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PROFESSIONAL NOTES NO. 8.

TEMPERATURES AND HUMIDITIES IN THE UPPER AIR: CONDITIONS FAVOURABLE FOR THUNDERSTORM DEVELOPMENT,

AND

TEMPERATURES OVER LAND AND SEA.

BY

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INTRODUCTORY NOTE.

"Meteor Flight" was established at the beginning of 1918, originally as a part of H.Q. Communication Flight, to supply observations of temperature and humidity in the upper air for use by "Meteor" in the preparation of reports and forecasts. The pilots responsible for the observations during the period covered by the following notes were Captain C. K. M. Douglas, A.F.C., Lieut. G. E. Marden, M.C., and Lieut. R. V. Sessions.

The following notes by Capt. Douglas upon the conditions of temperature, humidity and wind in the upper air during thunderstorms do not claim to give a full explanation: but rather to indicate certain local conditions and local changes associated with thunderstorms. Observations in the upper air over a wide area are needed for a closer examination of the causes and process of development of these phenomena. But these notes do throw much light on the subject, and should enable forecasters to interpret synoptic charts with more confidence: because hitherto the interpretation had depended primarily on experience and knowledge of previous similar surface conditions

There are at times irregularities in a general westerly current which bring squalls or showers of thunderstorm type which must be associated with differences of temperature and humidity in the current. Such conditions existed on August 26th, 1916, when thunderstorms occurred at LONDON, severe squalls at NANCY, and a heavy shower of squall type on the SOMME. On that occasion British aeroplanes were caught in the squall on the Somme, and 7 failed to return through it.

Again, very variable conditions must have existed towards the end of September, 1918. At 7h. on September 26th there was an inversion of 10°F at 5,500 feet above clouds: at 18h. the level of the inversion had risen to 7,000 feet, and the amount fallen to 3°F. In the early morning of September 27th over 5mm. of rain fell, and one would naturally have anticipated that the inversion had been dissipated: yet at 8h. on 27th there was an inversion of 5°F. at 7,800 feet in the upward flight, but only 2°F in the downward flight: and at 18h. on the 27th there was an inversion of 5°F. at 8,000 feet in the upward flight, and no inversion coming down. The following morning all traces of inversion had vanished and heavy rain fell in some localities: the amounts measured varied from 18mm. to less than 1mm.: nevertheless the rain, except in its distribution, bore no resemblance to thunderstorm rain: it was like thick mist and driving rain. No inversion was observed on the evening of September 28th, but an inversion of 3°F reappeared at 6,000 feet on the morning of the 29th. The upper winds at 10,000 to

20,000 feet were nearly due westerly for the whole of the period, varying from 50 to 80 m.p.h.; the differences of temperature may have originated in the westerly current drawing its air from two sources, the warm air over the anticyclone and the cold mass over the cyclone: but, however the differences originate, they will certainly produce instability in the current.

It was hoped to secure a series of observations in the upper air over the English Channel without interfering with the normal observations of temperature and humidity for Artillery and Forecasting; but after a few observations had been obtained it was decided that seaplanes were essential for observations at considerable distances from the shore. The few records obtained and some notes on them are given in a supplementary note.

E. Gold,
Lt.-Col.,
Commandant.

Meteorological Section, R.E. [Meteor.],
General Headquarters
British Armies in France,
8th October, 1918.

(24206—12) Wt. 12707—SOP 542 600 5/20 H. St. G. 3 A 2

TEMPERATURES AND HUMIDITIES IN THE UPPER AIR:

CONDITIONS FAVOURABLE FOR THUNDERSTORM DEVELOPMENT.

*** *The observations recorded in this Note were made by pilots of "Meteor Flight" stationed at Berck in N.E. France. The coast in that locality runs from North to South for over forty miles.*

The following notes show the upper air conditions on a number of days on which thunderstorms occurred in Northern France in 1918, the observations being in some cases made close to the storms themselves. Readings calculated from the tracings of a Dobson R.A.F. baro-thermograph are given in some cases, and it will be seen that they differ little from the observed readings; the heights given are in all cases the true heights, and not the aneroid heights.* In addition to the humidities obtained from the wet bulb readings, those from a self-registering hair hygrometer are given, read in most cases to the nearest 5 per cent. At great heights this instrument usually gave readings differing little from 100 per cent. in clouds, but in dry conditions sometimes gave exceedingly low readings whose accuracy is open to doubt.

As might be expected, the conditions on days when thunder occurred were as a general rule decidedly unstable. Sometimes the lapse of temperature was rapid at all heights, but occasionally there was a comparatively stable layer just above the limit of the ordinary daily convection, and a rapid fall of temperature at still greater heights. The most marked feature of the observations was the number of instances of an unstable condition above 8,000 feet. Provided that the humidity is not too low, this condition appears to be more favourable to thunder than a rapid fall of temperature up to 8,000 feet and a comparatively stable layer for three or four thousand feet above that. The latter distribution of temperature favours clouds and showers, but not thunderstorms. Examples of temperature "inversions" with thunderstorms occurred on April 24th and 29th, when there were inversions of a few degrees above fog layers which drifted from the North Sea and thunderstorms arrived up above from ENE. There were also slight "inversions" between 6,000 and 8,000 feet shortly before thunderstorms on August 23rd, which are referred to again later. The presence of an inversion does not preclude the chance of thunderstorms if the conditions are unstable up above, but the disturbance must obviously be due to causes other than convection currents due to heating at the surface. In some cases there is a complicated wind system, and

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**i.e.*, they are heights deduced from the aneroid heights by allowing for the actual observed temperature; they do not include any corrections for lag in the aneroid. Temperatures were read from mercury thermometers placed on a strut about 8 feet from the pilot and quite clear of hot air from the engine. The wet-bulb was mounted in the usual way but the water was contained in a small metal vessel, entirely closed except for a small hole through which the wick entered: the wick was kept from blowing out of the vessel by a small weight attached to the end inside the vessel. The method was devised by Captain Liddle, R.A.F., and Lieut. Marden.

probably vertical movement associated with wind variations, and consequent local convergence of the surface currents, starts the formation of the clouds, provided that the humidity is high enough.

The lapse rate of temperature is, of course, only one factor in the problem. Every thunderstorm in France in 1918 was associated with a shallow depression or secondary, and many of them with the arrival of cooler surface air. The upper air observations supplied some interesting information concerning the displacement of warm currents by cooler ones. The fall of temperature takes place first near the surface, and afterwards higher up; near the surface the temperature may fall abruptly from a high to a low level during a thunderstorm, but high up this change is spread over at least 24 hours. Sometimes the upper air temperature falls somewhat previous to the thunderstorm and so helps to cause unstable conditions, but abrupt changes do not take place.

With regard to humidity, the only general conclusion that can be drawn is that, if conditions are otherwise favourable, the higher the humidity the greater the chance of thunderstorms. This is certainly true as a general rule of any level up to 10,000 feet, and possibly higher. Perhaps, however, in some cases the presence of a high cloudsheet may interfere with the formation of local afternoon thunderstorms by preventing a large part of the sun's heat from reaching the surface. For the formation of these local thunderstorms the humidity of the lower air is of importance, as if it is very dry the day may remain cloudless even if convection currents reach 8,000 feet. On fine summer days there is usually a maximum relative humidity at the limit of convection, and above that the humidity may be very low If thunderstorms develop, their effect on the upper air humidity is quite local. On the other hand, when thunderstorms occur in rainy weather the humidity may be high at all heights. In warm southerly types, with upper winds from south-west, there is usually high humidity high up, and there may be a damp layer above a very dry layer, or even an alternation of dry and wet layers. It is important that there should be at least one fairly damp layer as low as 6,000 feet, as otherwise severe storms are unlikely to develop. For instance, on the evening of August 1st conditions were in most respects favourable for thunder, but the humidity was very low up to 10,000 feet (between 25 and 60 per cent.) and the lowest clouds were at 11,000 feet. Next morning, when the trough of the depression arrived, there was some heavy rain from a high level, but no thunder. No doubt thunderstorms do occur at high altitudes, but in our latitudes they are not usually severe if the base of the thunder clouds is above 8,000 feet; as a rule the cloud base is at about 5,000 or 6,000 feet in hot weather, lower in cool weather.

The form which the clouds assume is closely related to the temperature and humidity conditions. On fine hot days when the upper air humidity is low the clouds are usually limited to columns of cumulus. Though local thunderstorms may develop from a single column, severe storms usually develop from a group or a belt of large cumulus clouds. Sometimes the cumuli reach a height of 18,000 feet and even give rise to a little false cirrus, and then dissolve away without causing thunder. In unsettled weather with a comparatively high humidity at all levels there is apt to be much cloud of strato-cumulus type in addition to the cumulo-nimbus, mostly between 6,000 and 9,000 feet. When the lower air is comparatively stable, thunder clouds may develop up above. As a rule a general upward movement first causes a sheet of clouds to form in a damp layer, which afterwards grows to a large mass of cumulus and finally cumulo-nimbus. If there is a damp layer with a lapse of temperature above it greater than the adiabatic for saturated air, it is obviously a favourable factor for the development of thunderstorms, as any clouds that form soon turn into large cumulus. When there is an alternation of dry and damp layers, the clouds may form at two or three levels simultaneously, and finally join up.

When the formation of the clouds has started, their growth may be very rapid, but the rapid rate is not always maintained continuously by all parts of the cloud. When flying above the tops of growing clouds it is usually found that the air is ascending, and if the humidity is high clouds may begin to form which are afterwards joined by the lower clouds. Sometimes a cloud towers up and then sinks down again rapidly, and sometimes the top breaks away and dissolves. Both upward and downward currents are apt to be found in the vicinity of large cumuli, the downward currents being powerful in rifts of the clouds and under protruding shoulders.

The height ultimately attained by thunderclouds is very great. In hot weather the rounded tops reach 20,000 feet, and the false cirrus 30,000; in cool weather the rounded tops usually reach 15,000 feet, and the false cirrus exceeds 20,000 feet. A little thunder may, however, occur in clouds which do not attain quite such great heights. The false cirrus consists of snow which is usually formed from super-cooled water particles within the towering cumulo-nimbus. It may last long after the storm dissolves and be carried great distances by the upper winds. Downward currents are often found under the edges of anvils of false cirrus and also under degrading masses of false cirrus. They are particularly well marked under clouds of "mammato-cumulus" form.

From high up thunderstorms are visible for great distances. For instance, thunderstorms occurred in London on the evenings of July 12th, 18th, 24th and 25th, and September 5th, and in each case the clouds were easily visible from France above 8,000 feet. The extent of the visible horizon from 14,000 feet is much greater than on the ground and the visibility always good, and very distant thunderstorms are sometimes seen. Occasionally tall cumulo-nimbus is seen though no thunder or showers are reported from any of the daily stations. On May 19th and 20th at about 18h. cumulo-nimbus was visible far to SW, and on the evening of June 2nd an isolated column of cumulo-nimbus to the cirrus level was visible somewhere in the East of England, some distance NE of London. On none of these days was thunder reported from stations in the neighbourhood, though they were undoubtedly fully developed storms.

For convenience, the thunderstorms of 1918 may be classified according to what appeared to be the chief factor in causing instability Many of the thunderstorms in any summer could be placed in one of the three classes, though not, of course, all of them. The classes are as follows:—

(A) Those due mainly to heated surface air in fine sunny weather.

(B) Those associated with powerful upper currents from SW, the surface wind being light and variable or south-easterly (The tendency for thunderstorms with this wind system was pointed out by Capt. A. H. R. Goldie in 1916.)

(C) Those associated with very low upper air temperatures in the south-westerly or north-westerly currents of cyclonic depressions.

Class A.

Thunderstorms of this type are developed from the convection currents of hot summer afternoons, if the upper air temperatures are not too high. They are often associated with the arrival of cooler surface air, but they have little or no effect on the barometric pressure. Sometimes they are associated with no fall of temperature at all, except local cooling due to rain or hail. They usually occur with light winds, and often die out before travelling very far. Suitable conditions most commonly occur in early summer, when the upper air temperatures are lower than they are later in the season. For examples, we may take the thunderstorms of May 17th, 18th and 22nd, 1918, and also September 5th, 1918.

May 17th, 1918.—There were some large cumuli after 9h. with their bases at 5,000 feet, some of the tops exceeding 12,000 feet by 10h. Most of these dissolved away and only one short-lived thunderstorm occurred. About 17h. a large cumulus, 20 miles inland, grew to 20,000 feet, and formed cumulo-nimbus with false cirrus to 30,000 feet. It moved slowly towards NE or NNE and broke up about half an hour later, though the false cirrus remained for some time afterwards. Large masses of cumulo-nimbus were visible over England, and also far to the South. The temperatures, humidities and wind velocities are given below. The temperature at 1,000 feet was affected by the sea breeze; inland the surface temperatures rose to 78° F. locally in the afternoon. The humidity was high between 5,000 and 6,000 feet, and there was a good deal of cloud inland at that level. There was much smoke haze to 6,000 feet. The sea breeze extended inland as far as the region where the thunderstorm developed. The upper winds given below were further inland. At Montreuil at 19h. 45m. there was a NW wind at 1,000 feet, and a South wind at 4,000 feet.

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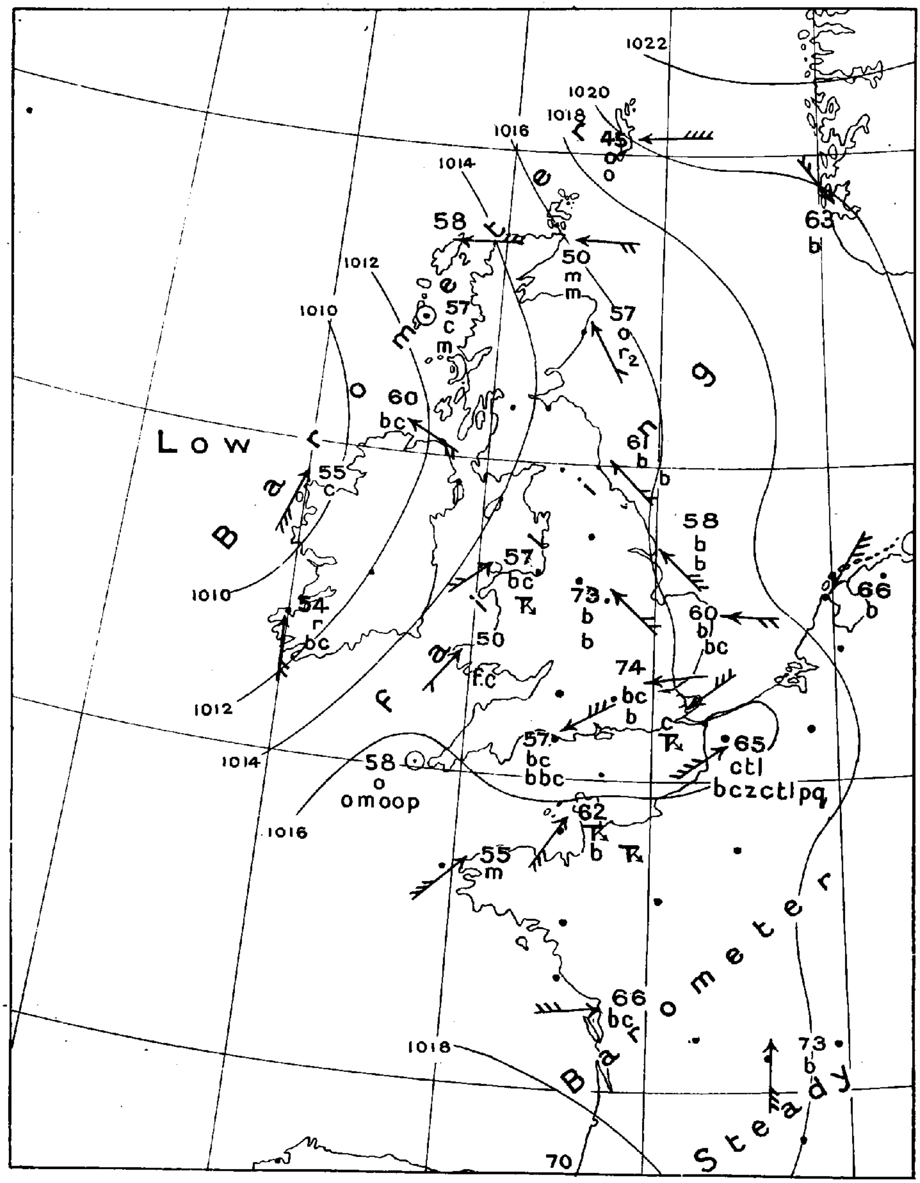
MAY 17TH.

Height (ft.).	Time of Start 16h. 30m. 13,000 ft. at 18h. 30m.				Upper Winds from evening chart.	
	Observed Temp. °F.	Temp. from baro-therm.	Observed Humidity %	Humidity from Hygrograph.	16h. 15m. Villers Bocage. (m.p.h.)	
				Read to nearest 5% if changing rapidly.		
25,000	—	—	—	—	SW by S	21
20,000	—	—	—	—	SSW	16
14,000	—	—	—	—	SW	8
13,000	23	23	—	25	—	
12,000	27	27	—	27	SW	5
10,000	33	33	—	20	SW	8
8,000	40	40	46	30	SW	8
6,000	46	46	88	85	S	3
4,000	56	56	79	75	SSW	4
2,000	66	66	57	55	S by W	6
1,000	69	69	52	50	S	6

May 18th, 1918.—Shortly after noon large cumuli formed rapidly about 20 miles inland, and by 13h. an anvil had developed up to the cirrus level. The thunderstorm moved very slowly to SSE and broke up and dissolved after 15h. By 17h. there was nothing left but cirrus clouds above 20,000 feet. Temperatures, humidities and wind velocities are given below. The humidity in the upper air had increased somewhat above 6,000 feet. This increase was associated with an upper wind from SW, above 10,000 feet. The motion of the storm appeared to be governed by the wind between 6,000 and 10,000 feet, though it was affected by the development of fresh thunderstorms at the edge of and on the rear side of the original one and joined to it.

MAY 18TH.

Height (ft.).	Morning Ascent. Start 8h. Top 9h. 30m.				Evening Ascent. Start 17h. 20m. Top 18h. 30m.			
	Observed Temp. °F.	Temp. from Baro. therm.	Observed Humidity %	Hydrograph Readings %	Observed Temp.	Temp. from Baro. therm.	Observed Humidity %	Hydrograph Readings %
14,000	16	16	—	72	18	18	—	45
12,000	24	24	—	78	27	27	—	68
10,000	30	30	—	75	33	33	76	65
8,000	37	37	75	70	40	38	57	55
6,000	47	47	72	65	49	47	59	60
4,000	54	55	58	50	56	56	67	65
2,000	62	62	61	60	65	65	57	65
1,000	64	64	61	55	68	69	56	50



DAILY WEATHER CHART, MAY 22ND 1918, 18H

(The lower groups of letters refer to past weather since 7h.)

P.S. 1124/119 Wt. 12707. D.S.O.P. 542 600 4/20. H.M. Stationery Office Press, Kingsway, W.C.

UPPER WINDS, MAY 18TH.

Height (ft.).	Aire 10h. 50m.		Montreuil 14h. 50m.	
	Direction.	Velocity m.p.h.	Direction.	Velocity m.p.h.
26,000	—	—	SW	17
25,000	SW by W	12	—	—
20,000	SW	11	WSW	11
14,000	SSW	10	SW by W	7
10,000	SW by S	5	NNW	6
6,000	NW	12	NNW	7
2,000.	NW by N	11	NW by N	7
1,000	NW by N	8	N by W	7
Surface	NW	6	N by W	5

May 22nd, 1918.—A severe local thunderstorm occurred over the aerodrome in the late afternoon of May 22nd, after a fine hot day with a shade maximum of 84° F. Cumuli started to form at 6,000 feet at 12h. 30m. and grew rapidly; they were tall and narrow, the tops leaning towards NW. False cirrus first appeared at 15h., and thunder began at 15h. 45m. The storm was in the form of a belt from SE to NW, and moved end on, the drift being from SE. It was accompanied by heavy hail and rain, with some forked lightning to the ground, but most in the clouds. It lasted till 18h., and there were afterwards thunder and lightning to SW and W till 20h. A large mass of false cirrus up to a great height was drifted towards the north. The surface wind changed to SW with the storm and brought a big fall of temperature which was limited to the surface layer, as is shown by the upper air temperatures given below. By midnight the upper winds were West of South, but the upper air temperatures remained unchanged from 6,000 feet upwards, as is shown by the figures for Ipswich on the following morning. In France the morning ascent was prevented by low clouds which drifted in from the West at 7h. after a fine warm morning. A strong West wind set in at all heights on the 23rd and the temperatures decreased considerably. The change was accompanied only by cloud and a slight shower, though thunderstorms occurred in the E of England.

The arrival of cold surface air no doubt contributed to the development of the thunderstorm of the 22nd, but the big lapse of temperature with height, due to the heated surface air, was also an important factor. It is worth recording that the cold surface air extended several miles to the NE of the storm belt, but had no effect on the barometric pressure. Other storms of less intensity occurred a long way further North. The chart at 18h. on the 22nd is reproduced in Fig I, showing the cooler SW surface current behind a small secondary depression.

MAY 22ND, 1918.

Height (ft.).	Morning Ascent. Start 7h. 30m. Top 9h.				Evening Ascent. Start 18h. 15m. 13,000 ft. at 19h. 45m.				Upper Winds. Aire 19h. 55m.	
	Observed Temp.	Temp. from Baro. therm.	Observed Humidity %	Hydrograph Readings%	Observed Temp.	Temp. from Baro. therm.	Observed Humidity %	Hydrograph Readings%	Direction.	Velocity m.p.h.
14,000	20	20	—	25	—	No record.	—	—	SE by S	28
13,000	—	—	—	—	23		—	40	—	—
12,000	27	27	—	30	26		63	55	SE by S	24
10,000	34	34	40	34	33		—	55	SE	17
8,000	43	43	51	45	41		69	65	SE	21
6,000	50	49	64	60	49		95	90	SE by S	18
4,000	60	61	54	56	59		67	70	S	18
2,000	68	69	56	50	68		52	45	S	26
1,000	70	70	—	60	71		42	40	S	25
Surface	—	—	—	—	62		—	80	—	—

MAY 23RD.

Height (ft.).	Ipswich 7h.	France. Start 17h. 14,000 ft. at 18h. 15m.		
	Temp. °F.	Temp. °F.	Observed Humidity %.	Hygrograph Readings %.
16,000	14	—	—	—
14,000	19	6	—	30
12,000	27	10	—	30
10,000	34	17	—	35
8,000	43	24	57	45
6,000	50	30	62	50
4,000	56	37	54	55
2,000	62	46	69	60
1,000	—	50	72	65

September 5th.—Local thunderstorms occurred on September 5th and 6th which may be conveniently placed in this class, although only due to a limited extent to heating at the surface. The thunderclouds consisted of columns of cumulo-nimbus with cirrus to a great height, and the individual storms existed for an unusually long time, some of them lasting till nearly midnight and travelling long distances with the WSW current. A rather severe storm occurred in this locality (Berck) about 22h. 30m., which was first observed on the horizon at 18h. With good visibility storms were followed for five hours on the NW horizon during the afternoon. The temperature gradient above 4,000 feet differed little from the adiabatic for saturated air, and with fairly high humidities conditions were quite favourable for thunder. The thunderstorms were associated with a shallow irregular depression. On September 6th, local thunderstorms again developed, temperature conditions being similar.

SEPTEMBER 5TH.

Height (ft.).	Temperatures and Humidities, 17h 18h.			Upper Winds (m.p.h.).	
	Temperature °F.	Observed Humidity. %	Hydrograph Readings. %	Poperinge 16h.	Montreuil, 18h.30.
14,000	18	—	70	—	—
12,000	25	85	85	WSW 28	W by S 26
10,000	32	60	60	WSW 30	WSW 24
8,000	40	69	60	WSW 28	WSW 25
6,000	45	72	60	WSW 24	WSW 27
4,000	53	74	75	WSW 21	SW by W 11
2,000	62	62	70	W by S 17	WSW 6
1,000	66	65	65′	W 9	WNW 4

Class B.

Thunderstorms of this class are associated with powerful upper currents from the south-west, and light variable or south-easterly surface winds. This combination is possible owing to the presence of heated surface air to the south-east, over Eastern France. At about 6,000 feet a steep gradient for SW winds prevails, but at the surface pressure is fairly uniform, owing to the air below 6,000 feet being much warmer to the south-east and, therefore, less dense. If this temperature difference is very well-marked the upper wind may be reversed and a north-east wind prevail at the surface. This wind distribution occurred on August 23rd; in the South of England it is not uncommon, and is known to be favourable to thunderstorms. If a definite south-east current prevails at the surface, the hot air lies to south rather than to south-east. The cooler SW upper current over the warm SE current causes an unstable condition, and the lapse-rate of temperature is also usually high within the SW current above 8,000 feet. Storms of this type differ from those of Class A in that the instability is due to a definite flow of cooler air over warm air, instead of to the heating of the surface layers by several hot sunny days. They therefore occur as often by night as by day. The upward movement appears to be usually started by small local irregularities of pressure. Sheets of cloud appear in one or more layers, which develop into cumulo-nimbus owing to the unstable conditions. Frequently clouds of the type known as "alto-cumulus-castellatus" are observed, which indicate high humidity and an unstable condition high up. These thunderstorms move rapidly with the SW upper current.

The most violent summer line-squalls are included in this class, and are illustrated by the storms of July 17th and 20th. Sometimes a cooler westerly current spreads in and causes thunderstorms without line-squalls, as on July 8th and September 7th. On the other hand thunderstorms of this class may not be followed by any fall of temperature, as on the night of July 15th. The thunderstorm of the night of August 23rd is also considered, as it illustrates the north-east surface wind with a

SEPTEMBER 5TH.

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	Tempera-ture °F.	Observed Humidity. %	Hydrograph Readings. %	Poperinge 16h.	Montreuil, 18h.30.
14,000	18	—	70	—	—
12,000	25	85	85	WSW 28	W by S 26
10,000	32	60	60	WSW 30	WSW 24
8,000	40	69	60	WSW 28	WSW 25
6,000	45	72	60	WSW 24	WSW 27
4,000	53	74	75	WSW 21	SW by W 11
2,000	62	62	70	W by S 17	WSW 6
1,000	66	65	65	W 9	WNW 4

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Thunderstorms of this class are associated with powerful upper currents from the south-west, and light variable or south-easterly surface winds. This combination is possible owing to the presence of heated surface air to the south-east, over Eastern France. At about 6,000 feet a steep gradient for SW winds prevails, but at the surface pressure is fairly uniform, owing to the air below 6,000 feet being much warmer to the south-east and, therefore, less dense. If this temperature difference is very well-marked the upper wind may be reversed and a north-east wind prevail at the surface. This wind distribution occurred on August 23rd; in the South of England it is not uncommon, and is known to be favourable to thunderstorms. If a definite south-east current prevails at the surface, the hot air lies to south rather than to south-east. The cooler SW upper current over the warm SE current causes an unstable condition, and the lapse-rate of temperature is also usually high within the SW current above 8,000 feet. Storms of this type differ from those of Class A in that the instability is due to a definite flow of cooler air over warm air, instead of to the heating of the surface layers by several hot sunny days. They therefore occur as often by night as by day. The upward movement appears to be usually started by small local irregularities of pressure. Sheets of cloud appear in one or more layers, which develop into cumulo-nimbus owing to the unstable conditions. Frequently clouds of the type known as "alto-cumulus-castellatus" are observed, which indicate high humidity and an unstable condition high up. These thunderstorms move rapidly with the SW upper current.

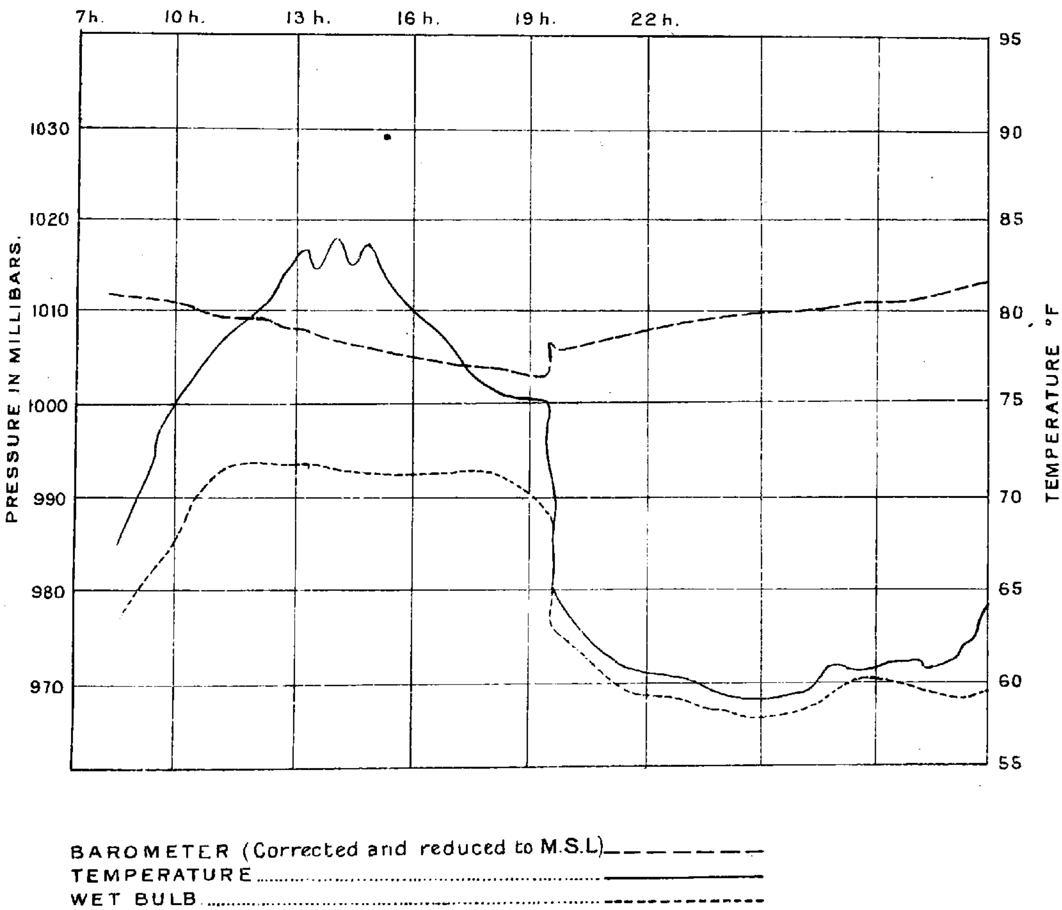
The most violent summer line-squalls are included in this class, and are illustrated by the storms of July 17th and 20th. Sometimes a cooler westerly current spreads in and causes thunderstorms without line-squalls, as on July 8th and September 7th. On the other hand thunderstorms of this class may not be followed by any fall of temperature, as on the night of July 15th. The thunderstorm of the night of August 23rd is also considered, as it illustrates the north-east surface wind with a south-west current above it, the conditions being unstable only above 8,000 feet.

July 17th, 1918.—The thundery conditions of the 16th (*see* p. 127) were maintained next day. After showers and local thunder in the morning, the weather became very fine and hot, with a surface wind from NE veering to SE, and still a strong upper current from SW. In the evening a violent thunderstorm occurred with a line-squall, which attained a velocity of fully 60 miles per hour for 10 minutes, the extreme velocity being much greater. The squall originated off the coast, and a few miles inland had spent most of its force.

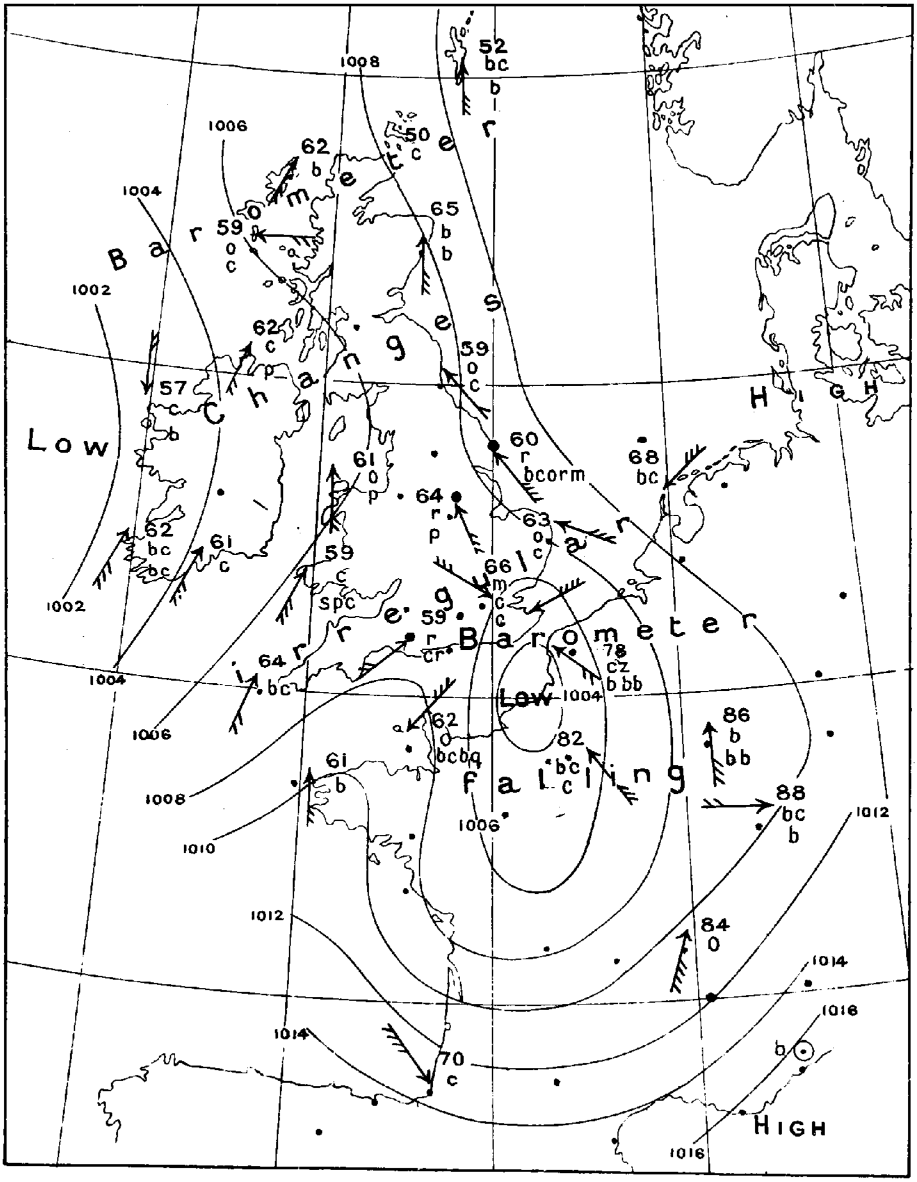
The first sign of the storm was the appearance of false cirrus on the W horizon at 16h. By 17h. 30m. dark masses of false cirrus type had arrived overhead, moving rapidly from SW. It was mostly above 15,000 feet, and was evidently the remains of a thunderstorm; to the south and also to NW it merged into thunderstorms still active, though high up and of little intensity; on the SW horizon the weather was fine. Under this high cloud mass descending air was encountered, the rate of descent being from two to five feet per second.

At about 17h. 45m. a belt of cumulus cloud began to form parallel to the coast about 15 miles out to sea, the base of the clouds being at 6,000 feet. They grew rapidly, and in half-an-hour part of the belt had joined the upper clouds at 16,000 feet, and soon developed into a thunderstorm, which moved NE. The belt of clouds extended southward, and about 19h. a thunderstorm broke all along the coast line in a belt three or four miles broad. At 18h. 50m. the sea was calm except just under a dark cloud, where there was a west wind. At 19h. the cloud just out to sea was very dark, and a rugged squall-cloud appeared at 1,000 feet soon afterwards. It rushed over at about 19h. 10m., bringing a violent squall from the west and a blizzard of rain and hail. The front part of the squall-cloud was rushing up rapidly. Before the squall there had been little rain but much thunder and lightning. The squall subsided after ten minutes, after which there were some minor squalls and showers till 19h. 45m. The automatic records at Montreuil, about 7 miles inland are shown in Fig II, showing a typical sudden increase of pressure and decrease of temperature. After the storm the surface wind was WNW, bringing some cloud at 200 feet, whose form indicated the presence of an inversion of the lapse of temperature. Higher up there were cumulus clouds from 4,000 to 12,000 feet, moving from SSW, and much cirro-stratus. From the upper air temperatures given below it is seen that the conditions were generally unstable, though there was a thin stable layer between 6,000 and 8,000 feet. The humidity was high between 4,000 and 6,000 feet, which was probably due partly to convection from the surface, as there was thick smoke haze up about 6,000 feet, and some up to 7,000 feet. The damp air at 6,000 feet and the rapid fall of temperature above 8,000 feet formed a combination favourable for thunderstorm development where the lower layer was forced up by the arrival of colder surface air. Next day the temperature was lower at all heights

AUTOMATIC RECORDS AT MONTREUIL, JULY 17TH, 1918.



P.S. 1124/119. WT 12707. D.S.O. P.547. 600. 4/20. H.M. Stationery Office Press Kingsway W.C.



DAILY WEATHER CHART, JULY 17TH 1918, 18H

(The lower groups of letters refer to past weather since 7 h.)

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but as usual, the decrease of temperature at 14,000 feet was spread over 24 hours. The chart of the evening of the 17th (reproduced in Fig. III) showed a well-marked secondary depression. Thunderstorms accompanied the passage of the trough over a wide area, but in the region where observations were made the line-squall only developed off the coast, and was probably the result of the large horizontal differences of temperature near the surface.

TEMPERATURES, JULY 17TH.

Start 17h. 20m. 11,500 ft. at 18h. 40m.

Height in ft.	Observed Temp. °F. up.	Observed Temp. °F. down.	Observed hum. (up) %	Temp. from baro. therm. up.	Temp. from baro. therm. down.	Humidity from hygrograph %
11,500	36	36	—	36	36	45
10,000	44	42	—	44	41	32
8,000	51	49	42	50	46	50
6,000	56	56	88	56	56	90
4,000	63	65	86	62	63	80
2,000	73	75	67	71	72	63
1,000	78	78	54	76	76	60
500	81	81	51	—	—	—
200	81	81	54	—	—	—
Surface	—	75	—	—	—	70

JULY 18TH.

Height (ft.).	7h.—7h. 45m. Observed Temp. °F.	7h.—7h. 45m. Observed Humidity.	7h.—7h. 45m. Humidity from Hygrograph. %	18h. 10m.—19h. Observed Temp. °F.	18h. 10m.—19h. Observed Humidity. %
14,000	18	—	26	13	—
12,000	25	—	30	21	—
10,000	31	—	40	27	—
8,000	36	—	57	32	77
6,000	44	—	54	40	57
4,000	56	—	64	47	69
2,000	54	—	60	56	53
1,000	56	—	80	60	58

UPPER WINDS.

Height (ft.).	July 17th. 15h. Villers Bocage.	m.p.h.	Montreuil 0h. 10m. July 18th.	m.p.h.
8,000	SW by W	50	SW by S	33
6,000	SSW	37	SW by S	30
4,000	S by W	24	W by S	31
2,000	SSE	27	W by S	29
1,000	SE by S	21	WNW	16
Surface	SE by S	11	W	5

but as usual, the decrease of temperature at 14,000 feet was spread over 24 hours. The chart of the evening of the 17th (reproduced in Fig. III) showed a well-marked secondary depression. Thunderstorms accompanied the passage of the trough over a wide area, but in the region where observations were made the line-squall only developed off the coast, and was probably the result of the large horizontal differences of temperature near the surface.

TEMPERATURES, JULY 17TH.

Start 17h. 20m. 11,500 ft. at 18h. 40m.

Height in ft.	Observed Temp. °F. up.	Observed Temp. °F. down.	Observed hum. (up) %	Temp. from baro. therm. up.	Temp. from baro. therm. down.	Humidity from hygrograph %
11,500	36	36	—	36	36	45
10,000	44	42	—	44	41	32
8,000	51	49	42	50	46	50
6,000	56	·56	88	56	56	90
4,000	63	65	86	62	63	80
2,000	73	75	67	71	72	63
1,000	78	78	54	76	76	60
500	81	81	51	—	—	—
200	81	81	54	—	—	—
Surface	—	75	—	—	—	70

JULY 18TH.

Height (ft.).	7h.—7h. 45m. Observed Temp. °F.	7h.—7h. 45m. Observed Humidity.	7h.—7h. 45m. Humidity from Hygrograph. %	18h. 10m.—19h. Observed Temp. °F.	18h. 10m.—19h. Observed Humidity %
14,000	18	—	26	13	—
12,000	25	—	30	21	—
10,000	31	—	40	27	—
8,000	36	—	57	32	77
6,000	44	—	54	40	57
4,000	56	—	64	47	69
2,000	54	—	60	56	53
1,000	56	—	80	60	58

UPPER WINDS.

Height (ft.).	July 17th. 15h. Villers Bocage.	m.p.h.	Montreuil 0h. 10m. July 18th.	m.p.h.
8,000	SW by W	50	SW by S	33
6,000	SSW	37	SW by S	30
4,000	S by W	24	W by S	31
2,000	SSE	27	W by S	29
1,000	SE by S	21	WNW	16
Surface	SE by S	11	W	5

July 20th.—A series of thunderstorms occurred on July 20th, of which that between 14h. 15m. and 14h. 45m. was accompanied by exceptionally heavy rain. After a fine warm morning with a light SE wind masses of high clouds came over from SW at about 9h. followed by a thunderstorm at 10h. 15m., with the base of the clouds at 8,000 feet, moving from SSW. A second storm came over at 11h. 45m. with a change of wind at the surface to NW, with a heavy gust at first and a fall of temperature. This storm lasted for an hour, but the thunder was not loud, all the lightning being in the clouds. An ascent made about 14h. showed that the base of the cumulo-nimbus clouds was at 6,000 feet; their motion was from a little east of south at 11h., but from S. at 14h. There were also a few low clouds from NNW, and the surface wind blew rather strongly from that direction; at 3,000 feet the wind was easterly. A remarkable belt of low cloud from 500 to 1,000 feet ran parallel to the coast from N to S about 2 miles out to sea for fully 20 miles, and slowly approached. The belt was bent round to SE within the next thunderstorm, which was approaching from the south. When the storm arrived the sky grew very dark, and a mass of cloud at 100 feet drifted over from SW with a violent squall, followed by floods of rain for half an hour. The lightning was incessant, but not bright, and there was a continuous low roll of thunder The heaviest rainfall reported anywhere within 30 miles was 46mm. at C. Gris Nez, and this figure was certainly at least equalled at the aerodrome. The wind returned to the NW during the storm and remained in that direction afterwards.

The upper wind observations at 15h. showed that above 4,000 feet wind was still SSW, which is always the case after thunderstorms moving from that direction. The remainder of the day was mostly fair, with much high cloud and a few showers. Later in the evening the surface wind became WSW and there were low clouds. The upper air temperatures show the following features:—

(1) In the morning the temperatures were unusually high near the surface, due to the SE wind, having risen during the night.

(2) At 14h. between the thunderstorms, the temperature had fallen up to 4,000 feet only, and was still above the normal at 5,000 feet.

(3) By 17h. 30m. the temperature had fallen at all heights, but at 14,000 feet was only 1° lower than at 8h. By 19h. the air below 6,000 feet was much colder.

(4) By the morning of the 21st the upper air temperatures had fallen considerably at all heights.

In Figs. IV and V, the baro-thermograph tracings of the afternoon and evening flights are reproduced. The first shows the "inversion" between 500 and 1,000 feet during the ascent, and the lower temperature during the descent in and above the low cloud belt. The temperature rose again after leaving the

July 20th.—A series of thunderstorms occurred on July 20th, of which that between 14h. 15m. and 14h. 45m. was accompanied by exceptionally heavy rain. After a fine warm morning with a light SE wind masses of high clouds came over from SW at about 9h. followed by a thunderstorm at 10h. 15m., with the base of the clouds at 8,000 feet, moving from SSW. A second storm came over at 11h. 45m. with a change of wind at the surface to NW, with a heavy gust at first and a fall of temperature. This storm lasted for an hour, but the thunder was not loud, all the lightning being in the clouds. An ascent made about 14h. showed that the base of the cumulo-nimbus clouds was at 6,000 feet; their motion was from a little east of south at 11h., but from S. at 14h. There were also a few low clouds from NNW, and the surface wind blew rather strongly from that direction; at 3,000 feet the wind was easterly. A remarkable belt of low cloud from 500 to 1,000 feet ran parallel to the coast from N to S about 2 miles out to sea for fully 20 miles, and slowly approached. The belt was bent round to SE within the next thunderstorm, which was approaching from the south. When the storm arrived the sky grew very dark, and a mass of cloud at 100 feet drifted over from SW with a violent squall, followed by floods of rain for half an hour. The lightning was incessant, but not bright, and there was a continuous low roll of thunder. The heaviest rainfall reported anywhere within 30 miles was 46mm. at C. Gris Nez, and this figure was certainly at least equalled at the aerodrome. The wind returned to the NW during the storm and remained in that direction afterwards.

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BARO-THERMOGRAPH TRACES.

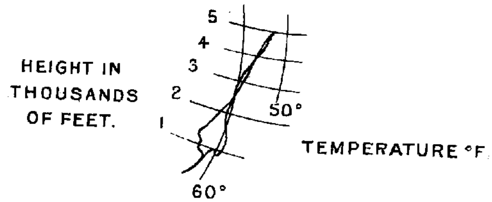

Fig. IV.

July 20th. 1918. 13h. 45m. to 14h.5m. Showing a large temperature difference in one layer.

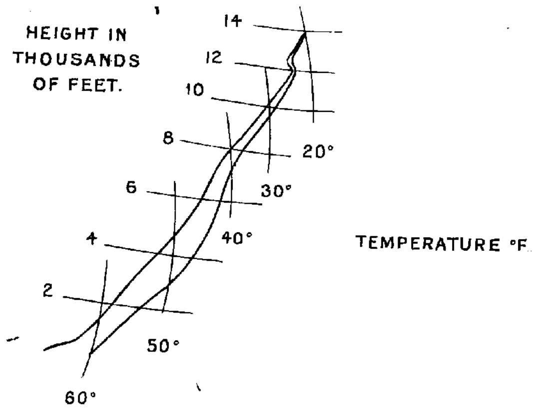

Fig. V.

July 20th. 1918. 17h. to 19h. Showing the fall of temperature during the flight.

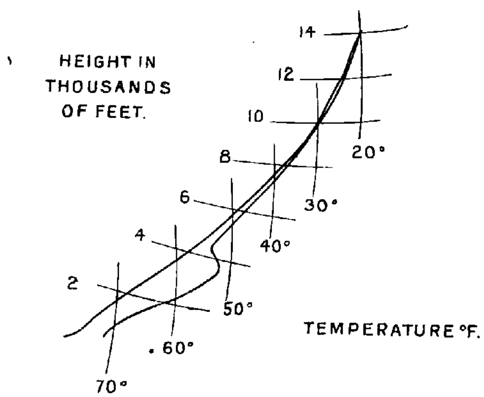

Fig. VI.

July 8th. 1918. about 18h. to 19h. Showing the arrival of cold air below 5,000 feet.

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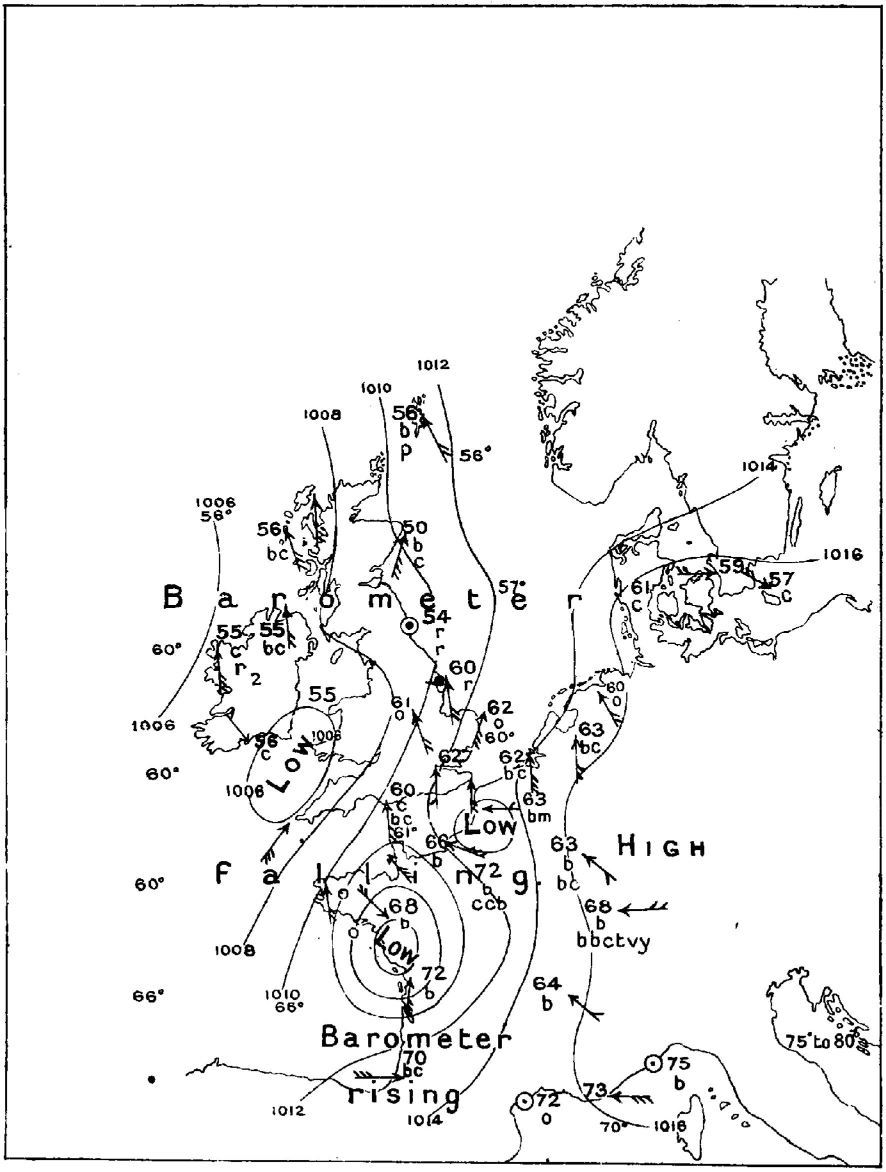
Figure VII.



DAILY WEATHER CHART, JULY 20TH 1918. 7H

(The lower groups of letters refer to past weather since 18 h. The temperatures over the sea are the July means.)

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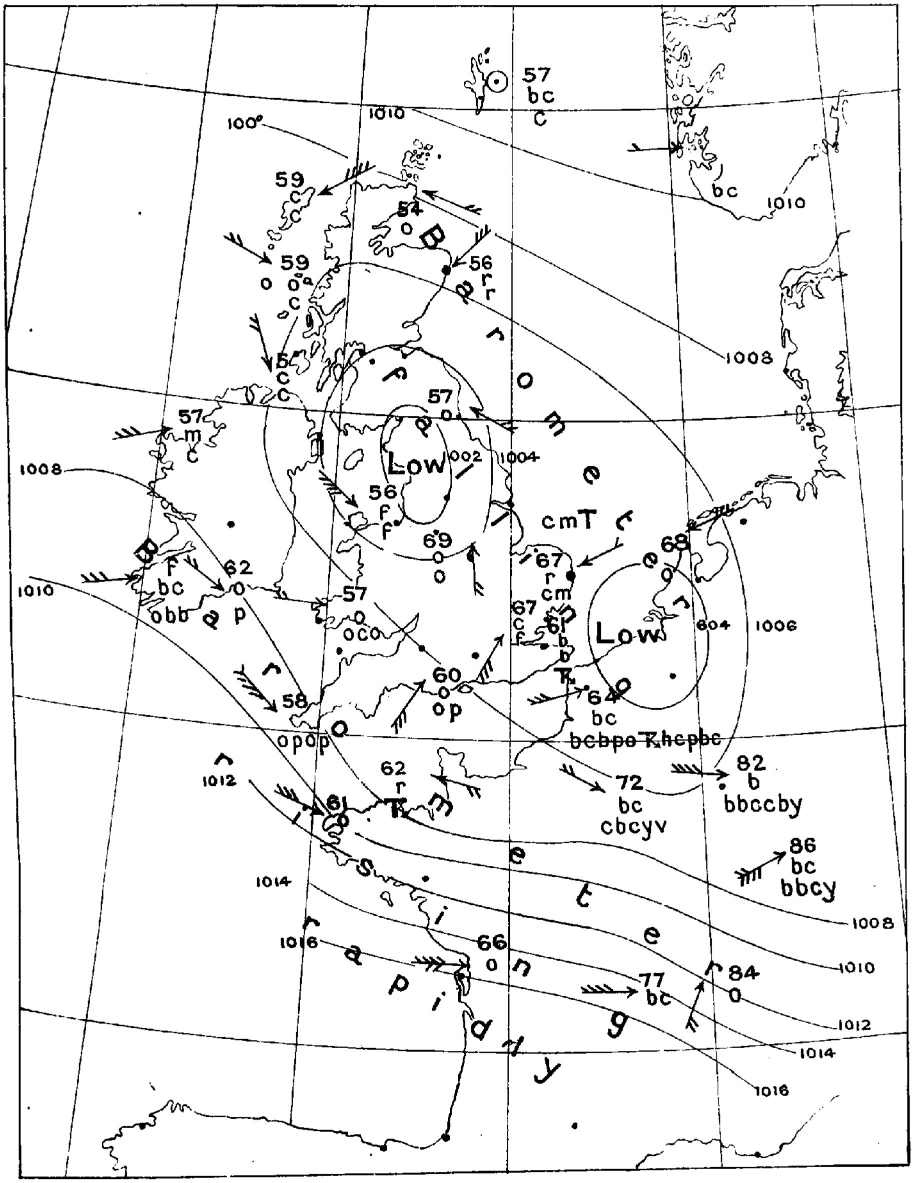
Figure VIII.



DAILY WEATHER CHART, JULY 20TH 1918, 18H

(The lower groups of letters refer to past weather since 7h.)

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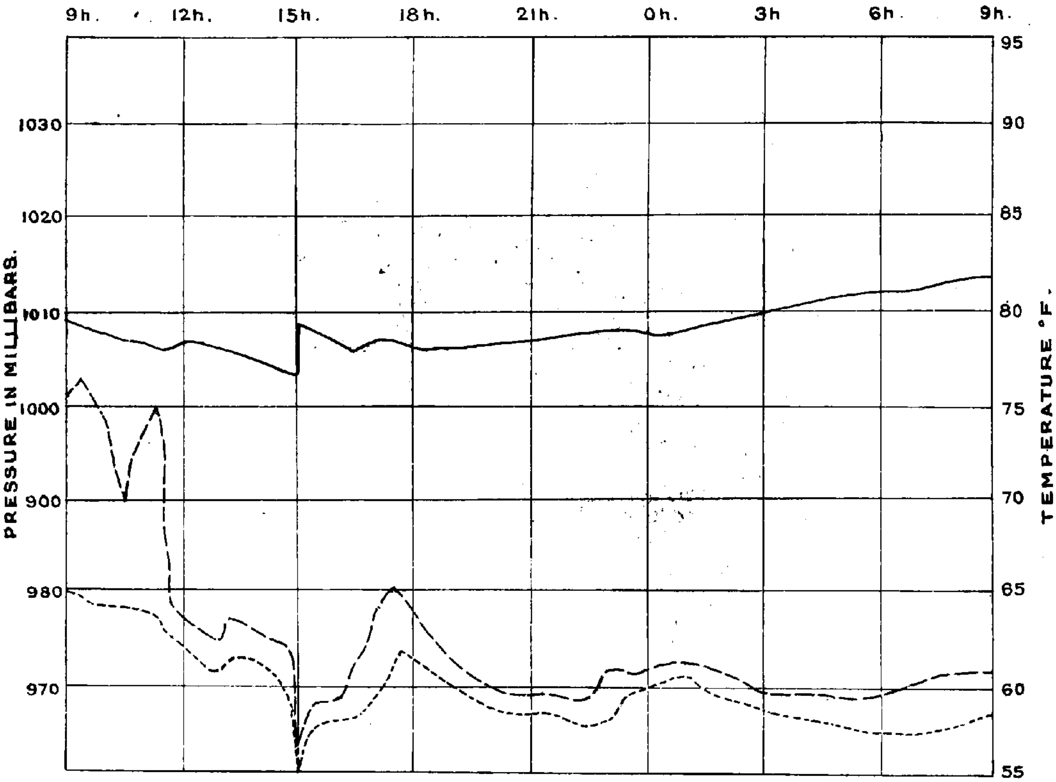
AUTOMATIC RECORDS AT MONTREUIL, JULY 20TH, 1918.



BAROMETER. (Corrected and reduced to M.S.L. ————————
TEMPERATURE .... — — — — — —
WET BULB .... - - - - - - - - - - - - -

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cloud belt flying level. The evening trace shows the large fall of temperature during the flight below 8,000 feet, associated with the arrival of a cloudsheet from WSW between 2,500 and 5,300 feet. Note the rapid fall of temperature below the alto-cumulus clouds at 12,000 feet.

The morning and evening charts are reproduced in Figs. VII and VIII, showing that the storms were associated with the passage of a shallow depression from SW to NE over Northern France. Fig. IX shows the automatic records of pressure, temperature, and humidity at the surface at Montreuil.

TEMPERATURES, JULY 20TH.

7h.—8h. 30m., TOP 8h.

Height in ft.	Observed temp.		Temp. from Baro-Therm.		Observed Humidity (Up).	Humidity from hygro-graph (Up).
	Up.	Down.	Up.	Down.		
14,000	21	21	20	20	—	32
12,000	28	30	28	28	57	40
10,000	37	37	36	36	72	58
8,000	45	46	42	42	32	60
6,000	49	50	48	48	84	73
4,000	57	60	57	57	71	50
2,000	67	70	65	66	56	55
1,000	68	67	66	66	59	60
			13h. 45m.—14h. 5m.			
5,000	55	55	54	54	79	—
4,000	57	57	57	57	79	—
3,000	60	60	60	59	80	—
2,000	62	62	62	60	77	—
1,000	65	59	63	59	73	—
500	61	61	61	61	94	—
Surface	63	63	63	63	94	—
			17h. 20m.—19h., TOP 18h. 30m.			
14,000	20	20	20	20	—	60
12,000	23	26	23	24	100	85
10,000	32	32	30	30	86	70
8,000	43	42	21	39	61	56
6,000	46	45	46	41	85	65
4,000	54	46	53	45	71	56
2,000	60	54	54	53	67	60
1,000	61	57	61	58	76	75
500	61	58	—	—	85	—

JULY 21ST.

Start 7h. 30m., at 14,000 feet, 8h. 40m.

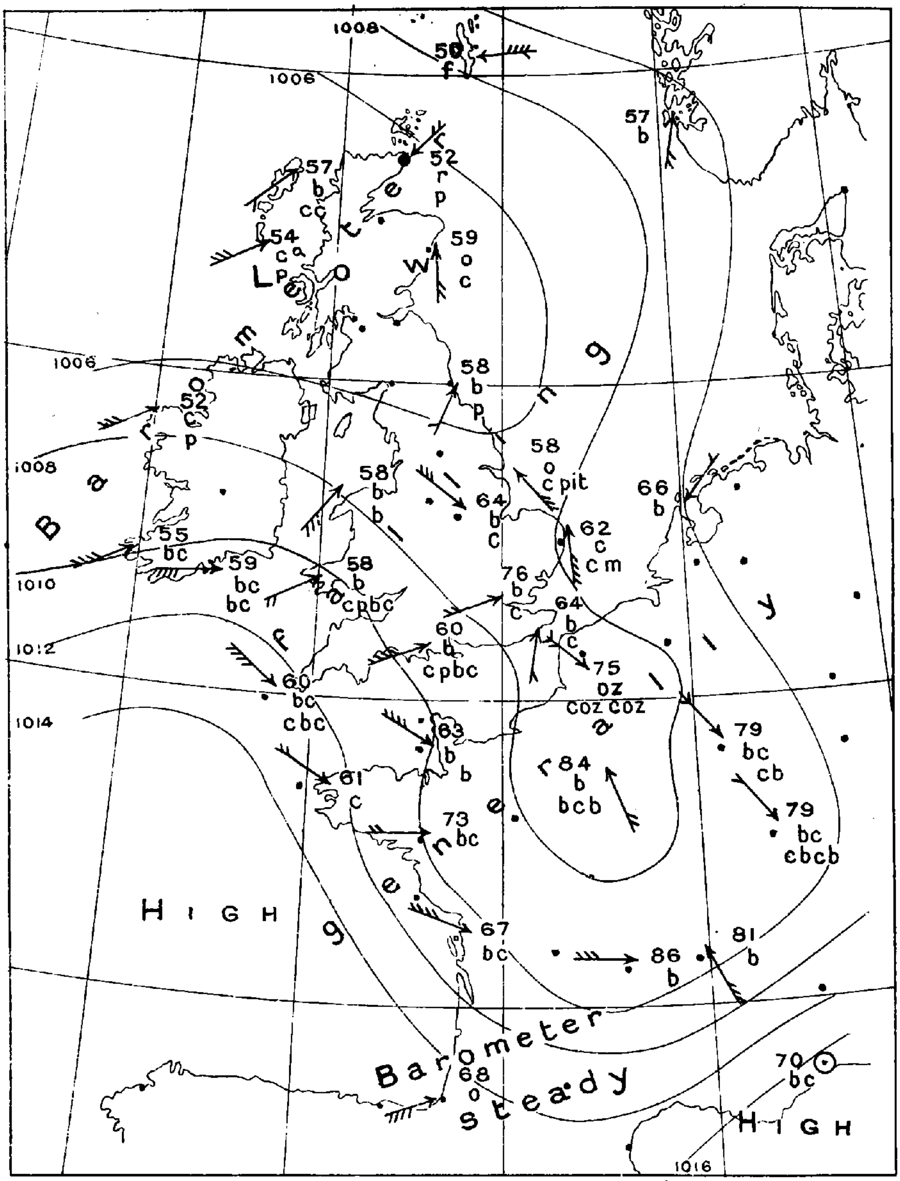
Height in feet.	Observed temp. °F.
14,000	11
10,000	25
8,000	36
2,000	52

UPPER WINDS, JULY 20TH (MONTREUIL).

Height in ft.	8h. 10m.		11h. 0m.		15h. 22m.	
	Wind direction.	Velocity in m.p.h.	Wind direction.	Velocity in m.p.h.	Wind direction.	Velocity in m.p.h.
12,000	SW	30	(9,000	feet).	—	—
10,000	SW	28	SSE	23	—	—
8,000	SSW	20	SSE	25	SSW	24
6,000	SSW	22	SE by S	24	SSW	18
4,000	S by W	20	SE	24	SW	19
2,000	S	29	SE	36	WNW	24
1,000	SSE	20	ESE	22	NNW	23
Surface.	E by S	5	NE by E	5	NNW	12

From anti-aircraft shell bursts—
Northern Section, 12h. 14m.
15,000 feet, SSW, 56 miles per hour.

July 8th, 1918.—This was a fine hot day, with a sheet of cirro-stratus which thickened into alto-stratus and some alto-cumulus at about 12,000 feet in the afternoon, moving from about WSW. About 18h. cumuli began to form at 6,000 feet and grew rapidly, joining the upper clouds and forming thunderstorms by 19h. The weather was fine out to sea to NW, but there was much cloud in all other directions and numerous thunderstorms. The weather cleared about 21h., and was then fine. With the development of the storms the surface wind, which had been very light from some south-easterly direction, changed to the west. The thunderstorm moved rather rapidly from SW to NE. The temperatures and humidities are shown below, and a reproduction of the automatic trace of the R.A.F. baro-thermograph is given in Fig. VI facing page 122. It shows a sudden fall of temperature below 5,000 feet, the temperature at 3,000 feet being 9°F. lower than during the ascent. The difference was probably due to the aeroplane having entered a cooler body of air on the west side of the storm, where the descent of the aeroplane took place. Another explanation suggested is that it was due to a local cold descending current. If the upper cold SW current contained enough cloud, the temperature of the descending air might increase at the saturated instead of at the dry adiabatic rate, and with temperatures such as those given below might develop into a cold katabatic current. But this explanation does not in this case fit in with the observed cloud phenomena. The development of the cloud was observed by the writer from the ground, and from the air by the pilot (Lt. Sessions), who made the evening observations. The upper clouds were not originally very dense, and there was no sign of their descending. The heavy cumulus clouds developed in the usual way, and the downward currents were at the edges of these and did not bring down the upper clouds. The high humidity above 6,000 feet was due to the cumulus clouds. The chart at 18h. is shown in Fig. X, and illustrates a typical thunderstorm



DAILY WEATHER CHART, JULY 8TH 1918, 18H

(The lower groups of letters refer to past weather since 7h.)

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type, with a cooler westerly current displacing the warm air. The change of wind with the thunderstorm was not accompanied by an abrupt fall of temperature at the surface, and there was no abrupt rise of the barometric pressure at Montreuil. Next day a cool WSW wind prevailed, with much cloud and a few showers. The upper air temperatures for that day are given, and show that the fall of temperature took place earlier in the lower air than it did high up, as is nearly always the case.

The thunderstorm of July 8th had some points of similarity with that of May 22nd, but differed materially as regards the upper wind conditions. On July 8th a strong upper current from SW prevailed, and this wind and the reduced pressure were partly responsible for the unstable condition, the temperatures having fallen from 27° to 20° at 14,000 feet between 19h. on the 7th and 19h. on the 8th; the hot air over France affected the pressure distribution sufficiently to annul the gradient for SW winds and allow the surface air in the north corner of France to become hot. On the other hand, on May 22nd the SE wind extended up to 15,000 feet, and the temperature at 14,000 feet had risen slightly, though not enough to prevent instability. On July 8th a SE wind prevailed at Montreuil at 18h. 45m. up to 2,000 feet, and at 20h. still prevailed at stations 30 or 40 miles inland. By midnight a WNW wind prevailed at 1,000 feet.

TEMPERATURES AND HUMIDITIES, JULY 8TH.

Height (ft.).	6h. 30m.—7h.		Start 17h. 40m. Top 18h. 50m.			Observed Humidity.	Hygrograph Readings.
	Temp.	Humidity. %	Observed Temp. °F.	Temp. from barotherm. Up.	Temp. from barotherm. Down.	%	%
14,000	—	—	20	20	20	—	60
12,000	—	—	25	25	25	100	95
10,000	—	—	32	30	30	93	81
8,000	41	—	40	38	38	94	84
6,000	47	56	50	48	48	74	75
4,000	51	63	58	58	53	69	60
2,000	57	75	68	68	62	52	43
1,000	62	62	72	71	67	46	43

JULY 9TH.

Height (ft.).	7h.—8h.			17h.—18h.		
	Temperature °F.	Observed Humidity. %	Hygrograph Reading. %	Temperature °F.	Observed Humidity. %	Hygrograph Reading. %
14,000	18	—	20	9	—	99
10,000	28	50	48	24	82	85
6,000	42	66	70	35	100	95
2,000	51	74	70	50	74	70
1,000	55	56	60	55	70	70

UPPER WINDS (miles per hour).

Height (feet).	July 8th. 16h. Villers Bocage.		July 8th. 18h. 45m. Montreuil.		July 9th. 0h. 5m. Montreuil.		July 9th. 1h. 0m. Villers Bocage.	
12,000	SW by W	36	—		—		—	
10,000	SW by W	30	—		—		SW by S	37
8,000	SW by W	26	—		—		SW by S	39
6,000	SSW	20	SSW	21	SW by S	26	SW by S	27
4,000	SSW	14	S	20	SW	25	SSW	16
2,000	SSW	12	SE	11	SW by S	16	W	9
1,000	SSW	10	E by S	12	W by N	20	WNW	21
Surface	SSW	2	Calm		WSW	3	WNW	5

September 7th.—A series of local thunderstorms from September 5th to 7th culminated in a severe general storm late in the evening of the third day, which was remarkable for the frequency and brilliance of the lightning. It advanced eastward across the country in a line approximately SSE to NNW, though the motion of the clouds at 5,000 feet was from SSW. It crossed the aerodrome between 18h. 45m. and 19h. 15m. G.M.T., accompanied by a slight squall without any effect on the barometer. Incessant lightning was visible all round the E horizon for three hours afterwards. Viewed from 14,000 feet at about 18h., the storm appeared as a dark mass of snow cloud extending to a great height, of a uniform grey aspect. In front of the storm, clouds with level bases but uneven tops developed from 5,000 to 8,000 feet, and from 9,000 to 14,000 feet the layers ultimately joining. The observations made just in front of the storm showed that the lapse rate of temperature was above the adiabatic for saturated air right up to 14,000 feet, and that the humidity was very high, so that conditions were ideal for thunderstorm development. The temperature at 14,000 feet decreased from 18° to 14° F. between 18h. on the 6th and 18h. on the 7th, although the upper winds had changed from W to SSW. In the lower air temperature had increased with the setting in of a southerly current; at the surface the wind was variable and mainly easterly, but SW after the storm. Next morning the temperature was lower up to 10,000 feet, but unchanged at that level, and the weather was of a wet south-westerly type. By the morning of the 9th the temperature had fallen to 3° at 14,000 feet. The changes during the period were thus similar to those of July 8th and 9th, July 17th-18th and 20th-21st. The thunderstorm was associated with the passage of a small V-shaped secondary, the primary centre passing over the NW of Scotland.

SEPTEMBER 7TH.

Height (ft.).	16h. 40m.—18h. 20m., top 18h.				Upper Winds (miles per hour).	
	Temperature °F.		Observed Humidity. %	Hygrograph Readings. %	Aire, 16h.	Avesnes, 20h.
	Up.	Down.				
14,000	14	14	—	90	—	—
12,000	23	23	92	80	—	—
10,000	31	31	100	100	SW 24	SW 36
8,000	40	40	87	85	SSW 32	SW 42
6,000	48	48	80	80	SW by S 29	SW by W 30
4,000	55	55	80	80	S by W 21	WSW 29
2,000	64	65	73	75	S 18	WSW 22
1,000	68	69	70	70	SSE 10	W 17
SEPTEMBER 8TH, 8h.—9h.						
11,500	25	—	50			
10,000	31	67	55			
8,000	36	73	70			
6,000	41	85	75			
4,000	47	81	85			
2,000	53	94	100			
1,000	57	95	95			

July 15th-July 16th, 1918.—Heavy thunderstorms occurred during the night of July 15th and 16th, the rainfall at one station amounting to 75mm. The weather on July 15th was cloudy with some showers, the clouds being mostly in layers between 3,000 and 12,000 feet moving from SW. A short-lived local thunderstorm occurred at about 18h. with false cirrus to 20,000 feet, which soon became detached from the cumuli-form cloud. The late evening was fine, but lightning began to south at about 22h. 30m. The storms passed to east, the lightning being vivid and frequent. Another storm came over at 3h. 30m., with a heavy squall from the west, which only caused a slight temporary fall in the temperature; the barometer rose 1mb. and then returned to its former level. The weather became very fine after 7h., though there was some alto-cumulus, including the variety known as alto-cumulus castellatus. In the evening there were large cumuli and local thunder showers. There was a powerful upper current from the SW in which the storms travelled, but the surface wind became SE in the afternoon of the 15th and was variable on the 18th. The upper air temperatures were more stable on the evening of the 15th than on any other day when thunderstorms occurred, but the temperature was increasing at 4,000 feet and probably by the time the severe thunderstorms occurred the temperatures had changed considerably. It will be noted that next morning the temperature had increased up to 10,000 feet, and that at Ipswich there was a fall of 10° F between 14,000 and 16,000 feet. The high humidity between 4,000 and 10,000 on the evening of the 15th was a favourable factor for thunderstorm development. The pressure chart of the morning of the 16th showed complex conditions over France in a general south-westerly type. (*See* Fig. XI.)

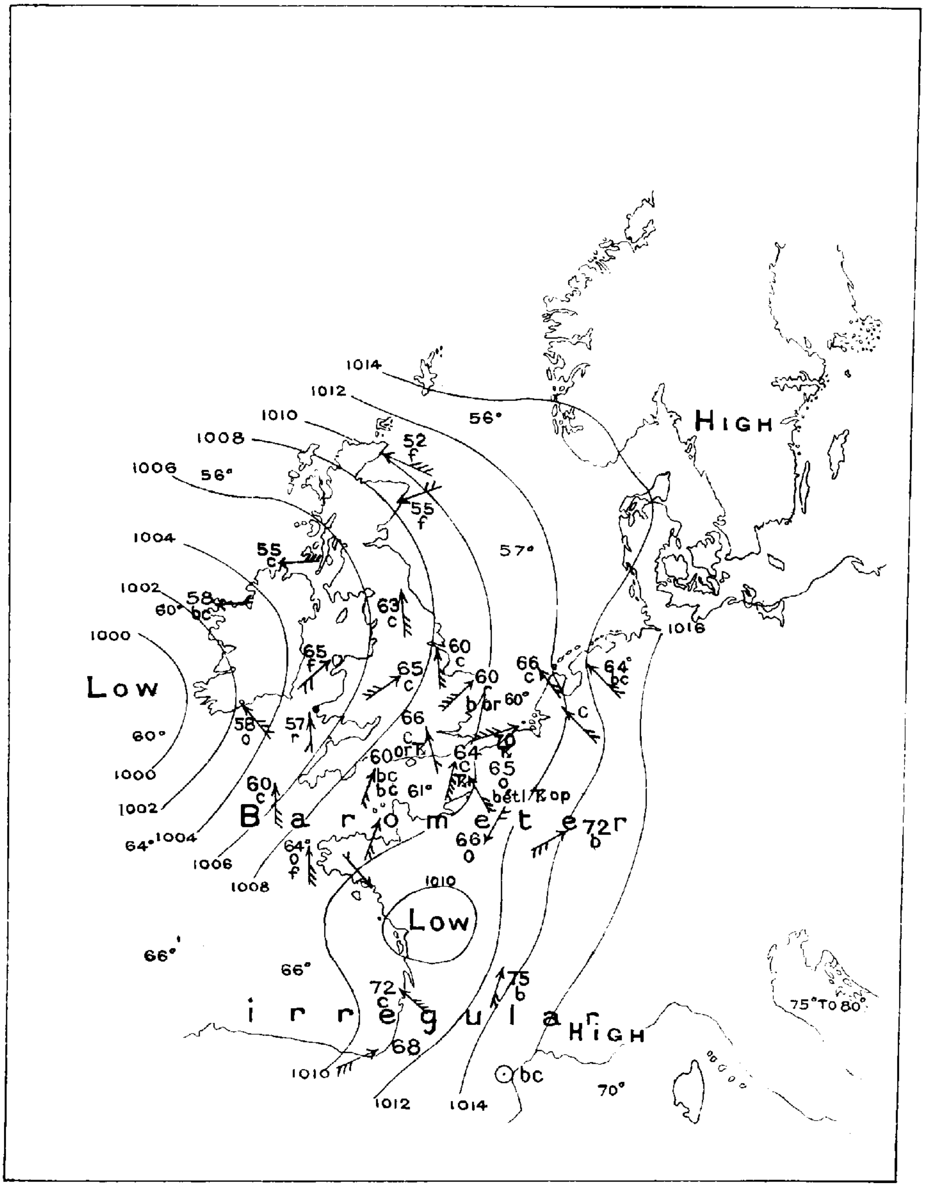
TEMPERATURES, JULY 15th–16th.

Height (ft.).	July 15th. 18.–19h. 45m. Observed Temp. °F. Up	Down	Observed Humidity %	Ipswich, July 16th, 8h. Temperature °F.	France, July 16th. 9h. 30m–11h. 30m. Observed Temp. °F. Up	Down	Observed Humidity (up) %	Hygrograph Readings. %
16,000	—	—	—	16	—	—	—	—
14,000	27	27	81	26	—	—	—	—
13,500	—	—	—	—	27	27	—	50
12,000	32	32	67	32	32	32	67	60
10,000	38	38	94	39	39	40	83	94
8,000	44	44	89	50	49	48	64	61
6,000	48	49	100	52	56	53	50	50
4,000	54	56	100	—	60	61	57	50
2,000	64	64	80	—	66	66	62	60
1,000	70	68	67	—	69	69	69	64

UPPER WINDS, JULY 15TH–18TH.

Height (ft.).	Montreuil, 23h. 55m. July 15th.	m.p.h.	Montreuil. July 16th. 7h. 50m.	m.p.h.
12,000	—	—	WSW	52
10,000	—	—	WSW	56
8,000	—	—	SSW	22
6,000	—	—	WSW	28
5,500	SW by S	30	—	—
4,000	SW	21	WSW	20
2,000	S by E	12	SW	21
1,000	SE by S	20	SW	21
Surface	Calm	—	N by E	3

August 23rd.—The conditions on August 23rd were rather different from those in the other storms of this group, but they were of great interest, particularly as a good many storms occur in England in rather similar conditions. The upper wind was south-west, but at the surface there was a rather cool north-east wind which caused stable conditions below 4,000 feet. Within the SW current the conditions were unstable for saturated air above 8,000 feet. In the evening there were large clouds of cumulo-nimbus type with their bases at 14,000 feet, causing showers, and there was also some cloud between 4,000 and 6,000 feet. There was extreme turbulence between 6,000 and 9,000 feet with variations in temperature and humidity, and in places the lower clouds were forced up, but were colder than the surrounding air. One set of ragged clouds was observed to rise



DAILY WEATHER CHART. JULY 16TH 1918, 7H

(*The lower groups of letters refer to past weather since 18 h. The temperatures over the sea are the July means.*)

P S 1124/119 Wt 12707 D.S.O.P 542 600 4/20 H.M.Stationery Office Press Kingway.W.C

bodily, *i.e.*, the bases of the clouds rose also. By 19h. the humidity had increased at 8,000 feet and the conditions were becoming more favourable for thunder, some of the lower clouds growing up to the upper layer at 14,000 feet. During the night, thunder occurred in places, but of no great intensity. If the temperature had been higher between 4,000 and 6,000 feet (within the SW current) severe storms might have occurred. It is worthy of note that during the ascent "inversions" of 3° were observed both at 6,300 and 7,800 feet, but the level of these inversions varied locally and they were not observed on the down journey. Next morning the temperature was much lower—up to 12,000 feet—the lower wind being northerly and the upper westerly. These changes were associated with the passage of a shallow depression north-eastward across France, the centre passing to SE.

AUGUST 23RD.

Height (ft.).	Temperatures and Humidities 17h. to 19h. At 15,000 feet 18h. 35m.				Upper Winds. Evening (m.p.h.).	
	Temp. °F. up.	Temp. °F. down.	Relative Humidity % (up).	Hygrograph Readings (up).	Aire 16h.	Villers Bocage 16h. Southern Section.
15,000	21	21	—	85	—	—
14,000	25	24	—	80	—	—
12,000	32	31	73	65	—	—
11,000	—	—	—	—	SW by W 30	—
10,000	40	40	75	55	WSW 30	—
8,000	51	48	46 (down 85)	50	SW by W 38	SW 29
6,000	48	51	87	75	SW 26	SW 26
4,000	·56	57	95	80	SE 6	SW by S 16
2,000	59	59	80	80	NE by N 28	ENE in 14
1,000	59	59	80	75	NE by N 20	NE 17
Surface	64	61	—	—	N by E 6	NNE 8

AUGUST 24TH.

Height in feet.	Temperatures and humidities, 6h. 30m.—7h. 30m.		
	Temperature °F.	Relative Humidity %.	Hygrograph. %
14,000	29	—	30
12,000	31	36	40
10,000	30	92	85
8,000	38	81	75
6,000	42	87	85
4,000	46	87	80
2 000	52	94	85
1,000	56	95	85
Surface	59	—	—

An inversion of 6° at 11,500 feet.

bodily, *i.e.*, the bases of the clouds rose also. By 19h. the humidity had increased at 8,000 feet and the conditions were becoming more favourable for thunder, some of the lower clouds growing up to the upper layer at 14,000 feet. During the night, thunder occurred in places, but of no great intensity. If the temperature had been higher between 4,000 and 6,000 feet (within the SW current) severe storms might have occurred. It is worthy of note that during the ascent "inversions" of 3° were observed both at 6,300 and 7,800 feet, but the level of these inversions varied locally and they were not observed on the down journey. Next morning the temperature was much lower—up to 12,000 feet—the lower wind being northerly and the upper westerly. These changes were associated with the passage of a shallow depression north-eastward across France, the centre passing to SE.

AUGUST 23RD.

Height (ft.).	Temperatures and Humidities 17h. to 19h. At 15,000 feet 18h. 35m. Temp. °F. up.	down.	Relative Humidity % (up).	Hygrograph Readings (up).	Upper Winds. Evening (m.p.h.). Aire 16h.	Villers Bocage 16h. Southern Section.
15,000	21	21	—	85	—	—
14,000	25	24	—	80	—	—
12,000	32	31	73	65	—	—
11,000	—	—	—	—	SW by W 30	—
10,000	40	40	75	55	WSW 30	—
8,000	51	48	46 (down 85)	50	SW by W 38	SW 29
6,000	48	51	87	75	SW 26	SW 26
4,000	56	57	95	80	SE 6	SW by S 16
2,000	59	59	80	80	NE by N 28	ENE in 14
1,000	59	59	80	75	NE by N 20	NE 17
Surface	64	61	—	—	N by E 6	NNE 8

AUGUST 24TH.

Height in feet.	Temperatures and humidities, 6h. 30m.—7h. 30m. Temperature °F.	Relative Humidity %.	Hygrograph. %
14,000	29	—	30
12,000	31	36	40
10,000	30	92	85
8,000	38	81	75
6,000	42	87	85
4,000	46	87	80
2 000	52	94	85
1,000	56	95	85
Surface	59	—	—

An inversion of 6° at 11,500 feet.

Class C.

A large number of thunderstorms are associated with the low upper air temperatures of cyclonic depressions, though many are only of slight intensity. Sometimes the surface temperatures are below the normal, but the deficiency is more marked up above. There is often a cold body of air on the south side of the centre of a depression, and this sometimes curves round into the south-east quadrant in the case of a slow moving depression. If the conditions in front of the depression have been such as to cause a well-defined warm southerly current, the displacement of this by the cooler current may be accompanied by thunderstorms of type B, and a day later one of the type C may occur. For instance, a thunderstorm of type B in London on the evening of July 17th was followed by one of type C on the 18th. In France one of type B on September 7th was followed by one of type C, on the night of the 8th. The chief difference between types B and C are that the latter class occur when the westerly current prevails at the surface as well as up above. It is noteworthy that even in winter unstable conditions may accompany the west and north-west, and sometimes even the south-west currents of depressions, and showers of cold rain, snow or soft hail fall from clouds of cumulo-nimbus type, occasionally accompanied by thunder.

Thunderstorms of this class may develop with winds from any westerly direction, but in summer they are commonest if the air has crossed a considerable land area. In Northern France they may occur with SW winds, but with W and NW winds they are commoner in the east of England. They may, however, develop with these winds in France also, and over the sea in late summer and autumn. Though thunderstorms of this type may be accompanied by squalls, they are less violent in summer than those of Class B.

July 10th.—As an example of thunderstorms in a cold SW. type we may consider those of July 10th. A series of thunderstorms occurred in the afternoon and evening, accompanied by squalls from the west. They caused a temporary fall of the surface temperature, but had little effect on the pressure. The motion of the thunder-clouds was from between SW and SSW, their bases being at about 4,000 feet. The surface wind varied between S and W It will be observed from the figures on page 131 that the surface wind was temporarily E of S at about 15h., but the conditions on the whole were of the cold south-westerly type. At 20h. the wind was WSW at 1,000 feet at all stations. There was a slow moving depression centred off the north of Ireland and a small secondary crossing the north of France. The upper air temperatures were unusually low. Several other thunderstorms occurred in July in very similar conditions, mostly of slight intensity.

JULY 10TH.

Height (ft.).	Start 6h. 45m., top 7h. 50m.			Upper Winds (m.p.h.).		
	Observed Temp. °F.	Observed Humidity %.	Humidity from hygrograph to nearest 5 %.	Montreuil 15h.	Aire 16h.	Anti-Aircraft (Central Section, near Berck) 10h. 30m.
15,000	—	—	—	—	—	SW by S 48
13,000	11	—	40	—	—	—
12,000	13	—	70	—	—	—
10,000	19	—	95	—	SSW 52	—
8,000	27	54	60	—	—	SW 38
6,000	32	87	85	SSW 53	SSW 41	—
4,000	40	76	70	SSW 45	SSW 40	SSW 33
2,000	49	73	65	S by W 31	SSW 24	—
1,000	54	59	70	S by W 16	SSW 22	—
Surface.	—	—	—	S by E 5	S by E 4	—

September 12th.—Squally showers with thunder occurred on September 12th, with a strong wind from SW veering to west, caused by a deep depression to the north. During the evening thunderstorms came in from the sea, and behind one of these the temperature up to 2,000 feet was found to have fallen 6° F. The clouds extended from about 1,500 to over 20,000 feet, the upper parts consisting of false cirrus. The upper air temperature was very low, 5° F., at 13,000 feet. On the night of September 8th, similar storms occurred, and the temperature on the morning of the 9th was 3° F., at 14,000 feet. These storms had only a slight effect on the barometer.

SEPTEMBER 12TH.

Height (ft.).	At 13,000 feet 10h. 25m.				Upper Winds.
	Temperature °F. up.	Temperature °F. down.	Observed Humidity (up). %	Hygrograph Readings. %	Montreuil 11h.
13,000	5	5	—	—	—
12,000	10	9	—	—	—
10,000	20	18	—	—	—
8,000	27	25	74	—	—
6,000	33	33	77	—	—
4,000	41	40	74	—	W by S 40
2,000	50	49	77	—	W 26
1,000	54	54	74	—	W 32

JULY 10TH.

Height (ft.).	Start 6h. 45m., top 7h. 50m.			Upper Winds (m.p.h.).		
	Observed Temp. °F.	Observed Humidity %.	Humidity from hygrograph to nearest 5 %.	Montreuil 15h.	Aire 16h.	Anti-Aircraft (Central Section, near Berck) 10h. 30m.
15,000	—	—	—	—	—	SW by S 48
13,000	11	—	40	—	—	—
12,000	13	—	70	—	--	—
10,000	19	--	95	—	SSW 52	—
8,000	27	54	60	—	—	SW 38
6,000	32	87	85	SSW 53	SSW 41	—
4,000	40	76	70	SSW 45	SSW 40	SSW 33
2,000	49	73	65	S by W 31	SSW 24	—
1,000	54	59	70	S by W 16	SSW 22	—
Surface.	—	—	—	S by E 5	S by E 4	—

September 12th.—Squally showers with thunder occurred on September 12th, with a strong wind from SW veering to west, caused by a deep depression to the north. During the evening thunderstorms came in from the sea, and behind one of these the temperature up to 2,000 feet was found to have fallen 6° F. The clouds extended from about 1,500 to over 20,000 feet, the upper parts consisting of false cirrus. The upper air temperature was very low, 5° F., at 13,000 feet. On the night of September 8th, similar storms occurred, and the temperature on the morning of the 9th was 3° F., at 14,000 feet. These storms had only a slight effect on the barometer.

SEPTEMBER 12TH.

Height (ft.).	At 13,000 feet 10h. 25m.				Upper Winds.
	Temperature °F. up.	Temperature °F. down.	Observed Humidity (up). %	Hygrograph Readings. %	Montreuil 11h.
13,000	5	5	—	—	—
12,000	10	9	—	—	—
10,000	20	18	—	—	—
8,000	27	25	74	—	—
6,000	33	33	77	—	W by S 40
4,000	41	40	74	—	W 26
2,000	50	49	77	—	W 32
1,000	54	54	74	—	

SEPTEMBER 12th—*continued.*

Height (ft.).	At 9,000 feet 17h. 25m.				Upper Winds.	
	Temperature °F.		Observed Humidity (up). %	Hygrograph Readings. %	Aire, 16h. m.p.h.	Anti-Aircraft (Central Section, near Berck) 15h.
	up.	down.				
15,000	—	—	—	—	—	W by N 46
9,000	24	24	—	60	—	W by N 41 (10,000)
8,000	28	28	79	80	—	—
6,000	33	33	69	70	W by N 36	WNW 41
4,000	40	40	88	90	W by N 36	—
2,000	50	44	84	85	W 42	—
1,000	56	50	74	75	W 27	—

April 7th.—An example of a thunderstorm from NW. occurred locally inland on April 7th, and being early in the season it was of no great intensity. There was uniform light wind from NNW up to 14,000 feet, and the low upper air temperatures are typical of north-westerly winds within the boundary of a depression.

TEMPERATURES, APRIL 7TH.

Height in ft.	Temp. °F., 9h.–10h.	Temp. °F., 17h. 40m.–18h. 45m.
14,000	−10	−8
12,000	−2	0
10,000	8	8
8,000	15	15
6,000	22	23
4,000	29	31
2,000	37	38
1,000	40	43

September 30th.—On the evening of September 30th, thunderstorms occurred in north-westerly conditions, accompanied by heavy hail and rain in places. The fall of temperature up to 9,500 feet was unusually rapid, the difference between the figures at 1,000 and 9,500 feet being no less than 36° F The clouds towered up to great heights, so that the rapid fall of temperature certainly continued above 9,500 feet. Next morning the upper temperatures were still very low, −2° F. at 13,000 feet, but the humidity was much lower and the weather was fine all day, with only a few small clouds. The barometer at 18h. on the 30th was 1013 mb and rising, but there were straight NNW isobars over Britain to beyond the North of Scotland, and the upper air temperature is always low under those conditions.

June 17th.—On June 15th and 16th there was a very cold north-westerly type, with thunderstorms in the E of England, and the upper air temperatures were unusually low, the figure being -3° F., at 14,000 feet on the morning of June 16th. On the 17th, the winds became light and the NW current was limited to the lower layers. The upper air temperatures were still low and thunderstorms occurred generally in Northern France. The temperatures, humidities and wind velocities were as follows:—

JUNE 17TH.

Height (ft.).	Observed Temp. °F.	Temp. from Baro-therm.	Observed Humidity %	Humidity from Hygrograph. %	Upper Winds, Montreuil.	m.p.h.
	Start 7h. Top 8h.				5h. 10m.	
14,000	1	2	—	25	W by S	14
12,000	10	10	—	30	W	8
10,000	16	17	—	35	W	4
8,000	24	24	57	40	NNW	3
6,000	30	31	62	55	NW by N	10
4,000	37	38	62	60	NNE	3
2,000	45	45	69	85	N by E	4
1,000	49	49	82	80	WNW	5
Surface	—	—	--	(read to nearest 5%)	Calm	
	Start 18h. Top 19h.				18h. 50m.	
14,000	3	4	—	45	W by S	12
12,000	11	11	—	50	WSW	6
10,000	17	17	—	60	WSW	7
8,000	24	24	--	75	SW	8
6,000	32	32	—	80	SW	4
4,000	39	40	79	80	N	2
2,000	49	49	56	60	N by W	10
1,000	52	52	77	70	NW	12
Surface	—	—	—	—	WNW	4

April 24th and 29th.—Thunderstorms which cannot be included in any of the three classes we have considered occurred on April 24th and 29th. On the first-mentioned date there was low mist all day with a North wind which drifted in from the North Sea as far South as Arras, and thunderstorms came over from ENE late in the evening, accompanied by a change of wind towards NE and a clearance of the mist. The temperatures at Ipswich, at 15h., on that day were as follows:—

Height in feet—	2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000
Temperature °F.—	52	45	37	28	23	16	12	5

In Flanders at 18h. the temperature was 46° at 500 and 49° at 1,000 feet. There was probably an inversion up to 2,000 feet and a steady fall of temperature higher up. Another very similar thunderstorm occurred five days later at about 19h. but the low mist was in a thinner layer and only occurred in patches.

There was a layer of alto-cumulus all day at about 10,000 feet, and the base of the thunder-clouds was at 3,500 feet.

The temperatures at Berck between 17h. and 18h. were as follows:—

Height in feet—	1,000	2,000	4,000	6,000	8,000	10,000	12,000
Temperature °F.—	48	51	44	37	28	22	14

The upper winds on April 24th and 29th were as follows:—
(At Montreuil).

Height (ft.).	April 24th, 18h. 50m.		April 29th, 15h. 20m.	
6,000	E by N	18	ENE	17
4,000	ENE	20	ENE	17
2,000	NE	33	NE by E	22
1,000	NE by N	20	NE	20
Surface	NNE	5	NNE	10

These wind distributions are very similar. In each case there was a shallow depression over France, and an anticyclone over the Scandinavian area. The warm damp layer at about 4,000 feet may have curved round from the South, and the cold surface current may have helped to start the upward movement.

In the case of the majority of thunderstorms the observations of temperature and wind velocities in the upper air afford information of considerable value, though they do not, of course, give a complete explanation of the disturbance. We have seen that, as a rule, when thunderstorms occur the lapse rate of temperature is high, and that the surface layers are displaced by a colder body of air. If this development near the surface is associated with the general replacement of a warm current by a cool one, the change of wind and temperature is abrupt near the surface, but more gradual higher up. At about the 14,000 feet level, the change may begin earlier than at the surface and help to cause an unstable vertical temperature gradient, but most of the change is spread out into the 24 hours following the thunderstorm. Just behind the thunderstorm there often is a NW surface current with a SW wind above it, the former being due to the effect on the isobars of the cold air spreading from the west.

It is of some interest to consider the bearing which these notes on thunderstorms have upon the general problem of rainfall. Those thunderstorms which occurred along the troughs of depressions, or in cold westerly types, illustrate conditions in which heavy rains may occur at any season, the variations of temperature and wind velocity being more or less similar These heavy rains fall from clouds whose tops resemble cumulo-nimbus even if there is a continuous sheet of lower cloud. On the other hand, steady rain may occur in comparatively stable conditions, the clouds consisting of thin mist up to a great height. Rainfall of this kind most commonly occurs in warm damp southerly or westerly types (including some cases when the upper wind is

There was a layer of alto-cumulus all day at about 10,000 feet, and the base of the thunder-clouds was at 3,500 feet.

The temperatures at Berck between 17h. and 18h. were as follows:—

Height in feet—						
1,000	2,000	4,000	6,000	8,000	10,000	12,000
Temperature °F.—						
48	51	44	37	28	22	14

The upper winds on April 24th and 29th were as follows:—
(At Montreuil).

Height (ft.).	April 24th, 18h. 50m.		April 29th, 15h. 20m.	
6,000	E by N	18	ENE	17
4,000	ENE	20	ENE	17
2,000	NE	33	NE by E	22
1,000	NE by N	20	NE	20
Surface	NNE	5	NNE	10

These wind distributions are very similar. In each case there was a shallow depression over France, and an anticyclone over the Scandinavian area. The warm damp layer at about 4,000 feet may have curved round from the South, and the cold surface current may have helped to start the upward movement.

In the case of the majority of thunderstorms the observations of temperature and wind velocities in the upper air afford information of considerable value, though they do not, of course, give a complete explanation of the disturbance. We have seen that, as a rule, when thunderstorms occur the lapse rate of temperature is high, and that the surface layers are displaced by a colder body of air. If this development near the surface is associated with the general replacement of a warm current by a cool one, the change of wind and temperature is abrupt near the surface, but more gradual higher up. At about the 14,000 feet level, the change may begin earlier than at the surface and help to cause an unstable vertical temperature gradient, but most of the change is spread out into the 24 hours following the thunderstorm. Just behind the thunderstorm there often is a NW surface current with a SW wind above it, the former being due to the effect on the isobars of the cold air spreading from the west.

It is of some interest to consider the bearing which these notes on thunderstorms have upon the general problem of rainfall. Those thunderstorms which occurred along the troughs of depressions, or in cold westerly types, illustrate conditions in which heavy rains may occur at any season, the variations of temperature and wind velocity being more or less similar. These heavy rains fall from clouds whose tops resemble cumulo-nimbus even if there is a continuous sheet of lower cloud. On the other hand, steady rain may occur in comparatively stable conditions, the clouds consisting of thin mist up to a great height. Rainfall of this kind most commonly occurs in warm damp southerly or westerly types (including some cases when the upper wind is

North-west and the lower wind South-west), and is due to a gradual ascent of a thick layer of saturated air, probably as the result of convergence of the air near the surface. Sometimes moderate rain may fall from a fairly high level (say 8,000 feet), though the lower air is quite dry before the rain started. Showers or drizzle may be caused by clouds below 8,000 feet, though the upper air is dry. On July 23rd, at 7h., with a SSE wind just before steady rain set in, which amounted to 23mm. at Boulogne, the temperature only fell from 55° to 34° between 1,000 and 11,000 feet, but the humidity was high at all levels, with a succession of cloudsheets from 1,000 feet to a great height. On September 14th, at about 7h., rain fell from clouds extending to a great height, though there was an inversion amounting to 9° in places at about 6,000 feet above strato-cumulus clouds which were joined to the thinner nimbus clouds above. This rain occurred at the SE boundary of a depression. During the night of September 26th (referred to in the Introductory Note) rain fell with stable conditions of temperature, but high humidity at all heights. At 18h. there was a series of thin clouds resembling meadow mists from 6,000 to 12,000 feet, as well as continuous strato-cumulus below and cirro-stratus above. None of the observations shed any light on the heavy rainfall often experienced just north of cyclonic centres, but the conditions in front of depressions suggest that these rains are probably often accompanied by a stable vertical temperature gradient up to the height of a few thousand feet, but unstable conditions higher up.

Though at present it is not easy to obtain observations in heavy rain, with observations from a number of stations it will at least be possible to find the conditions all round the rain area and thus obtain information which will throw more light on the causes of rainfall.

TEMPERATURES OVER LAND AND SEA.

Observations of temperature differences between the sea and the land at various heights were made on three typical fine afternoons in August, when the sea breeze was blowing. The results were similar on the whole, but showed some differences according to the general wind current. Judging from the Weather Maps and also from the presence of much smoke-haze the air had not been over the sea for long. At the surface the temperature of the air was probably a little higher than that of the sea water, but not much higher. Close to the surface there were slight "inversions" of the lapse of temperature, and there was no turbulence perceptible to aeroplanes. When the air reached the land it was rapidly heated from below, and the lapse-rate near the surface became adiabatic, with much turbulence. Rather less than ten miles inland the conditions were adiabatic to at least 4,000 feet, where the air was no warmer over the land than over the sea. When the general wind current was blowing inland or parallel to the coast, the temperature may

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The coast near Berck runs from North to South for over forty miles. The colder air over the sea tends to set up a local gradient for North winds at the coast. This effect was noticeable, and also a definite flow of air from the sea to the land; on one occasion (August 13th) there was evidence of a return current at about 4,000 feet.

The observations over the sea at 100 feet were made close to the shore, but at 4,000 feet were made fully six miles out. The land observations were made about ten miles inland, and a few were also made over the aerodrome, which was about one and a half miles inland.

The examples may now be considered in greater detail. The figures on August 11th at 14h. 30m. G.M.T. were as follows:—

Height (ft.).	Over Sea.		Aerodrome 1½ miles inland.		Inland (10 miles).	
	Temp. °F.	Relative Humidity %.	Temp. °F.	Relative Humidity %.	Temp. °F.	Relative Humidity %.
7,000	46	46	—	—	46	46
6,000	48	33	—	—	42	100
5,000	46	83	—	—	46	88
4,000	51	84	—	—	51	77
3,000	55	74	—	—	55	74
2,000	60	62	—	—	60	67
1,000	65	61	—	—	66	61
500	66	57	66	65	69	59
100	65	65	69	—	—	—
Surface	—	—	71	61	—	—

Upper Winds at Montreuil (about 7 miles inland) at 14h. 55m. G.M.T.

Height in ft.	Direction from N.	Velocity in miles per hour.
8,000	169°	7
6,000	128°	6
4,000	148°	8
2,000	147°	8
1,000	123°	6
Surface	108°	5

On the coast there was a NNW breeze up to at least 1,500 feet, which only extended a few miles inland.

At Berck Aerodrome the sea breeze only commenced about an hour before the ascent was made, the wind having been off the have been still higher further inland, but the rate of increase was certainly much less than it was below 3,000 feet over the coastal belt.

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6,000	48	33	—	—	42	100
5,000	46	83	—	—	46	88
4,000	51	84	—	—	51	77
3,000	55	74	—	—	55	74
2,000	60	62	—	—	60	67
1,000	65	61	—	—	66	61
500	66	57	66	65	69	59
100	65	65	69	—	—	—
Surface	—	—	71	61	—	—

UPPER WINDS AT MONTREUIL (about 7 miles inland) at 14h. 55m. G.M.T.

Height in ft.	Direction from N.	Velocity in miles per hour.
8,000	169°	7
6,000	128°	6
4,000	148°	8
2,000	147°	8
1,000	123°	6
Surface	108°	5

On the coast there was a NNW breeze up to at least 1,500 feet, which only extended a few miles inland.

At Berck Aerodrome the sea breeze only commenced about an hour before the ascent was made, the wind having been off the land previous to this. The temperature difference was small at 1,000 feet and zero at 2,000 feet, as the sea breeze did not extend to that height. It will be noted that the temperature was lower at 6,000 feet over the land than over the sea, which was owing to the land observation having been made in a cloud. There were strong convection currents over the land particularly over the coastal belt, and the tops of the upward currents ascended till they were colder than the air at their level, which is frequently the case. The clouds soon disappeared when they reached the sea, and all convectional movement died out rapidly. The clouds evidently sank down as they dissolved, as the temperature six miles out to sea was nowhere below 48° F. at 6,000 feet, and the humidity was low.

Another set of observations were obtained on August 13th at about 14h. (G.M.T.).

Height (ft.)	Over Sea.		Aerodrome. 1½ miles inland.		Inland (10 miles)	
	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %
5,000	48	59	—	—	48	59
4,000	51	55	—	—	50	84
3,000	54	53	—	—	55	74
2,000	58	58	—	—	60	76
1,000	62	62	—	—	65	67
500	64	69	64	—	—	—
200	65	—	—	—	—	—
100	64	73	67	—	—	—
Surface	—	—	68	64	—	—

UPPER WINDS.

Height (ft.)	Berck, 14h. 50m.		Montreuil, 14h. 40m.	
	Direction ° from N.	Velocity m.p.h.	Direction ° from N.	Velocity m.p.h.
8,000	340	14	331	18
6,000	13	10	358	12
4,000	18	12	6	6
2,000	355	18	356	15
1,000	329	12	360	10
0–250	306	14	—	—
Surface	—	—	350	10

The effect of the sea breeze is clearly noticeable in the difference between the winds at 1,000 feet at the two stations, and still more at the surface. The differences at 4,000 and 6,000 land previous to this. The temperature difference was small at 1,000 feet and zero at 2,000 feet, as the sea breeze did not extend to that height. It will be noted that the temperature was lower at 6,000 feet over the land than over the sea, which was owing to the land observation having been made in a cloud. There were strong convection currents over the land particularly over the coastal belt, and the tops of the upward currents ascended till they were colder than the air at their level, which is frequently the case. The clouds soon disappeared when they reached the sea, and all convectional movement died out rapidly. The clouds evidently sank down as they dissolved, as the temperature six miles out to sea was nowhere below 48° F. at 6,000 feet, and the humidity was low.

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Height (ft.)	Over Sea.		Aerodrome. 1½ miles inland.		Inland (10 miles)	
	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %
5,000	48	59	—	—	48	59
4,000	51	55	—	—	50	84
3,000	54	53	—	—	55	74
2,000	58	58	—	—	60	76
1,000	62	62	—	—	65	67
500	64	69	64	—	—	—
200	65	—	—	—	—	—
100	64	73	67	—	—	—
Surface	—	—	68	64	—	—

UPPER WINDS.

Height (ft.)	Berck, 14h. 50m.		Montreuil, 14h. 40m.	
	Direction ° from N.	Velocity m.p.h.	Direction ° from N.	Velocity m.p.h.
8,000	340	14	331	18
6,000	13	10	358	12
4,000	18	12	6	6
2,000	355	18	356	15
1,000	329	12	360	10
0–250	306	14	—	—
Surface	—	—	350	10

The effect of the sea breeze is clearly noticeable in the difference between the winds at 1,000 feet at the two stations, and still more at the surface. The differences at 4,000 and 6,000 feet may indicate a return current, though it is unlikely that a return current would prevail at the latter height. The temperature difference was perceptible up to 3,000 feet, being quite large below 1,000 feet, probably about 6° or 7° at 100 feet. The higher humidities over the land between 1,000 and 4,000 feet were due to convection. The "bumpiness" reached 500 feet over the aerodrome, 1,000 feet about six miles inland, and 4,000 feet ten miles inland; there were a few small clouds at the latter height. With a general northerly current the air had probably been over the sea for a longer period than on August 11th though at 7h. the gradient wind was off the land in the East of England. The top of the haze was at about 4,000 feet, but slightly lower over the Channel and North Sea.

Observations up to 2,000 feet were obtained at about 14h. 30m. on August 16th, and the temperature difference cannot have extended much higher. The figures were as follows:—

Height (ft.).	Over Sea.		Aerodrome 1½ miles inland.		10 miles inland.	
	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %	Temp. °F.	Relative Humidity %
2,000	61	71	—	—	62	67
1,000	64	61	—	—	66	57
500	64	65	66	65	—	—
100	65	73	—	—	—	—
Surface	—	—	69	64	—	—

WIND VELOCITIES.

Height (ft.).	Berck, 14h.		Montreuil, 15h. 10m.	
	Direction ° from N.	Velocity m.p.h.	Direction ° from N.	Velocity m.p.h.
4,000	Small clouds from	moving slowly SSW.	203	15
2,000	97	6	293	3
1,500	28	7	—	—
1,000	342	11	337	11
500	338	16	—	—
0–250	333	11	—	—
Surface	—	—	294	9

The sea breeze affected both stations: the velocity at 2,000 feet at Berck suggests a return current. Turbulence reached 500 feet over the aerodrome, and only 2,000 feet 10 miles inland.

The sea breeze had set in about noon at the aerodrome.

With strong westerly winds, the lower air is often in the adiabatic state over the sea. When it reaches the land it becomes very turbulent in the daytime, but the increase of temperature is slight within ten miles of the coast. In some conditions the temperature up to the height of a few thousand feet increases continuously for a long distance inland; this affects the pressure at the surface, so that if a south-west wind prevails above, the surface wind may be light and variable. These conditions are favourable to thunderstorms, and an example occurred on the afternoon of July 15th, between 14h. and 15h. (G.M.T.), some hours before thunderstorms developed. The following differences of temperature and humidity were observed:—

Height (ft.).	Over Sea.		7 miles inland (Montreuil).		40 miles inland (Avesnes-le-Comptes).	
	Temp. °F.	Relative Humidity %	Temp. °	Relative Humidity %	Temp. °F.	Relative Humidity. %
4,000	—	—	—	—	52	94
3,000	56	89	56	93	57	84
2,000	59	85	60	85	62	76
1,000	63	86	64	86	67	69

The wind at 4,000 feet was from SW. At the surface it was light and westerly on the coast; south-easterly inland.

The line-squalls of July 17th and 20th (*see* notes on thunderstorms) were probably associated with large temperature differences between the sea and the land. A difference of 5° F. in two miles was in fact observed at 1,000 feet at 14h. on July 20th, associated with a belt of cloud along the coast. In such conditions the temperature differences between the land and the sea are both interesting and important.

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