International Conference on Spatial Accuracy (2016): Space-Time Kriging of Temperature over Van-Turkey

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Predictions of the variables at points with no measurements are obtained by interpolation techniques. Space-time interpolation techniques that consider variation both in space and time provided a new research area. Temperature is an important climatic parameter varying both in space and time. Like other meteorological, hydrologic and environmental variables, temperature is measured at specific locations. In order to obtain predictions for all grid locations, kriging methods have been applied for a long time. In here, space-time Ordinary kriging (ST-OK) and space-time Universal kriging (ST-UK) have been used in annual temperature estimation over Lake Van Basin using at 13 meteorological station observations for 2001-2011. Elevation, land cover, distance to Van Lake are used as secondary information in ST-UK. Elevation at 500 m resolution are obtained by Nearest Neighbour resampling of 3 arc second Shuttle Radar Topography Mission (SRTM). MOD12Q1 land cover data set has been downloaded from USGS organization. This dataset has 500 m spatial resolution and 17 subclasses. Distance to nearest coast variable is obtained by calculating the Euclidean distances of each SRTM pixel to the nearest boundary of the Van Lake coast vector. Annual temperature values are analysed and predicted at 500m*500 m resolution for 11 year-period. One-fold cross-validation is used to assess accuracy performance of both methods. R-square and Root Mean Square Error (RMSE) are calculated and evaluated for each technique. Comparison of kriging methods and inclusion of secondary information is assessed.

Key words: Space-time kriging, Van Lake Basin, Temperature

Introduction

Spatial kriging methods have been used for many years to predict variables at unmeasured locations in many disciplines. The first geostatistics and spatial kriging applications started in mining and geology. The variables used in these sciences can often be assumed constant in time. After understanding the usefulness and reliability of kriging in these disciplines, it was also introduced to many other disciplines within the earth and environmental sciences, such as meteorology, climatology, agronomy, soil science, hydrology, etc. Generally variables in these sciences vary both in time and space. Therefore the requirement of kriging methods for space-time interpolation is raised (Heuvelink and Griffith, 2010). If the data have been measured in different time and space locations, then more data may be used for prediction, and this allows obtaining more accurate predictions, helps to parameter estimation and helps to define spatial and/or temporal auto-correlation in measurements (Gething et al., 2007). In case of space-time kriging, to predict the value of the variable of interest at a specific location and time, past and

future measurements are used to predict on the specified time. This may add more complexity to the kriging procedure but may help to gain more accurate results.
In this study space-time Universal kriging (ST-UK) method is applied to average annual temperature values measured from 9 meteorological stations from 2001 to 2011 over the Lake Van basin of Turkey. The aim is to discuss applicability of space-time kriging methods on annual temperature values by using limited number of meteorological station.

Study Area and Data
The study area is Lake Van Basin that is located at the Far East part of Turkey (Figure 1). The area of basin is about 16.000 km^2. Lake Van basin has a high topography. The high mountains are located at the northern and southern parts of the basin. The mean elevation of basin is about 2200-2400 m., minimum elevation is about 1500 m. and maximum elevation is approximately 4000 m (Figure 2). Lake Van which is the biggest lake of country is located at the basin (Figure 2). The Lake is a depression state in the middle of high mountains. Lake has a surface of 3574 km^2, length of shoreline is 505 km, and a volume of 607 km^3. The lake stands at 1650 m. above sea level. The Lake is a closed lake without any significant outflow. With a maximum depth of 451 m and a volume of 607 km^3, it ranks fourth in water content among all the closed lakes of the world (Degens et al., 1984).

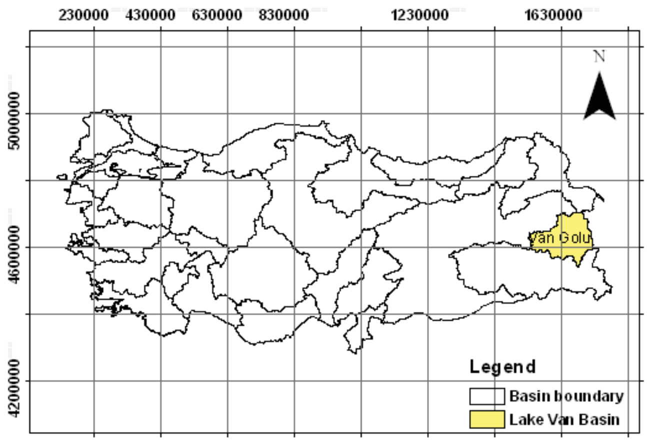

Figure 1: Location of Lake Van Basin on Turkey

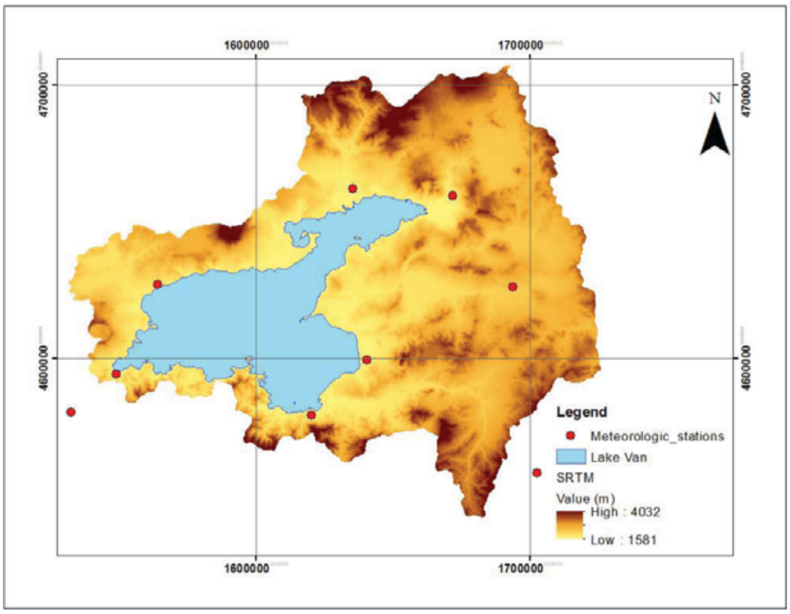

Figure 2: Location of Lake Van Basin on Turkey Lake Van, SRTM (90m) of basin, and distribution of meteorological stations over basin.

Data

The temperature data used in this study were obtained from the Turkish State Meteorological Service. The primary dependent data source was monthly temperature measured at 9 meteorological stations between 2001 and 2011. The spatial distribution of stations is not fairly uniform over the basin; when looking the overall distribution condensed placement can be seen near the Lake boundary (Figure 2). The highest average monthly temperature is between 24-25 ºC and is measured generally at the June. The lowest average monthly temperature is about -17 ºC and is measured at the January and Far East part of basin. It is observed in many studies that secondary information can often improve the spatial interpolation of environmental variables (Bostan et al., 2012; Lloyd, 2005; Hofierka, 2002; Boer, 2001). Therefore, three secondary variables correlated with temperature are selected to improve accuracy of predictions. As independent data source, an elevation map with 500 m spatial resolution was used (Figure 2). It was obtained by resampling the 3 arc second SRTM (the Shuttle Radar Topography Mission) (approximately 90 m spatial resolution) to 500 m spatial resolution. MOD12Q1 land cover data set has been downloaded from USGS organization. This dataset has 500 m spatial resolution and 17 subclasses. Distance to nearest coast variable is obtained by calculating the Euclidean distances of each SRTM pixel to the nearest boundary of the Van Lake coast vector.

Methodology

Annual temperature predictions are made on spatio-temporal framework. Space-time universal kriging (ST-UK) method is used to obtain predictions over the basin. Elevation, distance to nearest Lake Coast and land cover data sets are used as secondary variable. Seperable, productSum, Metric, sumMetric and simpleSumMetric variogram models are applied to sample variogram (Figure 3 and 4).

Space-time Kriging

Consider a variable z which varies in the spatial (s) and time (t) domain. Let z be observed at n space-time points (s_i, t_i), i=1, ..., n. These measurements constitute a space-time network of observations. However it is practically impossible to measure data point z at each spatial and temporal point. In order to obtain a complete space-time coverage, interpolation of z is required. The aim of space-time interpolation is to predict $z(s_0, t_0)$ at an unmeasured point (s_0,

t_0), which is a node of a space-time grid. To predict z at these nodes, it is assumed to be a realization of a random function Z which has a known space-time dependence structure. Next $Z(s_0, t_0)$ is predicted from the observations and using the assumed space-time model (Heuvelink and Griffith, 2010).

The random function Z can be defined with a deterministic trend *m* and a zero-mean stochastic residual *V* as follows (1):

$$Z(s,t) = m(s,t) + V(s,t) \tag{1}$$

The deterministic trend *m* represents large-scale variations whereas the stochastic component *V* represents small-scale variations (Heuvelink and Griffith, 2010).

Results and Discussion

Space-time Universal kriging is performed to dependent variable: annual temperature. Figure 3 and 4 represent the plots of sample and modelled variograms to data. Optimum parameter value of the modelled variograms are used to select the best variogram model (Table 1). In addition, visual interpretation of modelled variograms are considered while selecting the appropriate model. According to these values productSum and sumMetric models resulted minimum and very similar optimum values. Therefore productSum model is selected for kriging operation (Figure 5).

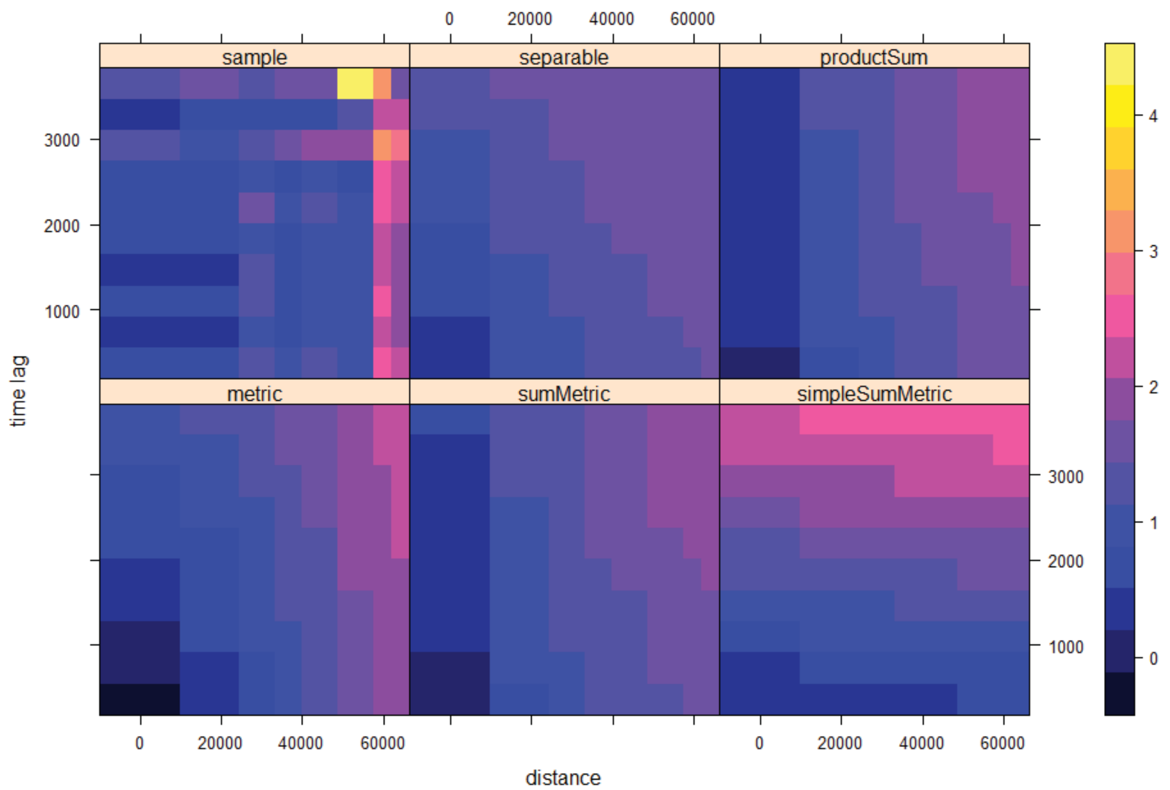

Figure 3: Plot of sample and modelled variogram models

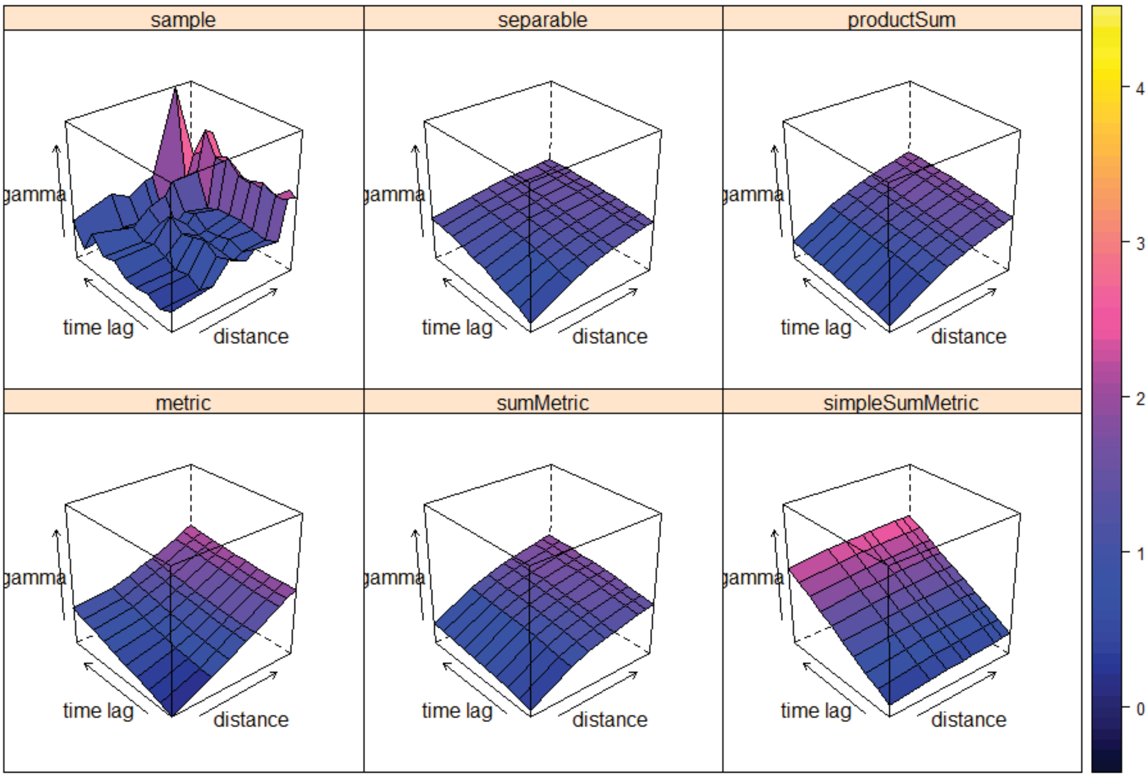

Figure 4: Wireframes of sample and modelled variogram models

Seperable	ProductSum	Metric	SumMetric	SimpleSumMetric
0,62	0,37	0,58	0,36	0,88

Table 1: Optimum Parameter Values of Variograms

Prediction maps of some selected years are represented at Figure 5. According to these maps, it is clearly seen that around the lake, temperature values are higher than the other regions. Around the Lake the area is more flat, after some distances elevation gets higher. So it can be said that distance to lake and elevation are highly correlated with temperature variable.

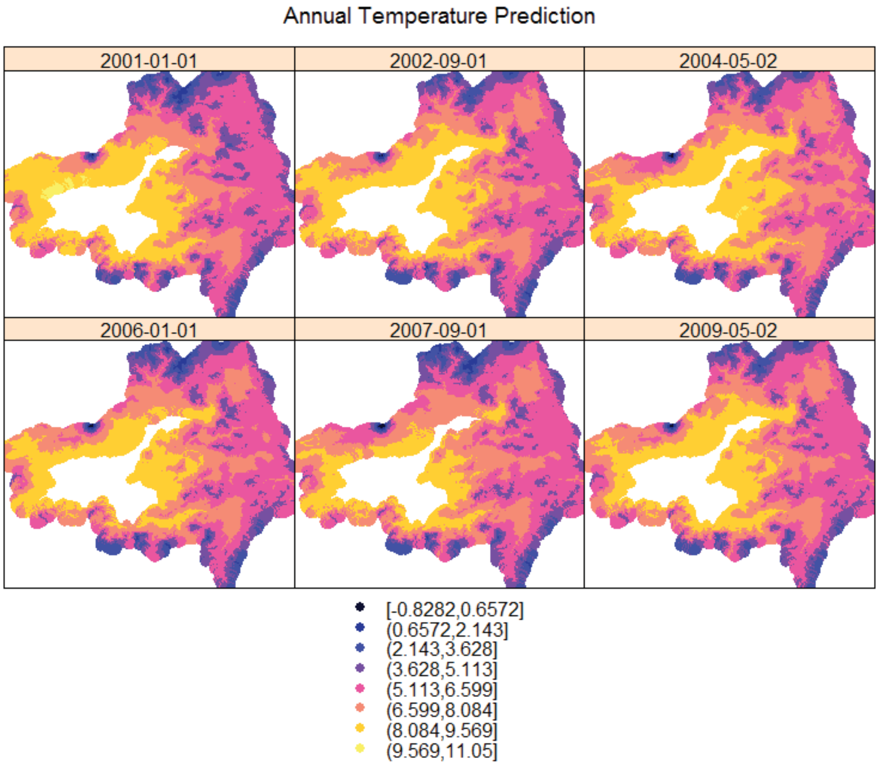

Figure 5: Prediction maps for some observation years

Conclusions

In this study space-time kriging method was applied to predict annual temperature of the Lake Van Basin, Turkey. Measurements obtained from nine meteorological stations were used for 2001-2011 time period. Secondary variables that vary in space but are static in time (elevation and distance to lake) and variable changes in space and time (land cover) were used by the space-time Universal kriging method. ST-UK method resulted with reasonable prediction values at space and time; however prediction values for each time scale are similar to each other. Limited number of observations were used at space-time kriging and gives satisfactory results with regard to spatial and temporal framework. However it is thought that using more dense observations would give more accurate results.

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