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Spatial Correlation between Altitude & other Climatic Variables : A Climatic Model of Kashmir Region using Regression Analysis

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Abstract: *Kashmir has been encountering expanded temperature and change in precipitation system, which may antagonistically influence the significant environments in the nation differentially. In this study a effort has been put forward to deduce a relationship between altitude & other climatic variables such as Annual average temperature, Annual average precipitation, Annual average wind speed, Annual average solar radiation, Annual average max temperature, Annual average min temperature & Annual average vapor pressure.*

The data used for this study was provided by worldclim (version2.0), the spatial resolution of the data was about 1 km².

The large study area & fine spatial resolution produced a vast amount of data points, which were analyzed with a significance level of the tests at 5%. Further for analysis the data was divided into zones categorized according to the elevation zones, this was mainly done to ease the work flow as the observation points were vast and also to reduce the standard error for each of the variables during analysis. Based on the climate data and the DEM (Digital Elevation Model) used for this study we deduced four multiple linear regression equations for four elevation zones, which describe the relationship between altitude & climatic variables. Although deducing a climate model which can precisely define relationship between the climatic variables & altitude is a challenge although an effort has been made to describe the relationship between elevation and climatic variables.

Keywords *: DEM (Digital Elevation Model), WorldClim, Correlation Analysis, Global and Local Spatial Auto correlation Analysis,Principal Component Analysis.*

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I. INTRODUCTION

Elevation is the stature or the rise of a spot, item or point comparable to the ocean level or ground level while climate is the genuine normal state of the weather at such spot for the most part over some undefined time frame as revealed by the temperature, precipitation, wind velocity .

To summarize the thought on how elevation influences the climatic conditions: Altitude or rise is the stature over a given level, as for instance, the ocean level. Atmosphere is the climate conditions in a given zone over an extensive stretch of time.

Typically, the climate of a place relies upon the height of the spot. The gaseous tension and the air temperature decline with rise in altitude. At higher elevations, the air is less thick as the air particles are increasingly spread out and less inclined to impact. Observe that the area in the mountains has genuine lower normal temperatures than one at the base of mountains. As we increment in height or rise, there is real less air above us in this way the weight in actuality diminishes. What's more, as the weight diminishes, the air particles spread out further and the temperature diminishes. In the event that moistness

is at a hundred percent, suppose for instance, since it is snowing, at that point the temperature truly diminishes all the more gradually with stature. In this study there is an effort to put a relationship between elevation & other climatic variables like minimum temperature, maximum temperature, annual precipitation , solar radiation, wind speed, water vapor pressure, annual mean temperature.

A multiple regression model was developed stating the relationship between elevation & other climatic variables as stated above. The climatic model was developed using the climatic mean observations of a time span of 30 years.

II. DATA & METHODS

A. Study Area & Data

Kashmir is located 33.7782° N latitude & 76.5762° E longitude in the top north part of India. The Kashmir & Jammu region is each divided in 10 districts & Ladakh region has 2 districts, however this study is confined only to Kashmir region. The area under investigation is about 16353.87 km² (Figure 1).The climate data used in study is obtained from WorldClim (1) which is a set of global climate layers (gridded climate data) with a spatial resolution of about 1 km² usually used for mapping & spatial modeling.

The DEM (Digital Elevation Model) used in study was derived from ALOS PALSAR (The Phased Array L-band Synthetic Aperture Radar)with a spatial resolution of about 40m. The elevation points derived from DEM were used as one of the independent correlating factors in the model. Further the Kashmir region was dived in four altitude zones classified on the basis of elevation (Figure 2). The climatic variables from WorldClim[1] data were acquired for a span of 30 years (1970-200). The were about 22876 observations in the study area for each climatic variable used. Auto correlation analysis was applied to the elevation and other climatic variables for each zone to check the consistency and the homogeneity. The significance level of the tests were applied at 5%. The result of each homogeneity tests were analyzed at a significance of 0.05.

III. METHODOLOGY

The spatial resolution of the climate data from WorldClim (1) is about 1 km² which resulted in 22876 observation points in the study area which were categorized with respect to the elevation zones the climatic data consisting the climatic variables (minimum temperature, maximum temperature, annual precipitation , solar radiation, wind speed, water vapor pressure, annual mean temperature) was divided in four zones in which elevation ranging form x to y this also resulted in the division of the climatic variables (Table 1).

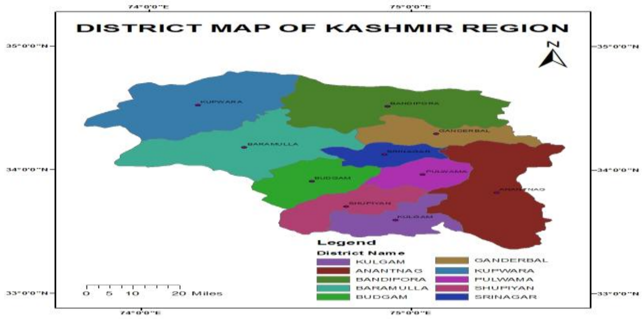

Fig. 1 : District map of Kashmir

Table I: Elevation range & obs. points in each zone

ZONES	ELEVATION (m)	OBS. POINTS OF CLIMATIC VARIABLES
ZONE I	1006-2073	8377
ZONE II	2073-2803	5320
ZONE III	2803-3558	5064
ZONE IV	3558-5321	4373

A. Correlation Analysis

The correlations were applied between zonal elevations of each zone & the climatic variables corosponding to that paticular zone, that resulted four correlation coefficients for every zone. It describes the correlation between the elevation zones & climatic zones in a better way & correlation matrix was formed (Table 2). The correlation coefficient used was (Pearson's correlation coefficient) with a 95% confidence intervals. The correlation coefficient (R) (Pearson's) can be calculated using the following equation Little (2013)

$$R = \Sigma i(Xi - X)(Yi - Y)/(n-1)SxSy \qquad (2)$$

to find the eigen values. The variances found between the components were represented

where X, Y, Sx, Sy are the sample means and standard deviations of Xi Yi, i = 1, . . . ,n. Correlation coefficients represent dependency between two variables with values ranging from □-1 to +1. It can be noted in the above matrix the the correlation coefficient between elevation & annual precipitation in ZONE I & ZONE II changes significantly from positive to negative, it can be stated as this happens as the elevation changes, the EMP (4) (elevation of maximum precipitation) generally at or below 1,500 m above which the precipitation decreases with increase in elevation. Except wind speed(m/s) having a positive correlation with all the zones every climatic variable has a negative correlation with the zonal elevations.

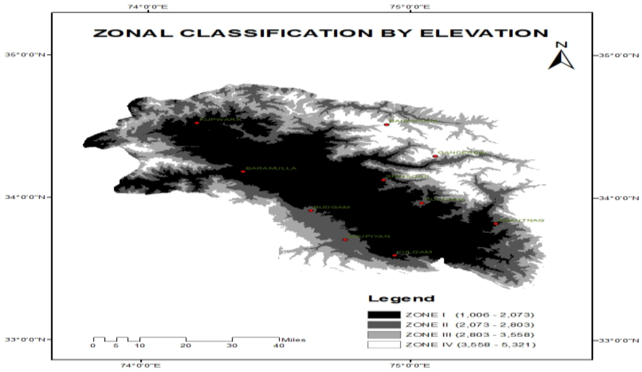

Fig. 2 : Zonal classification by Elevation

B. Global and Local Spatial Auto correlation Analysis

The local & global auto correlation tools measure spatial correlation. The spatial correlation between annual average temperature, annual precipitation & topography was measured. In this index we use spatial correlation coefficient for determining how two climatic variables are clustered ,randomized & clustered. For temperature & rainfall Moran's I was derived for the estimation of the type of precipitation. Moran's I can be derived by the following equation [6-9].

$$I = \frac{N}{So} \frac{\Sigma WijZiZj}{\Sigma (Zi)^2} \qquad (6\text{-}9)$$

where N is the quantity of stations, Zi and Zj are the deviation of factors from its mean, Wij is the spatial load of spatial areas I and j, The estimation of Moran's I lies between +1 to - 1 qualities close to +1 demonstrate grouping of the precipitation and the qualities close to - 1 shows scattered pattern , the incentive close to 0 demonstrates the irregular example of the precipitation. The spatial weights were given in GeoDa software an then imported to R studio where the spatial weights were converted to neighboring file & index was calculated about (0.94877) the value of Moran's I suggests that clustering of rainfall. The index calculated was only done to understand the pattern of rainfall & the elevation zones were not used as the index was calculated using the whole data set with no sub divisions.

C. Principal Component Analysis

The PCA resulted in five orthogonal components as five climatic variables were used (annual precipitation , solar radiation, wind speed, water vapor pressure, annual mean temperature)

Table II: Correlation matrix between elevation & climatic variables

Elevation zones	Annual average temperature	Annual average precipitation	Annual average wind speed	Annual average solar radiation	Annual average max temperature	Annual average min temperature
ZONE I	-0.9136571	0.6949493	0.5893868	-0.4271051	-0.9472712	-0.6624946
ZONE II	-0.9043795	-0.0542449	0.724702	-0.3824574	-0.8831018	-0.7292894
ZONE III	-0.8668584	-0.5303032	0.71942	-0.2273689	-0.87378	-0.7216475
ZONE IV	-0.9020903	-0.5352339	0.817872	-0.2588652	-0.8969376	-0.8340986

it was used in a form of screeplot (Figure 3). The first two components of PCA had a cumulative variance of about 93.86%, the explained variance of the components is represented in (Table 3)

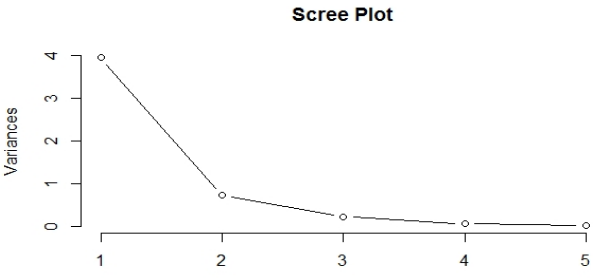

Fig. 3 : Screeplot between variance & components

while regression modeling the first two components annual mean temperature & annual precipitation will have more impact on the results as it can be seen in the above screeplot that the variance for first two components is much greater that the rest three components which have diminishing values.

Table III : Explained variance of components

Component	Eigen value	Variance	Cumulative Variance
Annual average temperature	1.9893352	0.7915	0.7915
Annual average precipitation	0.8575375	0.1471	0.9386
Annual average wind speed	0.4812757	0.04633	0.98489
Annual average solar radiation	0.2497595	0.01248	0.99737
Annual average vapor pressure	0.1147549	0.00263	1.00000

while regression modeling the first two components annual mean temperature & annual precipitation will have more impact on the results as it can be seen in the above screeplot that the variance for first two components is much greater that the rest three components which have diminishing values.

D. Regression Analysis

Multi linear regression between elevations & climatic variables stated a relationship between the independent & dependent variables. As a prescient analysis, the multiple linear regression is utilized to explain the connection between continuous dependent variable and two or more independent variables. The regression model can be calculated using the following equation (Hino et al-1979)

$$Yt = bo + b1x1 + b2x2 + ... bnxn + \varepsilon t \qquad (10\text{-}11)$$

where Yt is an estimate, *b0* and *b1* are the regression coefficients, *e*t is the error term & x is the independent variable Spatial regressions are utilized at some point in climatic analysis as illustrative models. In this study the multiple regression analysis was carried out for different elevation zones, this was done to minimize the standard error as a one single model maximized the standard error. The regression analysis with a confidence level of 99% & with a multiple R^2 of about 0.9507 that means about the climatic variables contribute about 95.07% to the overall variablity & with ($p < 0.01$).

The (Figure 4) represents the line of linear regression between elevation & annual average precipitation similar to this six other climatic variables were used, for elevation zones the same type of regression methods were used for the other climatic variables & a correlation matrix was deduced from the method which was stated earlier. The model for average minimum temperature & average maximum temperature with elevation has been developed independently & the intercepts & coefficients for each zone was calculated it also resulted in four different models or different elevation zones which are shown in (Table IV).

The intercepts & coefficients of other climatic variables were calculated in the similar way. The intercept & the coefficient for each climatic variable were calculated this was done for each of the elevation zones .

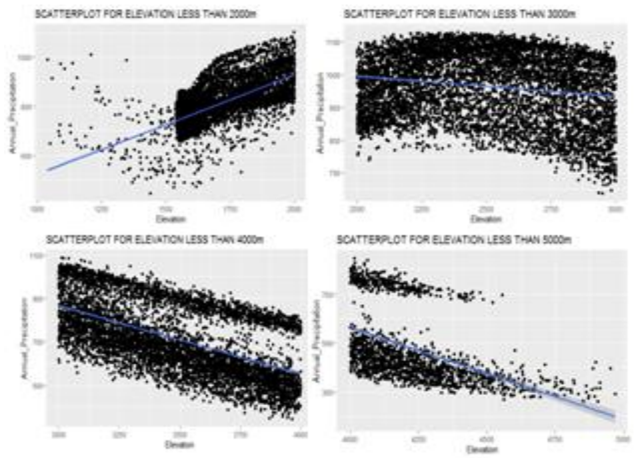

Fig. 4 : Regression line between elevation & annual mean precipitation

This resulted in four multi linear regression equations one for each zone.

Table IV: Intercepts & coefficients for min & max temperature

Elevation zones	Intercept	Coefficient for annual average minimum temperature	Coefficient for annual average maximum temperature
ZONE I	5087.65	-25.66	-153.29
ZONE II	4533.24	31.32	-138.44
ZONE III	4683.29	32.61	-136.43
ZONE IV	4445.86	0.07	-105.88

Table IV shows the intercept & coefficients between two climatic variables.

IV. RESULTS

The multiple linear regression model prepared in (Rstudio), with seven climatic variables resulted in four linear equations (one for each zone). This zonal classification was done to reduce the standard error of each variable, if the data was analyzed in bulk with no divisions the magnitude of standard error for each variable was greater if the data was subdivided. There were a total of eight variables and for each variable about 22877 values. The four liner regression equations deduced from the data are written below.

1. ZONE I = $(-1.864\times10^{3}) - (1.346\times10^{2} \times \text{Tav}) + (0.2206 \times \text{Pav}) + (3.582\times10^{2} \times \text{WSav}) + (0.3285 \times \text{SRADav}) - (3.349\times10^{2} \times \text{VPav})$
2. ZONE II = $(-2.117\times10^{3}) - (6.436\times10^{1} \times \text{Tav}) + (0.4633\times \text{Pav}) + (4.329\times10^{2} \times \text{WSav}) + (0.3237 \times \text{SRADav}) - (1.181\times10^{3}\times \text{VPav})$
3. ZONE III = $(-2.688\times10^{3}) - (6.591\times10^{1} \times \text{Tav}) + (0.3775 \times \text{Pav}) + (4.839\times10^{2} \times \text{WSav}) + (0.3963 \times \text{SRADav}) - (1.919\times10^{3}\times \text{VPav})$
4. ZONE IV = $(-4.176\times10^{3}) - (4.664\times10^{1} \times \text{Tav}) + (0.2134 \times \text{Pav}) + (5.242\times10^{2} \times \text{WSav}) + (0.5359 \times \text{SRADav}) - (3.289\times10^{3}\times \text{VPav})$

The the equations 1, 2, 3 & 4 show relationship between rest of the climatic variables, where Tav annual average temperature (°C), Pav annual average precipitation (mm), WSav represents annual average wind speed (m/s), SRADav represents annual average solar radiation (kJ/m²/day), VPav represents annual average vapor pressure (kPa) .

V. CONCLUSION

The procedure followed in this study was based on linear regression analysis, Initially the climatic variables were related to their corresponding elevation values & then later combined with geostatistics & GIS for further analysis. The multiple linear regression model was developed for four elevation zones which led to four models one for each zone. The models calculated the intercept & coefficients of the variables. To do this study first the climate data which was first obtained in the raster format was converted to vector data & the analysis was performed in R studio. Prior to that a DEM was used to extract the elevation points corresponding to the climate data. A total seven climatic variables were used & each variable had about 22786 value points. The above equation 1, 2, 3, 4 give the relation between elevation & average temperature (°C), average precipitation (mm), average wind speed (m/s), average solar radiation (kJ/m²/day), vapour pressure (kPa) where as the Table IV describes the relationship between elevation, minimum average temperature & maximum average temperature. Although an effort has been made to describe the relationship between the altitude & climatic variables but it does not describe the relation precisely. The linear regression model developed in this study used the climatic variables from 30 years to deduce the elevation zones & further the max & min average temperature.

REFERENCES

1. WorldClim version 1 was developed by Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC).
2. ESRI. Spatial Statistics Tools, ArcGIS Geostatistical Analyst, ArcMap 10.3; ESRI: Redlands, CA, USA, 2014.
3. ESRI. Spatial Statistics Tools (ArcGIS10.3); ESRI: Redlands, CA, USA, 2016.
4. Climate Variability and High Altitude Temperature and Precipitation,Mathias Vuille, Department of Atmospheric and Environmental Sciences University at Albany, State University of New York AlbanyUSA (DOI : https://doi.org/10.1007/978-90-481-2642-2_66)
5. Elevation effects on rainfall: A stochastic model, Journal of Hydrology,Lucien Duckstein, Martin M. Fogel, John L. Thames (DOI : https://doi.org/10.1016/0022-1694(73)90023-1)
6. Kuletz, K.J.; Ferguson, M.C.;
Hurley, B.; Gall, A.E.; Labunski, E.A.; Morgan, T.C. Seasonal spatial patterns in seabird and marine mammal distribution in the eastern Chukchi and western Beaufort seas: Identifying biologically important pelagic areas. Prog. Oceanogr. 2015, 136, 175–200.
7. Leguina, A. A primer on partial least squares structural equation modeling (PLS-SEM). Int. J. Res.Method Educ. 2015, 38, 220–221.Little, T.D. The Oxford Handbook of Quantitative Methods, Volume 1: Foundations; Oxford University Press: England, UK, 2013.
8. Lohmöller, J.-B. Latent Variable Path Modeling with Partial Least Squares; Springer: Berlin/Heidelberg,Germany, 2013
9. Hoell, A.; Shukla, S.; Barlow, M.; Cannon, F.; Kelley, C.; Funk, C. The Forcing of Monthly Precipitation Variability over Southwest Asia during the Boreal Cold Season. J. Clim. 2015, 28, 7038–7056.
10. IPCC Climate Change, 2013. The physical science basis. Summary for policymakers. In Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, 2013

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