COMMENTARY

Future Directions for Global Bulletins

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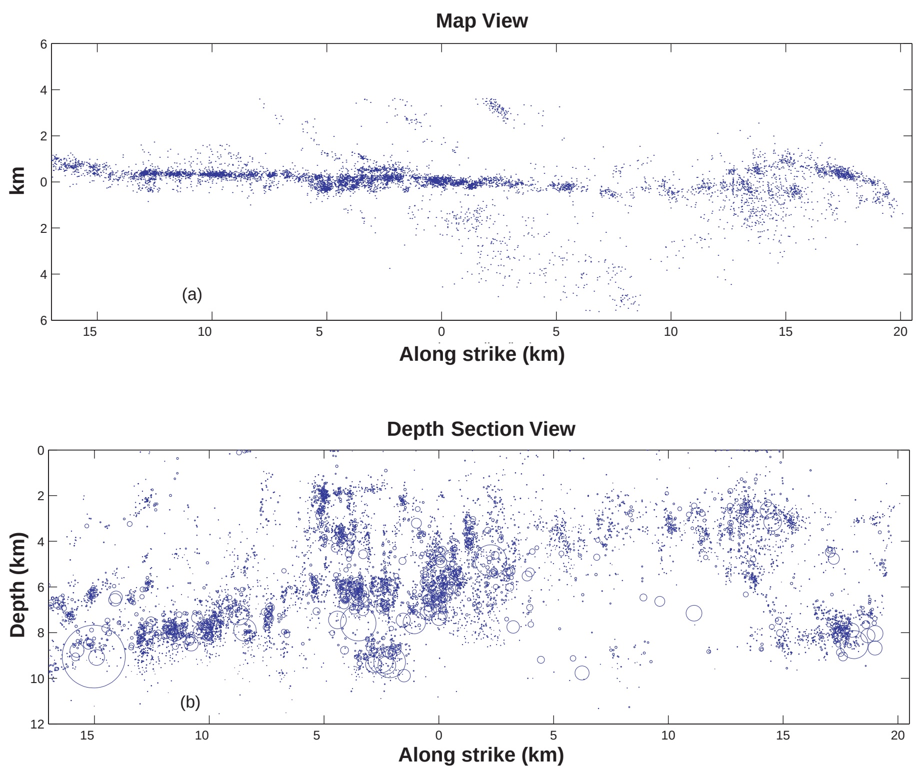
When most of us associated with the IRIS Consortium speak of "seismic data," we usually mean seismograms. But for much wider communities of Earth scientists and engineers, for policymakers—and for people in journalism, emergency management, nuclear test-ban monitoring, insurance, and business generally—the basic "seismic data" are not seismograms, but products derived from seismograms. Of these, the most important are lists of earthquake and explosion locations, with their origin times and magnitudes (or some other measure of ground motion). Such hypocenter lists, or seismicity catalogs, are often backed up by a published seismicity bulletin giving measured arrival times at the detecting stations—which may be regional or teleseismic.

Bulletins of seismicity, whether they are produced on a local, regional, national, or global basis, are now undergoing profound changes. Better accuracy, and/or better coverage to lower magnitude, has often been the key to new insight into earthquake processes and Earth structure, and has enabled new levels of confidence in the ability to monitor a region of interest. Of course, new insights and new monitoring capabilities are the very rationales upon which much work in seismology is funded.

Different Types of Bulletin

For some users, *prompt reporting* on all types of seismicity is essential. For others, the *most complete catalog* of earthquakes or explosions is needed, even if locations are not worked up until a few years after the events occur. For some users, *accuracy of the estimated event parameters* (hypocenter, magnitudes, moment) is paramount and it is acceptable if smaller events with poorly estimated parameters are ignored. For other users, it is more important to be sure that *all possible seismic events* are reported, even if special studies later show that some of these events are the result of false associations, and/or have poorly determined locations.

Since these different users cannot all be satisfied with the same type of global bulletin, it is helpful to consider the production of a range of products.



7577 earthquake locations estimated by the Northern California Earthquake Data Center, for the Calaveras Fault from 1984 to the present. (a) Map view of events rotated along the 146 degree strike of the Calaveras Fault. (b) Depth section displaying earthquakes on the fault with estimated source sizes based on a circular rupture model using a 3 MPa stress drop.

Such a range of products would help summarize seismic activity for many interested users outside seismology — in geophysical research, in quantitative estimation of seismic hazard, and in monitoring arms control treaties. For users inside the research community of seismologists these products could provide feedback to the question of where new stations should be sited. Improved reporting on seismicity would renew debate on the merits of borehole instrumentation, and increase the importance of quiet sites and station reliability.

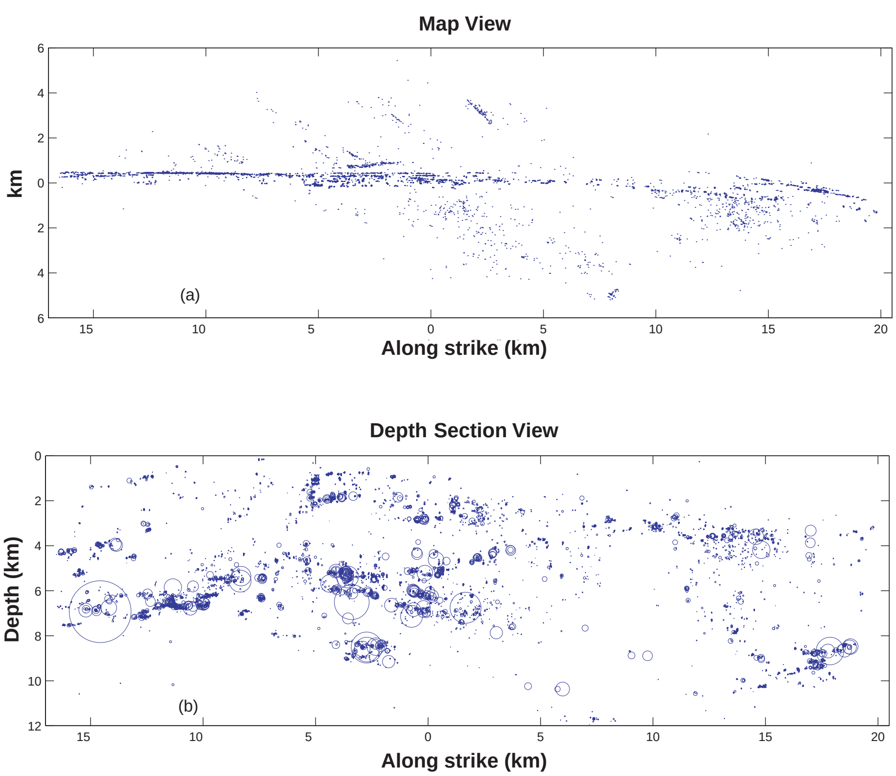
The commitment to produce an accurate global bulletin that is complete down to magnitude 4 (about 20 events per day) is surely now a realistic goal with openly available data. Since 70% of seismicity occurs beneath the oceans, and each decrease by one magnitude unit corresponds approximately to an eightfold increase in numbers of events, it follows that there are approximately 50 events per day on continents with magnitude 3. The goal of monitoring down to magnitude 3 on continents appears attainable on a time scale of about a decade. The number of events here, about 50/day, is comparable to the number of events handled routinely by regional data centers in seismically active areas such as California. (Of course, such data centers achieve complete regional coverage well below magnitude 3.)

New Procedures for Event Location

At present, all three of the global bulletins described in this newsletter rely heavily upon standard one-dimensional Earth models for purposes of interpreting arrival times, in the process of iteration to find the best-fitting location. Resulting location estimates can still be quite accurate provided there are enough reporting stations, with no large gap in azimuthal coverage. But for a sparse network, such as the IMS associated with the CTBT, a new approach must be adopted. It is desirable to calibrate each IMS station so that in effect the location of a new event can be located with reference to another event, whose location is known accurately and which, preferably, is not far from the new event. By using a sufficiently large number of calibration events, whose location is accurately known and whose signals are detected reliably at IMS stations, it is possible to generate a station-based travel time surface (a function of distance and azimuth), for each seismic phase. Different surfaces are needed for different event depths. For CTBT monitoring, the most important surface is that for zero depth. The IDC has begun using station-based empirically-determined travel times for stations in North America and northwestern Eurasia; and plans are in place to obtain and use such travel times for stations in North Africa, the Middle East, and East Asia. At present, errors in event location are caused by pick errors and model errors, with model errors being far the larger (at least for events above about magnitude 4.5). The use of station-specific travel times can be expected to achieve a significant reduction in the model errors.

Looking further to the future, it will be important to apply to global bulletin production some of the new methods of event location recently found useful in regional studies. The first method that has clearly been very important, is the use of cross-correlation techniques to measure relative arrival times accurately for two or more events observed at the same station. Such an approach reduces pick errors. The figures here show catalog locations for about 8000 events on the Calaveras Fault, California, and their relocations based upon inversion of relative arrival times determined by cross-correlation (work reported by Schaff and others, at the December 1999 AGU meeting: see also http://pangea.stanford.edu/~beroza/location.html). A key to such future work, needing millions of cross-correlations, is very fast access to digital waveform data. The underlying location method, developed by Waldhauser and others (in press with the Bulletin of the Seismological Society of America), can use conventional phase picks or cross-correlations. It is based on a double difference scheme that analyzes all possible pairs of events, and their relative arrival times at detecting stations.

Bulletins of global seismicity are the product of a vast community, rather than of a few smart hard-working people. But they reflect what the larger community wants. Given what is achievable over the next several years, this is probably the time to think how archives of seismic signals should be established, to achieve the kinds of improvement in seismic event location that now appear possible.



Improved location estimates using the correlation method for measuring relative arrival times at each station and a double-difference technique (Waldhauser and Ellsworth, Bull. Seismol. Soc. Am., in press). The same 7577 events are shown, and on the same scale. (a) Note the fine structure (seismicity lineaments) as well as several off-fault structures. (b) The great reduction of vertical errors shows that seismicity is largely concentrated into several discrete bands that contain events of widely varying magnitudes. [Figures are courtesy of David Schaff, Goetz Bokelmann, Greg Beroza, Felix Waldhauser, and Bill Ellsworth.]