Rip current observations on a low-sloping dissipative beach

Shari L. Gallop[1,2], Karin R. Bryan[3], Sebastian Pitman[2], Roshanka Ranasinghe[4,5,6], Dean Sandwell[3]
[1] Department of Environmental Sciences, Macquarie University, NSW, Australia; shari.gallop@mq.edu.au
[2] Ocean and Earth Science, University of Southampton, Southampton, United Kingdom
[3] School of Science, University of Waikato, Hamilton, New Zealand
[4,5,6] UNESCO-IHE and Deltares, Delft, The Netherlands; and Australian National University, Canberra, Australia

Abstract
Rip currents are the main cause of beach rescues and fatalities. Key drivers of rip current hazard are: (1) fast current speeds; and (2) the exit rate of floating material from inside to outside of the surf zone. Exit rates may vary temporally, such as due to Very Low Frequency (VLF) motions, which have a period on the order of 10 minutes. However, there is little field data to determine the driver(s) of exit rate. Therefore, the aim of this research was to determine rip current circulation patterns, and specifically, determine their relationship to surf zone exits, on a high-energy dissipative beach. Three days of field measurements were undertaken at Ngarunui Beach, New Zealand. Three daily surf zone flow patterns were found: (1) alongshore; (2) surf zone eddy with high exit rate; and (3) surf zone eddy with no exits. There were strong infragravity peaks in energy within the surf zone, at 30-45s, although none at VLF (~10 minute) frequencies. Further research is underway to determine what drove the high surf zone exit rate observed at Ngarunui Beach.

Keywords: rip currents, video imagery, dissipative beach, surf zone, infragravity waves

1. Introduction

Rip currents are the leading global cause of rescues and fatalities of beach users [1; 2]. Rips are jet-like flows that flow seaward across the surf zone [3; 4], and are a common feature on beaches in an intermediate morphodynamic state [5]. The risk of rips to beach users is influenced by: (1) current speed inside the rip; and (2) the exit rate from the surf zone. Rip currents are generally strongest at low tide [6]. Rip circulation patterns often form eddies inside the surf zone, from which there may be occasional exits [7]. The rip current hazard is thought to increase with exit rate. Also, exit rate may be important for determining the best escape strategy for people caught in a rip [8]. Rip current velocities, and exit rates vary temporally, due to wave groups and other low frequency motions. However, there has been a lack of measurements to evaluate these relationships [9]. Therefore, the aim of this research was to determine rip current circulation patterns, and specifically, determine their relationship to surf zone exits, on a high-energy dissipative beach.

2. Study area

This research focused on Ngarunui Beach, Raglan, on the west coast of the North Island of New Zealand (Figure 1).

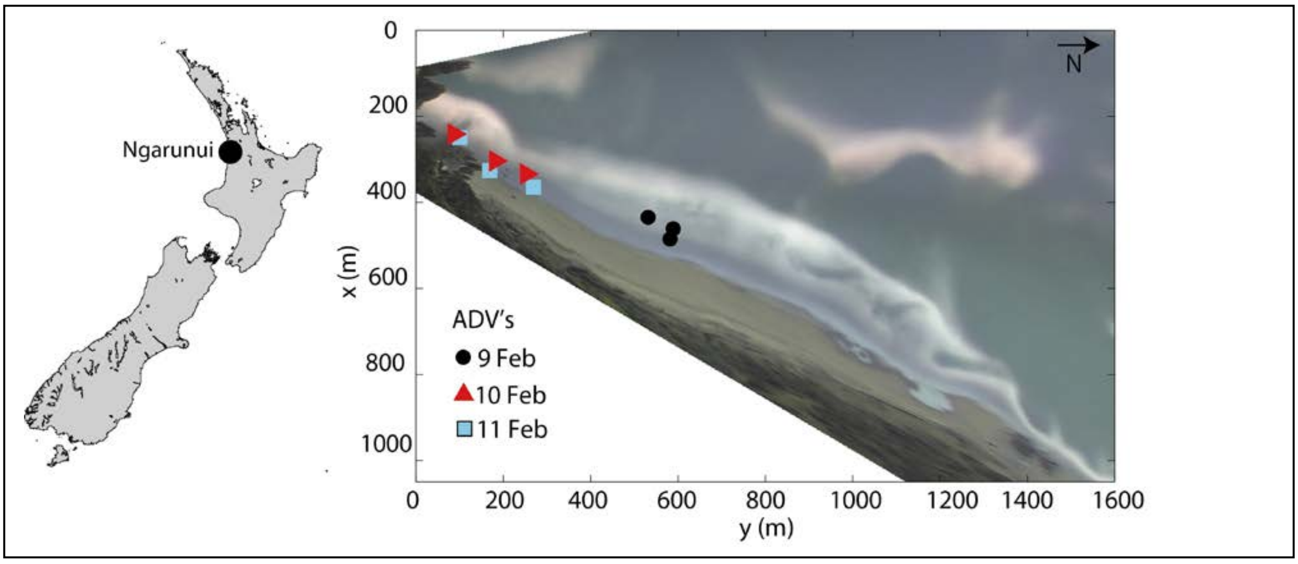

Figure 1 Location of Ngarunui Beach, New Zealand. Photo is geo-rectified, and averaged over 10 minutes from the Cam-Era video monitoring system, run by Waikato Regional Council and the National Institute of Water and Atmospheric Research (NIWA). White areas are breaking waves over sand bars. The symbols show ADV deployment locations on 9, 10 and 11 February 2015.

Ngarunui Beach is a 2 km-long, dissipative surf beach, bound by a tidal inlet to the north and a headland to the south. The beach consists of fine-medium iron sand [10] with median grain size of ~400 µm [11]. Tides are semidiurnal, with neap and spring ranges of around 1.8 and 2.8 m respectively [12]. The mean offshore significant wave height is 2 m, with period of 7 s [13].

3. Methods

Data were collected on 9–11 February 2015 using: (1) video imagery; (2) an offshore wave model; (3) three Acoustic Doppler Velocimeters (ADVs); and (4) ten GPS drifters (Figure 1). The Cam-Era video monitoring system has been in place at Ngarunui since 2007. This covers an area 1.5 km alongshore, and 150 to 800 m cross-shore. During daylight hours, a snapshot and ten-minute average image are collected half-hourly. Offshore wave data were obtained from the nzwave_12 forecast, which uses WAVEWATCH v3.14 and is run by NIWA. At the grid point closest to Ngarunui, hourly data are available from longitude -37.777834 and latitude 174.66760, at 53 m water depth. Three Triton Sontek ADVs were deployed in the surf zone (Figure 1), facing upwards. These were set to the maximum sampling rate for sea level and waves (4 Hz for 4086 samples). Ten GPS drifters were used, which were built based on the designs of [14] and [15]. The mean error and standard deviation for the QStarz BT-Q1000eX GPS was 3.78 ± 1.20 m, with velocity accuracy of ±0.05 m s^{-1}. These were deployed initially by wading out to waist-depth, and retrieved by swimmers and using a jet ski when they exited the surf zone, washed inshore, or went outside of the study area.

Figure 2 Photo showing the design of the GPS drifters used at Ngarunui Beach.

4. Results

4.1 Circulation patterns

Drifter deployments were made during the ebb tide on 9 Feb, and the flood tide on 10 and 11 Feb. Mean offshore H_s was 1.4 to 1.9 m during the deployments, with mean wave period between 7 and 12 s. Nearshore wave height measured with the ADVs ranged between 0.2 and 1 m at high tide. On 9 Feb, all the drifters travelled northwards, alongshore (Figure 3a). On 10 and 11 Feb, a clockwise surf zone eddy was revealed (where the offshore-directed flows are the rip current). On 10 Feb, it was common for drifters to circulate, then exit the surf zone (Figure 3b). On 11 Feb, the dominant behaviour was circulatory within the surf zone, with some drifters exiting the eddy to head northwards alongshore (Figure 3c).

4.2 Infragravity waves

Spectral analysis of ADV data revealed strong infragravity signals inside the surf zone, in the rip channel and feeder channels. There was a clear peak around 0.06–0.07 Hz (~14–17 s), and between 0.03–0.02 Hz (30 to 45 s) which is within the frequency range of infragravity waves.

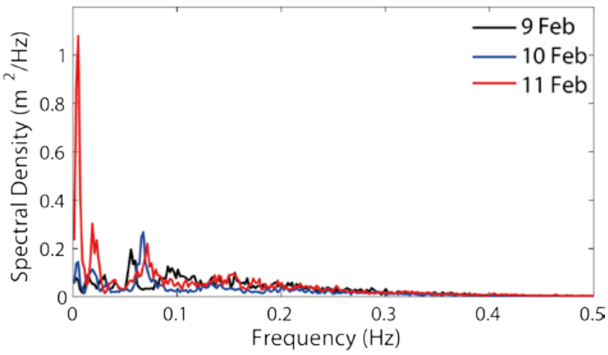

Figure 4 Mean spectra of pressure recorded by ADV1 on each day.

5. Discussion and conclusions

There were three main types of surf zone circulation patterns revealed at Ngarunui Beach. These are the first measurements of circulation at this popular surf beach. The dominant flow patterns on each day were: (1) alongshore; (2) circulation cell with high exit rate; and (3) circulation cell with no exits. This range of circulation patterns is similar to those observed in other (very different) environments. For example, three flow patterns were observed on the wind-wave dominated Dutch coast which were: circulation cell; an offshore-directed current deflected shore-parallel outside the surf zone; and (3) a meandering longshore current [16]. The longshore current at Ngarunui Beach was relatively linear rather than meandering (Figure 3a). The large variation in the dominant flow patterns over the 3 days would lead to different levels of risk to beach users. The high exit rate from the surf zone observed on 10 Feb suggests that the topographic and hydrodynamic conditions posed a greater risk to beach users than the other 2 days. Exits from the main rip current circulation cell have been documented elsewhere [17; 7]. It has been suggested that such exits are due to pulsations in the rip current surface velocity field [18]. [18] and [19] showed using numerical modelling, that the main driver for the exit of floating material in a rip current was Very Low Frequency (VLF) motions, on the order of 10 minutes. At Ngarunui Beach, measurements with ADV's inside the rip and feeder channels revealed a strong spectral peak within the infragravity band (Figure 4), although there do not appear to be any peaks in the VLF band. Further analysis is underway to understand what could be driving the exits of drifters from the surf zone that occurred on 10 Feb (Figure 3b), in the absence of VLF motions. This will help understand drivers of rip current risk to beach users.

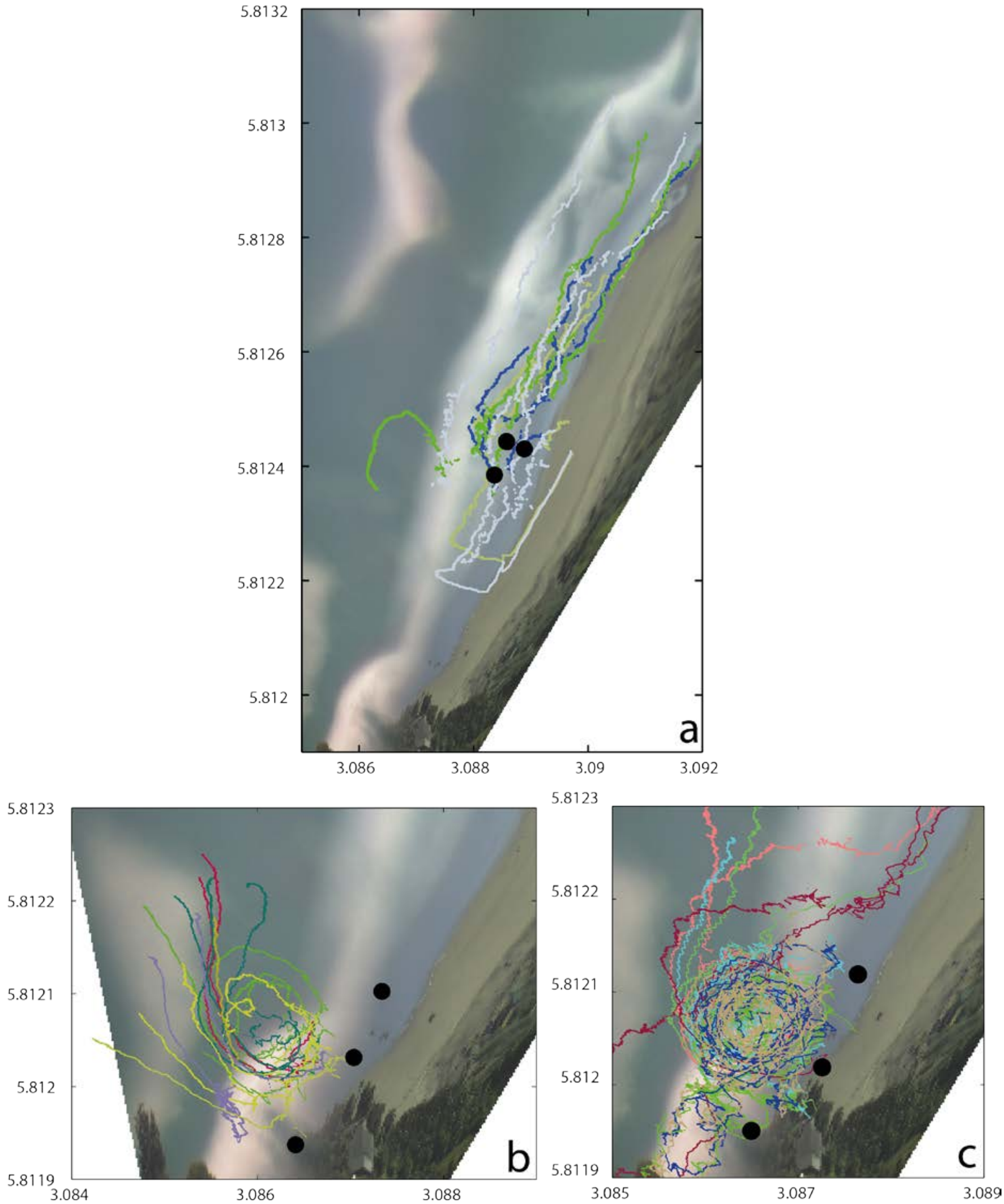

Figure 3 GPS drifter paths at Ngarunui Beach on: (a) 9 Feb; (b) 10 Feb; and (c) 11 Feb 2015. Black dots show locations of ADVs (Figure 1). Coordinates are in UTM where x is 10^5 and y 10^6.

6. Acknowledgements

Thanks to: the field volunteers including Mélanie Biausque, Carey Conn, Nicky Gallop, Steve Hunt, Jaco Labuschagne, Nicola Lovett, Chris Morcom, Julia Mullarney, Renaud Panier, Emily Woodhouse; the Raglan Coast Guard for helping us with their jetski, particularly Ed Aktin and Sebastian Boulay; the Raglan Surf Life Saving Club for being supportive; Brice Blossier for building and testing the drifters; Waikato Regional Council and NIWA for the Cam-Era video system; and Richard Gorman (NIWA) for providing offshore model wave data; and the Institute of Marine Engineering, Science & Technology (IMarEST) Laurie Prandolini Fellowship Award for funding the field work.

7. References

[1] Short, A.D. (1999). Beach hazards and safety, in: Short A.D. (Ed), Beach and shoreface morphodynamics, John Wiley and Sons, Chichester, pp. 292–304.

[2] Woodward, E., Beaumont, E. and Russell, P. (2015). Public understanding and knowledge of rip currents and beach safety in the UK, International Journal of Aquatic Research, Vol. 9, pp. 49-69.

[3] Aagaard, T., Greenwood, B. and Nielsen, J. (1997). Mean currents and sediment transport in a rip channel, Marine Geology, Vol. 140, pp. 25-45.

[4] Gallop, S.L., Bryan, K.R., Coco, G. and Stephens, S.A. (2011). Storm-driven changes in rip channel patterns on an embayed beach, Geomorphology, Vol. 127, pp. 179-188.

[5] Wright, L.D. and Short, A.D. (1984). Morphodynamic variability of surf zones and beaches: A synthesis, Marine Geology, Vol. 56, pp. 93-118.

[6] Brander, R.W. (1999). Field observations on the moprhodynamic evolution of a low-energy rip current system, Marine Geology, Vol. 15, pp. 199-217.

[7] Scott, T., Masselink, G., Austin, M.J. and Russell, P. (2014). Controls on macrotidal rip current circulation and hazard, Geomorphology, Vol. 214, pp. 198-215.

[8] McCarroll, R.J., Brander, R.W., MacMahan, J.H., Turner, I.L., Reniers, A.J.H.M., Brown, J.A. and Bradstreet, A. (2013). Assessing the effectiveness of rip current swimmer strategies, Shelly Beach, NSW, Australia, Journal of Coastal Research, Special Issue 65, pp. 784-789.

[9] MacMahan, J., Reniers, A.J.H.M., Thornton, E.B. and Stanton, T. (2004). Infragravity rip current pulsations, Journal of Geophysical Research, Vol. 109, C01033.

[10] Sherwood, A.M. and Nelson, C.S. (1979). Surficial sediments of Raglan Harbour, N.Z., Journal of Marine and Freshwater Research, Vol. 13, No. 4, pp. 475-496.

[11] Guedes, R.M.C., Bryan, K.R. and Coco, G. (2013). Observations of wave energy fluxed and swash motions on a low-sloping, dissipative beach, Journal of Geophysical Research: Oceans, Vol. 118, pp. 3651-3669.

[12] Walters, R.A., Goring, D.G., Bell, R.G. (2001). Ocean tides around New Zealand, New Zealand Journal of Marine and Freshwater Research, Vol. 35, No. 3, pp. 567-580.

[13] Gorman, R., Bryan, K.R. and Laing, A.K. (2003). Wave hindcast for the New Zealand region: Nearshore validation and coastal wave climate, New Zealand Journal of Marine and Freshwater Research, Vol. 37, pp. 567-588.

[14] Schmidt, W.E., Woodward, B.T., Millikan, K.S., Guza, R.T., Raubenheimer, B. and Elgar, S. (2003). A GPS-tracked surf zone drifter, Journal of Atmospheric and Oceanic Technology, Vol. 20, No. 7, pp. 1069-1075.

[15] MacMahan, J., Brown, J. and Thornton, E. (2009). Low-cost handheld global positioning system for measuring surf-zone currents, Journal of Coastal Research, Vol. 25, No. 3, pp. 744-754.

[16] Winter, G., van Dongeren, A.R., de Schipper, M.A. and van Thiel dr Vries, J.S.M. (2014). Rip currents under obliquely incident wind waves and tidal longshore currents, Coastal Engineering, Vol. 89, pp. 106-119.

[17] MacMahan, J., Brown, J., Brown, J., Thornton, E., Reniers, A., Stanton, T., Henriquez, M., Gallagher, E., Morrison, J., Austin, M.J., Scott, T.M. and Senechal, N. (2010). Mean Lagrangian flow behaviour on an open coast rip-channeled beach: A new perspective, Marine Geology, Vol.268, pp. 1-15.

[18] Castelle, B., Reniers, A. and MacMahan, J. (2013). Numerical modelling of surfzone retention in rip current systems: On the impact of the surfzone sandbar morphology, Proceedings of Coastal Dynamics 2013 (24-28 June, Arcachon).

[19] Reniers, A.J.H.M., MacMahan, J.H., Beron-Vera, F.J. and Olascoaga, M.J. (2010). Rip-current pulses tied to Lagrangian coherent structures, Geophysical Research Letters, Vol.37, L05605.