A Probabilistic Precipitation Model for the Prediction of Long Range Transport of Acidic Species in East Asia

[1]**Katatani, N.** and [2]Shindo, K.

[1]University of Yamanashi, [2]YSK e-com Co.Ltd., E-Mail: katatani@js.yamanashi.ac.jp

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EXTENDED ABSTRACT

Acid deposition is one of the most important environmental issues in East Asia including Japan. The long range transport of acidic species from Asian continent to Japan islands cause large amount of acid deposition especially in winter. These phenomena are strongly affected by the precipitation on the sea, however, it is not easy to get enough information on it. This study aims to develop a simplified probabilistic model to estimate the precipitation on the sea for long term prediction of transportation and deposition of acidic species in East Asia.

The estimation model developed in this study is based on the statistics of satellite monitoring data of precipitation and weather map patterns. The satellite data used in this study is called TRMM, launched and operated by the cooperation of Japan and US. This satellite mainly aims to get informations in the tropical region, but it covers southern part of Japan islands.

Firstly, the validation was carried using ground level precipitation data by Japan Meteorological Agency (AMeDAS). As a result, linear regression coefficient was slightly high, which means that TRMM data can be used to predict long term distribution of precipitation on the sea between Japan islands and Asian continent.

Secondly, the spatial distributions of precipitation on the sea above linear lines connecting Japan islands and Asian continent were classified using TRMM data. Finally, they were classified into five distribution patterns. Of course, these patterns are strongly related to whether map patterns i.e. the direction and density of isobaric lines, existence of fronts and existence of typhoons. Then these weather map patterns were also classified into 18 patterns. According to such classifications, the frequencies of each pattern and related weather map pattern were counted. As a result, a probability distribution matrix was obtained. Using this matrix, the precipitation on the sea can be estimated from the observed precipitation data at the seashore sites.

Finally, this probabilistic precipitation model was installed to the three dimensional long range transport model by authors. As a result, slightly good agreement of calculated and observed values of deposition was obtained.

The framework of this study is shown in Figure 1.

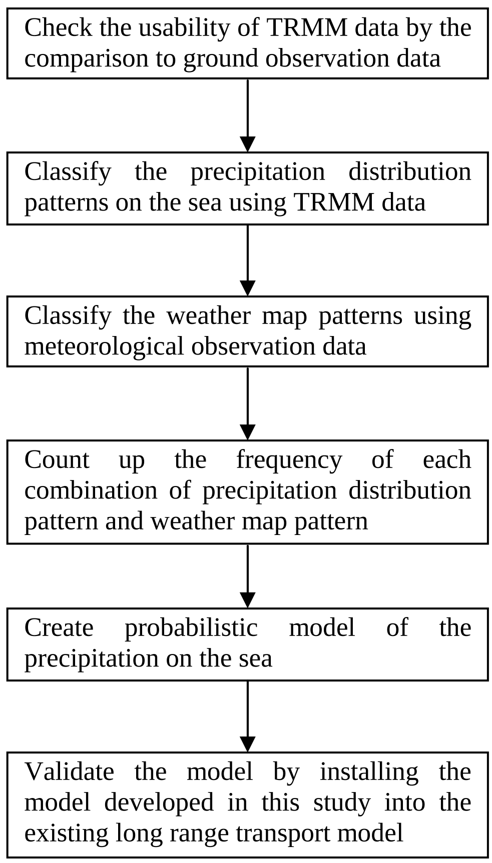


Figure 1. The framework of this study

In conclusion, the method developed in this study has a possibility to be applied into the estimation of oversea transport of pollutants.

1. INTRODUCTION

As well known, environmental deposition of acidic species including acid precipitation is one of the most serious problems in East Asia. These deposition processes are strongly related to precipitations. Precipitation data are available with high density on the land, however, most of the long range transport phenomena of pollutants in East Asia are occurred in oceanic area. Consequently, they are strongly affected by the precipitation on the sea. However, it is highly difficult to obtain precipitation data on the sea. The expression of them is a key issue in the modeling studies on such phenomena.

Figure 2 (a) and (b) show the examples of calculated SOx deposition by authors' model. As shown here, the difference of the assumptions on the precipitation on the sea gives remarkable difference on the calculated depositions.

Many modeling studies have been carried out to predict such kind of long range transport of pollutants in East Asia. Some of them include precise cloud physic processes to estimate the precipitation[1)], however, they are not always effective because they need large amount of computation. This study aims to develop a simplified method to predict precipitation intensity on the sea by some statistical approaches.

2. PROCEDURE

2.1. Outline of Procedure

The procedure of this study is summarized as follows:

1) Validation of satellite data
TRMM(Tropical Rainfall Measuring Mission) data were validated by the comparison to ground rainfall monitoring data (AMeDAS).

2) Pattern categorization of the distribution of precipitation on the sea
Distribution patterns were categorized into five patterns using TRMM data.

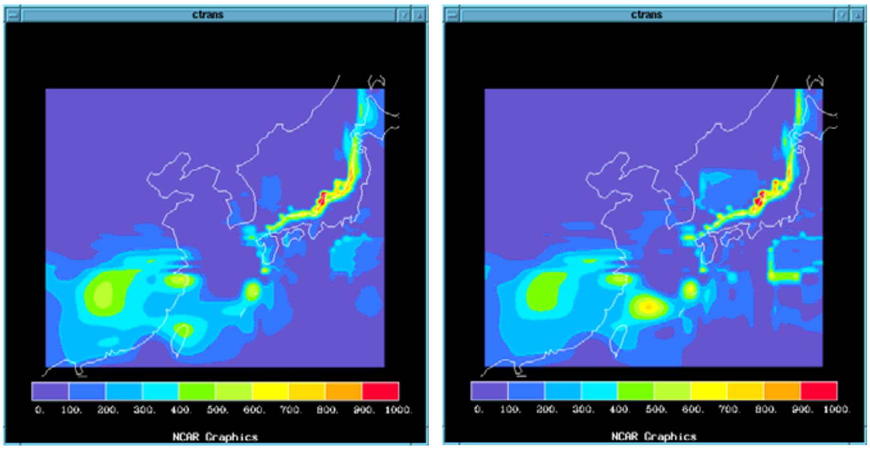
3) Pattern categorization of weather map and developing a statistical model
Weather map patterns were categorized into eighteen patterns regarding isobaric lines and fronts.

4) Making the probability matrix
The frequency of each combination of above-mentioned distribution pattern and weather map pattern was counted up and the resulted values were converted to the probability matrix.. This matrix is a base of the probabilistic model in this study. When observed precipitation data on the seashore were given, the precipitation on the sea will be estimated according to the probability matrix.

5) Installation of probabilistic model into the long range transport model
Above-mentioned model of precipitation on the sea was installed to the long range transport model which was developed by the author, and some trial calculation were carried out regarding SOx deposition in Japan.

2.2 Data Description

The satellite data previously used for the estimation of the precipitation on the sea were dominated by the cloud portrait data, however, TRMM(Tropical Rainfall Measuring Mission) observation started in 1997 has a new feature that it observes the precipitation intensity directly. From that point, it can be said that TRMM is the most appropriate satellite data for the objective of this study. TRMM was launched by the cooperative project between Japan (Japan Aerospace Exploration Agency) and the United States (NASA), and its main target is the observation of the tropical precipitation intensity which is strongly influenced to the global energy budget. The orbit of TRMM is longitudinal circle, and the range of the observation is between 38S and 38N. Not only precipitation radar but also several sensors i.e. microwave, ultra red, thunder, and so on. Figure 3 shows an example of TRMM precipitation data around Japan Islands. TRMM's designed observation duration has already been



(a) Linear interpolation (b) Non-linear interpolation

Figure 2 Examples of calculated SOx deposition in East Asia expired, so it will soon be stopped its work.

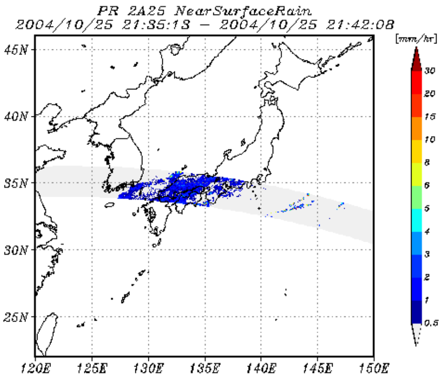


Figure 3 An example of TRMM data

The ground observation data used in this study is called AMeDAS(Automated Meteorological Data Aquisition System) operated by Japan Meteorological Agency. The observation sites are located more than 1300 points covering all over Japan. The precipitation intensity, wind velocity, wind direction, temperature and solar radiation are automatically observed on the hourly basis and the data are automatically collected through satellite.

3. RESULTS AND DISCUSSIONS

3.1 Comparison of TRMM AND AMeDAS

To validate the usefulness of TRMM data, they were compared to the ground observation (AMeDAS) data on the point-by-point basis. 36 observation sites were selected for this comparison from the seashore area and small islands in the western part of Japan which is covered by the TRMM observation area. The observation duration for the comparison was throughout the year of 2003 and all of the date on which TRMM data were given was used for comparison.

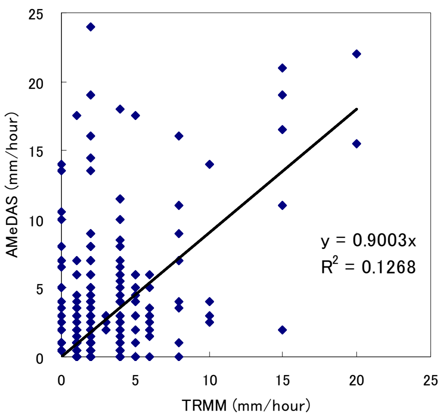
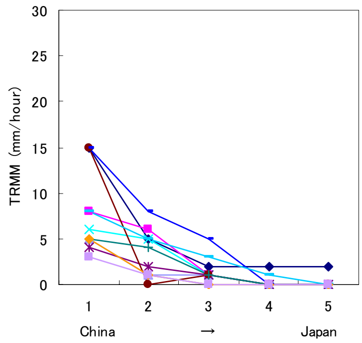


Figure 4 Comparison between TRMM and AMeDAS

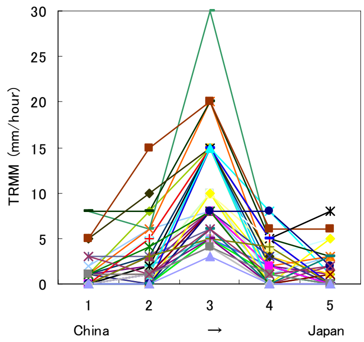
Figure 4 shows the relationship between them. As shown here, they are generally on the same level. Of course, much fluctuation can be seen, however, it seemed to be originated in the difference of spatial resolution in both data. Since the final objective of this study is to calculate long term depositions and the correlation coefficient is statistically significant ($p<0.05$), it can be concluded that TRMM data are suitable for the estimation of precipitation on the sea.

3.2 Categorization of Precipitation Distribution

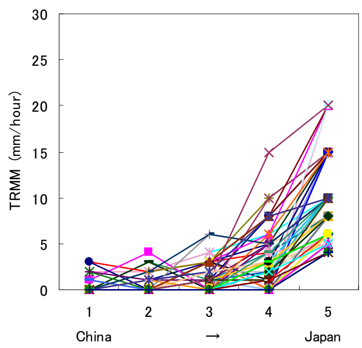
The categorization of the precipitation distribution on the sea was carried out using TRMM data of the days on which precipitation was observed on the sea between Japan Islands and Asian Continent.



(a) Pattern 1

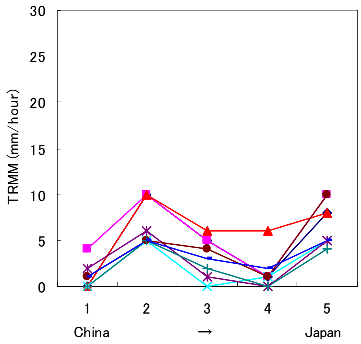


(b) Pattern 2

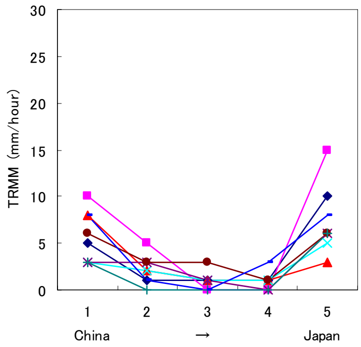


(c) Pattern 3

Figure 5 Distribution patterns of precipitation on the sea



(d) Pattern 4



(e) Pattern 5

Figure 5 (Continued) Distribution patterns of precipitation on the sea

Actually, Japan Islands and Asian Continent was combined by a linear line according to the orbit of TRMM, and the line was divided into four sections. Then five intersections including both ends of the line were determined. The precipitation distributions were judged by eyes using these five precipitation intensity values. Figure 5(a) through 5(e) show the categorized patterns of precipitation distribution on the sea between China and Japan. These distributions were approximated by exponential, second order and linear function.

3.3 Categorization of Weather Map Pattern and Performing Probability Matrix

The weather map patterns were classified by eyes considering the principal direction and density of isobaric lines and existence of fronts and thphoons. Finally they were classified into 18 patterns as shown in Table 1.

The numerical values shown in Table 1 indicate the probability of each combination of precipitation distribution pattern and weather map pattern shown in percentage. Using the probability of each pattern shown here, the probabilistic determination of the precipitation can be done by putting a weather pattern code and the ground precipitation data into the model.

3.4 Validation by Long Range Transport Model

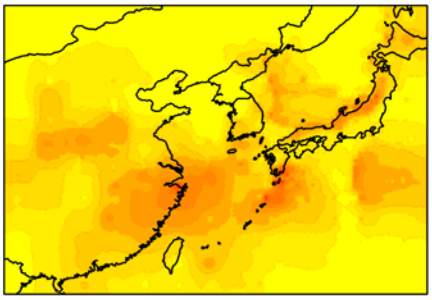
Validation calculation was carried out using a long range transport model developed by authors. This model is a three dimensional eulerian type one. The model domain is 120E-145E and 20N-47N and the horizontal grid size is about 40km around Japan Islands and about 250km in other regions. Vertical range was divided into 10 layers up to 700hPa. Target species were SO2 and SO4, and the model duration was set in February 1988. Emission inventory was given by Akimoto(1994).

Figure 6(a) and 6(b) show the calculated distribution of monthly SOx deposition amount in East Asia. Figure 6(a) shows the result of original model with simple extrapolation of precipitation on the ground to the oceanic area, and 6(b) shows the result of the model developed in this study. Remarkable difference can be found on the sea especially around Korean peninsula. However, the difference of the deposition in Japan is not so

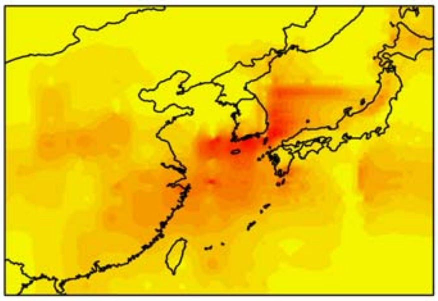
Table 1 Probability of each combination of precipitation pattern and weather map pattern (Unit: %)

Weather map catettory	Front	Direction of isobaric lines	Density of isobaric	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5
Ⅰ	None	North-South	High	0.0	33.3	50.0	16.7	0.0
Ⅱ	None	North-South	Low	0.0	55.6	44.4	0.0	0.0
Ⅲ	None	East-West	High	0.0	0.0	50.0	0.0	50.0
Ⅳ	None	East-West	Low	12.0	60.0	16.0	12.0	0.0
Ⅴ	Cold	North-South	High	0.0	25.0	25.0	50.0	0.0
Ⅵ	Cold	North-South	Low	0.0	55.6	33.3	11.1	0.0
Ⅶ	Cold	East-West	High	0.0	42.9	28.6	28.6	0.0
Ⅷ	Cold	East-West	Low	5.6	27.8	38.9	27.8	0.0
Ⅸ	Stable	North-South	High	0.0	33.3	33.3	33.3	0.0
Ⅹ	Stable	North-South	Low	5.3	52.6	26.3	10.5	5.3
ⅩⅠ	Stable	East-West	High	0.0	0.0	50.0	0.0	50.0
ⅩⅡ	Stable	East-West	Low	3.2	29.0	48.4	9.7	9.7
ⅩⅢ	Warm	North-South	High	0.0	0.0	0.0	0.0	0.0
ⅩⅣ	Warm	North-South	Low	20.0	40.0	20.0	0.0	20.0
ⅩⅤ	Warm	East-West	High	0.0	0.0	0.0	0.0	0.0
ⅩⅥ	Warm	East-West	Low	0.0	0.0	0.0	0.0	0.0
ⅩⅦ	Coase Isobaric Lines			20.0	40.0	40.0	0.0	0.0
ⅩⅧ	Typhoon			5.0	40.0	25.0	25.0	5.0

remarkable. These results means that the original method is still enough for such kind of long term predictions, however, the method in this study is more reliable because it is strongly based on the meteorological theory.



(a) Original model



(b) Model developed in this study

Figure 6 Comparison of calculated distribution of monthly SOx depositions (1988.2)

4. CONCLUSIONS

A simplified statistical method to estimate the precipitation on the sea was developed and installed to the long range transport model. This method can be applied to the long term prediction of depositions.

Future work is summarized as follows:
1) Obtaining probabilistic model with higher accuracy.
2) Compiling observational precipitation data on the sea and make comparisons.

5. REFERENCES

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