



**Australian Government**

**Bureau of Meteorology**

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

Bureau of Meteorology response to recommendations of the  
Independent Peer Review Panel

2 March 2015



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# Status of the Bureau's response to the recommendations

## Status of the Bureau of Meteorology response to recommendations of the Independent Peer Review Panel of the total of 31 recommendations of the Review:

- Completed: 18
- In progress: 12
- Under review: 1

### A. The observation practices employed by the Bureau of Meteorology for surface air temperature measurements

**A1.** Reduce the formal inspection tolerance on ACORN-SAT temperature sensors significantly below the present  $\pm 0.5$  °C. This future tolerance range should be an achievable value determined by the Bureau's Observation Program and should be no greater than the  $\pm 0.2$  °C encouraged by the World Meteorological Organization (WMO).

**A1 Status:** In progress. The Bureau is continuing to investigate options for improving its measurement and quality assurance process. These include implementing redundancy in measurement, improving field inspection and verification, and purchasing a new data acquisition system. The Bureau will continue to monitor developments in WMO and other countries. Implementation will be subject to resource prioritisation.

**A2.** Analyse and document the likely influence of any of the historical  $\pm 0.5$  °C inspection tolerance in temperature sensors, on the uncertainty range in both individual station and national multidecadal temperature trends calculated from the ACORN-SAT temperature series.

**A2 Status:** In progress. A study has commenced on metrology associated with the tolerance limits. It is anticipated that it will be complete in 2016. An analysis of the results of existing instrument tolerance checks was also carried out for ACORN-SAT stations over the last 5 years. This found that tolerance checks, which are carried out six-monthly

at most ACORN-SAT stations, were within 0.2 °C in 97% of cases and within 0.5 °C 99.5% of cases.

**A3.** The Review Panel suggests that the Bureau should give more attention to building redundancy into ACORN-SAT observation stations, particularly stations in remote areas of Australia. This can include redundancy in sensors, loggers, data storage and communications equipment, especially as the inexorable international trend towards automatic weather stations continues. The Panel suggests that the Bureau develops a strategy to make cost-effective investments in redundancy to ensure the continuing resilience of the ACORN-SAT network.

**A3 Status:** Completed. With provisions put in place, this task is ongoing and business-as-usual. In 2013-14 investment was made to strengthen data communications redundancy across 104 sites of the ACORN-SAT network. Extensive work is being done to implement the Bureau's new Observing System Strategy that includes delivering improvements in technology, systems, tools and network management. The ability to accommodate redundant sensors is part of the new automatic weather station strategy. The impact on the data archival system is also being investigated, particularly the ability to accommodate redundant temperature measurements.

**A4.** The Review Panel noted that most but not all of the possible historical monthly temperature records are digitised, and that some daily ACORN-SAT data remain undigitised. The Panel welcomes the statements they received from Bureau staff that undigitised ACORNSAT records will be targeted for future digitisation. The residual set of non-digitised data and metadata paper records for ACORN-SAT observation stations should be located as a matter of priority, and imaged. It is important that the digitisation of these remaining paper only daily temperature records then be completed.

**A4 Status:** In progress. This is a resource intensive task. Data from three additional ACORN-SAT locations Sale, Moree and Canberra have recently been digitised, and will be re-analysed and then released with the next version of ACORN-SAT that is currently due for release in 2015.

**A5.** *If resources for this task are not available, the Bureau should investigate the feasibility of using crowdsourcing techniques to accelerate the completion of the ACORN-SAT data digitisation process.*

**A5 Status:** In progress. The Bureau is closely involved with international initiatives which are likely to involve the development of an international portal for crowd sourced digitisation. The Bureau is particularly interested in ensuring that, where crowd sourced digitisation is utilised, effective quality assurance processes are in place.

**A6.** *The Bureau should include sufficient station metadata within the public ACORN-SAT station catalogue currently under development, to allow independent replication of homogeneity analyses for individual ACORN-SAT stations.*

**A6 Status:** Completed. The current version of the ACORN-SAT site catalogue (released in 2012 with the first version of the data set) provides a synopsis of information for each site to a level of detail—beyond that currently available, in succinct form, from other meteorological agencies. The next version of the ACORN-SAT site catalogue will be greatly expanded to provide more information on the homogeneity adjustment analysis for each location. An example of the type of information included in the next update can be found at the following link (<http://www.bom.gov.au/climate/change/acorn-sat/#tabs=Adjustments>). The Bureau continues to collect and store observations metadata using world best practice systems. Future enhancement of this will be considered when metadata user requirements are evaluated as part of the Bureau's commitment to WMO Integrated Global Observing System (WIGOS).

## **B. The methodology used to select stations for the ACORN-SAT dataset**

**B1.** *The Bureau should clearly define, document and observe objective criteria for selecting stations for, and excluding stations from, the ACORN-SAT network.*

**B1 Status:** In progress. Criteria are documented in [http://cawcr.gov.au/publications/technicalreports/CTR\\_049.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_049.pdf). Based on this criteria there are potentially 20 additional locations identified for possible inclusion in future updates.

**B2.** *Develop the investment case for a limited number of additional observation stations in remote (central and north-western) Australia which would further enhance the robustness of ACORN-SAT data for trend analysis work in regional Australia.*

**B2 Status:** In progress. The Bureau is preparing an investment proposition for augmentation of the ACORN-SAT network. This will outline the priorities and costings for potential new stations. The Bureau continues to review and improve station distribution as part of the Observing System Strategy. Whilst the Bureau is not currently funded for network expansion, future expansion of the ACORN-SAT network could be internally offset through closures in other parts of the network.

**B3.** *Require that when any area of the Bureau is considering the possibility of observation station closures or operational changes in future years, special consideration be given to the importance of continuity in the ACORN-SAT data series, and custodians of the ACORN-SAT dataset should be consulted before decisions are taken.*

**B3 Status:** Completed. The Bureau regularly engages with the Climate program with observation changes are proposed at ACORN-SAT sites. To the extent possible, observation overlaps of 12 to 24 months are instituted to facilitate analysis of the impact of station changes.

**B4.** *To provide maximum notice of the possibility of the (undesirable) closure of ACORN-SAT observation stations in the future, the Bureau should initiate a study of the viability and continuing long-term availability of the present ACORN-SAT observation sites. This would enable proactive preparations to minimise the negative impacts of such closures, including the timely establishment of overlapping observation stations.*

**B4 Status:** Completed

**B5.** *Maintain and improve mechanisms for consultation and collaboration between Climate Information Program and Observation Program staff, regarding ongoing planning for and operation of the ACORN-SAT network.*

**B5 Status:** In progress. The implementation of Bureau's observing system strategy, includes clear arrangements for ongoing engagement with all areas of the Bureau to ensure observing arrangements continue to meet operational requirements.

### C. The approach and methodologies applied to these data to ensure the homogeneity of the dataset

**C1.** *A list of adjustments made as a result of the process of homogenisation should be assembled, maintained and made publicly available, along with the adjusted temperature series. Such a list will need to include the rationale for each adjustment.*

**C1 Status:** Completed

**C2.** *The computer codes underpinning the ACORN-SAT dataset, including the algorithms and protocols used by the Bureau for data quality control, homogeneity testing and calculating adjustments to homogenise the ACORN-SAT data, should be made publicly available. An important preparatory step could be for key personnel to conduct code walkthroughs to members of the ACORN-SAT team.*

**C2 Status:** Completed

**C3.** *Both the raw and the homogenised ACORN-SAT datasets should be analysed with the same gridding and trend analysis method, to identify the effects of the data homogenisation.*

**C3 Status:** Completed

**C4.** *The Bureau should better clarify whether or not there were any network-wide changes in the instrument/observing practices that took place at all stations across large portions of Australia at about the same time. If so, it will be important to demonstrate how these network-wide changes were addressed. This is significant because tests based on comparing neighbouring station records usually cannot detect network-wide changes.*

**C4 Status:** Completed

**C5.** *The Bureau is encouraged to calculate the adjustments using only the best correlated neighbour station record and compare the results with the adjustments calculated using several neighbouring stations. This would better justify one estimate or the other and quantify impacts arising from such choices.*

**C5 Status:** Completed

**C6.** *The Panel notes the intention of the Bureau to consider 'infilling' data gaps in a small number of stations' data records. The Panel strongly recommends that, if the Bureau proceeds with this work, the processes should be carefully documented, and the infilled data should be flagged and maintained separately from the original.*

**C6 Status:** Completed. The Bureau considered in-filling data gaps for ACORN-SAT and determined that the approach recommended is (a) unlikely to significantly reduce uncertainties and (b) is less desirable for researchers who do not want such in-filling of the data.

**C7.** *Before public release of the ACORN-SAT dataset, the Bureau should determine and document the reasons why the new dataset shows a lower average temperature in the period prior to 1940 than is shown by data derived from the whole network, and by previous international analyses of Australian temperature data.*

**C7 Status:** Completed

**C8.** *Prior to release, the Bureau should establish version control arrangements for the raw and homogenised ACORN-SAT datasets to accommodate the evolving techniques of data homogenisation and the potential addition of more digitised data to the ACORN-SAT dataset. This would enhance the traceability of the dataset and decrease potential confusion among dataset users.*

**C8 Status:** Completed. Detailed information on all versions has been maintained internally and this will be published in the planned 2015 ACORN-SAT release.

#### D. The methodologies applied in the analysis of temperature trends in the ACORN-SAT dataset

**D1.** While the Bureau compared Australian national average ACORN-SAT temperature trends with trends from satellite data, the spatial pattern of trends derived from ACORN-SAT, particularly in data sparse areas, should also be compared to the spatial patterns of trends in satellite temperature observations. The absolute value of the trends may be different, but even satellite-derived temperatures of the lower troposphere produce spatial patterns of trends that commonly agree with the spatial pattern of in situ surface temperature. Comparing these different datasets therefore has the potential to help identify and quantify potential artefacts in the sub-national ACORN-SAT trend patterns.

**D1 Status:** In Progress. A comprehensive comparison has been undertaken between national average temperatures from satellites and the ACORN-SAT data. This has revealed that the satellite data show similar or slightly greater rates of warming, and confirms the reliability of the ACORN-SAT data. Extending the comparison to the regional level is being explored but is complicated by a number of factors, especially the coarse resolution of the satellite data.

**D2.** The Bureau should give careful consideration to the best form of visual presentation of temperature trends across the Australian continent. For example, the addition of dots at station locations shaded to indicate each station's trend can help the viewer visually assess whether a particular feature is the function of data from many stations or a single station. If a station only contributes information to part of the period being analysed, it would not be an 'apples to apples' comparison to shade that station location with the trend value for a different period. However, simply indicating the location of stations with partial periods would aid in understanding the causes of the spatial patterns of trends. Similarly 'bubble plots', which represent the magnitude of station trends by the size of a circle and the sign of a trend by the colour of the circle, provide a level of information hidden in the Bureau's standard maps. So the Bureau should consider providing this information as well as companion figures.

**D2 Status:** Completed

**D3.** The Bureau should compare temperature time series in a variety of subsets of stations versus different subsets, or the network as a whole, to assess and document the robustness of the data with respect to various classes of stations. These comparisons can be across the whole continent or averages of multiple neighbouring station comparisons. Examples of classes of stations that should be compared include: **1)** town stations versus country stations, **2)** airport stations versus non-airport stations, **3)** synoptic stations versus daily stations, **4)** liquid-in-glass thermometer stations versus electronic thermometer stations and **5)** stations that have undergone changes in their daily times of observation versus stations that have not.

**D3 Status:** In progress. The sensitivity of trends to methods was analyzed in detail in CAWCR Technical Reports No. 049 and 050, which can be found on the web at [http://cawcr.gov.au/publications/technicalreports/CTR\\_049.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_049.pdf) and [http://cawcr.gov.au/publications/technicalreports/CTR\\_050.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_050.pdf). There is ongoing research in this area and any additional research results will form part of the evaluation process prior to the planned ACORN-SAT 2015 release.

**D4.** The Bureau should specify the statistical uncertainty values associated with calculating Australian national temperature trends and make this information readily available whenever trends are discussed. Additionally, error bounds or confidence intervals along the time series would be useful.

**D4 Status:** In Progress. Some progress has been made through the CAWCR Technical Report No. 050 available at [http://cawcr.gov.au/publications/technicalreports/CTR\\_050.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_050.pdf). Additional research is underway to allow more robust uncertainty estimates for future ACORN-SAT versions. Calculating uncertainty consists of a number of parts. These include uncertainty associated with the observations at stations, uncertainty associated with the area averages, and uncertainty associated with statistical analysis of data (e.g., calculation of trends). A focus has been on the process of area averaging and statistical analysis. To the extent that artificial impacts from changes in the station network is captured by the process of homogenisation, the uncertainty with observations at stations is considered insignificant noting that nearly 100 stations are used for analysis.

A study is also in progress examining the uncertainty involved in individual adjustments and their robustness to different choices of reference stations and comparison periods.

**D5.** *The Bureau adopted the practice that monthly mean temperatures are calculated from daily temperature data for months with fewer than ten missing daily values. If nine days at the beginning of a month were missing, there is potential to ignore a significant portion of that month's climate signal. The Panel suggests the Bureau revisit this issue by conducting an analysis of the trade offs between decreasing the accuracy of the final analysis by not including as many valid monthly values versus the size of the potential error in a monthly value due to various levels of missing values.*

**D5 Status:** Completed

**D6.** *The Bureau should more actively investigate the possible use of non-instrumental proxy indicators of temperature such as ecological indices or paleoclimatic data to further test and validate the subnational regional robustness of the ACORN-SAT dataset. This is an example of one of the many research opportunities which will need to be pursued in parallel with the data service delivery functions of the Bureau.*

**D6 Status:** Under review. Developing proxy climate records involves significant amounts of work with long timelines, and this work has traditionally been carried out by the University sector in Australia and not the Bureau of Meteorology. However, the Bureau recently collaborated with researchers from the University of Melbourne on the South Eastern Australian Recent Climate History (SEARCH) project.

## E. Communications and transparency

**E1.** *An accessible introductory guide to the ACORN-SAT dataset should be prepared for publication, covering its origins, purpose, functions, operational arrangements, costs, limitations and international importance. This guide should include a clear explanation of why the ACORN-SAT dataset is needed and how it will improve on the existing network of observation stations.*

**E1 Status:** Completed

**E2.** *For both transparency and internal management purposes, the policies, protocols, procedures and practices for the collection, quality control and adjustment of ACORN-SAT data should be consolidated and kept up-to-date in a single, binding program management manual. The contents of the manual should be made available publicly in an accessible form, preferably on the internet.*

**E2 Status:** In progress. Documentation exists in two technical reports (at [http://cawcr.gov.au/publications/technicalreports/CTR\\_049.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_049.pdf) and [http://cawcr.gov.au/publications/technicalreports/CTR\\_050.pdf](http://cawcr.gov.au/publications/technicalreports/CTR_050.pdf)).

The Bureau has been undertaking the major task of migrating software applications to an entirely new computing system/architecture. Current operational procedures will be codified around October 2015 on completion of this migration task.

**E3.** *The processes used for network design, data quality control and data homogenisation in the development of the ACORN-SAT dataset should be published in peer-reviewed journals.*

**E3 Status:** Completed

**E4.** *A Technical Advisory Group should be established to meet approximately annually, to review progress on the development and operation of the ACORN-SAT dataset. The Group should comprise respected external scientists and statisticians, as well as representatives of data users, stakeholders with relevant experience in regional Australia, and representatives from other relevant functional areas of the Bureau. An alternative would be to establish a by-invitation annual technical advisory forum involving respected external scientists, statisticians and stakeholders to provide an opportunity for external comment on the further development of the ACORN-SAT system.*



**E4 Status:** In progress. A Technical Advisory Forum has been established and is scheduled to meet on 26 March 2015. Note also that the Bureau is well engaged with external organisations in the use of the ACORN-SAT dataset, e.g. with the CSIRO and the ARC Centre for Excellence for Climate System Science. The latter has a research program on the mechanisms explaining changes in Australian climate extremes. The Bureau is also active within World Meteorological Organization expert teams and task teams, including a task team specifically on homogenisation.

***E5.** When the ACORN-SAT dataset is released, the release package should include not only technical details of the dataset and the temperature trend estimates derived from the set, but also careful explanation and interpretive commentary about what the data series says about long-term temperature trends in Australia with a particular focus on the differences and reasons for the differences from other datasets.*

**E5 Status:** Completed

***E6.** The Review Panel recommends that the Bureau assembles and maintains for publication a thorough list of initiatives it has taken to improve transparency, public accessibility and comprehensibility of the ACORN-SAT dataset.*

**E6 Status:** Completed