Meteorology. — "*The semi-diurnal horizontal oscillation of the free atmosphere up to 10 km. above sea level deduced from pilot balloon observations at Batavia.*" By Dr. W. VAN BEMMELEN and Dr. J. BOEREMA. (Communicated by Dr. J. P. v. D. STOK).

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The great regularity of the semi-diurnal variation of the air pressure in the whole equatorial zone, as well as the constancy of its amplitude and phase all over the earth prove that the atmosphere as a whole also performs a regular semi-diurnal oscillation. Above all it was JUL. HANN who brought to light the simple laws commanding this phenomenon, while MARGULES proved this phenomenon probably to be a phenomenon of resonance by making it evident that an infinitely thin shell of the atmosphere has a period of oscillation of its own of nearly 12 hours and consequently will resound to a diurnal disturbance as caused by the sun's radiation.

From the wind observations on mountain tops in Europe and North America and also on those in southern British India HANN [1]) deduced that this variation of the air pressure is accompanied by a horizontal wind oscillation possessing an amplitude of some decimeters pro sec.

This horizontal atmospheric oscillation may be called an important geophysical phenomenon. Thus ARTH. SCHUSTER founded his theory of the diurnal variation of terrestrial magnetism on the presence of the above oscillation also in the very upper layers of the atmosphere, and it might, therefore, be desirable to try and obtain more information by observations in the free atmosphere, where disturbances caused by convection will be of less influence than they must be on high mountain tops.

Though this has already been done to some extent by means of cloud observations, no exhaustive nor distinct results could be obtained in this way.

The only suitable method of observation consists in a series of pilot balloon observations, which, however, are so complicated that

[1]) Sitzungsber. d. Ak. d. W. in Wien 1908.

they can only be applied in those regions where the atmospheric conditions are quiet enough to retain the series of observations within practicable limits.

Experience gained by means of pilot balloon observations at Batavia justified the supposition that here favourable results might be acquired by such investigation, and therefore during the last few years we have continued the ascension of pilot-balloons started in 1909. As early as 1912 ascensions at 2 p.m. and 7 p m. were added by the first mentioned of us to the ascensions which before that date usually took place at 8 a m., in order to gather further knowledge of the phenomenon of land and sea breezes. The results obtained induced him to start in 1913 an extensive series of observations at different hours between 6 a.m. and 6 p.m., more in particular with a view to study the diurnal and semi-diurnal variation of the wind. However, at the time he was not able to have nocturnal ascensions made of balloons carrying lights, like those that first took place in 1912, but in 1914 we again proceeded to these nocturnal observations, when the latter of us joined the investigation.

A continuation of these nocturnal observations was checked, however, by the outbreak of the war in August 1914, so that only a series of day balloons could be sent up and not before the latter part of 1915 was it possible to have an extensive series of nocturnal ascensions made.

From the above it will appear that on account of various circumstances, partly not under our control, the ascensions have by no means been conducted in such a manner as would have been most suitable to the investigation, i.e. equally distributed over the day and during the same season.

These drawbacks have partly been neutralized by the following circumstances.

For the deduction of the semi-diurnal variation, which is the most important and which it is our aim to investigate, it is sufficient to divide the observations over half a whole-day, as was usually done before.

The observations were made in periods as little disturbed by showers as possible, this being even more feasible for half days, or shorter parts of a day, than for whole-days.

The ascensions took place within the semester May/November, i.e. principally with northern declination of the sun and eastern winds.

Of the greater part of the ascensions the altitude reached by the balloons has been calculated trigonometrically from double-observation.

The direction and length of the bases were the following:

1912	311°	1860 m.
1914 (night balloons)	„	„
„ (day balloons)	348	908 „
1915 (night balloons)	296	2640 „

During 1913 single-observation only has been applied, and during the other years the same has been applied mostly for ascensions between 6 a. m. and 9 a. m., during which hours the lower layers are little or not disturbed by convection currents.

The material of observation consisted of the direction and velocity of the wind at various heights and at various hours, derived from series of consecutive balloon ascensions and the problem remained to deduce therefrom the diurnal and semi-diurnal oscillations.

To this end it was assumed in the first place that these oscillations are constant for each height. However, this is certainly not the case with the diurnal oscillations in the lower layers, because the latter are influenced by land and sea breezes, the intensity of which varies from day to day; but the departures from an average might be classified among all non-periodical variations of the wind.

However, the semidiurnal variation of the East-West-component might be surmised to possess a great constancy and also the North-South-component to retain the same sign during at least a semester.

In the second place the "difference method" was applied; each time two ascensions, succeeding each other at a short interval, were joined and by doing so it might be expected that the non-periodical variations would be eliminated for the greater part; moreover, ascensions with intervals not disturbed by showers were mostly joined and, as regards the lower layers, with intervals no longer than 24 hours. In case of the upper layers longer intervals were admitted.

Therefore, each couple of ascensions yielded the value of the following expression for each height and for each of the two components (E. W. and N. S.):

$$x_1(\sin t_1 - \sin t_2) + y_1(\cos t_1 - \cos t_2) + x_2(\sin 2t_1 - \sin 2t_2) + y_2(\cos 2t_1 - \cos 2t_2)$$

and the values of x_1, y_1, x_2 and y_2 were calculated from the whole for each height and for each of the two components according to the method of least squares.

When performing the ascensions, which took place by day and night, and the enormous amount of calculations attending the deduction of wind components and the making up and solving of the normal-equations, we have been greatly assisted by the staff of the Batavia Observatory, especially by Observator J. H. KATS, to all of whom we herewith desire to express our thanks

In order to gather further knowledge of the air currents in the lower layers, we collected and worked out particulars for each 100 m., up to 1500 m.; upwards of 1500 m. for each 500 m.

The following is a synopsis of the number of cases on which finally the normal-equations are based. In order to somewhat neutralize the diminution of those numbers in the higher levels, groups were formed for the deduction of the coefficients, resulting in the following figures:

0.1 km.	406	3.5 km.	302
0.5 „	406	4.0 „	284
1 0 „	400	4.5 & 5 „	509
1.5 „	387	5.5 & 6 „	432
2.0 „	357	6.5 & 7 „	341
2.5 „	338	7.5, 8 & 8.5 „	318
3.0 „	320	9—11 „	199

This compensation was also necessary to meet the growing uncertainty of the observation with increasing height and the increase of the (non-periodical) velocity of the wind.

However, the number of cases of such a combined group may not be regarded as being equivalent to a non-combined one of the same number, seeing that the non-periodical velocities of the wind — here appearing as accidental errors — are not independent of each other for successive heights.

It is, however, impossible to ascertain this difference quantitatively, although it should be remarked that it is principally dependent on two circumstances.

In the first place on the variability of the wind which the balloon encounters when ascending. As a rule this variability will be somewhat less in the higher layers than in the lower ones.

Secondly on the manner of combining the ascensions, i.e. whether the differences of the wind have been deduced from the same couple of ascensions or from various ones. E g. a balloon sent up at 3 a.m. is compared up to 6 km. with one sent up at 0 a.m., but higher up with one sent up the day before at 6 p.m. In this case the differences for e.g. 4.5 km. and 5 km. will be more dependent on each other than those for 5.5 km. and 6 km. The letter case will be more frequent in the upper layers.

From the above it will appear that it is impossible to state this dependency quantitatively to any amount.

The mean errors have been calculated for the groups 4 km. (6.5—7) km. and (9—11) km. as follows:

	4 km.		6.5—7 km.		9—11 km.	
	North	East	North	East	North	East
(x_1)	17	18	20	22	30	32
(y_1)	30	32	37	40	63	67
(x_2)	17	18	21	22	32	34
(y_2)	17	18	21	22	30	32

The equality of the mean errors of x_1, x_2 and y_2 and the greater value of the m. e. of y_1 are striking; this being a consequence of the distribution of the ascensions over the day.

The mean errors of x_1, y_1, x_2 and y_2 are mainly in inverse proportion to respectively [*sin t. sin t*], [*cos t cos t*], [*sin* 2*t sin* 2*t*] and [*cos* 2*t cos* 2*t*], and the greater part of the couples consisted of one ascension between the hours of 6—12 or 18—24 together with one between the hours of 0—6 or 12—18. For such a combination the values of [*sin t sin t*], [*sin* 2*t sin* 2*t*] and [*cos* 2*t cos* 2*t*] are indeed about the same, but [*cos t cos t*] is much smaller, which may be easily ascertained when making up the limits between which the values for *sin t*, *cos t*, *sin* 2*t* and *cos* 2*t* are fluctuating.

	sin t.	*cos t.*	*sin 2t.*	*cos 2t.*
6^h—12^h	1.0 to 0.0	0.0 to —1.0	0.0 over —1.0 to 0.0	—1.0 to 1.0
12^h—6^h	0.0 to —1.0	—1.0 to 0.0	0.0 over 1.0 to 0.0	1.0 to —1.0
(difference) absolute value	0 0 to 2.0	0.0 to 1.0	0.0 to 2.0	0.0 to 2.0

As regards the values determined for y_1, these show indeed — in accordance with the mean errors, which are nearly twice as large — a greater spreading than those for x_1, x_2 and y_2. The values determined are shown in the following table and graphic.

The figures in the table (p. 124) show, first: that the influence of land and sea breezes is distinctly visible in the curves for the diurnal variation of the N.-component; this influence seems to make itself felt up to 4 k.m. Together with this influence is mixed up the one, which

Coefficients of the sinus formula for the diurnal and semidiurnal wind oscillations at various heights, expressed in centimeters pro sec[d].

	Northcomponent				Eastcomponent			
	x_1	y_1	x_2	y_2	x_1	y_1	x_2	y_2
0.1 km.	−270	−240	165	−25	−23	1	−45	−20
0.2 „	−300	−198	168	−73	3	74	−34	−44
0.3 „	−231	−120	178	−60	15	130	−18	−26
0.4 „	−223	−120	149	−50	15	114	−33	−40
0.5 „	−193	−65	115	−40	9	110	−32	−35
0.6 „	−167	−27	70	−50	21	111	−49	−33
0.7 „	−145	−22	47	−49	33	90	−34	−32
0.8 „	−119	−15	23	−39	38	63	−30	2
0.9 „	−100	28	5	−35	64	62	−31	−6
1.0 „	−85	40	−18	−19	56	36	−31	6
1.1 „	−36	41	−11	−7	68	13	−46	21
1.2 „	−15	66	−29	−11	90	19	−33	39
1.3 „	15	67	−36	−9	90	−38	−26	41
1.4 „	40	46	−49	5	92	−23	−44	30
1.5 „	62	43	−57	14	71	−58	−50	25
2 „	138	−13	−47	44	16	−36	−46	13
2.5 „	116	3	−46	46	1	−1	−8	5
3 „	86	47	4	−1	−38	−17	−45	38
3.5 „	39	0	8	−8	6	5	−52	21
4 „	9	−47	4	0	14	−12	−40	43
4.5—5 „	32	−7	17	7	−25	−35	−43	27
5.5—6 „	−13	16	−15	19	−12	43	−31	23
6.5—7 „	−2	−81	−6	1	22	35	−34	2
7.5—8.5 „	13	37	−27	−1	−6	−72	−12	−26
9-11 „	−14	137	9	−21	22	78	50	−23

is the result of the intermixing of the layers of the air by convection (Espy-Köppen effect).

As regards the East component the land and sea breezes ought to be of small account, the direction of the coastline being mainly E.-W.; on the other hand the Espy-Köppen effect ought to be fairly well the same for both components. However, the sea wind blowing N.-S. exercises its influence on the East West component, in such a manner that the air above the sea, which is little or not susceptible to the Espy-Koppen effect, is forced landward, thereby diminishing its effect above the land in those layers where sea breezes occur.

The following phases of the diurnal oscillation of the East component clearly show the influence of the Espy-Köppen effect.

Phase of the diurnal oscillation of the East component.

Height	Phase	Height	Phase
0.1 km.	178°	0.9 km.	44°
0.2 „	88	1.0 „	33
0.3 „	84	1.1 „	11
0.4 „	82	1.2 „	12
0.5 „	85	1.3 „	337
0.6 „	79	1.4 „	346
0.7 „	70	1.5 „	321
0.8 „	59	2.0 „	294

Though in a smaller degree, the curves of the semidiurnal variation also distinctly show the influence of both phenomena of land and sea breezes and of the Espy-Koppen effect.

The main reason for this is probably that both phenomena do not run purely sinus-like, but deviate from it sufficiently to produce an important semi-diurnal term when applying harmonic analysis. Indeed both phenomena chiefly originate in insolation to and radiation from the earth, which do not run purely semidiurnal.

The graphs distinctly show that these influences make themselves felt principally below 3 km. and may be neglected above 4 km. Therefore, if we wish to arrive at results for the lower layers, not disguised by either of these effects, it will be necessary to operate far from the land and above the open sea, because here they are both absent.

Eventually we proceeded to these observations and the last mentioned of us together with the observator J. H. Kats started a series of ascensions from a small coral island in the Java Sea (one most north of the Duizend-Eilanden [1]); moreover he erected an anemograph (recording velocity and direction) on the neighbouring Noordwachter light house (50 m. above sea level). These balloon observations are still in hand, but of the wind records the results of a few months are available.

These, however, have shown that there also, i. e. at a distance of no less than 68 km. from the Sumatra coast, still considerable land and sea breezes, are found and, seeing that the islet whence the balloons were sent up is situated respectively 60 km and 70 km from the Java and Sumatra coasts, the results there obtained will neither be free from the effect of land and sea breezes [2]).

We trust to obtain and publish in due course the various results for land and sea breezes and Espy-Köppen effect, to be deduced from the foregoing observations, after the necessary reductions have been completed.

For the present we will deal with the results for the asmospheric layers above 4 km only.

Then it will at once appear from the graphs that the amplitude of the diurnal variation must be a minute one for both components, in any case too slight to be deduced with any certainty at all from the results obtained.

The semi-diurnal variation of the N. component is also a minute one, however, the scattering of the points of observation is much less and the curve drawn between these points deserves more confidence.

On the other hand, the amplitudes for the East component are much larger, whilst the scattering of the points is also slight.

According to this scattering one would expect mean errors of the

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1) The expenses for this investigation have for the greater part been covered by funds put at the disposal of the Director of the K. Magn et Met. Observatorium on the occasion of the dissolution of the Nederl. Ind. Ver. voor Luchtvaart (Netherlands Indian Association for Aeronautics) with the purpose that these funds should be utilised for such aerological researches.

2) According to the observations on Noordwachter during July—November 1916 the amplitudes of the diurnal variation of the E-W and N-S compenents are respectively 83 cm and 54 cm and, therefore are actually in inverse proportion to the distances to the Sumatra and Java coasts of respectively 68 km and 100 km seeing that $\frac{54}{83}=\frac{65}{100}$. The phases are respectively 249° and 204°, agreeing with the phase of the N. component above Batavia at 0.1 km i. e. 222°.

amplitudes smaller than those found for 4, 6.5—7 and 9—11 km, as may appear from the following summary.

Coefficients of the semi-diurnal oscillation, calculated and graphically deduced (in cm. pro sec.).

Height	N. S. Component						E. W. Component					
	x_2			y_2			x_2			y_2		
	calc.	graph.	Δ	calc	graph.	Δ	calc.	graph.	Δ	calc.	graph.	Δ
4 km.	4	10	- 6	0	0	0	—40	—45	5	43	30	13
4.5—5 „	17	9	8	7	7	0	—43	—43	0	27	28	1
5.5—6 „	—15	—1	—14	19	12	7	—31	—35	4	23	20	3
6.5—7 „	—6	—9	3	1	8	—7	—34	—27	—7	2	2	0
7.5—8.5 „	—27	—9	—18	—1	—1	0	—12	—9	—3	—26	—26	0
9—11 „	9	—4	13	—21	—21	0	50	30	20	—23	—23	0
Mean (absolute values)			10			2			7			3
Mean error 4 km.			17			17			18			18
Mean error 6.5—7 „			21			21			22			22
Mean error 9—11 „			32			30			34			32

Even if above 7 km the course of the curves may not be quite reliable and consequently the small deviations as assumed above be somewhat flattered, this is not the case below 7 km. Thus the fact that these deviations are so small must partly be explained by the circumstance that the values arrived at for successive levels are not independent of one another, because for the greater part they are based on observations obtained from the same couple of ascensions for a series of successive heights, and it is especially during undisturbed weather that the E-monsoon current exhibits a fairly amount of homogeneity between 4 and 11 km.

From the above may further be concluded that the course of the curves according to the heights possesses a certainty more approaching the above mentioned Δ's, but that the curves as a whole may have a greater error, i. e. that they are drawn either too high or too low on the graph.

Therefore, if their course may be trusted, it can be taken as fairly certain that, at least as regards the semi-diurnal East component, the values for x_2 and y_2 above 4 km. respectively increase and diminish, which comes to this that the phase runs from the second quadrant to the fourth through the third.

Considering the manner the curves are drawn on the graph, the following is arrived at for amplitude and phase.

Semidiurnal variation.

	North Component		East Component	
Height	Ampl.	Phase	Ampl.	Phase
4 km	10 cm.	0°	54 cm.	144°
5 "	13 "	51	48 "	147
6 "	13 "	108	38 "	152
7 "	12 "	150	22 "	181
8 "	10 "	280	24 "	243
9 "	13 "	230	28 "	287
10 "	20 "	259	38 "	317

As has been mentioned previously, the results obtained for the lower layers (below 4 km.) are strongly affected by land and sea breezes and the Espy-Koppen effect and only after final reduction of the observations above the Java Sea we may look forward to a better insight into the wind movement in these layers.

From the wind records of the Noordwachter lighthouse 50 m. above sea level, the following particulars have been derived for the semi-diurnal variation of the East component:

July—November	13 sin (2t—160°)
July—September	23 sin (2t—176°)

This value will probably for the greater part be free from the Espy-Koppen effect, but not quite from the influence of land and sea breezes, as the amplitude for the diurnal term amounts to 0.84 m and undoubtedly it will be accompanied by a semi diurnal one, as has been discussed previously for the analogical case at Batavia.

The graphic, however, distinctly indicates the presumable course of the curves between 0 and 4 km and this course is opposite to the one above 4 km.

	Height	Ampl.	Phase
Semi-diurnal variation East-Comp.	0 km.	28 cm.	180°
	1 "	35 "	167
	2 "	44 "	159
	3 "	51 "	151

The surface value of the phase, i. e. 180°, given above, agrees fairly well with the results for July—September obtained at Noordwachter, viz. 176°.

The principal results of the investigation as regards the East component therefore are:

From 0 up to 4 km. the amplitude increases and the phase decreases from about 180°—144°, higher up to 7 km. both return to the bottom values.

On higher level until 10 the phase seems to increase greatly and the amplitude to increase again.

When calculating the air displacement (velocity × density) we find:

Height	Ampl.	Air density	Air-displacement
0 km.	28 cm.	1.00	28
1 „	35 „	0.83	29
2 „	44 „	0.75	33
3 „	51 „	0.67	34
4 „	54 „	0.61	33
5 „	48 „	0.55	26
6 „	38 „	0.49	19
7 „	22 „	0.44	10
8 „	24 „	0 40	10
9 „	28 „	0 37	10
10 „	38 „	0.33	13

The foregoing points to a slight increase up to 4 km and a decrease from here upwards. The values above 7 km are too uncertain to warrant a fresh increase; a gradual decrease is more likely.

The original decrease of phase for the semi-diurnal oscillation of the East component in the lower parts of the atmosphere up to an altitude of 4 km corresponds with that for the semi-diurnal variation of the air pressure resulting from a comparison of the phases for Batavia and for the neighbouring Pangerango top.

		Air pressure		Oscillation of the wind Free atmosph
	Height	Ampl	Phase	Phase
Batavia	8 m.	1 00 mm.	160°	180°
Pangerango	3025 „	0.55 „	142°	151°

However the variation of air pressure on Mount Pangerango will not be wholly equal to that in the free atmosphere.

The difference in phase for windcomponent and airpressure therefore is:

at 0 km. 20°
and „ 3 „ 9°

As regards greater heights in the equatorial zone only the observations on the Misti top (5840 m. lat. — 16°16′)[1]) are available.

Here the phase for air pressure is 100° and for the wind 111° (presuming that the wind here blows principally from the W.) making a difference of 11°, i.e. quite in accordance with the value obtained for the Pangerango.

At the foot of the Misti the semi-diurnal variation of the air pressure has a phase of 164° (Mollende 24 m) and on the top of 114°, thus retarding 46° for a difference in height of 5.8 km. With regard to the Pangerango and Batavia this retardation amounts to 18° for a difference in height of 3.0 km., making per km. respectively:

$$\frac{46}{5.8} = 8^\circ \text{ and } \frac{18}{3} = 6^\circ$$

a little difference, seeing the uncertainty in phase for the two tops. The phase for the Misti has been calculated from one year's observations and the one for the Pangerango from three years', but only from two-hourly observations.

If one may go by the value set up for the Misti, one may fix the phase for airpressure above Java at 6 km. at 112°. This would, however make a difference with the phase of the windcomponent at 6 km. of 152°—112°=40°, going by which, we should arrive at: difference in phase of the semi-diurnal oscillation of wind and airpressure

0 km.	20°
3 „	9
6 „	40

and if still higher the phase of the air-pressure continues to decrease, the difference will increase to 180° at about 10 km.

This result therefore, gives no support to the reliability of our results as to the renewed increase of phase of the windvariation above 4 km., in so far that the difference of phase between the variations of air-pressure and wind do not remain constant. On the other hand this support is supplied by the observations of the Ci-drift made at the Batavia Observatory during 1906—10.

[1]) HANN, Sitz. Berichte Wien. Bd 118.

When calculating the drift components, it was assumed that the height of the clouds was constant: 11.0 km. for Ci and 10.5 km. for Ci Cu. [1])

For the East component has been found:

		Number of cases			Number of cases
6h—7 a.m.	6.1 m.p.s.	114	0—1 p.m.	5.0 m.p.s.	28
7 —8 "	6.3 "	74	1—2 "	4.0 "	31
8 —9 "	6.9 "	35	2—3 "	5.2 "	55
9 —10 "	4.5 "	36	3—4 "	5.0 "	30
10 —11 "	5.8 "	28	4—5 "	7.3 "	38
11 —12 "	2.9 "	28	5—6 "	7.1 "	140
			6—7 "	6.1 "	34

and consequently for the semi-diurnal term 124 cm. $sin\,(2\,t+266°)$. [2])

No doubt this result is pretty uncertain, but all the same it rather distinctly points to a high phase (266°), as did the results of the balloon observations (10 km. 317°), and it adds weight to the unexpected result that the phase after originally decreasing up to 4 km., would increase higher up, at first slowly and afterwards more quickly.

The question now arises, how do the results obtained agree with the theoretical ones?

Margules was the first to proffer a reasonable explanation of the phenomenon of the semi-diurnal barometrical oscillation, by demonstrating that the period of oscillation of an infinitely thin atmospheric shell comes near 12 hours, and consequently will be excited by the daily disturbance of the temperature. He therefore proceeds from the oscillation of the temperature and deduces barometer and wind oscillations, but by this process he finds the phases vastly different to those observed.

This is attributed by Gold [3]) to the neglecting of the vertical velocities, as a consequence of dealing with an infinitely thin atmospheric shell, assumed in order to overcome the otherwise unsurmountable mathematical difficulties.

Hence Gold proceeds on the contrary from the barometer variation and approximately solves the variations of temperature and wind (horizontal as well as vertical.)

[1]) Figee, Observations Batavia Observatory. Vol. XXX. App. II.

[2]) By applying the "difference method" afterwards has been found 42 Sin(2t 263°)

[3]) Phil. Mag. Vol. 19.

In this case it is not necessary for him to proffer an explanation of the change of the phase with the height, as shown by the variation of the airpressure.

Of this he only says (p. 37): "This diminution is probably due in part to the greater resistance to motion near the earth's surface; it may be due in part also to a change in the phase of the semidiurnal temperature variation in the free atmosphere".

As regards the latter, there are, in effect, only two determinations available for the free atmosphere, [1]) i.e. at Lindenberg and at Batavia. No trustworthy results may be derived from mountain stations.

Phase of the semidiurnal variation.

Height	Lindenberg		Batavia	
	Temp.	Airpress.	Temp.	Airpress.
0 km.	61°	136°	63°	160°
½ "	33	—	92	—
1—2 "	57	—	146	—
3 "	—	113	—	142

At Batavia, therefore, the phases of temperature and pressure move in opposite direction and at Lindenberg there is no pronounced sense of change for the temperature.

On p. 39 GOLD writes: "The difference of phase (between temperature and pressure variation) ought to diminish only slowly with the height; for latit. 45° this decrease would only be 45° at a height of 10 km.".

Lindenberg feebly agrees with the above, but at Batavia the diminution in difference of phase is too pronounced, the change in phase (with the height) of the airpressure agreeing indeed, although to a smaller degree.

Thus GOLD finds (see p. 38, note) from a graphical combination 38° diminution in phase for an increase in height of 3 km.; for Batavia-Pangérango (difference in height also 3 km.) 18° has been found.

Further from GOLD's results we find for the North and East components of the horizontal wind variation at the latitude of Batavia's (phase as compared to the one of the pressure variation)

[1]) See Observatory Batavia Verhandelingen 4, pg. XXXIX.

North comp.		East comp.	
Ampl.	Phase	Ampl.	Phase
5 cm.	20°	23 cm.	15°

whilst above from the balloon observations have been deduced 28 cm. and 20° as being the most probable values for the East component; a small value being found for amplitude of the North component.

Here, therefore, is a close agreement.

This agreement holds up to a height of 4 km., because the phase of the semi-diurnal variation of the East component follows the one of the air-pressure, and higher up the amplitude of the North component also remains considerably smaller than the one of the East component. E.g. at an average from 4– 5 km. we deduce from our observations:

North component 11½ cm. East component 51 cm.

proportion $\frac{51}{11.5} = 4.5$, whereas GOLD finds on the surface of the earth 5 and 23 cm., i.e. a proportion of 4.6; but as to a reverse in the change of phase there is nothing to be found in GOLD's treatise.

However, are there any indications to explain a similar reverse?

In the first place we looked for them in the vertical motion of the air, as found by GOLD's theoretical investigation and have considered whether, as a consequence of the rising or descending of air, a returning flow in the upper layers may take place.

According to GOLD the maximum vertical velocity of the semi-diurnal motion occurs about the time of the greatest horizontal velocity viz. an upward motion in the case of Western motion; e.g. close to the equator at 5 km. he finds an amplitude of the vertical oscillation of 2 mm. pro sec. If in consequence of this we assume an average rise of 1 mm. pro sec. occurring over $^1/_4$ of the earth's surface or 10.000 km., then we may also surmise that this air would again have to flow off through a layer of a thickness of say 10 km. This would make an average velocity of 1 m. pro sec., i.e. actually a velocity of the order required and it may be accepted as probable that this velocity is in inverse direction to that near the earth's surface.

Also, that on account of the ever increasing outflow and inflow with increasing height, a gradual increase (up to inversion) of phase should occur.

Apparently a similar explanation would not seem illogical, but often such arguments are misleading when we are solving suchlike problems, so that we will only consider it as a hint in that direction.

Finally we examined the possibility that the inversion of phase might have been occasioned by an accidental distribution of the errors of our observational results and in reality might not exist.

Let us take it that for the values found the real errors were the following ones:

Eastcomponent.

Height k.m.	x_2			y_2			Phase
	Value calcul.	real error	real value	value calcul	real error	real value	
6 5—7	—34	— 9	—25	2	—18	20	142°
7.5—8 5	—12	— 2	—10	—26	— 41	15	124°
9—11	50	52	— 2	—23	33	10	101°

According to the above the real values for amplitude and phase ought to be:

4	km.	59 cm.	133°
4 5—5	„	50 „	148
5.5—6	„	38 „	144
6.5—7	„	20 „	142
7.5—8.5	„	15 „	124
9—11	„	10 „	101

This would do away completely with the inversion and would carry on the original decrease of phase up to the highest heights observed, which should be accompanied by a rapid diminution of the amplitude.

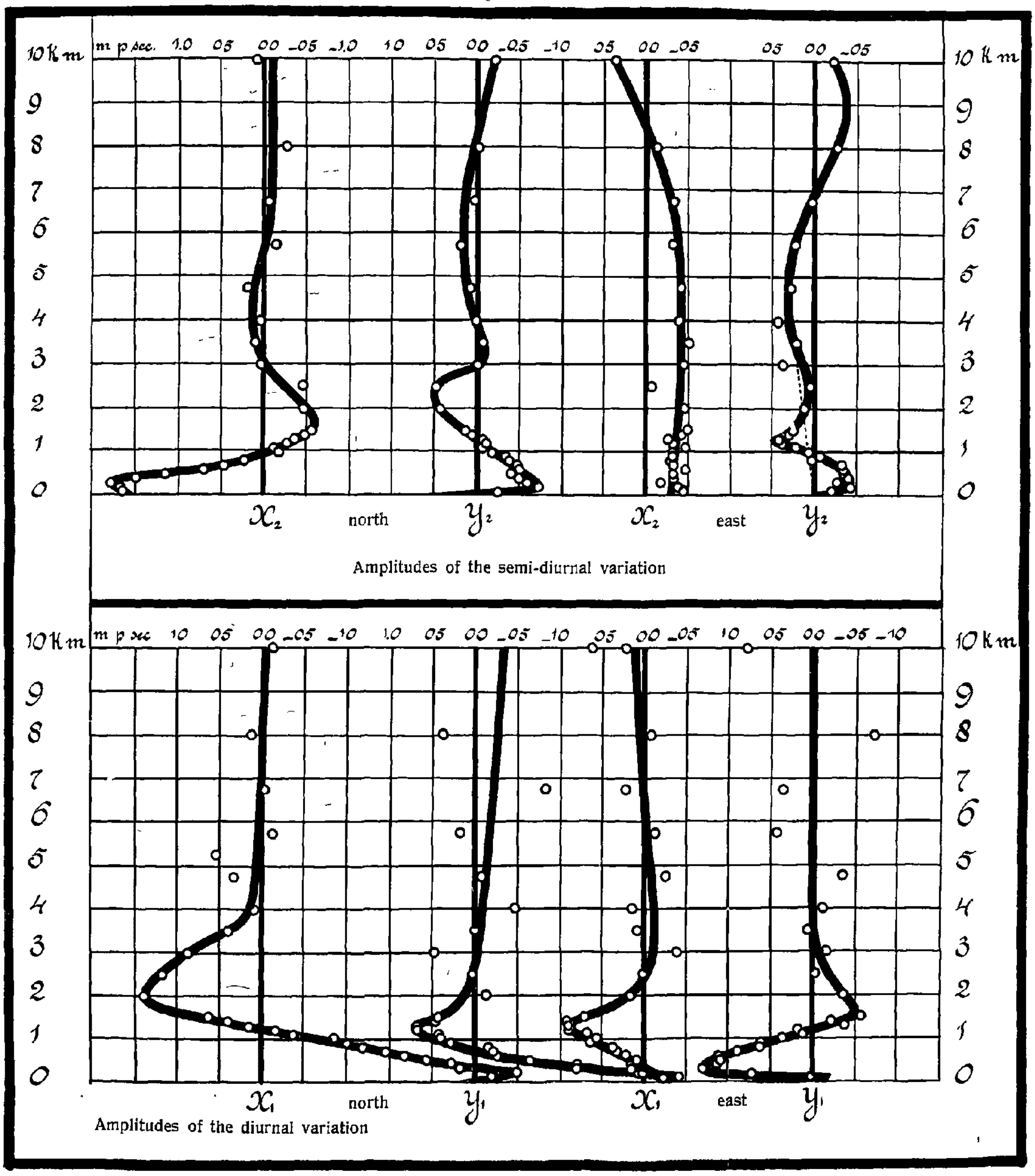
If we observe the real errors, it strikes us that, though the ones for y_2 are one-sidedly negative, they are of about the same size as the mean errors.

	accepted error	mean error
6.5—7 km.	—18	18
7.5—8.5 „	—41	—
9—11 „	—33	32

But, as has been explained above and has been proved by the graph, the mean error is much larger than the one to be expected.

As regards x_2 the real errors accepted for 6.5—7 and 7.5—8.5 km. are small, but the ones for 9—11 km. are much larger than the mean error, already exaggerated, viz. 52 against 34.

W. VAN BEMMELEN and J. BOEREMA: "The semi-diurnal horizontal oscillation of the free atmosphere up to 10 km above sea level deduced from pilot balloon-observations at Batavia."



Amplitudes of the semi-diurnal variation

Amplitudes of the diurnal variation

This consideration and the support, afforded by the phase previously arrived at for the Ci-drift, therefore leads to the following conclusion: "Possible but not probable" by which is indicated at the same time the manner to arrive at a better insight, viz. more observations.

The ascensions made on the Java-sea, which supplied a number of observations up to about 11 km., have partly met the above requirement, and may conceivably be taken as valid for Batavia.

On the other part it has been decided to commence further ascensions; these are now taking place during the change of the monsoon, when the velocity of the wind (the non-periodical one) as well as accidental errors [1]) will be slight.

SUMMARY.

1. With a purpose of investigating the diurnal and semi-diurnal oscillation of the motion of the air in the free atmosphere up to high levels, a great number of pilot balloon ascensions took place at Batavia during various hours of the whole day.

2. For the first time some series of nocturnal ascensions of balloons carrying lights, were then performed up to great heights, following the device indicated by C. H. Leij [2]) and as realized by him in some cases.

3. Afterwards will be published the various results for the lower layers of the atmosphere up to 4 km.

4. As regards the upper layers up to 10 km., it appears that the material of observations is insufficient for deducing a diurnal oscillation, on the other hand that for the semi-diurnal one leads up to positive results.

5. The amplitude of the semi-diurnal oscillation is larger for the East than for the North component, the phase of which remains uncertain.

6. In the lower layers the amplitude and phase seem to be in accordance with the theoretical results of Gold (Gold does not deal with the upper layers in that respect).

7. Up to 4 km. the phase of the semi-diurnal oscillation of the East component diminishes, in this respect following the corresponding phase of the oscillation of the air pressure.

8. Above 4 km. it is obviously probable that the phase again increases, thus effecting an inversion at a height of about 10 km.

1) Circumstances have prevented till now (May 1st) from doing so.

2) Quart. Journal. R. Meteor. Soc. 1909.