TITLE: The Importance of Model Validation: Two Case Studies

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The Southern California Bight (SCB) is distinguished by unique geography, climate, and life. The highly urbanized coastline is adjacent to complex ocean conditions as a result of offshore islands; a diversity of coastline characterized by headlands, bays, beaches, submarine canyons, estuaries and coastal mountain ranges, which influence the marine atmosphere. Two of the programs that support observations and models in this area include:

1. The Coastal Data Information Program (CDIP), funded by the California Department of Parks and Recreation, Division of Boating and Waterways (CDBW), and the U.S. Army Corps of Engineers (USACE), providing near real-time wave measurements, nowcast and forecast wave models, and surface temperature (SST).
2. The Southern California Coastal Ocean Observing System (SCCOOS) funded by the National Oceanic Atmosphere Administration (NOAA), with a focus on enhanced products for safe and efficient marine commerce and transportation, and improved coastal resiliency through accurate, geo-specific shoreline information.

(FIGURE 1.)

Two case studies are described below which demonstrate the value of high resolution wave observations and the critical importance of validating wave nowcast and forecast models.

1. Under Keel Clearance Project – Port of Long Beach

Maritime transportation plays a major role both in Southern California's economy and national security. Los Angeles and Long Beach, CA combined comprise the largest port in the United States and the eighth largest port in the world. With 140 shipping lines connecting Long Beach to 217 seaports, the Port handles $180 billion in trade annually, supporting hundreds of thousands of jobs. 47% of all container ships and 50% of California's oil enter through these ports. There are three unique challenges for marine operations in this area: (1) to assure that the vast amount of maritime traffic is provided with the highest quality ocean observations and models to assure safe and efficient transit; (2) to enable effective event responses as needed; and (3) to assure accurate historical data are present to allow for risk assessments and plan for new facilities. CDIP and SCCOOS have addressed these challenges by partnering with institutions and agencies to provide data access and visualization of critical oceanographic parameters necessary for safe and efficient maritime operations. A specific objective is to improve products for a wide, diverse user base and maintain and develop customized products: multi-layer views of observations, nowcast and forecast models including waves, currents, winds, SST, bathymetry, and navigation charts. For several years, based on CDIP buoy observations and models, port transits have been supported by customized, automated messaging to Long Beach Jacobsen Pilots and port marine operators when large swell has exceeded their operational limits.

One of the recent operational applications which highlights the importance of model validation is the Under Keel Clearance (UKC) Precision Navigation project at the Port of Long Beach. With the deepening of the Panama Canal, bigger, deeper draft vessels are requesting entry to the California ports. Out of the 4,422 vessels that entered the ports of Los Angeles/Long Beach in 2014, 606 were oil tankers. The issue is how can the port entry be maximized to accommodate these larger vessels, many of them carrying crude oil, while reducing the risk of a vessel running aground? At this time, the channel at the entrance to Long Beach is dredged to 19.8 m. Vessels must have a 10% clearance beneath them as they transit. However, when the waves approach the stern of the vessel, the vessel will start to pitch. A 1 degree pitch on an 335 m vessel will increase its draft by 2.9 m. Presently, five oil companies lighter their vessels 100 nm offshore California in order to accommodate the navigation specifications of the ports.

At the request of Jacobsen Pilots in Long Beach, many partners have collaborated to improve and inform the decision process for vessel entry. The Dutch company Protide has been contracted with to provide a real-time decision support tool for the project, taking into consideration the wave conditions, water levels, bathymetry and ship architecture. One of the issues is that in the San Pedro Bight, NOAA's National Centers for Environmental Prediction (NCEP)'s WAVEWATCH III forecast model has limited skill, often under or over predicting the wave energy. Over the next year, in collaboration with the Oxnard National Weather Service Office, NCEP will be developing and improving a nearshore model specifically designed for the Under Keel Clearance project. (FIGURE 2.)

In the meantime, CDIP has a few tools that are useful to the UKC project. The real-time observations from the Datawell wave buoy, deployed at San Pedro since 1998, show the wave action from the west and northwest. Also, with additional National Ocean Service/IOOS and industry funding, SCCOOS is supporting the UKC project with the installation of two new wave buoys. As shown in Figure 3, the San Pedro Buoy South measures the south swell and the Long Beach Channel Buoy measures the waves at the entrance to the channel. The data from these buoys are ingested by the Oxnard NWS and NCEP for model validation and for local real-time display (cdip.ucsd.edu/custom_pages/marine_exchange/). (FIGURE 3)

While NCEP's nearshore wave model is being developed, CDIP's high resolution nowcast/forecast wave model for the region will be ingested by Protide. The nowcast is generated based on buoy observations while the forecast model is based upon WW3 input. The buoy-driven nowcast is known to be biased, under predicting the waves at this location [O'Reilly et al. (2015)]. In comparing model output to the wave observations from the Long Beach Channel buoy, it is evident that the CDIP model under prediction is amplified by the effects of the Long Beach breakwater. Overall, however, the accuracy of forecasts is primarily limited by the WAVEWATCH III data which are used as input to the CDIP model in forecast mode. (FIGURE 4)

The hope is that in the future, both the CDIP- and NCEP-developed nearshore models will account both for the regional variability and the effect of structures. Since the tolerances that are involved with the UKC project are small, having the wave buoy data for model validation is critical. Once model accuracy improves, the efficiency and safety of vessel transits will increase due to reduced risk.

2. Three-Day Flooding Index

Coastal resiliency preparation is critical on the West Coast where inundation is often caused by the co-occurrence of high tides, energetic ocean waves and beach erosion. High waves raise the mean water level above the tide level (i.e. wave setup), and create large wave run-up in addition to setup. Erosion of the beach further increases the shoreward penetration of large waves. During storms, wave uprushes can reach more than 3 m above tide level, and beach face erosion can exceed 2 m vertical. The 2008 California Coastal Sediment Management Workgroups (CSMW), California Beach Restoration Survey indicates that many beaches and structures in the SCB are vulnerable to coincident high surf and tides. However, simple inundation models (where the uprush limit depends only on the tide level, wave height, and wave period) yield qualitative, general information, but do not include site-specific beach morphology. The vertical elevation reached by storm waves depends on the beach slope, which varies seasonally and spatially.

The long-term goal is to develop and distribute validated, customized warnings of wave and tide-induced coastal inundation, erosion, and nearshore transport. Localized warnings for highway closures and structure sandbagging require site-specific wave, beach slope, and berm elevations for model calibration. A field monitoring site at Cardiff State Beach, CA where routine monthly sand surveys are ongoing and in-situ water level and inundation measurements have been observed uses existing and new observations to examine the role of waves, tides, and nourishments on oceanfront flooding. The wave input for the flooding index is taken from the CDIP coastal wave model Monitoring and Prediction System (MOPS), includes both remotely generated swell and locally generated seas, and yields nowcast and forecast models of waves on the 10 m depth contour, immediately offshore of the surfzone with high temporal (hourly) and spatial (100 m alongshore) resolution.

Offshore boundary conditions are provided by the CDIP network of wave buoys and co-located point forecast spectra from the NOAA WAVEWATCH III global wave model. Field testing in SCB has extensively validated MOPS. Results include real-time and three-day inundation forecasts and improvements to the online site-specific website product (sccoos.org/data/flooding-storm-surge-models/). (FIGURE 5)

Specific objectives are to (1) develop site-specific models for tide and wave-driven inundation at additional locations (i.e. only Cardiff has an on-going field monitoring program which allows for the local bathymetry to be included in the flooding index calculation), (2) assemble databases of historical observations and bathymetry data for model development, calibration, and verification, and (3) develop and expand integrated, online products that will provide warnings of wave and tide-induced coastal inundation. A site-specific model for tide and wave-driven inundation will be calibrated with field observations of shoreline water level acquired during previous winter storms. (FIGURE 6)

The same infrastructure exists for disseminating inundation warnings to the Naval Air Warfare Center Division (NAWCD) at Point Mugu for an area that overtops during high tides and energetic waves. This is an area designated for recreational users on Point Mugu Naval Air Station. During a strong south swell, the berm which protects this area will overtop, and the area must be evacuated. The Naval Air systems Command (NAVAIR) has requested that warning messages be sent to them based upon the overtopping thresholds. (FIGURE 7)

In addition to coastal residents and beachgoers, several agencies are interested in the real-time and forecast inundation warnings including the National Weather Service (NWS), United States Army Corps of Engineers, Department of Transportation, California Coastal Commission, and city governments. Based upon threshold exceedance, model-based inundation warnings are now being disseminated directly to the NWS and coastal planners. Partnerships have been established with local municipalities to assist with equipment permissions and observational validation of inundation notifications.

In an attempt to quantify the effects of energetic wave action on the shoreline, through a citizen science project, citizens are encouraged to email their photographs of coastal flooding and/or shoreline structural damage to stormphoto@sccoos.org. Since geo-referencing information is included with smart phone photos, the photos will be correlated with the nearest wave observation or model, and posted on a website map. The posting will include the data/time/location information from the photo and the wave and tide statistics.

In summary, both of these case studies highlight the importance of model validation. With rising sea levels and El Niño California winters, it is critical that high resolution models be developed and validated for future safety, maritime commerce and protection of the coastal community. This effort will assure safe and efficient maritime operations, promote safe recreational use of beaches, help cities meet emerging challenges to coastal infrastructure resiliency, and reduce loss of life and property associated with nearshore waves and wave-driven currents in the populous coastal communities of the SCB.

REFERENCES:

Coastal Sediment Management Work Group, 2008: California Beach Restoration Survey 2008, 71 pp. [http://www.dbw.ca.gov/pdf/DraftCBReS_2008_12052008.pdf.]

O'Reilly W.C., C. Olfe, R. Seymour, J. Thomas and R.T. Guza. 2015: The California Coastal Wave Monitoring and Prediction System. *In preparation for Ocean Modelling 2015.*

Figures

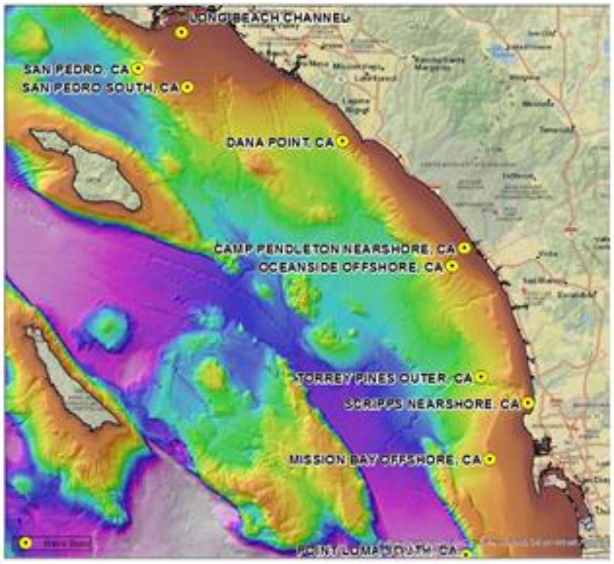

Figure 1. The San Pedro Bight is a complex area with offshore islands, deep water canyons and protruding points.

Figures

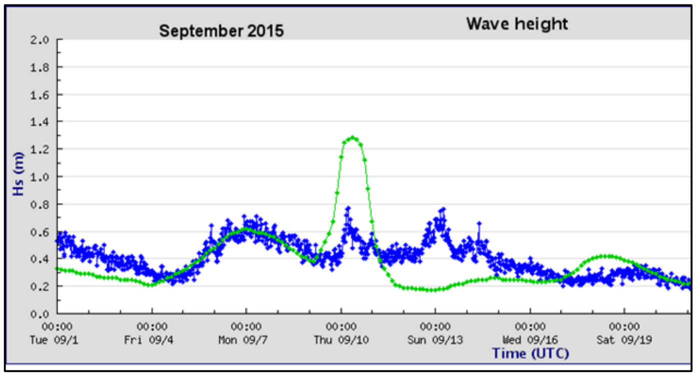

Figure 2. The figure above demonstrates the inconsistency of WAVEWATCH IIII forecasts peaking on September 10 in the San Pedro Bight, over and under-predicting wave height in comparison to the San Pedro Buoy actual observations.

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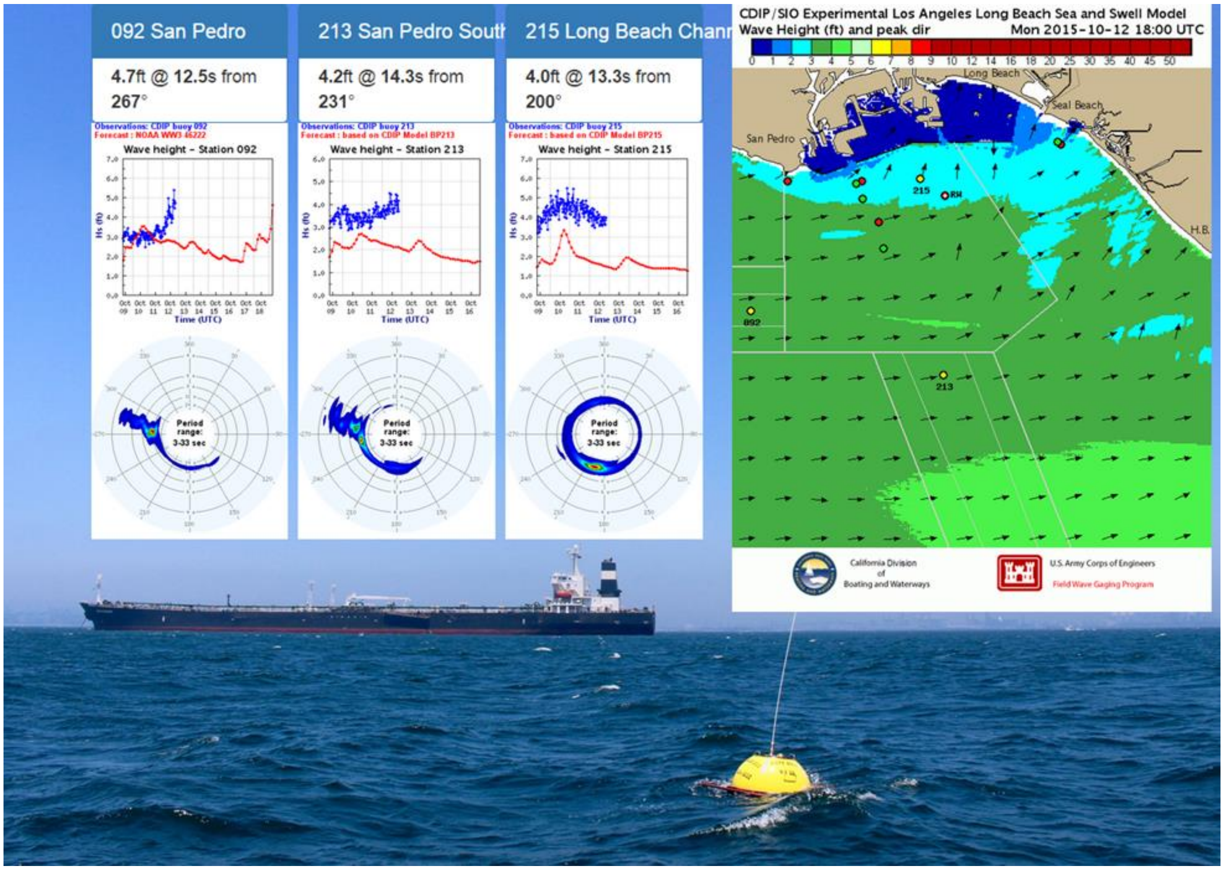

Figure 3. Real-time display at the Marine Exchange in San Pedro include wave observations from the three deployed buoys (wave height and directional wave rose) and CDIP wave model.

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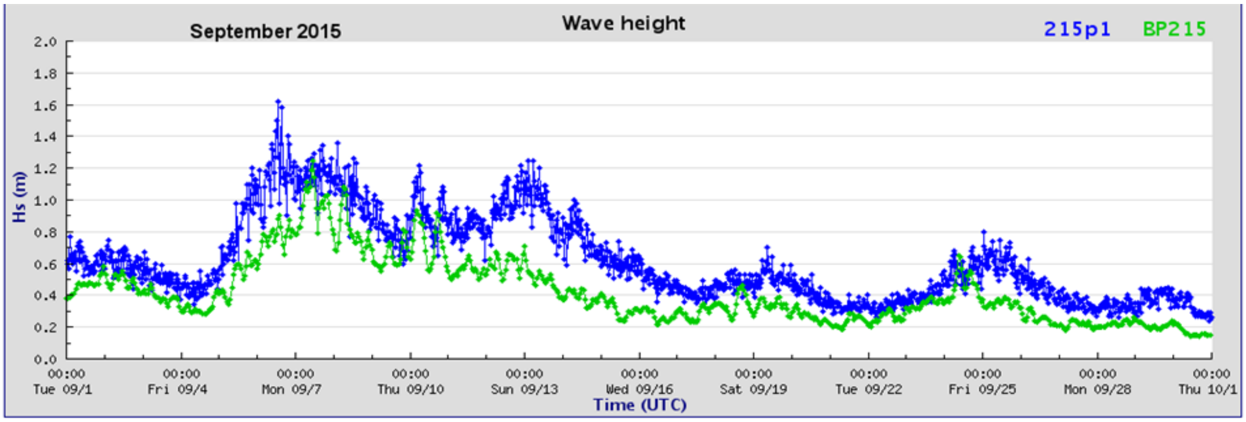

Figure 4. Under prediction of the CDIP wave model at the Long Beach Channel entrance (top line = model observation, bottom line = Long Beach Channel buoy).

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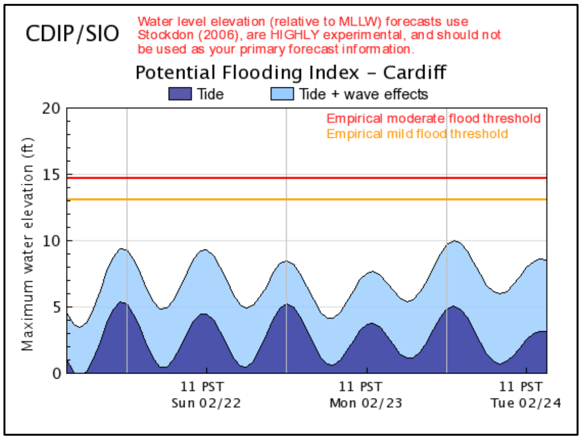

Figure 5. Flooding will occur in the restaurant parking lots and cause highway overtopping when thresholds are exceeded.

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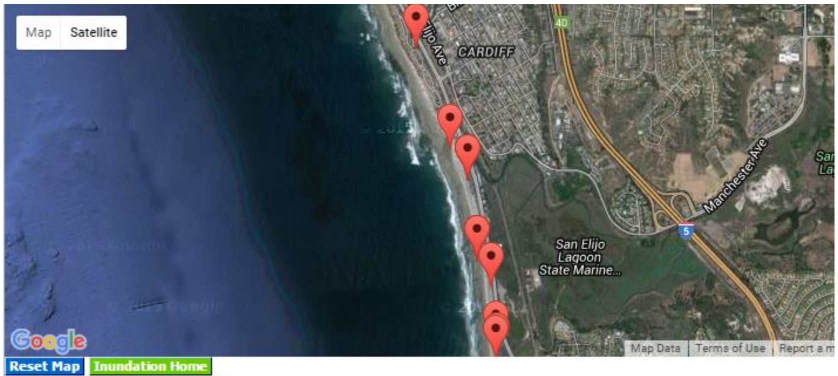

Id	Inundation Area	Date (UnixTS)	Location	MoP Id	Hs (m)	Tp (s)	Dp (deg)	Photos
7	Cardiff	2007-12-05 20:35	Seaside parking lot looking south	D0709	2.52	18.18	249	Yes
27	Cardiff	2010-01-20 19:15	Cardiff State Beach	D0667	2.82	13.33	265	Yes
28	Cardiff	2010-01-21 16:30	Cardiff State Beach	D0682	2.37	14.29	262	Yes
31	Cardiff	2010-01-27 08:00	Cardiff State Beach	D0680	1.00	11.76	261	Yes
32	Cardiff	2010-01-28 16:30	Cardiff State Beach	D0680	0.93	12.50	259	Yes
33	Cardiff	2010-01-29 16:45	Cardiff State Beach	D0680	0.84	11.76	261	Yes

Figure 6. CDIP hosts a historical database of flooding events. Historical records contain wave height, period, direction, as well as a geo-referenced photo index.

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