Calculation

National Meteorological Library and Archive
Factsheet 20 — From Sorcery to supercomputers

The National Meteorological Library and Archive

Open to everyone

The library was first mentioned in the 1870 Annual Report of the Meteorological Office.

In 1914 the archive was established as the official custodian of meteorological related records. It holds historic weather records on behalf of the nation and is an approved place of deposit under the Public Records Act.

The National Meteorological Library and Archive is a National Archive (TNA) Accredited Service.

The National Meteorological Library and Archive are open by appointment.

All of the images used in this fact sheet along with many others covering all aspects of meteorology can be obtained from the National Meteorological Library and Archive. For further information including our opening times please visit our web page at https://www.metoffice.gov.uk/research/library-and-archive
or email: metlib@metoffice.gov.uk

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From Sorcery to Supercomputers

A brief history of key developments in meteorology as illustrated by Treasures from the National Meteorological Archive collections

About us

The National Meteorological Archive (NMA) cares for the national memory of the weather. This consists of all of the weather observations produced by the Met Office since its incarnation and a large additional collection of rare books, international weather observations, private weather diaries and other materials which complement the collection and enable it to act as a holistic national and even international resource. We also hold the archive of the Royal Meteorological Society which further adds to and complements the collection, particularly in relation to rare books and 19th century meteorology.

The NMA works in tandem with the National Meteorological Library to form one comprehensive service. Where the archive cares for original records and materials which need to be preserved in perpetuity the library provides access to a vast collection of meteorological and climatological publications, papers and resources ranging from children's books to academic papers. The National Meteorological Library forms a national special collection focusing on meteorology and climatology. Both collections are open to all but prior booking is required for the archive.

Contents

Early meteorology

Aristotle

Any guide to the history of meteorology must start with mention of the great Greek philosopher Aristotle (384 BC–322 BC). While may of his ideas in relation to meteorology were somewhat wide of the mark he can be credited with coining the term 'meteorology' which derives from the Greek words meteoron 'thing high up' and logia 'treatment' and therefore can be translated literally as 'treatment of things high up'.

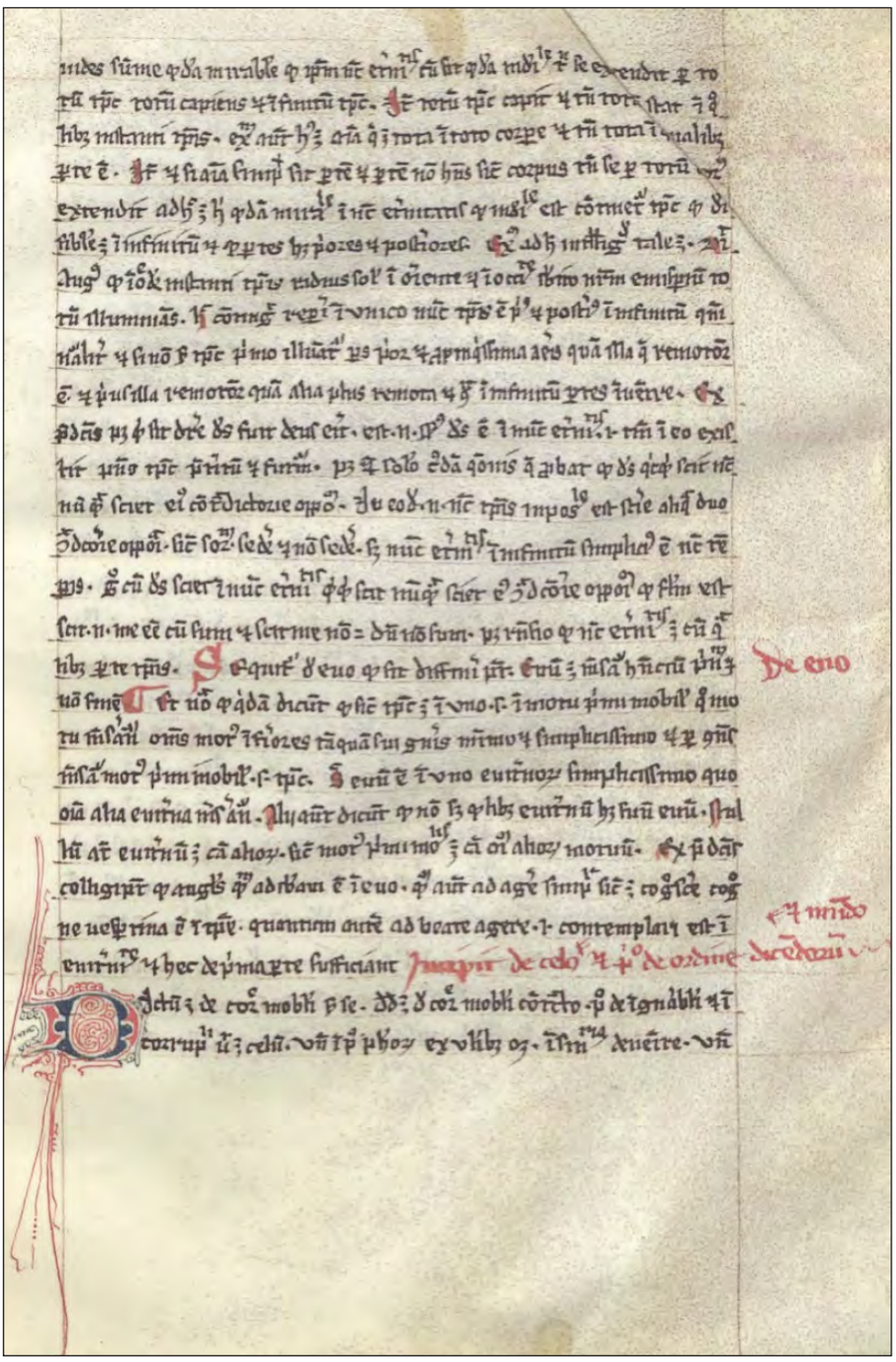
In his book Meteorologica he was the first person to theorise the existence of a landmass in the southern high-latitude region and call it 'Antarctica'. He was also the first person to accurately define the hydrological cycle (better known to many of us as the water cycle). An impressive achievement in the 4th century BC.

We have several copies of Aristotle's works in the NMA including one in both Greek and Latin. The picture below is taken from our earliest copy, which was published in 1610. This also gives it interest in its own right as a relatively early example of a printed book.

Aristotle, Meteorologica 1610

Albertus Magnus

From Aristotle we fast-forward to the late 13th century and an illuminated manuscript of the text De Negotii Naturali, which translates as ‘On Natural Business’. It is by the Austrian Bishop and thinker Albertus Magnus. Magnus died in 1280 and our volume of his work is an early copy circa 1290.



Albertus Magnus, De Negotii Naturali circa 1290

Even without knowing the content it is a special document. It is not printed but is actually an illuminated manuscript which would have been hand written by a monk in one of the religious houses of Europe. The text is in Medieval Latin with multiple contractions and is extremely difficult to read but it covers a range of subjects now commonly referred to as the natural sciences.

In an era when it was unwise to question the supremacy of God, or of the Catholic Church, Magnus seems to have taken a very analytical approach, questioning the work of Aristotle and of other great thinkers.

From a meteorological point of view one of the key things in his book is a study of optics; in this case reflection and refraction. By experimenting with light Magnus realised that the only way a rainbow could be formed was if raindrops were spherical. Considering the nature of white light itself was not understood until the work of Isaac Newton almost 400 years later this was an impressive achievement.

Saint Albertus Magnus, as he later became, is now the patron saint of natural scientists. Given the ideas explored in his 'De Rerum' this seems a most appropriate accolade.

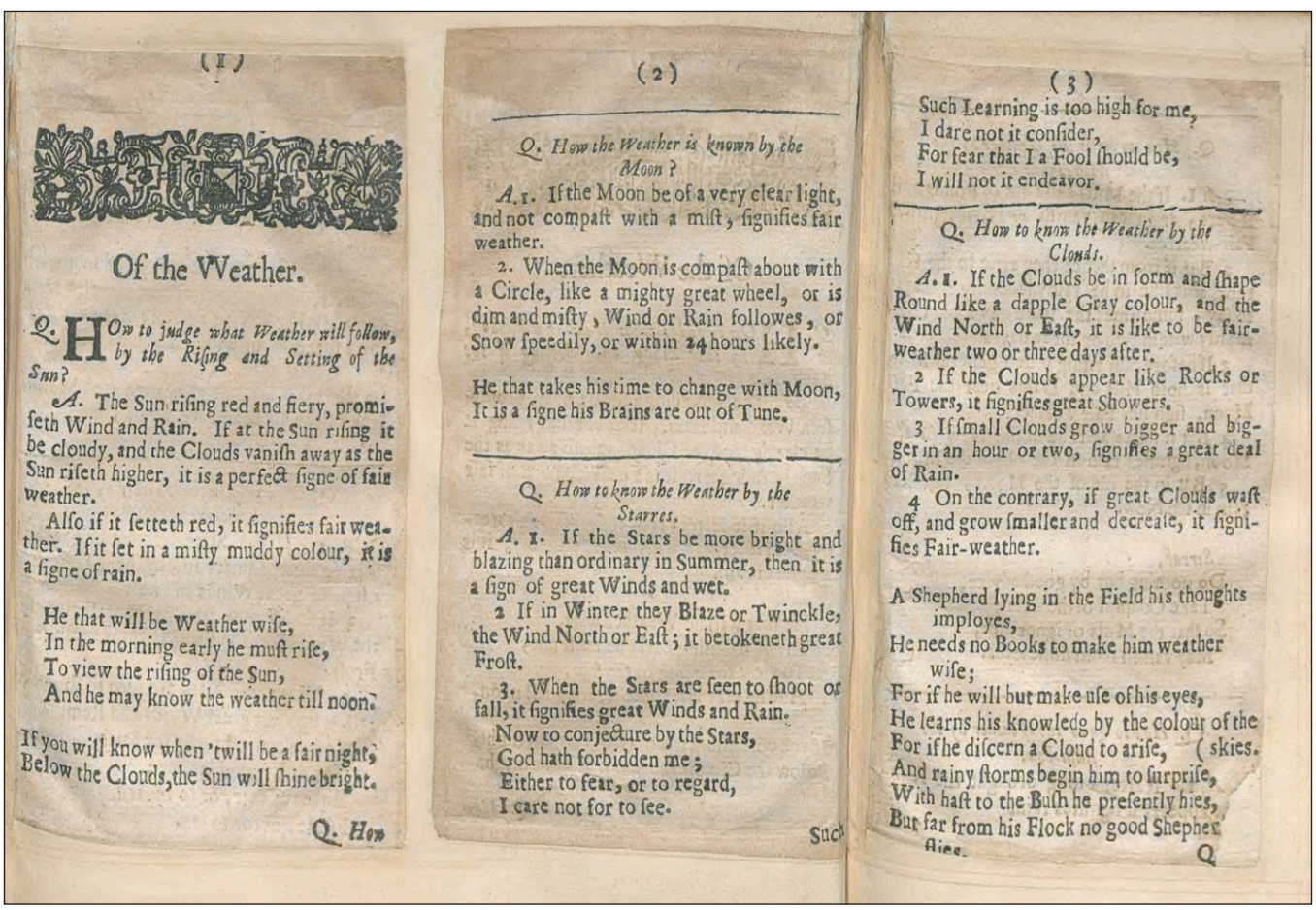
As is so often the case in science, the development of meteorological understanding was not linear and the work of Albertus Magnus marks the zenith of the subject for some time. Indeed foretelling the weather was outlawed as a form of sorcery by King Henry VIII as it was seen as prophecy and implied a magical ability to tell the future.

The weather was one thing, but those who could foretell the future might also look into the fate of the monarch, which was far less desirable. Further witchcraft acts of 1604 and 1735 reinforced the position and although some elements were removed the act was not fully repealed until 1951, when it was replaced with the fraudulent mediums act.

Parts of the act were repealed and replaced before 1951, but given that the Met Office was founded in 1854, some 97 years before the full repeal of the witchcraft act, it seems at least possible that for some of its 167 year history the legality of its weather forecasts may have been somewhat doubtful.

Weather lore

A lack of scientific progress, at least until the dawn of the enlightenment, does not mean that the period marks the equivalent of the meteorological dark ages in terms of archive treasures. While actively foretelling the weather might have been illegal, this did not prevent the development of much weather lore – an expansive subject covering meteorology and seasonal change across the natural world.



(1)

Of the Weather.

Q. HOw to judge what Weather will follow, by the Riſing and Setting of the Sun?

A. The Sun riſing red and fiery, promiſeth Wind and Rain. If at the Sun riſing it be cloudy, and the Clouds vaniſh away as the Sun riſeth higher, it is a perfect ſigne of fair weather.

Alſo if it ſetteth red, it ſignifies fair weather. If it ſet in a miſty muddy colour, it is a ſigne of rain.

He that will be Weather wiſe,
In the morning early he muſt riſe,
To view the riſing of the Sun,
And he may know the weather till noon.

If you will know when 'twill be a fair night,
Below the Clouds, the Sun will ſhine bright.

Q. How

(2)

Q. How the Weather is known by the Moon?

A. 1. If the Moon be of a very clear light, and not compaſt with a miſt, ſignifies fair weather.

2. When the Moon is compaſt about with a Circle, like a mighty great wheel, or is dim and miſty, Wind or Rain followes, or Snow ſpeedily, or within 24 hours likely.

He that takes his time to change with Moon,
It is a ſigne his Brains are out of Tune.

Q. How to know the Weather by the Starres.

A. 1. If the Stars be more bright and blazing than ordinary in Summer, then it is a ſign of great Winds and wet.

2 If in Winter they Blaze or Twinckle, the Wind North or Eaſt; it betokeneth great Froſt.

3. When the Stars are ſeen to ſhoot or fall, it ſignifies great Winds and Rain.

Now to conjecture by the Stars,
God hath forbidden me;
Either to fear, or to regard,
I care not for to ſee.

Such

(3)

Such Learning is too high for me,
I dare not it conſider,
For fear that I a Fool ſhould be,
I will not it endeavor.

Q. How to know the Weather by the Clouds.

A. 1. If the Clouds be in form and ſhape Round like a dapple Gray colour, and the Wind North or Eaſt, it is like to be fair-weather two or three days after.

2 If the Clouds appear like Rocks or Towers, it ſignifies great Showers.

3 If ſmall Clouds grow bigger and bigger in an hour or two, ſignifies a great deal of Rain.

4 On the contrary, if great Clouds waſt off, and grow ſmaller and decreaſe, it ſignifies Fair-weather.

A Shepherd lying in the Field his thoughts imployes,
He needs no Books to make him weather wiſe;
For if he will but make uſe of his eyes,
He learns his knowledg by the colour of the ſkies.
For if he diſcern a Cloud to ariſe,
And rainy ſtorms begin him to ſurpriſe,
With haſt to the Buſh he preſently hies,
But far from his Flock no good Shepherd

Q

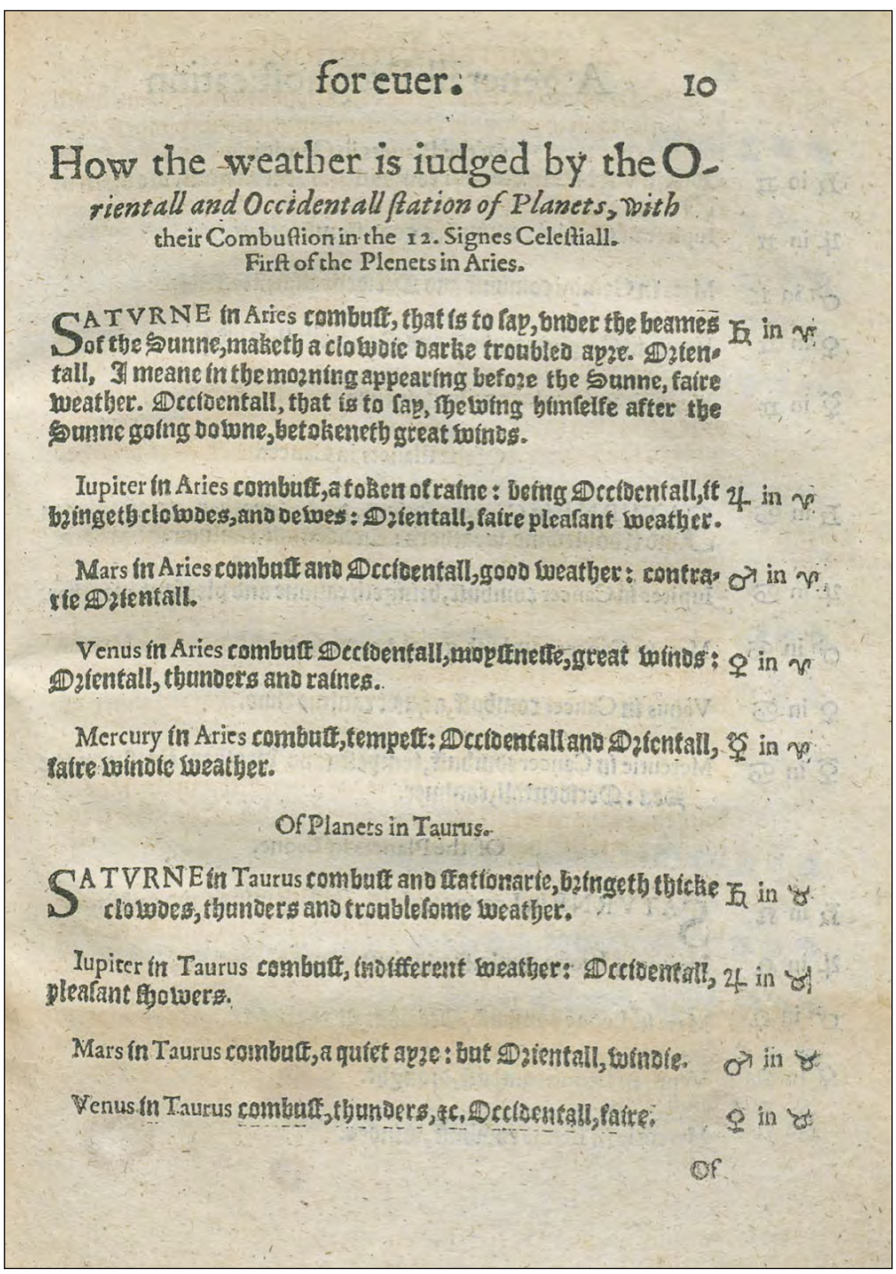
John Claridge, Shepherd of Banbury's Rules to judge the changes of the weather 1670

The earliest book of weather lore in the archives is a very rare, and possibly unique copy, of the 'Shepherd of Banbury's Rules to judge the changes of the weather' circa 1670. The rules, apparently produced as a result of 40 years' study, provide a series of indicators of good and poor weather, wind, rain, thunderstorms and snow. These include one of the first, if not the very first, versions of that most famous of observations 'Red Sky at Night', which does have a sound basis in meteorology.

The shepherd also accurately describes what we would now recognise as cumulonimbus clouds and the associated atmospheric conditions to be expected; 'If the Clouds appear like Rocks or Towers, it signifies great Showers' — we still describe large shower clouds as towering cumulonimbus.

We don't know much about the Shepherd of Banbury but his rules and observations were considered sufficiently accurate that several pages of the Met Office Meteorological Glossary were devoted to them even as late as the early 20th century.

It would be wrong to imply that all weather lore is useful or accurate. There was a popular connection between astrology and weather prediction. The results were unlikely to be very accurate, but were certainly very popular with the British public. One good example can be found in Thomas Digges' Prognostication Everlasting of Right Good Effect written in 1605. Here he discusses how 'Venus in Aries combust Occidentall, moystnesse, great winds: Orientall, thunders and raines' while 'Saturne in Taurus combust and stationarie, bringeth thicke clowdes, thunders and troublesome weather.'



for euer. 10

How the weather is iudged by the O-
rientall and Occidentall ſtation of Planets, with
their Combuſtion in the 12. Signes Celeſtiall.
Firſt of the Planets in Aries.

SATVRNE in Aries combuſt, that is to ſay, vnder the beames of the Sunne, maketh a clowdie darke troubled ayre. Orientall, I meane in the morning appearing before the Sunne, faire weather. Occidentall, that is to ſay, ſhewing himſelfe after the Sunne going downe, betokeneth great winds. ♄ in ♈

Iupiter in Aries combuſt, a token of raine: being Occidentall, it bringeth clowdes, and dewes: Orientall, faire pleaſant weather. ♃ in ♈

Mars in Aries combuſt and Occidentall, good weather: contrarie Orientall. ♂ in ♈

Venus in Aries combuſt Occidentall, moyſtneſſe, great winds: Orientall, thunders and raines. ♀ in ♈

Mercury in Aries combuſt, tempeſt: Occidentall and Orientall, faire windie weather. ☿ in ♈

Of Planets in Taurus.

SATVRNE in Taurus combuſt and ſtationarie, bringeth thicke clowdes, thunders and troubleſome weather. ♄ in ♉

Iupiter in Taurus combuſt, indifferent weather: Occidentall, pleaſant ſhowers. ♃ in ♉

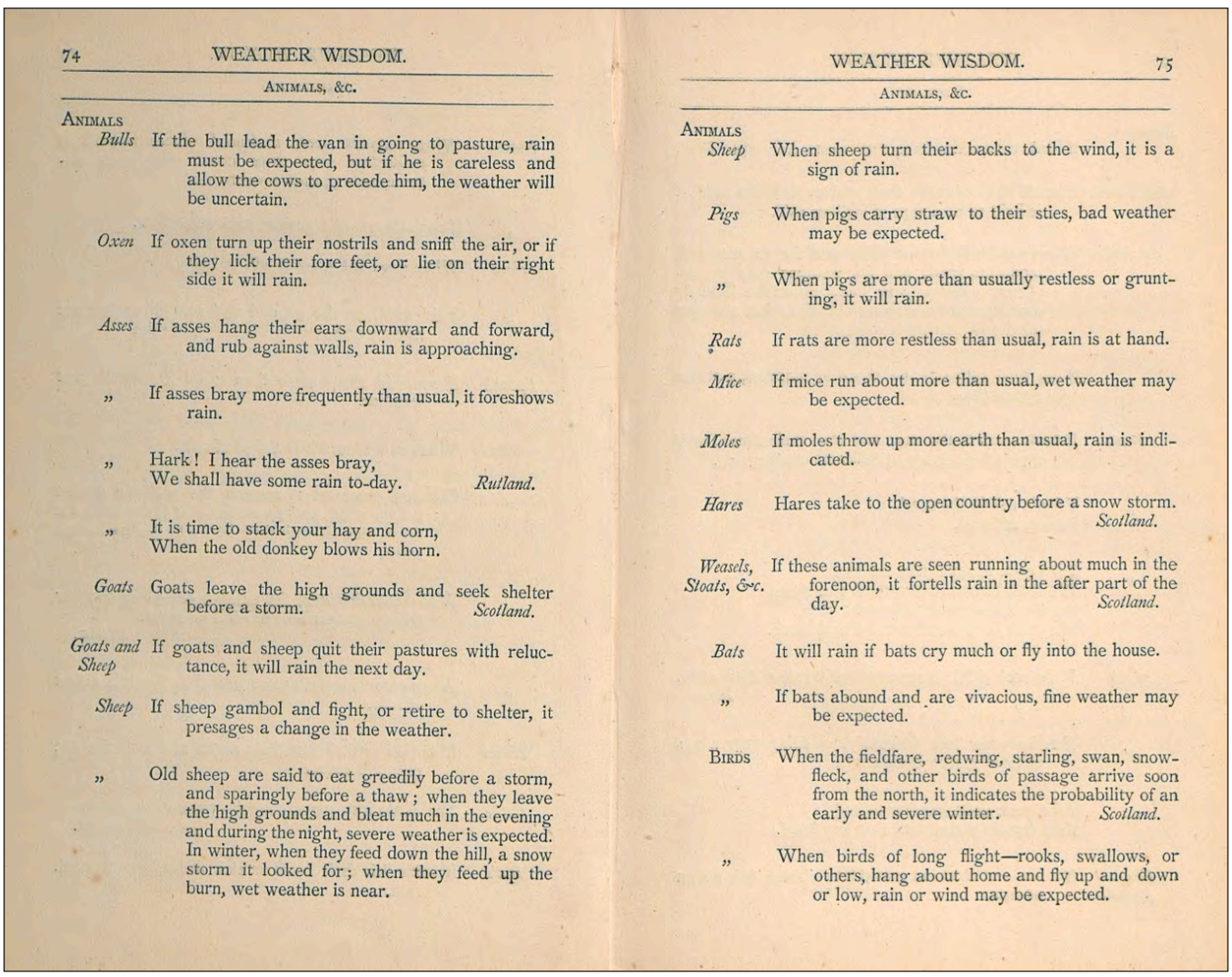
Mars in Taurus combuſt, a quiet ayre: but Orientall, windie. ♂ in ♉

Venus in Taurus combuſt, thunders, &c. Occidentall, faire. ♀ in ♉

Of

Thomas Digges, Prognostication Everlasting of Right Good Effect 1605

Other volumes list, often in great detail, all the changes one will find in nature that indicate a change in the weather. Indeed upon reading Richard Inward's Weather Lore you would be forgiven for thinking just about anything is a sign of rain: thirty of his thirty two signs in animals and forty two of his forty seven signs in birds are about rain, snow or bad weather.



74 WEATHER WISDOM.

ANIMALS, &c.

ANIMALS

Bulls If the bull lead the van in going to pasture, rain must be expected, but if he is careless and allow the cows to precede him, the weather will be uncertain.

Oxen If oxen turn up their nostrils and sniff the air, or if they lick their fore feet, or lie on their right side it will rain.

Asses If asses hang their ears downward and forward, and rub against walls, rain is approaching.

„ If asses bray more frequently than usual, it foreshows rain.

„ Hark! I hear the asses bray,
We shall have some rain to-day. *Rutland.*

„ It is time to stack your hay and corn,
When the old donkey blows his horn.

Goats Goats leave the high grounds and seek shelter before a storm. *Scotland.*

Goats and Sheep If goats and sheep quit their pastures with reluctance, it will rain the next day.

Sheep If sheep gambol and fight, or retire to shelter, it presages a change in the weather.

„ Old sheep are said to eat greedily before a storm, and sparingly before a thaw; when they leave the high grounds and bleat much in the evening and during the night, severe weather is expected. In winter, when they feed down the hill, a snow storm it looked for; when they feed up the burn, wet weather is near.

WEATHER WISDOM. 75

ANIMALS, &c.

ANIMALS

Sheep When sheep turn their backs to the wind, it is a sign of rain.

Pigs When pigs carry straw to their sties, bad weather may be expected.

„ When pigs are more than usually restless or grunting, it will rain.

Rats If rats are more restless than usual, rain is at hand.

Mice If mice run about more than usual, wet weather may be expected.

Moles If moles throw up more earth than usual, rain is indicated.

Hares Hares take to the open country before a snow storm. *Scotland.*

Weasels, Stoats, &c. If these animals are seen running about much in the forenoon, it fortells rain in the after part of the day. *Scotland.*

Bats It will rain if bats cry much or fly into the house.

„ If bats abound and are vivacious, fine weather may be expected.

BIRDS When the fieldfare, redwing, starling, swan, snow-fleck, and other birds of passage arrive soon from the north, it indicates the probability of an early and severe winter. *Scotland.*

„ When birds of long flight—rooks, swallows, or others, hang about home and fly up and down or low, rain or wind may be expected.

Richard Inwards, Weather Lore 1869

Texts such as these provide a source of amusement in today's world of rational thinking but also represent a window into the society of their times.

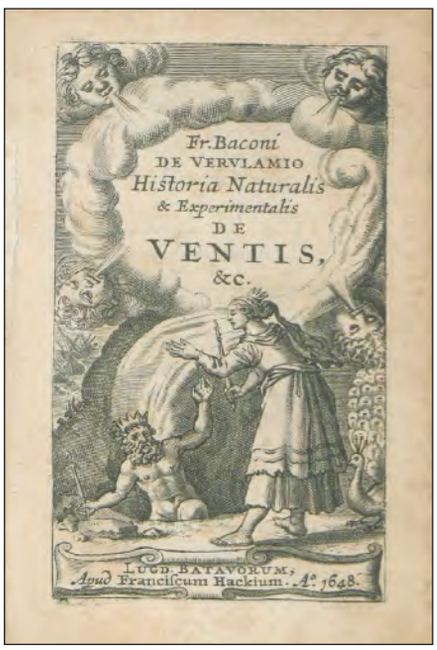
Some weather lore relates to the presence or absence of animals at given times of the year. Among the more unusual thinking was the belief that swallows hibernated in winter or even underwent some kind of metamorphosis and withdrew underwater in a slightly altered state. The great naturalist Gilbert White even mentions hibernating swallows in his Natural History of Selbourne 1789.

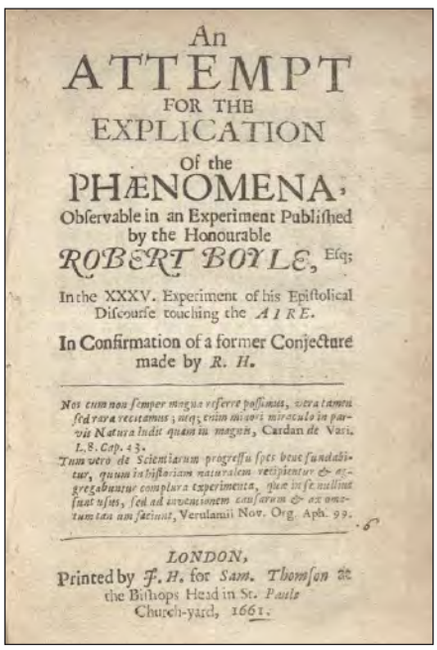
This reveals an understanding of the concepts of metamorphosis and hibernation — something that could be observed in any English garden or woodland — but shows that the idea of migration was as yet unknown to a society that rarely travelled more than a few miles.

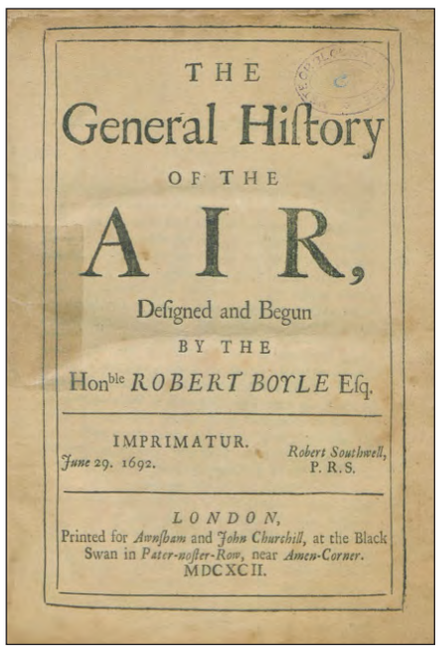
Weather lore may have been a less than perfect science but it was based on the concept of close observation of meteorological and climatological phenomena and as we have already seen there was accuracy among the myth. With the age of enlightenment came increasing interest in the desire for more accurate observations and the dawn of instrumental meteorology.

Laying the foundations of a science

The National Meteorological Archive rare book collection contains many of the seminal works that would go on to provide the building blocks of meteorological science by authors such as Bacon, Boyle and Hooke.







1 2 3

1: Francis Bacon, *Natural History and Experimental History of winds etc*. 1648

2: Robert Hooke, *An attempt for the explication of the phenomena observable in an experiment*. 1661

3: Robert Boyle, *The General History of the Air*. 1692

Luke Howard (1772–1864)

By the early 1800s meteorological instruments were firmly established scientific tools and were available to the wealthier classes in society and government institutions. Across the sciences there was an increasing desire for standardisation and meteorology was no exception. Between 1803 and 1806, two men, neither of them meteorologists by trade, would produce works that have left an indelible imprint on the world of meteorology to this day. They were Luke Howard and Francis Beaufort and we hold materials by both of them in the National Meteorological Archive.

Luke Howard (1772 – 1864)

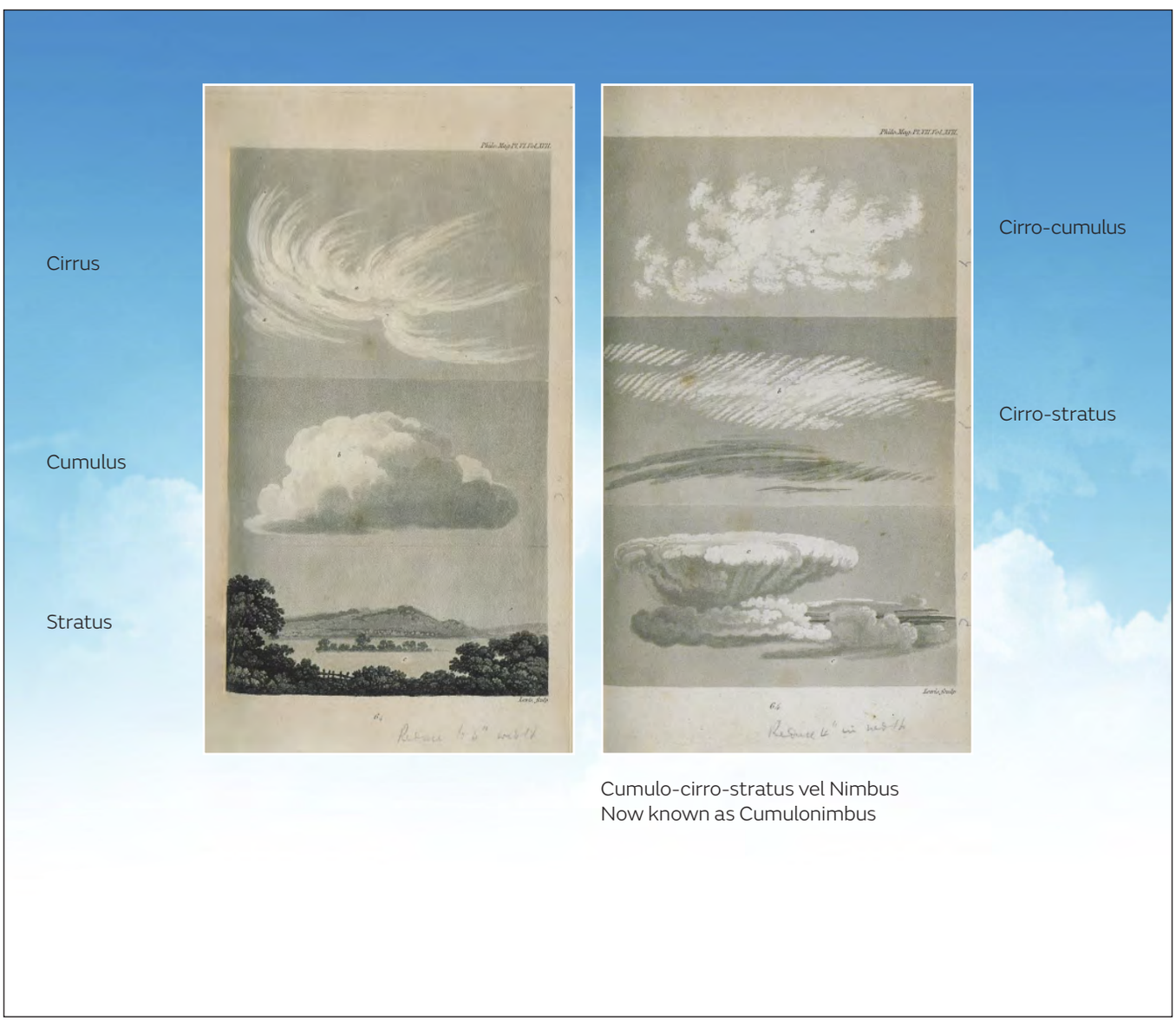
Luke Howard was a professional pharmacist and amateur meteorologist and has been dubbed the ‘father of meteorology’. He produced a series of comprehensive observations of the weather in the London area and is credited with having first discovered the concept of the urban heat island, where night time temperatures in the cities do not fall as low as those in the countryside. He attributed this to the numbers of coal fires burning in close proximity in the densely packed areas of housing a theory that was later shown to have some scientific credibility.

All of Luke Howard’s weather diaries are held in the National Meteorological Archive and they are considered one of the greatest treasures in the collection.

Although his detailed observations were undoubtedly influential Howard is perhaps better known as the ‘namer of clouds’. In 1803 he published his groundbreaking essay On the Modification of Clouds which set out to classify the three main types of cloud and some of their intermediate and compound forms.

Howard was not the first to attempt this feat but he was successful where others had failed because of his choice of terminology. As a Quaker he was keen that the names he chose should have no religious reference and so devised his nomenclature from latin or latinised words creating three key types and three compound forms.

Howard’s three main cloud types were: Cirrus (lock or tuft of hair), Cumulus (heap) and Stratus (flattened or spread out). From these he also named three compound forms: Cirro-Cumulus , Cirro-Stratus and Cumulo-cirro-stratus vel Nimbus which we now know as Cumulonimbus. Howard’s cloud names are still in use, although the range of modifications has been significantly increased and a few new terms have been added, but just as with his original classification system all new names are derived from latin or latinised vocabulary.



Luke Howard, On the Modification of Clouds 1803

Howard's work had a significant influence on some of his great artistic contemporaries. Turner and Constable are both thought to have observed and painted their clouds with greater accuracy after reading his work. His influence is especially clear in the works of Constable where the clouds are particularly realistic, as can be seen from two of his great paintings 'The Hay Wain' and 'Salisbury Cathedral'.

John Constable
The Hay Wain 1821

John Constable
Salisbury Cathedral 1831

Meanwhile the poet Goethe was so impressed that he wrote the poem 'In Honour of Mr Howard', of which this is a brief extract:

> But Howard gives us with his clear mind
> The gain of lessons new to all mankind;
> That which no hand can reach, no hand can clasp,
> He first has gained, first held with mental grasp.
> Defin'd the doubtful, fix'd its limit-line,
> And named it fitly. - Be the honour thine!
> As clouds ascend, are folded, scatter, fall,
> Let the world think of thee who taught it all.

Johann Wolfgang von Goethe In Honour of Mr Howard 1821

Admiral Sir Francis Beaufort

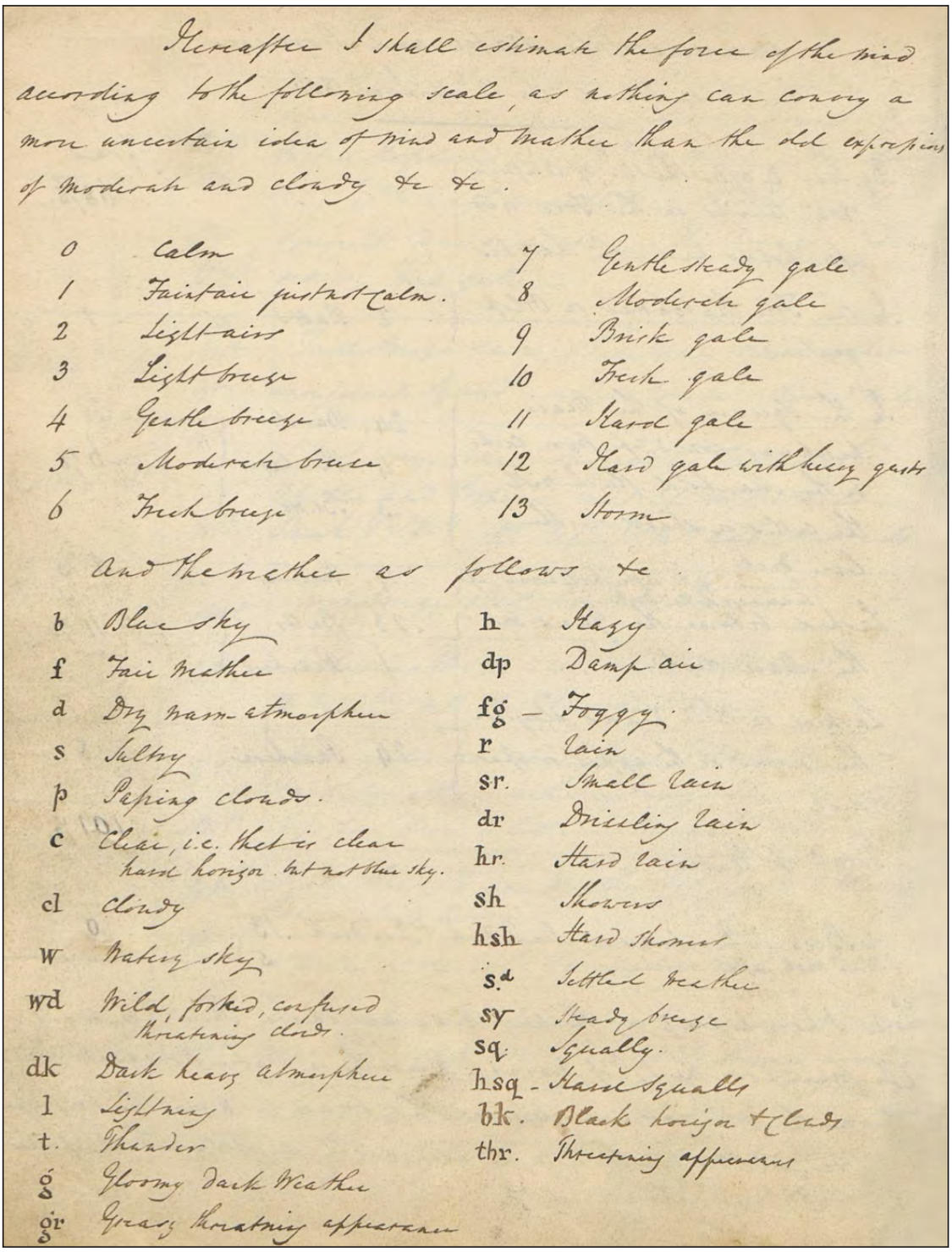
Arguably even more influential in the history of meteorology was Admiral Sir Francis Beaufort.

Francis Beaufort 1774–1857

Beaufort was born in 1774, the younger son of a protestant clergyman from County Meath, Ireland. He first went to sea at the age of 14 with the British East India Company and then joined the Royal Navy. Beaufort came to specialise in the creation of charts and as a skilled surveyor he understood the importance of accurate measurement.

As his career developed he became increasingly dissatisfied with the established means of measuring and recording wind speed in naval logs. He kept weather diaries throughout his career which include, amongst other things, mention of the Battle of Trafalgar and a secret code which we still haven't cracked but arguably the single most important diary entry dates to 16th January 1806 when, as Commander of HMS Woolwich he wrote the following words:

'Hereafter I shall estimate the force of the wind according to the following scale, as nothing can convey a more uncertain idea of wind and weather than the old expressions of moderate and cloudy etc. etc.' after which he inscribed the first ever version of the Beaufort Scale, followed by a series of Beaufort letters to describe weather conditions.



Hereafter I shall estimate the force of the wind according to the following scale, as nothing can convey a more uncertain idea of wind and weather than the old expressions of moderate and cloudy &c &c.

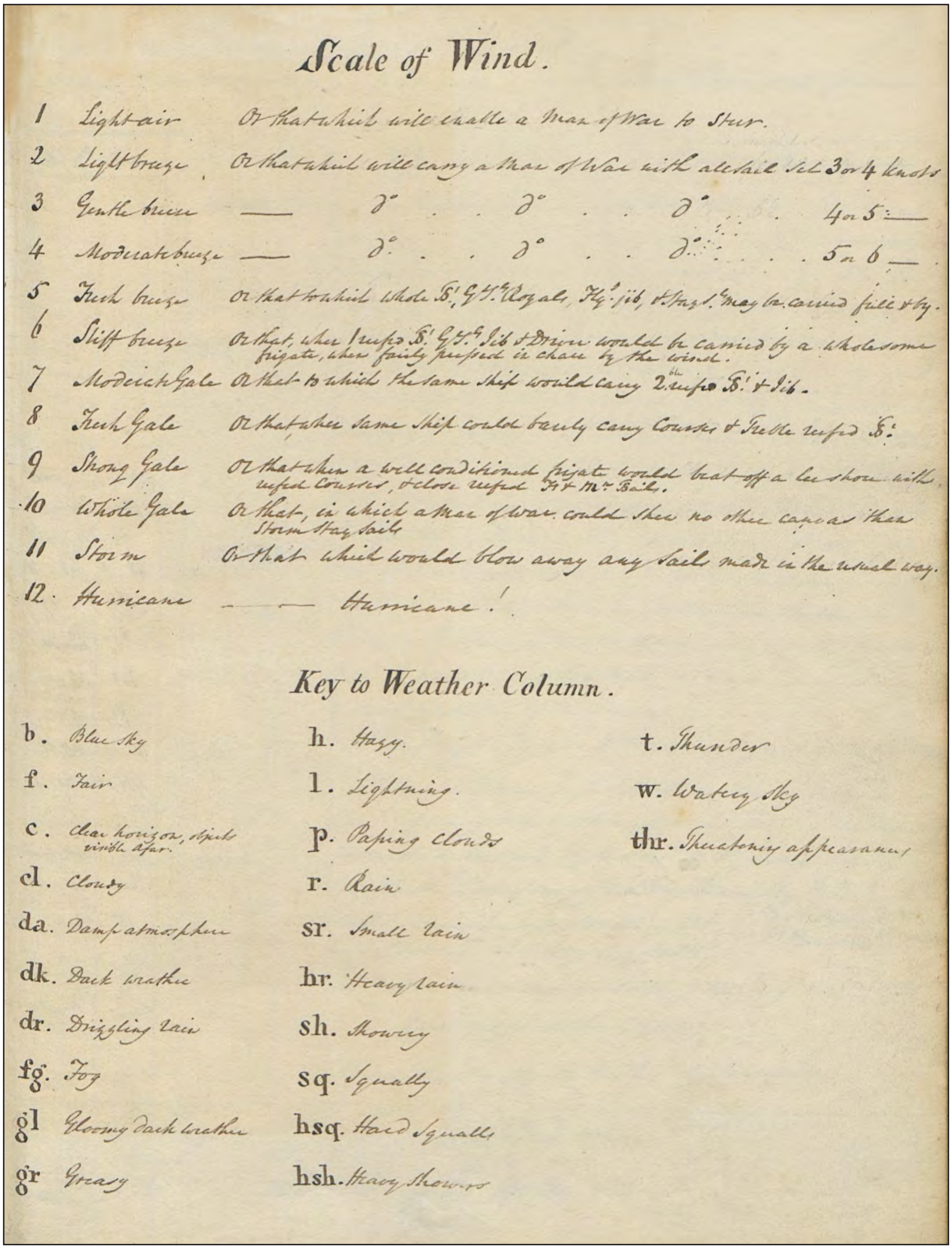
0	Calm	7	Gentle steady gale
1	Faint air just not calm.	8	Moderate gale
2	Light airs	9	Brisk gale
3	Light breeze	10	Fresh gale
4	Gentle breeze	11	Hard gale
5	Moderate breeze	12	Hard gale with heavy gusts
6	Fresh breeze	13	Storm

And the weather as follows &c.

b	Blue sky	h	Hazy
f	Fair weather	dp	Damp air
d	Dry warm atmosphere	fg	Foggy.
s	Sultry	r	Rain
p	Peping clouds.	sr.	Small rain
c	Clear, i.e. that is clear hazy horizon but not blue sky.	dr	Drizzling rain
		hr.	Hard rain
cl	Cloudy	sh	Showers
w	Watery sky	hsh	Hard showers
wd	Wild, forked, confused threatening clouds.	s.d	Settled weather
		sy	Steady breeze
dk	Dark heavy atmosphere	sq	Squally.
l	Lightning	hsq	Hard Squalls
t.	Thunder	bk.	Black horizon & clouds
g	Gloomy dark Weather	thr.	Threatening appearance
gr	Greasy threatning appearance		

Weather diary of Francis Beaufort 1807

The first scale had 13 wind forces and was not overly easy to use. It had four different types of breeze and six types of gale. But Beaufort rapidly honed and improved it — and in the first page of his 1807 diary he produced second and much more recognisable scale with 12 forces ending in hurricane and descriptions of how each would affect a standard Man of War (a Royal Naval Frigate). Today this would be termed an impact scale. Beaufort letters are less well known but were in use in meteorological observing until very recently and one or two still survive in aviation meteorology. Thanks to the pre-eminence of the Royal Navy and the imperial might of the British Empire Beaufort's wind scale was adopted around the world and continues in use to this day.



Scale of Wind.

1	Light air	Or that which will enable a Man of War to Steer.
2	Light breeze	Or that which will carry a Man of War with all sail set 3 or 4 knots
3	Gentle breeze	— do . . do . . do . . 4 or 5 —
4	Moderate breeze	— do . . do . . do . . 5 or 6 —
5	Fresh breeze	Or that to which whole Ts. Gt. Royals, Fly. jib, &c. may be carried full & by.
6	Stiff breeze	Or that, when 1 reefd Ts. Gt. Jib & Driver would be carried by a wholesome frigate, when fairly pressed in chace by the wind.
7	Moderate Gale	Or that to which the same ship would carry 2 reefd Ts. & Jib.
8	Fresh Gale	Or that when same ship could barely carry Courses & Treble reefd Ts.
9	Strong Gale	Or that when a well conditioned frigate would beat off a lee shore with reefd Courses, & close reefd Fr & Mn Sails.
10	Whole Gale	Or that, in which a Man of War could shew no other canvas than Storm Stay Sails
11	Storm	Or that which would blow away any sail made in the usual way.
12	Hurricane	— Hurricane!

Key to Weather Column.

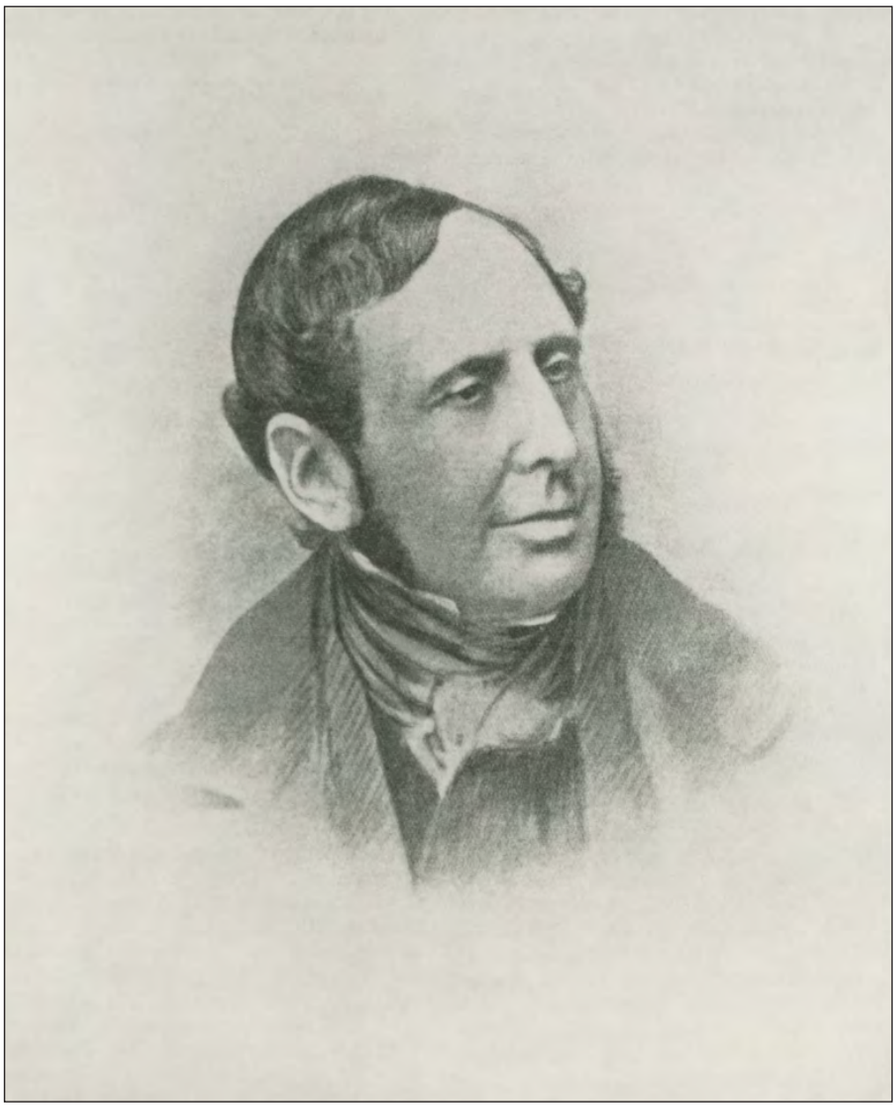
b. Blue sky	h. Hazy.	t. Thunder
f. Fair	l. Lightning.	w. Watery sky
c. Clear horizon, objects visible afar.	p. Passing clouds	thr. Threatening appearance
cl. Cloudy	r. Rain	
da. Damp atmosphere	sr. Small rain	
dk. Dark weather	hr. Heavy rain	
dr. Drizzling rain	sh. Showery	
fg. Fog	sq. Squally	
gl Gloomy dark weather	hsq. Hard Squalls	
gr Greasy	hsh. Heavy showers	

Weather Diary of Francis Beaufort 1807

Beaufort and his contemporaries and predecessors had provided the tools but the start of meteorological science in Britain came in 1854 with the foundation of the Meteorological Office or, as it was rather less snappily known at the time, the Office of Meteorological Statistics of the Board of Trade.

The establishment of a meteorological office at this moment in time was a response to the International Meteorological Conference of 1853 which was held at the behest of US Naval Lieutenant Matthew Fontaine Maury. At this meeting representatives from governments around the world agreed to share observation data from ships moving around the world's oceans in order to enable the creation of maritime charts showing prevailing winds and currents around the globe. Even political enemies were willing to share meteorological data to benefit from access to the resulting charts and indeed this marks one of the earliest global data sharing initiatives, perhaps even the earliest of all. Britain was no exception and established a Meteorological Office under the command of Robert FitzRoy whose title was Meteorological Statist to the Board of Trade.

Robert FitzRoy 1805–1865



Robert FitzRoy 1805–1865

Why FitzRoy? Who was he? Here Beaufort re-enters the story. FitzRoy was a brilliant Royal Naval surveyor and had come to the attention of Beaufort who treated him as protégée. Beaufort played a significant part in securing for FitzRoy the captaincy of the Beagle on her famous circumnavigation of the globe and even suggested the young naturalist Charles Darwin as a suitable gentleman companion for the voyage.

Beaufort later supported FitzRoy's election to the Royal Society and, when the government approached them to recommend a good candidate for the role of Meteorological Statist, it was of course Beaufort who suggested FitzRoy for the position.

FitzRoy was a man ahead of his time and a workaholic who cared perhaps too much about his work. He certainly took criticism very badly and very personally; never a good idea when working with the weather. Nevertheless his role in the history of meteorology should not be underestimated. The following archive treasures illustrate just some of his most significant achievements.

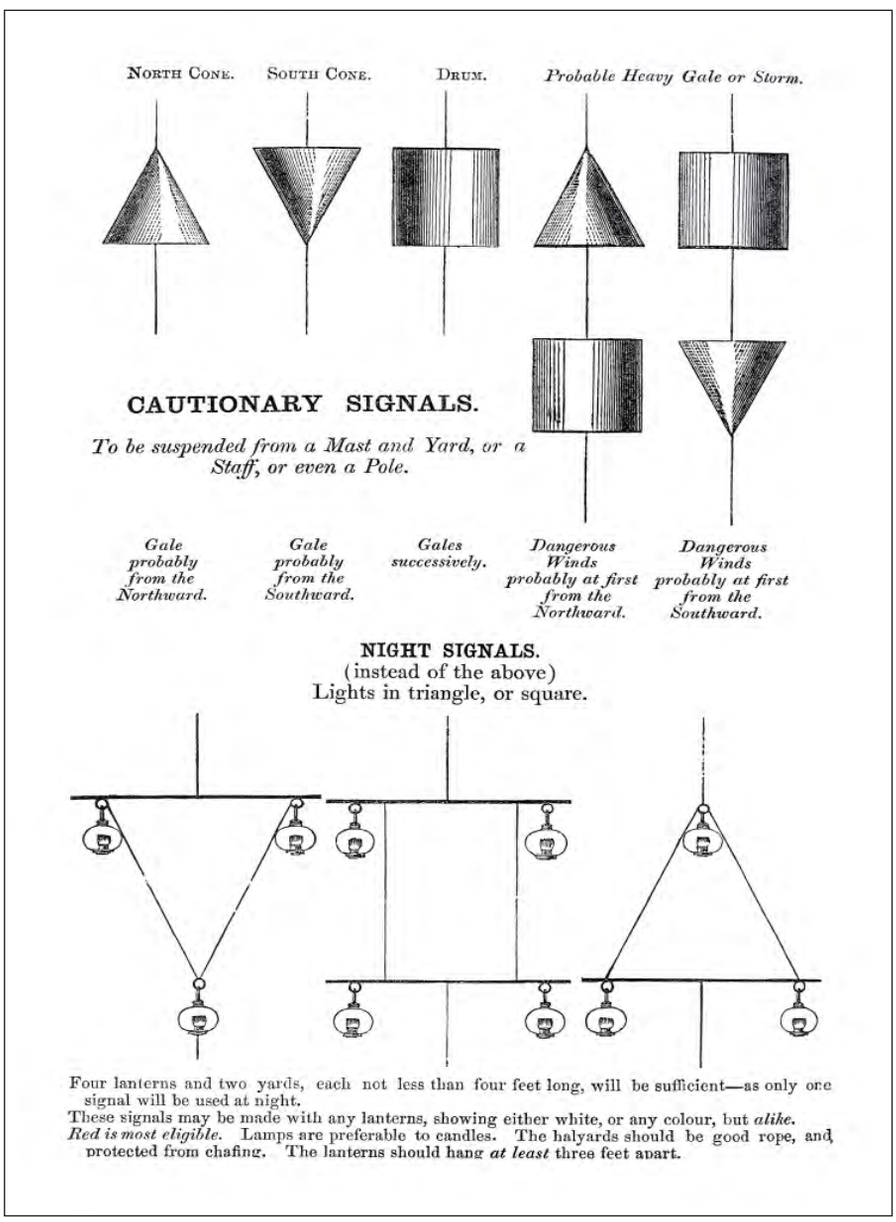
Royal Charter Gale synoptic chart 26 October 1859

This synoptic chart for 9 am on the 26 October 1859 is the oldest chart in our collection. The term “synoptic” was one of many terms coined by FitzRoy and simply means a synopsis of the weather observations at a given time presented on a chart. The chart depicts the Royal Charter gale, which was considered the most severe storm to hit the Irish Sea in the 19th century. The storm depression was first noted in the Bay of Biscay near Cape Finisterre on 24–25 October and the centre progressed northwards over Britain from Cornwall to the Yorkshire coast.

The strongest winds in the system developed as a rather narrow northerly stream over the Irish Sea reaching hurricane force 12 on the Beaufort Scale with gusts estimated at well over 100 mph. Indeed wind speeds on the Mersey were higher than any previously recorded. The storm took 800 lives and wrecked 133 ships with a further 90 badly damaged. Twice as many people were lost at sea around the British Isles in that one storm than in the whole of 1858. The most famous ship to founder during the night was the steam clipper Royal Charter.

The ship was on the last leg of her two month journey from Melbourne to Liverpool. She was one of the fastest and most famous emigrant ships operating during the years of the Australian Gold Rush and could carry up to 600 passengers and cargo.

As conditions in the Irish Sea deteriorated, the captain of the Royal Charter had to decide whether to seek shelter at Holyhead or carry on for Liverpool. He chose to continue but by 10 pm on the 25th the wind had reached force 10 and continued to rise and sea conditions prevented the Liverpool Pilot from reaching the ship. At 11 pm the decision was made to anchor but at 1.30 am the port anchor chain snapped, followed by the starboard chain an hour later. Despite cutting the masts to reduce the drag of the wind the Royal Charter was driven inshore and her steam engines were unable to make headway against the gale. She struck the rocks at Point Alerth, Anglesey, and battered by huge waves, quickly broke up. The precise number of dead is not certain as the complete passenger list was lost in the wreck however it is thought to be about 459 souls including all of the women and children aboard. There were only 40 survivors and it remains the highest death toll of any shipwreck on the Welsh coast.



Robert FitzRoy Storm Warning Signals 1861

The wreck gained much coverage in the national press and focused attention on the desire for storm warnings to reduce further such losses.

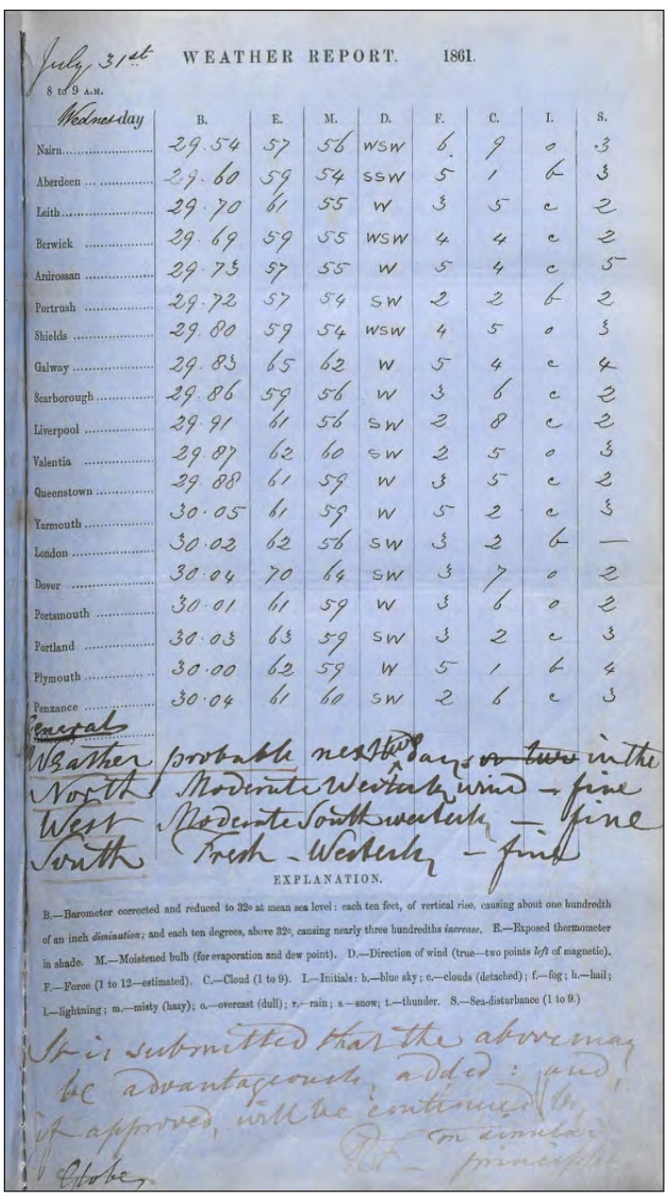
Based on his experiences collating meteorological observations over the previous five years, FitzRoy believed that his department could provide such a service. He produced a series of charts-and used them to write a detailed report to prove that the storm could have been predicted. The chart for 26 October 1859 is the only original known to have survived. Through his analyses of the Royal Charter and other storms, FitzRoy demonstrated the validity of his models and proposed a national storm warning system. There was doubt amongst the scientific establishment that the weather could be predicted in any meaningful way but the government permitted FitzRoy to test his new science of weather forecasting and to establish a Storm Warning service.

The service used the new electric telegraph to collect observations taken around the British coasts. These were assessed at the Meteorological Office headquarters in London and, if necessary, storm warnings were issued to the relevant areas. The warnings then had to be conveyed to ships before the days of radio communication so FitzRoy developed a brilliantly simple method of cones and drums made from canvas.

The shapes would appear the same no matter what angle they were viewed from and were hoisted from a mast or other tall object to convey the direction from which the storm could be expected. His system is credited with saving hundreds of lives and he became a hero to many in the maritime community, including the Royal National Lifeboat Institution (RNLI).

The first warning was issued on 5 February 1861. The Storm Warning service is believed to be the oldest national forecasting service in the world and it continues to this day and is now known as the Shipping Forecast. FitzRoy's visual cone and drum warning system was so effective that continued in use until 1984.

Public weather forecasting



July 31st WEATHER REPORT. 1861.

8 to 9 A.M.

Wednesday	B.	E.	M.	D.	F.	C.	I.	S.
Nairn	29.54	57	56	WSW	6	9	o	3
Aberdeen	29.60	59	54	SSW	5	1	b	3
Leith	29.70	61	55	W	3	5	c	2
Berwick	29.69	59	55	WSW	4	4	c	2
Ardrossan	29.73	57	55	W	5	4	c	5
Portrush	29.72	57	54	SW	2	2	b	2
Shields	29.80	59	54	WSW	4	5	o	3
Galway	29.83	65	62	W	5	4	c	4
Scarborough	29.86	59	56	W	3	6	c	2
Liverpool	29.91	61	56	SW	2	8	c	2
Valentia	29.87	62	60	SW	2	5	o	3
Queenstown	29.88	61	59	W	3	5	c	2
Yarmouth	30.05	61	59	W	5	2	c	3
London	30.02	62	56	SW	3	2	b	—
Dover	30.04	70	64	SW	3	7	o	2
Portsmouth	30.01	61	59	W	3	6	o	2
Portland	30.03	63	59	SW	3	2	c	3
Plymouth	30.00	62	59	W	5	1	b	4
Penzance	30.04	61	60	SW	2	6	c	3

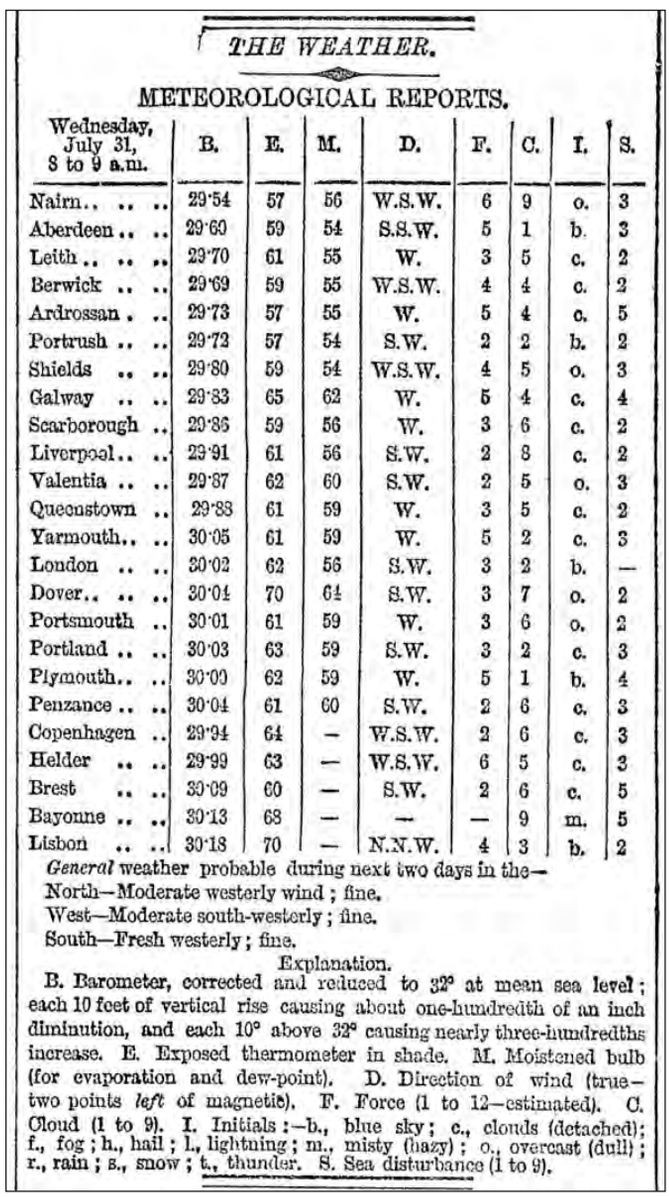
General Weather probable next two days or two in the North Moderate Westerly wind — fine
West Moderate South westerly — fine
South Fresh Westerly — fine

EXPLANATION.

B.—Barometer corrected and reduced to 32° at mean sea level: each ten feet, of vertical rise, causing about one hundredth of an inch *diminution*; and each ten degrees, above 32°, causing nearly three hundredths *increase*. E.—Exposed thermometer in shade. M.—Moistened bulb (for evaporation and dew point). D.—Direction of wind (true—two points *left* of magnetic). F.—Force (1 to 12—estimated). C.—Cloud (1 to 9). I.—Initials: b.—blue sky; c.—clouds (detached); f.—fog; h.—hail; l.—lightning; m.—misty (hazy); o.—overcast (dull); r.—rain; s.—snow; t.—thunder. S.—Sea-disturbance (1 to 9.)

It is submitted that the above may be advantageously added: and, if approved, will be continued in similar principle

Glaisher



THE WEATHER.

METEOROLOGICAL REPORTS.

Wednesday, July 31, 8 to 9 a.m.	B.	E.	M.	D.	F.	C.	I.	S.
Nairn	29·54	57	56	W.S.W.	6	9	o.	3
Aberdeen	29·60	59	54	S.S.W.	5	1	b.	3
Leith	29·70	61	55	W.	3	5	c.	2
Berwick	29·69	59	55	W.S.W.	4	4	c.	2
Ardrossan	29·73	57	55	W.	5	4	c.	5
Portrush	29·72	57	54	S.W.	2	2	b.	2
Shields	29·80	59	54	W.S.W.	4	5	o.	3
Galway	29·83	65	62	W.	5	4	c.	4
Scarborough	29·86	59	56	W.	3	6	c.	2
Liverpool	29·91	61	56	S.W.	2	8	c.	2
Valentia	29·87	62	60	S.W.	2	5	o.	3
Queenstown	29·88	61	59	W.	3	5	c.	2
Yarmouth	30·05	61	59	W.	5	2	c.	3
London	30·02	62	56	S.W.	3	2	b.	—
Dover	30·04	70	64	S.W.	3	7	o.	2
Portsmouth	30·01	61	59	W.	3	6	o.	2
Portland	30·03	63	59	S.W.	3	2	c.	3
Plymouth	30·00	62	59	W.	5	1	b.	4
Penzance	30·04	61	60	S.W.	2	6	c.	3
Copenhagen	29·94	64	—	W.S.W.	2	6	c.	3
Helder	29·99	63	—	W.S.W.	6	5	c.	3
Brest	30·09	60	—	S.W.	2	6	c.	5
Bayonne	30·13	68	—	—	—	9	m.	5
Lisbon	30·18	70	—	N.N.W.	4	3	b.	2

General weather probable during next two days in the—
North—Moderate westerly wind; fine.
West—Moderate south-westerly; fine.
South—Fresh westerly; fine.

Explanation.

B. Barometer, corrected and reduced to 32° at mean sea level; each 10 feet of vertical rise causing about one-hundredth of an inch diminution, and each 10° above 32° causing nearly three-hundredths increase. E. Exposed thermometer in shade. M. Moistened bulb (for evaporation and dew-point). D. Direction of wind (true—two points *left* of magnetic). F. Force (1 to 12—estimated). C. Cloud (1 to 9). I. Initials:—b., blue sky; c., clouds (detached); f., fog; h., hail; l., lightning; m., misty (hazy); o., overcast (dull); r., rain; s., snow; t., thunder. S. Sea disturbance (1 to 9).

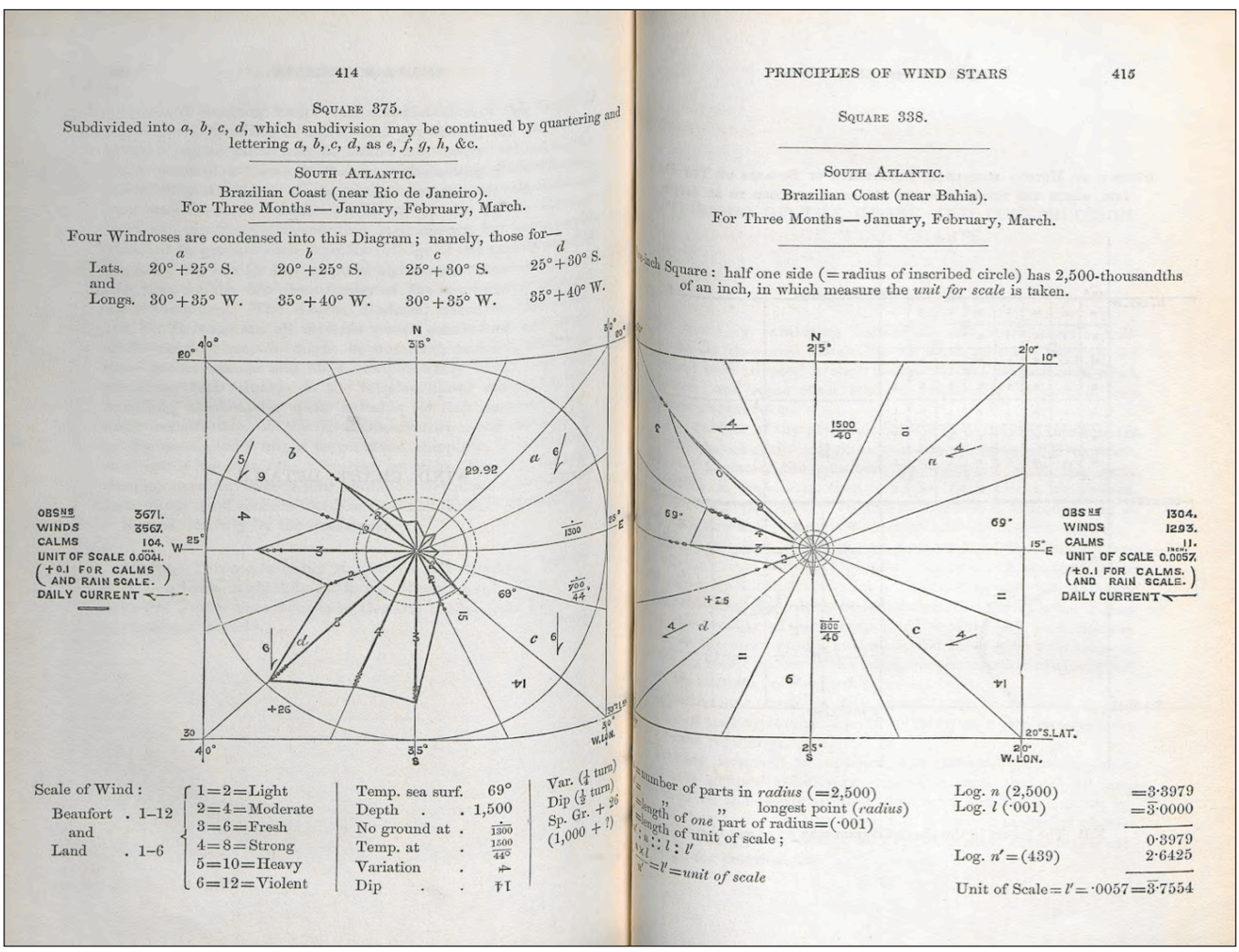
First public weather forecast 1 August 1861

Not content with saving lives at sea, FitzRoy felt that an awareness of the weather to be expected would also be of practical interest to the wider population. He therefore placed the first ever public weather forecast in the Times on the 1 August 1861. On the left above is the draft text written in the daily weather report book for 31 July 1861 and on the right is the final version published in the Times. The daily weather report (a list of weather observations from the previous day) was already published in the newspapers so FitzRoy slipped in a forecast just below the observation data.

Sadly as brilliant a man as he was, he may have over stretched himself here. The first forecast was actually correct but in more unsettled periods there was simply insufficient understanding and data to enable the production of accurate forecasts and his work was heavily ridiculed and criticised by the scientific establishment. FitzRoy took everything personally and became very depressed. Not only was FitzRoy subjected to constant criticism, he also faced personal bankruptcy having spent almost all his fortune on developing and distributing a barometer to aid fishermen who operated from small harbours that could not benefit from the storm warning service. These most stressful events may well have led to his tragic suicide in April 1865.

Given that he never received the recognition he deserved for his groundbreaking achievements it is rather ironic that his last forecast was produced on the orders of Queen Victoria, who required a weather forecast before sailing to her retreat at Osborne House on the Isle of Wight.

FitzRoy's Weather Book



414

SQUARE 375.

Subdivided into *a*, *b*, *c*, *d*, which subdivision may be continued by quartering and lettering *a*, *b*, *c*, *d*, as *e*, *f*, *g*, *h*, &c.

SOUTH ATLANTIC.

Brazilian Coast (near Rio de Janeiro).

For Three Months — January, February, March.

Four Windroses are condensed into this Diagram; namely, those for—

	a	*b*	*c*	*d*
Lats. and Longs.	20°+25° S. 30°+35° W.	20°+25° S. 35°+40° W.	25°+30° S. 30°+35° W.	25°+30° S. 35°+40° W.

OBS^NS 3671.
WINDS 3567.
CALMS 104.
UNIT OF SCALE 0.0041.
(+0.1 FOR CALMS AND RAIN SCALE.)
DAILY CURRENT

Scale of Wind:

Beaufort and Land . 1–12	1=2=Light
	2=4=Moderate
	3=6=Fresh
	4=8=Strong
	5=10=Heavy
	6=12=Violent

Temp. sea surf. 69°
Depth . . 1,500
No ground at . $\frac{1500}{1500}$
Temp. at . $\frac{1500}{44^{\circ}}$
Variation . ⇗
Dip . . ∓1

Var. ($\frac{1}{4}$ turn)
Dip ($\frac{1}{2}$ turn)
Sp. Gr. + 36
(1,000 + ?)

PRINCIPLES OF WIND STARS 415

SQUARE 338.

SOUTH ATLANTIC.

Brazilian Coast (near Bahia).

For Three Months — January, February, March.

Inch Square: half one side (=radius of inscribed circle) has 2,500-thousandths of an inch, in which measure the *unit for scale* is taken.

OBS^NS 1304.
WINDS 1293.
CALMS 11.
UNIT OF SCALE 0.0057.
(+0.1 FOR CALMS. AND RAIN SCALE.)
DAILY CURRENT

=number of parts in *radius* (=2,500)
=" " longest point (*radius*)
length of *one* part of radius=(·001)
length of unit of scale;
$\therefore n : l :: l' : n' \times l = l' =$ *unit of scale*

Log. n (2,500) $=3\cdot3979$
Log. l (·001) $=\bar{3}\cdot0000$
$0\cdot3979$
Log. $n' = (439)$ $2\cdot6425$
Unit of Scale $= l' = \cdot0057 = \bar{3}\cdot7554$

Robert FitzRoy, Weather Book 1863

To leave FitzRoy here would be to do the man a disservice to his substantial legacy. Above is a page from his Weather Book a 'small' tome of over 500 pages which FitzRoy wrote during a summer holiday! The above pages show FitzRoy's wind stars. Each star represents a 10 degree square on the chart and shows prevailing wind and weather for a three month period. It was a simple but very effective method of display prevailing global weather data in a useable format for mariners.

Of course, science has moved on and by no means is all of the content accurate but the Weather Book could be considered the first true textbook of the science of meteorology.

The term “forecast” is now universally understood, but it was actually invented by FitzRoy to differentiate his scientific approach, from previous methods. In his book FitzRoy states:

‘prophecies or predictions they are not: the term forecast is strictly applicable to such an opinion as is the result of a scientific combination and calculation’

FitzRoy understood that forecasting dealt with a chaotic atmosphere and therefore it could never be an exact science. He stated that ‘a forecaster....should only employ words indicative of probable extent of variability’. Using probabilities rather than certainties to describe expected weather conditions is the style of terminology still in regular use in all forecasting.

The work of FitzRoy and his successors brought about the birth of modern scientific meteorology and the start of the long road that leads to meteorological and climatological science as it stands today. The archive holds literally thousands of tonnes of observational documentation from 1854 to around 2005, after which most records are held in electronic format.

Expansion of meteorology

Although the foundations of science and observation were now in place the 20th and 21st centuries have seen ever increasing opportunities to use meteorology and climatology in new ways. The following treasures illustrate just a few examples.

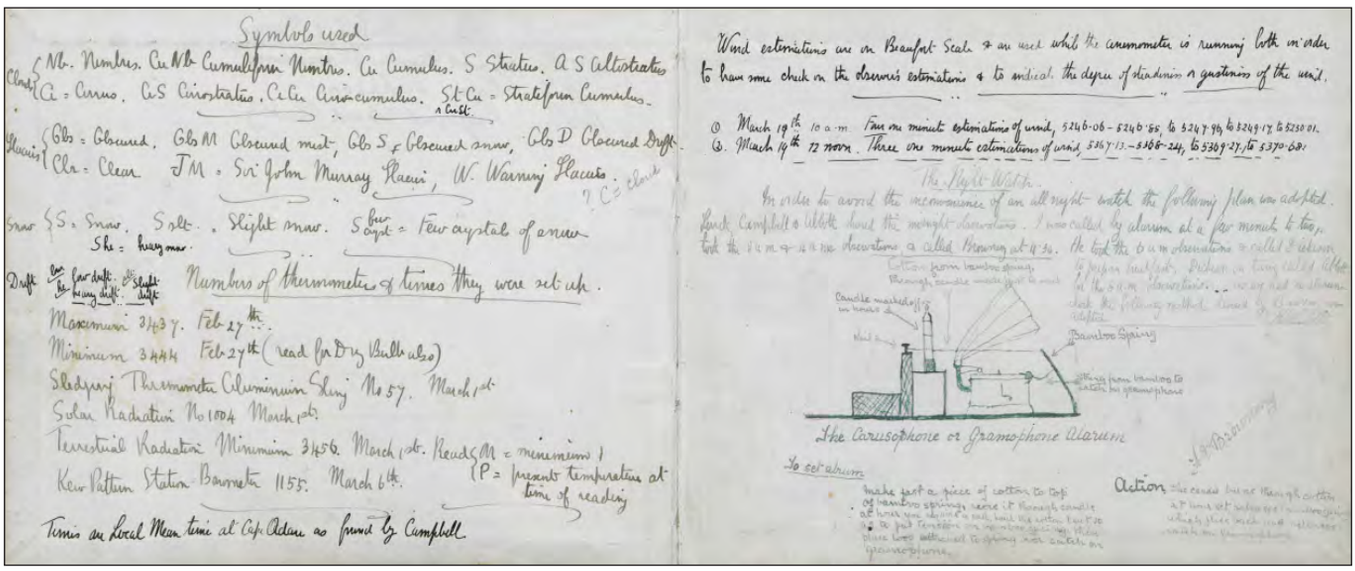
Terra Nova Expedition

The British are rather notorious for celebrating their failures and perhaps one of the most famous is the heroic but ultimately tragic 1913 race to the South Pole. The fate of Captain Robert Falcon Scott and his team is well known but many do not realise that scientific investigation and discovery lay at the heart of the Terra Nova Expedition. The meteorological registers produced by the expedition are held at the National Meteorological Archive.

The team spent many months, including two Antarctic winters, studying the unknown continent. An important part of their investigations was to make a detailed record of the weather and climate. To achieve this Scott appointed a team led by meteorologist George Simpson, who was apparently nicknamed ‘Sunny Jim’ because of his uncanny resemblance to the character on ‘Force’ cereal packets.

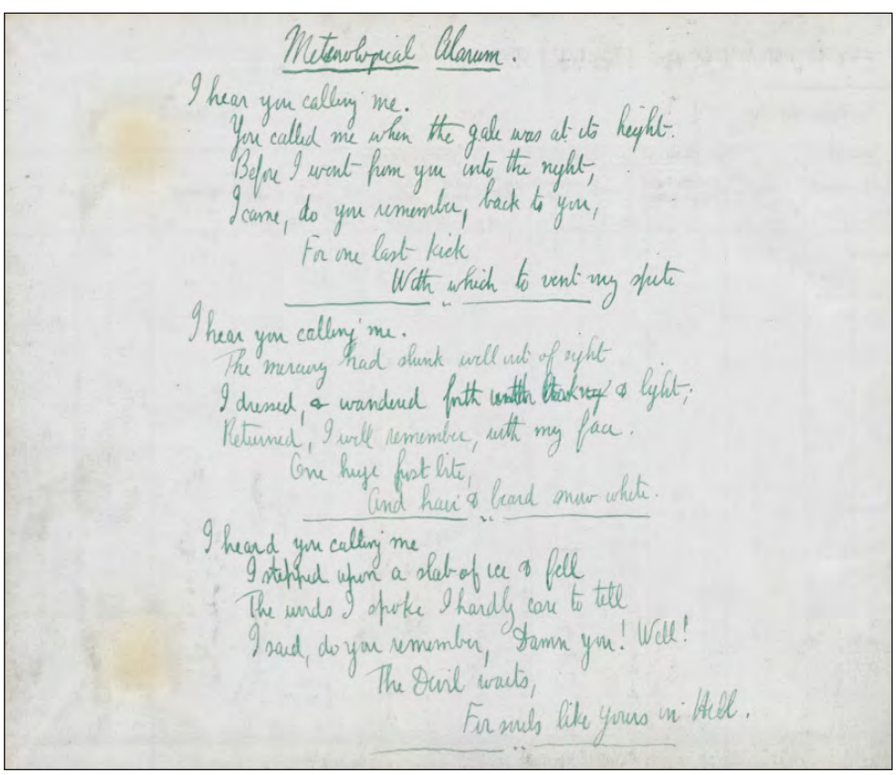
George Simpson taking observations in the Antarctic

The registers illustrate the conditions and the humour with which the team faced adversity. The Northern Party demonstrated considerable ingenuity when making meteorological observations. Rather than having to stay awake all night they designed an alarm clock to wake them in order to make night time observations. The device was called a 'Carusophone'. This was a gramophone with a needle that was released onto the record when a lighted candle burned through a string, that was tied to a bamboo cane under tension. When the string burned through the bamboo cane, which was also connected to the gramophone needle, the bamboo cane would spring back and release the needle onto the record.



Carusophone diagram from Terra Nova Meteorological Log

The Carusophone alarm clock was clearly not universally popular and observer Raymond Priestly penned a rather entertaining poem to the 'Meteorological Alarum' in the back of their meteorological register the final line of which reads 'the devil waits for souls like yours in hell'!



Meteorological Alarum.

I hear you calling me.
You called me when the gale was at its height.
Before I went from you into the night;
I came, do you remember, back to you,
For one last kick
With which to vent my spite

I hear you calling me.
The mercury had shrunk well out of sight
I dressed & wandered forth with frost & light;
Returned, I will remember, with my face.
One huge frost bite,
And hair & beard snow white.

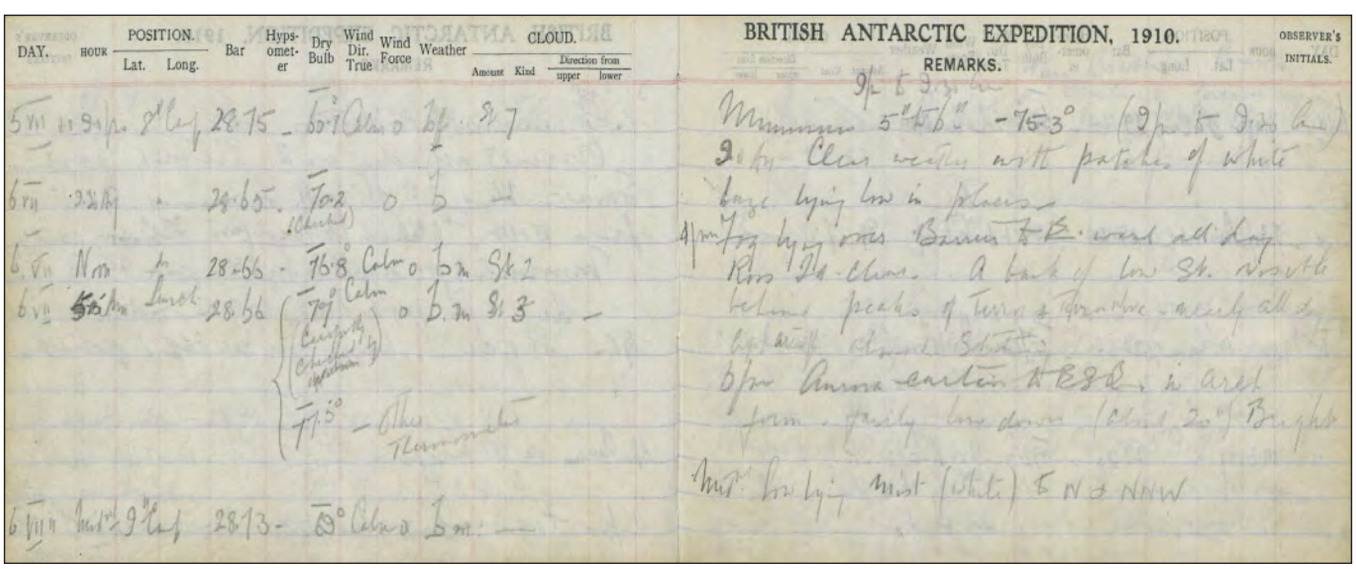
I heard you calling me
I stepped upon a slab of ice & fell
The words I spoke I hardly care to tell
I said, do you remember, Damn you! Well!
The Devil waits,
For souls like yours in Hell.

Poem to the 'Meteorological Alarum'

Edward Wilson, Henry Bowers and Apsley Cherry-Garrard experienced the lowest recorded temperature while trekking to Cape Crozier to recover three Emperor Penguin eggs. It was believed that the embryos inside would reveal the evolutionary link between reptiles and birds.

Cape Crozier Party, left to right: Bowers, Wilson, Cherry-Garrard

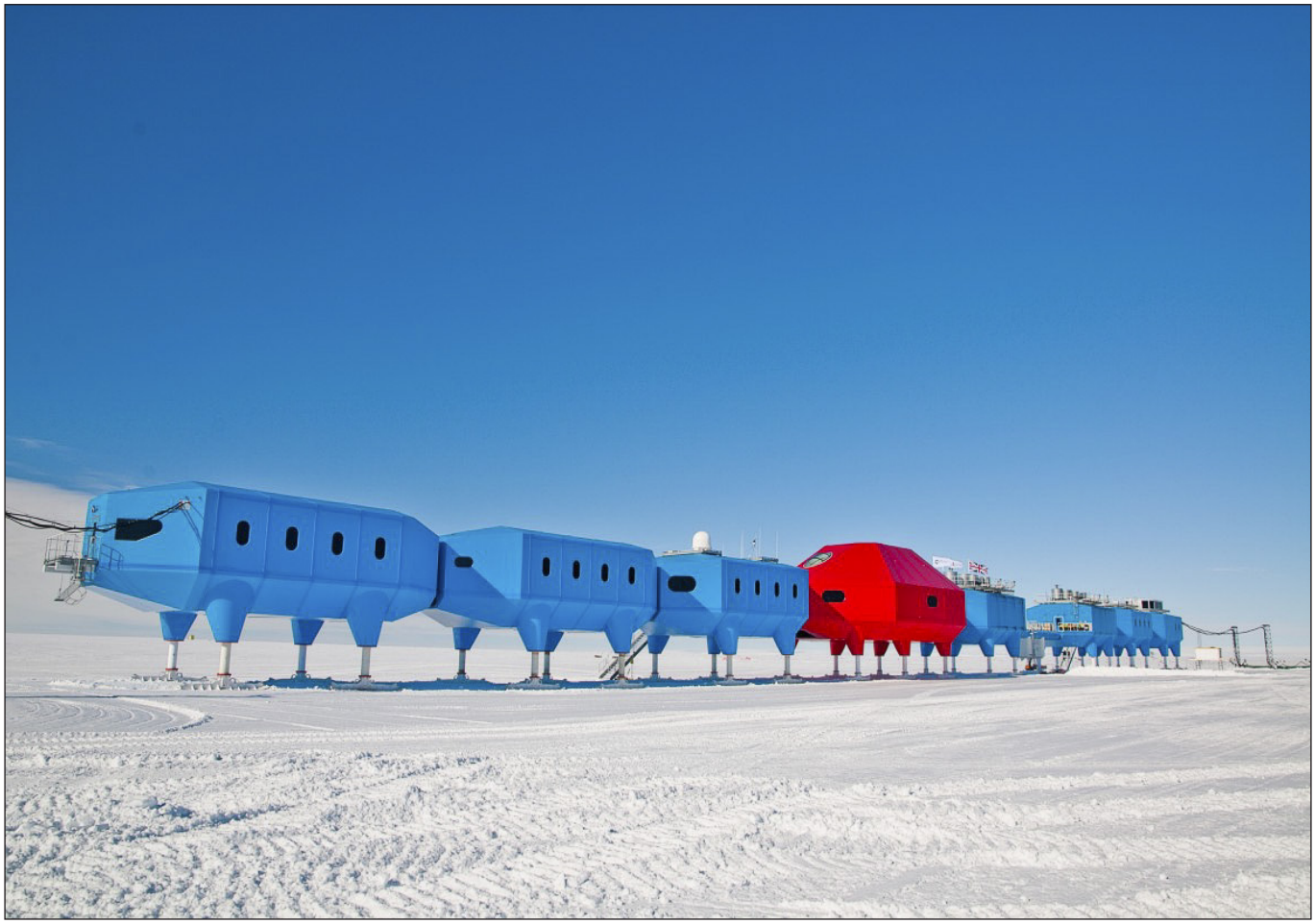
Cherry, who later described the journey in his book 'The Worst Journey in the World', never recovered from the trek. Bowers and Wilson would perish with Scott. The eggs are considered to be among the top ten most important items owned by the Natural History Museum, ranking alongside Archaeopteryx and a piece of moon rock from the Apollo landings. The lowest temperature recorded in their meteorological log for the journey is –77.5 Fahrenheit (–60.8 Celsius) on 6 July 1911.



British Antarctic Expedition Meteorological Log 19 showing lowest recorded temperature

These observation notebooks are of great importance to the historical record for their association with the Terra Nova expedition but they also furthered the understanding and science of Antarctic meteorology. On his return from the expedition George Simpson used the data they had collected to write an important account of the weather and climate of the continent. He concluded that Scott and his team had met with exceptionally low temperatures on their return from the Pole and also demonstrated that the transition from Antarctic summer to winter was far more rapid than previously thought.

This knowledge greatly assisted later expeditions, who would be better prepared for the conditions to be faced, and also highlighted the need for greater understanding of such extreme environments. Indeed that research continues to this day with Met Office staff regularly detached to the British Antarctic Survey research stations on the Brunt Ice Shelf and Adelaide Island.



Halley VI Research Station, Antarctica

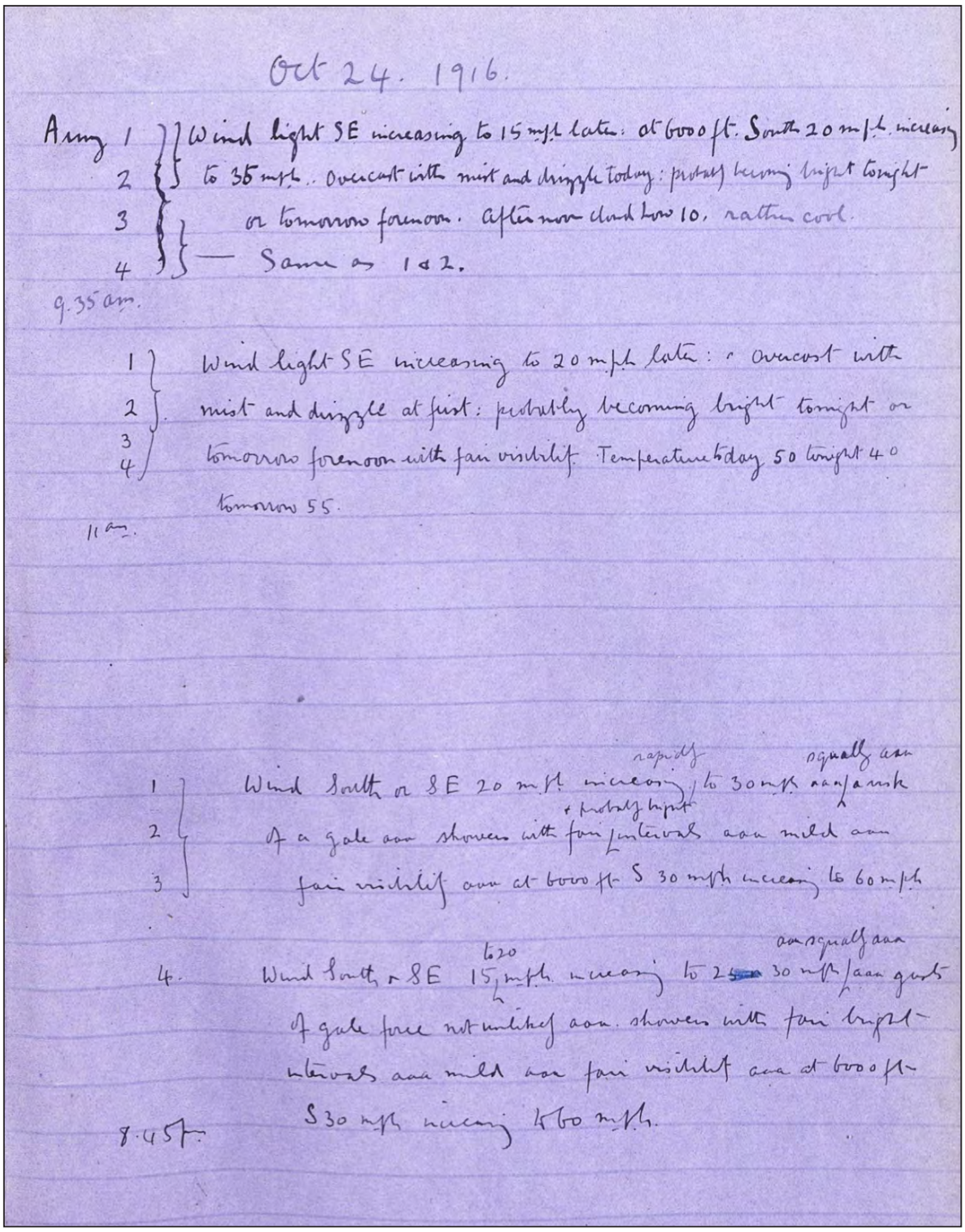
Military forecasting

A different type of adversity was experienced by meteorologists supporting British troops during the World Wars of the 20th Century.

The Meteorological Office was not involved in military forecasting at the start of the First World War. Although support was offered, the response came back that 'the army does not go to war with umbrellas'. Attitudes soon changed and the Meteorological Field Service, universally known as Meteor R.E. was established in the summer of 1915 and operated from the British Expeditionary Force General Headquarters at Montreuil, France. The service was supported by the Meteorological Office in London which became operational 24/7 for the first time.

Meteor provided three key services: gas forecasting to warn of conditions favourable for gas attacks, upper air observations to aid the artillery with high angle fire and the deployment of their artillery spotting balloons, and forecasts for the fledgling Royal Flying Corps. By October 1916 it had become clear that more detailed forecasts were required to assist with military operations and so Ernest Gold, the chief forecaster in France, produced the earliest known operational forecast for British military forces on 24 October 1916.

We don't know for certain whether the German forces also had a forecasting section but historical evidence including comments that the British seemed to have an uncanny ability to predict the ideal weather for military operations implies that perhaps they did not.



Oct 24. 1916.

Army 1, 2, 3, 4 } Wind light SE increasing to 15 m.p.h. later: at 6000 ft. South 20 m.p.h. increasing to 35 m.p.h.. Overcast with mist and drizzle today: probably becoming bright tonight or tomorrow forenoon. Afternoon cloud low 10, rather cool.
— Same as 1 & 2.

9.35 am.

1, 2, 3, 4 } Wind light SE increasing to 20 m.p.h. later: Overcast with mist and drizzle at first: probably becoming bright tonight or tomorrow forenoon with fair visibility. Temperature today 50 tonight 40 tomorrow 55.

11 am.

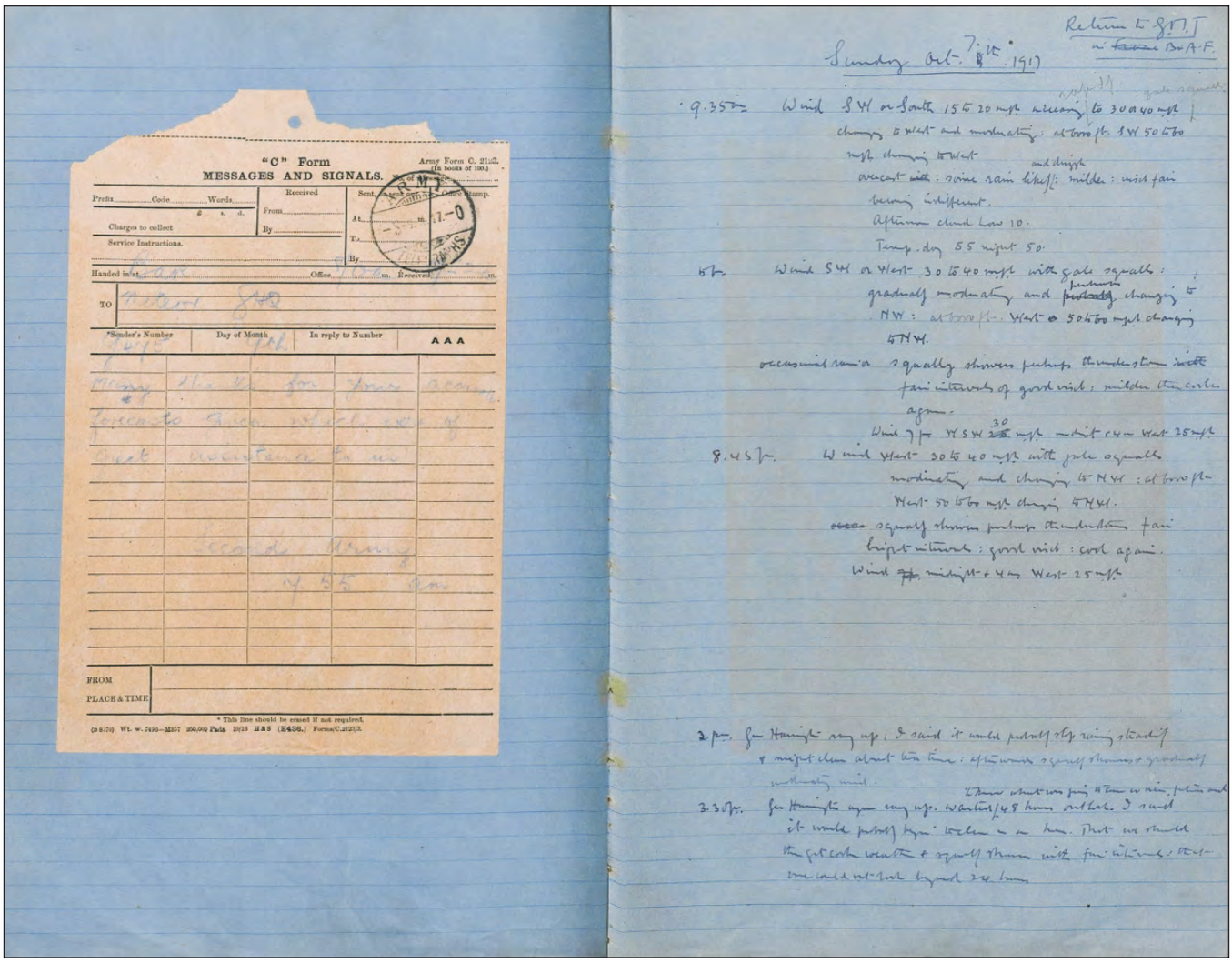
1, 2, 3 } Wind South or SE 20 m.p.h. increasing rapidly to 30 m.p.h. squally and + probably bright
of a gale and showers with fair intervals and mild and fair visibility and at 6000 ft. S 30 m.p.h. increasing to 60 m.p.h.

4. Wind South or SE 15 620 m.p.h. increasing to 25 30 m.p.h. and squally and
of gale force not unlikely and showers with fair bright intervals and mild and fair visibility and at 6000 ft. S 30 m.p.h. increasing 60 m.p.h.

8.45 p.m.

Earliest known Met Office Operational Military Forecast, 24 October 1916

Meteorological information actually proved so useful in the planning of one of the only allied advances during the battle of Passchendaele that one of the senior allied commanders sent a telegram to Meteor R. E. to thank them for their assistance.



Telegram of thanks from Second Army for accurate forecasts

By 1918 weather forecasting had become a firmly embedded element of British military strategy. Met Office personnel played key roles on all fronts in WW2, most famously advising on the planning of Operation Overlord and providing key forecasts in the run up to D-Day.

Conditions in early June 1944 were particularly unsettled and the forecasting teams had already advised against invading on the 5th (which would have meant forces leaving British shores on the 4th) because of poor weather. Stagg's diary reveals just how uncertain he was about advising of better weather on the 6th. It is far from easy to read but this page includes the lines...I am now rather stunned, it is all a nightmare.

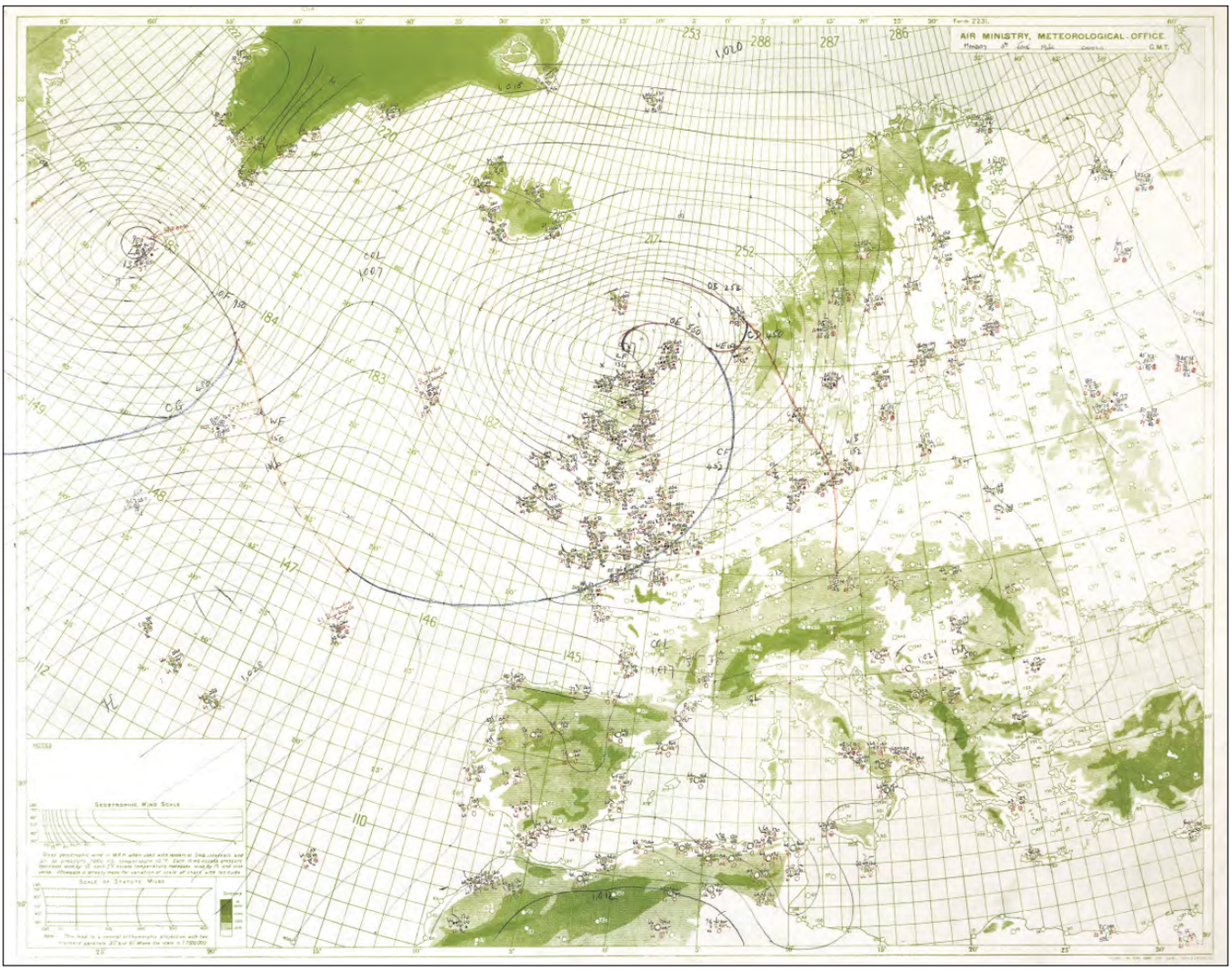
Saturday, JUNE 3, 1944.

Monday, JUNE 5, 1944.

Sunday, JUNE 4, 1944.

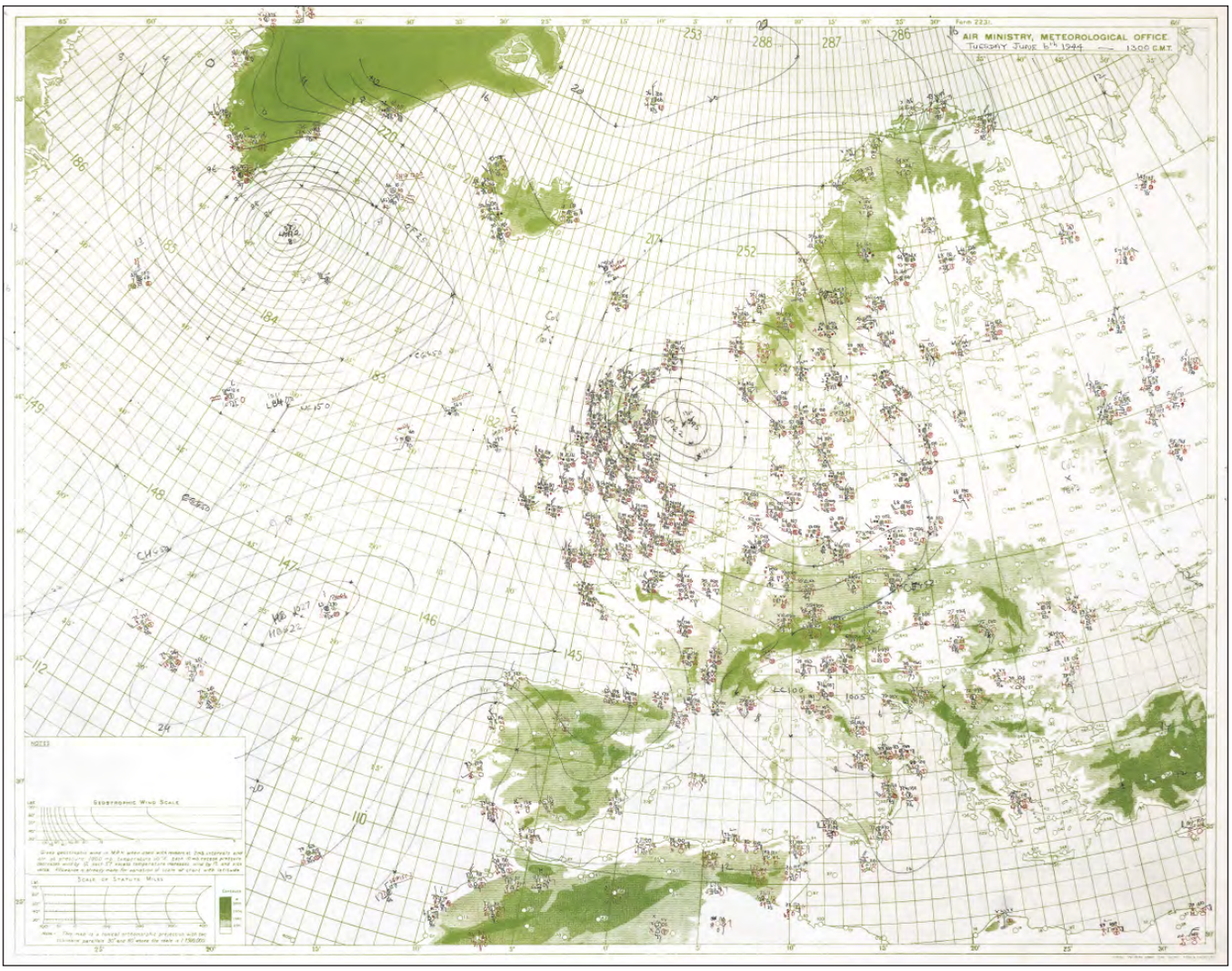
Diary of J. M. Stagg (above), showing his entries for the 3–5 June 1944

Group Captain James Martin Stagg



Met Office Synoptic Chart 0100 5 June 1944

The chart above shows the weather situation at 1 am on 5 June 1944. It was this chart that was used to provide forecast information at the 3 am conference on the 5 June 1944 when Eisenhower declared the invasion 'on'. The chart below shows the position at 1 pm on 6 June. This is known as the 'D-Day chart' and shows conditions during the period of some of the fiercest fighting.



Met Office Synoptic Chart 1300 6 June 1944

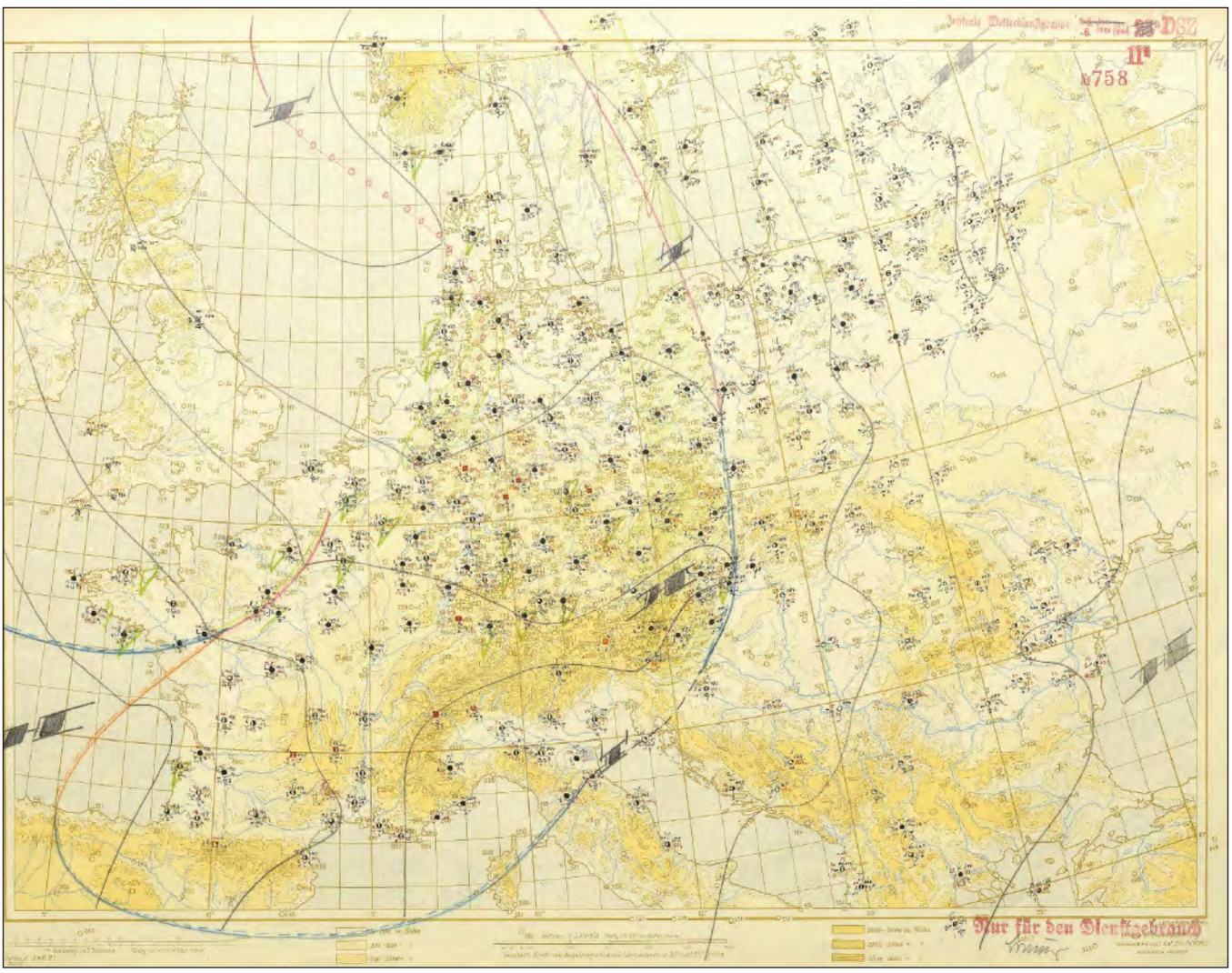
The area of high pressure building on the lower left of the chart from 5 June was expected to move in across the channel during the day but as you can see from the chart for 6 June, by which time troops were fighting on the beaches, it did not advance as much as predicted and conditions were really quite marginal for the channel crossing.

Having said that the poor weather did give the allies the advantage of surprise as German forecasters had advised that they thought the invasion was not possible. It also provided critical days of good weather after the initial invasion to bring in supplies and secure the bridgehead.

Enigma code

The difference between the allied and German opinions about the D-Day weather reflects a key allied advantage. Allied charts show observations across occupied Europe, as can be seen on the 'D-Day chart'. These reveal that they had broken the Enigma code and were able to read German meteorological communications. Indeed looking for the kind of repeating information which occurs in weather observations was part of the methodology used to crack the code in the first place.

By contrast the equivalent German charts show no observations across Britain or the Atlantic because they had not broken allied codes and also lacked air superiority. The resulting significant difference in the availability of weather observations affected forecast accuracy and arguably had a hugely significant impact on the outcome of the war.



Deutscher Wetterdienst (DWD) Synoptic Chart 1100 6 June 1944

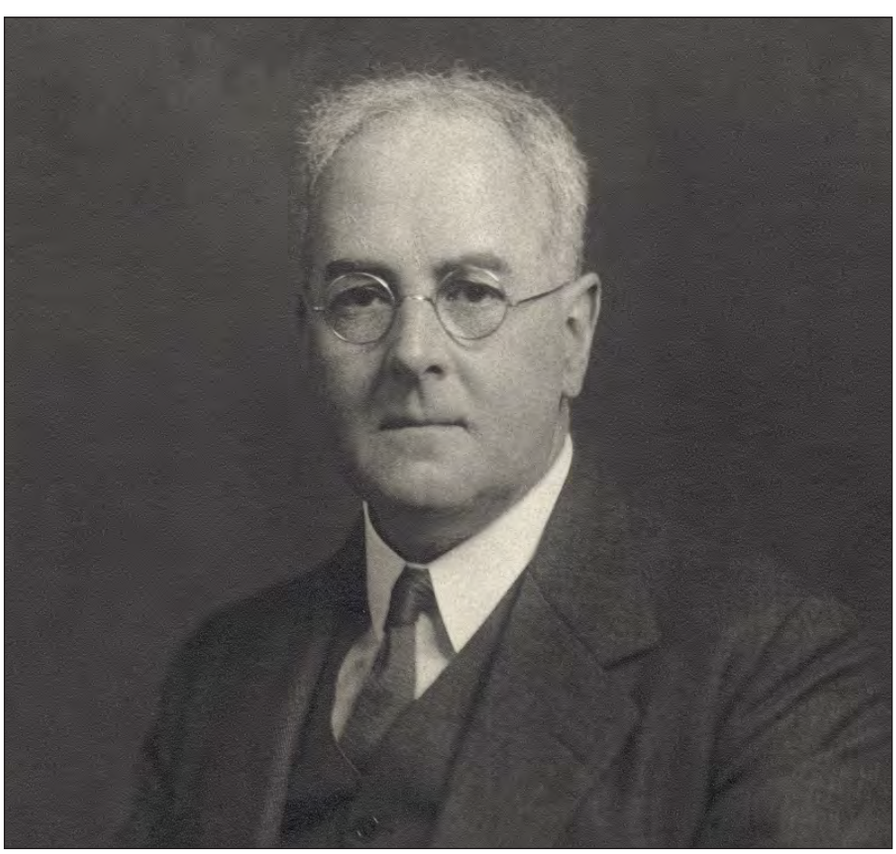
Mobile Met Unit

Weather forecasting remains a key element of military strategic operations and wherever British forces are deployed around the globe they are always supported by the Met Office Mobile Meteorological Unit (MMU). The MMU is a team of Met Office meteorologists who serve as RAF Reserve Officers.

Operational Meteorologist working as part the MMU

Meteorology and computing

No overview of history of meteorology would be complete without mention of computers. A critical, but largely unknown pioneer in this area of meteorological history is Lewis Fry Richardson (below), arguably the father of modern weather forecasting.



In 1922 Richardson published his great work 'Weather prediction by numerical process'. The title might not at first sound all that groundbreaking but in this volume Richardson set out all of the mathematical formulae required to produce a weather forecast using a computer. This was an extraordinary achievement given it was thirty years before the first viable computing machine was in existence. It was even more impressive when you look at Richardson's circumstances at the time of writing. Richardson worked as an ambulance driver during WW1 and developed his theory during rest periods in the trenches. Indeed the draft of his seminal work was nearly lost to history when it was sent behind the lines for safekeeping during the Battle of Champagne and vanished. It turned up months later under a heap of coal!

In his book Richardson not only laid out the basis for Numerical Weather Prediction (the method by which all modern forecasting is achieved) but also described the process by which he imagined his calculations could be carried out in a pre-computer age. In his text, the term computers actually means people carrying out computations – but the description he gives of a central individual controlling hundreds of separate modules and keeping them running in sync is actually remarkably close to the reality of how a computer operates. Several Met Office staff who specialise in software engineering have commented that it is as though Richardson is describing how to build a computer.

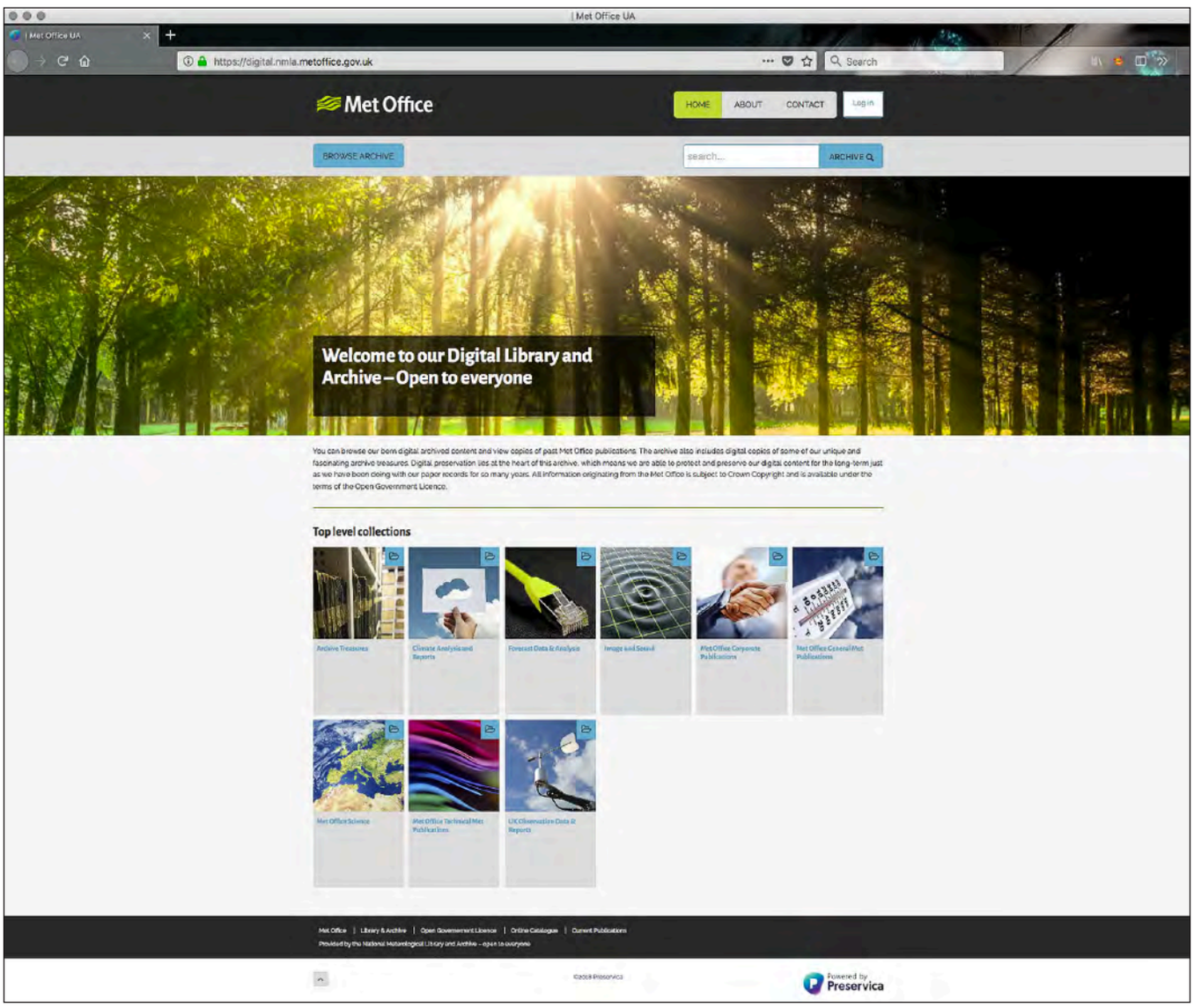
> "Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe. The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the Antarctic in the pit.
>
> A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation. The work of each region is coordinated by an official of higher rank. Numerous little "night signs" display the instantaneous values so that neighbouring computers can read them. Each number is thus displayed in three adjacent zones so as to maintain communication to the North and South on the map.
>
> From the floor of the pit a tall pillar rises to half the height of the hall. It carries a large pulpit on its top. In this sits the man in charge of the whole theatre; he is surrounded by several assistants and messengers. One of his duties is to maintain a uniform speed of progress in all parts of the globe. In this respect he is like the conductor of an orchestra in which the instruments are slide-rules and calculating machines. But instead of waving a baton he turns a beam of rosy light upon any region that is running ahead of the rest, and a beam of blue light upon those who are behindhand."
>
> Richardson, L. F. 'Weather Prediction by Numerical Process' 1922

As modern information technology moves towards exascale computing, the technical challenges include the creation of a brand new computer model of the atmosphere. This has been named LFRic in honour of Lewis Fry Richardson and will be a key part of the next generation of weather forecasting supercomputers.

Digital Library and Archive

In the digital era, archive services are no longer solely tasked with looking after physical paper records. We now care for digitised and born digital records too. It is a developing field, and one which brings with it many complications. In the fast-moving digital world how on earth do we keep something readable on whatever passes for a computer in one hundred or two hundred years' time when it was produced on a piece of software which became obsolete just a few years after it was written.

It is a huge challenge, but also brings great benefits. No longer do you have to come to Exeter to view many of the items mentioned in this factsheet. With the digital era comes the Digital Library and Archive and ours enables us only to care for electronic materials appropriately and securely but also share our treasures with the world.



Screenshot showing one of the Digital Library and Archive web pages

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