

WET NGU P1 6-7D : Conjugate Gradient&Cosine-Squared 3.36 1D-gradient starting model :

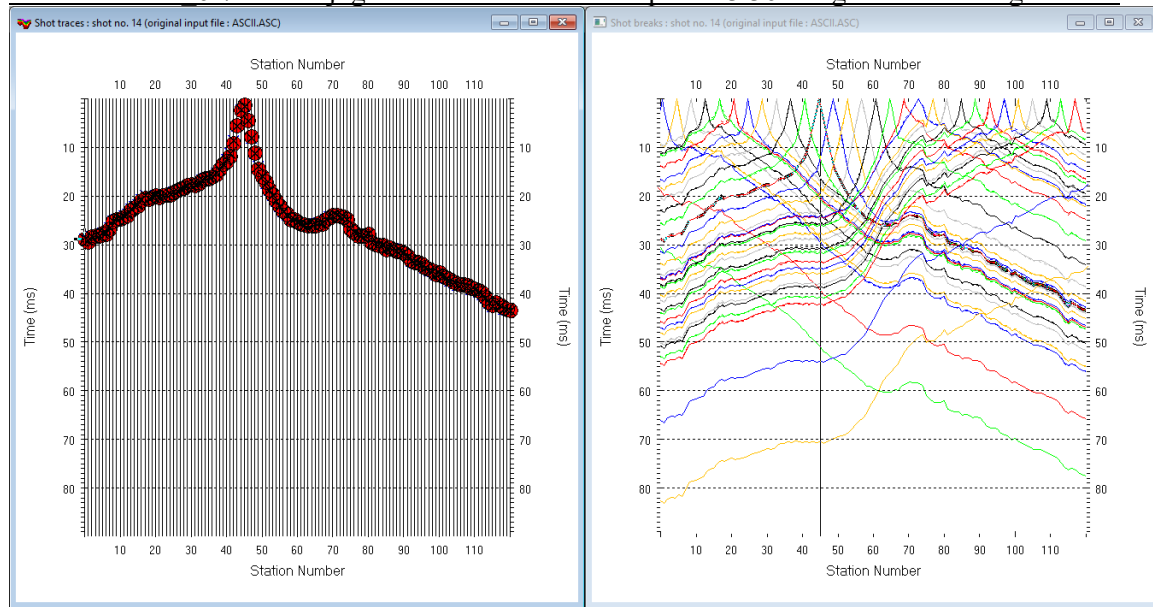


Fig. 1 : left : *Trace|Shot gather*, right : *Refractor|Shot breaks*. Shows fit between picked times (solid colored curves, red circles) and modeled times (dashed colored curves, blue crosses) obtained for 2D WET inversion output (Fig. 10)

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

- **File|New Profile...**, set *File name* to **P1_6-7D** and click *Save button*
- in **Header|Profile...** set *Line type* to **Refraction spread/line**. Set *Station spacing* to 2.0 m.
- check box *Force grid cell size* and set *Cell size[m]* to 0.4m. See Fig. 2.
- unzip archive [P1_6-7D.zip](#) with files **1_6-7DASCII.ASC**, **1_6-7DCOORDS.COR**, **1_6-7DSHOTS.SHO** & **P1_6-7D.CLR** in directory **C:\RAY32\P1_6-7D\INPUT**
- select **File|Import Data...** and set *Import data type* to **ASCII column format**. See Fig. 3.
- leave *Default spread type* at 10: **360 channels**
- click *Select button*, navigate into **C:\RAY32\P1_6-7D\INPUT** and select file **P1_6-7DASCII.ASC**
- set *Default sample count* to 900 to setup the y scale for *Trace|Shot gather* & *Refractor|Shot breaks*
- click **Import shots button** for batch import of all shots contained in **P1_6-7DASCII.ASC**
- select **File|Update header data|Update Station Coordinates**
- navigate into directory **C:\RAY32\P1_6-7D\INPUT**
- select file **1_6-7DCOORDS.COR**. Click *Open button*.
- **File|Update header data|Update Shotpoint coordinates** with **1_6-7DSHOTS.SHO**
- select **Trace|Shot gather** and **Window|Tile** to obtain Fig. 1

To configure and run Smooth inversion and display the 1D-Gradient starting model :

- uncheck **DeltatV|DeltatV Settings|Reduced offset 0.0 is valid trace with time 0.0**. See Fig. 13.
- check **DeltatV|DeltatV Settings|Suppress velocity artefacts**
- check **DeltatV|DeltatV Settings|Process every CMP offset**
- check **DeltatV|DeltatV Settings|Smooth CMP traveltimes curves**
- configure **Smooth invert|Smooth inversion Settings** as in Fig. 15
- select **Smooth invert|WET with 1D-gradient initial model** and confirm. Cancel WET continuation.
- select **Grid|Surfer plot Limits**. Click *Reset to grid*. Navigate into profile subdirectory **C:\RAY32\P1_6-7D\GRADTOMO**. Click on file **GRADIENT.GRD** & click *Open*.
- check box **Plot limits active**. Set *Min. elevation* to 20m. Set *Max. elevation* to 72m. See Fig. 4.
- set *Min. velocity* to 500 m/s and *Max. velocity* to 6,000 m/s. Edit fields as in Fig. 4. Click *OK*.

- select *Grid|Image and contour velocity and coverage grids* & above **GRADIENT.GRD** to obtain Fig. 8
- *Grid|Image and contour velocity and coverage grids* & ...\\model1\\P1_6-7_2018m_e4.grd to get Fig. 9

To configure and run WET inversion and display 2D inversion output :

- check *WET Tomo|WET tomography Settings|Blank no coverage after last iteration*.
- uncheck *WET Tomo|WET tomography Settings|Blank below envelope after last iteration*
- check *WET Tomo|WET tomography Settings|Write|Store modeled picks after last iteration only*
- check *WET Tomo|WET tomography Settings|Scale wavepath width*. See Fig. 16.
- check *WET Tomo|WET tomography Settings|Scale WET filter height*
- check *WET Tomo|WET tomography Settings|Edit maximum valid WET velocity*
- in *WET Tomo|WET velocity update* set *a* to 0.5 and *b* to 10.0. Click **OK**. See Fig. 5.
- set *WET Tomo|Interactive WET tomography|**Ricker differentiation*** to -2 [Cosine-Squared]
- set *Min. velocity* to 10 m/s & *Max. velocity* to 6,000 m/s. See Fig. 6 (left).
- click radio button **Conjugate Gradient**
- set *CG iterations* (outer loop) to 7 and *Line Search iters.* (inner loop) to 2. See [Shewchuk 1994](#) .
- click button *Edit grid file generation* & set *Store each nth iteration only : n =* to 20. Click **OK**.
- click **Edit velocity smoothing**. Check *Manual specification of smoothing filter* . See Fig. 6 (right).
- set *Half smoothing filter width* to 2 columns & set *Half smoothing filter height* to 1 rows
- uncheck *Adapt shape of filter*. Set *Maximum velocity update* to 15% .
- set *Smooth nth iteration : n =* to 3
- leave **Uniform** button checked. Set *Uniform central row weight* to 100.
- leave **Damping** at default of 0.9 for *Conjugate-Gradient* method. Click *Accept parameters* button.
- click **Iterate** button & check **WET runs active**. Edit as in Fig. 7 and click **button OK**.
- click button **Start tomography processing** to obtain Fig. 10 & 12
- in Surfer 16 click on menu *View*. Check *Properties* check box.
- in Surfer 16 window for Fig. 10 click on *Custom colormap* button to right of *Colors* label. Click on *Load* button. Navigate into **C:\\RAY32\\P1_6-7D\\INPUT** & select **P1_6-7D.CLR** . Click *Open&Apply&OK*.

Here some references to help file chapters and other relevant tutorials :

- for our **multiscale WET** inversion see updated [help file](#) chapter **WET tomography processing**
- our [SAGEEP11 tutorial](#) shows **Conjugate Gradient WET** inversion using 1D-gradient initial model for SAGEEP11 synthetic data forward-modeled over fault zone model
- our [twin tutorial](#) shows **Conjugate-gradient single-run WET inversion** using DeltatV+XTV pseudo-2D refraction starting model for same data as above (Fig. 1)
- [1_1D tutorial](#) shows multiscale **Conjugate-Gradient WET** inversion of [NGU profile 1_1D](#) data shown in Fig. 4.5.1 using DeltatV+XTV starting model
- our [2017 tutorial](#) shows **Steepest Descent WET** inversion using Plus-Minus layered refraction starting model for [NGU 2017](#) P1_1 synthetic data
- [Ostrowski et al.](#) show fault zone imaging using our WET inversion and dense shot spacing

Edit Profile

Line ID	P1_6-7D	Time of Acquisition	Date	
Line type	Refraction spread/line	Time		
Job ID	NGU synthetic data 2018			
Instrument		Time of Processing	Date	
Client		Time		
Company		Units	meters	
Observer		Sort	As acquired	
Note		Const		

Station spacing [m]	2.0000	<input type="checkbox"/> Left handed coordinates	
Min. horizontal separation [%]	25	<input checked="" type="checkbox"/> Force grid cell size	
Profile start offset [m]	0.0000	Cell size [m]	0.4000

Add borehole lines for WET tomography

Borehole 1 line	Select	
Borehole 2 line	Select	
Borehole 3 line	Select	
Borehole 4 line	Select	

OK Cancel Reset

Fig. 2 : Header|Profile

Import shots

Import data type: ASCII column format

Input directory: select one data file. All data files will be imported

Select: D:\ray32\P1_6-7D\INPUT\

Take shot record number from: Record number

Optionally select .HDR batch file and check Batch import

.HDR batch:

Write .HDR batch file listing shots in input directory

Output .HDR:

☐ Write .HDR only ☐ Import shots and write .HDR

Overwrite existing shot data: ☒ Overwrite all ☐ Prompt overwriting ☐ Limit offset

Batch import: ☒ ☐

Maximum offset imported [station nos.]: 1000.00

Default shot hole depth [m]: 0.00

Default spread type: 10: 360 channels

Target Sample Format: 32-bit floating point

☐ Turn around spread by 180 degrees during import

☐ Correct picks for delay time (use e.g. for .PIK files)

Default sample interval [msec]: 0.100000000

Default sample count: 900

Import shots Cancel import Reset import

Fig. 3 : File|Import Data

Edit Surfer plot limits

Plot Limits

☒ Plot limits active

Min. offset: 0.000 [m]

Max. offset: 240.000 [m]

Min. elevation: 20.000 [m]

Max. elevation: 72.000 [m]

Min. velocity: 500 [m/sec.]

Max. velocity: 6000 [m/sec.]

Plot Scale

☒ Proportional XY Scaling

☐ Page unit centimeter. Uncheck for inch.

X Scale length: 6.000 [inch]

Y Scale length: 4.000 [inch]

Color Scale

☒ Adapt color scale

Scale height: 1.340 [inch]

Velocity interval: 500 [m/sec.]

Coverage: 100 [paths/pixel]

OK Cancel Reset Reset to grid

Fig. 4 : Grid|Surfer plot Limits

WET update weighting

Parameters for Cosine-Squared weighting function

a : Cosine argument: 0.500 [power]

b : Cosine-Squared power: 10.000 [power]

Decrease velocity update in high-coverage areas

☐ Decrease update active

Velocity update: 0.000 [power]

OK Cancel Reset

Fig. 5 : WET Tomo|WET Update weighting

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
Select

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 [sigma] : 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 sigma
Uniform central row weight [1..100]

Smooth velocity update before updating tomogram
☒ Smooth velocity update ☒ Smooth last iteration

Damping of tomogram with previous iteration tomogram
Damping ☐ Damp before smoothing

Fig. 6 : WET Tomo|Interactive WET (left) . Edit velocity smoothing (right).

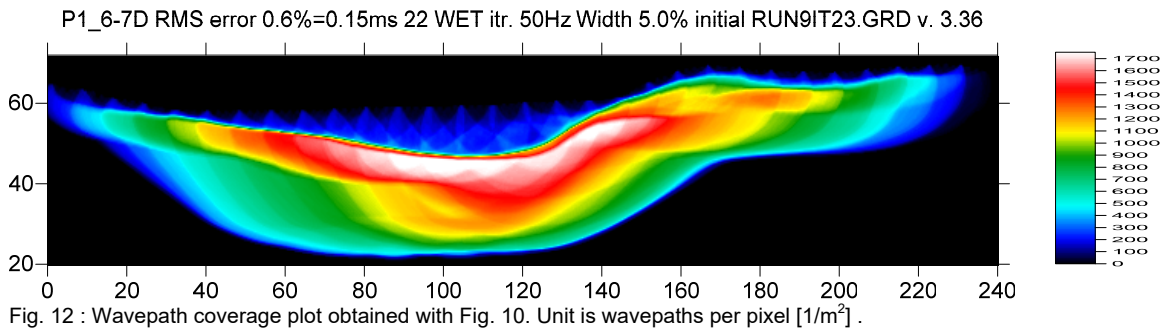
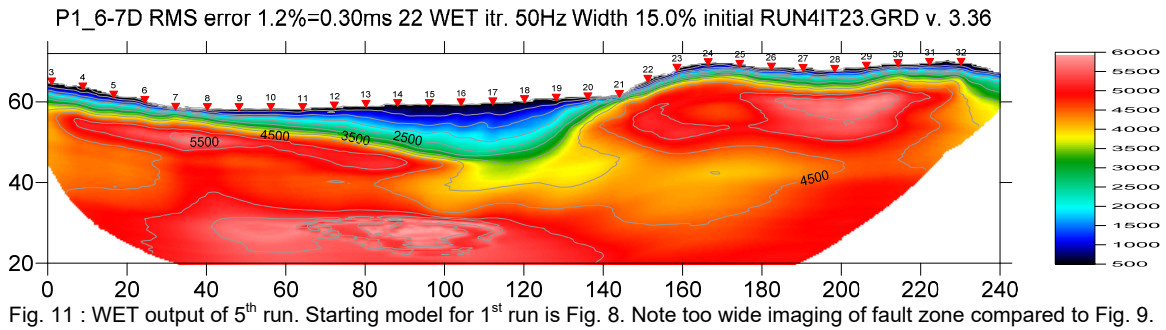
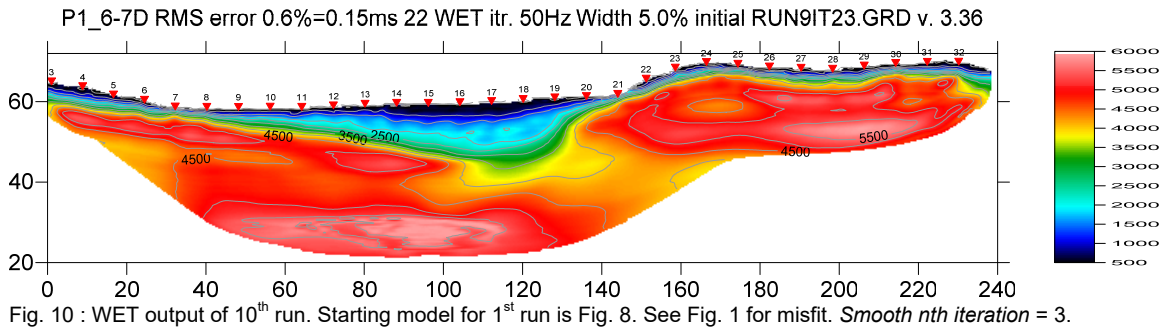
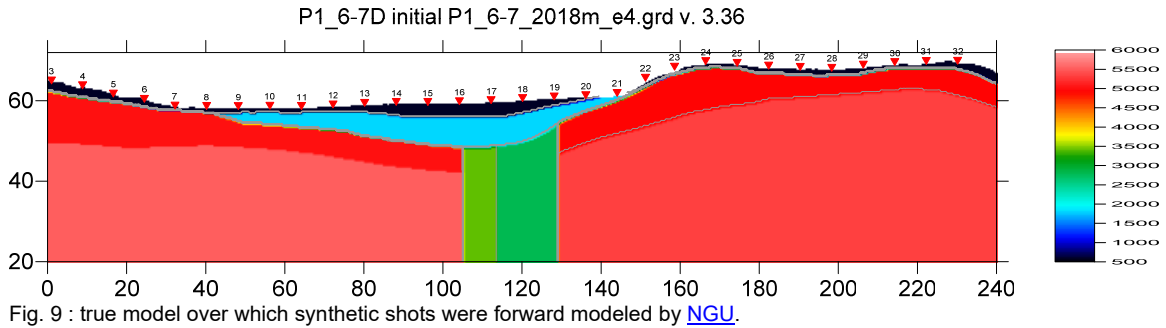
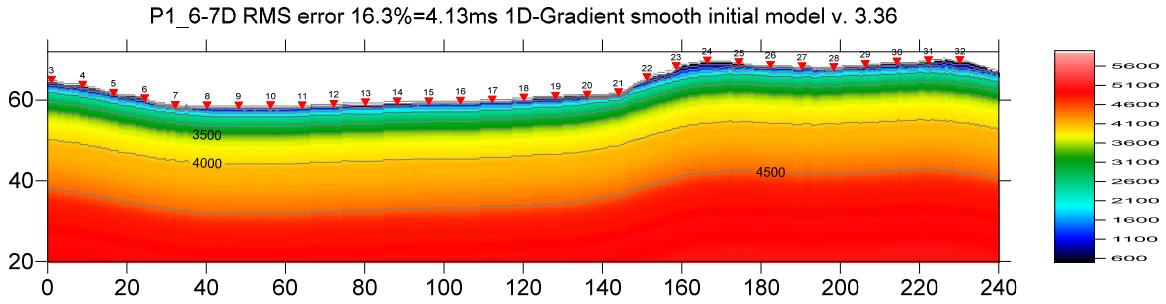
Edit WET runs - wavepath width

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 type="checkbox"/> Blank
Run 9	<input type="text" value="50.0"/>	<input type="text" value="6.0"/>	<input type="text" value="1.200"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 10	<input type="text" value="50.0"/>	<input type="text" value="5.0"/>	<input type="text" value="1.000"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank

☒ WET runs active
☐ Scale default widths
☒ Plot runs in Surfer
☐ Prompt run misfit
Runs
☒ All runs completed
Current run
☒ Resume current run

Blank below wavepath envelope
☐ Blank after each run ☒ Blank after last run

Fig. 7 : WET Tomo|Interactive WET|Iterate . Edit WET runs for multiscale WET.



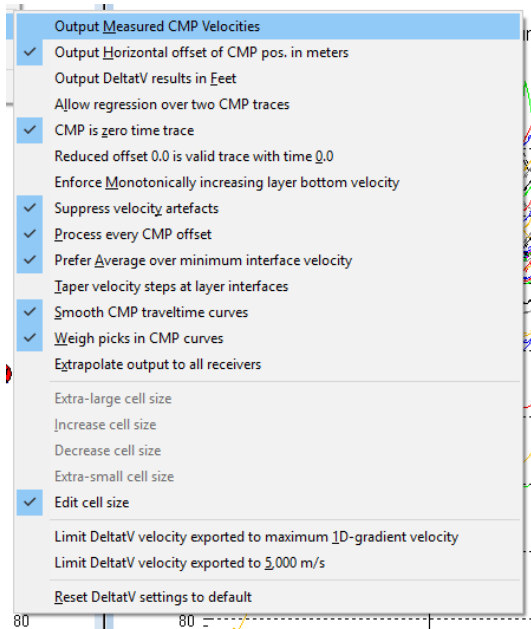


Fig. 13 : *DeltatV/DeltatV Settings*. Check *Suppress velocity artefacts* to enforce continuous CMP sorted traveltime curves and filter out bad picks from traveltime curves.

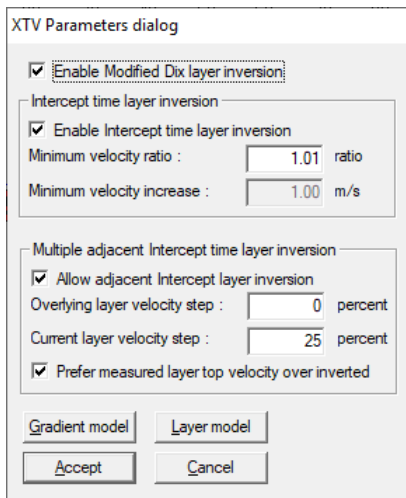


Fig. 14 : edit XTV parameters

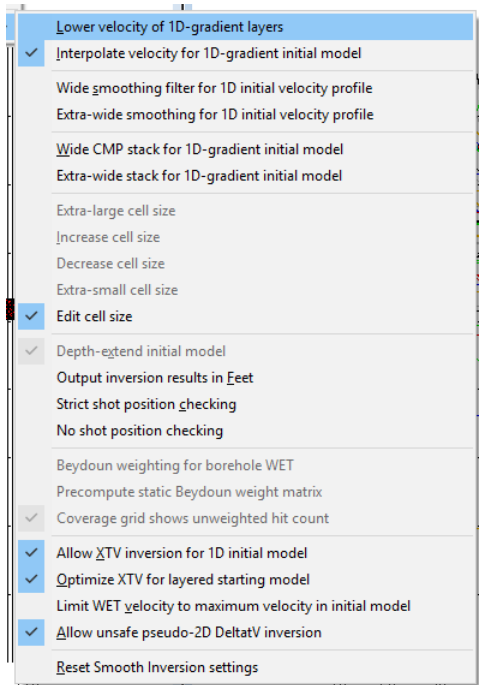


Fig. 15 : edit menu *Smooth invert*|*Smooth inversion Settings*

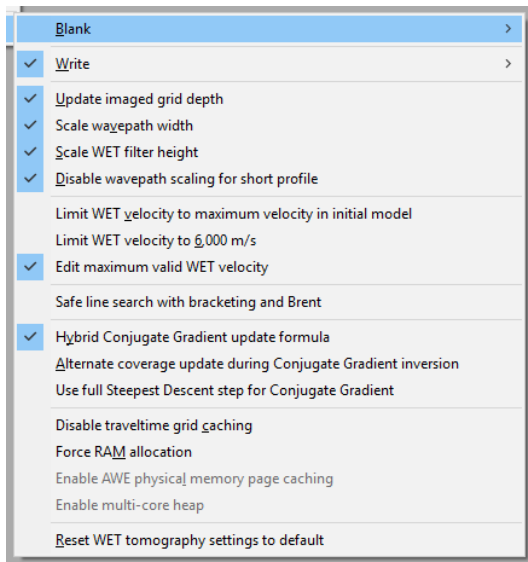


Fig. 16 : edit menu *WET Tomo*|*WET tomography Settings*

To restore database files and result files :

Subdirectories `C:\RAY32\P1_6-71D\GRADTOMO`, `...\INPUT`, `...\seis32_GradTomo_Mar19_2019` and `...\model` are available in this [RAR archive](#). Open the `...\GRADTOMO\WETRUN10\VELOIT23.PAR` file e.g. with Windows Notepad editor to review *WET inversion* parameters used.

Use Rayfract® 3.36 command ***Grid|Reset DeltatV and WET settings to .PAR file...*** with file `...\GRADTOMO\WETRUN10\VELOIT23.GRD` to reset your profile's *DeltatV* and *WET inversion* settings to `...\GRADTOMO\WETRUN10\VELOIT23.PAR`.

Or quit our software via **File|Exit**. In Windows Explorer copy all 34 **seis32.*** database files from directory ...\\seis32_GradTomo_Mar19_2019 into c:\\RAY32\\P1_6-7D directory. Now reopen your profile with **File|Open Profile...** and c:\\RAY32\\P1_6-7D\\SEIS32.DBD .

Summary :

NGU 2018 report with Fig. 4.5.2 showing *WET inversion* of above synthetic model data (Fig. 1) using DeltatV+XTV pseudo-2D refraction starting model and **Conjugate-gradient single-run WET inversion** is available at http://www.ngu.no/upload/Publikasjoner/Rapporter/2018/2018_015.pdf .

WET inversion shown in Fig. 10 using 10 WET runs with 7 Conjugate-Gradient iterations each and parameters shown in Fig. 6 and Fig. 7 took about 8 minutes on 2017 Apple iMac. This iMac comes with 2.3 GHz Intel Core i5 processor running 4 OpenMP threads under Windows 10 Pro 64-bit in Parallels Desktop 14 for Mac.

We recommend using our **1D-gradient starting model** with single-run or multirun WET inversion, as described above. Our **DeltatV+XTV starting model** as shown in our [twin tutorial](#) for above data shows strong artefacts which in this case cannot be completely removed by WET inversion. See [Sheehan et al. 2005](#) for an evaluation of our Smooth inversion method using our 1D-gradient starting model.

Multirun WET inversion may not make sense except if you have very accurate first break picks and exact recording geometry. Check traveltimes reciprocity in *Trace|Offset gather*. Also multirun WET inversion requires more time and effort to optimally tune the multirun schedule and WET smoothing.

We recommend using [overlapping receiver spreads](#) and profile-internal far-offset shots to reach deeper and more meaningful imaging of fault zones in basement.

Our Rayfract® software offers multiple interpretation methods and parameters to explore the non-uniqueness of the solution space. It is the user's job to sufficiently explore the solution space with our methods and varying parameters, and to find an appropriate combination of methods and parameters for each individual data set. This choice may be guided by a-priori information e.g. from boreholes or other geophysical methods.

We thank Dr. Georgios Tassis at NGU for making available above report and synthetic data.

For an objective comparison of tomographic refraction analysis methods see [Zelt et al. 2013](#) (JEEG, September 2013, Volume 18, Issue 3, pp. 183–194).

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