Communications of the
Dublin Institute for Advanced Studies
Series D, Geophysical Bulletin No. 28

An Analysis of Daily Magnetic Variation in Ireland

by

R. P. RIDDIHOUGH

DUBLIN
THE DUBLIN INSTITUTE FOR ADVANCED STUDIES
1970
Price 5/-

Communications of the
Dublin Institute for Advanced Studies
Series D, Geophysical Bulletin No. 28

An Analysis of Daily Magnetic Variation in Ireland

by

R. P. RIDDIHOUGH

DUBLIN
THE DUBLIN INSTITUTE FOR ADVANCED STUDIES
1970

Price 5/-

AN ANALYSIS OF DAILY MAGNETIC VARIATION IN IRELAND

I INTRODUCTION

One of the most constant problems in magnetic surveying is the removal from the survey results of the variation of the earth's magnetic field with time. This is done in aeromagnetic surveying by a rapid 'looping' method but in other surveys has to be based on the continuous record obtained at a static station, normally arranged to be as near as possible to the area of the survey.

For reasons of economy however, variations of the magnetic field at the nearest permanent Observatory are often used. This may be many tens of kilometres away from the survey area and in this case the uncertainties which its use introduces into the survey reduction are directly related to the problem of whether the magnetic variation measured at the Observatory is representative of that occurring over the survey area.

The present Bulletin presents the results and analysis of a group of continuously recorded total field stations run at various places in Ireland on various dates between 1967 and 1970 and their comparison with the magnetic records issued from Valentia Observatory. This same data has been used as the basis of a discussion of magnetic diurnal correction errors by the same author elsewhere, however much of the local and finer detail was omitted and is here presented both for completeness and to provide a foundation for any other similar work continued in Ireland.

2 DATA ACQUISITION

Field Stations

The station data were obtained using an Elsec Proton magnetometer coupled to an automatic recorder and a crystal clock. Readings of the total field were taken every 55 secs and recorded against time either digitally on an adapted adding machine or in analogue form on a potentiometric recorder. The latter was in use only for three days on the total field station at Valentia.

The stated accuracy of the system was $\pm$ 1 count which at the gate timing used for the majority of the work corresponds to an accuracy of $\pm$ 1 gamma. Readings were made for complete 27 hour intervals from 2230 GMT on one day to 0130 GMT on the day following the next.

Sites and dates were chosen principally for practical reasons concerned with the availability of the instruments between surveys and the power and supervision requirements of continuous recording. They are listed in Table 1 together with some notes on the detailed location of the sites.

Valentia Observatory

Total field measurements were obtained from the Observatory La Cour H and Z variometers as maintained by the Meteorological Service of the Dept. of Transport and Power (Irish Met. Service, 1956). These are recorded on normal 15 mm/hr magnetograms which are reproduced photographically. Base lines are checked every two or three days against absolute instruments and more recently against a proton magnetometer fitted with field neutralising coils.

The data were digitised from these records with a D-Mac Table plotter, proceeding directly from this to punch paper tape and computer input. The scale values for the magnetograms were such that an estimated $\pm$ 0·2 mm accuracy in positioning the 'follower' would result in errors of approximately $\pm$ 1 gamma in the total field.

3 DATA AND TREATMENT

To represent ground survey practice, spot values at 10 minute intervals were read from both the field station records and the Valentia magnetograms. The 162 ten-minute values for the station (2235 – 0125 GMT) were compared with the 144 ten-minute values of Valentia (0005 – 2355 GMT) in a series of calculations which were equivalent to 'sliding' the 144 point data set past the 162 point data set and measuring correlation parameters for the 19 positions of 144 point comparison which the overlap allowed.

The purpose of this was to test the degree of similarity between the magnetic variations at the station and at Valentia and to determine the sensitivity of various correlation parameters in indicating the position of closest fit and thus time difference between the two variations.

The correlation parameters calculated for each of the 19 positions were:

(i) the standard deviation of the arithmetic differences between the Valentia and the station points,

(ii) the linear correlation coefficient between the two data sets (CC),

(iii) the two linear regression coefficients between the two data sets.

The calculations were carried out on the Dublin Institute for Advanced Studies IBM 1620 computer located at Dunsink Observatory.

In practical terms these three parameters lead to:

(i) the standard error (SE) of a single subtraction between a station value and the equivalent Valentia value. As the standard deviation of the differences is the limit within which 68% of the differences lie around their mean, so it is also the limit within which the true mean value (taken as the average of all 144) will lie from any single subtraction for 68 out of 100 cases.

(ii) the identification of a maximum value which indicated the position of closest fit of the two curves represented by the data sets. In all cases correlation coefficients were high and very significant and indicated a predominantly linear relationship between the stations and Valentia.

(iii) The amplitude relationship between the magnetic variation at the station and at Valentia. The fact that the high correlation coefficients confirmed a linear relationship between the two data sets indicated that the mean of the two linear regression coefficients (Valentia on station and station on Valentia) represented the slope of the best straight line through the points defined by the two sets of values. If this was unity, then the magnetic variation had the same amplitude at Valentia as at the station; a departure from this value represented an amplitude difference between the variation at the station and at Valentia.

These results can be more clearly seen by reference to the figure which shows the results of the analysis for one day: 8.7.69. The graph plots the data set from Rosslare beginning at 2345 with the data set from Valentia beginning at 0005, i.e. with a time difference of 20 minutes. The graphs of CC and SE are the central parts of 19 position graphs and show the regular and marked peak which indicated the closest position of correlation between the two curves and the minimum position of the standard deviation of the differences. The maximum and minimum of these two values were always coincident.

4 RESULTS

The results of the analysis of the 43 days are shown in Table 2.

ΣKp and ΣKp^2 values indicating the magnetic character of the day were obtained for dates before July 1968 from 'Journal of Geophysical Research' and for days after that date from ESSA Res. Labs. 'Solar Geophysical Data (prompt reports)' published by the U.S. Dept. of Commerce. Mean Daily Range is the range between the hourly mean value centred at 1230 GMT and that centred at 1830 GMT. Time differences are estimated to the nearest 5 minutes, and the amplitudes in % of Valentia are those at the maximum correlation position. Positions up to 30 minutes either side of this produced less than 1% change in the value. Standard errors for the day are given for the minimum position, the simultaneous position (i.e. with zero time difference between the station and Valentia), and at the local time differences with Valentia as given in Table 1. These latter SE are interpolated from the ten-minute values where necessary. The daily mean difference is the difference between the mean value of 144 Valentia points and the mean value of 162 station points. Although these are not strictly comparable, the changes made by the consideration of 18 extra points at the station appear to be negligible because they are around midnight and involve very small deviations from the daily mean.

5 GENERAL ANALYSIS OF RESULTS

Detailed analysis of these results is being presented elsewhere, however a brief summary may be useful at this point, particularly with regard to the errors of differences that are of interest in survey reduction.

Firstly, the time and amplitude results seem to support the principle of the geographical distribution of daily magnetic variation as earlier investigated by the present author (Riddihough, 1967 and 1969). Secondly, the standard errors of subtractions between stations and Valentia can be seen to be virtually independent of the 'noisiness' of the day except in storm conditions. For non-storm days, the errors are strongly dependent upon the actual range difference between the daily magnetic variation at the station and at Valentia on the appropriate day. However, as the relative amplitude relationship between the station and Valentia has a geographical basis, the range differences on any day can be estimated from the range at Valentia on that day. In general, errors of individual subtractions range from $\pm$ 2 – 3 gamma to $\pm$ 6 – 7 gamma depending upon the daily range difference.

Thirdly, it can also be seen from these results that the influence on the errors of time differences in magnetic variation occurrence is small, so that the application of time corrections in survey reduction would produce no significant diminution in the errors and would be uneconomic of effort.

6 DAILY MEAN VALUES

The calculations for standard error for each day are based on the assumption that the mean of the 144 differences for the day is the true difference between the station and Valentia. However, as the daily magnetic variation is essentially a negative embayment in the total field, the calculated mean value of the day will be affected by its amplitude. Differences between the amplitude of this variation at Valentia and at the station will thus effect a slight change in the daily mean differences. These are shown in the last column of Table 2 and emphasize the difficulty or near-impossibility of obtaining a static difference between any two magnetic stations.

7. PARTICULAR ANALYSIS OF THE VALENTIA—ST. FINAN'S BAY RESULTS

The results for the three days, 22–24.3.70, during which a proton magnetometer was run at Valentia Observatory simultaneously with one at St. Finan's Bay, a distance of 12 km away, are of particular interest.

Firstly, the results for Valentia indicate that the daily variation as recorded by the proton magnetometer for this period is 106 ($\pm$ 2)% of that deduced from the reading and reduction of the H and Z variometers. The two regressions for a single day (Valentia on station and station on Valentia) do not have sufficient variation to encompass the 100% situation, e.g. 24.3.70: regression slope Proton/Val = 1·055 $\pm$ 0·008, regression slope Val/Proton (inverted) = 1·065 $\pm$ 0·008. This is not therefore, an uncertainty in the analysis. Mean daily ranges compared for 6 days around the same period gave an equivalent value of 107 ($\pm$ 2)%. Although the standard deviation of these means could bring the results nearer to 100% which it is assumed is the real relationship between the two fields, this does suggest the possibilities that either the scale factors for the reduction of H and Z from the variometers, or the recording system of the proton magnetometer, in this case a potentiometric chart recorder, could be producing a systematic error in the range of total field of the order of 1 or 2 gamma. Measurements of the scale factors at the variometers by the Observatory staff (personal communication) do not support the first explanation and therefore the second must be a possibility to be considered. However, other errors due to factors such as paper shrinkage during copying or storage may be possible.

St. Finan's Bay is notable in the differences it shows from Valentia. The proton magnetometer here, recording digitally, recorded a daily magnetic variation 108 ($\pm$ 2)% of the Valentia variometer variation and 2% higher than the proton magnetometer at Valentia. The position of closest fit of the two variations was 8 $\pm$ 3 minutes before Valentia. Although the minimum standard errors only increased a matter of 0·3 gamma from Valentia to St. Finan's Bay, the standard errors at simultaneity were 0·6 gamma greater. This indicates the considerable differences in the daily magnetic variation that can exist over short distances on even very quiet days.

ACKNOWLEDGMENTS

I would like to thank the Director of the Meteorological Service of the Department of Transport and Power, Dublin for permission to use Meteorological Stations as recording sites and to express my appreciation of the assistance and kindness show by the Staff of the stations at Belmullet, Clones, Rosslare and Valentia during the recording of the observations.

9 BIBLIOGRAPHY

Irish Met. Service, 1956, Magnetic Observations at Valentia Observatory 1954.

Riddihough, R. P., 1967, Daily Variation of Total Magnetic Field over the British Isles, *Nature*, 215, 720–722.

Riddihough, R. P., 1969, A Geographical Pattern of Daily Magnetic Variation over North-West Europe, *Ann. de Geophysique*, 25, 739–745.

July 1970.

School of Cosmic Physics,
5 Merrion Square, Dublin, 2
Ireland.

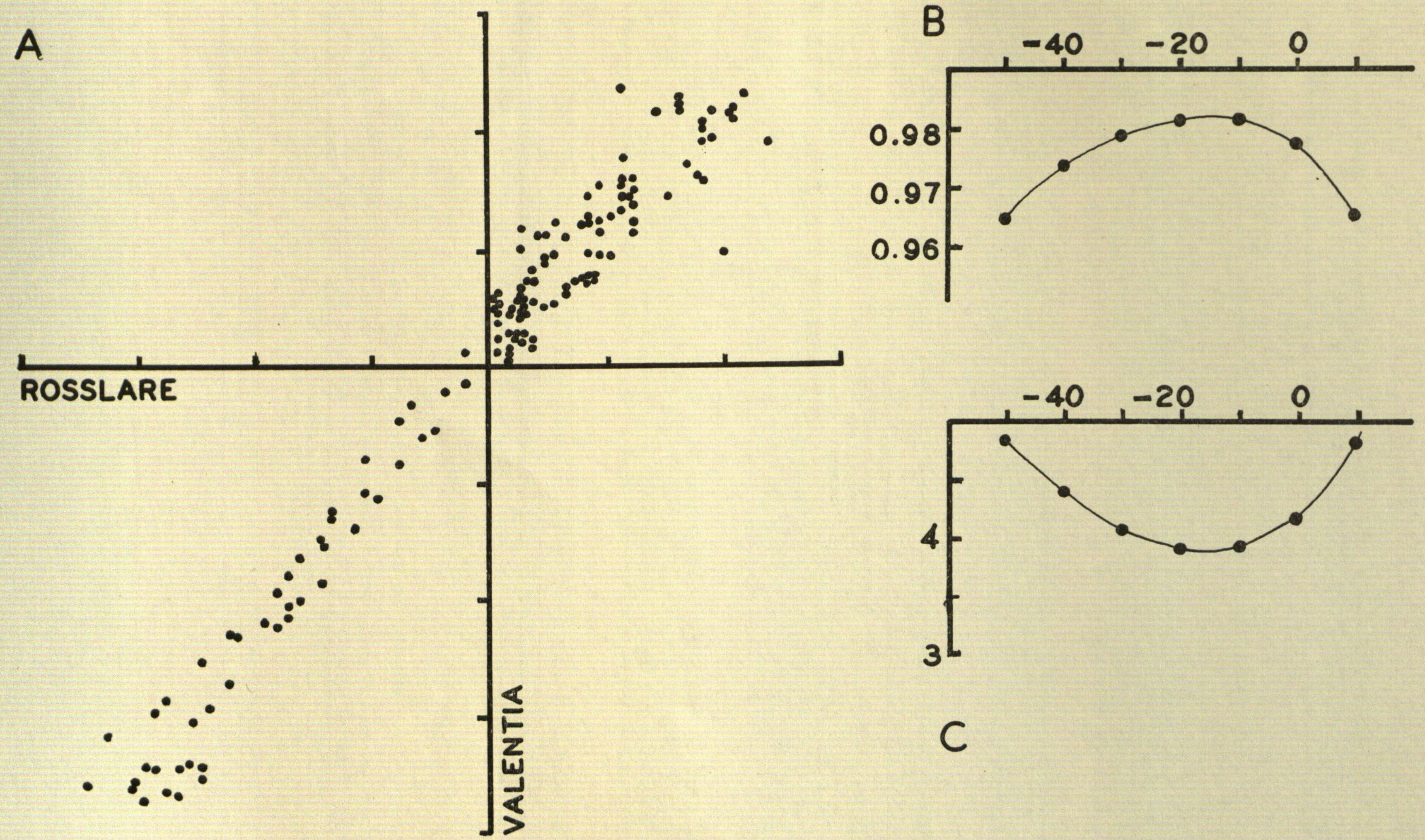
TABLE 1: Sites and dates of recording stations.

Station	Site	Recording Dates	Time difference from Valentia
			min
ARDARA, Co. Donegal	Open field, 1 mile west of town	28.5.68	−5
		29.5.68	
		30.5.68	
BELMULLET, Co. Mayo	Meteorological Station enclosure	23.5.69	0
		24.5.69	
		25.5.69	
		26.5.69	
		27.5.69	
		28.5.69	
CLONES, Co. Monaghan	Meteorological station enclosure	23.7.69	−10
		24.7.69	
		25.7.69	
		26.7.69	
		27.7.69	
		28.7.69	
		29.7.69	
		30.7.69	
DUN LAOGHAIRE, Co. Dublin	Private garden in suburban area	12.7.67	−15
		13.7.67	
		14.7.67	
		15.7.67	
		16.7.67	
		17.7.67	
		18.7.67	
		19.7.67	
		20.7.67	
DUNSINK, Co. Dublin	Observatory grounds	1.10.68	−15
		2.10.68	
		3.10.68	
		21.5.69	
		25.1.67	
		26.1.67	
ROSSLARE, Co. Wexford	Meteorological station enclosure	3.7.69	−15
		4.7.69	
		5.7.69	
		6.7.69	
		7.7.69	
		8.7.69	
		9.7.69	
		10.7.69	
ST. FINAN'S BAY Co. Kerry	Open field, 400 m from sea	22.3.70	0
		23.3.70	
		24.3.70	
VALENTIA OBSERVATORY, Cahirciveen, Co. Kerry	Meteorological station grounds. Between seismometer and Variometer huts—app. 100 m from the latter.	22.3.70	0
		23.3.70	
		24.3.70	

TABLE 2: Results of analysis

Station	Date	ΣKp	ΣKp^2	Mean daily range at Valentia	Max CC	Time diff.	Rel. Amp	Standard Error			Daily mean diff.
								min.	sim.	L.T.	
				γ		min.	% Val.	γ	γ	γ	γ
ARDARA	28.5.68	13–	24	64	0·993	0	96	2·23	2.23	2·51	525·3
	29.5.68	18–	42	78	0·990	–20	107	3·76	5·00	4·50	524·5
	30.5.68	19	49	46	0·965	–10	100	3·73	4·17	3·90	525·1
BELMULLET	23.5.69	19–	44	55	0·989	0	94	2·48	2·48	2·48	561·0
	24.5.69	19–	44	54	0·982	0	99	3·36	3·36	3·36	557·3
	25.5.69	13	29	49	0·985	+5	115	3·88	3·95	3·95	555·4
	26.5.69	8–	10	55	0·990	+5	101	2·52	2·63	2·63	558·8
	27.5.69	6	6	49	0·983	+15	117	3·95	4·38	4·38	556·1
	28.5.69	16+	40	45	0·990	+10	101	2·36	2·79	2·79	557·7
CLONES	23.7.69	10+	20	59	0·975	–25	90	3·97	5·07	4·32	158·9
	24.7.69	8–	7	36	0·967	–30	102	2·66	3·94	3·30	158·3
	25.7.69	8–	11	32	0·977	–30	94	2·57	3·44	2·94	156·9
	26.7.69	23–	92	29	0·908	–10	95	5·30	5·90	5·20	151·6
	27.7.69	31	152	52	0·958	–5	138	19·86	19·89	19·86	154·2
	28.7.69	8	10	40	0·975	0	84	3·35	3·35	3·41	158·4
	29.7.69	4–	2	38	0·964	0	79	4·35	4·35	4·38	156·4
	30.7.69	17+	58	86	0·972	–10	91	5·23	5·59	5·23	157·2
DUN LAOGHAIRE	12.7.67	17–	44	63	0·967	–15	81	5·27	5·51	5·27	–66·2
	13.7.67	12+	27	58	0·979	0	76	5·24	5·24	5·45	–66.9
	14.7.67	14+	28	54	0·973	–20	86	4·35	4·85	4·42	–64·3
	15.7.67	13	36	52	0·979	–5	97	3·60	3·62	3·75	–65·2
	16.7.67	8	15	44	0·973	0	85	3·43	3·43	3·68	–67·4
	17.7.67	9	13	38	0·952	+10	71	5·35	5·43	5·82	–70·0
	18.7.67	15–	31	58	0·960	+5	76	5·75	5·80	6·27	–73·0
	19.7.67	8+	14	36	0·940	–5	83	5·01	5·01	5·09	–72.6
	20.7.67	11–	17	43	0·942	–5	72	5·46	5·46	5·57	–74·2*
DUNSINK	1.10.68	23	72	37	0·967	0	99	4·17	4·17	5·07	109·7
	2.10.68	39–	210	39	0·963	0	107	6·12	6·12	8·39	111·4
	3.10.68	25–	117	15	0·955	0	109	5·00	5·00	6·83	111·7
	† 21.5.69	22	67	63	0·960	–10	85	5·91	6·11	5·95	56·4
	25.1.67	10	17	14	0·923	+50	74	1·85	2·48	2·74	111·3
	26.1.67	8–	11	16	0·930	0	66	2·56	2·56	2·58	110·4
ROSSLARE	3.7.69	6+	7	82	0·987	–10	82	5·40	5·56	5·53	–109·6
	4.7.69	4+	4	77	0·994	–20	82	4·76	5·67	4·88	–109·3
	5.7.69	4–	3	73	0·991	–10	76	5·54	5·90	5·55	–110·8
	6.7.69	9–	16	70	0·988	–20	75	5·84	6·54	5·95	–109·8
	7.7.69	12–	20	45	0·971	–20	80	4·92	5·52	4·98	–108·7
	8.7.69	10	14	55	0·982	–10	85	3·93	4·17	3·94	–109·8
	9.7.69	14	31	58	0·984	–10	89	3·67	3·77	3·90	–108·3
	10.7.69	14–	28	45	0·975	–10	89	3·56	3·80	3·60	–109·6
ST. FINAN'S BAY	22.3.70	4	4	54	0·994	–10	107	1·90	2·03	2·03	–60·3
	23.3.70	10	14	52	0·995	–5	110	1·96	1·96	1·96	–62·6
	24.3.70	4	3	66	0·997	–10	107	1·77	2·37	2·37	–61·6
VALENTIA	22.3.70	4	4	54	0·997	0	104	1·32	1·32	1·32	–161·8
	23.3.70	10	14	52	0·997	0	109	1·59	1·59	1·59	–163·9
	24.3.70	4	3	66	0·996	0	106	1·69	1·69	1·69	–162·6

* Possible slow movement of detector head giving progressive difference changes.
† Different site in Observatory grounds.



Comparison of Rosslare and Valentia total field on 8.7.69

A—Plot of ten-minute values with 20 minute time difference, (Scale intervals—10 gamma)

B—Correlation coefficients and C—SE (gamma) for varying time differences in minutes.

PRINTED AT
DUBLIN UNIVERSITY PRESS LTD.
TRINITY COLLEGE
DUBLIN

GEOPHYSICAL BULLETINS

No. 1: THOMAS MURPHY, Provisional Results of the Gravity Survey of Central Ireland; Dublin, March, 1950.

No. 2: THOMAS MURPHY, Provisional Values for Magnetic Declination in Ireland for the Epoch 1950-55; Dublin, February, 1951.

No. 3: L. W. POLLAK and NUALA O'BRIEN, Frequency of the Centres of Closed Low Pressure Systems over the North Atlantic Ocean; Dublin, April, 1951.

No. 4: JOHN S. JACKSON, Density of Irish Rocks; Dublin, July, 1951.

No. 5: R. FÜRTH, On the Theory of Stochastic Phenomena and its Application to some Problems of Cosmic Physics; Dublin, July, 1952.

No. 6: J. J. McHENRY, Condensation Nuclei Produced in the Laboratory; Dublin, February, 1953.

No. 7: P. J. NOLAN and P. S. MacCORMAIC, The Nuclei Produced by Disruptive Discharge at a Water Surface; Dublin, July, 1953.

No. 8: E. J. ÖPIK, Convective Transfer in the Problem of Climate; Dublin, October, 1953.

No. 9: REV. R. E. INGRAM, S.J. and J. R. TIMONEY, Theory of an Inverted Pendulum with Trifilar Suspension; Dublin, February, 1954.

No. 10: P. PETHERBRIDGE, Meteorological Aspects of the Daylighting of Buildings; Dublin, October, 1954.

No. 11: THOMAS MURPHY, A Vertical Force Magnetic Survey of the Counties Roscommon, Longford, Westmeath and Meath with parts of the adjacent Counties of Galway, Cavan, Louth and Dublin; Dublin, January, 1955.

No. 12: L. W. POLLAK and T. J. MORLEY, The Climate of Dublin City, Part I, Rainfall at Trinity College; Dublin, January, 1956.

No. 13: THOMAS MURPHY and RÓISÍN RYAN, The Latitudes and Longitudes of the Six-Inch Sheet Maps of Ireland; Dublin, September, 1956.

No. 14: THOMAS MURPHY, The Gravity Base Stations for Ireland; Dublin, April, 1957.

No. 15: ARVIDS LEONS METNIEKS, The Size Spectrum of Large and Giant Sea-Salt Nuclei under Maritime Conditions; Dublin, July, 1958.

No. 16: A. L. METNIEKS and L. W. POLLAK, Instruction for use of Photo-Electric Condensation Nucleus Counters, their Care and Maintenance together with Calibration and Auxiliary Tables; Dublin, April, 1959. Reprinted 1969.

No. 17: ANTONIO GIÃO, The General Problem of Dynamic Meteorology: An Introduction to Numerical Weather Forecasting; Dublin, July, 1959.

No. 18: THOMAS MURPHY, Gravity anomaly Map of Ireland. Sheet 5—South West; Dublin, March, 1960.

No. 19: A. L. METNIEKS and L. W. POLLAK, Tables and Graphs for Use in Aerosol Physics—Part I: Mobility v. Radius and vice versa; Dublin, June, 1961.

No. 20: A. L. METNIEKS and L. W. POLLAK, Tables and Graphs for Use in Aerosol Physics—Part II: Number of uncharged particles in per cent of total number of particles v. Radius and vice versa; Dublin, December, 1961.

No. 21: A. L. METNIEKS and L. W. POLLAK, On the Particle Size Analysis of Polydisperse Aerosols using a Diffusion Battery and the Exhaustion Method; Dublin, April, 1962.

No. 22: THOMAS MURPHY, Gravity Anomaly Map of Ireland. Sheet 4—South East; Dublin, December, 1962.

No. 23: T. J. MORLEY, The Climate of Dublin City, Part II, Temperature at Trinity College; Dublin, November, 1964.

No. 24: T. J. MORLEY, Wind in Dublin City; January, 1969.

No. 25: R. P. RIDDIHOUGH, The Reading and Reduction of Ground Total Field Magnetic Data with particular reference to Ireland. February, 1969.

No. 26: D. G. G. YOUNG, The Gravity Anomaly Map of County Donegal; Dublin, June, 1969.

No. 27: R. P. RIDDIHOUGH, Magnetic Map of the Ardara Granite and Southern County Donegal; Dublin, June, 1969.

No. 28: R. P. RIDDIHOUGH, An Analysis of Daily Magnetic Variation in Ireland, December, 1970

Address:

Meteorological and Geophysical Department,

School of Cosmic Physics, 5 Merrion Square, Dublin, Ireland.