WET NGU P1_6-7D : Conjugate Gradient&Cosine-Squared 3.36 1D-gradient starting model :

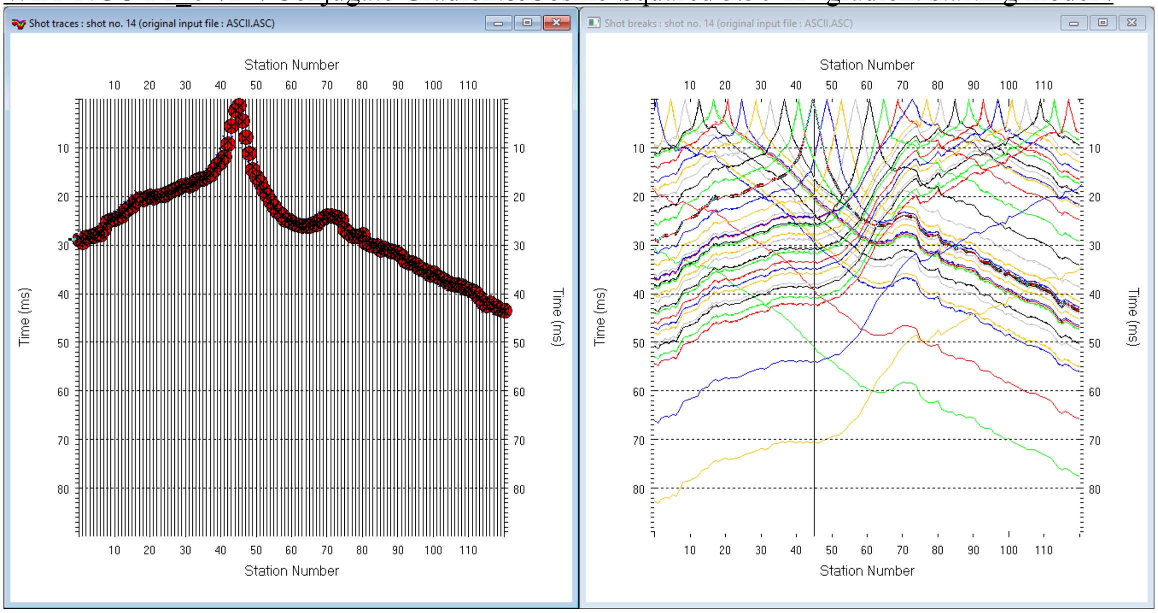

Fig. 1 : left : *Trace|Shot gather*, right : *Refractor|Shot breaks*. Shows fit between picked times (solid colored curves, red circles) and modeled times (dashed colored curves, blue crosses) obtained for 2D WET inversion output (Fig. 10)

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 traveltime 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* & …**\model\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

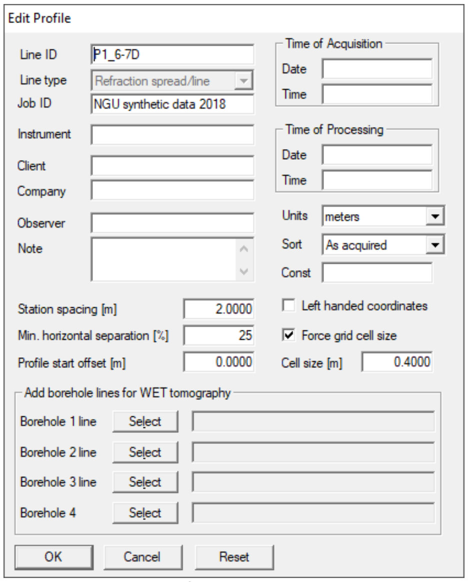

Fig. 2 : *Header|Profile*

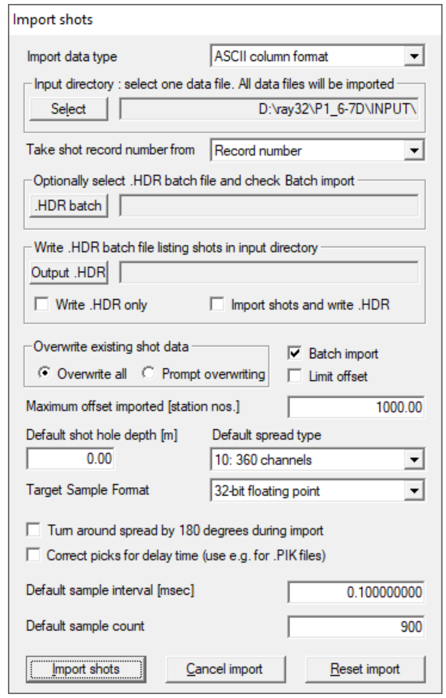

Fig. 3 : *File|Import Data*

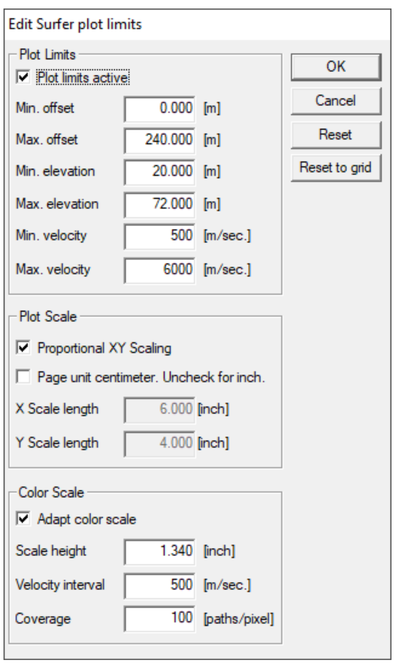

Fig. 4 : *Grid|Surfer plot Limits*

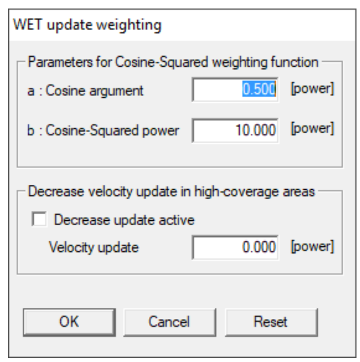

Fig. 5 : *WET Tomo|WET Update weighting*

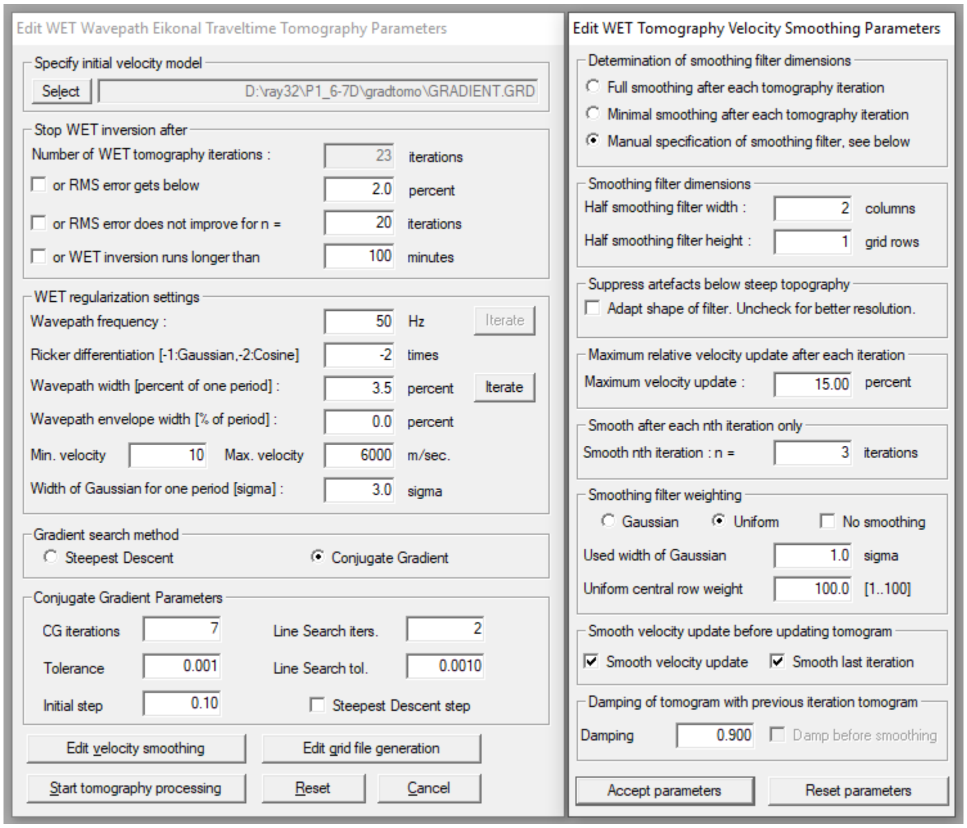

Fig. 6 : *WET Tomo|Interactive WET* (left) . *Edit velocity smoothing* (right).

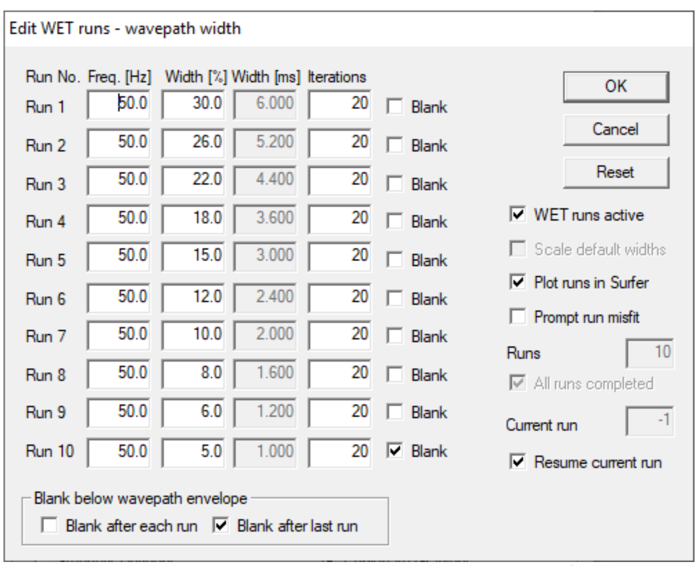

Fig. 7 : *WET Tomo|Interactive WET|Iterate* . Edit WET runs for multiscale WET.

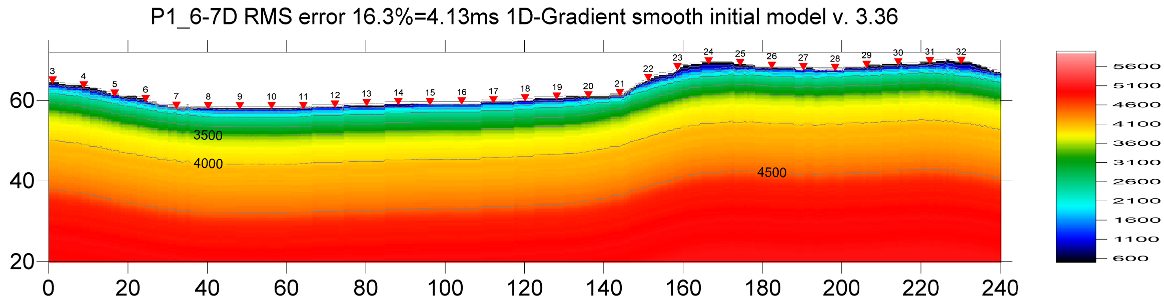

Fig. 8 : *Smooth inversion* starting model . See Fig. 13/14/15 for *DeltatV + XTV Settings & Smooth inversion Settings* .

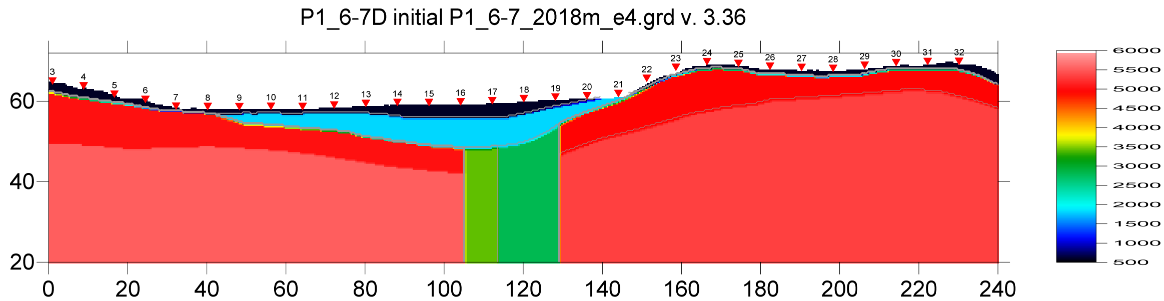

Fig. 9 : true model over which synthetic shots were forward modeled by NGU.

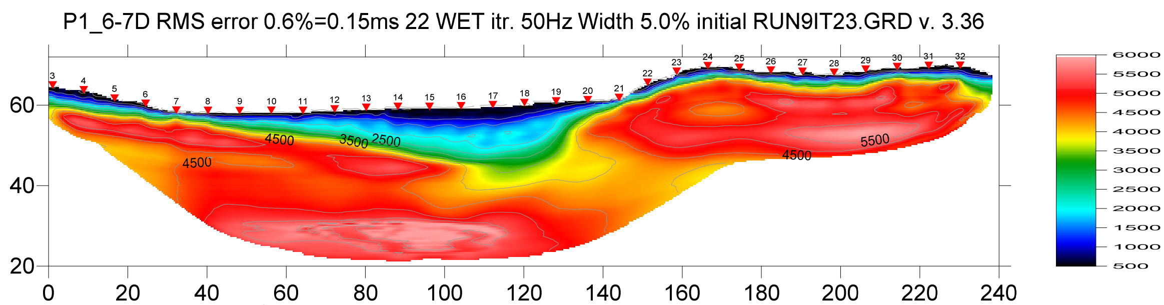

Fig. 10 : WET output of 10th run. Starting model for 1st run is Fig. 8. See Fig. 1 for misfit. *Smooth nth iteration* = 3.

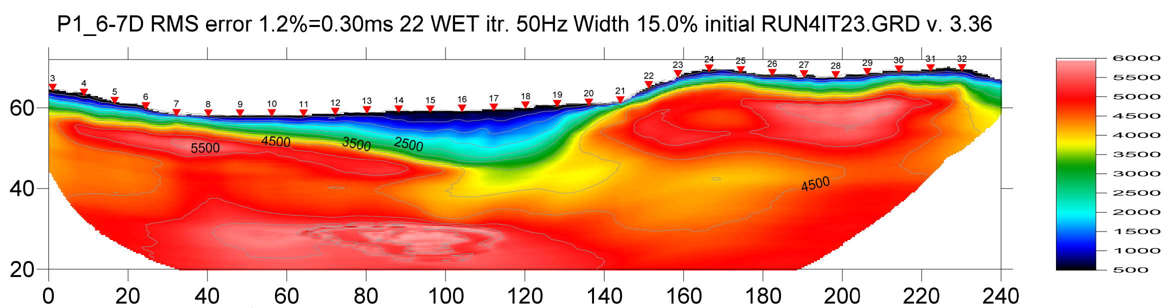

Fig. 11 : WET output of 5th run. Starting model for 1st run is Fig. 8. Note too wide imaging of fault zone compared to Fig. 9.

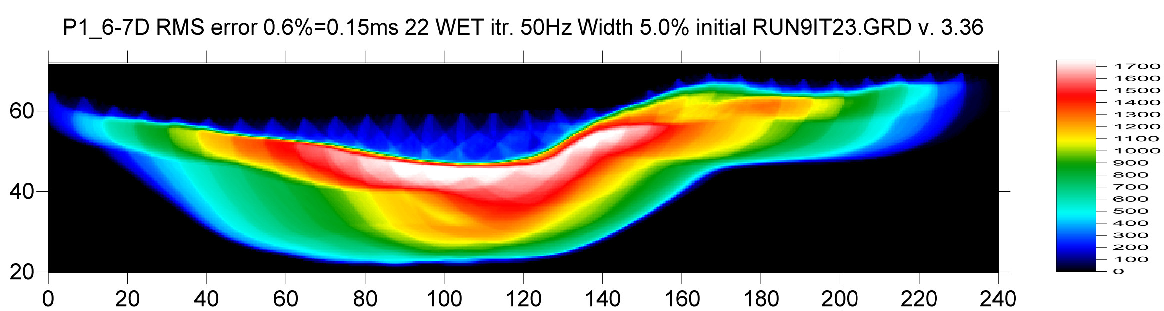

Fig. 12 : Wavepath coverage plot obtained with Fig. 10. Unit is wavepaths per pixel [1/m^2] .

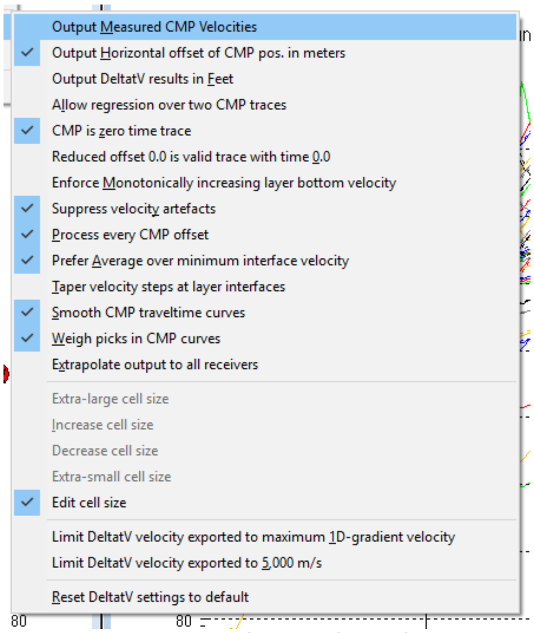

Fig. 13 : *DeltatV|DeltatV Settings*. Check *Suppress velocity artefacts* to enforce continuous CMP sorted traveltime curves and filter out bad picks from traveltime curves.

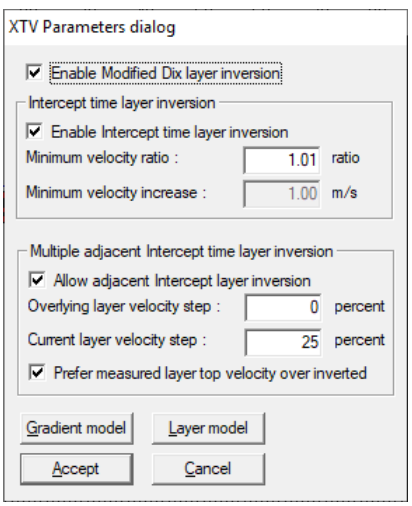

Fig. 14 : edit *XTV parameters*

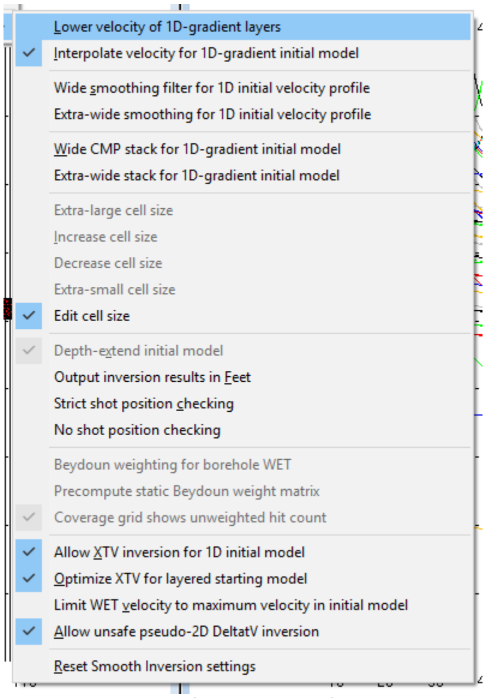

Fig. 15 : edit menu *Smooth invert|Smooth inversion Settings*

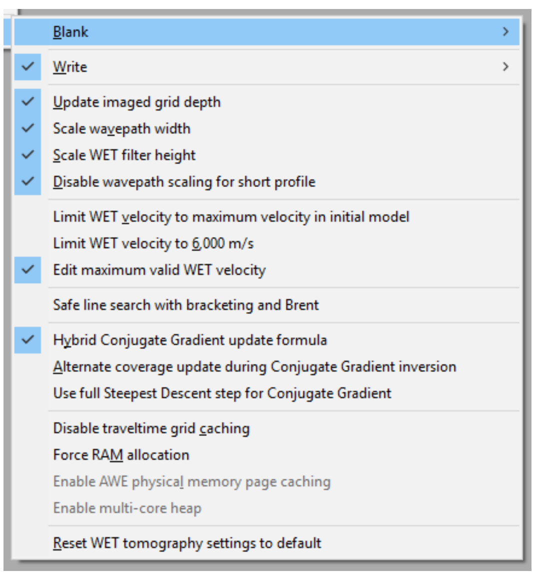

Fig. 16 : edit menu *WET Tomo|WET tomography Settings*

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 traveltime 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).