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Calculation of selected wavefields with the reflectivity method

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ABSTRACT

An important tool in the analysis and interpretation of seismic data is synthetic modeling, i.e. the simulation of the wave propagation under certain assumptions of the seismic medium. In the case of horizontally layered media these calculations can be done using the reflectivity method. Kinematic and dynamic effects are simulated with all wave propagation phenomena taken into account. Those are 3D wave propagation effects of surface waves, the direct wave, wave conversions and multiple reflections in 1D isotropic, elastic media.

INTRODUCTION

When modeling, it is important to perform a accurate selection of the wavefield to be calculated. Wavetypes, such as internal multiples, multiples of the free surface and converted waves can be disregarded without altering the remaining phases.
Predictive deconvolution is used as a tool for suppression of multiples in seismic data. It is founded on some assumptions that are not always appropriate in reality. These are assumptions about the convolution model, the wavelet (minimum phase and being time independent) and the properties of the seismogram (random noise and the series of the reflection coefficients must be uncorrelated). In spite of these concerns, this method has been applied successfully in many cases, although there are also a lot of examples where it fails. At this point the amplitude-consistent modeling with the reflectivity method can be usefully applied. One gets seismograms with defined and known properties and selected wavetypes that can be used for testing deconvolution methods and its underlying assumptions. The efficiency of the deconvolution can be directly judged since the desired output, namely the primary reflections of the medium, can also be obtained by the reflectivity method.

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MODELING

Figure 1 shows the selection of the wavefield for a marine 7 layer model with a weak contrast of the material parameters at the seabottom. The complete response of the medium is dominated by the multiples of the free surface. In the nearfield, there are reverberations, that have strong amplitudes despite of the low parameter contrast of the water and the underlying layer. For larger distances, the converted p-waves become important. Internal multiples play a minor role.

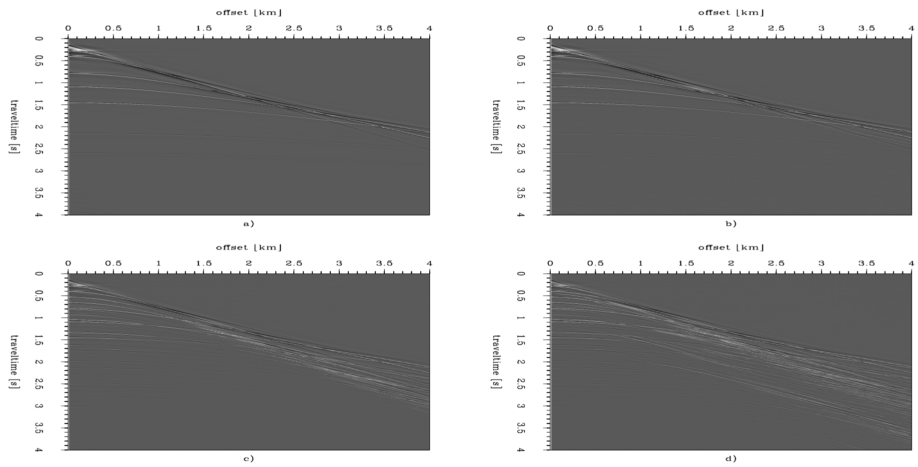

Figure 1: Different responses of a marine 7 layer model with weak parameter contrast at the seabottom: a) contains only primary reflections, b) internal multiples in addition, c) in combination with multiples of the free surface, and d) contains the full response of the medium including wave conversions.

We can learn something about the origin and the propagation of waves by variation of model parameters that modify the underground only slightly. This has been done for the depth of the waterlayer in a marine 7 layer model with strong seabottom contrast (Fig. 2). The response of the medium is dominated by seabottom multiples and their refracted phases independent of the water depth. This is true for their quantity as well as for the strength of occurance. With decreasing depth of the water layer, the number of visible reverberations and their head waves increases to a certain degree. From that onward, no additional phases are generated but the phases are compressed in the time domain. Converted phases and primary reflections of deeper horizons become clearly visible, even if they were hidden by reflections and refractions in the case of thicker water layers. Due to multiple reflections in the waterlayer all observed phases exhibit a band-like structure. This emphasizes the primary reflections in the case of a thin waterlayer.
For the modeling of the underground based on real log data the parameter of adjacent layers have been joined to produce a homogeneous layer for the input of the reflectivity method. This process is called ”Blocking”. The influence of different blocking rates on the response of the medium has been investigated using real log data. The data have been processed by a median filter and afterwards blocked equidistantly. It turned out that the thickness of the blocked layers should be larger than $\lambda/4$, otherwise, the response differs

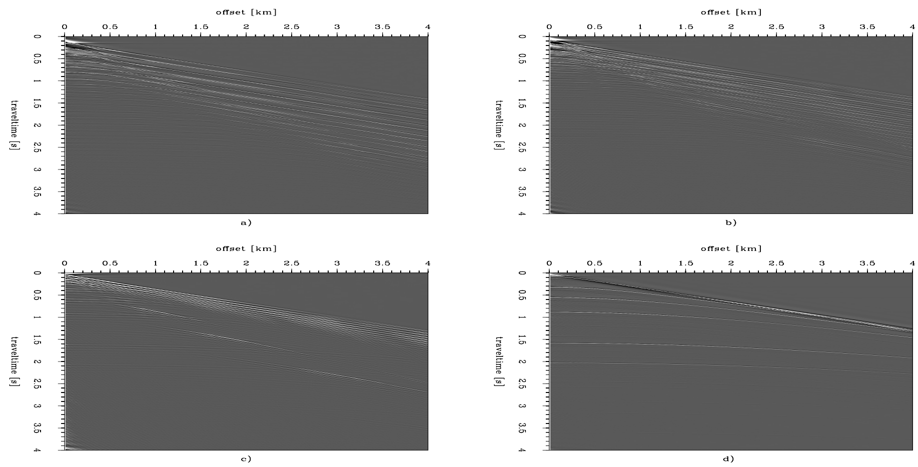

Figure 2: Change of the full wavefield of a marine 7 layer model with strong seabottom contrast for different water depths d_w: a) d_w =100 m, b) d_w =60 m, c) d_w =20 m and d) d_w =0 m.

qualitatively from the one produced by the original data. This is in contradiction to the accepted rule that the thickness of the blocked layers should not exceed λ/10. The number of reflection phases decreases due to the reduction of the total number of layers. The phases can be separated in the time domain and be attributed to different horizons. The velocity- and density data are smoothed with increasing thickness of the blocked layers. As a result, the strong oscillations of the parameters are reduced without destroying tendencies and detailed information on the layer boundaries.
If the shearwave velocities are not included in a log, its value has to be deduced from the known parameters for the modeling of the elastic response. The simplest assumption is V_P/V_S=const. It turned out that the absolute value of this constant had nearly no influence on the response of the medium.

PREDICTIVE DECONVOLUTION

If one wants to test a deconvolution algorithm, two ingredients are needed. First, a trace containing multiples, and second the ”optimal deconvolution result”, i.e. the primary reflections. Both can be computed separately using the reflectivity method preserving real amplitudes. It is therefore possible to study the influence of the filter parameters (length, prediction lag) as the fulfillment or non-fulfillment of the underlying assumptions on the quality of the suppression of multiples.
The predictive deconvolution and especially the prediction-error-filter can suppress multiples within a trace effectively. Both internal multiples and multiples of the free surface can be reduced, but the results in case of internal multiples is worse (loss of information and unwanted amplification of other phases). This is due to the properties of the autocorrelation function used for the determination of the filter coefficients.
The choice of the filter parameters strongly determines the efficiency of the deconvo-

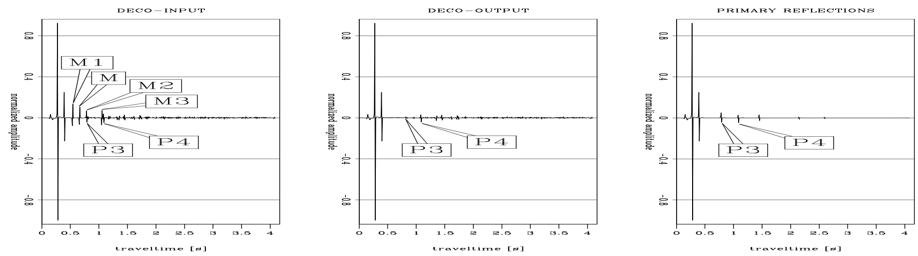

Figure 3: Predictive deconvolution using a model based prediction lag and an empirically determined filter length for best results. The input represents minimum offset and contains only primary reflections and multiples of the free surface (left-hand). The multiples are suppressed, but also the primary reflections P3 is destroyed since its traveltime coincides with the one if the double multiple M2 (diagram in the middle).

lution. Short filter lengths result in insufficient suppression but their amplitude is only modified whereas other phases are amplified. Too large filter lengths result in suppression of even primary reflections that do not coincide with multiples.

The prediction lag allows to select the events that are due for suppression. On the one hand, there is a model-based determination of this quantity, which is calculated from the traveltime of the signals. On the other hand, the prediction lag can be computed using the autocorrelation of the trace, which is called data-based determination of the prediction lag.

Independent of the choice of the filter parameters, only a small fraction of the multiples contained in a seismogram is affected by the deconvolution process. The gain in the loss of multiples is counterbalanced by the loss of primary reflections, or by the amplification of other multiples. On the other hand, noise statistics and the correction of the spherical divergence has hardly an effect on the quality of the predictive deconvolution.

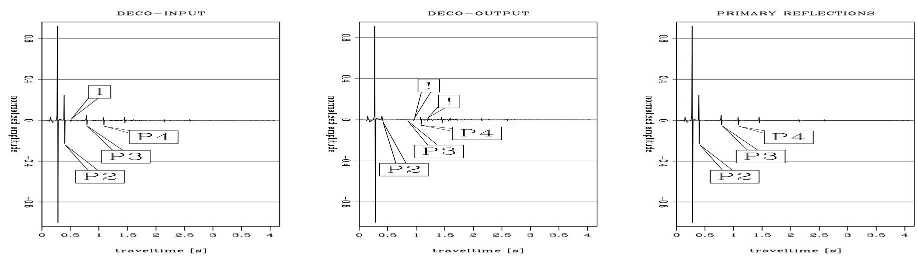

Figure 4: The input for the predictive deconvolution contains only primary reflections and internal multiples (left-hand). The filter output shows that the internal multiple I is removed according to the chosen prediction lag, but other internal multiples are amplified $\boxed{!}$. The primary reflections P2 and P3 are destroyed (middle).

REFERENCE

S. Laux, 1997, Calculation of selected wavefields with the reflectivity method, Diploma Thesis.