RESEARCH ARTICLE

Prediction method of ice temperature change in scenic spots of Kanas Lake under global warming

Yukun You*

School of Economics and Management, Yantai Institute of Technology, Yantai 264005, Shandong, China

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Ice temperature refers to the ice temperature of thick ice formed by freezing water surface. Studying the law of ice temperature change is of great value for ensuring the safety of ice transportation, ice buildings, and tourism. The change of ice temperature is directly affected by the ice temperature change rate. The influence of different ice temperature conditions on the change of ice temperature can be varied, which makes it more difficult to predict the law of ice temperature change. The current ice temperature change prediction method needs more than 1 minute to predict, and it is impossible to monitor the ice temperature accurately in real time. Kanas Lake is a famous freshwater lake in the north of Burqin County, Altay Prefecture, Xinjiang, China. It has a large area and a long ice age and is strongly eroded by glaciers. The surface of ice and stones block the valley and form the lake. Therefore, it is a typical sample to study the law of ice temperature change. A method for predicting the changes of Kanas Lake ice temperature under global warming was designed through this study. Kanas Lake ice temperature data was first collected. The relevant elements that might affect the lake surface ice temperature were then analyzed. The Kanas Lake ice temperature change law under global warming was finally concluded followed by the development of the global prediction method of Kanas Lake ice temperature change under the background of warming. The experimental results showed that the prediction times of ice temperature change prediction methods based on GA-SELM algorithm, EMD-IGA-SELM algorithm, and designed method from this study were different under different working conditions. However, the prediction time of designed method was always shorter than that of the experimental comparison methods, which confirmed that the prediction time of designed method for the change of ice temperature in Kanas Lake under global warming was the shortest one. The maximum prediction accuracy of the ice temperature change prediction method based on the algorithms of GA-SELM and EMD-IGA-SELM were 89.56% and 83.13%, respectively, while the maximum prediction accuracy of designed method was 98.65%, which indicated that the designed method was effective and could accurately and quickly predict the ice temperature change in Kanas Lake.

Keywords: global warming; ice temperature change; regular prediction; ice temperature rise; ice temperature drop.

***Corresponding author:** Yukun You, School of Economics and Management, Yantai Institute of Technology, Yantai 264005, Shandong, China. Email: youyukun2021@163.com.

Introduction

Due to the continuous accumulation of greenhouse effect, the energy absorbed and emitted by the earth atmosphere system is unbalanced. The energy is continuously accumulated in the earth atmosphere system, leading to ice temperature rise and global warming. In the case of global warming, the ice temperature in the area where the lake is located will increase, so the ice temperature of the lake ice layer will change to some extent. The dynamic change of ice and snow environment is closely related to the global climate. The processes of water vapor exchange, energy transfer, circulation, and biological activities all have a decisive impact on the change of ice temperature. Therefore, it can be said that the dynamic change of ice temperature is an intuitive indicator to respond to and reflect climate change. The rise of ice temperature will affect the stability of the environment of ice floe and its biochemical characteristics. The study of ice temperature change plays an important role in studying regional and global climate and environmental changes. In the past hundred years, the rapid increase of population as well as the increase of greenhouse gas emissions have led to the general rise of global ice temperature. People from all walks of life have paid attention to the impact of climate change on human beings and environment. Under the background of global warming, the ice layer of Kanas Lake is affected to some extent too. Kanas Lake, known as a national AAAAA tourist attraction, national geo-park, national forest park, China nature reserve, national natural heritage, national low-carbon tourism experimental area, and the most beautiful lake in China, is located in the north of Burjin County, Altay area, Xinjiang Uygur Autonomous Region, China. The lake water comes from the ice melting water and local precipitation of Kuitun, Youyi peak, and other mountains. The lake is 1,374 meters above the sea level with an area of 4,573 km^2. The deepest elevation of the lake is 1,181.5 meters with a depth of 188.5 meters and a storage capacity of 5.38 billion cubic meters. As the deepest moraine barrier lake in China, it is in the mountains and forests of Altay. Because of the high sensitivity of the ice layer of Kanas Lake to the climate and the important feedback function, the alpine lake and inland freshwater lake have attracted more and more attention. In all environmental systems affected by climate change, ice is the first to bear the brunt. It is also the most direct and sensitive part to climate change because it is the fastest, most important, and most iconic part of the world. So, the ice temperature is predicted to obtain the information for local climate change. Kanas Lake is in the deep inland, which is less affected by the sea, and belongs to a typical temperate continental climate with long cold period due to high latitude. The annual precipitation of the lake is small. However, the winter snow covering period is long. In addition to precipitation, the lake water mainly comes from glacial melt water. Because Kanas Lake is the most typical moraine dammed lake formed by Quaternary glaciation, studying the change of lake water ice temperature in Kanas Lake has a parallel reference role in studying the regional heat exchange and even the impact of glaciers on the global climate.

The traditional methods of prediction of vertical water ice temperature in lakes or reservoirs include the hybrid finite analysis method, the one-dimensional WRE model from American Water Resources Engineering Company, and the MIT model from Massachusetts Institute of Technology for ice temperature change in deep layered aquifers. More and more experts and scholars have begun to engage in research on lake surface ice temperature prediction. Shi, *et al*. studied the water ice temperature prediction method based on genetic algorithm-sequential extreme learning machine (GA-SELM) algorithm and the water ice temperature prediction method based on empirical mode decomposition-improved genetic algorithm-sequential extreme learning machine (EMD-IGA-SELM) [1, 2]. The GA-SELM method uses the weather index to correct the abnormal data collected in the wireless sensor network, and then, uses Pearson correlation analysis to study the relationship between the impact factor and the water ice temperature. The Softplus function is used as the activation function of extreme learning machine (ELM), and the GA algorithm is used to obtain the best initial weights and offsets of ELM to predict the water ice temperature of the lake. The EMD-IGA-SELM method mainly improves the GA-SELM method through empirical mode decomposition (EMD). Tests have proved that the two methods can predict the water ice temperature of the lake, and then analyze the local climate change. Both methods are used to predict the water ice temperature of the lake surface. In the process of predicting the ice temperature, the prediction time is long. There is an unstable phenomenon, which makes the accurate prediction of the ice temperature unable to be achieved. Therefore, the objective of this study was to design a method to predict the change of Kanas Lake ice temperature under global warming. The principles of this designed study were based on that the earth's energy budget was relatively balanced in a period, and the total radiation intensity of minor factors and uncertain factors could be obtained according to the total radiation of major factors in this period because the total radiation was constant during the whole study period

Materials and methods

Data collection from Kanas Lake

(1) Ice temperature data collection

In order to find out the characteristics and rules of the ice temperature data of Kanas Lake more effectively, time series analysis method was used to collect and preprocess the data. After the stationarity test and pure randomness test, the sequence was divided into different types and analyzed by different analysis methods. Data preprocessing formula was as follow:

$$A = \frac{S}{C} / d \tag{1}$$

where *C*, *S*, and *d* represented random test parameters, different types of sequence data, and data preprocessing parameters, respectively.

According to the theory of time-series teaching materials, the characteristics, variance, and mean of stationary time series were fixed. If a set of sequences was stable, the ice temperature change data would always fluctuate around a constant random. The fluctuation range in the up and down directions was limited, and at the same time, it could not show a certain trend or periodicity [3-5]. Before fitting the sequence, both sequence stability and authenticity (*i.e.*, white noise sequence) should be judged. A purely random sequence is one in which the correlation coefficient of the sequence values is zero. The sequence varies randomly over time, and the values that follow the sequence have no effect on the values that precede it. If the sequence was judged to have pure randomness by test, there was no need for further study. Therefore, after determining that the ice temperature change data sequence was a stable sequence, it did not mean that the sequence would meet the requirements of the study, and still needed to be analyzed. Finally, the key test was pure randomness test, which only passed the order of pure randomness test in order to simulate the series of ice temperature changes. The pure randomness of the series was tested by q-statistics. The test formula was:

$$F = G / H + \frac{b}{v} \tag{2}$$

where *G*, *H*, *v*, and *b* represented the difference sequence, the pure randomness test parameter, the non-white noise sequence, and the fitting parameter, respectively.

After preprocessing the collected observation value series, whether the series were stationary and non-white noise were determined to model the series. Model recognition is a key step in modeling. The type of recognition model is judged by the properties of sample autocorrelation coefficient and sample partial autocorrelation coefficient in time series analysis. Therefore, the characteristics of autocorrelation coefficient and partial autocorrelation coefficient of ice temperature change were found out from the sequence autocorrelation diagram after differential operation. The calculation formula was as follow:

$$Q = c / E\left(z + a\right) \tag{3}$$

where *c*, *E*, *z*, and *a* represented the autocorrelation coefficient of the sequence, the most of the sample correlation information in the

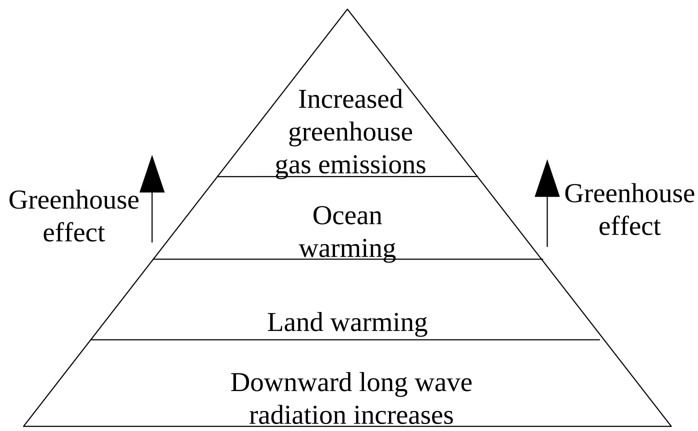

Figure 1. Dynamic mechanism of global warming caused by human activities.

sequence, the random error term, and the delay operator, respectively.

(2) Regression model construction

After investigating the significance of observation trend and the simulation trend as well as the observation consistency of the model under different conditions, the detection and attribution would be carried out. On this basis, a multivariate linear regression model was established to quantitatively analyze the contribution of different forcing signals to the long-term trend of observed ice temperature. To this end, the following regression model was established:

$$R(t) = u / i + q(m) \quad (4)$$

where *u*, *i*, *q*, and *m* represented the time series of observed ice temperature, the time series of ice temperature fluctuation caused by human activity, the error relative to the fitting result as the part of natural variability in the observation, and the scaling ratio of the simulated response trend of different external forcing signals to the actual observed trend.

The dynamic mechanism of ice temperature change caused by human activity is shown in Figure 1 [6-9]. The average temperature or reinforcement learning data set (RLDS) of 27 years from the first year of the experimental output of each model was taken as an estimated sample. There were 450 estimated samples on the ice temperature change. For each sample, about 450 surface ice temperature results were obtained, and then, the above samples were grouped according to different patterns. The mean of each group was leveled. The standard deviation was calculated based on the 450 adjustment values, which was regarded as the estimation of 27-year long-term trend standard deviation of climate variables in natural fluctuation. t-test was conducted to examine the significance of the results. The significance of observation trend was judged by one-sided test with 95% confidence.

For the large sample average, only significant grid points (5% or 10%) in the world will show significant trends or differences due to the random process. However, for a specific sample, due to the spatial consistency and slow change characteristics of humidity variables, there may be more grid points in the world because of the significant trend or difference of random process. Therefore, in order to investigate whether the global distribution of the trend of a field can be explained by the natural rate of change, the field significance test or field consistency test on 95% confidence was carried out. For the field significance test, each sample was taken according to the method of one-sided test, and the percentage of grid points that showed significance on 95% confidence was counted. The process was repeated for each control sample to obtain a set of percentages. The mean and standard deviation of the percentage were calculated to determine the upper critical value. In statistics, maximum likelihood estimation (MLE) is a method to estimate the parameters of statistical model under given ice temperature change data. The model parameters were assumed to be unknown, but the values were determined. Through reasonable model hypothesis, the parameter value corresponding to the maximum probability of event occurrence in the given data set was obtained. The linear model could be expressed as follow:

$$H = \frac{N}{C} + K \tag{5}$$

where *C*, *N*, and *K* represented the noise data that was assumed to obey the normal distribution, the probability density of each data point, and the joint density function of all data points, respectively.

(3) Judgment of model goodness of fit

The goodness of fit of this model was judged by the following two aspects which included the maximum likelihood function that was widely used to determine the optimal model and the number of parameters used in the fitting model. Generally, the fitting effect of the model is directly proportional to the value of the likelihood function. The larger the value of the likelihood function is, the better the model fitting is. The number of parameters in the model is also proportional to the fitting effect. More parameters means that there are many independent variables in the model. The more accurate the model, the better the fitting effect and the higher the accuracy. However, too many independent variables will also bring more complex factors to the estimation of the model, which will cause unnecessary correlation between the variables. The criterion is to consider the goodness of fit of the model and the comprehensive optimal configuration of the number of unknown parameters. Although the points used to express the ice temperature data could completely fall on the observation curve under ideal conditions, the actual observation data could not completely obey the law. They always scattered around the curve indicating that, in addition to the potential evapotranspiration and precipitation conditions, other factors also affected the water balance of the basin, and jointly controlled the ice temperature change under the comprehensive effect of multiple factors. As a result, all data points were independently and identically distributed. Therefore, the joint density function could be expressed as:

$$l = c / U + I \tag{6}$$

where *c*, *U*, and *I* represented the maximum likelihood function, the joint density function, and the maximum likelihood function, respectively. In addition, the contribution of the conditions to the observed ice temperature trend could be obtained through multiplying the observed ice temperature trend by the regression coefficient of the specified conditions. Through multiplying the confidence interval of the observed ice temperature trend by the regression coefficient, the estimated interval of the signal contribution under the specific confidence could be obtained, so as to complete the collection and preprocessing of ice temperature data.

Prediction of ice temperature change in Kanas Lake under global warming

(1) Sample data clustering based on K-means clustering

The purpose of K-means clustering is to classify n observation points into K clusters, and each observation point belongs to the cluster closest to the average value of each single cluster. Tyson polygon method is used to divide data space into multiple clusters. In general, K-means clustering method adopts the Euclidean metric, but for the convenience of calculation, it usually makes equivalent substitution to the Euclidean metric formula. The algorithm process applied in this study was as follows:

Step 1: selecting k data sample points from the input data set as the initial clustering center.

Step 2: calculating the metric values from all data points in the sample data to each cluster center. Based on the principle of minimization, the data points belonged to the cluster where the minimum metric lied.

Step 3: according to the classification results of ice temperature change sample data, recalculate each cluster center. The calculation formula was:

$$g = j / p * b \tag{7}$$

where *j*, *p*, and *b* represented air ice temperature data, data clustering factor, and data classification parameter, respectively.

(2) Influencing factors

The factors influencing the prediction of ice temperature change were identified based on the ice layer structure (Figure 2), which included thermal radiation, emissivity of blackbody radiation, and the average ice temperature of the earth's surface. Thermal radiation refers to that any object, as long as the ice temperature is not absolute zero, radiates various electromagnetic waves of different wavelengths at any other ice. The total energy radiated, and the distribution of energy are related to the ice temperature of the object. This radiation is known as thermal radiation and can cause ice temperature changes. Blackbody radiation and emissivity refer to the fact that the incident electromagnetic waves are all absorbed, neither reflected nor transmitted, and the blackbody itself still radiates outwards. Obviously, there is no real blackbody in nature. The ratio of the radiated energy to the absorbed energy is independent of the physical properties of the object itself, but only related to the wavelength and ice temperature. For the average ice temperature of the earth's surface, any object will radiate a certain amount of energy through a specific wavelength according to its own ice temperature. Since the earth is surrounded by the atmosphere, and has the mediation of the ocean, the earth's surface will not vary greatly in ice temperature due to the difference of day and night, seasons, and latitude. At the same time, the sun is the fundamental source of all energy in the climate system. Because of the existence of river dams, the flow speed of most ice layers gradually slows down, and there is basically no water turbulence. Since the density of water body is closely related to the water ice temperature, the ice temperature gradient formed by the deep reservoir water body from the bottom to the surface of the reservoir will inhibit the convection. The ice temperature performance of the reservoir water body in the horizontal plane is similar. In terms of vertical structure of water body, the water ice temperature of most reservoirs is stratified. The deeper the reservoir is, the more obvious the performance is. The water body of the reservoir exchanges heat with the external boundary due to the environmental factors such as the ice temperature of the water coming from the upstream of the reservoir, the surface ice temperature of the water body of the reservoir, solar radiation, wind wave shear, vertical circulation, vertical convection, bed rock ice temperature and so on. This kind of heat exchange results in different vertical ice temperature performance of the water ice temperature of the reservoir in front of the dam. The water ice temperature of the reservoir in front of the dam can be calculated according to its ice temperature vertical distribution. There are three types of differences: (1) mixed-type water ice temperature; (2) stratified-type water ice temperature; (3) transition-type water ice temperature. The transition-type water ice temperature combines the characteristics of the former two, with some differences. The mixed type is generally found in small reservoirs, and there is no obvious stratified water ice temperature structure in the vertical direction of the water body. Stable stratified water ice temperature stratification is the most obvious phenomenon, which is the characteristic of general ice layer.

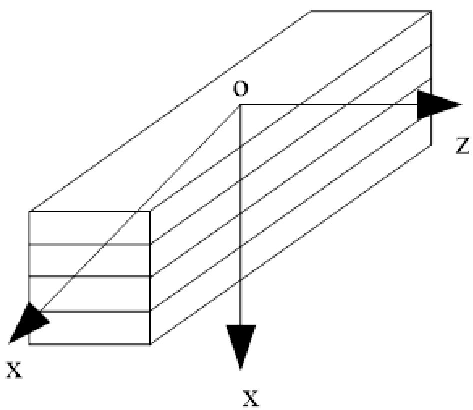

Figure 2. Stratification of ice structure.

(3) Prediction of ice temperature change

This study took stable stratified ice layer as the main research object to introduce the ice layer ice temperature stratification discrimination method and analyzed the ice layer ice temperature prediction method. Generally, empirical formula method, runoff storage ratio index method, and density Froude number method were used to distinguish ice temperature stratification. The index method of runoff storage ratio was as follow:

$$O = \frac{M}{J} \tag{8}$$

where *J*, *M*, and *O* represented the average runoff, the total reservoir capacity, and the inflow flood, respectively. In the case of mixed-type ice layer, the water ice temperature distribution in the vertical structure of the ice layer is relatively uniform, and there is obvious seasonality in a year. The annual change range of the water ice temperature in the bottom of the ice layer is large, and the main heat source of the mixed ice layer is solar radiation. The water ice temperature changes with the surface ice temperature of the reservoir water, and there is relatively obvious circulation flow between the water bodies. When the ice layer is stratified with stable water ice temperature, in summer, the surface ice temperature of the ice layer is affected by the solar radiation and will greatly exceed the ice temperature of the deep-water body. The water ice temperature gradient of the ice layer will increase, and the ice temperature of the ice layer will be stratified vertically with the most obvious characteristics. However, the deep-water body has a depth of up to 80 m. The following water bodies will form a relatively stable low-ice temperature water layer due to the small impact of seasonal ice temperature change and the sinking of low-ice temperature water bodies with high density. The surface ice temperature layer is affected by upstream water, wind wave shear, vertical circulation, vertical convection and solar radiation, and directly contacts with the air, which will cause the rise of water ice temperature, the heat exchange with adjacent water layers, and gradually transferring the heat to the next layer; the mixed variable ice temperature layer is located between the surface ice temperature layer and the stable low-ice temperature water layer, and the water ice temperature is higher near the surface ice temperature layer and near the stable low-ice temperature water layer. The ice temperature gradient of the mixed variable ice temperature layer is large because of the low ice temperature water layer; the water ice temperature of the stable low ice temperature water layer is relatively stable and uniform, and the ice temperature is also the lowest. Based on the above calculation and ignoring other aspects of climate change and based on the balance principle in hydrology, if the ice temperature continues to rise, the amount of ice melting will be greater than the amount of ice accumulation in the early stage of ice temperature rise. At this point, the material balance is negative, the ice runoff continues to increase, and the increased runoff can be called ice recession runoff. At the same time, the ice begins to shrink, the area decreases gradually. It is impossible for the ice runoff to increase infinitely with the rise of ice temperature. When the ice runoff increases to a certain value, the ice runoff will decrease as the accumulated loss of ice reserves is large and the absolute amount of ice area reduction is reduced. At the same time, when the ice layer is gone, the ice reserve of the ice layer is often not equal to zero, and sometimes the price is relatively large. This is because when the ice layer is cataloged, the ice reserve is estimated by the ice layer area. When the ice reserves are estimated using the ice area, the empirical formula used by the large ice layer and the small ice layer is not uniform, so the prediction results of the ice reserve are contradictory. However, this does not affect the prediction of ice runoff because, in the prediction process, the magnitude of ice runoff is only related to the change of ablation intensity and ice area. In this process, when the ice runoff returns to the initial state, that is, the retreat area expression of that ice runoff that is equal to the initial ice runoff as follow [10-15]:

$$k = \frac{u}{\eta} - E \tag{9}$$

where *η*, *μ*, and *E* represented runoff depth, material balance ratio of ice layer, and recession runoff, respectively.

The differential equation of heat conduction could be established as follow:

$$R = \frac{O}{L} / D \tag{10}$$

where *L*, *O*, and *D* represented the coefficient of thermal conductivity, the specific heat capacity, and the density of the object, respectively. Since the above equation was implicit, iterative calculation must be carried out. According to the ice temperature field at the last moment, the ice temperature field could be obtained by solving the ice temperature difference equation and the simultaneous flow equation at each point. Based on the above process, the law of ice temperature change of Kanas Lake ice layer under global warming was predicted.

Layout of measuring points

Five experiments were conducted by arranging five measuring points. The arrangement relationship of the measuring points was shown in Figure 3. A total of 5 measuring points were set with each of them as the central point of each experiment. By collecting the basic parameters of measuring points, the spacing between them was reasonably selected and the model was set. The results of three ice temperature change prediction methods including the designed method for this study, GA-SELM algorithm based method, and EMD-IGA-SELM based method were statistically analyzed to verify the accuracy of the three methods.

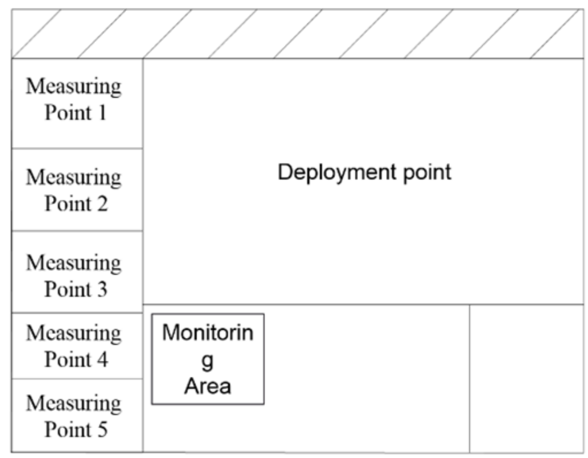

Figure 3. Simulated environment and layout of measuring points.

Different test conditions

Assuming that the ice layer of a river was 0.5 m thick, the ice layer ice temperature rise could be divided into three conditions. The first condition assumed that the initial ice temperature of the ice layer was linearly distributed, in which the external ice temperature was -10°C, and the ice temperature rises from -10°C to -5°C evenly within 2 h (Figure 4). The second condition assumed that the external ice temperature was -10°C, and the ice temperature raised from -10°C to -5°C uniformly within 4 hours (Figure 4). The condition 3 assumed that the initial ice temperature of ice layer was non-linear distribution, in which the external ice temperature was kept at -5°C for 4 hours (Figure

4). The experiment was carried out under the above three conditions, and the ice temperature change law of Kanas Lake under the global warming was predicted by different prediction methods. In order to ensure the accuracy of the experiment, the ice temperature change prediction method based on GA-SELM algorithm and the ice temperature change prediction method based on EMD-IGA-SELM were compared with the design method. The prediction time under the three working conditions was also compared.

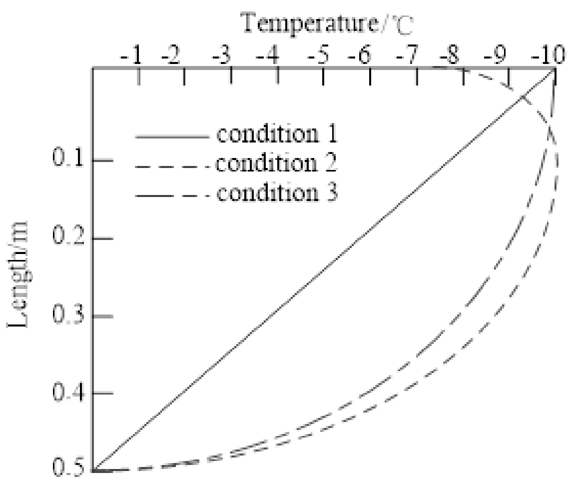

Figure 4. Distribution of initial temperature field.

Results and discussion

Comparison of prediction results of ice temperature variation under condition 1

The comparison of prediction results of proposed prediction method and the traditional prediction methods were shown in Figure 5. Further analysis showed that with the change of the external ice temperature, the internal ice temperature field of the ice layer was also changed, which would increase the prediction time of the ice layer ice temperature change rule. The prediction time of the method in this study was short and less than 1 minute, while the other two methods were from 1 to 3 minutes. The comparison results showed that the prediction method designed in this study was less affected by this factor and the prediction time was short. It required less forecasting time than the other two traditional methods.

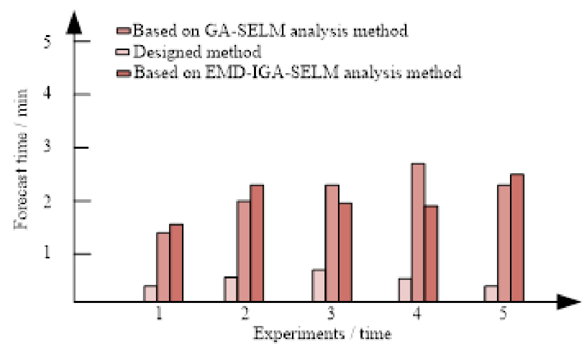

Figure 5. Comparison of prediction results of ice temperature variation under condition 1.

Comparison of prediction results of ice temperature variation under condition 2

Figure 6 showed the comparison of the prediction results of the designed method and two traditional prediction methods. The external ice temperature changed significantly under the condition 2. The prediction time of the designed method was controlled within 2 minutes, while the prediction times of the two traditional ice temperature change prediction methods were significantly increased to 2-5 minutes, which indicated that the designed method was less affected by the condition and took less time than that of traditional methods.

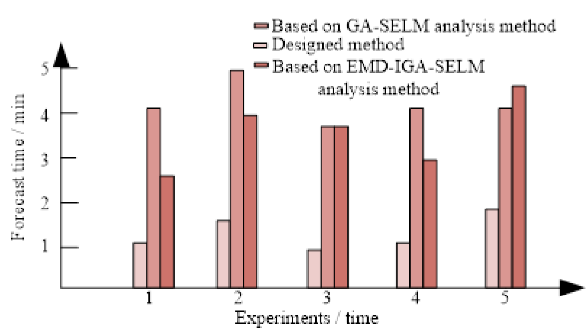

Figure 6. Comparison of prediction results of ice temperature variation under condition 2.

Comparison of prediction results of ice temperature variation under condition 3

The results of the three prediction methods of ice temperature change law were shown in Figure 7. The designed method demonstrated the predict time in 0-2 minutes, while the other two traditional methods were between 2-5 minutes. The forecast time of designed method was still shorter than that of the traditional methods. The reducing of the prediction time in designed method might be attributed to the points data preprocessing and the related data clustering. Therefore, it was proved that the designed prediction method was better than the other two traditional prediction methods.

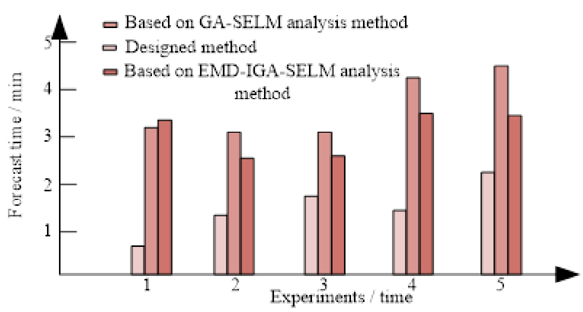

Figure 7. Comparison of prediction results of ice temperature variation under condition 3.

The prediction accuracy of the three methods for the change of ice temperature in Kanas Lake was compared in Table 1. The results showed that the maximum and minimum precision of the prediction of the ice temperature change in Kanas Lake based on the GA-SELM algorithm were 89.56% and 81.47%, respectively, while the EMD-IGA-SELM algorithm were 83.13% and 75.96%, respectively. However, the maximum precision of the method in designed method was 98.65%, and the minimum precision is 94.75%, which were the highest among the three methods. The results demonstrated that the designed method had the highest precision of the prediction of the ice temperature change in Kanas Lake.

The methods on the prediction of ice temperature have been developed in recent years. The GA-SELM based method established the index system of ice temperature change, which mainly extracted operational and quantitative indexes from the internal and external factors of the two main factors that affected ice change, and a more targeted and quantitative index system by cluster analysis, principal component analysis, and other methods. Only more accurate quantitative research can effectively improve the accuracy of the model. The EMD-IGA-SELM based method established the index system of ice system division through field investigation in some typical areas. This part of the work was not only difficult, but also needed greater human power, material, and financial investment. This was a remarkable work of ice temperature change prediction method from theory to practice. At present, this work is still needed to be implemented. The improvement of the prediction method of ice temperature change has always been a focus of the research groups. Although it has been expanded from the original simple prediction under the assumption of linear warming scenario to the prediction under the complex climate change scenario, and even the prediction under the cooling scenario, the precision is still a key point of later research. The method designed in this study was the comprehensive improvement one. The visualization of the prediction results of ice temperature changes under the climate change scenario is combined with GIS technology. The results showed that the prediction time of this designed method was between 1 and 2 minutes, which was better than the other two traditional methods and had better performance. It was worth popularizing and further studying.

References

1. Shi P, Yuan Y, Kuang L, Li G, Zhang H. 2018. EMD-IGA-SELM-based pond culture water temperature prediction method. Trans Chin Soc Agric Mach. 49(11):312-319.
2. Shi P, Yuan Y, Kuang L, Zhang H, Li G. 2018. Research on water temperature prediction method of factory aquaculture based

on GA-SELM algorithm. J Sens Technol. 31(10):1592-1597, 1612.

3. Balasbaneh AT, Marsono AKB. 2018. New residential construction building and composite post and beam structure toward global warming mitigation. Environ Prog Sustainable Energy. 37(4):1394-1402.
4. Andric I, Fournier J, Lacarriere B, Le Corre O, Ferrao P. 2018. The impact of global warming and building renovation measures on district heating system techno-economic parameters. Energy. 150(1):926-937.
5. Li H, Chen H, Wang H, Yu E. 2018. Future precipitation changes over china under 1.5°C and 2.0°C global warming targets by using CORDEX regional climate models. Sci Total Environ. 640(1):543-554.
6. Zheng XT, Hui C, Yeh SW. 2018. Response of ENSO amplitude to global warming in CESM large ensemble: Uncertainty due to internal variability. Clim Dyn. 50(12):4019-4035.
7. Wang Y, He C, Li T. 2020. Impact of global warming on western north pacific circulation anomaly during developing El Niño. J Clim. 33(6):2333-2349.
8. Kiat Y, Vortman Y, Sapir N. 2019. Feather moult and bird appearance are correlated with global warming over the last 200 years. Nat Commun. 10(2019):1-7.
9. Scheschonk L, Becker S, Hehemann JH, Diehl N, Karsten U, Bischof K. 2019. Arctic kelp eco-physiology during the polar night in the face of global warming: A crucial role for laminarin. Mar Ecol Prog Ser. 611(14):59-74.
10. Whitehorn J, Yacoub S. 2019. Global warming and arboviral infections. Clin Med. 19(2):149-152.
11. Wei Y, Yu H, Huang J, Zhou T, Zhang M, Ren Y. 2019. Drylands climate response to transient and stabilized 2°C and 1.5°C global warming targets. Clim Dyn. 53(3-4):2375-2389.
12. Levine XJ, Boos WR. 2019. Sensitivity of subtropical stationary circulations to global warming in climate models: A baroclinic Rossby gyre theory. Clim Dyn. 52(7-8):4873-4890.
13. Chen Y, Zhai P, Zhou B. 2018. Detectable impacts of the past half-degree global warming on summertime hot extremes in china. Geophys Res Lett. 45(14):7130-7139.
14. Tollefson J. 2018. IPCC says limiting global warming to 1.5°C will require drastic action. Nat. 562(7726):172-173.
15. Lee S, Min SK. 2018. Heat stress changes over East Asia under 1.5°C and 2°C global warming target. J Clim. 31(7):2819-2831.