KIRCHHOFF MIGRATION

Tsunami Development

TSUNAMI'S UNIQUE APPROACH TO KIRCHHOFF

When acquiring data in rough terrain or with irregular acquisition geometry, the use of the Kirchhoff algorithm is preferred due to its lower sensitivity to non-uniform spatial sampling. The Kirchhoff method does not require a flat datum and therefore offers the advantage of handling variable topography.

Kirchhoff migration works in the offset domain and is based on diffraction summation, which sums the contribution of all data within the migration aperture. The algorithm uses the actual ray path from every source to every receiver. These ray paths are used to construct a diffraction surface and migration is achieved by collapsing each diffraction hyperbola to its origin or apex.

TSUNAMI'S PRE-STACK TIME MIGRATION

Tsunami's Pre-stack Time Migration (PSTM) is a Kirchhoff-based algorithm suited for land, marine, and OBC environments. Straight ray and curved ray travel time options are available. The curved ray option supports both 6th order moveout and Eikonal methods. PSTM offers AVO-compliant amplitude preservation techniques. Tsunami's PSTM supports VTI anistropy through input of an Eta model, HTI through input of Vfast and Vfast azimuth models or a fully orthorhombic migration through input of both HTI and VTI models.

TSUNAMI'S PRE-STACK DEPTH MIGRATION

Tsunami's Pre-stack Depth Migration (PSDM) is a Kirchhoff-based algorithm suited for land, marine, and OBC environments. For imaging beyond 90° it's turning wave capability is useful for imaging salt overhangs or in overthrust geology. PSDM uses advanced amplitude preservation techniques for AVO-compliant output gathers. It supports VTI anisotropy through input of an Eta model and Epsilon/Delta ratio file or Epsilon and Delta models. PSDM performs TTI anisotropy through the input of VTI models and dip and azimuth files.

The travel time computation is performed in the Ray Tracer (RAYS) and the PSDM reads and inputs those travel times.

A Prepare Data for Input

B Build Trace Database

C Impulse Tests

D Quick Look Target Line(s)

E Fully Imaged Target Line(s)

F Final Migration

QC input data and impulse response before expensive full migrations.

INPUT FILE TYPES

As acquisition volumes continue to grow, re-formatting becomes an issue. PSTM and PSDM accepts SEG-Y, GCI, and DSOUT volumes. Tsunami also accepts trace data, little endian, big endian, and IBM float.

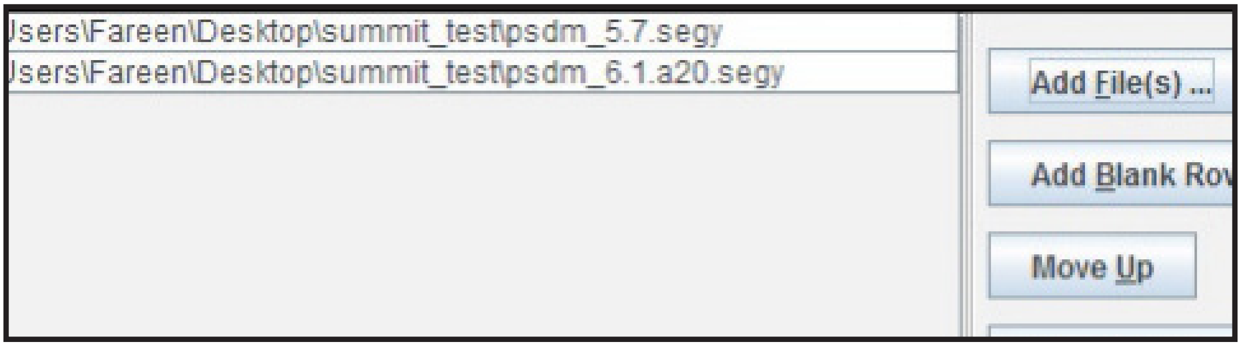


Figure 1: Input File Options

Users can input multiple Seg-Y files using an input file list.

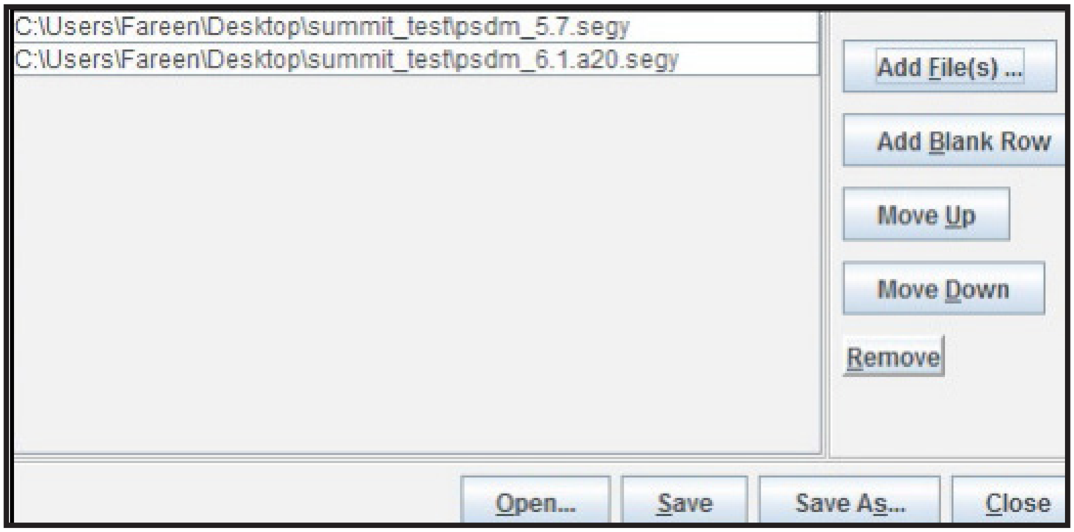


Figure 2: Input File List

Tsunami offers three header displays so users who are unsure of what the acquisiton crew has put in the headers can quickly QC their byte locations.

The only “database” file created by the software is the trace database file, trace.db. This file is an index, or pointer, into the seismic files and provides rapid access to the data stored in the trace headers. Once built, the trace.db can be used in all Tsunami migration modules for the entire time to depth workflow, including PSTM, PSDM, and RTM.

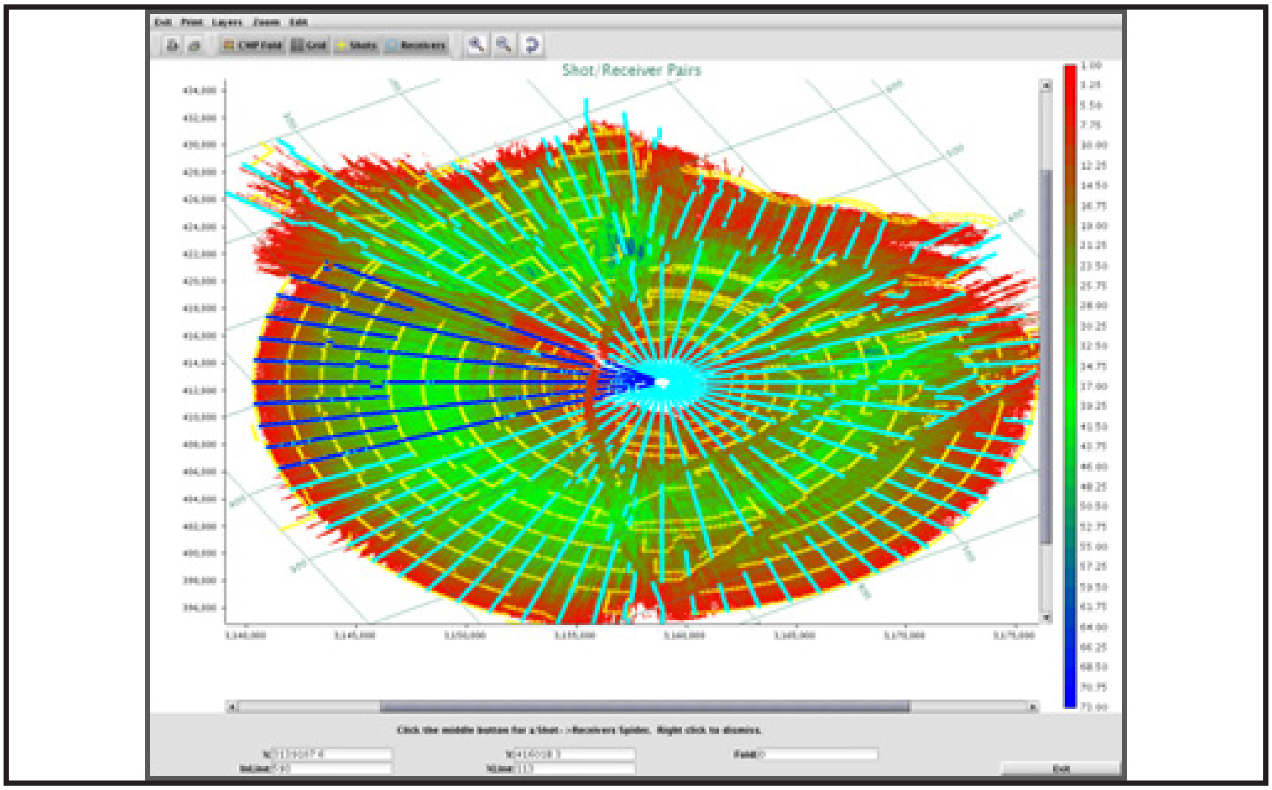


Figure 3: Fold Map with Source Receiver Arrays

The trace.db QC methods provides the user with the ability to answer many questions that may cause potential pitfalls in the migration workflow, including but not limited to:

- Are the inline and xline numbers correct?
- Does the offset calculated from coordinates match the offset header value?
- Do the cdp coordinates match the mid-point of the source and receiver coordinates?
- If using multiple input files, are all input traces included?
- If using merged surveys, are there areas of high folds that must be scaled?
- If imaging from floating datum, Is the static range correct?

All of these questions could be answered from the trace.db build log or the Geometry view options. Any concerns regarding geometry are quickly answered and eliminated.

Click to Enlarge

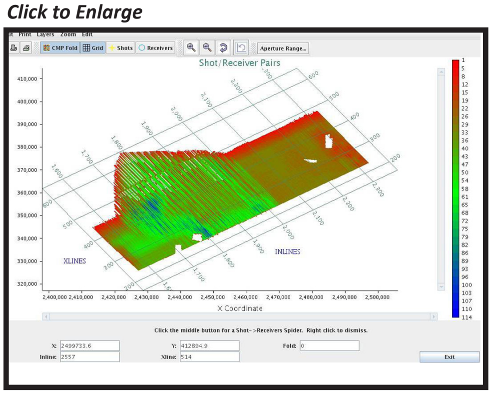


Figure 4: Fold Map in XY Coordinate Display

Click to Enlarge

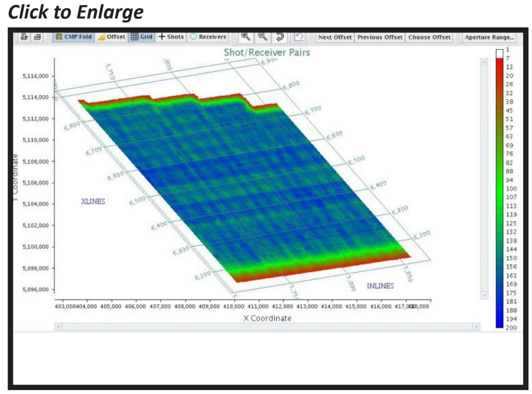


Figure 5: Folp Map in Inline/Xline Map

Click to Enlarge

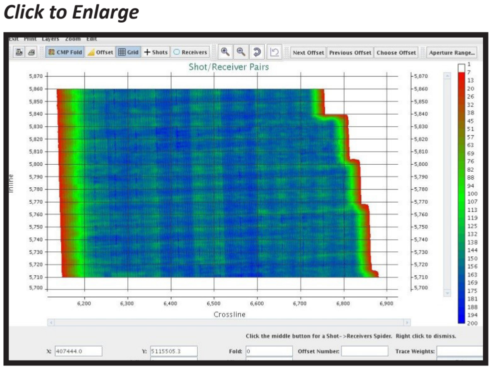


Figure 6: Azimuth Histograms

Click to Enlarge

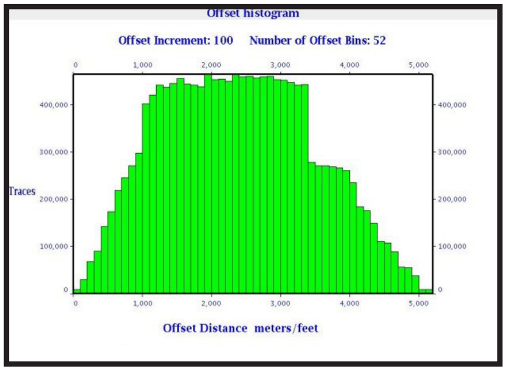
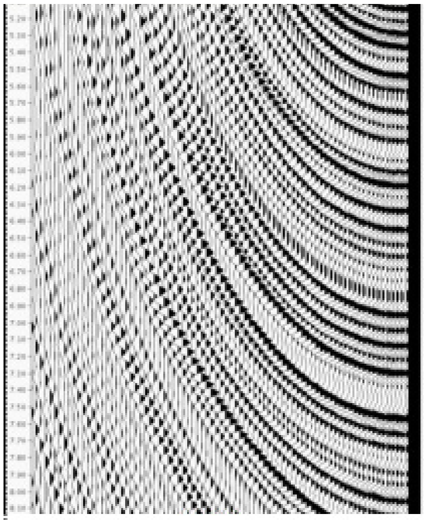


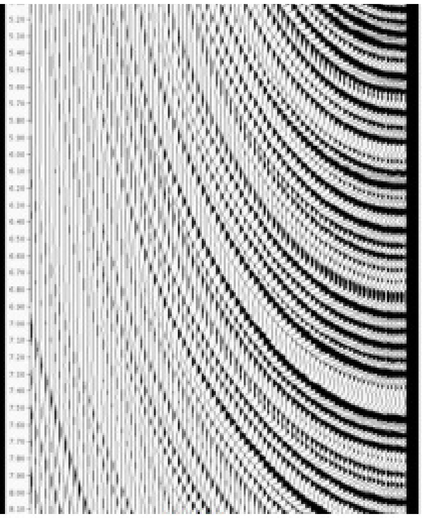
Figure 7: Static Shift Histograms

IMPULSE TEST

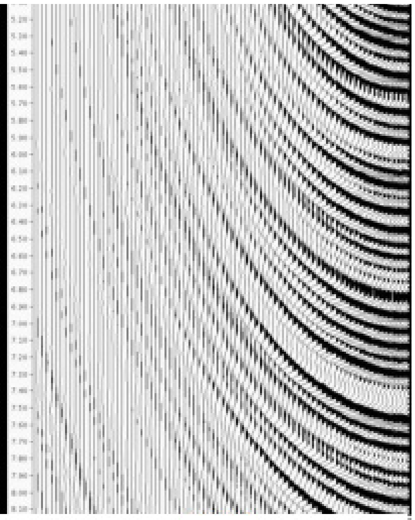
Impulse tests confirm, amongst other things, that the geometry and velocity information are correct and properly processed, and allow quick and accurate tests of migration parameters such as aperture and anti-aliasing. In Tsunami migration software, the impulse response is quick and intuitive to parameterize, and jobs running impulse responses are designed to run in a minute on one node.



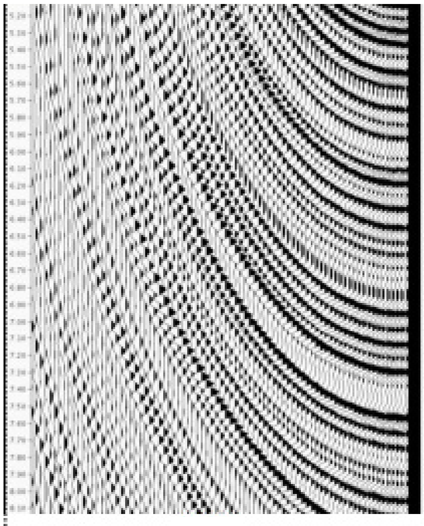
AA 0.2



AA 0.6



AA 1.0



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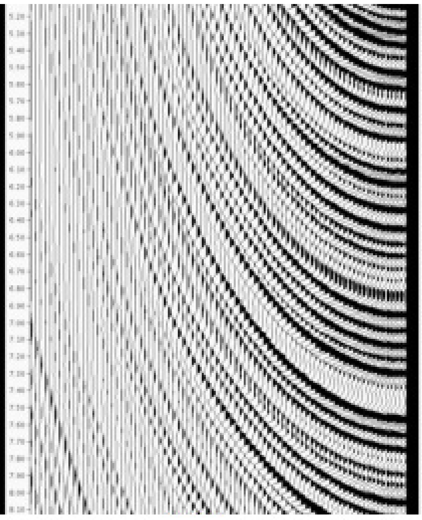
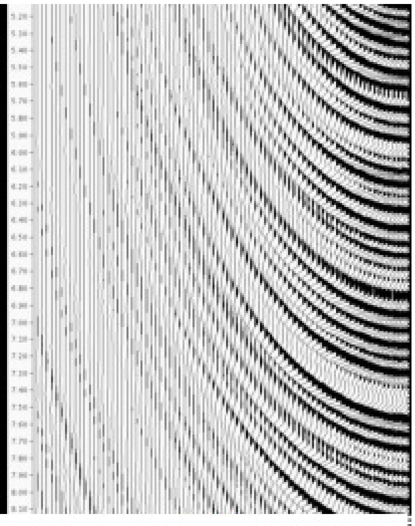


AA 1.4



AA 1.8

By varying the anti-aliasing p a r a m e t e r s , Tsunami ran 5 different jobs in under 5 minutes. Notice the trade-off between noise and signal from steep dipping events. Never be uncertain with what your final migration will look like with Tsunami PSTM.

Click to Enlarge

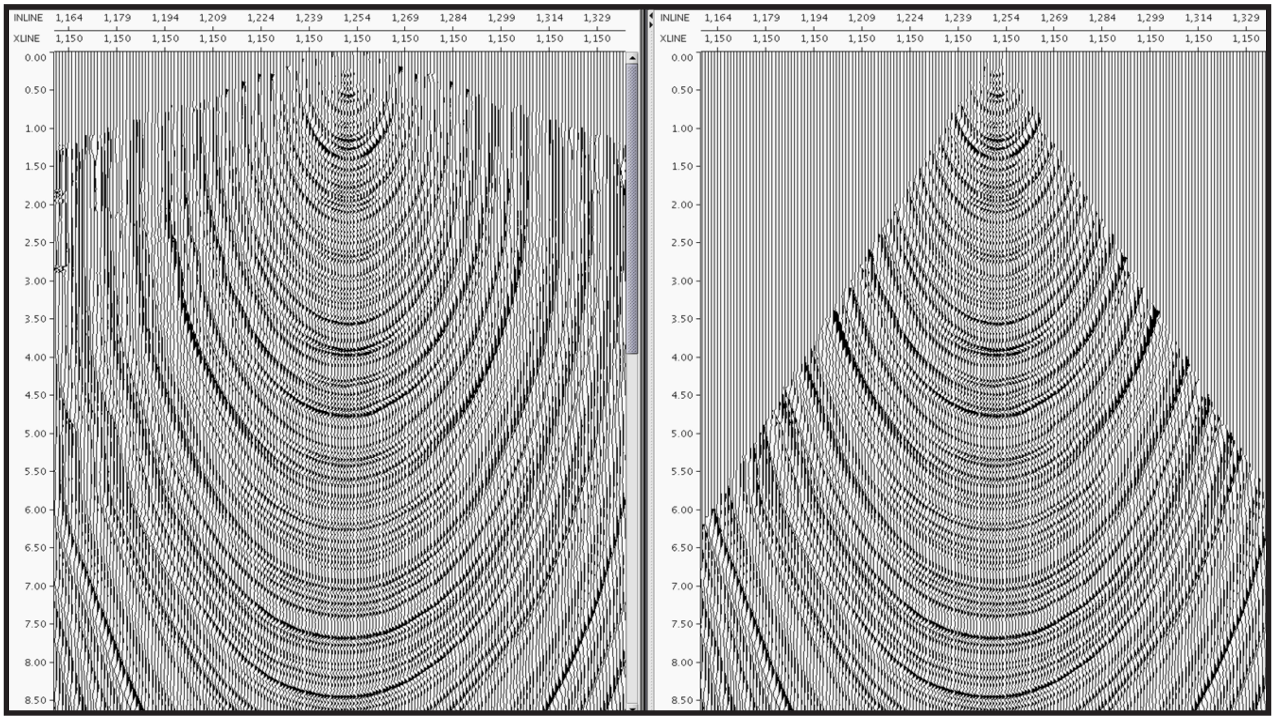


Figure 7: Another impulse response with aperture taper angle applied. Have an intuitive understanding of velocity contrasts with Tsunami PSTM.

FLOATING DATUM

When a survey is acquired over rough terrain or irregular topography it is common to process the data from a smoothed floating datum. At each CDP location the two way travel time between the floating datum and the final datum is stored in the trace database file.

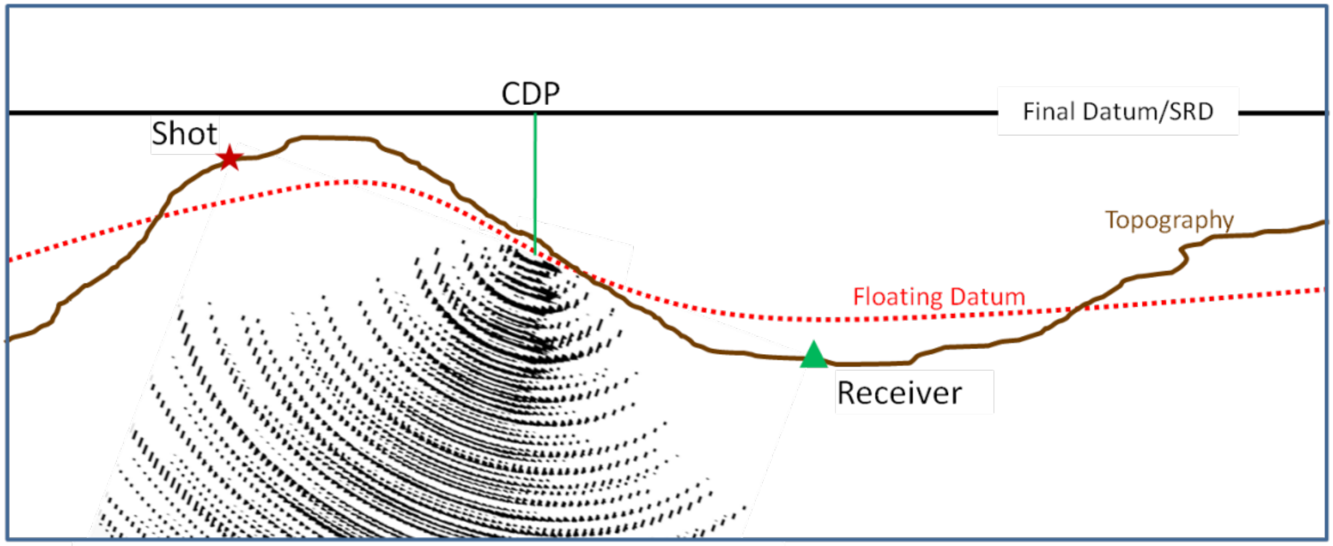


Figure 8: Smoothing Topography to Image with Floating Datuum

Tsunami uses this information to build a map of the floating datum service. When running jobs, this map is used to properly angle the migration operator or orthogonal to the surface, result in improved image quality. Tsunami handles two methods of floating datum:

- ***Two Way Travel Time***
- ***Elevation***

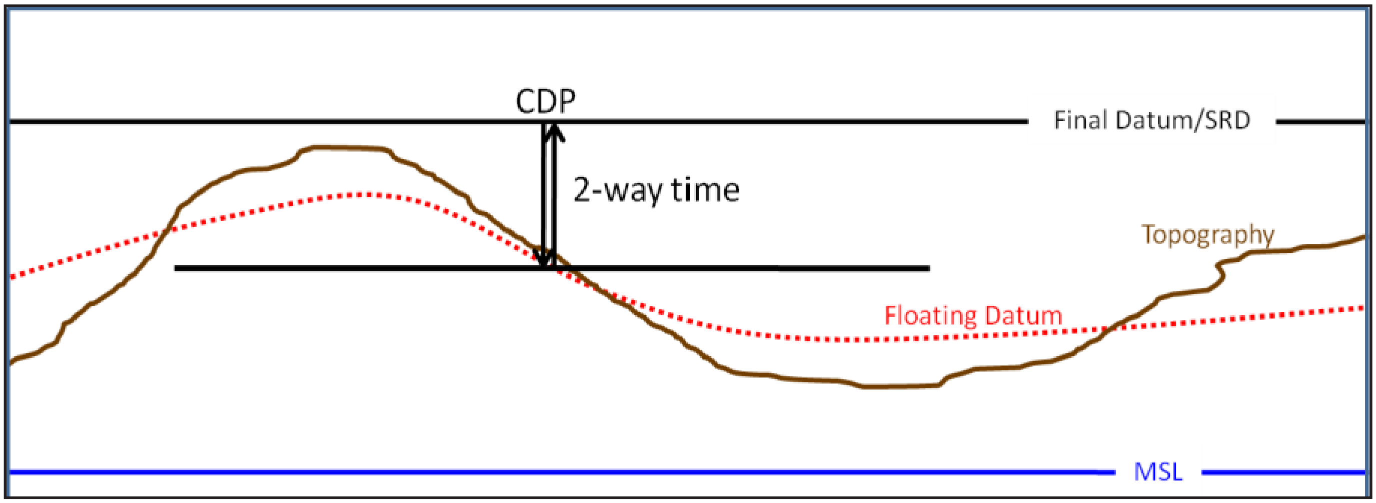


Figure 9: Two Way Travel Time

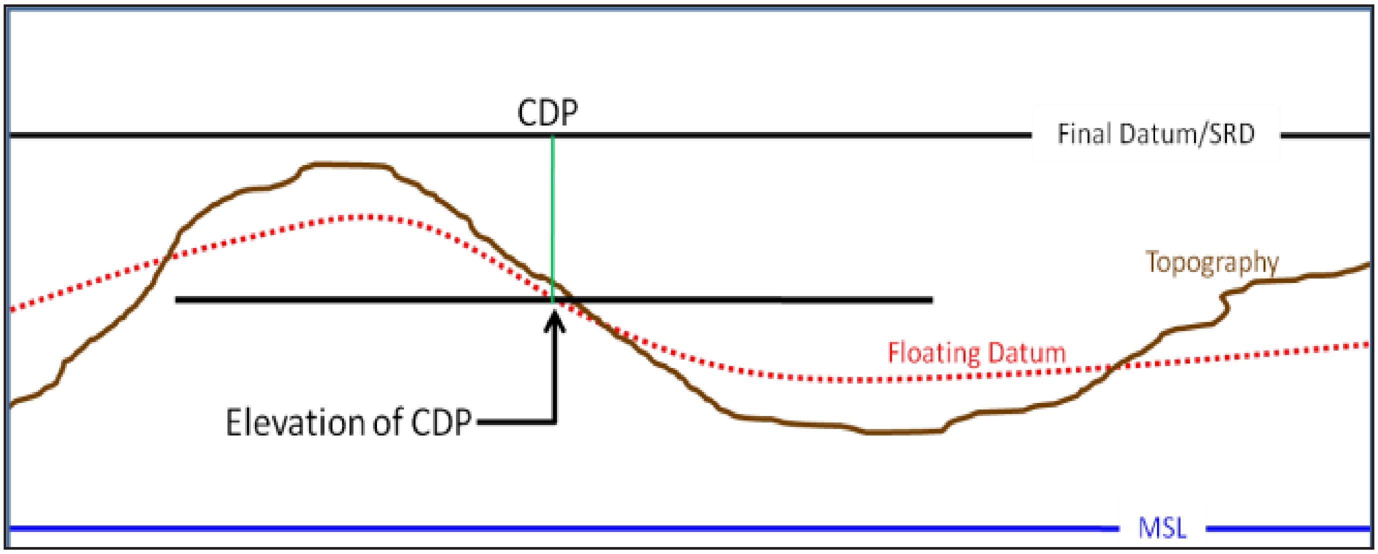


Figure 10: Elevation

RAY TRACER

The Tsunami Ray Tracer module (RAYS) generates travel times for the Tsunami Kirchhoff pre-stack depth migration module (PSDM). Individual rays are advanced using a 4th order Runge-Kutta solver. The program offers three methods of selecting which travel times are used in the event of multiple arrivals; minimum time, minimum distance and maximum energy. The program uses the wavefront reconstruction method to maintain accuracy as the rays move through the velocity model. The user has control over many parameters, and virtually any size velocity model can be used.

RAYS advances the individual rays as members of beams, or triangular sets of three adjacent rays. As the rays propagate through the model the individual ray times are extrapolated to a common point within the beam, and then compared to each other. If the times deviate by more than the allowed amount a new ray and associated beam are created. This ensures accuracy of the wavefront as the rays scatter.

The step size for advancing a given ray is determined automatically based on the local velocity gradient. As the velocity gradient increases the step size decreases. This mitigates the error in the Runge-Kutta equation associated with increasing angle as the velocity changes. All rays within a beam advance radially from the shot location to the next step. They are then evaluated to determine which velocity grids fall within the beam. Travel times are calculated for those grids that fall within each beam. In the event a grid falls within multiple beams its travel time is determined by the defined selection method of minimum time, minimum distance or maximum energy.

All travel time interpolation, both in the RAYS and PSDM modules, is done using slowness rather than seconds. This improves the accuracy of the interpolation, and allows the user to improve performance by selecting a larger increment in the input subsurface shot locations without a sacrifice in quality.

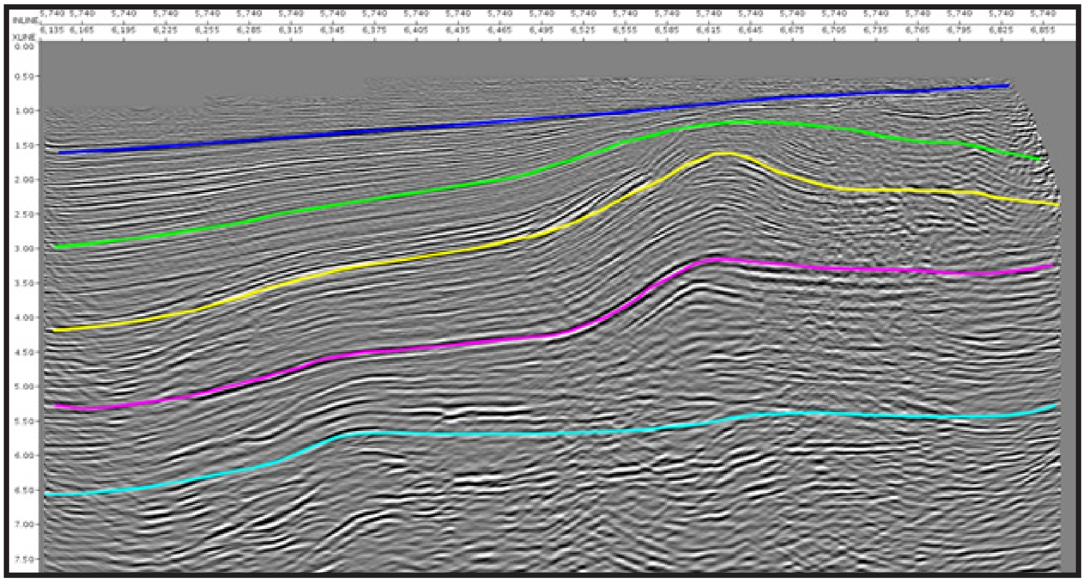


Figure 11: PSTM Section Converted to Depth with Horizons Picked

The RAYS travel time calculations will work with interval models created by other vendor's software. However, Tsunami also provides tools that allow you to quickly and reliably build the required interval model from the RMS velocity model used for time migration. Horizons are picked on the PSTM stack stretched to depth. These horizons are then used to constrain the Dix RMS to interval conversion.

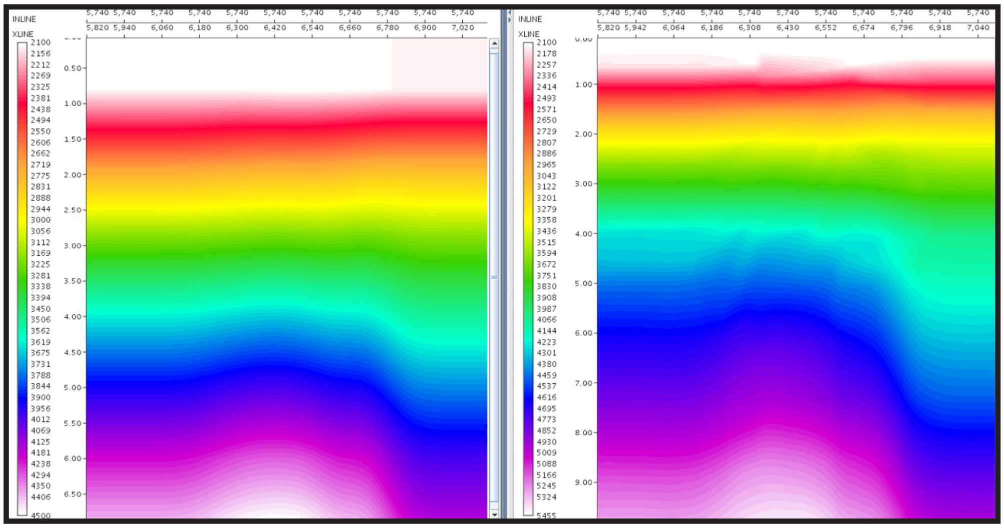


Figure 12: On the Left: RMS Velocity Model On the Right: RMS Velocity Model Converted to Depth Interval Velocities

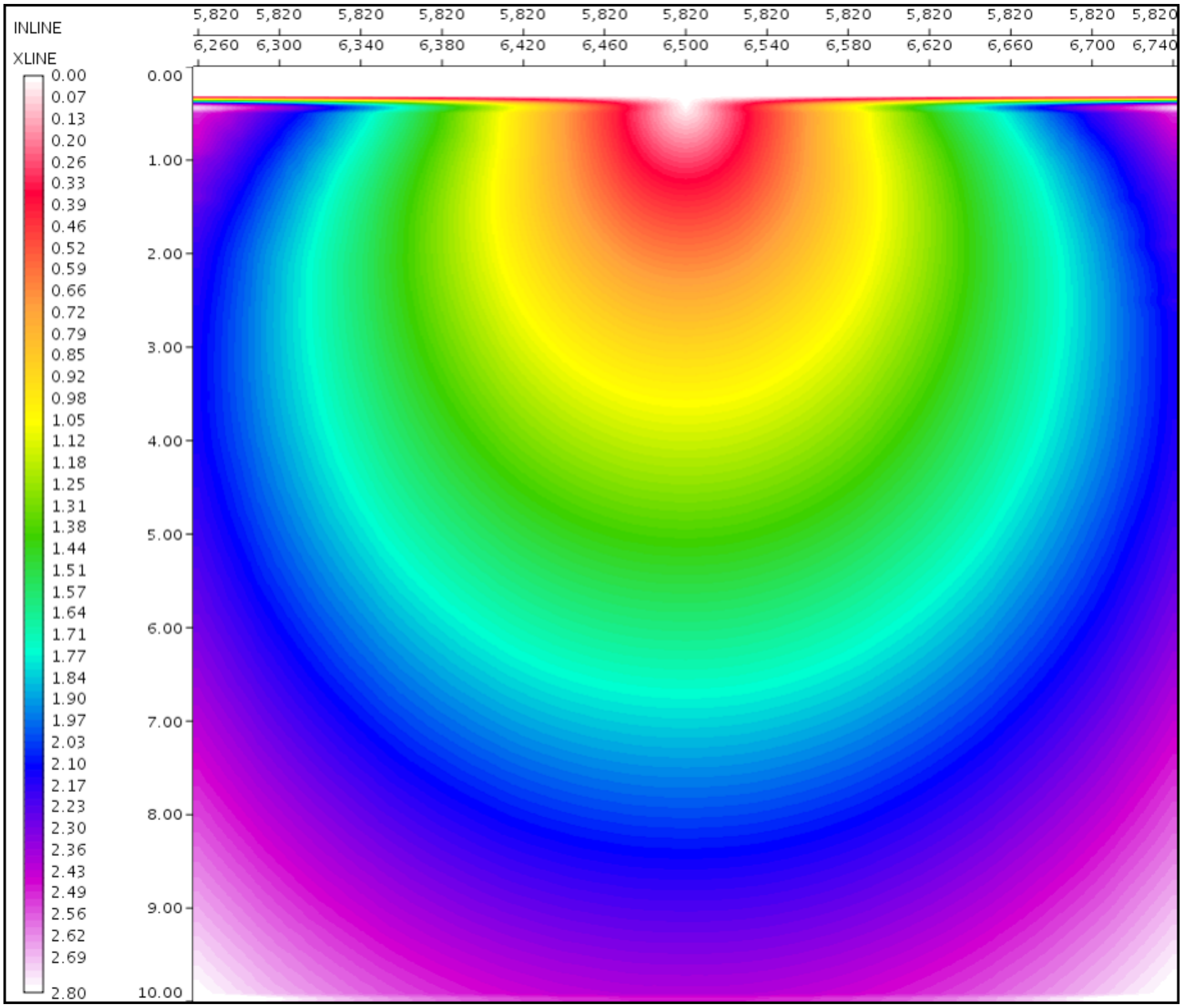


Figure 13: QC Raytracer Travel Times By Outputting a Seg-Y File

Tsunami allows you to QC the Raytracer travel time file before input into depth migration.

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