Annual-to-decadal Variations in Wave Power Statistics at NOWPHAS Stations around Japan

Hiroyasu Kawai, Katsumi Seki, Koji Kawaguchi and Tsutomu Inomata
Marine Information Field, Port and Airport Research Institute
Yokosuka, Kanagawa, Japan

ABSTRACT
The monthly and the annual wave power statistics including the median wave directions were estimated from 1970 at the NOWPHAS wave stations around Japan. The annual and the interannual variations in the monthly statistics were compared between the Pacific Ocean and the Sea of Japan coast and between the deepwater and the coastal stations. The statistics hindcasted by inputting JMA GCM sea surface wind data to the WAM model were compared with those observed at the deepwater stations.

KEY WORDS: Wave power; wave direction; annual variation; interannual variation; wave observation.

INTRODUCTION
Various research and projects on the acquisition of natural energy from sea wind, waves, and current have been done and are ongoing worldwide. Recent apprehension of the global warming and the nuclear accident due to the 2011 Tohoku earthquake raised the consciousness for the energy of the researchers and the citizen. Concerning the abundance of coastal wave energy, the wave power, namely the incident wave energy flux per unit length along the coast, is as a major index in the assessment. The variations in the wave power with a wide range of time scale from hour to multi decades are critical, not only to assess the stability of the energy acquisition, but also to understand the variations in meteorological conditions, such as the frequency, the tracks, and the intensities of cyclones. The representative wave direction is the other critical parameter.

The monthly-mean and the annual-mean wave powers have been determined from 1970 at the Nationwide Ocean Wave Information Network for Ports and Harbours (NOWPHAS) stations around Japan and their characteristics on the coast of the Pacific Ocean, the Sea of Japan, and the East China Sea were described (Tabata et al., 1980; Takahashi and Adachi, 1989; Nagai et al., 1998). When these assessments were done, pressure and ultrasonic wave gauges normally on a 20–50 m deep seabed and within 3 km from the coast (coastal wave gauges or WG) were the major equipment in NOWPHAS. The wave powers at these stations may be smaller than those at farther offshore and deepwater locations, owing to sheltering effects of capes and offshore islands as well as refraction and breaking on shallow-water bathymetry.

Recently wave buoys equipped with RTK-GPS rovers (GPS buoys or GB) are being installed normally at 100–400 m in water depth and 10–20 km from the coastal line (Kawai et al., 2012, 2013b). The various wave statistics including the monthly-mean wave power were compared between the GPS buoys and their geometrically adjacent coastal wave gauges (Nagai et al., 2008; Kawai et al., 2013a). Some of the GPS buoys accumulated wave data for 5 years or longer and the data are useful to discuss the interannual variations in the wave statistics.

This is the background why this study determined the monthly and the annual wave power statistics including the wave direction, on the coastal wave gauges and the GPS buoys, and then investigated their annual-to-decadal variations. This study also calibrated a wave hindcast model for estimating the statistics. This paper is aimed at providing fundamental statistics which are useful in the discussion on the abundance of the wave power at major locations around Japan and on the past change in meteorological conditions.

TARGET LOCATIONS AND ANALYSIS METHOD
Fig. 1 shows the target locations, where 5 coastal wave gauge stations (WG102, WG106, WG301, WG602, and WG604) started earliest in 1970 and 15 GPS buoys (GB801–GB815) started in 2007 or later. All the stations in the figure have been acquiring 20-min-long wave records. The intervals of the heads of the records were 2 h (repetition of a 20-min-long record and a 100-min-long break) at all the stations by 2003 and are 20 min (no break) except for a few stations now.

This study began with the determination of the 20-min-mean wave power every 2 h or 20 min at each station. The 20-min-mean wave power, $P$ (kW/m), can be estimated approximately as $0.5H_{1/3}^2T_{1/3}$, where 0.5 is the dimensional constant, and $H_{1/3}$ and $T_{1/3}$ are the 20-min-significant wave height (m) and period (s), respectively. Subsequently, this study determined the maximum value, $P_{\text{max}}$, the mean value, $P_{\text{mean}}$, the minimum value, $P_{\text{min}}$, the values locating at 10, 50, and 90 % on the