DATA DELIVERY

CLIMATE CHANGE IN AUSTRALIA

PROJECTIONS FOR AUSTRALIA´S NRM REGIONS

CSIRO

Australian Government
Department of the Environment
Bureau of Meteorology

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CLIMATE CHANGE IN AUSTRALIA
DATA DELIVERY

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ACKNOWLEDGEMENTS

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CSIRO Oceans and Atmosphere Flagship

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BACKGROUND

CSIRO, in partnership with the Bureau of Meteorology (BoM), has developed climate change projections for Australia's natural resource management (NRM) sector. The projections will be used to assist in sustainably managing Australia's natural resources in a changing climate. CSIRO and the Bureau worked closely with NRM and research communities to ensure climate change projections support regional planning needs. The projections have been developed with careful consideration of users' requirements for climate projection products (see Appendix 1).

A number of projection products and services have been made available:

- A technical report describing Australian observed climate variability and change over the past 100 years, an evaluation of the ability of climate models to simulate past climate, climate model projections for the 21st century, and how to use climate projections in impact assessment.
- A brochure and report for each of the eight NRM clusters.
- A website providing access to these reports. brochures, animations, guidance material and data.
- A Help Desk to handle queries.

The purpose of this document is to outline the data delivery component in order to provide stakeholders with information about what can and can't be provided with available resources.

DATA SOURCES

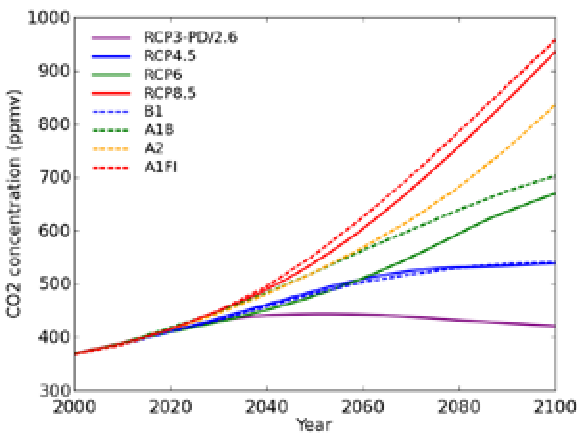
Climate change projection data are usually based on output from climate models driven by various scenarios of greenhouse gas and aerosol emissions (IPCC, 2013). Data can be accessed via a range of providers, such as national weather services, government departments, non-governmental organisations, academic institutions or research organisations. Identifying an appropriate dataset for use in risk assessment requires skill (Wilby *et al.*, 2009). The climate projections team from CSIRO and BoM has undertaken an assessment of the latest projections to give clients access to the results, with accompanying guidance on which products are fit for purpose.

For the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC, 2013), the scientific community defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs). The RCPs provide standardised greenhouse gas and aerosol concentration inputs for running climate models. Climate projections are available from model simulations using four RCPs: RCP8.5, RCP6, RCP4.5 and RCP2.6 (Moss *et al.*, 2010, Van Vuuren *et al.*, 2011) (Figure 1). These are named in accordance with a range of radiative forcing values (in Watts per square metre by the year 2100), which are a measure of the level of influence these gases have on the Earth's energy balance.

Each RCP is representative of a range of economic, technological, demographic, policy and institutional futures. RCP4.5 could be considered as a trajectory with intermediate emission reductions, consistent with the lowest (B1) scenario of the IPCC SRES suite developed in 2000 (Nakićenović and Swart, 2000). RCP8.5 is similar to the highest (A1FI) SRES scenario. RCP2.6 is lower than the lowest SRES scenario. Therefore, the range of climate projections based on RCPs is broader than those based on the SRES scenarios.

For the NRM climate projections, data from 16 to 40 climate models[1] have been analysed from the Climate Model Intercomparison Project (CMIP5) (Taylor *et al.*, 2012).

FIGURE 1: COMPARISON OF CARBON DIOXIDE CONCENTRATIONS FOR THE 21ST CENTURY FROM THE RCPs AND SRES SCENARIOS. RCP8.5 IS CLOSEST TO A1FI, RCP6 IS CLOSEST TO A1B, RCP4.5 IS SIMILAR TO B1, AND RCP2.6 IS LOWER THAN ANY OF THE STANDARD SRES SCENARIOS (FROM JUBB ET AL, REPRESENTATIVE CONCENTRATION PATHWAYS (RCPS), HTTP://WWW.CAWCR.GOV.AU/PUBLICATIONS/OTHERREPORTS/ACCSP_RCP.PDF).



1 For some Representative Concentration Pathways (RCPs) and climate variables fewer experiments were carried out so model numbers vary.

DOWNSCALING

In some cases, dynamical or statistical downscaling of information from global climate models (GCMs) offers more detailed information about climate change. Dynamical downscaling involves the use of fine resolution climate models (often using regional climate models: RCMs) which employ the same physical processes but with a finer resolution, opening up the possibility for a more accurate depiction of these processes, especially in regions with complex topography. Statistical downscaling involves applying observed statistical relationships (between large-scale and local climate) to large-scale changes in climate simulated by models, in order to estimate changes at local scales. However, downscaling doesn't always provide a superior projection of change for a given region, and there are numerous issues to contend with: selection of GCMs for downscaling, pros and cons of different downscaling methods, representation of the physical processes that drive change, internal consistency of projected changes across multiple variables, as well as practical issues around handling large datasets. Therefore, provision of downscaled data outputs will be undertaken with advanced users on a case-by-case basis at this stage.

CONFIDENCE IN CLIMATE PROJECTIONS

The projection data outlined in this document should be used in conjunction with guidance material found on the website and in the technical and cluster reports. This includes a description of the level of confidence in projections, which is higher for some models than others, and higher for some climate variables (e.g., regional temperature) than for others (e.g., local rainfall, extreme weather).

REPRESENTING THE RANGE OF CLIMATE PROJECTIONS

Users of climate projections are strongly advised to represent a range of climate model results in their studies and reports. CSIRO's Climate Futures approach has been developed to help capture the range of projection results relevant to a region (Whetton *et al*., 2012). The sample matrix below (Figure 2) shows how a large amount of climate model output (for a particular time period and emission scenario) can be arranged into a small number of climate change categories, called 'Climate Futures', each of which is defined by a range of change in two climate variables such as temperature and rainfall. This simplifies communication of climate projections and is supported by the Australian Climate Futures web-tool.

The matrix (Figure 2) shows four types of temperature futures (from slightly warmer to much hotter) and five types of rainfall futures (from much drier to much wetter). Users are able to identify appropriate Climate Futures that could include 'maximum consensus', 'best case' and 'worst case', depending on the context. For example, when using the table below to assess risks to water supply infrastructure, the 'Much hotter' and 'Much drier' climate might represent the 'worst case', while the 'Hotter' and 'Little change' climate represents the 'maximum consensus' future. The matrix can also be populated with results from dynamical or statistical downscaling, enabling comparison with results from global climate models.

FIGURE 2: CLIMATE FUTURES MATRIX CONCEPT DIAGRAM SHOWING GLOBAL CLIMATE MODEL (GCM) AND DOWNSCALED (DS) RESULTS FOR A PARTICULAR REGION, TIME PERIOD AND RCP. (COLOUR SHADING KEY: VERY LOW (<10 % OF MODELS); LOW (10 %–33 % OF MODELS); MODERATE (33 %–66 % OF MODELS); HIGH (66 %–90 % OF MODELS); VERY HIGH (>90 % OF MODELS)).

		ANNUAL SURFACE TEMPERATURE (C)			
		SLIGHTLY WARMER 0 TO 0.5	WARMER +0.5 TO 1.5	HOTTER +1.5 TO +3.0	MUCH HOTTER > +3.0
ANNUAL RAINFALL (% CHANGE)	MUCH WETTER > +15.0				
	WETTER +5.0 TO +15.0		2 OF 30 GCMs	9 OF 30 GCMs 1 OF 6 DS	2 OF 30 GCMs
	LITTLE CHANGE -5.0 TO +5.0			13 OF 30 GCMs 4 OF 6 DS	2 OF 30 GCMs
	DRIER -15.0 TO -5.0			2 OF 30 GCMs 1 OF 6 DS	
	MUCH DRIER < -15.0				

NOT PROJECTED VERY LOW LOW MODERATE HIGH VERY HIGH

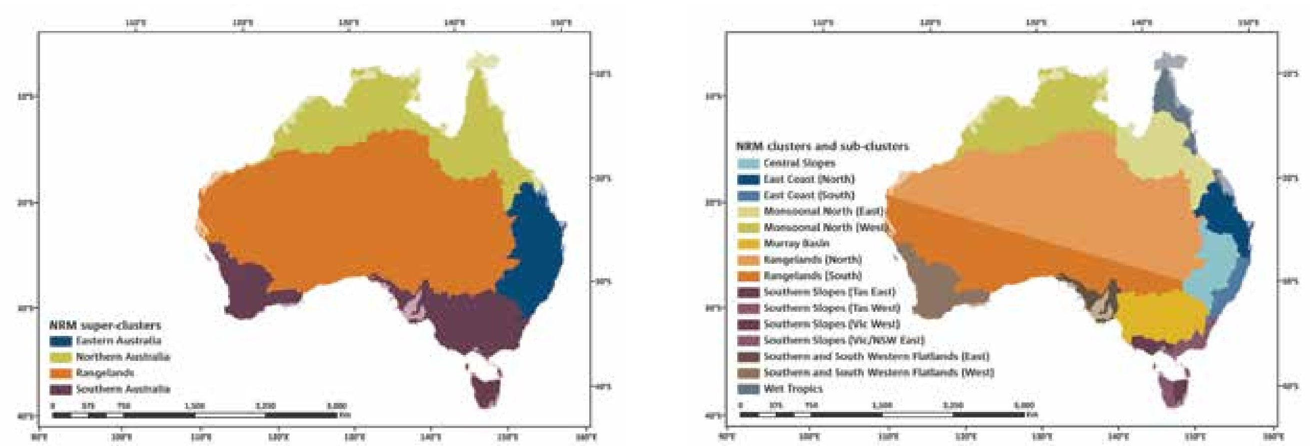
DATA PRODUCTS

Two types of data are delivered to NRM and associated research communities:

- Projected climate changes (relative to the IPCC reference period 1986–2005), based on CMIP5 global climate models judged to perform well over Australia, plus dynamic and statistical downscaling where appropriate;
- Application-ready future climate data (where projected climate change data are applied to 30 years of observed data (1981–2010) for use in detailed impact assessments). Data are provided from a subset of eight CMIP5 models that simulate most of the range of change in seasonal temperature and rainfall over most of Australia, plus downscaling where appropriate. This model selection simplifies the range of projection choices and reduces the effort required to manage data in risk assessments. The eight models were selected using the Climate Futures approach and other criteria (see Technical Report). For any given region, time period and emissions scenario, three of these models can be used to represent 'best case', 'worst case' and 'maximum consensus' scenarios.

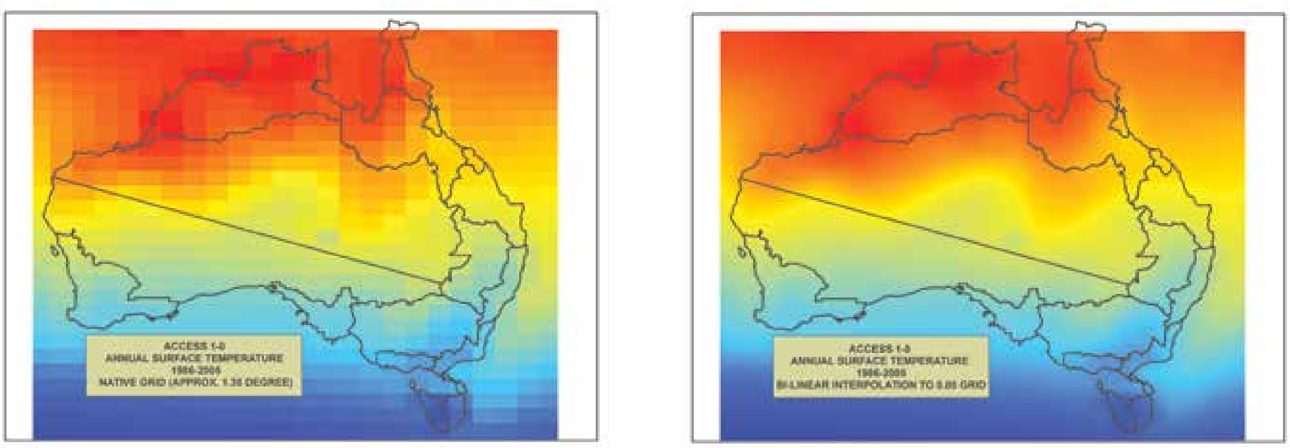
These data are provided at three levels of spatial detail to suit different purposes: 1) NRM super-clusters, NRM clusters, NRM sub-clusters (see Figure 3), 2) gridded, and 3) for some cities and towns (see Appendix 2), through a web portal. Supporting information has been made available in comprehensive technical and cluster reports.

FIGURE 3: NRM SUPER-CLUSTERS (LEFT), CLUSTERS AND SUB-CLUSTERS (RIGHT).



The CMIP5 models used in this assessment have an average spatial resolution (spacing between data points) of ~180km (ranging from ~67km to ~333km). The projected change data are made available at the native grid resolution for each model. For climate variables for which application-ready data have been available, the data have also been bi-linearly interpolated to a 5 km grid[2] (Figure 4).

FIGURE 4: COMPARISON OF THE NATIVE MODEL GRID VERSION (LEFT; 135 KM RESOLUTION) WITH THE BI-LINEARLY INTERPOLATED VERSION (RIGHT; 5 KM RESOLUTION) OF AUSTRALIAN SURFACE TEMPERATURE (1985–2005) GENERATED BY THE ACCESS 1.0 MODEL.



2 Although the data look more detailed and accurate when re-gridded to a finer scale, the process of bi-linear interpolation does NOT add extra information, and therefore is not more accurate than the coarser resolution data.

PROJECTED CLIMATE CHANGE DATA

Projected climate change data are informative for risk assessment and are made available for variables described in Table 1. The changes are relative to the period 1986–2005, e.g. a 10 % decrease in winter rainfall relative to 1986–2005. Annual, seasonal and monthly changes are supplied for 20-year periods centred on 2030, 2050, 2070 and 2090 for some variables (see Table 1). Some information is provided in qualitative form only (e.g. projections for tropical cyclones or runoff).

TABLE 1: PROJECTED CHANGE DATA FOR DIFFERENT CLIMATE VARIABLES AND A VARIETY OF TEMPORAL AND SPATIAL SCALES, FOR 20-YEAR PERIODS CENTRED ON 2030, 2050, 2070 AND 2090, RELATIVE TO 1986–2005. AREA AVERAGES ARE AVAILABLE AT CLUSTER, SUB-CLUSTER AND SUPER-CLUSTER SCALES. GRIDDED CHANGES ARE AVAILABLE FOR INDIVIDUAL CLIMATE MODELS, AND WHERE AVAILABLE FOR ALL 4 RCPS, ON THE NATIVE CLIMATE MODEL GRID. GREEN = AVAILABLE, BLUE = SUMMARY INFORMATION IN TECHNICAL AND CLUSTER REPORTS, WHITE = NOT AVAILABLE.

VARIABLE	ANNUAL		SEASONAL		MONTHLY	
	GRIDDED	AREA AVG.	GRIDDED	AREA AVG.	GRIDDED	AREA AVG.
MEAN TEMPERATURE[A]						
MAXIMUM DAILY TEMPERATURE[A]						
MINIMUM DAILY TEMPERATURE[A]						
RAINFALL[A]						
RELATIVE HUMIDITY[A]						
WET AREAL EVAPOTRANSPIRATION[A]						
SOLAR RADIATION[A]						
WIND-SPEED[A]						
EXTREME RAINFALL (INTENSITY OF 1 IN 20 YR EVENT)[B,C,G]						
EXTREME WIND (INTENSITY OF 1 IN 20 YR EVENT)[G]						
DROUGHT (SPI-BASED[D], DURATION, FREQUENCY, % TIME)						
FIRE[E]						
SEA LEVEL RISE (MEAN AND EXTREME)[F,H]						
SEA SURFACE TEMPERATURE[H]						
SEA SURFACE SALINITY[H]						
OCEAN ACIDIFICATION (ARAGONITE SATURATION)[G,H]						
TROPICAL CYCLONE FREQUENCY/LOCATION						
TROPICAL CYCLONE INTENSITY						
SNOW						
RUNOFF AND SOIL MOISTURE						

A Gridded changes will be available for individual climate models on the original climate model grid.

B Event is defined as 24-hour total rainfall.

C These data are considered an interim product and will be updated using higher resolution models and reported in the Australian rainfall and runoff (ARR) handbook (anticipated 2015).

D Standardised Precipitation Index, a probability index that considers precipitation only. Drought projections available for 20 models (RCP4.5 and RCP8.5) and 13 models for RCP2.6 (see McKee *et al.*, 1993 for a description of the method for calculation of the SPI).

E Fire-weather data are supplied at 39 sites for three models (see Appendix 2).

F Data for 16 tide gauge sites (see Appendix 2), not for individual models but for a multi-model range defined by the 5th to 95th percentile.

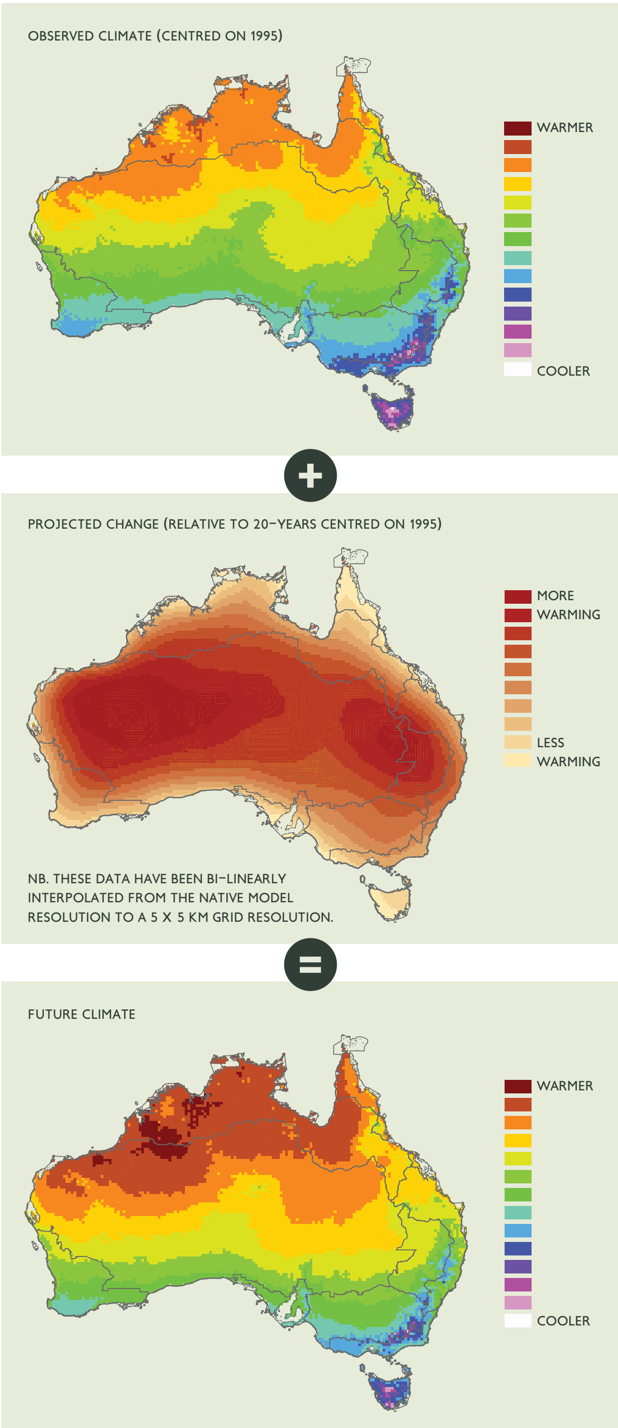
G Not available for RCP6.0.

H No data for individual models but for a multi-model range defined by the 5th to 95th percentile.

APPLICATION-READY DATA

Application-ready data describes a set of synthetic future data, generated by combining projected changes with observed data. These data can be used in detailed impact assessments for climate variables where appropriate observed climate data are available (having sufficient quality and duration). The approach for creating application-ready data in this project is through applying projected climate changes to 30-year observed datasets centred on 1995 (1981–2010)[3] using the delta change method (Figure 5) (also described in the Technical Report). Quantile scaling, a modification to the delta change technique that captures important changes in daily variance (see the Technical Report), is used in the production of daily rainfall data.

FIGURE 5: DELTA CHANGE METHOD FOR CALCULATING APPLICATION-READY FUTURE CLIMATE DATA.



Application-ready data include averages and time-series over a range of spatial scales, as shown in Table 2. They can be accessed through the website with guidance available via the decision tree (Figure 7, later in this document). Due to constraints on baseline data availability, spatial detail ranges from large-area-average, to a 5 km grid-average, to specific cities and towns. Changes are based on a subset of eight CMIP5 models that simulate most of the range of changes in seasonal-mean temperature and rainfall over most of Australia, plus downscaling where appropriate.

Engagement with NRM sector professionals and researchers led to recommendations for delivery of data that would align with various ecological and plant production modelling tools. Bioclimatic model developers identified a number of data requirements that have been addressed to maximise the integration with the climate projections products. In response to this engagement, monthly climate projection data for 'Bioclim' variables (Sutherst et al. 2007), ANUCLIM compatibility (Xu and Hutchinson, 2011) and text file format suitable for use in impacts modelling e.g. the crop modelling package APSIM (McCown et al. 1996) were recognised as a useful addition to the outputs from this project.

3 To reduce the influence of natural variability on observed climate averages over the baseline period — for example the recent south-east Australian drought — a 30-year baseline dataset is used, i.e. an extended period centred on 1995.

TABLE 2: 'APPLICATION-READY' FUTURE CLIMATE DATA FOR DIFFERENT CLIMATE VARIABLES AND A VARIETY OF TEMPORAL AND SPATIAL SCALES FOR FUTURE PERIODS CENTRED ON 2030, 2050, 2070 AND 2090, RELATIVE TO 1986–2005, AND WHERE AVAILABLE, FOR ALL 4 RCPs. THIS INCLUDES GRIDDED DATA AND DATA FOR CITIES AND TOWNS. DATA FOR CITIES AND TOWNS ARE LIMITED BY AVAILABILITY OF A RELIABLE BASELINE DATASET[C]. GRIDDED DATA ARE AVAILABLE FOR EIGHT CLIMATE MODELS ON A 5 KM GRID DERIVED FROM BI-LINEAR INTERPOLATION. GREEN = DATA AVAILABLE, WHITE = DATA NOT AVAILABLE.

TEMPORAL SCALE	ANNUAL				SEASONAL				MONTHLY				DAILY	
SPATIAL SCALE	GRIDDED		CITY/TOWN[C]		GRIDDED		CITY/TOWN[C]		GRIDDED		CITY/TOWN[C]		GRIDDED	CITY/TOWN[C]
CLIMATE VARIABLE	AVERAGES	TIME-SERIES	AVERAGES	TIME-SERIES	AVERAGES	TIME-SERIES	AVERAGES	TIME-SERIES	AVERAGES	TIME-SERIES	AVERAGES	TIME-SERIES	TIME-SERIES	TIME-SERIES
Mean temperature (°C)[E]	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Maximum daily temperature[E]	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Minimum daily temperature[E]	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Days above/below/between temperature thresholds[A,E]	Green	White	Green	White	Green	White	Green	White	Green	White	Green	White	White	White
Rainfall (mm)[E]	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Relative humidity (%)[H]	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Point potential evapotranspiration[D,J]	White	White	White	White	White	White	White	White	White	White	Green	Green	White	White
Wet areal evapotranspiration (mm)[F]	Green	Green	White	White	Green	Green	White	White	Green	Green	White	White	Green	White
Mean wind-speed (ms^{-1})[G]	Green	Green	White	White	Green	Green	White	White	Green	Green	White	White	White	White
Solar radiation (Wm^{-2})[I]	Green	Green	White	White	Green	Green	White	White	Green	Green	White	White	Green	White
Fire weather[B]	White	White	Green	Green	White	White	White	White	White	White	White	White	White	Green
Fire weather days above/below/between thresholds[B]	White	White	Green	White	White	White	White	White	White	White	White	White	White	White

A Thresholds presented in days per year above 'XX' °C (days), for example.

B Forest Fire Danger Index (FFDI) for 39 sites. Also see Appendix 2.

C For availability of data for cities and towns see Appendix 2.

D Proxy for Pan Evaporation.

Baseline datasets (1981–2010)

E Australian Water Availability Project (AWAP) time series data (0.05° grid) (Jones *et al.*, 2009).

F CSIRO Land and Water dataset (Morton, 1983, Teng *et al.*, 2012) (0.05° grid).

G ERA interim reanalysis (0.75° grid), but daily gridded wind data have quality control problems (Dee *et al.*, 2011). High quality daily wind speed data used in fire weather analysis were sourced from 39 sites—see Appendix 2.

H ERA interim reanalysis (0.75° grid), but daily humidity data at cities/towns have quality control problems (Dee *et al.*, 2011).

I ERA interim reanalysis (0.75° grid), but daily solar radiation data at cities/towns have quality control problems (Dee *et al.*, 2011).

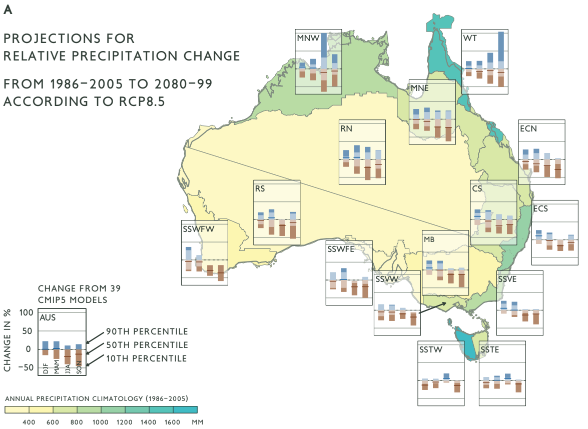
J Bureau of Meteorology high quality monthly pan-evaporation dataset (see Jovanovic *et al.* 2008).

REPORT-READY PROJECTED CHANGE INFORMATION

In many cases, simple images and tables are all that might be required for insertion into a report, or for a presentation. Along with images for model specific results for all of the variables, time periods and spatial scales described in Table 1 and Table 2, images and tables for ensembles of models indicating ranges of projected change are accessible as cluster averages. Some examples of the information that is available are provided in Figure 6 and, along with supporting text, have been made accessible through the website (www.climatechangeinaustralia.gov.au).

FIGURE 6: EXAMPLES OF TYPES OF REPORT AND/OR PRESENTATION-READY IMAGES: A) NATIONAL SUMMARIES, B) ENSEMBLE COMPARISONS, C) CLUSTER AVERAGE BAR PLOTS INDICATING RANGES OF CHANGE, D) CLUSTER AVERAGE TIME SERIES PLOTS, E) TABULAR DATA.

A



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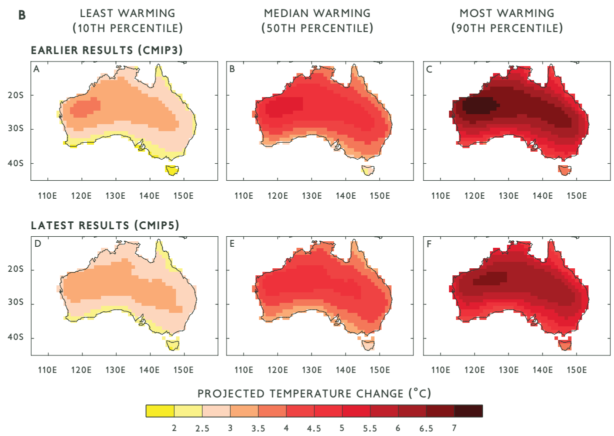

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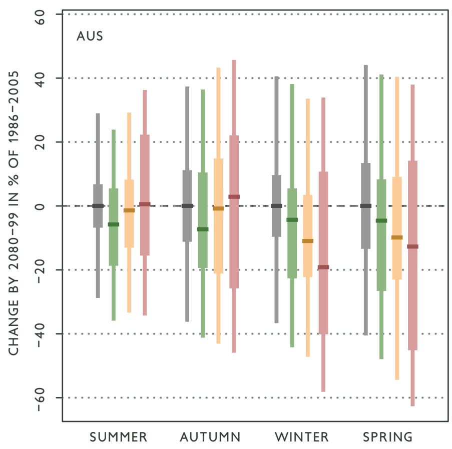

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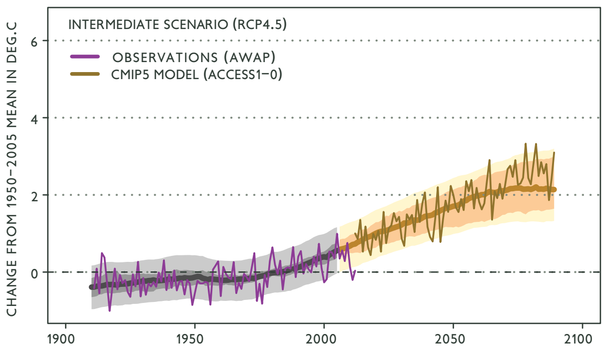


E

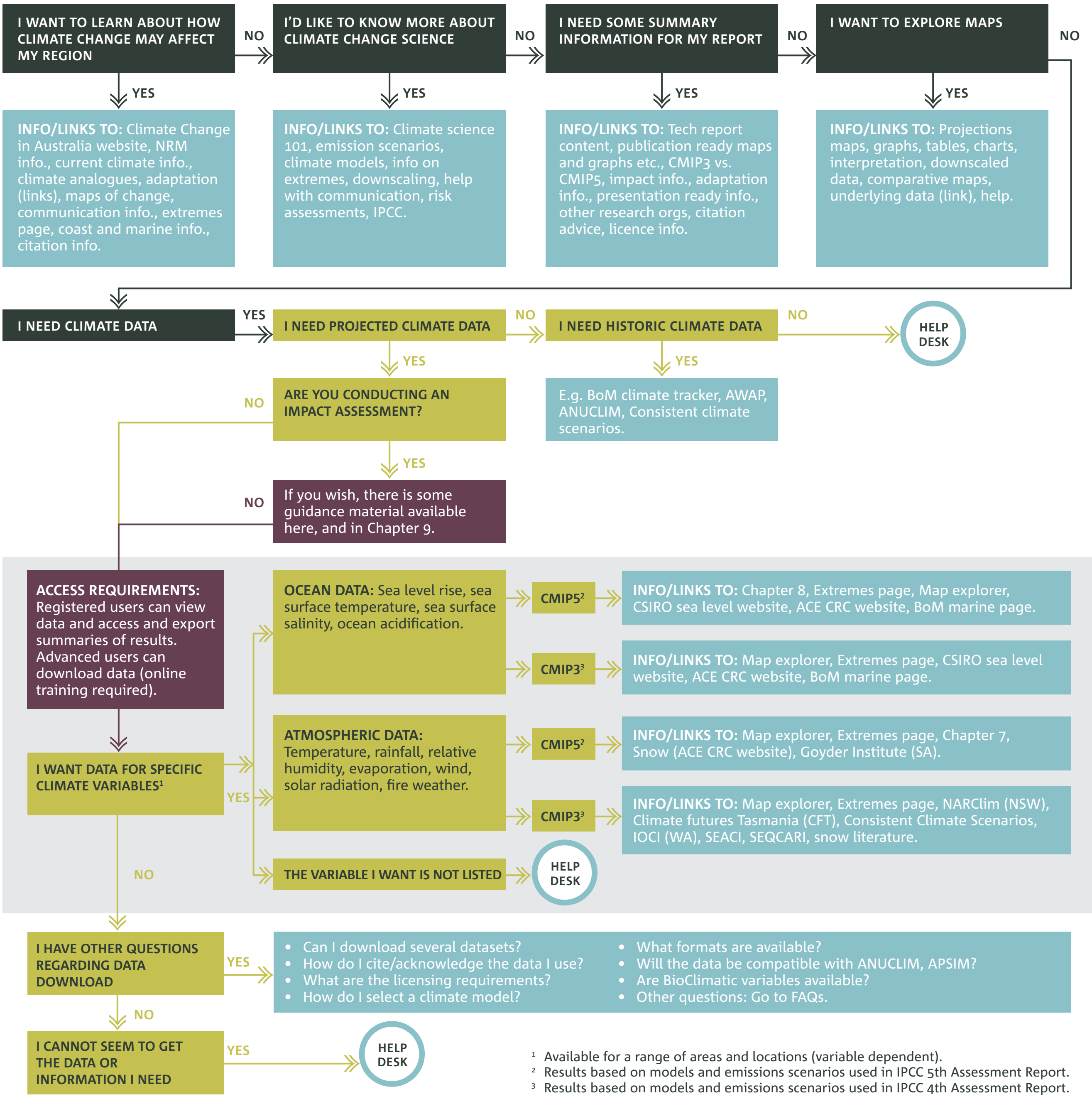
YEAR	RCP	ANNUAL TEMP. CHANGE (C°)
2030 (2020–2039)	4.5	0.6–1.1°C
	8.5	0.6–1.3°C
2090 (2080–2099)	4.5	1.3–2.5°C
	8.5	2.7–4.7°C

DECISION TREE

A decision tree has been used successfully in the United Kingdom climate projections portal (http://ukclimateprojections.defra.gov.uk/22531) (Street *et al*., 2009, Steynor *et al*., 2012). It helps users to proceed through accessing material with different levels of complexity, from simple information such as brochures, through to downloadable datasets for spatial assessments. A similar decision tree has been developed for Australian projections to help users select the type of climate information appropriate to their risk assessment (Figure 7).

Links to other sources of data, reports, supporting information and guidance material are accessible through this tool. However, accessing data via the decision tree is optional so that experienced users can save time by going directly to the section of the website that they need.

FIGURE 7: DECISION TREE AVAILABLE ON THE WEBSITE, WITHIN WHICH THE MAP EXPLORER PROVIDES A PATHWAY TO THE DOWNLOADABLE DATA PROVIDED FOR THE NRM PROJECT. PALE GREY BOX INDICATES REGISTRATION REQUIREMENT FOR ACCESS TO DATA AND INFORMATION.



LINKS TO OTHER PROJECTS

Links to other projects and sources of data, where results from the CMIP3 multi-model dataset (Meehl *et al.*, 2007) are used, have been made available through the website.

Information portals and State Government initiatives:

- Climate Futures for Tasmania: This project details the general impacts of climate change in Tasmania over the 21st century, with a description of past and present climate and projections for the future. It assesses how water will flow through various Tasmanian water catchments and into storage reservoirs under different climate scenarios. It also assesses specific climate indicators most important for productivity in several key agricultural groups. Working with emergency service agencies, the project identifies the climate variables of greatest concern to emergency managers (http://www.acecrc.org.au/Research/Climate%20Futures).
- South-east Australian climate initiative (SEACI): This program was established in 2005 to improve understanding of the nature and causes of climate variability and change in south-eastern Australia in order to better manage climate impacts (http://www.seaci.org/).
- Indian Ocean Climate Initiative (IOCI): This program investigated the causes of climate change in Western Australia and developed regional projections (http://www.csiro.au/science/ps62g).
- Goyder Institute: The Goyder Institute for Water Research was established in 2010 to support the security and management of South Australia's water supply and contribute to water reform in Australia (CMIP5 data used in this initiative) (http://goyderinstitute.org/).
- South-east Queensland Climate Adaptation Research Initiative (SEQCARI): This program provides access to information on climate projections and adaptation options for settlements in South-east Queensland (http://www.griffith.edu.au/environment-planning-architecture/urban-research-program/research/south-east-queensland-climate-adaptation-research-initiative).

Data Portals:

- James Cook University tropical data hub (https://eresearch.jcu.edu.au/tdh).
- NSW and ACT regional climate modelling: The NARCliM project has produced an ensemble of regional climate projections for south-east Australia in collaboration with the NSW Government Office of Environment and Heritage. This ensemble is designed to provide robust projections that span the range of likely future changes in climate. A wide variety of climate variables is available at high temporal and spatial resolution for use in impacts and adaptation research (http://www.ccrc.unsw.edu.au/NARCliM/).
- Consistent Climate Scenarios: This project produced Australia-wide projections data for 2030 and 2050 as daily time-series in a format suitable for most biophysical models. This project provided daily projections of rainfall, evaporation, minimum and maximum temperature, solar radiation and vapour pressure deficit for individual locations. Projections data were also developed on a 0.05 degree (approximately 5 kilometres) grid across Australia. (http://www.longpaddock.qld.gov.au/climateprojections/about.html)
- CliMond: This is a set of free climate data products consisting of interpolated surfaces at ~13 km and ~50 km for recent historical climate and relevant future climate scenarios. The data are available as monthly averages, 35 Bioclim variables, in CLIMEX format, and as the Köppen-Geiger climate classification scheme (https://www.climond.org/).
- Climate Futures Tasmania (data portal) (https://dl.tpac.org.au/tpacportal/).

APPENDIX 1. SURVEYS OF USER NEEDS

In 2011, CSIRO hosted workshops in seven capital cities to seek feedback on projections published by CSIRO and the Australian Bureau of Meteorology in October 2007. The objectives of each half-day workshop were to:

- share experiences about how the projections have been used, what has worked well, what hasn't worked well, and what is needed urgently or over the coming three years;
- discuss some of CSIRO's ideas about how to provide more reliable projections, better guidance material, easier data access and user-friendly tools, with the aim of releasing new projections by 2014.

Up to 30 people attended each workshop in Melbourne, Adelaide, Perth, Darwin, Brisbane, Sydney and Hobart. While the projections report, brochure, poster and website (CSIRO and Australian Bureau of Meteorology, 2007) were considered useful, participants said that it was hard to find data for use in risk assessments. The OzClim website www.csiro.au/ozclim was sufficient for some clients, but data tailored for specific risk assessments were required by many other clients. With support from the Federal Government, CSIRO provided a 'tailored projections' data service, but resources were limited to less than one staff member, so the service struggled to meet demand. Guidance material and training were lacking. However, downscaled climate projections for Tasmania (Holz *et al*., 2010) were considered highly useful by participants in the Hobart workshop.

Feedback indicated an ongoing need for:

- Legitimacy, credibility and relevance in projection products;
- Information about climate model reliability;
- Conveying complex information simply;
- Representing and dealing with uncertainty;
- An appropriate level of spatial and temporal detail, using some form of downscaling;
- Information about the next 10–20 years, 2050, 2070 and 2100;
- Information on year-to-year variability, extreme events and user-defined metrics;
- Guidance on what period should be used as the current climate baseline;
- Access to data, support and guidance material;
- Different formats: text summaries, PowerPoint slides, maps, graphs, data, animations;
- Climate analogues and storylines, e.g. Melbourne becomes more like Adelaide;
- Case studies showing how climate information can be used in risk assessments;
- Addressing issues raised by sceptics.

These insights aligned well with those from the UK following the publication of the UKCP02 projections in 2002. The UK experience (Gawith *et al*., 2009) indicated that scientists should:

- Establish an understanding of user requirements;
- Manage user expectations because tensions exist between meeting user requirements and delivering credible climate science;
- Help users incorporate inherent uncertainty into decision-making;
- Solicit a wide range of users' views about presentation and delivery, including projections themselves, delivery interface, guidance materials and training;
- Support sustained user engagement;
- Establish a Steering Group to oversee development and delivery of projections, and ensure they are fit for purpose;
- Establish a User Panel (involving users and providers) to formalise user engagement;
- Establish a User Panel webpage for information exchange and a repository of meeting notes;
- Facilitate meetings of User Communities after the projections launch to share experiences, identify case studies and suggest improvements;
- Provide training face-to-face and online;
- Provide a Help Desk to address queries and comments.

NRM USER PANEL

In the first six months of the NRM project, a user panel was formed to help ensure that the preparation and delivery of climate change projections meets the needs of the user community. The panel was made up of representatives from each NRM cluster, representatives from associated impacts and adaptation research projects, and other interested stakeholders with relevant expertise. To date these people have advised on activities undertaken and planned, with regard to:

- Climate variables and the ways in which they are being considered;
- Climate projections and how they are presented and communicated;
- Design, development, and communication of climate change projections through the web portal.

Examples of how climate projections information and data have been, or may be, used for impacts and adaptation research in the natural resource management sector were documented in a set of 24 case studies, based on 14 interviews. These represented a broad cross-section of industries and regions, as well as a range of complexity from simple information requirements through to complex data retrieval needs. This process has highlighted three broad categories that summarise user requirements (Table 3).

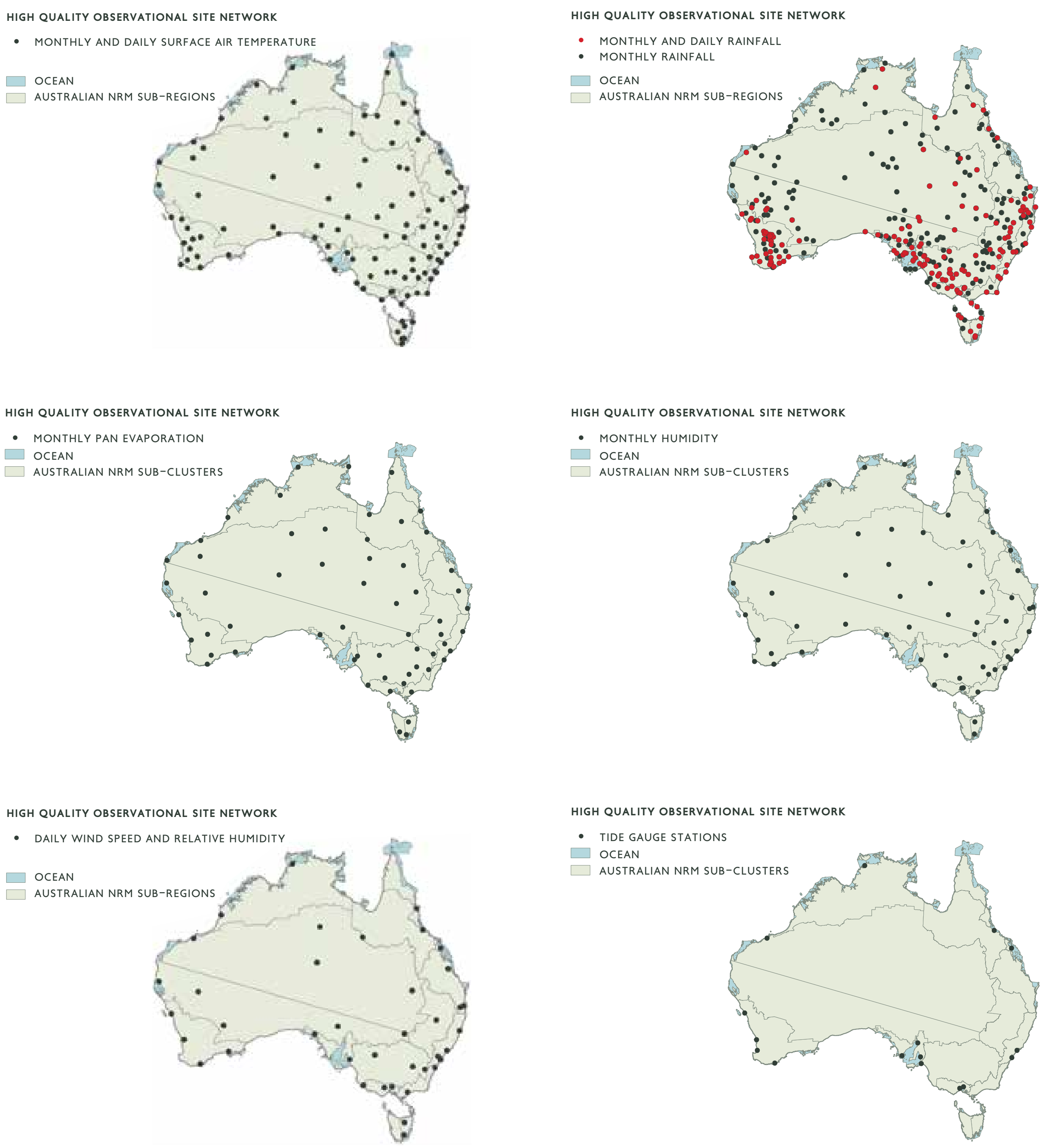
TABLE 3: THEMES REPRESENTING USER REQUIREMENTS THAT WERE IDENTIFIED DURING STAKEHOLDER ENGAGEMENT ACTIVITIES.

1. EXISTING ACTIVITIES	2. DESIRED ACTIVITIES	3. SUPPORTING ACTIVITIES
Simple communication tools (e.g. Climate change in Australia website)	Model selection	Receiving assurance and help
Access to data downloads (e.g. OzClim)	Climate extremes information	Help navigating the website
	Climate change ‘campus’ with guidance material and training	Updates on data or website changes
	Help with communication (e.g. presentation packs)	

APPENDIX 2. HIGH QUALITY SITE NETWORKS

Climate projections for cities and towns are available for sites with high quality observational data, as identified by the Bureau of Meteorology (Figure 8). Sites with high quality maximum and minimum temperature (ACORN-SAT; BoM, 2012), monthly and daily rainfall (Lavery *et al*., 1997), monthly pan evaporation (Jovanovic *et al*., 2008) are found at http://www.bom.gov.au/climate/change/hqsites/about-hq-site-data.shtml. Monthly relative humidity (Lucas, 2010), and daily wind speed (Lucas *et al*., 2007) have been published in separate reports. Fire weather information is limited to sites with high quality daily wind speed data. At some of these sites, projected daily data may not be supplied, as baseline data are not available for the relevant time period.

FIGURE 8. HIGH QUALITY SITE NETWORKS.



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