Government of **Western Australia**
Department of **Water and Environmental Regulation**

Climate Science Initiative WA

Technical information factsheet 20km Climate Projections

Climate Projections

Climate projections use highly complex models to project possible future climate changes under specific future conditions, or scenarios. Climate projections can help us understand what our future climate could look like under different plausible futures. They are a widely adopted tool to help focus climate change adaptation and mitigation efforts.

20km climate projections for WA

WA has recently released regional climate projections at a 20-kilometre (20km) resolution for temperature and rainfall using the latest available climate models, in line with other national and international efforts.

These projections will also be made available to non-technical users via an interactive online map through the Climate Science Initiative (CSI) program. This fact sheet explains the technical information relevant to the 20km projections.

More detailed projections for more variables at a 4-kilometre (4km) resolution are in production with further information here: Climate Science Initiative – Frequently Asked Questions.

About CMIP6 Climate Projections Data – data sources and analysis

The Western Australian Government, through the Climate Science Initiative, is producing high-resolution climate change projections for WA. Computer-modelled climate projections are one of the best information sources available on the future climate.

Using a process known as dynamic downscaling of global climate models (GCMs) from the latest phase of the Coupled Model Intercomparison Project (CMIP6), the whole of WA is now covered by 20km grid resolution climate projections. The data and projections at 20km have been produced in partnership with the NSW and Australian Regional Climate Modelling (NARCliM) Project. This project is producing high-resolution regional climate projections that cover the Australasian continent at a 20km resolution. They are currently available for technical users via the Shared Location Information Platform (SLIP).

Global climate models

(GCMs) are used to understand changes to the Earth's climate system and are computer simulations of our global climate system that divide the Earth into three-dimensional grid cells. These grid cells can range from 100 to 250 kilometres in size.

NARCliM Climate Projections

The NARCliM project develops high-resolution regional climate projections covering NSW and South-eastern Australia (referred to as the NARCliM domain) and the Australasian continent (referred to as the CORDEX domain, which is relevant for WA). The NARCliM project uses currently available GCMs and greenhouse gas (GHG) emissions scenarios from the latest phase of the Coupled Model Intercomparison Project (CMIP6), used in the Intergovernmental Panel on Climate Change (IPCC) reports, and applies regional dynamical downscaling using the latest Weather Research and Forecasting Model (WRF). These models provide a way to understand the changes in the climate, which are summarised in the assessment reports produced by the IPCC. The emissions scenarios used in NARCliM, and in the WA projections currently available are therefore consistent with the IPCC assessment reports.

Detailed technical notes for NARCliM2.0 are available, covering data licensing, more information on model selection, current known issues, full data and variable availability and details about how to access the data on the National Computing Infrastructure (NCI).

Emissions scenarios

Shared Socioeconomic Pathways (SSPs) are the most recent emissions scenarios adopted in the IPCC's Sixth Assessment Report. SSPs describe how greenhouse gas emissions and socioeconomic factors (e.g., population, education and economic growth) may change in the future. Results used in the 20km climate projections are shown for two plausible scenarios of the future:

- **SSP1-2.6:** A low emissions scenario where temperatures increase by about 1.8°C by 2100. This scenario envisions a future with stringent environmental policies and sustainable practices, leading to lower global greenhouse gas emissions.
- **SSP3-7.0:** A high emissions scenario where temperatures increase by about 3.6°C by 2100. This scenario is marked by high population growth, limited regulations, and a reliance on fossil fuels, resulting in elevated greenhouse gas emissions and a more severe impact on the climate.

For more detailed information about climate projection scenarios used in climate modelling, including an explanation of different climate scenarios, please refer to the Climate Science Initiative (CSI) factsheet on climate models and projections.

Model Selection

The Global Climate Models (GCMs) have been chosen based on the following three key criteria:

- Performance in simulating the current climate, i.e. reject models that poorly simulate the current climate.
- GCMs that consider the full range of possible future climates.
- GCMs that are independent to ensure model errors are uncorrelated.

Five CMIP6 GCMs were selected and are available for WA. Descriptions of the models used are in Table 1 below. Selection of models has occurred based on an evaluation of model performance for different regions. This work is compliant with the Coordinated Regional Downscaling Experiment (CORDEX) requirements. Modelling groups across Australia follow the CORDEX common set of guidelines to ensure a nationally consistent approach.

Downscaling helps to provide locally relevant information. For downscaling, the Weather Research and Forecasting (WRF) model was used with two RCM variants (R3 and R5) within the Climate Science Initiative (CSI) program for two Shared Socioeconomic Pathways (SSP1-2.6 and SSP3-7.0). SSP2-4.5 is currently under development. More information to assist with understanding SSPs is available here.

The models used by the CSI for WA are listed in Table 1 below:

Global Climate Model – CMIP6 Model name	Model name	Narrative	Institution Name	Country of Origin
ACCESS-ESM 1.5	Australian Community Climate and Earth System Simulator, version 1.5, CCAM atmospheric model version	A hotter and much drier future	CSIRO & BoM	Australia
EC-Earth3-Veg	European Community Earth System Model EC-Earth Version 3 with Dynamic Vegetation	A hotter and wetter future for much of Australia except the southwest of WA	European consortium of national meteorological services and research institutes	Various European countries
NorESM2-MM	Norwegian Earth System Model, version 2, 1 degree resolution	Lower warming, mid-range changes in rainfall	Norwegian Climate Centre	Norway
UKESM1-0-LL	UK Earth System Model, version 1.0, Low Resolution	Low probability, high impact case (high climate sensitivity high Australian warming)	UK Met Office Hadley Centre and Natural Environment Research Council	UK
MPI-ESM1-2	Max Planck Institute Earth System Model, version 1.2	Considered a relatively balanced model amongst the four selected.	Max Planck Institute for Meteorology	Germany

Table 1 Global Climate Models used in the Climate Science Initiative program

Models chosen are also represented visually in Figure 1 below.

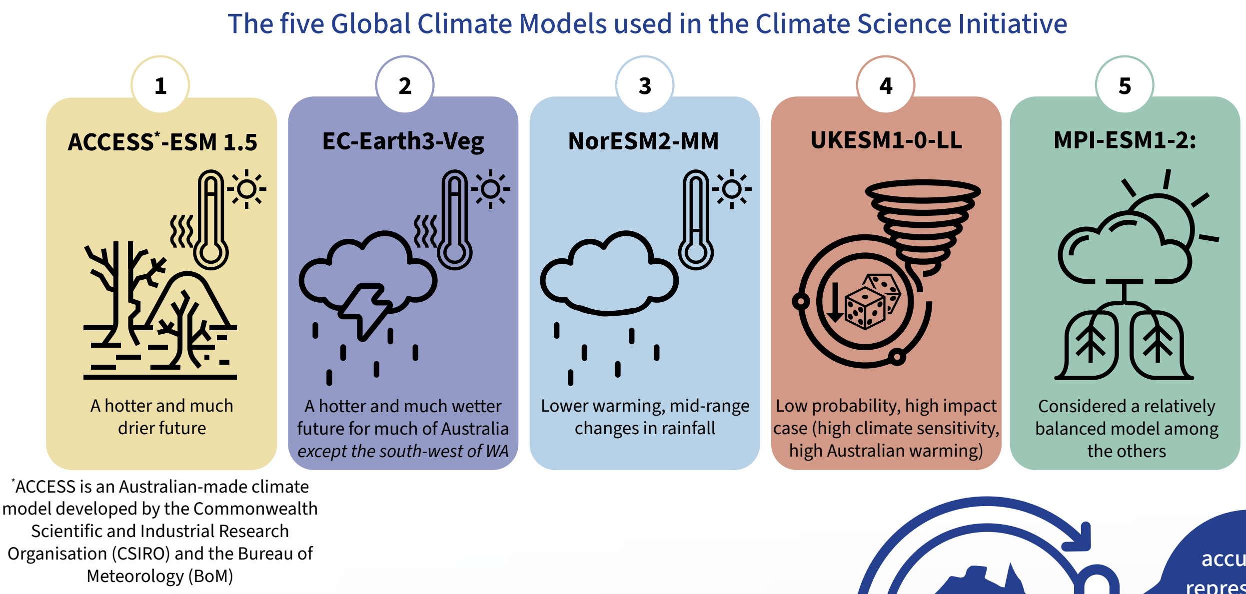
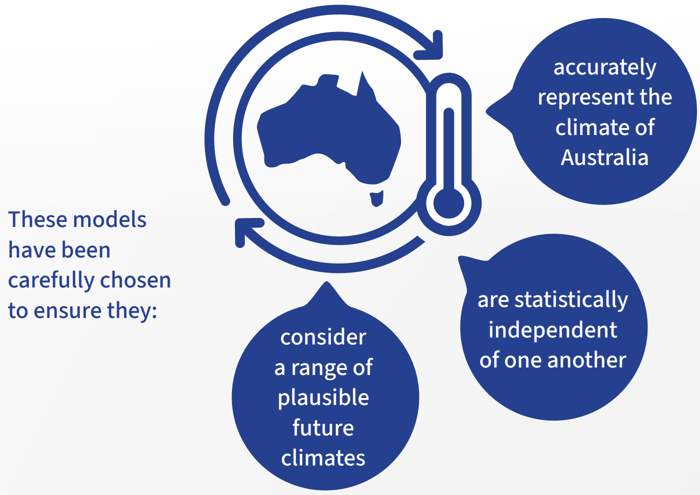


Figure 1 Five global climate models used in the Climate Science Initiative infographic

Further information on the global and regional climate models used by NARCliM is available here. Peer-reviewed literature on the GCM selection process for NARCliM2.0 is published in Earth's Future.



What projections should I choose?

There is no single textbook method to determine which climate projections to use, however, it is best practice to consider the results of multiple models and the full range of climate modelling data. This is because there is considerable variability among the five model combinations in their projections of temperature and rainfall.

It is recommended to:

- Consider the full range of projections data based on the purpose of your decision-making activity, for example to assess the impacts of climate change for risk assessments.
- Uncertainties will always exist within the modelling due to climate variability and emissions uncertainty, so there will be model-to-model differences. While climate projections provide a solid evidence base, they should be used as a guide to the future, and changes above or below the projected range should still be considered when managing risk.
- Consider the data from different emissions scenarios i.e., SSP1-2.6 and SSP3-7.0. It is recommended to consider SSP3-7.0 as a 'stress test' for sectors if resourcing only allows for one scenario, to support the development of adaptation responses that will withstand a range of climate futures.
- Even if one dataset is highlighted and presented as a primary data source, contextualising this source with the range of other available modelling is best practice.
- Other recommendations are discussed in the appendices and limitations of the data section below.

Below are some additional resources to help determine which climate projections to use:

- Planning your climate project or assessment with NARCliM | AdaptNSW
- National scale climate projections are available from Climate Change in Australia, with a guide on how to choose your information: I cannot seem to get the data or information I need
- Guidance materials from the Climate Systems Hub on how to find and select the right climate change projections and information for your needs and Understanding data inputs for a climate risk assessment.
- For further information on related work by the Australian Climate Service producing bias corrected CORDEX-CMIP6 data see here. Also, further links discussing its technical points and limitations is in the Important Information and Limitations of the data section of this document.

What data is available now?

Tranche 1

- Variables: Temperature (Minimum, Maximum), Rainfall (average)
- Scenarios: Historical, SSP1-2.6, SSP3-7.0
- Time slices: Seasonal (Summer, Autumn, Winter, Spring) and yearly
- Format: Multi-model average statewide projections (CSV, netcdf, gdb, shp)
- Bias corrected data

Future tranches (TBC)

- Variables: Evapotranspiration, Relative Humidity, Surface Wind, Solar Radiation
- Data on temperature and rainfall for additional scenario: SSP2-4.5
- Non-bias corrected data
- Individual regional climate model and global climate model results

Data processing and temporal averaging

A suite of derived parameters was calculated for every gridded point in the 20km bias-corrected rainfall and temperature datasets. For each weather variable, the average values of each ensemble were downloaded in monthly time slices from NCI storage via Thematic Real-time Environmental Distributed Data Services (THREDDS), a web-based system providing access to scientific data, especially related to climate and/or the environment. After passing quality assurance and quality control (QAQC), monthly averages were then grouped to represent annual and seasonal (Spring, Summer, Winter and Autumn) values for the weather variables (i.e tasmax (temperature maximum), tasmin (temperature minimum) and pr (rainfall)).

These values were then averaged (mean) across the climatological baseline period of 1990 – 2009, and each of four twenty-year future periods representing years 2030, 2050, 2070 and 2090, and represented in several output file formats (the standard deviation, minimum and maximum values for each period was also calculated).

This baseline period enables comparison between NARCliM 1.0 and 1.5 data, and aligns with past planning assumptions that still work on that baseline.

Data naming protocol

Variable		
	Max	tasmax, the average daily maximum temperature (degrees C)
	Min	Tasmin, the average daily minimum temperature (degrees C)
	Rai	pr, the average rainfall (mm / day)
Season		
	Annual	annual
	Au	Autumn (Mar-May)
	Wi	Winter (Jun-Aug)
	Sp	Spring (Sep-Nov)
	Su	Summer (Dec-Feb)
Time period		
	Ba	1990–2009 Baseline
	30	2020-2039
	50	2040-2059
	70	2060-2079
	90	2080-2099
Scenario		
	se	baseline
	126	SSP1-2.6
	370	SPP3-7.0
Global Climate Model		
	ENS	All models
	ACC	ACCESS-ESM 1.5
	ECE	EC-Earth3-Veg
	NOR	NorESM2-MM
	UKE	UKESM1-0-LL
	MPI	MPI-ESM1-2

Table 2: Data dictionary for NARCliM 2.0 first release variables

CSV naming convection

The CSV file contains all results where each row contains the results of each analysis at one location. It contains one unique fieldname (UniqueID) and the others which are the names of the analysis done, dependent on image type. The contents of these fieldnames are the names of the image formats described in the below three sections (NetCDF, Shapefile and Geodatabase). Unique names were required due to ESRI formats limitations on name size.

Example of the unique field is as follows:

FIELD NAME: UniqueID

FIELD DESCRIPTION: The coordinates are combined into a string that combines the coordinates (Longitute_Latitude_size) and the size of the cell.

CODE VALUES: Example, 128.900009109899E_-31.699985532289027S_20km

NetCDF (.nc) naming convention

The names of the layers in the netcdf files combines the components of Table 2.

For example:

1. The base prediction layer max_prAdjust_AnnualBa_SeR3R5ENS is the maximum value, of the bias adjusted precipitation, for all months in the years (Annual) for the baseline period (Ba i.e 1990 - 2009). The data analysed was produced by the historical Se model scenario, both R3 and R5 model types, all global climate models (ENS).
2. The future prediction layer max_prAdjust_Annual30_126R3R5ENS is the maximum value, of the bias adjusted precipitation, for all months of the years (Annual) in the future period centred on 2030 (30 i.e 2020 - 2039). The data analysed was produced by the future 126 model scenario, both R3 and R5 model types, all global climate models (ENS).
3. For the temporal difference calculation products, the layer's name is made by combining the names of two layers compared with a negative sign (-). For example, the product from subtracting the base from future examples described above would be max_prAdjust_Annual30_126R3R5ENS- max_prAdjust_AnnualBa_SeR3R5ENS.

Shapefile (shp) and geodatabase (gdb) field name explanation

First two characters are the statistical analysis done:

- Min = mi
- Max = mx
- Mean = mn
- Std deviation = sd

3rd and 4th are product modelled:

- Rainfall (pr in model files) = Ra
- tasmax = Tx
- tasmin = Tn

5th is the seasons or all months:

- Annual (all months) = A
- DJF (summer) = B
- MAM (Autumn) = C
- JJA (Winter) = D
- SON (Spring) = E

6th and 7th is the centre year of the interannual period being studied. For example:

- Present time model it is currently labelled as Ba (baseline).
- Future models are the last two numbers of the middle year of the period of interest e.g. 2020 to 2039 will be 30.
- Difference results have the last number of the middle year and the first character of Ba e.g. 2030 – base is 3B

8th is the model scenario i.e. present (called se), 126 and 370:

- Se = 0
- 126 = 1
- 370 = 2
- 126-base = 3
- 370-base = 4

9th is the R model type:

- R3 = 0
- R5 = 1
- R3R5 combined = 2

10th is the Main Model type that model scenarios and types are subsets of:

- ENS = 0
- ACC = 1
- ECE = 2
- MPI = 3
- NOR = 4
- UKE = 5

Geodatabase format alias naming conventions

The gdb files contain an alias name which is what is shown when layers are opened in packages such as QGIS and ArcGIS Pro by default. For the base (historical) and future predictions the gdb layers use the same naming convention as the netcdf files.

For the difference calculations, the names of the future and base predictions were combined. For example, the difference layer produced by subtracting max_prAdjust_Annual30_126R3R5ENS from max_prAdjust_AnnualBa_SeR3R5ENS is called max_prAdjust_Annual_30_126R3R5ENS_ Ba_SeR3R5ENS.

As discussed earlier, the shorter abreviated shp / gdb names are also in the files. To see in QGIS, on the layer of interest open layer properties -> fields. It is in the object ID field. To see it in ArcGIS Pro, open attribute table, click on any column and select fields. It will be visible in the Field Name field.

Important information and Limitations of the data

Bias Correction

- Bias corrected data was used in the model. This was produced by the NARCliM project. The method used to do the bias correction is the same as NARCliM 1.5, as discussed in NARCliM data processing and testing validation | AdaptNSW and NARCLiM1.5 Technical Method Report. Guidance on the use of bias corrected data is in Guidance on the use of bias corrected data.

Using a suite of GCM results and multi model mean data

- The ensemble mean (MMM) is the average value of all GCMs per grid cell and is available for rainfall and temperature variables at daily and monthly time slices. It is labelled the 'ensemble mean' and is recommended to be considered as a data point amidst a range of individual GCM results for each variable (i.e. tasmin – GCM x 5 plus MMM; tasmax GCM x 5 plus MMM; pr GCM x 5 plus MMM).

Re-gridding

- Data published on DataWA is re-gridded to Aus20i standards. This step is necessary given the NARCliM data is natively gridded using WRF standard formats (Aus18i) that may be slightly inconsistent with Aus20i.
- Regridded data is currently not available on NCI. Data currently available on NCI (described here) is in a native grid format (Aus18i), while the regridded dataset (Aus20i) is only available locally.
- The CSI team have requested an update on when this may become available and will provide an update shortly.
- Data published on DataWA will be re-gridded for use in GIS applications like ArcGIS.

Use of land masks and ocean cells

- Grid point values over water bodies are often not representative of land areas due to differences in physical properties and climate influences between land and water. Therefore, values from cells centred over major water bodies were excluded. Removing these values helps ensure that the data used for land-based climate modelling is more accurate and relevant
- Noting that islands may not have some or all of the regions.

Use of individual gridded cells to represent a small area:

- CSI scientists strongly recommend that end users do not use data at single grid point (e.g., the closest grid point to a particular town or location) but use averaged data from a reasonably large area of the region of interest, for instance, at the Local Government Area (LGA) level. Given the cell size is 20km, users must also note that the values at each grid-point represent an average across a spatial area the size of each model cell, so will vary from values observed in the area of the grid cell.

Future releases

- Extremes and indices will be publicly released for 20km data in future releases by the CSI, and this will be made available for WA audiences.

Data disclaimer and access

This information is made available in good faith for free and open use by users. It has been made publicly available as a part of a commitment under the Climate Adaptation Strategy. Please note that the data is open access.

Users are advised that any manipulation, modification or interpretation of the data by third parties is independent of the Department of Water and Environmental Regulation (DWER), and neither the Department or the Climate Science Initiative is responsible for any results or conclusions derived from altered data.

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