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ANALYSIS OF MACROSEISMIC FIELDS OF EAST ALPINE EARTHQUAKES ON THE TERRITORY OF THE CZECH REPUBLIC

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ABSTRACT. East Alpine earthquakes exert significant contribution to general seismic hazard to building sites located on the territory of the Czech Republic. Relations describing the decrease of macroseismic intensity with epicentral distance belong to necessary input models for assessment of this hazard. An empirical decrease function was derived on the basis of computerized analysis of macroseismic fields for five strong earthquakes from the East Alpine source zone. Results of former expert (eye fitting) and new (automatic) construction of isolines are compared and evaluated.

KEYWORDS: isoseismal maps, macroseismic intensity decrease relations

1. INTRODUCTION

Macroseismic data concerning geographical distribution of East Alpine earthquake's intensities on the territory of the Czech Republic are regarded as necessary input data for assessment of earthquake hazard to important engineering structures, such as nuclear power plants, dams, high-rise buildings, toxic- and radioactive-waste depositories etc. Such assessments expressed by probabilistic seismic hazard curves [Buben 1995] can be made on the basis of the following input data and models:

- maximum possible earthquakes (seismic potential) of source zones within the region of building site,
- models (empirical relations) describing the decrease of earthquake ground motion (expressed mostly by the degree of macroseismic intensity I) along paths D between foci and building site S.

Maximum possible earthquakes with foci in East Alpine source zone give rise of very important contribution to the entire seismic hazard to objects on nearly all sites S, located on the territory of Czech Republic. Although their epicentral distances R are over 200 km, the intensity decrease $\mathrm{d}I = I_0 - I_S = f(R)$ is unusually small.

It is well known, that strong historical East Alpine earthquakes have been felt on nearly whole territory of the Czech Republic. For some of them (with epicentral intensities $I_0 \geq 6.5°$ MSK-64) it was possible to compile isoseismal maps (isolines

of equal intensity values). Up to now, these isoseismals have been constructed by expert methods (eye fitting)
accuracy of macroseismic intensity determination, the step of isolines cannot be smaller than 0.5°.

Anomalous distribution of intensities on the territory of the Czech Republic could be used as input data for detection structural heterogeneities (faults, layers) in the crust. Necessary condition for using this method is the stability of anomalies for all earthquakes having foci inside certain source zone. Only in this case we can suppose, that the impact of geologic structure prevails over the noise in macroseismic data.

The aim of present paper is:
- verifying the stability of local anomalies of macroseismic fields for East Alpine earthquakes,
- to derive an empirical site – specified relation describing intensity – distance decrease,
- assessment of the uncertainty of decrease values calculated by this relation.

2. Method

Since the year 1938 there have appeared five strong East Alpine earthquakes, for which could be constructed the isoseismal maps based of a greater number of macroseismic observations. These maps have been drawn by expert methods (eye fitting) being more or less subjective.

On the contrary, in the present paper they are drawn by computer programs. Theoretical basis of this procedure goes out of mathematical constructions of digital plane fields and of computerized analyses using isolines [Vencovský 1989]. All of graphical results are then saved in the form of the so called DXF files. These can be drawn using e.g. ACAD, and therefore can also be completed with graphical information of arbitrary character. The Křovák's coordinate system was used for processing geodesic data. Computerized evaluation was used for all interpretations, based on classical smoothing methods [Böhm 1962].

3. Input Data

Results given in this paper were obtained by analyzing macroseismic data concerning five East Alpine earthquakes, which are put on in Tab.1.

Table 1.

No.	date d m y	width °N	length °E	intensity MSK–64	depth km
1	8.11.1938	47.95	16.4	7.0	9
2	18.09.1939	47.8	15.9	7.0	9
3	27.10.1964	47.8	15.9	6.75	12
4	16.04.1972	47.8	16.2	7.75	7
5	14.04.1983	47.67	15.4	6.0	20

Local distribution of observed intensities on the territory of the Czech Republic is given in [Kárník et al. 1957; Kárník et al. 1984; Procházková 1984].

4. Results

4.1. Isoseismal Maps

Isoseismal maps for above mentioned earthquakes, denoted as I1, I2, I3, I4 and I5, are depicted in Figs 1a, 2a, 3, 4 and 5. The scale is given in the right upper corner. Depths H (km) and epicentral intensities I° (MSK–64) are given in the left bottom corner. The epicentrum is labeled by a circle and by letter F. Isolines are marked with step of 0.1 intensity degree. Tectonic lineaments [Šťovíčková 1980] are drawn by dashed lines. The state frontier is drawn by thick line.

The shape of isoseismals in above mentioned Figs is rather complicated. From their comparison it follows, that the distribution of local extremes is not stable. Their location and shape do not show distinct relation to tectonic lineaments and faults, too. Therefore the tectonic information seems to be hidden in data noise.

In connection to this is can be mentioned, that isoseismals which have been formerly constructed by eye fitting method are not realistic enough. This follows from comparison of Figs 1a and 2a with Figs 1b and 2b, the last being constructed by eye fitting method [Zátopek 1948]. Significant differences are very distinct at first sight.

Low reliability of macroseismic data can be documented by Fig 6, which depicts isoseismal map of earthquake in Western Bohemian, 50.2° N, 12.4° E, $I_0 = 7°$, from Dec 21, 1985 constructed by automatic method. Isoseismals on this map follow the course of Czech–Germany state frontier. This phenomenon can be explained by differences in evaluating macroseismic observations used in both states. Moreover, these isoseists are not similar to those constructed by eye fitting method, which are reproduced in another paper in this issue [Buben et al. 1996]. These facts strongly support the opinion that the data contained in isoseists are generally of very low reliability. Strong influence of macroseismic noise even by very young and well documented earthquakes.

4.2. Intensity Decrease Relations

Because of the missing similarity of macroseismic fields for five earthquakes from equal source zone, the prognosis of macroseismic intensities for earthquakes in the years to come has to be based on smoothing of isoseists obtained for individual earthquakes. To a certain degree, this procedure can eliminate the considerable noise in macroseismic input data. Mathematical relations describing the intensity–distance decrease have to be optimized in the statistical sense.

In most cases, calculating probabilistic seismic hazard for East Alpine Earthquakes and a specified locality S, the intensity distance relations need not take in account the dependence on various azimuths (anisotropy), because they do not differ to much. To this end we chose the well known isotropic Blake's shape of decrease functions

$$I_0 - I_R = \mathrm{d}I = k \log(D/H)\,, \qquad (1)$$

where D is hypocentral distance, R is epicentral distance, H is depth of foci

$$D^2 = (R^2 + H^2)\,, \tag{1a}$$

k is the parameter characterizing the decrease.

This parameter was evaluated as a statistically balanced value from all observed N values of intensities $I'_{R,i}$ for all of evaluated macroseismic fields:

$$k = \frac{1}{N} \sum_{i=1}^{N} \frac{I_0 - I'_{R,i}}{\log(D/H)_i}\,. \tag{2}$$

The variance of input values can be determined by relation

$$s^2 = \frac{1}{N} \sum_{i=1}^{N} \left(I'_{R,i} - I_{R,i}\right)^2 \tag{3}$$

where $I_{R,i}$ is the value obtained from (1) inserting to it the coefficient k from (1).

Anomalies of intensity are defined as differences of observed values and those calculated from (1). Maps of such anomalies for all five earthquakes are depicted in Figs 7a to 11a. Their comparison illustrate low stability of this field.

As it is well known, formula (1) does not respect the absorption of seismic waves which manifests itself more distinctly only at greater epicentral distances. In the course of adapting the decrease function to this fact, a slightly modified shape was introduced, which has the form

$$\mathrm{d}I = k \log^n(D/H)\,, \tag{4}$$

The parameters k, n were derived by the minimum squares method [Böhm 1962].

Tab. 2 gives the parameters k, s, n calculated for formula (1) as well as parameters k, m_k, n, m_n obtained for (4). The mean values of k and n, i.e. m_k, m_n, were obtained by minimum squares, too. The variance s was calculated according to relation (3).

TABLE 2.

	formula (1)			formula (2)				
No.	k	m_k	s	k	m_k	n	m_n	s
1	2.6	0.02	0.5	3.1	0.05	0.3	0.06	0.4
2	2.4	0.02	0.4	3.5	0.08	0.6	0.09	0.4
3	2.7	0.02	0.5	3.2	0.05	0.25	0.06	0.4
4	3.0	0.02	0.5	3.8	0.09	0.4	0.06	0.4
5	3.7	0.03	0.5	3.8	0.03	0.4	0.07	0.4

From this table it follows, that the dispersion s decreased significantly in the statistical sense (Fischer's criterion) in the case of using relation (2). Therefore it can be recommended as more suitable. The distribution of negative intensity anomalies (dotted areas) and the positive ones are depicted in Figs 7b to 11b. It is more even than that given in Figs 7a to 11a, which concerns the use of formula (1).

For prognosis of the intensity I_R in a given site S when an earthquake with epicentral intensity I_0 will occur in the East Alpine source zone with hypocentral distance D (km) can be recommended the formula (4) with following parameters:

$$I_R = I_0 - K_0 \log^{n_0}(Q)\,, \tag{5}$$

$$K_0 = 3.5 \pm 0.05\,,$$

$$n_0 = 0.35 \pm 0.06\,,$$

where

$$Q = (D/H)\,.$$

This intensity decrease model can be completed by calculation of the mean error of the resulting value I_R according to the relation (6) derived by standard methods of mathematical statistics

$$m_{\mathrm{IRM}}^2 = m_{k,0}^2 \cdot \log^{0.7}(Q) + m_{n,0}^2 \cdot K_0^2 \cdot Q^{-2} \cdot \log^{-1.3}(Q) \cdot 0.02\,. \tag{6}$$

The second term in this relation has a negligible small value. Following, this relation can be transcribed to simplified form

$$m_{\mathrm{IRM}} = m_{k,0} \cdot \log^{0.35}(Q)\,. \tag{7}$$

This equation allows the assertion, that the intensity decrease for East Alpine earthquakes and building sites S anywhere in the Czech Republic could be predicted using the relation (5) with error of not exceeding 2 per cent.

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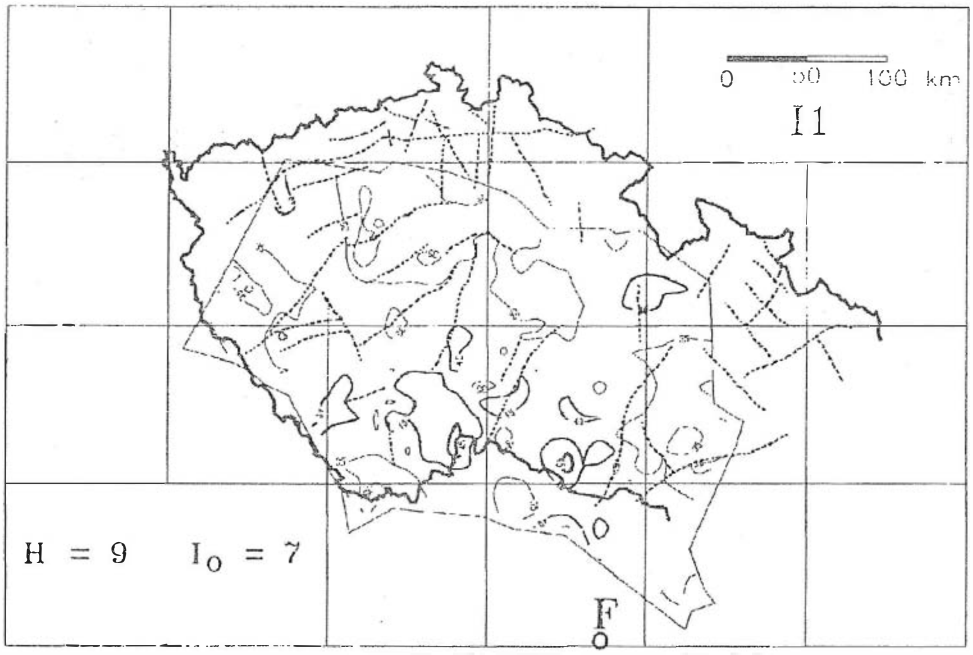


Fig. 1a

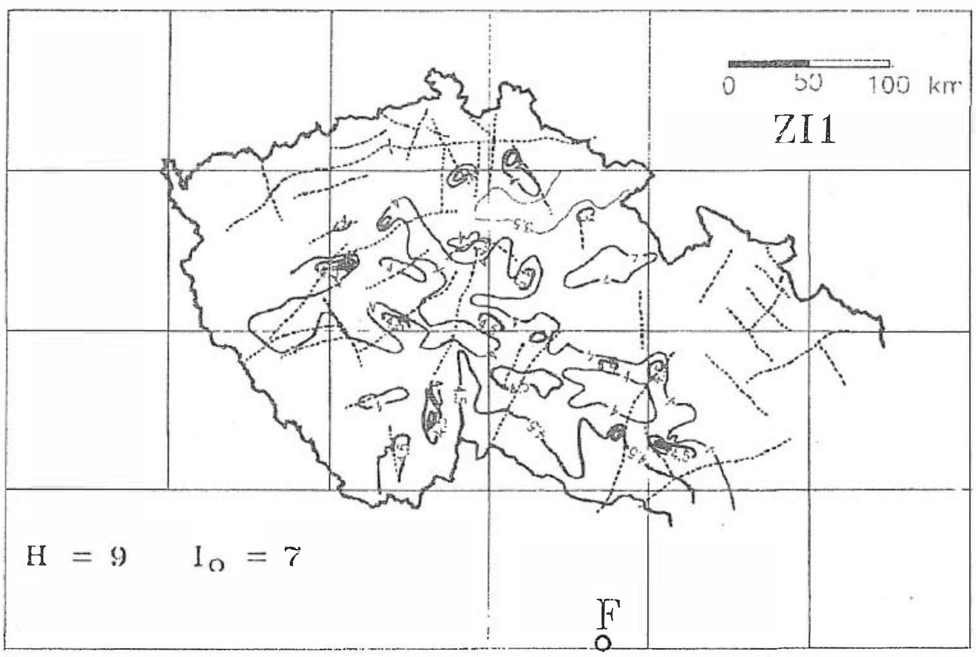


Fig. 1b

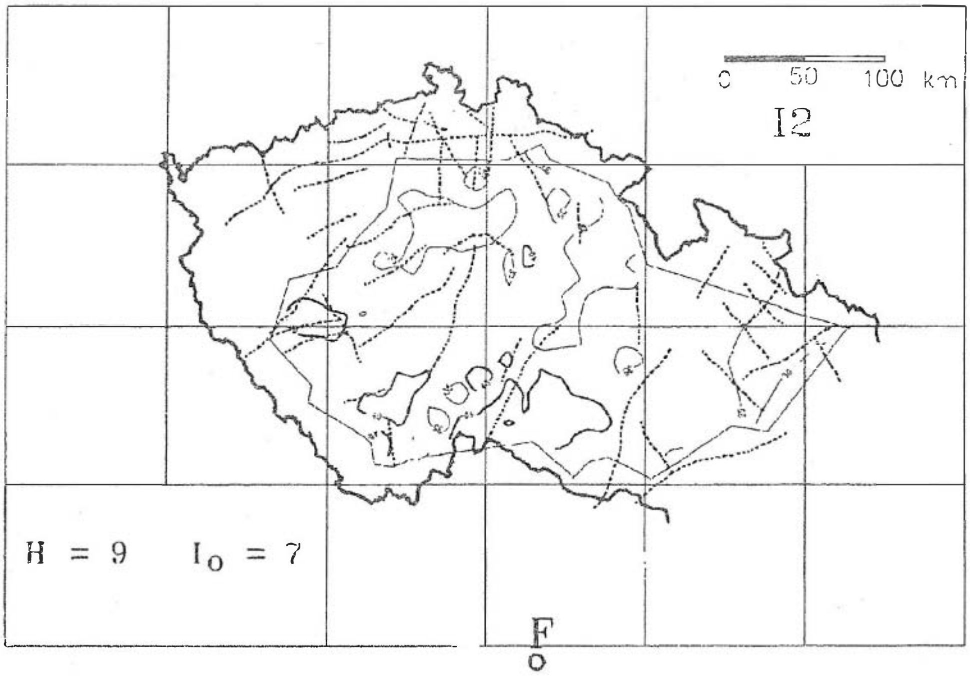


FIG. 2a

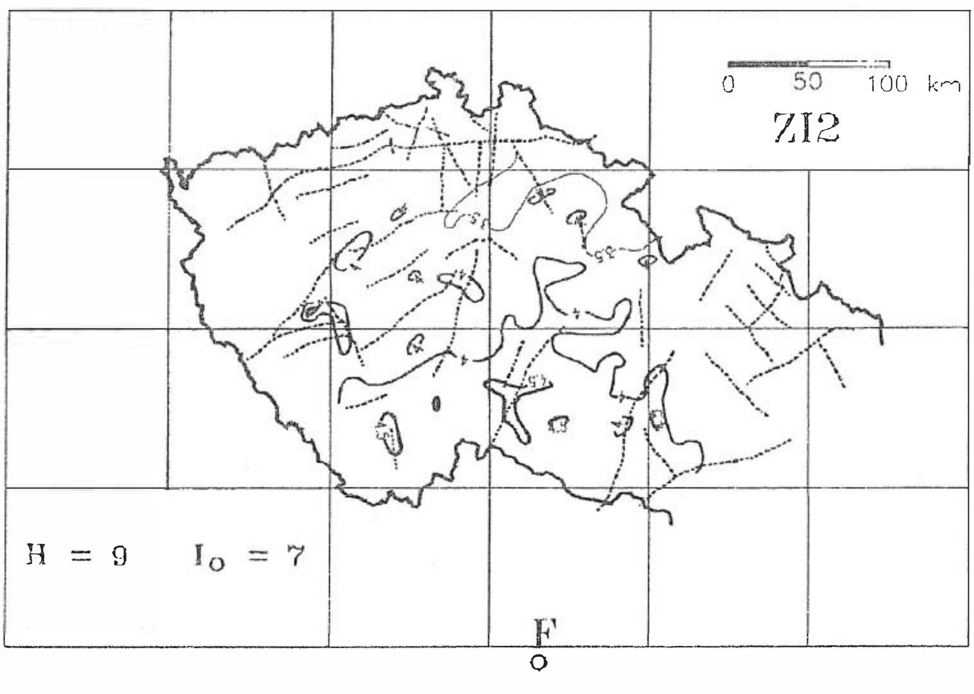


FIG. 2b

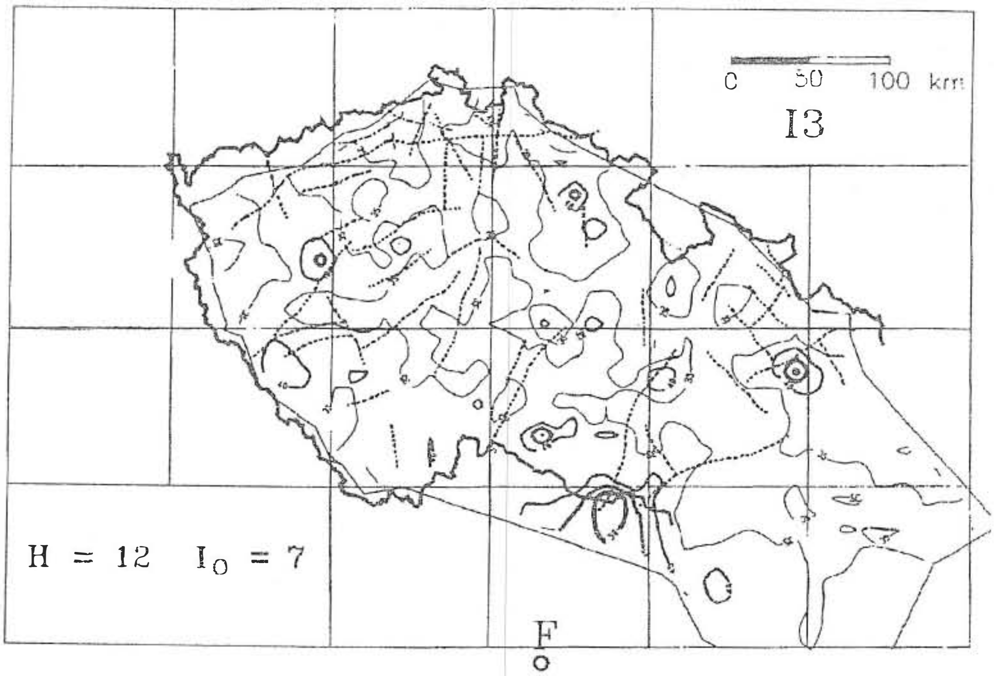


FIG. 3

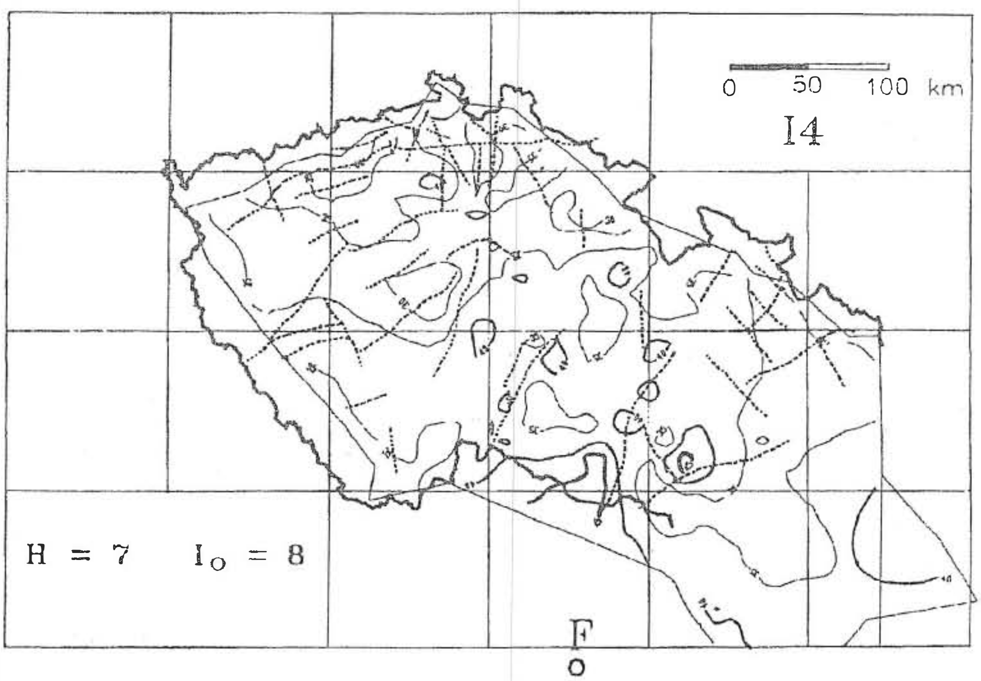
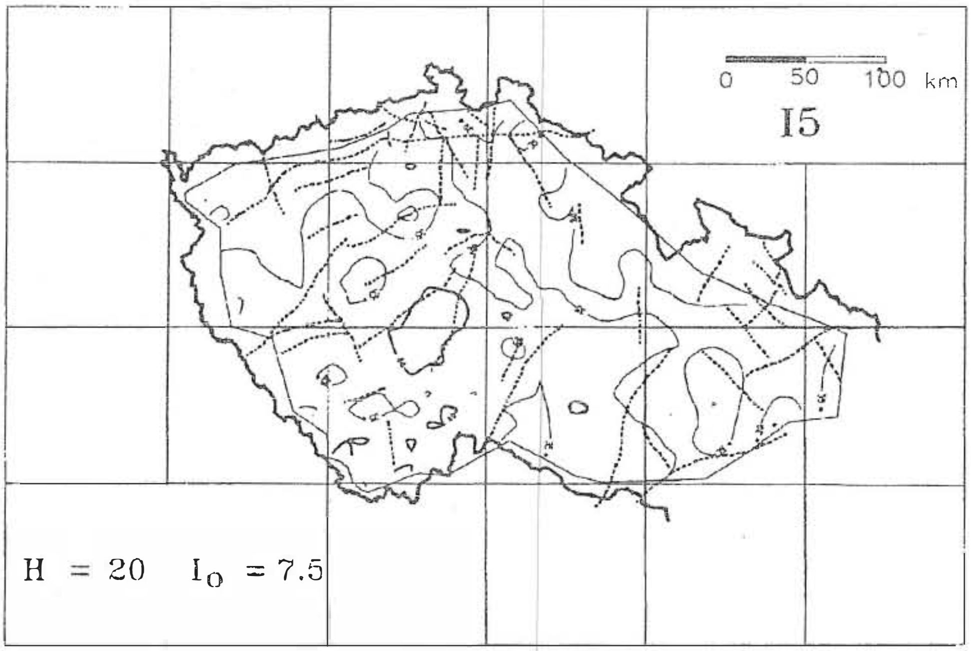


FIG. 4


0 50 100 km
I5
H = 20 I0 = 7.5

F
o

Fig. 5

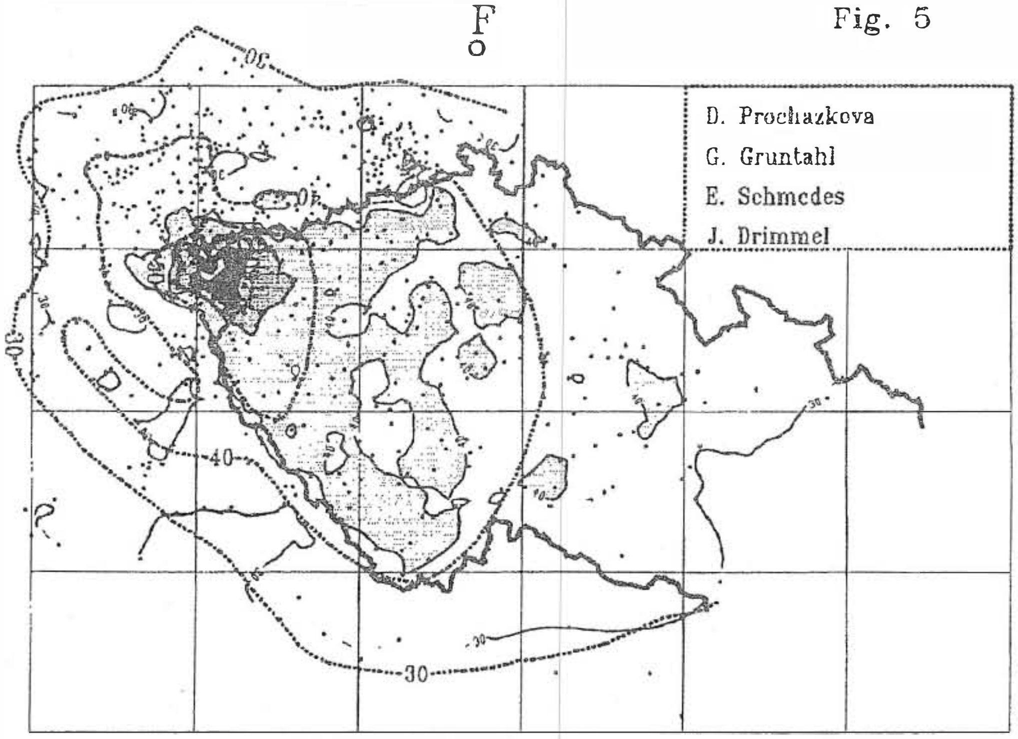

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Fig. 6

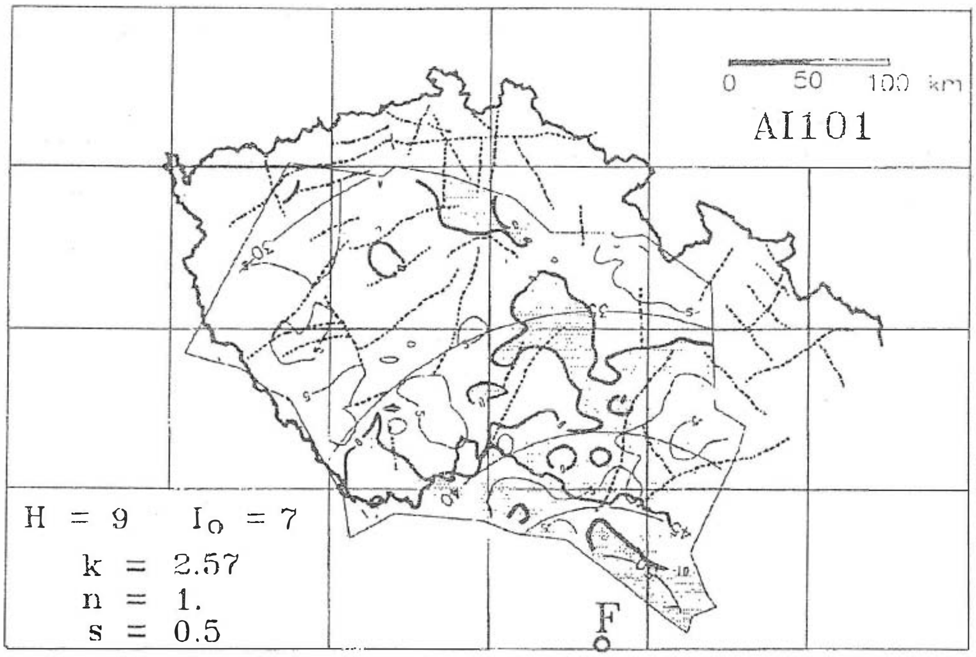

0 50 100 km
AI101
H = 9 I0 = 7
k = 2.57
n = 1.
s = 0.5
F

FIG. 7a

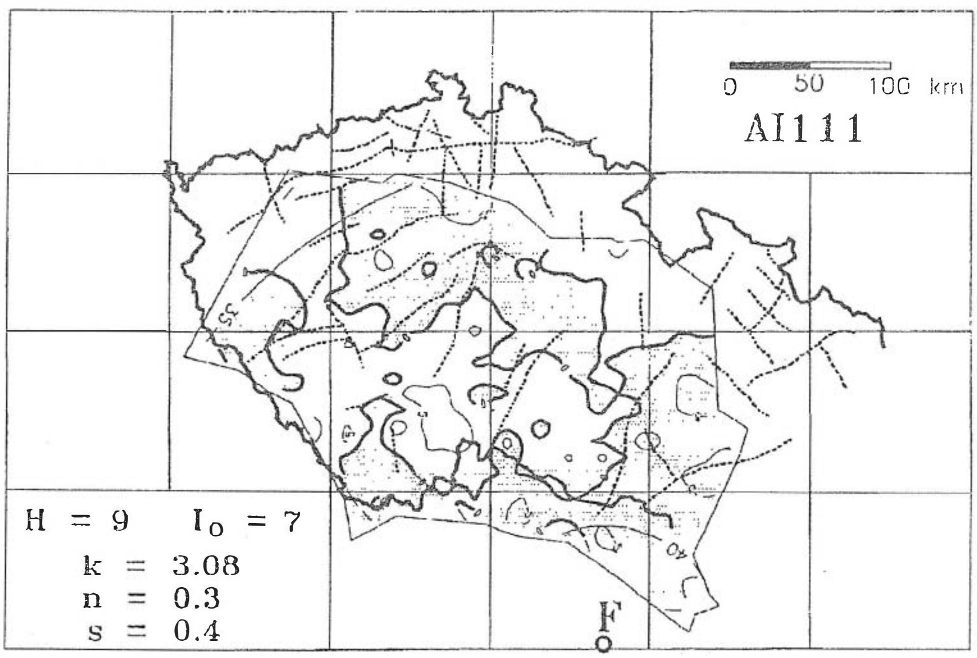

0 50 100 km
AI111
H = 9 I0 = 7
k = 3.08
n = 0.3
s = 0.4
F

FIG. 7b

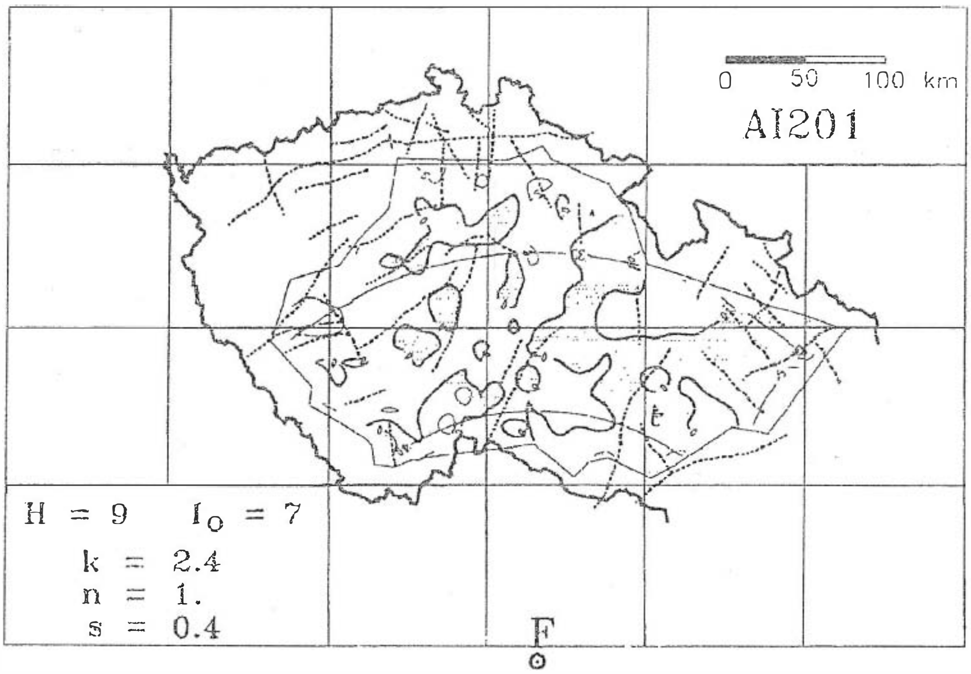

0 50 100 km
AI201
H = 9 I_0 = 7
k = 2.4
n = 1.
s = 0.4
F

FIG. 8a

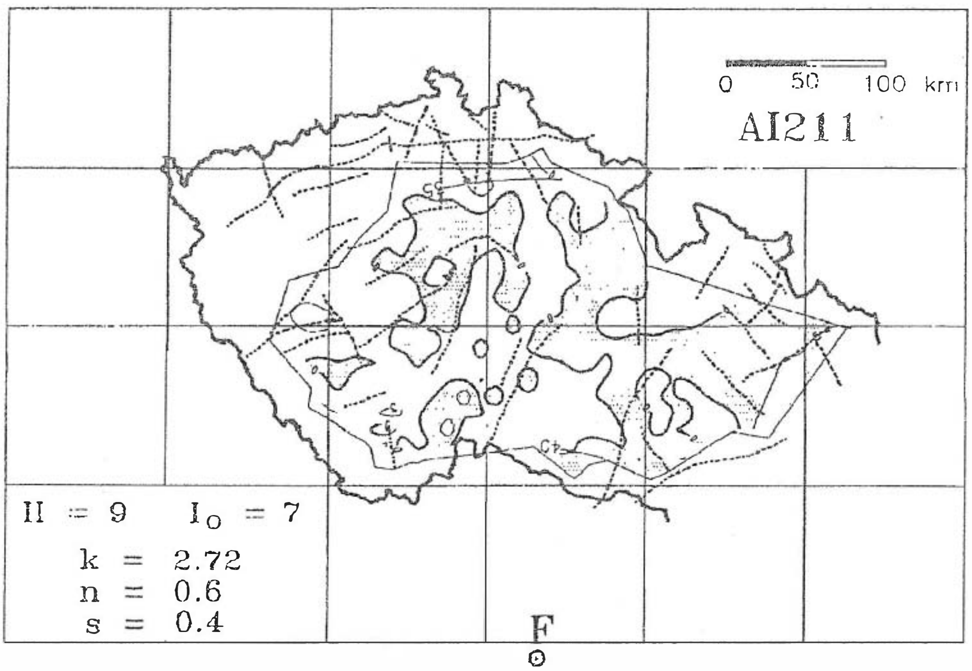

0 50 100 km
AI211
II = 9 I_0 = 7
k = 2.72
n = 0.6
s = 0.4
F

FIG. 8b

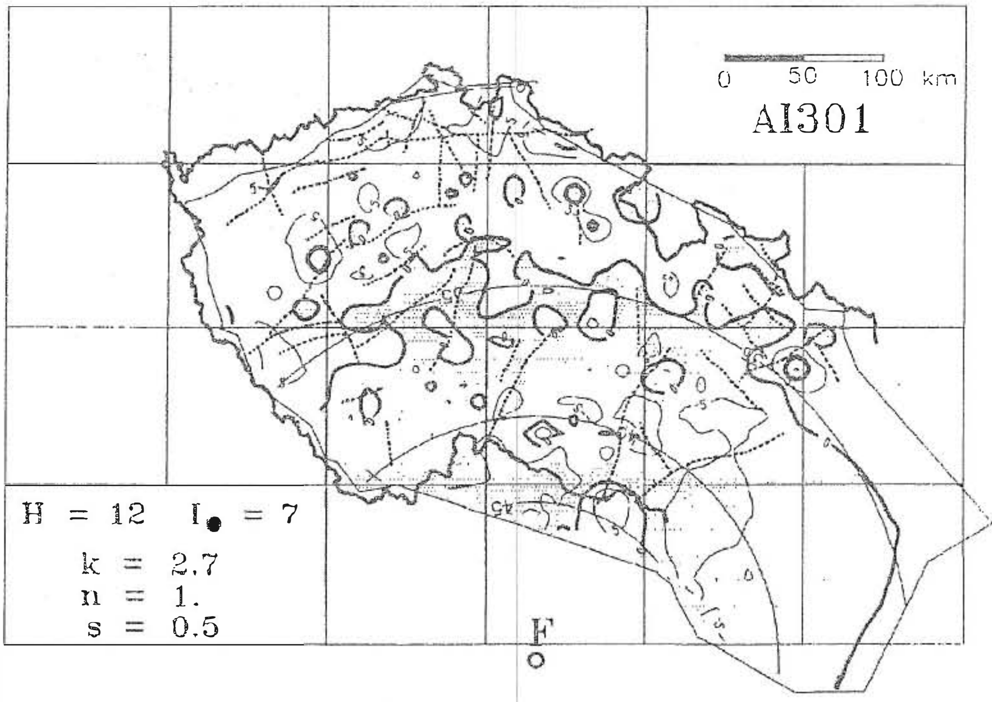

0 50 100 km
AI301
H = 12 I₀ = 7
k = 2.7
n = 1.
s = 0.5
F

FIG. 9a

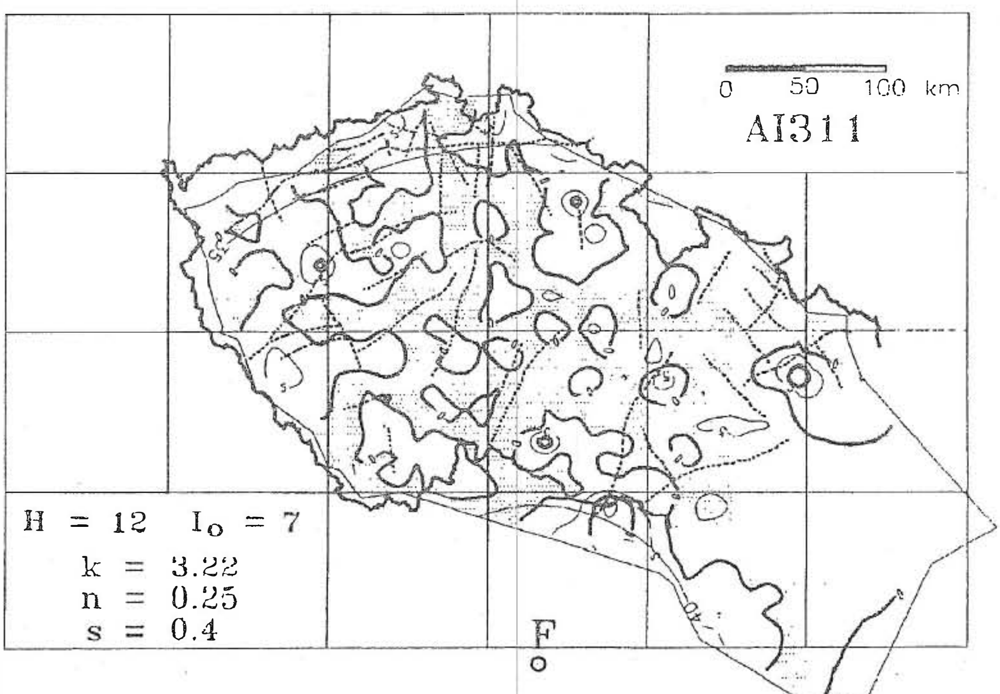

0 50 100 km
AI311
H = 12 I₀ = 7
k = 3.22
n = 0.25
s = 0.4
F

FIG. 9b

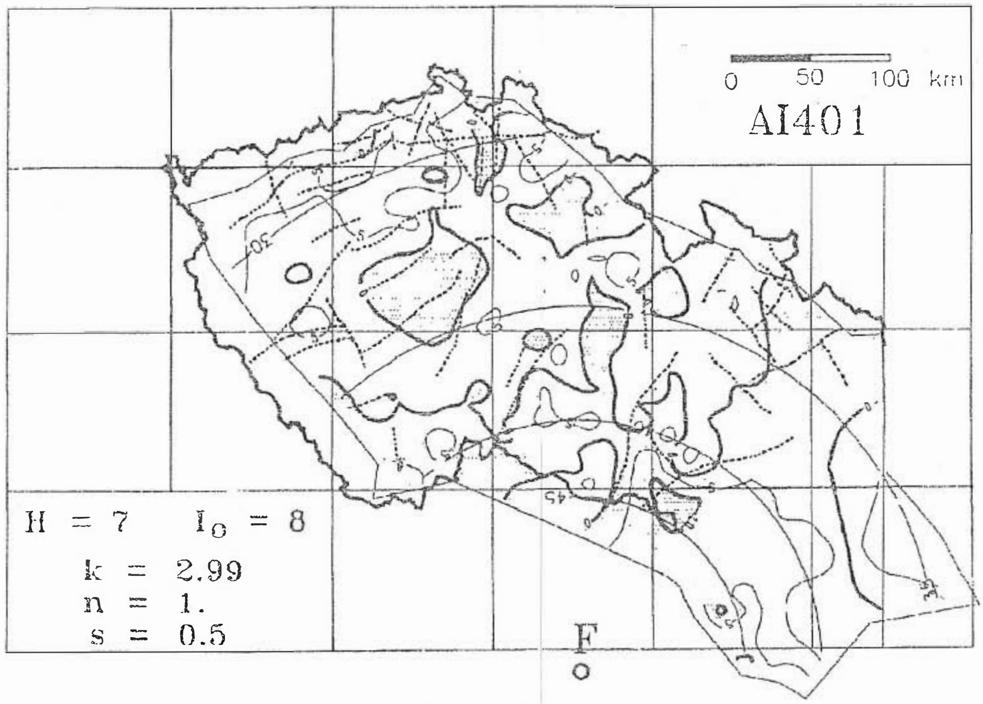


FIG. 10a

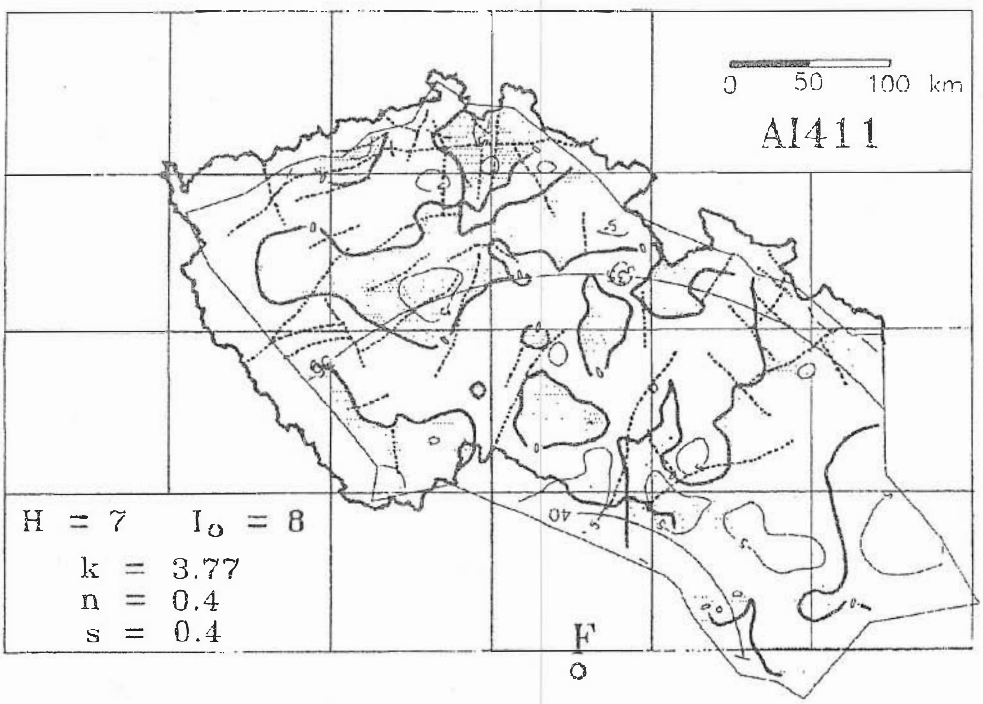
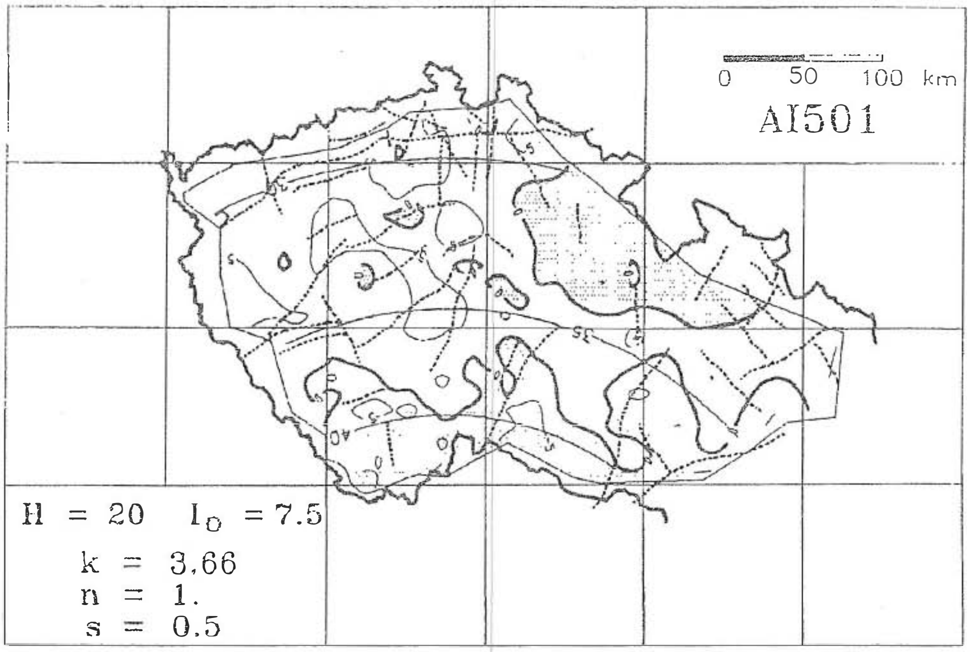
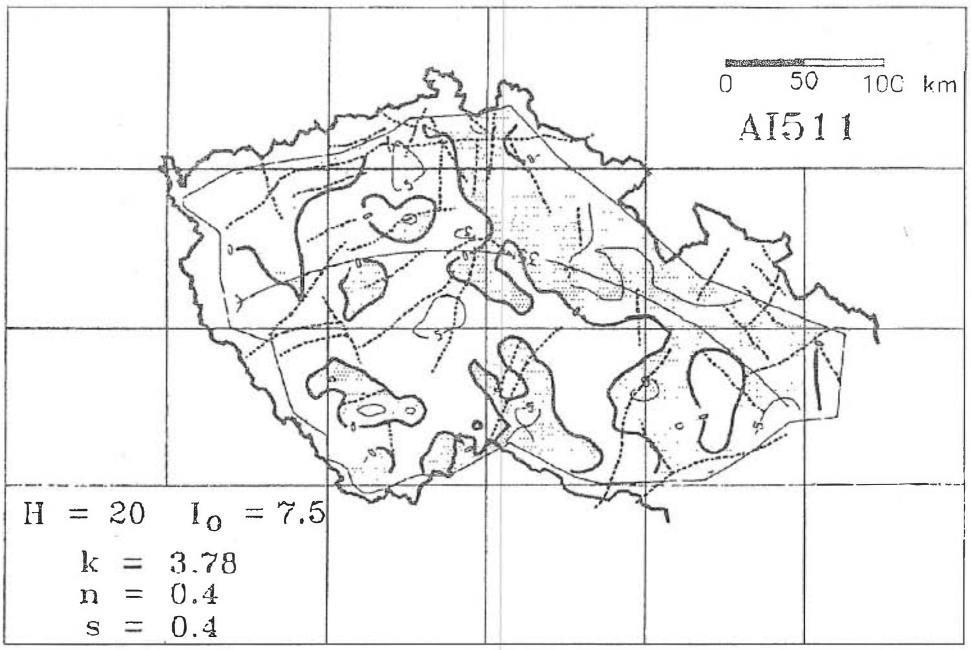


FIG. 10b



F_o

FIG. 11a



F_o

FIG. 11b

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