On the Structure of the Atmospheric Turbulence Near the Ground II[1,2]

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Introduction

In his last paper[1], using small wind-vanes which were made of paper and pins, the author ascertained the existence of eddies which seemed to be the immediate causes of the atmospheric turbulence. We thought that, though the wind-vane was very light, its innertia and friction were not negligible and it was unsuitable for the observation of the eddy with a horizontal axis. To avoid these defects, we made wind-vanes which were made of puppi of dandelion, and carried out observations similar to the last ones. Moreover, we investigated the vertical components of the wind close to the ground.

I Puppus wind-vane

To one end of a single fibre of rayon (artificial silk) (7μ in diameter, 1 cm. in length) a stem of a puppus of dandelion is attached and to the other end of it a small glass pipe is fixed, and the pipe is put on the top of a pin which is soldered to a nail. (Fig. 1). As the puppus was very light (0.14 mg), the effect of gravity to this wind-vane could be neglected as to the wind at a speed of more than 10 cm/sec., and in a wind tunnel, the vane showed a submissive movement. Further detailed dynamical characteristics are being now measured.

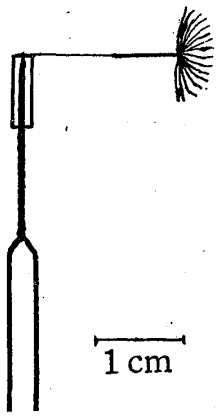

Fig. 1

II Method of observation

We set the wind-vanes in 14 rows with a distance of 5 cm to each other, and in a row 12 vanes were set every 3 cm. For the observation of the turbulence on a horizontal plane (the eddy with a vertical axis), we photographed these vanes from above (170 cm ca. high) by a cine-

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camera (Fig. 2).[3] The observation was almost similar to the last one except that a clock of one revolution in every 0.5 sec. was used and the

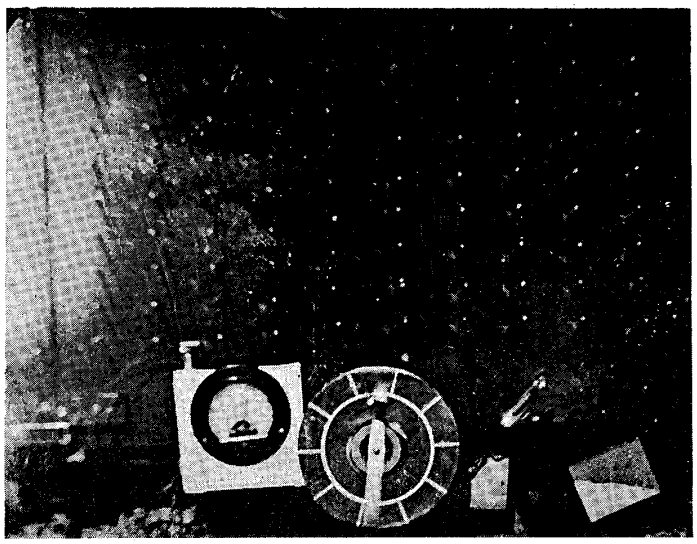

Fig. 2

height of the wind-vanes was 17 cm from the ground. For the observation of the turbulence in a vertical plane (the eddy with a horizontal axis), the vanes were set in 4 rows and 12 lines instead of 14 rows and 12 lines, and the plane of the setting was put vertically and in parallel with the mean wind direction, and the vanes were photographed from the side. The observations were made in breeze at a place 10 m from a beach near Zushi early in August.

III Results

A) Turbulence in a horizontal plane:—1) Analysed results are shown in Fig. 3, 4, 5 and Table 1, 2.[4] We could not find any particular difference from the last results. As the new wind-vanes were more sensible than the last ones, we intended to ascertain the assumptions for the eddies again. When we calculated the deflection angles of the vanes along the lines parallel to mean flow direction and marked the observational area with points of extremum deflections which corresponded to neighbouring points of an eddy, they formed a part of a circle. (Fig. 6)[5]. As in the last paper, we could accept from this result the assumption that an eddy has a circular cross section. The values of tangent of the deflection angles for the points which corresponded to those located

3 This figure is the original print of Fig. 4, No. 26.

4 In the Table 1, 2 and Fig. 5, odd number of the eddy denotes a positive eddy and even number denotes a negative one. Other notations have the same meaning as in the last report.

5 In this figure, the part of full line denotes the part corresponding to a diameter of an eddy.

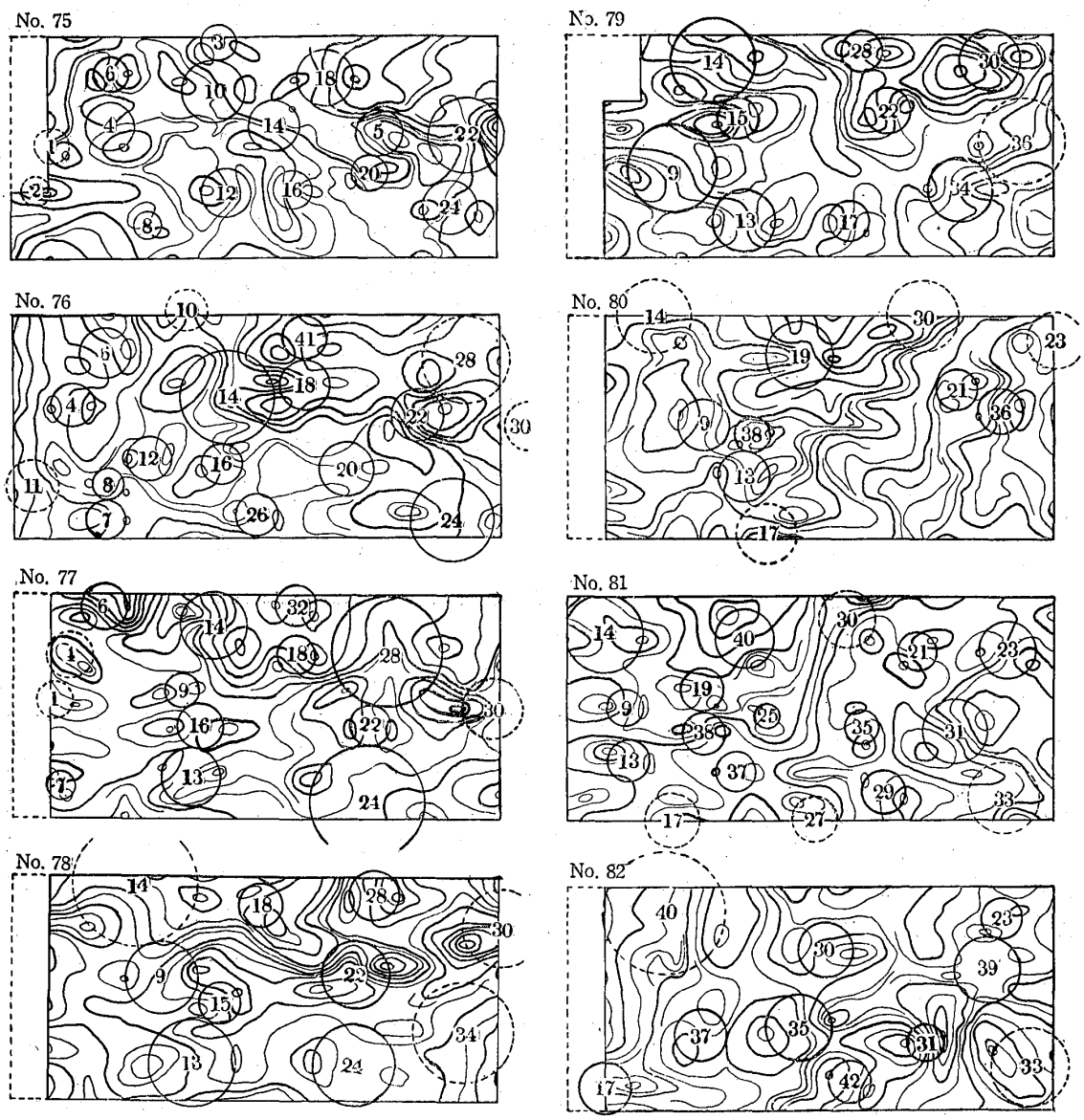

Fig. 3

on a diameter of an eddy were put in a straight line, (Fig. 7)[6], this result corresponding to the assumption that inside the eddy the vorticity (ζ) is constant. The values of tangent of the deflection angles of the points located on that line outside the eddy and the distance of the points from the center of the eddy on a log-log paper, were put in a straight line in each case and the angle of the line inclination was $-\pi/4$. (Fig. 8). From this result we could accept the assumption that the circulation (Γ) is constant outside the eddy.

6 These graphs could be made concerning only a few eddies which were scarcely affected by other eddies owing to the longer distance.

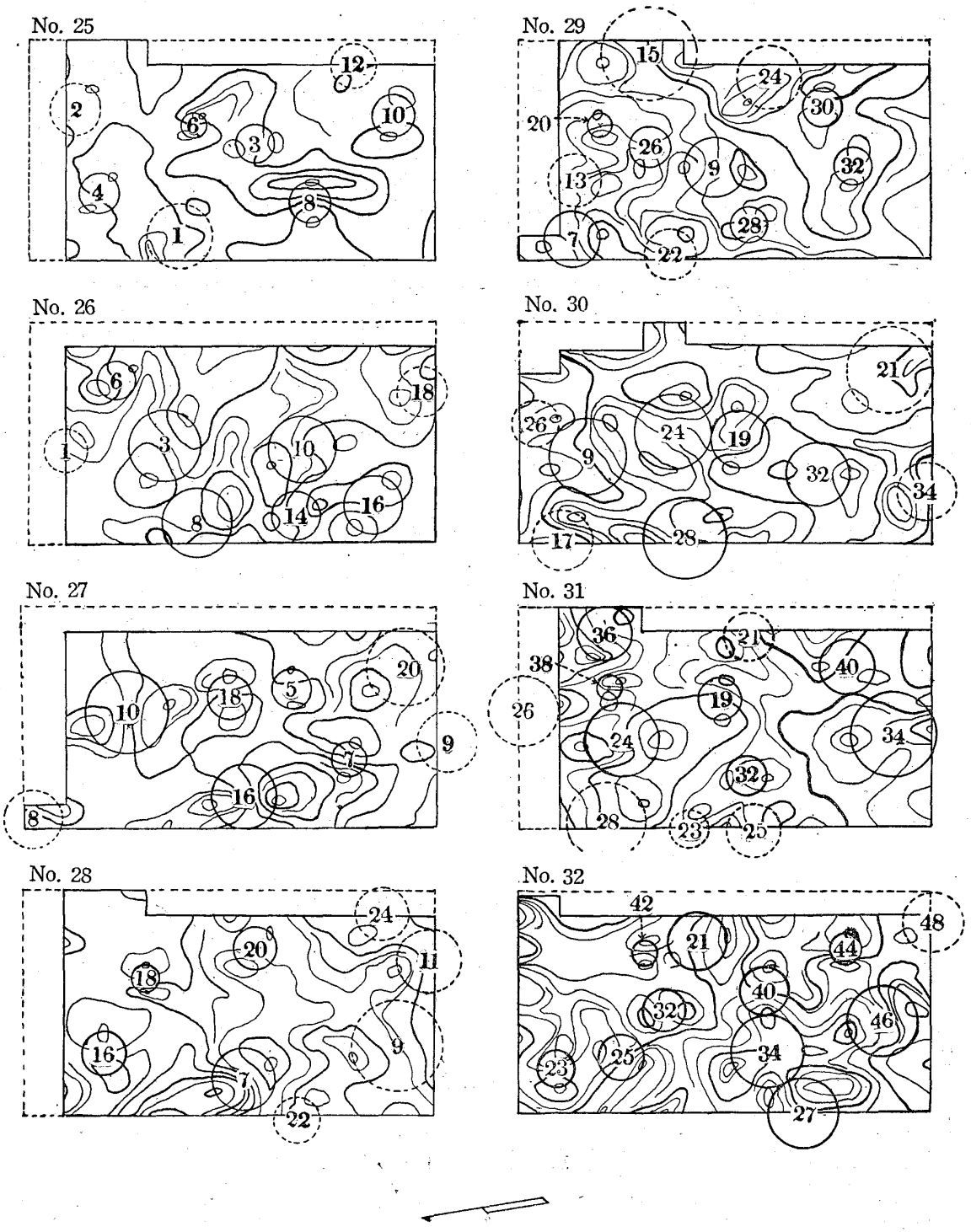

Fig. 4

2) When we traced the position of each eddy in each figure of Fig. 3 and 4, we could often find cases which might be looked upon as that, immediately after (within 0.06~0.12 sec.) an eddy became extinct, a new eddy with an "opposite sign" appeared in place of the old.—Observation I (Table 1, Fig. 3 and 5a):—No. 20 → 15, No. 26 → 13, No. 18 → 19, No. 24 → 17, No. 15 → 38, No. 34 → 21, No. 36 → 31; Observation II (Table

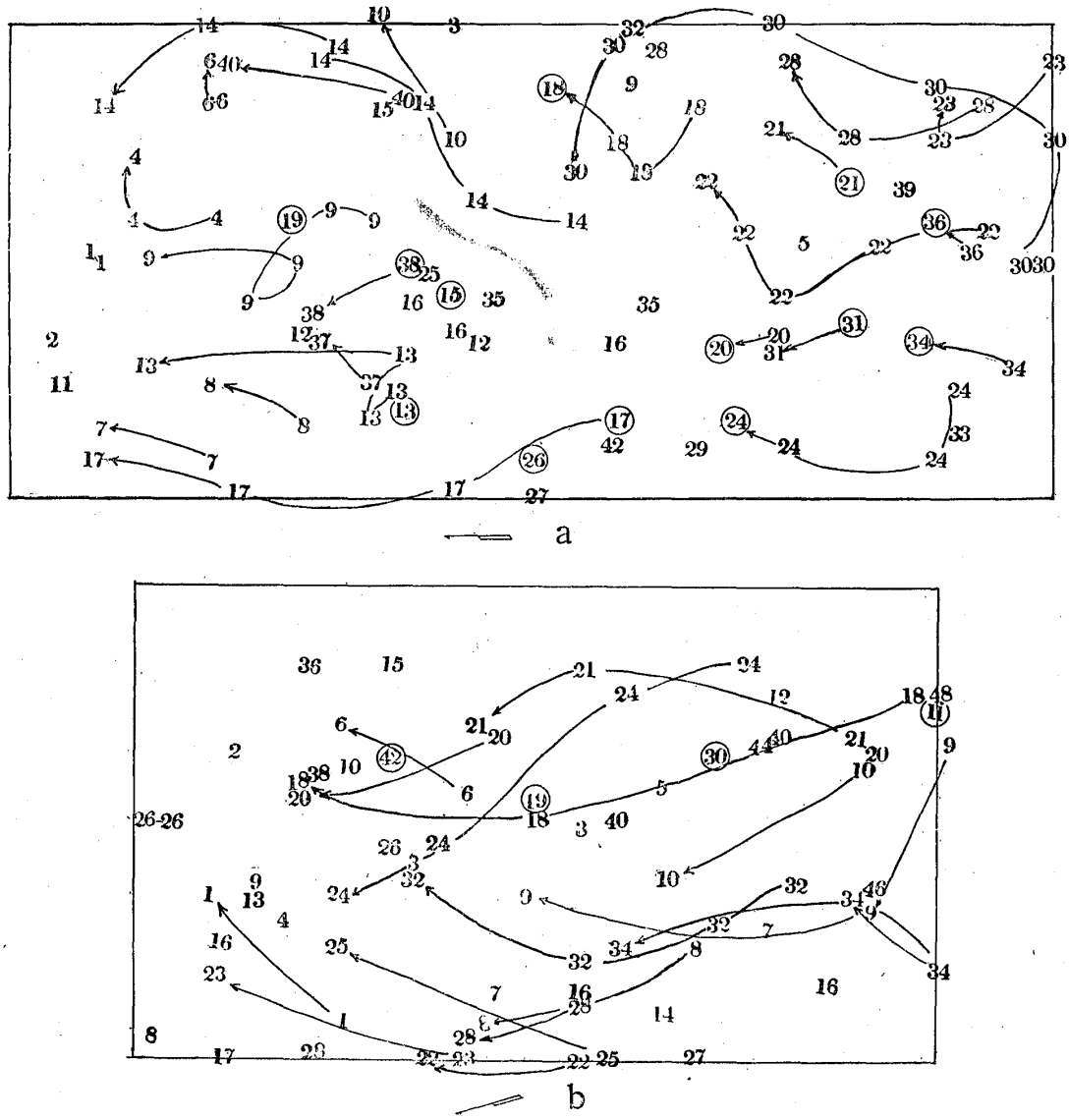

Fig. 5

2, Fig. 4 and 5b):—No. 11 → 30, No. 30 → 19, No. 19 → 42.[7]

B) Turbulence in a vertical plane. By plotting the vertical deflection angles of each vane, we got Fig. 9. In this observation, the values of wind speed were ranging from 1.2 to 1.6 m/sec. In this figure, A shows the line 8 cm high and B, C, D···K shows respectively the line 11, 14, 17...38 cm high from the ground. We can find that the fluctuations of the deflection angles for the lines A~H are considerably large, but those for J and K are very small. We made Fig 10, which shows the standard deviations (s) of the deflection angles for every line at each instant, versus the height from the ground. Then we calculated the mean values of s's for every line (Fig. 11), and we could conclude that, though the vertical turbulent components were large in the

7 These cases are respectively marked with circles in Fig. 5.

Table 1 (Observation I)

No. of Picture	75	76	77	78	79	80	81	82
Time (sec)	0.43	0.50	0.58	0 65	0.73	0.82	0.91	1.02
Wind Speed	1.15	0 90	0.90	1.00	0.90	0.97	0.90	0.87
No. of Eddy	D (cm) ζ (rad/sec) $\frac{V_p}{U}$ (%)							
1	／	／	／	×				
2	／	×						
3	5 4 4.2	×						
4	7 8 12.1	6 14 24.2	／	×				
5	7 16 24.2	✲						
6	5 12 13.2	7 13 25.9	6 29 48.4	×				
7	◎	5 7 9.8	4.5 10 13.0	×				
8	3.5 3 2.4	5 5 6.6	✲					
9	◎	7 8 14 8	5.5 1 1.9	10 9 22.6	11.5 6 18.2	11.5 3 11.4	5 10 13.9	×
10	8 12 21.1	／	×					
11	◎	／	×					
12	6 6 7.3	6 3 5.3	✲					
13		◎	7.5 4 8.7	11.5 6 16.5	8 6 13.3	7 5 10.2	6 7 11.6	×
14	7 10 15.8	13 16 56.6	9 26 64.8	／	11 11 34.2	／	／	×
15			◎	5.5 11 15.5	6 18 30.6	✲		
16	5.5 11 13.0	6 6 9.4	6.5 12 20.9	✲				
17				◎	4.5 18 22.9	／	／	／
18	7.5 14 42.7	8 22 49.7	5 20 28.3	6 12 18.0	✲			
19					◎	7.5 21.8 49.8	5.5 5 7.9	✲
20	5 14 15.5	7 1 2.3	✲					
21					◎	5 8 11.6	5 10 13.7	✲
22	9.5 43 88.8	8 32 71.1	5 9 11.9	10 27 66.5	6 25 42.0	✲		
23					○	／	8 9 21.5	✲
24	8 11 18.9	11 6 19.4	15 4 14.9	11.5 0 4 1.2	✲			
25						◎	3.5 5 4.7	5.5 7 10.3
26	◎	5 5 6.8	✲					
27						○	／	✲
28	○	／	13 10 36.6	6.5 16 25.8	6.5 5 16.9	×		
29						◎	5.5 7 11.4	✲
30	○	／	／	／	8.5 9 21.2	／	／	8 5 11.7
31						◎	9 13 22.1	10 9 26.0
32		◎	6 11 18.5	×				
33						○	／	／
34			○	／	9 11 27.2	✲		
35						◎	6 8 14.0	9 14 35.1
36				○	／	6 1 2.1		
37						◎	5 5 7.0	7 7 10.3
38					◎	4.5 7 11.4	5.5 8 11.4	✲
39							◎	9 14 35.1
40						◎	8 13 29.0	／
41								
42							◎	6 12 20.6

Table 2 (Observation II)

No. of Picture	25	26	27	28	29	30	31	32
Time (sec)	0.61	0.78	0.93	1.09	1.26	1.42	1.61	1.77
Wind Speed	2.8	3.3	2.7	2.8	2.8	2.4	2.1	2.4
No. of Eddy	D (cm) ζ (rad/sec) $\frac{V_p}{U}$ (%)							
1	／	／	×					
2	／	×						
3	4.5 28 11.7	8.5 25 16.0	×					
4	6 18 9.8	×						
5		○	5 14 6.3	✲				
6	4 52 18.7	／	×					
7		○	3.5 11 33.8	8 30 21.2	8 24 16.1	×		
8	6 82 44.1	8 36 21.9	／	×				
9		○	／	／	8 10 7.3	9 18 16.6		
10	6 12 6.6	7.5 50 28.1	10.5 21 21.2	×			✲	
11			○	／	✲			
12	／	✲						
13				◎	／	×		
14	○	6.5 12 59.6	×					
15				○	／	✲		
16	○	8 18 16.7	8.5 51 40.4	6 11 7.5	×			
17					◎	／	×	
18	○	／	6 28 15.8	5 26 11.4	×			
19					◎	7 16 11.4	5 15 8.9	✲
20		○	／	6.5 5 3.1	3 18 4.2	×		
21						／	6.5 17 3.5	7.5 10 7.8
22			○	／	／	×		
23						○	／	／
24			○	／	／	9 5 15 15.0	10.5 15 18 2	✲
25						○	／	5.5 20 11.2
26				◎	5.5 6 16.8	／	／	×
27							○	8.5 16 14.0
28				○	4.5 11 4.5	11 6 7.0	／	×
29								
30				◎	6 7 3.5	✲		
31								
32				○	5 8 4.0	8 8 7.0	5 11 6.3	5.5 17 9.6
33								
34					○	／	6 13 9.1	10.5 7 8.2
35								
36						○	7 14 11.6	×
37								
38						○	4 12 5.9	✲
39								
40						○	7 5 4.3	6 24 14.6
41								
42							◎	4 5 1.9
43								
44							○	3.5 31 11.2
45								
46							○	9 3 3.1
47								
48							○	／

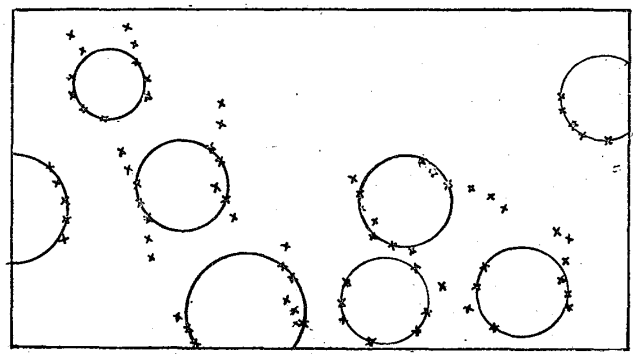

Fig. 6

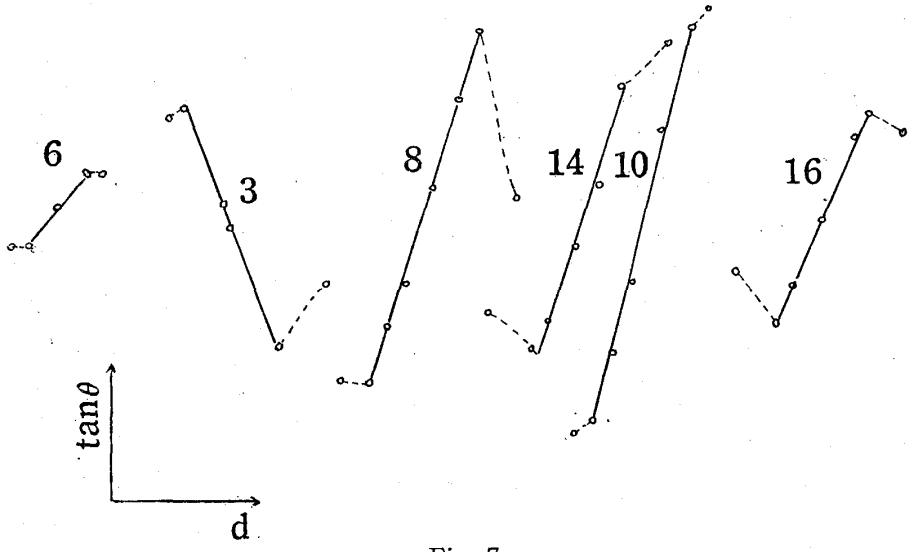

Fig. 7

region up to 25 cm ca. from the ground, they became smaller in the region higher than 40 cm. Formerly, Fujiwhara[2] and the author and others[3] discussed and verified experimentally that the vortices stand perpendicularly on walls. So we supposed that even in the natural wind near the ground, the eddy with a vertical axis would be more predominant than that with a horizontal axis. From these results of the observation, we can conclude that the fluctuations in a vertical plane, which are inevitably caused by roughness of the ground, exist only in a region very close to the ground, up to 50 cm, and the supposition is justified in a region higher than that.

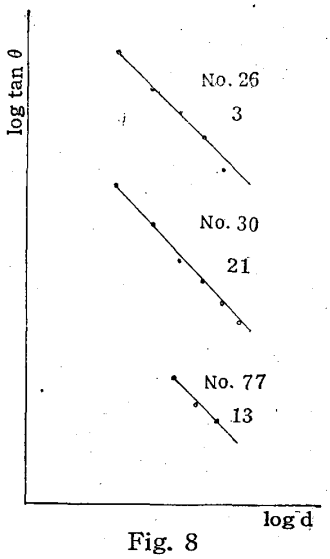

Fig. 8

IV Future planning

1) By setting the vanes in 3-dimension, we want to examine the spatial structure of the eddy. 2) By translating the setting along with

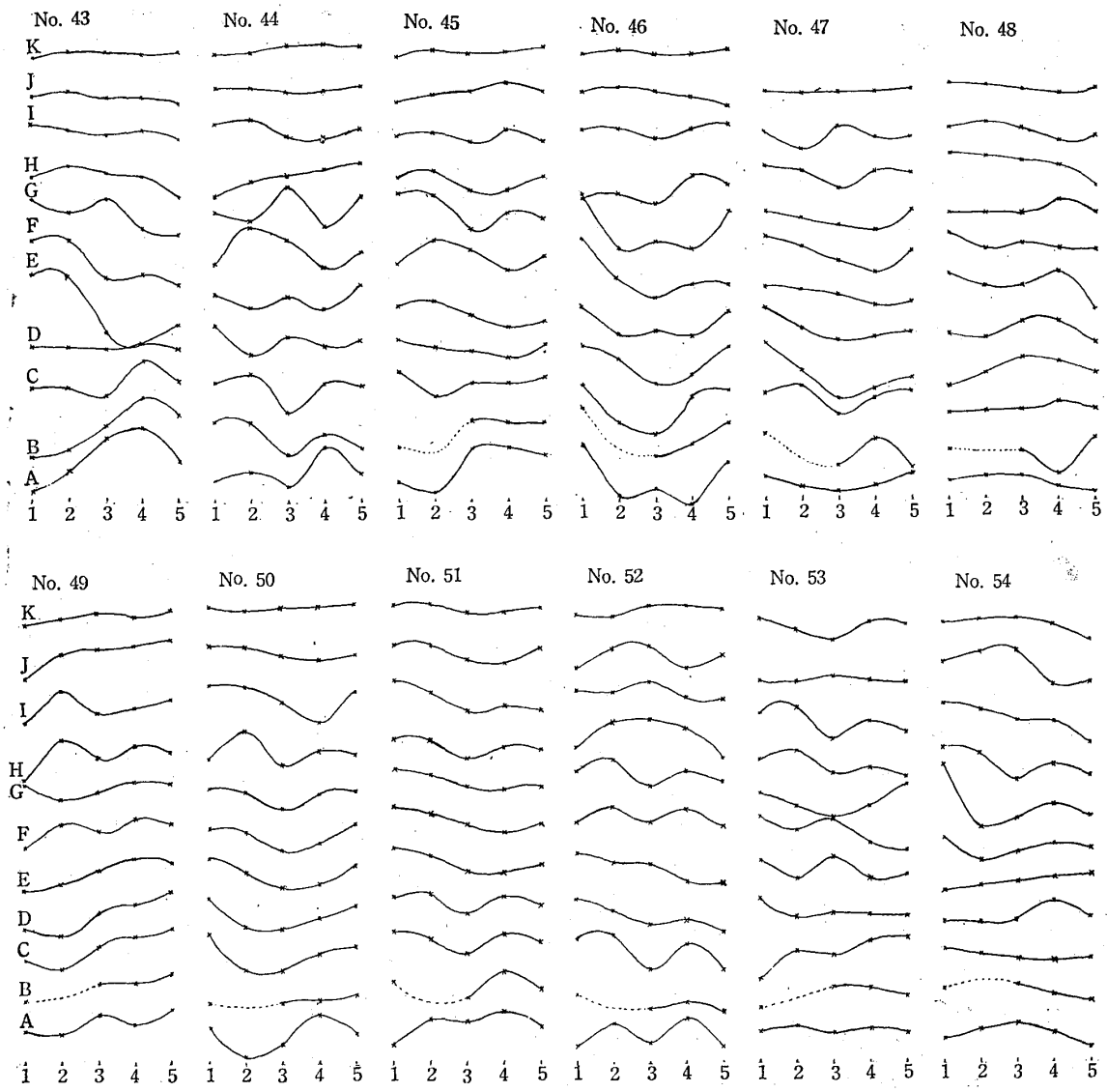

Fig. 9

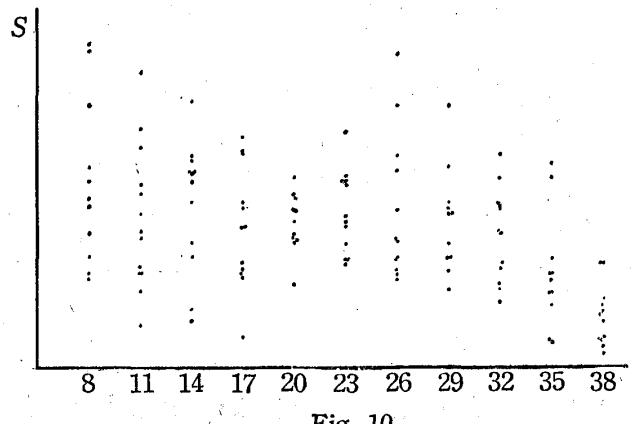

Fig. 10

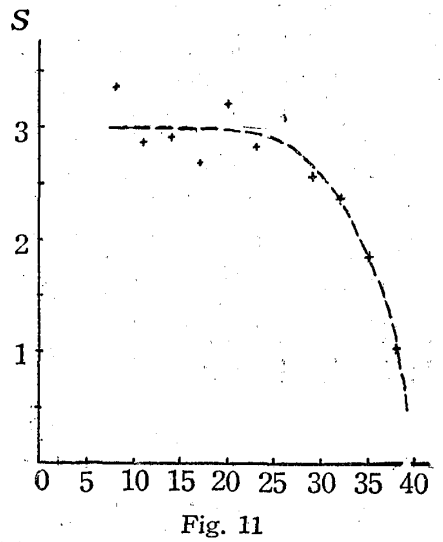

Fig. 11

the mean wind-velocity in order to eliminate its effects, we intend to clarify the existence of the eddy directly. 3) The observation for vertical turbulence reported in this paper was a preliminary one and the apparatus used was not satisfying yet, so we want to continue the observation with improved apparatus.

To carry out these observations, many assistances were offered by scholars of Ochanomizu University and especially many efforts were given by Miss M. Kanao. Here the author wants to express his deepest thanks to these persons.

Literature

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