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**MAPS OF HOURLY MEAN WIND SPEED
OVER THE UNITED KINGDOM
1965 - 73**

by

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Introduction

This Memorandum presents maps of hourly mean wind speed exceeded for various percentages of the time based on recordings made during the nine years from 1965 to 1973.

Coherent maps of hourly mean wind speed can be drawn only if local effects are eliminated. Sections 1 and 2 are concerned primarily with the method used to standardize the wind data for surface roughness, height of anemometer and altitude. When using the maps to obtain values for a particular site, local effects must be re-introduced. Two methods for obtaining percentile figures are given in Section 3, and Section 4 describes the derivation of average wind speeds. The representativeness of the period 1965-73 is discussed in Section 5.

1. The variation of mean wind speed with surface roughness

A study of winds in and around London has shown that gust speeds are relatively little affected by changes in surface roughness (the number and size of obstacles), whereas hourly mean speeds decrease and the ratio of gust speed to mean speed increases as the roughness increases towards the city centre (Caton, 1976). Although, outside London, the majority of anemograph stations are in open country with few obstructions to the wind flow, the surface roughness is found to vary between sites to an extent which interferes with the mapping of mean wind speeds as directly observed. An attempt has therefore been made to standardize the observations by applying a standard gust ratio to observed gust speeds, thus producing mean speeds appropriate to standard roughness conditions. The effect is to standardize the immediate surroundings of the anemograph sites, whilst leaving unaffected the broad-scale influences of topographical features.

Since January 1973 anemograph stations within the United Kingdom have tabulated for each clock hour the mean hourly speed and the maximum gust. The ratio of the maximum gust speed to the mean speed for individual hours at an effective height of 10 metres will be referred to as the gust ratio G . Mean values of G have been produced as functions of hourly mean direction and hourly mean speed and provide a useful characteristic of the anemograph site. For the present purpose, however, the mean values of G for the separate direction ranges were weighted according to the frequency of occurrence of each wind direction, and separate all-direction averages were obtained for each speed range on the Beaufort scale. This analysis was carried out using 21 864 hourly observations between January 1973 and June 1975; provided that there has been no change in site characteristics these average values of G were taken to apply to mean wind speeds observed in the years 1965-73. For the majority of stations G was found to decrease with increasing mean wind speed, the effect being most marked for speeds below 10 knots.

2. Preparation of data for the maps of hourly mean wind speed

There are currently some 140 anemograph stations in the United Kingdom of which 112 provide records at one site for four or more years during the period 1965-73. The summarized data give, for each station, the number of hours in each year for which the hourly mean speed lies in the ranges 0-3, 4-10, 11-21, 22-33 and >34 knots, and the number of hours with no record. The percentages of the time with record during which the speeds exceeded threshold values of 1.8, 5.4, 11.1 and 17.2 m/s (respectively 3.5, 10.5, 21.5 and 33.5 knots) were evaluated for each year, and means derived for the period 1965-73.

For a few stations computer analyses were available giving the percentages of time with speed exceeding threshold values separated by only 1 knot. For speeds greater than about 10 knots, these were found to fit closely a Weibull distribution; that is the probability p of exceeding a speed V was given by

$$p = \exp(-V/c)^k$$

where c and k were constants. It follows that a plot of values of $\log_e(-\log_e p)$ against $\log_e V$ gave a straight line of slope equal to k . For speeds less than about 10 knots the line was sometimes slightly curved.

It was decided to make use of this property in the general analysis. For each anemograph station, frequencies of speeds exceeding 1.8, 5.4, 11.1 and 17.2 m/s were plotted as Weibull distributions and from the graphs the speeds exceeded for 75%, 50%, 25%, 10%, 5%, 1% and 0.1% of the time were derived. Estimates of the 0.1 percentile speed were in doubt when the observed frequency of winds >17.2 m/s was very small or zero. Estimates

of the 75 and 50 percentile speeds were also liable to error, particularly for the more sheltered stations, owing to the curvature of the Weibull line at low speeds.

The percentile hourly mean speeds obtained from this Weibull analysis were then adjusted to a common standard in four respects:

(a) Adjustment for gust ratio

For wind speeds above about 5 m/s a gust ratio of 1.60 is typical of conditions at 10 metres above open countryside with few obstructions. It was decided that maps for all seven percentiles would be drawn for this standard gust ratio. Accordingly the percentile hourly mean speeds for each station were first multiplied by the factor $G/1.60$, where G was the gust factor appropriate to each speed concerned.

(b) Adjustment for height above ground

At stations where the effective height of the anemograph was other than 10 m, the percentile speeds were adjusted to 10 m using a power-law exponent of 0.085 over open country or 0.09 in an urban environment. These exponents are those normally used for gusts rather than hourly mean speeds, but are appropriate here because the adjustment performed in the previous paragraph produced a quantity equal to the percentile hourly maximum gust speed divided by 1.60.

(c) Adjustment for altitude of the observing site

The overall problem of topographical effects on wind speed is complex. However, it was found in this study that several apparent discontinuities could be smoothed out by applying an adjustment for altitude at two categories of site: (i) those situated on isolated hills or ridges obviously above the level of a surrounding plain, and (ii) those more than 70 m above mean sea level. Where (i) applied the effective altitude was the height of the station above the plain, and where (ii) applied the effective altitude was the actual altitude less 70 m. The magnitude of the adjustment was estimated from observations made between June 1973 and September 1974 at four anemograph sites at altitudes of 220-420 m above mean sea level between Manchester and Sheffield. The results suggested that, by comparison with stations on the Manchester and south Yorkshire plains, the high-altitude sites showed increases in the percentile hourly maximum gust speeds of between 7% (75 and 50 percentile speeds) and 9% (1 and 0.1 percentile speeds) per 100 m of effective altitude.

(d) Adjustment for period of record

Particularly in western districts of the United Kingdom, the years 1965-67 had higher frequencies of strong winds than most of the more recent years 1968-73. For stations where the record commenced in 1967 or subsequently, an adjustment to the percentile hourly mean speeds was made based on comparison with a nearby station having a complete record for the years 1965-73. The adjustment was very small at the 75 and 50 percentile speeds, and rarely exceeded 1 m/s (or 6%) at the 0.1 percentile speed.

3. Use of the maps of standardized hourly mean wind speed

Figures 1 to 7 respectively show isopleths of hourly mean wind speed (m/s) exceeded for 75%, 50%, 25%, 10%, 5%, 1% and 0.1% of the time during the period 1965-73 (1% of the time = 88 hours per year). The map values apply to a height of 10 m above ground at sites with standard surface roughness ($G = 1.60$) located between mean sea level and an altitude of 70 m, excluding isolated hilltops.

Where a site is clearly above the level of a surrounding plain or where the altitude exceeds 70 m, the map value must be increased by 7% (75 and 50 percentile speeds), 8% (25, 10 and 5 percentile speeds) and 9% (1 and 0.1 percentile speeds) per 100 m of height above the plain or above the 70 m contour as appropriate. These corrections are very tentative, particularly above 400 m altitude.

For a site with gust ratio G , the map value must be further adjusted using the formula

$$\text{Hourly mean speed at site} = \frac{\text{Map value} \times 1.60}{G} \quad \text{m/s}$$

Measurement of the gust ratio G at a site in the United Kingdom would involve anemograph readings for a period of perhaps 6 months, sufficient to sample a few times the majority of combinations of wind

direction and speed. If a measured value of G is not available, an estimate may be made by first selecting the most appropriate terrain description from those given in Table I (based on the classifications used in the British Standards Institution Code of Practice concerning Wind Loads BSI, 1972), and then using the corresponding value for $1.60/G$. It should be stressed that values of the mean hourly wind speed obtained in this way may occasionally be liable to appreciable error owing to the very generalized nature of the terrain descriptions.

The speeds exceeded for percentages of the time other than those covered by maps may be estimated from Table II. The Table is in two columns appropriate to exposed coastal and sheltered inland locations. These correspond approximately to 50 percentile map speeds >6 and <4.5 m/s in Scotland and Northern Ireland, >5.5 and <4.1 m/s in England and Wales. Values appropriate to locations with intermediate values of the 50 percentile speed may be obtained by interpolation. The standardized speed estimated from Table II should be adjusted for altitude and gust ratio as described in preceding paragraphs.

4. Average wind speed

The average wind speed is thought to be less useful than the percentile speeds presented in this Memorandum, since it contains no information concerning the frequency distribution of wind speeds. However, if required, the standardized average wind speed may be estimated from the 50 percentile map speed by addition of between 6% for exposed coastal locations and 11% for sheltered inland locations. The average wind speed for a particular site is obtained by adjustment for altitude and gust ratio as previously described.

5. Representativeness of the period 1965-73

It has already been remarked that the years 1965-67 had higher frequencies of strong winds than most of the years 1968-73; this is in no sense indicative of a general trend, and indeed, from 1974 onwards, higher frequencies of strong winds have again occurred. However, it is important to determine to what extent the period 1965-73 used in this analysis is representative of a longer period. Comparisons were therefore made at selected stations with the 19-year period 1956-74, and it appears that 1965-73 is closely representative of the longer period in respect of both 50 and 1 percentile speeds.

As already indicated there is considerable variation in windiness from year to year (particularly for the stronger winds) and considerable caution is necessary when applying the results in the Memorandum to any short period of future years.

REFERENCES

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|---------------------------------------|------|---|
| British Standards Institution, London | 1972 | Code of basic data for the design of buildings. Chapter V. Loading, Part 2. Wind loading. |
| CATON, P.G.F. | 1976 | Standardized maps of hourly mean wind speed over the United Kingdom and some indications regarding wind speed profiles. Fourth International Conference on Wind Effects on Buildings and Structures, London, 1975. Cambridge University Press, London (in press). |

Table I: Values of the factor 1.60/G

Category	Description of terrain	Map value (m/s) adjusted for altitude						
		2	2½	3	4	5	8	15
		<i>factor</i>						
1	Open country with no obstructions:							
(i)	coastal site with wind off sea	-	-	1.02	1.08	1.12	1.13	1.13
(ii)	inland airfields	0.83	0.89	0.93	0.97	0.98	0.99	0.99
(iii)	moorland slopes 250-350 m above mean sea level	0.83	0.86	0.88	0.90	0.92	0.95	0.98
(iv)	moorland summits <i>circa</i> 400 m above mean sea level	0.83	0.86	0.89	0.95	0.99	1.04	1.07
2	Flat or undulating country with hedges, scattered trees, and occasional buildings	0.67	0.73	0.77	0.83	0.86	0.89	0.92
3	Well-wooded parkland, towns and their suburbs, outskirts of large cities	0.48	0.57	0.63	0.72	0.77	0.80	0.82
4	Centre of large towns and cities	-	0.49	0.56	0.67	0.72	0.75	0.77

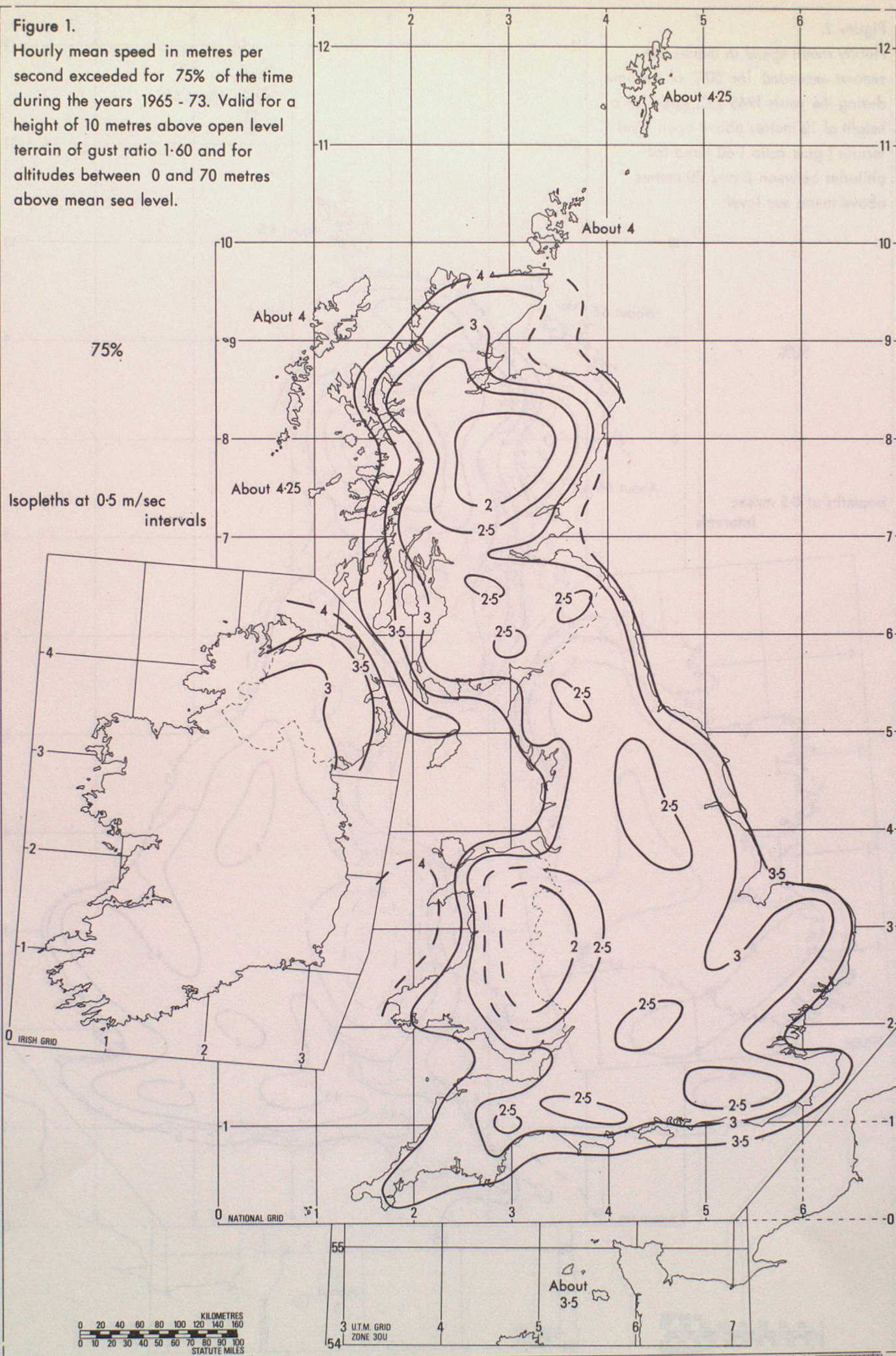
Notes: (a) a substantial number of measurements exist to support the values for terrain categories 1(i) and 1(ii). Many more measurements are required to substantiate the estimates for all other categories. Values in italics are particularly doubtful.

(b) For categories 3 and 4 the estimates refer to a height 10 m above the general level of the rooftops or other obstructions.

Table II: Values of the ratio of standardized wind speed for given percentiles to the 50 and 1 percentile standardized speeds for exposed coastal and sheltered inland locations

Percentile	Location			
	Exposed coastal		Sheltered inland	
	50%	1%	50%	1%
	<i>ratio</i>		<i>ratio</i>	
80	0.56		0.46	
75	0.64		0.56	
70	0.71		0.65	
60	0.86		0.83	
50	1.00		1.00	
40	1.15		1.18	
30	1.33		1.39	
25	1.42		1.51	
20	1.54		1.66	
15	1.70		1.81	
10	1.84	0.70	2.03	0.66
5		0.80		0.77
2		0.92		0.91
1		1.00		1.00
0.5		1.07		1.08
0.1		1.23		1.27
once/year		1.42		1.50
once/5 years		1.50		1.60

Hourly mean speed in metres per second exceeded for 75% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain of gust ratio 1.60 and for altitudes between 0 and 70 metres above mean sea level.



Hourly mean speed in metres per second exceeded for 50% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level.

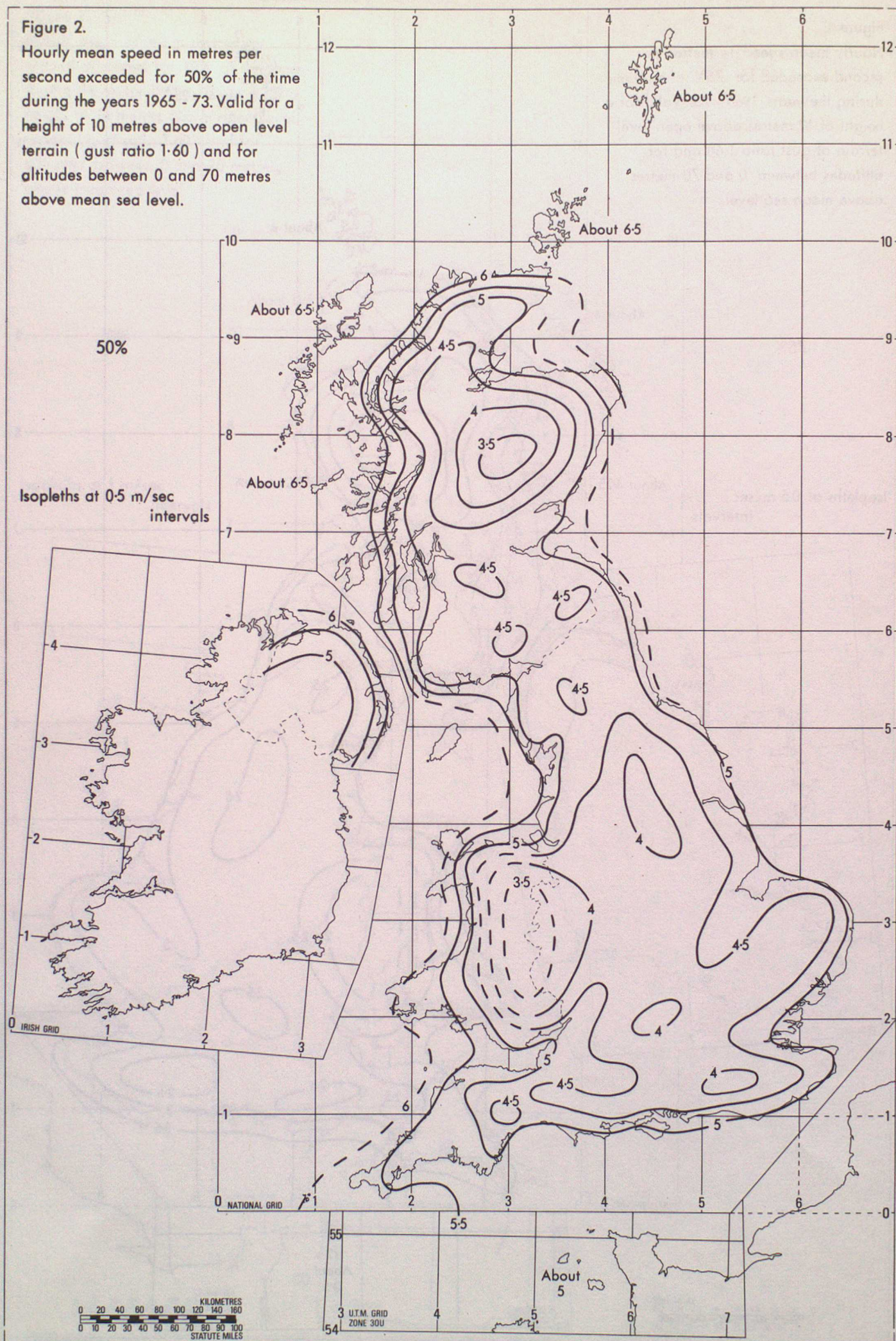


Figure 3.

Hourly mean speed in metres per second exceeded for 25% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level.

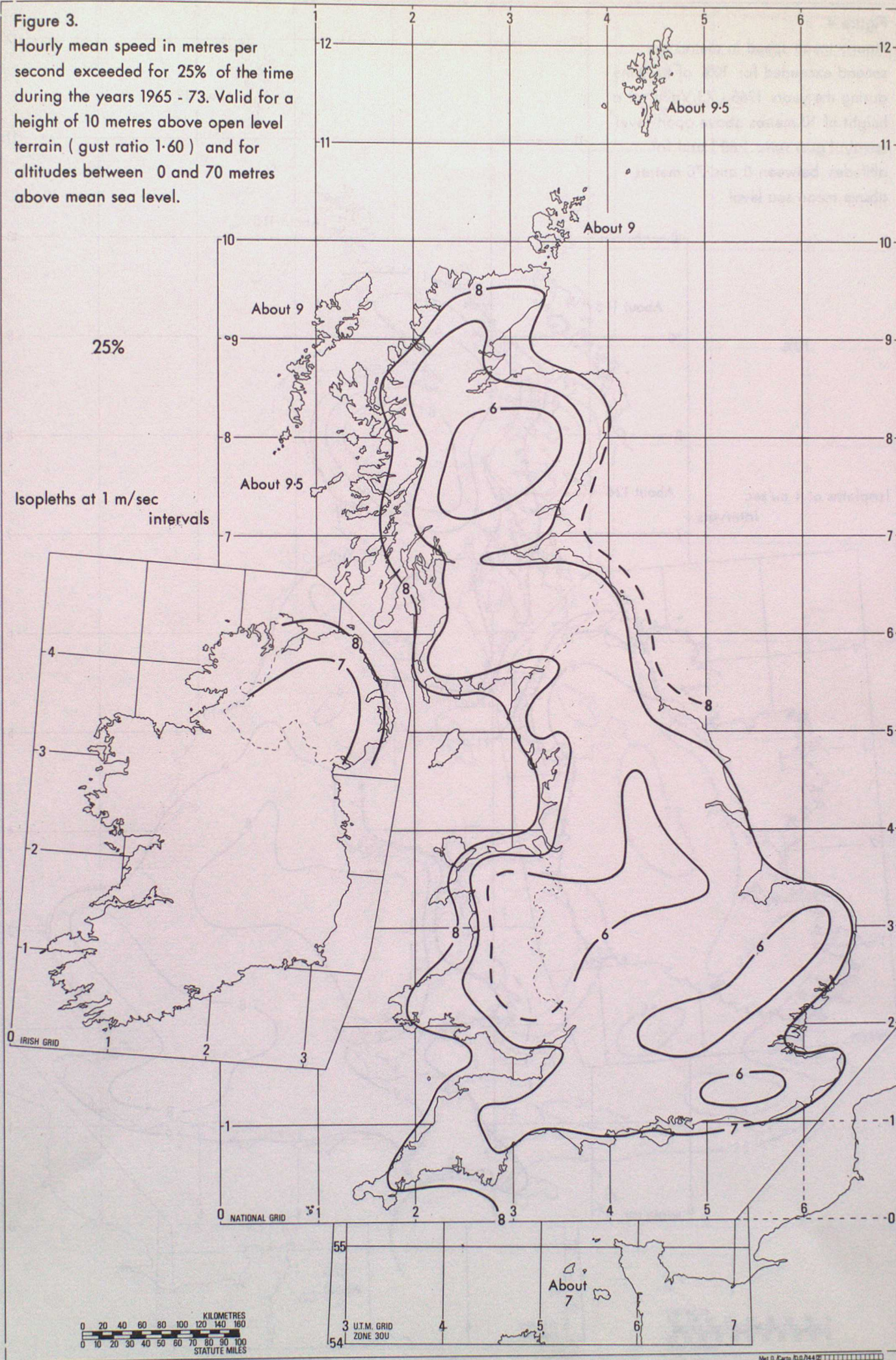


Figure 4.

Hourly mean speed in metres per second exceeded for 10% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level

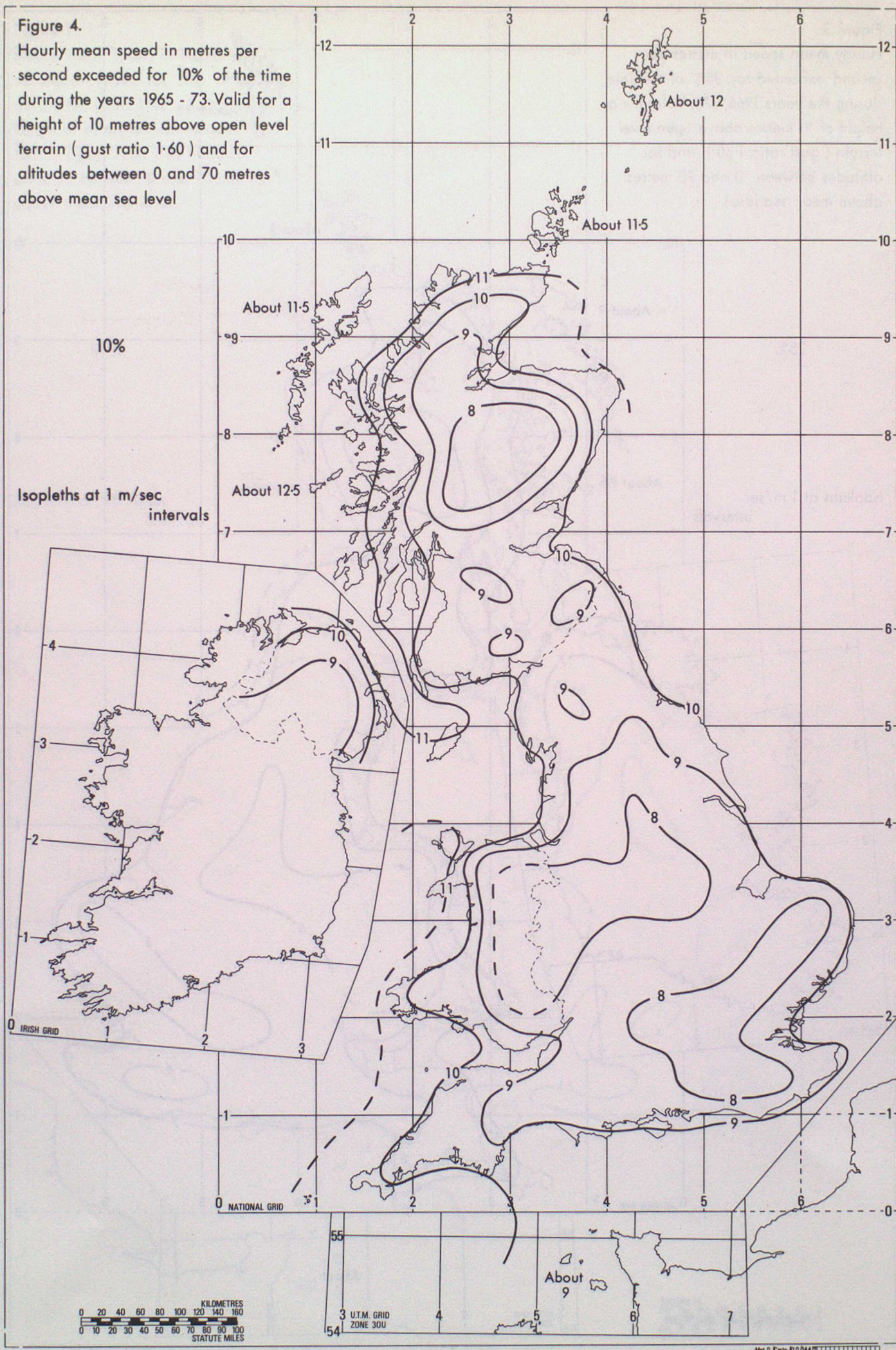


Figure 5.

Hourly mean speed in metres per second exceeded for 5% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level

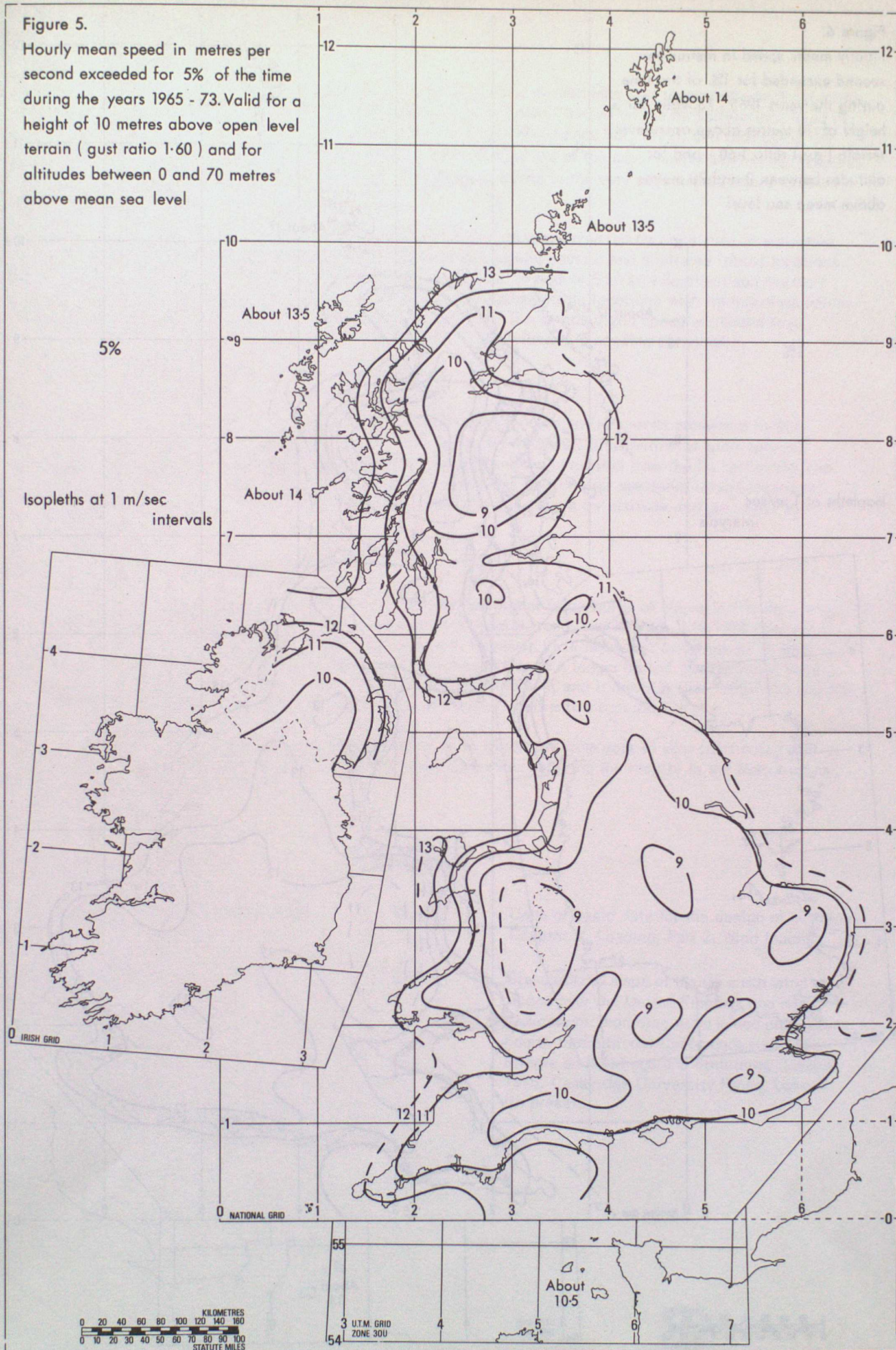
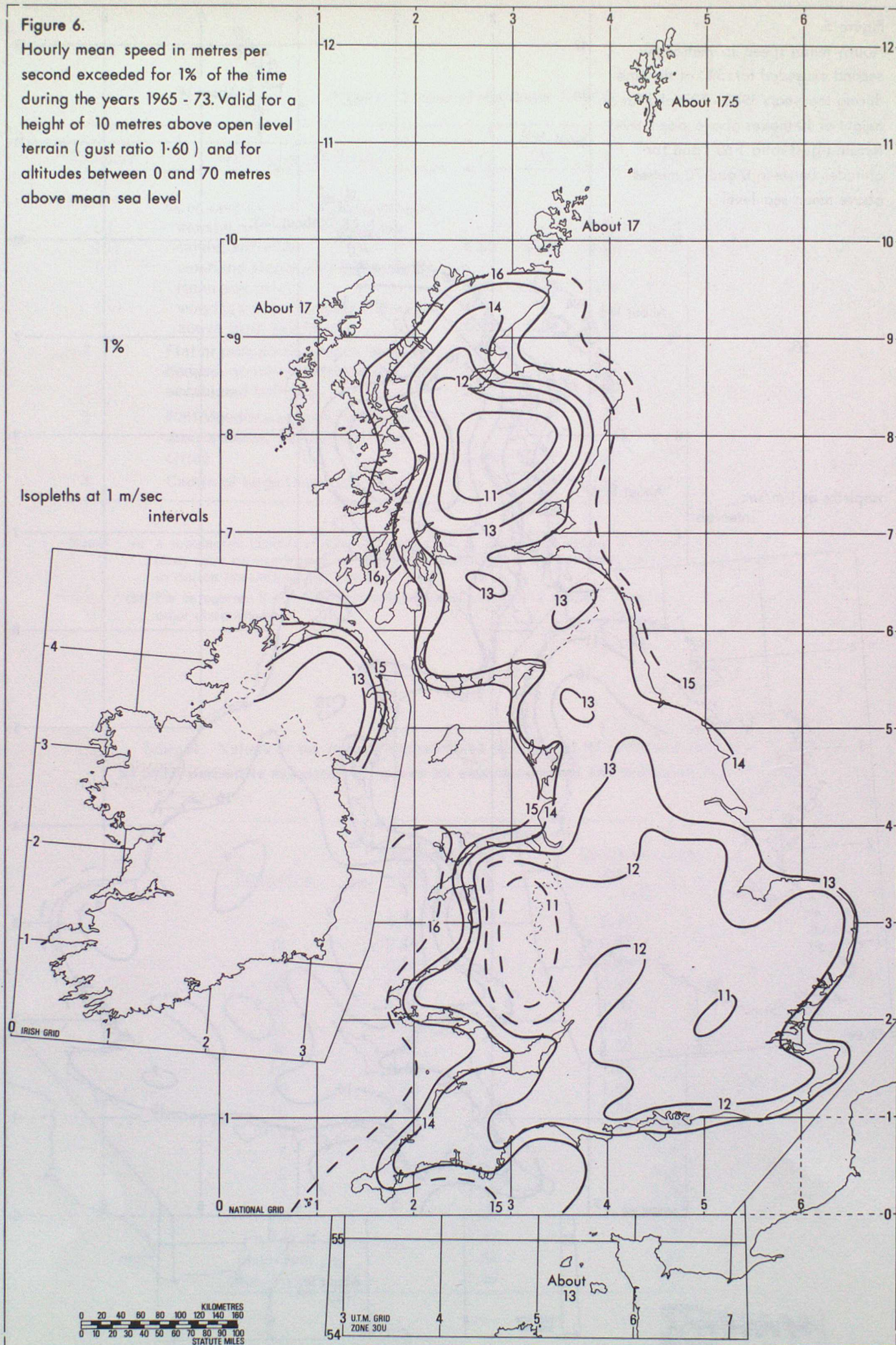


Figure 6.

Hourly mean speed in metres per second exceeded for 1% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level



Hourly mean speed in metres per second exceeded for 0.1% of the time during the years 1965 - 73. Valid for a height of 10 metres above open level terrain (gust ratio 1.60) and for altitudes between 0 and 70 metres above mean sea level.

