THE BIDECADAL CLIMATE CYCLE: ALIVE AND WELL

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We consider rainfall variability over the Lowveld in northeastern South Africa during the last 8 decades and demonstrate the persistence of a bi-decadal rainfall cycle in the region. We also note associations with the Southern Annular Mode and with the Southern Oscillation Index together with temporal changes in the association between these two indices, related to the global patterns associated with cycle.

KEYWORDS: Decadal variability, Southern Annular Mode, Antarctic Oscillation, Southern Oscillation, El Niño

Introduction

The bidecadal cycle is characteristic to the rainfall signal over northeastern South Africa and indeed much of subtropical southern Africa (Tyson 1980, Tyson et al. 2002). More recently, the cycle has been confirmed in the rainfall over northeastern South Africa into the 21st century (Malherbe et al. 2012). Furthermore, an association was noted with the direct impact of tropical cyclones over the Limpopo River Basin, associated with changes in the zonal steering flow at this time scale (Malherbe et al. 2012; 2014) and associated at a hemispheric scale with changes in the zonal pressure anomalies as reflected by the Southern Annular mode (SAM) during late summer (JFM), explaining certain teleconnections noted earlier by Tyson et al. (2002). The cycle was also demonstrated to be present over the period 1920 – 2015 in the extent of drought over South Africa, together with, at this time scale, the negative association with the SAM (Malherbe et al. 2016). Within the rainfall sequence, and despite being remarkably stable for multiple decades during the 20th century, the cycle displays a phase shift in the early part of the 20th century (Tyson 1975, Tyson et al. 2002). Nevertheless, the persistence of the 16-20-year cycle over the last few millennia has been deemed a striking feature of southern African climate variability (Tyson et al. 2002).

The recent strong El Niño in 2015/16 resulted in widespread drought over large parts of Southern Africa. The early summer was affected more negatively than the late summer during this event (Archer et al. 2017). Furthermore, the late-summer circulation patterns were characterized in the Southern Hemisphere by a strong positive SAM. While the association between ENSO and SAM is by no means linear, earlier studies suggested a negative relationship at inter-annual time scales (Pohl et al. 2009). However, the variation of the SAM with the bidecadal cycle during late summer despite the ENSO signal were demonstrated also (Malherbe et al. 2014).

Here we consider rainfall data together with circulation patterns to indicate the persistence of the bi-decadal climate cycle

Data and Methodology

Rainfall data from the South African National Parks for the Kruger Park were obtained, for a number of stations located in the park, starting as early as 1910 and continuing until 2018. Data were also obtained from SAEON (The South African Earth Observation Network) for one location, namely Phalaborwa, located just outside the western border of the park. Data were screened and where the record was incomplete, data were substituted with that of the nearest available station. Complete detests were created for the period 1941 – 2017 for 4 stations located in and around the Kruger Park: Punda Maria (north), Phalaborwa (central-west), Satara (central-east) and Skukuza (southwest). The rainfall values for these stations were normalized and averaged to obtain an index for the rainfall, on a yearly time scale, for the summer rainy season (July – June).

Other datasets used for the paper are: NCEP Reanalysis data for wind and geopotential height at various pressure levels (Kalnay et al. 1996), the monthly SAM (calculated by subtracting the normalized 850 hPa height at 65°S from that at 40°S - Gong and Wang 1999) using NCEP Reanalysis I. The monthly Southern Oscillation Index values were obtained from the Australian Bureau of Meteorology (BOM – www.bom.gov.au).

The impact of tropical cyclones over the region was quantified by the association of rainfall figures at the various stations with observed dates following landfall of systems, as identified by Malherbe et al. 2012 for the period 1948 – 2011, with a similar approach to identify systems (and associated rainfall) after 2011.

Results and Discussion

Figure 1 shows a wavelet analysis result based on the rainfall index derived from the annual July-June rainfall of all 4 stations considered for the period 1941 - 2018.

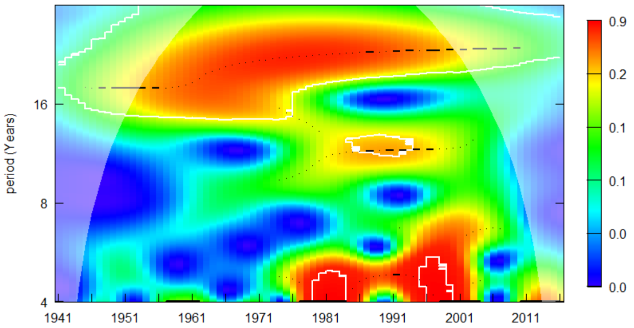

Figure 1 Wavelet power spectrum of the annual (July-June) total rainfall index at 4 stations in the Kruger National Park. The greyed out outer regions delineate the area under which power can be underestimated as a result of edge effects, wrap-around effects and zero padding. White contour lines show the 90 % confidence limits based on 5000 Monte Carlo simulations of the red noise background spectrum.

The significant oscillation at bidecadal scale is clearly visible in the wavelet power spectrum, throughout the time series. Figure 2 shows, for the same period the association between summer rainfall, the rainfall contributed directly by tropical systems from the Southwest Indian Ocean (see Malherbe et al. 2012) and the 18.6-year rainfall cycle.

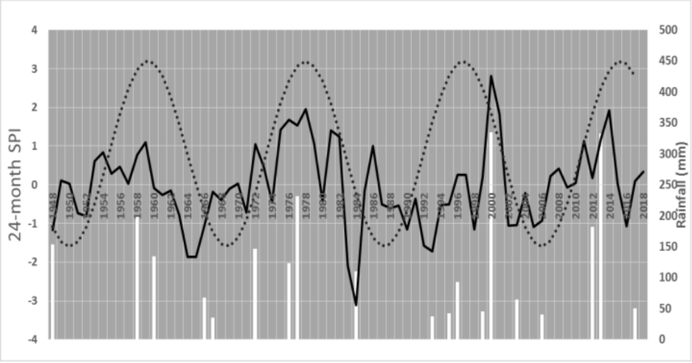

Figure 2 24-month Standardized Precipitation Index at Punda Maria in the north of the Kruger National Park (solid black line, primary y-axis), rainfall contributed directly by tropical systems from the Southwest Indian Ocean (white bars, secondary y-axis) and idealized 18.6-year rainfall cycle (broken black line).

Figure 2 shows the persistance of the rainfall signal together with the direct influence of tropical systems from the Southwest Indian Ocean continuing untill the present, following similar results in 2012 (Malherbe et al. 2012). During the most recent positive phase of the cycle, Tropical Storm Dando (2012) and a tropical depression in 2013 brought heavy rain to the region while Tropical Cyclone Dineo (2017) brought further widespread rain albeit lighter than the totals seen with the systems earlier in the wet epoch.

The association of rain from tropical systems moving inland from the Southwest Indian Ocean with the cycle remains one of the most striking elements and is associated with a strronger zonal easterly flow during late summer (Malherbe et al. 2014).

The lower rainfall associated with the 2015/16 El Niño is visible, similar to that of 1997/98 (during the previous wet epoch), but weaker so than during the strong El Niños outside the wet epochs (1991/92, 1982/83) indicated by the broken line in Figure 1. Both the 1997/98 and 2015/16 El Niños were associated with a positive late-summer SAM. This may suggest that global patterns during the high phase of the bidecadal cycle, associated with or forcing El Niño events, differ from that during the low phase. To demonstrate this possiblity, Figure 3 shows the rainfall-SAM association during the wet and dry epochs, according to the bidecadal cycle, respectively.

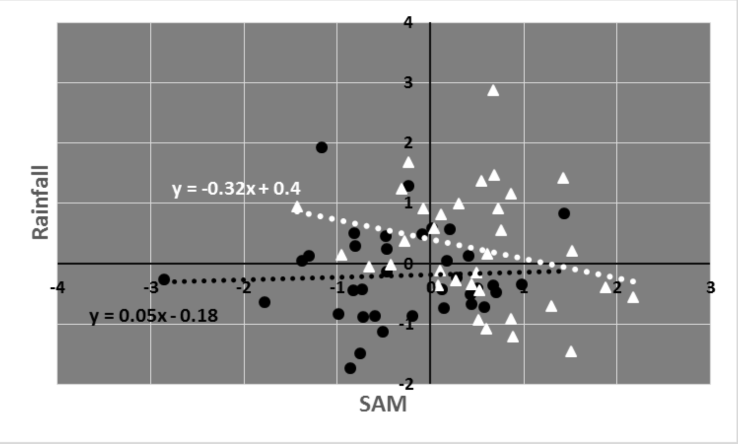

Figure 3 Scatterplot showing the association between rainfall, as represented by the rainfall index for 4 stations in the Kruger National Park (y-axis) with the JFM SAM (x-axis). The 2 series are for the wet phase of the cycle (as per Malherbe et al. 2014) (white triangles and white trend line) and dry phase of the cycle (black circles and black trend line).

Figure 3 shows that summer rainfall tends to increase (weak positive association – $R^2 < 0.01$) with increasing values of the

SAM during the dry phase of the bidecadal cycle while the association becomes negative ($R^2 = 0.12$) during the wet phase of the cycle. This change in rainfall-SAM association between wet and dry phases of the cycle is significant at the 90% confidence level as determined by identical treatment of 1000 randomized time series based on the original data. Figure 4 shows an example from the most recent high phase of the cycle as represented by the SAM and local circulation annomalies. It shows the existence of a cyclonic anomaly to the east of South Africa during JFM 2016, to the north of the subtropical high-pressure belt contracted very far south, while easterly anomalies over the subtropical latitudes around 15°S is very much weakened. In fact, weak anticyclonic centres are visible around 10 – 17.5°S, over the subcontinent and the Indian Ocean to the east. With a weakly negative SAM in JFM 2017, the high-pressure anomalies contributing to the SAM was somewhat further to the north, with anticyclonic centres from 30 – 20°S, and enhanced subtropical easterlies around 15°S. The anomalies juxtaposed here contribute to the enhanced negative correlation between rainfall over the Lowveld and the SAM during the high phase of the bidecadal cycle.

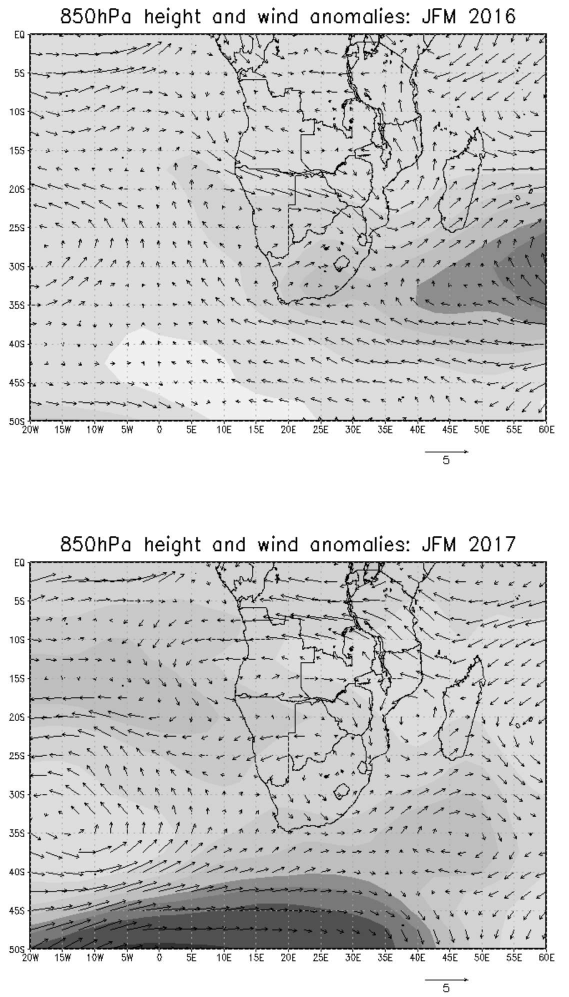

Figure 4 850 hPa anomalies in geo-potential meters (shading - gpm) and wind anomaly vectors (arrows – m/s) for JFM 2016 (strong El Niño and high SAM - top) and JFM 2017 (weak LA Niña, relatively low SAM - bottom).

Given the negative correlation between the SAM and rainfall over the Lowveld during the high phase of the bidecadal cycle, it may be expected that a similar weakened association between the SAM in JFM and the SOI will also be present. This is the case, as demonstrated by Figure 5.

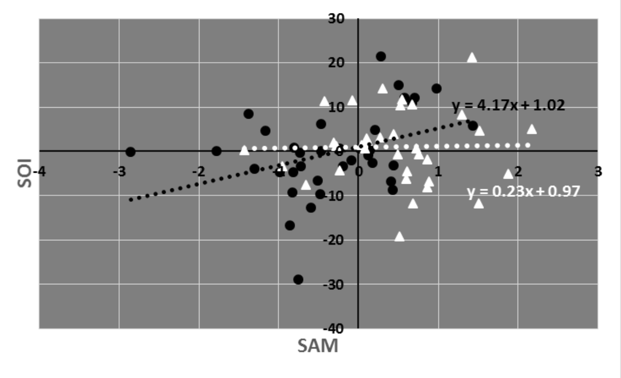

Figure 5 Scatterplot showing the association between the SOI (y-axis) with the JFM SAM (x-axis). The 2 series are for the wet phase of the cycle (as per Malherbe et al. 2014) (white triangles and white trend line) and dry phase of the cycle (black circles and black trend line).

Figure 5 shows a weakened correlation between the SOI and the SAM during the wet phase of the cycle ($R^2 < 0.01$) as opposed to during the dry phase ($R^2 = 1.2$).

Conclusion

The bidecadal climate cycle remains present in rainfall anomalies over the northeastern parts of South Africa until 2018. Here we also observed a weak correlation between rainfall and large-scale circulation anomalies over the Southern Hemisphere changing in association with the cycle, a feature that is also reflected in a similar change in the ENSO-SAM correlation at the bi-decadal time scale. It is outside the scope of the current work to consider reasons for the change in the SAM-SOI correlation, but changes in the driving mechanism of ENSO, as modulated at the bidecadal time scale, may possibly explain the feature.

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