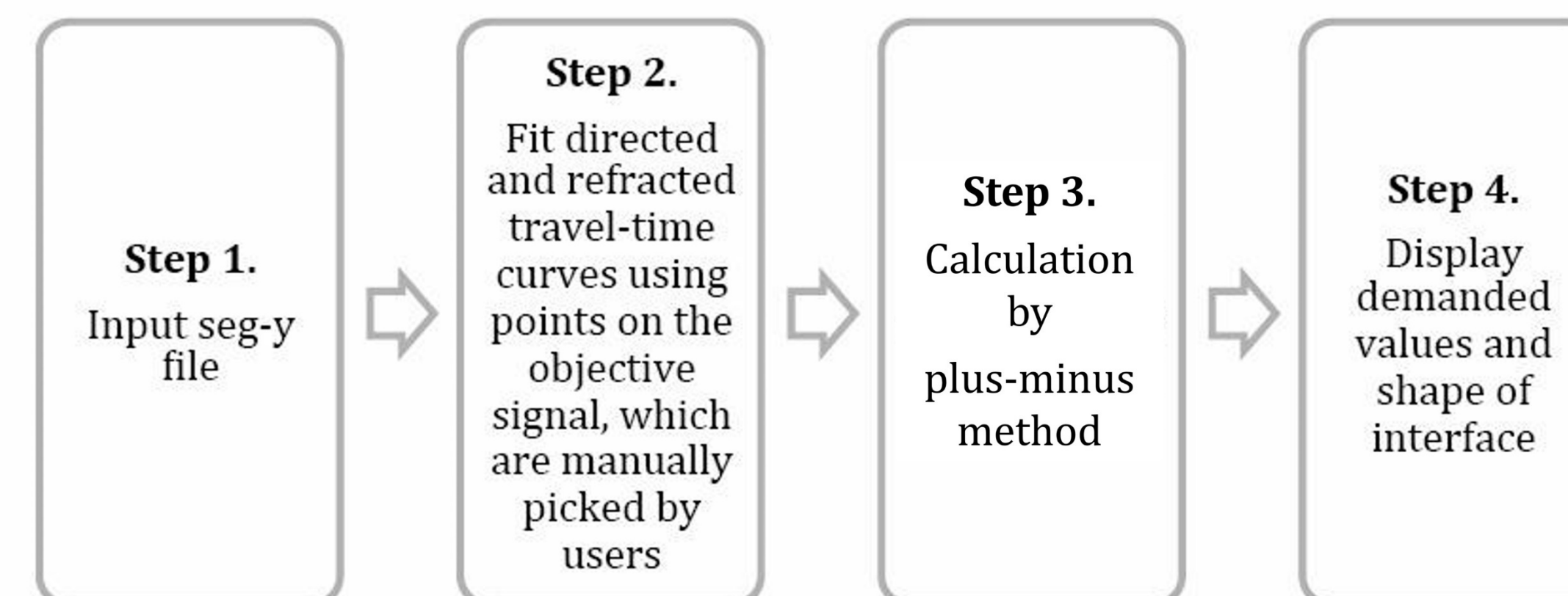
From those, get velocity of the refractor and thickness of its covering medium

$$C_1 = \frac{2}{\text{slope of } \tau^-}$$

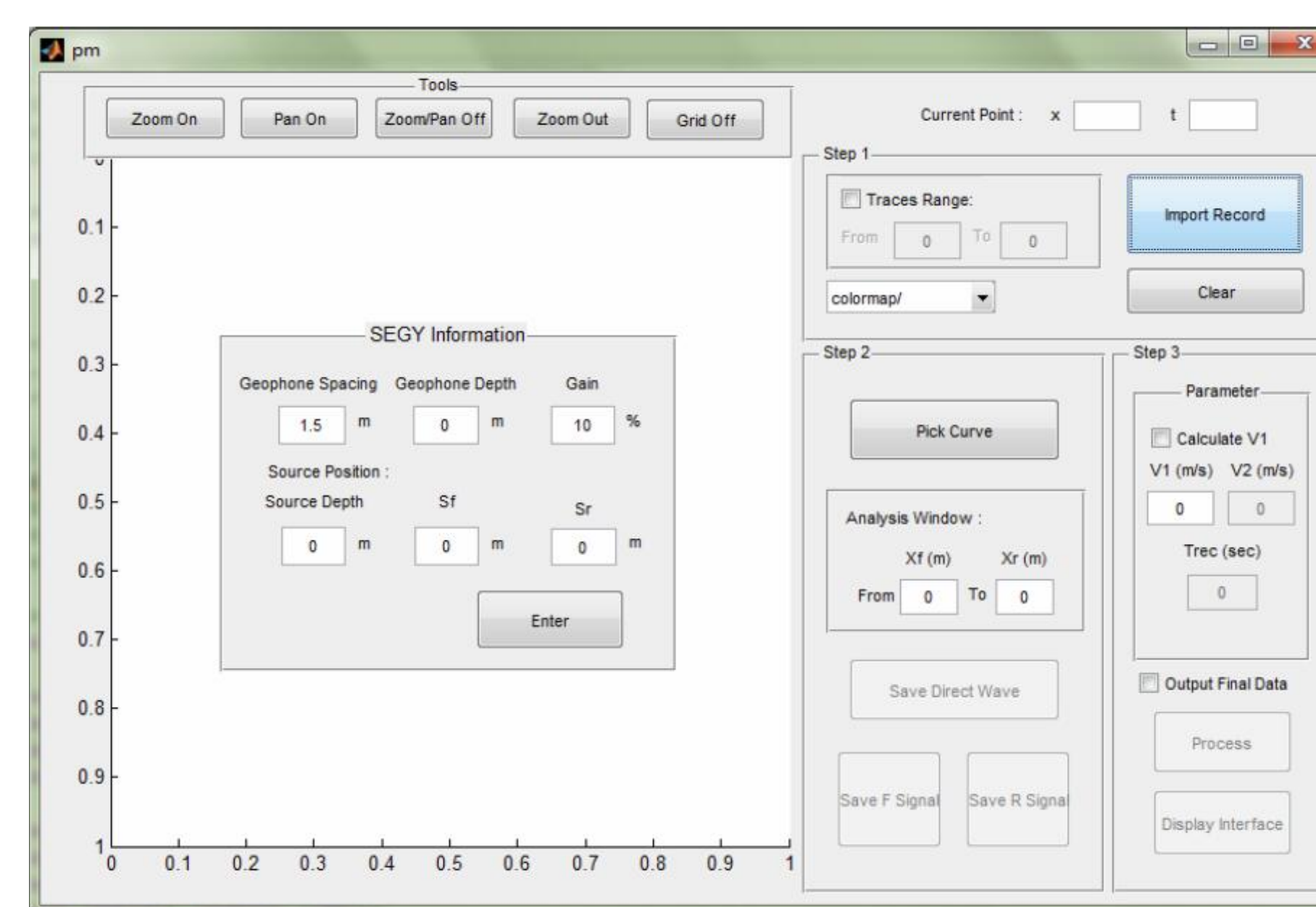
$$Z_0 = \frac{C_0}{2\cos\theta_c} \tau^+(X_g)$$

The graphical user interface (GUI) "pm"

The work flow

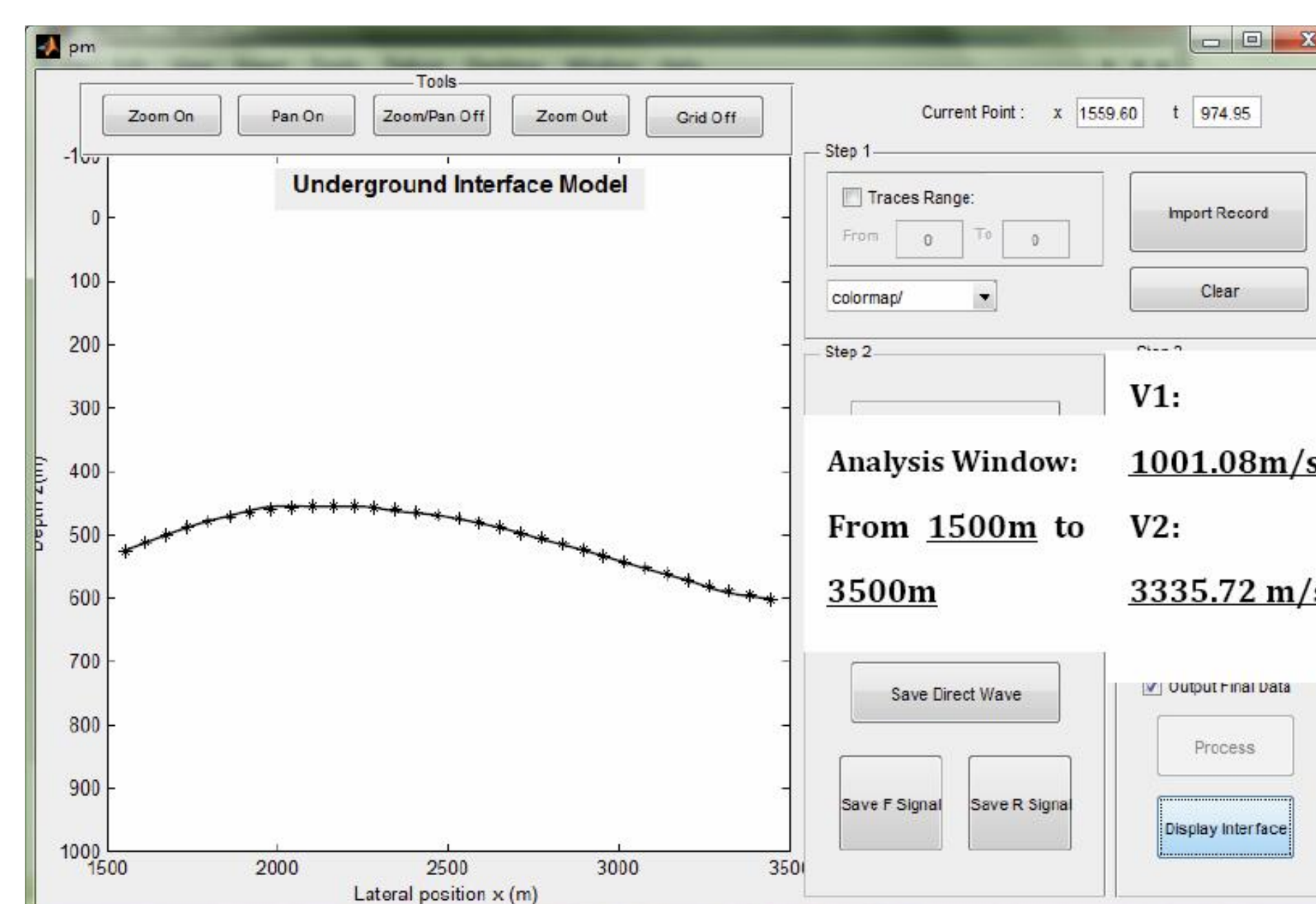
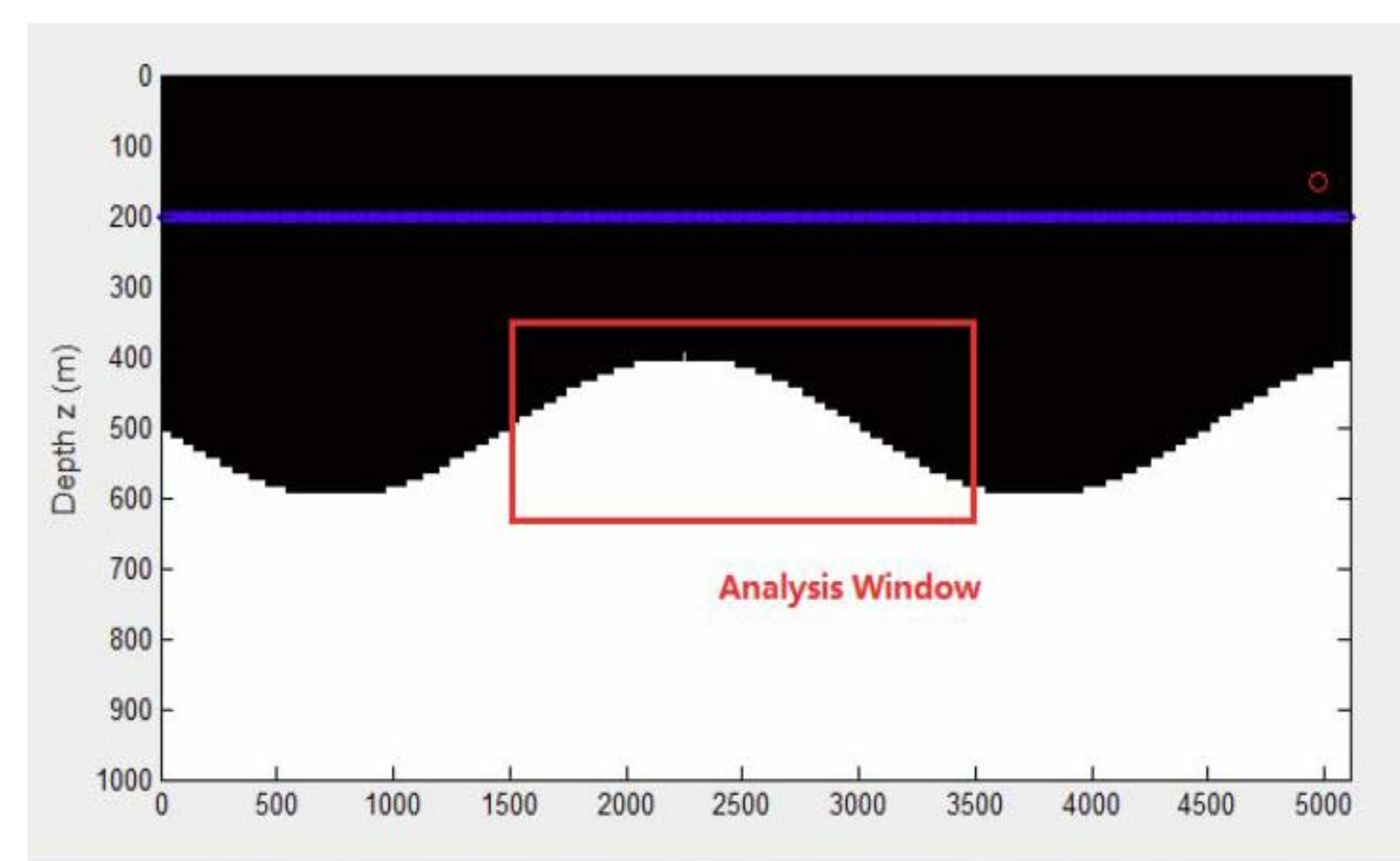


Layout



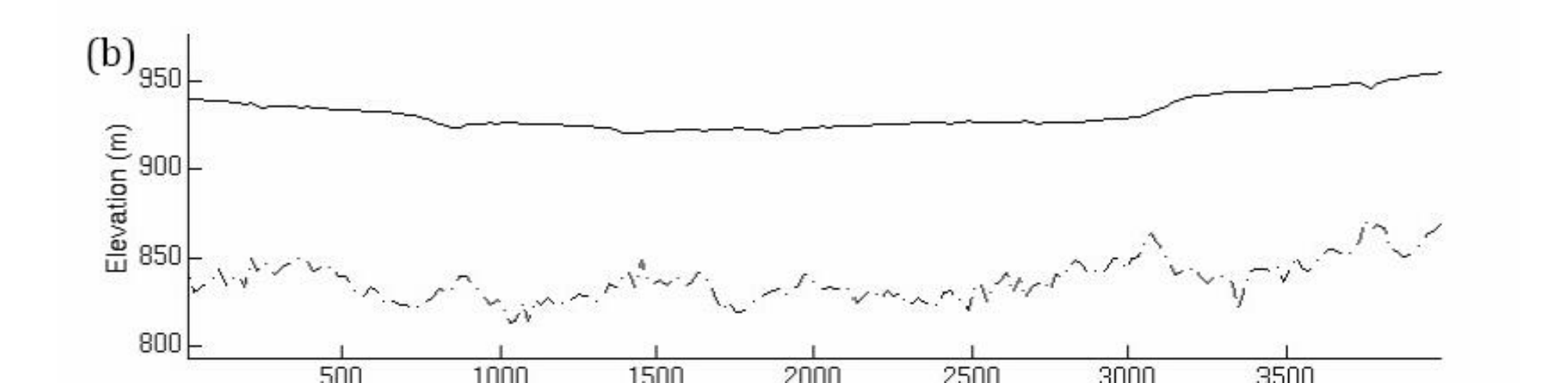
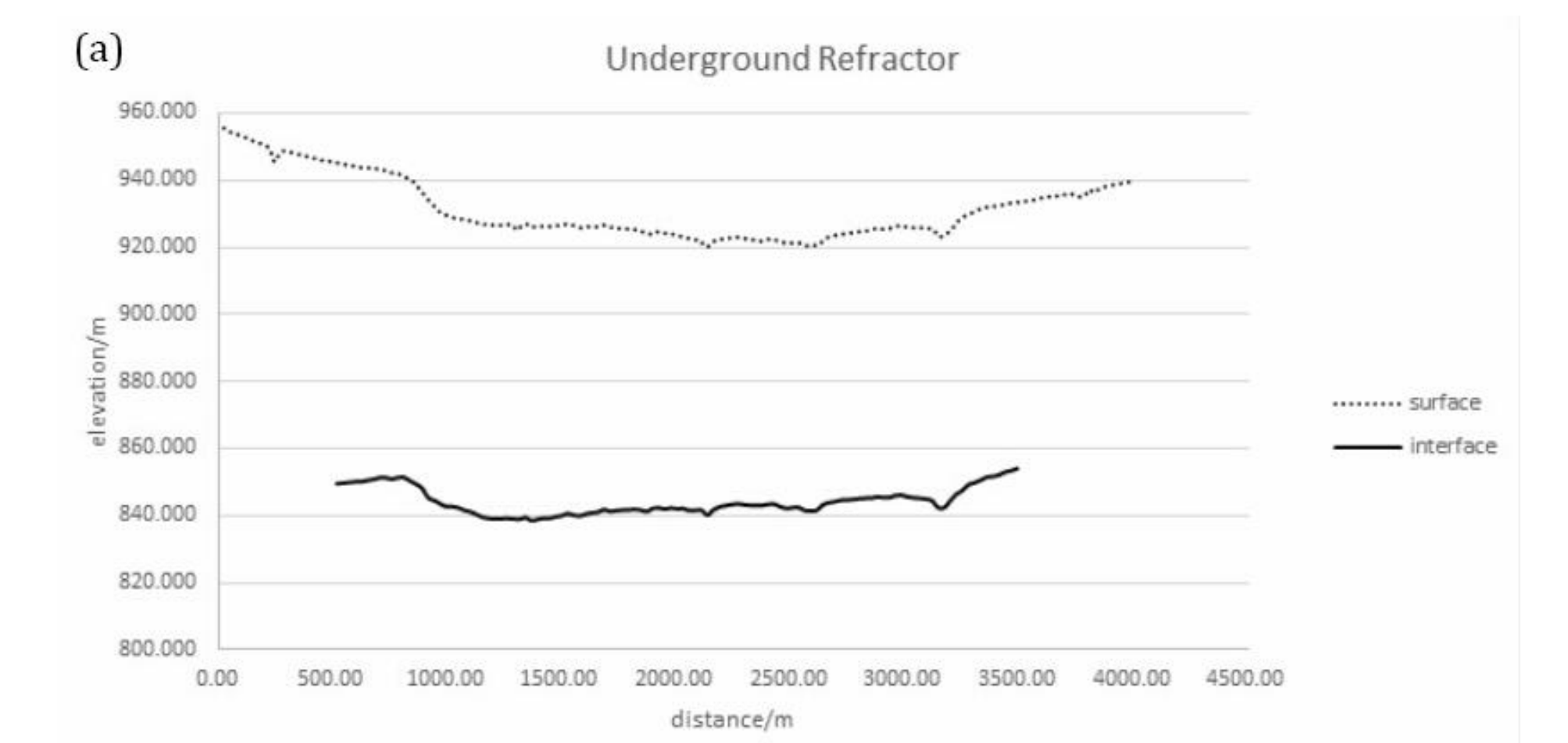
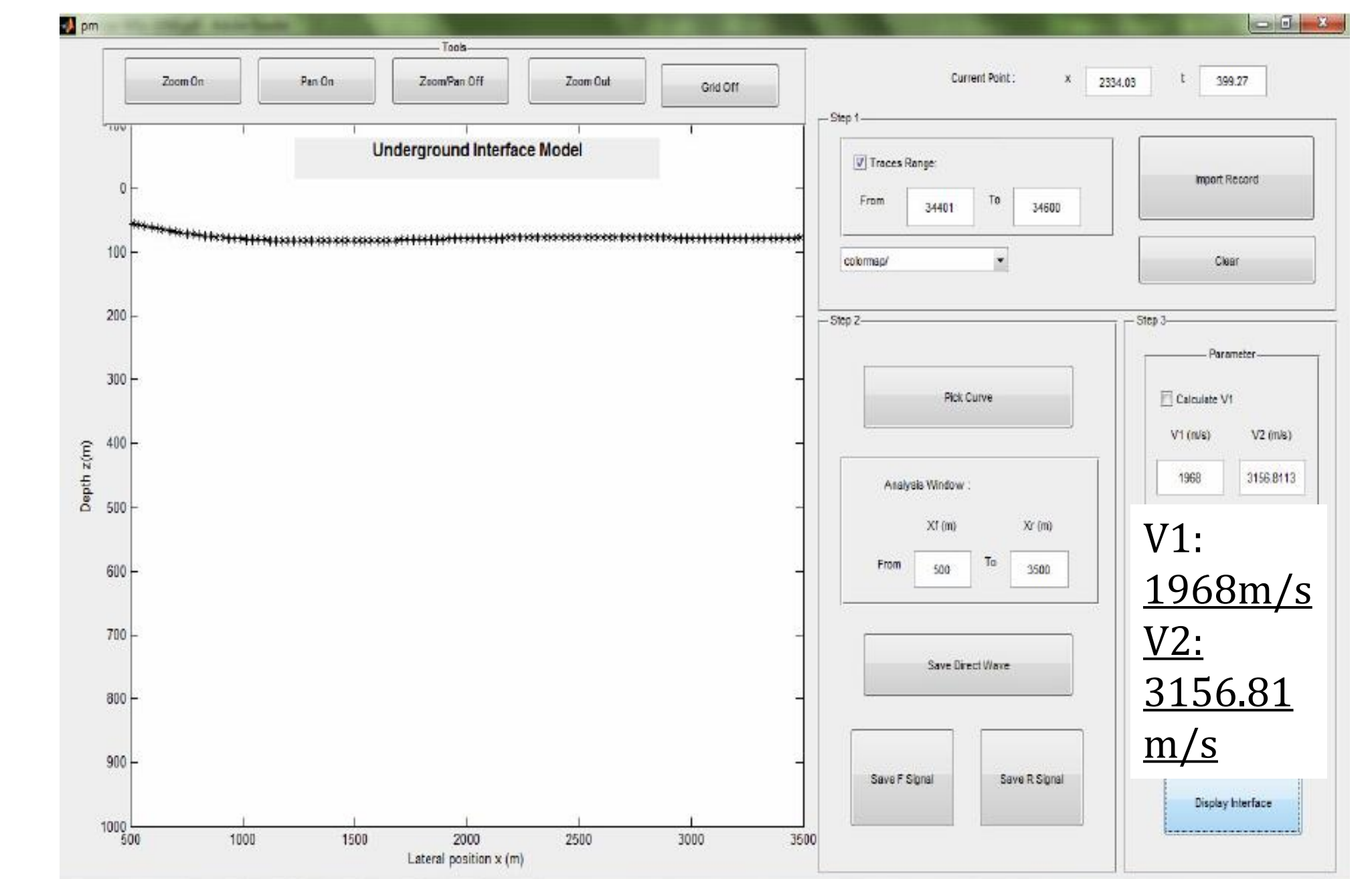
Model test

Upper layer velocity is 1km/s and lower layer velocity is 3km/s.



Field data test

2D data from Blackfoot oilfield is tested, which locates at 15km southeast of Strathmore, Alberta. We compared (a) the result from GUI with (b) Dufour's research (Dufour, 1996) of velocity and depth information in this field.



"pm" can rebuild refractor at the right level. In both results the refractor is buried at about 840m in elevation. "pm" gave out the refractor velocity as 3156.81m/s, which is pretty close to Dufour's 3100m/s.

CONCLUSION

Hagedoorn's Plus-minus method is an effective and convenient tool to collect underground information of simple undetected region. The realization of plus-minus method in Matlab GUI is successful. Through above tests, "pm" can recover the interface depth and trend of 2D finite-difference model and field data, and provide acceptable velocity estimations.

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