More on accuracy vs. speed in 1D and 1.5D internal multiple prediction

Pan Pan*, Kris Innanen
panp@ucalgary.ca

Introduction

The problems with internal multiples:

- ❑ Events which can be misinterpreted as primaries
- ❑ Events which can interfere with primaries
- ❑ Events which can obscure the task of interpretation

Task:

- ❑ Predict quantitatively which events are multiples, and interpret or remove

2D, 3D internal multiple prediction:

- ❑ Accurate but slow

1D internal multiple prediction

- ❑ Fast but exposed to error

1D internal multiple prediction algorithm

We use the following replacement on the 2D algorithm

$$k_g = k_s = 0, \quad (1)$$

Then we can obtain the prediction algorithm in 1D normal incidence case,

$$b_{3IM}(k_z) = \int_{-\infty}^{\infty} dz e^{ik_z z} b_1(z) \int_{-\infty}^{z-\epsilon} dz' e^{-ik_z z'} b_1(z') \int_{z'+\epsilon}^{\infty} dz'' e^{ik_z z''} b_1(z'') \quad (2)$$

where $k_z = 2\omega/c_0$ is the vertical wavenumber, which is conjugate of the pseudo-depth, c_0 is the constant reference velocity, $b_{3IM}(k_z)$ is the prediction of the algorithm, the entries $b_1(z)$ are the input data traces.

1.5D internal multiple prediction algorithm

If the data have offset but the Earth is nearly layered, in which

$$k_g = k_s, \quad (3)$$

but they are no longer necessarily equal to nil. We can obtain the 1.5D algorithm,

$$b_{3IM}(k_g,\omega) = \int_{-\infty}^{\infty} dz e^{ik_z z} b_1(k_g,z) \int_{-\infty}^{z-\epsilon} dz' e^{-ik_z z'} b_1(k_g,z') \times \int_{z'+\epsilon}^{\infty} dz'' e^{ik_z z''} b_1(k_g,z'') \quad (4)$$

where $k_z = 2q_g$. Compared to the 2D algorithm, the computation cost has been dramatically reduced, with the equivalent of a single 1D prediction for every output k_g. As fewer wavenumbers are participating in the calculation, it is much cheaper and faster than 2D.

Synthetic data

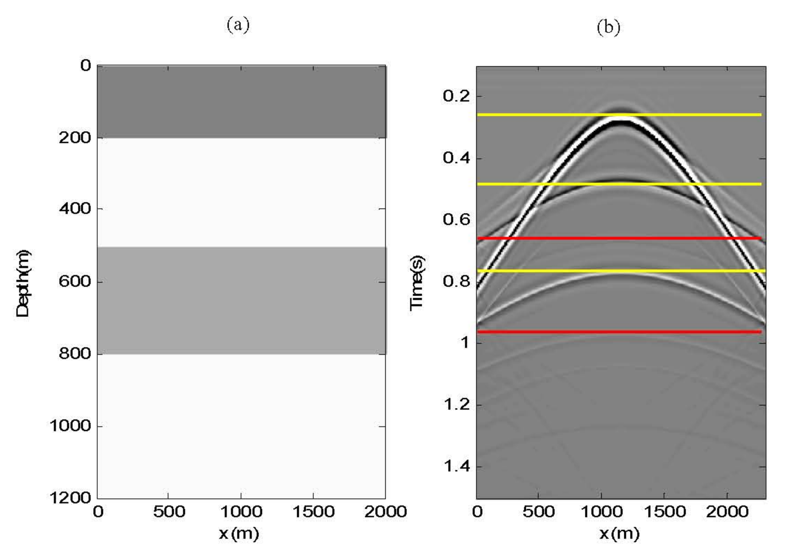

FIG. 1. (a) Three layered velocity model. (b) Shot record.

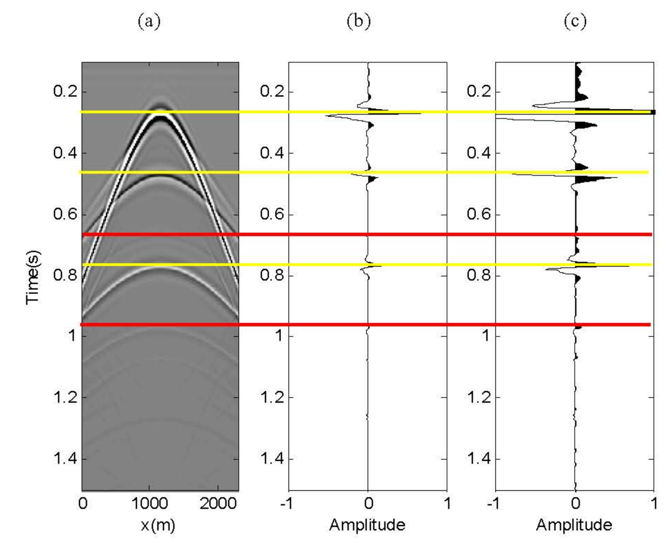

FIG. 2. (a) Shot record. (b) Zero offset trace. (c) The same trace with a larger wiggle format scale.

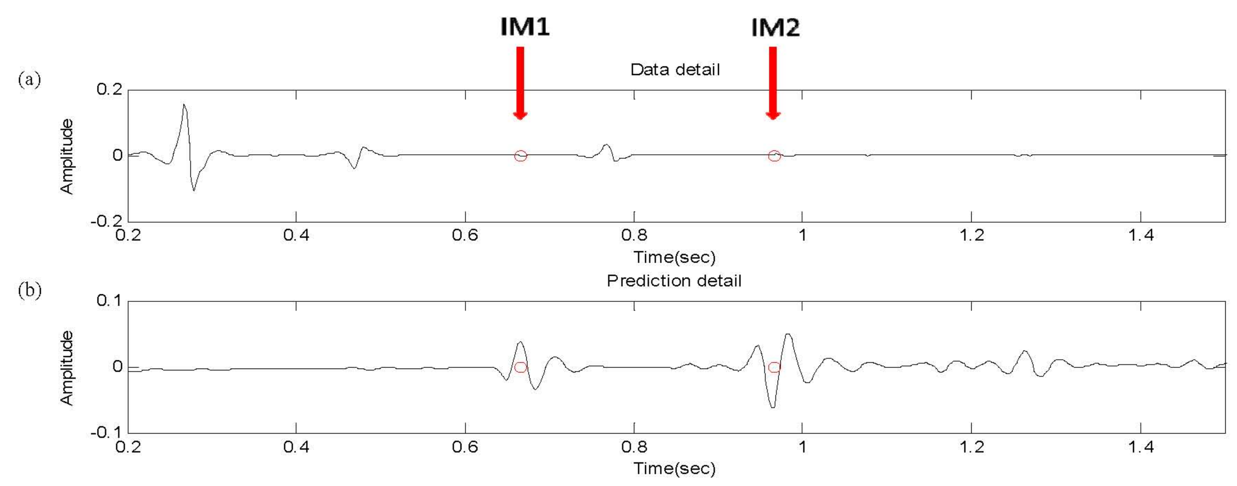

FIG. 3. (a) Input data. (b) Prediction output. Red circles indicate the positions of the internal multiples.

- The shot record we used is with direct wave removed.
- A frequency band is chosen to be [10 20 80 100] in order to get a localized wavelet.

A study of prediction accuracy in 1D

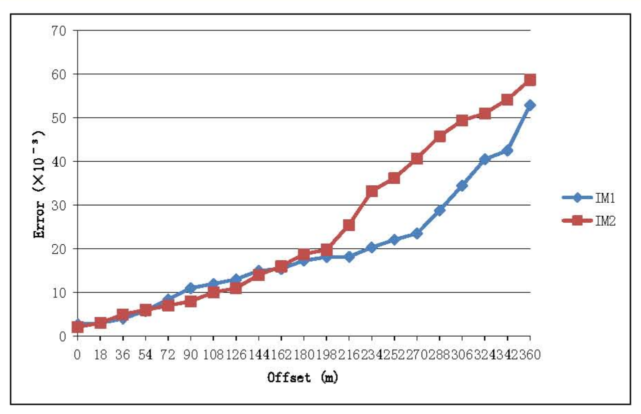

FIG. 4. Prediction errors plotted against an increasing series of offsets.

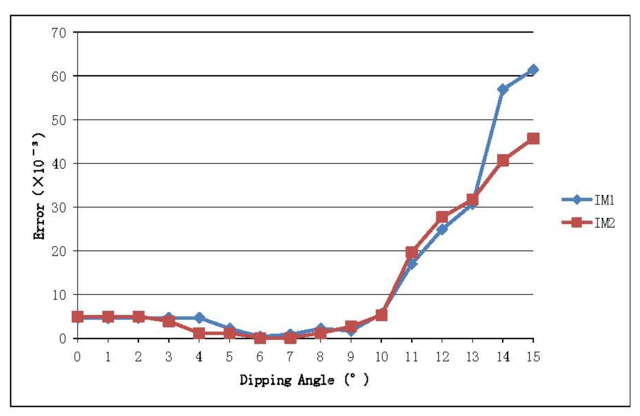

FIG. 5. Prediction errors in the zero offset trace plotted against an increasing series of dipping angles, the generator is the dipping interface.

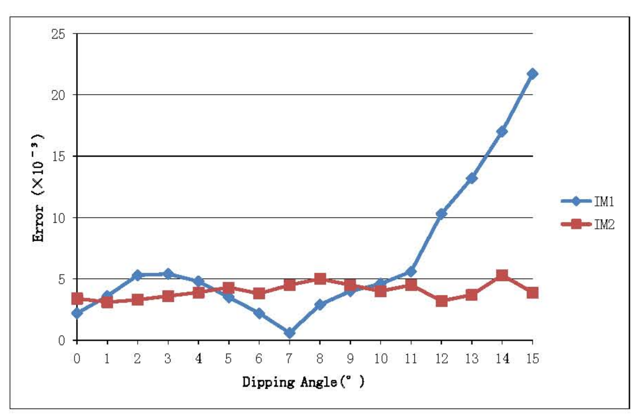

FIG. 6. Prediction errors in the zero offset trace plotted against an increasing series of dipping angles, the second layer is the dipping interface.

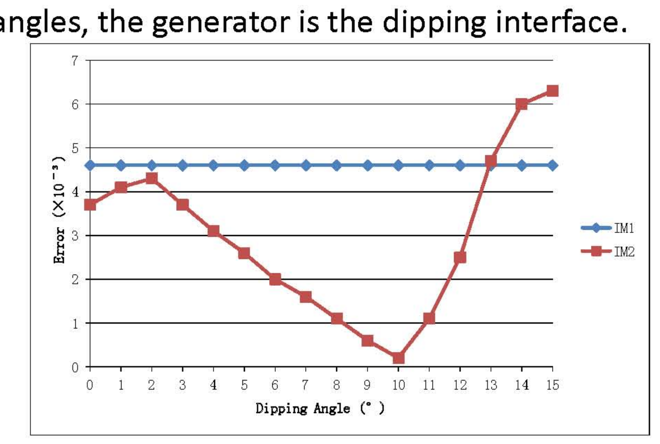

FIG. 7. Prediction errors in the zero offset trace plotted against an increasing series of dipping angles, the third layer is the dipping interface.

Recommendations

- ❑ We recommend applying 1D method when the offset is smaller than 300m.
- ❑ When we have information about the subsurface, all results up to 10° show good results in 1D method.
- ❑ Even without any advanced knowledge of the multiple generator, we recommend using this method when the dipping angle is within 10°.

Numerical analysis of 1.5D

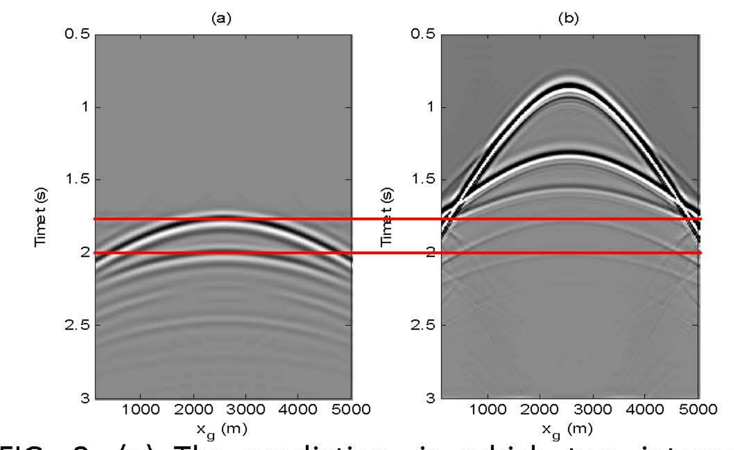

FIG. 8. (a) The prediction, in which two internal multiples are predicted. (b) The original data with both primaries and internal multiples shown in the data set.

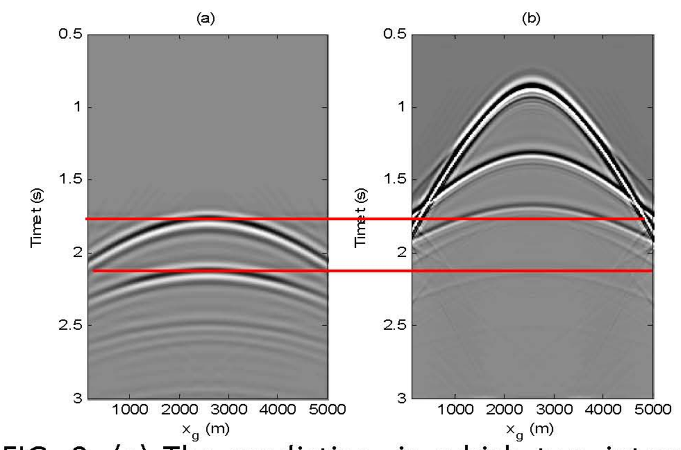

FIG. 9. (a) The prediction, in which two internal multiples are predicted. (b) The original data with both primaries and internal multiples shown in the data set.

- Even though a primary and an internal multiple are mixed together, our 1.5D prediction algorithm still yields promising result.

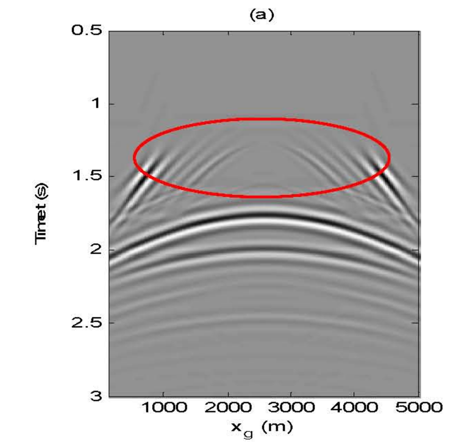

FIG. 10. The output of the 1.5D prediction with $\epsilon = 100$.

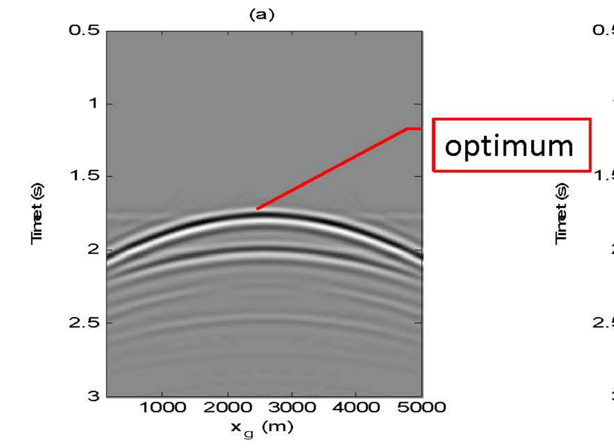

FIG. 11. The output of the 1.5D prediction with $\epsilon = 200$.

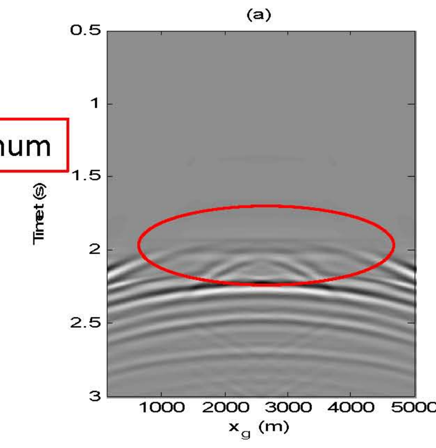

FIG. 12. The output of the 1.5D prediction with $\epsilon = 300$.

- For a smaller ϵ value, artifacts will be seen at the arrival times of primaries.
- For a larger ϵ value, it will damage the important information in the prediction output.

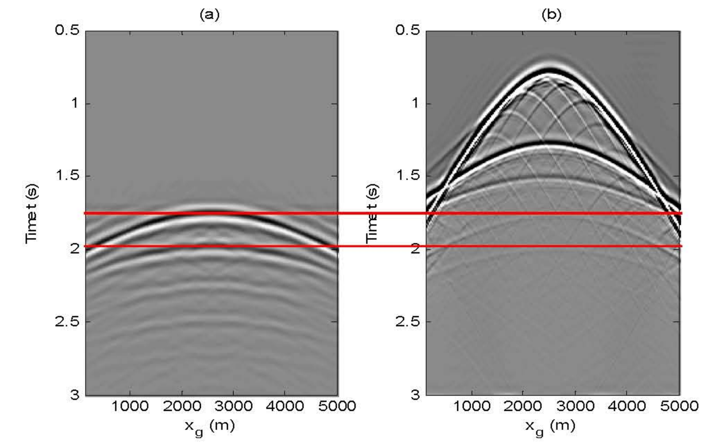

FIG. 13. The output of the 1.5D prediction with first layer's dipping angle of 2°.

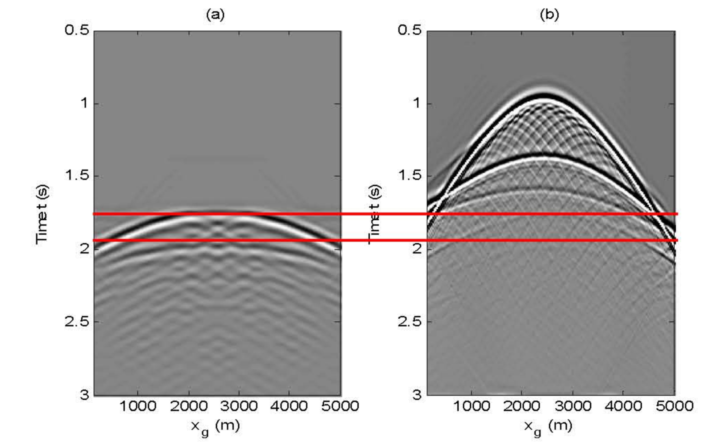

FIG. 14. The output of the 1.5D prediction with first layer's dipping angle of 5°.

- For the smaller dipping angle case, the results are more accurate as both the zero offset travel times and moveout patterns of the internal multiples are displayed correctly.
- For the larger dipping angle case, when the offset becomes larger, the prediction error increases.

Conclusions

- ❑ Compared to 2D method, the computation cost has been dramatically reduced in 1.5D method.
- ❑ According to the effects of various epsilon values, we can choose the epsilon value more efficiently.
- ❑ Our 1.5D method is demonstrated to be useful for situations where small dipping angles exist and primaries are mixed together with internal multiples.

Bibliography

Please see the corresponding CREWES reports for a full bibliography.