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A Climatology of Rapidly Intensifying Tropical Systems over the Southwest Indian Ocean

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The southwest Indian ocean (SWIO) has been poorly studied so far despite a similar TC activity to that of the North Atlantic. Under the responsibility of RSMC La Réunion, tropical systems that form in this area strike vulnerable islands such as Madagascar (22 million inhabitants with very fragile infrastructures and an agriculture-dominated livelihood) or the Mascarene islands that include La Réunion (840 000 inhabitants) and Mauritius (1.2 million inhabitants). To support international efforts toward the improvement of TC prediction, it is important to characterize the present-day TC activity over the SWIO in light of intensively-studied basins such as the North Atlantic.

Acronyms

CI	Dvorak Current Intensity
NA	North Atlantic
RI	Rapid Intensification
RSMC	Regional Specialized Meteorological Center
SWIO	Southwest Indian Ocean
TD	Tropical Depression (VMAX < 17 m s^{-1} or 34 kt)
TS	Tropical Storm (VMAX $>= 17$ m s^{-1})
TC	Tropical Cyclone (VMAX $>= 33$ m s^{-1} or 64 kt)
ITC	Intense Tropical Cyclone (VMAX $>= 46$ m s^{-1})
VITC	Very Intense Tropical Cyclone (VMAX > 59 m s^{-1})

Methodology

1. & 2. Statistical analysis of TC activity (part 1.) and of 24-h intensity changes (part 2.), using a 15-year (1999-2014) homogeneous database from RSMC La Réunion.
3. Investigation of the large-scale dynamic and thermodynamic conditions conducive for rapid intensification (RI) in the SWIO, using the Era-Interim dataset.

The methodology is that used for the Atlantic [1] and eastern North Pacific [2] to allow for basin inter-comparisons. To be analyzed at a given time t, a system must:

- be tropical
- have reached at least the TD stage
- be over water to ensure the Dvorak technique is valid

1. SWIO climatology

173 tropical systems formed over the 1999-2014 period. Each year on average:

- 9.3 / 11.5 systems develop into TSs.
- 4.9 of those go on to become TCs.

This is about 11% of global tropical activity and almost equals the NA activity [3].
The official TC season runs between 1 November and 30 April but the basin sees activity from September to June.

2. RI climatology

RI thresholds (24-h intensity change)

1. RI is defined by $\Delta V_{24} \geq 15.4$ m s^{-1} or 30 kt (94.4^{th} percentile of the cumulative frequency distribution of **24-h maximum wind speed changes**)
2. RI can also be defined by $\Delta P_{24} \leq -25hPa$ (resp. -45 hPa) corresponding to the 5th (resp. 1st) percentile of 24-h pressure changes.
3. RI also corresponds to $\Delta CI_{24} \geq +2.0$ (resp. $+2.5$ CI) using the 96.5^{th} (resp. 99th) percentile of 24-h Dvorak CI changes.

The ΔV_{24} threshold equals that of the NA basin [1, 2] but we used 10 min average winds instead of sustained winds so RI would correspond to a higher 24-h intensity change in the SWIO based on a 0.88 conversion factor.
This result must be put into perspective knowing that the NA dataset benefits from aircraft reconnaissance inputs and, thus, more reliable wind speed data. The ΔP_{24} threshold can be compared to the minimum 24-h pressure fall of 42 hPa found in the western North Pacific [4]. The ΔCI_{24} threshold is almost twice the climatological intensification rate of tropical systems defined by the Dvorak technique.

RI distribution

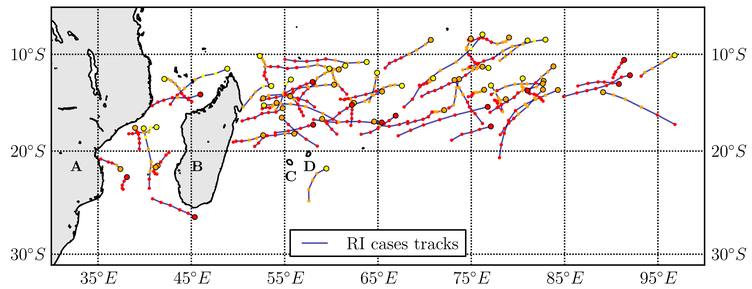

FIG. 1: *24-h tracks of all RI cases during the 15-year period; black circles indicate the start of each track; TDs are drawn in yellow, TSs in orange, TCs in red. Letters A, B, C, D indicate Africa, Madagascar, Reunion and Mauritius islands.*

Overall, 39% of all SWIO tropical systems underwent RI. 12% of systems that attained the TS stage, 41% of systems that attained TC intensity, 91% of ITCs and all VITCs underwent RI at least once during their lifetime. However, systems that did not exceed the TD stage never experienced a RI period. RI occurs preferably in March and April for TCs, coinciding with the end of the warm season when SSTs are maximized. The probability of RI for TDs decreases from November to April, suggesting that the large-scale atmospheric environment may play a more important role than ocean factors in inducing RI for tropical systems at the depression stage. RI cases are rather evenly distributed from $50°$ to $85°$E and confined within the $10-20°$S latitude band with a main west-southwestward track (Fig. 1). Very few RI cases occur southward of $20°$S, except in the Mozambique channel. The probability of RI as a function of the initial maximum wind speed of the system (Fig. 2) highlights a bimodal distribution with two peaks at 40–55 and 60–75 kts.

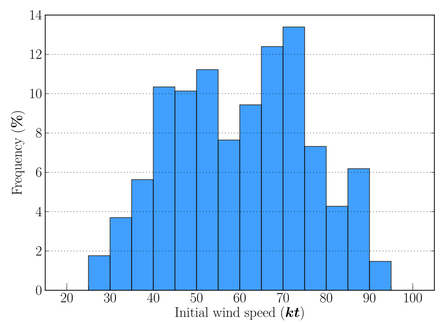

FIG. 2: *The frequency of RI (number of cases per 5-kt bin over the total number of RI cases) as a function of the maximum wind speed of systems at $t = 0$ h.*

3. Large-scale conditions associated with RI

An analysis of the dynamic and thermodynamic environmental fields in the 24-h intensification periods (in a 200–800-km region surrounding the storm center) using ERA-Interim data revealed five potential RI predictors (Fig. 3). For each of them, statistically significant differences are found to exist between the means of the RI and non-RI samples at the 99.9% level using a two-sided t test, after adjusting both sample sizes for serial correlation between cases [5].

RI predictors are: the previous 12-h change in maximum wind speed (DVMXM12), a high 200-hPa divergence (DIV200), a weak 850–200-hPa vertical wind shear (SHR), a high sea surface temperature in a 200-km radius surrounding the storm center (SST), and a weak upper-level cyclonic potential vorticity (on the 350-K isentrope, PV350). The storm's center latitude also showed statistically significant differences, but at the 99% level.

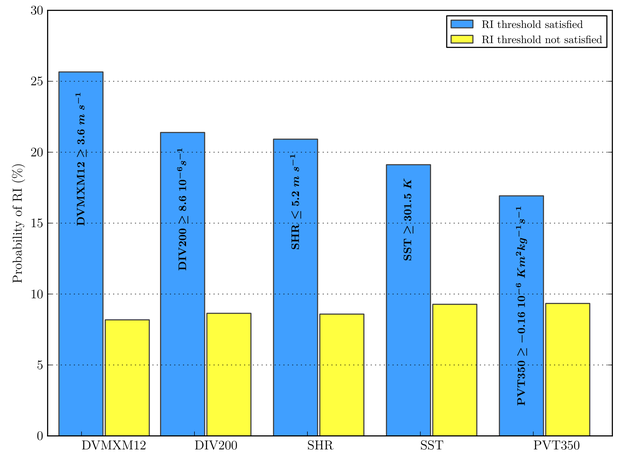

FIG. 3: *The probability of RI when the specified predictors (X-axis) were satisfied (blue) or not (yellow) for the whole sample. RI thresholds for each variable (in blue columns) were determined as their means in the RI sample. To illustrate, RI occurred 25% (8%) of the time when DVMXM12 was above (below) the 3.6 m s^{-1} threshold.*

Conclusions and perspectives

→ Further analyze the distribution in Fig. 2 and understand whether it results from a real atmospheric process driving RI or whether it is induced by the Dvorak technique application with satellite images that do not give the same amount of detail at different storm intensities (e.g., prior versus after eyewall formation).
→ Develop a statistical-dynamical tool for estimating the probability of RI using best multilinear regression of the most relevant environmental RI predictors over the basin and test it over the next cyclonic seasons.
→ Conduct the same study over the 1979-201X period to address climate change issues, as soon as the reanalysis project for TC intensity in the SWIO basin is completed by RSMC La Réunion.

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