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THE CONCENTRATION OF ATMOSPHERIC CONDENSATION NUCLEI AT VALENTIA OBSERVATORY

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Summary

Measurements of the concentration of condensation nuclei made twice daily at Valentia Observatory over the twelve years 1955 - 1966 are analysed. Concentrations are found to be generally higher in the afternoon than during the night and higher in summer than in winter. Precipitation at the time of observation or in the previous hour reduces the concentration by 30 - 40%. An analysis of the data obtained when there was no precipitation at the time of observation or in the previous hour shows that the concentration decreases with increasing wind speed. Highest values are found with calms or winds from the easterly sector where pollution by smoke and products of combustion would be most expected. High concentrations are associated with low relative humidity, with high temperature, and with clear or almost clear skies. The annual variation for all wind directions is influenced by the incidence of winds from the easterly sector, but for winds from the seaward sector the annual variation follows closely that of global solar radiation.

1. Introduction

Measurements of the concentration of atmospheric condensation nuclei were begun at Valentia Observatory in 1950. The results obtained up to December 1954 were analysed by McWilliams and Morgan (1). This paper discusses the results obtained during the period January 1955 to December 1966.

2. Site of the Observations

The observatory, which is in the extreme SW of Ireland, is situated on the SE side of the narrow estuary of Valentia River which runs approximately NE-SW (Fig.1). It is about 1 km. to the SW of the town of Cahirciveen.

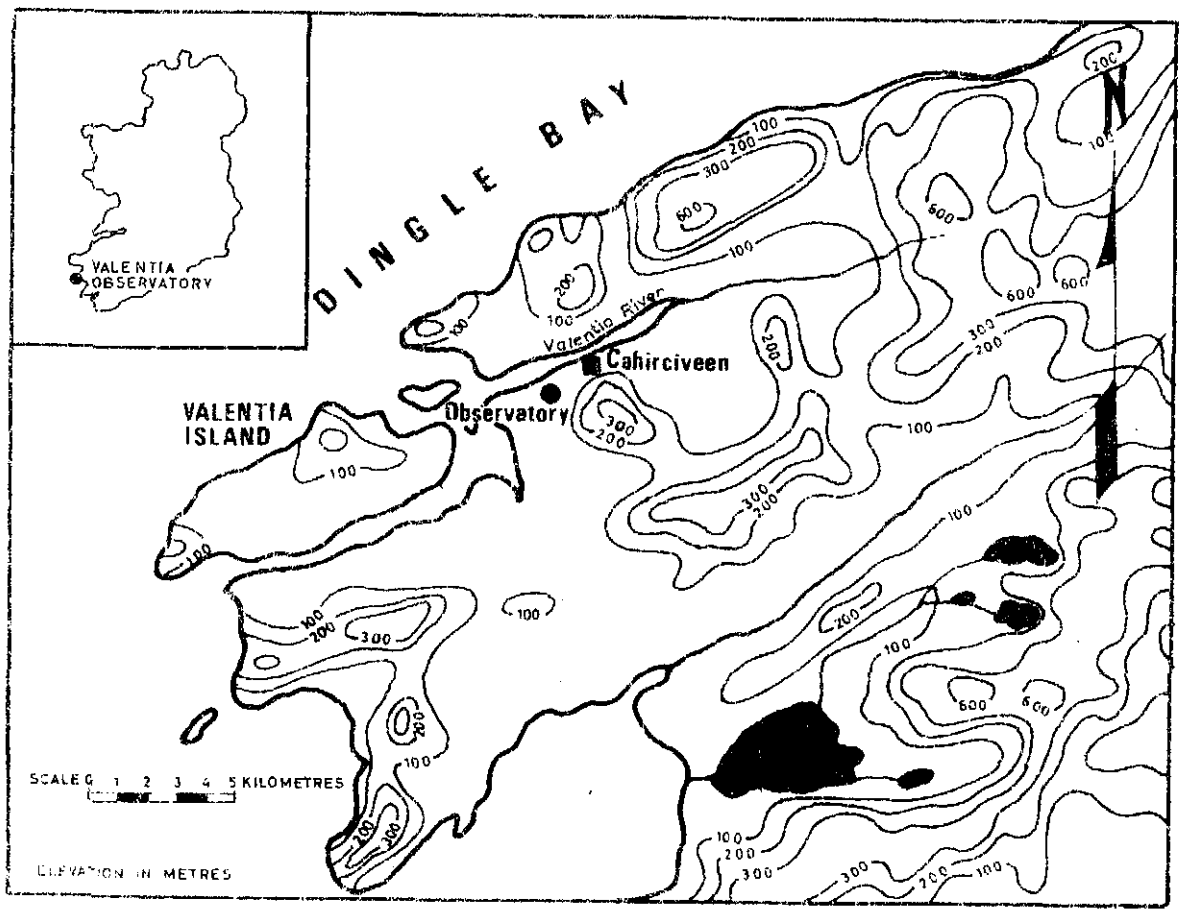

Fig. 1 Map showing the site of Valentia Observatory and its environs.

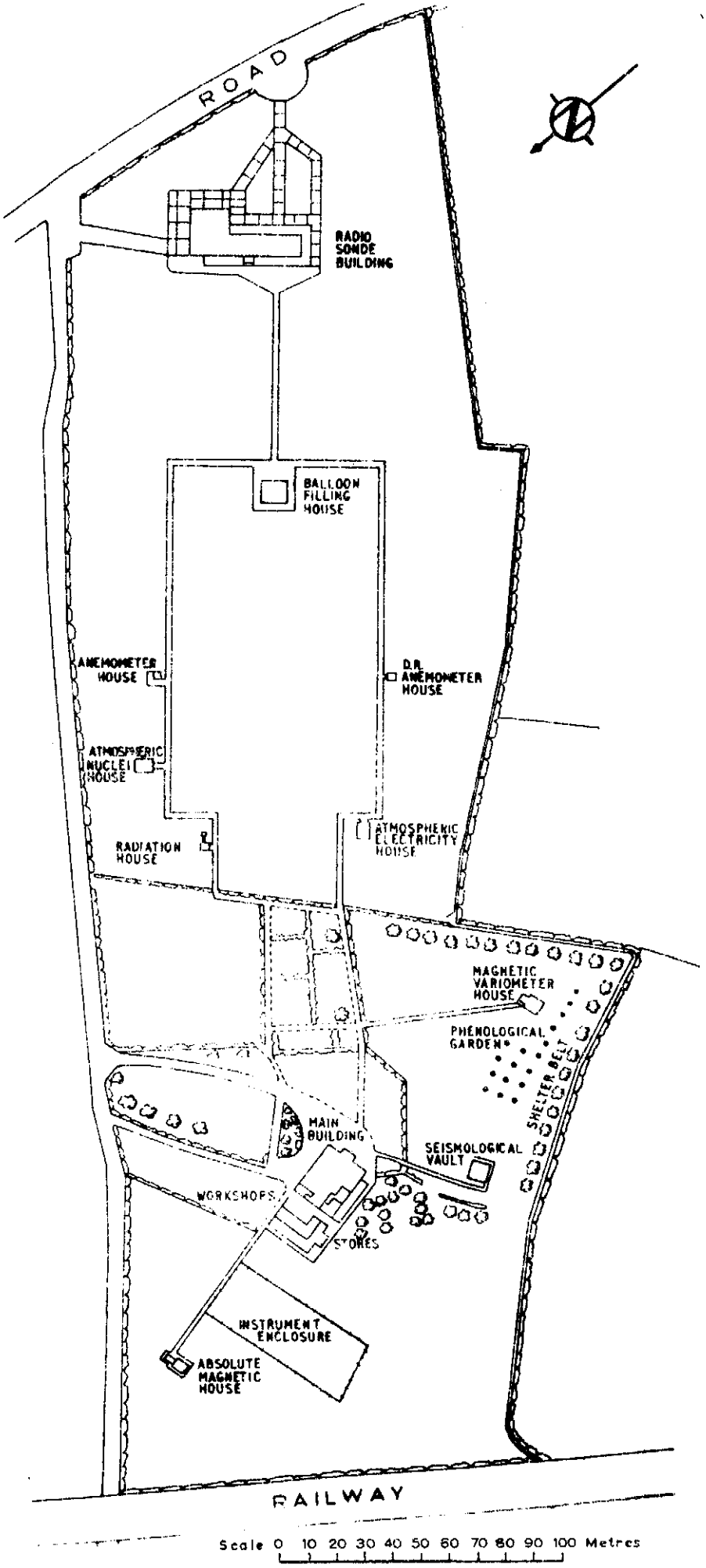

Fig. 2. General layout of Valentia Observatory

The population of Cahirciveen is approximately 1800 and apart from domestic fires for cooking and heating there are no major sources of smoke pollution. The rest of the area is very sparsely populated.

Measurements of the concentration of nuclei were made with a photoelectric nucleus counter as described in [2].

The nucleus counter was installed in a hut (indicated in Fig. 2) in the grounds of the Observatory. The instrument was connected with the outside atmosphere by means of rubber tubing, 12.5 mm. bore, about 1 metre long passing through the wall of the hut at a height of 1.73 metres above ground level.

3. Observational Routine

Observations were made twice daily throughout the period. Up to 31st. March 1957 times of observation were 00 h. and 12 h. GMT. As from that date upper air operations were scheduled for these times so the nucleus counter observations had to be changed to 03h. and 15h. GMT. At each observation time four readings were made with the counter and the arithmetic mean of the four counts taken as the number of nuclei. For convenience the number of nuclei per cm^3 so determined will be indicated by Z. Reference to numbers of nuclei will in all cases refer to the number per cm^3.

Other meteorological elements observed at the same time were:

(a) Temperature and humidity as determined by the Assmann aspirated psychrometer exposed near the intake pipe of the nucleus counter

(b) Wind speed and direction as recorded by a Dines pressure tube anemometer, with head at an effective height of 10 metres and situated about 30 metres to the ESE of the nucleus counter hut.

Values of other meteorological elements were those observed at the routine observations made at the same hour for synoptic purposes.

4. Use of Medians

As mentioned in [1] it was found that groups of moderately low values of Z occurred with a relatively small number of very high values. In order to avoid undue weight being given to these high values medians of Z are used throughout this analysis. The relation between the medians and the mean values is discussed in para. 6 below. Values given for "Winter" and "Summer" refer to the groups of calendar months October to March and April to September respectively.

5. Order of Magnitude of Z

Throughout the full period 8759 observations were made. Over 40% of observations gave values of Z less than 500. The percentage frequency of counts falling between different limits is shown in Table 1.

Table 1. Frequency Distribution of Ranges of Nucleus Concentration - All Observations

Concentration (Z)	Less than 500	500 to 750	750 to 1000	1000 to 1500	1500 to 3000	More than 3000
Number of Obs.	3601	1333	839	1178	1159	649
% of Total	41.1	15.2	9.6	13.4	13.2	7.5
% at Mace Head [3]	38.6(22)	29.8(17)	750 - 1500 14.0(8)		7.0(4)	10.5(6)

Figures in round brackets show number of observations.

Results obtained by O'Connor [3] at a similar site on the West coast of Ireland at Mace Head, Co. Galway are shown in the bottom line of Table 1. Although O'Connor's distribution is based on only 57 observations as compared with the 8759 observations at Valentia the derived distributions are in very good agreement especially for the range 0 - 500.

As will be seen below (para. 8) there is considerable pollution carried in winds from the easterly sector. Omitting the occasions when the wind was NE, E, SE or calm the remaining wind directions may be classified as "sea winds" transporting air which even if not always truly maritime will generally have had sufficient track over the sea to assume maritime characteristics. None of the winds reach the nucleus counter site directly from the sea but apart from the southerly direction, and to a lesser degree the northerly, the passage over land is generally relatively short. The frequency distribution for these "sea winds" is given in Table 2.

Table 2 Frequency Distribution of Ranges of Nucleus Concentration. Sea Winds Only

Concentration (Z)	Less than 500	500 to 750	750 to 1000	1000 to 1500	1500 to 3000	More than 3000
Number of Obs.	2974	939	523	640	502	216
% of Total	51.3	16.2	9.0	11.0	8.7	3.7
% at Mace Head [3]	48.8(21)	34.9(15)	750 - 1500 9.3(4)		2.3(1)	4.7(2)
% at O.W.S. Station [4]	48(13)	500 - 1000 30(8)			> 1000 22(6)	

Figures in round brackets show number of observations.

There is a marked shift in distribution towards the lower ranges and 51% of the observed values are less than 500.

O'Connor also found values for "maritime air" at Mace Head and these are shown in the third line of Table 2.

Moore [4] analysed a series of 27 observations made on board an Ocean Weather Ship in the North Atlantic and his results are reproduced in the last line of Table 2. Even though the number of observations is relatively small the distribution found both by O'Connor and Moore are in satisfactory agreement with the results at Valentia.

Of the values greater than 3000 68% occurred with calms or winds from the NE - SE sector where smoke pollution would be expected. This ratio remains almost constant when the values above 3000 are subdivided into further ranges. Thus in the range 3000 - 5000 there were 383 occasions, 251 (66%) of which occurred with winds from the easterly sector. In the range 5000 - 10000 there were 212 occasions, 144 (67%) of which occurred with easterly winds and of the 54 observed values above 10000, 38 (70%) occurred with winds from this same sector. The highest value observed was 23070 which occurred at midday in mid-January in a light variable wind (Calm to 4 knots). The upper air ascent showed that a steep inversion of temperature in the layer near the surface during the previous night still persisted at midday. The high concentration was obviously due to the local build-up of smoke particles and combustion nuclei trapped beneath the inversion.

The lowest concentration for which the counter is calibrated is 98 nuclei per cm^3. This minimum value was observed in 3.2% of the total number of observations.

Table 3 Median Values of Z for All Observations

	Summer	Winter	Year
Afternoon	673	706	688
Night	587	570	578
Full Day	637	622	629

Observations made at 00 h. and 03 h. are grouped together and classified as "night" observations while those done at 12 h. and 15 h. GMT. are grouped together and classified as "afternoon" observations.

The overall median value of the 8759 observations made throughout the period was 629. This is about 75% higher than the value found by McWilliams and Morgan for the earlier period of observations. The most likely explanation is that during the intervening twelve years there has been a considerable extension of the town of Cahirciveen towards the Observatory so that the main road from the Observatory to the town has become an almost completely "built-up" area. In fact the build up has now been extended past the Observatory to the south and south west. Although the new buildings are mainly dwelling houses the smoke and products of combustion from the domestic fires, must, especially due to their proximity, contribute considerably to the nucleus content of the rural air.

At Mace Head O'Connor got a range of Z from 120 - 12000 with a mean for all observations of 1300. When comparing "medians" at Valentia with the "means" by O'Connor and a number of other investigators it must be noted that the median value of Z is considerably lower than the corresponding mean value. From the frequency distribution for O'Connors observations given in Table 1 it is clear that though the mean value he got was 1300 the median value would come within the range 500 - 750 and probably between 600 and 650.

6. Comparison of Means and Medians of Z.

To facilitate the comparison between the Valentia medians and the mean values as reported elsewhere by other investigators the means were also computed for all the Valentia observations made at a time when no precipitation had occurred within an hour of the Z observations (See para. 7 below). The corresponding means and medians are shown in Table 4.

Table 4: Corresponding Means and Medians of Z

	Winter			Summer			Year		
	Night	After-noon	Full Day	Night	After-noon	Full Day	Night	After-noon	Full Day
Means	1244	1565	1405	1253	1318	1287	1249	1432	1343
Medians	729	889	815	727	769	747	723	820	774
Means / Medians	1.71	1.76	1.72	1.72	1.71	1.72	1.73	1.75	1.74

The ratio of the mean values to the median values is remarkably uniform for night and afternoon, summer, winter and all the year, ranging from 1.71 to 1.76 with an overall value of 1.74. Thus it may generally be accepted that the mean value of Z for a set of observations may be about 74% higher than the corresponding median value.

Table 5 Median Values of Z for Different Wind Directions and for Calms on occasions with:

(A) no precipitation at time of observation or in previous hour
(B) no precipitation at time of observation but with precipitation in the previous hour
(C) precipitation at time of observation
(D) all observations.

		Summer			Winter			Year		
		Night	After-noon	Full Day	Night	After-noon	Full Day	Night	After-noon	Full Day
Case (A)	NE	974	1613	1118	1124	2020	1454	1064	1829	1325
	E	1007	1982	1161	1153	1585	1317	1107	1685	1267
	SE	786	1333	1014	823	1242	979	786	1268	992
	S	578	928	711	526	756	650	555	844	681
	SW	437	527	493	350	502	413	398	510	458
	W	452	560	549	366	561	482	428	561	539
	NW	516	637	598	436	490	476	485	596	564
	N	638	1007	735	414	444	425	540	722	623
	Calm	1156	2937	1188	1121	1889	1319	1147	1923	1200
	All Winds	727	769	747	729	889	815	723	820	774
Case (B)	NE	700	925	700	653	1843	1060	653	1284	798
	E	707	1729	1212	515	1155	841	515	1270	1127
	SE	473	888	645	1077	686	767	749	734	749
	S	400	519	463	313	694	445	363	577	450
	SW	343	470	381	306	434	359	309	463	370
	W	378	432	425	342	378	359	360	417	383
	NW	304	537	396	320	486	349	313	493	384
	N	408	404	404	270	299	277	283	333	295
	Calm	444	863	608	596	6305	664	594	4152	612
	All Winds	379	502	453	330	510	415	363	504	432
Case (C)	NE	757	1152	825	873	1427	929	824	1395	902
	E	670	770	704	831	1155	940	742	1011	831
	SE	635	705	637	715	966	797	672	856	722
	S	323	591	392	331	563	420	328	567	407
	SW	328	354	343	287	320	307	322	343	327
	W	327	430	369	298	264	276	311	319	317
	NW	415	374	385	250	311	276	339	330	338
	N	437	621	440	289	268	275	378	342	351
	Calm	780	2088	816	478	1567	564	564	1828	740
	All Winds	392	511	441	392	455	424	392	495	432
Case (D)	NE	1073	1552	1134	1008	2038	1369	1035	1836	1248
	E	917	1352	1060	1083	1423	1214	1013	1390	1164
	SE	668	1088	920	749	1063	890	722	1074	900
	S	443	776	544	402	692	549	423	724	547
	SW	378	468	420	321	433	358	349	455	393
	W	422	546	506	349	430	387	376	509	451
	NW	446	502	483	354	423	403	409	461	439
	N	542	772	662	357	344	350	471	519	502
	Calm	1146	2088	1183	998	1923	1304	1116	1957	1200
	All Winds	587	673	637	570	706	622	578	688	629

7. Effect of Precipitation on Nucleus Concentration

In their analysis of the first four years of Valentia observations McWilliams and Morgan [1] found that precipitation at the time of observation reduced the value of Z by 40 - 50%. This feature is confirmed during the further 12 year period. The data were again divided into three catagories

(a) no precipitation at time of observation or in previous hour

(b) no precipitation at time of observation but with precipitation in previous hour

(c) precipitation at time of observation

Median values of Z for afternoon and night observations in summer, winter and for the full year are given in Table 5. It is clear that precipitation at the time of observation reduces the nucleus concentration by 30 to 40%. The "washing out" process is common to all wind directions, and is independent of the time of observation or the season. Table 6 shows the percentage reduction caused by precipitation for each wind direction and for calms.

Table 6 Percentage Reduction in Z caused by Precipitation

	N	NE	E	SE	S	SW	W	NW	Calm	Average
Pptn. at Time	43.7	31.9	34.4	27.2	40.2	28.6	41.1	40.1	38.3	36.2
Pptn. within past hour but not at time	52.6	39.8	11.0	24.5	33.9	19.2	28.8	31.9	49.0	32.3

The reduction in Z caused by precipitation within the hour prior to the observation but not at the time of observation is also shown in Table 6. In calm conditions and with north or north east winds the reduction is actually greater but the number of occasions of precipitation in past hour but not at the time was relatively small in these circumstances. The relevant medians are not therefore so reliable. For the remaining wind directions it would appear that recovery from the "washing out" process has begun but even an hour after the occurrence of precipitation the value of Z is considerably depressed.

O'Connor, Sharkey and Flanegan [5] found at Mace Head that "the lowest concentrations occurred with south west winds under conditions of prolonged outbreaks of rain or drizzle. Precipitation was usually accompanied by some decrease in Z but our results were not sufficient to isolate its effect from the other factors".

At Huancayo, Peru where the air is much more polluted than at Valentia Torreson [6] found a similar order of magnitude for the "washing out" effect of rain. In the dry season when there were only a few days of rain he got an average value of nucleus concentration greater than 20,000 per cm^3 but in the wet season when there was some rain nearly every day the average nucleus concentration fell to less than 10,000 per cm^3.

It is clear therefore that in any investigation into the relation between atmospheric nucleus concentration and various meteorological elements this "washing out" process must be borne in mind. For this reason the further analysis of Z values discussed below has been confined to observations in catagory A i.e. when there was no precipitation at the time of observation or in the previous hour.

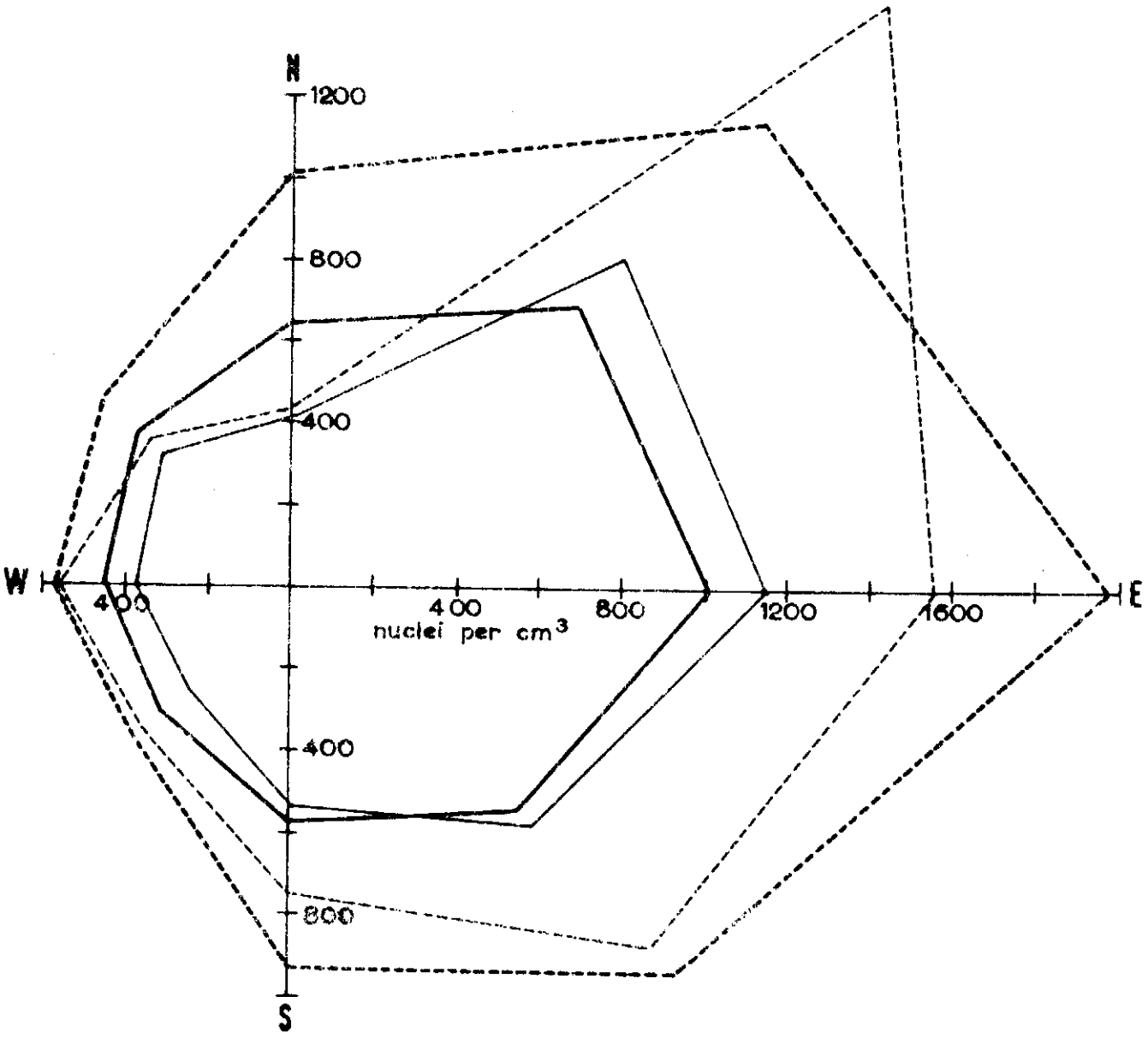

Fig. 3 Variation of concentration of nuclei with wind direction during
summer night ——— summer afternoon ------
winter night ——— winter afternoon ------

8. Variation of Z with Wind Direction

The median values for each wind direction as given in Table 5 (A) are shown diagramatically in Fig. 3. The pattern is similar to that found in the earlier investigation of McWilliams and Morgan [1]. The highest concentrations were observed with winds from NE - SE sector both in summer and winter.

The highest median value was associated with NE winds in winter. Winds from this direction pass over the town of Cahirciveen and even though there is no great industrial source of pollution the smoke and grime from domestic fires could be expected to contribute considerably to the nucleus content of air from this sector. However the general relatively high values observed with winds from the NE - E - SE sector indicate that some of the nuclei have their origin in the industrial centres to the east and possibly, as Dines and Mulholland [7] have suggested, from as far away as the English "Black Country". The transport of combustion nuclei over long distances was also suggested by Hess [8] who got an average for Z of 1370 in the western half of the Atlantic and 675 in the eastern half. He attributes the difference to the general circulation of the atmosphere from west to east tending to carry a great number of nuclei generated over American continent far out overthe Atlantic.

The lowest values of Z were observed with winds from the SW - W - NW sector, there being no significant difference between the median values for these three directions. Winds from this sector come almost directly from the Atlantic and are subject to little or no man-made pollution if we discount the few scattered farm houses and the small village of Knightstown on Valentia Island. Winds from the north and south show slightly higher values than the westerly sector and are probably showing the effects of a somewhat longer journey over land.

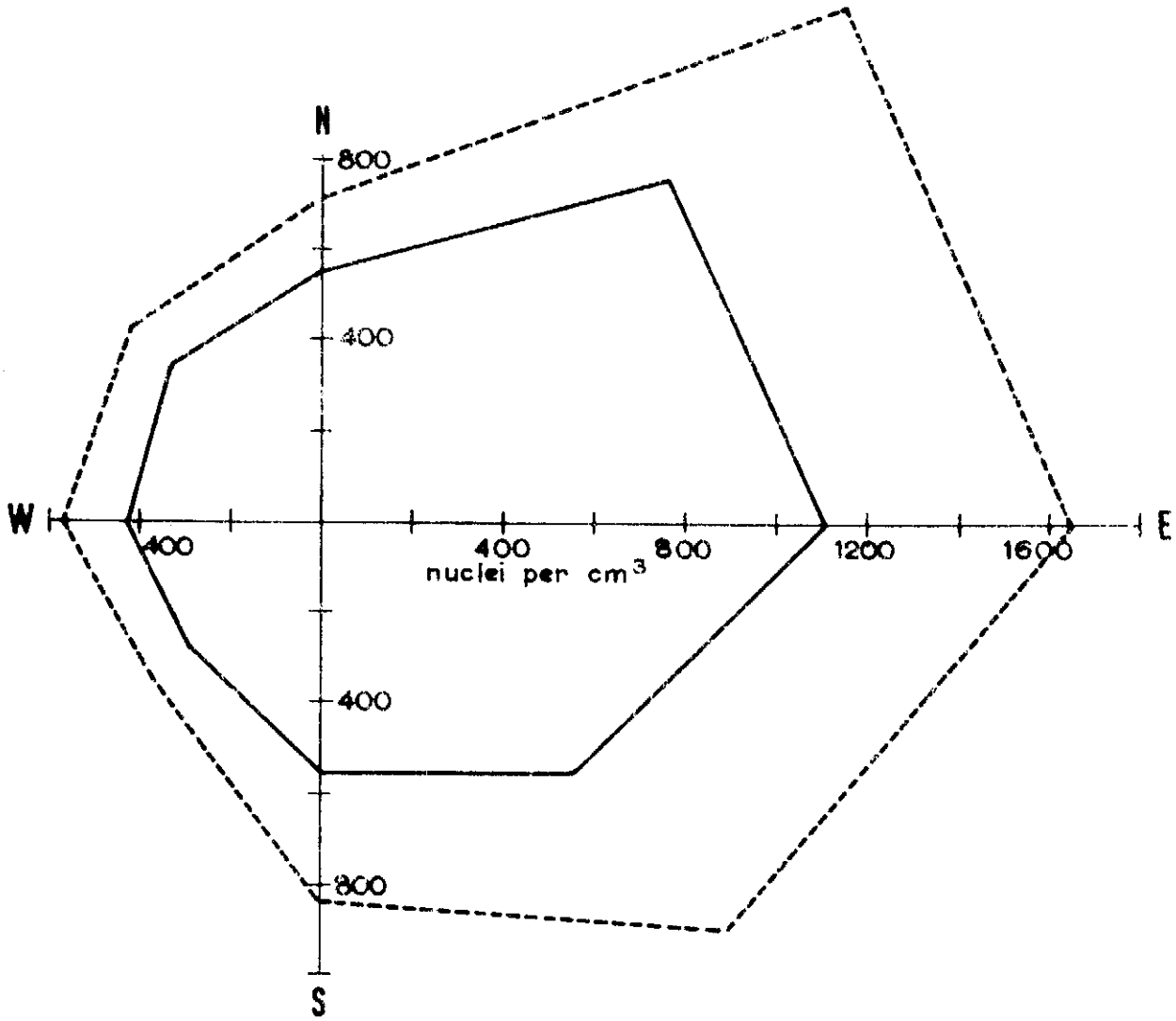

Fig. 4 Variation of concentration of nuclei with wind direction for whole year, night ——— afternoon - - - - - -

A very pronounced feature of the observed variation in concentration is the fact that values of Z in the afternoon are considerably higher than those observed at night. Fig. 4 shows the afternoon and night medians for the whole year. The excess of the afternoon value over the night value is common to all wind directions and in calm conditions the afternoon value is 68% higher than the night value. This suggests that apart from the nuclei carried in the air from outside sources there are local natural sources of nuclei probably produced by the action of sunlight. Increased evaporation of sea spray during the day could be a factor in the higher afternoon value for westerly winds. Moreover production of nuclei especially along sea shores has been noted by many investigators and Aitken [9] associated it with the action of sunlight. This could also be a factor in explaining the summer and winter variation in nucleus content shown in Fig. 5.

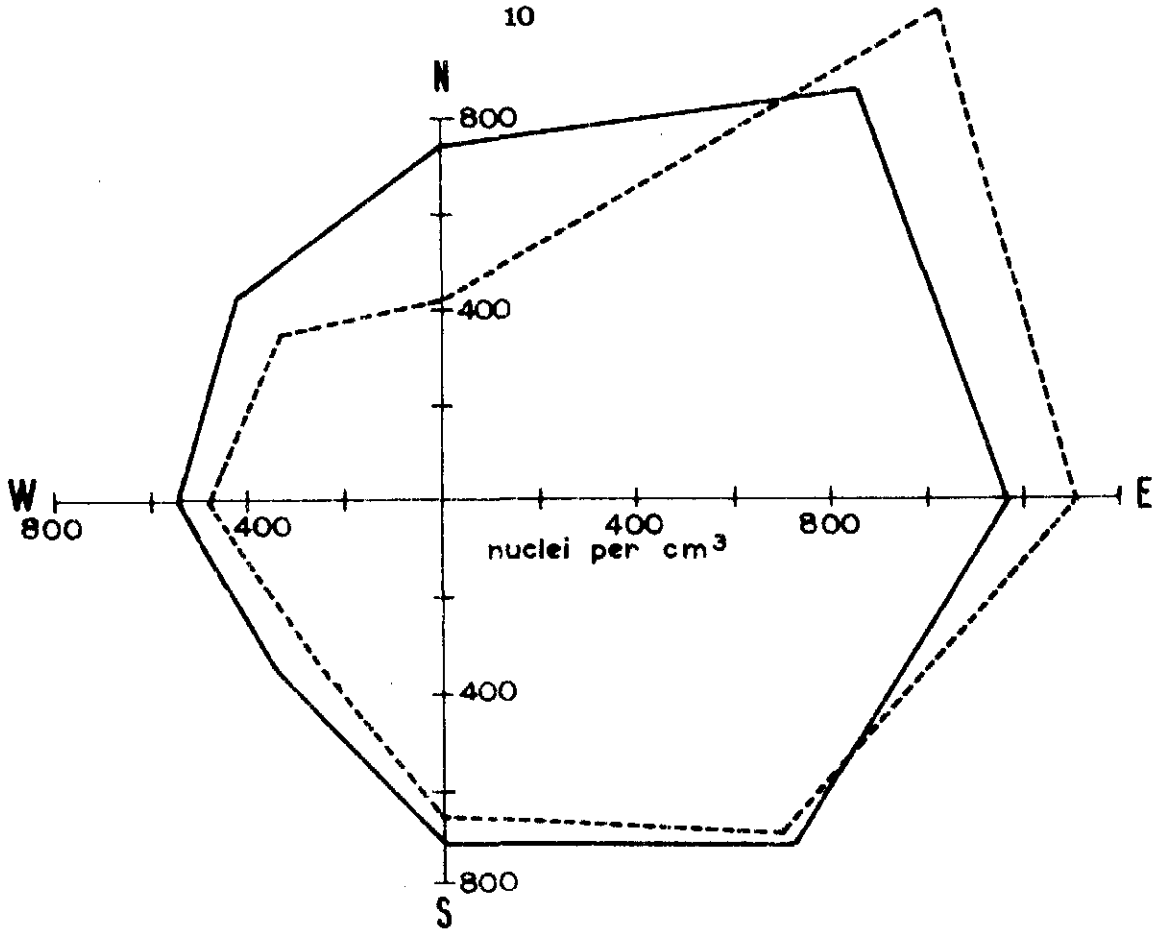

Fig. 5 Variation of concentration of nuclei with wind direction during summer ——— and winter -------

The summer medians are higher than the winter medians for all wind directions except NE and E. Since these are the directions from which smoke and combustion products would be expected it is not surprising that such man made nuclei carried in the wind probably from considerable distances eastward should upset the normal summer-winter relationship.

9. Annual Variation

The median values for each month of the year for all observations (dry conditions) are given in Table 7 and plotted on Fig. 6.

Table 7. Monthly Medians of Z

	All Winds			Sea Winds		
Month	Night	Afternoon	Full Day	Night	Afternoon	Full Day
January	757	986	841	397	555	521
February	601	853	714	369	481	414
March	821	770	781	437	534	497
April	825	707	756	547	601	581
May	692	791	736	453	677	569
June	808	804	807	672	743	706
July	805	838	831	609	793	700
August	707	681	697	552	635	619
September	649	774	712	503	623	555
October	668	832	765	544	770	649
November	834	1087	956	404	565	481
December	729	958	839	424	508	458

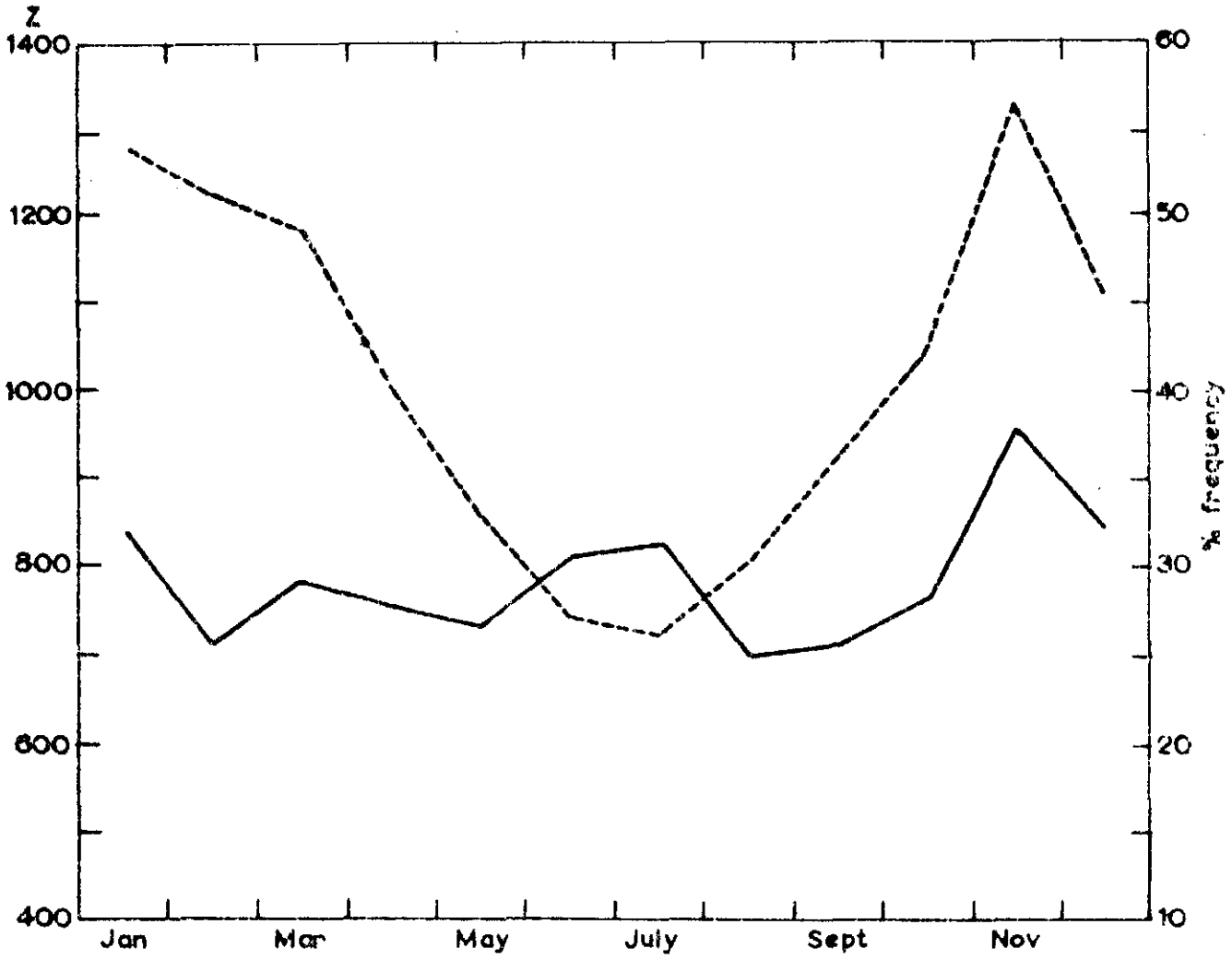

Fig. 6 Annual variation of nucleus concentration, all winds ———— and percentage frequency of winds from easterly sector ----------

From Fig. 6. the only pattern that seems to emerge is the fact that the highest values are observed in January and November. This would appear to contradict what has been said in para. 8 above regarding the excess in summer over winter. The apparent contradiction is due to the incidence of the contaminated winds from the easterly sector. The percentage frequency of winds from the easterely sector (including calms, which are characterised by man made pollution), for each month of the year, are also plotted on Fig. 6. It is clear that the incidence of these polluted winds have a dominating influence on the median value of Z.

The monthly medians for "sea winds" only are also given in Table 7 and plotted on Fig. 7.

The annual variation for the "sea winds" shows a definite pattern roughly following the sun's march. The annual variation in the global solar radiation is also plotted on Fig. 7. There is a significant similarity between the trend of the global radiation and nucleus content but the occurrence of maximum Z two months later than the maximum global radiation and the peak in the Z curve in October indicate that the nucleus count is a function of a number of variables.

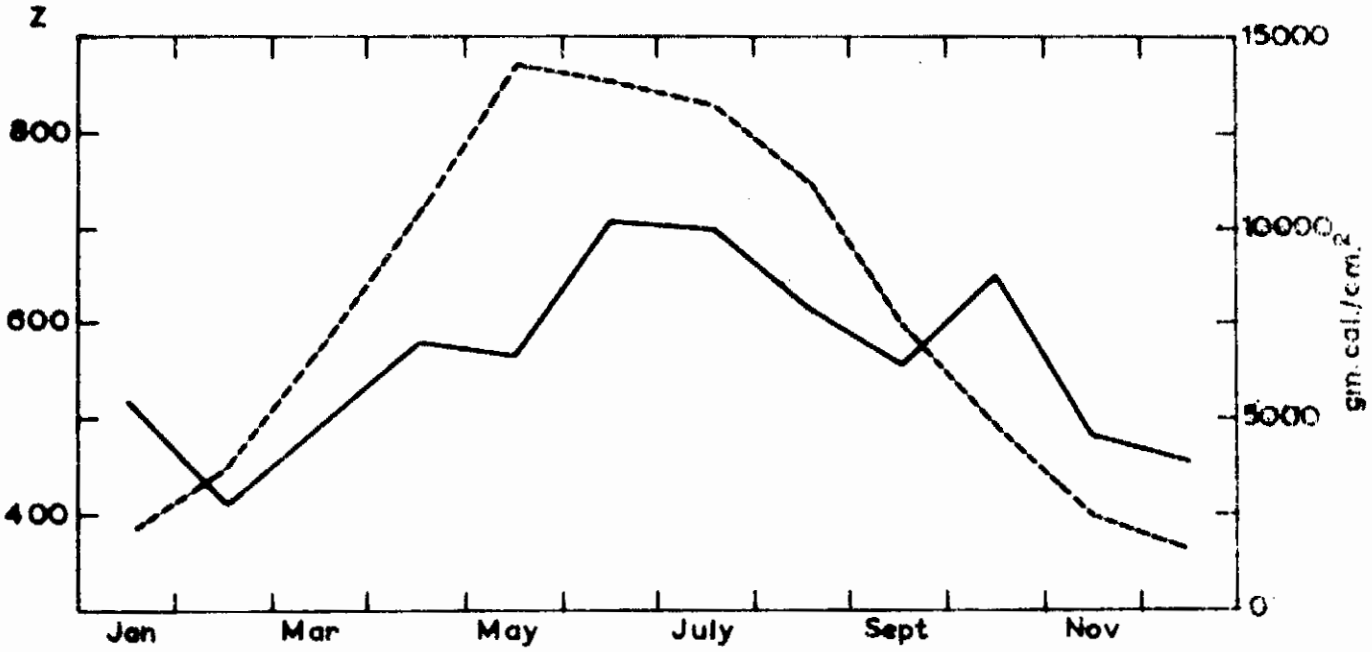

Fig. 7 Annual variation of nucleus concentration, sea winds ——— and annual variation of global solar radiation ----------

10. Variation of Z with Wind Speed

The data were grouped together in ranges of wind speed and the medians for each speed range are given in Table 8 and shown graphically on Fig. 8.

Table 8 Medians of Z for Ranges of Wind Speed

	Calm	1-3 kts.	4-6 kts,	7-10 kts.	11-16 kts.	>16 kts.
All Winds	1200	1175	852	783	672	550
Sea Winds	1200	897	710	610	527	496

The trend is the same for both night and afternoon observations and in both seasons so only the medians for all observations are shown.

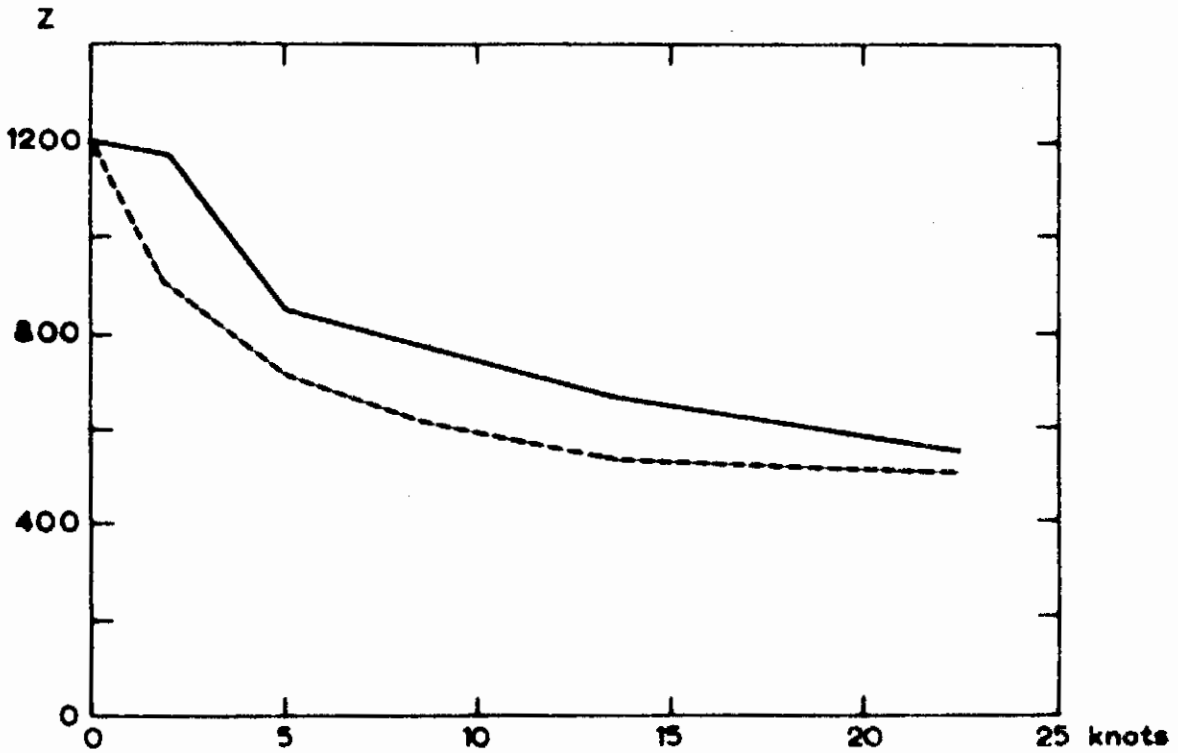

Fig. 8. Variation of concentration of nuclei with wind speed
All winds ——— Sea winds -------

The decrease with wind speed is quite well marked both with all winds and when the sea winds are considered separately. This confirms the findings of McWilliams and Morgan in their earlier investigation [1] and is in agreement with the findings of Landsberg [10]. Increased vertical transportation due to increased turbulence and mixing, as suggested by Landsberg, is undoubtedly a factor.

With sea winds only there is no significant difference in the trend, the decrease of Z with increasing wind speed is still quite definite, though the rate of decrease is slightly less.

Georgii and Metnieks [11] made measurements of the concentration of salt nuclei on Valentia Island about 3 km. to the south west of the Observatory site and found that there was an increase in the concentration of the sea salt nuclei with wind speed and that there was an inverse relationship between the number of sea salt nuclei and Aitken nuclei. It would appear therefore that even at a site quite close to the sea and even with winds blowing from the sea, the sea spray is not a major source of Aitken nuclei.

Davies and Waid [12] also found that over the Atlantic Ocean when high winds were encountered and spray was plentiful there was still no significant change in the nucleus content.

11. Variation of Z with Relative Humidity

Medians of Z for a number of ranges of relative humidity are given in Table 9 and plotted in Fig. 9.

Table 9 Medians of Z for Ranges of Relative Humidity

R. H. %	59 or less	60-69	70-74	75-79	80-84	85-89	90-100
All Winds	1586	897	746	753	690	737	719
Sea Winds	1200	626	546	552	583	587	518

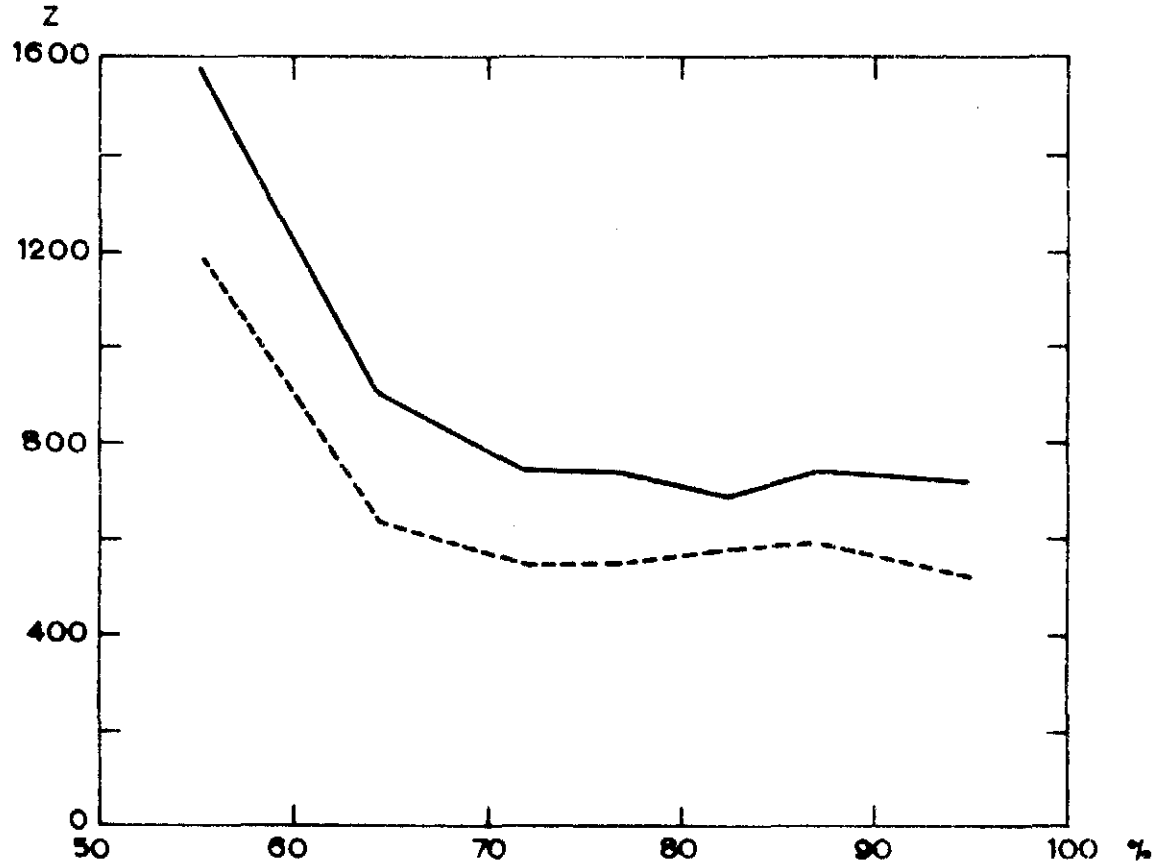

Fig. 9. Variation of concentration of nuclei with relative humidity
All winds ——— Sea winds - - - - - -

The trend for all winds and sea winds is similar. In both cases there is a definite increase in Z when relative humidity decreases below 75%. above this point however there appears to be little or no co-relation with relative humidity. This confirms results found by McWilliams and Morgan [1] and is in agreement with the findings of most other investigators.

12. Variation of Z with Visibility

Medians of Z for a number of ranges of visibility expressed in Kilometers are given in Table 10 and shown graphically on Fig. 10.

Table 10 Medians of Z for ranges of Visibility

Kilometers	0-9	10-16	17-22	23-29	30-35	36-42	42
All Winds	1094	835	700	638	714	826	1003
Sea Winds	646	533	546	499	558	673	747

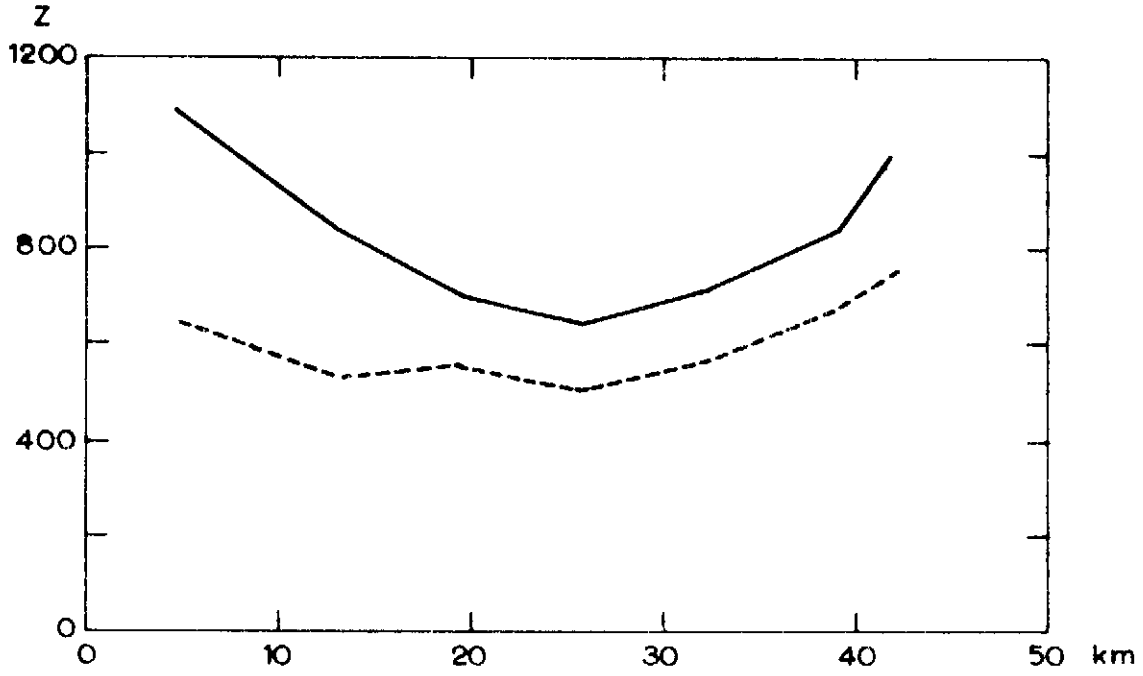

Fig. 10. Variation of concentration of nuclei with visibility
All winds ——— Sea winds --------

The pattern is similar to that found by McWilliams and Morgan [1] and confirms the unexpected feature found by them that while Z decreases with increasing visibility up to about 30 km. abcve this range the value of Z increases with visibility. When sea winds only are considered the range of Z is compressed but the general pattern is similar to that for all winds. Poor visibility in association with high values of Z and an improvement in visibility with decrease of Z have been found by Landsberg [10] and many other investigators. At Valentia however best visibilities are also associated with high values of Z even with sea winds. It is clear therefore that it is not the concentration of nuclei that is the main factor in determining visibility at Valentia but rather the type and size of the nuclei. When winds from all directions are considered Z is made up of combustion nuclei, smoke particles and sea salt particles and the resultant visibility will depend greatly on the value of the relative humidity. With sea winds the effect of smoke particles may be neglected and Z may be considered as a combination of sea salt and combustion nuclei. With winds from this sector poor visibility at Valentia is generally associated with high relative humidity and therefore with the growth of sea salt nuclei. Best visibilities at Valentia are usually experienced with polar air from the

north west and are usually accompanied by low humidity. With low humidity even a high concentration of salt nuclei would not affect visibility as according to Owens [13] the sea salt nuclei become crystalline at a humidity of about 70% and do not increase in size.

It would appear therefore that as Wright [14] has suggested the visibility in air free from smoke pollution depends mainly on the number and size of the sea salt nuclei, the size, which is controlled by the value of relative humidity, being the more important factor. It would appear that even with sea winds at Valentia a considerable proportion of the nucleus content is made up of combustion nuclei. These could be produced by ships or diffused by winds from land areas and could be carried in the air over long distances just in the same way as it is generally accepted that sea salt nuclei may be transported great distances inland.

13. Variation of Z with Temperature

Medians of Z for various ranges of temperature are given in Table II both for all winds and for sea winds. The variation of Z with temperature is shown graphically in Fig. 11.

Table II Medians of Z for Ranges of Temperature

Temp. °C	All Winds	Sea Winds
1.5	1525	848
1.6 - 3.9	1282	973
4.0 - 6.7	1057	559
6.8 - 9.5	691	454
9.6 - 12.3	641	500
12.4 - 15.1	679	587
15.2 - 17.9	821	665
18.0	1467	1358

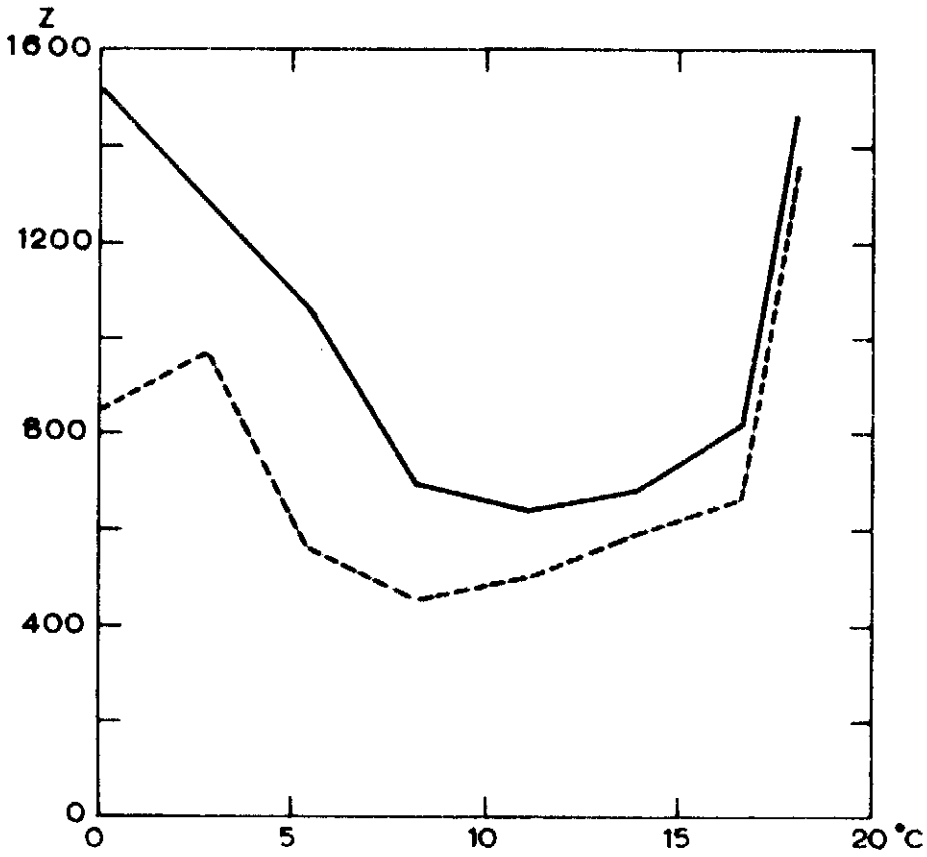

Fig. 11. Variation of Z with temperature

All winds ——— Sea winds -------

The pattern is similar to that previously obtained by McWilliams and Morgan. It must however be treated with considerable reserve. In the case of all winds temperatures below 7°C at Valentia are generally associated with winds from the easterly sector where combustion nuclei and smoke pollution are expected. The high values of Z are therefore attributable more to wind direction than to low temperature. When sea winds only are considered the medians for temperature below 4°C are based on so few observations that very little confidence can be placed in them. The medians for the higher ranges of temperature being based on a large number of observations can be accepted with more confidence. These show that both for all winds and for sea winds there is a tendency for Z to increase with increasing temperature. In the case of sea winds the mechanism suggested by Melander [15] may be operative, i.e. increased evaporation at the sea surface due to the higher air temperature.

14. Variation of Z with Cloud Amount

The medians of Z for ranges of cloud amount are given in Table 12 and plotted on Fig. 12.

Table 12 Medians of Z for Ranges of Cloud Amount

Cloud Amount Oktas	All Winds			Sea Winds		
	Night	After noon	Full Day	Night	After noon	Full Day
0 & 1	1003	1370	1135	546	1075	802
2 & 3	707	881	750	457	660	567
4 & 5	665	871	769	532	735	616
6 & 7	688	711	700	491	567	547
7+ & 8-	637	768	723	472	612	558
8	619	754	686	494	581	531

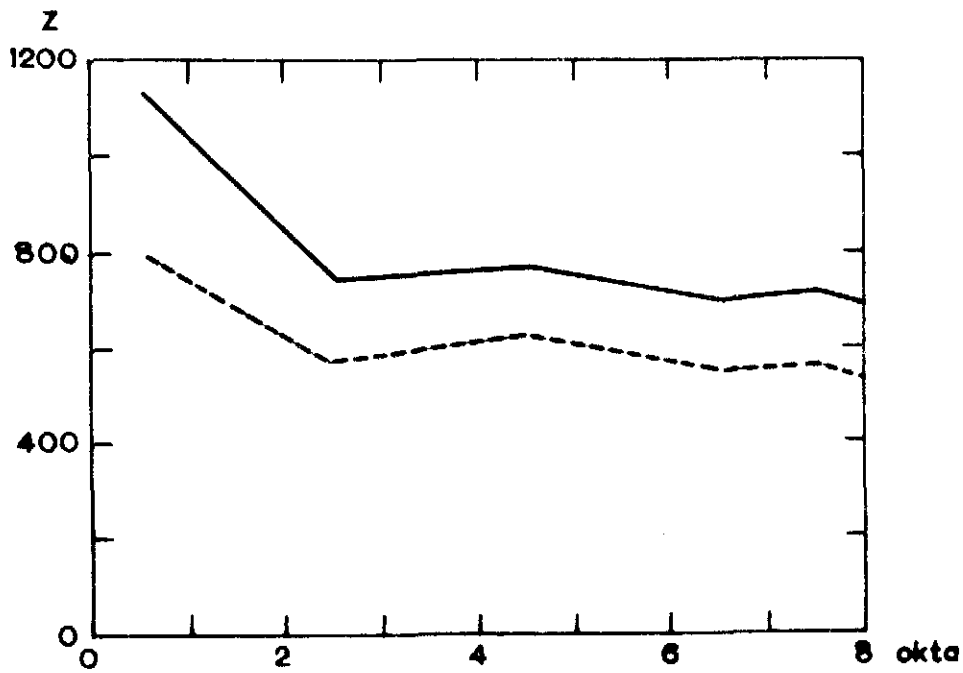

Fig. 12. Variation of nucleus concentration with cloud amount
All winds ——— Sea winds -------

The variation is the same for sea winds as it is when all winds are included. In both cases there is no significant relation between Z and cloud amount once the sky becomes about one quarter covered with cloud. High values of Z are however associated with occasions when the sky is less than one quarter covered.

When all winds are considered the association of high values of Z with little or no cloud is not surprising. Almost clear skies are generally associated with anticyclonic conditions when polluted air from the easterly sector is to be expected. However this is not the full explanation as the high values of Z in conditions of little cloud are also found when sea winds only are considered. The presence of another factor may be deduced from Fig. 13 which shows the variation for the afternoon and night for sea winds.

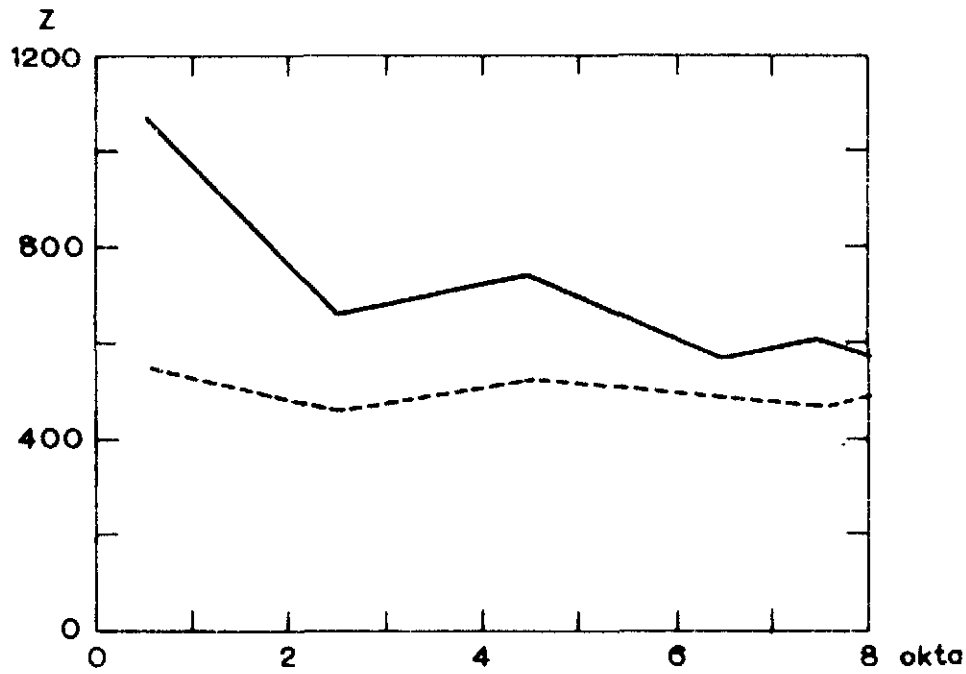

Fig. 13. Variation of nucleus concentration with cloud amount (sea winds)

Afternoon ——— Night - - - - - - - -

It can now be seen that at night time the value of Z is not affected by cloud amount. The high values of Z with low cloud amount are therefore associated only with the afternoon observations. These would also be the occasions of high temperature so the suggestion made in para. 13 above may apply here. The effect of increased ultra voilet radiation as suggested by Landsberg [10] may also be a contributory cause.

McWilliams and Morgan in their earlier investigation came to a similar conclusion regarding the relation between Z and Cloud amount although in their case the decrease in Z with increased cloud cover continuted until the sky was about half covered.

15. Conclusion

It is clear that even at Valentia where the air is relatively free from pollution the nucleus concentration is a function of many different variables most of which are interdependent. For a more precise determination of the variation of Z with each variable it will be necessary to regroup the data within much narrower limits aiming, if possible, to reduce the variables to one within each group. The problem then is to get sufficient data within each small group on which to base a conclusion. With the continued accumulation of

observations at Valentia this problem may soon be overcome. In the meantime the chief results of the present analysis generally confirm those previously found by McWilliams and Morgan and may be summarised as follows:

(1) 40% of all observations showed a concentration less than 500 per cm^3 and when sea winds only are considered the frequency in this range increased to 51%.

(2) Concentrations were higher during afternoon than during the night.

(3) Precipitation at the time of observations or in the previous hour reduced the concentration by 30 - 40%.

From measurements made when no precipitation occurred at the time of observation or in the previous hour it was found that

(1) Highest concentrations occurred with winds from the easterly sector (NE - E - SE) where pollution would be expected. There was no significant variation in concentration with winds from the other directions.

(2) When all wind directions were considered the incidence of winds from the polluted sector had a dominating influence in the annual variation. When only sea winds were considered the annual variation generally followed the intensity of the global solar radiation.

(3) Concentrations were high with calms and decreased with increasing wind speed.

(4) High concentrations were associated with low humidity but otherwise there was no significant relation between these two variables.

(5) Concentrations tended to increase with increasing air temperature.

(6) High concentrations were associated with clear or almost clear skies

(7) The nucleus concentration was not a major factor in determining visibility.

References

[1] McWilliams, S. & Morgan, W.A.
The relation between the concentration of atmospheric condensation nuclei and other meteorological elements at Valentia Observatory.
Geofisca pura e applicata, Vol. 31, 1955.

[2] Nolan, P.J. and Pollak, L.W.
The calibration of a photo-electric nucleus counter.
Proc. Roy. Irish Acad. Vol. 51 A.2, 1946.

[3] O'Connor, T.C.
Condensation nuclei in Maritime Air.
Journ. de Rech. Atm. Vol. 11 2e, No. 2 - 3, 1966.

[4] Moore, D.J.
Measurements of condensation nuclei over the North Atlantic.
Q.J. Roy. Met. Soc. Vol. 78, No. 338, 1952.

[5] O'Connor, T.C., Sharkey, W.P. and Flanegan, V.P.
Observations on the Aitken nuclei in Atlantic air.
Q.J. Roy. Met. Soc. Vol. 87, No. 371, 1961.

[6] Torreson, O.W.
Condensation nuclei in the atmosphere at the Huancayo Magnetic Observatory, Peru, and their relation to atmospheric-electric and meteorological observations.
Terr. Mag. and Atm. El. Vol. 44, No. 1, 1939.

[7] Dines, L.H.G. and Mullholand, P.I.
On the interrelation of wind direction with cloud amount and visibility at Cahirciveen, Co. Kerry.
M.O. Prof. Notes Vol. 3, No. 36, 1924.

[8] Hess, V.F.
Further determinations of the concentration of condensation nuclei in the air over the North Atlantic.
Journ. Geoph. Res. Vol. 56, No. 4, 1951.

[9] Aitken, J.
Proc. Roy. Soc. Edinburgh. Vol. 31, 1911.

[10] Landsberg, H.
Observations of condensation nuclei in the atmosphere
U.S. Mon. Weather Rev. Vol. 62, 1934.

[11] Georgii, H.W. and Matnieks, A.L.
An investigation into the properties of atmospheric freezing nuclei and sea-salt nuclei under maritime conditions at the West coast of Ireland.
Geofisica pura e applicata. Vol. 41, No. 3, 1958.

[12] Davies, F.T. and Wait, G.R.
Density of condensation nuclei over the North Atlantic.
IUGG Association
Terr. Mag. and El. Bull. No. 11, 1940.

[13] Owens, J.S.
Proc. Roy. Soc. (A) Vol. 110, 1926

[14] Wright, H.L.
Atmospheric Opacity at Valentia
Q.J. Roy. Met. Soc. Vol. 66, No. 283, 1940.

[15] Melander, G.
Sur la Condensation de la vapeur d'eau dans l'atmosphere de Helsingfors.
Imprimerie des Heritiers de Simelius, Helsingfors. 1897.