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# The Potential of Rip Current Formation Using Google Earth Pro Platform - A Case Study at West Coast of Sabah, Malaysia

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**Abstract** A rip current is known as rapid offshore-directed, narrow, intense jets of water originating from the surf zone and broadening towards the wave-breaking zone. Its formation can be a combination of wind, waves, and variations of bathymetric features. The rip contributes to one of the major coastal hazards in the world but lack of rip reports in the coastal areas of Sabah, Malaysia. The objectives of this study are to analyze the potential rip current area from satellite images and to determine the rip hotspots area on the west coast of Sabah. The rips were determined based on rapid offshore-directed currents formation and strong waves at coastal areas from Google Earth Pro between 2018 and 2021 (4 years). The selected study sites encompass the coastal areas between Papar and Kota Belud Districts, utilizing approximately 49 captured satellite images. The possible rip formations identified in Papar, Putatan, Kota Kinabalu, Tuaran, and Kota Belud Districts are 6, 2, 22, 25, and 3, respectively. The highest rip current formation (38%) was detected in Karambunai Beach, Kota Kinabalu. The average length of the rips was estimated as 0.13 (0.02±0.7) km. This study focuses only on rip current's appearance from open-source data. Ground data measurement and analysis are required for detailed characteristics of the rip current, and its impacts on drowning cases.

**Keywords** Rip Current, Coastal Area, Hazards, Google Earth Pro

## 1. Introduction

Rip currents are rapid offshore-directed, narrow, intense jets of water that originate in the surf zone and broaden towards the wave-breaking zone. Rips are the result of the naturally forming circulations from the combinations of wind, wave height, wave period, and variations of alongshore bathymetric features. This involves the transport and cross-shore mixing of heat, pollutants, nutrients, sediments, and biological species [1, 2]. Every year, hundreds of beach users drown, and tens of thousands more are saved from rip currents globally [3]. Several beach areas in Malaysia are constantly packed with a high number of tourists and leisure activities but often expose those visitors to rip currents. Rips can drag swimmers away from the shallows and out into deeper water within minutes. Sometimes a rip current can sweep out victims further offshore without notice by other beachgoers. A combination of exhaustion, panic, and limited water skills often results in death by drowning [5].

Accidental drownings have been recognized as one of the five leading causes of death in Malaysia, especially among children [6]. Most of the victims are those involved in commercial fishing, collision with other boats or objects, capsizing or falling overboard, as well as children who live near the coast with inadequate supervision and inability to swim. However, the leading causes of drowning-death cases recorded along Malaysia's coastline could be also due to the presence of rip currents. Since 2013, over 1345 drowning cases have been recorded in Malaysia, with an average of three deaths per day [7]. Out of the 1345 cases, 296 occurred at the beach [8]. Kelantan and Terengganu had the highest number of drowning deaths [9], while in Pahang, eight deaths and three rescues were recorded at Teluk Cempedak Beach, Kuantan from 2006 to 2018 [10]. So far there has been no direct statement related to the rip current incident in Sabah coastal areas.

Based on online newspaper reports [11], [12,13], [14,15.16] and [17,18], most of the drowning incidents reported along the shoreline of Papar to Kota Belud, Sabah could be associated with rip current hazards which manifest strong waves or strong currents as the reason for deaths. However, the majority reason of drowning incidents was recorded as unidentified by Kota Kinabalu Fire and Rescue Station [19]. The objectives of this study are to analyze the potential rip formation area from satellite images and to determine the rip current hotspots on the west coast of Sabah.

## 2. Materials and Methods

The study areas focus on the coastline of the west coast of Sabah starting from Papar and Putatan located south of Kota Kinabalu to Tuaran and Kota Belud districts located in the north (Fig.1). Sandy beaches dominate the northern part of Kota Kinabalu and are well known as one of the most popular seaside tourist destinations in Sabah. The southern part of Kota Kinabalu consists of large wetland areas and coastal structures dominating several lengths of the shoreline [21]. Therefore, fewer tourists and beachgoers were recorded within these beach areas compared to the northern part of the districts.

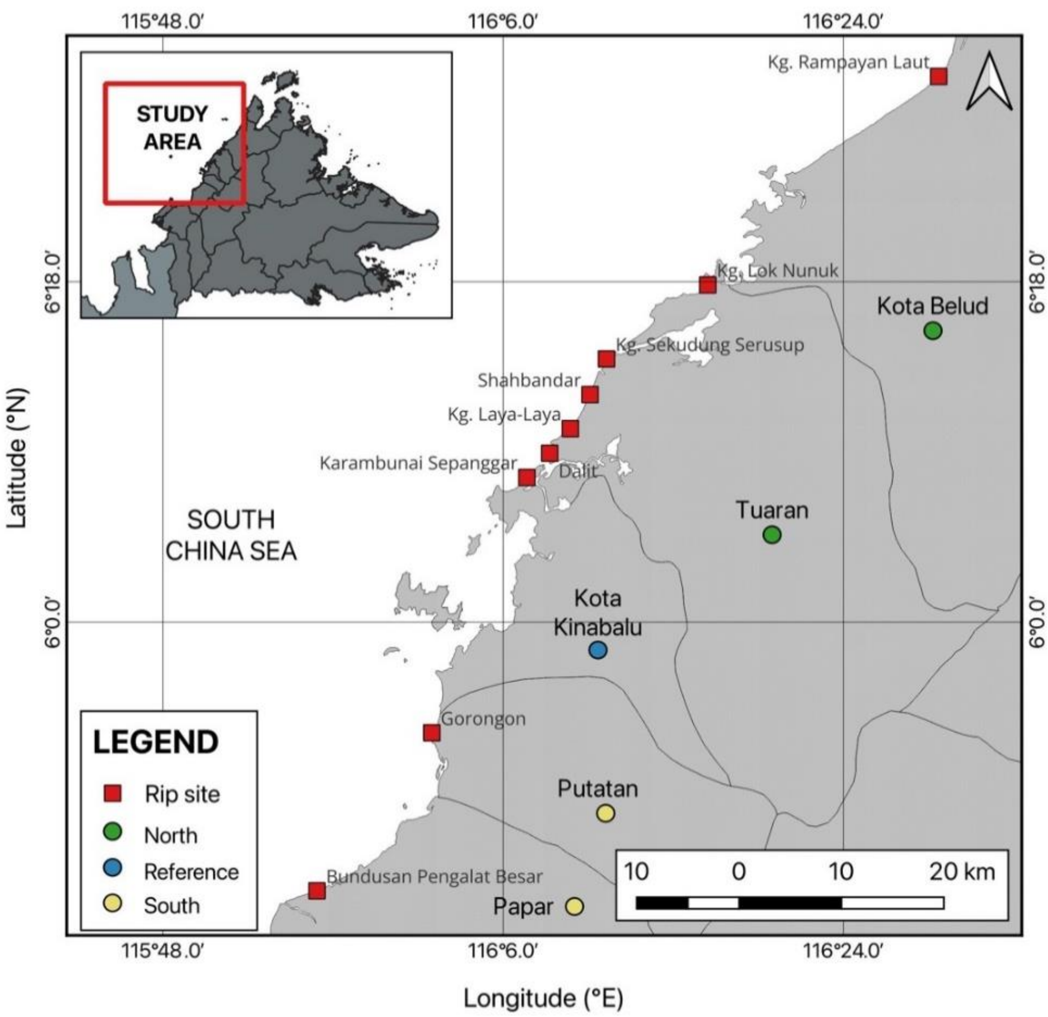


**Figure 1.** Location of the study areas (west coast of Sabah) divided into north and south parts of Kota Kinabalu

Generally, the coastline of the West Coast of Sabah is formed by several bays, islands, estuaries, headlands, and narrow beaches with mild coastal slopes [20]. However, part of the coastal areas also influenced by various local and regional factors such as river discharges, bathymetries, precipitation, waves, and wind.

The meteorological climate of Sabah is partly influenced by two monsoons, namely the Northeast monsoon (NEM) (November to March), and the Southwest monsoon (SWM) (May to September), and two shorter inter-monsoons (October and April) [22]. The northern part of Kota Kinabalu is mainly exposed to the open sea and sandy beach landform. Short seawalls, layers of rock revetment, and the moderate thickness of terrestrial vegetation occupied the sandy shoreline [20].

The rip current can be detected using several methods such as laser rangefinders, drone imaging, current meters, and pressure sensors. Beachgoers normally identify rip currents through direct observation with the naked eye. In this study, the rips were determined based on rapid offshore-directed currents, and strong waves using the Google Earth Pro satellite Landsat-8 images from 2018 to 2021 (4 years).

Identification of rip currents was based on its criteria [28]. The formation of a rip can be seen as foamy surface water probably caused by the interaction of outgoing rip flow and incoming waves, prominent shoreline rips embayment, and clouds of suspended sediment or debris expelled just outside the surf zone (Fig. 2a, 2b). Beach rip currents also can be seen as a darker green area between white water areas over neighboring shallow sand bars when wave break is reduced over deeper rip channels (Fig. 2b). This is the most dangerous in terms of drowning and rescues because it usually occurs during calm weather and low to moderate wave energy conditions, which appear more appealing, encouraging large beach crowds [23, 24]. Rip can appear as a narrow gap in the breaking waves and is observed as calm darker water between areas of breaking waves, suggesting all the tell-tale signs [25] that a rip channel may exist in that area (Fig. 2c, 2d).

Rip is commonly found at embayed beaches, either adjacent to headlands or in the middle of longer embayed beaches (Fig. 2e), and can extend 3-4 surf zone widths offshore during high wave conditions [26, 27]. Another representation of rips is a tongue of sediment-laden water flowing downstream, with irregular wave churning and choppiness and foamy water in the rip head's outer edges (Fig. 2f).

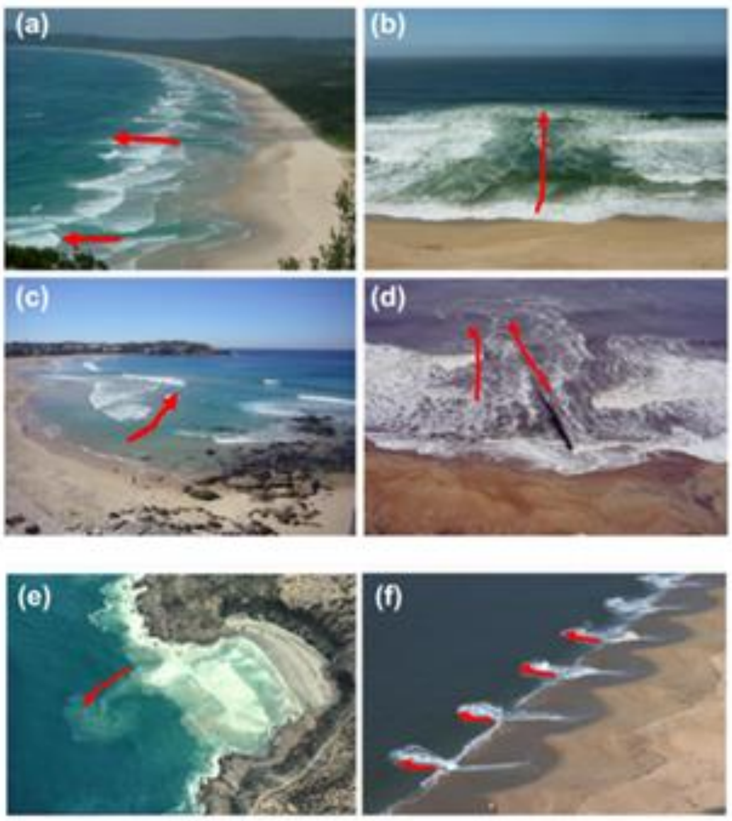


**Figure 2.** Rip current criteria: (a) rip current with outgoing and incoming waves; (b) rip current illustrating dark gap visual identifier; (c) rip current with a visual identifier of a narrow gap in the breaking waves; (d) rip current with darker, calmer water between areas of breaking waves; (e) rip current typically found in embayed beaches with plumes of sediment in the rip head; (f) rip current illustrating irregular wave churning and choppiness (red arrow indicate the direction of rip current) [28]

# 3. Results

## 3.1. Possible Rip Current Formation Captured by Satellite Images

Satellite images captured a total image of 49 images in the study areas between 2018 and 2021 (Table 1). In both 2018 and 2019, 11 images followed by 15 images in 2020 and 12 images in 2021 were captured by the satellite. Six percent of the total images (N=49) contained noise (cloud cover) recorded during the NEM season (once in January and twice in February). These images were excluded from this study.

**Table 1.** Number of possible rip formations detected in the satellite images

| Year | Number of captured satellite images | Number of possible rip current formations |
|---|---|---|
| 2018 | 11 | 8 |
| 2019 | 11 | 11 |
| 2020 | 15 | 26 |
| 2021 | 12 | 13 |
| **total** | **49** | **58** |

Out of the 49 images analyzed, a total of 16 images showed about 58 possible rip current formations at study areas between 2018 and 2021. In 2018, out of the 11 images analyzed, 8 possible rip current formations were detected, followed by 2019 with 11 possible rip formations detected in 11 images (Table 1). In the years 2020 and 2021, multiple occurrences of rip currents were detected in one image, with 26 rip formations detected in 15 images, and 13 rip formations in 12 images, respectively.

Based on the monthly analysis of satellite images, February had the highest number of satellite images captured (12 images), followed by January (9 images), June (7 images), and March (6 images), while no satellite images were captured in September (Fig. 3). Out of the four years, the year 2020 had the highest number of satellite images captured (15 images), followed by 2021 (12 images), while both 2018 and 2019 had the lowest number of captured satellite images (11 images).

Most of the satellite images were captured during the NEM between January and March (Fig.3). The month of January showed the highest number of possible rip formations detected (26), followed by February (23) and March (7), in which all three months coincide with the NEM (Fig. 4).

The year 2020 also recorded the highest number of rip formations (26), followed by 2021 (13) and 2019 (11), while 2018 had the lowest number of rip currents detected (8) (Fig. 4).

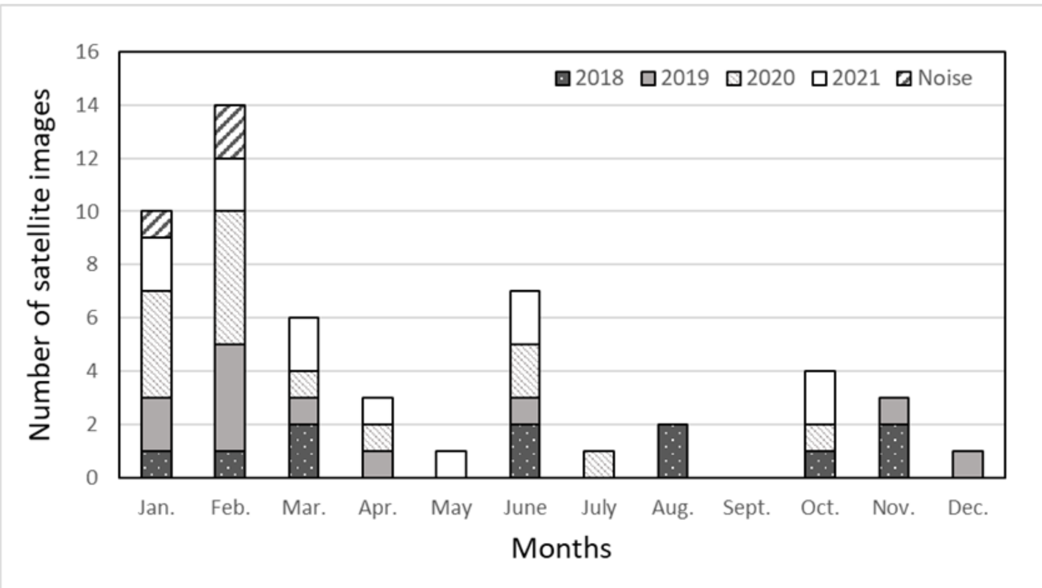


**Figure 3.** Number of satellite images across months. The different colour bar represents the year from 2018 to 2021

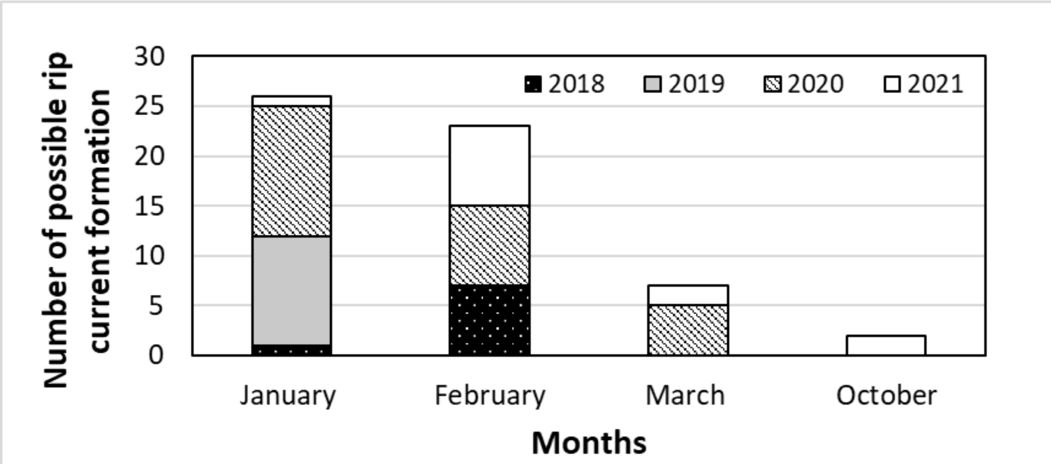


**Figure 4.** Number of possible rip current formations across months

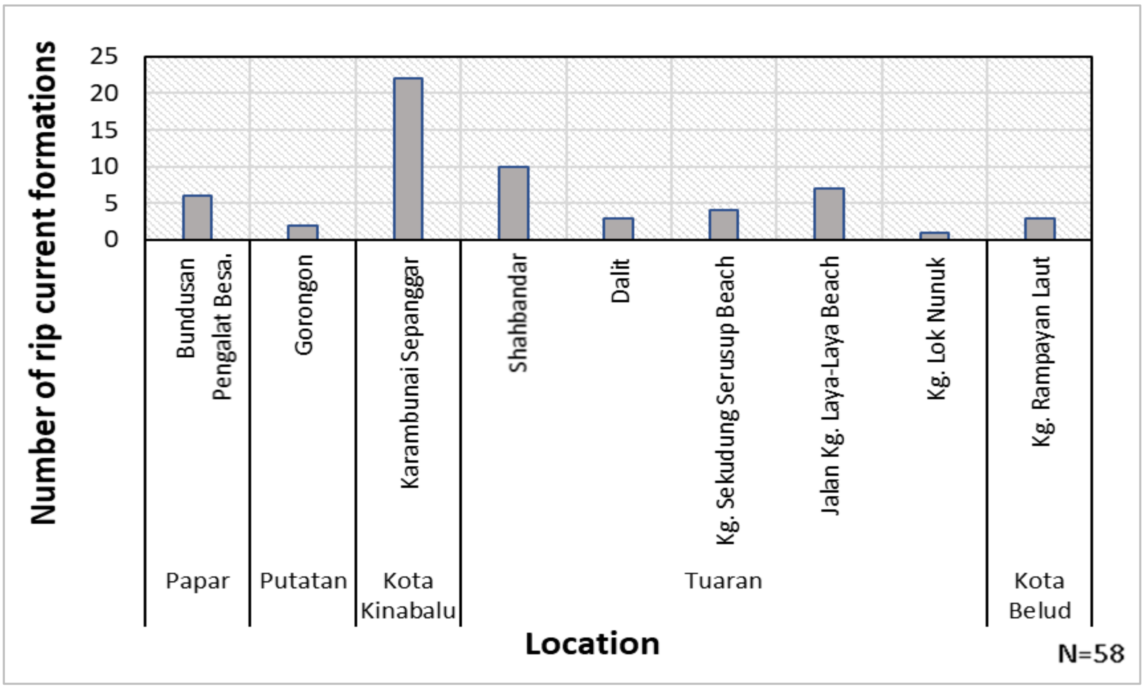


**Figure 5.** The number of rip formations by district from the Google Earth Pro

## 3.2. Potential Rip Currents Formation by District

The highest number of coastal images (30 images) captured by the satellite was in Paper District, followed by Kota Kinabalu (23 images) to Putatan (17 images), Tuaran (14 images), and Kota Belud (9 images) Districts (Table 2). However, only 8 rip formations across 4 different timeframes were identified in the Southern part of Kota Kinabalu. The hotspot of rips formation is in Bundusan Beach, Papar with 6 rips with an average length of 0.13 km. Another 2 rip formations were identified with an average length of 0.4 km and were detected in a single timeframe at Gorongon, Putatan. Kota Kinabalu District recorded 22 rip formations across 8 different timeframes.

**Table 2.** Number of satellite images captured and rips formation by districts from 2018 to 2021

| Districts | Satellite images captured | rip currents formation |
|---|---|---|
| Papar | 30 | 6 |
| Putatan | 17 | 2 |
| Kota Kinabalu | 23 | 22 |
| Tuaran | 14 | 25 |
| Kota Belud | 9 | 3 |

In the northern part of Kota Kinabalu, about 25 possible rip formations occurred in Tuaran District. The highest number of rip formations occurred at Shahbandar (10), Kg. Laya-Laya Beach (7), Kg. Sekudung Serusup Beach (4), Dalit (3), and Kg. Lok Nunuk (1) (Fig. 5). The longest rip formation was about 21 km at Kg. Laya-Laya Beach. The average length of rip in Shahbandar is ~ 0.09 km. Only 3 rip formations with an average length of 0.12 km were detected in a single timeframe at the Kg. Rampayan Laut Beach, Kota Belud.

# 4. Discussion and Conclusion

The satellite passes over the same places on Earth every few days. This is indefinitely influenced by the number of rips detected on satellite imagery in the study area. There is an increase in the number of images captured by the Landsat 8 satellite from 2018 to 2020 (Table 1). Regular updates on the Google Earth Pro software allow greater data archives to be recorded, hence the year 2020 has the highest number of captured satellite imagery. In 2021 may have recorded less satellite imagery than 2020 due to the noncontinuous update from Google, as it updates aerial photographs piece by piece [29].

Based on Google Earth Pro satellite images, the possible rip formations were mainly detected during the NEM. In January over 26 possible rip formations were detected from 9 satellite images while in February, about 23 possible rip formations were detected from 12 satellite images (Fig. 4). In 2020 also detected the highest possible formation of rip currents (45%), as it had the highest number of captured satellite imagery with 31% out of the total images (n=49) (Fig. 3).

Rip formations often persist for extended periods, ranging from hours to days, and their average velocities facilitate the offshore transport of significant sediment quantities, especially during storms [30, 31]. In this study, rip formations were only observed in January, February, March, and October from 2018 to 2021 (Fig. 4). The onset of the NEM, typically commencing in early November and lasting through late March, appears to trigger rip formations. Notably, the highest rip formation rates were recorded in January, while rip formation in October might be linked to the transitional weather patterns between the SWM and NEM seasons.

The northern part of Kota Kinabalu such as the Karambunai, Sepanggar has 22 rips formation (Fig. 5) as this area has the second-longest coastline (~ 6 km) [32] within the study areas. The sandy beach is subjected to moderate to strong wave attacks all year round and experiences greater longshore transport rates during the NEM [33]. Similar geographical location to Shahbandar Beach had a high number of rip formations along its' coastline with 10 possible formations (Fig. 5). This area receives moderate to strong wave attacks throughout the year (strongest during the NEM). Districts located in the southern part of Kota Kinabalu have very few formations of rip currents compared to the Northern districts due to their coastal morphology and being protected by several islands.

Satellite imagery can capture rip formation during bad weather. For example, during the NEM heavy rain and rough sea conditions [34] will hinder the study of in situ rips. With few limitations, satellite images do help to detect changes caused by unexpected events such as severe storms and floods.

### 4.1. Limitation of Study

Google Earth Pro posted the best satellite image quality on the website. Therefore, the majority of the images were used to detect rip formation along the studied coastline with a relatively small percentage (6%) of the images with cloud cover. However, limited coverage of the Landsat 8 satellite only allows images at certain places with certain timelines to be captured. Papar District recorded the highest number of satellite images (Table 2). Kota Kinabalu and Putatan registered a total of 23 and 17 captured satellite images, respectively. The presence of rip currents is very much dependent on the frequency of the Landsat satellite captured in the study areas. Therefore, the occurrence of the fast-moving rip formation was not captured during the passing of the satellite to the study areas. Local effects (e.g bathymetry and morphology) and unpredictable weather conditions may increase the unpredictability of rip current formation.

The Google Earth Pro detected 58 possible rip current formations from Papar to Kota Belud Districts (Fig. 5). High rip formations mainly occurred in January and February, but they were also detected in October. The rip currents formation was more frequently detected in the northern part (28 formation) than in the southern (8 formation) of Kota Kinabalu. The hotspot of rip currents formations is in Karambunai Sepanggar, Kota Kinabalu (22 formations), followed by Shahbandar, Tuaran (10 formations). Bundusan Pengalat Besar, Papar has the strongest rip current with an average length of 0.13 ($0.02 \pm 0.7$) km.

This study primarily focuses on the appearance of rip formations using open-source data. Nevertheless, the utilization of satellite imagery with high spatial and temporal resolutions enables more precise detection of rip current occurrences and their formation processes. Understanding of rip currents can be improved by combining satellite data with ground-based measurements, such as drifters, bathymetric surveys, and current meters. Additionally, employing hydrodynamic simulations can provide accurate predictions regarding the position, direction, formation, and velocity of rip currents. Lastly, conducting interviews with local communities is highly recommended to corroborate the existence of rip currents and assess their impacts on beachgoers at the respective study sites.

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