Developing a Regional Model Guidance for predicting Rip Currents on Beaches

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Background

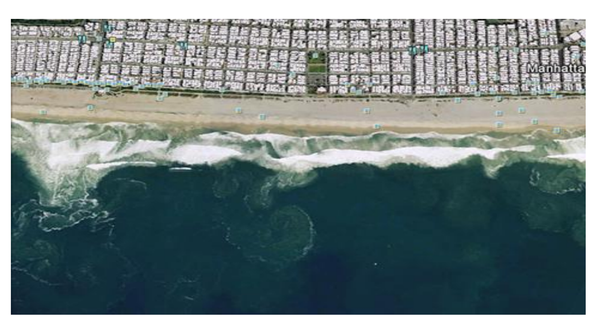
Rip currents on beaches can pull beachgoers away from shore and cause fatalities. The National Weather Service (NWS) is developing a proto-model to integrate rip current dynamics into an internet-based reporting system in support of forecast operations. Real-time beach observations recorded by lifeguards are communicated with marine forecasters to improve beach safety operation. The beach monitoring system has resulted in improved NWS hazard outreach by raising public and media awareness of rip current risk. Using the real-time data of waves and current observations as well as wind and tide levels, Forecast Offices can effectively deliver warning to better respond to beach hazards, high surfs, and rip current activities on beaches. Here, we first describe the rip current risk threat identification and categorization. We discussed methods of predicting rip currents and the last section a dynamic-based approach is proposed.

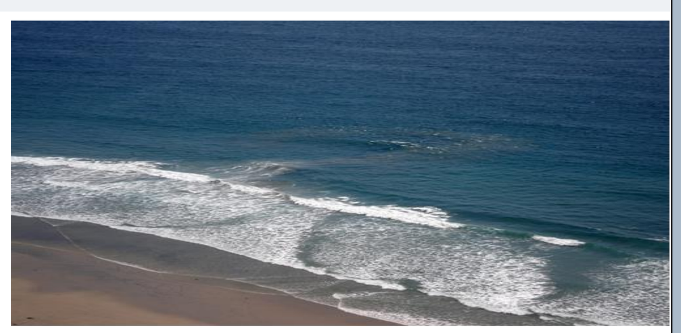
NWS's Surf Zone Forecasts and Rip Current Outlook

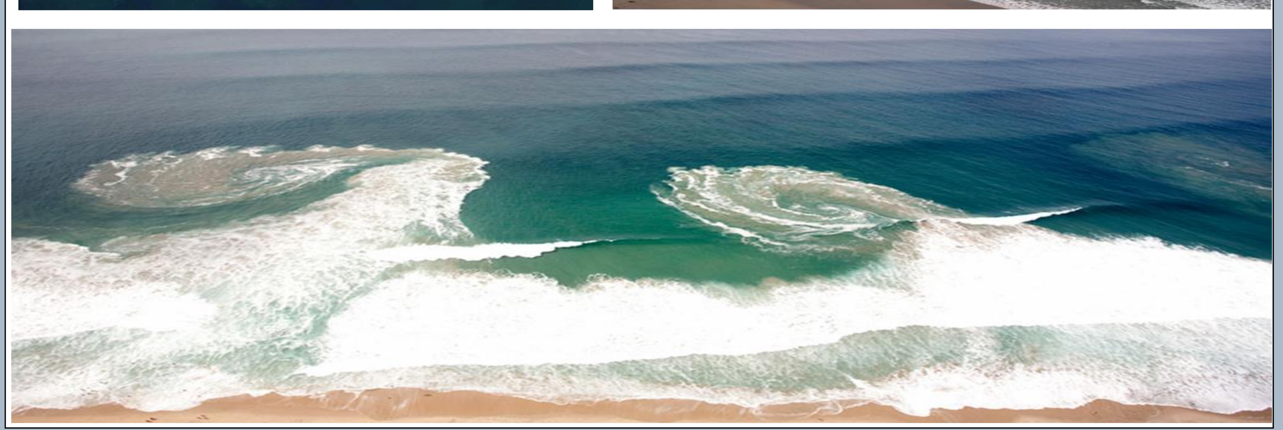
The NWS Marine and Coastal Services team has been standardizing Rip Current warning in three-tiers of Rip Current Outlook (2003): Low, Moderate, and High risk with a local disclaimer statement for the coastal marine zone. Through a field interpretation of beach safety, we adopt visual observations as a way to obtain real-time information and a source to issue forecast waning guidance. For each beach strand, we collect surfs, tides and rip current status to determine the relationship of rip current strength and corresponding rip current risk index for operation.

Categorizing Rip Current Threat in Near shore zone

- Rip current intensities vary from weak (< 0.10 cm/sec) to very strong (2 m/sec). At one beach, lifeguard may see nothing, or single rip pull, or outbreak rips in an hour (see below). The frequency and intensities of rip currents vary at regional coasts. Based on US fatality record, S. California beaches and southeast Florida coasts are frequent rip occurrence and mid-GOM beach is ghost coast.
- For issuing warning operation, we define three levels of threat based on rip fatality. This is implemented by beach lifeguard observations as **low, moderate, high risk** with respect to NWS mission statement of Rip Current Outlook. In the West Coast, we characterize rip current status or activity as no, weak, moderate and strong.
- In the field, the lifeguard's ability to report rip current is not consistent. Some lifeguards can identify the rip speed, others can only describe the status of rip threat from the beach safety and rescue viewpoint. To make a operational rule, **rip strength** is identified from the distance of rip pull. If the rip is limited in the mid-surf zone, the rip is weak; if the rip pull is beyond two times of the surf zone width, this rip is strong. This identification, however, could be less clearer when a rip is between moderate strong or moderate weak, as it reaches the edge of the surf zone width.







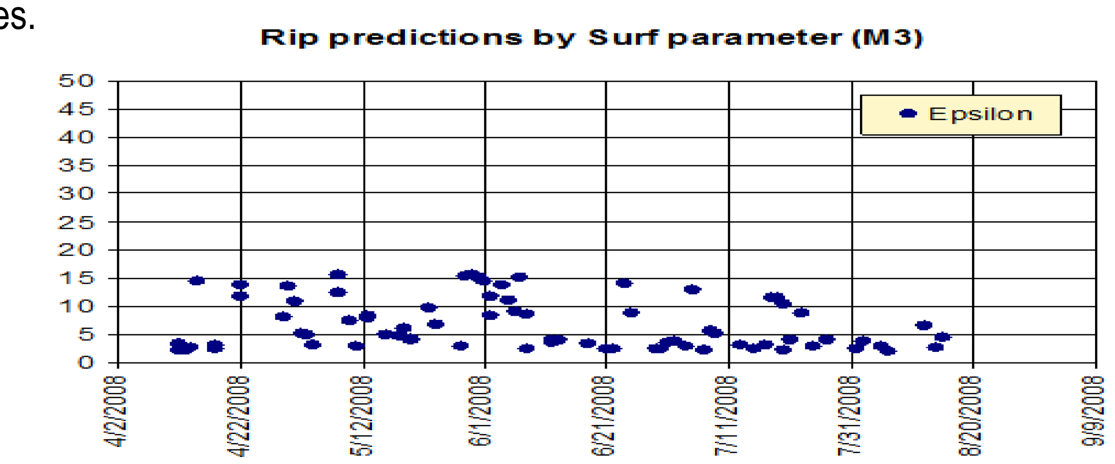
Prediction of Rip Currents Threat

In previous study, we developed a numerical model (Wu and Liu, 1985) in which the dominant factors affecting rip current occurrence are water waves, water levels, beach topography variations. In the field, beach sand size is an indicator of beach profile in surf zone. The author also found that onshore sea breezes can amplify surfs. In low-wave sheltered area, winds could play a important role in forming the rip currents. To formulate a simple predictor method: we focus on fixed type rip currents (Wu and Brewster, 2011) . Most frequently fatal case is under moderate waves normally attack beaches at any sea levels.

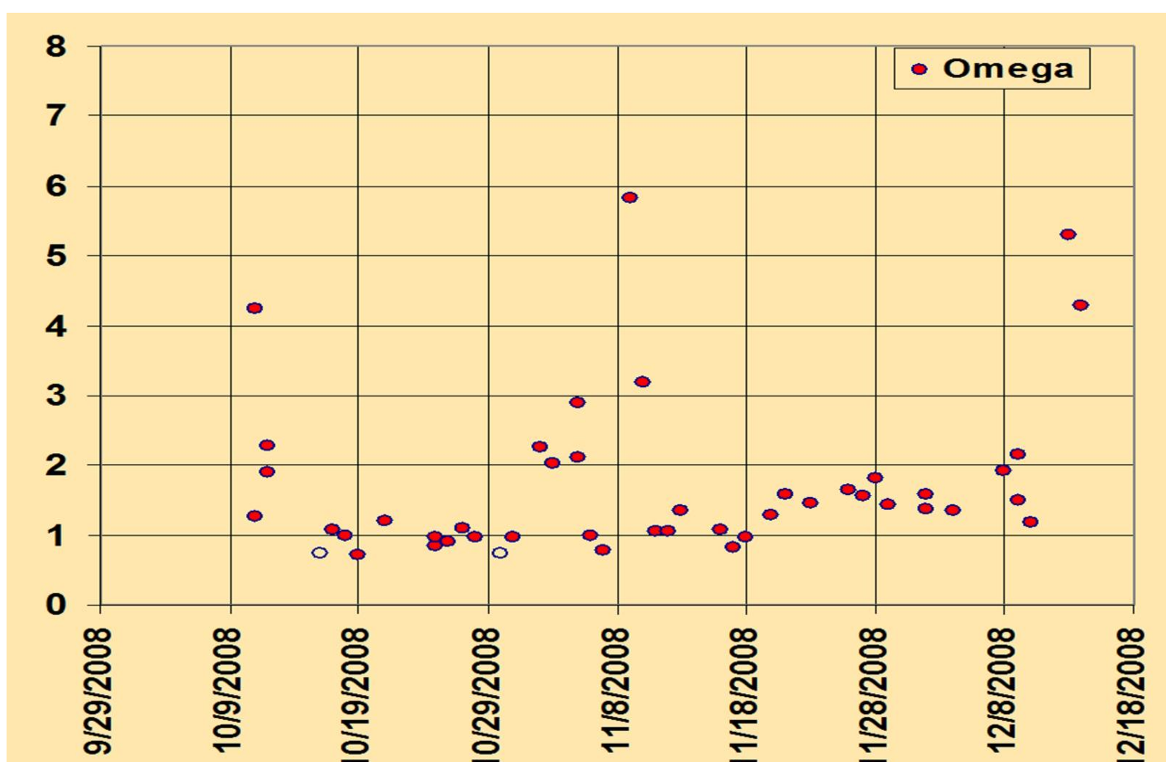
Three methods for predicting rip current are briefly reviewed herein:

1. **Surf parameter** (Guza and Inman, as listed in Ref 1).
2. **Beach state parameter** (Short, listed in Ref 1).
3. **Regression-Analysis Rip Index** (Varjola and Dalrymple 2011, and others)

The surf parameter is essentially the breaking parameter **ε** , the ratio of wave steepness to the beach slope. For **ε** < 2.5, no rips, and rip presents for 2.5 < **ε** < 25. Using **Moonlight Beach** data, the observed rips are falling within the right ranges.



The Dean parameter, Omega = Hs/(T ω) is a beach state parameter, has been applied in Hawaii beaches by Dr Short, it works well for swell dominated beaches. We have applied at **Moonlight Beach, CA** and found Omega values vary between 0 and 6.



The red dots are confirmed rip occurrences by lifeguards. In applying Short's formula: Omega < 1.0 for no rip conditions ; 1.0< Omega < 2.5 for moderate rip risk and Omega > 2.5 for high rip risk. The ω (sand particle falling velocity) must be calibrated with the beach face sediments in middle surf zone. In practice, the sand grain size varies with the seasonal change of beach profile. In winter time, sand grain size is larger than that in summer period. As a result, the falling speed is slower in summer. To best utilize the formula, one has to obtain accurate surf height and choice of ω with the seasonal change. For wide ranges of summer and fall period, the formula is applied and obtained reasonable good results.

Practical Cases of Issuing Rip Current Threats

(1) On July 8, 2011, the offshore waves were small wind swells of 16 sec arriving at the falling tide level below MSL. Applying surf parameter. ε is 12, indicating high risk rip presence; rip currents are observed throughout the beach,.

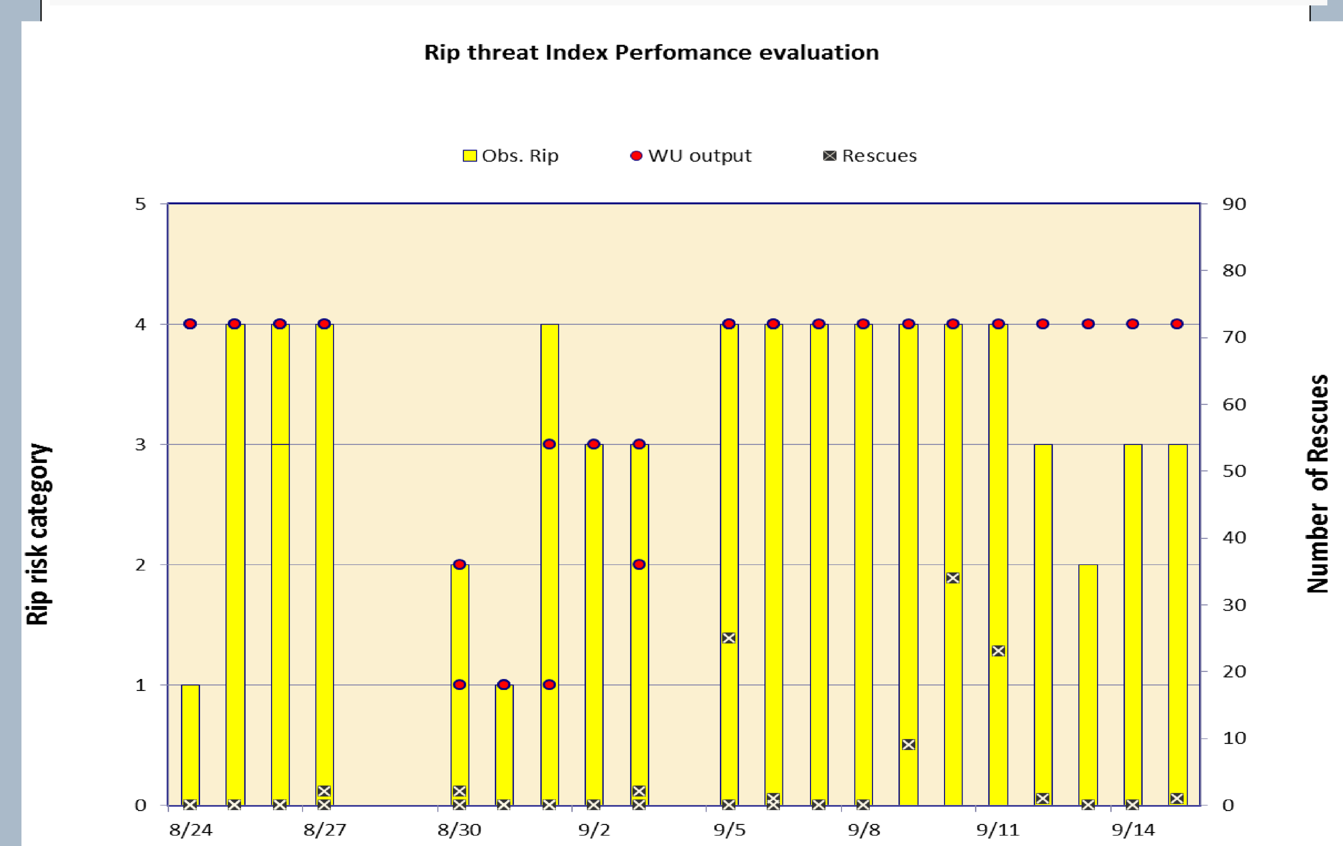
(2) On Oct 6 a.m., 2014, the southern swells above chest level were from SSW direction driving longshore currents with weak rip cells. Omega is small due to large angle diverted from shore-normal and onshore surf small and the long swell period. Nonetheless, rips appear in the afternoon when water levels are low. Rip currents warning are updated with vulnerable wave directions and water levels.

LOCATION: Mission Beach (L58)	LOCATION: Moonlight Beach
	OBSERVATION TIME (L): 10/6/2014 0825
OBSERVATION TIME (Z): 2011-07-08T00:30:00	SURF HEIGHT (FT): 4-5
SURF HEIGHT (FT): 1-2	SURF ZONE WIDTH (YDS): 120
SURF ZONE WIDTH (YDS): 200	WAVE DIRECTION: From South of Shore
TIDE CATEGORY: Falling	WATER LEVEL CATEGORY: Rising
WAVE DIRECTION: North	RIP CURRENT OBSERVED (Y/N): Yes
RIP OBSERVED (Y/N): Yes	RIP CURRENTS ACTIVITY: Weak
RIP CURRENTS ACTIVITY: Strong	RIP RESCUES: 0
COMMENTS: Rip currents throughout the entire	WATER ATTENDANCE: Low
area. Beginning to pull strong with the dropping tide	LIFEGUARD: Rob.

Linear Regression Analysis of Rip Current Threat in East Coast

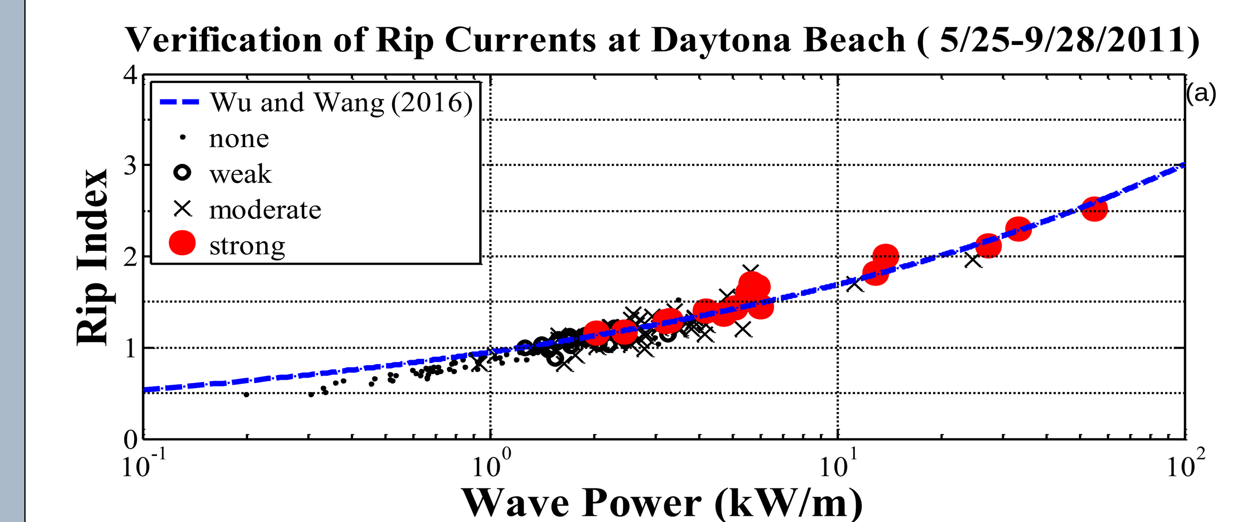
In applying Methods 1 and 2, we need beach sand or beach slope data that are not readily available. In 2004 Rip current Symposium, researchers attempted to predict rip current threat by statistical regression with field data. The Varjola and Dalrymple's (VD) model is to define rip threat factors through logistic decision tree as *onshore wave height (H), wave period (T) and water levels(d) at the beach.* This applies to saturated or unsaturated breaking zone, the former is popular in the East Coast where waves are primarily depth-controlled, regardless of the wave frequency in ranges of 0.12- 0.15 Hz. Varjola derived Risk Index in two ranges: H < 2 ft. or > 2 ft. The choice of 2 ft is determined from the data obtained from Daytona Beach, with respect to the observed data of surfs and rip intensities.

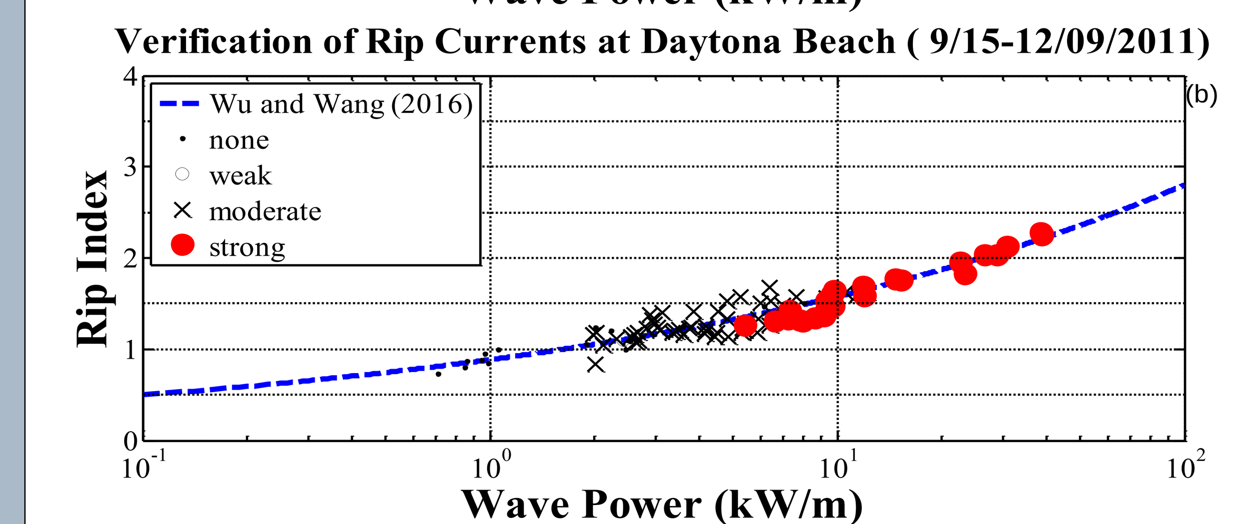
The VD model is applied to the Daytona Beach of Florida for a storm period and obtained 70% hit rate. The evaluation of model performance is shown in the figure below. The predicted rip threat compared with rip observations are displayed by the aforementioned Rip threat Index = **1**, when RI < 1.0, **2**, when 1.0 < RI < 1.1; **3**, when 1.1< RI <1.25 and **4**, when RI> 1.25, where 1, 2, 3, 4 represents no rip, weak, moderate and high risk, respectively. The ranges of RI plays the role as probability function, the value indicates the potential probability of threat in four tiers. The observed rip status (in yellow) and rescue number corresponding to the case are drawn in the circle with a cross.



Dynamics-based Parameterization of RI

RI is derived using observational data by regression. The fitting coefficients could vary significantly due to the variations in beach characteristics and nearshore wave patterns. The applicability of RI model, thus, could be highly localized. Here, we proposed a parameterization of RI by a dynamics-based formula. This parameterization is to relate RI with nearshore wave dynamics and can expand the applicability of RI. Here we showed the parametrization for RI from Dayton Beach (FL) during the summer and fall seasons.





Here, wave power is modified using incoming wave height and wave period. Different symbols are for observed rip threat status by lifeguards.

Summary:

Model forecasts are proposed to assess the threat of rip currents in the surf zone. The dynamical form is formulated to provide beach hazard now-casts for the coastal community. It helps address a data-gap in in-situ observations that hinders operation of NWS rip current warnings. Due to the subjective nature of the beach variability, a statistical model requires routine check and verification to maintain quality. The new model is less sensitive to beach conditions. Accuracy is sensible for incoming waves. We plan to use gridded model forecast for areas with high risk rip currents. Then the predictions may be improved to meet local lifeguard requirement.

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Reference:

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