ANALYSIS ON PREDICTABILITY OF METEOROLOGICAL PARAMETERS OF THE 1 KM RESOLUTION USING WRF METEOROLOGICAL MODEL IN SOUTHERN KYONGGI-DO AREA

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Abstract: -

WRF meteorological model is applied to investigate the mesoscale meteorological phenomena in southern Kyonggi-do area. Statistical analysis of meteorological parameters with 1-Km horizontal grid resolution was performed. For this purpose, the numerical simulation of WRF meteorology model is carried out during June in year 2011. The statistical analysis between real measurement and simulated meteorological parameters is done using IBM's SPSS Ver.21 program. The simulated results of 1 km grid resolutions were statistically analyzed with the observations in 4 surface meteorology weather stations of Songdo, Siheung, Yongin, Osan. The correlation coefficient(R2) between model simulation and real-measurement of air temperature and wind speed with high grid resolution (1 km) showed good agreement. Statistical credibility of the predicted meteorological parameters (air temperature, wind speed) permits us to conclude that the WRF meteorology model can be applied to analyze the regional air pollution dispersion in these regions.

Keywords: - *Statistical analysis, Meteorological parameters, Horizontal Grid resolution, WRF model*

I. INTRODUCTION

In coastal areas and complex terrain, meteorological data with low horizontal resolution are the cause of errors when this data is applied to air pollution diffusion analysis. The prediction accuracy of meteorological parameters are very important. The accuracy of the 1 km horizontal grid resolution was analyzed by correlating the measurement data of meteorological parameters and model prediction values. The actual measured values of four automatic weather stations in the southern part of Gyeonggi-do, and the predicted values of the WRF model were compared. In addition, the prediction accuracy was analyzed focusing on meteorological parameters such as air temperature and wind speed that can be used for evaluating the impact of the atmospheric pollutants environment by analyzing the patterns of the measured meteorological field and the simulated meteorological field. Previous studies have improved the predictive ability of meteorological parameters by subdividing the surface characteristics, which are model input elements (Cheng and Byun 2008; Kim et al. 2011), and this study has a direction to predict meteorological fields more accurately by increasing the grid resolution of the model (Gego et al. 2011; An 2012). These studies have been used to analyze the spread of air pollution, and many studies have been conducted on the diffusion of air pollution in connection with meteorological models that produce accurate meteorological parameters (Jialiu and Yixiu 1994; Cheng 2001; Park 2007). In this study, meteorological phenomena in southern part of Gyeonggi-do were analyzed by applying WRF, a three-dimensional numerical model. In the study area adjacent to the west coast of korean peninsula, it can be said that the regional meteorological fields are large influenced due to the combined action of synoptic weather and sea-land winds at these regions. The numerical simulation of meteorological parameter is a very important factor in the analysis of air pollution for air quality environmental impact assessment (EIA). If the horizontal grid resolution cannot be increased with meteorological field input data, it is difficult to apply a model that is widely applied to the current environmental impact assessment. Therefore, improving the predictive reliability of the meteorological field with high horizontal resolution of 1 km will be a very important factor in evaluating the impact of the air pollutants. This study conducted an analysis for one month period in June 2011 using IBM's SPSS Ver.21 to verify predictive reliability by comparing between simulated values and real measured values.

II. WRF meteorological model and research method

The WRF meteorological model used in this study is a numerical model developed by UCAR/NCAR and can be applied to numerical simulation of urban-scale meteorological in large-scale meteorological phenomenon analysis. In order to generate a necessary meteorological field in the air pollution model, this study attempted to compare and analyze the accuracy of meteorological parameters according to the resolution of the meteorological model grid through numerical analysis of the WRF model at grid intervals of 1km. The topography and land characteristics are generated using WPS, a pre-processing model for building input data (Grell et al. 2005; Peckham et al. 2011). In the GEOGRID process, 30-second geographic data of USGS (United States Geological Survey) were used. In addition, NCEP/NCAR Reanalysis data with 1。X 1。 resolution were used to generate input data of initial and boundary. For specific numerical simulation, the model was run with grid spacing of 27 km, 9 km, 3 km for domains 1, 2, and 3, respectively, and minimum grid spacing of 1 km for domain 4, respectively. From the East Asia domain, which is the largest, which is 27 km, the second domain includes the Korean Peninsula, and the third domain is the metropolitan area including Kyonggi, Incheon, and Seoul, and the nesting grid method is applied sequentially. The smallest domain with 1 km grid resolution includes Yongin, Osan, Siheung, Songdo. The detailed model domain configuration is shown in Table 1 and Fig. 1.

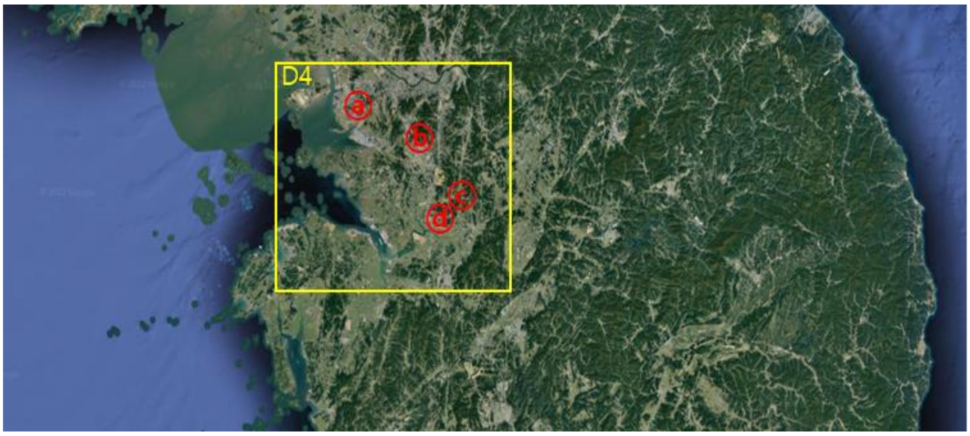

Fig. 1. Model domains of D4 and Surface meteorology measure stations (a, Songdo; b, Siheung; c, Yongin; d, Osan).

Table 1. Description of model domains and initial conditions for WRF meteorological simulations

domain	domain 1 (East Asia)	27 km (124*131)
	domain 2 (Korea peninsular)	9 km (73*85)
	domain 3 (Metropolitan area)	3 km (70*73)
	domain 4 (Shiwha·Banwol industry complex area)	1 km (121*121)
initial condition	domain center	126。E / 38。N
	Map projection	Lambert Conformal
	Vertical Layer	28 Layer
	Initial meteorological data	NCEP/NCAR, GDAS analysis (1º* 1º)
	Grid nesting	One way
	Microphysics	WSM 6 Scheme
	PBL scheme	YSU Scheme

In order to compare between real measurements and model simulation results, the data from June 1 to 30, 2011 from the automatic weather station in Table 2 were used. In this study, IBM SPSS Statistics Version 21 was used for statistical analysis. Hourly data from the automatic measuring station of the Korea Meteorological Administration was used for this study. There were almost no missing values through the improvement of the stability of the measuring device. However, for accurate statistical analysis, the missing measurement value displayed as 0 in the Excel data during the SPSS processing process.

Table 2. Surface meteorology measure stations in research area

station	latitude	longitude
Yongin	37˚ 15´	127˚ 12´
Osan	37˚ 10´	127˚ 02´
Siheung	37˚ 21´	127˚ 46´
Songdo	37˚ 20´	126˚ 37´

Analysis was performed by selecting the nearest automatic weather station in latitude and longitude within the grid of the meteorological model. As meteorological observation data, analysis was performed using data such as hourly air temperature (°C), and wind speed (m/sec.). The correlation coefficient (R2) indicates the degree of correlation between the model value and the measured value. In this study, Root Mean Square Error (RMSE) was used to evaluate the error between the measured data of 4 ground meteorological stations and the prediction results using the regression analysis formula. To evaluate the accuracy of prediction, the root means square error using Equation (1) was performed for 4 measurement points (Seo et al. 2009).

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(C_{p,i} - C_{m,i})^2} \quad (1)$$

III. Result and discussion

3.1. Prediction accuracy of time series analysis of air temperature

In this study, statistical analysis was performed using numerical simulation and actual data for one month in June 2011. The national average temperature in June, the study period, was 21.9℃ and the average minimum temperature was 17.6℃, 0.6℃ and 0.8℃ higher than the average year, respectively (Korea Meteorological Administration 2011). The average monthly temperature in Osan area was the highest at 22.2℃, and Siheung and Yongin showed a tendency to show middle temperature. And Songdo showed a lower average monthly temperature by about 1.8℃ compared to Siheung. In Yongin, Osan, Siheung, and Songdo regions, the temperature was relatively low compared to the measured temperature in the first ten days of a month and the middle ten days of a month, but was higher than the measured temperature in the last ten days of a month. In particular, in the Siheung and Songdo regions, the predicted temperatures were predicted to be 2.9℃ and 4.3℃ lower than the average measured temperature in June.

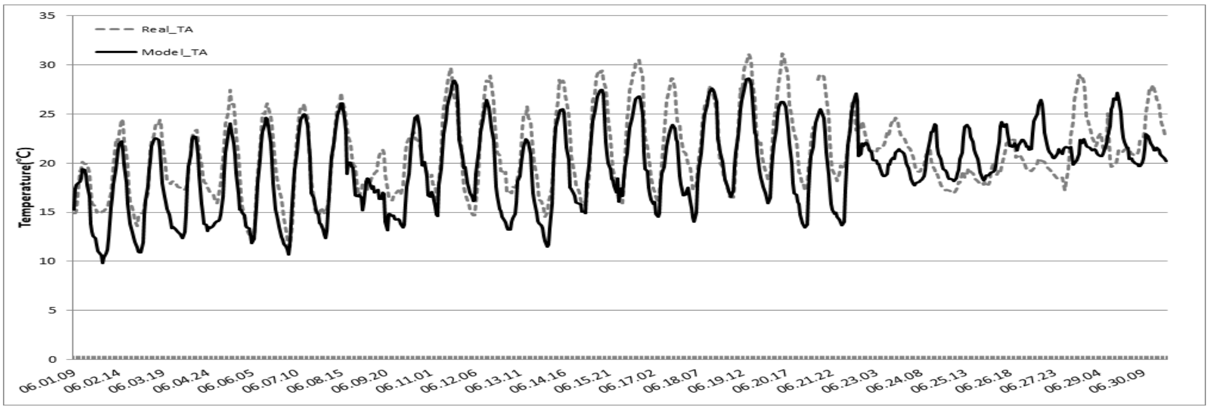

Fig. 2. Comparison between observed and 1 km resolution model Air temperature at Yongin meteorology measure station in June of 2011.

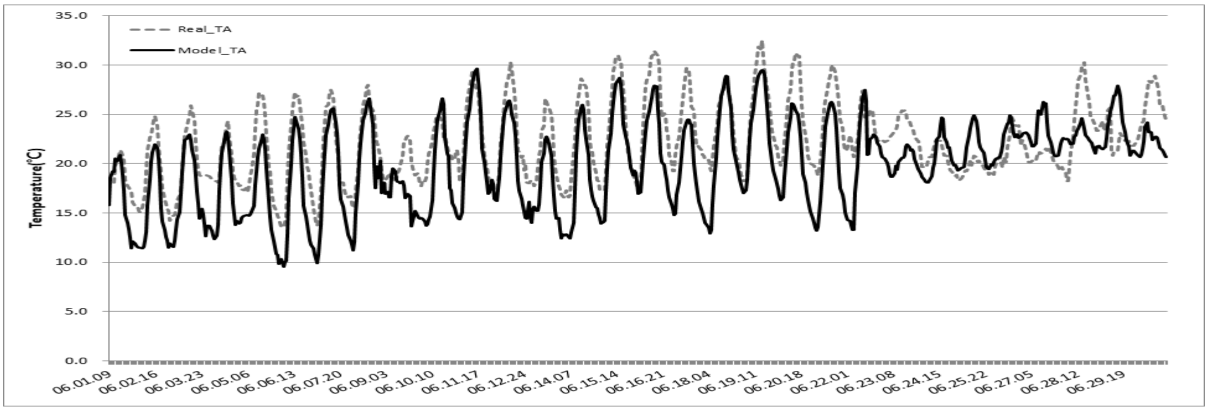

Fig. 3. Comparison between observed and 1 km resolution model Air temperature at Osan meteorology measure station in June of 2011.

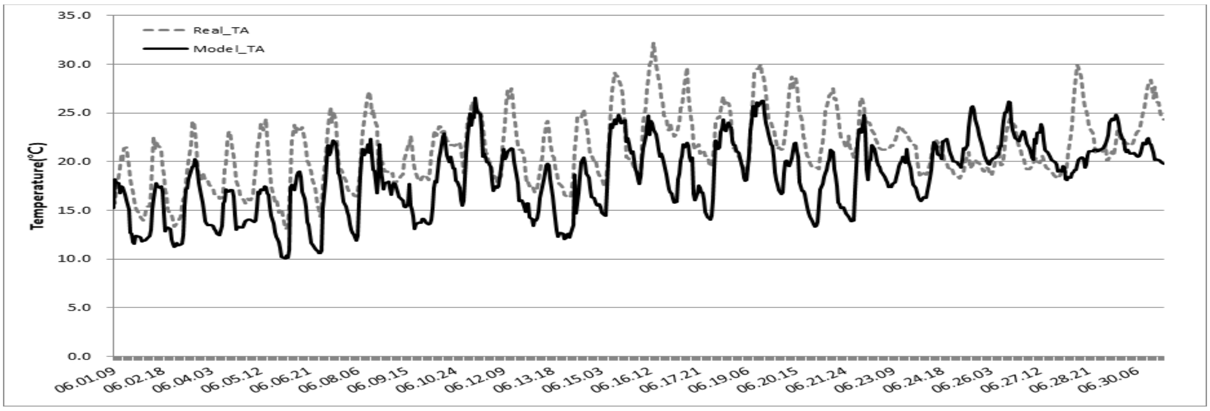

Fig. 4. Comparison between observed and 1 km resolution model Air temperature at Siheung meteorology measure station in June of 2011

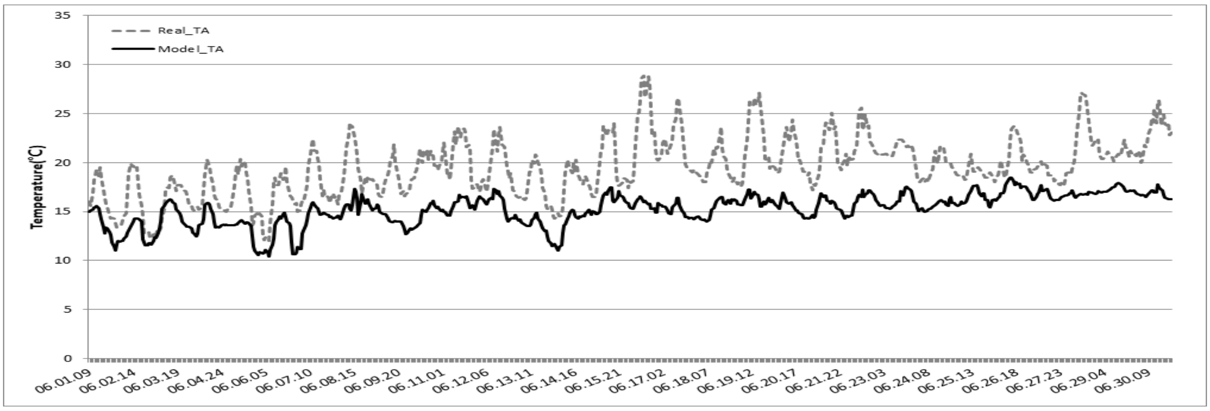

Fig. 5. Comparison between observed and 1 km resolution model Air temperature at Songdo meteorology measure station in June of 2011

3.2. Scatter-diagram analysis of air temperature with 1 km horizontal grid resolution

As a result of numerical simulation with a grid resolution of 1 km, relatively reliable results were shown for observation points located relatively far from the coast, but large deviations were shown at measurement points close to the coast. As a result of numerical simulation with a grid spacing of 1 km, Fig. 2-5 show the WRF model results and measured values of the Yongin, Osan, Siheung, and Songdo automatic weather stations. Fig. 6-9 shows the results of the scatter-diagram showing the correlation using SPSS. Through the statistical data expressed by the correlation coefficient between the time series results presented above, the WRF model results and the actual data, it was shown that air temperature of the local area were predicted reliably. It is considered that the Gaussian-type pollution diffusion model, which is mainly used in environmental impact assessment, can be well adapted to build a meteorological field as a meteorological input data. The study results of Ham (2012) showed high prediction accuracy by performing correlation analysis between actual temperature values and model prediction values in 4 places including Wonju, Gangwon-do in the 3 km domain. In this study, it was confirmed that the prediction accuracy was improved as in the above-mentioned statistical indicators when numerical simulations of 1 km were performed. The result of correlation analysis between the actual temperature measurement value and the model prediction value of this study was $R^2 > 0.49$. It has been shown that the WRF model can be well applied to high-resolution numerical simulations through small grid resolution. In addition, Kim (2011) suggested that a more accurate prediction is possible in the case of numerical simulation with a resolution of 1 km performed in this study in urban Meteorological prediction. Jung (2010) showed that in the case of coastal areas such as Sokcho, the model with a dense grid spacing can improve the accuracy of temperature forecasting in the results of the Gangwon Regional Model (GWRF), which was performed with the WRF model increased grid resolution.

Table 3. Correlations coefficient of air temperature in Yongin, Osan, Siheung and Songdo meteorology measure stations

Meteorology station	Domain 4 (1 km)
	Correlations coefficient(R^2)
Yongin	0.658
Osan	0.662
Siheung	0.492
Songdo	0.490
Average	0.576

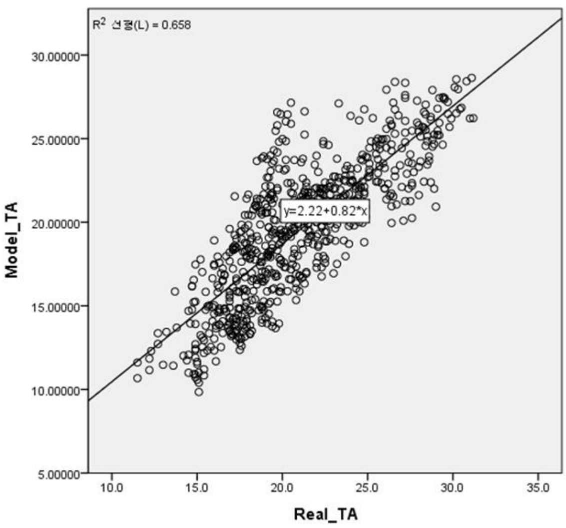

Fig. 6. Scatter diagram observed and 1 km resolution model Air temperature at Yongin meteorology measure station in June of 2011.

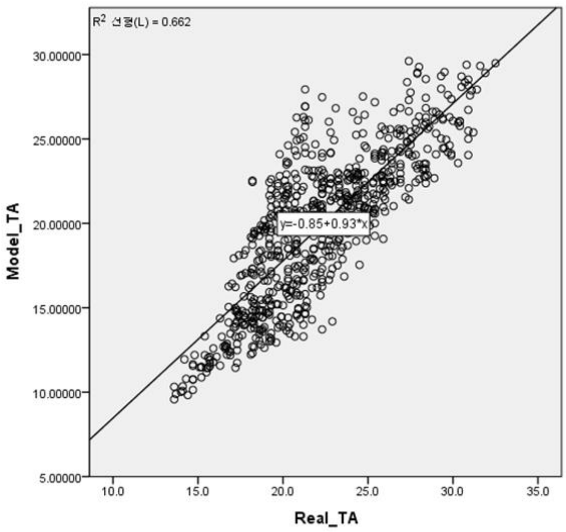

Fig. 7. Scatter diagram observed and 1 km resolution model Air temperature at Osan meteorology measure station in June of 2011.

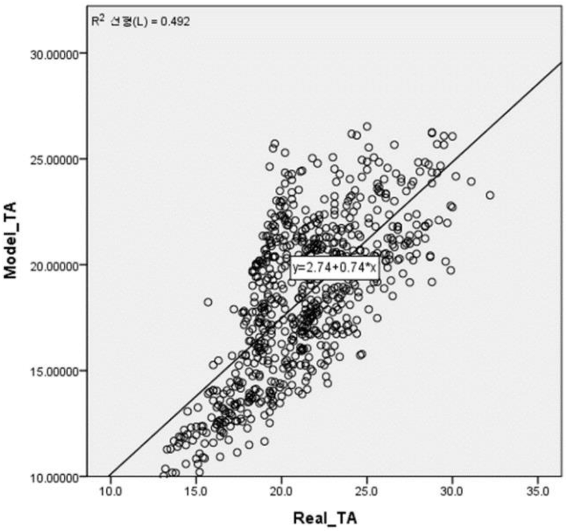

Fig. 8. Scatter diagram observed and 1 km resolution model Air temperature at Siheung meteorology measure station in June of 2011.

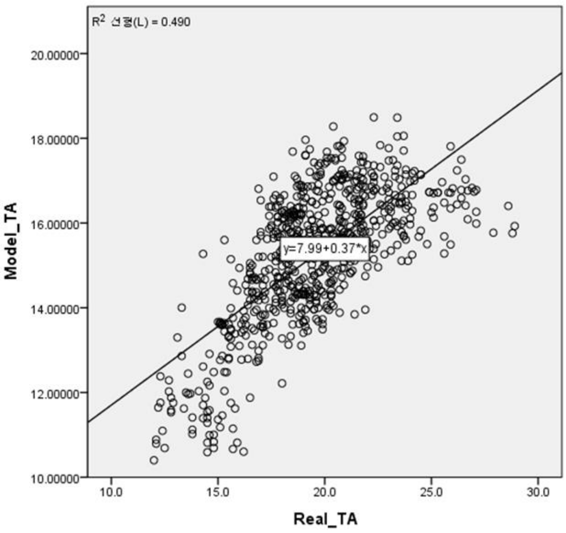

Fig. 9. Scatter diagram observed and 1 km resolution model Air temperature at Songdo meteorology measure station in June of 2011.

3.3. Prediction accuracy of time series analysis of wind speed results

The following Fig. 10-13 show the actual measured values of wind speed and WRF model results at the automatic weather stations in Yongin, Osan, Siheung, and Songdo. The results of the time series analysis show that the measured values and the simulation results agree well at 4 points. It is considered that the time series analysis showed a relatively high degree of agreement between the model results and the measured values. In particular, the WRF model showed reliable results in speed and tendency at 2-3 m/sec. wind speed in early and mid-June. However, it shows that there is a lot of error in the prediction during the period of strong winds in late June. Since air quality evaluation in environmental impact assessment is applied under average weather conditions, it can be seen that the predictive ability of the model is relatively good. It is thought that it can be very usefully used for air pollution dispersion prediction. in connection with this. the correlation between the predicted value and the measured value was lower than that of the temperature, similar to the results of other studies presented below. It can be seen that the predictability of wind speed with large fluctuations in proportion to the temperature is lowered. Although this paper presented only wind speed as a result, it is possible to provide three-dimensional wind field data including three-dimensional wind direction and wind speed through numerical simulation. These three-dimensional wind field data can be used as very important input data in the environmental impact assessment of air quality. Nowadays, the models applied to environmental impact assessment generally use the annual or seasonal average of the JFF (joint frequency function) data as meteorological input data. The application of 1 km resolution meteorological data from this WRF model could bring significant improvement in the air quality prediction applied in the environmental impact assessment.

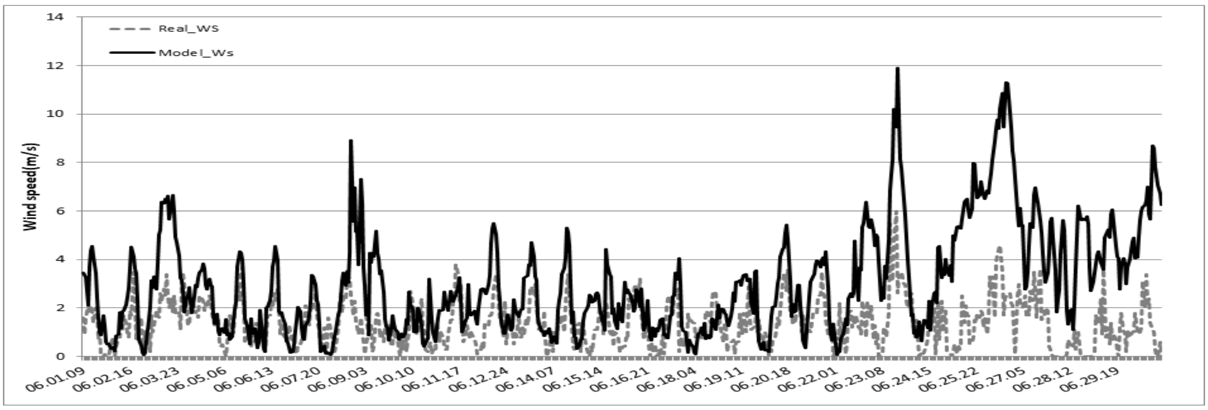

Fig. 10. Comparison between observed and 1 km resolution model wind speed at Yongin meteorology measure station in June of 2011.

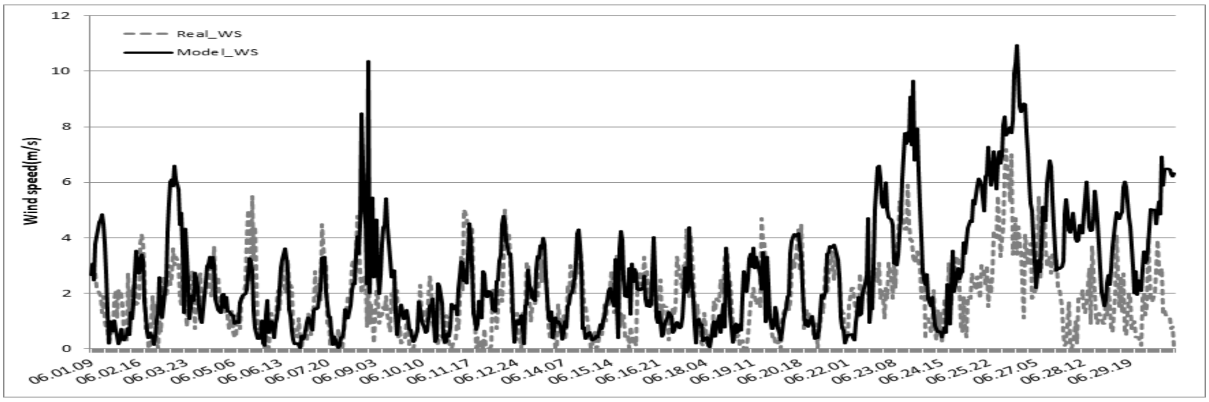

Fig. 11. Comparison between observed and 1 km resolution model wind speed at Osan meteorology measure station in June of 2011.

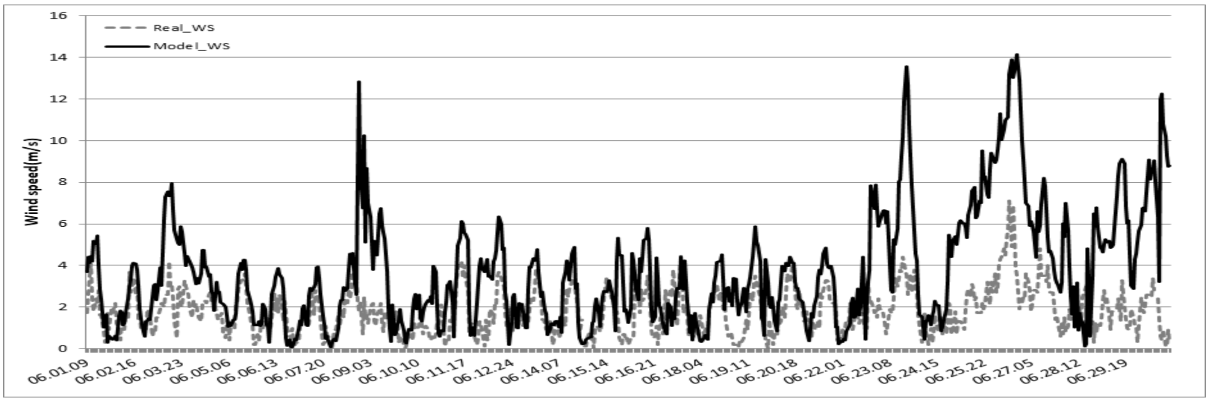

Fig. 12. Comparison between observed and 1 km resolution model wind speed at Siheung meteorology measure station in June of 2011.

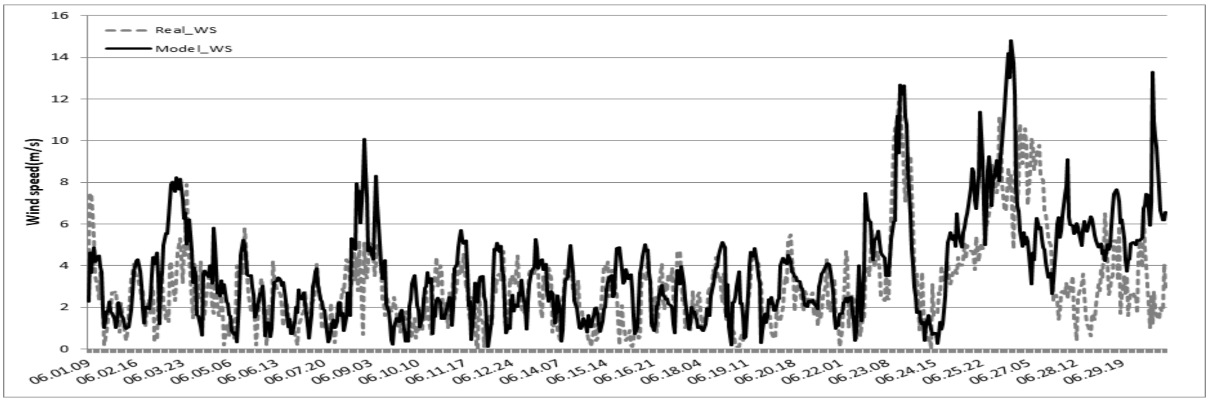

Fig. 13. Comparison between observed and 1 km resolution model wind speed at Songdo meteorology measure station in June of 2011.

3.4. Scatter-diagram analysis of wind speed results of 1 km horizontal grid resolution

Fig.14-17 show the results of the scatter-diagram showing the correlation using SPSS. As a result of numerical simulation, wind speed showed a low correlation coefficient compared to temperature, so numerical simulations of weather elements were performed with high grid resolution of 1 km. The average of the correlation coefficient was 0.288 in 4 places. Unlike the graph of the time series analysis, the scatter-diagram showed a low correlation coefficient value. This is considered to be the reason that the predictions were simulated significantly different from the model results due to strong winds in late June. The study of Ham (2012) suggested that the correlation coefficient R showed a value of 0.27 to 0.41 in the case of wind speed, but the result of this study was 0.20 to 0.36, However, the reason for the rather low correlation coefficient in the scatter-diagram is that the range of fluctuation is large due to the nature of the wind speed. Among them, Yongin is considered to have a influence of complex terrain as it is located inland.

Table 4. Correlations coefficient of wind speed in Yongin, Osan, Siheung, Songdo meteorology measure stations

Meteorology station	Domain 1 (1 km)
	Correlations coefficient(R)
Yongin	0.195
Osan	0.304
Siheung	0.292
Songdo	0.361
average	0.288

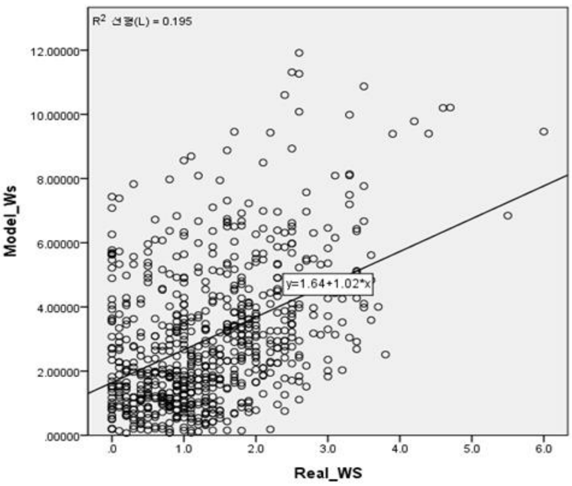

Fig. 14. Scatter diagram observed and 1 km resolution model Air temperature at Yongin meteorology measure station in June of 2011

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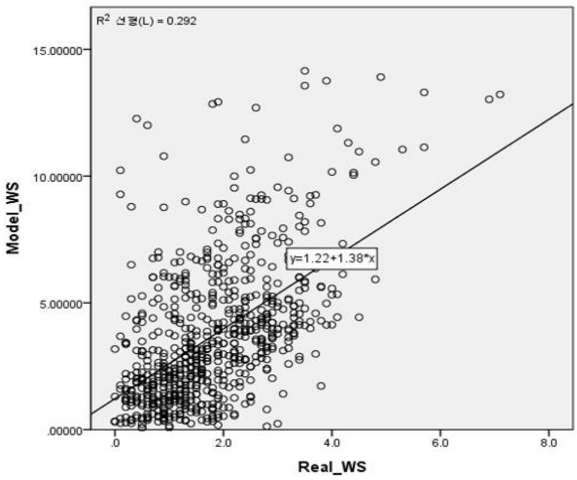

Fig. 16. Scatter diagram observed and 1 km resolution model Air temperature at Siheung meteorology measure station in June of 2011.

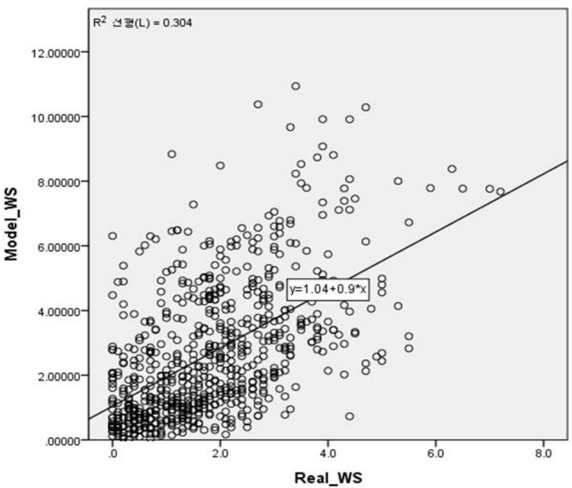

Fig. 15. Scatter diagram observed and 1 km resolution model Air temperature at Osan meteorology measure station in June of 2011.

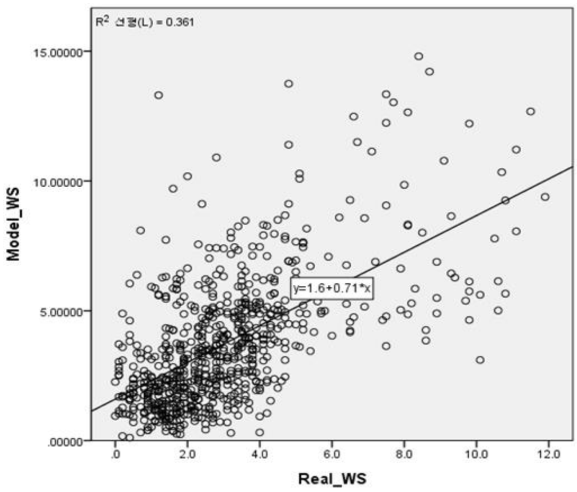

Fig. 17. Scatter diagram observed and 1 km resolution model Air temperature at Songdo meteorology measure station in June of 2011.

IV. Conclusion

In this paper, the three-dimensional numerical model WRF was applied to analyze the meteorological parameters through statistical analysis in Yongin, Osan, Siheung, and Songdo automatic weather stations in the southern Gyeonggi-do region. Accuracy was analyzed according to the horizontal grid resolution of 1 km through correlation analysis between the measured data of meteorological elements and the predicted values of the model. In this study, using IBM's SPSS Ver.21, the following conclusions were obtained through analysis for one month in June 2011.

1) As a result of analyzing the correlation between the temperature measurement values and the predicted values of the WRF model at four automatic meteorological stations in the southern Gyeonggi-do region, a high reliability of 0.49-0.66 (R^2) was shown.

2) In the case of Songdo, as it is located in the coast, the correlation coefficient (R^2) between the measured temperature and the predicted value of the WRF model decreased due to the influence of sea-land winds, etc.

3) As a result of analyzing the correlation between the measured value of wind speed and the predicted value of the WRF model, a correlation coefficient (R^2) of 0.2-0.36 was shown.

4) As for wind speed, the correlation coefficient (R^2) between the measured value and the predicted value of the WRF model was the lowest in Yongin, which is located inland with a relatively large topographical influence.

5) It was considered that the temperature and wind field could be well used as three-dimensional input data in the environmental impact assessment of air quality.

V. REFERENCES

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