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Authors: MacMahan, Jamie, Reniers, Ad, Brown, Jenna, Brander, Rob, Thornton, Ed, et al.

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EDITORIAL

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# An Introduction to Rip Currents Based on Field Observations

**Jamie MacMahan[†], Ad Reniers[‡], Jenna Brown[†], Rob Brander[§], Ed Thornton[†], Tim Stanton[†], Jeff Brown[††], and Wendy Carey[‡‡]**

[†]Naval Postgraduate School
Oceanography Department
Monterey, CA 93943, U.S.A.
jhmacmah@nps.edu
jabrown@nps.edu
thornton@nps.edu
stanton@nps.edu

[‡]Rosenstiel School of Marine and
Atmospheric Science
University of Miami
Miami, FL, U.S.A.
areniers@rsmas.miami.edu

[§]School of Biological
Earth and Environmental Sciences
University of New South Wales
Sydney 2052, Australia
rbrander@unsw.edu.au

[††]Coastal Engineering Division
LEAP Engineering LLC
Galveston, TX 77550, U.S.A.
jeff.brown@leapengineering.com

[‡‡]Delaware Sea Grant College Program
University of Delaware
Lewes, DE 19958, U.S.A.
wcarey@udel.edu

## ABSTRACT

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Rip currents are fascinating, natural, surf zone phenomena that occur daily on many beaches throughout the world. My colleagues, students, advisors, and I have been studying rip currents for more than 10 years and have performed more than 10 comprehensive field experiments on various beaches throughout the world using different observational techniques and model simulations to improve our understanding and prediction of rip currents. We have written a series of scientific articles describing the intricacies and complexities of rip current behavior using statistical and mathematical equations. These manuscripts are typically published in professional journals, which often do not communicate our results to those who would benefit from the information—the beachgoing public and ocean swimmers. Herein, we summarize our findings to help people of all ages gain a better understanding of currents at the coast.

## INTRODUCTION

Rip currents are important in shaping our beaches through the transport of sand, in mixing of surf-zone water, and in flushing of the surf zone with the deeper water offshore. They are commonly and comfortably used by surfers and lifeguards to quickly exit the surf zone. However, rip currents are also the number-one beach hazard for many swimmers and visitors to the coast. In our opinion, increased knowledge is the best approach to making a rip current "foe" into an "understandable friend."

### Waves and Surf Zone Currents

The *surf zone* is defined as the area shoreward of where waves are breaking. Typically, it is the characteristics of both the approaching waves and the shape of the sandy beach bottom that ultimately determine the type and magnitude of associated surf-zone currents. In general, the bigger the waves, the faster the surf-zone currents. There are three primary types of surf-zone currents: (1) undertow, (2) alongshore currents, and (3) rip currents. There are additional currents induced by tides and winds, but they tend to either be weak or site specific.

As waves propagate toward the shoreline, they grow in height (a process known as shoaling), and they change their angle of approach (a process known as refraction), such that the top of the wave (the wave crest) is nearly parallel to the shoreline upon breaking. Waves start to break when the water depth is approximately two times their wave height, which is known as depth-limited wave breaking. Waves may either continue breaking as the water depth decreases while they move (propagate) toward the shoreline or waves may stop breaking with increasing water depth. This implies that big waves break farther offshore in deeper water, and small waves break closer to shore in shallow water. As a result, the pattern of wave breaking is an indication of the shape of the offshore sandy bottom (underlying bathymetry), which can help us to

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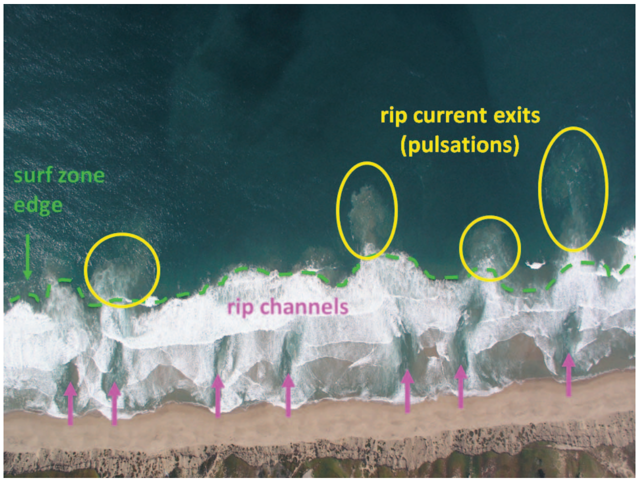

Figure 1. Aerial photograph of a rip-channeled beach, where wave breaking is seen as white areas and marks the edge of the surf zone (green line). Waves break more intensely over the shallow regions and less intensely in the rip channels, indicating the alongshore variability in the beach. Evidence of rip currents exiting the surf zone can be seen as plumes of suspended sediment outside of the surf zone.

identify relatively deep and shallow areas as well as rip-channel locations (see Figure 1).

*Undertow* is a seaward-directed flow of water that has maximum flow speeds near the ocean bottom. The undertow balances the onshore movement of water caused by breaking waves. If the onshore/offshore flow were not balanced, all of the water would pile up against the shoreline. Although undertow can obtain large velocities when wave heights are especially high (*e.g.,* during storms), it is generally a weak flow. Undertow will not suck you under and drag you out to sea! Sometimes undertow is thought of as an invisible sea monster that would pull unsuspecting bathers under the water for minutes while moving you offshore. This is not true. Rather, breaking waves are the primary mechanism that push you below the sea surface and can be especially dangerous at shore breaks on steep beaches with vigorous breaking near the waterline, trapping you inside and tossing you around like a washing machine.

*Alongshore currents* develop when the waves break at an angle, thereby pushing the surf-zone water along the beach. The flow is parallel to the shoreline and is fastest near the outer edge of the surf zone. As with undertow, alongshore currents do not pull you under. As their name suggests, all they do is move you along the beach, requiring you to walk back to your beach umbrella and towel. However, when the alongshore current is blocked by a structure farther along the beach, such as a groin, jetty, or pier, it turns offshore along the structure, creating hazardous swimming conditions. So a good rule of thumb is to stay about two surf-zone widths away from coastal structures.

*Rip currents* tend to exist when the breaking wave angle is small, *i.e.,* the waves are coming right at the beach or *closing out*. The most commonly observed rip currents develop on beaches that have alongshore variations in the nearshore sandy bottom. Many beaches have sandy bottoms that undulate quasiperiodically up and down along the beach. These alongshore variations in the sandy bottom induce alongshore variations in the depth-limited wave breaking, where shallow regions have intense wave breaking and deeper regions have less wave breaking. Similar to the alongshore current, the surf-zone water is pushed onshore by the breaking waves in the shallow areas known as *shoals*. This water then returns through the deeper rip channels where wave breaking is minimal. An example of a beach with rip channels and alongshore variation in wave breaking is shown in Figure 1.

## Rip Current Circulation Patterns and Fluctuating Speeds

Simply stated, rip currents develop when there are alongshore variations in wave breaking. Depth variations in the alongshore sandy bottom are the most common cause of variations in wave breaking and are the focus of our discussion, but there are also many other causative factors. Regardless of the mechanism that creates alongshore variations in wave breaking, the underlying physics of rip-current generation remain the same. A flow develops that moves from the region of intense wave breaking toward the region of reduced or no wave breaking inside the surf zone. It turns out that this flow is a current that moves in a circular pattern, described as an eddy. This was clearly illustrated when we recently deployed floating devices (known as drifters) equipped with Global Positioning Systems (GPSs) to observe how they would behave when traveling in a rip current. We also attached GPSs to swimmers as they floated in the rip current. Results showed that both the floating devices and the swimmers behaved similarly. An example of GPS-equipped floater tracks is shown in Figure 2. The drifter pattern shows that if you were to float in a rip current, you would eventually travel in a complete circle in about 7 minutes, which is a long time to stay afloat. However, you will likely find yourself in shallow water (where you can stand up) in approximately 5 minutes (which is still a long time). If you floated in a rip current, you would move offshore to the location of wave breaking, and then along the beach, and then back onshore. Occasionally, you would be squirted offshore outside of wave breaking, as shown in Figure 2. This circular behavior of rip currents has been observed on all beaches with rip currents that we have studied, as well as in a recent laboratory study performed by other colleagues.

Don't be afraid of rip currents. There is nothing in a rip current that will pull you under—only breaking waves can push you under water. Our drifter experiments demonstrate that if you're traveling in a rip current, you will most likely go around and around in a circular pattern. Relax, stay afloat, and signal for help if you are not a good swimmer. Remember to float in the current—when compared with swimming, floating requires less physical energy. If you are moving seaward within the surf zone, enjoy the rip current ride and conserve your energy. Once you move into the onshore flow you can keep floating, or to expedite your return you can bodysurf the waves into shore. Remember, this floating trip in the circular current is going to take several minutes to complete, so you need to stay calm. If you are squirted outside of the surf zone, it is best to

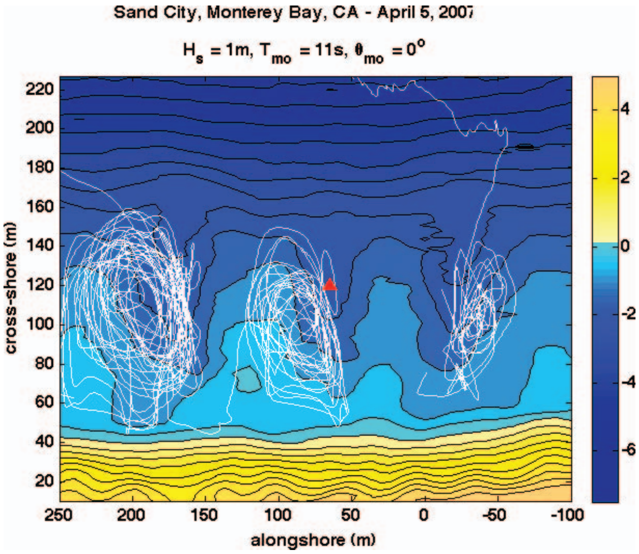

Figure 2. Plot of multiple GPS-equipped drifter tracks (white lines) over a time span of 30 min, with the contours of the underlying sandy beach bottom given in the background (color scale to the right). The dark regions are the locations of the rip channels. The drifters predominantly moved in circles inside the surf zone, with only two incidents of the drifter moving offshore. The triangle near the center of the image indicates the location at which rip-current speeds were measured (shown in Figures 3 and 4).

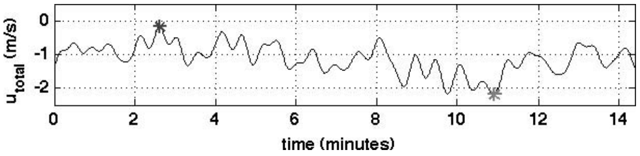

Figure 3. Rip-current speed (in which we filtered out the individual waves) measured in a rip channel (triangle in Figure 2). The fluctuations in the flow can been seen where the rip current is relatively weak at one time (blue) and can be twice as strong as the mean velocity (red) a short time later (~8 min).

swim parallel to the breaking waves, and unfortunately, you will have to swim back to shore because the onshore-returning flow outside of the surf zone is very slow.

It is sometimes difficult to get an idea about how fast a rip current actually moves, so here are some numbers that compare rip current and swimming speeds. The average rip-current speeds are 0.5 to 1 m/s. Olympic swimmers swim around 2 m/s and the average swimmer at half that speed.If an average person swims against a rip current, they will make little to no forward progress. This is why it is recommended that you never swim against a rip current. A typical surf zone is 100 m wide. It would take an average person 2 minutes to swim this distance with no opposing current. Swimming against 0.5 m/s current, it would take 4 minutes and against a 1-m/s current, you would make no forward progress. Our drifter experiments showed that if you were to float in a rip current, it would take 7 minutes to complete a revolution because the average speed in the rip current eddy is 0.5 m/s and you are moving offshore for 100 m and back onshore for 100 m.

The average width of the offshore-directed rip current is approximately 50 m. Assuming you were in the middle of the rip current and swam parallel to the beach, it would take an average swimmer 30 seconds to move away from its path. But as we mentioned, the rip current is an eddy, so you are still swimming against a current that is 0.5 to 1 m/s, so your time doubles or you make no forward progress.

We have jumped in a number of rip currents throughout the world, and people always ask us "what does it feel like?" The answer is nothing—rip currents do not suck you out, and there is no grip. While riding in a rip, you may sense that you're moving in a seaward direction if you see a stationary object as a reference point, but there's really no feeling of suction or pulling. When you float in a fluid that is moving, you do not notice anything because you are also moving with the fluid. Now, if you were able to stand still in the moving fluid, only then would you notice the flow against your body. You may not notice the speed of a fast-moving flow that is only ankle deep, but if that same flow is waist deep, it will become harder and harder to maintain your balance and position. Another analogy is floating in a river. In most cases, this is not considered dangerous, unless you are in rapids with a lot of rocks. You simply float downstream and your only sense that you are moving is by looking at objects along the riverbank moving past you. Now, if you happen to overshoot your destination and start to swim against the river, you do not notice anything except the fact that you are not making forward progress. Most people would not choose to swim against a fast-moving river current but would rather swim across the current to the bank and then walk back upstream. Floating in a rip current is a very similar situation, except the flow is in a circular pattern, and you may not be aware of your location in the circle. Owing to this complexity, we suggest that it's best to stay afloat, and do not panic.

A very important rip current fact—THEIR SPEEDS PULSE OR FLUCTUATE AND THIS MAKES THEM VERY DANGEROUS! Waves in the ocean often travel in sets or groups (wave groups) with wave sets of varying heights arriving at the coast anywhere from 30 seconds to 5 minutes apart. Surfers often wait for the biggest wave of the group to ride to the shoreline, and then swim back out, and wait for the next set of big waves. This variability in wave height repeats itself and causes onshore and offshore fluctuations in the flow and water level. The fluctuations add and subtract from the average rip current speed, so at one point in time, the flow can be near zero, and a few minutes later, the flow can be twice as large. In addition, the water level changes dramatically with the wave groups, with the potential of sweeping bathers off their feet because of the large flow and the fact that the flow is higher on your body (the ankle-deep to waist-deep analogy). These fluctuations can easily catch swimmers off guard. To demonstrate this, we placed a current meter in a rip current and observed the flow fluctuations (Figure 3). In approximately 8 minutes, the rip current speed increases from near 0 m/s to 2 m/s, *i.e.,* from safe to extremely hazardous.

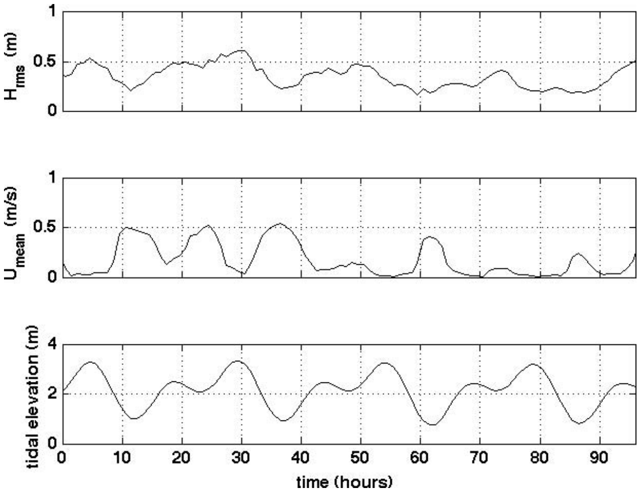

Figure 4. Wave height (top), hourly averaged rip-current speed (middle), and tidal elevation (bottom) measured on a rip-channeled beach (triangle in Figure 2). Rip currents are fastest during low tides, demonstrating the effect of tidal fluctuations.

Although rip currents are not directly caused by tides, fluctuating water levels resulting from the daily tidal cycle may have an effect on rip-current velocities. Tides change the water level at the beach on an approximately 12-hour cycle. Because the tide changes the water level, the depth-limited wave breaking patterns also change with the tide. On most beaches, the alongshore bathymetric variations in wave breaking are the largest at lower tides, and this is why rip currents are the fastest at low tides. However, there are beaches that have stronger alongshore variations at high tide, which create the fastest rip currents at high tide. Using the same current meter in Figure 3, we can observe the tidal fluctuations on the hourly, mean rip-current speeds, which increase with decreasing tidal elevation (Figure 4). Note that these increased flow velocities at low tide are not related to the tidal velocity, *i.e.,* we are not looking at a flow forced by the tide, but are a result of the increased alongshore variability in wave breaking at low tide. Rip currents are not a result of tidal forcing.

## Parting Thoughts

We recommend that you learn how to swim and swim only at beaches with lifeguard protection. Lifeguards are experts that keep you out of harm's way—pay attention to their warnings. They have a lot of local knowledge and can explain the surf-zone conditions at the beach you are visiting, including any high surf or current hazards you should be aware of before entering the water. If there are no lifeguards present and you do not know the beach, do not go in the water past your knees.

Shorelines differ from region to region, and because there are many factors that exert control on local wave-breaking characteristics (water depth, shape of the nearshore bottom, *etc.*), there can be many variations in surf-zone currents along any stretch of coast. The rip currents that we described above are referred to as *open-coast rip currents,* which are not adjacent to coastal structures (piers, groins, jetties, and headlands) or near submarine canyons. Rip currents often occur near coastal structures, and their behavior can vary significantly near these structures. Note that there are also locations in the world that generate persistent large rip currents, which behave differently than those described here and are likely to occur at embayed beaches.

Rip currents occur on many beaches. If you understand how rip currents work, and if you know how to swim and float, you may not be alarmed nor become panicked if you find yourself riding in a rip current. Don't be afraid of rip currents, but don't be overconfident and seek them out unless you are an experienced surfer or surf swimmer. We simply want you to avoid panic if you happen to unsuspectingly be in a rip current. We found that rip currents follow a circular pattern within the surf zone and episodically exit the surf zone. The exiting jet can extend a couple of surf-zone widths offshore. The rip current is fastest within the surf zone and quickly slows outside of the surf zone. It takes approximately 7 minutes to complete one rip current revolution within the surf zone.

Educate yourself and your family about the ocean before entering it!

## ACKNOWLEDGMENTS

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