

A New Way of Compensating for Water Column Variation by Velocity Estimation of Sea Layer

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SUMMARY

Compensating for water velocity variations remains a key challenge in seismic data processing, where the water velocity varies over time. In a 3D seismic survey, adjacent sail lines are recorded at different times, and subsequently the recorded wave-field will be different. To take this effect into account at the seismic processing stage, it is necessary to estimate the water velocity. This paper proposes a new method of estimating the water velocity that can be used to compensate for the effect of water velocity variation using a novel water layer replacement method. When the water bottom becomes more complex, the established techniques underperform as they rely upon accurate water bottom model. In this paper it is demonstrated that the correct approach is to estimate the water layer velocity in migrated space. The method is also desirable for 4D processing and projects requiring merging of multiple datasets from many different vintages.

Introduction

The water velocity is a function of physical properties such as temperature and salinity. These physical properties can vary with time; hence water velocity will also vary as a function of time. In a 3D seismic survey adjacent sail lines can be acquired at different times, ranging from days, weeks or even months apart. Consequently, data which are spatially adjacent but acquired at different times may experience a change in water velocity and therefore the recorded travel time to the same reflection point could be different. The effect can be easily observed as lateral discontinuity (jitters) on cross line sections or on 3D CDP gathers. If the variability in water velocity is not taken into account during seismic processing, any travel time discontinuity will degrade the quality of process such as stacking and migration (Wombell, 1996).

When considering 4D seismic campaigns, the base and monitor surveys are acquired typically years apart, which gives opportunity for diversity in the magnitude of water velocity with respect to time. It is known that the quality of any 4D signal is sensitive to and reliant upon minimisation of timing differences between the vintages of 4D seismic surveys. In this case it becomes critical to correct for the water velocity variation between the surveys requiring accurate estimation of the water velocity. In this paper we present a method to estimate the water velocity, to improve the robustness and quality of 4D attributes. The method is also advantageous for depth velocity model building (VMB) and imaging of an area comprising several surveys of varying vintages.

Various methods have been proposed (Wombell, (1996); Xu and Pham, (2003); Fried and MacKay, (2003); Ritter (2010)), which would partially solve the problem. Most of these methods underperform in the presence of a complex water bottom as they either are reliant upon an accurate water bottom interpretation or estimating velocity from un-migrated data where significant reflector dip would compromise accurate velocity derivation. Furthermore most of the previous methods assume that velocity does not vary significantly within an acquisition sail line which is not always a valid assumption. For example when the sea bottom is significantly varying along the shooting direction the vertical variation of water velocity should not be ignored.

In this paper a method to estimate the water velocity in the migrated domain is proposed to avoid the assumptions of the previous methods discussed above. It should be noted that water velocity variation might not be the only source of travel time shifts. Tidal variations can also cause travel time variations (Lacombe et al. 2006). All the results presented in the paper have been shown after tidal static correction applied using tide tables.

Velocity estimation of sea layer

Water velocity can be better estimated in the migrated domain especially in the presence of a rugose water bottom; additionally, in the migrated domain, the water velocity estimation is not biased by dip effects. However, full 3D migration will not be suitable to address the problem presented here as such a migration will typically require contribution of data from several adjacent sail lines using the same velocity field, whereas in this case water velocity will be different for different sail lines.

In the proposed method, we perform a migration for each sail line independently to optimally image the water bottom using an initial water velocity function. Common Mid-Point (CMP) gathers are generated for central subsurface line of each sail line. This method requires the acquisition spread to be wide enough in order to be able to produce an optimal image of water bottom event. Typical acquisition configurations tow at least 10 cables with 100m separation thus giving 900m of data for the cross line aperture. Such aperture is typically sufficient to image the water bottom reflection correctly.

Once migrated, a velocity update is performed to generate a velocity profile along the sail line. Iterations of migration and velocity update can be performed if required. Generally one or two iterations are sufficient when the initial water velocity model is a close representation of the true

water velocity. Once the water velocity has been derived, the correction for water velocity variation is implemented using a water layer replacement method (Lacombe et al. 2006). The goal is to replace the estimated water velocity with a “reference velocity”. The methodology used for velocity replacement is described as follows:

- Data are NMO corrected using the derived velocity
- A static is applied to compensate for the velocity difference at zero offset between the reference and derived velocity, which is computed as follows

$$\Delta t = 2 * Z_{wb} * \left(\frac{1}{V_{ref}} - \frac{1}{V_{est}} \right)$$

where Δt is zero offset time shift in "sec"

Z_{wb} is depth of water bottom in m

V_{ref} is water velocity which will be used as reference velocity for water column

V_{est} is derived water velocity for each sailline

- A reverse NMO correction is then applied to data using reference velocity

It must be noted that the reference velocity is arbitrarily selected but should be a typical value for the survey area. In 4D processing, the data will be time-shifted to a common datum if the same reference velocity is used for the base and monitor surveys. This is essential to ensure optimal repeatability and consequently robust derivation of 4D attributes. This method does not rely on very accurate interpretation of the water bottom, which can easily be compromised by residual tidal statics.

Results on field dataset

The application of the proposed method is shown using two datasets from the North Sea. The first dataset has a very rugose water bottom, which means that any method, which relies upon water bottom interpretation, will underperform. Figure 1 shows the velocity profile obtained for one sail line using the proposed method. The water velocity profile clearly shows a good correlation with the shape of the seabed reflection. (N.b. we expect to observe decreasing water velocity with increasing water depth). Figure 2 shows seismic data along the cross line direction before and after water layer replacement is applied. Arrows point to the location of discontinuity due to water velocity variations (boundary between sail lines).

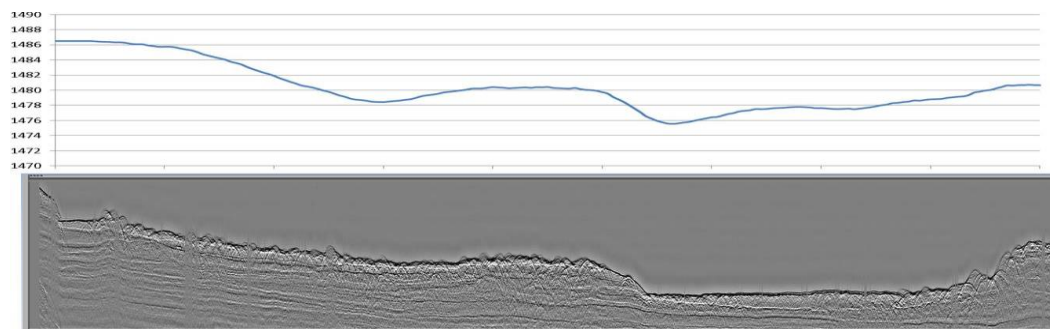


Figure 1 Velocity profile obtained from method for one sail line. Top image shows the velocity profile along sail line, whereas bottom image shows water bottom profile for the same sail line

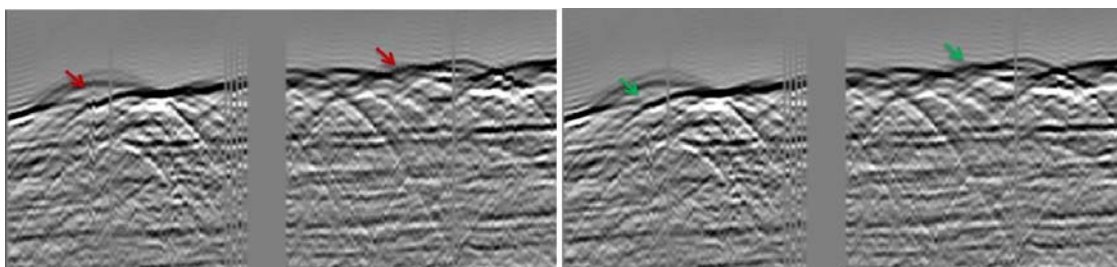


Figure 2 Cross line section from near offset (~850m) cube before (left) and after (right) water layer replacement. Arrows point at the location of sail line boundary

Figure 3 shows some example of 3D CDP gathers before and after water layer replacement. One can clearly observe that gathers have fewer discontinuities after the new workflow has been applied.

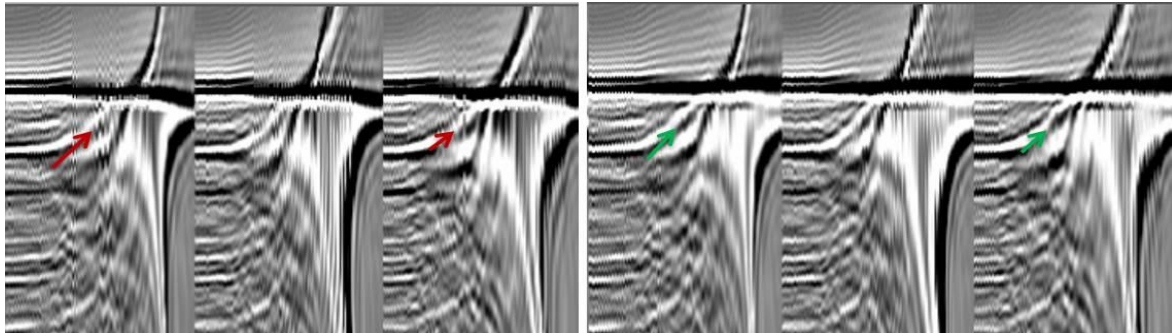


Figure 3 3D CDP gathers before (left) and after (right) water layer replacement

Figure 4 shows a map of cross line gradient calculated along water bottom event. Discontinuities at water bottom due to water velocity variation will produce strong gradient which will be aligned along the shooting direction. Strong lineation are clearly visible before the correction (left image), which have clearly been much better resolved after water layer replacement (right image).

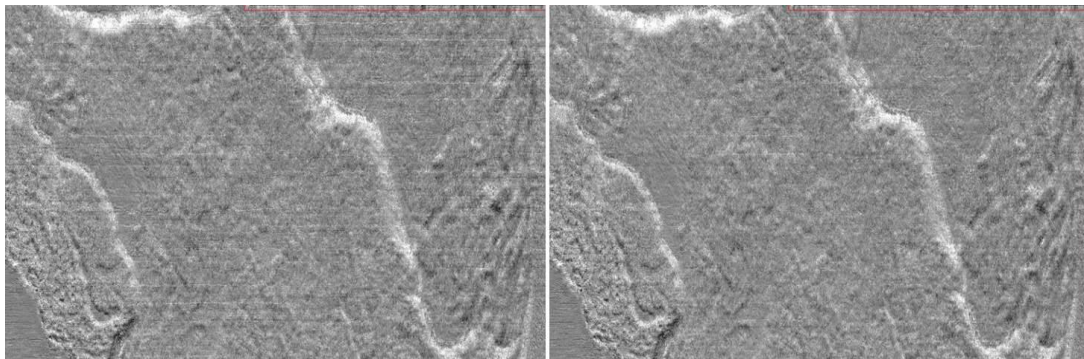


Figure 4 Cross line gradient along water bottom before (left) & after (right) water layer replacement

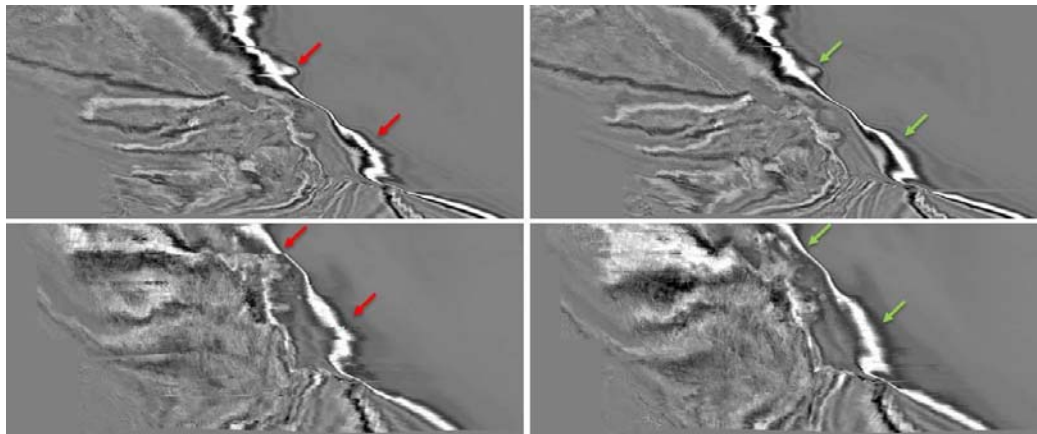


Figure 5 Time slices of near offset (400-500m, top) and mid offset (2200-2330m, bottom) before (left) & after (right) water layer replacement

The second dataset has been taken from a project where several surveys (acquired at different time) were to be merged. The objective was to make the water layer consistent across all surveys. Our proposed method was successfully applied to achieve this objective. Figure 5 shows time slices before and after application of the water layer replacement. The top two time slices are from a near offset (400-500m) cube, whereas the bottom two time slices are from a mid-offset (2200-2300m) cube. A clear improved continuity of the event (marked with arrows) can be observed. Figure 6 shows the intersection point (yellow arrow) between two surveys (acquired in different year and with different acquisition configuration and azimuth) before (top) and after (bottom) water layer replacement.

Clearly event times are well matched after water layer replacement. It is to be noted that the velocity has been estimated independently for each survey.

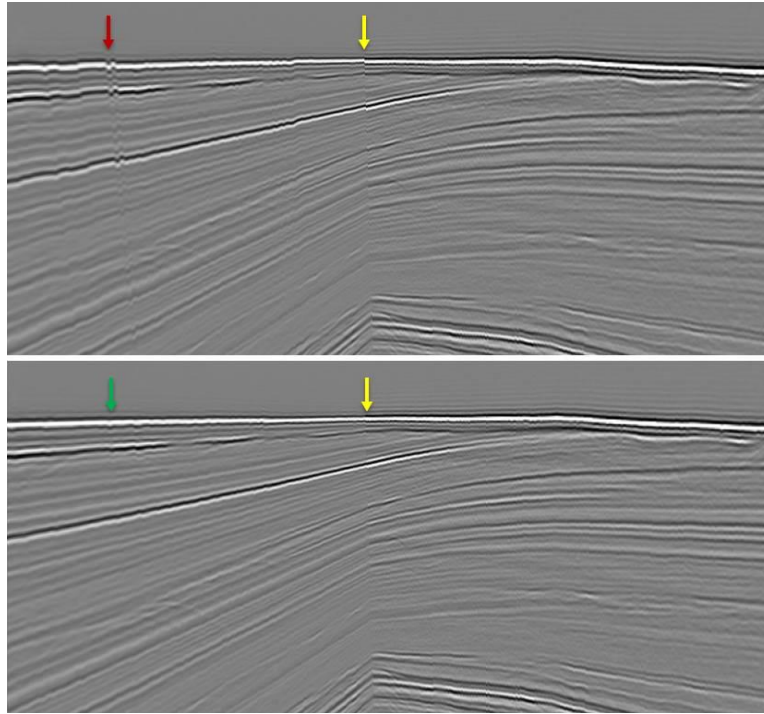


Figure 6 Near offset seismic before (top) and after (bottom) water layer replacement. Yellow arrow shows the intersection point between two surveys, where the events are better matched after water layer replacement. Green and red arrow shows the effect of water layer replacement within survey

Conclusions

In this paper we propose a new method for water velocity estimation which can be used to compensate for water velocity variation effects in seismic data. In the proposed method we estimate accurately the water velocity allowing successful implementation of a standard water velocity replacement workflow. The two examples of application clearly demonstrate that the method can be applied to dataset with very complex water bottom geometry. The method is also suitable for projects requiring merging of multiple datasets from many different vintages.

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