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RIASSUNTI ESTESI DELLE COMUNICAZIONI

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remove the effects of the near-surface velocity variations, and sometimes the near-surface coherent noise such as the Rayleigh waves. A more standard static correction solution was also tested: since the imaging and migration is performed at the topography and not at a CMP-consistent floating datum, the statics are computed between the actual position of source and receivers, an intermediate datum and a final smoothed topography or depth-defined, surface-consistent floating datum. The small scale near-surface velocity variations and the topographic irregularities are actually a key challenge of the CROP-03 dataset. And the conventional reflection-based residual static corrections struggle to compensate them unless an initial solution is successful. A tomography based and refraction-residual static solution is proven to be particularly effective in compensating for the near-surface effects. The effectiveness of the perturbation corrections is evident from the comparisons between the images created using data with and without the short period perturbations.

Then the noise attenuation is applied using an iterative strategy, starting from mild and short FX filters and rank reduction filters and avoiding large multichannel dip filters. This is essential to preserve low-amplitude primary energy, including reflections and diffractions, needed to image the targets.

To ensure a correct imaging of the complex structures, an accurate, horizon consistent pre-stack migration velocity picking is performed.

Conclusions. The results are very encouraging, as we managed to obtain a considerable improvement of the images: the coherency and continuity of events, with locally large dips and complex structures. The improvement of the images reveals shallow structures that were not seen in previous processing, which were targeting mainly deep crustal features.

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EXPERIENCE OF FWI ON MARINE SEISMIC DATA USING A ROBUST OPTIMIZATION PROCEDURE

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Introduction. Full Waveform Inversion (FWI) represents an important tool to obtain high resolution model of subsurface from active seismic data (Tarantola, 1986; Virieux, *et al*. 2009). In the last years many aspects about FWI have been studied concerning the implementation of efficient modelling algorithm (Chaljub *et al*, 2007; Moczo *et al.*, 2007) and the formulation of inversion procedures (Fichtner, 2010). However, its application to real data requires specific operations on the seismograms to obtain an observed data that can be reproduced by a modelling algorithm. Besides, the use of an iterative gradient method requires the estimation of a starting model that must be as close as possible to the valley of the global minimum of the misfit function (Beydoun *et al.,* 1988).

In this work, we present an application of acoustic FWI on a marine seismic data. Specific processing operations are applied on both predicted and observed data to increase the robustness of the inversion procedure against the cycle skipping phenomenon, thus improving the reliability of the final model estimation. The predicted data are obtained by solving the 2D acoustic wave equation, whereas in the local optimization procedure the steepest descend algorithm is employed, using the L^1 norm difference between the predicted and observed data to compute the misfit function. As the starting model, we use a model obtained in a previous work (Tognarelli *et al*., 2015; Mazzotti *et al*., 2017) by a global optimization method based on genetic algorithms. To validate the final model, we pre-stack depth migrate the data using the final estimated velocity field, and we check the improvements of the flattening of the events in the common-image-gathers (CIGs).

The seismic data. The data used pertains to an inline extracted from a 3D marine survey. From the entire data set, we select 56 shot gathers evenly distributed along the line with a source-receiver offset varying from 180 m to 2000 m; in this way, a total of 3910 traces are considered. The receiver interval is 25 m, the time sampling is 4 ms and the record length is 1.6 s. The sea bed is flat with a depth of about 300 m. The sources and the receivers are located 12.5 m under the sea surface.

A specific time window is defined to focus the inversion on the diving waves and on the shallow reflections of the data. The window length varies from a minimum of 0.1 s to a maximum of 0.5 s. Fig. 1a displays an example of a raw shot gather, whereas Fig. 1b shows its amplitude spectrum. In Fig. 1a the red contour represents the time window used to select the data for the inversion.

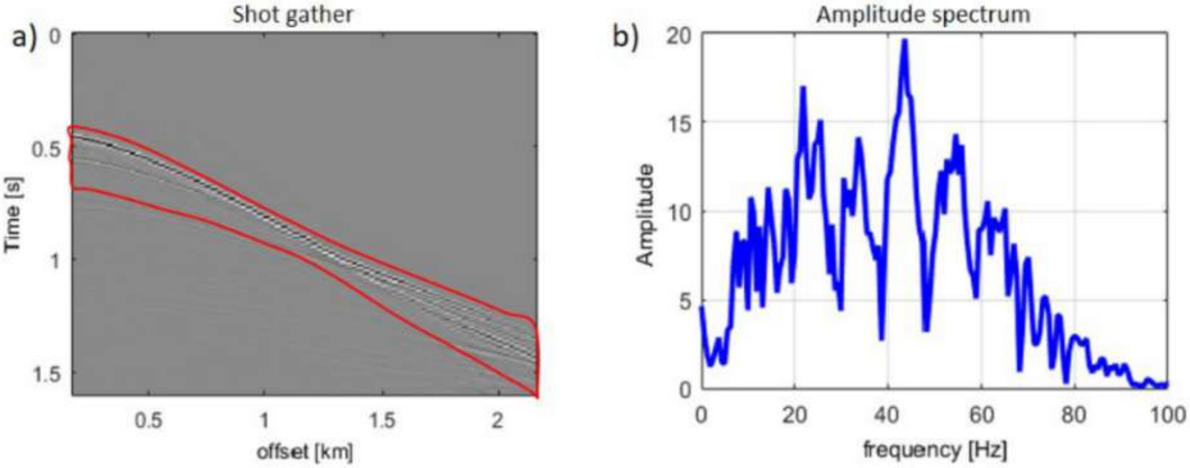

Fig. 1 - a) A shot gather of the inline data and b) its amplitude spectrum. The red polygon delimits the portion of the seismogram considered in the inversion.

Modelling. The synthetic data are obtained by means of an explicit, 2nd order in time, finite difference algorithm which is used to solve the 2D acoustic wave equation. The model dimensions are approximately 7 km in length and 1.2 km in depth. The modelling grid is made by 242x40 nodes, with a uniform grid size of dx–30 m. The sea bed is situated at the 10th row of the grid. The order of approximation of the spatial derivatives is optimized to reduce the numerical dispersion. We put absorbing boundary conditions on the lateral and bottom sides of the model and reflecting boundary conditions at the top side to simulate the sea-air interface. More details of the numerical scheme can be found in (Galuzzi *et al*., 2015). The source wavelet is estimated from the sea-bed reflection.

Misfit function. The data misfit is the L^1 norm between the predicted and the observed data. However, for both data a processing sequence that includes low pass filtering up to 10 Hz, trace-envelope computation and trace-by-trace normalization is applied. The filtering and the envelope operations are used to reduce the cycle skipping effect and, in general, the non-linearity of the misfit function. This gives a more robust inversion procedure than using the signal waveform, which can also be applied to data where the S/N ratio at low frequencies is low.

Initial model. The initial model plays an important role in a high non-linear inverse problem such as FWI. To assure the convergence of a local optimization method, the starting point must

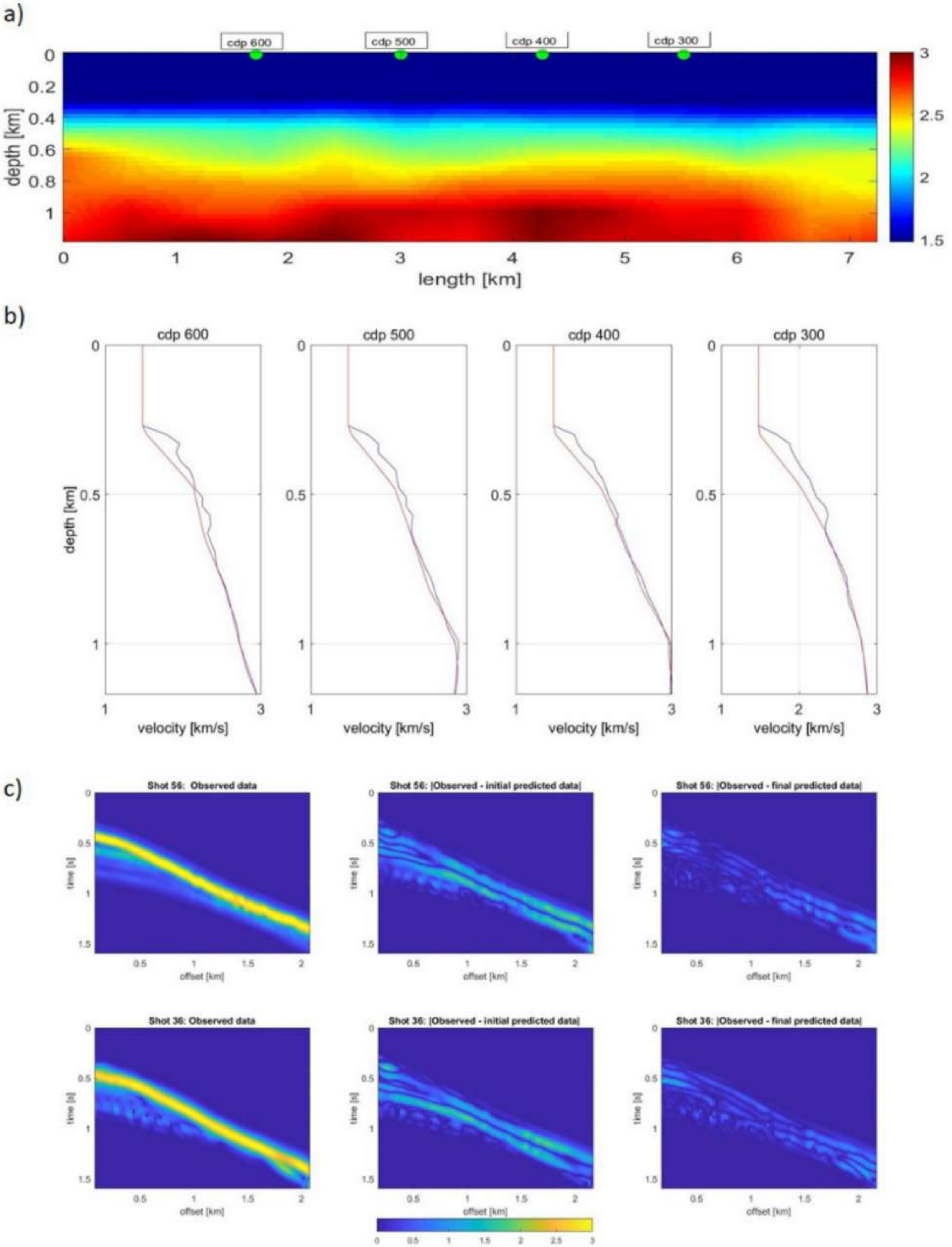

Fig. 2 - a) Starting velocity model for the local optimization procedure. b) Comparison of four vertical velocity profiles: the red curves represent the velocity profiles related to the starting model; the blue ones represent the velocity profiles related to the final model. c) Observed data for two shot gathers (left) and difference between predicted and observed data before (center) and after (right) the local inversion.

be on the same valley of the misfit function as the global minimum. This means that the initial model must be accurate enough to give a good match between the observed and predicted data. To attain this, in our work, we use the velocity model obtained from a previous inversion (Fig. 2a), that makes use of the application of genetic algorithms on a coarse grid (Sajeva *et al.*, 2016). The details and the results can be found in Tognarelli et. *al*. (2015) and Mazzotti *et al.* (2017). The model accuracy is checked by the degree of flattening of the events on the CIGs, obtained after the pre-stack Kirchhoff depth migration (PSDM). Fig. 3a shows 11 CIGs evenly spaced along the profile up to 1.2 km of depth (the maximum depth of the modelling grid), computed with the starting model of Fig. 2a. In Fig. 3a a trace-by-trace normalization and a gain is applied for display purposes. A preliminary alignment of some events can be observed, but the gathers still present complex move-outs that can be improved using a local FWI based on a gradient line-search method.

Inversion procedure and results. As a local optimization method, we use the steepest descend algorithm (Nocedal *et al.,* 2006), where the descend direction corresponds to the negative direction of the gradient of the misfit function and the step length is obtained by a line search that satisfies the Wolfe conditions (Wolfe, 1969). The gradient is computed using the adjoint method (Tromp *et al.*, 2005; Plessix, 2006). The unknowns are the model velocity values situated under the sea layer, for a total of 242x30 unknowns. The velocities range between 1480 m/s and 3500 m/s. We perform 500 iterations for the minimization procedure. Fig. 2b shows a comparison of four vertical velocity profiles obtained at the end of the inversion process, related to four CDP positions along the seismic profile (the green points in Fig. 2a). The long-wavelength structure of the starting model is not significantly changed, except for the upper part just below the sea bed where a consistent change of the velocity values can be noted. Fig. 2c shows the difference between the observed and predicted data for two shot gathers before and after the optimization procedure, where the decrease of the differences of the inverted data can be observed. Finally, Fig. 3b shows the CIGs obtained by pre-stack depth migrating the data, using the final velocity model. Comparing Fig. 3a and Fig. 3b, a significant improvement of the horizontal alignment of the events can be noted, especially for the events just below the seabed reflection and located in the central part of the model.

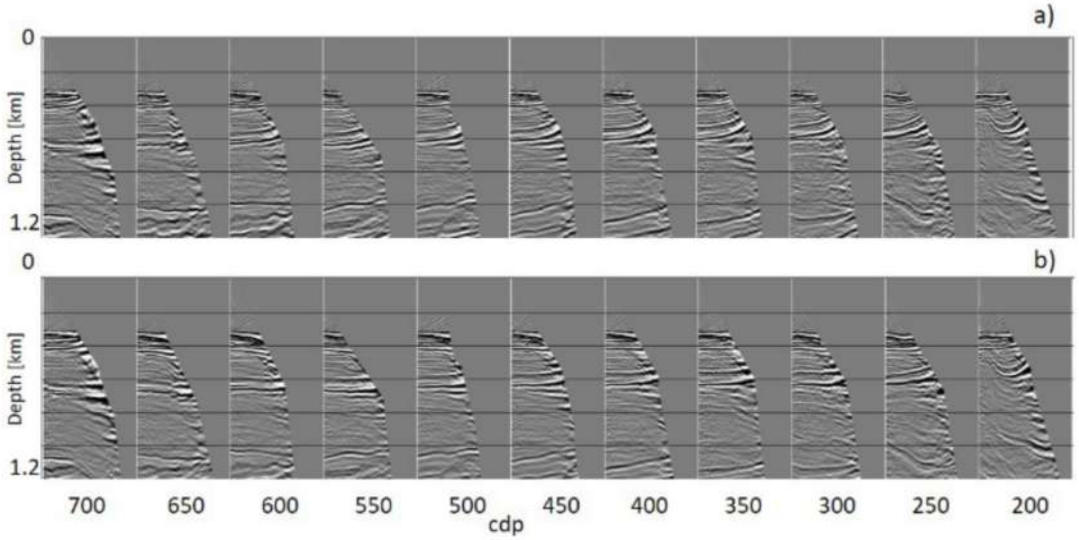

Fig. 3 - CIGs derived from PSDM (Kirchoff) using (a) the starting velocity model for the local optimization and (b) the final velocity model obtained at the end of the optimization procedure.

Conclusion. In this work, we have described an acoustic FWI experience made on a 2D seismic marine data set extracted from a 3D volume. We designed a specific processing sequence to be applied on the observed and the predicted data to reduce the non-linearity of the misfit function. This allows to make the whole procedure more robust against the cycle skipping problem, and applicable at low seismic frequencies where the S/N ratio could be low. Starting from a velocity model obtained by a previous global optimization procedure based on genetic algorithms we estimated, by means of a gradient-based method, a final model whose quality is assessed by the good correspondence between the predicted and the observed data and by the improvements of the horizontal alignment of the events in the CIGs.

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ANALYSIS OF GLACIMARINE SEDIMENTS BY TRAVEL TIME REFLECTION TOMOGRAPHY IN THE EASTERN ROSS SEA (ANTARCTICA)

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Introduction. This work presents the results of a study whose aim is to investigate the nature of acoustic facies and of their seismic interfaces, from geophysical analysis in order to reconstruct P waves velocity of glacial sediments across the drill site DSDP270 (Hayes and Frakes, 1975), in the Eastern Ross Sea (Antarctica).

The applied technique, combined with lithological information from the drill site, allows to identify petrophisical properties (e.g. compaction, fluid content) related to the depositional process, that originated the different acoustic facies. The correlation of seismic facies in the