Global Trends in Duration and Volume of Rapid Intensification Events

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1. Introduction

Rapid intensification (RI) of tropical cyclones (TCs) remains one of the major challenges in hurricane modeling and forecasting. Several studies have been conducted by the scientific community to find the potential connections between the RI events and a warming climate, suggesting an overall increase in their frequency (Klotzbach et al. 2022, Bhatia et al. 2022, Manikanta et al. 2023, Li et al. 2023). This study introduces the concept of rapid intensification volume (RIV) to quantify the combined effects of duration and intensification magnitude. For the duration component of the RIV analysis, we adopted the definitions of RI event and RI case suggested by Tao et al. (2017) and Kieper and Jiang (2012), as well as their approach to characterize the life cycle of the entire RI event, including the phases before, during and ending.

The trends of RI events are presented in light of their RIV occurrences across all global basins and all TC intensity categories (including tropical depressions) through the analysis of 40 years of best-track data(1982-2022). Preliminary results show that RIV is slightly increasing globally. Regarding basin activity, the RIV increasing trend is more pronounced in the North Atlantic and South Indian Ocean. Further analysis of the RIV components suggests that the increasing trend is more attributed to intensification gradients than variation in the RI duration.

2. Motivation

Based on the use of 4 decades of filtered Best-Track information, the motivation of this study is to answer the following scientific questions:

- Are the duration and the magnitude of RI events increasing as part of the effects of a warmer climate?
- How do the duration and magnitude of RI events vary across global TC-prone basins?
- Considering the full life cycle of an RI event, is any phase particularly affected by the increasing trends in RI?

3. Data and Method

Data:

- Four (4) decades of filtered Best track records from the IBTrACS (version 4, Knapp et al. 2018). We used both the original 6-hourly and the intermediate interpolated 3-hourly values.
- Environmental conditions around the storms are obtained from the Statistical Hurricane Intensity Prediction Scheme (SHIPS, Last updated: April 2024) developmental dataset, which includes 6-hour retrievals of observational and derived data over various annular regions calculated from the TC center (DeMaria and Kaplan 1994, 1999; DeMaria et al. 2005; Schumacher et al. 2013)

Table 1. Number of RI events and cases in different basins (1982 – 2022)

	ATL	EPA	NWP	NIO	SIO	SPA	TOTAL
Event	**230**	**327**	**569**	**50**	**297**	**179**	**1652**
Cases	**1194**	**2124**	**3849**	**379**	**1866**	**1085**	**10497**

Table 2. Number of single vs. multiple RI events per basin (1982 – 2022)

	ATL	EPA	NWP	NIO	SIO	SPA	TOTAL
Single	**143**	**245**	**343**	**42**	**196**	**115**	**1084**
Multiple	**41**	**32**	**107**	**4**	**46**	**30**	**260**

Note: Multiple events could be dual, triple, or quadruple

Method

- 24-h intensity changes (ΔV24) are calculated as the difference in Vmax of TC over every 24-h period (Future 24h minus current)
- Each 24-h period with an intensity variation ≥ 30 kt is defined as a RI case
- Consecutive RI periods (overlapping), are grouped together into a RI event
- RI length is defined as the time delta (Δt) between the first and the last RI case within an RI event.
- We define single-RI TCs as those who have undergone RI only once in their lifetime.
- A TC is considered multiple-RI if it features more than one RI event separated by a non-RI or negative 24-hour intensity change.
- For each RI case/event we calculate the Rapid Intensification Volume (**RI_Volume = Delta time * Vmax**)

Rapid Intensification Life Cycle Definition

The studies using the RI case-based-only definition have a problem of not being able to place the individual case within the context of the entire RI event. Therefore, in this research, we followed the method from Tao et al. (2017), in which we can distinguish between stages of an RI event, including before RI onset, at or around RI onset, during the middle (or continuing stage) of an RI event, and the ending period of an RI event.

4. Rapid Intensification Volume

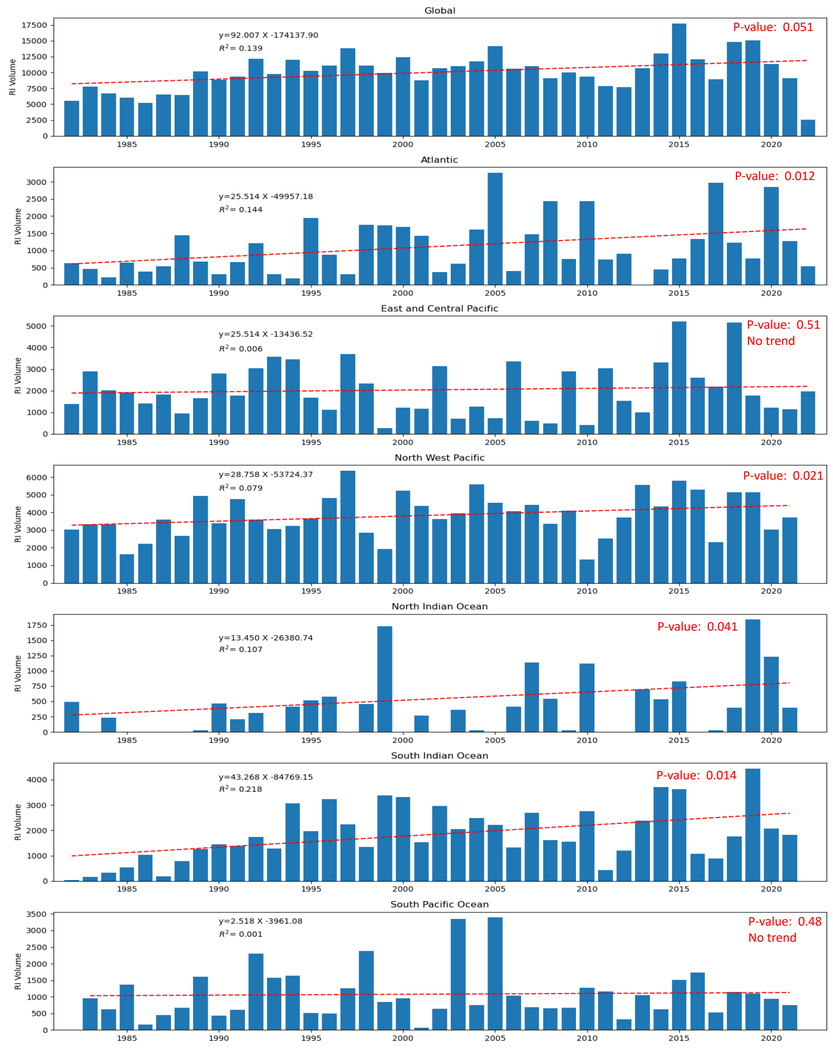


Figure 1. Time series of Rapid Intensification Volume over global basins. All panels show increasing trends for the period from 1982-2022. Trends in Global, Atlantic, Northwest Pacific, North Indian Ocean, and South Indian Ocean are statistically significant (>99%). However, trends in the South Pacific and East-Central Pacific are not statistically significant.

5. Duration of Rapid Intensification events

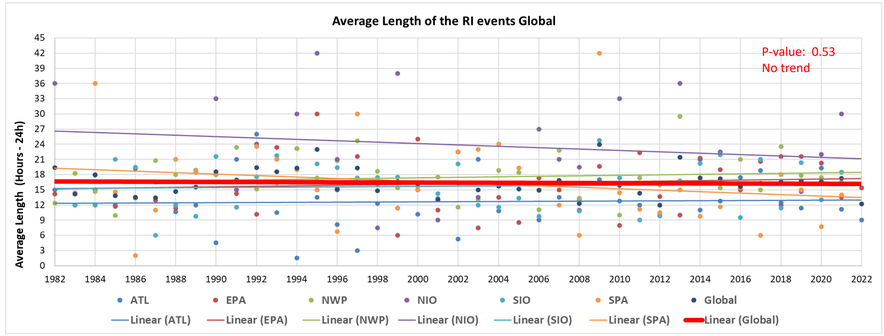


Figure 2. Time series of the averaged duration of Rapid Intensification events over global basins. Linear regressions for each basin and the overall trend are shown. No apparent indication of an increase or decrease is observed, suggesting that the duration of RI events has remained stable over the last four decades.

6. Trends in the Sea Surface Temperatures

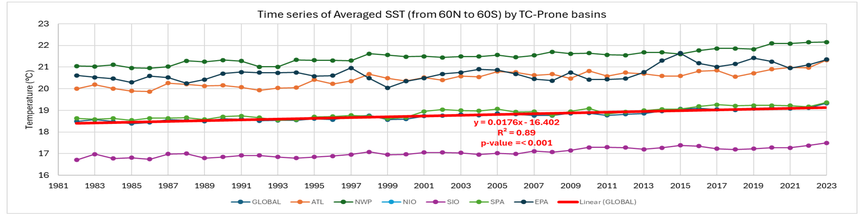


Figure 3. Time series of averaged Sea Surface Temperatures over global basins. Linear regression for global trends is shown in red. Increasing trends are statistically significant for all basins (>99.9%). Temperatures on the y-axis calculated from Reynold's SST (OISST Version 2)

7. Summary and Conclusions

The trends of Rapid Intensification events are presented across all global basins and all TC intensity categories (including tropical depressions) through the analysis of 40 years of best-track data(1982-2022). Results show that Rapid Intensification Volume (RIV) is increasing globally.

Regarding intra-basin activity, the increasing trend of RIV is more pronounced in the North Atlantic and South Indian Ocean, while in contrast, East & Central Pacific and South Pacific do not exhibit any trend at all.

Further analysis of the RIV components (Magnitude and duration) suggests that the increasing trend is more attributed to intensification magnitude than variation in the RI duration. In fact, time series of duration lengths do not show statistically significant trends.

Analysis of Sea Surface Temperatures across global basins exhibits statistically significant increasing trends (SHIPS and OISST), which explains the rise of the RIV in most TC-prone basins. However, further environmental condition analysis is necessary since the relationship between SST and RI is not homogeneous, particularly in the East & Central Pacific and the South Pacific basins, where the RI events do not show trends at all.

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