Data Requirements in Low-Frequency Seismology (0.3 – 20mHz)

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The observation of the Earth's free oscillations probably sets the most stringent data requirements of all seismic applications. Since the analysis of some modes requires very large deep earthquakes, seismologists may have to wait for 10 years to acquire the necessary seismic records. In addition to this, requirements regarding the quality of seismic records are exceptionally high. These include a high signal-to-noise ratio at frequencies between 0.5 and 10mHz and continuous data streams of several days or sometimes up to more than a month, depending on the mode to analyze. All of this can currently be met only by observatory quality installations (GSN and equivalent permanent installations) of very broadband seismic sensors (e.g. STS-1). The rate of seismic records available at the IRIS-DMC (data management center) that are fit for analysis is typically 75% but this rate is expected to become smaller since sensors are now nearing the end of their lifetime. The imminent ''sensor crisis'' and the surprisingly clear observation of very low frequency modes on STS-2 sensors, which are typically not chosen as primary sensor at an observatory-quality site, prompted the comparisons I present in this talk.

The quality of a station is usually determined through its noise characteristics, and average noise statistics and seasonal variations are published in the FDSN station book. In this presentation I concentrate on the quality of the actual signal that is analyzed. For example, free oscillation spectra on vertical components of the GSN and comparable networks are compared for the 20 largest earthquakes in the last 10 years. A little less than 50% of the records of Wielandt-Streckeisen STS-1 vault sensors (132) meet the highest quality requirements, while the 46 Teledyne-Geotech KS5400 borehole installations (and its predecessor KS36000) yield less than 10% high-quality records. Surprisingly, the fraction of such records at 85 STS-2 and Guralp CMG3 (CMG-3t and CMG-3b) installations is almost as large. Overall, I find that 70% STS-1 records are ''acceptable'' for analysis, 50% KS54000 records, but less than 30% STS-2/CMG3 records which clearly stresses the importance of observatory-quality very-broadband installations.

It is often argued that KS54000s are typically deployed in noisy environments so that my comparison should not be used directly to judge the value of a KS54000. The recently installed GSN station at the South Pole, QSPA, gives us the rare opportunity to compare all four co-located sensors more directly. Inspection of the three largest earthquakes in 2003 reveals that the STS-1 usually gives the best spectra. However, the noise level for the large September 25 Hokkaido earthquake is high below 1.5mHz. This inhibits the observation of 0S8 that is clearly visible in the STS-2 and CMG-3B records. On the other hand, the noise level below 6mHz is higher in the KS54000 records than in those of the STS-2 and CMG-3B for all three earthquakes. The three 2003 earthquakes were records by several other GSN stations that have primary (STS-1/KS54000) and secondary (STS-2/CMG3) sensors and hence allow a similar comparison. At 12 of these sites, the IRIS-DMC provides 10s or 1s data streams that allow a quick comparison. In 92% of the cases when an STS-1 is involved, it provides the best records. The same is true for only 46% of the KS54000 records, which implies that in more than half of the cases the secondary sensor (STS-2 or CMG3) provides the better record.

The question now arises whether STS-2s would be fit for deployment as primary sensors at future GSN stations. It appears that this is indeed the case as the 10% STS-2 sites mentioned in the first comparison consistently produce good records. However, caution is in order. Even at the best installation, modes below 0S4 (lower than 0.5mHz) can not be observed for the June 23, 2001 Peru earthquake which is considered the largest earthquake that has been recorded since digital seismograms became widely available about 20 years ago.

The comparison shown here includes only vertical component seismic records. Inspection of the horizontal components is pending but interesting food for thought for this workshop is whether gravimeters should be revived and co-located at future GSN sites, together with a separate set of newly developed sensors to record horizontal ground motion.

Finally, I would like to add a few comments on so called ‘’broad-band’’ sensors in temporary deployments such as PASSCAL experiments. Quite often, such experiments are carried out with one or two major scientific objectives in mind that usually involves the analysis of relatively short-period signals (periods shorter than 20s). Open data access provided at the IRIS-DMC a few years later to colleagues not involved in the original experiment ensures that the maximum amount of science can to done with such data. The set of chosen ‘’broad-band’’ sensors in PASSCAL experiments typically includes STS-2 and CMG3 but recently also CMG-40Ts. These sensors typically have unfavorable noise characteristics at periods 40s and longer, which greatly inhibits the observation of surface waves beyond 50s. In many experiments such surface waves carry important information, if not the only one, on the deeper lithosphere and asthenosphere. An increasing group of principle investigators realizes the caveats of deploying 40T equivalent sensors and would rather invest the extra cost for deploying true broad-band sensors. This becomes particularly important as the OBS (ocean bottom seismometer) community is planning PASSCAL experiments on the ocean floor and is searching for an adequate low-power sensor for the new OBS instrument pool. Ideally, this workshop is the first of many more to come to stimulate the increasingly important dialog between colleagues from both groups, instrument developers and data users.