VECTOR MEAN WINDS AT THE ARGENTINE ISLANDS, GRAHAM LAND, 1954-58

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ABSTRACT. Upper wind observations at the Argentine Islands, Graham Land, for the period January 1954 to December 1958 are used to calculate the annual and seasonal vector mean winds. Scalar mean speeds, constancy and standard vector deviation are also computed.

THE Argentine Islands are about 5 miles (8 km.) off the west coast of Graham Land at lat. 65°15′S., long. 64°17′W. They lie to the south of the mean tracks of depressions which generally move in an easterly direction through Drake Passage and to the north of the recurrent south polar anticyclone. Upper air observations began in 1954 (July to October only) but from 1 January 1955 daily ascents have taken place using the Kew Mark II radio-sonde. There is no radar and all upper wind observations are obtained by following the balloons by visual theodolite. This means that results are biased in favour of weather conditions with small amounts of cloud.

Frequency tables of upper winds at standard pressure levels are published annually by the Falkland Islands and Dependencies Meteorological Service. Van Rooy (1957) has published statistics for the period 1952–55 but otherwise no detailed study has been made of the winds in the area.

SOURCES OF DATA

The data used in this report consist of the upper winds obtained from both radio-sonde and pilot balloon observations published in the *Falkland Islands and Dependencies Meteorological Service Daily Weather Reports* from 1 January 1954 to 31 December 1958.* On some occasions more than one series of observations per day were reported. In these cases only the highest ascent for each day was used. A total of 444 flights was analysed consisting of 350 sonde pilots and 94 pilots (83 with an assumed rate of ascent and 11 with tail ascents). Unfortunately, while pilot observations were reported at standard height intervals sonde pilots were at either standard pressure levels, standard height intervals, or both. In this report standard height intervals are used as these give a more detailed picture. When winds at pressure levels only were reported for some flights in the years 1954, 1955, 1956 and 1957 they were included with the relevant heights.

COMPUTATIONAL PROCEDURE

The following symbols are used throughout this report:

- h = Height in thousands of feet.
- N = Number of observations.
- q = Constancy.
- V = Wind speed in knots.
- V_E = East component of wind.
- V_N = North component of wind.
- V_R = Vector mean wind speed in knots.
- V_S = Scalar mean wind speed in knots.
- α = Vector mean wind direction measured clockwise from north in degrees.
- σ = Standard vector deviation in knots.
- θ = Wind direction measured clockwise from north in degrees.

A vector is a quantity which can be represented by a straight line possessing length and direction; in the case of winds, length represents the speed and direction is that from which

* All of the observations reported in this paper were made in English units and they have not been converted into metric units which are now generally used.

the winds are blowing. Any vector may be regarded as the sum of the two vectors at right angles to one another. It is conventional to resolve winds into north and east components. If V is the speed of the wind on any occasion and θ is its direction, then by simple trigonometry (Fig. 1) the north and east components are

$$V_N = V\cos\theta \quad \text{and} \quad V_E = V\sin\theta. \tag{1}$$

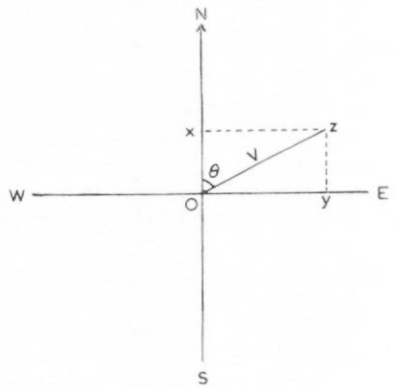

Fig. 1. Wind components.
oz = Wind of direction θ and speed V.
ox = $V_N = V\cos\theta$ (north positive).
oy = $V_E = V\sin\theta$ (east positive).

By summing the components of a series of wind observations it is simple to obtain the module and direction of the vector mean wind.

If
$$V^2 = V^2\cos^2\theta + V^2\sin^2\theta = V_N{}^2 + V_E{}^2 \tag{2}$$
and
$$\tan\theta = \sin\theta/\cos\theta = V_E/V_N, \tag{3}$$
then the vector mean wind obtained from N observations is given by

$$\text{magnitude:} \quad V_R = \frac{1}{N}\left[(\Sigma V_N)^2 + (\Sigma V_E)^2\right]^{\frac{1}{2}}$$
$$\text{direction:} \quad \tan_\alpha = \Sigma V_E/\Sigma V_N. \tag{4}$$

The standard vector deviation (σ) is a measure of the dispersion of vectors in all directions about the vector mean. σ is computed directly from the speeds of the wind observations, as shown by Brooks and Carruthers (1953), using the expression

$$\sigma^2 = \Sigma V^2/N - V_R{}^2 \tag{5}$$
or
$$\sigma = (\Sigma V^2/N - V_R{}^2)^{\frac{1}{2}}. \tag{6}$$

Another parameter of some importance is constancy which is defined as

$$q = 100 V_R/V_S. \tag{7}$$

q will be zero if a set of winds blows equally frequently with the same average speed from all directions; and it will be 100 when they blow from the same direction but not necessarily with the same speed. In other words, constancy may be considered as a coefficient of steadiness.

Results

1. *All years combined*

The vector mean winds, scalar mean wind speed, standard vector deviation and constancy were calculated for the following height intervals: surface, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 23, 27, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 and 100×10^3 ft. Com-

bining all the years, the results are given in Table I. Fig. 2 shows these parameters plotted against height on an arithmetic scale. The mean height of the tropopause is also shown.

TABLE I. PARAMETERS OF UPPER WINDS AT THE ARGENTINE ISLANDS, 1954–58
(All years combined)

h	N	α	V_R	V_S	q	σ
Surface	444	181	1·6	4·3	37	7
1	421	193	2·0	7·1	28	9
2	422	192	2·0	8·1	25	10
3	376	186	2·0	9·3	21	12
4	432	197	2·3	10·6	22	13
5	397	206	3·3	12·1	27	15
6	347	220	3·8	13·1	29	15
7	361	219	4·6	14·2	32	17
8	317	221	5·5	15·3	36	18
9	334	219	6·0	16·0	37	18
10	327	216	7·3	16·9	43	19
12	218	215	9·4	19·5	48	21
14	213	214	9·4	19·9	47	22
16	250	220	11·1	22·5	49	24
18	168	208	12·6	24·0	53	27
20	150	215	12·6	25·4	50	27
23	224	221	14·6	28·4	51	30
27	228	217	16·5	31·9	52	35
30	196	221	17·8	31·4	57	34
35	190	228	17·9	28·4	63	29
40	119	232	20·2	28·6	71	28
45	142	230	20·0	28·4	70	28
50	136	247	22·8	31·6	72	33
55	77	243	22·1	31·5	64	34
60	68	246	19·9	31·1	64	35
65	41	232	18·7	29·5	63	36
70	32	218	18·5	31·8	58	42
75	27	225	16·4	32·4	51	42
80	23	211	9·4	21·9	43	27
85	18	167	7·7	19·2	40	22
90	13	195	4·5	21·5	21	27
95	4	281	4·3	17·5	25	22
100	1	100	18·0	18·0	100	0

Mean height of tropopause: 30,960 ft.

(a) α. The direction of the vector mean wind (Fig. 2a) generally veers with height from around south at the surface to south-west at 6,000 ft., although there is a marked discontinuity of direction between 1,000 and 3,000 ft. It remains roughly south-west but continues to veer slightly to 60,000 ft. Above this height the number of observations in the five years studied decreases from 41 at 65,000 ft. to 1 at 100,000 ft. Although the sample is very small, the winds have a tendency to back between 60,000 and 85,000 ft., by which height they are almost south-east. No marked change of direction is discernible around the mean height of the tropopause.

(b) V_R *and* V_S. Fig. 2b shows the speed of the vector and scalar mean wind. The former remains constant at about 2 kt. up to 4,000 ft. and then increases steadily to 9 kt. at 14,000 ft. and then at a slower rate to 18 kt. at the mean height of the tropopause (30,000 ft.). The mean

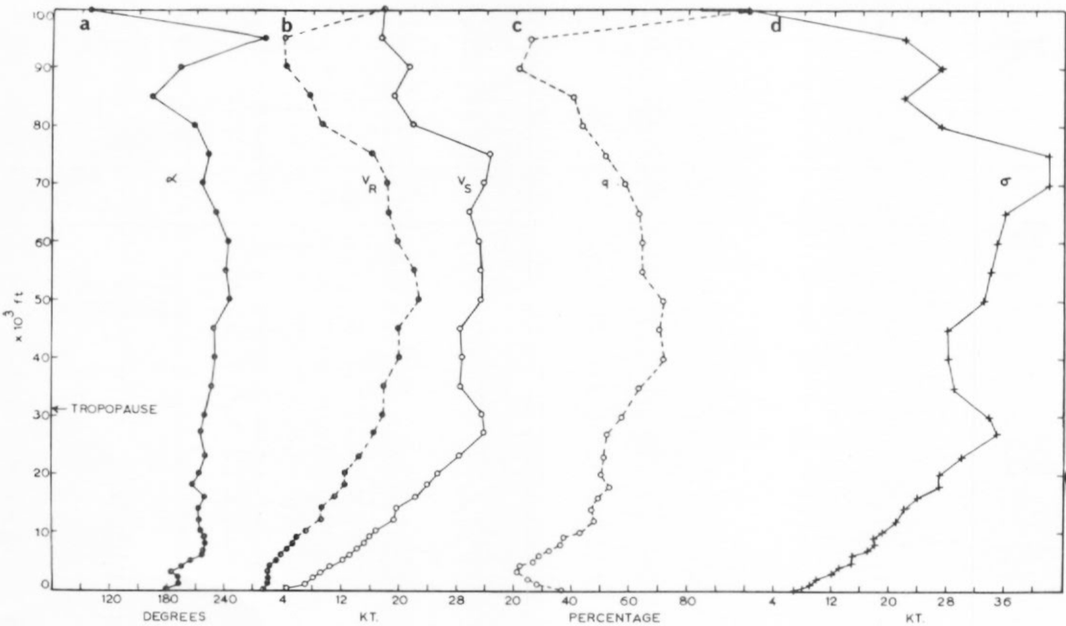

Fig. 2. Wind parameters at the Argentine Islands, 1954–58; all years combined.
a. Vector mean wind direction.
b. Vector mean wind speed; scalar mean wind speed.
c. Constancy.
d. Standard vector deviation.

speed continues to increase to a maximum at 50,000 ft. above which it decreases to just over 4 kt. at 90,000 ft. The scalar mean speed increases to a maximum of 32 kt. at 27,000 ft.—just below the tropopause. It decreases to about 28 kt. between 35,000 and 45,000 ft. before reaching another maximum of 32 kt. at 50,000 and 75,000 ft. Above this the speed decreases rapidly but erratically. Table II shows the rate of increase and decrease (in kt.) of V_R and V_S

TABLE II. RATE OF CHANGE OF V_R AND V_S WITH HEIGHT

V_R		V_S	
Heights ($\times 10^3$ *ft.*)	*Increase* (+) *and Decrease* (−) *in Speed per* 1,000 *ft.*	*Heights* ($\times 10^3$ *ft.*)	*Increase* (+) *and Decrease* (−) *in Speed per* 1,000 *ft.*
4–14	+0·7	0–12	+1·3
14–30	+0·5	12–27	+0·8
30–50	+0·25	27–35	−0·4
50–75	−0·25		
75–90	−0·8	75–90	−0·7

per 1,000 ft. in different height ranges. The table shows that V_S increases more rapidly than V_R in the troposphere, but above 75,000 ft. they both decrease at about the same rate.

(c) *q*. The constancy, or the ratio of the vector mean speed to the scalar mean speed, is shown in Fig. 2c. Constancy decreases from nearly 40 per cent at the surface to a minimum of just over 20 per cent at 3,000–4,000 ft. This is precisely the level at which the vector mean

wind speed begins to increase and also the level at which the backing in the direction of the vector mean wind from 193° at 1,000 ft. to 186° at 3,000 ft. becomes a veer towards south-west. In other words, the coefficient of steadiness is at a minimum at about 3,000 ft. From this minimum value constancy increases rapidly to the region of 50 per cent at 12,000 ft. and then more slowly and irregularly to a maximum of just over 70 per cent between 40,000 and 50,000 ft. Above this height constancy decreases reasonably steadily to another minimum of 21 per cent at 90,000 ft.; but this is partly due to the small number of observations. However, as this is the part of the atmosphere above 100 mb., it may be due to the easterly flow mentioned by Hofmeyr (1957).

(d) σ. Finally, Fig. 2d shows the values in knots of the standard vector deviation. Again, there is a similar pattern of a steady increase up to 27,000 ft., a falling off to 45,000 ft., a further increase to a maximum of 42 kt. at 70,000 and 75,000 ft., and a final decrease in the dispersion of the winds about the mean wind above this level.

2. *Seasons*

The same parameters were calculated for the four seasons: summer (December, January, February), autumn (March, April, May), winter (June, July, August), and spring (September, October, November). Slight discrepancies between these values and the mean annual values are due to the fact that the Decembers of 1953 and 1958 were excluded from the summer calculations. The results are given in Table III and are plotted in Fig. 3.

(a) α. At all seasons there is a discontinuity in mean wind direction about 7,000 ft. (Fig. 3). In summer, winds back to this level and then veer, while in the other seasons it veers before backing slightly, or, in spring, remains steady. This height is approximately between 1,000 and 2,000 ft. above the general level of the west side of the Graham Land peninsula in the vicinity of the Argentine Islands. Between 7,000 and 30,000 ft. directions are just west of south in summer, autumn and winter, and south-west in spring. Above the tropopause winds veer to the south-west in autumn, winter and spring, but in summer they back gradually above 45,000 ft.

(b) V_R *and* V_S. The vector and scalar mean wind speeds in each season are shown in Fig. 3. Both speeds are lower at all heights in summer than in the other seasons. The speeds in winter and spring are higher than those of autumn above the tropopause. In general, the curves for V_S have the same shape as those for V_R but naturally their values are higher. The summer curves show that while V_R reaches a maximum of about 13 kt. at 23,000 ft. and above 70,000 ft., V_S reaches a marked maximum (28 kt.) just below the tropopause at 27,000 ft., thereafter decreasing in value to 65,000 ft. In autumn both V_R and V_S reach a maximum at the level of the tropopause (19 and 37 kt., respectively), remain steady or decrease over the next 15,000 ft. and then both increase to just under 40 kt. at 65,000 ft. It is interesting to note the decrease in V_R between 3,000 and 6,000 ft. in autumn which is not apparent in the V_S curve; similarly, in spring between 2,000 and 4,000 ft. The very marked maximum shown in winter curves at 18,000 ft. is probably due to the small number of observations at this height. The winter and spring curves show no marked change of shape in the vicinity of the tropopause but speeds increase sharply at 45,000 ft. In all seasons the maximum speeds of both V_R and V_S are reached about 70,000 ft., which is around 45 mb. pressure.

(c) q. The graphs of constancy are given in Fig. 3. The annual minimum value at 3,000 ft. occurs only in winter and spring, while in summer and autumn this height shows an increase in value. There are marked small values of constancy (about 20 per cent) at 6,000 ft. in summer and autumn, and a decrease 1,000 ft. higher in winter and spring. Values increase to around 50 per cent in all seasons at 14,000 ft. Between this and the tropopause constancy decreases in summer, remains steady in autumn, and increases slowly in winter and spring. Above the tropopause a steadying or decrease is found in all seasons except spring between 45,000 and 60,000 ft. In contrast, the spring curve increases to a maximum at 55,000 ft.

TABLE III. PARAMETERS OF UPPER WINDS AT THE ARGENTINE ISLANDS, 1954–58

(a) *Summer*

h	N	α	V_R	V_S	q	σ
Surface	126	187	1·3	4·0	33	7
1	111	190	0·9	5·7	16	8
2	112	146	1·0	6·2	16	8
3	111	124	1·8	7·3	25	9
4	124	118	1·7	8·1	21	10
5	107	135	1·9	8·6	22	11
6	106	163	1·6	9·2	17	11
7	104	195	2·5	9·8	25	12
8	97	200	2·7	10·7	25	13
9	94	197	4·2	11·3	37	13
10	90	192	4·3	11·7	37	13
12	63	192	6·3	14·6	43	16
14	56	194	8·5	15·3	56	16
16	62	217	9·9	17·7	56	18
18	52	199	11·7	20·0	59	21
20	47	196	12·1	21·9	55	23
23	59	224	13·0	23·8	55	24
27	77	207	12·1	28·3	43	31
30	72	208	11·9	25·0	48	27
35	68	218	9·5	18·6	51	21
40	45	206	10·3	17·3	59	18
45	60	219	10·1	15·0	67	14
50	54	207	6·6	13·7	48	14
55	39	190	6·7	13·0	52	13
60	34	187	6·9	13·4	51	13
65	21	147	10·0	13·3	75	11
70	17	139	13·9	16·1	86	12
75	13	117	13·3	16·8	79	12
80	12	120	11·7	13·4	87	9
85	10	113	13·9	14·5	96	8
90	8	098	14·8	15·1	98	8
95	2	050	6·6	7·0	94	2

Mean height of tropopause: 29,200 ft.

(b) *Autumn*

h	N	α	V_R	V_S	q	σ
Surface	63	158	1·6	3·8	42	6
1	58	193	2·5	7·0	36	9
2	58	194	3·0	7·9	38	10
3	57	196	3·9	9·5	41	12
4	63	213	3·6	10·1	36	13
5	55	201	3·1	10·6	29	13
6	54	214	3·3	12·5	26	14
7	52	202	5·7	14·7	39	16
8	52	202	6·1	16·7	37	19
9	51	199	7·0	16·6	42	18
10	49	202	6·7	16·5	41	19
12	30	213	11·9	21·7	55	21
14	26	208	9·0	17·2	52	19
16	37	207	11·5	23·0	50	24
18	26	200	10·5	20·6	51	21
20	16	184	14·1	27·3	52	28
23	34	200	15·5	31·9	49	34
27	35	207	18·3	35·4	52	40
30	26	214	19·1	36·6	52	41
35	29	231	17·8	29·3	61	31
40	12	248	19·1	27·7	69	27
45	17	265	20·0	29·5	68	24
50	17	267	23·7	27·6	86	20
55	5	225	31·2	35·6	88	19
60	9	259	32·1	37·8	85	23
65	5	256	37·5	38·8	97	18
70	4	247	35·1	35·7	98	9
75	4	248	34·4	34·7	100	11
80	4	253	39·5	40·0	99	16
85	4	251	35·2	36·0	98	18
90	4	258	35·8	36·5	97	23
95	1	270	41·0	41·0	100	0

Mean height of tropopause: 30,160 ft.

(c) *Winter*

h	N	α	V_R	V_S	q	σ
Surface	126	167	2·2	4·3	51	6
1	126	180	2·3	7·5	31	9
2	126	192	2·4	9·0	27	11
3	92	198	2·4	10·9	22	13
4	123	207	3·3	12·4	27	14
5	121	215	4·8	14·4	33	17
6	85	224	6·1	16·5	37	18
7	98	223	5·2	16·9	31	19
8	72	217	7·1	18·6	38	20
9	88	214	5·8	18·1	32	20
10	90	207	8·8	19·6	45	21
12	54	203	8·4	20·6	41	22
14	61	203	11·1	22·8	49	25
16	67	208	9·6	23·5	41	25
18	29	183	16·8	39·2	43	38
20	31	222	10·1	24·2	42	25
23	55	206	13·4	27·3	49	28
27	45	206	17·5	29·3	60	28
30	38	213	17·7	29·8	59	30
35	39	221	19·6	29·8	66	27
40	24	240	26·2	32·5	81	26
45	26	243	26·2	36·1	73	28
50	24	245	40·4	51·0	79	43
55	5	259	64·1	69·2	93	26
60	3	268	81·1	83·3	97	21
65	1	270	99·0	99·0	100	0
70						
75						
80						
85						
90						
95						

Mean height of tropopause: 32,610 ft.

(d) *Spring*

h	N	α	V_R	V_S	q	σ
Surface	114	185	1·4	5·0	28	7
1	111	199	2·8	8·1	35	10
2	111	203	1·8	9·1	20	11
3	101	208	1·6	10·2	16	13
4	108	212	2·4	11·9	20	14
5	100	224	4·1	13·7	30	16
6	88	241	5·1	15·2	34	18
7	93	244	5·6	16·3	34	19
8	82	246	7·4	17·6	42	19
9	87	246	8·4	18·6	45	20
10	84	242	9·6	19·7	49	22
12	57	237	12·3	21·9	56	23
14	58	244	8·6	21·8	40	24
16	72	235	12·4	25·0	50	27
18	49	234	12·6	25·7	49	27
20	44	238	13·4	27·2	49	29
23	64	240	15·2	29·7	51	32
27	59	237	17·8	34·3	52	37
30	49	241	22·1	35·6	62	36
35	44	243	26·1	37·1	70	35
40	30	243	28·8	38·1	76	32
45	31	256	35·1	44·5	79	37
50	33	258	39·9	47·8	84	37
55	21	259	51·4	56·8	91	34
60	15	260	49·2	56·1	88	37
65	8	250	53·6	64·3	83	49
70	6	258	65·4	78·2	84	65
75	6	256	60·7	72·5	84	60
80	3	249	35·2	43·3	81	36
85						
90						
95						

Mean height of tropopause: 31,490 ft.

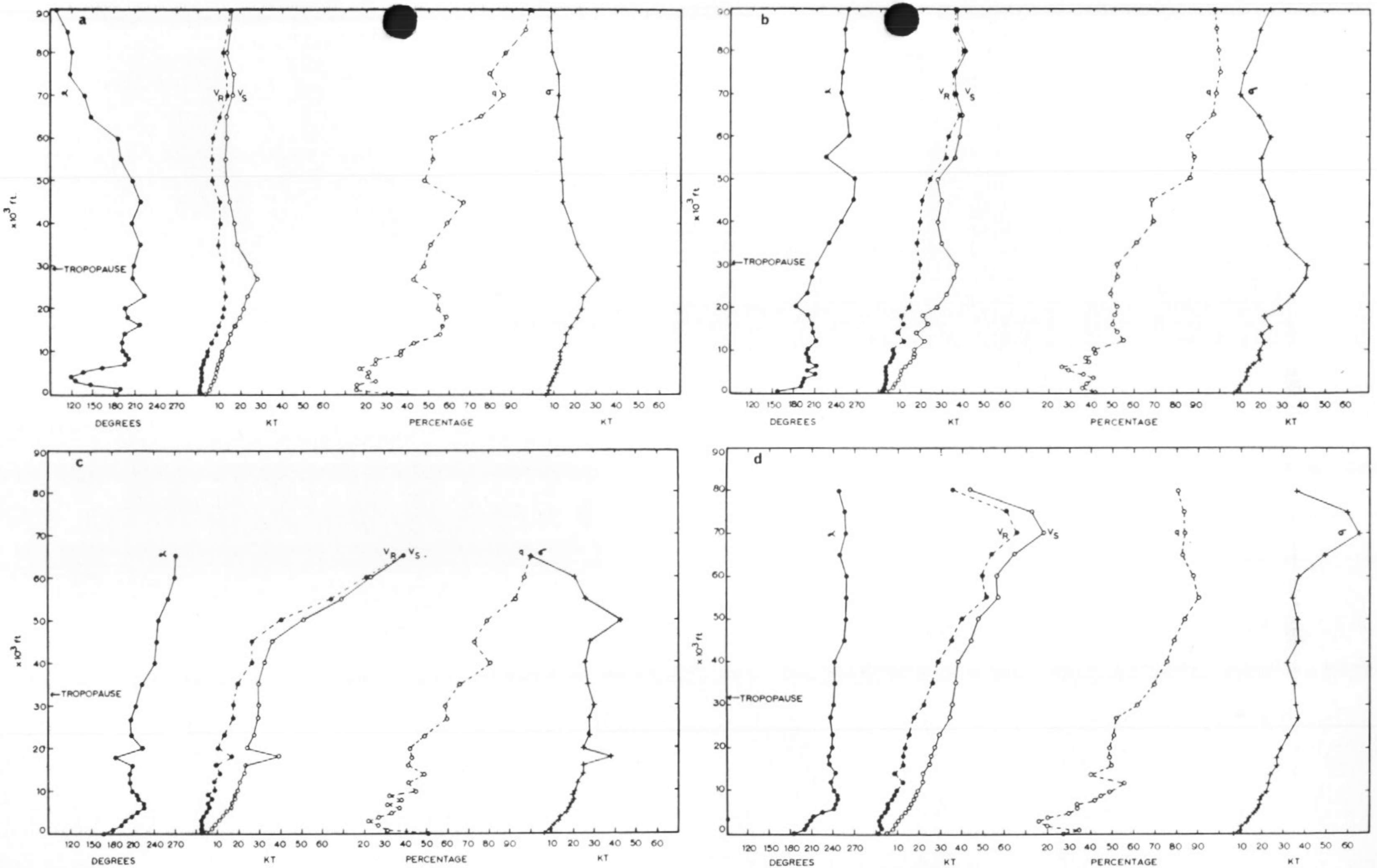

Fig. 3. Wind parameters at the Argentine Islands, 1954–58; seasons of all years combined.

a. Summer: α, V_R, V_S, q, σ.
b. Autumn: α, V_R, V_S, q, σ.
c. Winter: α, V_R, V_S, q, σ.
d. Spring: α, V_R, V_S, q, σ.

Taking all seasons together and ignoring these small fluctuations the following points can be made. At the surface constancy is between 30 and 50 per cent. It is less than 40 per cent up to 10,000 ft. but is 40–80 per cent between 10,000 and 45,000 ft. Above this values are over 80 per cent.

(d) σ. The standard vector deviation (Fig. 3) shows an irregular increase in all seasons from 6 kt. at the surface to about 30 kt. just below the tropopause. It then decreases rapidly to 40,000 ft., continues this decrease in summer and autumn but shows an increase in winter and spring at 50,000 ft. The minimum in autumn at 70,000 ft. is in complete contrast to the maximum in spring, while the few observations available suggest that in summer and winter values decrease above this level.

Conclusion

The value of these findings lies in the fact that few statistics have been published on upper wind observations in the Graham Land region. In the concept of modern meteorology this study may be considered limited, because of the bias in favour of fair weather conditions. However, it provides a foundation for future studies when a long series of radar observations are available.

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