

Summary

The article entitled '*Last Summer was not actually angrier than other summers*', in The Australian on Wednesday, 4 May 2013 contains a number of errors that warrant a response from the Bureau of Meteorology.

The Bureau stands by its climate analysis that portrays the last Australian summer as exceptional. So many temperature records were broken over such a wide area of the continent during this summer past, that it is absurd to argue otherwise. The Bureau rejects assertions that surface based climate observations made and analysed by the Bureau of Meteorology are somehow fatally flawed.

A recent independent peer review of our observation methods, data curation and trend analysis methods supports our approach and rates it amongst the world's best. We have published all of our data and methods and make them freely available online. Contrary to claims in the article: (1) the data we use to detect climate change in Australia is not obscured by the urban heat island effect, (2) our data adjustment methods are neither arbitrary nor obscure; they are endorsed by international experts and published in great detail, and (3) our surface temperature observations provide adequate temporal and spatial coverage of the continent to assess climate change trends with confidence.

The article also claimed that recent satellite-based estimates of temperature provide a more accurate assessment of changing climate than the Bureau's long-term surface based observations. This is wrong. The two methods are complementary, though it should be noted that there are well-known problems of inferring surface temperature from satellites.

The Bureau rejects as entirely false that our reporting on climate change is politically motivated. The Bureau of Meteorology is a scientific body; its research is peer-reviewed, and its data and methodologies are publicly available for scrutiny.

Details

On the basis of a few sporadic episodes, which in any other era would have been regarded as marginal weather (infrequent but perennial), the Climate Commission has proclaimed that such events are now the norm - the signature of climate change come home to roost.

The characterisation of heat records set during the summer of 2012 and 2013 as being related to weather that is *infrequent but perennial*, is not supported by thorough data analysis of the observational temperature record.

Australia has just experienced a remarkable stretch of warm conditions with many temperature records being set. These include Australia's hottest day, hottest month and hottest summer on record, and a number of record-breaking heatwaves. Record high temperatures were reached at many individual locations as well.

Far from perennial, the range of temperature records set were statistically exceptional by definition. The summer was 1.11 degrees above the long-term average, the first time that season has been over a degree warmer than normal in the long-term record. In isolation this might be seen as a remarkable statistical fluke, but it is not. Australia has warmed by 1 degree since the 1950s.

And perhaps the most remarkable event of the summer was the duration of the national heatwave at the start of 2013. Heatwaves are an annual occurrence, but a heatwave this hot. This widespread and this protracted has not been seen before.

It is uncommon for the Australian-average temperature to exceed 39°C for even two days in a row. A run of three days above 39°C has occurred on only three occasions, and a run of four days just once, in 1972.

The January heatwave saw a sequence of Australian temperatures above 39°C of seven days, and above 38°C of 11 days straight.

The sequence of Australian mean temperature was just as unusual. The first two weeks of January 2013 holds the record for: the hottest Australian day on record, the hottest two-day period on record, the hottest three-day period, the hottest four-day period and every sequential-days record stretching from one to 14 days for daily mean temperatures.

In terms of the climate change context, the records set are firmly consistent with a warming trend across Australia that is providing more frequent instances of record-breaking heat, in all of the metrics described above. These changes are observed and published.

Six of the hottest ten summers on record have occurred this century, and only two occurred before 1990.

The statement provided in this article –

“On the basis of a few sporadic episodes, which in any other era would have been regarded as marginal weather (infrequent but perennial)”

– is completely unsupported by the data outlined above. These recent records are even more unusual the further back in time one goes.

“On a continental scale (the scale relevant to climate), Australian temperature this summer was unremarkable - it was within the range of previous variability.”

The Bureau maintains that the temperatures experienced this summer were indeed remarkable. It is unclear what data analysis has been performed to support the contention that the experienced temperatures were within the range of previous variability. Based on the extensive observations we have made, we can categorically state that the temperatures were not within the range of previous variability.

Our analysis of the climate record shows clearly that the distribution of Australian temperatures has shifted over time. Exceptionally hot temperatures, defined as being two standard deviations above the mean, are now around five-times more likely to occur than 40 years ago. This means that, by definition, many of the recent temperature records are outside previous ranges of natural variability.

The scientific literature has repeatedly shown that warming over the last century is unlikely to be consistent with natural variability alone, and is most likely associated with increasing greenhouse gases. This includes studies looking at Australian temperature.

“The surface record has been termed by the bureau as its high-quality data. If it is high quality, it is certainly not robust. The bureau's record is routinely readjusted, the next high-quality reincarnation rendering its predecessor obsolete.”

The Bureau rejects the assertion that its climate data is not robust. The Bureau's data has been externally reviewed and found to be among the best in the world. This article attempts to portray continual improvement of the observational climate record as undesirable. This view is at odds with

international best practice. There are many reasons for the Bureau, and indeed every major meteorological agency around the world, to reanalyse temperature records.

Reanalysis occurs, for example, due to the addition of new data to the records. This includes recent data, as well as historic paper records that have been recently digitised. Additionally, new research and the development of improved data analysis techniques should be applied to the data as appropriate.

The Bureau strives to maintain the best possible data, using the latest techniques, as the public would expect from one of Australia's premier science institutions.

The Bureau's climate monitoring dataset is known as the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT). This data is sourced from sites across Australia with long records. It is perhaps the world's only continent-wide, long-term daily temperature dataset that has been prepared for climate change research, with most other agencies preparing only monthly or annual data in this way.

In 2012 the Bureau of Meteorology completed an extensive and dedicated international peer review, through a panel of independent world-leading experts, of its preparation of observational temperature data for Australia, and specifically climate monitoring data. That review ranked the Bureau's procedures and data analysis as among the best in the world, and the results of this review have been published online: <http://www.bom.gov.au/climate/change/acorn-sat/>

“The adjustments performed are discretionary, applied differently to different sites in the surface network. And if the adjustments are understood, it is by few, if any, outside the bureau.”

This statement is incorrect. All of the Bureau's analysis follows objective methodologies that are published in peer-reviewed literature. All of the data, including raw data, are publicly available. Every station used for analysis, every adjustment and all computer code is also available a large international community of climate scientists and academics working on analysing temperature data.

The ACORN-SAT dataset has been analysed and adjusted to account for various changes in temperature measurement over the years. Applying corrections to the temperature record is a long-established necessity for climate analysis, removing spurious influences on the record caused by things such as change in the location of thermometers. This is done because it is the scientifically correct thing to do. All of the world's main climate data sets have corrections applied for such influences, providing a more reliable temperature record.

A more detailed description of the ACORN-SAT methods can be found in the FAQ.

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

The suggestion that these adjustments have influenced the records posted over the summer has no factual basis.

The Bureau analyses its temperature records in different ways, in order to test the robustness of the conclusions we draw from data analysis. Several comparisons between raw, adjusted and unadjusted data have been published by the Bureau, and by other international centres.

The Bureau's *Real-time Monitoring System (AWAP)* is a daily dataset that analyses around 700 thermometers located across Australia, published on the Bureau's website every day. These data are

prepared using a different methodology to ACORN-SAT, and are not adjusted for inconsistencies that affect the data over time.

The record heatwave in January, including the hottest day on record, was analysed using both data analysis methodologies (AWAP and ACORN-SAT), and found to produce consistent results in terms of the records and ranks, including those for heatwave duration.

Because the data sets are prepared in very different ways, and use different underlying networks, comparison of the two data sets provides an important validation of the daily and weekly records. In other words, the records were not dependent on the analysis method or adjustments.

“For this reason, the recent proclamation that this summer was unprecedented arrives with curious timing: it coincides with the onset of campaigning for the next federal election.”

The Bureau has been producing special climate statements for many years. There are many parts of our society that require the monitoring information that the Bureau records, analyses and communicates.

The Bureau rejects as entirely false the claim that its reporting on climate change is politically motivated. The Bureau of Meteorology is an apolitical and dedicated part of the Australian Public Service and as a scientific body its research is peer-reviewed, and its data and methodologies are publicly available for scrutiny.

“Even exclusive of uncertainties surrounding its adjustment, the surface record suffers from two intrinsic limitations:

Contamination by urban development. Operational thermometers historically have been installed in association with human settlement. Station measurements are therefore biased through the so-called urban heat island effect.”

This statement is at odds with the peer-reviewed literature and research on this topic. We are not aware of any analysis that supports this statement. These comments have typically appeared on internet blogs over the years, but have failed to make it into the scientific literature because there is no factual basis for them. Such arguments have been disproved many times.

The national and state temperature averages calculated using ACORN-SAT specifically exclude sites known to be affected by urbanisation.

In the international literature, the impact of urbanisation on large-area-averages of surface temperature anomaly trends over time has been found to be small in adjusted temperature datasets. The research associated with the development of ACORN-SAT (links above) is consistent with overseas studies.

Importantly, record temperatures for Australia this summer were consistent with record sea-surface temperatures, which are measured entirely differently to temperatures over land. Just as Australia's land surface experienced its hottest summer on record, so too the oceans around Australia experienced the hottest summer on temperature. There is no temperature impact from urbanisation in the oceans.

“Consequently, individual measurements are often representative of localised conditions, but not of the expansive area.”

This statement is false and demonstrates an unfamiliarity with surface temperature data and the relevant scientific literature.

Surface temperatures can be analysed in different ways. It is an observable fact that temperature anomalies (departures from a long-term average) have much longer 'length scales' than regular temperatures. This means that temperature anomalies typically represent a reasonably expansive area. For this reason, the ACORN-SAT data are analysed as anomalies.

Additionally, temperatures averaged at monthly and longer timescales are well-correlated at distances of at least a few hundred kilometres.

The recent record for the hottest and longest national heatwave on record was analysed using both the sparser ACORN-SAT network of anomalies, and the much higher-density network of regular temperatures from the real Time Monitoring System. This found identical ranks for all those records that the Bureau reported.

Comparison of the satellite and surface based temperatures also show that the coverage of the thermometer network is adequate for characterising Australian temperature.

“Non-uniform sampling of the continent. Owing to Australia's sparse population, historical records of temperature are concentrated in a small fraction of the continent. Exacerbated by their proximity to infrastructure, the irregular sampling by the surface network complicates the evaluation of continental mean temperature”.

The changes that occur in network coverage over time is one of the main reasons that the Bureau and other agencies analyse the data. Whilst they do complicate the analysis they by no means invalidate the conclusions we draw from them. The Bureau has published data comparisons and sensitivity testing to understand and account for these changes. These studies show that area-averaged temperature changes since the 1940s are reasonably insensitive to network changes and choice of network. This is the period of the most significant warming over Australia.

One record averts these limitations: satellite measurements from microwave sounding units and advanced microwave sounding units provide continuous coverage of Australia, with uniform sampling of the continent.

The satellite temperature record provides recent estimates of temperatures over Australia, with records starting in the late-1970s. Satellite data has one advantage over surface-based observations in that it has total coverage over the Australian continent. Satellites also have several disadvantages as well, when it comes to climate monitoring.

They are of short duration – only dating back to 1979.

They do not measure surface temperature – rather they measure an “average” temperature through some depth of the atmosphere some kilometres in depth.

They are not global – for example high elevations and polar regions require interpolation or extrapolation.

They are not perfect, requiring the piecing together of numerous satellite, and constant corrections. As an example, a NASA satellite failed in March 2013 providing highly spurious temperature recordings.

Satellites remotely sense radiation and calculate temperatures through an algorithm. This means that they do not directly measure surface temperatures, but must derive them from other quantities that they sense, such as radiation from a large section of the atmosphere. The satellite record is complimentary to the all of the other temperature data, and the Bureau and climate scientists compare these records routinely. The Bureau's surface temperature measurements for Australia compare well with the remotely sensed satellite record in terms of area-averaged variability and warming trends.

Globally, the satellite data are warming at the same rate as the surface and show remarkable agreement. In the case of Australia the satellite data are actually warming a little faster than the surface observations.

“The satellite record derives from a single instrument family. It follows from a single treatment applied uniformly to all data, yielding a record of continental temperature that is homogenous and stable. “

This statement is incorrect and shows an unfamiliarity with satellite sensors.

Like all observations, the satellite record is subject to changes over time that may affect the consistency of the data. A major source of potential inconsistency in the satellite record comes from the splicing together of data from multiple, different satellite missions over time. These different satellite missions have different instrumentation (the use of the term 'family' to describe these instruments is misleading. All types of thermometers that ever existed, for example, could be said to belong to a 'family of instruments'). Missions may have different orbital characteristics, and slight changes in the orbits of satellites over time have been shown to introduce inconsistencies in the data. The number of satellite changes that have occurred since the 1970s greatly exceeds the number of changes made to any ACORN-SAT station over the same period.

This means that satellites do not provide the consistency through time that this article claims, and are likely less suitable for analysing long-term trends than surface observations.

Another considerable disadvantage of the satellite measurements is the way they are calibrated. The Bureau's surface thermometers are regularly calibrated to a master instrument that is kept to an international standard. This is known as 'traceability'. This process does not occur for satellite records, where temperatures are converted from remotely sensed radiation readings (as no direct temperature measurement is recorded by a satellite).

“Unlike surface measurements, it represents temperature in the lowest couple of kilometres of the atmosphere. However, departures from average temperature in this layer mirror departures from average surface temperature - especially under summertime conditions, when convective overturning exchanges air vertically on time scales of only hours. Figure 1 displays the record of Australia mean temperature during January (blue) in its anomalous value (the departure from the long-term average January temperature).”

This statement is misleading. Surface temperatures and temperatures in the lowest kilometres of the atmosphere are similar – but not the same. Further, they are not similar all of the time. Indeed, some differences between the satellite record and the surface thermometers are understood and to be expected. This is particularly true over Australia during El Niño events or particularly dry and hot periods, such as the recent summer.

Satellites measure the temperature of the air well above the surface.

Research over the past 20 years has shown that dry summers are hot at the surface and wet summers are cool at the surface. The "reverse" holds aloft (higher in the atmosphere) due to differing lapse rates – the rate at which temperatures cool as you go higher in elevation. The upper levels of air tend to cool off considerably, compared to the surface, when it is hot and dry over Australia. This means that record summer temperatures in Australia are less likely to be matched by records higher in the atmosphere.

These differences were documented many years ago (this is documented by Bureau scientists Drosdowsky, W., and M. Williams, 1991: The Southern Oscillation in the Australian region. I: Anomalies at the extremes of the oscillation. J. Climate, 4, 619-638).

This point is also largely irrelevant to the reporting of exceptional conditions on the ground, since people live at the surface.

“Last January was warmer than recent Januaries, but hardly unprecedented. It lies about a standard deviation above the average January temperature. And even during the relatively short satellite era, two Januaries were warmer. Superimposed is anomalous summertime temperature (red). It is even less remarkable. Near the three-decade average, it is no more significant than in preceding years. Neither record evidences a sustained shift in the continental baseline.”

Shifts in continental baselines, or trends, are not measured by taking the difference between record extreme events alone over time. Warming trends are robustly determined by looking at changes in maximum, mean and minimum temperatures. The warming of Australian temperatures has been recorded by multiple data sets, is consistent with warming in the oceans, and is consistent with global and hemispheric trends.

For many on Australia's eastern seaboard, this summer was not anomalously hot but, rather, anomalously cool and wet. This is confirmed by the temperature record at Sydney. The central station reported only two marginal days. And during the entire summer maximum temperature reached 32C on only three days.

Out of all the errors and inaccuracies in this article, this statement is a particularly misleading example of cherry picking, and is a favoured method of disinformation on climate change. While the records over summer were set for individual locations, and for Australia, and for daytime records, monthly and weekly records, seasonal records and duration of heat records, it is always possible to find some locations where the temperatures were less extreme. Finding the odd exception in no way invalidates the Bureau's argument that Australia's last summer, overall, was exceptional.

It is further noted here, that one of the days reported as marginal was in fact a record-setting hot day for Sydney. Given the breadth of records broken, including at locations that were on the whole cooler than the rest of the country, it is absurd to argue (statistically or physically) that these were all the result of problems with the data and the analysis.