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A MINOR LINE-SQUALL.

BY

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A MINOR LINE-SQUALL (14TH AUGUST, 1919).

BY CAPT. M. T. SPENCE, B.Sc.

The following investigation was commenced at the suggestion of the Superintendent of the Forecast Division, because the phenomenon appeared to be the unusual one of a line-squall advancing from east to west, or at least with an appreciable component in that direction. The result of the investigation indicates that the direction of motion was more nearly from north to south, so that the identification of a line-squall, with a general motion from east to west, has yet to be made. Nevertheless, the results of the enquiry indicate that the direction of motion and the direction of winds on this occasion were unusual, and that the squall advanced into a region of increasing pressure near the centre of an anticyclone. Further, some pilot balloon observations near the time of the squall are available, and it is believed that this is the first occasion on which pilot balloon observations have been discussed in connection with a line-squall.

The cold air supply of the squall of August 14th, 1919, seems to have come originally from the area to the North of Scotland. At Thorshavn the temperature was 48°F. at 7h. on the 13th and 14th August. At Lerwick the temperature on the morning of the 13th was 53°F., and on the morning of the 14th 52°F. A north-westerly to northerly current from the north of Scotland was carrying the cool air from that region into the North Sea. This current was well maintained from mid-day on the 13th.

At 7h. on the 14th August the barometer at Spurn Head was inclined to fall. At Helder, Gorleston, Liverpool, and at Holyhead, the barometer was falling very slowly. This fall of pressure gave rise to an irregularity in the isobars which moved south or south-east. The irregularity and its movements are shown on the accompanying maps for the day in question. This irregularity, together with the relatively high temperatures over the land area of England, appears to have induced a circulation from north-east bringing a current of cold air from the North Sea across eastern England. This current is shown by the autographic records to have reached Cranwell in Lincolnshire and Chatsworth in Derbyshire at 11h. At Chatsworth the temperature fell from 70°F. to 64°F. At Cranwell the humidity rose from 60 per cent. to 80 per cent. and the wind veered from west to north, increasing in a squall from 20 m.p.h. to 30 m.p.h.

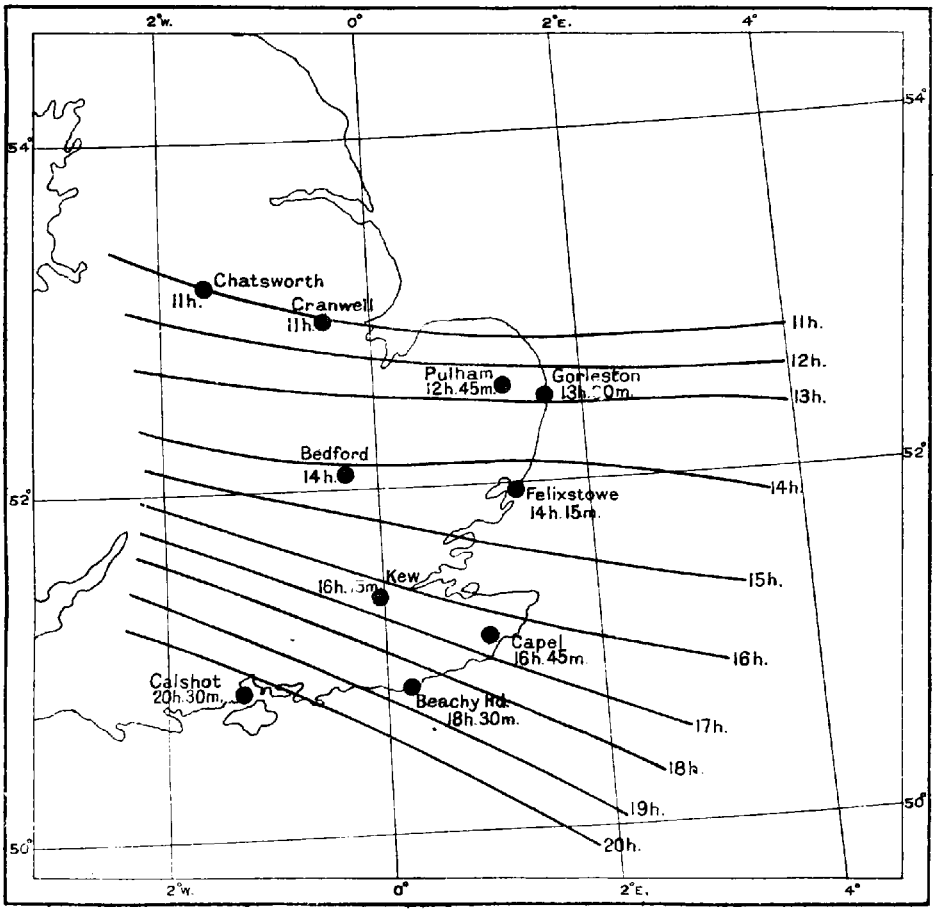

Fig. 1. CHART SHOWING THE APPROXIMATE POSITION OF THE FRONT OF THE N.E. CURRENT BETWEEN 11h. AND 20h., ON THE 14th. AUGUST 1919.

Figure 2.

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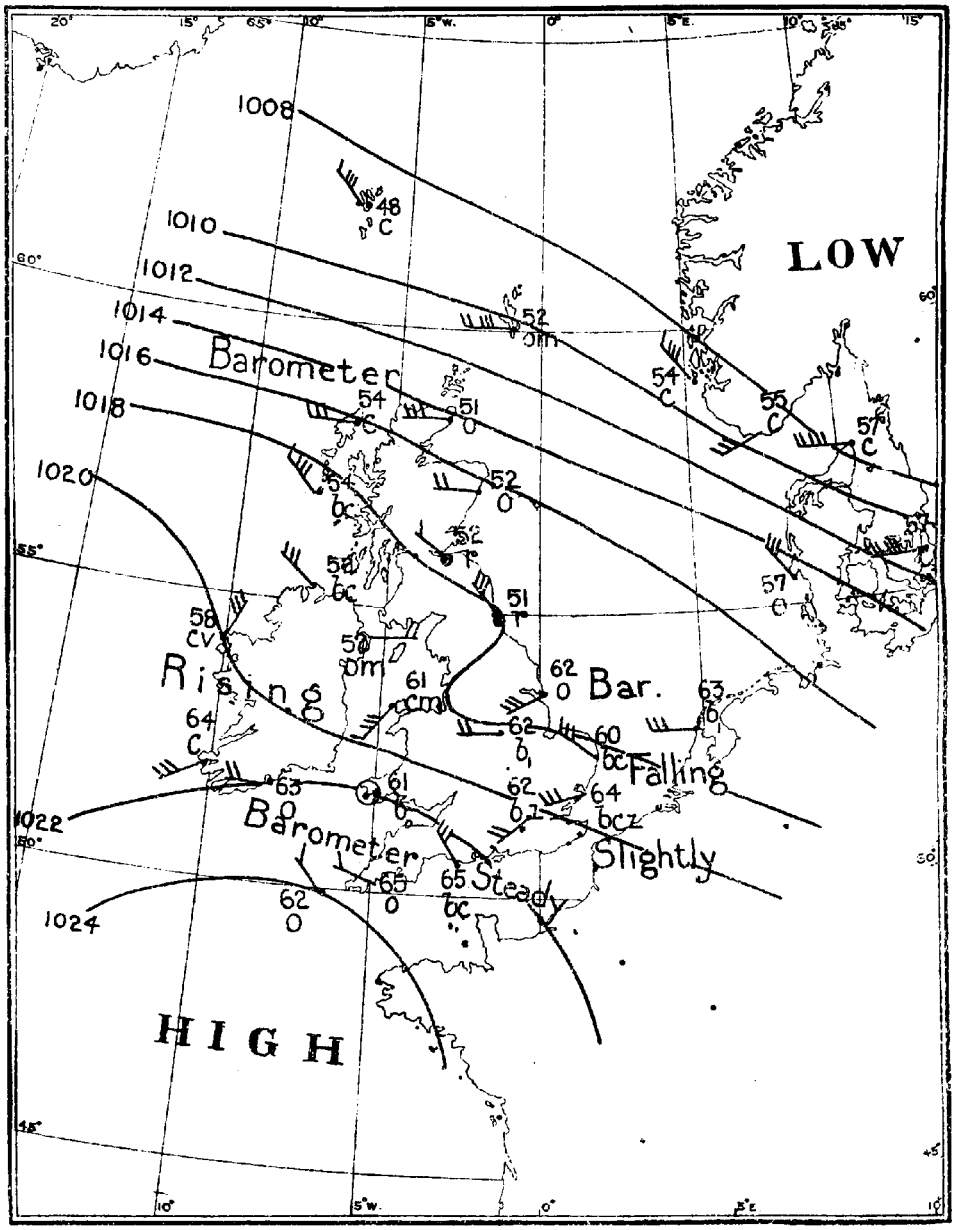

Fig. 2. CHART OF WEATHER IN NORTH-WESTERN EUROPE.
THURSDAY, 7h., 14th. AUGUST, 1919.

Figure 3.

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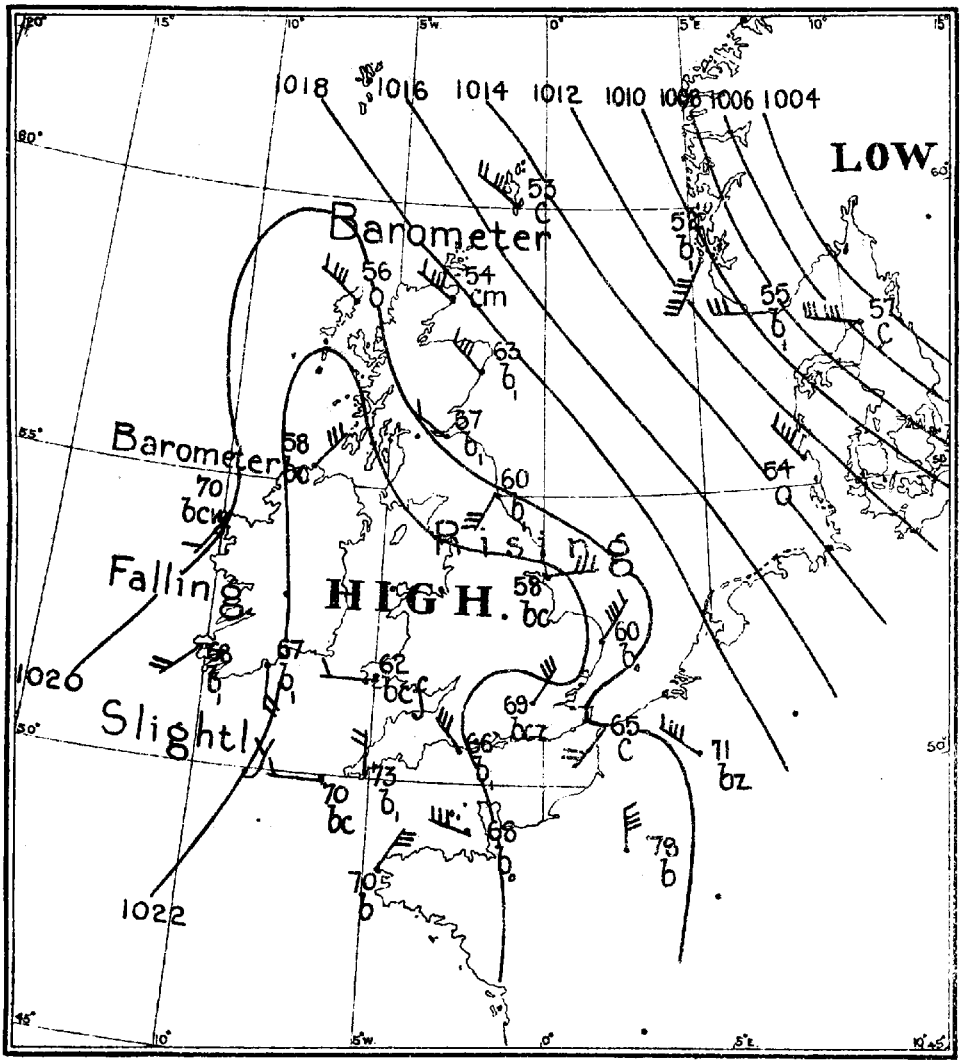

Fig. 3 CHART OF WEATHER IN NORTH-WESTERN EUROPE, THURSDAY 18h., 14th. AUGUST, 1919.

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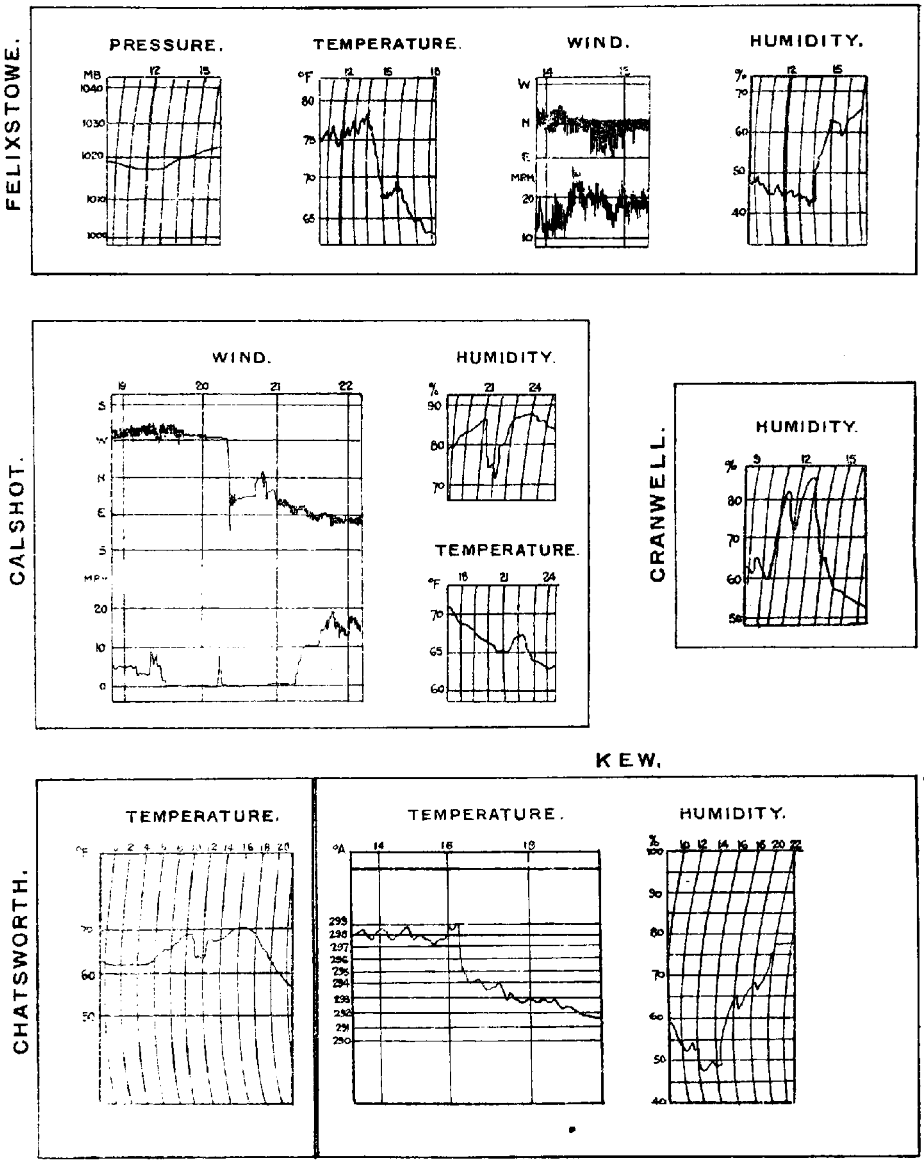
AUTOGRAPHIC RECORDS.
14th. AUGUST 1919.



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The map in Fig. 1 shews approximately the position of the front of the NE. current at intervals of an hour from 11h. to 20h. The average rate of travel of the front was about 22 miles per hour.

The following changes experienced at Felixstowe, are typical of those at the majority of stations over which the squall passed. Temperature fell from about 77°F. to 67°F. within an hour. Humidity, during the same period, increased from 43 per cent. to 62 per cent. The wind veered from NNW. to NE. and increased in a squall from about 14 m.p.h. to 22 m.p.h. The barograph showed a small upward jump at the onset of the colder current and then continued to rise slowly and steadily. An outstanding feature of the temperature changes was that, just before the fall of temperature there was a minor increase of about 2°F. with a corresponding fall in humidity. Just after the cessation of the fall of temperature there was a sudden increase of 2°F. followed by a further gradual fall.

No rain fell. This may be accounted for by the dryness of the warm air. At Felixstowe, before the squall reached there, the humidity was about 45 per cent. and the temperature 77°F. Assuming a lapse rate of 3°F. in 1,000 feet the surface air would have to be lifted about 8,000 feet before it was saturated.

At Calshot as a result of radiation, the temperature had fallen to 60°F. when the squall reached there. There was no decided fall of temperature registered on the thermograph. The wind, however, showed a veer from W. to ENE. with a corresponding feeble squall from calm to 5 m.p.h.

A fall of temperature of as much at 16°F. was shown by the thermograph at Capel near Folkestone.

Mr. Penlington wrote from Eastbourne as follows :—

> " There was a strong line-squall here at 6.30 p.m. G.M.T. The wind changed from gentle west wind to very strong east wind, probably 35-40 m.p.h. lifting clouds of dust into the air and driving people indoors from the front. The maximum force lasted only 6 minutes, but it blew freshly from east all the evening and is E. or ESE. force 4, this morning, 15th."

At Beachy Head a pilot balloon ascent at 12h. 30m. showed a wind of 30 m.p.h. from NW. at 10,000 feet. Evening ascents at Eskdalemuir, Luce Bay, Barrow and Anglesey showed winds from between west and north-west with velocities of 20 to 30 m.p.h. between 10,000 feet and 20,000 feet. An ascent at Capel (near Folkestone) at 17h. 45m., one hour after the passage of the squall, showed a wind from NW. by W. of 23 m.p.h. at 6,000 feet. It may be assumed from these that the general current at 8,000 feet over the British Isles was from about WNW. with a velocity of about 25 m.p.h. With relatively cold air over the North Sea and the central area of an anticyclone over south-west England north-westerly upper winds were to be expected.

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Capel Pilot Balloon.
Ascent at 17h. 45m.

6,000 feet	NW. by W.	23	m.p.h.
5,000 „	NW. by W.	17	„
4,000 „	WNW.	11	„
3,000 „	NW.	10	„
2,000 „	N. by W.	9	„
1,000 „	NE. by N.	39	„
Surface	NE. by E.	17	„

The velocity of 39 m.p.h. at 1,000 feet is probably false. The station is situated near the edge of a cliff, over which the balloon is blown by winds with a northerly component. When the balloon passes over the edge of this cliff it usually ascends at a rate slower than the assumed rate, giving an exaggerated velocity when computed from the elevation and azimuth readings of one theodolite. Neglecting this value we have, one hour after the passage of the squall, a north-easterly current of no great velocity extending to a height of no more than 1,000 feet. At 3,000 feet the north-westerly current was well established. The north-easterly current, however, was not so shallow in the evening at places which experienced the squall earlier in the day. At Cranwell at 17h. 45m. (seven hours after the squall passed) a balloon which reached 4,000 feet showed a wind of 7 m.p.h. from NE. at that height. At Felixstowe an ascent three hours after the squall passed showed a wind of 12 m.p.h. from N. by E. at 2,000 feet. Unfortunately there were no higher ascents from which the depth of the NE. current could be estimated.

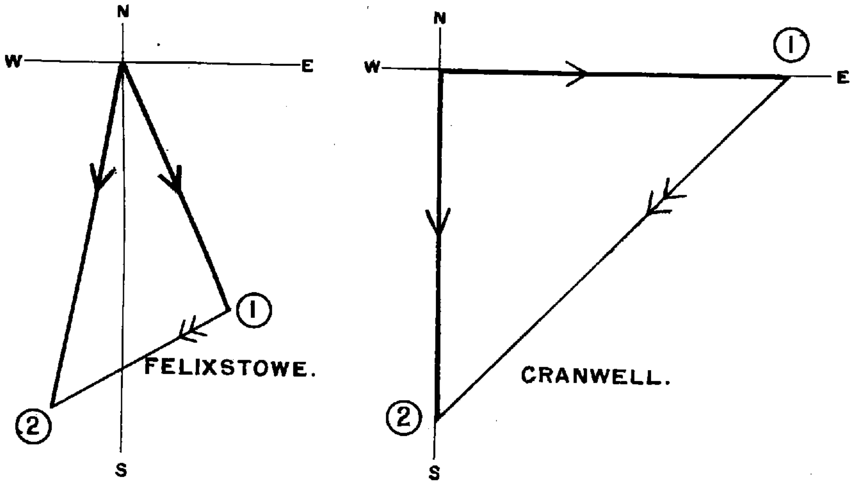
Beachy Head Pilot.
Balloon Ascent at 17h. 30m.

8,000 feet	N. by W.	10	m.p.h.
7,000 „	NW. by N.	20	„
6,000 „	N. by W.	7	„
5,000 „	N.	7	„
4,000 „	NE. by E.	18	„
3,000 „	NE.	18	„
2,000 „	N.	12	„
1,000 „	W. by N.	23	„
Surface	—	—	

At Beachy Head, one hour *before* the squall reached there, a westerly wind at 1,000 feet changed to a north-east wind at 3,000 feet with a velocity of 18 m.p.h., which again reverted to a north-westerly wind at 7,000 feet. This would suggest that at 3,000 feet the NE. current had gained on the linear front, though the squall, as described by Mr. Penlington, was quite intense in the Eastbourne district. There was no other balloon ascent which showed the north-east upper current in advance of the squall. An ascent at Pulham, immediately in front of the squall, showed a north-westerly wind up to 4,000 feet. An ascent at Calshot, three hours before the squall reached there, showed a wind mainly north-westerly up to 8,000 feet.

The vector (*see* Fig. 5), which has to be added to the wind in front of the squall to produce the wind behind the squall, has a NE. to SW. direction. The direction of the linear front was mainly WNW. to ESE. Lempfert and Corless (*Q.J.R. Met Soc.* 1910, Vol. 36, pp. 135-170) showed that, in the case where the components of the wind perpendicular to the linear front on both sides of it were the same, the direction of the linear front and of the added vector were the same, whereas in this

Surface wind immediately in front of squall (1.)
" " " behind " (2.)
Vector shown with double arrow.



GRADIENT.

Gradient in front of squall (1)
" behind " (2)
Vector to produce (2) from (1) shown with a double arrow.

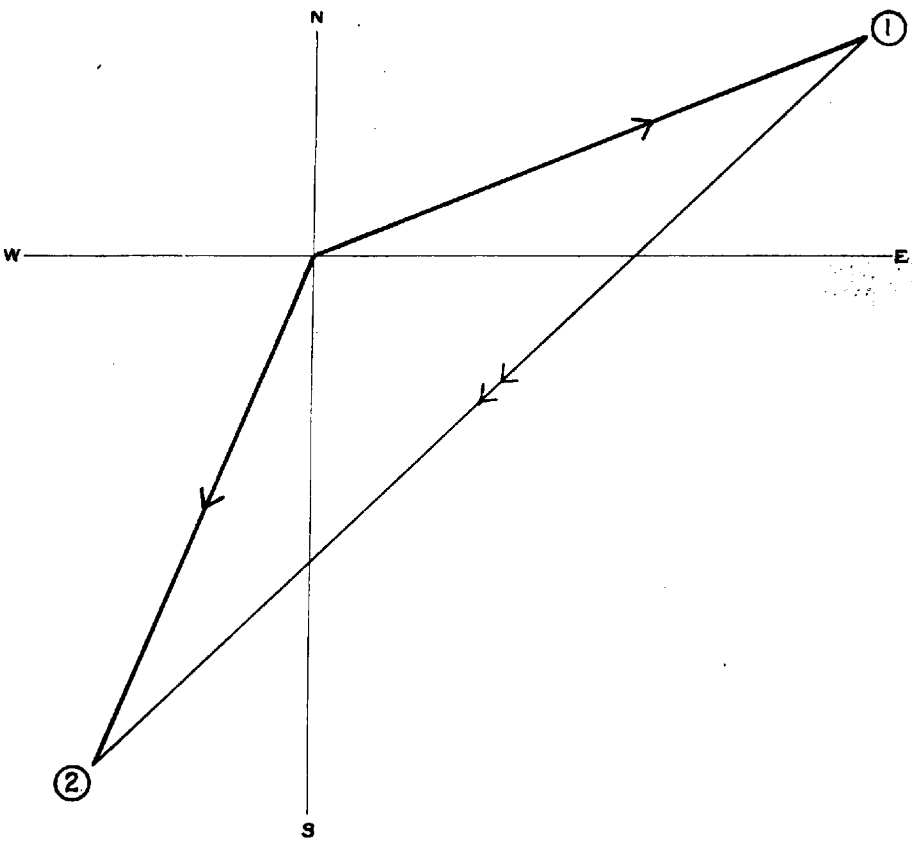


Fig. 5.

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case the two directions were nearly at right angles. The components in this case, however, were equal in magnitude, but opposite in direction. A slowing down of the cold air over the land, as compared with its velocity over the sea, may have caused some clockwise rotation of the linear front; but actually its direction seems to have been so nearly at right angles to the direction of the wind of the cold current as to suggest that the theory referred to can be replaced in this case by a simple straightforward displacement of the warm air by the cold.

In front of Squall.			In rear of Squall.			Average rate of advance of squall.
Gradient Velocity m.p.h.	Component along squall line (approx.).	Component perpendicular to squall line (approx.).	Gradient m.p.h.	Component along squall line (approx.).	Component perpendicular to squall line (approx.).	
WSW. 30 m.p.h.	21 m.p.h.	21 m.p.h.	NNE. 28 m.p.h.	11 m.p.h.	26 m.p.h.	22 m.p.h.

The rate of advance of the linear front (22 m.p.h.) approximates very closely, to the component of the gradient wind, at right angles to the front, in the rear of the squall.

The sudden and temporary increase of wind and the accompanying changes of temperature and pressure are those usually associated with a line-squall, but the veer of the wind from some point west of north to north-east is exceptional in line-squalls. When the history of the cold air is examined, however, it is found to be similar to that of the corresponding air in the average line-squall. Immediately before this cold air became a NE. current it had travelled from the region to the North of Scotland, and probably from still further north. The cold current, therefore, had been a north or north-west current for a considerable time before it was deviated round the irregularity in the isobars and arrived over England from NE. The warm air, which this NE. current replaced, owed its comparatively high temperature near the surface mainly to the fact that it had been heated over the inland area of England under fine anticyclonic conditions with feeble air circulation. Before this warm air reached England it had come from the Atlantic, and from latitudes south of the British Isles.