Changes of Winter Extreme Rainfall over SWWA

Since late 1960s, rainfall over southwest Western Australia (SWWA) has experienced a substantial drying trend with a winter rainfall decrease of some 25%, putting further constraints on water resources in an already dry area. The decline is manifest as a reduction of high-intensity extreme rainfall events. There has been vigorous debate as to what is forcing the drying trend, i.e., whether it is driven by secular forcings such as increasing atmospheric CO2 concentration or whether it is part of multidecadal variability. Previous results from greenhouse warming experiments suggest that the SWWA rainfall shows a drying trend with an increasing mid-latitude mean sea level pressure (MSLP) under increasing atmospheric CO2, which is expressed as an upward trend of a dominant atmospheric circulation mode of the Antarctic Oscillation (AAO). We present our recent results on statistical modeling of winter extreme rainfall over SWWA and its associated changes with the AAO. The possibility of the rainfall reduction being a part of multidecadal variability was discussed by using outputs of the CSIRO Mark 3 climate model in an experiment without CO2 forcing.

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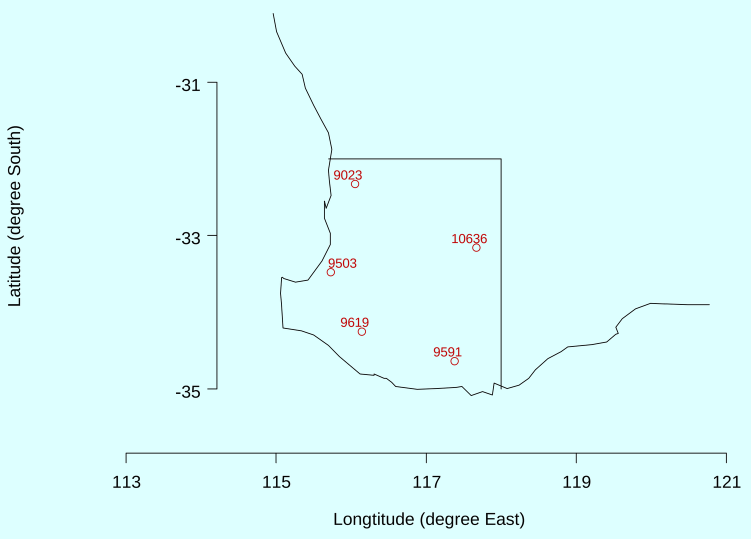
Changes of Winter Extreme Rainfall

Change points in the extreme rainfall distribution

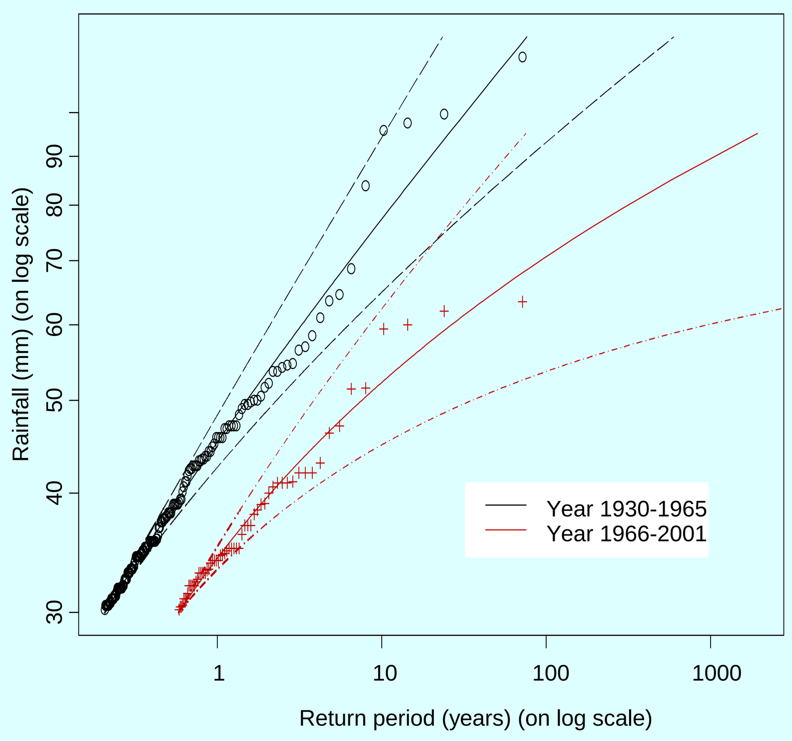
We analyse daily rainfall over five geographically dispersed and homogenized weather stations within SWWA. The Mann-Whitney-Pettitt (change point) test was applied to detect changes in annual, winter (May-October) and summer (November-April) maximum daily rainfall. Change points for winter extreme daily rainfall were found around 1965 based on different individual stations, with winter extreme daily rainfall reduced since then.



Results of the Mann-Whitney-Pettitt Test (change point year, decrease (D), increase (I), significance probability of the change-point for the Annual, Winter (May-October) and Summer (November-April) daily maximum rainfall from 1889-2001 at the five studied stations. Here "D" means the variable decreases post the change-point year and "I" means the variable increases post the change-point year.

Time	Station 9619 Manjimup	Station 9023 Jarrahdale	Station 9503 Boyanup PO	Station 9591 Pardelup	Station 10636 The Oaks
Annual	1965-D-0.01	1968-D-0.35	1967-D-0.48	1966-D-0.09	1965-D-0.39
Winter	1965-D-0.01	1965-D-0.14	1966-D-0.05	1965-D-0.05	1965-D-0.02
Summer	1976-D-0.36	1966-I-0.02	No change	1965-D-0.62	1965-I-0.05

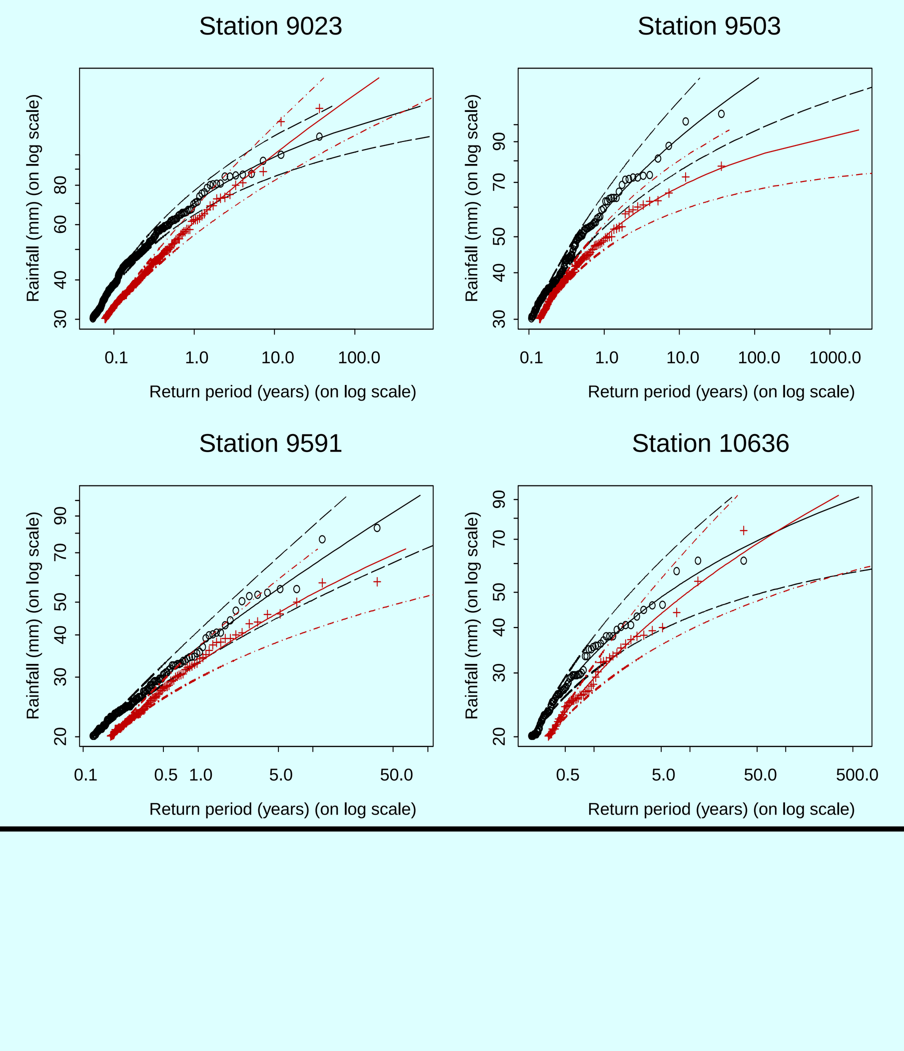
Quantifying the changes in winter extreme rainfall



Return periods of winter extreme daily rainfall at Manjimup station. Black "o" points represent the empirical return period of winter extreme rainfalls observed in 1930-1965 and red "+" points in 1966-2001. The black and red solid curves represent return period based tail estimates based on fitted generalized Pareto distributions with 95% confidence interval given as black dash lines (1930-1965) and red dot-dashed line (1966-2001). It is evident that the return period of the winter extreme daily rainfall in the post-change period (1966-2001) has greatly increased for the same extreme rainfall levels, which indicates that winter extreme daily rainfall has decreased since 1965.

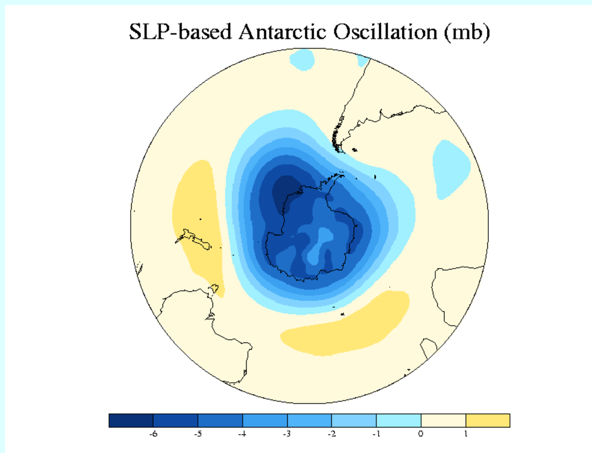
Extreme daily rainfall (mm) Manjimup Station	Return period (years) and its 95% C.I.(1930-1965)	Return period (years) and its 95% C.I. (1966-2001)
30	0.130 (0.129, 0.131)	0.390 (0.389, 0.391)
35	0.23 (0.21, 0.25)	0.83 (0.71, 1.09)
40	0.39 (0.34, 0.50)	1.77 (1.23, 3.67)
45	0.65(0.51, 0.95)	3.78 (2.05, 16.2)
50	1.05 (0.74, 1.79)	8.03 (3.28, 108)
55	1.64 (1.05, 3.33)	17.5 (5.17, 1700)
60	2.50 (1.45, 6.07)	38.5 (7.96, 218000)

Return period of winter extreme rainfall over SWWA between pre-change period 1930-1965 and post-change period 1966-2001 at four stations 9503, 9023, 9591 and 10636. Generally, the return period for winter extreme rainfall of the averaged rainfall series of five stations over SWWA has increased, which implies that extreme rainfall over SWWA has decreased since the change point year 1965.



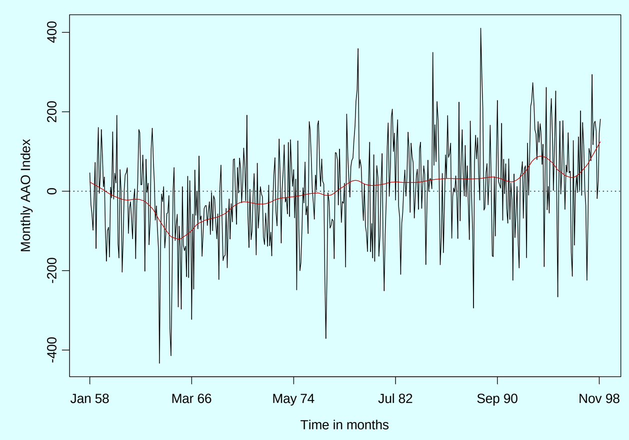
Causes of Winter Extreme Rainfall Decrease

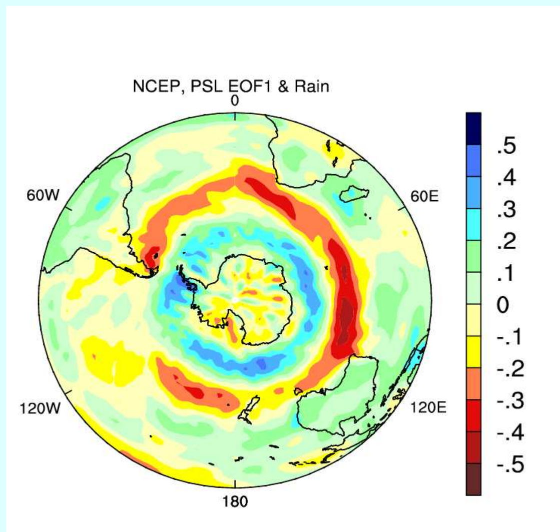
Possible connection to the AAO



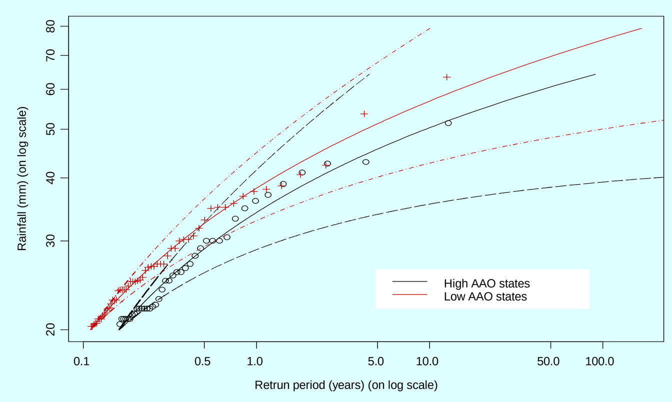
In the Southern Hemisphere (SH), the dominant mode of variability is the Antarctic Oscillation (AAO). The mode describes a large scale alternation of mid-latitude mean sea level pressure (MSLP) and high latitude surface pressure: when the MSLP is anomalously high, simultaneously in the mid-latitudes the MSLP is anomalously low. The AAO is also referred to as the Southern Annular Mode (SAM).

Li et al. (2005) demonstrated that the observed decrease in winter rainfall started to decrease at around 1965, a time which coincides with the onset of uptrend of the AAO with increasing MSLP in middle-latitudes. Thus the increasing middle-latitude MSLP is associated with a reduction in the frequency of high-intensity extreme rainfall episodes. The result offers qualified support for the argument that the AAO may contribute to the drying trend.





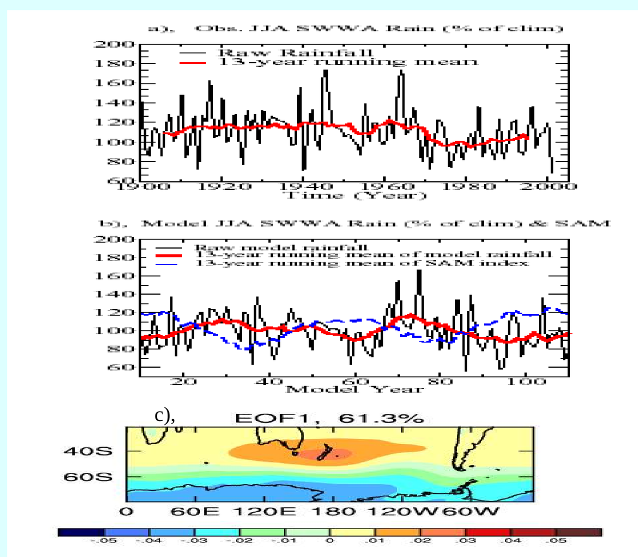
Correlation between the AAO and Rainfall

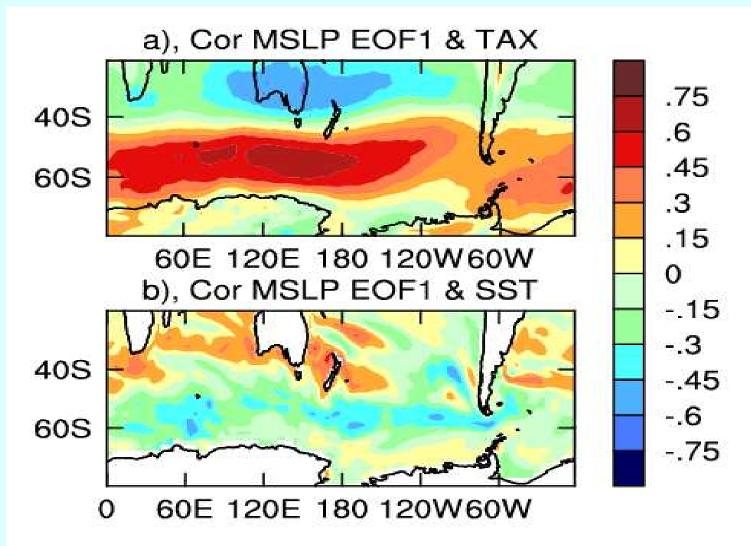


Return period of stratified winter extreme rainfall based on AAO in its high and low states

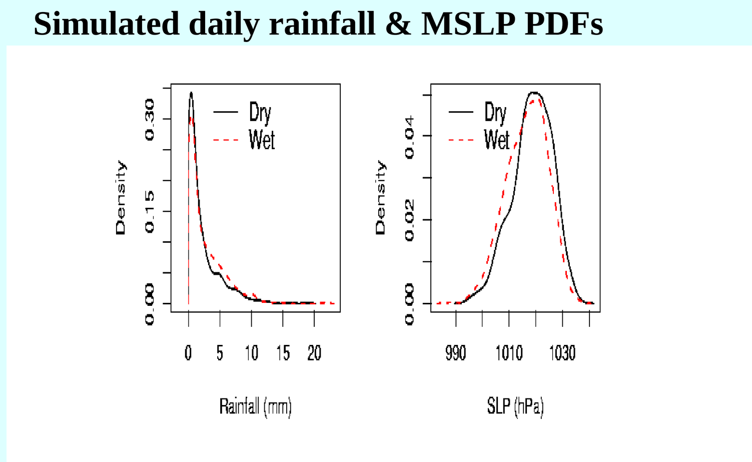
Multidecadal fluctuations of winter rainfall simulated in the CSIRO Mark 3 model

The multidecadal drying trends share several observed features: the decrease is manifest as a reduction in high-intensity rainfall events and is accompanied by an upward trend of the AAO with anomalously high mid-latitude MSLP. Our results suggest that multidecadal variability may have conspired with CO2 forcing to produce the observed winter rainfall reduction since the late 1960s (Cai et al. 2005).

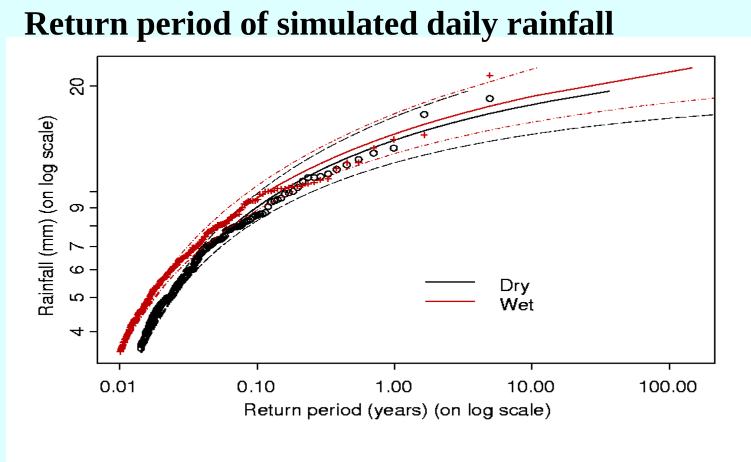




Simulated daily rainfall & MSLP PDFs



Return period of simulated daily rainfall



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Reference:
[1] Yun Li, Wenju Cai and Eddy Campbell (2005). Statistical modelling of extreme rainfall in southwest Western Australia, *Journal of Climate* **18**, No. 6, 852-863.
[2] Wenju Cai, Ge Shi and Yun Li (2005). Multidecadal fluctuations of winter rainfall over southwest Western Australia simulated in the CSIRO Mark 3 coupled model. *Geophysical Research Letters.* Vol. 32, L12701, doi:10.1029/2005GL022712.