Mountain air pollution evaluation and tourism brand building based on remote sensing image processing

Mingzhen Zhou¹ · Hongfen Zuo² · Peihua Xiao³ · Xiaoguang Zhang⁴

Received: 17 June 2021 / Accepted: 1 August 2021 / Published online: 21 August 2021
© Saudi Society for Geosciences 2021

Abstract
In recent 20 years, China has made a lot of efforts and achieved some results in air governance. However, it is not ideal from the result. Some areas of pollution also affect the daily life and physical and mental health of the people, which is an important environmental problem that China needs to solve. This paper presents a double star cooperative AOT inversion algorithm with complex background in urban area. Aiming at the difficulty of AOT inversion on urban area highlighted surface, the paper uses the double satellite remote sensing data and the atmospheric radiation transmission model to realize the inverse reflection of AOT parameters in urban area by using satellite remote sensing image processing. With the development of society, the progress of the times, and the rapid development of urbanization, the environmental pollution problems in some areas also follow. However, this problem is more difficult, because it involves many factors. At present, there is no comprehensive evaluation model to comprehensively evaluate various pollution situations. In this paper, we have carried out a detailed study on the typical model of mountain air pollution and the evaluation method of mountain air pollution. This work provides a practical solution for simulating the air pollution in mountain areas and analyzing environmental data. With the development of economy, people pay more attention to tourism, and the construction of tourism brand has become a trend. Higher and better service has become a new pursuit of consumers in the process of tourism, which makes the rural people get rid of poverty, and further improves the attention and protection of ecological environment. Therefore, this paper studies the assessment of mountain air pollution and the construction of tourism brand by using remote sensing image processing technology, which promotes pollution prevention and tourism industry development.

Keywords Remote sensing image processing · Mountain air · Pollution assessment · Tourism brand building

Introduction
In the process of the development of human society, the city has always been an important production and life center. When the air pollutants discharged in the process of human production and life exceed the air purification capacity of nature itself, cities will face serious air pollution, which will bring serious harm to human production and life and affect human physical and mental health. Cities are highly populated areas, and are also the main targets of air pollution control (Armstrong-Altrin et al. 2020). Air pollution in mountain areas has been widely concerned all over the world. China's economy has developed rapidly in recent years, but it has also brought serious mountain air pollution assessment problems, especially haze particulate pollution. Haze pollution mainly includes two types, one is less than 2.5 μm aerosol particles PM_{2.5} is the main pollutant of haze pollution. The other is that the aerodynamic diameter is less than 10 μm. Estimation of
near surface PM using satellite remote sensing data. PM$_{2.5}$ concentration and spatiotemporal distribution characteristics is a rapidly developing technology in recent years, and it is also a hot research field in the world (Bhatia 1983). Long time sequence processing China’s remote sensing image processing is not limited by the spatial distribution of the ground stations, simultaneous interpreting the spatial distribution of air pollution in large scale areas and the characteristics of long time series changes. More abundant and valuable data are provided for the study of air pollution transmission mode and formation mechanism. With the rapid development of modern economy, the living pressure of urban residents is increasing day by day. More and more residents are willing to leave the urban environment and go to other places to relieve this pressure, so that their body and mind can be relaxed. China’s No. 1 central document issued in 2018 has proposed that the strategy of revitalizing the mountain village should be completed in 2050, and the rural areas will be revitalization and farmers will be prosperous and strong (Carter and Moss 1999). The promotion and implementation of Rural Revitalization Strategy can effectively solve the difficulties encountered in the process of rural development in recent years, optimize and upgrade the rural industrial structure, cultivate new professional farmers, and rectify the rural living environment, so that they can quickly integrate into the pace of rural development in the new era. From the perspective of tourism development in recent years, tourists are more willing to experience rural life instead of simply visiting rural environment and scenery, which promotes the rapid development of tourism brand construction (Chen et al. 2017). The renewal and improvement of China’s vacation system also helps the mountain village tourism industry to develop rapidly and stably.

**Materials and methods**

**Data sources**

The satellites used in this experiment are fy-3c meteorological satellite of China and Terra satellite of the US, both of which are sun synchronous orbit satellites (Darby et al. 2001). Fy-3c is the third of the FY-3 series satellites managed by the China Meteorological Administration and the National Satellite Meteorological Center. The main task of fy-3c is to provide atmospheric data for medium and long-term numerical weather forecast and global climate research, such as the geophysical parameters needed to study the global climate change laws such as temperature, humidity and cloud radiation, and monitor all kinds of natural disasters and ecological environment (Davis et al. 2002). Fy-3c satellite was successfully launched at 10:00 on September 23, 2018 by carrying the “Long March 4C” carrier rocket at China’s Taiyuan Satellite Launch Center, crossing the equator from south to north. The medium resolution image spectrometer on fy-3c has the function of earth observation, and the spectral band distribution is similar to MODIS sensor on Terra satellite. MERSI has 20 spectral channels, of which the spatial resolution of five frequency bands is 250m, and the spatial resolution of the rest frequency bands is 1000m. The US satellite Terra was launched at 10:30 am on December 12, 1999, flying over the equator from south to north. The MODIS sensor on Terra satellite has 36 spectral channels with a spectral range of 0.4 to 14 μm. We provide surface observation image every one to two days. Each MODIS satellite remote sensing image has three different spatial resolutions of 500m, 250m, and 1000m. MODIS sensors are designed to provide a wide range of global dynamic data measurement, including changes in cloud cover, earth energy radiation, ocean, land, and low altitude. The experimental data sensed by the algorithm are two remote sensing images off Terra and fy-3c on September 9, 2019. There is no sudden change of precipitation or aerosol characteristics during the satellite transit time interval. The algorithm also uses the AOT data of mod04 and AERONET to verify the inversion.

**Remote sensing image processing algorithm design**

Because most of the urban areas are composed of bright surface, the traditional “dark pixel algorithm” fails to retrieve atmospheric aerosol over the bright surface. For example, modisdt algorithm is suitable for dense vegetation area. This algorithm uses empirical correlation model between visible band and short wave infrared band to carry out AOT inversion, and DB algorithm is suitable for high reflectivity area.

AOT is not only related to aerosol properties (particle size distribution, extinction coefficient, refractive index, etc.), but also depends on the total amount of aerosol. Ångström, a formula for calculating aerosol scattering optical thickness is proposed Ångström turbidity equation:

\[
\tau_A^\lambda = \beta \lambda^{-\alpha}
\]

(1)

β be called Ångström turbidity coefficient, α It’s called wavelength index, λ Is the wavelength, $\tau_A^\lambda$ Is the wavelength optical thickness (AOT) under the same condition. Using this formula, the problem of calculating AOT is transformed into how to calculate α and β two parameters.

According to the analysis of Chandrasekhar and kondratev, the atmospheric radiative transfer of the earth atmosphere system can be expressed as follows:

\[
\frac{\cos \theta}{\rho} \frac{\delta I^\lambda}{d z} = \frac{\delta}{4\pi} \int [I^\lambda(z, r')] r^{\lambda}(z, r') \delta \omega (k + \sigma) I^\lambda(z, r) \, d \omega
\]

(2)

In the formula, $I^\lambda(z, r)$ is the radiation intensity at wavelength λ, height z, and direction r; θ is the satellite zenith
angle; $\rho$ is the apparent reflectivity of the satellite; $r^\lambda(z,t)$ is the scattering phase function; $k$ is the absorption coefficient; $\sigma$ is the scattering coefficient; $\omega$ is the solid angle. In order to obtain an analytical solution, Kontratev introduced the optical thickness $\tau$, namely:

$$\tau = \int \sigma \rho dz$$  \hspace{1cm} (3)$$

Therefore, the relationship between the surface reflectance $A$ and the satellite apparent reflectance $A'$ is as follows:

$$A = \frac{(A'b-a) + a(1-A')e^{(a-b)z_0} \sec \theta}{(A'b-a) + b(1-A')e^{(a-b)z_0} \sec \theta}$$  \hspace{1cm} (4)$$

$a$ is the secant function of the solar zenith angle $\theta$, namely $\sec \theta$; $b$ is 2; $\varepsilon$ is the backscattering coefficient, generally 0.1; $\theta$ is the satellite zenith angle; $\tau_0$ is the atmospheric aerosol at the wavelength $\lambda$ when the satellite passes through Optical thickness.

In the model described by formula (4), only the scattering effects of atmospheric aerosols and atmospheric molecules are considered. It is assumed that the optical thickness of atmospheric aerosol $\tau_0^\lambda$ consists of two parts: Rayleigh scattering of atmospheric molecules $\tau_M^\lambda(\infty)$ and aerosol particle scattering $\tau_A^\lambda(\infty)$. Therefore, the atmospheric aerosol optical thickness $\tau_0^\lambda$ can be expressed as:

$$\tau_0^\lambda = \tau_M^\lambda(\infty) + \tau_A^\lambda(\infty)$$  \hspace{1cm} (5)$$

For the Rayleigh scattering of atmospheric molecules $\tau_M^\lambda(\infty)$, Linke gives an approximate calculation formula:

$$\tau_M^\lambda(\infty) = 0.00879\lambda^{-4.09}$$  \hspace{1cm} (6)$$

The optical thickness $\tau_A^\lambda(\infty)$ scattered by atmospheric aerosols is calculated using the Ångström turbidity formula:

$$\tau_A^\lambda(\infty) = \beta\lambda^{-\alpha}$$  \hspace{1cm} (7)$$

According to the above assumptions, that is, formula (4), this paper proposes an algorithm that can simultaneously invert the surface reflectivity and aerosol optical thickness AOT($\tau_0^\lambda$). The algorithm is based on the following assumptions:

1. There is no change in the reflection properties of the earth during the satellite observation interval.
2. There is almost no change in the type and nature of aerosols, that is, the wavelength index $\alpha$ does not change, and the particle concentration, namely the turbidity coefficient $\beta$, changes.

Therefore, if two satellites observe the same area twice in a short period of time, and the two satellites have similar visible light bands, we can obtain a nonlinear equation system:

$$A_{j,\lambda} = \frac{(A_j'b-a_j) + a_j(1-A_j')e^{(a_j-b)z_0} \sec \theta_j}{(A_j'b-a_j) + b(1-A_j')e^{(a_j-b)z_0} \sec \theta_j}$$  \hspace{1cm} (8)$$

In the formula, $j$ represents the observation of different satellites, $i$ represents the band of the observation satellite, and the meanings of other parameters are consistent with formula (4).

In the actual situation, the bidirectional reflection property of the ground object is not only related to the wavelength, but also depends on the geometric position between the sun, the ground and the satellite. Therefore, for satellite observations at different times, geometric position changes need to be considered. The ratio of the reflectivity between the two satellite observations is:

$$K_{\lambda} = \frac{A_{1,\lambda}}{A_{2,\lambda}}$$  \hspace{1cm} (9)$$

In the formula, $K_{\lambda}$ represents the ratio between the surface reflectance of the i-th observation of the solar wavelength $\lambda$ and the second observation of the surface reflectance of the i-th wavelength $\lambda$. $A_{1,\lambda}$ and $A_{2,\lambda}$ are the first observation of the surface reflectance of the i-th wavelength $\lambda$. $A_{2,\lambda}$ is the second observation of the surface reflectance of the i-th wavelength. Because the short-wave infrared band is penetrating to atmospheric aerosol particles, and the ratio $K$ depends on the geometric position changes between different observations, and has nothing to do with the wavelength, the ratio $K_{SWIR}$ in the short-wave infrared band is also applicable to the ratio $K_{\lambda}$.

The final nonlinear equations are as follows:

$$\begin{cases} A_{j,\lambda} = \frac{(A_j'b-a_j) + a_j(1-A_j')e^{(a_j-b)z_0} \sec \theta_j}{(A_j'b-a_j) + b(1-A_j')e^{(a_j-b)z_0} \sec \theta_j} \\ K_{SWIR} = K_{\lambda} \end{cases}$$  \hspace{1cm} (10)$$

In the above formula, $j$ represents observations from different satellites (values 1, 2); $i$ represents the band of the observation satellite (values 1, 2, and 3); $a_j$ is the secant function of the j-th observation of the sun’s zenith angle; $b$ is 2; $\varepsilon$ is the backscattering coefficient, generally 0.1; $\theta_j$ is the satellite zenith angle. By solving the nonlinear equations, the Ångström turbidity coefficient $\beta$ and the wavelength index $\alpha$ are obtained when the satellite transits and the spatial distribution of AOT can be obtained.

**Fuzzy evaluation model of mountain air pollution**

In this paper, based on the pollutant emission limits set by the air quality standards, and based on the above fuzzy queuing theory, an air quality evaluation model is established.
According to China’s air quality standards, air quality levels are basically divided into three categories: environmentally friendly, general pollution and heavy pollution. Each level corresponds to a concentration limit and is described by S1, S2, and S3. These can form a set of evaluation criteria in the form of \( v_i = \{S1, S2, S3\} \). Given C and V, the fuzzy relationship between environmental factors and metrics can be described by the membership function \( U \). The shape of the membership function for different pollutant levels is shown below.

\[
\begin{align*}
U_1(x) &= \begin{cases} 
x - S_1 \leq 0 & \text{if } 0 < x < S_2 \\
S_2 - x & \text{if } S_2 \leq x \leq S_3
\end{cases} \\
U_2(x) &= \begin{cases} 
S_1 - x & \text{if } S_1 < x < S_2 \\
x - S_3 & \text{if } S_2 \leq x \leq S_3
\end{cases} \\
U_3(x) &= \begin{cases} 
x - S_2 & \text{if } S_1 < x < S_2 \\
S_3 - x & \text{if } S_2 \leq x \leq S_3
\end{cases}
\end{align*}
\]

According to China’s air quality standards, air quality levels are basically divided into three categories: environmentally friendly, general pollution and heavy pollution. Each level corresponds to a concentration limit and is described by S1, S2, and S3. These can form a set of evaluation criteria in the form of \( v_i = \{S1, S2, S3\} \). Given C and V, the fuzzy relationship between environmental factors and metrics can be described by the membership function \( U \). The shape of the membership function for different pollutant levels is shown below.

\[
\begin{align*}
U_1(x) &= \begin{cases} 
x - S_1 \leq 0 & \text{if } 0 < x < S_2 \\
S_2 - x & \text{if } S_2 \leq x \leq S_3
\end{cases} \\
U_2(x) &= \begin{cases} 
S_1 - x & \text{if } S_1 < x < S_2 \\
x - S_3 & \text{if } S_2 \leq x \leq S_3
\end{cases} \\
U_3(x) &= \begin{cases} 
x - S_2 & \text{if } S_1 < x < S_2 \\
S_3 - x & \text{if } S_2 \leq x \leq S_3
\end{cases}
\end{align*}
\]

U1, U2, and U3 in the equation respectively represent the probability values of pollution degree basically no pollution, general pollution and serious pollution, and its structure is in the form of fuzzy matrix.

In the comprehensive fuzzy assessment of multiple pollutants, the values of various pollutants must be individually weighted to determine the weight of the index. The higher the weighting coefficient, the greater the influence of pollutants on the atmosphere.

Results

Analysis of characteristics of mountain air pollution

API/AQI time change characteristics

Figure 1 is a scatter plot of the daily changes of API/AQI in mountainous areas from 2005 to 2020. It can be seen that there is more pollution in winter and spring in mountainous areas, and less pollution in summer and autumn. Most major pollution accidents occur in winter. From the moving average analysis, we can see that API/AQI has a bimodal distribution, that is, to say, approximately December, January, March and April are peak periods, and February and June-September are troughs. According to the estimation analysis of the linear trend of the API annual average value from 2006 to 2017, the linear regression coefficient is \(-0.79\), and the correlation coefficient \( r = -0.79 \) indicates that the API is on a downward trend in mountainous areas, and the correlation coefficient \( |r| > 0.001 = 0.78 \), yes It shows that from 2006 to 2017, the air pollution in this mountainous area has decreased, and the air quality has been better changed.

In this article, in order to better understand the changes in the air quality in mountainous areas the API/AQI ≤100 standard (good) and the number of pollution days with API/AQI >200 from 2005 to 2020, we have conducted statistics, as shown in Fig. 2.

It can be seen from Fig. 2 that in 2005 and 2006, the number of days with API>200 reached 61 days, and air quality has been fluctuating ever since. The peaks in 2010 and 2014 were 80 days and 24 days, respectively, and in 2012, 2015, and 2016, the peaks were less than 10 days. Since 2017, the evaluation criteria have changed. The number of days with AQI>200 has increased to 17 days this year, and it will remain within 10 days in the next three years. From 2005 to 2007, it rose sharply from 106 days to 202 days; in 2016, it was less than 10 days.

Characteristics of AQI’s primary pollutants

The main pollutant refers to the pollutant with the highest air quality index (IAQI) among all pollutants with an air quality index (AQI) greater than 50. By analyzing the primary pollutants of AQI in mountainous areas from 2018 to 2020, we found that the main pollutants in mountainous areas are mainly PM10 for a total of 610 days, and PM2.5 accounted for 32.7%. A total of 236 days, accounting for 22.3%. The pollutant days in the investigation of NO2 and NO3 were the same, 123 days and 119 days, respectively, 11.6% and 11.3%. SO2 and CO have not occurred in the ranks of major pollutants for 3 years. Figure 3 shows the monthly average changes of the four pollutants as the main pollutants from 2018 to 2020.

According to this figure, the annual air pollution in mountainous areas is mainly PM10. From February to October, the main pollutant was “PM10,” which exceeded 50%. Among them, 89.2% occurred in March, and June was the trough, 52.2%. The proportion of PM10 as the main pollutant was low in November, December and January, all below 50%, and it was the lowest in December, at 26.7%.

Characteristics of atmospheric pollutant concentration changes

API and AQI are comprehensive non-dimensional indicators that characterize air quality. It can reflect air quality, but not the concentration of pollutants. Therefore, this article describes the characteristics of changes in the concentration of different types of air pollution in the past 16 years. Since only the pollutant concentration data from 2005 to 2015 are collected, SO2, NO2, and PM10, the summary analysis is as follows: Starting from January 18, 2017, these pollutants will be classified into three Class pollutants O3, CO and PM2.5, the initial analysis time of the pollution concentration data is from January 18, 2017 to December 31, 2020. Figure 4 shows the
daily changes of the three concentrations of SO$_2$, NO$_2$ and PM$_{10}$. It can be seen from the figure that in the past ten years, the concentration of SO$_2$ has dropped significantly.

Figure 5 shows the daily variation of the concentration of PM$_{2.5}$, CO and O$_3$-8h in mountainous areas from January 18, 2017 to December 31, 2020. In the past 4 years, the mountain concentration has shown a significant downward trend. In 2019, the lowest was 49$\mu$g.m$^{-3}$, but it was still 40% higher than the Chinese standard. PM$_{2.5}$ The characteristic of concentration changes is high in winter and low in summer. In most of the year, the highest concentration is in November and December, and the lowest is August and September. There is a small peak in April, May, or July.

**Case analysis of mountain air pollution**

WRF CHEM mode can output various pollutant concentrations. We mainly select the pollution levels of PM$_{2.5}$, PM$_{10}$, SO$_2$ and NO$_2$. Figure 6 shows the comparison of daily average concentrations of PM$_{2.5}$, PM$_{10}$, SO$_2$ and O$_3$ in mountainous areas, simulated by boundary layer parameterization schemes YSU and ACM2.

The simulation effect of the model shows that the simulation effect of pollutant concentration is not as good as that of meteorological factors. For example, on the 4th day of the monitoring value, the pollution concentration was high on the 23rd day and dropped to the lowest value on the 24th day, but the simulated value was small on the 23rd day and appeared to rise on the 24th day. But in principle, the model can simulate changes in the daily average pollutant concentration. The two simulated values of the boundary layer parameterization scheme had high daily average concentrations of PM$_{2.5}$ and PM$_{10}$ from the 27th to the 29th, and showed the highest value on the 28th day.

Table 1 shows the average time deviation (deviation), root mean square error (RMSE), and standard deviation (STDE) of the four pollutants simulated using different boundary layer parameterization schemes. These three tests are respectively used: the simulation effect of the index rating model on the concentration of pollutants.
The root mean square error shows that the two boundary layer schemes have slight differences in the simulation deviation of particulate pollutants. The deviation of the YSU scheme for gaseous pollutants is smaller than that of the ACM2 scheme.

The characteristics of local air quality changes are determined by the combination of factors such as the intensity of pollution sources and weather conditions. The higher the boundary layer, the stronger the vertical diffusion capacity of pollutants and the lower the concentration of pollutants. Due to the complex terrain of the valley, the surface wind field is dominated by static small winds. The horizontal diffusion ability is very weak, and it is believed that the change of pollutant concentration is mainly affected by vertical diffusion, as shown in Fig. 7.

In Fig. 8, from the 22nd to the 27th, the mountainous area below 500m above sea level was dominated by breeze and light wind. The wind speed was basically less than 4m·s⁻¹, and the wind speed was greater than or equal to 500 m, rarely exceeding 4m·s⁻¹. A northerly or southerly wind indicates that the weather is stable and will not cause the spread of pollutants. From the 28th to the 29th, small winds below 4m·s⁻¹ below 400 meters in mountainous areas prevailed, but the wind speed in the sky increased significantly, stronger than the northwest wind at 8m·s⁻¹. From 16:00 to 24:00 UTC on the 19th, southwest winds above 4m·s⁻¹ occurred in mountainous areas below 500 m, which promoted the diffusion of soil pollutants. PM2.5 and PM10 dropped sharply near the ground. On the 30th, 08:00-12:00 UTC (16:00-20:00) is at a relatively low level. The pollutant concentration is caused by the northeast wind above the altitude of 8m·s⁻¹, and the pollution level is relatively low.

Figure 8 shows the time series of the potential temperature gradient curve. The soil reversed strongly at night from the 22nd to the 27th and the 30th, the inversion potential temperature gradient below 400m exceeded 20K·km⁻¹, the solar heat and the valley floor mixed layer during the day were 10–16, and the solar altitude was less than 250 m. The potential temperature gradient is less than 0. From 28th to 29th, not only a strong inversion layer appears at night, but also a daytime inversion layer grows in the valley during the day. The stable atmospheric stratification conditions did not promote the diffusion of pollutants. Shows that this process is a typical continuous cold pool event.

Analysis of the results of mountain air pollution assessment

Taking the exhaust gas emitted by the power plant as the experimental object, take the coordinate points (1200, 300, 100) in the exhaust direction of the chimney of the power plant, and the sampling interval is 0.5 h. The exhaust gas and atmosphere are measured in Gaussian mode, and the real-time values of the above parameters are estimated to obtain SO2. Concentration values of nitrogen oxides and fine particles. The data is shown in Table 2.

According to the emission limits of the three pollutants specified by the Chinese standards, the membership function of the membership function SO2 is determined as S1=0.05, S2=0.15, S3=0.25, and the membership function of NOx is S1=0.05, S2=0.10, S3 =0.15, particle membership function s1=0.05, S2=0.15, S3=0.25. Combining the measurement and evaluation parameters, the identification matrix of the three pollutants is obtained according to the equation, as shown in Table 3.

The formula gives the normalized results of the weights of the three pollutants, gives the probability of different degrees of pollution in the area, and selects the case with the highest probability as the final result. The data is shown in Table 4.
The results show that the use of Gaussian prediction models combined with measured meteorological and source intensity parameters can provide estimates of air pollutant concentrations. The air pollution rating result obtained by combining the predicted value and the fuzzy matrix rating method is essentially the probability that the 10 test results after “general pollution” are “generally no pollutants” and “severe.” Therefore, we believe that the development of this method is feasible and will provide a good reference for practical air environment monitoring.

**Application of satellite remote sensing in mountain air pollution monitoring**

PM$_{2.5}$ daily average sample set has established two sets of PM$_{2.5}$ estimation models, the first model (Model-I) uses PM$_{2.5}$ 24 hourly average value as the daily average PM$_{2.5}$, the second model uses the average value of PM$_{2.5}$ from 10 am to 2 pm as the daily average value of PM$_{2.5}$, and both the Terra and Aqua MAIACAOT averages are used for AOT. After model fitting and model verification, the estimated values of PM$_{2.5}$ of Model-I and Model-I are obtained, and
the R between the estimated value of PM$_{2.5}$ at each station and the observed value of PM$_{2.5}$ on the ground is calculated through the R language. 2. Slope (slope), MPE and RMSPE statistical description, Figure 9 is the model fitting site box plot.

It can be seen from the model performance box plot of the 36 stations in Fig. 9 that for “Model-I,” the station $R^2$ range is 0.60~0.96, the slope range is 0.68~1.20, and the range of RMPSE is 9.08 μg/m$^3$~26.36 μg/m$^3$, MPE range 6.86 μg/m$^3$~22.57 μg/m$^3$; for “Model-II,” the station $R^2$ range is 0.46~0.94, the slope range is 0.65~1.10, The range of RMPSE is 11.76 μg/m$^3$~33.22 μg/m$^3$, and the range of MPE is 8.40 μg/m$^3$~22.31 μg/m$^3$. Figure 10 is a box diagram of the model verification site.

Table 5 is a summary of the overall model performance of “Model-I” and “Model-II” in 2018. It can be seen that both models have better estimation capabilities, and the model “Model-I” is better. Compared with model fitting, the $R^2$ of model verification has decreased, while MPE and RMSPE have increased. Therefore, the estimation performance of the model has decreased, and both models have a certain degree of overfitting (Fig. 11).
PM$_{2.5}$ scatter plots of model estimates and ground observations. In general, “Model-I” has better estimation capabilities than “Model-II,” so this article finally uses “Model-I”s PM$_{2.5}$ estimate results to analyze the spatial distribution and seasonal change characteristics of the urban agglomeration.

In this paper, we use the improved LMEMPM$_{2.5}$ inversion model (Model-I) to estimate PM$_{2.5}$ in a mountainous area in 2019. The results show that the model fits the estimated value of PM$_{2.5}$ and ground observations. The $R^2$, RMSPE, and MPE between the values are 0.94, 17.85 $\mu g/m^3$, 10.16 $\mu g/m^3$, respectively. Compared with the previous model, the improved modelPM$_{2.5}$ has certain inversion accuracy the improvement. As shown in Fig. 12.

**Discussion**

**Characteristics of tourism brand building**

**Brand and brand building**

Brand can be simply understood as the degree of consumer recognition of the product and its series. It is a series of comments and understandings of people on the company, its products and value, and it is also a kind of trust. It is also a concentrated expression of the comprehensive quality of goods and is representative. When people think of a certain brand, they will think of vocabulary such as fashion and culture. After the establishment of the brand, the company continues to expand its brand culture and fashion. With the rapid development of the company, the added value of products continues to increase, and the advantages of many products have also been brought to a very high level. Only when the culture expressed by the brand is accepted by the market can the brand have value. The combination of today’s business environment and consumer emotions has given a new definition: When people come into contact with goods, services, and related promotions, they are already familiar in their minds. The most lasting meaning and essence of a brand are value, culture and personality.

**Mountain tourism brand building**

Tourism brand is the core part of tourism attractiveness and competitiveness. Mountain village tourism brand building is based on the uniqueness of its products, through publicity, planning and other activities, to create a brand image with a beautiful environment and good reputation in the hearts of tourists, build specific emotional awareness and trust, and attract tourists come and consume.

(1) The mountain village tourism brand is unique: China has a vast land and abundant resources, and its geographical location is different, and its customs and customs are also different. The locations of mountain village tourism are mainly concentrated in the vast mountain villages. The mountain village area has a unique style, customs, and rustic flavor (Du et al. 2017). These factors are conducive to the development of mountain village tourism and

**Table 1**  Statistical evaluation of hourly concentration simulation results of 4 pollutants (unit: $\mu g/m^3$)

| Pollutant | YSU | ACM2 | YSU | ACM2 | YSU | ACM2 | YSU | ACM2 |
|-----------|-----|------|-----|------|-----|------|-----|------|
| Bias      | 12.36 | 2.53 | 34.63 | 24.76 | 7.85 | 8.38 | -0.82 | 2.96 |
| RMSE      | 61.87 | 61.09 | 92.13 | 90.80 | 19.85 | 21.14 | 18.19 | 27.06 |
| STDE      | 60.62 | 61.04 | 85.37 | 87.35 | 18.23 | 19.41 | 18.17 | 26.90 |

![Fig. 6](image-url)  Comparison of daily average simulated and monitored values of 4 pollutant concentrations during the simulation period (unit: $\mu g/m^3$). (a) PM$_{2.5}$, (b) PM$_{10}$, (c) SO$_2$, (d) NO$_2$. 

Arab J Geosci (2021) 14: 1851
provide great uniqueness to the development of products (Fan et al. 2009). This uniqueness is well reflected in its travel brand.

(2) The mountain village tourism brand is integral: the mountain village tourism brand is not a tangible asset; it can appear in every link of the six major elements of tourism. Not only can it express the attributes of the product to tourists, it is also a representative of its product implication and service level, and it is a comprehensive manifestation of the combination of internal and external products. When creating and marketing a mountain village tourism brand, we must pay attention to the integrity of the brand (Fedo 2003). Otherwise, a problem in any small part of the constituent elements may lead to the demise of the brand (Geng et al. 2010).

Problems in mountain tourism brand building

(1) The brand awareness of mountain village tourism is relatively weak, and the quality of brand building is low: a brand is an intangible asset, and the uniqueness of the tourism industry is an important part of brand building. A brand with a good reputation can effectively open up greater prospects for the local tourism industry, and it can also provide a large amount of funds and effective impetus to tourist destinations. The current boom in mountain village tourism in China has spread too many regions, and many different tourism brands have been produced on this basis, but few of them have value. The main reason for this phenomenon is that most regions have not established good brand awareness (Hou et al. 2011).

(2) The propaganda and promotion of mountain village tourism brand is low, and its popularity needs to be improved: Mountain village tourism regional brands have certain limitations, that is, the audience range is small. Once the scope is exceeded, the brand effect will drop sharply. With the transformation of people’s consumption patterns, the Internet has slowly entered people’s lives, and the Internet has gradually penetrated into people’s lives. So far, it has become a key way to buy and sell products. Compared with traditional tourist attractions such as cultural scenic spots, people do not have a high degree of understanding of tourist attractions in mountain villages (Hu et al. 2013).

(3) The structure of the target source market is too single and restricted: The tourist source market refers to the actual purchasers and potential purchasers of a specific tourism product in the tourist area. It is a huge and complex market with different beliefs and personalities, culture, and needs. Therefore, the demand of the source market is diversified.

(4) Tourism professionals are scarce, and the quality of tourism services in mountain villages is not high: The information contained in the tourism industry is relatively
complex, generally including tourist sources, tourism channels, etc., and various other factors are included in different aspects. These factors determine that tourism practitioners need to have versatility (Jian et al. 2005).

As a rising star in China’s tourism industry, mountain village tourism is still in the early stage of its overall development. At present, because there are more or less deficiencies in all aspects of mountain village tourism, its

---

**Table 2** Sampling data of three pollutants (mg/m³)

| Sampling | SO₂  | NOₓ  | KL  | Sampling | SO₂  | NOₓ  | KL  |
|----------|------|------|-----|----------|------|------|-----|
| 1        | 0.0956 | 0.0450 | 0.1369 | 6        | 0.0853 | 0.0518 | 0.0815 |
| 2        | 0.0155 | 0.0621 | 0.2248 | 7        | 0.0814 | 0.0742 | 0.1369 |
| 3        | 0.0963 | 0.1158 | 0.1036 | 8        | 0.0896 | 0.0936 | 0.1125 |
| 4        | 0.0425 | 0.0963 | 0.1120 | 9        | 0.1836 | 0.0731 | 0.2147 |
| 5        | 0.0268 | 0.0584 | 0.0752 | 10       | 0.1247 | 0.0582 | 0.0936 |
level of development is more than ideal (Lei et al. 2017). The main reason for this phenomenon is that the local tourism management personnel are not professional enough.

Countermeasures and suggestions for tourism brand building

Clarify the market positioning of the brand and build an exclusive mountain village tourism brand

(1) Clarify the target source market: On the basis of satisfying the party building training personnel, we should also increase efforts to create some brands that local tourists need. While meeting the needs of locals, some facilities that conform to the local culture can also be established; which will attract more foreigners to visit (Li et al. 2007).

(2) Clarify its own positioning: Combining the actual local culture, cooperate with the government, schools and other institutions, clarify its own positioning according to its actual situation, and formulate a tourism image and publicity slogans that match it.

(3) Determine the main body of the brand: After determining the content of the above two aspects, the main body of the brand needs to be determined on this basis. To put it simply, it is to formulate the internal meaning and external manifestation of the brand, and at the same time establish a legend that conforms to the characteristics of the brand.

| Table 3 Discrimination matrix of three pollutants |
|-----------------------------------------------|
| $SO_2$ Discriminant matrix | $NO_X$ Discriminant matrix | KL Discriminant matrix |
| Basically no pollution | General pollution | Serious pollution | Basically no pollution | General pollution | Serious pollution | Basically no pollution | General pollution | Serious pollution |
| 0.5398 | 0.4628 | 0 | 1.3332 | 0 | 0 | 0.1857 | 0.8182 | 0 |
| 0.5715 | 0.4257 | 0 | 0.7015 | 0.2548 | 0 | 0 | 0.2436 | 0.7515 |
| 1.0001 | 0 | 0 | 0 | 0.6135 | 0.3856 | 0.4536 | 0.5441 | 0 |
| 0.6435 | 0.3695 | 0 | 0.1936 | 0.2541 | 0 | 0.5896 | 0.5563 | 0 |
| 1.0004 | 0 | 0 | 0.8725 | 0.1836 | 0 | 0.7749 | 0.0548 | 0 |
| 0.6482 | 0.3515 | 0 | 0.8124 | 0.4857 | 0 | 0.6258 | 0.3680 | 0 |
| 0.6329 | 0.3648 | 0 | 0.5149 | 0.8386 | 0 | 0.1024 | 0.1546 | 0 |
| 0.6128 | 0.3825 | 0 | 0.1634 | 0.5148 | 0 | 0.3154 | 0.2548 | 0 |
| 0 | 0.6832 | 0.3621 | 0.4827 | 0.3658 | 0 | 0 | 0.4749 | 0.6954 |
| 0.2864 | 0.7125 | 0 | 0.8946 | 0.2458 | 0 | 0.8686 | 0.558 | 0 |

| Table 4 The normalized results of the weights of the three pollutants and the final normalized results of the data |
|-----------------------------------------------|
| The normalized results of the weights of the three pollutants (w) | Processing results of ten sets of monitoring data |
| Basically no pollution | General pollution | Serious pollution |
| 0.3325 | 0.2115 | 0.4536 | 0.4751 | 0.5212 | 0 | General pollution |
| 0.2254 | 0.2336 | 0.5417 | 0.2934 | 0.2931 | 0.4114 | Serious pollution |
| 0.1269 | 0.5561 | 0.3269 | 0.2711 | 0.5104 | 0.2135 | General pollution |
| 0.2847 | 0.3958 | 0.3214 | 0.3564 | 0.6425 | 0 | General pollution |
| 0.3269 | 0.4518 | 0.3968 | 0.8540 | 0.1425 | 0 | Basically no pollution |
| 0.2536 | 0.3361 | 0.4146 | 0.6920 | 0.3020 | 0 | Basically no pollution |
| 0.3644 | 0.3215 | 0.3458 | 0.3758 | 0.6235 | 0 | General pollution |
| 0.5879 | 0.3948 | 0.3695 | 0.3305 | 0.6614 | 0 | General pollution |
| 0.3569 | 0.2236 | 0.4236 | 0.1052 | 0.4836 | 0.4026 | General pollution |
| 0.4022 | 0.2758 | 0.3258 | 0.5269 | 0.4710 | 0 | Basically no pollution |
Use “Internet +” to intensify the promotion of mountain village tourism brands

Mountain village tourism mainly faces urban consumers. How to stimulate tourists to visit to a greater extent should not only fully display the local cultural characteristics, but also increase the degree of brand promotion through other ways. Today, electronic media has become an important means for consumers to obtain information. Official accounts can be established in apps such as Weibo and Douyin, and pictures and pictures of scenic spots can be posted every day. Small videos of the tour, etc., enable tourists to more intuitively feel the scenery of the tourist area before traveling.

Strengthen the diversified development of tourism products in mountain villages and expand the source market

Tourism destination brands should be connected with the characteristics and environment of the region to conduct research on how to improve their own competitiveness, and the most important link is to dig out their own cultural connotations, carry out appropriate packaging and beautification, and give tourists unique travel experience. In the process of building a mountain village tourism brand, the most important thing is to combine the unique local geological scenery, cultural landscape, and cultural customs. Therefore, in the process of branding packaging, simplicity, naturalness, and coordination must be embodied. Most tourists who choose to travel in mountain villages want to experience farm life, release the pressure of being in a fast-paced city, and learn about the local customs. If mountain villages want to go on the road of tourism branding, they need to combine their unique characteristics. The historical and cultural background of China excavates and amplifies its unique cultural spirit, and combine various tourism products well.

Strengthen the training of tourism talents and improve the quality of tourism products and services in mountain villages

Whether the tourism market can develop well and whether a tourism brand can gain the trust and satisfaction of tourism consumers is determined by the quality of tourism services,
and the overall level of employees and the training and use of tourism professionals are the improvement of service quality. It can strengthen cooperation with universities and establish a counterpart support system for tourism talents; organize an expert group to train and evaluate local management and service personnel within a fixed period of time, as well as evaluate infrastructure, and continue to promote local tourism with the pace of the times quality.

**Conclusion**

Satellite remote sensing technology is a technical means that can obtain large-scale regional information by large-scale, low-cost, long-term observation, and has been widely used in various fields of human development. Air pollution is a major environmental problem faced in the development of human society, and it is particularly important to study its occurrence and development mechanism. Although traditional ground monitoring can provide long-term series and high-precision pollutant concentrations, the sites are sparsely distributed, unable to provide fine spatial distribution of atmospheric pollutants, and high maintenance costs. Satellite remote sensing can complete long-term continuous observation of a large area, and it can achieve a short-term 2.5 atmospheric aerosol particulate matter, also known as “haze.” Since 2011, haze pollution has caused widespread concern in society. In the field of remote sensing, this paper has carried out the

| Table 5: Model performance summary |
|-----------------------------------|
| Model & \( N \) & \( M \) & Model fitting & Model validation |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
| & & & & |
research of atmospheric pollution parameter PM$_{2.5}$ based on satellite remote sensing data, and realized the inversion of the distribution of PM$_{2.5}$ in urban areas. Due to the complex surface types in urban areas and mainly composed of bright surfaces, AOT inversion in urban areas is extremely difficult. In response to this problem, this paper carried out a research on the AOT inversion algorithm for urban areas, using the WRF model to perform numerical simulation analysis on the spring dust-type pollution caused by cold air, and using the WRF-which is completely online coupled with the weather model and the chemical model. The Chem model analyzes the change characteristics and influencing factors of static air pollution in a certain mountainous area in winter. In recent years, mountain village tourism has gradually developed and grown, and its influence on society has gradually increased. In particular, the current economic structure is constantly changing, the scale of economic development has become larger and larger, and the forms have begun to become diversified, which has promoted mountain villages. The development of tourism has increased the income of residents. After people’s unremitting exploration, the tourism development prospects of mountain villages have become clearer. However, at this stage, mountain villages still have many problems in brand building, such as low brand quality, low publicity, a relatively single source market, and imperfect construction of tourism supporting facilities. These problems have seriously hindered the development of mountain village tourism brand building. In view of these problems in the development of mountain village tourism brand building, this article analyzes the successful typical cases of domestic and foreign mountain village tourism development, and takes brand building related theories, tourism destination life cycle theory, sustainable development theory and mountain village revitalization strategy theory as guidance. Put forward suggestions to strengthen
brand awareness, improve the quality of tourism products and services, increase brand promotion, strengthen the diversified development of tourism products, expand the source market, improve infrastructure construction, and implement the concept of sustainable development, etc., aiming to build a unique The brand of mountain village tourism makes the development prospects of mountain village tourism broader.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Declarations

Conflict of interest The authors declare no competing interests.

References

Armstrong-Altrín JS, Ramos-Vázquez MA, Hermenegildo-Ruiz NY, Madhavaraju J (2020) Microtexture and U–Pb geochronology of detrital zircon grains in the Chachalacas beach, Veracruz, Mexico. Geol J 55(1):1–27. https://doi.org/10.1002/gj.3984
Bhatia MR (1983) Plate tectonics and geochemical composition of sandstones. J Geol 91(6):11–627. https://doi.org/10.1086/629311
Carter A, Moss SJ (1999) Combined detrital-zircon fission-track and U–Pb dating: a new approach to understanding hinterland evolution. Geology 27(3):235–238
Chen NHC, Zhao GC, Sun M, Zhou H (2017) U-Pb zircon ages and Hf isotopes of 2.5Ga granitoids from the Yinshan Block, North China Craton: implications for crustal growth. Precambrian Res 303:171–182. https://doi.org/10.1016/j.precamres.2017.08.022
Darby BJ, Davis GA, Zheng YD (2001) Structural evolution of the southwestern Daqing Shan, Yinshan Belt, Inner Mongolia, China, in Hendrix MS, Davis GA, Eds, Paleozoic and Mesozoic tectonic evolution of Central and Eastern Asia: from continental assembly to intracontinental deformation. Geol Soc Am Memoir 194:199–214
Davis GA, Darby BJ, Zheng Y, Spell TL (2002) Geometric and temporal evolution of an extensional detachment fault, Hohhot metamorphic core complex, Inner Mongolia, China. Geology 30(11):1003–1006. https://doi.org/10.1130/0091-7613(2002)0302.0.C0:2
Du LL, Yang CH, Wyman DA, Nutman AP, Zhao L, Lu ZL, Song HX, Geng YS, Ren LD (2017) Zircon U–Pb ages and Lu–Hf isotope compositions from elastic rocks in the Hutuo Group: further constraints on Paleoproterozoic tectonic evolution of the Tianshan–North China Orogen. Precambrian Res 303:291–314
Fan HR, Hu FF, Yang KF, Wang KY, Liu YS (2009) Geochronology framework of late Paleozoic dioritic-granitic plutons in the Bayan Obo area, Inner Mongolia, and tectonic significance. Acta Petrol Sin 25(11):2933–2938
Fedo CM (2003) Detrital zircon analysis of the sedimentary record. Rev Mineral Geochem 53(1):277–331. https://doi.org/10.2113/0530277
Geng YS, Shen QH, Ren LD (2017) Late Neoarchean to Early Paleoproterozoic magmatic events and tectonothermal systems in the North China Craton. Acta Petrol Sin 26(7):1945–1966
Hou WR, Nie FJ, Hu FL, Liu YP, Zhang K (2011) Geochronology and geochemistry of Sanadegai granites in Wulashan area, Inner Mongolia and palaeo-tectonic significance. J Jilin Univ (Earth Sci Ed) 41(6):1914–1927
Hu B, Zhang B, Deng P, Liu F, Diwu CR, Wang HZ, Zhang HD (2013) Late Paleoproterozoic to Neoproterozoic geological events of the North China Craton: evidences from LA–ICP–MS U–Pb geochronology of detrital zircons from the Cambrian and Jurassic sedimentary rocks in Western Hills of Beijing. Acta Petrol Sin 29(7):2508–2526
Li XP, Zhang Q, Liu DY, Jin WJ, Jia XQ, Qian Q (2005) SHRIMP dating and geological significance of Late Achaean high-Mg diorite (sanukite) and hornblende-granite at Guyang of Inner Mongolia. Acta Petrol Sin 01:153–159
Lei KY, Liu CY, Zhang L, Wu BL, Wang QJ, Cun XN, Sun L (2017) Detrital zircon U-Pb dating of Middle-Late Mesozoic Strata in the Northern Ordos Basin: implications for tracing sediment sources. Acta Geol Sin 91(7):1522–1541
Li QL, Chen F, Guo JH, Li XH, Yang YH, Siebel W (2007) Zircon ages and Nd–Hf isotopic composition of the Zhaertai Group (Inner Mongolia): evidence for early Proterozoic evolution of the northern North China Craton. J Asian Earth Sci 30:573–590. https://doi.org/10.1016/j.jseaes.2007.01.006