Establishment of Models for Analyzing Extreme Weather Conditions

Bingbing Xie[1], Rongzu Jin[1], and Qiyang Yuan[2]

[1] School of Metallurgy and Energy, North China University of Science and Technology, Tangshan 063000, China

[2] School of Metallurgy, North China University of Science and Technology, Tangshan 063000, China

Abstract

In this paper, through the collection and processing of weather conditions, the distribution of extreme weather with space is first analyzed by Markov prediction method, and the future development trend of extreme weather is obtained through international environmental analysis and Q-type cluster analysis - that is, it is becoming more and more frequent. For question 1: Analyzing the laws of extreme weather and space, through the Markov prediction method, the azimuth angle of the location of extreme weather occurrence is analyzed, and the relationship between extreme weather and spatial distribution is obtained, that is, the probability of extreme weather in the northeast, southwest and northwest regions of the United States will be greater than that of other parts. For problem 2: Solve it by combining the actual algorithm model. First of all, through the analysis of the global environment, it is found that the global environmental environment is getting worse and worse with the development of industry and science and technology, and the bad environmental conditions will affect the weather conditions, and the occurrence of extreme weather will become more and more frequent; Secondly, through the Q-type cluster analysis method, 10 years is selected as a time interval, and the distribution of extreme weather in the 10-year time interval is observed through cluster map, and the distribution of extreme weather in each interval is compared, and it is found that extreme weather will occur more and more frequently in the future.

Keywords

Extreme Weather; Markov Chain Prediction Method; Analytic Hierarchy Method.

1. Introduction

1.1 Background to the Problem

Globally, more than 5 million people die each year and major property damage, which is often referred to as extreme weather, is associated with natural disasters caused by extreme changes in the climate. The occurrence of extreme weather should be a small probability event, but in recent years, with the global warming, extreme weather has become more frequent, and seriously affect people's daily production and life.

1.2 Restatement of the Problem

Question 1: Establish a Markov model to study and analyze whether the occurrence of certain weather events has certain spatial laws and make reasonable predictions.

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Question 2: Use known models and data to explain whether extreme weather has become more frequent in recent years.

2. Problem Assumptions

1) Extreme weather needs to be basically stable, and exogenous variables have little impact on the model.

2) The probability of transition of a spatial variable in each period or state is the same and does not change over time.

3) The data collected for the solution is true, accurate, and trustworthy. Errors in data processing are largely non-existent.

4) Extreme weather can have a stable regional character after many years.

3. Symbol Description

1) πj(k) represents the probability that an event will be in state Mb at the k-time after a k-time state transition under the condition that the state is known at the initial (k=0).

2) π(0) =[π1(0),π2(0),...,πn(0)] are the initial state probability vectors.

3) Pij=Mij=Pab, which represents the probability of a state change.

4) π is the ultimate prediction probability.

4. Model Building and Solving

4.1 Model Building and Analysis of Problem One

4.1.1 Modeling and Analysis

Analyzing the spatial characteristics of extreme weather can be transformed into analyzing the regional characteristics of extreme weather, based on the largeness and stability of the data, we use the Markov prediction model here to analyze the regional characteristics of the occurrence of extreme weather.

A comprehensive prediction of an event must not only be able to point out the various possible outcomes of the occurrence of the event, but also give the probability of each outcome, indicating the degree of probability that the predicted event will appear during the forecast period. This is about predicting the probability of an event occurring.

Markov prediction is a method of predicting the probability of events occurring. It is a method of predicting the movement of an event at various times (or periods) in the future based on its current state.

Markov chain model has strong adaptability, forecast accuracy higher and other else advantages, which is suitable for this problem.[1].

The basic concept of the Markov model:(1) State transition probability In the process of the development and change of an event, the possibility of starting from one state and moving to another state at the next moment is called the state transition probability. According to the definition of conditional probability, the state transition probability P is transferred from state, M-a. to state, M-b. state transition probability:

$$\mathrm{P}\ (M_a \rightarrow M_b)$$

It is the conditional probability P $(\frac{M_a}{M_b})$, namely.

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$$\mathrm{P}\left(\frac{M_a}{M_b}\right) = P_{ab}$$

(2) State transition probability matrix Assumes that one of the predicted events is M-1.,,, M-2...., M-n., a total of n possible states. Remember that M-ab. is the slave state, M-a. is the state, and M-b. is the state transition probability, which is the matrix:

$$R = \begin{bmatrix} P_{11}, P_{12} \cdots & P_{1n} \\ \bullet\bullet & \bullet \\ \bullet\bullet & \bullet \\ \bullet\bullet & \bullet \\ P_{21}, P_{22} \cdots & P_{2n} \\ P_{m1}, P_{m2} \cdots & P_{mn} \end{bmatrix}$$

Then R is called the state transition probability matrix.

If a certain event being predicted is currently in state, M-a., then at the next moment it may be turned by state, M-a., M-1., M-2.,..., M-a...., M-b. any of the states. So the conditions are met:

$$\begin{cases} 0 \le P_{ab} \le 1 \quad (a, b = 1,2, \dots, n) \\ \sum_{b=1}^{n} P_{ab} = 1 \quad (a = 1,2,3 \dots . n) \end{cases}$$

In general, we refer to any matrix that satisfies the above criteria as a random matrix, or a probability matrix. It is not difficult to prove that if P is a probability matrix, then for any number m>0, the matrix, P-m. is a probability matrix.

If R is a probability matrix, and there is an integer m>0, so that the probability matrix, all elements of R-m. are non-zero, then R is called the standard probability matrix. It can be shown that if R is a standard probability matrix, there is a nonzero vector:

$$a = [x_1, x_2, \cdots, x_n]$$

And satisfied:

$$[0 \le x_i \le 1 \text{and} \sum_{i=1}^{n} x_i = 1]$$

Make: ap=a.

Such vectors α called equilibrium vectors, or ultimate vectors.

4.1.2 Calculation of the State Transition Probability Matrix

Calculating the state transition probability matrix P is the transfer probability that each state is required to move to any other state.

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P_{ab}(a,b=1,2,…,n). To find each P, we use the idea of frequency approximation probability to calculate it.

For this topic, after data analysis, we found that tornado weather occurs much more frequently and has obvious geographical changes than other extreme climates, so here we use tornadoes as an example to predict regional changes. We abstract the region as azimuth coordinates and divide them into eight azimuths of east, south, west, north, southeast, northeast, southwest, and northwest, and record them in turn as, M-1.,,M-2.,,M-3.,,M-4.,,M-5.,,M-6.,,M-7.,,M-8.. The following table shows the coordinates and status changes of tornado areas from 1950 to 2021:

Table 1. the coordinates and status changes of tornado areas from 1950 to 2021

$M_1 \rightarrow M_1$	$M_1 \rightarrow M_2$	$M_1 \rightarrow M_3$	$M_1 \rightarrow M_4$	$M_1 \rightarrow M_5$
1	3	4	1	1
$M_1 \rightarrow M_6$	$M_1 \rightarrow M_7$	$M_1 \rightarrow M_8$		
1	3	1		

Through data analysis, from the stateM_1,there are a total of 15 cases of departure, of which it becomes a stateM_2 There are 3 kinds of situations, then there are:

$$P_{12} = \frac{3}{15} = 0.2$$

According to the calculations described above, it is obtained:

$$P_{11} = 0.06$$
$$P_{13} = 0.24$$
$$P_{14} = 0.066$$
$$P_{15} = 0.066$$
$$P_{16} = 0.066$$
$$P_{17} = 0.2$$
$$P_{18} = 0.066$$

and a series of required probabilities.

Calculate the probabilities we need to follow the same method as above, listing the state transition matrix:

$$A = \begin{bmatrix} 0.066 & 0.2 & 0.24 & 0.066 & 0.066 & 0.066 & 0.2 & 0.066 \\ 0.2 & 0.066 & 0.24 & 0.2 & 0.066 & 0.066 & 0.066 & 0.066 \\ 0.083 & 0.083 & 0.083 & 0.083 & 0.166 & 0.25 & 0.083 & 0.166 \\ 0.091 & 0.273 & 0.182 & 0.091 & 0.091 & 0.091 & 0.091 & 0.091 \\ 0.217 & 0.087 & 0.043 & 0.087 & 0.261 & 0.174 & 0.087 & 0.043 \\ 0.133 & 0.133 & 0.066 & 0.20 & 0.066 & 0.066 & 0.20 & 0.133 \\ 0.117 & 0.05 & 0.05 & 0.10 & 0.083 & 0.35 & 0.083 & 0.167 \\ 0.24 & 0.08 & 0.04 & 0.04 & 0.12 & 0.36 & 0.08 & 0.12 \end{bmatrix}$$

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4.1.3 Ultimate Prediction

Using Markov prediction we set a state probability πj(k). There is according to the nature of probability:

$$\sum_{j=1}^{N} \pi_j(k) = 1$$

Starting from the initial state, after the k-state transition to the state, M-J. This state transition process can be seen as first reaching the state after the (k-1) state transition, M_i. (i = 1,2,...,n), and then by, M_i after a state transition to the up state M_j. According to the unprovoked and Bayes conditional probability formulas for Markov's process, there is:

$$\pi_j(k) = \sum_{i=1}^{n} \pi_i(k-1) P_{ij} (j = 1, 2, \cdots n)$$

If the row vector π(k) = [π1(k), π2(k),...,πn(k)], the recursive formula for calculating the probability of state one by one can be obtained from the above equation:

$$\begin{cases} \pi(1) = \pi(0)R \\ \pi(2) = \pi(1)R = \pi(0)R^2 \\ \vdots \\ \pi(k) = \pi(k-1)R = \pi(0)R^k \end{cases}$$

π(0)=[π1(0),π2(0),...,πn(0)] are the initial state probability vectors.

From the above analysis, it can be seen that if the initial state of an event at the 0th moment (or period) is known (that is, π (0) is known), then using the recursive formula, it is possible to find the probability (i.e., π (k)) that it is in various possible states at the kth time (period) after the k-time state transition, so as to obtain the state probability prediction of the event at the kth moment (period).

The state probability obtained after an infinite number of state transitions is called the ultimate state probability, or the equilibrium state probability. If you remember that the ultimate state probability vector is π = [π1,π2,...,πn], then:

$$\pi_i = \lim_{k\to\infty} \pi_i(k) \qquad (i = 1,2,3, \ldots .n)$$

That is:

$$\lim_{k\to\infty} \pi_i(k) = \lim_{k\to\infty} \pi_i(k+1) = \pi$$

The above equation is substituted into the recursive formula of Markov's prediction model:

$$\pi = \pi R$$

In this way, the conditions that the ultimate state probability should satisfy are obtained:

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(1)π=πP.

(2)$0 \leq \pi i \leq 1 i = 12 \ldots n)$.

(3)$\sum_{i=1}^{n} \pi_i = 1$.

The above conditions (2) and (3) are requirements for state probability, where condition (2) means that after an infinite number of state transitions, the event must be in any of n states; condition (1) is the formula used to calculate the ultimate state probability. The ultimate state probability is important information used to predict what trends will occur in the distant future of markov processes.

In this topic, the final state probability is set to:

$$\pi=[\pi_1,\pi_2,\pi_3,\pi_4,\pi_5,\pi_6,\pi_7,\pi_8]$$

So:

$$[\pi_1,\pi_2,\pi_3,\pi_4,\pi_5,\pi_6,\pi_7,\pi_8] = [\pi_1,\pi_2,\pi_3\pi_4,\pi_5,\pi_6,\pi_7,\pi_8]$$

$$A = \begin{bmatrix} 0.066 & 0.2 & 0.24 & 0.066 & 0.066 & 0.066 & 0.2 & 0.066 \\ 0.2 & 0.066 & 0.24 & 0.2 & 0.066 & 0.066 & 0.066 & 0.066 \\ 0.083 & 0.083 & 0.083 & 0.083 & 0.166 & 0.25 & 0.083 & 0.166 \\ 0.091 & 0.273 & 0.182 & 0.091 & 0.091 & 0.091 & 0.091 & 0.091 \\ 0.217 & 0.087 & 0.043 & 0.087 & 0.261 & 0.174 & 0.087 & 0.043 \\ 0.133 & 0.133 & 0.066 & 0.20 & 0.066 & 0.066 & 0.20 & 0.133 \\ 0.117 & 0.05 & 0.05 & 0.10 & 0.083 & 0.35 & 0.083 & 0.167 \\ 0.24 & 0.08 & 0.04 & 0.04 & 0.12 & 0.36 & 0.08 & 0.12 \end{bmatrix}$$

Then:

$$\pi=[0.087,0.043,0.087,0.087,0.043,0.217,0.261,0.174].$$

4.1.4 Explanation of the Rule

The final prediction means that after an infinite number of changes, the probability of extreme weather in the Northeast, Southwest, and Northwest of the United States will be greater than in other parts.

4.2 Model Building and Analysis of Problem One

4.2.1 The State of the International Environment in Recent Years

With the strengthening of international industrialization and science and technology, environmental problems have become a major problem that the world must face, the current speed of human governance of the environment is still unable to catch up with the speed of destruction of the environment, the environment is developing in an increasingly bad direction, the following figure is the situation of greenhouse gas emissions in recent years.It is likely that the greatest impacts of climate change on human and natural systems will come from increasingly frequent and severe extreme weather and climate events.[2]

A series of environmental conditions emerge in an endless stream, such as: global warming, deforestation, soil erosion, land desertification and other environmental problems, which have a great impact on atmospheric circulation, ocean currents, etc. Due to the different geographical locations of each region, the changes in weather conditions in each region are different over time, but the overall international trend is that environmental issues will have a great impact on weather changes. Climate change continues to expose more of the global population to more frequent and severe extreme weather events.[3].

The main factors affecting the weather conditions are atmospheric circulation, solar radiation, sea and land position, ocean currents, etc., of which the atmospheric circulation has a greater impact on the weather. And because environmental issues affect atmospheric circulation, extreme weather times will become more and more frequent.

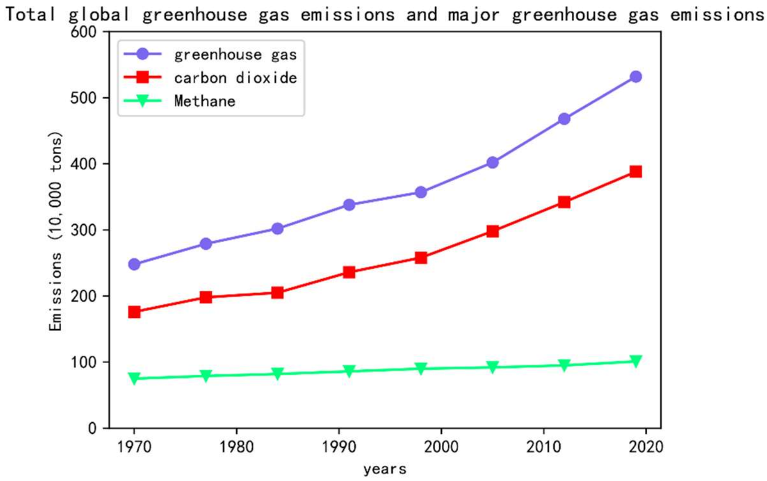

Figure 1. The situation of greenhouse gas emissions in recent years

4.2.2 Analyze Against the Model

The use of Q-type cluster analysis to classify weather conditions can intuitively and clearly show the numerical classification results, which is more meticulous, comprehensive and reasonable than the traditional classification method, and can better reveal the differences and connections between various weathers.[4].

The Q-type cluster analysis method is used to select every 10 years as a time period, and the period from 1950 to 2021 is divided into 7 time period areas, and the distribution of extreme weather in the time period is obtained by cluster analysis method, and the frequency of extreme weather in 7 time zones is observed according to the clustering spectrum diagram to predict the occurrence of extreme events in the future.

Through the process of building models, analysis and forecasting, it is found that extreme weather will occur more and more frequently.

5. Conclusion

Through the Markov prediction method, the spatial distribution of extreme weather is obtained as follows: the probability of extreme weather in the northeast, southwest and northwest regions of the United States is greater than that in other regions; through the analysis of international environmental conditions in recent years, and through Q-type clustering, it is found that extreme weather will occur more frequently in the future.

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