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Estimating unbiased magnitudes for the announced DPRK nuclear tests, 2006-2016

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The seismic disturbances generated from the five (2006-2016) announced nuclear test explosions by the Democratic People's Republic of Korea (DPRK) are of moderate magnitude (body-wave magnitude mb $\sim$ 4-5) by global earthquake standards. An upward bias of network mean mb of low- to moderate-magnitude events is long established, and is caused by the censoring of readings from stations where the signal was below noise level at the time of the predicted arrival. This sampling bias can be overcome by maximum-likelihood methods using station thresholds at detecting (and non-detecting) stations. Bias in the mean mb can also be introduced by differences in the network of stations recording each explosion – this bias can reduced by using station corrections. We apply a maximum-likelihood (JML) inversion that jointly estimates station corrections and unbiased network mb for the five DPRK explosions recorded by the CTBTO International Monitoring Network (IMS) of seismic stations. The thresholds can either be directly measured from the noise preceding the observed signal, or determined by statistical analysis of bulletin amplitudes. The network mb of the first and smallest explosion is reduced significantly relative to the mean mb (to < 4.0 mb) by removal of the censoring bias.