Actuaries Institute.

Design Documentation

Australian Actuaries Climate Index v2.0

Introduction

The Australian Actuaries Climate Index (AACI) has been developed to measure whether the frequency of extreme weather conditions is changing over time.

It is designed to provide an easy to interpret and valuable metric for actuaries, policy decision-makers and the general public to refer to when monitoring changes in climate[1]. The Institute commissions Finity Consulting to produce the Index and Rade Musulin, Principal at Finity Consulting, leads the team who collate the Index.

The Index was initially released in 2018. Version 2.0 of the Index, which uses reanalysis data, was released in 2025.

The AACI includes a series of component indices and a composite index.

- The component indices show changes in the frequency of extreme levels of each of temperature (high and low), rainfall, drought, wind, and sea level.

- The v2.0 composite index combines the measures of high temperature, rainfall, wind and sea level into a single index.

Actuaries specialise in understanding risk, and this Index has been designed to correlate with climate risk, within the constraint of being reasonably easy to interpret. This has been done through the selection of climate metrics that are indicators of risk and also through the focus on the 'extreme' tail of the metric distributions.

Potential future improvements include additional indices measuring specific risk attributes that consider the relationship between the data on extremes and historical risk data on, for example:

- Risk of damage to property.
- Risk of damage to health.
- Risk of excessive energy demands.

Reference Period

A reference period of 1981 to 2010 has been used as a base from which to measure change, and data from this period has been used to determine a reference value for each metric. The index measure for each component represents the change between current conditions and the reference period value. We have chosen a relatively recent reference period to provide a contemporary view of how the extremes are changing.

Results are produced for each season, such that autumn is compared to previous autumns, summer is compared to previous summers, etc.

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[1] The Actuaries Climate Index™ (ACI) has been developed in North America with a similar objective. http://actuariesclimateindex.org/home/

Individual Component Indices

There are six individual indices available which have been chosen for the impact and risk they pose to people and the economy. The data used for the indices is available from the ERA5 and ORAS5 reanalysis datasets and is described in Section 6. The indices are described in Table 1.

Table 1 – Components of Index

Component	Description
High Temperature	Frequency of maximum and minimum temperatures above the 99th percentile.
Low Temperature	Frequency of maximum and minimum temperatures above the 1st percentile.
Precipitation	Frequency of rainfall over five consecutive days above the 99th percentile.
Wind	Frequency of daily wind speed above the 99th percentile.
Consecutive Dry Days	Seasonal maximum consecutive dry days.
Sea Level	Seasonal mean sea sea surface height.

Temperature

For the high temperature, the AACI measures the change in the proportion of days in a month on which the maximum and minimum temperatures exceed the 99th percentile of the reference period distribution for the relevant day. The results for the maximum and minimum temperatures are then averaged.

The low temperature measure is calculated using a similar process by looking at the frequency above the 1st percentile.

Both the high and low temperature components therefore record if there is a warming in temperature. While colder temperatures, particularly lower low temperatures, pose a climate risk to people and the economy, this is considered to be a less significant risk than warming temperatures in Australia.

Precipitation

Extreme precipitation over short periods is a key driver of flood and storm damage. The rainfall component of the index focuses on extreme rainfall over a consecutive 5-day window.

Wind

During severe wind weather events such as storms and cyclones, it is the maximum wind gusts that are likely to lead to higher risk and damage. The wind metric measures the monthly frequency of daily maximum wind gust above the 99th percentile.

Consecutive Dry Days

Consecutive dry days is included in the index as an indication of drought conditions. It is defined as the number of consecutive days with less than 1mm of rain up to a maximum of 365 days. The cap is included for practical purposes and has no material impact on the index.

Sea Level

The sea level measure tracks movements in the monthly mean sea surface height, an important risk factor for coastal inundation.

The AACI

The headline AACI combines four of the individual component indices in version 2.0:

- High Temperature
- Precipitation
- Wind and
- Sea Level.

The other individual metrics were excluded from the composite index for the following reasons:

- Low Temperature – to ensure that temperature was not overweighted in the composite, noting that High temperature is included.
- Consecutive Dry Days - The drought measure was excluded as it shows a strong inverse correlation with the rainfall measure.

Calculation of Exceedance Thresholds

The measures for temperature, precipitation and wind track the frequency of events that are in excess of calculated exceedance thresholds. These thresholds represent the 99th percentile of events observed over the base period.

These 99th percentile thresholds are calculated for each day of the year during the base period. The calculation process is described through an example:

- Using 6 March as an example, we use all daily maximum temperature values for 6 March between 1981 and 2010. In order to increase the available data, we also take the observations for the five days before and after. This gives 330 days. From that data we take the temperature on the 4th warmest of the 330 days as the 99th percentile.
- The index then tracks the proportion of temperature values in a month that exceed the baseline.

The measures for sea surface height and consecutive dry days are calculated directly from the data in the manner defined.

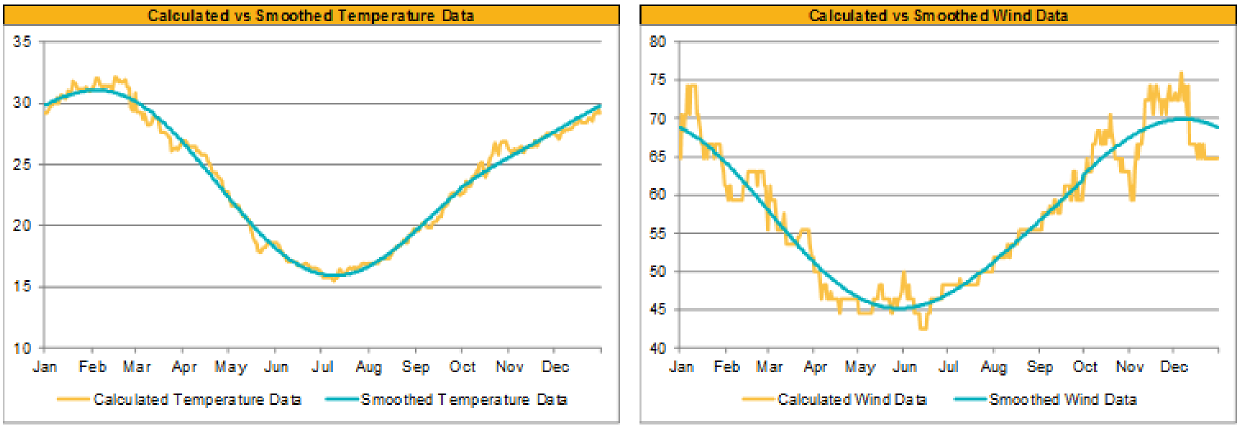
Smoothing

The one-sided nature of exceedance calculations means that when cut-offs are calculated directly from the data, bias can be introduced by the normal random variability associated with the process. This issue is discussed in Avoiding Inhomogeneity in Percentile-Based Indices of Temperature Extremes by Zhang et al (2004). This bias can mean that non-base period metrics appear higher than base period.

We aimed to minimise this bias by fitting smoothed curves (using generalised additive models or GAMs) to the exceedance thresholds before calculating metrics. This adjustment reduced bias from 0.2% to 0.05% when tested on simulated data. The simulated data had similar variability and seasonality as our raw time series, but without any trend over time.

The charts below show examples for temperature and wind. For temperature the curve tended to be straightforward to fit as the variability is limited. Wind was more challenging. In the example shown the assumed wind threshold is well above the observed 30 years of experience in October and below the experience in late November and early December. We have taken the view that variations in the actual experience like these reflect randomness, rather than real differences in the weather conditions.

Figure 1 – Smoothed GAMs to calculate exceedance thresholds



Data Sources

ERA5 and ORAS5 reanalysis data from the Copernicus Climate Change Service was relied on to construct the index. Details of the data sources used are provided in Table 2.

Table 2 – Data sources

Component	Source	Comments
High Temperature	11,154 reanalysis grid points	0.25° x 0.25° grid – grid points are approximately 31 km apart.
Low Temperature	11,154 reanalysis grid points	0.25° x 0.25° grid – grid points are approximately 31 km apart.
Precipitation*	11,154 reanalysis grid points	0.25° x 0.25° grid – grid points are approximately 31 km apart.

Wind	11,154 reanalysis grid points	0.25° x 0.25° grid – grid points are approximately 31 km apart.
Sea Level	174 reanalysis grid points	All points within 3 km of the coastline have been included. 1° x 1° grid – grid points are approximately 100-110 km apart.

*Note that the Consecutive Dry Days metric is calculated based on precipitation data.

ERA5 and ORAS5

The ERA5 dataset is a global reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) through the Copernicus Climate Change Service. It provides a detailed and consistent record of atmospheric, land surface, and ocean wave variables from 1950 to the present. With hourly resolution, near-real-time updates, and global coverage at ~31km spatial resolution, ERA5 is widely used for climate monitoring and research. It integrates a vast range of observations from satellites, weather stations, aircraft, and ocean platforms, making it one of the most comprehensive sources of historical climate information.

Complementing this is ORAS5, the ocean reanalysis system from ECMWF, which reconstructs past ocean conditions using the OCEAN5 framework. ORAS5 assimilates satellite and in-situ measurements into a physically consistent model of ocean dynamics. It provides monthly data from 1958 onward at ~100km resolution, covering key ocean variables such as sea surface height, temperature, salinity, and currents.

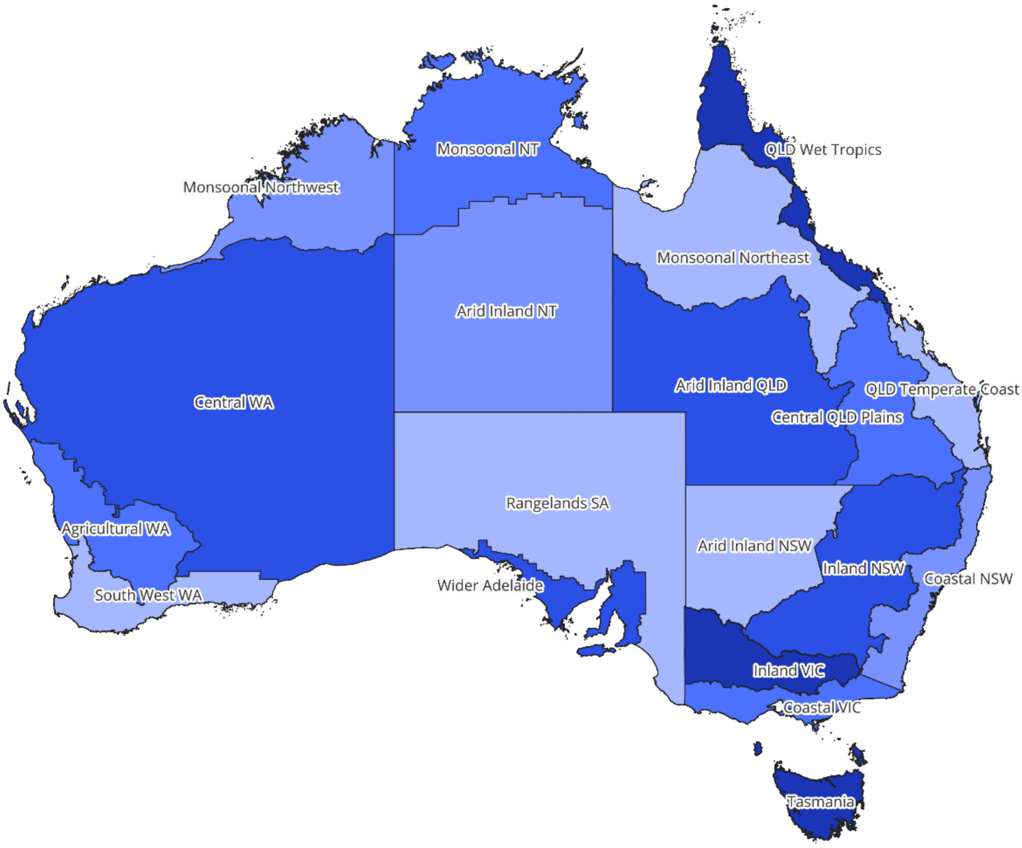
Together, ERA5 and ORAS5 offer long, consistent, and regularly updated datasets that include both atmospheric and oceanic components. Their breadth of variables and near-real-time availability make them highly suitable for climate analysis and for applications that require integrated land, ocean, and atmospheric information.

Regions

Results are available for Australia and for 19 climatologically consistent regions of Australia as shown in Figure 2. These regions are based on groupings of the administrative National Resource Management (NRM) regions. Two modifications have been made with additional datasets to better capture climatological variation:

- The northern parts of Western Australia and the Northern Territory have been split based on the climatological National Resource Management regions to reflect wet / dry differences.
- The east coast of Queensland has been modified using CRESTA (Catastrophe Risk Evaluation and Standardizing Target Accumulations) zones to better capture the differences between coastal and inland parts of the state, including cyclone risk. CRESTA is a common global classification system used in insurance.

Figure 2 – AACI v2.0 Regions



Aggregation of Results

Geographic Aggregation

All calculations are done at an individual grid point level and then aggregated to a region level by taking the average of all grid points within that region. This is done to ensure extreme observations are not averaged out in the index (which would be the case if we first averaged the station data and then calculated the measures).

Aggregation of the regions to an Australia-wide metric is also done by taking a simple average of the individual regions. This means there is no weighting of regions by either land area size or population.

Aggregation of Component Metrics into Index

In order to make the measures comparable, they are standardised using the mean and standard deviation of each measure over the reference period. We subtract the mean from the result and then divide through by the standard deviation. This ratio creates a standardised anomaly, which measures the statistical significance of the change over time relative to the underlying level of variability and importantly allows the different measures to be aggregated into a single index.

To ensure that the index is easy to understand, the AACI uses a simple aggregation method, and takes the simple average of each of the three component measures (once they have been standardised).

$$AACI\ v2.0 = mean(HighTemp_{std}\ , Precip_{std}\ , Sea\ Level_{std}, Wind_{std})$$

The index is provided at quarterly time periods and updated on a quarterly basis. The primary metric used is a five-year moving average, which smooths some of the volatility and weather cycle impacts from the measure.

References

- The Actuaries Climate Index™ (ACI) has been developed in North America with a similar objective.
- *Avoiding Inhomogeneity in Percentile-Based Indices of Temperature Extremes*, Zhang et al, 2004