THE VON NEUMAYER LEGACY IN AUSTRALIAN METEOROLOGY

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Georg von Neumayer established the first formal program to take meteorological observations in Melbourne in 1858 at the Flagstaff Hill Observatory. In doing this he set the platform for a long-term climate record of Melbourne of immeasurable value to the city of Melbourne and the nation. He also helped set in train an ever expanding program of weather recording in Victoria, and around the country. This program of observing the weather then evolved into the sophisticated system which exists today. Today's weather observation program underpins the modern weather forecasting service, which the nation depends on so much for short and longer term activities.

Key words: Georg von Neumayer, observation, record, climate, legacy

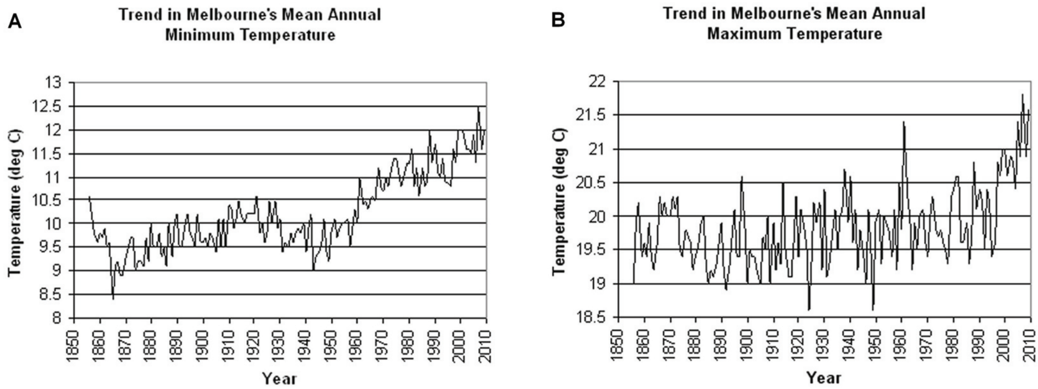
WHEN Georg von Neumayer commenced the first program to take meteorological observations in Melbourne in 1858 at the Flagstaff Hill Observatory, he could not have anticipated the value of the record which would follow, nor how observing systems would evolve during the next 150 years. Although he most likely would have foreseen the value of an accurate climate record for Melbourne, it is most unlikely that he would have thought of the many uses that meteorological records are put to today. This paper demonstrates that the weather observations collected over the last 150 years have been used to establish an accurate climate record for Melbourne. In addition, over the years the weather observations taken at Melbourne have also become part of a national and international network that is instrumental in underpinning the science of weather forecasting. These records also play a role in checking the validity of forecasts. More recent records are used for such diverse reasons as establishing the weather facts before a court of law.

The observational methodology has changed dramatically over the years, with new techniques capable of measuring meteorological variables both directly and remotely being very much part of the 21st century observations system. In the paragraphs that follow, a brief description of the climate record at Melbourne is followed by an outline of the evolution of the weather observing system in Australia and how these weather observations are used to underpin the modern weather forecasting process.

THE EARLY OBSERVATIONAL RECORD AT MELBOURNE AND THE CLIMATE RECORD

The first weather observations were taken at the Flagstaff Observatory by Georg von Neumayer from 1858. These observations were of temperature, wind, weather and rainfall. These weather parameters have been recorded ever since, right up to the present day. The observation site was moved to the Melbourne Observatory in 1863 where the same meteorological parameters were measured at least daily. The Observation site then moved to the current location at the Royal Society of Victoria in 1908. Since this move the frequency of observations being collected has changed from twice per day, at 9 am and 3 pm, from January 1909 till 1913, to three times per day including the 9 pm observation from 1913 till 1940. After 1940 the observation frequency was increased to three hourly throughout the day except for midnight. From 1953 the observation frequency was further upgraded to include the midnight observations.
Since those early days some of the instruments used have not changed and are still used as standards today. These include the mercury thermometers, mercury maximum and minimum temperature thermometers, sunshine recorders and evaporation pans. The primary instrument for measuring atmospheric pressure for many years has been the mercury barometer.

The continuity of record for the last 150 years has allowed a very good climatology of Melbourne to be established. For example the temperature record



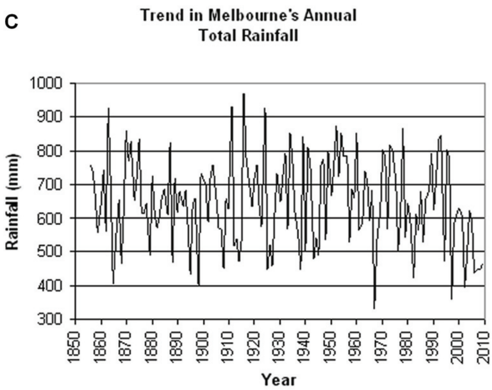


Fig. 1. Long term records from the weather observation station at Melbourne. (A) shows the annual minimum temperatures, (B) the annual maximum temperatures and (C) the annual rainfall records.

provides considerable insight into changes that have occurred to both the climate in the vicinity of Melbourne and the micro-climate record of Melbourne itself. The maximum temperatures in Melbourne show a gradual rise from 19.7°C (1856–1885) to 20.4°C (1980–2009). These appear to be consistent with observations from nearby sites, although those records are not nearly so long. The minimum temperature at Melbourne has risen from 9.5°C to 11.4°C for the same period showing a steeper rise. Comparisons with data from nearby locations show that the increase in minimum temperatures is restricted to Melbourne where the site appears to be largely affected by the surrounding buildings and roads which have become more prominent over the years. The temperature records at Melbourne give a very good opportunity to examine the climate in the vicinity of Melbourne as well as the micro climate of Melbourne, and an opportunity to examine the influence of urban development. On the other hand the rainfall record for Melbourne shows a tendency towards lower rainfalls from about 1980 onwards, with a distinct downward trend apparent during the last 15 years. This trend is unlikely to be associated with local effects as the exposure to rain at the site is still good. Fig. 1 A, B and C show the long term minimum temperature, maximum temperature and rainfall record for Melbourne.

Long term observational records such as those initiated by von Neumayer have enabled very good climatologies to be developed across Australia, and changes in climate to be accurately documented. It is these records which have led to the 'Climate of Australia' to be produced and maps of climate change across the country prepared. These climatologies provide the base for the calculation of records when they occur. For example on 7 February 2009 when Victoria experienced its hottest ever day at many locations, Melbourne had a maximum temperature of 46.4°C. This was 0.8°C hotter than the highest previous all time maximum of 45.6°C recorded on 13 January 1939, and an extraordinary 3.2°C hotter than the old February record set in 1983. These records could not have been calculated without the climatology started by von Neumayer back in 1858.

THE EVOLUTION OF THE OBSERVATION SYSTEM

Observation systems have evolved over time, but it is really during the last 60 years that major changes have occurred and newer technologies have burst on the scene that have taken the observing network into the 21st century. There are a plethora of new observing systems in place now, or which are about to be deployed, and which have taken the measurement of the atmosphere into a new era. There are far too many new systems to describe in this paper; however, a handful of them will be briefly described below.

The largest change in the taking of surface observations in recent years has been the advent of the Automatic Weather Station. Automatic Weather Stations have been around since the 1950s when they were deployed in some of the more remote locations around the country. However, since the 1980s they have been put into more widespread use, becoming the 'standard' observing platform in many cases. These devices constantly monitor a range of atmospheric variables. Observations are generated regularly, usually half hourly, and also when sudden changes in the weather meet designated criteria. These observations are transmitted back to the Bureau's networks and forecasters within a minute or two.

The Automatic Weather Stations are robust, can be positioned in inhospitable environments, require minimal maintenance and form the basis for the surface observation network now. Many of these devices are now being fitted with instruments which can measure visibility and cloud base height automatically. In the near future some will be fitted with digital cameras which will transmit visual information back to the Victorian Regional Forecasting Centre in near real time. The Automatic Weather Station has made possible high frequency, highly accurate observations of the primary weather elements of temperature, wind, humidity and pressure. It is also now possible to place portable Automatic Weather Stations at strategic locations, for example in the vicinity of bushfires, as was done during the wildfires of 7 February 2009. Although the Automatic Weather Station has made possible the collection of weather data in ways that would not have been possible otherwise, only observations taken by a human can fully account for all visible components of the weather, including a full description of the cloud types and heights, weather elements such as fog, rain, recent rain, distant rain or changes in visibility at a distance from the observing site. A complete observation network today comprises both Automatic Weather Stations and manual observing sites, the latter being critical for activities such as aviation in particular.

Surface observations over the sea have always been hard to come by as they are normally taken by staff on merchant ships. While there have traditionally been plenty of observations from this source where ships ply the high seas between major ports, this is not the case over the southern ocean where merchant ship routes are sparse. Since the late 1970s drifting ocean buoys with weather measuring instruments have been deployed by 'ships of opportunity' as they travel along their commercial routes. These are a special type of Automatic Weather Station which drift with the currents and routinely transmit their locations and weather reports by satellite. These reports are received by the Meteorological Services of the world. The deployment of drifting buoys has resulted in a revolution in weather forecasting in the southern hemisphere in particular, where valuable meteorological data collected from the oceans have enabled vastly superior forecasts over longer time periods to be produced today.

The surface observing network is supplemented by an upper air network which was established in the 1950s. This consists of a program of timed weather balloon releases which are tracked by radar as they rise through the atmosphere. As these balloons move horizontally with the flow, the wind speed is calculated for many levels through the atmosphere. However, this technology is now being superseded by devices such as vertically pointing radars that are capable of measuring the wind through the vertical remotely. Packages called radiosondes attached to balloons measure temperature, humidity and pressure as they rise through the atmosphere. This technology is still likely to be used for many years as this method is the standard for measuring atmospheric variables in the atmosphere above the surface. A special class of radiosonde measures ozone amount in the stratosphere, which is above the weather-producing component of the atmosphere.

A new class of observing systems now play a major role in measuring the atmosphere, both for the purposes of establishing the climate record and forecasting the weather. These are remote observing systems which do not measure atmospheric variables directly, but can retrieve the required atmospheric variables either by active or passive means. The active systems are typically radar. Radars transmit pulses of electromagnetic radiation into the atmosphere. By tracking the intensity and locations of the return signals the occurrence and intensity of rainfall well away from the radar can be located and mapped. Weather Watch Radars, as they are now known, collect valuable rainfall location and intensity data across much of Australia. Radars can now be used to derive wind information directly from clear air echoes as well as to locate wind changes in a dry atmosphere. Figure 2 shows the recently installed weather watch radar at Laverton.

Passive remote sensing devices include lightning trackers. These work by using a network of detectors across the country that locate individual lightning strikes and provide this information to forecasters virtually immediately after occurrence. This technology is now capable of very reliably positioning lightning strikes for use by forecasters in all conditions. Satellite images of clouds have been used by meteorologists for some 50 years and are a powerful tool for location of weather features, particularly intense weather systems including severe thunderstorms and tropical cyclones. However, satellites do not just take pictures of the clouds. By measuring emitted radiation from the atmosphere, computer algorithms are capable of determining temperature profiles through the atmosphere. These measurements are critical for today's accurate weather forecasts. The next generation of satellites will be capable of measuring the total atmosphere in much more detail than is currently the case.

The evolution of the observing system, particularly during the last 50 years, has been quite extraordinary. No one will know what von Neumayer saw as the future of observing the weather. However, he could not have conceived of a system which was capable of obtaining accurate measurements over the land and the sea, at frequent intervals, as well as through the depth of the atmosphere, and using a range of instruments which measure atmospheric variables directly as well as by remote means.

Fig. 2. The weather watch radar at Laverton. This radar produces images of rainfall across central Victoria. These images include information about rainfall intensity as well as the winds through multiple layers of the atmosphere.

HOW WEATHER OBSERVATIONS ARE USED IN FORECASTING

Forecasting the weather has always relied on weather observations. In other words, an accurate description of the state of the atmosphere at a prescribed time, known as an analysis, is a prerequisite for preparing a forecast. Analyses are based on observations, and it is the quality and extent of coverage of these analyses that to a very large extent allows a good quality forecast to be made.

The traditional way of preparing a forecast has been to prepare an analysis of the weather through the preparation of a 'synoptic' chart, which is a chart that is prepared from weather observations taken at a predetermined time across a large domain, for example across Australia and the waters to the south. A forecaster would then compare these analyses with earlier ones and, using all his or her knowledge of the evolution, development and decay of classical weather systems, make a prediction. The forecaster would then convert these predictions into words, using plain English to describe the expected weather. The two main limitations to accurate forecasts several days into the future has always been the quality and quantity of weather observations, and a fundamental ability to predict the future which was based on understanding of the behaviour of weather systems at a particular time.

A major breakthrough occurred with the evolution of numerical weather prediction models. These models became capable of making reliable predictions of the atmosphere, firstly 24 hours ahead, and now up to seven days ahead. Now some models are starting to show that this useful skill is achievable beyond seven days. The forecaster uses these models as the primary tool to assess the likely future state of the atmosphere, and then adds knowledge of weather system behaviour. This is where human expertise comes into the process to make the best possible prediction of the weather in the future. The forecaster then produces the words, or forecasts as we know them, for distribution to the public. It is important to recognise that these numerical prediction models would not be capable of making accurate predictions at all without a comprehensive set of observations upon which a very good starting analysis is based.

Another major change has recently occurred in the Victorian Office of the Bureau of Meteorology. A new system known as the Next Generation Forecast and Warning System has been introduced which allows the forecaster to edit the fields of temperature, rainfall and pressure etc. which have been generated by the numerical weather prediction models. By this means the best possible predictions of the atmospheric state is made, which arises from a mix of the best of the numerical prediction models and human skill. These fields are then interrogated by a computer system that produces the worded forecasts. After fine tuning they are released to the public. Graphic fields are now posted to the Bureau's web site for any user to access directly. The underlying data are also available to anyone who can make use of this information and potentially ingest it into a range of end user systems. This new service should be of great value to all sectors of the community that depend of weather forecasts, particularly farmers, aviators, and those involved in the provision of emergency services. Figure 3 shows an example of a graphical display of a wind forecast for Victoria.

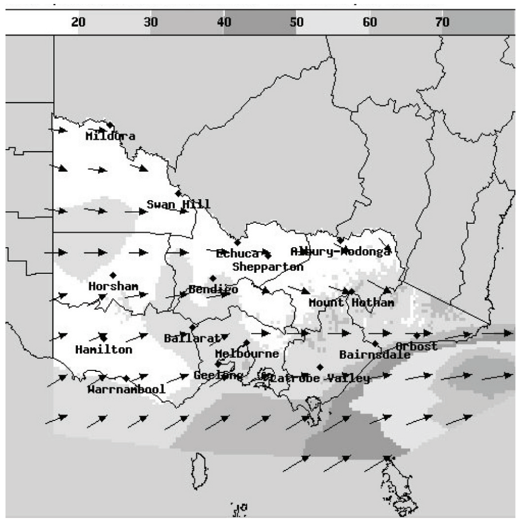


Fig. 3. An example of a forecast of the winds across Victoria. The arrows show the wind direction and the speed (km/h) according to the shaded scale at the top.

CONCLUSION

It is worth reflecting on what has been achieved during the last 150 or so years since Georg von Neumayer started the first official weather recordings at Melbourne. An obvious legacy is the valuable climatology of Melbourne which is derived from that record of observations. But there are other legacies. It would be impossible to believe that he could have foreseen where observations of the weather at Melbourne would eventually take us. We now live in a world where reliable forecasts and warnings are taken for granted. Dependable information on the state of the climate is expected by the community at large and is crucial to making informed judgements on climate change in the future. None of this would be possible without a sophisticated and reliable observation network that has been implemented and refined over many years. In particular the climate and weather of Melbourne could not have been documented to the degree that it has without the long term observational record started some 150 years ago. This is the legacy that Georg von Neumayer has left for us.