WHOI PE runs in support of the QPE Pilot Experiment

Art Newhall, Ying-Tsong Lin, and Jim Lynch

8/8/08

Background

In order to study acoustic propagation conditions in the shallow water shelf/slope/canyon environments that will be encountered in the QPE study area, five 20 km long propagation paths were identified in a workshop held at MIT in late July, 2008. These five "TL run" paths were, specifically: 1) a shallow (~130m), constant bathymetry along-shelf run, 2) a shallow, slowly varying bathymetry across-shelf run, 3) an across-slope run, H~250m, which also crosses one of the Mien-Hua canyons, 4) an across-slope run, parallel to the canyon in the last run, and 5) a run along the axis of this particular Mien-Hua canyon. These runs were made with the source at 50m depth (nominally below any usual surface mixed layer, and near the "sweet spot" for shallow water ducts in general). The runs were also made twice, with the source at each of the endpoints of the tracks identified. This way, one can see what the tradeoffs are should the receivers have to be placed at one end or the other due to fishing activity. The runs were also made at 300, 600, and 900 Hz, to give a reasonable span of LF behavior, and in the range that the OMAS sources can produce, as well.

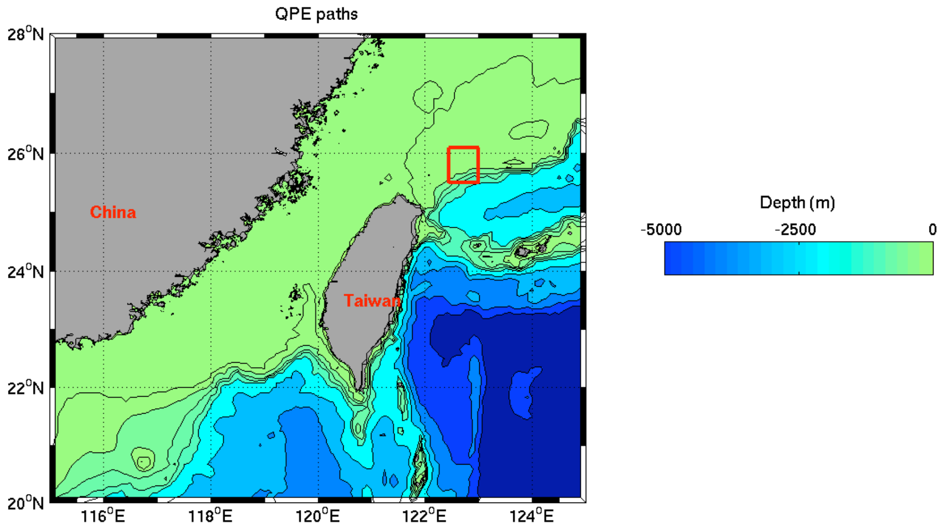
These runs are simple first looks, with fairly smooth bathymetry, simple (representative) water column SVP's, and an isovelocity halfspace bottom (based on surface sediment properties). Much more detailed work is justified to look at the effects of specific water column and seabed properties, and we will make suggestions about this. However, this first set of runs is just for "beginning thinking" on this experiment and area.

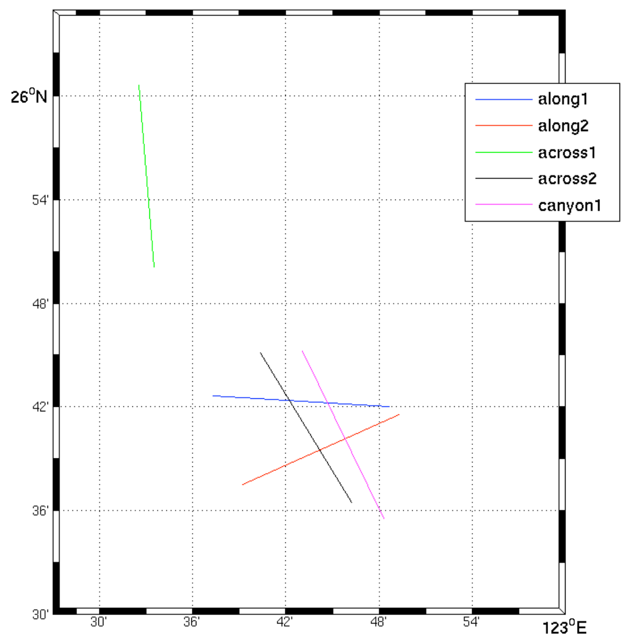
1. QPE Area

The QPE shallow water component will be conducted in a reasonably well studied and well measured area NE of Taiwan (Figure 1). Area includes shelf, slope and Mien Hua Canyon

Five paths were selected for our acoustic study: 1) across shelf path on shelf (x1), 2) across shelf path over shelfbreak (x2), 3) along shelf path near shelfbreak (a1), 4) along shelf path over canyon (a2), and 5) path directly down the canyon (c1). These are shown with lat long endpoints and tracks in Figure 2.

Figs 3-7 show the five tracks superposed on a low-res bathymetry map.





Figures 1,2. Study area and acoustic tracks.

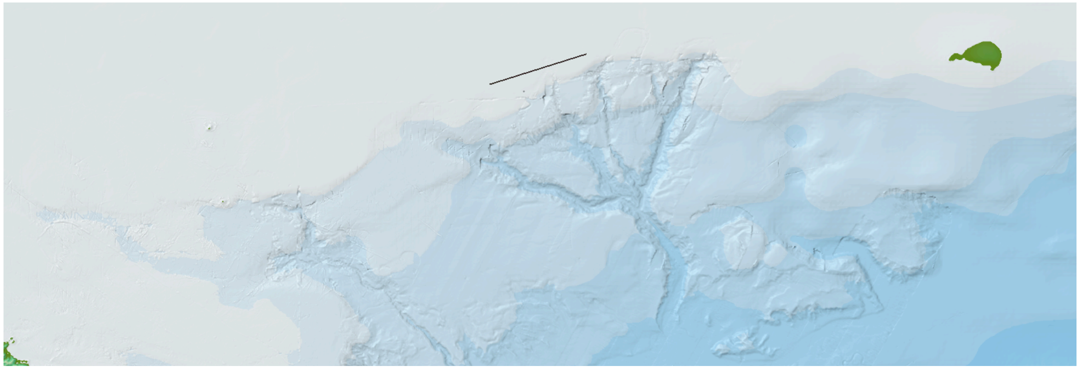


Figure 3. Along shelf path

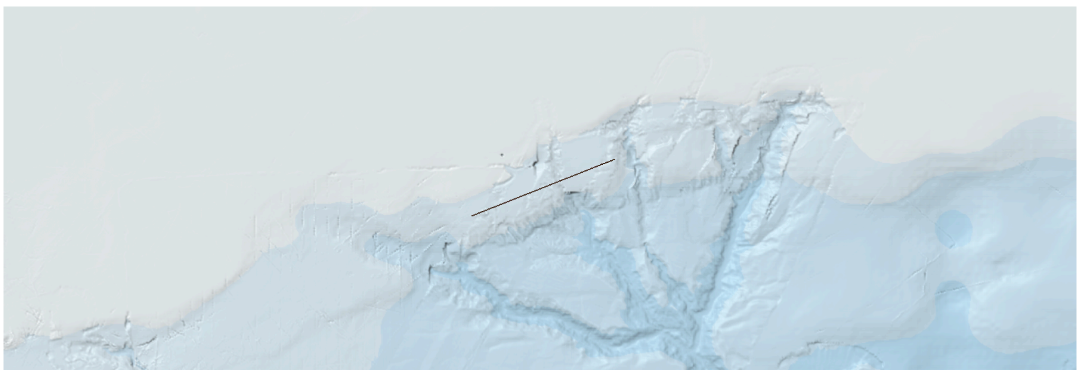


Figure 4. along slope path

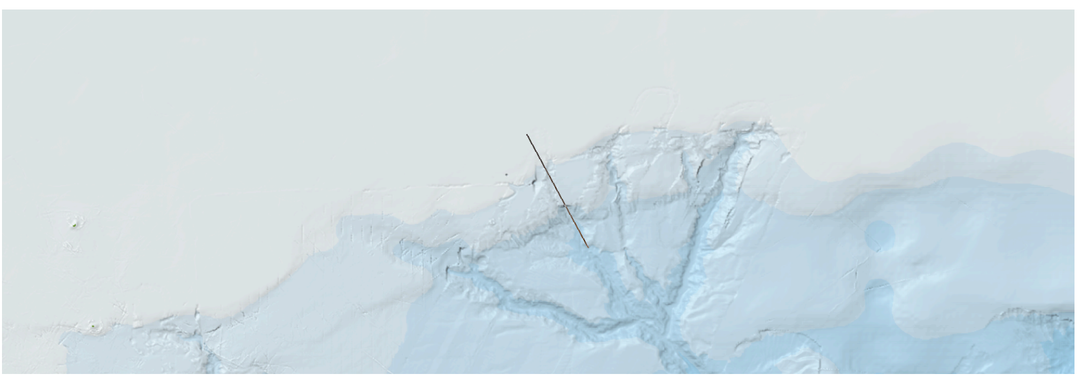


Figure 5. Along canyon path

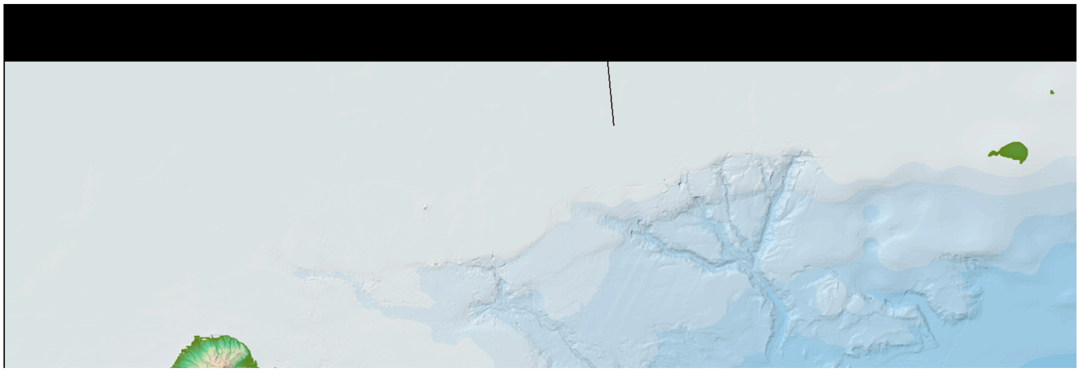


Figure 6. Across shelf path

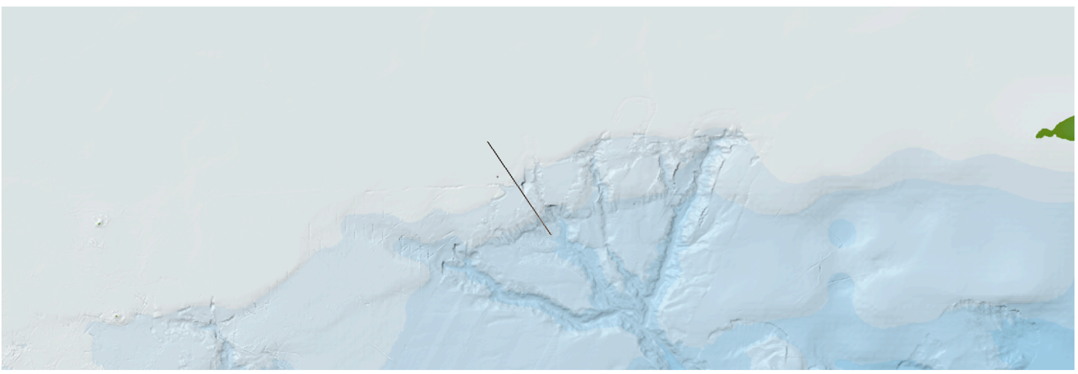


Figure 7. Across slope path

2. Water column soundspeed profiles

The shallow shelf profile was created from CTD casts taken in the area during a preliminary environmental study in the summer of 2007. It shows a typical 3-layer SW system - a mixed surface layer, a thermocline/gradient layer, and a bottom mixed layer. The mean profile taken from this compares well with Taiwanese climatology (1985-2005, Autumn) temperature data for that area. (See Figure 8). We note that this profile does not contain any fine scale oceanography (internal tides and waves), nor does it account for eddies, intrusions, etc. Those effects can be included in later studies.

Extension of the shelf results to the slope is straightforward, at least to first order. One just gets rid of the bottom mixed layer in the shelf profile, and extends the downward refracting gradient layer to the typical downward refraction one gets in the first kilometer depth due to the exponential temperature decrease, using the climatology of the region as a guide. This gives the profile shown in Figure 9. Again, this is a generic, mean profile, and does not include the effects of fronts, eddies, IW's, finestructure, etc. These also merit further study.

Figure 8. Shallow water 3-layer soundspeed profile.

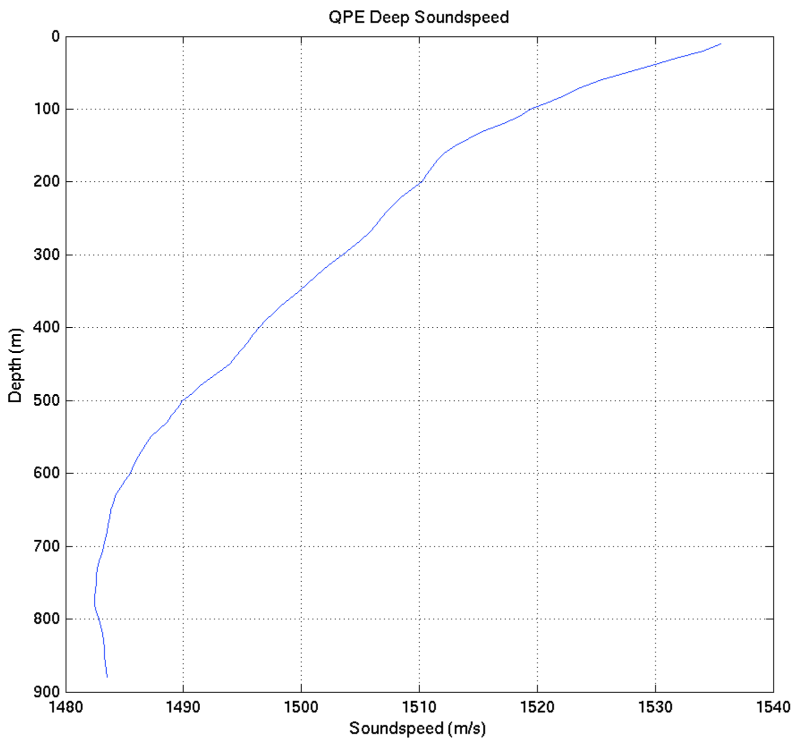


Figure 9. Deeper, slope profile, taken from climatology.

Glen Gawarkiewicz 8/11/08 4:01 PM
Deleted: d

3. Bottom bathymetry

Bathymetry used was obtained from the UNH database, as per discussions at the meeting. Database supplied was in 1 meter intervals. However, for numerical convenience, we decimated to 10 meters. This did not make any noticeable difference in the TL runs, other than improving speed.

4. Bottom type and parameters

The bottom was taken as an isovelocity half-space for these runs. One expects bottom penetration to (roughly) an acoustic wavelength in depth, so that we at most need ~5m bottom properties for the frequencies we modeled. Over this short depth, an isovelocity half-space approximation is probably not too bad. However, the range variability of the surface sediments, particularly on the slope and in the canyon, is probably of some importance, and is not modeled here. Again, this is a point for future consideration.

We took the surface sediment types from a look at the NCOR bottom database online at http://www.ncor.ntu.edu.tw

Paths on the shelf were mostly sand. Paths in the canyon area were mostly mud.

Path a1: sand
Path a2: mud
Path x1: sand
Path x2: mud
Path c1: mud

Bottom parameters were taken from Barry Ma's charts and compared with Hamilton's equations. Agreement was good. An absorbing bottom layer was included 50 meters below the water-bottom surface to preclude spurious reflections from the sub-bottom.

	Cb	Rho	Attn
mud	1575	1.7	1.0
sand	1650	1.9	.8

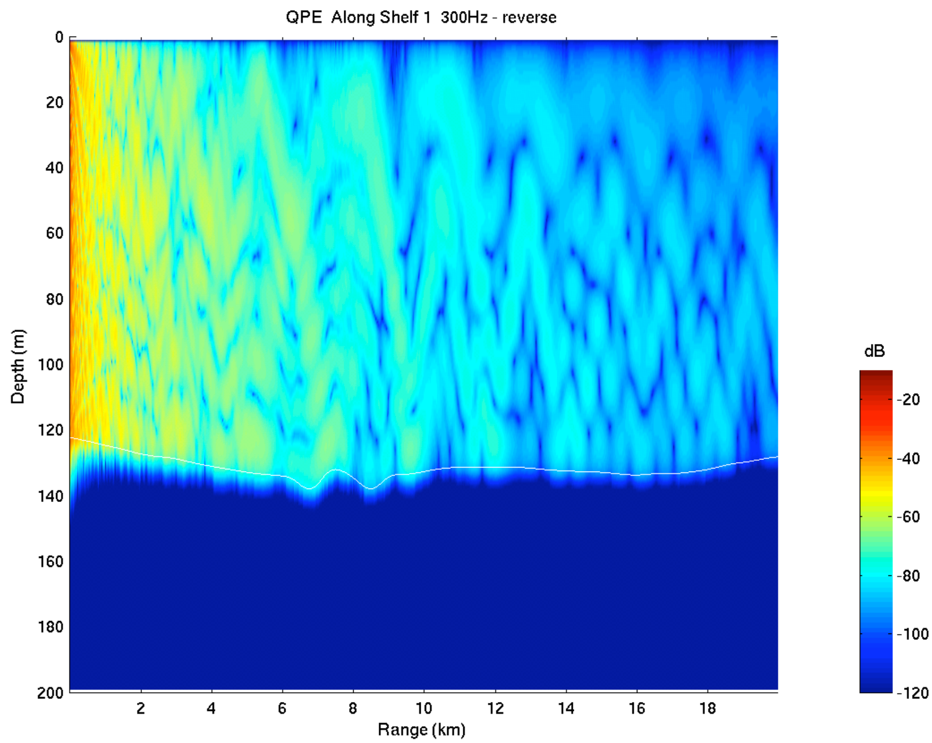
5. Discussion of modeling runs

The PE runs are discussed next, mainly in the context of preparation for the pilot experiment and future QPE work, and are not intended for producing "absolute numbers for TL" or even "best guess predictions." These are just "intermediate products."

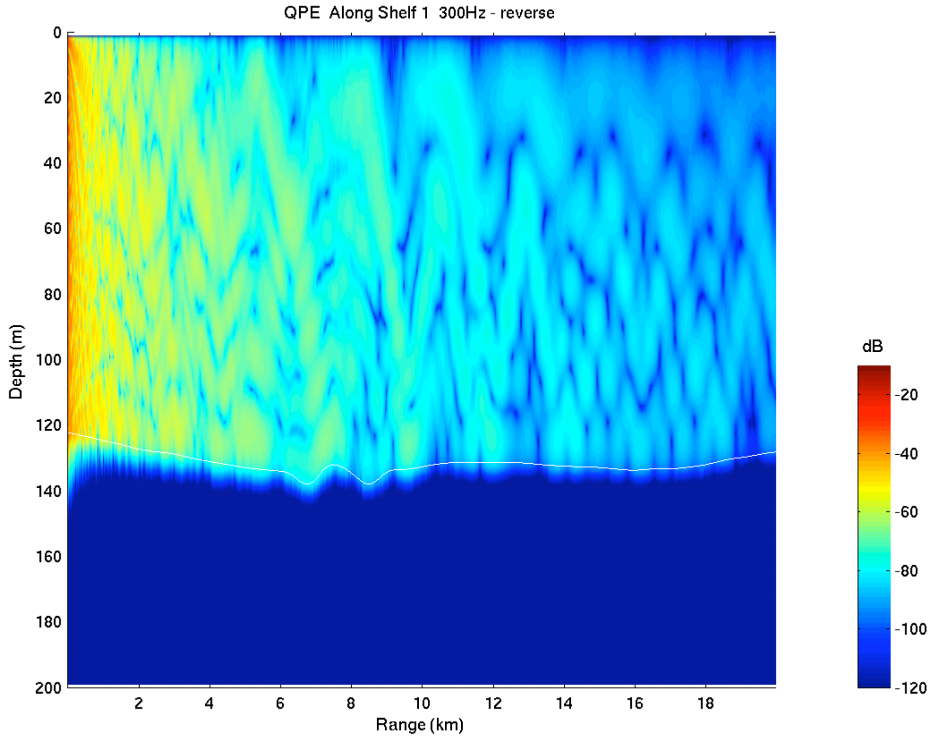
A. Shallow water, along shelf runs (path a1) – Figs 10-15

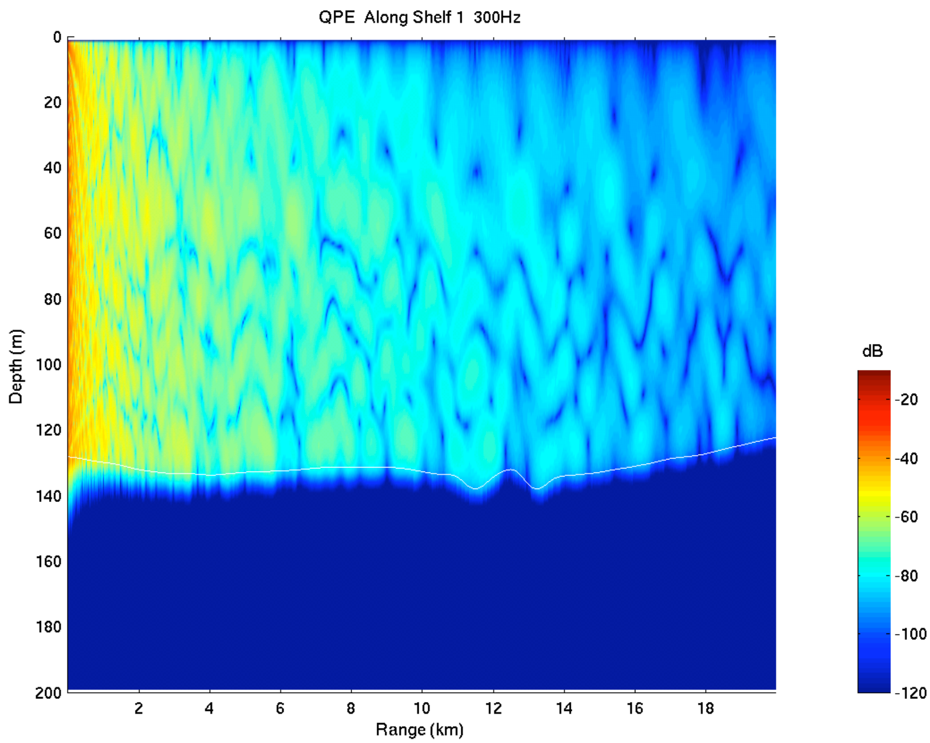
The six runs (figures 5-10) for the along shelf, shallow path, are the "plain vanilla" ones for this pilot test. For the climatological water column profile, simple bottom, and flat bathymetry, one will get a very standard shallow water shelf result. One can put source and receiver at either end, with no noticeable difference. Only if the oceanography is perturbed, or if there is some unexpected bottom feature, will this case produce anything "out of the usual." Internal waves may do this, though. It is a good baseline study.

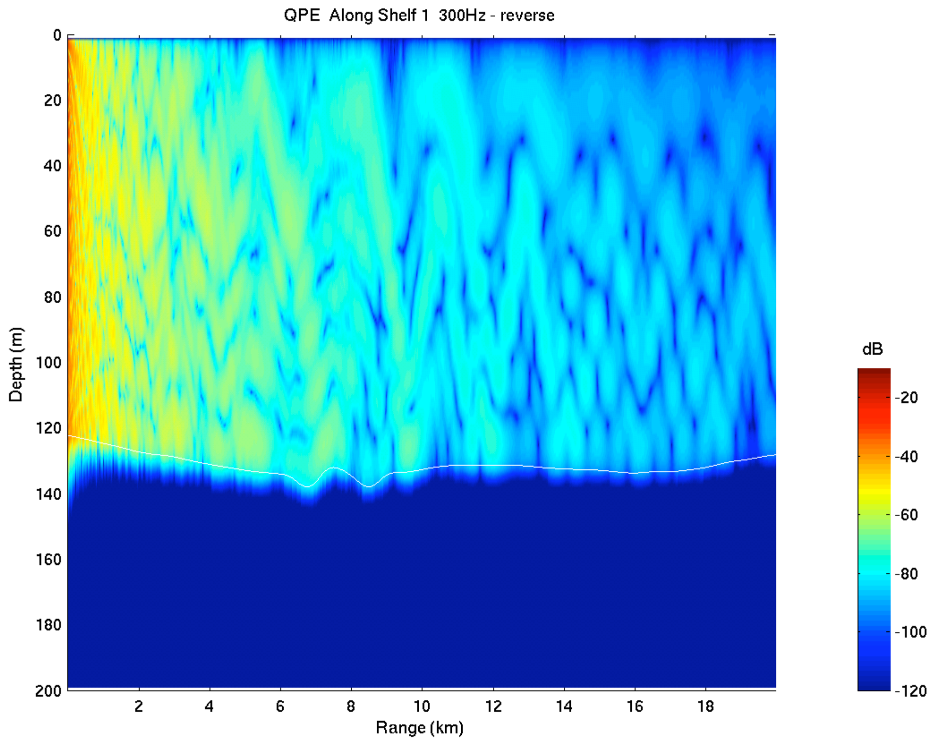
Glen Gawarkiewicz 8/11/08 4:02 PM
Deleted: r



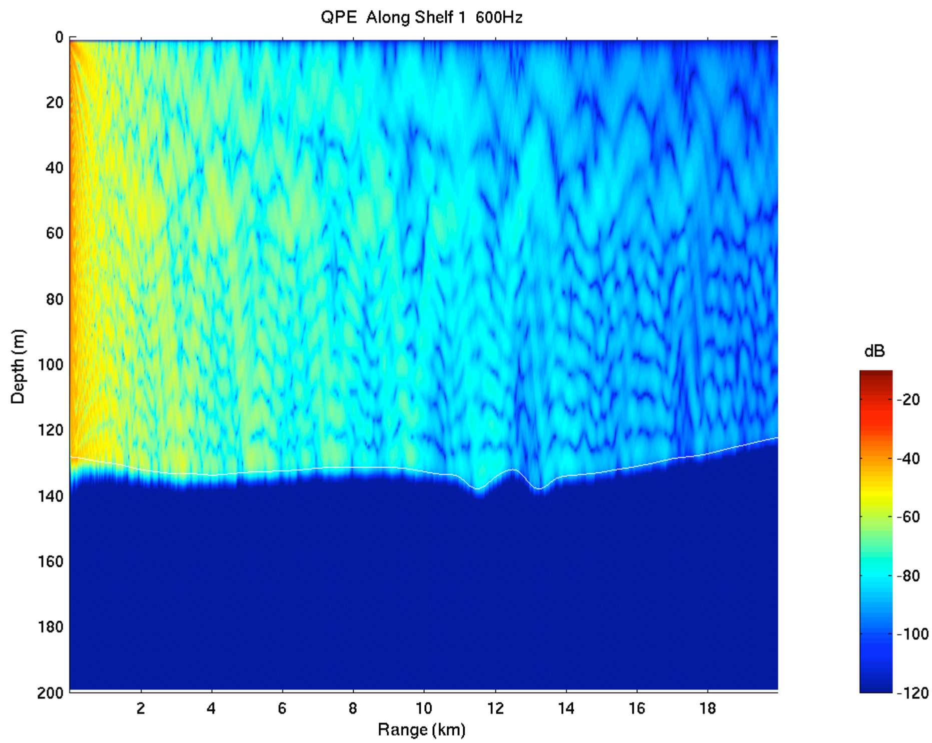
QPE Along Shelf 1 300Hz - reverse
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
Range (km)
2
4
6
8
10
12
14
16
18
dB
-20
-40
-60
-80
-100
-120

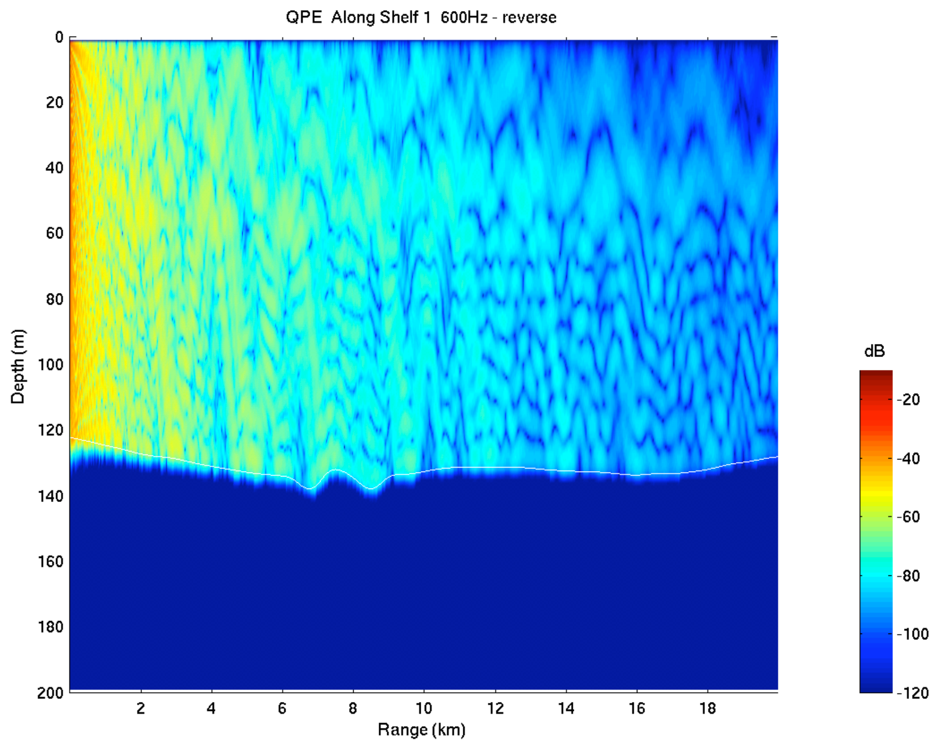

QPE Along Shelf 1 300Hz - reverse
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120


QPE Along Shelf 1 300Hz
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120

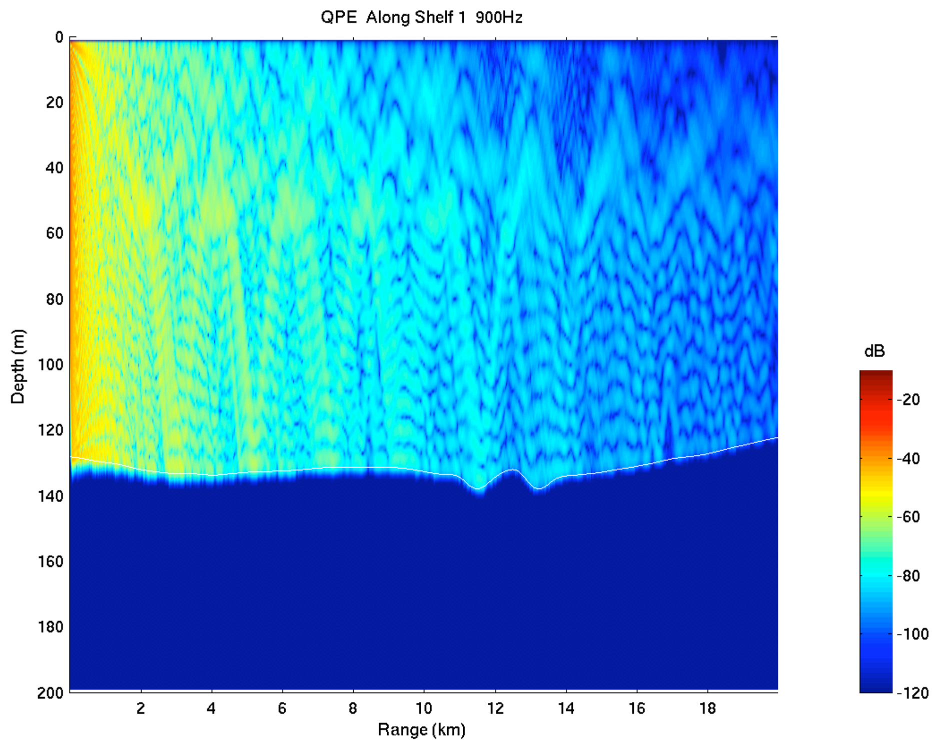


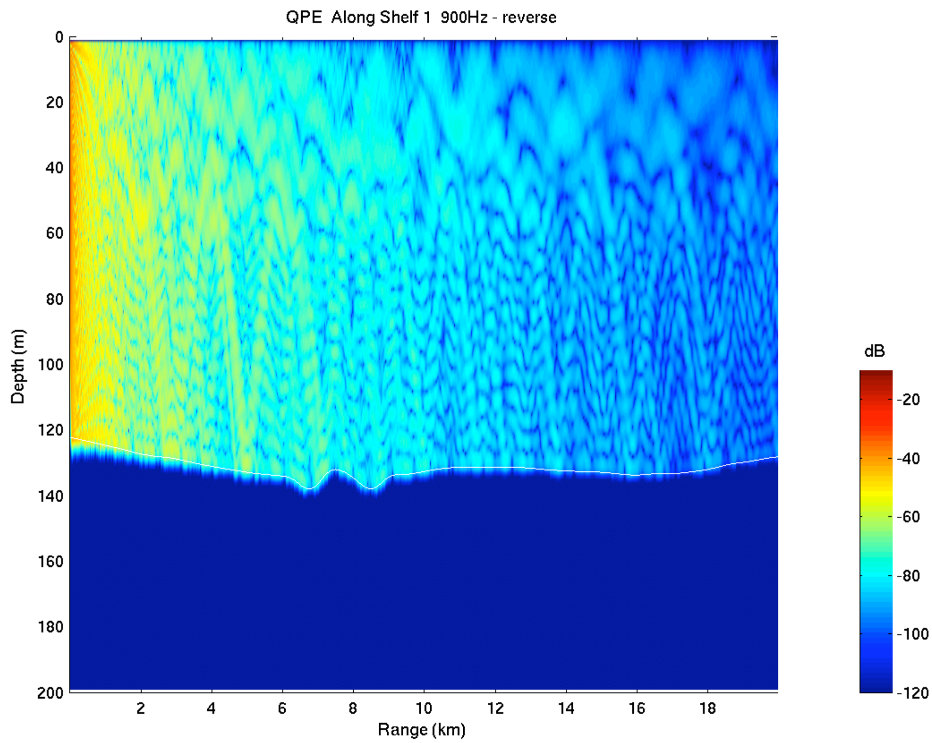
QPE Along Shelf 1 300Hz - reverse
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120


QPE Along Shelf 1 600Hz
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120



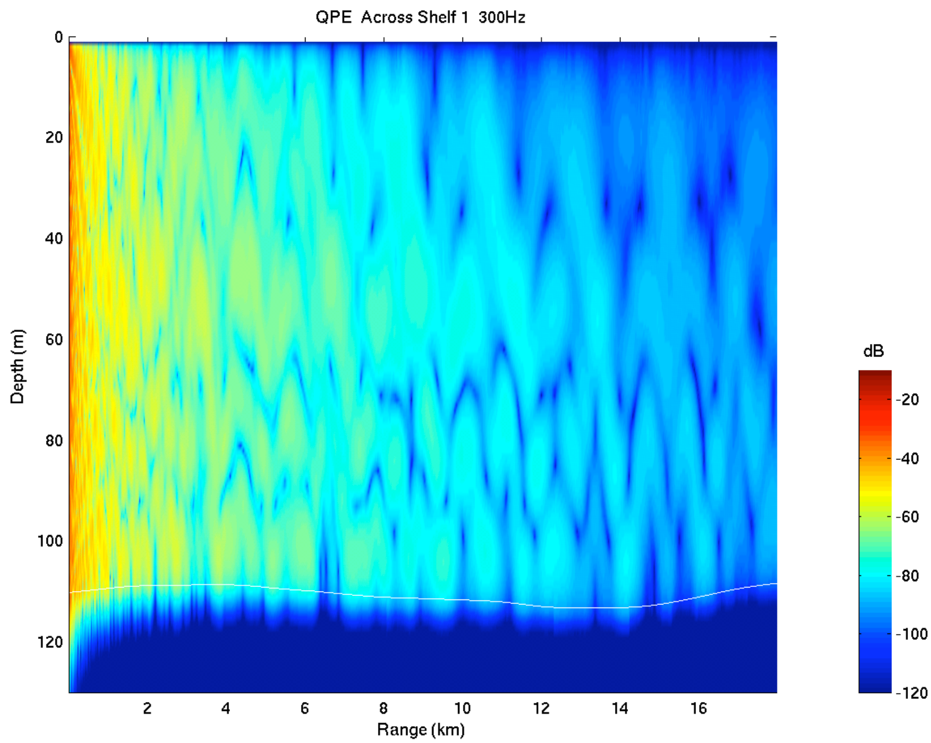
QPE Along Shelf 1 600Hz - reverse
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120


QPE Along Shelf 1 900Hz
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120

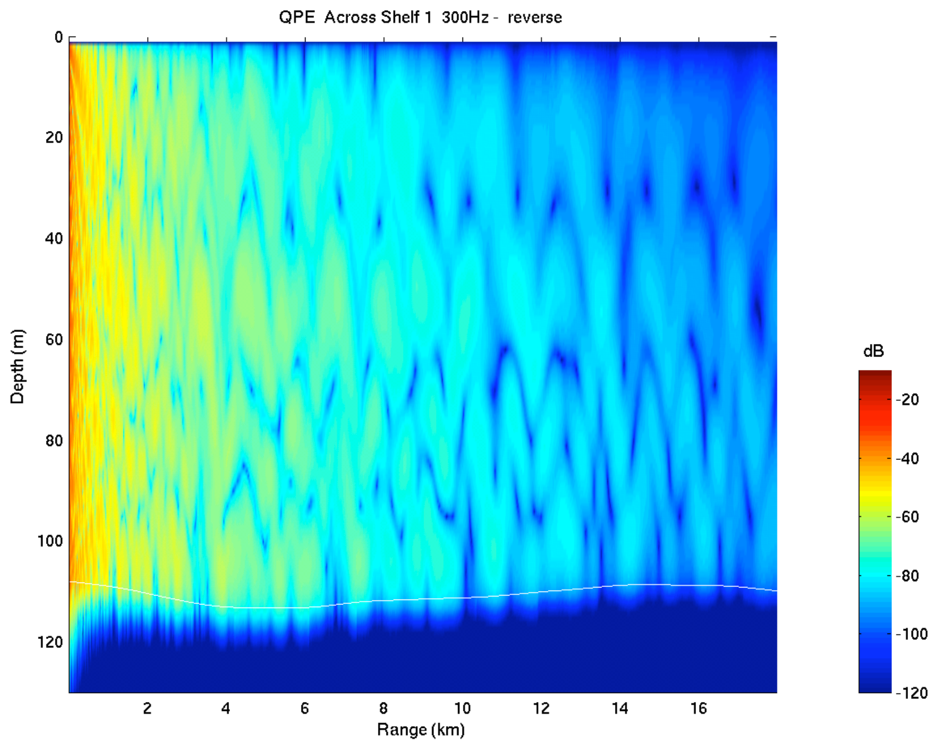


B. Shallow water, across shelf runs (path x1) – Figs 16-21

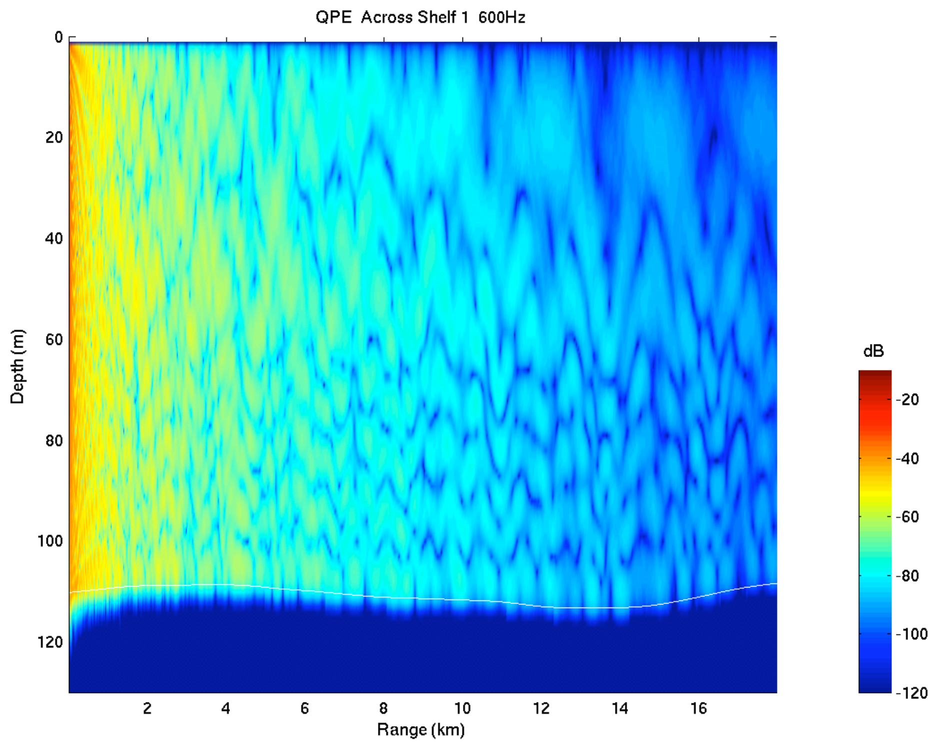
The six runs (figures 16-21) for the across-shelf, shallow path, are also "plain vanilla" ones for this pilot test. For the climatological water column profile, simple bottom, and (still) flat bathymetry, we again get a very standard shallow water shelf result. One can put source and receiver at either end, with no noticeable difference. Only if the oceanography is perturbed, or if there is some unexpercted bottom feature, will this case produce anything "out of the usual." Internal waves may do this, though. It, too, is a good baseline study.



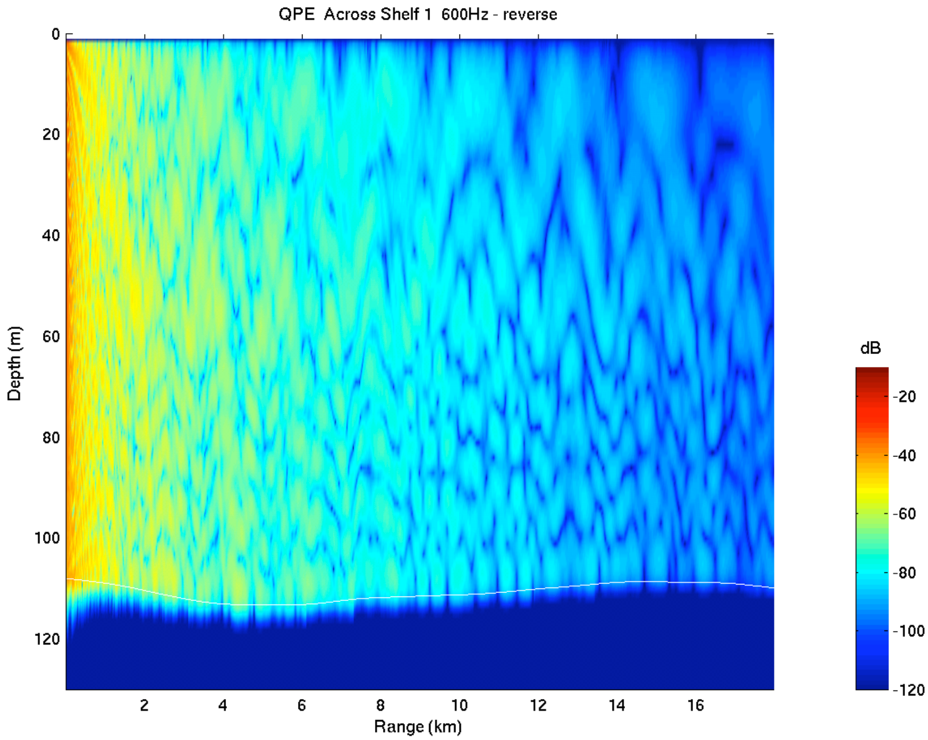
QPE Across Shelf 1 300Hz
Depth (m)
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



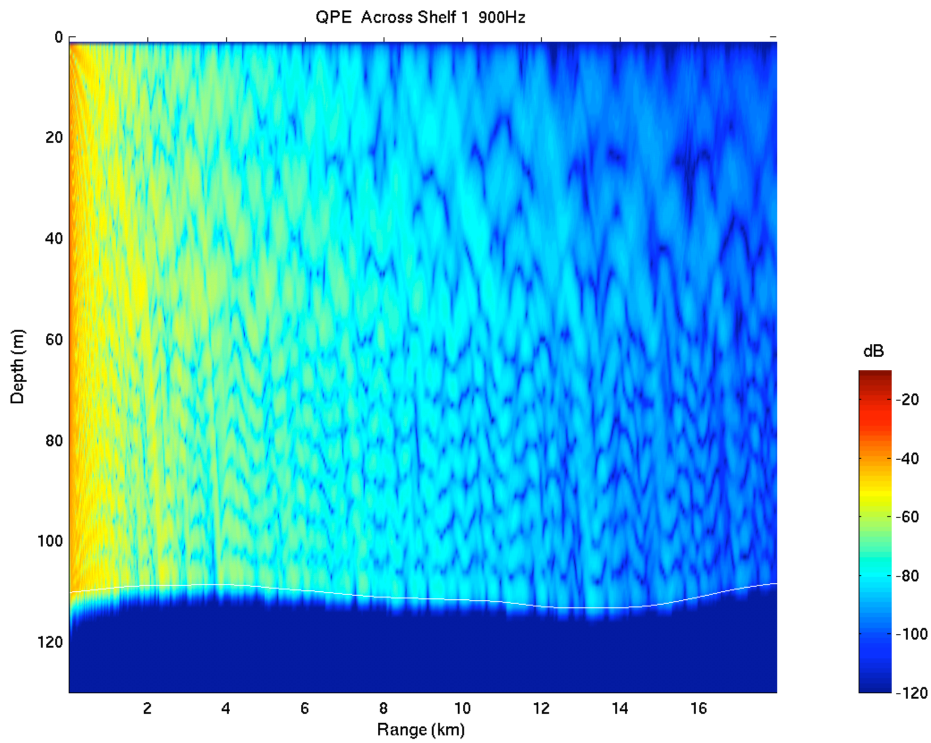
QPE Across Shelf 1 300Hz - reverse
Depth (m)
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

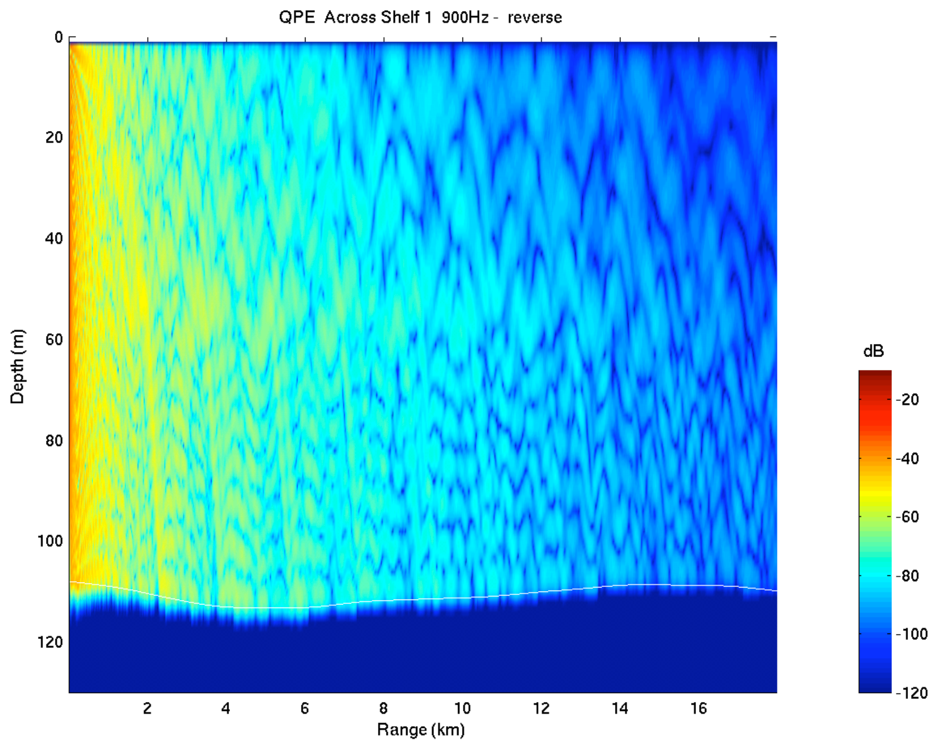


QPE Across Shelf 1 600Hz
Depth (m)
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



QPE Across Shelf 1 600Hz - reverse
Depth (m)
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

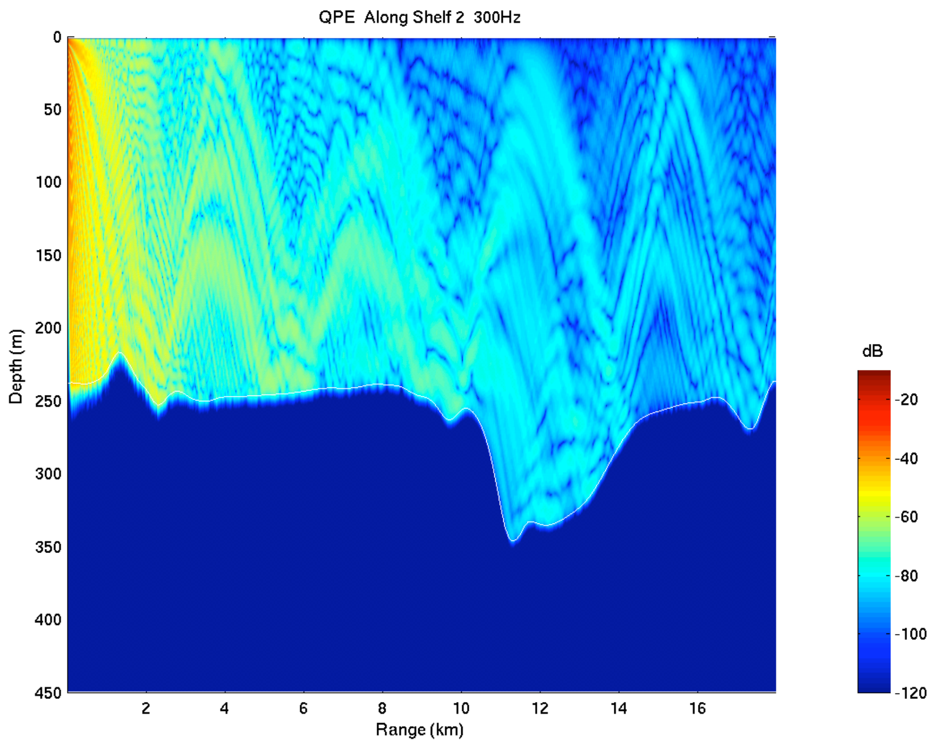

QPE Across Shelf 1 900Hz
Depth (m)
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

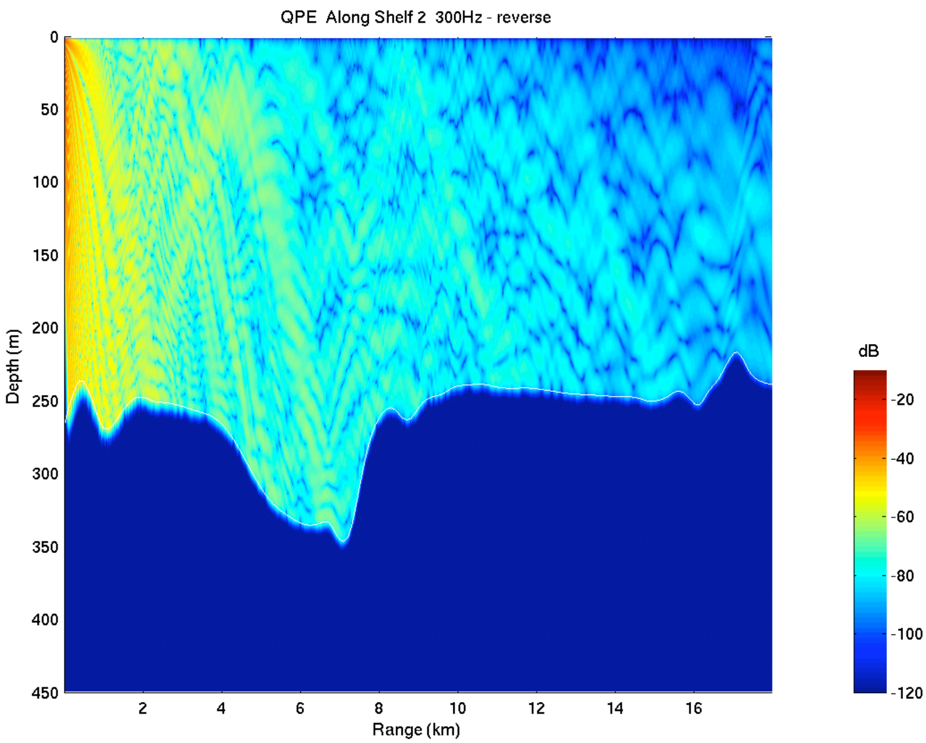


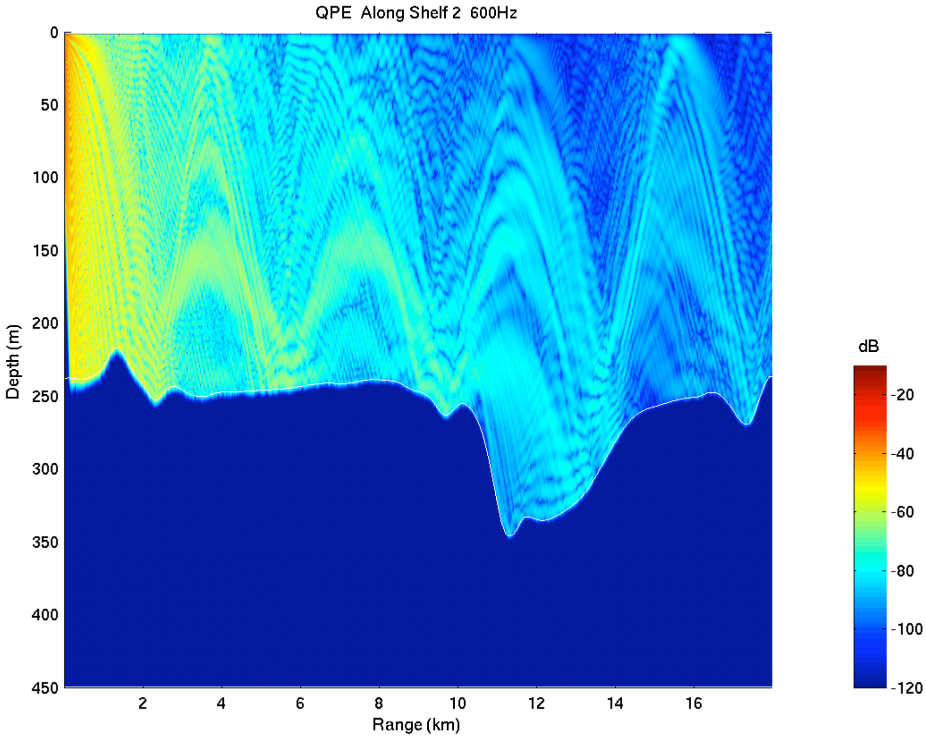
C. Along slope, across canyon run (path a2) – Figs 22-27

Interestingly, this set of runs, while seeing some effects and asymmetry due to the canyon cutting across the propagation path, still looks mainly like a 250m, constant depth along slope run. There ARE left-right asymmetries seen due to the canyon, but they are not severe, even at the 15-20 km ranges. This is due to the canyon being comparatively narrow and shallow. We would note that since this path is along a slope, that 3-D, out of plane refraction may be important, so that our 2-D slice results should be improved on, or at least compared to full 3-D. Also, the water column SVP in the canyon might be substantially different from what we used. This needs to be explored as well.

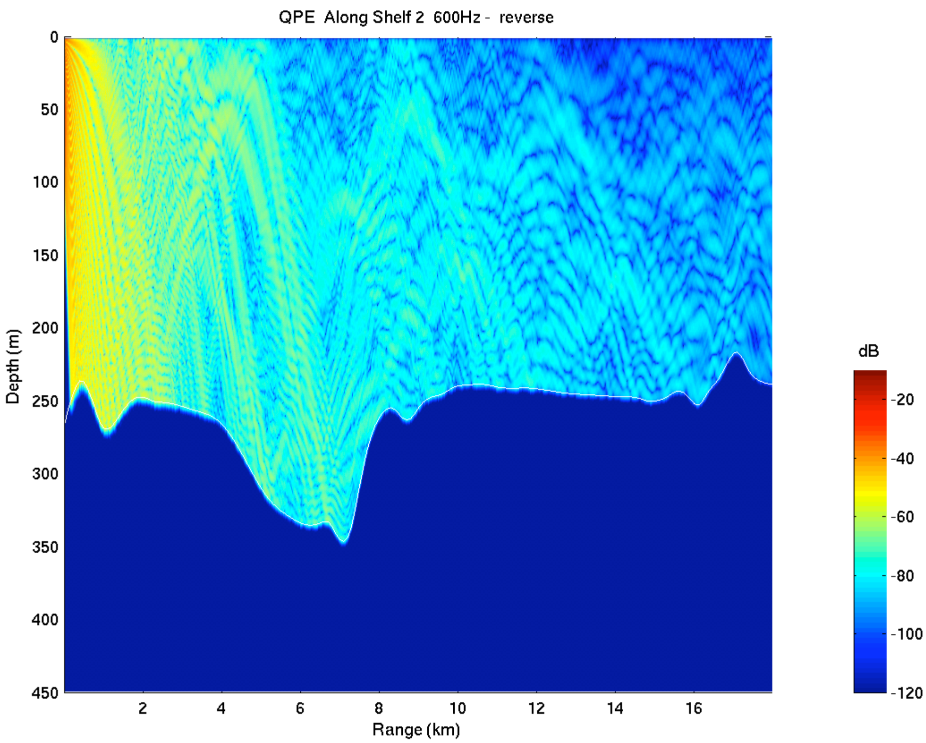
Glen Gawarkiewicz 8/11/08 4:05 PM
Deleted: e


QPE Along Shelf 2 300Hz
Depth (m)
0
50
100
150
200
250
300
350
400
450
Range (km)
2
4
6
8
10
12
14
16
dB
-20
-40
-60
-80
-100
-120

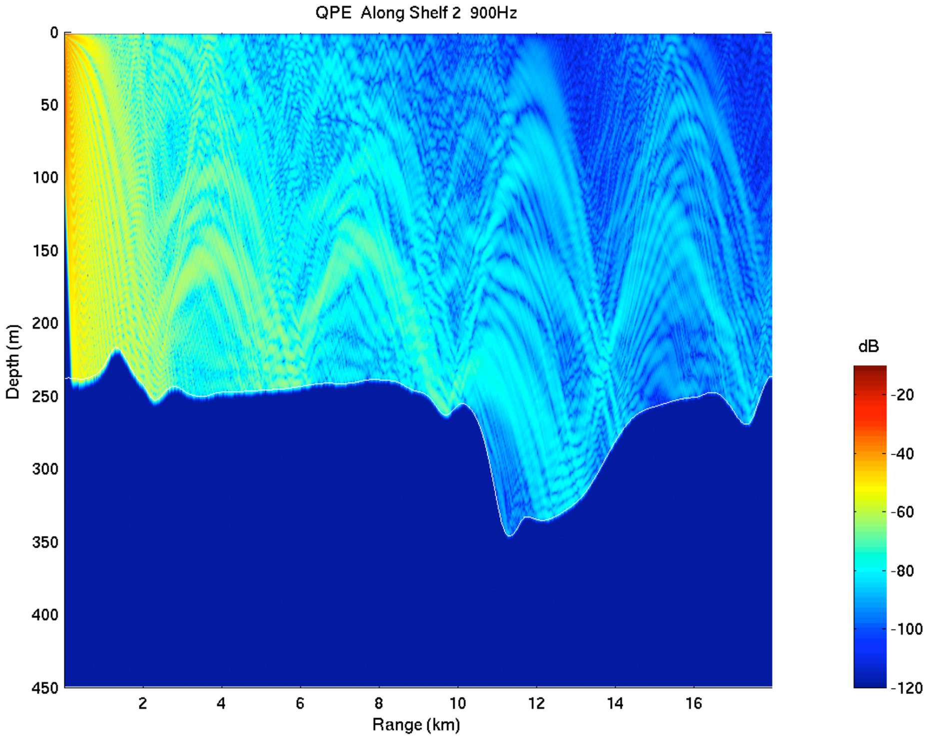

QPE Along Shelf 2 300Hz - reverse
Depth (m)
0
50
100
150
200
250
300
350
400
450
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

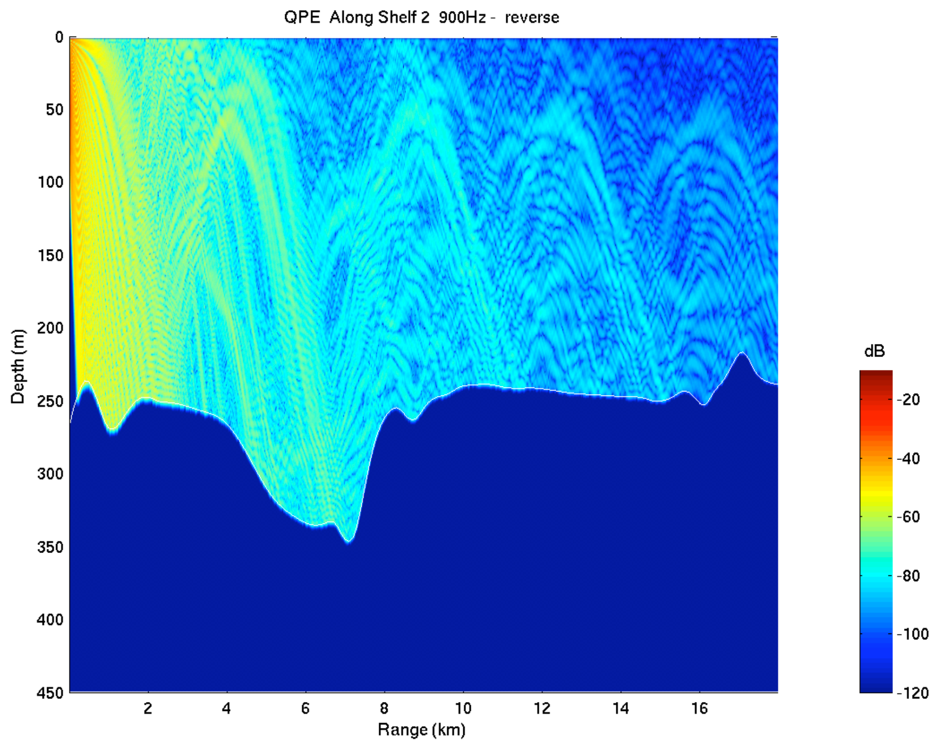


QPE Along Shelf 2 600Hz
Depth (m)
Range (km)
dB
0
50
100
150
200
250
300
350
400
450
2
4
6
8
10
12
14
16
-20
-40
-60
-80
-100
-120



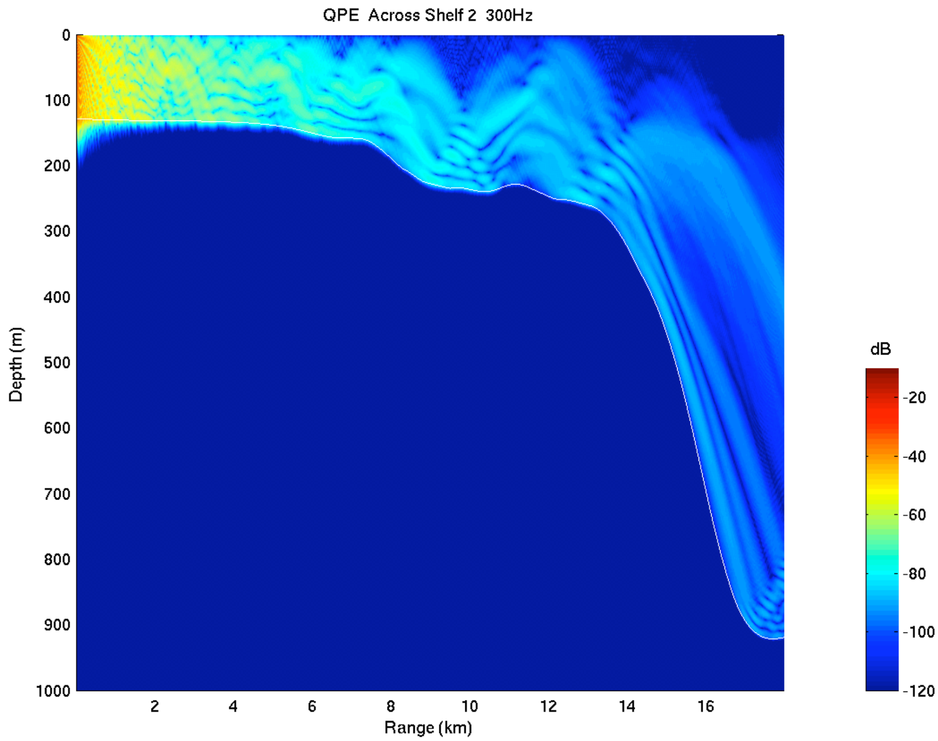
QPE Along Shelf 2 600Hz - reverse
Depth (m)
Range (km)
0
50
100
150
200
250
300
350
400
450
2
4
6
8
10
12
14
16
dB
-20
-40
-60
-80
-100
-120

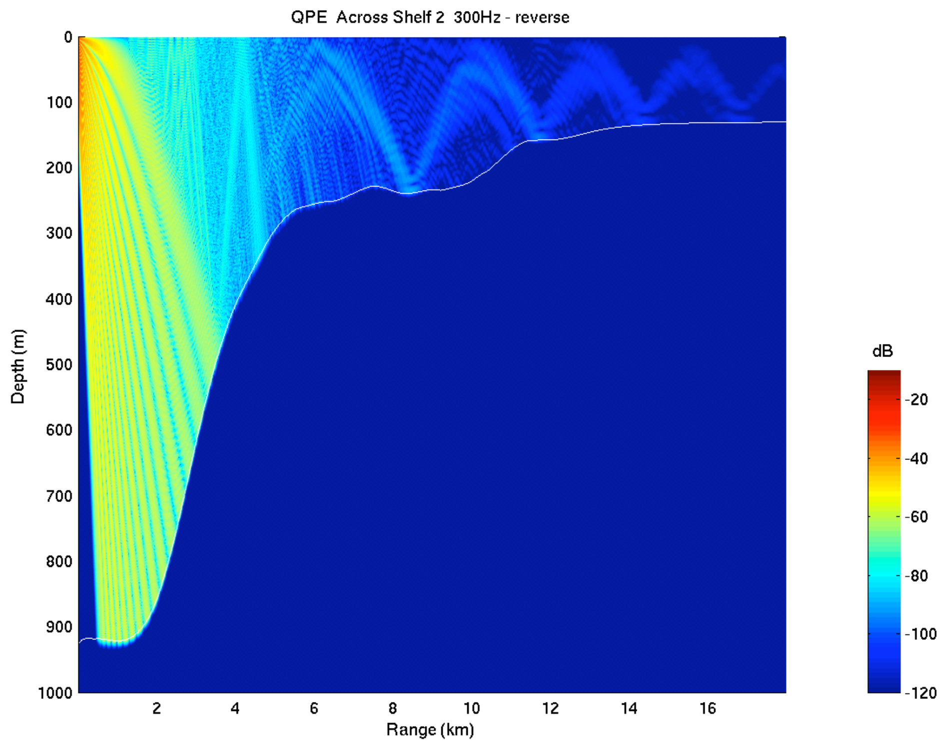

QPE Along Shelf 2 900Hz
Depth (m)
0
50
100
150
200
250
300
350
400
450
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



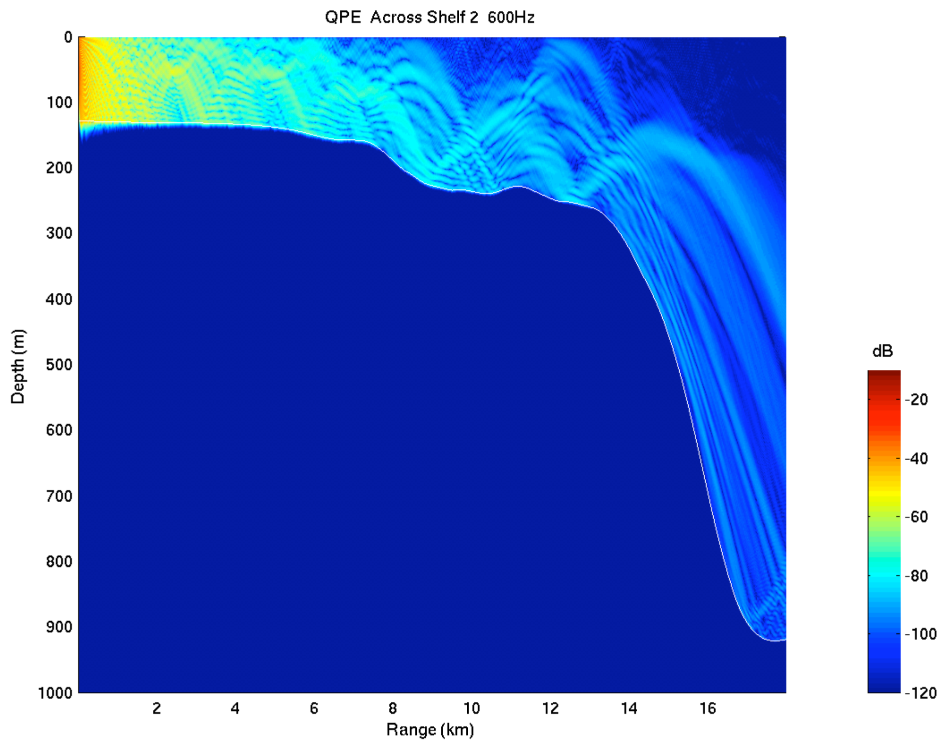
D. Across slope (parallel to canyon) runs (path x2) – Figs 28-33

This tends to be a more "exciting" geometry, in that one sees a distinct, near surface shadow zone at the receiver end when transmitting from shallow to deeper water. This effect is caused by the downward refracting profile making the sound (particularly the energetically important low modes) "hug" the bottom, and works at all frequencies. However, ensonification of targets near bottom should be good. Going the opposite way, another interesting effect is noted. In this case, the sound energy initially hits the slope at a high angle (the sum of the bottom slope and the steep mode angle, the latter due to downward refraction), causing very high bottom loss. This leads to a weak signal once the sound passes the range of the "first bottom bounce." Before that, good ensonification is seen throughout the water column. Again, this case probably has a strong 3-D component, in that along-slope bathymetry variations probably make this problem more 3-D than one would expect from our initial "along slope symmetry" prejudices. Canyon areas are likely to be very "un-symmetric" in this sense.

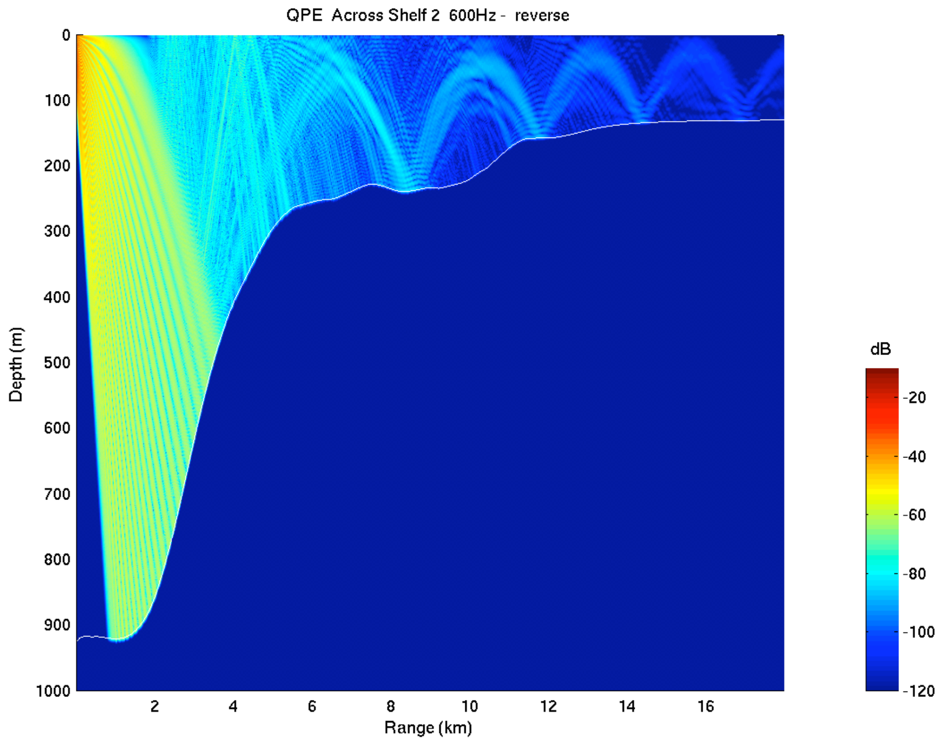

QPE Across Shelf 2 300Hz
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



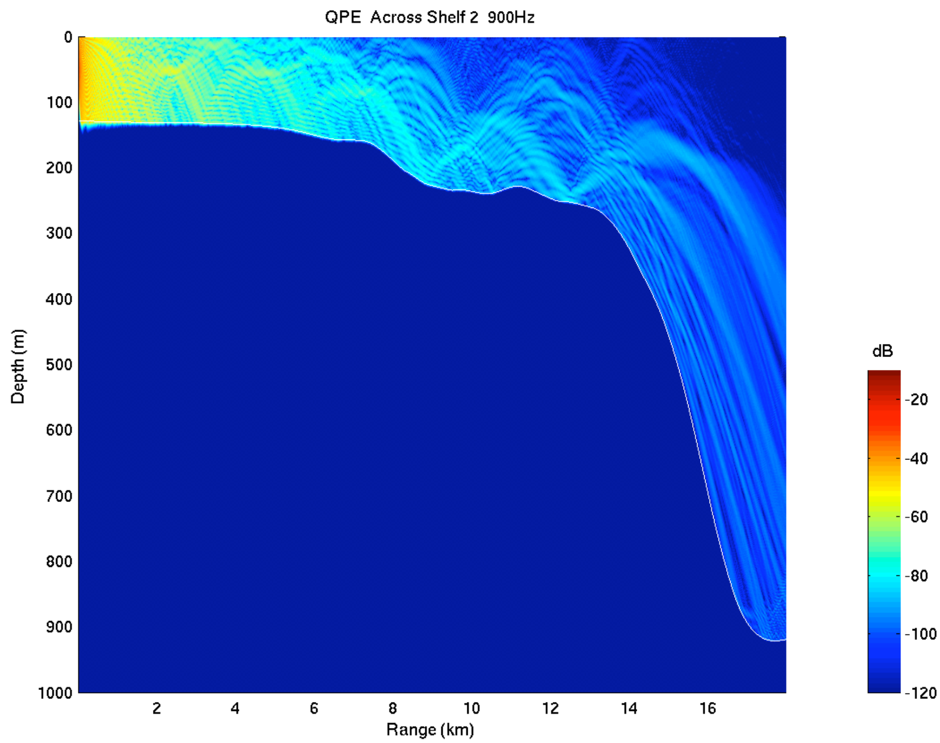
QPE Across Shelf 2 300Hz - reverse
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



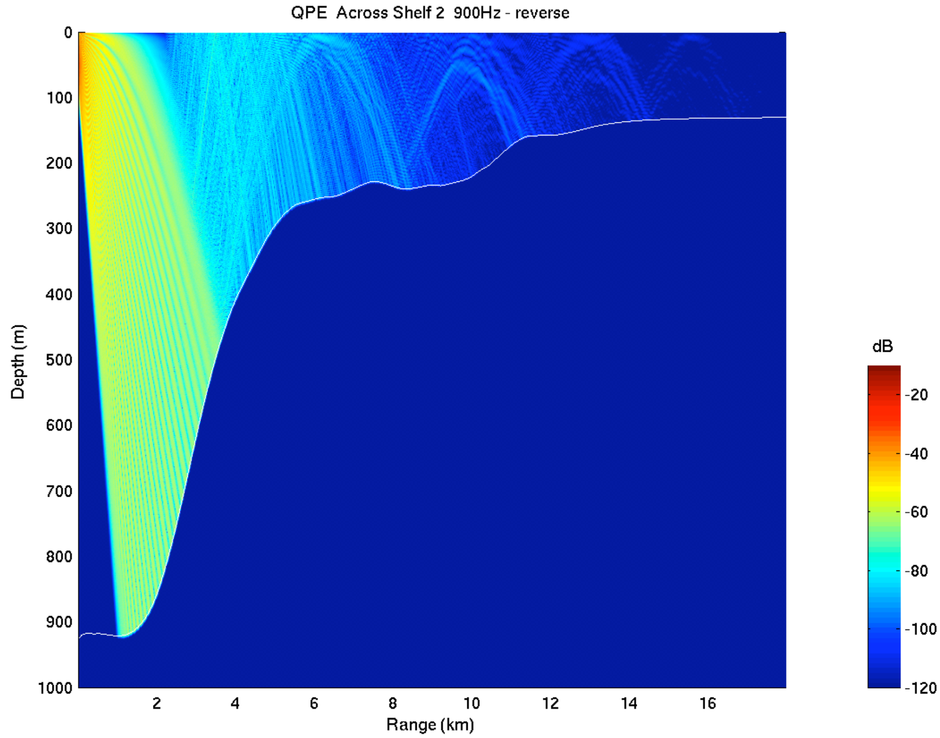
QPE Across Shelf 2 600Hz
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120



QPE Across Shelf 2 600Hz - reverse
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

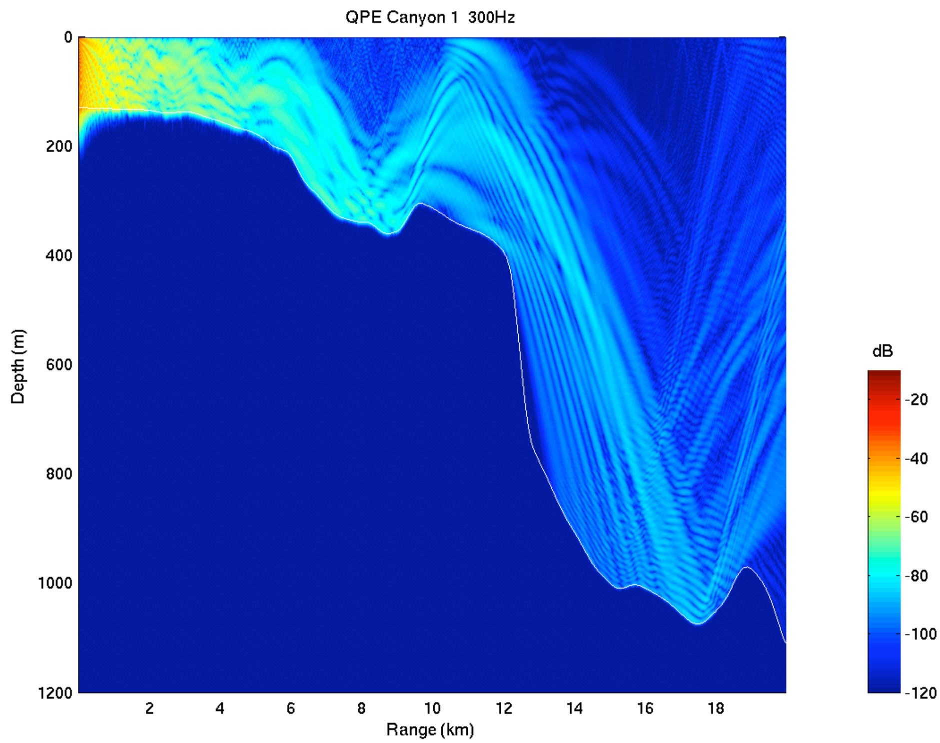


QPE Across Shelf 2 900Hz
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
16
Range (km)
dB
-20
-40
-60
-80
-100
-120

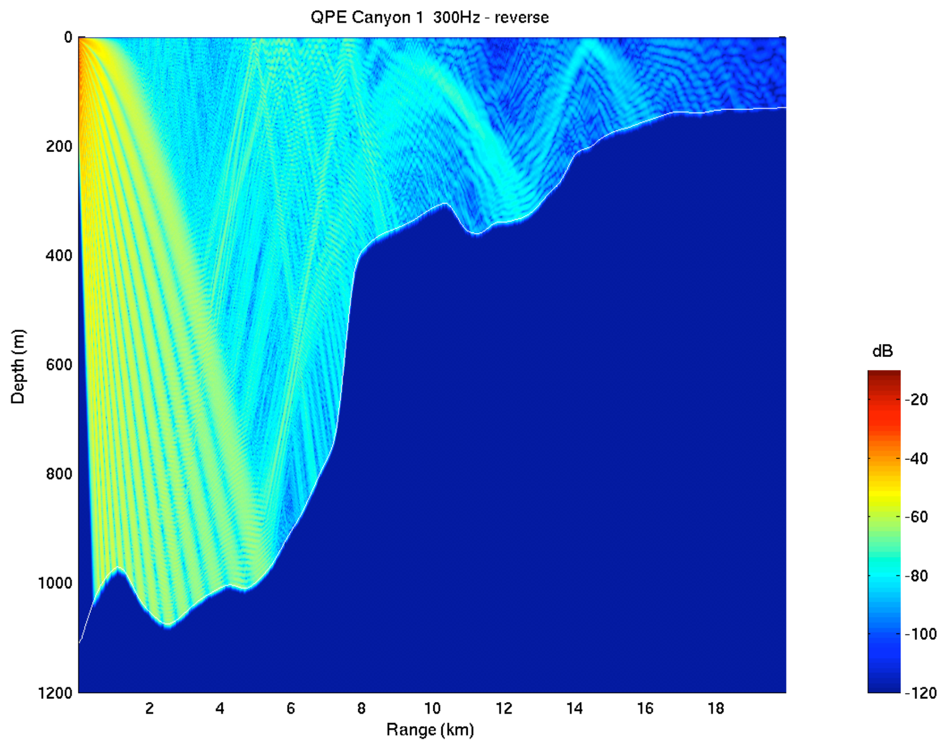


E. Along canyon axis runs (path c1) – Figs 34-39

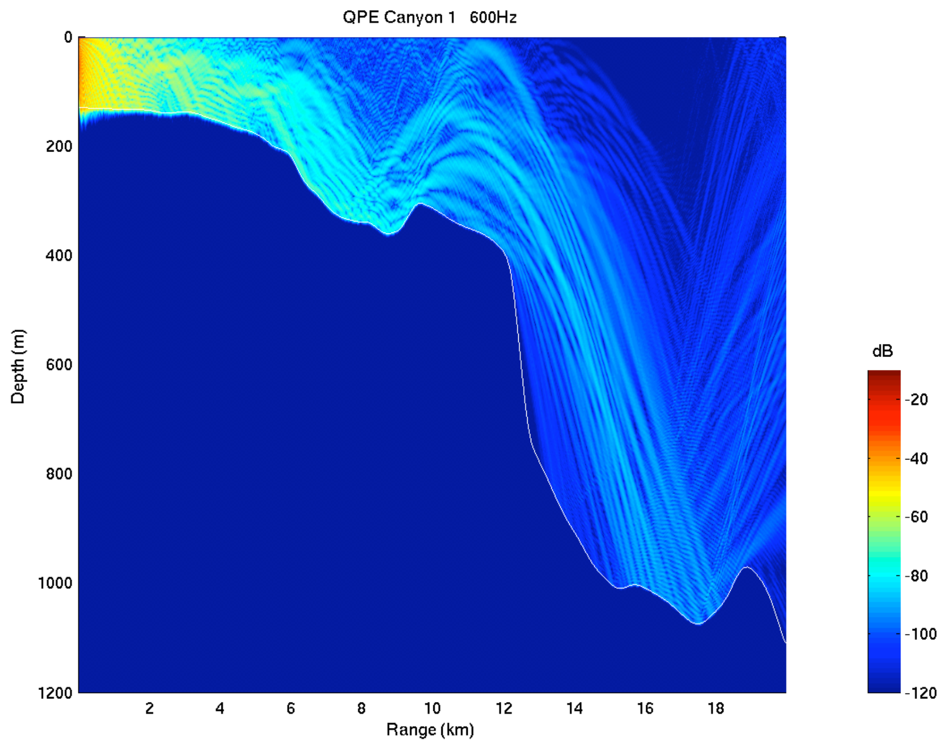
This is probably the most interesting run, overall, in terms of phenomena. It is similar, to first order, to the down-slope run. The seaward going path has the sound hug the bottom, whereas the shoreward going path hits the canyon walls at a fairly steep angle. However, in this case, the details of the bathymetry very obviously determine where (in range) one is going to see convergence zones and shadow zones. A technical challenge here is to see how well one can predict where these zones are seen. Also, this will be an extremely 3-D problem, and our first (obvious) guess is that the sound will be steered considerably along the canyon axis direction. We note that there is a small, spurious ducting artifact in the 900 Hz runs-this will be corrected later.

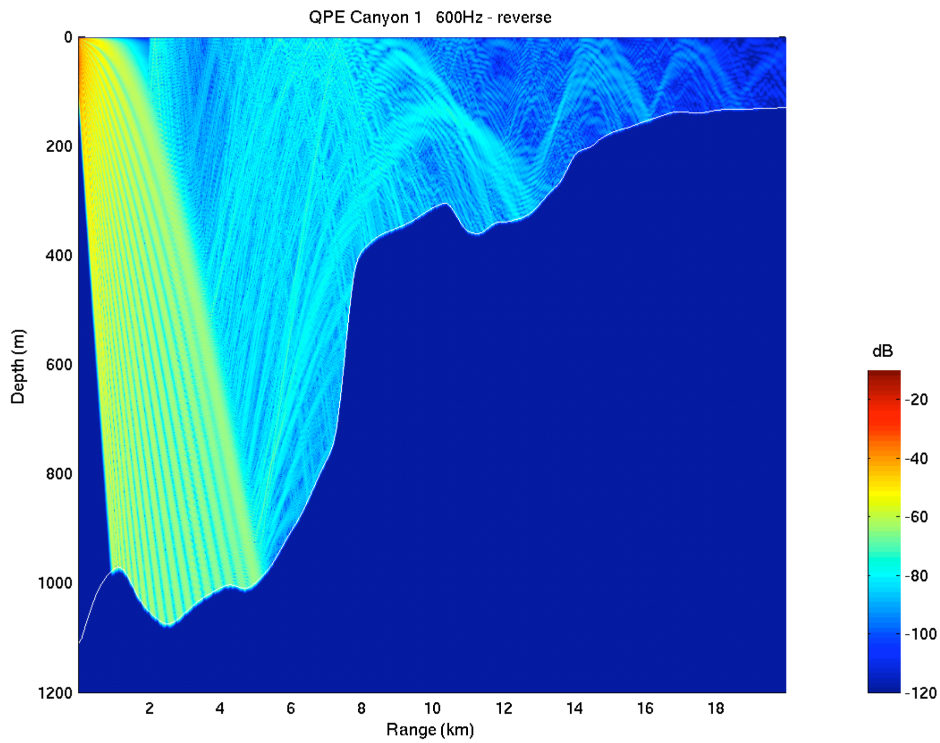


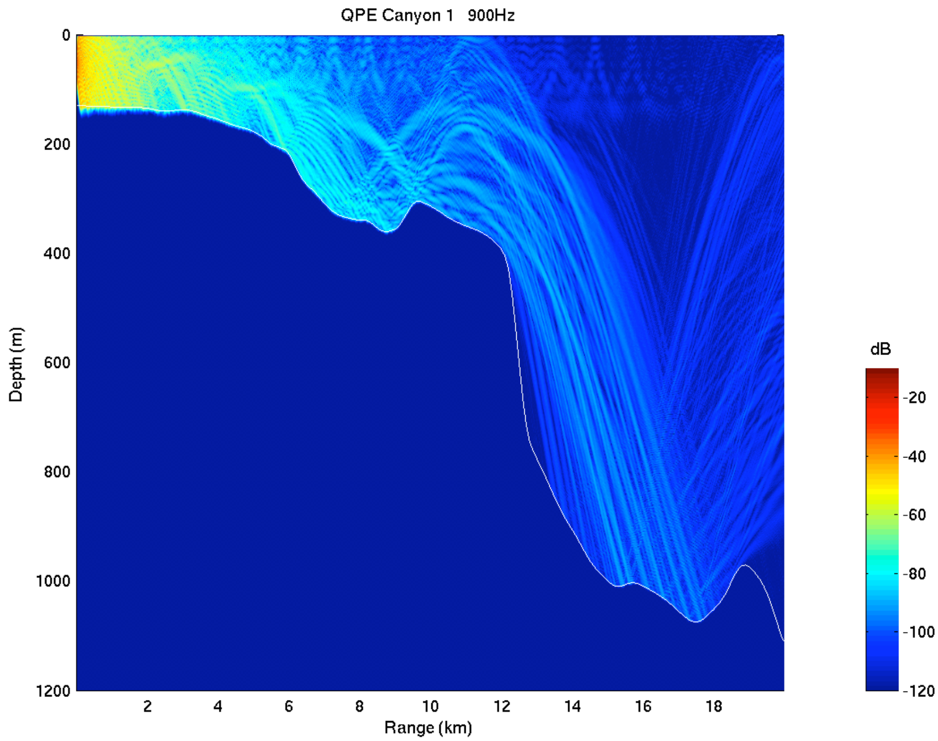
QPE Canyon 1 300Hz
Depth (m)
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120

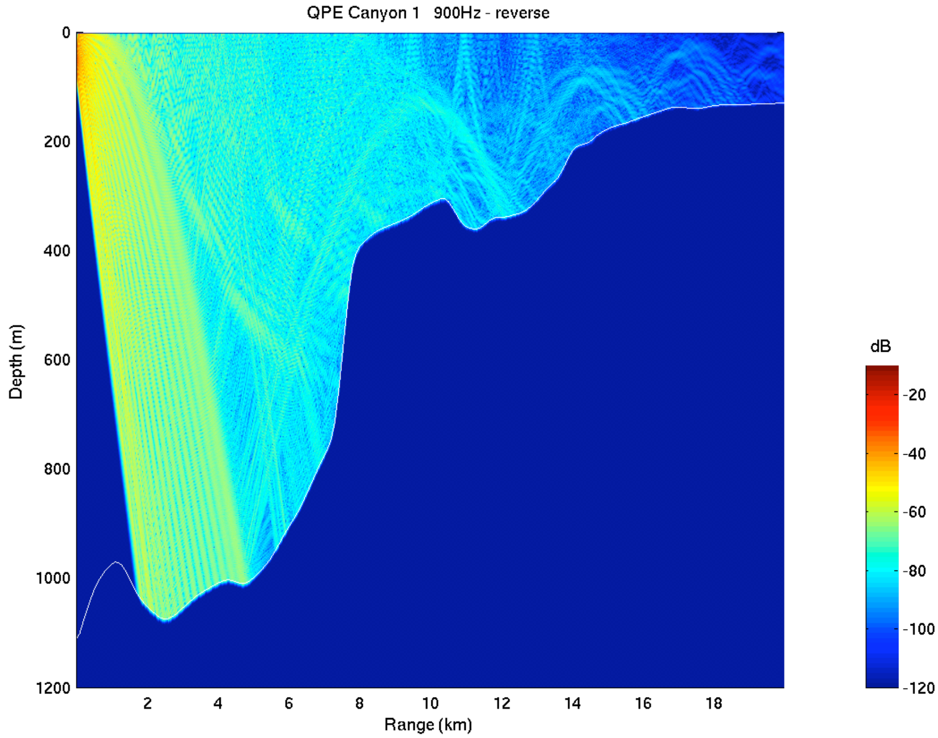


QPE Canyon 1 300Hz - reverse
Depth (m)
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120


QPE Canyon 1   600Hz
Depth (m)
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18
Range (km)
dB
-20
-40
-60
-80
-100
-120


QPE Canyon 1 600Hz - reverse
Depth (m)
0
200
400
600
800
1000
1200
Range (km)
2
4
6
8
10
12
14
16
18
dB
-20
-40
-60
-80
-100
-120


QPE Canyon 1 900Hz
Depth (m)
Range (km)
dB
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18
-20
-40
-60
-80
-100
-120



QPE Canyon 1   900Hz - reverse
Depth (m)
Range (km)
dB
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18
-20
-40
-60
-80
-100
-120