Geohydraulik und Ingenieurhydrologie

Correction and informed Regionalization of Precipitation Data in a high mountainous Region (Upper Indus Basin) and its Effect on SWAT-modelled Discharge

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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:
  - Correction for systematic errors;
  - Using or improving them with Satellite or radar based gridded data sets (dense coverage)
  - Applying data interpolation techniques to improve the spatial coverage, (based on gauge data or some external variable or may be satellite data)

- But all these methods may have limitations due to ,
  - limited information and quality for some areas,
  - Time , efforts and technical skills required etc.

Aims and Objective:

- The current study intended to :–

identify suitable method for improving precipitation

data quality and spatial coverage:

  - Which is informed by the hydro-meteorological and glacier mass balance knowledgebase, and
  - which is possibly less time and effort consuming.

Study Area: Upper Indus Basin (UIB)

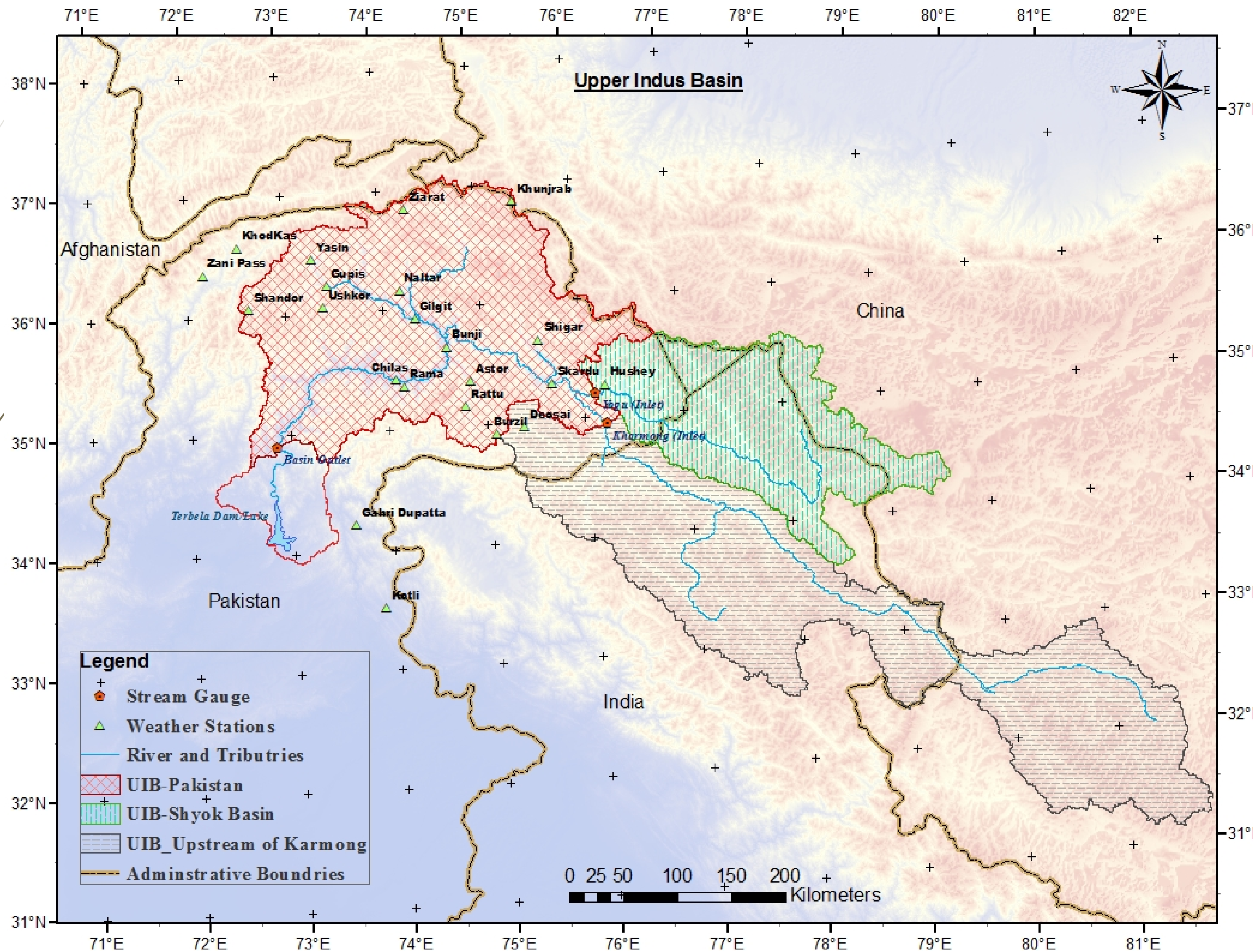
- **Area:** about 165,000 km^2
- **Length (UIB):** about 1125 km long
- **Location:** between 31° - 37° N

  72° - 82° E

Features

- Feed Largest irrigation system of the world
- UIB contains the greatest area of perennial glacial ice cover (around 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



Study Area - Weather Station

Sr. No.	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

Three step correction strategy :–

Step-1: Adjustment methods for Systematic errors

- Correction Method Suggested by Richter (1995) – M1

$$P_{korr} = P + \Delta P \qquad \text{while} \qquad \Delta P = b * P^{\varepsilon}$$

With:

- ***P***= measurement value at gauge
- ***b***= coefficient for the influence of wind
- ***ε***= empiric coefficient for the precipitation type

Precipitation Type	Coefficient ε	Coefficient b (shielding)	
		2° Open Space	5° Light Shielding
Rain (summer)	0.38	0.345	0.31
Rain (winter)	0.46	0.34	0.28
Mixed Perc.	0.55	0.535	0.39
snow	0.82	0.72	0.51

Adjustment methods for Systematic errors (cont…)

- Method Suggested by Ma *et al.* (2015) and Yang *et al.* (2001) – M2

$$Pc = K(Pm + \Delta Pw + \Delta Pe + \Delta Pt)$$

and

$$K = 1/CR$$

where

Pc is the 'true' precipitation,

Pm is the measured value by gauges,

ΔPw is wetting losses

ΔPe is evaporation losses

ΔPt is trace amount and

K is the adjustment coefficient due to wind-induced error.

CR is the catch ratio (%), defined as a function of wind speed

	Snow	Mixed	Rain
ΔPw	0.15	0.15	0.20
ΔPe	0.10	0.30	0.30
ΔPt	0.10	0.10	0.10
CR	100/1.13	100/1.05	

Step-2: Interpolation and informed Regionalization

- This step included the following activities:

1. For each region / sub-basin P-Lapse calculated / estimated based on:

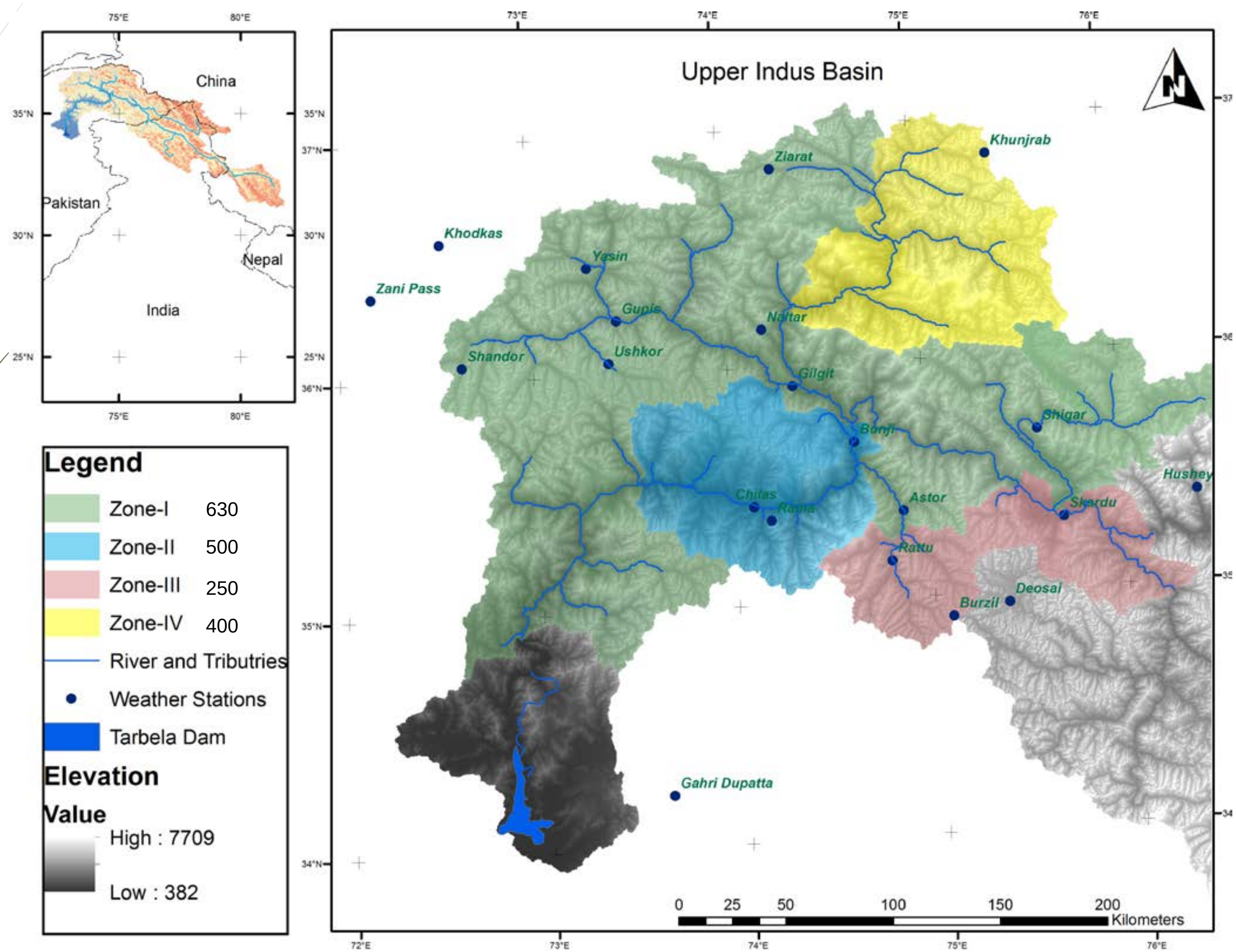
   - Glacier Mass balance studies and maps
   - Observed discharge at outlets of different sub catchments.
   - Real evapotranspiration estimates (SWAT and literature)

Based on these information UIB was divided in Zones with different P-Lapse.

(map on next page)

Interpolation and informed Regionalization

Different Zones of UIB according to mean Precipitation Lapse rate



Interpolation and informed Regionalization (con..)

2. All stations adjusted at same elevation (4000), according to P-Lapse

$$P_E = P_d + (EL_T - EL_{gauge}).plapse / 1000$$

(modified from Neitsch *et al. 2009*)

Where

- P_E is precipitation at target elevation (mm)
- P_d is precipitation at recorded at gauge station (mm)
- EL_T is elevation at target point
- EL_{gauge} is elevation at gauge station,
- **plapse** is precipitation lapse rate for the zone (mm/km)

(plapse for Zone-I: 630, Zone-II: 500, Zone-III: 250 and Zone-IV: 400)

3. Interpolation (Simple Kriging)
4. Re-adjustment of interpolated data according to interpolated point elevation (or band elevation) and P-Lapse

Step-3:
Validation through hydrologic Model - SWAT

- observed and estimated precipitation used as SWAT input.
- SWAT Elevation band also used for maximum regionalization

Results :–

Validation through hydrologic Model - SWAT

Precipitation Input for SWAT Model estimates	NSE	r^2	M. A. disc (m^3/s)	% Bias	M. A. PCP (mm/y)
Raw Station Data	0.28	0.76	1278	-47.3	452
Raw Station Data-Interpolated	0.44	0.61	1621	-33.1	696
Corrected Station Data (Method-1)	0.19	0.6	1490	-38.5	570
Method-1 & Interpolated	0.66	0.66	2163	-10.7	1011
Method-1, Interpolated & Elevation Grids	0.87	0.88	2471	2.0	1122
Corrected Station Data (Method-2)	0.51	0.7	1356	-44.0	619
Method-2 & Interpolated	0.68	0.69	2139	-11.7	982
Method-2, Interpolated & Elevation Grids	0.88	0.88	2461	1.6	1096
Observed Discharge Observed Discharge as depth at basin scale	2423 (m^3/s) or 818 (mm/y)				

Conclusions

- The swat estimates improved with correction, interpolation or adjustment for lapse rate, individually or in combinations.
- Dividing sub-basins into Elevation Grids further improved the estimates.
- This method, based on known facts, may be an easy and a better option for mountainous and glaciated regions, having sparse observation points such as UIB.