NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 2-77/78

SEMIANNUAL TECHNICAL SUMMARY

1 October 1977 - 30 April 1978

Edited by

H. Gjøystdal

Kjeller, May 1978

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 2551

VI.7 A Maximum Likelihood Procedure for Local Event Location Based on Observed S-P Time Differences at Two or More Stations

A method has been developed in order to compute local event locations merely based on the relative arrival times of P and S waves observed at a number of individual stations. The method, which has been applied on data from the Svalbard microearthquake network (see section VI.5, and Bungum et al, 1978) takes advantage of the fact that there normally is a constant ratio between P and S velocities in the crust, making (for short distances) the epicentral distance Δ approximately linearly dependent upon the S-P time:

$$\Delta \simeq k \cdot t(S\text{-}P) \tag{1}$$

Knowing the epicentral distance from two stations, we may usually compute two epicenters symmetrically located about the line connecting the stations. Having a distance observation from one or more additional stations located non-symmetrically relative to the former ones, we will generally be able to choose the proper solution, however, in this case the final location should be based on a sort of 'averaging process' since the 'distance circles' will normally not intersect each other in one single point, due to the distance errors involved.

The present location procedure is based on the maximum liklihood principle from statistical theory. Assuming that the error in the 'observed' epicentral distance Δ_i for a given station i is normally distributed with zero mean and standard deviation σ_i, we may locally (close to the epicenter) approximate the 'distance circle' by a straight line and express the associated probability density function as a 'Gaussian ridge' distributed about this line (see Fig. VI.7.1):

$$p_i(x,y) = \frac{1}{\sqrt{2\pi}\,\sigma_i}\, e^{-\frac{1}{2}\left(\frac{a_i x + b_i y + c_i}{\sigma_i}\right)^2} \qquad (2)$$

Here, x and y are rectangular coordinates centered in a point in the vicinity of the true epicenter, and a_i, b_i and c_i are parameters defining the 'distance line' in this coordinate system.

Having chosen the origin of this system, f.ex., in the intersection point between two arbitrarily chosen distance circles, the parameters a_i, b_i and c_i may be easily computed from the station coordinates and the 'observed' value of the distance Δ_i.

When an expression like (2) has been found for N stations, we may compute the joint probability density of the epicenter by forming the product

$$p(x,y) = \prod_{i=1}^{N} p_i(x,y) \qquad (3)$$

and locate the epicenter in the point corresponding to the maximum value of p(x,y) which can be shown to represent a binormal distribution for $N \geq 2$. In addition to the location of the maximum point (point of maximum likelihood), we can analytically find the axes and orientation of the confidence ellipses of the resulting distribution.

H. Gjøystdal

References

Bungum, H., H. Gjøystdal, B. Hokland and Y. Kristoffersen (1978): Seismicity of the Svalbard region: A preliminary report on the microearthquake activity. NORSAR Tech. Rep. 2/78.

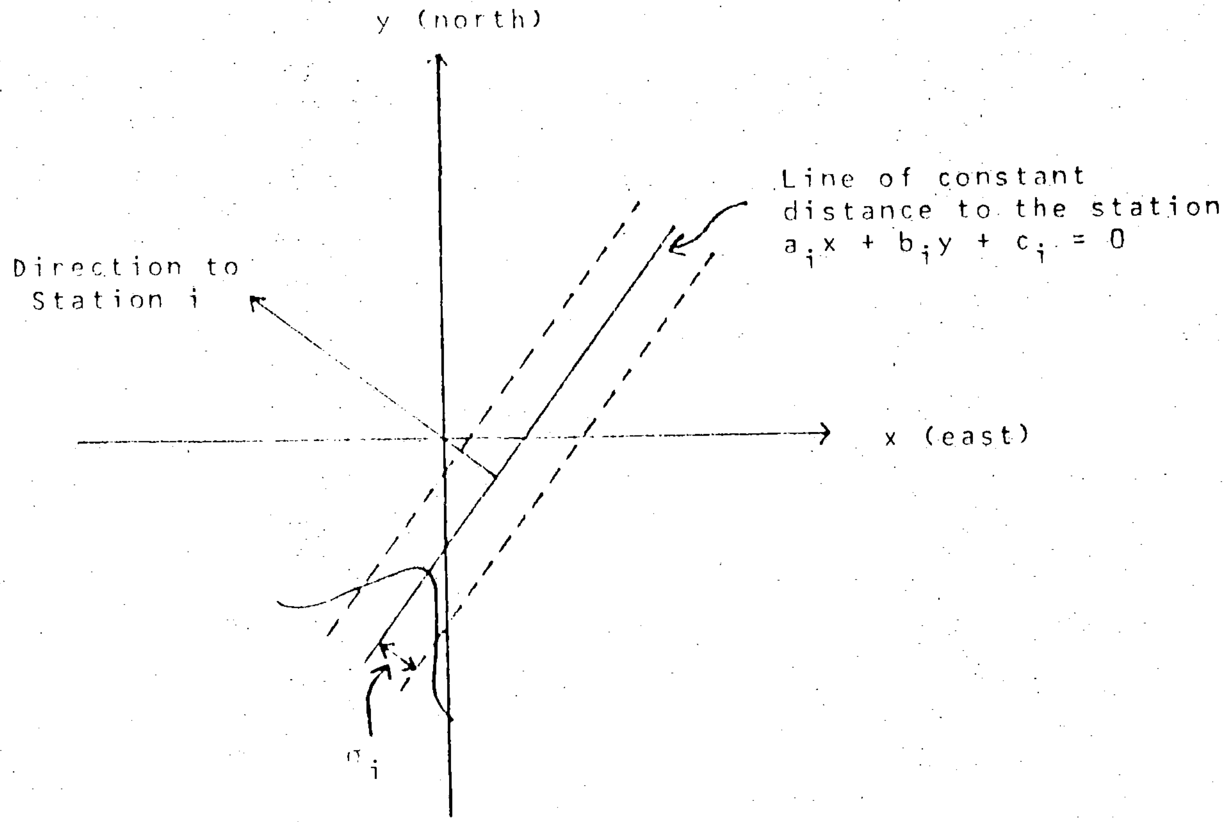

Fig. VI.7.1 Error distribution of the 'distance line' from each station, calculated from the P-S times.