Wave mode separation for a surface with slope using the free-surface response

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INTRODUCTION

- Each one of the orthogonal components on multicomponent receivers can record P and S- wave modes. The separation of these two wave-modes would be advisable for processing and analysis.
- At the earth's surface the free surface has an effect on both wavefield phase and amplitude. This effect has been taken into account for wavemode separation by Dankbaar (1985), assuming a horizontal free surface, with receivers normal to it.
- However, if the receivers are placed vertically and there is a slope, as in the case of rough topography, this method is not applicable. This work extends the method to the case of a free surface with slope.
- It can contribute to improvement of the seismic data in rough terrain for P- and S-waves.

DANKBAAR'S METHOD

- Wave mode separation taking into account the free surface effect. The response characteristics of the vertical and horizontal receivers are defined as a function of the velocities Vp and Vs and horizontal slowness p, are defined as $R_z^P(p)$, $R_z^S(p)$, $R_x^P(p)$, and $R_x^S(p)$, where the R subscripts indicate the direction and the superscripts the wave mode.
- For example $R_x^P(p) = 4V_P p * E * N/R_0(p)$ where

$E = \left(T^2 - V_S^2 p^2\right)^{1/2}$, $N = \left(1 - V_S^2 p^2\right)^{1/2}$, and $R_0(p) = \left(1 - 2V_S^2 p^2\right)^2 + 4p^2 V_S^2 * E * N$.

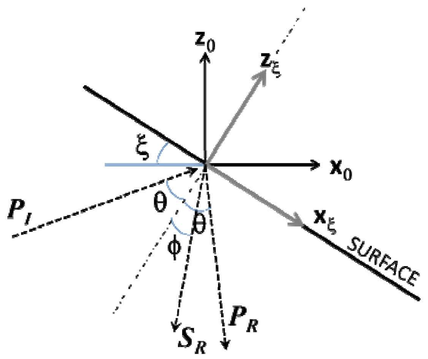
- Thus, the response of the vertical and horizontal receivers can be defined as:

$$U_z = P_{in} R_z^P + S_{in} R_z^S \text{ and } U_x = P_{in} R_x^P + S_{in} R_x^S ,$$

where P_{in} is the incident P-wave and S_{in} is the incident S-wave.

- Then if we know the response characteristics of the vertical and horizontal components, and the field data it would be possible to obtain P_{in} and S_{in} .
- It is carried using a plane wave decomposition method, such as Fourier or t-p transforms.

THE SLOPING SURFACE



- **FIG. 1:** The sloping surface case: The slope has an angle $\boldsymbol{\xi}$.
- P_I corresponds to the incident P –wave, P_R to the reflected P-wave, and S_R to the reflected S-wave.

- The sloping surface case is illustrated in Fig. 1 for an incident P-wave.
- Two orthogonal coordinate axes are defined, one corresponding to the vertical and horizontal directions (x_0-z_0) and the other one to the directions parallel and normal to the surface (x_ξ-z_ξ).
- The relations between the recorded components in the vertical and horizontal axes and the components in the axes normal and parallel to the surface are:

$$U_{z\xi} = U_{z0} * \cos\boldsymbol{\xi} - U_{x0} * \sin\boldsymbol{\xi} \text{ and } U_{x\xi} = U_{x0} * \cos\boldsymbol{\xi} + U_{z0} * \sin\boldsymbol{\xi}$$

- These equations allow us to rotate the data recorded in the vertical and horizontal directions, and then apply the method corresponding to the directions parallel and normal to the surface.

EXAMPLE

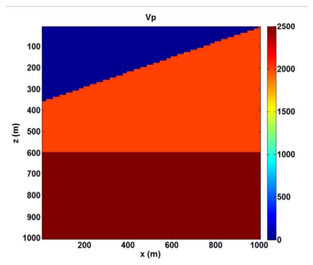


FIG. 2. Geological model to test the method, illustrated by the P-wave velocity.

- Sources and receivers are located on the sloping surface.

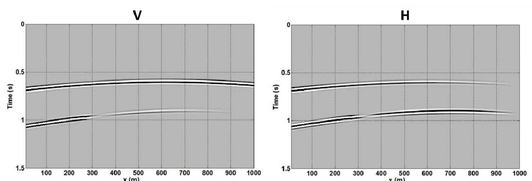


FIG. 3. Common receiver gathers at the receiver located in x=1000.

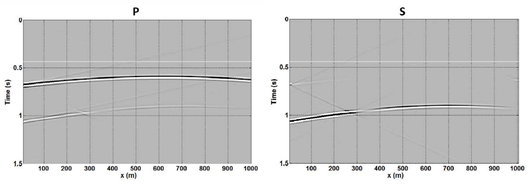


FIG. 4. P- and S- wave fields after the wave mode separation for the receiver at x=1000 m

CONCLUSIONS

- A method for wave mode separation for a sloping surface has been proposed, taking into account the free surface response.
- The examples, from a simple model and with data generated by using ray tracing, show expected characteristics for such a wave mode separation method.
- A possible application of this method is the improvement of P and S-wave data in rough terrain.

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