

Import SEG-2 .DAT & Update header data & Smooth invert shear wave SH 60M v. 5.01 :

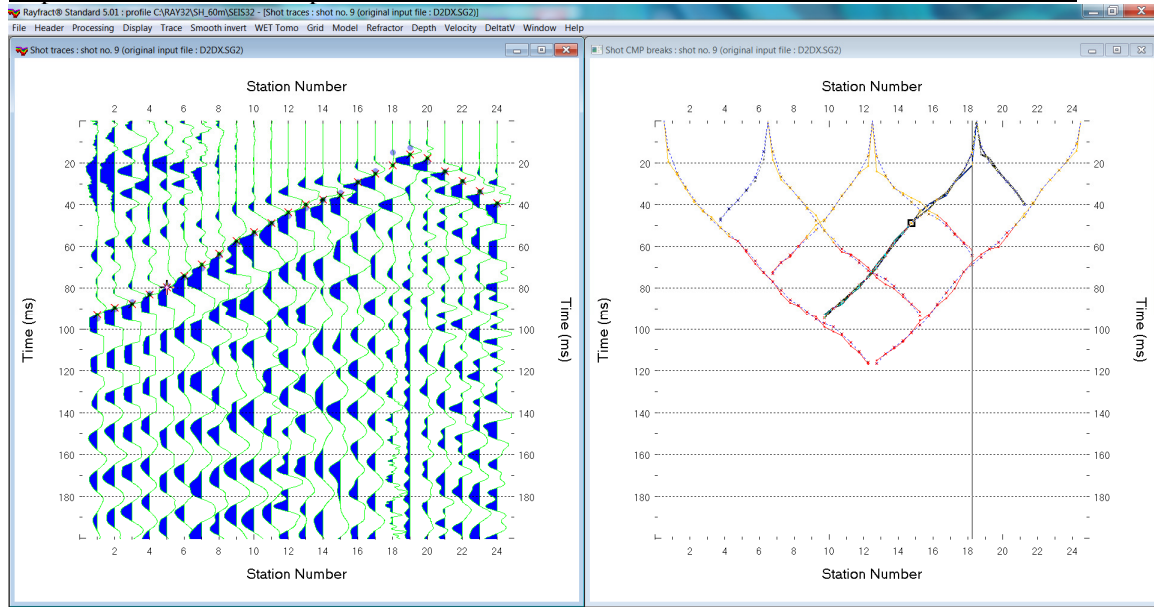


Fig. 1 : check *Trace/Open Refractor/Shot CMP breaks*. Left : *Trace/Shot gather*. Right : *Refractor/Shot CMP breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed blue curves, blue dots). Green dots are your reciprocal picks.

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

- **File>New Profile...**, set *File name* to **SH_60M** and click *Save button*
- in the prompt shown next (Fig. 4) click **Yes** button to force **Profile start** / first channel at station no. 1
- in **HeaderProfile...** select *Line type* **Refraction spread/line**. Set *Station spacing* to 2.5 m. See Fig. 2.
- unzip archive https://rayfract.com/tutorials/SH_60M_INPUT.zip with SEG-2 .SG2 shot files & file **BREAKS.LST** in directory **C:\RAY32\SH_60M\INPUT**
- select **File/Import Data...** and set *Import data type* to **SEG-2**. See Fig. 3.
- click **Select button** and navigate into **C:\RAY32\SH_60M\INPUT**
- set control **Files of type** to **ABEM files (*.SG2)** and select a file e.g. **ADX.SG2** & click **Open**
- set control **Take shot record number from** to **File number**
- leave **Default spread type** at **10: 360 channels**
- click **Import shots button**.
- leave **Layout start** at 1 for all shots displayed in our **Import shot** dialog
- specify **Shot pos. [station no.]** 0.5, 0.5, 24.5, 24.5, 12.5, 12.5, 6.5, 6.5, 18.5, 18.5 and click **Read button** for Shot Number 1 to 10
- select **File/Update header data/Update First Breaks**. Select file **BREAKS.LST** & click **Open**.
- select option **Trace/Open Refractor/Shot CMP breaks with Shot gather**
- select **Trace/Shot gather** to obtain Fig. 1
- press **SHIFT+Q** to show **Frequency filter** dialog. Uncheck **Filter active**. Click **Filter**. See Fig. 11.
- click on title bar of **Trace/Shot gather** window and press **CTRL+F1** to zoom trace amplitude
- browse shots in **Trace/Shot gather** window with **F7/F8** (Fig. 1 left)
- click on title bar of **Refractor/Shot CMP breaks** window (Fig. 1 right) and press **ALT+P**. Edit **Maximum time** to 200 ms & press **ENTER** key to redisplay. Do the same for **Trace/Shot gather** window (Fig. 1 left).

Run default fail-safe Smooth inversion with 1D-gradient laterally averaged starting model :

- check option *Grid\Receiver station ticks on top axis*
- check option *Grid\CS_CENTERED font for shot points and receivers* to workaround Surfer symbol display issues
- edit *Grid\Surfer plot Limits* as in Fig. 8
- select *Model\WDVS Smoothing* and click radio button *restore WET smoothing and discard WDVS smoothing only*. Leave box *use WDVS for forward modeling of traveltimes* unchecked (Fig. 9).
- select ***Smooth invert\WET with 1D-gradient initial model***
- wait for the 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 6 & 7

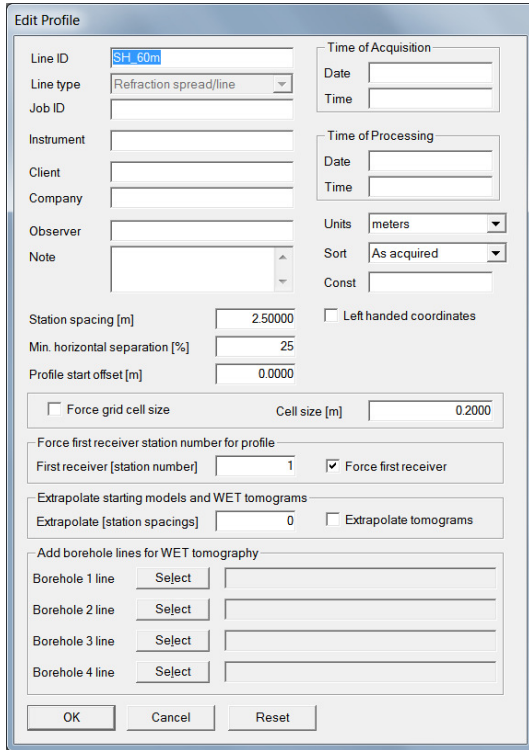


Fig. 2 : Header\Profile

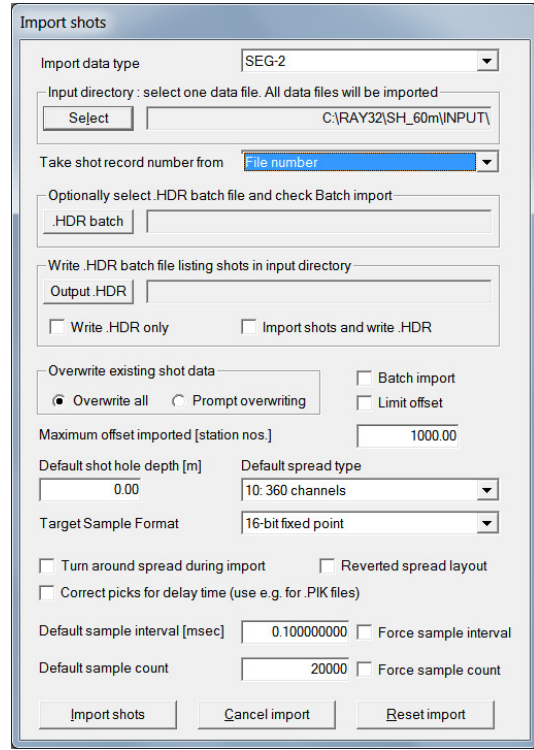


Fig. 3 : File\Import Data

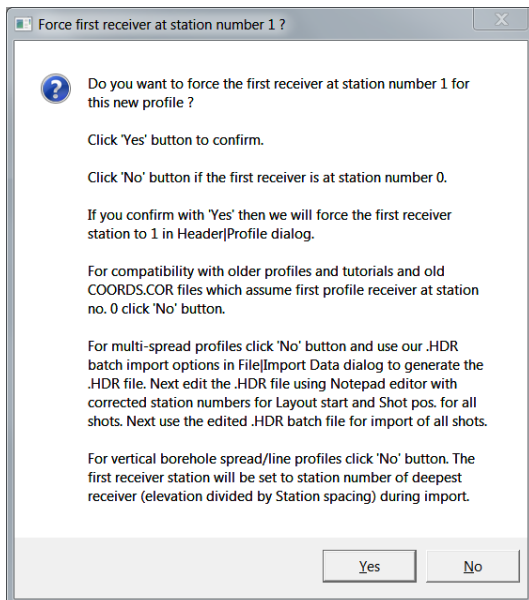


Fig. 4 : click Yes button to force the first receiver at station number 1 for this profile.

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button. For multi-spread profiles click No button and use our .HDR batch import options in *File\Import Data* dialog to generate the .HDR file. Next edit the .HDR file using MS Notepad editor with corrected station numbers for Layout start and Shot pos. for all shots. Next use the edited .HDR batch file for import of all shots.

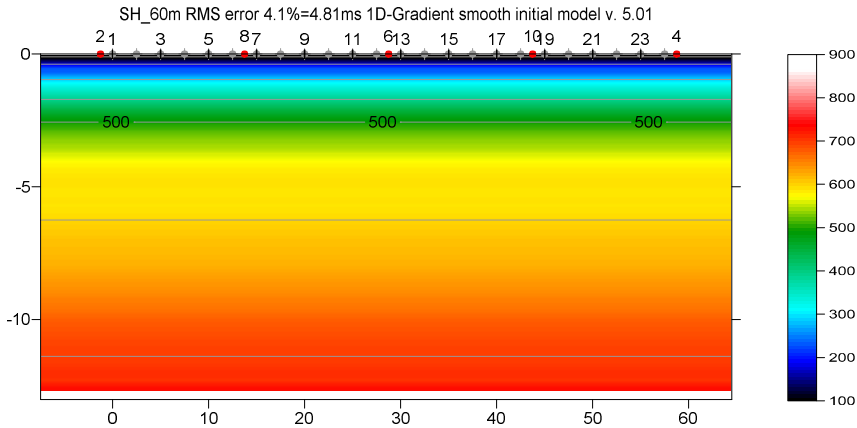


Fig. 5 : 1D-gradient starting model obtained with *Smooth invert|WET with 1D-gradient initial model*.

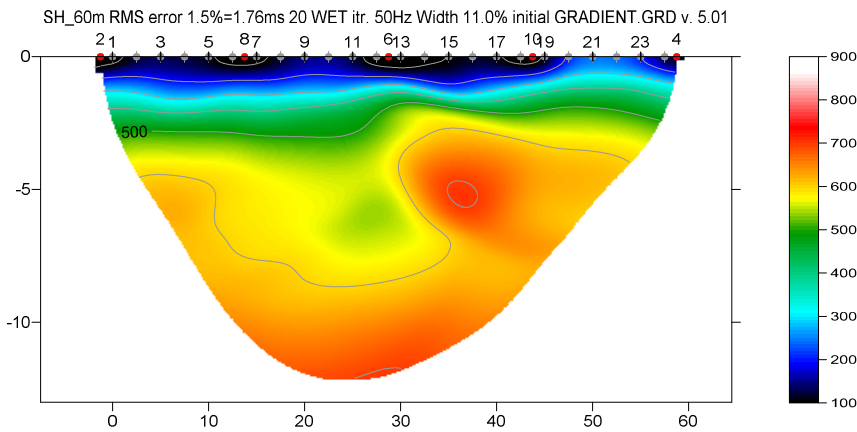


Fig. 6 : 2D WET output obtained with *Smooth invert|WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Don't discard WET smoothing after forward modeling. Leave WDV5 disabled (Fig. 9).

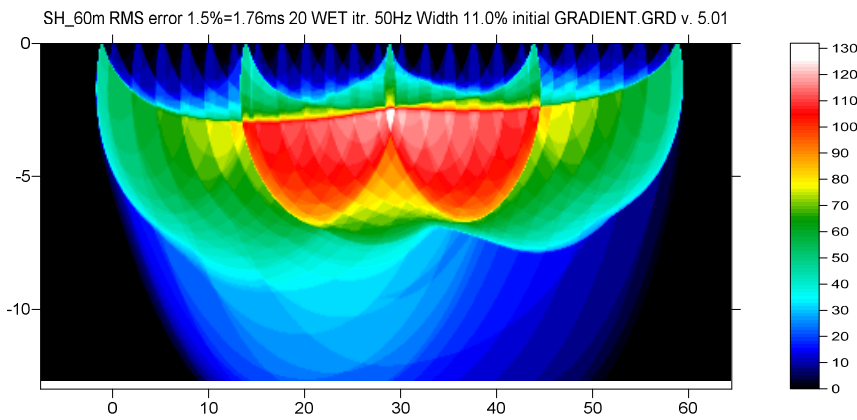


Fig. 7 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per grid cell.

Edit Surfer plot limits

Plot Limits

Plot limits active Use data limits

Min. offset [m]

Max. offset [m]

Min. elevation [m]

Max. elevation [m]

Min. velocity [m/sec.]

Max. velocity [m/sec.]

Plot Scale

Proportional XY Scaling

Page unit centimeter. Uncheck for inch.

X Scale length [inch]

Y Scale length [inch]

Color Scale

Adapt color scale

Scale height [inch]

Velocity interval [m/sec.]

Coverage interval [paths/pixel]

Receiver labeling

First station [station no.]

Station interval [station no.]

Use station index or station no. offset

OK
Cancel
Reset
Reset to grid
Redisplay grid

Fig. 8 (left) : Grid/Surfer plot Limits dialog .

Edit WDVS (Zelt & Chen 2016)

Edit parameters for wavelength-dependent velocity smoothing

use WDVS for forward modeling of traveltimes

fast WDVS : less accurate mapping of scan line nodes to grid nodes

add nodes once only with overlapping scan lines for velocity averaging

add all velocity nodes within WDVS area with radius of one wavelength

pad WDVS area border with one grid cell

WDVS frequency [Hz]

Angle increment between scan lines [Degree]

Regard nth node along scan line [node]

Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)

a : Cosine argument power [power]

b : Cosine-Squared power [power]

Modify WET smoothing mode : discard after forward modeling

discard WET smoothing and WDVS smoothing after modeling

restore WET smoothing and discard WDVS smoothing only

OK
Cancel
Reset

Fig. 9 : Model/WDVS Smoothing dialog .

Edit parameters for reciprocal error file (Jim Whiteley 2020)

Select output .ERR file

Select error file

Sort lines in .ERR file by decreasing reciprocal error

Sort .ERR lines by relative reciprocal error

Sort .ERR lines by absolute reciprocal error in ms

Sort .ERR lines by offset and CMP (as in Trace/Offset gather display)

CMP interval for mapping common-offset sorted traces to same midpoint

Reciprocal CMP interval [station no.] to search for reciprocal traces

Export to .ERR
Cancel
Reset

Fig. 10 : Trace/Export reciprocal errors and update database

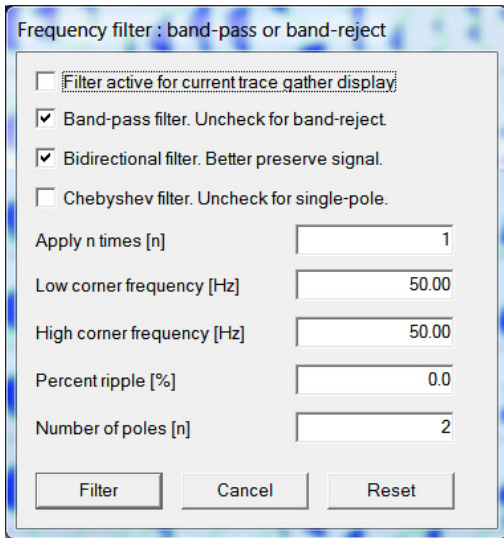


Fig. 11 : press SHIFT+Q in *Trace/Shot gather*. Uncheck box *Filter active for current trace gather display*. Click button *Filter*.

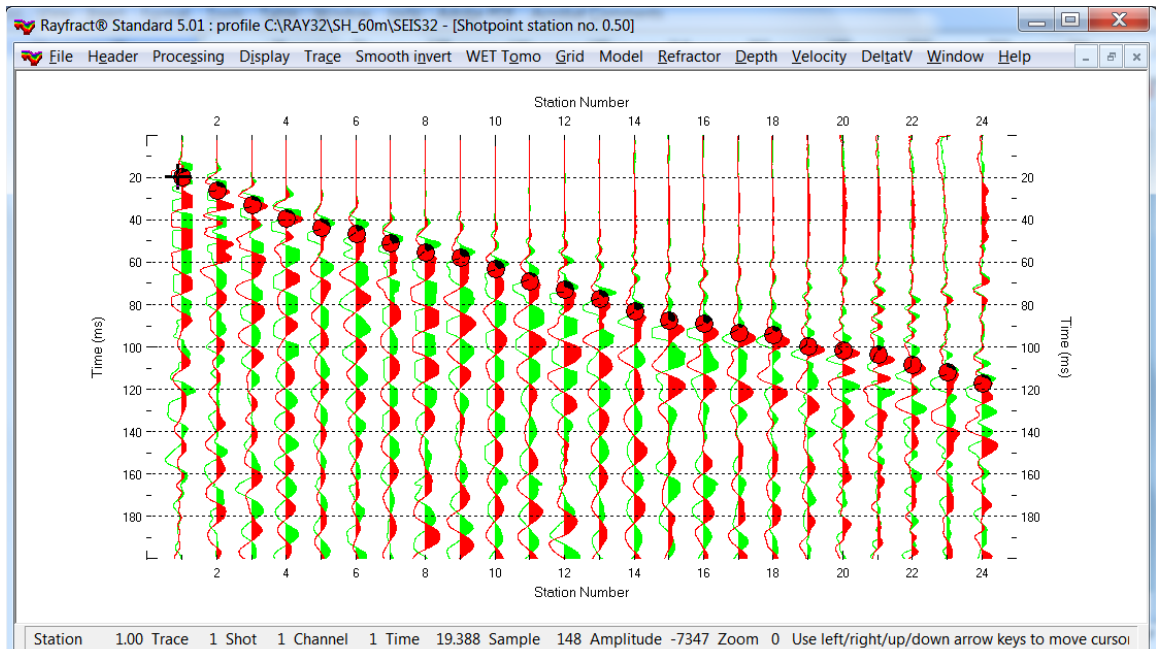


Fig. 12 : select *Trace/Shotpoint gather*. Browse gathers with F7/F8. Check *Display/Color traces*. Uncheck *Display/Color trace outline*. Check *Display/Show picks on time axis*. Check *Processing/Pick all shots, in shot point gather*.

Pick shear-wave first breaks in Trace/Shotpoint gather display

- select *Trace/Shotpoint gather*. Browse gathers with F7/F8. See Fig. 12.
- check *Display/Color traces*. Uncheck *Display/Color trace outline*.
- check *Display/Show picks on time axis*.
- check *Processing/Pick all shots, in shot point gather*.
- press SHIFT+Q. Uncheck box *Filter active*. Click button *Filter*. See Fig. 11.
- pick S-wave first breaks with left mouse button. See Fig. 12. Solid red circles are your picks.
- select *File/Export header data/Export First Breaks to .LST*. Click *Save* to save to **BREAKS.LST**.

Plot your reciprocal traveltimes picks on shot-sorted trace gathers :

Plotting your reciprocal traveltimes picks on shot-sorted trace gathers lets you quality-control your first break picks and check the validity of your recording geometry specification (shot station numbers and receiver station numbers) :

- select *Trace|Export reciprocal traveltimes picks and update database*
- click button *Select error file* and click *Save* button (Fig. 10)
- click button *Export to .ERR*
- optionally check new option *Trace|Open Refractor|Shot CMP breaks with Shot gather*
- select *Trace|Shot gather* to obtain a window display as in our Fig. 1
- check new version 4.05 option *Display|Show reciprocal picks on Shot Gather*
- browse and zoom trace gathers with function keys F7/F8, F1/F2 etc. as usual
- navigate traces with arrow-left and arrow-right keys
- if a reciprocal pick was determined/matched to the current trace then this is plotted as a green dot on the trace
- also we show *Reciprocal Shot/Channel* and *Reciprocal offset[m]/CMP* in status bar at bottom of window (Fig. 1 left) if a reciprocal pick is available in the .ERR file

Here is the link to the .RAR archive with the SH_60M profile folder for above Fig. 6 :

https://www.dropbox.com/scl/fi/vjqy70ux4lh4vcrnh5lt/SH_60m_Oct5_2024_DisableWDVS.rar?rlkey=mx0qhf3bls3tik96jxwqdr3t7&st=dw630das&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Interactive WET tomography using default fail-safe 1D-gradient starting model

Next we show interactive WET tomography (Fig. 13) using the same 1D-gradient starting model obtained with *Smooth invert|WET with 1D-gradient initial model* as shown in Fig. 5. We discard WET smoothing after forward modeling (Fig. 16) trying to reach a better resolution. We increase the number of *WET iterations* from default 20 iterations to 50 iterations. Also we modify the *Ricker differentiation* from default *-1 [Gaussian]* to *0 [Ricker wavelet]* to better deal with the velocity inversion at depth of about 8m (Fig. 6).

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 C:\RAY32\SH_60m\GRADTOMO\GRADIENT.GRD

Stop WET inversion after

Number of WET tomography iterations : iterations

or RMS error gets below percent

or RMS error does not improve for n = iterations

or WET inversion runs longer than minutes

WET regularization settings

Wavepath frequency : Hz

Ricker differentiation [-1:Gaussian,-2:Cosine] : times

Wavepath width [percent of one period] : percent

Wavepath envelope width [% of period] : percent

Min. velocity : Max. velocity : m/sec.

Width of Gaussian for one period [SD] : sigma

Gradient search method

Steepest Descent Conjugate Gradient

Conjugate Gradient Parameters

CG iterations Line Search iters.

Tolerance Line Search tol.

Initial step Steepest Descent step

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions

Full smoothing after each tomography iteration

Minimal smoothing after each tomography iteration

Manual specification of smoothing filter, see below

Smoothing filter dimensions

Half smoothing filter width : columns

Half smoothing filter height : grid rows

Suppress artefacts below steep topography

Adapt shape of filter. Uncheck for better resolution.

Maximum relative velocity update after each iteration

Maximum velocity update : percent

Smooth after each nth iteration only

Smooth nth iteration : n = iterations

Smoothing filter weighting

Gaussian Uniform No smoothing

Used width of Gaussian [SD]

Uniform central row weight [1..100]

Smooth velocity update before updating tomogram

Smooth update Smooth nth Smooth last

Damping of tomogram with previous iteration tomogram

Damping [0..1] Damp before smoothing

Fig. 13 : WET Tomo|Interactive WET main dialog (left). Edit as shown. Click *Edit velocity smoothing* (right). Leave at default *Full smoothing* and click *Accept parameters*. Click *Start tomography processing* to obtain Fig. 14 and 15.

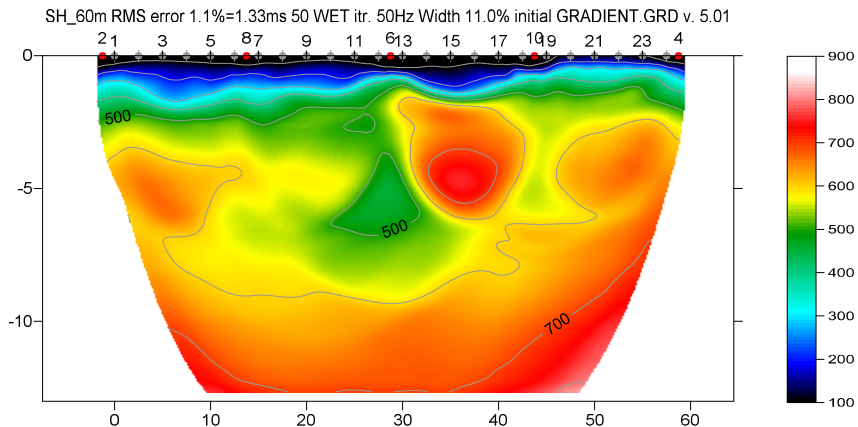
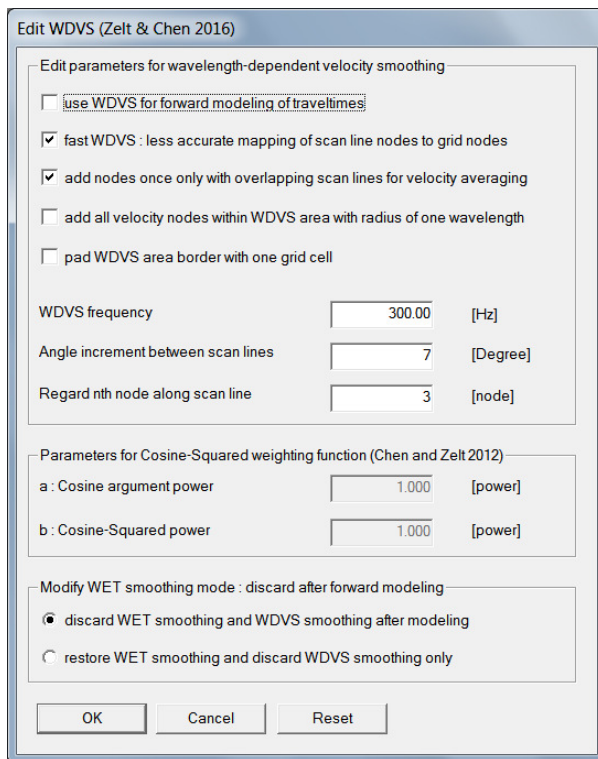
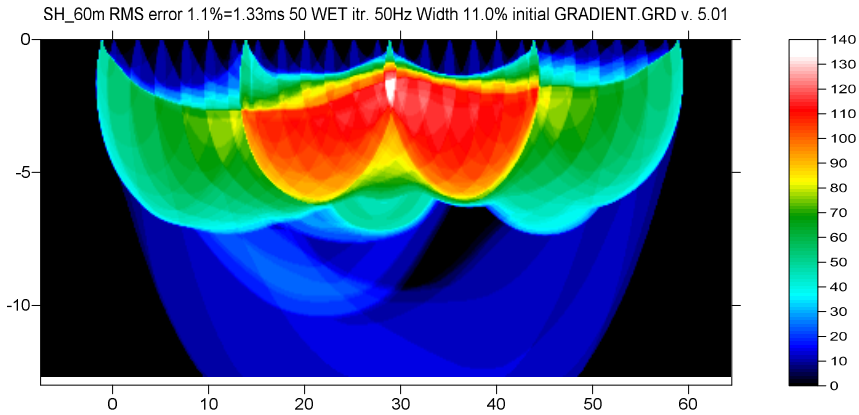


Fig. 14 : 50 Steepest-Descent WET iterations using a Ricker wavelet for weighting of WET velocity update across the wavepath (Fig. 13 left). Leave WET smoothing at default *Full smoothing* (Fig. 13 right). Starting model is Fig. 5. Discard WET smoothing (Fig. 16).

In Fig. 14 we reach a smaller RMS error compared to Fig. 6. Also the velocity inversion at depth of about 8m becomes better visible.



Here is the link to the .RAR archive with the SH_60M profile folder for above Fig. 14 :

https://www.dropbox.com/scl/fi/7pt1naxzdeekpeh2f17kt/SH_60m_GradTomo_50WETIters_RickerDiff0_Oct13_2024.rar?rlkey=tq1t20738dg9ly381zpl9vjsf&st=8gmu4vjy&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Smooth invert using 1D-gradient starting model and discarding WET smoothing

Next we show re-running our Smooth invert using the same 1D-gradient starting model shown in Fig. 5. But now we discard the WET smoothing as shown in Fig. 16 :

- select *Model\WDVS Smoothing*
- check option *Discard WET smoothing* (Fig. 16) and click button OK.
- select *Smooth invert\WET with 1D-gradient initial model*
- wait for the same 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain refined WET output shown in Fig. 17 & 18

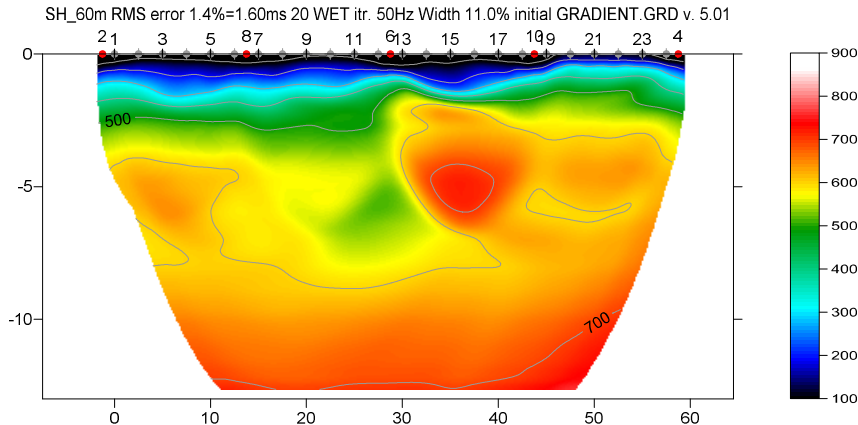


Fig. 17 : 2D WET output obtained with *Smooth invert\WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 16).

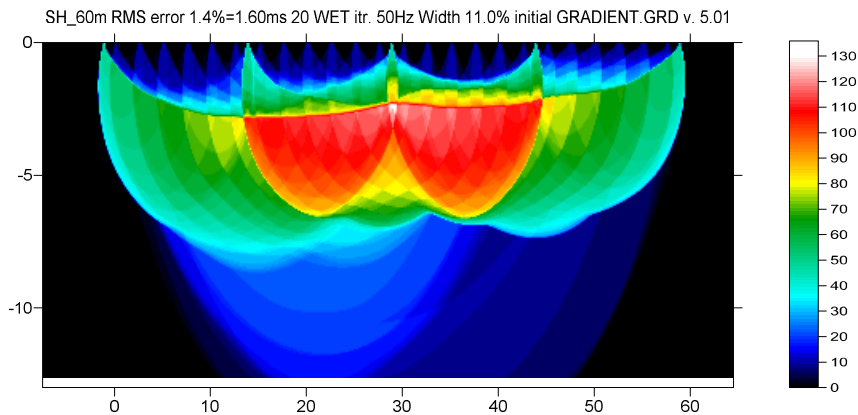


Fig. 18 : WET wavepath coverage obtained with Fig. 17. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the SH_60M profile folder for above Fig. 17 :

https://www.dropbox.com/scl/fi/ku4os7jrb1j1gn5epsehk/SH_60m_GradTomo_SmoothInvert_DiscardWET_Oct18_2024.rar?rlkey=ufm7of2fyvltoe2vibg2pwqx0&st=9u3x7zdd&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Smooth invert using pseudo-2D DeltatV starting model and discarding WET smoothing

Next we show running our Automatic DeltatV and WET inversion using the pseudo-2D DeltatV starting model shown in Fig. 19. We again discard the WET smoothing as shown in Fig. 16 :

- select *Model\WDVS Smoothing*
- check option *Discard WET smoothing* (Fig. 16) and click button OK.
- select *DeltatV\Automatic DeltatV and WET inversion*
- wait for the pseudo-2D DeltatV starting model to display as in Fig. 19
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 20 & 21

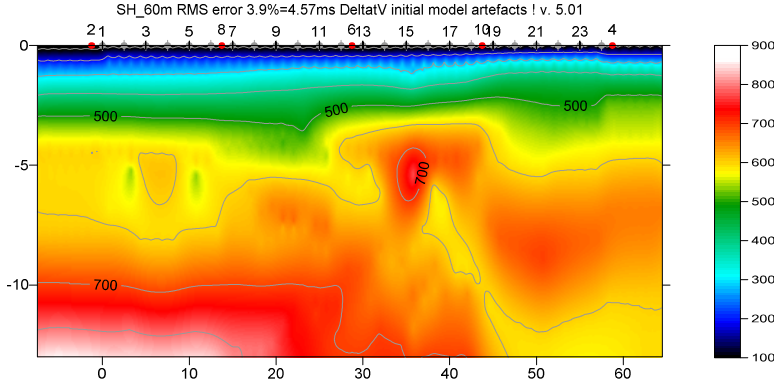


Fig. 19 : Pseudo-2D DeltatV starting model obtained with *DeltatV\Automatic DeltatV and WET inversion*. We leave DeltatV settings in *DeltatV\DeltatV Settings* menu at their defaults. See Fig. 22.

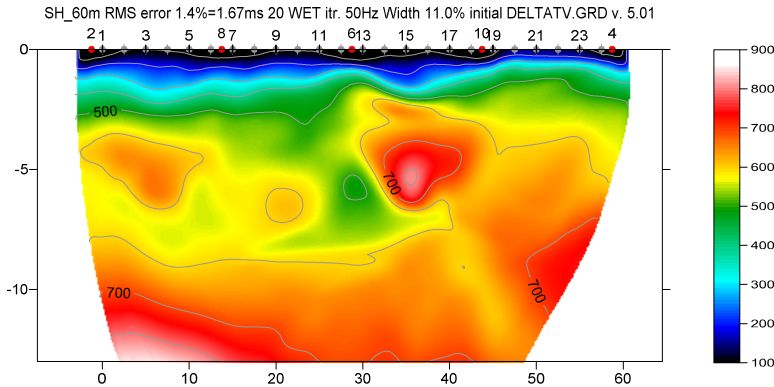


Fig. 20 : 2D WET output obtained with *DeltatV\Automatic DeltatV and WET inversion* & starting model shown in Fig. 19. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 16). We leave DeltatV settings in *DeltatV\DeltatV Settings* menu at their defaults. See Fig. 22.

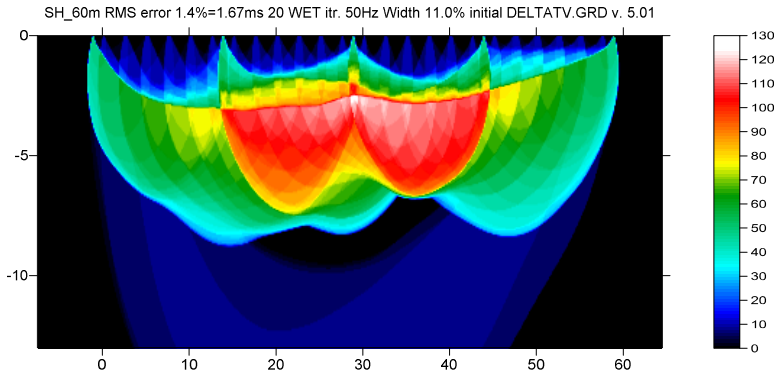


Fig. 21 : WET wavepath coverage plot obtained with Fig. 20. Unit is number of wavepaths per grid cell.

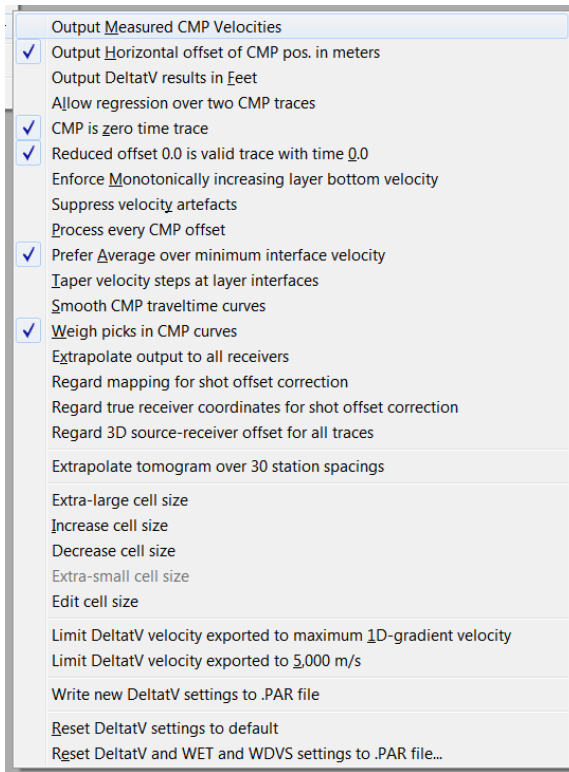


Fig. 22 : *DeltatV/DeltatV Settings*. Leave settings at their defaults as shown.

Note the good match between the pseudo-2D DeltatV starting model in Fig. 19 and the resulting 2D WET tomogram in Fig. 20. Also note the good match between Fig. 20 and Fig. 17 using our fail-safe 1D-gradient starting model.

Pseudo-2D DeltatV fails to give a realistic starting model in case of strong topography or with strong lateral velocity change in the overburden. See e.g. our tutorial https://rayfract.com/tutorials/1_1D.pdf . Always first run our Smooth invert as shown above in Fig. 6 using our fail-safe 1D-gradient starting model obtained by laterally averaging 1D DeltatV velocity profiles (Fig. 5; Sheehan 2005).

Here is the link to the .RAR archive with the SH_60M profile folder for above Fig. 20 :

https://www.dropbox.com/scl/fi/junrcad5tcdg22bi5mxg4/SH_60m_DeltatV_And_WET_Nov3_2024.rar?rlkey=ft5eh9ujo833pnrp3b8tx3ny7&st=rpcgpnrx&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Multiscale WET inversion using 1D-gradient starting model and discarding WET smoothing

Next we run our *multiscale WET inversion* to further improve the resolution in the WET tomogram. We use the same *fail-safe 1D-gradient starting model* shown in Fig. 5. We again discard the WET smoothing as shown in Fig. 16. We edit the *Surfer plot Limits* to better visualize the velocity inversion. We enable scaling of *WET wavepath width* and *WET filter height*. We use proven default settings in *WET Tomo\Interactive WET* dialog and default WET smoothing :

- select *Model\WDVS Smoothing*
- check option *Discard WET smoothing* (Fig. 16) and click button *OK*.
- select *Smooth invert\WET with 1D-gradient initial model*
- wait for the same 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain refined WET output shown in Fig. 17 & 18
- edit *Grid\Surfer plot Limits* as in Fig. 23. Click button *OK*.
- uncheck option *WET Tomo\Blank\Blank below envelope after last iteration*
- uncheck *WET Tomo\WET tomography Settings\Disable wavepath scaling for short profile* (Fig. 24).
- select *WET Tomo\Interactive WET*. Edit main dialog and WET smoothing as in Fig. 25 : reset parameters to their defaults.
- in *WET Tomo\Interactive WET* main dialog click *Iterate* button. Leave settings at defaults (Fig. 26).
- check box *WET runs active* (Fig. 26). Click *OK* button. Click button *Start tomography processing*.

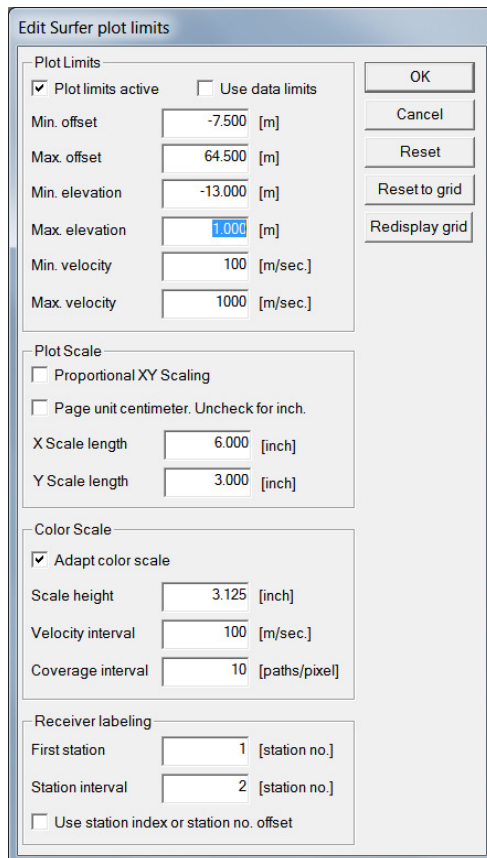


Fig. 23 : *Grid\Surfer plot Limits*

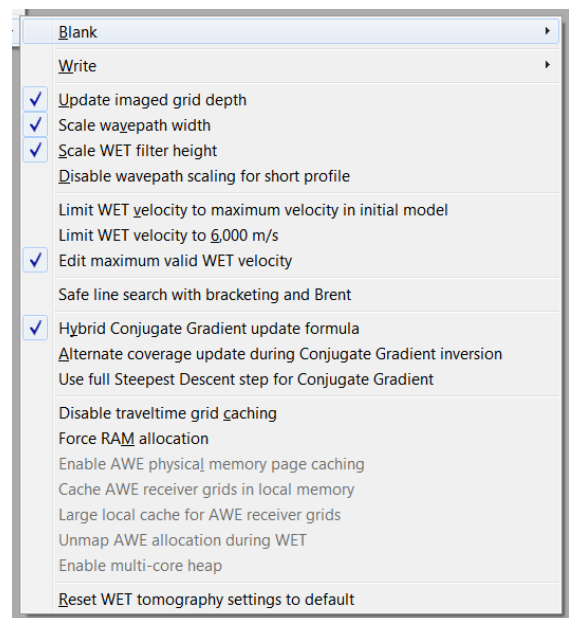


Fig. 24 : *WET Tomo\WET tomography Settings*. Uncheck *Disable wavepath scaling for short profile* to enable scaling of wavepath width and WET filter height.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 C:\RAY32\SH_60m\GRADTOMO\GRADIENT.GRD

Stop WET inversion after

Number of WET tomography iterations : iterations

or RMS error gets below percent

or RMS error does not improve for n = iterations

or WET inversion runs longer than minutes

WET regularization settings

Wavepath frequency : Hz

Ricker differentiation [-1:Gaussian,-2:Cosine] : times

Wavepath width [percent of one period] : percent

Wavepath envelope width [% of period] : percent

Min. velocity : Max. velocity : m/sec.

Width of Gaussian for one period [SD] : sigma

Gradient search method

Steepest Descent Conjugate Gradient

Conjugate Gradient Parameters

CG iterations Line Search iters.

Tolerance Line Search tol.

Initial step Steepest Descent step

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions

Full smoothing after each tomography iteration

Minimal smoothing after each tomography iteration

Manual specification of smoothing filter, see below

Smoothing filter dimensions

Half smoothing filter width : columns

Half smoothing filter height : grid rows

Suppress artefacts below steep topography

Adapt shape of filter. Uncheck for better resolution.

Maximum relative velocity update after each iteration

Maximum velocity update : percent

Smooth after each nth iteration only

Smooth nth iteration : n = iterations

Smoothing filter weighting

Gaussian Uniform No smoothing

Used width of Gaussian [SD]

Uniform central row weight [1..100]

Smooth velocity update before updating tomogram

Smooth update Smooth nth Smooth last

Damping of tomogram with previous iteration tomogram

Damping [0..1] Damp before smoothing

Fig. 25 : select *WET Tomo/Interactive WET*. Click *Reset* in main dialog (left). Click button *Edit velocity smoothing*. Click button *Reset parameters* (right). Click button *Accept parameters*. Click button *Iterate*. Edit as in Fig. 26.

Edit WET runs - wavepath width

Run No.	Freq. [Hz]	Width [%]	Width [ms]	Iterations	
Run 1	<input type="text" value="50.0"/>	<input type="text" value="30.0"/>	<input type="text" value="6.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 2	<input type="text" value="50.0"/>	<input type="text" value="26.0"/>	<input type="text" value="5.200"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 3	<input type="text" value="50.0"/>	<input type="text" value="22.0"/>	<input type="text" value="4.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 4	<input type="text" value="50.0"/>	<input type="text" value="18.0"/>	<input type="text" value="3.600"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 5	<input type="text" value="50.0"/>	<input type="text" value="15.0"/>	<input type="text" value="3.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 6	<input type="text" value="50.0"/>	<input type="text" value="12.0"/>	<input type="text" value="2.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 7	<input type="text" value="50.0"/>	<input type="text" value="10.0"/>	<input type="text" value="2.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 8	<input type="text" value="50.0"/>	<input type="text" value="8.0"/>	<input type="text" value="1.600"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank
Run 9	<input type="text" value="50.0"/>	<input type="text" value="7.0"/>	<input type="text" value="1.400"/>	<input type="text" value="0"/>	<input checked="" type="checkbox"/> Blank
Run 10	<input type="text" value="50.0"/>	<input type="text" value="6.0"/>	<input type="text" value="1.200"/>	<input type="text" value="0"/>	<input checked="" type="checkbox"/> Blank

WET runs active

Scale default widths

Plot runs in Surfer

Prompt run misfit

Runs completed

All runs completed

Current run no.

Resume current run

Blank below wavepath envelope

Blank after each run Blank after last run

Fig. 26 : *Edit WET runs* dialog for Multiscale WET inversion. Check box *WET runs active*. Click button *OK*.

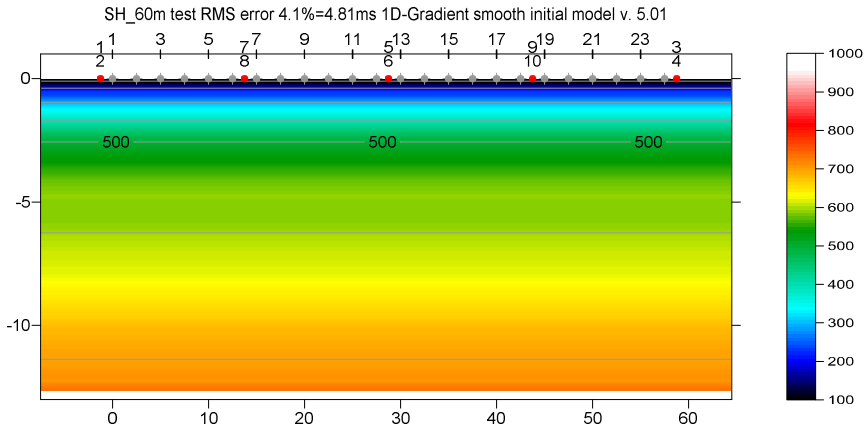


Fig. 27 : 1D-gradient starting model obtained with *Smooth invert/WET with 1D-gradient initial model*. Same as Fig. 5.

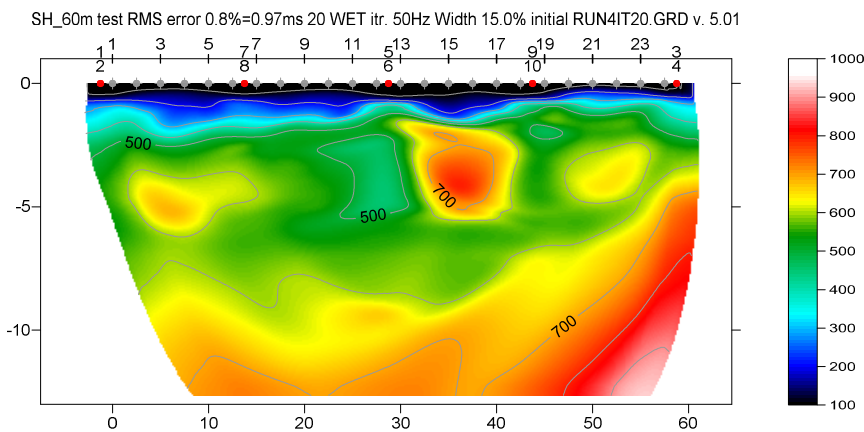


Fig. 28 : WET output after 5 WET runs. Scale *WET wavepath width* and *WET filter height* (Fig. 24). *Discard WET smoothing after forward modeling* (Fig. 16). Default *WET Tomo/Interactive WET* settings and default WET smoothing (Fig. 25). Enable ***multiscale WET inversion*** (Fig. 26). Starting model for first WET run is Fig. 27.

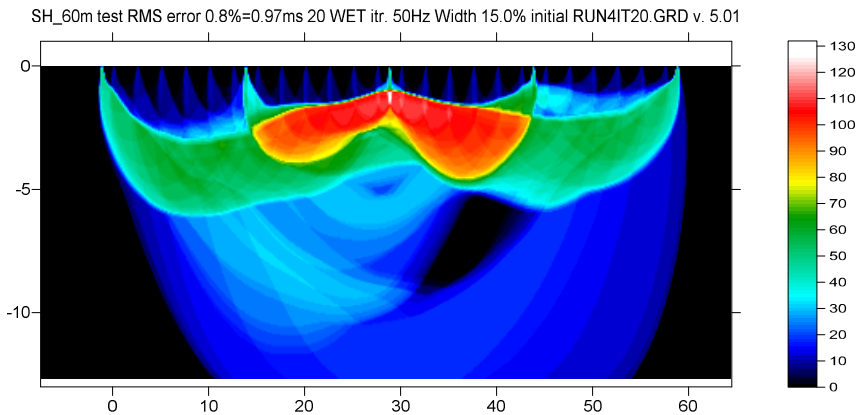


Fig. 29 : WET wavepath coverage plot obtained with Fig. 28. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the SH_60M profile folder for above Fig. 28 :

https://www.dropbox.com/scl/fi/nqepgn9ybio1k89lnjk31/SH_60m_Multiscale_WET_Nov10_2024.rar?rlkey=0gee5zhhv07ts8iyjs4esl8p4&st=293msux2&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

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