

# Secular and Recent Variations of Atmospheric Turbidity at Nagasaki

Kimio ARAO

Department of Earth Science, Faculty of Education

Nagasaki University, Nagasaki

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## Abstract

The measurements of direct solar radiation by a silver disc pyrheliometer and of solar radiation at a wavelength of  $0.5 \mu$  by a Volz sunphotometer have been made at Nagasaki since 1971 and 1969, respectively. Two kinds of turbidity coefficient are evaluated from these data and the secular variation of atmospheric turbidity estimated from two sets of direct solar radiation data taken at Nagasaki in the years 1937-38 and 1972-73 is also given. As a result, the atmospheric turbidity at Nagasaki is small compared with those of other cities, but the present amount of aerosols is about 2.3 times as large as that of the prewar days.

## 1. Introduction

Atmospheric turbidity is an important factor not only of the radiation balance of the earth-atmospheric system but also of local air pollution. The secular variation of it over Japan has been studied by Yamamoto *et al.* (1971) and an extension of this study was attempted by the present author (1974). According to these studies, the atmospheric turbidity over Japan steadily increased after 1950 until it reached the maximum in about 1966 and a noticeable decrease appeared in urban cities thereafter. In order to estimate the secular and recent variations of it at Nagasaki from this point of view, the measurements of direct solar radiation by a silver disc pyrheliometer and by a Volz sunphotometer have been made since November 1971 and October 1969, respectively. In this paper, two kinds of turbidity coefficient corresponding to the measurements of these instruments are analyzed and their changes are discussed.

## 2. Locality of observation site

Nagasaki is located in the western part of Kyushu facing on the East China Sea and has a population of about 440,000. Therefore, Nagasaki is characterized as a middle-sized city situated in the west end of the Japanese Islands. Fig. 1 shows

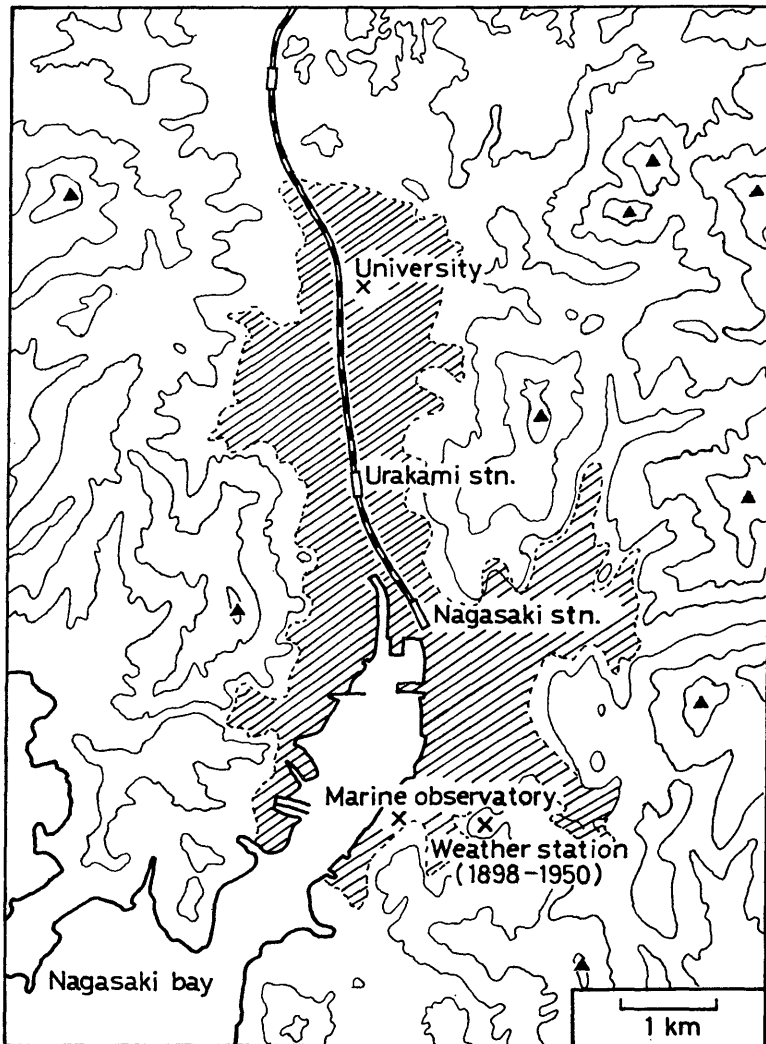


Fig. 1 Map of Nagasaki City. Shaded zone indicates the urban area. The contour line is drawn at intervals of 100 m.

the map of Nagasaki City. Nagasaki University, where the measurements of solar radiation were made recently, is located in the northern part of the city and has an elevation of 15 m. On the other hand, the site of Nagasaki Weather Station where the direct solar radiation measurements had been made in the prewar days is in the south, and its elevation is 131 m. The urban area of this city is surrounded by hills but slightly opened in the south.

### 3. Secular variation of atmospheric turbidity at Nagasaki as estimated from direct solar radiation measurements without filters.

The author have made the measurements of direct solar radiation with a silver disc pyrheliometer at Nagasaki University since November 1971. Since the same

measurements had been made at Nagasaki Weather Station before the World War II, we can compare the turbidity values as a secular variation over a 35 year period. The data used in this investigation consist of two periods; 1937-38 and 1972-73. The records of the former period were made available by Japan Meteorological Agency in Tokyo. The number of days of observation in the former and latter period was 99 and 134, respectively. The turbidity coefficient,  $\beta$ , was evaluated through the method proposed by Yamamoto *et al.* (1968), but the precipitable water was estimated from the surface vapor pressure for both periods. The coefficient,  $\beta$ , used here is equivalent to Angström's turbidity coefficient under the assumption that the size distribution of aerosols obeys the Junge distribution.

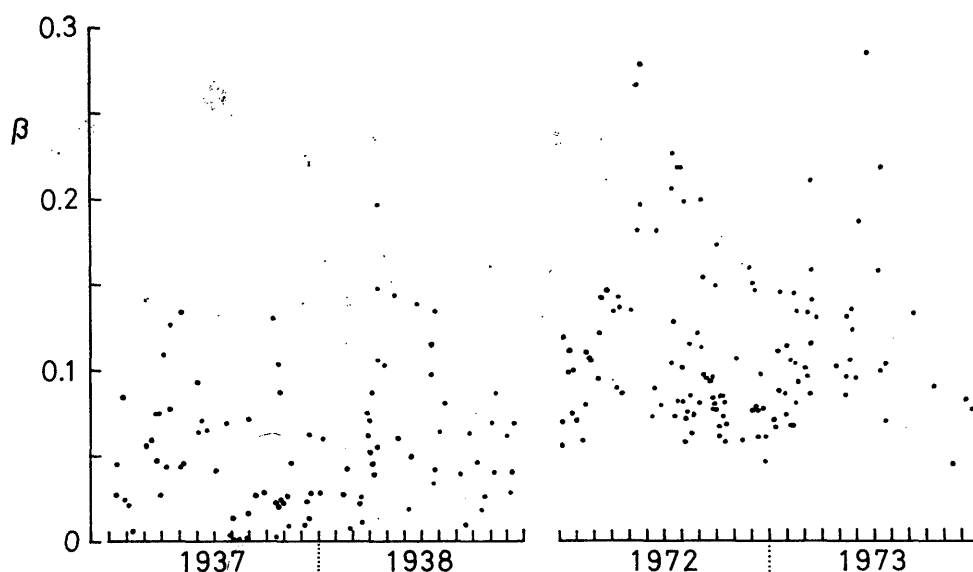


Fig. 2 Daily mean values of the turbidity coefficient,  $\beta$ , at Nagasaki in the two periods.

Fig. 2 shows the variation of daily mean values of  $\beta$  in the two periods. As seen from the figure, the values of  $\beta$  in the prewar days had been nearly in a range between 0.001 and 0.150. On the other hand, those of recent years were in a range between 0.050 and 0.250. It is evident that the values of  $\beta$  less than 0.050, which had appeared very frequently in the former period, could hardly be seen in the latter period.

The annual variations of  $\beta$  in both of the periods are shown in Fig. 3. The seasonal changes in these periods were almost the same except for the month of the highest average turbidity, which appeared in April in the former period and in June in the latter. The biennial mean values of  $\beta$  were 0.050 and 0.122 for the prewar and recent years, respectively. These values are both in lower levels compared with those of other cities in Japan (Arao, 1974). In an attempt to evaluate the increasing rate over a period of 35 years, an altitude correction should be performed. Since the

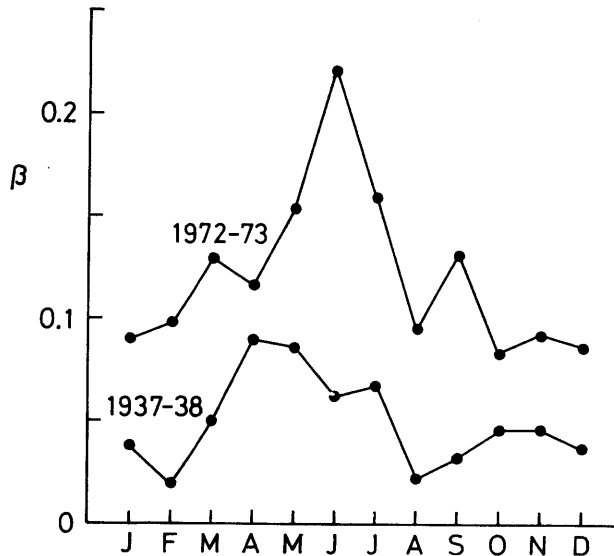


Fig. 3 Annual variations of the turbidity coefficient,  $\beta$ , at Nagasaki in the two periods.

measurements of solar radiation in the recent years were made on the roof of a university building, the difference in altitude between Nagasaki University and Nagasaki Weather Station is about 100 m. Applying the Elterman distribution to the profile of vertical aerosol densities (Elterman, 1964), the figure of 0.050 at the weather station comes to 0.054 at the level of the university. Accordingly, it is inferred that the present amount of aerosols at Nagasaki is 2.3 times as large as that of the prewar days.

#### 4. Recent variation of atmospheric turbidity at Nagasaki as estimated from the measurements of a Volz sunphotometer.

The measurements of solar radiation at  $0.5 \mu$  by a Volz sunphotometer have been also made at Nagasaki University since October 1969. This instrument was developed by Volz (1959) for the purpose of estimating the so-called decadic turbidity coefficient,  $B$ , which was introduced by Schüepp (1949). The same measurements were only made by Fujimoto (1966) in Japan but extensive turbidity networks using the instrument have been established over the United States (Flowers *et al.*, 1969). Although the Volz sunphotometry is attended with some errors as reported recently by Laulainen and Taylor (1974), it seems useful to obtain a broad view of turbidity change if treated carefully.

In practice, the value of  $B$  was evaluated after the following corrections were made.

- (1) Correction of air mass; Air mass values obtained from a diopter which is attached to the side of the instrument were checked by calculated values from local times of observation, geographic coordinates and the known celestial coordinates of the sun, and then a regression curve was formulated.

- (2) Correction of the meter deflection; Since the fact that some departures from the linearity occur for higher deflections was informed by Volz (1972), this correction was made by checking the meter deflection by a Epply dual wavelength sunphotometer. The result of this check is shown in Fig. 4. Consequently, the meter

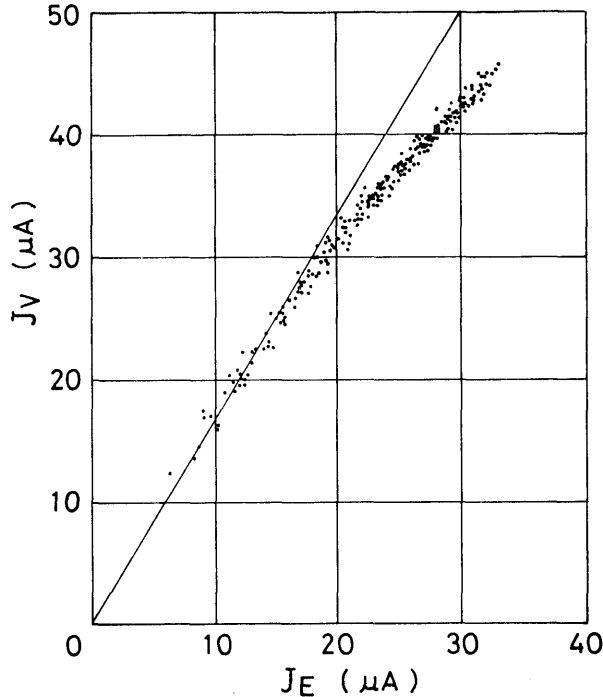


Fig. 4 Relation between the meter deflection of the Volz sunphotometer ( $J_V$ ) and that of the Epply dual wavelength sunphotometer at  $0.5\mu$  ( $J_E$ ). The solid line indicates the linearity applied in this study.

deflection which would be expected outside the atmosphere was also revised on the basis of this result.

- (3) Correction of the sun-earth distance; This was performed not by season but by day.

The evaluation of  $B$  was performed by the use of a computer so as to avoid the errors due to diagrammatic readings. The number of days of observation in each of the years was in a range between 100 and 150.

Fig. 5 shows the time series of the monthly mean values of  $B$  in the recent four years. The annual mean values of it were in a level of 0.065 and any marked change could not be seen during the years. Since the difference between the annual mean values of  $\beta$  and  $B$  depends on their definitions, the spectral measurements of direct solar radiation should be desired to relate them exactly. Hence, only the change of  $B$  in the recent years would be noteworthy in this study. Together with the result obtained in the above section, the fact that atmospheric turbidity at Nagasaki kept the same level during the recent four years would lead a conclusive remark that Nagasaki has been comparatively free from the air pollution due to aerosols, because

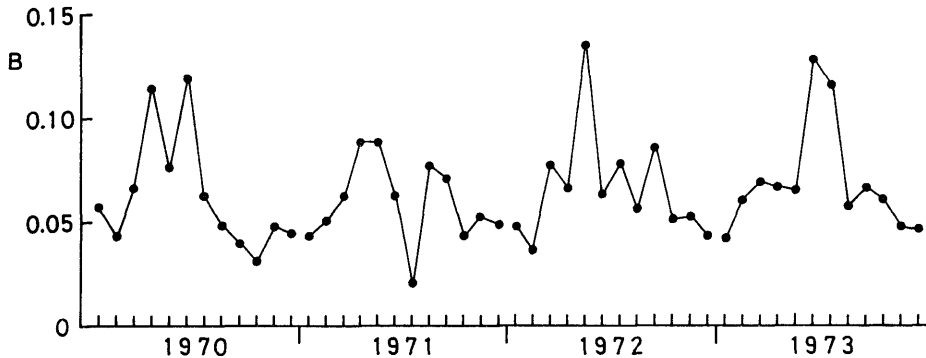


Fig. 5 Time series of the monthly mean values of the decadic turbidity coefficient, B, at Nagasaki.

the atmospheric turbidity in urban cities in Japan showed a noticeable decrease in the same years.

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