SPECIFIC METHOD OF SOURCE AREA OF CEDAR POLLEN TRANSPORTING TO HIGH DENSITY POPULATION PLACE

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ABSTRACT

In order to estimate the source area of cedar pollen which is transported to high density population places in the Kinki district of Japan, the cedar pollen potential production was presumed from the forest database and the amount of cedar pollen deposition on March 2005 was calculated by using MM5 / the dispersal model. The calculated deposition amount reasonably reproduced the observed deposition amount at 7 sampling sites. The potential distribution of the source area of cedar pollen which is transported to high density population places was estimated by back trajectory analysis. By eliminating some sources with high potential, it was found that the cedar deposition amount decreased

INTRODUCTION

The number of patient with hey fever is said to be 10-20% of all people in Japan. The most effective countermeasure is to decrease the exposure of pollen as antigen. Recently, pollen transportation forecast is announced through the mass media such as the newspaper and TV. Additionally the network of automatic pollen deposition counting system was constructed. However its accuracy is not necessarily high. Almost hey fever is caused by cedar pollen. Almost cedar forests are located at country areas far away from urban areas. Hey fever at urban areas is caused by the transportation of cedar pollen from country areas. In order to decrease cedar pollen amount at urban areas, it is necessary to specify the source areas of cedar pollen transporting to urban areas. Especially it is important to specify the source areas of cedar pollen with high supply for urban areas. The effective countermeasures are deforestation and conversion of non-pollen cedar. In order to perform such countermeasures required the long time, the assessment by the numerical simulation is one of the useful tools.

In this research, the cedar pollen potential production in the Kinki district of Japan was presumed from the forest database, the amount of cedar pollen deposition on March 2005 was calculated by using MM5 / the dispersal model, the calculated deposition amount was compared with the observed deposition amount and the validity of the numerical model was discussed. Furthermore, the potential distribution of the source area of cedar pollen which is transported to urban areas was estimated by back trajectory analysis.

CEDAR POLLEN POTENTIAL PRODUCTION

From forest database including species, area, age, biomass and so on and the number of male flower per hectare, the cedar pollen potential production in the Kinki district of Japan was presumed. Cedar over tree age of 25 years produces pollen and the number of pollen produced doesn't depend on year. For cedar over tree age of 25 years, cedar pollen potential product per hectare was calculated by

$$TP = MF \times P \qquad (1)$$

where TP is total cedar pollen product [number/ha/year[, MF is male flower product [number/ha/year], P is number of pollen per a male flower [-]. The average value of MF between 1990 and 1999 in the Kanto district was reported to be 8,386 [number/m^2/year] (Hashizume). MF In 2005 was five times more than the average MF. Therefore MF was set to the constant of 396,000. The map of pollen product in 2005 in the Kinki district is shown in Figure 1. This pollen product was used in the diffusion calculation.

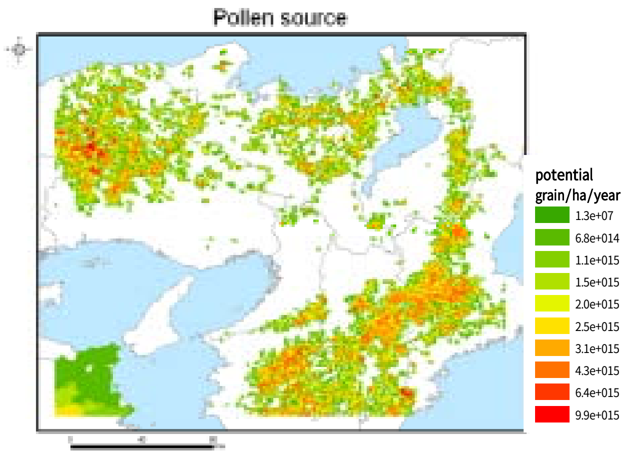


Figure 1 pollen product in 2005 in the Kinki district

CEDAR POLLEN DEPOSITION SIMULATION

Meteorological model

MM5 (The Fifth-Generation NCAR / Penn State Mesoscale Model) was used as the meteorological model. The model options used in the MM5 are summarized in Table 1.

Table 1 Summary of the model options used in the MM5

Horizontal grid	Lambert conformal conic
Cumulus parameterization	Grell (Grell)
Cloud Physics	Simple Ice (Dudhia)
PBL scheme	Medium range forecast PBL (Hong)
Radiation scheme	Dudhia's longwave & shortwave scheme (Chen)
Surface scheme	Multi-layer Soil Thermal Diffusion Model (Chen)

In order to initialize MM5 model, the national mesoscale grid point value data (MSM-GPV; resolution $0.1° \times 0.125°$ for the ground data and resolution $0.2° \times 0.25°$ for each pressure level) provided by the Japan Meteorological Agency was used.

Diffusion model

The vertical coordinate system of MM5 is σ coordinate system following pressure level. The vertical coordinate system of this diffusion model is $z*$ coordinate system following topography. Therefore all data obtained from MM5 were converted to $z*$ coordinate system.

The diffusion model is expressed by

$$\frac{\partial C}{\partial t} = -\vec{V} \cdot \nabla C + \nabla(K \cdot \nabla C) + Q + D \qquad (2)$$

where C is pollen concentration, $\vec{V}$ is wind speed vector, K is the diffusivity coefficient, Q is the emission rate, D is the deposition. Assuming the diameter of cedar pollen to be 40 μm, the terminal velocity of cedar pollen was set to the constant of 0.0258 m/s.

Calculated domain and period

The calculated domain is the range of longitude 134.32399 - 136.59686 and of latitude 33.88142 - 35.72850 and the domain size is 201km in the east-west direction and 201km in the north-south direction and mesh size is 1 km. The top height of the domain is 5000m and the vertical domain is divided with 15 layers with fine mesh near ground surface. The calculated period is for 28 days from 3 March to 31 March in 2005, because March is the flowering season of cedar.

Emission model

If the flux of cedar pollen is observed, it is desirable to use this data. As such observations usually are few, several modeling of emission as a function of temperature, precipitation and so on was examined. In this research, we tried the same modeling. But the calculated results weren't necessarily improved. Therefore the emission of pollen was set as follows.

Usually male flower is opened accompanying with sunrise and is closed at sunset. The diurnal variation of the pollen emission was assumed to be normal distribution with the peak at 2 p.m. as shown in Figure 2.

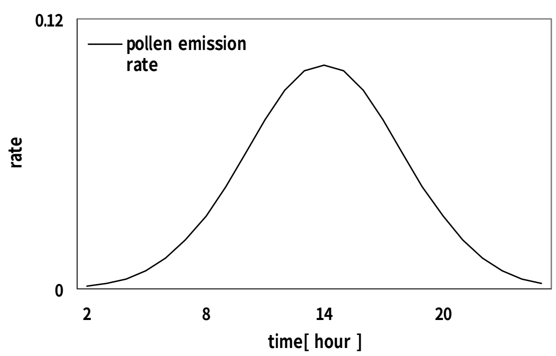


Figure 2 Diurnal distribution of pollen emission

The emission height of pollen is proper to be tree height. The mesh resolution used in this research is coarse and can't express the sub-scale phenomena such as updraft by thermal plume. Therefore the vertical distribution of the pollen emission was assumed to be one-side normal distribution with the standard deviation σ_h of 80m as shown in Figure 3.

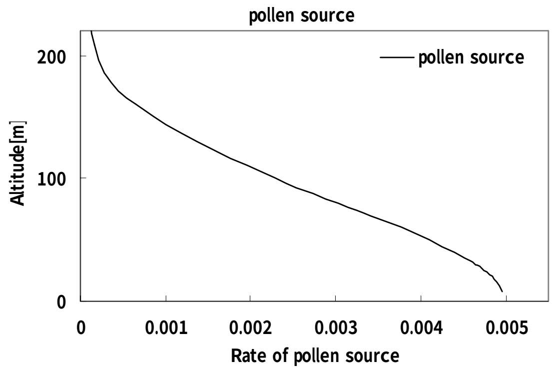


Figure 3 Vertical distribution of pollen emission

It was reported that the flowering season was related to altitude. Takahashi reported that after one month when cedar at the altitude of 200m flowered, cedar at the altitude of 900m flowered. Taira reported that the period of continuously pollen emission was 18 days. On the base on these data, the period of pollen emission each altitude on March was assumed as Figure 4.

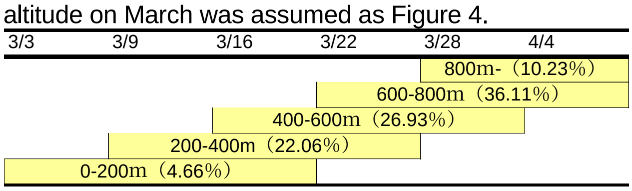


Figure 4 Flowering season each altitude

Result and discussions

Figure 5 shows the distribution of the total deposition of cedar pollen on March. The pollen was transported to the urban areas such Osaka City and Kobe City far away from cedar forests. When the wind direction was north or north-west, the amount of the pollen deposition increased. On the contrary, when wind direction was south or south-west, the amount of the pollen deposition extremely decreased, because of a few source of cedar pollen.

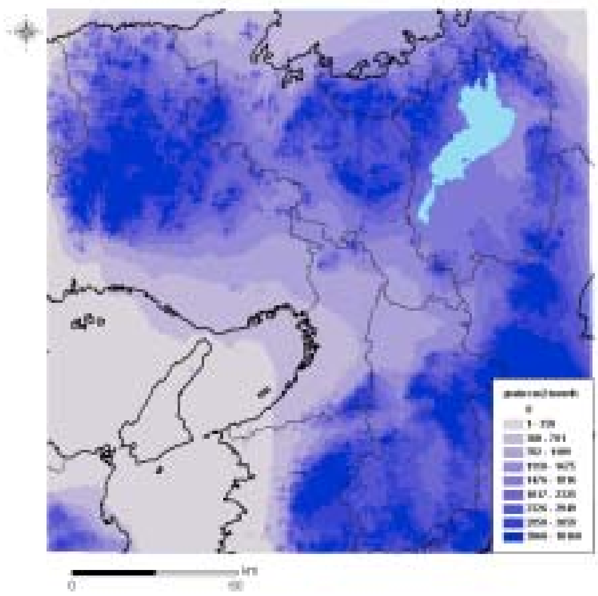
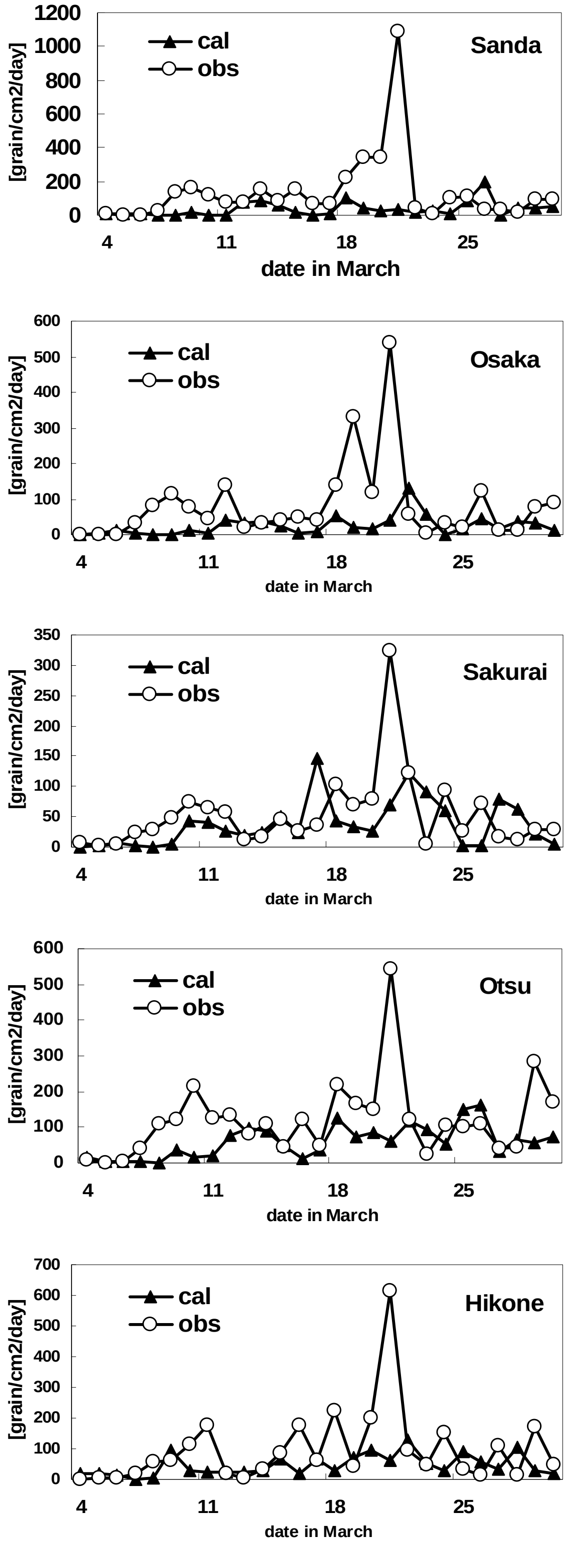


Figure 5 Pollen deposition on March

Figure 6 shows the observed pollen deposition at 7 sampling sits with calculated pollen depositions. At all of the sampling sites, the relatively high deposition was observed on 26 March. The calculation couldn't reproduce this high deposition. However, except for this day, the calculated pollen deposition reasonably agreed with observed pollen deposition. These results suggested that the emission model used in this research was believable validity.



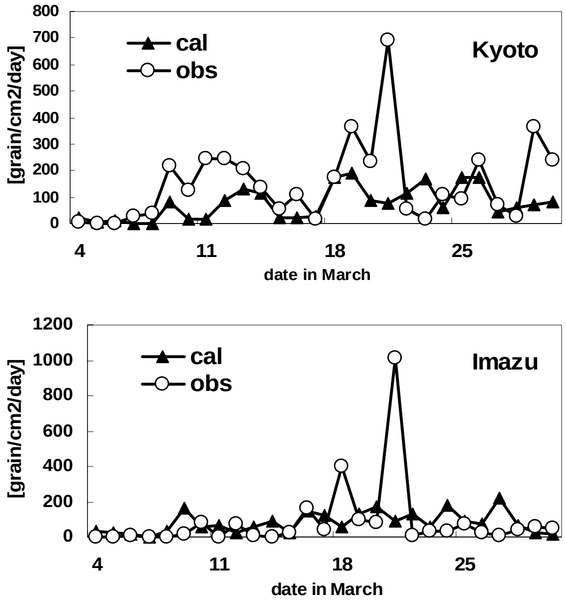


Figure 6 Comparison of observed and calculated pollen deposition

BACK TRAJECTORY ANALYSIS
Method

Back trajectory is the method to calculate the trajectory from a start point by using equation (3).

$$x_{n-1} = x_n - u\Delta t$$
$$y_{n-1} = y_n - v\Delta t \qquad (3)$$
$$z_{n-1} = z_n - \left(w + w_g\right)\Delta t$$

where u, v, w are wind component of x, y, z direction, respectively. w_g is terminal velocity. Δt is time interval. n represents time step.

In regard to an arbitrary point of the trajectory (A), the contribution of deposition of a source area to a start point was assumed as follows.

(1) Inverse proportion for wind speed and for dispersion width of the distance from a start point
(2) Exponentially decrease for the distance d from a source area to the point A
(3) Exponentially decrease for the altitude h from ground level to the point A

The outline of the above process is shown in Figure 7.

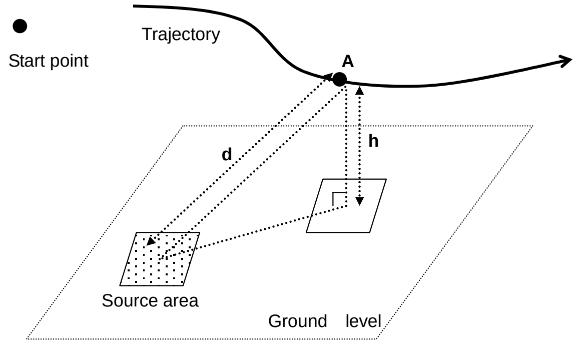


Figure 7 Outline of the contribution of deposition of a source area

The contribution for deposition of a source area of processes (1),(2) and (3) C_p is expressed by

$$C_p = \frac{1}{U\sigma_y\sigma_z}\exp\left(-\frac{d^2}{2\sigma_y{}^2}\right)\exp\left(-\frac{h^2}{2\sigma_h{}^2}\right)\times \mathrm{Pr}od \qquad (4)$$

where σ_y and σ_z are the dispersion width of the distance from a start point in the normal direction of trajectory and in the vertical direction, respectively and were calculated from the neutral dispersion width of Pasquill – Gifford. $\mathrm{Pr}od$ is the production of cedar pollen in a source area.

Results and discussions

Setting a start point to Kyoto, the trajectory at 2pm on March 18 is shown in Figure 8. The solid line of the top figure shows the horizontal trajectory. The dots show the C_p defined by the equation (4). The solid line, the dashed area and the bar of the bottom figure show the vertical trajectory, the topography and C_p, respectively. The trajectory was drawn along the ground level at the neighborhood of the start point. Especially, C_p became large on the condition that the trajectory height was close to the ground level.

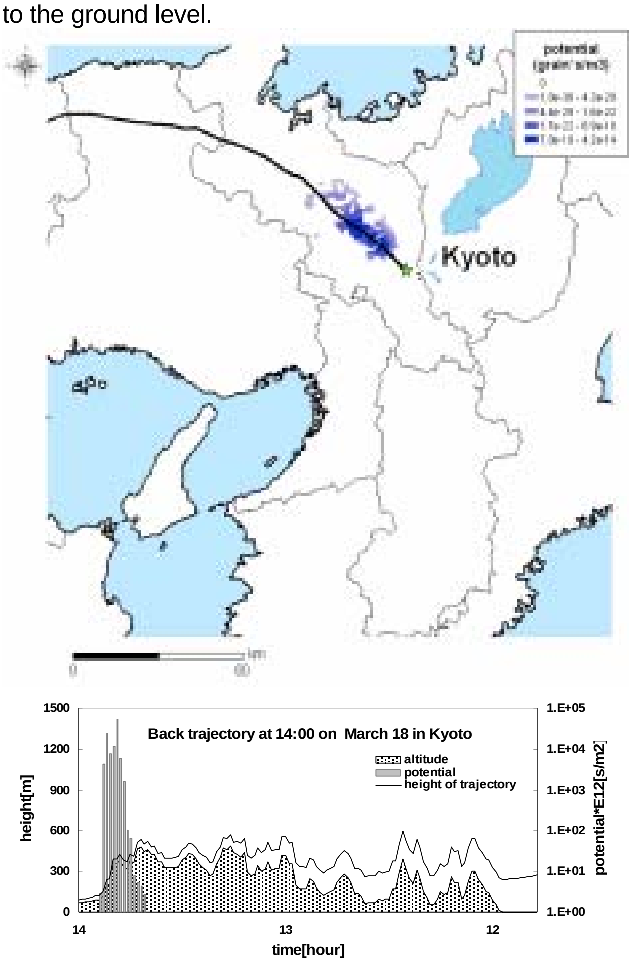


Figure 8 Trajectory and Contribution for deposition of a source area. Top: Horizontality. Bottom: Verticality

Setting a start point to Kyoto, the trajectory at all time of March was calculated and the contribution for deposition of a source area was also evaluated. This result shows in Figure 9. The dense color shows 1000 meshes with the especially high contribution for deposition. The Kita Mountain had the largest contribution for deposition. Yosino Mountain and the Chugoku Mountains with the large emission were the second largest contributions.

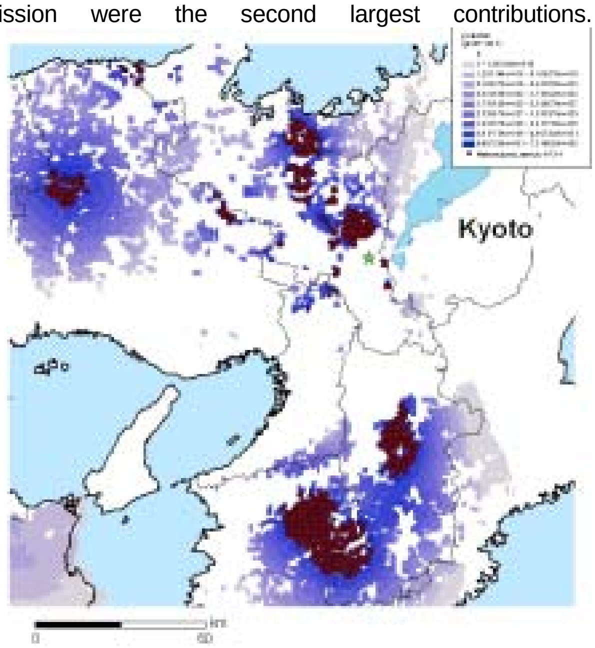


Figure 9 Map of the contribution for deposition of a source area

In order to verify the contribution for deposition, the cedar pollen deposition was re-calculated on the condition for eliminating the source of 1000 meshes with the especially high contribution for deposition. Figure 10 shows the calculated diurnal cedar pollen deposition both at the normal condition and at the elimination condition. In the result of the elimination, the total cedar pollen deposition decreased by 32% and the highest deposition on March 19 decreased by 45%. This result suggested that it is one of the effective countermeasures to cut down cedar with the high contribution for deposition.

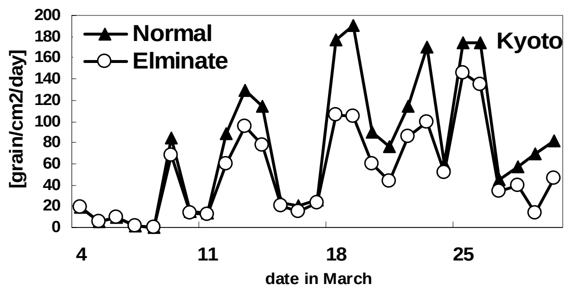


Figure 10 Calculated diurnal cedar pollen deposition both at the normal condition and at the elimination condition

CONCLUSIONS

In order to estimate the source area of cedar pollen which is transported to high density population places in the Kinki district of Japan, the amount of cedar pollen deposition on March 2005 was calculated by using MM5 / the dispersal model. The diurnal variation and the vertical distribution of the pollen emission was assumed to be normal distribution with the peak at 2 p.m and to be one-side normal distribution. Furthermore the period of pollen emission was related with the altitude. The deposition amount calculated by using these emissions reasonably reproduced the observed deposition amount at 7 sampling sites.

On the base of the back trajectory analysis, the contribution for deposition of a source area was evaluated. The calculation setting a start point to Kyoto showed that the total cedar pollen deposition decreased by 32% and the highest deposition on March 19 decreased by 45% by eliminating the source of 1000 meshes with the especially high contribution for deposition.

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