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1 **Estimating How Variations in Precipitation and**
2 **Snowmelt Affect Kunhar River Resources**

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7 **Abstract.** Over half of the nonpolar glacial watersheds are found in the Himala-
8 yayas and they are sources of water for billions of people. Understanding how vari-
9 ations in precipitation and snowmelt will affect their lives is thus of prime inter-
10 est. As very scarce data are available, modeling should be adapted. The proposed
11 hydrological framework is based on the distributed conceptual model HBV set
12 up to account for snowmelt in the Greater Hymalayas. Spatialization is carried
13 out with respect to terrain constraints (hydrology, land cover, elevation). Applied
14 to the Kunhar's watershed, this reveals the key role of correlated temperature and
15 elevation variables.

16 **Keywords:** Hydrology, Alpine Watershed, Data Scarcity, Conceptual Model-
17 ing, GIS modeling.

18 **1 Introduction**

19 Over half of the nonpolar glacial watersheds are found in the Himalayas and they
20 are sources of water for billions of people. Understanding how variations in precipita-
21 tion and snowmelt will affect their lives is thus of prime interest. As very scarce data
22 are available, modeling should be adapted according to the numerous sources of uncer-
23 tainty. The watershed of Kunhar River lying in Pakistan's Himalayas is considered as
24 a case study.

25 **2 Method**

26 The proposed hydrological framework is based on the conceptual hydrological model
27 HBV [1] set up to account for snowmelt. Spatialization is carried out thanks to the
28 TopoToolbox [2] applied to digital elevation models and the WatPart software [3] for
29 the partition of watersheds with respect to terrain constraints. Uncertainty computations
30 will be discussed in a further paper.

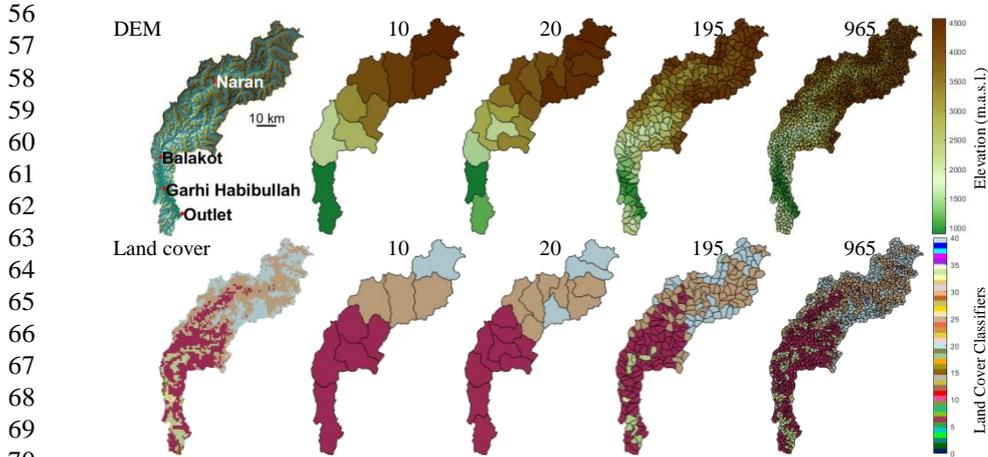
31 Model calibration is an issue when very few data are available. Data gaps and lacks
32 should be valuated prior to and during the simulations to ensure their adequacy with the
33 foreseen hydrological modeling.

34 Free digital elevation models (DEMs) and land cover rasters are distributed with a
 35 resolution at equator of 1 arc-second and of 1 km², respectively. Meteorological and
 36 gauging stations are often scarcely distributed. Although regional re-analyses may be
 37 available, a resolution of 25 km as for Aphrodite data may limit the number of points.
 38 Filling data gaps in spatial or temporal dimensions is thus welcome. Thiessen polygons
 39 may be used to interpolate precipitations while an affine dependence between height
 40 and temperature can be considered. Gaps can also be modulated by adding knowledge
 41 and assumptions. Firstly, we delineate the watershed into small hydrological units to
 42 agree with land cover resolution and height variations. The DEM is downscaled by
 43 averaging height over the sub-basins delineated using Topotoolbox and WatPart. Ap-
 44 proximated temperatures and precipitations can then be assigned to the sub-basins. Sec-
 45 ondly, the conceptual model is used on clusters of subdomains [4]. Finally, scarce gaug-
 46 ing data are used to tune hydrological parameters.

47 3 Results

48 Located in the north of Pakistan, the Kunhar River (2631 km²) drains the southern slope
 49 of the Greater Himalayas. This tributary of Jhelum River passes through Naran (Na,
 50 2409 m.a.s.l.), Balakot (Bk, 980 m.a.s.l) and Garhi Habibullah (GH, 820 m.a.s.l.). It
 51 contributes to about 11% of the Mangla Reservoir.

52 Raster data are the 1 arc-second DEM from USGS and the Global Land Cover 2000
 53 raster from EU Science HUB with a resolution of 1 km. On-site data involve 2 meteor-
 54 ological (Na&Bk) and 2 gauging (Na&GH) stations only. More detail about other avail-
 55 able data is provided in [5].



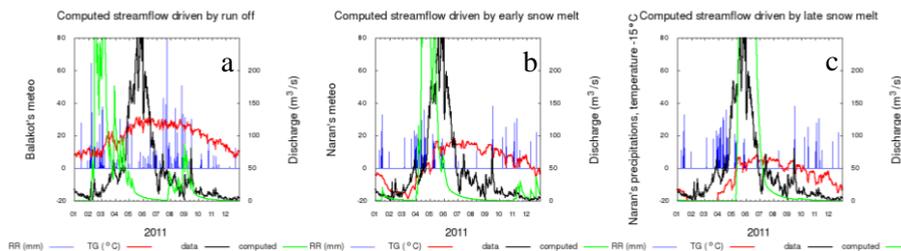
71 **Fig. 1.** Downscaling elevation and land cover on nested partitions of the watershed.

72
73 The first partition is carried out with respect to the observation stations and the conflu-
 74 ence with Jhelum River using the TopoToolbox on the DEM. In Fig. 1, nested partitions
 75 are then computed using WatPart. Mean elevation and dominant land cover are

76 assigned to the subdomains. Downstream lower fields are covered by herbaceous veg-
 77 etation (6:burgundy) and slope agriculture (34:green), while higher areas are covered
 78 by snow (40:grey). The central medium height area is dominated by shrubs (25:brown).
 79 There is clearly a correlation between height and land cover in Kuhnar’s watershed.
 80 Higher the number of subdomains, better the approximation of elevation. Temperature
 81 fields are deduced from height information by using Naran’s data.

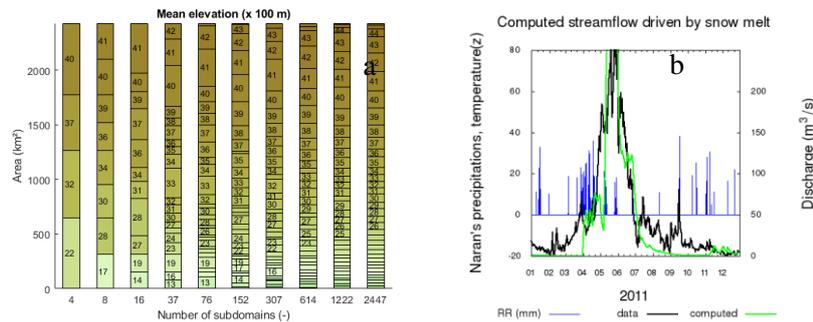
82 As the 60% of the watershed are higher than 3000 m, the streamflow is mainly driven
 83 by temperature and snowmelt. In this study, we thus assume that precipitations are ho-
 84 mogeneous over the watershed. Soil properties implementing the 4 main land cover
 85 classes will be considered in a future work.

86 The HBV model is run on the watershed (2429 km²) delineated by the GH gauging
 87 station to evaluate the influence of temperature on the streamflow. The mean height is
 88 3240 m.a.s.l.. Meteorological and discharge data are plotted in Fig. 2. The simulations
 89 are carried out from 2007 to 2011. After a 1-year warm up, the identification runs from
 90 2008 to 2010. The 2011 data are used for validation.



91 **Fig. 2.** Influence of temperature on computed discharges using meteorological data from Bala-
 92 kot (a), Naran (b), and the temperature from Naran -15 °C (c).

93
 94 As expected, the temperature is a major driver of streamflow. In Fig. 2.a, the computed
 95 discharge is driven by rainfall. In Fig. 2.b and 2.c, snow melt occurs too early and too
 96 late, respectively. Moreover the discharge peak is too narrow. There is a need for a
 97 watershed decomposition that accounts for “snow-melt” at high altitudes and “rainfall-
 98 runoff” at low ones. This may be carried out by considering several sub-domains.



99 **Fig. 3.** Accounting for height and temperature variations: Nested partitions (a), streamflow (b).
 100

101 We delineate a set of nested partitions. Mean isohypses and areas are reported in Fig.
102 3.a. The temperature field is adapted according to the partition into 8 sub-basins (about
103 300 km² each). The computed streamflow (Fig. 3.c) better agrees with discharge data,
104 even if it could be still improved using Balakot rainfall at low altitudes.

105 **4 Discussion**

106 The different flow regimes occurring in Kunhar's watershed can be reproduced by im-
107 plementing the HBV model on several sub-basins, the areas and mean heights of which
108 are key parameters. These can be inferred by splitting the watershed into small hydro-
109 logical units. The framework will be tested on larger partitions, possibly up to 2500
110 sub-basins to agree with the resolution of GLC 2000 (Fig .1). In addition, the stream-
111 flows computed along the corresponding routing network could then be compared to
112 the streamflows computed using HEC-RAS 1D, for instance.

113 The proposed method is clearly able to evaluate the role of height and temperature
114 on such an alpine watershed. Once validated, climate change scenarios could be used
115 to estimate how variations in precipitation, temperature and snowmelt will affect
116 Kunhar river resources, and more generally Jhelum river resources. This study will be
117 carried out by accounting various modeling uncertainties.

118 **5 Conclusions**

119 Computed snowpack and snowmelt are expected to be highly variable over the Jhelum
120 River sub-watersheds. The proposed method enables to deal with height and tempera-
121 ture in the HBV framework in a fair manner. Consequently, it will be extended to the
122 Jhelum watershed to cautiously quantify streamflow variations under climate change
123 scenarios through uncertainty computations.

124 **References**

- 125 1. Bergstrom, S. (1995): The HBV model. In: Singh, V. P. (Ed.), *Computer Models of Wa-*
126 *tershed Hydrology*, pp. 443–476, Water Resources Publications, Highlands Ranch, CO (1995).
- 127 2. Schwanghart, W., Kuhn, N.J.: *TopoToolbox: a set of Matlab functions for topographic*
128 *analysis*. *Environmental Modelling&Software* 25, 770–781 (2010).
- 129 3. Hariri, S., Gustedt, J., Weill, S., Charpentier, I.: *Pairing GIS and distributed hydrological*
130 *models using Matlab*. In: *2nd Conference of the Arabian Journal of Geosciences, CAJG, Sousse,*
131 *Tunisia (2019)*.
- 132 4. Singh, V., Kumar Goyal, M., Surampalli, R.Y., Munoz-Arriola, F.: *Sub catchment Assess-*
133 *ment of snowpack and snowmelt change by analyzing elevation bands and parameter sensitivity*
134 *in the high Himalayas*. *Hydrology and Earth System Science*, 2017, 1–31 (2017).
- 135 5. Mahmood, R., Jia, S., Babel, M.S.: *Potential Impacts of Climate Change on Water Re-*
136 *sources in the Kunhar River Basin, Pakistan*. *Water* 8, 23 (2016).