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Profiles of mean wind speeds and vertical turbulence intensities measured at seashore and two inland sites using Doppler sodars

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Abstract

The authors' group has been conducting full-scale measurements of wind velocities with Doppler sodars. It is very important to accurately assess the profiles of mean wind speeds and turbulence intensities in relation to terrain roughness. In this study, the profiles were evaluated for all data measured over a long period at a seashore and two inland sites. It is confirmed that for strong winds the profiles can be approximated by a single power law at altitudes between 50 and 340 m. The power law exponents of the mean wind speed profiles are approximately 0.1 for wind from the sea and 0.2–0.3 for wind blown over land. Those of the turbulence intensity profiles are approximately 0 and −0.2 to 0.4, respectively.

Keywords: Doppler sodar; Mean wind speed profile; Turbulence intensity profile; Terrain roughness; Natural wind observation

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1. Introduction

Information on wind speed profiles is necessary to solve various problems in wind engineering. There have been many papers on wind speed profiles, mainly for synoptic winds, e.g. Deaves and Harris (1978), Peil and Nolle (1992) and Cook (1997), and also on thunderstorms, e.g. Choi (2000) and Chen and Letchford (2005). However, only a few full-scale data are available on wind speed profiles up to a high altitude, say 500 m or more. One useful tool for investigating wind characteristics at high altitudes is Doppler sodars. Thomas and Vogt (1993), Vogt and Thomas (1995) and Ito et al. (1996) compare wind speed data measured by Doppler sodars with those measured by anemometers mounted on towers, and checked the validity of Doppler sodars. Hayashida et al. (1996) used Doppler radars and Powell et al. (1999) used GPS drop sondes to measure wind characteristics near eye walls of tropical cyclones at higher altitudes than 2000 m.

The authors conducted simultaneous wind observations at a seashore in Hiratsuka city, Kanagawa prefecture ('Seashore', hereafter) and at a northern residential area of Hiratsuka city ('Res-A'), or at a southern residential area of Machida city, Tokyo ('Res-B') in the southern Kanto plain in Japan, using two sets of mono-static Doppler sodars. Wind data were obtained over a long period. The longitudinal mean wind speed profiles in the same storms were compared for two pairs of sites to study the variation in longitudinal mean wind speed as it is affected by inland terrain roughness in Tamura et al. (1999, 2001a, b). In this paper, profiles of mean wind speeds and vertical turbulence intensities are evaluated for data categorized into groups based on mean wind speed or wind direction to study the characteristics of strong wind at each measuring site. Moreover, the effects of terrain roughness are discussed through comparison of these characteristics at the three sites.

2. Measured data and data processing method

The three observation sites are in the southern Kanto plain in Japan, as shown in Fig. 1. The observation site 'Seashore' is 100 m from the beach line. 'Seashore', 'Res-A' and 'Res-B' are located on a nearly SSW-NNE line and are 8 and 15 km apart. In the area from 'Seashore' to 'Res-A', there are no large town centers, but flat condensed residential areas with many low-rise houses and factories and some middle-rise apartments, and agricultural sites are scattered among them. The northern area of 'Res-A' comprises some undulations and the altitude gradually grows higher toward 'Res-B'. In the vicinity of 'Res-B', there are undulations comprising small-scale hills with altitudes of 60–70 m, including one with an altitude of about 100 m in its northern area.

The observation periods were about 6300 h from 7th February, 1996 until 11th November, 1997 at "Seashore", about 2300 h from 24th August, 1996 until 18th December, 1997 at "Res-A" and about 1450 hrs from 7th February, 1996 until 30th July, 1996 at "Res-B". In this study, the characteristics of natural wind were investigated at each site using only daytime data from 8:00 to 18:00. Three typhoons, T9617, T9707 and T9708, passed within 150 km of the sites during the measurement period from 1996 to 1997. However, the highest reference mean wind speeds measured at 'Seashore' were $U_R = 17.2$, 11.4, 14.9 m/s for Typhoons T9617, T9707 and T9708, respectively, and typhoon winds near eye walls were not included. Therefore, almost all the data were of non-typhoon winds, and the results should be basically treated as profiles for synoptic winds.