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SIMPLE MODELS OF CLIMATE
IN GREAT BRITAIN

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1. Introduction

Research is currently being undertaken by the Institute of Terrestrial Ecology (ITE) on a wide range of problems related to the past, present, and future patterns of land use, and the distribution and dynamics of semi-natural ecosystems and organisms. All of this research requires a better understanding of the influence of climate than is at present available. Indeed, it is, perhaps, little short of astonishing that, in a country with one of the highest densities of climatological recording stations in the world, we should still have so little knowledge of the patterns of variation of climate over Britain.

In part, this lack of knowledge is due to our pre-occupation with meteorological forecasting, but a large part of the blame must also be attached to our obsession with maps and other forms of visual assessment and presentation which has inhibited the analysis and modelling of the information we have taken such pains to collect. It must also be admitted, however, that the mass of available data is itself an obstacle, presenting a somewhat daunting prospect to any would-be analyst. Scientists frequently complain of the difficulties of collecting the necessary information for their research, but, in the field of meteorology and climatology, it has been only too easy to amass data at rates which considerably complicate the analysis and synthesis of information, even with the most modern electronic computers.

One of ITE's research projects, therefore, is concerned with the selection of meteorological variables relevant to the description of climate, the analysis of data from a sample of climatological stations to provide information on the dynamic patterns of variability of climate in time and space, and the synthesis of the results of such analysis in models of climate for Britain. The project is necessarily a long-term one. It has taken several years, for example, to obtain the data required for the analysis in a form in which they can be handled conveniently and rapidly, and to check and validate the individual observations. Although there are many dogmatic assertions about the importance of individual variables, and the ways in which these variables should be combined into indices measuring particular parameters of climatological variation, we have preferred to rely on the internal evidence of the data set in the search for independent dimensions of variation and in the definition and measurement of spatial and temporal variability. Some of the results of this research have already been published by White (1974) and by White and Lindley (1976).

In anticipation of the results of this more extensive project, however, it has been thought useful to derive some simpler models of climate over Britain as a whole, partly to illustrate the kinds of models which are currently being developed, and partly to provide some working models for ongoing research in other fields. The data given by Bibby and Mackney (1969) for 106 climatic stations in Scotland, England and Wales, and Northern Ireland have, therefore, been used as a simple data base for some preliminary models. These data include four primary variables, namely:-

1. Height above mean sea level (feet)
2. Average rainfall (mm), April to September
3. Average potential transpiration (mm), April to September
4. Long-term average of mean daily maximum temperature (°C), April to September

There are obvious limitations to this small set of variables, but there are compensating advantages in working with only a few variables to demonstrate the properties of the models themselves, and in being able to compare the results of the analysis of this data set with the conclusions derived by Bibby and Mackney (1969) on the way in which these particular variables should be used to characterise climate in relation to land use capability classification.

Finally, it is perhaps worth stressing that climatological research in ITE is firmly based on the philosophy of systems analysis. In essence, we can summarise that philosophy by four statements, although these statements will themselves be an oversimplification. First, we are as much interested in the variability of climate in space and time as in its stability and average tendencies. Second, if we are to understand the variability of the system and its complex interactions with other systems, we will need to work through mathematical models of varying degrees of complexity. Third, it will be necessary to develop several (and perhaps many) alternative models before we can decide which (if any) of those models are most

appropriate for the solution of any particular problem. Fourth, in the development of any one model, there will necessarily be many iterative stages as the model is slowly improved and validated.
This paper presents a range of alternative approaches to the derivation of simple mathematical models of climate in Britain, as a starting point for further development and refinement of such models.

2. A classification model of climate

One possible approach to the modelling of climate in Britain is to regard the 106 climatic stations as a sample of the total population of possible climates, and to construct a classification of these climates. The disadvantage of this approach is that these 106 stations almost certainly do not provide an unbiased sample of the total population of climates - the more extreme climates are likely to be under-represented because of the difficulty of establishing stations in such localities. Nevertheless, if we can assume that the recording stations broadly cover the range of climates, then a classification of the stations may reveal groupings which can be extended to the assessment of other sites.

Our data base provides four variables for each of the 106 climatic stations, namely elevation, rainfall, potential evapotranspiration, and temperature, and these data may be subjected to some form of cluster analysis to identify discontinuities in the distribution of the climatic stations in multivariate space. The range of cluster analysis techniques currently available is now extensive: see, for example, Fisher and Van Ness (1971), Cormack (1971), Anderberg (1973), and Clifford and Stephenson (1975). The method used in this paper is one of the simplest, and is based on a principal component analysis of the four variables (Kendall, 1957), followed by a modification of the minimum spanning tree of Gower and Ross (1969). This represents, effectively, a single-linkage cluster analysis on the four variables, reduced to the smallest possible number of dimensions necessary to describe the variation contained by the variables. Any alternative method of the reader's choice can be tried for comparison.

The values of the four basic variables for the 106 climatological stations are summarised in Table 1, and the correlations between these variables are given in Table 2. All of the correlations are highly significant by the criterion of the usual test for product-moment correlation coefficients (a test of doubtful validity in this context!); elevation and rainfall, and potential transpiration and temperature are positively correlated, but elevation and rainfall are both negatively correlated with potential transpiration and temperature.

Table 1. Summary of basic variables for the 106 climatological stations

Variable	Minimum	Mean	Maximum	Standard deviation
Elevation	7	358.7	2377	438.2
Rainfall	251.5	454.5	1112.3	171.4
Potential transpiration	318.5	423.6	486.4	35.27
Temperature	9.9	16.25	19.6	1.64

Table 2. Coefficients of correlations between basic variables

Elevation			
0.499	Rainfall		
-0.547	-0.465	Pot. transp.	
-0.542	-0.498	0.704	Temperature

The principal components of the correlation matrix of Table 2 are summarized in Table 3. The first component, accounting for 65.8 per cent of the total variability described by the four variables, is a weighted average giving roughly equal weight to all four variables, but contrasting elevation and rainfall with potential transpiration and temperature. We may regard this component as a general index of exposure. The second component, accounting for a further 14.8 per cent of the variability, is very largely a measure of rainfall, though with small positive weightings on the other three variables. The third component, accounting for a further 12 per cent of the variability is almost entirely a measure of elevation, stations with a high elevation having large positive values of this component, only slightly modified by rainfall and by potential transpiration and temperature. The last component, accounting for only 7.4 per cent of the variability, is almost entirely a contrast between potential transpiration and temperature, but should probably be regarded as residual "noise" in the four-dimensional system.

Table 3. Principal component analysis of climatic variables

Variable	Component I	Component II	Component III	Component IV
Elevation	0.929	0.221	1.000	0.067
Rainfall	0.871	1.000	-0.488	-0.109
Pot. transp.	-0.990	0.595	0.195	0.977
Temperature	-1.000	0.487	0.311	-1.000
Percentage of total variability	65.8	14.8	12.0	7.4

The first two components account for just over 80 per cent of the total variability described by the four original variables, and we may reasonably confine our classification to the two-dimensional space defined by these components. The third component is mainly a measure of elevation, which is not strictly a meteorological variable and has, in any case, already been incorporated in the first component, while the fourth component is relatively insignificant. As has been confirmed by further investigation, inclusion of the third component has very little effect on the subsequent classification. It is interesting to note that none of the functions defined by the analysis represent the difference between rainfall and potential transpiration used by Bibby and Mackney as the basis for their climate classification, unless we regard this difference as a relatively inefficient (in the sense that it does not use all the variables) measure of the first component.

The computed values of the first two components are plotted in Figure 1. The climatological stations show a wide range of variation in the second component when the values of the first component are high, but, as the value of the first component decreases, the variability of the second component also decreases.

Single linkage cluster analysis of the 106 climatological stations, based on the first two components, gives eight main groups of stations, each of which is further subdivided into secondary classifications. The eight groups are shown in Table 4, and the projection of these groups on the first two components in Figure 2. The first cluster represents exposed sites with a complete range of rainfall from very low to very high. The next three

Table 4. **Cluster analysis of the climatological stations, based on the first two components of the correlation matrix**

Cluster Number	Climatological Stations
1 Exposed sites	Achnashellach, Helmshore, Hawkeridge, Buxton, Eskdalemuir Sourhope, Alwen, Bwlchgwyn, Onecote Braemar, Glenmore Lodge Leadhills, Malham Tarn Lowther Hill, Moor House, Princetown, Blaenau Ffestioniog
2 Moderately exposed Low rainfall	Benbecula, Tiree Dumfries, Bradford, Little Rissington Marchmont, Strathy, Ushaw Dyce, Rattray Head, Stornaway, Wick Cape Wrath, Carnwath, Fettercairn, Huntly
3 Moderately exposed Average rainfall	Colonsay, Chapel-en-Frith, Douglas, Llandrindod Wells Glenlee, Keswick
4 Moderately exposed High rainfall	Fort William, Glenbranter, Kinlochewe, Onich Darwen, Rochdale
5 Moderately sheltered Low rainfall	Arbroath, Fortrose, Blairgowrie, Leuchars, Lossiemouth, Kinloss, Nairn, North Berwick Perth Turnhouse Pitlochry, Tynemouth Cupas, Forres, Kelso, Durham, Belfast
6 Moderately sheltered Average rainfall	Colmonell, Kilmarnock, Aberystwyth, Burnley, Macclesfield Prestwick, Huddersfield, Lyonshall, Upavon, Valley Falkirk, Renfrew
7 Sheltered	Birmingham, Blackpool, Lyneham Cleethorpes, Coventry, Exmouth, Long Ashton, Lowestoft Norwich, Nottingham, Penzance, Shrewsbury, York Cardiff, Newport
8 Very sheltered	Bath, Eastbourne, Tunbridge Wells Brighton, Cranwell, Hastings, Oxford, Reading Cambridge, Clacton, Dungeness, Margate Kew, Portsmouth, Southend Weymouth, Worthing

clusters represent stations with moderate exposure, but at low, medium and high levels of rainfall, respectively. The next two clusters represent moderately sheltered sites with low and moderate rainfall, and the following two clusters represent sites with progressively more shelter.

From subjective assessment of the climatological stations, the classification does not seem unreasonable. It is, however, interesting to compare it with the rather simpler classification produced by Bibby and Mackney, who only distinguished three classes. Their groups 2 and 3 correspond very roughly to the first four groups of the cluster analysis, but the cluster analysis gives a much finer series of subdivisions of Bibby and Mackney's group 1. It seems fair to assess that the cluster analysis has provided a more detailed and a more precise grouping of the climatological stations, and that the components might be used to allocate other locations to similar classes. For example, the components could be used as the basis for a simple discriminant model for climate in Great Britain, by allocating individual localities to broad climatic groupings.

3. A discriminant model of climate

An alternative approach to the modelling of climate, and one which follows logically from the classification model of the previous section, is to identify the climate of any new locality with *a priori* groupings of existing climatic stations. If we have any theoretical basis for our *a priori* groupings, we can, indeed, test the ability of our data base to support such discrimination, using the now well-established technique of discriminant analysis (Marriott, 1974; Harris, 1974; Lachenbruch, 1975). Where the groupings are derived by analysis rather than *a priori*, the formal calculation of discriminant function is not usually necessary, but can be derived directly from the clustering algorithm.

For example, the allocation to the eight climatic types distinguished by the cluster analysis can be affected by evaluating the two basic linear functions:-

$$C1 = 0.490 \left(\frac{E - 358.8}{438.2}\right) + 0.459 \left(\frac{R - 454.5}{171.4}\right) - 0.522 \left(\frac{P - 423.6}{35.27}\right) - 0.527 \left(\frac{T - 16.25}{1.64}\right)$$

$$C2 = 0.174 \left(\frac{E - 358.8}{438.2}\right) + 0.780 \left(\frac{R - 454.5}{171.4}\right) + \left(\frac{P - 423.6}{35.27}\right) + 0.381 \left(\frac{T - 16.25}{1.64}\right)$$

where E is the elevation in feet above mean sea level

R is the average rainfall in millimetres (April to September)

P is the average potential transpiration in millimetres (April-Sept)

T is the long-term mean daily maximum temperature (April-Sept)

The suggested limits of the eight climatic types are indicated in Figure 3, being a slightly modified version of the groupings derived from Figure 2.

4. Trend surface model of climate

The allocation of new locations to pre-established clusters of climatic stations gives only the simplest possible model of climatic variation in Britain, although it does provide indications of affinities of the location with known climatic stations. As, however, the national grid reference for each of the 106 climatic stations was known, it is possible to relate the original variables, or, alternatively, the principal components of these variables, to geographical location by the use of trend surface plotting. This technique has been described by Merriam and Harbaugh (1964) as a method of studying the relationship between large-scale regional features and small-scale residual features of spatially distributed variables. An application to ecological data is given by Gittins (1969) and some of the theoretical and practical difficulties of the method are summarised by Unwin and Hepple (1974).

The cumulative proportions of the variability accounted for by the linear, quadratic, and cubic trend surfaces of the four basic variables and the first two principal components of the correlations between these variables are summarised in Table 5. For all the variables and components, except temperature, the quadratic components of the trend surfaces were significant or appreciable, but for temperature only the linear component of the trend surface was significant. It is notable, however, that the trend surfaces accounted for very different amounts of variability for the four different variables. Elevation, as might be expected, was not well-related to the grid references of the climatic stations, and the quadratic trend surface accounted for 18.1 per cent of the total variability. The quadratic trend surface accounted for 31.0 and 42.4 per cent of the variability in rainfall and temperature respectively, but was most successful in the case of potential transpiration, where it accounted for 62.5 per cent. For the two principal components, the quadratic trend surface accounted for 37.3 per cent of the first component and 41.6 per cent of the second component, and it is interesting that, although the second component is mainly an expression of rainfall, the quadratic trend surface accounts for very much more of the variability of the second component than for rainfall alone.

The trend surfaces for rainfall, potential transpiration and temperature are plotted in Figures 4, 5 and 6 respectively, where a dot indicates the sea, and a digit or blank indicates the land area. The trend surface for rainfall shows the highest concentration in the Outer Hebrides and then decreases progressively through west Wales and Scotland, the driest area being in East Anglia and Kent. The trend surface for potential transpiration shows the highest levels in Kent and then progressively lower values towards north and east Scotland, with moderately high values breaking out in the Outer Hebrides and western islands. Temperature shows a simple linear trend, with higher temperatures in the south east and lower temperatures towards the north west of Britain

Table 5. Cumulative proportions of variability accounted for by linear, quadratic and cubic trend surfaces

Variable	Cumulative proportions of total variability		
	Linear	Quadratic	Cubic
Elevation	0.0192	0.1807	0.1974
Rainfall	0.2620	0.3098	0.3499
Potential transpiration	0.4819	0.6252	0.6406
Temperature	0.4108	0.4236	0.4432
Component 1	0.2902	0.3729	0.3852
Component 2	0.3415	0.4159	0.4442

The trend surfaces for the two components are plotted in Figures 7 and 8 respectively. The first component, representing exposure and increasing altitude shows a marked trend towards maximum values in Scotland and northern England, with gradually decreasing values towards the south east of England. The second component runs almost at right angles to the first, with high values on the western seaboard and particularly on the south west of Britain, and decreasing values towards the north east.

The calculation suggests that something between two-thirds and two-fifths of the variability in the main dimensions of climate measured by the four variables can be accounted for by the grid references of the localities of the individual sites. The remaining variation is accounted for by local differences. Bearing in mind that the two components themselves account for 80 per cent of the variability contained by the four original variables, the broad regional trends which are shown by the trend surfaces are of some interest. It is also useful to compare these trend surfaces, either for the individual variables, or for the components, with the more usual maps of climatic variation, as, for example, those given as templates in the Botanical Atlas of the British Isles (Perring and Walters, 1962). For one thing, it is doubtful, from present evidence, that the irregularities shown in the climatic maps are really justified. The human brain, informed by the eye, is perhaps the most efficient computer yet designed for detecting pattern, but it also has the sometimes unfortunate characteristic of detecting more pattern than is justified by the facts. The trend surface analysis suggests that no significant further information is added by including cubic terms in the regression, although it is possible that other forms of trend surface, not based on polynomials, might provide a closer fit to the climatic variables.

5. Regression model of climate

An alternative model of the spatial pattern of climate can be derived from the regression of average rainfall, average potential transpiration, and the long-term average of mean daily maximum temperature on the co-ordinates of the grid references of the climatic stations and the elevations of the stations. Starting with the regression of each of the three primary variables on the linear, quadratic, and linear interaction terms of the grid reference co-ordinates, it is relatively simple to test the significance of adding the linear and quadratic terms of elevation, and the linear interactions of elevations with the grid reference co-ordinates. The analyses of variance for these regressions are summarised in Table 6 and the resulting regression equations are given in Table 7.

The regression of average rainfall on the linear, quadratic, and linear interaction terms of the national Grid co-ordinates, and the linear term of elevation, accounts for 51.0 per cent of the variability of average

Table 6. Analysis of variance for regressions of rainfall, potential transpiration, and temperature on grid reference co-ordinates and elevation

Average rainfall

Source of variation	df	Sum of squares	Mean square	F-value
Regression on grid co-ordinates	5	955 782.2	191 156.44	8.98***
Residual	100	2 129 596.0	21 295.96	
Elevation	1	618 423.0	618 423.00	40.51***
Residual	99	1 511 173.0	15 264.38	
$(\text{Elevation})^2$	1	3 841.0	3 841.0	
Residual	98	1 507 332.0	15 380.94	
Elevation x co-ordinates	2	43 399.0	21 699.50	1.42
Residual	96	1 463 933.0	15 249.30	

Potential transpiration

Source of variation	df	Sum of squares	Mean square	F-value
Regression on co-ordinates	5	81 661.09	16 332.22	33.35***
Residual	100	48 975.00	489.75	
Elevation	1	28 754.38	28 754.38	140.78***
Residual	99	20 220.62	204.25	
$(\text{Elevation})^2$	1	1 823.88	1 823.88	9.72**
Residual	98	18 396.74	187.82	
Elevation x co-ordinates	2	1 957.29	978.65	5.72**
Residual	96	16 439.45	171.24	

Table 6 (continued)

Temperature

Source of variation	df	Sum of squares	Mean square	F-value
Regression on grid co-ordinates	5	119.8283	23.965660	14.70***
Residual	100	163.0765	1.630765	
Elevation	1	99.5565	99.556500	155.17***
Residual	99	63.5200	0.641616	
$(\text{Elevation})^2$	1	5.7057	5.705700	9.67**
Residual	98	57.8143	0.589941	
Elevation x co-ordinates	2	1.4639	0.731950	1.25
Residual	96	56.3504	0.586984	

Table 7. Regression equations for rainfall, potential transpiration and temperature

$$R = 532.12 - 0.082X_1 + 0.064X_2 + 5.905X_1^2.10^{-6} - 3.623X_2^2.10^{-6} - 8.762X_1.X_2.10^{-6}$$
$$+ 0.1935E$$

$$P = 475.41 - 2.670X_1.10^{-3} - 3.905X_2.10^{-3} + 1.124X_1^2.10^{-6} - 3.741X_2^2.10^{-8}$$
$$- 1.22X_1X_2.10^{-6} - 0.08301E + 2.079E^2.10^{-5} + 8.729X_1.E.10^{-6}$$
$$- 4.307X\ .E.10^{-6}$$

$$T = 13.935 + 1.801X_1.10^{-3} + 2.789X_2.10^{-4} - 1.749X_1^2.10^{-7} - 3.938X_2^2.10^{-8}$$
$$- 7.452X_1.X_2.10^{-8} - 1.102E.10^{-3} - 8.200E^2.10^{-7}$$

where R = average rainfall in mm (April - September)

P = average potential transpiration in mm (April - September)

T = long-term average of mean daily maximum temperature in °C (April - September)

X_1 = Easting of national grid co-ordinates

X_2 = Northing of national grid co-ordinates

E = height above mean sea level in feet

rainfall, with a standard deviation from regression of 123.55 mm. Addition of the quadratic term for elevation and the linear interactions between elevation and the grid co-ordinates gives no significant improvement in the predictive capability of the equation. The trend of average rainfall at sea level with variations in the grid co-ordinates is given in Figure 9.

The regression of average potential transpiration on the grid co-ordinates and elevation is considerably more complex; in addition to the quadratic and linear interaction terms of the grid co-ordinates, the linear and quadratic terms of elevation, and the linear interactions of elevation and the grid co-ordinates are all significant. The regression equation accounts for 87.4 per cent of the total variability in potential transpiration with a standard deviation from regression of 13.1 mm. The general trends of average potential transpiration with the grid co-ordinates at both sea level and an elevation of 1000 ft are given in Figure 10.

The regression of the long-term average of mean daily maximum temperature includes the quadratic and linear interaction terms of the grid co-ordinates, and the linear and quadratic terms of elevation. This equation accounts for 79.6 per cent of the total variability of mean daily maximum temperature, with a standard deviation from regression of 0.768°C. The general trends of mean daily maximum temperature with the grid co-ordinates at sea level and an elevation of 1000 ft are given in Figures 11 and 12 respectively.

Consideration of such regression equations, however, is never complete without some further examination of the residual deviations from regression. Figures 13, 14 and 15 give the geographical distributions of the positive and negative deviations from the regressions for rainfall, potential transpiration, and temperature respectively. No marked "clumping" of positive or negative deviations is apparent, but the human eye is easily misled by such representations, and a more powerful test of the extent to which there is spatial autocorrelation among residuals from fitted regressions is given by Geary's contiguity ratio (Geary, 1954; Jeffers, 1973). Table 8 gives the calculated values of the contiguity ratio before and after fitting the regressions obtained by linking each climatic station to its closest neighbours. The standard error of the contiguity ratio C depends partly upon the total number of stations and partly upon the number of connections with neighbouring stations. For these data, the standard error is approximately 0.072, and the ratio

$$R = \frac{1 - C}{SE(C)}$$

may be regarded as a standard normal deviate.

Table 8. Contiguity ratios (C) before and after fitting regressions

Variable	Before fitting C	Before fitting R	Residuals C	Residuals R
Rainfall	0.66	4.65***	0.92	1.13
Potential transpiration	0.39	8.90***	0.86	1.89
Temperature	0.58	5.80***	0.79	2.92**

The results confirm that there is highly significant ($P < 0.001$) spatial autocorrelation in the values of rainfall, potential transpiration, and temperature for the 106 climatic stations before fitting the regressions. The residuals from the fitted regressions have no significant spatial autocorrelation for rainfall and potential transpiration, but retain significant ($P < 0.01$) spatial autocorrelation for temperature.

Re-examination of Figure 15 suggests that, in contrast to Figures 13 and 14, there is some considerable spatial "clumping" of positive and negative deviations. The positive deviations are concentrated around the inland stations in Scotland and in a broad belt across East Anglia and the southern midlands, with outliers around the NE Scottish border and in Cornwall. The negative deviations are concentrated on the east and west Scottish coasts, across the whole of northern England and along the south coast of England. No clear reason for this spatial grouping of the residuals has so far been advanced, but further investigations are currently proceeding.

Discussion

This paper has attempted to construct four different kinds of models (i.e. classification, discriminant, trend surface, and regression models) of climate over Britain from a data base of four variables derived from 106 climatic stations. Because the four models all use the same data base, they are obviously not independent, but the purposes of the models differ markedly, and these purposes are dictated by the various ecological projects of ITE. For example, sampling within the upland land use project will depend upon our ability to discriminate between broad climatic types, while much of the work on productivity and alternative sources of energy will depend upon our ability to predict the variation in climate for a wide range of geographical localities and site factors.

The main data base with which we are currently working is, of course, much larger, and represents 33 variables from 73 climatic stations for the period 1960-1969 inclusive. The problems of handling a data set of this magnitude are considerable, even with the aid of computers, but the underlying models of the main project do not differ in their fundamental concepts, except by the introduction of variation in the additional dimension of time - a feature which is notably lacking in the simple models described in this paper. We also expect to follow up the current analyses by an investigation of the same variables for the period 1970-1979, when these are available.

Simple though the models described in this paper are, it should not be imagined that they are therefore of little practical use to the ecologist. The ability to discriminate between preassigned climatic groups helps the ecologist to characterize sites included in his surveys quickly and economically, and provides a consistent basis for the stratification of field sampling. Similarly, the trend surface analysis of the original variables, or any combination of these variables, helps the understanding of the spatial and temporal variation of climate in Britain, and, especially where interactive computing systems are available, enables the research scientist to experiment with many different interpretations.

It is, however, perhaps with the regression models that further development of the study of spatial and temporal variation of climate will most aid ecology. It is, for example, readily easy to convert the values of rainfall, potential transpiration, and temperature given by the equations of Table 7 to estimates of net primary productivity, using the relationships suggested by Lieth (1975). The separate estimates may then be examined to determine the factors likely to be limiting to forestry and agriculture, as a basis for studies of land use planning, but the results of this analysis will be presented in a later paper.

Finally, it is interesting to compare the results of these analyses with those obtained by Bibby and Mackney (1969), who came to the conclusion (correctly from the analysis of this paper) that it is not easy to divide Britain into climatic regions, and emphasised the establishment of an inventory rather than a classification of climate. They derived three climatic groups, defined as follows:-

Group I, for which R - P <100 mm and T $>15^{o}$C and there are no, or only slight, climatic limitations imposed on crop growth.

Group II, for which R - P <300 mm and T $>14^{o}$C, but excluding Group I, suffering from a moderately unfavourable climate which restricts the choice of crops.

Group III, for which R - P >300 mm or T$<14^{o}$C, having a moderately severe to extremely severe climate which further limits the range of crops.

These climatic groups were then combined with other characteristics including gradient, soil texture and wetness, elevation, and erosion, to define seven land use capability classes.

The first of the two criteria used by Bibby and Mackney is broadly similar to the first component of the principal component analysis - a measure of exposure. The second criterion, however, ignores the strong correlation between temperature and potential transpiration. The component analysis suggests that rainfall is a much more important variable than potential transpiration and is almost orthogonal to the axis of the first component. The resulting classification gives considerably more detail, as can be judged by the great mass of points which fall in Group I in their diagrammatic presentation of the climate classification. Both classifications discriminate between the extreme climates, but that based on the more rigorous analysis gives better discrimination among the less extreme climates.

Clearly much more analysis of climatic data needs to be done in the future, if the ecologist is to use climate as a factor in improving his understanding of the factors determining the structure, composition and processes of terrestrial ecological systems and the abundance and performance of individual species and organisms. What is perhaps less frequently emphasised is that the statistical methods do not necessarily have to be complex to provide a sounder basis than is presently available for predicting and modelling environmental trends, permitting a more critical assessment of the need for specific measures to protect and manage the environment.

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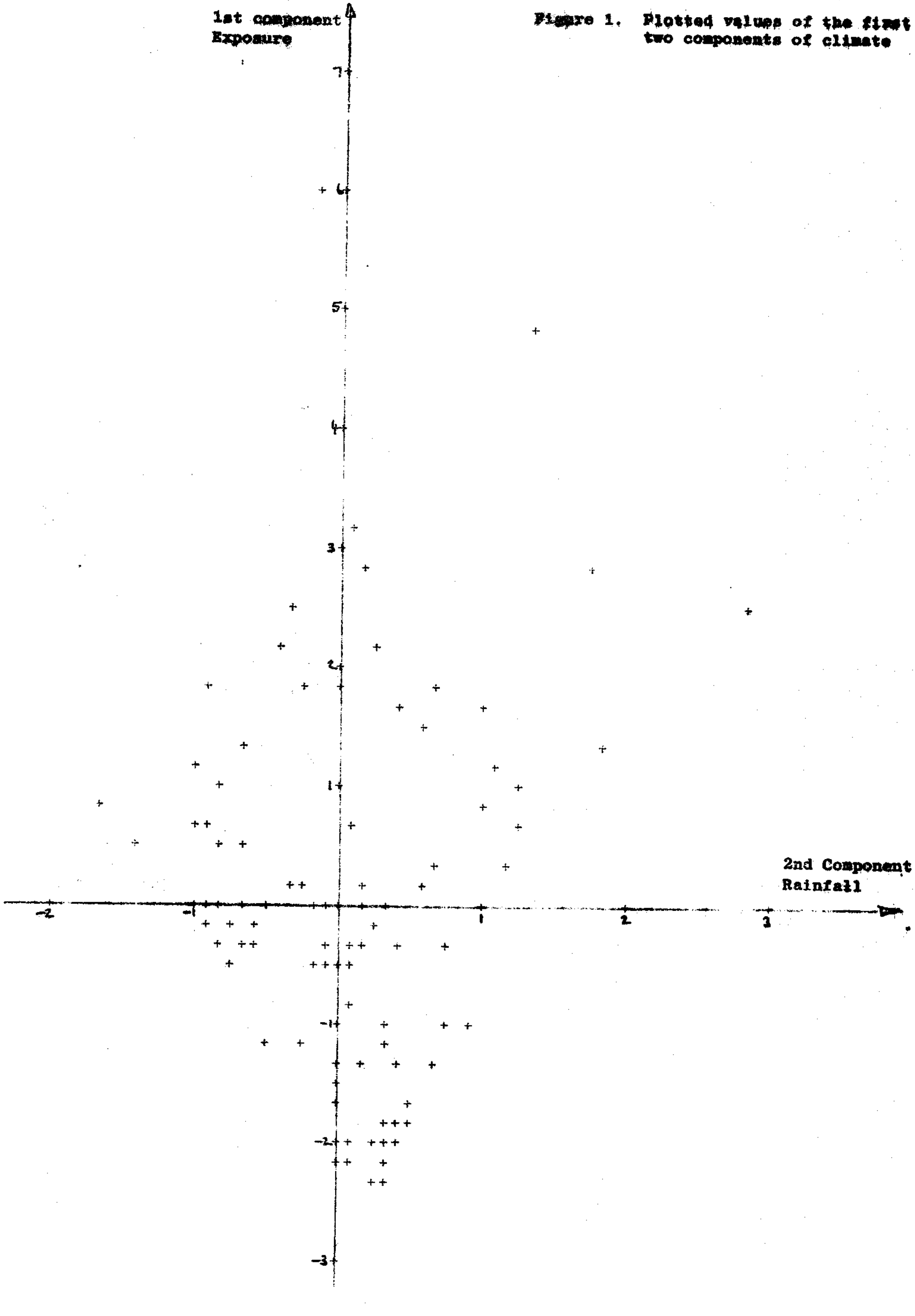

Figure 1. Plotted values of the first two components of climate

Figure 2. Cluster analysis groupings of climatological stations

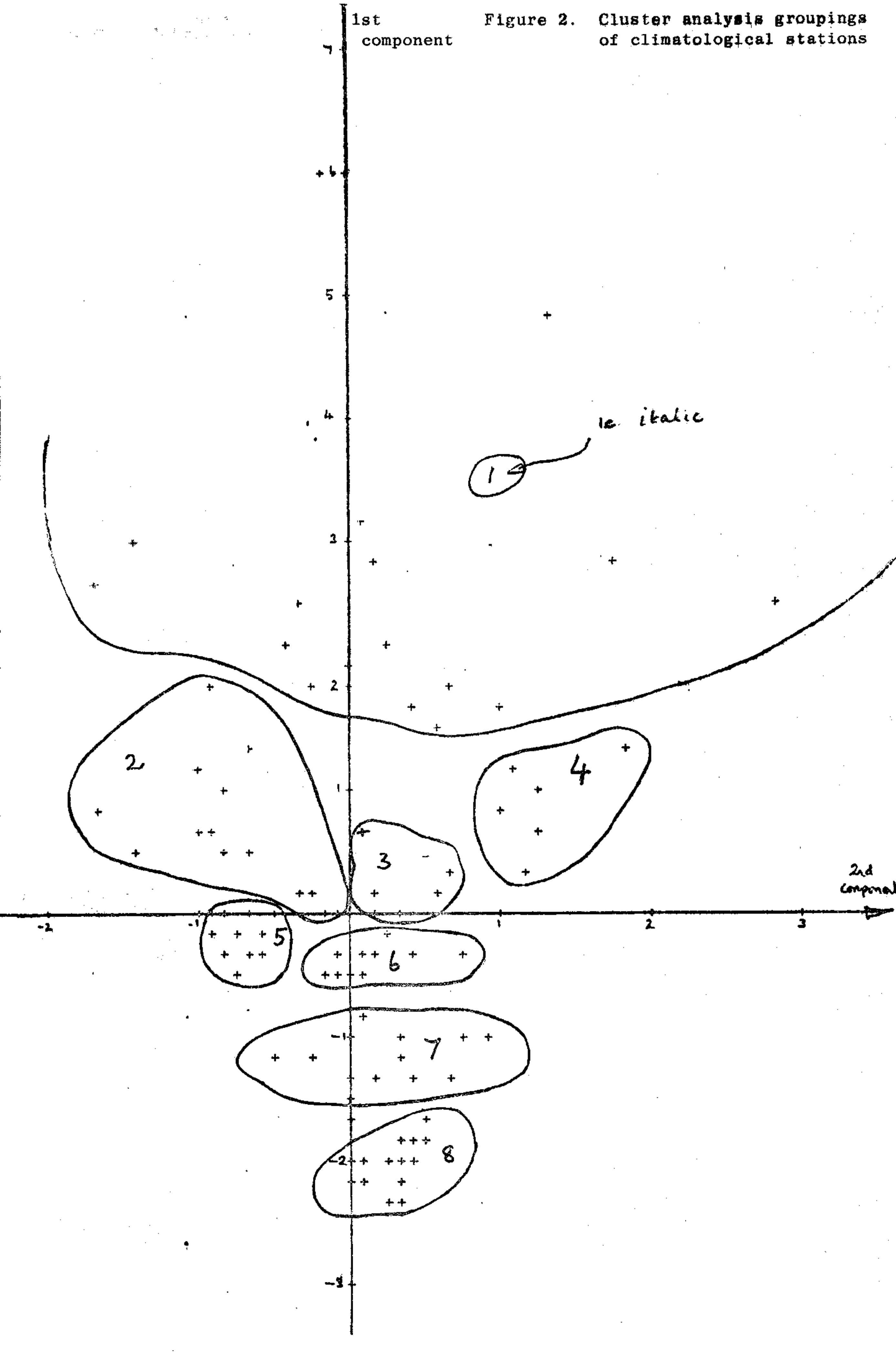

Figure 3. Discrimination of climatic groups

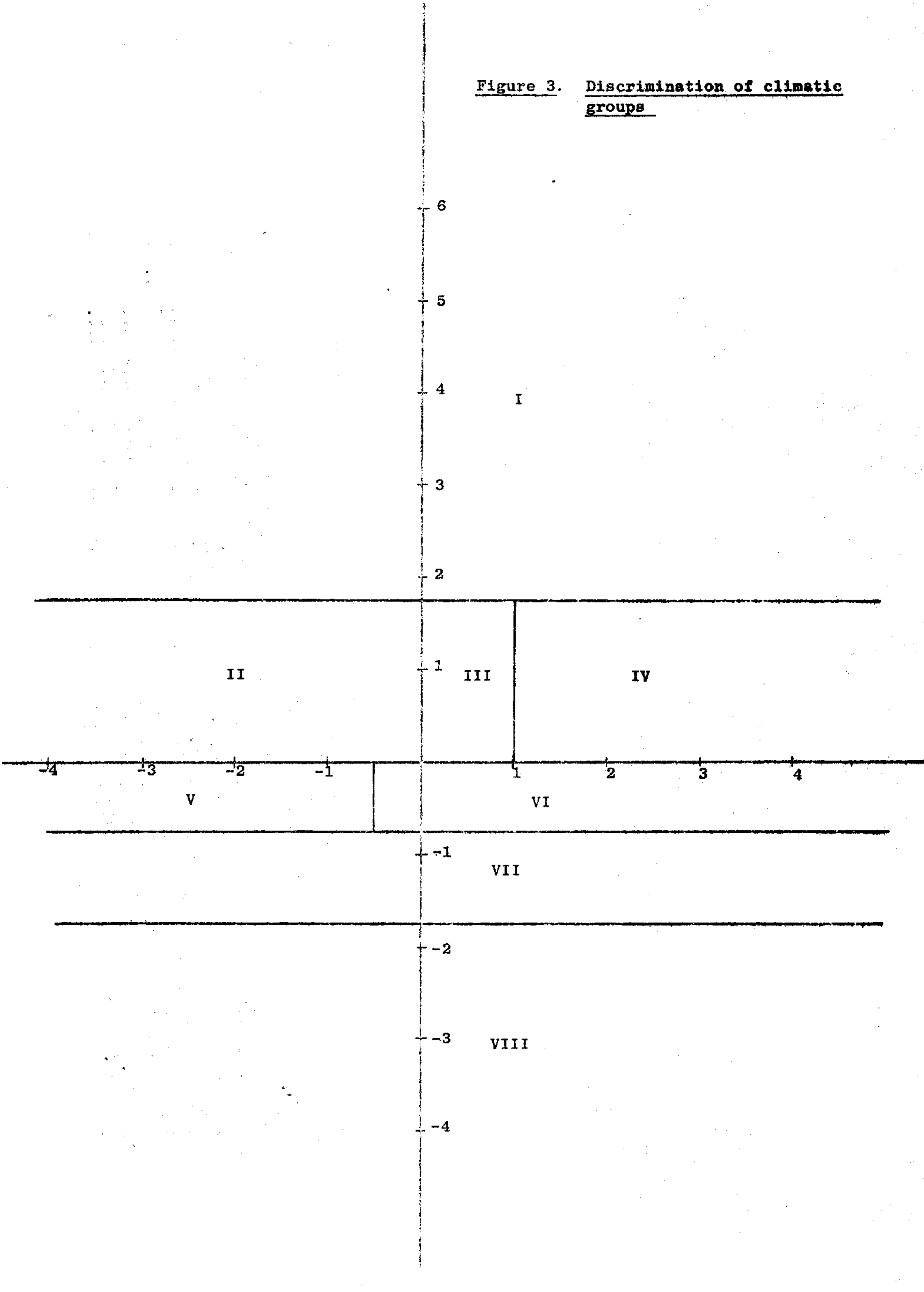

Figure 4. Quadratic trend surface for rainfall

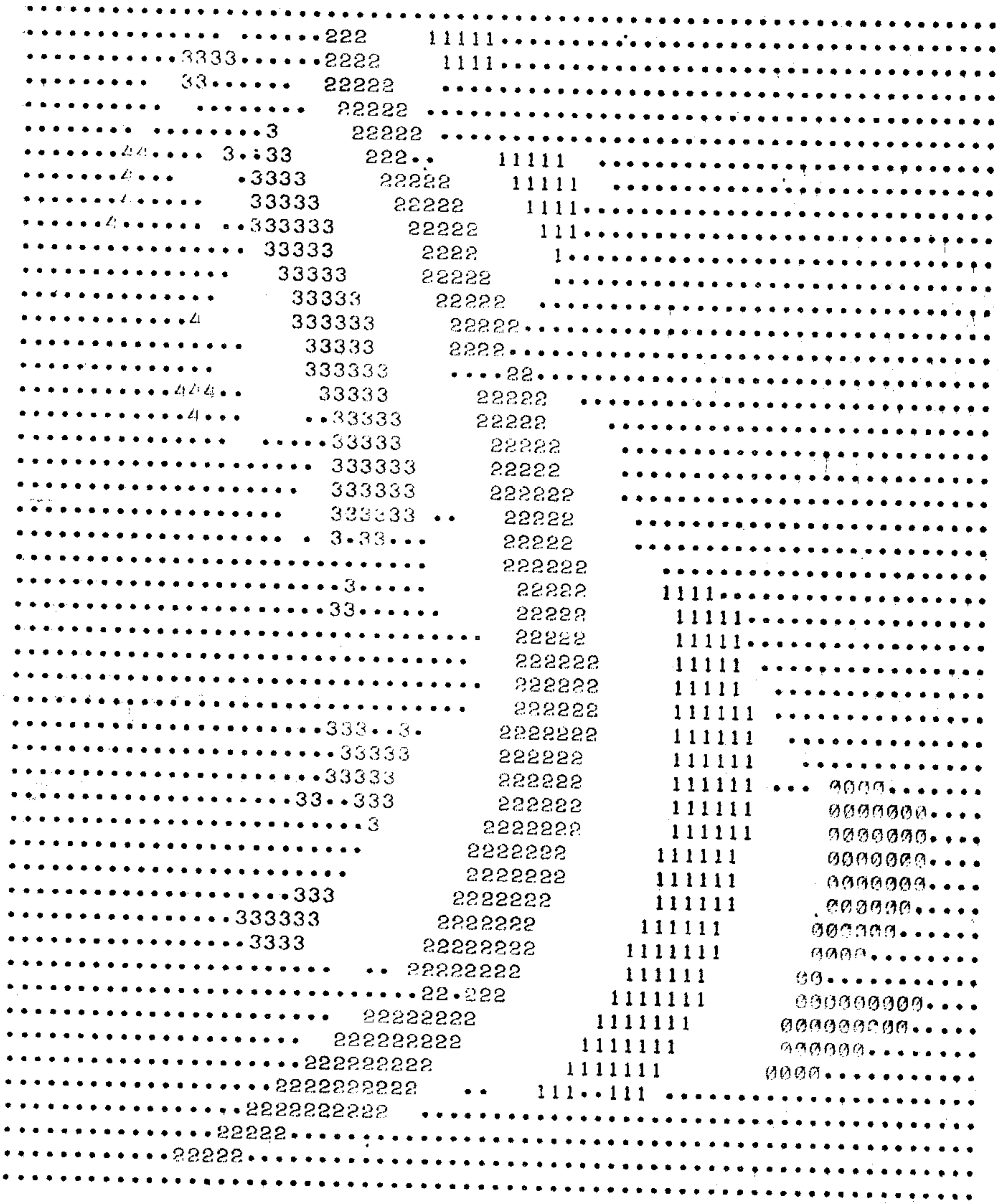

Figure 5. Quadratic trend surface for potential transpiration

Figure 6. Linear trend surface for temperature

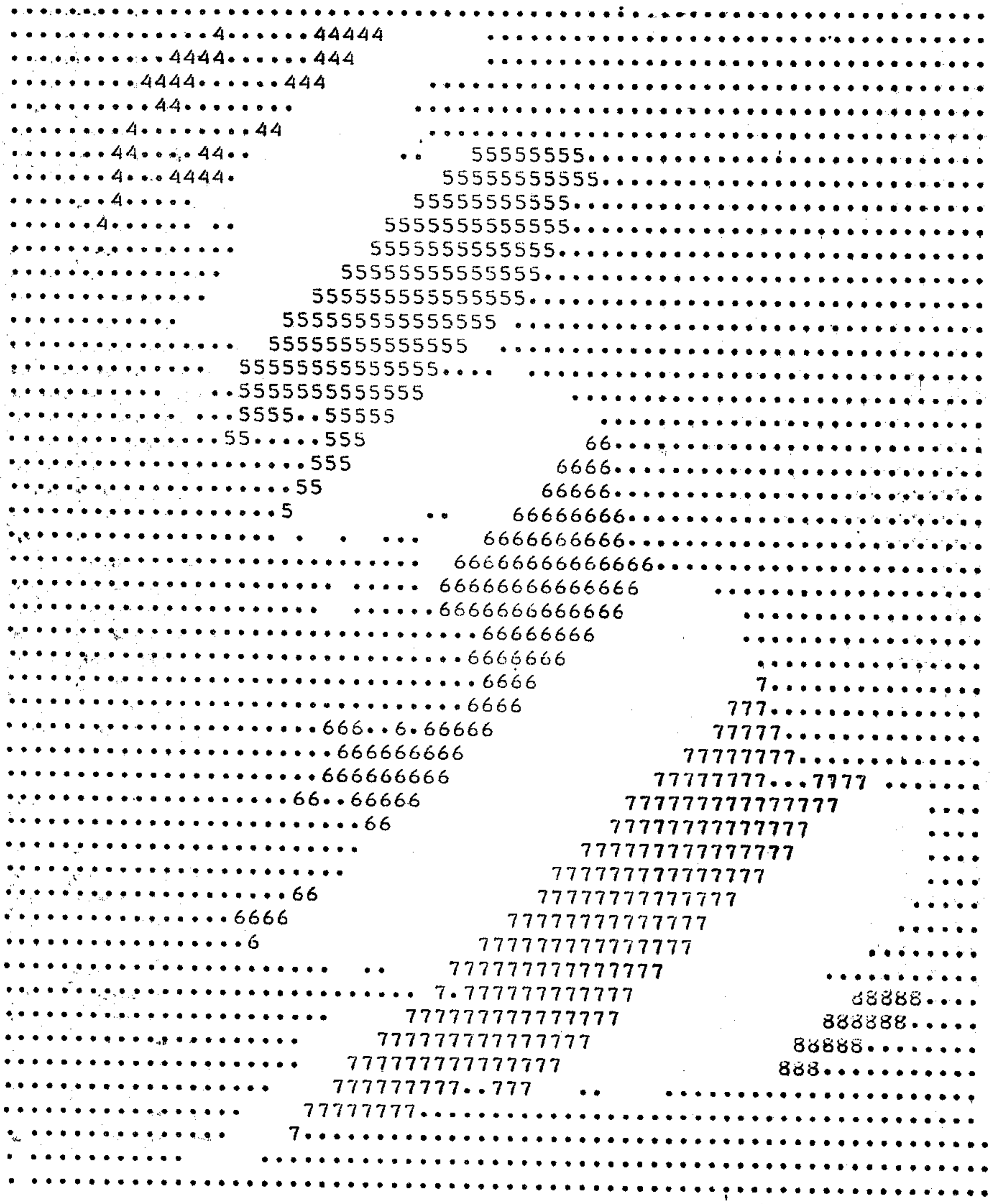

Figure 7. Quadratic trend surface of the first climatic components

Figure 8. Quadratic trend surface of the second climatic component

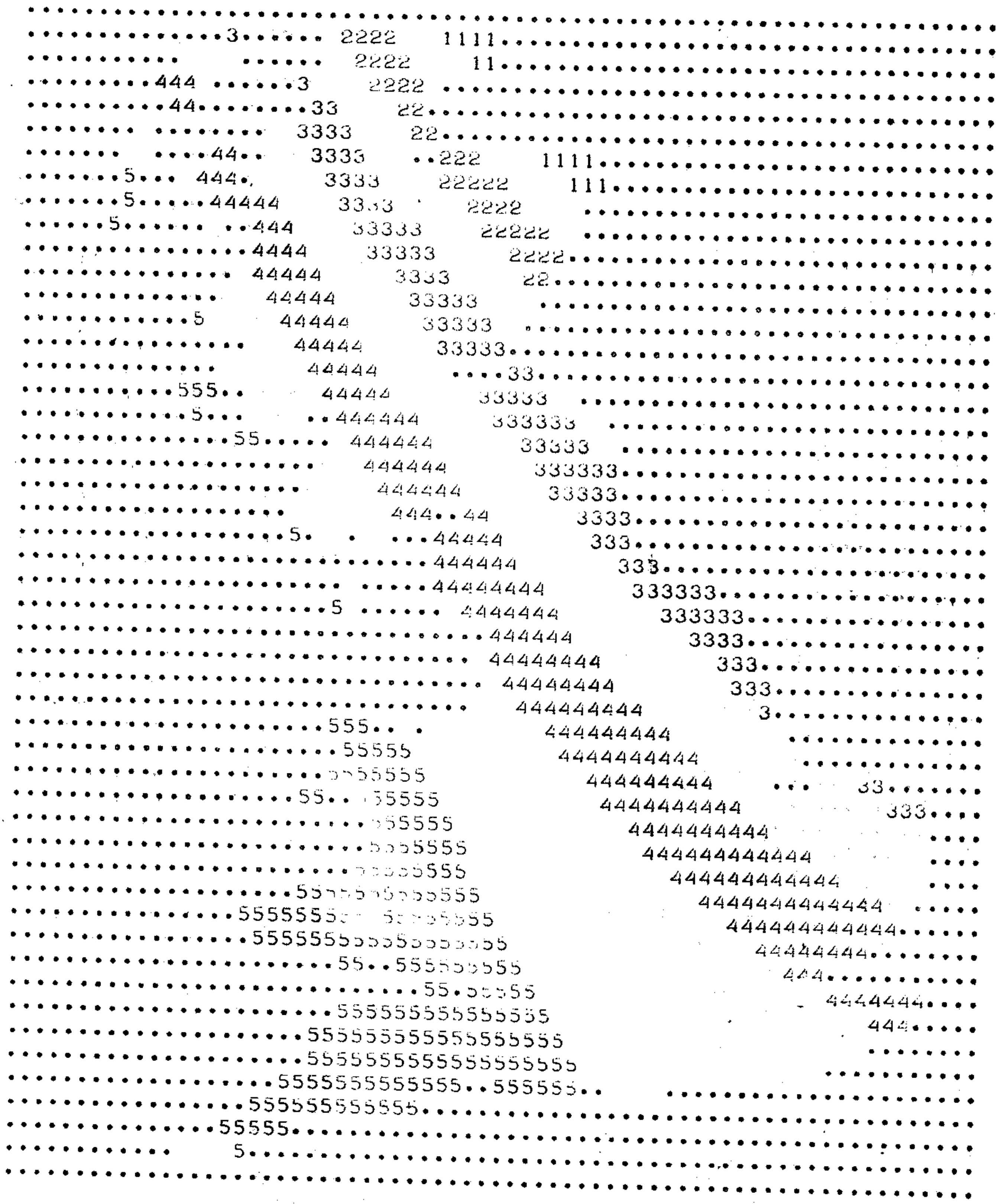

Figure 9. Variation in average rainfall at sea level (mms) with grid co-ordinates

(Rainfall increases by 19.4 mms for each 100 ft above sea level)

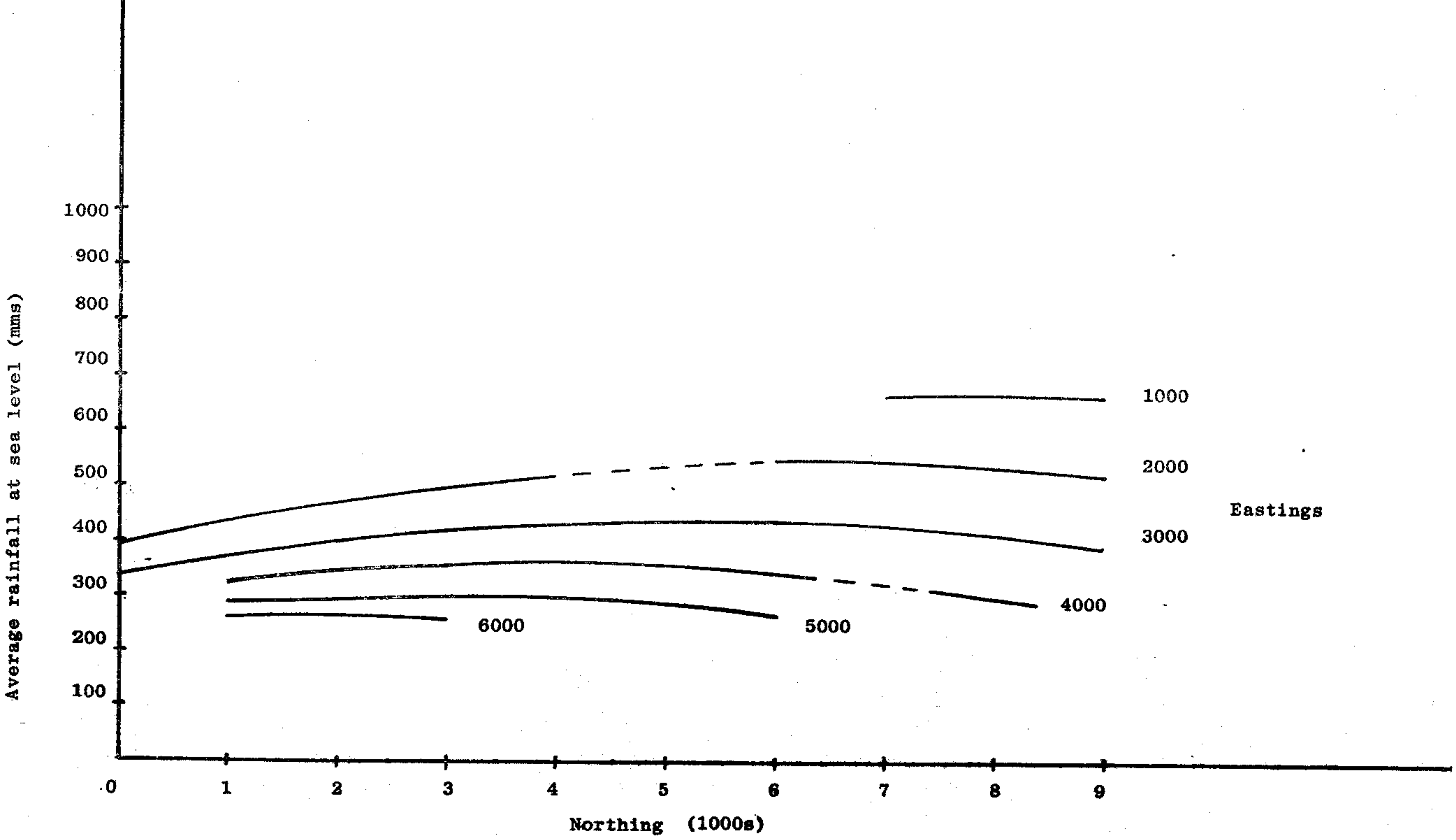

Figure 10. Variation in average potential transpiration (mms) with grid co-ordinates

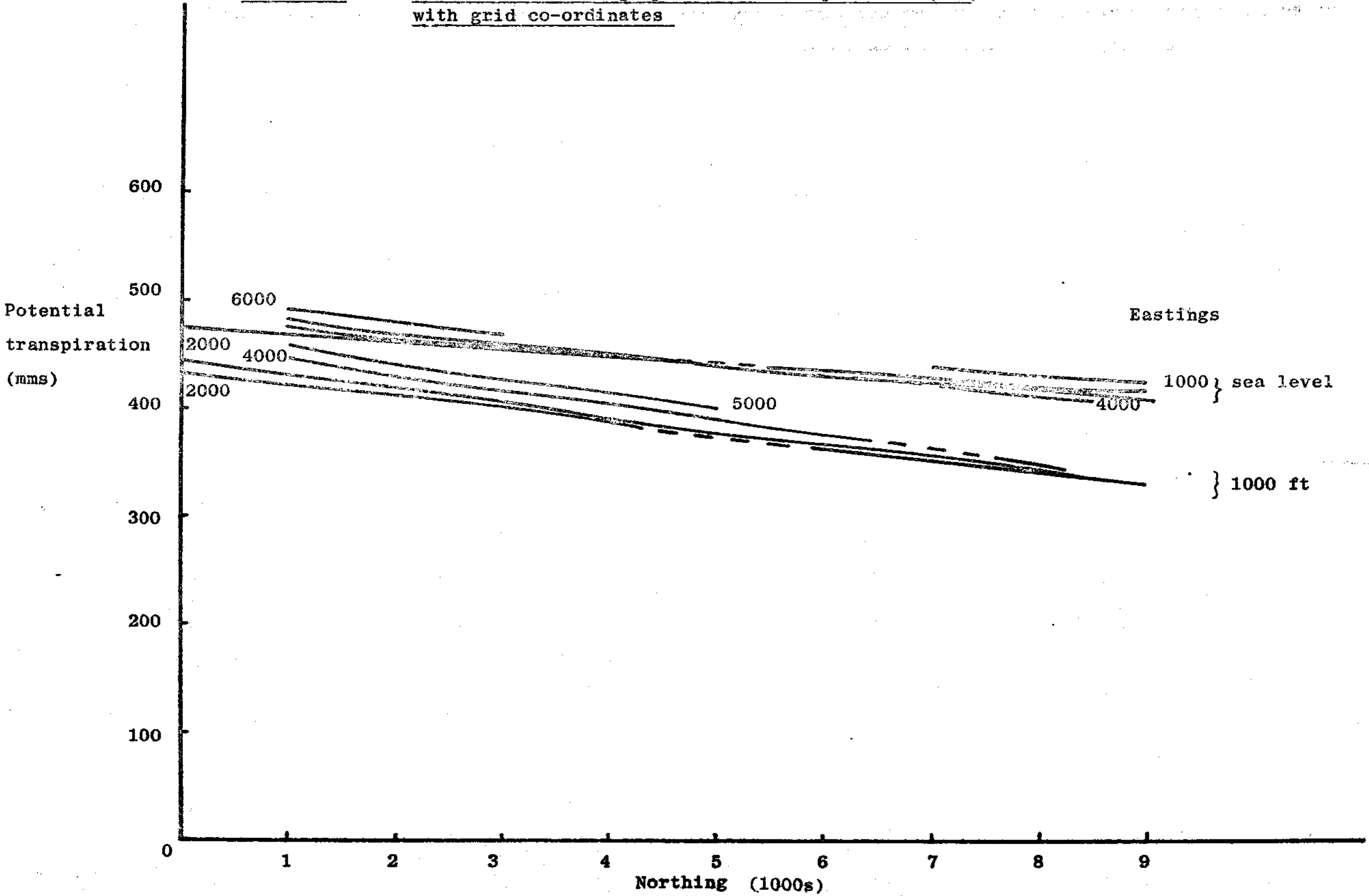

Figure 11. Variation in long-term average of mean daily temperature at sea level (°C) with grid co-ordinates

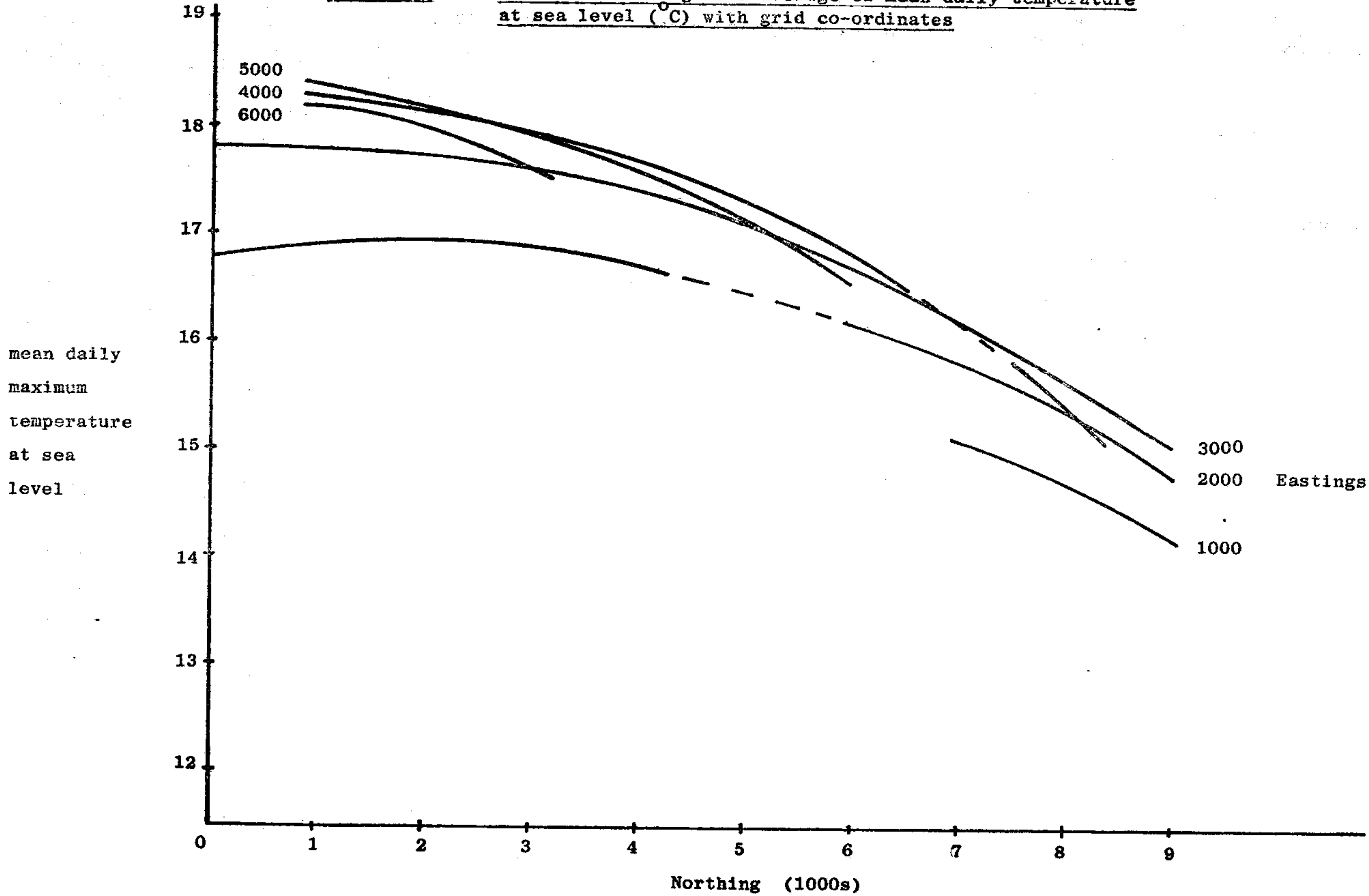

Figure 12. Variation in long-term average of mean daily maximum temperature at 1000 ft with grid co-ordinates

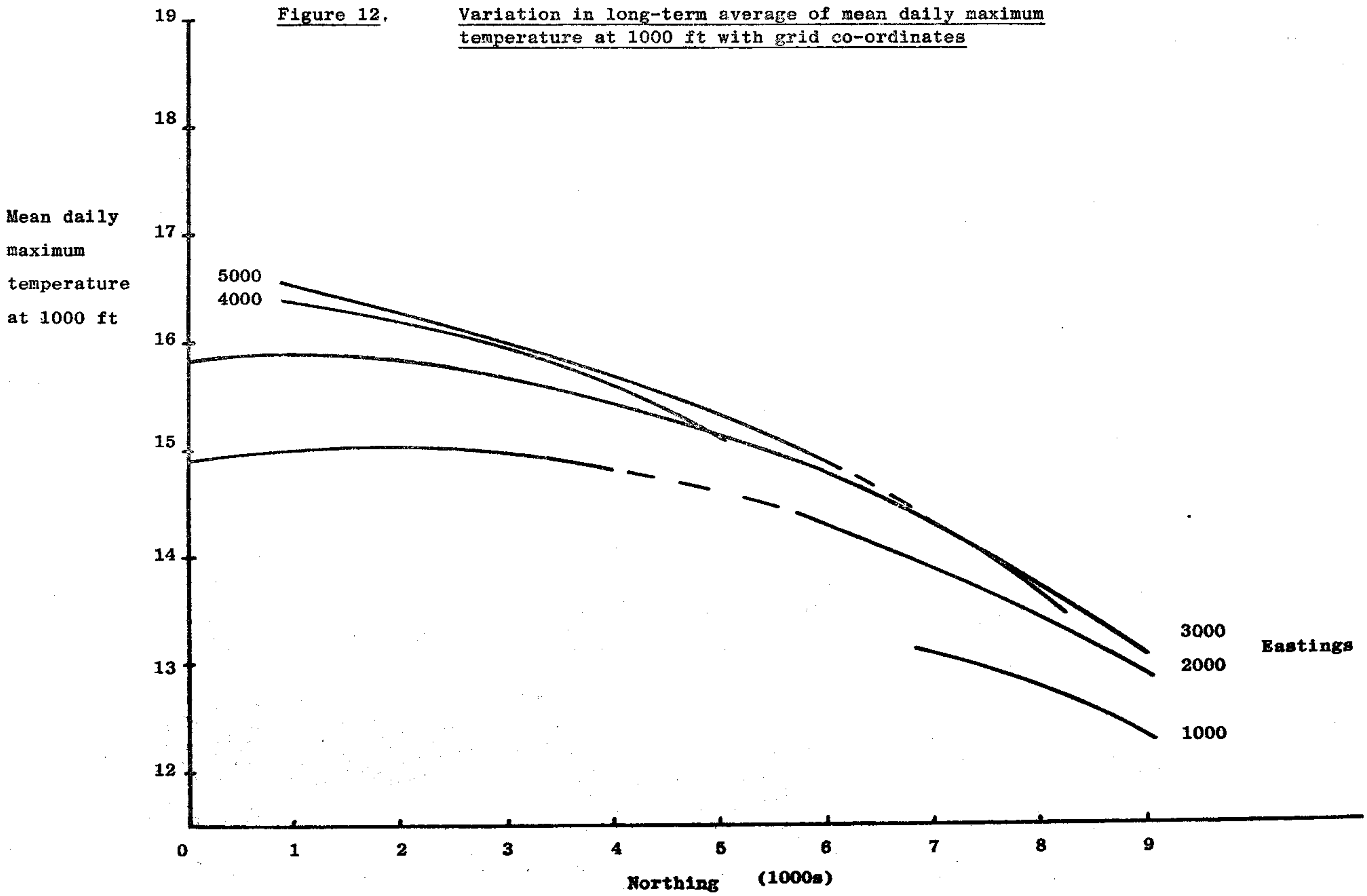

Figure 13. Positive (+) and negative (=) deviations from the predictive equation for rainfall

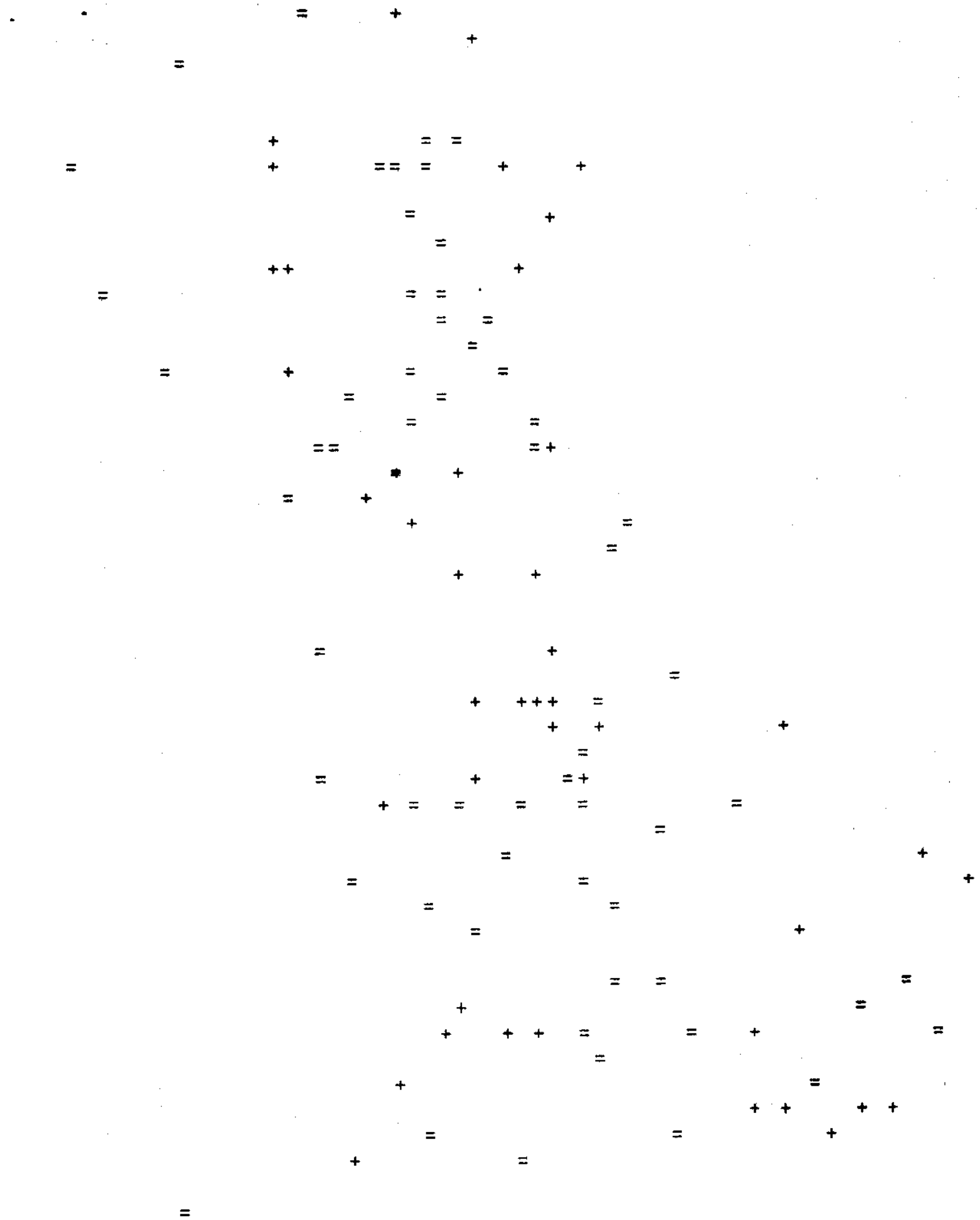

Figure 14. **Positive (+) and negative (=) deviations from the predictive equation for potential transpiration**

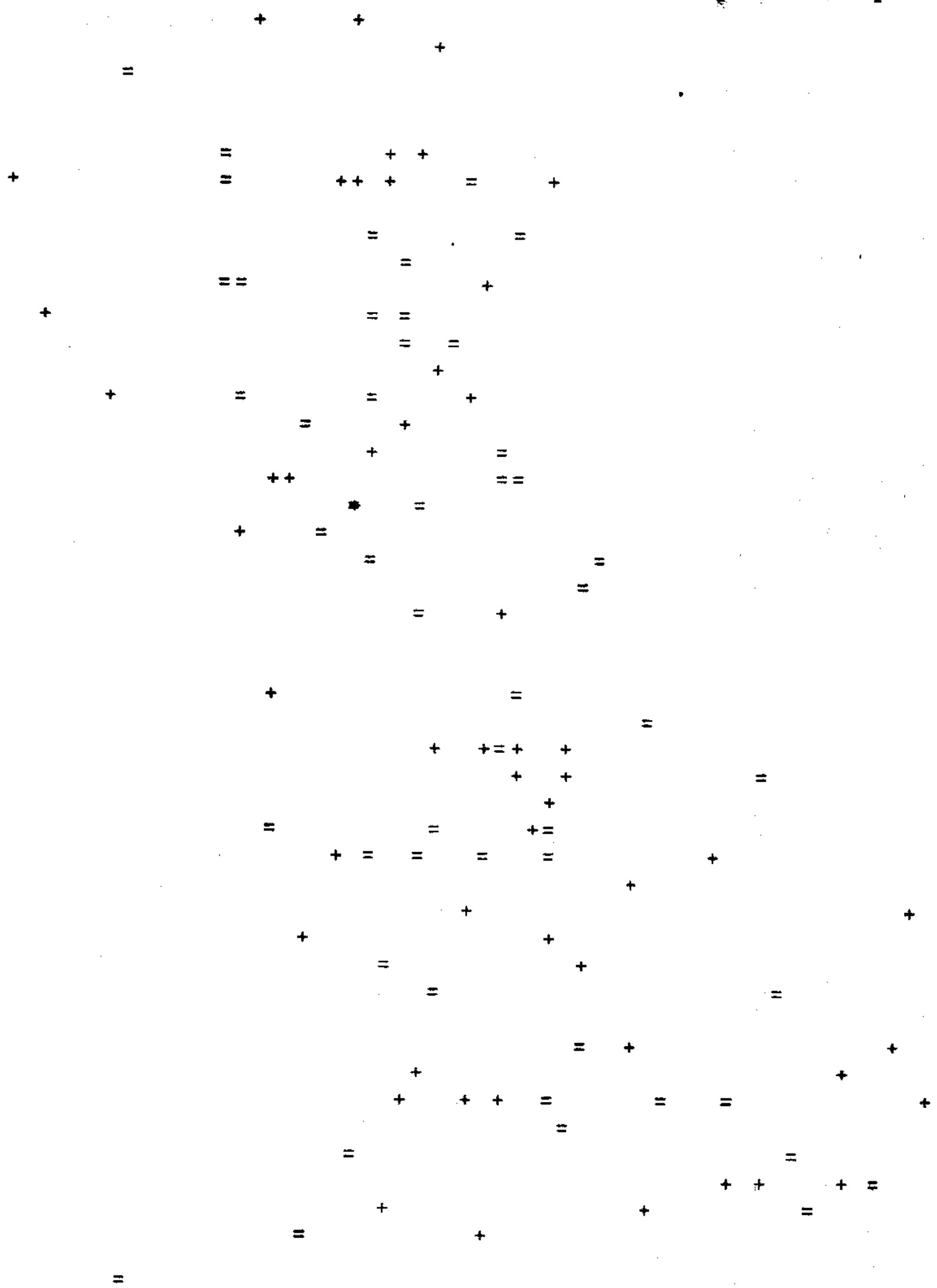

Figure 15. Positive (+) and negative (=) deviations from the predictive equation for temperature