A GIS-BASED APPROACH TO SPATIO-TEMPORAL ANALYSIS OF URBAN AIR QUALITY IN CHENGDU PLAIN

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ABSTRACT:

Environmental pollution of urban areas is one of key factors that state authorities and local agencies have to consider in the decision-making process. Understanding temporal and spatial distribution of air quality at the landscape scale is essential in assessing the potential ecological conditions for ecological restoration and in making decisions for regional management. To find a compromise among many criteria, spatial analysis extended by geostatistical methods and dynamic models has to be carried out. In this case, spatial analysis includes processing of a wide range of air, water and soil pollution data and possibly noise assessment and waste management data. Other spatial inputs consist of data from remote sensing and GPS field measurements. Integration and spatial data management are carried out within the framework of a geographic information system (GIS). From a modeling point of view, GIS is used mainly for the preprocessing and postprocessing of data to be displayed in digital map layers and visualized in 3D scenes. Moreover, for preprocessing and postprocessing, deterministic and geostatistical methods (ordinary kriging, IDW, i.e., inverse distance weight) are used for spatial interpolation; geoprocessing and raster algebra are used in multi-criteria evaluation and risk assessment methods. GIS is also used as a platform for spatio-temporal analyses or for building relationships between the GIS database and stand-alone modeling tools. Finally, air quality data are generally very complex to model due to the underlying correlation among several pollutants. The significant differences among the results obtained from the techniques, indicated that proper air quality management requires sensitive air quality evaluation. It was demonstrated that geostatiscal tools integrated with time series techniques are quite appropriate techniques for air quality management. Processed data, spatial analysis and models are integrated within the framework of the GIS project, providing an approach that state and local authorities can use to address environmental protection issues. In spite of a wide range of problems associated with technical, data and financial constraints, the final results of this GIS project could contribute to improving environmental management in Chengdu Plain. The methods used can also be applied for the environmental analysis of other urban areas. DEM data processed using 3D spatial interpolation can be a valuable tool for assessing pollutant distribution in space. It can be used as screening methods to more closely target key areas and to develop more detailed measuring and modeling strategies. Integration of all data within a GIS framework therefore represents a useful approach for performing more complex environmental analyses that can support the decision-making processes of urban planning.

1. INTRODUCTION

As for general public, the questioner usually will not be satisfied with raw data, time-series plots, statistical analysis and other complex findings pertaining to air quality. The complexity in information often results in loss of interest among the people and they can neither appreciate the state of air quality nor the pollution mitigation efforts undertaken by regulatory agencies. Also, awareness of the daily air quality levels of urban air pollution is often important to those who suffer from illness, caused by air pollution. The success of the nation's commitment to improve the air quality depends on the support of its citizens who are well-informed about local and nation-wide air pollution problems and about the progress on abatement of pollution. With an objective to address the above concerns, concept of air quality index (AQI) has been developed and used effectively in many industrialized countries for over last three decades. AQI is defined as an overall scheme that transforms the weighted values of individual air pollution related parameters such as sulphur dioxide (SO_2) , nitrogen dioxide (NO_2) and particulate matter < 10µm (PM_{10}) , etc., into a single number or set of numbers. The result is set of a rule (for example, an equation) that translates parameter values into a more parsimonious form by means of numerical manipulation.

This paper addresses an evaluation methodology for urban air quality using geostatiscal tools integrated with time series techniques. Air pollutants data of SO_2, NO_2 and PM_{10} collected at forty different air quality monitoring stations located in Chengdu Plain, during 2001-2005, was used in this evaluation. This case study involved incorporating environmental data from monitoring networks and field measurements into digital map layers for the purpose of illustrating the application of spatial analysis to the urban areas of Chengdu Plain. ArcGIS was used to provide spatial data management and analysis, extended by modeling tools developed in the ArcObjects environment with Geostatistical Extension and Spatial Extension. Ordinary kriging methods were employed to predict pollutant concentrations together with estimates of variability. The autoregressive moving average (ARMA) method, implemented by Box-Jenkins model, was used to forecast the AQI time series in different seasonal specification. With this methodology, the sampling for the air pollutants data can be done through space at each day (i.e., time series of spatial statistics), through time at each location (i.e., spatial patterns of temporal statistics), or

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both through space and time (i.e., one number characterizes the entire simulation). Digital elevation models (DEM) created with photogrammetric tools by processing images and data from terrain measurements was used to get the pollutant variations in different terrain.

2. METHODS

2.1 Study area

According to function zoning characteristics of the atmosphere, with the area of Chengdu plain, 36 automatic air-monitoring sites (as shown in Figure 1), 24h day of the three major air pollutants, sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and respirable particulate matter (PM_{10}) monitoring the concentration.

Because of equipment failure or some other accidental causes, five of data for monitoring points will have different degrees of lack measurement and quality issues, we will each pollutant monitoring the normal daily number of hours of monitoring arithmetic mean value, as this , The corresponding value of monitoring the concentration of air pollutants, after which the same five days of monitoring points in the three kinds of pollutants concentration of the average value respectively, as Chengdu, the pollutant concentration in urban areas, so that the period 2001-2005 Chengdu plain area SO_2, NO_2, PM_{10} three pollutants effective monitoring of the value for 1422.

In this study, the variation of API time series and the corresponding air pollutant concentrations are analyzed and discussed in the urban area of Chengdu City from 2001 to 2005. The study would focus on the prediction of daily mean API time series using the auto-regressive moving average (ARMA) method (Box and Jenkins, 1976; Box et al., 1994) and the performance assessment of the adopted models. The API forecast may serve as an alert to the public before the onset of serious air pollution episodes. It helps the public, especially susceptible groups such as those with heart or respiratory illnesses, to consider taking precautionary actions if necessary.

2.2 Acquisition of air pollution data

Comprehensive evaluation in order to study the atmospheric pollution in the region, we monitor the five points of the air pollution index for statistical analysis. Air Pollution Index (Air pollution Index, short API) is the world's many developed countries and regions used to assess the status of an air quality index, which is based on ambient air quality standards, and various pollutants on human health and ecological environmental impact Pollution index to determine the grade and the corresponding pollutant concentration limits.
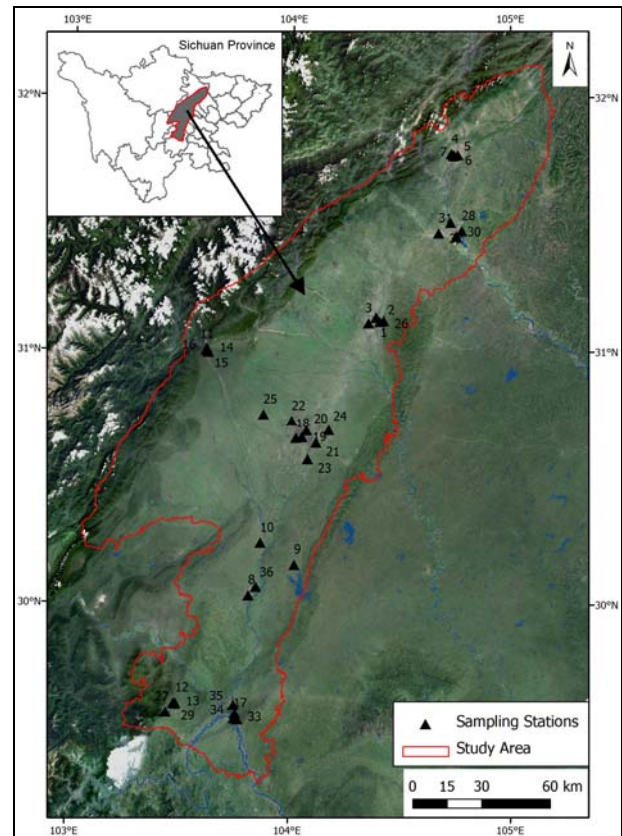

Figure 1. Map of study area and air sampling stations

API sub-index	Concentration (μg/m³)				
	SO_2 24-h	NO_2 24-h	PM_{10} 24-h	CO 1-h	O_3 1-h
0	0	0	0	0	0
50	50	80	50	5000	120
100	150	120	150	10000	200
200	800	280	350	60000	400
300	1600	565	420	90000	800
400	2100	750	500	120000	1000
500	2620	940	600	150000	1200

Table 1. API sub-index levels and their corresponding air pollutant concentrations

2.3 Processing of data with Geostatistical methods in GIS

The key to statistical analysis of samples of a series of check data and analysis, such as normal QQPlot distribution, trend analysis and a half variation / covariance analysis to find the appropriate statistical analysis model. ArcGIS the statistical analysis tools provide a wealth of data validation tool, here not elaborate. The use of these tools through the eastern part of Chengdu plain on 8 stations a total of 39 monitoring points in the SO_2 concentration value check and found that the sample data with the U-shaped clear trend line, using ordinary kriging interpolation method. Interpolation in the process of adjusting the parameters, by orthogonal verification to check the statistics (interpolation) model of accuracy and reasonableness.

3. RESULTS AND DISCUSSION

3.1 Temporal distributions of main pollutants

Through the above three kinds of air pollutant concentrations and API changes in the value of analysis and time series based on the theory and method, we can see that the Chengdu Plain 2001-2005 API can be considered a smooth time series, you can use the time Sequence of the moving average since the reunification model (ARMA) their analysis and simulation. ARMA model of generic mathematical expression are as follows:

$$y_t - u = \phi_1(y_{t-1} - \mu) + L + \phi_p(y_{t-p} - \mu) + e_t - \theta_1 e_{t-1} - L - \theta_q e_{t-q} \quad (1)$$

Where, y is the time sequence variable, ϕ_i and θ_j are sliding since the reunification model and the model of the i and j parameters, u is the sequence mean, et is white noise sequence.
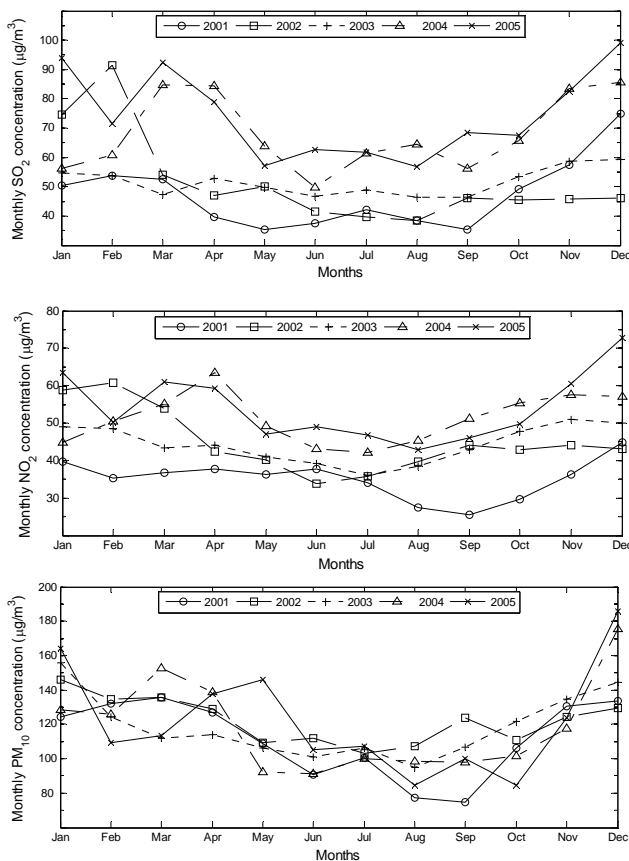

Figure 2. Monthly variations of air pollutant concentrations during 2001-2005

3.2 Spatial distributions of main pollutants

In this study, by the end of the forecast error as shown in Figure 3, including the standard average of 0.0000992, close to 0; RMS to 0.01301, the average standard error of 0.013, close to RMS; RMS error of the standardized 1.002, close to 1. This shows that the choice of statistical model is the best. 19 monitoring sites in urban concentrations of SO_2 interpolation results see figure, we can see that in 2006 there are concentrations of SO_2, Chengdu and Zigong City, two higher

value of the region, was on the spatial distribution of the southeast - Northwest decreasing trend. It also verified the previous air quality evaluation of the results of the consistency, in addition, described in this section of the research method can also be used for NO_2 concentration, PM_{10} concentrations, integrated pollution index and the spatial pattern of air quality evaluation.
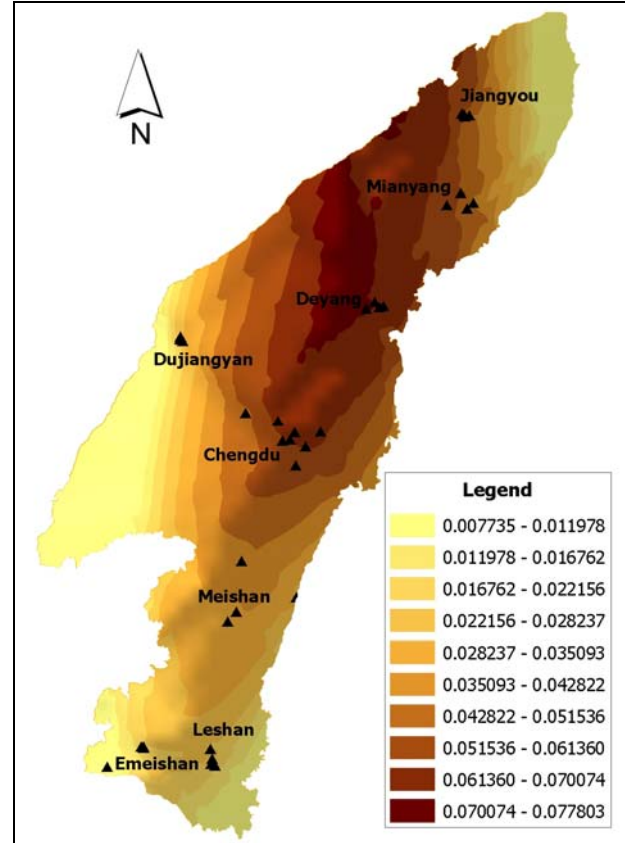

Figure 3. Interpolation result of SO_2 concentration (mg/m^3)

4. CONCLUSIONS

A detailed study on variations of major air pollutants and daily air pollution index (API) in Causeway Bay area during the period of 1999－2003 is reported in this paper. Based on the statistical analyses, the diurnal variations of SO2, NO2, CO and RSP levels three basic phases, i.e., the early morning phase (00:00－5:00 am) with low pollution levels, the daytime phase (6:00 am－18:00 pm) with increasing pollution levels, and the evening phase (18:00 pm－0:00) with descending pollution trends. The monthly varying processes of main pollutants present different patterns during the studied period but generally with lower levels in summer and higher levels in other seasons. Concerning the variations of daily API time series, the daily APIs can be regarded as stationary time series because the statistical parameters such as the mean, the standard deviations and the percentile are independent of the time. Therefore, the auto-regressive and moving average (ARMA) method can be used as a cost-effective toll to forecast the API trends in different time series. In this study, the most suitable ARMA models for summer period and other seasons are ARMA (1, 1) and ARMA (2, 2) respectively. Both models can

produce reliable and satisfactory results comparing with the corresponding observations.

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