Australian Government
Bureau of Meteorology

Improving Australia's climate record

Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT)

The Bureau of Meteorology has released an updated and improved Australian temperature dataset.

Known as the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) the new dataset has been developed specifically to monitor climate variability and change in Australia.

The ACORN-SAT dataset employs the latest analysis techniques and takes advantage of newly digitised observational data to provide a daily record of Australian temperatures over the last 100 years.

It is the world's first continent-wide daily temperature record of its kind.

This dataset will enable climate researchers to better understand long-term changes in monthly and seasonal climate, as well as changes in day-to-day weather—such as the frequency of heat and cold extremes.

The dataset is available from the Bureau's website www.bom.gov.au/climate/change/acorn-sat

A short history of Australian observational records

The history of instrumental weather observations in Australia stretches back to European settlement. Within months of the arrival of the First Fleet, Australia's first 'meteorologist', Lieutenant William Dawes, set up an astronomical observatory and commenced recording weather observations.

Over the next century, amateur and official meteorologists continued taking observations in settlements dotted around the continent, providing documentary evidence of climate variability in Australia.

Unfortunately for modern-day scientists, there was no common standard for observing equipment during the colonial period. Any number of instrument configurations were used, including—perhaps iconically—thermometers housed in beer crates on outback verandas.

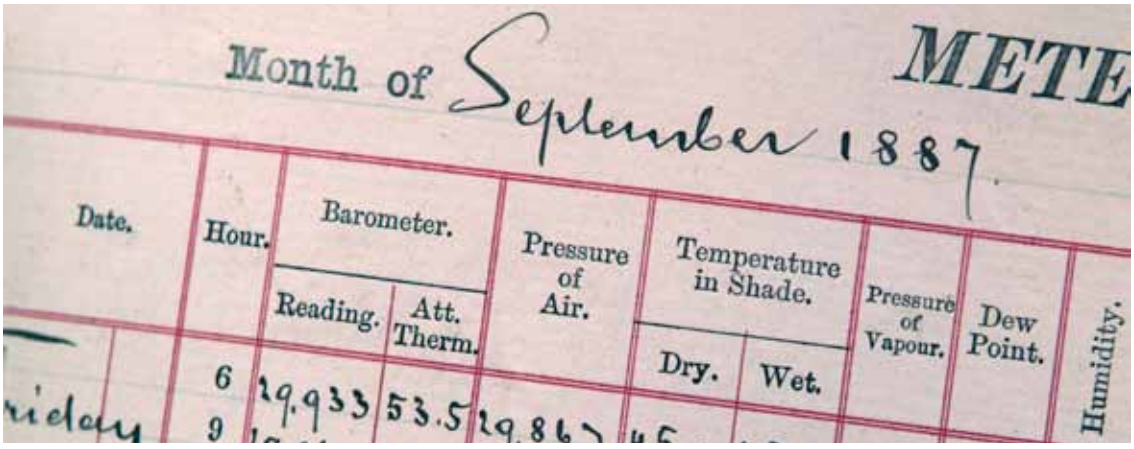
By 1910, however, the newly formed Australian Bureau of Meteorology had established standardised equipment in many parts of the country.

Over the past century, the Bureau has expanded, developed and advanced its network of observing sites. In 2011, the Bureau had 774 temperature recording sites and nearly 6000 rain gauges operating across Australia.

Creating the modern record

Creating a modern Australian temperature record from the high volumes of data collected takes a lot of work.

Some of the work requires digitising records from last century—manual data entry from paper-based records to electronic databases. Other tasks require a great deal of scientific knowledge, such as understanding the impact of technology changes on the consistency of the data over time.


Month of September 1887

Date.	Hour.	Barometer. Reading.	Barometer. Att. Therm.	Pressure of Air.	Temperature in Shade. Dry.	Temperature in Shade. Wet.	Pressure of Vapour.	Dew Point.	Humidity.
	6	29.933	53.5	29.862					

Climate records, like this one from September 1887, are archived by the Bureau of Meteorology

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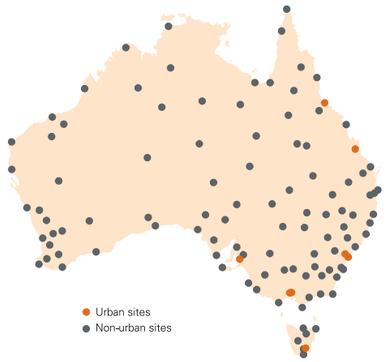
While equipment has been generally standardised and calibrated by the Bureau since 1908, there have been large changes in technology since that time. This includes the gradual replacement of manual observers with automated equipment. There are now 530 automatic weather stations, 490 of which report data every minute.

The Bureau's climate data experts have carefully analysed the digitised data to create a consistent —or homogeneous—record of daily temperatures over the last 100 years.

The ACORN-SAT homogenised temperature database comprises 112 carefully chosen locations that maximise both length of record and network coverage across the continent.



The ACORN-SAT network comprises 112 observation locations across Australia

What causes errors in meteorological data?

Among the hundreds of thousands of climate observations recorded in the Bureau's database each day, it is unavoidable that some records contain errors. This can be due to automated equipment faults, human error in manual observations and a range of other glitches.

The Bureau maintains a layered approach to correcting data errors. Each day, automated and semi-automated quality control systems identify observational errors using methods such as comparison with data from nearby sites.

An extensive audit trail of data and metadata keeps track of corrections that may need to be applied. The data from each ACORN-SAT observing location is subject to ten different quality control checks.

Additionally, the Bureau maintains multiple temperature datasets—analysed in different ways—to provide a consistency check on the accuracy of temperature observations.

For example, the Bureau maintains a fully automated 'real-time' temperature product separately to the manually analysed ACORN-SAT dataset.

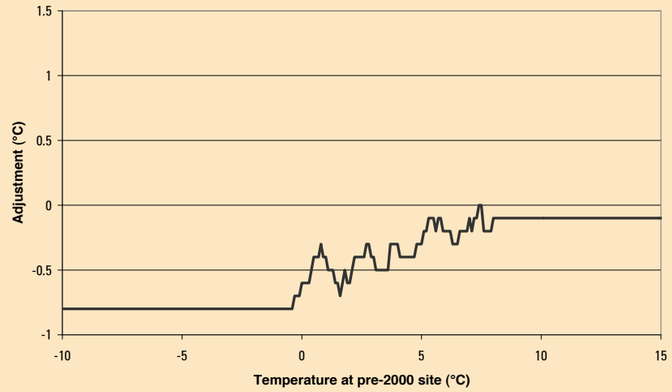
Each day, the real-time monitoring system uses all available reporting sites—the entire observational network—to create a high-resolution, gridded temperature analysis for the Bureau's website. Climatologists periodically cross-check this data with the ACORN-SAT dataset.

An example of the adjustment process

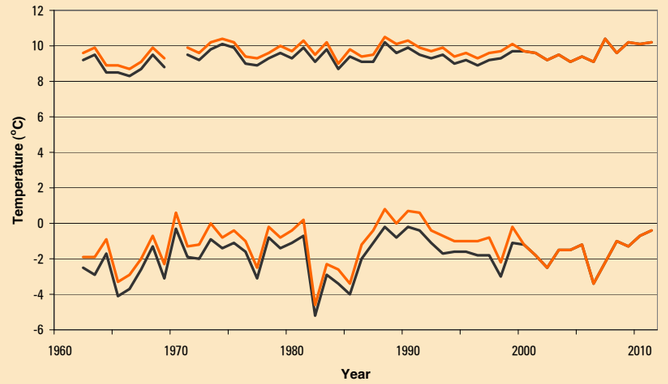
Kerang in northern Victoria is one of the 112 ACORN-SAT locations. The site was moved one kilometre to the north on 18 January 2000, from a location in the town centre near the Post Office to a more open site in parkland.

This site move resulted in a 'drop' in overnight minimum temperatures, particularly in the cooler months. The move, as is common for shifts to more open locations, had a larger impact on clear, calm nights (which are more likely to be cold, especially in winter) than it did on cloudy and windy nights. The adjustment procedure takes this into account (see right), with temperatures from the old site adjusted by 0.8 °C on the coldest nights in July, but only 0.1 °C on the mildest nights.

As a result of the adjustment for the move in 2000, average pre-2000 minimum temperatures were adjusted by approximately 0.4 °C, but extreme low minimum temperatures had a larger adjustment of between 0.6 °C and 1.0 °C. These adjustments result in the observed trends at Kerang being more consistent with other sites in the region.



Adjustments of July minimum temperatures at Kerang to correct for the site move in 2000



Unadjusted (orange) and adjusted (grey) temperatures at Kerang for the annual mean minimum temperature (top) and the lowest minimum temperature of each year (bottom)

What affects consistency of temperature observations over time?

A large number of factors affect the consistency of the temperature record over time. So many, in fact, that raw temperature recordings are found to be unsuitable for correctly characterising climate change over long periods. For this reason, a carefully prepared dataset such as ACORN-SAT is vital for climate research.

While considerable effort is made to keep observational practices consistent—and to keep a careful log of changes at each site—each change in methodology or technology can leave its mark on the record.

Climatologists carefully analyse records to find any evidence of spurious artefacts in the data, which introduce changes over time that are not related to climate variability.

These include artificial changes in the record due to the replacement of thermometers or changes in observing practices, such as the change from imperial to decimal units in the middle of last century.

The network itself has also changed over time. As the population has grown and expanded into remote parts of the continent, so too has the Bureau's station network. As Australia is so large and contains a rich variety of climates, climatologists need to carefully account for changes in the network. They need to make sure, for example, that the expansion of the network into the hot desert interior and tropical north have not produced biases in Australian-average temperature over time.

Changes in infrastructure also affect the Bureau's network. Over time, towns and cities grow, new roads and airports are built, and rural land use changes. These developments can force the movement and replacement of thermometers and other equipment.

Each site relocation has the potential to disrupt the continuity of records, since no two sites have exactly the same climate.

Observations began in 1910 at the Post Office in Carnarvon, Western Australia, and after several moves it has operated as an automatic weather station since 1996

The Bureau employs world-leading methods and analysis techniques to account for such changes so that records can be confidently compared from one period to another throughout the last century.

ACORN-SAT: the improved dataset

The Bureau began developing the ACORN-SAT dataset in 2009.

Rather than simply updating existing homogenised datasets, ACORN-SAT involved a complete re-analysis of the Australian temperature record. ACORN-SAT replaces the following homogenised datasets that were developed to analyse long-term climate variations:

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- The annual dataset, developed by Torok and Nicholls in 1996 then updated by Della-Marta et al. in 2004 with a network comprising 224 sites and using annual data back to 1910.
- The daily dataset, developed by Trewin in 2001 with a network comprising 103 sites and using daily data back to 1950.

ACORN-SAT is a substantial improvement on these datasets in two important areas. First, the dataset is at the daily timescale all the way back to 1910, thereby allowing analysis of climate extremes, such as heatwaves and frequency of warm and cold weather, as well as changes in temperature averages. Second, the update makes use of large volumes of recently digitised historical temperature data, thereby providing improved temporal and spatial coverage. It employs better analysis techniques in a complete re-analysis of data from 1910 to 2010.

Peer review of the ACORN-SAT

Recognising the importance of the integrity of homogenised data—as the basis for climate change analysis—the Bureau ensures that all its datasets, and the methods used to develop them, are rigorously reviewed.

All of the Bureau's published scientific works are subject to the expert peer review process required for publication in scientific journals or technical reports. For ACORN-SAT, the Bureau has initiated an additional international peer review of its processes and methodologies.

A panel of world-leading climate experts convened in Melbourne for a week in 2011 to examine the methods used to analyse the Bureau's temperature data. This included receiving submissions and presentations from the scientists developing ACORN-SAT, as well as an examination of all Bureau processes—from instrument to final product—to maintain a homogenised temperature record.

The panel affirmed the considerable importance of ACORN-SAT and was satisfied, overall, with the methodologies used by the Bureau to develop the dataset. It ranked the Bureau's procedures and data analyses among the best in the world.

As part of the extensive publication of data, science and information for the new dataset, the Bureau has released the findings of the international peer review panel, including all 31 recommendations regarding the future management of ACORN-SAT.

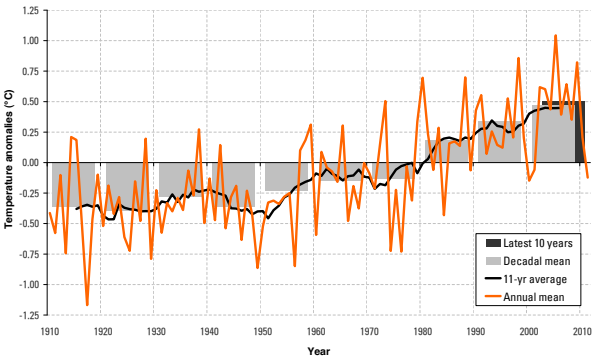
The Bureau began implementing several of these recommendations prior to releasing the ACORN-SAT dataset and will continue investigating how best to resource and implement the other recommendations.

> 'The Panel is convinced that, as the world's first national-scale homogenised dataset of daily temperatures, the ACORN-SAT dataset will be of great national and international value. We encourage the Bureau to consider the dataset an important long-term national asset.' *ACORN-SAT International Peer Review Panel Report, 2011*

Climate trends

ACORN-SAT reaffirms climate trends identified previously by the Bureau.

The new data show that Australia has warmed by approximately 1°C since 1910. The warming has occurred mostly since 1950.



Annual and decadal mean temperature anomalies for Australia (departures from the 1960–1990 average)

The frequency of daily temperature extremes has also changed since 1910. The number of weather stations recording very warm night-time temperatures and the frequency with which these occur has increased since the mid 1970s. The rate of very hot daytime temperatures has been increasing since the 1990s.

The warming in Australian temperature data is very similar to that shown in international analyses of Australian data—for the globe and other regions—and very closely matches warming of sea surface temperatures around Australia. This agreement provides added confidence for decision– and policy-makers, and reinforces our understanding of climate change and global warming.

Further information

For information on Bureau products and datasets visit **www.bom.gov.au/climate**