***OBSrange* v1.0 README**

DRAFT

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1 SCOPE

The primary goal of ***OBSrange*** is to provide a robust, efficient, open-source OBS location code to the marine geophysical community.

OBSrange is a set of scripts written in both MATLAB and PYTHON for precisely locating ocean bottom seismometers (OBSs) ~~via the results of~~ acoustic ranging surveys. Thus, the starting point for the code are sets of acoustic ranging survey files obtained during deployment. Using these survey files, the code inverts for instrument locations, turn-around times, and depth averaged sound speeds in water. Additionally, ***OBSrange*** generates several figures visualizing these results as well as estimates of parameters uncertainties. For a more detailed description of the algorithms we use for our inversion, synthetic tests, and our results, please refer to our paper (put reference here).

2 GETTING STARTED

2.1 Preliminaries – Dependencies and Versions

Note that the MATLAB implementation of ***OBSrange*** is completely self-contained, meaning that the MATLAB scripts don't require any toolboxes beyond those available with the standard installation. In the case of the PYTHON implementation, the scripts have been written for PYTHON 3 and require the following open-source libraries (it's recommended to have versions at least as great as the versions listed):

- numpy v1.13.1
- scipy v0.19.1
- matplotlib v2.2.2
- pymap3d v1.7.4

2.2 Survey File Format

Since acoustic ranging survey files are the input for ***OBSrange,*** in its current incarnation, these files **must** follow the format shown in the figure below.

EE01.txt

```
 1 Ranging data taken on:  2018-04-16 03:42:00.588000
 2 Cruise:                 obs-cruise
 3 Site:                   EE01
 4 Instrument:
 5 Drop Point (Latitude):  -4.94605
 6 Drop Point (Longitude): -130.38178
 7 Depth (meters):         4670
 8 Comment:                confusing depth
 9 ==================================================
10
11  6206 msec. Lat: 4 56.7506 S  Lon: 130 22.9231 W  Alt: 22.20 Time(UTC): 2018:106:10:42:35
12  6206 msec. Lat: 4 56.7506 S  Lon: 130 22.9231 W  Alt: 22.20 Time(UTC): 2018:106:10:42:35
13  6205 msec. Lat: 4 56.7497 S  Lon: 130 22.9234 W  Alt: 23.49 Time(UTC): 2018:106:10:42:43
14  6205 msec. Lat: 4 56.7491 S  Lon: 130 22.9234 W  Alt: 24.17 Time(UTC): 2018:106:10:43:43
15  6206 msec. Lat: 4 56.7477 S  Lon: 130 22.9239 W  Alt: 25.43 Time(UTC): 2018:106:10:44:43
16  6205 msec. Lat: 4 56.7474 S  Lon: 130 22.9223 W  Alt: 25.25 Time(UTC): 2018:106:10:45:44
17  6204 msec. Lat: 4 56.7552 S  Lon: 130 22.8851 W  Alt: 24.39 Time(UTC): 2018:106:10:46:44
18  6206 msec. Lat: 4 56.8168 S  Lon: 130 22.8162 W  Alt: 25.79 Time(UTC): 2018:106:10:47:44
19  6218 msec. Lat: 4 56.8816 S  Lon: 130 22.7224 W  Alt: 24.21 Time(UTC): 2018:106:10:48:44
20  6246 msec. Lat: 4 56.9525 S  Lon: 130 22.6149 W  Alt: 23.71 Time(UTC): 2018:106:10:49:45
21  6295 msec. Lat: 4 57.0161 S  Lon: 130 22.4979 W  Alt: 22.30 Time(UTC): 2018:106:10:50:45
22  6359 msec. Lat: 4 57.0784 S  Lon: 130 22.3800 W  Alt: 20.71 Time(UTC): 2018:106:10:51:45
23  6438 msec. Lat: 4 57.1397 S  Lon: 130 22.2617 W  Alt: 18.13 Time(UTC): 2018:106:10:52:46
24 Event skipped - Timeout or Badly formatted data was received
25 Event skipped - Timeout or Badly formatted data was received
26  6584 msec. Lat: 4 57.2314 S  Lon: 130 22.0897 W  Alt: 16.39 Time(UTC): 2018:106:10:54:13
27  6703 msec. Lat: 4 57.2942 S  Lon: 130 21.9712 W  Alt: 16.22 Time(UTC): 2018:106:10:55:14
28  6831 msec. Lat: 4 57.3579 S  Lon: 130 21.8519 W  Alt: 16.05 Time(UTC): 2018:106:10:56:14
29  6976 msec. Lat: 4 57.4197 S  Lon: 130 21.7348 W  Alt: 15.86 Time(UTC): 2018:106:10:57:14
30  *7132 msec. Lat: 4 57.4839 S  Lon: 130 21.6154 W  Alt: 19.01 Time(UTC): 2018:106:10:58:15
31 Event skipped - Timeout or Badly formatted data was received
32 Event skipped - Timeout or Badly formatted data was received
33 Event skipped - Timeout or Badly formatted data was received
```

Note that the survey file in this example is a *.txt* file that has been generated by a Scripps Institute of Oceanography (SIO) PYTHON script (is there a specific name for this script? More professional way to reference it?). In practice the acoustic ranging survey is conducted using an EdgeTech 8011M deck box or a similar instrument (find actual instrument name if not this one) ~~and the SIO script simply formats the output from the EdgeTech deck box into a *.txt* file like the one shown above.~~ The header information is contained in exactly 9 lines followed by a blank line at the 10th line. From the 11th line onward the results of individual "pings" (sonar sends and receives) are logged. The necessary data obtained from the header of these *.txt* files by ***OBSrange*** are the site name, drop coordinates, and estimated drop depth. And below the header, ***OBSrange*** reads in the two-way travel time of each ping, the ship coordinates *when each ping was received*, as well as the *UTC* time at which each ping was received. Finally, in the figure of the example *.txt* file shown above, we see that bad results either begin as "Event skipped ..." or are flagged by an asterisk. ***OBSrange*** *can* handle both of these cases, in that it does not read in such results, but note that bad results **must** be designated in this exact manner for the time being.

2.3 Setting Parameters

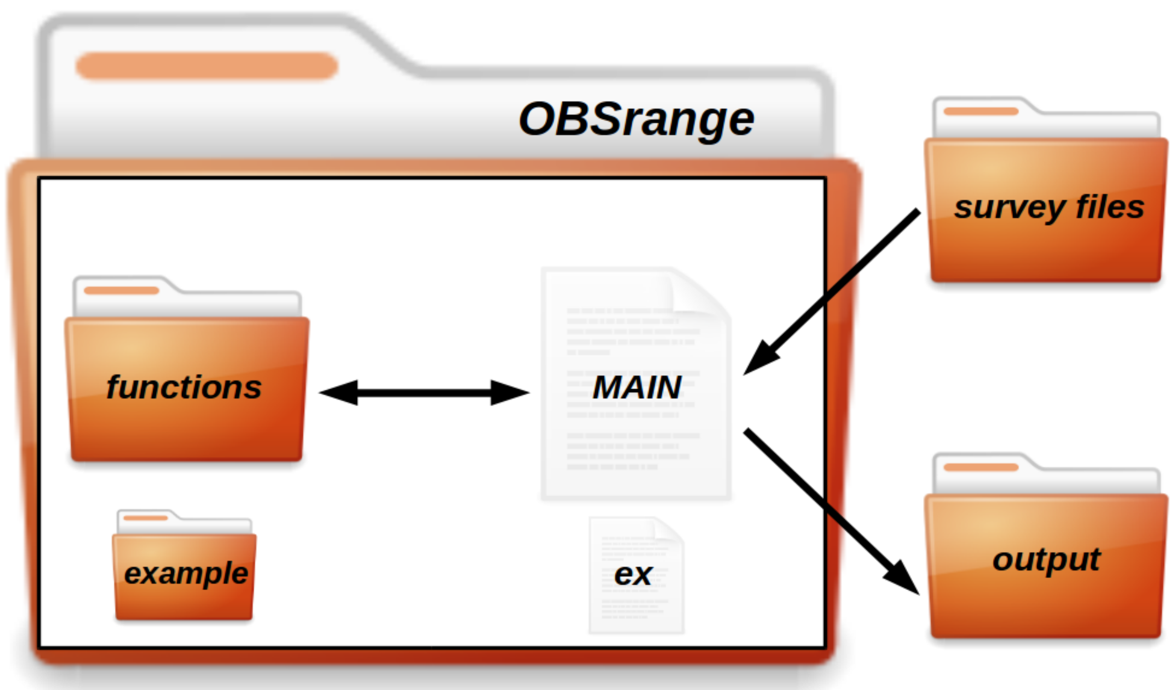
Slight design differences exist between the MATLAB and PYTHON versions of the code, but the main usage remains the same between the two. In both cases parameters are set in a single main script which will run and execute every other aspect of the code. Ideally, the only edits users ever need make are in editing the parameters of these main scripts. In the case of the MATLAB version, this script is called *MAIN_locate_OBS_bootstrap.m* and these parameters are set in the top lines of that script. In the case of the PYTHON version, the main script is simply called *OBSrange.py*, and parameters are set in that script. The parameters to be set by users are described and compared in the following table (sorted alphabetically by MATLAB parameter names):

MATLAB Parameter	PYTHON Equivalent	Description
datapath	*survey_fles*	Path to the directory containing the survey files.
ifplot	-	Option to plot results. In PYTHON plots are created and saved by default but not displayed when *OSBrange.py* is run. In MATLAB plots are created, saved, and displayed while running *MAIN_locate_OBS_bootstrap.m* only if this parameter is set to 1.
ifQC_ping	*QC*	Option to perform quality control on ping results obtained from the survey files. Pings with two-way travel times beyond a certain threshold are filtered out of any analysis (see *res_thresh* below).
ifsave	-	By default the MATLAB version will write single station results to *.txt* files. If this parameter is set to 1, then it will additionally write single station results to *.mat* files. PYTHON writes single station results to both *.pkl* and *.txt* files by default.
onesta	-	Option to process a single station. PYTHON will process whatever survey files are located in the directory represented by *survey_fles*.
outdir	*output_dir*	Path to output directory.
par.dampdvp	*dampdvp*	Normal damping for water sound speed.
par.dampTAT	*damptat*	Normal damping for turn-around time.
par.dampx	*dampx*	Normal damping for station x-coordinate.
par.dampy	*dampy*	Normal damping for station y-coordinate.
par.dampz	*dampz*	Normal damping for station z-coordinate.

par.epsilion	*eps*	Global norm damping for stabilization.
par.if_twtcorr	*twtcorr*	Option to apply a correction to two-way travel times due to the ship's radial velocity.
par.N_bs	*N_bs*	Number of bootstrap iterations.
par.E_thresh	*E_thresh*	RMS reduction threshold for the inversion.
par.npts_movingav	*npts*	Number of points in an *N*-point moving average smoothing filter applied to the ship's velocity. Note that if this parameter is set to "1" that no smoothing is applied.
par.TAT_bounds	*bounds*	Bounds for turn-around time ~~solutions.~~
par.TAT_start	*tat*	~~Assumed~~ turn-around time.
par.vp_w	*vpw*	~~Assumed~~ water velocity.
projpath	-	Directory for both input and output (MATLAB only).
res_thresh	*res_thresh*	Residual threshold for pings if applying quality control (see *ifQC_ping/QC* above).

Again, in both the MATLAB and PYTHON versions, once these parameters have been set, these scripts may be run and will produce results.

2.4 Structure



In this section we~~'ll~~ briefly describe the general structure of ***OBSrange***, illustrated in the above figure. In both the MATLAB and PYTHON versions of the code, the top-level directory of ***OBSrange*** includes the main script (*MAIN_locate_OBS_bootstrap.m* or *OBSrange.py*, respectively), in which the parameters for running the code are set by the user (see previous section). Once parameters have been set, the main script can be run; it will loop through files in the survey files ~~sub-~~directory~~, making several calls to~~ various functions contained within the functions ~~sub-~~directory. All results will be written into an output ~~sub-~~directory. Note that paths to the ~~sub-~~directories for the survey files and output are specified by the user in the main script. In the case of the MATLAB version, these ~~sub-~~directories are themselves contained within a single folder, set via the *projpath* variable. Finally, ***OBSrange*** includes a single station example which will be discussed in the next section.

3 EXAMPLE

3.1 General Output

The example provided with ***OBSrange*** locates the OBS package deployed at site WC03 of the PacificORCA array (reference). Simply run the example script for your corresponding version of the code, either *OBSrange_example.py* or *MAIN_locate_OBS_bootstrap_ex.m*. These scripts will read the example survey *.txt* file contained within ***OBSrange***'s example sub-directory (see previous figure) and will also write the output into that sub-directory. In the case of the PYTHON version, the output will consist of a *.pkl* file named *WC03_location.pkl*, a *.txt* file similarly named *WC03_location.txt*, and six figures. In the case of the MATLAB version the output will consist of a *.txt also* named *WC03_location.txt*, a *.mat* file called *WC03_data.mat*, and the same ~~6~~ figures.

3.2 The .txt files

PYTHON example has been seeded np.random.seed(0), so output in the *.txt* should look **exactly or nearly exactly** like the figure below. Is there a way to do this in MATLAB?

The *.txt* files created by the MATLAB and PYTHON versions are formatted slightly differently, but the results are the same. In the figure below we show the first 40 lines of *WC03_location.txt* created by the PYTHON version and describe the general features of this file.

```
WC03_location.txt
 1  Bootstrap Inversion Results (± 2σ uncertainty)
 2
 3     Station: WC03
 4         Lat:    -5.70770 ° ± 0.00002
 5         Lon:  -134.09130 ° ± 0.00003
 6           X:    -27.75585 m ± 3.19437
 7           Y:     15.93968 m ± 2.22539
 8       Depth: -4487.35169 m ± 9.14744
 9         TAT:     13.57709 m ± 1.52709
10  Water Vel.:  1508.25005 m ± 2.69316
11       Drift:     32.04250 m ± 2.47205
12    Drift Az:   299.92331 m ± 5.36596
13          dz:      2.64831 m ± 9.14744
14
15         RMS:      2.22005 ms ± 0.68317
16
17  Bad Pings Removed: 2
18  ================================================================================
19         Lat (°)   Lon (°)     Range (m)   Resid (s)  Vr (m/s)  TWT corr. (ms)
20     1    -5.70585  -134.09381  4500.31179   3.21938   0.00000   0.00000
21     2    -5.70585  -134.09381  4501.19851  -2.34280  -0.03479  -0.13795
22     3    -5.70627  -134.09350  4490.71719  -1.54593  -0.06358  -0.25189
23     4    -5.70677  -134.09312  4488.98180  -2.46242  -0.05432  -0.21505
24     5    -5.70756  -134.09283  4487.68038  -1.21277  -0.01463  -0.05787
25     6    -5.70854  -134.09286  4488.21031   0.45123   0.06119   0.24216
26     7    -5.70968  -134.09342  4507.29197  -2.26024   0.19252   0.76298
27     8    -5.71060  -134.09496  4520.16749   0.20216   0.39501   1.57183
28     9    -5.71133  -134.09693  4552.45671   2.48054   0.62396   2.50033
29    10    -5.71207  -134.09898  4591.04820   3.24125   0.83524   3.37982
30    11    -5.71303  -134.10085  4644.68120   2.06181   1.01877   4.17063
31    12    -5.71498  -134.10449  4783.88016   7.59024   1.29091   5.44864
32    13    -5.71833  -134.10792  4983.77033   2.43887   0.47544   2.09164
33    14    -5.72947  -134.08964  5092.72356   1.29795   0.37464   1.68208
34    15    -5.72919  -134.08764  5093.15573  -2.38731  -0.30793  -1.38116
35    16    -5.72681  -134.08426  5026.87496   0.68485  -0.56207  -2.48760
36    17    -5.72535  -134.08298  4989.03855  -2.39669  -0.67885  -2.97795
37    18    -5.72371  -134.08172  4941.35851  -4.08709  -0.60521  -2.63294
38    19    -5.71964  -134.07870  4879.23393  -0.37932  -0.20320  -0.87393
39    20    -5.71789  -134.07747  4876.21538  -0.80651  -0.05663  -0.24315
40    21    -5.71608  -134.07628  4880.33943   1.39850   0.03467   0.14893
```

In both versions, the header of *WC03_location.txt* summarizes the main results of the inversion performed by ***OBSrange*** on this station. Shown in the header are the final estimates for the *X* and *Y* coordinates of the package relative to the drop point, as well as their converted latitude and longitude, the sensor turn-around time (*TAT*), and the final depth estimate (*Depth)*. Additionally, the header contains the total package drift distance (*Drift*) and azimuth (*Drift Az.*), the difference between the initial estimated depth and final depth estimate (*dz*), and the depth averaged velocity of sound in water (*Water Vel.*). Finally, the header contains the overall *RMS* misfit for this site and also displays the number of pings that were removed via the ping quality control. Below line 18 of *WC03_location.txt* the details of each ping are logged, namely, the ship latitude, longitude, estimated distance to the sensor, two-way travel-time residual, the ship's radial velocity and corresponding travel-time correction (whether it was applied or not).

3.3 The *.pkl* and *.mat* Files

In this example PYTHON will also create a *.pkl* file called *WC03_out.pkl* and MATLAB will create a *.mat* file called *WC03_out.mat*. In essence, both of these files are simply containers which hold various results of the bootstrap inversion. The *.pkl* file contains a PYTHON *dictionary* object of various results and values and the *.mat* file contains a *1x1 struct* object called *datamat.* Both data structures contain many of the same fields, all of which are listed in the table below (sorted alphabetically by MATLAB parameter names):

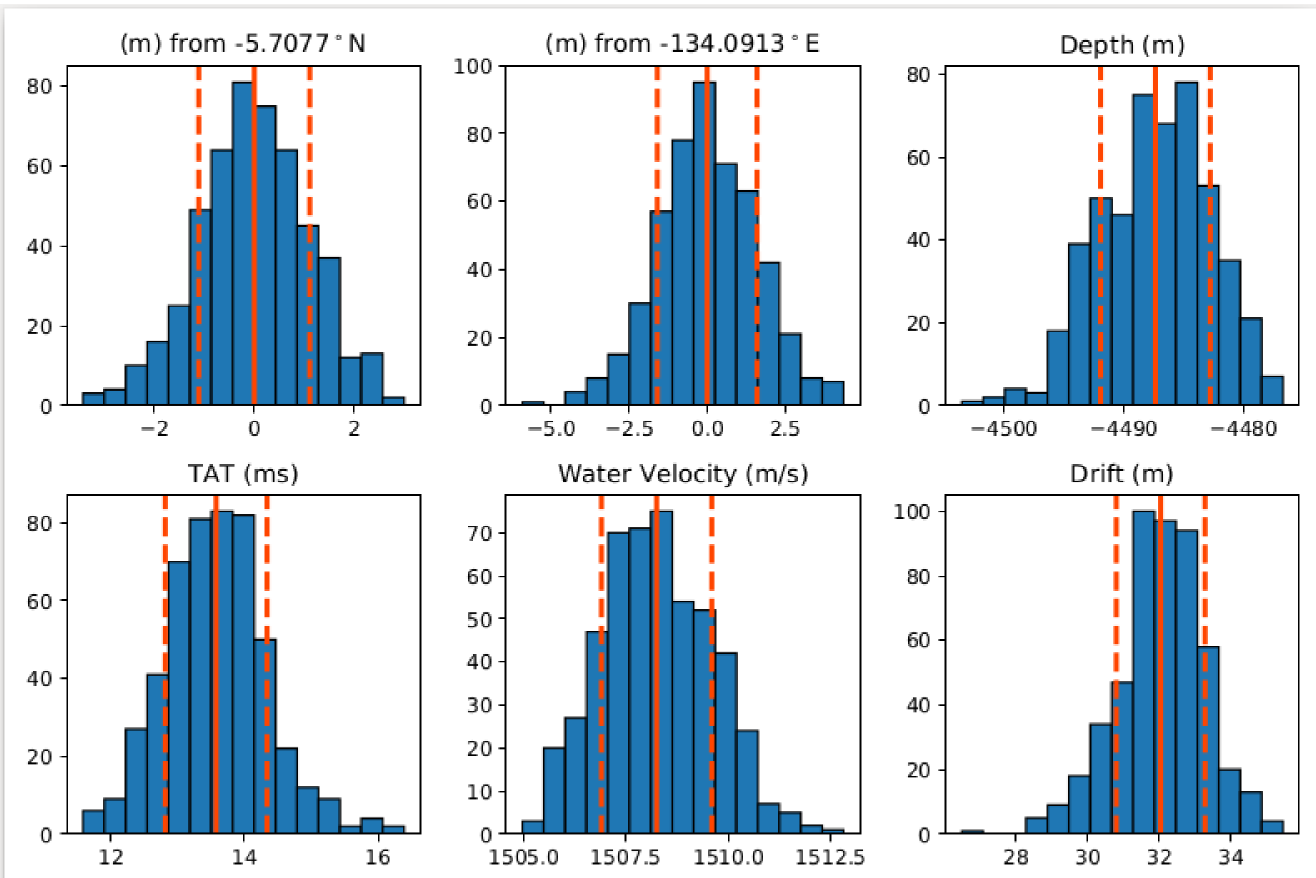
MATLAB	PYTHON	Description of Field
-	vrs	Ship's radial velocity at each survey point
-	Nbad	The number of pings removed via quality control
-	dzs	The depth difference after each bootstrap iteration
azi_bs	azs	Sensor drift azimuth after each bootstrap iteration
Cm_mat	cov	Model covariance matrices after each bootstrap iteration
drift_bs	drifts	Sensor drift distance after each bootstrap iteration
drop_lonslatz	drop_geo	Geographic drop coordinates
dtwt_bs	dtwts	Final twtt residuals at each survey point
dtwtcorr_bs	corrs	Final twtt corrections at each survey point (whether applied or not)
E_rms	E_rms	RMS after each bootstrap iteration
Ftest_res	Ftest_res	F-test grid search results
lat_sta_bs	lat_sta	Sensor latitude after each bootstrap iteration
lats_ship	svy_lats	Latitudes of survey points
loc_lolaz	loc_geo	Final sensor location (geographic coordinates)
loc_xyz	loc_xyz	Final sensor location (Cartesian reference frame)
lon_sta_bs	lon_sta	Sensor longitude after each bootstrap iteration
lons_ship	svy_lons	Longitudes of survey points
mean_drift_az	drift_az	Final sensor drift distance and azimuth
R_mat	resol	Model resolution matrices after each bootstrap iteration
sta	sta	Station name
TAT_bs	tats	Sensor turn-around time after each bootstrap iteration
twtcorr_bs	twts	Final two-way travel-times (twtts) at each survey point

v_ship	svy_vs	Ship velocity vectors at survey points
V_w_bs	vpws	Average speed of sound in water after each bootstrap iteration
x_ship	svy_xs	x-coordinates of survey points
x_sta_bs	x_sta	Sensor x-coordinate after each bootstrap iteration
y_ship	svy_ys	y-coordinates of survey points
y_sta_bs	y_sta	Sensor y-coordinate after each bootstrap iteration
z_ship	svy_zs	z-coordinates of survey points
z_sta_bs	z_sta	Sensor z-coordinate after each bootstrap iteration

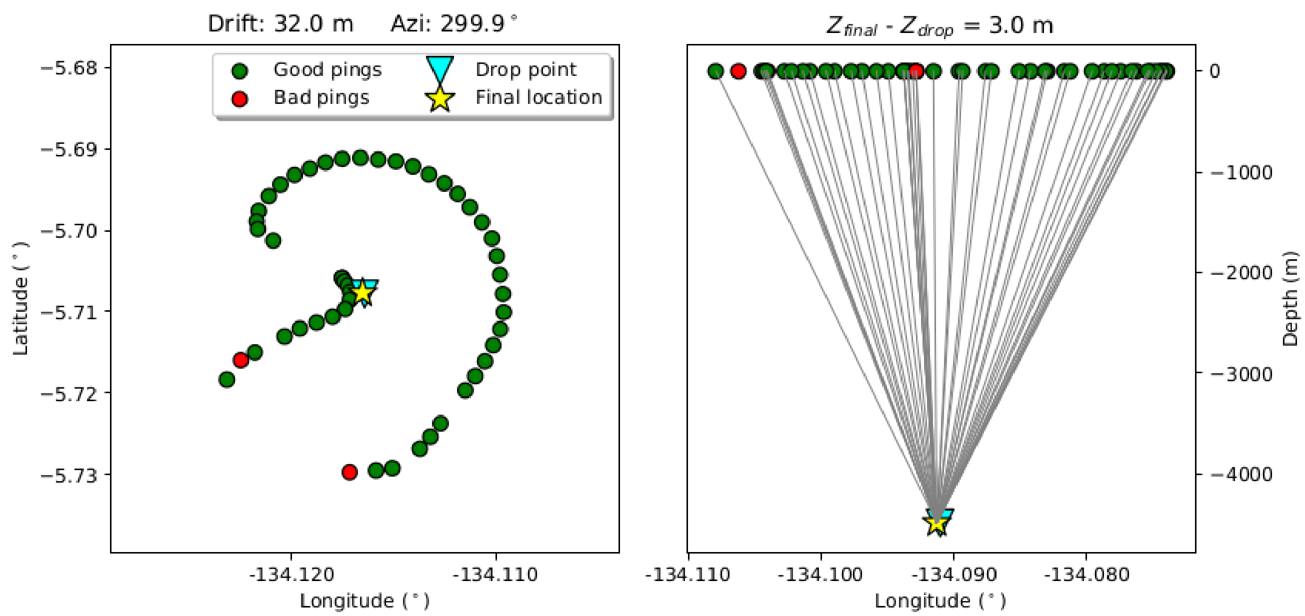
3.4 Figures

We now show the six figures produced after running ***OBSrange.py.***

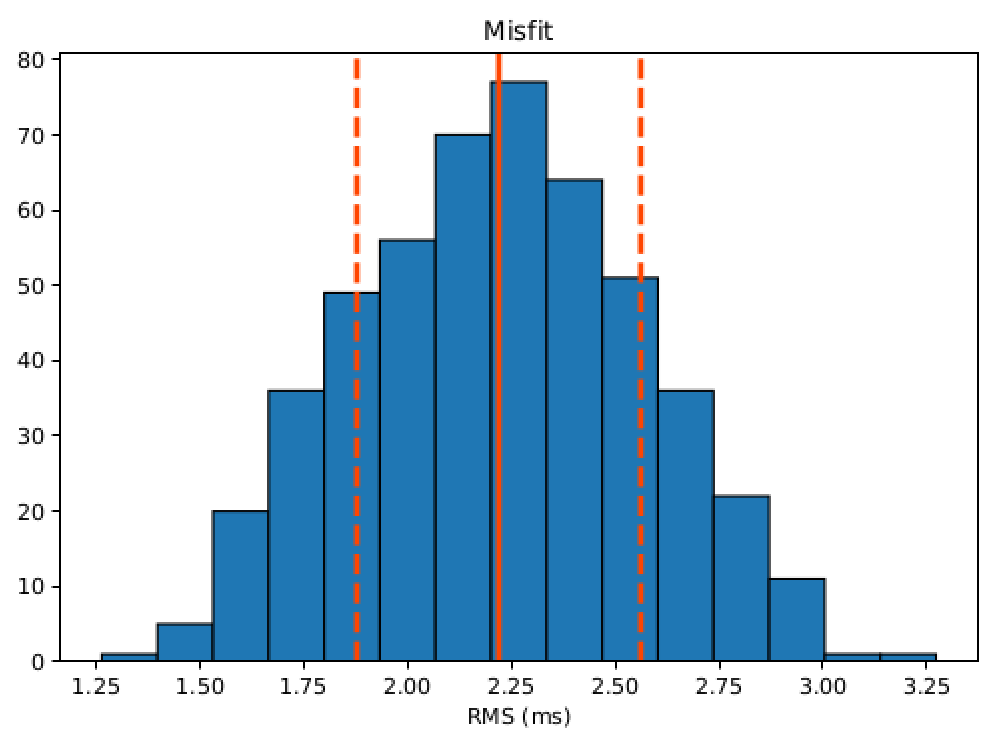
3.4.1 Model Parameter Histograms



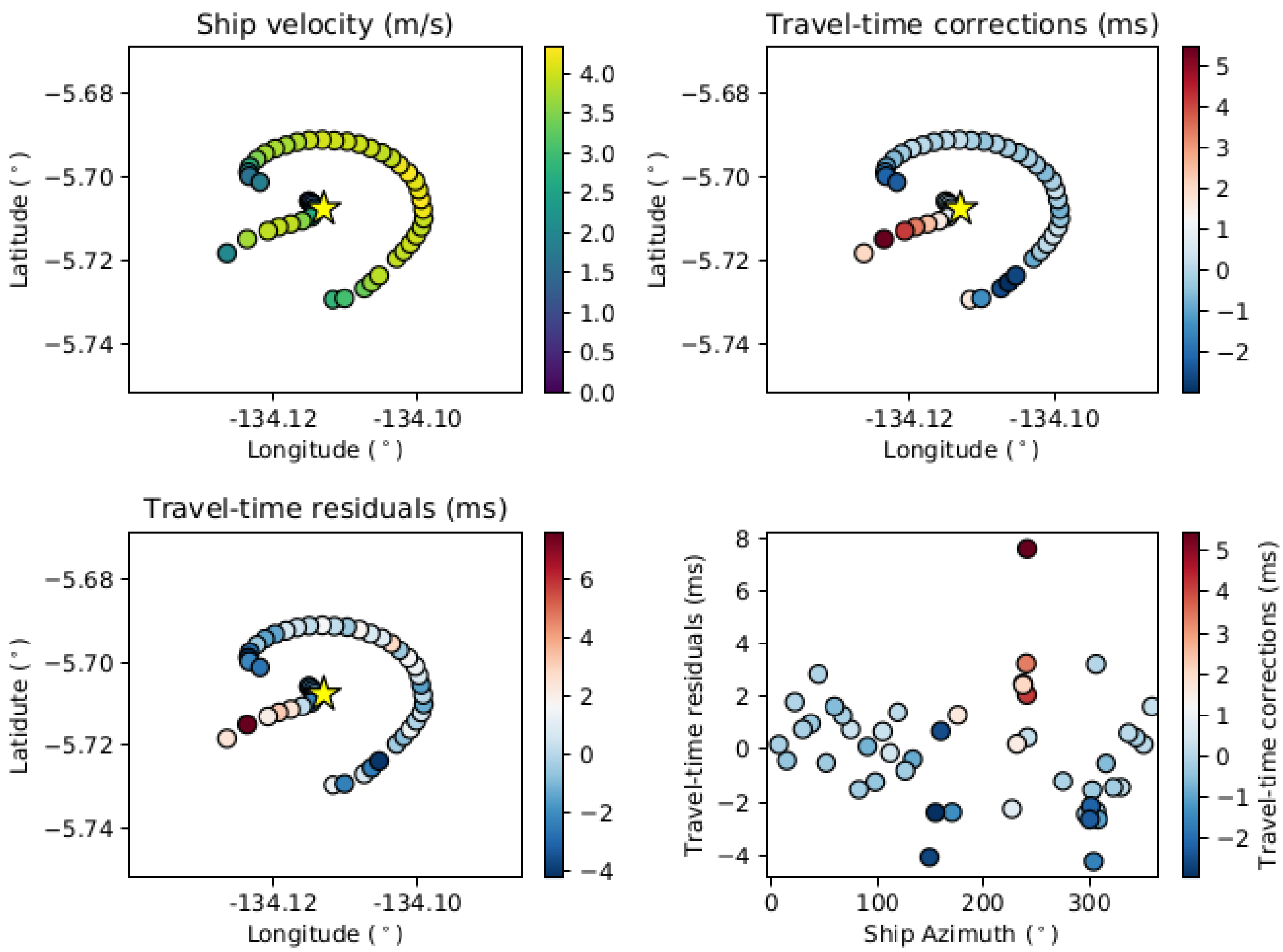
3.4.2 Survey Maps



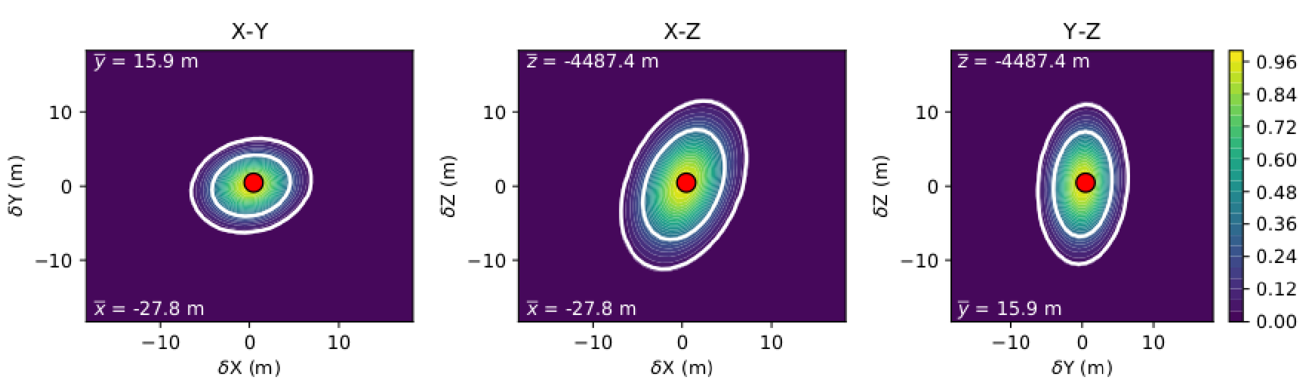
3.4.3 Final Model Misfit



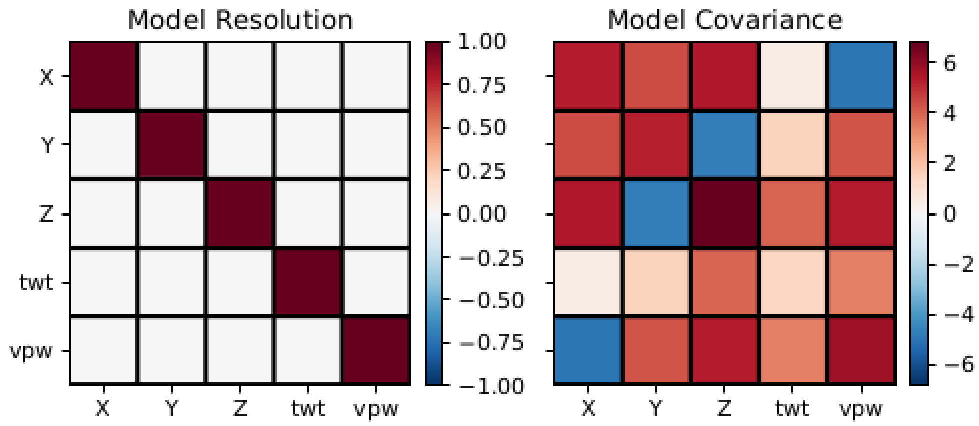
3.4.4 Two-Way Travel-Time Residuals by Survey Point



3.4.5 F-Test Derived Location Uncertainty



3.4.6 Final Model Resolution and Covariance



REFERENCES

Our Paper

Others?