IHO TWCWG Data Analysis Comparison – Work Plan Task B

Land Information New Zealand

Purpose:

To compare the results of Land Information New Zealand's (LINZ) tidal analysis procedure with other IHO partners.

Procedure:

Input files

Observed data files were obtained from five tidal stations: Boston, Bahia de Corral, Port Nolloth, Punta Arenas, and Saint Malo. Files were in various formats and had to be re-formatted into a "Date-Time-Height" file before loading into the LINZ tidal database and using LINZ's Sea Level Information Management System [1] (SLIMS) to analyse the data and generate predictions.

Predictions and/or constituents calculated by the respective tidal offices were supplied by all but Saint Malo. A summary of the files available for this exercise are as follows:

Site	Coordinates	Observed Data	Predictions/Constituent File
Boston, United States	42.35N, 71.05W	2010 – hourly	Predictions (NOAA, UKHO) – hourly
Bahia de Corral, Chile	39.52S, 73.26W	1994, 1995 – hourly	Constituent File (SHOA)
Port Nolloth, South Africa	29.25S, 16.87E	2010 – hourly	Constituent File, Predictions – hourly (SANHO)
Punta Arenas, Chile	53.10S, 70.54W	1992, 1993 – hourly	Constituent File (SHOA)
Saint Malo, France	48.64N, 2.02W	1986-2013 – 15 min (gaps)	N/A (SHOM)

Constituent Analysis

Data were loaded into SLIMS and checked for gaps and any obvious erroneous data. Constituents were computed on this observed data using SLIMS for the year that the supplied data covered. For the Chilean sites, constituents were computed over the 2-year period, and for Saint Malo, LINZ's mult-year analysis procedure was followed.

In this multi-year procedure, constituents are computed for a period of 379 days for each calendar year (normally from 25 December of the previous year to 7 January of the following year). This was modified, depending on whether there were large gaps of data in the year. The yearly constituents were then entered into LINZ's "Harmonic Analysis" spreadsheet [2] and a selection of constituents was identified who's error and signal-to-noise ratios fell within certain tolerances. This selection makes up the "Master Set" of constituents and is used to calculate predictions.

Predictions

Predictions were computed using SLIMS for the year that the observed data covered, using the same time interval (i.e. 1 hour or 15 min). For cases where multiple years were provided, the latest

[1] SLIMS uses Mike Forman's analysis and prediction algorithms, Pacific Marine Science Report 77-10.
[2] This spreadsheet was developed by William Crawford, International Hydrographic Review, LXXII(2), 1995.

complete year was chosen. For example, the year 2010 was selected for Saint Malo because of data gaps in the years 2011 to 2013.

Predictions were supplied for the Boston (NOAA and UKHO) and Port Nolloth sites. Harmonic files were supplied for the Chilean sites. These constituents were imported into SLIMS and used to calculated predicted tides for the appropriate time period.

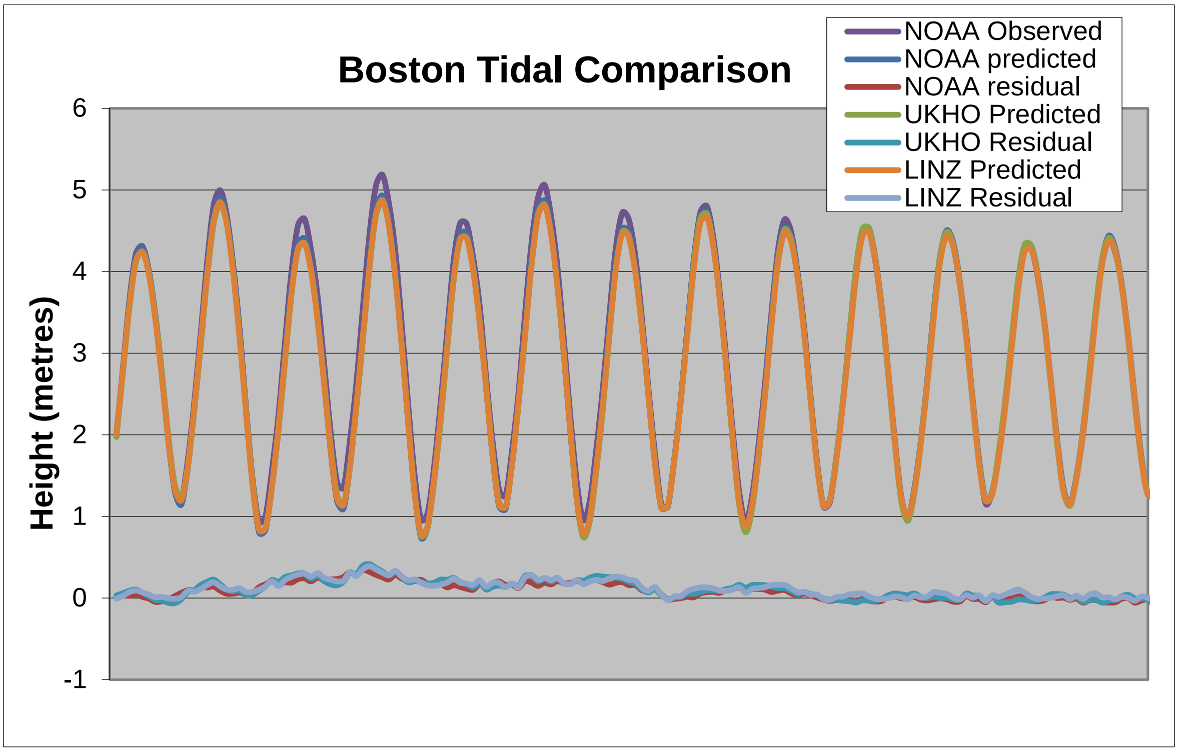
Observed tides and the various sets of predictions were copied into a spreadsheet. The levels were plotted, along with the residuals to see how the results compared.

Results:

Boston

Predicted tides for 2010 were computed for Boston. Also available were predicted tides from NOAA, and predicted tides from the UKHO. The observed tides were compared to each of the predicted sets.

As a sample, observed, predicted and residual values were plotted for the first week in 2010:

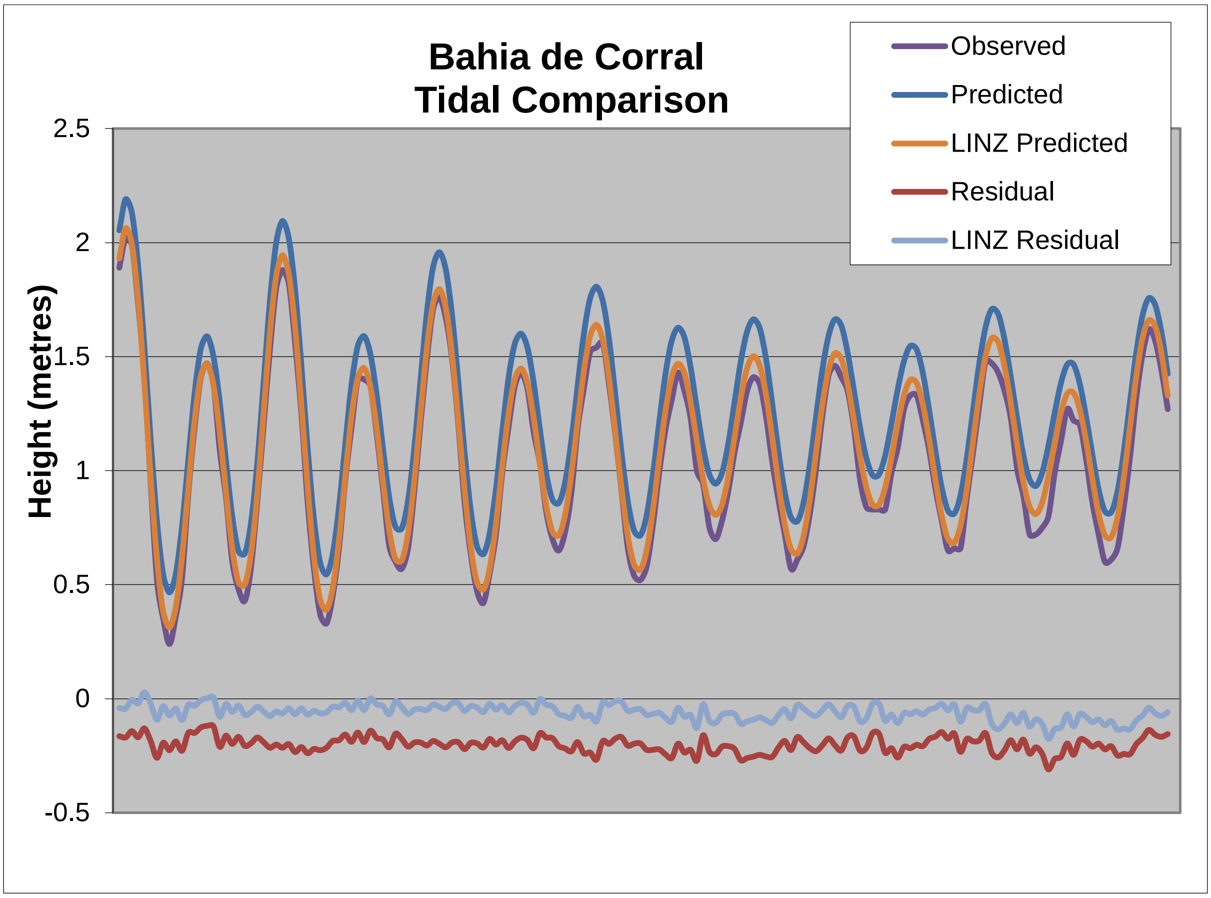


The average difference, or residual, between observed and predicted tide was calculated for the three prediction sets. Standard deviation, maximum difference and minimum difference were also calculated for the residuals. Differences were similar between sets, and ranged between approximately -0.7 to 0.9 metres. The statistics are as follows:

Stats	***NOAA***	***UKHO***	***LINZ***
Average Difference	0.000	0.005	0.000
Standard Dev	0.128	0.132	0.131
Max difference	0.943	0.931	0.964
Min difference	-0.746	-0.723	-0.738

Bahia de Corral
Predicted tides for 1995 were computed for Bahia de Corral using the constituents calculated by SLIMS. Predictions were also created for the same year using constituents provided by SHOA. The observed tides were compared to each of the predicted sets.

Due to gaps in data, observed, predicted and residual values were plotted for the **last** week in 1995:

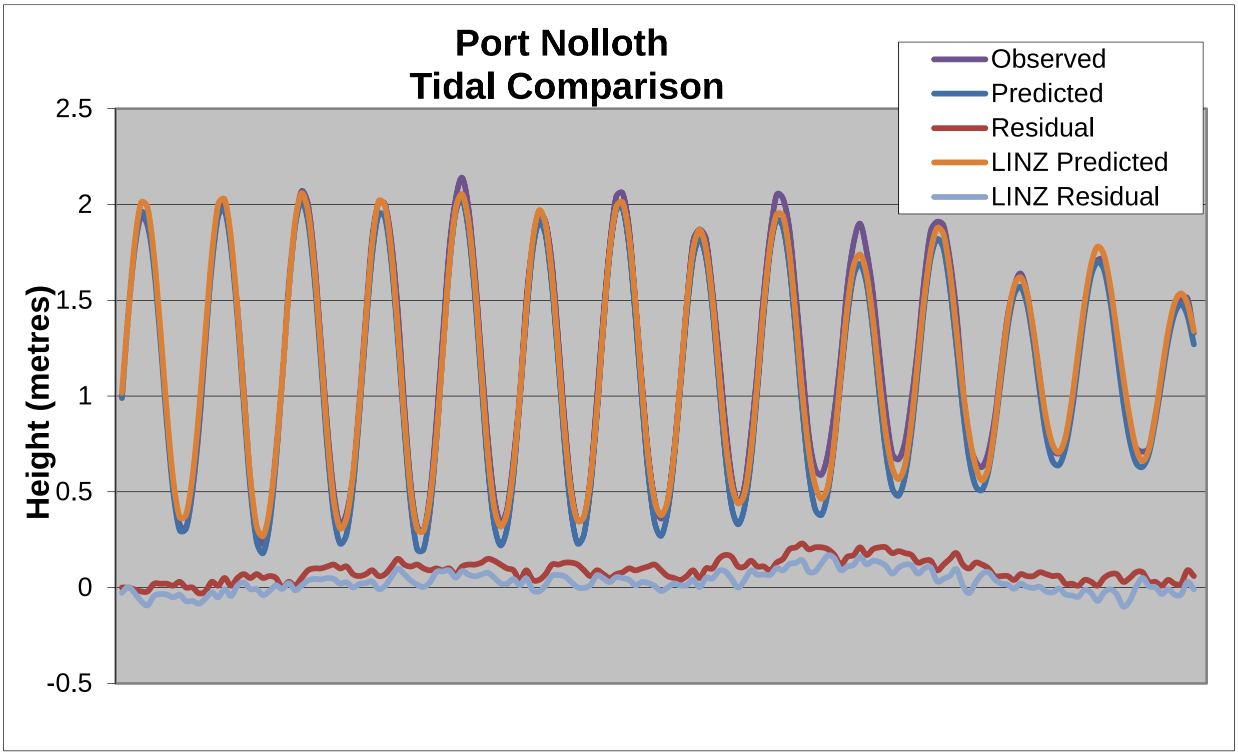


The average difference, or residual, between observed and predicted tide was calculated for the two prediction sets. Standard deviation, maximum difference and minimum difference were also calculated for the residuals. Differences were similar between sets, ranging between -0.4 to 0.8 metres for the supplied harmonics, to -0.4 to 0.7 metres for the LINZ predictions. The statistics are as follows:

Stats	***SHOA***	***LINZ***
Average Difference	-0.037	-0.028
Standard Dev	0.147	0.112
Max difference	0.821	0.731
Min difference	-0.418	-0.352

Port Nolloth
Predicted tides for 2010 were computed for Port Nolloth using the constituents calculated by SLIMS. The observed tides were compared to both the LINZ predictions and the predictions supplied by SANHO.

As a sample, observed, predicted and residual values were plotted for the first week in 2010:



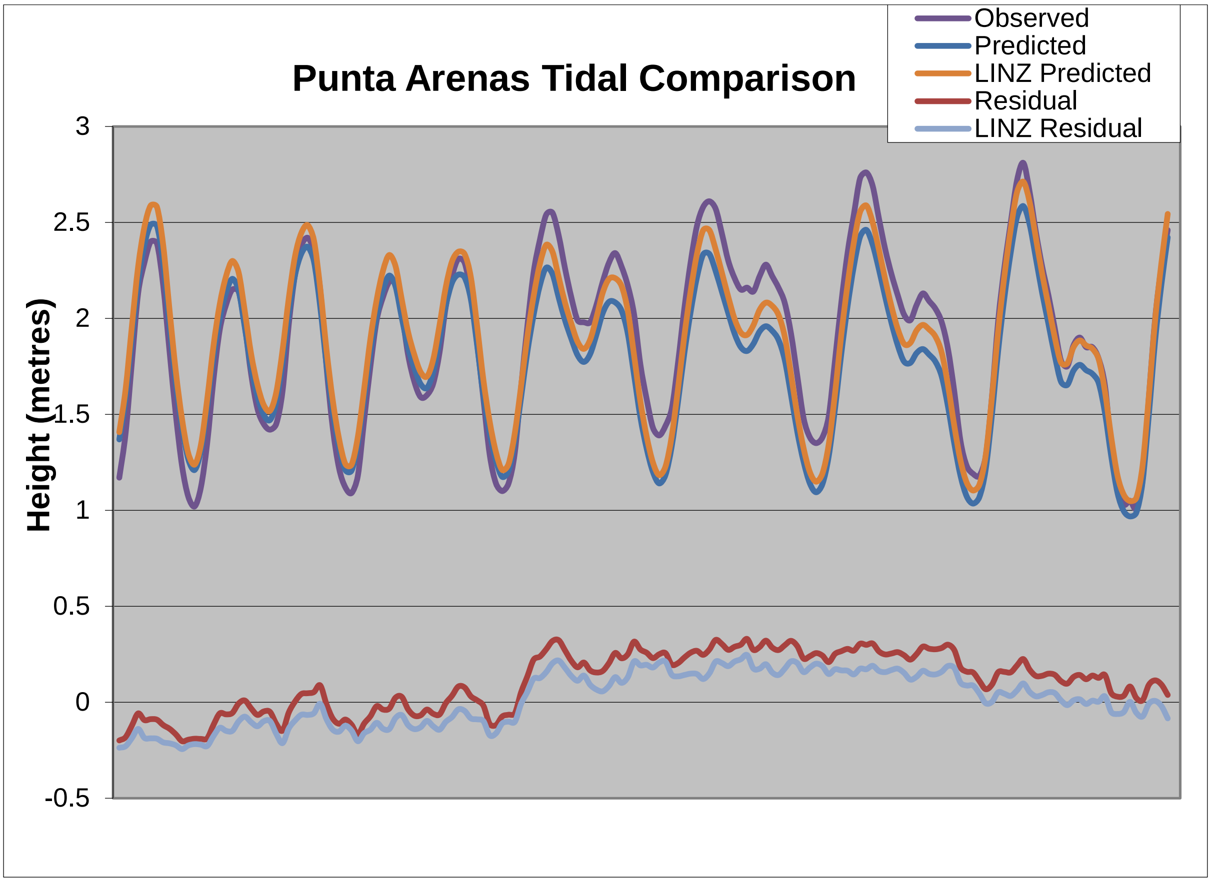
The average difference, or residual, between observed and predicted tide was calculated for the two prediction sets. Standard deviation, maximum difference and minimum difference were also calculated for the residuals. Differences were similar between sets, ranging between -0.2 to 0.5 metres for the supplied predictions, to -0.4 to 0.4 metres for the LINZ predictions. The statistics are as follows:

Stats	***SANHO***	***LINZ***
Average Difference	0.092	0.000
Standard Dev	0.077	0.084
Max difference	0.480	0.408
Min difference	-0.220	-0.367

Punta Arenas

Predicted tides for 1993 were computed for Punta Arenas using the constituents calculated by SLIMS. Predictions were also created for the same year using constituents provided by SHOA. The observed tides were compared to each of the predicted sets.

As a sample, observed, predicted and residual values were plotted for the first week in 1993:



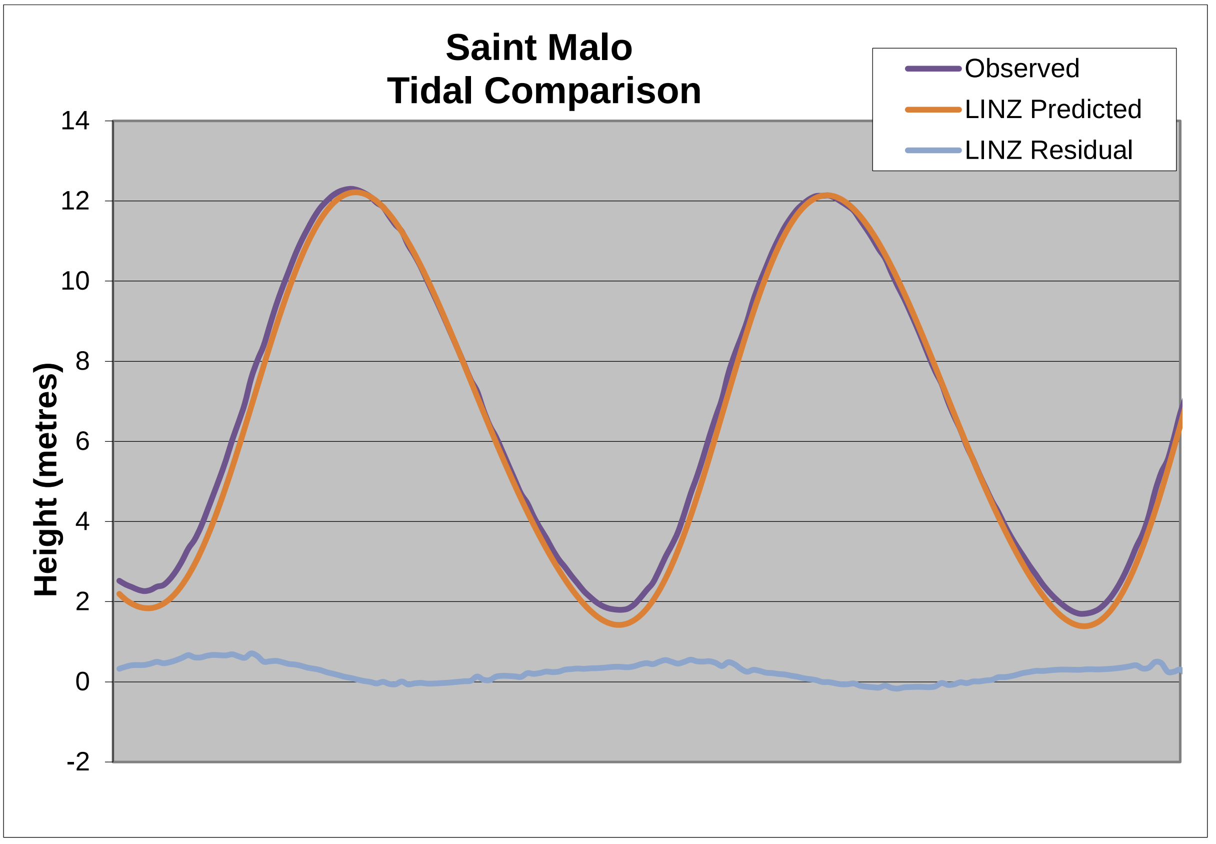
The average difference, or residual, between observed and predicted tide was calculated for the two prediction sets. Standard deviation, maximum difference and minimum difference were also calculated for the residuals. Differences were similar between sets, ranging between -0.5 to 0.6 metres for the supplied harmonics, to -0.5 to 0.5 metres for the LINZ predictions. The statistics are as follows:

Stats	***SHOA***	***LINZ***
Average Difference	0.076	0.037
Standard Dev	0.187	0.170
Max difference	0.596	0.525
Min difference	-0.479	-0.450

Saint Malo

Predicted tides for 2010 were computed for Saint Malo using the constituents calculated by SLIMS. The observed tides were compared to the LINZ predictions. Neither predictions nor a harmonic file were supplied for this comparison.

As a sample, observed, predicted and residual values were plotted for the first week in 2010:



The average difference, or residual, between observed and predicted tide was calculated for the prediction set. Standard deviation, maximum difference and minimum difference were also calculated for the residuals. Differences ranged between -0.7 to 0.9 metres. The statistics are as follows:

Stats	***SHOM***	***LINZ***
Average Difference	N/A	0.017
Standard Dev	N/A	0.190
Max difference	N/A	0.931
Min difference	N/A	-0.745

Appendix – Master Constituents Computed by LINZ:

Boston

Name	Amplitude	Phase	SNR
Z0	281.5461	0.00	
M2	138.4661	109.33	74405.117
N2	32.6123	77.83	4127.420
S2	20.9558	146.08	1704.215
K1	13.9748	203.86	1355.897
O1	11.4168	186.75	904.949
M4	2.3708	27.39	349.310
L2	8.6667	162.60	291.490
M6	3.2969	280.35	251.411
NU2	6.7543	88.23	177.042
K2	5.9225	147.62	136.121
P1	4.3139	200.37	129.204
2MN6	2.0822	239.42	100.281
MN4	1.2624	9.58	99.041
M8	0.6004	249.46	52.858
MO3	0.7092	200.82	49.858
MS4	0.8792	61.76	48.039
2N2	3.3678	59.12	44.016
MK3	0.5602	235.64	31.109
2MS6	1.1338	328.76	29.733
Q1	1.7025	165.31	20.124
LDA2	2.0504	137.01	16.315
M3	0.3654	140.73	13.235
NO1	1.0780	198.45	8.068
2MK5	0.2556	106.42	6.770
SO3	0.2540	228.11	6.395
J1	0.9329	220.33	6.042
2MK6	0.4257	338.83	4.192
MU2	0.8413	66.91	2.747
MK4	0.2039	68.22	2.584
3MK7	0.0961	343.74	2.528
SIG1	0.5786	153.72	2.324
SN4	0.1878	65.49	2.192
RHO1	0.5241	176.02	1.907
S4	0.1679	120.22	1.752
EPS2	0.6594	113.29	1.687
SO1	0.4746	210.82	1.564
2SM6	0.2313	21.01	1.237
MF	2.7044	270.63	1.228
MSK6	0.2207	18.17	1.127
OO1	0.4027	243.84	1.126
SSA	2.4987	355.92	1.048
SK4	0.1195	118.61	0.887
PHI1	0.3488	226.34	0.845
SK3	0.0892	309.23	0.789
MSN2	0.4378	64.41	0.744
MSM	2.0439	316.57	0.701
MKS2	0.3996	245.97	0.620
OQ2	0.3876	60.13	0.583
2SK5	0.0706	86.73	0.516
BET1	0.2633	167.82	0.481
ALP1	0.2526	116.22	0.443
2Q1	0.2507	72.26	0.436
UPS1	0.2390	65.71	0.397
MSF	1.5289	65.25	0.392
TAU1	0.2168	240.96	0.326
ETA2	0.2134	16.58	0.177
MM	0.9840	77.79	0.163
CHI1	0.0902	128.59	0.056
THE1	0.0509	147.45	0.018

Corral

Name	Amplitude	Phase	SNR
Z0	114.0086	.00	
M2	44.5692	334.37	31518.291
S2	16.6316	344.63	4388.954
K1	16.3365	354.29	4995.854
O1	11.1732	315.08	2336.936
N2	10.4483	307.15	1732.145
SSA	5.6716	173.35	3.295
K2	5.2930	340.24	444.526
P1	4.9803	350.37	464.304
MM	4.3514	66.93	1.939
MF	3.3542	30.12	1.152
MU2	2.1277	285.44	71.831
Q1	2.1075	288.60	83.143
MSM	1.6427	290.39	0.276
NU2	1.6164	323.89	41.456
2N2	1.4517	267.78	33.438
J1	.9290	9.86	16.156
NO1	.9044	352.05	15.311
MKS2	.5949	303.23	5.615
RHO1	.5428	307.52	5.515
SIG1	.4491	243.95	3.776
THE1	.4445	67.63	3.699
LDA2	.4288	251.97	2.917
UPS1	.4284	34.98	3.436
EPS2	.4082	274.67	2.644
L2	.3998	350.44	2.536
PHI1	.3973	330.34	2.955
OO1	.3862	60.92	2.792
M4	.3758	284.90	26.516
ALP1	.3611	255.19	2.441
BET1	.3414	298.12	2.182
MSF	.3329	213.13	0.011
TAU1	.3225	14.84	1.947
ETA2	.3171	4.15	1.595
SK3	.2959	43.38	11.801
MK3	.2672	274.85	9.622
2Q1	.2509	218.98	1.178
CHI1	.2462	352.41	1.135
MS4	.2423	325.64	11.023
2MS6	.2301	200.31	10.516
SO1	.2045	246.62	0.783
SK4	.1922	251.47	6.936
M3	.1834	199.98	4.533
MSN2	.1793	211.74	0.510
M6	.1683	120.16	5.626
MO3	.1599	206.51	3.446
S4	.1541	329.13	4.459
SO3	.1276	271.78	2.194
MN4	.0810	304.95	1.232
3MK7	.0723	79.48	1.077
OQ2	.0688	199.21	0.075
2MN6	.0669	136.66	0.889
MK4	.0619	267.72	0.719
2SK5	.0605	315.47	0.733
SN4	.0566	211.72	0.601
MSK6	.0563	316.58	0.630
2MK6	.0536	134.41	0.571
M8	.0528	49.86	0.508
2MK5	.0355	169.14	0.252
2SM6	.0306	346.71	0.186

Port Nolloth

Name	Amplitude	Phase	SNR
Z0	118.1528	0.00	
M2	55.3381	89.42	35008.254
S2	23.5231	108.12	6325.737
N2	12.0808	78.60	1668.451
K2	6.6311	104.49	502.682
K1	5.5494	117.63	334.347
MSF	2.6044	252.93	1.868
NU2	2.5094	68.59	71.988
MU2	1.8976	60.25	41.165
O1	1.6818	248.86	30.708
2N2	1.6451	58.76	30.939
P1	1.5120	109.45	24.820
MS4	1.4285	227.60	61.666
MF	1.3670	61.43	0.515
MSM	1.2912	348.38	0.459
L2	1.1630	83.71	15.463
2SM6	0.9945	238.45	48.418
Q1	0.9747	219.56	10.314
MM	0.7359	187.93	0.149
RHO1	0.7181	160.78	5.599
M4	0.6918	196.30	14.463
M3	0.6364	303.23	6.260
SSA	0.6190	307.83	0.106
J1	0.5524	125.31	3.313
THE1	0.5354	329.59	3.112
SN4	0.4994	233.37	7.537
2SK5	0.4207	249.45	3.468
MO3	0.3889	208.66	2.338
MSN2	0.3778	43.13	1.632
2MS6	0.3755	202.21	6.903
EPS2	0.3708	50.22	1.572
OO1	0.3564	170.11	1.379
SO1	0.3427	324.81	1.275
2Q1	0.3186	175.09	1.102
2MK5	0.3133	4.65	1.924
ETA2	0.3097	136.42	1.096
MN4	0.2946	130.56	2.623
MKS2	0.2883	142.26	0.950
LDA2	0.2711	147.78	0.840
NO1	0.2575	260.03	0.720
S4	0.2509	266.60	1.902
2MN6	0.2345	356.36	2.692
M6	0.2336	80.83	2.671
SK3	0.2191	229.61	0.742
SIG1	0.2111	162.41	0.484
MSK6	0.2072	279.82	2.102
TAU1	0.1800	51.01	0.352
MK4	0.1627	265.12	0.800
CHI1	0.1583	107.74	0.272
OQ2	0.1541	95.17	0.271
SO3	0.1527	86.70	0.360
UPS1	0.1399	177.84	0.212
ALP1	0.1292	130.59	0.181
PHI1	0.1157	95.68	0.145
M8	0.0940	224.01	1.419
3MK7	0.0914	87.82	0.667
SK4	0.0785	237.90	0.186
BET1	0.0495	229.75	0.027
2MK6	0.0472	252.98	0.109
MK3	0.0336	168.55	0.017

Punta Arenas

Name	Amplitude	Phase	SNR
Z0	181.9091	0.00	
M2	49.6469	355.17	32153.875
K1	30.1111	65.28	15605.515
O1	21.4858	20.58	7945.623
S2	20.3277	87.29	5390.456
P1	8.6755	56.49	1295.430
L2	8.3703	44.46	913.968
N2	8.2785	318.09	894.031
K2	5.9456	90.67	461.148
M6	4.3742	104.48	627.674
MU2	4.0336	149.76	212.244
Q1	3.9150	354.11	263.808
SA	3.6979	358.55	1.411
2MS6	3.2203	163.71	340.196
2MN6	2.9324	67.40	282.087
LDA2	2.8391	31.02	105.150
NU2	2.3704	331.93	73.298
S1	2.3042	261.36	91.383
MF	2.2036	109.85	0.501
NO1	1.8921	48.74	61.619
EPS2	1.8499	111.47	44.642
MSF	1.8370	263.69	0.348
MSM	1.7557	237.03	0.318
T2	1.5397	69.47	30.926
MSN2	1.5146	280.16	29.926
J1	1.3028	96.57	29.213
MKS2	1.2885	178.43	21.658
SSA	1.1847	159.61	0.145
SO1	1.1150	309.57	21.398
GAM2	1.1083	311.70	16.024
H2	1.0849	116.04	15.354
TAU1	0.9499	45.59	15.530
2MK6	0.8893	162.30	25.944
MM	0.8006	252.14	0.066
H1	0.6460	354.78	5.444
MO3	0.6133	334.31	72.301
M4	0.5835	299.54	147.275
PI1	0.5608	59.32	5.413
RHO1	0.5497	346.04	5.201
SIG1	0.5305	338.92	4.844
2N2	0.4870	221.01	3.094
M8	0.4822	6.28	124.603
PHI1	0.4665	62.19	3.746
THE1	0.4581	65.18	3.612
2SM6	0.4492	204.26	6.619
MK3	0.4406	44.19	37.315
OO1	0.4172	186.77	2.996
PSI1	0.3774	125.05	2.451
MSK6	0.3697	209.16	4.484
CHI1	0.3388	17.21	1.976
SK3	0.3083	257.41	18.270
OQ2	0.3003	101.83	1.176
MN4	0.2995	261.61	38.801
ALP1	0.2780	233.35	1.330
2Q1	0.2611	346.96	1.173
BET1	0.2470	5.19	1.050
UPS1	0.2049	347.13	0.723
MS4	0.1791	39.20	13.875
SO3	0.1631	43.51	5.113
R2	0.0956	158.33	0.119
ETA2	0.0893	321.60	0.104
M3	0.0781	199.03	1.172
MK4	0.0522	20.91	1.179

3MK7	0.0484	130.39	1.391
SN4	0.0479	63.38	0.992
2SK5	0.0316	347.23	0.416
S4	0.0267	138.56	0.308
SK4	0.0148	247.57	0.095
2MK5	0.0144	184.69	0.086

Saint Malo

Name	Amplitude	Phase	SNR
Z0	677.7761	0.00	
M2	367.4270	177.36	538689.688
S2	143.7583	227.54	82463.625
N2	71.8372	160.96	20591.850
K2	40.9332	225.35	6685.716
M4	26.5487	278.64	14880.449
MU2	25.3157	195.74	2557.269
MS4	19.7826	335.64	8262.211
L2	18.1653	151.95	1316.684
NU2	12.3937	144.32	612.912
MN4	9.9928	255.75	2108.162
LDA2	9.4552	139.67	356.729
K1	9.4346	95.13	7614.086
2N2	8.5434	143.24	291.245
O1	8.1488	344.15	5680.127
T2	7.8087	214.73	243.307
MSN2	6.3322	12.11	159.995
EPS2	5.9065	183.64	139.206
MK4	5.6537	335.47	674.831
SN4	3.5323	344.42	263.418
P1	3.4059	84.46	992.281
M3	3.2405	170.44	2396.667
S4	2.8527	61.70	171.807
Q1	2.2862	303.13	447.094
M6	2.1563	341.95	3355.345
2MS6	2.1089	38.00	3209.451
MK3	1.5678	224.15	561.003
S1	1.4766	262.56	186.508
SK3	1.2463	270.64	354.510
2MN6	1.2457	312.44	1119.813
MO3	1.2284	144.25	344.400
SO3	0.7584	185.57	131.274
M8	0.6316	267.03	515.770
2MK6	0.6001	36.78	259.876
2SM6	0.5371	79.81	208.175