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# Research on Extreme Weather Prediction Based on ARIMA Modeling

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**Abstract.** The greatness of nature is often astounding, but few people realize that behind its greatness lies a host of impacts from extreme weather, and with global climate change continuing to intensify, it poses unprecedented challenges to the property insurance industry. In this paper, we develop a broadly applicable risk scoring model that provides the property insurance industry with critical insights for more accurate risk assessment and adjustment of underwriting strategies. In this paper, we use an ARIMA model to predict the expected annual losses from extreme weather hazards in different regions, and based on this, we develop a premium calculation model to ensure that insurers can cover compensation costs and realize expected profits.

**Keywords:** Extreme Weather; Prediction; ARIMA Model.

## 1. Introduction

While you're enjoying the bright sunshine in the state of Hawaii, does it occur to you that thousands of kilometers away, Iowa is being hit by a blizzard? Weather is as complex and volatile as a child's temperament. Extreme weather has taken a huge toll on the world's economy, and that toll is likely to increase further. Common weather extremes include: high winds, blizzards, cold snaps, dust storms, and droughts. Insurance companies are also shying away from extreme weather, and more and more insurers are looking to avoid large payouts due to extreme weather. Insurers are thus caught in a dilemma, with the choice between making more money on premiums or paying out less money on premiums becoming a huge issue for insurers. Communities and real estate developers are also in a quandary - how do you make real estate decisions? How do community leaders protect culturally and economically significant neighborhood buildings? The truth is, we can minimize financial losses while maximizing gains for insurers, real estate companies and community leaders [1-2].

Based on background information and constraints, this paper addresses an insurance company's dilemma: deciding on an underwriting policy for a specific region. Evaluate the feasibility of its underwriting policy through extreme weather [3].

From the perspective of the insurance market, natural disasters in recent years have shown a trend towards more frequent occurrence of medium- and low-level disasters and a rise in secondary disaster losses.

However, due to insufficient segmented risk data, bias in historical loss data, and failure of risk assessment models, the insurance industry is unable to adequately reflect the changing status of risks; from the demand side, due to the low frequency of natural disaster risks, the public's awareness of such risks and related insurance is relatively limited, and the main bearers of disaster risks such as enterprises, families, and individuals often don't take the initiative to take out insurance, which results in the overall level of protection being lower. In the U.S., the following seven types of natural disasters are currently major risks [4].

Insurance company administrators may choose to pay out as little as possible, however this is not an easy task. This problem requires us to find the most appropriate underwriting method.

In the modeling process, we begin by assessing the risk, and the impact of different extreme weather conditions. For specific areas, we use more sophisticated models that diversify the variables to account for local population density, building density, geographic features and other factors [5-6]. If the insurance company underwrites financial compensation insurance, the insurance company only needs to assess the premiums and compensation for the area, that is, how much compensation will be required in the event of an accidental catastrophic incident. The insurance company will determine the premium based on the predicted probability of occurrence of the disaster and the number of casualties, considering the premium and compensation costs [7].

Specifically, after predicting the probability of disaster occurrence, it is also necessary to predict the expected loss caused by the disaster, which is intuitively handled by directly predicting the expected number of casualties or the expected loss in the local area in that period [8].

On this basis, we can use the ARIMA time series model to predict the expected compensation loss in different regions each year, and then propose the calculation method of expected premium.

## 2. The fundamental of SIR models

To get the expected losses, we first counted the number of occurrences of different natural disasters in the U.S., the losses caused by natural disasters, and the number of deaths and injuries, and represented them in a bubble chart, with larger bubbles indicating more deaths, and the results of the calculations are shown in Figure 1. For ease of calculation, we counted the number of deaths and total losses by year because different disasters are mixed and the time is not consistent. We counted the total losses caused by natural disasters in the U.S. from 1980-2021, and the calculations are shown in Figure 2. Then we counted the losses caused by natural disasters in Africa from 1974-2023, and the calculation is shown in Figure 3.

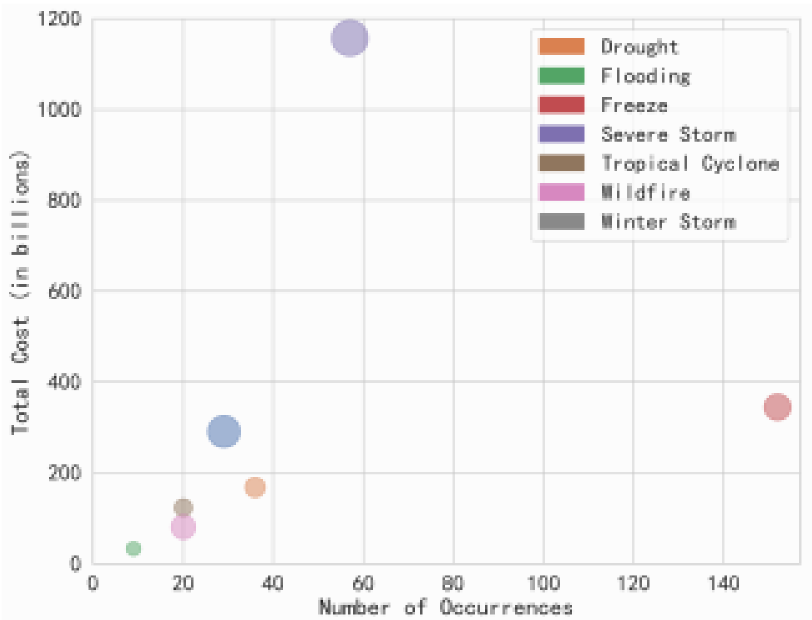


**Figure 1.** USA disaster impact

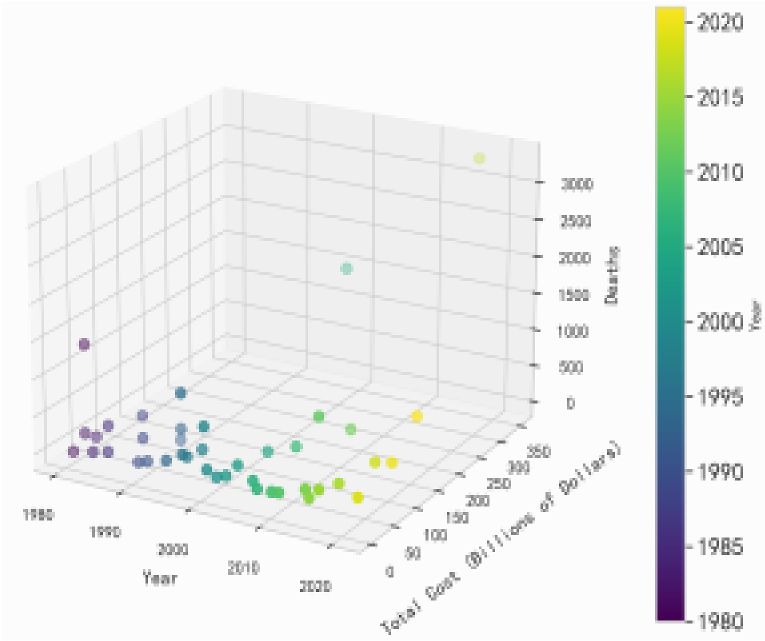


**Figure 2.** USA Annual Cost and Deaths from Disasters

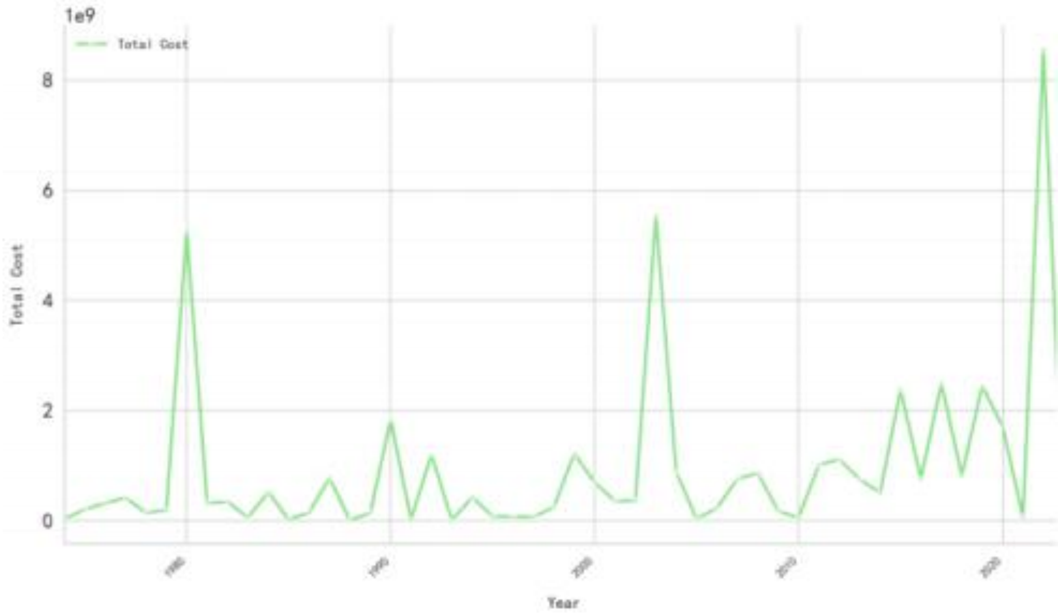


**Figure 3.** The losses due to natural disasters in Africa

Based on the previous assumptions, we predict the expected loss for each year and get the expected loss prediction for the next seven years. In the ARIMA model, we need to analyze the parameters first and select the appropriate parameters by first performing an ADF test to see if the data is stable, if it is stable, then the difference order is 1. Then, the ACF and PACF plots are used to help determine the appropriate autoregressive (AR) and moving average (MA) parameters. The AR parameter (p) is usually determined by the last significant lag after the PACF truncation, while the MA parameter (q) are determined by the last significant lag in the ACF plot [9-10]. The flow of the ARIMA model is shown in Figure 4.

Based on this information, we can construct the formula for the ARIMA model, where: p is the number of autoregressive terms in the model; d is the number of times the data need to be differenced to achieve equilibrium; and q is the number of moving average terms. The formula can be written as

$$\left(1-\sum_{i=1}^{p}\phi_i L^i\right)(1-L)^d y_t=\left(1+\sum_{i=1}^{q}\theta_i L^i\right)\varepsilon_t \tag{1}$$

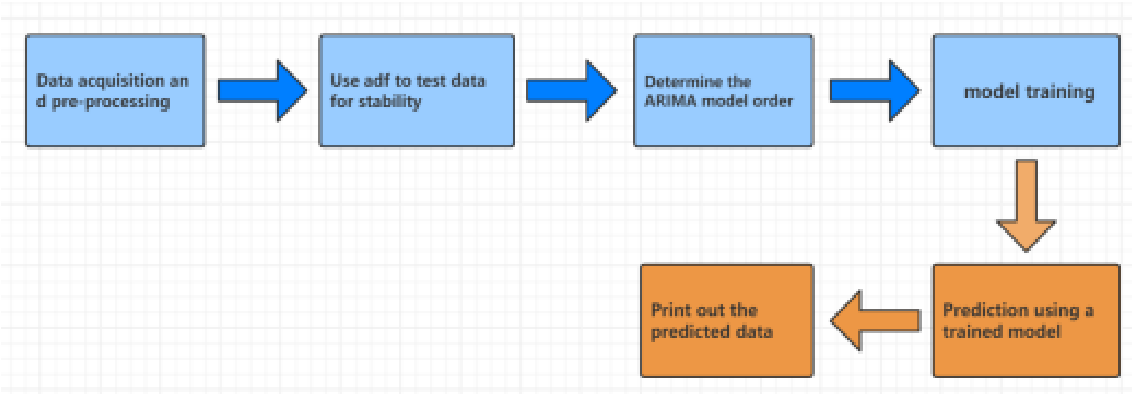


**Figure 4.** The process of analysis

## 3. Results

The ACF and PACF in the United States are shown in Figure 5. ACF and PACF in Africa are shown in Figure 6.

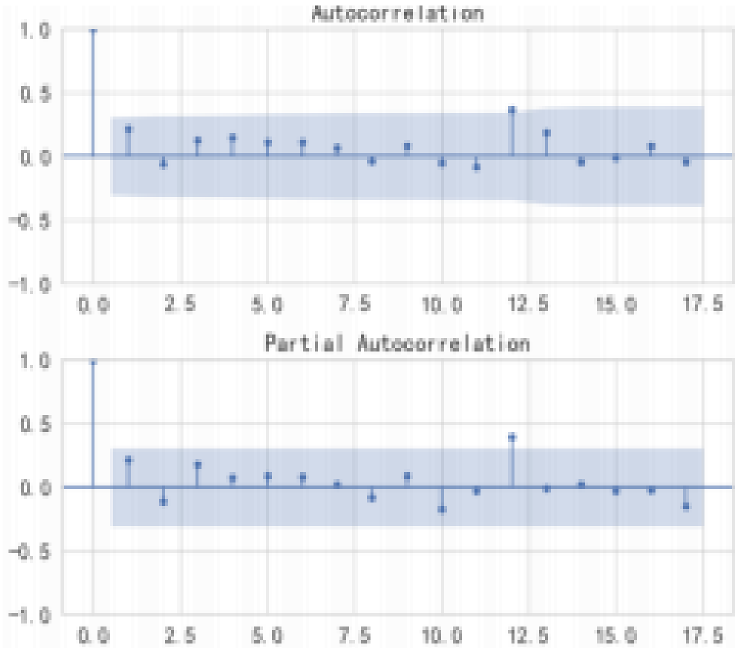


**Figure 5.** ACF and PACF in the United States

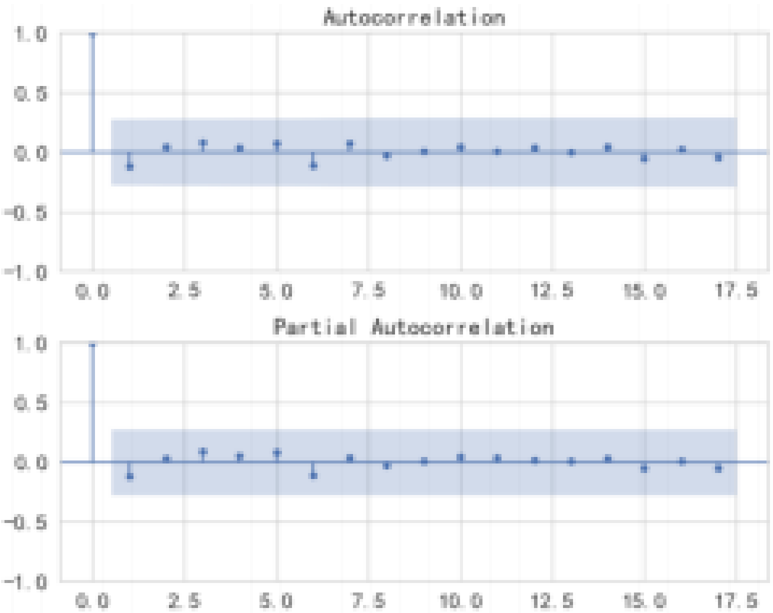


**Figure 6.** ACF and PACF in Africa

The final projection of expected losses for the United States is calculated as shown in table 1, as is the projection of expected losses for Africa, which is calculated as shown in table 2.

**Table 1.** USA's expected losses

| Year | Projected losses (billions) |
|---|---|
| 2022 | 113.80 |
| 2023 | 91.24 |
| 2024 | 118.85 |
| 2025 | 119.27 |
| 2026 | 129.23 |
| 2027 | 132.43 |
| 2028 | 136.96 |

**Table 2.** Africa's expected losses

| Year | Projected losses (billions) |
|---|---|
| 2024 | 23.54 |
| 2025 | 24.87 |
| 2026 | 19.15 |
| 2027 | 21.90 |
| 2028 | 21.44 |
| 2029 | 21.16 |
| 2030 | 21.40 |

Once we have determined the loss estimates through the ARIMA model, we can propose a methodology for calculating future premiums. Considering the expected profit (P), the amount of compensation required per person (N), the specific premium per person can be adjusted to ensure that the company will be able to cover the cost of compensation and realize the required profit: assuming that the specific premium per person is (C), the total premium income will be (M x C).

## 4. Conclusion

Extreme weather events are becoming a crisis for property owners and insurers alike, and the challenges posed by climate change are enormous, especially given the risk management role played by the insurance industry throughout the economy. Extreme events, characterized by acute climate risks, and the continued deterioration of climatic factors, characterized by chronic climate risks, pose specific challenges to different sectors of the insurance industry. This paper proposes a forecasting study using the ARIMA model for extreme weather scenarios based on the variability of extreme weather and draws the desired conclusions. In future research, the findings of this paper can provide theoretical support to insurance companies to formulate reasonable premium policies for extreme weather conditions.

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