論 文 の 内 容 の 要 旨

論文題目
Statistical Analysis and Spatial Distribution of Transient Wind in Sea off Coast of Japan
（日本周辺海域における風の急変発生の統計解析および空間分布に関する研究）

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With the rapid growth of utilization in deep ocean areas, a variety of marine operation is increasing nowadays, such as carbon dioxide capture and storage, wind farm construction, deep ocean mining, and ultra-deep ocean drilling. Strong wind and big waves are always a serious threat to an offshore structure survived in the ocean. However, coping with the adverse metocean environment is much more challenging to marine operations, especially in some non-stationary phenomenon. Transient wind is a short duration variation of wind condition. On land, it is a considerable factor in wind engineering as well as aviation and train operation because of its unique wind profiles and suddenness. In ocean engineering, it attracts attention on the mooring system recently as being called squall. Squall is defined by World Meteorological Organization as a sudden increase of wind speed of at least 8 m/s, the speed rising to 11 m/s or more and lasting for at least one minute. Squall is one of the significant factors in designing Floating Production Storage and Offloading in West Africa. However, little information is available on squalls in the sea off the coast of Japan due to the absence of observation data.

For the safety of marine development, the studies conducted in this thesis focus on the statistical characteristics and spatial distribution characteristics of squalls in the sea off the coast of Japan. The biggest challenge is how to understand more about squalls without directly enough related data.

The thesis consists of seven chapters. The summary of each chapter is shown as follows.

Chapter 1: The background of the thesis is given. It includes the introduction of the transient wind in ocean engineering and the motivation of this study. Also, the specific research objectives and the scope of the study are stated.

Chapter 2: The meteorological environments for transient wind are investigated in ocean development areas (West Africa, United States, Brazil, Australia) and Japan. First, the occurrence of transient wind on the land of Japan is investigated through previous studies. Then, transient wind (squall) is confirmed its existence in the sea off the coast of Japan based on the weather observatory data at remote islands. Two case studies show squall can be caused by pre-frontal squall line and mesoscale convective system. The characteristics of wind change are different from those in West Africa as documented in previous studies. A questionnaire survey among experienced workers indicates that its danger on the marine operation. Seventy-four percent of experienced offshore workers had been exposed to the dangers posed by sudden

changes in wind conditions like squalls during offshore operations. Transient wind may cause problems with lifting and recovery systems and the motion of operation ships during marine operations.

Chapter 3: Due to the lack of specific observational data, the squalls occurred in four remote islands are investigated to understand their statistical characteristics in the sea off the coast of Japan. The four islands are Minami-daito Island, Minami-tori Island, Hachijo Island, and Yonakuni Island. The result presents that squalls have different occurrence frequencies in different regions. Squalls occur most frequently in Hachijo Island. Minami-daito Island and Minami-tori Island have a similar level of squall occurrence. The squall observed in remote islands shows it can happen any time and have seasonal characteristics. Besides, most squalls change its wind speed accompany the change of wind direction. The most significant variation in wind direction can reach 180 degrees.

Extreme value statistical analysis is done on the rate of wind change and the peak wind of squalls. The classical peak over threshold approach of extreme value analysis has applied the study the intensity of a squall. The characteristics of squalls and property value of different return periods are obtained in the sea off the coast of Japan.

Chapter 4: Regarding the squall outsides the remote islands, the relationships between satellite imagery and squall occurrence are investigated. This study focuses on the imagery from the geosynchronous weather satellite in Japan – Himawari-8. What kind of satellite imagery and their characteristics may relate to squall occurrence are studied. Cases studies show clouds with special texture in the visible image are approaching the island around the squall occurrence. However, nothing can be observed at night by a visible image. In infrared imagery, cases studies present that low IR (thermal infrared temperature) and high BTD (IR - water vapor temperature) relate to squall occurrence. Time-series data indicates a local minimum IR and a local maximum for BTD near squall occurrence time. The local minimum of IR and the local maximum of BTD appear more than once in the same day. Beside the brightness temperature, the image itself is analyzed by its image entropy. During the occurrence of a squall, the image entropy of both IR image and BTD image over a selected threshold becomes large and lasting for a relatively long time. The high level of image entropy can happen before or/and after squall occurrence.

Although extremum of IR varies significantly in different cases, extremum of BTD is within specific ranges. During Himawari-8 operation period, nine-eleventh of squalls in two islands have high BTD near occurrence time. BTD is expected to estimate squall occurrence from satellite imagery.

Chapter 5: In order to obtain long-term statistical analysis, Himawari-6/7 satellite imagery from 2006 are analyzed. However, Himawari-6/7 satellites have lower temporal-spatial resolution comparing to those in Himawari-8. Error analysis in spatial resolution shows an error of about 2k at around the peak of BTD in a squall.

An algorithm of detecting squalls from satellite imagery is developed in this chapter. It contains the nearby detection and extended detection. In extended detection, cloud tracking is applied to

improve the performance of the algorithm. The performance is discussed by comparison with observed squall data in Minami-daito Island and Minami-tori Island. The result shows the algorithm can detect 97% of squalls and 75% of squalls that observed at two islands, respectively. The seasonal characteristics mainly coincide with that from the observed data at islands. Besides, for the return-type squalls, the algorithm detects 100% of them in Minami-daito Island, and 80% of squalls at Minami-tori Island, respectively. Although the algorithm has some limitations, it achieves the possibility of understanding the squall distribution in the entire sea.

Chapter 6: The algorithm of detecting squalls from satellite imagery is applied to investigate the spatial distribution of squall occurrence in the entire sea off the coast of Japan. The overall spatial and temporal patterns suggest the region or season where squalls are more likely to happen. The result through a year shows spatial pattern indicates a larger frequency of squall occurrence on the coastal waters.

The squall occurrence as estimated from satellite data in monthly shows its seasonal characteristics. In winter and early spring, squall seems easy to occur in the northeastern sea area. June has the highest squall occurrence frequency near the main island of Japan. However, the least squall occurrence frequency in a year is in August. BTD in the eastern area of Japan is mainly less than 1 k, while high BTD clouds (over 1 k) happen more frequently near Kagoshima-ken and Minami-tori Island than other areas, especially in June, July and August.

Rough detection of squall occurrence in the widespread sea off the coast of Japan is done by analyzing BTD in extended detection. Compared with squall occurrence in the low-latitudes sea area, the overall squall occurrence in the sea off the coast of Japan is at a low level. It should be noted that occasionally squall occurrence in the eastern sea area of Japan has a similar level as those in the low-latitudes sea area, especially in winter and early spring.

Chapter 7: It presents the main results and conclusions emerging from this thesis. Suggestions for further research are also given in this chapter.

The findings in this thesis add substantially to the understanding of transient wind (squalls) in the sea off the coast of Japan. All the conclusions suggest that squall events can occur anywhere and anytime around Japan. The knowledge obtained in this thesis provides insight into assuring the safety of marine development against squalls.