CARICOOS Beach Water Quality

Sylvia Rodríguez-Abudo, Peter Rivera Casillas and Priscila Vargas Babilonia
Department of Engineering Sciences and Materials
University of Puerto Rico-Mayaguez
Call Box 9000
Mayaguez, PR 00681-9000
email: rodriguez.abudo@upr.edu

LONG-TERM GOALS

CARICOOS beach water quality efforts aim at developing decision making tools to provide timely and accurate information to beachgoers and coastal managers across the region regarding beach water quality in their locality. This initiative is part of the CARICOOS Coastal Hazards Focus Area, as well as its Observational and Modeling Subsystem, and is well aligned with CARICOOS goal of integrating observations and models into coastal intelligence for the US Caribbean region.

MILESTONES / OBJECTIVES

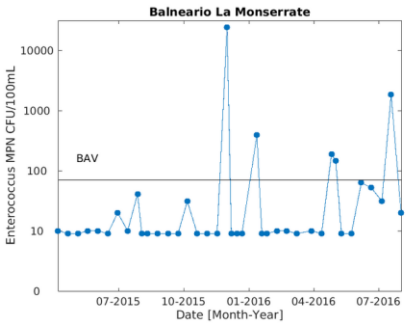
A. Develop and improve beach water quality data products.
B. Validate and fine-tune Rincon Public Beach (RPB) Beach Water Quality Experimental Nowcast.
C. Develop two additional nowcasts for Crashboat, Aguadilla and Playa Santa, Guánica.
D. Formalize collaboration with the Puerto Rico Environmental Quality Board.

WORK COMPLETED

A. Develop and improve beach water quality data products:
Since April 2016, CARICOOS provides historic time series of beach water quality data for 48 beaches around Puerto Rico. During the performance period, said data products were enhanced by adding additional data, increasing resolution and improving data visualization (Figure 1). Additionally, a validation product was developed for the RPB Beach Water Quality Nowcast (Figure 2).

B. Validate and fine-tune RPB Beach Water Quality Experimental Nowcast.
The RPB Beach Water Quality Nowcast has evolved into six different versions outlined in Table 1. All are computed every hour, 24/7. A hierarchy has been established based on validation results to decide which prediction will be published online. At this moment version 2.1 leads the hierarchy followed by version 2.2.

A validation product for each nowcast version has been generated for internal use (Figure 3). The product runs daily to check for new water quality data, and computes model performance based on sensitivity, specificity and accuracy (Table 4). A visual output of



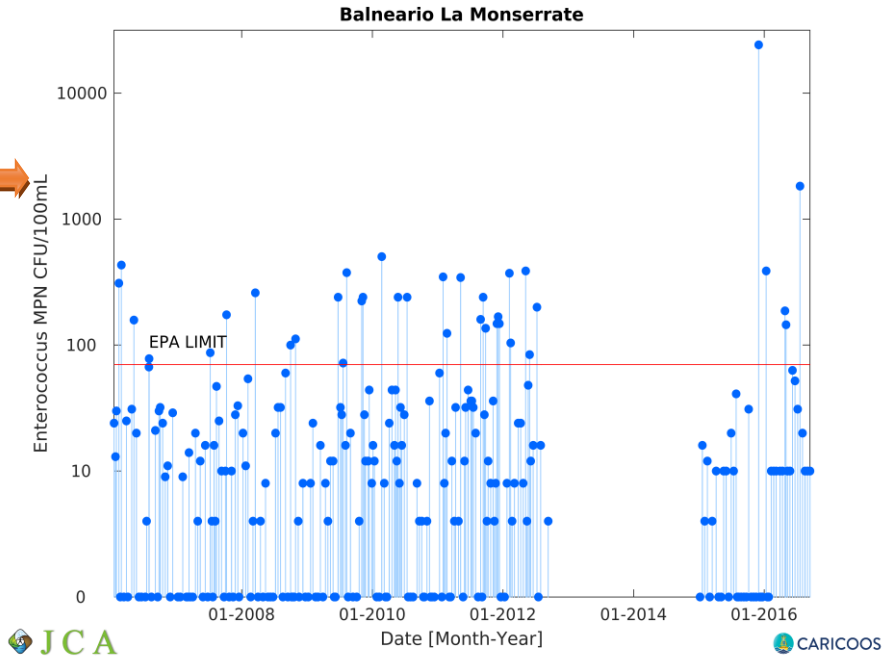


Figure 1 (above and right). Improvement of historic beach water quality data products.

Table 1: Nowcast Versions

Nowcast1: Rainfall from station KPRRINCO3*	
1.0	Output = Eqn. 1[&]
1.1	If rain=0, output<BAV[+], else output = Eqn. 1[&]
1.2	If rain=0, output = Eqn. 2[&], else output = Eqn. 1[&]
Nowcasts2: Rainfall from station IRINCNRI2*	
2.1	Output = Eqn. 1[&]
2.1	If rain=0, output<BAV[+], else output = Eqn. 1[&]
2.2	If rain=0, output = Eqn. 2[&], else output = Eqn. 1[&]

**Weather Underground ID*
[+]BAV=Beach Action Value (90 MPN CFU/100mL)
[&]Eqns. 1 and 2 are provided in Table 2 and 3, respectively.

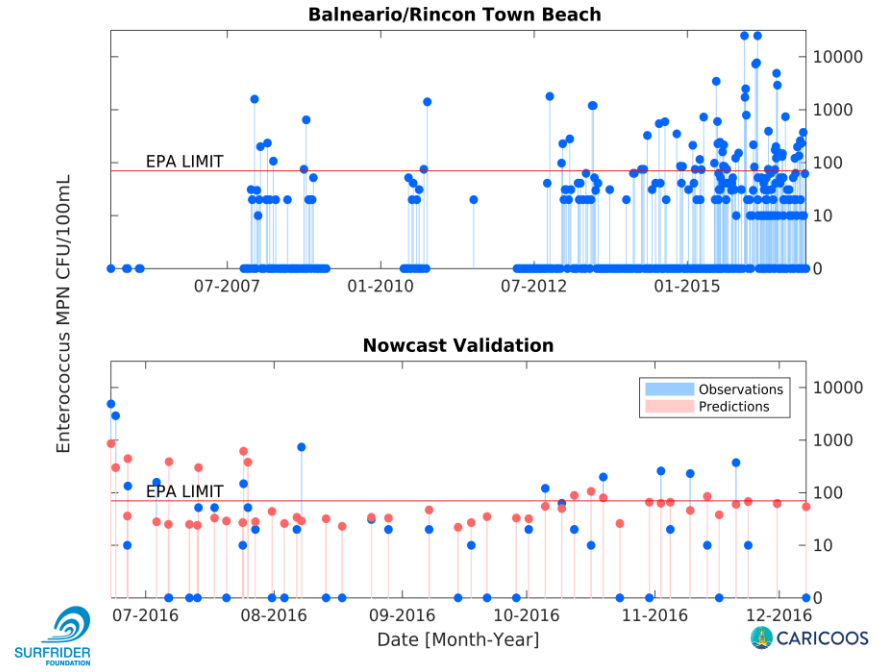


Figure 2 (right). Historic data product and nowcast validation product for Rincón Public Beach.

Tables 2 and 3: Multivariate linear regression model for Equation 1 (left) and Equation 2 (right), Ent = Most Probable Number of Colony Forming Units of Enterobacteria.

$$log10\ Ent = \beta_0 + \Delta\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6$$

	Variable	β±ε	Transformation	P-value
β_0	Intercept	-7.30± 2.28	-	0.0021
$\Delta\beta_0$	Offset	$-\log_{10}(1.12)$	-	-
x_1	Accumulated Precipitation	0.68 ± .08	$x^{1/4}$	$2.06*10^{-13}$
x_2	Wind Speed	-0.12 ± .06	$1/x$	0.0284
x_3	Wind Direction	1.43 ± 0.55	$1.642 + 0.002\,x - 3.314 * 10^{-6}\,x^2$	0.0108
x_4	Wave Height	2.66± 1.67	$1.820 - 0.261\,x - 0.114\,x^2$	0.0148
x_5	Wave Direction	0.22 ± .06	$1/x$	0.0005
x_6	Tides	1.18 ± .40	$1.682 - 1.728\,x + 12.767\,x^2$	0.0042

$$log10\ Ent = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$$

	Variable	β ± ε	Transformation	P-value
β_0	Intercept	1.58034± .0352	-	0.0000
x_1	Wind Direction	0.0008 ± .0002	x	0.0030
x_2	Wave Height	0.8175 ± .3240	$log10(x)$	0.0165
x_3	Tide	2.225 ± 1.1475	x^2	0.0608

each transformed variable is also provided in order to visually inspect model dependence to each variable (Figure 3).

Table 4: Validation results for all nowcast versions.

	Nowcast 1.0	Nowcast 1.1	Nowcast1.2	Nowcast 2.0	Nowcast 2.1	Nowcast 2.2
Number of observations (N)	101	101	101	45	45	45
Number of observations > threshold	20	20	20	11	11	11
Number of observations < threshold	81	81	81	34	34	34
Number of true positives (tp)	13	7	9	8	4	5
Number of false positives (fp)	35	9	15	19	3	6
Number of true negatives (tn)	46	72	66	15	31	28
Number of false negatives (fn)	7	13	11	3	7	6
Accuracy: (tp+tn)/N	0.58	0.78	0.74	0.51	0.77	0.73
Sensitivity: tp/(tp+fn)	0.65	0.35	0.45	0.72	0.36	0.45
Specificity: tn/(fp+tn)	0.56	0.88	0.81	0.44	0.91	0.82

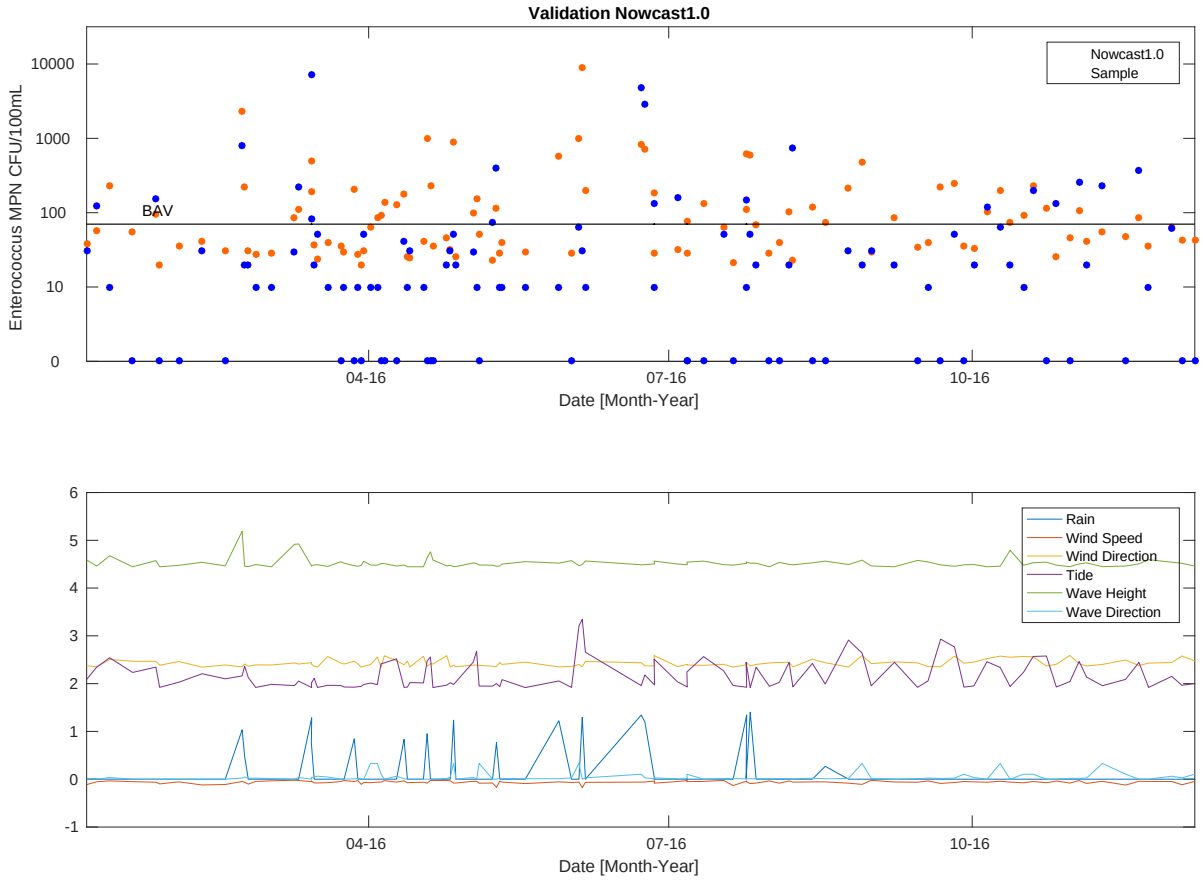


Figure 3: Example of validation product (for internal use only).

In order to further validate the RPB experimental nowcast, a 48-hour sampling campaign was carried out at RPB to better understand the behavior of Enterococci in seawater. The experiment started on October 14 at 5:00 PM and ended on October 16 at 5:00 PM. Water was tested every hour in 8 different stations, two of the stations were freshwater streams believed to be the main carriers of fecal bacteria contamination. Discharge from the two

streams was approximated using the float method. HOBO data loggers were used to measure dissolved oxygen, salinity, and water temperature during the experiment, while ADCPs were deployed to assess the site's current forcing. A Davis Vantage Pro2 weather station was installed nearby to measure solar irradiance, precipitation, wind speed and direction, and air temperature. Drifters were deployed in two occasions to estimate surface currents and dispersion near one of the streams. While most of this data is still being analyzed, preliminary findings suggest that the stream QsN (Quebrada sin Nombre) provides the main source of fecal bacteria input to RPB (Figure 4). Depending on the alongshore current direction and streamflow, plumes of bacteria can reach the beach in approximately one hour.

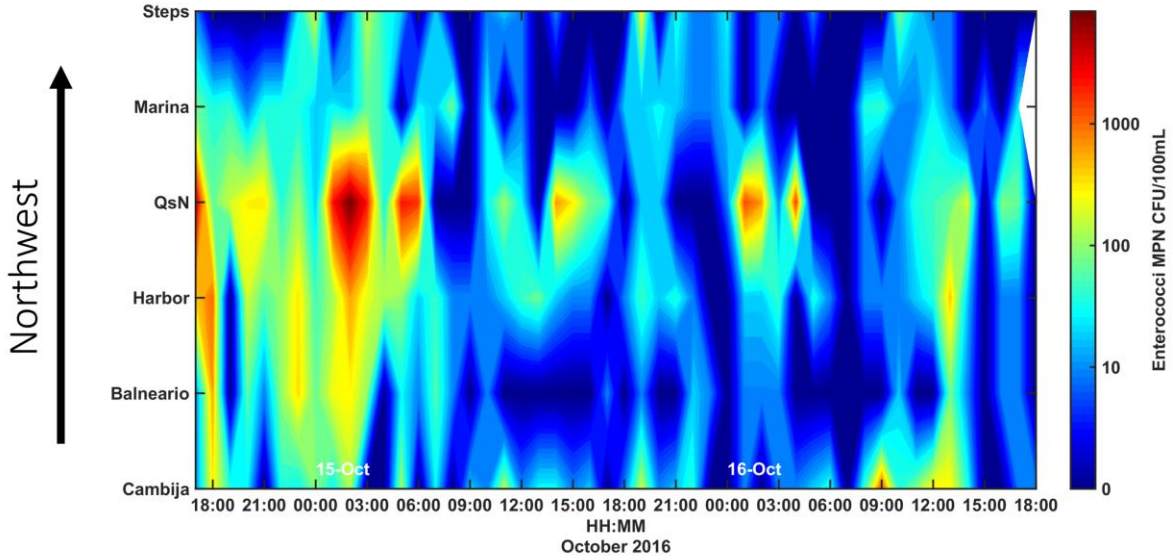


Figure 4: Enterococci levels for seawater stations during RPB 48-hr sampling campaign.

A new and preliminary version of the RPB nowcast (nowcast3.1) was developed using the weather station installed near RPB as part of the 48-hr sampling campaign (Figure 5). Even with a modest number of observations (N=49), this nowcast version seems to perform pretty well (86% accurate, 63% sensitive, 90% specific).

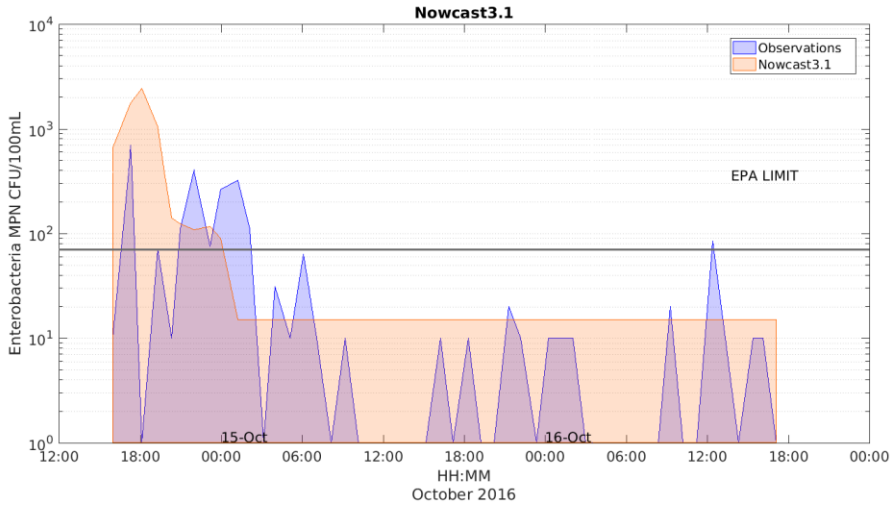


Figure 5: Nowcast3.1 performance during RPB 48-hr sampling campaign.

C. Develop two additional nowcasts for Crashboat, Aguadilla and Playa Santa, Guánica. Data gathering to develop these nowcasts has started. Finding long time series of rain data from metereological stations near the sites has proven difficult. The team is now evaluating the possibility of using radar information to develop the new nowcasts.

D. Formalize collaboration with the Puerto Rico Environmental Quality Board. No progress to report.

E. Other: CARICOOS RPB nowcast and historical plots are now generated in the cloud.

MAJOR OUTCOMES

CARICOOS beach water quality data products have been significantly improved during the performing period. For the case of the RPB nowcast, the model performance and reliability has increased significantly due to further fine tuning, validation efforts and migration to the cloud.

RELATED PROJECTS

In situ biosensor: CARICOOS is providing seed money to Pedro Resto's group to calibrate a bench version of the biosensor with respect to the Enterolert quantitray and to convert the current prototype into an in situ buoy unit. This entire process, including the design of a buoy system, should take a few years to complete.

WORK PLAN FOR UPCOMING PERFORMANCE PERIOD (Dec. 1 – May 31 2016)

A. Continue to analyze data from the 48-hr RPB sampling campaign in order to further fine tune the RPB nowcast. Finalize nowcast3.1 using the Tres Palmas weather station if available.
B. Develop two additional nowcasts for Crashboat, Aguadilla and Playa Santa, Guánica based on weather radar information.
C. Formalize collaboration with the Puerto Rico Environmental Quality Board.
D. Submit at least one manuscript to the Journal of Water and Health.