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METEOROLOGICAL OFFICE

CLIMATOLOGICAL SERVICES (Met.O.3)

CLIMATOLOGICAL MEMORANDUM No.63

THE CLIMATE OF NORTH STIRLINGSHIRE, SOUTH PERTHSHIRE AND CLACKMANNAN

by

F.H.DIGHT, O.B.E., B.Sc.

PREFACE

This memorandum is one of a series dealing in some detail with the differing climates of various regions of Scotland. The boundaries of the regions as delineated in the areal maps are artificial, but for convenience they coincide with areas for which the Macaulay Institute for Soil Research are currently engaged on preparing a series of Memoirs of the Soil Survey of Great Britain. This memorandum, and the others in the series are being used as a basis for the chapters on "Climate" in the corresponding memoirs of the Soil Survey.

It is hoped that the design of the memoranda is such as to be useful to a wide variety of interests. The approach is not purely one of presenting in consolidated form the data available in the Meteorological Office, but in some degree a more dynamic approach in relating cause and effect has been adopted.

The policy has been to build the climatic picture round the analysed data available from climatological stations which have been in operation over a long period of years and to supplement this information not only from the observations at stations now no longer operative but also by the inclusion of data from the many stations that have come into being during the past 10 years or so and for which a useful summary can now be made. Data for stations outside the nominal boundaries of the regions have been exploited where it is considered that these add representative detail to the picture or where it gives an important lead, especially in the absence within the boundaries of the region of a station with a similar exposure.

The periods on which the climatic tabulations have been constructed are given. The averages on the major elements, temperature, rainfall and sunshine (unless otherwise stated) are those for the standard 30 or 35 year periods currently in use but for the climatological summaries the observations up to and including those for 1964 have normally been utilised. When a station has suffered breaks in its records, either partially or completely and where these breaks are considerable, or otherwise appear important, a suitable annotation is made. It is relevant to remember that at meteorological offices at defence establishments and civil airports the weather watch is continuous for most or all of the 24 hours and the staff have opportunities for noting phenomena which the observer at a climatological station might miss.

In order to keep the tabulations within reasonable limits, full climatic data are normally given for long term stations, but for subsidiary stations some items, even where available, e.g. the number of rain days, are not given unless they show significant variations or there are other specific reasons for not presenting the figures as comparative data. Annual averages which are normally large, e.g. numbers of rain days, days of ground frost etc. are rounded off to the nearest whole number.

In accordance with official Meteorological Office policy, temperatures are usually given in degrees Celsius. Practically all the temperature data are recorded however, in degrees Fahrenheit and for this reason ^{o}F have been retained for individual extreme readings.

These maxima and minima were originally recorded in whole degrees ^{o}F obtained by throwing to the odd so that a recorded $32^{o}F$ could be any value from $31.6^{o}F$ to 32.4 F, and a recorded $33^{o}F$ could be any value from $32.5^{o}F$ to $33.5^{o}F$ and so on. Recorded values of $32^{o}F$ are important in relation to the frequency of frost. An air frost is currently defined as a day when the screen minimum

/fell

fell below 32.0°F(0.0°C) but until 1st January 1963 a screen minimum which was recorded as 32°F (i.e.4°F or less) was counted as a day of air frost. The average frequencies are therefore a little higher than they would be had the present more precise definition been operative.

Statistics of "ground frost" given in the climatological tables also need some qualification. Formerly a "ground frost" was recorded when the near surface temperature fell to 30.4°F and this criterion applies to practically all the observations on which the statistics are based. "Ground frosts" are not now recorded, the term being reserved for use in forecasting only. In their place grass minimum temperatures below 0.0°C are recorded. The average number of "ground frosts" given in the tabulations based on the former criterion are comparable among themselves and are not yet significantly affected by the new procedure.

The following key is applicable to the headings of the climatological summaries:-

R	=	a day with	0.01 in. or more of rain (09-09h GMT)
W	=	" " "	0.04 in. or more of rain
S	=	" " "	snow or sleet falling
SL	=	" " "	snow lying (snow covering one half or more of the ground representative of the station at 0900h GMT)
H	=	" " "	hail
T	=	" " "	thunder heard
F	=	" " "	fog at 09h GMT
AF	=	" " "	air frost)) - for criteria see above ground frost)
G	=	" " "	gale

In the areal maps, stations are indicated as follows:-

■ = Meteorological Office stations

▲ = Co-operating climatological stations

● = Rainfall stations

For purposes of comparison with other localities and regions, the following publications may be consulted:-

M.O. 735	Averages of temperature for Great Britain and Northern Ireland 1931-60	H.M.S.O.
M.O. 743	Averages of bright sunshine for Great Britain and Northern Ireland 1931-60	"
M.O. 635	Averages of rainfall for Great Britain and Northern Ireland 1916-50	"

M.O. 421 Averages of Humidity for the British Isles H.M.S.O.

M.O. 488 Climatological Atlas of the British Isles "

*Climatological Memoranda No. 38, 1931-60
Averages of temperature and sunshine
for stations not included in M.O. 735

*No. 40. Frequencies of snow depth for given
ranges at selected stations in Scotland

* Available from Meteorological Office (Met O 3b) Bracknell

*Hydrological Memoranda

No. 1 (Revised) Part II - Monthly averages of rainfall for Scotland and Northern Ireland, 1916-50, for MWR stations.

" 26 Rainfall, 1916-50, over the areas of Solway, Ayrshire and Clyde

" 27 Rainfall, 1916-50, over the areas of Kintyre and S.W. Islands, Add, Awe, Etive, Lochy and Linnhe

" 28 Rainfall, 1916-50, over the areas of Shield, Alsh, Maree, Inner and Outer Hebrides and Laxford

" 29 Rainfall, 1916-50, over the areas of Naver, Thurso and Wick Water to Conan

" 30 Rainfall, 1916-50, over the areas of Beauly and Ness, Banff, Moray and Nairn

" 31 Rainfall, 1916-50, over the areas of Dee and Don, N & S. Esk and Tay

" 32 Rainfall, 1916-50, over the areas of Forth, Lothians and Tweed

* Available from Meteorological Office (Met O 8b) Bracknell

THE CLIMATE OF NORTH STIRLINGSHIRE, SOUTH PERTHSHIRE AND CLACKMANNAN

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F.H. Dight, O.B.E., B.Sc.

Introduction

Considerations of geography and economics rather than county boundaries largely dictate the section of mid-Scotland under review in this memorandum (Fig. 1). The area comprises part of southern Perthshire, much of the eastern half of Stirlingshire and much of Clackmannan. It features prominently the 20 miles or so of the broad valley of the River Forth from the Kincardine Bridge almost to the Lake of Menteith and Loch Venachar with the valleys of the feeder rivers - the Teith to the northwest, the Allan Water to the north and northeast (Strathallan) and the Devon eastwards through Clackmannan. This Forth-Teith-Devon valley complex, delineated by the 500 ft. contour is a broad belt oriented WNW-ESE averaging some 10 miles in width, but rather less in the central section and broader on the eastern side. A considerable part is, in fact, below 250 ft. and the slow flowing River Forth meanders languidly but extensively through a belt which does not rise above 100 ft. Strathallan, for the most part, is above the 250 ft. contour but north of Gleneagles is the lower lying district of Auchterarder.

South of the Forth and in the Southwest corner of the area are the Fintry Hills rising to 1500ft. at the highest points. The most formidable upland country is that of the Ochil Hills in the northeast between the Allan Water and the River Devon where the plateau exceeds 1500ft. in height and the highest peak Bencleuch is nearly 2400ft. The Braes of Doune, between the River Teith and the Allen Water, are the foothills to the most southerly outcrop of the Scottish Highlands and the ground here rises steadily to 1500ft. in the extreme northwest corner of the sector.

There is no high ground immediately to the west, and to the southeast is the broadening expanse of the Forth estuary, so that the town of Stirling is the geographical gateway between east and west Scotland.

General Climate

This rather extensive and largely land-locked valley area is well removed from the recognised "centre of depression" routes and very rarely subject to the near passage of secondary developments. The main weather control is thus exercised almost completely by the large scale circulations and the fronts embedded therein as modified by the local topography. The orientation of the main valley WNW-ESE is therefore important as providing no important barriers to the westerly or easterly airstreams in their seasons. The central area has some shelter from the southwesterlies, a consideration which does not apply to the Ochil Hills area in the east.

The long term composite picture is thus that of a transitional climate reflecting the maritime influences of the mild and wetter west of Scotland and the greater continentality of the drier and colder eastern counties. Very occasionally the harsh continental winter of the Highlands may intrude from the north (usually only temporarily) and any major contribution from the Highland country is possibly the thundery activity of summer. The valley rainfall increases from southeast to northwest and, as will be seen in the section on Rainfall, there is a subtle difference in the seasonal distribution from one side to the other. The lower ground, being a partially land locked inland basin,

/enjoys

enjoys the advantages usual to such locations; it is shielded to some extent from rain and wind, and the afternoons of the summer half year derive maximum from the sunshine. In spite of the close proximity of the Highland mass, temperatures for the most part tend to avoid the extremes that might be expected in the colder months, except possibly in the extreme northwest and in the Flanders Moss district in the extreme west.

Winds

An indication of the general wind distribution over the area is conveniently obtained from some detailed assessments of the wind flow at some 1500 ft. to 2000 ft (geostrophic winds) made from the official daily charts. The analysis is represented by the wind roses in Figs. 2 & 3 - annual and seasonal - based on four assessments daily, the mid point of the assessment area being some 11 miles due south of the town of Stirling. (Winds near the surface are normally backed up to some 30° from these "free" winds and the speeds appreciably reduced).

Southwesterly/westerly winds largely representing the maritime airflow generated by the North Atlantic/Hebridean depressions predominate at all seasons and in the autumn the westerly component is very well marked. These winds have reasonably easy access to the area and then to be funnelled through the valley.

Easterly winds penetrate easily into the central valley area, the unobstructed flow of the southeasterlies being especially well canalised as they sweep in over the upper reaches of the Forth estuary. Their frequency is markedly increased in the later winter period and in spring. Northerlies are least frequent, and have been markedly infrequent in the spring months in recent years.

Gales

The strongest high level winds apparently have some preference for the sector SE-SW, particularly in winter and spring and thus tend to blow across the western section of the main valley and are partially blocked by the Ochil Hills on the eastern side. Thereby are the chances of surface gales from these directions decreased in the lower lying districts. The strongest surface gales are probably from a westerly point in association with the not inconsiderable frequency of upper winds from this direction, and probably attain their highest speeds in the Stirling gap between the Ochil and Fintry hills, and then decreases in speed as they fan out eastward of Stirling. Strathallan forms a convenient funnel for the northeasterlies but high winds generated there must rapidly lose their force on entering the Forth valley. The implication that the upper valley of the Forth itself is not very prone to gale force winds is supported by the long period average figure of only three days of gale annually for Stirling itself (Table 7) and a computed figure of 5 days for an open exposure.

There are insufficient observations to indicate just how extensive is the apparent shelter from gales afforded by the Fintry Hills. It would seem likely that the southwesterlies are revitalised at the surface on reaching the foothills and the Strathallan valley funnel in the North of the area. The low lying southeastern section of the area extending into Clackmannan is almost certainly outside the shelter area and here the average number of days of gale may approximate more nearly to the 12 days per annum of Midlothian.

/During

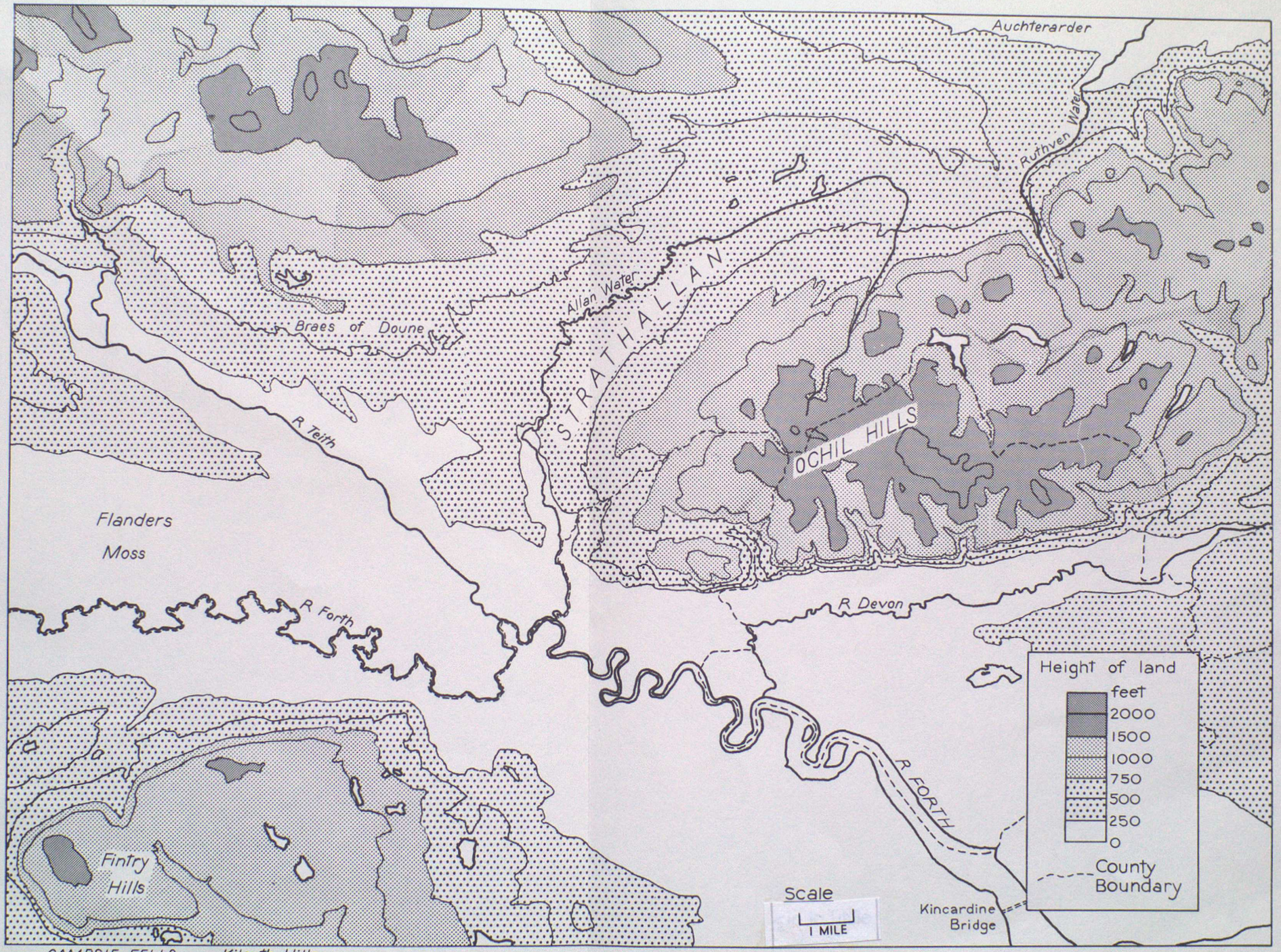


Fig 1. Relief and drainage of North Stirlingshire, South Perthshire and Clackmannan

During the exceptionally violent gale of the night of 14th-15th January 19 68, the anemograph on the harbour master's building at Grangemouth went off the scale at 106 m.p.h.! Gales are most frequent in the period December to February with the greatest liability after the turn of the year.

A less rigorous analysis of the once daily observations (at 0900 G.M.T.) for the neighbourhood of Stirling town is represented by the wind roses at Fig. 4. The exposure of the observing station is not ideal and at 09h. the real day-time wind is not fully established especially in the colder half of the year. The diagrams do however indicate the marked directional effect of the funnelling effect through the Stirling Gap and the marked reduction in wind speeds in the valley.

Rainfall

The driest district is the eastward facing wedge-shaped sector of the Forth valley with its apex round the confluence of the three main rivers (Fig.5). This area receives an average annual fall of about 35 to 40 in. Round Auchterarer it is almost as dry, but in Strathallan the figure is some 45 in. or more. Rainfall increases westward toward the upper reaches of both the Forth and Teith even below the 500 ft. contour. With increasing height the rainfall increases steadily; over 60 in. occur annually at the highest levels of the Fintry hills in spite of the shielding effect of higher ground to the southward. The near precipitous southern escarpment of the Ochil hills boosts the fall from 40 in. in the Devon valley to over 70 in. at heights exceeding 1500 ft. within a (horizontal) distance of some three miles. The wettest area is in the northwest corner, which is on the fringe of the wet regime of the western Highlands and where, above 1500 ft. the annual figure rises to 80 to 100 in.

Table 1. Average Monthly and Annual Rainfall (Inches)

(Period 1916-1950)

Station	Ht. ft.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Callander	230	7.34	4.97	3.88	3.51	3.58	3.27	4.18	5.09	5.09	6.92	6.18	6.61	60.62
Dunning (Kippen Hse.)	450	5.18	3.42	3.01	2.71	3.14	2.63	3.88	4.03	3.69	4.68	4.37	4.76	45.50
Blackford	520	5.40	3.78	3.01	2.82	3.11	2.82	3.73	4.16	4.21	5.21	4.64	4.93	47.82
Loch Vennachar	275	6.64	4.64	3.54	3.38	3.76	3.47	4.38	5.28	5.20	6.88	5.80	6.10	59.07
Dunblane (Old Doune Rd.)	230	4.85	3.20	2.59	2.34	2.63	2.38	3.08	3.57	3.66	4.48	4.03	4.27	41.08
Ochtertyre	14	4.78	3.06	2.61	2.36	2.61	2.36	3.10	3.63	3.59	4.48	3.99	4.20	40.77
Tillicoultry (Cemetery)	80	3.99	2.94	2.38	2.16	2.57	2.27	3.09	3.53	3.35	3.94	3.53	3.46	37.21
Stirling	151	4.55	2.87	2.31	2.17	2.62	2.24	3.15	3.46	3.42	4.17	3.76	3.78	38.50
Earlsburn Res.	1202	7.17	4.95	3.93	3.87	4.06	3.74	4.76	5.77	5.58	6.98	6.22	6.41	63.44
North Third Res. (No. 1)	574	6.18	4.22	3.35	3.25	3.52	3.14	4.22	4.92	4.76	5.84	5.30	5.41	54.11
North Third Res. (No. 3)	989	6.49	4.48	3.56	3.44	3.73	3.39	4.42	5.28	5.05	6.26	5.57	5.74	57.41
Tulliallan	90	3.53	2.50	2.13	1.86	2.47	2.10	3.11	3.39	3.01	3.56	3.21	2.98	33.85

As can be seen from Table 1, the wettest month on balance over the years is January and there is a secondary maximum in October, but November and December are not very markedly less wet on average, especially December. This is the period with the Hebridean depressions largely in control and this distribution pattern, which is conspicuous from Stirling westwards, is mainly characteristic of that of the Western Highlands. The build up to the October peak begins in July with the development of thundery conditions, many of the rain areas being associated with storms formed in the mountains and which drift over the Forth valley to the Lothians on the prevailing NW winds of later summer. Indications of a change to the distribution pattern characteristic of the area surrounding the Forth estuary become increasingly noticeable moving eastwards from Stirling. The January maximum in particular begins to fall away noticeably, the October secondary maximum to wane with the growth of a new peak in August. This increase in August reflects the occasional intrusion, borne on the E to SE winds, of the reasonably recurrent wet period in the Borders and SE Scotland in this month (mean date around 13th August*).

The dry season is from February to June everywhere and is often characterised by rather persistent easterly winds especially in spring.

The number of "wet" days (those with 0.04 in. of rain or more) and the number of "rain" days (0.01 in. or more) on the long period average for Stirling, and a short period mean for Balfron are given in Table 4. The "wet" days at Stirling range in number from 10 in the drier months to 15 in the wetter months and average out at 145 yearly. "Rain" days are not markedly more frequent and this suggests that in the Forth valley at least, damp, drizzly days are not as frequent as in many other areas. At round 1100 ft. in the Fintry hills a derived estimate of the number of "wet" days indicates an increase of some 20% to 25% over the annual figure in the valley.

Extremes of Rainfall

Very wet days, yielding 1.5 in. or more in the recognised 24 hour daily period (09h.-09h. G.M.T.) appear to be very conservative in their incidence in the Forth Valley. Not one has been logged in the 46 years of the Stirling record over the four months February to May. Such visitations occur most frequently in September and August. On 17th August 1920 2.54 in. fell at Stirling and over 3 in. in the hills - a notorious date in the weather records of S. E. Scotland when exceptionally heavy and widespread rain caused extensive damage and flooding, with Strathallan being one of the badly affected areas. A very wet day in September 1953 gave 2.25 in. Over the wetter western side of the area, a fall of over 1.5 in. occurs on at least one day in most years (Balfron 342 ft.). Although August and October are most prone to these downpours, the record is held by a January day with 3.34 in. Fortunately long period averages are no criteria for individual years, so that although it is not surprising that very dry months are most prone to occur in the first half of the year, they are by no means confined to this season. The central districts appear to have an unusually high liability to dry periods. In 44 years, 22 months have produced no more than 0.67 in. per month; August 1947 had no measurable rain, and February 1932 only one day with a slight fall. In recent years there were 26 days without measurable rain in February-March 1953, and 20 days in August-September 1959.

/Snow

*The Lammas Flood period, recognised in the meteorological history for at least 200 years.

Snow

The average expectancy of days of snow falling is some 17 days per season. Although in the valley it has been reported as early as September and as late as May, it is rarely of practical significance before December or after early March, as will be appreciated from the "mornings of snow lying" in Table 7. At lower levels the area is at real risk probably for little more than two months. Even so the liability to heavy snowfall does not appear to be marked probably since the snow-bearing N to NE winds are apt to be robbed of their precipitation by the Ochil Hills. The major valleys, with the possible exception of the Auchterarder area, are well shielded from the worst effects of these, and a level covering six inches deep is unusual. The greatest depth of level, undrifted snow at the Stirling station was 7 in. in January 1940 (when away to the west roads were blocked by 12 to 14 in. of snow) and again in the winter of 1953/54. In view of this tendency to only moderate snowfalls in the central (and eastern) Forth valley, some details of the persistency of the snow cover are of interest. The weather diaries for Stirling for the 46 years from 1918 show that the unduly long periods of persistent cover have all occurred in the second half of the period:- 53 days in the winter period of 1962-63, 37 days in early 1942 and for a total of 39 days in February-March 1947 (temporarily broken in mid February). No periods of near comparable duration occurred in the first half of the period. These figures of persistent cover may be compared with the average total number of 14 individual days with snow lying per season at the lower levels. The counts rise with increasing altitude and/or precipitation. Nearing the 500 ft. contour the number of individual snow-lying days rises to near 25 per season and the maximum depth of undrifted snow in bad storms to some 12 to 15 in. (cf. Balfron Table 7). Plausible estimates of days with snow lying at about 1500 ft. indicate some 45 to 50 per annum in the Fintry Hills and 55 to 60 on the Ochil Hills. Over the higher ground of the northwest corner of the area heavier and more frequent snowfall is suggested by the considerable precipitation figures for the cold months but the liability to more frequent and rapid thaws may well keep the average number of days with snow lying down to about 65 at 2000 ft.

The Auchterarder and Strathallan districts are probably more prone to snowfalls than the central Forth districts.

Evapotranspiration

Evaporation and transpiration must be considered in relation to the incidence of the rainfall before the real water need in a normal year can be assessed. The accepted estimates of the evapotranspiration (potential transpiration - P.T.) for covered green surfaces for the main area are given below in inches of water.

Table 2. Average values of Potential Transpiration

	April	May	June	July	August	September	Summer	Winter	Year
Inches of water	1.95	3.20	3.45	3.25	2.50	1.55	15.90	2.15	18.05

Comparison with the average rainfall figures above - the soil being assumed to be at field capacity at the end of March, - indicates that a deficit begins to build up with the approach of May and this increases to about 1.5 in. by early July in the Forth Valley and Strathallan. The tendency to dry spells in spring and early summer is associated with a threat of retarded germination and the development of young crops (but see "The Growing Season" p.).

/Temperature

Temperature

The temperature regime is the resultant of a rather complex but favourable series of controls. The mild winter conditions of W and SW Scotland can be shared by the extensive valleys because of the relative ease of penetration of the SW to W maritime winds. Unduly low temperatures characteristic of an inland location of this type are thereby often prevented except during anticyclonic conditions and then there is a leaning toward the "semi-continental" winter type with really cold frosty nights. The anticyclonic periods in the colder part of the year are frequently initiated by and even maintained by a northeasterly wind regime. These snow-bearing winds of winter and the raw cold winds of spring and even of early summer are hindered by the not inconsiderable barrier of the Ochil Hills and are apt to have their cloud sheets broken up if not cleared altogether. The intrinsically cold air entering the basin then tends to stagnate and conditions are ideal for substantial night radiation. The resultant pools of cold surface air are not easily dislodged. The saucer like configuration of the terrain is such as to ensure maximum use of any isolation during most of the year and under quiet anticyclonic conditions from mid spring into autumn the Forth valley warms up quickly. The results are two fold. The Forth/Teith valley district and the adjacent foothills are, by and large, about the warmest area in Scotland on the basis of the mean temperature for the year, with the increased warmth of the summer half year often cancelling out the greater mildness of its western competitors (e.g. the Solway area and the Ayrshire plain) in the colder six months. Further the upward surge of temperature with the lengthening days is noticeably more marked and regular than it is in areas immediately to the eastward, giving advantageous conditions for earlier plant growth and a longer growing season.

From Flanders Moss to the Fintry hills, lacking topographical benefits of the central Forth valley, the winter is longer and more bleak. (see under Frost).

The top right hand sector of the picture must be painted in more sombre hues. Strathallan may enjoy some benefits from the maritime influence but it is also a convenient funnel for the northeasterly winds in their season and must be considered climatically as a transitional district to the distinctly harsher, more continental like climate of the Auchterarder district from about November to May. Its only maritime influence is that of winds off the cold North Sea.

Table 3. Averages of Temperature 1931-1960 and Extremes

Month	STIRLING 151 ft./ Average (°C.) Max.	Min.	Mean	ØExtremes (°F.) Max.	Year	Min.	Year	FALKIRK 100 ft.‡ Average (°C.) Max.	Min.	Mean	ØExtremes (°F.) Max.	Year	Min.	Year
Jan.	5.6	0.3	2.9	56	/	06	1918	5.8	-0.3	2.8	57	1958	12	1955
Feb.	6.6	0.8	3.7	58	1953	07	1956	6.7	0.3	3.5	59	1953	06	1966
Mar.	8.9	2.3	5.6	69	1945	12	1947	9.1	1.7	5.4	64	1957	08	1947
Apr.	12.2	4.0	8.1	74	1955	24	1924	12.2	3.6	7.9	68	1949	25	1953
May	15.5	6.3	10.9	80	1919	29	1927 1929	15.6	5.7	10.7	80	1952	27	1948
June	18.3	9.4	13.8	85	1939	33	1927	18.6	8.8	13.7	85	1950	34	1963
July	19.5	11.3	15.4	87	1955	38	1920 1962	19.8	10.9	15.4	86	1955	40	1962
Aug.	18.9	11.1	15.0	83	1945	35	1962	19.3	10.7	15.0	83	1955	36	1964
Sep.	16.3	9.1	12.7	77	1926 1964	29	1954	16.9	8.6	12.7	79	1959	30	1954
Oct.	12.3	6.4	9.4	74	1959	25	1926	13.0	5.8	9.4	77	1959	25	1950 1955
Nov.	8.9	3.2	6.0	62	1927	08	1919	9.1	2.8	5.9	60	1947	15	1947
Dec.	6.9	1.8	4.3	59	1921	17	'23'25 '47'61	7.0	1.3	4.2	57	'48'54 '59	16	1950
Year	12.5	5.5	9.0	87	1955	06	1918	12.8	5.0	8.9	86	1955	06	1966

Month	BALFRON 342 ft. *Average (°C.) Max.	Min.	Mean	ØExtremes (°F.) Max.	Year	Min.	Year
Jan.	5.5	-0.8	2.3	56	1942	02	1940
Feb.	6.1	-0.3	2.9	55	1939 1945	07	1947
Mar.	8.1	1.2	4.7	67	1945	09	1947
Apr.	11.4	2.6	7.0	68	1942	23	1944
May	15.1	4.9	10.0	78	1941	25	1938
June	17.4	8.0	12.7	84	1950	35	'39'42 '49
July	18.9	10.2	14.5	81	1943	38	1939
Aug.	18.2	9.8	14.0	77	1938	36	'40'42 '44'48
Sep.	15.7	7.9	11.8	71	'39'41 '49	26	1943
Oct.	12.0	5.4	8.7	66	1949	25	'48'50
Nov.	8.9	2.4	5.7	58	1938	18	1947
Dec.	6.7	1.0	3.9	54	1942	07	1950
Year	12.0	4.4	8.2	84	1950	02	1940

/1918-Feb. 1920, 74 ft.

‡10 ft. w.e.f. Dec. 1966.

ØSee Preface for explanation of use of °F.

*Balfron, computed from short period record.

/1922, 1925, 1932, 1957, 1958 & 1965.

Extreme values for periods:-

Stirling. Max. 1918-1967 with break 1947-Apr. 1951.
Min. 1918-1967 with minor breaks.

Falkirk. Max. 1947-1967 with break Apr.-Sep. 1947.
Min. 1947-1967 except Apr. 1947.

Balfron. Max. 1938-June 1951 with break July 1945-May 1949.
Min. 1938-June 1951 with minor breaks.

The range of the mean daily temperature at Stirling (Table 3) is from 2.9°C. in January to 15.4°C. in July; the average maximum temperature rises by some 14°C. from 5.6°C. to 19.5°C. over the same period. The average minimum temperature for the short July night is 11.3°C. as against 0.3°C. for the long January nights. This latter figure - only slightly above freezing - reflects the quite low night temperatures that can occur in the open valley.

Extreme Temperatures

Temperatures very occasionally fall below -12°C. with winter anticyclonic conditions, the absolute low value at Stirling being -14.5°C. Very mild winter weather is not uncommon with temperatures well above 10°C. both before and after the turn of the year. A maximum of 15°C. has been recorded in December giving an absolute range of winter temperature of nearly 30°C. The summer extremes give an equally large range; maxima have exceeded 26.5°C. in each month May to September with an absolute high of 30.5°C. in July, whereas a night temperature approaching freezing point in June although exceptional is not unknown (0.5°C. at Falkirk).

The "Hardening" of the winter climate in the Auchterarder district indicated by the very limited data available has already been referred to. For temperature change with height a reduction of 2°C. per 1000 ft. (or pro rata) on mean temperature values for a location near sea level gives a good approximation to conditions at various levels.

Table IV Average number of days with maximum air temperatures within ranges stated at STIRLING. Period 1951-65.

Maximum temperature	J	F	M	A	M	J	Jy	A	S	O	N	D	Yr.
equal to or less than 35°F	4	2	<1								<1	3	9
" " " " than 40°F	13	9	4	<1							3	8	37
exceeding 60°F			<1	4	13	23	27	26	15	2			111
" 65°F			<1	1	5	11	16	13	5	<1			52
" 70°F				<1	1	4	6	4	1	<1			16
" 75°F					<1	1	3	1	<1				5

Frost

The "frost season" in the valleys, has an average duration of almost six months. The average date of the first air frost of the season at Stirling is 24th October, and of the last 20th April, but air frost has occurred as early as 6th September and as late as 31st May although not in the past 10 years; a "touch of ground frost" is not unknown in the middle of summer. Some idea of the prolongation of the colder period of the year over the extreme westward side of the area can be seen by reference to the climatological Table 7. The numbers of frosty nights at Balfron on the 14 year mean are very substantially greater than those shown for Stirling, the marked incidence of May frosts being specially noteworthy. (The short period means for Stirling over the same 14 years as the Balfron observations are lower, except for January, than the long period monthly averages - obviously the early period was a somewhat colder period). The number of "Freezing Days" is a useful index to the winter climate, where a "freezing day" is as defined by Belasco, one on which the mean of the maximum and minimum temperatures for the day does not exceed 32.5°F. (0.3°C.) and in practice is one on which the frost does not "give out" during the day. The figure for

/Stirling,

Stirling, averaging out over 40 years at about 12 days per winter season, is surprisingly small for a low lying inland area such as the Forth valley. Comparative data for Falkirk* confirms this low figure, which is only slightly higher than that for the Ayrshire plain but indicates five fewer days than are experienced in apparently similar open locations in East Lothian. As a further indication it may be noted that the mean value of the number of days per annum with air temperatures continuously below freezing point throughout a period of 24 hours at Stirling over the 10 years 1955-64 is only 2-6 days and the longest period one of 72 hours.

In quiet frosty weather, the temperature recovers very quickly from the (often) low overnight value and tends to rise very appreciably above freezing point, giving large values to the daily temperature range - a glen effect noted by Dight† in the Spey valley and other Scottish glens.

Individual years show considerable variation; no persistent "freezing" days were recorded during two of the mild winters of the early 1930's, but there were about 50 in 1947 of which 40 in the first three months of the year probably constitute a record for the present century. In 1940 and again in 1955 there were 29 of these freezing days. The winter from November 1962 to March 1963, inclusive, produced 42 such days of which 32 occurred in January and February 1963. A derived estimate suggests that in the upper Teith valley the period average of "freezing" days is some 50% higher than that for the Forth area, and it is unlikely that the Auchterarder district fares any better than the Teith valley.

The Growing Season

Growth, it is now fairly generally accepted, does not begin for many plants until the mean temperature reaches about 42°F. and the rate of recovery of temperature to this threshold from the harshness of the winter season is probably of greater import than the normal severity of that season. This recovery rate over much of the area under review, and particularly the Forth valley, is probably among the highest in Scotland. The progress from month to month is indicated in Table 5, giving the monthly averages of "Accumulated temperatures" above 42°F. expressed in degree days. Following a rapid rise in late spring, the June average compares quite favourably with that of many districts considerably further south in England, thanks to the combination of the maritime effect with the topographical advantage of a semi-landlocked inland area designed by nature to derive the maximum benefit of any sunshine. Given adequate moisture - and the watertable associated with the slow flowing Forth is presumably high - germination and steady early growth are encouraged in spite of the inherent tendency to dry weather at the beginning of the growing season.

Table 5. Accumulated Temperatures above 42°F.

	J	F	M	A	M	Ju	Jly	A	S	O	N	D	Year
Degree days	50	50	102	156	298	447	549	527	387	214	72	46	2898

This favourable regime must obviously be expected to become progressively less marked with increase in height, but the natural decline in air temperature with height may well be offset partially by higher soil temperatures than might normally be expected. The topographical east-west alignment of much of the area with the main slopes and foothills facing south is such that maximum areas enjoy the full benefit from any sunshine, especially in the normally sunny months of May and June. Strathallan is the district with the least favourable orientation for the enjoyment of this "bonus".

/Sunshine

*Includes the very cold spell of early 1947 - not in the Stirling records.

Sunshine

Sunshine figures, lacking consistently good records, may best be estimated from the monthly maps giving period averages for 1931-60 prepared by the Meteorological Office (Table 6.). In the eastern valley the figure for the year isabout 1250 hours, with June and May the sunniest months and the totals differing only slightly from 180 hours. These averages credit approximately 56% of the total for the year to the first six months although the January and December figures are roughly the same at rather over 30 hours. General conditions suggest a slow falling off in sunshine toward the west. Average expectations for individual days are some 85 days per annum with no sun and some 30 or so with over 9 hours.

Table 6. Estimated Average Sunshine Values (1931-60) - Stirling

	J	F	M	A	M	Ju	Jly	A	S	O	N	D	Year
Hours	34	65	99	141	177	181	161	132	108	77	45	31	1252

Thunder and Hail

Thunder may be heard at any time of the year, but only very rarely in the early months. The showery weather of April is apt to bring a short, sharp storm as is the "clearing shower" of the autumnal rains. The thunderstorm season proper which is quite marked, waxes during May, reaches a peak in July and wanes during August and early September. The whole area (together with a part of southern Perthshire) comprises the zone of greatest thundery activity in Scotland. The "rolling" type of storm is apt to develop more or less "in situ" - due to the relatively excessive heating of stagnant air in the basin-like formation and juxtaposition of the rising ground - and these storms are augmented from July onwards by storms generated in the Highland country and drifting down on the seasonal prevailing Northwest winds.

It is interesting to note that as in some other districts of Scotland, the frequency of occurrence of hail runs counter to the incidence of thunder. (Table 7) Hail is most commonly experienced in April when the frequency of thunder is still low but the frequency, although remaining significant, falls off in May whilst the thunder activity is increasing. It is unusual to have hail during the height of the thunderstorm season.

Statistically there is a sharp rise in the number of reports of hail to a secondary maximum in December and a significant level of frequency for the following three months. The reports however over the period covered are not confined to the hard hail stones, but include those of snow pellets or granular snow, which probably fall as frequently as hailstones, if not more so, during the coldest period of the year.

Fog and Haar

Reference to Table 7 indicates a relatively high average incidence of about 30 foggy mornings in the Stirling district in the winter half year. The pooling of cold air in the valley basin and the slow flowing river favour this high incidence following quiet clear nights, and the fogs are probably common to much of the broad Forth valley. In such situations the surrounding higher ground will often remain clear except for a short period when the fog is lifting and dispersing from the valley. The tendency to a quick rise in temperature after a sharp frost, already referred to, probably assists a fairly rapid lifting of the fog on days when it might tend to persist in less favoured situations.

/HAAR

HAAR is associated with the light or moderate easterly winds which often bring in fog or very low cloud from the North Sea. The very low cloud which develops at times in association with a general area of rain or drizzle from frontal cloud masses is sometimes loosely termed "haar". It deepens the general gloom and the feeling of raw cold and is prone to occur with the August rains although no month is entirely immune except that it is least likely to occur in winter.

In the present connection however it is the more tempermental, if equally disappointing form of haar - the true haar - which is of greater importance, when the fog/low cloud drifts over in otherwise clear fine weather. Usually the fog begins to move inland in the late afternoon or evening of the spring and early summer months, shrouding the windward slopes of the rising ground and filling the valleys as it thickens. With sunrise the forward edge begins to dissipate and considerable areas often clear rapidly.

This type of haar is much less troublesome in the area under review than it is on the east coast and in the areas bordering the Forth estuary, since the wind direction needs to be critically aligned to carry the obscuration well inland. The statistics suggest however that the situation does arise occasionally. This haar can cut off appreciable incipient sunshine in the season, but can also provide some condensed moisture to the young vegetation at a period when the soil moisture deficit is building up.

Table 7. Climatological Summaries - Average Number of Days per Month of Occurrence of Specified Phenomena - Period as Indicated
(for explanation of headings, see Preface)

Month	Stirling (1918-46; 1952-63) 151 ft.								
	R	W	S	SL	H	T	F	AF	G
Jan.	18	15	5.4	5.1	0.4	0.1	5.2	14	0.9
Feb.	15	12	4.0	3.9	0.4	0	3.9	11	0.5
Mar.	14	10	2.5	1.8	0.5	0+	3.2	8	0.2
Apr.	14	10	1.0	0.3	1.0	0.3	0.6	3	0+
May.	14	10	0.3	0+	0.7	0.7	0.2	0.5	0.2
June	13	10	0+	0	0.1	0.7	0.2	0	0+
July	15	12	0	0	0.1	1.1	0.3	0	0+
Aug.	18	13	0	0	0.1	0.8	0.5	0	0+
Sep.	16	12	0+	0	0.1	0.4	1.3	0.2	0.1
Oct.	15	13	0.2	0+	0.1	0.2	3.8	2	0.3
Nov.	17	13	1.0	0.5	0.2	0+	5.5	7	0.3
Dec.	18	15	2.7	2.7	0.6	0.2	5.3	10	0.5
Year	187	145	17.1	14.3	4.3	4.5	30.0	56	3.0

Table 6 (contd.)

Table 7 (contd.)

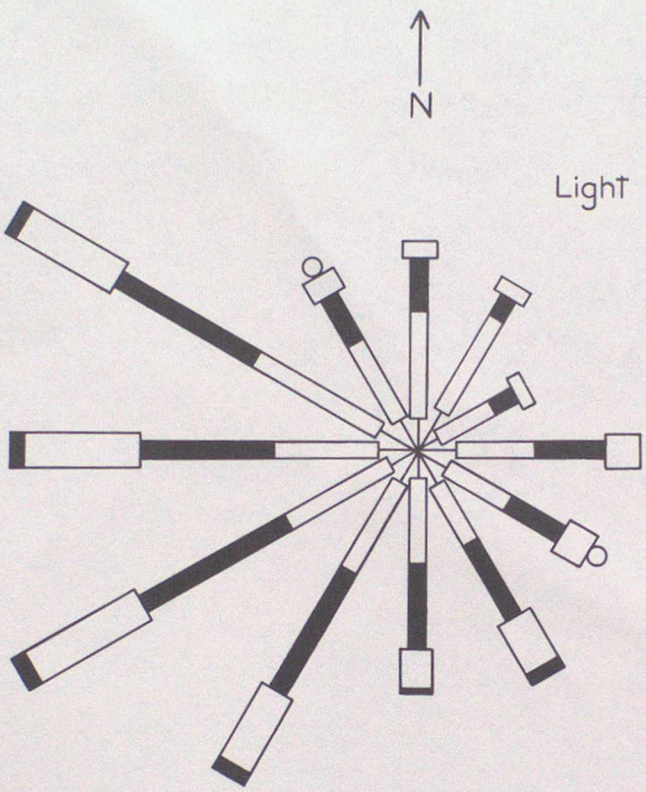
Month	Balfron (1938-51)* 342 ft							
	R	W	S	SL	H	T	F	AF
Jan.	20	17	7.5	8.2	0.8	0.3	1.9	19
Feb.	18	15	4.8	5.9	0.5	0.4	0.9	15
Mar.	17	13	3.9	3.0	1.1	0	2.3	10
Apr.	17	13	0.9	0.1	0.5	0.2	0.2	6
May	15	11	0.5	0	0.2	1.0	0.4	3
Jun.	16	12	0.1	0	0	0.6	0	0
Jul.	18	14	0	0	0	1.6	0.3	0
Aug.	18	14	0	0	0	0.8	0.5	0
Sep.	19	15	0	0	0	0.4	0.5	1
Oct.	20	16	0	0	0.2	0.3	1.4	4
Nov.	21	17	1.0	0.1	0.4	0.4	1.6	9
Dec.	20	16	2.5	2.5	0.3	0	1.9	15
Year	219	173	21.2	19.8	4.0	6.0	11.9	72

*Some breaks 1945 and 1946.

Reference

Dight, F. H. The diurnal range of temperature in Scottish glens Met. Mag. London, 96, 1967 pp. 327-334.

Fig 2. Annual percentage frequency of Geostrophic wind velocities over CUMBERNAULD at 00, 06, 12, 18 h. G.M.T. Sept 1962 - Aug 1965



Scale.

Percentage frequency

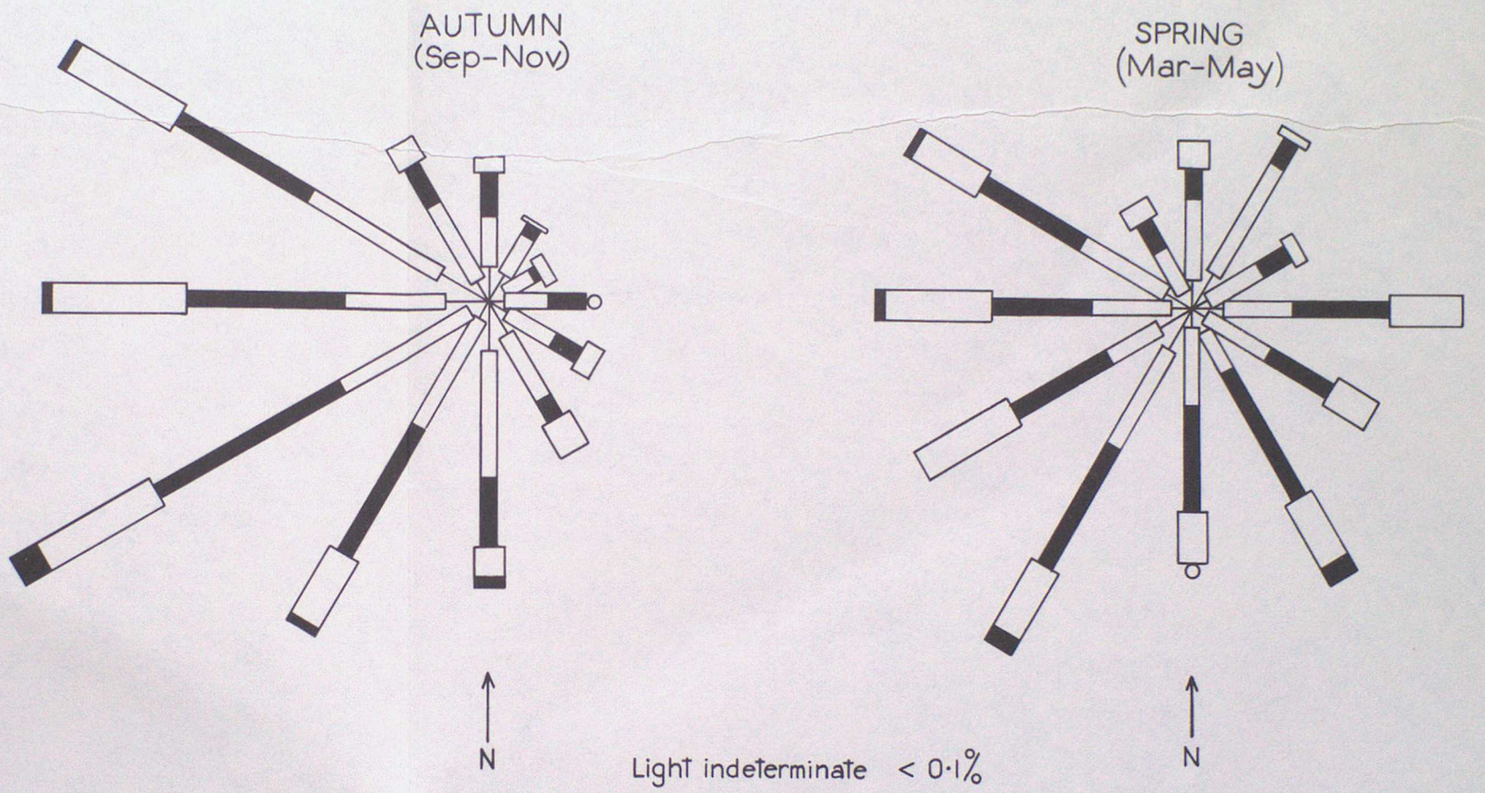
0 1 2 3 4 5 %

O Frequency less than 0·1%

Key.

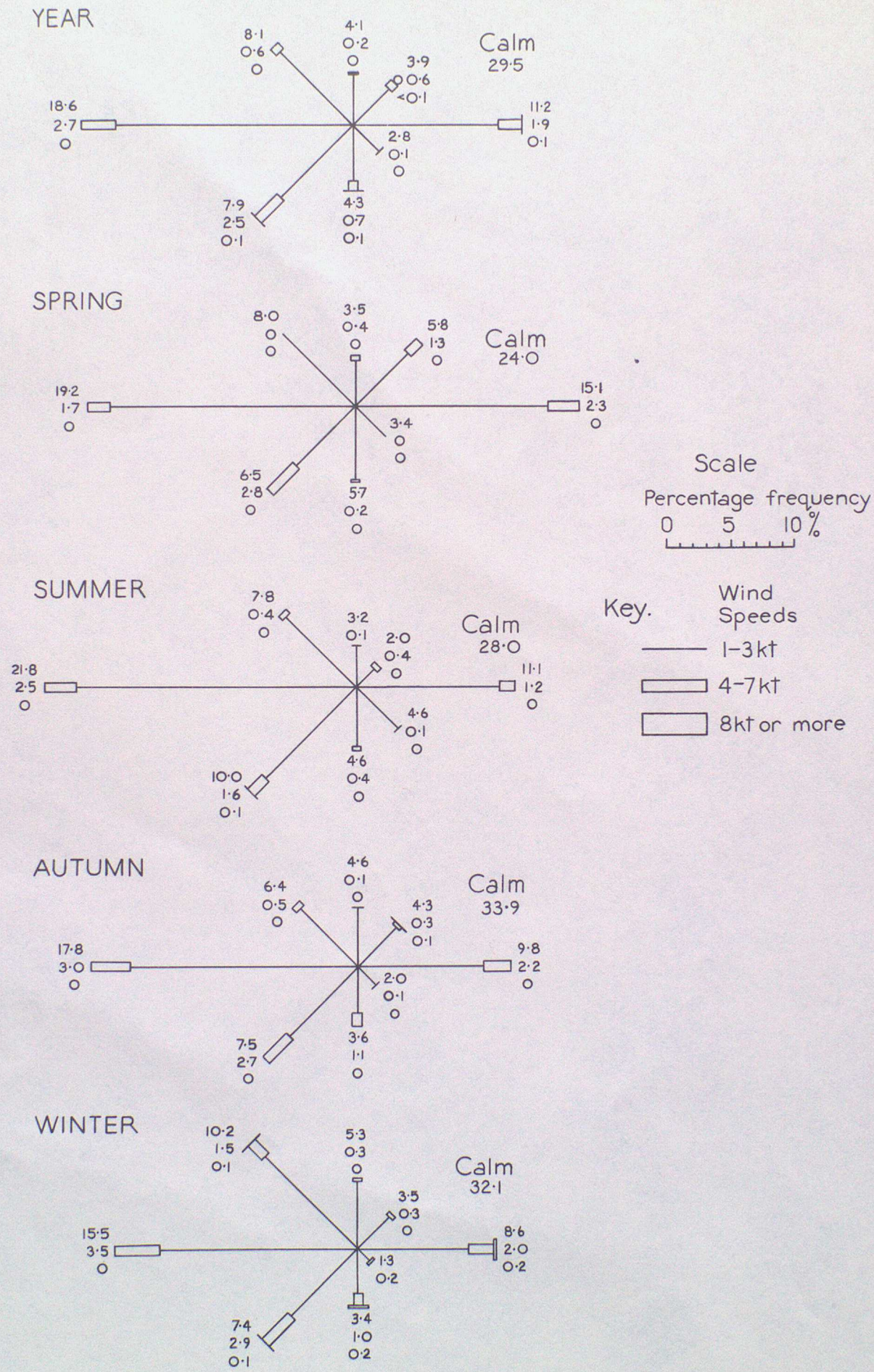
Wind Speeds	
4–10 kt	
11–21 kt	
22–33 kt	
34–55 kt	
over 55 kt	

Fig 3. Seasonal percentage frequency of Geostrophic wind velocities over CUMBERNAULD at 00, 06, 12, 18 h G.M.T.
Sept 1962 to Aug 1965



For Scale and Key see Fig 2

Fig 4. Seasonal percentage frequency of wind velocities at STIRLING (0900h G.M.T.) 1956–1965



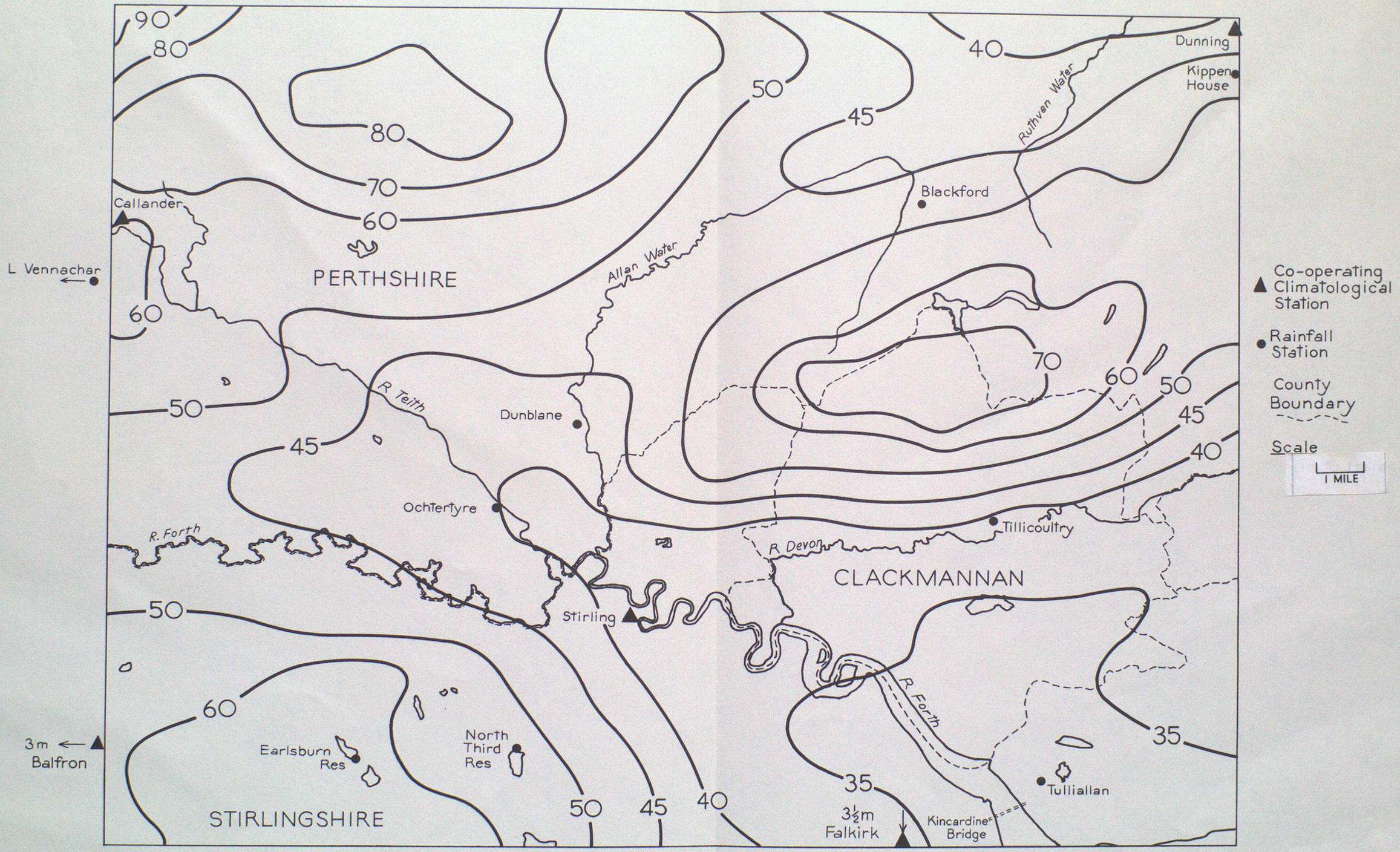


Fig 5. Average Annual Rainfall (inches) 1916-50 over North Stirlingshire, South Perthshire and Clackmannan