Are the antecedent drought conditions magnifying the summer hot extremes in Australia?

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1. Motivation

The simultaneous or sequential occurrence of extreme climate events such as droughts and heatwaves can have negative economic, environmental and social impacts. The occurrence of hot days/nights was shown to be correlated to drought conditions in Mediterranean areas [1]. Recently the catastrophic fire seasons of 2019/2020 in Australia has been pointed out to be associated with severe drought and extremely hot conditions [2].

2. Data

- Monthly Precipitation and Temperature from CRU TS4.03, with a spatial resolution of 0.5°, covering the period 1901-2018.
- Hourly 2m Temperature from ERA5, with a spatial resolution of 0.25°, covering the period 1979-present.
- Hourly Temperature from ACORN-SAT v2, starting in 1910.

3. Methods

- SPEI was computed for the time scales of 1, 3, and 6 months, using data from CRU TS4.03. The Modified Hargreaves method was used to estimate reference evapotranspiration [3]. SPEI was resampled to match ERA5 spatial resolution.
- The indices Number of Hot Days (NHD) and Number of Hot Nights (NHN) [4] were computed using gridded data from ERA5 and homogenized station data from ACORN-SAT v2.
- A correlation was computed between monthly NHD/NHN in December, January and February and monthly SPEI in the concurrent and previous months (p-value=0.1). All time series (NHD, NHN, and SPEI) were previously detrended, after fitting the most appropriate polynomial, as chosen by AIC.
- Copula functions were used to estimate the joint probability of occurrence of hot and dry events [5]. Gaussian, student's t-copula, Clayton, Gumbel, Frank, and Joe copulas were tested. For each case, the copula function was selected using BIC. SPEI and NHD (from ERA5) were spatially averaged over Australia. The conditional probability of exceedence (CPE) of the 80th percentile of NHD was computed, under drought (SPEI<-0.84) and non-drought (SPEI>-0.84) conditions.
- The assessment was performed in the common period of 1979-2018.

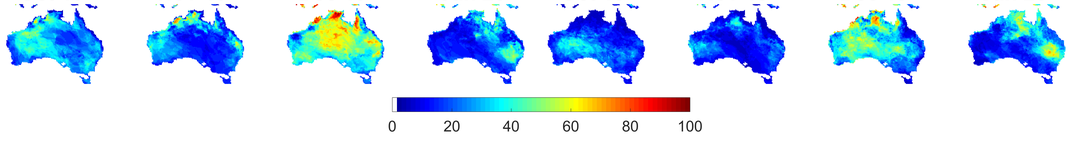

Fig. 1—NHD (left) and NHN (right) from October 2019 to January 2020 (%).

4. Results

From October 2019 to January 2020, several regions in Australia presented extremely high temperatures, as shown by the high NHD and NHN (Fig. 1). A significant negative correlation was obtained in most of the cases analyzed (Figs. 2-5), pointing to a relation between drought conditions (negative SPEI) at different time scales and temperature extremes (high NHD/NHN). These results are more frequent in the concurrent month, on all time scales analyzed, showing that the cummulative drought conditions of up to 6 months are correlated with NHD. It is also possible to see large areas of negative correlations in the months preceding the temperature extremes. The time scale of SPEI does not seem to affect the results, as evidenced by the similar spatial patterns obtained. Small areas of positive correlations are present. The patterns obtained with data from ERA5 and ACORN-SAT v2 are consistent.

The conditional probabilities of exceedence of the 80th percentile of NHD in January are almost always higher under drought conditions. The months showing the highest propabilities are January (concurrent) and December.

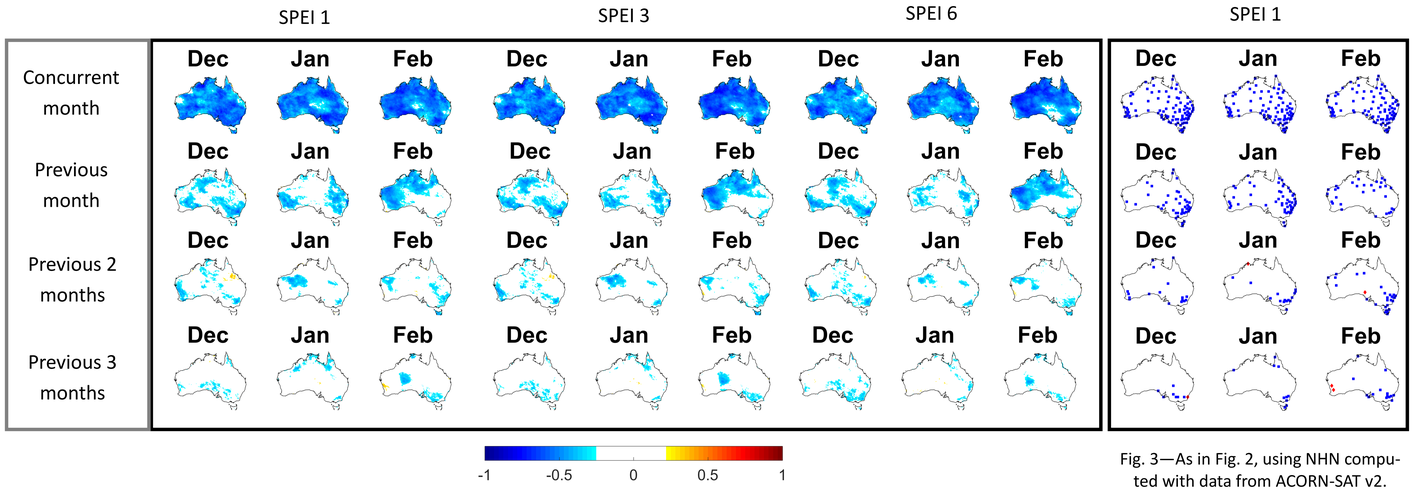

Fig. 2—Correlation between NHD in the specified month and SPEI in the concurrent and previous months, in the period 1979-2018. NHD was computed with data from ERA5.

Fig. 3—As in Fig. 2, using NHN computed with data from ACORN-SAT v2.

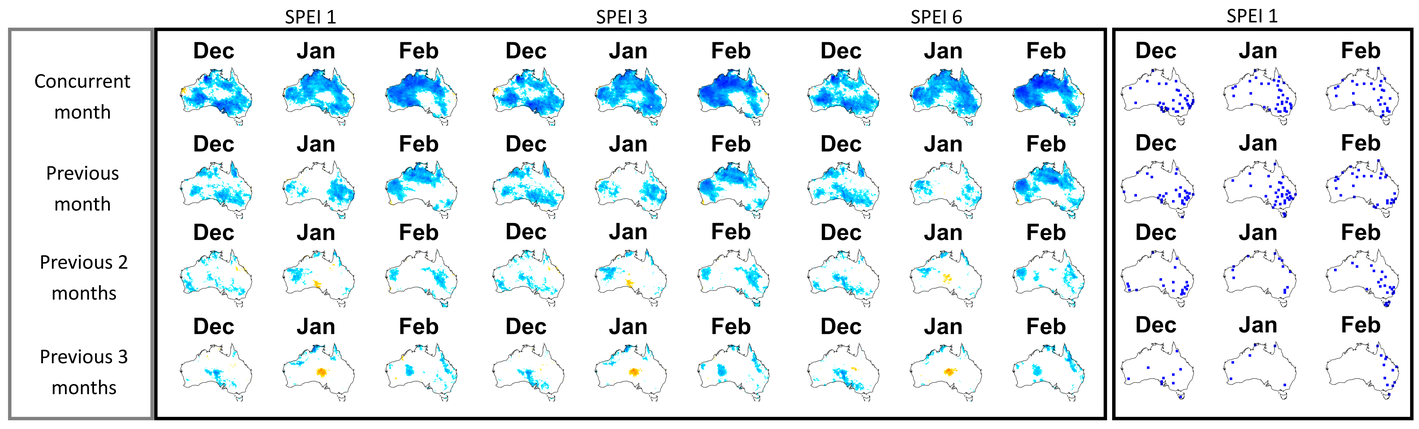

Figure 4—As in Fig. 2, using NHN.

Fig. 5—As in Fig. 3, using NHD computed with data from ACORN-SAT v2.

Table 1—CPE (%) of the 80th percentile of NHD in January, under drought or non-drought conditions, in the concurrent and previous months.

	October		November		December		January	
	Drought	Non-drought	Drought	Non-drought	Drought	Non-drought	Drought	Non-drought
SPEI 1	29	18	25	19	37	17	36	17
SPEI 3	28	18	28	19	36	17	33	17
SPEI 6	34	17	31	18	31	18	18	20

5. Final Remarks

A negative correlation between NHD in January and drought conditions in the previous months has been obtained before [6]. Here, we show that all summer months have a correlation with drought conditions up to the 3 previous months, at different SPEI time scales. These results are obtained with gridded ERA5 data and with station data.

The use of copula functions allowed to estimate the joint probabiliy of dry and hot events, and showed a higher probability of extreme hot events in January under drought conditions, when compared to non-drought conditions. These results were obtained using SPEI and NHD spatially averaged in the entire country, and so it is likely that using a higher spatial resolution will improve these results.

References

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Acknowledgements: This work was partially supported by projects FireCast (PCIF/GRF/0204/2017), and IMPECAF (PTDC/CTA-CLI/28902/2017). Andreia Ribeiro thanks FCT for the Grant PD/BD/114481/2016.