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C.G. Korevaar

A climatological study on the occurrence of easterly gales on the North Atlantic Ocean.

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Koninklijk Nederlands Meteorologisch Instituut,
Postbus 201,
3730 AE De Bilt,
Nederland.

U.D.C.: 551.553.8

A climatological study on the occurrence of easterly gales on the North Atlantic Ocean.

Summary.

The numbers of easterly gales that occurred in the North Atlantic Ocean north of 25°N have been estimated by using a selection criterion involving minimum values for the meridional pressure gradient, for each day of the period 1881-1970. To do this use has been made of magnetic tapes from the "Deutscher Wetterdienst" with daily pressure values (for 12 hours GMT) in gridpoints. This method is not without shortcomings, because the windfield depends on more factors than the pressure gradient only. When the pressure difference indicates an easterly gale there are two possibilities: the statement is correct or not correct. By applying a statistical method an estimate could be made of the percentages of (in)correct statements. The percentage of correct statements appeared to be around 80% in the area between 70°N and 35°N. South of 35°N this percentage decreases considerably.

On the North Atlantic Ocean January is the month with the most frequent and July the month with the least frequent easterly gales. In general the maximum number of easterly gales is found in the area between Iceland and Greenland, while a secondary maximum is found south of the American coast between New York and Newfoundland. From the maxima southwards the numbers of easterly gales gradually decrease. In autumn a secondary maximum occurs in the area between the Azores and the English Channel, while in spring to the contrary a secondary minimum is found in this area.

More interesting is the following. Looking at the number of days per year on which an easterly gale did occur it appears that especially in the area between 70°N and 50°N there are considerable differences between the successive periods 1881-1900, 1901-1920, 1921-1940, 1941-1960 with a minimum in the second period and a maximum in the last period. The differences between these periods are often highly significant. The fluctuations in the numbers of days per year with an easterly gale can be explained by the climatic

fluctuation, connected by Willett [4] with the cycle of solar activity with a period of 80-90 years.

The correlation between the average values over five years of the variation in yearly sunspot numbers and the numbers of easterly gales averaged over the same periods of five years appears to be significant in the latitude belts 70°N - 65° N, 65°N - 60°N and 60°N - 55°N. This is in agreement with the fact that several research-workers, including Schuurmans and Willett, found the greatest increase of air pressure after a solar flare in these areas.

It can be concluded that the occurrence of various numbers of easterly gales during the 80-90 years cycle of solar activity is a confirmation of the theories of Willett and Schuurmans.

Next to influencing the frequency, the solar activity also influences the persistence and extensiveness of easterly gales.

Introduction.

Most marine climatological publications are directly based on ships' observations. Usually all available observations for certain areas are taken together for a period as long as possible, after which for example monthly charts with isolines, roses, etc. are composed.

In this study a different method has been followed. Use has been made of pressure data at sea level in gridpoints, which cover a great part of the northern hemisphere. These pressure data, which come from the "Deutscher Wetterdienst" at Offenbach, are available on magnetic tape from 1881 onwards and apply to 12 hours GMT of each day. The positions of the gridpoints in the North Atlantic are shown in Figure 1. They always lie at distances of five degrees of latitude and ten degrees of longitude from each other.

For each day of the period 1881-1970 (earlier results have been published for the period 1881-1967 in the Netherlands periodical "Nautisch Technisch Tijdschrift DE ZEE" [1] it has been determined where easterly gales occurred in the area of the North Atlantic Ocean north of 25°N by using the relation between windfield and pressure field. The advantage of this method is that one has an even distribution of the data, both in place and time. Moreover in this way -in the framework of the more and more spread idea that the climate is subject to certain fluctuations- one is able to determine whether in the course of years important variations have occurred in the number of easterly gales.

In this study an easterly gale has been defined as each windfield with a direction between NE and SE, in which wind-velocities of 17 m s^{-1} or more(windforce 8 or more according to the Beaufort Scale) occur. When there is mention of numbers of easterly gales, then always the number of days is meant, on which an easterly gale occurred at 12 hours GMT.

<u>Method applied to find the easterly gales from the pressure data in gridpoints.</u>

Assume that A and B are two gridpoints on the same meridian, where the pressures are respectively P_A and P_B, while A is situated north of B at a distance Δy. For an easterly wind between A and B it is necessary that $p_A > p_B$. For an easterly gale it is moreover necessary that the pressure difference $\Delta p = p_A - p_B$ is larger than a certain minimum value.

To determine this minimum value use has been made of the equation for the geostrophic wind:

$$v_g = \frac{1}{2\rho\Omega \sin\varphi} \cdot \frac{\Delta p}{\Delta n} \qquad (1)$$

in which v_g is the geostrophic windspeed, ρ the density of the air, Ω the angular velocity of the earth rotation, φ the geographical latitude and where $\Delta p / \Delta n$ represents the pressure gradient. The surface wind v then follows from:

$$v = c\, v_g \qquad (2)$$

According to [2] on an average the friction factor c can be taken as equal to 0.7.

Combining Equations (1) and (2) for the pressure difference the following expression can be written:

$$\Delta p = 2\, \frac{v}{c}\, \rho\Omega\, \Delta n \sin\varphi \qquad (3)$$

If we put here $v = 17 \text{ m s}^{-1}$, $c = 0.7$ and $\Delta n = \Delta y$ (the distance AB), we have the minimum pressure difference between A and B for an "easterly gale" in case the geostrophic wind is exactly east.

However, according to the definition given an "easterly gale" may have directions between NE and SE. This implies that the minimum value for the pressure difference in the N-S direction between the two gridpoints A and B becomes less. From Figure 2 it follows that in the case of a SE-ly gale this pressure difference becomes:

$$\Delta p\ (SE) = \Delta p\ (E)\ \cos 45^{o} \qquad (4)$$

where Δp (E) is given by (3).

Finally, the selection criterion chosen here is that the minimum pressure difference between A and B is

$$\Delta p = 2\ \frac{v}{c}\rho\Omega\Delta y\ \sin\varphi \cos 45^{o} \qquad (5)$$

In Table 1 these pressure differences are given in dependence of the latitude φ. Actually these pressure differences correspond to geostrophic winds with an average east component equal to $vc^{-1}\cos 45^{o}$, or 17.3 m s^{-1} if v = 17 m s^{-1}, c = 0.7.

Using Equation (5) more easterly gales are found than there were in reality because of the reduction of the minimum values in order to include gales from directions varying between NE and SE. Other causes for "misses" can be: a strong cyclonic curvature of the isobars, a very stable or unstable condition of the atmosphere, erroneous pressure data on the magnetic tapes.

With a view to the directions a concession had to be made too, because of the fact that in reality the wind direction makes an angle with the isobars. As Figure 3 shows in the case of a SE-ly gale the pressure difference between A and B becomes actually

$$\Delta p\ (SE) = \Delta p\ (E)\ \cos (45^{o} + \alpha) \qquad (6)$$

in which α is the angle between the wind direction and the isobars. According to [2] this angle depends on the difference between air- and sea temperature (T-Ts). The relation between α and T-Ts is practically a linear one. At T-Ts = -4^{o}C α is about 12^{o}, at T-Ts = 0^{o}C α is about 18^{o} and at T-Ts = 2^{o}C α is about 21^{o}.

In the case of a NE-ly gale the pressure difference between A and B becomes

$$\Delta p\ (NE) = \Delta p\ (E)\ \cos (45^{o} - \alpha) \qquad (7)$$

So the minimum pressure difference between A and B for a SE-ly gale is smaller than the minimum pressure difference between A and B for a NE-ly gale. In fact with the method followed gales are found between directions $45^{o} - \alpha$ and $135^{o} - \alpha$.

In the next section a statistical method is used to estimate the percentage of "misses", due to the causes mentioned above.

Determination of the value of the results obtained.

In order to check the value of the numbers of easterly gales found the statistical method discussed below has been applied.

When the pressure difference criterion indicates an easterly gale there are two possibilities: this statement is correct or not correct. So there is a question of an alternative distribution with an (unknown) chance p of success. A stochastic variable $\underline{x}$ has an alternative distribution if:

$$P\ (\underline{x} = 1) = p$$

and $P\ (\underline{x} = 0) = q = 1-p$ with $0 < p < 1$

The expectation (μ) and the variance (σ^2) of $\underline{x}$ are respectively p and pq.

Assume that $\underline{x}$ has an alternative distribution with parameter p, while $\underline{x}_1, \ldots\ldots\ldots\ldots, \underline{x}_n$ are mutual independent with the same distribution as $\underline{x}$ and

$\underline{k} = \sum_{i=1}^{n} \underline{x}_i$, then the frequency distribution of the number of successes $\underline{k}$ is a binomial distribution with parameters n and p with $P\ (\underline{k} = k) = \binom{n}{k}\ p^k\ q^{n-k}$; $\mu = np$ and $\sigma^2 = npq$.

For large n the binomial distribution may be approximated by the normal distribution with the same expectation and the same standard deviation.

When n independent samples are taken from an alternative distribution with an unknown parameter p (chance of success) and k successes are found then the 95% conficence interval of p can be determined from

$$P\ \left(-A < \frac{k-np}{\sqrt{npq}} < A \right) = 0.95$$

in which - A is the $2\frac{1}{2}$% point and A the $97\frac{1}{2}$% point of the standardized normal distribution (A = 1.96).

One may write

$$P\left(p - 1.96\sqrt{\frac{pq}{n}} < \frac{k}{n} < p + 1.96\sqrt{\frac{pq}{n}}\right) = 0.95$$

The limits of the confidence interval of p are found by solving

$$\frac{k}{n} = p \pm 1.96\sqrt{\frac{pq}{n}}$$

With the help of weather charts for a larger number (n) of cases and for different latitude belts the correctness of the statements has been checked and the 95% confidence interval of p has been determined. The results are shown in Table 2. From this table it appears for example that for the latitude between 70° and 65°N the maximum likelihood estimate ($\frac{k}{n}$) of the chance of a correct statement is 85.5% with a 95% confidence interval between 82% and 89%.

For the five degrees latitude belts between 65°N and 35°N the maximum likelihood estimate of the chance of a correct statement always lies in the vicinity of 80%. South of 35°N the chance of a correct statement decreases strongly. A possible cause for this is the fact that at lower latitudes the number of ships' observations becomes too small for an accurate analysis of the weather charts.

In the foregoing there has not yet been reckoned with the possibility that in reality there was an easterly gale, but that this was not noted. If between two gridpoints an easterly gale blows there are two possibilities again: the gale is noted or not. Here too we have an alternative distribution. With the help of the same sample taken at random the fractions of the easterly gales not noted have been determined. They are given in Table 3. Using Tables 2 and 3 it is possible to apply a correction to the numbers of noted easterly gales, by which a better estimate is obtained of the numbers of easterly gales which occurred in reality.

Distribution of the number of easterly gales over the North Atlantic Ocean in dependence of the time of the year.

In Figures 4-19 the numbers of easterly gales for the period 1881-1970 are shown for the 12 months and the 4 seasons of the year. These numbers have been corrected with the help of Tables 2 and 3. The isolines numbered 450, 270, 180 and 90 correspond respectively to an average of 5, 3, 2 and 1 easterly gale(s) per month/season. The isolines numbered 45, 22, 11 and 5 correspond respectively to an average of 1 easterly gale per 2, 4, 8 and 18 years in the relevant month/season.

Winter (December, January, February).

In all winter months a maximum number of easterly gales (more than two per month on an average) is found in the area between Iceland and Greenland. A secondary maximum is found south of the American coast between New York and Newfoundland. It is not so surprising that the maxima are found in these areas. For they lie south of those areas where, because of the continental character, the tendency exists of the forming of an area of high pressure and they lie north of the most important depression tracks.

The directions of the isolines almost coincide with the directions of the depression tracks. From the maxima southwards the numbers of easterly gales gradually decrease.

Spring (March, April, May).

The general picture looks much like that in the winter months. However the number of easterly gales decreases strongly from March to June. In the maximum between Iceland and Greenland on an average still about 2 easterly gales occur in March, in April about 1, while in May only about 1 easterly gale per 2 years occurs. Remarkable is the occurrence of a secondary minimum in these months in the area between the Azores and Iceland. Maybe this can be explained by the fact that the climatological Azores high gets an extension into the direction of the English Channel during this time of the year.

Summer (June, July, August).

During the summer months gales are rather exceptional. In July the lowest number of easterly gales occur. Remarkable is the shifting of the maximum in June towards the area south of Greenland between latitudes 60°N and 55°N. Probably this is connected with the shifting of the Icelandic low into a westerly direction during the summer months and with the fact that Greenland remains rather cold which causes a thermal high.

Autumn (September, October, November).

The general picture looks much like that in spring. However, in detail there are some remarkable differences. In the area just south of the American coast between New York and Newfoundland and east of Newfoundland and Labrador the number of easterly gales in spring is much larger than in autumn. From a thermal point of view one would expect this to be just the other way around as in autumn the sea water is warmer than in spring, which makes the differences between continent and ocean larger. From the Marine Climatic Atlas of the World [3] it appears that in autumn the (climatological) area of high pressure which extends from the Bermuda Islands in a westerly direction to the American continent tends to have a more northerly position than in spring. Consequently in autumn the depression tracks in general lie somewhat more northerly than in spring, which can be an explanation for the difference in the numbers of easterly gales near the American coast in these seasons.

A second explanation is possibly the following. From a study over the period September 1961 - June 1966 it appears that in this period in spring on 39 days a blocking high has been situated above Strait Davis and/or adjacent areas, while in the area west of 40^{o}W the lows were situated south of 50^{o}N. In autumn this occurred only on 12 days. So this circulation type occurred more often in spring than in autumn in the period mentioned, which can also be an explanation of the fact that east of Labrador and near Newfoundland during spring more easterly gales occur than during autumn. However the difference in occurrence of this circulation type in spring and autumn is not big enough to be statistically significant.

In contrast with the foregoing in the area near the Bermuda Islands more easterly gales occurred in autumn than in spring. A possible cause for this fact form the hurricanes moving through this area in autumn.

Another difference is that in the area between the Azores and the English Channel a secondary maximum is found in autumn, while in spring on the contrary a secondary minimum is found here.

An explanation for this could be that in the area near the British Isles in autumn more often a blocking high is found than in spring. This is confirmed by the same study over the period September 1961 - June 1966 from which it appears that in spring on 32 days and in autumn on 59 days a situation occurred with a blocking high near the British Isles, while above the eastern part of the North Atlantic Ocean South of 50°N a separated area of low pressure was present. Again however the difference in occurrence of this circulation type in spring and autumn was not big enough to be statistically significant.

Distribution of the number of days per year, on which in various latitude belts an easterly gale occurred over the period 1881-1970.

This distribution is shown in Table 4. The numbers mentioned in the Table have not been corrected as in the foregoing paragraph. From Table 4 it appears again that in general the largest number of easterly gales occurs between 70°N and 65°N, while the number decreases from the maximum southwards. Between 45°N and 40°N in most years a secondary maximum is found, which arises partly from the fact that starting from this latitude belt soutwards 7 instead of 5 gridpoints are considered (Figure 1). Making allowance for this nevertheless a secondary maximum remains, which is caused (see foregoing paragraph) by the larger number of easterly gales south of the American coast between New York and Newfoundland. An exception forms the period 1901-1920 in which the maximum does not lie between 70°N and 65°N. In this period peaks occur between 60°N and 55°N and between 50°N and 45°N.

More interesting is the following. Looking at the latitude belt between 70°N and 65°N it appears that considerable differences in numbers of easterly gales are occurring in the various periods. For example in the period 1881-1900 the number was 668; in the following period 1901-1920 however only 215; in the period 1921-1940 the number increased again to 496, while in the period 1941-1960 even 1152 days with an easterly gale have occurred.

The numbers for the other latitude belts can be found in Table 5. It appears that with the decreasing of the latitude also the differences in numbers during the successive periods are decreasing.

In order to check the significance of the differences it is not allowed to apply the Student's- or t-test. A condition for this is namely that the standard deviations in the periods to be compared are equal. With Fisher's F-test however it can be proved that these are differing significantly in some cases. Therefore the Wilcoxon-test, which is a parameter-free test, has been applied. This test is applied as follows. Each number of easterly gales per year from a certain period, for example 1881-1900 (period A) is compared with all numbers of easterly gales per year from an other period, for example 1901-1920 (period B). At each comparison points are given. Firstly the number of easterly gales in 1881 is compared with all numbers per year in period B; then we get

31 and 7 : 1 point for period A,
31 and 4 : 1 point for period A, etc.

Secondly the number of easterly gales in 1882 is compared with all numbers in period B, etc.. Finally a total score of 367-30 in the advantage of period A is get. The difference ($Q = 337$) between these numbers of points is used as testing-quantity. According to the zero-hypothesis there will not be a difference between the numbers of easterly gales in the two periods and a mean $\mu_Q = 0$ is expected. The real values of Q will have a symmetrical random distribution around this mean. For samples larger than 10 the distribution of Q may be approached by a normal distribution with $\mu_Q = 0$ and

$$\sigma_Q = \frac{n_1 n_2 \, (n_1 + n_2 + 1)}{3} ,$$

in which σ_Q is the standard deviation of Q, n_1 the number of years in period A and n_2 the number of years in period B. In our case $n_1 = n_2 = 20$.

According to the zero-hypothesis Q has a normal distribution with $\mu_Q = 0$ and $\sigma_Q = 74$. Reducing the distribution to the standardized normal distribution the excentricity of the value $Q = 337$ becomes

$$U = \frac{Q - \mu_Q}{\sigma_Q} = \frac{337}{74} = 4.55$$

To this value belongs a propability P of being exceeded of less than 0.001, which means that the difference between the numbers of easterly gales in the period A and B is highly significant. In Table 5 the usual terminology for the degree of significance has been used.

$P \leq 0.001$	highly significant
$0.001 < P \leq 0.01$	significant
$0.01 < P \leq 0.05$	propably significant
$0.05 < P \leq 0.1$	there is an indication of a difference

The periods 1881-1900, 1901-1920, 1921-1940, 1941-1960 have been indicated respectively by A, B, C, D; the numbers of easterly gales in the periods A, B, C, D by a, b, c, d.

Table 5 shows that $a > b$ for all latitude belts considered and that nearly everywhere $b < c$ and $c < d$. In general the degree of significance decreases with decreasing latitude. In general it can be concluded that the occurring differences are not accidental. So there must exist a certain cause.

Figure 20 gives for the latitude belt between 70°N and 65°N a graph of the over five years averaged numbers of days ($\overline{N}$) per year and per season, on which an easterly gale occurred in this area. Figure 20 clearly confirms the differences in numbers of easterly gales found in the successive periods 1881-1900, 1901-1920, 1921-1940, 1941-1960. In the first period the number is about 30 per year. There is a rather abrupt transition to the second period in which only about 10 easterly gales occur per year in this latitude belt. In the third period the number increases gradually, while in the fourth period a peak occurs with about 70 easterly gales per year.

The seasons autumn, winter and spring show the same characteristics with most easterly gales in winter. There is not much difference between spring and autumn.

Figures 21-26 show the graphs for the latitude belts respectively between 65°N and 60°N, 60°N and 55°N, 55°N and 50°N, 50°N and 45°N, 45°N and 40°N, 40°N and 35°N. With decreasing latitude the differences between the various periods also decrease. The differences between the seasons autumn, winter and spring are decreasing too with decreasing latitude.

Climatic fluctuation with a period of 80-90 years in connection with the 80-90 years cycle of the solar activity.

This climatic fluctuation has been noted by Willett [4]. In short it comes to the following. The sunspot activity, described by the relative sunspot number of Zürich, shows variations with periods of about 11 years, 22 years and 80-90 years. The 80-90 years cycle is characterized by an irregular increasing of the intensity of the sunspot maxima from a low level during the first quarter of the cycle to a high level during the last quarter of the cycle, while a rather abrupt transition occurs between the great sunspot activity in the last quarter and the small sunspot activity in the first quarter of the cycle.

According to Willett [4] the corresponding pattern in the climate shows a well-marked change-over from a pattern with above normal atmospheric pressure at rather northern latitudes (near 70°N) with as a consequence much cellular blockings during the fourth quarter of the solar cycle to a zonal circulation pattern at lower latitudes during the first quarter of the cycle. During the second and third quarters of the cycle the zonal pattern gradually shifts to the north. The weakening of the zonal circulation at low and medium latitudes corresponding herewith causes a strengthening of the normal climatic differences between continent and ocean south of 50°N.

Willett considered the period 1900-1919, 1920-1939, 1940-1959 as to correspond to the three last quarters of the cycle of solar activity. A number of characteristics in the numbers of easterly gales per year can be explained by this theory. An example of this is the great number of easterly gales at higher latitudes (between 70°N and 55°N) during the last quarter of the cycle (Figure 30). Namely, when a blocking high exists at northern latitudes north of the depressions a larger gradient will arise, by which the chance of the occurrence of an easterly gale increases. The minimum number of easterly gales per year occurs in the second quarter of the cycle (Figure 28), in which according to Willett a zonal pattern dominates. During the first quarter of the cycle still a large number of easterly gales occurs (Figure 27), especially between 70°N and 60°N. According to Willett a rather southern zonal circulation exists in this period. This does not need to exist at higher latitudes. According to Table 5 the number of easterly gales in the latitude belt between 35°N and 30°N has a maximum in the third quarter of the cycle (Figure 29), which can correspond to a zonal circulation at higher latitudes. A zonal circulation at high latitudes in this period is confirmed by a minimum of easterly gales (Figure 29) north of the Azores, which can mean a northern position of the Azores high and a corresponding northern zonal circulation.

On the whole it can be concluded that the occurrence of various numbers of easterly gales during the 80-90 years cycle of solar activity is a confirmation of the theory of Willett.

Correlation between the sunspot variability and the number of days with an easterly gale in the various latitude belts.

A measure for the sunspot activity is the relative sunspot number (R) of Zürich, determined by the formula

$$R = k\ (10\ g + f)$$

in which f is the daily number of sunspot, irrespective of their size, while g denotes the number of groups of sunspots. A large group can be composed of more than hundred spots. while smaller groups can consist of a few spots or only one spot. The number of groups (g) alone is not a good measure for the sunspot activity because the groups are differing considerably in size. Also the number of sunspots (f) alone does not satisfy, because a greater activity corresponds to one spot appearing in an area where no spots were still present than to a spot which is joining an already existing group. The coefficient k depends on the instruments and counting methods used.

Waldmeier [5] has published many sunspot data, among which the yearly means of the relative sunspot numbers.

Solar flares, which according to Schuurmans [6] are responsible for changes in the circulation pattern, occur especially during a fast developing or declining of the groups of sunspots. If there is little change in the numbers of sunspots in a group then according to Waldmeier [7] the solar flare activity is negligible.

In agreement with Schuurmans [6] as a measure for the solar flare activity the variation in yearly sunspot numbers ΔRy has been chosen, which is defined by

$$\Delta Ry = \frac{|Ry + 1 - Ry| + |Ry - Ry - 1|}{2}$$

where Ry denotes the sunspot number of year y. By $\overline{\Delta Ry}$ we shall understand the over five years averaged value of ΔRy and by $\overline{N}$ the over five years averaged number of days with an easterly gale in the various latitude belts.

For the latitude belts between 70°N and 65°N, 65°N and 60°N, 60°N and 55°N, 55°N and 50°N, 50°N and 45°N, 45°N and 40°N $\overline{\Delta Ry}$ and $\overline{N}$ are given in Table 6. For these areas the correlation coefficient (r) between $\overline{\Delta Ry}$ and $\overline{N}$ has been calculated for the period 1881-1970. The calculated correlation coefficients (Table 7) are significant for the latitude belts between 70°N and 65°N, 65°N and 60°N, 60°N and 55°N. With the further decreasing of the latitude the correlation strongly decreases, which is also shown clearly from Figures 31-36 in which graphs of the relation have been drawn. At lower latitudes (south of 55°N) the angle between the regression lines becomes larger and larger. In the area between 45°N and 40°N these lines are nearly perpendicular. So here there is no talk of a relation between the sunspot variability and the numbers of days with an easterly gale.

The duration of easterly gales in winter (December, January, February).

In Table 8 a summary is given of the duration of easterly gales in winter for the five degrees latitude belts between 70°N and 40°N in successive periods of ten years. By the duration of an easterly gale is meant the number of successive days on which between two gridpoints an easterly gale was noted. Because of the restriction of the material (pressure data in gridpoints once a day) it is not possible to follow a moving easterly gale on its track.

It appears that in only about 22% of the number of cases an easterly gale lasted longer than one day. About 7% lasted longer than 2 days and about 1.2% longer than 4 days. The longest duration in the period 1880-1970 was 10 days. This occurred only two times.

When the mean duration is considered, it appears to have the same trend, however not so significant as has been seen before for the numbers of days with an easterly gale, with a minimum in the period 1901-1920 and a maximum in the period after 1940. So in a period in which less easterly gales occur the mean duration is shorter, while in a period with more easterly gales the mean duration is longer. This suggests that the changes in the frequencies partly arise from the changes in the mean duration. It can be concluded that next to influencing the frequency of easterly gales the solar activity also influences the persistence of them.

<u>The extensiveness of the areas with easterly gales in winter (December, January, February).</u>

Table 9 gives a summary of the extensiveness of easterly gales in winter for the area between 70°N and 40°N in successive periods of ten years. By the extensiveness of an easterly gale is meant the number of adjacent sections in which an easterly gale was noted. By a section is meant the area between two adjacent gridpoints on the same meridian, which extends over a distance of five degrees of longitude on each side of the gridpoints concerned.

It appears that in about 36% of the number of cases an easterly gale was extending over an area consisting of at least 2 sections. About 15% extended over an area of at least 3 sections, about 7% over at least 4 sections, about 3% over at least 5 sections and about 1.3% over at least 6 sections. The largest number of adjacent sections with an easterly gale in the period 1880-1970 was 10. This occurred only two times.

When the mean extensiveness is considered it appears, especially in the northern areas, to be in general smaller in the period 1901-1920 and larger in the period after 1940. So in a period in which less easterly gales occur the mean extensiveness is smaller and in a period with more easterly gales the mean extensiveness is larger.

It can be concluded that next to influencing the frequency and the persistence of easterly gales the solar activity also influences the extensiveness. Namely in periods with more (less) solar activity more (less) easterly gales are occurring. On an average they are lasting then longer (shorter) and are more (less) extensive.

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Table 1. Minimum pressure differences, in dependence of the latitude, between two adjacent gridpoints on the same meridian needed for an easterly gale.

latitude belt	pressure difference in mbar
70°-65°	16.3
65°-60°	15.7
60°-55°	14.9
55°-50°	14.0
50°-45°	13.0
45°-40°	11.9
40°-35°	10.7
35°-30°	9.5
30°-25°	8.2

Table 2. The determination, for each of the latitude belts, of the 95% confidence interval for the chance of a correct statement (there was an easterly gale).

latitude belt	statements					estimated chance of success $p=\frac{k}{n}$	95% confidence interval of p
	total number(n)	not correct		correct			
		number	%	number(k)	%		
70°-65°	367	53	14.5	314	85.5	0.855	0.82-0.89
65°-60°	383	68	17.8	315	82.2	0.822	0.78-0.86
60°-55°	356	74	20.8	282	79.2	0.792	0.75-0.83
55°-50°	310	64	20.6	246	79.4	0.794	0.75-0.84
50°-45°	210	47	22.3	163	77.4	0.774	0.72-0.83
45°-40°	275	43	15.6	232	84.4	0.844	0.80-0.89
40°-35°	96	21	21.8	75	78.2	0.782	0.70-0.86
35°-30°	39	12	30.8	27	69.2	0.692	0.55-0.84
30°-25°	38	25	65.8	13	34.2	0.342	0.19-0.49

Table 3. The determination, for each of the latitude belts, of the percentage of easterly gales which are not noted.

latitude belt	number of easterly gales	not noted	
		number	%
70°-65°	321	7	2.2
65°-60°	327	12	3.7
60°-55°	285	3	1.1
55°-50°	262	16	6.1
50°-45°	181	18	9.9
45°-40°	243	11	4.5
40°-35°	78	3	3.8
35°-30°	28	1	3.6
30°-25°	13	-	-

Table 4. Number of days per year, on which in the various latitude belts an easterly gale occurred over the period 1881-1970.

years	latitude belts								
	70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°	40°-35°	35°-30°	30°-25°
1881	31	34	19	22	19	17	8	4	4
1882	34	24	21	20	16	18	11	5	3
1883	33	19	21	24	12	20	19	12	3
1884	54	25	12	13	4	20	7	8	9
1885	45	27	18	15	18	28	5	11	5
1886	35	11	15	17	16	25	12	10	3
1887	31	20	11	25	22	39	8	10	6
1888	34	33	18	25	16	26	10	6	2
1889	32	24	6	4	7	33	10	11	6
1890	46	16	3	9	13	17	9	6	4
1891	49	25	12	15	15	25	15	6	2
1892	43	26	23	27	23	39	17	4	11
1893	28	18	10	18	17	28	8	2	8
1894	33	22	9	18	9	32	9	3	5
1895	22	28	23	25	26	21	5	2	4
1896	30	16	4	13	17	31	12	3	1
1897	38	49	32	18	13	17	10	6	10
1898	37	28	12	14	11	27	16	3	6
1899	7	20	19	22	15	15	11	2	2
1900	6	12	16	8	7	18	7	2	2
1881-1900	668	477	304	352	296	496	209	116	51

years	latitude belts								
	70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°	40°-35°	35°-30°	30°-25°
1901	7	9	13	10	19	37	15	6	-
1902	4	17	11	17	15	28	8	5	1
1903	15	12	13	5	4	20	7	12	1
1904	7	9	7	10	9	21	8	3	1
1905	5	13	14	7	5	11	6	4	2
1906	11	2	9	8	6	24	13	9	4
1907	14	14	8	5	7	18	8	12	1
1908	10	10	15	12	4	8	11	10	1
1909	17	5	16	23	17	18	2	4	2
1910	12	5	11	9	5	16	2	6	3
1911	13	5	8	11	8	19	7	3	2
1912	5	20	17	12	12	9	3	2	1
1913	11	11	13	6	4	9	10	2	3
1914	14	22	13	10	7	18	5	4	1
1915	9	16	19	14	15	22	10	2	1
1916	19	10	8	16	14	14	7	7	2
1917	6	9	10	10	7	22	6	4	1
1918	16	13	10	8	6	16	6	2	1
1919	8	9	20	14	12	15	2	2	-
1920	12	20	10	5	2	15	9	3	-
1901-1920	215	231	245	212	178	360	145	102	28

years	latitude belts								
	70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°	40°-35°	35°-30°	30°-25°
1921	19	7	6	9	10	29	7	5	3
1922	15	18	12	19	11	16	3	1	1
1923	19	19	8	13	10	16	14	2	3
1924	19	15	10	14	13	14	7	5	9
1925	13	19	15	9	15	20	11	7	2
1926	33	36	18	8	9	16	8	10	4
1927	28	20	20	12	9	26	9	8	5
1928	30	16	12	14	6	10	8	6	-
1929	22	26	29	17	13	16	8	3	1
1930	19	12	12	12	11	15	10	6	4
1931	26	12	15	17	23	24	10	9	-
1932	29	22	10	19	20	23	9	10	1
1933	25	21	18	19	14	18	11	7	6
1934	33	20	10	9	9	13	10	7	3
1935	33	31	19	12	8	19	12	5	1
1936	15	21	12	13	8	7	10	14	5
1937	34	15	18	19	16	20	13	5	2
1938	28	2	1	8	13	19	9	6	2
1939	27	35	28	13	6	15	8	1	-
1940	29	32	26	23	11	19	8	3	2
1921-1940	496	399	299	279	235	355	185	120	54

years	latitude belts								
	70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°	40°-35°	35°-30°	30°-25°
1941	24	18	28	18	7	22	6	4	1
1942	53	37	29	21	9	16	8	2	-
1943	51	28	20	5	2	15	8	2	3
1944	37	34	34	23	15	17	9	-	1
1945	59	44	26	17	21	24	7	1	3
1946	43	42	29	9	12	11	13	1	3
1947	49	51	56	35	19	17	9	4	3
1948	65	41	22	19	15	29	14	8	5
1949	67	28	26	11	9	22	11	12	7
1950	85	37	24	16	9	23	9	6	10
1951	92	67	32	12	17	27	16	1	3
1952	70	35	15	23	31	25	8	7	2
1953	82	26	20	11	11	27	10	1	2
1954	59	47	24	15	10	18	9	4	9
1955	45	57	53	46	29	29	8	3	8
1956	57	31	25	17	12	27	17	9	3
1957	44	44	38	17	20	15	8	3	2
1958	52	45	47	32	25	32	8	2	7
1959	65	57	39	20	15	12	5	5	5
1960	53	58	39	19	17	20	9	7	3
1941-1960	1152	827	626	386	305	428	192	82	80

years	latitude belts								
	70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°	40°-35°	35°-30°	30°-25°
1961	66	42	32	26	17	31	8	4	4
1962	43	42	37	29	21	32	17	6	5
1963	55	49	50	27	22	26	7	3	4
1964	47	42	48	24	16	23	15	8	5
1965	40	45	48	24	16	15	5	4	3
1966	39	48	49	26	23	26	9	-	5
1967	23	33	13	5	5	17	7	3	5
1968	30	31	37	8	7	11	5	1	2
1969	26	18	26	11	6	22	17	5	-
1970	31	22	16	11	8	11	3	3	-
1961-1970	400	372	356	191	141	214	93	37	33

Table 5. Numbers of easterly gales a, b, c, d in the periods A (1881-1900), B (1901-1920), C (1921-1940), D (1941-1960) and the determination of the rate of significance between the differences in a, b, c and d for the various latitude belts.

latitude belt	numbers of easterly gales				Comparison of the various periods by means of the Wilcoxon-test														
					A ⟷ B					B ⟷ C					C ⟷ D				
	a	b	c	d		Q	u	P	significance		Q	u	P	significance		Q	u	P	significance
70°-65°	668	215	496	1152	a > b	337	4.55	<0.001	highly significant	b < c	369	4.98	<0.001	highly significant	c < d	376	5.08	<0.001	highly significant
65°-60°	477	231	399	827	a > b	323	4.36	<0.001	highly significant	b < c	235	3.18	0.002	significant	c < d	336	4.54	<0.001	highly significant
60°-55°	304	245	299	626	a > b	110	1.49	0.136	not significant	b < c	90	1.22	0.220	not significant	c < d	329	4.46	<0.001	highly significant
55°-50°	352	212	279	386	a > b	255	3.41	<0.001	highly significant	b < c	172	2.32	0.02	probably significant	c < d	148	2.00	0.046	probably significant
50°-45°	296	178	235	305	a > b	229	3.10	0.002	significant	b < c	150	2.03	0.04	probably significant	c < d	124	1.68	0.093	indication of a difference
45°-40°	496	360	355	428	a > b	203	2.74	0.006	significant	b > c	4	0.05	0.96	not significant	c < d	129	1.74	0.082	indication of a difference
40°-35°	209	145	185	192	a > b	186	2.51	0.012	probably significant	b < c	166	2.24	0.025	probably significant	c < d	17	0.23	0.820	not significant
35°-30°	116	102	120	82	a > b	48	0.65	0.516	not significant	b < c	63	0.85	0.396	not significant	c > d	140	1.89	0.059	indication of a difference
30°-25°	96	28	54	80	a > b	321	4.34	<0.001	highly significant	b < c	139	1.88	0.060	indication of a diffe-rence	c < d	113	1.53	0.126	not significant

Table 6. The five year mean variation in yearly sunspot numbers ($\overline{\Delta Ry}$) and the five year mean number of days ($\bar{N}$) with an easterly gale in the various latitude belts over the period 1881-1970.

five yearly periods	$\overline{\Delta Ry}$	$\bar{N}$					
		70°-65°	65°-60°	60°-55°	55°-50°	50°-45°	45°-40°
1881-1885	9.1	39.4	25.8	18.2	18.8	13.8	20.6
1886-1890	9.5	35.6	20.8	10.6	16.0	14.8	28.0
1891-1895	21.2	35.0	23.8	15.4	20.6	18.0	29.0
1896-1900	9.6	23.6	25.0	16.6	15.0	12.6	21.6
1901-1905	13.8	7.6	12.0	11.6	9.8	10.4	23.4
1906-1910	12.6	12.8	7.2	11.8	11.4	7.8	16.8
1911-1915	12.3	10.4	14.8	14.0	10.6	9.2	15.4
1916-1920	24.5	12.2	12.2	11.6	10.6	8.2	16.0
1921-1925	14.9	17.0	15.6	10.2	12.8	11.8	19.0
1926-1930	14.6	26.4	22.0	18.2	12.6	9.6	16.6
1931-1935	15.0	29.2	21.2	14.4	15.2	14.8	19.4
1936-1940	22.7	26.6	21.0	17.0	15.2	10.8	16.0
1941-1945	20.3	44.8	32.2	27.4	16.8	10.8	18.8
1946-1950	32.7	61.8	39.8	31.4	18.0	12.8	20.4
1951-1955	31.5	69.6	46.4	28.8	21.4	19.6	25.2
1956-1960	41.5	54.2	47.0	37.6	21.0	17.8	21.2
1961-1965	18.6	50.2	44.0	43.0	26.0	18.4	25.4
1966-1970	19.0	29.8	30.4	28.2	12.2	9.8	17.4

Table 7. Correlation between the five year mean variation in yearly sunspot numbers and the five year mean number of days with an easterly gale in the various latitude belts over the period 1881-1970.

latitude belt	correlation coefficient r	significance of r
70°-65°	0.658	significant
65°-60°	0.675	significant
60°-55°	0.629	significant
55°-50°	0.440	indication of correlation
50°-45°	0.400	indication of correlation
45°-40°	0.058	no correlation

Table 8[a]. Duration of easterly gales in winter in the latitude belt between 70°N and 65°N.

Periods	duration in days										mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	155	31	3	3	2						1.28
1890-1900	141	22	6	3							1.25
1900-1910	57	6									1.09
1910-1920	76	5									1.06
1920-1930	126	23	2								1.18
1930-1940	130	26	2		2						1.24
1940-1950	200	39	29	9	1	2			1		1.52
1950-1960	225	65	19	4	4	1					1.43
1960-1970	120	59	17	3	2						1.55
1880-1970	1230	276	78	22	11	3			1		1.35

Table 8[b]. Duration of easterly gales in winter in the latitude belt between 65°N and 60°N

Periods	duration in days										mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	66	12	2	2			1	1		1	1.52
1890-1900	66	21	5	1							1.37
1900-1910	41	4	2								1.17
1910-1920	64	3									1.04
1920-1930	105	22	4	1							1.25
1930-1940	89	20	6								1.28
1940-1950	148	27	17	2	3			1			1.43
1950-1960	140	24	12	8	5		1			1	1.51
1960-1970	112	36	12	9	3	1	1				1.63
1880-1970	831	169	60	23	11	1	3	2		2	1.41

Table 8^c. Duration of easterly gales in winter in the latitude belt between 60°N and 55°N

Periods	duration in days										mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	31	13	4								1.44
1890-1900	39	7	6	4		1					1.63
1900-1910	36	1		1	1						1.20
1910-1920	56	4	2	1							1.17
1920-1930	45	7	7	2	1	1					1.57
1930-1940	66	13	3		1						1.28
1940-1950	93	22	3	1	1						1.29
1950-1960	107	13	5	2	1		1				1.30
1960-1970	102	30	11	3	1	1	2				1.55
1880-1970	575	110	41	14	6	3	3				1.39

Table 8^d. Duration of easterly gales in winter in the latitude belt between 55°N and 50°N.

Periods	duration in days										mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	46	8		1		2					1.37
1890-1900	53	7	2	2							1.27
1900-1910	29	2	1	1							1.21
1910-1920	30	4									1.12
1920-1930	40	4	2	2							1.29
1930-1940	64	6	1	1							1.15
1940-1950	61	9	1								1.15
1950-1960	76	8	3		2			2			1.40
1960-1970	72	16	5	2	1	1					1.42
1880-1970	471	64	15	9	3	3		2			1.29

Table 8[e]. Duration of easterly gales in winter in the latitude belt between 50°N and 45°N.

Periodes	duration in days									mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	38	9	2	1							1.32
1890-1900	43	12	2	2							1.37
1900-1910	34	6	1	1							1.26
1910-1920	24	2									1.08
1920-1930	25	2	1								1.14
1930-1940	39	5	1	1	1	1					1.40
1940-1950	37	4	2	1							1.25
1950-1960	57	11	1								1.19
1960-1970	50	7	3	1	1	1	1				1.48
1880-1970	347	58	13	7	2	2	1				1.30

Table 8[f]. Duration of easterly gales in winter in the latitude belt between 45°N and 40°N

Periods	duration in days										mean duration in days
	1	2	3	4	5	6	7	8	9	10	
1880-1890	94	11	1	3							1.20
1890-1900	81	23	2								1.25
1900-1910	80	9	3								1.16
1910-1920	46	8	3								1.25
1920-1930	56	6	1								1.13
1930-1940	62	8	2								1.17
1940-1950	59	12									1.17
1950-1960	79	17	4	1	1						1.31
1960-1970	68	8	3								1.18
1880-1970	625	102	19	4	1						1.21

Table 9[a]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 70°N.

Periods	extensiveness in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	107	40	15	6	3	2					1.63
1890-1900	103	39	10	1	2						1.45
1900-1910	43	12	1	1							1.30
1910-1920	45	13	4	1	1		1				1.52
1920-1930	51	38	16	1	5	1					1.87
1930-1940	72	41	11	4	2		1				1.68
1940-1950	119	58	42	20	11	4		1			2.07
1950-1960	136	63	51	18	2	4	3				1.96
1960-1970	69	46	29	10	12	4	2				2.24
1880-1970	745	350	179	62	38	15	7	1			1.84

Table 9[b]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 65°N.

Periods	extensiveness in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	42	13	9	1	1		1			1	1.78
1890-1900	52	12	6	5	3	2	2				1.89
1900-1910	27	6	3	1	1						1.50
1910-1920	40	8	2	3							1.40
1920-1930	49	17	12	2	2	4	2		2		2.14
1930-1940	48	26	4	8	2	2					1.84
1940-1950	75	30	10	4	7		1				1.76
1950-1960	59	44	18	11	1	2					1.94
1960-1970	75	23	11	10	7	5	1	1			2.06
1880-1970	467	179	75	45	24	15	7	1	2	1	1.87

Table 9[c]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 60°N.

Periods	extensiveness in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	27	3	3	3							1.50
1890-1900	32	12	2	2							1.46
1900-1910	26	4	3			1					1.44
1910-1920	36	9	3	1							1.37
1920-1930	21	7	2	5	1	1					1.95
1930-1940	34	12	3	1							1.42
1940-1950	57	20	6		2	1					1.52
1950-1960	58	14	7	3	3	1					1,63
1960-1970	61	30	8	8	8					1	1.96
1880-1970	352	111	37	23	14	4				1	1.63

Table 9[d]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 55°N.

Periods	extensivenses in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	37	6	3	1	2						1.48
1890-1900	31	11	3	2	2						1.63
1900-1910	21	5	1				1				1.46
1910-1920	25	4									1.23
1920-1930	21	4	2	1							1.39
1930-1940	41	11	6								1.40
1940-1950	44	9	1								1.21
1950-1960	53	12	7	2							1.43
1960-1970	35	16	8	1							1.58
1880-1970	308	78	31	8	4		1				1.43

Table 9[e]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 50°N.

Periods	extensiveness in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	35	6	3	1	1						1.41
1890-1900	36	10	6	1	1						1.54
1900-1910	33	4	2		1						1.30
1910-1920	26	3	1								1.17
1920-1930	23	2									1.08
1930-1940	44	5	1	1							1.20
1940-1950	38	9									1.19
1950-1960	49	6	4	2				1			1.43
1960-1970	47	6									1.11
1880-1970	331	51	17	5	3			1			1.29

Table 9[f]. The extensiveness of the areas with easterly gales in winter and with the northern boundary along the parallel of 45°N.

Periods	extensiveness in numbers of sections										mean extensiveness in nr. of sections
	1	2	3	4	5	6	7	8	9	10	
1880-1890	70	8	4	3							1.29
1890-1900	75	19	2	1							1.27
1900-1910	68	14	2								1.21
1910-1920	50	11	1								1.21
1920-1930	47	12	1								1.23
1930-1940	57	11	1								1.19
1940-1950	45	15	2	1							1.35
1950-1960	70	16	8								1.34
1960-1970	58	13	4								1.28
1880-1970	540	119	25	5							1.27

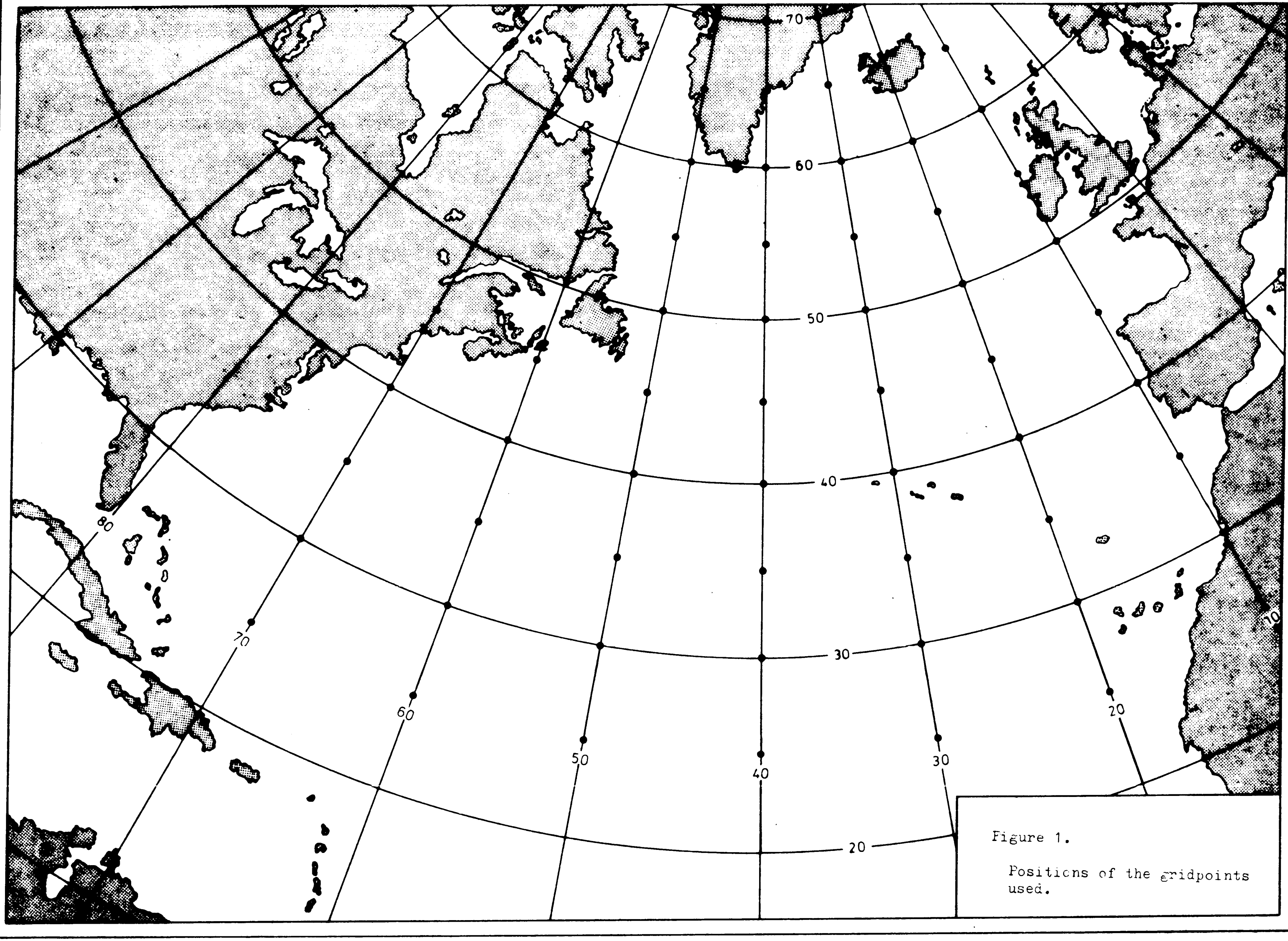

Figure 1.

Positions of the gridpoints used.

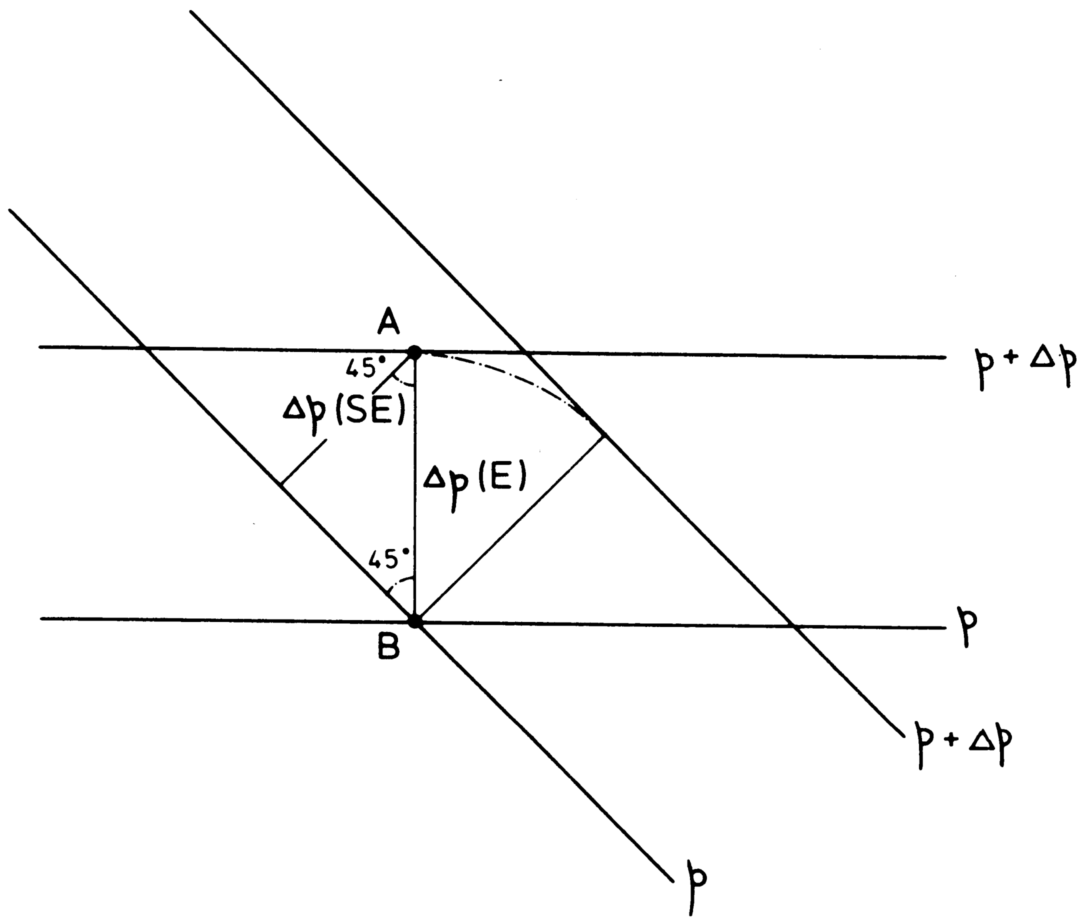

Figure 2

Pressure difference between A and B in the case of a SE-ly gale.

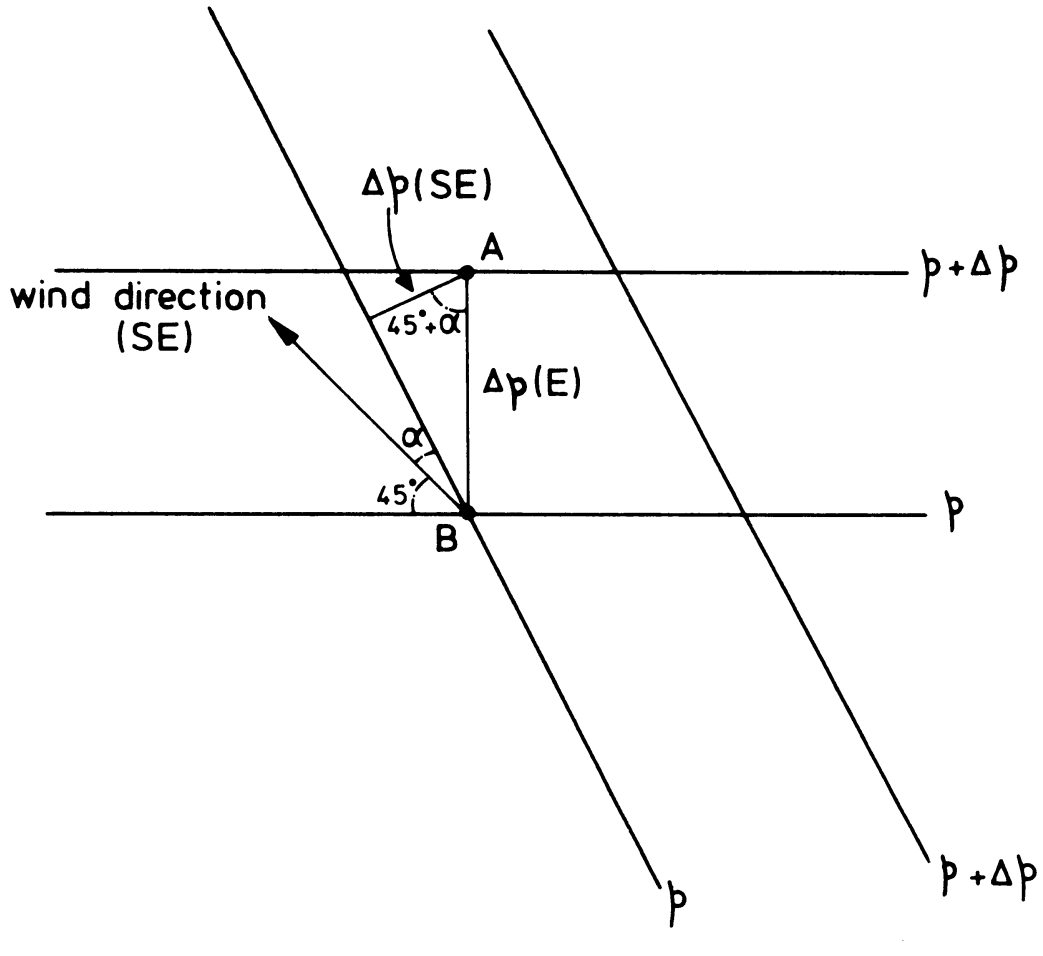

Figure 3

Actual pressure difference between A and B in the case of a SE-ly gale.

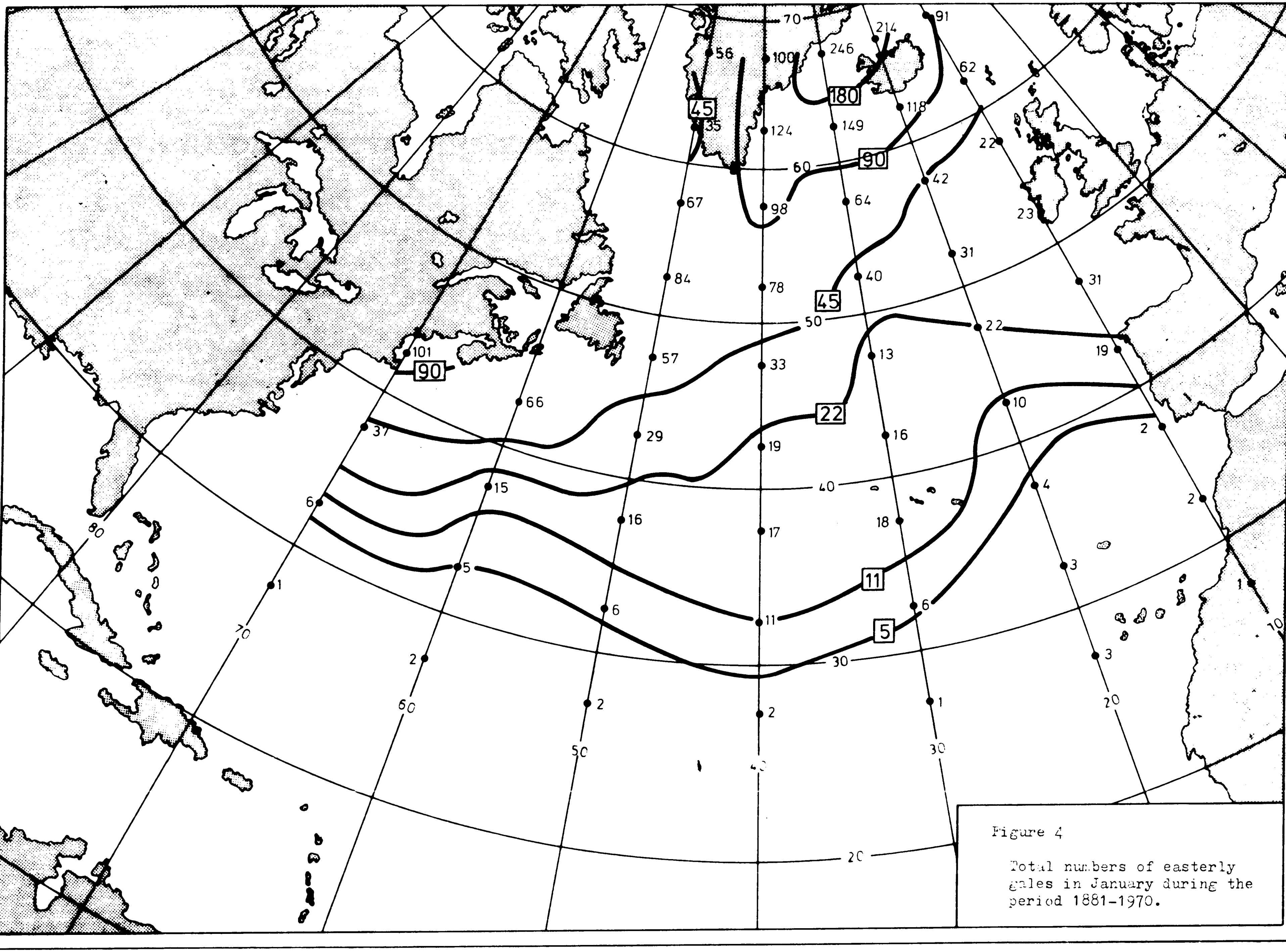

Figure 4

Total numbers of easterly gales in January during the period 1881-1970.

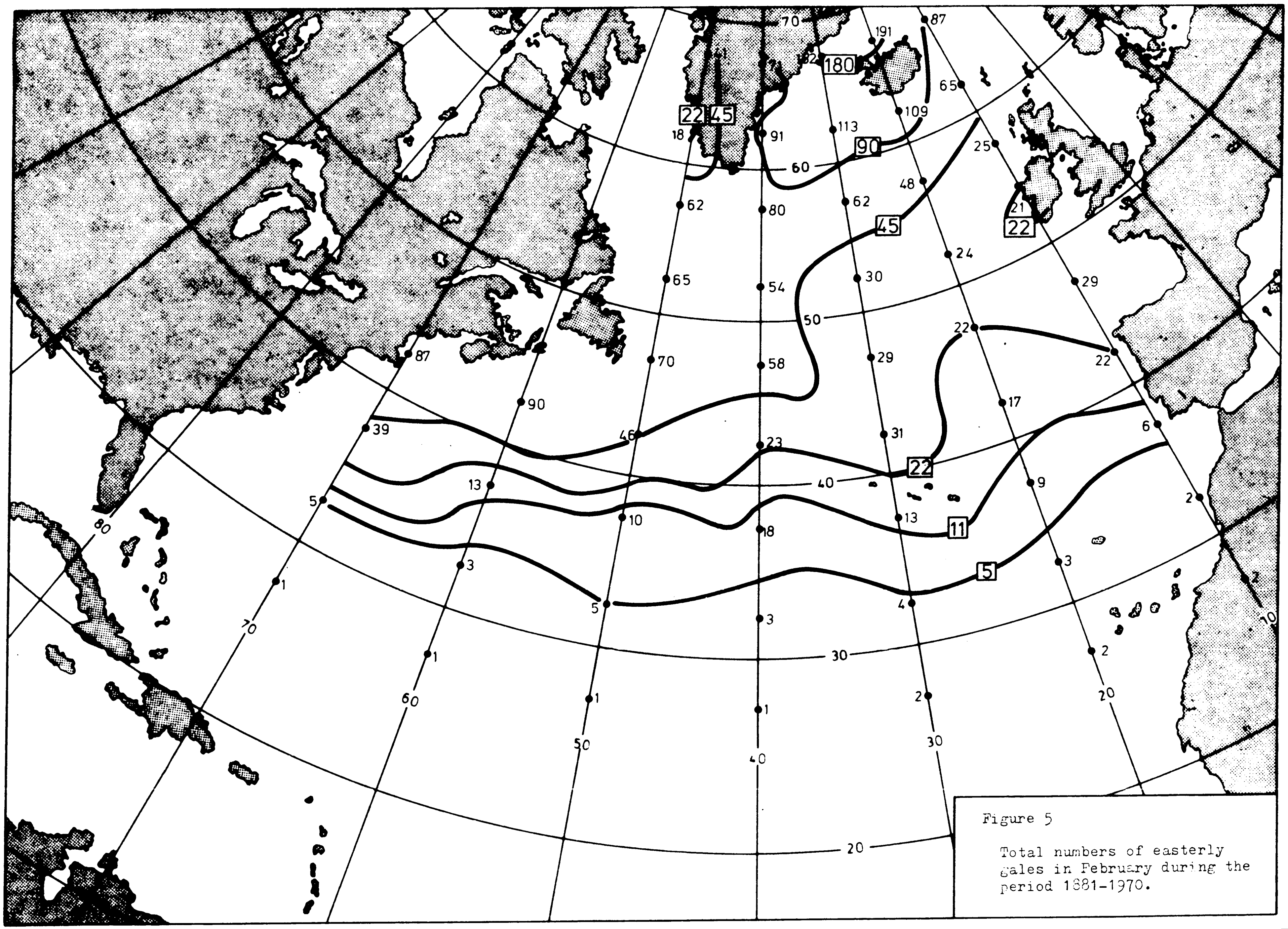

Figure 5

Total numbers of easterly gales in February during the period 1881-1970.

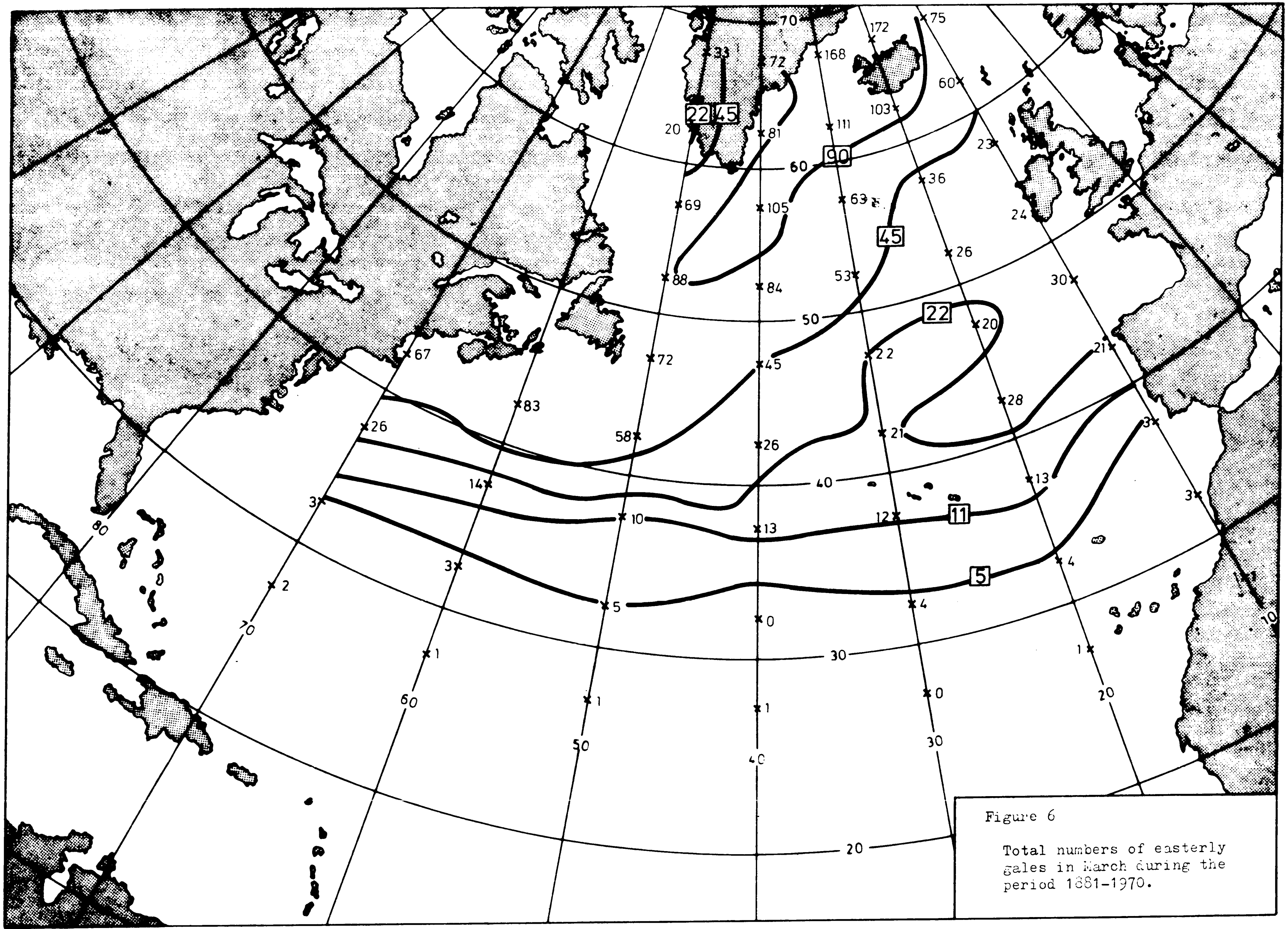

Figure 6

Total numbers of easterly gales in March during the period 1881-1970.

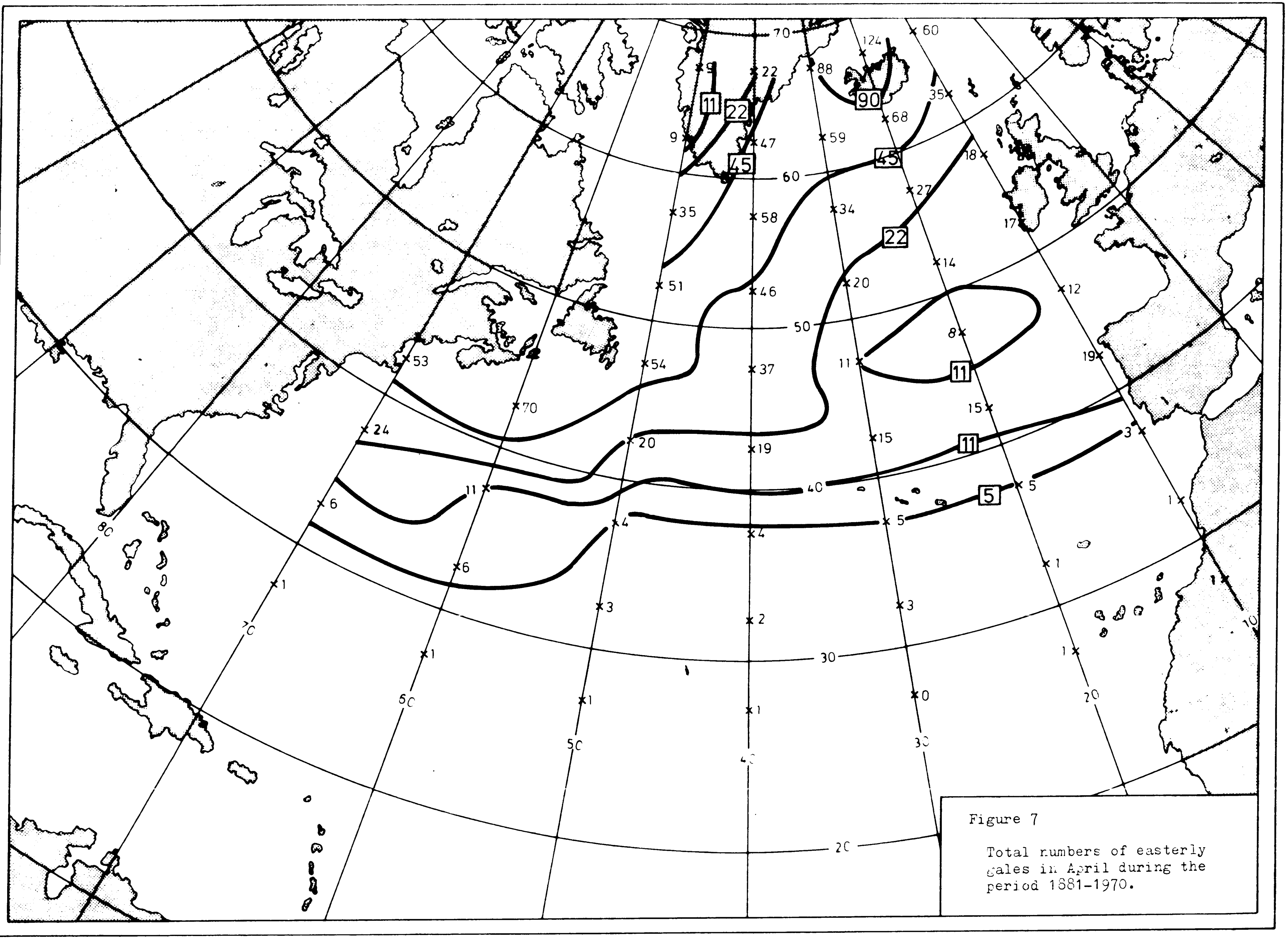

Figure 7

Total numbers of easterly gales in April during the period 1881-1970.

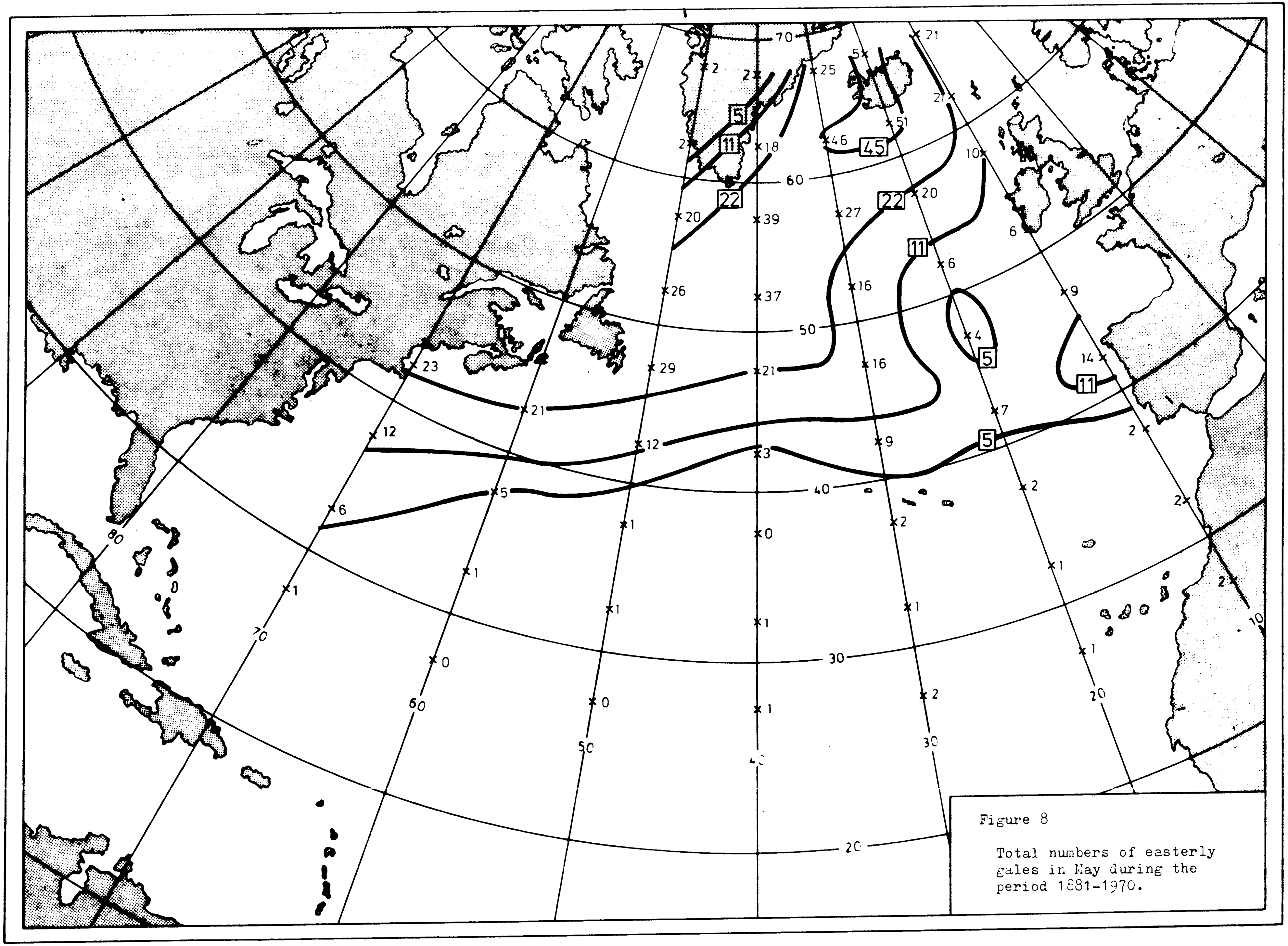

Figure 8

Total numbers of easterly gales in May during the period 1881-1970.

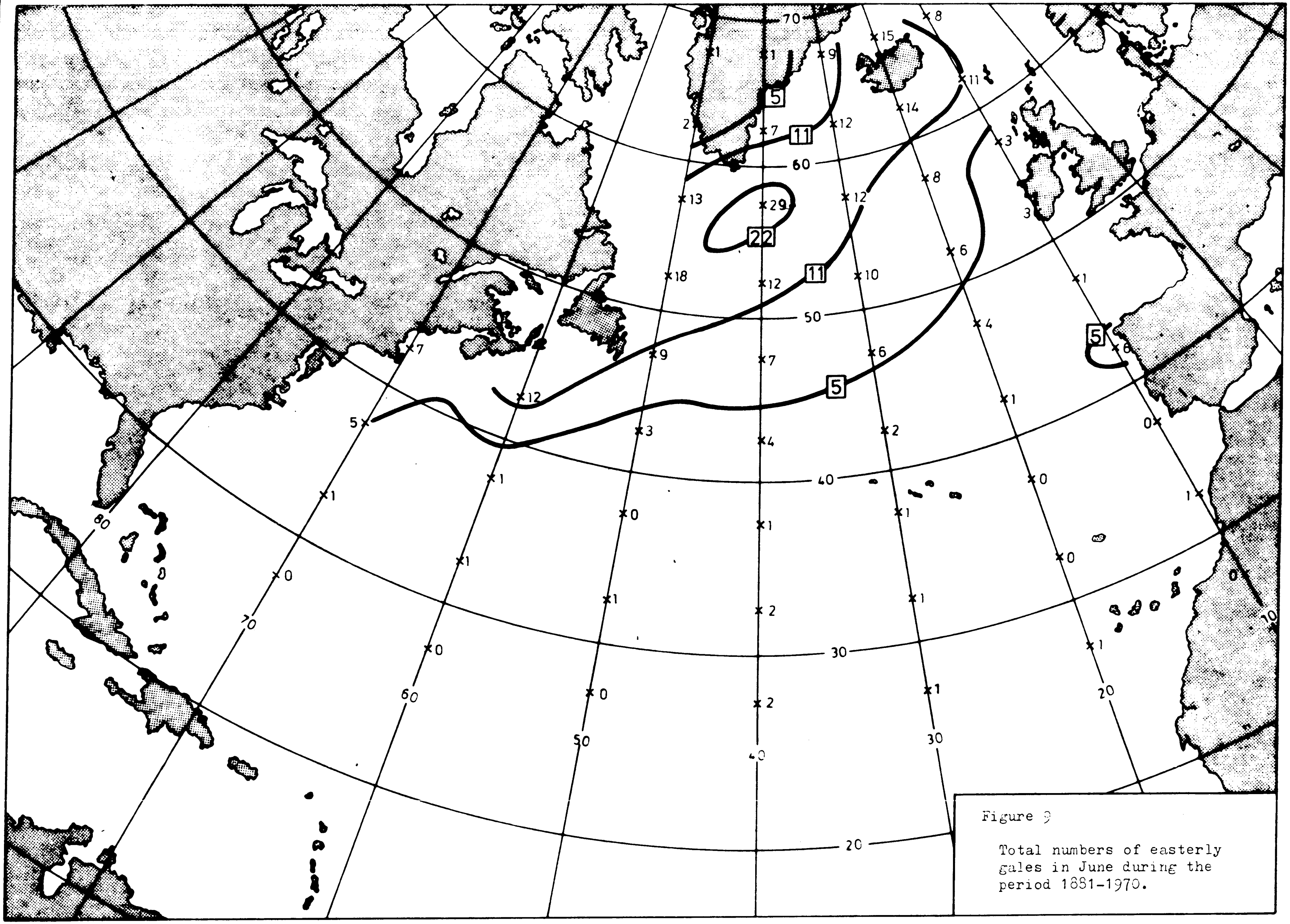

Figure 9

Total numbers of easterly gales in June during the period 1881-1970.

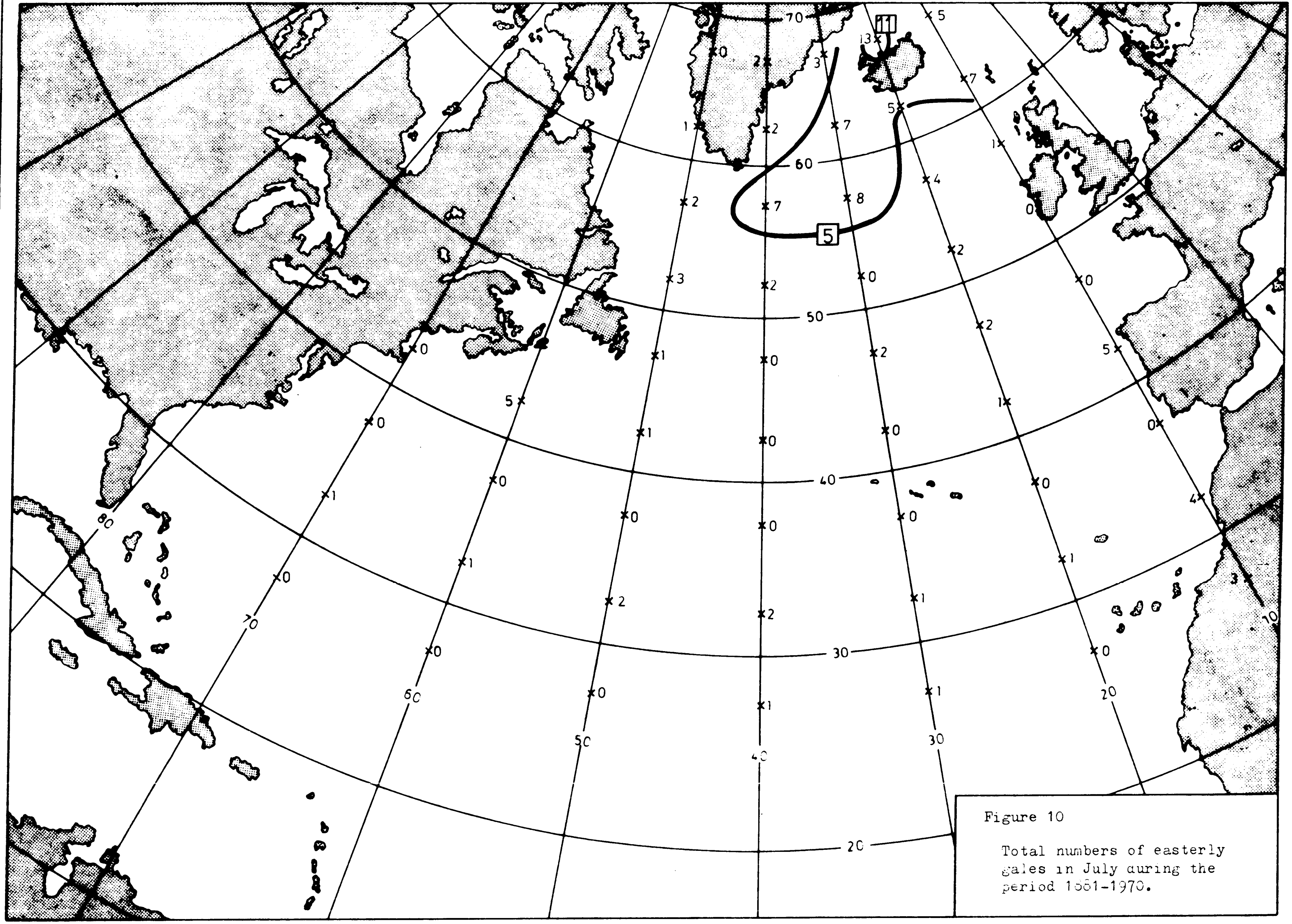

Figure 10

Total numbers of easterly gales in July during the period 1961-1970.

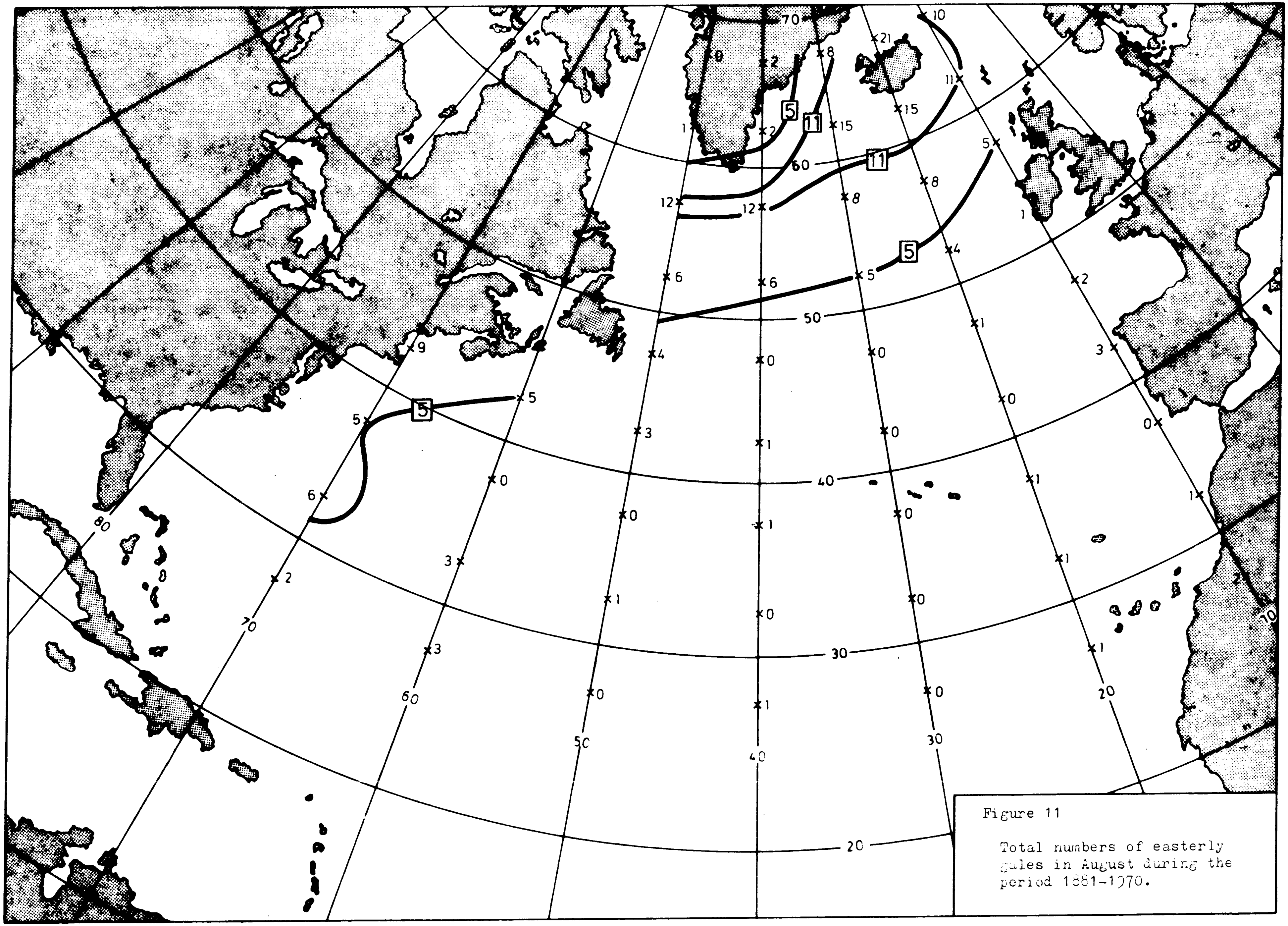

Figure 11

Total numbers of easterly gales in August during the period 1881-1970.

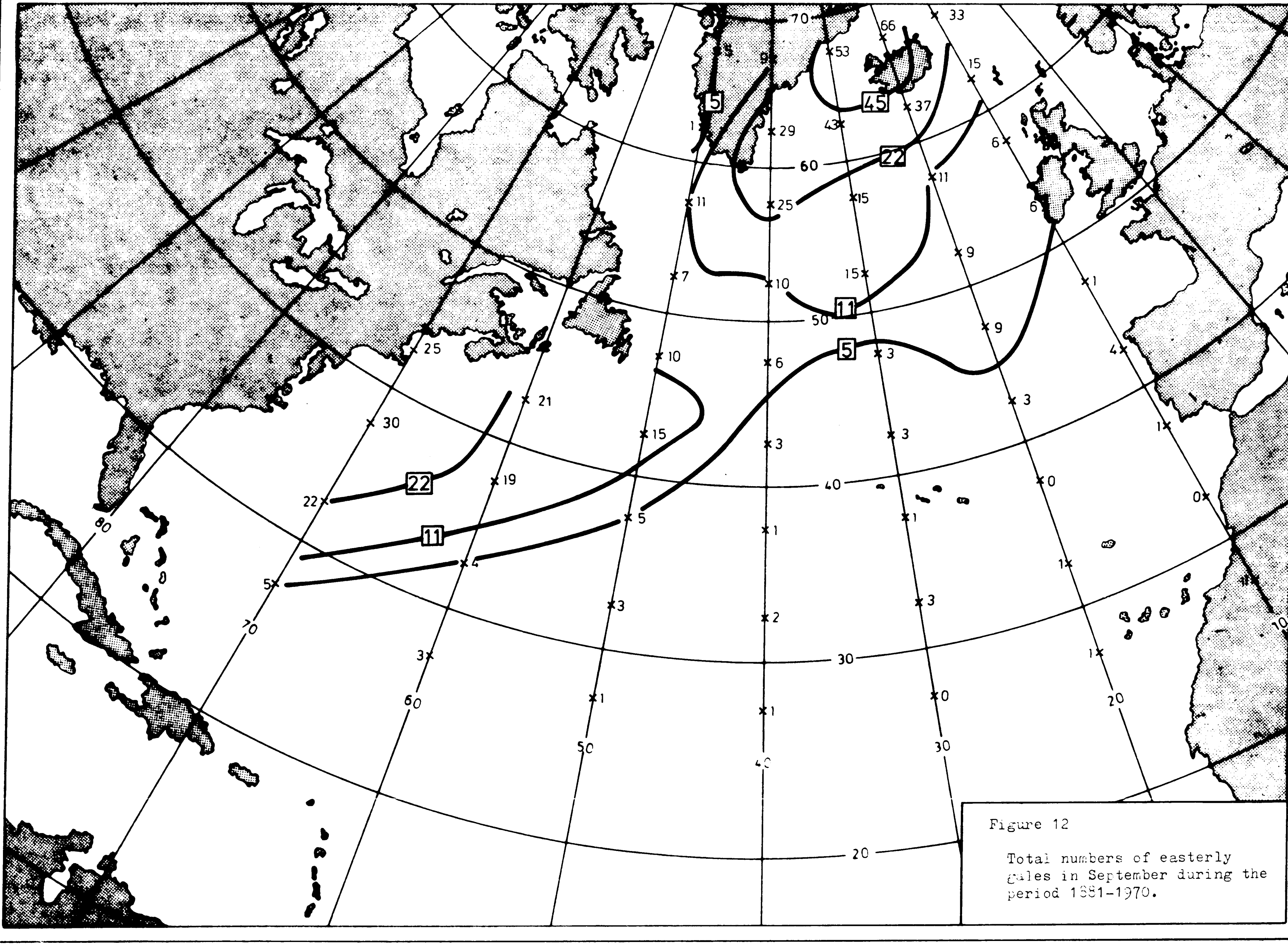

Figure 12

Total numbers of easterly gales in September during the period 1881-1970.

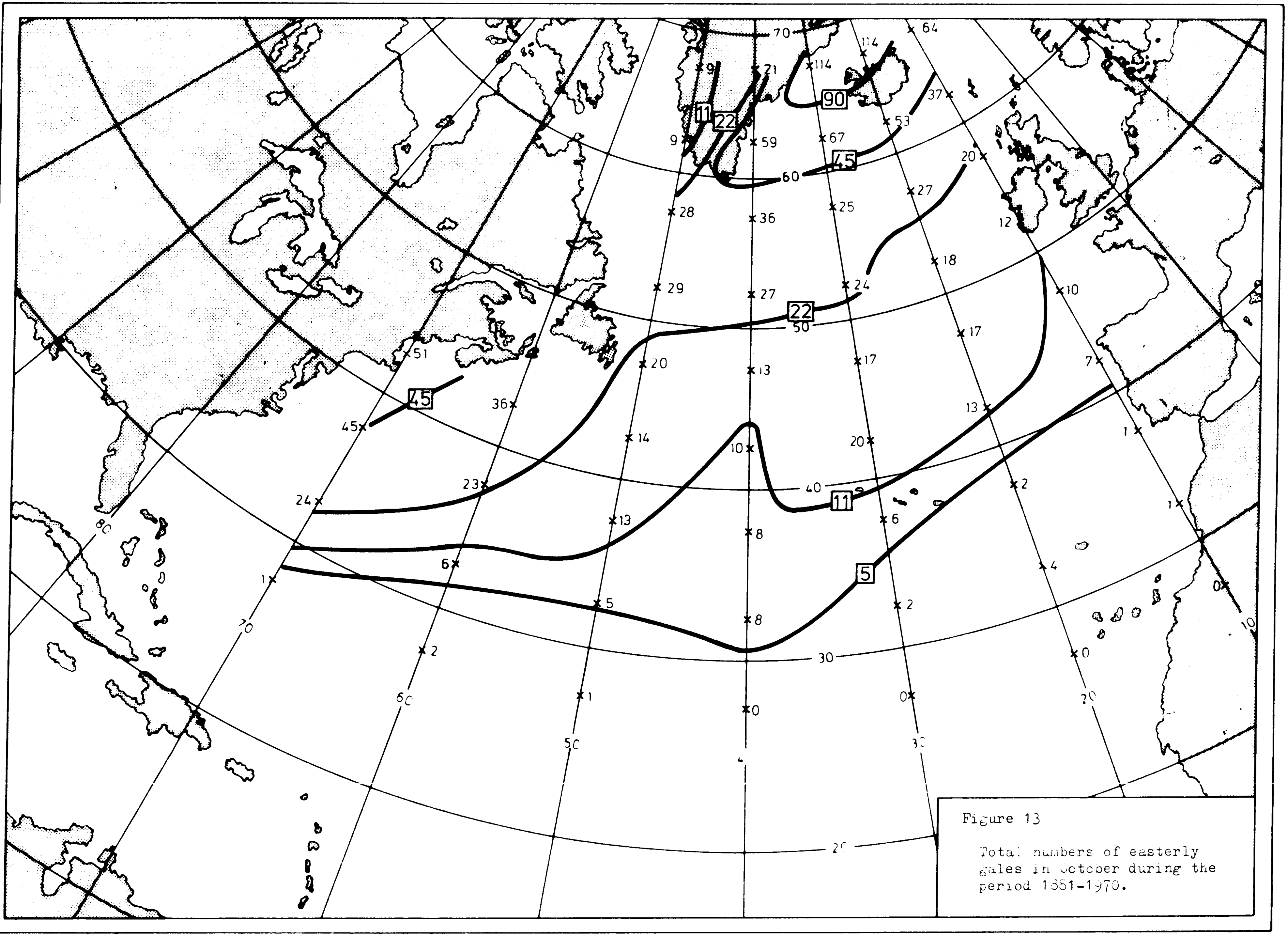

Figure 13

Total numbers of easterly gales in October during the period 1961-1970.

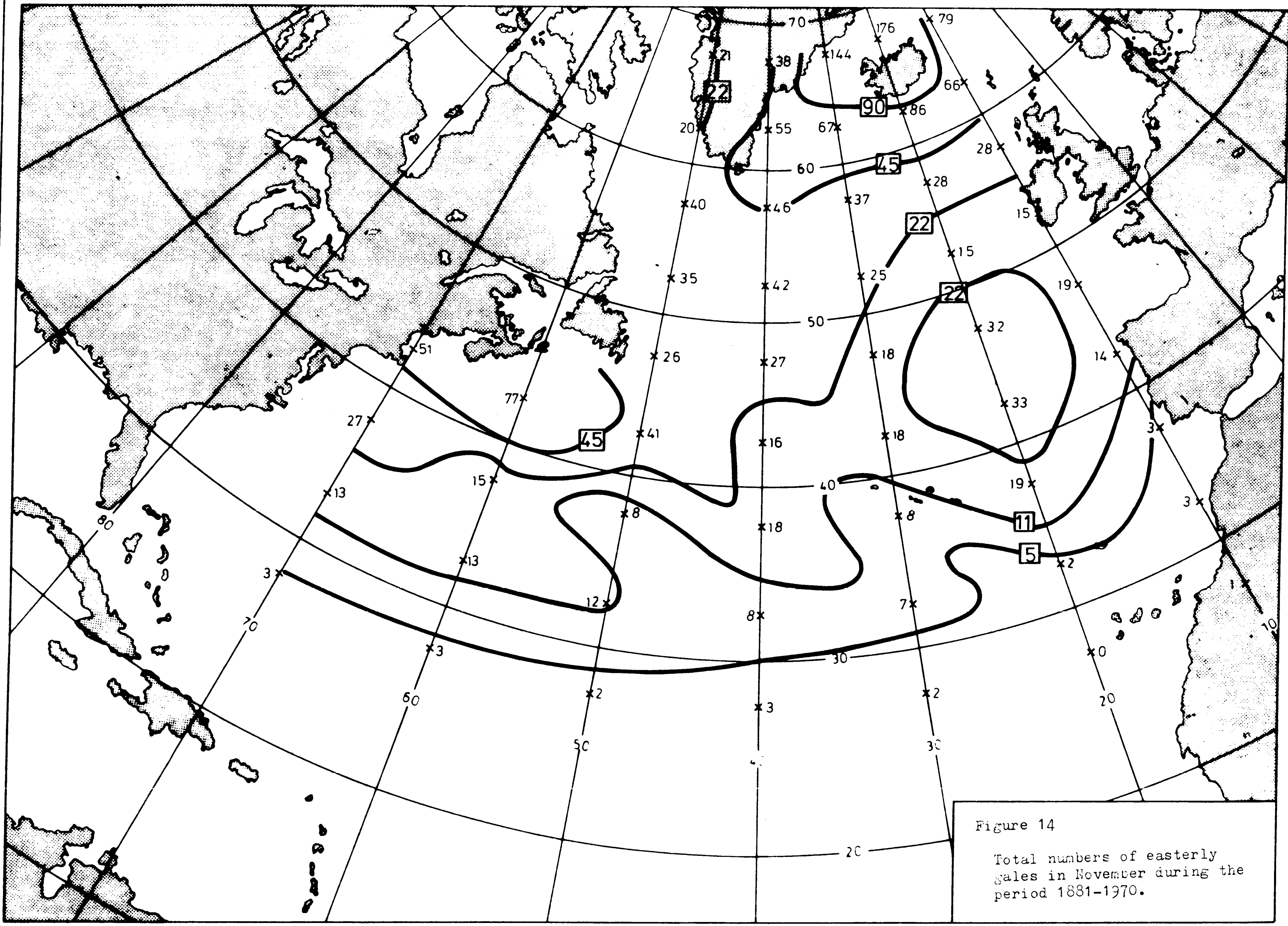

Figure 14

Total numbers of easterly gales in November during the period 1881-1970.

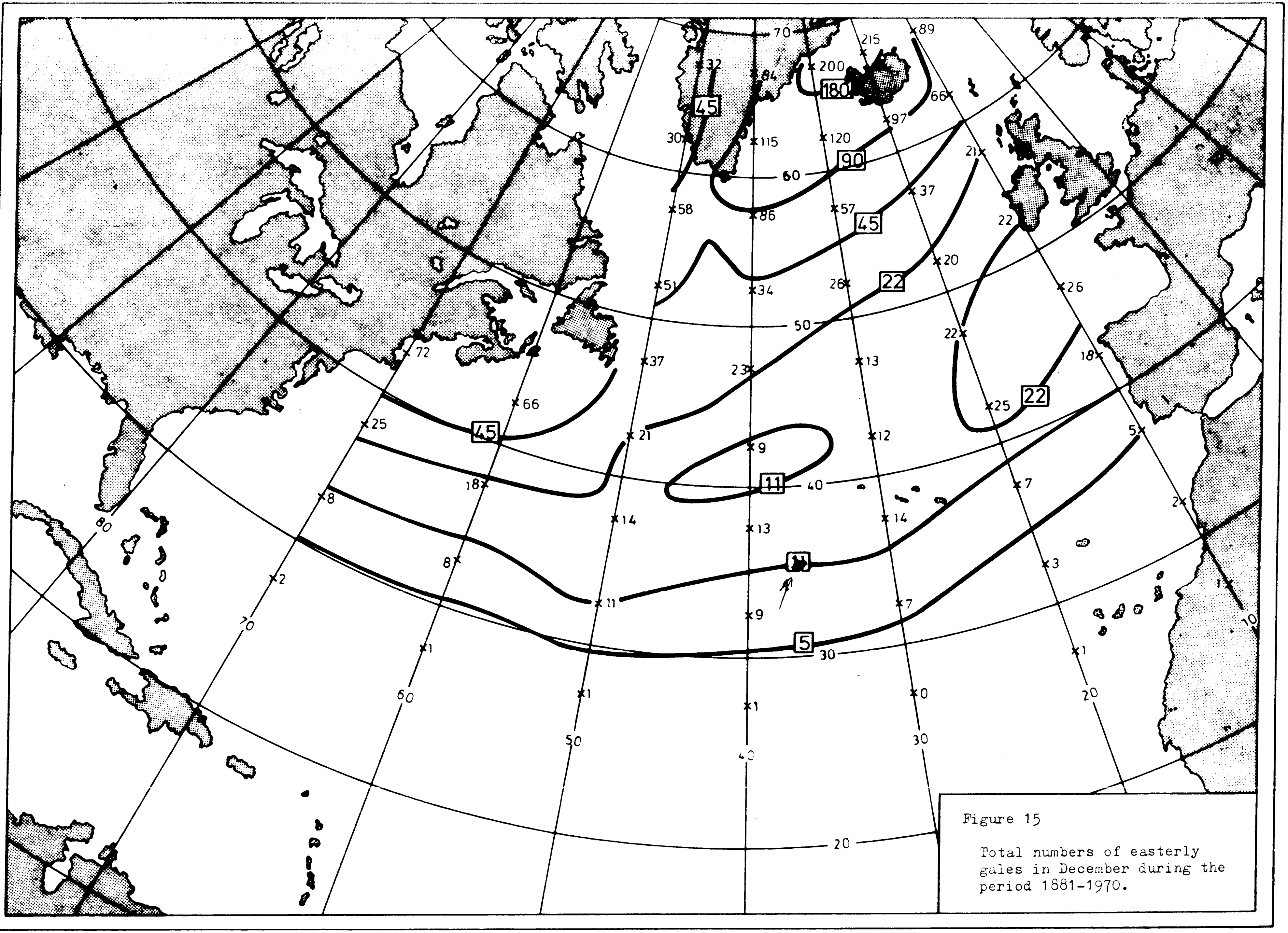

Figure 15

Total numbers of easterly gales in December during the period 1881-1970.

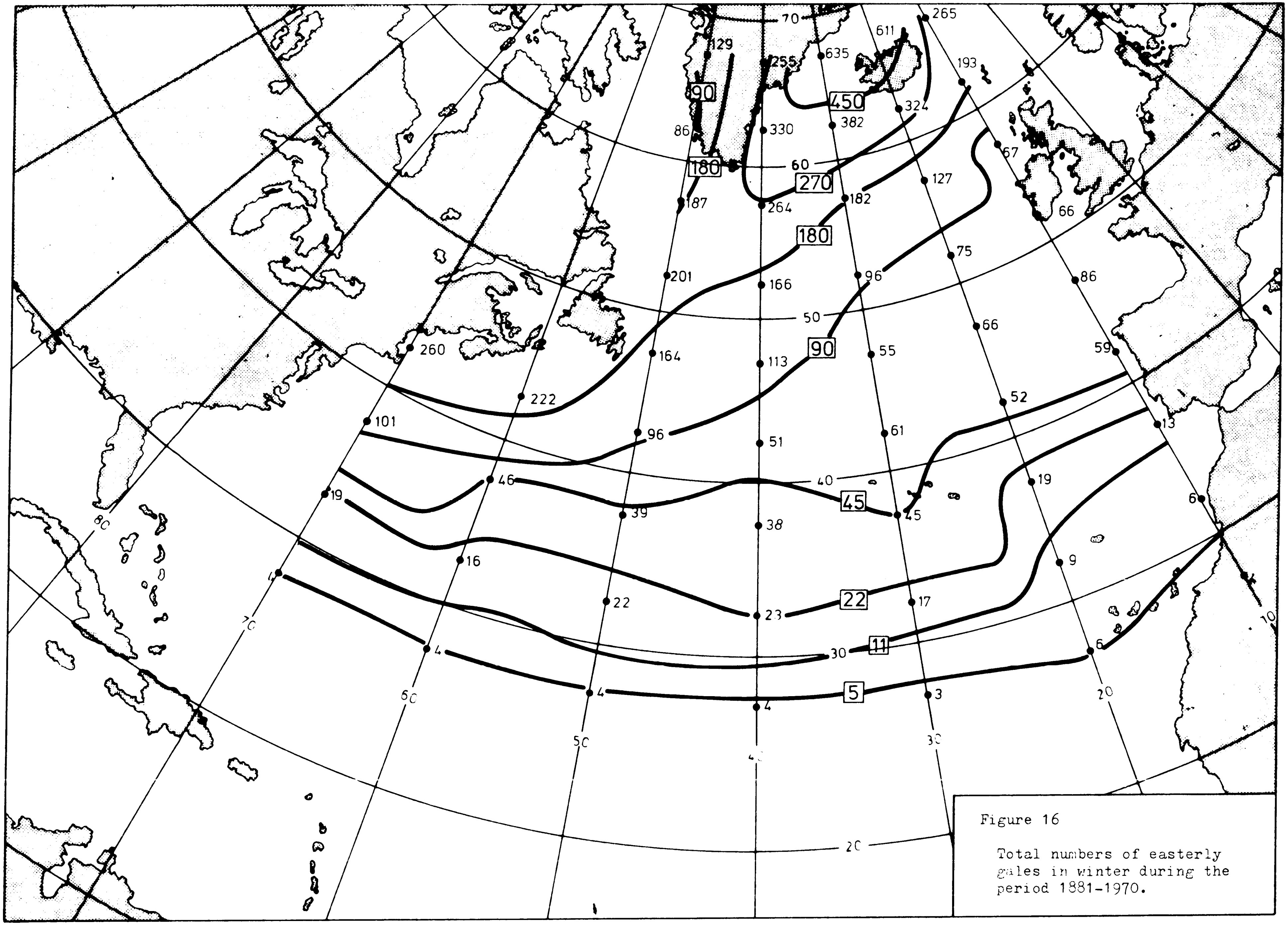

Figure 16

Total numbers of easterly gales in winter during the period 1881-1970.

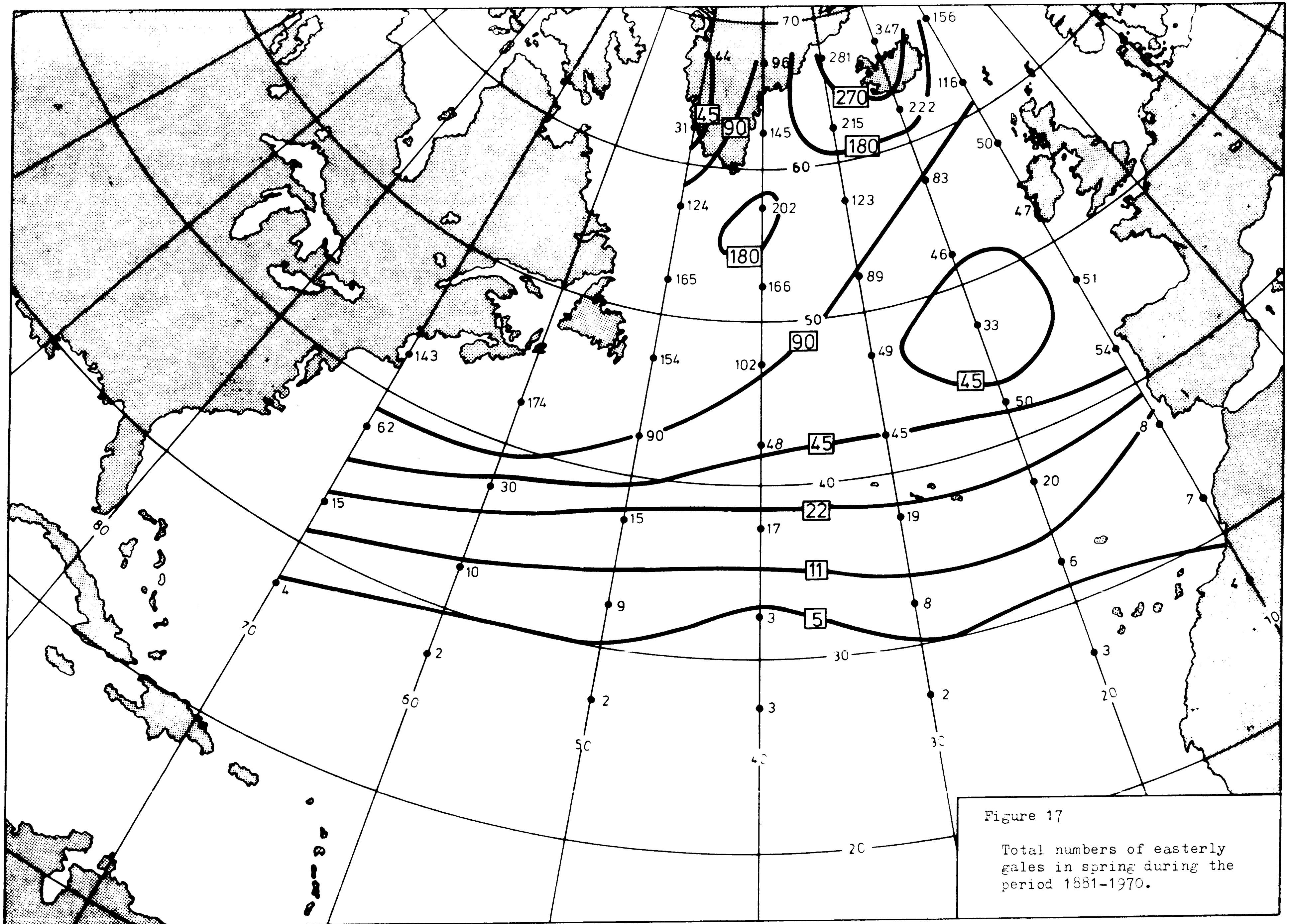

Figure 17

Total numbers of easterly gales in spring during the period 1881-1970.

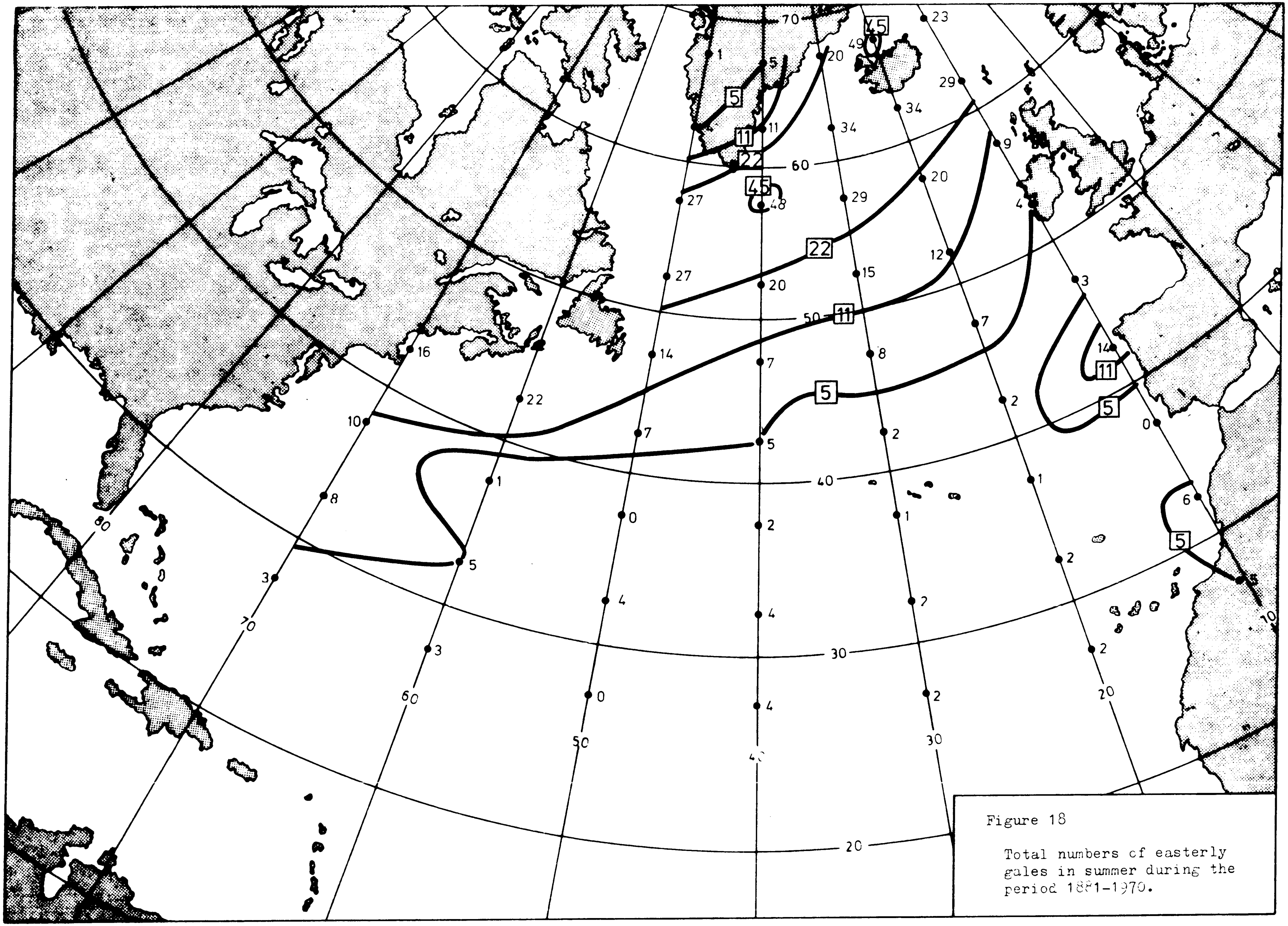

Figure 18

Total numbers of easterly gales in summer during the period 1881-1970.

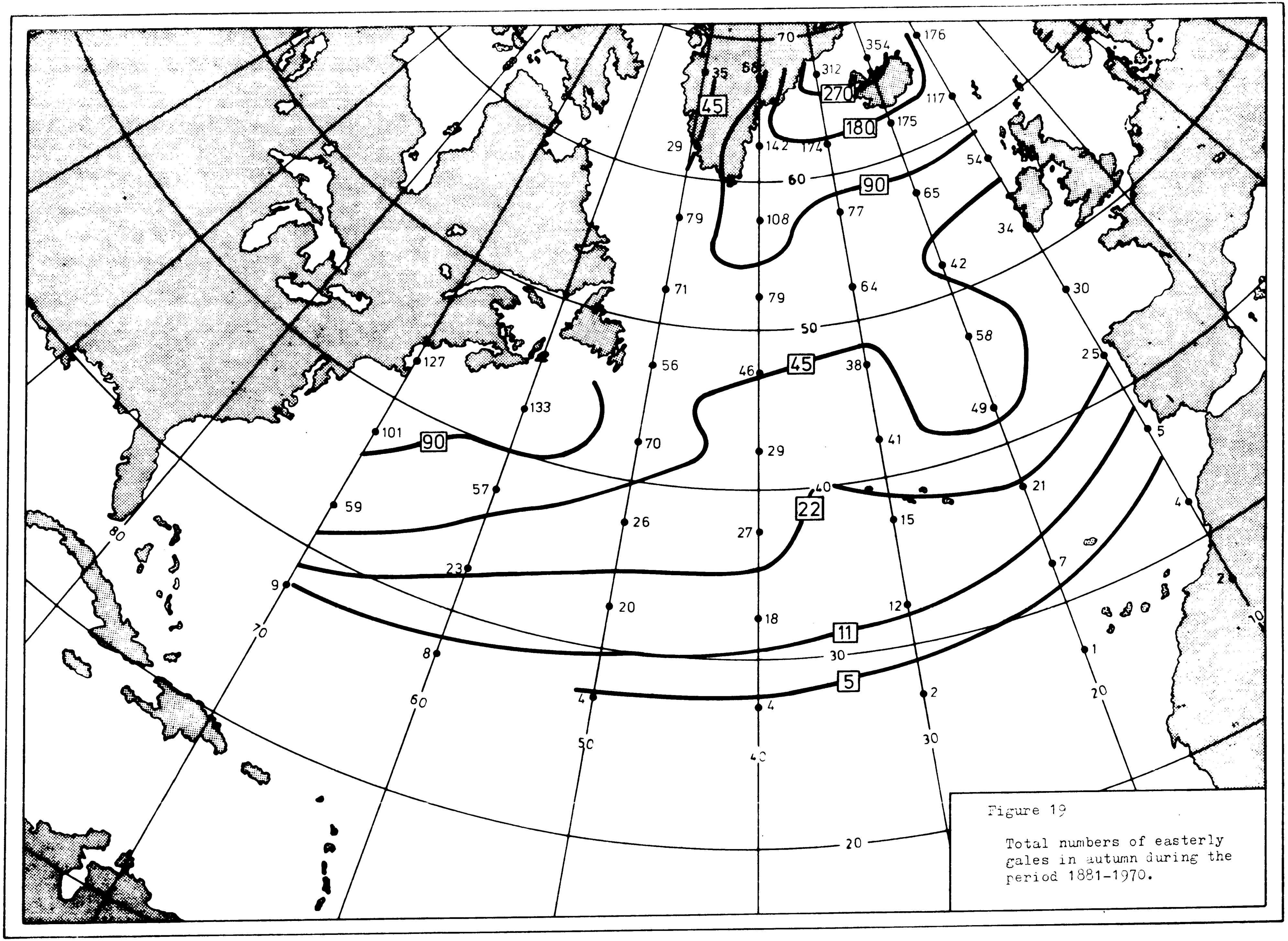

Figure 19

Total numbers of easterly gales in autumn during the period 1881-1970.

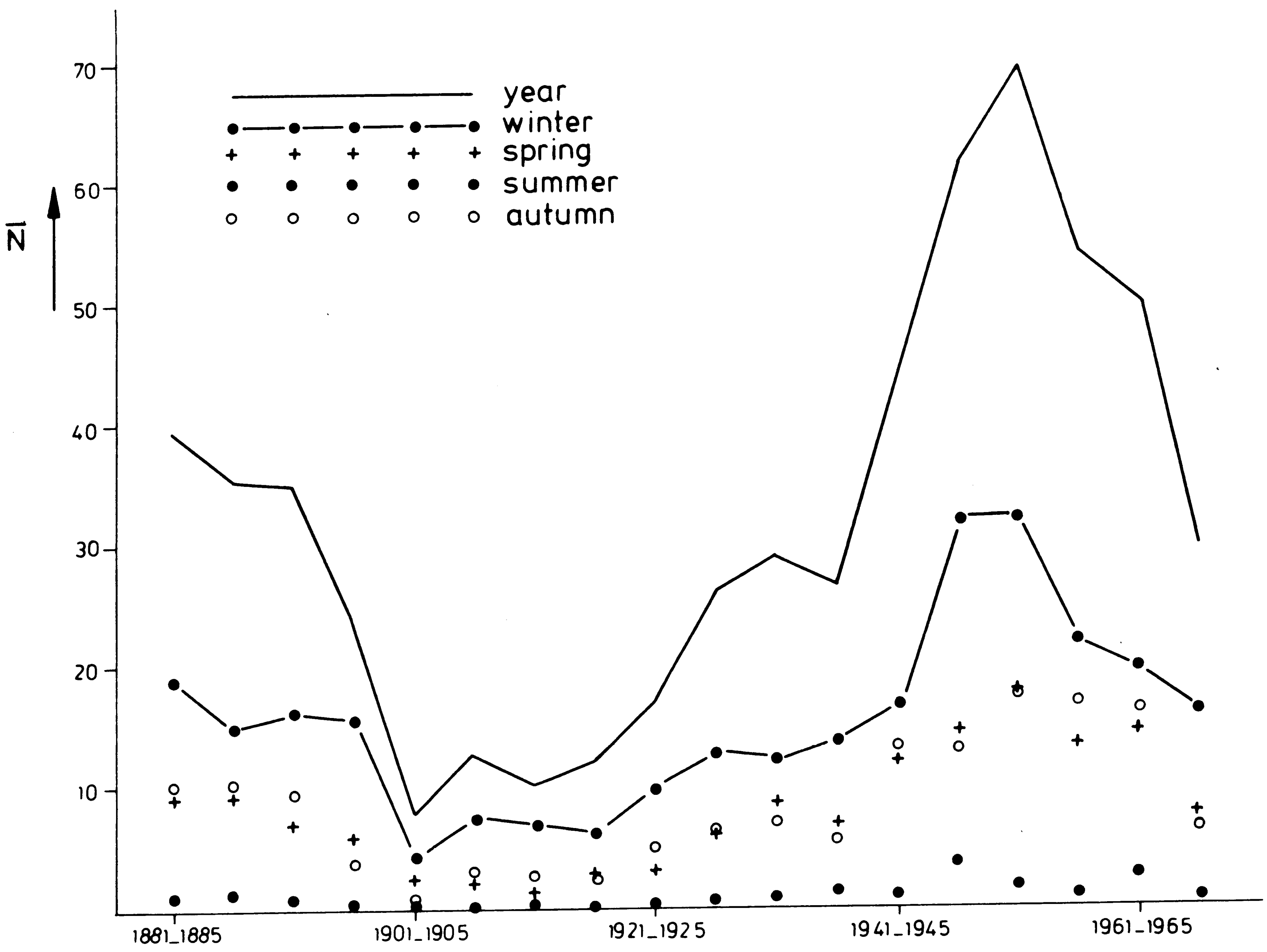

Figure 20

Over five years averaged numbers of days ($\overline{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 70°N and 65°N.

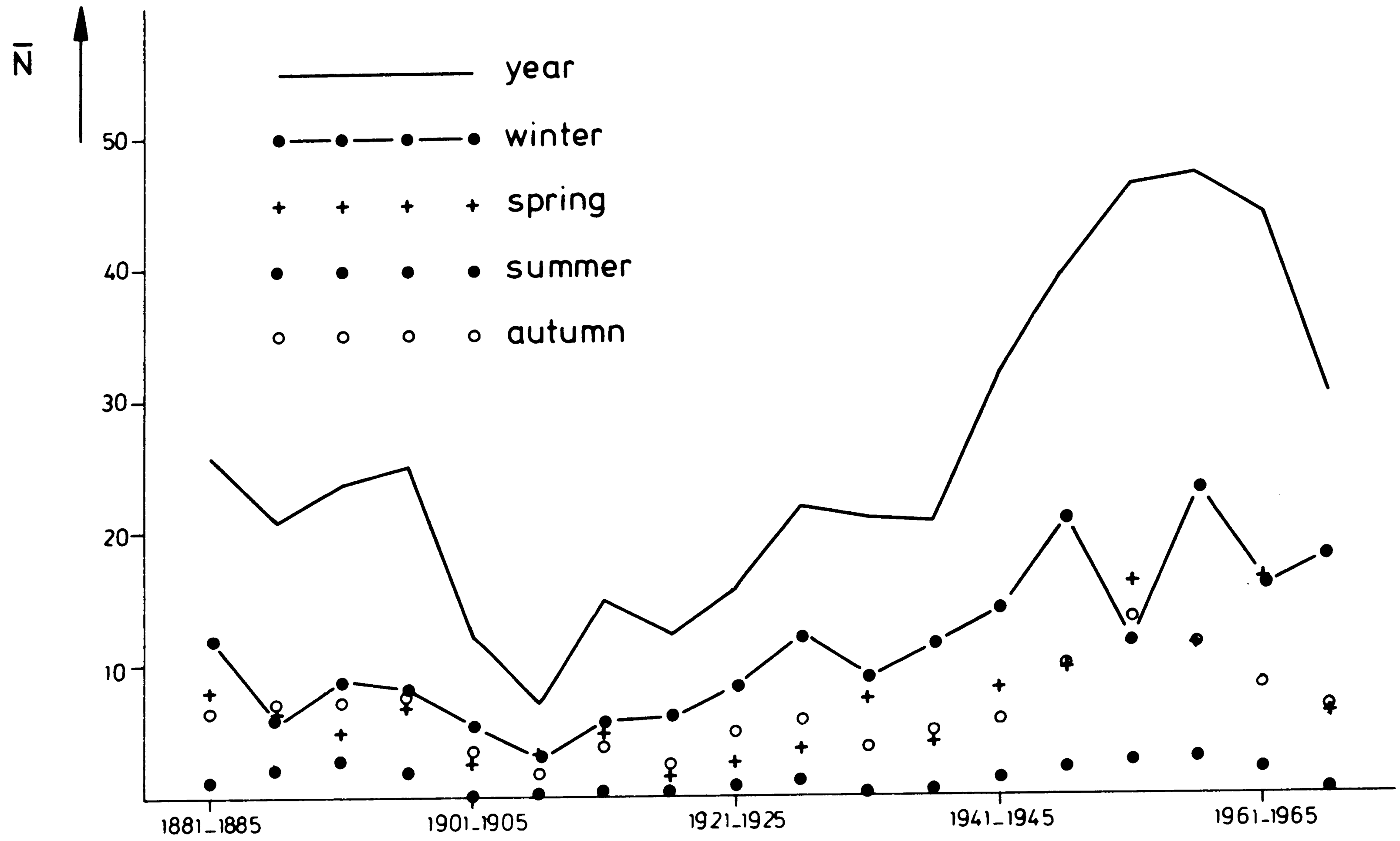

Figure 21

Over five years averaged numbers of days ($\bar{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 65°N and 60°N.

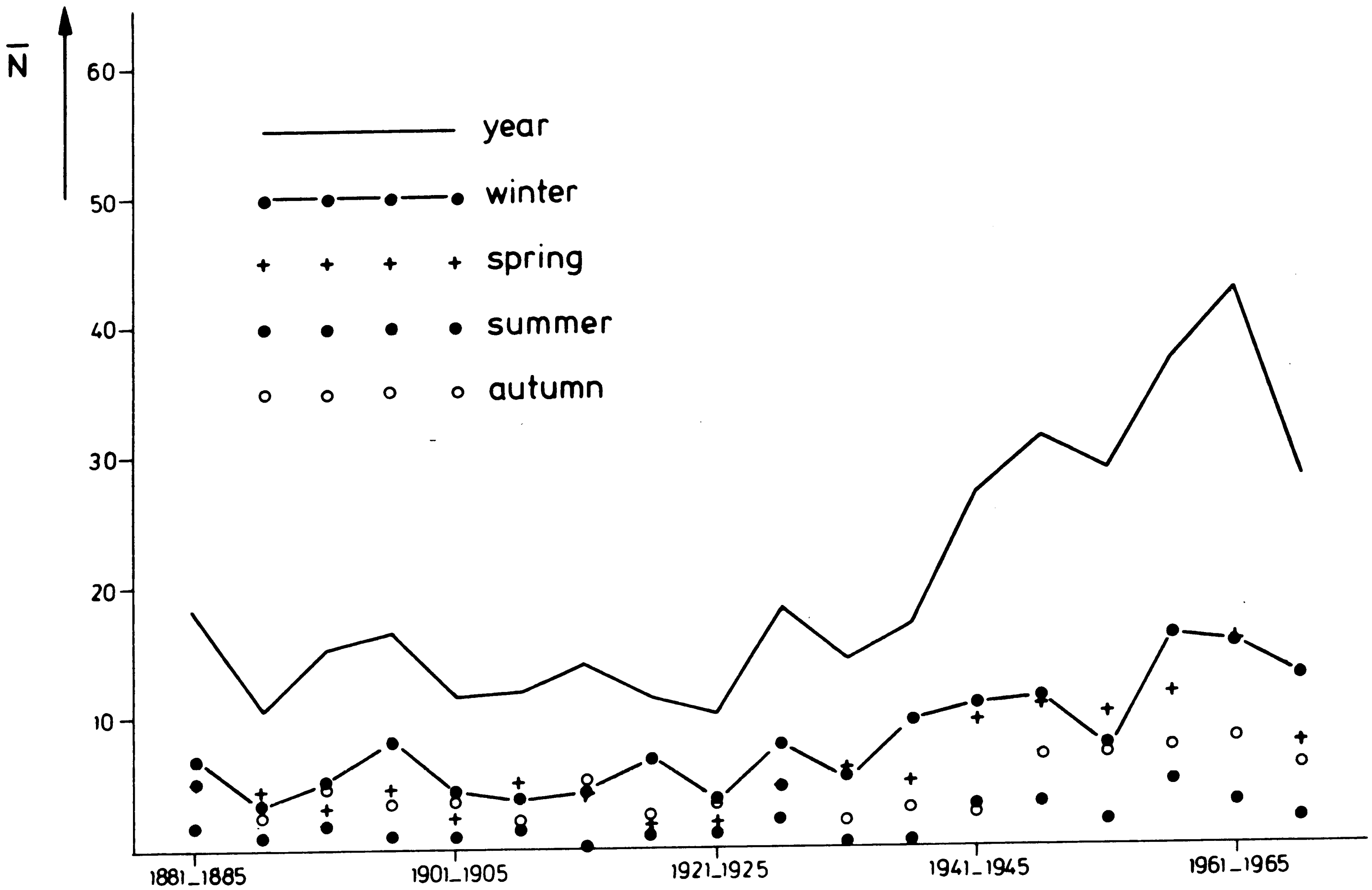

Figure 22

Over five years averaged numbers of days ($\overline{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 60^{o} N and 55^{o} N.

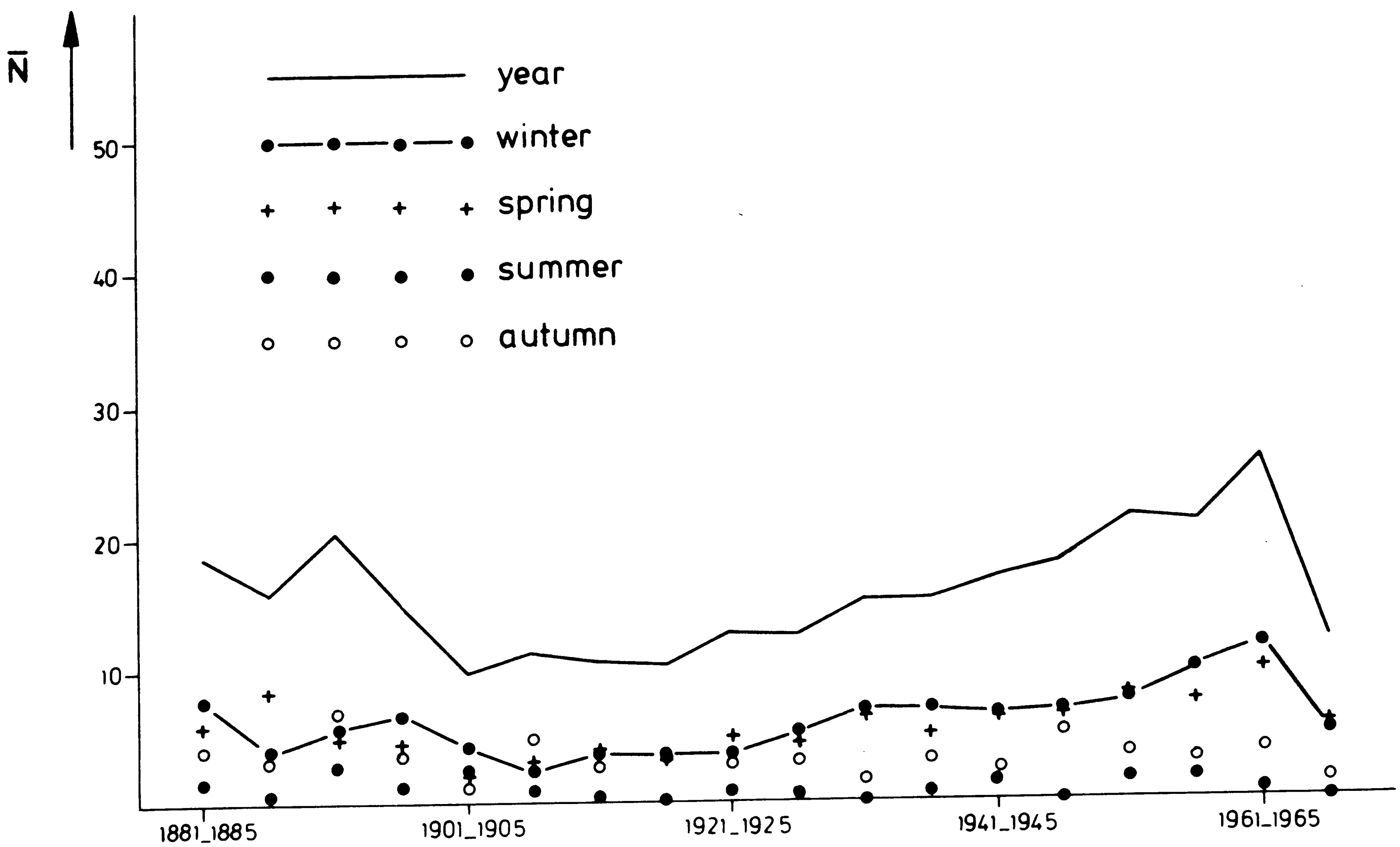

Figure 23

Over five years averaged numbers of days ($\overline{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 55°N and 50°N.

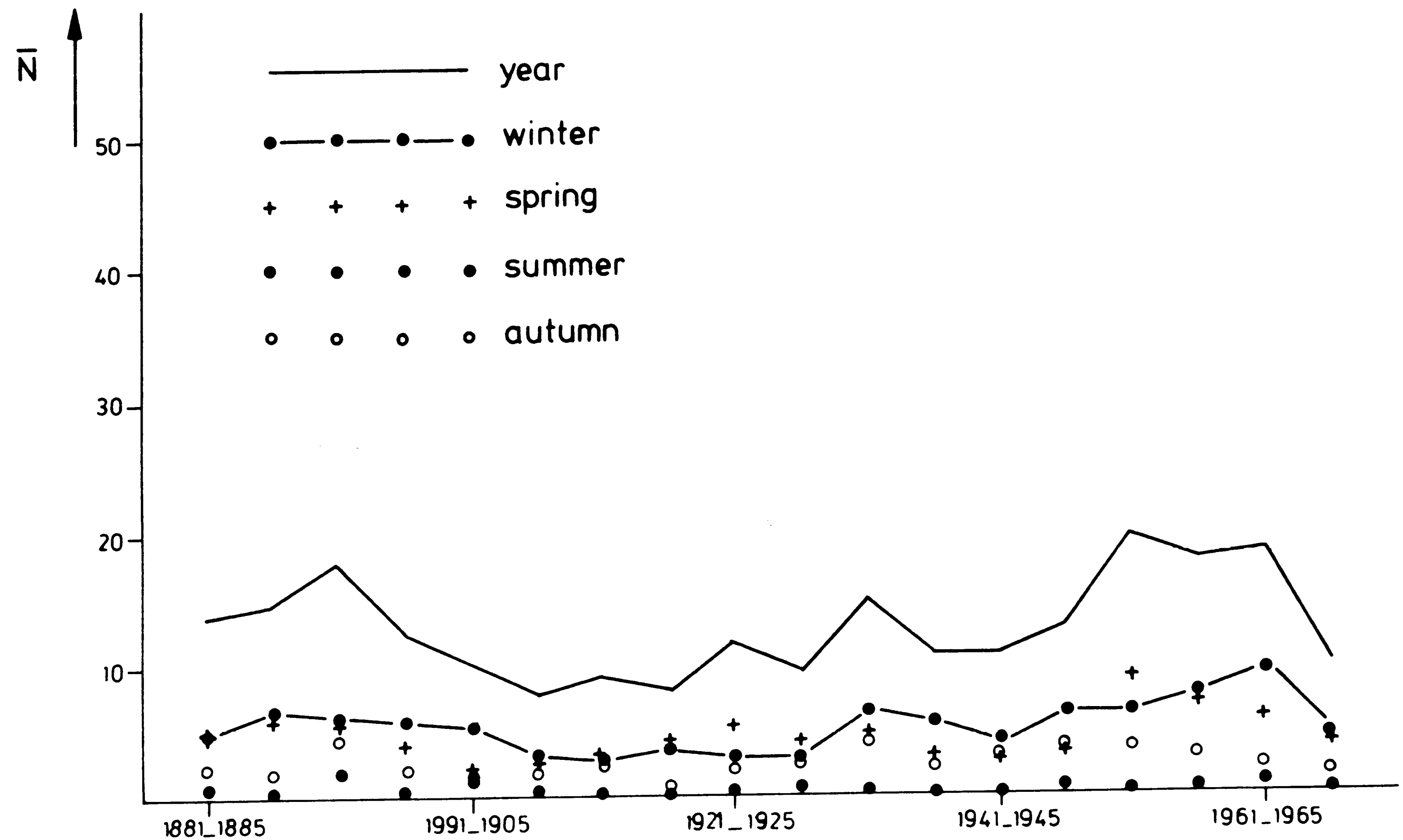

Figure 24

Over five years averaged numbers of days ($\overline{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 50^{o}N and 45^{o}N.

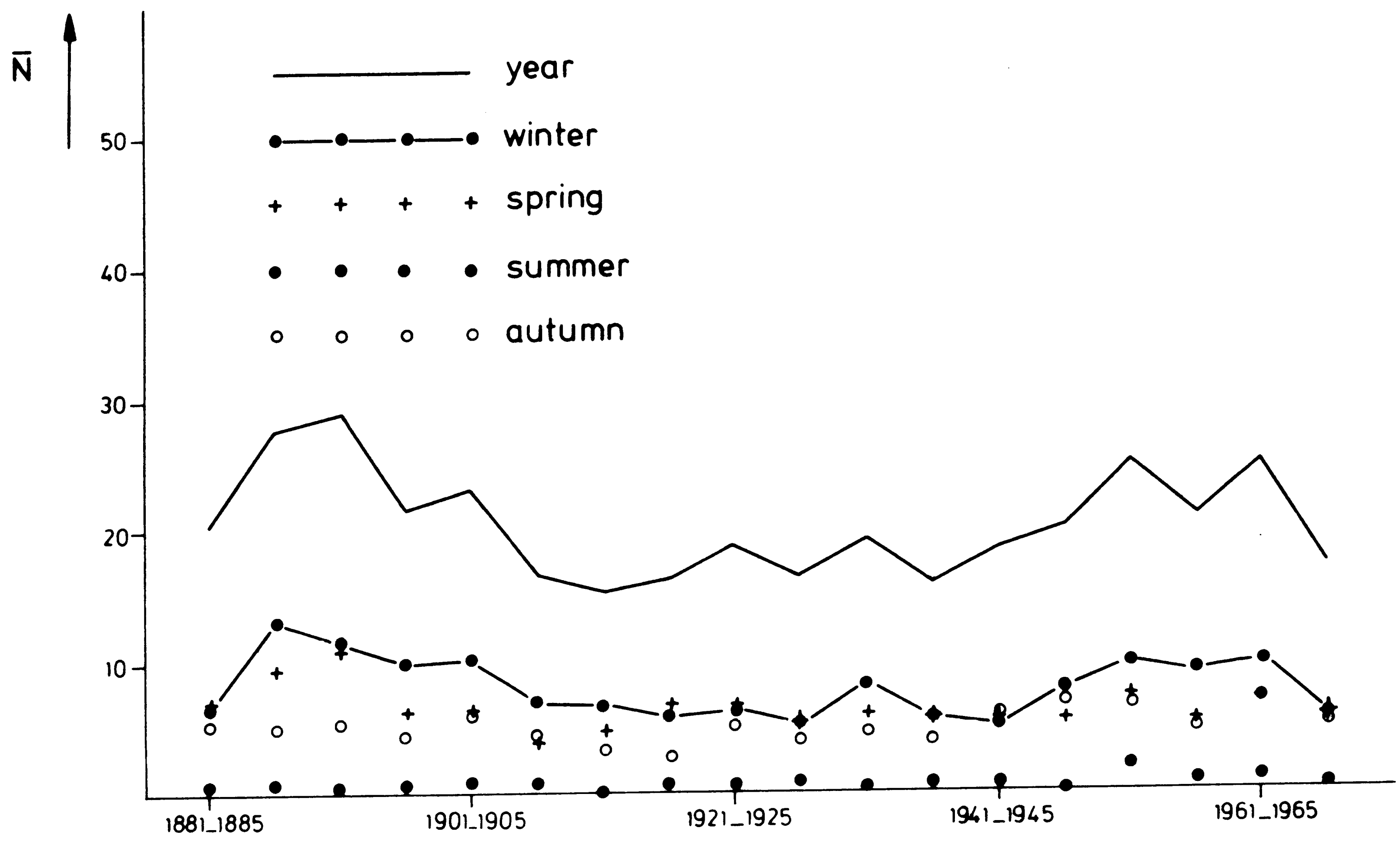

Figure 25

Over five years averaged numbers of days ($\bar{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 45°N and 40°N.

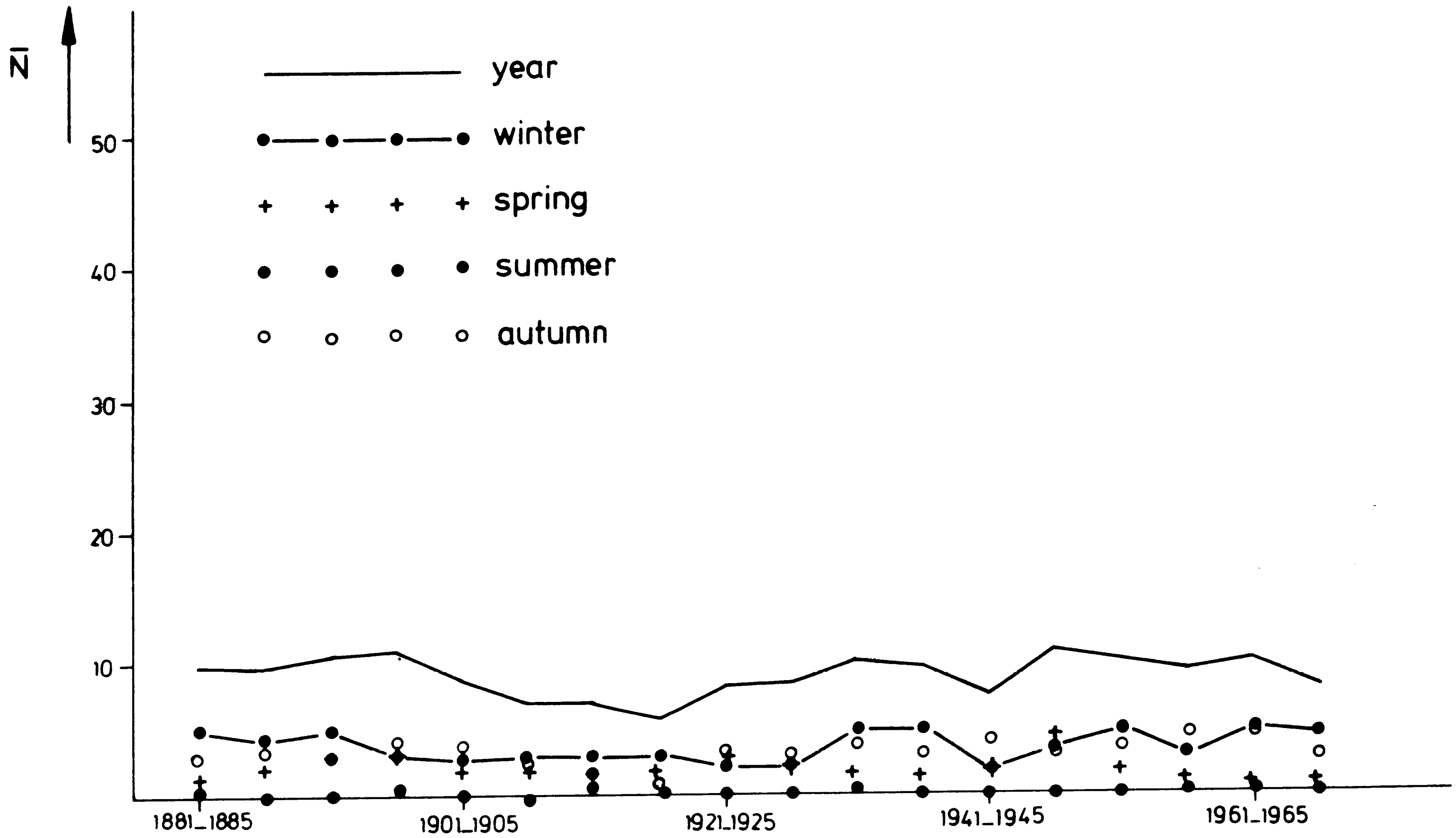

Figure 26

Over five years averaged numbers of days ($\overline{N}$) per year and per season on which an easterly gale occurred in the latitude belt between 40°N and 35°N.

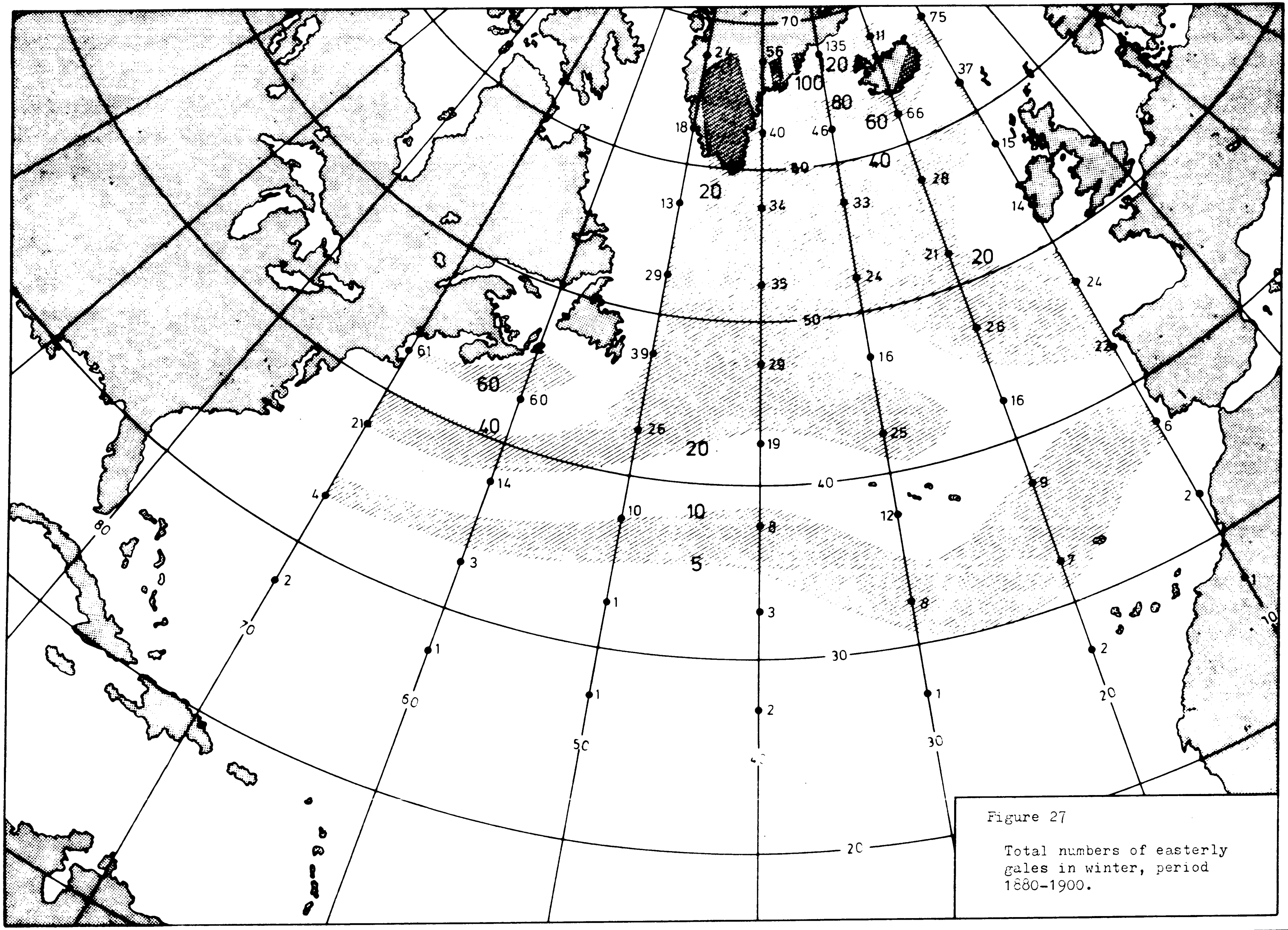

Figure 27

Total numbers of easterly gales in winter, period 1880-1900.

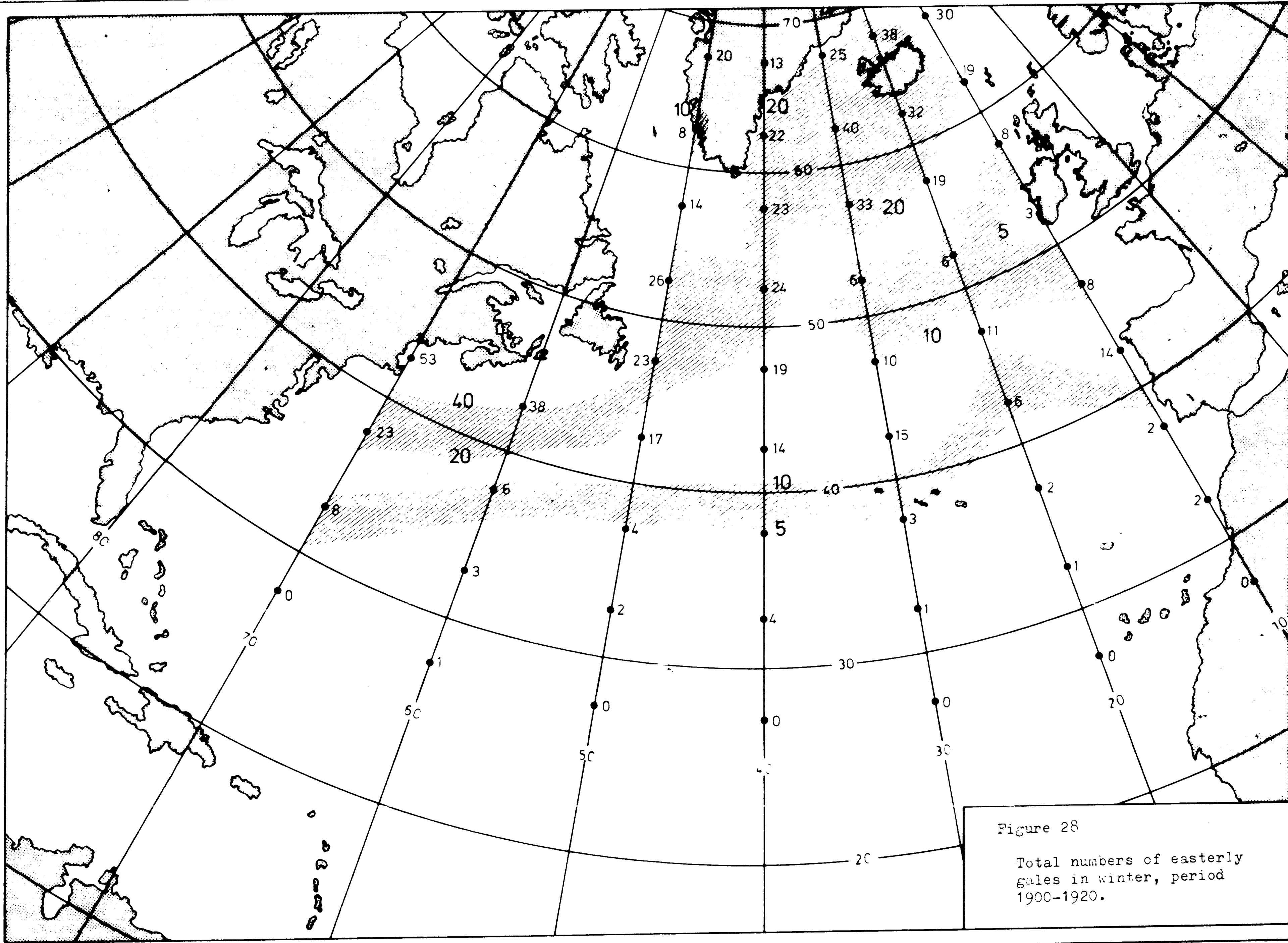

Figure 28

Total numbers of easterly gales in winter, period 1900-1920.

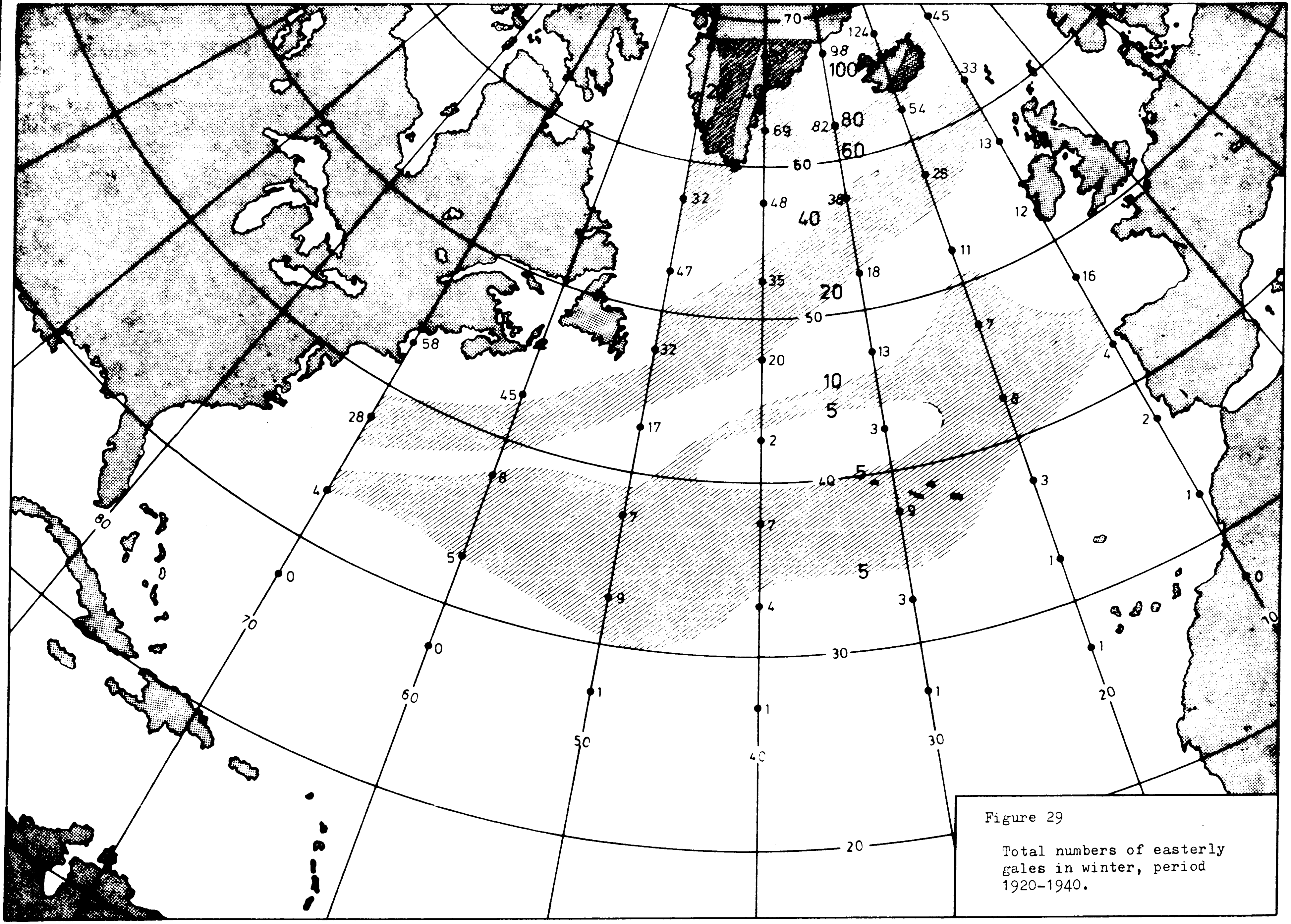

Figure 29

Total numbers of easterly gales in winter, period 1920-1940.

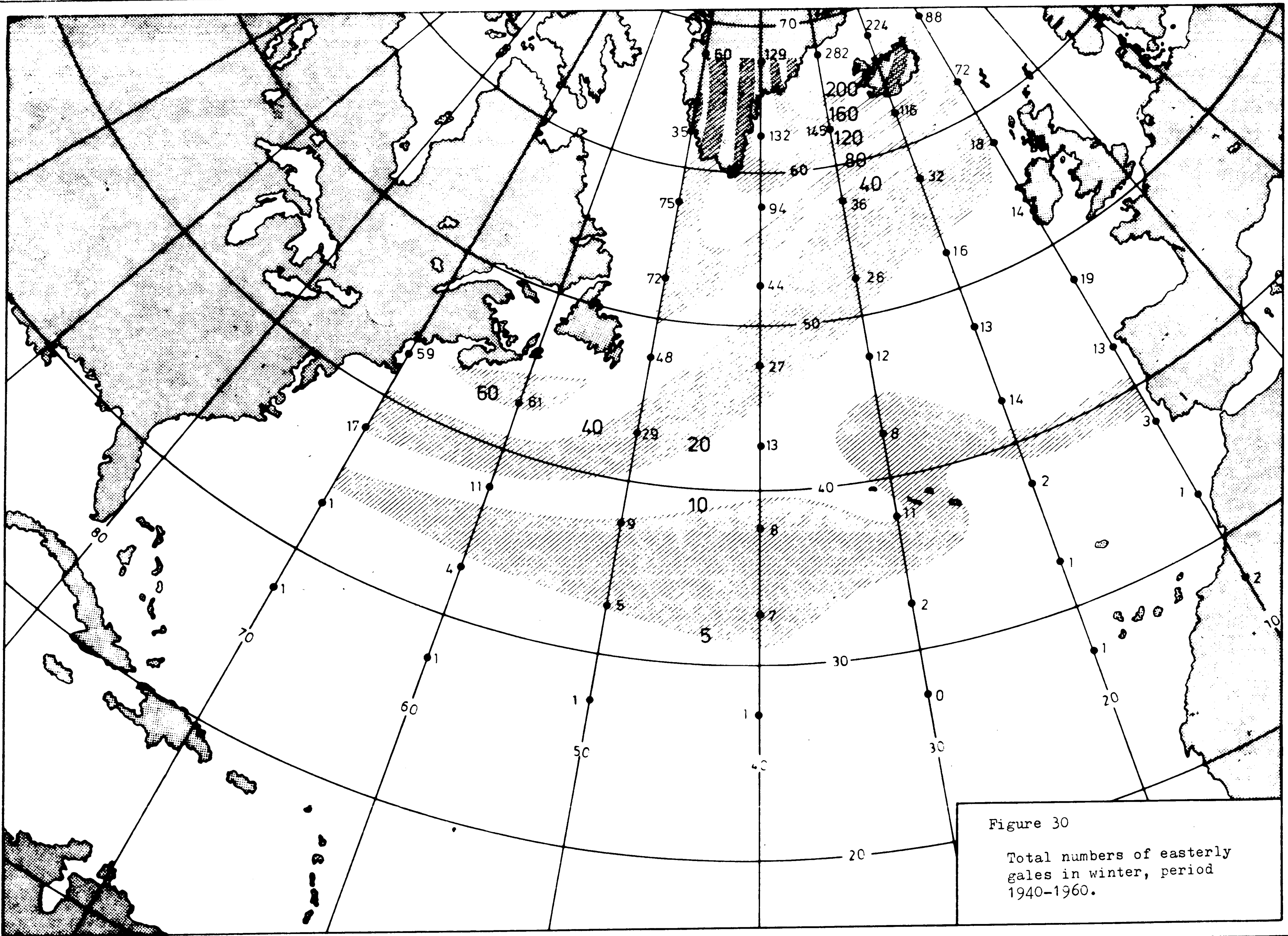

Figure 30

Total numbers of easterly gales in winter, period 1940-1960.

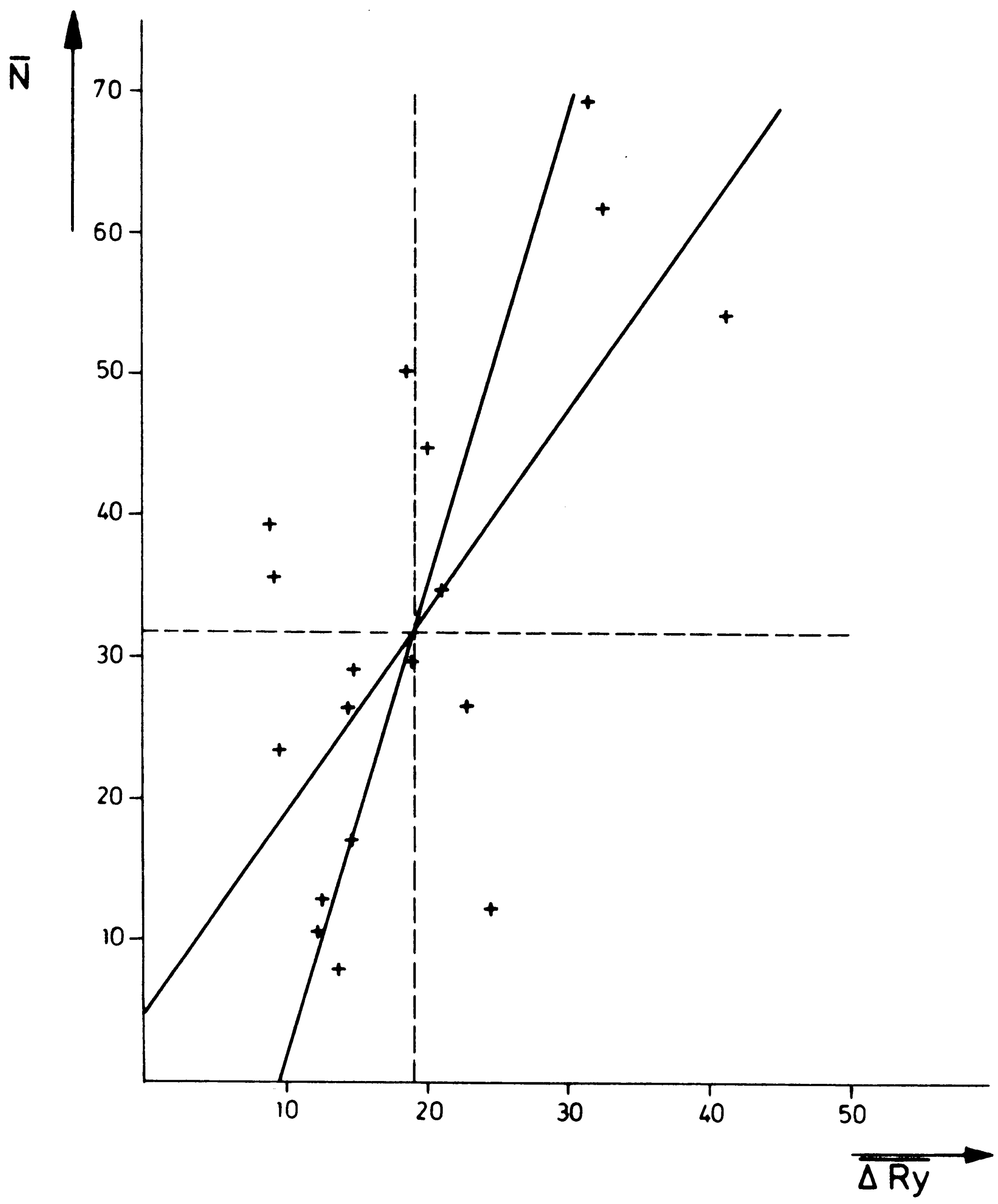

Figure 31

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\overline{N}$) in the latitude belt between 70°N and 65°N.

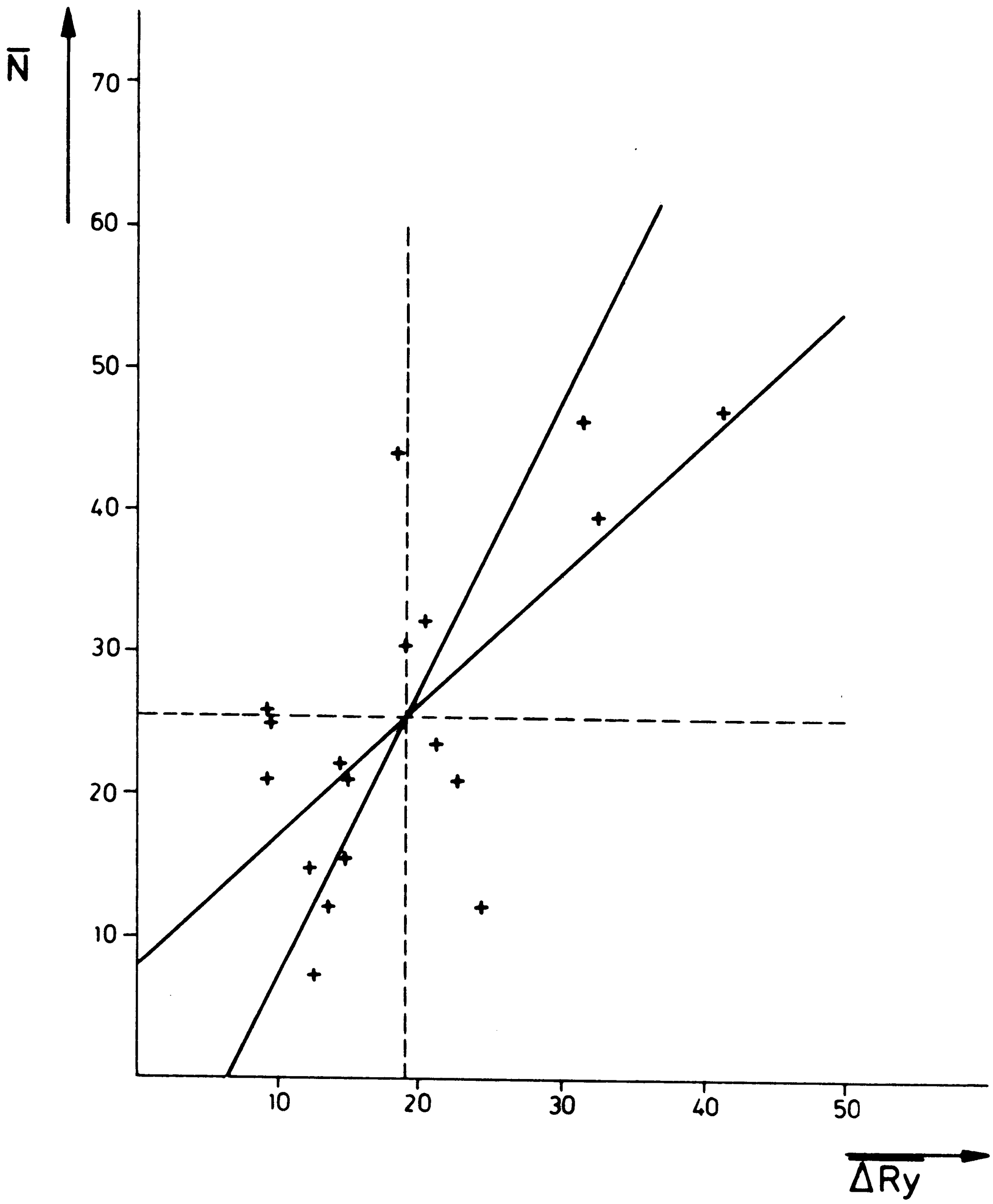

Figure 32

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\overline{N}$) in the latitude belt between 65°N and 60°N.

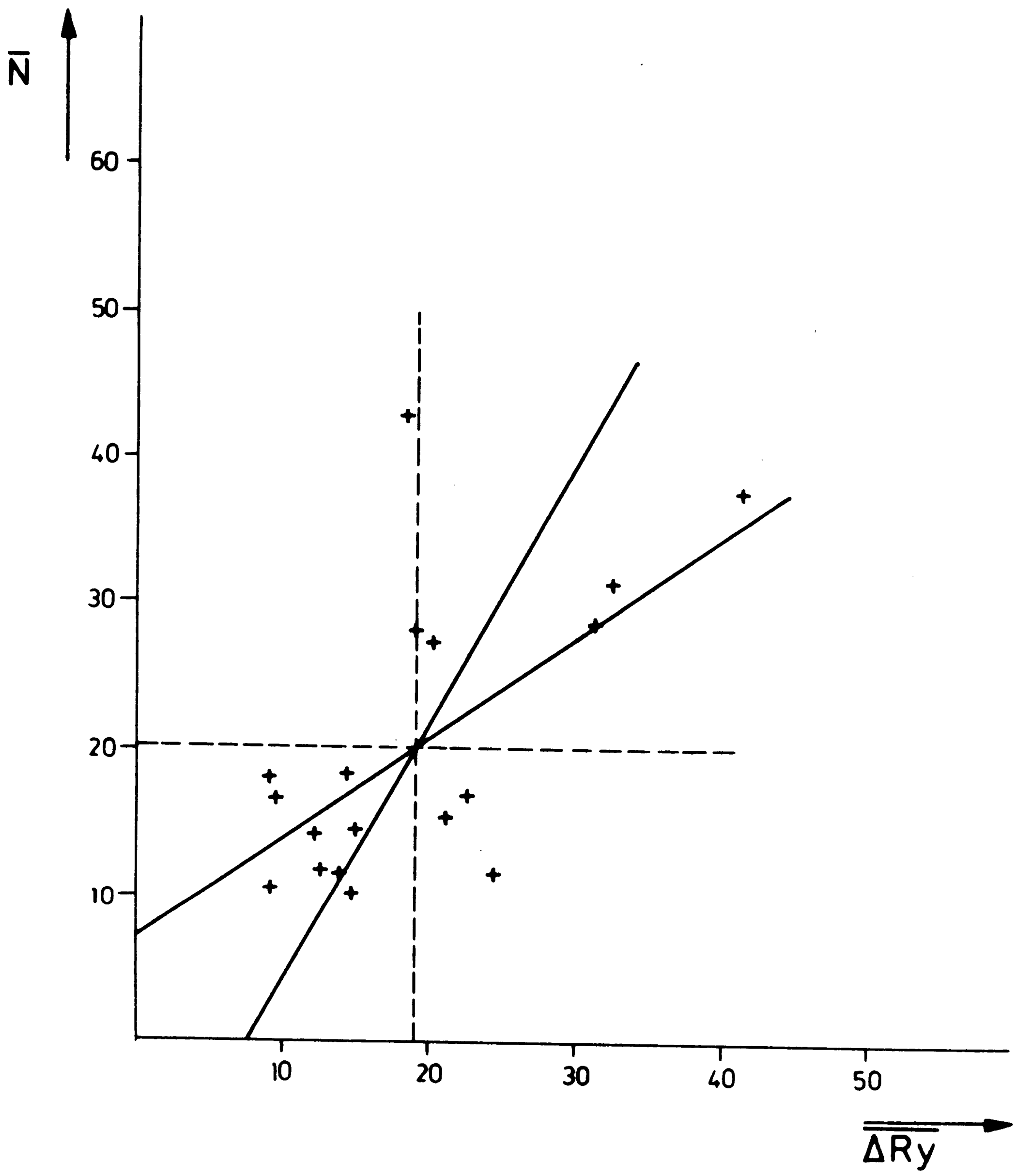

Figure 33

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\overline{N}$) in the latitude belt between 60°N and 55°N.

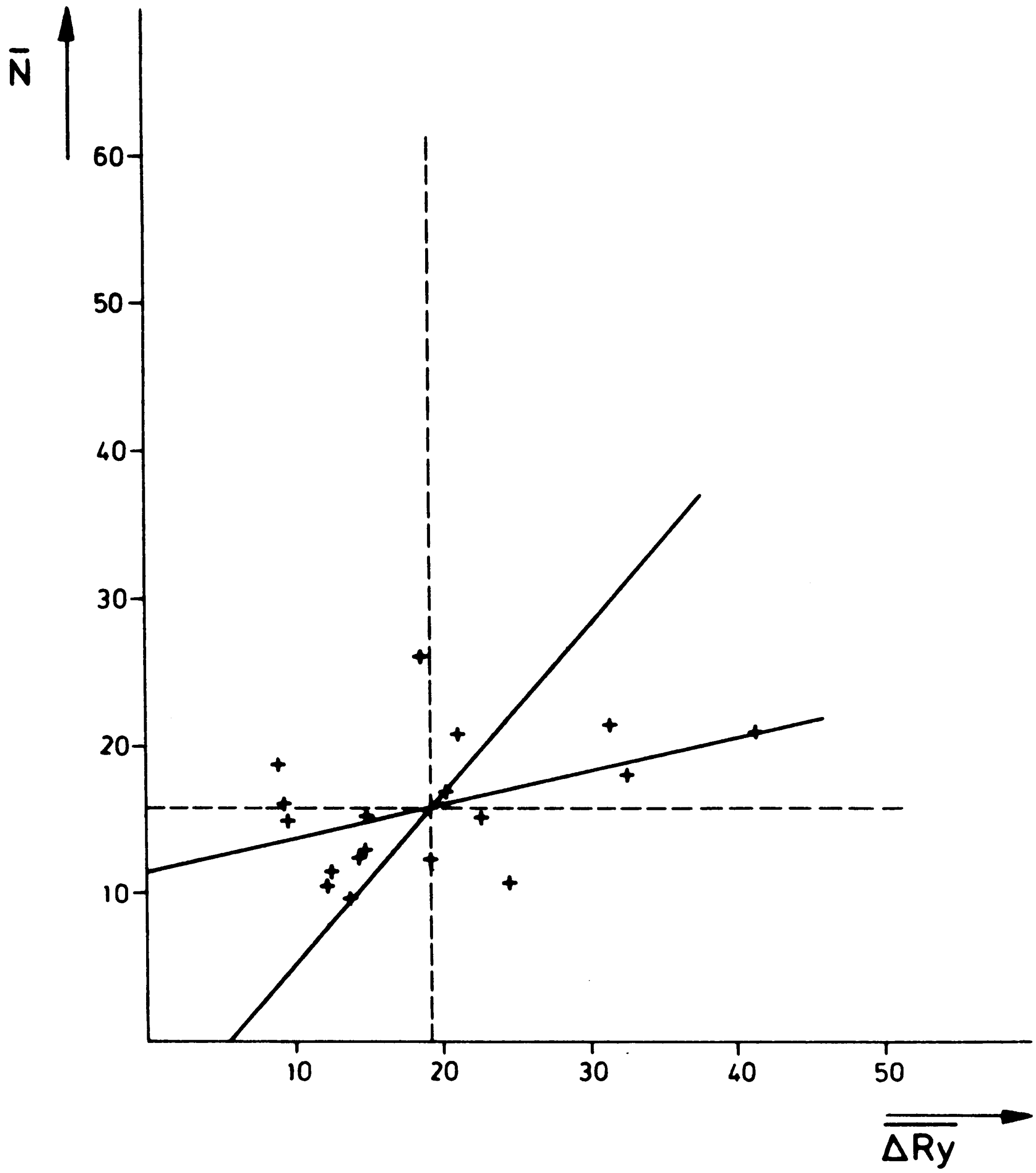

Figure 34

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\bar{N}$) in the latitude belt between 55°N and 50°N.

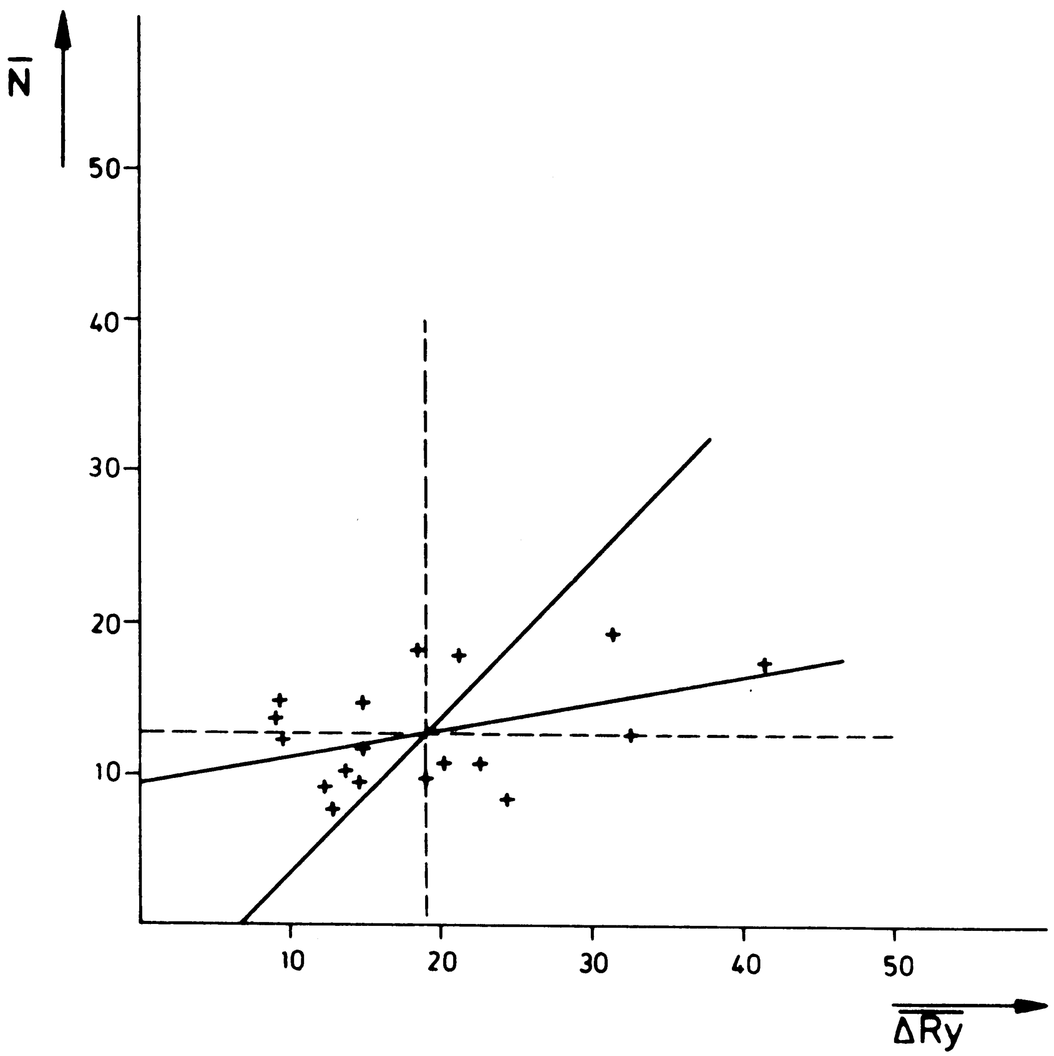

Figure 35

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\overline{N}$) in the latitude belt between 50°N and 45°N.

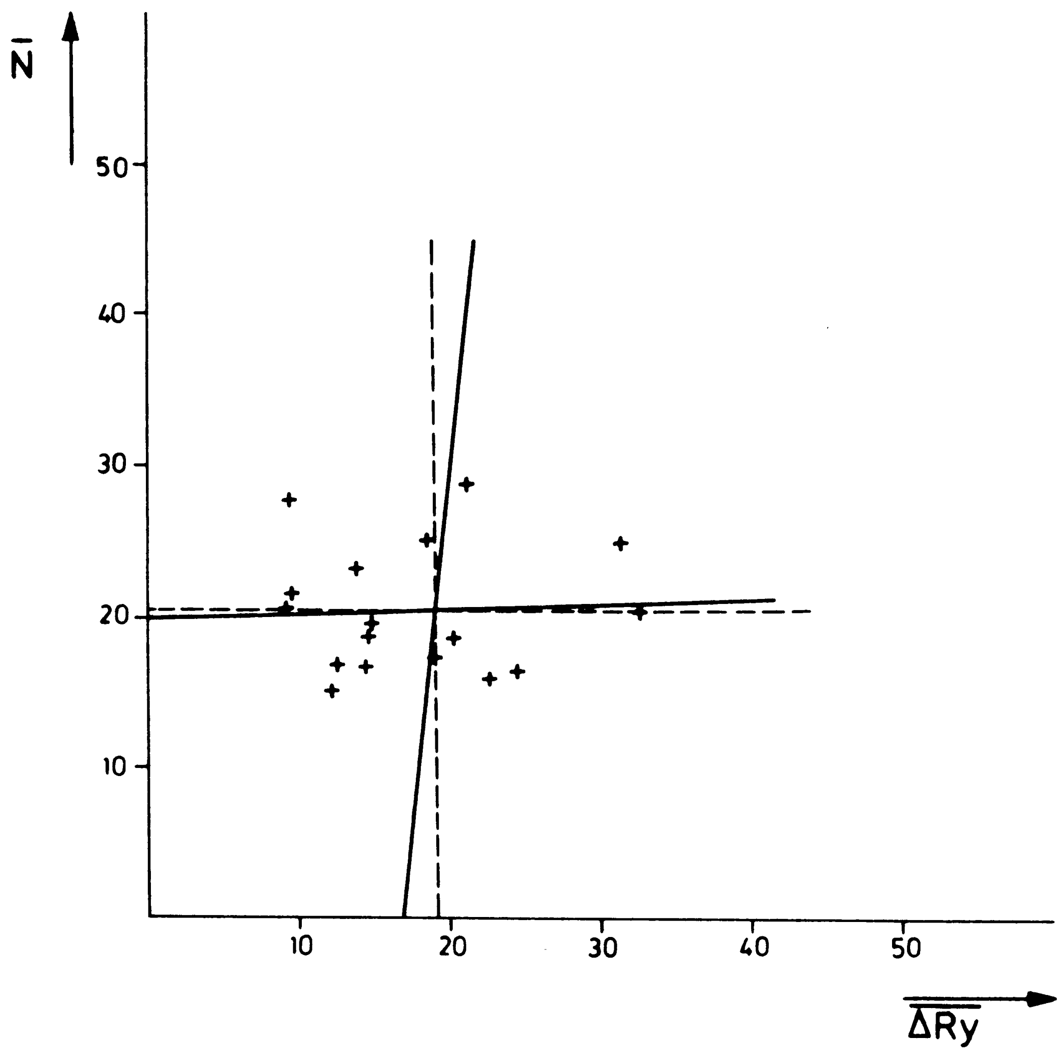

Figure 36

The relation between the over five years averaged sunspot variability ($\overline{\Delta Ry}$) and the numbers of easterly gales ($\overline{N}$) in the latitude belt between 45°N and 40°N.