Spatial-altitudinal and temporal variation of Degree Day Factors (DDFs) in the Upper Indus Basin

Asif Khan (1,2,3), Haleema Attaullah (2), Tabinda Masud (2), and Mujahid Khan (2)

(1) University of Cambridge, Cambridge University, Engineering, Cambridge, United Kingdom (engrasif_civil@yahoo.com),
(2) Department of Civil Engineering, University of Engineering and Technology Peshawar, Pakistan, (3) International Institute for Applied System Analysis, Schlossplatz 1 A-2361 Laxenburg, Austria

Melt contribution from snow and ice in the Hindukush-Karakoram-Himalayan (HKH) region could account for more than 80% of annual river flows in the Upper Indus Basin (UIB). Increase or decrease in precipitation, energy input and glacier reserves can significantly affect water resources of this region. Therefore improved hydrological modelling and accurate future water resources prediction are vital for food production and hydro-power generation for millions of people living downstream, and are intensively needed. In mountain regions Degree Day Factors (DDFs) significantly vary on spatial and altitudinal basis, and are primary inputs of temperature-based hydrological modelling. However previous studies have used different DDFs as calibration parameters without due attention to the physical meaning of the values employed, and these estimates possess significant variability and uncertainty. This study provides estimates of DDFs for various altitudinal zones in the UIB at sub-basin level. Snow, clean ice and ice with debris cover bear different melt rates (or DDFs), therefore areally-averaged DDFs based on snow, clean and debris-covered ice classes in various altitudinal zones have been estimated for all sub-basins of the UIB. Zonal estimates of DDFs in the current study are significantly different from earlier adopted DDFs, hence suggest a revisit of previous hydrological modelling studies. DDFs presented in current study have been validated by using Snowmelt Runoff Model (SRM) in various sub-basins with good Nash Sutcliffe coefficients ($R2 > 0.85$) and low volumetric errors ($Dv<10\%$). DDFs and methods provided in the current study can be used in future improved hydrological modelling and to provide accurate predictions of future river flows changes. The methodology used for estimation of DDFs is robust, and can be adopted to produce such estimates in other regions of the, particularly in the nearby other HKH basins.