

Enrichment of airborne Japanese cedar (*Cryptomeria japonica*) pollen in mountain ranges when passing through a front accompanying temperate low pressure

Yuichi Takahashi  · Shigeto Kawashima  · Yusuke Suzuki · Nobuo Ohta ·
Seiji Kakehata

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Abstract Values obtained by the real-time pollen monitors set up at 14 measuring points in the Tohoku region indicate that a large amount of Japanese cedar pollen was dispersed along the western region and northern flank of the Ou Mountain Range when a front accompanying the temperate low pressures passed through the west sea of northern Hokkaido. We are sure that this phenomenon is related to pollen enrichment by mountain ranges. The time at which highest concentrations of pollen grains were observed shifted from the western to the eastern side, in accordance with the path of the front. No pollen was seen after the passage of the cold front.

Keywords Airborne pollen · Cold front · *Cryptomeria japonica* · Mountain ranges · Pollen enrichment · Warm front

Y. Takahashi (✉) · Y. Suzuki · S. Kakehata
Department of Otolaryngology, Head and Neck Surgery,
Faculty of Medicine, Yamagata University,
Yamagata 990-9585, Japan
e-mail: yuichita7510@gmail.com;
yuichi@ksirius.kj.yamagata-u.ac.jp

S. Kawashima
Graduate School of Agriculture, Kyoto University,
Kyoto 611-0011, Japan

N. Ohta
Department of Otolaryngology, Tohoku Medical and
Pharmaceutical University, Sendai 981-8558, Japan

1 Introduction

Most pollen released by the Japanese cedar (*Cryptomeria japonica*, henceforth referred to as ‘cedar’) forest falls within the immediate vicinity. However, it can be transported considerably far away, depending on weather conditions. Generally, a high concentration of pollen grains gets deposited in places where winds from different directions collide. The place where such a phenomenon occurs is referred to as a wind shear zone. Using a helicopter, Sahashi (1998) investigated the distribution of pollen by wind shear in regions where land and sea breezes dominate. A survey conducted in the middle of May showed that pollen was most abundant at 2000 m (for the *Cryptomeria*) and 3000 m (for the *Pinus*) above sea level. Such a survey indicates that pollen can be carried up to greater heights. In Yamagata City, abrupt changes were observed in the quantity of pollen grains transported by a front accompanying the temperate low pressures (Takahashi et al. 1989). This phenomenon has been experienced recurrently. However, it is debatable whether this phenomenon occurs particularly in basins like the Yamagata.

Studies on how the topography affects the dynamics of airborne pollen were made in two research fields. From a paleological perspective, the study relates to pollen deposition over longtime periods (Cour et al. 1999; Fontana 2003; Pan et al. 2013). The spatial scale of this type of study is generally large. Another is the phenological approach, which mainly examines how

the flowering phenomenon is affected by elevation and topography (Van de Water & Levetin 2001; Cariñanos et al. 2004; Charalampopoulos et al. 2013). Sikoparija et al. (2013) discussed the mechanism for long-distance transportation of pollen considering the meteorological conditions in meso-scale. The study suggested that there exists a local meteorological effect on the dispersal process of airborne pollen.

In this paper, data were collected from the Tohoku region (northeastern part of the Japanese archipelago) during 2016, when the cedar was in full bloom, especially at that time a front accompanying the temperate low pressure had passed through. The data were gathered concurrently using automatic cedar pollen monitors at 14 measuring points within the Tohoku region.

Numerous confirmations were made to ascertain whether the particles counted by the monitor were cedar pollen. Positive correlations are often obtained between the values from the monitor and pollen counts by microscope; however, differences have also been pointed out (Seno et al. 2003; Yoda et al. 2005). Snowfall and other type of pollen such as *Juglans* pollen (Takahashi et al. 2001) and *Fagaceae* pollen (Yoda et al. 2005) often contaminate the count. Since it is not easy to count cedar pollen manually every hour, a lot of studies are conducted on a daily basis. An immunochemical method (Takahashi et al. 1993) was introduced to solve this problem, and it became possible to count airborne samples on an hourly basis (Kawashima et al. 1995). As a result, it can be said that the counts of cedar pollen are reliable if it is not snowing and if recorded at a time before other types of pollen appear in the air (Takahashi et al. 2001, 2011).

2 Materials and methods

All the data were obtained using a KH-3000 (Yamato Co. Ltd, Yokosuka City, Japan 238-0013) real-time pollen monitor established by the Pollen Information Association. Details of the instrument used in this study are described in Kawashima et al. (2007, 2017), but here only the necessary parts are described. A semiconductor laser beam is directed at particles present in the air, and the forward and side scattering of the beam is measured. By measuring the length and width at the same time, the spherical cedar pollen can be identified. Furthermore, the scattering of the beam only identifies particles with

the same dimensions as cedar pollen (28–35 μm). The number of cedar pollen per cubic meter was obtained at each hour. For Yamagata City, the number of cedar pollen was measured simultaneously using a personal volumetric air counter (Burkard) and compared to the value obtained by the pollen monitor. The sampled surface of a slide glass is stained with a basic fuchsin solution, and the counts measured were then converted to cubic meter.

3 Results

Figure 1 shows the values recorded by monitors located in the cities of (a) Aomori, (b) Hirosaki, (c) Yokote and (d) Yamagata. The values recorded on March 30 were remarkably high in these cities. Interestingly, a front accompanying the low pressure had passed through the region on the same day. The comparison between the results obtained by the monitor and the samples collected by the air counter is shown in Fig. 1d. The correlation coefficient (r) between them is 0.890 (March 5 to April 23, $n = 50$). Therefore, within the examined period, most measurements obtained by the monitors can be considered to be cedar pollen. Table 1 shows the time corresponding to the maximum dispersion of cedar pollen on March 30 at each of the 14 measuring points in the Tohoku region. In the table, the data are grouped according to the geographical position of each city. It is observed that the time concurring with the maximum pollen dispersion is delayed from the west to the east. Essentially, it extends from 3 a.m. to 7 a.m. on the western side of the coastal area and from 6 p.m. to 9 p.m. on the eastern side of the coastal area. High concentrations of pollen grains are deposited inland, especially on the west and northern flanks of the Ou Mountain Range (VMR, vertebral mountain range in the northeastern Japanese archipelago) that lie close to a low-pressure zone. Table 1 also indicates the time at which the maximum temperature of the day and the time of the onset of rain (the time of a cold front passing through the region) were recorded. The hour of onset of the rain was also delayed from the west to the east. Usually, it is observed that the largest concentration of pollen grains occurs when daily temperatures reach a maximum or several hours later. However, on this day, the peak concentration advanced from the western to the eastern side along

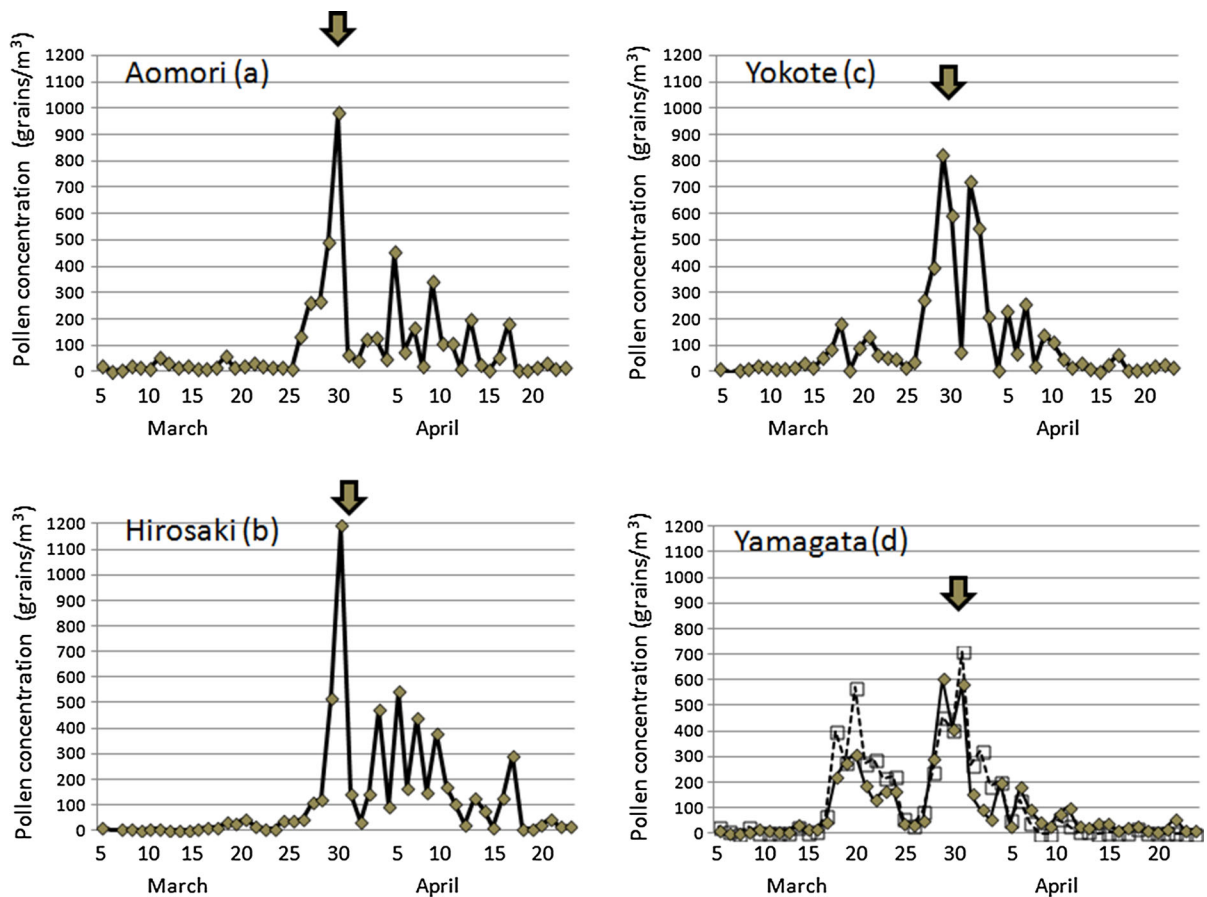


Fig. 1 Daily fluctuations in the pollen counts during the cedar pollen season of 2016 as recorded in four cities. Arrows indicate the date March 30 in 2016. The two lines in the chart of

the course of the front rather than corresponding to the temperature. Figure 2 indicates the quantity of pollen dispersed at 12 p.m. as recorded by the monitors positioned in each city. The area of the circle represents the volume of pollen recorded by a monitor. It is clearly visible that high concentrations of pollen grains were dispersed in the western flank and the northern end of the Ou Mountain Range. The weather chart at 12 p.m. is shown as an inset in the upper left corner of the figure. On comparing weather charts at 9 a.m. (not shown) and 12 p.m., it appears that the cold front travelled toward the east and the warm front progressed toward the south.

4 Discussion

The KH-3000 monitor does not identify the cedar pollen morphologically since it counts any particles

Yamagata City represent measurements made using the following instruments: $\square$ Microscope, $\blacklozenge$ KH-3000 monitor

existing in the air that have the same scattering properties as cedar pollen. Fortunately, cedar pollen makes up the largest category among floating particles. As seems from the study conducted at Yamagata City (Fig. 1d), pollen concentrations obtained in both the microscope and the automatic pollen monitor were relatively well matched. In addition, large volumes of cedar pollen grains get dispersed before other types of pollen appear in the air. Furthermore, cedar pollen can be transported for long distances (Kawashima & Takahashi 1999) like ragweed pollen (Bilińska et al. 2017) and birch pollen (Hjelmroos 1991) among others. As noted from Yamagata City (d) in Fig. 1, cedar pollen having the largest concentration among floating particles, such a condition is fortunate that the value of the monitor at this time can be regarded as cedar pollen. Based on the instrument comparison study, observations using automatic pollen monitors

Table 1 The highest concentration of pollen grains in 1 m³ of air on March 30, 2016, at the 14 points in Tohoku region and time when the temperature reached the maximum value of the day

Point		Maximum pollen concentration and its time		Maximum temperature of the day		Time when rain started		
		Pollen grain	Hour	Hour	Temperature	Pollen grain	Hour	Temperature
The sea of Japan side								
a	Nigata	200	4	11	16.5	8	14	13.8
b	Nagacka	631	3	13	18.7	12	19	11.6
c	Mkawa	922	5	10	16.7	94	12	14.0
d	Akita	762	7	10	13.5	20	12	11.7
Inland area								
West of VMR								
e	Aomori	4751	8	10	15.7	114	13	9.3
f	Hirosaki	4292	7	10	15.3	94	12	9.4
g	Yokote	2000	13	12	15.4	217	15	9.3
h	Yamagata	1451	12	12	17.3	0	19	10.6
i	Yonezawa	959	10	12	17.8	24	19	9.8
East side of VMR								
j	Moroka	1295	14	13	14.8	20	18	9.0
k	Fukushima	815	15	14	20.2	32	20	12.5
Pacific side								
l	Sendai	328	18	13	15.5	32	19	13.5
m	Ishinomaki	229	19	13	13.7	4	20	9.0
n	Iwaki	910	21	16	18.5	4	22	12.3

Furthermore, the time, temperature and pollen concentration when rain started as a result of the passing through the cold front

are found suitable for cedar pollen measurements in Japan. It is observed that high concentrations of cedar pollen grains were dispersed due to the passage of a front, particularly on the western side of the Ou Mountain Range and in the northern end close to where the low pressure occurs. An increased occurrence of pollen grains was found in places where there are physical obstacles, like the windward side of mountain ranges. The mountain range appears to facilitate pollen enrichment, like water droplets in the atmosphere gathering on the windward side of a mountain range and resulting in precipitation. However, in the case of pollen, aggregation as seen with rain drops is not made because it never gathers but only enrichment occurs. Considering the following scenario, when a warm front passes through, an ascending air current occurs in the warm air mass of the front which carries large amounts of pollen grains. This pollen is transported upwards when there is a contact of this surface with cold air, the

pollen falls and enrichment occurs. A similar consideration can be made when cold fronts pass through. Aomori City and Hirosaki City where close to the center of the low pressure, there was little distance between the warm and the cold fronts. Here, enrichment occurred between the two fronts and further enrichment occurred close to the mountain range (at the Shirakami Mountains and the northern end of the Ou Mountain Range). Sikoparija et al. (2013) reported a notable increase in concentration of ragweed pollen. Several cases in their study appear to be similar to the phenomenon observed in the current study results.

There exists little information about the increase in the volume of pollen accompanying a passing cold front. Research indicating increased concentration of pollen grains during rainfall in London has also been conducted by Norris-Hill & Emberlin (1993). In this study, the central zone of low pressure passed through the sea to west of northern Hokkaido. A large portion

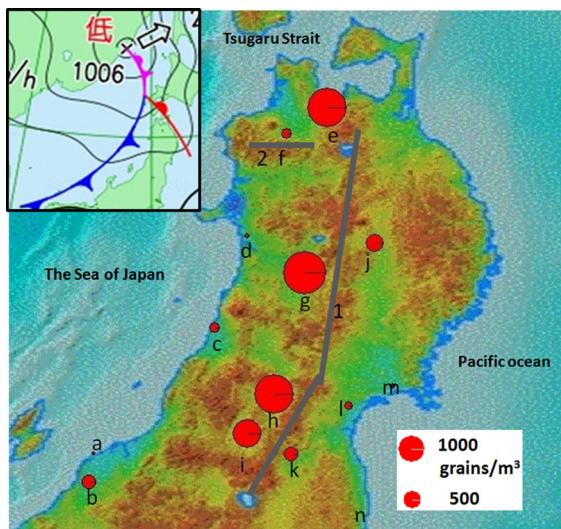


Fig. 2 Concentration of cedar pollen grains (the area of the circle) at 14 measurement points in the Tohoku region at 12 p.m. on March 30 in 2016. Letters *a–n* indicate cities. Numbers 1 and 2 indicate the Ou Mountain Range (VMR) and the Shirakami Mountains, respectively

of pollen dispersion occurred in Yamagata City when the low pressure passed through rather southern region (located near Tugaru Strait) than observed in the current study (Takahashi et al. 1989). In future studies, attempts to collect basic data, over larger temporal durations, can be made. Also, the relationship between rapid changes in pollen count affected by a front can be analyzed, and clinical symptoms using a mobile information such as a 'pollen check sheet' (Takahashi et al. 2007) and symptom data of a patient's Hayfever diary could be made available (Bastl et al. 2014).

5 Conclusion

In order to use the data from real-time pollen monitors in the Tohoku region, it is verified that cedar pollen enrichment occurs due to passage of a front along with temperate low pressures in places close to the center of low pressures. This can be observed at the western part of the VMR when the cedar is in full bloom. A large amount of cedar pollen is dispersed when warm fronts pass through. No pollen was seen after the passage of the cold front. The time at which highest concentrations of pollen grains were observed shifted from the western to the eastern side, in accordance with the path of the front.

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