Received: 22 January 2020 | Revised: 25 April 2020 | Accepted: 8 July 2020

DOI: 10.1002/gdj3.103

DATA PAPER

Geoscience Data Journal | RMetS | WILEY

Ireland's pre-1940 daily rainfall records

Ciara Ryan[1,2] | **Conor Murphy**[1] | **Rhonda McGovern**[1] | **Mary Curley**[2] | **Séamus Walsh**[2] | **476 students**

[1]Irish Climate Analysis and Research Units, Department of Geography, Maynooth University, Maynooth, Co., Kildare, Ireland

[2]Climate and Observations Division, Met Éireann, Dublin 9, Ireland

Correspondence
Ciara Ryan, Irish Climate Analysis and Research Units, Department of Geography, Maynooth University, Maynooth, Co. Kildare, Ireland.
Email: ciara.ryan@mu.ie

Funding information
This article was partly funded by a grant from the Irish Research Council (IRC) as part of the IRC Employment Based PhD Programme (EBP/2017/441). CM was funded by the Irish Research Council COALESCE scheme (Grant COALESCE/2019/43). Additional funding was provided by the Maynooth University Research Incentivisation Scheme (RIS) and the Irish Climate Analysis and Research UnitS (ICARUS) for the purchase of the Metis digital scanner.

Abstract

This article presents daily rainfall data and metadata for Ireland transcribed from historical manuscript and printed copies of rainfall registers located in Met Éireann's archives. To facilitate the transcription of rainfall observations from paper records, the historical manuscripts were scanned and integrated into Met Éireann's digital archives. The transcription from digital image to data format was undertaken in collaboration with students at Maynooth University as part of a novel crowdsourcing initiative to integrate data rescue activities into the classroom. In total, 3,616 station years of rainfall data (~1.32 million daily values) were transcribed. The data, which was double keyed, have undergone basic quality assurance to check for transcription errors and the resultant raw data and associated metadata are presented here. Ongoing work involves the application of further quality assurance and homogenization techniques to develop a long-term, quality assured daily rainfall network for Ireland.

KEYWORDS

data rescue, historical data, Ireland, precipitation

Dataset

Identifier: http://hdl.handle.net/2262/91347

Creator: C. Ryan, C. Murphy, R. McGovern, M. Curley, S. Walsh and 476 students

Title: Ireland's pre-1940 daily rainfall records

Publisher: edeposit Ireland

Publication year: 2020

Resource type: Dataset

Version: 1.0

1 | INTRODUCTION

There is an increasing demand for climatological information to support scientific understanding of the impacts of climate change. Accurate and reliable long-term meteorological records are essential for understanding climate trends and variability, evaluating reanalysis products and climate models and climate risk management (e.g. Matthews *et al*., 2014; Wilby *et al*., 2016; Noone *et al*., 2017; Murphy *et al*., 2019). Consequently, much work is being carried out internationally to rescue historical climate data and develop long-term climate series (e.g. Cornes *et al*., 2012; Allan *et al*., 2016; Ashcroft *et al*., 2018; Hawkins *et al*., 2019; Coll *et al*., 2019).

There is a long history of meteorological observation in Ireland. The earliest known weather observations were recorded at Kilkenny for the Duke of Ormond by John Kevan in 1682. From 1684 to 1686, William Molyneux and George Ashe, under the auspices of the Dublin Philosophical Society, documented weather at Trinity College, Dublin. Records resumed here in 1708 to 1709 when Samuel Molyneux documented observations of temperature, rainfall and pressure. In 1787, Richard Kirwan established the first Irish meteorological station at Cavendish Row, Dublin. These records are the earliest surviving observations compiled with the aid of accurate instruments. Kirwan maintained the observations until 1808, by which time regular meteorological observations had commenced at the National Botanic Gardens (Dixon, 1987). Observations from Armagh Observatory date from 1796 to present, providing the longest continuous series from any single site on the island (Butler *et al*., 2007). In 1829, the Ordnance Survey Office located in Phoenix Park, Dublin began recording systematic meteorological measurements providing continuous readings up to the present day.

In 1859, George James Symons, working with a network of voluntary observers, set up a system for gathering and publishing rainfall records from across Britain and Ireland. The data from Symons' observational network were published in British Rainfall (formerly English Rainfall), which for the year 1860 reports that there were then 168 stations in the network. No observations were included from sites in Scotland or Ireland, and only three from Wales (Glasspoole, 1952). The earliest available observations taken at Irish sites are from 1864. In 1900, the network founded by Symons became known as the British Rainfall Organisation and was later (in 1919) formally transferred to the aegis of the British Meteorological Office. At this time, there were approximately 5,000 observers contributing to the rainfall network (Glasspoole, 1952).

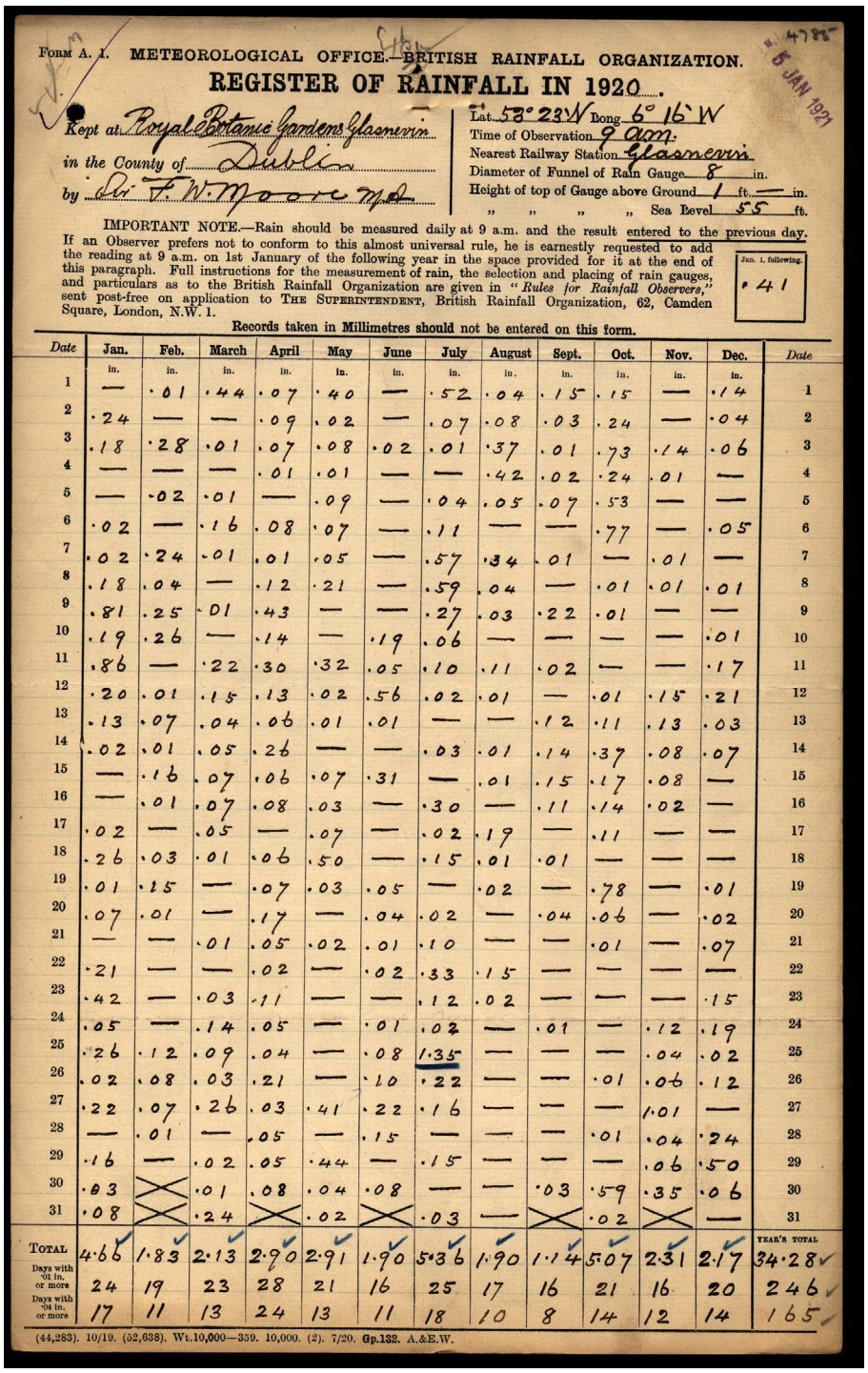
At the end of the 19th century, under the direction of the British Meteorological Department, led by Admiral Robert Fitzroy of the Royal Navy, an operational network of observing stations was established. In 1868, the Met Office equipped seven observatories, including two in Ireland, with autographic instruments, providing the first continuous record of a variety of meteorological parameters at a selection of locations (Eden, 2009). The records, along with the Phoenix Park records, which were maintained by the Royal Engineers, represent the early efforts of the British Meteorological Office to establish a network of meteorological stations across Britain and Ireland.

The Irish Meteorological Service, later Met Éireann, was established in December 1936 and subsequently took over responsibility for the network of Irish stations from the British Meteorological Office. The registers that pre-date the establishment of the Irish Meteorological Service were later transferred from the British Meteorological Office to the current service in Ireland. The substantial paper records are carefully preserved in Met Éireann's archives, but until now have largely remained in paper format for years prior to 1941.

Met Éireann maintains the National Climate Database. The database comprises observations received by Met Éireann from the current network of staffed, synoptic, climatological and rainfall stations. Observations are quality controlled and archived in Met Éireann's database. Daily observations of rainfall have been digitized back to 1941 and temperature to 1961 (Walsh, 2013). Work to digitize and transcribe long-term daily minimum and maximum air temperatures is currently underway at the National University of Ireland (NUI), Galway (Mateus *et al*., 2020). Other long-term series include work by Murphy *et al*. (2018) to compile a 305-year continuous monthly rainfall series for the island of Ireland (1711–2016) utilizing data from the UK and Ireland, including previously unpublished work from the 1970s by the British Meteorological Office. The comprehensive monthly series builds on the work of Noone *et al*. (2015) which developed a monthly rainfall series for 25 stations throughout Ireland for the period 1850–2015. However, until now there has not been a concerted effort to construct a long-term daily rainfall series for Ireland using historical records.

This paper describes recent work, undertaken as part of the PhD research of the lead author, to digitize and transcribe historical daily rainfall records from Met Éireann's extensive archive collection. The main objective of this work was to create a digital archive of the paper records of Ireland's longest meteorological stations, and from these imaged records and additional rainfall registers to extend the availability of long-term daily rainfall data prior to 1941. The data presented here are the raw data and associated metadata. It is envisaged that by presenting the data in its original state it can be easily integrated into current international data rescue initiatives, for example Copernicus Climate Change Service Global Land and Marine Observations Database, and that future research will have recourse to the raw data.

The remainder of the paper is organized as follows: Section 2 provides a description of the data. First, we discuss the digitization of historical records from Met Éireann's archives;



FORM A. I. METEOROLOGICAL OFFICE.—BRITISH RAINFALL ORGANIZATION.

REGISTER OF RAINFALL IN 1920.

Kept at Royal Botanic Gardens Glasnevin
in the County of Dublin
by Dr. F. W. Moore M.D.

Lat. 53° 23' N Long. 6° 16' W
Time of Observation 9 am.
Nearest Railway Station Glasnevin
Diameter of Funnel of Rain Gauge 8 in.
Height of top of Gauge above Ground 1 ft. — in.
" " " " Sea Level 55 ft.

IMPORTANT NOTE.—Rain should be measured daily at 9 a.m. and the result entered to the previous day. If an Observer prefers not to conform to this almost universal rule, he is earnestly requested to add the reading at 9 a.m. on 1st January of the following year in the space provided for it at the end of this paragraph. Full instructions for the measurement of rain, the selection and placing of rain gauges, and particulars as to the British Rainfall Organization are given in "*Rules for Rainfall Observers*," sent post-free on application to THE SUPERINTENDENT, British Rainfall Organization, 62, Camden Square, London, N.W. 1.

Jan. 1, following: .41

Records taken in Millimetres should not be entered on this form.

Date	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Date
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
1	—	.01	.44	.07	.40	—	.52	.04	.15	.15	—	.14	1
2	.24	—	—	.09	.02	—	.07	.08	.03	.24	—	.04	2
3	.18	.28	.01	.07	.08	.02	.01	.37	.01	.73	.14	.06	3
4	—	—	—	.01	.01	—	—	.42	.02	.24	.01	—	4
5	—	.02	.01	—	.09	—	.04	.05	.07	.53	—	—	5
6	.02	—	.16	.08	.07	—	.11	—	—	.77	—	.05	6
7	.02	.24	.01	.01	.05	—	.57	.34	.01	—	.01	—	7
8	.18	.04	—	.12	.21	—	.59	.04	—	.01	.01	.01	8
9	.81	.25	.01	.43	—	—	.27	.03	.22	.01	—	—	9
10	.19	.26	—	.14	—	.19	.06	—	—	—	—	.01	10
11	.86	—	.22	.30	.32	.05	.10	.11	.02	—	—	.17	11
12	.20	.01	.15	.13	.02	.56	.02	.01	—	.01	.15	.21	12
13	.13	.07	.04	.06	.01	.01	—	—	.12	.11	.13	.03	13
14	.02	.01	.05	.26	—	—	.03	.01	.14	.37	.08	.07	14
15	—	.16	.07	.06	.07	.31	—	.01	.15	.17	.08	—	15
16	—	.01	.07	.08	.03	—	.30	—	.11	.14	.02	—	16
17	.02	—	.05	—	.07	—	.02	.19	—	.11	—	—	17
18	.26	.03	.01	.06	.50	—	.15	.01	.01	—	—	—	18
19	.01	.15	—	.07	.03	.05	—	.02	—	.78	—	.01	19
20	.07	.01	—	.17	—	.04	.02	—	.04	.06	—	.02	20
21	—	—	.01	.05	.02	.01	.10	—	—	.01	—	.07	21
22	.21	—	—	.02	—	.02	.33	.15	—	—	—	—	22
23	.42	—	.03	.11	—	—	.12	.02	—	—	—	.15	23
24	.05	—	.14	.05	—	.01	.02	—	.01	—	.12	.19	24
25	.26	.12	.09	.04	—	.08	1.35	—	—	—	.04	.02	25
26	.02	.08	.03	.21	—	.10	.22	—	—	.01	.06	.12	26
27	.22	.07	.26	.03	.41	.22	.16	—	—	—	1.01	—	27
28	—	.01	—	.05	—	.15	—	—	—	.01	.04	.24	28
29	.16	—	.02	.05	.44	—	.15	—	—	—	.06	.50	29
30	.03	X	.01	.08	.04	.08	—	—	.03	.59	.35	.06	30
31	.08	X	.24	X	.02	X	.03	—	X	.02	X	—	31
TOTAL	4.66	1.83	2.13	2.90	2.91	1.90	5.36	1.90	1.14	5.07	2.31	2.17	YEAR'S TOTAL 34.28
Days with .01 in. or more	24	19	23	28	21	16	25	17	16	21	16	20	246
Days with .04 in. or more	17	11	13	24	13	11	18	10	8	14	12	14	165

(44,283). 10/19. (52,638). Wt. 10,000—359. 10,000. (2). 7/20. Gp.132. A.&E.W.

FIGURE 1 Sample rainfall register. The annual forms report daily rainfall observations and station metadata for various locations throughout Ireland

then, we outline the data transcription process and provide details of the stations transcribed, followed by a description of the metadata that was collected during the transcription process. In Section 3, we describe the process of checking for errors in the transcribed data. Section 4, provides details of dataset use, while Section 5 concludes with a proposed pathway to complete the imaging and transcription of stations and meteorological data that remain on paper.

2 | DESCRIPTION OF THE DATA

2.1 | Data sources

The daily rainfall data were largely taken from annual Rainfall Registers and Meteorological Registers held in Met Éireann's archives. These registers are described in detail below. In addition, digital images of station records for Kells

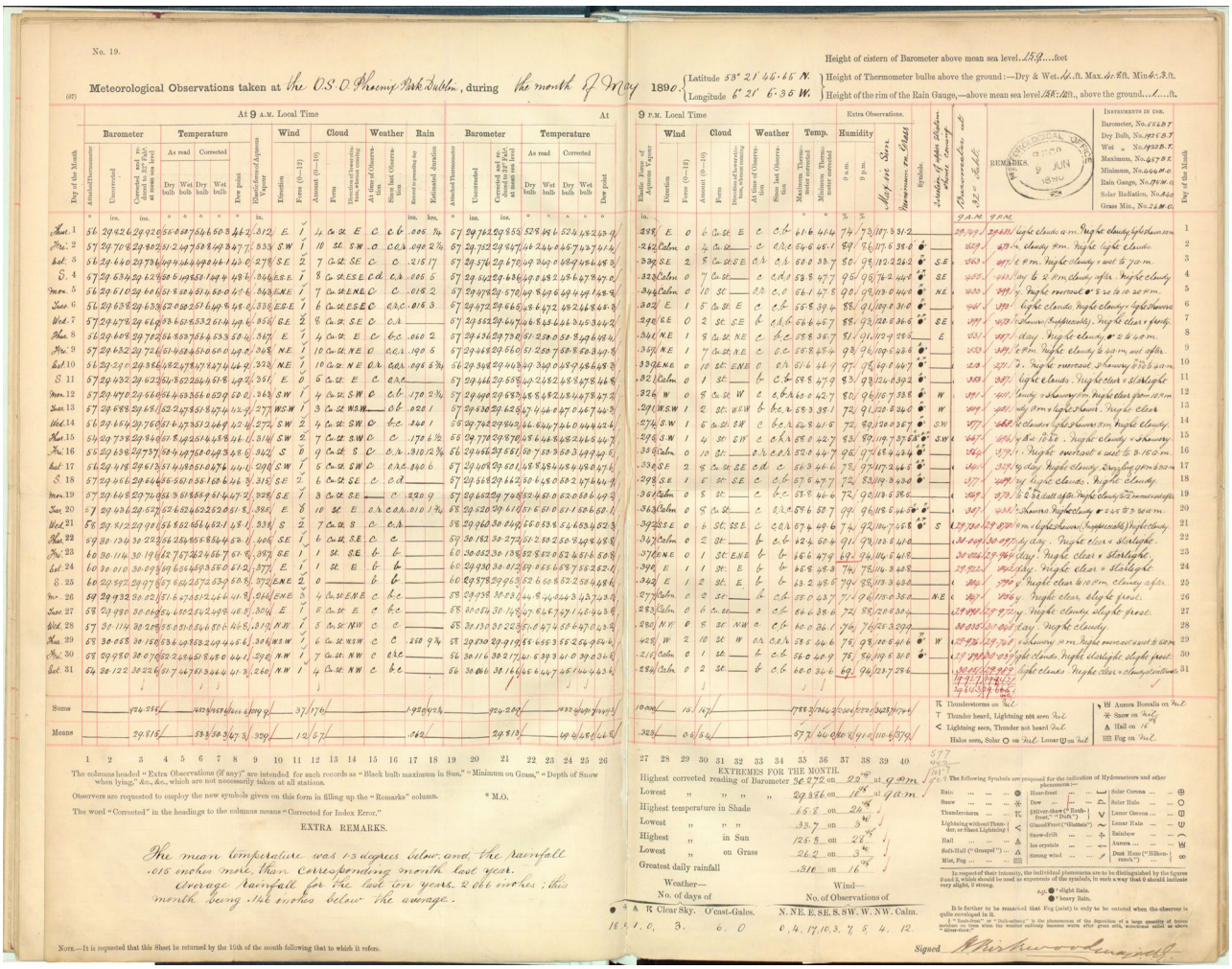


FIGURE 2 Sample meteorological register. The monthly forms report daily observations for multiple parameters including temperature, pressure, precipitation, sunshine, wind and other parameters

(Headfort) and the National University of Ireland (NUI), Galway were obtained from the National Library of Ireland and NUIG, respectively.

2.2 | Data imaging

2.2.1 | Rainfall registers

Previous work by Met Éireann focused on imaging the single-sheet annual rainfall registers collected from the early rainfall network, specifically the original handwritten rainfall observations that were taken by the volunteers who worked as part of Symons' rainfall network in Ireland (Treanor *et al*., 2011). In 2014, the Met Éireann Library received funding to collate, catalogue and preserve the registers in this collection. The records are known as the 'Rainfall Registers' and contain daily rainfall data and station metadata from various locations throughout Ireland. Readings were taken once a day and recorded on a standard form issued by Symons and later the British Rainfall Organisation (Figure 1). The collection includes readings from every county in the Republic of Ireland and intermittent observations taken in Antrim, Armagh, Derry, Down, Fermanagh and Tyrone in Northern Ireland. There are over 700 stations in total, which return data for varying time periods between 1864 and 1940.

2.2.2 | Meteorological registers

Non-digitized records include a collection of meteorological registers consisting of 224 bound volumes, 128 folders and 353 folios of station records covering the period 1855–1976. The collection includes observations from Ireland's longest operating stations, many of which are still operational. The registers have been arranged by date and region and catalogued by their location in the archives at Met Éireann (Treanor *et al*., 2011). They provide a daily record of weather parameters at various locations throughout Ireland covering the mid-19th century until the latter part of the 20th century.

Observers recorded data from a selection of instruments that measured temperature, pressure, precipitation, sunshine and other fields. Readings were taken at least once a day and recorded on a British Meteorological Office issued broadsheet form that was designed to contain a month's data (Figure 2). At the end of the month, the forms were posted back to the British Meteorological Office for centralized calculations and corrections.

A Metis EDS professional digital scanner (Figure 3) was purchased to progress the digitization of the historical meteorological registers. To date, meteorological observations from eight long-term stations have been scanned and integrated into the digital database (Table 1). Work is ongoing to digitize the remaining manuscripts. Individual pages were scanned as high quality tif files and categorized using the standard naming convention adopted by Met Éireann. The scanned images were then uploaded to Met Éireann's database where they will be made available for research purposes.

2.3 | Data transcription

Daily rainfall observed at 114 sites throughout Ireland was transcribed as part of this work (Figure 4). Stations were selected based on record length, continuity and spatial distribution. Additional stations that could potentially be used to infill gaps in long-term data series were also included. The transcription from paper and digital image format to digital numerical format was largely undertaken by final year Geography students at Maynooth University as part of a novel crowdsourcing initiative to integrate data rescue activities into the classroom. Ryan *et al*. (2018) presented an innovative approach to data rescue by developing a research-led project to engage students in data rescue tasks for credit. The study explored (a) the potential for integrating data rescue activities into the classroom, (b) the ability of students to produce reliable transcriptions and (c) the achieved learning outcomes for students. The work was facilitated by the provision of student aids including written guidelines, transcription templates with an automated quality-assurance check, a video tutorial, in-class workshops and an online discussion forum. An evaluation of learning outcomes and student's perceptions of the project demonstrated a positive educational experience. Following the success of the initial

FIGURE 3 Metis EDS Gamma professional digital scanner used to image historical meteorological registers held in Met Éireann

TABLE 1 Meteorological registers imaged and integrated into Met Éireann's digital archives

Station	Start year	End year
Birr	1873	1951
Blacksod	1884	1956
Fitzwilliam Square	1869	1935
Malin Head	1885	1955
Markree	1869	1968
Phoenix Park	1866	1959
Roches Point	1873	1956
Valentia	1873	1950

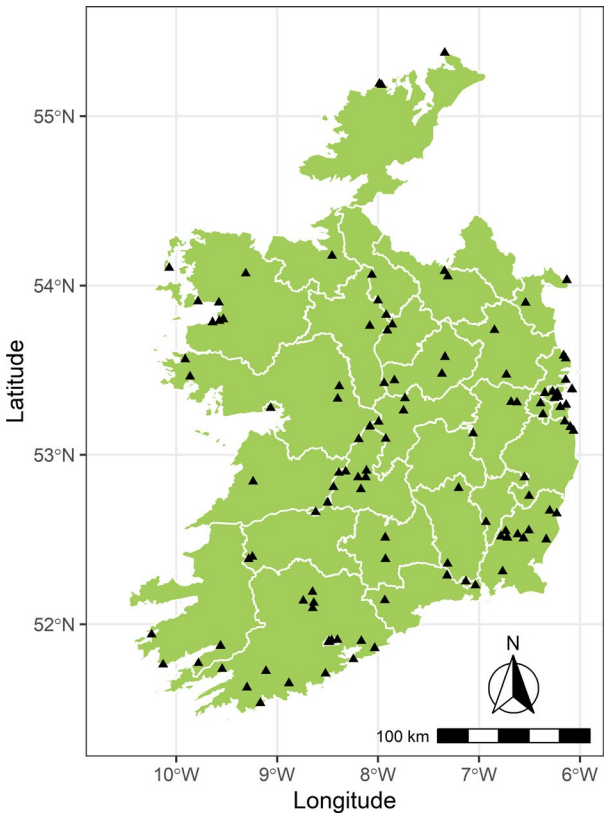


FIGURE 4 Location of stations for which daily rainfall data was transcribed as part of this work. Individual folders containing a data file and metadata file are available for each station

TABLE 2 Station details for data transcribed as part of this work

Station	Lat	Lon	County	Start year	Start month	Start day	End year	End month	End day	% NA	Units
Abbeyfeale (Presbytery)	522,300	91,700	Limerick	1936	1	1	1940	12	31	5.6	Inch
Abbeyfeale (Springmount)	522,350	91,440	Limerick	1925	1	1	1940	12	31	3.2	Inch
Ahascragh (Clonbrock)	532,410	82,300	Galway	1876	1	1	1940	12	31	14.1	Inch
Ardee (Lisrenny)	535,350	63,220	Louth	1886	1	1	1913	7	31	0.0	Inch
Ardgillan	533,509	60,942	Dublin	1894	1	1	1938	2	28	2.6	Inch
Athlone (Twyford)	532,620	75,020	Westmeath	1872	1	1	1940	12	31	14.6	Inch
Athlone O.P.W.	532,520	75,630	Westmeath	1902	1	1	1940	12	31	2.7	Inch
Ballinacurra	515,400	81,000	Cork	1904	4	1	1959	11	30	0.0	IN/MM
Ballycumber (Belair)	532,000	74,400	Offaly	1923	1	1	1940	12	31	8.5	Inch
Ballyhaise (Agr.Coll.)	540,305	71,835	Cavan	1923	1	1	1943	12	31	31.0	Inch
Ballynahinch castle	532,740	95,150	Galway	1913	1	1	1940	12	31	0.1	Inch
Banagher (Canal HSE.)	531,140	75,940	Offaly	1893	1	1	1940	12	31	46.1	Inch
Belgard castle	531,810	62,320	Dublin	1914	4	1	1940	12	31	8.2	Inch
Birr castle	530,540	75,530	Offaly	1875	1	1	1951	12	31	2.0	IN/MM
Blacksod point S.W.S.	540,610	100,410	Mayo	1884	10	1	1956	10	31	1.6	IN/MM
Borris	523,610	65,550	Carlow	1,890	1	1	1895	12	31	19.6	Inch
Bray (Fassaroe)	531,146	60,900	Wicklow	1871	1	1	1916	12	31	0.0	Inch
Caheragh	513,732	91,755	Cork	1910	9	1	1935	12	31	0.3	Inch
Cahir abbey	522,300	75,540	Tipperary	1924	1	1	1940	12	31	11.8	Inch
Cashel (Ballinamona)	523,038	75,543	Tipperary	1911	1	1	1940	12	31	0.0	Inch
Castlecomer HSE	524,810	71,210	Kilkenny	1908	1	1	1940	12	31	6.4	Inch
Castleconnell rectory	524,300	83,000	Limerick	1914	1	1	1939	12	31	0.9	Inch
Castleforbes	534,610	75,130	Longford	1911	1	1	1940	12	31	3.4	Inch
Castletownshend (Glenbarrahane)	513,200	91,000	Cork	1892	1	1	1940	12	31	5.1	Inch
Castletownshend (Seafield)	513,200	91,000	Cork	1914	1	1	1940	12	31	0.0	Inch
Clonakilty (Shannon vale)	513,900	85,300	Cork	1910	1	1	1931	12	31	14.6	Inch
Clongowes wood coll	531,840	64,100	Kildare	1906	1	1	1940	12	31	32.6	IN/MM
Cloondra O.P.W.	534,400	75,430	Longford	1902	1	1	1940	12	31	5.1	Inch
Cloverhill	540,500	72,030	Cavan	1896	1	1	1933	7	31	0.2	Inch
Cork (Park view)	515,412	82,738	Cork	1910	1	1	1937	12	31	0.4	Inch
Cork (The Palace)	515,340	82,850	Cork	1895	1	1	1911	12	31	0.0	Inch

(Continues)

TABLE 2 (Continued)

Station	Lat	Lon	County	Start year	Start month	Start day	End year	End month	End day	% NA	Units
Derrynane Abbey	514,540	100,750	Kerry	1871	1	1	1940	12	31	23.3	Inch
Dromod (Ruskey)	534,930	75,510	Leitrim	1902	1	1	1940	12	31	2.6	Inch
Drumshanbo (Lough allen sluices)	540,340	80,340	Leitrim	1902	1	1	1940	12	31	2.6	Inch
Drumsna (Albert lock)	535,440	80,000	Roscommon	1903	1	1	1940	12	31	2.6	Inch
Dublin (Clontarf)	532,150	61,330	Dublin	1912	1	1	1940	12	31	17.2	Inch
Dublin (Fitzwilliam square)	532,008	61,512	Dublin	1908	1	1	1937	9	30	0.0	Inch
Dublin (Phoenix park)	532,150	62,050	Dublin	1881	1	1	1959	12	31	0.0	IN/MM
Dublin (Ringsend)	532,030	61,250	Dublin	1912	1	1	1940	12	31	13.9	Inch
Dun laoghaire (Harbour yard)	531,740	60,810	Dublin	1905	1	1	1940	12	31	0.2	Inch
Dunfanaghy (St.Patrick's)	551,100	75,800	Donegal	1,880	1	1	1940	12	31	46.7	Inch
Dunmanway	514,320	90,637	Cork	1905	1	1	1937	6	30	3.1	Inch
Enfield (Summerhill)	532,820	64,340	Meath	1896	1	1	1940	12	31	2.2	Inch
Enniscoe	540,410	91,842	Mayo	1874	1	1	1923	12	31	4.1	Inch
Enniscorthy (Ballyhighland)	523,040	64,312	Wexford	1871	1	1	1919	10	31	0.0	Inch
Enniscorthy (Enniscorthy rectory)	523,024	63,335	Wexford	1926	1	1	1929	12	31	0.0	Inch
Enniscorthy (Monart rectory)	523,144	63,706	Wexford	1903	1	1	1907	12	31	2.2	Inch
Enniscorthy (Monksgrange)	523,104	64,658	Wexford	1925	1	1	1931	12	31	0.3	Inch
Enniscorthy (Summerville)	523,310	63,018	Wexford	1908	1	1	1923	12	31	0.0	Inch
Enniscorthy (Woodbrook)	523,255	64,410	Wexford	1902	1	1	1940	12	31	54.2	Inch
Foulkesmill (Longraigue)	521,838	64,559	Wexford	1874	1	1	1940	12	31	11.2	Inch
Glenasmole D.C.W.W.	531,420	62,200	Dublin	1900	1	1	1940	12	31	13.2	Inch
Glengarriff (Ilnacullin)	514,405	93,245	Cork	1914	1	1	1940	12	31	7.4	Inch
Gorey (Courtown house)	523,910	61,345	Wexford	1908	1	1	1941	12	31	0.0	Inch
Gorey (Ram's gate)	524,010	61,800	Wexford	1928	1	1	1940	12	31	2.4	Inch
Gorey (Wells)	523,000	62,000	Wexford	1893	1	1	1923	12	31	6.6	Inch
Greenore	540,150	60,750	Louth	1876	1	1	1940	12	31	6.3	Inch
Greystones (Burnaby lodge)	530,831	60,356	Wicklow	1928	1	1	1940	12	31	0.1	Inch
Greystones (Rathdown HSE.)	530,949	60,540	Wicklow	1918	1	1	1929	7	31	8.7	Inch
Hacketstown rectory	525,200	63,300	Carlow	1918	1	1	1940	12	31	0.0	Inch
Horn head	551,123	75,916	Donegal	1892	1	1	1917	12	31	15.4	Inch
Howth castle	532,310	60,440	Dublin	1913	1	1	1940	12	31	0.0	Inch

(Continues)

TABLE 2 (Continued)

Station	Lat	Lon	County	Start year	Start month	Start day	End year	End month	End day	% NA	Units
Inagh (MT. Callan)	525,030	91,418	Clare	1908	1	1	1940	12	31	6.1	Inch
Kells (Headfort)	534,410	65,050	Meath	1893	10	1	1952	6	30	0.4	Inch
Kenmare (Derreen)	514,610	94,650	Kerry	1912	1	1	1939	12	31	49.8	Inch
Kenmare (Sheen falls)	515,220	93,340	Kerry	1921	1	1	1940	12	31	10.0	Inch
Kilconnel (Rectory)	531,952	82,404	Galway	1875	1	1	1886	12	31	0.1	Inch
Killaloe (Ballina)	524,830	82,630	Clare	1866	1	1	1940	12	31	22.4	Inch
Kinsale (Scilly HSE.)	514,225	83,120	Cork	1922	1	1	1940	12	31	0.0	Inch
Kylemore castle	533,350	95,439	Galway	1889	1	1	1904	12	31	6.3	Inch
Limerick (Mulgrave St.)	523,940	83,710	Limerick	1924	1	1	1940	12	31	0.0	Inch
Lismore castle	520,824	75,600	Waterford	1909	1	1	1940	12	31	41.6	Inch
Lota lodge NO.1	515,422	82,407	Cork	1909	1	1	1937	3	31	3.5	Inch
Lota lodge NO.2	515,422	82,407	Cork	1911	1	1	1925	12	31	0.0	Inch
Malahide (Seamount)	532,630	60,830	Dublin	1908	1	1	1939	3	31	3.2	Inch
Malin head	552,220	72,020	Donegal	1885	1	1	1955	12	31	0.1	IN/MM
Mallaranny	535,420	94,700	Mayo	1919	1	1	1940	12	31	0.4	IN/MM
Mallow (Hazelwood)	521,125	83,900	Cork	1928	1	1	1943	12	31	13.1	Inch
Mallow (Longueville)	520,814	84,426	Cork	1896	1	1	1937	12	31	0.0	Inch
Mallow (Old dramore)	520,537	83,852	Cork	1,890	1	1	1895	12	31	4.7	Inch
Mallow (Summerhill)	520,732	83,817	Cork	1896	1	1	1921	6	30	0.3	Inch
Markree castle	541,030	82,720	Sligo	1874	11	1	1940	12	31	0.0	Inch
Meelick (Victoria lock)	531,000	80,450	Offaly	1902	1	1	1940	12	31	2.6	Inch
Monasterevin (Moore abbey gardens)	530,735	70,333	Kildare	1898	1	1	1918	12	31	0.8	Inch
Mullingar (Ballynegal)	533,440	72,010	Westmeath	1908	1	1	1940	12	31	12.4	Inch
Mullingar (Belvedere HSE)	532,840	72,200	Westmeath	1898	1	1	1940	12	31	9.3	Inch
Nenagh (Ballygibbon)	525,422	80,653	Tipperary	1901	1	1	1912	12	31	0.0	Inch
Nenagh (Castle lough)	525,340	82,320	Tipperary	1875	2	1	1940	12	31	19.3	Inch
Nenagh (Clashnevin)	525,200	80,720	Tipperary	1884	1	1	1899	9	13	0.0	Inch
Nenagh (Nenagh Lodge)	525,403	81,918	Tipperary	1879	1	1	1889	12	31	4.9	Inch
Nenagh (St.Mary's rectory)	525,200	81,156	Tipperary	1919	1	1	1930	10	31	0.0	Inch
Nenagh (Traverston)	524,746	81,013	Tipperary	1907	1	1	1937	12	31	0.1	Inch

(Continues)

TABLE 2 (Continued)

Station	Lat	Lon	County	Start year	Start month	Start day	End year	End month	End day	% NA	Units
Newport (Burrishoole HSE.)	535,352	93,442	Mayo	1899	1	1	1919	12	31	0.1	Inch
Nuig	531,635	90,350	Galway	1864	1	1	1952	6	30	12.6	Inch
Piltown (Kildalton Abbey)	522,120	71,840	Kilkenny	1877	1	1	1940	12	31	45.4	Inch
Portlaw (Mayfield)	521,710	71,900	Waterford	1881	1	1	1940	12	31	3.9	Inch
Portumna O.P.W.	530,530	81,130	Galway	1929	1	1	1940	12	31	16.7	Inch
Queens College Cork	515,334	82,925	Cork	1866	1	1	1907	12	31	40.7	Inch
Roches point	514,735	81,440	Cork	1873	7	1	1940	12	31	0.0	IN/MM
Royal Botanic Gardens (Glasnevin)	532,221	61,618	Dublin	1,880	1	1	1925	12	31	2.2	Inch
Shanagarry (Kinoith)	515,130	80,200	Cork	1910	1	1	1940	12	31	3.0	Inch
Shillelagh (Coollattin)	524,520	63,010	Wicklow	1908	1	1	1940	12	31	3.6	Inch
Skerries (Milverton hall)	533,410	60,830	Dublin	1908	1	1	1940	12	31	9.1	Inch
Stillorgan (Farmleigh)	531,655	61,138	Dublin	1915	1	1	1935	12	31	4.8	Inch
Straffan HSE	531,830	63,730	Kildare	1883	1	1	1940	12	31	0.1	Inch
Strokestown (Castlenode)	534,540	80,500	Roscommon	1908	1	1	1940	12	31	0.0	Inch
Turraun (Bord Na Mona)	531,540	74,450	Offaly	1913	1	1	1940	12	31	10.8	Inch
UCC (Univ.Coll.Cork)	515,359	82,910	Cork	1910	1	1	1940	12	31	3.3	Inch
Valentia (Observatory)	515,617	101,436	Kerry	1875	1	1	1950	12	31	0.0	IN/MM
Waterford (Brook lodge)	521,345	70,205	Waterford	1876	1	1	1931	12	31	20.6	Inch
Waterford (Tycor)	521,510	70,750	Waterford	1888	1	1	1939	12	31	15.5	Inch
Westport (Murrisk Abbey)	534,655	93,823	Mayo	1900	1	1	1904	12	31	0.0	Inch
Westport (St. Helens)	534,726	93,420	Mayo	1903	1	1	1920	12	31	11.5	Inch
Westport HSE	534,800	93,200	Mayo	1911	1	1	1940	12	31	3.1	Inch

Note: Individual folders containing data files and metadata files are provided for each station listed. Station coordinates are given in degree, minutes, seconds (DMS).

project, a further two iterations have been executed across three cohorts of final year Geography students at Maynooth University, producing in excess of 3,500 station years of historical daily rainfall data. A detailed description of the methodology and access to resources is provided by Ryan *et al*. (2018) (https://doi.org/10.1175/BAMS-D-17-0147.1).

The majority of the data was transcribed from the annual rainfall registers. Additional rainfall data were extracted from the long-term meteorological registers listed in Table 1. Rainfall register observations were, for the most part, recorded in inches of rainfall. Data extracted from the meteorological registers were recorded in millimetres from the start of record up to 1914/15 when the unit of measurement changed to inches. Table 2 provides a quick reference to the different units of measurement used at each station. Detailed changes of units of measurement are provided in the individual station metadata files. The original units of measurement have been preserved here. The number of stations varies significantly throughout the years, with only a small number of stations available in the early record (Figure 5). The earliest observations recovered were taken at the National University of Galway (NUIG) in 1864. From 1900, the number of stations increases significantly. In total, 3,616 station years (~1.32 million daily values) were transcribed. Details of all stations transcribed are provided in Table 2.

2.4 | Metadata

In addition to the rainfall observations, metadata for each station were extracted from the individual station records and recorded in separate text files (Figure 6). These files provide information on station name and location, observer, record length, missing data, diameter of gauge, changes in gauge height, gauge pattern, time of observation, unit of measurement and distance to nearest railway station. A section for 'Additional Information' provides details of observations made while transcribing the data, for instance, the presence of a multiday accumulation. A separate section for 'Notes' provides a transcription of any handwritten notes recorded on the original record by the observer. For example, an observer may note an exceptional rainfall event or a leak in the gauge. These notes are transcribed verbatim.

The British Meteorological Office coordinated the meteorological network by supplying instruments and instructions for observations. Nevertheless, before standard equipment and procedures for meteorological observations were introduced from the late-nineteenth century to mid-twentieth century, the design and placement of rain-gauges varied considerably. Observer bias, instrument changes, sampling periods, as well as external factors relating to site exposure (e.g. proximity to buildings) effect the accuracy and consistency of observations (Kunkel *et al*., 2005; Daly *et al*., 2007; Green *et al*., 2008). In general, such changes were recorded on the station record and subsequently transcribed to the metadata files. Detailed metadata presented here provide the comprehensive account of station changes and can be used as an aid in determining the reliability of station records. This information will be particularly valuable in helping to explain the presence of any abrupt shifts identified when further quality assurance and homogenization techniques are applied (Aguilar *et al*., 2003).

3 | ERROR CHECKING

At each stage of the transcription process, quality assurance measures were employed to preserve the integrity of the data being rescued. Keying guidelines were developed ensuring conformity to World Meteorological Organisation (WMO) standards (WMO, 2016). Monthly totals were examined against the derived sum of the daily entries to identify potentially incorrect data entries. The data were double keyed and the entries from different transcribers compared.

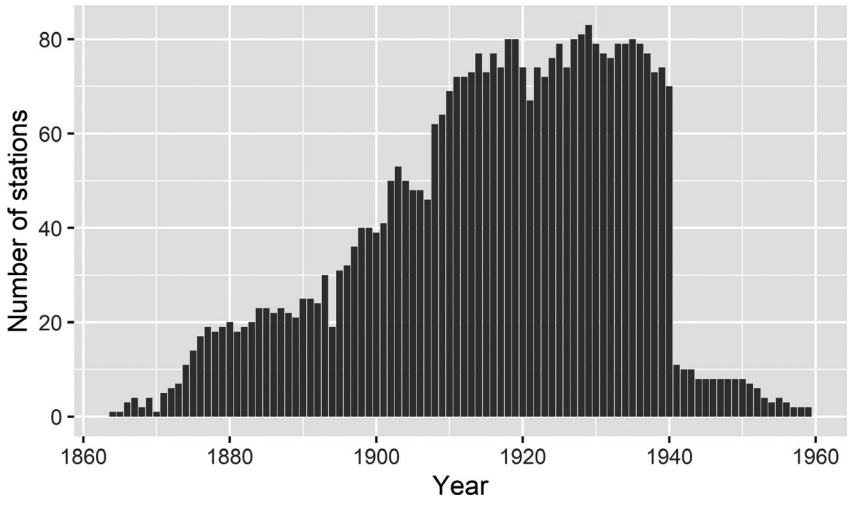
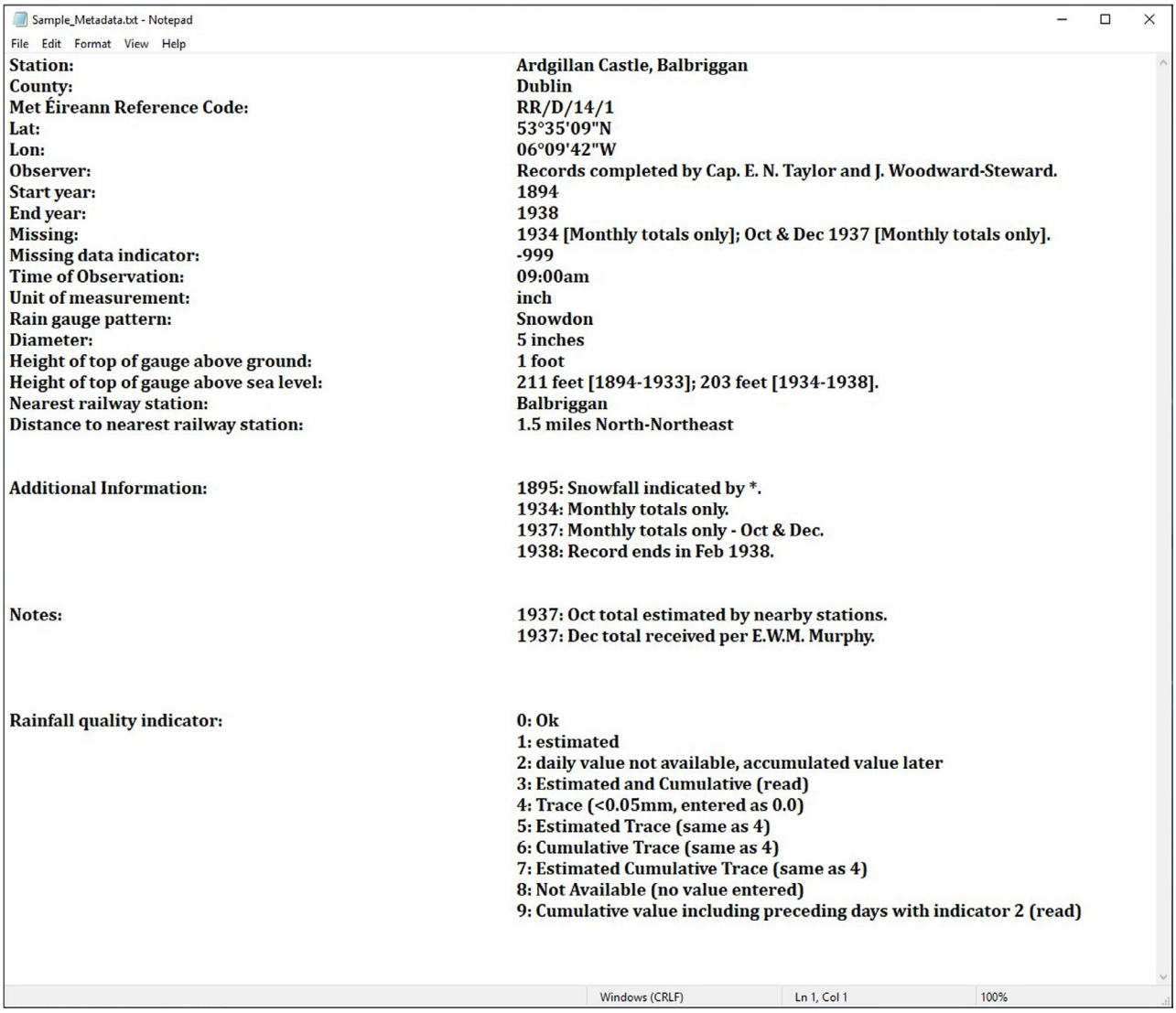


FIGURE 5 Number of stations each year for which daily rainfall data was transcribed. Post-1940 data are available through Met Éireann's website


Sample_Metadata.txt - Notepad

File Edit Format View Help

Station:	**Ardgillan Castle, Balbriggan**
County:	**Dublin**
Met Éireann Reference Code:	**RR/D/14/1**
Lat:	**53°35'09"N**
Lon:	**06°09'42"W**
Observer:	**Records completed by Cap. E. N. Taylor and J. Woodward-Steward.**
Start year:	**1894**
End year:	**1938**
Missing:	**1934 [Monthly totals only]; Oct & Dec 1937 [Monthly totals only].**
Missing data indicator:	**-999**
Time of Observation:	**09:00am**
Unit of measurement:	**inch**
Rain gauge pattern:	**Snowdon**
Diameter:	**5 inches**
Height of top of gauge above ground:	**1 foot**
Height of top of gauge above sea level:	**211 feet [1894-1933]; 203 feet [1934-1938].**
Nearest railway station:	**Balbriggan**
Distance to nearest railway station:	**1.5 miles North-Northeast**
Additional Information:	**1895: Snowfall indicated by *.** **1934: Monthly totals only.** **1937: Monthly totals only - Oct & Dec.** **1938: Record ends in Feb 1938.**
Notes:	**1937: Oct total estimated by nearby stations.** **1937: Dec total received per E.W.M. Murphy.**
Rainfall quality indicator:	**0: Ok** **1: estimated** **2: daily value not available, accumulated value later** **3: Estimated and Cumulative (read)** **4: Trace (<0.05mm, entered as 0.0)** **5: Estimated Trace (same as 4)** **6: Cumulative Trace (same as 4)** **7: Estimated Cumulative Trace (same as 4)** **8: Not Available (no value entered)** **9: Cumulative value including preceding days with indicator 2 (read)**

Windows (CRLF) Ln 1, Col 1 100%

FIGURE 6 Sample metadata file providing information regarding station name and location, observer, record length, missing data, diameter of gauge, changes in gauge height, gauge pattern, time of observation, unit of measurement and distance to nearest railway station. A section for 'Additional Information' provides details of observations made while transcribing the data, for instance, the presence of a multiday accumulation. A separate section for 'Notes' provides a transcription of any handwritten notes recorded on the original record by the observer

Where the entries agreed, the value was provisionally accepted as the raw data value. If the values disagreed, the original record was manually examined to ascertain the true observed value. An examination of errors across all transcriptions revealed a percentage error of <1%. Multiday accumulations were identified and flagged using the original records as a reference. A description of numerical flag values is included in the metadata files. These indicator flags will facilitate the re-distribution of multiday accumulations to the respective days on which no observation was recorded. This will be undertaken prior to the application of further, more sophisticated, quality-assurance techniques. As a final check for transcription errors, the upper and lower 1% of observations (non-zero precipitation) were examined for each individual station record. Values identified as outliers were cross-checked against the original record.

4 | DATASET USE

The data are freely available from the edepositIreland data centre (http://hdl.handle.net/2262/91347). The dataset comprises daily rainfall data for 114 stations at various locations throughout Ireland for varying time periods. Individual station folders contain two files: a data file in ASCII format and a corresponding metadata text file as described in section 2.4. Data files consist of five columns providing the observation date (year, month and day), followed by rain value and indicator value. The indicator value provides information about the nature of the observation and identifies multiday accumulations. A key to the respective indicator values is provided in the metadata files. Rainfall values run continuously from start date to end date of the data recovery period, with missing values denoted using a −999 indicator. Work is currently underway to

produce a network of long term, quality assured daily rainfall stations using the datasets whose generation is described in this paper. Preliminary quality assurance checks have been applied to assess the accuracy of the transcription process. A second, comprehensive set of quality assurance techniques will be applied to detect both systematic and non-systematic errors, this will be described in a subsequent paper. Post-1940 daily rainfall records are readily available from Met Éireann's climate database. The newly transcribed data will be added to the database and used to extend these station records back to the late 19th Century. Once joined, the full series will be homogenized and analysed to assess variability and changes in the characteristics of rainfall events over the long-term record.

5 | FUTURE WORK ON DATA RESCUE

The importance of historical climate data is being increasingly acknowledged for its role in supporting effective climate risk management through reanalysis and validation of climate models. As a consequence, climate data rescue has experienced a substantial rejuvenation in recent years, with a number of national and international projects underway, for example Copernicus Climate Change Data Rescue Service (C3S) and the International Data Rescue (I-DARE). The data presented here mark a significant and innovative effort to progress data rescue efforts for Ireland. Nevertheless, a considerable amount of data has not yet been digitized and exist only in hard copy format. Met Éireann, as part of their current operational business plans, has considered opportunities to advance data rescue initiatives within the organization and through collaboration with other agencies to create a comprehensive climate data bank and to facilitate the creation of high-quality data products.

Met Éireann are involved in a number of ongoing projects and initiatives aimed at enhancing climate data availability and accessibility. These include a collaboration with The Central Statistics Office (CSO) to transcribe all parameters and metadata from the eight meteorological registers imaged during the course of this work (see Table 2 for station details). As part of this, transcription of the entire Phoenix Park series has recently been completed. The data series which spans the period 1829 to present is the longest continuous series for the Republic of Ireland and the second longest in Ireland after Armagh Observatory. The extent of the data available for the Phoenix Park makes it one of the most comprehensive series available worldwide.

Engagement of non-experts or 'citizen scientists' on a voluntary basis has become increasingly significant to the rescue and refinement of observational data across multiple scientific disciplines (Bonney *et al.*, 2014). The success of ongoing citizen science applications – for example, OldWeather.org (www.oldweather.org/), the Weather Rescue Project (https://weatherrescue.wordpress.com/) and Data.Rescue@Home (http://www.data-rescue-at-home.org) underscores the potential of crowdsourcing as a data rescue strategy. Further, the data rescue project developed by Ryan *et al.,* (2018) as a collaboration between Met Éireann and Maynooth University will continue as an integral part of the Climate Change module delivered by Dr. Murphy. It is hoped that the project will be developed further through the use of an online platform designed to host Ireland's historical meteorological records. Such an application would facilitate the extension of the data rescue project to other teaching programmes and significantly advance contributions from citizen scientists.

Climate data rescue must be viewed as a continuous, long-term activity (Brönnimann *et al.*, 2018). The priority for Met Éireann over the coming years is to catalogue and image all historical records currently held in the archives for integration into the climate repository, an effort enhanced by the development of resources (including a digital scanner) as part of this work. Continued effort is also being made to recover records held in other libraries and institutes in Ireland and abroad. Met Éireann have recently recruited an archivist to document the vast historical record holdings including meteorological and climatological collections, weather diaries, monthly bulletins, annual reports, weather maps and site inspection reports. Providing access to these records, along with an inventory of what is available is important to promote collaborations and knowledge sharing between interested stakeholders.

ACKNOWLEDGEMENTS

The research presented in this paper was partly funded by the Irish Research Council (IRC) as part of the IRC Employment Based PhD Programme. CM was funded by the Irish Research Council COALESCE scheme (Grant COALESCE/2019/43). The authors are grateful to all the students who contributed to the development of this dataset as part of their GY313 Climate Change module with Dr. Conor Murphy at Maynooth University. We also thank the Maynooth University Research Incentivisation Scheme (RIS) allocation to Dr. Murphy and the Irish Climate Analysis and Research UnitS (ICARUS) for their support in purchasing the Metis digital scanner currently housed in Met Éireann.

OPEN PRACTICES

This article has earned an Open Data badge for making publicly available the digitally shareable data necessary to reproduce the reported results. The data is available at http://hdl.handle.net/2262/91347. Learn more about the Open Practices badges from the Center for OpenScience: https://osf.io/tvyxz/wiki.

ORCID

Ciara Ryan https://orcid.org/0000-0001-6281-5123
Conor Murphy https://orcid.org/0000-0003-4891-2650
Rhonda McGovern https://orcid.org/0000-0002-3931-1944
Mary Curley https://orcid.org/0000-0002-6209-8221

REFERENCES

Aguilar, E., Auer, I., Brunet, M., Peterson, T.C. and Wieringa, J. (2003) Guidelines on climate metadata and homogenization. *World Meteorological Organisation*, 1186, 55.

Allan, R., Endfield, G., Damodaran, V., Adamson, G., Hannaford, M., Carroll, F. *et al*. (2016) Toward integrated historical climate research: The example of Atmospheric Circulation Reconstructions over the Earth. *Wiley Interdisciplinary Reviews: Climate Change*, 7(2), 164–174.

Ashcroft, L., Coll, J.R., Gilabert, A., Domonkos, P., Brunet, M. and Aguilar, E. (2018) A rescued dataset of sub-daily meteorological observations for Europe and the southern Mediterranean region, 1877–2012. *Earth System Science Data*, 10(3), 1613–1635. https://doi.org/10.5194/essd-10-1613-2018

Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J. and Parrish, J.K. (2014) Next steps for citizen science. *Science*, 343, 1436–1437. https://doi.org/10.1126/science.1251554

Brönnimann, S., Brugnara, Y., Allan, R.J., Brunet, M., Compo, G.P. and Crouthamel, R.I. (2018) A roadmap to climate data rescue services. *Geoscience Data Journal*, 5, 28–39. https://doi.org/10.1002/gdj3.56

Butler, C.J., Garcia-Suarez, A. and Palle, E. (2007) Trends and cycles in long Irish meteorological series. *Biology and Environment: Proceedings of the Royal Irish Academy*, 107B, 157–165.

Coll, J.R., van der Schrier, G., Aguilar, E., Rasol, D., Coscarelli, R. and Bishop, A. (2019) *Daily rescued meteorological observations across Europe (1917-1990), PANGAEA*. https://doi.org/10.1594/PANGAEA.896957

Cornes, R.C., Jones, P.D., Briffa, K.R. and Osborn, T.J. (2012) A daily series of mean sea-level pressure for London, 1692–2007. *International Journal of Climatology*, 32, 641–656. https://doi.org/10.1002/joc.2301

Daly, C., Gibson, W.P., Taylor, G.H., Doggett, M.K. and Smith, J.I. (2007) Observer bias in daily precipitation measurements at U.S. Cooperative Network stations. *The Bulletin of the American Meteorological Society*, 88, 899–912.

Dixon, F.E. (1987) Early Irish weather records. In: Shields, L. (Ed.) *The Irish meteorological service: The first fifty years* (pp. 1936–1986). Dublin, Ireland: Met Éireann.

Eden, P. (2009) Traditional weather observing in the UK: An historical overview. *Weather*, 64, 239–245. https://doi.org/10.1002/wea.469

Glasspoole, J. (1952) The British rainfall organisation. *Weather*, 7(3), 85–87. https://doi.org/10.1002/j.1477-8696.1952.tb01449.x

Green, J.S., Klatt, M., Morrissey, M. and Postawko, S. (2008) The comprehensive pacific rainfall database. *Journal of Atmospheric and Oceanic Technology*, 25, 71–82.

Hawkins, E., Burt, S., Thomas, S., Lockwood, M., Brohan, P., Richardson, H. *et al*. (2019) Hourly weather observations from the Scottish Highlands (1883–1904) rescued by volunteer citizen scientists. *Geoscience Data Journal*, 6, 2, 160–173. https://doi.org/10.1002/gdj3.79

Kunkel, K.E., Easterling, D.R., Redmond, K., Hubbard, K., Andsager, K., Kruk, M. *et al*. (2005) Quality control of pre-1948 cooperative observer network data. *Journal of Atmospheric and Oceanic Technology*, 22, 1691–1705.

Mateus, C., Potito, A. and Curley, M. (2020) Reconstruction of a long-term historical daily maximum and minimum air temperature network dataset for Ireland (1831–1968). *Geoscience Data Journal*, 1–14. https://doi.org/10.1002/gdj3.92

Matthews, T., Murphy, C., Wilby, R.L. and Harrigan, S. (2014) Stormiest winter on record for Ireland and UK. *Nature Climate Change*, 4, 738–740. https://doi.org/10.1038/nclimate2336

Murphy, C., Broderick, C., Burt, T.P., Curley, M., Duffy, C., Hall, J. *et al*. (2018) A 305-year continuous monthly rainfall series for the island of Ireland (1711–2016). *Climate of the Past*, 14, 413–440. https://doi.org/10.5194/cp-14-413-2018

Murphy, C.Wilby, R.L., Matthews, T.K.R., Thorne, P., Broderick, C., Fealy, R. *et al*. (2019) Multi-century trends to wetter winters and drier summers in the England and Wales precipitation series explained by observational and sampling bias in early records. *International Journal of Climatology*, 40(1), 610–619. https://doi.org/10.1002/joc.6208

Noone, S., Murphy, C., Coll, J., Matthews, T., Mullan, D., Wilby, R.L. *et al*. (2015) Homogenization and analysis of an expanded long-term monthly rainfall network for the Island of Ireland (1850–2010). *International Journal of Climatology*, 36, 2837–2853. https://doi.org/10.1002/joc.4522

Noone, S., Broderick, C., Duffy, C., Matthews, T., Wilby, R.L. and Murphy, C. (2017) A 250-year drought catalogue for the island of Ireland (1765–2015). *International Journal of Climatology*, 37, 239–254. https://doi.org/10.1002/joc.4999

Ryan, C., Duffy, C., Broderick, C., Thorne, P.W., Curley, M., Walsh, S. *et al*. (2018) Integrating data rescue into the classroom. *Bulletin of the American Meteorological Society*, 99(9), 1757–1764. https://doi.org/10.1175/BAMS-D17-0147.1

Treanor, M., Keane, A. and Lonergan, T. (2011) *Meteorological Observations in Ireland 1855-1976: an archival Finding Aid*. Technical Note 6. Met Éireann.

Walsh, S. (2013) Setting the scene: the climate of Ireland 1900-2012. In Gleeson, E., McGrath, R. and Treanor, M. (Eds) *Ireland's climate: The road ahead*. Dublin, Ireland: Met Éireann, pp. 17–19.

Wilby, R.L., Noone, S., Murphy, C., Matthews, T., Harrigan, S. and Broderick, C. (2016) An evaluation of persistent meteorological drought using a homogeneous Island of Ireland precipitation network. *International Journal of Climatology*, 36, 2854–2865. https://doi.org/10.1002/joc.4523

World Meteorological Organization (2016) *Guidelines on Best Practices for Climate Data Rescue 2016*.

How to cite this article: Ryan C, Murphy C, McGovern R, Curley M, Walsh S; 476 students. Ireland's pre-1940 daily rainfall records. *Geosci Data J*. 2021;8:11–23. https://doi.org/10.1002/gdj3.103