

Meteorological Field Generation Method for CALPUFF Model

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ABSTRACT

CALPUFF is one of the recommended air pollution models by EPA with AERMOD. It has been used to simulate the ambient concentration of critical air pollutants as well as non-critical pollutants such as persistent organic matters and the organic materials causing odor. In this model, the air pollutants go through dispersion, transportation, chemical reaction, and deposition process. These mechanisms are significantly influenced by meteorological condition. This study produces the meteorological field in three different methods for the simulation of SO₂ using CALPUFF: 1) CALMET model by using both ground-level and aerological observation, 2) CALMET model by using MM5 results with NCEP/NCAR reanalyzed data, 3) CALMET model by using MM5 results in which FDDA is applied with NCEP/NCAR reanalyzed data as well as the meteorological data of Korea Meteorological Administration. As a result of CALPUFF model, the resolved concentration of SO₂ showed different behaviors in three cases. For the first case, the fluctuation of SO₂ concentration was frequently observed while the fluctuation is reduced in the second and third cases. In addition, the maximum concentration of SO₂ in the first case was about 2~3 times higher than the second case, and about 4~6 times higher than the third case. These results can be caused by the accuracy of the resolved meteorological field. It is inferred that the meteorological field of the first case could be less accurate than other two cases. These results show that the use of correct meteorological data can improve the result of dispersion model. Moreover, the contribution of various sources such as point, line, and area sources on the ambient concentration of air pollutant can be roughly estimated from the sensitivity analysis.

Keywords: CALPUFF, NCEP/NCAR, MM5, CALMET Model.

1. Introduction

The CALPUFF model, as one of the recommended models designated by US EPA with AERMOD, is widely used in developed countries to simulate odors, persistent organic pollutants (POPs) and noncritical pollutants as well as criteria pollutants^[1].

The meteorological realm used for the CALPUFF model is obtained by using the result files of the CALMET model. The weather input data of the CALMET model uses the simulation results of surface and aerological observation data or MM5 (Mesoscale

Meteorological Model V). In the existing researches, the results of the MM5 simulation or the MM 5 simulation using FDDA (Four Dimension Data Assimilation) showed closer to the actual meteorological realm than the results of the CALMET model using the surface and aerological observation data^[2-5].

In this research, for the input data of the CALMET model, we try to use 1) the surface and aerological observation data, 2) the result files of MM5 not using four dimension data assimilation, and 3) the result files of MM5 using four dimension data assimilation. By using the result files created in this process for SO₂ simulation of the CALPUFF model, we examined SO₂ concentration distribution according to each weather input data so that when using CALPUFF model, we can know the difference of results according to meteorological realm, and generate the appropriate meteorological realm. Thus it can be helpful to carry out the CALPUFF model.

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2. Research Contents and Method

2.1. CALMET Model Input Data

The input data required by the CALMET model is divided into geophysical data and meteorological data, and geophysics data is divided into altitudinal data and topographic data, and meteorological data is divided again into aerological observation data and surface observation data and precipitation data.

2.2. Geophysical Data

MAKEGEO is a program that creates input data of altitudinal data and topographic map data of CALMET model. In composing altitudinal data and topographic map data of CALMET model, it is first necessary to decide what kind of projection to use for the generation of input data. In this research, UTM (Universal Transverse Mercator measure: km) is used. In addition, TTM (Tangential Transverse Mercator), LCC (Lambert Conformal Conic), and EM (Equatorial Mercator) can be adopted in the CALMET model. UTM divides longitude into 60, and sets from 174 degrees to 180 degrees west longitude to Zone 1. Thus UTM Zone of Korea is 52. When using the UTM coordinate system, it is necessary to convert the coordinates of longitude and latitude and the TM coordinate system of emission source data to UTM, and it can be converted using Coords.exe provided by GUI of CALPUFF model.

For altitudinal data, SRTM30/GTOPO30 Data, SRTM Data, USGS DEM Data are provided as shown in Table 1 in ASG (Atmospheric Studies Group) Homepage which provides CALPUFF model.

In this research, data of 100 m interval provided by Korea land cover map was used in order to utilize altitudinal data with higher resolution than those introduced in Table 1. High efficiency of this has been studied^[4].

For topographic map data as well, GLCC Database, USGS CTG Land Use/ Land Cover (LULC) Data, and USGS National Land Cover Data 1992 (NLCD92) are also provided in ASG (Atmospheric Studies Group) Homepage. The GLCC Database is data of 1,000m interval and includes all the earth data, but other data provided is limited to some regions or data with large grid length. Table 2 shows a classification table of 37 types of topographical map data applied by CTGPROC which is the input data preprocessing program of the topographic map data among the sub programs of the CALMET model. In this research, using the Korea land cover map which has the classification shown in Table 3, data was generated by applying and transforming to the classification table of 37 types. MAKEGEO generated geophysical data, which is input data of CALMET model, by using each result files of altitudinal data and topographic map data.

2.3. Meteorological Data

Meteorological data of the CALMET model is classified into aerological observation data, surface observation data, and precipitation data. In this research, aerological observation data was received from Radiosonde Database provided by FSL (Forecast Systems Laboratory) and NCDC (National Climatic Data Center) and passed through the preprocess with READ62 program and then used as input data of CALMET. In this research, we used the data of WMO (World Meteorological Organization) station 47122, Osan Station which is the closest aerological observation data station to the simulation section. For the surface observation data, data of Incheon Meteorological Observatory which is one meteorological observatory in the simulation section and the surface observation data of 12 AWS stations in the simulation section (UTMX: 285.0~315.0 km, UTM Y: 4130~4170 km) were obtained and

Table 1. Terrain data by supplied ASG homepage

	Classification	Region	Grid spacing
SRTM30/GTOPO30 Global Data	-	Global	900 m
Shuttle Radar Topography Mission(SRTM)	SRTM3	Global	90 m
	SRTM1	U.S region	30 m
USGS Digital Elevation Model(DEM) Data	GLCC Database	Global	1000 m
	7.5 minute USGS DEM	U.S region	30 m
	1 degree USGS DEM	U.S region	90 m

Table 2. U.S.Geological survey land use and land cover classification system for remotes sensor data

LEVEL I		LEVEL II	
1	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Shrub and Brush Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetland	61	Forested Wetland
		62	Nonforested Wetland
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
8	Tundra	81	Shurb and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground
		84	Wet tundra
		85	Mixed Tundra
9	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

used by converting into the surface input data and the precipitation input data which were required from the CALMET model. The location information of 12 AWS was shown in Table 4.

In order to utilize the result of MM5 as input data in

the CALMET model, a program called CALMM5 must be used. CALMM5 extracts the meteorological factors from the position of longitude and latitude designated from the result files of MM5 and creates a result file called MM5.DAT

Table 3. Land use and land cover 31 classes of the Korea LULC data

Class	Description	Class	Description
0	Ocean	16	Irrigated crop
1	Lakes, Rivers, Streams (Inland water)	17	Bog or marsh
2	Ice cal/Glacier	18	Evergreen needleleaf forest
3	Evergreen needleleaf tree	19	Evergreen broadleaf forest
4	Deciduous needleleaf tree	20	Deciduous needleleaf forest
5	Deciduous broadleaf tree	21	Deciduous broadleaf forest
6	Evergreen broadleaf tree	22	Mixed cover
7	Short grass	23	Woodland
8	Tall grass	24	Wooded grassland
9	Desert	25	Closed shrubland
10	Semi-desert	26	Open shrubland
11	Tundra	27	Grassland
12	Evergreen shrub	28	Cropland
13	Deciduous shrub	29	Bare ground
14	Mixed woodland	30	Urban and built up
15	Crop/Mixed farming		

Table 4. UTMX, UTM Y of AWS station

AWS Station No.	UTMX	UTMY
404	310.1	4158.1
405	313.0	4156.1
411	314.5	4158.0
417	314.3	4148.7
423	308.5	4152.5
510	314.5	4156.1
511	295.3	4158.4
512	291.9	4140.0
544	304.0	4149.0
565	303.6	4134.2
570	292.6	4165.9
589	305.8	4165.6

2.4. Input Data of MM5 Model

The input data of the MM5 requires altitudinal data and meteorological data like CALMET. For altitudinal data, data of 30 seconds was used. For meteorological data, NCEP/ NCAR reanalysis data were used, and they are classified into data on 17 layers and the surface data. This data was created in the form of netCDF.

2.5. Input Data of MM 5 - FDDA Applied Model

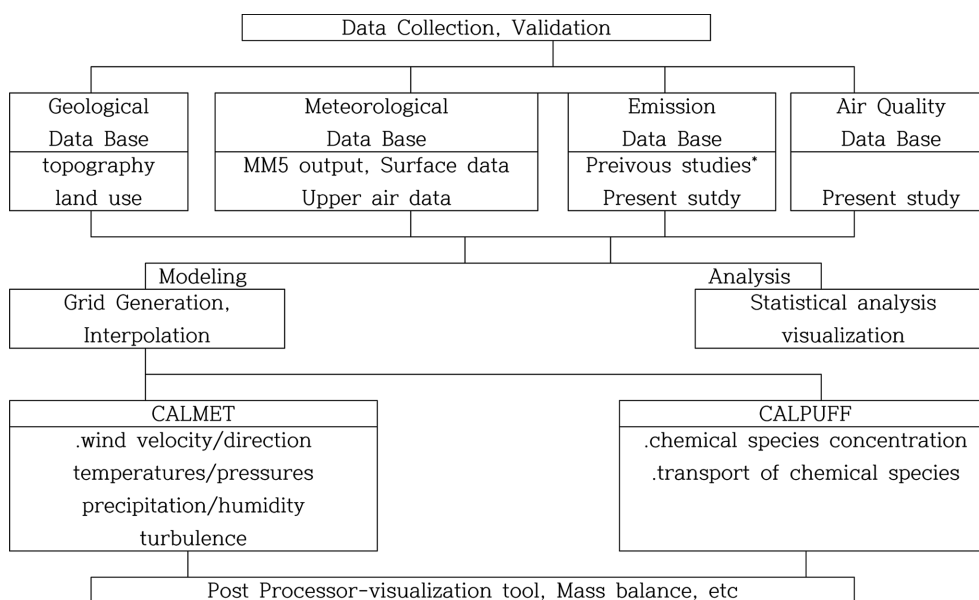
FDDA (Four Dimension Data Assimilation) methods are roughly divided into two methods. One is Analysis or Grid Nudging, and the other is Station or Observational Nudging. In the Analysis or Grid Nudging method, while the model performer defines the relax-

Table 5. The NCEP/NCAR reanalysis data

File Name	Description
air.sig995.yyyy.nc	
pres.sfc.yyyy.nc	- 4 times daily
rhum.sig995.yyyy.nc	- 2.5degree × 2.5degree
uwnd.sig995.yyyy.nc	- Surface or near the surface (.995 sigma level), or entire atmosphere (eatm)
vwnd.sig995.yyyy.nc	
air.yyyy.nc,	
hgt.yyyy.nc	- 4 times daily
rhum.yyyy.nc	- 2.5degree × 2.5degree
uwnd.yyyy.nc	- 17 Pressure level (mb) :
vwnd.yyyy.nc	1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10

Table 6. Station or observational nudging input data file format

Variable	Description
TIMEOB	Julian date in dddhh
RIO	y-location - I dot-point location on coarse mesh
RJO	x-location - I dot-point location on coarse mesh
RKO	z-location - K half - σ level
IVAR(1)	u wind - in m/sec rotated to model grid
IVAR(2)	v wind - in m/sec rotated to model grid
IVAR(3)	temperature - in Kelvin
IVAR(4)	water vapor mixing ratio - in kg/kg
IVAR(5)	Pstar - in cb(only used in hydrostatic model)

**Fig. 1.** The connection between input data and CALPUFF

ation time and reaches the relaxation time, the model linearly interpolates the input data and nudges the data. The station or observational nudging method is a method used when the analysis or grid nudging method is ineffective and a relaxation term is calculated according to the error from the data value of the observation station. The relaxation term calculated in this way will reduce this error. The method of four dimension data assimilation used in this research is the station or observational nudging method. Since there is no standard program for generating input values of this method, observation data of stations must be converted as shown in Table 6. In this research, the data of 75 domestic meteorological observatories were transformed as

shown in Table 1.6 and used as input data.

2.6. Input Data of CALPUFF Model

The input data of the CALPUFF model is largely classified into meteorological realm data and emission quantity data. In addition to this, data on the boundary surface of the simulated section and data on the terrain may be also input when detailed simulation of the terrain is desired. Moreover, since the CALPUFF model can simulate the abnormal state of PUFF, more accurate simulation can be performed by putting data on the change of emission quantity of point, line, and surface pollution sources at each time. And, as a model to consider the chemical reaction, it can be applied to simu-

lation by putting the ozone concentration data for each hour and the reaction speed value against the user's simulated chemical species. In this study, the chemical species to be simulated was set to SO₂, so the reaction of the chemical species of the CALPUFF model on the reaction was not examined. Also, the change in emission quantity over time was not applied.

The data of meteorological realm of CALPUFF model can also be made through ISC, etc. not only through CALMET model. In this research, we constructed a meteorological realm through CALMET model. The connection between the input data and the CALPUFF model was shown in Fig. 1.

For input data of emission source of CALPUFF model, we used data of the atmospheric environmental policy support system in 2003, and for the chemical species, SO₂ was selected and extracted from point, line, and surface pollution sources corresponding to the simulated section, and input in calpuff.inp which is the control file of CALPUFF model.

2.7. Simulation Method of CALMET & CALPUFF Model

The simulation of the CALMET model was done by three methods of 1) the use of surface and aerological observation data of the Korea Meteorological Agency, 2) use of the result files using NCEP/NCAR reanalysis data for MM5 model, 3) use of NCEP/NCAR reanalysis data for MM5 model and use of the result files applied of four dimension data assimilation method by using data of meteorological observatories all across the country, the simulated region is UTMX: 285~315 km, UTM Y: 4130~4170 km, and the simulation period is from January 17, 2007 to February 8, 2007.

3. Results and Discussion

3.1. Comparison of Simulation Results of CALPUFF Model

After simulating the CALPUFF model, by using the program to extract the result files in the form of a table or grid of data of hourly SO₂ concentration from the result of the CALPUFF model named CALPOST, the values of SO₂ concentration of 10 hybrid receptor stations were extracted and shown in Fig. 2. They were also compared with the actual SO₂ concentration of each hybrid receptor corresponding to the simulation

period. Fig. 3 marked the position of the ground meteorological stations (AWS and Incheon Meteorological Observatory) and hybrid receptors in the simulated section.

By using the surface and aerological observation data, CALMET model was simulated and the results of the CALPUFF model with these results as the input data were generally high. On the other hand, by using MM5 and MM5 (FDDA), CALMET model was simulated and in the concentration of the CALPUFF model with these results as the input data, neither were high. In addition, simulation results using the surface and aerological observation data showed more vibration of concentration than the results using MM5 and MM5 (FDDA). And in the results using the surface and aerological observation data of most hybrid receptors, the concentration tended to show high from January 28 to January 29. In the result of using MM5, this became about 50% lower than the result using the surface and aerological observation data, and the result of using MM5 (FDDA) showed about 10% lower in Sinheung-dong, Nonhyeon-dong and Seoknam-dong, and about 50% lower in the other areas than the result of using MM5. The measured value of the concentration of Geomdan showed 3~6 times higher than that of all three cases, this can be said that the emission quantity of Geomdan displayed in this atmospheric environmental policy system was evaluated lower than the actual. And the concentration of Seoknam-dong rapidly increased from February 5, but other areas did not show such a rapid increase, so it seems that the temporary discharge of pollutants that could not be displayed in the atmospheric environmental policy system was limited to Seoknam-dong measurement station. In this research, when the emission source was input to the CALPUFF model through the sensitivity analysis, the ship emission source which is one of the non-road mobile sources of the line pollution sources was removed and selected as the emission quantity of the basic simulation condition of CALPUFF simulation. However, looking at Fig. 2 for the 4 stations of Sinheung-dong, Nonhyeon-dong, Songdo and Soongeui-dong, which were considered to have many influences of ship pollution sources, it seemed that in the four stations, the emission quantity including the ship emission source was more appropriate rather than the emission quantity excluding the ship emission source.

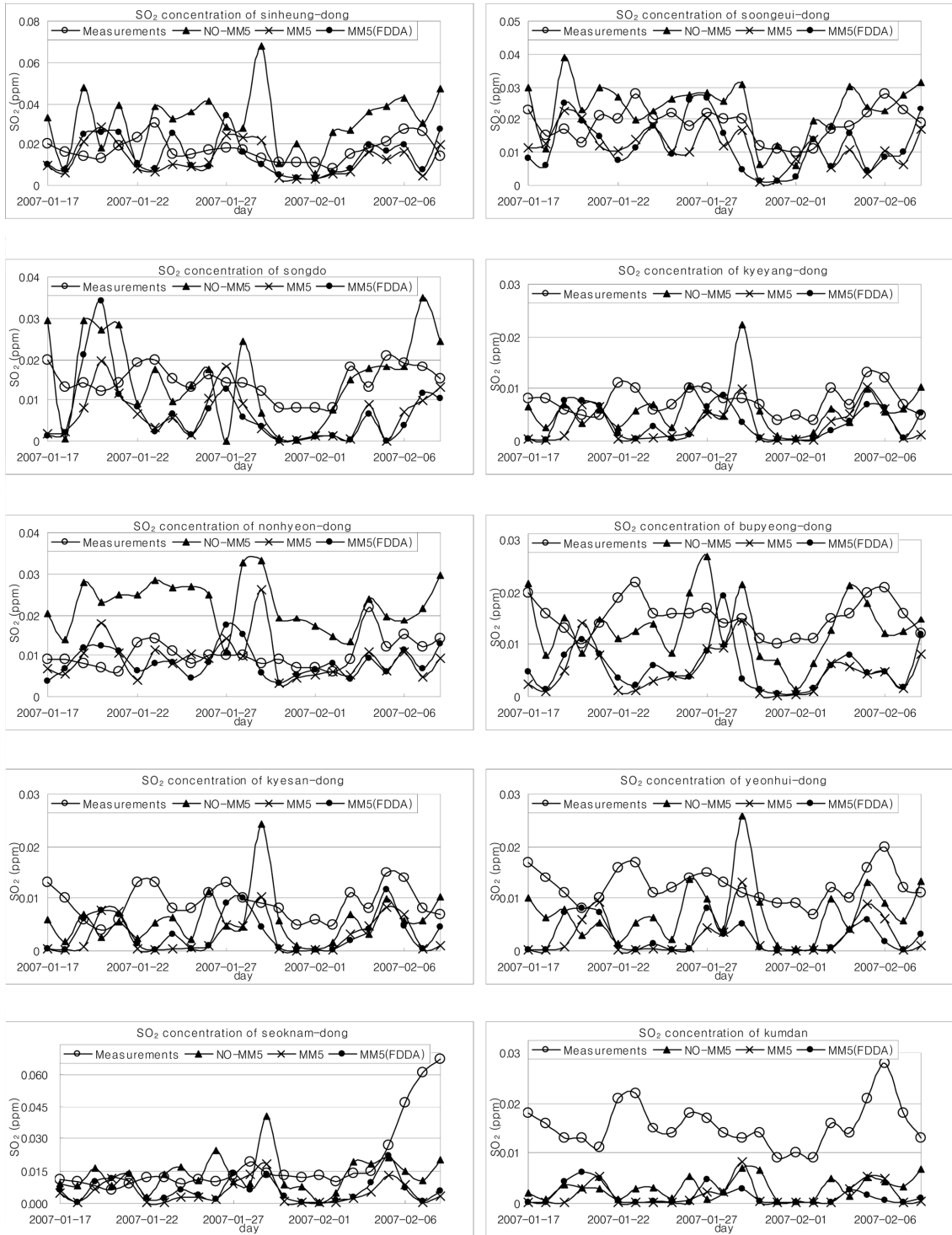


Fig. 2. Comparisons with SO₂ concentration by CALPUFF modeling.

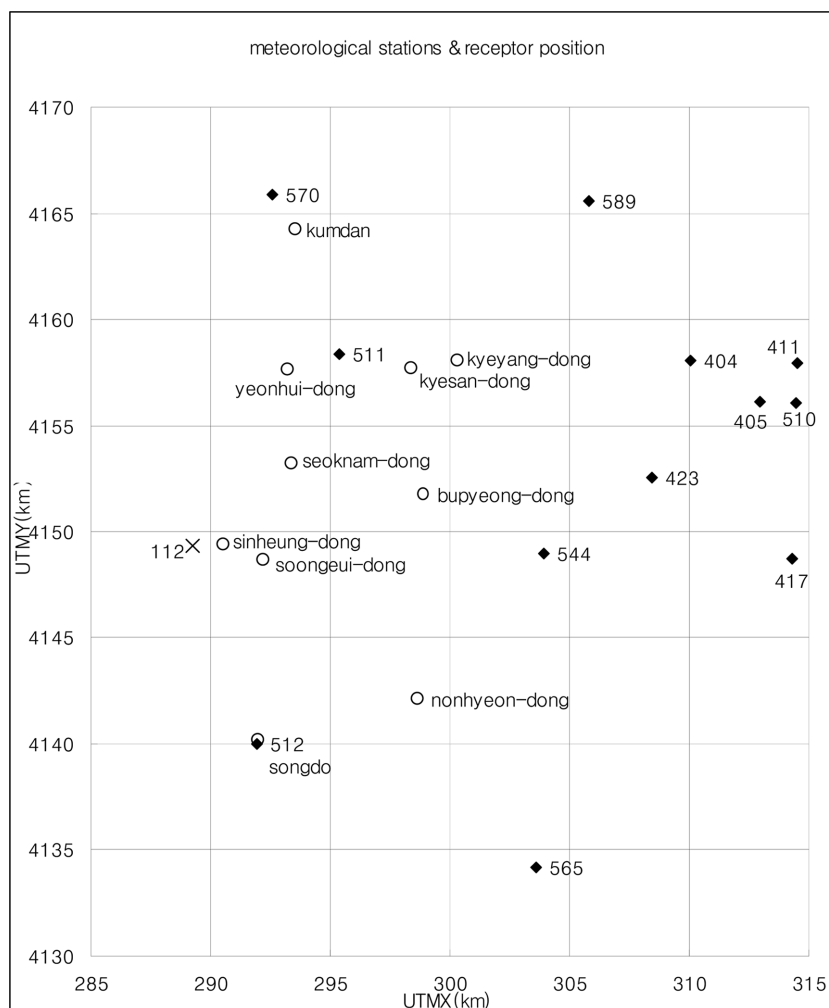


Fig. 3. Surface Meteorological stations and Receptor positions

4. Conclusion

In the generation of meteorological realm of SO₂ simulation of CALPUFF model, the research on the comparison between the simulation with CALMET model using the surface observation data (AWS, Incheon Meteorological Observatory) and aerological observation data and the simulation using the results of MM5, MM5 (using data applied of four dimension data assimilation: FDDA - meteorological observatories throughout the country) for CALMET model is summarized as follows.

1. The simulation of CALPUFF model which gener-

ated the meteorological realm by using MM5 and MM5 applied of FDDA tended to show more similarity and the concentration value as measured values in general than the simulation of CALPUFF model which generated the meteorological realm by using the surface and aerological observation data. In addition, we could see that the vibration in the results using the surface and aerological observation data was much softened in the results using MM5 and MM5 applied of FDDA. We thought that this was because the meteorological realm in the diffusion model determines the diffusion and transport of pollutants and the chemical reaction, etc.

2. The emission quantity of this research was based

on data from the national atmospheric environment policy system in 2003. When looking at the final result, the measured value of Geomdan was higher than that of the simulated result of three cases. We believe that it is reasonable to consider that this is because there are many emission sources that were not listed in the data of the national atmospheric environment policy system of the Geomdan region rather than the reason that the emission quantity of Geomdan region became 2~3 times larger.

The CALPUFF model is one of the recommended models designated by US EPA with AERMOD. As the meteorological realm in such a diffusion model dominates diffusion and reaction, it is very important input data. Making this meteorological realm closer to the actual measured values helps to draw efficient results. In this research, we examined how efficient it was to simulate the CALPUFF model through MM5 model that could better simulate the meteorological realm and the application of MM5 model to four dimension data assimilation and we could see that it was more efficient. However, there are other methods to improve the meteorological realm in addition to four dimension data assimilation in MM5, and there are other models of the meteorological realm as well. We think it is necessary for the researches on conducting simulations by applying these other meteorological models. In addition, in this research, we simulated by setting a comparatively small simulation section of 30 km×40 km, but we think it is necessary for the researches on conducting larger

scale simulation section than this with the CALPUFF model, or conducting simulations with other medium and small scale models to investigate the efficiency of improving meteorological realm.

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