# Australian Climate Observations Reference Network

## Surface Air Temperature (ACORN-SAT)

**Report of the Technical Advisory Forum**
**September 2017**

26 July 2017

The Hon Josh Frydenberg MP
Minister for the Environment and Energy
Parliament House
CANBERRA ACT 2600

Dear Minister

It is with great pleasure that I attach the third and final annual report on the Australian Climate Observations Reference Network—Surface Air Temperature (ACORN-SAT) dataset on behalf of the Technical Advisory Forum. We have prepared this report as required by our Terms of Reference.

The Forum was appointed by the previous Parliamentary Secretary to the Minister for the Environment in 2015. The Forum was established for a three-year period to annually review the development and operation of the ACORN-SAT dataset and to provide advice and recommendations on further developments to the Bureau of Meteorology who manage the dataset. This report is the result of a two-day meeting of the Forum in May 2017, and follows two previous annual reports released in 2015 and 2016.

This report supports the conclusion of the Forum's previous reports that the ACORN-SAT dataset is well maintained and represents an important source of information on the climate trends affecting Australia. The Forum commends the Bureau for their progress in addressing our recommendations. We have made three new recommendations we feel will contribute to the Bureau's ongoing improvement of the ACORN-SAT dataset. The Forum is confident the Bureau will continue to improve the development and operation of the ACORN-SAT dataset following the conclusion of the Forum this year.

The Forum members would like to thank the Department of the Environment and Energy for the support and management of the Forum's membership. We are also grateful for the information provided by the Bureau and for their commitment to answering the Forum's questions. The Bureau have consistently demonstrated a strong commitment to the Forum's process.

I have provided a copy of the report to Dr Andrew Johnson, Director of the Bureau, and look forward to the Bureau's response. I would be very pleased to discuss the Forum's report with you, if you would like further details about our deliberations or conclusions.

Yours sincerely

Dr Ron Sandland AM FTSE
Chair, ACORN-SAT Technical Advisory Forum

On behalf of: Emeritus Professor Bob Vincent (Vice Chair), Dr Phillip Gould, Dr John Henstridge, Ms Susan Linacre, Professor Michael Martin, Professor Patty Solomon, Professor Terry Speed

26 July 2017

Dr Andrew Johnson
Director of Meteorology
Bureau of Meteorology
GPO Box 413
BRISBANE QLD 4001

Dear Dr Johnson

It is with great pleasure that I attach the third and final annual report on the Australian Climate Observations Reference Network Surface Air Temperature (ACORN-SAT) dataset on behalf of the Technical Advisory Forum. We have prepared this report as required by our Terms of Reference.

As you are aware, the Forum was appointed by the previous Parliamentary Secretary to the Minister for the Environment in 2015. The Forum was established for a three-year period to annually review the development and operation of the ACORN-SAT dataset and to provide advice and recommendations on further developments to the Bureau of Meteorology as managers of this dataset. This report is the result of the two-day meeting of the Forum in May 2017 which you participated in. It follows two previous annual reports released in 2015 and 2016. I have also provided a copy of the report to the Minister for the Environment and Energy, the Hon Josh Frydenberg MP.

This report supports the conclusion of the Forum's previous reports that the ACORN-SAT dataset is well maintained and represents an important source of information on the climate trends affecting Australia. The Forum commends the Bureau for their progress in addressing our recommendations. We have made three new recommendations we feel will contribute to the Bureau's ongoing improvement of the ACORN-SAT dataset.

I congratulate the Bureau staff for their ongoing work on the ACORN-SAT dataset, and extend the Forum's thanks and appreciation to the Bureau staff for their detailed and energetic presentations and responses to the Forum's questions. Under your leadership, the Bureau has continued to demonstrate a strong commitment to the Forum's process. The Forum is confident the Bureau will continue to improve the development and operation of the ACORN-SAT dataset following the conclusion of the Forum this year.

I would sincerely like to thank you for the support you have given the Forum since becoming Director of the Bureau, and wish you all the best for your future leadership of the agency.

Yours sincerely

Dr Ron Sandland AM FTSE
Chair, ACORN-SAT Technical Advisory Forum

On behalf of: Emeritus Professor Bob Vincent (Vice Chair), Dr Phillip Gould, Dr John Henstridge, Ms Susan Linacre, Professor Michael Martin, Professor Patty Solomon, Professor Terry Speed

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# Acronyms

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| ACORN-SAT | Australian Climate Observations Reference Network—Surface Air Temperature |
| ADAM | Australian Data Archive for Meteorology |
| ARC | Australian Research Council |
| IPR | Independent Peer Review |
| TAF | Technical Advisory Forum |
| WMO | World Meteorological Organization |

# Executive summary

This is the third and final annual report of the Technical Advisory Forum established by the Australian Government in January 2015. The Forum was established to review the development and operation of the Bureau of Meteorology's Australian Climate Observation Reference Network —Surface Air Temperature (ACORN-SAT) dataset and to review, provide advice and make recommendations on further developments in the maintenance, reporting and use of that dataset.

The ACORN-SAT is the Bureau's long-term homogenised dataset of Australian daily temperatures covering the period from 1910 to the present. In light of the importance of the integrity of this dataset in understanding long-term climate trends affecting Australia, the Bureau initiated an independent peer review of the ACORN-SAT dataset in 2011. The peer review expressed overall confidence in the Bureau's management of the dataset and considered its practices to be amongst the best in the world. One of the recommendations of the independent peer review was to establish a Technical Advisory Forum to review and provide advice on the ongoing development and operation of the dataset.

The Forum was established to meet annually for three years from 2015 to 2017. The Forum's Terms of Reference require it to consider the following over this three-year period:

- the extent of the public availability of the ACORN-SAT information;
- developments since the 2011 Independent Peer Review of the Bureau's data and analysis methods; and
- the scientific integrity and robustness of the Australian climate record and the homogenisation process.

In forming its recommendations, the Forum undertook a technical examination of the operation and management of the ACORN-SAT dataset. The Forum held extensive technical discussions with Bureau representatives to inform its internal anaylsis and consideration of its recommendations.

This report outlines the Bureau's progress against the recommendations made by the Forum in its second report in 2016 and contains three new recommendations following deliberations at the Forum's meeting in May 2017. This is the final report of the Forum, and it is not expected that the Forum will meet again. The report should be read alongside the contextual information provided in the first and second annual reports and the Bureau's responses to these, all of which are available on the Bureau's website.

### 2015 report

The Forum met for the first time in March 2015 and released its first annual report in June the same year. Following detailed examination and deliberation, the Forum concluded that the ACORN-SAT dataset is well maintained and an important element of Australia's climate record. The Forum recognised that homogenisation plays an essential role in eliminating artificial non-climatic systematic errors in temperature observations so that a meaningful and consistent set of records can be maintained over time.

At its first meeting, the Forum examined a broad range of information and data concerning the management and development of the ACORN-SAT dataset provided by the Bureau. The Forum also considered unsolicited submissions from some members of the public. The Forum made five recommendations to support the Bureau's continuous improvement of the ACORN-SAT dataset which are outlined in detail in its first annual report available on the Bureau's website. Briefly, those recommendations provided specific guidance to support the Bureau to continue to: improve communications related to the ACORN-SAT dataset, particularly with regard to reporting on uncertainty; improve accessibility of ACORN-SAT data and information; enhance statistical methods employed in developing the ACORN-SAT dataset; improve access and handling of metadata information; and expand the ACORN-SAT dataset and supporting analyses.

### 2016 report

The Forum held its second annual meeting in June 2016. At the meeting, Forum members scrutinised the Bureau's progress with improving elements of the ACORN-SAT dataset and associated analyses in line with the 2015 recommendations. The Forum noted the Bureau's progress against the recommendations and its ongoing commitment to the process. In particular, the Forum welcomed the Bureau's progress in improving the communication and accessibility of the dataset, improving the access and handling of metadata, and expanding the ACORN-SAT data and supporting analyses.

The Forum reiterated the importance of homogenisation in supporting the maintenance of a meaningful and consistent set of temperature records over time. The Forum made three new recommendations to support the Bureau's ongoing management of the ACORN-SAT dataset. Briefly, these recommendations provided advice on: continuing to improve the communication and accessibility of the ACORN-SAT dataset; building on existing domestic and international engagement with the statistical research community on the ACORN-SAT dataset; and making continued progress in the handling of ACORN-SAT metadata and homogenisation. The Forum released its second annual report in September 2016, which contains details of these recommendations, and is available on the Bureau's website.

## 2017 meeting and report

The Forum met for a third and final time in May 2017 to review the Bureau's progress against its 2016 recommendations. The Forum examined the Bureau's progress in addressing their recommendations, and questioned Bureau staff on specific aspects of the management and operation of the ACORN-SAT dataset. The Forum welcomed the positive manner in which the Bureau had addressed the recommendations, including the Bureau's initial work to meet the Forum's longer-term recommendations. The Forum's views on the Bureau's progress against the recommendations is outlined in the body of this document and summarised in Appendix A. The meeting agenda, minutes and Chair's communique are in Appendices B, C and D respectively.

Although the Bureau is still actively implementing some aspects of the Forum's recommendations, the Forum recognises the substantial progress that has been made against all of the recommendations. The Forum remains satisfied with the Bureau's ongoing development and operation of the ACORN-SAT dataset, and notes that the Bureau has consistently demonstrated a genuine commitment to best-practice management of the dataset.

## Progress against 2016 recommendations

The Forum commends the Bureau on their progress in addressing the three 2016 recommendations. A summary of progress against each recommendation is provided below. A more detailed discussion is provided in the body of this report.

In addressing recommendation 1, the Forum notes the recent improvements the Bureau has made to the communication and accessibility of the ACORN-SAT dataset, including the development of factsheets and case studies for release later in 2017, and the availability of source code for the dataset through their website. The Forum also notes the Bureau's efforts in updating the ACORN-SAT data in anticipation of releasing Version 2 of the dataset later in 2017.

The Forum is pleased with the progress the Bureau is making on engaging the statistical community under recommendation 2. The Bureau's willingness to collaborate demonstrates their strong commitment to improving the ACORN-SAT dataset through developing research partnerships with non-climate experts to enhance analytical, data-based approaches to understanding Australian temperature data. In particular, the Forum acknowledges the Bureau's intentions to continue to engage with expert statisticians on estimating uncertainty, and encourages them to keep progressing this work.

The Forum also acknowledges the advances made against recommendation 3 in the documentation and handling of ACORN-SAT metadata. The Forum continues to support the Bureau's methodological approaches to homogenisation practices, and reiterates the importance of homogenisation in supporting the maintenance of a meaningful and consistent set of temperature records over time. The Forum noted again that the Bureau is recognised internationally for its expertise in homogenisation, which is demonstrated through their continued engagement and leadership on this topic within the international climatological science community.

## 2017 recommendations

Despite substantial progress against the 2016 recommendations, the Forum has identified three key areas where the Bureau can continue to strengthen their management of the ACORN-SAT dataset. The three new 2017 recommendations replace the Forum's previous recommendations. They can be grouped in the same three themes as the 2016 recommendations: (1) improving the communication and accessibility of the ACORN-SAT dataset; (2) supporting continued engagement with the Australian and international statistical community; and (3) handling of the ACORN-SAT metadata and homogenisation.

In light of the Bureau's progress and commitment to best practice, the Forum is confident the Bureau will continue to improve the development and operation of the ACORN-SAT dataset following the conclusion of the Forum in 2017. The Forum supports the Bureau's proposal to establish a new assurance advisory mechanism to provide expert and independent advice on data management and analysis more broadly within the Bureau. The Forum considers the new mechanism an appropriate group to promote the Bureau's goal to adhere to scientific best-practice in its stewardship and use of Australian climate data. Considering the Forum will conclude mid-2017, the new assurance advisory mechanism could provide ongoing oversight of any outstanding matters from the Forum's process, including progress against the 2017 recommendations.

# 2017 recommendations

The Forum acknowledges the substantial progress the Bureau has made against its 2016 recommendations. To support the ongoing development and improvement of the ACORN-SAT dataset, the Forum proposes the following 2017 recommendations acknowledging that these will be subject to resourcing considerations.

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**RECOMMENDATION 1**

To support continued progress on improving the communication and accessibility of the ACORNSAT dataset, the Forum recommends that the Bureau:

a) Develop communication material for public release alongside Version 2 of the ACORN-SAT dataset by the end of 2017 that:

   i. Outlines the rationale for developing Version 2 of the ACORN-SAT dataset, and what criteria would be applied to warrant future major version updates beyond Version 2;

   ii. Outlines the key updates made to Version 1 of the ACORN-SAT dataset that have been implemented within Version 2, and explains both scientifically and in lay terms any potential changes in estimated temperature trends between the two versions;

   iii. Explains the basis and rationale for legacy rounding practices utilised within homogenisation algorithms that were applied in development of Version 1 of the ACORN-SAT dataset, how this issue has been revised to conduct all interim calculations without rounding to reflect current computing practices, and what implications this revised approach has had for Version 2 of the dataset;

   iv. Outlines how the Forum's previous recommendations have been incorporated in the development of Version 2 of the ACORN-SAT dataset.

b) Finalise and publish a set of case studies presented to and discussed at the Forum following appropriate quality control and peer review processes.

c) Develop a new case study which outlines how the ACORN-SAT dataset may be used alongside the Bureau's climate models to compare observed temperatures with those predicted by physical climate modelling.

d) Publish the same version of the ACORN-SAT source dataset used by the Bureau on the Australian Data Archive for Meteorology (ADAM) and the Climate Data Online portal.

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## RECOMMENDATION 2

To support their continued engagement with the Australian and international statistical community, the Forum recommends that the Bureau:

a)  Proceed with its proposal to establish a new assurance advisory mechanism comprising independent experts to advise the Bureau on the handling of data. The proposed mechanism could provide ongoing oversight of any outstanding matters from the Forum's process, including the Bureau's responses to the 2017 recommendations.

b)  Continues to engage with appropriately qualified statistical experts to understand and quantify the uncertainty inherent in measuring temperature within a geographically dispersed network of weather stations. The aim of quantifying this uncertainty is to produce a coherent description of Australian temperature patterns at national and regional levels, and the variability associated with these patterns, so that the confidence that can be placed in conclusions from related analyses can be assessed.

c)  Organise and host the proposed one-day homogenisation research workshop with relevant climate and statistics experts.

d)  Make the work on pre-1910 historical climate data available on the Bureau's website, and develop appropriate communication materials to promote this development as an adjunct to ACORN-SAT in providing a more complete description of Australia's long-term temperature record and to place ACORN-SAT in a broader historical perspective.

e)  Engage an appropriately qualified statistician to: (1) advise the Bureau on the experimental design and implementation of the project to update the screens at ACORN-SAT weather stations with the goal of quantifying any systematic effects of the new screens on temperature measurements; and (2) support the Bureau in modelling and analysing uncertainty in the data and assisting in producing appropriate estimates of standard error.

## RECOMMENDATION 3

To support continued progress in the handling of ACORN-SAT metadata and homogenisation, the Forum recommends the Bureau:

a)  Finalise and publish the fact sheets for all 112 ACORN-SAT reference stations following appropriate quality control processes. The factsheets should be released alongside the release of Version 2 of the ACORN-SAT dataset.

b)  Continues to explore options to develop an automated homogenisation process in the long-term.

# 1. Introduction

This is the third and final annual report containing the findings and recommendations of the Technical Advisory Forum on the Australian Climate Observations Reference Network—Surface Air Temperature (ACORN-SAT) dataset. This report should be read as a companion to the Forum's 2015 and 2016 annual reports, and the Bureau's responses to these, published on the Bureau's website.

## Australian Climate Observations Reference Network— Surface Air Temperature

The ACORN-SAT is a dataset of national temperature records maintained by the Bureau of Meteorology. It contains long-term, homogenised surface air temperature data from 112 stations across Australia dating back to 1910.

Homogenisation is the standard approach in meteorology and climate science that enables weather monitoring institutions to maintain a consistent set of temperature records over time, while eliminating non-climate factors that affect temperature readings. Non-climate related factors can include:

- the replacement of thermometers;
- changes in observing practices;
- expansion of the network into remote locations;
- changes in infrastructure surrounding a weather station;
- relocation of weather stations.

The homogenisation adjustment process helps to eliminate artificial systematic errors or artefacts induced by such changes and is a key requirement for compiling and then analysing long-term records of daily maximum and minimum temperatures for a given location. While similarly adjusted datasets are maintained by meteorological institutions around the world, ACORN-SAT is the world's first continental-scale homogenised dataset of daily temperatures.

In 2011, the Bureau initiated an independent and detailed peer review of the ACORN-SAT dataset to investigate the robustness of its observing practices, station selection, data homogenisation, calculation of trends and overall public confidence in ACORN-SAT.

The independent peer review expressed overall confidence in the Bureau's practices and noted that its practices are among the best in the world. The peer review made 31 recommendations to further increase public confidence levels and ensure the highest levels of transparency are maintained. As of July 2017, 21 of these recommendations are complete and 10 are in the process of being addressed. One of the recommendations was to establish a Technical Advisory Forum to review and advise the Bureau on the ongoing development and operation of ACORN-SAT.

## Technical Advisory Forum

The Technical Advisory Forum was established by the former Parliamentary Secretary to the Minister for the Environment on 19 January 2015 to review the development and operation of the ACORN-SAT dataset annually and to comment on further developments for a three-year period to 2017.

Forum members were chosen for their expertise in disciplines such as atmospheric physics and statistics to provide independent advice on the Bureau's statistical and data analysis methods. Nominations for Forum Members were made by Australia's Chief Scientist, the Acting Australian Statistician, the Australian Academy of Science and the Australian Academy of Technological Sciences and Engineering. The members of the Forum are listed below. Biographies for the Forum members are available at Appendix E.

| | |
|---|---|
| Dr Ron Sandland AM FTSE | Forum Chair |
| Emeritus Professor Bob Vincent FAA | Forum Vice Chair |
| Dr Phillip Gould | Forum Member |
| Dr John Henstridge CStat, AStat, AFAIM, QPMR, FSS | Forum Member |
| Ms Susan Linacre | Forum Member |
| Professor Michael Martin PFHEA | Forum Member |
| Professor Patty Solomon | Forum Member |
| Professor Terry Speed FRS, FAA | Forum Member |

## Terms of Reference

The Technical Advisory Forum is to examine and provide comment on:

1.  The extent of the public availability of the ACORN-SAT information including:

    • Raw and adjusted data;

    • Documentation of data methods;

    • Computer code;

    • Adjustments;

    • Metadata;

    • Inputs and outputs of peer review; and

    • Ability to reproduce findings.

2.  Developments since the 2011 Independent Peer Review (IPR) of ACORN-SAT data and methods including:

- ACORN-SAT network, in the context of the Bureau's Observation strategy;
- Addition of new temperature data, including from individual stations and data post-2010, and whether there is merit in inclusion of pre-1910 data;
- Progress with metadata to allow independent replication of homogeneity analyses;
- Progress against the IPR recommendations; and
- Extent of scientific adoption of data and analyses.

3.  The scientific integrity and robustness of the Australian climate record and the homogenisation process including:

- Compared to raw (unadjusted) data, how does homogenisation affect the overall climate trend for Australia?
- Compared to other available datasets how do the trends indicated by ACORN-SAT compare?
- How does the Bureau's curation methods compare to other international curation methods?
- What steps should be taken to document or improve the consistency of decision making for the selection of data periods or stations and of the adjustment methods and decisions?
- How has the ABS assessed ACORN-SAT as part of the Essential Statistical Assets for Australia?

## 2015 report

The Forum held its first meeting on 26 March 2015. Following detailed examination and deliberation, the Forum concluded that the ACORN-SAT dataset is well-maintained and is an important element of Australia's climate record. The Forum was satisfied with the Bureau's commitment to continuous improvement and their approach to the methodological development and operation of the ACORN-SAT dataset. In particular, the Forum noted the approach adopted by the Bureau in implementing the recommendations of the 2011 independent peer review and its commitment to transparency and information provision. The Forum noted that the Bureau is recognised internationally for its expertise in methodological approaches to homogenisation.

The Forum also recognised that homogenisation plays an essential role in eliminating artificial non-climatic systematic errors in temperature observations so that a meaningful and consistent set of records can be maintained over time. There is a need to adjust the historical temperature record to account for site changes, changes in measurement practices, and identifiable errors in measurement. In 2015, the Forum considered that the analyses conducted by the Bureau reflect good practice in addressing the problem of how to adjust the raw temperature series for

systematic errors. To this end, the Forum supported the need for the Bureau's homogenisation process to incorporate both metadata-based adjustments and adjustments based on the statistical detection of atypical observations.

The Forum examined the Bureau's activities in detail against each of the three key considerations in the Terms of Reference and made five recommendations in their first annual report to support and inform the Bureau's continuous improvement of the ACORN-SAT dataset. Briefly, these recommendations offered advice on improving the clarity and accessibility of information provision and refining some of the Bureau's data handling and statistical methods. The Forum released its first annual report in June 2015 which is available on the Bureau's website.

## 2016 report

The Forum held its second annual meeting on 16 and 17 June 2016. At the meeting, Forum members scrutinised the Bureau's progress against its 2015 recommendations. The Forum commended the Bureau on its progress against the recommendations and thanked the Bureau's staff for demonstrating a strong commitment to improving the dataset and associated analyses, and responding to the Forum's recommendations and questions.

In particular, the Forum welcomed the Bureau's progress in improving the communication and accessibility of the dataset to the public; improving the access and handling of metadata; and expanding the ACORN-SAT data and supporting analyses. The Forum noted that the Bureau intended to release a major update to the ACORN-SAT dataset, thereby implementing more of the recommendations related to the communication and accessibility of the dataset.

The Forum continued to support the need for the Bureau's homogenisation process to incorporate both metadata-based adjustments and adjustments based on the statistical detection of atypical observations. It reiterated the importance of homogenisation in supporting the maintenance of a meaningful and consistent set of temperature records over time.

The Forum continued to be satisfied with the Bureau's commitment to continuous improvement of the ACORN-SAT dataset. The Forum identified areas where the Bureau's progress against the recommendations could be strengthened or where it considers that further guidance would be beneficial. These areas relate to the Bureau's engagement with the statistical and research community, and the Bureau's efforts at characterising and estimating uncertainty within ACORN-SAT. The Forum made three new recommendations to guide future work in these areas.

The new recommendations and an outline of what was discussed at the Forum's second meeting is outlined in their 2016 report available on the Bureau's website.

## Submissions

Members of the Forum were appointed to provide advice on the basis of their formal expertise, and the Terms of Reference do not require the Forum to receive or respond to unsolicited submissions. Before the first annual meeting in 2015, the Forum received around 20 unsolicited submissions from some members of the public about the dataset and the nature of these are outlined in the Forum's first annual report. In the opinion of the Forum members, those unsolicited submissions did not provide evidence or offer a justification for contesting the overall need for homogenisation and the scientific integrity of the Bureau's temperature records. No unsolicited submissions were received prior to the Forum's 2016 or 2017 meetings.

## Ensuring continued independent and expert advice on data management

Independent and expert advice on data management practices is essential for the Bureau in maintaining public confidence in the work they do. Soliciting, receiving and considering such advice is an important element of organisational governance that supports continual review and improvements to the Bureau's work. Following the conclusion of the Forum in 2017, the Bureau have committed to establishing a new assurance advisory mechanism comprised of independent experts from relevant scientific disciplines to support the ongoing maintenance and development of the Bureau's climate datasets, including ACORN-SAT. Considering the Forum will conclude mid-2017, the new assurance advisory mechanism could provide ongoing oversight of any outstanding matters from the Forum's process, including the Bureau's response to the 2017 recommendations.

# 2. Public availability of the ACORN-SAT information

In its first annual report, the Forum outlined in detail the public availability of the ACORN-SAT dataset and related information. In the context of the Forum's 2016 recommendations, the following discussion outlines where progress has been made and where further opportunities exist to improve the public accessibility of ACORN-SAT data, analyses and other information. The findings presented in this section are based on information presented by the Bureau and associated deliberations at the Forum's third and final annual meeting in May 2017.

The following information should be read in conjunction with the Forum's first and second reports along with the Bureau's respective responses, all of which are available on the Bureau's website. See also Appendix A, which sets out the Forum's 2016 recommendations alongside an evaluation summary of the Bureau's progress.

## Progress against 2016 recommendations

The Forum commends the Bureau for their progress with improving the public availability of the ACORN-SAT dataset. The Forum notes that the Bureau's website remains one of the most popular government websites in Australia, and that climate information on this site remains in high demand. The Forum notes that there continues to be a strong demand for the ACORN-SAT data and associated analyses.

The Forum acknowledges the substantial work undertaken by the Bureau against the Forum's 2016 recommendations, noting that many of the recommendations will be fully implemented when Version 2 of the ACORN-SAT dataset is released in late 2017.

In particular, the Forum welcomes:

- The improvements made in developing Version 2 of the ACORN-SAT dataset to be released later this year, including:
  - The application of multiple detection methods in parallel, with three internationally-developed methods used to support more robust breakpoint identification and investigation;
  - Improved diagnostics to identify and replace inhomogeneous reference stations and unrepresentative reference periods, incorporating a second-round homogenisation procedure which is aligned with best practice homogenisation approaches;
  - Incorporation of additional digitised data and metadata for several stations;
  - Methodological improvements to modernise legacy rounding practices based on historical World Meteorological Organization (WMO) guidance in the code used to develop Version 1 of the ACORN-SAT dataset; and

- Correction of cases where adjustment produced a spurious negative diurnal temperature range artefact on individual days.

- The development of a suite of draft case studies to provide the public with real world examples of how climate data can be used to support decision making.

- Improved articulation of the value and purpose of the ACORN-SAT dataset, including updates to the ACORN-SAT Frequently Asked Question 19 and other areas on the website to clarify that the ACORN-SAT dataset is not an input to future forecasts/projections, but instead supports comparison between past projections and observations.

- The publishing of effective weights for each ACORN-SAT station in a compressed archive file (tar.gz format) on the Bureau's website.

- The availability (by request) of both the inhomogeneity detection and adjustment algorithm computer code in Python for the ACORN-SAT dataset.

The Forum also welcomes the updates on the joint work between the Bureau's climate and observation programmes to identify new sites for current weather stations that need to move.

## Recommended next steps

The Forum is pleased with the substantial progress made by the Bureau in improving the public availability of the ACORN-SAT dataset and, in particular, commends the Bureau on the development of Version 2 of the ACORN-SAT dataset which incorporates a significant number of the Forum's 2015 and 2016 recommendations. The Bureau has demonstrated a genuine commitment to communicate and make the related information publicly available. To support this work into the future, the Forum has identified areas where the Bureau can further strengthen this work.

The release of the second version of the ACORN-SAT dataset provides the Bureau an opportunity to clearly articulate to the public the need for a major revision of the dataset. Considering the significant developments that are proposed for Version 2, the Forum encourages the Bureau to clearly communicate to the public what the key changes are and why they are needed upon release. In particular, if there are any changes to the temperature trend shown in the ACORN-SAT dataset as a result of the Version 2 updates then the Bureau will need to communicate the scientific rationale supporting such changes—for instance, improved robustness of anomaly detection and correction, updating of legacy computing practices, and additional data availability. The Forum also encourages the Bureau, when releasing ACORN-SAT Version 2, to outline what criteria would be applied in assessing the need for further major version updates to the dataset in the future.

In discussing Version 2 updates, the Bureau noted that a legacy rounding practice based on historical WMO advice concerning maintaining precision within temperature calculations to

one decimal place had been identified in the code used to construct Version 1 of the ACORN-SAT dataset. The Forum agrees it is important the Bureau update their procedures in this regard to reflect current computing practices to retain higher precisions throughout calculations, and to communicate the nature of the former coding protocols to the public, including any material impact the updated code makes to the dataset. In discussions with the Bureau, the Forum agreed that it was preferable to maintain the highest practicable precision within all homogenisation and other adjustment calculations, acknowledging that final, reported results may need to be rounded for the purposes of effective public communication. The Bureau has undertaken to incorporate this recommendation in the construction of Version 2 of the ACORN-SAT dataset.

The Forum commends the Bureau for addressing their previous recommendation of developing broad-appeal case studies to show how the ACORN-SAT dataset can be used in the real-world to inform decision-making. Acknowledging that the case studies presented to the Forum in May 2017 were in early draft form, the Forum encourages the Bureau to undertake appropriate quality control and peer review of the case studies to ensure they represent appropriate statistical practice and scientific process. The Forum looks forward to reviewing the final drafts of the case studies where appropriate out-of-session, and to the ultimate public release of the case studies in late 2017 alongside Version 2 of the ACORN-SAT dataset.

In addition to the case studies currently in draft, the Forum recommends the Bureau draw on existing work and develop a new case study. The case study should outline how the ACORN-SAT dataset, as Australia's long-term temperature record, aligns with temperatures implied by physical climate models used by the Bureau to predict future temperatures. This comparison is important to show how the observed data compares to climate model predictions.

The Forum acknowledges the Bureau's commitment and progress in making the ACORN-SAT dataset and the underlying source code available through the Bureau's website. This has been demonstrated by the Bureau's decision to implement algorithms originally programmed in FORTRAN in the now more widely used Python computing language, and to make this Python code available on request to the public. To support full transparency, the Forum recommends ensuring the ACORN-SAT source dataset version used by the Bureau to create ACORN-SAT is available publicly and in full through Australian Data Archive for Meteorology (ADAM) and the Climate Data Online portal, together with the code as actually used. If there are administrative or technical barriers to such dissemination, then overcoming any such limitations should be a priority for the Bureau. It is important these portals support the Bureau in making relevant climate data available for public use and replication purposes.

# 3. Developments since the 2011 Independent Peer Review of ACORN-SAT data and methods

In its first annual report, the Forum acknowledged and commended the work of the Bureau in implementing the recommendations of the 2011 independent peer review. In the context of the Forum's 2016 recommendations, the following discussion outlines where progress has been made and where opportunities exist to further advance the implementation of the recommendations of the peer review. The findings presented in this section are based on information presented by the Bureau and associated deliberations at the Forum's third and final annual meeting in May 2017.

The following information should be read in conjunction with the Forum's first and second reports along with the Bureau's respective responses, all of which are available on the Bureau's website. See also Appendix A, which sets out the Forum's 2016 recommendations alongside an evaluation summary of the Bureau's progress.

## Progress against 2016 recommendations

The Forum commends the Bureau for the substantial progress made in broadening its engagement with the Australian statistical science community. Since the 2016 Forum meeting, the Bureau has been in regular contact with key experts and has actively engaged in workshops and conferences.

In assessing progress against the 2016 recommendations, the Forum welcomes:

- The Bureau's participation in numerous panel sessions, conferences, workshops and research meetings involving statistical experts;
- Ongoing engagement with statisticians from the National Institute for Applied Statistics Research Australia at the University of Wollongong, and the ARC Centre of Excellence for Mathematical and Statistical Frontiers;
- Progress on two externally-funded projects looking to advance spatial analysis techniques for temperature;
- The Bureau's intention to hold a one-day homogenisation workshop with relevant climate and statistics experts as a satellite meeting to the International Conference on Southern Hemisphere Meteorology and Oceanography in Sydney in 2018;
- Presentations of research using ACORN-SAT data by Bureau staff at two relevant conferences: the 2016 Australian Statistics Conference and the 2017 Australian Meteorological and Oceanographic Society National Conference, noting in particular the engagement with the broader statistical community promoted through the former;

- The Bureau's ongoing commitment to extending Australia's long-term temperature record to include pre-1910 data, including engaging a leading Australian expert on the recovery and analysis of historical data.

The Forum acknowledges the work of the Bureau in fostering cross-disciplinary collaboration between the meteorological and statistical communities, and notes that the Bureau is already benefiting from these connections. The Forum also notes the Bureau's intention to publish two articles in peer-reviewed journals in the second half of 2017 associated with the release of Version 2 of the ACORN-SAT dataset.

The Forum continues to acknowledge that the Bureau is recognised internationally for its expertise and leadership in developing methodological approaches to homogenisation. This reputation is evident through the Bureau's involvement with various international steering committees and working groups. For example, its work with the WMO to develop guidance on data homogenisation, and its coordination with the International Surface Temperatures Initiative to establish teams to consider parallel observations and their impacts on observed climate variables.

The Forum would like to especially acknowledge the presentation at the Forum's meeting in May 2017 on pre-1910 Australian climate data. The Forum congratulates the Bureau for positively engaging with this topic and encourages it to continue to do so. The Forum notes that public interest in historical temperature data is high. The public discourse on historical temperature trends benefits greatly from very early data being considered both seriously and within a rigorous framework. This work will support the Bureau to consider the potential for incorporating pre-1910 data into the ACORN-SAT dataset.

## Recommended next steps

The Forum recognises the strong commitment the Bureau has made to engage with the statistical community in relation to the ACORN-SAT dataset. The Forum sees collaboration with the broader research community as a good way to address complex statistical challenges in the climate sciences. In light of this view, the Forum recommends the Bureau continues to build on this engagement, in particular, through collaborating with statistical groups, presenting at conferences, publishing peer-reviewed articles and hosting the proposed one-day homogenisation workshop.

The Forum is particularly keen for the Bureau to continue engaging with expert statisticians on estimating uncertainty. In this context, the Forum suggests the Bureau develops approaches to explain as much of the observed variability in the data as possible by attributing it to known sources, such as to changes in geographical area, changes over time, or to random variation that

is not known. Homogenisation also accounts for "systematic" sources of error or uncertainty, some of which can be adjusted for directly. When an observed mean maximum annual temperature is reported, for example, there will be a standard error attached to that mean. An appropriate estimate of uncertainty will enable reporting of an associated standard error or confidence interval to convey the precision of that estimate of the mean and allow a better understanding of what the data indicate about maximum annual temperatures.

The Forum appreciates that developing uncertainty measures in the context of measuring temperature is complex. It recognises the inherent challenges in this context given that Australian temperature measurements are conducted within a geographically-dispersed network of sites, hence a number of factors such as spatial correlation impact the precision with which broad, national temperature estimates can be constructed. While the Forum recognises that the Bureau has made progress, further work in developing robust and meaningful measures of variation within temperature trends is needed. To this end, the Forum recommends the Bureau engage the services of an appropriately qualified statistician to support the Bureau in modelling and analysing uncertainty in the data and assisting in producing appropriate estimates of standard error. Ideally, the statistician would meet with the ACORN-SAT team within the Bureau regularly to actively assist in producing appropriate estimates of standard error for the summary statistics (e.g. mean National anomaly temperature) constructed by the Bureau for public consumption.

In addition to the ongoing work on developing uncertainty measures, the Bureau may also wish to consider engaging a senior statistician to advise the Bureau on ongoing statistical processes internally. The appointment within the Bureau of a senior statistician would help to bolster the Bureau's existing engagement with the statistical community and overcome barriers associated with cross-disciplinary differences. While the Forum recognises that the establishment of such a role would be subject to resources being available, it is firmly of the view that such an initiative would strongly support the Bureau's commitment to data integrity and the scientific rigour of analyses involving the Bureau's data.

The Forum recommends the work on pre-1910 Australian climate data be made available to the public on the Bureau's website. Providing access to this work will help to extend the information on Australia's long-term temperature record back further than ACORN-SAT currently provides and would set the ACORN-SAT dataset in an appropriate historical context, acknowledging the extraordinary advances in the precision with which temperature can be measured over the last few decades. Given high public interest in historical perspectives on climate, the Bureau should develop a factsheet to promote this work as a method for positively engaging the community in this area. This work also provides the basis for the Bureau to consider the potential to incorporate pre-1910 data in the ACORN-SAT dataset.

The Bureau indicated to the Forum that it is commencing a project to replace screens at all ACORN-SAT weather stations. The project will transition out the current wooden screens and replace them with state-of-the-art new screens. The Bureau confirmed an advisory group has been established to provide advice on this transition. Acknowledging that any adjustments to weather stations may systematically influence the data recordings, the Forum recommends the Bureau engages an appropriately qualified statistician on the experimental design elements and implementation of the project to ensure that such effects can be reliably estimated.

To ensure the Bureau continues to receive ongoing independent expert advice on the handling of data, the Forum recommends that the Bureau proceed with its proposal to establish a new assurance advisory mechanism. The Forum feels the proposed mechanism could provide ongoing oversight of any outstanding matters from the Forum's process, including the 2017 recommendations.

# 4. The scientific integrity and robustness of the Australian climate record and the homogenisation process

In its first annual report, the Forum outlined its findings regarding the scientific integrity and robustness of the Australian climate record and the homogenisation process. In the context of the Forum's 2016 recommendations, the following discussion outlines where progress has been made and where opportunities exist to strengthen the scientific integrity and robustness of the ACORN-SAT dataset. The findings presented in this section are based on information presented by the Bureau and associated deliberations at the Forum's third and final annual meeting in May 2017.

The following information should be read in conjunction with the Forum's first and second reports along with the Bureau's respective responses, all of which are available on the Bureau's website. See also Appendix A, which sets out the Forum's 2016 recommendations alongside an evaluation summary of the Bureau's progress.

## Progress against 2016 recommendations

The Forum welcomes the Bureau's continued progress in improving the ACORN-SAT dataset and analyses in response to its previous recommendations. The Forum reiterates its view from the first and second reports that the historical temperature record should be adjusted to account for site changes, changes in measurement practices, and identifiable, systematic errors in measurements. The Forum continues to strongly support the Bureau's homogenisation process, which incorporates both metadata-based adjustments and adjustments based on the statistical detection of atypical observations.

In reviewing progress against the 2016 recommendations, the Forum welcomes:

- The development of factsheets for all 112 ACORN-SAT reference stations, due for release alongside the release of Version 2 of the ACORN-SAT dataset later in 2017; and
- The Bureau's ongoing commitment to automating the homogenisation process in the long-term.

## Recommended next steps

The Forum notes the good progress made with developing factsheets for all ACORN-SAT reference stations. The factsheets contain information on the timing of and reason for adjustments at each reference station over time. As committed to by the Bureau, and following a quality control check for accuracy, the Forum recommends the factsheets are made publicly available in 2017 when Version 2 of the ACORN-SAT dataset is released.

The Forum recommends the Bureau continues to explore options for an automated homogenisation process in the long-term, acknowledging that full automation may not be possible owing to the associated costs and the requirement for ongoing manual checking regardless of improved automation. The codification of the process towards automation has the potential to reduce the required resources for future updates and reanalyses of the data.

# 5. Conclusion

This is the third and final report of the Forum. Following in-depth analysis and technical review over the past three years, the Forum is satisfied with the Bureau's development and operation of the ACORN-SAT dataset. The Bureau has consistently demonstrated a genuine commitment to best-practice management of the dataset. The Forum's analysis and recommendations outlined in the first and second annual reports are both available on the Bureau's website.

In particular, the Bureau has made substantial improvements in the communication and accessibility of the ACORN-SAT dataset. The Forum commends the Bureau for their progress against the recommendations in the 2011 independent peer review, including through engagement with the broader statistical community, a key recommendation of this Forum. Furthermore, the Forum continues to support the Bureau's methodological approaches to homogenisation practices, and reiterates the importance of homogenisation in supporting the maintenance of a meaningful and consistent set of temperature records over time.

The Forum has confidence in the Bureau's ability to continue to improve the development and operation of the ACORN-SAT dataset following the conclusion of the Forum in 2017. The Forum supports the Bureau's proposal to establish a new assurance advisory mechanism to provide expert and independent advice on data management and analysis more broadly within the Bureau. The Forum considers the new advisory group an appropriate mechanism to have oversight of the Bureau's progress against the Forum's 2017 recommendations as one of its activities.

The Forum would like to thank the Bureau and its staff for their engagement throughout this process, and for their willingness to answer the Forum's questions. The Forum would also like to thank the Department of the Environment and Energy for their support during the Forum's process.

# Appendix A
# Forum's summary of the Bureau's progress against the 2016 recommendations

The Forum acknowledges the Bureau's substantial progress towards meeting the 2016 recommendations, noting that not all recommendations were expected to be completed before the Forum's final meeting. The below table provides a short summary outlining the Forum's views on the Bureau's progress against the 2016 recommendations.

| Forum's 2016 recommendations | The Bureau's progress against the Forum's 2016 recommendations |
|---|---|
| **1. To support continued progress on improving the communication and accessibility of the ACORN-SAT dataset, the Forum recommends that the Bureau:**<br><br>a. Continues to implement its communication and accessibility work plan for the release of the updated ACORN-SAT dataset, and advise the Forum when this work has been completed so it can be reviewed against the relevant 2015 recommendations;<br><br>b. Develops case studies that illustrate how the ACORN-SAT dataset and similar data can be used to support climate analyses and decision-making, and make them available on the Bureau website;<br><br>c. Refines its articulation of the ACORN-SAT dataset's value and purpose both in its context of providing an accurate description of Australia's historical temperature record and also in relation to its potential use in testing or evaluating climate models. Clarity in this regard could be enhanced by expanding the details provided in response to ACORN-SAT Frequently Asked Question 19 to more explicitly state the way that ACORN-SAT is used in validation and testing of climate models. The Bureau could also identify other appropriate areas on the website and in public communication material to clarify the dataset's purposes; | The Forum acknowledges the substantial work undertaken by the Bureau against the Forum's 2016 recommendations, noting that many of the recommendations will be fully implemented when Version 2 of the ACORN-SAT dataset is released in late 2017.<br><br>In particular, the Forum notes the Bureau's proposed updates to Version 2 of the ACORN-SAT dataset. The new release is expected to incorporate many of the previous recommendations put forward by the Forum.<br><br>The Forum notes progress with drafting a set of case studies showcasing the relevance and use of the ACORN-SAT dataset in the context of topical, real-world settings. The Forum felt the themes of the case studies were well selected, of likely high public interest, and highly relevant to today's decision-making context. The Forum noted that further work is needed to strengthen the cases studies to ensure they accurately represent the information, and acknowledges the Bureau's intentions to have the case studies peer-reviewed and subjected to a rigorous quality control process before release.<br><br>The Forum notes the updates to the ACORN-SAT web pages within the Bureau's website and other information to support clear articulation of the purpose and use of the ACORN-SAT dataset. The Forum feels there remains room to improve the articulation of how the dataset is used alongside climate models in understanding Australia's weather. |

| Forum's 2016 recommendations | The Bureau's progress against the Forum's 2016 recommendations |
|---|---|
| d. Publishes, as part of the ACORN-SAT dataset, effective weights for every ACORN-SAT station at each time point as well as an explanation of how each station influences the national average temperature anomaly, to further improve the transparency and robustness of the ACORN-SAT dataset. The Bureau should seek further guidance and advice from the Forum as needed within the process of developing and communicating such effective weights;<br><br>e. Continues to expand its practice of making source code available for the ACORN-SAT dataset, despite low demand for the source code from users to date. This will improve the transparency of the Bureau's data adjustment procedures and further align their practices to trends of open access and reproducibility. In making this recommendation, the Forum acknowledges that this is a longer-term project that will be subject to resourcing considerations. | The Forum recommends that a case study comparing ACORN-SAT as a record of Australia's long-term temperature record against predictions coming from the Bureau's physical climate modelling is developed and published online to support the utility of the ACORN-SAT dataset.<br><br>The Forum was satisfied that the effective weights for each ACORN-SAT station had been published and were available through the website. The Forum also acknowledges the Bureau's efforts in making source code available through their website, despite limited uptake of the code in the past. The Forum notes in particular the efforts of the Bureau to modernise the code base for developing the ACORN-SAT dataset from FORTRAN to Python, and further notes that this process has led to refinements to the coding to reflect current computing standards, for example with regard to rounding. The Forum encourages the Bureau to ensure that the same version of the ACORN-SAT source dataset used within the Bureau is also made publicly available to support independent replication of the work if needed by interested parties. |

| Forum's 2016 recommendations | The Bureau's progress against the Forum's 2016 recommendations |
|---|---|
| **2. To build on existing domestic and international engagement with the statistical research community on the ACORN-SAT dataset, the Forum recommends that the Bureau:**<br><br>a. Undertakes targeted and active consultation with expert statisticians about the Bureau's work plan on understanding and communicating uncertainty. This work should recognise the disciplinary differences between meteorologists, climatologists and statisticians in describing and estimating uncertainty, with a view to optimising the Bureau's approach by adopting appropriate methods from each of these disciplines;<br><br>b. Continues with its preparations to hold a one-day homogenisation workshop prior to the 2017 ACORN-SAT Forum meeting. The Forum is available to assist the Bureau to identify relevant literature and participants for the workshop if required;<br><br>c. Seeks opportunities to present their work on understanding and analysing climate data, for example by presenting at relevant conferences or by publishing in appropriate peer-reviewed journals;<br><br>d. Considers options to undertake a comparative analysis of pre-1910 data at south-eastern sites (for example, by supporting an honours student) to assess whether the inclusion of pre-1910 data is worthwhile in attempting to understand current temperature patterns. Within this recommendation, the Forum acknowledges the Bureau's current efforts to engage with the research community on this question. | The Forum notes the Bureau's initiative and progress in engaging with the statistical community.<br><br>The Forum acknowledges that the Bureau has directly engaged with the National Institute for Applied Statistics Research Australia at the University of Wollongong, and the ARC Centre of Excellence for Mathematics and Statistical Frontiers. The Forum notes the Bureau's presentations at conferences and additional collaboration with the statistical community. The Forum encourages the Bureau to continue with its proposal to publish its work in peer-reviewed journals. It also acknowledges the Bureau's proposal to host a one-day homogenisation workshop with relevant climate and statistics experts as a satellite meeting to the International Conference on Southern Hemisphere Meteorology and Oceanography in Sydney in 2018.<br><br>The Forum notes the Bureau's progress on developing uncertainty measures in the context of ACORN-SAT and acknowledges this is a longer-term project that will likely be of interest to the broader climate science research community. The Forum recognises that while this is a priority for the Bureau, there are challenges related to cross-disciplinary differences. The Forum encourages the Bureau to continue to engage with appropriately qualified statisticians on estimating uncertainty.<br><br>The Bureau notes the presentation on pre-1910 Australian climate data. The Forum encourages the Bureau to present this work on their website and to promote it with the community as offering an interesting and useful perspective on historical climate data in the context of understanding Australia's long-term temperature record. |

| Forum's 2016 recommendations | The Bureau's progress against the Forum's 2016 recommendations |
|---|---|
| **3. To support continued progress in the handling of ACORN-SAT metadata and homogenisation, the Forum recommends the Bureau:**<br><br>a. Continues to develop high-level metadata factsheets for each station following the release of the next ACORN-SAT dataset. The factsheets should specify the timing of and reasons for adjustments and the reference stations used in making those adjustments;<br><br>b. Further considers the need for and feasibility of transition to an automated homogenisation process, acknowledging that this would require a longer-term program of work and be subject to resourcing considerations. | The Forum acknowledges the Bureau's ongoing efforts to strengthen the handling of ACORN-SAT metadata and homogenisation.<br><br>The Forum notes the development and planned release of factsheets for all 112 ACORN-SAT reference stations. The Forum encourages the Bureau to ensure the factsheets are appropriately checked for quality and accuracy. The Forum also notes the Bureau's ongoing commitment to consider the development of an automated homogenisation process in the longer term.<br><br>The Forum acknowledges that while this would be a useful development, they had not seen full automation in a similar dataset and to do so would be subject to resource considerations. |

# Appendix B
# Technical Advisory Forum—
# May 2017 Meeting Agenda

## ACORN-SAT TECHNICAL ADVISORY FORUM
## THIRD ANNUAL MEETING
## AGENDA

**15 and 16 May 2017**
**Bureau of Meteorology Head Office**
**700 Collins Street, Melbourne, VIC**

## Attendees:

**Technical Advisory Forum**
Dr Ron Sandland (Chair), Emeritus Professor Bob Vincent (Vice Chair), Dr Phillip Gould,
Dr John Henstridge, Ms Susan Linacre, Professor Michael Martin, Professor Patty Solomon
and Professor Terry Speed

**Bureau of Meteorology**
Various technical experts and representatives from the secretariat

**Department of the Environment and Energy**
Representatives from the secretariat

| AGENDA: Day 1—Monday 15 May | | | | |
|---|---|---|---|---|
| **Time** | **No.** | **Description** | **Lead** | **Timing** |
| **8:30** | | *Arrival, tea and coffee* | | |
| 9:00 | 1. | Introduction | Chair | 30 minutes |
| | | 1. Welcome, introductions and purpose of meeting. Review agenda and TAF Terms of Reference | | |
| | | 2. Opening from the Department—Briefing from DoEE on Government related matters | DEE | |
| | | 3. Greetings and remarks from the Bureau | BoM | |
| 9:30 | | 4. Proposal for Post-TAF arrangements | BoM | 15 minutes |
| 9:45 | 2. | Contextual update since second annual TAF meeting: Briefing from BoM on (a) demand for ACORN-SAT data and metadata since the first TAF, (b) international developments and (c) the 2017 ACORN-SAT version 2.0 | BoM | 30 minutes |
| *10:15* | | *Morning Tea (provided)* | | *15 minutes* |
| 10:30 | 3. | Progress since second annual TAF meeting: Response and progress against recommendations *Recommendation 1. Improving communications and accessibility of the data set* | BoM | 30 minutes (10 minute introduction + 20 minute discussion) |
| 11:00 | 4. | Progress since second annual TAF meeting: Response and progress against recommendations (continued) *Recommendation 2. Engaging with the statistical research community* | BoM | 60 minutes (30 minute introduction + 30 minute discussion) |
| *12.00* | | *Lunch (provided)* | | *60 minutes* |
| 13:00 | 5. | Progress since second annual TAF meeting: Response and progress against recommendations (continued) *Recommendation 3. Metadata, automated homogenisation* | BoM | 40 minutes (10 minute introduction + 30 minute discussion) |
| 13:40 | 6. | Exploration of Australia's pre-1910 climate data *Relevant to recommendation 3d from TAF1 (2015)* | BoM | 30 minutes (20 minute introduction + 10 minute discussion) |
| 14:10 | 7. | Opportunity to finalise any discussions around TAF recommendations | Chair | 60 minutes |
| *15:10* | | *Afternoon tea (provided)* | | *20 minutes* |

| AGENDA: Day 1—Monday 15 May | | | | |
|---|---|---|---|---|
| 15:30 | 8. | Post TAF arrangements and learnings:<br>What have we learnt and what worked well?<br>What might be improved?<br>Mechanisms for reporting continued progress and status updates?<br>Next steps for the Forum and recommendations. | Chair | 30 minutes |
| 16:00 | 9. | Outstanding matters: Next steps for TAF3 and report; day 2 approach; media handling; and any other matters | Chair | 30 minutes |
| 16:30 | 10. | Closing remarks | BoM and Chair | 10 minutes |
| 16:40 | | End | | |
| *18:30* | | *Forum dinner* | | |

| AGENDA: Day 2—Tuesday 16 May | | | | |
|---|---|---|---|---|
| | | | | |
| **Time** | **No.** | **Description** | **Lead** | **Timing** |
| 9:00 | 1. | Forum discussion on TAF3 report key points and findings | Chair | 90 minutes |
| *10:30* | | *Morning Tea (provided)* | | *30 minutes* |
| 11:00 | 2. | Drafting report continued | Chair | 90 minutes |
| *12.00* | | *Lunch (provided)* | | *60 minutes* |
| 13:30 | 3. | Drafting report continued | Chair | 90 minutes |
| 15:00 | 4. | Close | Chair | |

# Appendix C
# Technical Advisory Forum—
# May 2017 Meeting Minutes

**ACORN-SAT TECHNICAL ADVISORY FORUM**
**THIRD ANNUAL MEETING**
**MEETING MINUTES**

**Monday 15 May 2017**
**Bureau of Meteorology Head Office**
**700 Collins Street, Melbourne, VIC**

## Attendees:

**Technical Advisory Forum**
Dr Ron Sandland (Chair), Emeritus Professor Bob Vincent (Vice Chair), Dr Phillip Gould,
Dr John Henstridge, Ms Susan Linacre, Professor Michael Martin, Professor Patty Solomon
and Professor Terry Speed

**Bureau of Meteorology**
Various technical experts and representatives from the secretariat

**Department of the Environment and Energy**
Representatives from the secretariat

**Acronyms used in these minutes:**

| ACORN-SAT | Australian Climate Observations Reference Network—Surface Air Temperature |
|-----------|--------------------------------------------------------------------------|
| TAF | Technical Advisory Forum |
| CEO | Chief Executive Officer |

### 1. Welcome, introductions and purpose of meeting

The Forum Chair welcomed attendees and outlined the purpose of the Forum meeting. The Forum Chair confirmed this is the third and final Forum meeting. The Forum will conclude following the delivery of the third annual report in mid-2017.

A representative of the Department of the Environment and Energy thanked the Forum members for their participation and acknowledged the important contribution they have made to improve the Bureau of Meteorology's climate data over the past two years. They further acknowledged the Bureau's ongoing commitment to the Forum's process, noting that the Bureau's datasets are essential for supporting Australia to analyse and manage climate change.

A representative of the Bureau of Meteorology also welcomed Forum members to the Bureau's office and expressed gratitude for their work over the past two years. They reiterated to the Forum that their work is important for providing public assurance in the quality of the Bureau's data. The dataset, which the Bureau and the broader science community rely on, must be reliable and the Forum's recommendations have been valuable for improving its communication, visibility, and engagement with the broader mathematical and statistical community.

The Bureau representative also acknowledged this was the third and final Forum meeting. They thanked the Department for their support over the three year Forum period. To continue to build trust with the community, the Bureau is considering establishing an assurance advisory mechanism to support ongoing advice and input from technical experts on the management of the Bureau's datasets. The Bureau welcomed the Forum's views on the scope and mission of the proposed assurance advisory mechanism.

### 2. Contextual update since the second annual TAF meeting in 2016

A contextual update was provided on developments since the Forum met in June 2016. The presenter described the international developments including: the World Meteorological Organization Task Team on Homogenisation, and continuous improvements to global climate datasets. The presenter also outlined the second version of the ACORN-SAT dataset which includes improvements recommended by the Forum in previous reports, and is planned for release before the end of 2017.

### 3. Progress since second annual TAF meeting: Response and progress against recommendation 1: *Improving communications and accessibility of the data set*

The presentation included an outline of the case studies that are being prepared in response to this recommendation. The presenter outlined three of the ten case studies that are in development (wheat, viticulture and snow) and are aimed at helping the public to understand the application of the ACORN-SAT dataset in decision-making. The Forum provided suggestions for improvement to the case studies.

### 4. Progress since second annual TAF meeting: Response and progress against recommendation 2: *Engaging with the statistical research community*

The presenter outlined the Bureau's collaboration, including new relationships, with the broader statistical community, as per the Forum recommendation. The presenter described plans for further collaboration over the coming months and years including a joint ARC Centre of Excellence for Mathematical & Statistical Frontiers (ACEMS) workshop and a proposed 1-day homogenisation workshop. The presenter also described the Bureau's approach to handling data uncertainty, including plans to engage with the statistical community to support this work.

### 5. Progress since second annual TAF meeting: Response and progress against recommendation 3: *Metadata, automated homogenisation*

The presenter provided an update on the ACORN-SAT station metadata fact sheets and the homogenisation process, including what can be automated and where manual processes and decision making must be applied.

The Forum discussed the ACORN-SAT algorithm, detection methods and independence. Bureau scientists clarified how the decision to homogenise any given point is made.

### 6. Exploration of Australia's pre-1910 climate data: Relevant to recommendation 3d from TAF1 (2015)

The presenter outlined work on pre-1910 climate data which is available for Southeast Australia. The Forum discussed particular aspects of the pre-1910 data and its relationship to the ACORN-SAT dataset.

### 7. Opportunity to finalise any discussions around TAF recommendations

The Forum revisited any outstanding matters from the day and considered potential recommendations for the 2017 report.

### 8. Post TAF arrangements and learnings

In the context of the Bureau's proposal to establish a new assurance advisory mechanism following the conclusion of the Forum process, the Forum discussed the potential membership, scope and focus of the proposed mechanism and provided initial feedback to the Bureau noting that more detailed information would be contained in their 2017 report.

### 9. Outstanding matters and next steps

The Forum Chair reviewed administrative items including media handling, the release of the Chair's communiqué and the proposed approach for drafting the report.

### 10. Closing remarks

The Forum Chair provided a summary of the day's discussions, noting it was productive and beneficial for the Forum in considering their final report. The Forum Chair thanked the Bureau for their presentations and for answering the Forum's questions. They also thanked the Bureau and the Department for their support. Representatives from the Bureau and the Department thanked the Forum Chair for his leadership as Chair and the Forum for their expert advice. The Forum noted their report will be delivered mid-2017.

Meeting closed at 4:30 pm.

Forum members met again the following day on Tuesday 16 May 2017 to discuss the 2017 recommendations and commence drafting the third annual report, in line with the Forum's Terms of Reference.

Minutes prepared by the ACORN-SAT Technical Advisory Forum Secretariat, Bureau of Meteorology.

# Appendix D
# Technical Advisory Forum—
# May 2017 Chair's Communiqué

**Technical Advisory Forum meets for the final time to review progress on climate record management**
**Released on the Bureau's website: 15 May 2017**

The Technical Advisory Forum held its third and final annual meeting today to advise the Bureau of Meteorology on the Australian Climate Observations Reference Network—Surface Air Temperature (ACORN-SAT) dataset—a key component of Australia's official climate record. The ACORN-SAT dataset is the record of daily temperatures from locations around Australia from 1910 to the present. It is maintained by the Bureau of Meteorology.

The Australian Government appointed the Forum as an independent advisory body in 2015. Over the past three years the Forum has undertaken a comprehensive review of the ACORN-SAT dataset. We have considered a broad range of information and data relevant to the management and development of the ACORN-SAT dataset. As outlined in our two previous annual reports which are available on the Bureau's website, we have found the dataset is well maintained, and is an important part of Australia's climate record. We have no reason to question the accuracy of the dataset.

The Forum has made a series of recommendations to support and inform the Bureau's approach to continuously improve the ACORN-SAT dataset. Today's discussions were productive. The Forum reviewed the Bureau's progress against our recommendations, and discussed how oversight of these recommendations could continue following the conclusion of the Forum this year. Further details, along with any final recommendations, will be outlined in our 2017 annual report.

The Forum would like to thank the commitment from the Bureau to the Forum process. In particular, we thank them for their generosity with time and expertise in answering the Forum's questions today. The Forum would also like to thank the Department of the Environment and Energy for managing the Forum's membership and assisting the Chair for the past three years.

I would personally like to thank the experts, who make up the Forum, for their excellent engagement over the past three years. Their contributions will help to inform the Bureau's ongoing dataset management and analyses practices.

The Forum will deliver its third and final annual report mid-2017.

Dr Ronald Sandland AM FTSE
Chair of the ACORN-SAT Technical Advisory Forum
15 May 2017

# Appendix E
# Technical Advisory Forum Member Biographies

### Dr Ron Sandland AM FTSE (Chair)

Dr Sandland holds a PhD in statistics from the University of New South Wales. His research interests concerned applying statistics to solve challenging real problems in areas as diverse as growth of organisms, analysis of mark-recapture experiments, ore-reserve estimation and quality improvement.

He was appointed the Deputy Chief Executive for CSIRO in 1999 and led the Flagship Initiative. This involved six major cross-disciplinary research programs and was aimed at addressing problems of a national priority.

He is an Honorary Life Member of the Statistical Society of Australia and is a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE), and was made a member of the Order of Australia in 2007.

### Emeritus Professor Bob Vincent FAA (Vice Chair)

Robert Vincent is Emeritus Professor in the School of Physical Sciences at the University of Adelaide. His major expertise is in the area of the atmospheric sciences with a background in experimental studies of atmospheric processes including the development of radar hardware, software and data analysis techniques.

He has served on international and national panels covering Antarctic research and solar-terrestrial physics. His professional standing is recognised by election to the Australian Academy of Science, election as a Fellow of the American Geophysical Union, and as President of the International Council for Science/Scientific Committee for Solar-Terrestrial Physics from 2007–2011.

### Dr Phillip Gould

Dr Gould holds a PhD from Monash University specialising in time series econometrics.

He is currently managing the Education and Data Integration Branch within the Australian Bureau of Statistics and has also worked there as a methodologist, managing a team which delivers high quality analytical work for the ABS and external clients. Prior to joining the ABS Dr Gould worked in banking and finance with a focus on econometric modelling of time series data.

### Dr John Henstridge CStat, AStat, AFAIM, QPMR, FSS

Dr Henstridge holds a PhD from the Australian National University and in 1988 he founded Data Analysis Australia which is now the largest private statistical organisation in Australia.

He is a Fellow and Chartered Statistician of the Royal Statistical Society and an Accredited Statistician of the Statistical Society of Australia. He has served as President of both the Statistical Society of Australia's Western Australian branch and of the Geostatistical Association of Australasia and is currently the National Vice President and the immediate past President of the Statistical Society of Australia.

### Ms Susan Linacre

Ms Linacre holds a first class honours degree in Statistics and an Economics degree, both from the Australian National University.

She has spent most of her career at the Australian Bureau of Statistics where she held a number of senior roles including Deputy Australian Statistician (Social Statistics Group) and First Assistant Statistician (Methodology Division). Ms Linacre has also worked in the UK as head of the Directorate of Methodology and IT in the Office for National Statistics. She is a Member of the International Statistical Institute and past President of the International Association of Survey Statisticians.

### Professor Michael Martin PFHEA

Professor Martin holds a PhD from the Australian National University where he is currently Professor of Statistics in the Research School of Finance, Actuarial Studies and Statistics and the Centre for Higher Education, Learning & Teaching.

His research interests are applied statistics, statistical theory and statistical education. He also has been deeply involved in the teaching of statistics and has won a number of awards for teaching excellence. He is a Fellow of the American Statistical Association, an elected Member of the International Statistical Institute and a Principal Fellow of the Higher Education Academy.

### Professor Patty Solomon

Professor Solomon is Professor of Statistical Bioinformatics at the University of Adelaide.

Her research interests include Biostatistics, Bioinformatics, Statistical data mining, Clinical trials and Epidemiology. She has over 100 publications and has been funded by the Australian Research Council and the National Health and Medical Research Council.

Professor Solomon is an elected Member of the International Statistical Institute and is a member of the American Statistical Association, International Society for Clinical Biostatistics, Statistical Society of Australia and the Australian Mathematical Society.

### Professor Terry Speed FRS, FAA

Professor Terry Speed holds a PhD from Monash University and is a lab head in the Bioinformatics division at the Walter and Eliza Hall Institute of Medical Research. His research interests include the statistical and bioinformatic analysis of microarray, DNA sequence and mass spectrometry data from genetics, genomics, proteomics and metabolomics.

He has served as President of the Institute of Mathematical Statistics and has been awarded a number of prizes including the Pitman medal in 2002 and the Prime Minister's Prize for Science in 2013.

bom.gov.au/climate/change/acorn-sat/