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Determination of Relationships Between Radon Gas (222rn), Earthquake and Meteorological Parameters with Kriging and Regression Methods

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Abstract

Radon gas (^{222}Rn) is very important earthquake sign. ^{222}Rn concentration emitted from soil shows that nonlinear feature. Therefore, it is necessary to understand the change determine of ^{222}Rn propagation characteristic. In this study, a new prediction algorithm was obtained for explaining the non-linear behaviors of ^{222}Rn concentrations from soil. On the other hand, Kriging method estimate unmeasured points using regional variability. Estimated results were compared with the regression method. We used Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and R^2 coefficient of determination. The results indicate that the nonlinear dynamical approximation is suitable for characterization and prediction of the ^{222}Rn concentration. In this paper, soil ^{222}Rn gas measurements were applicated to Yakapınar Region in the East Anatolian Fault Zone.

Key Words: Kriging Methods, Multiple Regression Analysis, Radon, Estimates.

1. Introduction

Many works have defined that various geophysical and geochemical parameters are nearly related to earthquakes [1, 2]. Earthquake prediction studies, the change of ^{222}Rn gives very meaningful results on earthquake prediction [3]. Although is not fully understood the origin and mechanism of the relationship between the earthquake and the radon, it is seen that the radar transitions from the rocks to the ground due to the varies in the shape of the earth's shell. Before the start of seismic activity, a change is observed in radon concentrations in the surrounding well and spring waters [4]. The presence of this change is a sign that are related the radon and the earthquake. Radon concentration affected by various physical factors soil structure, earthquake severity and depth of earthquake [5]. Radon concentration emitted from fault line and earthquake data (depth, intensity) provide meaningful results for many changes that cannot be explained by laws of physics. In order to establish this relationship in a healthy way, it is necessary to monitor how radon concentration changes with respect to earthquake depth for months or even years [6]. The decomposition product of ^{238}U, ^{222}Rn has a half-life of 3.82 days. ^{222}Rn is a radioactive noble gas that occurs conclusion radioactive decay of natural uranium in rock, soil and water [6]. Since the main source of the radon is uranium, radon concentration varies on earth, region to region. Thus, radon concentration levels are distributed in the vicinity in proportion to the geological and geophysical structure of the area studied. In this paper, soil ^{222}Rn concentration measurements are searched and Kriging estimation with regression analysis was performed. The results were compared with multiple regression analysis. The implementation is performed for data from Yakapınar regions near the East Anatolian Fault Zone, Turkey.

1. MATERYAL METHOD

1.1. Study Area

Investigation region, are given in Fig. 1 which extends between east longitude 35°37'38'' and north latitude 36°57'04″. This region is a tectonically hampered and seismically active region of the Anatolian Fault Zone Turkey [7]. The data used in this study was taken with a measurement interval of 15 minutes, recorded data from 1 January to 31 December 2007.

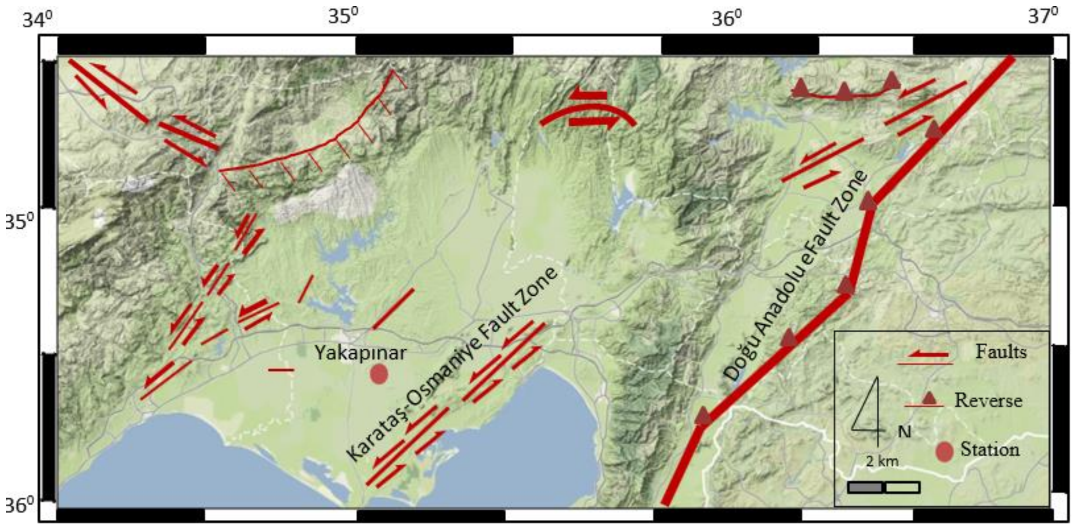

Fig. 1. Fault map of the study area.

1.2. Experimental Data Set

This research, ^{222}Rn concentration is saved with an alpha detector (Alphameter 611). This detector has delicacy for 1.5 MeV energy levels of permanent tracing. The data accumulated per 15-min union time. The dispersion of ^{222}Rn concentration in the soil, alpha particles detected. Tarakçı et al. have indicated it [8].

1.3. Kriging Methods Principles

The Kriging technique, which is a geostatistical analysis, examines the spatial variation by adding account the distance between the regional variables and its calculations are a statistical method based on stationary random functions. Kriging allows the estimation of unknown values in un-sampled locations [9,10,11,15]. Kriging calculates using the weights of the variogram function, which symbolize the spatial variation [12,13].

In geostatistics, the distance-dependent changes of regional variables are determined by the function of Variogram or Semivariogram (SV) and this function (Eq. 1) is expressed as the variance of two spatial variables having distance up to h between them [11]. According to the basis of geostatistic, the same variable exhibits a greater similarity comparatively to locations that are distant, in locations close to each other. At the same time, this function is based on the idea that the similarity will end up as the distance increases.

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (Z(x_i) - Z(x_{i+d}))^2 \tag{1}$$

Here, γ_h, SV value at distance h; Z_i, the value of the regional variable in location i; Z_{i+d}, the value of the regional variable measured after distance h from i; $N(h)$, refers to the total number of sample distances. The curve of the theoretical SV is determined by fitting a curve fit to the obtained experimental SV graph and so that information about the spatial structure of the region is elicited. The most used models in the literature are spherical, exponential, gaussian and linear models.

According to this method, in order to estimate the value in an unmeasured position, is taken weighted average of data in neighboring locations changing with distance. For this to be possible, the positional relationship between the measurement positions must be determined. This spatial dependence can be defined either by covariance function or by using a SV function [14].

The general equation of the Kriging method,

$$Z(x_0) = \sum_{i=1}^{n} W_i Z(x_i) \tag{2}$$

Here, $Z(x_0)$, the predicted value at x_0 point of the regional variable; $Z(x_i)$ the real value of the regional variable at position x_i; W_i weights; n is the number of point used in the calculation of $Z(x_0)$.

1.4. Multiple Linear Regression Analysis

Regression analysis is defined as the process by which a relationship between a dependent variable and an independent (simple regression) or multiple independent (multiple regression) variables is explained by a mathematical equation. Simple linear regression model can be suitable for many situations. However, in fact, two or more explanatory variables are needed to explain many models. Multiple explanatory variable models are called multiple regression models [15]. In addition, multiple regression analysis are offers many opportunities such as easy, interpreted, adjustable by variables. Simple and multiple linear regression model equations are written as follows,

$$Y = b_0 + b_1 x_1 + \cdots b_n x_n + \varepsilon \tag{3}$$

in the model equations, where, Y is dependent variable, $x_1, \cdots x_n$ predictor variables, $b_0, \cdots b_n$ calculated coefficient parameters, ε is the term error. Multiple linear regression analysis was done in IBM SPSS Statistics Version 25 package program and model equation was created. Lineer regression analysis are generally fit using least squared method [14].

1.5. Performance Assessment

Regression models was measured computing the subsequent statistical variables: correlation coefficient (R^2), mean square error (MAE), mean absolute error (MAPE), root mean squared error (RMSE) are given as Eqs. (4-6) respectively:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|\hat{q}_i - q_i\right| \tag{4}$$

R^2 ensures the variability evaluate of the variable accrue in the model. MAPE shows if the tracked data are or underprice.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\hat{q}_i - q_i}{q_i}\right| \times 100 \tag{5}$$

MAE and RMSE evaluate remain errors, which give a global idea of the difference between the observed and modelled values.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{q}_i - q_i)^2} \quad (6)$$

The rates of d checked the distinction between the mean, the predicted and the observed data, signed the degree of error independent for the predictions [15].

Table 1. Estimated error rates for the radon measurements (regression)

	RMSE[a]	MAE[b]	MAPE[c]
Yakapınar region ^{222}Rn data	1.219	0.006	0.003

MAPE, MAE and RMSE error values for Yakapınar station are given in Table 1.

2. RESULT and DISCUSSION

In this study ^{222}Rn activity concentration prediction was made with soil samples for unmeasured points within the study area by using Kriging method. ^{222}Rn radionuclide distribution maps were generated and spatial distribution model of ^{222}Rn radionuclide were determined by using Kriging method. In this way, ^{222}Rn activity values in the study area were used to predict radiological interpolation values for other parts of the area where soil samples were not taken.

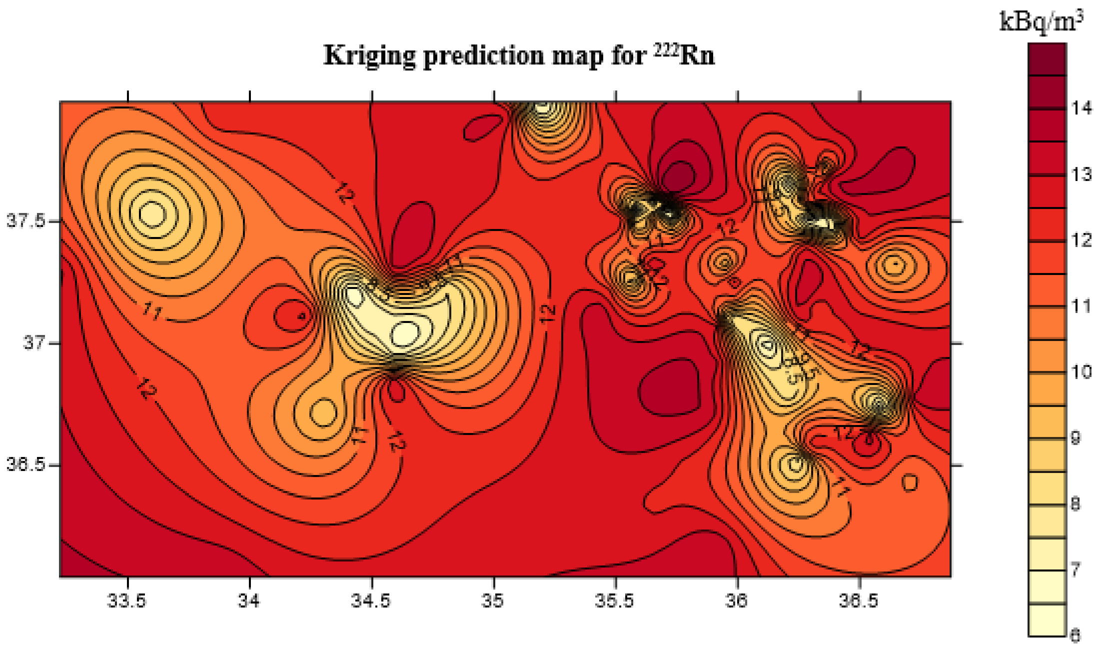

Fig. 2. Kriging map for ^{222}Rn concentration measured in Yakapınar region.

According to the determined model, the radiological maps generated for the ^{222}Rn measured in soil samples are shown in Fig. 2. Kriging in these maps specifies the general distribution. As can be seen from the study areas, activity concentrations of ^{222}Rn in the soil samples, specially ^{222}Rn activity in the southwest and northern east parts of the study area, were relatively high according to northwest and southeast parts of the study area.

Regression analysis shows us whether there is a linear relationship between two variables collected on an intermittent scale about normal scatter. One of the variables is the estimation variable and one other is result variable. Regression analysis is showed between statistically significant positive linear relationships. Regression formula is given equally to show this relation.

$$y = 0.11x_1 + 0.16x_2 + 0.13x_3 - 0.32x_4 - 0.72x_5 - 0.14x_6 - 0.72x_{7+}e \quad (7)$$

Where x_1 is the ^{222}Rn concentration value, $x_2$is depth of earthquake, x_3 is pressure, x_4 is temperature of soil (depth:10), x_5 is temperature of soil (depth:20), x_6 is temperature of soil (depth:50), x_7 is dry bulb, x_8 is wet bulb and e estimated value and observed value the difference between.

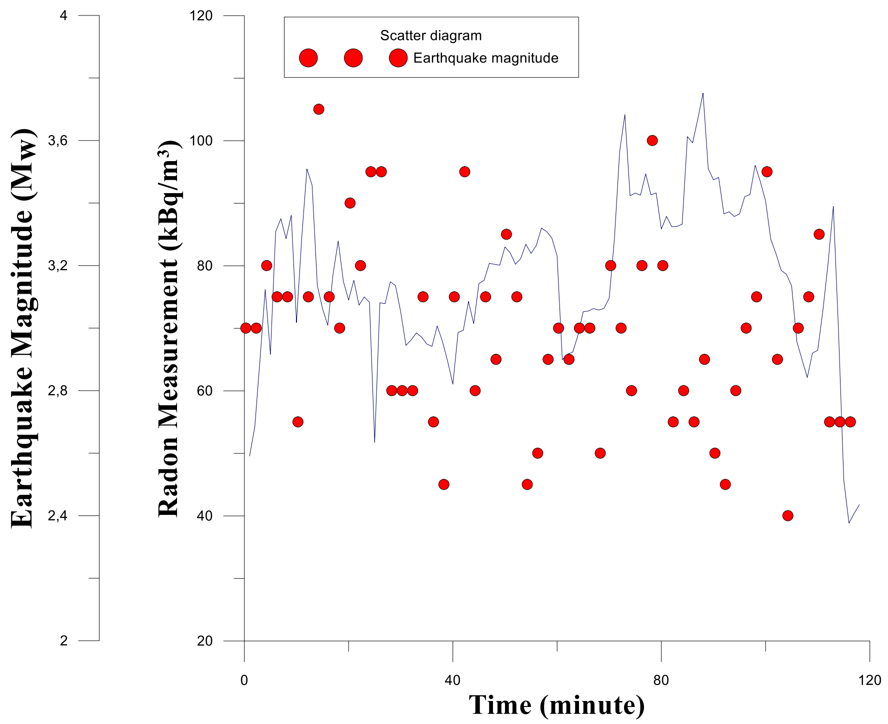

Fig. 3. Time series of earthquake magnitude and measured values of radon during the observation.

As indicated in Figure 3 the time series of earthquake magnitude and measured values of radon during the observation period. Figure 4 is show predicting was drawn by ROC curve. Table 2 shows that prediction value, residual, standard prediction value, standard residual for study parameter, respectively.

Table 2. Residual statistic results

	Minimum	Maximum	Mean	Std. Deviation	N
Prediction Value	2,7634	3,4706	3,0822	,13586	118
Residual	-,56058	,96286	,00000	,27069	118
Std. Prediction Value	-2,346	2,859	,000	1,000	118
Std. Residual	-1,999	3,433	,000	,965	118

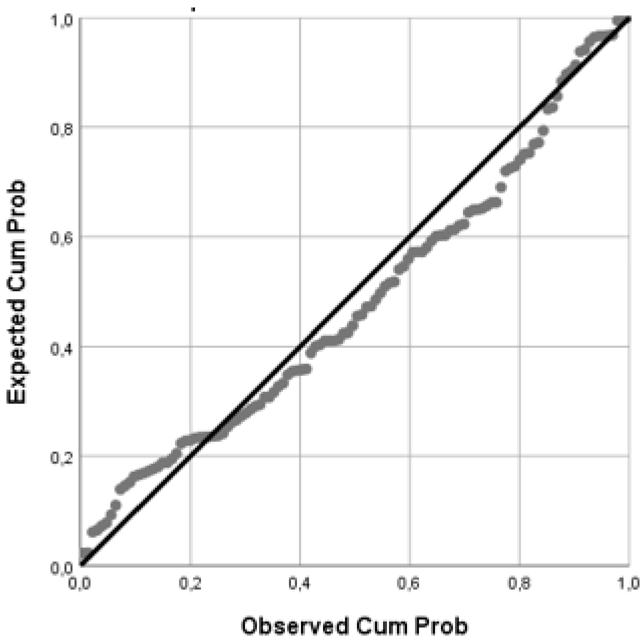

Fig. 4. The predicted earthquake magnitude values and measured ^{222}R values

Kriging is the name given to the estimation technique used in geostatical studies. Kriging is a geostatistics method that predicts the value in a geographic area given a set of measurements. It's used in mining, soil, geology and environmental science. There's no one cookie-cutter methodology that works for everyone. For this reason, these significance tests have also been shown to be very sensitive to signs.

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