Applying source-receiver Marchenko redatuming to field data, using an adaptive double-focusing method

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The Marchenko method is a novel technique in geophysics that allows for the creation of virtual sources and virtual receivers at any position inside the medium, without the need to resolve overlying layers first (Broggini et al. (2012); Wapenaar et al. (2014)). The method is data-driven, only requiring the one-sided reflection response and a smooth velocity model. The core of the method is the retrieval of the focusing function, an operator that relates wavefields measured at the acquisition surface to Green functions inside the medium. These Green functions contain all orders of internal multiples and can be used to correctly redatum or image.

In this paper, we focus on the field data application of source-receiver Marchenko redatuming. Conventionally, a source-receiver redatumed reflection response is obtained by first applying the Marchenko method for receiver-redatuming and then performing a multi-dimensional deconvolution (MDD) for source-redatuming (Wapenaar et al. (2014)). The obtained reflection response is free from any interactions with the overburden. However, the MDD solves an ill-posed inverse problem (van der Neut et al. (2011a)), which makes it sensitive to imperfections in the data and the acquisition geometry. This is a problem for the field data application, since neither the data nor the acquisition geometry are ever perfect. In addition, MDD is computationally expensive.

Therefore, we investigate an alternative source-redatuming step that is more suitable for the field data application. We propose the double-focusing method, which introduces a second focusing step that seamlessly complements the first focusing step from the Marchenko method. Instead of using both one-way Green functions resulting from the Marchenko method in an MDD, we now convolve the upgoing Green function with the downgoing focusing function to retrieve a source-receiver redatumed reflection response. This method is less sensitive to imperfections since inversion is no longer required. Also, it is significantly cheaper.

Moreover, the properties of the selected wavefields make the double-focusing method particularly suitable for adaptive subtraction. Only two iterations of the Marchenko scheme are sufficient to find the kinematically correct wavefields. This is advantageous for field data, since every iteration of the Marchenko method convolves and cross-correlates the data with itself, thereby degrading the data quality. Amplitude updates that would otherwise be provided by subsequent iterations are replaced by adaptive subtraction in the curvelet domain (e.g., Wu and Hung (2015)). In addition, an adaptive filter can correct for amplitude mismatch due to incomplete data, inaccurate knowledge of the source signature or attenuation (Wapenaar et al. (2014a); van der Neut and Wapenaar (2016)). This makes the adaptive double-focusing method less sensitive to many types of imperfections that are typically found in field data compared to the MDD method.

We have successfully applied the proposed method to field data of the Santos basin offshore Brazil, where accurate imaging of the reservoir is hindered by internal multiples originating from the complex salt structure in the overburden (Cypriano et al. (2015)). Figure 1 shows the image of the reservoir before and after applying the adaptive double-focusing method. Red circles and arrows indicate areas where multiple removal is clearly visible. The most significant result is highlighted by a blue circle: here we have improved the geological interpretation in the area, despite an imperfect acquisition geometry and imperfect data.

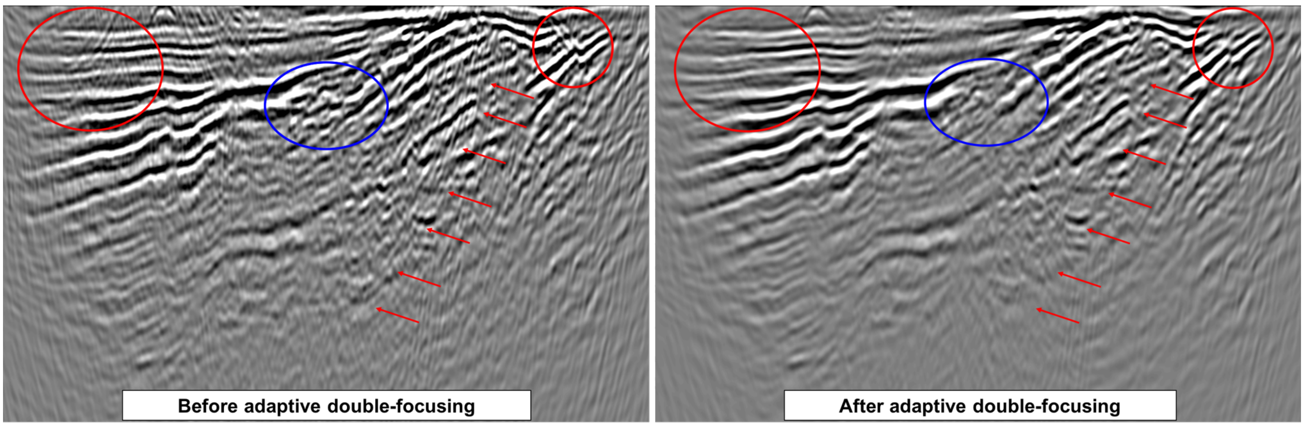

Figure 1 – *Images resulting from the application of the adaptive double-focusing method to 2D field data of the Santos basin.*

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