Lamont Waveform Quality Center Report to the GSN Standing Committee

Prepared April 1, 2010
Meredith Nettles and Göran Ekström

1 Executive Summary

Our recent analyses find serious, systemic problems with data quality at GSN stations. The types of problems identified include long-term, undocumented sensor malfunctions; large time- and frequency-dependent errors in reported frequency-response functions; and unacceptably high noise levels at stations that once were quiet. Most of the problems identified could have been detected easily through routine, or occasional, calibration and inspection of calibration results. These problems should have been identified, and fixed, early on. The problems we have identified are unlikely to be limited to the stations, or the sensor types, we have studied to date. We believe they stem from a lack of clear policies, procedures, and metrics to assure and document the quality of the GSN data stream.

We believe it is urgent to restore GSN-quality data recording at the GSN stations, in the interest of achieving the scientific goals of the IRIS community. We urge a broad-based and thorough review of GSN policies and procedures; communication of current and developing data-quality status to the IRIS community; and immediate action to provide high-quality backup data streams at severely affected stations.

2 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. 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.

For more than a decade, the activities of the WQC were funded through a subaward from the IRIS DMC; following guidance from NSF, the WQC is currently funded through a grant from the NSF Instrumentation and Facilities Program. 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 GSN 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`

3 Longitudinal Studies

In the past, much of our effort has 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; other analyses are updated at irregular intervals. We routinely calculate noise levels at GSN stations, using continuous near-real-time data acquired through a variety of protocols. We also estimate station misorientation, for GSN and USArray stations, following the approach described by Ekström and Busby (2008). 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, Dalton, and Nettles (2006).

4 GSN Station-Performance Reports

The longitudinal studies described above 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. The station reports are posted on our web site:
`www.globalcmt.org/WQC.html`

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.

Some of the STS-1 problems have been associated with dampness in feedback-electronics boxes (FBEs; Hutt and Ringler, 2009). Replacing the old FBEs with new Metrozet E300 FBEs appears to have fixed the problems in a few cases; in others, the symptoms remain, or have returned. The time-varying frequency-response functions are very difficult to reconstruct without regular calibration data.

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.

5 Observations of the February 27, 2010, Chile earthquake, $\mathbf{M}_W$ 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 and stations not currently delivering data in near-real time. 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 and distressing.

6 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.

7 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.

Hutt, C. R., and A. T. Ringler, Causes and corrections for STS-1 gain changes in the Global Seismographic Network, *EOS Trans. AGU*, 90, S23A-1735, 2009.

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.