Analysis of climate change characteristics of wind in Baoshan—Based on annual data from 2011 to 2020

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Abstract. Based on the meteorological data of Baoshan from 2011 to 2020, this paper used SPSS software to fit the climate change characteristics of dominant wind direction and wind force in Baoshan City in recent 10 years. The results show that the wind direction and wind data of Baoshan from 2011 to 2020 are processed. The main wind force is light wind, accounting for 72.7%. The wind force of 5-6 occurred during February 11-13, 2012 and March 10, 2012. The main wind direction was non-continuous wind direction, accounting for 69.2%. The ARIMA(3,0,1) model in time series analysis theory was used to fit the wind data, and the validity was good.

1. Introduction

Wind is one of the important meteorological elements. The observation of surface wind and wind direction, which are mainly affected by atmospheric circulation situation, surface friction and terrain, is of great practical significance for the utilization of air pollution diffusion wind resources in urban construction. In recent years, the research results of many scholars show that the wind speed of most stations in China has been significantly weakening for many years. Besides the influence of large-scale circulation background, the distribution of wind direction is also greatly influenced by topography, landform and observation environment [1-7]. Baoshan City is located in the western part of Yunnan Province, bordering Lincang District of Dali Prefecture in the east, Nujiang Prefecture in the north, Dehong Prefecture in the west, and Myanmar in the northwest due to the south. The border is 167.78 kilometers long, with a land area of 19,600 square kilometers. Baoshan is a low latitude mountain subtropical monsoon climate, because of the low latitude plateau, complex topography. The highest elevation in the region is 3780 meters, while the lowest is 535 meters. Climate change may be complex. Therefore, the significance of this paper is to make a statistical analysis of the climatic characteristics of wind direction and wind speed in Baoshan City in the last 10 years, to master the variation law of wind weather in Baoshan area, and then improve the forecast accuracy, which is of reference significance to the forecast of surface wind and meteorological services, and to provide a scientific basis for the government's decision-making and economic development.
2. Methods

2.1. Data collection and analysis software

In the research on wind climate change, domestic and foreign scholars mostly focus on the research on the climate change characteristics of coastal monsoon and strong wind. The research results show that the spatial distribution of strong wind in China is uneven, and the characteristics of strong wind climate trend generally show a downward trend, but there is an increasing trend of strong wind in some places, with great regional differences [1-5]. For example, Yang Xueyan focused on analyzing the variation trend of mean wind speed and strong wind, climate abrupt change characteristics and spatial climate change characteristics in Northeast China in recent 46 years [3]. Tian Li et al. analyzed the climate change characteristics of wind speed in Northwest China [4], but the study of wind change characteristics in Southwest China was not obvious. Therefore, We use web crawler to collect the daily maximum and minimum temperature weather situation wind direction and wind data of Baoshan City from 2011 to 2020, and use SPSS software to match the climate change characteristics of the dominant wind direction and wind force in Baoshan City in recent 10 years.

2.2. Measures used

**AR(p) model**: pth-order autoregressive model [6].

\[ y_t = c + \theta_1 y_{t-1} + \cdots + \theta_p y_{t-p} + \epsilon_t \]

Then, \( y_t \) is the observed value at the first moment of the time series, namely, is the dependent variable or explained variable, \( y_{t-1}, y_{t-2}, \ldots, y_{t-p} \) are the lag sequence of time series \( y_t \). It is called an independent variable or an explanatory variable in this paper. \( \epsilon_t \) is random error term; \( \theta_1, \ldots, \theta_p \) are the autoregressive parameter to be estimated.

**MA(q) model**: qth-moving average model [6].

\[ y_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \cdots - \theta_q \epsilon_{t-q} \]

\( \mu \) is the average of time series. But when the sequence \( \{y_t\} \) moves around 0, Apparently \( \mu = 0 \). This item can be deleted, \( \epsilon_t, \epsilon_{t-1}, \cdots, \epsilon_{t-q} \) are the error of the model in phase \( t, t-1, \cdots, t-q \). \( \theta_1, \theta_2, \cdots, \theta_q \) are the moving average parameter to be estimated.

**ARMA(p,q) model**: Auto regression Moving Average Model [6].

\[ y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + \epsilon_t - \theta_1 \epsilon_{t-1} - \cdots - \theta_q \epsilon_{t-q} \]

**ARIMA(p,d,q) model**: ARIMA(p,d,q) Model is improved ARMA model. Here is the order of phase-by-phase difference of the original sequence, the purpose of difference is to make some non-stationary (with a certain trend) sequence transform into stationary. Generally speaking, the values of \( d \) are 0, 1, 2. For non-stationary time series with trend, the model cannot be established directly, but can only be established for new stationary time series after stabilization treatment. The smoothing treatment here can be differential treatment, logarithmic transformation, or a combination of the two, logarithmic transformation first and then differential processing.

The general steps to establish the ARIMA model are shown in Figure 1.
Figure 1. Flow chart of the construction of ARIMA model.

3. Results

3.1. Variation characteristics of wind
SPSS and Excel software were used to process the wind data of Baoshan from 2011 to 2020. The main wind force was light wind, accounting for 72.7%. On February 11-13, 2012, March 10, 2012, April 19, 2016 and April 2, 2017, there were 5-6 force winds (gale). The main wind direction is non-continuous wind direction, accounting for 69.2%, as shown in Tables 1 and 2.

Table 1. The statistics of wind power in 2011 and 2020.

| Frequency | Percent | Valid percent | Cumulative percentage |
|-----------|---------|---------------|-----------------------|
| Breeze    | 2421    | 72.7          | 72.7                  |
| Light air | 250     | 7.5           | 80.3                  |
| Light breeze | 208 | 6.3           | 86.5                  |
| Level 1-2 | 74      | 2.2           | 89.0                  |
| Level 3-4, breeze | 316 | 9.5           | 98.5                  |
| Level 4-5, breeze | 47  | 1.4           | 99.9                  |
| Level 5-6 | 4       | 0.1           | 100.0                 |
| Total     | 3328    | 100.0         | 100.0                 |

Table 2. The statistics of wind direction in 2011 and 2020.

| Frequency | Percent | Valid percentage | Cumulative percentage |
|-----------|---------|------------------|-----------------------|
| Unsustained wind direction | 2304 | 69.2 | 69.2 | 69.2 |
| Southwester | 733  | 22.0 | 22.0 | 91.3 |
| Northwester | 66   | 2.0  | 2.0  | 93.2 |
| southeaster | 44   | 1.3  | 1.3  | 94.6 |
| Northeaster | 17   | 0.5  | 0.5  | 95.1 |
| Wester | 140  | 4.2  | 4.2  | 99.3 |
| Norther | 6    | 0.2  | 0.2  | 99.5 |
| The south wind breeze | 15   | 0.5  | 0.5  | 99.9 |
| The east wind breeze | 1    | 0.0  | 0.0  | 100.0 |
| Easter | 2    | 0.1  | 0.1  | 100.0 |

3.2. Wind power fitting of Baoshan City from 2011 to 2020 based on ARIMA model
The wind data of Baoshan from 2011 to 2020 were selected and SPSS software was used to carry out ARIMA(p,d,q) modeling and improvement for many times [8]. ARIMA(3,0,1) with good fitting condition was selected for modeling. From Table 3, it can be seen that the eight goodness of fit indexes of the model were stable, R-squared was 0.668 and R-squared was 0.617, so stable was more representative and ARIMA(3,0,1) model had good fitting condition.
Table 3. Model fit.

| Fit Statistic | Mean  | SE   | Minimum | Maximum | 5    | 10   | 25   | 50    | 75    | 90    | 95    |
|---------------|-------|------|---------|---------|------|------|------|-------|-------|-------|-------|
| Stationary R-squared | 0.668 | 0.00 | 0.668   | 0.668   | 0.668| 0.668| 0.668| 0.668 | 0.668 | 0.668 | 0.668 |
| R-squared     | 0.617 | 0.000| 0.617   | 0.617   | 0.617| 0.617| 0.617| 0.617 | 0.617 | 0.617 | 0.617 |
| RMSE          | 1.054 | 0.000| 1.054   | 1.054   | 1.054| 1.054| 1.054| 1.054 | 1.054 | 1.054 | 1.054 |
| MAPE          | 23.859| 0.000| 23.859  | 23.859  | 23.859| 23.859| 23.859| 23.859| 23.859| 23.859| 23.859|
| MaxAPE        | 582.698| 0.000| 582.698 | 582.698 | 582.698| 582.698| 582.698| 582.698| 582.698| 582.698| 582.698|
| MAE           | 0.466 | 0.000| 0.466   | 0.466   | 0.466| 0.466| 0.466| 0.466 | 0.466 | 0.466 | 0.466 |
| MaxAE         | 5.911 | 0.000| 5.911   | 5.911   | 5.911| 5.911| 5.911| 5.911 | 5.911 | 5.911 | 5.911 |
| Normalized BIC| 0.118 | 0.000| 0.118   | 0.118   | 0.118| 0.118| 0.118| 0.118 | 0.118 | 0.118 | 0.118 |

Table 4 shows the fitting statistics and Ljung-box statistics of the model. The stable R squared is 0.669, while the R squared is 0.618, which is consistent with the stable R squared fitted by model ARIMA(3,0,1). The Ljung-box statistic is 27.68, and the significance level is 0.027(<0.05). Therefore, the null hypothesis that residual sequences are listed as independent sequences is rejected, indicating that the residual sequences after model fitting are autocorrelated, and the fitting condition of ARIMA(3,0,1) model is good.

Table 4. Model Statistics

| Model | Number of Predictors | Stationary R-squared | R-squared | RMSE | MAPE | MAE | Max APE | Max AE | Normalized BIC | Statistics | DF | Sig. | Number of Outliers |
|-------|----------------------|----------------------|-----------|------|------|-----|---------|--------|---------------|------------|----|------|-------------------|
| Wind Force Model_1 | 1 | 0.668 | 0.617 | 1.054 | 23.859 | 0.466 | 582.698 | 5.911 | 0.118 | 25.890 | 14 | 0.027 | 0 |

The ARIMA(3,0,1) model parameters are given in Table 5. There are two parts in the ARIMA(3,0,1) model, namely AR and MA. The significance level of the three items in the AR autoregressive part is all 0.000, while the significance level of one item in the AM moving average part is 0.000.

Table 5. ARIMA model parameters.

| Estimate | SE   | T     | P     |
|----------|------|-------|-------|
| Constant | 0.382| 0.137 | 2.792 | 0.005 |
| Lag 1    | 1.466| 0.021 | 70.692| 0.000 |
| Lag 2    | 0.370| 0.030 | -12.252| 0.000 |
| Lag 3    | -0.099| 0.019 | -5.240| 0.000 |
| MA Lag 1 | 0.934| 0.011 | 85.307| 0.000 |

Figure 2 shows the ACF graph and partial autocorrelation function (ACF) graph of residual sequence. We further tested the feasibility of the ARIMA(3,0,1) model, finding out that both of the two graphs have no obvious trend feature (trailing or truncating), so it can be judged that the ARIMA(3,0,1) model fits better.
Figure 2. Correlation diagram of ARIMA model residuals.

Figure 3 shows the variation temperament of the model fitting sequence of the actual observed wind value series in Baoshan City from 2011 to 2020 using the ARIMA(3,0,1) model. We found that the actual observed value and the fitted value fit well in the whole interval [9]. The actual value and the predicted value are in good agreement, the fitting value and the real value are basically the same, and the fitting effect is good.

Figure 3. Fitting diagram of ARIMA model.

4. Discussion
The main wind force is breeze, and the occasional 5-6 wind may be related to the subtropical monsoon climate in the low latitude mountains where Baoshan is located. The climate types cover seven climate types, namely, the northern tropics, the south subtropical zone, the subtropical zone, the south temperate zone and the plateau climate. The characteristics are as follows: the annual temperature difference is small, the daily temperature difference is large, and the annual average temperature is 14 to 17 °C. The annual rainfall of 700 to 2100 mm may be related to the complex topography and landform of Baoshan Mountain, which is located in a low latitude plateau. The ARIMA(3,0,1) model has a good wind power fitting effect for Baoshan City from 2011 to 2020, which indicates that the ARIMA(3,0,1) model has a certain theoretical value for the wind power prediction of Baoshan, to further understand the variation law of wind weather in Baoshan area is of reference significance to the forecast of surface wind and meteorological service, and to provide a certain scientific theoretical basis for the government decision-making, and economic development and may have a certain guiding value for agricultural practice.
5. Conclusion
The annual wind force in Baoshan is mainly breeze, with 5-6 wind occasionally occurring. The theoretical time series model ARIMA(3,0,1) without continuous wind direction has a certain theoretical value for the wind data prediction of Baoshan.

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Conflicts of Interest
The authors declare no conflicts of interest regarding the content and implications of this manuscript.

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