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A WORLD-WIDE NETWORK OF ARRAY STATIONS - A SEISMOLOGICAL EXPERIMENT

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ABSTRACT

A suggestion is made for determination of seismic sources by a world network of existing array stations supplemented by array stations in southern Africa and Antarctica. Accuracies of source location should be compared with results from world networks (preferably homogeneous) of ordinary stations.

INTRODUCTION

At the same time as I like to express my congratulations to the NORSAR array and my wishes for its grand future, I would like to suggest a test for increased accuracy of source parameter determination.

The accuracy of source parameter determination has increased considerably in the last decade. This is witnessed among others by world seismicity maps of the USCGS (now USNOS) covering the interval 1961-1969. They demonstrate very clearly the mid-Atlantic rift zone and its branches into adjacent oceans, and particularly that these structures are very limited in width. Similarly, the arrangement of hypocenters in the circum-Pacific zones is well demonstrated. A more accurate knowledge of the earth's seismicity is of great significance for many studies and applications, for example the modern hypotheses on global tectonics.

The increased precision is based upon a favorable cooperation between a number of factors, of which the following are most important:

1. A better distribution of stations over the earth.
2. Installation of special array stations.

3. Increased time accuracy, by general use of well-controlled quartz crystal clocks.
4. More accurate travel times, especially of P-waves, derived from records of nuclear explosions.
5. Application of large computers in the evaluation of the observations.

In the present note, I shall limit the discussion to points 1 and 2 above. Even though advances have been made in these two respects, much still remains to be achieved. In an earlier paper (Båth, 1964), I advocated the idea of homogeneous networks over the globe. The viewpoints and the principles which were developed in that paper are still valid today. I am not going to repeat them here. Instead, I will go a step further and apply the ideas to the development of a world network of array stations. And in the present note, I will base my proposal upon already existing array stations, rather than suggesting a homogeneous network (which may be unrealistic).

TELESEISMIC EVENT LOCATION

A world network, preferably as homogeneous as possible, is required for numerous seismological studies (see Båth, 1964). I shall here limit the discussion to the determination of source parameters, especially hypocenter coordinates and origin time. With regard to this problem, we can summarize commonly used methods of determination as follows, considering only teleseismic events:

1. Using only one station, by combination of times and of three-component amplitudes of different waves.
2. Using a limited network, say of 5-10 stations over an area of roughly $10^{\circ} \times 10^{\circ}$ in extent, primarily by combination of P-wave readings.
3. Using one array station, say of 1°-2° in extent and with numerous sensors, essentially by combination of P-wave readings.
4. Using a world network of ordinary stations, by combination of P-wave arrival times. This refers to the determinations made at some world centers, as for example USNOS, BCIS, ISC.

Let us consider the accuracies achieved by the different approaches mentioned. Method 1 can only provide a preliminary location, sometimes with wide margins, and its purpose is only to deliver rapid messages to certain institutions and to news agencies. Method 2 is usually not applied to teleseismic events, but only to regional ones. Method 3 has been practised by several array stations, and it has become customary that each array makes its own determinations. They have frequently very large error margins. My efforts to use some of this information in combination with bulletin work, have nearly always been a failure, because the source data have an insufficient accuracy. This experience, which demonstrates the limitation of method 3, in fact prompted this note. Method 4 is still superior to any other method, and yields data of great value to seismology.

WORLD-WIDE NETWORK OF ARRAY STATIONS

The question now appears if there is any possibility to improve source data information and then, in what ways. Method 1 has always a justification for rapid information on epicentral area (and magnitude, etc.) but has to be left out from the discussion of improvements. Comparisons of methods 2 and 3 would be very informative. Some comparison of this kind has been made, but I have not seen any systematic study of this problem. The longer base lines provided in method 2 have to be weighed against the greater number of sensors generally available in method 3. For increased accuracy, these methods alone are insufficient. In order to achieve higher precision, method 3 could be amplified by the use of a world-wide network of array stations, instead of just one station at a time. Method 4 could be improved by extended and preferably homogeneous networks, as discussed by Båth (1964).

Let us consider a world-wide network of array stations. With greatest emphasis on an equal geographical distribution of such stations, we could list the following locations:

Europe (several arrays exist)
Asia (one array exists in India)
Australia (one array exists)
North America (arrays exist both in Canada and the USA)

South America (one array exists in Brazil)
Africa (this represents a gap, which could preferably be filled by an array in southern Africa)
Antarctica (one array would be necessary)

This system would include about 10 array stations with quite a good coverage of the world. In applying this system to hypocentral location, all information available from array stations should be used, i.e. they should be treated as arrays and not as single stations. In other words, all data which single array stations put into their source location programs should be combined for this world system. Then the accuracy of the results should be compared with results already obtained from method 4. I have not seen any such detailed and systematic study, and therefore I would like to make a strong suggestion for this project to anybody with access to primary data from all existing array stations (including calibration data) and to a large computer.

Comparative studies of the achievements of the world net of array stations and the usual method 4 are very significant for further development of the whole project, for instance, if the additional array stations (in southern Africa and Antarctica) would fill a need or not. A combination could also be envisaged of the world net of arrays and of method 4, i.e. the world net of ordinary stations, and the accuracy achieved by this combination should be compared with either of the two methods applied separately.

We have discussed accuracy of source determination by different methods. Closely related to this problem is the sensitivity of any seismograph system. The networks suggested should be compared also from this point of view and particularly the lower magnitude limit should be specified, above which a homogeneous world-wide material can be guaranteed.

Finally, let us consider the accuracy of hypocenter location from another viewpoint. Due to its inhomogeneous structure, the earth itself puts a certain limit to the obtainable accuracy in location of teleseismic events. And this limit can be approached but hardly surpassed by improved stations and networks, excepting the cases where an earthquake is well surrounded by near stations. Therefore,

in the teleseismic case, it appears reasonable to try to work up to this limit. The problem is which method will lead to this goal in the easiest and most practicable way: a world net of array stations, a (homogeneous) world net of ordinary stations or a combination of the two. This is my question and my suggestion for closer investigation.

REFERENCE

M. Båth: Futur développement des réseaux de stations séismologiques, Scientia, 99, 184-191, 1964.