likely scenario to the customer. With technology allowing more automation in some areas, the role of the meteorologist has shifted a little more towards that of an expert consultant, tasked with giving the customer the information they demand in a clear and timely manner.

The future will bring further challenges and opportunities. The further development of very high-resolution models, which simulate more explicitly processes such as convection, is one which brings both. Such models might allow forecasters to have higher confidence in severe or extreme convective events. For example, on 28 June 2012, MeteoGroup’s WRF model predicted supercell thunderstorms across the Midlands; later that day several developed, bringing very large hailstones and a couple of tornadoes. However, such models also have a very high chance of being misleading if the output is simply sent to customers. This type of output is great for meteorologists in giving extra information and guidance on these extreme events, but the chance of the simulation getting the storms in exactly the right place is low. Thus, careful management of this data is of key importance.

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New insights into the history of the Campbell-Stokes sunshine recorder

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When, in 1853, J. F. Campbell designed his first sunshine recorder, he could hardly have thought that 160 years later the instrument would still be in use, having become the most commonly-used device to measure hours of bright sunshine across much of the world since the 1880s, and playing a significant role in helping us to understand climate in the context of current climate change. Little is known, though, of the establishment of the Campbell-Stokes recorder as the standard instrument in meteorological stations across the United Kingdom and worldwide, although some insights were given by Stanhill (2003). The present paper presents an overview of Campbell’s life, along with the principal stages in the development of the Campbell-Stokes recorder, from its initial design in 1853 to the improvements made thereto by G. G. Stokes in 1880.

The life of John Francis Campbell

John Francis Campbell (Figure 1), also known as Young John of Islay, was born in Edinburgh in December 1821. He spent his childhood on Islay (Inner Hebrides), which had belonged to Campbell’s family since the 1720s. The aristocratic lineage of his family did not stop him getting to know the Gaelic-based culture of the island from direct contact with the local inhabitants. Hence he learnt the Gaelic language and handicraft techniques, which would later influence his adult life. After receiving secondary education at Eton, Campbell started law studies at the University of Edinburgh, although he was more interested in the natural sciences.

The bankruptcy of his father in the late 1840s forced the Campbells to sell their country estates, including the one on Islay. The young Campbell was forced to move to London in the early 1850s, where he worked as a secretary in different jobs, such as for the Board of Health and the Lighthouse Commission. He was active in different scientific fields, including the natural sciences, photography and optics, was an enthusiastic traveller and developed a reputation as an authority on Celtic folklore (Anon., 1885).

He was a modest man and did not seek fame or fortune from his work (Anon., 1885). As a result of his personality, he was considered an eccentric and was not always understood by his contemporaries. He was proposed as a candidate for the first Chair of Celtic studies at the University of Edinburgh in 1883 but declined the offer, preferring not to be tied down by a position or to be fitted with spikes and be pelted with jaw-breakers, which clearly points to an attitude of hostility towards the academic world.

Having withdrawn from his last post, during the final years of his life Campbell focused mainly on his scientific activities, as can be seen in his manuscript ‘Thermography’ (Campbell, 1883). He spent the winter months in Cannes (France) and died there in February 1885, being buried far from his beloved Highlands.

More on the life of Campbell can be found at http://www.islayinfo.com/john_francis_campbell.html and http://www.scottishrepublicanssocialism.org/Pages/SRSMArticlesJohnFrancisCampbellTheFolkHeroofCelticScotland.aspx

Campbell’s first sunshine recorder

It is well-known that Campbell designed his first device to measure the duration of sunshine in 1853; what is less known is what motivated him to do so. It is quite possible that his interest in photography and optics influenced his early thoughts on how to measure the heat of the sun. He commented that his interest in optics and...
History of the Campbell-Stokes sunshine recorder

was replaced by a solid sphere of glass (Figure 2(b)). The instrument was described by Campbell in a paper entitled ‘On a New Self-Registering Sun Dial’, published in the Report of the Council of the British Meteorological Society (Campbell, 1857).

Campbell’s first sunshine measurements

We have already learned of Campbell’s initial motivation for designing a device for measuring the sun’s heat. But why and when did he become interested in using this device as a meteorological instrument for measuring sunshine duration?

In order to answer this question, we need to recall that he was the Secretary of the General Board of Health in London during this time. Specifically, a crucial event may have been the cholera outbreak in London in 1854 (Anon., 1855). One of the actions taken by the Board of Health after this outbreak was to set up 13 new meteorological stations in order to complete the previously existing network in London, with the aim of studying the weather conditions during the cholera outbreak. One of these new stations was the building hosting the General Board of Health in Whitehall. In a report by James Glaisher, Superintendent of the Department of Meteorology at the Royal Observatory of Greenwich, it was stated that Campbell and John C. Haile were the observers in Whitehall (Glaisher, 1855). In this temporary observatory, they made two observations per day of different meteorological variables.

In his report summarizing the weather conditions during the cholera outbreak, Glaisher stated that it appears that the high day temperature of London has generally been below that of the surrounding districts; nor is this remarkable, the sun’s rays having first to penetrate the thick atmosphere which generally overhangs all large towns and cities, but more particularly London, and for this reason the duration of high day temperature is shorter than in the country. In order to support this description, Glaisher added an interesting note, referring to Campbell’s device, to our knowledge for the first time:

During the months of September and October 1854 J. Campbell, of the Board of Health, kindly furnished me with pieces of black ribbon which he had placed daily in the focus of a spherical lens at the Board of Health and which, whenever the sun shone, was marked by a burnt line, or on partially clear days by a series of holes. The duration and time of sunshine was thus shown by this ingenious contrivance of Mr. Campbell’s, and would have been highly valuable in this investigation had a similar apparatus been simultaneously in action in the suburban districts (Glaisher, 1855). Several years later, Campbell mentioned that another instrument had been installed at Niddry Lodge on Campden Hill,
Kensington, a suburban area in west London (Campbell, 1857; 1865), where he lived (Campbell, 1879b).

Hence, it is obvious that Campbell himself performed daily observations of sunshine duration, at least during the first months, in the Board of Health’s provisional meteorological station. Campbell was aware, especially because of his position as secretary of the Board, of the important role of sunlight in the context of human health, as well as the role it played in the process of the cholera epidemic. Thus he started to perform daily measurements in September 1854, while making the standard daily observations established by the Board of Health. A few months later he devised a method, using a bowl of mahogany, in order to obtain a six-monthly record, perhaps for easier maintenance. Systematic measurements started during the winter of 1854 (Scott, 1885). Campbell’s sundial was in continuous operation in the same building for two decades, until the winter solstice of 1874, even after the disappearance of the Board of Health in 1858 and his reassignment as secretary of the Lighthouse Commission. Indeed, Haile continued to be in charge of the recorder until his retirement in the mid-1870s (Campbell, 1865; Scott, 1885).

The Campbell recorder at the Kew and Greenwich Observatories

Just before Haile’s retirement, Campbell demonstrated and explained his instrument and records to the head of the Meteorological Office, who approved them (Campbell, 1880). This meeting appears to explain the transfer of Campbell’s instrument to Kew Observatory after the last bowl was measured in Whitehall in the winter of 1874 (Anon., 1875). His original instrument was used at Kew until the summer of 1897; in all over 80 bowls, one for each half-year, were used between 1854 and 1897 (Anon., 1898). Roscoe and Stewart (1875; 1884) studied the cavities made in these wooden bowls from 1858 to 1882 and developed a method to estimate the volume of the hollows, which led them to make a connection between sunshine and sunspot frequency.

In addition, during the first months in the new location, different experiments were in progress by Kew staff in order to obtain daily records (Anon., 1875; Scott, 1877). Specifically, after receiving Campbell’s recorder and the entire series of bowls in 1873, Robert H. Scott started to consider how to perform daily records, as it is obvious that the plan of hollow wooden bowls is not suitable for such a purpose, in as much as the track of the sun for each day overlaps that for the preceding day, and the result is, at best, merely a rude representation of the general effect of the sun’s heat (Scott, 1877). It is worth mentioning that Kew staff may have been unaware of the test for daily records performed by Campbell in 1854, which was only mentioned by Glaisher in 1855 and was not public knowledge.

Scott conducted experiments to obtain daily records using a ribbon or tape inside the bowl, recognizing that Campbell had already explained this system in the description of the instrument made in 1857 (Campbell, 1857). With the assistance of R. J. Lecky and S. Jeffery, who worked with him at Kew Observatory, Scott devised a system to hold the strip of paper by means of clips along the inner surface of a ring which is concentric with the spherical lens, and whose radius is equal to the radius of the lens plus its focal length. This ring is attached to a vertical circle, along which it is moved to correspond with the varying declination of the sun (Scott, 1877). The material used for the paper was thin millboard, and he showed a table with the results from September. It seems, however, that the improvements made by Scott were not considered entirely satisfactory, and he and his colleagues continued working on it at the Meteorological Office, resulting in the modifications suggested by Stokes in 1879, which are detailed in the next section.

Independently of this work at Kew, there was, in 1876, a request from the General Register Office of England that, because of its impact on public health, sunshine duration should be recorded at the Royal Observatory in Greenwich (Ellis, 1877). Consequently, George Biddell Airy, the Astronomer Royal at Greenwich, wrote to Campbell enquiring about the possibility of obtaining a sunshine recorder, and one was installed there in May 1876 (Ellis, 1877; 1880). Campbell was on good terms with Glaisher at Greenwich Observatory, and with his successor, William Ellis (Campbell, 1880). The instrument provided by Campbell to the Royal Observatory consisted of a very accurately-formed glass sphere, measuring four inches in diameter, which was manufactured in February 1861 by James Chance of the Birmingham Glass Works (Campbell, 1865; 1879a). The sphere was supported concentrically within a well-turned hemispherical metal bowl, which was manufactured by Sir William Armstrong at his Newcastle workshops and had engraved upon it the motto ‘Horas non numero nisi serenas’ (‘only the hours that are serene count’) (Campbell, 1879a) (Figure 3). Daily measurements were performed at Greenwich Observatory with a strip of some material being fixed in the bowl, which is removed after sunset, and a new one fixed ready for the following day (Ellis, 1877). Prior to using it, Campbell tested the instrument and found to work well upon black Indian-rubber cloth fixed upon the metal surface, with a waterproof solution, and changed daily, clearly pointing out that such daily observations belong to an observatory supervised by meteorological observers. From Campbell’s words we know that at least some daily measurements were made in London in 1874 with a set of mounted pliable bands (Campbell, 1883), which means that daily measurements were performed before the improvements made by Scott in the measurements at the Kew Observatory.

Further improvements and institutionalization

In the late 1870s, George Gabriel Stokes, a mathematician and physicist at the University of Cambridge, received a request

Figure 3. (a) Sunshine duration recorder, with the metallic bowl, delivered by Campbell to Greenwich Observatory and in use from May 1876 to the end of 1886 © National Maritime Museum, Greenwich, London, Repro ID AST0770 http://collections.rmg.co.uk/collections/objects/10932.html.) (b) Engraving of the Greenwich Observatory from 1880, with Campbell’s recorder in the foreground © National Maritime Museum, Greenwich, London.)
from the Meteorological Office to improve the modifications made to Campbell’s instrument by Scott at the Kew Observatory (Scott, 1877). The main improvements suggested by Stokes consisted of substituting the bowl with a metallic semi-ring with grooves to hold the cards used for daily measurements, a new platform to support the half ring, and the use of three different cards for the equinoctial, winter and summer seasons (Stokes, 1880).

The Meteorological Office accepted these modifications, and from then the instrument was adopted across the United Kingdom (Scott, 1885) although at some stations, such as Greenwich, Campbell’s design for daily measurements remained in use for some years. Overall, the final design suggested by Stokes is almost identical to the device we know as the Campbell-Stokes sunshine recorder (Figure 4), as only minor modifications were subsequently made in order to standardize its size, material and types of cards (WMO, 2008).

Furthermore, the modifications suggested by Stokes attempted to solve deficiencies in Campbell’s previous instruments at Kew and Greenwich by means of a cheaper system, and by ensuring that it should demand little skill on the observer’s part in the placing of the cards (Stokes, 1880). It is odd that Stokes refers in the text to Mr. Scott’s modification of the instrument in order to perform daily measurements at Kew (as described above). A few sentences later he pointed out that the most obvious way of supporting the slip would be to make it rest against the inner surface of a hemispherical bowl, which has been the plan adopted at the Royal Observatory (Greenwich). Thus, Stokes omits Campbell’s name as the author of these modifications made in Greenwich, which is quite strange as Ellis had already described the modifications made by Campbell three years earlier (Ellis, 1877).

Furthermore, in the discussion section of the paper published by Stokes, Ellis supported the instrument designed by Campbell, arguing that the paper written by Stokes appeared to give an impression that in the Greenwich instrument there was considerable liability to error in placing the strips in position. The plan was perhaps suitable only for an observer of some experience, but he might mention, that with the appliances provided, an error in this respect was of rare occurrence (Stokes, 1880). Thus, it seems that Stokes, or the Meteorological Office itself, attempted to conceal Campbell’s authorship of the instrument placed at the Greenwich Observatory, as well as his contribution to the design by the Meteorological Office in the second half of the 1870s.

Indeed, a few years later Campbell wrote some sentences that seem to relate to this: A known invention, if worth anything, is apt to spread like a ring wave started by a stone, and the inventor like the stone, is apt to disappear…This small inventor has often been amused at being ignored by those who honoured his small work with notice. From that human weakness sprang ‘patents’; to protect interests of more solidity. None of these contrivances are ‘patents’. Being here printed, nobody can patent them (Campbell, 1883).

From these lines we can assume that Campbell considered that the Meteorological Office, which years before had ‘honoured’ his instrument, had ignored it possibly due to its interest in patenting the instrument and making a profit from it. Moreover, in the same publication Campbell appears to criticise the modifications made by Stokes, or at least to defend his own instrument: for example, Various devices have been adopted which are intended to facilitate the placing of materials in frames, at latitudes which these frames suit when properly set. The original device projects a moving picture of the sky from zenith to horizon upon a surface, in true perspective, in any latitude. All other devices fail in proportion to their departure from the principle of concentric spheres (Campbell, 1883).

Further evidence of this underestimation of Campbell’s contribution to the sunshine recorder adopted by the Meteorological Office can be seen in the Reports of the Kew Committee. The report of 1880 explained that the recorder, including the modifications by Stokes, had been installed at the Observatory and also noted that Campbell had visited the station, perhaps to observe these modifications (Anon., 1880). Subsequently, in none of the following reports from 1880 to 1910 was Campbell’s name mentioned, and it is only after 1911 that the ‘Campbell-Stokes recorder’ is specified as the instrument used for measuring sunshine duration.

In the annual reports made by Greenwich Observatory, it is clearly specified that the recorder used since 1876 is the instrument provided by Campbell. In June 1886 it is explained that a modification of the Campbell form of instrument, as arranged by Sir G. G. Stokes for use at the observing stations of the Meteorological Office was introduced to the Greenwich Observatory (Anon., 1889). It is then written that a very complete account of the Campbell-Stokes instrument is given in the Stokes publication (Stokes, 1880). Thus, in this report by Greenwich Observatory, the name of Campbell-Stokes is used for the final design by Stokes, but is omitted in the reports by Kew Observatory and by Stokes in his publication when the instrument was first introduced.

In 1888, Ellis, now president of the Royal Observatory in Greenwich, presented a study at the Annual General Meeting of the Royal Meteorological Society (Ellis, 1888). Therein he explained that the new Campbell-Stokes recorder had been installed in the Observatory, this being the first time that, to our knowledge, the name ‘Campbell-Stokes’ was used in the Quarterly Journal of the Royal Meteorological Society. There was a subsequent increase in the use of the expression, which implies that Campbell-Stokes became the name to be used when referring to Stokes’ final design.

We believe that the use of ‘Campbell-Stokes’ came from pressure from the staff of the Royal Observatory, or perhaps from scientists or manufacturers who considered that the addition of Stokes’ name would help to promote the instrument, as suggested also by Stanhill (2003), although we have not found evidence for this hypothesis.

Future of the Campbell-Stokes recorders and records

With the increase in the automatic measurements of sunshine duration that have...
become available in the last few decades (e.g. Kerr and Tabony, 2004), the meteorological stations equipped with the Campbell-Stokes instrument have been diminishing in number. Although the advantages of these new devices are obvious, as for example the fact that the cards do not need to be changed daily which make them useful for remote locations, traditional measurements performed in well-maintained observatories with long-term measurements ought to be maintained in order to avoid the introduction of inhomogeneities in these time series (Stanhill, 2003).

It is true that, with the development of surface solar radiation measurements since the 1950s, these sunshine data are less valuable. Nevertheless, the sunshine duration records have been proven to be very useful for our understanding of climate variability and change, especially regarding the decadal variations of global and direct solar radiation (e.g. Stanhill, 2003; Sanchez-Lorenzo et al., 2008; Wild, 2009; Wood and Harrison, 2011; Sanchez-Lorenzo and Wild, 2012) and aerosol concentrations (e.g. Horsemann et al., 2008). In fact, Campbell already considered it important to increase the number of the measurements performed with his invention, as more dial records would help to settle the question of periodical increase and decrease in solar radiation (Campbell, 1879a).

Consequently, and just 160 years after Campbell’s first design in 1853, an effort is to be made in the near future to compile all the traditional measurements available worldwide before this information is lost forever.

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