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Supplement of

Tropical influence on heat-generating atmospheric circulation over Australia strengthens through spring

Roseanna C. McKay et al.

Correspondence to: Roseanna C. McKay (roseanna.mckay@bom.gov.au)

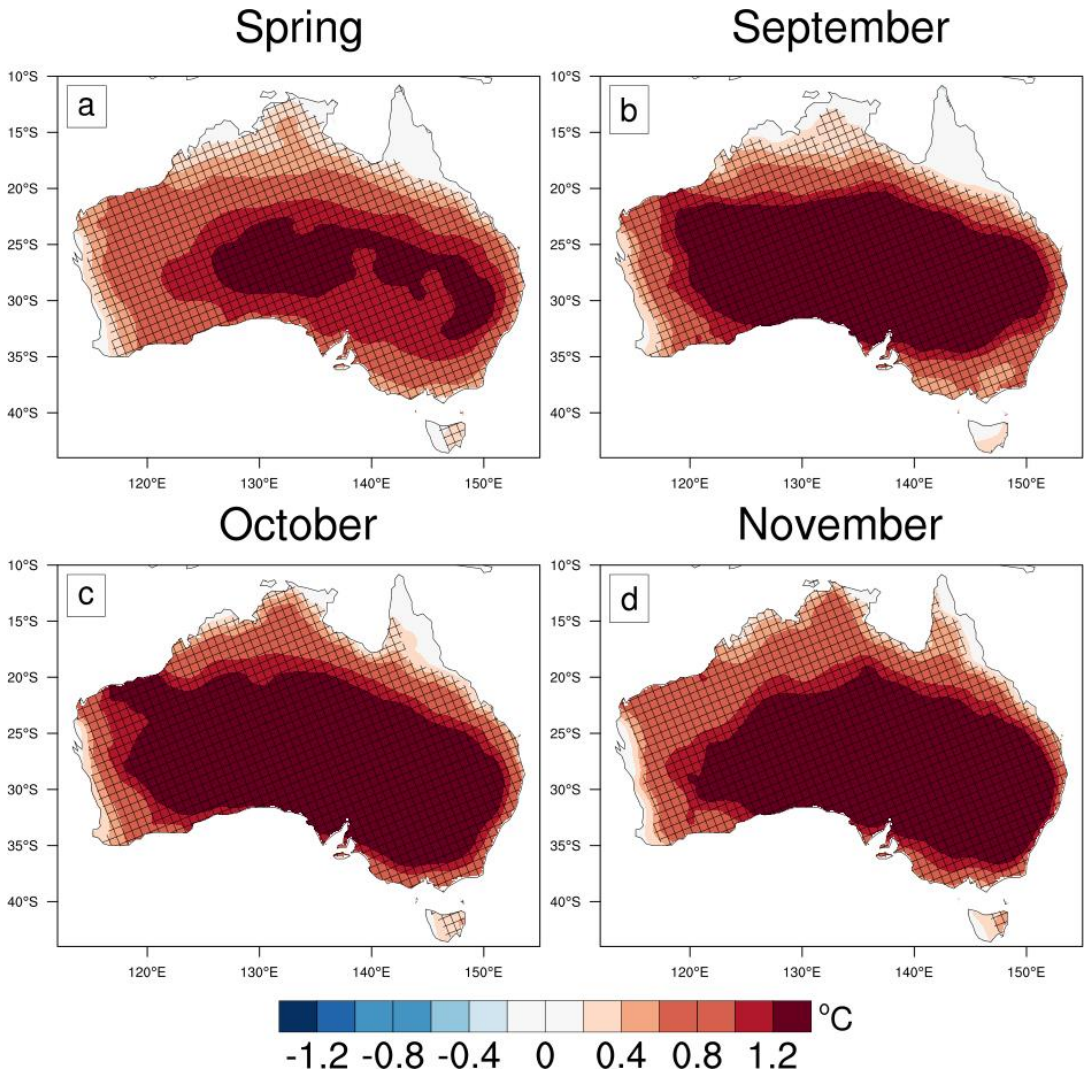

Figure S1. Australian weighted area-averaged maximum temperature linearly regressed onto gridded Australian maximum temperature for spring (a), September (b), October (c) and November (d) over the years 1979 to 2019. Anomalies are relative to a 1981 to 2010 climatology. All variables were detrended, and the area-averaged maximum temperature time series was standardised before regression. Hashing shows where the regression was statistically significant at the 95% confidence level using a two-sided Student's t-test with 39 independent samples.

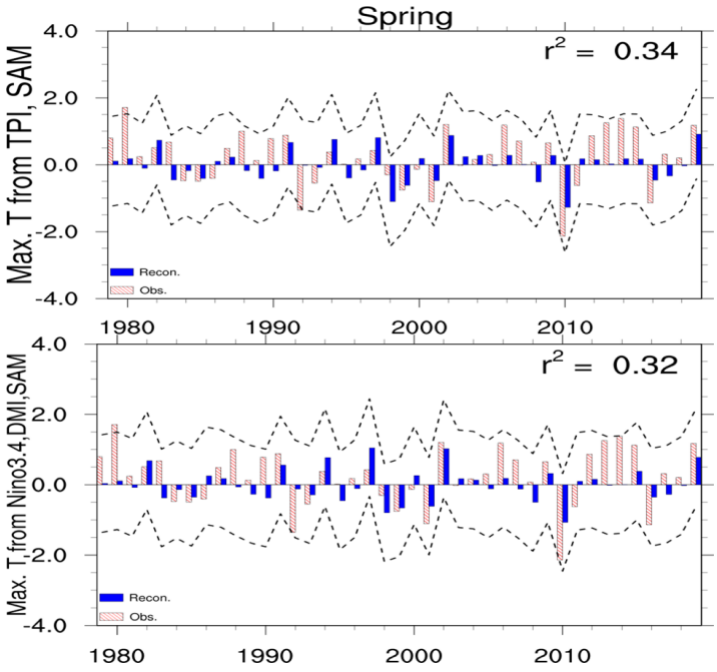

Figure S2. Spring (SON) Australian-averaged maximum temperature statistically reconstructed using the tropical TPI and SAM (top) and Niño3.4, DMI and the SAM bottom) (blue bars) between 1979 to 2019. The red dashed bars show the observed temperature anomaly for each month. The dotted line shows the 95% confidence interval. The percent variance explained (r^2) for each month is in the top right of each figure.

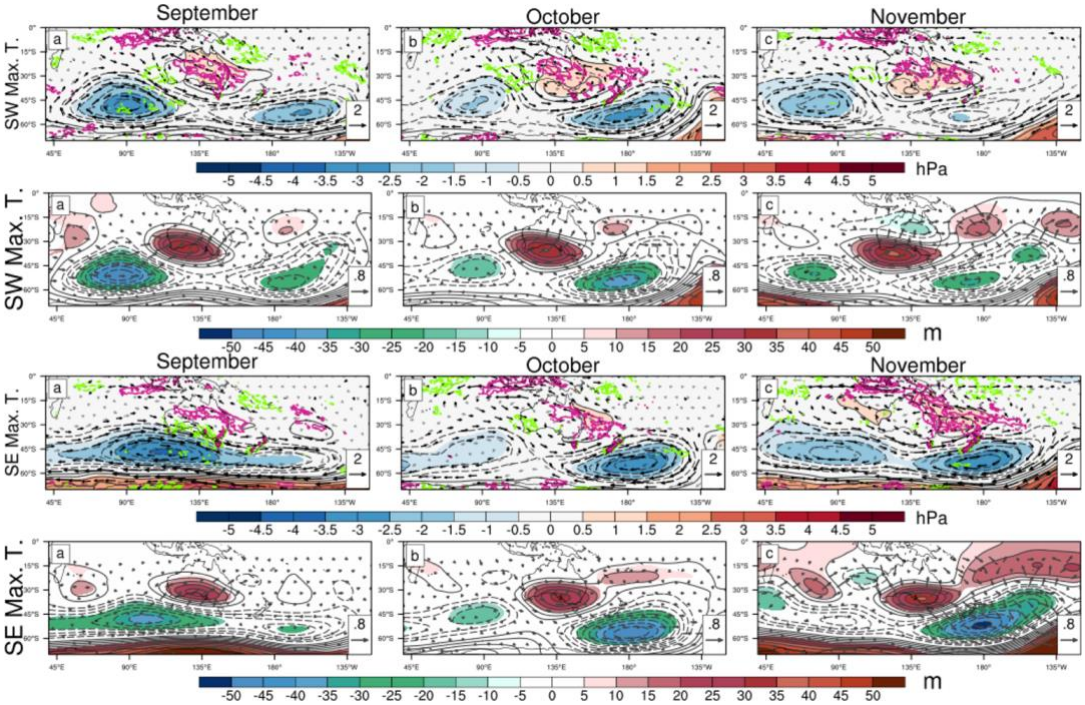

Figure S3. Low-level (rows 1 and 3) and upper-level (rows 2 and 4) circulation regressed onto weighted area-averaged maximum temperature averaged over southwest (SW: 25° S-36° S,110° E-125° E) and southeast (SE: 25° S-45° S,135° E-155° E) Australia. Low-level circulation is represented by anomalous mean sea level pressure (hPa) (black and filled contours), 850 hPa wind vectors (m s^{-1}) and 500 hPa omega (hPa s^{-1}) contours from -0.02 to 0.02 hPa s^{-1} in steps of 0.01 hPa s^{-1} (magenta contours are positive (downward motion) and cyan contours are negative (upward motion); zero contour not plotted). Upper-level circulation is represented by 200 hPa geopotential height (black and filled contours and wave activity flux vectors (m^2 s^{-2}).
Filled contours, bold wind vectors, cross-hatching, and all vertical motion contours are significant at the 95% confidence level using a Student's t-test with 39 independent samples.

Sep	SAA	SAA|ns	SAA|nt	SWC	SWC|ns	SWC|nt	SEC	SEC|ns	SEC|nt	TSH	TSH|ns	TSH|nt
W500	0.26	0.26	0.26	0.38	0.19	**0.45***	-0.04	-0.13	0.29	0.10	0.24	-0.02
V850	**0.44***	**0.44***	**0.44**	**0.69***	**0.74***	**0.69***	-0.21	-0.27	**0.69***	**0.47***	**0.58***	**0.50***
U850	0.19	0.19	0.20	**0.65***	0.30	**0.63***	**0.37***	0.20	**0.66***	**-0.37***	-0.14	**-0.34***
Oct												
W500	0.31	**0.36***	0.27	0.14	-0.05	0.25	**0.45***	**0.37***	0.05	0.24	**0.39***	0.02
V850	**0.52***	**0.53***	**0.52***	**0.59***	**0.62***	**0.59***	0.05	0.03	**0.59***	**0.59***	**0.65***	**0.63***
U850	0.02	0.09	0.04	**0.63***	**0.45***	**0.59***	**0.57***	**0.46***	**0.65***	**-0.34***	-0.18	-0.26
Nov												
W500	**0.32***	0.27	0.25	0.24	-0.07	**0.31***	**0.35***	0.17	0.02	0.14	0.09	0.09
V850	**0.52***	**0.50***	**0.55***	**0.55***	**0.52***	**0.52***	0.01	-0.11	**0.56***	**0.63***	**0.61***	**0.65***
U850	0.08	0.02	0.01	**0.39***	0.06	**0.45***	**0.50***	0.30	0.18	-0.03	-0.1	-0.08

Table S1: Spearman's ranked correlation coefficients of weighted area-averaged dynamical heat mechanisms (W500: sub-tropical 50 0hPa vertical motion; U850 and V850: 850 hPa horizontal and meridional wind) correlated with key circulation features (SAA: southern-Australian anticyclone; SWC: southwest cyclone; SEC: southeast cyclone; TSH: Tasman Sea High) identified in main text. Partial correlations where either negative SAM or negative TPI were first linearly regressed out of the circulation feature timeseries are marked as ns and nt respectively. Correlations that are statistically significant at the 95% confidence level using a Student's t-test with 39 degrees of freedom are in bold and marked with an asterix.

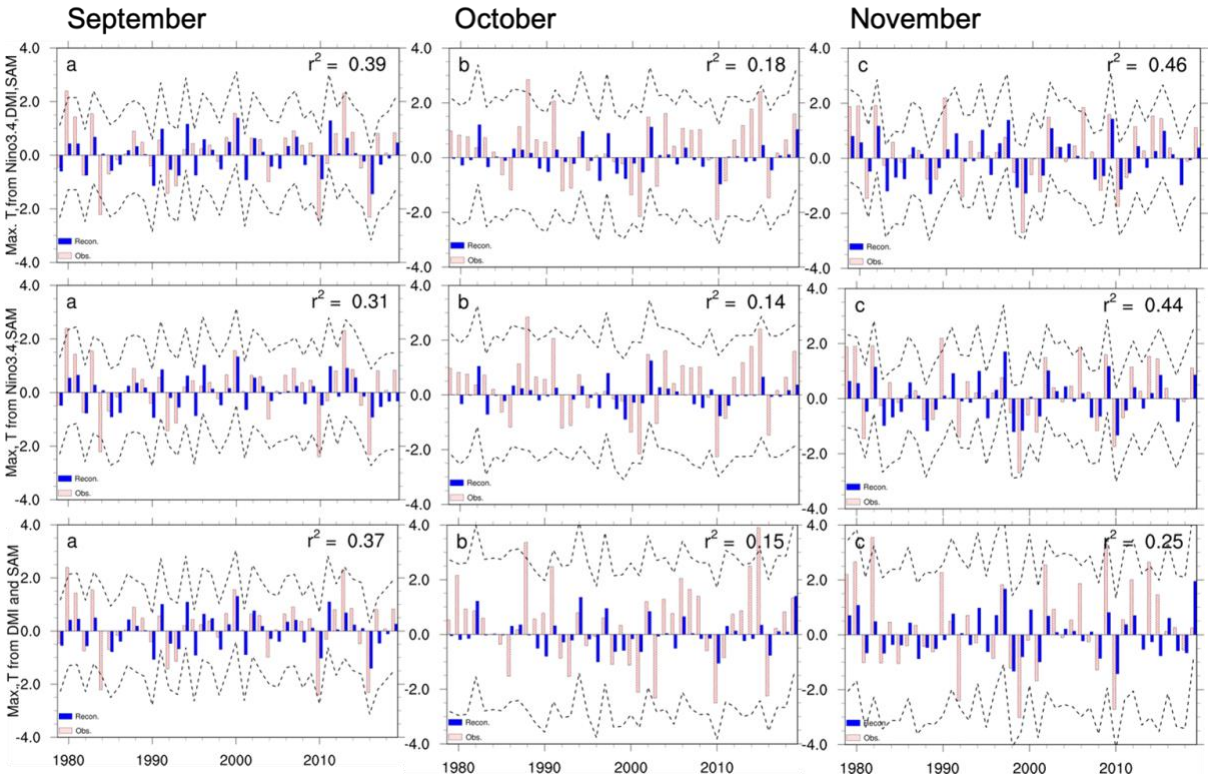

Figure S4. Australian weighted area-averaged maximum temperature statistically reconstructed using different combinations of Niño3.4, DMI and the SAM for September, October and November (blue bars) between 1979 to 2019. The red dashed bars show the observed temperature anomaly for each month. The dotted line shows the 95% confidence interval. The percent variance explained (r^2) for each month is in the top right of each figure.

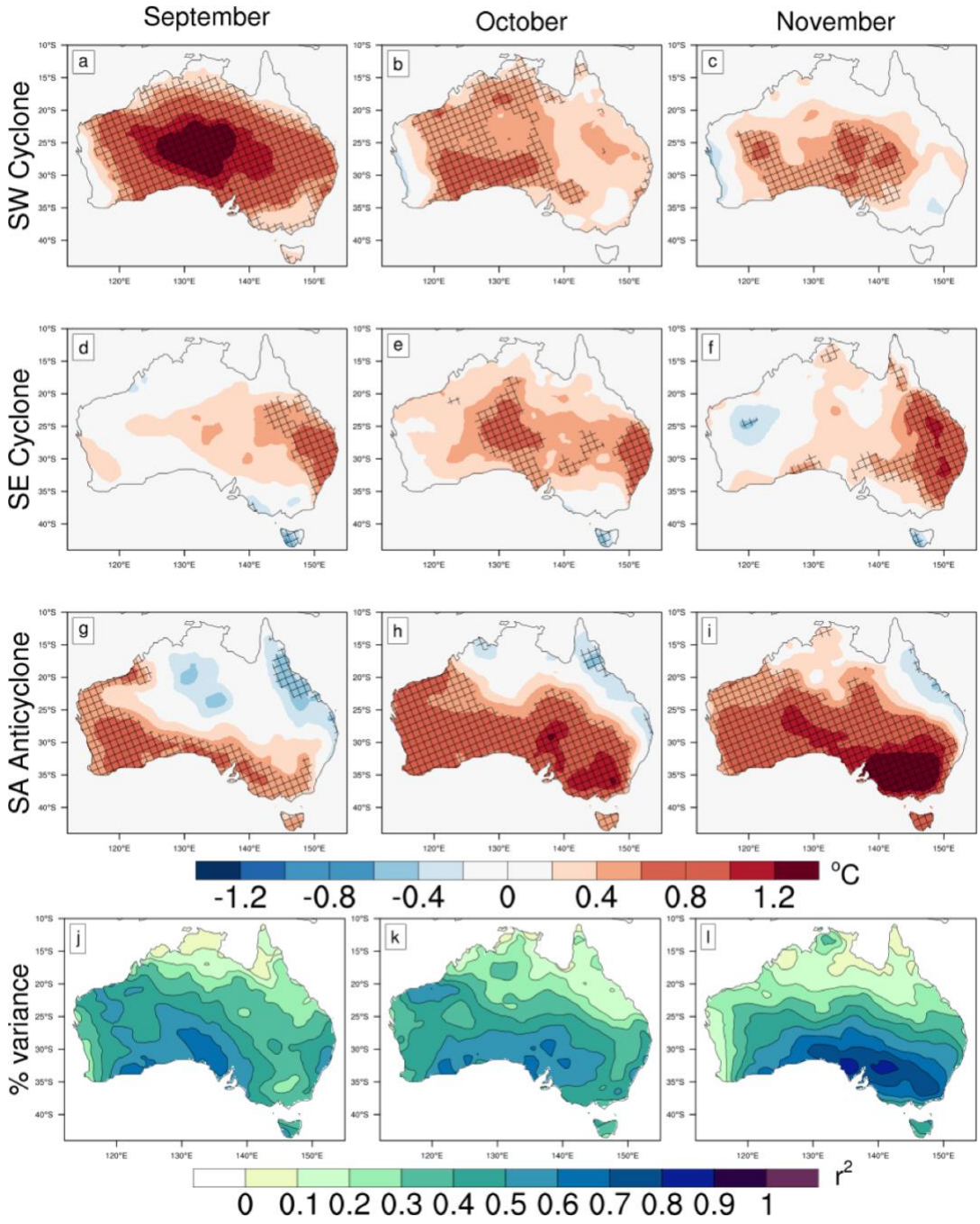

Figure S5. Multi-linear regression coefficients of standardised indices southwest-cyclone, southeast cyclone and southern Australian anticyclone onto Australian maximum temperatures calculated over 1979 to 2019 for September, October and November (a-i) and percent Australian maximum temperature variance explained (r^2) by SWC, SEC and SAA (j-l). Anomalies are relative to a 1981 to 2010 climatology. All variables were detrended, and the weighted area-averaged maximum temperature time series was standardised before regression. Hashing shows where the regression was statistically significant at the 95% confidence level using a two-sided Student's t-test with 39 independent samples.

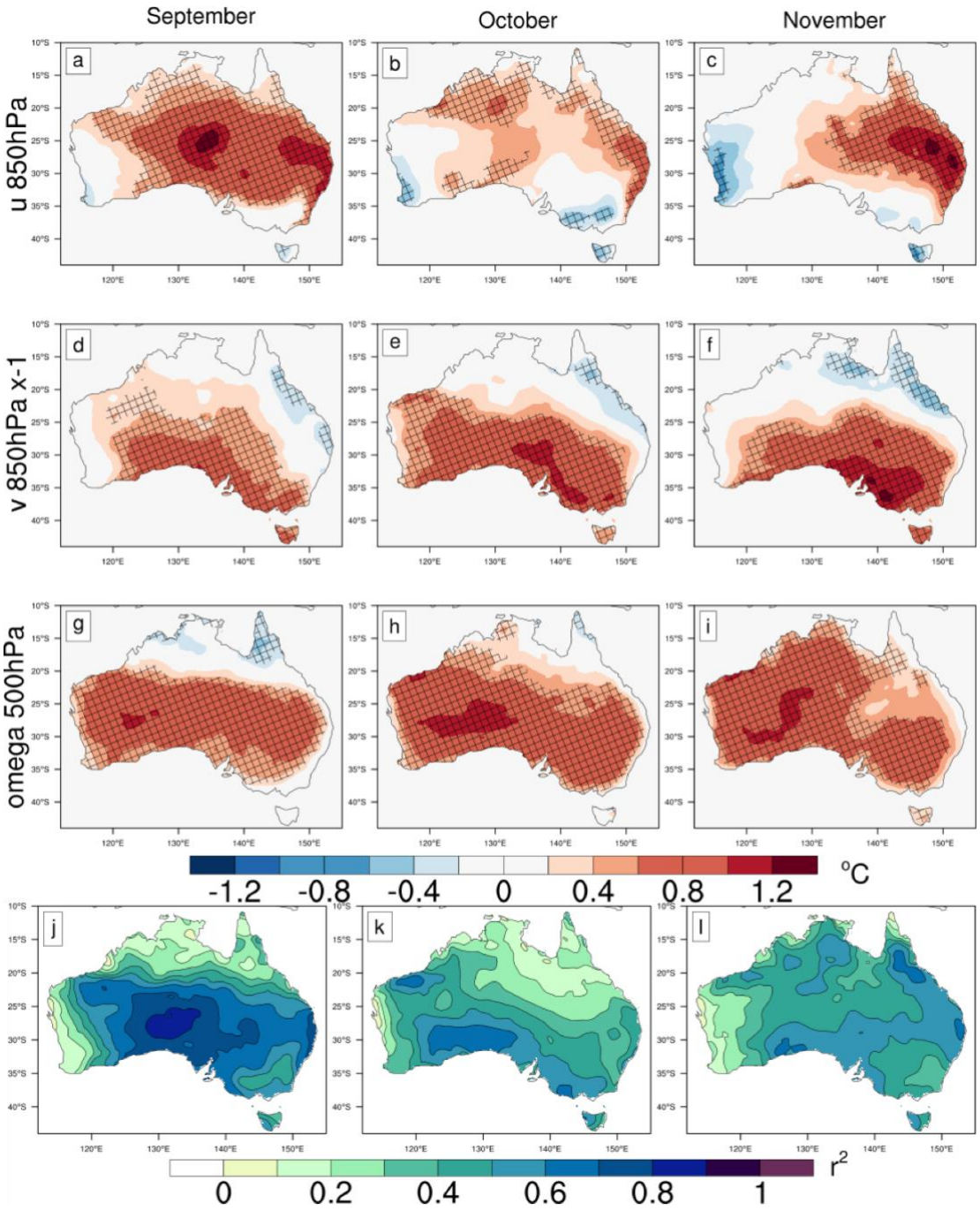

Figure S6. As with figure S5, but for the three dynamical heat mechanisms: southern Australian-averaged 850 hPa horizontal wind (u850 hPa), and meridional wind (v850 hPa, multiplied by negative 1) and subtropical Australian sinking motion (omega 500 hPa).

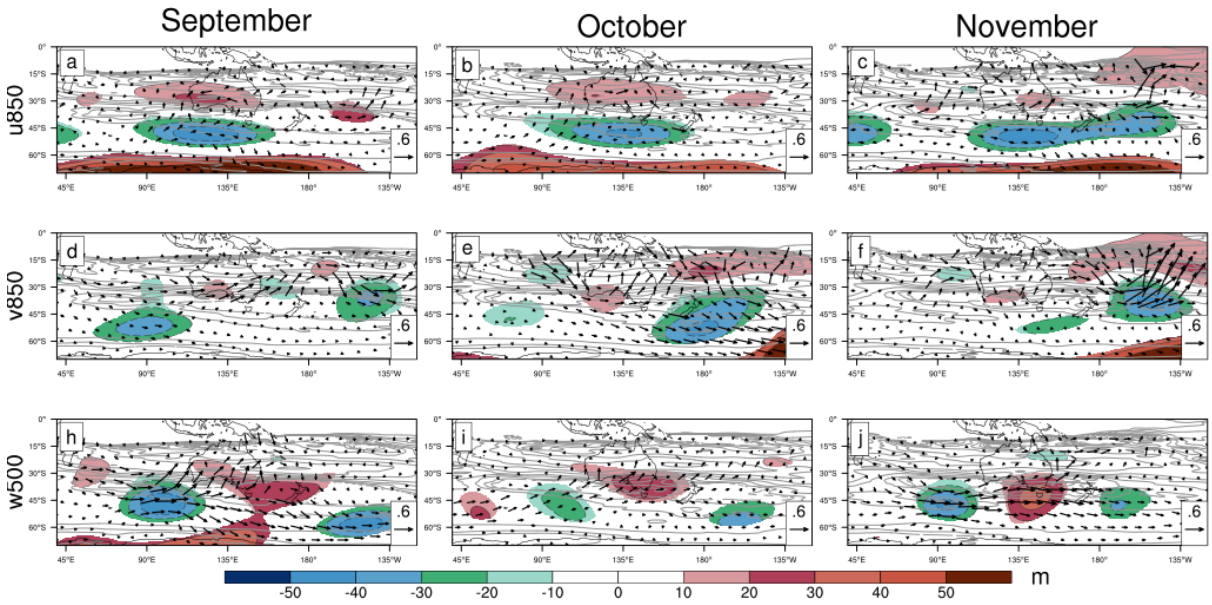

Figure S7. Linear regressions of standardised time series of the three dynamical heat mechanisms (low-level zonal and meridional wind, and sinking motion) onto upper-level circulation (200 hPa geopotential height (filled contours) and wave activity flux vectors ($m^2 s^{-2}$).) The grey contours show the monthly climatological total wave number. Only 200 hPa geopotential height regression coefficients that were statistically significant at the 95% confidence level (calculated using a Student's t-test with 39 samples) are shown.

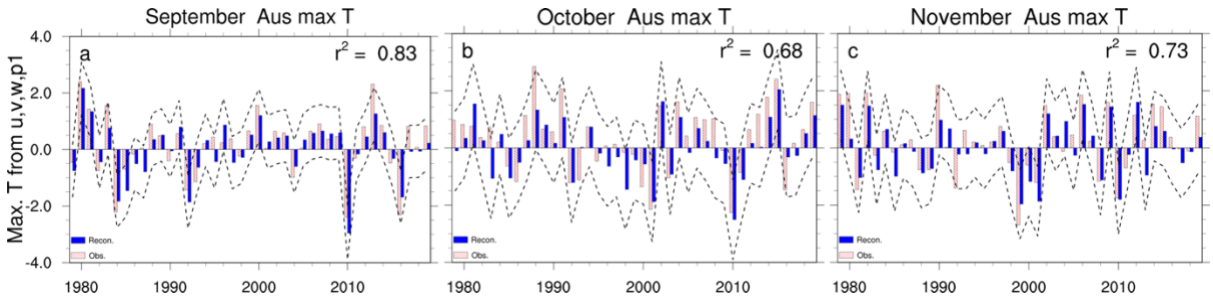

Figure S8. Australian weighted area-averaged maximum temperature statistically reconstructed using the three dynamical heat mechanisms (anomalous zonal wind, anomalous meridional wind (x-1), 500 hPa vertical motion) and the previous month's Australian weighted area-averaged precipitation anomaly for September, October and November (blue bars) between 1979 to 2019. The red dashed bars show the observed temperature anomaly for each month. The dotted line shows the 95% confidence interval. The percent variance explained (r^2) for each month is in the top right of each figure.