Dear OBSIP,

I am writing to request a recut of all of the Santorini OBS SEGY data to correct three timing errors: (i) Langseth source timing errors on all OBS, (ii) time drift on SIO OBS 102, (iii) two additional timing statics. We have also relocated some mislocated source positions and provide the final seafloor locations of the OBS. Our report on determining these corrections is attached (*OBSRelocation_Update_version_2.docx*)

OBS SEGY data recut:
Together with the folks on the Langseth, we have nailed down a source timing offset that existed during the first 3 days of the Santorini experiment - a trigger line with a 160 millisecond delay was inadvertently being used. I am attaching a new corrected shot file (*MGL1521.obsip.v3*) in which 160 sec have been added to the recorded shot time for all shots prior to, but not including, shot # 15122.

SIO OBS 102 timing correction:
Our OBS relocation process shows that a timing correction needs to be applied to this station. We solve for a drift of -0.006s/day (-6.9^10^-8 s/s) and an offset of -.00093s. In this definition the station, at the time of the first shot, was already early by ~1 ms and continued to get earlier by 6 ms per day. The ~1 ms offset is with respect to the first shot instance, which I have as epoch time 1.448256844930804e+09. Let me know if you need this defined differently or in different units.

SIO OBS 107 and OBS 126:
Jeff resolved timing issues on these two stations using common earthquakes and was already planning to recut the SEGY for these sites (email from May 3, 2016). We have not yet received the SEGY files.

Request: Could I get a record of the timing corrections that were applied to the SIO and the WHOI stations?
At the end of the cruise Ernie mentioned to me that a couple of the stations had large time drifts. However, I have no record of the timing corrections that were applied. I would like to add this to the cruise report. It is a useful reference for assessing issues like the above.

Relocations SHOT positions and two additional shot statics:
Some of the shots on line 17 had source positions that were mislocated and there were two shots with additional large timing offsets (subtraction of 0.2124 sec from the recorded shot origin time). We have solved for these using the water wave arrivals.
I have attached another shot file in which the 160 sec static for shots < 15122 is applied AS WELL AS corrections for the Source locations and additional time statics for line 17 (shots 14820 to 15165 with time statics on shots 15133 and 15134) have been corrected (*MGL1521.obsip.v4*). We have NOT corrected the ship location in this file particular shots.

Relocations OBS positions:
We have relocated the OBS for which we had time correct SEGY files and a file with the final locations is also attached. Is it possible for these locations to go into the SEGY header? I have

attached an Excel file which contains the relocated OBS positions as well as my notes on each OBS (*OBSInstrumentTable1-Relocated_v2.xlsx*)

We would like to have the SEGY files regenerated to correct for the timing offsets and timing drifts and also to include the final source and station positions. Once this is received we will be able to make final picks on the data!

Please let us know where we can clarify anything.

Thanks,
Emilie

OBS Relocation Process

The following describes how the Ocean Bottom Seismometer (OBS) positions on the sea floor were determined and the time offsets and mislocations of the airgun source that were identified in this process. The OBS were relocated using the water wave (P_w) arrival times from air gun shot at distances predominately < 2 km from the station and inverted to determine station locations.

<u>Pw phase picking:</u> Water wave arrival time picks were made for subregions of the experiment by Ben Heath and Dan O'Hara. The SEGY data was filtered using a Butterworth filter with frequencies between 30 and 90 Hz; a reduction velocity of 1.5 km/s (typical velocity of P-wave through water) was applied to better view the water wave arrivals; data was scaled as needed to best visualize the Pw phase; and an uncertainty of 5 ms was assigned to the arrival time. The zero crossings associated with the highest-amplitude wave features were picked (Fig. 1). Picking on water wave first motion as opposed to the highest amplitude wave features gives noticeably erroneous travel times because the shot time records the time of peak energy and not the time of first energy.

<u>Relocation inverse problem</u>: The station locations were determined using a script written by William Wilcock at the University of Washington, obsloc. On the basis of the shallow depths of the OBSs and the sound velocity profile determined using XBTs during the cruise, we assumed a constant water velocity of 1.52 km/s for the inversions. Initial RMS travel time misfits varied from 4 to 58 msec. Final RMS travel time misfits of less than 5 msec were considered good OBS location determinations, whereas higher values suggested arrival times needed to be inspected. All station locations ended with rms values of ~10 ms or less.

<u>Time offsets for the airgun source</u>: We discovered that the earliest shot lines of the experiment had very large (~160 msec) initial RMS misfits (Fig. 2). Upon inspection of the record sections this was found to be due to an offset in timing of the airgun source (See Appendices: *Santorini_StaticOffest.pdf* and *MGL1521 Shot Timing Issues.pdf*). To correct for the offset in source, an a priori static 160 ms offset was added to the recorded origin time of these shots. This corresponds to removing 160 ms from the travel times that were picked on the uncorrected record sections. This correction was applied to shots occurring <u>before</u> (but not inclusive of) eventid 15122.

<u>Issues with OBS102</u>: Station 102 has large and inconsistent misfits. To understand these misfits we picked a larger number of arrivals, choosing more lines that spanned a larger range of shot origin times. While plotting misfit as a function of shot position showed that the residuals were not predominately due to station mislocation (see initial residuals figure for Station 102), plotting misfit as a function of shot origin time showed a clear consistent pattern where residuals increased with increasing shot origin time (Figure 3). This means that station 102 suffers from clock drift. To account for this issue, we solve for both a slope and static offset of the clock drift for station 102 (and only station 102), finding a slope of ~-6 ms/day (negative means station clock was faster than the actual clock) and an offset ~0.9 ms (where positive offset means the station clock was late). Solving for both the clock drift terms as well as associated mislocation drastically reduced the associated misfit with this station from ~59 ms to ~8 ms.

Line 17 Shot Relocation: It was noticed based on variations in the water wave arrival time that several shots from line 17 were clearly mislocated. To locate these shots, we picked many near proximity stations. Keeping shots with 6 or more station picks, we are able invert for event locations. We invert using the station locations found using the approach described above. We invert only for x and y locations. We use a water velocity of 1.5163 km/s and delay our travel times by ~3 ms. These values were found by plotting water wave travel time as function of range and fitting a linear line (Figure 4). The 3 ms delay is likely due to the fact that we pick the zero crossing near the maximum amplitude as opposed to the maximum amplitude itself (see Section on Pw phase picking). Two shots are very poorly fit by this analysis (event ids 15133 and 15134) because these shots also had timing errors. We average the associated a priori residuals from these events to solve for the timing offset (adding 0.2414 sec to the travel time, or subtracting 0.2414 sec from the recorded origin time of these two shots). Using the new residuals we solve for event position. Event locations before and after solving for these various spatial and temporal effects are shown below (Figures 4,5 and 6).

****Line 4 was noticed to have similar problems to line 17. Specifically, there appear to be clear and obvious shot origin time errors. These errors have NOT been corrected. We have avoided picking traces with clear origin time errors. ****

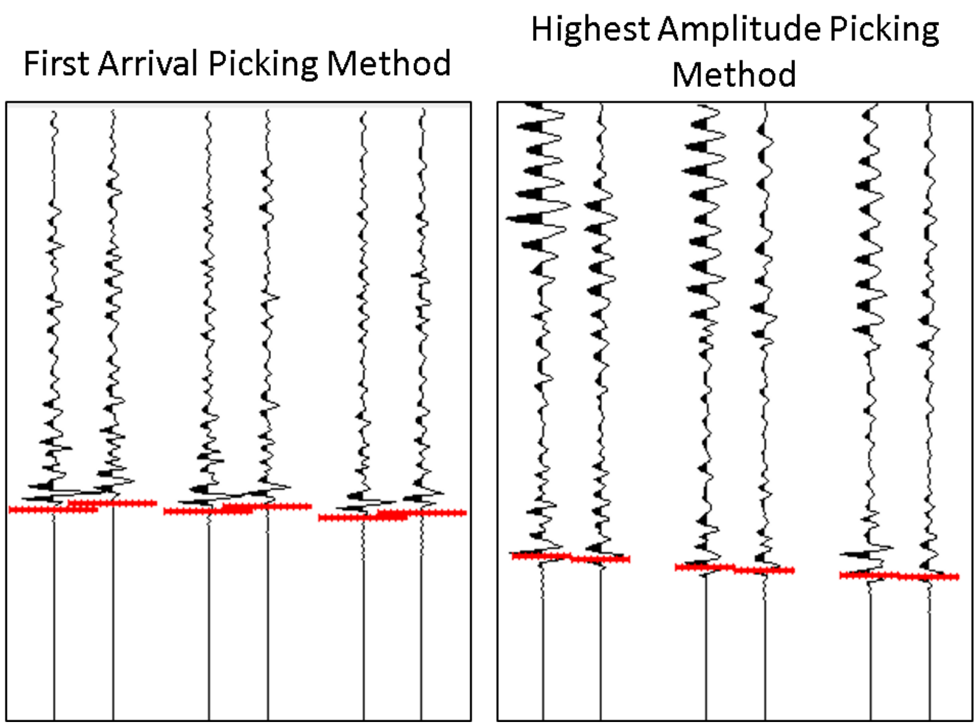

Figure 1 – Methods used for picking P_w arrivals. The latter method is the preferred method because shot times reflect time of maximum and not initial energy. For the highest amplitude picking method we pick the zero crossing associated with the highest amplitude features.

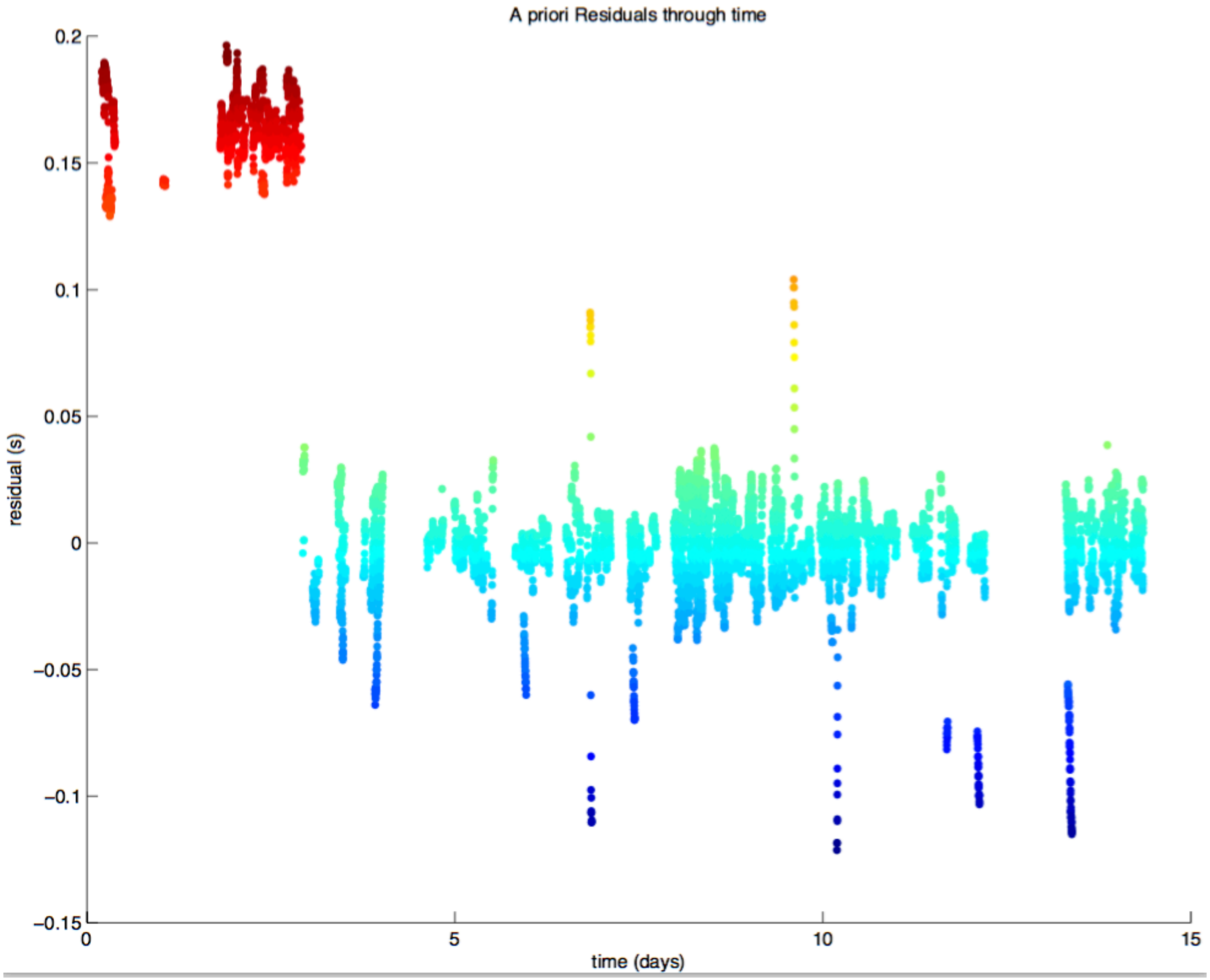

Figure 2 Plot of residuals as function of shot origin time. Dots are colored by residual (y axis). We can see a clear offset of ~.16 s for the first several days.

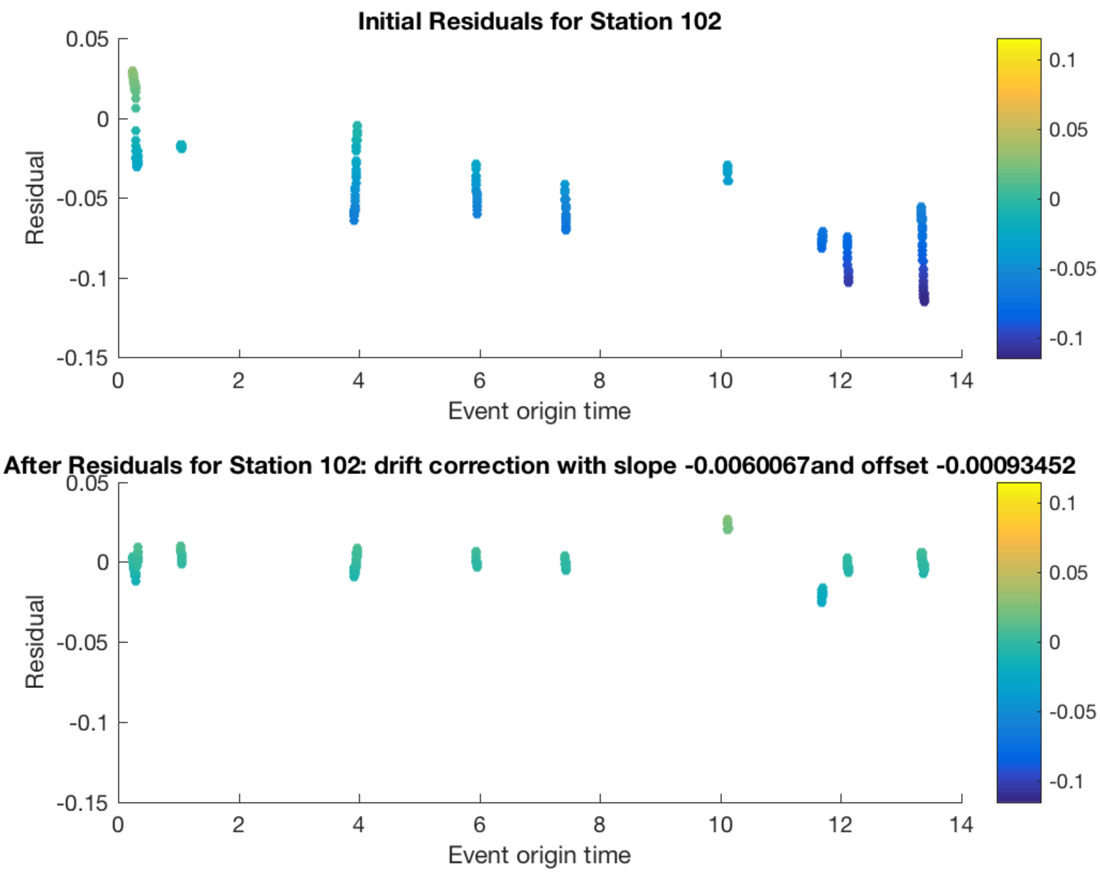

Figure 3 – Residuals for line 102 as function of event origin time (days). We can see a clear linear drift

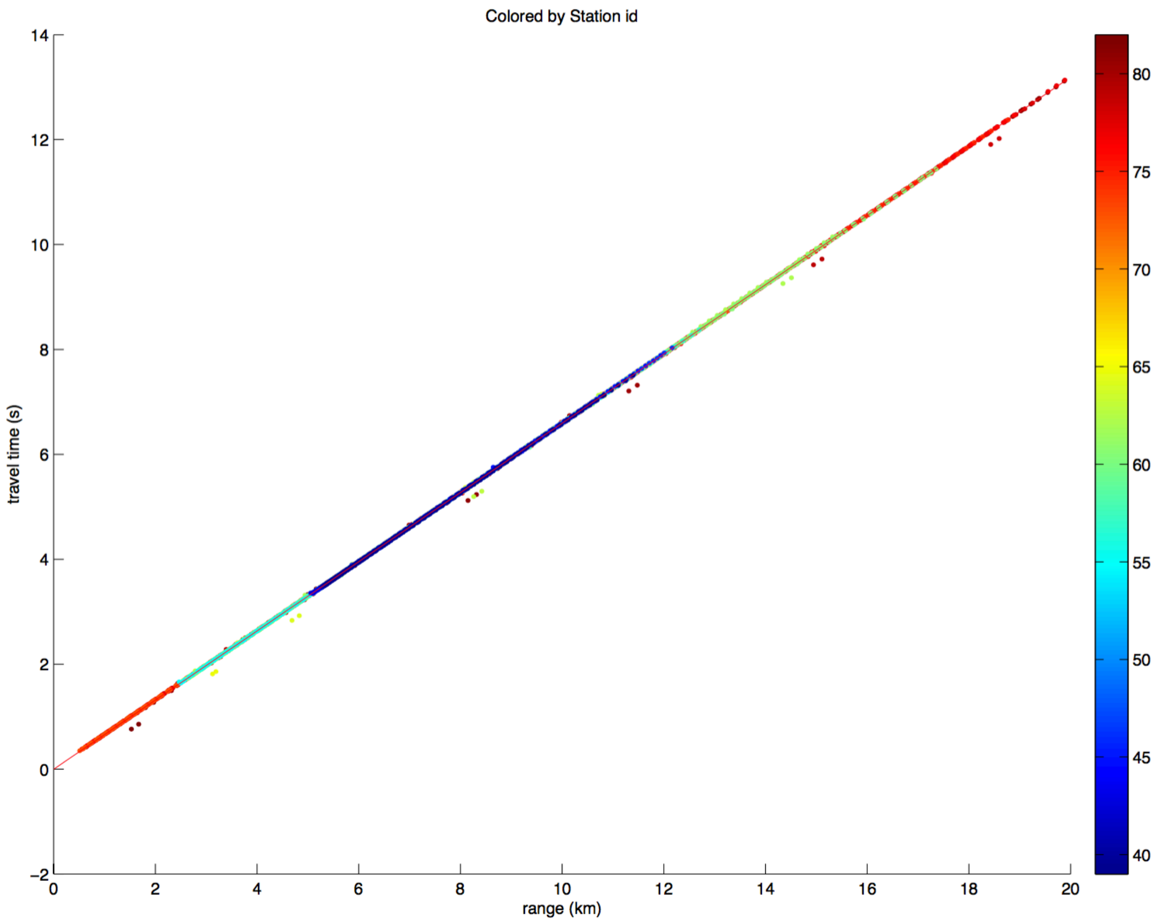

Figure 4: Plot of travel time as a function of range for line 17. We can see the picks are quite accurate. There are several noticeable picks that fall off the linear trend. These are due to two events with time errors (event ids 15133 and 15134).

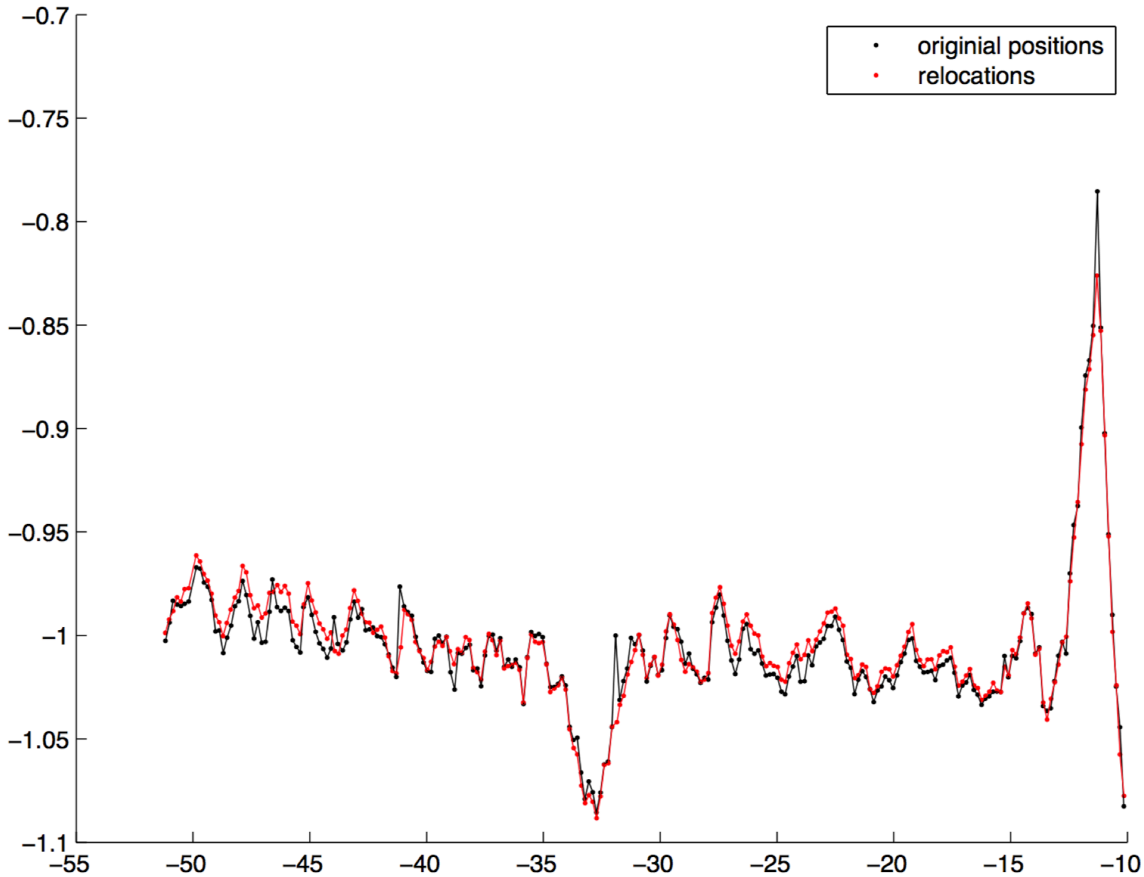

Figure 5: Line 17 Event relocations as a function of x and y.

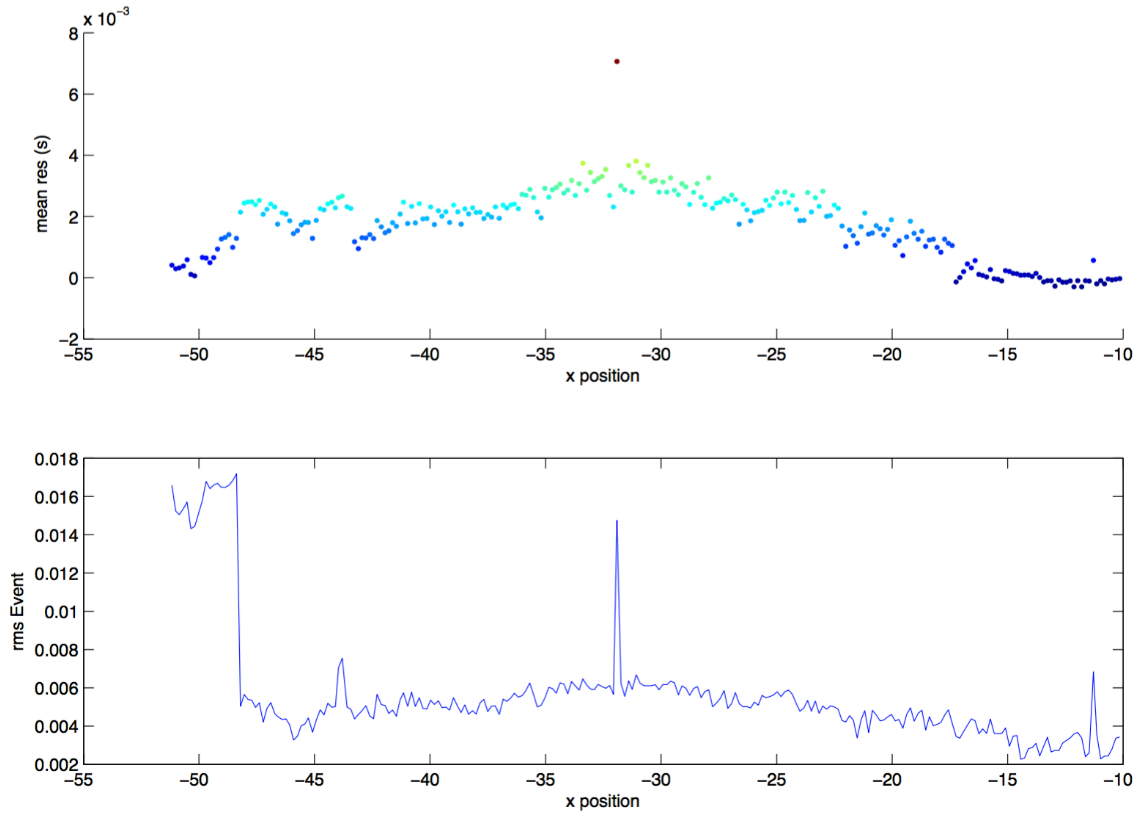

Figure 6: Plots of mean residuals and rms residuals for all relocated events on Line 17, plotted as a function of x position (position along the line).