The NOAA Coastal Hazards Resilience Workshop: Rip Currents and Wave Runup

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EXECUTIVE SUMMARY

One of NOAA's primary missions is to understand and predict changes in climate, weather, oceans, and coasts. With improved understanding, more accurate predictions, and actionable and effective communication of coastal hazards, lives and property are protected and the national economy is enhanced. This paper focuses on two important issues related to public safety near the coast: rip currents and wave runup. These topics were the subject of the NOAA Coastal Hazards Resilience Workshop held in April 2015.

Coastal hazards are an ever-present phenomena which require attention from local, state, and federal officials. For instance, coastal authorities focus their efforts on keeping the public safe during the swimming season from rip currents. Several approaches are used to inform the public of rip current dangers, including signage, public media, and education. Present approaches in predicting rip currents include the probabilistic rip current forecast model, driven by the Nearshore Wave Prediction System (NWPS), which provides on-demand nearshore wave model guidance to coastal WFO forecasters. The probabilistic rip current forecast model was developed to provide coastal and public service officials an objective method to predict the likelihood of hazardous rip currents. It has undergone initial verification and validation testing at two Weather Forecast Offices, with plans to expand to additional offices and eventually transition to NWS operations.

Wave runup is the maximum vertical extent of wave reach on a beach associated with breaking waves, contributing to increased water levels, overwash, and beach erosion, and therefore is another coastal concern. In fact, the Hurricane/Post-Tropical Cyclone Sandy Service Assessment recommends "NWS should develop guidance...for wave runup on U.S. coasts for all wind-forced surge and inundation events" (Recommendation 16). Similar to the probabilistic rip current forecast model, the proposed U.S. Geological Survey (USGS)-developed wave runup model is initialized using NWPS wave output and assesses current and future overwash potential. Verification of wave runup techniques requires the cooperation of numerous local coastal authorities. Calibration may be necessary for dissimilar locales implemented due to the nature of the independent variables and microscale influences. The Federal Emergency Management Agency (FEMA) is one of numerous agencies interested in wave runup and its changes, as resulting damage may affect sea walls, coastal structures, and maritime interests.

The NOAA Coastal Hazards Resilience Workshop (http://www.regions.noaa.gov/secar/wp-content/uploads/2015/06/NOAA-Coastal-Hazards-Workshop-Report.pdf) was designed to bring coastal hazard experts together to address these coastal issues and provide a pivot point to launch further collaborative forecasting and messaging advancements.

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1 INTRODUCTION

Coastal storms, even those far from the coast, produce strong winds and large waves affecting beaches and often leading to the development of rip currents. Rip currents are the greatest public safety risk at the beach worldwide and in the United States. The United States Lifesaving Association (USLA) estimates the annual number of fatalities due to rip currents in the U.S. exceeds 100 (USLA). According to the USLA's National Lifesaving Statistics Report (2012), over 82% of rescues at surf beaches are necessitated by distress in rip currents. Hence, an effective Weather-Ready Nation needs to receive timely and accurate forecasts of rip current risk in easy-to-understand language and in a consistent manner. Furthermore, the public must understand: (a) how to avoid getting caught in a rip current; (b) how to interpret rip current risk forecasts issued by the National Weather Service (NWS); (c) the meaning of warning flags; (d) actions to take while at the beach for protection of life; and (e) if caught in a rip current, how to escape and survive.

Wave runup is an important but complex component to coastal inundation. It contributes to the total water level behind barrier beaches and determines the incursion of the velocity zone, where the greatest risk from wave battery occurs. The complexity of the foreshore environment and immediate shore topography makes wave runup calculations resource-intensive for operational application. This wave runup project incorporates a parameterization scheme based on algorithms developed by Dr. Hilary Stockdon of the USGS for 25 surveyed forecast points along the middle Atlantic and New England coasts. The wave runup model determines whether dune erosion, overwash, or inundation is forecasted at high tide within the next 72 hours based on beach morphology and wave conditions input. This is a joint project with NOAA's North Atlantic and Southeast and Caribbean Regional Collaboration Teams (NART and SECART). NART plans to test and evaluate an automated prototype version of this program at established forecast points and transition it into experimental operations by the fall of 2016.

The NOAA Coastal Hazards Resilience Workshop: Rip Currents and Wave Runup was held on April 14-16, 2015 at the Virginia Modeling, Analysis, and Simulation Center (VMASC) on the Old Dominion University Campus in Suffolk, Virginia. The workshop assisted NOAA in further developing and improving strategies to mitigate problems associated with rip currents and wave runup and was co-sponsored by the NOAA Coastal Storms Program (CSP), NART, SECART, and NWS Office of Science and Technology Integration (NWS/OSTI). Approximately 80 participants attended the workshop, representing NWS forecasters and other NOAA scientists from the National Ocean Service and National Sea Grant Office, state Sea Grant programs, lifeguards, emergency managers, researchers, and the private sector and media (Figure 1). All US coasts were represented, including Alaska and Hawaii. Other attendees included forecasters from the Great Lakes and Puerto Rico, as well as an expert on rip currents from the University of New South Wales in Australia. Days 1 and 2 of the workshop were focused on rip currents; Day 1 efforts concentrated on forecasting and modeling, while rip current communication and messaging were addressed on Day 2. Wave runup was the topic of discussion on Day 3 and a subset of workshop attendees participated in an offsite wave runup field experiment on the afternoon on Day 2.

Figure 1: Group Photograph of Workshop Participants

This whitepaper describes key discussions from the workshop and is organized into two parts: (Part 1) rip currents and (Part 2) wave runup. The first part of the whitepaper, describing rip currents, is further split up into "messaging" and "forecasting".

2 PART 1 - RIP CURRENTS

2.1 *Current Capabilities and Rationale for Change*

A. Messaging

The "Break the Grip of the Rip!®" Campaign was initiated in 2004 by the NWS, Sea Grant and USLA. The campaign aims to educate the public of the dangers associated with rip currents by providing information about rip currents, including why they are dangerous, how to identify them, what to do if caught in a rip current, and how to help someone else if they are caught in a rip current. This message is disseminated through various means such as the NWS Rip Current Safety webpage, brochures, beach signs, logos on beach balls and whistles, fact sheets, stickers, the NOAA Ocean Today Kiosk, NWS seasonal campaigns, press conferences, videos, newspapers, articles, and television. NWS has recognized the need to review "Break the Grip of the Rip"® to ensure rip current messaging is scientifically sound, as well as effective and clear in reaching all age groups and demographics. The workshop provided the opportunity to hear from stakeholders and partners on the effectiveness of present messaging in both graphical and text format.

Coastal and Great Lakes Weather Forecast Office (WFO) forecasters issue rip current risk as part of the Surf Zone Forecast or Beach Hazards Statement. In general, these forecast products are not disseminated in a consistent manner among offices and therefore are not communicated seamlessly. This issue was addressed during the workshop by having forecasters from multiple offices summarize how rip current risk is communicated to the public from their respective offices. NWS headquarters and WFO representatives collectively discussed how to move forward in a more unified manner.

B. Forecasting

Rip current risk forecasts issued by forecasters at most coastal and Great Lakes WFOs are presently limited in functionality and accuracy, as forecasts rely upon an antiquated and functionally limited observational index developed in 1991 (Lushine, 1991). To address the need for an improved forecast system, a probabilistic rip current forecast model, which relies upon wave, water level, and bathymetry inputs, was created (Dusek and Seim, 2013a). The model has been coupled with the NWS' Nearshore Wave Prediction System (NWPS; Van der Westhuysen, et al., 2013) to compute the statistical likelihood of hazardous rip currents, on a scale ranging from 0 to 1 (Figure 2). Compared to the index method presently utilized, initial studies at Kill Devil Hills, NC (KDH) show a 67% improvement at forecasting hazardous rip current occurrence and a significant improvement during high-rescue periods. (Dusek and Seim, 2013b). By coupling the rip current forecast model with the NWPS, the system is able to provide output every 3 hours, for up to a 90-hour rip current forecast at a high resolution (~500m and higher) along the coast (Dusek et al., 2014). The model was developed using lifeguard observations collected at KDH and is running experimentally at WFOs Morehead City, NC (MHX) and Miami, FL (MFL; Gibbs et al., 2014), with plans to expand to additional offices and transition to NWS operations.

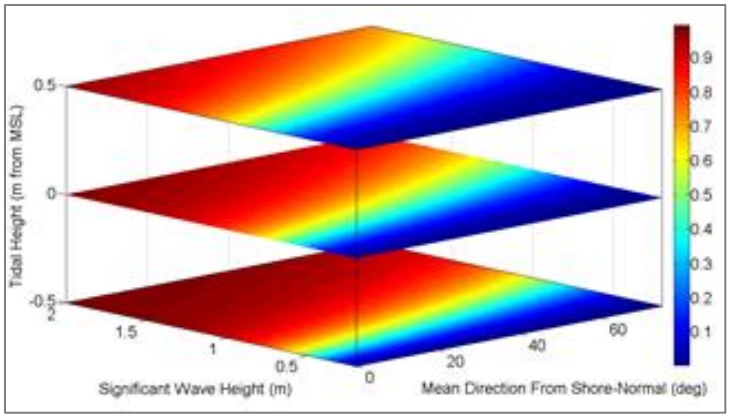

Figure 2: Model rip current likelihood (from 0 to 1)

To communicate model output to forecasters, and potentially to lifeguards, emergency managers (EMs), and the general public, a prototype Google Map-style visualization was created (Figure 3). The visualization provides a starting point for discussion and evaluation of effective forecast and risk communication, as generation of forecast guidance and dissemination of products will be instrumental in providing impact-based decision support services (IDSS) to lifeguards, EMs, and the public.

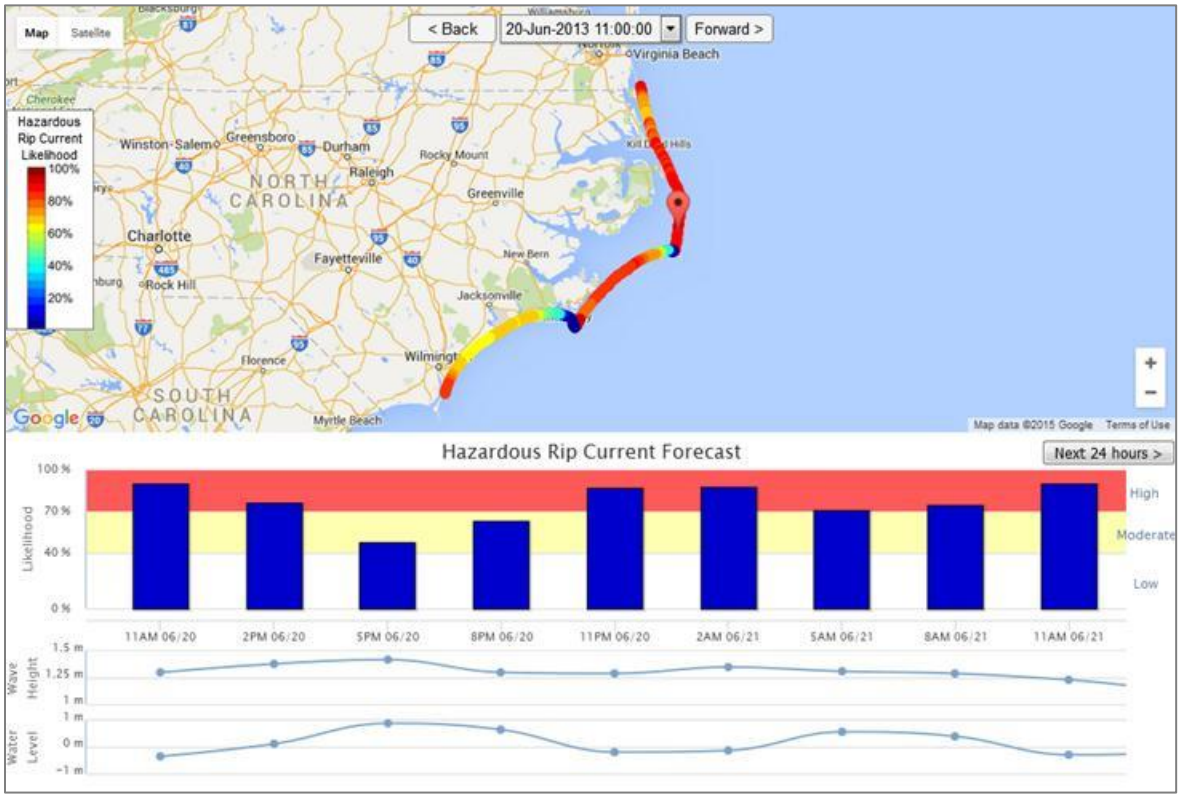

Figure 3: Prototype Google Map-style interface for the probabilistic rip current forecast model

The workshop was a means to obtain feedback from participants on the utility of the model, as well as strategies for expanding the model to additional WFOs, performing validation

studies, and eventually transitioning to NWS operations. Furthermore, focus groups were conducted to determine the most effective visualization of model output by utilizing the Google Map-style interface prototype as a starting point, and to communicate the risk associated with dangerous wave and current events in the best possible manner.

2.2 Workshop Discussions, Requirements, High-Level Actions

A. **Messaging**

The importance of evaluating present methodologies for communicating rip current forecasts and expected hazards was conveyed during workshop discussions. Many attendees stressed the need for a rigorous social science evaluation before any significant changes are made to national public safety messaging, such as the "Break the Grip of the Rip!" ® campaign.

Workshop discussions also addressed inconsistencies that presently exist in the way coastal and Great Lakes WFOs disseminate rip current risk in their respective Surf Zone Forecasts and Beach Hazards Statements. While a national standardization is required to ensure a seamless suite of products, focus groups highlighted the importance of tailoring some aspects of risk communication to specific demographics, regions, or beaches.

Focus group discussions yielded several items for consideration with respect to national messaging content, target audience(s), and dissemination mechanisms, as described in the bulleted list below.

- The focus of national messaging should be on tourists and visitors, keeping in mind locals may be at greater risk due to a false sense of security.

- Regional demographics should be addressed in coordination with local lifeguards. Messaging content, targeting these demographics, should be conveyed in an actionable and understandable manner. Dissemination mechanisms should also be explored to reach these specific groups. Those methods may include, but are not limited to, the following: radio, internet, television, social media, signage in multiple languages, magnets and brochures in rental properties, or face-to-face interactions, such as lifeguards teaching students in schools.

- National safety messaging initiatives, such as the "Break the Grip of the Rip!" ® campaign, should take advantage of the most recent social media outlets for delivery of information to the public. It is envisioned the public would become more familiar with and aware of beach safety by utilizing the latest technological advancements in social media.

- The public is more inclined to watch eye-catching positive messaging via outlets such as enhanced web pages, short videos, mobile devices, and signage. Therefore, content and delivery should be updated accordingly.

- Given the current technology infusion of social media and fact that much of the public utilizes cell phones or tablets as their primary means for internet content, a mobile-friendly interface would be an effective means for relaying information.

- Multimedia suggestions were made, including the creation of real-time video(s) demonstrating what to do if caught in a rip current. This would provide the viewers with the perception of what rip currents look like from a beach perspective. Dye release videos would also be "catchy" and an effective way to illustrate to the public how rip currents move in the surf zone.

- Potentially utilizing a well-known spokesperson in a rip current video or PSA may attract viewers to the messaging.

- Social science studies in messaging indicate certain verbiage is effective (e.g. "stay calm", "wave and yell for help", "rips will not pull you under").

- NWS and lifeguards should maintain close relationships to ensure messaging is consistent and effective. Lifeguards suggested messages should focus on prevention of accidents and injuries, thereby reducing the number of rescues.

Suggested high-level actions were as follows:

- NOAA should baseline statistics for rip current-related drownings and study demographics to ensure proper messaging.

- "Break the Grip of the Rip!®" campaign messaging should be thoroughly evaluated with social science research before any adjustments are made to the graphic or text.

- The phrase, "Always swim near a lifeguard", should be incorporated into NWS messaging.

- Consider implementing rip current prevention training in K-12 curriculum.

- Review visualizations of safety messages for rip currents and communication of rip current forecasts (including prototype websites).

- Revisit the utilization of "low" risk, when issuing "low", "moderate", or "high" rip current risk forecasts.

- Standardize NWS rip current risk forecasts on a national level, with room for regional adjustments.

B. **Forecasting**

The probabilistic rip current forecast model was largely embraced by workshop participants, especially in the forecasting community. Forecasters cited the need to utilize detailed forecasts, as opposed to the presently used index-based approach, to provide more accurate

and effective products for public dissemination. Lifeguards see the benefit of the model to "learn from yesterday and prepare for tomorrow."

Scientific considerations and viable approaches for expanding the model to additional WFOs were discussed at length, as well as requirements for transitioning the model to NWS operations. Accelerated development of unstructured grids was identified as a priority in moving from research to operations (R2O). Ideally, existing unstructured grids would be leveraged for multiple purposes (e.g. rip currents, wave runup, and bar forecasts), rather than continuing to develop nested structured NWPS grids. Strategies for prioritizing WFO expansion locations would also be required, noting specific criteria for choosing ideal locations.

Model validation strategies were reviewed and a recommendation was made to compile detailed validation instructions, or a Standard Operating Procedure (SOP), to provide guidance on specific steps for validation. These steps include, but are not limited to: the length of time required for data collections; the number of locations to be sampled; establishing climatology, methodology, and sensitivity studies; and the identification of high-impact "hotspots" for testing. The model will require validation on multiple coasts with varying wave regimes. Opportunities for incorporating more accurate bathymetry, such as the institutionalization of partnerships, should be explored. The Weather Service will also need to determine the appropriate office, Center, lab, or WFO to conduct validations. Validation techniques and observational networks, such as webcams, lifeguard-reported observations, and citizen science, were also discussed. Ideally more quantitative sources such as webcams, satellite imagery, bathymetry, UAVs, drifters, and trained observers would be used for model validation to mitigate the subjectivity and variability of lifeguard observations.

Rip current observation reports from lifeguards provide impact-based decision support services to the public and are also utilized to validate model performance. Thus, participants examined how to better foster engagement with lifeguards at the WFO level in receiving the near-real-time reports. For purposes of IDSS and model validation, lifeguards would prefer to be engaged early-on in the forecast development process and should have access to the resulting products in order to understand the importance of their contributions. As a result of the workshop, it is recommended the rip current observation reporting effort be streamlined and expanded. A reporting system suitable to all WFOs issuing rip current risk should be developed.

Focus groups were convened to explore the utility and appropriateness of a prototype Google Map-style interface to disseminate model output for guidance purposes and potentially to lifeguards, EMs, and public as an operational product. Feedback indicated rip current model output should be "binned" as "low", "moderate", or "high", based on a predetermined range of rip current risk forecasts. Many participants prefer the "low" risk (or green color) to be removed from NWS messaging due to the false sense of security it may give beachgoers. Additional social science studies are needed to gather firm requirements with respect to the resulting model output guidance and forecast products. Model output should not be shared outside of NOAA until it has been thoroughly validated. A suggested approach is for two different visualizations: one to be released to the public with very simplified information and

graphics (once the model is thoroughly validated), and a detailed version available only to lifeguards and NWS forecasters. Lastly, forecaster training needs were investigated to ensure background information, setup, execution, and validation instructions will be available.

The probabilistic rip current forecast model output should be utilized to provide a more detailed product, both in text and graphics formats. Specifically, the following improvements were suggested:

- Specific locations should be mentioned in forecast products or included on graphics
- Selected locations should include high attendance/rescue areas
- USLA annual data can be used to help identify hot spots
- Possibly adopt the storm surge watch/warning paradigm and utilize a grid-based forecast

The use of model forecast output should be indicated as experimental. Workshop participants suggested exploring the use of forecast output to create decision support-services briefing graphics.

Suggested high-level actions were as follows:

- Develop a working group or forum to share implementation experiences among offices as they implement the probabilistic rip current forecast model and incorporate into forecast operations
- Develop a formal WFO implementation strategy, or R2O plan, including prioritization of the order of implementation
- Develop formal validation instructions, or an SOP, to assist WFOs in collecting the appropriate data on the correct temporal and spatial scales
- Form an NWS working group to address the risk categories, including addressing how to deal with the issues associated with using the term “low risk”
- Develop a plan on how to share forecast model output with lifeguards in the experimental/validation stage of implementation

2.3 *Gaps and Challenges, Progress to Date*

There were a number of gaps identified for both the messaging and forecasting aspects of rip currents. Although progress has already been made since the conclusion of the workshop in filling these gaps, significant effort still remains.

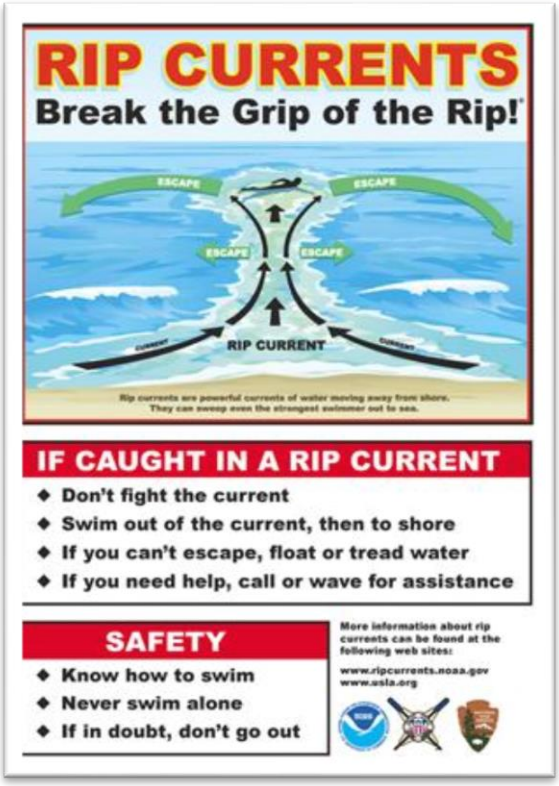

Figure 4: Current sign for the "Break the Grip of the Rip!®" campaign

A. **Messaging**

Gaps in rip current communication and messaging included the following:

- HD video footage of rip currents from beach level to aid in both scientific and public safety messaging (completed in summer of 2015)
- Updates to rip current animations and PSAs given scientific and communication advancements (completed in summer of 2015)
- Rigorous studies, covering multiple U.S. coasts, are needed to determine the effectiveness of the "Break the Grip of the Rip!®" campaign (Figure 4) (initiated)
- Compilation of all rip current social science related research into one document to provide an overview of what has been done (initiated)

Since the conclusion of the workshop, progress has been made on a number of the rip current messaging fronts. More specifically, real-time HD rip current footage was captured from a beach perspective, in collaboration with University of North Carolina's Coastal Studies Institute, Kill Devil Hills Ocean Rescue, and NOAA's Ocean Today, during the summer of 2015. The footage will be included with filming for media partners, to use in scientific presentations by NOAA personnel or in NOAA-developed PSAs and outreach materials. In addition, updates to the rip current PSAs are required to take advantage of this footage and to incorporate recent scientific and communication advancements.

Figure 5: NOAA Ocean Today's Animated Rip Current Awareness Video

Furthermore, NOAA's Ocean Today produced an animated Rip Current Safety Awareness video (Figure 5) during the summer of 2015, highlighting many of the main messaging points discussed at the workshop. The video may be viewed at the following URL: http://oceantoday.noaa.gov/ripcurrentsafety/.

Additionally, an in-person OMB-approved survey was conducted at Ocean City, MD in July 2015, to gauge the public's understanding of rip currents and how to escape them.

Lastly, Texas A&M University, in collaboration with Texas Sea Grant and the University of New South Wales, initiated a research study in 2015 to establish quantitative data which will provide guidance for updating existing beach safety education material in continuing to reduce the number of fatalities involving rip currents.

B. **Forecasting**

Gaps related to rip current forecasting include the following:

- R2O plan for the rip current forecast model (initiated in FY15)
- Validation of NWPS and rip current forecast model in different coastal regions with different physical characteristics (ongoing)
- Validation of NWPS and rip current forecast model utilizing more quantitative observations at additional locations (ongoing)
- High resolution unstructured NWPS grids for validation locations (initiated)
- SOP detailing rip current forecast model validation procedure for WFOs (TBD)
- Nearshore bathymetry to aid in model validation and development (TBD)
- Climatology of rip current activity to determine potential critical locations or hotspots (TBD)

Since the conclusion of the workshop, progress has been made on a number of the rip current forecast gaps. An R2O plan has been drafted to detail the steps necessary to implement the probabilistic rip current forecast model at a number of pilot WFOs. As part of this R2O plan, a number of potential validation sites at coastal and Great Lakes locations with different physical characteristics have been identified. This step is especially important as it is critical to assess, and if necessary, tune the forecast model in these cases. Additionally, the workshop stressed the importance of collecting more quantitative observations to aid with validation. Work on this has begun at a study site on Emerald Isle, NC where rip current and bathymetry observations are being collected via camera systems, and wave data are being collected using two wave profilers. These observations will aid in validation of the model in southern North Carolina and will also provide a template for similar studies in other locations. Lastly, tests using high resolution nested NWPS grids at validation sites have been initiated on the Outer Banks with the Morehead City WFO, and in Miami Beach at the Miami WFO.

Gaps that still need to be addressed include the development of an SOP for detailing rip current forecast model validation procedures for WFOs. Also, a significant data gap exists for nearshore bathymetry observations to aid in model validation and development, which is a considerable challenge given the cost and complexity of obtaining these observations. Furthermore, it would be beneficial to establish a climatology of rip current activity to aid in the selection of critical forecast locations. The lifeguard observations collected by the NWS' Meteorological Development Laboratory (MDL) could help address this need. Lastly, a high priority outcome of the workshop is to accelerate the development of high-resolution unstructured NWPS grids for validation sites, as the continued development of high-resolution nested grids is not a viable long-term solution.

2.4 *Strategy in Moving Forward*

The workshop resulted in some concrete near-term actions and gaps, as noted in Sections 2.2 and 2.3, and strategic paths forward to advance both rip current messaging and forecasting.

A. **Messaging**

To ensure the public is Rip Current-Ready, NWS must ensure ample base resources continue to be provided to support rip current messaging, including the "Break the Grip of the Rip!®" campaign, ongoing education and outreach through the NWS Rip Current Safety webpage, brochures, beach signage, media, and videos. A dedicated full-time employee (FTE) is needed to oversee messaging efforts, hold training sessions with national and local media on rip current science and communication, and lead the National Rip Current Messaging Team teleconferences. This effort is further augmented by the National Sea Grant College Program network, whose niche is integrating research, outreach, and education. The Program has and will continue to work in local communities, promote and educate rip current awareness by means of communicating and working with beach patrols and local weather forecast offices, and produce educational and outreach programs.

The National Rip Current Messaging Team has reconvened regular meetings to evaluate recent physical scientific findings, as well as social science results in determining whether adjustments should be made to "Break the Grip of the Rip!®" messaging. The Team is also investigating where additional social science studies are needed, such as adopting Dr. Rob Brander's Australian rip current survey, evaluating the effectiveness of NWS rip current risk, initiating a survey to query those who have been caught in a rip current and/or lifeguards who have been involved in rip current rescues, and conducting public surveys with existing and alternative messaging.

NWS will move toward consistent, standardized messaging among coastal and Great Lakes WFOs to ensure a seamless suite of products. The national rip current webpage (http://ripcurrents.noaa.gov/) is a means to foster standardization, yet allow for regional tailoring. Messaging will be disseminated through relevant social media outlets to reach target audiences. NWS will also consider additional ways to disseminate messaging in order to reach demographics that may be underserved

B. **Forecasting**

A project manager from NWS' marine program must be identified to champion the successful implementation of the model into operations, addressing both science/technology and products/services requirements. The project manager(s) would initiate an active working group (WG), including representatives from each of the NWS Regions to continue to build and evolve the R2O plan. A subset to a larger R2O WG has been initiated and convenes on a bi-weekly basis to develop the initial R2O plan. The plan addresses validation of the NWPS and probabilistic rip current forecast model in different coastal regions with varying physical characteristics; utilization of more quantitative observations at additional locations; development of high-resolution unstructured NWPS grids for validation locations; generation of a SOP for WFOs to perform validation at their respective beaches; documentation of

bathymetry requirements and opportunities for leveraging data; and development of climatology of rip current activity to determine potential critical locations, or hotspots.

Base resources from NWS have been requested to perform extensive model expansion and validation in FY16 (and beyond) and to advance the probabilistic rip current forecast model from research to NWS operations. Additional NWS base resources are being sought to conduct social science research on the Google Map-style interface for dissemination of model output. In advance of an FY18-20 operational implementation, funding will be requested to develop forecaster training material as well. In-kind support from forecasters will be needed for implementing and validating the model at the WFOs. Additional in-kind scientific expertise from NOS/CO-OPS will be leveraged. Partnerships with NART, SECART, Sea Grant programs, IOOS regional associations, USLA, and lifeguards will continue to be utilized. Other funding opportunities will continue to be explored to accelerate model transition, including but not limited to the CSP, SECOORA, and the NOAA Research Transition Acceleration Program (RTAP). For example, program managers have successfully leveraged an FY15 FFO opportunity with SECOORA to have rip current and nearshore wave observations deployed in Emerald Isle for validation purposes. A UNC-Wilmington Sea Grant student will conduct validation and hindcast studies on the SECOORA-funded observations during the 2015-16 academic school year. Program managers have also formally submitted a Letter of Intent to apply for FY17 NOAA RTAP funding. Operations and Maintenance (O&M) funding for the probabilistic rip current forecast model will be included with that of the NWPS, thereby eliminating the need to secure resources for a separate O&M tail.

Ultimately, the goal of this project is to build the necessary unstructured wave grids in support of extending the probabilistic rip current forecasts to all U.S. coasts. Upon completion of validation and hindcast studies in pilot locations as well as development of a validation SOP, WFOs would be self-sufficient in both institutionalizing a strong relationship with their local lifeguards in obtaining near-real-time observations of rip currents and in following the SOP to perform the necessary validation for their own beach locations. Lifeguard observations would be stored in a robust national database for use by WFOs, lifeguards, and researchers. The model would be utilized experimentally or as forecast guidance until the office deems the model is of operational maturity level per SOP guidance. Operational support of the probabilistic rip current forecast model would be ongoing at NWS/NCEP/EMC as part of NWPS O&M.

3 PART 2: WAVE RUNUP

3.1 *Current Capabilities and Rationale for Change*

Wave action along the coasts of the United States can be one of the most destructive forces from coastal storms and hurricanes. Although storm surge plays a large role in coastal destruction, the waves on top of the surge often result in the most damage. While there have been numerous advances in storm surge forecasting and messaging in the past several years, wave runup capabilities have lagged behind. NOAA Regional efforts to improve this forecasting capability have begun in the Northeast United States, largely through efforts funded by the NART. These efforts have been closely collaborated with the United States Geological Survey (USGS), employing some of their modeling techniques for shoreline change analysis that also account for wave runup. Efforts have spread from the Northeast to the Southeast as well, with support from the NOAA SECART. Wave runup and shoreline vulnerability forecasts have been made possible from high-resolution output from the NWPS, coupled with surge and tidal forecast models. Once fully developed and coupled with a robust display and communication research, this forecast system will enable NOAA to provide relevant, actionable information to coastal residents, thereby contributing greatly to NOAA's total water forecasts.

On Day 2 of the workshop, a group of participants attended a field trip to a nearby shoreside location to demonstrate the survey techniques being used as the foundation for the wave runup forecast model (Figure 6). NART representatives demonstrated the measurements of dune height from base to top, and high water mark locations. A SECART representative demonstrated the use of GPS survey equipment to aid in this effort.

Figure 6: Wave Runup Field Demonstration

3.2 *Workshop Discussion Topics*

The goal of the workshop was to bring together the knowledge gained from NART, SECART, local forecast office initiatives, and the USGS to formulate a coordinated path forward to employ the best methodology for forecasting wave runup across NOAA.

Workshop presenters provided information on a number of initiatives, including: NART efforts; WFO Caribou's strategy to address overtopping seawalls; WFO Taunton's Coastal Flood Program; wave runup model testing at the Morehead City, Tampa Bay, Miami and Boston WFOs; wave and surge modeling in Puerto Rico and the Virgin Islands; expansion procedures from the Northeast to Southeast, considering methodology, erosion, sand dunes; utilizing the NWPS to produce wave runup forecasts; user and partner information needs; and erosion, overwash, inundation initiatives.

Following the exchange of information during presentations, focus groups delved into some specific issues. The first breakout session focused on identifying a good implementation strategy for applying NART survey and forecast techniques, which were often developed for rocky or sea wall locations, to the southeast, which features mostly sand dune waterfronts that frequently change. The second focus group explored how to best use NWPS output to aid in wave runup forecasting and its impacts. The third focus group explored the needs of users and partners for forecast information, and erosion, overwash, and inundation. The fourth group focused more in-depth on survey techniques demonstrated on Day 2 of the workshop.

3.3 *Requirements and High-Level Actions Collected at Workshop*

NWS/NCEP/EMC intends on delivering site specific forecast data to wave runup survey sites for WFOs Caribou, Gray, Taunton, Wakefield and Morehead City by the end of 2015. These offices will conduct an informal test and evaluation during the winter of 2015-16 to assess the wave runup site forecast accuracy and reliability for high impact coastal flood events.

Workshop discussions on wave runup forecast techniques yielded a recommendation to adopt the methodology developed by the USGS of a probabilistic approach in addition to or in place of relying on frequent surveys of vulnerable locations. The USGS methodology gathers all available survey information from the past of shoreline structure and dune heights, and creates a range of potential impacts, based on that window. This methodology will also allow for modeling across entire stretches of coastline, rather than on individual "hot spots". WFOs, including Morehead City and Miami, plan to work with USGS to test this further. To better accommodate this testing, WFO Morehead City requested assistance from NWPS modelers to test an unstructured version of the NWPS model on its local server, and run the USGS model for an entire shoreline. Assistance would also be needed to develop the best method to display this output.

Wave runup project leads aspire to implement the model experimentally at the start of FY17, with support from NWS headquarters.

In short, high-level actions include the following:

- Wave-runup forecast methods developed by the NART should be formally expanded across the NWS, where applicable, as a first step in providing enhanced forecasts of wave runup and its impacts. A plan for testing and implementation should be developed.
- Wave runup forecasting efforts should be merged with the USGS forecast methodology to expand from point-based forecasts to the entire shoreline (in parallel). A plan for testing and expansion should be developed.
- Social science funding should be provided to evaluate the best method to display and communicate wave runup and its impacts.
- A single NOAA visualization product should be adopted based on social science research.

3.4 *Gaps and Challenges, Progress to Date*

Forecast site surveys are labor intensive. Therefore, forecast offices are encouraged to seek out public sector engineers to assist in original site surveys and follow-up surveys every 2 to 3 years to account for changes in beach structure. To accommodate situations where assistance from the public sector cannot be found, coastal WFOs would benefit from funding for GPS survey equipment similar to or better than the units obtained by SECART for a storm surge measurement project.

Testing and evaluation during the winter of 2015-16 is dependent upon NWS/NCEP/EMC's delivery of forecast data to the participating WFOs. If those offices do not have adequate time to assess forecast data accuracy and reliability, experimental implementation may be delayed by 6-9 months.

WFOs need the capability to run unstructured NWPS output along the coast to improve resolution while keeping short run times. WFO Morehead City seeks to run such a test during the fall of 2015. WFOs also need support to develop an appropriate display of wave runup and shoreline change forecasts (collision, overtopping, and inundation). Social science research is needed on the most effective display of graphical information and the best way to include that information in routine NWS text products. Parallel efforts on modeling and social science will ensure this important new forecast capability becomes operational in a faster timeframe.

3.5 *Strategy in Moving Forward, High-level Actions, Dependencies, Next steps*

Participating offices are moving forward with a test and evaluation in anticipation that the forecast data will be delivered by the end of 2015. The test manager will need to brief NWS headquarters officials in the spring of 2016 on forecast performance and reliability.

To ensure the wave runup project is considered in future NWS base resource requests, a project manager from NWS' marine program must be identified to champion the successful

implementation of the model into operations, addressing both science/technology and products/services requirements. The project manager(s) would initiate an active working group, including representatives from each of the NWS Regions to gather requirements and continue to build and evolve the plan for testing and implementation. The wave runup project should is included in the NOAA Storm Surge Roadmap portfolio.

In-kind support from WFO forecasters will be needed as they implement the model at their respective offices. Partnerships with the USGS, NOAA NART and SECART, Sea Grant programs, and IOOS regional associations will be vital to the success of this work. Other resource opportunities should also be explored to accelerate model testing and evaluation.

4 CONCLUSION

Rip currents and impacts from wave runup are two of the most impactful phenomena in coastal locations. There have been a variety of uncoordinated efforts related to improving the forecasts of these events and identifying the impacts they will have. This workshop brought together a wide range of participants with experience in these areas, who shared information on what was being developed and/or experimented with, and identified ideas for a coordinated best path forward for NOAA to make a significant impact by improving rip current and wave runup forecasts. By following the recommendations from this workshop, NOAA will align efforts and avoid a duplication of effort on parallel and sometimes diverging paths.

Rip current and wave runup forecasting are closely tied together with high resolution nearshore wave modeling capabilities being the core input needed for improvements in both areas. Both require strategic planning from NWS Headquarters, for example, to write R2O plans; vet regionally for requirements and input; and seek necessary resources to conduct research, development and ultimately transition to NWS operations. Potentially, there may be bathymetric and observational leveraging opportunities common to both areas, as well. For example, utilization of webcams for observations in validating both models at agreed-upon, coordinated locations. Social science research on better communicating new forecast outputs, both graphically and in routine text products, is also common to both subject areas. Additional social science efforts can also help to provide better outreach and communication on how to understand, prepare for, and react to the possible impacts. Finally, One-NOAA coordination and partner collaboration are the key ingredients to ensuring the public is resilient in the face of coastal hazards associated with rip currents and wave runup. The NOAA Coastal Hazards Resilience Workshop provided the necessary forum to bring experts together and acted as a stimulus for advancing the rip current and wave runup forecasting and messaging initiatives.

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