Profiles of Wind and Temperature in the Lowest 250 Meters in Tokyo

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Profiles of Wind and Temperature in the Lowest 250 Meters in Tokyo

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Abstract

Wind and temperature profiles up to 253 m observed at the Tokyo Tower are analysed. The profile due to the similarity theory explains the observed results up to about 200 m height above the ground. It is noted that the friction velocity u_* as well as the roughness parameter z_0 are large in the large city. It is concluded that the thickness of the layer of constant shearing stress is greater over the rough surface than over the smooth surface.

1. Introduction

Using the similarity theory of Monin and Obukhov (1954), many workers as Ellison (1957), Yamamoto (1959), Businger (1959), and Panofsky, Blackadar and McVehil (1960) developed the theories of turbulent transfer near the ground. In their theories, shearing stress τ is regarded as independent of height above the ground. Monin and Obukhov (1954) showed that the thickness of the layer of constant shearing stress is about 50 m in natural circumstances. Therefore, the applicability of the theories of Ellison, Yamamoto, Businger, and Panofsky et al. seems to be in the range of about 50 meters from the ground. In order to examine the theoretical prospect of Monin and Obukhov, profiles of wind and temperature to higher levels in Tokyo are analysed.

2. Results

Temperature, wind speed and wind direction at several heights up to 253 m have been observed continually on the Tokyo Tower at Minato-ku, Tokyo, by the co-operation of the Tokyo District Meteorological Observatory, the Electric Power Development Co. Ltd., and the Japan Radio Tower Co. Ltd. Temperature and wind speed have been measured automatically by the specially designed mercury thermometers and three-cup anemometers, respectively. Mean values of these quantities over ten minutes are analysed in the present study. From observations during 1960 and 1961, 244 logarismic wind profiles were obtained, by which the roughness parameter z_0 and mean friction velocity $\bar{u}_*$ were found to be $z_0=165\pm20$ cm and $\bar{u}_*=59$ cm sec^{-1}. From the observations in 1963, wind and temperature profiles in extremely unstable and near-isothermal (or extremely stable in potential temperature) conditions were examined, and illustrated in Fig. 1, with the profiles derived from the theory of

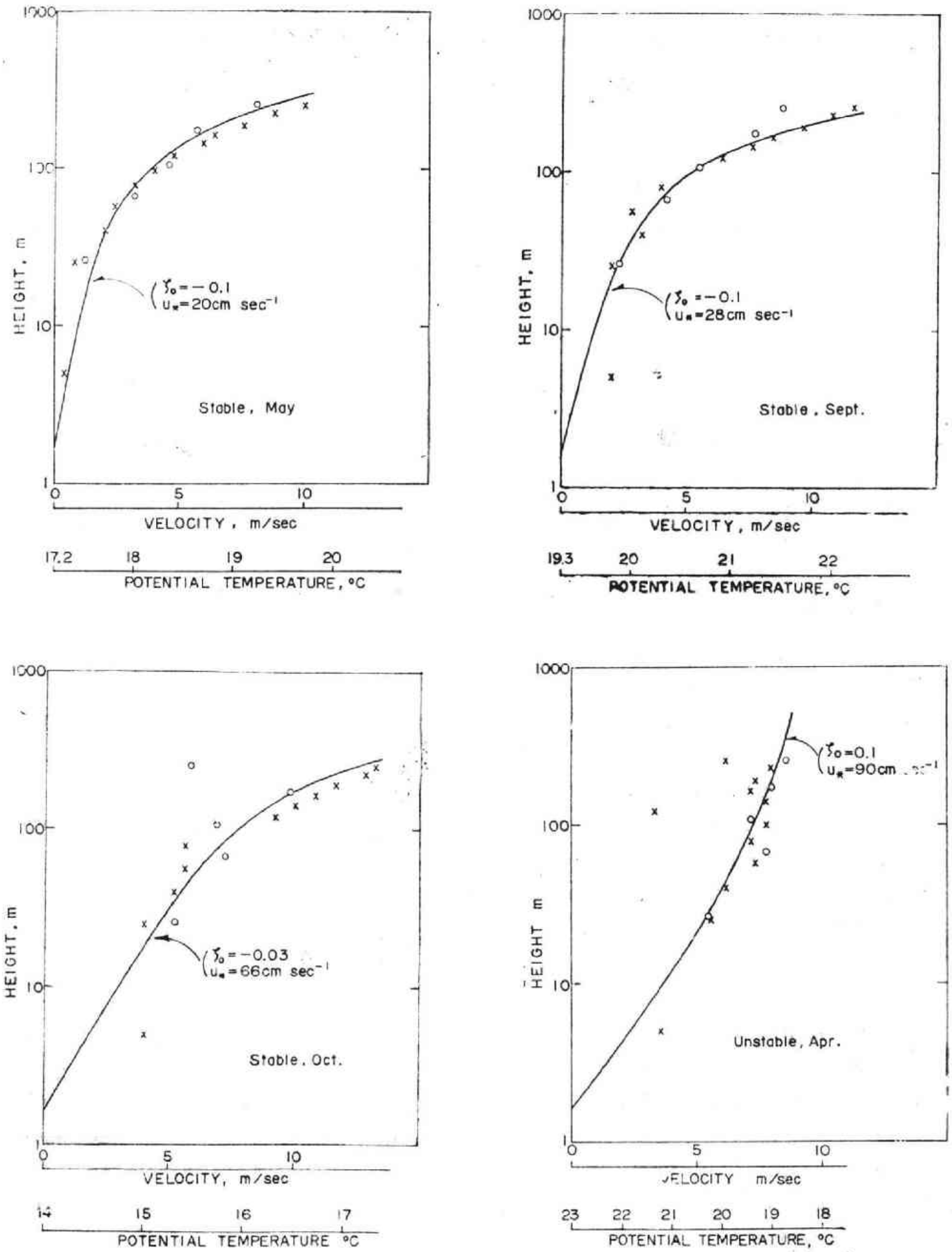
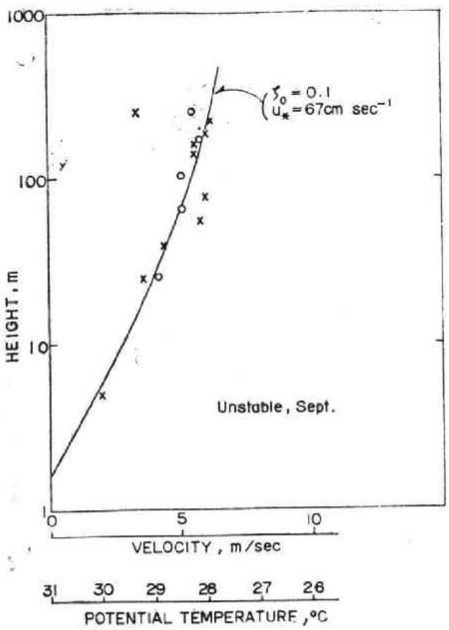


Fig. 1 Profiles of wind speed (circle mark) and temperature (cross mark) observed at Tokyo Tower, and the curve calculated from the theory of Yamamoto.



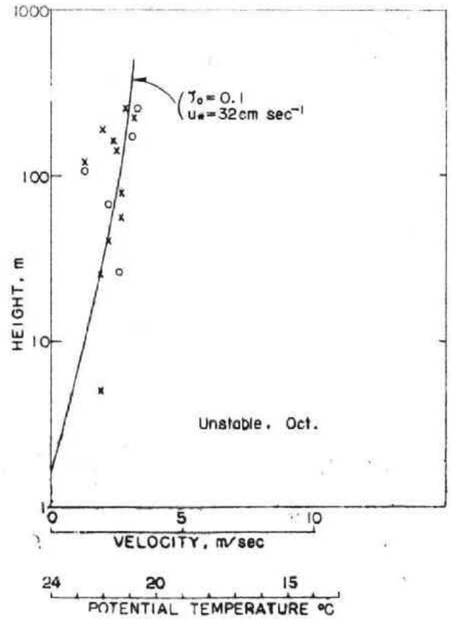


Fig. 1 (continued)

Yamamoto (1959). Coincidences in observed and theoretical profiles in Fig. 1 are generally good, except a few observations such as the velocity at 253 m in stable conditions, and the temperature at 120 m and 253 m in unstable conditions. Fig. 1 is concerned with the values averaged over the samples whose frequency of occurrence is shown in Table 1.

Table 1

		Frequency of occurrence	ζ_0	u_*
Stable	May	3	−0.1	20 cm/sec
	Sept.	5	−0.1	28
	Oct.	4	−0.03	66
Unstable	Apr.	8	0.1	90
	Sept.	4	0.1	67
	Oct.	6	0.1	32

The value of the friction velocity u_* $(=(\tau/\rho)^{1/2}$, τ being the shearing stress and ρ the density of air) corresponding to each case in Fig. 1 is given in Table 1, with that of the stability parameter ζ_0 defined by Yamamoto (1959). The values of u_* shown in Table 1 seem to be greater than those estimated on a smoother surface. For instance, the values of u_* estimated from observations by Rider on the grass surface with $z_0=0.48$ cm were within the range of $4.6\sim56.3$ cm sec^{-1}, (See Yamamoto, 1959.) as compared to the present values of $20\sim90$ cm sec^{-1} in Tokyo. Monin and Obukhov (1954) showed that the thickness of the layer of constant shearing stress is proportional to the square of the friction velocity. The fact shown in Fig. 1 that the observed profiles agree with the theoretical ones beyond 50 m on the rough surface supports the theoretical prospect of Monin and Obukhov at least qualitatively.

It should be noted that the profiles such as shown in Fig. 1 occurred only in some suitable meteorological conditions. Most of extremely unstable conditions up to 253 m occurred in spring or autumn when Japan was covered by an anticyclone. Both extremely stable and unstable conditions are difficult to occur in Tokyo district in winter, because of the prevailing strong monsoon wind. In summer, on the other hand, local effects such as land and sea breezes superimpose on the general wind system. As a result uniform stability conditions do not generally attain up to 250 m and wind and temperature profiles do not obey the theoretical profiles. Although, the present discussion refers only to extremely unstable and extremely stable conditions which appear in spring and autumn, moderate stability conditions are found the year round, in which observed profiles agree with theoretical ones.

Conclusion:

According to the present analysis, the transfer theory based on the hypothesis of constant shearing stress is found to be applicable up to about 200 m above the ground in large cities, in the case of uniform stability.

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