Millions of digitized historical sea-level pressure observations rediscovered

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DATA ARTICLE

Millions of digitized historical sea-level pressure observations rediscovered

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Abstract

Millions of sub-daily sea-level pressure observations taken between 1919 and 1960 over the British and Irish Isles were transcribed from paper records in the early 2000s but were not published and subsequently forgotten. A chance discussion led to the rediscovery of the transcribed data and 5.47 million observations from 160 locations are now made available, although the data have not been fully quality-controlled. Much of the data are 3-hourly, allowing for detailed examinations of synoptic weather variations for this region and time period, and will be invaluable for constraining future reanalyses. We illustrate the value of the data using a stormy period during October and November 1928 and discuss the remaining quality-control issues.

KEYWORDS

data rescue, pressure, Ireland, UK

Dataset

Identifier: 10.5281/zenodo.6424344

Creator: Ed Hawkins

Title: Weather Rescue Data v1.0

Publisher: Zenodo

Resource type: Dataset

Publication year: 2022

Version: 1.0

1 | INTRODUCTION

In 1887, John Venn used daily observations of atmospheric pressure from a single weather station in the United Kingdom to demonstrate that the natural world could exhibit non-Gaussian behaviour. Specifically, he highlighted that low pressures had a longer tail than high pressures (Venn, 1887). The significant impacts on society that can result from both extreme low and high pressure events emphasizes the importance of better quantifying the variations of atmospheric pressure on timescales from hours to decades. Long records of atmospheric pressure will help monitor whether the properties of such events are changing as the world continues to warm (e.g. Allan et al. 2009; Woollings et al. 2018).

Measurements of surface or sea-level pressure also allow a picture to be constructed of the variations of the atmosphere from the surface upwards and, due to the relative simplicity of the measurement, this quantity has been observed for centuries. These pressure observations enable a detailed reconstruction of the variations in the weather as far back as 1836 (the 20th Century Reanalysis; Slivinski et al. 2021), in contrast to reanalyses of the modern era which use a much wider range of observations, but only extend back to about 1950 (e.g. ERA5; Hersbach et al., 2020). However, huge quantities of meteorological observations, including of atmospheric pressure, remain unavailable to science as they are still only recorded on paper in various archives or, if we are lucky, in scanned images of the original documents. Many recent projects have added to our databases of surface pressure observations (e.g. Freeman et al. 2016; Ashcroft et al. 2018), including through citizen science activities (e.g. Hawkins et al. 2019; Craig & Hawkins 2020), but gaps remain. It is essential to ensure that the data from any new transcription of observations to digital formats becomes widely available for use and scientific analysis.

This study briefly discusses a set of more than 5 million sea-level pressure observations which were manually transcribed from paper documents many years ago but were subsequently forgotten and remained unpublished until a fortuitous scientific discussion led to the rediscovery of the data. The necessary tasks to make the data available have now been completed.

2 | DATASET DESCRIPTION

2.1 | The Daily Weather Reports

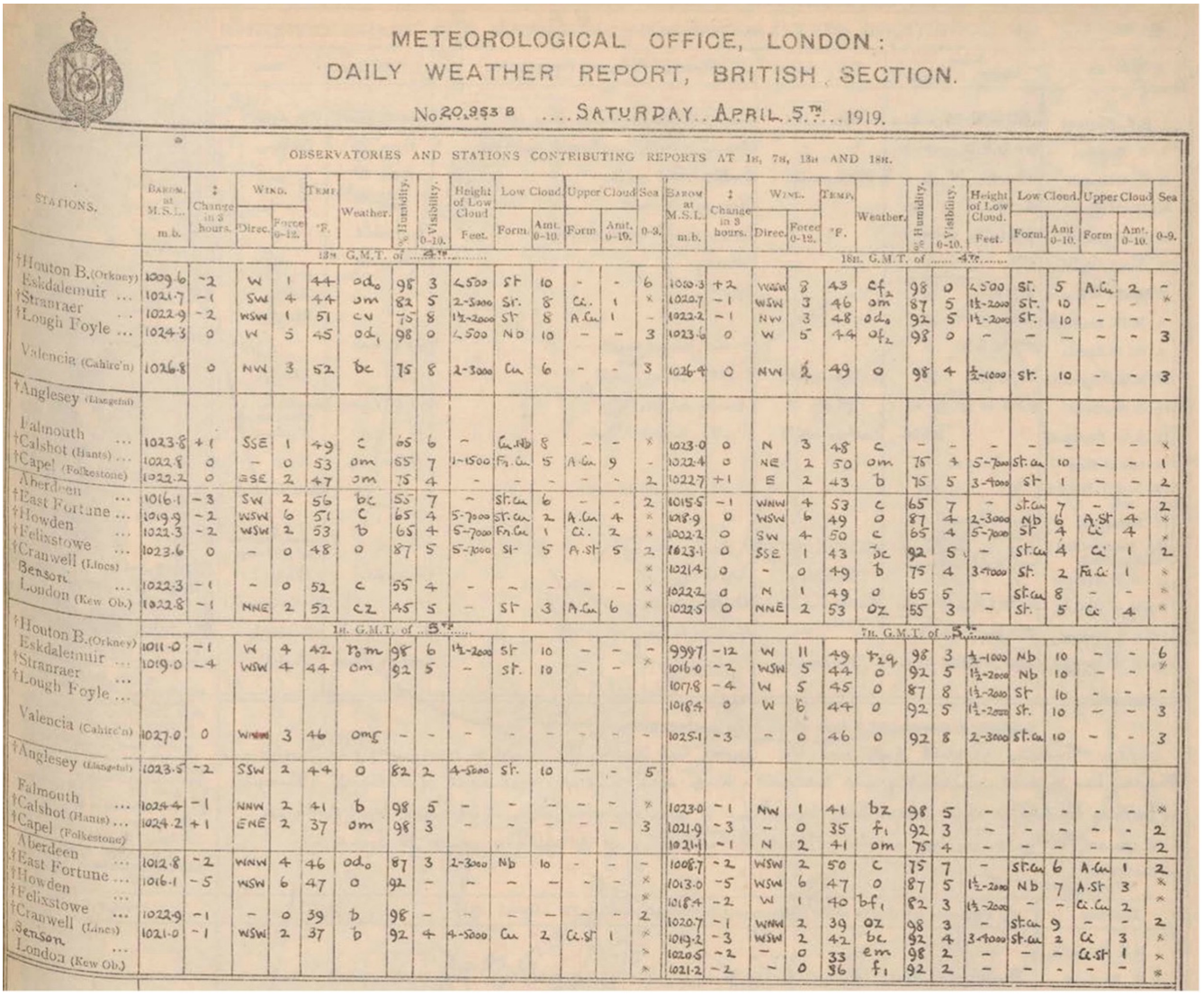
The UK Met Office produced a Daily Weather Report (DWR) every day from September 1860 until 1980. These DWRs contain detailed weather observations, mainly taken around the British and Irish Isles, but also including data from stations across Europe and beyond; these were transmitted to the Met Office each day, initially by telegraph. Scanned copies of the DWRs are now all online and freely available (Met Office Digital Library and Archive, 2022) and are a valuable source of historical weather data. For example, the temperature, rainfall and pressure observations from the 1900–1910 DWRs were recently digitized using citizen scientist volunteers (Craig & Hawkins, 2020). The format and information contained within the DWRs changed many times, from once-per-day observations taken at around 15 stations in the 1860s, to twice-per-day observations taken at around 50 stations in the early 1900s, and six- or eight-times-per-day observations taken at tens of stations in the 1920s onwards. Several stations are included for large fractions of this period (see Section 3.1).

Figure 1 shows an example DWR page from 5th April 1919, showing the stations from which eight sea-level pressure observations per day can be derived. Each station has a listing for 01Z, 07Z, 13Z and 18Z, with a pressure observation converted to sea-level (given to a precision of 0.1 mb) and a change in pressure over the previous 3 hr. This allows the pressures for 22Z, 04Z, 10Z and 15Z to be calculated, but with a small uncertainty as the change is only given with a precision of 1mb. Note that the rows are not always complete, highlighting missing data, especially for 01Z, and therefore also for 22Z the day before.

Figure 2 shows another DWR page showing observations from 28th December 1960, listing many stations with complex codes describing the various weather variables recorded. These variables include pressure observations every 6 hr and a pressure tendency over the previous 3 hr, allowing 3-hourly data to be similarly produced. After 1945, the times of observation included were a regular 3-hourly schedule (00Z, 03Z, 06Z, 09Z, 12Z, 15Z, 18Z and 21Z).

2.2 | Transcription and dataset rediscovery

In the early 2000s, the Met Office funded a commercial company to undertake the transcription from the paper records of the 3-hourly pressure observations taken at the British and Irish stations contained within the 1919–1960 DWRs. This transcription project did not include other types of weather observation or any data from the many 'foreign' stations also listed in the DWRs; those data, consisting of many millions of individual weather observations, remain largely unrescued. In addition, for 1919–1921, there is a separate section listing a group of around 25 UK and Ireland stations



METEOROLOGICAL OFFICE, LONDON:
DAILY WEATHER REPORT, BRITISH SECTION.
No. 20,953 B .... SATURDAY.. APRIL 5TH.... 1919.

OBSERVATORIES AND STATIONS CONTRIBUTING REPORTS AT 1H, 7H, 13H AND 18H.

STATIONS.	Barom. at M.S.L. m.b.	Change in 3 hours.	Wind. Direc.	Wind. Force 0-12.	Temp. °F.	Weather.	Humidity. %	Visibility. 0-10.	Height of Low Cloud Feet.	Low Cloud. Form.	Low Cloud. Amt. 0-10.	Upper Cloud. Form.	Upper Cloud. Amt. 0-10.	Sea 0-9.
1H G.M.T. of 5TH.														
†Houton B. (Orkney)	1009·6	-2	W	1	44	od$_0$	98	3	<500	St	10	-	-	6
Eskdalemuir ...	1021·7	-1	SW	4	44	om	82	5	2-5000	St.	8	Ci.	1	×
†Stranraer ...	1022·9	-2	WSW	1	51	cv	75	8	1½-2000	St	8	A.Cu	1	-
†Lough Foyle ...	1024·3	0	W	5	45	od$_1$	98	0	<500	Nb	10	-	-	3
Valencia (Cahire'n)	1026·8	0	NW	3	52	bc	75	8	2-3000	Cu	6	-	-	3
†Anglesey (Llangefni)														
Falmouth ...	1023·8	+1	SSE	1	49	c	65	6	-	Cu.Nb	8	-	-	×
†Calshot (Hants) ...	1022·8	0	-	0	53	om	65	7	1-1500	Fr.cu	5	A.Cu	9	-
†Capel (Folkestone)	1022·2	0	SSE	2	47	om	75	4	-	-	-	-	-	2
Aberdeen ...	1016·1	-3	SW	2	56	bc	55	7	-	St.cu	6	-	-	2
†East Fortune ...	1019·9	-2	WSW	6	51	c	65	4	5-7000	St.cu	2	A.Cu	4	×
†Howden ...	1022·3	-2	WSW	2	53	b	65	4	5-7000	Fr.Cu	1	Ci.	2	×
†Felixstowe ...	1023·6	0	-	0	48	0	87	5	5-7000	St	5	A.St	5	2
†Cranwell (Lincs)														×
Benson ...	1022·3	-1	-	0	52	c	55	4	-	-	-	-	-	×
London (Kew Ob.)	1022·8	-1	NNE	2	52	cz	45	5	-	St	3	A.Cu	6	×
7H G.M.T. of 5TH.														
†Houton B. (Orkney)	1011·0	-1	W	4	42	r$_0$m	98	6	1½-2000	St	10	-	-	-
Eskdalemuir ...	1019·0	-4	WSW	4	44	om	92	5	-	St.	10	-	-	×
†Stranraer ...														
†Lough Foyle ...														
Valencia (Cahire'n)	1027·0	0	WNW	3	46	om$_5$	-	-	-	-	-	-	-	-
†Anglesey (Llangefni)	1023·5	-2	SSW	2	44	0	82	2	4-5000	St.	10	—	-	5
Falmouth ...	1024·4	-1	NNW	2	41	b	98	5	-	-	-	-	-	×
†Calshot (Hants) ...	1024·2	+1	ENE	2	37	om	98	3	-	-	-	-	-	3
†Capel (Folkestone)														
Aberdeen ...	1012·8	-2	WNW	4	46	od$_0$	87	3	2-3000	Nb	10	-	-	-
†East Fortune ...	1016·1	-5	WSW	6	47	0	92	-	-	-	-	-	-	×
†Howden ...														×
†Felixstowe ...	1022·9	-1	-	0	39	b	98	-	-	-	-	-	-	2
†Cranwell (Lincs)	1021·0	-1	WSW	2	37	b	92	4	4-5000	Cu	2	Cu.St	1	×
Benson ...														×
London (Kew Ob.)														×

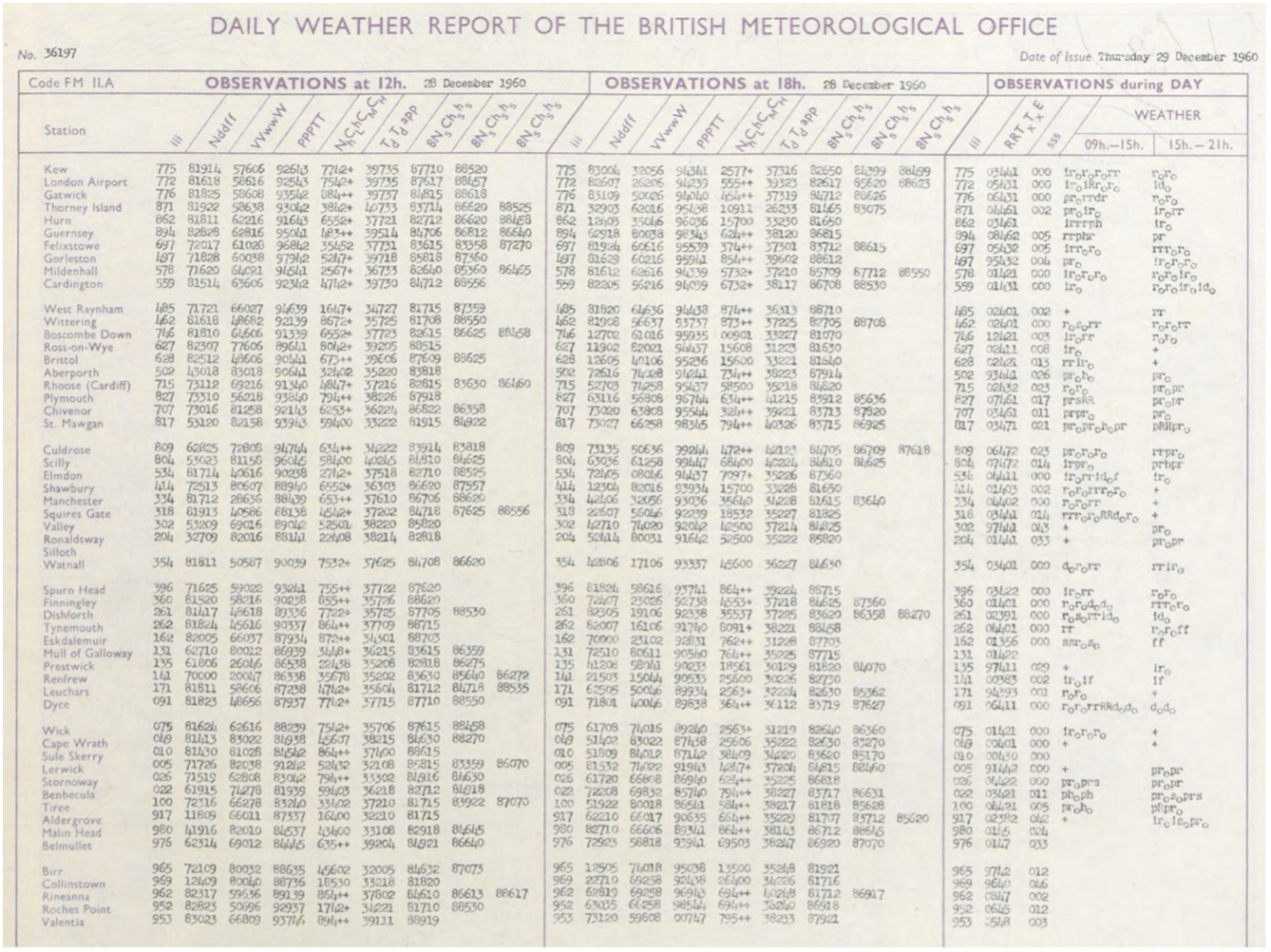
STATIONS.	Barom. at M.S.L. m.b.	Change in 3 hours.	Wind. Direc.	Wind. Force 0-12.	Temp. °F.	Weather.	Humidity. %	Visibility. 0-10.	Height of Low Cloud. Feet.	Low Cloud. Form.	Low Cloud. Amt. 0-10.	Upper Cloud. Form.	Upper Cloud. Amt. 0-10.	Sea 0-9.
13H G.M.T. of 5TH.														
†Houton B. (Orkney)	1030·3	+2	WSW	8	43	cf$_2$	98	0	<500	St.	5	A.Cu	2	-
Eskdalemuir ...	1020·7	-1	WSW	3	46	om	87	5	1½-2000	St.	10	-	-	×
†Stranraer ...	1022·2	-1	NW	3	48	od$_0$	92	5	1½-2000	St.	10	-	-	-
†Lough Foyle ...	1023·6	0	W	5	44	of$_2$	98	0	-	-	-	-	-	3
Valencia (Cahire'n)	1026·4	0	NW	2	49	0	98	4	½-1000	St.	10	-	-	3
†Anglesey (Llangefni)														
Falmouth ...	1023·0	0	N	3	48	c	-	-	-	-	-	-	-	×
†Calshot (Hants) ...	1022·4	0	NE	2	50	om	75	4	5-7000	St.cu	10	-	-	1
†Capel (Folkestone)	1022·7	+1	E	2	43	b	75	5	3-4000	St	1	-	-	2
Aberdeen ...	1015·5	-1	WNW	4	53	c	65	7	-	St.cu	7	-	-	2
†East Fortune ...	1018·9	0	WSW	6	49	0	87	4	2-3000	Nb	6	A.St	4	×
†Howden ...	1022·2	0	SW	4	50	c	65	4	5-7000	St	4	Ci	4	×
†Felixstowe ...	1023·1	0	SSE	1	43	bc	92	5	-	St.cu	4	Ci	1	2
†Cranwell (Lincs)	1021·4	0	-	0	49	b	75	4	3-4000	St.	2	Fr.Cu	1	×
Benson ...	1022·2	0	N	1	49	0	65	5	-	St.cu	8	-	-	×
London (Kew Ob.)	1022·5	0	NNE	2	53	0z	55	3	-	St.	5	Cu	4	×
7H G.M.T. of 5TH.														
†Houton B. (Orkney)	9997	-12	W	11	49	r$_{29}$	98	3	½-1000	Nb	10	-	-	6
Eskdalemuir ...	1016·0	-2	WSW	5	44	0	92	5	1½-2000	Nb	10	-	-	×
†Stranraer ...	1017·8	-4	W	5	45	0	87	8	1½-2000	St	10	-	-	-
†Lough Foyle ...	1018·4	0	W	6	44	0	92	5	1½-2000	St.	10	-	-	3
Valencia (Cahire'n)	1025·1	-3	-	0	46	0	92	8	2-3000	St.cu	10	-	-	3
†Anglesey (Llangefni)														
Falmouth ...	1023·0	-1	NW	1	41	bz	98	5	-	-	-	-	-	×
†Calshot (Hants) ...	1021·9	-3	-	0	35	f$_1$	92	3	-	-	-	-	-	2
†Capel (Folkestone)	1021·1	-1	N	2	41	om	75	4	-	-	-	-	-	2
Aberdeen ...	1008·7	-2	WSW	2	50	c	75	7	-	St.cu	6	A.Cu	1	2
†East Fortune ...	1013·0	-5	WSW	6	47	0	87	5	1½-2000	Nb	7	A.St	3	×
†Howden ...	1018·4	-2	W	1	40	bf$_1$	82	3	1½-2000	-	-	Cu.Cu	2	×
†Felixstowe ...	1020·7	-1	WNW	2	39	0z	98	3	-	St.cu	9	-	-	2
†Cranwell (Lincs)	1019·2	-3	WSW	2	42	bc	92	4	3-4000	St.cu	2	Ci	3	×
Benson ...	1020·5	-2	-	0	33	em	98	2	-	-	-	Cu.St	1	×
London (Kew Ob.)	1021·2	-2	-	0	36	f$_1$	92	2	-	-	-	-	-	×

FIGURE 1 An example page from the DWRs for 5th April 1919 showing the locations with observations four times per day, but which also include a change in pressure over the previous 3 hr (columns 1 and 2 in each of the four sections). Note that the names of the locations are repeated for the top and bottom halves of the table

with observations four times per day, but these were not transcribed (around 70,000 observations). After transcription, the resulting dataset was partly processed, but not published or included in any national or international databases.

One of the main reasons the dataset production process was not completed in the early 2000s was that the 'additions and corrections' component of the DWRs, published once per month until the 1930s, were not transcribed. This is because the original paper copies of the DWRs had not been scanned at that time and could not be sent out for digitizing; the duplicate copies that were sent did not include the 'additions and corrections' section. All the DWRs are now scanned and online (Met Office Digital Library and Archive, 2022). This means that any observations that were initially missing (but subsequently arrived after the daily publication of the DWR) could not be included in the dataset without considerable additional transcription. In addition, any observation found to be transmitted or written on the DWR incorrectly could not be corrected in the dataset. It is a significant undertaking to complete these quality-control tasks and the resources were not available at the time. The dataset was then largely forgotten.

In 2019, author EH gave a seminar, describing the recovery of the observations contained in the 1900–1910 DWRs using citizen science (Craig & Hawkins, 2020). Author LVA was in the audience and recalled leading the project at the Met Office many years earlier to digitize pressure data contained in the DWRs. Subsequent discussions led to the fortunate rediscovery of the 1919–1960 DWR pressure data on an old laptop owned by author



DAILY WEATHER REPORT OF THE BRITISH METEOROLOGICAL OFFICE

No. 36197 Date of Issue Thursday 29 December 1960

Code FM 11.A — OBSERVATIONS at 12h. 28 December 1960 — OBSERVATIONS at 18h. 28 December 1960 — OBSERVATIONS during DAY

Station	iii	Ndd ff	VVwwW	PPPTT	$N_hC_LC_MC_H$	T_d app	$8N_sCh_sh_s$	$8N_sCh_sh_s$	$8N_sCh_sh_s$	iii	Ndd ff	VVwwW	PPPTT	$N_hC_LC_MC_H$	T_d app	$8N_sCh_sh_s$	$8N_sCh_sh_s$	$8N_sCh_sh_s$	iii	RRT_RT_ss	sss	WEATHER 09h.–15h.	WEATHER 15h.–21h.
Kew	775	81914	57606	92613	7742+	39735	87710	88520		775	83004	32056	94341	2577+	37316	82650	84399	86499	775	05461	000	$ir_or_or_or_r$	r_or_o
London Airport	772	81618	58616	92543	7542+	39735	87617	88457		772	82607	26206	94239	555++	39323	82617	85620	88623	772	05431	000	$ir_oiR_or_o$	id_o
Gatwick	776	81825	58608	93542	0844++	39737	81815	88618		776	83109	50026	94640	454++	37319	84712	86626		776	06431	000	ir_or_or	r_or_o
Thorney Island	871	81922	58638	93042	3812+	40733	83714	86620	88525	871	32903	62016	95438	10911	26233	81465	83075		871	01461	002	pr_oir_o	ir_or_r
Hurn	862	81811	62216	91643	6552+	37721	82712	86620	88483	862	12403	35046	96036	15700	33230	81650			862	03461		$irrrrh$	ir_o
Guernsey	894	82828	62816	95041	4834+	39514	84706	86812	86640	894	62918	80038	98345	6244+	38120	86815			894	08462	005	$rrphr$	pr
Felixstowe	697	72017	61028	96842	3545Z	37751	83615	83358	87270	697	81924	60616	95539	374++	37301	83712	88615		697	05432	005	irr_or_o	rrr_or_o
Gorleston	497	71828	60038	97362	5217+	39718	85818	87360		497	81629	60216	95942	854++	39602	88612			497	95432	004	pr_o	$ir_or_or_o$
Mildenhall	578	71620	64021	94641	2567+	36733	82640	85360	86465	578	81612	62616	94339	5732+	37210	85709	87712	88550	578	01421	000	$ir_or_or_o$	$r_or_oir_oid_o$
Cardington	559	81514	63606	92342	4712+	39730	84712	86556		559	82205	56216	94039	6732+	38127	86708	88530		559	01431	000	ir_o	$r_or_oir_oid_o$
West Raynham	485	71721	66027	94639	1647+	34727	81715	87359		485	81820	64636	94638	874++	36313	88710			485	02401	002	+	rr
Wittering	462	81618	48682	92139	8672+	35725	81708	88550		462	81908	56657	93737	873++	37225	88705	88708		462	02401	000	r_oe_or	r_or_or
Boscombe Down	716	81810	61606	91339	6552+	37723	82615	86625	88458	716	12702	61016	95935	00901	33227	81070			716	12421	003	ir_or	r_or_o
Ross-on-Wye	627	82307	77606	89641	8042+	39205	88515			627	11902	82021	94437	15608	31223	81630			627	04413	008	ir_o	+
Bristol	628	82512	48606	90343	673++	39606	87609	88625		628	12605	40106	95236	15600	33221	81640			628	02421	013	$rrir_o$	+
Aberporth	502	43018	83018	90641	3242Z	35220	83818			502	72616	74028	91641	734++	38223	87914			502	93441	026	pr_oe_o	pr_o
Rhoose (Cardiff)	715	73112	69216	91340	4847+	37216	82815	83630	86460	715	52703	71258	95437	58500	35218	84820			715	02432	023	r_or_o	pr_opr
Plymouth	827	73310	56218	93840	794++	38226	87918			827	63116	56808	96744	634++	41215	83912	85636		827	07461	017	$prRR$	pr_opr
Chivenor	707	73016	81258	92143	6253+	36221	86822	86358		707	73020	63808	95544	321++	39221	83713	87820		707	03461	011	$prpr_o$	pr_o
St. Mawgan	817	53120	82158	93943	5940Z	33222	81915	84922		817	73027	66258	98345	794++	40326	83715	86925		817	03471	021	$pr_opr_or_opr$	$pRRpr_o$
Culdrose	809	62825	72808	94744	6344+	34222	83914	83818		809	73135	50636	99244	4724+	42123	84705	86709	87618	809	06472	023	$pr_or_or_o$	$rrpr_o$
Scilly	804	53023	81158	96045	5840Z	40245	84810	84625		804	63036	61258	99447	6840Z	40224	84610	84625		804	07472	014	$irpr_o$	$prhpr$
Elmdon	534	81714	40616	90238	2742+	37518	82710	88525		534	72405	08046	94437	7097+	35226	87360			536	04411	000	ir_orrid_of	ir_o
Shawbury	414	72513	80607	88940	6552+	36303	86620	87557		414	12304	82016	93934	15700	33228	81650			414	01403	002	$r_or_orrr_or_o$	+
Manchester	334	81712	28636	88439	653++	37610	86706	88620		334	42406	32056	93036	3564Q	31228	81615	83640		334	04402	000	r_or_orr	+
Squires Gate	318	61913	40586	88138	4542+	37202	84718	87625	88556	318	22607	56046	92239	18532	35227	81825			318	03441	014	$rrr_or_oRRd_or_o$	+
Valley	302	53209	69216	89042	5250L	38220	85820			302	42710	74020	92042	42500	37214	84825			302	97441	043	+	pr_o
Ronaldsway	204	32709	82016	88141	2240R	38214	82818			204	52414	80031	91642	52500	35222	85820			204	01441	033	+	pr_opr
Silloth																							
Watnall	354	81811	50587	90039	7532+	37625	84708	86620		354	42806	17106	93337	45600	36227	84630			354	03401	000	d_or_or	$rrir_o$
Spurn Head	396	71625	59022	93041	755++	37722	87620			396	81824	58616	93741	864++	39224	88715			396	03422	000	ir_orr	r_or_o
Finningley	360	81520	58216	90238	655++	35726	88620			360	72407	23056	92738	4553+	37218	84636	87360		360	01401	000	$r_or_od_od_o$	rrr_or_o
Dishforth	261	81417	48618	89336	7722+	35725	87705	88530		261	82305	19106	92338	35537	37225	83620	86358	88270	261	02391	000	$r_oe_orrid_o$	id_o
Tynemouth	262	81824	45616	90337	864++	37709	88715			262	82007	16106	91740	8091+	38221	88658			262	04401	000	rr	r_or_off
Eskdalemuir	162	82005	66037	87934	872++	34501	88703			162	70900	23102	92831	762++	31228	87703			162	01356	000	snr_oe_o	ff
Mull of Galloway	131	62710	80012	86939	3648+	36215	83615	86359		131	72510	80611	90540	764++	35225	87715			131	01422			
Prestwick	135	61806	26046	86538	2248R	35208	82818	86275		135	41208	58043	90233	18561	30129	81820	84070		135	97411	029	+	ir_o
Renfrew	141	70000	20047	86338	3567R	35202	83630	85640	86272	141	21503	15044	90533	25600	30226	82730			141	00383	002	ir_oif	if
Leuchars	171	81811	58606	87238	4742+	35604	81712	84718	88535	171	62505	50046	89934	2563+	32224	82630	85362		171	94393	001	r_or_o	+
Dyce	091	81823	48656	87937	7742+	37715	87710	88550		091	71801	40046	89838	364++	36112	83719	87627		091	06411	000	$r_or_orrRRd_od_o$	d_od_o
Wick	075	81624	62616	88239	7542+	35706	87615	88458		075	61708	74016	89240	2563+	31219	82640	86360		075	01421	000	$ir_or_or_o$	+
Cape Wrath	069	81423	83022	81938	4567Z	38215	84630	88270		069	51402	83022	87438	25606	35222	82630	83270		069	00401	000	+	+
Sule Skerry	010	81430	81028	81542	864++	37600	88615			010	51809	84012	87142	38409	34220	83620	85170		010	00430	000		
Lerwick	005	71726	82038	91212	5242Z	32108	85815	83359	86070	005	61532	74022	91943	1427+	37204	84815	88460		005	91442	000	+	pr_opr
Stornoway	026	71519	62808	83042	794++	33302	81916	84630		026	61720	66808	86940	624++	35225	86818			026	04422	000	pr_oprs	pr_opr
Benbecula	022	61915	71278	81939	5940Z	36218	82712	84718		022	72208	69832	85740	794++	38227	83717	86631		022	03421	011	ph_oph	pr_oe_oprs
Tiree	100	72316	66278	83240	3340Z	37210	81715	83922	87070	100	51922	80018	96541	584++	38217	81818	85628		100	04421	005	pr_oh_o	$phpr_o$
Aldergrove	917	11809	66011	87537	1640Q	32210	81715			917	62210	66017	90635	654++	35229	81707	83712	85620	917	02382	042	+	$ir_oie_or_o$
Malin Head	980	41916	82010	84537	4340Q	33108	82918	84645		980	82710	66606	89343	864++	38143	86712	88645		980	0116	024		
Belmullet	976	62314	69012	84446	635++	39204	81921	86640		976	72923	56818	93941	69503	38247	86920	87070		976	0147	033		
Birr	965	72109	80032	88635	4560Z	32005	84632	87073		965	12505	74018	95038	13500	35248	81921			965	9742	012		
Collinstown	969	12409	80040	88736	1853Q	33218	81820			969	22710	69258	92438	26400	34226	81716			969	9640	016		
Rineanna	962	82317	59536	89139	8614+	37802	84610	86613	88617	962	62819	69258	96943	694++	42048	81712	86917		962	0847	002		
Roches Point	952	82823	50696	92937	1742+	34221	81710	88530		952	63035	66258	98544	694++	35240	86918			952	0645	012		
Valentia	953	83023	66809	93746	894++	39111	88919			953	73120	59808	00747	795++	38233	87921			953	0548	003		

FIGURE 2 An example page from the DWRs showing observations for 28th December 1960 for the locations with pressure observations (columns PPP) four times per day, and which also include a barometric tendency (columns app) for the change in pressure over the previous 3 hr. These observations are shortened using specific codes described in the DWRs

LVA. The data have now been reprocessed into Station Exchange Format (SEF) files so that they can finally be included in updates to the International Surface Pressure Databank (ISPD, Compo et al. 2019) and developing databases such as C3S and GHCN-h.

2.3 | Quality control

The issues around the quality-control of the data remain, that is, that the 'additions and corrections' are not applied. It is the view of the authors that this issue is less relevant now than when the dataset was initially transcribed, mainly due to the subsequent development of centennial reanalyses such as the 20th Century Reanalysis (20CRv3, Slivinski et al. 2021). Such reanalyses will be a major user of the data, especially as 20CRv3 only assimilates historical pressure observations to produce dynamical reconstructions of past weather variations. These scientific developments mean that pressure data are more valuable to climate science than previously, making it important to ensure data availability. In addition, the reanalysis assimilation process naturally down-weights or rejects observations that are likely to be erroneous.

The issues that will exist with small fractions of the dataset include:

1. Missing data which were never taken, or not transmitted to the Met Office
2. Late arriving data which are in the additions pages but not added here
3. Errors which are listed in the corrections pages but not corrected here
4. Measurement or writing errors which were not identified at the time
5. Errors made during the modern transcription from the hand-written sheets
6. Systematic biases

Some observations within (1) could be found in other sources such as the original logbooks of the station, if they can be located. In principle, issues (2) and (3) could be addressed with a significant time investment using the 'additions and corrections' pages; targeted efforts to address such issues for certain significant weather events may be worthwhile in future. Even if this process was undertaken, errors of types (4) and (5) will still exist, and these are harder to find and potentially more numerous. Examining individual timeseries for 'jumps' in pressure (inhomogeneities) may allow some of these errors to be identified through manual checking of the original DWRs; for example, this time-consuming process was performed by Alexander & Power (2009) for a station in Australia. Examples of probable type (4) errors are shown later, along with examples of type (2) missing observations. Systematic biases (type 6) could exist due to, for example, an incorrect station elevation being used for the correction to sea level, or an incorrect calibration.

The use of these data within a reanalysis framework could pick up many of the errors by flagging individual observations which are rejected by a reanalysis assimilation process, but that is only possible after all the observations have been added to databases such as ISPD. An example of this identification for a type (5) issue from a different dataset is discussed in Craig & Hawkins (2020). Systematic biases are also estimated and removed when pressure observations are assimilated in 20CRv3 to account for type (6) issues.

For these reasons, the authors believe it is far better to produce a pressure dataset that is (say) 97% correct, 2% missing and 1% erroneous than no dataset at all, even though we cannot be certain about the percentages that are missing or erroneous. We note that some users of the data may want to undertake their own quality-control procedures depending on the application.

3 | PRESSURE OBSERVATIONS: LOCATIONS, EXAMPLES AND COMPARISONS

3.1 | Observations and locations

Figure 3 summarizes the number of stations and observations included in this dataset. A total of 5.47 million observations are made available from 160 locations covering different time periods. The first data available are in April 1919 and the last data are in December 1960. From April 1921 onwards, more than 40 stations have 3-hourly pressure data available, although this is often actually six times per day with 22Z and 01Z missing. From December 1943 to December 1948, around 70–80 stations are available, before this number drops to around 60. Three locations (Eskdalemuir, Valentia and Aberdeen-Dyce) have largely complete data for the whole time period with several other stations largely complete from April 1921 onwards. Figure 4 shows the locations where sub-daily pressure data are available in this dataset during example years between 1919 and 1960, and Figure 5 labels the locations mentioned in the text. We note that we have not identified precise coordinates for every station due to lack of metadata available

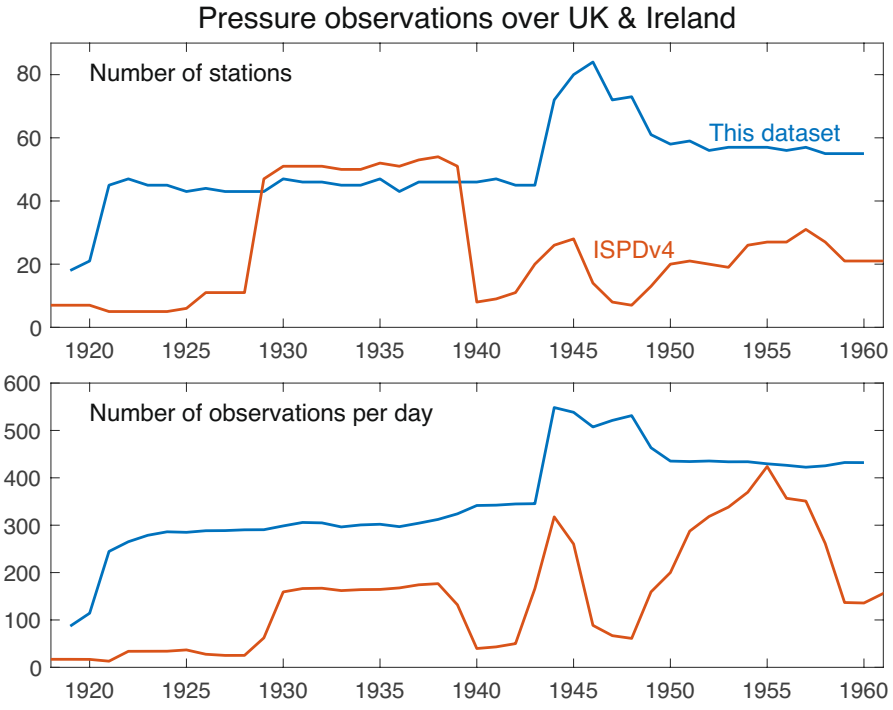


FIGURE 3 Number of stations for which observations have been recovered, and the average number of available observations per day in each year, for both ISPDv4 (existing; orange) and this dataset (blue). There is a considerable overlap between stations in the 1929–1939 period, although higher frequency observations are available in this new dataset

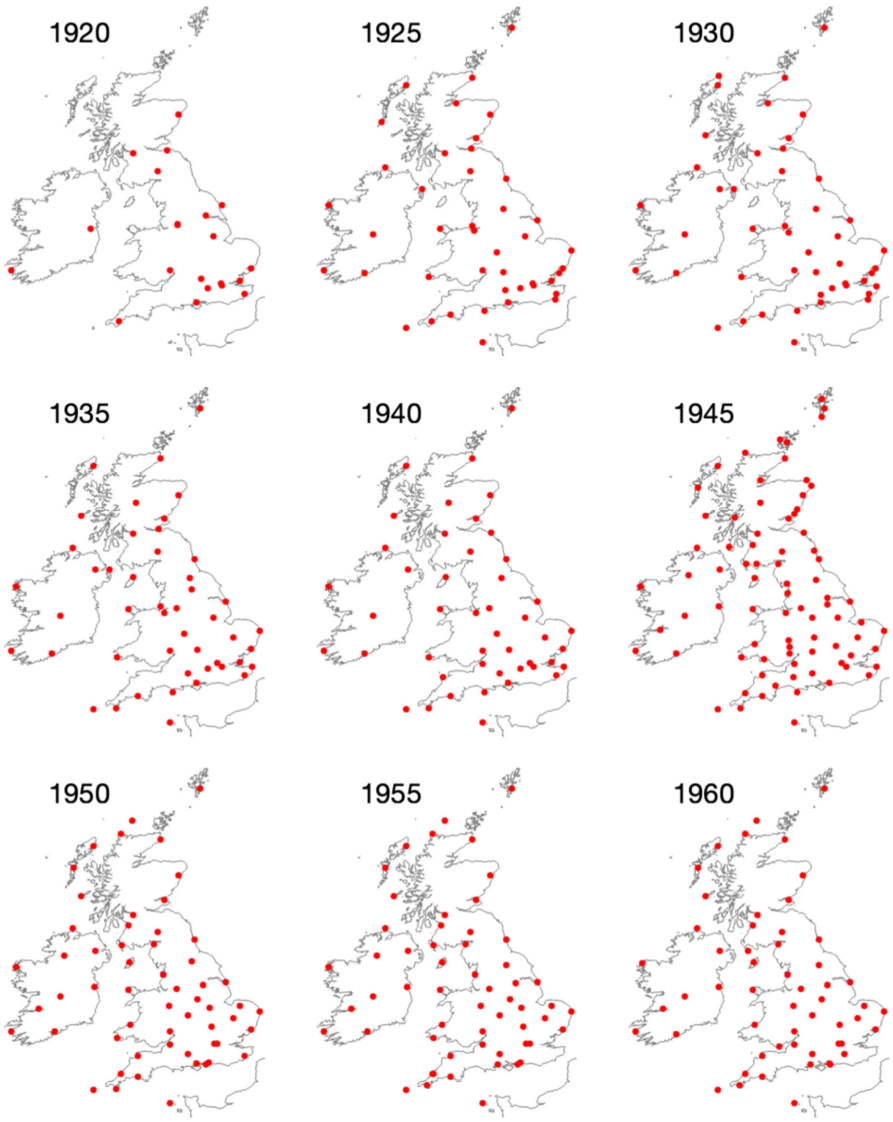


FIGURE 4 Locations of the rescued data from example years between 1919 and 1960. Each red point represents a location with at least 200 observations during the year

on the DWR sheets. But, given that pressure is relatively insensitive to the site details, we do not consider this to be a serious issue.

Figure 3 also shows the number of stations and observations available for the United Kingdom and Ireland in the same period from ISPDv4. This dataset will increase the total number of observations available considerably. For the 1929–1939 period, there is overlap between the two datasets, but this dataset has higher frequency data from the stations that are already in ISPDv4.

3.2 | Example of observations available in 1928

To highlight the ability of this dataset to provide information about synoptic variations, Figure 6 shows all the observations during October and November 1928. This was a stormy period, with at least three low pressure systems (<960 mb) moving over the British and Irish Isles. The top row of Figure 7 maps the individual observations at the peak of those storms with darker blue colours used to denote lower sea-level pressures.

Note there are missing data for some of the times shown in Figure 7, that is, there are stations which are reporting for some events but not others. This is frequently seen around historical severe storms which caused delays to the transmission of the data. Some of these missing observations will be in the monthly 'additions' pages of the DWRs, and some appear written in red ink on the online copies of the DWRs, but these were not transcribed because the duplicate copy of the DWRs being used the earlier stage of the digitization process did not include them (see Section 2.2). For example, the missing observation at Eskdalemuir in southern Scotland at 15Z on 23rd November is 946 mb, with other missing observations in Ireland from Malin Head at 968 mb and Blacksod Point at 982 mb. Recovering such individual missing observations may be worthwhile if analysing case studies of particular severe storms.

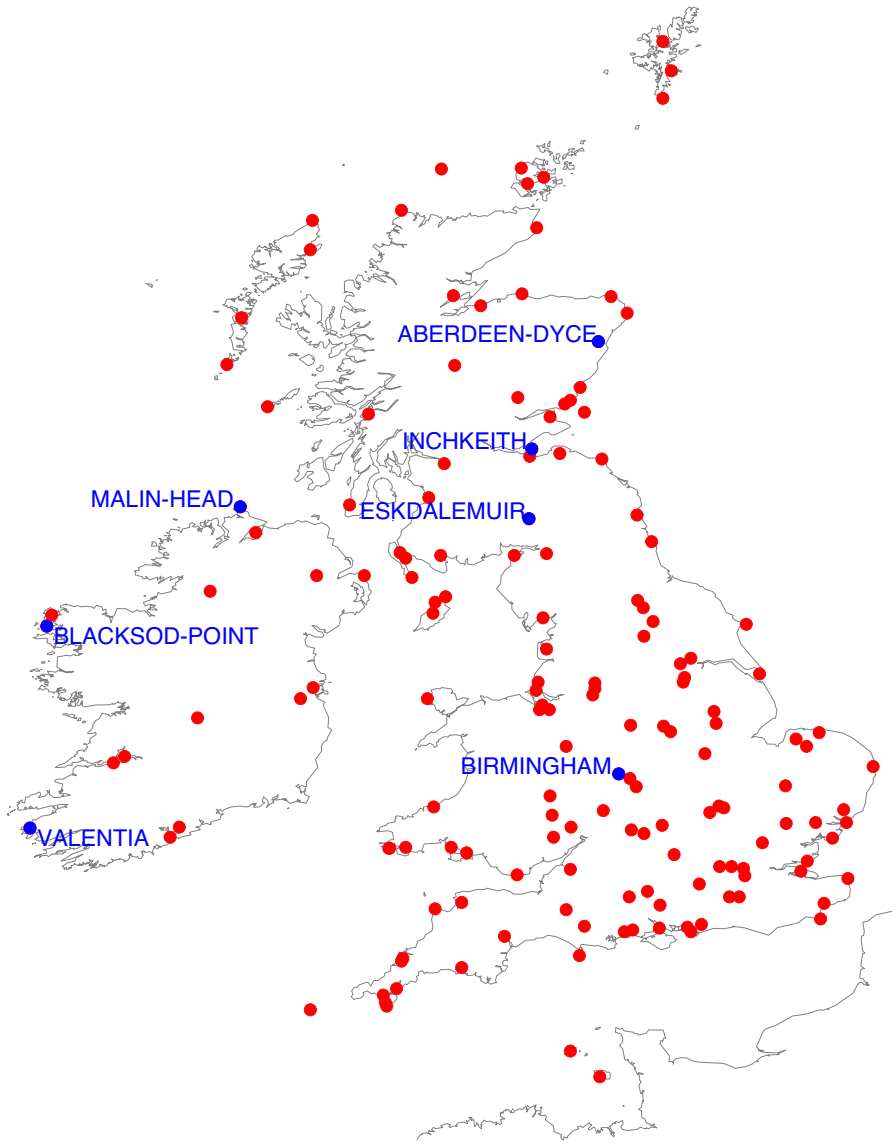


FIGURE 5 All locations appearing in the dataset (dots), with those mentioned in the text shown in blue and labelled

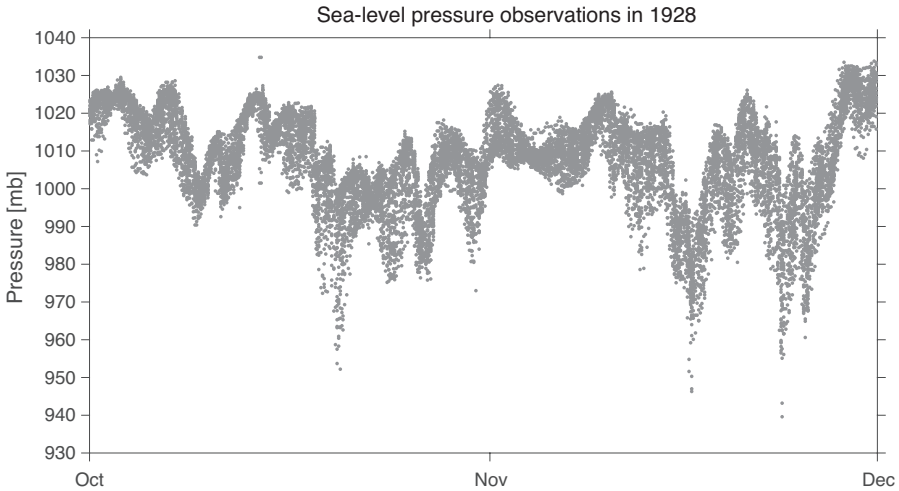


FIGURE 6 Sea-level pressure observations for October and November 1928, highlighting a series of low pressure events over the British and Irish Isles

Note one almost certainly erroneous observation in the middle panel of the top row of Figure 7. The 991 mb observation for Birmingham (south-east of the lowest pressure values) at 15Z on 16th November 1928 has no correction listed in the DWRs and is correctly transcribed from the original DWR sheets. The 18Z observation is 975 mb, and

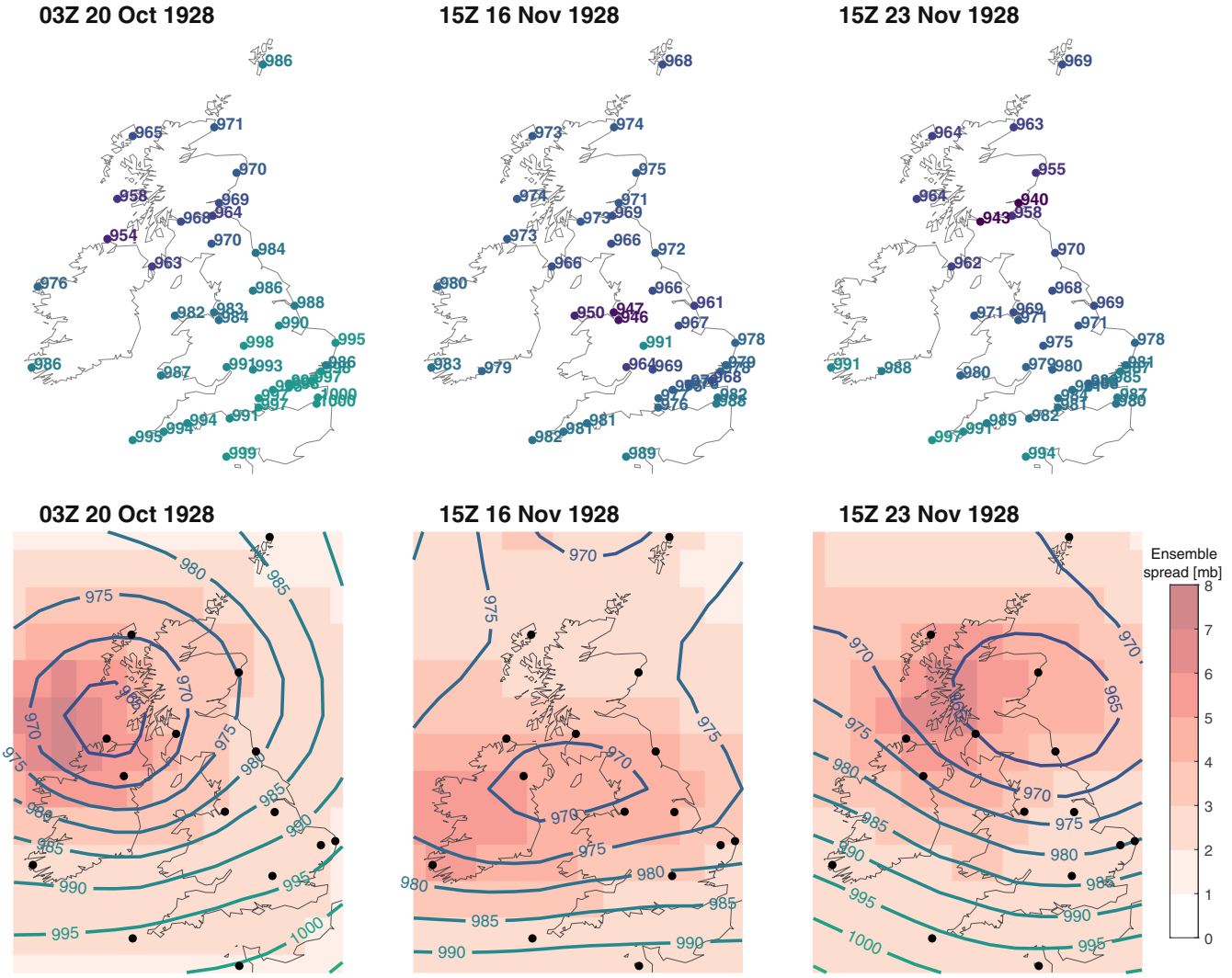


FIGURE 7 (top) Map of locations and sea-level pressure observations from this new dataset for three low pressure events during October and November 1928. (bottom) Maps showing ensemble spread (red shades) and the ensemble mean of sea level pressure (contours) from 20CRv3 for the same times. The black dots indicate stations where some data exist for the same day in ISPDv4 and so were used to produce 20CRv3

FIGURE 8 The 18Z pressure observation for Birmingham on 16th November 1928. Note that this is the resolution of the online scanned copies of the DWRs. Higher resolution images exist but are not online

this is indicated to be minus 16 mb from 3 hr earlier, resulting in a 991 mb observation for 15Z (Figure 8). It seems highly likely that the handwritten '−16' should be '+16', and that the 15Z observation was actually 959 mb, rather than 991 mb; this would fit the other available observations of the synoptic situation. There will be other examples such as this in the dataset, but they would likely be rejected in a reanalysis assimilation. This is an example of issue (4) listed above and suggests that the data at times derived from both a transcribed observation and a change in pressure will contain more errors. The 958 mb at Inchkeith at 15Z on 23rd November also looks too high but is similarly transcribed correctly with no correction reported.

The bottom row in Figure 7 shows isobars for the same times from 20CRv3 (Slivinski et al. 2021) which only assimilates previously digitized pressure observations contained within ISPDv4. Just 16 observations from 11 locations (black dots) were available during each day for this time period (around half at 06Z, and none at 03Z or 15Z). These are enough data to place the low pressure centres in roughly the correct positions, but the severity of the

storms is not well represented. The ensemble spread (red shades) highlight that the uncertainty can reach ~7 mb for some parts of the domain shown. With ~250 observations per day from ~40 locations now available for the same spatial region, subsequent reanalyses of these events will be much improved with a much reduced uncertainty.

The value of having spatially diverse and high-frequency data is clear, especially for storms which cross the country at night when traditional once- or twice-per-day climatological observations are not made.

3.3 | Observation comparisons

Comparing the locations of observations in the top and bottom rows of Figure 7 highlights that some of the newly digitized data come from places where observations already exist in ISPDv4 for at least some of the period. This allows a comparison of the two different digitizations of the same data to check accuracy. Figures 9 and 10 show comparisons for Eskdalemuir and Valentia, comparing ISPDv4 (grey) and this dataset (blue).

Overall, there is high agreement between the different digitizations. For Eskdalemuir, there are just 35 differences out of 10,790 overlapping observations covering 1929–1939, with an overall standard deviation between the two series of 0.2 mb. For Valentia, there are numerous small differences during 1919–1960, with an overall standard deviation of 0.7 mb between the time series. The standard deviation of differences is larger during 1922–1929 at 1.3 mb. It is unclear why, but we speculate that this could be due to variations in the conversion from station pressure to sea-level pressure in different sources. There could also be some errors in the ISPDv4 version of the data. There are 362 differences out of 94,392 overlapping observations which are larger than 5mb for Valentia. Note that some of the Valentia data are already hourly within ISPDv4 so this dataset will not add much new information for this site.

4 | SUMMARY

More than 5 million sub-daily sea level pressure observations are made available, from 160 locations around the British and Irish Isles between 1919 and 1960. If using these data, it is important to recognize that some quality-control procedures may need to be applied, depending on the specific use planned.

These data will be submitted to global datasets and therefore be available for use in projects such as future reanalyses of the historical period. Experiments are planned to include these data within dedicated simulations with both ERA5 (Hersbach et al. 2020) and 20CRv3 (Slivinski et al. 2021) reanalysis systems to demonstrate the value of such data for reconstructing the atmospheric circulation during particular extreme weather events. These additional data also have potential to augment time series of pressure for distinct locations in the United Kingdom, to understand storminess via gridded datasets or 'pressure

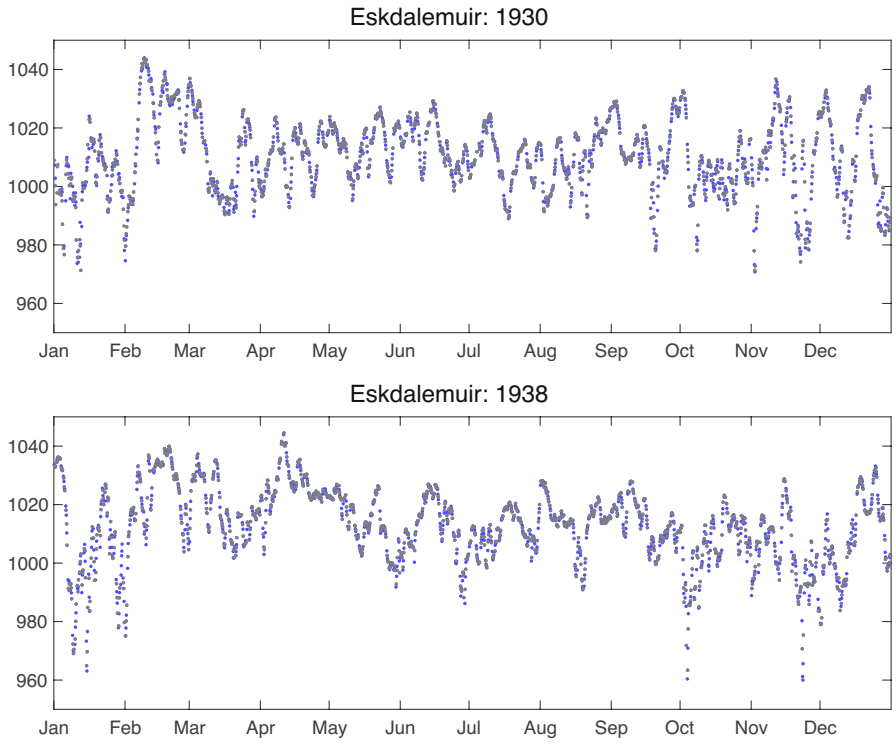


FIGURE 9 Comparing sea-level pressure data for Eskdalemuir during two example years from ISPDv4 (grey) and this dataset (blue). Note that this dataset contains 3-hourly data and ISPDv4 is 6-hourly and appears plotted on top of the data from this dataset

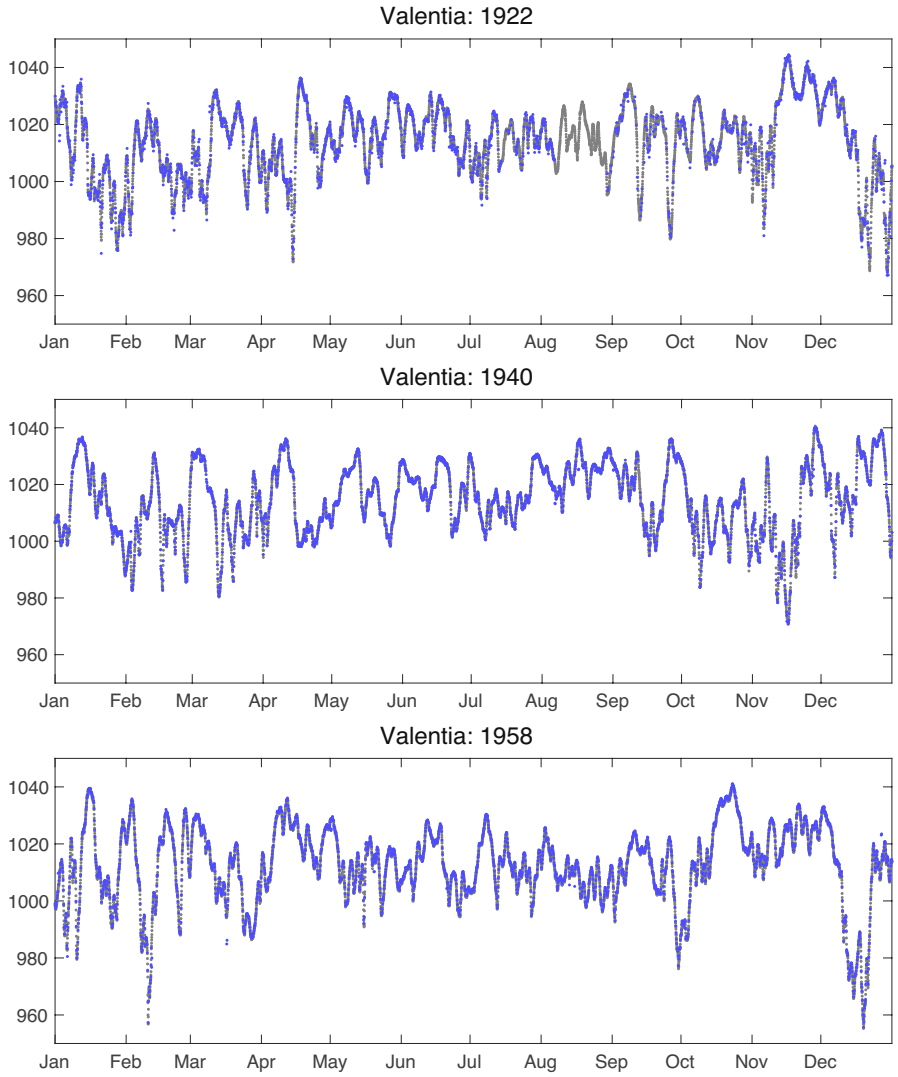


FIGURE 10 Comparing sea-level pressure data for Valentia Observatory during three example years from ISPDv4 (grey) and this dataset (blue). Note that ISPDv4 contains hourly observations for Valentia for some of this period, but this dataset contains 3-hourly data and appears plotted on top of the ISPDv4 data

triangle' approaches (e.g. Wang et al. 2009; Cornes & Jones 2011), and for classification of weather patterns (e.g. Lamb weather types; Jones et al. 2014).

AUTHOR CONTRIBUTIONS

Ed Hawkins: Data curation (equal); formal analysis (lead); project administration (equal); visualization (lead); writing – original draft (lead); writing – review and editing (supporting). **Lisa Alexander:** Conceptualization (lead); data curation (equal); funding acquisition (lead); project administration (equal); writing – review and editing (supporting). **Rob Allan:** Data curation (supporting); project administration (supporting); writing – review and editing (supporting).

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