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SOUNDINGS WITH PILOT BALLOONS IN THE ISLES OF SCILLY

NOVEMBER AND DECEMBER 1911

BY

CAPTAIN C. J. P. CAVE, M.A.

AND

J. S. DINES, M.A.

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SOUNDINGS WITH PILOT BALLOONS IN THE ISLES OF SCILLY:

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§ 1. Introduction.

In order to observe the conditions of wind direction and velocity in the free air in a place where the effect of land masses may be regarded as a minimum, a series of soundings with pilot balloons was made in the Isles of Scilly, in November and December 1911. The Isles of Scilly are a group of small islands situated about 40 kilometres S.W. of the Lands End (see map, Plate I.). The largest island, St Mary's, is about 4 kilometres long by about three and a half broad. The land rises in a few points to about 50 metres above sea-level. A balloon is soon carried out of the reach of the influence of land.

In the series of ascents particular attention was given to the following points :—

(1) The relation of the observed wind velocity at different heights to the gradient velocity. (§ 5.)
(2) The rate of increase of velocity in the lower layers. (§ 6.)
(3) The rate of ascent of the balloons. (§ 7.)

It was desired also to compare the results of the observations with those made at Ditcham Park which have been discussed by one of the authors in his work on *The Structure of the Atmosphere in Clear Weather*.

§ 2. Methods of Observation.

The observations in the Isles of Scilly were made with two theodolites of similar pattern, made by Messrs Cary Porter for the Meteorological Office from the design of M. de Quervain, with some modification of the original model. The balloons used were supplied by M. Paturel of Paris: they weighed about 30 grammes. To fill them, a balance made by Bosch of Strasbourg was used, by means of which the lift could be measured while the balloon was being filled without taking it off the filling apparatus.

The balloons were filled and liberated on the island of St Mary, at a building originally intended as married quarters of the artillery. This building was kindly placed at the disposal of the observers by the late Mr Dorrien Smith, of Tresco. This station, called the Garrison in the following paper, consists of several buildings surrounded by an earthwork.

At the west end is a mound covering the fire-control station, and it was on this mound that one of the theodolites was usually placed. If, however, the wind was strong,

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the theodolite was placed below the bank to avoid vibration. In one or two ascents on the last day of the observations the theodolite was placed inside the fire-control station.

Four base lines were used as occasion demanded, the Garrison in all cases being one end of the base. The base from which most of the observations were taken was from the Garrison to the Coastguard Look-out on Bryher. These two stations are marked with an X on the map (Plate I.). The length of this base was 5260 metres; the height of the Garrison station was about 42 metres above sea-level, and the Bryher station was almost exactly at the same height. Quite close to the Garrison station was Lloyd's signal tower, from which there was a telephone to the coastguard cottages on Bryher. The theodolite on Bryher was usually placed on the south side of the look-out station, but sometimes it was moved to one side to get shelter from the wind. Altogether 27 ascents were made with the Bryher base. The direction of the Bryher station from the Garrison was N. 23° W.

Three sets of observations were made with a base extending to Penninis Point, the direction from the Garrison being E. 25° S., and the distance 1445 metres. The height of this station was about 30 metres above sea-level. One ascent was made with a base from the Garrison to Starr Castle. The direction was N. 10° E., and the length 410 metres; the height of the station being about 33 metres above sea-level. One ascent was made with a base line from the Garrison to the Wireless Station, the direction being N. 36° E., and the length 2295 metres. The height of this station was about 49 metres above sea-level. Nine ascents were observed with one theodolite only; for these a uniform rate of ascent was assumed.

The following was the method ordinarily adopted for sending up the balloon :—The observer at the out-station having set up his theodolite, went to the telephone and compared his watch with that of the observer at the home station; he started a stop-watch to agree with the second's hand of the Garrison observer's watch. It was agreed that the balloon should be sent up after a definite interval, usually ten minutes. After the balloon was liberated, observations were taken at each station at exact minutes from the start until the balloon ceased to be visible, either because it entered a cloud, or on account of the distance; or, as happened on two occasions, because the balloon was seen to burst. A telephone was available at Bryher and at the Wireless Station, but at Penninis Point and Starr Castle it was necessary to rely on flag or semaphore signals. The observers were assisted by coastguards kindly placed at their disposal by Mr Bradley, Divisional Officer of Coastguard; the coastguards gave the minute signals and wrote down the observations. On a few occasions the observers took the time and wrote down the observations without any assistance; this is quite easy to do when the balloon is moving slowly both in altitude and azimuth.

§ 3. Particulars of Ascents.

Particulars of the individual ascents are set out in Table I.

The wind velocity and direction for each ascent, at height steps of 200 m. in the lowest kilometre and 500 m. above this level are given in Table II.

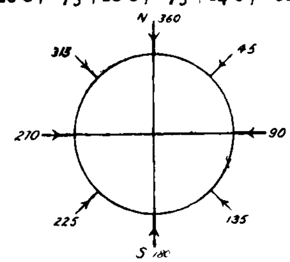
Wind directions are expressed in degrees measured clockwise from N., so that 90° = E., 180° = S., and so on. Velocities are in metres per second.

TABLE I.—PARTICULARS OF INDIVIDUAL ASCENTS.

No.	Date.	Time.	Wind Velocity at 50m.	Wind Velocity at 150m.	Wind Direction Quadrant.	Gradient Velocity.	Reached at	Ratio Gradient / Surface.	Clouds at	Greatest Height Theodolite. 1.	Greatest Height Theodolite. 2.	Remarks.
		h m	m/s.	m/s.		m/s.	k.		k.	k.	k.	
1	Nov. 22	12 8	6.5	9.0	NE	12.5	0.7	2	1.7	1.7	1.6	
2	22	14 0	7.5	12.0	NE	12.5	0.6	2	1.9	1.9	1.5	
3	23	12 20	11.5	11.5	NE	20.0	18 at 0.4	2	0.8	0.8	0.8	
4	23	12 45	10.5	14.0	NE	20.0	17 at 0.4	2	0.8	0.8	0.8	
5	24	11 5	7.5	11.0	NE	14.0	12 at 0.4	2	0.3	0.3	0.3	
6	25	15 22	8.0	12.0	NE	10.0	0.07	1	0.8	0.8	0.8	
7	27	11 0	0.0	0.5	SE	Imperceptible	...	...	1.7 & 3.0	3.0	1.7	Veer of 200° in first km.
8	27	12 30	0.0	2.5	SW	"	...	...	1.7	1.7	1.6	Veer of 100° in first km.
9	27	14 40	0.0	1.0	SW	"	...	...	...	6.3	5.2	Veer of 170° in first 2 km., then back 130°.
10	27	16 0	2.0	3.5	SW	"	...	...	5.3	7.3	5.3	Veer of 150° in first 2 km., then back 130°
11	28	11 50	3.0	4.0	SE	9.0	1.3	3	...	5.3	4.8	Veer of 110° in 0.8 km.
12	28	15 10	0.0	2.5	SW	9.0	0.9	...	...	4.7	4.4	
13	29	12 0	3.5	4.5	SE	Imperceptible	...	...	...	1.8	1.6	Veer of 150° in 1.1 km., then back 160°.
14	29	12 40	4.0	4.5	SW	"	...	...	...	2.9	2.8	Veer of 80° in 0.7 km., then back 270°.
15	29	14 30	6.0	7.0	SE	"	...	...	about 1.8	8.7	7.8	
16	30	11 45	8.0	12.5	SW	12.5	0.1	1.5	0.4	0.4	...	
17	Dec. 1	11 10	8.0	12.5	SW	14.5	13 at 0.3	2	0.25	0.25	0.25	
18	1	11 30	8.0	13.0	SW	14.5	0.4	2	3.1	3.1	2.2	
19	1	14 45	8.0	13.5	SW	14.5	0.1	2	...	4.7	4.3	
20	2	11 40	12.5	18.0	SW	23.0	0.3	2	0.4	0.4	0.4	
21	4	11 30	7.5	9.5	SW	16.5	1.7	2	? 2.5	4.0	2.5	
22	4	12 28	6.5	9.5	SW	16.5	2.1	2.5	...	4.0	3.6	
23	4	13 30	6.5	10.0	SW	16.5	2.0	2.5	? 2.8	2.8	2.4	
24	4	14 30	8.0	12.5	SW	16.5	15 at 0.8	2	1.8	1.8	1.8	
25	5	12 5	12.5	13.0	NW	12.5	Anemometer	1	2.1	4.2	2.1	}
26	5	13 0	13.0	14.0	NW	12.5	{ Exceeded at Anemometer }	1	2.5	2.5	1.1	} Wind close to gradient in velocity and direction.
27	5	14 0	12.0	12.5	NW	12.5	0.1	1	1.2	4.5	1.2	}
28	5	15 0	11.5	12.0	NW	12.5	0.2	1	3.3	4.0	3.3	}
29	6	10 50	6.5	8.0	SW	17.5	Not reached	3	...	5.1	4.1	
30	6	11 50	8.0	13.0	SW	19.0	"	2	1.5	3.8	1.5	
31	6	12 50	8.5	12.5	SW	21.0	"	2.5	1.2	1.2	1.2	
32	6	13 50	9.5	15.0	SW	22.5	"	2.5	3.6	3.6	2.6	
33	6	14 35	9.5	14.5	SW	23.5	"	2.5	2.2	4.0	2.3	
34	7	11 0	10.0	9.0	NW	14.5	1.2	1.5	1.5	1.5	...	
35	7	14 12	7.5	7.5	NW	13.0	Not reached	2	0.7	0.7	...	
36	7	15 35	6.5	9.0	NW	11.0	1.5	2	4.0	5.0	4.0	
37	8	10 5	15.5	16.5	SE	?	...	...	0.2	0.2	...	}
38	8	12 15	7.5	12.0	SW	?	...	...	0.2	0.2	...	}
39	8	12 48	16.0	20.0	NW	?	...	...	0.6	0.6	...	} Pressure changing rapidly.
40	8	14 3	10.0	11.0	SW	?	...	...	0.7	0.7	...	}
41	8	16 26	14.5	16.0	NW	?	...	...	1.1	1.1	...	}

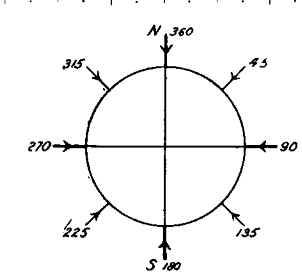
TABLE II.—VELOCITY AND DIRECTION OF THE UPPER WIND FOR EACH ASCENT.

No. Date. Time. 2 theods. to km.	1. Nov. 22. 12·8 p. 1·5.		2. Nov. 22. 2·0 p. 1·5.		3. Nov. 23. 12·20 p. 0·8.		4. Nov. 23. 12·45 p. 0·8.		5. Nov. 24. 11·5 a. 0·2.		6. Nov. 25. 3·22 p. 0·8.		7. Nov. 27. 11·0 a. 1·5.		8. Nov. 27. 12·30 p. 1·5.		9. Nov. 27. 2·40 p. 5·0.		10. Nov. 27. 4·0 p. 5·0.		11. Nov. 28. 11·50 a. 4·5.		12. Nov. 28. 3·10 p. 4·0.		13. Nov. 29. Noon. 1·5.		14. Nov. 29. 12·40 p. 2·5.		15. Nov. 29. 2·30 p. 7·5.	
	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°
Gradient wind.	12·5	45	12·5	45	20·0	75	20·0	75	14·0	80	10·0	115			Imperceptible.						9·0	205	9·0	220			Imperceptible.			
5000 m.	...	...											...	...	...	...	12·5	270	13·0	265	12·0	235	...	...	...	...	...	...	4·0	335
4500	...	...											...	...	...	...	12·0	260	11·0	260	10·0	230	13·0	240	...	...	...	...	4·0	330
4000	...	...											...	...	...	...	9·5	270	8·0	260	11·0	230	11·5	225	...	...	...	...	4·5	20
3500	...	...											...	...	...	...	7·0	275	6·5	255	10·5	230	10·0	240	...	...	...	...	4·5	45
3000	...	...											5·0	325	...	...	6·0	285	5·0	260	10·5	220	12·0	240	...	...	...	...	2·0	30
2500	...	..											7·5	350	...	...	3·0	310	2·5	240	12·5	220	11·0	240	...	...	2·5	330	0·5	25
2000	...	...	12·0	35									6·0	360	...	...	5·0	40	2·5	360	12·5	215	11·0	245	...	...	4·5	110	4·0	110
1500	12·5	35	12·5	40	...	...	..	...	...	...	...	...	5·0	20	3·0	360	6·5	350	3·5	330	13·5	205	10·0	240	1·0	210	2·0	180	4·5	175
1000 m.	12·5	35	12·5	40	...	...	...	...	...	...	...	...	6·0	330	4·0	355	4·0	325	4·0	305	3·5	195	11·0	265	2·0	145	3·5	150	4·5	160
800	12·5	35	13·0	40	17·5	50	17·0	55	...	...	12·5	120	4·0	310	4·0	310	4·0	315	3·5	270	1·5	190	7·5	265	3·0	150	4·5	140	6·0	145
600	12·0	35	12·5	40	18·0	55	17·0	55	..	..	11·0	115	1·0	280	3·5	290	3·0	300	4·0	245	2·0	140	5·5	260	3·5	120	5·0	130	7·5	145
400	11·5	40	11·5	40	18·0	55	17·0	55	...	...	12·0	90	1·0	210	2·5	280	2·5	265	3·5	245	4·0	120	4·0	250	4·5	120	5·5	130	7·0	145
200	9·5	50	12·0	40	13·5	55	14·5	55	11·5	75	11·5	80	1·0	165	2·5	260	1·5	240	3·5	240	4·0	120	2·5	260	4·5	120	5·5	125	7·0	145
Anemometer.	6·5	50	7·5	40	11·5	55	10·5	55	7·5	65	8·0	70	0·0	...	0·0	...	0·0	...	2·0	235	3·0	120	0·0	...	3·5	120	4·0	120	6·0	145



No. Date. Time. 2 theods. to km.	16. Nov. 30. 11·45 a. ...		17. Dec. 1. 11·10 a. 0·2.		18. Dec. 1. 11·30 a. 2·0.		19. Dec. 1. 2·45 p. 4·0.		20. Dec. 2. 11·40 a. 0·4.		21. Dec. 4. 11·30 a. 2·5.		22. Dec. 4. 12·28 p. 3·5.		23. Dec. 4. 1·30 p. 2·0.		24. Dec. 4. 2·30 p. 1·5.		25. Dec. 5. 12·5 p. 2·0.		26. Dec. 5. 1·0 p. 1·0.		27. Dec. 5. 2·0 p. 1·0.		28. Dec. 5. 3·0 p. 3·0.		29. Dec. 6. 10·50 a. 4·0.		30. Dec. 6. 11·50 a. 1·5.	
	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°
Gradient wind.	12·5	205	14·5	205	14·5	205	14·5	205	23·0	205	16·5	250	16·5	250	16·5	230	16·5	230	12·5	290	12·5	290	12·5	290	12·5	290	17·5	215	19·0	215
5000 m.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	14·0	310	...	..
4500	...	...	...	...	...	...	16·0	230	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11·5	260	...	...	13·0	305	...	...
4000	...	..	...	...	...	...	16·5	225	...	...	17·0	285	19·5	285	...	...	...	...	13·5	270	...	...	11·0	270	10·0	280	9·0	310	...	...
3500	...	...	...	...	...	...	16·5	220	...	...	16·0	275	18·5	270	...	...	...	...	13·5	275	...	...	11·0	270	8·5	275	10·5	235	11·0	235
3000	...	...	...	...	18·5	225	17·0	230	...	...	19·0	275	21·0	270	...	...	...	...	14·0	280	...	...	13·5	280	11·5	285	10·5	235	13·0	235
2500	...	...	...	...	17·0	225	15·0	225	...	...	19·5	275	19·0	265	18·0	260	...	...	14·0	290	11·0	280	13·0	280	11·0	285	10·5	235	13·5	225
2000	...	...	...	...	14·5	200	16·0	220	...	...	16·5	270	15·5	280	16·5	250	...	...	12·5	290	12·0	290	13·5	285	10·0	290	10·5	225	11·0	215
1500	...	...	...	...	16·5	210	15·5	215	...	...	14·0	255	14·0	245	13·0	250	15·0	230	12·5	290	12·0	290	10·5	290	11·0	290	11·0	215	12·5	210
1000 m.	...	...	...	...	15·5	220	16·0	220	...	...	11·0	260	12·0	235	13·0	235	15·0	220	13·0	295	12·5	290	13·0	295	13·0	290	10·5	215	12·0	205
800	...	...	...	...	14·5	215	16·0	220	...	...	10·5	260	12·0	230	12·0	225	15·5	215	13·0	295	12·5	290	13·0	285	13·0	290	11·0	210	12·5	195
600	...	...	...	...	14·5	205	16·5	215	...	...	10·5	250	10·5	220	12·0	215	13·5	210	12·0	290	12·5	290	13·5	285	12·0	290	11·0	205	12·5	195
400	16·5	200	...	...	14·0	200	17·5	205	23·0	190	10·0	245	10·0	220	10·0	210	13·5	200	14·0	290	13·5	290	12·5	285	12·5	290	10·5	200	12·5	195
200	13·0	195	13·0	190	13·5	195	15·0	205	20·0	185	10·0	245	9·5	220	10·0	210	13·0	200	13·0	290	14·0	285	13·0	285	12·5	290	8·5	195	12·0	200
Anemometer.	8·0	180	8·0	175	8·0	195	8·0	205	12·5	185	7·5	250	6·5	220	6·5	220	8·0	195	12·5	290	13·0	285	12·0	295	11·5	290	6·5	195	8·0	200

No. Date. Time. 2 theods. to km.	31. Dec 6. 12·50 p. 1·0.		32. Dec. 6. 1·50 p. 2·5.		33. Dec. 6. 2·35 p. 2·0.		34. Dec. 7. 11·0 a. ...		35. Dec. 7. 2·12 p. ...		36. Dec. 7. 3·35 p. 4·0.		37. Dec. 8. 10·5 a. ...		38. Dec. 8. 12·15 p. ...		39. Dec. 8. 12·48 p. ...		40. Dec. 8. 2·3 p. ...		41. Dec. 8. 4·26 p. ...	
	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°	m/s.	°
Gradient wind.	21·0	210	22·5	210	23·5	210	14·5	340	13·0	340	11·0	340	?	?	?	?	?	?	?	?	?	?
5000 m.	...	...	...	...	...	...	...	...	...	...	18·0	305										
4500	...	...	..	...	...	...	...	...	...	...	18·0	305										
4000	...	...	...	...	12·5	250	...	...	...	...	18·0	310										
3500	...	...	10·0	240	11·5	225	...	...	...	...	16·5	320										
3000	...	...	12·5	220	15·5	225	...	...	..	...	15·0	320										
2500	...	...	15·0	215	16·5	215	...	...	...	...	12·5	320										
2000	...	...	17·0	210	17·5	210	...	...	...	...	11·0	315										
1500	...	...	16·0	200	19·0	205	13·5	335	...	...	10·5	315										
1000 m.	14·0	205	16·0	195	18·0	205	12·5	330	...	...	8·5	315	...	...	...	...	...	...	...	...	18·5	265
800	13·5	200	15·5	195	17·5	205	11·0	325	...	...	8·5	310	...	...	...	...	...	...	...	...	19·5	265
600	13·5	200	16·0	195	18·0	200	9·5	330	6·5	315	8·0	310	...	...	...	...	13·0	285	14·5	260	20·0	270
400	13·0	195	16·0	195	17·5	200	10·5	330	5·5	320	8·0	310	...	...	...	...	17·5	290	12·0	255	14·0	275
200	13·0	195	15·0	195	16·0	195	10·0	330	6·0	315	9·0	310	19·0	165	13·0	205	20·0	290	11·0	255	14·5	275
Anemometer.	8·5	200	9·5	195	9·5	195	10·0	330	7·5	305	6·5	310	15·5	170	7·5	190	16·0	285	10·0	255	14·5	275

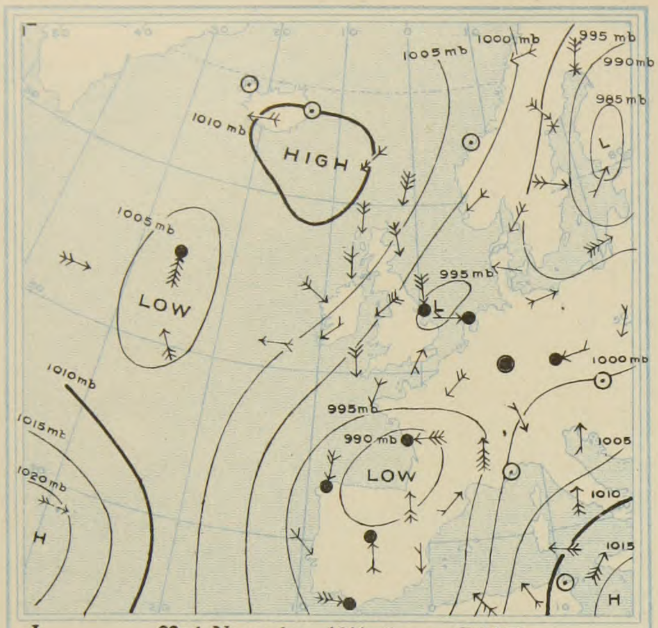


In addition, the upper parts of ascents Nos. 9, 10, and 15 show:

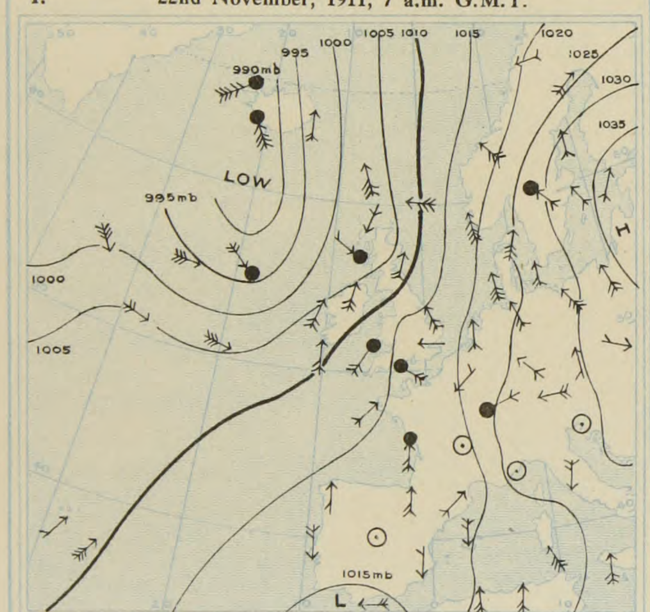
No. 9, at 6000 m. 11·0 m/s, 270°.

No. 10, at 6000 m. 11·5 m/s, 265°; at 7000 m. 12·0 m/s, 260°.

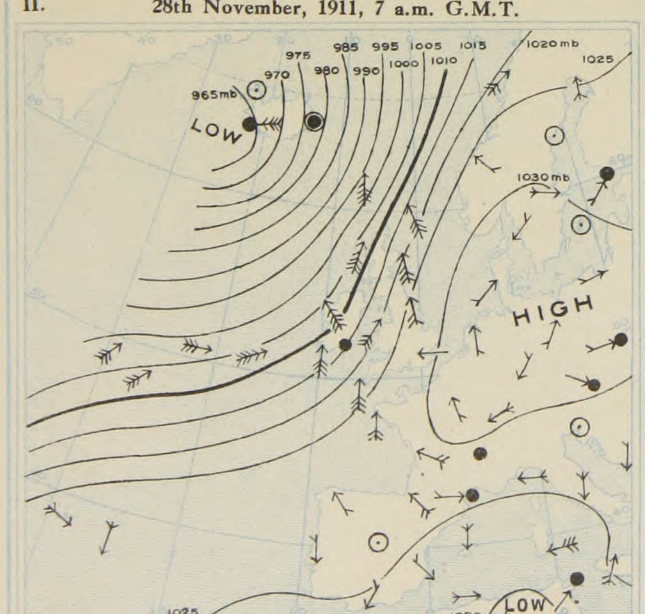
No. 15, at 6000 m. 6·0 m/s, 280°; at 7000 m. 10 m/s, 290°; at 8000 m. 11·0 m/s, 305°.



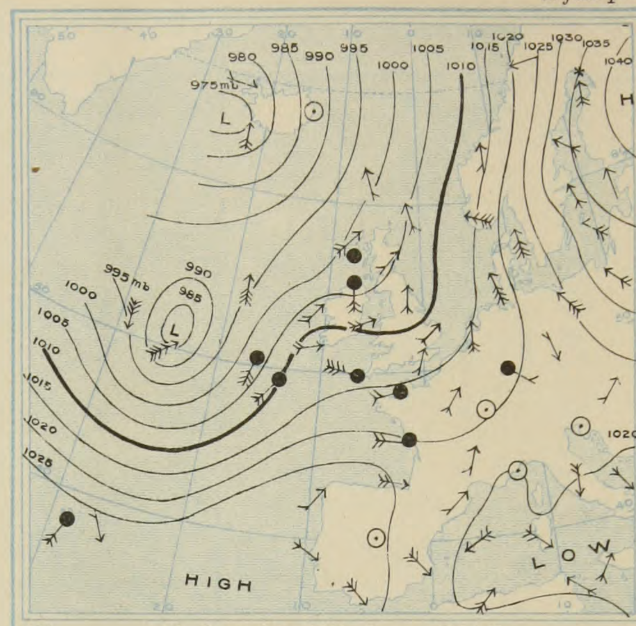
I. 22nd November, 1911, 7 a.m. G.M.T.



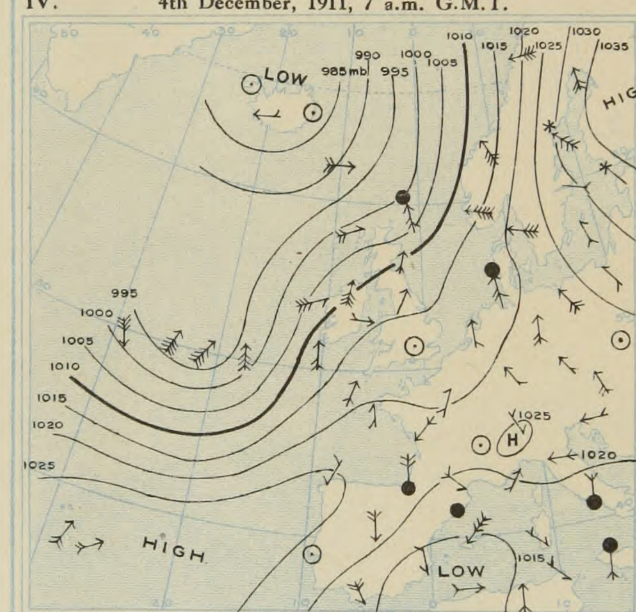
II. 28th November, 1911, 7 a.m. G.M.T.



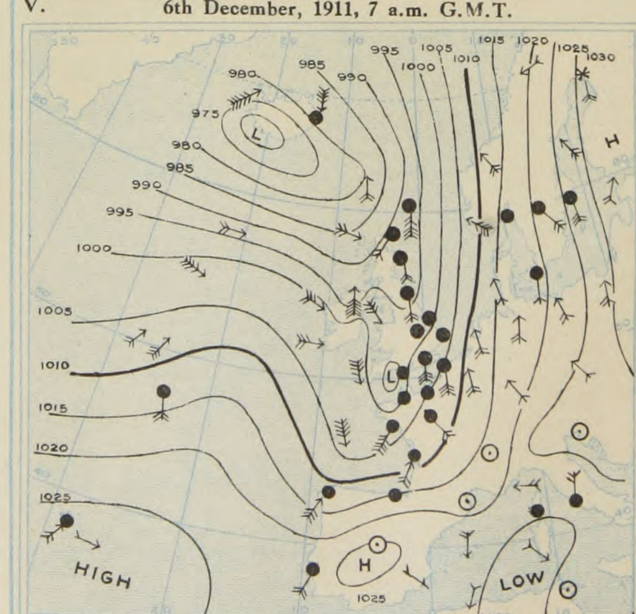
III. 30th November, 1911, 7 a.m. G.M.T



IV. 4th December, 1911, 7 a.m. G.M.T.



V. 6th December, 1911, 7 a.m. G.M.T.



VI. 7th December, 1911, 7 a.m. G.M.T.

Wyman & Sons, Ltd., M.O. Press, London, S.W. 7. Ps. 609, 6899, 587, 600. 9/19.

§ 4. THE SEQUENCE OF WEATHER IN RELATION TO THE STRUCTURE OF THE UPPER AIR.

The sequence of weather in the period from November 22nd to December 8th was specially typical of what may be called the establishment of normal or characteristic winter conditions over the North-Eastern Atlantic. Pressure maps for selected days are shown in Plate II.

The main feature of the conditions thus referred to is a great cyclonic system centred near Iceland and covering the British Isles and Western Europe with isobars which have a general trend from South-West to North-East. (See Chart III., Plate II.) The position of the main centre varies from day to day, but there is always a minimum somewhere near Iceland. Within the area of the depression there appears a succession of secondaries, which pass from west to east over the southern part of the area of the system, and which may develop separate centres and thus give the appearance of the passage of independent depressions over the British Isles.

The distribution thus described is called normal, because it is represented, though with diminished intensity, by the chart of normal isobars for December. The type was specially characteristic of December 1911. The chart of mean pressure for that month in the *Monthly Weather Report* shows isobars running from South-West to North-East with a pressure difference of nearly 0·5 inch (17 mb.) between Dover and the Hebrides, the normal difference being about 0·3 inch (10 mb.). During the period under investigation, the characteristic depression of vast area centred near Iceland appears on the maps as fully developed on November 30th (Chart III., Plate II.).

The period before that is concerned with the gradual establishment of the system, the period following it with the local variations which are incidental to it, as the system in some form or other persisted until the end of December.

The period of development, November 22nd to November 30th, has some interesting features. The state of affairs at the commencement (Chart I., Plate II.) is represented by a high-pressure area between Iceland and the British Isles, separated from another high-pressure area over the Eastern Mediterranean by a belt of low-pressure areas extending from the North of Spain to the Baltic, with three separate centres. There are signs of low-pressure systems over the Atlantic west of the Iceland-Azores line, but few details are shown on the available maps, and it was not till the 25th that a definite low pressure was indicated near Iceland, repeated in each of the subsequent maps. By the 28th (Chart II., Plate II.) the irregular distribution of low pressure had become more or less consolidated in a large area over the Atlantic, separated from high pressure over Western and Northern Europe by a 1010 mb. line which ran from South-West to North-East through the Irish Sea. That isobar moved *Westward* during the 28th and 29th, while there were two "low" centres to the West, but it came back again over Ireland with the concentration of the whole system in a depression with a single centre on November 30th (Chart III., Plate II.).

On November 22nd the surface current at Scilly was apparently related to a low-pressure area over the Bay of Biscay, and the wind was consequently Northerly to Easterly, and remained so until the 25th. The soundings for those three days are not high, one on the 22nd shows a very slight falling off of the wind in the second kilometre, otherwise there is no information.

There were no effective observations on the 25th and 26th. The sounding for

15h. on the 27th shows the first indication of the general Westerly circulation by disclosing a Westerly wind beginning at 2 kilometres and increasing up to 7 kilometres, while the surface winds were very irregular.

A noteworthy feature of the typical distribution described above was brought out in the work on *The Structure of the Atmosphere in Clear Weather* in the shape of a wind from NW. in the upper layers crossing a South-Westerly wind in the lower layers. The North-Westerly current appears to pass from above the low centre across the surface isobars.

The first indication of this feature in the period under consideration was on the 28th (Chart II., Plate II.), when the cirrus cloud was observed to be moving from 10° North of West, while the air at 5 kilometres was moving from the SW. On the 29th the existence of a strong North-Westerly wind at 8 kilometres was identified at 2 p.m., but in consequence presumably of peculiarities in the temperature distribution, the transition beneath was not to SW. but through N. and NE. to E. and SE. On the following day, however (Chart III., Plate II.), the South-Westerly wind had set in at the surface, and the great cyclonic system was well established, and it would appear that for that day and the following the South-Westerly wind extended throughout the troposphere; for on the 1st December a South-Westerly current was noted up to 5 kilometres, and cirrus cloud moved from 10° South of West.

Opportunities for observing balloons to any great height were at this period very rare in consequence of the frequency of low clouds.

On December 4th (Chart IV., Plate II.), at about noon, the wind to 4 kilometres was nearly West throughout; between noon and 13h. it had veered a little to Northward at 4 kilometres and backed to Southward in the lowest kilometre. The backing in the lower layers was extended in the next two hours, the upper current being unascertained. In the night following, the first *ligne de grain* passed, and in the afternoon of the 5th the state of things was reversed. A North-Westerly current occupied the lowest three kilometres, while apparently up above the wind had a Southerly component indicated by one observation of a balloon at 4½ kilometres at 14 h., and of cirrus cloud at noon.

On the morning of the 6th (see Chart V., Plate II.) a new secondary was approaching, the *ligne de grain* of which passed about 19h. In front of it a North-Westerly wind was shown at 5 kilometres with W. and SW. winds below. The South-Westerly wind got stronger and showed itself up to 4 kilometres between 14h. and 15h., but on the next day, the 7th (Chart VI., Plate II.), a North-Westerly current filled the whole air up to 5 kilometres.

On the following day the third secondary passed, and the passage of the trough occupied the greater part of the day. The observations during the passage of the *ligne de grain* are most complicated; they do not extend beyond 0·75 kilometre, and they show the following changes :—

Time.	Anemometer.		150 m.		300 m.		500 m.		700 m.	
h m	m/s	°	m/s	°	m/s	°	m/s	°	m/s	°
10 5	16	170	17	165	25	165	...	...	...	...
12 15	7·5	190	12	200	15	220	...	...	...	...
12 48	16	290	20	290	20	290	15	290	...	...
14 3	10	250	11	250	11	250	13	250	17	260
16 26	14	275	16	275	14	275	17	270	20	265

The air currents near the ground changed rapidly from strong SSE. to SW. and W. The only evidence of the displacement of the NW. wind in the upper layers between the passage of the second and third *ligne de grain*, as there was between the first and second, is a little backing from NW. at the highest level observed and a doubtful observation of the motion of cloud from a SW. point.

We note, therefore, the following types of structure during the period of the cyclonic system, with one persistent minimum near Iceland :—

Ascents Nos.

9, 10. i. A Westerly current gradually increasing in the reaches from $2\frac{1}{2}$ to 7 kilometres with an irregular circulation underneath it, while the surface distribution is also very irregular on the 27th.

11, 12. ii. A South-Westerly current reaching the surface in the afternoon of the 28th, with an indication of a North-Westerly current above in the motion of cirrus cloud.

14, 15. iii. A strong NW. current at 8 kilometres on the 29th, with a very complicated structure beneath it, preceding the establishment of the homogeneous cyclonic distribution of the 30th; followed by

17–19. iv. A South-Westerly current extending to great heights on December 1st.

21–24. v. Then, after some gradual transformation, a current veering from West towards North-West at 4 kilometres on the 4th, with wind backing to SW. underneath, preceding the *ligne de grain* which passed in the night and gave place to

25–28. vi. A North-Westerly wind at the surface in excess of the gradient wind and up to 4 kilometres, where it was Westerly with a South-Westerly current above on the 5th; giving place again to

29–33. vii. A North-Westerly wind at 5 kilometres, with SW. below it increasing during the day (6th), leading up to the passage of another *ligne de grain* in the evening; followed by

36. viii. A North-Westerly current on the 7th, extending with increasing velocity from the surface up to 5 kilometres, with a little backing at that level; followed the next morning by

ix. Another secondary, which could not be analysed in consequence of the cloud and rough weather.

The following is an abbreviated summary :—

i. Strong Westerly current at 6 kilometres, diminishing downwards to calm at $2\frac{1}{2}$ kilometres.
ii. (?) NW. above with SW. beneath.
iii. NW. current with reversal below.
iv. SW. current uniform right up.
v. Possible NW. above with SW. beneath, like ii.
vi. SW. above NW.
vii. NW. above SW.
viii. NW. backing above.
ix. (?)

The observations on December 4th and 6th are interesting as illustrating certain rules formulated by M. Guilbert for weather forecasting. M. Guilbert bases forecasts on the occurrence of winds that are convergent or divergent to the normal direction corresponding to the isobars; a wind that is below the gradient velocity is divergent, in that a divergent component must be given to the gradient to give the observed wind. Divergent winds, according to M. Guilbert, indicate the advance of a low-pressure system. The observations for the above-mentioned days illustrate M. Guilbert's rules, and, moreover, suggest an explanation: the divergent current is the current blowing away from a depression above the surface currents; this would cause a divergent component of the gradient wind, thereby reducing its velocity. On December 5th the wind in the upper air was somewhat convergent, while the surface wind was fully equal to the gradient velocity, and even slightly exceeded it, thereby illustrating M. Guilbert's rule that a convergent wind indicates a depression that is passing away or filling up.

§ 5. The Relation of the Observed Currents to the Surface Current and the Pressure Gradient.

Table I. (p. 81) shows the wind velocity at the anemometer head (50 m.) and at a height of 150 metres above sea-level; it also shows the relation of the surface velocity to the gradient, and the height at which the gradient velocity was reached in those cases in which it was reached at all.

As regards the currents just above the surface, the most noteworthy characteristic was a considerable increase of velocity shown between the anemometer velocity and the velocity at 100 metres above the ground; the mean ratio was 1 to 1·5 for twenty-four cases, shown in the following soundings:—Nos. 1 and 2 (November 22nd); 4 (23rd); 5 (24th); 6 (25th); 10 (27th); 11 (28th); 16 (30th); 17, 18, and 19 (December 1st); 20 (2nd); 21, 22, 23, and 24 (4th); 29, 30, 31, 32, and 33 (6th); 36 (7th); 38 and 39 (8th). The cases in which the velocities at the two levels were the same or nearly so were Nos. 3 (November 23rd); 13, 14, and 15 (29th); 25, 26, 27, and 28 (December 5th); 34 and 35 (7th); 37, 40, and 41 (8th). There were four cases in which it was calm on the surface, namely, Nos. 7, 8, and 9 (November 27th) and No. 12 (28th).

In a number of cases the surface wind was less than the gradient velocity, but the latter was approximately reached within half a kilometre, after a more or less rapid increase from the surface; this was the case in soundings 1 and 2 (November 22nd); 3 and 4 (23rd); 5 (24th); 6 (25th); 16 (30th); 17, 18, and 19 (December 1st); 20 (2nd); and 24 (4th). There were some cases in which the gradient was reached at a higher level by a gradual increase in velocity and a gradual veer in direction; namely, soundings 21, 22, and 23 (December 4th). There were also cases in which the gradient was not related to the surface wind, namely, 11 and 12 (November 28th), when the gradient was reached after a more or less sudden change of wind; and 29 to 33 (December 6th), when the velocity was considerably below the gradient at all heights observed. In four cases the gradient velocity was reached at the surface, namely, Nos. 25, 26, 27, and 28 (December 5th). In seven cases the gradient was imperceptible, namely, 7, 8, 9, and 10 (November 27th); 13, 14, and 15 (29th). Soundings 34, 35, and 36 (December 7th) probably belong to those in which the gradient was reached at a greater height than one kilometre by gradual increase in velocity, but the direction is somewhat backed from the gradient, especially in the last ascent. On December 8th during the passage of the *ligne de grain*, the conditions were changing so quickly that it was not possible to calculate the value of the gradient for the times of the ascents.

It has been pointed out by Prof. William R. Blair (*Astrophysical Journal*, vol. 37, p. 300), that in the soundings at Ditcham considered by the first of the Authors of the present Memoir, there is shown "a peculiarity in the lower as well as in the upper region of inverted temperatures." In the case of "all the soundings considered, 87 per cent. show a decrease in velocity with altitude somewhere between 1 and 4 kilometres; 4 per cent. show neither increase nor decrease for one or more kilometres in the same region; and only 9 per cent. show an increase in velocity with altitude at all levels explored."

This peculiarity is also apparent in the observations in the Isles of Scilly; of all the soundings one only, namely, No. 36, fails to show some trace of this decrease, or at any rate slackening of the increase, at some level below about 4 kilometres.

§ 6. The Rate of Increase of Wind Velocity near the Surface.

From former observations made at Ditcham on the South Downs, and from observations made with kites at Pyrton Hill, Glossop Moor, and Brighton, it appears that the wind increases rapidly with height above land stations, such increase approximating to a linear function of the height of the station above sea-level; if the wind velocity is plotted against the height, it is found that the first two observations, and sometimes more, lie on a line through the origin. This means that for Ditcham,

$$V_h = \frac{h}{h_0} V_s$$

where V_h is the velocity at a height h above sea-level, h_0 is the height of a well-exposed anemometer above sea-level, and V_s is the wind velocity recorded by the anemometer.

Sir Napier Shaw says:[1] "There is . . . a consensus of opinion that velocity increases with height by factor and not by constant addition. A likely formula is

$$V = \frac{H+a}{a} V_0$$

where H is the height above the ground, V the velocity there, and V_0 the anemometer velocity, and a a constant. At Ditcham, $a = 550$ feet. At a well-exposed coast station a may be very small, so that the limiting or gradient velocity is soon reached." This applies to day observations in particular.

This anticipation is borne out by the observations at Scilly; the rate of increase was found to be far more rapid than at Ditcham; neither the first two points of the wind-height diagram lie on a line through the origin, nor do the two points representing the wind velocity at the anemometer and the wind velocity at the point of the first balloon observation. Plate III., fig. 1, shows the mean relation of wind velocity to height for the one-theodolite and for the two-theodolite observations respectively. In the case of the two-theodolite observations, the wind increases very little above the level of the first balloon observation, and neither curve if prolonged passes at all near the origin; there is thus a difference from the conditions that had been found at Ditcham. From this we may conclude that the effect of the ground and surface obstacles upon the velocity of the moving air does not amount to more than about 20 per cent. loss at the height of the anemometer, instead of from 35 to 50 per cent. as obtained from the average of the observations at Ditcham. If there is any rapid

[1] Advisory Committee for Aeronautics, *Reports and Memoranda*, No. 9, p. 8.

falling off of velocity near the ground it is confined to the 6 metres below the level of the anemometer vane, and is not distributed over some 500 metres, as is the case with the inland observations.

The reason for the greater wind velocity shown by the ascents observed with one theodolite is that on several days, when there was a very strong wind, observations were not practicable at Bryher, sometimes owing to rain, sometimes because it was too rough to cross St Mary's Roads in an open boat, and consequently the observations had to be made from St Mary's with one theodolite only.

Plate III., fig. 2, shows the mean relation of height to wind velocity at Ditcham in the case of 100 one-theodolite and 36 two-theodolite observations. In the case of the one-theodolite observations the curve prolonged passes close to the origin. It is probable that at Ditcham in normal cases the curve does pass through the origin, or at any rate very close to it; but there are abnormal cases occurring in anticyclonic weather with light winds, when the velocity may remain constant for some distance above the surface or may even decrease in the lowest kilometre; in such cases it is probable that the surface distribution of wind is not in accordance with the pressure which obtains at the surface. It is these cases which cause the curve of mean velocity to depart somewhat from the rule which holds good with the majority of cases. It will be noticed that the curve deduced from the two-theodolite observations does not pass as close to the origin as the other deduced from the one-theodolite observations. It is suggested in *The Structure of the Atmosphere* that the reason for this is to be found in the fact that the position of the balloon as calculated from the first observation with two theodolites depends on the sine of what is usually a very small angle, and is therefore much influenced by small errors. This, however, though it might explain individual cases, would not account for the departure from the general rule exhibited by the mean of the cases shown in Plate III., fig 2, which were observed with two theodolites. It is probable that the explanation is to be found in the fact that the two-theodolite observations are not a typical set of the whole; two-theodolite observations were made at Ditcham when the weather was especially clear, or when it seemed likely that the balloon would not drift far from the points of observation—that is, when there was little wind; or when there were indications of a reversal—that is, when the wind would be likely to fall off with height. Thus the two-theodolite observations were more or less a selected set, and they were selected from the very occasions when the general rule would not hold. But even in the case of the two-theodolite observations 42 per cent. of the cases conform to the rule. It seems probable, therefore, that at Ditcham the curve showing the relation of wind velocity to height does in normal cases pass through or very close to the origin, and up to the height of half a kilometre or a little more the increase of velocity is nearly linear.

The change of wind direction with height has also been calculated for Scilly, and the result is shown in Plate III., fig. 1. The full line represents the mean from all two-theodolite ascents, the differences being taken for each ascent from the direction at 400 m. and then meaned. It will be noticed that the direction by the anemometer is slightly veered from the wind direction at 200 m. as given by the pilot balloons. Above this there is a veer of wind with increase of height, which continues up to the 1000 m. level, in contrast to the wind velocity, which shows no change above 300 metres. Inspection of the individual ascents in Table II. shows that in several of the earlier ascents—as, for example, No. 7—there was a very large veer in the first kilometre, which was

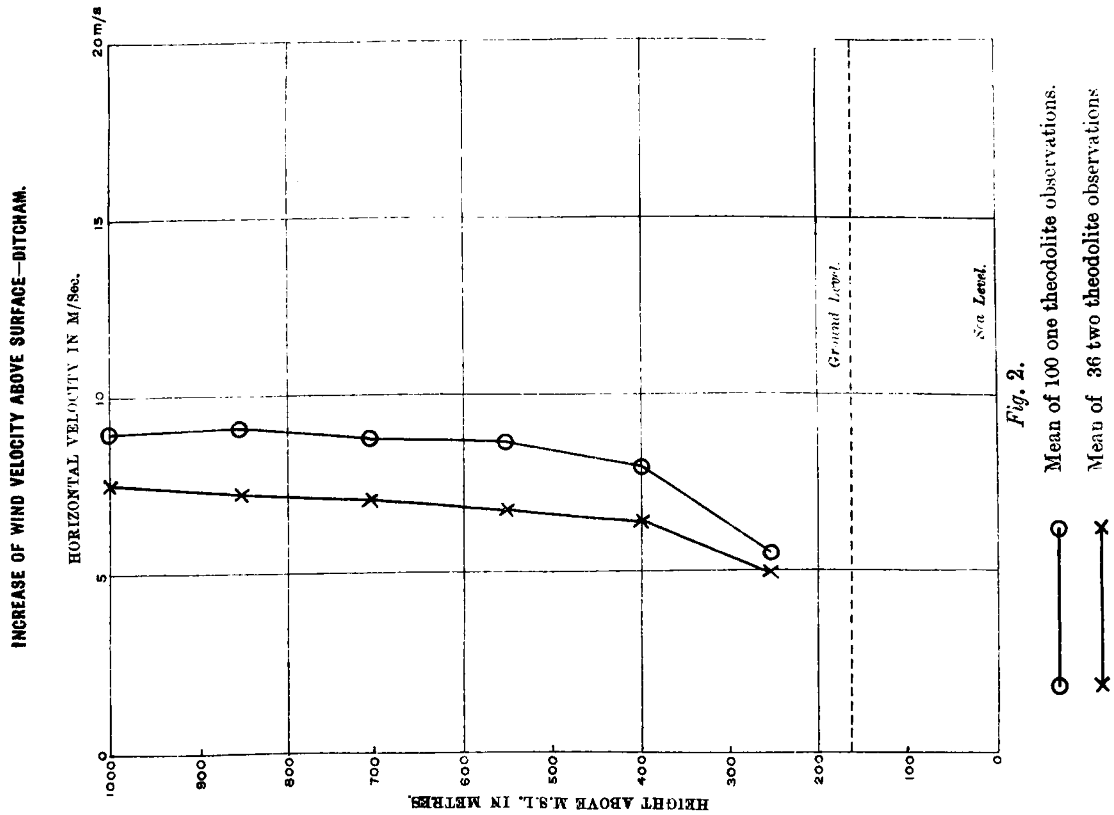


Fig. 2.

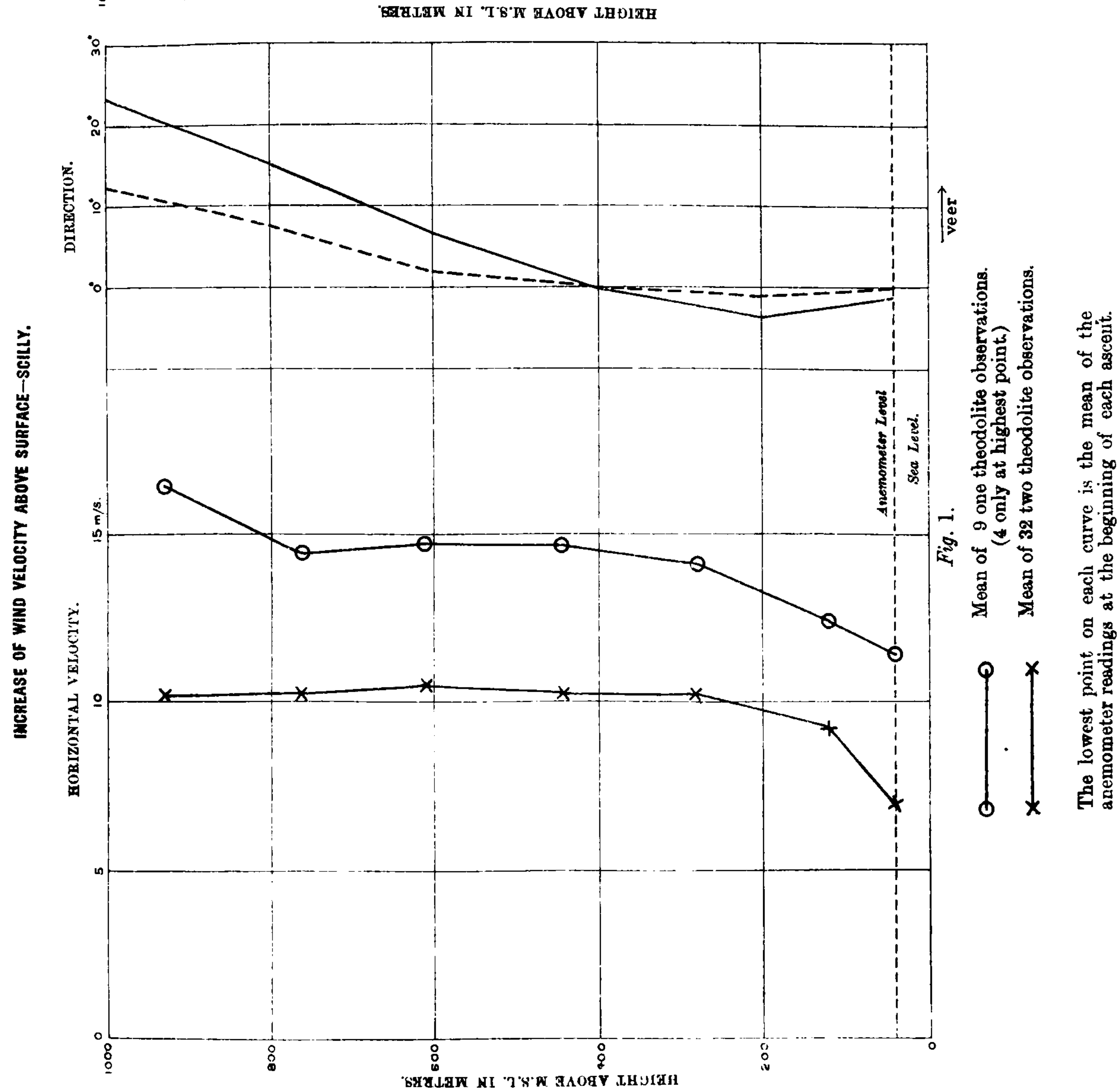


Fig. 1.

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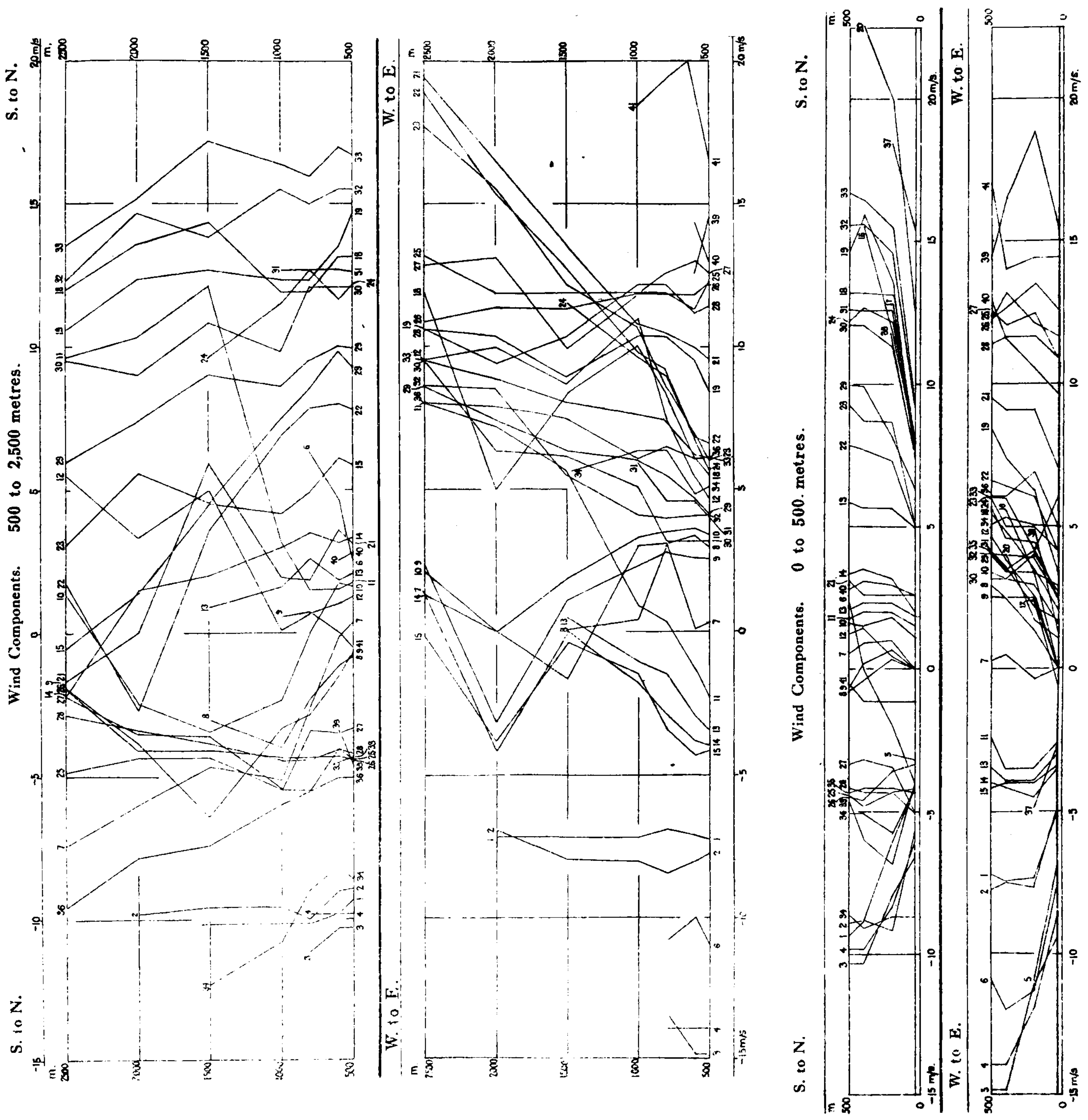

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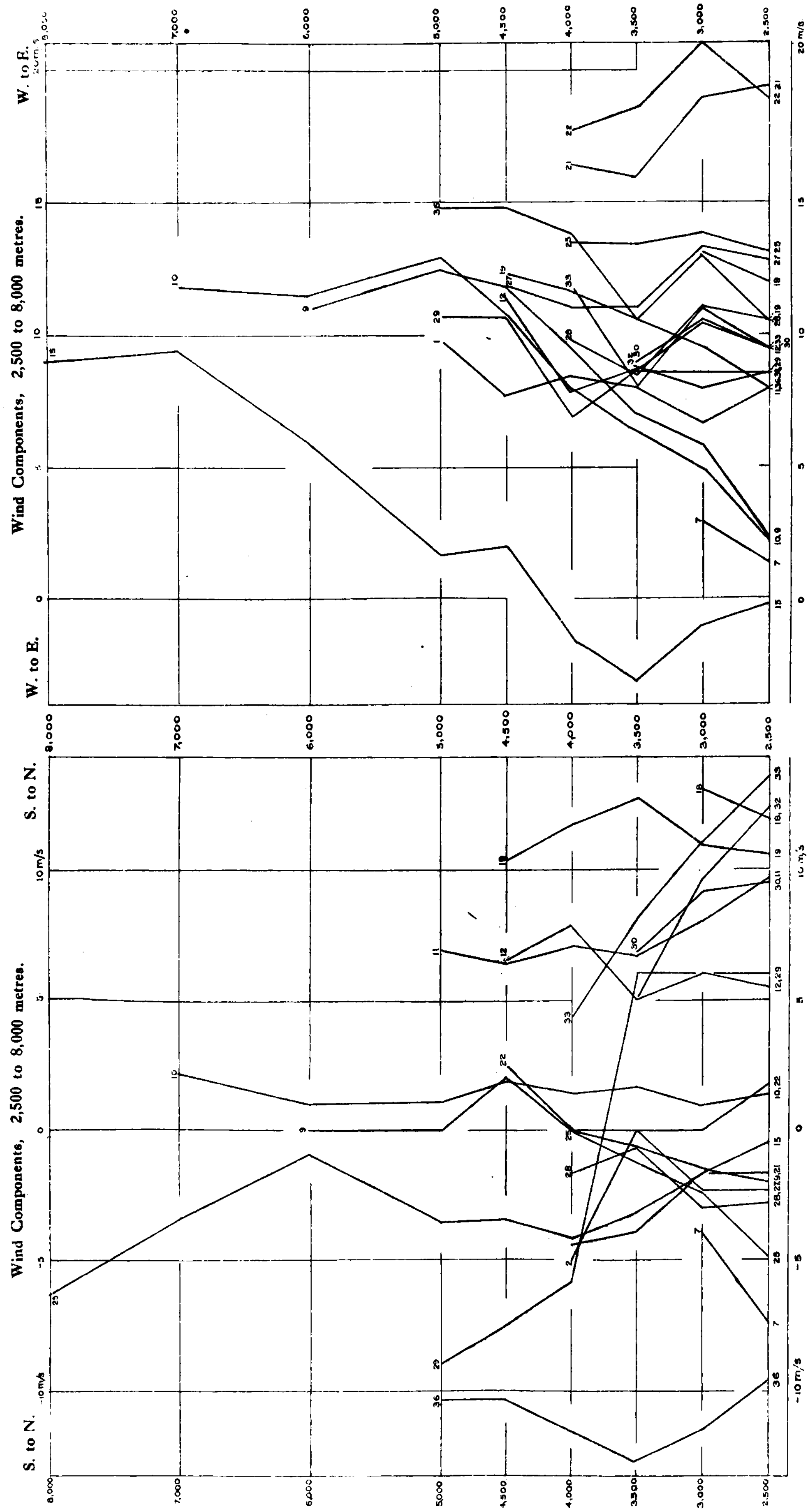

W. to E.
Wind Components, 2,500 to 8,000 metres.
W. to E.
S. to N.
Wind Components, 2,500 to 8,000 metres.
S. to N.
8,000
7,000
6,000
5,000
4,500
4,000
3,500
3,000
2,500

probably unconnected with surface friction but due to some other cause. In order to eliminate this disturbing effect all two-theodolite ascents from No. 13 onwards have been meaned, and the change of direction is shown by the broken line in Plate III., fig. 1. The veer with height extending up to 1000 m. is here less pronounced than in the solid line, but it is still plainly shown and seems to be a real phenomenon. It amounts to 13° between 200 and 1000 m. height.

At the suggestion of Sir Napier Shaw the individual ascents, the data for which are set out in Table II., are plotted in Plates IV. and V. The components, S. to N. and W. to E., have been plotted separately, following the method adopted in the *Manual of Meteorology*, Part IV. For this purpose the ascents have been broken up into three height steps: the surface layer 0–500 m., the intermediate layer 500–2500 m. (Plate IV.), and the main layer of the troposphere 2500 m. to the highest point reached (Plate V.). The curves for the surface layer show in a very marked manner the shallowness of the surface influence, it being evident that in most cases the main increase of velocity in either component is accomplished within about 200 m. of sea-level. In the intermediate layer the tendency for an increase of wind from W. to E. is becoming clearly marked, the bundle of curves having a distinct inclination to the right hand. In the S. to N. component the band covered remains of about the same width throughout the layer, with if anything a slight tendency for algebraical increase of the component from N. In Plate V., 2500 m. and upwards, the curves become rather scanty; the sloping to the right-hand side is still plainly shown in the W. to E. component. In the S. to N. section there is some indication of a neck at 3000 m. where the curves tend to come into a rather compact bundle spreading out above and below. This is probably accidental, but attention is directed to the point because a similar feature is shown in the curves for Ditcham Park on p. 71 of the *Manual*, the height in this case being 2500 m.

§ 7. The Rate of Ascent of the Balloons.

The balloons used were rubber balloons weighing about 30 grammes. Professor Hergesell has investigated the rate of ascent of small rubber balloons, and, according to the data which he gives, the balloons used in the Scilly observations should have had a rate of ascent of 150 metres per minute.

The second of the present Authors has also investigated the problem and given the formula for V, the rate of ascent, as

$$V = A\frac{L^{\frac{1}{2}}}{(W+L)^{\frac{1}{3}}},$$

where V is the velocity in metres per minute, L the free lift in grammes, and W the weight. "A" is a constant and is found to be equal to 81.[1] With this formula the rate of ascent of the balloons used in the Scilly observations works out to 153 metres per minute.

Similar balloons, with the same lift, have been used at Ditcham, and from a number of observations a rate of ascent of 152 metres per minute has been deduced. The lift was originally adjusted to give the balloon a rate of ascent of 500 feet per minute, and subsequent observations with two theodolites confirmed the rough measurements first made. Balloons of the same size, with the same lift, were always used at Ditcham, and

[1] The value $A=84$ has more recently been adopted (July 1918).

were used also at Scilly. The rate of ascent of the balloons used at Scilly was found to be somewhat greater than that observed at Ditcham. A table (Table III.) is given

TABLE III.—RISE OF BALLOON FOR EACH MINUTE IN METRES.

No. of Ascent.	Minutes from Start.																								
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
1	159	259	187	168	122	140	138	114	140	167	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	124	160	143	148	144	106	125	162	152	130	166	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	213	217	166	164	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	191	192	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	147	172	175	172	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	166	...	...	...	...	121	181	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	174	170	160	182	157	163	168	186	177	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	194	145	153	154	157	151	177	150	152	...	...	...	...	...	...	...	...	...	...	...	...	...	170	228	122
10	140	144	127	156	174	154	150	152	156	196	154	146	137	166	178	144	141	116	146	171	171	176	168	146	139
11	176	141	166	151	184	170	...	...	...	142	177	176	182	171	179	176	153	148	138	145	137	160	160	160	210
12	157	144	145	152	157	158	160	147	148	176	171	160	136	184	140	150	168	175	157	210	130	155	163	165	168
14	175	145	154	152	169	160	161	162	168	173	178	138	152	173	165	180	175	...	...	...	...	...	...	...	...
15	164	158	156	163	171	166	156	162	163	162	147	146	174	175	173	161	160	161	172	192	173	...	...	157	167
18	185	167	163	156	158	141	179	166	147	132	166	185	185	157	...	...	...	...	...	...	...	...	...	...	...
19	178	175	155	152	164	161	160	158	153	166	159	182	175	142	185	148	142	163	150	140	155	145	182	180	150
21	144	168	139	141	167	186	201	180	154	164	131	145	137	177	181	165	...	...	...	...	...	...	...	...	...
22	162	181	142	135	104	108	114	140	156	184	180	167	182	142	147	114	138	181	194	158	182	160	140	120	...
23	180	174	184	185	153	134	139	142	156	168	184	182	181	150	191	...	...	...	...	...	...	...	...	...	...
24	160	158	169	161	160	167	181	...	...	163	186	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	156	138	156	132	183	181	160	186	172	164	167	180	170	...	...		...	...	...	...	...	...	...	...	...
26	122	172	149	154	140	134	149	164	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...
27	139	185	183	198	200	193	145	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	128	162	123	144	149	142	157	149	163	150	161	165	142	193	168	172	132	175	135	178	137	168	...	...	...
29	209	168	153	158	143	146	166	179	157	156	150	175	168	185	161	154	187	139	164	165	195	182	175	177	123
30	166	135	160	159	180	170	170	160	147	166	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	187	243	204	172	167	144	137	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32	151	138	147	128	155	171	158	155	150	171	162	136	158	159	180	191	150	...	...	...	...	...	...	...	...
33	173	169	162	137	136	152	182	150	157	171	141	164	168	175	165	...	...	...	...	...	...	...	...	...	...
36	125	127	156	175	172	162	174	176	138	169	141	129	150	146	103	165	180	205	175	140	165	157	130	160	128
Mean			161					158					163					161					160		

showing the rise for each minute up to the 25th minute for each ascent observed with two theodolites, with the exception of No. 13, in which case the balloon was given a greater lift than usual. From this it will be seen that the average rate of ascent for the first five minutes was 161 metres per minute, for the second five minutes 158 metres, for the third 163, for the fourth 161, and for the fifth five minutes 160 metres per minute. A table (Table IV.) is also given, showing the mean rate of ascent from the ground level to each kilometre of height.

TABLE IV.—RATE OF ASCENT FROM GROUND LEVEL TO EACH KILOMETRE HEIGHT IN METRES PER MINUTE.

Height.	No. of Ascent.																								
	1.	2.	8.	9.	10.	11.	12.	14.	15.	18.	19.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	36.	Mean.
k.																										
5	...	...	...	155	156	...	...	...	165	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	159
4	...	...	...	155	154	163	159	...	165	...	161	...	...	...	...	...	...	...	...	166	...	...	...	...	156	160
3	...	...	...	...	152	164	157	...	162	...	161	...	151	...	...	...	...	...	154	164	...	...	...	...	154	158
2	...	...	...	...	153	161	155	161	161	162	161	158	150	165	...	164	...	...	149	163	...	...	152	159	154	158
1	171	139	171	162	149	165	153	159	163	162	164	158	135	168	163	158	146	183	144	163	162	194	148	155	156	160

Table V. shows the mean rate of ascent for each ascent, up to the time when the balloon was lost to sight from one or other of the stations. From this it will be seen that the mean rate for each ascent is very fairly uniform, and if there had been a greater rate of ascent at one time it was, with few exceptions, compensated by a decreased rate at another time.

TABLE V.—MEAN RATE OF ASCENT FOR EACH SOUNDING OBSERVED WITH TWO THEODOLITES.

No. of Sounding.	No. of Minutes Observed.	Rate of Ascent Metres per Minute.	Wind Direction Quadrant.
1	10	159	NE
2	11	142	NE
7	10	174	SE
8	9	173	SW
9	34	155	SW
10	34	156	SW
11	30	163	SE
12	28	159	SW
14	17	163	SE
15	52	162	SE
18	14	164	SW
19	27	161	SW
21	16	161	SW
22	24	152	SW
23	15	167	SW
24	11	168	SW
25	13	165	NW
28	22	154	NW
29	25	165	SW
30	10	160	SW
32	17	156	SW
33	15	160	SW
36	26	156	NW
		Mean = 160·6	

This point is important, as it shows that the trajectory of a balloon calculated from the observations of one theodolite on the assumption of a uniform vertical velocity is probably not far from the truth. If the smoke from a factory chimney is watched for some minutes it will be seen to rise faster at one time than at another, and the trail of smoke instead of being straight will be wavy, implying an up-and-down component in the wind; it is very likely a similar cause which gives rise to the irregularities in the upward movement of balloons on some occasions, but it would be difficult, if not impossible, to disentangle the motion due to this cause from the apparent increases and decreases of vertical velocity due to small errors of reading.

It thus appears from the tables, that while the average rate of ascent of the balloons was fairly uniform, the actual rates of ascent from minute to minute varied considerably. Some of these variations may be attributed to the uncertainties of observation; some, on the other hand, cannot be accounted for in this way, and must be attributed to real movements of the air, up or down. Variations near the commencement of the ascent may be caused by currents of air over the islands, rising on the windward side and descending on the leeward; it is clear that such must exist, and on one occasion smoke from a fire on St Mary's was seen blowing down on the leeward side of the island from the top almost to sea-level. Diagrams have been prepared, Plate VI., showing the rate of ascent for each minute in its relation to the height of the balloon; cross shading shows when the balloon was over a land surface. In these diagrams the movement of the curve to the right or left shows a rising or falling movement in the air respectively, and the distance from the central vertical line shows the magnitude of the rising or falling velocity. No. 13 alone is an exception, as here the balloon was filled to give a greater lift than the normal and consequently rose at a greater rate;

thus the curve is displaced to the right of the vertical line. On several occasions balloons passed over St Martin's, a large part of which rises to 30 metres, and part to nearly 50 metres above sea-level; on some occasions the passage of the balloon over the island corresponds to a rise in vertical velocity, in other cases to a decrease. There seems to be no real connection between the two, nor is it likely that such heights as 50 metres would influence the air currents at the height attained by the balloon after a few minutes from the beginning of the ascent.

The apparent variations in the rate of ascent in No. 28 above two kilometres are almost certainly due to small errors of readings; but some of the larger departures from the normal rate of ascent, extending over several minutes, such as those in ascents Nos. 21 and 22, must certainly be attributed to real rising or falling of the air in which the balloon happened to be at the time. On the day of these ascents, December 4th, there was a considerable amount of cloud, which increased during the period of the ascents, and later on there was cumulo-nimbus and rain fell. On December 6th there were also cumulus clouds during the ascents, and showers occurred just after. No. 31 on this day shows a remarkable increase in vertical velocity at the beginning of the ascent.

As a rule in these observations there does not appear to be any marked connection between the wind elements and the vertical rate of ascent of the balloon, but in Nos. 14 and 15 there is a temporary decrease in the vertical velocity, which occurs at the beginning of the reversal of wind direction; a reversal of this type is very likely to be accompanied by a temperature inversion, a warm westerly current flowing over a colder easterly one; a balloon entering a warm layer from a colder one would have its vertical velocity checked for a short time till it came into thermal equilibrium with the warm layer.

It has been found at Ditcham,[1] and also by Professor Hergesell[2] at Strasbourg, that in the first half kilometre a balloon ascends with a velocity about 30 metres per minute above its mean rate of ascent, and in the first kilometre about 20 metres per minute above the mean; this increased rate of ascent falls off more or less regularly with height. It is impossible to suppose that there should be a rising current over the whole of a land surface, and one of us has suggested the following explanation of the phenomenon:—If there is an upward current in one place, there must be a compensating downward current in the neighbourhood; these currents would not reach quite to the ground level, but near the ground there must be a horizontal flow of air from the base of a descending to the base of a rising current; a balloon liberated near the surface would thus tend to be drawn into the rising current, and would more often ascend in a rising current than in still air or in a descending current.

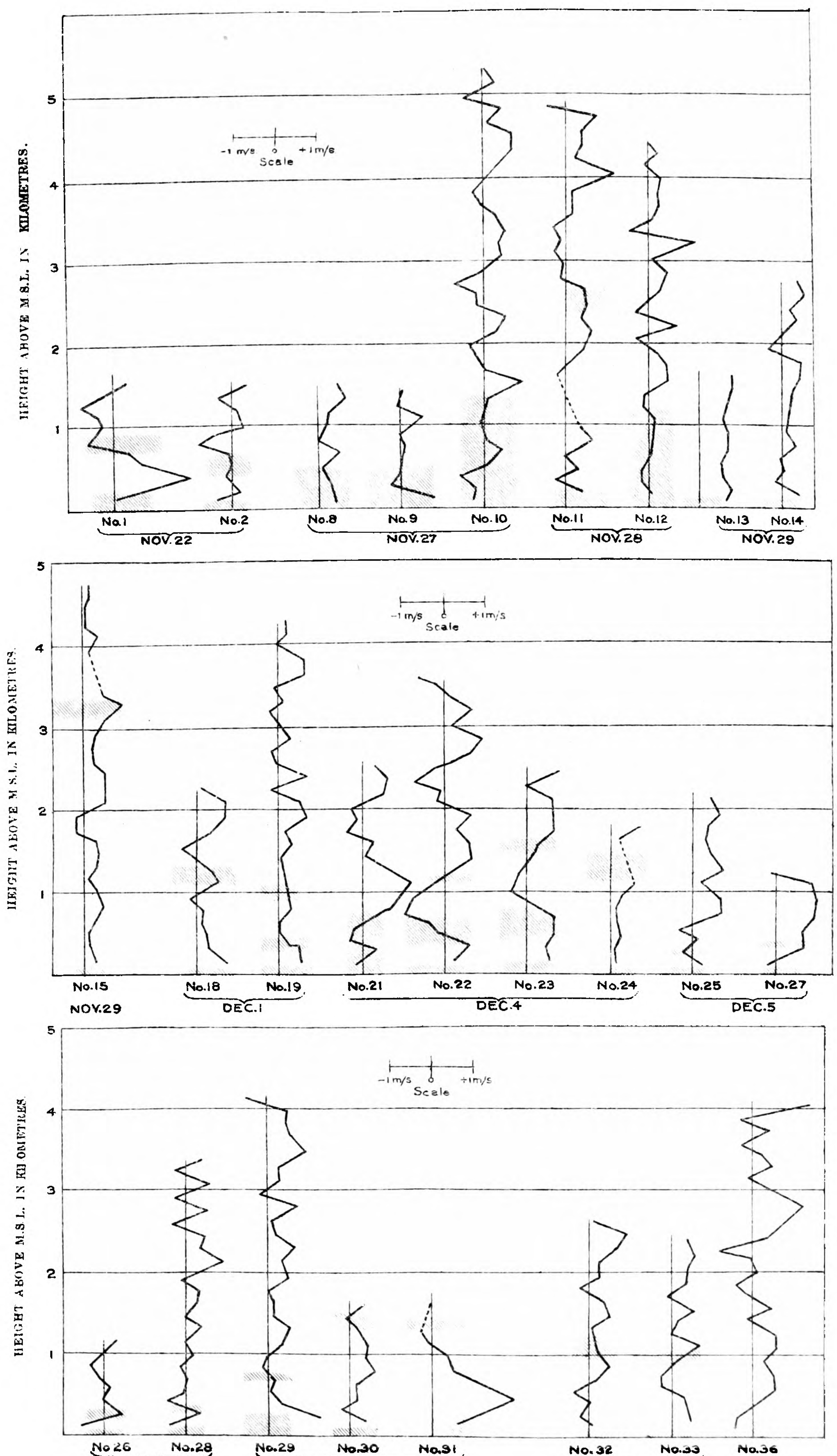
In the observations in the Isles of Scilly there seems to be no evidence of any average increase in the rate of ascent of balloons in the lower layers of the atmosphere, and this points to the probability that vertical currents are less in evidence there than at a land station.

§ 8. The Observations of Clouds.

Table I. shows the heights at which clouds were observed. The figures, however, can only be looked upon as approximate; the heights are those at which the balloon was

[1] *Structure of the Atmosphere in Clear Weather*, p. 27.
[2] *Sixième Réunion de la Commission Internationale pour l'Aérostation Scientifique*, p. 99.

DIAGRAMS SHOWING THE VARIATIONS IN RISING RATE OF THE BALLOONS.



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Ps. 609, 6899, 587, 600. 9/19.

lost to sight behind a cloud at one or both stations; in some cases the cloud heights ought to be lower, for the balloon might be watched to a certain height in a clear patch and might then be lost to sight behind a cloud at some level lower than that reached by the balloon; on one occasion, too, the balloon was seen to enter the side of a cumulus cloud. In some cases, when there was more than one layer of cloud, the balloon might be observed till it was above the layer of low detached clouds and not be lost to sight till it entered the upper cloud layer.

In Sounding No. 3 (November 23rd) the observed wind direction was 55° and the gradient wind 75° (wind directions are measured in degrees clockwise from N. Thus 90° = E., 180° = S., and so on.) About two hours before the ascent an upper cloud sheet was seen through breaks in the lower, and the direction of the upper wind was seen to be 160°, showing that there was an outflow at a high level from a low-pressure system centred over Biarritz.

In Sounding No. 7 (November 27th) there were low clouds at or below 1·7 kilometres, and A.–Cu. at 3 kilometres. There was also some cirrus from 337°, agreeing well with the observed wind direction at 3 kilometres.

On November 27th there was some strato-cumulus, which was almost stationary, and must have therefore been at a height of about 2 kilometres, where the reversal of wind velocity occurred; cirrus was observed moving from 255°, which agrees very closely with the observed direction from 3 to 7 kilometres.

On November 28th, at 11 h. 50 m. (Sounding No. 11), small cumulus was observed from 135° corresponding to the top of the surface current, at the same time cirrus and cirro-cumulus were noticed coming from 270°; the upper wind was from 230° between 3 and 5 kilometres, and was veering at the last balloon observations. By 15 h. 10 m. the surface current had died out. At 16 h. cirro-cumulus was observed from 240°, the direction of the wind at 4·5 kilometres, and cirrus was seen moving from 280°. This suggests outflows from a low to the West, and at a higher level from a low to the North-West; there are indications that there was a low to the West during the day, but by the following morning the dominant low was one of great intensity whose centre was over Iceland. (See Chart II., Plate II.)

On November 29th cirrus was seen moving from 325°, the wind above the reversal at 2 kilometres being from about the same direction. Some low clouds, which were very thin, were observed moving from 140°; these were therefore moving in the surface current, probably near its upper boundary.

On December 1st the low clouds in which the first balloon was lost were from 225°; cirrus was moving from about 260°, the wind at the cirrus level being slightly veered from that at 4 kilometres.

On December 4th there was a great development of cloud at various levels, cirrus was moving from 280°, alto-cumulus from 250°; cumulus and low clouds were developing, and a bank of alto-stratus spread from a Westerly point; by 14 h. 30 m. the sky had become overcast, and the balloon was lost in the general cloud sheet below 2 kilometres. At this time there were patches of detached clouds at about 1 kilometre.

On December 5th cirrus was moving from 250°, and cumulus from 290° at noon; at 14 h. 30 m. cirrus was from 270°, cumulus from 300°. In this connection it should be noticed, however, that at 15 h. 45 m. the shadow of a cumulus cloud was seen projected on clouds similar to those that had been taken for true cirrus, and a band of the same was seen in front of another cumulus. The first-mentioned cumulus was evidently high, and its top was drawn out as though it had got into a South-Westerly wind. The motion of the cirrus on this day agreed with the observed wind at the highest observations, 4·5 kilometres, the upper wind being backed in respect to the lower.

On December 6th cirrus was seen moving from 320°, and small cumulus from 235°. The cirrus direction was about 10° veered with respect to the wind direction at the highest point observed, and there was a sudden veer of the wind with height at 4 kilometres. During the day the sky became obscured by cirrus, cirro-stratus, and alto-stratus, which came up in a bank from a Westerly point.

In conclusion, the Authors must express their thanks to Sir Napier Shaw, F.R.S., who helped them in the preparation of this discussion of the ascents, and who lent the theodolites with which the observations were made; to Mr W. H. Dines, F.R.S., who came to the Isles of Scilly for a few days to help in the commencement of the observations. The Authors' thanks are also due to the late Mr T. A. Dorrien Smith for his kindness in helping the work in every possible way, and to his agent, Mr J. Magg, at St Mary's. Also to Mr Bradley, Divisional Officer of Coastguards, who placed the services of the Coastguard at the disposal of the observers, and to the Elder Brethren of Trinity House, who brought over the cylinders of hydrogen in their steamship *Mermaid*. Also to Mr W. Hayes, of the Forecast Division of the Meteorological Office, for the preparation of Plates II., IV., and V., and to some other members of the division for help in the final preparation of the paper.

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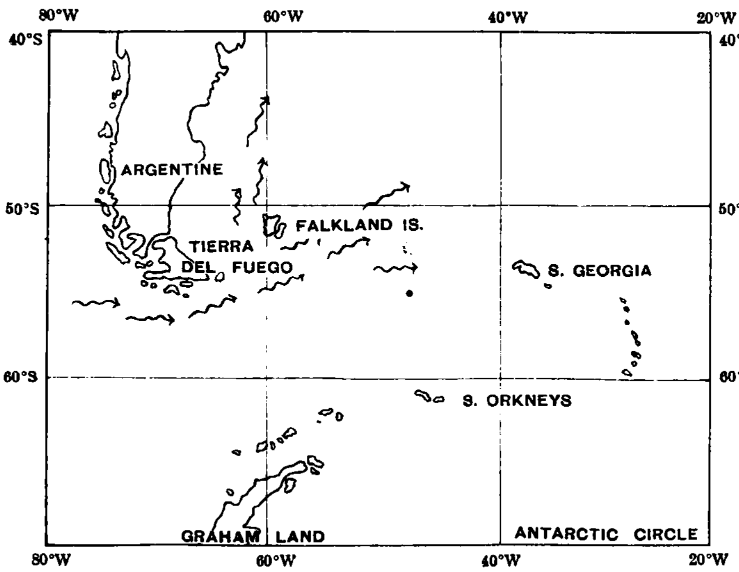

Fig. 1.—ISLANDS IN THE S. ATLANTIC.

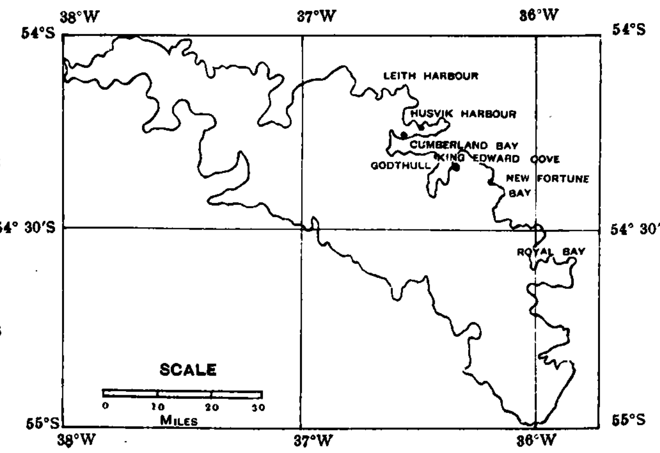

Fig. 3.—SOUTH GEORGIA.

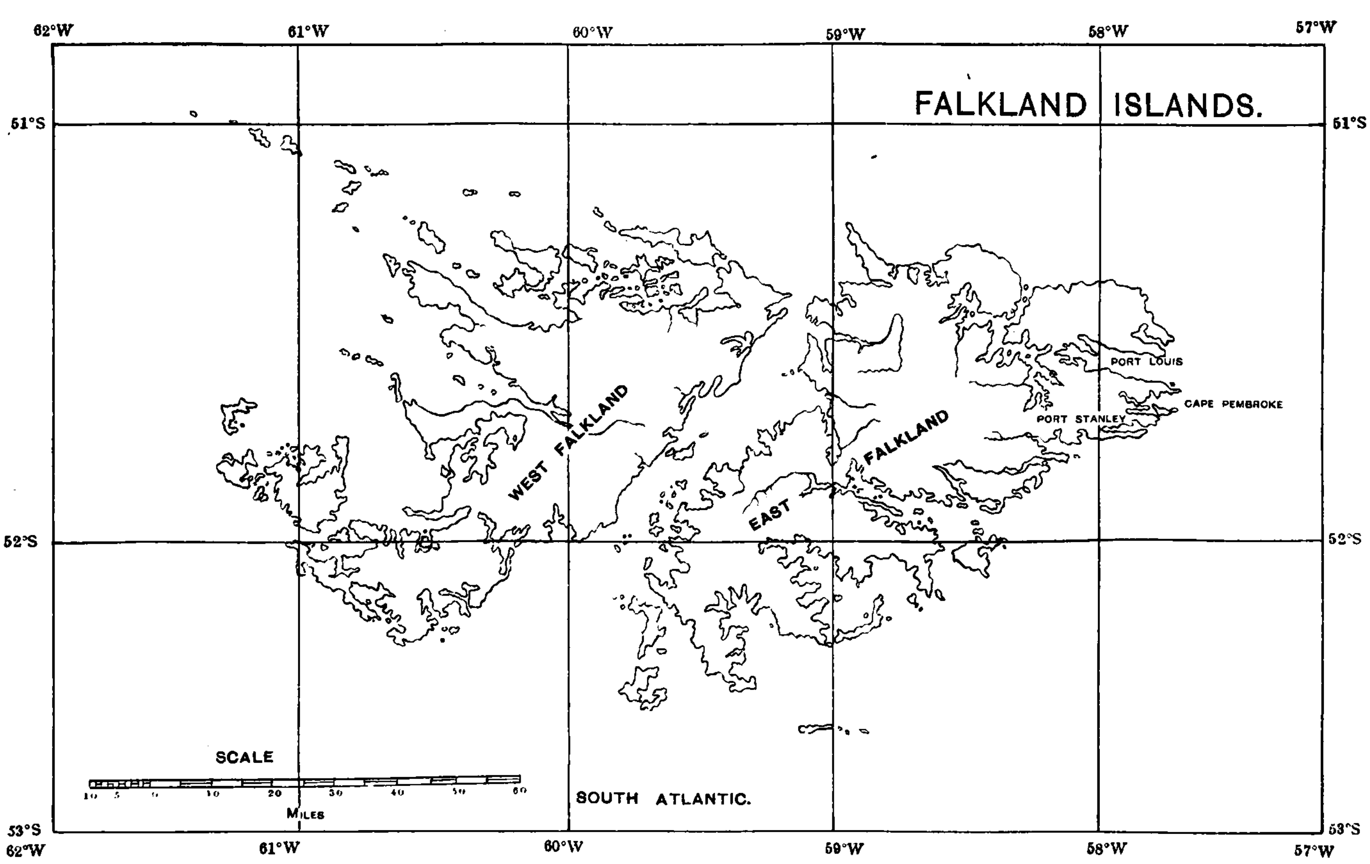

Fig. 2.—FALKLAND ISLANDS.

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