Salton Sea Modeling Journal

Beginning Jan-08-2015

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Contents

Thursday, 8 January 2015

1 Modeling varying interfaces for the SSAF

Try various surface expressions of the high-velocity interface to investigate how well-constrained this is, and if the interface is more likely to be to the East or West of the SSAF surface trace. This will aid in determining what fault structure is present; if the fault is to the west of the surface trace of the SSAF, it is more likely a normal fault in the Salton Sea, not visible on land. If it intersects the surface trace, it is likely that the fault may have a westward dip/oblique component; if to the east, there may be a larger normal fault cross-cutting the modern-day SSAF.

To modify the starting model and adjust the interface's surface trace, use the script:

/Modeling/salton_line7base/vm/line7tomographymodels_
/salton7base_manip2.m

1.1 Last time...Inversions 11, 12, and 13

In October, inversions 12 and 13 were run; it turns out the "final" model I had before did not include constraints on the interface from the MCS reflector picks. Inversions 12, and the final (13) were to correct this.

Inversions 12 and 13 were run with MCS constraints; the final model had a poorer chi sq than the other model; the question was why. The best misfit came from inversion iteration 21, raytracing iteration 22, after applying the nullspace shuttles method. This chi sq was 1.88, whereas without the MCS data it's 1.3. The differences between the two are not that great, but with the MCS constraints the model looks a little splotchier because of where the layer 1 rays are turning. The original final model, from inversion 11, can be seen in figure Figure 1; the final model with MCS constraints is seen in Figure 2.

Alistair suggested looking at the reflection residuals:

"I would look at how well, or not, the prediction of the previous model simply fits the trend in MCS reflection times, i.e. does it predict an increase in reflections times at about the same rate as seen in the MCS data? If it does then it is possible that

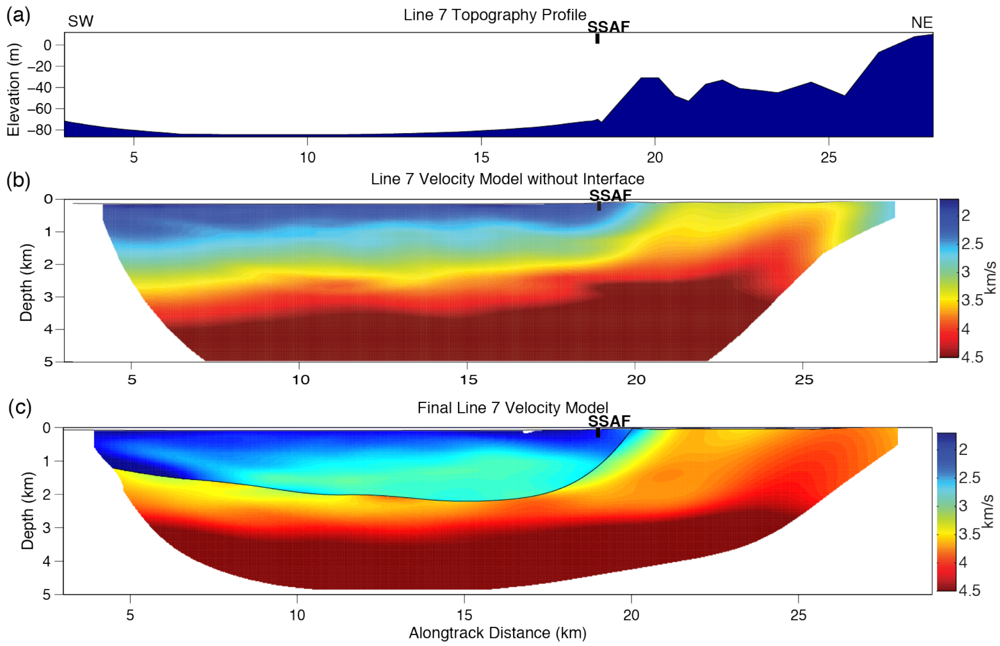

Figure 1: Inversion 11 final model, without MCS constraints. (a) shows a topography profile; (b) shows the model without an interface; (c) shows the final model, with no MCS constraints, and with an interface. Chi sq = 1.3.

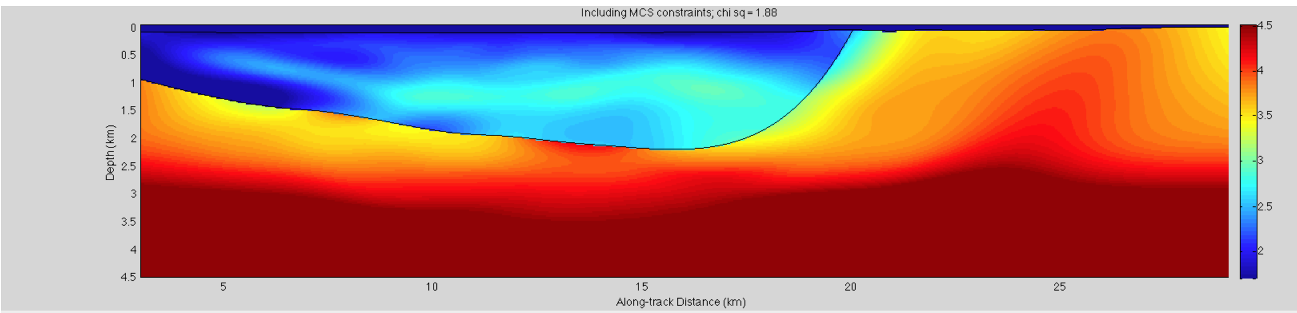

Figure 2: Inversion 13 final model, with MCS constraints. Chi sq = 1.88.

the is mostly a static time shift in your MCS picks relative to the OBS times. If the trends aren't really compatible then you probably are doing about as well as you can in reconciling the different data within an single model. and we should probably reconsider the possibility of the MCS reflections transgressing velocity contours."

To determine if this higher misfit is due to a consistently offset reflector, I plotted the just the reflection ray paths of the model with MCS constraints (Figure 3).

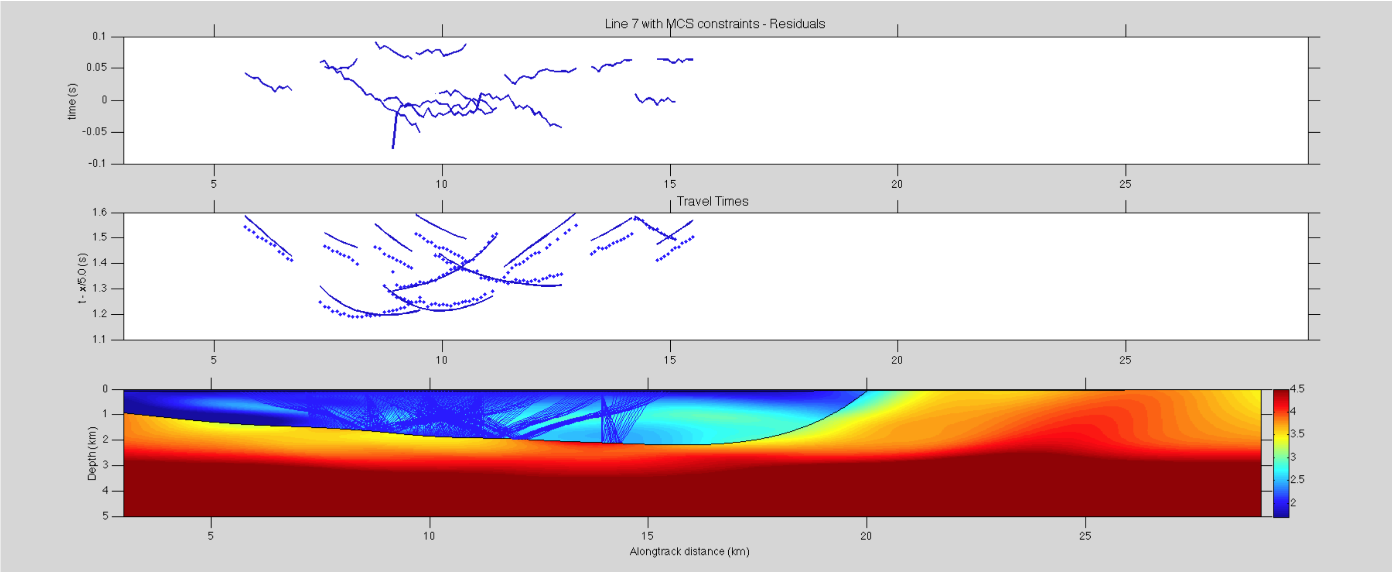

Figure 3: Inversion 13 final model ray path residuals.

1.2 Inversion 14

Start running inversions with varying interface surface traces. For inversion 14, run an example with the SSAF trace set at x=18.94299186; this is commented in salton7base_manip2.m.

The starting model is under inversion14, and is named salton7base_14_0.vm, seen in Figure 4. This inversion will include constraints from MCS data; therefore, the file salton7base_1_4.ray will be included; this is the ray file for the MCS reflector picks. The raytracing csh file is salton7base_raytr14.csh and includes append = 1, so that the rays from the MCS file will be appended to the rayfan.

The other settings are as follows:

set maxnode = 300, set cmax = 0.75, set gdx = 1041, set gdy = 1, set gdz = 323

set stx = 10, set sty = 0, set stz = 9, set ang = 0.5

set tstat = 0.0, set xextension = 2.0, set yextension = 2.0

Rayfan plotting is in script plot_salton7_raypaths_14.m.

The inversion csh file is salton7base_14.csh. The parameters are as follows:

set sr = 10.0, set sz = 5.0

set slh = 0.02, set jph = 0.005, set rfh = 0.1, set tstath = 0.04

set reg0 = 1.0, set reg1 = 1.0, set reg2 = 4.0

set asr = 5.0

set crf = 2, set cjp = 1

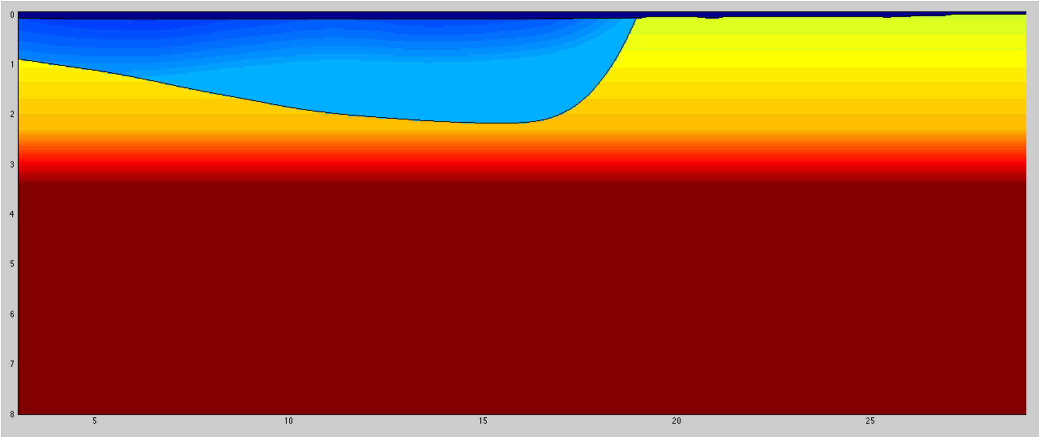

Figure 4: Inversion 14 starting model.

1.3 Raytracing and Inversion Output

Found in the tables 1.3, Table 1.3.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0514	0.1174	73.2913	50.0788	0.0241
It1	-0.0182	0.1075	47.3309	43.8783	0.0241
It2	-0.0068	0.0906	25.6917	25.2468	0.0241
It3	-0.0131	0.0644	14.3934	13.6786	0.0241
It4	-0.0135	0.0527	8.7668	8.3057	0.0241
It5	-0.0110	0.0446	5.2944	5.2898	0.0241
It6	-0.0117	0.0382	3.1804	3.3014	0.0241
It7	-0.0116	0.0360	2.5369	2.7169	0.0241
It8	-0.0112	0.0349	2.2200	2.4544	0.0241
It9	-0.0116	0.0339	2.0821	2.3345	0.0241
It10	-0.0110	0.0338	1.9729	2.2349	0.0241
It11	-0.0104	0.0336	1.9733	2.2920	0.0241
It12orig	-0.0108	0.0336	1.9329	2.2353	0.0241
It12	-0.0039	0.0439	3.2228	3.4501	0.0241
It13	-0.0114	0.0346	1.9718	2.1610	0.0241
It14	-0.0112	0.0335	1.8335	2.1037	0.0241
It15	-0.0101	0.0337	1.8931	2.2218	0.0241
It16	-0.0120	0.0340	2.0673	2.2598	0.0241

Table 1: Inversion 14: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	45	45.460	55886.17
It1	25	25.561	62766.52
It2	14	14.326	69724.12
It3	8	7.9459	75484.60
It4	5	4.9981	77469.94
It5	3	2.9994	86143.92
It6	2.3	2.3256	84903.17
It7	2.1	2.1429	81591.07
It8	1.8	1.8184	86594.72
It9	1.8	1.8618	83126.27
It10	1.8	1.8382	81169.54
It11	1.8	1.8382	79752.90
It12	2.0	2.0432	79529.48
It13	1.7	1.7128	83947.84
It14	1.7	1.7564	81046.24
It15	1.7	1.7376	79148.52

Table 2: Inversion 14: Inversion outputs.

Friday, 9 January 2015

1 Continuing Inversion 14

Continuing from Thursday.

1.1 Inversion 14 steps and results

Continued running Inversion 14 (output referenced in 1.3 and Table 1.3).

Run nullspace shuttles on inversion iteration 11 (vm 12). The pre-shuttled model, with a chi sq of 1.9329, is the best fit so far but is quite splotchy. See in Figure 5. I used salton7_shuttle_update.m to create the shuttled model;

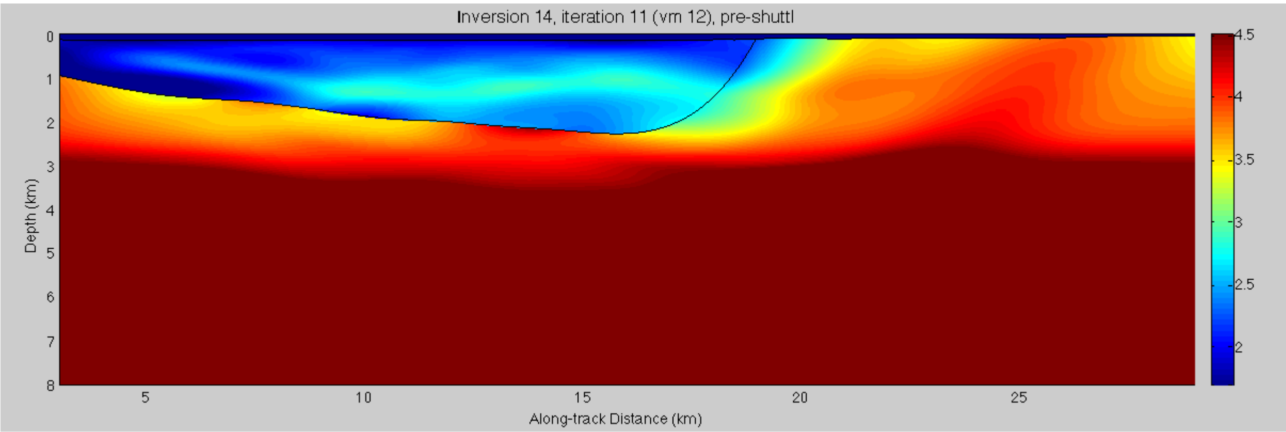

Figure 5: Inversion 14, iteration 11 (vm 12), pre shuttle.

Moving forwards, I named the output, shuttled model "Shuttles/line7shuttles/salton_smshuttle_inv14.vm". This was copied into inversion14/, and renamed to salton7base_14_12.vm. In inversion14, I renamed 12.ray, 12.vm, 12_rough.vm, and 12_raytr.out to orig.

In inversion_temp, I renamed all iteration 11's to _orig; including the anz, inz, nlr, rhsc, rhsn, sol, vecm_in, and vecm_out iteration 11's.

After this, ray trace on the new shuttled model; so re-run ray-tracing iteration 12. In the tables, the pre-shuttled statistics (ray-

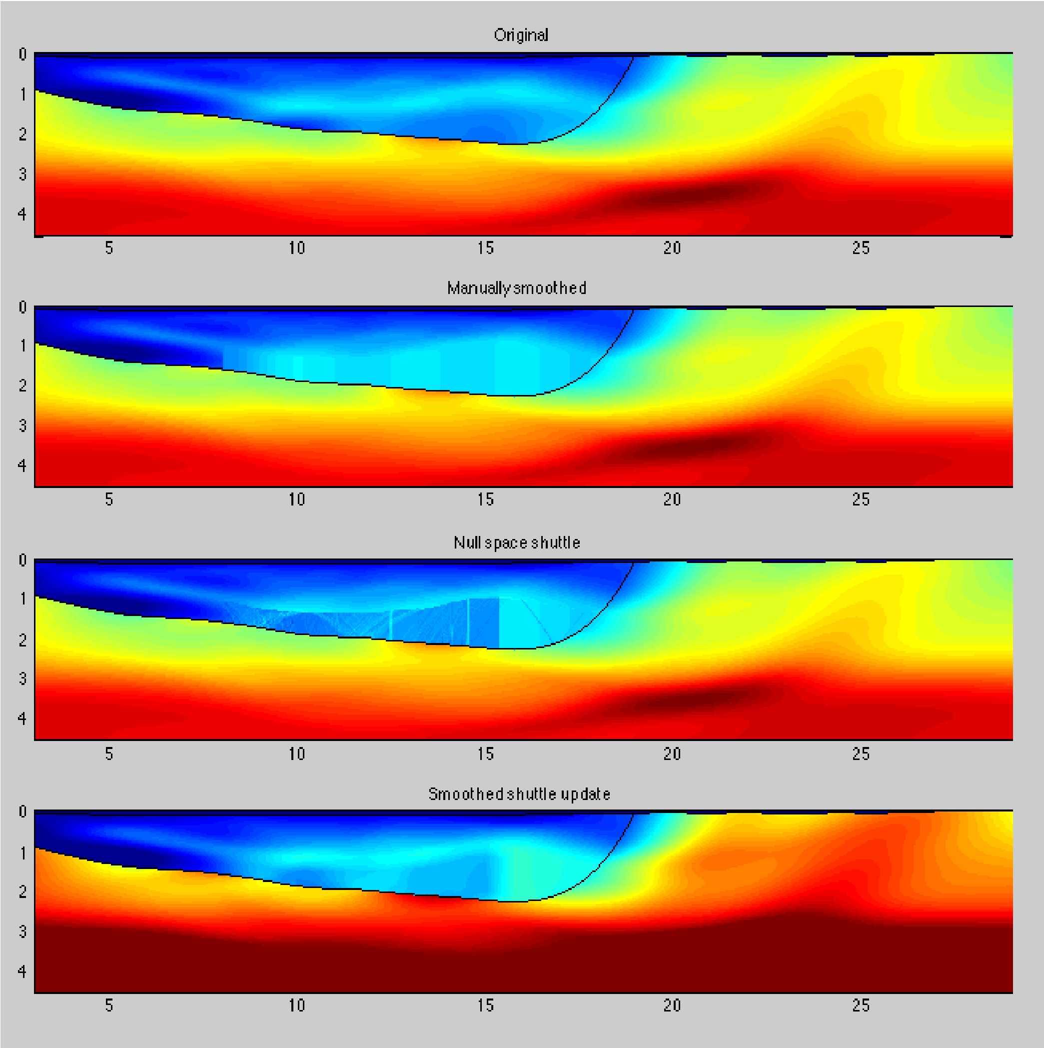

Figure 6: Inversion 14, iteration 11(vm12), post shuttle.

tracing it12) have been renamed to original. The post-shuttled raytracing will be the new It12; this velocity model is in Figure 6.

After several more iterations, I find that vm 14 (raytracing iteration 14, inversion iteration 13) has the lowest misfit (chi sq = 1.8335), and looks the "best" (the smoothest). The final model is seen in Figure 7.

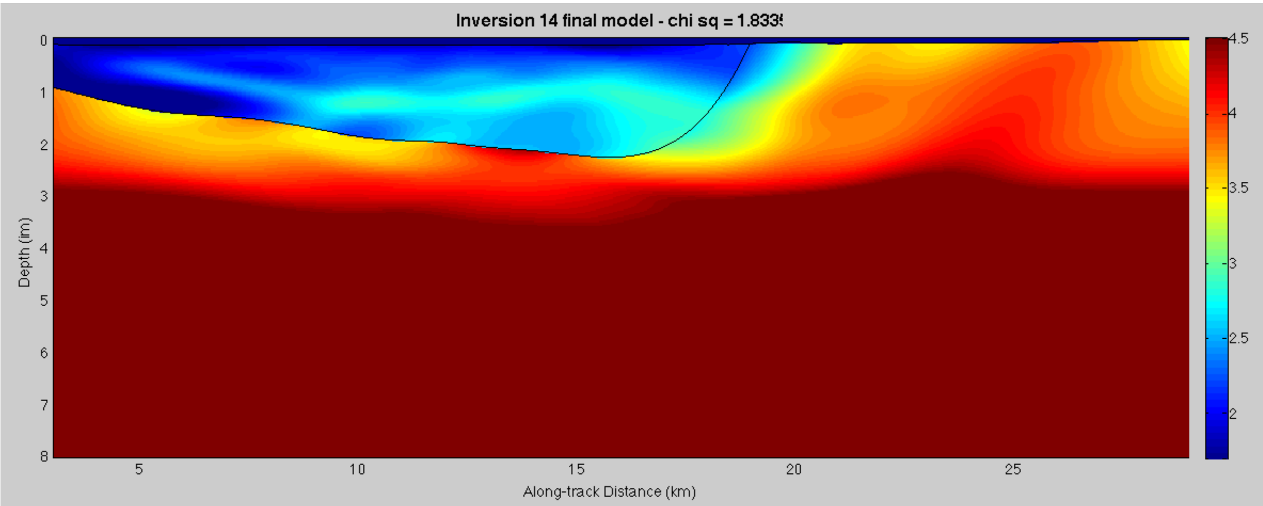

Figure 7: Inversion 14, final model. Vm number 14; chi sq = 1.8335.

Thursday, 15 January 2015

1 Inversion 15 - Interface to the W of the SSAF trace

Starting inversion 15. Here, the interface intersects the surface at 17.9km along-profile, about 1 km west of the surface trace of the SSAF.

To create the starting model, I once again used the script salton7base_manip2.m. The output model (starting model) is salton7base_15_0.vm, in inversion15/. This is seen in Figure 8. This inversion will include constraints from MCS data; therefore, the file salton7base_1_4.ray will be included; this is the ray file for the MCS reflector picks. The raytracing csh file is salton7base_raytr15.csh and includes append = 1, so that the rays from the MCS file will be appended to the rayfan.

The other settings are as follows:

set maxnode = 300, set cmax = 0.75, set gdx = 1041, set gdy = 1, set gdz = 323

set stx = 10, set sty = 0, set stz = 9, set ang = 0.5

set tstat = 0.0, set xextension = 2.0, set yextension = 2.0

Rayfan plotting is in script plot_salton7_raypaths_15.m.

The inversion csh file is salton7base_15.csh. The parameters are as follows:

set sr = 10.0, set sz = 5.0

set slh = 0.02, set jph = 0.005, set rfh = 0.1, set tstath = 0.04

set reg0 = 1.0, set reg1 = 1.0, set reg2 = 4.0

set asr = 5.0

set crf = 2, set cjp = 1

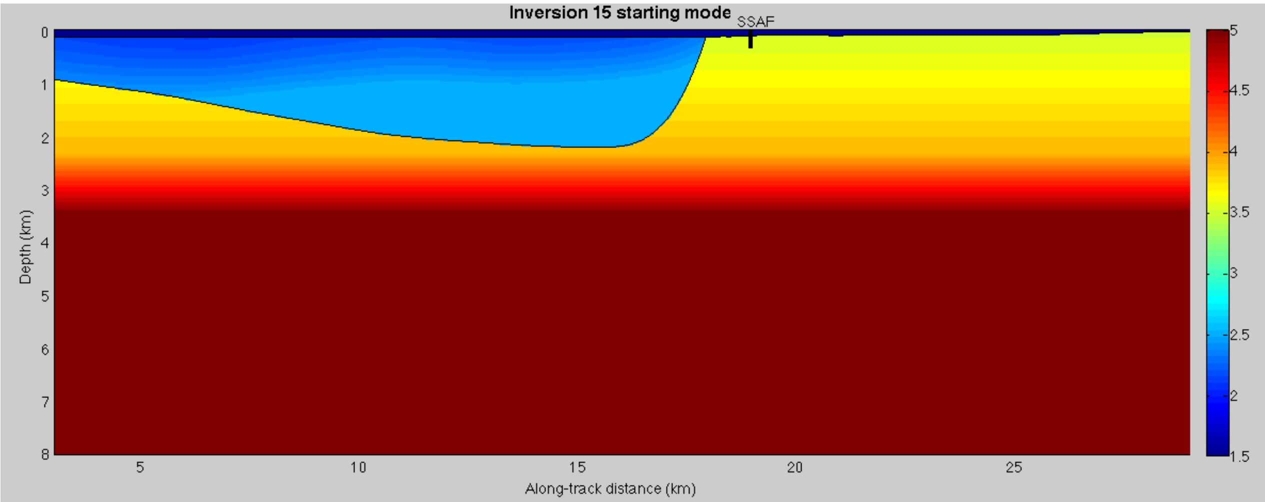

Figure 8: Inversion 15 starting model.

1.1 Raytracing and Inversion Output

Output found in 1.1 and Table 1.1.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0529	0.1197	77.0745	52.4152	0.0241
It1	-0.0222	0.1102	52.0758	47.1082	0.0241
It2	-0.0055	0.0948	29.0273	28.6880	0.0241
It3	-0.0134	0.0696	17.7654	16.8745	0.0241
It4	-0.0135	0.0586	11.9874	11.4367	0.0241
It5	-0.0111	0.0494	7.6122	7.5095	0.0241
It6	-0.0098	0.0456	5.6006	5.6730	0.0241
It7	-0.0105	0.0420	4.3647	4.4582	0.0241
It8	-0.0110	0.0370	2.9838	3.1563	0.0241
It9	-0.0112	0.0365	2.7190	2.9174	0.0241
It10	-0.0109	0.0352	2.3849	2.6462	0.0241
It11	-0.0104	0.0349	2.2980	2.5895	0.0241
It12	-0.0113	0.0344	2.2386	2.4955	0.0241
It13	-0.0107	0.0341	2.1513	2.4475	0.0241

Table 1: Inversion 15: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	50	50.182	144875.5
It1	30	29.006	149535.8
It2	17	17.770	152034.2
It3	11	11.190	153989.8
It4	7	7.1052	159624.0
It5	5	5.2451	154047.7
It6	4	4.0112	153415.7
It7	3	2.8625	163787.0
It8	2.5	2.4805	158431.1
It9	2.3	2.3184	157304.5
It10	2.1	2.1941	155617.3
It11	2.0	2.0898	155357.0
It12	2.0	2.0662	153650.9

Table 2: Inversion 15: Inversion outputs.

1.2 Inversion 15 Results

I did not run the nullspace shuttles method on this model. It appears that the the misfit increases as the interface is moved further west; likewise, there are more artifacts observed in the model. For previous inversions, the model fit the data with a lower misfit at the same place in the inversion. The final model here has a chi sq of 2.1513, and can be seen in Figure 9.

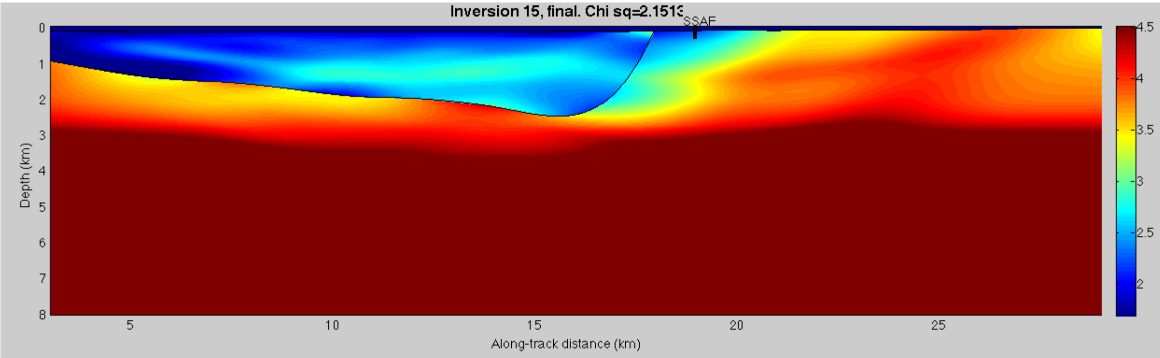

Figure 9: Inversion 15 final model, chi sq = 2.1513.

2 Inversion 16

Here, I move the interface even further west of the SSAF.

2.1 Inversion 16 setup

In inversion 16, the interface intersects the surface at 15.9 km along-track distance. The MCS data ends at approximately 15.5 km along-track distance, and I am including constraints from the MCS reflector times; therefore, I leave the bottom of the interface at 15.5 km depth where it is observed (and picked) in the constraining MCS data.

To create the starting model, I used the same script as I did for the previous inversion (salton7base_manip2.m). The starting model can be seen in Figure 10. As before, raytracing includes MCS reflector picks as a constraint for the interface, so append = 1 in the raytracing file. The raytracing file has been copied from inversion 15 (and that from inversion 14), so all the parameters are the same as above. Same for the inversion file. The new raytracing and inversion files are, respectively, salton7base_raytr16.csh and salton7base_inv16.csh.

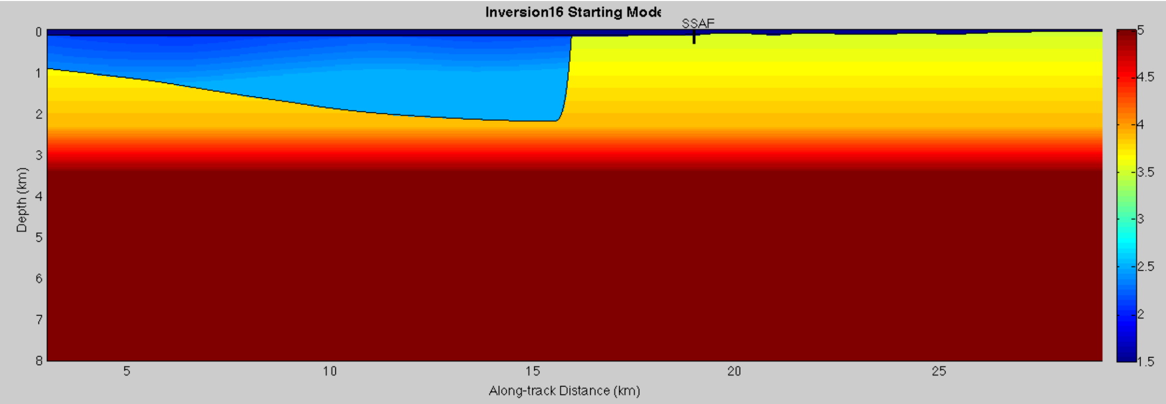

Figure 10: Inversion 16 starting model.

2.2 Raytracing and Inversion Output

Output found in 2.2 and Table 2.2.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0631	0.1416	112.2396	77.2975	0.0241
It1	-0.0220	0.1136	54.0334	49.8177	0.0241
It2	-0.0267	0.0811	28.8202	26.1150	0.0241
It3	-0.0203	0.0724	26.8071	26.3205	0.0241
It4	-0.0234	0.0688	20.0351	18.7892	0.0241
It5	-0.0217	0.0666	18.0069	17.7185	0.0241
It6	-0.0227	0.0591	12.1935	11.6280	0.0241

Table 3: Inversion 16: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	60	61.156	0.1114872E+08
It1	30	30.564	9220897
It2	20	20.267	8360667
It3	18	18.422	7846056
It4	15	15.474	7464322
It5	10	10.072	7227253

Table 4: Inversion 16: Inversion outputs.

2.3 Inversion 16 results

It appears that this is too far west to place the interface-surface intersection; the interface dips too steeply. After 5 iterations, I decided to stop running this; the misfit was not improving and the velocity model looks quite bad... Figure 11: 'nuff said.

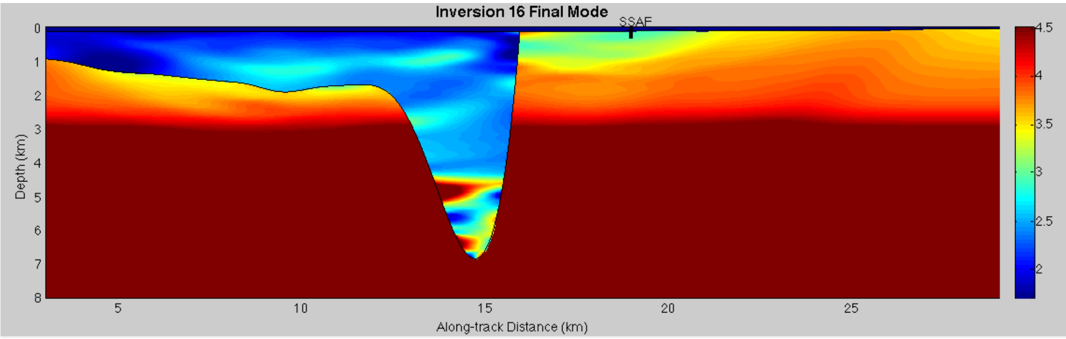

Figure 11: Inversion 16 final model.

Friday, 16 January 2015

1 Move Interface East of the SSAF Surface trace - Inversion 17

The next few inversions are to explore the fit of an interface that intersects the surface to the east of the SSAF surface trace.

1.1 Inversion 17 Setup

Inversion 12/13 had the interface at 20km along-track distance, which is approximate 1 km to the east of the SSAF surface trace.

Inversion 17 places the interface at 21.9 km along-track distance, which is 3km to the east of the SSAF surface trace. Again, salton7base_manip2.m was used to create the starting model, which can be seen in Figure 12. This was copied into the directory inversion17, from which this model will be run.

The parameters are the same as the past several inversions, and MCS reflector picks are included to constrain the interface depth.

The raytracing file is salton7base_raytr17.csh, and the inversion file is salton7base_inv17.csh.

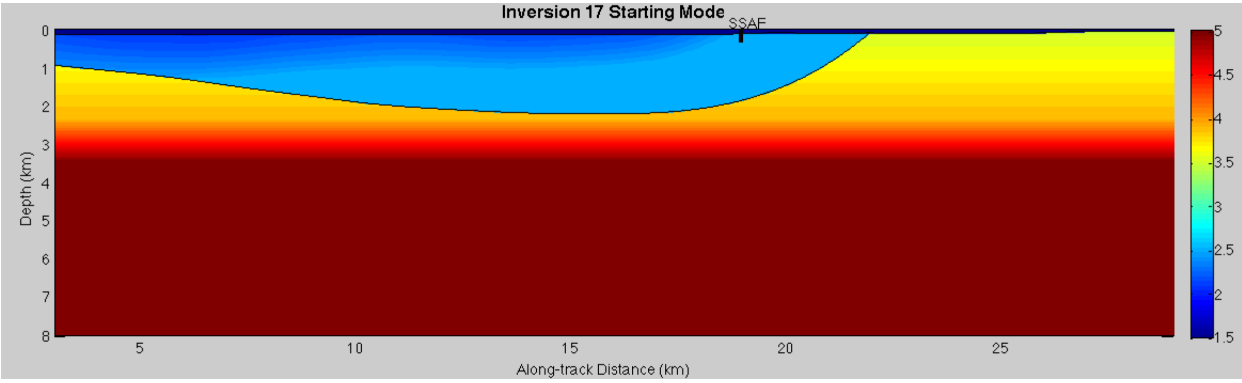

Figure 12: Inversion 17 starting model.

1.2 Inversion 17 Raytracing and Inversion Output

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0454	0.1084	59.1925	41.4194	0.0241
It1	-0.0158	0.0990	37.0039	34.5539	0.0241
It2	-0.0048	0.0853	20.1304	19.9383	0.0241
It3	-0.0087	0.0745	15.2529	14.8563	0.0241
It4	-0.0075	0.0624	10.0163	9.9648	0.0241
It5	-0.0079	0.0553	7.3091	7.3324	0.0241
It6	-0.0098	0.0467	5.0138	5.0799	0.0241
It7_orig	-0.0097	0.0433	3.9889	4.1470	0.0241
It8_orig	-0.0106	0.0391	3.1342	3.3032	0.0241
It9_orig	-0.0115	0.0368	2.5874	2.7596	0.0241
It7	-0.0056	0.0568	6.5518	6.6610	0.0241
It8	-0.0124	0.0428	4.3133	4.2603	0.0241
It9	-0.0109	0.0391	3.0443	3.2042	0.0241
It10	-0.0111	0.0370	2.5758	2.7711	0.0241
It11	-0.0118	0.0351	2.2134	2.4003	0.0241
It12	-0.0111	0.0347	2.0743	2.3365	0.0241
It13	-0.0112	0.0340	1.9712	2.2259	0.0241
It14	-0.0107	0.0344	1.9761	2.2546	0.0241
It15	-0.0109	0.0338	1.8934	2.1826	0.0241
It16	-0.0108	0.0337	1.8875	2.1801	0.0241

Table 1: Inversion 17: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	35	35.220	13802.58
It1	20	19.960	18595.53
It2	15	15.165	14939.56
It3	10	9.9271	16998.00
It4	7	7.2088	19035.86
It5	5	5.0090	23574.42
It6	4	4.0140	24373.59
It7_orig	3	3.0159	29915.57
It8_orig	2.5	2.4266	35008.20
It7	4	4.0609	27968.18
It8	3	2.9973	33597.40
It9	2.5	2.4453	34715.13
It10	2.0	2.0206	41483.15
It11	1.9	1.9327	38489.62
It12	1.8	1.8218	39072.30
It13	1.8	1.8698	33794.29
It14	1.8	1.8090	33865.78
It15	1.8	1.7680	32857.09

Table 2: Inversion 17: Inversion outputs.

1.3 Inversion 17 Shuttles

After Inversion iteration 6 (velocity model 7 and raytracing iteration 7), more artifacts become present in the model. The chi sq of inversion iteration 6 is 3.9889; I run the nullspace shuttles method to update this model and rerun the inversions. The pre-shuttle model is seen in Figure 13.

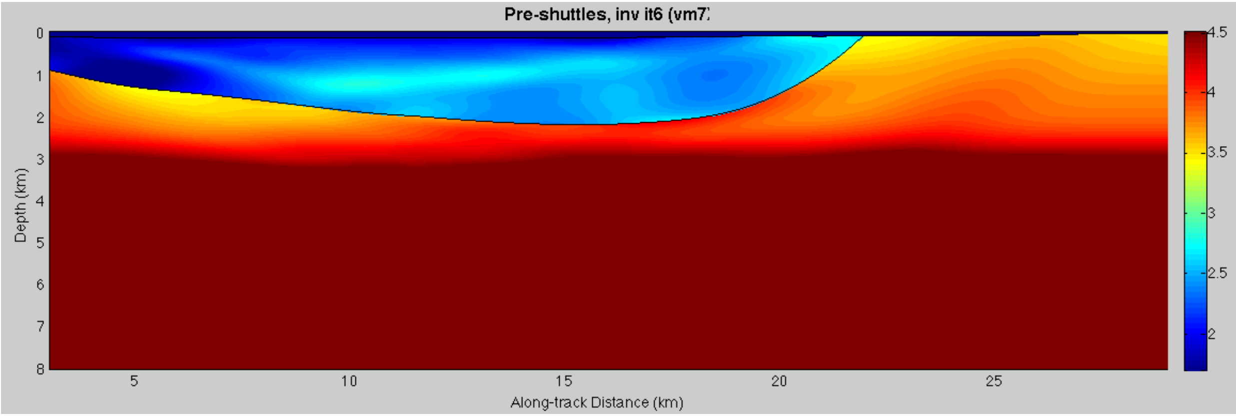

Figure 13: Inversion 17, pre-shuttles method. Inversion iteration 6; chi sq = 3.9889.

There is a low velocity patch to east of the sedimentary basin; the main shuttles code (salton7_shuttle_update.m) maintains this low velocity patch and does not smooth it because of the current algorithm for updating ("filtering") the model. This is seen in Figure 14.

To fix this, I added some conditionals in the filtering portion of the code; these changes are in salton7_shuttle_update_in17.m. I run this on inversion iteration 6 to get the newly shuttled model. This shuttled model (and other info) can be seen in Figure 15.

The resulting model is in salton_smshuttle_inv17.vm, in the Shuttles/line7shuttles. I copy this intone /inversion17, and name it salton7base_17_7.vm. This will be the new vm 7, so the next iteration will be raytracing iteration 7 and then inversion iteration 7.

Rename all inversion 17, iteration 7, and 8 files in the inversion_temp directory to 7_orig and 8_orig; rename all iteration 7 files (anz, inz, nlr, rhsc, rhsn, sol, and vecm) to _orig17. In the inversion17 directory, rename all iteration 7, 8, and 9 files to _orig.

Restart now by raytracing on this model; raytracing iteration 7. In the tables, the pre-shuttle iterations of these will be named _orig (so raytracing iterations 7, 8 and 9 and inversion iterations 7 and 8).

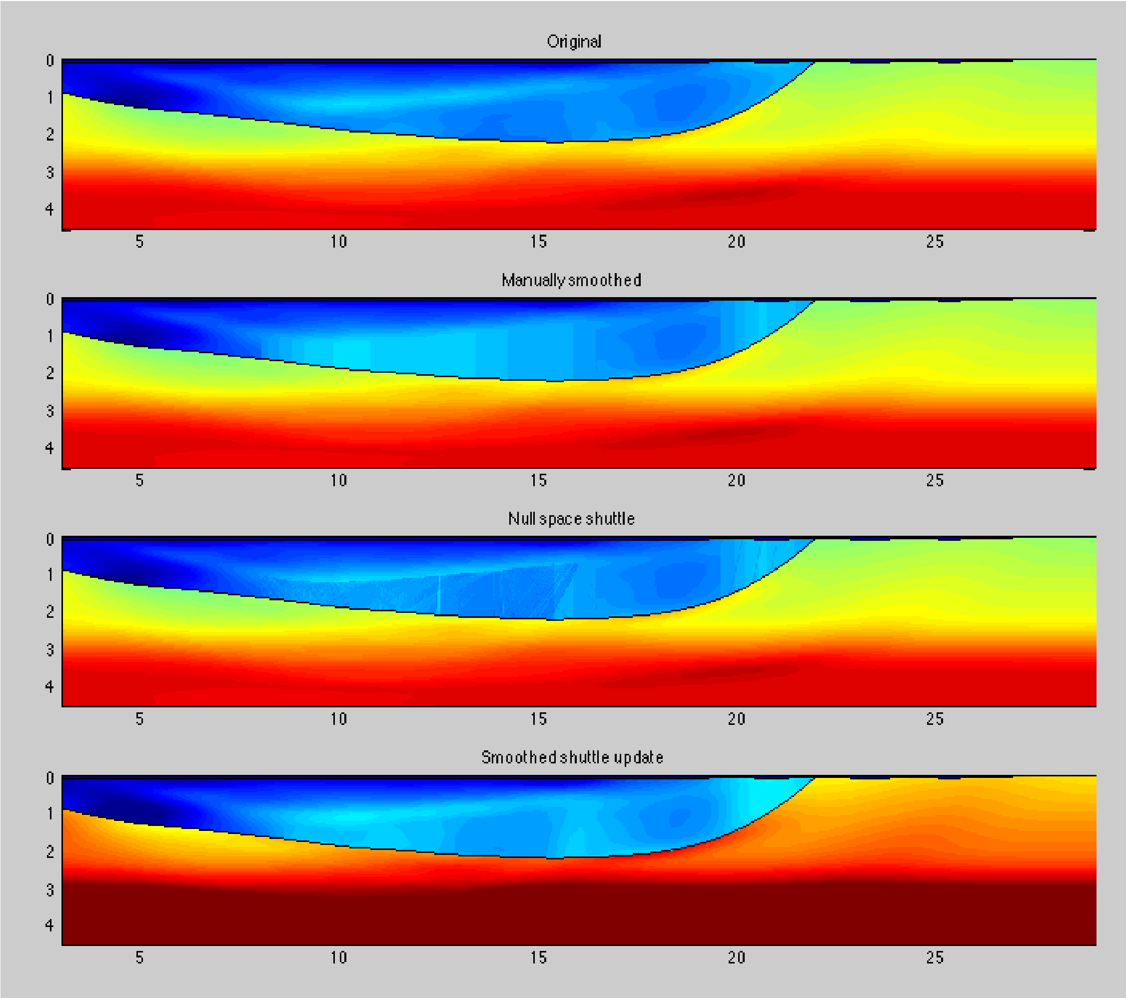

Figure 14: Inversion 17, post-shuttles method with the original shuttles script.

1.4 Inversion 17 Results

After inversion iteration 11, the velocities around the interface/surface intersection become very high/low relative to the remainder of the layer. Because of this, I pick iteration 11 (Velocity model 12) as the final model, with chi sq = 2.07. This is seen in Figure 16. The ray paths and residuals for this model are in Figure 17.

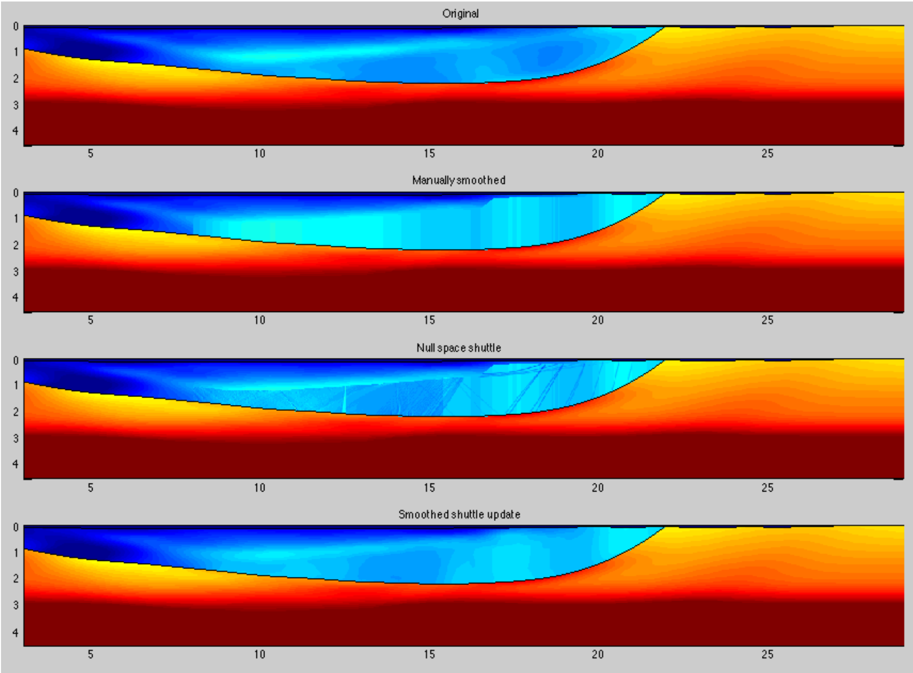

Figure 15: Inversion 17, nullspace shuttles model.

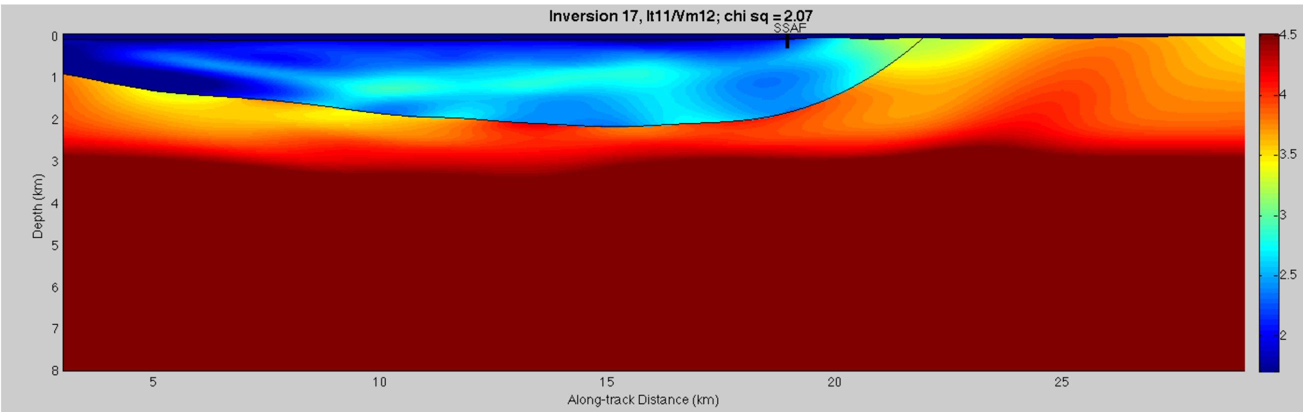

Figure 16: Inversion 17, iteration 11 (vel model 12). "Final" model, chi sq = 2.07.

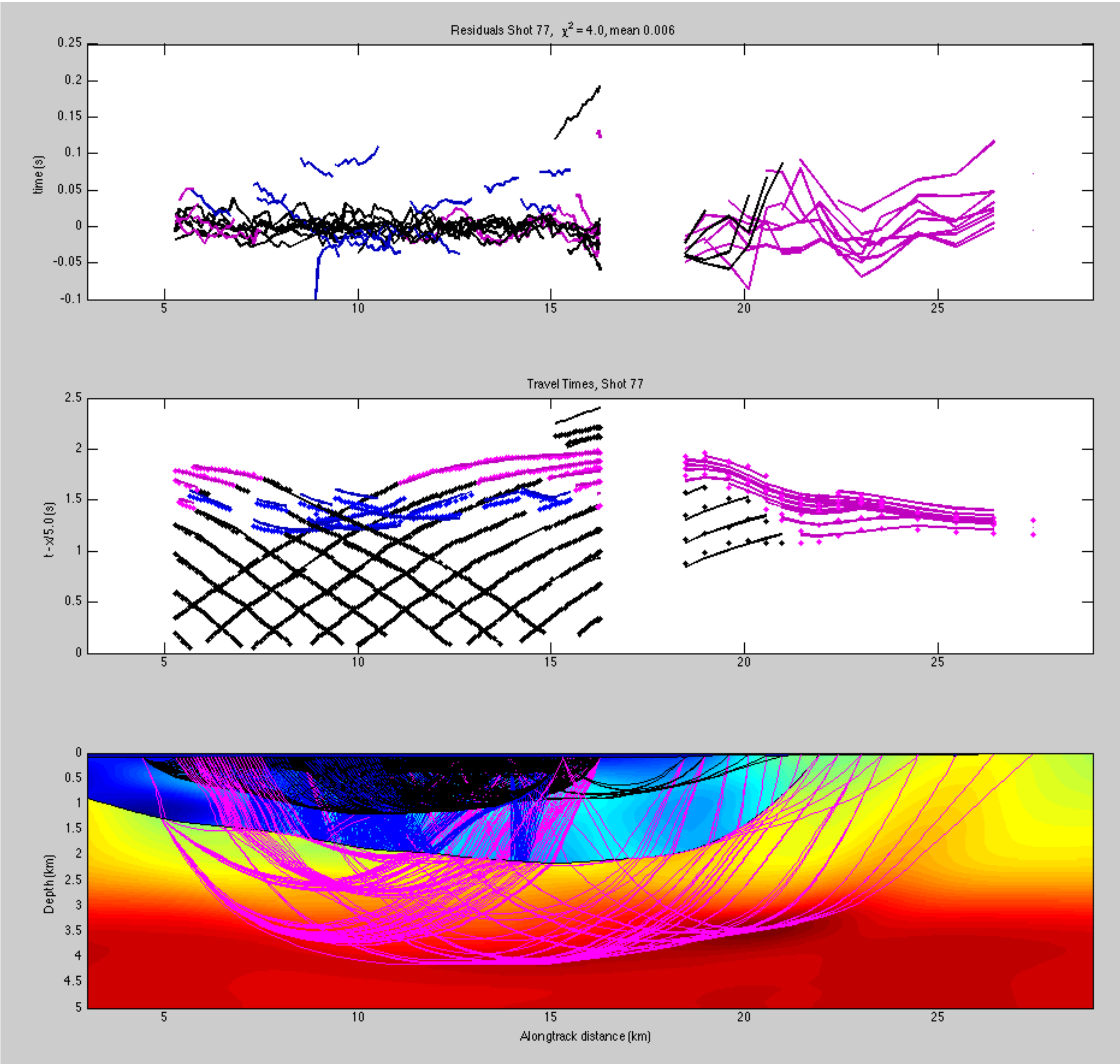

Figure 17: Inversion 17, final model, ray paths and residuals.

2 Inversion 18

Move the interface further west (5 km east of SSAF trace).

2.1 Inversion 18 setup

Here I move the interface surface intersection to 23.9 km along-track distance, which is 5km to the east of the SSAF surface trace. The script salton7base_manip2.m is used to create the starting model salton7base_18_0.vm, seen in Figure 18, and in the directory inversion18.

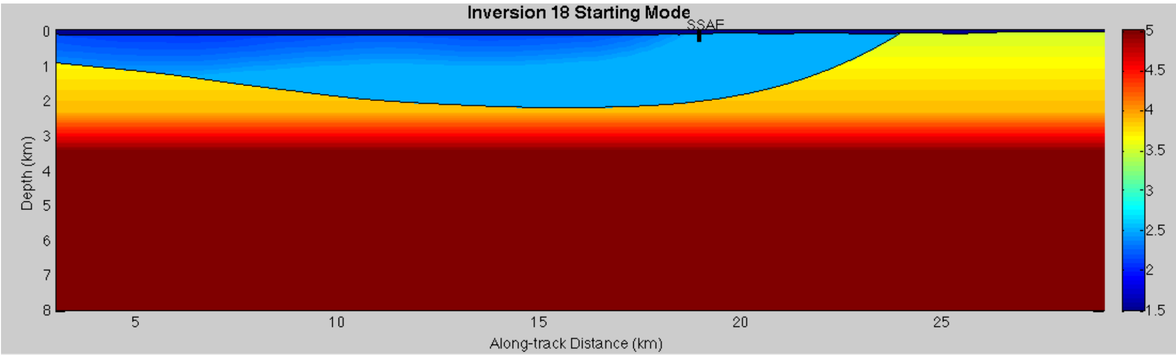

Figure 18: Inversion 18 starting model.

The scripts used are salton7base_raytr18.csh and salton7base_inv18.csh; the same parameters are used as the past several inversions, and MCS rays are used to constrain the interface (append = 1).

2.2 Inversion 18 Raytracing and Inversion Output

See in tables

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0415	0.1087	59.6053	44.9305	0.0241
It1	-0.0185	0.1006	41.5355	38.4409	0.0241
It2	-0.0066	0.0944	30.5015	30.0822	0.0241
It3	-0.0077	0.0762	17.4766	17.2563	0.0241
It4	-0.0096	0.0603	10.7631	10.6810	0.0241
It5	-0.0110	0.0520	7.0319	6.9810	0.0241
It6	-0.0110	0.0453	4.9075	5.0264	0.0241
It7_orig	-0.0105	0.0428	4.0593	4.2240	0.0241
It7	-0.0083	0.0546	6.4912	6.5738	0.0241
It8	-0.0097	0.0474	5.1137	5.2320	0.0241
It9	-0.0099	0.0431	3.9336	4.0762	0.0241
It10	-0.0103	0.0393	3.0517	3.2352	0.0241
It11	-0.0108	0.0371	2.5810	2.7943	0.0241
It12	-0.0118	0.0351	2.2893	2.4825	0.0241
It13	-0.0110	0.0345	2.0634	2.3417	0.0241
It14	-0.0112	0.0341	2.0394	2.3096	0.0241
It15	-0.0111	0.0338	1.9382	2.2083	0.0241
It16	-0.0104	0.0338	1.9337	2.2528	0.0241
It17	-0.0108	0.0337	1.9035	2.1977	0.0241

Table 3: Inversion 18: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	40	39.992	8932.743
It1	30	30.241	8148.220
It2	18	17.529	15017.25
It3	11	10.602	18093.48
It4	7	6.9742	19841.03
It5	5	4.9734	22544.40
It6	4	4.0191	21136.95
It7	5	5.0950	19466.58
It8	4	3.9825	19439.88
It9	3	3.5683	17018.32
It10	2.5	2.5128	27059.59
It11	2.0	2.0141	35238.67
It12	1.9	1.9400	35232.77
It13	1.8	1.8323	37072.04
It14	1.8	1.8397	35876.99
It15	1.8	1.8315	34804.32
It16	1.8	1.8277	33951.56

Table 4: Inversion 18: Inversion outputs.

2.3 Inversion 18 Shuttle Method

Use the nullspace shuttles method on iteration 6 (velocity model and raytracing iteration 7); this model has a high velocity patch just at the surface (Figure 19).

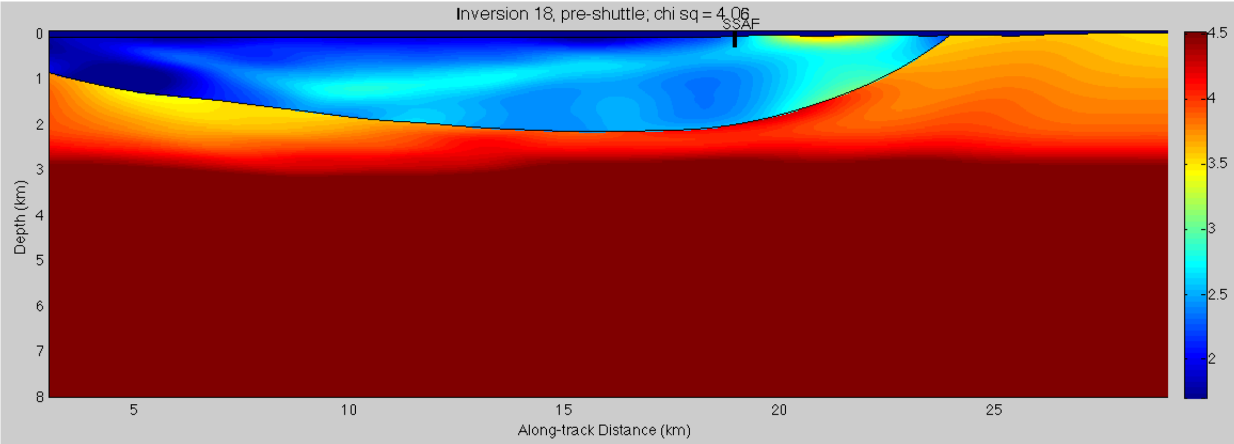

Figure 19: Inversion 18, iteration 6, before using the shuttle method. chi sq = 4.06.

Thus, the resulting shuttled velocity model have a streak of high velocity patch downwards into the model. To create the shuttled model (the new velocity model 7), use the original shuttle script (salton7_shuttle_update.m). Like all other shuttled inversions (except inversion 17), this takes the highest velocity observed in a column in the first layer, and propagates it downwards to the basement interface. The result in velocity model can be seen in Figure 20.

This new velocity model is in the Shuttles/line7shuttles directory; it is salton_smshuttle_inv18.vm. I copy this into inversion18 as salton7base_18_7.vm; the original velocity model 7 is renamed _orig, as are raytracing iteration 7, rough.vm, raytracing output, and inversion iteration 6 output. In the inversion_temp directory, all inversion 18 iteration 6 jp, rf, and sl files are renamed to _orig, as well as the iteration 6 anz, ins, nlr, rhsc, rhsn, sol, vecm_in, and vem_out.

In the raytracing output table, iteration 7 has been renamed to it7_orig. After copying the shuttled velocity model into the inversion17 directory, I re-raytrace through it in raytracing iteration 7. This is the iteration 7 in the raytracing table.

After an iteration or two, it seems that the shuttles method should have been run on a model from a few iterations earlier, to avoid the large velocity patch; it seems to me that this may be unrealistic, and the inversion keeps re-updating so that the

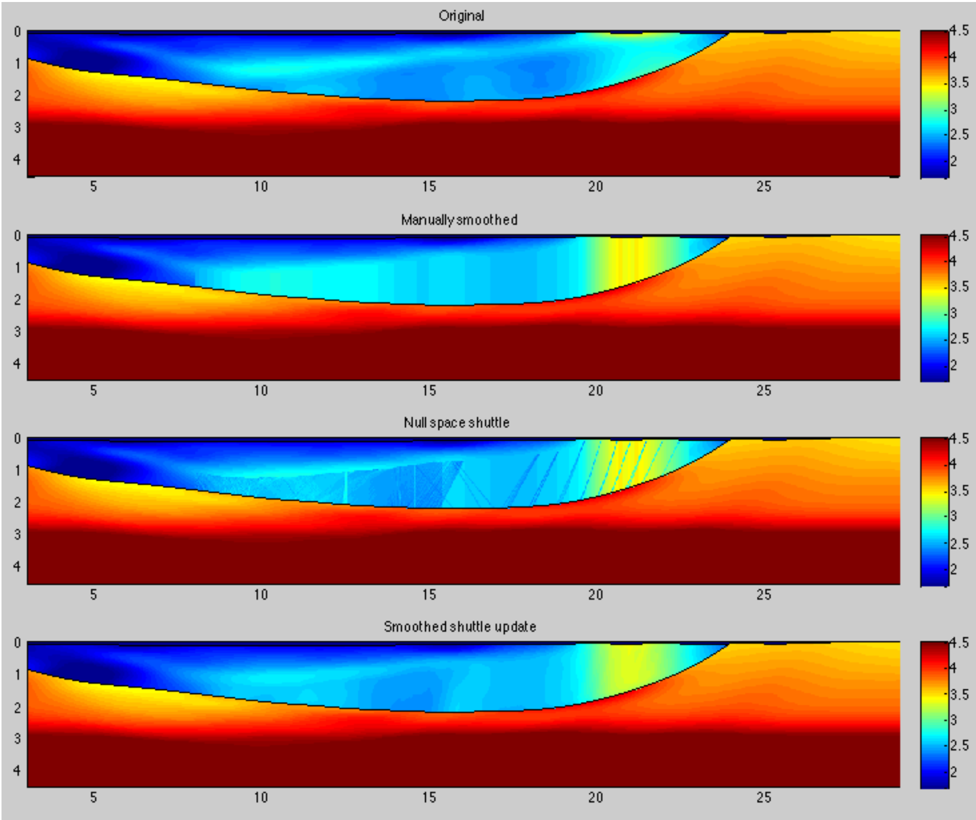

Figure 20: Inversion 18, iteration 6, result of using the shuttles method on velocity model 7 (iteration 6).

bottom is slower to accommodate the "pink" rays, as well as "black" rays. I may run a separate inversion 19 in which i run nullspace shuttles earlier, to make the velocity more uniform and see what happens from here.

2.4 Inversion 18 Results

After about iteration 14, the velocity model does not change much in appearance. A low-velocity patch (2.2 km/s) around 17 - 20 km develops, and a slightly higher velocity patch (3.1 - 3.6 km/s) in layer 1 develops around 21.2 km along-track distance. However, the misfit improves over the course of the next 4 iterations, so I take the final iteration (inversion iteration 16, velocity model 17) to be the final model. This can be seen in Figure 21.

The model with raypaths and residuals can be seen in Figure 43

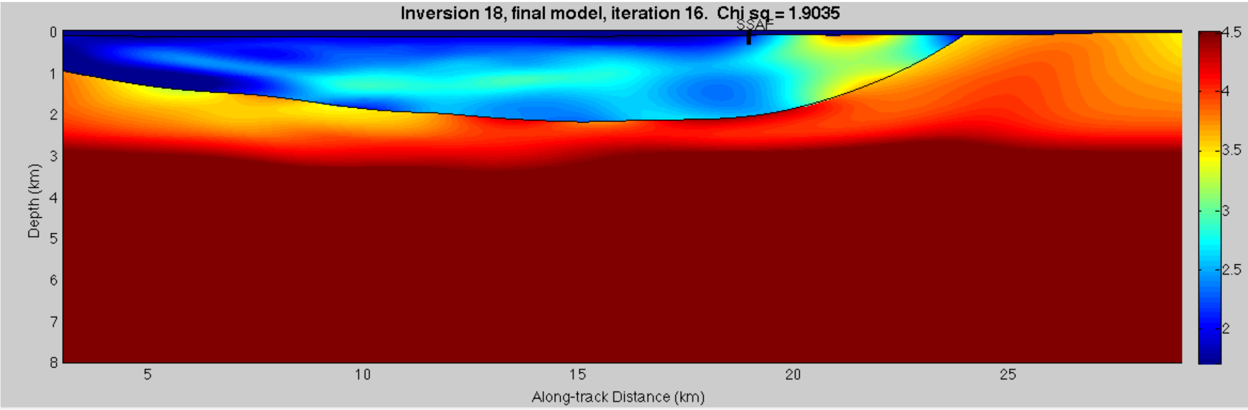

Figure 21: Inversion 18, inv iteration 16; velocity model 17. Final model for inversion 18 with chi sq = 1.90.

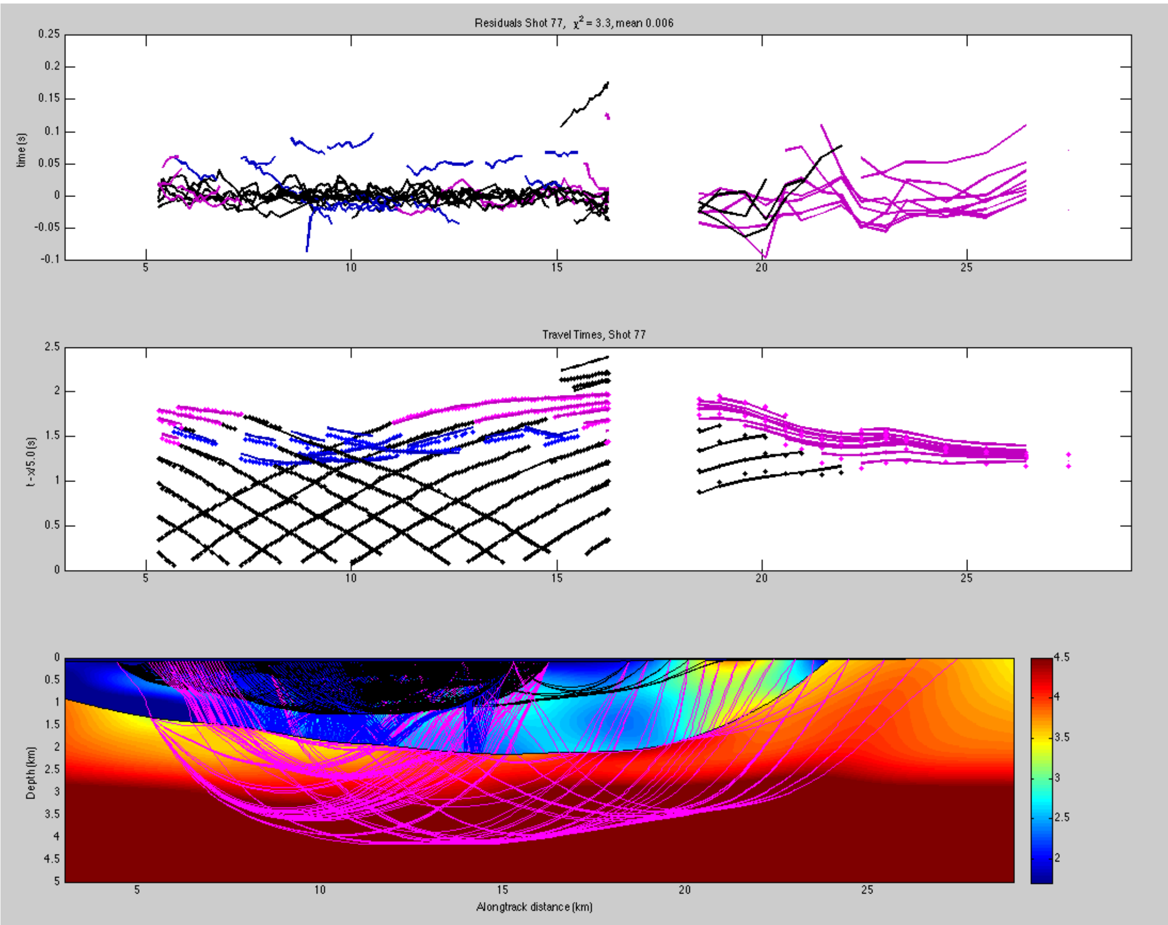

Figure 22: Inversion 18, inv iteration 16; velocity model 17. Raypaths and residuals.

3 Inversion 19; Run shuttles earlier on inv 18

I noticed on inversion 18 that the iteration on which I ran the shuttles may have influenced the end result of the high velocity patch in the east. To test whether this is the case, I copy the first few iterations of inversion 18 into inversion 19 and run shuttles on an earlier iteration.

3.1 Inversion 19 Setup

Run the nullspace shuttles method on inversion 18 iteration 5 (velocity model 6). See Figure 23 and Figure 24. The resulting shuttled model is salton_smshuttle_inv19.vm, which I copy into the inversion 19 directory as salton7base_19_0.vm.

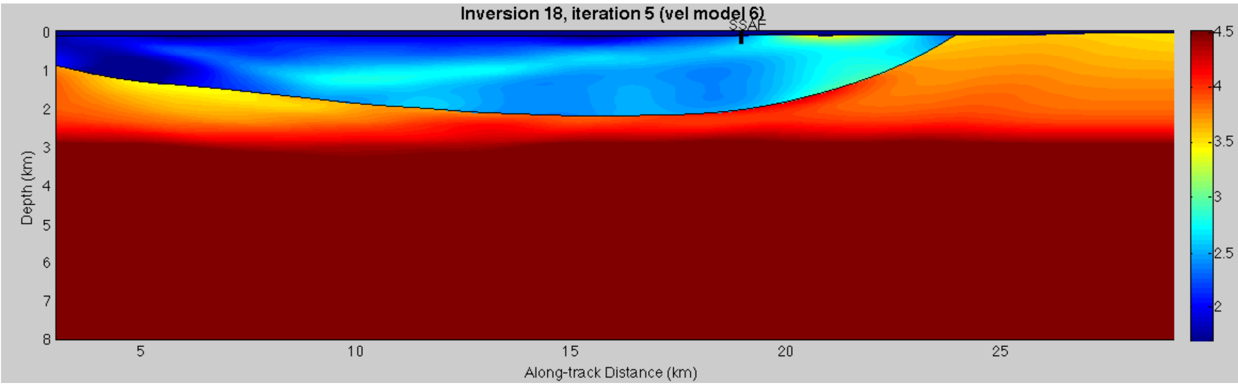

Figure 23: Inversion 18, inv iteration 5 (velocity model 6). chi sq = 4.91. Run the shuttles method on this model to form the "starting" model for inversion 19.

The starting model by itself can be seen in Figure 25. I also copy over salton7base_1_4.ray.

To run the inversion, I use the same parameters as before, in the files salton7base_raytr19.csh and salton7base_inv19.csh.

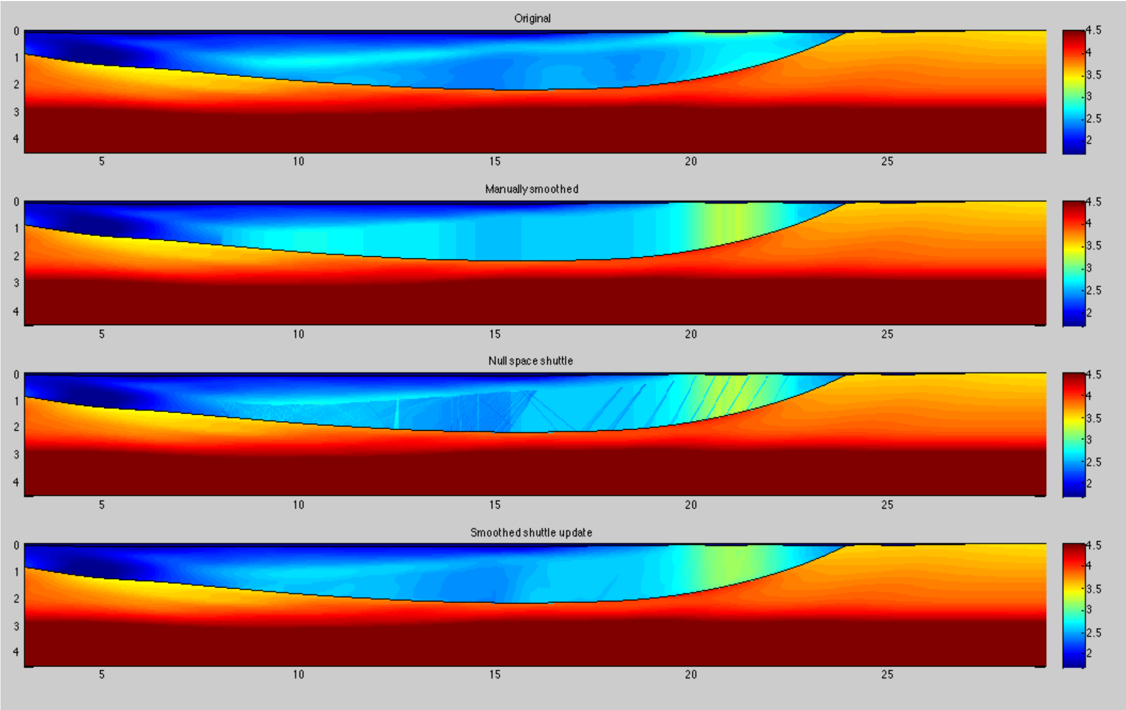

Figure 24: Using the shuttles method on inversion 18 iteration 5; the bottom model will be the starting model for inversion 19.

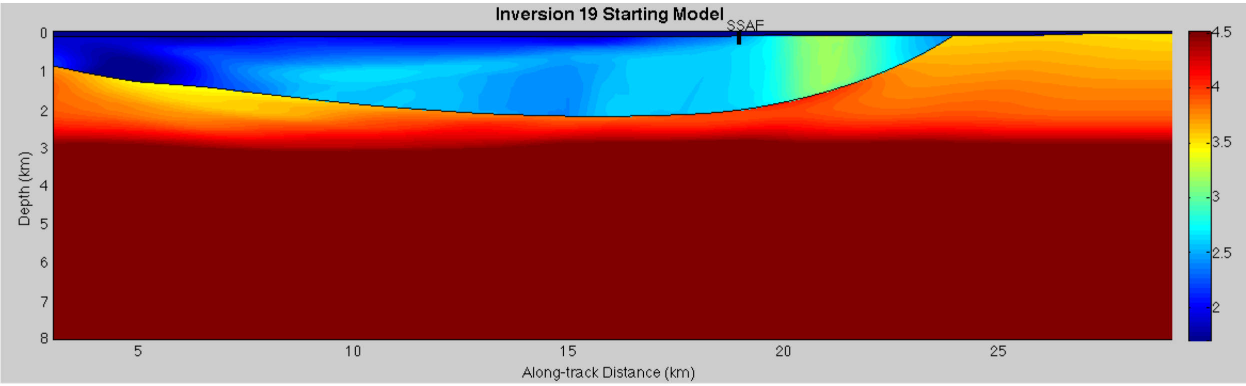

Figure 25: Inversion 19 startin model.

3.2 Inversion 19 Raytracing and Inversion Output

Raytracing and Inversion output can be seen in 3.2 and Table 3.2. At inversion iteration 4, I change reg1 (first derivative smoothing) and reg2 (second derivative smoothing). Before, these were set to reg1 = 1; reg2 = 4. At iteration 4, I change reg1 = 5 and reg2 = 20.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0080	0.0610	8.3738	8.3645	0.0241
It1	-0.0118	0.0461	5.3498	5.3419	0.0241
It2	-0.0106	0.0427	3.9472	4.0706	0.0241
It3	-0.0106	0.0389	3.0678	3.2368	0.0241
It4	-0.0116	0.0364	2.4807	2.6565	0.0241
It5	-0.0115	0.0348	2.1705	2.4027	0.0241
It6	-0.0116	0.0345	2.1458	2.3752	0.0241
It7	-0.0107	0.0347	2.0637	2.3439	0.0241
It8	-0.0108	0.0345	2.0462	2.3489	0.0241

Table 5: Inversion 19: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	5	5.1420	24736.99
It1	4	4.0636	23474.95
It2	3	3.0132	27237.83
It3	2.4	2.3808	33565.06
It4	2	2.0072	957605.2
It5	1.9	1.9232	928151.3
It6	1.9	1.9913	798585.9
It7	1.9	1.9715	772211.0

Table 6: Inversion 19: Inversion outputs.

3.3 Inversion 19 Results

I choose inversion iteration 5 (velocity model 6) as the "final" model for inversion 19; after this iteration, the fit does not improve much but the model becomes "splotchier". The misfit for this model is 2.1458, and is in Figure 26. The ray paths and residuals are in Figure 27. In the lake, from about 3 to 16/17 km along-track distance, the first layer exhibits what are likely lake sediments. From 16 to 20 km along-track distance, there is a lower velocity patch of approximately 2.5 km/s, lower than most of these lake sediments, and beyond this the velocities increase until layer 2 is reached. the ray coverage in this region of varying velocities is approximately the same (mostly land shots, some marine shots), so I think this may be real. This low velocity patch could be a damage zone related to the SSAF and another (normal!) fault, and the higher velocities to the east reflect the lacustrine, but compacted, Borrego Formation.

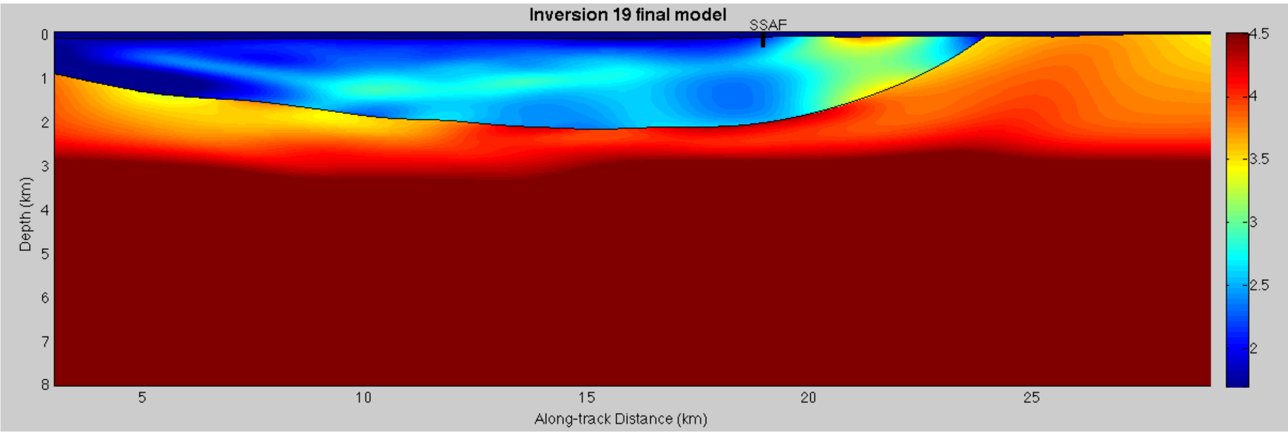

Figure 26: Inversion 19 final model, chi sq = 2.1458.

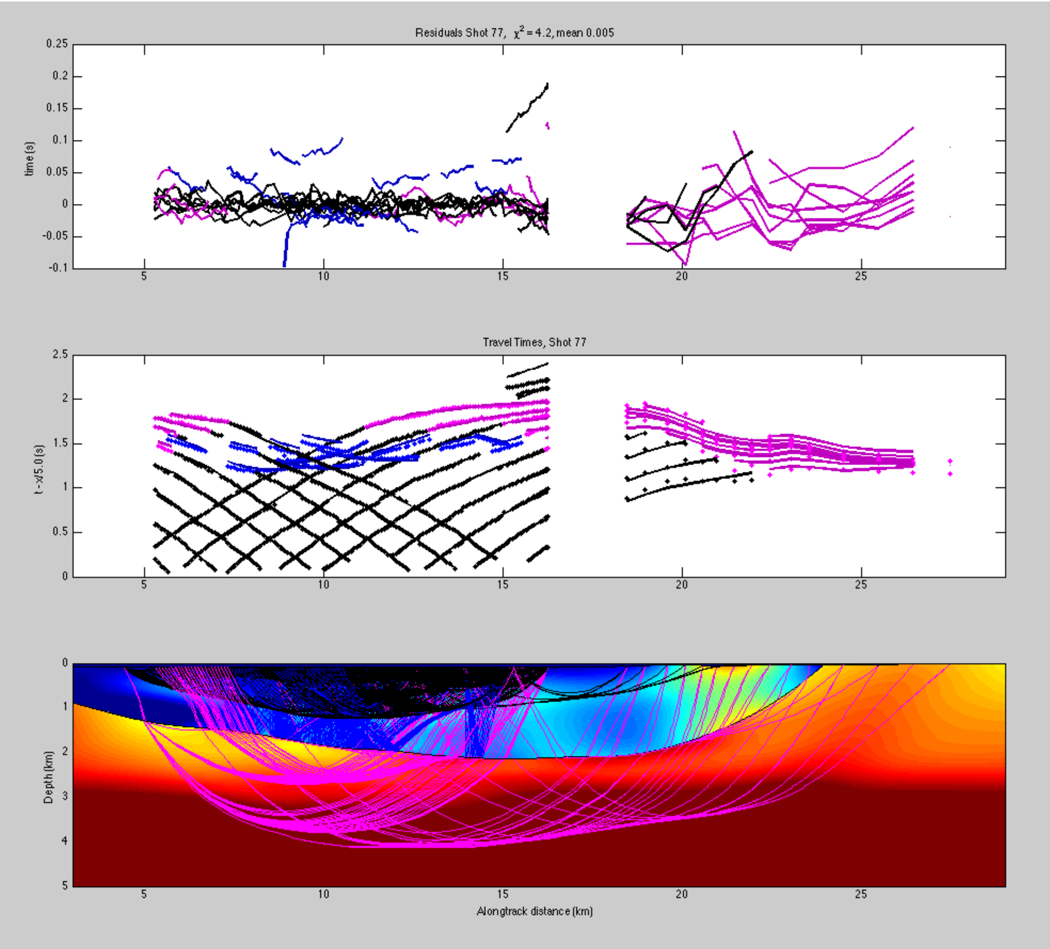

Figure 27: Inversion 19 final model, chi sq = 2.1458; ray paths and residuals. The colorbar is the same as all the above figure (1.7 km/s to 4.5 km/s).

4 Inversion 20: Inversion 17 without MCS constraints

Essentially running inversion 17 without including MCS constraints.

4.1 Inversion 20 setup

Here I use the same starting model as inversion 17. In this case, the interface intersects with the surface approximately 3 km to the east of the SSAF surface trace. This model is created using salton7base_manip2.m, and can be seen in Figure 12.

I do not use constraints from interface picks in the MCS data; I wish to see how the velocity model develops without using these, so as to compare with inversion 17. Therefore, in salton7base_raytr20.csh, I set append = 0. All the other parameters are the same as inversion 17. Likewise, in salton7base_inv20.csh, the parameters are all the same as inversion 17's inv shell script.

4.2 Inversion 20 Raytracing and Inversion Output

Seen in 4.2 and Table 4.2.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0496	0.1317	91.4024	62.9833	0.0152
It1	0.0024	0.1184	53.2251	53.8442	0.0152
It2	0.0066	0.0990	30.3647	31.5226	0.0152
It3	0.0071	0.0828	20.7694	21.6819	0.0152
It4	0.0065	0.0688	14.2876	14.8850	0.0152
It5	0.0047	0.0558	9.2968	9.6312	0.0152
It6_orig	4.9578e-04	0.0444	6.2895	6.3200	0.0152
It7_orig	-6.1330e-04	0.0357	4.2755	4.2476	0.0152
It6	0.0088	0.0660	10.9565	11.5418	0.0152
It7	-1.1790e-04	0.0451	6.9680	6.9605	0.0152
It8	4.8140e-04	0.0415	5.2106	5.2368	0.0152
It9	3.7569e-04	0.0369	4.3638	4.3790	0.0152
It10	-0.0015	0.0317	3.2893	3.2283	0.0152
It11	-0.0020	0.0296	3.0128	2.9356	0.0152
It12	-0.0027	0.0267	2.5557	2.4520	0.0152
It13	-0.0017	0.0252	2.1650	2.1178	0.0152
It14	-8.8259e-04	0.0250	2.0280	2.0115	0.0152
It15	-9.5464e-04	0.0244	1.9192	1.9017	0.0152
It16	-8.8819e-04	0.0241	1.8761	1.8646	0.0152
It17	-0.0011	0.0247	1.9218	1.9047	0.0152
It18	6.8491e-05	0.0248	1.9649	1.9653	0.0152
It19	-9.9049e-04	0.0245	1.9030	1.8900	0.0152
It20	1.9587e-05	0.0246	1.9414	1.9414	0.0152

Table 7: Inversion 20: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	50	51.104	14107.46
It1	30	29.685	17073.58
It2	20	20.422	17092.00
It3	14	14.005	17744.63
It4	9	8.9986	21881.66
It5	6	5.8927	25123.21
It6_orig	4	4.0016	30759.92
It6	6	6.1300	25204.87
It7	5	5.0299	23606.95
It8	4	4.0304	23084.88
It9	3	3.0037	28845.18
It10	2.5	2.4586	28798.93
It11	2.0	2.0127	33113.56
It12	1.8	1.8486	30816.13
It13	1.8	1.8236	27384.25
It14	1.8	1.7716	25599.62
It15	1.8	1.7144	24697.77
It16	1.8	1.8243	21345.34
It17	1.8	1.9951	18642.92
It18	1.8	1.8336	19567.24
It19	1.8	1.8467	18806.85

Table 8: Inversion 20: Inversion outputs.

4.3 Inversion 20 shuttles

I run the shuttle method on inversion iteration 5 (velocity model 6) of inversion 20. Velocity model 6 can be seen in Figure 28. I used the script salton7_shuttle_update_inv17.m to update run the shuttle update; it outputs to salton_sm_shuttle20.vm. I copy this to inversion20 as salton7base_20_6.vm.

In the inversion 20 directory, I renamed all files relating to inversion iterations 5 and 6 to _orig. In the inversion_temp directory, I renamed all iteration 5 and 6 jp, rf, and sl files for inversion20 to _orig, and renamed vecm_in iteration 5 and 6 to _orig20.

After this, I rerun raytracing inversion 6; inversion iteration 6, and raytracing iteration 6 and 7 before this are renamed to _orig.

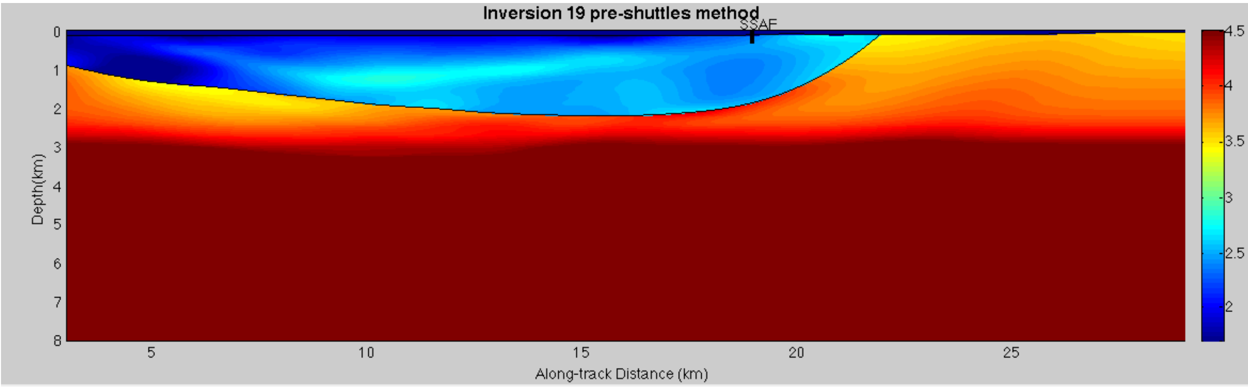

Figure 28: Inversion 20, inversion iteration 5, velocity model 6. Chi sq = 6.2895. The velocity model pre-shuttles method.

4.4 Inversion 20 Results

I take the final model to be inversion iteration 15 (velocity model 16), with the best misfit, chi sq = 1.8761. This model is a still a little "splotchy", but has fewer artifacts than inversion 17's final model and a better misfit. The final model is in Figure 30, and the ray paths and residuals are in Figure 31.

The low velocity patch around 16 - 21km is still present, and transitions to higher velocities around 21 km along-track distance.

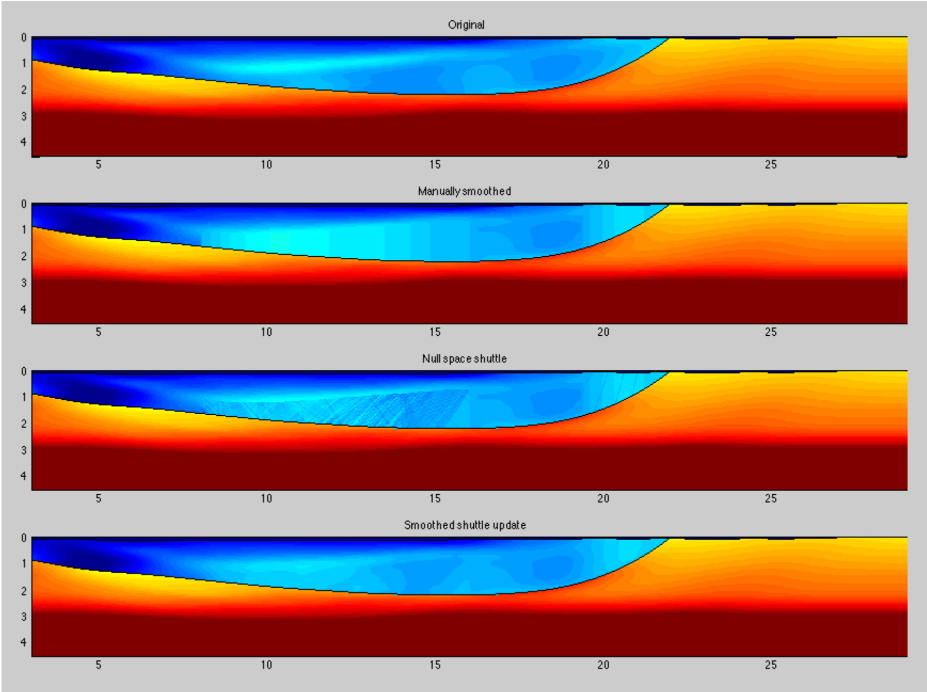

Figure 29: Inversion 20, post shuttle method. Colorbar is the same as other figures, going from 1.7 km/s to 4.5 km/s.

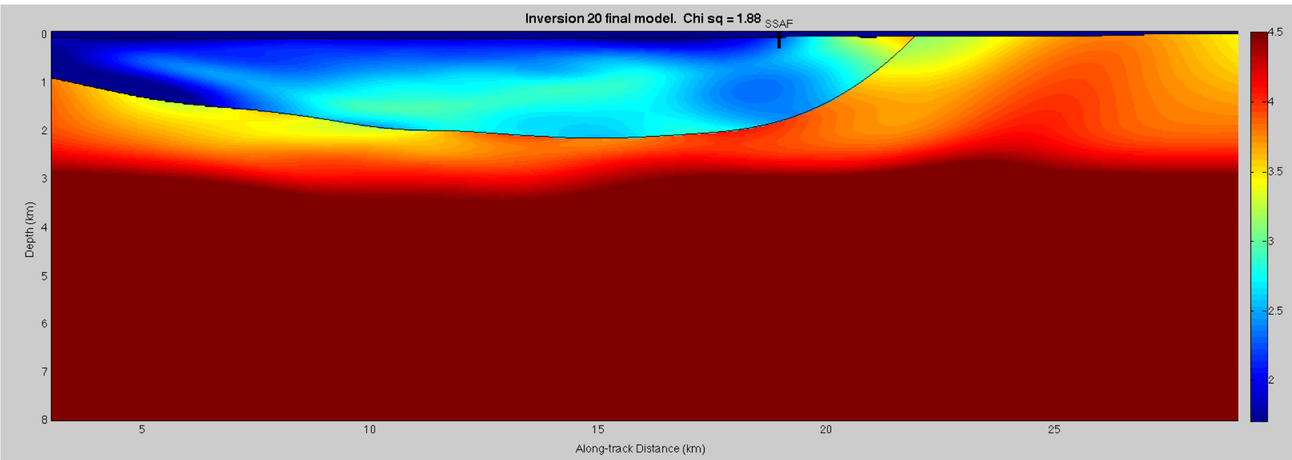

Figure 30: Inversion 20, final model. Inversion iteration 15, velocity model 6. Chi sq = 1.88.

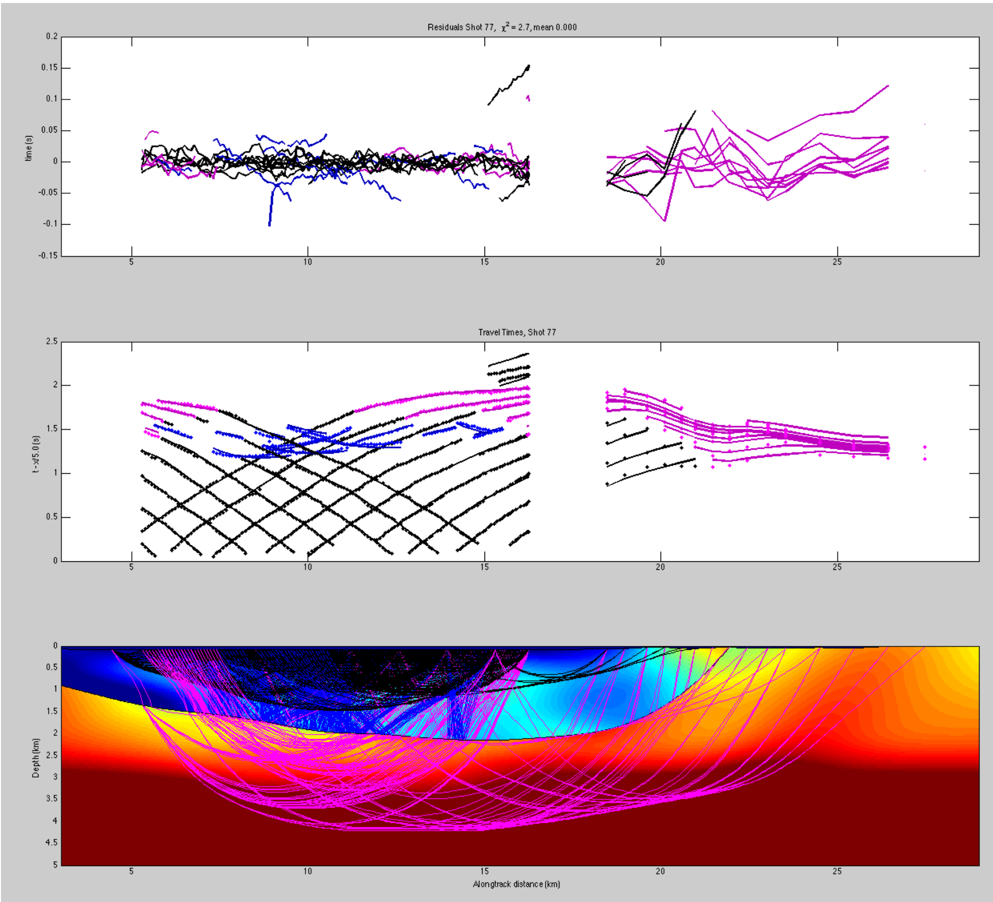

Figure 31: Inversion 20, final model, ray paths and residuals. Colorbar is the same as in all other figures.

5 Inversion 21 - Inversion 18 w/o MCS constraints

In here, I run a separate inversion of 18's starting model, without using MCS constraints.

5.1 Inversion 21 Setup

I copy inversion 18's starting model into the inversion21 directory; I rename it to salton7base_21_0.vm.

I copy inversion 18's raytracing and inversion shell scripts, and rename them salton7base_raytr21.csh and salton7base_inv21.csh, respectively.

I do not want to constrain the interface location with MCS reflection times, so in the raytracing script I set append = 0.

All the other parameters remain the same as inversion 18.

The starting model is the same as inversion18's, and so can be seen in Figure 18

5.2 Raytracing and Inversion Output

Output in 5.2 and Table 5.2.

Raytr, It =	tmean	trms	chi sq	chi r	meanErr
It0	-0.0435	0.1321	92.0438	69.1595	0.0152
It1	0.0113	0.1111	43.9665	45.8497	0.0152
It2	0.0041	0.0887	26.6384	27.2143	0.0152
It3	0.0063	0.0712	17.2119	17.7273	0.0152
It4	0.0053	0.0622	12.4187	12.7683	0.0152
It5_orig	0.0020	0.0501	8.3514	8.4667	0.0152
It5	0.0069	0.0711	13.9968	14.5312	0.0152
It6	0.0020	0.0501	8.6722	8.7863	0.0152
It7	-1.7766e-04	0.0435	6.0834	6.0732	0.0152
It8	-8.4956e-04	0.0360	4.4337	4.3947	0.0152
It9	-0.0025	0.0315	3.3912	3.2751	0.0152
It10	-0.0014	0.0295	2.9143	2.8602	0.0152
It11	-0.0025	0.0260	2.3574	2.2778	0.0152
It12	-9.9098e-04	0.0250	2.0713	2.0486	0.0152
It13	-7.7869e-04	0.0246	1.9692	1.9565	0.0152
It14	-3.8399e-04	0.0246	1.9213	1.9161	0.0152
It15	-6.0576e-04	0.0240	1.8804	1.8739	0.0152
It16	-6.4310e-04	0.0236	1.7967	1.7894	0.0152
It17	-5.7020e-04	0.0242	1.8856	1.8805	0.0152

Table 9: Inversion 21: Raytracing outputs.

Inv, It =	set chi sq =	out chi sq =	Penalty
It0	40	41.952	14072.16
It1	25	26.226	15913.26
It2	17	16.726	15878.74
It3	12	12.221	15053.86
It4	8	8.0967	19587.86
It5	8	8.1305	20655.54
It6	6	6.0130	21002.41
It7	4	4.0702	25407.77
It8	3	2.9995	29351.58
It9	2.5	2.4723	28122.16
It10	2	2.0019	33306.32
It11	1.8	1.8569	30866.71
It12	1.8	1.8307	27351.31
It13	1.8	1.8273	25003.34
It14	1.8	1.7573	24597.83
It15	1.8	1.7368	23738.40
It16	1.8	1.8179	21112.01

Table 10: Inversion 21: Inversion outputs.

5.3 Inversion 21 Shuttles Method

I apply the shuttles method to inversion iteration 4, velocity model 5. The original model is in Figure 32 and the shuttled model is in Figure 33.

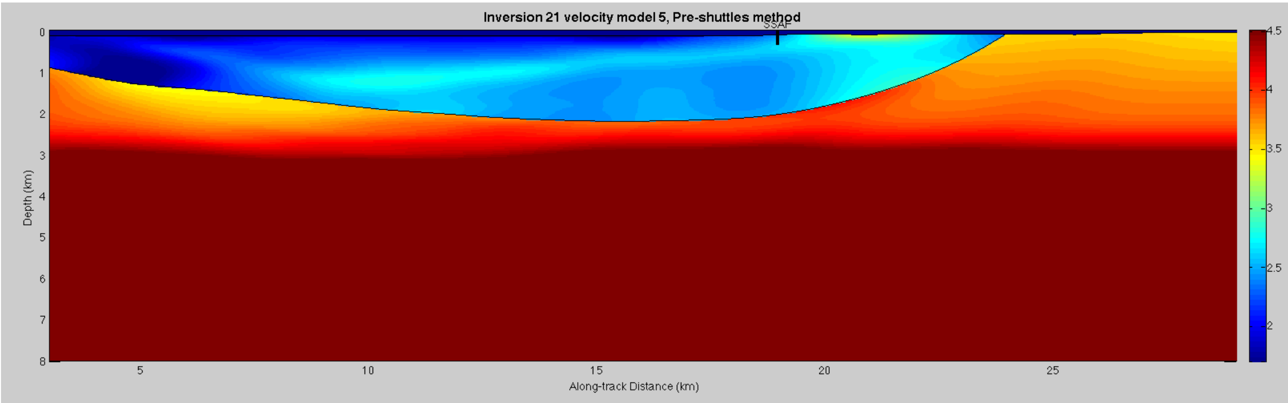

Figure 32: Inversion 21, pre-shuttles method. Chi sq = 8.35.

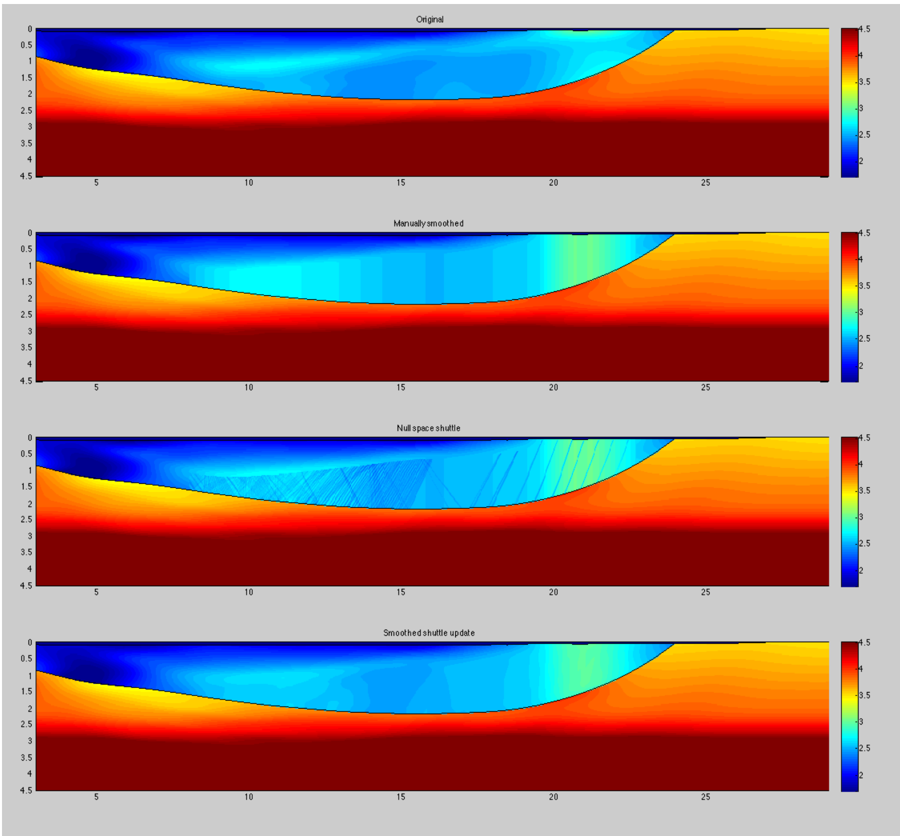

Figure 33: Inversion 21, post-shuttles method. Chi sq = 13.99.

I use the script salton7_shuttle_update.m, and the output shuttled model is in salton_smshuttle_inv21.vm. I copy this into the inversion21 directory; I rename all iteration 5 files to _orig, and rename the shuttled velocity model to salton7base_21_5.vm. I then ray trace through it. The statistics for raytracing through the original iteration 5 are in the table as It5_orig, and through the shuttled model is It5.

5.4 Inversion 21 Results

I choose inversion iteration 15, velocity model 16, as the final model. This had the lowest misfit and did not look splotchier than the other iterations. The final model is in Figure 34, and the ray paths and residuals in Figure 35.

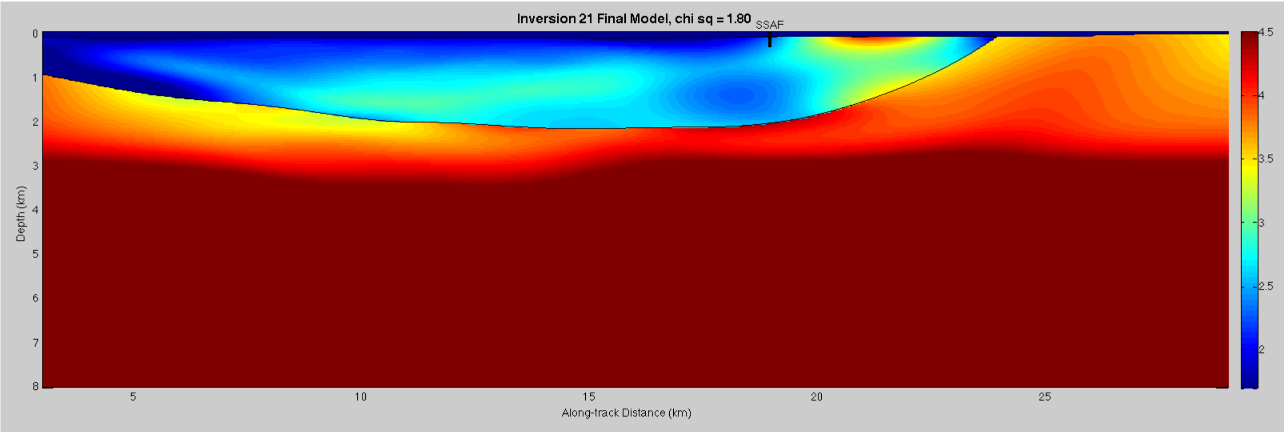

Figure 34: Inversion 21, final model. Inversion iteration 15, velocity model 6. Chi sq = 1.80.

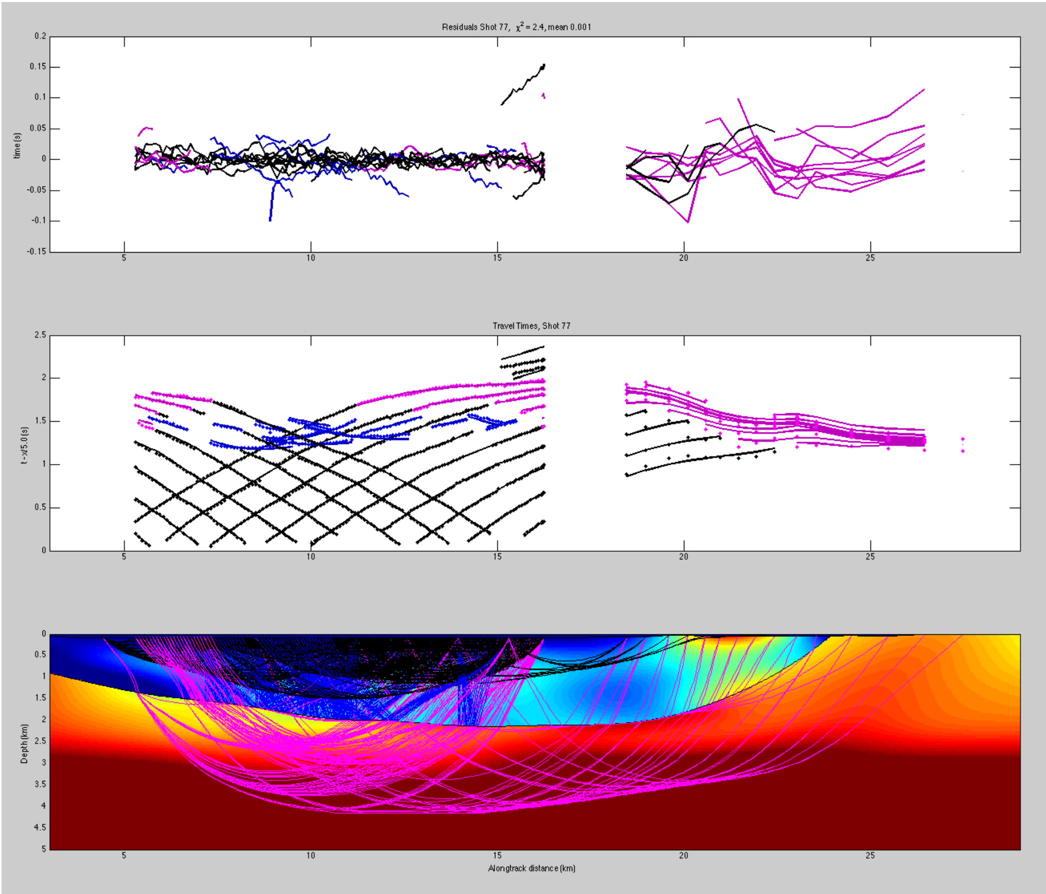

Figure 35: Inversion 21, final model, ray paths and residuals. Colorbar is the same as in all other figures.

Thursday, 29 January 2015

1 Summary

Summary of the above inversions. I printed these plots using the script plot_sfinalint.m.

1.1 Interface at the SSAF surface trace

Inversion 14 was run at the SSAF trace, and included MCS constraints. The final model is in Figure 36.

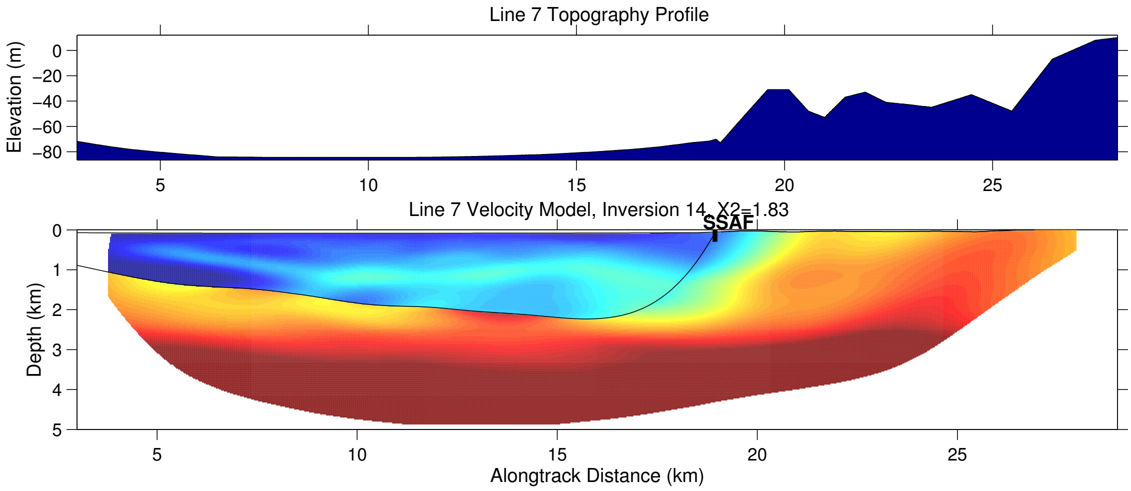

Figure 36: Inversion 14, final model plotted with DWS and 1 km ray extension. $\chi^2 = 1.83$.

1.2 Interface to the West of the SSAF surface trace

There are 2 inversions with the interface intersecting the surface to the west of the SSAF trace: Inversion 15, where it intersects 1 km to the west, and Inversion 16, in which it interests 3 km to the west. These are seen in Figure 37 and Figure 38. In either these two instances, the inversion tries to update velocities that are in layer 2, but adjacent to and to the west of the SSAF, to be slower. It seems that the best fit would be to move the interface to the east of the SSAF surface trace.

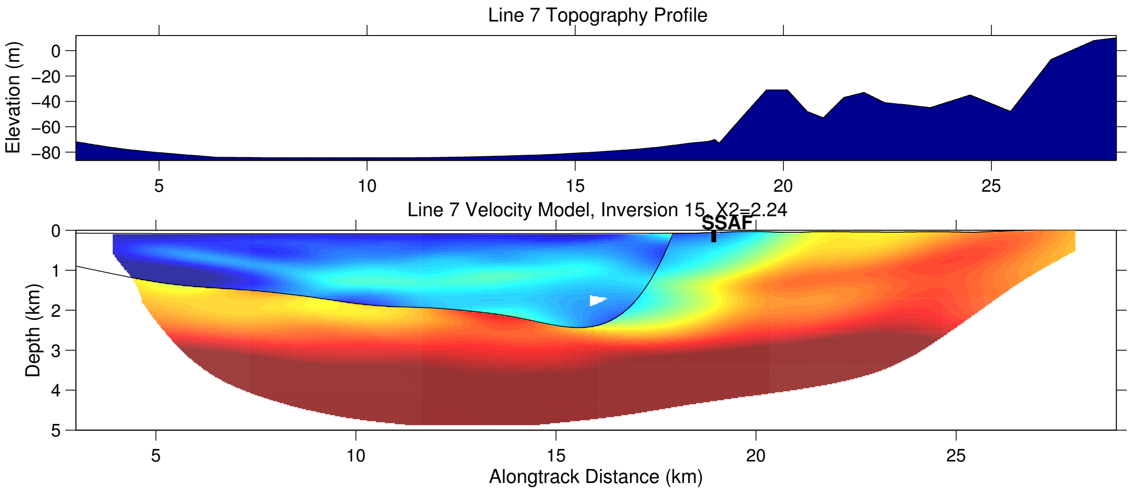

Figure 37: Inversion 15, final model plotted with DWS and 1 km ray extension. $\chi^2 = 2.15$.

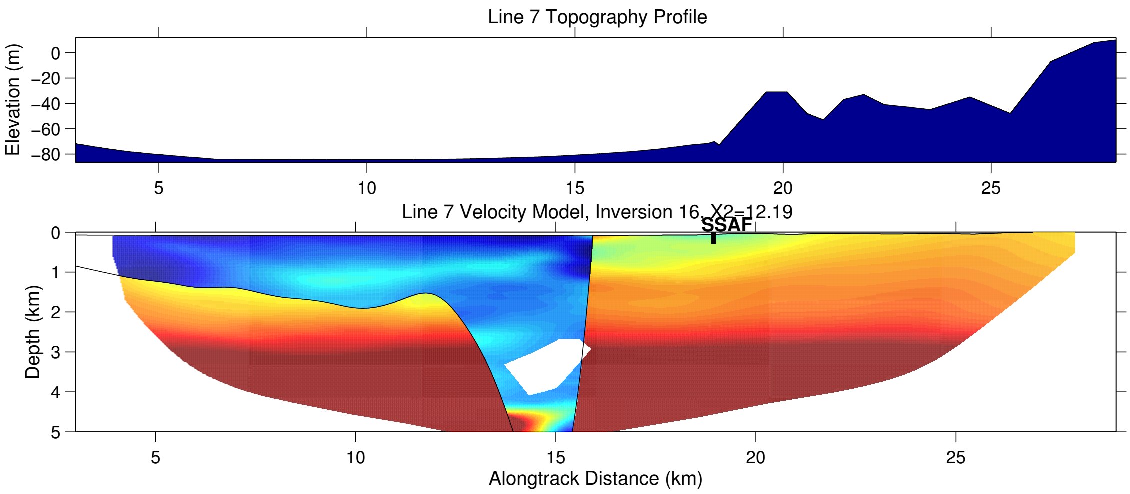

Figure 38: Inversion 16, final model plotted with DWS and 1 km ray extension. $\chi^2 = 12.19$.

1.3 Interface to the East of the SSAF trace

There are 4 final inversions with the interface to the east of the SSAF trace: Inversion 17 and 20 (3 km to the east of the SSAF), Inversion 18 and 21 (5 km to the east of the SSAF). Inversions 17 and 18 use MCS constraints on the interface, and Inversions 20 and 21 do not (Inversion 20 corresponds to 17, and

21 to 18). Inversions 17 and 20 are plotted in Figure 39 and Figure 40. Inversion 20 has a lower misfit than 17; $\chi^2_{17} = 2.07$, and $\chi^2_{20} = 1.88$.

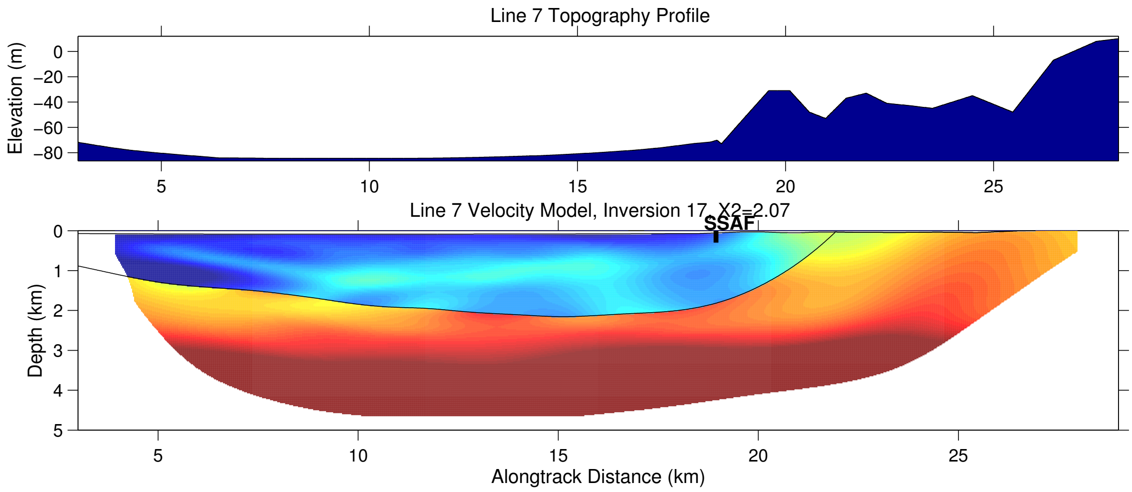

Figure 39: Inversion 17, final model plotted with DWS and 1 km ray extension. $\chi^2 = 2.07$.

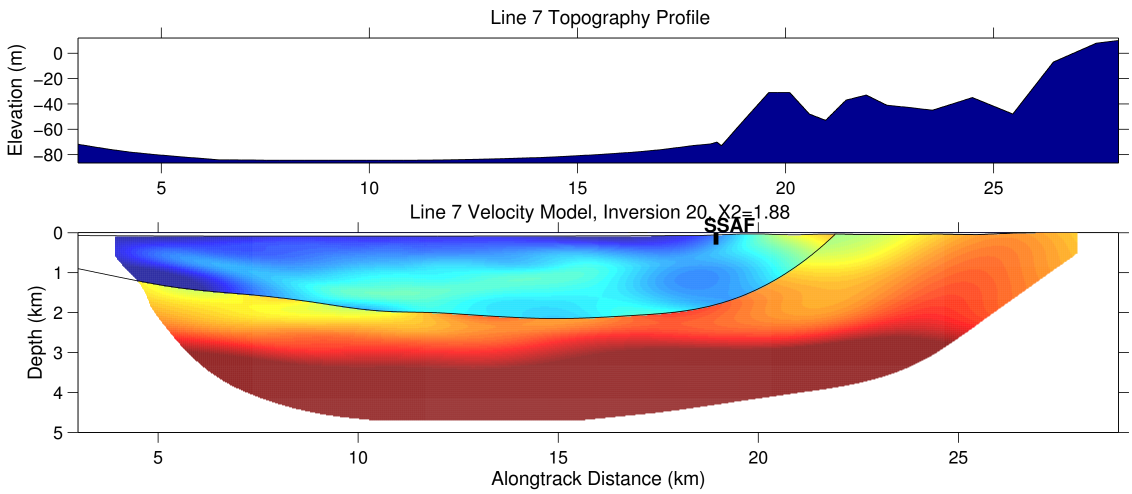

Figure 40: Inversion 20, final model plotted with DWS and 1 km ray extension. $\chi^2 = 1.88$.

Inversions 18 and 21 are in Figure 41 and Figure 42. These two have the best fit overall: $\chi^2_{18} = 1.90$ and $\chi^2_{21} = 1.80$. Inversion 21 has a lower misfit and smoother sedimentary basin and high velocity patch, but Inversion 19 also fits the MCS interface constraints (though it has a low velocity "streak" in the basin, and high velocity patches around 20 km along-track distance). The ray paths and residuals plots for 18 and 21 are seen in Figure 43 and Figure 44, respectively.

Because inversion 18 constrains the interface with MCS picks, I take this final model as the "best-fitting" model, and use it for the schematic.

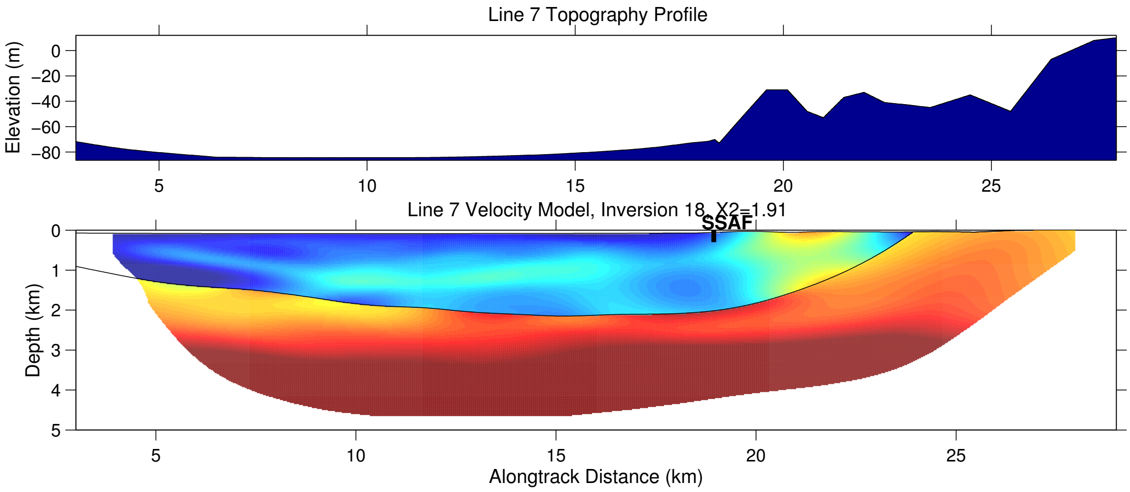

Figure 41: Inversion 18, final model plotted with DWS and 1 km ray extension. $\chi^2 = 1.90$.

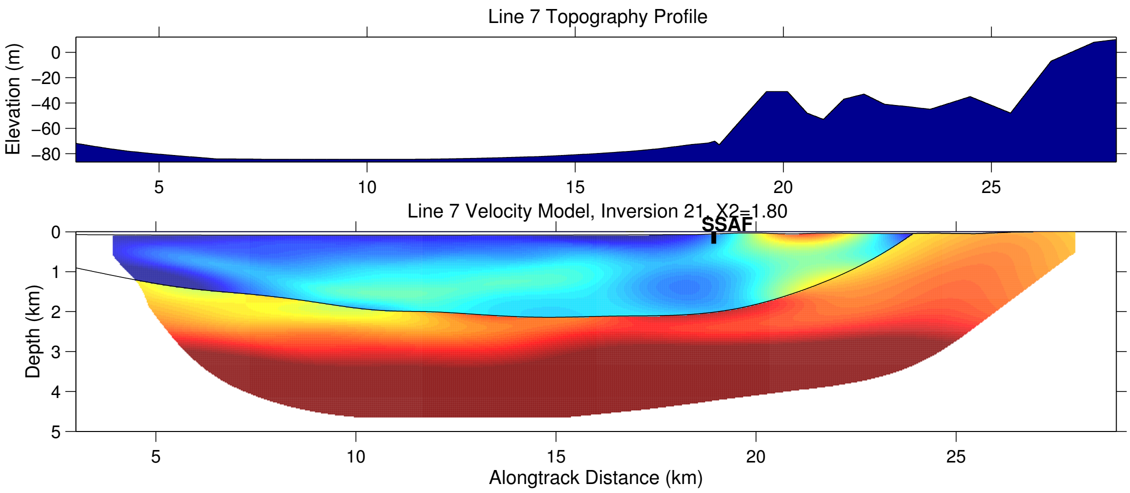

Figure 42: Inversion 21, final model plotted with DWS and 1 km ray extension. $\chi^2 = 1.80$.

1.4 Conclusions??

The current hypothesis (providing I have not overlooked anything with the velocity models) derives its foundation from two main lines of evidence:

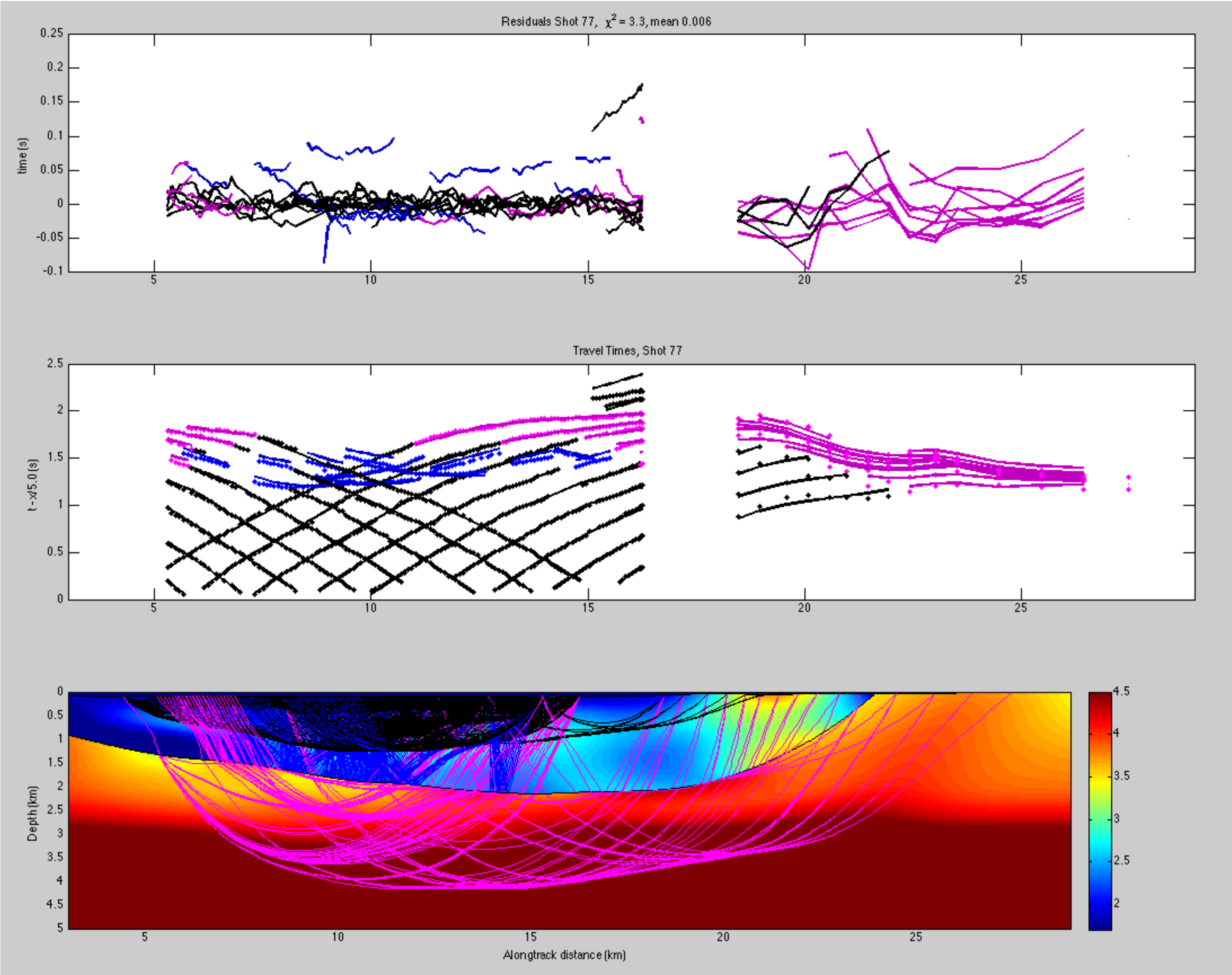

Figure 43: Inversion 18 ray paths and residuals

1) The velocity model. There appears to be a sedimentary wedge, reflecting compacted lake sediments that spatially converge with the dipping reflectors in the sea. To the east of this, there is a small patch of low-velocities, and further to the east of this the velocities must increase.

2) Mapped folds from Babcock, 1974. He observes intense folding between the SSAF and the Salton Sea shoreline; the westernmost layers dip to the west, and the easternmost layers dip into the SSAF.

Because of these two observations, we suggest that the low velocities in the sea are in fact from lake sediments. The low velocity zone ends approximately near the SSAF surface trace, about 1 km to the east (I'm not sure how well the lateral extent of this can be constrained). This is likely a damaged zone, which

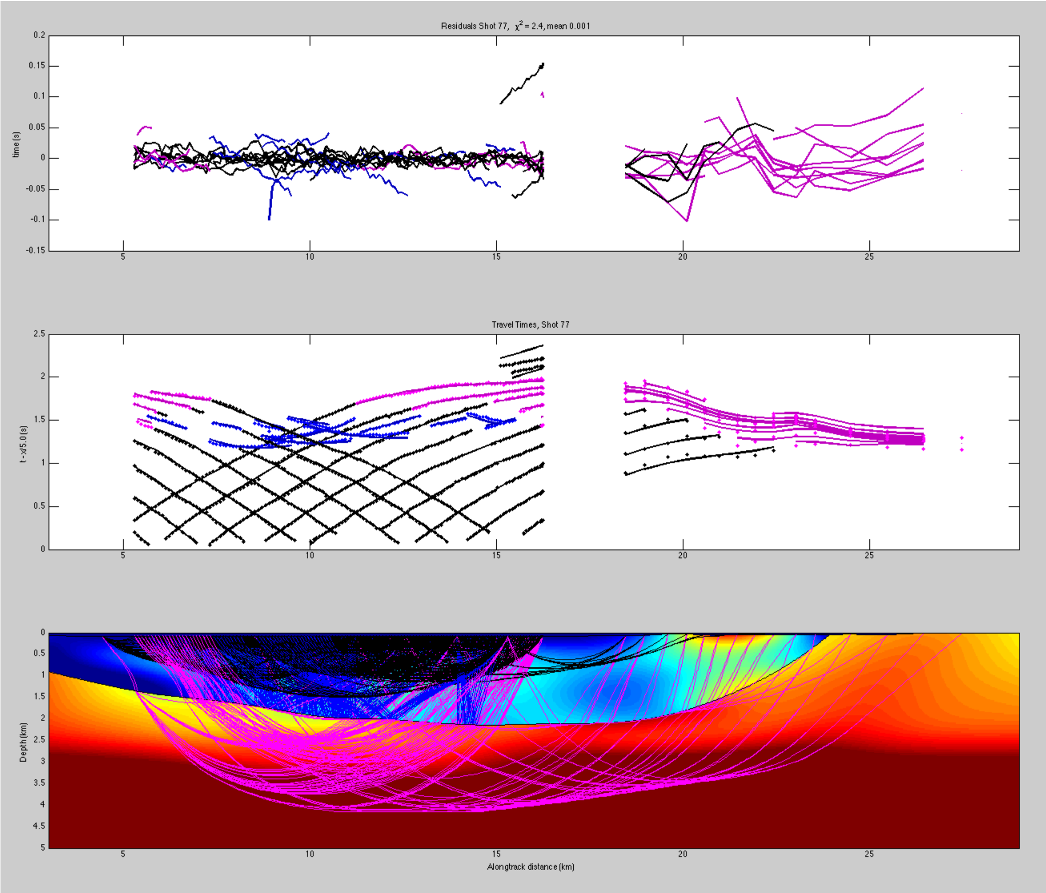

Figure 44: Inversion 21 ray paths and residuals

is evident on the surface from the folding that Babcock observes. The folding is probably caused by a left jog in the SSAF (which also creates uplift at Durmid Hills). The layers in the west that dip to the west may fall into a transtensional, slightly-westward dipping fault that surfaces in the Salton Sea.

This hypothesis is illustrated by the schematic in Figure 45.

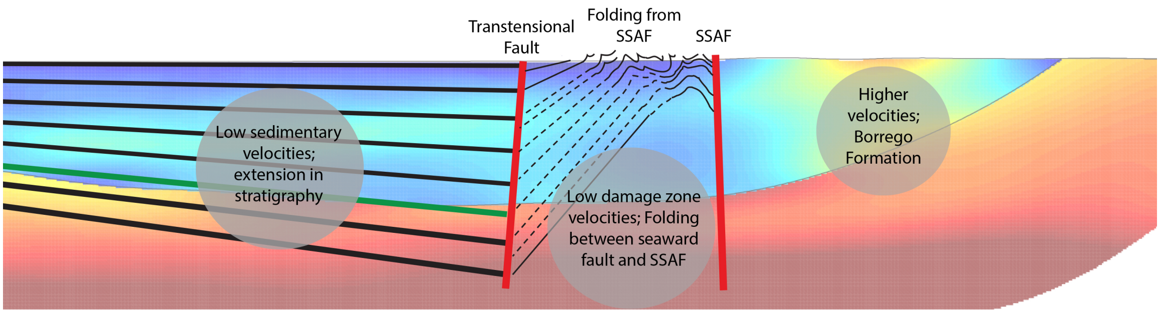

Figure 45: Schematic illustrating the current hypothesis. The green line denotes the basement reflector observed in the MCS data; between the transtensional fault and the SSAF, folds in solid represent the approximate representation of Babcock's mapped folds, and the dashed lines are an interpretation of how they relate to the greater system.

Bibliography

[1] Leslie Lamport, LaTeX: A Document Preparation System. Addison Wesley, Massachusetts, 2nd Edition, 1994.