

# Pre-stack Land Surface and Interbed Demultiple Methodology An Example from the Arabian Peninsula

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## Introduction

This case study shows the application of data-driven multiple removal techniques to a land data set from the Arabian Plate. Strong surface and internal reverberations are removed using a standardised processing flow, while preserving the original geometry for subsequent processing. This paper highlights some of the practical aspects of applying these techniques in the production processing of land seismic data.

On land, strong surface multiples can contaminate the data when the near surface layer is consolidated and a strong surface reflector is present. In most land cases there is no sufficient difference between primary and multiple stacking velocities and thus multiple and primary reflected energy have similar moveout characteristics. Demultiple technologies; such as Radon application (and its enhanced versions) based on velocity discrimination and consequently curvature differentiation are likely to fail. In addition, long period surface multiples are often present which makes demultiple methods based on predictive deconvolution (either in  $t$ - $x$  or  $t$ - $\rho$ ) not always the optimal solution. Data-driven multiple removal methods like Surface-Related Multiple Elimination (SRME) and Interbed Multiple Elimination (IME) have proven to be valuable tools to remove multiples (surface and interbed) without using any type of *a priori* information about the subsurface. Figure 1, shows the types of multiple handled by:

- (a) SRME – All surface multiples
- (b) IME – interbed multiples.

However, because these techniques employ the recorded data in order to predict and then subtract the multiples, the pre-conditioning of the input data is paramount to the successful application of the method. In comparison with marine data, land datasets often exhibit highly irregular geometries, complex azimuthal distribution and poor signal-to-noise ratios.

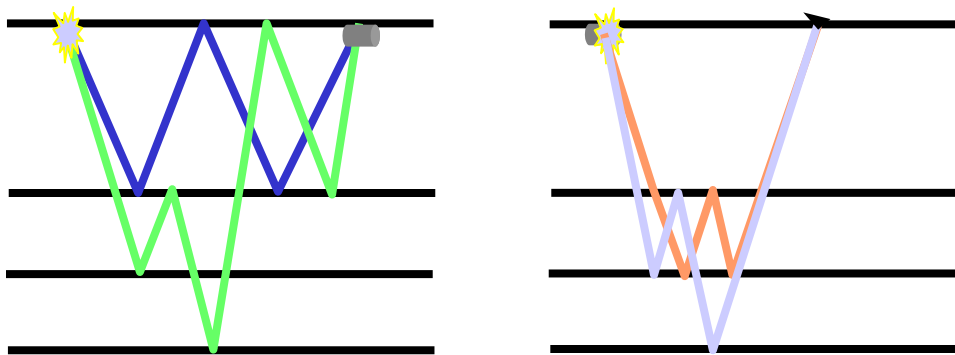


Figure 1. On the left, examples of ray paths of free surface multiples removed by SRME. On the right examples of ray paths of interbed multiples removed by IME.

## Surface and Interbed Multiple Elimination

In surface related multiple elimination (SRME), the multiple-contaminated data is used as estimate of the multiple-free data. After a 2D convolution of the multiple-contaminated data with itself, the predicted surface multiples are subtracted from the measured multiple-contaminated data in an adaptive way. For each user-defined window in time and space, a temporal filter is computed such that after convolution of this filter with the predicted multiples and subtraction of this result from the multiple-contaminated input data, a minimum energy is obtained. Considerable care must be taken in choosing the filter length and the window size. If the filter length is too long, it is possible to remove primaries, whereas if it is too short may lead to violation of the

minimum energy criterion when primaries and multiple are interfering. However, a properly designed adaptive subtraction process should lead to good primary amplitude preservation.

There are two common implementations of interbed multiple elimination (IME). Figure 2 illustrates the concept of boundary-related interbed multiple prediction, where interbed multiples generated by an identified (picked during interpretation) boundary are predicted. This procedure requires the multiple generator to be picked before the interbed multiple prediction can proceed.

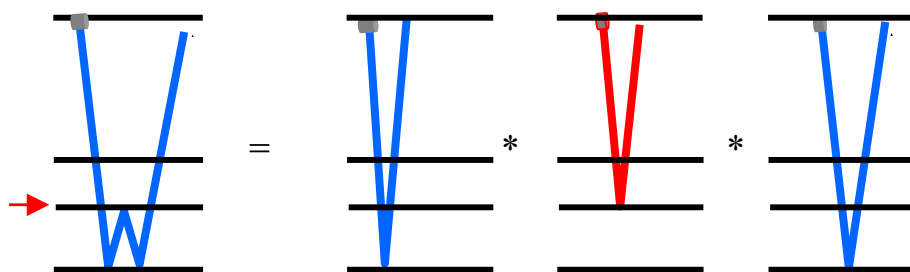


Figure 2. This figure illustrates the concept of boundary interbed multiple prediction. Note that interbed multiple generated by the indicated boundary (red arrow) can be composed of the three events through weighted temporal and spatial convolutions.

A second approach to remove interbed multiples is to assume a particular 'pseudo boundary' interface which does not necessarily have to follow a strong reflector (see Figures 3 and 4). The obvious advantage of this last approach is that less effort is required to pick such a 'pseudo boundary' as it may be a smoothed horizon between two strong reflectors, or even flat. Muting needs to be performed at the level of the 'pseudo boundary' interface (see Figures 3 and Figures 4a-4f).

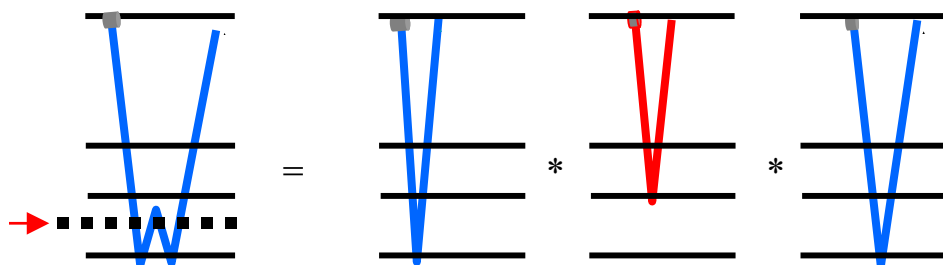


Figure 3. This figure illustrates the concept of pseudo-boundary interbed prediction.

### Data Example

For these data from the Arabian Peninsula, the pre-processing sequence consisted of application of statics, ground roll removal by  $f-k$  filter, and a noise burst removal. The data were contaminated by short noise bursts, of unknown origin, at sporadic times down the record and in random locations. To remove this noise, sub spectral balancing was applied to the data using sample-wise median thresholding within frequency sub-bands in time-frequency space. The data were then binned to the 3d processing grid and CDPs were gathered into super CDPs (SCDP) to decrease the offset spacing and enhance even more the signal to noise ratio. Next, Fourier regularisation was applied in order to regularise the offset distribution within the obtained SCDPs and thus allow to use SRME processing within each SCDP gather. Fourier regularisation allows the user to output data traces at any chosen grid spacing, thus it is possible to select an output trace distribution optimum for the SRME processing. After the prediction of the free-surface multiples, the next stage is the adaptive subtraction of the predicted multiples. The following options exist: 1) restore the original geometry to the predicted multiples by inverse regularisation, and apply the adaptive subtraction from the original (non-regular) data in CDP domain or in the SCDP, or 2) apply the adaptive subtraction in the regularised domain, create a difference section to obtain the subtracted multiples, de-regularise the result, and subtract it from the original data (Kelamis and Verschuur, 2000). The inverse regularisation is applied to restore the data back to the original trace positions. The corresponding stack sections namely, with and without free surface multiples are depicted in Figures 5(a) and 5(b), respectively. Figure 5(c) depicts the difference of the stack before and after the SRME application. A substantial reduction of surface multiple reverberations can be observed. When the surface related multiples have been attenuated the interbed multiples now stand out.

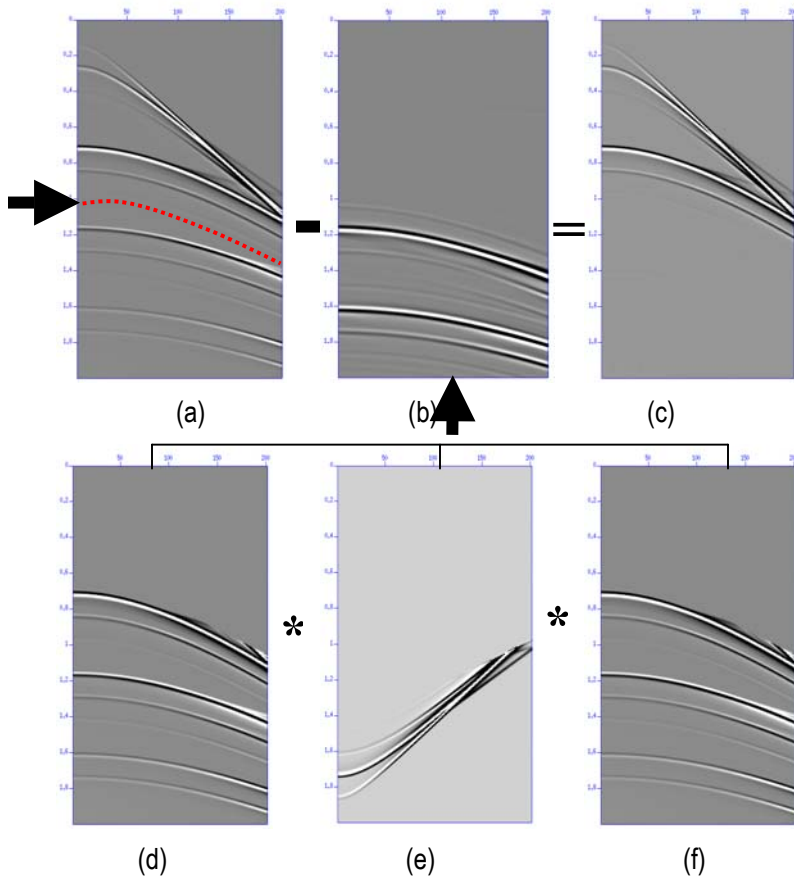
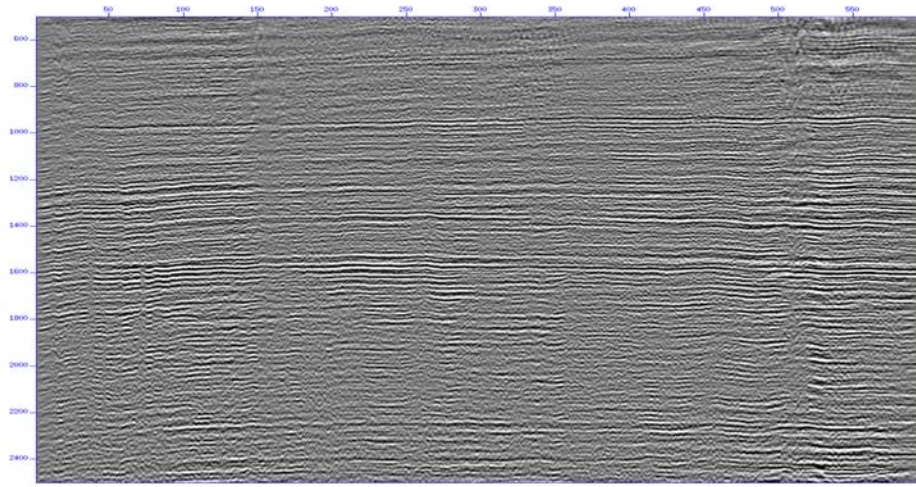


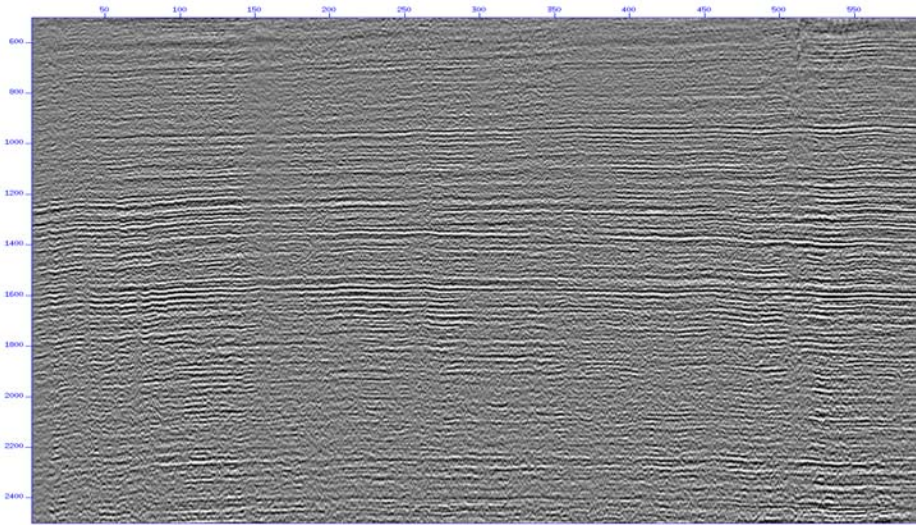
Figure 4 a). Input gather with primaries and interbed multiples. b) Predicted (computed) gather with interbed multiples which crossed the pseudo boundary (dotted line indicated by the red arrow). c) The output primaries only gather after the adaptive subtraction (a-b). This figure illustrates the ‘double’ convolution process of data for the ‘pseudo-boundary’ method. Data selected from below the pseudo-boundary (d) and (f) is convolved with the time-reversed data above the (chosen) pseudo-boundary (e).

The removal or attenuation of the interbed multiples can be addressed by an SRME related technique proposed by Jakubowicz (1998) and illustrated by Van Borselen (2002). The approach requires only the identification (i.e. picking) of the multiple generator(s), or alternatively, a ‘pseudo-boundary’ across which interbed multiples have propagated. Then, through a double convolution of appropriate gathers, internal multiples can be predicted followed by an adaptive subtraction step, similar to the one performed during the SRME application. The optimised processing strategy leads to efficient removal of either interbed multiples that are generated by a (chosen) internal reflector, or interbed multiples that have crossed a (chosen) pseudo boundary during wavefield propagation.

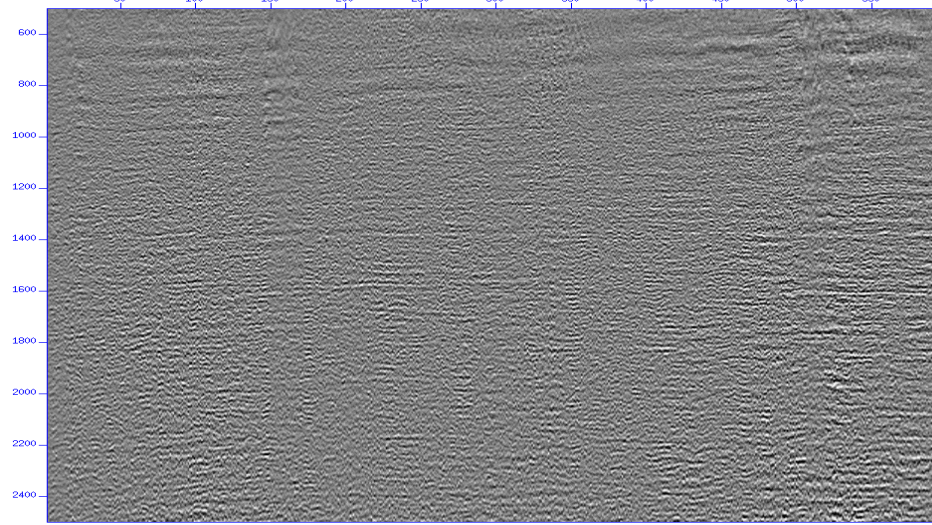
For this case study, it was deemed best to process the data using the later approach since the location of the main interbed generators were unclear. A Fourier regularisation step was also necessary during the application of Interbed Multiple Elimination (IME). After the identification of the pseudo-boundary, as depicted by the yellow line on Figure 6(a) above the target horizon, IME was run on the regularised SCDPs. To preserve geometry and maintain all azimuthal information, the predicted multiples are ‘de-regularised’ before the adaptive subtraction from the original (irregular) data. Figures 6(a) shows a stack of the pre-processed input data (same as Figure 5(a)). Figure 6(b) shows the stacked results after the application of SRME and IME with the pseudo boundary method as depicted with the yellow line shown in Figure 6a. Figure 6(c) illustrates the difference of the two sections. Figures 7 a, b and c are detailed sections which clearly illustrate the differences and the added value to the interpretation of the free surface and interbed multiple removal processes. Note the significant additional reduction of internal reverberations in the data.



(a)

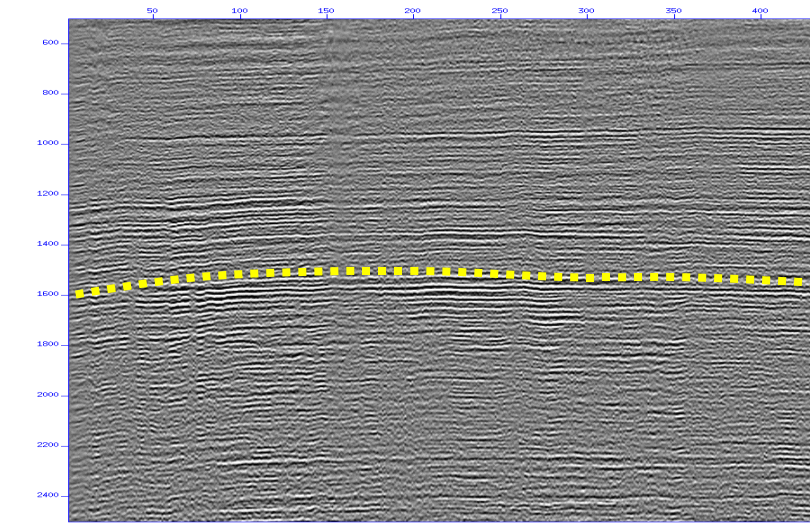


(b)

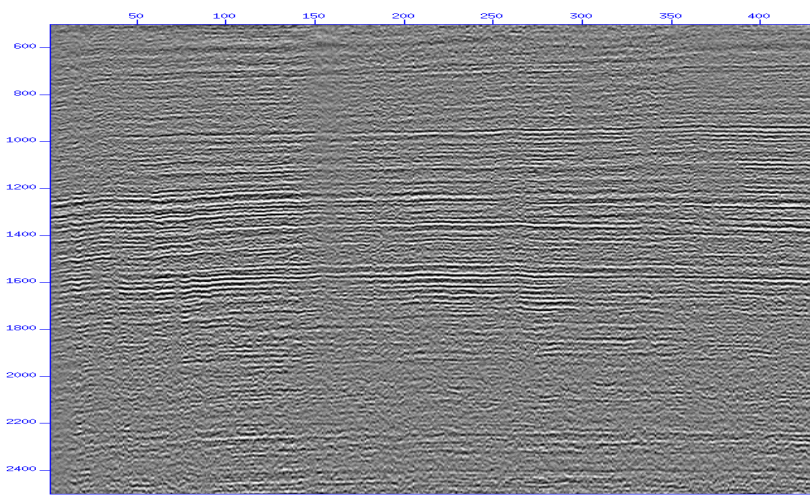


(c)

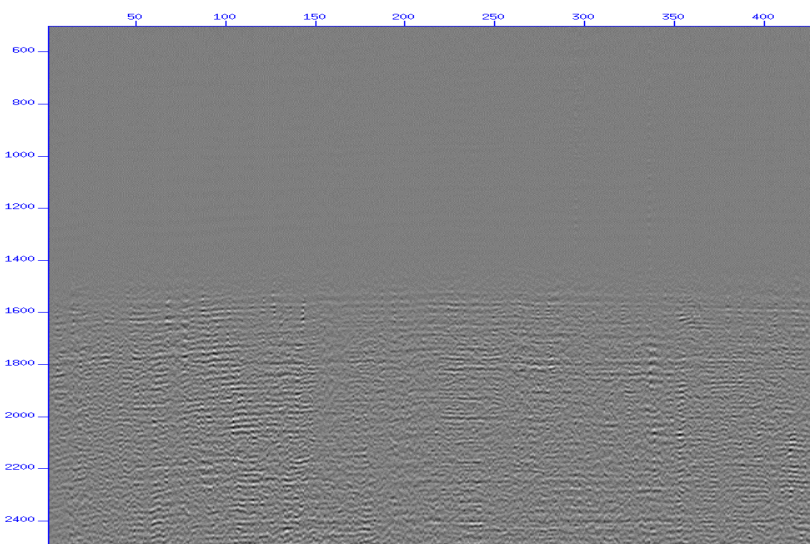
Figure 5. a) Input stack with surface and interbed multiples. b) Stack with surface multiples eliminated. c) Difference stack between a and b. Note some coherent and non coherent noise has been eliminated as well.



(a)



(b)



(c)

Figure 6 a) Same stack section as in Figure 5(a) with the pseudo boundary identified (yellow dotted line across the section). b) Stack section with surface and interbed multiples eliminated. c) Difference stack section of a – b. Note the significant additional reduction of free-surface and internal reverberations in the data.

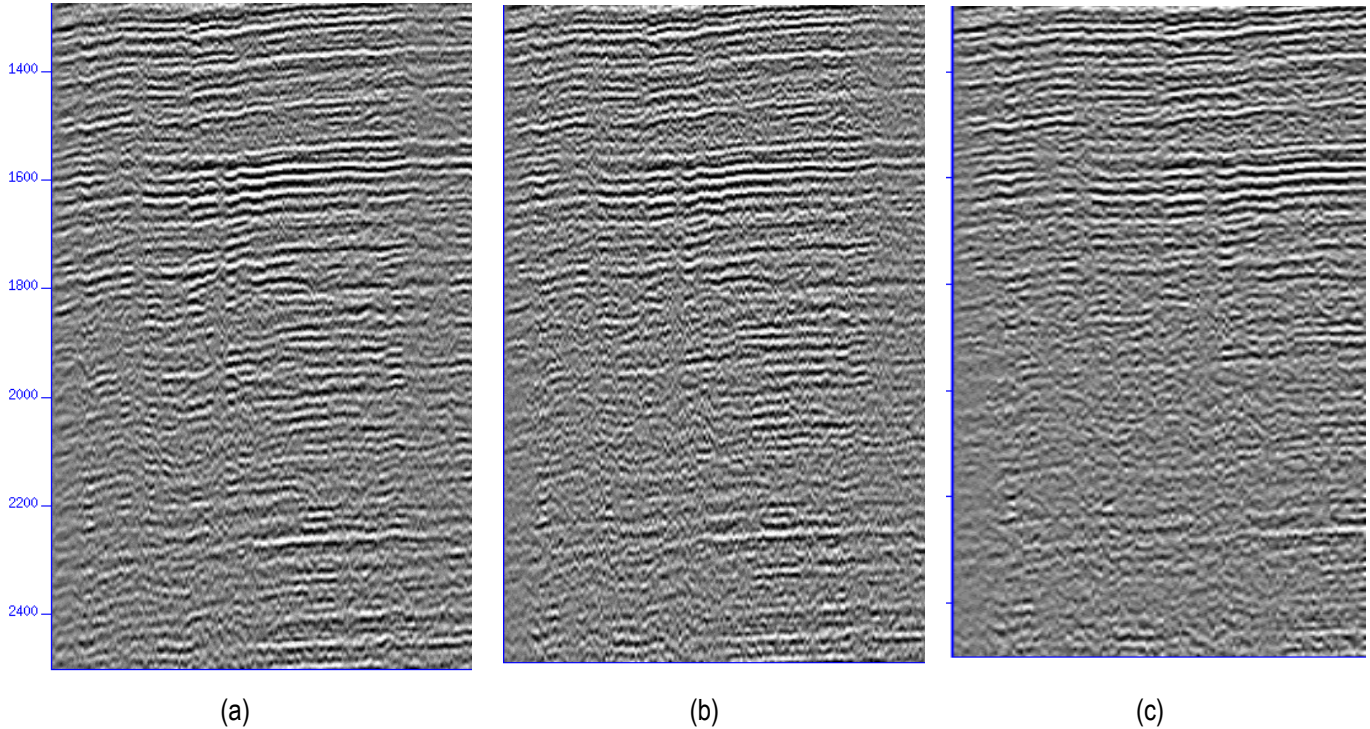


Figure 7. Close up sections of a) Stack section contaminated with free surface and interbed multiples. b) Stack section with Surface multiples removed and c) Stack section with surface and interbed multiples removed (assuming the pseudo boundary as depicted in Figure 6a).

### Conclusions

In situations during land data processing, where the primary and the multiple stacking velocities exhibit similar moveout characteristics, data-driven multiple removal techniques, such as, SRME and IME can be effectively applied in order to reduce surface and interbed multiple contamination and consequently enhance seismic interpretation. The main pre-processing steps include removal of spurious events and surface waves, surface consistent amplitude balancing and residual statics corrections. In addition, the use of Fourier regularisation and inverse regularisation on the multiple model estimates allows an effective adaptive subtraction and the preservation of geometry configuration for subsequent processing.

### ACKNOWLEDGMENTS

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