Relationship between large amounts of *Cryptomeria japonica* D. Don pollen dispersion and cold front passage

Yuichi Takahashi (✉ yuichita7510@gmail.com)

Department of Otolaryngology, Yamagata University Faculty of Medicine <https://orcid.org/0000-0003-0887-9921>

Shigeto Kawashima

Graduate School of Agriculture, Kyoto University

Yusuke Suzuki

Department of Otolaryngology, Yamagata University Faculty of Medicine

Seiji Kakehata

Department of Otolaryngology, Yamagata University Faculty of Medicine

Research Article

Keywords: airborne pollen, automatic pollen monitor, cold front, *Cryptomeria japonica*

Posted Date: July 13th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-701133/v1>

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Abstract

Recently, with the proliferation of automatic *Cryptomeria japonica* pollen monitors, it has become possible to obtain data measured simultaneously from multiple locations. The KH-3000 monitor used by the Pollen Observation System of the Japanese Ministry of the Environment, “Hanako-san”, and the “Pollen Robo” monitor created by Weathernews Inc. were installed in various places in the Tohoku region for collection of simultaneous pollen count data, and the results indicated that the period of the day when large amounts of *C. japonica* pollen were dispersed may be related to the passage of a cold front extending from a low pressure system. When the types of pollen dispersed on that day were examined under a microscope, most of them were *C. japonica* pollen. Therefore, we investigated the relationship between the periods of these two events, with transit time of the cold front determined from the point when the wind direction changed from eastward to westward. The area with a high concentration of *C. japonica* pollen moved from the Sea of Japan side to the Pacific Ocean side in conjunction with the movement of the front. In 40% of the cases, the highest dispersion of *C. japonica* pollen occurred at the same time as the front passed, and 90% of the cases were within two hours before or after the passage. The number of dispersions was high in the northern part of the Tohoku region close to the low pressure system at the end of the front and low in the southernmost part of the Tohoku region away from this system.

Introduction

Japanese cedar (*Cryptomeria japonica* D. Don) blooms and releases pollen during periods of rapid temperature increase. As a result, of the majority of *C. japonica* pollen disperses between the afternoon and midnight with little distribution from midnight to dawn. However, occasionally a large amount of pollen is observed even in inclement weather if the temperature is sufficiently high. Based on our *C. japonica* pollen dispersal data, it is evident that the amount of pollen increased each day as the warm sunny days continued, reaching a maximum amount immediately before extreme weather events. In such cases, a warm front often preceded the passing of the cold front. Our previous older studies showed a sharp increase in the amount of *C. japonica* pollen during warm and cold fronts, followed by a sharp decrease in the amount of pollen with rainfall after the cold front passed. This phenomenon was reported in the Yamagata Basin in Yamagata City, from hourly pollen data collected in a seven-day recording volumetric spore trap (Burkard Manufacturing Co., Ltd., hereinafter abbreviated as Burkard sampler) (Takahashi et al. 1989). At that time, our aim was to understand the relationship between the time of passage of the front and the change in the amount of *C. japonica* pollen released over a wide area. Since such a study requires hourly data taken at multiple points simultaneously, it was challenging to use the conventional method of counting pollen under a microscope. In recent years, automatic *C. japonica* pollen monitors have become widespread in Japan, making it now possible to retrieve hourly values from multiple locations simultaneously. We determined that the cold front passed on the same day as the greatest amount of *C. japonica* pollen was dispersed in 2020; therefore, this study aimed to locate the cold front on the map and identify where the large amounts of *C. japonica* pollen were distributed.

In Japan, there are two main automatic *C. japonica* pollen observation networks, the one is “Hanako-san” and the other is “Pollen Robo”. The Pollen Observation System of the Japanese Ministry of the Environment is commonly known as “Hanako-san”. The measuring device used by the “Hanako-san” is the KH-3000 monitor created by Yamato Manufacturing Co., Ltd. Since it draws a standard 4.1 L of air per minute, the number of pollen per hour (per m³) can be calculated. We once verified the accuracy of the KH-3000 monitor using Burkard sampler which installed side by side, and the number of *C. japonica* pollen was calculated using a microscope. The results obtained by the two methods were in good agreement (Takahashi et al. 2001). The details of the device are described by Kawashima et al. (2007, 2017). The the advantage of “Pollen Robo” is the large number of measurement points in Japan, and about 1,000 monitors are installed nationwide every year during the *C. japonica* pollen season. Since the hourly values are computerized in real time, “Pollen Robo” users can see at a glance the hourly trends of *C. japonica* pollen in the place where they live. It has a mechanism to inhale the atmosphere equal to the amount of breathing of adults, and the amount of pollen inhaled by humans during breathing can be confirmed. In this study, we first investigated the quantitative changes in pollen dispersal dynamics over time using the data from “Hanako-san,” followed by a determination of the relationship between the cold front passage and the amount of dispersion using “Pollen Robo” data.

Meteorological data from the Automatic Meteorological Data Acquisition System (AMeDAS) is also available near the pollen measurement locations, and by using data obtained from this system near the “Pollen Robo” measurement point, it is possible to determine the time the front passed in each area.

Materials And Methods

Our target area was the Tohoku region, which extends from north to south in the northern part of the Japanese archipelago. In the spring of 2020, 13 measurement points for “Hanako-san” and 72 for “Pollen Robo” were set up in the area. Among these, data retrieved from 8 points of “Hanako-san” and 52 points of “Pollen Robo” were used (Fig. 1). These points were chosen as locations where AMeDAS points were nearby and meteorological data could be obtained. “Pollen Robo” data in these areas were obtained from Weathernews Inc. We used the wind direction/velocity of the AMeDAS to determine the transit time of the front, obtained from the Japan Meteorological Agency website. The wind directions are shown by the 16 arrows, and the wind speeds are indicated by the length of each arrow. The passage time of the cold front was determined by taking advantage of the knowledge that the wind direction changes from eastward to westward, and in cases where it was not clear, we included wind speed data in our determination.

Results And Discussion

According to the nationwide results of *C. japonica* pollen dispersal in 2020, the constant pollen dispersal period in the Tohoku region occurred from mid-March to early April. Peaks were observed on March 11, 15, 19–20, and 27 (Fig. 2). The largest amount of pollen dispersal occurred on March 19–20, prior to the beginning of other types of pollen being released. Therefore, we analyzed the data of this day in detail. *C. japonica* pollen dissemination usually occurs between noon and midnight; however, the peaks in March

19–20 were observed from midnight on March 19 to dawn on March 20. When the types of pollen dispersed on that day were examined under a microscope, most of them were *C. japonica* pollen. Figure 3 shows the differentiation between the numbers of dispersions in major cities in the northern Tohoku region. The time when the most *C. japonica* pollen was dispersed was 01:00 on the March 20th in Akita City (A) on the Sea of Japan coast, 03:00 in Morioka City (M) and Yokote City (Y) in the inland area, and 05:00 in Ofunato City (O) on the Pacific Ocean coast. Therefore, the pollen wave moved from the Sea of Japan side of the region to the Pacific Ocean side, coinciding with the passage of the front. During this period, there was a low pressure system in the western sea of Hokkaido, releasing a cold front that spread from north to south and extended along the Tohoku region. When then examined the data from “Pollen Robo,” and the results are presented in Fig. 4. Since the wind direction changes from eastward to westward, we were able to determine the passage time of the front. The pollen numbers change dramatically with the passage of the front, and they are shown as logarithmic values on the map. As is clear from the figure, many dispersal points moved from the Sea of Japan side to the Pacific Ocean side. We examined the relationship between the time of frontal passage and the greatest pollen dispersal, and found that they were highly positive correlated ($r = 0.8005$, $n = 52$) (Fig. 5). The majority of the pollen was dispersed within two hours before or after the passing of the front; of the 52 points, 22 (42% [22/52]) were simultaneous, namely, the greatest dispersion of *C. japonica* pollen occurred at the same time as the front passed; and 90% (47/52) of cases were within two hours before or after the time of passage (Fig. 6). The number of dispersions was high in the northern part of the Tohoku region close to the low pressure system at the end of the front and low in the southernmost part of the Tohoku region away from this system.

We found that the maximum value of pollen dispersion was recorded at the time the front was present or within 2 hours before or after its passage. It is speculated that a large amount of pollen was generated in areas where the temperature had risen by a passing warm front, and the generated pollen was carried by the cold front that followed, causing pollen enrichment prior to the cold front arrival, although this has not been confirmed. During this study, the front moved from west to east, but we plan to collect data and create a model to determine if the same results are found when the front moves in different directions. We previously observed that pollen enrichment was affected by mountains (Takahashi et al. 2018); therefore, we are interested in whether the passage of the cold front and the effect of the topography relate to the same mechanism, which will be considered in future studies.

The KH-3000 monitor and “Pollen Robo” count pollen utilizing the intensity of reflected light and cannot identify the pollen morphology. Therefore, it is not possible to differentiate pollen when many types of pollen are dispersed simultaneously, because particles with similar reflected light intensity (mainly particles of similar size) are grouped together. Fortunately, in Japan, *C. japonica* releases the majority of the airborne pollen in the first half of the *C. japonica* pollen season and in substantial quantities. In addition, the size of the pollen is larger than that of other suspended particles, so it could be possible to count only *C. japonica* pollen. Therefore, automatic pollen monitors that count airborne pollen from the particle size are useful during the *C. japonica* pollen season. The monitor is straightforward, and it is possible to obtain high-density geodetic points and a considerable amount of data. Grass and mugwort

pollen, along with *C. japonica* are prevalent causes of pollinosis in some areas of Japan and other countries. We once focused on pollen antigens (allergens) and quantifying the amount of the major pollen antigen present in the air, such as Cry j 1 or Dac g, which are common to this region (Takahashi et al. 2007, 2008), with the aim of gaining knowledge to ultimately aid pollinosis patients. However, these methods have not been widely adopted for practical use in terms of cost and the availability of automation. The development of automatic pollen monitors that count pollen by type appears to be a reasonable concept. There are 130 automatic pollen and spore monitoring stations globally as of 2016, although the range is limited (Buters et al. 2018). Various automatic pollen monitors have been developed that recognize pollen morphology, such as automatic image recognition (BAA-500) (Oteros et al. 2015, 2020), Plair PA-300 (Crouzy B. et al. 2016), Rapid-E (Šauliene et al. 2018), auto-fluorescence analysis (Mitsumoto et al. 2010) and so on. A network that brings together these various efforts is currently being formed in Europe (Clot et al. 2020). We believe that it is possible to confirm whether the phenomenon observed in this study can be found in other species of pollen using the data obtained from such a network.

Conclusions

1. Due to the passage of a cold front, the area with a high concentration of *C. japonica* pollen changed from the Sea of Japan side to the Pacific Ocean side according to the movement of the front.
2. At 40% of the observed points, the count values reached the maximum at exactly the time the cold front passed, and 90% of the points reached the maximum within 2 hours before or after the front passed.
3. The maximum number of dispersions was high in the northern part of the Tohoku region, close to the low pressure system and low in the southernmost part of the Tohoku region away from the system.

Declarations

Acknowledgements

Data for “Pollen Robo” was provided by Weathernews Inc. We would like to express our deep gratitude to Weathernews Inc., especially Ms. Ayumi Kusada of Weathernews Inc. for providing the “Pollen Robo” data in 2020 of Tohoku region. We also thank Dr. Sahashi, N., the Executive Secretary of the Pollen Information Association and Mr. Nakanishi, H. the Managing Director of “Hanako-san”, and the Atmospheric Environmental Division, Ministry of the Environment of Japan, who permitted the use of the pollen data.

This research did not receive any specific grant from funding agencies from the public, commercial, or nonprofit sectors.

We would like to thank Editage (www.editage.com) for English language editing.

Competing interests: The authors declare no competing interests.

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Figures

Figure 1

The Tohoku region of our target area. The numbers are indicated the “Pollen Robo” survey points and the numbers in the square are “Hanako-san” measurement points. The location of the Tohoku region in Japan is indicated in the right figure.

Figure 2

Daily measurement results of *C. japonica* pollen during the constant pollen dispersal period in 2020 (March 9 to April 6). (1) Results by “Hanako-san” (KH-3000 monitor) in major cities in the northern part of Tohoku. (2) Similar results in the southern part of Tohoku. (3) Results by “Pollen Robo” in major cities in southern Tohoku.

Figure 3

Hourly measurement results of *C. japonica* pollen by “Hanako-san” (KH-3000 monitor) at the first peak of the *C. japonica* pollen season (20:00 on March 19 to 16:00 on March 20). Sea of Japan coast: Akita City (A), inland area: Morioka City (M) and Yokote City (Y), Sea of Pacific Ocean coast: Ofunato City (O).

Figure 4

Changes in the amount of *C. japonica* pollen dispersed at each point in 23:00 on the 19th, and 02:00, 04:00, and 08:00 on the 20th are shown in the size of a circle along with wind direction/speed.

Figure 5

Relationship between the time when the front passed and the time of maximum *C. japonica* pollen concentration in the air. The numbers in parentheses show the number of points that overlap because the times of vertical axis and horizontal axis are the same.

Time elapsed from the time when pollen reached its maximum

Figure 6

Time difference between the maximum concentration of *C. japonica* pollen and the passage of the front.