Analyses of Extreme Wave Heights in the Gulf of Mexico for Offshore Engineering Applications

Vijay Panchang
Texas A&M University,
Maritime Systems Engineering Department,
200 Seawolf Parkway,
Galveston, TX 77553
e-mail: panchanv@tamug.edu

Chan Kwon Jeong
Dockwise USA,
16340 Park Ten Place,
Suite 200,
Houston, TX 77084
e-mail: chankwon.jeong@gmail.com

Zeki Demirbilek[1]
U.S. Army Engineer Research
and Development Center,
Coastal & Hydraulics Laboratory,
3909 Halls Ferry Road,
Vicksburg, MS 39180
e-mail: zeki.demirbilek@usace.army.mil

The 2004–2008 hurricane season in the Gulf of Mexico (GOM) saw several exceedances of what was regarded, prior to that period, as the 100-year significant wave heights (SWHs) that are used for the design of offshore oil and gas facilities. As a result, these facilities sustained considerable damage and disrupted U.S. energy supplies. The wave climatology in the GOM is therefore studied in detail. A 51-year database of SWHs was constructed by using a combination of wind and wave models, and both individual wave heights and statistical measures were validated, to the extent possible, using buoy data. Analyses of the modeled data show that there is an increasing trend in the annual maximum SWHs in the eastern part of the GOM; the maximum trend is approximately 5.6 cm/year, which is of the same magnitude as that reported for the U.S. west coast. The western part; on the other hand, shows a decreasing trend. The maximum estimated 100-year SWHs (denoted by SWH_{100}) are 19.1 m, 22.6 m and 26.7 m for the Gumbel, Weibull, and the GEV distributions, respectively. The estimates obtained here using the Weibull distribution are comparable to those obtained independently by API (API—American Petroleum Institute, 2007, "Interim Guidance on Hurricane Conditions in the Gulf of Mexico," API Bulletin No. 2INT-MET). However, the use of objective criteria to identify the optimal distribution suggests that the GEV estimates are to be preferred if the engineer wishes to emphasize the upper tail where extremes are likely to occur. The maximum increase in the SWH_{100} due to the 2004–2008 season is of the order of 0.9 m to 2.7 m (depending as the distribution). Information generated here is intended to supplement the design recommendations provided by API (American Petroleum Institute, 2007, "Interim Guidance on Hurricane Conditions in the Gulf of Mexico," API Bulletin No. 2INT-MET).
[DOI: 10.1115/1.4023205]

1 Introduction

Until recently, significant wave heights (SWHs) corresponding to the 100-year return period used for the design of various oil and gas facilities in the Gulf of Mexico (GOM) were of the order of 11 m (API [1]; Palao et al. [2]; Panchang et al. [3]). During the years 2004–2008, however, the GOM (shown in Fig. 1) experienced waves of unusual height relative to the "extreme" conditions. For instance, during Hurricane Ivan in 2004, SWH's of the order of nearly 16 m were recorded by a National Data Buoy Center (NDBC) buoy before it malfunctioned; and, SWHs as large as 17.9 m (corresponding to "maximum" wave heights of approximately 27.9 m) were recorded by Wang et al. [4], who suggest that even larger waves may have occurred. Comparably large (and at some locations, larger) wave heights, well in excess of the 100-year return period estimate, were recorded again during Hurricanes Katrina (Sept. 2005), Dennis (July 2005), Rita (Sept. 2005), and Ike (Sept. 2008). The extreme storm surge, wind, and wave conditions, which have been documented and analyzed in part by Hovis [5] (2005) and by Panchang and Li [6] (2006), caused extensive damage to the numerous oil and gas facilities in the Gulf of Mexico [7].

The National Data Buoy Center (NDBC) maintains eleven wave buoys in the GOM (Fig. 2) that provide wave data for time periods ranging between 7 and 33 years. Table 1 provides a summary of these data and includes the highest and second highest SWHs recorded at the buoy locations. When the maximum measured SWHs are associated with a recent storm, the name has been included. It is clear that, at seven of the buoy locations (42001, 42,003, 42,007, 42,019, 42,035, 42,039, and 42,040) maximum measurements for the 2004–2008 hurricane seasons are larger than previous maxima. While the differences are marginal at some of the buoy locations, they are substantial at three locations (42039, 42,040, and 42,007): the previous largest SWH recorded at these locations were 9.3 m (in 1998), 10.8 m (in 1998), and 4.9 m (2002), respectively. Although two of these locations have relatively short datasets, the differences are notable at the

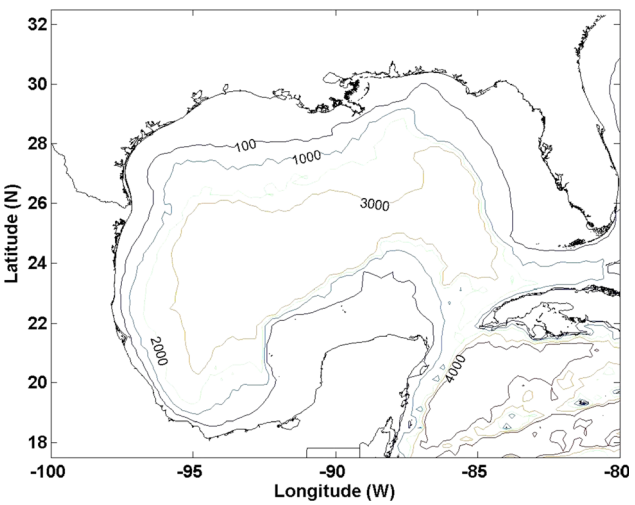

Fig. 1 Gulf of Mexico, map and bathymetry (m)

[1]Corresponding author.

Contributed by the Ocean, Offshore, and Arctic Engineering Division of ASME for publication in the JOURNAL OF OFFSHORE MECHANICS AND ARCTIC ENGINEERING. Manuscript received May 14, 2012; final manuscript received September 9, 2012; published online May 2, 2013. Assoc. Editor: Hideyuki Suzuki.