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The analysis on distribution of NOX pollutant concentration from exhaust flues in shahid montazeri power plant at Isfahan using combined WRF-CALPUFF model

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ABSTRACT: by means of correlation of Weather Research and Forecasting (WRF) numerical model with air pollution dispersion model (CALPUFF) in this study, distribution of NOX air pollutant concentration from exhaust flues of Montazeri Power Plant at Isfahan was simulated in two intervals of 20 days during cold and warm seasons in 2014 and then the potential of the model was assessed in data simulation using statistical analysis. The results of statistical parameters used in this investigation, suggest good potential of California Meteorological (CALMET) model in simulation of 3-D meteorological field needed for CALPUFF model. Similarly, the results of statistical parameters indicate good agreement between simulated data by CALPUFF model and observed concentration data in pollution surveying stations so that the value of R-index for NO2 is placed within range (0.706-0.932) in cold year interval and in (0.567-0.804) during warm year interval. This shows high correlation between the observed data and simulated data. The value of FB index for NO2 is placed within ranges of (0.051-0.285) and (0.040-0.370) in cold and warm year intervals, respectively. The results of FB index indicate that the model given for the results of concentration of pollutants has generally forecast it below the actual level. Overall, the results of statistical assessments show good performance of CALPUFF model in forecasting of concentration for the given pollutants.

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1- Introduction

In the last couple of decades, due to the rapid growth in population, heavy urbanization, development of industrial sectors, and increase in fossil fuel consumption, air pollution has been one of the most complicated problems and challenges, especially in mega cities. Accordingly, nowadays air pollution and its prevention is of vital importance [1].

Estimation of air pollutants for the assessment of air quality is a complicated matter, because the production and dispersion of several gaseous and liquid pollutants from various constant or mobile sources, complex impacts of weather conditions on dispersion, transportation, and deposition of pollutants, atmospheric chemical reactions and the interactive impacts of all of these factors have made it a challenging problem. This complication caused the development of air quality models for the estimation of the spatiotemporal distribution of the pollutions from several sources, and their assessment and inspections as well [2]. Air quality models are useful means for understanding the processes relevant to transportation, dispersion, and chemical transformations in the atmosphere [3]. Such models by applying mathematical equations and numerical methods, simulate these processes in the atmosphere [4]. Over the recent years, the CALPUFF dispersion model has delivered a fine performance in the simulation of several pollutants over complex terrain, particularly for the domains larger than 50 kilometers [5]. Moreover, this model has the capability to be run over any specific regions of the world and for any period of time, which shows its considerable flexibility [6].

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Because of the good flexibility of the model CALPUFF, several studies have been carried out in air pollution dispersion modeling by CALPUFF in recent years. In this study, first, by coupling the Weather Research and Forecasting (WRF) model and diagnostic meteorological CALMET model, the 3D meteorological fields are simulated, and then using this 3D meteorological field and combining it with the data and other aspects of the emission source in the CALPUFF dispersion model, the distribution of NOX from the stacks of Montazeri Power Plant is simulated. Then the results of average concentration for 1 hour predictions for NO2 compared with the standard national concentration. Finally, using statistical analyses, the average meteorological data and pollution concentrations in meteorological and air quality stations are verified. The time periods used in this study is the cold and warm seasons of the year 2014, which are modeled individually.

2- Research Method

The domain of simulation in this study is a region with 10000 square kilometers. Shahid Montazeri Power Plant is in the center of the domain with the longitude and latitude of 51.497 and 32.897 respectively.

The topographical and land use data are processed by TERREL and CTGPROC models respectively, and finally the outputs of these two models are combined in MAKEGEO model. The Geo.dat file as the output of MAKEGEO model can be directly used as the input of CALMET model. For running the model CALMET, in addition to the Geo.dat file, another file

(3D.dat) with appropriate format, containing meteorological data is required for the model CALMET. For specifying the meteorological aspects of the region and making the file 3D.dat, the synoptic stations data as well as upper atmosphere data are required. These data either are not provided within the study area or are very scarce with a lot of errors. For specifying boundary layer height, at least two reports of upper atmospheric data are required. Hence using these data in CALMET model is practically impossible. Therefore, in this study the weather research and forecasting (WRF V3.5.1) model is used for the preparation of 3D meteorological fields.

For running the model CALPUFF, in addition to the CALMET model output, emissions data and physical aspects of the pollution source are required. The information of the exhaust gases is analyzed by the Testo XL350 instrument. Table 1 indicates the results of the analysis of the pollutants and the aspects of the pollution sources.

Table 1. Stack characteristics and emission rates of NOX from Montazeri power

Period	Fuel used	stack	Stack temp. (k)	Exit velocity (m/s)	NOX emission rate (g/s)
Cold period	Fuel oil	1	443.7	20.1	370.7
		2	437.2	20.8	438.4
Warm period	natural gas	1	427.2	18.4	185
		2	425.1	18.6	268.3

3- Results and Discussion

Figures 1 and 2 illustrate the distribution of NO_2 concentrations over the study area since the year 2014, with two cold and warm periods and based on 1 average hours. Shahid Montazeri Power Plant is located on the center of Figures 1 and 2. As can be seen, the pattern of pollution dispersion over the cold period is similar to the shape of an umbrella which the Montazeri Power Plant is located on its center. The formation of this pattern can be due to the low wind speed, distribution of wind and decrease in the height of mixed layer. On the other hand, considering the formation of NO_2 during the warm period of the year, it is apparent that the wind direction and the rise in the height of mixed layer causes the pollution to be dispersed over a wider domain, towards mountainous regions. Therefore, Isfahan city is less exposed to air pollution during this period.

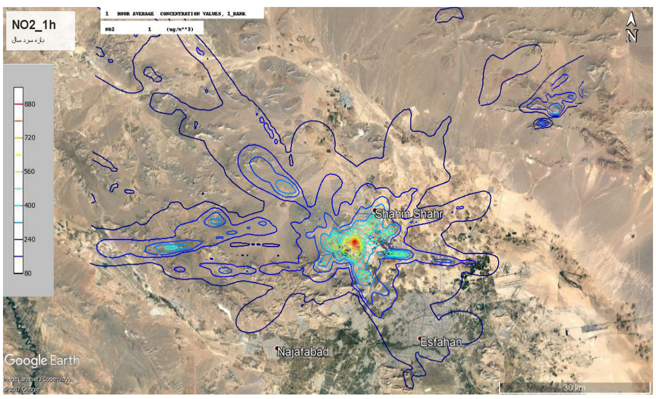

Figure 1. Distribution of NO_2 pollutant concentrations as an average of one hour in the cold period of 2014.

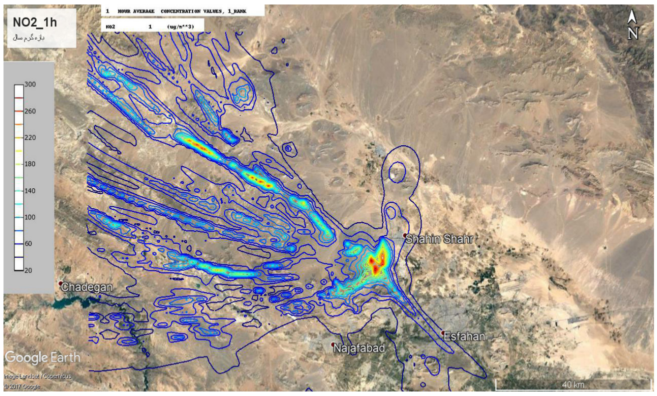

Figure 2. Distribution of NO2 pollutant concentrations as an average of one hour in the warm period of 2014.

4- Conclusions

In this study, using the coupled WRF/CALPUFF model, the dispersion of NOX from the stacks of Shahid Montazeri Power Plant in Isfahan have been simulated. At first, some relevant studies about the performance, limitations, and capabilities of the model CALPUFF and its preprocessors, such as the model CALMET have been carried out; then the coupling of WRF weather numerical model with the CALMET diagnostic model for generating 3D wind fields over the region has been discussed. At the next stage, all the information related to the measured emitted pollutants from the stacks of the power plant and measured meteorological parameters from the weather stations in the region are collected to be used in running the model CALPUFF. After running the model, to verify the performance of various sectors of the processes, the output results from running the models have been compared with the observation data from the environmental monitoring stations and have been verified with statistical analyses.

The results of four statistical indices used in the analysis of the meteorological modeling of the study area indicate a reliable accuracy for the model WRF in predicting meteorological data and also the good accuracy of the model CALPUFF in the simulation of meteorological data over the region, by integrating the WRF output data with topographical and land use data. The results of statistical analyses for the model CALPUFF indicate a good performance between the model predictions and observations in four separate receptors around the power plant. Overall, according to the verifications, the model CALPUFF has shown a reasonable performance in predicting the air pollutants concentrations. In the case of quality control management, such as the development of control strategy and assessment of the transportation capacity of the air pollutants over the region, the quantity and the form of pollutant emissions in the region must be considered. Hence, the model CALPUFF could be used as a strong scientific tool in the analysis of control strategies and the reduction and prevention of air pollution.

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