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Marine Climate Data Sampling for Infrared Signature Assessment

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ABSTRACT:*A study was conducted on the efficient extraction method of marine climate data used for ship infrared signature assessment. To this end, we obtained ocean meteorological data with complete quality test by Korea Meteorological Administration, and eliminated outliers by setting the available interval of the data. Then, the population was reduced through simple random sampling considering geopolitical threats and effective area of the buoy for probabilistic analysis of the signature. The number of samples in this study was set as 100, 200 and 400 considering the population size and 95% confidence level, and the 2-dimensional stratified sampling method was used based on water and air temperature with high correlation. An empirical cumulative distribution function and probability density function were used for qualitative comparison and evaluation of the population and samples. Through this process, this study presented the appropriate size of ocean meteorological conditions to analyze probabilistic infrared signature of naval ships.*

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I. INTRODUCTION

The infrared stealth technology of naval ships is one of the special performances necessary for developing new ships, and many studies have been conducted upon entering the 2000s on technology independence through joint research with global advanced engineers and on improving signature reduction improvement [1].

Studies in Korea about infrared stealth of naval ships include those coming up with key environmental variables affecting infrared signature and estimating sensitivity of each variable that affects infrared signature [2], analyzing the effect of ocean meteorology on the surface infrared signature of naval ships [3-4], and examining ocean meteorology sampling [5]. Studies overseas include those on software development to predict infrared signature radiated from the naval ships in normal state considering all of the 3-dimensional shape of naval ships, operating conditions and ocean meteorology [6-7], and on analysis of meteorological data to establish reliable ocean meteorological conditions [8].

Local and global research data have discovered that infrared signature of naval ships changes sensitively to ocean meteorology and emphasized the importance of sampling to set the meteorological conditions. However, there is insufficient research on determining sample size to represent ocean meteorology that changes real-time. This study is about the sampling method of marine climate data required for the assessment of infrared signatures from naval ships. After collecting the latest marine weather data from the Korea Meteorological Administration, outliers were eliminated through quality tests, the data size was reduced through simple random sampling considering geopolitical threats and effective area of buoys. Then, considering population size and 95% confidence level, sampling data size was set to 100, 200, and 400, and final sampling was performed by two-dimensional stratified sampling method based on highly correlated water temperatures and temperatures. The results showed that 100, 200, and 400 samples all reflected population characteristics and tendencies well, and there were no significant errors in population and samples. Therefore, it seems that there is no problem if we use 100 samples of marine weather data to save time and cost when analyzing infrared signatures from naval ships.

II. POPULATION DATA SETTING

Korea Meteorological Administration is operating total 17 ocean meteorological buoys: 5 in Donghae, 6 in Seohae, and 6 in Namhae.

The ocean meteorological buoys measure the data of water temperature (WT), air temperature (AT), relative humidity (RH), wind direction (WD) and wind speed (WS) at one-hour intervals.

This study used total 146,652 cases of data measured for a year in 2017 based on water temperature, air temperature, relative humidity, wind direction and wind speed that are known to have sensitive effects on infrared signature of naval ships through previous studies.

III. REFORMATION OF DATA

The population for sampling is reduced considering geopolitical threats and effective area of the buoy to reflect the probabilistic characteristics of ocean meteorological data for analysis of infrared signature of naval ships.

Geopolitical threats were set in different values considering the locations of territorial sea of the Korean Peninsula divided into Donghae, Seohae and Namhae.

Donghae is close to North Korea, Seohae is the area where there have already been multiple engagements, and Namhae is relatively far from North Korea. Accordingly, relative threats were set as 1.5 in Donghae, 2.0 in Seohae, and 1.0 in Namhae. Figure 1 shows the map of geopolitical threats set in this study and the location of each buoy.

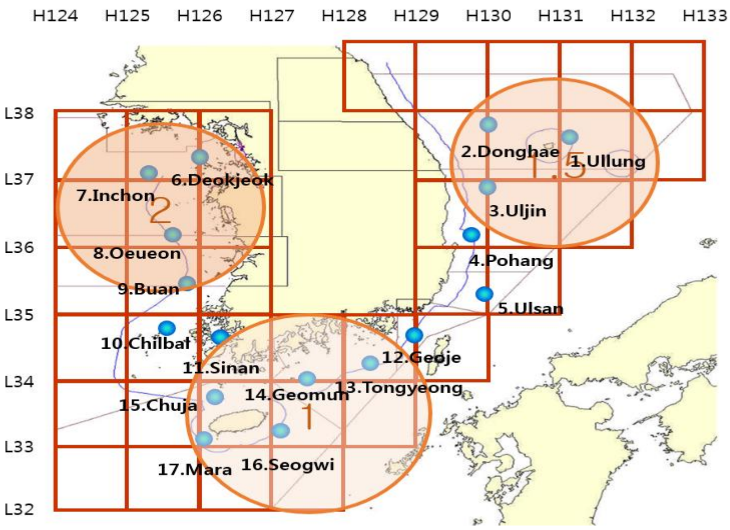

Figure 1: Geopolitical Significance of Korea Territorial Sea

To analyze the infrared signature of naval ships in Korea, it is necessary to consider all the ocean meteorology within the exclusive economic zone (EEZ) where naval ships operate. However, there are total 17 buoys managed by Korea Meteorological Administration, which are all fixed and installed in different places, which indicates that the measured data did not reflect all ocean meteorology within the EEZ.

To make up for this, we set up the effective area of meteorological data measured in the installed buoy based on the borders of the EEZ in Korea. Figure 2 shows the effective areas and the location of each buoy set up in this study.

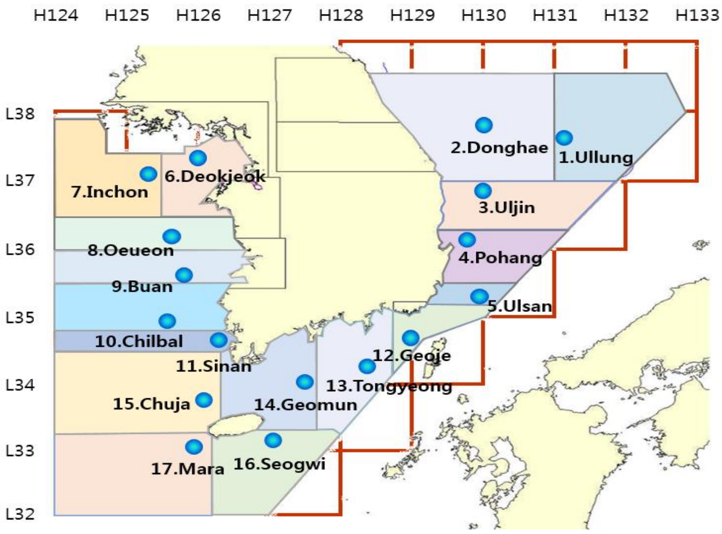

Figure 2: Effective area of operating buoys

We calculated the reduction ratio of each buoy data considering the map of geopolitical threat and effective area of the buoy, which is summarized in Table 1. The data reduction ratio implies that there is more probability of sampling in relatively important waters in the sampling process and less probability of sampling in relatively not important waters.

Simple random sampling was used to sample the probabilistic population in the Korea Meteorological Administration data applying the data reduction ratio. The number of samples in the probabilistic population was reduced to 85,045.

Table 1: Reduction ratio of buoy

	Buoy		Hazard	Area	Multiply	Ratio(%)
East	1		1.5	9.3	14.0	97
	2		1.5	9.6	14.4	103
	3		1.5	6.4	9.60	67
	4		1.5	5.9	8.90	62
	5		1.5	1.9	2.90	20
West	6		2.0	2.8	5.60	39
	7		2.0	5.2	10.4	72
	8		2.0	4.0	8.00	56
	9		2.0	4.3	8.60	60
	10		2.0	6.5	13.0	90
	11		2.0	5.0	10.0	70
South	12		1.0	3.2	3.20	22
	13		1.0	6.0	6.00	42
	14		1.0	4.1	4.10	29
	15		1.0	9.7	9.70	68
	16		1.0	5.3	5.30	37
	17		1.0	9.7	9.70	68

IV. DATA REDUCTION

The stratified sampling method considered in this study requires criterion variable and level to divide the samples into multiple strata that are not redundant. Therefore, the criterion variable is established by calculating the correlation of five environmental variables with greatest effect on changes in infrared signature of naval ships, which are water temperature, air temperature, relative humidity, wind direction, and wind speed.

The correlation coefficients of water temperature and air temperature were highest at 0.884, based on which this study used the 2-dimensional stratified sampling method based on the two variables that are water temperature and air temperature. The 2-dimensional stratified sampling is a method proved to have an excellent effect on sampling of ocean meteorological data in previous studies [5].

The infrared signature radiated from the surface of sailing naval ship changes very sensitively due to the surrounding ocean climate. However, it requires a great deal of time to analyze the infrared signature of naval ships while considering all ocean meteorological conditions that change real-time. Therefore, it is necessary to establish ocean meteorological conditions in an appropriate size to analyze the infrared signature of naval ships more accurately while considering all ocean meteorological data.

This study used the sample size determination formula necessary for mean estimation to determine the initial size of ocean meteorological conditions, which is as shown in (1).

$$n = Z^2 \frac{\sigma^2}{d^2} \qquad (1)$$

Here, n is sample size, Z is threshold at a certain confidence level, σ is variance of the population, and d is allowable error.

Table 2 summarizes the data values to determine sample size. In Table 2, Z (threshold of the confidence level) is set as 1.96 (95%), standard deviation as that of the population reflecting probabilistic characteristics, and allowable error as the measurement error of a general measuring instrument. The sample size calculated using the values was minimum 40 to maximum 500, but this study came up with 100, 200 and 400 samples based on the result of air temperature and water temperature with high correlation that have the biggest impact on infrared signature changes.

Simple random sampling is used in many fields due to its advantage in that the probability of being selected as a sample is all the same. However, there is also a possibility that the selected sample may be limited to a certain area of the population. On the other hand, stratified sampling extracts samples by dividing the population into multiple strata that are not redundant, thereby preventing the tipping effect that may occur in simple random sampling. This study used the 2-dimensional stratified sampling method for final sampling, and came up with 100, 200 and 400 samples.

Table 2: Data values to determine sample size

	WT	AT	RH	WD	WS
Z-value	1.96	1.96	1.96	1.96	1.96
Standard Deviation	6.2ºC	8.0ºC	15.9%	115.4º	3.3m/s
Tolerance	1ºC	1ºC	5%	10º	1m/s
Sample Size	149	248	39	511	40

V. SAMPLING RESULTS

For qualitative evaluation of the samples, this study used empirical cumulative distribution function (ECDF) and probability density function (PDF). The ECDF is used to evaluate the suitability of data distribution or compare many other sample distributions, and can estimate the percentile of the population from the samples. Figure 3 shows the comparison of ECDF result. Figure 4 shows PDF results that, like the result of the ECDF, all five meteorological variables have similar characteristics as the population.

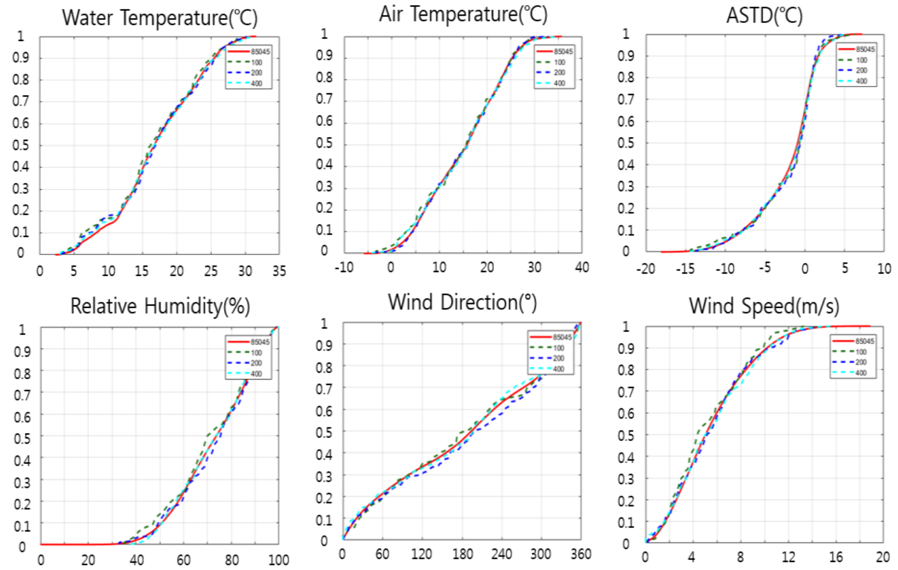

Figure 3: ECDF results of population & samples

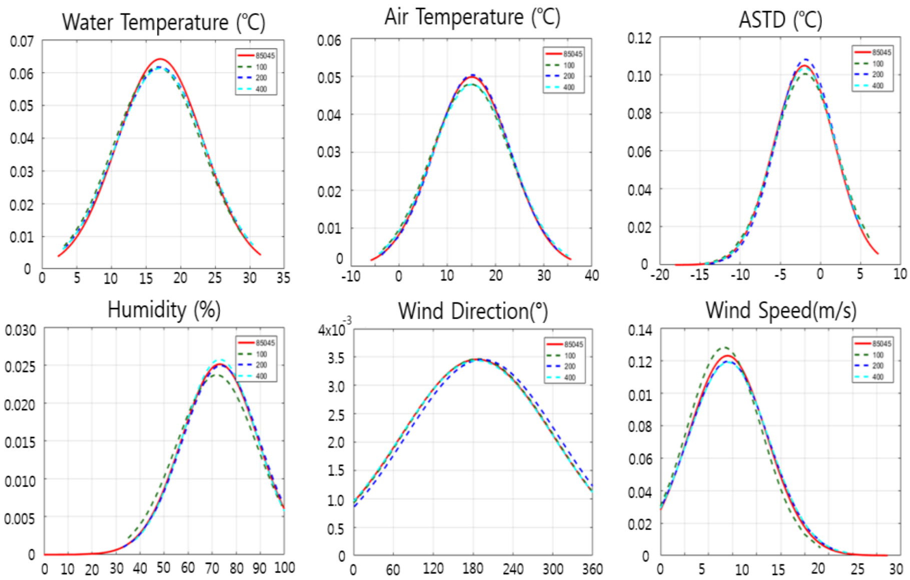

Figure 4: PDF results of population & samples

VI. CONCLUSION

This study was conducted on determination of sample size of ocean meteorology to analyze infrared signature of naval ships, and the contents and results are summarized as follows.

- We received the ocean meteorological data of one year in 2017 with complete quality test by Korea Meteorological Administration, calculated the mean and standard deviation of each meteorological variable, set the range including about 95%, and eliminated outliers.
- We set the geopolitical threats map in the waters of the Korean Peninsula and effective area of the buoys installed, and reduced the population data provided by Korea Meteorological Administration, in order to reflect probabilistic characteristics on the population data in the process of final sampling.
- For the population data reflecting probabilistic characteristics, the correlation was calculated in each meteorological variable, and 2-dimensional stratified sampling was carried out based on water temperature and air temperature with highest correlation.
- The initial sample size was set as 100, 200 and 400 using the sample size determination formula for mean estimation. Then, the ECDF and PDF were used in comparison for qualitative evaluation, and standard square error and confidence interval are estimated for quantitative evaluation.
- The results of this study show that 100, 200 and 400 samples all well reflect the population characteristics and tendency, and there is no significant error in the population and samples. Therefore, it seems there is no problem in using 100 samples of ocean meteorological data considering the time and cost in the process of analyzing infrared signature of naval ships.

The results of this study can be used as the baseline data for analyzing infrared signature of naval ships sailing on the waters of the Korean Peninsula in the design and construction of naval ships in Korea. Additional research will be conducted to predict infrared signature of naval ships using extracted ocean meteorological data and identify the relevance of the extracted data by comparatively analyzing the data.

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