Warming levels projections – average temperature and rainfall Technical Note 2 – emergence of temperature

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Introduction and context

Emergence relates to whether the ‘signal’ of climate change has completely emerged from the ‘noise’ of climate variability. When each year is above the entire range expected in the early climate, then the climate is said to have ‘emerged’ from that earlier climate (Hawkins et al. 2020). In other words, the climate is now ‘unknown’ to the previous era. A related idea is the first year when the signal-to-noise ratio crosses a threshold of one, which is the ‘time of emergence’ from the previous era (Hawkins and Sutton 2012).

It is of interest if the annual temperature has emerged for Australia and in states and territories as context for interpreting the historical context and warming levels projections presented here.

Methods

Two different methods of estimating the ‘signal’ of the long-term trend and the ‘noise’ of climate variability relevant to emergence are tested here. They are:

1. Removing the long-term or secular trend in temperature as a measure of the ‘signal’ and then gauging the remaining temperature variability through the standard deviation of inter-annual temperature as the ‘noise’
2. Regression against change in Global Mean Surface Temperature (GMST) as an estimate of the ‘signal’, using the method of Hawkins et al. (2020)

For method 1, the long-term trend can be estimated using a linear fit or using a smoother (Figure 1). Detrending using a linear fit means that early and late years are pushed up and the middle years are pushed down (Figure 1, top, also see webpage – Future Climate Scenarios > Global Warming Levels > Australian warming), which in turn gives a higher value of standard deviation of the detrended series (0.36 °C) than that detrended using the smoother (0.32 °C). These values could be used to represent the ‘noise’ in emergence calculations (there is a different value for each state and territory).

The second method uses an estimate of global temperature change as a more reliable estimate of the ‘signal’ of global climate warming, rather than the long-term trend in the data itself (which will contain the global ‘signal’ but also some regional climate variability). A large fraction of the variance in local climate changes can be represented by changes in GMST (Sutton et al. 2015), and the remaining variance is a measure of the ‘noise’ not related to global warming. Following Hawkins et al. (2020), global mean surface temperature (GMST) is taken from the Berkeley Earth dataset (Rohde and Hausfather 2013) and a 41-year Lowess filter is applied.

Regressing against a global signal gives a larger standard deviation of the noise compared to removing the smoothed trend from the data itself (for Australia, the standard deviation is 0.34 °C and 0.32 °C respectively). The value is not much larger given the smoothed series is not that different than the smoothed trend for the data. Interestingly, the noise estimated from this method is actually lower than when using a linear trend (0.36 °C). We use the regression against GMST for further analysis.

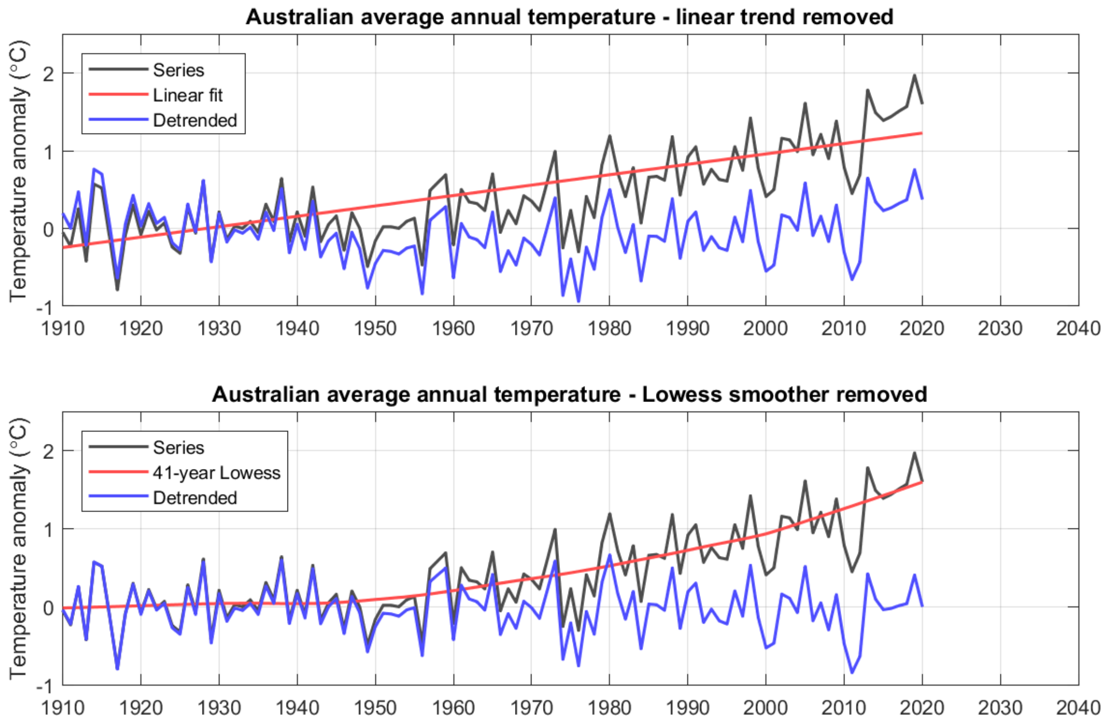

Figure 1. Australian average annual temperature anomaly from 1910-1930, with top: linear trend and bottom: 41-year Lowess filter trend calculated and then removed.

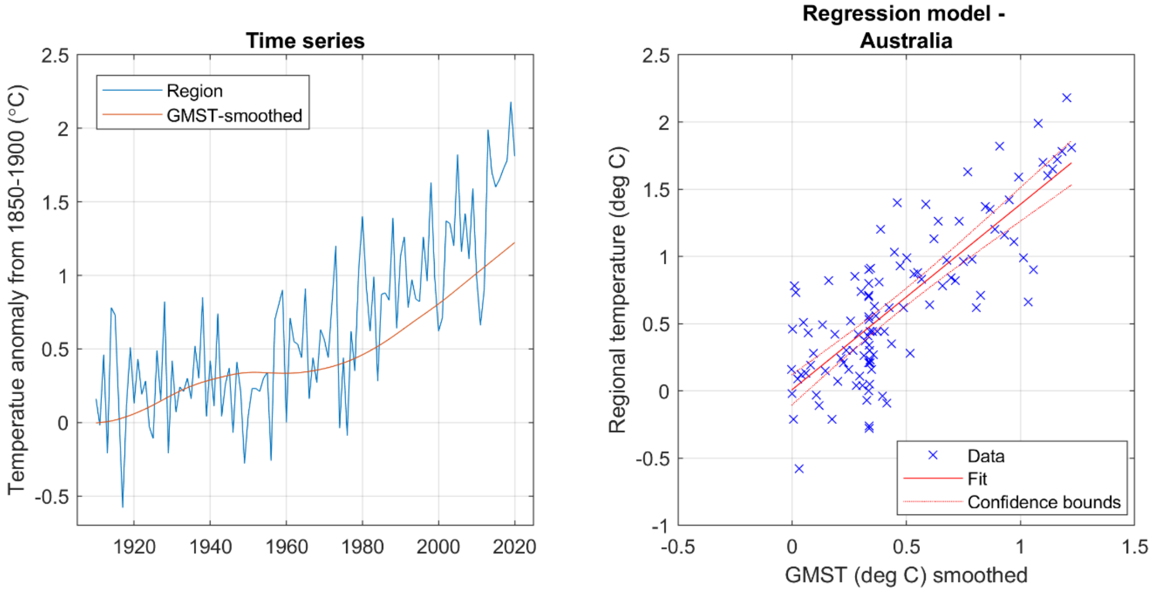

Figure 2. Australian average annual temperature anomaly and GMST relative to 1850-1900 (GMST has a 41-year Lowess smoother applied), and right a linear regression between them

Results

Using the regression to GMST over the 1910–2020 timespan for Australian as a whole, the 'noise' is 0.34 °C, and the 'signal' is 1.4 °C, giving a signal to noise ratio (S/N) of 4.0. The correlation of Australian temperature to smoothed GMST is R = 0.79, correlation of smoothed Australian temperature to smoothed GMST is R = 0.98.

This means that the average annual Australian temperature has almost certainly emerged from the 1850–1900 climate (Figure 3). To emphasise the separation of the 2x standard deviation windows, it is added to the smoothed trend (dashed lines). The two bands have been separated since 2007, and the last individual year within two standard deviations of the 'noise' around the preindustrial annual temperature was 2011 (a relatively cool La Niña year).

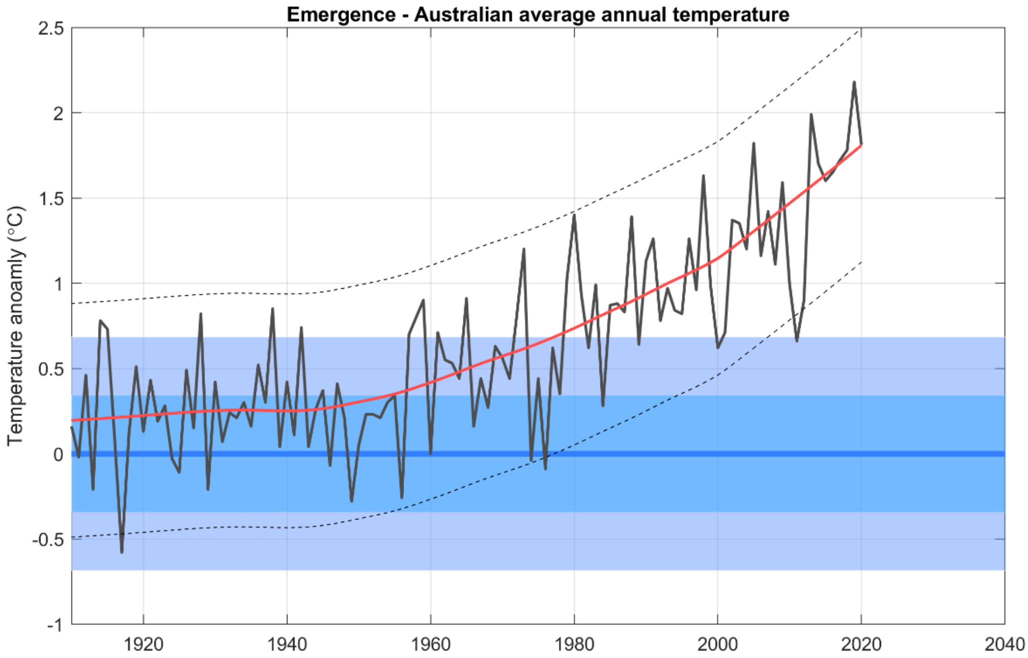

Figure 3. Mean annual temperature in Australia relative to 1850–1900 (black line), the 41-year Lowess smoother (red line) and two standard deviation range around of Australian temperature above and below the smoothed series (dashed lines). One and two standard deviation ranges around the 1850-1900 baseline (light and dark blue shading).

References:

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