Attribution of Extreme Heat Event Using a Seasonal Forecast Framework

Australian Government
Bureau of Meteorology

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1 Introduction

Here we present a method for the attribution of extreme climate events using an initialised climate prediction system to attribute the degree of influence from increasing levels of atmospheric carbon dioxide (CO_2) on an extreme heat event. Compared with other methods (e.g., using coupled models or SST forced atmospheric models) our method allows little time for the growth of model-driven biases as the simulation is initialized from the observation and only run for the period of the event.

The method is illustrated first, then the method is applied to attribute the causes of two recent month long record heat events that occurred in October 2014 and 2015 over Australia.

2 Estimate ocean-atmosphere-land changes due to CO2 increase an operational seasonal prediction system

The POAMA coupled model seasonal prediction system:

- Atmospheric model: Bureau of Meteorology Atmospheric Model v3
- Land model: simple bucket model for soil moisture and three soil levels for temperature
- Ocean model: Australian Community Ocean Model v2
- Initial conditions from the ocean, atmosphere and land assimilations.

Low CO_2 of 315 ppm representing 1960, and high CO_2 of 400ppm representing 2010s were used. The procedure for deriving the ocean change due to CO_2 increase is illustrated in Fig. 2.

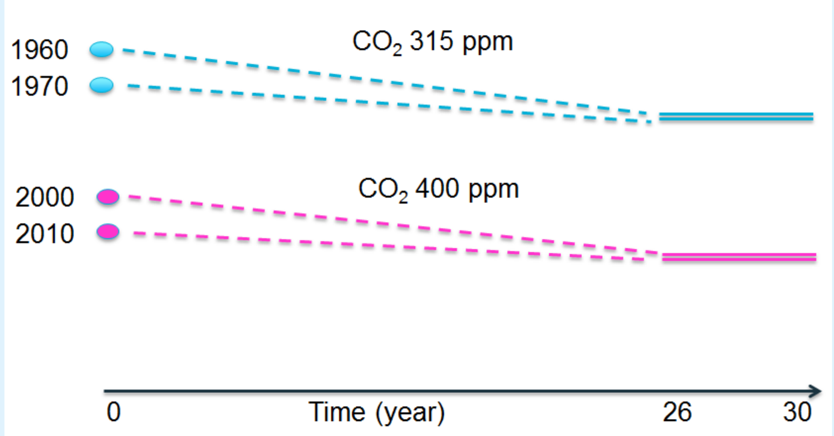

Fig. 1. Two 30 year long simulation initialized decade apart sampling decadal variability were conducted for both high and low CO_2. The difference of the average ocean conditions in the last 5 years of simulation between high and low CO_2 is used as an estimate of the ocean change due to CO_2 increase from 315ppm to 400ppm.

As the land simulation in low CO_2 long run suffers from severe drift, we derive the low CO_2 land condition by further running two month lead forecasts initialized from the above estimated low CO_2 ocean. The land (and atmosphere) responds to the oceans in monthly to seasonal time scales. These two month lead forecasts were run for every year over 2000-2014. The average land condition in these forecasts will filter out the interannual variability and retain the CO_2 influence from the low CO_2 ocean. Similar two month lead forecasts were run with high CO_2 and initialized from realistic ocean for each year over 2000-2014. The average difference in land and atmosphere between the two sets of the short lead forecasts gives the estimate of land and atmosphere changes due to CO_2 increase since 1960. The estimated October change in SST, soil moisture and atmospheric temperature from low to high CO_2 are shown in Fig. 2.

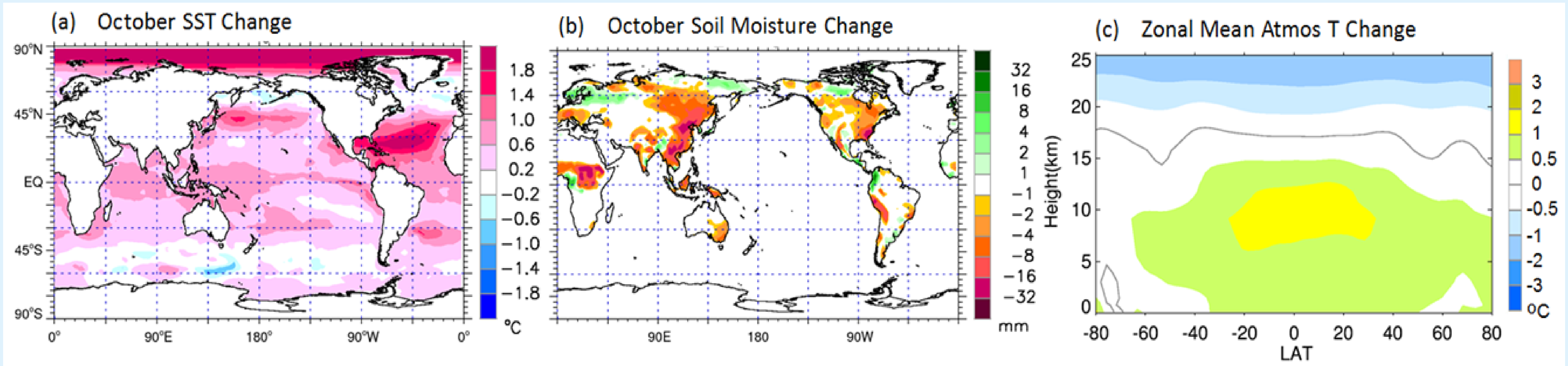

Fig. 2. The estimated mean October changes in (a) SST, (b) soil moisture and (c) zonal mean temperature in the atmosphere due to CO_2 increase from 315ppm to 400ppm. These changes are in many aspects similar to those obtained using CMIP5 models.

3 The extreme heat event and the attribution forecast

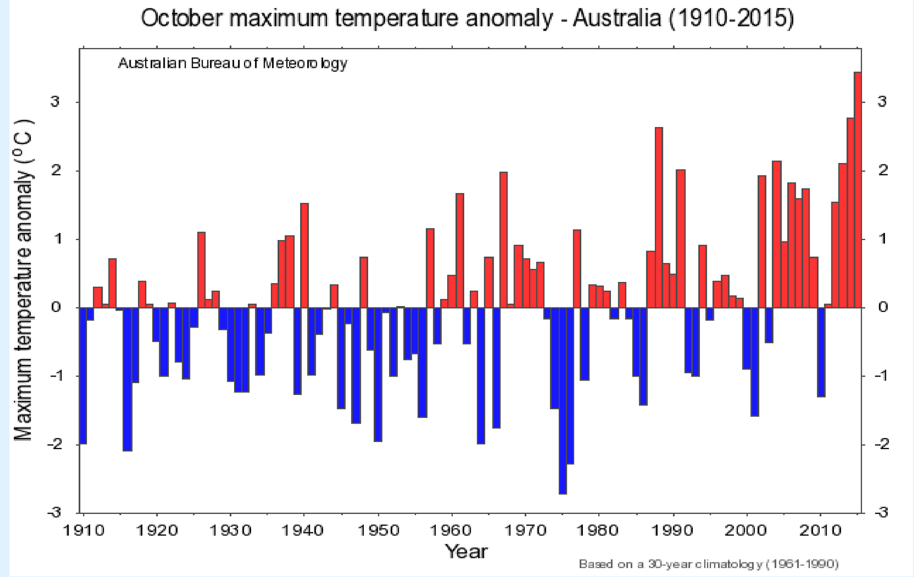

Fig. 3. Observed mean Australian October maximum temperature (AusTmax) anomalies (ºC, relative to 1961–1990) during 1910 to 2015.

AusTmax anomaly is 3.4 ºC in 2015, and 2.7 ºC in 2014.

October 2014 and 2015 were record heat events (Fig. 3). We use the above estimated changes in ocean-atmosphere-land due to CO_2 (Fig. 2) to conduct attribution forecast for the two events. The events were forecast twice, one initialised with realistic analysed ocean-atmosphere-land states and run with high CO_2 concentration and another with altered ocean-atmosphere-land states and low CO_2. The altered initial conditions in the low CO_2 forecasts were formed by removing the changes due to CO_2 (e.g. Fig. 2) from the analysed initial conditions.

The mean AusTmax is warmed by 1 ºC from low to high CO_2 (Fig. 4a). Relative to the climatology with CO_2 level of 1960, half of the heat anomaly forecasted across Australia in 2015 can be attributed to global warming associated with increased CO_2 (Fig. 4b). For 2014 event two thirds heat anomaly can be attributed to the increased CO_2 (Figure not shown).

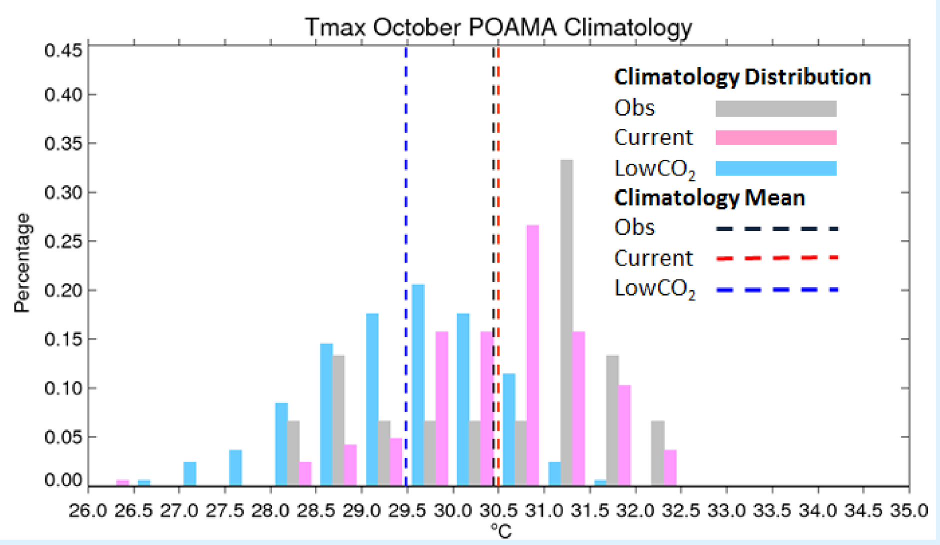

Fig. 4a, October AusTmax climatology distribution for 2000–14 from observations (gray bars), and the climatology estimated using 115 October forecasts during 2000–14 for the current climate (pink solid bars) and the low CO_2 climate of 1960 (light blue solid bars). The climatology means are shown in dashed lines: black for observations, red for current, and blue for low CO_2.

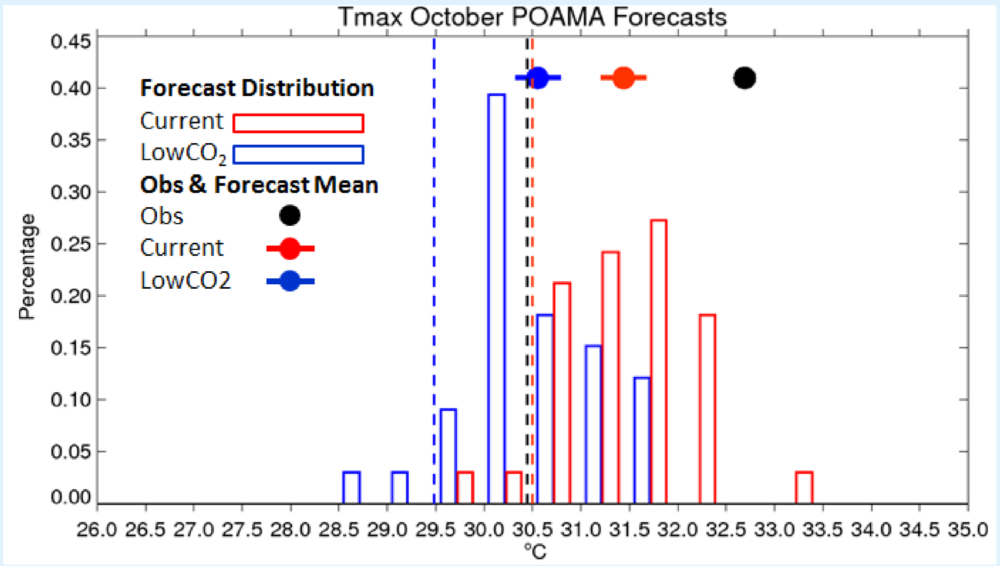

Fig. 4b. The distribution of the forecast October 2015 AusTmax is estimated with 33 member forecasts for high (red open bars) and low CO_2 (blue open bars) climates. The mean value for the observed event in October 2015 is shown by the top black dot (32.7 ºC), with the event ensemble means for high CO_2 by red dot (31.4 ºC) and low CO_2 by blue dot (30.6 ºC).

4 Sensitivity experiment

Additional sensitivity experiments were conducted to assess the impact of the internal climate drivers on the events. The sensitivity experiment results suggest that the atmospheric circulation anomalies played more important role than the direct impact from the ocean in promoting extreme heat across Australia (Fig. 6).

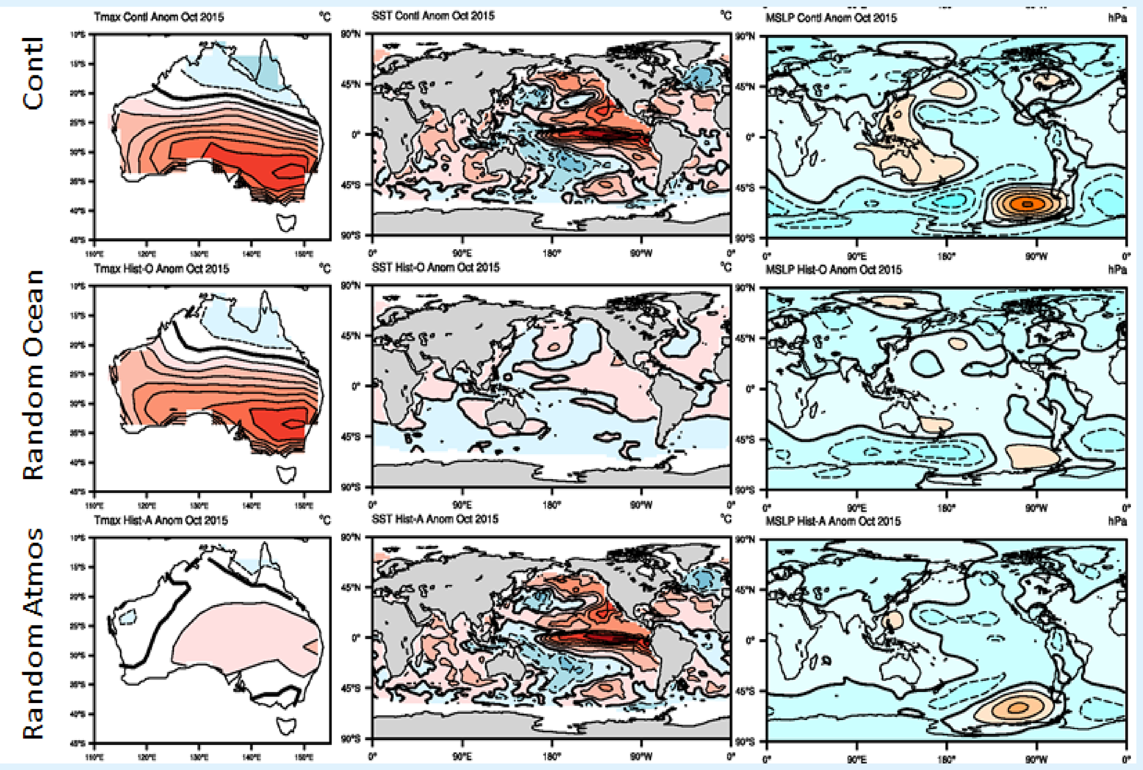

Fig. 6 October 2015 anomalies of Tmax over Australia and SST and MSLP over the globe (left to right). From top to bottom: control forecast and experimental forecasts with removing information about the ocean or atmosphere in the initial conditions in the two rows below. Contour intervals for Tmax, SST and MSLP are 0.4 ºC, 0.5 ºC and 2 hPa, respectively. Thick lines are zero contours.

5 Summary

A new method for attribution of extreme heat event using initialized seasonal prediction system has been developed. CO_2 concentration increase since 1960 has caused mean October Tmax across Australia by 1ºC. October 2015 Tmax anomaly forecast reached 1.9 ºC relative to "natural world" 1960s climate. If CO2 had not increased the Tmax forecast was reduced to 1.1ºC. This suggests about half of the heat anomaly forecasted across Australia in 2015 can be attributed to global warming associated with increased CO_2. The atmospheric circulation anomalies played more important role than direct impact from the ocean in promoting the extreme heat in Australia. Our method can be run in real-time alongside an operational seasonal forecast.

References

Hope, P., G. Wang, E.-P. Lim, H. H. Hendon, and J. M. Arblaster, 2016: What caused the record breaking heat across Australia in October 2015? Bull. Amer. Meteor. Soc., 97, S122–S126.