Australian temperature data – information about the datasets used and their application to the recent heatwave event

Background information: temperature data at the Bureau of Meteorology

All scientific work at the Bureau is subject to expert peer review. Almost all of our methodologies are published in the peer-reviewed scientific literature. The associated publications are available widely.

In 2012 the Bureau of Meteorology completed an extensive and dedicated international peer review, through a panel of world-leading experts, of its preparation of observational temperature data for Australia.

That review ranked the Bureau's procedures and data analysis as amongst the best in the world, and the results of this review have been published.

A package of information around the temperature record can be found at the following links.

FACT SHEET:
http://www.bom.gov.au/climate/change/acorn-sat/documents/ACORN-SAT-Fact-Sheet-WEB.pdf

WEBSITE:
http://www.bom.gov.au/climate/change/acorn-sat/

This package includes research papers including an assessment of urbanisation on the network, and its treatment in the Australian Climate Observations Reference Network-Surface Air Temperature network definitions and methodologies. In the international literature, the impact of urbanisation on large-area-averages of surface temperature anomaly trends over time has been consistently found to be small in homogenised temperature datasets. The research in the ACORN-SAT papers linked to above is consistent with overseas studies, most relevantly, an assessment published by the National Climatic Data Centre in the US (and references therein) can be found at the following link
http://www1.ncdc.noaa.gov/pub/data/ushcn/v2/monthly/menne-etal2010.pdf

Some other useful references can be found at the end of this document.

Multiple methodologies as a consistency check

Depending on the type of analysis being sought, it is appropriate to analyse temperature data in different ways. The requirements for instantaneous event analysis, such as the spatial description of intense heat, are somewhat different to the requirements for temperature trends.

The Bureau of Meteorology therefore prepares and maintains multiple temperature analyses that are fit for purpose. This means that temperatures are analysed using more than one independent methodology, for example with and without homogeneity adjustments, as a consistency check and to provide the most appropriate tailored information for various uses.

The two main datasets are the real-time temperature monitoring system, developed under the Australian Water Availability Project (known as AWAP) and the Australian Climate Observations Reference Network–Surface Air Temperature dataset (known as ACORN-SAT). The AWAP and ACORN-SAT datasets commenced in 1911 and 1910 respectively, corresponding to the widespread standardisation of temperature instrument screens (“Stevenson Screens”); following the formation of the Bureau of Meteorology in 1908.

Temperature measurement from before approximately 1910 used a wide variety of non-standard configurations and are therefore not directly comparable to modern measurements.

The real-time monitoring system (AWAP) for daily maximum and minimum temperature data is generated at 1pm EST (2pm EDST) each day for the previous day. The AWAP suite of daily monitoring products also includes humidity (vapour pressure) and solar exposure data for the

previous day, and rainfall for the present day. All of these products, as well as vegetation greenness (NDVI) are also generated at monthly and longer timescales.

These data are freely available at the following link

http://www.bom.gov.au/climate/maps/

Describing the recent heatwave

A complete description of the January 2013 heatwave, including the main elements that were notable, can be found in an article prepared for the academic news site, The Conversation
What's causing Australia's heat wave?

https://theconversation.edu.au/whats-causing-australias-heat-wave-11628

A more detailed summary of climate observations across the Australian continent is available in a Special Climate Statement at http://www.bom.gov.au/climate/current/statements/scs43c.pdf

The national daily average temperature has been calculated by the Bureau of Meteorology since the creation of the AWAP dataset. Its use in recent reports has been driven by extraordinary climatic conditions that have not occurred during the period that this data has been analysed (in real-time; noting that the analysis is applied retrospectively).

There are some reasons behind our increased confidence in this metric.

While we had previously calculated these measures from 1996, the AWAP methodology was not extensively published in the peer-reviewed literature until 2009. Additionally, the reanalysis of daily temperature data that was completed in March 2012, provided us with the ability to cross-check daily temperature diagnostics against multiple methods. A comparison between AWAP and ACORN-SAT is detailed in the research papers linked to above.

In this way, we are now able to report some daily metrics with high confidence; due to a combination of improved technology and improved methodology.

The major heatwave experienced during the first two weeks of January 2013 was exceptional for two reasons (i) the spatial extent of very high temperatures across the country and (ii) the duration of that continental-scale pattern of extreme temperatures.

There are two appropriate diagnostics for representing the exceptional nature of the heatwave as described above. They are the proportion of the continent above particular threshold values (such as through percentile analysis) or, perhaps more intuitively, the area-averaged daily temperature. The area-averaged daily temperature is a grid-point average based on a spatially interpolated surface of station-based temperature measurements.

To gauge the extent of heat across the continent, the most appropriate data-set to use is the AWAP daily gridded data. This data uses all available and unhomogenised temperature measurements from around 700 stations daily. The network is not fixed in time due to network changes and basic quality control, however sensitivity analyses (as documented in the published papers referenced in the links above) shows stability in the calculations post 1950. This period also corresponds to the most significant trends in Australian temperature, as described in the linked references.

The spatial distribution of the stations used in real-time are shown at
http://www.bom.gov.au/jsp/awap/temp/index.jsp .
The number of sites and their location is provided in the maps under RMSE – see
http://www.bom.gov.au/jsp/awap/temp/index.jsp (for an example). Each dot indicates a station location, and the size of the dot is the root-mean-square error (RMSE) that is associated with the difference between analysed gridded data at a point that corresponds to the station observation.

The calculation of daily area averages dates back to the mid-1990s, when computing power first allowed for these intensive calculations.

The analysis can be applied retrospectively from 1910. It should be noted that calculations of monthly and annual temperatures are based on the technique for analysing daily temperatures and comprise the same data. In other words, the daily calculation is mathematically identical to that used for monthly and annual temperatures reported by the Bureau. Calculations of global-mean temperature by international research centres also use similar techniques, with the earliest estimates dating back into at least the 1980s.

We estimate the AWAP network definition alone (which stations are used at each time-step) comprises around 13 million temperature records over 102 years of data. This information is archived at the Bureau of Meteorology. In effect, the input data represents nearly all of the digital temperature archive managed by the Bureau of Meteorology, with the same data also available on the Bureau's website.

It is therefore perhaps more convenient to absorb the methodology as described in the peer-reviewed paper Jones et al. (2009) available at http://www.bom.gov.au/amm/docs/2009/jones.pdf and specifically Figure 1 shown in this paper. The current available data is a now a little better than shown in Figure 1; as a result of continued historical digitisation.

Daily maps of all the AWAP variables are presented online, with various drop-down menus available for the user. Area averages, such as state and cropping region averages, as well as a whole host of other diagnostics from the AWAP real-time monitoring system, across multiple variables, are calculated from the daily analyses. However we do not explicitly publish all of our analyses and diagnostics that we produce each day — as the data volumes are very large.

The area-average diagnostics are occasionally used in regular reporting products or Special Climate Statements — as appropriate to describing significant events. Special Climate Statements are routinely prepared for significant weather, and can be found at the following link.

http://www.bom.gov.au/climate/current/special-statements.shtml

Extreme nature of the event: comparisons and reasons for using AWAP data

The AWAP data is the most appropriate dataset for capturing the spatial extent of recorded temperature, since it maximises the network coverage across Australia for event analyses. The ACORN-SAT data uses a more limited and fixed network of temporally homogenised data that is specific for estimating change over time, and particularly climate change. Temporal homogenisation refers to analyses that attempts to account for spurious (non-climate related) changes in the data.

The ACORN-SAT dataset is analysed as anomalies (which is standard international practice for homogenised temperature data) whereas the AWAP data, a spatial interpolation of all available measurements, is more suited to absolute temperatures. The spatial analysis accounts for spatial (x,y,z) changes in the network through time. In terms of the impact of temperatures, such as fire potential, it is more obvious to use absolute temperatures.

A detailed comparison of AWAP and ACORN-SAT datasets was performed as part of the international review of our practices, and is contained in the scientific papers linked to above. While there are differences between the two data sets at the local scale, the differences between the two datasets for large area-averages are typically small (in the order of a few hundredths of a degree for annual means) over the last 50 to 60 years. As mentioned above, this corresponds to the period of the most significant warming trends for Australia.

In addition to the comparisons published as part of the ACORN-SAT analyses, real-time comparisons are routinely made between the two datasets, as a consistency check for climate monitoring metrics.

As such, the ranks for daily-averaged temperature for the January 2013 heat event are consistent across the independently analysed AWAP data and the ACORN-SAT dataset. Specifically, ranks for

the highest three days on record are from the same events in both analyses. That is, 1st and 3rd were set in January 2013, while 2nd was set in the December 1972 - January 1973 event.

As described above, due to the different length scales of anomalies versus absolute temperatures, the ACORN-SAT data is best analysed as anomalies (departures from a climatological mean). The national average daily anomaly from ACORN-SAT for the 7th January 2013 was 5.36°C. This can be converted to an absolute temperature by adding the national climatological average for the period 1961-1990 of 34.64°C, giving a national temperature of 40.00°C. However we believe that the AWAP derived average of 40.33°C is likely to be more accurate, since the coverage of the network is maximised.

The 20 highest AWAP-ranked daily maximum temperatures also compare closely with the ACORN-SAT-ranked daily maximum temperatures.

However, perhaps the most notable feature of this event was the duration for which continental-wide extreme temperatures persisted.

In this regard, the only two events that are comparable in the entire historical record are a two-week period during the summer of 1972-73 and the heatwave at the start of January in 2013. This is clear from all available datasets and methods. In fact, these events are so unusual in their characterisation that sensitivity and uncertainty due to elements such as network changes are very unlikely to affect their comparison with climatology. This fact greatly increased our confidence in reporting on the exceptional nature of the January 2013 event.

In summary, the January 2013 event in aggregate terms was warmer than the 1972-73 event on individual days. Those extreme high temperatures, both in average daily maximum temperature and, more particularly, mean temperature (the average of daytime maximum and night-time minimum) also persisted for significantly longer.

This fits with a shift in the daily distribution of weather toward higher temperatures observed locally; accompanied by a notable increase in hot days and extreme hot days, particularly in the past 15 years. This is turn is consistent with an additional global warming of approximately 0.4°C since the early 1970s.

A more detailed analysis of the current heat-event, including changes in daily average temperatures is being submitted to an international peer-reviewed journal. Upon publication of this research paper, the historical analysis of daily AWAP temperatures will be made publicly available. We expect that to occur in the next few months.

References:

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