Studies and Developments of Meteorological Instruments for Cloud Physics and Micrometeorology (III)

—New Instrument for Measurement of Wind Direction in Light Air*—

by

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Abstract

A new instrument was designed for measuring the wind direction in light air. Four hot wire sensors are placed each at one of the cardinal points based on the principle of the hot wire anemometer. The wind direction is indicated as one of the eight directions. The instrument can be used for wind speeds down to 15 cm/sec. Some preliminary measurements using this instrument were made in connection with cloud physical observation of river fog.

1. Introduction

Observation of light wind is important in many problems associated with micrometeorology and cloud physics. In general, a wind vane has been used for the measurement of wind direction. It is, however, very difficult to make the vane free from the effects of friction and moment of inertia, even though we make it as light as possible and improve on its shape. For example, NEMOTO (1957) proposes the use of a fine and light rod supported vertically instead of the vane. The rod has a ping-pong ball on the head and inclines toward the lee in response to the pressure which acts on the ball, and the wind direction is picked out electrically.

There are, however, inevitable limits to the sensibility and rapidity of response of the instruments so long as they are constructed mechanically.

Recently SAKAGAMI (1967) developed a new type of instrument for measuring wind direction. It is based on measuring the thermal wake formed in the lee of a heated body. This instrument is much better than others because it does not contain any mechanical parts.

Another type of instrument which does not contain any mechanical system has been developed by the author and is to be described below.

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2. Description of the instrument

The schematic illustrations of the instrument are shown in Fig. 1a and Fig. 1b. Fig. 1a shows the frame of the instrument. Two circular brims I and II, about 3 cm in width, are fixed to both ends of pipe E, about 6 cm long and 3 cm on the inside. Its external appearance is, briefly, a hand-drum. The frame is partitioned into four quadrant sections with screens A, B, C and D which are supported by the two brims

Fig. 1a. The schematic illustration of the instrument.

Fig. 1b. The top view of the instrument from above.

outside pipe E. The width of the screens is slightly smaller than that of the brims for the reason to be described later. The frame is made of acrylic. Each of the four fine platinum wires, all $50\ \mu$ in diameter and 1 cm long, P_1 , P_2 , P_3 and P_4 is placed in the middle of the two brims in each section, and their both ends connected with supporters of fine wire, 0.1 cm in diameter, which are installed on the two brims opposite to each other. The symmetrical arrangement of the four platinum wires is seen in Fig. 1b, which shows the instrument as looked at downward from above.

The power supplied to the two ends of the platinum wire is 2–3 volts and it is used as a wind sensor based on the principle of the hot-wire anemometer. Each of the two pairs of hot wire P_1 – P_3 and P_2 – P_4 composes two arms of each Wheastone bridge. Each output of the two Wheastone bridges is recorded on each of the two oscillographs, and adjusted to zero when the hot wires are sheltered from the wind. The sensing part shown in Fig. 1a is firmly mounted within the acrylic pipe which has four openings of about 0.5 cm in diameter on its surface in order that the hot wire facing the wind way may be directly exposed to the wind. Crevices were made between each screen and the inner wall of the pipe so that the air coming in through the opening may escape. If the crevices are too broad the air stream coming in at the opening affects the other platinum wires of both sides and decrease the accuracy of the instrument. We believe by experience that the proper width of the crevice is 0.5 mm or less.

Fig. 2. Wind directions and corresponding records.

If before observations are made one of the platinum wires, for example P_1 , is directed toward the north, then the others, P_2 , P_3 and P_4 , are directed toward the west, the south and the east, respectively. Two outputs of the bridges are adjusted to zero as mentioned above. If the north wind blows, the balance of the bridge containing P_1 and P_3 is lost and the output deflects the record of the oscillograph from zero. Of course, the output of the bridge containing P_2 - P_4 remains zero in this case. On the contrary, the south wind produces the opposite deflection of the record. The bridge containing P_2 - P_4 shows similar behavior to the east or west wind. When the northeast wind blows, one bridge indicates the north the other the east. We can, therefore, obtain the wind direction in terms of eight directions by a combination of two such records.

The relationship between wind direction and corresponding deflection of the record is schematically shown in Fig. 2. The photograph of the instrument is shown in Fig. 3. This instrument has also the thermistor anemometer at the center of Pipe E, and measure the wind speed simultaneously.

Fig. 3. Photograph of the instrument equipped with a thermistor anemometer through its center.

Fig. 4. Reproduction of the actual record obtained by the instrument. The records give, from the top, the time variations of the wind speed registered by the thermistor anemometer attached to the instrument, the same by the hot wire anemometer, the actual records of wind direction by two bridges and the records modified by the pulse circuit which is able to record wind direction for wind speeds larger than about 20 cm/sec.

An actual record obtained by the instrument is shown in Fig. 4. The instrument was placed at the center of an office room whose window and door at the south and west side were kept open. In order to obtain the instantaneous wind speed at the same time a hot wire anemometer was operated close by the instrument parallel to the thermistor anemometer which was attached in the instrument.

The upper four graphs in Fig. 4 show the time variations of wind speed by thermistor and hot-wire anemometer and reproduce the actual record of the two bridges, respectively, and the two curves at bottom are the records modified through the pulse circuit, which is able to record the wind direction for wind speeds larger than about 20 cm/sec.

The confidence of the instrument is examined by comparing it with the drift of smoke in light air or a calm and with an aero-vane in a breeze, and their results are found sufficiently to agree with each other.

3. Results

Test observations of wind by the instrument were made at Iida city, Nagano Prefecture, on 8th of October 1967, in a cloud physical and micrometeorological sur-

Fig. 5. Observation result showing the characteristic behavior of the air masses in light air.

vey of river fogs. Some results are shown in Fig. 5. In this figure, the mean wind direction over a minute are shown by small arrows at the bottom, and the duration for the same wind direction is distinguished by vertical dotted line and represented by heavy arrows. The wind speed and the dry and wet temperatures were measured by a thermistor anemometer and thermistor thermometer assembly whose response times were about a few seconds.

The figure shows that the direction of the light air alternate between east to west and west to east at intervals of about 10 minutes apart and the wind speed at the transition stage being 15 cm/sec or less and the wind direction north or south.

The time variation of wind speed and temperature show periodical changes which correspond completely to those of wind direction.

The results will make us interested in the behavior of air masses in light air. The detailed results and discussions will be described in a subsequent paper. Another fact which shows the relationship among wind speed, wind direction and the occurrence of the fog will be described in the following. The observation point is covered with fogs soon after above-mentioned time. Fig. 6 shows the relationship among them. In Fig. 6, the cloud physical characteristics of the fogs and shown in addition to the observation elements in Fig. 5. The open histograms at the bottom show the size distribution in terms of number per cc in the size interval of 5μ and the shaded ones the corresponding water contents (arbitrary unit).

The fogs covered the observation point twice. One of them occurred successively from 0638JST to 0715JST, another one 0735JST to 0815JST. In both cases the wind speed increased rapidly and the wind direction changed to the south or to the southeast. The Tenryu river and its tributary water run on the southeast side of the observation point. It may be thought from this fact that the fogs were not formed near the observation point but formed over the river and drifted into the area surrounding the observation point.

The first fog, moreover, immediately began to disperse without the deformation of the size distributions when the wind direction changed to the east. On the contrary, the concentration of the fog considerably decreased for the second one while

Fig. 6. Observation result showing the relationship among wind direction, wind speed and the occurrence of fog at the observation site.

the wind direction did not change. These facts may indicate that the former was pushed back by the easterly wind but the latter was dispersed by the radiation after sunrises.

It will be sure that the cloud physical properties of fog and cloud, for example, the size spectrum is mainly determined by their dynamical fine structure. Therefore, it is necessary for understanding the results of cloud physical observation to carry out the micrometeorological observation at the same time.

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雲物理および微気象測器の研究ならびにその開発 (Ⅲ)

——新しい微風向計の開発——

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熱線風速計を利用した微風向計を開発し、野外観測に使用した。測定可能な風速は約 15cm 以上である。

構造は第 1 図(a)(b)に示す如く、直径 3cm、長さ 6cm の中空円筒の上下に巾 3cm のドーナツ状の「ツバ」を付け鼓形にする。これを仕切板 A, B, C, D, で四象限に区切り、夫々の象限中央なるべく外側に、太さ 50μ 、長さ約 1cm の白金線 P_1, P_2, P_3, P_4 をたて、その両端は太さ 0.1cm の真鍮棒で支持する。第 1 図(b)はこの俯瞰図で、白金線及び仕切板の配列の様子を示したものである。

これらの白金線の両端は 2~3 Volts の電圧をかけ熱線風速計と同じ働きをさせる、更に相対する白金線 P_1-P_3, P_2-P_4 を組込んだ 2 組の Wheatstone bridge を作り、これら bridge の output を夫々別々に osciograph に記録させる。この装置全体は内径 9cm、長さ 6cm の太い Pipe でピッタリとおおう。但しこの pipe には白金線の位置する部分に直径 0.5cm ほどの小穴をあけ、風向に面した白金線に直接風が当たるようにしてある。又この風の逃げ道として仕切板と pipe の間に 0.5mm 程度のごく細い隙間を開けておく。今任意の白金線例へば P_1 を真北に向けると、 P_2, P_3, P_4 は西、南、東、を向いて配列される。

測定の始めに風を完全に遮断し 2 つの bridge を夫々平衡にしておく、これに北風が吹くと P_1-P_3 を含む bridge の平衡が崩れ、記録器は一方向に振れる、この振れは南風に対しては逆になる、この間もう一方の bridge は平衡を保っていることは勿論である。東、西風に対しては P_2-P_4 を含む bridge が同じ様に作用する。又北東風の場合は、 P_1-P_3 を含む bridge は北を、 P_2-P_4 bridge は東を指す、従って 2 組の記録を組み合わせることに依って風向を 8 方位で示すことが出来る。

第 2 図は各風向と記録の関係を模式的に示したものである。

第 3 図は実際に使用しているもので、真中に thermistor 風速計を備えている。

第 4 図は実際の記録を示したもので、上の 2 段は thermistor 及び白金熱線風速計に依る風速変化、中の 2 段が風向計の記録を示したもので、下の 2 段は、この記録をパルスに変換したもので、ほぼ風速 20 cm/sec 以上の風速を記録しているようである。この記録は室内の換気を調べたときのものである。

第 5 図は野外観測の結果で特に 5時から 6 時すこし前即ち日の出前の風向の交互の変化、それに対応した風速、温度の変化は、微風時の air mass の運動を示すものとして興味がある。

第 6 図は同じく、風向変化と霧の出現、消散との関係を示したものである。