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A Study on the Calculation Method for the Coverage Rate of Early Warning Release

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Abstract. The coverage rate of early warning release is an important indicator of early warning releasing capacity. How to calculate the coverage rate of early warning in a certain area objectively and reasonably plays an important role in evaluating the effectiveness of early warning releasing. This paper analyzes the principle and components of the coverage rate calculation for early warning releasing, and puts forward three combination calculation methods. They are inclusion-exclusion principle, method of weighting and maximum value method .This paper also analyzes the differences between the three methods in calculation feasibility, calculation accuracy and rationality of the results, so as to confirm that the relative best method for calculating the coverage rate of early warning is maximum value method. Finally, combined with the characteristics of China's early warning release system and administrative regionalization, the paper further proposes national, provincial and municipal three level calculation models of early warning releasing coverage rate, and provides a calculation example, and discusses the enlightenment to improve the early warning releasing capacity.

1. Introdution

In March 2017, WMO released the 2016 Global Climate Status Statement which pointed out that global temperature, sea ice area, sea level rise, and ocean heat all hit a record in 2016. In addition, according to monitoring data, the frequency of global weather and climate disasters has increased four times and the economic loss has increased seven times. At the same time, natural disasters, accident disasters and public health risks have increased significantly in China, and their impact on the economy and people's lives and property has been increasing. Therefore, party committees and governments at the central and local levels and all sectors of society have put forward higher requirements for disaster prevention, reduction and relief work. To improve the capacity and level of natural disaster risk prevention and control, it is necessary to further enhance the capacity of early warning information releasing and increase the coverage of early warning information releasing[1]. In the latest opinions on strengthening meteorological disaster monitoring and warning information releasing issued by the State Office, it is clearly put forward that the public coverage rate of China's disaster warning has reached over 90% at the end of the 12th five-year plan. Therefore, the quantitative and objective calculation of early warning information coverage will help to evaluate the capacity of early warning information releasing, to improve the mechanism of meteorological early

warning, and also to provide scientific basis for operating equal, high-quality and efficient meteorological disaster prevention and mitigation work[2-3].

At present, the concept of coverage has been widely applied in the fields of forestry, telecommunications, education and social security, but the research on the coverage of early warning information in China is still in the exploratory stage, lacking authoritative and unified calculation methods. Therefore, through analyzing the main factors that influence the early warning information releasing coverage and calculation characteristics, this paper studies inclusion-exclusion principle, method of weighting and maximum method, three kinds of suitable calculation methods for early warning information coverage. And from the aspects of calculation feasibility, calculation accuracy, rationality of the results, this study carries out difference analysis and confirms the relative optimal calculation method. And this optimal calculation method is applied to the national, provincial, municipal and county four-level early warning system of the national early warning system and a calculation model for the coverage rate of the third-level early warning information is established, which provides a revelation to enhance the capacity of early warning information releasing.

2. Related Concepts of Warning Information Release Coverage

2.1. A Comprehensive Population Coverage of Early Warning Information Releasing

The comprehensive population coverage rate of early warning information releasing ("early warning information coverage rate" for short) refers to the proportion of the public that can be covered by the emergency early warning information released and disseminated to all the public in a certain region under the current transmission capacity.

2.2. Releasing Means

After the early warning information is released in various forms, the public can know the content of the early warning information by means of watching, listening and browsing. At present, China's main means of releasing early warning information to the public include TV, radio, Internet, whole network short message, tweeter, display screen, APP, weibo, WeChat etc.[4].

3. Different Calculation Methods and Difference Analysis of the Releasing Coverage Rate of Early Warning Information

Based on the analysis of national early warning information releasing, the main elements for calculating the coverage rate of early warning information releasing are determined, and three methods for calculating the coverage rate of early warning information releasing are obtained through analysis. They are respectively the principle of inclusion and exclusion, method of weighting and maximum method. Finally, the difference analysis of three methods for calculating the releasing coverage rate of warning information is made, and the relative optimal calculation method is determined.

3.1. Components of Early Warning Information Releasing Coverage

At present, China's main means of releasing early warning information to the public include TV, radio, website, whole network short message, tweeter, display screen, APP, weibo, WeChat and Beidou satellite. Among them, websites, apps, weibo and WeChat adopt Internet transmission, and they belong to the category of Internet in this paper. Although the transmission means of loudspeaker, display screen and Beidou satellite are different, public terminals are adopted in the transmission process of them, so they fall into the category of public terminals in this paper. Based on the above analysis, this paper calculates the components of the coverage rate of early warning information, including the coverage rates of early warning information issued by TV, radio, Internet, SMS throughout the network and public terminals.

Each means of distribution is mapped to a corresponding event, then TV is event X_1, broadcast is event X_2, Internet is event X_3, network short message is event X_4, public terminal is event X_5. The

coverage rate of warning information issued by TV is set as P_1, issued by radio is set as P_2, issued by Internet is set as P_3, issued by SMS is set as P_4, and issued by public terminal is set as P_5.

In the actual calculation, the coverage rates of the five events are adopted from the data on the official websites of the National Bureau of Statistics or the official websites of government at all levels.

3.2. Different Calculation Methods

3.2.1. Inclusion-exclusion Principle. When calculating with the principle of inclusion and exclusion, it is necessary to calculate the number of objects contained in the content without considering the overlapping situation, and then exclude the number of repeated calculations[5-7]. When using this method to calculate the coverage rate of a region's early warning information, it is necessary to calculate the coverage rates of the early warning information of five means at first and then gradually to exclude the repeatedly calculated coverage rates. Therefore, according to the principle of inclusion and exclusion, the calculation formula of the releasing coverage rate of warning information P is:

$$P=\sum_{i=1}^{5} P_i - \sum_{i=1}^{5}\sum_{j>i}(P_i \cap P_j)+\sum_{i=1}^{5}\sum_{j>i}\sum_{k>j}(P_i \cap P_j \cap P_k)$$

$$-\ldots+(P_1 \cap P_2 \cap \ldots \cap P_5)$$

Among them, P_i is the releasing coverage of warning information of various releasing means.When calculating the coverage rate of warning information releasing in a certain region with this formula, five distribution means' coverage rates of warning information releasing can be obtained from the official websites of the National Bureau of Statistics or that of government agencies. Considering that some TV viewers can get warning information by mobile phones, radio or loudspeaker; Some mobile phone users can also obtain warning information from the Internet, broadcasting and other means. In other words, there are many overlapping cases among the five means, so the repeated covering part needs to be removed. However, relatively accurate data of the repeated coverage cannot be obtained from official channels, so this calculation method cannot be applied to the accurate calculation for coverage of warning information releasing.

3.2.2. Methods of Weighting. The method of weighting is to confirm the relative importance of the index in the overall calculation or evaluation. The setting of weighting generally includes subjective experience method, primary and secondary index queuing classification, expert survey method etc[8-9]. When calculating the coverage rate of warning information releasing by this method, it is necessary to determine the degree of importance of each releasing method in the overall calculation results, that is, the weight coefficient of each releasing method coverage value. Due to large differences in the releasing of early warning in different regions across the country, in order to make the weight coefficient relatively reasonable and accurate, the expert survey method is adopted and relevant experts are employed. Each expert should firstly set the weighting of the assessment index independently, and then take the average of the weighting of each assessment index as the final weighting. According to the coverage value and weight coefficient of each method, the coverage rate of comprehensive warning information releasing is calculated synthetically.According to the weighting method, the calculation formula of the warning information releasing coverage is as follows:

$$P = \sum_{i=1}^{5} P_i w_i$$

Among them, P_i is the warning information releasing coverage value of various releasing means, w_i is the weight coefficient of the warning information releasing coverage of various releasing means.When using this formula to calculate the releasing coverage of warning information, the specific coverage value can be calculated. However, due to too much subjectivity in determining the weight coefficient, the accuracy of the calculation result needs to be verified in practice.

3.2.3. Maximum Method. The maximum method is taking the maximum from the calculation data as the calculation result. The maximum value method is used to calculate the releasing coverage rate of early warning information, that is, the maximum value is taken from the releasing coverage rates of five release methods. According to the maximum method, the calculation formula of the warning information releasing coverage is as follows:

$$P = \max_{p}\{P_1, P_2, P_3, P_4, P_5\}$$

Among them, P_i is the releasing coverage of warning information of various releasing means.Using this formula to calculate the coverage of early warning information, the specific coverage value can be calculated.

3.3. Analysis of Differences

According to the calculation formulas of the releasing coverage rate of early warning information by different calculation methods, this paper compares these calculation methods from the aspects of calculation feasibility, calculation accuracy and rationality of the results. And the results are shown in table 1.:

Table 1. Difference Analysis of Three Calculation Methods.

	Calculation Feasibility	Calculation Accuracy	Rationality of the Results	Shortcomings of Calculation Methods
inclusion-exclusion principle	no	poor	reasonable calculation methods, no calculation result	a lack of official coverage data, cannot be calculated
the method of weighting	feasible	average, need verification	reasonable calculation methods, results need to be verified	subjective weight coefficient, a lack of accurate verification
the maximum method	feasible	relatively accurate	reasonable calculation methods,relatively reasonable results	approximation, relatively small results

Through the analysis of the situation of early warning information releasing in China, and the analysis of differences of the above calculation methods from three aspects, the calculation feasibility and the calculation accuracy and rationality of the results, it can be determined that the maximum value method is the relatively optimal calculation method for calculating the coverage of the early warning information releasing in a certain region under the situation of repeated coverage of China's early warning information audiences.

4. Calculation Models of Early Warning Information Releasing Coverage

According to the characteristics of China's early warning information releasing system and administrative region, this paper puts forward the calculation models of coverage rate of national, provincial and municipal early warning information releasing by using the method of weighting.

4.1. Calculation Model of National Early Warning Information Releasing Coverage

The national early warning information releasing coverage is weighted by the coverage rate of each provincial early warning information releasing and the coverage rate of national-level early warning information releasing center. The calculation model is:

$$P = \frac{n}{n+1}\sum_{i=1}^{n} W_i C_i + \frac{1}{n+1} C_0, W_i = \frac{N_i}{N}$$

Among them, P is a national warning information releasing coverage, n represents the total number of provinces, C_i is the ith province's (municipality directly under the Central Government) early warning information releasing coverage (see Section 3.2), C_0 is the coverage published by international-level early warning information releasing center, W_i is the weight coefficient of the releasing coverage rate of the early warning information of the ith province (municipality directly

under the central government); N_i is the total population of the ith province (municipality directly under the central government) at the end of the year.

4.2. Calculation Model of Provincial Warning Information Releasing Coverage

The coverage rate of provincial warning information releasing is weighted by the coverage rate of provincial warning information releasing and the coverage rate of provincial-level warning information releasing center. The calculation model is:

$$C_i = \frac{m}{m+1}\sum_{j=1}^{m} W_{i,j}C_{i,j} + \frac{1}{m+1}C_{i,0}, W_{i,j} = \frac{N_{i,j}}{N_i}$$

Among them, C_i is the warning information releasing coverage of the ith province, m is the total number of municipalities under the jurisdiction of the ith province, $C_{i,j}$ is the early warning information releasing coverage of the jth city in the ith province (see Section 3.3), $C_{i,0}$ is releasing coverage value released by the early warning information releasing center of the ith province, $W_{i,j}$ is the weight coefficient of the early warning information releasing coverage of the jth city in the ith province; $N_{i,j}$ is the total population at the end of the year of the jth city in the ith province, N_i is the total population of the ith province at the end of the year.

4.3. Calculation Model of Municipal Warning Information Releasing Coverage

The coverage rate of city warning information releasing is obtained by weighting the coverage rate of each county (district) and that of municipal warning information releasing center. The calculation model is:

$$C_{i,j} = \frac{q}{q+1}\sum_{k=1}^{q} W_{i,j,k}C_{i,j,k} + \frac{1}{q+1}C_{i,j,0}\ , W_{i,j,k} = \frac{N_{i,j,k}}{N_{i,j}}$$

Among them, $C_{i,j}$ is the early warning information releasing coverage of the jth city in the ith province, q is the total number of counties (districts) under the jurisdiction of the jth city in the ith province, $C_{i,j,k}$ is the early warning information releasing coverage value of the $k$thcounty (district) of the jth city in the ith province(calculated by the maximum method), $C_{i,j,0}$ is releasing coverage value released by the early warning information releasing center of the jth city in the ith province, $W_{i,j,k}$ is the early warning information releasing coverage weight coefficient of the kth county (district) of the jth City in the ith province; $N_{i,j,k}$ is the total population at the end of the year of the kth county of the jth city in the ith province, $N_{i,j}$ is the total population at the end of the year of the jth city in the ith province.

4.4. Calculation Examples

In order to have a more intuitive understanding of the calculation model of the coverage rate of the releasing of warning information, Huizhou city of Guangzhou province was selected to carry out the actual calculation to verify the rationality of the calculation model of the coverage rate of the warning information releasing at municipal level so as to facilitate the more effective construction of the releasing methods in the future. This example calculates the coverage rate of Huizhou warning information releasing in 2016, which is carried out from three parts: the coverage rate of municipal warning information releasing center, of each district and county, the weight coefficient of the coverage rate of each district and county, and the coverage rate of municipal warning information releasing.

4.4.1. Instances Selection. Since 2012, Guangdong province has set up an early warning information releasing work pattern with Guangdong characteristics and basically completed an integrated provincial, municipal and county early warning information releasing system. As for the releasing means of early warning information, 10 channels such as weibo, WeChat and websites were expanded

and built on the basis of making full use of traditional media. In 1,957 administrative villages, they have at least one releasing method which can obtain early warning information. Hence, Guangdong province is one of the outstanding provinces in the national early warning information construction. Located on the coast of Dongjiang river in southeast Guangdong province and adjacent to Daya Bay in the South China Sea, Huizhou city has diversified warning types and highly intensive tourism resources. Its coverage of warning information releasing needs to be effectively guaranteed. Therefore, Huizhou city is selected to carry out early warning information releasing coverage calculation. Huizhou now has jurisdiction over Huicheng district, Huiyang district, Huidong county, Boluo county and Longmen county, and has two state-level development zones, namely Daya Bay Economic and Technological Development Zone and Zhongkai High-tech Industrial Development Zone.

4.4.2. The Early Warning Information Releasing Coverage Calculation of the Municipal Warning Center, Each District and County. The analysis of the early warning information releasing means of Huizhou municipal-level early warning information releasing center and that of seven counties' releasing agencies[10] are shown in table 2.

Table 2. Early Warning Information Releasing Means Statistics of Huizhou City in 2016

Region	Early Warning Information Releasing Means									
	TV	Radio	Internet				Whole Network SMS	Public Terminals		
			Website	APP	Weibo	WeChat		Tweeter	Display Screen	Beidou Satellite
Huizhou city（warning center）	√	√	√	√	√	√	√	√	√	
Huicheng district	√	√	√	√			√		√	
Huiyang district	√	√	√	√			√		√	
Huidong county	√	√	√	√				√		
Boluo county	√	√	√	√				√		
Longmen county	√	√	√	√				√		
DaYaBay Economic and Technological Development Zone	√	√	√	√			√		√	
ZhongkaiHigh-tech Industrial Development Zone	√	√	√	√			√		√	

According to the statistics of warning information distribution means of warning information releasing agencies of Huizhou city in table 2, the coverage rate of each releasing method is summarized[10,11,12], see table 3:

Table 3.Coverage of Releasing Means in 2016

ReleasingMeans	Index	Coverage	Note
TV	Comprehensive population coverage of TV programs（%）	98.9	Data Sources：http://data.stats.gov.cn/
	Rural television population coverage（%）	98.5	
Radio	Comprehensive population coverage of radio programs（%）	98.4	
	Rural radio population coverage（%）	97.8	
Internet	Internet penetration rate（%）	53.2	

Add to Table 3

ReleasingMeans	Index	Coverage	Note

Whole Network SMS	Mobile penetration rate (a / 100 persons)	95.6	Data Sources：http://data.stats.gov.cn/
Public	Loudspeaker coverage	85.83	Data Sources：http://www.cma.gov.cn/；http://10.0.65.221:8080/qxyj/pageHtml/index.jsp
Terminals	Display coverage	68.67	

According to the statistical data in table 2 and table 3, the relative optimal calculation method (maximum method) for the releasing coverage of early warning information is used to calculate the coverage rate of the municipal warning information releasing center and that of each district and county, and the influence of each county is not taken into account when the municipal warning information releasing coverage is calculated. The calculation results are shown in table 4:

Table 4. Warning Information Releasing Coverage Rates of Huizhou City in 2016

Region	Coverage of Warning Information Releasing Means（%）					Warning Information Releasing Coverage（%）
	TV	Radio	Internet	Whole Network SMS	Public Terminals	
Huizhou（Municipal warning center）	**98.9**	98.4	53.2	95.6	85.83	**98.9**
Huicheng district	**98.9**	98.4	53.2	95.6	68.67	**98.9**
Huiyang district	**98.9**	98.4	53.2	95.6	68.67	**98.9**
Huidong county	**98.5**	97.8	53.2	95.6	85.83	**98.5**
Boluo county	**98.5**	97.8	53.2	95.6	85.83	**98.5**
Longmen county	**98.5**	97.8	53.2	95.6	85.83	**98.5**
DayaBay Economic and Technological Development Zone	**98.9**	98.4	53.2	95.6	68.67	**98.9**
ZhongkaiHigh-tech Industrial Development Zone	**98.9**	98.4	53.2	95.6	68.67	**98.9**

4.4.3. The Warning Information Releasing Coverage Rate Weight Coefficient Calculation of Each District and County. The weight coefficient of warning information releasing coverage rate is calculated according to the population proportion. According to the statistical bulletin of Huizhou Bureau of Statistics in 2016, the permanent population of all districts and counties in Huizhou at the end of 2016 is summarized [13], and the weight coefficients of warning information releasing coverage rates of all districts and counties are calculated, as shown in table 5:

Table 5. Permanent Population and Warning Information Releasing Coverage Weight Coefficient of Huizhou in 2016

	Hui zhou	Huicheg district	Huiyang district	Huidog county	Boluo county	Longmn county	DayaBay Economic and Technological Development Zone	ZhongkaiHigh-tech Industrial Development Zone
Permanent Population in 2016（10000）	477.5	120.05	59.86	93.58	107.19	31.79	20.85	44.19
Weight Coefficient（Reserve two decimals）	1	0.25	0.13	0.20	0.22	0.07	0.04	0.09

4.4.4. The Early Warning Information Releasing Coverage Calculation of Huizhou. According to the calculation model of the coverage rate of city warning information releasing, the coverage rate of Huizhou warning information releasing is weighted by the coverage rate of each county (district) and

that of municipal warning information releasing center. The calculation process and results of the coverage rate of Huizhou warning information releasing are shown in table 6:

Table 6. Early Warning Information Releasing Coverage Rate of Huizhou in 2016

Region	Warning Information Releasing Coverage C（%）	Weight Coefficient W	Coverage Weighting （W*C）（%）	ReleasingMechanism Proportion S	Municipal-level ReleasingCoverage （W*C*S）（%）
Huizhou （Municipal warning center）	98.9	1	98.9	1/8=0.125	12.3625
Huicheng district	98.9	0.25	24.725	7/8=0.875	86.366
Huiyang district	98.9	0.13	12.857		
Huidong county	98.5	0.2	19.7		
Boluo county	98.5	0.22	21.67		
Longmen county	98.5	0.07	6.895		
DayaBay Economic and Technological Development Zone	98.9	0.04	3.956		
ZhongkaiHigh-tech Industrial Development Zone	98.9	0.09	8.901		
Early Warning Information ReleasingCoverage Rate of Huizhou in 2016					98.7285

According to the statistics of the releasing means and coverage rates of all districts and counties in Huizhou, using the municipal coverage rate calculation model of warning information releasing, it was calculated that the coverage rate of Huizhou warning information releasing in 2016 was 98.7%. Based on this calculation procedure and the calculation models of municipal-level, provincial-level and national-level warning information releasing coverage rates, all warning information releasing coverage rates of municipal-level, provincial-level and national-level can be calculated successively.

5. Conclusion

Based on the analysis of early warning information releasing coverage, this paper puts forwards three calculation methods and makes a comparative analysis of the three calculation methods from the aspects of calculation feasibility, calculation accuracy and rationality of the results, and confirms that the maximum method is a relatively optimal calculation method for calculating the coverage of early warning information releasing. Finally, the calculation models of the coverage rate of national, provincial and municipal warning information releasing in different regions are further proposed by means of the method of weighting.

The research in this paper shows that the early warning information coverage calculation method obtained from the existing study is only an approximation of the real coverage, while the specific and accurate coverage requires the investigation and statistics of the releasing means in specific areas. Since the releasing coverage rate of early warning information has important reference significance in measuring the capacity of early warning releasing, data basis and methods should be explained when adopting such indicators. In addition, the study also shows that in improving the capacity of early warning releasing, it is necessary to pay attention to the releasing means with the largest local coverage and constantly strengthen the releasing of early warning information through effective communication means. When releasing the early warning information to the public, the first choice is the means with the maximum coverage so as to improve the effectiveness of the early warning releasing. However, it should also be recognized that the early warning information releasing coverage is only the effective coverage to the public and does not meet the actual delivery of early warning information to the public. In the future, with the improvement of science and technology and the strengthening of China's emergency warning work, the assessment of the delivery rate of early warning information will become an important evaluation index for early warning releasing.

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