THE FUTURE OF ALMANAC SERVICES — AN HMNAO PERSPECTIVE

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ABSTRACT. This talk will explore the means for delivering almanac data currently under consideration by HM Nautical Almanac Office in the near to medium future. While there will be a need to continue printed almanacs, almanac data must be available in a variety of forms ranging from paper almanacs to traditional web services through to applications for mobile devices and smartphones. The supply of data using applications may call for a different philosophy in supplying ephemeris data, one that differentiates between an application that calls on a web server for its data and one that has built-in ephemerides. These ephemerides need to be of a reasonably high precision while maintaining a modest machine footprint. These services also need to provide a wide range of applications ranging from traditional sunrise/set data though to more specialized services such as celestial navigation. The work necessary to meet these goals involves efficient programming, intuitive user interfaces, compact and efficient ephemerides and a suitable range of tools to meet the user's needs.

1. HISTORY

An almanac is a list of forthcoming events, be they meteorological or astronomical, usually occurring in the coming year. A calendar is the most obvious form of almanac giving information on days of the week and the day of the week on which a particular date falls. The origin of the word almanac is unclear. It may come from the Greek word "almenichiaka" which means calendar or possibly from an Arab word "al-manach" meaning to count. The latter may also be translated as climate and the natural change in weather patterns over the year. The first documented use of the word is by Roger Bacon in 1267.

Almanacs have a long history, perhaps dating back as far as the second millennium BCE. These almanacs originated in western Asia and include hemerologies and parapegma. Hemerologies, from the Greek word hemera meaning "day", can be composed of lists showing favourable and unfavourable days for various activities. An example of such a work is the Babylonian Almanac dating back to 1100-800 BCE.

Parapegma, using an inscribed stone and movable pegs inserted into the holes within the stone, were used to indicate days of the month in ancient Greece. Ptolemy, in the second century, wrote a treatise on the motions of the fixed stars which was underpinned by a parapegma listing the dates of seasonal weather changes, the first and last appearances of stars and constellations at both sunrise and sunset as well as solstices organized on a yearly basis.

The almanac can also be linked to Babylonian astronomy where tables of planetary periods were used to make predictions of lunar and planetary phenomena. In the medieval Islamic world, similar results were obtained with the Zij, the Persian word for cord, tabulating parameters used for calculating the position of the Sun, Moon and planets. Another example of an almanac of that period is the Calendarium Cracoviense, Poland's oldest known print, which was first produced in 1474 by Kasper Staube. It was an astronomical wall calendar which listed church holidays and astronomical data as well as planetary oppositions and conjunctions and included the optimum days for bloodletting!

The "modern" almanac, which started to appear in the second half of the 16^{th} century, differs from all of the ones described here by the fact that the positions of celestial bodies are given directly with no further computation. These almanacs were produced in English by such individuals as Anthony Askham, Thomas Buckminster, John Dade and Gabriel Frende. These publications were very popular, selling in numbers second only to the Bible. Examples of what we now recognize as traditional almanacs started with *La Connaissance des Temps ou calendrier et éphémérides du lever & coucher du Soleil, de la lune & des autres planètes* by Picard in 1679, the *Astronomische Ephemeriden* by Hell in 1757, *The Nautical Almanac and Astronomical Ephemeris* by Maskelyne in 1767 and the *Berliner Astronomisches Jahrbuch*

by Bode in 1776. Most of these publications are still available today although in certain cases their titles have changed and their contents are very different.

It is interesting to note that even GPS uses an almanac to transmit data to the constellation of satellites. In the same way that the Babylonian Almanac provided data to find celestial bodies, the almanac for the GPS satellites contains information on the orbit of each satellite, an ionospheric model for predicting orbit decay and the necessary information to relate GPS time to UTC.

2. EXAMPLES OF HMNAO SERVICES

For the purposes of this talk, I will use the products and services of HM Nautical Almanac Office (HMNAO) as an example. The office is composed of six staff based at the UK Hydrographic Office (UKHO) in Taunton, England generating publications and services for a wide range of customers, both commercial and scientific and including the general public.The publication side of HMNAO's work involves several annual almanacs including *The Nautical Almanac*, *The Astronomical Almanac*, *Astronomical Phenomena*, *The Star Almanac for Land Surveyors* and *The UK Air Almanac*. The first three are joint publications with the Nautical Almanac Office of the US Naval Observatory (USNO). The UK Air Almanac is available as an online publication only. Other publications available on a five year time scale are *Navpac and Compact Data*, *Rapid Sight Reduction Tables for Navigation* and *Planetary and Lunar Coordinates* available on a twenty year cycle. Volume 1 of *Rapid Sight Reduction Tables for Navigation* is also jointly produced with the USNO. The web services operating under the URL http://astro.ukho.gov.uk can be broken down into several different sub-sites as described below.

The first are dynamical services, providing data "on the fly" i.e. as a direct response to user input. Websurf is HMNAO's source of data which provides information on rise/set data for the Sun, Moon and planets, twilight timings, transit times, altitudes and azimuths at a specific time, azimuths of objects at specific altitudes, altitudes of objects at specific azimuths, solstices and equinoxes, moon phases, crescent moon visibility and prayer times for the Islamic community. We also provide topocentric almanac data for the Sun, Moon and planets, generating right ascensions, declinations, azimuths, altitudes, distances, magnitudes, semi-diameters and visibilities. Locations can be specified in a variety of formats including databases of locations and postcodes, manual entry of latitude and longitude and location entry and refinement using *Googlemaps*. Output is generally provided in ascii and/or pdf format but other formats are under consideration.

Crescent moon visibility information is available through a public participation project initially run in collaboration with the Institute of Physics called Crescent MoonWatch. This web site provides information of the global visibility of the crescent moon over the first three days of each lunation. It then allows observers to record their sightings of the crescent moon allowing HMNAO to use these data to improve their predictions of the new crescent moon. This site is of use to the Islamic community whose calendar is still dependent on the sighting of the new crescent moon. The information supplied by HMNAO is unbiased and is independent of any religious grouping. Warnings of the impending new moon can be sent out to users who sign up for this information.

Eclipses Online is HMNAO's eclipse resource and is designed for those wishing to visualise the progress of an eclipse for a specific location. In conjunction with the US Naval Observatory, HMNAO have provided a canon of eclipses based on software used in the production of *The Astronomical Almanac*. It can be seen as a replacement for the *USNO Eclipse Circulars* published by the USNO. This canon provides global and local circumstances, animations and eclipse panoramas for partial, annular, total and hybrid solar eclipses in the period 1501 CE to 2100 CE. Pre-generated animations for a gazetteer of around 1500 locations are provided for those locations in the eclipse footprint. This site comprises around 300,000 animated gif files in addition to many thousands of static graphics files. Similarly, global circumstances of penumbral, partial and total lunar eclipses are available for the same period.

HMNAO can also provide information on ground illumination. This is usually generated for a 24-hour period and displayed for a variety of cloud obscurations, indicating when photopic, mesopic and scotopic vision is likely. This information can be used in connection with Police investigations and legal cases as well as maritime applications particularly in twilight and moonlight. Although this work is not currently available as a web application, it could be easily be made available. An animated ground illumination diagram is presented in this talk for the north-west Indian Ocean region. The ground illumination is represented by colour contours and the altitudes of the Sun and Moon are represented by individual line contours.

3. CURRENT PRACTICE

Paper almanacs are usually annual publications which tend to be somewhat expensive to produce when compared with their digital counterparts. Their availability should be widespread if not global but in certain cases this may be limited by the use of distributor chains. They are usually geocentric, giving data in specific reference planes, systems, timescales and coordinate systems. However, topocentric data can easily be produced for defined locations on the Earth's surface. They can require a certain amount of expertise in order to make full use of them. Their main advantage is that they are a book and everyone knows how to use a book. They do not require specific electronic devices to read them. They are archival by nature, their storage does not require technology that may become obsolete in the passage of time and are well suited for long term storage e.g. libraries. Sadly library capacity is fast becoming a dwindling resource. Almanacs do not lend themselves well to electronic publication formats as they contain large amounts of tabular data formatted in very specific ways.

Web services need internet access. They provide flexibility in the sense that topocentric data can easily be generated as opposed to traditional paper almanacs. These services are dynamic by their very nature. They are useless without appropriate connection to the internet i.e. by wireless, broadband or mobile telephony. Web services tend to be generated around specific services and therefore tend to be somewhat inflexible. Web services can provide large amounts of data or give access to large amounts of data i.e. large ephemerides and extensive databases. Some services are ephemeral in their own right as they can be taken down or moved with little or no notice leaving potential users with little more than a dead link.

To use HMNAO as an example once again, there are five annual paper publications and three paper publications produced over a longer production cycle. *The Nautical Almanac* is also available as an e-publication, principally to the maritime community, being part of a product range using a customised pdf viewer reading encrypted files and licensing system. *Navpac and Compact Data* includes a software package for Windows PC's called *Navpac* which provides a means of reducing astronomical sights made with a sextant to generate a position at sea. This provides organisations such as the Royal Navy with a backup solution should GNSS signals be jammed or otherwise interfered with. Another hybrid product is *AsA Online*, the web companion to *The Astronomical Almanac*. This web site provides functionally not easily provided in book form e.g. mapping of phenomena and a means of reporting information within the publication year after the book has gone to press.

4. NEXT GENERATION DATA SERVICES

It is difficult to see how paper publications can change significantly with the exception of layout and content. Publications that are used in the teaching of such topics as celestial navigation may benefit from additional material but it is wise to retain the layout described in the teaching material. Customers may not be best pleased with unexpected changes to books as it may incur significant costs in training processes and modifications to material.

Web services are potentially in a continuous state of change reflecting new technologies, techniques and hardware capabilities. One area that is yet to be fully explored by most almanac offices is that of SOAP / REST servers. Here a request is sent to the web server for a particular type of data. The information is sent back to the requesting server along with a description of the formatting of that data. It is then up to the requesting server to not only interpret that data but also to layout the data in a form specific to that users requirement, This has the advantage to the user of customising the appearance of the data rather than going to a web site and accepting the formatting of that web site. Other areas where new technologies have made their mark is the selection of locations as input to a topocentric calculation. The most obvious is the use of *Googlemaps* in conjunction with location sensitive software.

Mobile applications are a major growth area. These generally fall into two categories, one is an application running solely on the mobile device itself. The other is an application that uses the device's internet connections to access databases on a web server somewhere. Typically, a self-contained application needs a compact ephemeris perhaps with an accuracy of around one arcsecond. This requires the generation of ephemerides specifically designed for their small footprint, rapid evaluation and reasonable timespans. The output of the application makes full use of the display facilities of the mobile device as well as the location and orientation sensors on the device. It is also possible to use the camera facilities on such devices to provide augmented or mediated reality. A live direct view of a physical scene can have sound, video or graphical data added to the scene.

5. FUTURE SERVICES

Development of web services and mobile applications are likely to be the main area of progress and much will depend on changes in technologies and software. It is also likely that the means by which material is disseminated will change. For instance, one area might be more flexible licensing of data to make the creation of new products simpler. This will mean that derived products from generated data from the almanac offices may provide commercial opportunities for not only the almanac offices themselves but other entrepreneurial entities downstream from the offices. Repackaging of data with other forms of commercial data such as that already described for electronic version *The Nautical Almanac* may become much more widespread. Disseminating data via such outlets as *YouTube* will become more popular, especially where animations and data visualisations are concerned. Indeed the embedding of almanac data into social media such as *Facebook* and *Twitter* will become more pervasive.

On the subject of the visualisation of data, HMNAO are looking at the use of different map projections for the phenomenological presentation of data. This may involve the use of unusual and little used map projections such as the Peirce quincuncial projection (Taylor & Bell, 2013). This map projection requires considerable computation but provides a projection well suited to showing global or all-sky data particularly in the polar regions with relatively little distortion. As it renders a sphere as a square, it can be tiled in all directions. Another possibility in this area is the use of *Blender*, an open source 3-D graphics authoring tool. This is an extensive package capable of many tasks but for our purposes it can turn a static crescent moon visibility diagram into a one that the observer can fly around. This may have applications for the presentation of solar eclipse data, allowing the viewer to fly along the track of totality or indeed explore the obscuration of the Sun in the rest of the eclipse footprint.

The influence of external factors on almanacs will remain an issue. An upcoming example is the decision on whether or not to drop leap seconds which will be made by the International Telecommunications Union in late 2015. If the decision is to drop leap seconds, this will be a major impetus to switch from UT1-based almanacs to ones using UTC as the time system. Some offices already supply such data, but it will mean that all almanac offices will have to take a more proactive role in assisting their customers with the prediction of UT1-UTC differences and how that affects the data they publish. Paper almanacs will find these issues harder to deal with than their electronic counterparts.

The future of almanacs and indeed almanac offices probably lies in the provision of electronic data via the web and, more likely, through mobile applications. The future of paper publications is perhaps more limited but will remain a necessity for emergency applications and archival purposes. This will mean that almanac offices and the skills of their staff will migrate towards a more software focused approach. What will not change is the requirement for the fundamental skill set of their staff to be retained and enhanced.

6. REFERENCES

Taylor, D.B., Bell, S.A., 2013, "Astronomical applications of the quincuncial map projection", Astronomy & Geophysics, 54, pp. 13–15.