The Zonal Movement of South Pacific& Indian High Pressure system's in Austral Winter

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Abstract

Southeastern part of Australia (SEA) has seen low rainfall from 1997 to 2006. It has noted before in the 20th century, but conditions of ongoing drought are exacerbated with the increase in temperature. Impacts of this dry spell are wide-spread, so an effective research effort is carried out to understand the current climate of this state and its variability. Southern Annular Mode (SAM),El Niño – Southern Oscillation (ENSO), and the Indian Ocean Dipole (IOD) are those factors which have so much influence in the climate of south east Australia. This study investigates rainfall variability and trends within the region of South East Australia over the past century. Most of the region of Australia experiences large variations in rainfall over space and time. We apply the approach known as "center of action" for the variation's study in winter precipitation across the above mentioned region by considering the variations in Indian Ocean and South Pacific High pressure systems. Using gridded rainfall data of high resolution and indices of Centre of action , the relationship between COA indices and winter precipitation in South East Australia have been examined and it is found that east-west shifting in the position of the subtropical Indian Ocean High and South Pacific high are significantly influence in winter rainfall . The negative correlation between Indian ocean high longitude and the rainfall implies that when the Indian High shifted towards east there is less rainfall over south east Australia and Positive correlation shows that when the South Pacific High Pressure is minimum there is less rainfall, In a similar way when the South Pacific High shifted towards west rainfall decline observed and vice versa, (IOHLN, SPHPS and SPHLN) explain 31% variability of rainfall over SEA. Our *calculations suggest that the variability of winter precipitation over South East Australia is not only influenced by the intensity of Indian Ocean and South Pacific High pressure systems but it also depends on their zonal movements.*

Key words: South Pacific High Pressure, Indian Ocean High Pressure, Precipitation, Teleconnection
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1. INTRODUCTION

The continent of Australia features the wide range of climatic zones; it is the world's second driest continent on earth. Australia has seen one of the lowestrainfallsin the world and approximately three-quarters of its land are arid or semi-arid. Records of rainfall shows regular drought cycles sometimes continue for a decade and beyond which are varied with years of above-average rain. From an economic and environmentalperspective these rainfall trends are very important. Australia has faced strong year-to-year rainfall variations from thousands of years.

Particularly, in South East Australia, there is decrease in rainfall and no pause in the evolution of hot extremes over land since 1950[1]. Projections of climate change indicate that in future it is likely to become drier and hotter. From late 1990s most parts of South-Eastern Australia (SEA) has observed rainfall decline(National Climate Centre – NCC- 2008).The changing climate of South East Australia shows an increasing risk of below average rainfall and worst drier conditions.

Over the first half of 20th century, Australian climate was drier but increase significantly in the late 1940s [2]. Mostly southern Australia experienced widespread rainfall deficiencies known as the Millennium Drought as shown in Figure 1, particularly in south east and south west regions that has a large populationand extremely affected the Murray-Darling Basin and most of the southern cropping zones.Decrease of 44% in stream flow has observed in southern Murray Darling Basin because of reduced rainfall of 13% [3].

The dominant factors which are responsible for the climatic variations in South East Australia include the El Niño – Southern Oscillation, the Indian Ocean Dipole and the Southern Annular Mode. The ENSO, IOD and SAM represent the effects of the Pacific Ocean, Indian Ocean and atmospheric circulation at high latitudes respectively. These factors have significant influences on seasonal rainfall patterns.

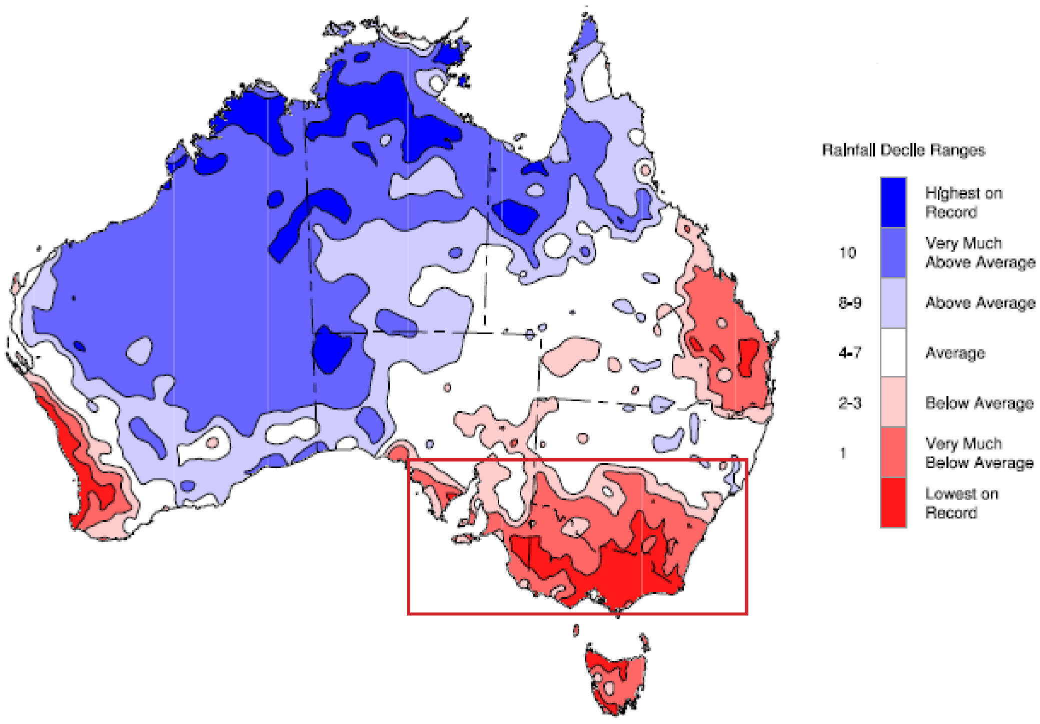

Fig 1. Rainfall decline over Australia from January 1997 to December 2009; found on climatology from 1900 - 2009 (Bureau of Meteorology).

In this studythe Center of Action (COA) approach is used to investigatethe Rainfall variability over South East Australia (33.5ºS and 135.5ºE). Basically COA has three indices that represent the area-averaged latitude, pressure and longitude. The atmospheric centers of action are the large scale semi-permanent features of high as well as low pressure that are prominent in seasonal maps of global sea level pressure. Various current studies have shown the advantages of this approach over others, including zooplankton's variation in the Gulf of Maine [4], GulfStream's position [5], the variability of African dust transport's variability across the Atlantic [6], and the wintertime Greenland tip jet variations [7]. These studies have shownthat the changes in pressure are not the only cause of regional climate, longitudinal and latitudinal positions of COA are also play the important role in it.

One of these studies is also determines that the impact of the Indian Ocean high on winter rainfall over western and southWestern Australia [8]. In point of fact, the Indian and South Pacific High are the centers of action that dominates atmospheric circulations which are the main cause to bring moisture in south eastern part of Australia. Thus, this study suggeststo finding the impact of changes in position and pressure of the Indian Ocean and South Pacific High on periodic rainfall.

2. Data

This study is based on the rainfall data of 1950-2008, taken from Australian Bureau of Meteorology (BOM) which is gridded monthly. It was developedwith the help of topographyresolving analysis methods applied to allavailable rainfall station data (see, http://www.bom.gov.au). It's one of the best datasetsto be used for the analysis of rainfallvariability.

Average gridded monthly mean sea-level pressure(MSLP) data were usedfrom 1951–2008 which were taken from theNational Center for EnvironmentalPrediction (NCEP) reanalysis [9] to calculate theindices of COA approach for the average monthlypressure, longitude andlatitude of theboth (i.e.Indian Ocean High and the South PacificHigh systems), as mentioned in[5]. Composite maps were made to investigate meteorological changes associated with several extreme conditions by using NCEP reanalysis.

On ClimateData Centre, National Centers for Environmental Prediction, Southern Oscillation Index is also given. Over the high latitudes of the southern hemisphere, there is small number of stations that's why we have only limited observations of SAM. All calculations which are given in this paper are for June to August (JJA) season.

3. Method

A quantitative assessment is used to obtain the relationship between the atmospheric pressure fluctuation and rainfall variability over Australia. The index of pressure$I_P$for a High pressure system is given as an area-weighted pressure departure in the domain (I, J)from a threshold value, as proposed by Santer[10] anHameedet al. [11]

$$I_{p,\Delta t} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\cos\emptyset_{ij}\delta_{ij,\Delta t}}{\sum_{i=1}^{I}\sum_{j=1}^{J}\cos\emptyset_{ij}\delta_{ij,\Delta t}}$$

where average value of MSLP at grid point (i, j) over a time interval $\Delta t$is represented by $P_{ij,\Delta t}$, here monthly MSLP values are got from NCEP reanalysis, P_t shows the threshold MSLP value(which is same for both the Indian Ocean High and the South Pacific High,1016 hPa), φ_{ij} represents the latitude of the grid point. If $(P_{ij,\Delta t} - P_t) > 0$ then $\delta = 1$ and if$\left(P_{ij,\Delta t} - P_t\right) < 0$ then$\delta = 0$ which shows thatHigh pressure system causes pressure difference. It means the intensity is a measure of the anomaly of the atmospheric mass across the section (I, J). The domain of the Indian OceanHigh was taken as (10°S - 45°S) and (40°E - 120°E) and for South Pacific High, (10°S - 45°S) and (160°E - 70°W).In a Similar way,the latitudinal index is given as:

$$I_{\varphi,\Delta t} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\varphi_{ij}\cos\emptyset_{ij}\delta_{ij,\Delta t}}{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\cos\emptyset_{ij}\delta_{ij,\Delta t}}$$

and the index of longitude$I_{\lambda,\Delta t}$is defined in similar manner.

4. Rsdult and disscussion

First we need to assess the dominant key drivers (COA indices, including pressure, latitude and longitude ofSouth Pacific High), ofSouth East Australia (SEA) precipitationby finding out the

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correlation ofrainfall at each grid point with these indices over SEA. For this we have to move in a 3 month window and then observe the driver that has strongest correlation in each 3 month season. The results are given below in Table1.

Table 1: Matrix of correlation for JJA Precipitation across South East Australia and Center of Action variables during 1951– 2008. Values significant at the 0.05 statistical levels are shown in bold.

COA Variables	SEA Rainfall
South Pacific High Pressure(SPHPS)	**0.277**
South Pacific High Longitude(SPHLN)	**0.417**
South Pacific High Latitude(SPHLT)	-0.070
SOI	**0.584**
Southern Annular Mode (SAM)	**-0.295**
Indian Ocean Dipole (IOD)	**-0.397**

The two variables that were found to have significant correlation with south east Australia precipitation are South Pacific high Pressure and South Pacific high Longitude.Table 2 shows the coefficient matrix to find the interdependencies among these variables.

Table 2: Matrix of correlationfor South Pacific High pressure, South Pacific High Longitude, Indian Ocean High Longitude, SOI andSouthern Annular mode, Indian Ocean Dipole (IOD) for JJA season during 1951–2008. Values significant at 0.05statistical levelsare shown in bold.

	South Pacific High Pressure(SPHPS)	South Pacific High Longitude (SPHLN)	Indian Ocean High Longitude (IOHLN)	SOI	SAM	IOD
South Pacific High Pressure(SPHPS)	1.00	0.054	-0.240	**0.537**	-0.015	-0.201
South Pacific High Longitude(SPHLN)	0.054	1.00	-0.193	**0.365**	**-0.386**	-0.194
Indian Ocean High Longitude(IOHLN)	-0.240	-0.193	**1.00**	**-0.327**	**-0.315**	**0.374**
Southern Oscillation index(SOI)	**0.537**	**0.365**	**-0.327**	1.00	-0.187	**-0.547**
Southern Annual Mode(SAM)	-0.015	**-0.386**	**-0.315**	-0.187	1.00	0.267
Indian Ocean Dipole(IOD)	-0.201	-0.194	**0.374**	**-0.547**	0.267	1.00

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The South Pacific High longitude and South Pacific High Pressure are mutually independent also Indian ocean high longitude was also significantly correlated with South East Australia (SEA) precipitation and independent to these two variables as mentioned in[12] so we construct a linear model of winter rainfall over SEA which yields:

$$\text{SEAprecip} = -4639.048 - 1.548(\text{IOHLN}) + 4.621(\text{SPHPS}) + 0.421(\text{SPHLN})$$

Here the value ofR2 is 0.319 that shows the influence of Indian Ocean high longitude, South Pacific high pressure and South Pacific high longitude on winter rainfall over south east Australia. Our result is consistent with the drying trend in South East Australian rainfall as mentioned earlier.

4.1. Physical Mechanism for the Relationship between South Pacific High and Rainfall

As we have seen the trend towards dryness in South East Australian rainfall is apparent in Figure 1. Also Table1 reveals that the rainfall is positively correlated with the South Pacific high Longitude consequently there is more rainfall in winter when South Pacific high Longitude was the highest is constructed and compared with composites obtained for the 10 winters in which South Pacific High Longitude was lowest. Using NCEP/NCAR reanalysis monthly averaged fields, the composite difference of vector wind at 500 mb and 850 mb between the ten winters when the SPH was located most to the east (more rain in SEA) and the ten winters when the High was located most to the west (less rain in SEA) is plotted in Figure2(a) and (b). We can see the wind flow from the Indian Ocean that brings moisture towards the east and its effects reaches in south east Australia.

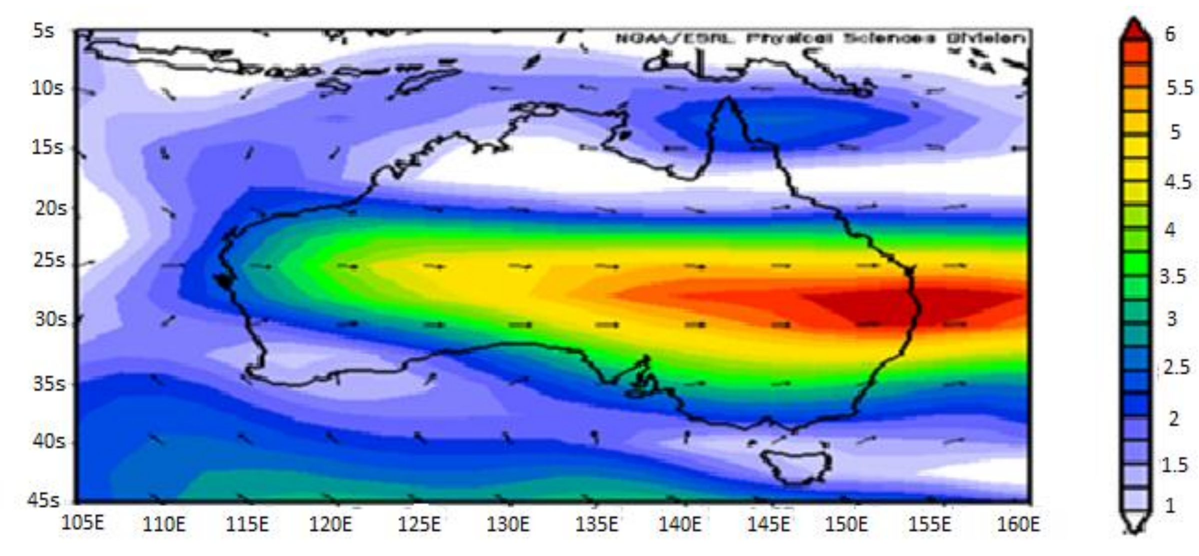

Fig 2(a): Composite difference of Vector wind (500 mb) forthe ten winterswhen the South pacific high was located most to the east and whenthe South Pacific High was located most to the west.

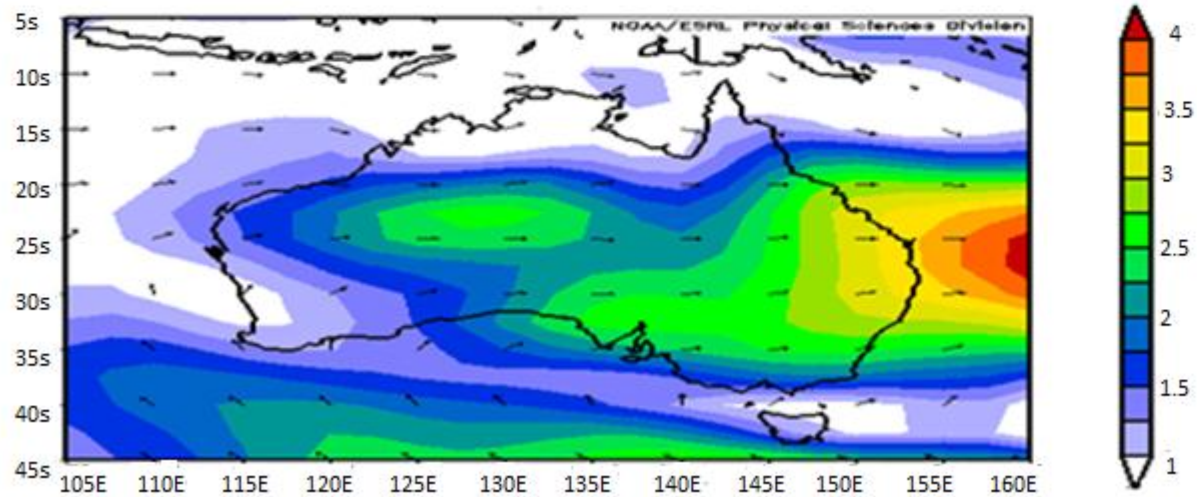

Fig 2(b): Composite difference of Vector wind (850 mb) between the ten winterswhen the South pacific high was located most to theeast and the ten winters whenthe South Pacific High was located most to the west.

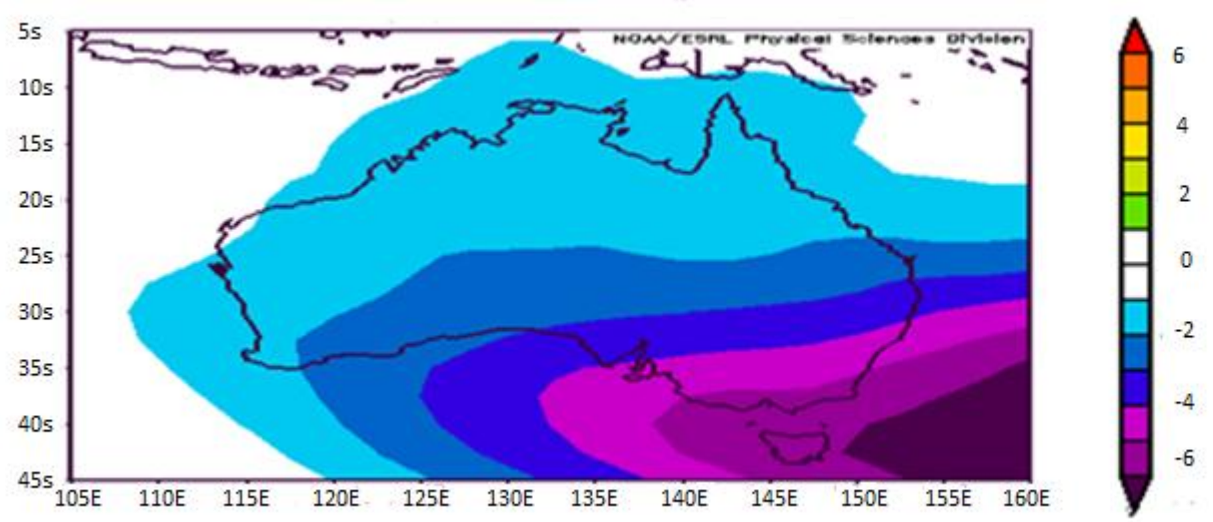

Fig 3: Composite difference ofPressure (surface) during 1951–2008, between the tenwinters When South Pacific High Longitude was maximum (more rain in SEA) and the ten winters when the South Pacific High Longitude was minimum (less rain in SEA) .

Also, Figure 3 shows the Composite difference of Pressure(surface)during 1951–2008, between the ten winters when South Pacific High Longitude was maximum (more rain in SEA) and the ten winters when the South Pacific High Longitude was minimum (less rain in SEA) ,in which low pressure is developed in our region which cause precipitation.

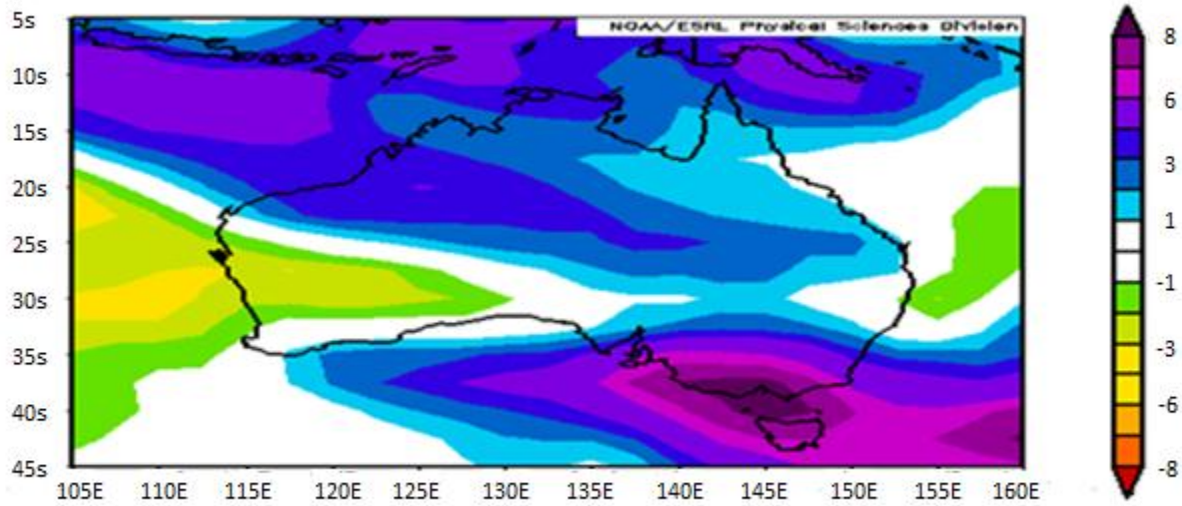

Fig 4: Composite difference of Relative Humidity (500mb) during 1951–2008, between ten Winters when South Pacific high longitude was maximum (more rain in SEA) and the tenwinter when the Southpacific high longitude was minimum (less rain in SEA).

Figure 4 shows that relative humidity was high when South Pacifichigh was maximum and the weather is less humid when South Pacific high is minimumso that the composite difference is positive i.e. 8% in SEA. The weather was more humid when the SPH was located most to the east (more rain in SEA) as was located most to the west (less rain in SEA).Finally, it is noted that the impacts of Zonal Movement of South Pacific High Longitude on SEA rainfall shows dominant seasonal variations. NCEP reanalysis data reveals that atmospheric circulation is uniform with our calculations.

5. Conclusion

Previous studies have determined that theIndian Ocean Dipole (IOD),El Niño – Southern Oscillation (ENSO), and the Southern Annular Mode (SAM) are the dominating factors that affect the climate of South Eastern part of Australia especially rainfall patterns. This paper has revealed this connection in terms of the kinetics of the IndianOcean and South Pacific High pressure systems that dominates atmospheric circulations which are the main cause to bring moisture in south eastern part of Australia.Specifically, it was observed that the shifting in the position of the subtropical Indian Ocean High and South Pacific high have significant impact on winter precipitation in South East Australia. The negative correlation shows that when the Indian High shifted to the east there is less rainfall across south east Australia and Positive correlation indicates that when the South Pacific High Pressure is minimum there is less rainfall .Similarly when the South Pacific High shifted to the west there is less rainfall observed and vice versa, (IOHLN, SPHPS and SPHLN) explain 31% variability of rainfall over SEA, it shows that the Indian High pressure in the winter has steadily increased and expanded since the 1950s which is the evidence of this dryness over the South East Australia. The pressure and the longitude of the SPH and IOHLN are independent so a statistical model of

JJA rainfall is presented by using the SPHPS, SPHLN and IOHLN. It explains 31 percent variability in observed rainfall. Our results suggest thatthis winter precipitation's variability across South East Australia is not only affected by the intensity of Indian Ocean High and South Pacific High pressure systems but it also depends on their zonal movements.

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Declaration

All these results are original and this paperis neither published nor under consideration elsewhere also, it has approved by all authors andif it is acceptedthen its copyright will be given to JOGSS.