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## Wisdom on the Alert Line: Combating Avalanches with Data

### Summary

For question one, to measure the risk of avalanche occurrence, snow-related indicators and easily measurable meteorological factors were selected as parameters. Pearson correlation analysis was conducted using the snow season observation data from the Tianshan Snow Avalanche Research Station in China from 2019 to 2020, to verify the independence of these parameters. Avalanche risk was categorized into three levels. In this study, the daily avalanche risk level during the snow season in the dataset was used as the dependent variable, with the other parameters as independent variables. A risk assessment model based on the Random Forest algorithm was established, using 30% of the data as the test set, achieving a high accuracy of **76.2%**. To further analyze the main causes of risk, an importance analysis of the parameters was conducted, and the Local Interpretable Model-agnostic Explanations (LIME) method was used for model interpretation.

For question two, to determine the appropriate timing for triggering minor avalanches through blasting, the Tianshan area in China was again considered. Data on the first snowfall day, snow melting day, and snow disappearance day from 1967 to 2020 in the Tianshan area were collected. Preliminary forecasting of the snow season for 2020-2021 was conducted using the Exponential Smoothing method, determining the initial snowfall day as November 8, 2020. The model from question one was then applied to assess the daily risk during the snow season from 2017 to 2019. It was analyzed that the avalanche risk in the Tianshan area showed a low-high-low-high trend. Avalanche risk level information from 2017 to 2020 was used as known data, revealing that avalanche risk has a seasonal trend, with the period from early November to the end of March as the snow season cycle. A risk prediction model based on the SARIMA algorithm was established, predicting daily avalanche risk situations for the 2020-2021 snow season. Two key dates were identified: December 17, 2020, and February 13, 2021. Considering the hardening of snow due to the accumulation of strong wind effects, the morning of a clear day around **December 17, 2020**, at 10 am was chosen as the blasting time.

For the second part of question two, which involved determining the placement and blasting capacity of explosives to trigger an avalanche, a slope model with a height of 50m and a width of 160m was constructed. The initial environment was based on snow-related indicators and meteorological factors from corresponding periods in past snow seasons. Variables such as the amount of TNT, placement depth, and height were considered. The constraints included reducing the risk level and ensuring a safe distance from the explosion shock wave. The objective was to minimize the energy required to induce an avalanche. A blasting strategy planning model based on the Particle Swarm Optimization algorithm was established. The results showed that placing explosives at the center of a 15m-high slope, with a placement depth of **31.55cm** and a TNT amount of **1.1494kg**, minimized the total energy to **15552J** and resulted in an average snow depth reduction of **15cm**.

Keywords: **Random Forest, LIME, Exponential Smoothing, SARIMA Forecast**

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# 1 Introduction

## 1.1 Problem Background

Avalanches are an extremely dangerous natural phenomenon. At present, we have a better understanding of avalanche formation, but still can not predict the cause of avalanches and when and where they occur. Using explosives to trigger artificial avalanches can reduce the amount of snow that accumulates before an avalanche, thereby avoiding the formation of a large avalanche. Although the use of more explosives to trigger avalanches can better ensure human safety, it can also disrupt the normal life of animals living in these areas.

## 1.2 Restatement of the Problem

There are two tasks needing to be solved:

- Find useful and easily measured parameters to predict the risk of avalanche occurrence
- Pick the right time to use the explosion to trigger a small avalanche and calculate the location of the explosive

## 1.3 Our work

Our main work is as follow:

- In order to measure the risk of avalanche occurrence, snow related indicators and meteorological factors that are easy to measure are selected as parameters, and the observed data of the snow accumulation period from 2019 to 2020 at the Tianshan Snow and Avalanche Research Station in China are used as references to conduct Pearson correlation analysis to verify their independence. Avalanche risk is divided into three levels. We take the daily avalanche risk level in the snow accumulation period as the dependent variable and other parameters as the independent variable, and establish a risk assessment model based on random forest algorithm. In order to further analyze the main causes of risks, the importance of parameters was analyzed, and Local Interpretable Model-Agnostic Explanations were used for Model interpretation.
- We used exponential smoothing and SARIMA to predict future snow and avalanche risks, which determined the timing of the explosion. We then constructed a simple slope model and calculated where the explosives were placed using PSO.

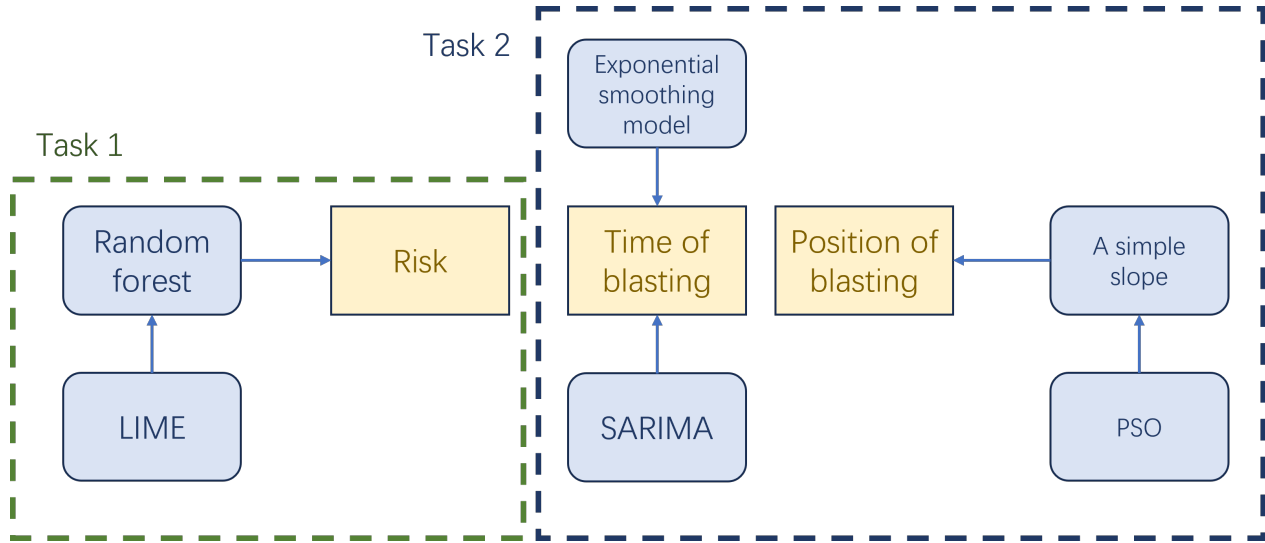


Figure 1: Our work

## 2 Preparation of the Models

### 2.1 Assumptions

To simplify our problems, we make the following basic assumptions, each of which is adequately justified.

- To utilize data for problem-solving, it is assumed that the observational data collected from the Tianshan Snow Avalanche Research Station in China are all authentic and reliable.
- To facilitate the unified calculation, it is assumed that there is no avalanche risk in other time periods except for the snow cover period in the Tianshan Mountains of China, and the snow depth is negligible.
- To simplify the model, it is assumed for question two that the slope gradient of the constructed slope is uniform, the snow distribution is even, and the total mass of the avalanche increases in a manner similar to the accumulating mass of a rolling snowball.
- To simplify the model, it is assumed for question two that the depth at which the explosives are placed and the amount of explosives will affect the initial kinetic energy and mass of the moving snow. The kinetic energy is directly proportional to the placement depth, and the mass is directly proportional to both the placement depth and the amount of explosives.

## 2.2 Notations

The primary notations used in this paper are listed in table 1.

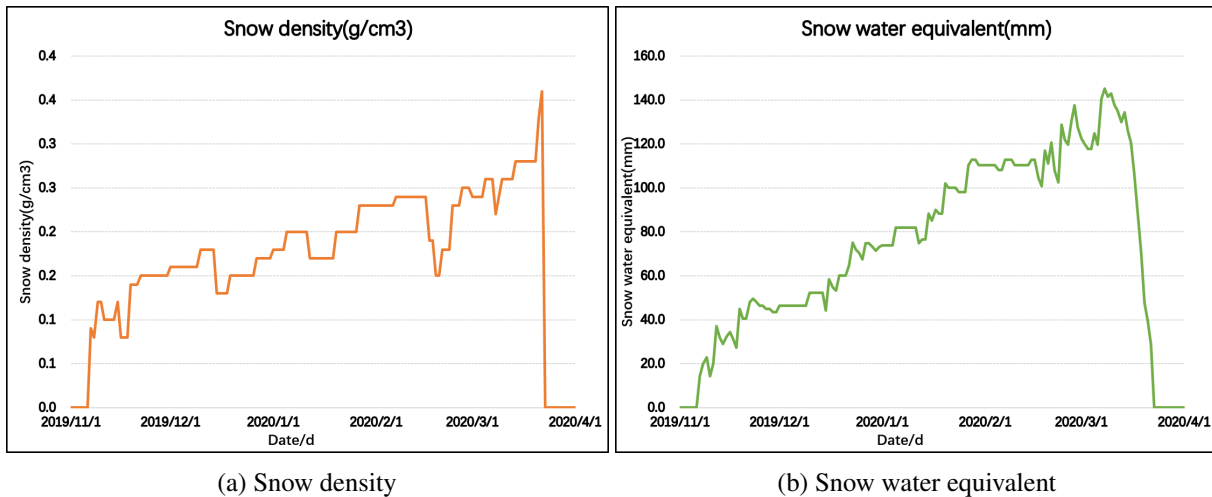
Table 1: Notations

Symbol	Definition
$a$	the amount of explosion
$d$	the depth of explosion
$h$	the height of explosion
$m$	the mass of snow
$w$	the width of the ramp

## 3 The Models

### 3.1 Data Collection And Description

This paper collected avalanche data for the Tianshan Mountains from 2017 to 2020, including weather conditions and avalanche risk levels. The changing process of snow depth and Snow water equivalent from 2019 to 2020 is shown in figure 2. It can be analyzed that the snow density and snow water equivalent increase over time during a snow cover period until the snow melts.



In this paper, we also collected information on the initial snowfall day, snow melt day, and snow disappearance day in the past snow cover period in the Tianshan Mountains of China[1]. From 2019 to 2020, the first snowfall day, the snow melt day, and the snow disappearance day were January 7, 2020, March 15, 2020, and March 22, 2020, respectively, and the snow cover period lasted for 137 days. The snow depth distribution map of the snow cover period from 2019 to 2020 is shown in figure 3.

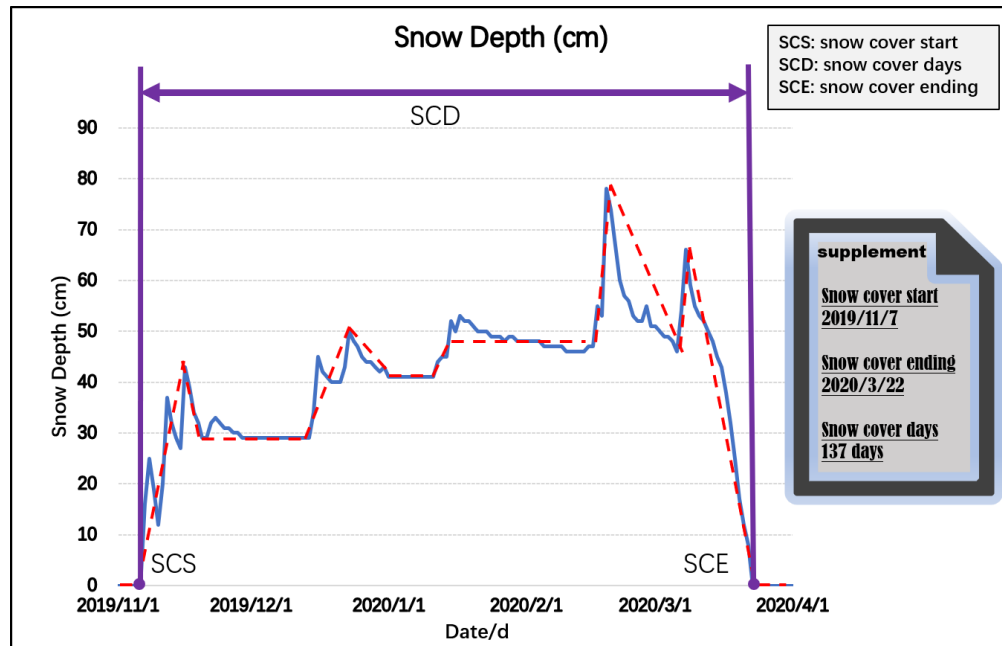


Figure 3: Snow depth

## 3.2 Random Forest Model with An Interpreter

### 3.2.1 Random Forest Model

Random forest is a classifier containing many decision trees, which has a good tolerance for outliers and noise, and has better prediction and classification performance than decision trees[2]. The rules for generating trees in a random forest are as follows:

- Step1. Sample selection: From a sample with a sample size of  $N$ , the sample is extracted  $N$  times, and 1 sample is extracted each time, and finally  $N$  samples are formed. These  $N$  samples are used to train a decision tree as a sample at the node of the decision root.
- Step2. Feature selection: When each sample has  $M$  features, when each node of the decision tree needs to be split,  $M$  attributes are randomly selected from these  $m$  features, and the condition  $m \ll M$  is met. Then, from these  $m$  features, we use the feature importance to select an attribute as the sub-feature of this node.
- Step3. Decision tree formation: In the process of decision tree formation, each node must split according to the above steps until it can no longer split. Note that pruning is not performed throughout the decision tree formation process.
- step 4. Repeat steps: Follow steps 1-3 above to build a large number of decision trees, thus forming a random forest.

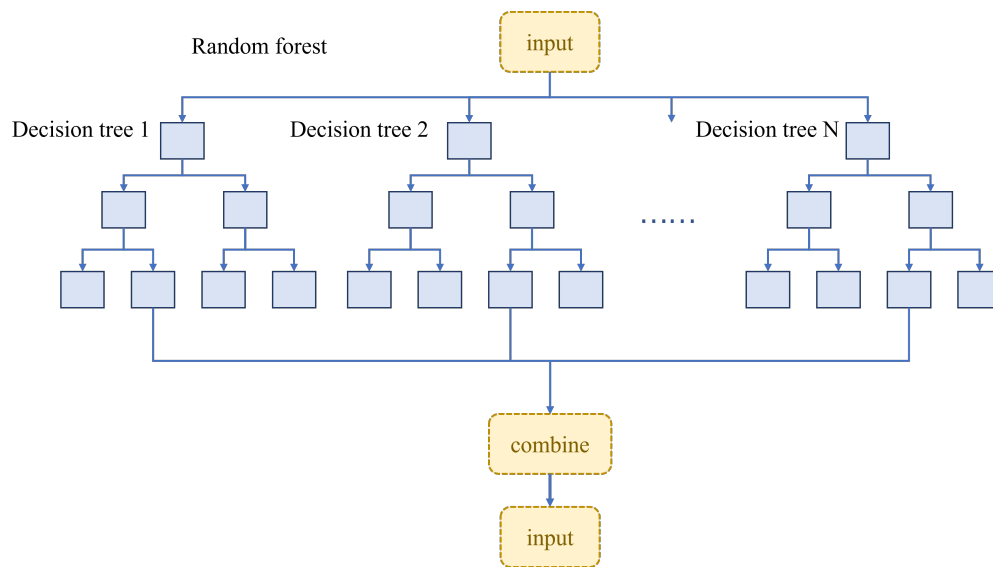


Figure 4: Schematic diagram of random forest model

Then we build the model based on the principle of random forest:

**Feature Selection.** The linear correlation between the features of the generated random forest should be as small as possible. We select indexes including snow depth, snow density, water equivalent of snow cover(SWE), average temperature, air pressure, humidity, precipitation, vapor pressure, depth change. And the Pearson correlation coefficient between each index is calculated as figure 5. Therefore, we select eight indexes with correlation coefficients less than 0.3 as the features of random forests.

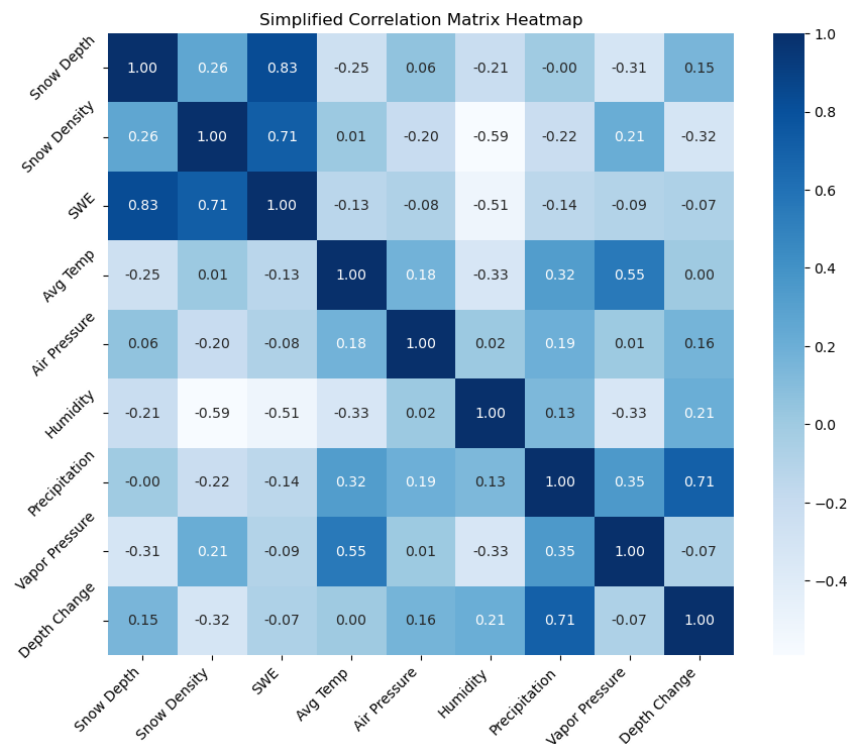


Figure 5: The result of Pearson correlation

**Feature importance.** Random Forest is a set of Decision Trees. Each Decision Tree is a set of internal nodes and leaves. In the internal node, the selected feature is used to make a decision on how to divide the data set into two separate sets with similar responses within. The features for internal nodes are selected with some criterion, which for classification tasks can be Gini impurity. We can measure how each feature decreases the impurity of the split (the feature with the highest decrease is selected for internal node). For each feature, we can collect how on average it decreases the impurity. The average over all trees in the forest is the measure of the feature importance. The importance of these 8 features is calculated based on the Gini impurity in figure 6.

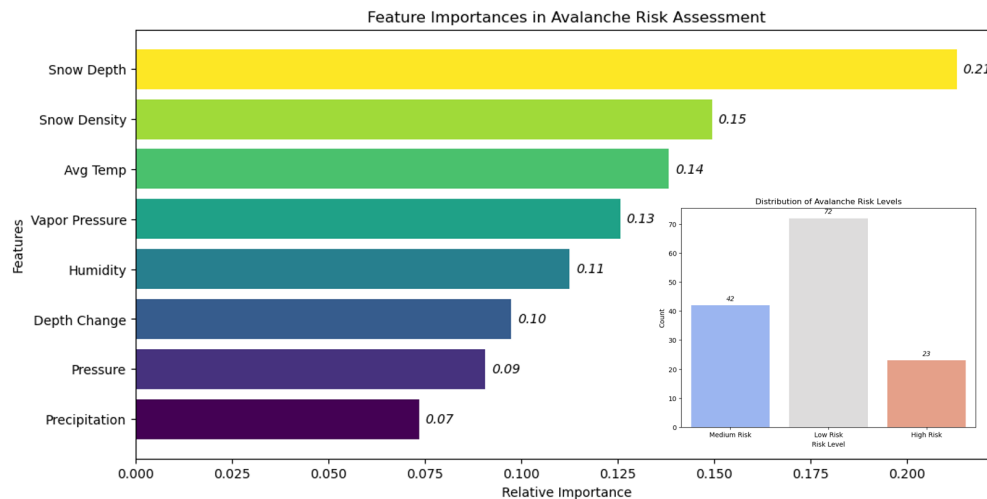


Figure 6: The importance of features

**Forecast result of random forest.** We divided the training set and the test set according to 7:3, and the predicted results of each risk degree is shown in table 2.

Table 2: Result of random forest

risk type	precision	recall	f1-score	support
medium risk	0.82	0.64	0.72	14
low risk	0.80	0.91	0.85	22
high risk	0.83	0.83	0.83	6

### 3.2.2 The Interpreter of Random Forest Model - LIME

It is very difficult to directly explain the classification results of random forests. Local Interpretable Model-Agnostic Explanations (LIME) provides a local interpretable approach: Select an interpreted instance and use a simple linear regression model to fit the decision boundary, thus explaining how the model makes decisions on this boundary.

The steps of LIME algorithm are as follows:

- Step1: The data is divided into cell blocks, and the cell blocks where the random disturbance



is interpreted generate new samples, which are fed into the prediction results of the random forest model.

- Step2: Give sample weights according to sample similarity (feature distance). The kernel function is used to calculate the degree of similarity between the new disturbed sample and the interpreted instance. The more similar (closer) the sample is to the interpreted instance, the greater the weight is given, and the less similar (farther away) the weight is given.
- Step3: Train a simple linear regression model based on the disturbed sample and interpret the example according to the coefficients of the model.

We select the first sample for interpretation and obtain the interpretation output in figure 7.

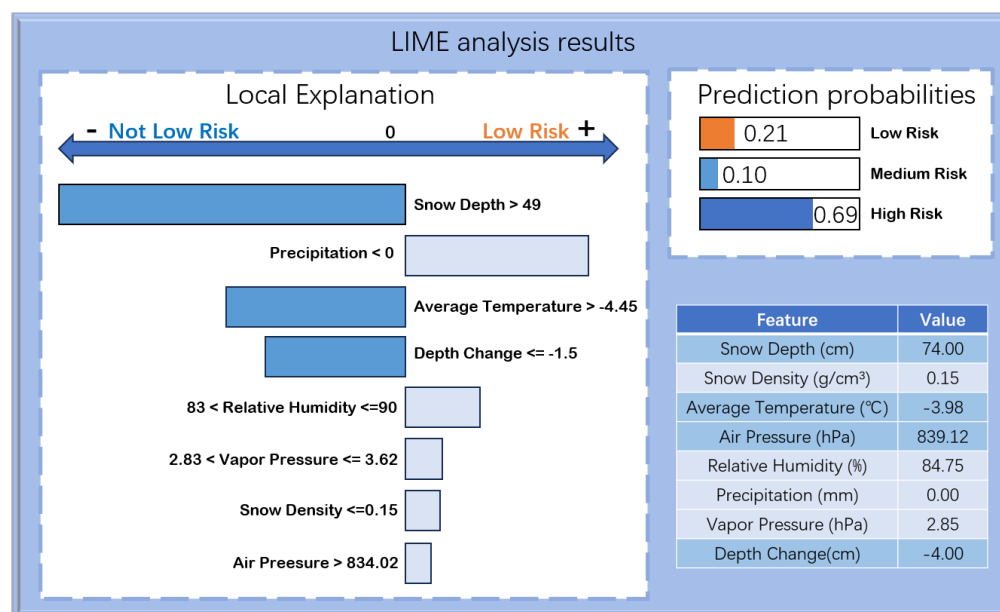


Figure 7: The interpretation of the first sample

The interpretation has three parts:

- The upper right section shows the probability of prediction, for this sample, the probability of low risk is 0.21, the probability of medium risk is 0.1 and the probability of high risk is 0.69.
- The left section returns the most important features. For binary classification tasks, it comes in two colors: dark blue/light blue. Attributes in dark blue support class 1 (Not Low Risk), and attributes in light blue support class 0 (Low Risk). It can be seen that the main reason why this sample is classified as high risk is that the snow depth is >49, which is consistent with the first importance of snow depth in the random forest model. Floating-point numbers on the horizontal bar represent the relative importance of these features.
- The color coding of the lower right section is consistent across sections. It contains the actual value of features.

### 3.3 Result of Task 1

Useful and easily measured parameters for predicting the risk of avalanche occurrence are: snow depth, snow density, average temperature, relative humidity, vapor pressure, depth change, pressure, precipitation. Their corresponding Gini importance is: 0.21, 0.15, 0.14, 0.13, 0.11, 0.10, 0.09, 0.07.

### 3.4 A Simple Exponential Smoothing Model

In order to determine the time of small avalanches induced by blasting, we first use a simple exponential smoothing model to determine the date of the next snowfall onset, snow melt, and snow disappearance in the future, and then use the seasonal autoregressive moving average model to predict the future avalanche risk.

The exponential smoothing method is actually a special moving average method, equivalent to the weighted moving average method. According to the actual value and predicted value of the current period, a simplified weighting factor, that is, smoothing coefficient, is introduced to solve the predicted value of the next period.

Set the actual value of phase  $t$  as  $X_t$ , the predicted value as  $F_t$ , and the smoothing coefficient as  $\alpha$ , then the predicted value of phase  $t + 1$  is:

$$F_{t+1} = \alpha X_t + (1 - \alpha)F_t \quad (1)$$

The predicted value  $F_{t+1}$  of phase  $t + 1$  can be interpreted as follows: part of it comes from the actual value  $X_t$  of phase  $t$ , and the rest comes from the predicted value  $F_t$  of phase  $t$ .

When the smoothing coefficient  $\alpha$  is smaller, the prediction is more stable (the fluctuation is less obvious). The larger the smoothing coefficient  $\alpha$ , the more sensitive the prediction (the fluctuation is obvious). The smoothing coefficient  $\alpha$  can be selected by means of the mean square error(MSE).

$$MSE = \frac{\sum_{t=1}^n (X_t - F_t)^2}{n} \quad (2)$$

It means that the mean square error of the predicted value corresponding to each  $\alpha$  is calculated firstly with multiple  $\alpha$ , and finally the  $\alpha$  with the smallest mean square error is selected as the final smoothing coefficient, because the smaller the mean square error, the closer the actual value and the predicted value are. The  $\alpha$  of this time series is calculated as 1.49e-08.

### 3.5 Seasonal Autoregressive Integrated Moving Average Model

The SARIMA model (Seasonal AutoRegressive Integrated Moving Average) is a statistical model for time series analysis and prediction, which is especially suitable for data with obvious seasonality[3]. SARIMA model combines four basic methods:

- Autoregressive(AR). Describe the relationship between the current value and the historical value, and use the historical time data of the variable to predict itself. The order of AR model is recorded as  $p$  value. The formula is as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \cdots + \alpha_p y_{t-p} + \varepsilon_t \quad (3)$$

where,  $\alpha$  is the coefficient,  $\varepsilon_t$  stands for error.

- Integrated(I). When the time series becomes stationary, the difference needs to be made, and the order of the difference is recorded as d value. Generally, first order is enough.
- Moving average(MA). Moving average model focuses on the accumulation of error terms in autoregressive model. The order of MA model is recorded as q value. The formula is as follows:

$$y_t = c + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (4)$$

where, c represents the constant term,  $\varepsilon_t$  is the white noise process of variance, and  $\theta$  is the coefficient.

- Seasonal(S). Seasonal model describes the pattern of the time series repeating within a certain cycle. The time interval of the seasonal component repeats is record as s value.

The general steps of SARIMA model for time series analysis and prediction are as follows:

- 1)Data exploration: Visualization and statistical analysis of time series data are done to understand its characteristics and trends. The result is shown in the figure 8.

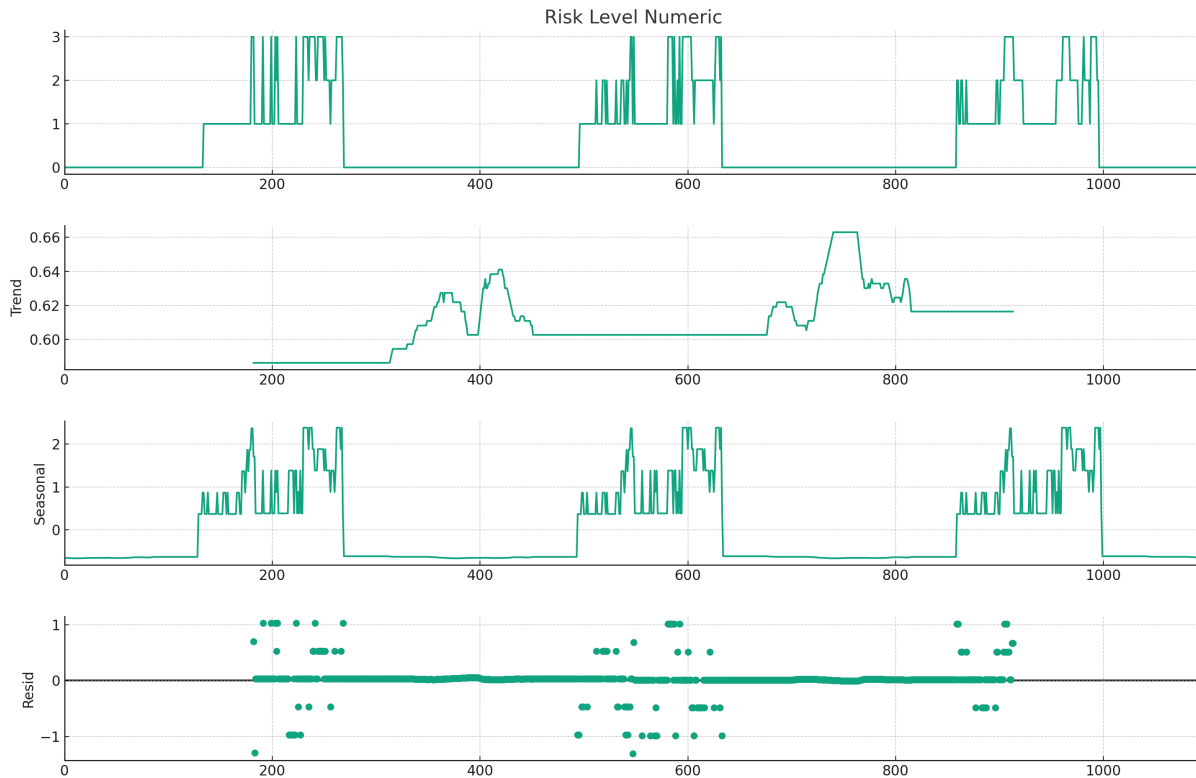


Figure 8: The interpretation of the first sample

- 2)Stabilization test: It is tested that the time series is stationary and no difference is needed.
- 3)Parameter determination: There are four parameters needing to be determined. From the autocorrelation function and partial autocorrelation function in figure 9, it can be determined that the p-value is 0 and the q value is 2.

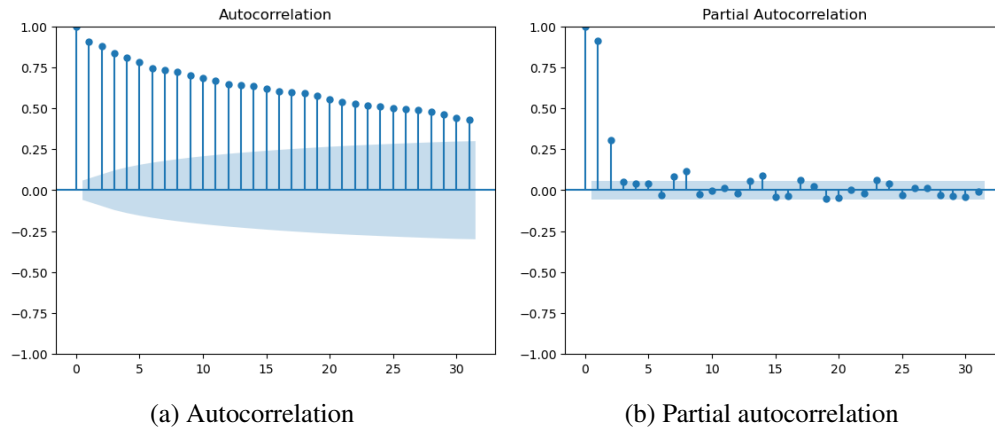


Figure 9: Figures of autocorrelation and partial autocorrelation

- 4) Model prediction: Based on the fitted SARIMA model, make predictions for the future period of time.

The result of combination of exponential smoothing model and SARIMA is shown in the figure 10. It suggests that we should make small avalanches induced by blasting in the morning on November 17, 2020.

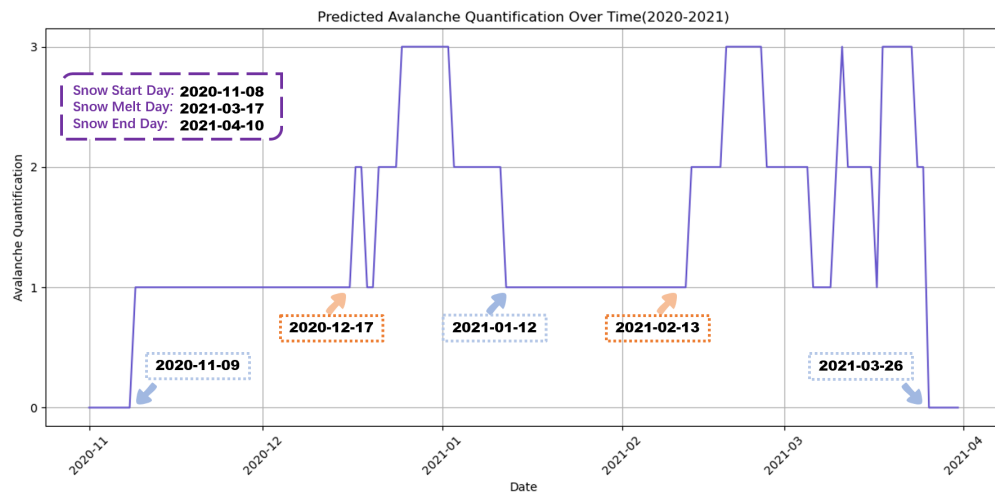


Figure 10: 2020-2021 Risk level forecast chart

The first peak occurred in late December 2020 due to a significant increase in snow depth due to heavy snowfall, and the trough appeared in late January 2021 due to the hardening of the previously accumulated snow compression due to strong wind compression, and the stability was enhanced, and then the peak occurred due to heavy snowfall and spring ice and snow melting, and the inflection points of low risk and medium risk were selected as the preliminary dates of blasting, and two dates of December 17, 2020 and February 13, 2021 were obtained. Considering that it is difficult to use explosives to induce avalanches in dense snow[4], the blasting work was carried out in the early stage of the first peak. According to the study, blasting is most suitable at 10 a.m. on a sunny day, so 10 a.m. on a sunny day around December 17, 2020 was selected as the specific blasting time.

### 3.6 Blasting Model Based on Particle Swarm Optimization

In order to determine the placement and blasting ability of explosives[5], we construct a slope model as figure 10 with a height of 50m, a width of 160m and a tilt Angle of 35°[6].

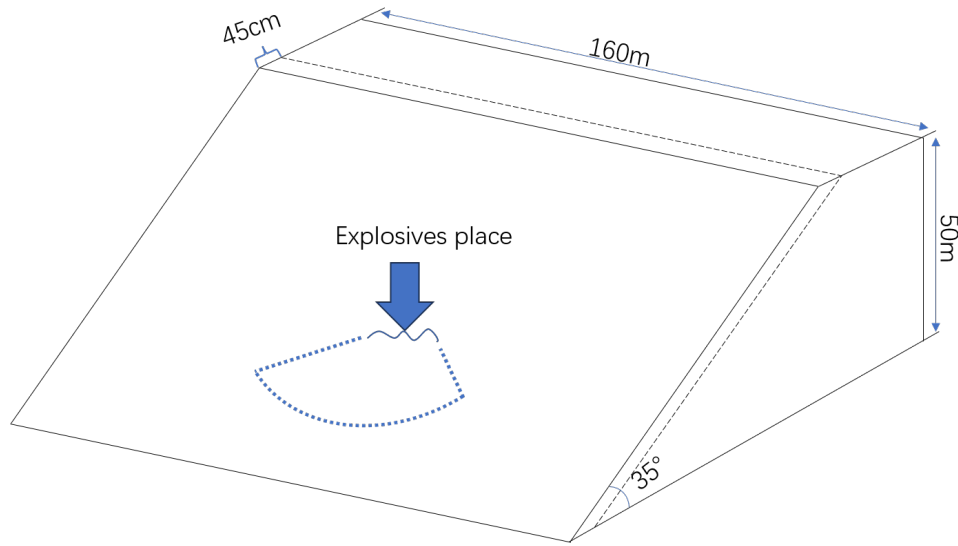


Figure 11: Slope model

- The total energy of the explosion is:

$$p = c_1 a \quad (5)$$

where,  $c_1$  is equal to 4200000J/kg.

- The initial moving snowpack is:

$$m_0 = d \left( \frac{p}{c_2} \right)^{\frac{2}{3}} \quad (6)$$

where,  $c_2$  is equal to 1500.

- The energy from the explosion is converted into the kinetic energy of the snow as:

$$W_{snow} = \frac{pd}{100} \quad (7)$$

Then, the initial speed of snow is:

$$v_0 = \sqrt{\frac{2W_{snow}}{m_0}} \quad (8)$$

- The total distance of snow slide is:

$$d_{total} = \frac{h}{\sin 35^\circ} \quad (9)$$

- The mass of the snow will increase with the rolling distance(x):

$$m(x) = (b_1 x + b_2)^{\frac{3}{2}} \quad (10)$$

where,  $b_1$  is 0.15,  $b_2$  is  $(m_0)^{\frac{2}{3}}$ .

- The total energy of the snow that falls to the bottom of the slope from the explosion is:

$$W_{total} = W_{snow} + \int_0^h m(x)g(1 - \frac{c}{\sin 35^\circ})dx \quad (11)$$

where,  $g$  is gravitational acceleration,  $c$  is dynamic friction coefficient of snow.

- The reduction of snow depth is:

$$d_{reduction} = \frac{m(d_{total})}{0.15wd_{total}} \quad (12)$$

where,  $w$  is the slope width  $160m$ . Then we can predict the risk level of avalanches after the blasting using random forest model.

The goal of the optimization model is to minimize the total energy of the snow that falls to the bottom of the slope from the explosion( $w_{total}$ ) and the risk level after the explosion. There is a constraint condition:

$$R = 25(a)^{\frac{1}{3}} < d_{total} \quad (13)$$

where,  $R$  is safe distance of the blasting[7].

### 3.6.1 Particle Swarm Optimization

Particle swarm optimization algorithm is an optimization algorithm based on swarm intelligence. Its principle is to continuously adjust the position and speed of particles to find the global optimal solution by simulating the predation behavior of birds.

In the PSO algorithm, each possible solution is expressed as a particle, each with its own position vector and velocity vector, as well as fitness related to the objective function. All particles travel at a certain speed in the search space to find the global optimal value by following the optimal value currently searched.

By simulating society, the PSO algorithm adopts the concepts of "group" and "evolution" and operates according to the adaptive values of individuals. However, different from traditional evolutionary algorithms, there is no evolutionary operator in PSO, and the flight speed of particles is dynamically adjusted according to individual flight experience and group flight experience.

Specifically, the basic flow of PSO algorithm includes the steps of initializing the particle position and velocity, calculating the fitness function, updating the particle velocity and position, and selecting the optimal solution. Among them, the updating rule of particles is based on the individual extreme value and the global extreme value, that is, the particle will adjust its speed and position according to its own optimal position and the optimal position of the group.

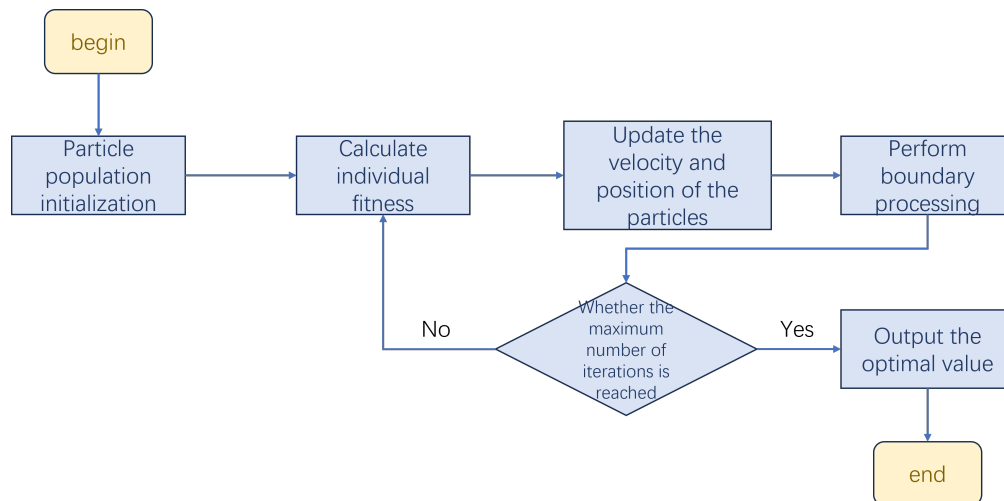


Figure 12: Flow chart of PSO

The results of using PSO to solve the above optimization problem is as follows: The placement depth of TNT is  $d=31.55\text{cm}$ , the amount of explosive is  $a=1.149\text{kg}$ , and the explosion height is  $h=15\text{m}$ .

### 3.7 Result of Task 2

The best time for blasting is in the morning on November 17, 2020. And for a slope model with a height of 50m and a width of 160m, the best position for blasting is at the center of a 15m-high slope, with a placement depth of 31.55cm and a TNT amount of 1.1494kg, minimized the total energy to 15552J and resulted in an average snow depth reduction of 15cm.

## 4 Strengths and Weaknesses

### 4.1 Strengths

- The preprocessing of exponential smoothing before risk forecasting is performed, and a brief preliminary exploration of the forecasted data is conducted.
- Considering the seasonal changes in the time series data of this topic, the use of SARIMA model can capture and predict seasonal trends more accurately.
- The optimization model established in this paper combines the simulated snowy mountain environment with the comprehensive consideration of rainfall and other indicators to minimize the impact on the natural environment.

### 4.2 Weaknesses

- Considering the complexity of parameter estimation of the physical model of the explosives' effect on the snow cover, several iterations and model selection are required. And the pa-

parameter selection of the model has a great influence on the experimental results, and if the parameters are not properly selected, it may lead to inaccurate conclusions.

- The placement and power of the explosives is selected for the specific environmental parameters of the field study, so the model does not have universal applicability.

### 4.3 Recommendations

- 1. For the selection of parameters in the model, more accurate estimates can be made by avalanche simulation or data mining.
- 2. Consider layering the snow for force analysis, so that the optimization model is more in line with the actual real-world scenarios.

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# Report on Use of AI

## 1. OpenAI ChatGPT (April, 2023 version, ChatGPT-4)

**Query 1:** I am participating in a mathematical modeling competition, please help me analyze the topic.

**Output:** Your Mathematical Modeling Competition topic is about preventing avalanches. The specific content and tasks are as follows:

- **Background:** Avalanches are a dangerous phenomenon. We have some understanding of how they form, but we cannot accurately predict their exact causes and timing. There are various methods to protect villages and roads from avalanches, such as limiting construction in fragile areas, preventing avalanches by planting forests or installing barriers, using protective structures like snow sheds to reduce impact, and artificially triggering small-scale avalanches using explosives to prevent excessive snow accumulation.
- **Key Issue:** The focus is on using explosives to trigger controlled small-scale avalanches, needing to determine the appropriate time and related parameters for triggering explosions. Although using more explosives can increase safety, it can also disrupt local wildlife. It is crucial to balance human safety with environmental impact.
- **Task:** Identify useful and easily measurable parameters to assess the risk of avalanche occurrence; for slopes at risk of avalanches, conduct field surveys to determine the appropriate time for blasting, the placement of explosives, and the appropriate blasting power.

**Additional Guidance:** In researching the above issues, if parameters related to snow environments are involved, you can find the necessary data yourself, or calculate fictional examples in your paper. However, you should provide a reasonable definition of the required parameters and a feasible, low-cost measurement method so that measurements can be implemented according to your measurement plan, and produce final results.

## 2. OpenAI ChatGPT (April, 2023 version, ChatGPT-4)

**Query 2:** Please help me with mathematical modeling.

**Output:** Certainly, I can help you develop a mathematical modeling framework to address your MCM topic. Based on your topic, we can divide the modeling process into several main parts:

1. **Determine Parameters and Collect Data:** Your first task is to identify parameters for assessing avalanche risk. These may include:
  - **Snowfall:** Accumulated snowfall over a past period.
  - **Temperature Changes:** Daily and seasonal temperature variations.
  - **Slope Angle and Direction:** Terrain factors affecting avalanche occurrence.
  - **Snow Layer Structure and Stability:** Analyzed through borehole samples.
  - **Historical Avalanche Records:** Frequency and scale of avalanches in the area historically.

2. **Avalanche Risk Assessment Model:** Establish a model using the above parameters to assess the probability of avalanche occurrence. This could be a statistical model, like logistic regression, or a more complex machine learning model. The goal of the model is to predict the risk of avalanches under given conditions.
3. **Explosive Usage Strategy:** After determining the risk of avalanches, you need to develop a strategy to decide when and how to use explosives to trigger small-scale avalanches. This includes:
  - **Timing of Blasting:** Determine the best time based on the risk assessment model.
  - **Placement and Quantity of Explosives:** Determine based on the slope's characteristics and snow layer conditions.
  - **Environmental Impact Assessment:** Evaluate the potential impact of explosive use on the surrounding environment, such as wildlife habitats.
4. **Simulation and Verification:** Before implementation, test your strategy with computer simulations. This helps you understand the effectiveness of your strategy under different conditions and make necessary adjustments.
5. **Reporting and Presentation:** Your model and findings need to be clearly presented and explained. The report should include:
  - **Detailed Description of the Model:** Including the data used, parameter selection, and model building process.
  - **Results and Analysis:** Results of the simulations and a detailed analysis of those results.
  - **Conclusions and Recommendations:** Specific recommendations based on the findings of the model.
6. **Considerations:**
  - **Complexity of the Model:** Ensure the model is complex enough to capture the relationships between key variables, but simple enough for understanding and implementation.
  - **Reliability of Data:** Ensure the data used is accurate and up-to-date.
  - **Environmental Protection:** Consider the minimal impact on the environment when solving the problem.

This is a basic framework that can be adjusted according to your specific needs. Remember, mathematical modeling is an iterative process and may require multiple adjustments and tests to achieve optimal results. Best of luck in your competition!

### **3.OpenAI ChatGPT (April, 2023 version, ChatGPT-4)**

**Query 3:** The above is my mathematical modeling competition and reference literature. I now want to use the data I collected to analyze the first question.

**Output:** The first question of your mathematical modeling competition is about preventing avalanches. The task requirements are as follows:

1. Find useful and easily measurable parameters to assess the risk of avalanches.

2. For slopes with avalanche risk, determine the appropriate time for blasting to trigger small avalanches, the placement of explosives, and the appropriate blasting power.

Additionally, if your research involves parameters related to the snow environment, you need to find the required data yourself or calculate some fictional examples in your paper. However, you should provide a reasonable definition of the required parameters and a feasible, low-cost measurement method so that measurements can be implemented according to your measurement plan and produce final results.

#### **4.OpenAI ChatGPT (April, 2023 version, ChatGPT-4)**

**Query 4:** The data I uploaded is about the Tianshan Mountains in China, including the corresponding literature I request you to read.

**Output:** In the first question of your mathematical modeling competition, the data from the central section of the Tianshan Mountains in China and the related literature provide important information and directions for analysis. Here is a summary and key findings of Qin Qiyong's research:

##### **1. Overview of Avalanches:**

- Avalanches are a natural disaster characterized by suddenness, potential danger, rapid movement, immense destructive power, and unpredictability.
- In the central Tianshan Mountains, avalanches occur frequently, seriously threatening the safety of life and property in surrounding areas.
- As human activities expand into mountainous areas, more people and infrastructure exposed to avalanche dangers increase the severity of avalanche disasters.
- Avalanche risk assessment is crucial for disaster prevention and management.

##### **2. Main Characteristics of Avalanches:**

- Avalanches mainly occur on slopes with angles between  $28^{\circ}$  and  $48^{\circ}$ , with an average angle of  $37.2^{\circ}$ .
- Avalanche frequency shows a bimodal distribution, with peaks typically occurring in early December and late February.
- Surface dry snow avalanches have a higher degree of harm and activity than other types of avalanches and are the most destructive.
- The highest risk of avalanches occurs in February, which requires enhanced prevention and control measures.

##### **3. Influencing Factors of Avalanches:**

- The occurrence of avalanches is influenced not only by snow accumulation but also by various natural and climatic conditions.
- The central section of the Tianshan Mountains is affected by wind and terrain, leading to frequent avalanche disasters due to abundant snowfall.
- The instability of snow accumulation is the fundamental cause of avalanches, influenced by weather, climate, terrain, and triggering factors.

- Comprehensive risk assessment and prevention strategies for avalanches in the central Tianshan Mountains have been developed.

Based on this information, you can consider using snow data, terrain data, and historical avalanche data to analyze the spatiotemporal distribution characteristics and risk levels of avalanches. These analyses can help you determine the risk of avalanches in mathematical modeling and provide a basis for developing effective avalanche prevention and control strategies. Key parameters to consider may include snow depth, snow density, slope angle, slope direction, and the timing and location of historical avalanche events. How would you like to proceed with the analysis?

### **5.OpenAI ChatGPT (April, 2023 version, ChatGPT-4)**

**Query5:** This is my mathematical modeling topic. I have now completed question 1 and would like to address question 2: For slopes at risk of avalanches, we need to conduct a simple field survey to determine the appropriate time for blasting to trigger small avalanches, the placement of explosives, and the appropriate blasting power.

**Output:** The second question in your mathematical modeling topic is about conducting a simple field survey for slopes at risk of avalanches to determine the appropriate time for blasting to trigger small avalanches, the placement of explosives, and the appropriate blasting power. To address this question, you need to consider the following aspects:

1. **Avalanche Risk Assessment:** First, assess the avalanche risk of the slope. This may involve measuring the thickness, density, temperature, and structure of the snow layer, as well as the slope's angle, direction, and terrain features.
2. **Determining the Appropriate Time:** Identifying the best time to trigger small-scale avalanches is key. This requires considering weather conditions (such as temperature, snowfall, wind speed) and changes in snow layer stability. Generally, blasting in the morning when temperatures are lower is safer.
3. **Placement of Explosives:** Determining the placement of explosives is crucial and should consider the slope's terrain and the characteristics of the snow layer. Explosives usually need to be placed at key points on the slope to maximize the triggering of avalanches.
4. **Determining Blasting Power:** The appropriate blasting power needs to be determined based on the size and type of avalanche, as well as the specific conditions of the slope. The aim is to achieve the desired effect with the minimum amount of explosives to reduce environmental impact.
5. **Environmental Impact Considerations:** Before blasting, consider the impact on local ecology and wildlife habitats, as well as the safety of nearby residents.
6. **Data Collection and Model Building:** Collect relevant data and build a mathematical model to simulate and predict the effects of blasting, helping to make more accurate decisions.

This question requires combining knowledge of geography, meteorology, physics, and environmental science, as well as skills in mathematical modeling. You may need to look for related literature and studies to obtain more detailed data and methods.