

SENIOR PROJECT-GEOP402

Near Surface Refraction Tomography

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A Generalized Simulated-Annealing Optimization for Inversion of First-Arrival Times

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Abstract

We employ a Monte Carlo-based optimization scheme called generalized simulated annealing to invert first-arrival times for velocities. We use "dense" common depth point (CDP) data having high multiplicity, as opposed to traditional refraction surveys with few shots. A fast finite-difference solution of the eikonal equation computes first arrival travel times through the velocity models. We test the performance of this optimization scheme on synthetic models and compare it with a linearized inversion. Our tests indicate that unlike the linear methods, the convergence of the simulated-annealing algorithm is independent of the initial model. In addition, this scheme produces a suite of "final" models having comparable least-square error. These allow us to choose a velocity model most in agreement with geological or other data. Exploiting this method's extensive sampling of the model space, we can determine the uncertainties associated with the velocities we obtain.

<http://faculty.kfupm.edu.sa/ES/oncel/2dtomographypaper.pdf>

Please select the OBS, REC, and SRC files **STEP 1**

Look In: Oncel_Picked_2007

- output_HIGH
- output_HIGHEST
- output_HIGHEST1
- oncel_default_obs.txt
- oncel_default_rec.txt
- oncel_default_src.txt

OBS.txt: Observation File
REC.txt: Receiver File
SRC.txt: Source File

File Name: "oncel_default_obs.txt" "oncel_default_rec.txt" "oncel_d
Files of Type: All Files

Open Cancel

CLICK "SeisOPT@2D"

oncel_default_src - WordPad

-17.50	0.00	32
17.50	0.00	32
37.50	0.00	32
57.50	0.00	32
77.50	0.00	32
97.50	0.00	32
117.50	0.00	32
137.50	0.00	32
172.50	0.00	32

INPUT FILE: SOURCE

Shot Location (m)

Elevation (m)

Shot Number

oncel_default_rec - Word...

0.00	0.00
5.00	0.00
10.00	0.00
15.00	0.00
20.00	0.00
25.00	0.00
30.00	0.00
35.00	0.00
40.00	0.00
45.00	0.00
50.00	0.00

INPUT FILE: RECEIVERS

Receiver Location (m)

Elevation (m)

once...

11.75
15.125
18.375
23.375
25.625
29
31.75
33.375

INPUT FILE: RECEIVERS

Picked Data (milisec)

UNIT

- Please be careful about the unit of data provided by SeisPicker a data is in SECOND while INTERPEX provides a data in Milliseconds.
- Make sure what the unit of your data is? Otherwise your model will be wrong and program might not work properly.

RIOTS SETTING

Refraction Inversion OpTimization

STEP2

After clicking the files, you opened the Seis-2D.
Now, Click "RIOTS SETTING"

SENIOR PROJECT-GEOP402

Contents

- Automatic Velocity Calculation
- Manually Velocity Calculation
- Results

SENIOR PROJECT-GEOP402

Automatic Velocity Calculation

- 1.Run RIOTS with default Highest Setting (**Autocal on**). Give the run an extension say "1". In my case, I gave oncel_1.
- 2.Note down the nx, nz, hx, hz values. Run to completion, or click end/terminate to stop the process.

Browse "Your Files"

STEP3

The "Time Units" can be in "seconds" by SeisPicker or "milliseconds" by Interpex. Be sure what is the unit of your data?

Work under the option "Autocal" and select "Highest" or "HIGH". Do not forget to browse your files and define file of your output. Then, Click "OK"

Continue

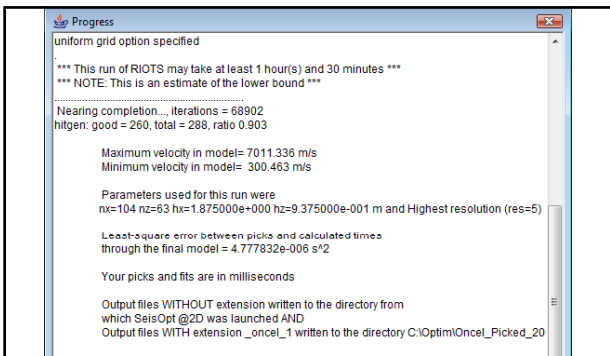
STEP3

Source Count should be 9 (since you have 13 shot points).

Pick Count should be 288 (total number of picks in your obs file). DO NOT select "Set Iteration". DO NOT set "Max Iteration" DO NOT select "Restart"

I gave a simple name for out put as "oncel_1". Then, following iterations, I will continue as "1, 2....". You can select a labeling for your data depending your interest.

The last three are for further refining after you run the model once. Don't worry about those now.



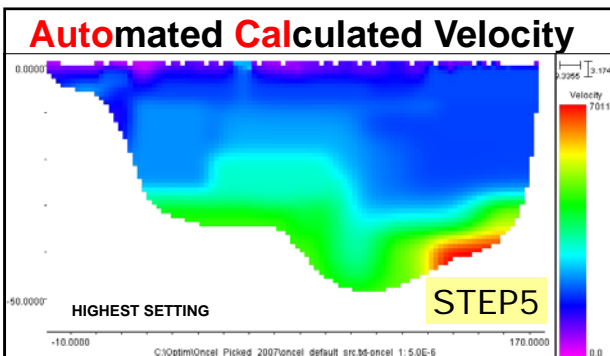
Note down the nx, nz, hx, hz values. Run to completion, or click end/terminate to stop the process. Because, these values are used for manually selecting the model resolution, and become active when autocall is off.

Click "Run RIOTS" STEP4

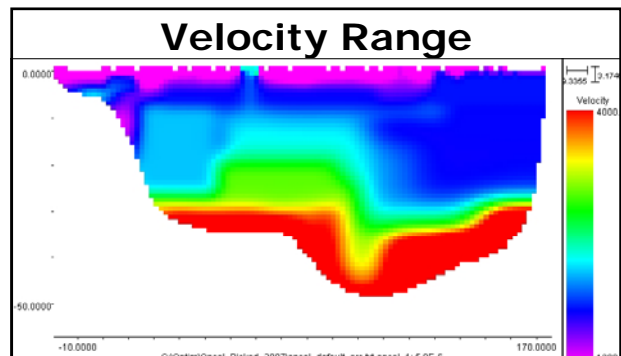
First Progress is finished in your 2D Velocity Modeling since "DONE" is appeared.

Next, Click the button "Go" to see first VELOCITY MODEL

First, Click the button "End/Terminate process"



I have received the automated calculated velocity and next step I will try to find better model than present this using the calculated parameters as nx, nz, hx, hz. My strategy would be as: nx,nz,hx=CONSTANT while nx will be variable.



I have just changed velocity range and made it from 1200 to 4000 m/s. Then, one can have a chance to compare models within the range of fixed velocity model.

SENIOR PROJECT-GEOP402

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Manually Velocity Calculation

 1. Click on RIOTS Settings window. Use the same nx, hx, hz values as in step 2, but increase nz by 1. Give it an extension, say "2". Click "OK". This will create a file called "riotsinput_2" in the folder specified for the output files
 2. Repeat step1 by increasing nz by 1.
 3. Repeat step 1 and 2 until you have created 5 riotsinput files that have "nz" values greater than default nz, each time increasing by 1. DO the same, for 5 riotsinput values that have nz values less than default nz, each one 1 less than the previous.
 4. You will end up with 11 riotsinput files, including the default nz.
 5. Set up the Batch file by loading all 11 riotsinput files.
 6. This will create a file called "riotsbat.BAT" in C:\optim\2dv50\
 7. Click on riotsbat.BAT to run all 11 riotsinput files.
 8. Once all the runs are complete, review the errors in the "riotsmsg" files that will be written out to the output folder.

Steps

- **First step** is over by Automated Calculation of Velocity Model based on HIGHEST option. Then, optimization parameters "nx, nz, hx,hz" are provided.
- **Next step, creating different input files**, we will release depth resolution parameter (nz) while keeping others are kept constant. Then, we will use those files for BATCH process. Then, we will review the errors and try to find best model.

NZ values

nx=104 nz=63 hx=1.875000e+000 hz=9.375000e-001 m

- **Step 1:** Click on RIOTS Settings window. Use the same nx, hx, hz values as in step 2, but increase nz by 1. Give it an extension, say "2". Click "OK". This will create a file called "riotsinput_2" in the folder specified for the output files
- **Step 3:** Repeat step1 by increasing nz by 1.

Playing with values of nz (=63)			
nz		OUTPUT EXT.	
Down	Up	Down	Up
62	64	d1	u1
61	65	d2	u2
60	66	d3	u3
59	67	d4	u4
58	68	d5	u5

- **Step 3:** Repeat step 1 and 2 until you have created 5 riotsinput files that have "nz" values greater than default nz, each time increasing by 1. DO the same, for 5 riotsinput values that have nz values less than default nz, each one 1 less than the previous.

RIOTSINPUT

STEP6

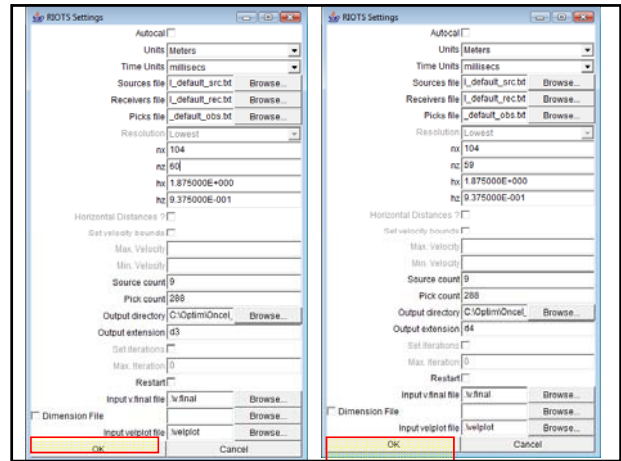
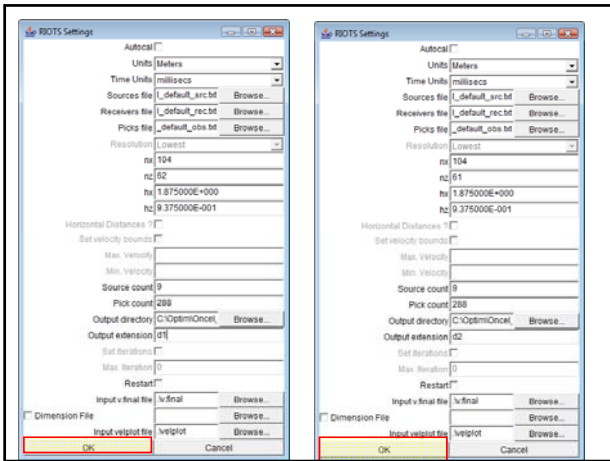
Now for the next run, I keep nx,hx,hz same but decrease by 1. That is nz=63

NEXT STEP

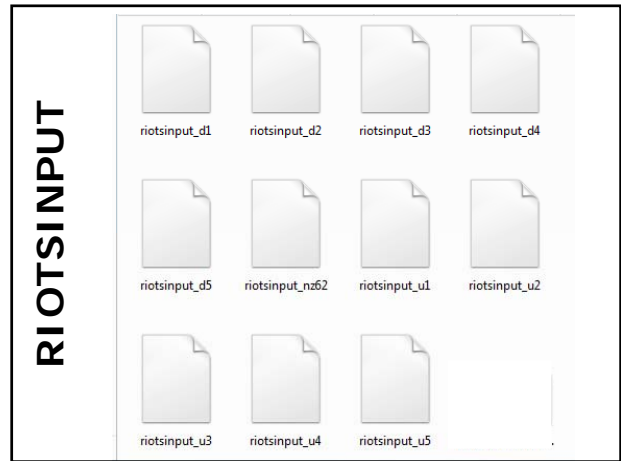
➤ I do runs with nz=58,59,60,61,62 and nz=64,65,66,67,68. That is 5 up and 5 down.

➤ I will use different extensions as shown in Table, to avoid **overwriting existing files from previous ones.**

Playing with values of nz (=63)			
nz		OUTPUT EXT.	
Down	Up	Down	Up
62	64	d1	u1
61	65	d2	u2
60	66	d3	u3
59	67	d4	u4
58	68	d5	u5



1. Now, I ended up with 11 riotsinput files, including the default nz.
2. Set up the Batch file by loading all 11 riotsinput files.
3. This will create a file called "riotsbat.BAT" in C:\optim\2dv50\
4. Click on riotsbat.BAT to run all 11 riotsinput files.
5. Once all the runs are complete, review the errors in the "riotsmsg" files that will be written out to the output folder.



STEP 7

RESET SETTINGS

riotsinput files

Number of riotsinput files	11
t_HIGHEST1riotsinput_d1	Browse...
t_HIGHEST1riotsinput_d2	Browse...
t_HIGHEST1riotsinput_d3	Browse...
t_HIGHEST1riotsinput_d4	Browse...
t_HIGHEST1riotsinput_d5	Browse...
t_HIGHEST1riotsinput_nz63	Browse...
t_HIGHEST1riotsinput_u1	Browse...
t_HIGHEST1riotsinput_u2	Browse...
t_HIGHEST1riotsinput_u3	Browse...
t_HIGHEST1riotsinput_u4	Browse...
t_HIGHEST1riotsinput_u5	Browse...
Ok	Cancel

Set Up Batch File

Set Up/Run-Batch Process **STEP8**

Then, upload files of riotsinput which are saved in directory of output. Now, Click "Set Up Batch File" under the directory "C:\Optim\2Dv50". Now, window for DOS is opened and calculation for different values of nz is done in DOS.

The BATCH PROCESS is to run models with different NZ's.

Riotmsg Message

The error information and everything you see on the "Progress" window is stored in a file by the name "riotsmsg_[ext]", where ext is the extension you give (like d1, u1)

Picking and Errors

- PICKS can vary from user to user, thus picks have errors in them too.
- When dealing with inversion problems, one has to look at the models and decide what looks realistic based on expected geology, in addition to just the error.
- The reason why one has to run with different "nz" values is to get a suite of models that one can then compare in order to determine to best model.

Contents

- Automatic Velocity Calculation
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SENIOR PROJECT-GEOP402

Results

1. Choose the ones that have the lowest error (say **3 lowest errors**), and load the Velfiles and Hitfiles corresponding to these into SeisOpt2d.
2. Select the one that best corresponds to geology.
3. Repeat all of the above with "High" if model is complex and has too many low-vel /anomalous zones that don't appear real.

SENIOR PROJECT-GEOP402

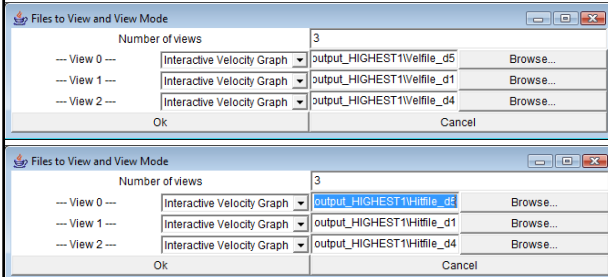
Visualizing RIOTS output **STEP9**

Make sure to press the **Reset** button before loading from new runs and Click **Settings**.

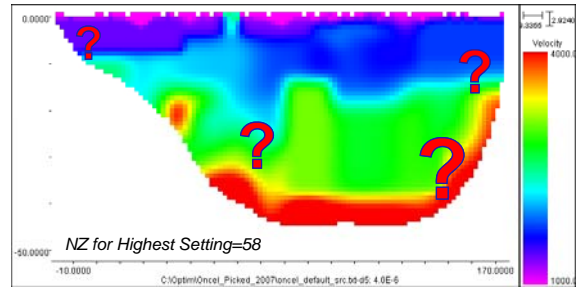
Click **OK** . Then, select your former files as done below and Click "Open".

Review

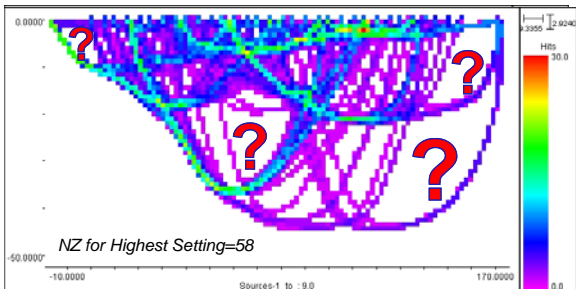
Click Settings and SET UP HITFILES and VELFILES to REVIEW.



TOP 1_Velocity

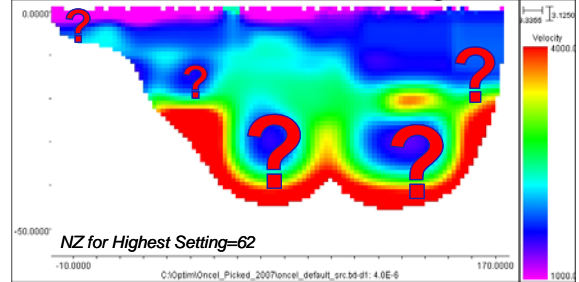


TOP 1_HITFILE



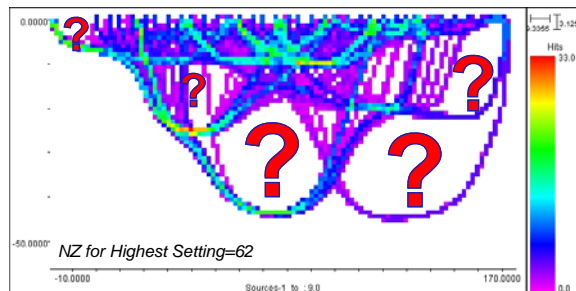
The "hitcount" is here the number of rays that sample a particular cell.

TOP 2_Velocity

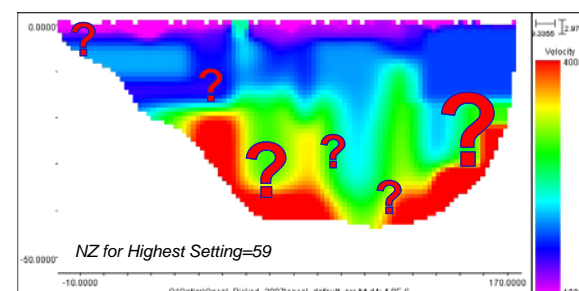


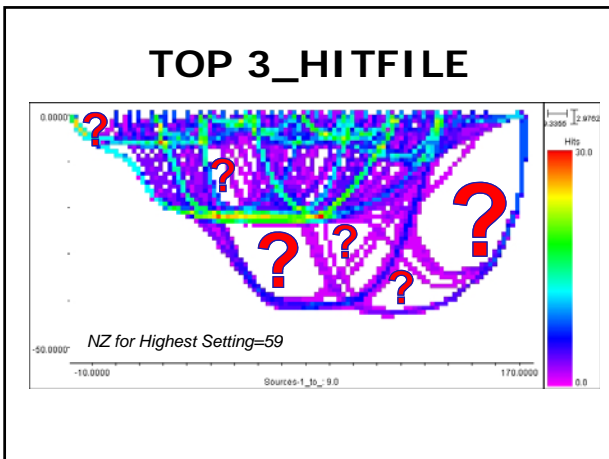
Let's ignore this model and prefer next best model regarding least error since present model includes a low velocity zone where areas of no hits.

TOP 2_HITFILE



TOP 3_Velocity





Suggestions

- Please note previous modeling is based on the case for running data at the "HIGHEST" setting.
- Also, one may want to run it at the "High" setting.
- Sometimes that works better than "Highest". So you should do the same with High settings and see if the errors are comparable.

Personal Communication, Dr.Satish, 2007

Difference in Settings

- Difference between Highest and High is with "hz" parameter.
- **High Setting:** hx=hz
- **Highest Setting:** hx≠hz, because Highest hz = (High hz)/2.

So, HIGH setting are sampling the depth direction more not horizontal. You will end with higher resolution in depth, but that is not necessarily always desirable. You may end with structures that are not real.

Setting Errors

	nz	Name	Error
High Setting	38	u5	3.90E-06
	30	d3	4.37E-06
	36	u3	4.50E-06
	29	d4	4.54E-06
	32	d1	4.80E-06
	33	Autocal	5.26E-06
	37	u4	5.45E-06
	35	u2	5.52E-06
	28	d5	5.87E-06
	31	d2	6.60E-06
34	u1	6.82E-06	
Highest Setting	58	d5	3.82E-06
	62	d1	3.88E-06
	59	d4	3.97E-06
	65	u2	4.22E-06
	64	u1	4.24E-06
	68	u5	4.24E-06
	61	d2	4.60E-06
	63	Autocal	4.77E-06
	67	u4	4.88E-06
	60	d3	4.98E-06
66	u3	5.03E-06	

That what we do here is running different nz values, then sorting them based on error and selecting the best one among the best fit models? What setting provides a better estimates of velocity model?

nz	Name	Error
58	d5	3.82E-06
62	d1	3.88E-06
38	u5	3.90E-06
59	d4	3.97E-06
65	u2	4.22E-06
64	u1	4.24E-06
68	u5	4.24E-06
30	d3	4.37E-06
36	u3	4.50E-06
29	d4	4.54E-06
61	d2	4.60E-06
63	Autocal	4.77E-06
32	d1	4.80E-06
67	u4	4.88E-06
60	d3	4.98E-06
66	u3	5.03E-06
33	Autocal	5.26E-06
37	u4	5.45E-06
35	u2	5.52E-06
28	d5	5.87E-06
31	d2	6.60E-06
34	u1	6.82E-06

I mixed errors up and sorted them to list the best three models. We already ignored model 2 before.

I would say the difference between High and Highest best runs are less than 10%. Considering how complex the model is (with low-velocity zones), I would be conservative and go with the smoother model. In other words, the best High model you have (Personal Communication, Dr.Satish, 2007)

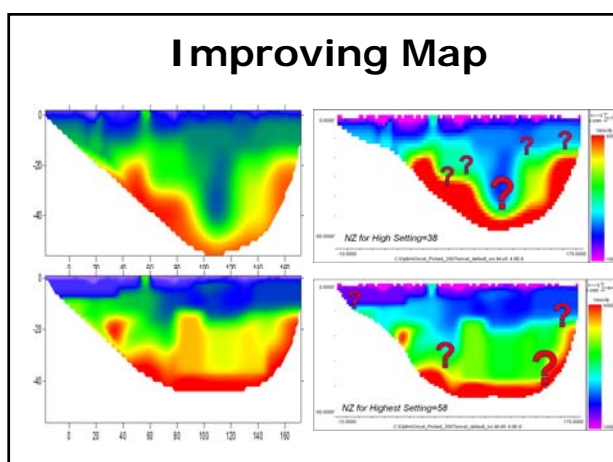
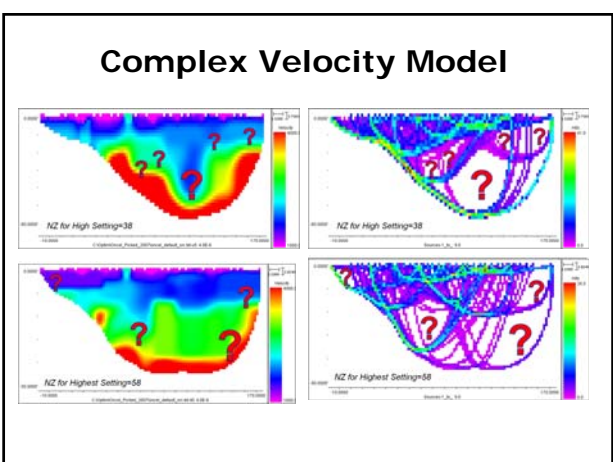
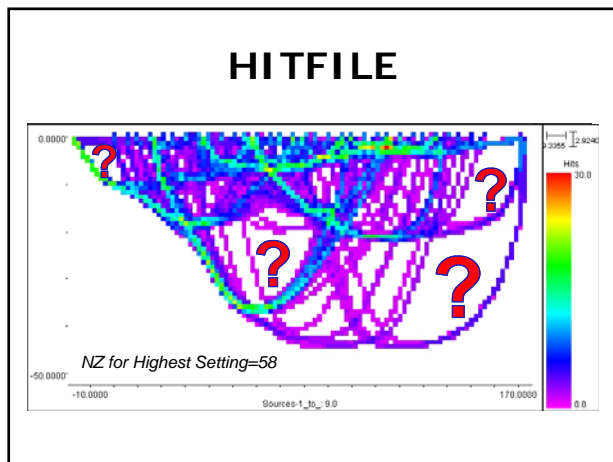
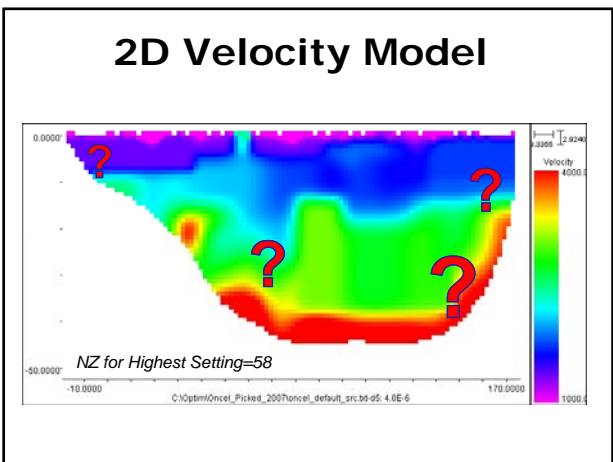
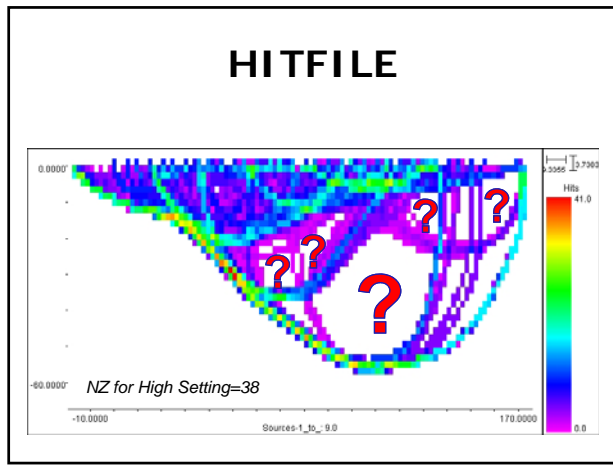
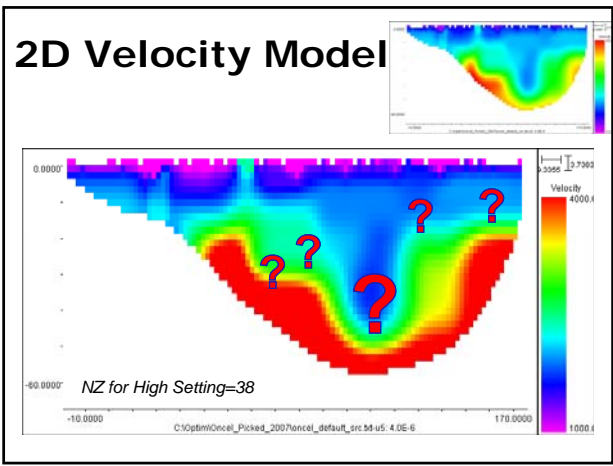
Least Square Error

1. Compute travel times through an initial model. Determine the least-square error, E_0 . For any iteration i , we can define the least-square error, which is the objective function, as:

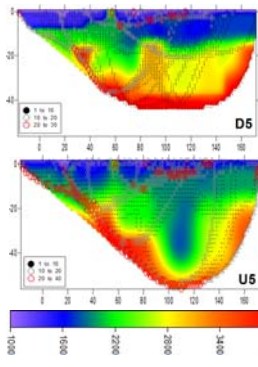
$$E_i = (1/n)(\sum(t_j^{obs} - t_j^{cal})^2)$$

where n is the number of observations, j denotes each observation and t_j^{obs} and t_j^{cal} are the observed (data) and calculated traveltimes respectively. The summation goes from $j=1$ to $j=n$.

Source: Equation 1 of Dr.Satish's paper, 1994



Mapping of Velocity Data



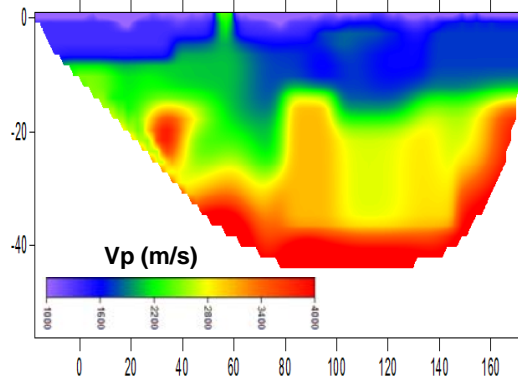
You can use the data of velocity and hit counts to map under different program. For example, I used SURFER to map the map of velocity.

Do you think that it might be a good idea to integrate velocity data which is presented by two maps? What can you suggest?

Understanding Geology

- Interpretation for the created maps of velocity can be conducted if we can understand the area of geology where the survey is done. One can select one of best models which velocity model fits the geology of the area.
- Looking up local geology or lithology logs to see what is to be expected might enhance our understanding.

Final Velocity Model



Remarks for Future Works

- 1) **Model Integration:** It can be checked model integration to increase sensitivity of Velocity following creating by a couple maps of average velocity.
- 2) **Maps of Error:** One can also create maps of standard errors, then it might be easier to distinguish a range from the best part of model to the worst part of model.

OVERVIEW

1. Run RIOTS with default Highest Setting (**Autocal on**). Give the run an extension say "1".
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3. Click on RIOTS Settings window. Use the same nx, hx, hz values as in step 2, but increase nz by 1. Give it an extension, say "2". Click "OK". This will create a file called "riotsinput_2" in the folder specified for the output files
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11. Choose the ones that have the lowest error (say 3 lowest errors), and load the Velfiles and Hitfiles corresponding to these into SeisOpt2d.
12. Select the one that best corresponds to geology.
13. Repeat all of the above with "High" if model is complex and has too many low-vel /anomalous zones that don't appear real.

Courtesy of Dr.Satish

Summary

- **RUN** it with default settings (Highest or High).
- **CREATE** different input files with different NZ values, keeping NX, HX and HZ same.
- **SET UP** and run BATCH process.
- **REVIEW** all models (Velfile, Hitfile and riotsmsg file).
- **CHOOSE** best model based on error and geology

Acknowledgement

- I have prepared tutorial for making help for users of [SeisOPT@2D](#).
- I appreciate very much to [Dr.Satish Pullammanappallil](#) from Optim Company, who always provided me continuous support for any problem.
- Please let me know if you have any problems for any step through my e-mail: oncel@kfupm.edu.sa