

## 1. Accuracy of the Determination of Earthquake Source Parameters in and around Japan.

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### Abstract

The accuracy of the determination of epicenter and origin time of shocks is studied using the simulation method. The medium is assumed to be uniform and earthquakes occur at a certain depth. Assumed observation errors are normally distributed with the standard deviation=0.1 sec and mean value=0. These errors are allotted to 30 Japanese stations nearest to the epicenter, and the expected error of epicenter location ( $\delta R$ ) and that of origin time ( $\delta T$ ) are calculated. The equal error contours based on the random trials (at least 128, average 200) are strongly governed by the strand lines of Japanese islands, but the minute features are different in two figures. The  $\delta T$ -map shows a rather narrow valley closely connected with the shore lines, while  $\delta R$ -map shows a flat basin of  $\delta R$ .

1. Determination of the epicenter location and the origin time of earthquake is usually done based upon the arrival times of certain seismic phases at a number of seismic stations. Consequently the accuracy of these earthquake parameters depends upon the geographical distribution of epicenters and stations. In order to make this effect clear calculations were performed following the method suggested by E. HERRIN<sup>1)</sup>, and the present paper that deals with the earthquakes in and near Japan is one of the serial works in this direction.<sup>2),3)</sup>

1) E. HERRIN, "Errors in Epicenter Locations," Symposium of Geophysical Theory and Computers, Moscow, June, 1964.

2) Y. SATÔ, "Optimum Distribution of Seismic Observation Points," *Zisin* [iii] 18 (1965), 9, (in Japanese).

Y. SATÔ, and D. SKOKO, "Optimum Distribution of Seismic Observation Points. II," *Bull. Earthq. Res. Inst.*, 43 (1965), 451.

3) D. SKOKO, Y. SATÔ, I. OCHI and T. K. DUTTA, "Accuracy of the Determination of Earthquake Source Parameters as Determined by Monte Carlo Method. Observation on Indian Network," *Bull. Earthq. Res. Inst.*, 44 (1966), 893.

2. The seismic stations belonging to Japan Meteorological Agency count as many as 112, which are listed and illustrated in Figures 1a and 1b. Among these stations, however, only the nearest 30 are used for the actual data processing for the earthquake parameter determination. Hence for simulating the observation errors at each station only the same number of stations were adopted and used.

3. Since the uniformity of the medium is assumed the basic equation is simple. The unknowns are  $\delta x$ (=eastward correction of the epicenter location),  $\delta y$ (=northward correction of the epicenter location),  $\delta z$ (=depth correction of the focus) and  $\delta t$ (=origin time correction). The numerical assumptions used are

- 1° Wave velocity=7 km/sec.
- 2° Focal depth=35 km.
- 3° Observation errors (Normal distribution) are given by random numbers

Mean=0,

Standard deviation=0.1 sec.

4. For the actual computation, epicenter locations are assumed at intervals of  $1^\circ$  both in longitude and latitude. There are 481 foci, covering Japan and her vicinity, for which computations were made.

Numerical calculations were repeated for at least 128 sets of random numbers allotted to 30 stations. The average number of trials is about 200. The results are illustrated in Figure 2 ( $\delta T$ , the origin time) and in Figure 3 ( $\delta R$ , which is the vectorial sum of  $\delta x$  and  $\delta y$ ). The expected error for the depth ( $\delta z$ ) is not given here, because the way with which the  $\delta z$  is calculated is different from the actual procedure of depth determination. This problem will be separately treated in future.

General features of two figures are not much different; namely the equal error contours are governed by the strand lines of four large islands of Japan. If, however, we look more carefully the  $\delta T$ -map shows a rather narrow valley closely connected with the strand lines of islands, while the  $\delta R$ -map shows a flat basin which is not very narrow.

The minimum values of errors are

for  $\delta T$  about 200 msec

and for  $\delta R$  about 500 m.

SEISMIC STATIONS  
BELONGING TO JAPAN METEOROLOGICAL AGENCY

STATION	LATITUDE	LONGITUDE	ELEV	STATION	LATITUDE	LONGITUDE	ELEV
1 WAKKAN	45 25 00	141 40 30	3	61 OWASE	34 04 00	136 11 42	16
2 RUMOI	43 57 00	141 37 00	24	62 AJIRO	35 02 36	139 05 48	67
3 ASAHIK	43 46 12	142 22 24	113	63 YOKOHA	35 26 12	139 39 18	38
4 ABASHI	44 01 00	144 17 00	39	64 TOMISA	34 55 12	139 49 42	13
5 SAPPOR	43 03 30	141 19 54	18	65 OSHIMA	34 45 42	139 22 42	191
6 OBIHIR	42 55 12	143 13 18	40	66 HACHIJ	33 06 06	139 47 18	81
7 KUSHIR	42 58 42	144 23 42	34	67 MATSUS	36 32 18	138 12 30	440
8 NEMURO	43 19 42	145 35 12	26	68 SAIGO	36 12 18	133 20 00	28
9 SUTTSU	42 47 24	140 14 24	17	69 MATSUE	35 27 18	133 04 18	19
10 MURORA	42 19 00	140 59 00	42	70 YONAGO	35 26 00	133 20 36	3
11 TOMAKO	42 38 00	141 35 00	8	71 TOTTOR	35 30 42	134 10 42	18
12 URAKAW	42 09 30	142 46 48	35	72 TOYOOK	35 32 12	134 49 12	33
13 MORI	42 06 18	140 34 30	12	73 MAIZUR	35 28 18	135 23 12	31
14 HAKODA	41 48 48	140 45 30	35	74 HAMADA	34 53 36	132 04 24	19
15 HIROO	42 17 00	143 19 00	33	75 KYOTO	35 00 42	135 44 06	42
16 MIZUSA	39 08 00	141 08 00	61	76 HIKONE	35 16 24	136 14 48	89
17 AOMORI	40 49 00	140 47 00	4	77 SHIMON	33 57 12	130 56 30	48
18 HACHIN	40 31 30	141 31 36	28	78 HIROSH	34 21 48	132 26 12	30
19 AKITA	39 43 06	140 06 06	10	79 OKAYAM	34 40 54	133 54 54	5
20 MORIOK	39 41 48	141 10 06	156	80 HIMEJI	34 50 12	134 42 06	18
21 MIYAKO	39 38 42	141 58 06	47	81 KOBE	34 41 18	135 10 48	59
22 SAKATA	38 54 12	139 50 12	3	82 OSAKA	34 38 54	135 32 18	8
23 YAMAGA	38 15 12	140 21 00	155	83 SUMOTO	34 20 06	134 54 30	112
24 SENDAI	38 15 36	140 54 00	40	84 WAKAYA	34 13 36	135 10 00	15
25 ISHINO	38 25 30	141 18 12	44	85 SHIONO	33 26 54	135 45 48	75
26 FUKUSH	37 45 24	140 28 30	68	86 NARA	34 41 00	135 50 00	106
27 SHIRAK	37 07 06	140 13 30	357	87 IZUHAR	34 12 12	129 17 42	22
28 ONAHAM	36 56 42	140 54 24	6	88 FUKUOK	33 34 48	130 22 48	4
29 OFUNAT	39 03 42	141 43 06	37	89 SAGA	33 14 42	130 18 18	6
30 WAJIMA	37 23 24	136 53 54	7	90 OITA	33 14 00	131 37 24	6
31 AIKAWA	38 01 12	138 14 30	36	91 FUKUE	32 42 00	128 50 00	27
32 NIIGAT	37 54 36	139 03 03	4	92 NAGASA	32 43 54	129 52 12	27
33 KANAZA	36 32 48	136 38 54	29	93 UNZEND	32 44 06	130 15 12	852
34 TOYAMA	36 42 24	137 12 30	10	94 KUMAMO	32 48 36	130 42 36	39
35 NAGAND	36 39 36	138 11 48	420	95 ASOSAN	32 52 42	131 04 30	1143
36 TAKADA	37 06 18	138 15 00	14	96 KAGUSH	31 34 24	130 33 12	5
37 UTSUNO	36 32 48	139 52 18	121	97 MIAYAZA	31 55 00	131 25 36	8
38 FUKUI	36 03 12	136 13 36	11	98 YAKUSH	30 27 00	130 29 48	15
39 TAKAYA	36 09 06	137 15 18	561	99 NOBEOK	32 35 00	131 41 00	21
40 MATSUM	36 14 36	137 58 24	611	100 ASHIZU	32 43 00	133 01 00	32
41 OIWAKE	36 20 24	138 33 06	1001	101 MATSUY	33 50 24	132 46 48	32
42 MAEBAS	36 24 06	139 03 54	113	102 TAKAMA	34 19 00	134 03 30	11
43 KUMAGA	36 08 48	139 23 06	31	103 UWAJIM	33 13 30	132 33 30	44
44 KAKIOK	36 13 54	140 11 36	27	104 KOCHI	33 33 00	133 32 00	2
45 MITO	36 22 42	140 28 18	29	105 TURUGI	33 51 06	134 05 48	1946
46 TSURUG	35 39 00	136 03 54	3	106 TOKUSH	34 03 54	134 34 36	24
47 GIFU	35 23 54	136 45 54	14	107 MUROTO	33 14 54	134 10 42	185
48 NAGOYA	35 09 54	136 58 06	52	108 TORISH	30 28 54	140 18 18	82
49 IIDA	35 30 36	137 50 06	483	109 ISHIGA	24 20 00	124 10 00	7
50 KOFU	35 39 54	138 33 30	261	110 NAHA	26 14 00	127 41 00	36
51 FUNATS	35 29 54	138 45 48	861	111 TUKUBA	36 12 42	140 06 36	280
52 CHICHI	35 59 30	139 04 54	219	112 SHIMIZ	32 46 30	132 57 42	4
53 CHOUSHI	35 43 30	140 50 36	28				
54 KAMEYA	34 51 24	136 27 54	71				
55 TSU	34 42 06	136 31 06	4				
56 HAMAMA	34 42 30	137 43 24	33				
57 OMAEZA	34 36 12	138 12 48	47				
58 SHIZUO	34 58 24	138 24 24	15				
59 MISHIM	35 06 42	138 55 48	22				
60 TOKYD	35 41 12	139 45 42	21				

Fig. 1a. Seismic stations belonging to Japan Meteorological Agency.

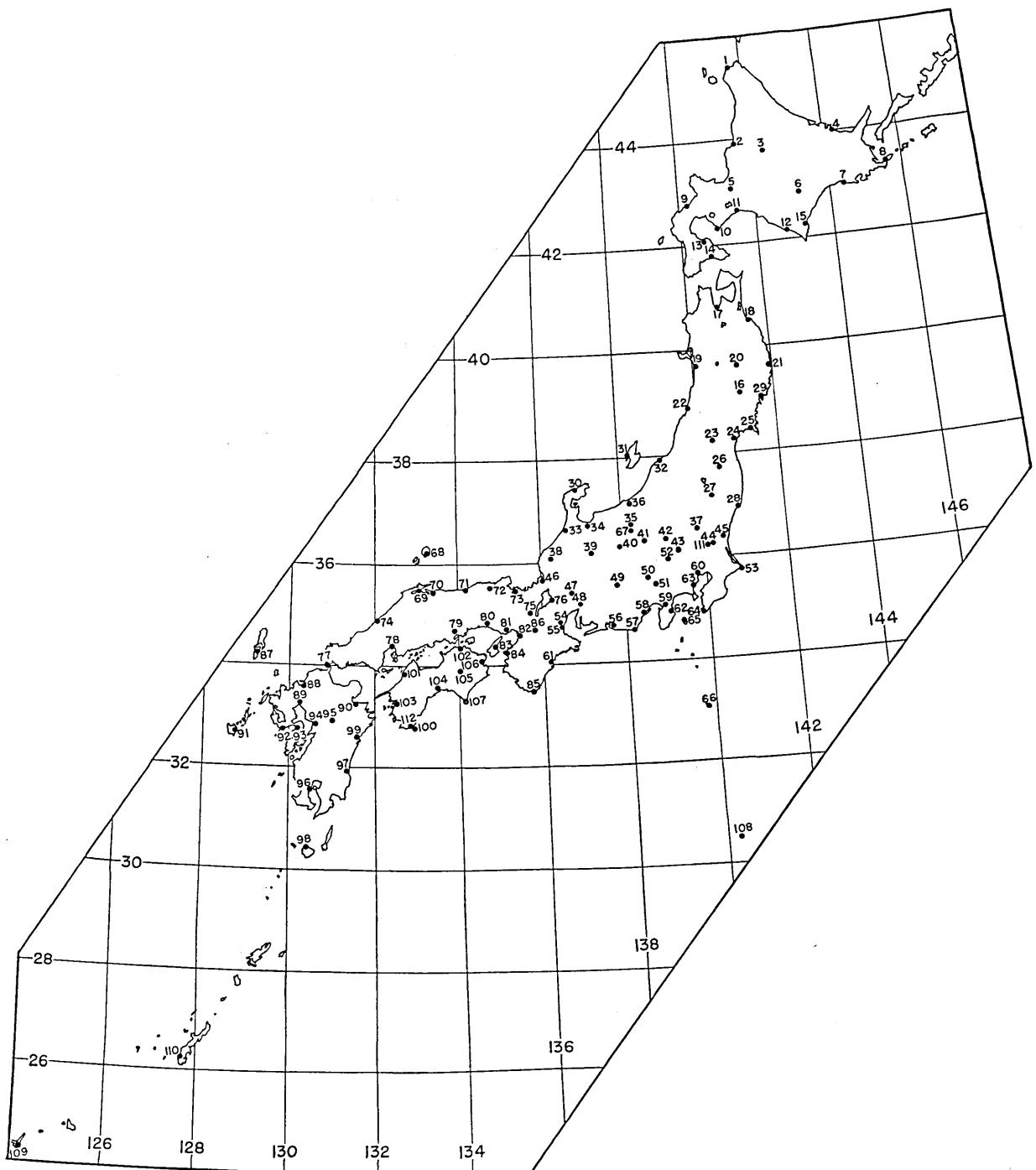


Fig. 1b. Seismic stations belonging to Japan Meteorological Agency.

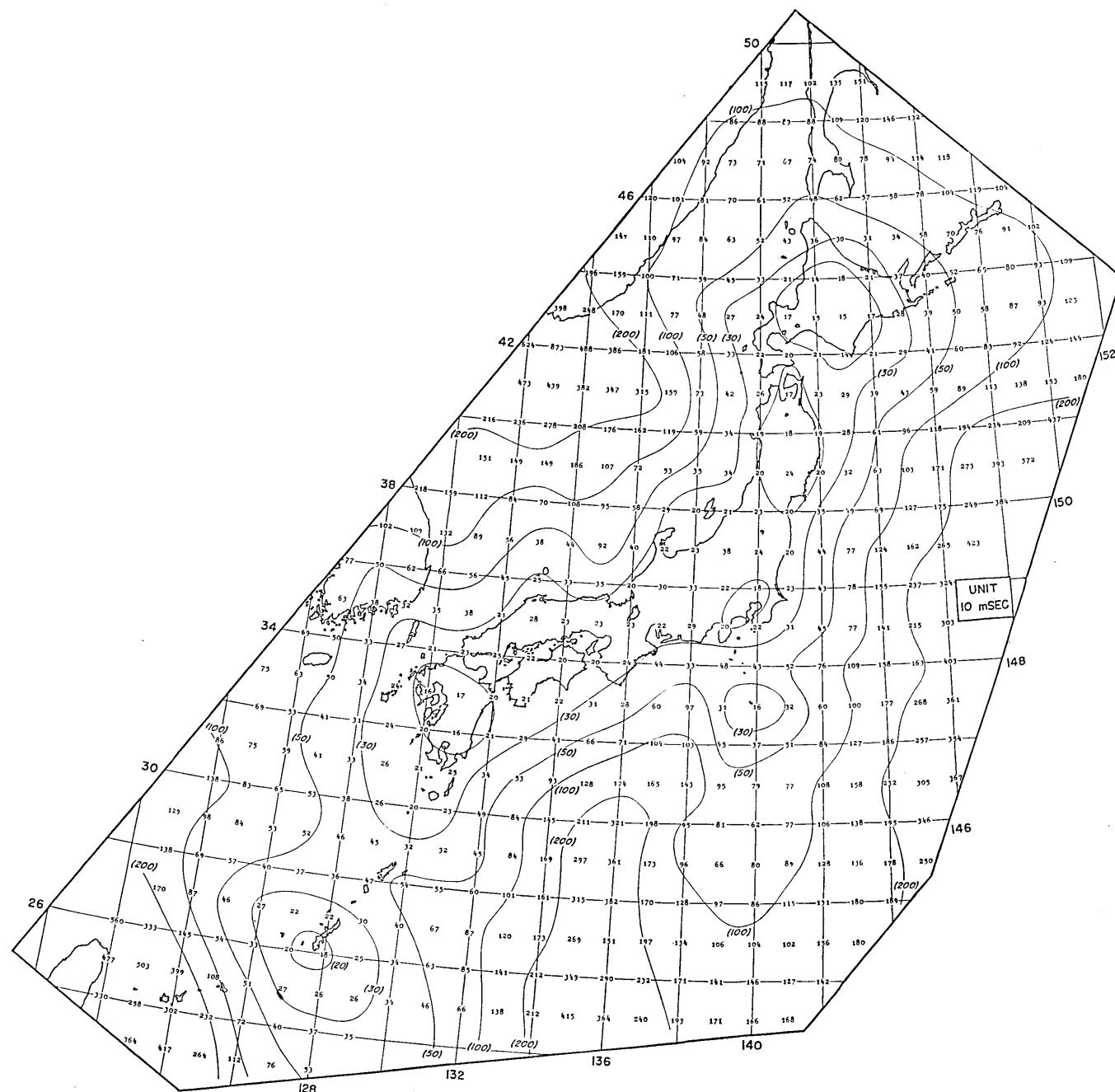


Fig. 2. Expected error of the origin time.  
Observation error: Mean=0, Standard Deviation=0.1 sec.



For the offshore earthquakes, however, these values easily become 10 times as large. These characteristics will be of use for the estimation of the precision of the travel time, underground structure and other similar studies.

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## 1. 日本附近に起る地震の震源および発震時の決定精度

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1. 震央や発震時の決定精度は、単に観測精度ばかりではなく、震源および地震観測所の地理的分布の影響をうけることが少なくない。この問題を明らかにするために、過去2年間シミュレーションの方法を用いて幾つかの計算を行って来たが<sup>2), 3)</sup>、本研究もその一環をなすものである。

2. 気象庁には現在 112 の地震観測所が所属しているが、(第1図 a, b)、現に気象庁で実際に行っている手続きに従い、此の 112 の観測所のうち震央に近い 30 点を取り、 $\delta x$  (震央位置の東西方向の補正)、 $\delta y$  (震央位置の南北方向の補正)、 $\delta z$  (震源の深さの補正)、 $\delta T$  (発震時の補正) の 4 個の未知量に対する 30 個の観測方程式を作り、最小二乗法によってこれらの量を決定した。

3. その際媒質は一様とし、

1° 波の伝播速度は 7 km/sec

2° 震源の深さ 35 km

3° 観測点には、平均 0、分散 0.1 秒の正規分布をなす観測誤差がでたらめに生ずることを仮定した。

4. 震央としては、緯度・経度とも 1 度おきにとった日本を覆う 481 の点を取り、これを計算に使用した。そしてその各に対し 30 の観測点を用いて行う最小二乗法の計算を、少なくとも 128 回、平均ほぼ 200 回くり返し行い、信頼できる誤差の期待値の算出につとめた。

$\delta x$  と  $\delta y$  を合成した  $\delta r$  (震央位置の誤差) と  $\delta T$  の分布を図によって示す。二つの地図は共に日本列島の海岸線の形に強く支配された形の等高線を示し、陸地においては小さく、陸を離れると大きな値をとる性質において一致している。ただし、 $\delta T$  の分布は島の形に近い幅せまい谷を作るのに対して、 $\delta r$  の分布は、島を含む円形に近い盆地を作る様に見える。

陸地での最小値は

$\delta T = \text{ほぼ } 200 \text{ msec}$ ,  $\delta r = \text{ほぼ } 500 \text{ m}$

であるが、陸を離れればいずれの値も軽く 10 倍を越える。こうした性質は走時曲線、地殻構造等を論ずるに当って参考となることであろう。