Comparing interpolation techniques for annual temperature mapping across Xinjiang region

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Abstract. Interpolating climatic variables such as temperature is challenging due to the highly variable nature of meteorological processes and the difficulty in establishing a representative network of stations. In this paper, based on the monthly temperature data which obtained from the 154 official meteorological stations in the Xinjiang region and surrounding areas, we compared five spatial interpolation techniques: Inverse distance weighting (IDW), Ordinary kriging, Cokriging, thin-plate smoothing splines (ANUSPLIN) and Empirical Bayesian kriging (EBK). Error metrics were used to validate interpolations against independent data. Results indicated that, the ANUSPLIN performed best than the other four interpolation methods.

1. Introduction
Climate variables provide an essential input in global environmental change [1]. Prediction of the impacts of a changing climate on the distribution and functioning of terrestrial ecosystems requires as a first step, the development of reliable, spatially-explicit models of current climate [2]. The development of methods to interpolate climatic data from sparse networks of stations has been a focus of researchers [3-6]. There are several commonly used interpolation methods, such as Inverse distance weighting (IDW), Ordinary kriging, spline-method, etc.[7,8], yet it is critical to choose the optimal interpolation method, due to the variations of used data and the different characters of research areas [9]. Hence, comparative studies have been conducted to determine which method of spatial interpolation is best suited for different contexts, but as of yet, no decisive conclusions have been made [10]. It is important to continue research in this direction in order to gain a better understanding of proper applications of these interpolation techniques [11, 12].

As a typical arid and semi-arid region, there are only 66 meteorological stations in Xinjiang within the scope of 160 * 104 km² area, and most stations are distributed within the oasis and unevenly distributed. In actual work, using the meteorological stations data of surrounding areas as an auxiliary data for climatic variations interpolation are considered to be a good solution [13].

In this paper, based on the 66 meteorological stations monthly temperature data and 88 surrounding areas, such as Gansu and Qinghai meteorological station as auxiliary data, we investigate the integration of additional sources of data for comparison of five interpolation methods: IDW, Ordinary
kriging, Cokriging, ANUSPLIN and EBK, and validate the interpolation results against independent data. In order to provide a basis for climatic data interpolations in this region and other similar areas.

2. Data sources and methods

2.1. Data sources
The monthly temperature data used in this study were obtained from the 154 official meteorological stations in the Xinjiang region and surrounding areas, among them, the domestic meteorological stations data were acquired from the website of China meteorological science data sharing service (http://cdc.cma.gov.cn/), the meteorological data of outside china were acquired from the US meteorological data sharing website of NOAA (http://www.ncdc.noaa.gov/ghcnm/v3.php). For minimize the edge effect of interpolation, the scope of experimental area was set to be larger than Xinjiang administrational border, approximately cover the area of 70.7-99.20 E and 31.3-51.40 N (Figure 1).

The Digital Elevation Model (SRTM-DEM) data covering the study area with a resolution of 90 m, was received from the website (http://srtm.csi.cgiar.org/),The data was geo-referenced to the Universal Transverse Mercator (UTM) coordinate system, Zone 45 North with World Geodetic System Datum of 1984 (WGS84).

2.2. Interpolation methods
Usually Interpolation techniques predict the variable of interest at a specific location by taking known values from the surrounding region into account, and using them to estimate the value at a location where it is unknown. While all of these different types of methods present viable options for interpolation, we only compared five methods. These were chosen based on a number of factors, including computational complexity, ease of implementation, the capabilities of the software being utilized and a thorough review of recent literature. Given these criteria, Inverse distance weighting (IDW), Ordinary kriging, Cokriging, thin -plate smoothing splines (ANUSPLIN) and Empirical Bayesian kriging(EBK) were chosen as the appropriate spatial interpolation techniques.

Figure 1. Distribution of meteorological stations in Xinjiang and surrounding areas
2.3. Model evaluation and accuracy assessment

According to the study areas and its current conditions, we choose 15 meteorological stations as validation sites. We assessed the performance accuracy of different interpolation procedures based on the magnitude and distribution of errors between observed and model-predicted values using a series of statistical measures: Mean Absolute Error (MAE), Mean Relative Error (MRE) and Root Mean Squared Error (RMSE). These measures were calculated using the following equations:

\[
MAE = \frac{1}{n} \sum_{i=1}^{n} |Z_{oi} - Z_{ei}|
\]

(1)

\[
MRE = \frac{1}{n} \sum_{i=1}^{n} \frac{Z_{ei} - Z_{oi}}{Z_{oi}}
\]

(2)

\[
RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (Z_{ei} - Z_{oi})^2}
\]

(3)

Where \(Z_{oi}\) and \(Z_{ei}\) represent the observed and model-predicted values of temperature, \(n\) represent the number of stations.

3. Results and discussion

After interpolating the time series temperature data, we compared the results of 5 interpolation methods in two ways. At first we compared the interpolation results with independent data using the MAE, MRE and RMSE as a criterion. Secondly, the interpolation results are compared on the basis of temperature distribution pattern in Xinjiang. Figure 2 shows the Comparison results of cross-validation MAE, MRE and RMSE for monthly mean temperature during 10 years across all stations. The MAE value for annual average temperature are ranged differently: ANUSPLIN < COK < EBP < OK < IDW, their values were 2.17mm, 3.11mm, 3.43mm, 3.73mm, 3.74mm respectively. The ANUSPLIN also has the smallest MRE (0.45) and RMSE (2.1mm) values in comparison to other methods, the Cokriging interpolation method has highest RMSE value of 2.69mm. Above all, AUNSPLIN produced the lowest errors when evaluated by all three error metrics (MAE, MRE, RMSE). It can be seen that AUNSPLIN interpolation works best in Xinjiang region.
Figure 2. Comparing analysis of cross-validation MAE, MRE and RMSE for monthly mean temperature during 10 years across all stations for the six interpolation methods.

Even though the interpolation was carried out from 1995-2004, we only selected the interpolation results of average temperature in January 2000 and July 2000. Figure 3 shows the spatial distribution map of interpolation results from 5 methods in January 2000. IDW, EBK and Kriging interpolation results are consistent in spatial distribution, but have certain difference in the maximum and the minimum temperature value. For the Cokriging interpolation method, the lowest temperature are mainly distributed in northern Xinjiang and Hami areas, the temperature is mainly in the range of -21.8~0°C. For the ANUSPLIN interpolation method, the highest temperature is located in the Tarim basin, the lowest temperature in the Altai Mountain and high altitude area of Tianshan Mountain, the temperature decreases with the rise of altitude, and the temperature range in -31.5~ -1.3 °C.

![Spatial distribution maps for January 2000](image)

**Fig 3.** The spatial distribution map of monthly mean temperature on January in Xinjiang.

Figure 4 shows the spatial distribution map of interpolation results from 5 methods in July 2000. The spatial distribution of temperature from the IDW, EBK, Kriging, Cokriging and ANUSPLIN interpolation results are consistent, the Tarim basin and Junggar basin have highest temperature, but Altai, Tianshan and Kunlun mountains temperature are lower. In the range of temperature there are certain difference between those five region (Tarim basin, Junggar basin, Altai, Tianshan and Kunlun mountains), their temperature ranged from 6.8~32.7°C, 9.9~31.3°C, 13.6~28°C, 14.5~26.9°C and 3.8~31.5 °C respectively. It can be speculated that ANUSPLIN, which was generally found to perform the best than other methods, and the temperature was evidently affected by altitude that consistent with the study areas climate distribution.

![Spatial distribution maps for July 2000](image)
4. Conclusion

This study assessed five different interpolation techniques and their ability to accurately predict monthly mean temperature in Xinjiang. IDW, EBK, Kriging, Cokriging and ANUSPLIN were selected as appropriate methods for interpolating temperature for January to December of 1995 through 2004. Finally, the results were compared of cross-validation MAE, MRE and RMSE for monthly mean temperature during 10 years across all stations. The results shows that, ANUSPLIN interpolation method was found to perform the best in spatial distribution and produced low values from all three error metrics.

Interpolating a climatic variable such as temperature is very much dependent on the settings, thus more methods must be tested in order to determine which methods perform well on a consistent basis, and will be taken into account in future research.

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