Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 11, Issue, 03, pp.1913-1916, March, 2019

DOI: https://doi.org/10.24941/ijcr.34656.03.2019

ISSN: 0975-833X

RESEARCH ARTICLE

A CLIMATOLOGY OF INDIAN OCEAN SUBTROPICAL ANTICYCLONE

[1,*]Saqib-Ur-Rehman, [2]Bilal Ahmed Usmani, [3]Abdul Jamil Khan, [3]Kamran Khan, [1]Syeda Sadia Zia and [1]Syed Adnan Hussain

[1]Department of Mathematics, University of Karachi, Karachi, Pakistan
[2]Department of Bio Medial Engineering, NED University of Engineering and Technology, Karachi, Pakistan
[3,4]Mathematical Sciences Research Center, Federal Urdu University of Arts, Sciences and Technology, Karachi, Pakistan

ARTICLE INFO

Article History:
Received 26th December, 2018
Received in revised form
23rd January, 2019
Accepted 27th February, 2019
Published online 31st March, 2019

Key Words:
Anticyclone, Indian Ocean,
Mann Kendall, Center of Action

ABSTRACT

Present study uses the nonparametric Mann Kendall trend test to analyse the temporal variations in anticyclones over the Indian Ocean. The increasing trend in the anticyclones over 1020 hPa intensity starts to organize over the Indian Ocean during summer months. The area as well as the intensity of the high pressure system further increases during autumn months and it covers the entire southern part of the domain. During winter time further intensification and expansion covers the entire band with more anticyclones. During spring the center moves to the westwards over the Indian Ocean due to this the anticyclones started to decrease over the continent and then it attains the summer positions again.

Corresponding author:* **Saqib-Ur-Rehman

Copyright©2019, Saqib-Ur-Rehman et al. *This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*

Citation: Saqib-Ur-Rehman, Bilal Ahmed Usmani and Abdul Jamil Khan, Kamran Khan, Syeda Sadia Zia and Syed Adnan Hussain, **2019.** "A climatology of Indian Ocean subtropical anticyclone", *International Journal of Current Research*, 11, (03), 1913-1916.

INTRODUCTION

It has been observed that wind pressure gradients over a region, also referred to as the Global Circulation, greatly affect the weather system. The Azores High is a semi-permanent anti-cyclonic region. It is basically a high pressure system and is formed as a result of sinking air over the North Atlantic Ocean (NAO). The NAO weather phenomenon is formed due to the difference between the Icelandic low pressure system. In order to investigate the weather variations due to the wind pressure gradients, localized averages of the pressures are used. However, based on the concept by (Rossby, 1939) and the technique developed by (Hameed, 1995), the Centre of Action (COA) approach can be utilized to provide a better visualization of wind circulation patterns. COA is a quantitative assessment of the fluctuations in mean sea level pressure (MSLP) to study the centers of high or low pressure systems over a domain. It consists of the intensities of high or low pressure systems and their corresponding positions (Rossby, 1939) worked on the idea of averaging daily atmospheric pressure charts through which the center of high and low pressure systems was identified. These centers were referred as the semi-permanent centers of action. The three objective indices namely, intensity of pressure system and the latitude and the longitude positions at that intensity provide a better understanding of the fluctuations in MSLP and its associated climatic patterns (Hameed *et al.,* 2012). Investigated the precipitation over African Sahel zone and found that the variations in the Sahel precipitation was influenced by the fluctuations in the Azores High and the South Asia Low (35°E-95°E, 10°N-35°N) pressure systems (Hameed *et al.,* 2017). Also investigated the winter rainfall over SWWA and found that the intensity and longitude positions of IOH (40°E-120°E, 10°S-45°S) explained the variability in winter rainfall (1951-2008) over SWWA than the other climate parameters of the study. COA can also be applied to explore the associations between ocean and regional stream flow variability as done by (Nazimabad, 2014) by using COA, it was found that the winter (May-August) variability in the intensity and the longitude positions of the Indian Ocean High (IOH) also explained the Southwest Western Australia's (SWWA) winter stream flow variability. Hameed *et al.,* 2017 and Nazimabad, 2014 showed that there exists a strong inverse association of the mean central pressure as well as its longitude positions over the Subtropical Ridge (STR), (30°S) over the Indian Ocean with SWWA rainfall and its stream flow variability respectively. STR is the region near mid-latitudes where the average high atmospheric pressure prevails. The existence of STR is due to the heat exchange (by wind) between the equator and the subtropics by Hadley cell (Cai *et al.,* 2011). The subtropical belt showed significant increasing trends during 20th and early 21st centuries in the vicinity of eastern Australia (Timbal *et al.,* 2013). Drosdowsky, (2005) defined the subtropical ridge for Southeast Australia (SEA) as the zonal average of the maximum MSLP over the region bounded by 145°E–150°E, 10°S–44°S and is referred as the STR intensity and STR positions are the latitude positions which hold the high pressure found that the autumn rainfall declined over SEA is associated with STR intensity and its latitude positions over southeast Australia. The objective of this study is to explore the seasonal trends of anticyclones over STR for the period of 1951-2016. The large scale of the domain (40°E-155°E, 10°S-50°S) of STR over the Indian Ocean and the Australian continent is chosen because maximum variations occurred over the large region (Hameed *et al.,* 2017; Nazimabad, 2014; Cai and Cowan, 2013) of STR.

DATA AND METHODS

We used daily MSLP observations (with resolution 2.5° longitude by 2.5° latitude) data for the domain 40°E-155°E, 10°S-50°S. The MSLP data for this domain obtained from the National Center for Environmental Prediction (NCEP) (Collins *et al.,* 1996). We applied the nonparametric (Mann, 1945; Kendall, 1975) trend test on the percentage of the frequency of anticyclones data. It was used to analyze the monotonic increasing or decreasing trends in the water data (Hirsch and Slac, 1984). The obtained results were tested at $p<0.05$ statistical significance level. The rejection of the null hypothesis H_0 was characterized as the existence of an increasing or decreasing trend in the data set (Blain, 2012). Mathematically the test is explained by (Bower *et al.,* 2000) as, if y_j and y_k are the independent and identically distributed random data values the test static “s” defined as,

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(y_j - y_k)$$

Where the sign function $sgn(y)$ is given below,

$$sgn\,(y) = \begin{cases} 1 & when y > 0 \\ 0 & when y = 0 \\ -1 & when y < 0 \end{cases}$$

For a sample size of 30 or greater, the hypothesis tests can be obtained by applying the following test statistic, in which z is the magnitude of a standard normal deviation

$$z = \begin{cases} \frac{s-1}{\sqrt{m}} when s > 0 \\ 0 \quad when s = 0 \\ \frac{s+1}{\sqrt{m}} when s < 0 \end{cases}$$

N is the size of the sample and m is the variance of s that is given below,

$$m = \frac{N(N-1)(2N+5) - \sum_{i=1}^{G} T_i(T_i - 1)(2T_i + 5)}{18}$$

Where G is the total number of groups of values y_i that have same magnitude (i.e. ties) and the total number of ties in ith group is represented by T_i.

The Mann-Kendall trend test was not only used to analyze the trend in water data but was used in other climate time series data as well (Nazimabad, 2014) applied the Man-Kendall trend test to find the trends in 288 temperature stations of New South Wales. They found that 51% of the stations showed increasing trends which were significant at $p<0.01$ statistical level while only 7% of the stations showed decreasing trend which was insignificant over the period of 1966-2011.

RESULTS

The center of the high exhibits a large seasonal variation in the intensity and longitude positions than the latitude positions. Figure 1 provides the summary of the variations observed during the months in the center of the IOH. From Summer to Spring, the results depict more variations over the longitude than the latitudes in the anti-cyclonic behavior. These observations are consistent with the observations of Larsen and Baker-Reid (2009). They observed large variations across Australian longitudes which associated with the southern Australian rainfall. It was also observed that the center of the IOH remained more southward during autumn than winter time conditions of the IOH. An overview of each seasonal analysis is discussed below:

Figure 1a shows during summer the IOH originates to intense and expand more over the domain and remains southward of the domain. (Grose *et al.,* 2010) found that the summer rainfall over the western Tasmania is projected to decrease and this decrease is consistent with the southerly movements and intensification of the STR. Figure 1b shows that during autumn, more expansion and intensification takes place in the center of the high than the summer. The center of the high during autumn attains 60% of the total anticyclones with intensity more than 1020 hPa. Southern Australia bears 10-40% of the total anticyclones which increase southwards over the continent.

Figure 1c shows that during winter, the high attains its peak expansion and intensification over the Indian Ocean. The center attains 80% of the anticyclones around it while the southern part of the continent bears maximum of 60% of the anticyclones during winter. This result is consistent with the results of who showed that more anticyclones tend to track over the continent during winter than the other austral seasons. This is due to the presence of high density of transient anticyclones observed over the pole ward side than undisturbed equator ward flow (Drosdowsky *et al.,* 2005; Jones, 1994). Figure 1d shows the position of the high during spring. The center of the high is comparatively less intense than the winter time conditions. The southern part of the continent bears 20% of the anticyclones which is weaker than the autumn time conditions.

The Mann-Kendall trend test was used to study the trends in the seasonal percentage of anticyclones. Figure 2 illustrates the results of the trend analysis. Contour areas which were bounded by the values over 1.96 show the evidence of statistically significant increasing trends at 0.05 statistical level in the high pressure system over STR. We have in shown in Fig. 2a, during summer the increasing trend in the large area of the high pressure system over the southward direction is statistically significant at $p<0.05$ level while the increasing trend over the southern Australian is insignificant. Figure2b shows the significant trend areas are widely spread over the entire domain including southern Australia except blue shaded areas which are bounded by either zero or positive one values. This means that the increasing trend in the anticyclones during autumn is statistically significant at $p<0.05$ level of significance. Figure 2c shows the increasing trend in the entire band of STR during winter time the anticyclones remain statistically significant at 0.05 statistical level. Figure 2d shows, during spring the band from 40°E-80°E remains significant while the trends over the continent remains insignificant.

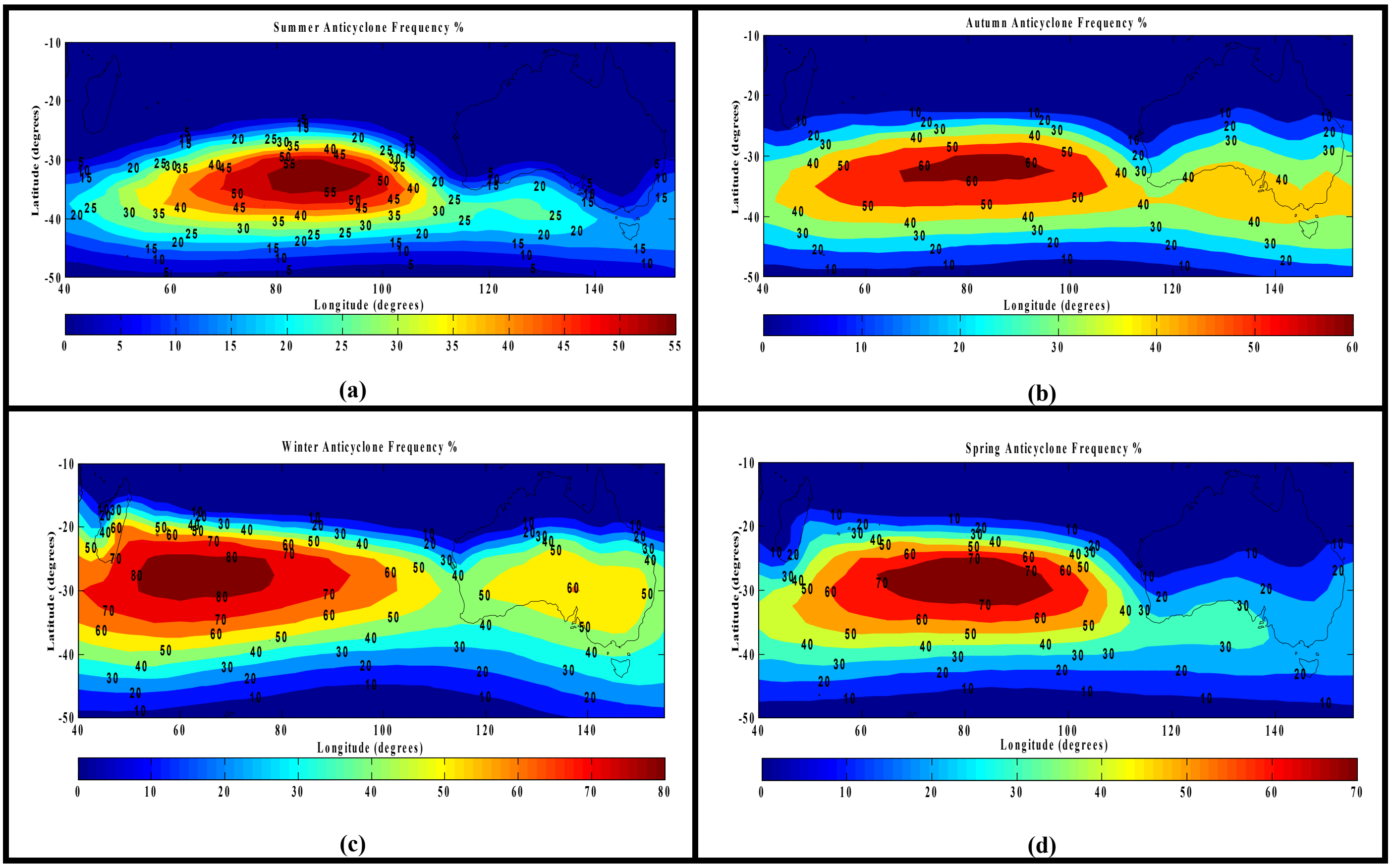

Fig. 1 Seasonal variation in the Indian Ocean High based upon observations from 1951-2016, for, (a) Summer (December-February), (b) Autumn (March-May), (c) Winter (Jun-August) and (d) Spring (September-November)

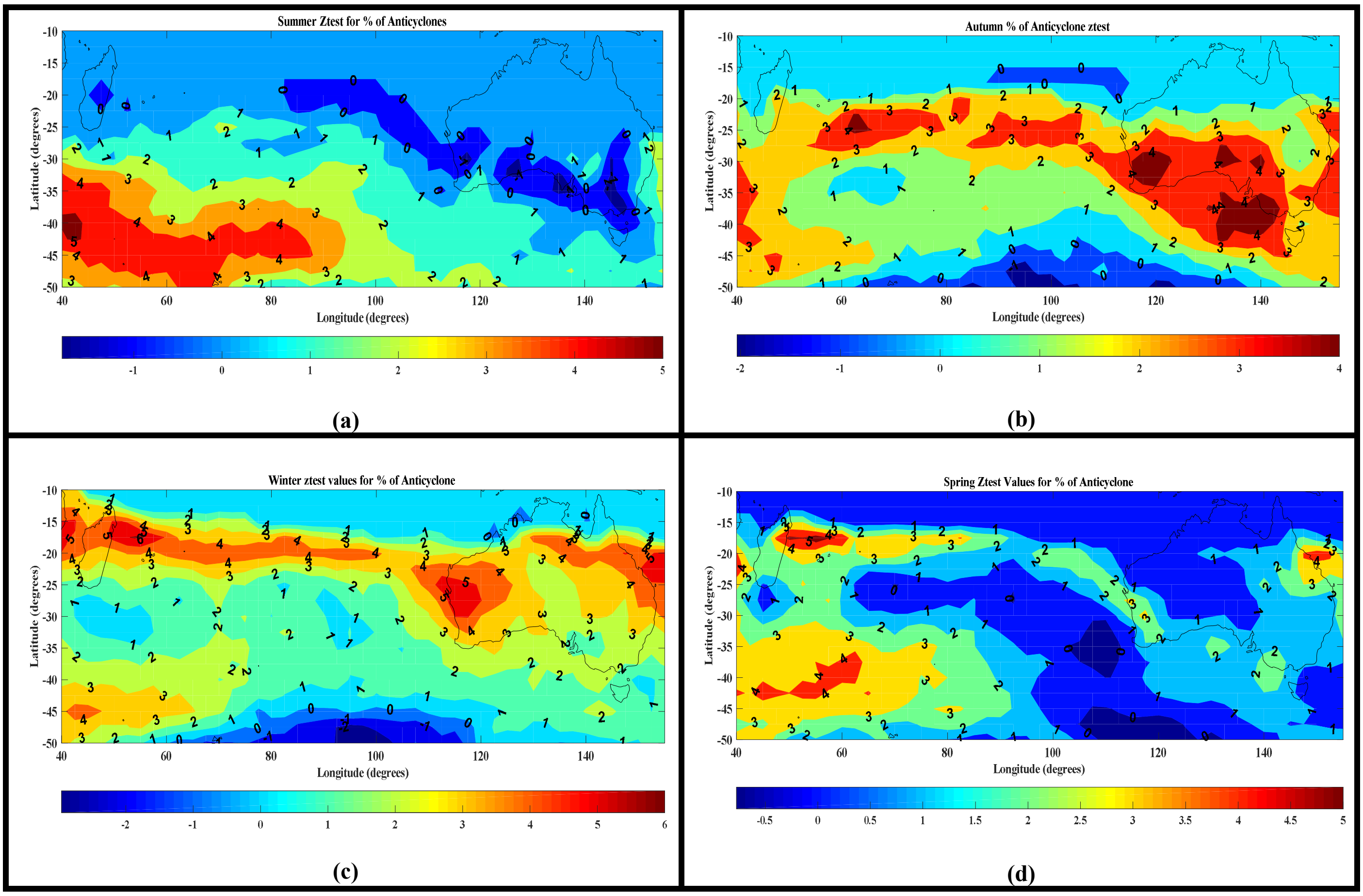

Fig. 2 Shows the Mann-Kendall trend test results, areas bounded by values over 1.96 are significant at 0.05 level of significance from 1951-2016, for, (a) Summer (December-February), (b) Autumn (March-May), (c) Winter (Jun-August) and (d) Spring (September-November)

Conclusion

The intensity of the high pressure over the subtropical belt is increasing (Timbal *et al.,* 2013; Solomon *et al.,* 2007). The largest tropical expansion rates are observed over Asia, Australia and New Zeland (Lucas *et al.,* 2015). Many researchers found that the intensification and expansion in the STR is associated with the variations in the Hadley Circulations, for example, (Williams *et al.,* 2009) found that the variations in the Hadley Circulations over the southern hemisphere and the variations in the meridional circulations are related to the southeastern Australian high and the southeastern high pressure system significantly associated with the seasonal rainfall over the continent (Grise *et al.,* 2018). who showed a statistically significant intensification of their Hadley circulation indices throughout the second part of the 20th century (Allen and Kovilakam, 2017). Observed the expansion in the tropical belt over the few decades and found the mechanisms that related to this expansion (Evans *et al.,* 2012). Found also that the expansion rate in the Hadley circulation observed as 0.55° per decade which remained most pronounced and significant during summer and autumn in each hemisphere over the period of 1979-2009 (Larsen *et al.,* 2009). Study the variability of STR during austral winter for the period 1850-2006. They found that the expansion in the longitude of the STR around 17° and the intensity of the mean central pressure of the center increased around 1.5hpa (Larson *et al.,* 2005). found that the mean winter circulation over the Australian and New Zealand region is strongly associated with the persistent anti-cyclonic activity. Our findings are consistent with the above findings. The increasing trend in the anticyclones over 1020 hPa intensity starts to organize over the Indian Ocean during summer months. The area as well as the intensity of the high pressure system further increases during autumn months and it covers the entire southern part of the domain. During winter time further intensification and expansion covers the entire band with more anticyclones. During spring the center moves to the westwards over the Indian Ocean due to this the anticyclones started to decrease over the continent and then it attains the summer positions again.

REFERENCES

Allen RJ, Kovilakam M. 2017. The role of natural climate variability in recent tropical expansion. *J Clim.,* 30(16):6329–50.

Blain GC. 2012. Monthly values of the standardized precipitation index in the State of São Paulo, Brazil: trends and spectral features under the normality assumption. *Bragantia*, 71(1):122–31.

Bower D, Mcgregor GR, Hannah M, Sheridan SC. 2000. Development of a spatial synoptic classification scheme for western Europe Abstract, 2023–39.

Brunetti M, Maugeri M, Nanni T. 2001. Changes in total precipitation, rainy days and extreme events in Northeastern Italy. *Int J Climatol.,* 21(7):861–71.

Cai W, Cowan T. 2013. Southeast Australia autumn rainfall reduction: A climate-change-induced poleward shift of ocean-atmosphere circulation. *J Clim.,* 26(1):189–205.

Cai W, van Rensch P, Cowan T. Influence of global-scale variability on the subtropical ridge over Southeast Australia. *J Clim.,* 24(23):6035–53.

Collins W, Deaven D, Gandin L, Iredell M, Jenne R, Joseph D. 1996. The NCEP NCAR 40-Year Reanalysis Project. *Bull Am Meteorol Soc.,* 77(3):437–72.

Dadaser-Celik F, Cengiz E. 2014. Wind speed trends over Turkey from 1975 to 2006. *Int J Climatol.,* 34(6):1913–27.

Drosdowsky W. 2005. The latitude of the subtropical ridge over eastern Australia: The L index revisited. *Int J Climatol.,* 25(10):1291–9.

Evans A, Nguyen H, Timbal B, Smith I, Lucas C. 2012. The Hadley Circulation in Reanalyses: Climatology, Variability, and Change. *J Clim.,* 26(10):3357–76.

Grise, K.M., Davis, S.M., Staten, P.W. and Adam, O. 2018. Regional and seasonal characteristics of the recent expansion of the tropics. *Journal of Climate,* 31(17), pp.6839-6856.

Grose MR, Barnes-Keoghan I, Corney SP, White CJ, Holz GK, Bennett J, et al. 2010. Climate Futures for Tasmania: *General Climate Impacts Technical Report,* 72 p.

Hameed S, Iqbal M, Saqib-ur R, Collins D. 2017. Impact of the Indian Ocean high pressure system on winter precipitation over western and southwestern Australia. *Aust Meteorol Oceanogr J.,* 61(3):159–70.

Hameed S, Riemer N. 2012. Relationship of Sahel Precipitation and Atmospheric Centers of Action. *Adv Meteorol.,* 1–8.

Hameed S. 1995. Investigation of the Centers of Action in the North Atlantic and the North Pacific. InProceedings of the First International AMIP Scientific Conference, Monterey, CA, 1995.

Hirsch RM, Slack JR. 1984. A nonparametric trend test for seasonal data with serial dependence. *Water Resources Research,* 20(6):727-32.

Jones KC. 1994. Observations on long-term air-soil exchange of organic contaminants. *Environmental Science and Pollution Research,* 1;1(3):172.

Kendall K. 1975. Thin-film peeling-the elastic term. *Journal of Physics D: Applied Physics,* 11;8(13):1449.

Larsen K, Baker-Reid F. 2009. Adapting to Climate Chanbge and Building Urban Resilience in Australia. *Urban Agric Mag.,* 22(22):22–4.

Larson KM, Freymueller J. 1995. Relative motions of the Australian, Pacific and Antarctic Plates estimated by the Global Positioning System. *Geophys Res Lett.,* 22(1):37–40.

Lucas RJ, Mills A, Wright S, Black AD, Moot DJ. 2015. Selection of sub clover cultivars for New Zealand dryland pastures. *J New Zeal Grasslands,* 77:203–10.

Mann HB. 1945. Nonparametric tests against trend. Econometrica: *Journal of the Econometric Society,* Jul 1:245-59.

Nazimabad N. 2011. Influence of Indian Ocean high pressure on streamflow variability over southwestern Australia. 2014;

Partal T, Küçük M. 2006. Long-term trend analysis using discrete wavelet components of annual precipitations measurements in Marmara region (Turkey). *Physics and Chemistry of the Earth,* Parts A/B/C. 1;31(18):1189-200.

Rossby CG. 1939. Relation between variations in the intensity of the zonal circulation of the atmosphere and the displacements of the semi-permanent centers of action. *J. Mar. Res.,* 2:38-55

Solomon S, Qin D, Manning M, Averyt K, Marquis M, editors. Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC. Cambridge university press; 2007 Sep 10.

Timbal B, Drosdowsky W. 2013. The relationship between the decline of Southeastern Australian rainfall and the strengthening of the subtropical ridge. *Int J Climatol.,* 33(4):1021–34.

Williams M, Cook E, van der Kaars S, Barrows T, Shulmeister J, Kershaw P. 2009. Glacial and deglacial climatic patterns in Australia and surrounding regions from 35 000 to 10 000 years ago reconstructed from terrestrial and near-shore proxy data. *Quat Sci Rev.,* 28(23–24):2398–419.

****