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*Supplement of*

## **Multi-century cool- and warm-season rainfall reconstructions for Australia's major climatic regions**

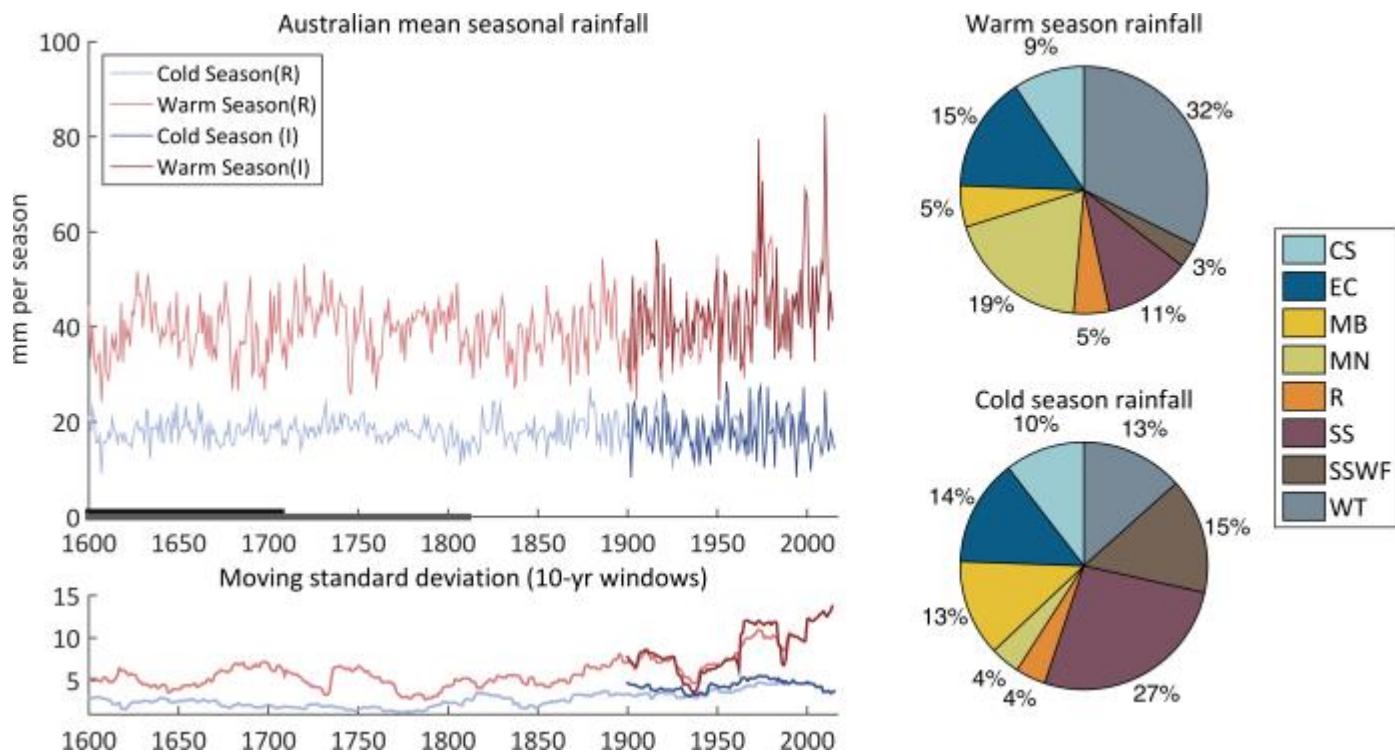
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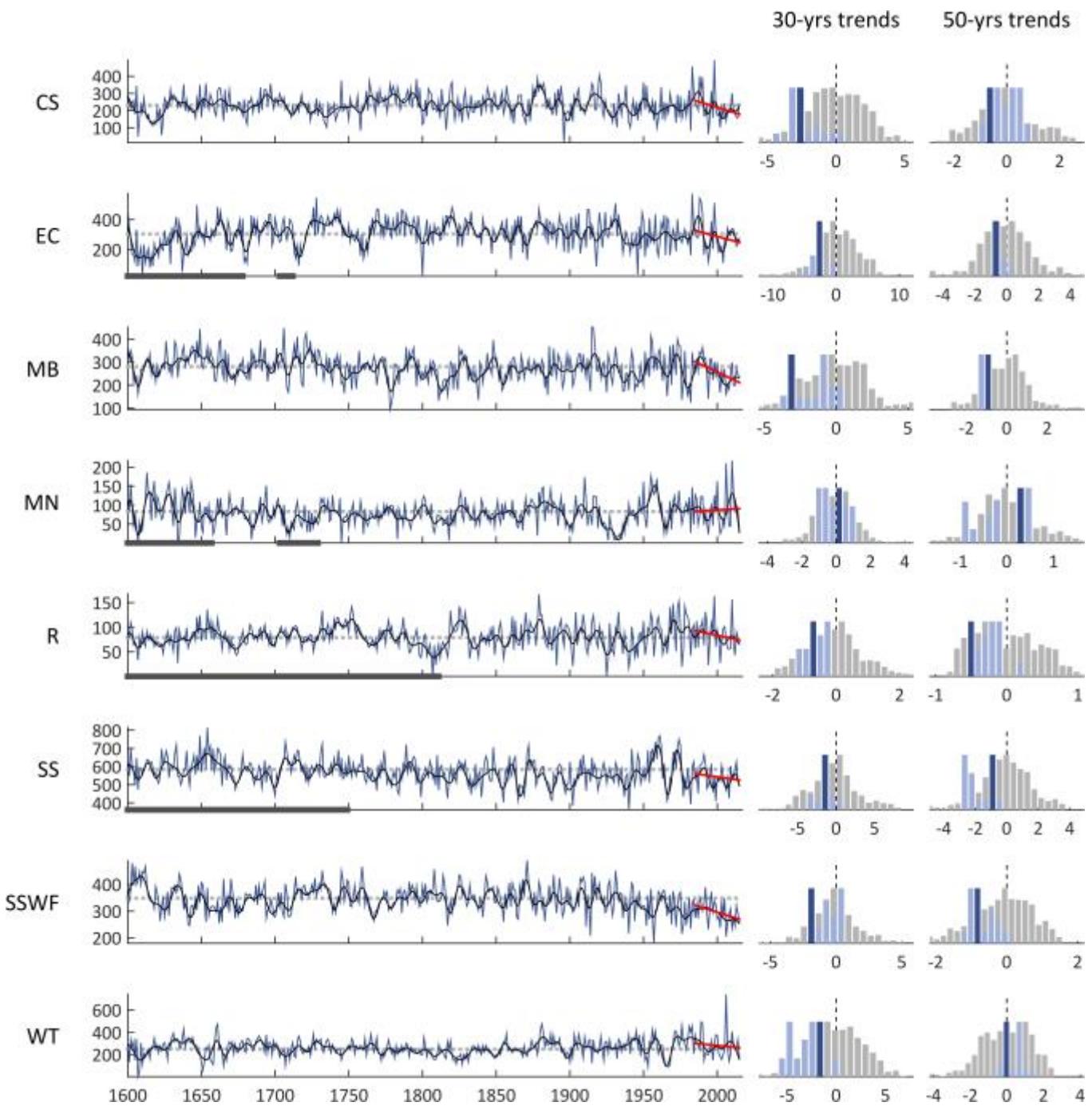
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**Table S 1** Information on proxy data used in this study. Details on individual records are given in Column 1-9. Source 1: ANZDA (Palmer et al. 2015) and pers. comm. K. Allen and J. Palmer, Source 2: Aus2k (Neukom & Gergis 2011) and NOAA World Data Center for Paleoclimatology (WDCP), Source 3: Ocean2k (Tierney et al. 2015) and WDCP, Source 4: pers. comm. I. Heinrich. Resolution (Res) indicates the number of measurements per year. First year (FY) and Last year (LY) refer to the initial/end year of the record. Column 12- 19 refers individual records and to regions and seasons (W-warm season, C-cool season) by binary code (1=used, 0=not used).

Region	Source	Site	Type	Lat	Lon	Res	FY	LY	Reference	URL	CS W	EC W	MD C	MN W	R C	SS W	SSWF C	WT C	
Australasia	1	Sepuljung Kuanan Island Trusk	TR	-6.52	115.32	1	1760	2000	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19634">https://www.ncdc.noaa.gov/paleo/study/19634</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Saradan Klangen Composite Trusk	TR	-7.3	111.45	1	1614	2005	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19637">https://www.ncdc.noaa.gov/paleo/study/19637</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Saradan Java Trusk	TR	-7.3	111.43	1	1689	2000	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19260">https://www.ncdc.noaa.gov/paleo/study/19260</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Papergum Composite Trusk	TR	-7.2	110.16	1	1776	2004	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19255">https://www.ncdc.noaa.gov/paleo/study/19255</a>	1	1	1	1	1	1	1	1	1
Australasia	1	New Borneo Composite Trusk	TR	-7.1	111.41	1	1604	2004	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19258">https://www.ncdc.noaa.gov/paleo/study/19258</a>	1	0	0	0	0	0	0	0	0
Australasia	1	Muna Sulawesi Trusk	TR	-5.3	123	1	1565	2005	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19267">https://www.ncdc.noaa.gov/paleo/study/19267</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Klangon Natural Forest Trusk	TR	-7.3	111.47	1	1614	2005	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19266">https://www.ncdc.noaa.gov/paleo/study/19266</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Dusoloway Cager Abun Java Trusk	TR	-7.52	111.12	1	1617	2005	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19265">https://www.ncdc.noaa.gov/paleo/study/19265</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Bentong Peak Trusk	TR	-7.0	111.26	1	1604	2004	Cook et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19268">https://www.ncdc.noaa.gov/paleo/study/19268</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Wiseby Creek Noso	TR	-4.5	171.25	1	1760	2006	Noso (1998)	<a href="https://www.ncdc.noaa.gov/paleo/study/19270">https://www.ncdc.noaa.gov/paleo/study/19270</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Wilberforce Lili Xiong	TR	-4.4	171.17	1	1674	1992	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19278">https://www.ncdc.noaa.gov/paleo/study/19278</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Warrawara Plateau Forest Argus	TR	-35.22	173.17	1	1462	2002	Palmer et al. (1988)	<a href="https://www.ncdc.noaa.gov/paleo/study/19283">https://www.ncdc.noaa.gov/paleo/study/19283</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Waduhua Shuan Pagl Palmar	TR	-38.39	175.38	1	1528	1984	Palmer et al. (1988)	<a href="https://www.ncdc.noaa.gov/paleo/study/19285">https://www.ncdc.noaa.gov/paleo/study/19285</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Waduhua Tengzai Pagl Palmar	TR	-38.42	175.36	1	1651	1986	Palmer et al. (1988)	<a href="https://www.ncdc.noaa.gov/paleo/study/19291">https://www.ncdc.noaa.gov/paleo/study/19291</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Urenwari Lili Xiong	TR	-38.41	177.12	1	1140	1999	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19277">https://www.ncdc.noaa.gov/paleo/study/19277</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Troonan Karui Park	TR	-35.45	173.39	1	1408	2004	Fowler et al. (2007)	<a href="https://www.ncdc.noaa.gov/paleo/study/19290">https://www.ncdc.noaa.gov/paleo/study/19290</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Tremont Forest Pine Fewu	TR	-35.29	173.51	1	1504	2002	Almend and Ogden (1985)	<a href="https://www.ncdc.noaa.gov/paleo/study/19298">https://www.ncdc.noaa.gov/paleo/study/19298</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Takapuri Rooli Lili Xiong	TR	-40.4	175.59	1	1296	1992	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19275">https://www.ncdc.noaa.gov/paleo/study/19275</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Stratford East Egmont	TR	-39.19	174.7	1	1626	1999	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19274">https://www.ncdc.noaa.gov/paleo/study/19274</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Sloping Point Pink Pine	TR	-46.22	170.7	1	1585	1991	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19288">https://www.ncdc.noaa.gov/paleo/study/19288</a>	1	1	0	1	1	1	1	0	1
Australasia	1	Ruthong Corulu Lili Xiong	TR	-39.17	170.18	1	1473	1991	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19270">https://www.ncdc.noaa.gov/paleo/study/19270</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Ratu Creek Noso	TR	-43.19	171.48	1	1787	2006	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19265">https://www.ncdc.noaa.gov/paleo/study/19265</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Rahn Saddle Lili Xiong	TR	-42.19	172.7	1	1560	1991	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19263">https://www.ncdc.noaa.gov/paleo/study/19263</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Pegesong Pine Forest	TR	-46.35	167.44	1	1667	1991	D'Argiro et al. (1996)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903992">https://www.ncdc.noaa.gov/paleo/study/1903992</a>	0	1	1	1	0	1	1	1	1
Australasia	1	Mount Gouland Pink Pine	TR	-41.37	172.2	1	1461	1999	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount Gouland Pine Fewu	TR	-42.4	171.2	1	1367	1999	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount French Pink Pine Fewu	TR	-42.4	171.2	1	1339	1999	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19266">https://www.ncdc.noaa.gov/paleo/study/19266</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount French Cedar Fewu	TR	-42.4	171.2	1	1339	1999	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount French Pine Fewu	TR	-42.4	171.2	1	1339	1999	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount Egoia Lili Xiong	TR	-39.15	174.5	1	1616	1992	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19273">https://www.ncdc.noaa.gov/paleo/study/19273</a>	1	1	0	1	0	1	0	1	0
Australasia	1	Mount Mount Lili Xiong	TR	-45.5	170.32	1	1492	2010	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19262">https://www.ncdc.noaa.gov/paleo/study/19262</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount Bonar Pink Pine Fewu	TR	-43.5	170.39	1	1463	1994	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Moan Park Lili Xiong	TR	-39.56	172.56	1	1490	1991	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19268">https://www.ncdc.noaa.gov/paleo/study/19268</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Moan Park Pine Fewu	TR	-39.53	172.56	1	1490	1994	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19269">https://www.ncdc.noaa.gov/paleo/study/19269</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount Gouland Pink Pine	TR	-36.54	173.33	1	1369	1998	Almend and Ogden (1985)	<a href="https://www.ncdc.noaa.gov/paleo/study/19267">https://www.ncdc.noaa.gov/paleo/study/19267</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Mount Little Barrier Island Agus	TR	-36.12	175.8	1	1790	1985	Almend and Ogden (1985)	<a href="https://www.ncdc.noaa.gov/paleo/study/19268">https://www.ncdc.noaa.gov/paleo/study/19268</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Lake Peason Agus	TR	-43.7	171.45	1	1748	2006	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19271">https://www.ncdc.noaa.gov/paleo/study/19271</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Kitakata Agus	TR	-37.36	175.52	1	1688	1996	Fowler et al. (2004)	<a href="https://www.ncdc.noaa.gov/paleo/study/19265">https://www.ncdc.noaa.gov/paleo/study/19265</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Hellfire Ridgeby Mt 360	TR	-46.59	167.45	1	1694	2013	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19255">https://www.ncdc.noaa.gov/paleo/study/19255</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Huia (Waitakere) Agus	TR	-36.58	174.34	1	1720	1981	Almend and Ogden (1985)	<a href="https://www.ncdc.noaa.gov/paleo/study/19249">https://www.ncdc.noaa.gov/paleo/study/19249</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Huipuhi Agus	TR	-36.39	171.23	1	1384	1999	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/1903988">https://www.ncdc.noaa.gov/paleo/study/1903988</a>	0	1	1	1	1	1	1	1	1
Australasia	1	Clewart Lake Xiong	TR	-39.38	176.6	1	1450	1991	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19262">https://www.ncdc.noaa.gov/paleo/study/19262</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Camp Agas Agas	TR	-36.53	174.23	1	1682	1982	Fowler et al. (2007)	<a href="https://www.ncdc.noaa.gov/paleo/study/19267">https://www.ncdc.noaa.gov/paleo/study/19267</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Camp Creek Cedar Fewu	TR	-42.4	170.26	1	1490	1994	Duncun et al. (2010)	<a href="https://www.ncdc.noaa.gov/paleo/study/19269">https://www.ncdc.noaa.gov/paleo/study/19269</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Camp Creek Cedar Fewu	TR	-42.4	171.34	1	1400	1998	Fowler et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19268">https://www.ncdc.noaa.gov/paleo/study/19268</a>	1	1	1	1	1	1	1	1	1
Australasia	1	Ghost Creek Noso	TR	-43.15	171.47	1	1795	2006	Palmer et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19265">https://www.ncdc.noaa.gov/paleo/study/19265</a>	1	0	0	0	0	0	0	0	0
Australasia	1	Flanagan Hut Libi Xiong	TR	-41.16	172.36	1	1683	1999	Fowler et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19263">https://www.ncdc.noaa.gov/paleo/study/19263</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flapjack Peak Trusk	TR	-42.17	171.23	1	1481	2000	Fowler et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19274">https://www.ncdc.noaa.gov/paleo/study/19274</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hall	TR	-41.36	174.5	1	1576	2004	Xiong and Palmer (2000)	<a href="https://www.ncdc.noaa.gov/paleo/study/19223">https://www.ncdc.noaa.gov/paleo/study/19223</a>	1	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-42.2	166.33	1	1730	2009	Alman et al. (2017)	<a href="https://www.ncdc.noaa.gov/paleo/study/19273">https://www.ncdc.noaa.gov/paleo/study/19273</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-42.2	166.33	1	1730	2009	Alman et al. (2017)	<a href="https://www.ncdc.noaa.gov/paleo/study/19273">https://www.ncdc.noaa.gov/paleo/study/19273</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-42.2	166.45	1	1730	2009	Alman et al. (2017)	<a href="https://www.ncdc.noaa.gov/paleo/study/19273">https://www.ncdc.noaa.gov/paleo/study/19273</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-41.45	165.15	1	1581	2011	D'Argiro et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19269">https://www.ncdc.noaa.gov/paleo/study/19269</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-41.45	165.15	1	1581	2011	D'Argiro et al. (2015)	<a href="https://www.ncdc.noaa.gov/paleo/study/19269">https://www.ncdc.noaa.gov/paleo/study/19269</a>	0	0	0	0	0	0	0	0	0
Australasia	1	Flower Hill	TR	-41.45	165.15	1													



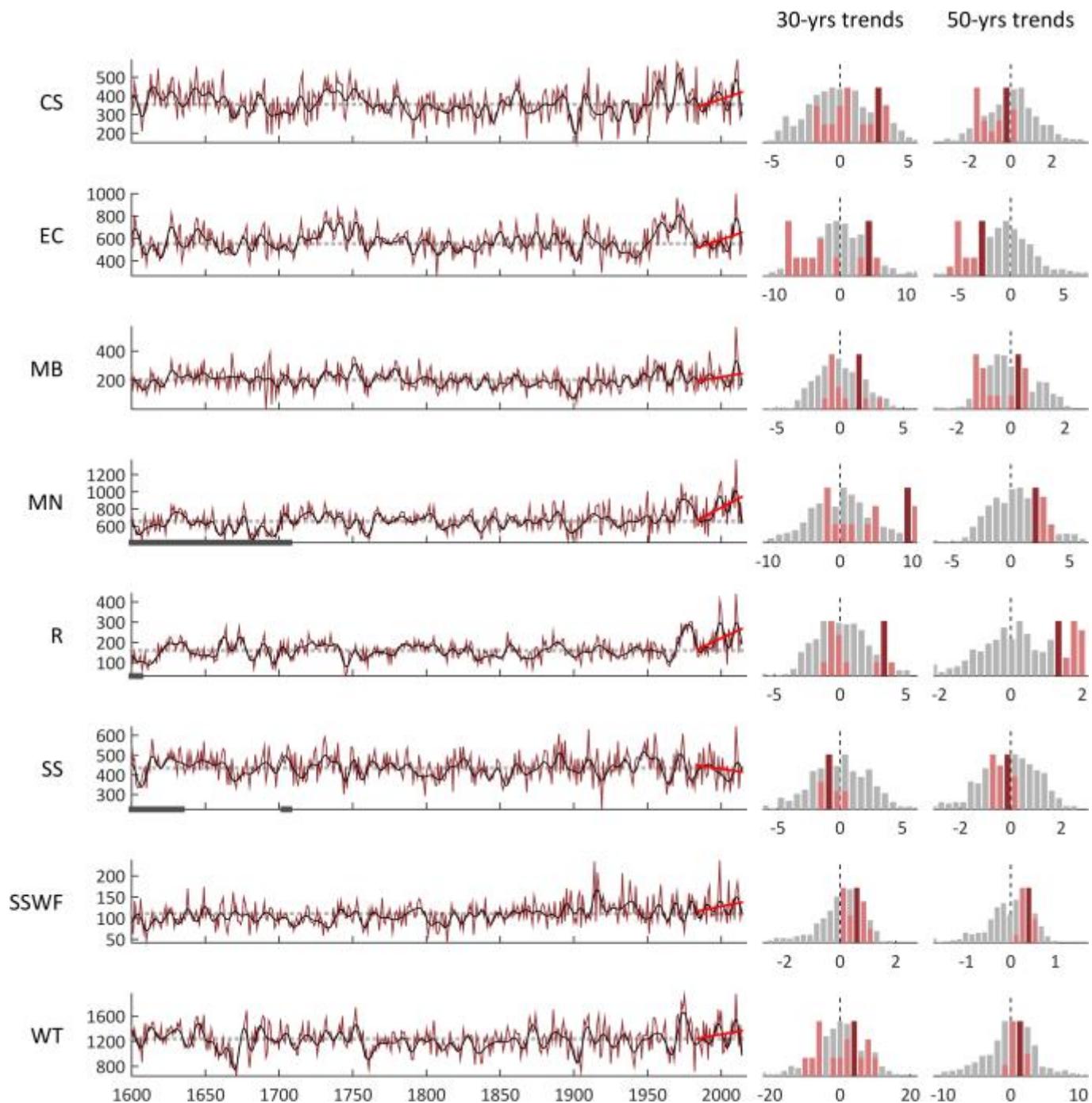
**Figure S1 Top:** Time series of seasonal rainfall area averaged for all NRM regions in Australia. Bars on the bottom indicate time periods which one or more regions are not positive verified (Dark grey=warm season, light grey= cool season). Bottom: 10-year moving standard deviation for instrumental and reconstructed rainfall all Australian rainfall. Right: Pie charts attribute the amount of seasonal rainfall to individual NRM regions (Upper: warm season, Lower: cool season). Note that periods not verified were still used to build in this average



**Figure S 2. Cool season time series plot and trend estimation for each NRM cluster region.**

Left panels show regional rainfall reconstructions since 1600 for cool seasons (blue colour) with 10-yr (black line) low pass Chebyshev filter. Grey bars along the x-axis denote non-verified periods for each reconstruction. Right: Histogram of 30-yr and 50-yr regional trends on mm/yr. Light colouring highlights recent trends beginning since 1970/1950 for

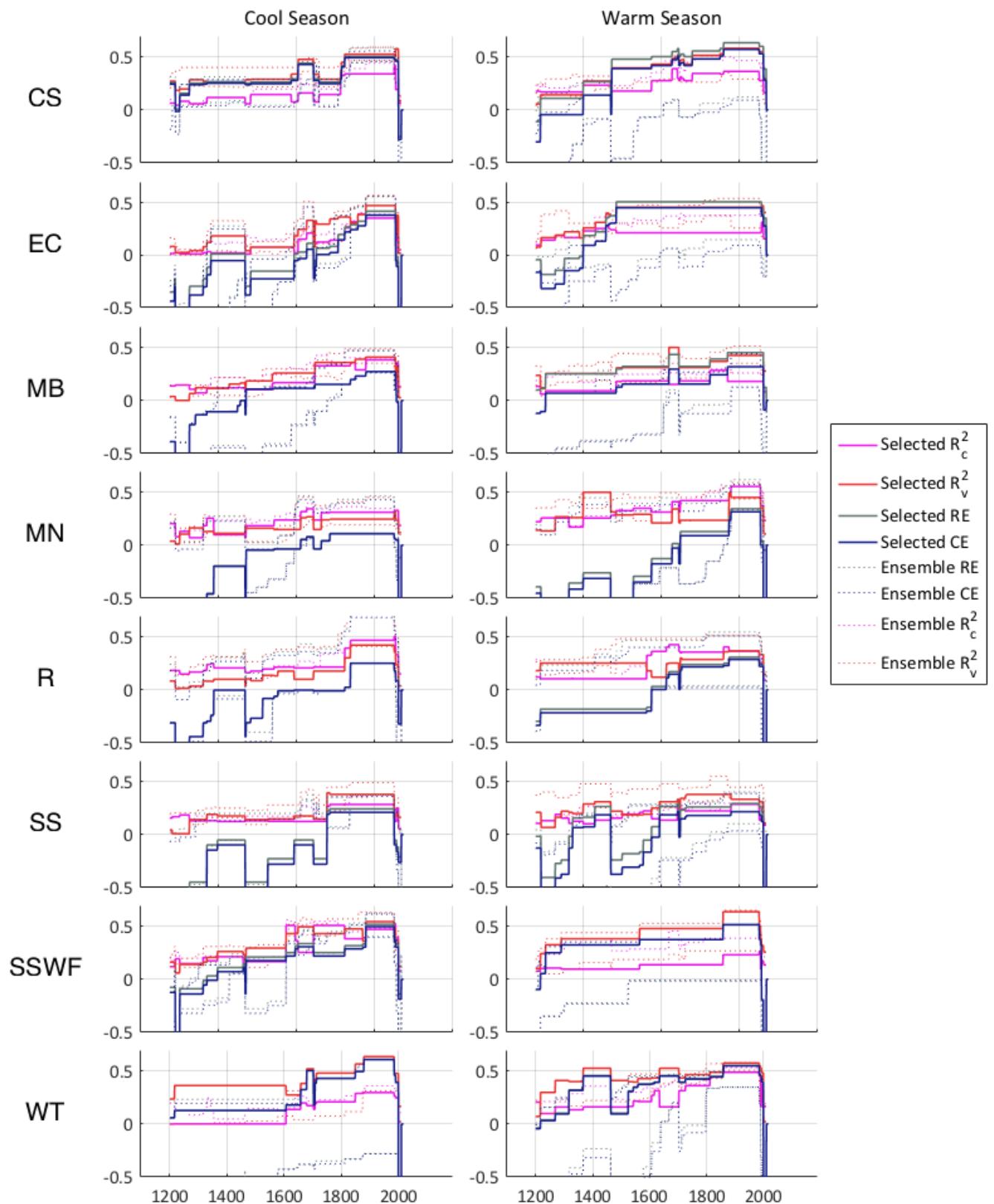
30/50-yr periods whereas the dark coloured bar indicates the most recent trend. Bar heights are normalised by the maximum occurrence for each region.



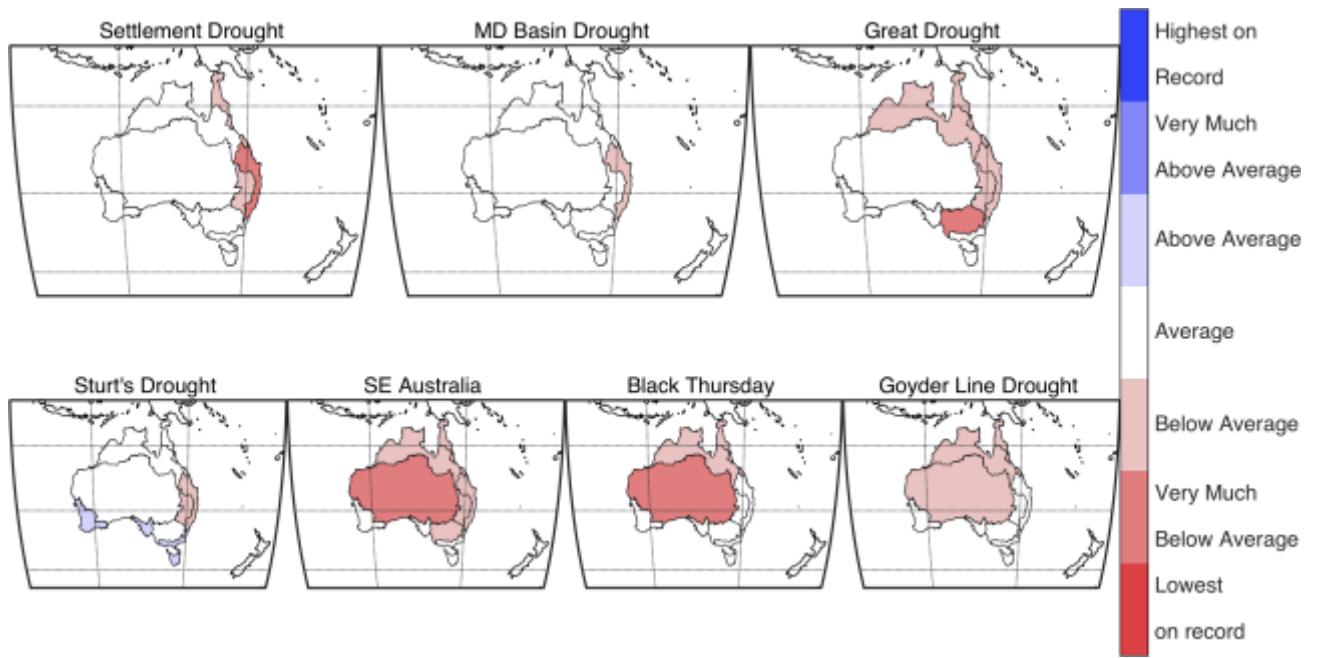
**Figure S3. Warm season time series plot and trend estimation for each NRM cluster**

**region.** Left panels show regional rainfall reconstructions since 1600 for cool seasons (red colour) with 10-yr (black line) low pass Chebyshev filter. Grey bars along the x-axis denote

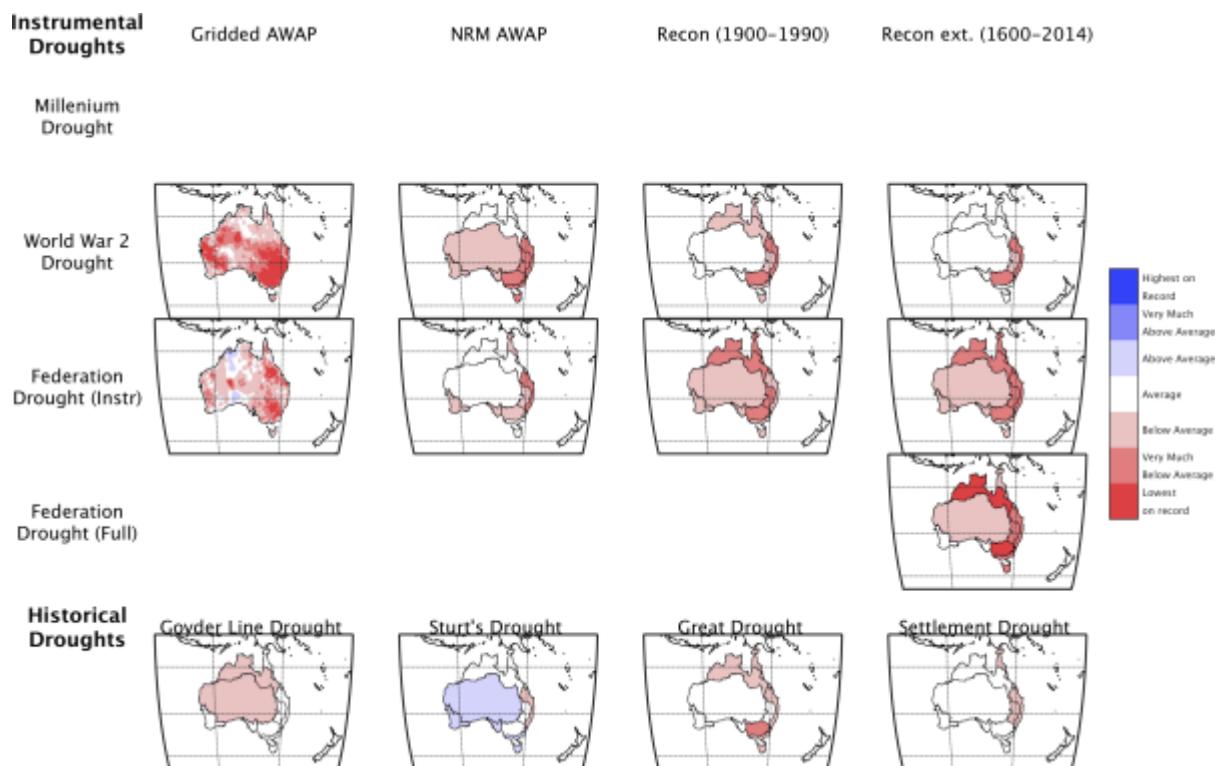
non-verified periods for each reconstruction. Right: Histogram of 30-yr and 50-yr regional trends in mm/yr. Light colouring highlights recent trends beginning since 1970/1950 for 30/50-yr periods whereas the dark coloured bar indicates the most recent trend. Bar heights are normalised by the maximum occurrence for each region.



**Figure S4. Regional calibration and verification statistics for the cool and warm season.**



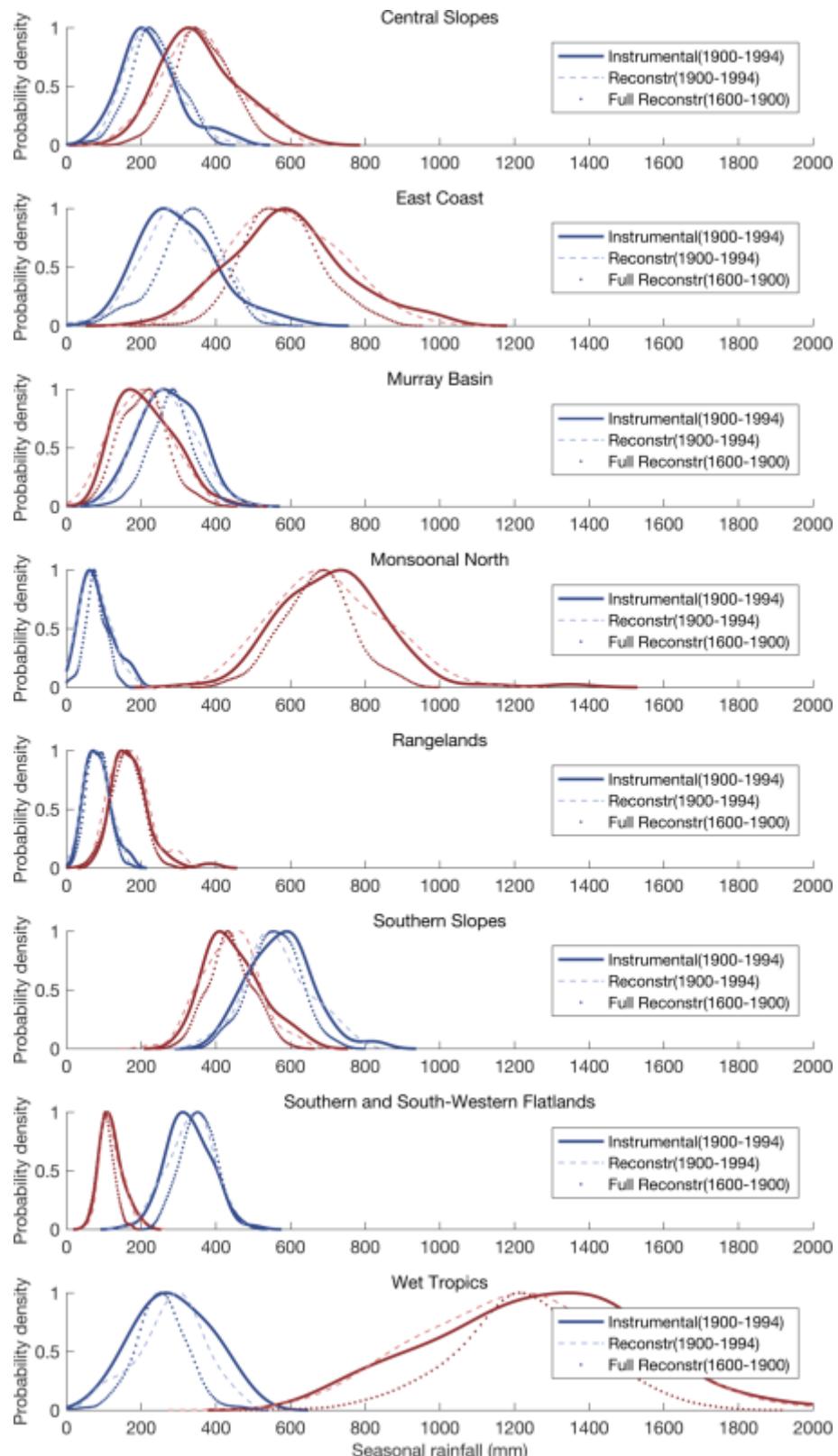
**Figure S5.** Additional annual deciles for historical droughts.



**Figure S 6.** Annual deciles for major droughts prior to the Millennium drought. Plots

for a) Significant drought periods during the instrumental period. Rankings of drought intensity are shown for three major instrumental period droughts, Column 1: AWAP gridded rainfall (1900-1990), column 2: NRM clusters (1900-1990), column 3: Regional

reconstructions during instrumental period (1900-1990), column 4: Regional reconstructions during a four-century period (1600-1990). b) Rankings of major drought periods during the reconstruction period (1600-1990).



**Figure S7.** Normalised probability density distribution of the instrumental records (1900-1994), the reconstructed records during the instrumental period (1900-1994) and through the entire reconstructed period (1600-1900). Cool season records are shown in blue, warm season

records are shown in red. Note all cool season records follow approximate a normal distribution according to a Chi-square test (5% significance level) while warm season records of Central Slopes, Rangelands and Southern Slopes are not normally distributed.

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