

Import SEG-2, Smooth invert, DeltatV & Plus-Minus & WDVS 4.02. Discard WET smoothing :

Fig. 1 : top : Trace|Shot gather, bottom : Refractor|Shot breaks. Shows fit between picked times (solid curves, red circles) and modeled times (dashed curves, blue crosses) obtained for Smooth inversion (Fig. 7). Browse shots with F7/F8.

To create the profile database, import the data and browse the imported shots with F7/F8 do these steps :

- File New Profile ..., set File name to 3016_SEG2 and click Save button
- in the prompt (Fig. 42) click *No* button to leave *Profile start* and first receiver at station no. 0.
- in *Header* | *Profile*... set *Line type* to Refraction spread/line . Set *Station spacing* to 5.0 m.
- check box Force grid cell size and set Cell size[m] to 0.5m. See Fig. 2.
- unzip updated archive <u>3016 seg2.zip</u> with DMT SUMMIT .seg2 shot files & coords.cor & shotpts.sho & breaks.lst in directory c:\ray32\3016_seg2\input
- check File|SEG-2 import settings|Ignore SEG-2 station numbers in trace headers. See Fig. 17.
- check File|SEG-2 import settings|Receiver coordinates specified in SEG-2 trace headers (Fig. 17).
- select *File Import Data*... and set *Import data type* to **seg-2**. See Fig. 3.
- click Select button and navigate into C:\RAY32\3016_SEG2\INPUT
- set Files of type to DMT files (*. SEG2) and select any file e.g. Rec_00001.seg2 & click button Open
- click button *Import shots button*. For each shot shown in dialog click *Read* button.
- select File|Update header data|Update Station Coordinates & COORDS.COR. Click Import & Reset.
- File|Update header data|Update Shotpoint coordinates with SHOTPTS.SHO. Click Open button.
- select File|Update header data|Update First Breaks. Select file BREAKS.LST & click Open button
- select *Trace*|Shot gather and select Window|Tile horizontal to obtain Fig. 1
- click on title bar of *Refractor*|*Shot breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 150 ms & press ENTER key to redisplay. Do same for *Trace*|*Shot gather* window (Fig. 1 top).
- select *Trace*|Shot gather. Select *Display*|Show picks on time axis (Fig. 11 a).

To configure and run Smooth inversion :

- select Grid|Surfer plot Limits. Edit fields as in Fig. 4. Click OK button.
- uncheck WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration
- uncheck Grid|Label shot points on tomogram. Check Grid|Receiver station ticks on top axis (Fig. 9).
- select *Model WDVS Smoothing* and configure as in Fig. 5. Check option *discard WET smoothing*.
- check Smooth invert|Smooth inversion Settings options Extra-wide smoothing for 1D initial velocity profile and Extra-wide stack for 1D-gradient initial (Fig. 10).

- select *DeltatV*[*Interactive DeltatV*]*Static Corrections*. Set *Inverse CMP offset power to 0.2* (Fig. 11). *Click Accept & Cancel buttons*. This gives a smoother 1D-gradient DeltatV-based starting model.
- select Smooth invert | WET with 1D-gradient initial model
- wait for the starting model to display as in Fig. 6. Confirm to continue to obtain WET output Fig. 7&8.

Line ID Line 3016 Time of Acquisition Line type Refraction spread/line Date Job ID Reimport SUMMIT.SEG2 Time of Processing Instrument Time of Processing Date Otient Date Date	_
Line type Refraction spread/line Job ID Reimport SUMMIT.SEG2 Instrument Client Client Date Time Date Time Time Date	-
Job ID Reimport SUMMIT.SEG2 Time Time Time Time Time Time Time Time	_
Instrument Time of Processing Date Take shot record number from DOS file name	-
Client Date Date Date Dots file name	1
Time	•
Company Optionally select HDR batch file and check Batch import	
Observer Units meters I.HDR batch	
Note Sort As acquired Vite HDR batch file listing shots in input directory	
Const Output.HDR	-
Station spacing (m) 5.00000 Left handed coordinates	
Min. horizontal separation [%] 25 [¥ Force grid cell size	
Frome start onset [m] 0.0000 Cell size [m] 0.0000 C	
Overwrite all O Prompt overwriting Limit offset	
Add borehole lines for WET tomography Maximum offset imported [station nos.] 100	.00
Borehole 2 line Select Default shot hole depth [m] Default spread type	_
Borehole 3 line Select	<u> </u>
Borehole 4 line Select	–
Turn around spread during import	ut
OK Cancel Reset	
Fig. 2 : HeaderlProfile Default sample interval [msec] 0.100000	000
Default sample count 20	000
Edit Surfer plot limits Cancel import	
Fig. 3 : File Import Data	
OK OK	
Min. offset -15.001 [m] Cancel Edit WDVS (Zelt & Chen 2016)	
Max. offset 734.999 [m] Reset FIG. 4.	
Min. elevation 250.000 [m] Reset to grid plot Limits	
Max elevation 305.000 [m] Redisplay grid (left)	
Min. velocity 400 [m/sec.]	
Max. velocity 3000 [m/sec.]	
Max. velocity 3000 [m/sec.]	
Max. velocity 3000 [m/sec.] Plot Scale Proportional XY Scaling	
Max. velocity 3000 [m/sec.] Max. velocity 3000 [m/sec.] add nodes once only with overlapping scan lines for velocity averaging add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad WDVS area border with one grid cell Proportional XY Scaling WDVS frequency Page unit centimeter. Uncheck for inch. WDVS frequency	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Proportional XY Scaling pad WDVS area border with one grid cell WDVS frequency 100.00 X Scale length 6.000 [inch] Angle increment hetween scan lines	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad WDVS area border with one grid cell WDVS frequency 100.00 X Scale length 6.000 Y Scale length 3000 Image: Scale length 3000	
Max. velocity 3000 [m/sec.] Plot Scale add nodes once only with overlapping scan lines for velocity averaging Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Proportional XY Scaling pad WDVS area border with one grid cell WDVS frequency 100.00 [Hz] X Scale length 6.000 [inch] Y Scale length 3.000 [inch] Regard nth node along scan line 3 [node]	
Max. velocity 3000 [m/sec.] Max. velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Proportional XY Scaling pad WDVS area border with one grid cell WDVS frequency 100.00 X Scale length 6.000 3000 [inch] Y Scale length 3000 Color Scale	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Proportional XY Scaling pad WDVS area border with one grid cell WDVS frequency 100.00 [Hz] X Scale length 6.000 [inch] Y Scale length 3.000 [inch] Fig. 5 : a: Cosine argument power 1.000 [power]	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad WDVS area border with one grid cell WDVS frequency 100.00 [Hz] Angle increment between scan lines 7 [Degree] Regard nth node along scan line 3 [node] Color Scale Fig. 5 : Model/WDVS Valagibis integral 100 [mch] Valagibis integral 100 [mch]	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad wDVS area border with one grid cell WDVS frequency 100.00 [Hz] Angle increment between scan lines 7 [Degree] Regard nth node along scan line 3 [node] Color Scale 7 [Degree] Adapt color scale 7 [Degree] Scale height 3 000 [inch] Velocity interval 100 [m/sec.] Colorstale 5 [notth/ing] Color scale 7 [Degree] Scale height 3 000 [inch] Yelocity interval 100 [m/sec.] Coverage interval 5 [notth/ing] Coverage interval 5 [notth/ing]	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad WDVS area border with one grid cell WDVS frequency 100.00 [Hz] X Scale length 6.000 [inch] Y Scale length 3.000 [inch] Color Scale 7 [Degree] Regard nth node along scan line 3 [node] Parameters for Cosine-Squared weighting function (Chen and Zelt 2012) a : Cosine argument power Scale height 3.000 [inch] 5 [paths/pixel]	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Plot Scale pad WDVS area border with one grid cell WDVS frequency 100.00 [Hz] Age increment between scan lines 7 [Degree] Y Scale length 3.000 [inch] Color Scale 7 [Degree] Regard nth node along scan line 3 [node] Velocity interval 100 [m/sec.] Coverage interval 5 [paths/pixel] Receiver labeling Modify WET smoothing mode : discard after forward modeling @ discard WET smoothing and WDVS smoothing after modeling	
Max velocity 3000 [m/sec.] Max velocity 3000 [m/sec.] Plot Scale add all velocity nodes within WDVS area with radius of one wavelength Proportional XY Scaling page unit centimeter. Uncheck for inch. X Scale length 6.000 [inch] Y Scale length 3.000 [inch] V Scale length 3.000 [inch] Fig. 5 : Mode/[WDDVS Scale height 3.000 [inch] Velocity interval 100 [m/sec.] Coverage interval 5 [paths/pixel] First station 0 [station no.]	
Max velocity 3000 [m/sec.] Plot Scale add nodes once only with overlapping scan lines for velocity averaging Plot Scale page unit centimeter. Uncheck for inch. X Scale length 6000 [inch] Y Scale length 3000 [inch] V Adapt color scale 7 [Degree] Regard nth node along scan line 3 [node] Velocity interval 100 [m/sec.] Coverage interval 5 [paths/pixel] Receiver labeling 0 [station no.] First station 0 [station no.]	



Fig. 6 : 1D-gradient starting model obtained with Smooth invert|WET with 1D-gradient initial model



Line 3016 RMS error 2.9%=1.79ms 20 WET itr. 50Hz Width 6.5% initial GRADIENT.GRD v. 4.02

Fig. 7 : 2D WET output obtained with *Smooth invert*|*WET with 1D-gradient initial model* & starting model shown in Fig. 6. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Check *discard WET smoothing after forward modeling* (Fig. 5) to speed up WET convergence towards small RMS error.



Line 3016 RMS error 2.9%=1.79ms 20 WET itr. 50Hz Width 6.5% initial GRADIENT.GRD v. 4.02

Fig. 8 : WET wavepath coverage plot obtained with Fig. 7. Unit is wavepaths per pixel.

A *borehole* at station no. 101 shows strongly weathered and fractured sandstone at bottom depth of 12m (absolute elevation 292m) for this geotechnical refraction profile in Australia. At depth of 5m (elevation 299m) a detached sandstone layer was drilled in the same borehole, with thickness of about 0.4m and with alternating/<u>interbedded</u> gravelly and clayey sand layers below this sandstone layer and sand layers above.





Fig. 11 : DeltatV|InteractiveDeltatV|Static Corrections

Display Trace Smooth invert DeltatV WET Tomo Gri Show dead traces Trace display... ALT+P Edit offset range, disable offset zoom ALT+N ✓ Edit time window, disable time zoom ALT+I Trace annotation... ALT+A Display raytraced traveltimes ALT+T Color traces ALT+C ALT+S Color traces by source type ✓ Color trace outline ALT+O Red trace outline ALT+R Show picks on time axis ALT+X Use red cross for picked first breaks ALT+U Solid color pick display ALT+D Picks always cover traces ALT+V Refresh breaks display... ALT+Y

Fig. 11a : Trace|Shot gather, Display menu

Decreasing *Inverse CMP offset power* from default 0.5 to 0.2 (Fig. 11) results in a more laterally and vertically smoothed 1D-gradient initial model plot for this profile (Fig. 6) especially in overburden just below topography. See our <u>updated .pdf reference</u> chapter *DeltatV Static Corrections* on page 208.

Shots were stacked at the same shot point 5 times using the DMT SUMMIT X One seismograph. See .seg2 files in your c:\ray32\3016_seg2\input folder, trace header field STACK. Use e.g. the free XVI32 hexadecimal editor available at http://www.chmaas.handshake.de/delphi/freeware/xvi32/xvi32.htm. We fixed bad RECEIVER_LOCATION for dead trace from 1 to 115.0 in DMT SUMMIT X One .SEG2 files using XVI32 editor for this profile.

Frequency filter : band-pass or band-reject	Frequency filter : high-pass or low-pass
 Filter active for current trace gather display Band-pass filter. Uncheck for band-reject. Bidirectional filter. Better preserve signal. Chebyshev filter. Uncheck for single-pole. 	 Filter active for current trace gather display High-pass filter. Uncheck for low-pass. Bidirectional filter. Better preserve signal. Chebyshev filter. Uncheck for single-pole.
Apply n times [n] 1	Apply n times [n] 1
Low corner frequency [Hz] 50.00	Cutoff frequency [Hz] 50.00
High corner frequency [Hz] 100.00	Percent ripple [%] 0.0
Percent ripple [%] 0.0	Number of poles [n] 2
Number of poles [n] 2	Filter Cancel Reset
Filter Cancel Reset	

Fig. 12 : Band-pass filter. Press SHIFT+Q in Trace/Shot gather. Fig. 13 : Low-pass filter. ALT+Q in Trace/Shot gather.

For optimal noise suppression and enhanced visibility of first breaks at large source-receiver offsets use both *band-pass filter* (Fig. 12) and *low-pass filter* (Fig. 13). These two filters are applied to recorded traces after each other, for trace display.



Fig. 14 : same as Fig. 7 but WDVS activated at 100Hz with check box **Use WDVS for forward modeling** (Fig. 18). Note the enhanced velocity contrast between layers in the overburden, compared to Fig. 7.

Discarding WET smoothing after forward modeling but leaving WDVS smoothing deactivated (Fig. 5) helps to improve resolution especially in overburden without incurring increased WET runtime needed for WDVS smoothing.

Compare Fig. 7 (no WDVS smoothing but discard WET smoothing after forward modeling, Fig. 5) with Fig. 14 (WDVS activated with check box *Use WDVS for forward modeling*, Fig. 18). WDVS does help to further enhance velocity contrast between layers in overburden and improves fit with borehole stratigraphy described below Fig. 8.

Smooth inversion shown in Fig. 7 with WDVS deactivated (Fig. 5) and using 20 Steepest-Descent WET iterations took about 2 minutes on 2017 Apple iMac. This iMac comes with 2.3 GHz Intel Core i5 processor running 4 OpenMP threads under Windows 7/10/11 Pro 64-bit in Parallels Desktop 17 for Mac. The same *Smooth inversion* but with WDVS activated (Fig. 18) shown in Fig. 14 took about 6 minutes. We determined these WET runtimes under Windows 7 Pro 64-bit.



Fig. 15 : Trace|Offset gather for common offset of 82.5m



Fig. 16 : Trace|Offset gather for common offset of 47.5m



Fig. 17 : File|SEG-2 import settings

Edit WDVS (Zelt & Chen 2016)						
Edit parameters for wavelength-dependent velocity smoothing						
I use WDVS for forward modeling of traveltimes						
I fast WDVS : less accurate mapping of scan line nodes to grid nodes						
add nodes once only with overlapping	add nodes once only with overlapping scan lines for velocity averaging					
add all velocity nodes within WDVS are	ea with radius of one	wavelength				
🔲 🔲 pad WDVS area border with one grid c	ell					
WDVS froquency	100.00	() -)				
WDV3 hequency	100.00	[HZ]				
Angle increment between scan lines	7	[Degree]				
Regard nth node along scan line	3	[node]				
Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)						
a : Cosine argument power	1.000	[power]				
b : Cosine-Squared power	1.000	[power]				
Modify WET smoothing mode : discard after forward modeling						
G discard WET smoothing and WDVS smoothing after modeling						
C restore WET smoothing and discard WDVS smoothing only						
OK Cancel Reset						

Fig. 18 : Model WDVS Smoothing with WDVS activated



Fig. 19 : WDVSTIME.GRD written to C:\RAY32\DAT during Smooth inversion with option WET|WET tomography Settings|Write|Write blanked and mask grids and WDVS debug grids checked. Unit is delay time in seconds, along scan lines originating at center of WDVS area. See our <u>updated .pdf reference</u> chapter Forward model traveltimes section WDVS velocity smoothing on page 167.

In Fig. 19 we image the wDVSTIME.GRD written to C:\RAY32\DAT folder during WET inversion with option WET Tomo|WET tomography Settings|Write|Write blanked and mask grids and WDVS debug grids checked. The color scale shows time incurred from center of WDVS area along scan lines and using current WET grid velocity, in seconds. WDVS frequency of 100Hz (Fig. 18) corresponds to one period of 0.010s. See (Zelt and Chen 2016) Fig. 4 and equation (1).

You may notice that scan lines in Fig. 19 are not completely straight when zooming into this figure. To obtain more straight scan lines uncheck option *Fast WDVS* in *Model, WDVS Smoothing* dialog (Fig. 18) and click *OK* button. Now reselect *Smooth invert, WET with 1D-gradient initial model*.

To image the WDVSTIME.GRD as shown in Fig. 19 using Golden Software Surfer version 23 :

- > open Windows Explorer window
- navigate into folder c:\ray32\dat
- create subdirectory named after your current profile e.g. C:\RAY32\DAT\3016_SEG2
- copy wdvstime.grd from c:\ray32\dat into c:\ray32\dat\3016_seg2 during WET inversion
- select File, New, Plot document
- > in box Search commands and Help... type Map Wizard and click Map Wizard
- > in Map Wizard Select Your Data dialog click Browse... button
- select C:\RAY32\DAT\3016_SEG2\WDVSTIME.GRD and click Open button. Click Next button.
- > in Map Wizard Select Your Map Type dialog select Color Relief. Click Finish button.
- ➢ in View menu check Properties box
- left-click image map to show properties in tab on left (Fig. 20)
- ▶ in General, Terrain representation change from Hill shaded to Color only (Fig. 20)
- ▶ in *General, Colors* change to Rainbow2 (Fig. 20)
- uncheck Interpolate pixels box (Fig. 20)
- check Show color scale box (Fig. 20)
- ➢ in NoData change Color to Ghost Green (Fig. 20)
- select View, Fit to window
- > in box Search Commands and Help... type Limits. Click on Set Limits.
- > position mouse cursor over yellow square in center of right or left vertical axis and drag to left or right
- > position mouse cursor over yellow square in center of bottom horizontal axis and drag upwards
- > press ENTER key to confirm changed plot limits
- select View, Fit to window
- > left-click color scale and drag left next to right axis of resized image map
- > drag top and bottom of color scale down/up to align with top/bottom of resized image map
- left-click color scale
- > position mouse cursor over green square in center of right vertical boundary of color scale
- > drag left double-arrow cursor until text labels of color scale look fine / are readable
- click on left vertical axis of image map
- click on Labels tab in Properties tab on left (Fig. 21)
- expand Font properties by clicking on plus symbol (Fig. 21)
- decrease Size (points) to 4 (Fig. 21)
- click on bottom horizontal axis of image map
- decrease Size (points) to 4
- ▶ select *File, Save As* and enter *File name* and click *Save* button

	File	Home	Lay	out	Featu	res
Properties - Color Relief-WDVSTIME.G 🗜 🗙						
Coordinate System Info						
General			Layer			
	Input	Grid				
	Grid fil	e		C:\ 👪) 💕 İ	
🗏 General						
Terrain representation			on	Color only		
Colors				📕 Ra	💌	
Interpolate pixels						
	Show of	olor scale		V		
	NoDat	a				
	Color			G	-	
	Opacit	у		100 %		0

Fig. 20 : Properties for WDVSTIME.GRD

	File H	lome Lay	out	Features		
Pro	perties - Lef	t Axis		Ψ×		
	Scaling Grid Lines			Info		
	General Ticks			Labels		
	Labels					
	Show		V			
	Angle (degrees)			270		
	Offset from axis			0.01527778 in 🚔		
	Label format			d.ddddddd		
	Font properties					
	Font			libri 💌		
	Size (points)			-		
	Foreground color			B 💌		
	Foregro	und opacity	100 %			
	Backgro	und color		W. 💌		
	Backgro	und opacity	0 9	%		
	Bold					
	Italic					
	Strikeou	t				
	Underlin	ne				

Fig. 21 : edit left axis

Surfer plot limits shown in Fig. 4 are used for WET inversion output (Fig. 7&8) only and not for the 1D-gradient starting model (Fig. 6). To display the starting model using these plot limits :

- select Grid Image and contour velocity and coverage grids
- ▶ navigate into directory C:\RAY32\3016 SEG2\GRADTOMO
- select file gradient.grd

For correct geometry specification during SEG-2 import we recommend to first update SEG-2 trace header fields SOURCE_LOCATION and RECEIVER_LOCATION with true x/y/z coordinate triples as shown in our <u>SR6 tutorial</u> using <u>SEG2_EDIT</u> utility. You can use our <u>SEG2_Update</u> utility for batch invocation of SEG2_EDIT for updating trace headers of SEG-2 files with <u>matching_3D.TXT</u> response files. See bullet dated Dec 5, 2021 in our <u>release notes</u>. Run our <u>SEG2_Update installer</u> and then invoke SEG2_Update via *File, SEG-2 import settings, Update SEG-2 files with coordinates* or via its desktop icon.

Once you have updated SEG-2 trace headers with correct source and receiver x/y/z coordinates as described in previous paragraph you can import these updated SEG-2 files as shown above on first page with SEG-2 import settings as shown in Fig. 17. Also check import option *File*, SEG-2 import settings, *Receiver coordinates specified* before importing these updated SEG-2 trace files.

Also you can use our .HDR batch import as shown in our <u>P6 tutorial</u> and as described in our updated <u>.pdf</u> reference chapter *File formats* on page 257.

Here is <u>DropBox link</u> to .RAR archive with seis32.* profile database files for Fig. 7. Here is <u>DropBox link</u> to .RAR archive with GRADTOMO folder files for Fig. 7. Here is <u>DropBox link</u> to .RAR archive with GRADTOMO folder files for Fig. 14.

Next we obtain the pseudo-2D DeltatV starting model with *DeltatV*[*Automatic DeltatV* (Fig. 22) and then use interactive WET tomography with minimal WET smoothing (Fig. 25) and with WDVS activated (Fig. 27) to obtain Fig. 23 :



Fig. 22 : DeltatV starting model obtained with DeltatV Automatic DeltatV and default DeltatV settings (Fig. 26). When prompted to continue with WET inversion press Cancel button.





Fig. 23 : 20 Steepest Descent WET iterations obtained with interactive WET (Fig. 25) using DeltatV starting model Fig. 22. Ricker differentiation 0. Wavepath width 6.5%. Wavepath frequency 50Hz (Fig. 25 left). Minimal WET smoothing (Fig. 25 right). WDVS active @100Hz. Fast WDVS disabled. Discard WET smoothing (Fig. 27).



Line 3016 RMS error 3.0%=1.89ms 20 WET itr. 50Hz Width 6.5% initial DELTATV.GRD v. 4.02

Fig. 24 : WET wavepath coverage plot obtained with Fig. 23. Unit is wavepaths per pixel.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters	
Specify initial velocity model	Determination of smoothing filter dimensions	
Select D:\ray32\3016_SEG2\TOMO\DELTATV.GRD	C Full smoothing after each tomography iteration	
Stop WET inversion after	Minimal smoothing after each tomography iteration	
Number of WET tomography iterations : 20 iterations	 Manual specification of smoothing filter, see below 	
	- Smoothing filter dimensions	
2.0 percent	Half smoothing filter width : 7 columns	
or RMS error does not improve for n = 20 iterations	Half smoothing filter height:	
or WET inversion runs longer than 100 minutes	gird towa	
WET regularization settings	Suppress artefacts below steep topography	
Wavepath frequency : 50.00 Hz Iterate	Adapt shape of filter. Uncheck for better resolution.	
Ricker differentiation [-1:Gaussian,-2:Cosine] : 0 times	Maximum relative velocity update after each iteration	
Wavepath width [percent of one period] : 6.5 percent lterate	Maximum velocity update : 25.00 percent	
Wavepath envelope width [% of period] : 0.0 percent	Smooth after each nth iteration only	
Min. velocity : 10 Max. velocity : 6000 m/sec.	Smooth nth iteration : n = 1 iterations	
Width of Gaussian for one period [SD]: 3.0 sigma	Smoothing filter weighting	
- Gradient search method	C Gaussian	
Steepest Descent C Conjugate Gradient	Used width of Gaussian 1.0 [SD]	
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]	
CG iterations 10 Line Search iters. 2	Smooth velocity update before updating tomogram	
Tolerance 0.001 Line Search tol. 0.0010	Smooth update Smooth nth Smooth last	
Initial step 0.10 Steepest Descent step	Damping of tomogram with previous iteration tomogram	
Edit <u>v</u> elocity smoothing Edit <u>g</u> rid file generation	Damping [01] 0.000 Damp before smoothing	
Start tomography processing Reset Cancel	Accept parameters Reset parameters	

Fig. 25 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right). Settings used for Fig. 23.

	Output Measured CMP Velocities	Edit WDVS (Zelt & Chen 2016)
✓	Output Horizontal offset of CMP pos. in meters	Edit parameters for wavelength-dependent velocity smoothing
	Output DeltatV results in Feet	
	Allow regression over two CMP traces	use WDVS for forward modeling of traveltimes;
✓	CMP is zero time trace	fast WDVS : less accurate mapping of scan line nodes to grid nodes
✓	Reduced offset 0.0 is valid trace with time 0.0	add nodes once only with overlanning scan lines for velocity averaging
	Enforce Monotonically increasing layer bottom velocity	
	Suppress velocity artefacts	add all velocity nodes within WDVS area with radius of one wavelength
	Process every CMP offset	pad WDVS area border with one grid cell
<	Prefer Average over minimum interface velocity	
	Taper velocity steps at layer interfaces	WDVS frequency 100.00 [Hz]
	Smooth CMP traveltime curves	[12]
✓	Weigh picks in CMP curves	Angle increment between scan lines 7 [Degree
	Extrapolate output to all receivers	Regard nth node along scan line
	Regard mapping for shot offset correction	
	Regard true receiver coordinates for shot offset correction	
	Regard 3D source-receiver offset for all traces	Parameters for Cosine-Squared weighting function (Chen and Zelf 2012)
	Extra-large cell size	a : Cosine argument power 1.000 [power]
	Increase cell size	b : Cosine-Squared power 1 000 [power]
	- Decrease cell size	
	Extra-small cell size	- Modify WET smoothing mode : discard after forward modeling
\checkmark	Edit cell size	
	Limit Deltat//uslesity superted to maximum 1D gradient valesity	 discard WET smoothing and WDVS smoothing after modeling
	Limit Deltaty velocity exported to maximum <u>1</u> D-gradient velocity	C restore WET smoothing and discard WDVS smoothing only
	Limit Denaty velocity exported to 3,000 m/s	
	Write new DeltatV settings to .PAR file	OK Cancel Reset
	Reset DeltatV settings to default	
	Reset DeltatV and WET and WDVS settings to .PAR file	

Fig. 26 : DeltatV|DeltatV Settings used for Fig. 22

Fig. 27 : Model WDVS Smoothing settings for Fig. 23.

Note the further improved resolution in overburden of WET tomogram (Fig. 23) compared to Fig. 14 and Fig. 7 for both of which we used full WET smoothing and Ricker differentiation -1 (default settings for *Smooth invert, WET with 1D-gradient initial model*).

Also note the good match between DeltatV starting model (Fig. 22) and final WET tomogram (Fig. 23) using default DeltatV settings (Fig. 26).

The RMS error for DeltatV starting model (Fig. 22) is 2.9ms only while RMS error for default 1D-gradient starting model (Fig. 6) is 7.56ms, more than twice as high.

- > to determine the RMS error of our DeltatV starting model select *Model*|*Forward model traveltimes*
- select c:\ray32\3016 seg2\tomo\deltatv.grd and click Open button
- ▶ select *Grid Image and contour velocity and coverage grids*
- ▶ again select C:\RAY32\3016_SEG2\TOMO\DELTATV.GRD and click Open button to obtain Fig. 22

As shown in Fig. 4 in our <u>synthetic thrust fault zone tutorial</u> our pseudo-2D *DeltatV inversion* can image local velocity inversions, with close enough shot and receiver spacing and favorable subsurface geology.

However in general and especially for short lines and with strong topography and/or with strong refractor curvature in overburden we recommend using our default 1D-gradient initial model for 2D WET inversion instead of using DeltatV starting model. See (Sheehan et al. 2005).

When you select *DeltatV menu* items *Automatic DeltatV* or *Interactive DeltatV* we warn you about pseudo-2D DeltatV artefacts and ask you to confirm if you want to continue anyway (Fig. 28).

Pseud	o-2D initial model will cause artefacts : Continue anyway ?
2	Pseudo-2D DeltatV inversion will result in velocity artefacts, in case of strong refractor curvature or strong topography curvature and for lines shorter than 500m. See our tutorials http://rayfract.com/tutorials/epikinv.pdf and http://rayfract.com/tutorials/fig9inv.pdf . We recommend to use our Smooth inversion method instead, based on a 1D gradient initial model. See http://rayfract.com/SAGEEP10.pdf . Do you want to proceed with pseudo-2D based inversion anyway ?
	Yes <u>N</u> o

Fig. 28 : DeltatV artefacts warning prompt shown when selecting *DeltatV menu* items *Automatic DeltatV* or *Interactive DeltatV*.

Here is <u>DropBox link</u> to .RAR archive with seis32.* profile database files for Fig. 23. Here is <u>DropBox link</u> to .RAR archive with TOMO folder files for Fig. 23.

For above seis32.* profile database we checked option *WET Tomo*|*WET tomography Settings*|*Write*|*Write blanked and mask grids and WDVS debug grids* so you can copy and image WDVSTIME.GRD files as described for Fig. 19. This does slow down WET inversion significantly.

Next we redo Fig. 23 with same parameters but using WET *wavepath frequency* of 30Hz instead of default 50Hz to obtain Fig. 29 :





Fig 29 : same as Fig. 23 but decreased WET wavepath frequency to 30Hz from default 50Hz.

Fig. 30 : multirun Steepest-Descent WET. Manual WET smoothing. Half-width of WET smoothing filter is 10 columns (Fig. 38 and Fig. 39). Showing 8th WET run. DeltatV starting model for 1st WET run is Fig. 22. WDVS@100Hz (Fig. 27).



Fig. 31 : multirun Steepest-Descent WET. Manual WET smoothing. Half-width of WET smoothing filter is 10 columns (Fig. 38 and Fig. 39). Showing 9th WET run. DeltatV starting model for 1st WET run is Fig. 22. WDVS@100Hz (Fig. 27).

Compare Fig. 29 WET tomogram with Fig. 23. The low-velocity layer in overburden is imaged a bit less clearly in Fig. 29. But there are fewer vertical artefacts in Fig. 29 in overburden due to wider wavepaths. For Fig. 30 and Fig. 31 we increase lateral smoothing with half-width of *WET smoothing filter* set to 10 columns instead of default 7 grid columns for minimal WET smoothing.

Here is <u>DropBox link</u> to .RAR archive with seis32.* profile database files for Fig. 29. Here is <u>DropBox link</u> to .RAR archive with TOMO folder files for Fig. 29.

Here is <u>DropBox link</u> to .RAR archive with seis32.* profile database files for Fig. 30 and Fig. 31. Here is <u>DropBox link</u> to .RAR archive with TOMO folder files for Fig. 30 and Fig. 31.

Next we map traces to 2 refractors and 3 layers in *Refractor*|*Midpoint breaks* (Fig. 32) and run our *Plus-Minus refraction* method to obtain layered refraction starting model (Fig. 35).



Fig. 32 : map traces to 2 refractor in *Refractor*|*Midpoint breaks*. Press ALT+M and edit as shown. Click *Map traces* button. Pess ALT+G to edit crossover distance smoothing dialog (Fig. 33).

Crossover distance smoothing	-
Crossover distance smoothing	
Overburden filter [station nos.]	5
Basement filter [station nos.]	10
Offset limit basement coverage	
Offset limit [station nos.]	20
<u>A</u> ccept <u>R</u> eset	<u>C</u> ancel

5 1			
Recompute traveltime chara	acteristics		
Prefer CMP overburden refractor mapping			
Prefer regressed traveltimes	5		
Regression tolerance [msec.]	0.000001		
Smoothing parameters			
Overburden filter [station nos.]	5		
	-		
Base filter width [station nos.]	5		



Fig. 34 : edit Plus-Minus method parameters. Select Depth|Plus-Minus. When prompted to continue with WET click No. Reselect Depth||Plus-Minus and press ALT+M in Plus-Minus depth section window.



Fig. 35 : select Depth|Plus-Minus and click No button when prompted to continue with WET. Press ALT+M in Plus-Minus depth section window. Edit as in Fig. 34 and press ENTER key to obtain this Plus-Minus method layered refraction starting model.



Fig. 36 : multirun Steepest-Descent WET. Manual WET smoothing. Half-width of WET smoothing filter is 10 columns (Fig. 38 and Fig. 39). Showing 8th WET run. Plus-Minus starting model for 1st WET run is Fig. 35. WDVS@100Hz (Fig. 27).



Fig. 37 : WET wavepath coverage plot obtained with Fig. 36. Unit is wavepaths per pixel.

Line 3016 RMS error 3.0%=1.85ms 20 WET itr. 50Hz Width 12.0% initial RUN7IT20.GRD v. 4.02

Note the good match between Fig. 36 using Plus-Minus starting model and Fig. 30 using DeltatV starting model. Multiscale WET inversion output can be quite independent of the starting model.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters	
Specify initial velocity model	Determination of smoothing filter dimensions	
Select C:\RAY32\3016_SEG2\LAYRTOMO\PLUSMODL.GRD	C Full smoothing after each tomography iteration	
Stop WET inversion after	Minimal smoothing after each tomography iteration	
Number of WET tomography iterations : 20 iterations	Manual specification of smoothing filter, see below	
or RMS error gets below 2.0 percent	Smoothing filter dimensions	
ar PMS error dees not improve for n =	Half smoothing filter width : 10 columns	
	Half smoothing filter height : 0 grid rows	
or WET inversion runs longer than 100 minutes		
WET regularization settings	Suppress artefacts below steep topography	
Wavepath frequency : 50.00 Hz Iterate	Adapt snape of litter. Uncheck for better resolution.	
Ricker differentiation [-1:Gaussian,-2:Cosine] : 0 times	Maximum relative velocity update after each iteration	
Wavepath width [percent of one period] : 12.0 percent Iterate	Maximum velocity update : 25.00 percent	
Wavepath envelope width [% of period] : 6.0 percent	Smooth after each nth iteration only	
Min. velocity : 10 Max. velocity : 6000 m/sec.	Smooth nth iteration : n = 1 iterations	
Width of Gaussian for one period [SD]: 3.0 sigma	Smoothing filter weighting	
Gradient search method	🔿 Gaussian 🔎 Uniform 🔲 No smoothing	
Steepest Descent C Conjugate Gradient	Used width of Gaussian 1.0 [SD]	
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]	
CG iterations 10 Line Search iters. 2	Smooth velocity update before updating tomogram	
Tolerance 0.001 Line Search tol. 0.0010	I Smooth update	
Initial step 0.10 Steepest Descent step	Damping of tomogram with previous iteration tomogram	
Edit velocity smoothing Edit grid file generation	Damping [01] 0.000 Damp before smoothing	
Start tomography processing Reset Cancel	Accept parameters Reset parameters	

Fig. 38 : WET Tomo|Interactive WET main dialog (left) settings used for Fig. 36. Edit velocity smoothing (right).

Edit WET ru	ins - wavep	ath width				
Run No.	Freq. [Hz]	Width [%]	Width [ms]	Iterations		ОК
Run 1	50.0	30.0	6.000	5	🔽 Blank	
Run 2	50.0	26.0	5.200	5	Blank	Cancel
Run 3	50.0	23.0	4.600	5	Plank	Reset
Run 4	50.0	20.0	4.000	5	🔽 Blank	✓ WET runs active
Run 5	50.0	18.0	3.600	10	🔽 Blank	🔲 Scale default widths
Run 6	50.0	16.0	3.200	20	🔽 Blank	Plot runs in Surfer
Run 7	50.0	14.0	2.800	20	🔽 Blank	Prompt run mistit
Run 8	50.0	12.0	2.400	20	🔽 Blank	Runs completed 10
Run 9	50.0	11.0	2.200	20	🔽 Blank	Current run no
Run 10	50.0	10.0	2.000	20	🔽 Blank	Resume current run
Blank b	elow wavep ank after eac	ath envelop h run 🔽	e Blank after	lastrun		

Fig. 39 : WET Tomo Interactive WET Iterate. Edit WET run schedule used for Fig. 36.

Here is <u>DropBox link</u> to .RAR archive with seis32.* profile database files for Fig. 36. Here is <u>DropBox link</u> to .RAR archive with LAYRTOMO folder files for Fig. 36.



Fig. 40 : WDVSTIME.GRD with WDVS frequency set to 66Hz in Model|WDVS Smoothing dialog (Fig. 27). Unit is delay time in seconds along radial scan lines with origin at center of current WDVS area. See (<u>Zelt and Chen 2016</u>) Fig. 4 and equation (1).

In Fig. 40 we show another sample WDVSTIME.GRD obtained during WET inversion using DeltatV starting model (Fig. 29). We imaged this WDVSTIME.GRD using Surfer 23 as described below Fig. 19.

Note the asymmetry of the WDVS area in Fig. 40 determined by maximum delay time of 0.015 seconds (one period for *WDVS frequency* of 66Hz) along radial scan lines. This asymmetry is caused by decreasing grid velocity towards upper left of WDVS area compared to lower right of WDVS area. See Fig. 29 at elevation 285m and horizontal offset 260m. For WDVS theory see (Zelt and Chen 2016) Fig. 4 and equation (1).



Fig. 41 : WDVSTIME.GRD with WDVS frequency set to 100Hz in Model|WDVS Smoothing dialog (Fig. 27). Unit is delay time in seconds along radial scan lines with origin at center of current WDVS area.

In Fig. 41 we show another sample WDVSTIME.GRD centered at elevation 295m and horizontal offset 734m with *WDVS frequency* set to 100Hz (Fig. 27). One period amounts to 0.010 seconds. Compare with Fig. 29 to explain the shape of the WDVS area.

In our experience WDVS smoothing can help to obtain better resolved WET tomograms using fewer WET iterations. Tuning of *WDVS frequency* and *WET smoothing* is subjective and trial-and-error based. See also our updated <u>.pdf reference</u> chapter *WDVS velocity smoothing* on page 167 and our <u>SAGEEP 2021</u> and <u>EGU</u> 2021 publications.



Fig. 42 : click No button to leave *Profile start* and first receiver station at station no. 0.

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button.

Copyright © 1996-2023 Intelligent Resources Inc. All rights reserved.