Amplitude-dependent station magnitude

Y. Radzyner[1], Y. Ben Horin[1] and D.M. Steinberg[2]
(1) NDC of Israel Soreq NRC
(2) Department of Statistics and Operations Research, Tel Aviv University.

CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE
T1.2-P3

Introduction

The magnitude adjusts measurements of ground motion for epicentral distance and source depth. The IDC defines the j'th station body wave magnitude for event i as:

$$m_b(sta_{j,i}) = \log_{10}(A_{j,i}/T_{j,i}) + C(\Delta_{j,i}, h_i) \qquad (1)$$

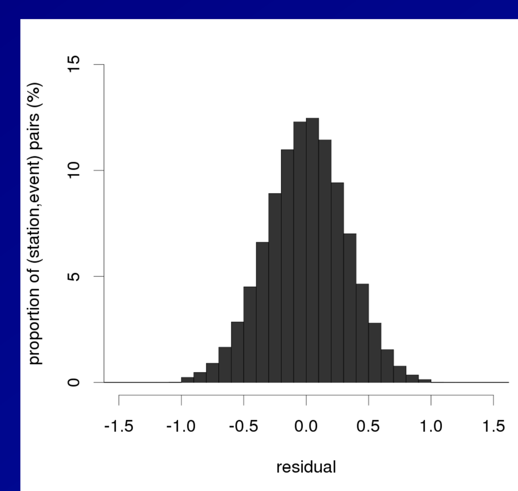
Where $A_{j,i}$ is the maximum ground motion amplitude within a 5 seconds window after the P arrival, $T_{j,i}$ is the associated period, and C is the Veith-Clawson correction, which depends on epicentral distance ($20^o<\Delta_{j,i}<105^o$) and source depth (h_i).

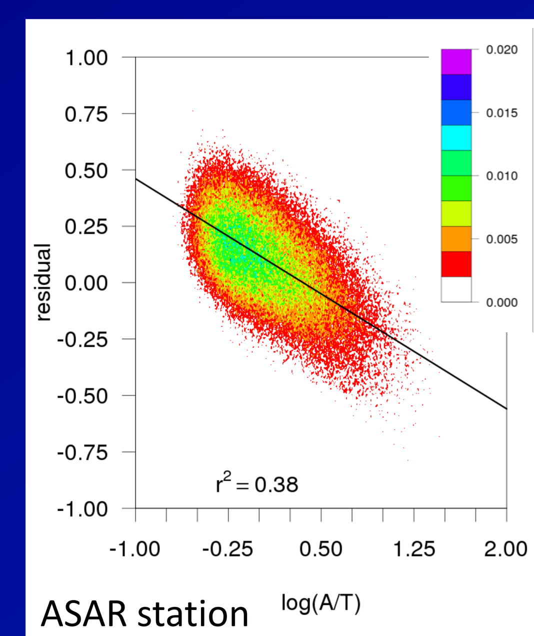
The network magnitude is calculated as the average of station magnitudes. The IDC magnitude estimation is used for event characterization and discrimination and it should be as accurate as possible.

The residual is defined as the difference between the network magnitude and the station magnitude for that event.

Observation

We notice that the residual is of the order of the station magnitude and depends linearly on log(A/T).





Goal

Eliminate systematic dependence of the residual on log(A/T). This would reduce the residual, rendering the magnitude more reliable.

Linear Station Corrections

Taking into account the observed dependence of the residual on log(A/T) we suggest:

$$m_b^{new}(sta_{j,i}) = (a_j + 1)\cdot \log_{10}(A_{j,i}/T_{j,i}) + C(\Delta_{j,i}, h_i) + b_j \qquad (2)$$

Where a_j and b_j are station dependent parameters.

Method

For each station n calculate "jackknifed" network magnitude:

$$m_b^{J,n}(net_i) = \frac{1}{N^i - 1}\sum_{j=1, j\neq n}^{N^i} m_b(sta_{j,i})$$

Fit the residual, $m_b^{J,n}(net_i) - m_b(sta_{n,i})$, to $\log_{10}(A_{n,i}/T_{n,i})$ and obtain station parameters a_n, b_n.

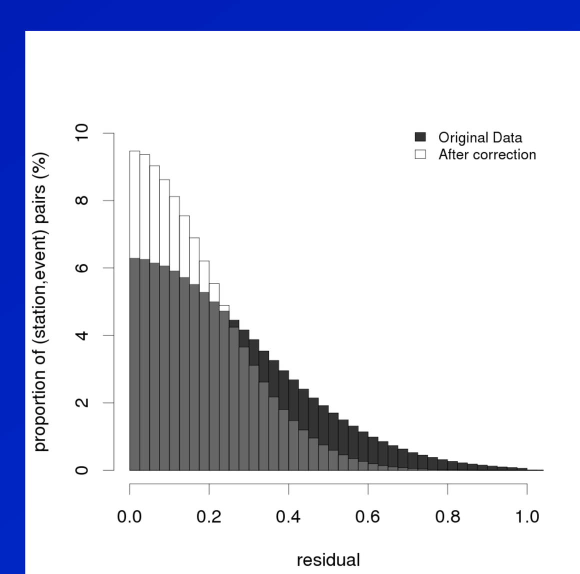
For each measurement at each station n calculate the new station magnitude according to (2). Calculate the new network magnitude by averaging over all participating stations.

Data set

The data set was composed of ~430K events recorded in the REB database from June 1999 to November 2016.

Results

We demonstrate marked reduction in the residual, by ~30%.



Simulation

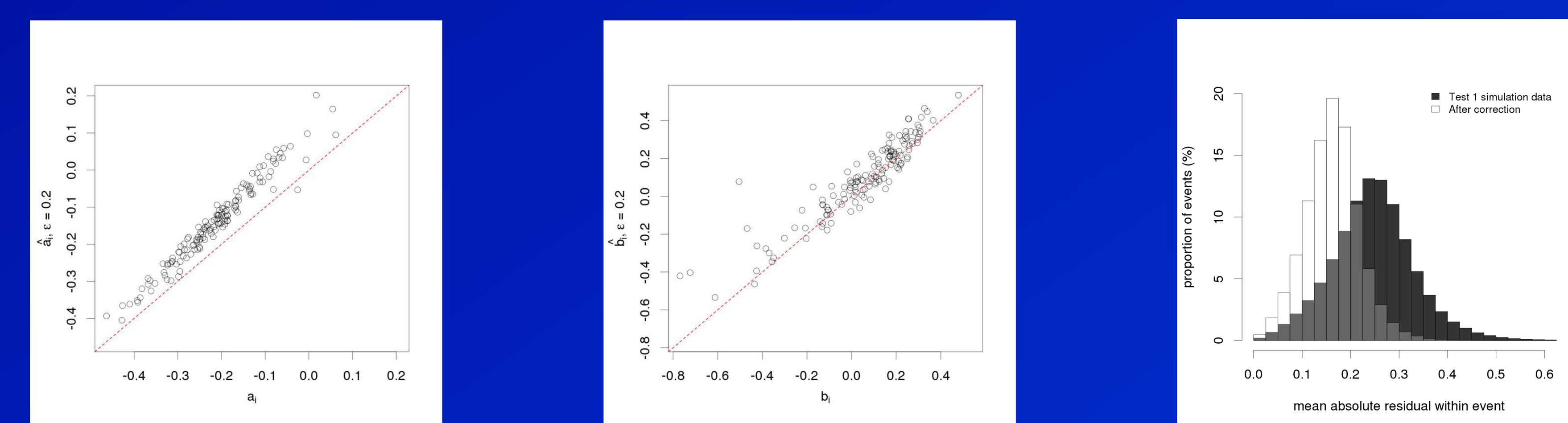
We use simulations to demonstrate that our method generates good estimates for station parameters, generating two synthetic data sets and applying our method to them.

We implement the tests by simulating data from both models ((1) and (2)). The event set used to generate both synthetic data sets is the same set of REB events that we have analyzed. Thus the observed data dictate the set of events, including event magnitude, list of stations contributing to each event and values of all Veith-Clawson correction terms. We only need to calculate the synthetic observations at the stations (i.e the logarithm of the amplitude period ratio):

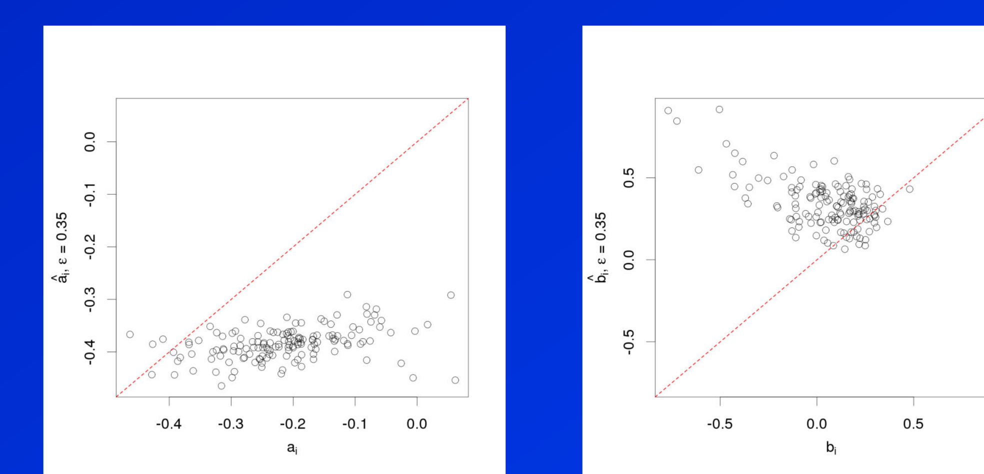
$$\log_{10}(A/T) = \frac{1}{1+a_i}\left(m_b^j - VC(\Delta_{j,i}, h_i) - b_i + \varepsilon_{j,i}\right)$$

where $\varepsilon_{j,i}$ are independent errors drawn from a Gaussian distribution with mean zero and standard deviation of σ_ε.

Test 1 ("model mixing"): Observed station magnitudes are described by our model (2), but are calculated using IDC model (1). For this test we create synthetic data with a_i and b_i from previous analysis. In this case our analysis gives accurate estimates of the station parameters and reduces the residual.



Test 2: station magnitudes follow model (1), but we still apply the correction method, trying to force our model (2) on the data. For this test we create synthetic data with a_i = b_i = 0. In this case our analysis generates similar, though non-0, parameter values at all stations, a feature that could be predicted from statistical random effects models when the simulation values are 0.



Conclusions

We proposed an alternative method for station magnitude calculation (2) following our observation that jackknifed residuals continue to show a dependence on log(A/T) that is not removed by the IDC station magnitude calculation. After correcting for this dependence the residuals decrease by about 30%. We demonstrated, by means of the bootstrapping method, that the station parameter estimates are stable. We show that the correction process presented did not reduce residual variance by removing inter-event magnitude variance and that the dependence of the residual on log(A/T) is not an artifact of the averaging process. Simulations illustrate that the correction method can differentiate between underlying models. When the underlying model is the one used by the IDC (1) the resulting adjustment parameters are nearly station independent, and when the underlying model is the one proposed here, we accurately recover the station dependent magnitude parameters.