Association of Regional Precipitation patterns with the Dynamics of Anticyclone over the Subtropical Indian Ocean

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Abstract

This study showed that the variability in the intensity of mean central pressure (MCP) and its zonal movements (east to west or vice versa) over the Subtropical Indian Ocean explained the variability in the average monthly rainfall over the coherent districts (districts which showed the similar pattern in the average monthly rainfall) of Tasmania from March-May for the period of 1951-2017.The intensity of MCP and its longitude positions showed the inverse association with the monthly average rainfall over the coherent districts of the state. The MCP and its longitude positions were strongly correlated than the other climate variables of the study with the exception of March where the intensity not correlated but its positions represented its association. We have found the increasing trend in the intensity of MCP from March-May and also most of the time it observed in the west coast of Tasmania which caused the declined in the autumn (March-May) average rainfall over Tasmania, Australia for the period of 1951-2017.

Keywords: Indian Ocean Subtropical High Pressure, Intensity, Variability, Mean Central Pressure Coherent Rainfall Districts, Climate Variables, Inverse Association, Correlation.

1. INTRODUCTION

Tasmania is the southernmost state of south east Australia. The state stretches from40° E to 43.5° Ewhere it experiences the westerly air stream which brings moisture content to onshore from the subtropical Indian Ocean (IO) to the west coast of the state.The high elevation of mountains in the west and the westerly airstream cause majority of the rain in the west than the other parts of the state.[1]found that winter time rainfall over Tasmania is projected to increase. The East-Coast low is the term used locally to denote cyclonic systemthat formsover the Pacific

Ocean near east-coast of Australia that also contributes more rainfall in the eastern Tasmania[2] and [3], this rainfall system contributes more water into the water bodies for the agricultural districts of eastern Tasmania [4].[5] stated that Tasmania has been experienced the declined in the rainfall since the mid of the 1970s. There may be many climate drivers that operating over the southern oceans that influenced the rainfall systems of Tasmania. [6] found the variability in the inter-annual rainfall associated with Pacific South American mode (PSA), Southern Annular Mode (SAM) and El-Nino Southern Oscillation (ENSO). [7] found the association between ENSO and the Stream flow anomalies over Tasmania.[8] found the association between winter time rainfall over some parts of Victoria, Southern South Australia and Tasmania.The annual rainfall over southeast Australia has been declined since 1950s and there was no association between the subtropical ridge intensity (STR) and the SAM over the autumn (March-May) rainfall where the maximum declined has been occurred since 1980 [9]. The IOSHPS and IOSHLN were associated with the autumn (March-May) streamflow over Arthur River and Tamar River catchments of Tasmania for the period of 1951-2012 [10] and [11] respectively.
The objective of the study was to identify the districts of Tasmania which showed the similar patterns in the average rainfall during March-May months and to explore the relationship between the average rainfall over the coherent districts (similar average rainfall districts) and the large scale climate variables which operating over the IO and Pacific Ocean for the period of 1951-2017.

2. Data Descriptionand Method

We have obtained the mean sea level pressure (MSLP) data (2.5° latitude and longitude) from National Center for Environmental Prediction (NCEP) reanalysis [12].The MSLP data used to construct the indices of Indian Ocean Subtropical High (IOSH) (defined below)

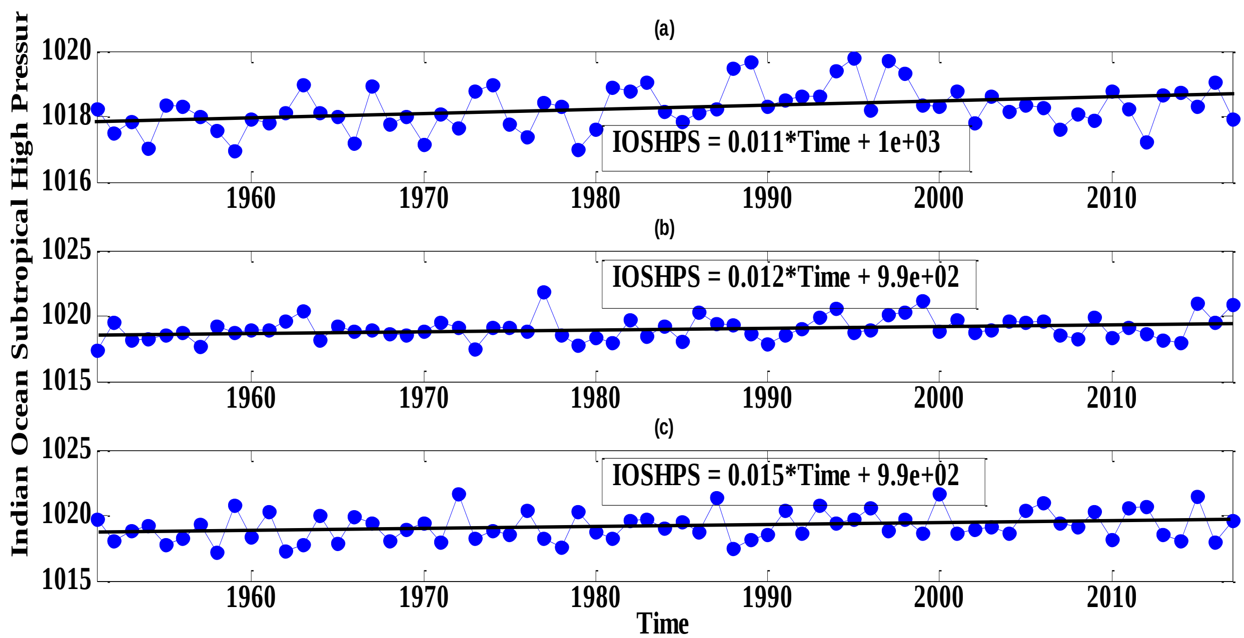

Fig.1 Show the trend of Indian Ocean Subtropical High Pressure (hpa) with time from 1951-2017 during (a) March (b) April and (c) May.

For the period of 1951-2017 for the autumn (March-May) months.The monthly average rainfall for autumn months March-May over the districts of Tasmania obtained from Bureau of Meteorology of Australia (BoM).

[13] Claimed that the centers of high (low) sea level pressure systems and their positions influenced the climate of associated regions and named this approach as the center of action (COA). This approach also applied by [14], [15] and [16].The approach was further improved by [17] have used this form and calculated IOSH indices over the domain (102.5 to 142.5 °E – 10 to 50 °S) of Indian Ocean (IO) for the period of 1951-2017.The IOSH are the three objective indices, namely,the IOSHPS, IOSHLN and IOSHLT. The IOSHPS is the index of the average of the maximum intensities of MSLP over the domain of IO at a time t and the IOSHLN and IOSHLT are the indices of the average of the longitude and latitude positions of the corresponding maximum intensities of the IO domain at a time t. We have also noticed the increasing trend with time in the IOSH indices (Fig.1 and Fig.2) which explains thatduring the autumn (March-May) monthsthe intensity of mean central pressure (MCP) is increased (Fig. 1) and it mostly observed near the west coast (Fig.2) of Tasmania over the study era.

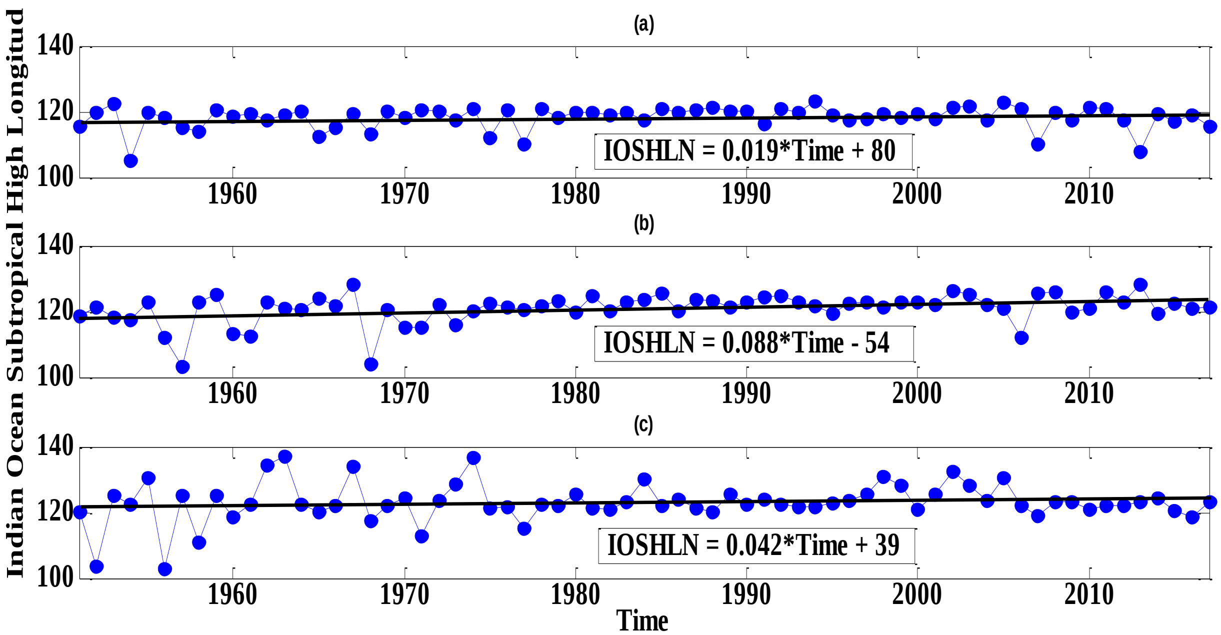

Fig.2 Show the trend of Indian Ocean Subtropical High Longitude (degrees) with time from 1951-2017 during (a) March (b) April and (c) May with time from 1951-2017.

On the other hand, We have observed that the average monthly rainfall over each district is highly variable (noisy) and the trend analysis is difficult to perform because of the high noise, we have removed the high frequency fluctuations and reconstructed each time series by applying discrete wavelet transform Daubechies4 (db4) (up to a four-level of decomposition), which extracts local linear trends from highfrequency variations[18]. The reconstructed time series of average monthly rainfall over each district and each month from March-May plotted against time.

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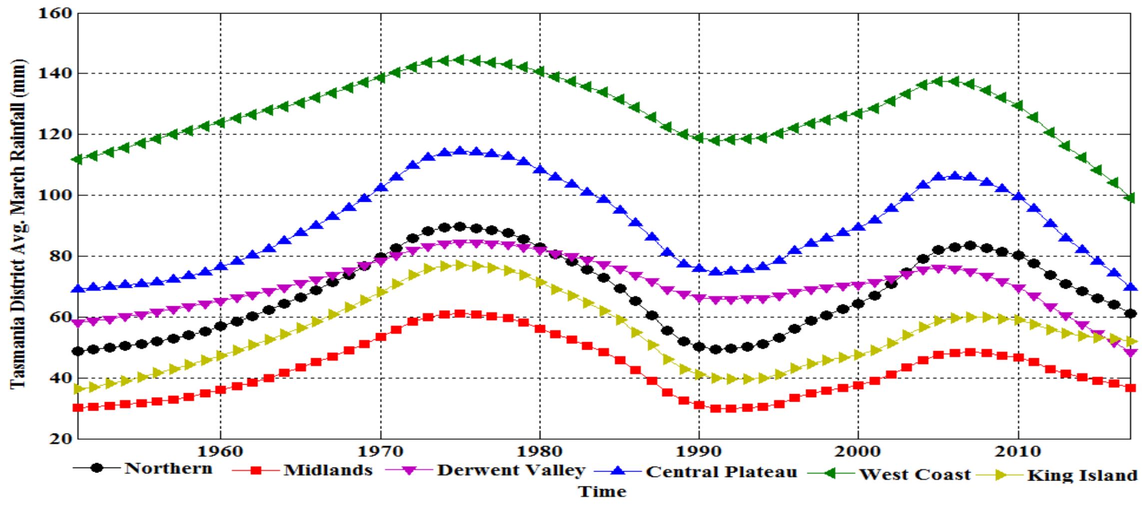
(a)



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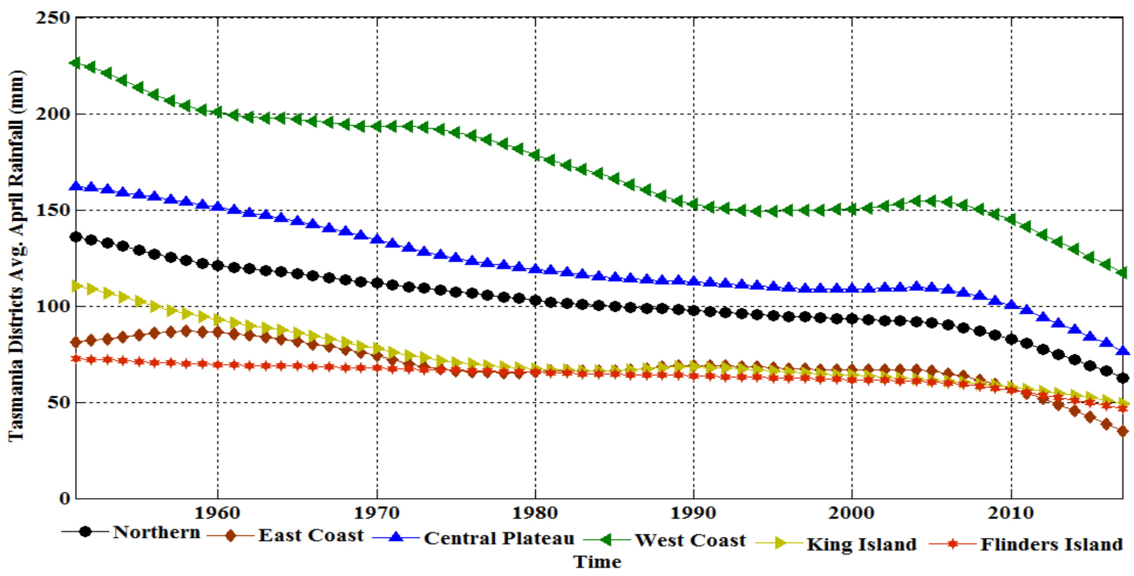

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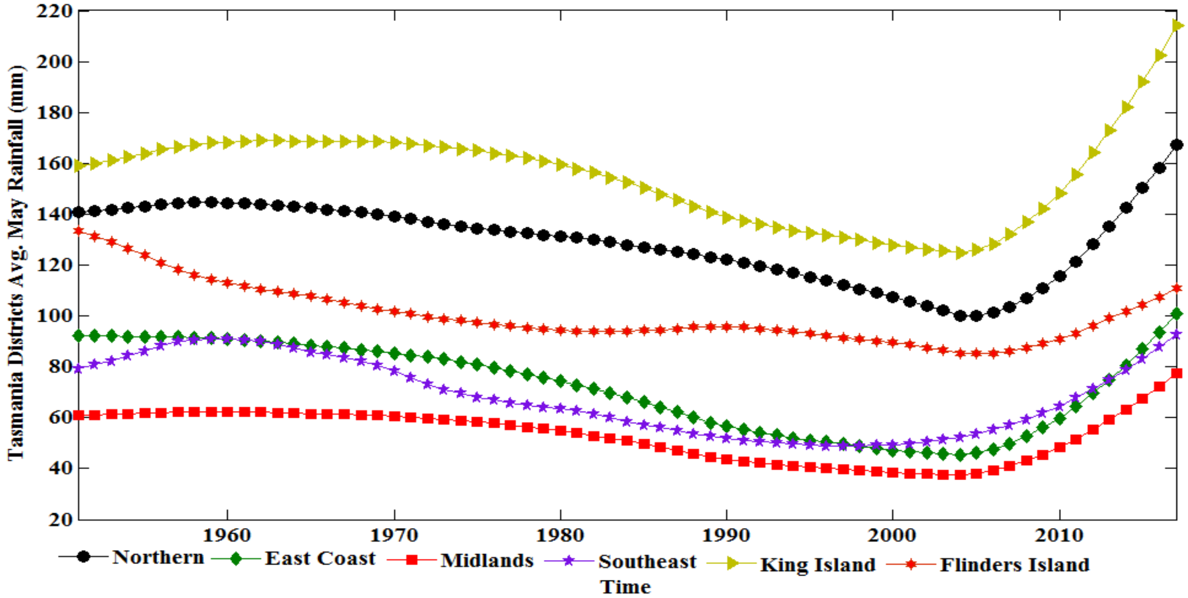
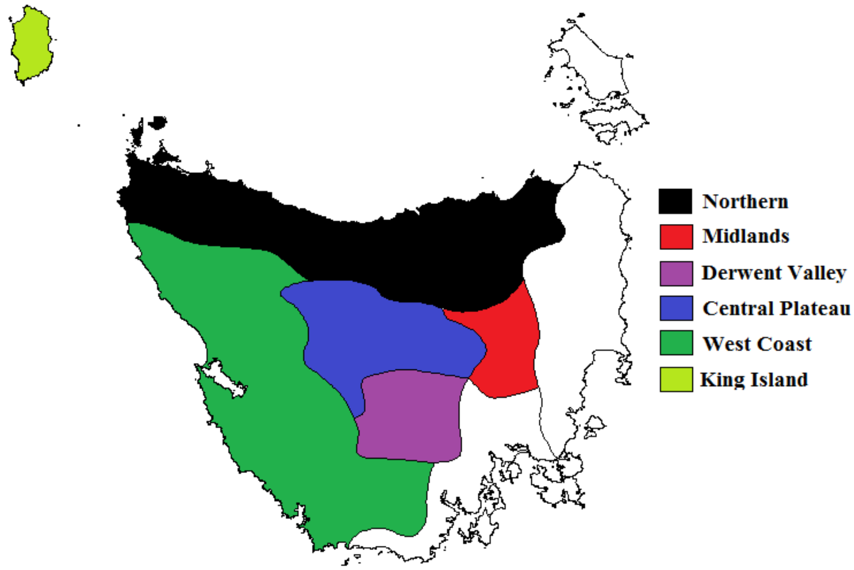


Fig.3 Show the average rainfall over the coherent rainfall districts (districts whose average rainfall shows similar patterns with respect to time) during (a) March (b) April and (c) May.

In this way, we have constructed 27 figures (9 districts and three months (March-May)). Thedistricts which showed the similar trend in average rainfall with time in a month (Fig.3) their average rainfalls were averaged to make one coherent average rainfall that may be interpreted as the representative of all those districts (Fig.4)

(a)



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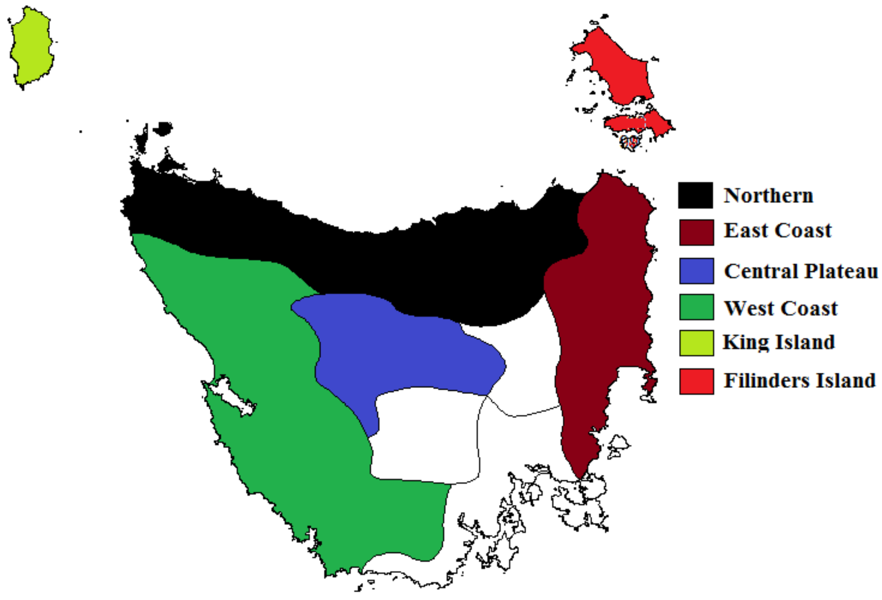

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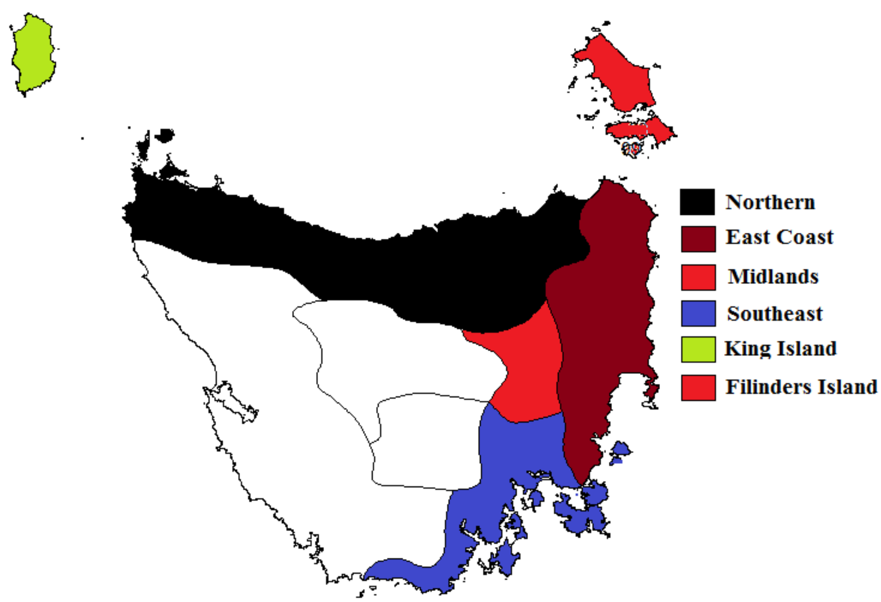

Fig.4 Show the geographical locations of the coherent rainfall districts in Tasmania for (a) March (b) April and (c) May.

which showed the similar rainfall variability in that month. In this way, we have obtained threeaverage rainfall indices (Fig.5)

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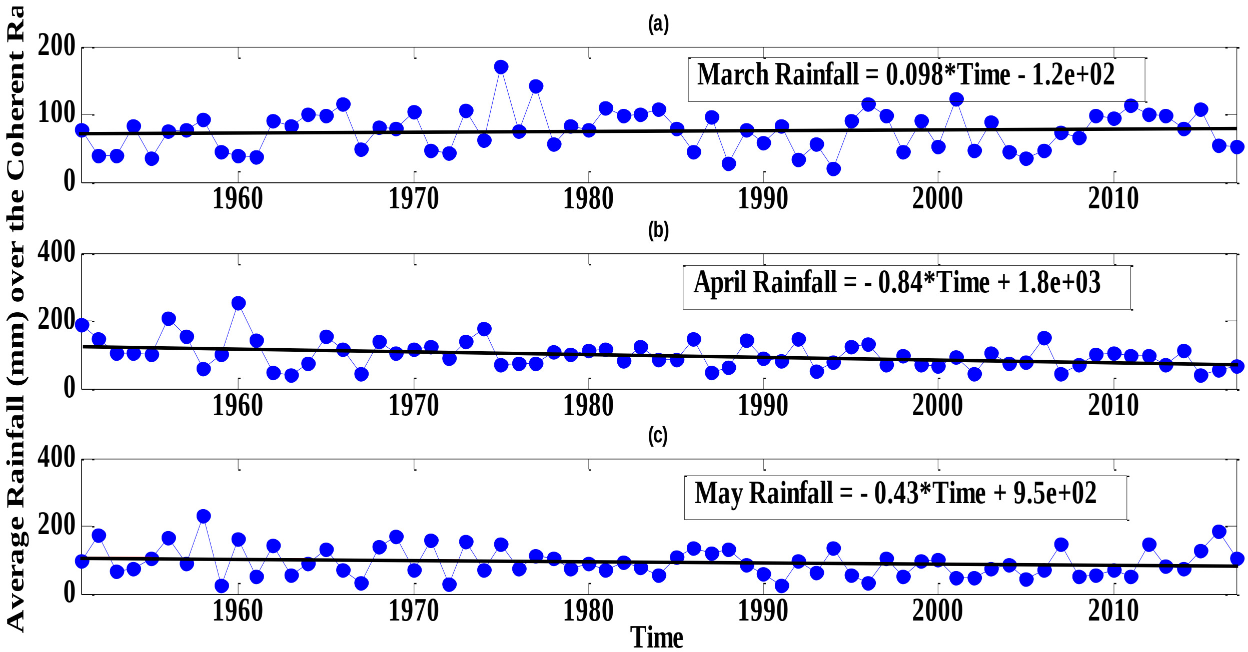


Fig.5 show the average rainfall (mm) over the coherent rainfall districts for the period of 1951-2017 during (a) March (b) April and (c) May.

onefor each month of the autumn (March-May) months for the period of 1951-2017 over the coherent districts.In order to find any relationship between the coherent average rainfall districts and the IOSH indices correlation analysis was performed among the large scale climate variables and the obtained three average rainfallindices (one for each month (March-May)) over the districts. The obtained correlation coefficients have shown in Table 1.

Table 1. Shows correlation of Tasmaniaautumn-time precipitation and coherent rainfall districts among large scale climate variables 1951–2016.Values significant at 95% statistical levels are shown in bold.

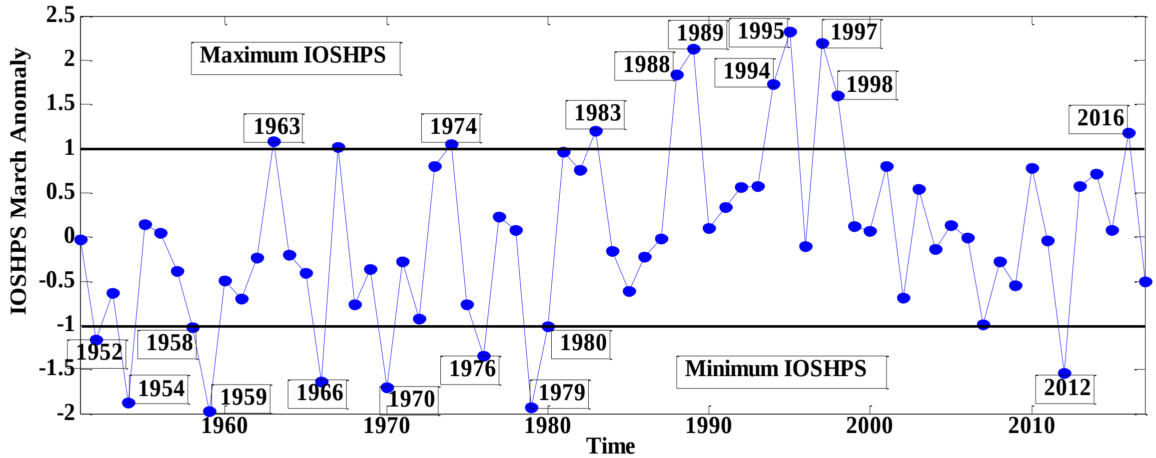
Predictors	**March**		**Apr**		**May**		**Autumn (Mar-May)**	
	Rain	**Detrend**	**Rain**	**Detrend**	**Rain**	**Detrend**	**Rain**	**Detrend**
Nino3	-0.02	--	-0.12	--	-0.12	--	-0.12	--
Nino3.4	-0.05	--	-0.17	--	-0.11	--	-0.08	--
Nino4	0.00	--	**-0.27**	-0.17	-0.10	--	-0.08	--
MEI	-0.05	--	-0.12	--	-0.08	--	-0.06	--
SOI	0.06	--	0.20	--	0.19	--	0.15	--
SAM (1951-2011)	0.02	--	-0.13	--	-0.08	--	-0.06	--
IOD	0.05	--	**-0.41**	**-0.35**	-0.11	--	-0.15	--
IOSHPS	-0.07	--	**-0.31**	**-0.24**	**-0.46**	**-0.42**	**-0.37**	**-0.25**
IOSHLN	**-0.49**	**-0.50**	**-0.57**	**-0.46**	**-0.55**	**-0.54**	**-0.63**	**-0.56**
IOSHLT	**0.27**	**0.27**	0.09	--	**0.44**	**0.45**	**0.34**	**0.36**

3. Results and Discussion

We were focused only thoseclimate predictors of our study which were correlated with the autumn (March-May) months and also show their relationship with autumn (March-May) average rainfall over Tasmania for the period of 1951-2017.It is observed from the correlation analysis that the IOSH indices are highly correlated (Table 1) than the other climate variables of the study from March-May and also these indices showed the strong relationship with average autumn time rainfall over the state. The strong negative relationship showed that the average rainfall over the coherent districts of Tasmania was inversely associated with the IOSH indices over the era.

In order to justify this association we have standardized the time series of IOSH indices and obtained the yearsthat were above 1 standard deviation which characterized as those years during which IOSHPS was above normaland the years that were below -1 standard deviation which characterized as the years during which IOSHPS was below normal (Fig.6).

(a)



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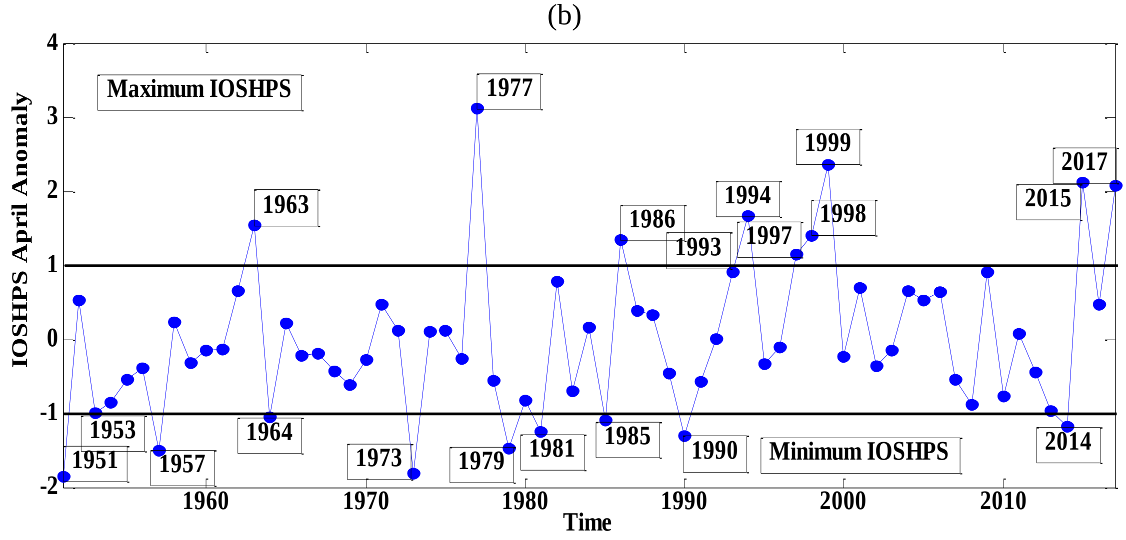

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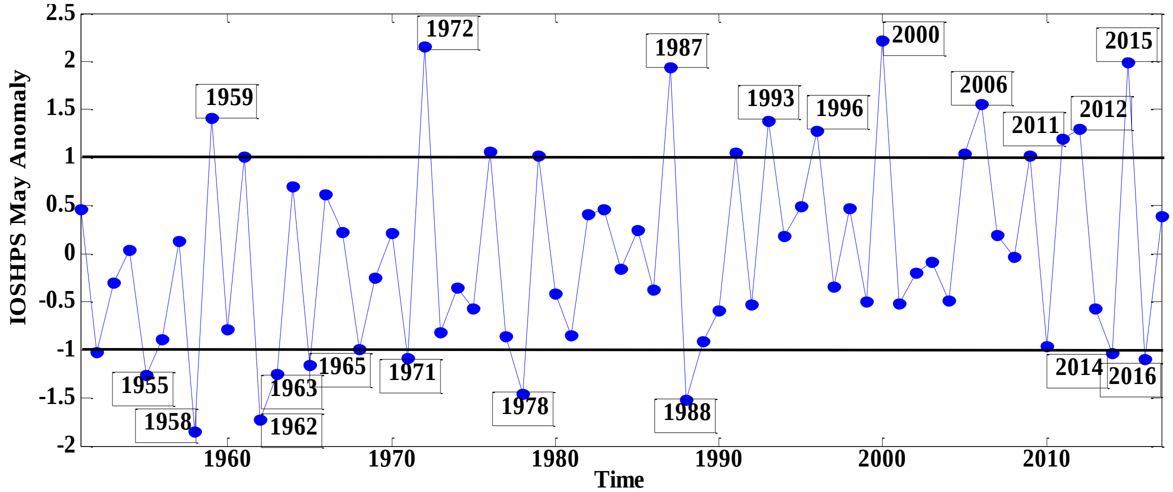
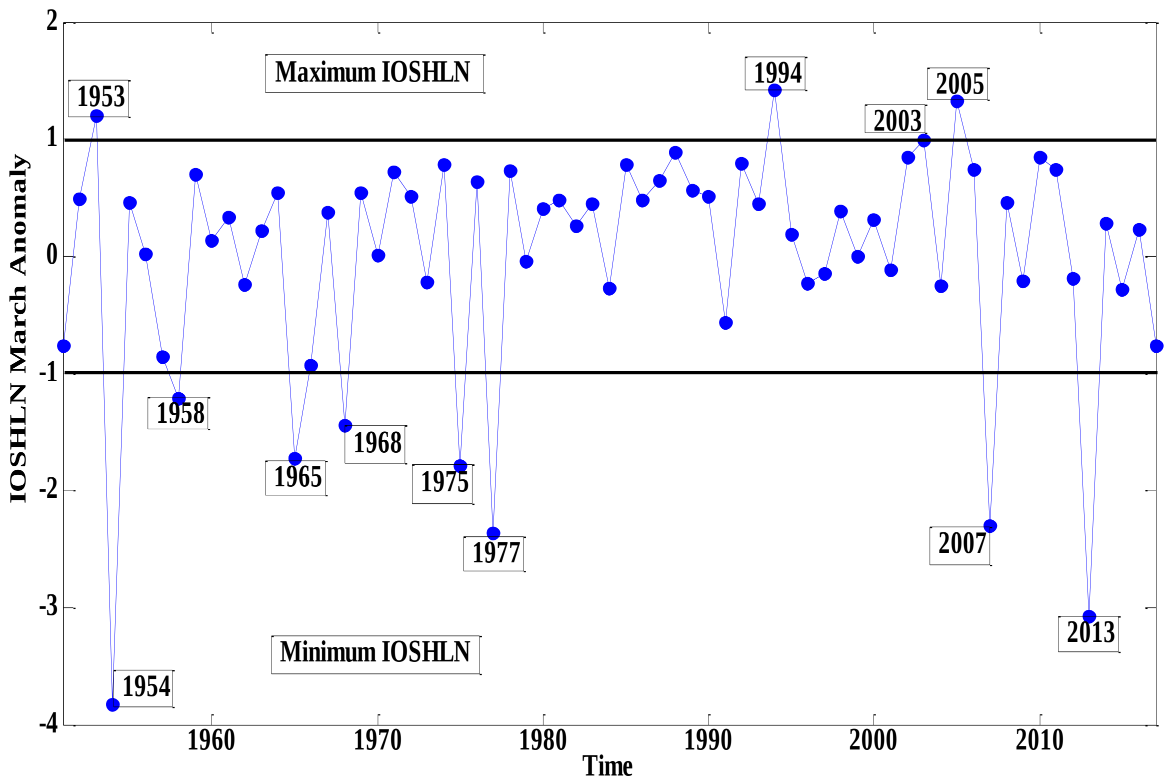


Fig.6 Show the years during which Indian Ocean Subtropical High Pressure (hpa) was maximum and minimum for (a) March (b) April and (c) May for the period of 1951-2017.

Similarly, the years that were above 1 standard deviationwhich characterized as those years during which IOSHLN was remained east (maximum IOSHLN values) of the stateand the years that were below -1 standard deviation which characterized as the years during which IOSHLN was remained westof state (Fig.7).

(a)



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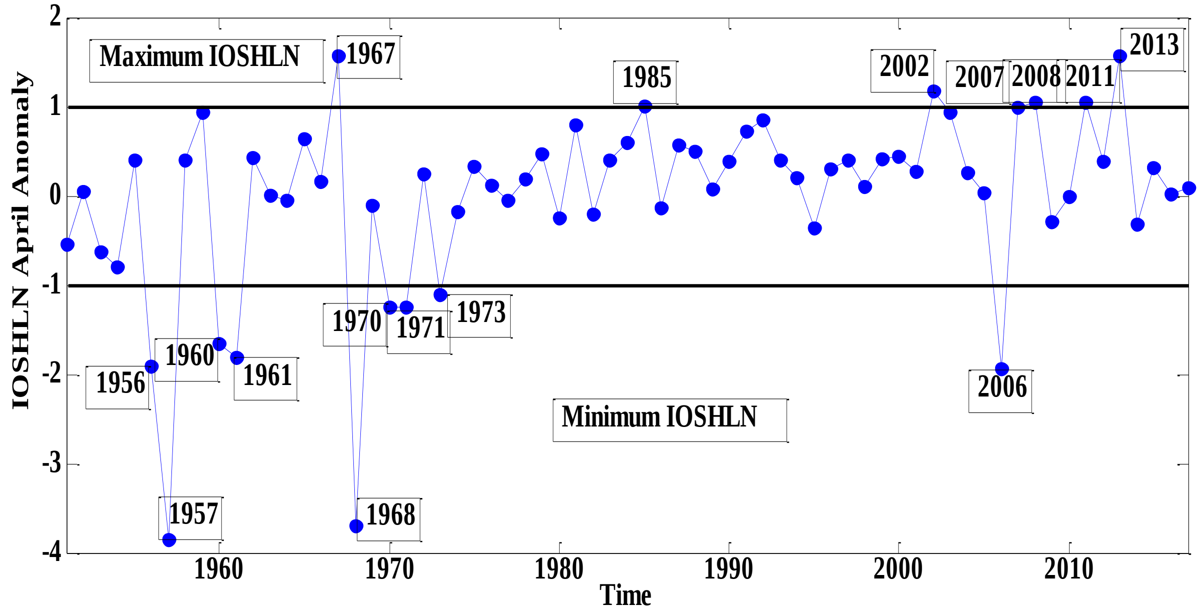

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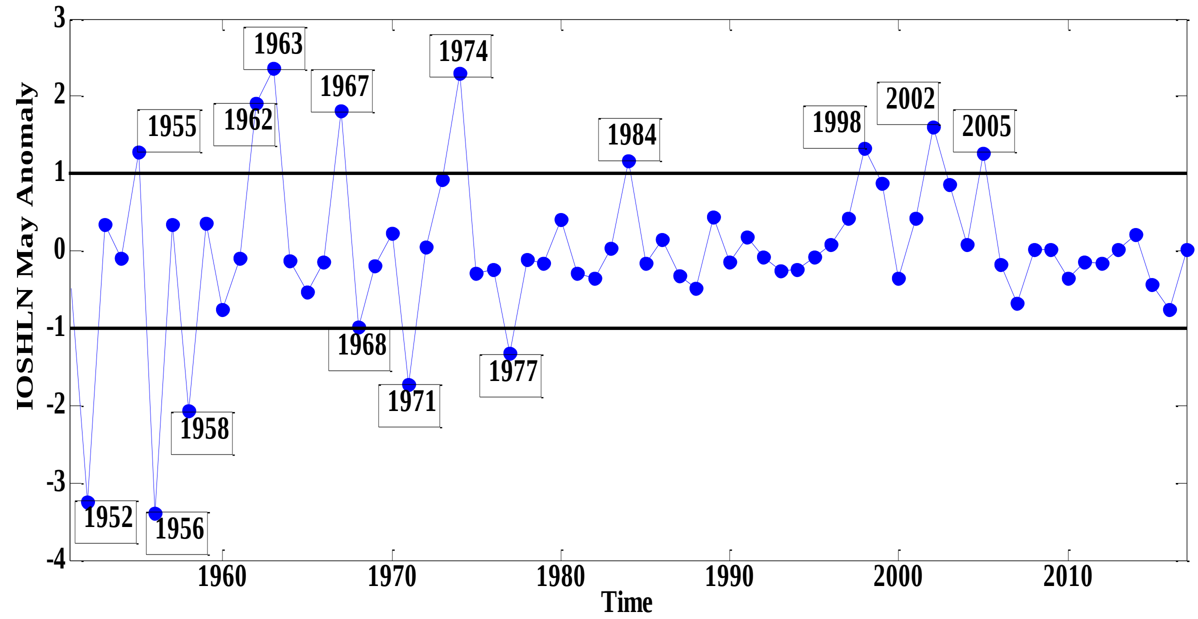
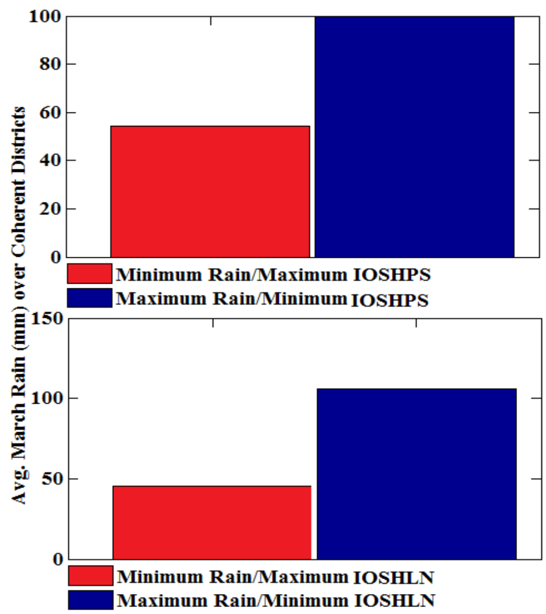


Fig.7 Show the years during which Indian Ocean Subtropical High Pressure (hpa) was maximum and minimum for (a) March (b) April and (c) May for the period of 1951-2017.

We have discussed earlier that the IOSHLN represents the longitude positions of the IOSHPS for this reason, the maximum values of IOSHLN characterized as the intensity of IOSHPS observed in the east of the state while minimum values of IOSHLN characterized as the intensity of IOSHPS observed in the west of the state.

We have extracted the corresponding average rainfall from the corresponding monthly indices of the coherent districts according to maximum and minimum years of the IOSH indices. We have compared the average IOSHPS intensity (Fig.8)

(a)



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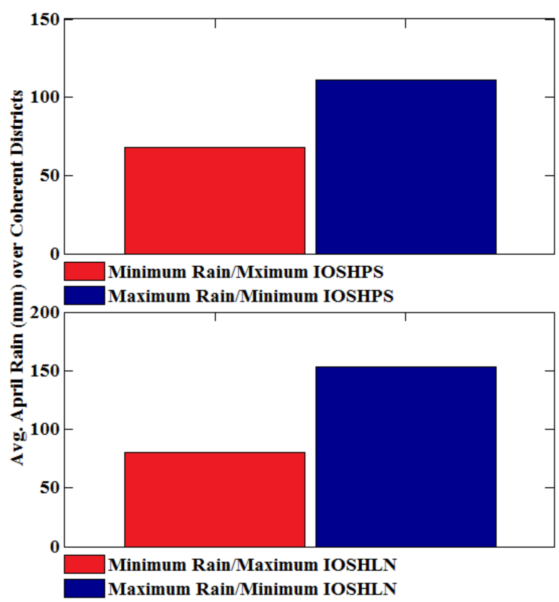

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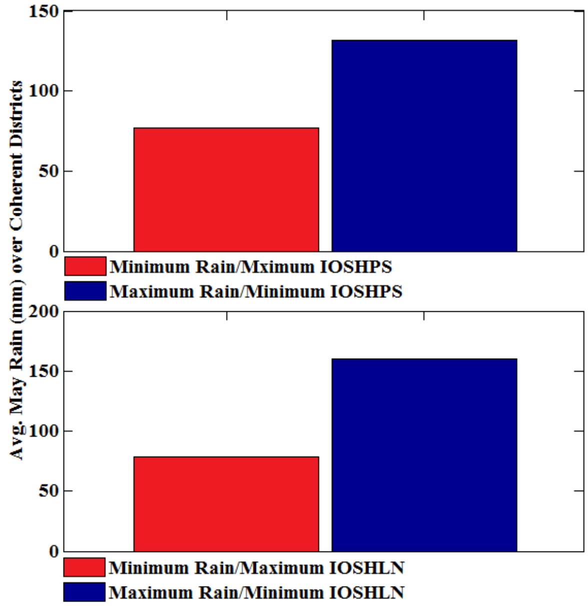

Fig.8 Show the amount of average rainfall (mm) received over the coherent districts of Tasmania during maximum and minimum Indian Ocean Subtropical High indices years for (a) March (b) April and (c) May.

during which it was maximum (minimum) with the corresponding average rainfall over the coherent districts of the state.We haveobserved the decrease (increase) in the average rainfall over the districts when IOSHPS was maximum (minimum). Similarly, we have observed the decrease (Fig.8) in the corresponding average rainfall values over the coherent district during which the average IOSHLN observed in the east (maximum) of the state while the average rainfall over the coherent districts has increased during which IOSHLN observed in the west (minimum) of the state.In the comparative analysis, it is cleared that how the inverse association of IOSH indices influenced the average rainfall over the coherent districts of Tasmania.[19] found the inverse association between the winter (May-August) time streamflowover the Southwest Western Australia (SWWA) and the winter (May-August) time MCP and its longitude positions over the subtropical IO.[20] and [21], in case studies,also found the inverse association between high pressure system over a subtropical IO and the winter (May-August) streamflowover the Collie and Warren River catchments, SWWA.

4. Conclusion

In the light of the above analysis, we have concluded that the MCP over the subtropical IO has been increased and it mostly observed near the west coast of Tasmania from March to May over the period of 1951-2017. The Intensity of the MCP as well as its zonal movements (east to west or vice versa) causedthe variability in the average rainfall over the coherent districts of Tasmania. The presence of MCP over the subtropical IO suppresses the rainfall systems over the coherent districts of Tasmania. It was also noticed that the average rainfall over the coherent districts from March-May have increased but the overall trendsin the average monthly rainfall

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and the autumn time average rainfall have been decreasing with the exception of March as a little increasing trend has observed. The increased in the average rainfall from March-May may be resulted due to the extra-tropical cyclones activity that present when MCP shifted to the western subtropical IO (before 110° E) or during when MCP shifted towards the south-coast of Victoria, Australia.

References

[1] Hope P., Grose R. M., Timbal B., Dowdy J. A., Bhend J., Katzfey J. J., Bedin T., Wilson L. and Whetton H. P., 2015, Seasonal and regional signature of the projected southern Australian rainfall reduction,Australian Meteorological and Oceanographic Journal 65:1 October 2015 54–71.

[2] Dowdy J. A, Mills A. G., Timbal B. and Wang Y., 2013, Changes in the Risk of Extratropical Cyclones in Eastern Australia, Journal of Climate, 26: 1403-1417.

[3] Bennett, J.C., F.L.N. Ling, D.A. Post, M.R. Grose, S.P. Corney, B. Graham, G.K. Holz J.J. Katzfey and N.L. Bindoff, 2012. High resolution projections of surface water availability for Tasmania, Australia, Hydrol. Earth Syst. Sci., 16: 1287–1303.

[4] Pook M., Risbey J., and McIntosh P., 2010, East coast lows, atmospheric blocking and rainfall: a Tasmanian perspective, IOP Conf. Series: Earth and Environmental Science 11 (2010) 012011, doi:10.1088/1755-1315/11/1/012011.

[5] CFT, 2010. Climate Futures for Tasmania water and catchments: the summary, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania

[6] Hill K. J, Santoso A. and England M. H., 2009, Interannual Tasmanian Rainfall Variability Associated with Large-Scale Climate Modes, American Meteorological Society, Vol. 22, 4383-4397.

[7] Chiew F.H.S., McMahon T. A, Dracup T.A., Piechota T., 1994, El-Nino/Southern Oscillation and Streamflow Patterns in South-East Australia, Australian Civil Engineering Transections, Vol. CE 36. No. 4, p. 285-291.

[8] Meneghini B., Simmonds I. and Smith I. N., 2007, Association between Australian rainfall and the Southern Annular Mode, Int. J. Climatol., 27: 109–121.

[9] Cai W., Cowan T., 2013, Southeast Australia Autumn Rainfall Reduction: A Climate-Change-Induced Poleward Shift of Ocean–Atmosphere Circulation, Journal of Climate, 26: 189-205.

[10] Rehman S., Khan K. and Masood A., 2015(a), Regional Runoff Patterns Associated With Indian Ocean Subtropical High: A Case Study Over Arthur River Catchment, Research Journal of Fisheries and Hydrobiology, 10(11): 33-39.

[11] Rehman S.,Khan K. and Masood A., 2015(b), An analysis of Runoff Variability in Tasmania in the last sixty two years: A Case Study over Tamar River Catchment, Adv. Environ. Biol., Vol. 9(14):50-56.

[12] Kalnay E (1996). The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc., 77: 437-471.

Journal of GeoSpace Science, 2(1) September 2017, Pages: 01-14

[13] Rossby, C. G. and co-authors, 1939, Relation between variations in the intensity of the zonal circulation of the atmosphere and the displacement of the semi-permanent centers of actions, J. Marine Res., 2, 38–55.

[14] Hameed S., Shi W., Boyle J., Santer B., 1995, Investigation of the centers of action in the North Atlantic and North Pacific in the AMIP simulations (Diagnostic Subproject 23), Proceedings of the First International AMIP Scientific Conference, Monterey, California, WCRP, 92: 221.

[15] Hameed S., Iqbal M. J., Rehman S., Collins D., 2011, Impact of the Indian Ocean high pressure system on winter precipitation over western and southwestern Australia, Australian Meteorological and Oceanographic Journal 61: 159–170.

[16] Rehman S., Saleem K., 2013, Forecasting Scheme for Swan Coastal River Streamflow Using Combined Model of IOHLN and Niño4, Asia-Pacific J. Atmos. Sci., DOI: 10.1007/s13143-014-0009-6.

[17] Rehman S., Khan K. and Masood A.,2015(c), Dependence of Winter Runoff Variability and Indian Ocean Subtropical High: A Case Study over the Snug River Catchment, Adv. Environ. Biol., 9(11), 79-85.

[18] Daubechies I., 1992, Ten Lectures on Wavelets, 64 CBMS-NSF Regional Conference Series in Applied Mathematics. Society for Industrial Mathematics.

[19] Rehman S., 2014, Influence of Indian Ocean high pressure on streamflow variability over southwestern Australia, Annals of Geophysics. 57(2):2. (doi:10.4401/ag-6398).

[20] Rehman S., Saleem K., Tayyab N., Nasir H., Zia S. S. and Ansari W. A., 2012, The Impactof Indian Ocean High Pressure System on Rainfalland Streamflow, The Nucleus, 49(2), 89-99.

[21] Rehman S., 2013, COA Induced Rainfall-Streamflow Variability in Warren River: Case Study, Journal of Science and Technology, 5(1), 49-64.