British Naval Logbooks from the Late Seventeenth Century: New climatic information from old sources

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Introduction

The recently completed CLIWOC[1] project funded by the EU has demonstrated the value of the climatic information to be found so abundantly in old naval logbooks (Garcia-Herrera *et al*, 2005). This project was, however, confined to the period from 1750 to 1850 and, whilst many logbooks, especially in the UK, survive from much earlier times, they were not included in the analysis. This paper takes the opportunity to examine the oldest collection of logbooks that exist in sufficient quantities to provide a daily, regionally-based, series of weather observations and to gauge their value as sources of scientific data and information. Logbooks of this antiquity are those of Royal Navy officers, lieutenants and captains, preserved in the National Maritime Museum at Greenwich, South East London and in the National Archives in Kew, South West London. They cover the period from 1685 onwards that, fortuitously, embraces both a large part of the Late Maunder Minimum and the coldest phase of the so-called Little Ice Age. The character of the data is examined and some preliminary conclusions are drawn regarding the climate of the period.

Climatic data are abundant for this period, particularly in Europe: ice core records, dendrochronological information, terrestrial and lacustrine sediments combine with a rich legacy of documentary sources to yield a comprehensive picture of the contemporary climate (Jones and Mann, 2004). Equally importantly, the first instrumental data also extend back into the seventeenth century in the form of Gordon Manley's Central England Temperature series, the oldest such data set in the world (Manley, 1974). Luterbacher *et al.* (2002) have forged these sources together to create valuable multi-proxy pressure field reconstructions for the period. It might, therefore, be asked what new insight logbooks can lend to this already well-developed field of study? The answer is three-fold. In the first instance, no new data source should be overlooked in the search for a clear understanding of the changes that climate has undergone in the past centuries. Secondly, and more significantly, the logbook data provide information for a

[1] CLIWOC: Climatological Database for the World's Oceans: 1750 to 1850. www.ucm.es/info/cliwoc .

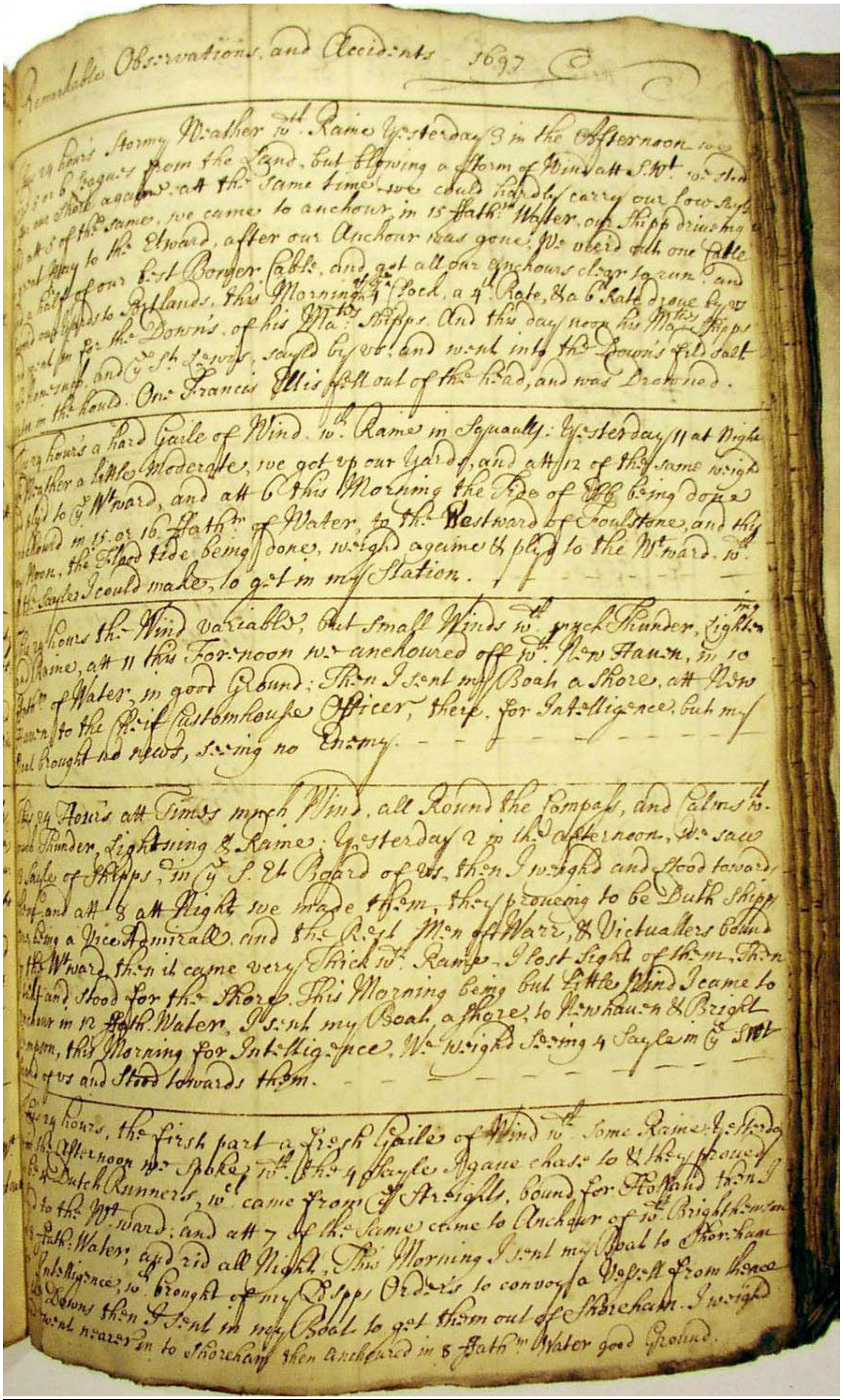
part of the Earth's surface that is notoriously under-represented in such studies – the seas and oceans – and do so in the form of direct observations that are 'non-proxy' in character. Finally, logbook data provide an unrivalled scale of temporal resolution, with observations being made at least daily, often more frequently.

The nature of logbook climatic information

Almost as soon as mariners sailed out of sight of land and needed to maintain a record of their vessel's speed, direction of sailing and other navigational details, some form of account was kept on board ship. Christopher Columbus provides one of the earliest examples of this type of record (Fuson, 1987). From haphazard beginnings, matters became more regularised as the years went by and the size of navies became larger and voyages more frequent. By the late seventeenth century logbooks assumed a form that has endured with only minor changes until the present-day. A typical example of such an early logbook is given in Figures 1a and 1b. These reveal the degree of detail contained within those venerable documents. On the left-hand page were recorded the date, latitude, longitude, bearings, wind directions and ship's course. The right hand side contained a daily account that includes notes on wind force and weather. Other information recorded here were the formal proceedings and accounts of the management of the vessel.

By these means all weather observations are located in space and time; the former by date and the latter by latitude and longitude or, when close to shore, by bearings to observed landmarks. Both, however, require cautious interpretation. Dates in English documents of the period were based on the Julian Calendar, which was then ten days behind the more accurate Gregorian Calendar that was used across much of Europe. The latter was not adopted in England until 1752. Latitude could be determined with reasonable accuracy at this time, but longitude was a problem not fully resolved until the closing decades of the eighteenth century when the marine chronometer had been perfected (Hewson, 1983). Longitudinal corrections can, nevertheless, be applied by plotting the route of the vessel and checking against points of known longitude on the voyage, such as ports of arrival and departure. These issues are discussed more fully in Koek and Können (2005).


Months Years Days
Week days
Winds
Course
Dist. in Miles
Latt. Correct.
Longt. Correct.
Bearing of ye Known land last Seen.
1697.
June.
4th
S.S.W. to the W.S.Wt & S.Wt.
This day Noon the South Foreland N.N.Et. 4 Miles
5th
S.Wt. to ye S.B.Et.
6th
Et. to the S.S.Et.
And all round ye Compass
7th
All Round the Compass.
5 Leagues off.
8th
S.Wt. to ye W.S.W
Calme some part


Remarkable Observations, and Accidents 1697

Figs. 1a and 1b. Facing pages from a logbook typical of the period. These were written by an unknown officer on board HMS Experiment and date from June 1697. Courtesy of the National Maritime Museum.

Observations of wind direction were made, as they are today and had then been for over a century, on the basis of the 32-point compass. As all such records were in the form of magnetic bearings, and corrections for magnetic variation need to be applied to express them by reference to true north. Variation changed, however, through time and space, although studies have now provided detailed reconstructions of this phenomenon with which it is possible to convert any wind direction in magnetic form to its 'true' equivalent (Bloxham & Gubbins, 1985). In the present case, such corrections were minimal.

Weather descriptions, included within the general accounts, were written in the unadorned language of the day, and would have been readily understandable to any contemporary reader. Most remain comprehensible today, if the spelling ('raine', 'rayne' etc.) is idiosyncratic and rules of punctuation applied in an anarchic fashion. The handwriting is often surprisingly clear, and presents few difficulties.

The greatest challenge is offered by the wind force terms, which were included within the general descriptions. These were of a more technical nature, less familiar to those unaccustomed to the ways of the sea and formed part of the arcane vocabulary that mariners employ even today. The Beaufort Scale was not adopted by the Royal Navy until well into the nineteenth century (Wheeler and Wilkinson, 2004), but the logbook entries point unequivocally to the adoption, even in these formative times, of a limited number of widely-used descriptors, suggesting an unofficial precursor to the scale proposed by Francis Beaufort.

The collection of early logbooks held at the National Maritime Museum was used in this study, and a sample compiled from ships sailing in the confined but frequently navigated area of the English Channel. Although some logbooks survive from the 1670s (Wheeler, 2004) they are sufficiently abundant to provide for a daily series of observations only from 1685. The abstracted series concludes in 1700. The sample was comprised of 52 logbooks, with a smaller sub-set of randomly selected duplicate logbooks to act as checks for consistency of the record. The daily series derived from the sample yielded 5500 days of data. These were gathered into a database, the elements of which are listed in Table 1.

The content of the database gives notable testimony to the volume and variety of climatic information that can be abstracted, and inferred, from logbook daily entries. Whilst none of the information is based on instrumental evidence, and much depends upon the judgement of the recording officer, it must be recalled that such officers would have enjoyed many years of experience on board Royal Navy vessels and would have been tutored in the manner of observation, ship management and navigation. Even today it is commonplace for VOSs (Voluntary Observing Ships) to report important meteorological data based on just such judgment-based observations. The published advice to present observers could apply with equal veracity to those of the late seventeenth century:

> Non-instrumental observations are very important and, being estimates, they are dependent upon the personal judgement of the observer. This judgement is the product of training and experience at sea, together with practice in making the observations. (Meteorological Office, 1977, p.37).

Table 1. Summary of climatic data derived from seventeenth century English logbooks.

variable	notes
ship's name	As recorded in the logbook
NMM catalogue reference	The NMM has a printed catalogue of all logbooks in its collections. Currently this is not available on-line.
Julian date	As given in the logbook, but note should be made that the nautical day begins at noon and 12 hours ahead of the civil day.
Gregorian date	At this time the Julian date was ten days behind the Gregorian.
bearings to landmarks	It was common practice when in the English Channel to give location by bearings to known landmarks.
wind force	The original term is entered here.
wind direction	As recorded on a 32-point compass. No local corrections for magnetic variation were required for this period.
weather	As recorded in the logbook (original spellings retained).
Rain, snow, thunder, hail, fog	These are derived data, and columns (yes/no entry) are provided to indicate when the 'weather' text includes any of these distinct elements.
frost/cold day	When the weather text indicates cold or frosty conditions, that inclusion is indicated here.
Beaufort wind force	Each original entry is re-expressed as its present-day Beaufort Scale equivalent (see below).
gale day	If the Beaufort expression is gale force or stronger, it is flagged here.
wind by cardinal quarter	Each wind direction is re-expressed in its appropriate cardinal quarter (N, S, E or W)

The seventeenth century wind force scale

The most well-known summary of the wind force scale said to be used by mariners of the late seventeenth century is that offered by Daniel Defoe in his collection of letters and accounts that describe the 'Great Storm' of 1703 (Defoe, 1704). This scheme is reproduced in Table 2. It is interesting to note the similarities to the Beaufort Scale, but it is clear that it does not compare in every respect with the vocabulary found in the logbooks of the period.

Defoe claimed the terms in Table 2 to have been in popular usage, and most were indeed encountered in the logbook sample, but no record of either 'top sail gale' or of a 'fret of wind' was found, while 'fine breezes' were only rarely encountered. On the other hand, there are terms in popular use at the time that appear frequently in the database, for example 'moderate gales' and 'blows hard', which Defoe did not recognize. The principal logbook vocabulary of the age is summarized in Table 3 in which the eleven most widely used terms are included. Over 70 different wind force terms were found but, as is evident from the cumulative frequencies, the eleven most frequently used items account for nearly 88 per cent of all entries, and many of the remainder were used only once or twice. Some, but not all, of these terms survived to be adopted a century later by Francis Beaufort. The evolution of the vocabulary during that period and the means by which the scales have been rendered comparable have been reviewed in Wheeler and Wilkinson (2005). Fortunately most of the archaic wind force terms could be expressed in present-day Beaufort equivalent descriptors, leaving only some 1 per cent of wind force entries that could not be translated.

Table 2. Defoe's 'table of winds' as described in his account of the 'Great Storm' of 1703. Defoe did not number his scale, the system being adopted here only for purposes of clarity. It is not intended to translate into Beaufort's terms.

Term	grade*	Term	grade
stark calm	0	a top sail gale	6
calm weather	1	blows fresh	7
little wind	2	a hard gale of wind	8
a fine breeze	3	a fret of wind	9
a small gale	4	a storm	10
a fresh gale	5	a tempest	11

Table 3. Absolute and cumulative frequency (over all entries) of usage of the 11 most widely used wind force terms from the late seventeenth century. † indicates terms that have appeared in one or more of the Beaufort Scales used since 1806.

Rank of usage	Term	Frequency	Cum. Frequency (%)
1	fresh gales†	1261	30.6
2	little wind	621	45.7
3	moderate gales†	457	56.8
4	hard gale	342	65.1
5	small gale	215	70.2
6	blows hard	207	75.2
7	variable	134	78.5
8	fine gales	129	81.6
9	blows fresh	101	83.1
10	calm†	99	85.5
11	strong gales†	99	87.9

Preliminary findings from the database

Careful use of the vocabulary allows the database to be completed along the lines noted in Table 1. From the resulting daily series it is possible to estimate the monthly means and counts that summarise the overall trends and changing climate of the period. The preliminary findings can be summarised as follows:

Wind direction

A general picture of prevailing wind directions is recreated in Table 4 in which the directional frequencies are resolved to monthly level but are based on data that have been converted from 32-point to 4-point form, each original entry being classified into one of the cardinal points.

Table 4. Mean monthly wind directions (in proportions of each month) for 1685-1700.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	year
N	0.24	0.16	0.22	0.18	0.25	0.17	0.22	0.17	0.18	0.19	0.19	0.20	0.20
E	0.25	0.26	0.25	0.23	0.28	0.20	0.20	0.14	0.13	0.23	0.21	0.19	0.21
S	0.13	0.21	0.20	0.22	0.20	0.23	0.12	0.19	0.15	0.22	0.20	0.24	0.19
W	0.37	0.37	0.34	0.37	0.27	0.40	0.47	0.51	0.54	0.36	0.40	0.37	0.40

This is the first time that it has been possible to view the behaviour of the wind over the sea for such distant times at anything other than the coarsest of resolutions. Moreover, whilst contemporary land-based records are by no means absent, they are dogged by the fact that wind direction is profoundly altered by the boundary layer conditions and may make it unrepresentative of the synoptic states that prevailed at the time of their measurement. This problem is not wholly resolved by the use of these marine data, but they represent a marked improvement on land-based observations. Westerlies, not unexpectedly, dominate the picture, but attention should be drawn to the higher frequency of easterlies in late winter and early spring. More specifically, Figure 2 shows the changing degree of westerliness from 1685 to 1700 using data aggregated to the monthly statistics.

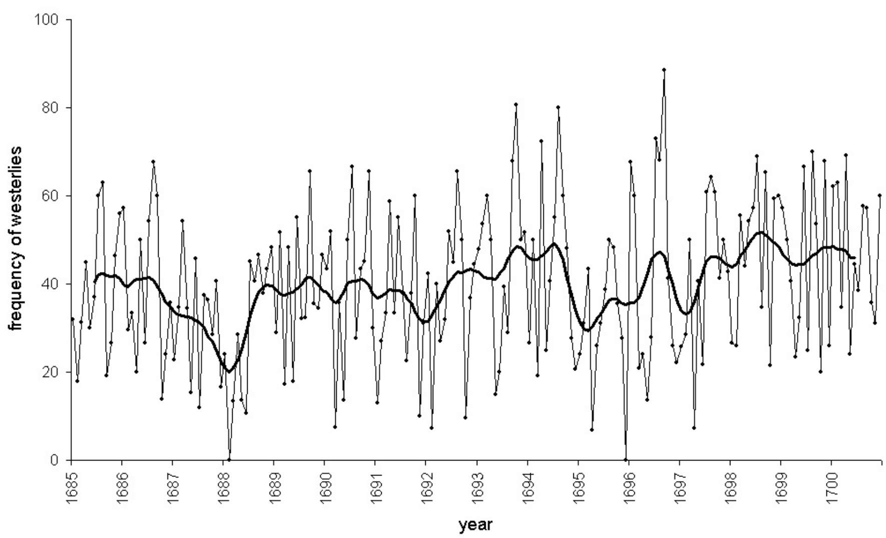


Fig. 2. Monthly index westerliness based on logbook observations. A Gaussian filter running mean is superimposed.

This important parameter is closely related to, but not identical to, the North Atlantic Oscillation index (the correlation between the two over the study period is r = 0.363 for the year, but r = 0.533 for the period December to February: both are significant at the 0.01 level). Slonosky *et al.* (2001) have suggested that the region in question – that of the English Channel – is a key location for the study of synoptic scale climatic behaviour over a much wider area of the north-east Atlantic region. It is important, therefore, to recall that this 'index of westerliness' is not a proxy dataset, but is based on direct observations of the conditions of the day and that is may represent conditions that prevailed beyond the immediate limits of the study region. There is a high degree of temporal detail, and particular periods can be readily identified for future study. Among them, those around 1688, 1695 and 1697 are noteworthy, as are those particular months when westerlies appear to have been absent (February 1688, March 1690, February 1692, December 1695 and April 1697). This finding is important because it emphasises the inherent variability of climate at this time. The episodic character of the periods in which westerlies are poorly represented shows also that the coolness of the British Isles at this time – as witnessed by the Central England temperature series (Manley, 1974) – cannot be accounted for by persistent winter easterlies drawing cold polar continental air towards the region and that any tendency to such meridionality manifests itself in only a discontinuous fashion. Nevertheless, the record suggests that winter easterlies were generally more frequent at this time than is the case today by a margin of some 10 per cent.

Gale frequencies

The database's gale series provide a particularly valuable data set that suggests that gales were far more frequent in the closing decades of the seventeenth century than they were three hundred later at the close of the twentieth (Figure 3). More importantly, as Wheeler and Dominguez-Suarez (2006) have shown, the greatest increase in gale frequencies occurred during the period March to October and, remarkably, they were less frequent in the winter season. This is probably accounted for by the steeper summer temperature gradients between the sub-tropical and high latitudes during summer, drawing the polar jet southwards and providing the system with a greater potential for active cyclonic development than is the case in the warmer summers that currently prevail. The appearance of well-developed continental anticyclones in winter might provide for 'blocking' situations in which the cyclones would adopt paths that avoided the British Isles, thereby decreasing the incidence of gales at that season.

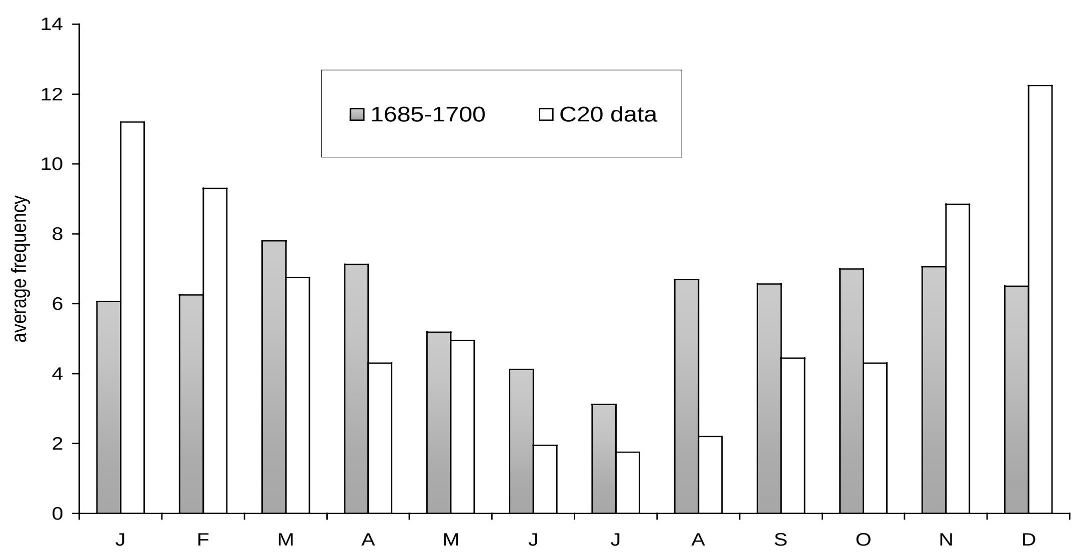


Fig. 3. Monthly mean frequencies of days with winds of Beaufort force 8 or more for the period 1685-1700 (shaded) and for the mid-twentieth century.

Precipitation

Even today, measurement of precipitation at sea is fraught with problems. In the late seventeenth century no attempt was made to measure the depth of rainfall but officers made careful note of precipitation when it was seen, usually taking care to distinguish between snow, hail and rain. The latter might be further qualified by the use of terms such as 'heavy', 'light', 'showers' or, even, 'small rain' and 'mizzling'. The latter probably referring to drizzle (it is a term encountered in some parts of Britain today). Typical logbook entries would read "squalls of raine [sic] and hail", or "the weather frosty with snow". The most common entry would be in the form of a reference to wind force, followed "with rain" or "with snow".

With these observations it is possible to reconstruct a series of rain days. Figure 4 shows this series, in which the daily data have been aggregated into monthly counts. The average number of rain days per year was 87, reaching a maximum of 140 in 1697 and a minimum of 50 in 1695. Unless the climate had been notably drier at this time (and there is no evidence that it was) such data suggest under-recording of precipitation, emphasising the need to concentrate on the patterns of relative and not absolute frequencies. Greater care yet is needed with reference to fog, and it is evident that the term was used to embrace conditions that would not today qualify for such an entry and was used as a general description for poor visibility, be it fog or mist *sensu stricto* or those times when sea spray might have obscured visibility; fog [sic] was often recorded with strong gales.

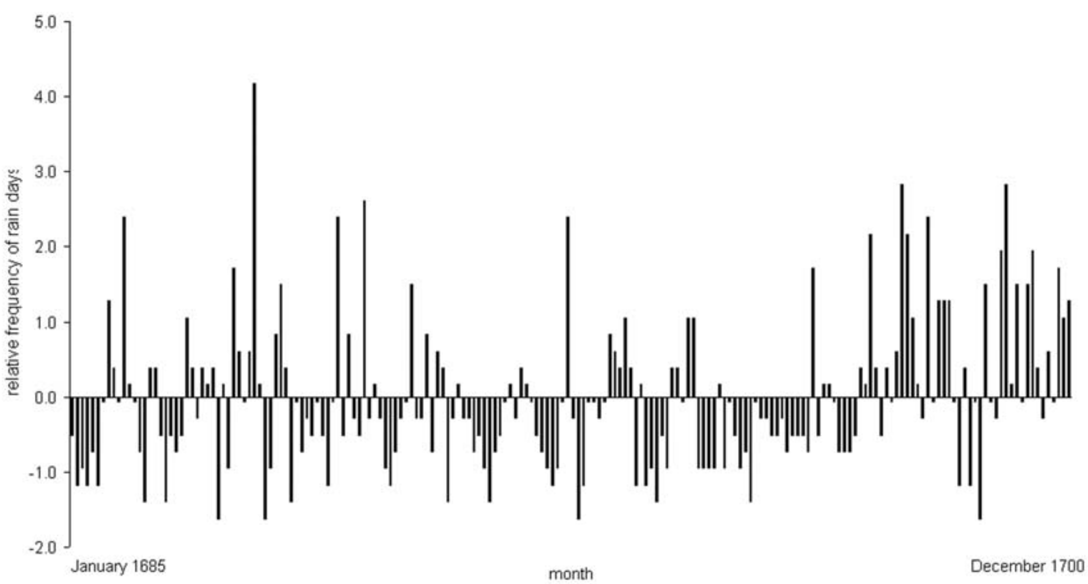


Fig. 4. Series of rain days (by months) for the English Channel 1685 to 1700.Units are standard deviations about the overall mean.

Allowing for the fact that there may be unavoidable under-recording of precipitation, it is still possible to recreate the patterns of wet and dry spells, and Figure 4 reveals the predominantly wet conditions that characterised the close of the study period and the drier conditions of the immediately preceding months.

Cold weather

No ships of this period carried thermometers but, perhaps because of the difficulties that frost and very cold conditions made for ship management, cold weather tended to be noted. Hot weather was not accorded the same degree of attention. The CET for this period is expressed in monthly form only, and daily temperature data are rare for this period, nevertheless, individual cold days are chronicled in the logbooks sometimes identifying protracted periods of such conditions and defining with precision the start and conclusions of such spells of weather. The most marked of these are summarised in Table 5, in which the corresponding wind directions and CET anomalies are included.

It is informative to note that these spells coincide with notably cold months in the CET and that they are commonly the result of outbreaks of easterly winds. They give, however, a finer degree of resolution and detail to the temperature regime than has hitherto been possible.

Table 5. Summary of cold spells noted in the logbooks for the period 1685 to 1700.

dates (NS) of cold weather spells	**description**	**winds**	**CET anomaly for the month (deg. C)**	**details**
10-13 & 17th Jan. 1685	frosty	between NE and S	-2.1	Recorded at the Downs on HMS *Deptford* by an unknown officer
29th Dec. - 7, 9-11, 13, 15 & 16th Jan. 1689	frosty and frosted hard	exclusively from NE	-2.1	Recorded at Portsmouth on HMS *Elizabeth* by an unknown officer
31st Jan. & 4, 5, 11, 14, 16, 19th Feb. 1692	cold and frosty	Mostly NE until 11th Feb, then between N and E	-2.6 (Feb.)	Recorded by Lt. W Bridgman on HMS *Hope* at the Downs. From 10th February the record is from HMS *Centurion* (officer unknown) off the southern Irish coast.
29th Nov. – 3rd Dec. 1693	frosty and cold raw	Winds mostly NW	-0.3 (Dec.)	Recorded at Plymouth on board HMS *Devonshire* (officer unknown)
14, 17-19 & 24th Jan. 1694	frosty	Winds between NW and NE	-2.6	Recorded at St Helens on board HMS *Dragon* (officer unknown)
15-17th March 1699	frosty	Winds NE to ESE becoming S on 17th	-0.6	Recorded off North Foreland on board HMS *Bedford* (officer unknown).

Conclusions

The use of logbooks for purposes of climatic reconstructions is still very much in its infancy. Nevertheless, as the above example shows, the abstracted and carefully treated data can provide a unique insight into the climate of past centuries. For the first time, scientists can see the how the oceanic weather was behaving at a daily scale of resolution, and can aggregate these data to recreate a longer-term, climatic impression at monthly, seasonal or annual scales should it be necessary. Equally importantly, the data source has a notable degree of homogeneity; the vocabulary is tolerably consistent and the methods of observations in all probability identical between officers. While logbooks exist in such huge quantities as they do (over 120,000 exist in UK archives for the period 1680 to 1850) there is abundant scope for this modest exercise to be repeated at a much larger scale, as has been done by the EU-funded CLIWOC (Climatological Database for the World's Oceans:1750 to 1850) cited in the opening paragraph.

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