Visibility characteristics over Fuzhou during 1956-2016

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Abstract. This research analyzes atmosphere visibility characteristics in Fuzhou. For residents to choose the best travel time and improve the quality of their life. The results show that the average atmospheric visibility in 1957-2016 is 17.98 km and the trend is -2.86 km / decade. The highest atmospheric visibility occur in the summer, the lowest value appears in the winter, further observation shows that atmospheric visibility in July showed the maximum value, and in March shows the lowest value. The "bad" level of atmospheric visibility showed a modest upward trend between 1956 and 2006, and showed a high growth after 2006, indicating that effect of governance to improve the air quality is not obvious, and the trend of "good" level of is decline from nearly 90% in 1956 to nearly 20% in 2006. In 1956-1987 Ridit values are greater than 0.5, the highest value of 0.77, in the upward trend in the fluctuation, in 1987-2005 Ridit value of 0.5 up and down, in a steady period of time the trend is not obvious, and in 2006-2016 Ridit value is less than 0.5, the lowest value of 0.28, indicating that the trend of atmosphere is decline. The value of atmospheric visibility about worst 20%, 50% and best 20% is in a downward trend.

1. Introduction

Atmospheric visibility is defined as the maximum horizontal distance between person's eye and the visible target\cite{1}, which not only reflects the regional atmospheric quality\cite{2-3}, but also closely related to the life quality of the inhabitants. For the significance of life, in recent years, atmospheric visibility has become the most popular issue of public\cite{4}. During the haze days in London\cite{5}, Brimblecombe do the first research of the impact of air pollutants on atmospheric visibility. Followed by the research reports of atmospheric visibility continue to emerge. According to previous studies, the most influencing factors of atmospheric visibility are the aerosol scattering effect, especially particular meter (PM)\cite{2}. Some scholars have reported that atmospheric pollutants such as nitrogen dioxide (NO\textsubscript{2}) meteorological factors as concentration (RH), wind speed (WS), atmospheric temperature (T) and atmospheric pressure (P) are directly work on atmospheric visibility, and there is a significant correlation between atmospheric pollutants and atmospheric visibility\cite{6}. In addition, some scholars have pointed out meteorological parameters such as relative humidity (RH) has an indirect relationship on visibility\cite{7-10}. It shows that atmospheric visibility is of great significance as the monitoring index.
of air environmental quality. However, most studies focused only on 1-3 years of variation, whereas long-term monitoring studies were rarely reported.

Rapid urbanization process and economic development led to a sharp increase in resource consumption, many areas are facing a serious decline in atmospheric visibility challenge. The problem is particularly heavy in the coastal city. Fuzhou is located in the eastern part of Fujian Province, one of the most population density city in China. Fuzhou has experienced a rapid economic development and urbanization. However, the impact of atmospheric pollutants and meteorological factors on atmospheric visibility in this region has never been reported. Fuzhou, as a typical city of Mindong, the study can not only be a data support for improving the atmospheric visibility and air quality, but also provide reference for the other cities of the South China.

2. Materials and methods

2.1. Data
Atmospheric visibility and weather data are available from the National Oceanic and Atmospheric Administration (NOAA, https://www.climate.gov/) and the data monitoring interval is 1 hour.

2.2. Analytical methods
The study used five kinds of statistics and analysis methods: 1) statistical analysis of the annual variation of atmospheric visibility and diurnal variation; 2) analysis of atmospheric visibility monthly "better" (> 19.9 km), "poor" (<4 km); 3) using the SPSS 19.0 software for atmospheric visibility Ridit analysis; 4) calculating the atmospheric visibility Cumulative percentiles; 5) using the method [12], to calculate the atmospheric visibility and atmospheric pollutant regression equation, in order to make the regression equation more typical, eliminate fog, rain and other effects of visibility of the special weather is screen out. Because the higher air humidity has a strong deterrent effect, the relative humidity which > 90% of the monitoring data group is also removed [13].

Extinction coefficient $\beta_{ext}$ reference Koschmieder's research method to come [1]:

$$\beta_{ext} = \frac{3.912}{V}$$  \hspace{2cm} (1)

Where $\beta_{ext}$ is the extinction coefficient (km$^{-1}$); V is the atmospheric visibility (km).

Data processing
Data analysis and image analysis are performed using SPSS 19.00 and EXCEL 2010.

3. Results and analysis

3.1. Yearly Variation
Table 1 shows the mean value of atmospheric visibility and annual variation trend of Fuzhou during 1957-2016. The average atmospheric visibility in 1957-2016 is 17.98 km and the trend is -2.86 km / decade. Indicating that with the development of economy, atmospheric visibility is gradually reduced. Figure 1 shows the annual average of atmospheric visibility 1957-2016 in Fuzhou, showing a decreasing trend from 1980 to 1990, and the trend of change from 1990 to 2005 is gently. During 2006-2016, due to the increase of government's efforts to control air pollution, the value of atmospheric visibility is increased.

| Year       | 1957-1964 | 1973-1976 | 1977-1986 | 1987-2006 | 1997-2006 | 2007-2016 | 1957-2016 | 60-year trend |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|---------------|
| FuZhou     | 26.67     | 22.75     | 19.42     | 15.67     | 15.93     | 12.03     | 17.98      | -2.86         |

Table 1. Summary statistics of yearly visibility in Fuzhou (1956–2016).
3.2. Seasonal and monthly variation
The highest atmospheric visibility occurs in the summer, the lowest value appears in the winter, further observation shows that atmospheric visibility in July showed the maximum value, and in March shows the lowest value. Atmospheric visibility in the summer shows the highest value may be with the heavy rain, high temperature, and frequent typhoon weather.

3.3. Monthly Percentage of Atmospheric Visibility at Different Levels
The ratio of "good (> = 20km)" and "bad (<4km)" levels of atmospheric visibility is quite important for the residents. Figure 3 shows the ratio of annual visibility in different levels of visibility during 1956-2016. The "poor" level of atmospheric visibility showed a modest upward trend between 1956 and 2006, and showed a high growth after 2006, indicating that effect of governance to improve the air quality is not obvious, and the trend of "better" level of is decline from nearly 90% in 1956 to nearly 20% in 2006.

Fig. 1 Variations of yearly value of visibility during 1956-2016 in Fuzhou city

Fig. 2 Variations of the monthly and seasonal value of visibility in Fuzhou city

Fig. 3. Percentiles of “quit good” and “quit bad” visibility.
3.4. Ridit Analyze
The Ridit value can reflect the trend of atmospheric visibility. When the Ridit value is greater than 0.5, it indicates that the atmospheric visibility in this year is on the rising trend, and if it is less than 0.5, it indicates that it is declining. In 1956-1987 Ridit values are greater than 0.5, the highest value of 0.77, in the upward trend in the fluctuation, in 1987-2005 Ridit value of 0.5 up and down, in a steady period of time the trend is not obvious, and in 2006-2016 Ridit value is less than 0.5, the lowest value of 0.28, indicating that the trend of atmosphere is decline.

![Ridit Analysis](image)

**Fig. 4** The Ridit value of Fuzhou city during 1956-2016

3.5. Cumulative percentiles
From Figure 5 we can see that the value of atmospheric visibility about worst 20%, 50% and best 20% is in a downward trend. The best trend of the best 20%, 50% and worst 20% are -0.39, -0.36 and -0.25km/year, respectively. Further analysis of the best 20% in 1987-2006 has a modest upward trend that may be related to the 1980s reform and opening up. In this period, the value of 50% and worst 20% are changing gentle. And in the 1956-1986 and 2006-2016, the value of the worst 20%, 50% and best 20% of the atmospheric visibility are in a sharp downward trend, indicating that the period of pollution control also need to improve.

With the change of extinction coefficient, the concentration of atmospheric particulates is increasing. The worst 20% increase of 0.03 km\(^{-1}\)/year is greater than 50% (0.004 km\(^{-1}\)/year) and best 20% (0.003 km\(^{-1}\)/year). Indicating that the frequency of extreme pollution of the weather is increasing, and better atmospheric visibility frequency of the decline is relatively slow. May be related to the variation of temperature, humidity, and wind speed and so on.
Fig. 5. The variation of the best 20%, 50% and worst 20% visibility in Fuzhou city during 1956-2016.

4. Conclusion

The average atmospheric visibility is 17.98 km over Fuzhou city during 1956-2016, the highest value occur in summer and the lowest appears in winter, showing an inverted "V" font. The ratio of "better" and "poor" levels of atmospheric visibility is quite important for the residents. The study find that "poor" atmospheric visibility in the spring and winter appear high frequency, and the in summer and early autumn the ratio of "better" atmospheric visibility is higher than the average ratio.

The results of previous studies show that the atmospheric visibility decreases with the increase of the light scattering effect of the atmospheric particles, and pointed out that the atmospheric pollutant concentration has a certain correlation with the atmospheric visibility [11, 15-18]. Dan Xue et al. [19] found that atmospheric visibility is positively correlated with the concentration of O₃ and negatively correlated with other pollutants. Wei Huang et al. [20] analyzed the relationship between atmospheric visibility, air pollutants and mortality in Shanghai. The correlation between atmospheric visibility and atmospheric pollutant concentration is similar to that of Dan Xue et al [19].

Some researchers have found that atmospheric visibility is closely related to the concentration of atmospheric particulates. The results show that the atmospheric visibility is closely related to the atmospheric particulate matter concentration when the meteorological factors are excluded.

However, due to the limited data acquisition conditions, the research take the data of only one station, further research must set more monitoring station (such as: city center, suburbs, suburbs, etc.) for an in-depth study and related research needs to be further carried out.

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