Meteorology. — "*Preliminary report upon the investigation of the upper air-layers begun at Batavia in* 1909". By Dr. W. VAN BEMMELEN and Dr. C. BRAAK.

In the beginning of 1909 the necessary funds for the purchase of apparatus for an aërological investigation at the Batavia observatory were placed at the disposal of the first named of the authors by the Colonial Secretary.

As it seemed desirable not to proceed to liberating registering balloons before having acquired some more knowledge about the wind in different atmospheric layers above the island of Java by means of pilot-balloons, a number of pilots with instruments were sent out.

With pilot-balloons of the Continental Caoutchouc & Guttapercha Company of Hannover no heights greater than 5.5 K.M. could be reached and a great number burst already during inflation.

In September 1909 pilot-balloons were received (45 gr. weight) from the firm Paturel of Paris, which gave much better results.

In 124 experiments 11 balloons burst during the process of inflation but, almost without exception, considerable heights were attained; e. g. 25 times a height of more than 10 K.M., 14 times of more than 12 K.M. and once a height of 15 K.M. was reached.

These very satisfactory results are due to the circumstance that in the early morning hours at Batavia the sky is mostly clear, and that the velocity of the wind above Java is small, so that it was possible to give the balloon a buyoancy of only half that of the amount usual in Europe.

Up to April 1st the last named of the authors conducted the experiments; afterwards the first named, on his return from Europe, resumed the management.

A most valuable assistance was offered by the naval lieutenant A. E. RAMBALDO who, in the beginning of September 1909, arrived at Batavia with an equipment for kite and balloon work, and was detached at the Observatory.

Ascents of kites and captive balloons were organised and on November 22 the first experiments took place on the "Koningsplein" at Batavia.

The balloon had a capacity of 30 $M.^3$ and reached a height of 1800 M., the kites a height of 2200 M.

Three new balloons of a capacity of 36 $M.^3$ and two registering apparatus with ventilation, sent out by Prof. Dr. R. ASSMANN, the

Director of the Aëronautical Observatory at Lindenberg, have just been received.

We are under great obligations to Prof. ASSMANN for his assistance, as well as to Prof. Dr. H. HERGESELL who, on the occasion of our visits to Strassburg, gave us his valuable advice.

In January 1910 the last named of the authors made a voyage with Mr. RAMBALDO to the Natuna Isles in the South China-Sea, and then found an opportunity to conduct nine successful kite-ascents; the greatest height, attained with a team of four kites, was 3075 M.

Twice a kite was lost in a squall.

Not till December 1909 some registering balloons (of the Continental Company at Hannover) were sent out; six registering apparatus, of the firm BOSCH at Strassburg, were received some weeks previously.

The diameter and weight of the balloons were 1.5 M. and 1.5 K.G.

As we were afraid that the balloons, when liberated so near the seaside as Batavia, would fall into the sea, the first were sent up, tandem-fashion, at Depok, half way between Batavia and Buitenzorg.

The first tandem attained a height of 12 K.M. and was soon brought back; the registration was in good order. Two tandems subsequently liberated were soon lost in the clouds and have as yet not been recovered.

Twice during the month of May a balloon provided with a parachute was sent up at the Observatory.

Both balloons have been recovered, but of the first the diagram was lost, having been wiped out by an inquisitive native and, owing to a cloudy sky, the trigonometrical measurements failed.

Measures have now been taken against the spoiling of instruments and records.

The second balloon, sent up on May 19 during the passage of the earth through the tail of Halley's comet, was immediately recovered. Its position was measured from a basis line of 1.5 K.M. and the diagram is in perfect order; the balloon however burst at a height of 7 K.M.

Once a 1.5 M. balloon was let up without recording instrument and as a pilot balloon; this balloon could be followed from two points situated at a distance of 4.5 K.M. and attained a height of more than 18 K.M.

The considerable amount of data obtained up to the present time has been nearly all worked out.

We found very variable circumstances, which make it difficult even to draw preliminary conclusions, but nevertheless we will try to give some of our results which, to a considerable extent, may be considered fairly accurate.

Temperature-Gradient. The temperature-gradient of the lower 2 K.M. of the atmosphere has been determined in three ways, namely:

1. above the land with the captive balloon and light wind.
2. above the land with a moderate westerly wind and with kites.

TEMPERATURE-GRADIENT (Decrease per 100 M.)

Height in M.	Captive balloon observations		Number of cases	Kite-observations above the land		Number of cases	Kite-observations above the sea		Number of cases	Coast and adjacent sea, East-Africa after BERSON
0— 100	0°.81		(24)	0°.85		(13)	1°.17		(15)	
100— 200	78		(24)	94		(13)	1.00		(16)	
200— 300	89	0°.77	(24)	81	0°.87	(13)	80	0°.91	(15)	1°.08
300— 400	78		(24)	87		(13)	80		(15)	
400— 500	60		(24)	86		(13)	78		(14)	
500— 600	57		(24)	87		(13)	66		(12)	
600— 700	73		(24)	67		(13)	79		(12)	
700— 800	52	0°.57	(23)	60	0°.72	(13)	58	0°.59	(12)	0°.50
800— 900	53		(22)	61		(14)	62		(12)	
900—1000	52		(19)	87		(11)	30		(10)	
1000—1100	30		(14)	46		(11)	64		(10)	
1100—1200	47		(14)	44		(11)	52		(10)	
1200—1300	45		(11)	38	0°.44	(10)	69	0°.71	(10)	0°.57
1300—1400				49		(10)	44		(8)	
1400—1500							29		(6)	
1500—2000								0°.34	(3)	0°.49
2000—2500								0°.50	(3)	0°.46
2500—3000								0°.46	(2)	0°.50

3. above the sea (14—20 Jan.), the sky being cloudy and the weather rainy, with kites.

These three series of gradients are not immediately comparable as, above the land, the observations with the captive balloon took place in earlier morning hours than the kite observations, whilst the kite experiments at sea were made in the morning as well as in the afternoon.

For the sake of comparison the values of the gradient, as found by Prof. BERSON during his aëronautical expedition to East-Africa above the coast and littoral, is given in the last column. The gradient for the first 500 M., as stated by BERSON, is still larger than that found here.

Temperature-inversion. At a height of about 1 K.M. the gradient found by means of kite- as well as by means of balloon-ascents shows a sudden decrease. The reason of this is to be found in the inversion often found at this height, occurring in the so-called fine weather cumuli.

Owing to the rising air currents the formation of these clouds is seen to commence about 10—11^{h} a.m.; sometimes they pile up to high cumuli, but often they remain floating as small white clouds.

In the latter case an inversion of temperature and humidity has repeatedly been observed, commencing at the cloud base.

Thus a confirmation is here afforded of what has been found and communicated as a still unknown phenomenon by Prof. ROTCH (Nature Oct. 14, 1909, p. 473). AITKEN (Nature Nov. 18, p. 67) ascribes this increase of temperature to diffuse sun's radiation within the cloud. The radiation on the rather thin cumulus layer is very important at Batavia, owing to the high position of the sun. In the interior of larger cumuli, where an active air motion exists and the influence of the sun's radiation is unimportant, this inversion does not occur; on the contrary, during the passage of these clouds a decrease of temperature was always observed and the humidity approximated to saturation as the apparatus entered the cloud.

During kite ascents only once, on January 19, inversions have been found to occur, as shown by the following data.

Height	Temperature	Humidity
374 M.	23°.2	
567	23 .1	100°/₀
741	23 .2	
1235	19 .5	
1300	19 .4	73
1381	19 .5	
2040	14 .7	78
2198	14 .7	

Southerly Winds. As to the direction of the wind, it can be noticed that, besides the south wind which can be regarded as a land breeze, often another south wind is found, the origin of which is probably to be sought in a pushing forward of air layers from the Indian Ocean; the height of these layers is 1.0 to 1.5 K.M.

They were not observed on January and February; perhaps the west-monsoon was then too strong to be pushed aside.

A synoptic summary of the wind's direction from kilometer to kilometer for the period September to May clearly shows that the general air-current has easterly components up to the greatest heights attained (10—15 K.M.) and how during shorter or longer periods the west-monsoon thrusts itself below it. Nothing is to be seen of an anti-trade wind; the east-monsoon consists of one mighty air-current.

The rapid increase of the wind's velocity with increasing height in the lower layers is remarkable.

Whilst at the earth's surface during the night a perfect calm always reigns and during the day the motion of the air (at least at land) is slight, the wind's velocity increases to about 3 M. at a height of 100 M.

The small gradients which at this height are capable of causing motion in the air are evidenty too small to overcome friction at the earth's surface.

At the division between easterly currrents above and westerly currents in the lower parts alto-cumuli may often be observed which explains their general occurrence in the west-monsoon and their absence during the east-monsoon.

The average height of the Alto-cumuli above Batavia, determined at 5.4 K.M., during the international cloud year 1896—97, from numerous measurements by VAN DER STOK and Figee is in perfect agreement with the average height of the division of west- and east-monsoon as found by the authors.

In the following 19 experiments the division could be determined with considerable accuracy.

Date 1909	Height of Westmonsoon	Date 1910	Height of Westmonsoon
2 Sept.	5.0 K.M.	6 Jan.	2.0 K.M.
8 Nov.	5.7	21 Febr.	2.5
9 „	5.5	16 Mrch.	5.8
15 „	4.2	15 Apr.	6.0
8 Dec.	7.4	24 „	9.9
9 „	7.0	14 May	4.0
11 „	6.0		
13 „	3.7		
15 „	4.5		
16 „	4.2	Average	
24 „	8.0	Sept.-May	5.4
27 „	8.5		
31 „	2.0		

The higher easterly, as well as the lower westerly winds are sometimes affected by strong northerly or southerly components.

So e. g. on September 15 a south wind of a velocity from 2– 8 K.M. was observed; on the contrary on September 22 a north wind of from 5—8 K.M.

On May 27 we found the following directions:

0— 1 K.M.	W.
1— 4	S.
4— 5	N.
5— 7	W.
7— 9	S.
9—10	Calm
10—14	N. E.

Influence of the earth's rotation. Often the direction of the wind shows a well marked veering to the left, mostly in the lower layers, which may be ascribed to the influence of the earth's rotation. The deviating force at a latitude of 6°11′ is certainly a small quantity, the sine being not more than 0.11, but, on the other hand, the force determined by the pressure gradient is also very small. Therefore the influence on the direction can become important; it must be noticed however that veering to the right occurs as well, although much more rarely.

Inversions. Sudden turnings of the wind within small intervals of height, mostly accompanied by a notable reduction of velocity, have been observed in many cases up to a height of 10 K.M.

Probably these are also accompanied by inversions of the temperature.

W. wind at 17 K.M. During his expedition to East-Africa, Prof. BERSON found the unexpected occurrence of strong westerly winds at heights from 10—20 K.M., between or above the general easterly current, a phenomenon which is still waiting for an explanation.

It is very remarkable that, on the first occasion upon which a balloon attained 18 K.M., at Batavia a wind of the same description was encountered.

As the balloon was followed by means of theodolites from two points favourably situated at a distance of 4340 M. apart, (the angles of inclination being still 54° and 53° at the moment of the bursting of the balloon), the following data are certainly quite trustworthy.

Height	Direction of the wind	Velocity of the wind, m. p. sec.
16.6—16.9 K.M.	N.E.	9.0
16.9—17.3 .	W.	0.8
17.3—17.6	W.S.W.	5.6
17.6—17.9	W.S.W.	5.6
17.9—18.3	W.S.W.	5.5

Velocity of rising. This balloon ascent may be cited as an example showing the possible errors made when a calculated velocity of rising is assumed; whereas the calculated velocity was 200 M. per minute, the actual velocity was

0.0— 2.0 K.M.	198 M. p. min.	=	3.3 M. p. sec.
2.0— 4.8	280		4.7
4.8— 7.3	256		4.3
7.3—10.2	288		4.8
10.2—13.3	312		5.2
13.3—16.6	330		5.5
16.6—18.3	324		5.4

The considerable increase of velocity up to a height of 5 K.M. may be explained by assuming that the gas of the large balloon (161 c.m. diameter) gave off its heat but slowly so that the difference of its temperature and that of the surrounding layers continually increased. With pilot-balloons, where the proportion between capacity and area is more than three times less, these differences will be much smaller; in fact they appear to have a constant velocity up to a height of 12 K.M.

When using balloons of 80 cm. diameter, sent up tandem-fashion, BERSON also found an increase of the same order as that found by the authors in the three experiments cited here:

Aug. 6, 1908.		Aug. 30, 1908.		Sept. 5, 1908.	
	m. p. s.		m. p. s.		m. p. s.
2.8 — 3.6 K.M.	3.4	9.3 — 11.1	3.7	5.9 — 8.3	3.2
3.6 — 5.6 „	4.7	11.1 — 13.0	4.0	8.3 — 9.6	3.6
		13.0 — 15.0	4.4	9.6 — 11.3	3.7
		15.0 — 18.0	5.1	11.3 — 14.1	4.6
				14.1 — 16.9	5.2

Registering-balloons. In the following table the results are given obtained by means of the registering-balloon, let up at Depok on February 16, 1909.

Depok is situated 95 m. above the sea-level.

The balloons of the tandem-system had a diameter of 150 cm. They were inflated until a buoyancy of resp. 3.5 and 2.2 KG. was attained. The free buoyancy of the whole system was 2.75 KG.

Local time.	Height in meters.	Temp.	Temp. gradient per 100 m.	Relat. humidity.
8 h. 50 m. a. m.	95	27°.0 C		79 %
			0°.67	
53	869	21 .8		83
			0 .54	
9 0	3072	9 .8		66
			0 .47	
8	5415	— 1 .2		67
			0 .63	
14 [1])	6740	— 9 .5		79
			0 .60	
20 [2])	8150	—18 .0		73
			0 .44	
26	9370	—23 .4		59
			0 .74	
33 [3])	10711	—33 .5		52
59	11543	—42 .6		45
			0.68	
10 8	9287	—27 .2		53
			0.75	
15 [4])	7002	—10 .0		75
			0.54	
22	5284	— 0 .8		92
			0.52	
30	3265	9 .6		76
			0.50	
38	1635	17 .8		99
			0.63	
45	95	27 .5		76

Remarks. [1]) From 9 h 14 m to 21 m the wind veers from WSW to ENE; [2]) Afterwards the temperature decreases somewhat more quickly (above 8000 m.); [3]) Here one balloon becomes leaky and the system is floating, showing influence of radiation. Finally the balloon bursts and a quick descent sets in. In descending the ventilation is sufficient; at a height of 2000 m. during the ascent there seems to be some influence of radiation. [4]). The increase of the humidity can be explained by the occurrence of alto-cumuli which in the mean time are being formed at a height of 5 K.M., and of cumuli at 1.5 K M.

The diagram of the registering-balloon on May 19, during the passage of the earth through the tail of Halley's comet has as yet not been worked out.

It shows no other remarkable feature than an inversion of temperature between 6 and 7 K.M.; as stated above, the balloon burst at a height of somewhat more than 7 K.M.