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Short communication

Localized strong winds associated with extensive fires in central Tokyo: Cases of the Great Kanto Earthquake (1923) and an air attack in World War II (1945)

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ABSTRACT

Localized strong winds were observed in the Central Meteorological Observatory (CMO) in Tokyo under big fires after the Great Kanto Earthquake in September 1923. As the CMO buildings were threatened and caught by fire, wind speed exceeded 15 m/s under high temperature reaching 40 °C, while temperature remained below 30 °C and wind speed was less than 5 m/s at a site distant from fires. Strong winds were also observed in extensive fires due to an air attack in World War II in May 1945. This article outlines the meteorological facts in the two cases as examples of fire-induced strong winds.

1. Introduction

The Central Meteorological Observatory of Japan (CMO), which is currently the Japan Meteorological Agency (JMA), lost most of its buildings in extensive fires subsequent to the Great Kanto Earthquake in 1923 (hereafter denoted by "Earthquake"). The CMO was damaged also in a big fire due to an air attack in 1945. In both cases, unusually high temperature was accompanied by strong winds of 15–20 m/s lasting for a few hours or more, without a marked change in wind direction.

The sequence of events in the Earthquake disaster have been documented in the report of Central Meteorological Observatory (1924), including the occurrence of strong winds during the fire. For air attacks during World War II, Hatakeyama (1946) stated that fire whirls and strong winds were commonly experienced under attacks in many cities. He presented the observation data at CMO for some cases of air attacks in Tokyo, and discussed the causal mechanism of strong winds. Further information of the two disasters is obtained from the narrative by Fujiwhara (1926, 1950), who was one of the main staff of the CMO, and also from memoirs compiled by the Japan Meteorological Agency (1975).

The possibility of big fires to drive anomalous winds has received the attention of some researchers in recent years. For example, Coen et al. (2013) stated "It has long been recognized that fires 'create their own weather'. That is, the heat and moisture created by the fire feed back into the atmosphere, creating intense winds that drive the fire's behavior, sometimes overwhelming the effect of ambient winds.". He et al. (2013) wrote "It is less well known, although increasingly shown through anecdotal evidence, that bushfires are not a passive companion of wind, but indeed they interact with winds and can together cause significant damages —". Quintiere, 1993 described a case of field experiment in which an approaching bushfire was accompanied by an increase of wind speed from 5 m/s to 12 m/s, with a nearly constant wind direction. He also mentioned the generation of "firestorms" in extensive fires in cities including those caused by the 1923 Earthquake in Tokyo, and air attacks in World War II in Japan and Germany. However, strong winds in these documents appear to include both fire whirls and continued strong winds, with more emphasis on the former.

The aim of the present article is to describe meteorological facts of the strong winds in the Earthquake case in 1923, and an air attack case in 1945 in Tokyo for the sake of documentation toward further understanding of fire-induced strong winds.

2. Data

The CMO report (Central Meteorological Observatory, 1924) provides hourly data of temperature, wind, and some other quantities at the CMO for a few days during the Earthquake disaster in 1923. Observations of meteorological quantities including temperature, humidity and wind were made hourly, and documented on observation sheets that are available in TIFF images in the JMA. The CMO was located to the northeast of the Imperial Palace in the central area of Tokyo since January 1923, before which it was at Daikancho, about 600 m west (see Figs. 1 and 4 shown later). Hourly temperature and wind data at the

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Fig. 1. Area burned in the Earthquake disaster in Tokyo City (shade). Thin lines indicate the boundary of cities and wards, and think lines indicate rivers, railways, and main roads. A red star indicates the former Army Clothing Depot. After Central Meteorological Observatory, 1924. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Shinagawa branch, which was about 8 km south of CMO, and temperature data at two sites near the northern border of the city, Kagomachi and Nishigahara (Fig. 1), are listed as well. In addition, some images of recording paper at the CMO and Daikancho, where observation equipments were maintained for use in training and testing, are available. For the air attack cases in 1945, observation sheets of the JMA were used to document hourly changes in surface temperature and wind at the CMO.

It is to be noted that observation of wind speed was made using a four-cup anemometer (Robinson anemometer), for 20-min sustained wind in 1923 and 10-min sustained wind in 1945. Since the anemometer factor was changed to 70% of the old one in 1925, this article is based on values that are 0.7 times of the original data for the Earthquake case. No other modification was made to the data, although wind speed observed with a four-cup anemometer is believed to be larger than the value measured with a currently used vane anemometer by the order of 10% (Fujitani, 1990; Kristensen, 1998).

3. The strong winds in the earthquake case

The Earthquake occurred at 1158 JST (0258 UTC) on 1 September 1923 with a magnitude of 7.9. The epicenter is estimated to have been 60–100 km southwest of Tokyo. The fatalities of the Earthquake were over 100,000, most of which were due to fires that lasted for a few days in Tokyo and Yokohama. The population of these cities was 2.2 million and 0.4 million, respectively, according to the census in 1920. The fires were accompanied by many “fire whirls” including those which attacked the former Army Clothing Depot, where 38,000 people are reported to have been killed within an area of 7 ha (Central Meteorological Observatory, 1924; Terada, 1925). The area destroyed by the fire covered the eastern part of the city, and the CMO was located on its southwestern side (Fig. 1).

Fig. 2 shows the surface pressure patterns on the day and the next day of the Earthquake. In the morning of 1 September, a low was located in the southern part of the Sea of Japan. It was a tropical storm that had passed western Japan on the previous day. The storm was accompanied by a cold front, which passed central Japan in the evening. Fig. 3 shows the local wind and pressure fields of central Japan at 1400 and 2200 JST on 1 September. The wind in Tokyo and the environs was southerly with a speed of 6–10 m/s at 1400 JST, while it changed to the northwest by 2200 JST as the cold front passed the area. In can be seen that the wind at 2200 JST was much stronger at Tokyo (13 m/s) than at nearby stations.

Fig. 4 shows the spread of fire with time. A large area to the north of the CMO was burned by 1800 JST, but the CMO was hardly affected because it was on the upwind side of fire under southerly winds. After 1800 JST, the wind changed to the west and gradually to the north, so that the CMO began to be exposed to sparks. According to the observation sheets, 60% of the sky was covered with smoke at 1800 JST, 80% at 1900 JST, and the sky was fully covered with heavy smoke by 2000 JST. The fire spread southeastward along the river and moat on the north of the Imperial Palace, and the CMO was almost surrounded by fires that made the area “as bright as daytime” (Central Meteorological Observatory, 1924) after 2200 JST. Fig. 5 shows the disposition of CMO buildings. The main office was a two-story building, about 50 m wide and 36 m long. It caught fire at 2350 JST, and burned down by 0300 JST on 2 September. Other buildings also burned, except for the library and the anemometer tower.

Fig. 6 shows the time series of hourly temperature and wind at the CMO and the Shinagawa branch. The temperature at the CMO began to

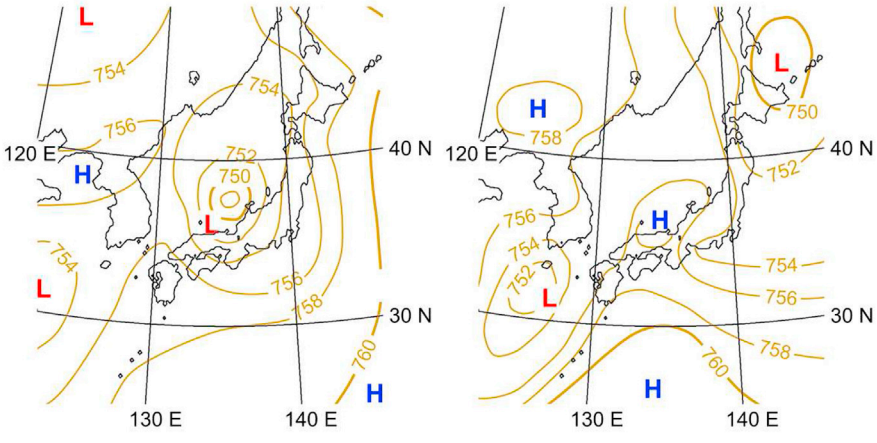

Fig. 2. Surface weather maps at 06 JST on 1 and 2 September 1923. Isobars are every 2 mmHg (760 mmHg = 1013.25 hPa). After Central Meteorological Observatory, 1951.