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ON THE METEOROLOGICAL TOWER AND ITS OBSERVATIONAL SYSTEM AT TSUKUBA SCIENCE CITY

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気象研究所技術報告

第3号

筑波研究学園都市に新設された気象観測用鉄塔施設

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概 要

筑波研究学園都市の南部にある気象研究所の敷地内に高さ213 mの気象観測用鉄塔が建設された。この気象観測用鉄塔は，大気境界層下部の気象要素の平均的プロファイルと大気乱流に関する乱流統計量を連続して観測できるsystemを持っているもので，気象観測塔としては世界的にもユニークなものである。

塔の構造は，一辺が4 mの正三角形で支線式open typeであり，塔の端から6 m突き出た水平支柱の先端に測定器が設置できるようになっている。

水平支柱は6高度(200, 150, 100, 50, 25および10 m)にそれぞれ120°の角度で3本ずつ設置されている。平均的気象要素の測定には，エーロベン型風向風速計，白金抵抗温度計，容量型湿度計が設置されている。風向風速については塔体の影響を避けるため，鉄塔頂部に取りつけられた風向風速計の風向信号を使って，塔体の影響の最も小さいと考えられる水平支柱に設置された発信器を選択する構造になっている。一方，温度，湿度については，3本のうちの2本に同型の測定器を設置して，同時記録をとることになっている。

乱流統計量の測定については，風向風速，気温変動については新しく開発された3次元超音波風速温度計を，湿度変動については銅ーコンスタンタン熱電対乾湿計を使用した。

超音波風速計による風向風速については，平均値の測定の場合と同様に鉄塔の頂部に設置した2次元超音波風向風速計の出力により，3個のプローブのうちの1個を選択するようになっている。さらにこれらの測定器を使って，乱流統計量(平均値，標準偏差，相関係数等)を算定するための処理装置が設置されている。

最後にこのsystemを使って実施した実際の観測例について述べるとともに今後の問題点についてもふれる。

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気象研究所技術報告 第3号 1979

On the Meteorological Tower and Its Observational System at Tsukuba Science City

by

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Abstract

In order to investigate the structure of the planetary boundary layer and the interaction between the planetary boundary layer and larger scale of meteorological phenomena, the construction of a meteorological research tower has been planned.

The observational site is a part of Kanto plain and about 20km south from the nearest foothills of the Mt. Tsukuba whose height is 876 m above the sea level and about 10 km west from the Lake Kasumigaura and so that the planetary boundary layer will be largely unaffected topographycally.

The centered area near the tower within a radius 150 m is covered with short lawn and the outside area is unarranged ground with pine forests in places whose height are about 10 m at most.

The Meteorological Research Institute's main building of about 40 m height is about 300 m north east of the tower and then, in the case of northeasterly wind direction, some error caused by this building may occur.

The tower is a guyed open lattice design 213 m tall. The structure is galvanized steel with the three legs spaced 4 m apart as illustrated in Fig. 3.1 in this paper. In the center of the tower a three men elevator with maximum carring capacity of 250 kg can go up and down by a man or automatically from 10 m to the 200m

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level of the tower as well as ladder.

At six levels (10, 25, 50, 100, 150 and 200 m) there are a landing and three booms at angle of 120 each other to which instruments will be attached. The boom's length is 6 m from the edge of the tower and its length was determined by the experimental results in wind tunnel as shown in this paper. In the case of repairing or adjustment of the instruments, we can slide only the stand by hand as shown in Fig. 3.4 in this paper. In addition to these six levels, there are many landings for the temporary observations every 15 m height.

A sub-tower whose height is 25 m with four legs spaced 2 m apart has been constructed about 300 m north part from the main tower in order to investigate the surface boundary layer specially. Its tower has a movable carriage for loading instruments, which can go up and down, and stop at every 1 m height during a request duration.

The instruments of the tower are devided two groups according to the instrument's response, one group is to measure the mean profiles of the meteorological elements, the other, to measure the fluctuations of meteorological elements and tabulated in Table 1.

(a) The slow response instrumentation

The specifications of the slow response instrumentation are shown in Table 2. One of the three anemometer's sensor at each level, which is considered to be less influenced by the shadow of the tower, can be selected by the signal of the wind direction by the anemometer at the top of the tower. The sensors for the measurement of air temperature and humidity are put in together a same radiation screen ventilated at about 7 m/sec and there are two sensors at same level to check the tower effects.

(b) The high response instrumentation

The specifications of the high response instrumentation are shown in Table 3 and the characteristics of the each instrument are described as below briefly.

(i) Three dimensional sonic anemometer-thermometer

The new developed one has the following four main benefits comparing with a traditional one:

(1) "One head" system has no mechanism zero shift and the simple shape has few shadow effect on wind field.

(2) For the measurement of wind speed, there is no effect of atmospheric conditions such as air temperature, humidity and atmospheric pressure.

(3) The calculation of the sonic pulse time difference is carried out digitally and then the accuracy is elevated still more.

(4) In order to check the attitude of the probe all the time, there is a clinometer in the pre-amplifier box beneath the probe.

One of the three sonic anemometer's sensors at each level can be selected by the signal of the wind direction obtained by the two dimensional sonic anemometer at the top of the tower.

(ii) Thermocouple psychrometer

The copper-constantan thermocouple psychrometer whose diameter is 80 μm is used to measure humidity fluctuations and water from a water tank on the each floor is supplied automatically at every constant time interval (20 min - 12 hours). The transistor thermometer is sealded in the sensor unit for the measurement of a temperature of cold point.

Data acquisition systems are also divided two groups according to the instruments' response as mentioned just before.

(a) The data acquisition system for slow response instrumentation

The all signals from slow response instruments are recorded on the magnetic tapes and printed out on the chart digitally at every one hour as well as the analog chart monitally. The block diagram of the observational system and data acquisition system is shown in Fig. 4.22.

(b) The data acquisition system for high response instrumentation

In the study of atmospheric turbulence in the planetary boundary layer, the main three properties such as means, standard deviations of meteorological elements and covariance between them are at least necessary. These quantities can be easily evaluated by the hybrid analog data acquisition system.

The input signals from the sensors are pre-processed by the component analog computing circuit with a low pass filter whose cut off frequency is 0.0073 Hz (= correspond to about 60 sec moving average) in the output side. Then the signals are sampled by slow speed scanner at the sampling rate of one or two times per minute per channel and recorded on the magnetic tapes by digital form and finally integrated by a computer.

The analog computing unit are listed in Table 4 and the block diagram of the observational system for high response instruments is shown in Fig. 4.23. The method to estimate the statistical quantities of atmospheric turbulence by using same kind of analog unit is discussed in details in this paper.

Some test experiments of using this system were carried out in various meteorological conditions. The full papers on each experiment will be published in near future and then the only preliminary results on some topics described below are discussed briefly in this paper.

(i) Time variations of meteorological parameters during outbreak of the surface inversion

(ii) The height dependency of the sensible heat flux

(iii) The time variation of momentum flux

(iv) Spectral scale of vertical velocity

Table 1. Instrumentation and measurement height

Height	Item	Instrumentation	Remarks
213 m	Mean wind direction and speed	Aerovane type anemometer (FF-3R)	
		Aerovane type anemometer (MV-110)	*1
	Mean air temperature	Pt resistance thermometer	
	Mean humidity	Capacitance hygrometer	
	Wind fluctuation	Two dimensional sonic anemometer (DA-200)	*1
200 m	Mean wind direction and speed	Aerovane type anemometer (MV-110)	*2
	Mean air temperature	Pt resistance thermometer	*3
	Mean humidity	Capacitance hygrometer	*3
	Wind and temperature fluctuations	Three dimensional sonic anemometer thermometer (DAT-300)	*2
	Dry and wet bulb temperature fluctuations	Copper-constantan thermocouple psychrometer	
150	Same as 200 m height		
100	"		
50	"		
25	"		
10	"		

*1 : The wind direction signal can be used to select one of three same type anemometer's sensors at the other heights.

*2 : Three sensors at one level.

*3 : Two sensors at one level.

Table 2. Specifications of "slow response" instrumentation

Measuring Properties	Sensor	Registration	Remarks
Wind speed and Direction	Aerovane Type Anemometer MV-110 & FF-3R Response distance: 4.0m(MV-110) 6.0m(FF-3R) Starting speed: 0.4m/s(MV-110) 2.0m/s(FF-3R)	Range of measurement: 0.4 ~ 10m/s, 0.4 ~ 25m/s, 0.4 ~ 60m/s (MV-110) 2.0 ~ 35m/s, 2.0 ~ 70m/s, 2.0 ~ 90m/s (FF-3R) Working accuracy: 0.3m/s (<10m/s), 3 % (>10m/s) (MV-110) 0.5m/s (<10m/s), 5 % (>10m/s) (FF-3R) Chart speed: 30mm/h, 3600mm/h	Measuring height: FF-3R : 213 m MV-110: 213, 200, 150, 100, 50, 25, 10 m One of three sensors at same level can be selected by the signal of wind direction of the anemometer at the top of the tower.
Air Temperature	100 Ω resistance thermometer in radiation screen ventilated at 7m/s Response time: about 120sec	Range of measurement: -20°C ~ 40°C Working accuracy: ±0.3°C Chart speed: 15mm/h, 30mm/h, 60mm/h	Measuring height: 213, 200, 150, 100, 50, 25, 10 m
Relative Humidity	Humicup sensor in radiation screen ventilated at 7m/s (together with a resistance thermometer)	Range of measurement: 0 - 100 % Working accuracy: ±3 % Chart speed: 15mm/h, 30mm/h, 60mm/h	Two sensors at same level except 213 m

Table 3. Specifications of "high response" instrumentation

Measuring Properties	Sensors	Registration	Remarks
Wind direction & Speed	Two dimensional sonic anemometer	Range of measurement: 1: 0 ~ ±10m/s, 2: 0 ~ ±20m/s 3: 0 ~ ±30m/s Working accuracy: ±1 % Resolution: 0.5 cm/s Output: 0 ~ ±1V full scale Operating temp.: Main unit: -10 ~ 40°C Probe & junction: -20 ~ 50°C	Measuring height: 213 m Two dimensional one is used to select the one of three 3 dimensional sonic ones at same level as well as to measure wind speed and wind direction at the top of the tower.
	Three dimensional sonic anemometer	Range of measurement: Horiz. Vertical 1 0 ~ ±5m/s 0 ~ ±1m/s 2 0 ~ ±10m/s 0 ~ ±2m/s 3 0 ~ ±25m/s 0 ~ ±5m/s 4 0 ~ ±50m/s 0 ~ ±10m/s Other registration is same as the two dimensional one	Measuring height: 200, 150, 100, 50, 25, 10 m. Three sensors at same level.
Air Temperature	Sonic thermometer	Range of measurement: -10 ~ 40°C Fluctuation ±5°C Working accuracy: 1 % Resolution: 0.025°C	
Dry and wet bulb Temperature	Thermocouple psychrometer	Measuring mode: 80μm copper-constantan thermocouple without a radiation screen and ventilation Water supply: 20min. ~ 12h Capacity of a tank: 4 ℓ Operating temp.: -10 ~ 40°C	Measuring height: 200, 150, 100, 50, 25, 10 m.

Table 4. Specifications of analog computing units

Unit name	Function	Specifications
Mean meter	to obtain a mean value	It is the active low pass filter whose cutoff frequency is 0.0073 Hz. The output signal from this unit is correspond to the 60 sec moving average to input signal.
Sigma meter	to obtain a covariance deviation	The fluctuations in the frequency range from 0.0073 Hz to 10 Hz are squared and then the output signals are filtered by the active low pass filter whose cutoff frequency is 0.0073 Hz.
Flux meter	to obtain a covariance between two variables	Two signals in the frequency range from 0.0073 Hz to 10 Hz are multiplied instantaneously and then the output signals are filtered by the active low pass filter whose cutoff frequency is 0.0073 Hz.
Vector synthesizer	to obtain scalar wind speed and direction	Two horizontal signals are synthesized after being modulated by sine and cosine waves