Initial Evaluation of NOAA Probabilistic Rip Current Forecast Model:
Path to National Implementation

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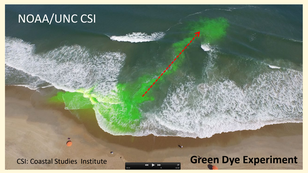
Introduction

The National Weather Service (NWS) and the National Ocean Service (NOS) are collaboratively transitioning the NOAA probabilistic rip current forecast model (Dusek and Seim 2013; Dusek et al. 2014) into NWS operations. This model predicts the statistical likelihood of hazardous rip currents using a logistic regression technique. In a staged implementation along the US coasts, the model is running experimentally as a component of the National Center for Environmental Prediction (NCEP)'s Nearshore Wave Prediction System (NWPS; Van der Westhuysen et al. 2013) in select areas.

As the hazardous rip current probability forecasts have been generated, rip current observation reports have been collected from lifeguards in coordination with local NWS Weather Forecast Offices (WFOs). The NWS Meteorological Development Laboratory (MDL) is using these rip current observations to perform validation studies of the model at pilot beaches across the US. The beaches are in widespread locations that can present rip current modeling challenges due to varied wave and beach bathymetry conditions. This presentation shows initial verification results at WFO pilot sites and suggests how to improve the model based on the verification scores and detailed investigations.

What is a Rip Current (RC)?



- Rapid offshore-directed jets of water that originate in the surf zone
- One of the most lethal natural hazards worldwide
- Taking swimmers of all ability levels into deeper water within minutes
- United States Lifesaving Association (USLA) reported that 53% of the 49,693 recorded beach rescues in 2016 were caused by rip currents (http://arc.usla.org/Statistics/view/displayAgency.asp).
- Rip currents are the number one public safety risk at the beach

NOAA Probabilistic RC Forecast Model

- A logistic regression model[+] developed using lifeguards' rip current observations (predictand) and predictors of the observations of
  - Significant Wave Height (Hs)
  - Mean Wave Direction (MWD)
  - Tide Water Level
  - Bathymetry Proxy (Postwave event occurrence, Ep)

  at Kill Devil Hills, NC

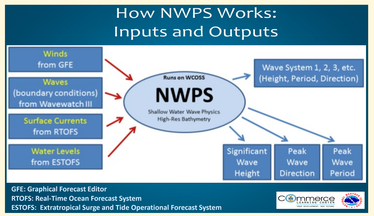
[+] **Logistic Regression Model:**
The probability of a particular outcome is linked to the linear predictor function:

$$\log it(p) = \ln\left(\frac{p}{1-p}\right) = \beta \bullet X = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n$$

$$p = \log it^{-1}(\beta \bullet X) = \frac{1}{1+e^{-\beta \bullet X}} = \frac{e^{\beta \bullet X}}{1+e^{\beta \bullet X}}$$

- Output: Statistical likelihood of hazardous rip currents
- Computing the probability using NWPS's wave parameter and tide water level forecasts
- Running experimentally at NWS/WFOs pilot sites (using the regression coefficient parameters developed for NC)
- Validation performed for Kill Devil Hills in coordination with WFO MHX (Morehead City, NC)
- Prototype Google Map-style visualization created

Nearshore Wave Prediction System



Common Sources of Error

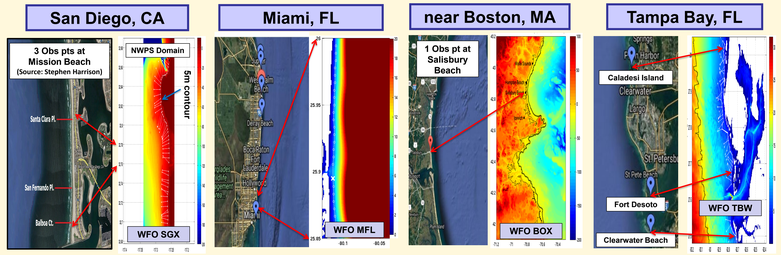
- Wind Grids (within model domain)
- GFS Winds/WW3 Waves (outside model domain)
- RTOFS Currents & ESTOFS Water Levels (forced by GFS)
- Spatial and Temporal Tracking of Wave Systems

GFS: Global Forecast System
WW3: Wavewatch3

Validating the Model

1. Pilot Beaches

"Matching the RC observation point with the closest NWPS forecast point"



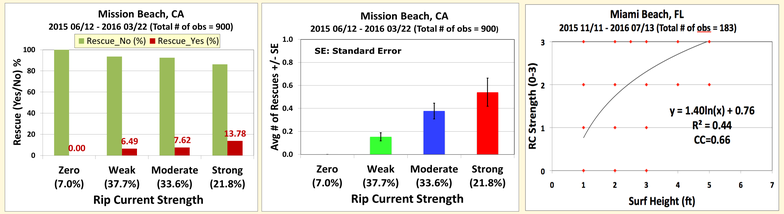
$D_{obs<->frcst}$ < 500 m | $D_{obs<->frcst}$ >> 500 m (~10 km) | $D_{obs<->frcst}$ ~ 500 m | $D_{obs<->frcst}$ < 500 m*

(Note: Usual RC range is 10-500m in the alongshore direction)

*Exception at Fort Desoto: ~5km

2. Assessing the Quality of the RC Observations

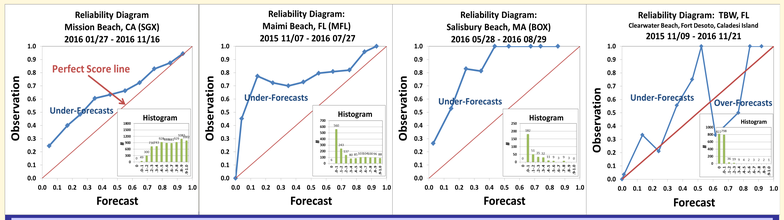
Are RC strength obs reliable to be used to compute model verification statistics?

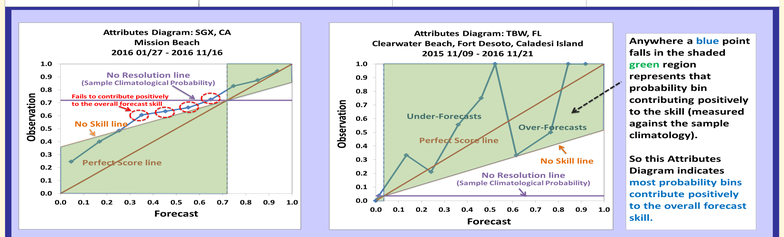


*Discretion: # of rescues are dependent on # of swimmers in the water (which is influenced by weather, lifeguard warning, etc.).

3. Initial Verification Results

	SGX (CA)				MFL (FL)				BOX (MA)				TBW (FL)	
Period	2016 01/27-2016 11/16				2015 11/07-2016 07/27				2016 05/28-2016 08/29				2015 11/09-2016 11/21	
# of Frcst Data	7533				1602				335				1698	
Brier Score	0.198				0.336				0.303				0.027	
RC obs category	Zero	Weak	Mod	Strong	Zero	Weak	Mod	Strong	Zero	Weak	Mod	Strong	No	Yes
Obs occurrence	0.5%	21.5%	46.8%	31.2%	33.8%	19.3%	27.6%	19.3%	48.9%	25.5%	17.0%	8.5%	91.3%	8.7%
Assumption			Hazardous				Hazardous				Hazardous			Hazardous



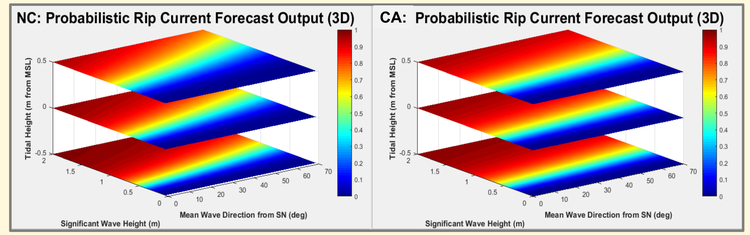


Summary and Future Research

NWS is implementing a real-time forecast system for hazardous rip currents based on a statistical model developed using lifeguard observations, nearshore wave measurements, and tidal elevation.

- Goal: National implementation of the NOAA probabilistic forecast model
- Current Status: Experimental run in NWPS on WCOSS for WFO pilot sites using one regression equation developed at Kill Devil Hills (KDH), NC.
- Verification: In general, results are encouraging in the WFOs of SGX (San Diego, CA), MFL (Miami, FL), BOX (Boston, MA), and TBW (Tampa Bay, FL), but indicate under-forecast skills in the Reliability Diagram. The reasons could be that 1) the RC model is without local calibration, 2) the NWPS inputs are biased (e.g., MWD, low Hs, etc.), and/or 3) the lifeguard observations are biased.
- New Regional Regression Equations are being developed using lifeguard observations (predictand) and NWPS forecast data (predictors) at the Mission beach, CA, for the SGX region.

Comparison of KDH (NC) and SGX (CA)



Logit of NC model (Dusek and Seim, 2013)

1.05 + 3.51 ln (Hs) – 0.027 |MWD| + 0.42 Ep – 1.70 Tide

*Note: Ep = 1 was used for the above figure.

Logit of CA model

1.46 + 3.13 ln (Hs) – 0.011 |MWD| – 0.97 Tide

Selected Predictors are different than NC's.

- Verification with the new equation indicates improvements over the current experimental products at the Mission beach (SGX) in the Reliability Diagram and Brier Skill Scores (not provided here).
- NWPS is now transitioning from structured to unstructured mesh grids. Once this upgrade is complete and retrospective run data are available, new equations for each regional domain will be developed and implemented.

More improvements will be able to be made by

- Developing backup equations and/or adding a backup system to prepare for missing ESTOFS's tide water level
- Testing additional predictors from other available models
- Obtaining more data such as high-resolution digital video camera observations
- Developing threshold probabilities to provide deterministic (yes/no) forecasts along with probabilistic forecasts
- Developing dynamic regression equations

References & Acknowledgments

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