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Algorithm for forecasting the total amount of airborne birch pollen from meteorological conditions of previous years

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ABSTRACT

The birch tree (genus *Betula* L.) disperses airborne pollen annually from April to June, causing severe symptoms in pollinosis sufferers. Because of interannual variations in pollen levels, there is an urgent need to develop a forecasting model with greater precision in order to provide accurate information to patients and medical personnel regarding airborne pollen levels. We developed an algorithm for forecasting the total amount of airborne birch pollen. This equation suggested that the total amount of airborne pollen in a given season could be estimated using only the meteorological data from previous years. In order to discover potential predictive relationships, a data set including airborne pollen data from 1996 to 2015 and meteorological data from 1990 to 2014 was used to construct forecasting models. Statistical evaluation results were examined to select the optimal model, showing that forecasting models obtained the highest accuracy when using meteorological data from June and the best model performance was achieved using the average daily maximum air temperature and solar radiation of the previous five years. We also developed an extended model that included relative humidity, which demonstrated better predictive capability. These findings clarify that a model with greater predictive power can be constructed using the meteorological conditions from the previous five years. In order to assess this conclusion, the algorithm was tested by forecasting the total amount of airborne birch pollen in Japan with good results.

1. Introduction

Airborne pollen is essential for the reproduction of wind-pollinated plants, but pollen can cause pollinosis in sensitized individuals. Pollinosis is a global public health problem; people who suffer seasonal pollen allergies typically experience symptoms such as sneezing, blocked nasal passages, and eye irritation, for which the severity can range from mildly annoying to severely disruptive (Karatzas et al., 2014). The geographical distributions of plants have an important influence on their allergenic impacts. For example, ragweed (*Ambrosia* L.) is a major source of allergenic pollen in the United States, Europe, and Australia (Thibaudon et al., 2014), whereas Japanese cedar (*Cryptomeria japonica*) pollen is problematic in Japan (Okuda, 2003), and birch (*Betula* L.) pollen is known to cause issues in Europe and Hokkaido, Japan (WHO, 2003).

Birch is, in fact, the major pollen-allergen-producing tree in northern Europe and the source of the most widely distributed airborne pollen (D'Amato et al., 2007) in that region. It also produces a considerable proportion (20%–36%) of airborne pollen in Hokkaido (Kobayashi et al., 1998; Takeuchi et al., 1999), which is dispersed annually from April to June and is estimated to cause 60% of the regional pollinosis cases (Gotoda et al., 2001).

Allergy symptoms are costly to treat and can require a considerable level of medical intervention. Globally, the prevalence of pollinosis in industrialized countries is approximately 5%–30% (Zhang et al., 2015), and is estimated to be 25% in Japan. Moreover, pollinosis is thought to be on the rise because of poor air quality and the widespread presence of allergens (D'Amato et al., 2016). In addition, the "hygiene hypothesis" claims that the urban westernized lifestyle, with its relatively limited exposure to infectious agents during childhood, might be responsible for the increasing prevalence of allergic disorders over the past few decades (Graham-Rowe, 2011). The triggering of allergic reactions is highly correlated with the concentration of allergenic pollen, and the severity of pollinosis is strongly related to the threshold value of response in a susceptible individual (Voukantsis et al., 2010).

In order to apply appropriate countermeasures to manage the

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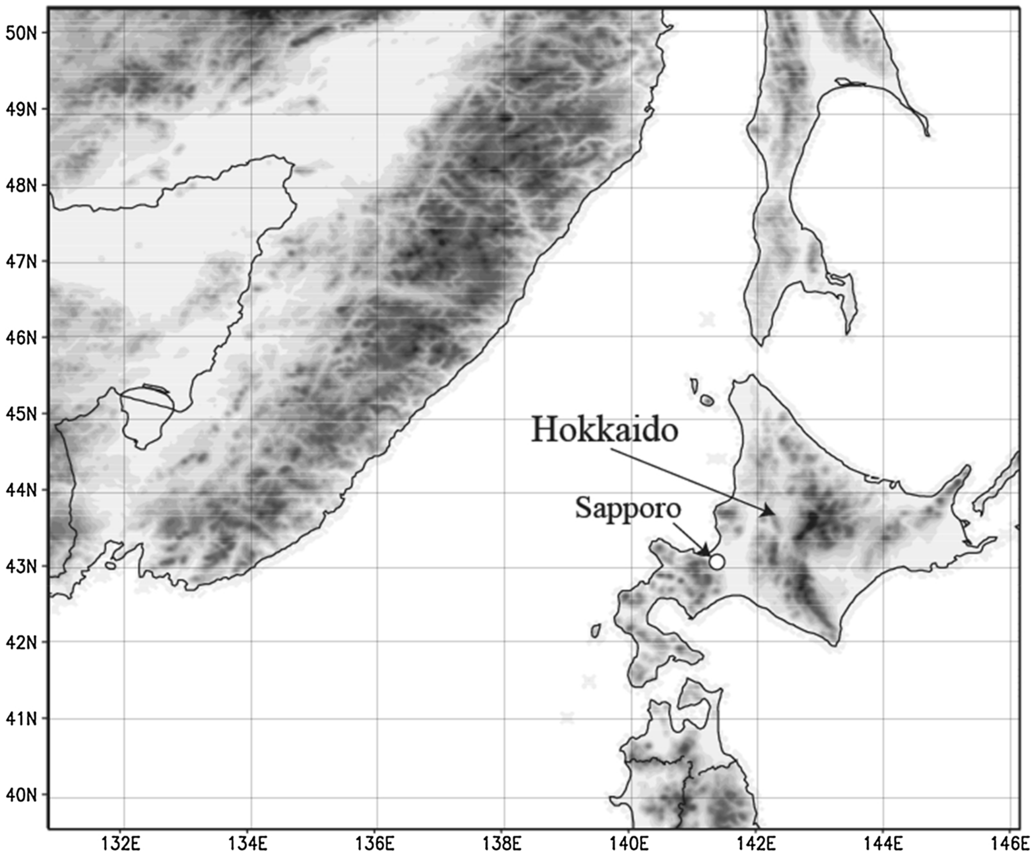

Fig. 1. Location of the experimental observation site (Hokkaido Institute of Public Health) in the city of Sapporo on the northern Japanese island of Hokkaido.

severity of allergic reactions, it is important to monitor and predict the dynamic dispersal of airborne pollen. Recent research related to the dynamic dispersal of pollen has focused on three aspects of this problem: the main pollen season (MPS) (temporal), seasonal total airborne pollen counts or temporal changes in airborne pollen counts (amount), and pollen dispersal (spatial). Of these three, studies related to the amount of airborne pollen are capable of perceiving the dynamics of airborne pollen. Studies on the relationship between weather conditions and pollen concentration have focused mainly on the daily variations of airborne pollen concentrations and are mostly based on linear regression models (Aira et al., 1998; de la Cruz et al., 2008; Norris-Hill, 1995; Ribeiro et al., 2003; Ritenberga et al., 2016; Rodríguez-Rajo et al., 2005; Rodríguez-Rajo et al., 2004). However, some are based on artificial neural networks (Ranzi et al., 2003), whereas others adopt time series (Rodríguez-Rajo et al., 2006) or other data-driven models (Voukantsis et al., 2010). Research suggests that pollen concentration is correlated positively with temperature, solar radiation, sunshine duration, wind speed, and wind direction, whereas it is correlated negatively with relative humidity, rainfall, and the number of rainy days (Ezike et al., 2016; Grewling et al., 2014; Ribeiro et al., 2003).

Early notification of changes in pollen concentrations can help patients and medical personnel take appropriate precautions such as the determination of proper dosages and the potential period of medical treatment that can consequently reduce allergic symptoms. The seasonal total amount of airborne pollen is useful for determining the overall dispersal outcome in each year. Therefore, the establishment of a reliable model for forecasting the seasonal airborne pollen concentration would be very beneficial.

In birch trees, the male flowers begin to form between May and the end of June of the year before flowering (Caesar and Macdonald, 1984; Caesar and Macdonald, 1983). Since the pollen dispersed in a given year is related to the quantity of male flowers that developed in summer of the previous year, the total pollen count is closely related to meteorological variables from the previous summer (Ranta et al., 2008; Yasaka et al., 2009). Of these, temperature and sunlight are thought to be the most important (Matthews, 1955; Norton and Kelly, 1988) as they affect the assimilation efficiency for generating carbohydrates during male flower formation (Dahl and Strandhede, 1996). However, meteorological information from the previous year alone is insufficient for predicting the following year's pollen counts. Trees are capable of producing large quantities of flowers and seeds at one time (called masting behavior) as this can increase pollination efficiency (Nilsson and Wastljung, 1987) and lead to predator satiation (Silvertown, 1980). Therefore, low total pollen counts can occur even if the meteorological conditions in the previous year were suitable for male flower formation. Earlier studies (Dahl and Strandhede, 1996; Masaka and Maguchi, 2001) overcame this problem by considering both the quantity of male flowers and the meteorological conditions of the previous year, yet complications were encountered with regards to the reliability and representativeness of male flower quantity data.

Because of the low reliability and representativeness of male flower quantity data and the insufficient accuracy of estimations based on pollen sampling in a single year, this study aimed to develop a forecasting model for the total annual airborne pollen amount using only meteorological data. We developed an algorithm to replace the quantity of male flowers with a more reliable and regional representative factor (meteorological variables from previous years) and constructed a model for the prediction of annual total airborne birch pollen amount. Twenty years of airborne birch pollen data (1996–2015) from Hokkaido were used to construct and validate the proposed model. Moreover, we used statistical evaluations to determine the most appropriate source month for the meteorological data, the most suitable number of years for these observations, and the optimal combination of meteorological elements necessary for accurate forecasts.