# Comparison of Interpolation Methods for Precipitation Data in a mountainous Region (Upper Indus Basin-UIB)

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# Contents

# Introduction

- Hydrological models are important tools of water resources

- High quality Precipitation data → Prerequisite
  - any errors in the input are amplified in the runoff simulations
  - Better spatial coverage of data points better estimates
  - In Hydrological models -weather data assigned to the functional sub-units.
  - SWAT utilize method based on "Nearest Neighbor (NN)

# Introduction (cont...)

- Gauge station data → may have quality and spatial coverage issues,
- therefore may need different pre-processing or strategies for their improvement.

- These may include:
  - Satellite or radar based gridded data sets (dense coverage)
  - data interpolation techniques to improve the spatial coverage, (based on gauge data or some external variable or may be satellite data)

# Introduction (Aims)

- The current paper intend to :–

1. identify and use the most feasible method or combination of methods possible to improve spatial coverage of data

2. evaluate and compare the performance of commonly used spatial interpolation methods and geostatistical approaches in improving the spatial resolution of rainfall data in UIB, Including NN, used by SWAT

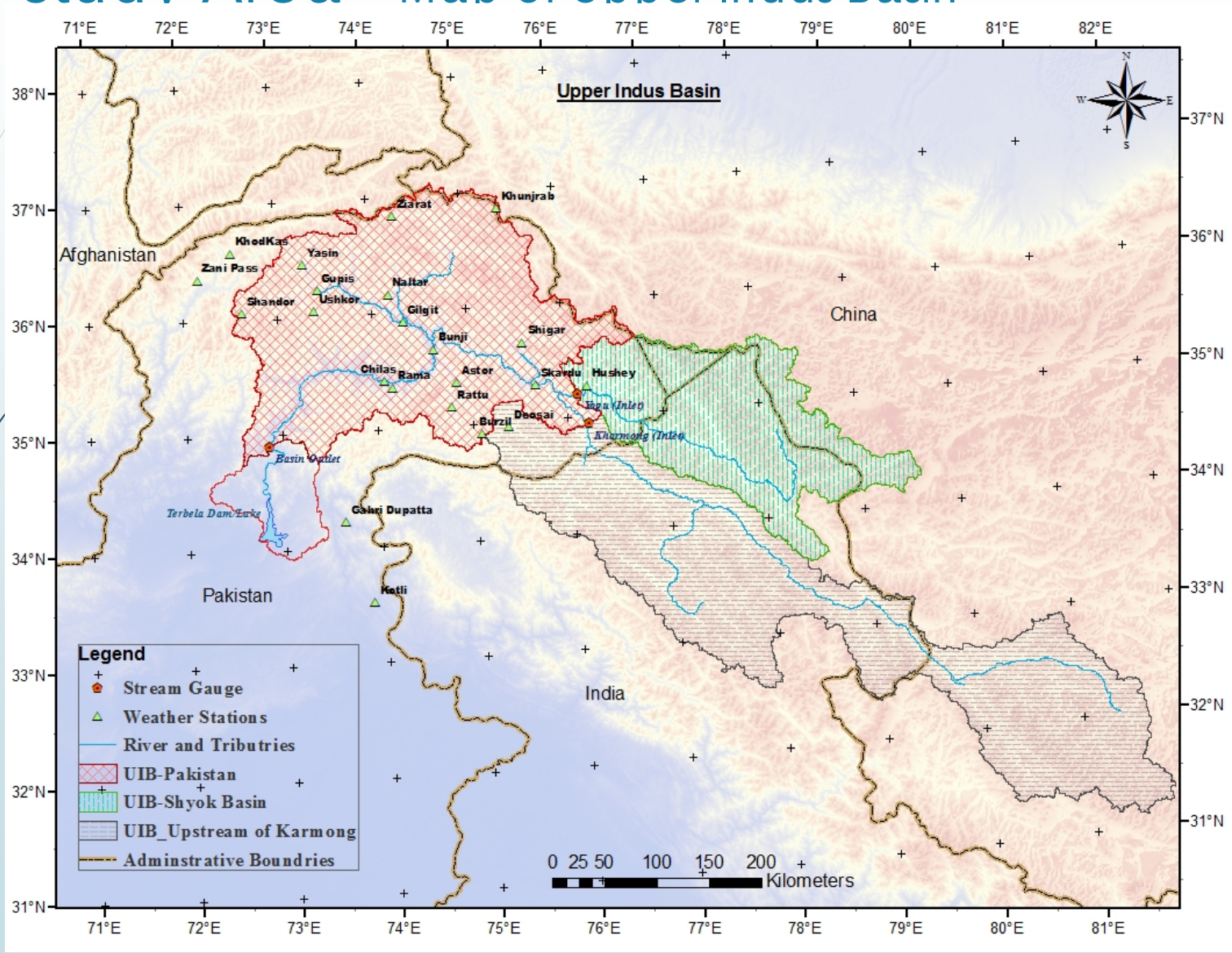
# Study Area: Upper Indus Basin (UIB)

- **Area:** about 165,000 $km^2$
- **Length (UIB):** about 1125 km long
- **Location:** between 31° - 37° N
  72° - 82° E

## Features

- Feed Largest irrigation system of the world
- UIB contains the greatest area of perennial glacial ice cover (22 000 $km^2$) outside the polar regions of the earth
- The altitude within the UIB ranges from about 600 m to height of 8611 m (K2).
- Annual precipitation –
  - major part originates in the west and falls in winter and spring
  - Some monsoonal incursions in summer.

# Study Area – Map of Upper Indus Basin



# Geographical attributes of Weather Stations

| S r . N o . | Station Name | Lat. (N) | Long. (E) | Elevation (m.a.s.l.) |
|---|---|---|---|---|
| 1 | Astor | 35.33 | 74.90 | 2168 |
| 2 | Bunji | 35.66 | 74.62 | 1372 |
| 3 | Burzil | 34.906 | 75.902 | 4030 |
| 4 | Chillas | 35.42 | 74.1 | 1250 |
| 5 | Deosai | 34.95 | 74.383 | 4356 |
| 6 | Garhi Dupatta | 34.22 | 73.61 | 813.5 |
| 7 | Gilgit | 35.92 | 74.33 | 1460 |
| 8 | Gupis | 36.16 | 73.42 | 2156 |
| 9 | Hushey | 35.376 | 76.4 | 3010 |
| 10 | Khot | 36.517 | 72.583 | 3505 |
| 11 | Khunjerab | 36.85 | 75.4 | 5182 |
| 12 | Kotli | 33.517 | 73.88 | 614.0 |
| 13 | Naltar | 36.128 | 73.185 | 2100 |
| 14 | Rama | 35.358 | 74.806 | 3 140 |
| 15 | Rattu | 35.153 | 74.187 | 2920 |
| 16 | Shendure | 36.086 | 72.525 | 3719 |
| 17 | Shigar | 35.53 | 75.592 | 2470 |
| 18 | Skardu | 35.295 | 75.683 | 2210 |
| 19 | Uskore | 36.018 | 73.358 | 3353 |
| 20 | Yasin | 36.454 | 73.3 | 3353 |
| 21 | Zani | 36.334 | 72.167 | 3895 |
| 22 | Ziarat | 36.853 | 74.278 | 3688 |

# Interpolation methods used

- Nearest Neighbours (NN)
- Inverse Distance Weighted (IDW).
- Ordinary Kriging (OK).
- Simple Kriging (SK)
- Kriging with External Drift (KED).
- Simple Kriging with Varying Local Means (SKlm).

# Performance evaluation

## Two types of cross-validation techniques used:

Gauge points removed temporarily, one at a time and estimated values are checked against the observed values to evaluate the accuracy of interpolation methods.

- Quantitative (magnitude) cross-validation
- Qualitative (occurrence) cross-validation

# Quantitative (magnitude) cross-validation

- Quantitative (magnitude) cross-validation applied for data at different time aggregation:
  - Daily;
  - Monthly;
  - Seasonal; and
  - Annual.
- *They included:*
  i. Correlation Coefficient (*r*);
  ii. Nash-Sutcliffe Efficiency (*Nse*);
  iii. Mean Absolute Error (*MEA*); and
  iv. Root Mean Square Error (*RMSE*).

# Qualitative (occurrence) cross-validation (only for Daily data)

- The cross-validation is based on four indicators as given in the "Contingency table 2X2" (rain events, no events, misses and false-alarms). Based on these the derived categorical statistical indices include:
  - accuracy (Ac);
  - bias score or frequency bias index (FBI;
  - probability of detection (POD);
  - false alarm ratio (FAR);
  - critical success index (CSI) and
  - true skill statistics (TSS)

# Contingency table 2X2

| | | Observed values (Gauge data) | | Total |
|---|---|---|---|---|
| | | YES | NO | |
| **Estimated values (Interpolation -estimates)** | YES | -**a**- Hits | -**b**- False Alarms | Total-Yes Estimated |
| | NO | -**c**- Misses | -**d**- Correct Negative | Total-No Estimated |
| **Total** | | Total-Yes Observed | Total-No Observed | Total |

$$Ac = \frac{a+d}{Total}$$

$$FBI = \frac{a+b}{a+c}$$

$$POD = \frac{a}{a+c}$$

$$FAR = \frac{b}{a+b}$$

$$CSI = \frac{a}{a+b+c}$$

$$TSS = \frac{a}{a+c} - \frac{b}{b+d} = \frac{ad-bc}{(a+c)(b+d)}$$

# RESULTS: Cross validation results

- Quantitative (Magnitude) Cross Validation Results

| Method | *r* | # | *MAE* | # | *RMSE* | # | *NSE* | | # | Average Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *value* | *%positive* | | |
| **SKlm** | 0.54 | **1** | 1.711 | **1** | 4.06 | **1** | 0.13 | 87.19 | **1** | **1.0** |
| **SK** | 0.35 | 2 | 1.719 | 2 | 4.42 | 2 | 0.03 | 71.61 | 2 | **2.0** |
| **OK** | 0.11 | 6 | 1.833 | 3 | 4.83 | 3 | -0.29 | 22.92 | 3 | **3.8** |
| **KED** | 0.19 | 4 | 1.868 | 4 | 4.95 | 5 | -0.46 | 21.03 | 5 | **4.5** |
| **IDW** | 0.23 | 5 | 1.866 | 5 | 5.19 | 4 | -0.49 | 20.85 | 4 | **4.5** |
| **NN (TP)** | 0.27 | 3 | 2.023 | 6 | 6.00 | 6 | -0.91 | 18.64 | 6 | **5.3** |

The Quantitative (magnitude) cross-validation results at annual monthly and seasonal aggregate followed the same pattern as for the daily time aggregates. **SKlm** had the best average values for r (0.63), MAE (252.26), RMSE (319.15) and also NSE (0.16) for data at annual time aggregate, while also showed best values for these indices for data at seasonal and monthly time aggregate.

# RESULTS: Cross validation results

- Qualitative Cross Validation (Occurrence) Results

| Method | Qualitative evaluation indices and their performance rank | | | | | | | | | | | Average Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ac | # | FBI | # | POD | # | FAR | # | CSI | # | TSS | # | |
| SKlm | 0.88 | **1** | 1.43 | 5 | 0.84 | 1 | 0.351 | 2 | 0.58 | 1 | 0.63 | 1 | **1.83** |
| SK | 0.88 | 1 | 1.43 | 5 | 0.85 | 2 | 0.362 | 5 | 0.57 | 2 | 0.61 | 2 | **2.83** |
| KED | 0.85 | 3 | 1.32 | 4 | 0.76 | 3 | 0.357 | 3 | 0.53 | 3 | 0.56 | 3 | **3.17** |
| IDW | 0.85 | 5 | 1.14 | 2 | 0.70 | 5 | 0.337 | 1 | 0.50 | 5 | 0.54 | 5 | **3.83** |
| OK | 0.85 | 4 | 1.28 | 3 | 0.76 | 4 | 0.359 | 4 | 0.52 | 4 | 0.56 | 4 | **3.83** |
| NN (TP) | 0.77 | 6 | 0.99 | 1 | 0.56 | 6 | 0.387 | 6 | 0.40 | 6 | 0.43 | 6 | **5.17** |

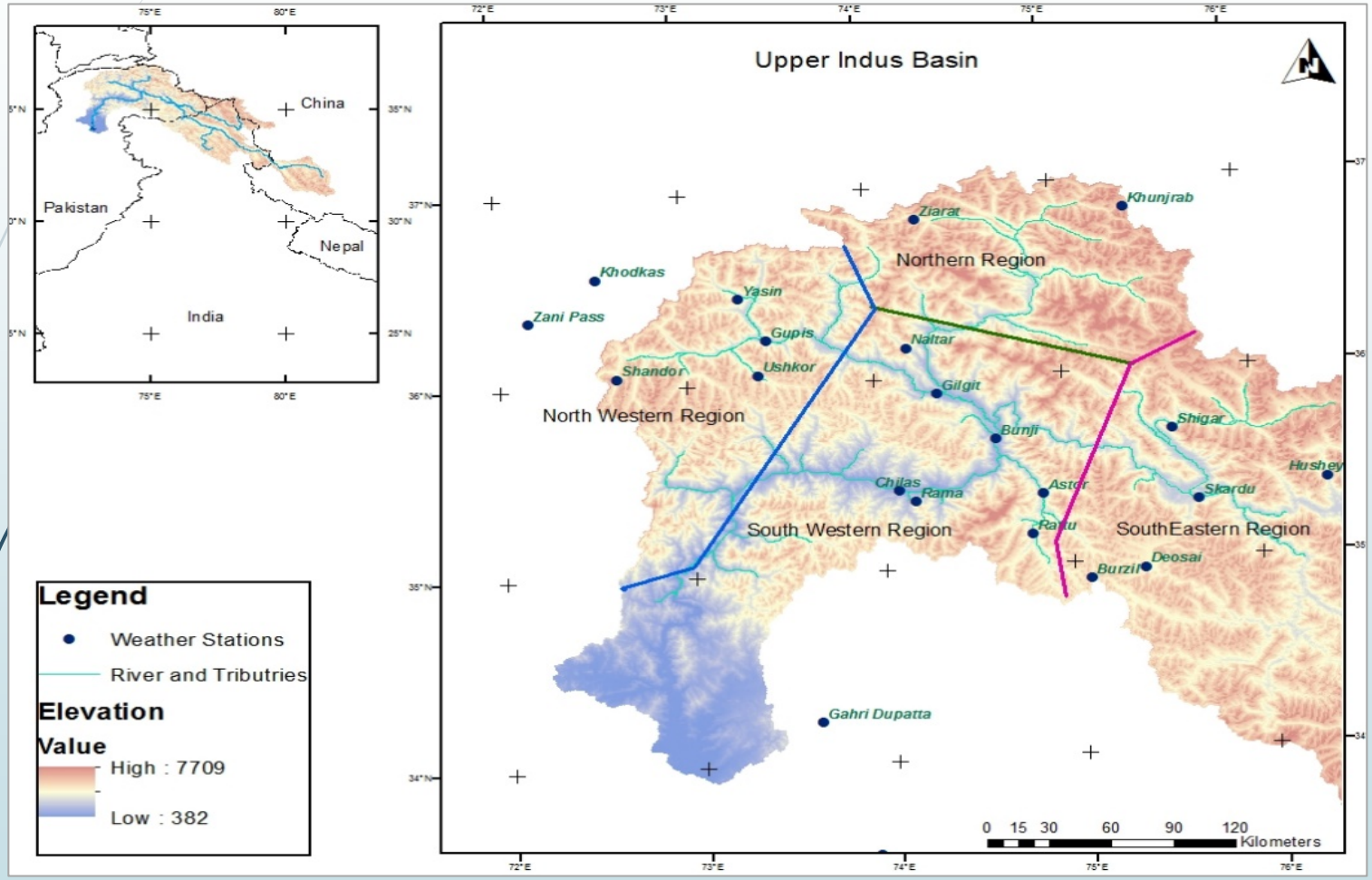
# Conclusion

- All Methods had their own advantages and disadvantages, but SKlm proved to be the best suited for the study area.
- For both quantitative and quantitative cross validation (magnitudes and occurrences)--SKlm performed better than other methods for data aggregates at all time scales.
- SKlm, therefore could be a better option for interpolating precipitation data in the Upper Indus Basin-UIB

# Thank you

# RESULTS:

## Precipitation vs elevation analysis




- UIB (Pakistan), with hydro-climatological zones

# RESULTS:

## Precipitation vs elevation analysis (cont..)

| Time Aggregates | | Correlation coefficient for precipitation amount vs elevation in different regions of UIB | | | | |
|---|---|---|---|---|---|---|
| | | North-Western | Central South | South-Eastern | Average Regional | Whole UIB |
| **Mean-Monthly** | | **0.72** | **0.93** | **0.90** | **0.85** | **0.30** |
| Monthly | January | 0.98 | 0.97 | 0.96 | **0.97** | 0.26 |
| | February | 0.77 | 0.93 | 0.98 | **0.89** | 0.25 |
| | March | 0.92 | 0.89 | 0.92 | **0.91** | 0.22 |
| | April | -0.88 | 0.99 | 0.84 | **0.32** | 0.00 |
| | May | 1.00 | 0.99 | 0.73 | **0.91** | 0.23 |
| | June | 0.96 | 0.86 | 0.99 | **0.94** | 0.43 |
| | July | 0.92 | 0.96 | 0.94 | **0.94** | 0.57 |
| | August | 0.55 | 0.93 | 1.00 | **0.83** | 0.45 |
| | September | 0.80 | 0.78 | 0.98 | **0.85** | 0.40 |
| | October | 0.67 | 0.93 | 0.90 | **0.83** | 0.31 |
| | November | 1.00 | 0.98 | 0.89 | **0.95** | 0.27 |
| | December | 1.00 | 0.99 | 0.67 | **0.88** | 0.21 |
| **Mean-Seasonal** | | **0.79** | **0.94** | **0.97** | **0.90** | **0.31** |
| Seasonal | Winter | 0.97 | 0.97 | 0.98 | **0.97** | 0.15 |
| | Spring | 0.29 | 0.99 | 0.97 | **0.73** | 0.51 |
| | Summer | 0.92 | 0.91 | 0.99 | **0.94** | 0.35 |
| | Autumn | 0.99 | 0.90 | 0.94 | **0.94** | 0.25 |
| **Annual** | | **0.99** | **0.99** | **0.98** | **0.99** | **0.33** |

# RESULTS:

## Precipitation vs elevation analysis (cont..)