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Research Article

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Prediction of Latitude and Longitude of Earthquakes at Global Level Using the Regressive Objective Regression method

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Summary

Objective: *To model the series of data of a set of earthquakes at a global level included in the period from 2014-08-27 23.22.23 UTC until 2014-08-27 04.47.36 UTC, there were 50 earthquakes taken globally and it was determined a model to predict the longitude and latitude of these events.*

Methods: *The Regression Objective Methodology, ROR, is used. Two models are calculated, the first for latitude and the second for longitude, the models are determined in a short term.*

Results: *The correlation coefficients are obtained between the real value and the forecast of 0.716 for model 1 with an error of 25.09 significant degrees at 99% and, for model 2, R = 0.637 with an error of 74.64 degrees significant at 90%. Earthquakes for latitude depends on the value 1.16.12 earthquake behind, the parameter returned 16 steps back are significant at 99%. For this model the trend is 0.118 not significant, model 2 depends on 1,2,11,21 steps back, earthquakes 1 step back is significant at 90%, the trend of the series for model 2 is a rise in length by 4,637 significant at 95%.*

Discussion: *Our work shows the longitude and latitude of earthquakes occurrence are perfectly predictable parameters similar to the variable wind, so a careful attention must be paid to the prevention planes of these phenomena to reduce vulnerability in cities.*

Conclusions: *It is concluded that model 1 is the least error while trend in model 2 has a significant increasing. Global earthquakes are regressive event sat planet level and what happens in one place has repercussions in another, not randomly or due to chance, but rather a well-determined phenomenon.*

Keywords: Global Modeling, Earthquakes, Prediction, Length, Latitude

Introduction

An earthquake is a geological phenomenon produced by a sudden release of energy at a certain point in the earth's crust. This movement causes shock waves, also known as seismic waves; because they propagate from the point of origin and travel through the earth. The earthquakes are manifested in the formation and decomposition of rocks and soils, in the variation of their physical and stratified conditions, as well as in the formation and variation of the Earth's surface relief. Also, they are present in the construction of crust and in the internal structure of Earth. Its study and prediction is extremely important due to its influence on soil stability, respectively, in existing constructions, construction plans, under construction works, etc. (i.e. cities, buildings, bridges, dams, roads, tunnels, airports, mines). The possible occurrence of earthquakes is a threat whose impact can cause serious injuries or geological risks [1].

Some studies have determined that the seismic risk leads to follow three fundamental steps: 1) the assessment of danger, 2) vulnerability and 3) the evolution of risk. Changes in one or more of these parameters influence the risk itself. To consider these elements, it is necessary to use or design a methodology that provides as much detail as possible to determine the risk behavior in a given geographical area [1].

The ROR methodology has been widely implemented [2, 3], the Box and Jenkins methodology will not be used since it has limitations [4, 2]. The ROR methodology was also applied in the forecast of high intensity earthquakes in Cuba [5]. It was also used in the control of mosquitoes according to [6], its results have been used in climate change and health studies in Villa Clara Cuba [7], these mathematical models were applied in Malaria [8]. The ROR methodology was applied in Meteorology, basically in the modeling of cold fronts and the impact of sunspots [9]. Furthermore, it has been used in the long term for the prediction of the larval density of anopheles mosquitoes [10]. The ROR methodology opens a wide range of possibilities for its use, and especially within the subject we are dealing with, it is possible to use it [11], where an increase in earthquakes is foreseen at a global level.

That is why our goal will be:

To model the series of data of a set of earthquakes at Global level included in the period from 2014-08-27 23.22.23 UTC until 2014-08-27 04.47.36 UTC, as well as to determine a model to predict the longitude and latitude of these events.

Materials and Methods

A set of earthquakes at a global level is used, included in the period from 2014-08-27 23.22.23 UTC until 2014-08-27 04.47.36 UTC, from them the latitude and longitude are taken. The use of the ROR methodology allows us to model this series; the procedure was carried out with the help of the statistical package SPSS version 13.

In the ROR methodology the variables DS and DI represent the ups and downs of the series, while NoC represents the trend of the same, so that DS and DI take alternate values of zero and one which represents two states. The daily data were taken from [12].

Results and Discussion

Then the results obtained:

In Table 1 it can be observed that there is no significant correlation between the Latitude with the Length in which the earthquakes occur. However, this series shows significant correlations at 90%, which encouraged the authors to try the ROR methodology [2], for the earthquakes at a global level on a daily basis, this methodology had already been tested for the most intense earthquakes for Cuba [6] and at the global level as well [13].

Correlations

		Latitud	Longitud
Latitud	Pearson Correlation	1	.261
	Sig. (2-tailed)		.067
	N	50	50
Longitud	Pearson Correlation	.261	1
	Sig. (2-tailed)	.067	
	N	50	50

[Table 1] Correlation of the Latitude with the Length of the last 50 earthquakes at the Global level.

The results obtained for Latitude can be seen in Table 2, the R is 0.716, this value is similar to the models obtained for daily precipitation in Villa Clara Province, so we intuit that these models can have a predictive utility in case of global earthquakes.

Table 2: Summary of the ROR Model for latitude.
Model Summary[c,d]

Model	R	R Square	Adjust R Square	Std. Error of the Estimate	Durbin-Watson
1	.716[b]	.513	.409	25.09024	1.973

a. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R square for models which include an intercept.
b. Predictors: lag12Latitud, lag 16Latitud, DS, lag1Latitud, DI, NoC
c. Predictors: lag12Latitud, lag16Latitud, DS, Lag1Latitud, DI, NoC
d. Linear Regression through the Origin

In Table 3 the variation analysis for the model obtained for Latitude is significant to 99%

Table 3: Variation analysis for the model obtained
AVOVA[c,d]

Model	R	R Square	Adjust R Square	Std. Error of the Estimate	Durbin-Watson
1 Regression	18585.388	6	3097.565	4.921	.002[a]
Residual	17626.568	28	629.520		
Total	36211.956[b]	34			

a. Predictors: lag12Latitud, lag16Latitud, DS, lag1Latitud, DI, NoC
b. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
c. Dependent Variable: Latitud
d. Linear Regression through the Origin

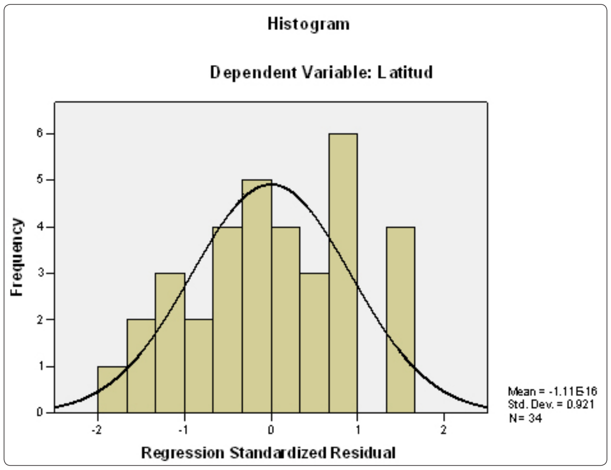
In Table 4 the coefficients of the model, DS and DI are the parameters that indicate the ups and downs of the series. NoC is the trend of the series that although positive is not significant, a significant regression parameter is observed at 99% for the delay 16 (Lag16Latitud). Other parameters are not statistically significant, however they provide information about the variance explained, that is why they are maintained in the model.

Table 4: Latitude model coefficients
Coefficients [a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	DS	21.408	16.674	.464	1.284	.210
	DI	27.487	17.505	.596	1.570	.128
	NoC	.118	.450	.126	.262	.795
	lag1Latitud	.277	.165	-.272	-1.678	.104
	lag16Latitud	-.411	.160	-.403	-2.577	.016
	lag12Latitud	-.044	.158	-.043	-.277	.784

a. Dependent Variable: Latitud
b. Linear Regression through the Origin

(Figure1) shows the histogram of the standardized residuals, which do not differ from the normal distribution, moreover is very beneficial for the model.



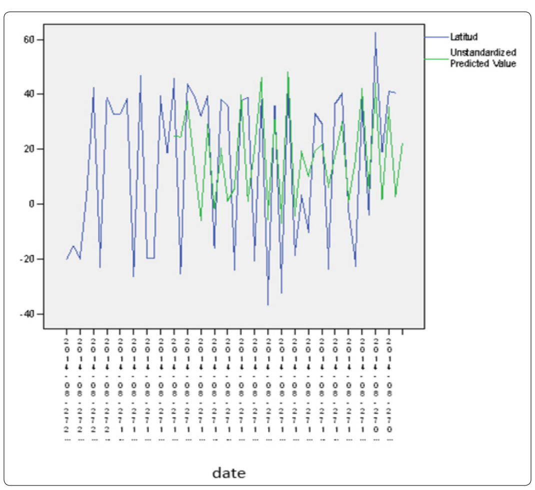
(Figure 1) Histogram of residuals for Latitude.

Finally, we calculate the correlation of the real value of the latitude with the predicted value, obtaining 0.567 significant at 99% [Table 5].

Table 5: Correlation of latitude with prognosis
Correlations

		Latitud	Unstandardized Predicted Value
Latitud	Pearson Correlation	1	.567**
	Sig. (2-tailed)		.000
	N	50	50
Unstandardized PredictedValue	Pearson Correlation	.567**	1
	Sig. (2-tailed)	.000	
	N	34	35
**.Correlation is significant at the 0.01 level (2-tailed).			

Figure 2 shows the good agreement between the real and forecasted values.



(Figure 2) Real and predicted values for latitude.

For the case of the Length models were also made, obtaining an R of 0.637 with 74.6 errors [Table 6].

Table 6: Model summary for Length
Model Summay [c,d]

Model	R	R Square	Adjust R Square	Std. Error of the Estimate	Durbin-Watson
1	.637[b]	.406	.217	74.64210	2.157

a. For regression through the origin (the no-intercept model), R Square measure the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R square for models which include an intercept.
b. Predictors: lag1Longitud, NoC, lag11Longitud, lag2Longotud, lag21Longitud, DS, DI
c. Dependent Variable: Longitud
d. Linear Regression through the Origin

This time the analysis of variance is only significant at 90% (Table 7), then it is more difficult to determine the length where the earthquake will occur, however we obtained the model for the length. (Table 8).

Table 7: Analysis of Variance for Length
ANOVA[c,d]

Model	R	R Square	Adjust R Square	Std. Error of the Estimate	Durbin-Watson
1 Regression	83676.383	7	11.953.769	2.146	.081[a]
Residual	17626.568	28	5571.443		
Total	36211.956[b]	34			

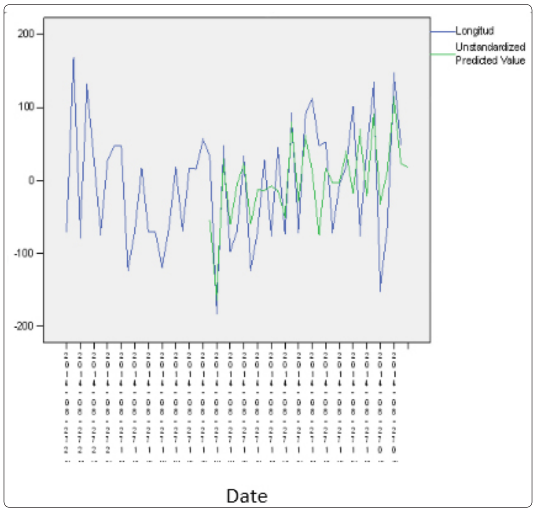
a. Predictors: lag1Longitud, NoC, lag11Longitud, lag21Longitud, DS, DI
b. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
c. Dependent Variable: Longitud
d. Linear Regression through the Origin

In this model for the length, the parameters DS, DI and NoC are significant at 99% and the delay in one step was significant at 90%, the other parameters were not significant but they provide variance to the model, it is noteworthy that the NoC trend of the length is to increase in length, that is, earthquakes should be more likely for high lengths, this parameter should be studied in more detail. [Table 8].

Table 8: Model coefficients for Length
Correlations [a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	DS	-188.111	76.221	-1.550	-2.468	.022
	DI	-180.124	77.772	-1.536	-2.316	.030
	NoC	4.627	2.046	2.028	2.261	.0.34
	lag21Latitud	-.300	.200	-.289	-1.501	.148
	lag11Latitud	-.347	.226	-.307	-2.534	.139
	lag2Latitud	-.213	.184	-.202	-1.155	.261
	lag1Latitud	-.311	.175	-.312	-1.773	.090

Figure 3 shows the behavior of the real and the forecast for the variable length.



(Figure 3) Actual and predicted values for the Length.

This time the correlation between the real and forecasted values is 0.637, which is significant at 99% [Table 9].

Table 9: Correlation of the length with the forecast

Correlations

		Latitud	Unstandardized Predicted Value
Latitud	Pearson Correlation	1	.637**
	Sig. (2-tailed)		.000
	N	50	29
Unstandardized PredictedValue	Pearson Correlation	.637**	1
	Sig. (2-tailed)	.000	
	N	29	30

**.Correlation is significant at the 0.01 level (2-tailed).

Then the last 10 cases of earthquakes with their modeling for Latitude [Table 10]

Table 10 Results for Latitude

Case Summaries[a]

	Fecha	Latitud	Unstandardiz ed Predicted Value	Unstandardiz ed Residual
1	2014-08-27 11.25. 26 UTC	-20.16	6.62959	-26.78959
2	2014-08-27 10.59. 17 UTC	36.67	17.77040	18.89960
3	2014-08-27 10.38. 23 UTC	40.11	29.17766	10.93234
4	2014-08-27 10.07. 29 UTC	-2.49	1.26939	-3.75939
5	2014-08-27 10.04. 55 UTC	-20.80	15.81456	-36.6 1456
6	2014-08-27 10.02. 32 UTC	35.85	41.13014	-5.28014
7	2014-08-27 06.59. 10 UTC	-2.89	5.87855	-8.76855
8	2014-08-27 06.10. 19 UTC	59.43	41.83327	17.59673
9	2014-08-27 05.03. 49 UTC	18.87	1.69463	17.17537
10	2014-08-27 04.48. 59 UTC	41.08	33.90 196	7.17804
11	2014-08-27 04.47. 36 UTC	40.55	3.31141	37.23859
12		.	22.25856	.
Total N	12	11	12	11

a. Limited to first 100 cases.

For the length, Table 11 shows the errors and the forecast of the next event.

Then the next event must occur in Latitude: 22.25 and Longitude: 17.84.

Table 11: Results for the length

Case Summaries[a]

	Fecha	Latitud	Unstandardiz ed Predicted Value	Unstandardiz ed Residual
1	2014-08-27 11.25. 26 UTC	-69.15	-2.41733	-66.73267
2	2014-08-27 10.59. 17 UTC	-5.15	-2.50323	-2.64677
3	2014-08-27 10.38. 23 UTC	19.84	38.65982	-18.81982
4	2014-08-27 10.07. 29 UTC	102.06	-18.29047	120.35047
5	2014-08-27 10.04. 55 UTC	-70.05	65.50261	-135.55261
6	2014-08-27 10.02. 32 UTC	40.64	-19.93014	60.57014
7	2014-08-27 06.59. 10 UTC	128.79	88.31911	40.47089

8	2014-08-27 06.10.19 UTC	-145.65	-29.97304	-115.67696
9	2014-08-27 05.03.49 UTC	-65.10	11.93949	-77.03949
10	2014-08-27 04.48.59 UTC	143.12	110.14078	32.97922
11	2014-08-27 04.47.36 UTC	48.71	23.25016	25.45984
12			17.84526	
Total N	12	11	12	11
a. Limited to first 100 cases.				

The earthquakes longitude and latitude of occurrence are perfectly predictable parameters, similar to wind, which has a correlation coefficient of 0. 80 [13] so careful attention must be given to the prevention plans of these phenomena to reduce vulnerability mostly in cities.

Conclusions

It is concluded that Model 1 is the least error, while in Model 2, the trend is significant to the increase. Global earthquakes are a regressive event on the planet and, what happens in one place has repercussions in another, not randomly or due to chance, but rather a well-determined phenomenon.

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