REGIONAL DISASTER PROFILES IN THE SOUTH PACIFIC REVEALED BY THE SOUTH PACIFIC CONVERGENCE ZONE POSITION

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ABSTRACT

The present research seeks to investigate if disasters in Oceania could be explained by the South Pacific Convergence Zone (SPCZ) position and if future hazards could be observed in using the Data Integration Analysis System to provide a basis for discussion with scientific evidence for resolving the discrepancies between what is observed and what is projected. The results of this research shows that the SPCZ position strongly influences rainfall throughout Oceania, especially with drought and flood disasters in Fiji. Moreover, SPCZ position appears to influence cyclone genesis and track in the Southern hemisphere. Hence, SPCZ is an important indictor towards the onset of disasters in Oceania. Analysis of projected changes in Global Circulation Models (GCM) suggests that Fiji would become wetter during cyclone season while the North West and East of Oceania would become drier in accordance with SPCZ projection. Given the uncertainties in the GCMs with respect to cyclone, further research is needed in SPCZ position as possible proxy of disaster under the future climate.

Keywords: South Pacific Convergence Zone, Disasters, Oceania,

INTRODUCTION

Climate related disasters have been increasing globally, where it has been recognized that the Pacific region of Oceania have been the only geographic region in the world for having experienced increased vulnerability (Mucke *et al.* 2017). The Pacific region of Oceania consists of Island states, which is commonly referred to as Small Islands Developing States (SIDS). Given its remoteness, size and proneness to disasters, SIDS faces special challenges with respect to sustainable development and resilience.

Discrepancies in what is observed and what Global Circulation Models (GCMs) projects poses challenges to policy makers in the region (IPCC, 2014). Thus, there is a need to understand how disasters in Oceania are caused and to identify if there exists any climatological indicators that could be linked with disasters. Previous studies in Fiji's rainfall suggested that the South Pacific Convergence Zone (SPCZ) greatly influence Fiji rainfall (Kumar et al, 2014).The movement of the SPCZ have been described by the SPCZ Index (SPCZI) which was formulated by Salinger et al. (2013) and Vincent et al. (2009) classified four position of the SPCZ as shown in Figure 1.

The study area is located in the South Pacific region in which the Island countries are divided into three segments. The South West segments consists of Vanuatu, Fiji and Tonga, and the North West segment includes Tuvalu and Samoa while Cook Island and Tahiti constitute the East segment.

The purpose of this study is to examine if disasters can be explained by SPCZ and to examine if such hazards could be projected towards the future under climate change. In all this research tries to provide basis for discussions based on scientific evidence.

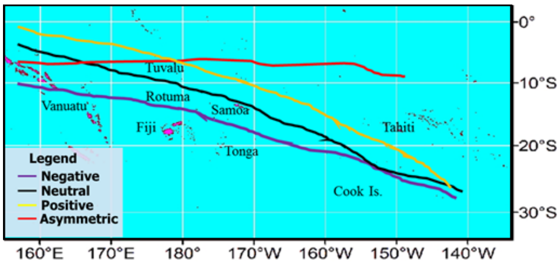

Figure 1. The study area with respect to SPCZ position

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METHODOLOGY AND DATA

General Overview

The approach of this research is to link the climatological hazards in the SIDS by comparing what was observed to SPCZ movement and position from previous studies. In line with the objective of this study, understanding the mechanism of the climate system is essential for sustainable development, as it provides awareness on risks that needs to be considered when formulating developmental policies and projects. This study also examines possibility to project future hazards in the South Pacific under the future climate by utilizing the state of the art earth environmental data analysis system. Detailed description other than following section can be found in the main body of the master thesis.

Regional Damage Analysis

The analyzed disaster statistics of the seven countries in the study area with respect to economic loss and mortality was download from the Prevention Web database (https://www.preventionweb.net) and analyzed in a pie chart to reveal the past disaster profiles of each segments.

Rainfall Analysis: Ground and Reanalysis Data

The ground rainfall data was obtained from the Fiji Meteorological Services while the Reanalysis rainfall data for the other six island countries were obtained from the Japanese 55 years Analysis Project (JRA55). Both dataset were analyzed using the same methods; the annual sum precipitation with 10 moving average and annual rainfall anomaly was calculated using R software. The moving average was calculated by consecutively averaging the annual rainfall by a factor of 10 years whereas the rainfall anomaly was calculated by subtracting the monthly total rainfall to the long term (58 years) monthly mean. Both analysis outputs were compared and related to past SPCZ movement which are available in aforementioned literatures of SPCZI with SPCZ position respectively.

Cyclone Analysis

The cyclone tracks was downloaded from the International Best Track Archive for Climate Stewardship (IBTrACS) database (https://www.ncdc.noaa.gov/ibtracs/) in which the tracks within the study area was extracted. The cyclone tracks were visualized using the source code written by Strazzo *et al.* (2013) in R to visualize cyclone genesis and tracks via a hexagonal grid.

Climate Change Analysis

The ground rainfall data from Fiji was used also for bias correction of the GCMs using the Data Integration Analysis System (DIAS). Five well performed models was then selected to analyze projected future changes in rainfall within Fiji (see thesis). In addition the Global Precipitation Climatology Project (GPCP) dataset was used to visualize SPCZ and as reference data to analyze the GCMs performance with respect to spatial correlation, where three well performed models were selected. The three selected models was then used to project future changes in the SPCZ position.

RESULTS AND DISCUSSION

Past Disaster Profile

The vulnerabilities of SIDS towards climate related disaster are clearly outlined on the breakdown of disasters and its contribution towards economic loss and mortality. From the three segments, high economic loss was a result of disasters caused by cyclones where it contributed more than 80% of losses in the three segments except for Fiji in the South West segment, where economic loss was a result of cyclones (60%), Flood (28%) and drought (12%).

Lives lost due to disasters varies among segments, in the South West segment, mortality in Vanuatu and Tonga were mostly caused by geo-hazard disasters such as Tsunami and Earthquake, which was similar to Samoa in the North West segment. The East segment mortality were mostly caused by climate related disasters such as cyclones and landslides caused by extreme rainfall. Climate related disasters was also the main cause of mortality in Fiji, where like its economic loss tropical cyclone (63%) and floods (23%) contributed significantly to mortality. Moreover unlike other SIDS which mainly have to consider cyclones, Fiji has to consider cyclones, flood and drought with respect to mortality and economic loss.

Rainfall trend in Fiji

The decadal rainfall patterns in all the three divisions in Fiji appears to be the same (Figure 2). However, Rotuma, located 646 km north from the main land, appears to have an opposite pattern. An almost alternating pattern could be observed between Fiji and Rotuma. Such pattern could be explained by the SPCZ movement that during the mid-1940's to mid-1970's the SPCZ was displaced South West in the late 1970's the SPCZ was displaced North East (Folland *et al.* 2002). Analysis of rainfall anomaly shows that Fiji rainfall anomaly (Figure 3a) appears to be inversely related to SPCZI while in Rotuma (Figure 3b)

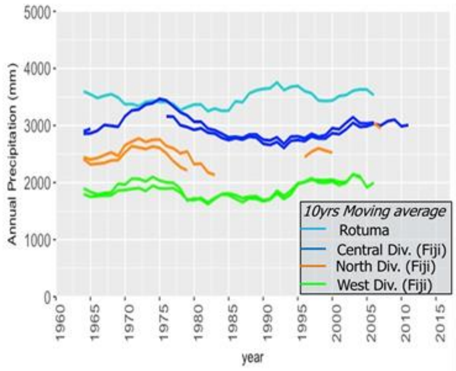

Figure 2. Ten year moving average comparison between Fiji and Rotuma

a) b)

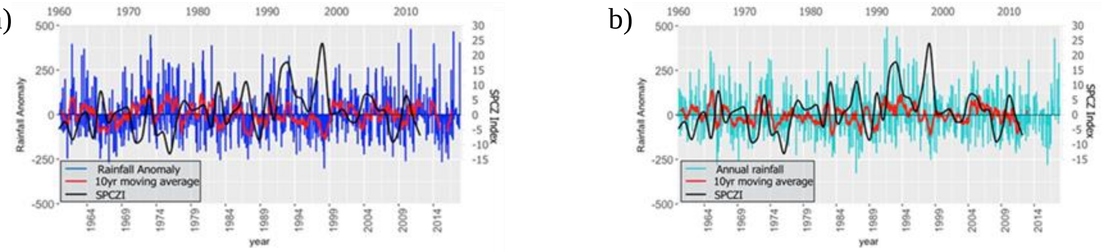

Figure 3. Rainfall anomaly and SPCZI in a) Fiji and b) Rotuma

follows similar patterns as the SPCZI except during 1998 when SPCZ was further North. Thus, suggesting that SPCZ affects SIDS differently with respect to their geographic location.

Rainfall trend in SIDS

The SIDS decadal rainfall pattern appears to show similar trends observed in Fiji and Rotuma. The South West segment follows the same trend as Fiji while the North West segment follows Rotuma, the East segment on the other hand shows mixed trends since Cook Island and Tahiti are located on the bounds of the three SPCZ position (*see thesis*). However, variation appears to exist within segments, for instance the in the North West segment Tuvalu's decadal pattern appears to be decreasing in 1985 (Figure 4a) while during the same period Samoa's (Figure 4b) decadal trend appears to increasing. The declining Tuvalu pattern coincides with the negative SPCZ position in which the SPCZ is further South whereby Samoa is still in close proximity to the SPCZ during such event as compared thus the variation in the trend. Moreover during Asymmetric years (1998) Tuvalu appears to be less affected as heighted in its rainfall anomaly with SPCZI (Figure 5) as compared to other SIDS (*see thesis*), since it's located close to the SPCZ at such events.

a) b)

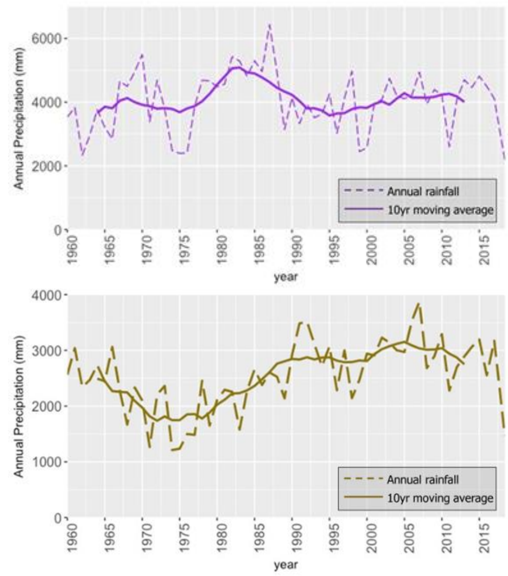

Figure 4. Variation in decadal patterns

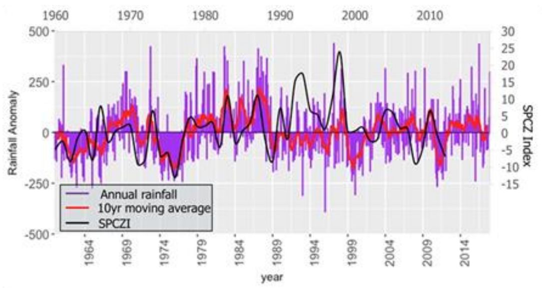

Figure 5. Tuvalu rainfall anomaly and SPCZI

Tropical cyclone genesis and track

The Position of the SPCZ appears to influence the cyclone genesis and cyclone track in the Southern hemisphere. During negative position of the SPCZ cyclones appears to form southwards and the track appears to be concentrated in the South West segment (Figure 6a), whereby the North West and East segments tend to be less affected during such event. However, for the South West segment, Vanuatu seems to receive more cyclones as compared to Fiji and Tonga.

During neutral position, cyclone formation tends to be concentrated towards the North West segment, where both North West and South West segments receives more cyclones compared to the East which appears to be less affected (Figure 6b).

The positive position shows similar cyclone genesis patterns to those observed in the neutral SPCZ position. However it is more scatted in distribution. The cyclone tracks appear to be more focused on the South West and North West segment. It is important to note that cyclone tracks appears to be more concentrated as well on the lower portion of the Eastern segment (Figure 6c).

During Asymmetric position of the SPCZ, cyclone genesis appears to be concentrated northwards and the cyclone tracks appears to affect all segments of the study area (Figure 6d). The study carried out by Vincent *et al*. (2009) shows that the mean cyclone genesis location was influenced by the position of the SPCZ. This research also includes cyclone tracks which also appears to be influenced by the position of the SPCZ. For instance, no cyclone was observed to travel northwards of the SPCZ, it only travels down south of the SPCZ as outlined in Figure 6a to Figure 6d.

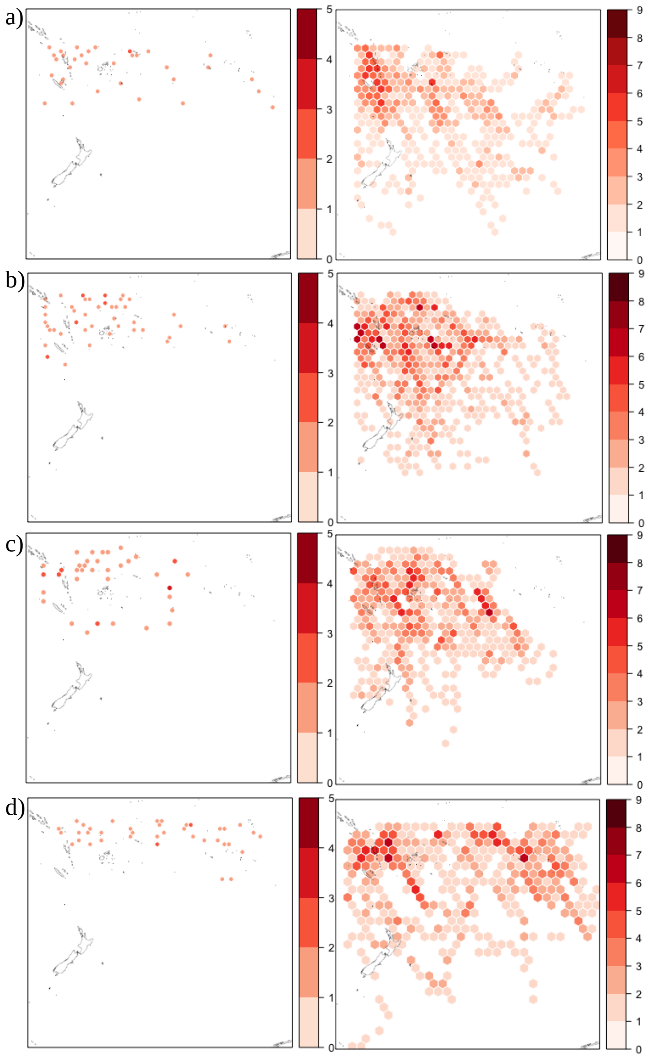

Figure 6. Cyclone genesis and track when SPCZ position is a) Negative, b)Neutral, c)Positive and d) Asymmetric

Table 1. SPCZ position with passing cyclones

	SOUTH WEST			NORTH WEST		EAST	
	Vanuatu	Fiji	Tonga	Tuvalu	Samoa	Cook Is.	Tahiti
Negative	5	2	3	0	3	1	2
Neutral	11	10	0	0	5	2	0
Positive	11	12	9	6	0	5	0
Asymmetric	25	16	0	2	4	3	31

Table 1 summarizes the number of passing cyclone in each segment during each SPCZ position. The table clearly shows the well-established relationship that cyclones only travels southwards of the SPCZ, for instance during Negative and Neutral positions Tuvalu is situated Northward with respect to the SPCZ. Hence during such position no cyclones passed near Tuvalu. However, during Positive and Asymmetric position cyclone passed near Tuvalu since it's located more southward with respect to the SPCZ. Moreover during Asymmetric position, cyclones became more prominent in Tahiti as Vincent *et al.* (2009) described, with accordance to Table 1 about 31 cyclone appears to pass near its territory

Table 2. Fiji Disaster damage cost with SPCZ position

SPCZ Position	Damage cost due to disasters
Negative	1999: Cyclone – US$3.5 million
Neutral	No major damages recorded
Positive	1990: Cyclone – US$38 million, Flood – US$18 million 1993: Cyclone – US$100 million, Flood – US$95 million 1995: Cyclone – US$19 million, Drought – US$60 million
Asymmetric	1983: Cyclone – US$35 million, Flood – US$75 million 1998: Drought – US$165 million

Disasters in Fiji with SPCZ position

The past disaster profile in SIDS indicates that with respect to climate related disasters, Fiji need to consider cyclone, flood and drought while the rest of the Island countries mostly have to consider cyclones. The previous sections clearly outline the influence of SPCZ position with respect to rainfall and cyclones. Figure 7 shows the influence of SPCZ position with respect to disaster damage cost in Fiji where from the four SPCZ positions, high damage cost (US$19-US$165) were mostly associated with Positive and Asymmetric positions where cyclones, flood appears to be more prominent.

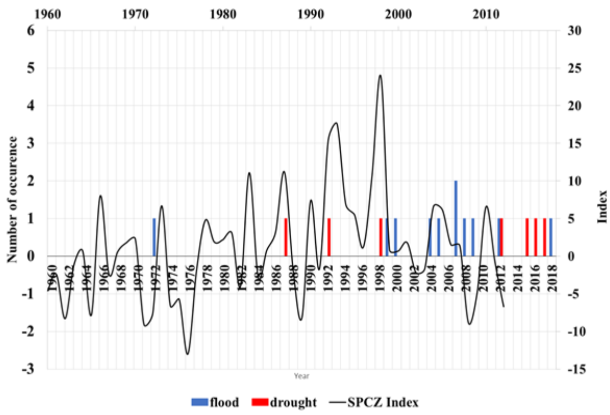

Figure 7. SPCZI in relation to flood and drought in Fiji

Furthermore, the Flood and drought disaster in Fiji could be related to the SPCZI, Figure 7 shows that drought becomes more prominent when the index is more than 10, while Flood occurrence become common when the SPCZI is below 10. The SPCZI and the four positions of the SPCZ shows clear relations to disasters in Fiji as highlighted in Table 2, whereby cyclone and flood appears to occur simultaneously, given that cyclones are usually associated with heavy rainfall as stated by Kumar *et al.* (2014), thus resulting in flooding in low lying areas.

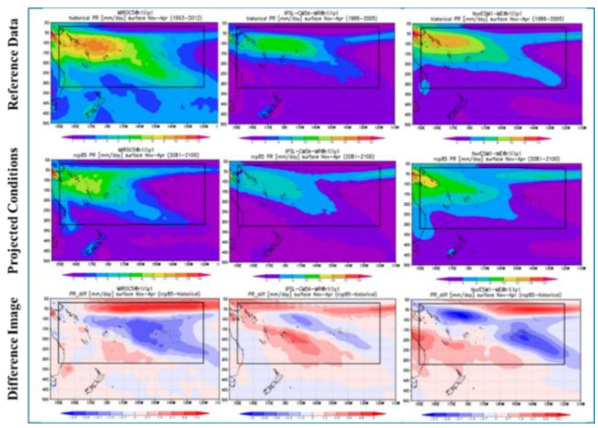

Figure 8. GCM projected November to April SPCZ position

Projected SPCZ in Oceania

The SPCZ position has been identified in previous sections to play a vital role in climate related disasters in Oceania. With respect to climate change Figure 8 shows the projected SPCZ position for the years 2081-2100 from three GCMs under the RCP8.5 scenario, where emissions continues to rise throughout the 21st century. MIROC5, IPSL-CMSA-MR and NorESM1-ME models all show similar results, where the SPCZ appears to be more closely located South East during the November to April month. The differences indicates that the South West segment of the Study area would become wetter during this months, while the North West and East segment would become drier. The November to April projection of the SPCZ clearly links with the projected increase in rainfall in Fiji by using bias corrected GCM with gauged data, where rainfall during the same months tends to increase during the same time period (*see thesis*).

CONCLUSION AND RECOMMENDATION

The South Pacific Convergence Zone has been identified from this research to be a key indicator for disasters in SIDS of Oceania. Rainfall as a flood and drought proxy in Fiji is strongly influenced by the movement and position of the SPCZ, the same was observed throughout Oceania in using reanalysis rainfall data (JRA55). Considering the past disaster profiles, countermeasures needs to be considered by island basis where the SPCZ can be used as a potential tool for effective and efficient planning, and designing of sustainable development projects among SIDS with varying vulnerability, especially for flood and drought in Fiji, and cyclones throughout SIDS.

Moreover, it is important to note that although flood and drought was only observed in Fiji's past disaster profile, the statistics used only considers economic loss and mortality, with regard to smaller Island in the region, SPCZ is likely to affect their fresh water resources and thus impacting livelihood with respect to water and food security. Furthermore this research provides a strong basis for SIDS policy makers and researchers from various disciplines to re-engage in the discussion of SPCZ given its prominence in the South Pacific region, as it may hold a key towards a sustainable development approach in Oceania and most importantly its contribution towards disaster risk reduction.

Further studies and analysis is needed in the present climate condition to clarify SPCZ and hazards in the South Pacific. For instance, SPCZ forecasting would provide valuable information to SID policy makers in terms of disaster preparedness logistics such as water management strategies and food security which will contributes to resilience and adaptation at all levels in the face of changing environmental conditions. In addition, due to GCM uncertainties, discrepancies in projecting future cyclones remains a challenge. Therefore the analysis of projected changes in SPCZ and its statistical analysis can be used as a proxy rather than directly focusing on cyclone genesis as conducted in previous studies.

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