Summary

The high-density moveout parameter fields provided by automatic picking tools require appropriate filtering which is able to preserve the moveout and the geophysical meaning of the parameters. In the case of two-parameter processing: velocity \( V \) and anellipticity \( \eta \), this task is more difficult. Because we are able to pick simultaneously \( V \) and \( \eta \) using uncorrelated parameters, we propose in this paper an extension of this approach to the simultaneous filtering of \( V \) and \( \eta \). Variogram studies point to the two-parameter filtering route. Using geostatistical techniques on two new uncorrelated fields, we are able to process simultaneously the full moveout parameters \( V \) and \( \eta \). Before any filtering, the reliability of raw automatic picks, which correspond to the local estimation of \( V \) and \( \eta \), is improved by introducing the lateral coherency and the Dix-inversion abilities of both parameters. The filling of both \( V \) and \( \eta \) fields, is done simultaneously using 3D ordinary kriging on the uncorrelated parameters. In order to preserve the moveout resolution, the uncorrelated parameters are filtered using 3D factorial kriging. Different kinds of noise patterns are removed. The back-projection of the uncorrelated filtered fields to \( V \) and \( \eta \) allows the requested simultaneous filtering. The time processing using high-density fields, for far offset focusing as well as for steep dip migration, is feasible.

Introduction

The moveout of the large-offset data is no longer hyperbolic and requires two parameters: velocity and anellipticity (Alkhalifah 1997). The focusing process has been significantly improved by the use of automatic two-pass techniques based on analysis of residual moveout: first near-offset residuals due to the velocity, second residuals at far offset due to \( \eta \) alone (Le Meur et al., 2001). In order to reduce the strong variability of the automatic \( \eta \) field obtained by the two-pass techniques, Siliqi et al. (2003) are proposing a new one-pass automatic bispectral picking. The new automatic dense picking of \( V \) and \( \eta \) is based on the full non-hyperbolic moveout. Moreover, the use of some internal time parameters, such as the residual moveout at the largest offset \( (dtn) \) and the zero-offset travelttime at shifted hyperbola coordinate \( (\tau_0) \), affects all offsets.

However, mis-picks, interference and various artifacts contaminate the parameter fields provided by automatic pickings. Geostatistical techniques are usually employed to control their quality as well as to perform the filling and filtering of dense fields (Le Meur and Herrmann, 2002). This approach has been successfully applied on velocity fields. The daily practice of two-parameter processing shows how critical it is to separately filter \( V \) and \( \eta \). The moveout quality at far offsets is not always preserved. Nevertheless, since Siliqi and Bousquié (2000) introduced the anelliptic velocity \( V_{an} \), a Dix-type velocity, which is a special combination of \( V \) and \( \eta \), a filtering scheme for \( \eta \) has been proposed (Le Meur et al., 2001). This technique stabilizes the filtering of \( \eta \) but it cannot restore the errors already done on \( V \).

Uncorrelated moveout parameters \((dtn, \tau_0)\)

The bispectral analysis proposed by Siliqi (2001), which represents a double-scan of \( V \) and \( V_{an} \) is shown in figure 1b. This picture illustrates the correlation between these parameters: all plausible \( V-\eta \) solutions are located through the skewed red pattern. On the other hand, the \( dtn-\tau_0 \) panel demonstrates the non-correlation of these new moveout parameters (figure 1a). The best \((dtn, \tau_0)\) pair seems to be much better constrained. The \( dtn \) resolution is striking and the variation of \( \tau_0 \) is restricted to a small area around the maximum of the semblance. In spite of the stretched pattern the \( \eta \) resolution remains acceptable. It is enough to compare the gap between the zero and the estimated \( \eta \) on both panels.

Figure 1: Bispectral panels allowing the picking of \( V \) and \( \eta \). The scanned parameters cover the same range of \( V \) and \( \eta \).

a) new approach \((dtn, \tau_0)\) - time axes.

b) current approach \((V, V_{an})\) - velocity axes.
The lateral extension of $dm$ and $\tau_0$, presented in figures 2a and 2b, illustrates the differences and similarities of both fields. In order to analyze their features, we propose to compute experimental variogram maps on $dm$ and $\tau_0$ residual scatters obtained after removing a drift estimated on the same support. The spatial behavior seems to be different for the two maps (figures 3a and 3b). The ranges of the main geological structures are different as well as the main anisotropic axes. A difference between X and Y range is observed for the $\tau_0$ parameter, which is not the case for $dm$, where the variogram map is practically circular. Moreover, the $dm$ anisotropic axes are slightly tilted. The analysis of these experimental variograms shows that the 3D variogram modeling for the filling and the filtering steps have to be different for $dm$ and $\tau_0$. These processes can be completely independent from each other and finally $dm$ and $\tau_0$ fields can be considered as uncorrelated, especially for the modeling of the organized noise.

**Simultaneous filling and filtering of V and $\eta$**

The first step is the simultaneous filling of empty areas, where the automatic picking failed or various QC's based on lateral coherencies and Dix-inversion abilities removed values. $V$ and $\eta$ fields are simultaneously filled using the 3D neighborhood of $dm$ and $\tau_0$. Using experimental variograms or adequate a-priori variogram-modeling, the filling of $dm$ and $\tau_0$ is performed separately using the 3D ordinary kriging. Thanks to this technique, each data point is weighted according to its influence on the 3D neighborhood. The weights take into account the spatial behavior of the field (Matheron, 1963). Moreover, this exact interpolator, which is an unbiased version of the statistical average, does not change any original picked value.

The goal of the filtering step is the removal of the non-geological features, which corrupt the full $dm$ and $\tau_0$ fields. More advanced techniques, such as 3D factorial kriging, seem to be appropriate for this task. Separate modeling of the $dm$ and $\tau_0$ 3D experimental variograms allows filtering of outlier patterns and directional artifacts without harming the small-scale variations of these fields. The optimal filtering of the uncorrelated parameters $dm$ and $\tau_0$ corresponds to the requested simultaneous filtering of $V$ and $\eta$. Time slices on $V$ and $\eta$ fields show the benefits of this approach: various artifacts are removed and high-frequency geological content is preserved (figures 4a and 4b).

The advantage of the non-hyperbolic over the hyperbolic moveout on long streamer data is demonstrated in figures 5a and 5b. Note that the use of dense $V$ and $\eta$ fields succeeds in flattening events for the full far-offset (7 km) without any use of mute functions. The focusing improvement at far offsets is remarkable when the time slices extracted from the near and far stack volumes are compared (figures 6a and 6b). The amplitude balance between the near and the far stack is reinforced as well as the S/N ratio. Geological feature interpretation as well as fault location definition benefits from the increase in far-offset resolution.

**Conclusions**

The focusing of the large offset data requires the handling of accurate parameters $V$ and $\eta$. Automatic picking on bi-spectral panels of uncorrelated parameters in the shifted hyperbola coordinates increases the sensitivity of the analysis. Moreover, mis-picks and outlier patterns due to the locally independent measurement must be removed. Geostatistical techniques for the filling and the filtering must be performed on uncorrelated parameters. The different kinds of outliers and noise could be efficiently removed on decoupled parameters to obtain an optimal filtering of the $V$ and $\eta$ fields. These filtering methods have a clear impact not only on the resolution of the attributes but also on its effectiveness in delivering a higher quality image stack. The far-offset/angle stacks on real data have shown the benefits of our filtering procedure. It is clear that AVO analysis will benefit from this high accuracy in $V$ and $\eta$ fields.

**References**


Le Meur, D. and Herrmann, F., 2002, Pre-conditioning of the densely sampled stacking velocity field. 64th EAGE Annual Meeting.


Siliqi, R., 2001, Technological leap in time processing focuses the data throughout anisotropic media: First Break, 19, No. 11.

Figure 2a: Time slice on the raw $dtn$ field. White color corresponds to empty area.

Figure 2b: Time slice on the raw $\tau_0$ field. White color corresponds to empty area.

Figure 3a: 2D variogram map on residual $dtn$. Main anisotropic axes are in white.

Figure 3b: 2D variogram map on residual $\tau_0$. Main anisotropic axes are in white.

Figure 4a: Time slice on the final filtered velocity field superimposed on the stack section.

Figure 4b: Time slice on the final filtered $\eta$ field superimposed on the stack section.
Figure 5a: Hyperbolic NMO, using dense velocity picking. Residuals at far offset are due to the anisotropy.

Figure 5b: Non-hyperbolic NMO, using dense bispectral picking. The gathers are flat for all offsets.

Figure 6a: Time slice on the near offset stack.

Figure 6b: Time slice on the far offset stack.