G.M.T. From this we see that the nearest approach to the earth should occur on May 20, the distance then being 14·3 million miles. The revised elements indicate that the comet should transit the sun's disc on May 18d. 14h., but the transit will, of course, be invisible in Europe. It appears possible that, at that time, the comet's tail may extend beyond the earth and be visible in the midnight sky.

From observations made with the 40-inch Yerkes telescope Prof. Barnard concludes that the comet is brightening rapidly, and was not fainter than magnitude 13·5 on October 17–19; the diameter was estimated at 15″, the comet being a little brighter towards the centre.

The Astronomischen Gesellschaft prize has now been definitely awarded (*Astronomische Nachrichten*, No. 4366) to Messrs. Cowell and Crommelin.

SATURN.—A telegram from the Flagstaff Observatory announces that the lacings crossing Saturn's equatorial bright belt, detected at that observatory, have now been photographed there (Circular No. 114, Kiel Centralstelle).

MERCURY.—From the careful study of some twenty photographs, taken at the Massegros Observatory during the elongation of September last, M. Jarry-Desloges arrives at the conclusion that the rotation period of Mercury coincides with the period of revolution. The photographs show a number of details (*Astronomische Nachrichten*, No. 4366, p. 375, November 1).

THE "FLASH" SPECTRUM WITHOUT AN ECLIPSE.—Yet another important development in solar spectroscopy emanates from Mount Wilson, Messrs. Hale and Adams, in No. 3, vol. xxx., of the *Astrophysical Journal*, describing the apparatus and method whereby they have succeeded in photographing the bright-line spectrum of the lower chromosphere without waiting for a total eclipse. With their apparatus such photographs may now be obtained at any time when the sun is observable.

After describing the previous attempts to attain this end, made at Kenwood, Yerkes, and Meudon, they give a brief description of the additions to the 30-foot spectrograph which enabled them to accomplish it.

The main difficulty in such photography is to keep the solar image exactly tangential to the slit, but they have overcome this by fitting a slipping-plate over the slit-plate. This slipping-plate is moved, parallel to the slit-plate, by a fine screw, and carries a right-angled prism which reflects the image of the limb on to a second, similar, prism fixed in front of the slit so as to reflect the rays between the slit jaws. The observer watches the spectrum, and by moving the slipping-plate preserves the tangential position, which gives the "flash" spectrum, throughout the exposure. The tower telescope gives a solar image of 6·7 inches diameter, and a grating having 568 lines per mm. on a ruled surface 49 mm. by 82 mm. is employed; better results are anticipated when the new 150-foot tower telescope becomes available. At present provisional wave-lengths are given for 124 "flash" lines, which are tabulated to show coincidences with Rowland's solar lines and with the eclipse lines observed by Evershed, Frost, Jewell, and Lockyer, respectively. The deviation of the wave-lengths of these lines from those given by Rowland for the corresponding solar lines is less than the probable error of measurement; if the bright lines of the "flash" spectrum were due to anomalous refraction at the sun's edge, as suggested by Julius, the two sets of wave-lengths should differ considerably.

SEARCH-EPHEMERIS FOR GIACOBINI'S COMET, 1896 V.—A revised set of elements for the comet discovered by Giacobini on September 4, 1896, is published by that observer in No. 4364 of the *Astronomische Nachrichten*, and gives the probable date of perihelion passage as December 19, 1909.

Three search-ephemerides are also given, one assuming that perihelion will occur on December 19·364, the others for ten days before and after, respectively. The position for November 4 is α=18h. 13·1m., $\delta=15^\circ\ 1'$ S., and the brightness is given as 0·58, unity being about equivalent to magnitude 12·0. The southerly declination and comparative faintness of the object render it unlikely that the comet will be observable, if found, except by the largest instruments.

THE UPPER AIR.[1]

THE past decade has been very fruitful in the investigation of the upper air. By the use of kites sufficient results have been obtained to furnish a tolerably complete knowledge of the variation in the meteorological elements up to a height of 2 km., while registering balloons have furnished information regarding the distribution of temperature up to heights of 15–20 km. The results of the Berlin manned balloon ascents were arranged and discussed very fully ten years ago, but no such comprehensive discussion of the much more numerous kite and registering balloon ascents has yet been attempted. The present report deals with the instruments and methods of investigation, and with the results for temperature and for wind.

The most important series of the earlier ascents with manned balloons was that made by Glaisher in 1860–70. Unfortunately, he was led to believe that artificial ventilation of the thermometers was unnecessary, with the result that his observations at great altitudes are untrustworthy. In the series of ascents made from Berlin in 1888–95, observations made with careful ventilation proved beyond doubt that large errors would arise in the absence of proper ventilation, and that Glaisher's results were almost certainly affected by such errors.

The following table shows the nature of the errors, and incidentally furnishes a comparison with one of the earlier *ballon-sonde* ascents:—

Height, metres	Fall of temperature °C. per 1000 metres		July 31, 1901	
	Glaisher	Berson	Berson and Süring	Ballon-sonde
0–1000	7·5	5·0	7·2	8·3
1000–2000	6·5	5·0	6·8	6·1
2000–3000	5·0	5·4	3·7	4·2
3000–4000	4·2	5·3	5·2	5·1
4000–5000	3·8	6·4	7·4	5·7
5000–6000	3·2	6·9	5·5	6·3
6000–7000	3·0	6·6	7·2	4·7
7000–8000	2·0	7·0	7·2	7·6
8000–9000	1·8	9·0	3·6	7·1

Temperature observations in manned balloons are now usually taken with an Assmann's aspirator, in which a ventilating current of about 4 m.p.s. is forced by a fan through a polished tube containing the thermometer and screening it from radiation.

The instruments used with registering balloons are of two types. In the large type the record is made on a metal or photographic sheet, covered with lamp-black, and wrapped round a revolving cylinder driven by a clock. Pressure, temperature, and humidity are recorded by separate pens. The barometer is a Bourdon tube or an aneroid, the thermometer some form of bimetallic instrument, and the hygrometer a bundle of hairs. In the small type the temperature record is traced on a cylinder or plate, which is itself moved at right angles to the direction of motion of the temperature lever by the changes of pressure. The temperature and pressure are then given by the ordinates and abscissæ of the trace obtained. The advantage of this arrangement is that no clock is required, and the instrument can be made much lighter and is more easily tested. The loss of the humidity trace is unimportant, because the hygrometric records at low temperatures are very untrustworthy, and the observations in the lower layers can be made with kites or manned balloons.

The instruments used with kites are similar to the *ballon-sonde* instruments of the larger type, but they have an arrangement for recording wind velocity. In the Dines instrument the records are traced on a flat, circular sheet of cardboard rotated by means of a clock and resting on a wooden tray beneath which the instruments are placed.

The *ballon-sonde* instruments are tested either (1) by keeping the thermometer at ordinary atmospheric pressure in testing for temperature, and the barometer at ordinary temperatures in testing for pressure, or (2) by testing the thermometer through the temperature range at different pressures and the barometer through the pressure range at

[1] Report on the Present State of our Knowledge of the Upper Atmosphere as obtained by the use of Kites, Balloons, and Pilot Balloons." Report of the Committee, consisting of Messrs. E. Gold and W. A. Harwood, presented at the Winnipeg meeting of the British Association, 1909.

different temperatures. The second is, of course, the more desirable plan, but the difficulties involved in applying it to the larger type of instrument are so considerable that the former method is generally adopted where such instruments are used. The simplicity of the smaller type of instrument devised by Dines enables the second method to be adopted in testing it, without elaborate and expensive apparatus.

Temperature records obtained simultaneously with different instruments show differences which, in the mean, do not exceed 1° C., and the temperatures may, in general, be taken to be correct to this degree of accuracy, but lagging of the instruments makes it doubtful if in all cases the recorded temperatures and heights actually correspond.

In dealing with the observations, it is found convenient to express temperatures in degrees C. above the absolute zero, −273° C. on the ordinary scale. Where necessary the letter A is used to characterise this scale. Atmospheric temperatures, both at the surface and in the upper air, lie almost always between 200° A and 300° A, so that the 2 may be dropped without risk of confusion. Gradients of temperature are expressed in degrees C. per km., and are reckoned + when temperature decreases upwards.

The mean value of the gradient up to 3 km. is as follows:—

	°
From the Berlin manned balloon ascents, 1888–1897	5·1
" " " 1897–1907	4·8
" Berlin and Lindenberg kite ascents	4·7
Calculated by Hann from mountain observations	5·7

It follows from these results that the mountains are colder than the free atmosphere at the same height, and many observers have verified this fact by direct comparison. Shaw and Dines found that in July, 1902, the temperature on Ben Nevis was 2·6° C. below that of the free atmosphere at the same height to the west of the mountain. Schmauss found that the temperature on Zugspitze (nearly 3000 m.), which lies on the northern edge of a mountainous region, was continually lower than that of the free atmosphere, but was higher than that at the same height on Sonnblick, which lies in the middle of the Alps.

It was pointed out by Von Bezold that increase of temperature on a mountain is limited by convection, whereas no immediate limit is set in this way to cooling. There is a one-sidedness in the heat exchange between the mountain surface and the atmosphere which would tend to produce the result found by observation. Moreover, convection always tends to raise the temperature of the upper air above what it would be otherwise, and, in addition, the cold of winter is, as it were, stored up in the snow, while no such process holds for the warmth of summer. Both conditions are probably effective in increasing the temperature difference. The most important deduction to be made from the results is that the mountains are not cold because the upper air is cooled by convection, but they are cooled by their radiation to space.

The mean values of the gradients up to 15 km., found from registering balloon ascents at ten European stations and for St. Louis, U.S.A., are given in the table:—

Height	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8 km.
Gradient Europe	3·6	4·3	5·2	5·8	6·3	6·8	7·2	7·4
Gradient St. Louis ...	5·1	5·3	4·7	5·2	5·9	6·2	7·8	8·7

Height	8–9	9–10	10–11	11–12	12–13	13–14	14–15 km.
Gradient Europe	6·8	5·0	3·3	0·7	−0·8	0·0	−0·1
Gradient St. Louis ...	7·4	6·7	5·5	2·9	1·4	0·6	−0·9

The maximum value occurs in the layer 7–8 km., and its magnitude indicates that the effect of radiation is to leave practically unchanged the natural gradient in air in vertical motion. Gold showed that in the upper layers absorption exceeded radiation, and in the lower layers radiation exceeded absorption, and both processes would diminish the temperature gradient. At an intermediate stage absorption and radiation must balance, and the results indicate that this is the case at a height of 7–8 km. The temperature at different heights up to 15 km. shows practically no variation for the ten European stations except in the case of Pavlovsk, where the temperature is uniformly lower up to 10 km. and higher above 10 km. than at the other stations. The difference of temperature between Strassburg and Pavlovsk, taken to represent lat. 50° and lat. 60° respectively, is sufficient to produce a gradient of pressure at a height of 10 km. which would correspond to a steady west wind of about 24 m.p.s. (54 miles per hour). The difference between Strassburg and St. Louis (representing lat. 39°) would at the same height correspond to a steady west wind of 15 m.p.s. in intermediate latitudes. The observations are not sufficiently extensive to warrant much stress being laid on the absolute values of these velocities, but it is of interest to note that the approximate ratio of the west winds in lats. 45°, 55°, deduced from Oberbeck's solution by a purely theoretical treatment of the problem of the general circulation, is 16/21 for the upper strata, a result in tolerable agreement with the ratio 15/24 deduced from the temperature observations.

The problem of the vertical distribution of temperature in cyclones and anticyclones depends for its solution on upper-air observations. Hann deduced from the temperatures at high-level observatories that cyclones were colder than anticyclones, the mean difference of temperature up to 3·5 km. being as much as 5° C. Grenander found similar results by a consideration of the kite and balloon ascents at Hald and Berlin, while Von Bezold deduced from the Berlin manned balloon ascents that the relative coldness of the cyclone was maintained even up to 8 km.

The results in the present report, obtained by taking only those cases in which the sea-level pressure exceeded 770 mm. or was less than 750 mm., and correcting the observations for seasonal and local variations, showed that the cyclone was colder than the anticyclone up to 9 km., while at greater heights the conditions were reversed, and the anticyclone became much colder than the cyclone; but the effect of the temperature difference in the lower layers on the pressure difference is so considerable that even at 14 km. the pressure gradient is not reversed. In these circumstances it is difficult to see how air can be brought into the anticyclonic and out of the cyclonic regions in the upper air. The cirrus observations imply a definite outward motion over cyclonic regions, but a rotation in the same direction as at the surface, which can be the case only if the gradient of pressure is also in the same direction as at the surface. These results imply that there is motion across the isobars from the lower to the higher pressure. Now, although it is possible for such motion to exist if the velocity in the cyclonic region exceeds a certain value, or, in the anticyclonic region, lies between certain limits, it is not possible to have steady motion of this type, and the effect of damping would be to make the motion from the higher to the lower pressure. The evidence points to the conclusion either (1) that cyclones and anticyclones arriving in the European area are in general dissipating systems which are continually replaced by other systems arriving from what may be called productive regions, or (2) that there is interchange of air with regions in which the surface temperature or the temperature gradient differs sufficiently to produce mean temperatures greater in low-pressure areas and less in high-pressure areas than are found over Europe.

It is interesting in connection with this part of the subject to note that Shaw and Lempfert deduced from a discussion of surface air currents that the central areas of anticyclones were not the regions of origin of currents, and could not, therefore, be places where descent of air was taking place to any considerable extent. The temperature observations in the first 3 km. agree with this conclusion, since they show that there is no approach to a regular adiabatic gradient near the centres of anticyclones.

Perhaps the most remarkable phenomenon revealed by the observations from registering balloons is the comparatively sudden cessation of the fall of temperature at a height which varies from day to day, but is roughly equal to 10 km. Above this height, which may be regarded as the height of an irregular, but roughly horizontal, surface dividing the atmosphere into two regions, the temperature at any time varies very little in a vertical direction, showing, on the average, a slight tendency to increase. The lower and upper regions are characterised by the terms "convective" and "advective" respectively, and the height and temperature of the dividing surface are denoted by H_c and T_c. The following table gives the values of H_c, T_c, for certain places in Europe:—

	Mean of 13 Stations	Munich	England	Strassburg	Paris	Pavlovsk	Koutchino	Milan	Vienna	Berlin
H_c	10·6	10·9	10·8	10·8	10·4	9·6	10·6	10·7	10·2	10·7
T_c	16°	16°	18°	15°	18°	18°	14°	17°	15°	16°
No. of cases ...	336	53	32	67	57	28	18	25	24	32
Latitude	—	48°	52°	49°	49°	60°	56°	45°	48°	52°

There is very little variation for places between lat. 45° and lat. 55°, but at Pavlovsk H_c is about 1 km. below the average. Observations made in the equatorial regions show that the value of H_c there exceeds 15 km., so that there must be a considerable increase in its value in crossing the limit of the trade-wind region, and it appears probable that the equatorial currents and the trade winds form a closed system with little interchange of air with higher latitudes.

The annual variation in H_c, T_c is shown by the following table:—

Annual Variation in H_c.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
Mean of 13 stations...	10·3	10·4	9·1	10·1	10·5	10·7	10·9	11·4	10·4	11·9	10·8	10·1
Number of cases ...	26	22	32	39	31	27	24	61	46	38	25	25
Munich	10·0	10·4	9·2	9·2	11·2	11·0	11·7	12·0	10·3	12·3	11·8	11·4
Number of cases ...	4	3	6	4	2	4	3	11	5	5	2	5
Strassburg...	10·5	10·6	9·4	9·4	10·6	10·9	10·8	12·3	10·9	11·9	11·0	11·1
Number of cases ...	5	5	5	5	4	5	4	9	8	6	6	5

Annual Variation in T_c.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean of 13 stations...	13	11	16	16	17	20	20	18	22	14	15	14
Munich	14	10	16	19	25	20	15	16	26	9	10	13
Strassburg...	11	10	16	20	17	17	21	15	23	13	12	10

The remarkable feature is the relatively high temperature and low value of H_c in March and September. This peculiarity and the fact that T_c is least near the equator suggest that the general nature of the process may be as follows. The cool air above the equator moves polewards, and in the natural course descends again to feed the trade winds. Owing to the irregularities of the earth's surface, the change of seasons and the very considerable difference between the northern and southern hemispheres, the process will be neither regular nor symmetrical. Consequently, the equatorial cold air will encroach on the advective region of temperate latitudes, and such encroachments will produce anticyclonic regions. The advective atmosphere would be reached there at a higher level, and initially at a lower temperature than in the average state, but the temperature would be gradually raised by absorption of thermal radiation to the normal value for that latitude.

The fact that H_c has minimum values in March and September, when equatorial temperatures are highest, appears at first to be contrary to this view; but the first effect of increased temperature will be to increase the strength of the trade winds, and as at the same time there is a transference of air across the equator to the southern hemisphere, a transference which can be made only through the upper return current, there will be a deficiency of descending air, and the equatorial cold air will encroach less than usual on the northern advective region. The reverse process would be expected to occur in September, but the autumnal transference of air to the northern hemisphere will be initially much more intense towards the great continental regions than to the Atlantic and European area, and it may well be that the equatorial current again encroaches less than usual on that region. It may be expected that the value of H_c in Asia and America will not show the September minimum.

The explanation of the discontinuity in the temperature gradient appears to be this. The fall of temperature is governed mainly by convection, and a necessary condition for convection to persist is that the radiation shall exceed the absorption in the upper layers of the convective system. A limit is therefore set to the height to which convection can extend, and at this limit the discontinuity in the fall of temperature occurs. It has been shown that the observed height is about the same as the limiting height of the convective system found from theoretical considerations based on the experimental knowledge of the radiating power of the atmosphere.

The results of the observations of wind velocity may be briefly summarised as follows. In general, the velocity increases with height, the greater part of the increase up to 2000 m. taking place in the layers immediately above the surface; 75 per cent. of the total increase takes place in the first 160 m. Above 500 m. numerous cases occur where the velocity decreases with height. The velocity for heights up to 10 km. is given approximately by the equation $V\rho = V_0\rho_0$ (Egnell's law), where V is velocity and ρ density, $V_0\rho_0$ being the values near the surface. The law implies that the pressure gradient remains constant and independent of the height. Now, owing to the fact that the temperature is higher over regions of high pressure than over regions of low pressure, the ratio of pressure gradient to density increases with height. The condition for a constant gradient up to 8 km. is approximately

$$t_0 = \frac{74\,\delta p}{p} \text{ degrees C.,}$$

where t_0 is the excess of the mean temperature of the air-column at a place at pressure $p + \delta p$ above that at a place at pressure p. Observations show that for $\delta p = 20$ mm., $t_0 = 4°$ C. nearly, or double the amount necessary for constant gradient. It is to be expected, therefore, that $V\rho$ will increase up to 8 km., and the few pilot-balloon observations available point to such an increase.

The direction of the upper wind usually veers from that at the surface. The following table shows the deviations for winds from different quadrants in England and at Berlin:—

Deviation of the Upper Wind.

England.

Heights	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
W.	9°	14°	14·5°	14°	8°	8°
N.	4	8	3	−1	−3	−15
E.	15	22	20	28	35	21
S.	14	26	32	38	41	50

Berlin.

Heights	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
W.	18°	23°	23°	20°	23°	22°
N.	13	17	20	20	15	25
E.	27	30	38	45	46	44
S.	38	46	48	49	53	46

The deviation at Berlin is in nearly all cases greater than in England, especially for north winds, which back slightly in the upper air in England.

There is no marked difference between anticyclonic and cyclonic conditions in the change of wind velocity and direction with height. The following table gives the values deduced from observations at Berlin and Lindenberg in 1905:—

	Height	Surface	1 km.	2 km.
Anticyclonic (A)	Deviation	—	30°	33°
	Velocity	4·1	8 2	8·4 m.p.s.
	Ratio to surface velocity	1·0	2·0	2·05
Cyclonic (C)	Deviation	—	30°	37°
	Velocity	5 9	10·5	10·7
	Ratio to surface velocity	1·0	1·78	1·82

The deviation is slightly greater and the ratio slightly less in C than in A. It would be natural to suppose that surface friction and irregularities would produce a decrease in velocity which increased at a greater rate than the velocity itself, and in that case the ratio in C would be greater than in A, as was actually found by Berson from the manned balloon observations.