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Analysis of Tropical Cyclone Rapid Intensification in the Southwest Pacific Region

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Abstract

This study statistically investigates the characteristics of tropical cyclones (TCs) undergoing rapid intensification (RI) in the Southwest Pacific (SWP) region in the 37 years from 1986 to 2022. Among 364 TCs, 82 rapidly intensifying TCs (RI-TCs) were defined as TCs that experienced maximum wind speed increase of 30 kt (15.4 m s^{-1}) or more in a 24-h period. RI-TCs are frequently observed over the zonally elongated area around coral sea, south of Solomon Islands (Solomon Sea), Vanuatu, Fiji, Tuvalu, Tokelau and Samoa. Frequency of RI-TC occurrence shows a slowly increasing trend over the 37-year period. However, this increasing trend was not statistically significant at the 95% confidence level. In El Niño years, TCs tend to undergo RI more frequently presumably due to the average genesis to the further north where sea surface temperature (SST) and ocean heat content were high. In contrast, RI-TCs occurred less frequently during La Niña years. The RI onset typically occurs 0–42 h after TC genesis with a peak frequency observed just after genesis (0–6 h). The RI duration is usually 1–2 days with a peak at 24 hours. The mean lifetime of RI-TCs lifetime was 7.86 days, longer than that of non-rapidly intensifying TCs (NR-TCs) (3.72 days). In terms of average intensity, RI-TCs have significantly lower lifetime central pressure and higher lifetime maximum wind speed than NR-TCs. RI-TCs tend to develop into more severe TCs as a result of formation in environments favorable for TC development such as weak vertical wind shear, deep moist layer, high SST and TC heat potential.

Introduction

One of the great challenges for disaster prevention associated with intense TCs is the prediction of rapid intensification (RI) (Rappaport et al. 2012; Smith et al. 2015; Ito 2016). The statistical characteristics of RI-TCs around the SWP region have never been investigated according to the authors' knowledge.

The main objectives of this study are (1) to examine the distribution and annual changes in RI-TC activity (e.g. if RI occurrence trend has increased or not) over the 37 years from 1986 to 2022 and (2) to investigate the characteristics of RI-TCs associated with the large-scale environmental parameters that influence RI, including both atmospheric and oceanic features.

The final form of this study was accepted on 25 December 2024 for publication in Journal of the Meteorological Society of Japan.

Data and Method

This study is based on the Southwest Pacific Enhanced Archive for Tropical cyclones (SPEArTC) best track (BT), which is a six-hourly dataset from 1986 to 2022, as described by Diamond et al. (2012).

The monthly El Niño Southern Oscillation (ENSO) indexes were obtained from BoM (available at http://www.bom.gov.au/climate/enso/soi/, accessed on 30 October 2024). The specific humidity, air temperature, geopotential height, zonal and meridional wind datasets were taken from the Japanese 55-year Reanalysis (JRA-55; Kobayashi et al. 2015) (details available online at http://jra.kishou.go.jp/JRA-55/index_en.html).

As for oceanic data, SST was taken from the delayed model version of Merged Satellite and in-situ data Global Daily Sea Surface Temperature (MGDSST) (Kurihara et al. 2006) and TC heat potential (TCHP) was taken from Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan Coastal Ocean Predictability Experiments- Forecasting Global Ocean (JCOPE-FGO) (Kido et al., 2022).

We calculated statistical summaries and significant differences between RI-TCs and NR-TCs in the following physical parameters: magnitude of VWS, atmospheric relative humidity, SST and TCHP (1) within the radius of 300 km and (2) within an annulus of 200–800 km from the TC center.

Results

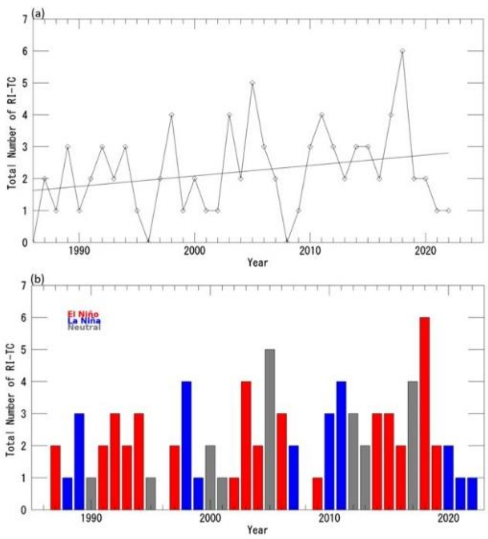

Fig. 1. (a) Number of RI-TC occurrences per year over the 37-yr analysis period. Regression for each dataset is represented by a thin line. (b) the same as (a), except it shows the total number of RI-TC formed during each ENSO condition, (blue) La Niña, (red) El Niño and (grey) Neutral.

Table 1. Statistical summary of oceanic environmental physical parameters around RI-TCs (RI) and NR-TCs (NR), and their sum (All), over the 37-yr analysis period. If differences from grand means are statistically significant at the 95% confidence level in a two-tailed *t*-test, the values are marked in italics red. The numbers without parentheses are the differences calculated at 200-800 km around the TC center, while the numbers in parentheses are the differences calculated at 0-300 km around the TC center.

		RI	NR	ALL
Genesis time	SST (°C)	*29.03 (29.10)*	*28.30 (28.4)*	28.47 (29.79)
	TCHP (kJ cm^{-2})	*70.75 (73.06)*	*50.93 (50.81)*	55.70 (56.16)
Mature time	SST (°C)	*28.06 (28.12)*	*27.52 (27.58)*	27.64 (27.70)
	TCHP (kJ cm^{-2})	*44.23 (44.77)*	*34.65 (31.12)*	36.96 (34.42)
Decay time	SST (°C)	*21.87 (19.75)*	*24.70 (24.41)*	24.07 (23.36)
	TCHP (kJ cm^{-2})	*11.23 (7.76)*	*19.71 (14.97)*	17.66 (13.22)

Table 2. As in Table 1, but for environmental physical parameters around RI-TCs and NR-TCs, and their sum (All), over the 37-yr analysis period.

		RI	NR	ALL
Genesis time	RHLO (%)	79.53 (85.06)	78.57 (85.89)	78.45 (85.70)
	RHMD (%)	*73.19* (83.77)	*71.19* (83.42)	71.64 (83.50)
	VWS (m s^{-1})	*13.02 (9.8)*	*16.76 (11.74)*	15.92 (11.34)
Mature time	RHLO (%)	77.57 (87.89)	77.45 (87.09)	77.48 (87.27)
	RHMD (%)	69.56 (87.18)	69.02 (85.17)	69.14 (85.62)

References

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