Lamont Waveform Quality Center Report to the DMS Standing Committee

Prepared March 10, 2010

Meredith Nettles and Göran Ekström

1 Background

The Waveform Quality Center (WQC) provides both routine and targeted analyses of data quality for stations of the Global Seismographic Network (GSN) and other seismographic stations, including USArray. The WQC operates in close association with the Global Centroid Moment Tensor (GCMT) Project. For more than a decade, the activities of the WQC were funded through a subaward from the IRIS DMC: This activity was initially suggested by IRIS, who saw value in receiving structured reports on the quality of the data products generated by the GSN facility. The CMT Project makes use of data from GSN stations and also depends on the real-time distribution of seismic waveforms (and the protocols associated with this distribution) as well as the IRIS DMC waveform archive. These characteristics make the CMT Project well suited for detecting, investigating, and reporting problems associated with both data and data-distribution mechanisms.

In the fall of 2007, NSF directed the PIs not to seek additional funding from the IRIS consortium for our WQC activities, instead encouraging submission of a single proposal for CMT and WQC activities to the NSF Instrumentation and Facilities Program. As a result, WQC investigations of the quality of seismic waveforms from the GSN and other seismic networks are now funded directly by NSF.

However, we believe the best way to achieve our objective of contributing to the quality of the GSN is through continued communication with IRIS. This report summarizes recent activities and findings of the WQC, and provides some recommendations for improving station quality. We welcome feedback from the DMS Standing Committee on the contents of the report, and on WQC activities.

Most of the results described here can be found on our web site,
`http://www.globalcmt.org/WQC.html`

2 Ongoing WQC activities

Much of our ongoing effort in the last few years has been focused on longitudinal studies to investigate the performance of the GSN, and to verify key station parameters. Some of these analyses are now performed close to real time, with the results continously updated and posted to our web site. For example, we routinely calculate noise levels at GSN stations, using continuous near-real-time data acquired through a variety of protocols. These results are updated daily and monthly. We also estimate station misorientation, for GSN and USArray stations, following the approach described by Ekström and Busby (2008), updating orientation estimates with each event that provides a useful estimate at a given station.

Other results of longitudinal studies are updated at irregular intervals, through an update to or reprocessing of some data set. For example, we identify large errors in channel gain and frequency response by systematic comparison of CMT synthetic seismograms and data, calculating the scaling factor that would bring the synthetic and data seismograms into the best agreement (following Ekström et al., 2006). Such estimates for most stations are available on our web site through 2007.

In addition to these longitudinal studies, our examination of large numbers of seismograms occasionally identifies specific problems with station metadata, which we report directly to the network operators. For example, in December, 2009, we identified, and worked with the IDA group to correct, an error in the long-period corner frequency reported in dataless SEED volumes for STS-2 sensors at II stations. We also identified an inconsistency in the reporting of normalization frequencies and constants for II channels that resulted in an error in total sensitivities (a factor of $\sim$0.66) for VH channels derived from KS54000 sensors, and in smaller errors for other channels and sensors. The IDA group has revised these response descriptions so that the product of the individual stage sensitivities agrees with the cumulative sensitivity given in stage 0. A remaining open issue, which may require discussion about the use of stage 0 sensitivities in the DMC program `evalresp`, is that the stage-0 sensitivity for VH channels does not represent the overall sensitivity of the whole system at the frequency specified.

Other recent miscellaneous activities have included assisting with metadata verification at stations of the LCSN (network code LD) and GLISN.

We note that updates to metadata that change the response characteristics (overall system gain and/or shape of the frequency-response function) should trigger an update of the data-quality products generated at the DMC that rely on knowledge of the system characteristics: for example, power-spectral-density calculations. It is not clear to us that such a recalculation occurs at the DMC at the current time.

3 Recent WQC activities: GSN Station-Performance Reports

The longitudinal studies described earlier typically apply one type of analysis to many stations, with the results grouped by the type of analysis. Since January, 2010, we have undertaken a set of station-focused analyses, motivated by our sense that a comprehensive review of data from a single GSN station over several years could provide a complementary view of some data-quality issues that are usually addressed by focusing on current (near-real-time to a few months behind real time) data and operations.

As of this writing, we have completed station-performance reports for ten stations: CASY-IU, KIP-IU, ALE-II, XAN-IC, DGAR-II, WCI-IU, DAV-IU, RPN-II, KONO-IU, SSE-IC. The selection of stations has been relatively haphazard. Some of them were chosen because of our own research interest in the polar regions (e.g., CASY, ALE); some of them are stations we have examined in previous WQC work and to which we have now returned (e.g., KIP); others are in interesting places for particular types of studies (e.g., XAN). All of the primary sensors in this initial group are STS-1s, and most have secondary broadband sensors, which allows coherence analysis in addition to other measures we have previously applied.

The station reports identify a number of serious problems with GSN station quality. Of the ten stations examined, eight have suffered, on one or more components, a frequency-dependent loss of long-period gain (change in frequency response) like that described by Ekström et al. (2006). In several cases, the loss of gain is greater than a factor of two; in some cases, the frequency-dependent variations in gain are also severely time dependent. Half of the stations provided good-quality data only for a short time period after installation; at least one of them has never provided data of GSN quality. The secondary broadband sensors (STS-2s) at five of the stations do not provide high-quality backup data streams; one of the stations (WCI) does not have a secondary broadband sensor. At least one station (KIP) shows a recurrence of the STS-1 problem even after replacement of the feedback electronics.

Our analysis has also identified two stations of very good quality: ALE and RPN. Data quality at DGAR has also been very good, with the exception of a time period of $\sim$1 year with long-period gain loss on one channel. Data quality at KONO has been variable, but generally (and currently) relatively good.

4 Observations of the February 27, 2010, Chile earthquake, M_W 8.8

Following the M_W 8.8 earthquake in Chile on February 27, 2010, we examined the waveforms available in near-real time for GSN stations, focusing on the period range from 200 s to 500 s. Approximately 30% of the II, IU, and IC stations are currently recording one or more primary-sensor channels that were unusable for analysis of the Chile mainshock. This is based on data from the 95 stations with the II/IU/IC network codes that we received in near-real time following the mainshock; it excludes near-source stations. The problems identified include non-linear response to the large-amplitude ground motions at stations more than 40° from the source, dead or non-seismic channels, and incorrect descriptions of the frequency response. An analysis of a single earthquake typically does not allow for identification of, for example, gain errors smaller than $\sim$20%, so stations with such problems will not be identified by this kind of single-event inspection. While some stations recorded spectacular data, the high rate of data problems is surprising.

5 Summary and recommendations

The GSN design goals (IRIS, 1985; Lay et al., 2002) specify a 1% tolerance for relative response characteristics, and provide similar criteria for station orientation and response stability over time. These functional specifications, like others related to the fidelity of station response to great earthquakes at teleseismic distances, criteria for station spacing, etc., are derived from the scientific goals and mission of the IRIS community. Long-period phase shifts of a few degrees and amplitude variations of 10% and smaller are interpreted as signals in modern seismological studies of earth structure and earthquakes. These analyses require well-calibrated seismic stations.

Our current results suggest that many stations of the GSN do not provide data of GSN quality. Most of the problems we have identified could have been detected easily through routine, or occasional, calibrations, and interpretation of the calibration results. Simple step calibrations would suffice for identification of these problems (e.g., Ekström and Nettles, 1997).

We believe an urgent effort is needed to restore GSN-quality data recording to these stations. This includes a complete and regular cycle of calibrations. The problem with the STS-1 sensors remains incompletely understood, and we urge immediate improvement of the STS-2 sensor installation at locations where the secondary sensor does not currently provide a high-quality backup data stream, as well as installation of secondary broadband sensors at stations where they are currently lacking.

We have no reason to believe that the types of problems we have identified are limited to the stations we have studied to date. We believe a thorough review should be undertaken as soon as possible to develop the policies and procedures, including station-quality metrics, that should be implemented to rectify the current problems and prevent their reoccurrence.

In addition — and importantly — we believe that information about the quality of GSN data needs to be conveyed to the IRIS community in a timely and transparent manner.

6 References

Ekström, G., C. A. Dalton, and M. Nettles, Observations of time-dependent errors in long-period gain at global seismic stations, *Seism. Res. Lett.*, 77, 12–22, 2006.

Ekström, G., and R. W. Busby, Measurements of seismometer orientation at USArray Transportable and Backbone stations, *Seism. Res. Lett.*, 79, 554-561, 2008.

Ekström, G., and M. Nettles, Calibration of the HGLP seismograph network and centroid-moment tensor analysis of significant earthquakes of 1976, *Phys. Earth Planet. Inter.*, 101, 219–243, 1997.

IRIS, *The design goals for a new global seismographic network*, IRIS GSN committee report, 31 pages, 1985.

Lay, T., J. Berger, R. Buland, R. Butler, G. Ekström, B. Hutt, B. Romanowicz, *Global seismic network design goals update 2002*, IRIS GSN committee report, 2002.