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Monstrous ocean waves during typhoon Krosa

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Abstract. This paper presents a set of ocean wave time series data recorded from a discus buoy deployed near northeast Taiwan in western Pacific that was operating during the passage of Typhoon Krosa on 6 October 2007. The maximum trough-to-crest wave height was measured to be 32.3 m, which could be the largest $H_{\max}$ ever recorded.

Keywords. Meteorology and atmospheric dynamics (Ocean-atmosphere interactions; Waves and tides) – Oceanography: physical (Surface waves and tides)

1 Introduction

In the early days of last October, the tropical depression that originated east of the

Philippines in the Western Pacific Ocean, rapidly intensified to become Typhoon Krosa and further upgraded later to a Category 4-equivalent super typhoon as it advanced

Northeastward toward Taiwan, with its track hovered into a small loop over the northeastern coastal waters of Taiwan before making landfall on 6 October 2007 (Fig. 1). There were three instrumented buoys deployed along the northeastern coast of Taiwan at the time where wave conditions during Krosa were summarily recorded. In particular, the buoy located at (121°55′30″ E, 24°50′57″ N) with 38 m water depth near the small Gueishantao Island, 12 km offshore of the northeast coast town of Suao, which was located close to the center of Krosa, recorded a very large trough to crest maximum wave height of 32.3 m, which could be the highest known $H_{\max}$ ever recorded.

The existence of gigantic maximum wave heights during a hurricane or typhoon in the world oceans is by no means new. Wang et al. (2005) reported a $H_{\max}$ of 27.7 m derived from a deep-sea pressure gage in the northern Gulf of Mexico during the passage of hurricane Ivan in 2004. Holliday et al. (2006), on the other hand, discovered a recorded $H_{\max}$=29.1 m from the Shipborne Wave Recorder onboard RRS Discovery on 8 February 2000 in the northeast Atlantic Ocean 250 km west of Scotland during a developing storm. While larger than usual wave heights during a typhoon or hurricane are to be anticipated, there is no tangible knowledge regarding what a typical wave height magnitude is. In this brief report we wish to present the above mentioned wave data as recorded at the Gueishantao Island buoy during Typhoon Krosa that has manifestly exceeded all the previous known extreme wave records.

2 The measurement

The wave data was recorded from a moored 2.5 m circular discus hull foam buoy that was deployed and maintained by Central Weather Bureau of Taiwan since 1997. The buoy is equipped with heave, pitch and roll accelerometers sampled at 2 Hz frequency for 10 min duration hourly. The surface fluctuations as inferred from the heave displacements at 13:00 h, 6 October 2007 are given in Fig. 2.

In the time-series plot of Fig. 2, note the trough at time 76.5 s and the subsequent crest at 82.5 s, as marked by the two asterisks. The trough-to-crest wave height of 32.3 m tops this unprecedented time series measurement of monstrous ocean waves that has a standard deviation (significant) wave height of 23.9 m. (Here we use the notation that: standard deviation wave height = significant wave height = 4*standard deviation.) As we alluded before, this could be the largest wave height ever recorded. While the data in this figure could possibly become the exemplary data set of very large waves, some local concern was raised because it was later discovered that a subtle drift in the buoy location took place around the time the typhoon was approaching landfall. The GPS positions showed a transient buoy stray ensued during a 5-h

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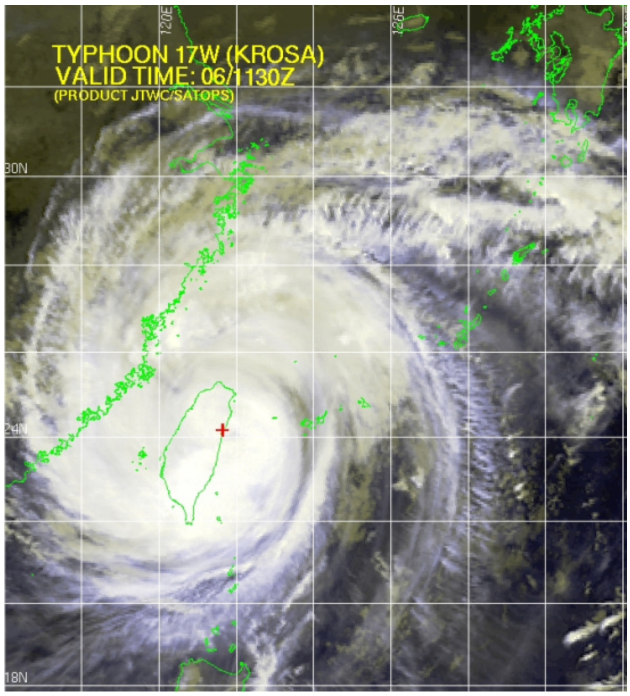

Fig. 1. Typhoon Krosa made landfall on Taiwan.

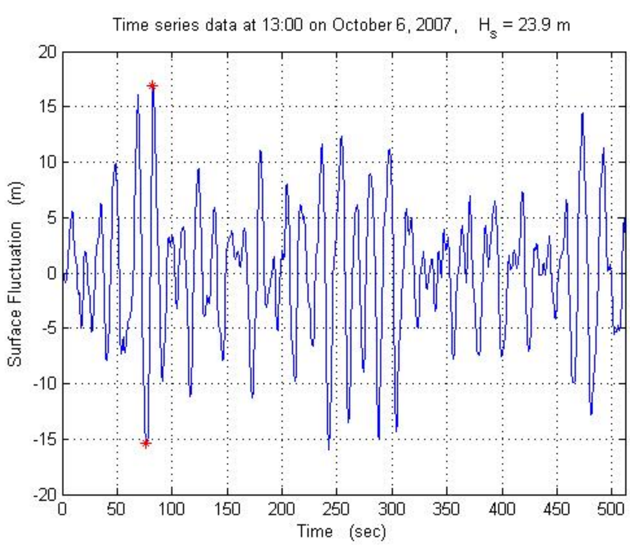

Fig. 2. Time series from Gueishantao buoy recorded at 13:00 h on 6 October 2007 during the height of Typhoon Krosa.

time span, around the time the track of Krosa was making the small loop over the northeastern coast area. The drift moved the buoy southwestward for about 350 m in the same vicinity. The accelerometers were working impeccably throughout, and the 91 m steel mooring chain remained intact. The buoy suffered some damage in one of the solar panels, along with the barometer, and one of the wind anemometers.

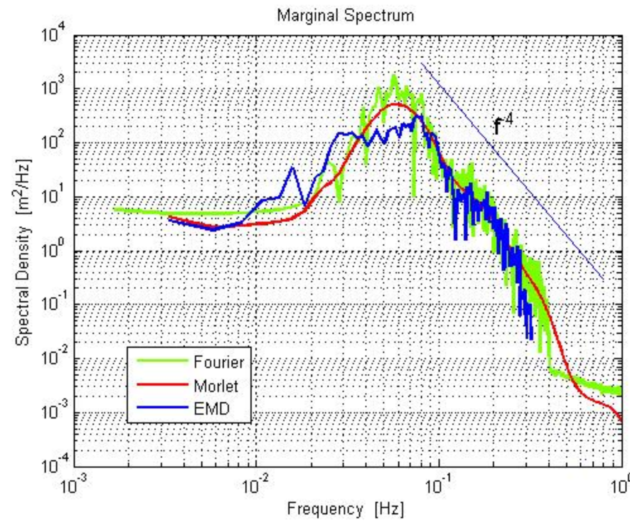

Fig. 3. Spectrum analysis of the data in Fig. 2.

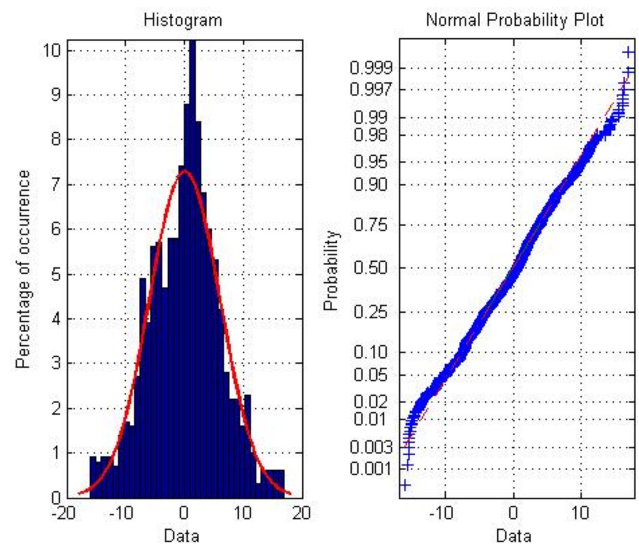

Fig. 4. A testing of the normal distribution hypothesis.

3 Analysis and discussion

Following the conventionally established basic approach we first applied spectrum analysis to the data in Fig. 2 with the results shown in Fig. 3.

Using traditional Fast Fourier Transform along with Wavelet Transform with Morlet wavelet, and the Empirical Mode Decomposition of the Hilbert-Huang Transform, all approaches led to practically the same familiar wind wave spectrum that we are all acquainted with, even confirming to the generally expected f^{-4} slope on the high frequency side.

Additionally we also performed the basic statistical analysis to testing the customary assumption of normal distribution as shown in Fig. 4. The results again confirmed the expected empirical behaviors. Being mindful of the buoy drift, we can find no problems because of it. Thus it led us to consider the data set as totally unblemished. It is by any means a typical data set of wind generated ocean waves, only this one is larger than most ever recorded. Indeed in just that 512 s stretch of recording, there occurred one wave height over 30 m high, four over 25 m, ten waves over 20 m, and fourteen of them over 15 m in height – a clearly unprecedented recording.

Three things should be considered: First, since this is a buoy recording and buoys are well-known for their difficulty in delivering sharp crested waves, it is entirely possible that the actual waves were higher than what was recorded. Second, the ratio of $H_{\max}/H_s$ in this case is surprisingly low at 1.35, thus this is just a monstrous wave and should never be confused with a freaque wave. (Here we coined the word “freaque” to combine the customarily used interchangeable words of freak or rogue waves.) Freaque waves are large waves that occur unexpectedly. There have been frequent reports of freaque waves causing major damage during heavy storms. It is doubtful that a distinction can be made during a storm, as freaque waves can be large but large waves are not necessarily freaque waves as we have seen in this case. Finally it should be noted that the local water depth of the buoy where the recording was made is only mildly larger than the maximum or significant wave height. While the wave heights may not be affected by shoaling, they have undoubtedly subjected to wave breaking process. At any rate this is certainly an enticing record with no shortage of inspiring questions.

4 Concluding remarks

We commend the Central Weather Bureau of Taiwan for deploying and maintaining the wave measurement facilities. There is much to learn about how high a wave can be during the height of a hurricane or typhoon. It is of interest to note that while waves during Krosa were mostly come from southward, preliminary directional spectrum analyses show that the data in Fig. 2 had a strong northerly component superimposed prior to the track looping – which only actual measurements can provide these details. The need for deploying additional wave measurement instruments throughout the world’s oceans can not be overstressed. Without tangible measurements, no amount of modeling or theoretical simulations can truly divulge the reality of what is really happening during the passing of a typhoon or hurricane.

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