Operational Ocean Monitoring Technologies around Taiwan

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***Abstract*—This article introduces operational ocean monitoring technologies for the purpose of coastal flooding warning in Taiwan. The in-situ sea state data and field images are linked to the coastal monitoring network of Taiwan. This network provides real-time meteorological and oceanographic information, which is not only for the climate change study but also for the hazard mitigation purposes as well. The whole network has been operated for more than 10 years in Taiwan. It plays an important role on the decision making for the mitigation of coastal flooding.**

Keywords- ocean monitoring; coastal flooding warning

I. INTRODUCTION

The heat storage capacity of the oceans, which cover over half area of the Earth's surface, is four times greater than that of the land. This is one of the reasons that the ocean always plays a critical role in adjusting regional climate and in global climate variation. On the other hand, the ocean environment is affected by the climate change, too. To study the interaction between the ocean and the climate change, long term monitoring is one of the most significant means. The information obtained from our ocean environment is also the basis for performance improvements of ocean and coastal activities. Navigation, harbour construction, fishing and cultivation, coastal disaster protection, recreation and even defence capabilities have become much more dependent on the availability of long-term, stable and high quality oceanographic information. Ocean monitoring always plays an important role on evaluating and describing oceanic characteristics.

Taiwan, located between the tropics and the subtropics, lies on the border between the largest land mass and the largest ocean in the world, so that the marine and atmospheric environments here are complex and sensitive. Flooding in coastal areas is becoming severer with increasing uncertainty of global meteorological system. Because of the low-lying land, the flooding events in Taiwan are often happened in the coastal area. Coastal flooding will be probably happened if the sea level rises by storm surge or by the overtopping of huge waves or their joint effects. For more complete understanding of these phenomena, techniques of field investigation are necessary.

Field measurement is the main approach to obtain the ground-truth ocean data. Field data are necessary used for numerical models calibration and verification. Over the past few decades, the in-situ measurement of ocean has undergone enormous changes as a result of significant advances in technology. These advances have improved the precision and reliability of in-situ instruments. Since the 1990s, the Water Resources Agency, Central Weather Bureau and Tourist Bureau in Taiwan have been established a coastal monitoring network around Taiwan coast. One of the purposes of this network is to provide real-time information and prospective message for the references of coastal flooding mitigation decision. By integrating the in-situ data from this coastal monitoring network and applying the web-based technology, simple use and rich data production are the basic requirements. The purpose of this study is to introduce this coastal watch technology in Taiwan. We also present some special records from our coastal watch network during typhoon and tsunami events.

II. SYSTEM COMPONENTS

Generally speaking, sea-state monitoring can be distinguished into two major categories: one is short-term observation for research or engineering purpose; the other is long-term operational routine monitoring. The object of long-term operational monitoring is to build national marine meteorology and coastal hydrology database to satisfy present and potential future needs, which include navigation, weather prediction, fisheries, ocean and coastal engineering design and planning, water sport safety, coastal hazard warning, disaster mitigation and coastline management. Due to these needs, a guiding principle for developing a comprehensive marine environment monitoring system can be derived, namely the system shall be able to operate on long-term basis and has capable of real-time data transmission in providing data for decision marking as well as for marine weather prediction.

Based on the principle we mentioned above, the nationwide coastal monitoring network as shown in Fig. 1 was jointly established by different governmental departments around Taiwan's coast waters [1]. The basic observation items within this network include: wave height, period and direction, tidal elevation, surface current, wind speed and direction, air temperature, sea surface temperature and barometer. The observation time interval for most of the systems is one hour. To obtain complete tide information around Taiwan, the time interval of tide station within the coastal watch network is six minutes. To cope with some more complicated ocean phenomena, it is possible to observe water level every minute by these tide stations too. In addition to record the quantifiable parameters, the coastal watch network also includes the component of field video images as auxiliary information. High resolution cameras are installed at the high building or on a pile at the coastal area. To obtain the real time field information, a long-distance wireless data transmission technology was applied. The camera observation systems are allowed to remotely adjust the looking direction, focal length, and to record the interests. This camera component is always the attraction for decision markers.

All the measured data are transmitted to a data quality check center via GSM, GPRS, Satellite or long-distance wireless technologies in real-time, depending on the location of the stations [2]. This network has been started to be built since 1997. It has been identified that these systems have high sea resistance to forestall any potential interruption. In addition, when hazardous weather systems such as typhoons approach, the system can accept remote control in shorten the time interval to increase the monitoring intensity and maintain the integrity of long-term database. By 2010, there are 13 coastal data buoys, 12 tide stations, 12 coastal weather stations and 5 camera stations to form this observation network (Figure 2). All the in-situ data and images are imported to the presented system in real-time to display on the screen and to store in the MS SQL-Server constructed database.

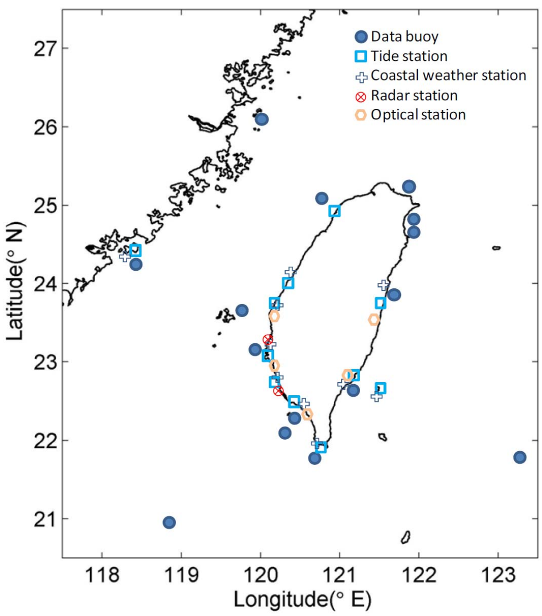

Figure 1. The real-time and in-situ measurement network around Taiwan.

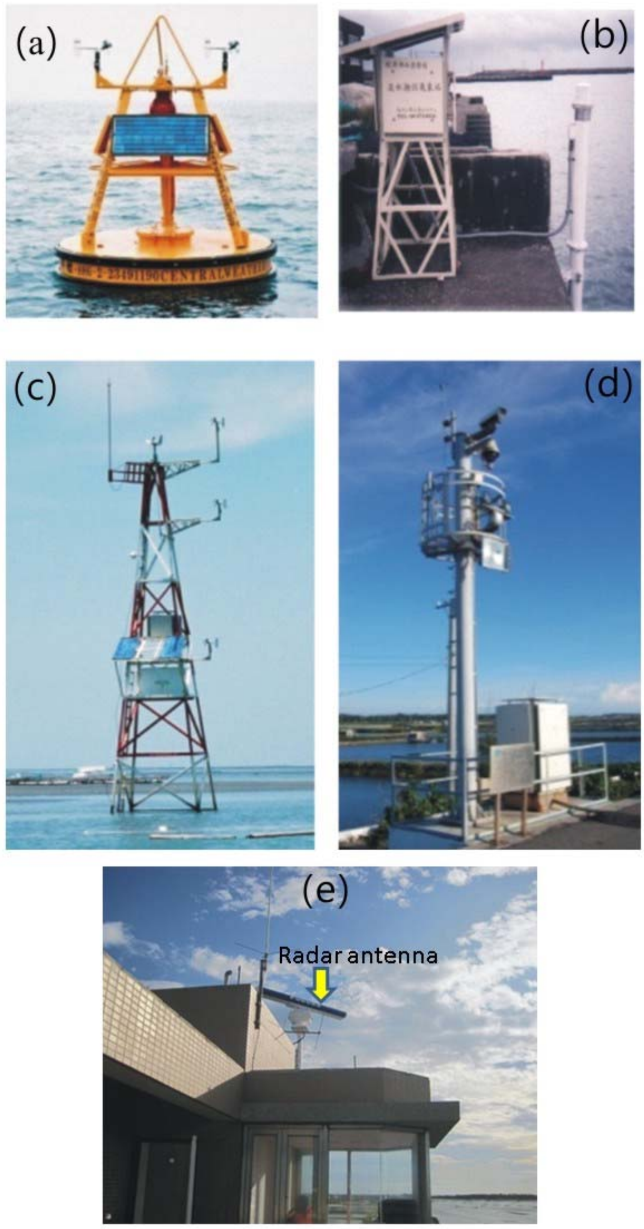

Figure 2. Different ocean monitoring technologies in Taiwan: (a). data buoy; (b). tide station; (c). coastal weather station; (d). camera station; (e). radar station.

III. LONG-TERM STATISTICS FROM OBSERVATION

The coastal watch network in Taiwan has proven its reliability and survival ability in the harsh environments especially in typhoons through their long term operation. To understand the scale of typhoon wave quantity at Asia Pacific, we analyze the significant typhoon wave heights (STWH). The results of Hualien Buoy and Hsinchu Buoy are shown in Figure 3. We define the parameter STWH as the mean value of the wave heights of first 50% records in the typhoon duration. We think this parameter represents the wave property for a typhoon period. The typhoon duration described above is the alarm period given by the Central Weather Bureau in Taiwan. The typhoon duration is often around three days. The average

STWH of several typhoons in that year at Hualien (locates at eastern Taiwan Waters) is 1.89m. However it is 1.18m for Hsinchu Buoy which locates at Taiwan Strait. The difference is due to the location of the stations. For the eastern part of Taiwan, it faces to the Pacific Ocean and receiving large typhoon waves. Within Taiwan Strait, it is shaded by the island.

From the studies of the impacts of global climate change, trends of increasing wave height in the Northeast Atlantic were identified in the late 1980s and early 1990s [3],[4]. It was suggested increases in mean wave height of some 2% per year. More recent studies have identified similar changes in the Pacific [5]. Statistics of the duration of large waves (DLW) within typhoons is also carried out in this study. Figure 4 shows the variation of DLW of each buoy station in each year. The duration is defined as the time when SWHs are large than 5m. The number in the figure is the summarized hours of all typhoons in a specific year. We find the index increases rapid in recent years. It means that recent typhoon brought larger waves than before. Some years ago, it was not often to see more than 5m ocean waves during a typhoon or its duration were relative short. Nowadays, however the sea is long-time occupied by severe status during typhoons. In Figure 4, the Hsinchu Buoy observed few cases that the maximal typhoon SWH larger than 5m because of its location. The DLW is longer than five hours in 2007 and 2008 that it never happened in the past six years. The increasing duration of large typhoon waves will bring very high impacts to the coastal inhabitants, the coastal morphology, and the ocean relative activities.

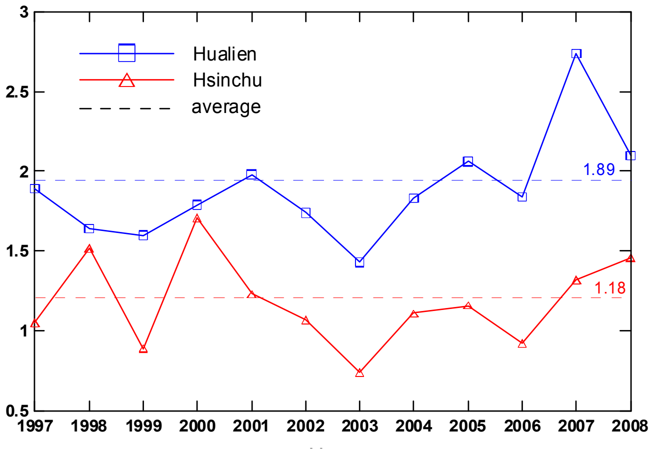

Figure 3. Distribution of the data for each buoy.

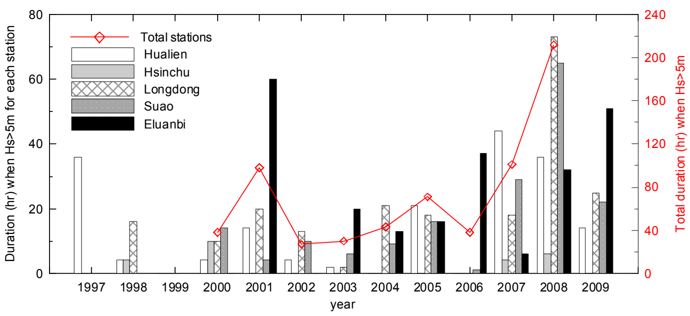

Figure 4. Trend of the duration of large waves (DLW) during typhoons (Definition of DLW is the summarized time when Hs>5m).

IV. MONITORING OF TSUNAMI RUN-UP

The Pacific is considered as the most tsunami-dangerous region. During the past 10 years (not counting the tragedy caused by the Indonesian tsunami in 2004) tsunami waves in the Pacific Ocean took the lives of more than 10,000 people [6]. Although most of the tsunami wave amplitude in deep water area is less than 2 m, the amplitude increases as it approaches the coast. To understand the features of tsunami run-up, the coastal water level monitoring is an efficient way.

In addition to measure the astronomical tides and storm surges, the coastal tide gauge is also capable of detecting the features of Tsunami run-up nearshore. On March 11 of 2011, the well-known Tsunami events occurred near Japan. In Taiwan, the in-situ tide stations also detect the impacts of Tsunami after Japanese earthquake. Figure 5 presents one case of the coastal water level records in Taiwan on March 11. After 17:30 (Taiwan local time), the tide stations around Taiwan detected the abnormal oscillations signals from the water level records. Besides the eastern coasts of Taiwan, we also detect the abnormal oscillations from water level records in the western coasts. The abnormal sea level rise around Taiwan after Sandai earthquake is presented in Fig. 6. Figure 7 presents the time when the abnormal wave run-up started. The figure revealed that the tsunami wave arrived at the eastern coast first, and moved into the Taiwan Strait from the north and south parts of Taiwan.

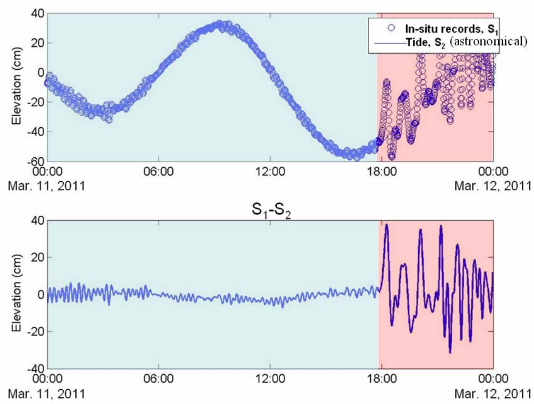

Figure 5. Sea elevation records on Mar. 11, 2011

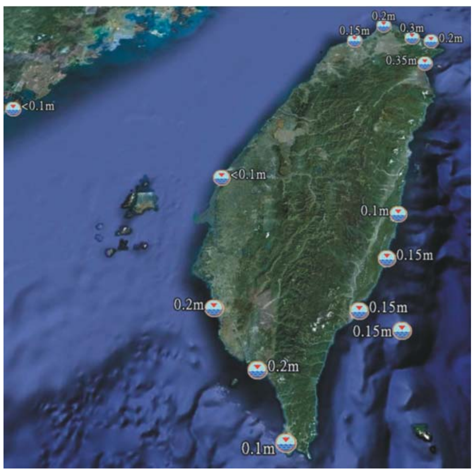

Figure 6. Abnormal sea level rise around Taiwan after Sandai earthquake.

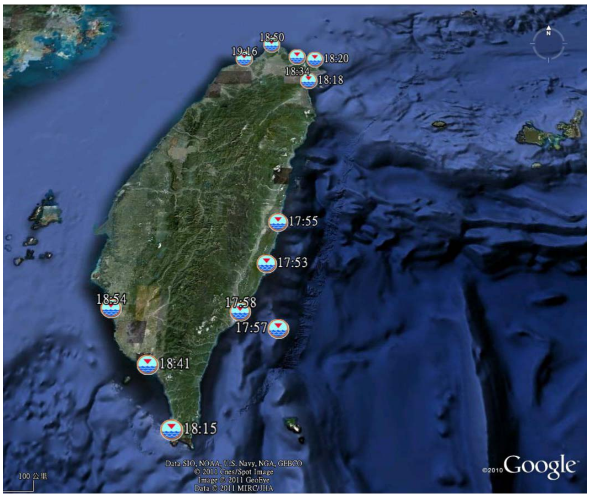

Figure 7. The time (Taiwan local time) when the abnormal wave run-up started

V. SUMMARY

Climate change and its influence on coastal hazard, such as sea level rise, storm surge and wave run-up, have received considerable attention in recent years. Our article presents the coastal ocean monitoring technologies in Taiwan. These technologies play an important role to understand the ocean features during typhoon or other severe events. The whole coastal watch network has been operated for many years and did assist decision marker knowing the sea-states and making necessary decisions by its training and improvement.

ACKNOWLEDGMENT

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REFERENCES

[1] C.C. Kao, K.C. Jao, D.J. Doong, H.L. Chen, and C.L. Kuo, “Buoy and radar observation network around Taiwan,” Proceedings of the OCEANS'06 Asia Pacific IEEE, May 2006.

[2] D.J. Doong, S.H. Chen, C.C. Kao, and B.C. Lee, “Data quality check procedures of an operational coastal ocean monitoring network,” Ocean Engineering, vol. 34, pp. 234-246, 2007.

[3] D.J.T. Carter and L. Draper, “Has the North-East Atlantic become rougher?” Nature, vol. 332, pp. 494, 1988.

[4] S. Bacon and D.J.T. Carter, “Wave climate changes in the North Atlantic and North Sea,” Int. J. Climatol., vol. 11, pp. 545-558, 1991.

[5] J. Allan and P. Komar, “Are ocean wave heights increasing in the Eastern North Pacific?” Eos Trans. AGU, vol. 81, pp. 561-567, 2000.

[6] B. Levin and M. Nosov, “Physics of Tsunamis, ” Springer, 2009.