ESTIMATION OF DESIGN WAVE HEIGHT AND COASTAL DEFENSE: CONSIDERATION OF GLOBAL CLIMATE CHANGE

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Abstract

Two types of long term wave climate information are desired for many marine and coastal applications especially for the design of coastal structures: the design waves and operational waves. In conventional method of design criteria estimation, it is assumed that the climate is stationary and the statistics and extreme analysis using the long-term measured or hindcasted data are used in the statistical prediction for the future. However, such assumption of steady state is argued recently due to the global climate change.

Since the availability of the field wave data for the waters around Korean peninsular is limited to cover climatically significant period of time to provide a reliable wave statistics, the wave climate information needs to be generated by means of long-term wave hindcasting using available meteorological data. Design wave height for the return period of 30, 50 and 100 years for 16 direction at each grid point of 18 km grid size for thewaters around Korean peninsular has been estimated by means of extreme wave analysis using the detailed wave simulation data for major typhoons that affected Korea since 1951 and the continuous hindcasted wave data since 1979.

The methods of extreme statistical analysis to consider the recent extreme events like typhoon Maemi in 2003 was evaluated for more stable results of design wave height estimation for the return periods of 30-50 years, which is commonly applied in designing coastal structures like breakwater. The impact of global climate change in the estimation of design wave height for the return period of 30 and 50 years was analyzed and discussed

Keywords: Design wave height, Typhoon intensity, Wave simulation

1. Introduction

The Wave Measuring System in Korea had been improved following the detailed design of the wave monitoring and prediction system proposed by Lee et al.(1986) based on the concept that long term wave statistics can be indirectly obtained by means of wave hindcasting by using the up-to-date wave models and utilizing the wave data taken from limited number of wave stations along the coast of Korea to improve the reliability of the hindcasting. Technology for numerical modelling which will supplement the data for arbitrary point of interest is to be established for the economic and effective ocean information system.

Main objective of the system is the reliable estimation of long term wave climate for coastal waters of Korea. Two types of long term statistical information of the wave conditions are desired for many practical applications: the information on the design waves and operational waves. The design criteria can be estimated by means of extreme value analysis when we have long-term data based on the assumption that the climate is stationary for 30 or 50 years. Since the availability of the field wave data in the coastal regions of Korea is limited to cover climatically significant period of time to be able to provide a reliable wave statistics, wave climate information is produced by means of wave hindcasting.

2. Synthesis of continuous wave time series

As a part of wave monitoring program in Korea, two types of long-term wave data base have been prepared: one with continuous wave simulation since 1979 and the other with wave simulation during the passage of typhoon cases since 1951. The wind fields used in the continuous wave simulation is the reanalyzed wind data conducted by

European Midrange Weather Forecasts(ECMWF), which were interpolated to the grid points and time steps of wave simulation model. Fourier transformation method was used in interpolation of the wind field for each time step of wave model.

Continuous wave simulation had been carried out for 25 years from 1979 by using HYPA Model(Hasselmann et al., 1976; Gunter et al., 1979). The grid system of the hindcasting wave model is shown in Fig. 1. The grid size of regional wave model is 1/6 degree(18km). Third generation wave model WAM has been used for the simulation for the storm cases. The time series of wind wave data obtained from the continuous wave simulation for 25 years since 1979 using ECMWF reanalyzed wind data are archived as a basic data base. The integration parameter such as significant wave height, period and direction have been recorded at all computation grid points, while the detailed wave spectral parameters have been recorded for grid point along the coast of Korea and other major points.

3. Estimation of Design Wave Height for the Waters around Korean Peninsular

The design wave height estimated by Korea Ocean Research and Development Institute(KORDI) in 1988 only for 23 points with grid size of 54 km along the coast as shown in Figure 2 with one or two major wave directions has been used in Korea in designing coastal and offshore structures.

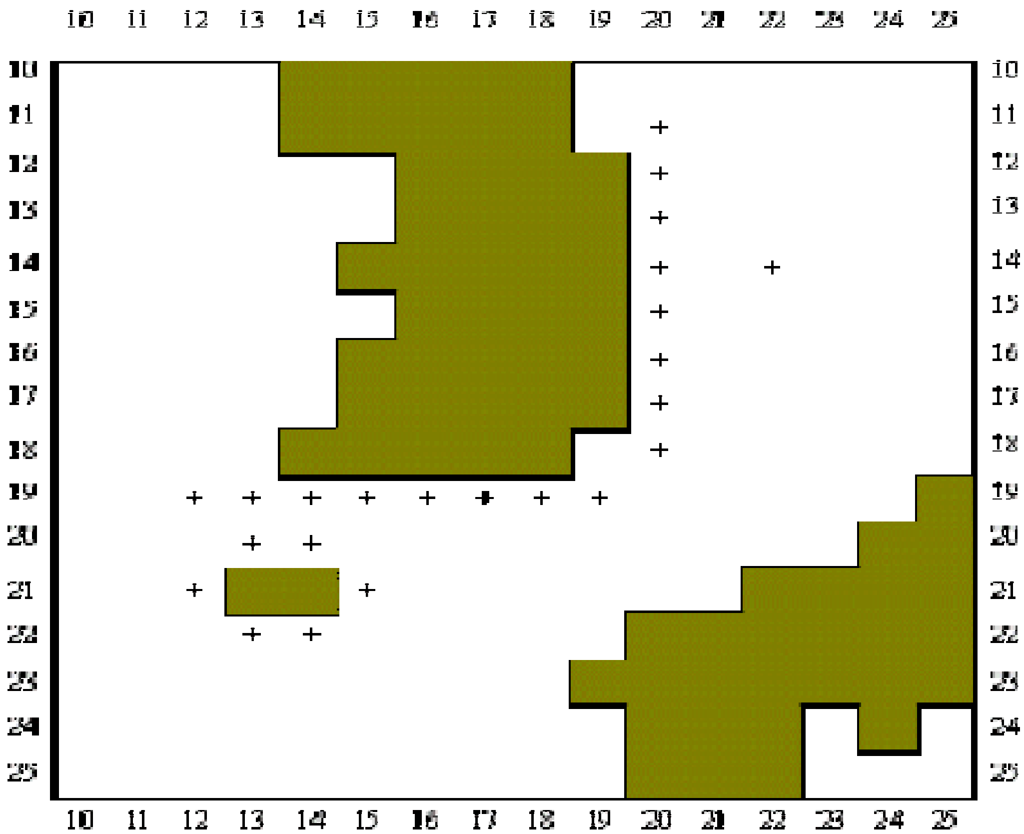

Figure 1. The grid points of design wave height calculation in 1988.

It is requested to revise the design wave height by more accurate wave simulation using updated wave models and wind input and by making most of the wave measurement data accumulated since the establishment of the wave observing network. Design wave height for more precise grid size and wave direction is needed for many engineering applications. Figure 2 shows the grid points where detailed design wave height was produced for each 16 wave direction.

From meteorological aspect, the area is affected by two distinct storm types: typhoon and extra-tropical storm. The advent of typhoon in this region is not so frequent that wave simulation of 25 years is not long enough for extreme value analysis to provide stable results. Winds induced by typhoon vary rapidly in space and time during the passage of typhoon, which can not be properly modeled by large scale weather analysis program. The typhoon winds were calculated by typhoon wind model using typhoon parameters analyzed using most of the available data in this region such as observed surface air pressure, satellite remote sensing data, etc.

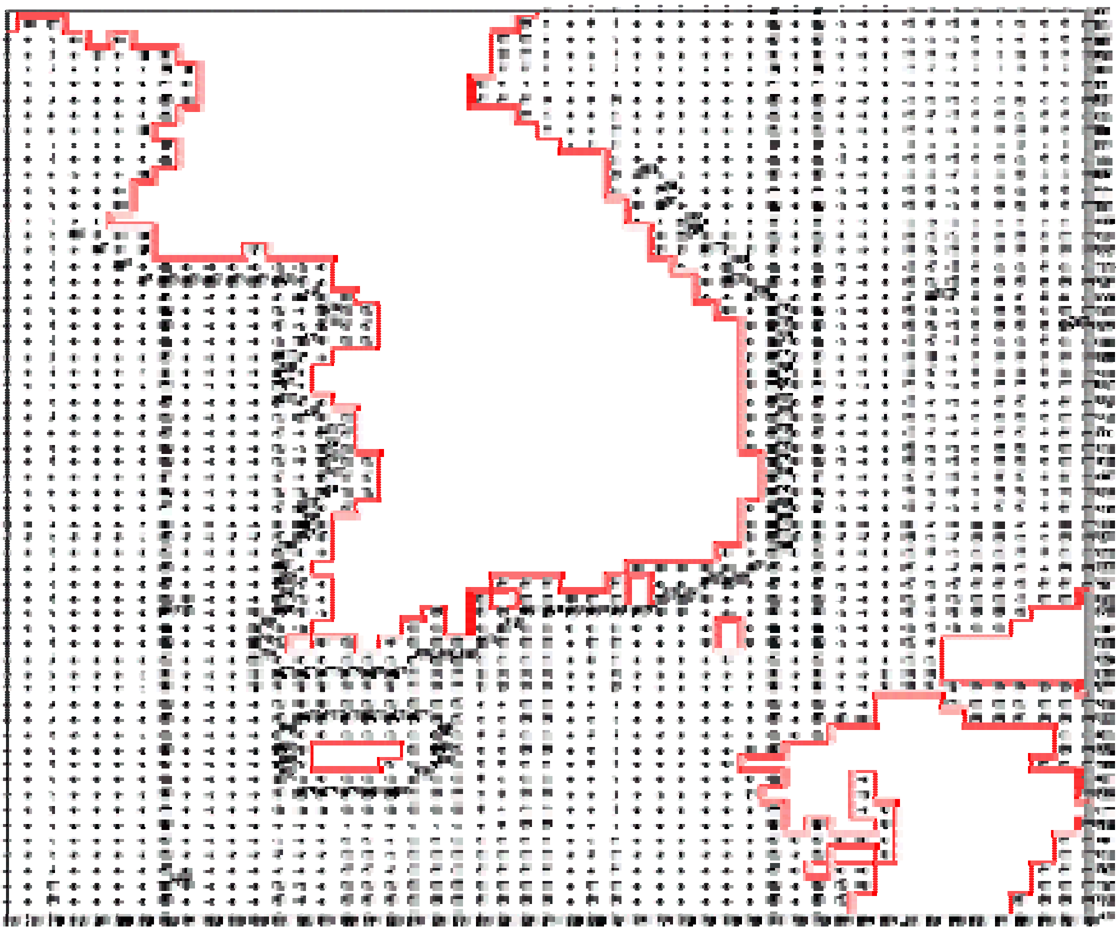

Figure 2. Grid points for design wave height estimation.

Design wave height for each return period for 16 directions at each grid point of 18 km grid size has been estimated by means of extreme wave analysis using the two types of long-term hindcasting data: continuous wave simulation for 25 years for extra-tropical storm cases and 53 years typhoon wave hindcasting. Since the extra-tropical storm and typhoon have different characteristics, the extreme value analysis is made independently for these two different weather systems. The design wave heights for return period of 10, 20, 30 and 50 years were calculated independently for all 16 wave directions and the larger wave height out of these two independent estimation was chosen..

The design wave height calculated by using 53 years of typhoon since 1950 was larger by about 3-4 meters compared to that estimated in 1988 which has been used in Korea up to now. The inclusion of typhoon Maemi occurred in 2003 caused such an abrupt increase of design wave height along the track of the typhoon. Normally wave height generated by typhoon is limited because of the restricted fetch of typhoon generated waves with rapid change of wind direction. However, the forwarding speed of typhoon Maemi was so fast and similar to the wave energy propagating speed for wind waves in the south-eastern sea of Korea that the effective fetch is considered much larger, which caused extremely high waves in the south-eastern part of Korea. The 50 years return period design wave heights as results of extreme analysis with and without inclusion of typhoon Maemi in 2003 are compared in Figure 3 along the coast of Korea. The design wave height estimated with inclusion of 2003's event is much higher along the south-eastern coast of Korea. . The abrupt increase of design wave height may cause many problems since it would require a considerable amount of budget for the proper coastal hazard reduction measure based on such increased design wave height.

The coastal structures like breakwater is different compared to offshore structure like oil platform in a sense that the demage is mostly partial that can be recovered and that lthere is normanlly no life casualty. Design wave heights for the return periods of 30 - 50 years are commonly applied in designing coastal structures like breakwaters. For more stable results of design wave height estimation for the return period of 30-50 years, the extreme statistical analysis is made using the simulation data up to 2002 year excluding the severe wave induced by typhoon Maemi in 2003. Design wave height estimation excluding wave data caused by typhoon Maemi in 2003 is shown in Fig.ure 4. The maximum wave height during typhoon Maemi, marked ▭ in the figure, is shown to be equivalent to design wave height for return period of 120 years in this example.

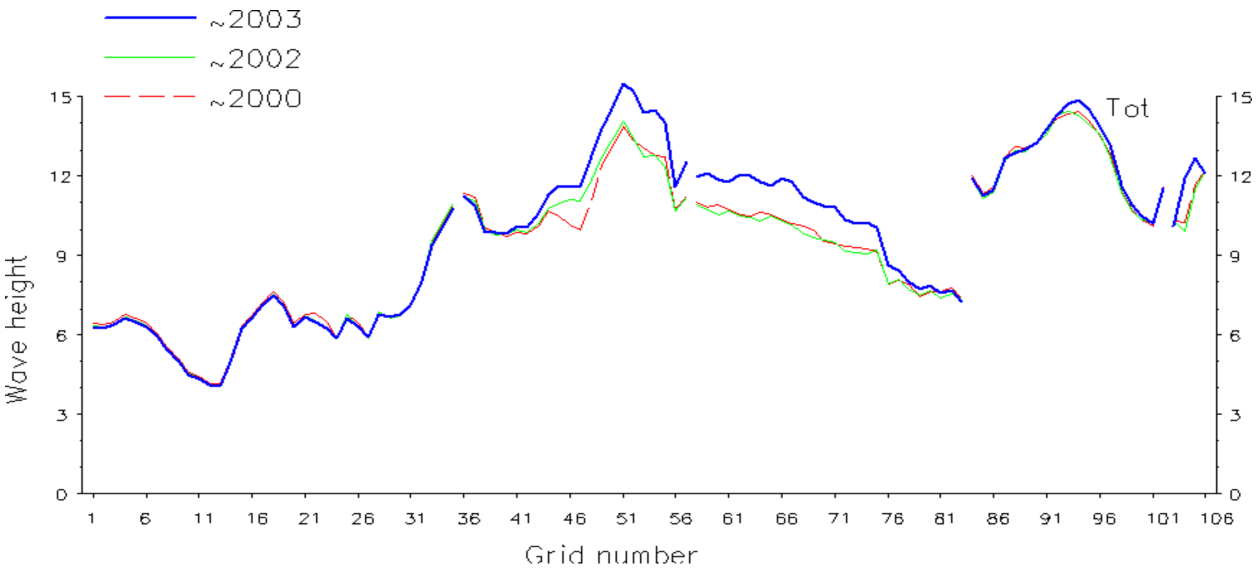

Figure 3. Comparison of design wave height for return period of 50 years along the coastal grid points estimated for different period of hindcasting duration.

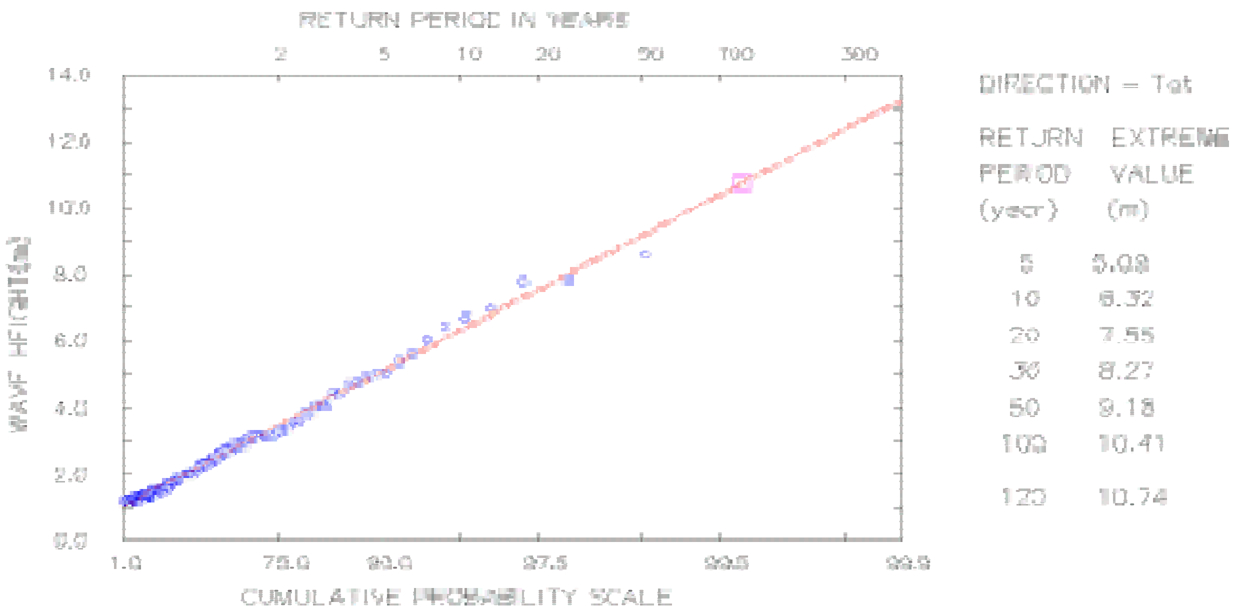

Figure 4. Design wave height estimation excluding wave data during typhoon Maemi in 2003. (The maximum wave height during typhoon Maemi, marked ▭ in the figure, is shown to be equivalent to design wave height for return period of 120 years)

The wave height for typhoon Maemi is shown to be equivalent to the design wave height for return period of more than 100 years for many grid points in the eastern part of the South Sea of Korea. For more stable results for design wave height for return period of 30 and 50 years, it is suggested to use the results analyzed excluding the extreme case of typhoon Maemi, which can be tentatively used for the design of coastal structures like breakwaters.

4. Impact of global climate change on design wave height estimation.

The intensity of tropical storm seems to be tremendously increased in last few years. Examples are typhoon Maemi in 2003 in Korea, four hurricanes with storm intensity of 100 years return period in Floria in 2004 and hurricane Katrina in 2005. It is not obvious wether it is the impact of global climate change or not. Figure 5 shows an example of variation of occurrence frequency of typhoon from 1951 to 2000 and Figure 6 shows an example of time variation of typhoon's central pressure in western Pacific area. It is difficult to see the impact of global climate change in the above figures. Changes globally in tropical and extra-tropical storm intensity and frequency are considered to be dominated by inter-decadal to multi-decadal variations, with no significant trends evident over the 20th century.

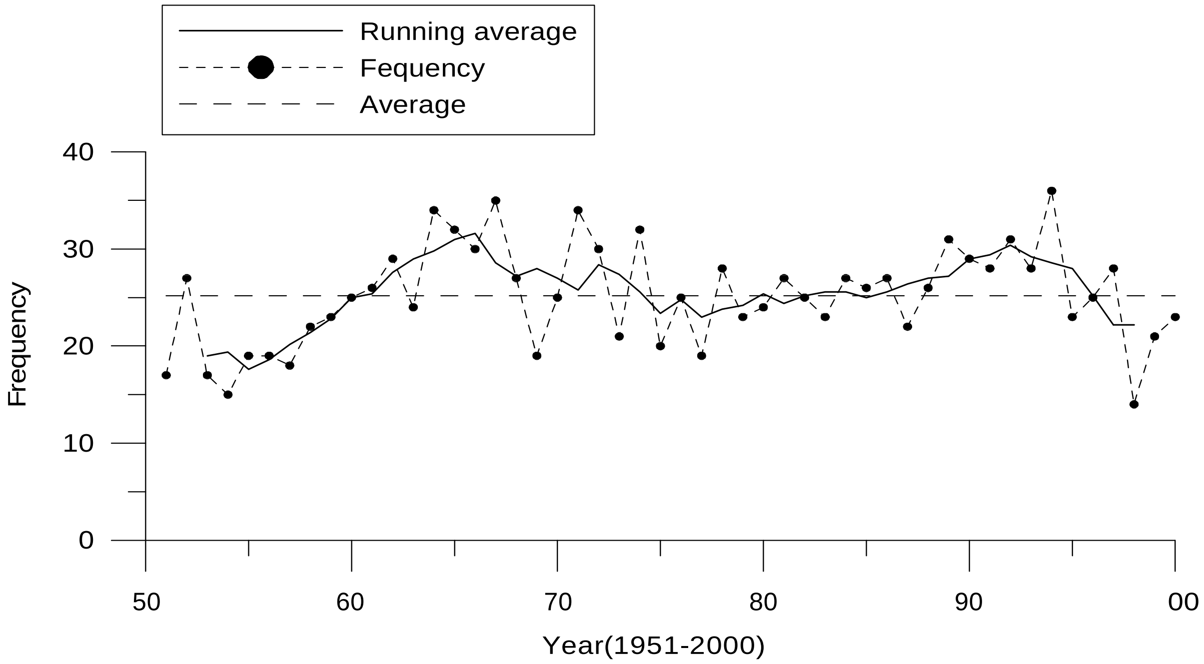

Figure 5. The variation of occurrence frequency of typhoon form 1951 to 2000. The heavy line represents five-year running average.

It is wondered that the impact of global warming may possibly caused such increase of intensity of tropical storms recently. It can be expected that the impact of global climate change on the change of typhoon intensity would occur in the future. Intergovernmental Panel on Climate Change (IPCC) reported that the global-average surface temperature has increased since 1861. Over the 20th century the increase has been about 0.6 C. Tide-gauge data show that global-average sea level rose between 0.1 and 0.2 meters during the 20th century. Global-ocean heat content has increased since the late 1950s, the period for which adequate observations of sub-surface ocean temperatures have been available. Since the generation and development of tropical storm is directly related to the sea surface temperature, it can be expected that the intensity and frequency of tropical storm would increase in the future as the increase of sea surface temperature due to the global climate change.

Since the social and economic impact of the estimation of design wave height is big, the proper estimation is needed. However, present knowledge science is restricted to carry out the job properly. The problem is how to estimate the increase of typhoon intensity quantitatively as an impact of global climate change and the resultant increase of wind and wave design criteria. The assumption of stationary state may not be valid in the future due to the impact of global climate change. New method of estimation of design wave height may be needed to be developed to cope with the impact of global climate change in the future with accumulation of extreme wave data induced by typhoon and study of the impact of global climate change on the increase of typhoon intensity in the future.

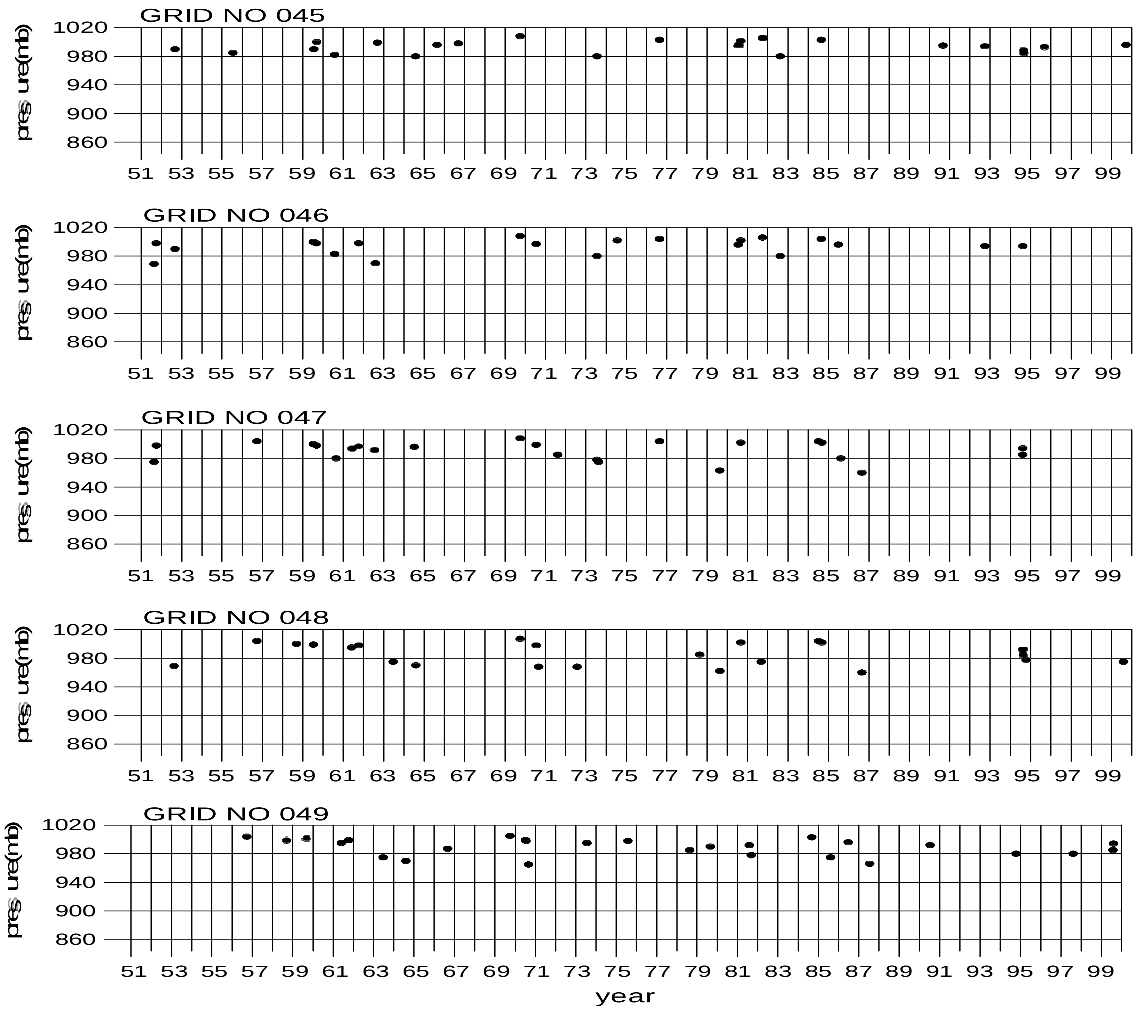

Fig. 6. Example of time variation of typhoon's central pressure in western Pacific area.

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