Dated: March 11, 2017

The Editor,

Earth System Dynamics

Re-Revised submission of ESDD-2015-12

Dear Editor,

We are pleased to submit the re-revised version of our paper "**Prevailing climatic trends and runoff response from Hindukush-Karakoram-Himalaya, upper Indus basin**". We have addressed all the referees' comments and revised the manuscript for the requisite changes. Our point-by-point response (in green) to the referees' comments (in black), followed by the track changes from previous version is given below.

We hope that the revised paper is now in the form acceptable for final publication in ESD and that it will contribute to the understanding of prevailing hydroclimatic state over the upper Indus basin, and subsequently its melt-runoff dynamics.

With kind regards,

Shabeh ul Hasson

REVIEWER # 3

This manuscript describes the climatic constraints on water availability of the upper Indus Basin in Pakistan. The authors rely on station data (temperature and precipitation and discharge) which are sparse in this region. The authors make important observations on climate trends and decompose them by season/months. The authors address the topic of the Karakoram Anomaly - this is a timely topic in a region that receives lots of attention, but is characterized by a lack of ground and station data. The authors attempt to fill that niche – although this manuscript is not a presentation of a lot of new station data, it is a very useful overview and synthesis.

We are very much thankful to the reviewer for his encouraging remarks and kind guidance which have substantially improved our manuscript.

1. Overall, the manuscript is well written, but is certainly on the lengthy and wordy side. In that respect, does the methods section really need the statistical basis of the MK/TS/etc explained with formulas? This seems like a lot of additional material and weight that is not necessary. In short, while the authors are thourough and the manuscript contains important information, it is too long. For example, the results start at line 512 – this is the length of some other entire manuscript. While informative and important, the results of the discharge data alone are 1.5 pages (>40 lines).

   Following kind suggestions of the reviewer, the length of the manuscript has now been reduced by one-third in the revised version, without a significant information loss. The statistical formulations of the MK/TS test have also been excluded while the text brevity has been improved throughout the manuscript.

Some minor suggestions and wording comments:

2. I'm also not convinced that the section on trends vs lat/lon is helpful. There should be a lot more local topography impact than pure lat/lon impact (e.g. aspect, distance from mountain front as proxy for rain shadow, distance to local peaks). So, an analysis of trends vs elevation/relief/aspect would be more instructive. Given the length of the manuscript and the focus (and the extensive trend analysis), I suggest to remove this part, because it doesn't provide the detail and thoroughness as other parts of the manuscript.

   The Section 5.3 titled 'Tendencies versus latitude, longitude and altitude' and related text on line 504-505 has been removed in the revised manuscript.

3. L835 they suggest a weakening of the westerlies, which disagrees with other interpretation and literature, and then on the next page suggest an increase in the strength of westerly storms (citing Cannon et al.). This seems inconsistent – please rephrase.

   Clarifying such inconsistent needs further explanation and in view of the need to cut the manuscript length short Lines 833 to 840 have been removed in the revised manuscript.

4. Figure 1: Station locations are difficult to see. I suggest to use a grayscale image for elevation or other symbols. Almost impossible to identify glaciers.

   The Figure 1 has been revised with a greyscale topography and clearly shown glacier cover.

5. Table 4, 6, and others: I always tend to use one significance level and use ONLY that significance level. Using two significance levels (0.9 vs 0.95) is misleading. Most importantly, that add clutter and noise to the table that is unnecessary.

   In the revised manuscript, slopes on only at 90% significance level are shown in bold.

6. I am struggling with the last 3 figures (Figure 9-11). While these are useful in terms of data-generation and visualization effort, they do not convey any useful information – unless you are willingly to stare at least 5 minutes at one figure. Grid lines would be helpful, but also an indication what information these figures should convey. As pointed out before, the manuscript would not be weaker, if these are removed. Especially considering the facts that there are a dozen stations over 5 degree of longitude (550 km) in some of the roughest terrain on earth! IF the authors decide to leave them in, I strongly urge them to revisit them, make colors and symbols clearer and indicate what these are supposed to document (trends)? Otherwise the reader will interpret them as that there is not climatic relation with topography.

   Agreeing with the reviewer, Figures 9-11 have been removed as the corresponding Section 5.3 on 'Tendencies versus latitude, longitude and altitude' has also been removed in response to the reviewer's comment #2.

REVIEWER # 4

The manuscript has done comprehensive assessment of prevailing trends for relevant hydro-climatic variables in the upper Indus basin (UIB). Relations among hydro-climate, monsoon, westerly disturbances and water availability in this high-altitude mountain basin were reasonably discussed. Overall, this is a well written manuscript and the results are interesting.

We are very much thankful to the Reviewer for his/her guidance, which has improved the revised manuscript considerably.

I only have two main concerns for this study:

1. 18-year data series look too short to do trend analysis;

   We fully agree with the reviewer's concern about the short observational dataset used for trends analysis. Keeping in view such constraint, authors have employed multiple measures of assessing robust signal ranging from analyzing the statistical significance to ascertaining the practical relevance. For instance, Mann Kendall test has been used for station-wise trend detection for which time series length is coarsely reasonable. Then, the medium-term trends (1995-2012) have been compared to the long-term trends from six stations for their consistency. The results are further compared with the earlier reports employing subset of the stations but over distinct periods in the Discussions section. Further, local climatic trends are assessed for their field significance within 10 identified sub-regions of the UIB in order to obtain the robust signal of change. Such field significant trends are further qualitatively compared with the tendencies in discharge out of corresponding sub-regions (as well as with the earlier reports of hydro-cryospheric changes from data scarce regions on lines 596-603) to investigate the practical relevance of statistically identified trends. The issues of spatial incompleteness and shortness of observations have been discussed on lines 608-615, while future direction about the use of proxy observations is also proposed, in view of the fact that challenges of sparse and short in-situ observations within the UIB will remain same in the coming decades. Further, kindly see our response to comments #1 of the Reviewer # 5.

2. the interactions between atmosphere and the mountainous hydrological processes in UIB could be better interpreted if a land surface model/atmosphere-land coupled model is being used other than intensively relying on statistics. That would be more helpful in understanding the underlying processes.

   We fully agree with the reviewer for this important suggestion on application of hydrological and regional climate models over the study region in order to better understand the local-scale physical processes over highly complex terrain and their interactions with the synoptic weather system and associated precipitation regime. Applying hydrological model coupled with the hypothetical scenario representing prevailing climatic trends over the UIB as observed here, Hasson (2016) has recently confirmed our anticipated changes in the future water availability. Further, efforts are underway to simulate a high resolution climate of the region using mesoscale climate model WRF to investigate the responsible driving forces for the anomalous observed cooling within the UIB.

Hence my recommendation is to be published after revision.

Minor comments:

3. Figure 1-2, I suggest unify the formats of figure 1 and figure 2. For example, the use of North Arrow, Scale bar, ranges of latitude and longitude, font size, markers for the same theme such as Discharge Stations and Rivers, should be unified in these figures. The ticks should be displayed either inside (or outside) of the dataframe. I also suggest not show the major division ticks for axes which have not been labeled, e.g., the left and bottom axes in the dataframe.

   Formats of the Figures 1 and 2 have been made same accordingly.

4. Figure 9-10, missing the "37.0" in y-label for DTR. Try to unify the scale of y-axis in Figure 9 and Figure 10. Even in Figure 10, the y-labels are the same for all subplot, but the scales are a little bit different, e.g., the subplot for DTR.

   In response to comment #6 of the Reviewer #3, Figures 9-11 have been removed from the revised manuscript.

5. Figure 9-11, the units of trends should be oC/yr or mm/yr, please specify them in these figures.
   In response to comment #6 of the Reviewer #3, Figures 9-11 have been removed from the revised manuscript.

REVIEWER # 5

We thank the reviewer for his precious time for reviewing our manuscript and for his/her invaluable comments and suggestions, which have significantly improved the revised manuscript.

1. Paper analyses trends in precipitation, temperature and runoff in the Upper Indus Basin (UIB). There have been a number of previous studies focusing on trends in this context, but the main novelty of this paper is in calculating trends using high elevation automatic weather station (AWS) data. However, given that data for these stations are only available for 1995-2012, the trend analysis is conducted for a relatively short period (although this is compared with longer-term trends from lower elevation stations). My main concern is whether trend analysis is meaningful and justified for these short record period data, even if the focus is stated as "prevailing climatic conditions" rather than longer-term trends. This is a critical issue for the paper, as all of the results are dependent on the robustness of the trend analysis. The methods employed for trend analysis are standard (non-parametric Mann-Kendall test, Sen's slope and pre-whitening), but the practical significance of the results may be limited by the time series length.

   We agree with the reviewer's concern. However, as pointed out by the reviewer himself, multiple measures have been taken while testing the robustness of detecting the trends from a short times series that include: selection of the trend detection test; comparison of high-altitude station trends with long-term trends over 1961-2012 period and with their previously reported findings for selected periods; assessing the field significance of local trends that implicitly shows which regions are most likely effected by sparse and short observational data; and then comparison with the discharge tendencies; and also with the reports of consistent changes in the hydro-cryosphere for the regions of least data availability like eastern Karakoram. From all these distinct measures, cooling within the monsoon months that coincides with the main glacier melt season and warming within spring to pre-monsoon months that coincides with the main snowmelt season are widely apparent and their existence at least on a qualitative scale cannot be ruled out for prevailing hydroclimatic scenario. It is to mention that efforts to further update the high-altitude stations time series are underway since the first submission of the manuscript, indicating that the hydroclimatic research over the study region is not only hindered by the availability of the in-situ observations but equally by their accessibility too. Kindly see our response to comment #1 of Reviewer #4.

   In addition, the authors divide the UIB into sub-regions for testing the field significance of calculated trends. While this may be a potentially new approach in the UIB context, one of the difficulties with it is the relatively small number of stations (18) with which to estimate statistical field significance in such a complex setting (even with a bootstrapping method). This is particularly so given that some of the sub-regions contain very few stations (minimum 2?). Plotting the stations on Figure 2 or tabulating the number of stations in each sub-region would make this more transparent.

   We completely agree with the reviewer's concern. It is to clarify that the field significance as per its theoretical basis requires minimum of 2 stations to suggest the statistical robustness. Nevertheless, in view of the on-ground reality of large sub-basin extents and sparse observational network within the complex terrain, the field significance has been employed only as one of the many measures to obtain the robust signal of change. The rest of measures include comparison of: observed discharge tendencies with the field significant climatic trends; to consistent hydro-cryospheric changes reported earlier; to the long-term trends ascertained in the study and those reported earlier. Yet, robust signal is found only for few months when statistical significance is well complemented by the practical relevance, such as, July/September cooling (March/May warming) and subsequent decreasing or weakly rising (increasing) discharges during main glacier (snow) melt seasons for almost all sub-regions. Kindly also see our response to comment #1 and comment # 1 of Reviewer #4. All the hydrometric stations analyzed for field significance are plotted in the Figure 2 as suggested and were already given in the last column of the Table 1.

2. Description of the methods could probably be clearer and more carefully written. For example, it might be useful to explain briefly the bootstrap resampling approach rather than just provide a reference. Not all of the symbols used in the equations seem to be defined in the text (e.g. theta in Equation 2, t in Equation 6 – all should be checked). Equation 12 might also be clearer if split in two.

   We agree with the reviewer to briefly explain the resampling approach. However, in view of the much-needed shortening of the manuscript length and in response to comment #1 of Reviewer #3 who suggested otherwise, further explanation on already published/established approach is not included in the revised manuscript. Instead, formulations of the well-known Mann-Kendall and Sen's slope methods have been removed in the revised manuscript due to similar concerns.

3. While a range of plausible explanations for the estimated trends are presented, the discussion and interpretation of results could be a little more carefully presented. Some trends may be consistent with mechanisms and processes that have been put forward in the literature, but the manuscript reads a bit too definitively in parts (with quite a lot of assertion). The level of interpretation does not feel consistently justified by the results. Explaining recent historical changes in terms of climate model projections for the future also seems ambitious. The discussion section could therefore benefit from adjusting its emphasis and tone to be less conclusive. Along the same lines, the conclusions on trends reached in the paper should be more clearly stated in the conclusions section, with less emphasis on interpretation in terms of processes here.

   The Discussion section has been carefully revised accordingly and climate models' projections have been removed. Conclusion section is rewritten pointing out main findings and their practical relevance.

   The overall presentation and structure is clear, but the manuscript still seems long and might benefit from transferring some of the detail to the supplementary material. For example, there are long descriptions of delineation of the UIB catchment boundary and data sources where some of the detail could be moved out of the main text. The introduction and results section could be shorter and more focused. The standard of English in the manuscript should be improved further (it is reasonable overall but not fluent in all parts).

   We fully agree with the Reviewer. The description of the UIB delineation from the forthcoming manuscript was included for addressing the major objections indecently raised by the Reviewers # 1 and #2 on how authors have delineated the UIB boundary. Therefore, it is sought that the details on the UIB delineation that seem irrelevant here to be included in the manuscript dedicated to such topic. The rest of manuscript has gone through text brevity, clarity and filtering out irrelevant details, avoiding any significant loss of information. Overall the length of the manuscript has been reduced by one-third.

4. Some improvements to the tables are needed. Latitude and longitude seem to be the wrong way around in Table 2. The latitude and longitude of gauging stations should be quoted to a lower number of decimal places in Table 3. Tables 4 to 7 are very large. It may be better to move the full results to supplementary material and synthesise the key findings in the main text. Also, the signs of the numbers do not always seem to agree with the colour coding as described in the captions (e.g. Table 4 caption says that blue means an increasing temperature trend, but the numbers coloured blue are negative). If gradational colour scales are to be used with the tables, I think more care and consistency is required (e.g. consistency between tables and more explanation of what is being shown).

   We are thankful to the reviewers for pointing these typo corrections. In Table 2, column headings of Latitude and Longitude are now rightly placed while their values are limited to two decimal places. Given that the Figures 9-11 have been removed in response to comments #6 of Reviewer #3, Tables 4 to 7 have been retained in the revised manuscript. Caption of Table 4 now correctly indicates the color coding while captions of other tables are made consistent.

5. The station names are difficult to read on Figure 1, and Figure 2 might benefit from showing (unlabelled) station locations to clarify how many stations are being used to determine field significance. Figure 8 requires a key to explain the size and colour of the symbols (and ideally some spatial reference, e.g. UIB sub-regions or rivers). Overall, I am concerned that trend analysis and field significance tests are inappropriate given the record periods and number of stations available. The analysis and interpretation may be beyond what is justifiable for the dataset.

   The Figure 1 has been revised that now more clearly shows the station names. Unlabeled stations are plotted on the Figure 2 in order to clarify that the field significance is determined based on how many number of stations, as already had been mentioned in the last column of the Table 1. Legend and UIB sub-regions have been added to the Figure 8 as suggested. Regarding the short length of the observations and/or little number of available stations, kindly see our response to comments #1 and #2 and to comments #1 of reviewer #4.

6. line 353: <typo> "DTR - Tx - Tn" should read "DTR = Tx - Tn"

   The expression has been corrected on line 239 of the revised manuscript.

7. lines 785-791 & 842-852: While the increase in (late) summer precipitation reported by the authors is not disputed, its attribution to monsoonal weatherly systems rather than westerly disturbances, other than aligning with theoretical future circulation changes, seems to be conjecture rather than substantiated. In effect, the additional summer precipitation at high elevation/latitude stations could be a result of greater (than previous historical period) penetration of westerly systems due to weakening/southerly position of the monsoon which structurally is more generally a lower altitude system. Furthermore the teleconnections cited,

particularly NAO, have been principally associated with variability of westerly disturbances rather than monsoonal circulation.

We fully agree with the reviewer as studies so far has only anticipated the enhanced influence of the monsoonal offshoots within the Karakoram, which needs to be confirmed by concrete analysis. Against this background, we have revised our discussion on lines 494-501 and 532-535.

REFERENCES

Hasson, S.: Future Water Availability from Hindukush-Karakoram-Himalaya upper Indus Basin under Conflicting Climate Change Scenarios. Climate. 26;4(3):40, 2016.

Prevailing climatic trends and runoff response from Hindukush-Karakoram-Himalaya, upper Indus basin

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Abstract

Largely depending on the meltwater from the Hindukush-Karakoram-Himalaya, withdrawals from the upper Indus basin (UIB) contribute ~~to~~ half of the surface water availability in Pakistan, indispensable for agricultural production systems, industrial and domestic use and hydropower generation. Despite such importance, a comprehensive assessment of prevailing state of relevant climatic variables determining the water availability is largely missing. Against this background, ~~we present a comprehensive hydroclimatic trend analysis over~~this study assesses the ~~UIB. We analyze~~ trends in maximum, minimum and mean temperatures ~~(Tx, Tn, and Tavg, respectively),~~, diurnal temperature range ~~(DTR)~~ and precipitation from 18 stations (1250-4500 ~~m asl~~masl) for their overlapping period of record (1995-2012), and separately, from six stations of their long-term record (1961-2012). ~~We apply~~For this, Mann-Kendall test on serially independent time series is applied to ~~assess~~detect the existence of a trend while its true slope is estimated using the Sen's slope method. Further, ~~we~~locally identified climatic trends are statistically ~~assess the~~ assessed for their spatial scale ~~(field)~~ significance ~~of local climatic trends~~ within ten identified sub-regions of the UIB, and ~~analyze whether~~the spatially (field) significant ~~(field significant)~~ climatic trends are then qualitatively ~~agree~~compared with ~~a trend~~the trends in discharge out of corresponding sub-regions. Over the recent period (1995-2012), we find a well agreed ~~and mostly field significant cooling (~~warming~~) during monsoon season i.e. July-October (March-May and November), which is~~

~~higher in magnitude relative to long term trends (1961-2012). We also find a general cooling in Tx and a mixed response of Tavg during winter season as well as a year round decrease in DTR, which is stronger and more significant at high altitude stations (above 2200 m asl), and mostly due to higher cooling in Tx than in Tn. Moreover, we find a field significant decrease (increase) in late-monsoonal precipitation for lower (higher) latitudinal regions of Himalayas (Karakoram and Hindukush), whereas an increase in winter precipitation for Hindukush, western- and whole Karakoram, UIB-Central, UIB-West, UIB-West-upper and whole UIB regions. We find a spring warming (field significant in March)~~ and drying ~~(except for Karakoram and its sub-regions), and subsequent rise in~~of spring season (field significant in March) and a rising early-melt season ~~flows. Such early melt response together with effective cooling during monsoon period subsequently resulted in a substantial drop (weaker increase) in~~ discharge ~~out~~from most of the sub-regions, likely due to a rapid snowmelt. In stark contrast, most of ~~higher (lower) latitudinal regions (Himalaya and UIB-West-lower) during late-melt season,~~ the sub-regions feature a field significant cooling within the monsoon period (particularly ~~during July. The~~ in July and September), which coincides well with the main glacier melt season. Hence, a falling or weakly rising discharge is observed ~~hydroclimatic trends~~from the corresponding sub-regions during mid-to-late melt season (particularly in July). Such tendencies, being ~~driven by certain changes in the monsoonal system and westerly disturbances,~~largely consistent with the long-term trends (1961-2012), most likely indicate dominance ~~(~~of the nival but suppression~~)~~ of ~~nival (~~the glacial~~) runoff~~ melt regime, altering ~~substantially the~~ overall hydrology of the UIB in future. These findings, though constrained by sparse and short observations, largely contribute ~~to~~in understanding the UIB melt runoff dynamics and address the hydroclimatic explanation of the 'Karakoram Anomaly'.

1 Introduction

The hydropower generation has key importance in minimizing the on-going energy crisis in Pakistan and meeting the country's burgeoning future energy demands. ~~In~~For this~~ regard~~, seasonal water availability from the upper Indus basin (UIB) that contributes to around half of the annual average surface water availability in Pakistan is indispensable for exploiting 3500 MW of installed hydropower potential at country's largest Tarbela reservoir immediate downstream. ~~This~~Withdrawals from the UIB further ~~contributes~~contribute to the country's agrarian economy by meeting extensive irrigation water demands. The earliest water supply from the UIB after a long dry period (October to March) is obtained from melting of snow (late-May to late-July), the extent of which largely depends upon the accumulated snow amount and the concurrent temperatures (Fowler and Archer, 2005; Hasson et al., 2014b). Snowmelt runoff is then overlapped by the glacier melt runoff (late-June to late-August~~),~~) that primarily ~~depending~~depends upon the melt season temperatures (Archer, 2003). Snow and glacier melt runoffs, originating from the Hindukush-Karakoram-Himalaya (HKH) Ranges, together constitute around 70-80% of the mean annual water available from the UIB (SIHP, 1997; ~~Mukhopadhyay and Khan, 2015;~~ Immerzeel et al., 2009). ~~As opposed to large~~Unlike major river basins of the South and Southeast Asia~~, which~~ that feature extensive summer monsoonal wet regimes downstream, the lower Indus basin is mostly arid and hyper-arid and much relies upon the meltwater from the UIB (Hasson et al., 2014b).

~~Climate change is unequivocal and increasingly serious concern due to its apparent recent acceleration. For instance, the last three decades have been the warmest at a global scale since 1850, while the period of 1983-2012 in the Northern Hemisphere has been estimated as the warmest since last 1400 years (IPCC, 2013). The global warming signal, however, is spatially heterogeneous and not necessarily equally significant across different regions (Yue and Hashino, 2003; Falvey and Garreaud, 2009). Similarly, local impacts of the regionally varying climate change can differ substantially, depending upon the local adaptive capacity, exposure and resilience (Salik et al., 2015), particularly for the sectors of water, food and energy security. In view of high sensitivity of mountainous environments to climate change~~In view of high sensitivity of the mountainous environments to climate change (MRI, 2015; Hasson et al., 2016d) and the role of meltwater as an important control for the UIB runoff dynamics, it is crucial to assess the prevailing climatic state ~~over~~of the UIB and the subsequent water availability. Several studies have been performed in this regard. For ~~example~~instance, Archer and Fowler (2004) have ~~analyzed trends in precipitation from four stations within the UIB and~~ found a significant increase in winter, summer and annual precipitation ~~during~~over the period 1961-1999. ~~By analyzing temperature trends~~ For the same period, Fowler and Archer (2006) have found a significant cooling ~~in~~during summer ~~and~~but warming ~~in~~during winter. Sheikh et al. (2009) have documented ~~a~~ significant cooling ~~of mean temperatures during~~ and wetting of the monsoon ~~period~~ (July-September~~), and consistent~~) but warming ~~during~~of the pre-~~monsoonal months~~monsoon season (April-May) ~~for~~over the ~~period~~ 1951-2000~~. They have found a significant increase in monsoonal precipitation while non-~~

~~significant changes for the rest of year~~ period. Khattak et al. (2011) have found winter warming, summer cooling (1967-2005), but no definite pattern for precipitation. It is noteworthy that ~~reports from the above mentioned studies~~these findings are based upon at least a decade old data records. Analyzing updated data for the last three decades (1980-2009), Bocchiola and Diolaiuti (2013) have suggested that winter warming and summer cooling ~~trends~~ are less general than previously thought, and can be clearly assessed only for Gilgit and Bunji stations~~, respectively. For~~. They have found mostly insignificant precipitation~~, they found an~~ increase over the Chitral-Hindukush and northwest Karakoram ~~regions and~~while decrease over the Greater Himalayas~~ within the UIB, though most of such precipitation changes are statistically insignificant. By~~. Analyzing temperature record for ~~the period~~ recent six decades (1952-2009~~,~~), Río et al. (2013) have also reported dominant warming during March and pre-~~monsoonal period, consistent with findings of Sheikh et al. (2009).~~monsoon season.

The above mentioned studies have analyzed observations from only a sub-set of half dozen manual, valley-bottom, low-altitude UIB stations, being maintained by the Pakistan Meteorological Department (PMD~~) within the UIB (Hasson et al., 2014b).~~). Contrary to ~~these~~ low-altitude stations, observations from high-altitude stations in the South Asia mostly feature opposite sign of climatic changes and extremes, possibly influenced by the local factors (Revadekar et al., 2013). Moreover, the bulk of the UIB ~~streamflow~~stream flow originates from the active hydrologic zone (2500-5500 ~~m asl~~masl), when thawing temperatures migrate over and above 2500 ~~m asl~~masl (SIHP, 1997). ~~In view of~~Given such a large altitudinal dependency of the climatic signals, data from the low-altitude stations, though extending back into the first half of 20th century, are not optimally representative of the hydro-meteorological conditions prevailing over the UIB frozen water resources (SIHP, 1997). Thus, ~~an~~the assessment of climatic trends over the UIB has been much restricted by the limited availability of high-altitude and most representative observations as well as their accessibility, so far.

~~Amid~~ Above mentioned studies~~,~~ of Archer and Fowler (2004), Fowler and Archer (2006) and Sheikh et al. (2009) have used linear least square method for trend analysis. ~~Though~~ Such parametric tests ~~more~~though robustly assess the ~~existence of a~~ trend ~~as compared~~relative to non-parametric ~~trend~~ tests (Zhai et al., 2005), ~~they~~but need the sample data to be normally distributed, which is not always the case for hydro-meteorological observations (Hess et al., 2001~~; Khattak et al., 2011). In this regard~~). Hence, a widely adopted non-parametric test, such as, Mann Kendall (MK - Mann, 1945; Kendall, 1975) is ~~a~~more pragmatic choice, ~~which has been extensively adopted for the hydro-climatic trend analysis (Kumar et al., 2009 and 2013). The above mentioned studies of Khattak et al.~~as employed by Khattak et al. (2011), Río et al. (2013) and Bocchiola and Diolaiuti (2013~~) have used MK test in order to confirm the existence of a trend along with Theil-Sen (TS – Theil, 1950; Sen, 1968) slope method to estimate true slope of a trend.~~).

Most of the hydro-climatic time series contain red noise because of the characteristics of natural climate variability, and thus, are not serially independent (Zhang et al., 2000; ~~Yue et al., 2002 & 2003;~~ Wang et al., 2008). ~~On the other hand~~However, MK ~~statistics~~statistic is highly sensitive to the serial dependence of a time series (Yue and Wang, 2002; Yue et al., 2002 & 2003~~; Khattak et al., 2011~~). For instance, the variance of MK statistic *S* increases (decreases) with the magnitude of significant positive (negative) auto-correlation of a time series, which leads to an overestimation (underestimation) of the trend detection probability (Douglas et al., 2000; ~~Yue et al., 2002 and 2003;~~ Wu et al., 2008; Rivard and Vigneault, 2009). To eliminate such ~~an effect~~affect, von Storch (1995) and Kulkarni and von Storch (1995) proposed a pre-whitening procedure that ~~suggests~~removes the ~~removal of a~~ lag-1 auto-correlation prior to applying the MK ~~-~~test~~.~~, as employed by Río et al. (2013) ~~have analyzed trends using pre-whitened (serially independent) time series. This~~amid the above cited studies. However, such procedure~~, however,~~ is particularly inefficient when a time series either features a trend or~~ it~~ is serially dependent negatively (Rivard and Vigneault, 2009). In fact, presence of a trend can lead to false detection of significant positive (negative) auto-correlation in a time series (Rivard and Vigneault, 2009), removing which through a pre-whitening ~~procedure~~ may remove (inflate) the portion of a trend, leading to ~~an~~the underestimation (overestimation) of trend detection probability and trend magnitude (Yue and Wang, 2002; Yue et al., 2003). ~~In order to address~~To avoid this~~ problem~~, Yue et al. (2002) ~~have~~ proposed a ~~modified pre-whitening procedure, which is called~~ trend free pre-whitening (TFPW~~). In TFPW, a~~) in which the trend component of a time series is separated ~~before the~~prior to pre-whitening ~~procedure is applied,~~ and ~~after the pre-whitening procedure,~~ then blended back to the resultant time series~~ is blended together with the pre-identified trend component for further application of the MK test.~~ , as adopted by Khattak et al. (2011~~) have applied TFPW to make time series serially independent before trends analysis. The TFPW method takes an advantage of the fact that estimating auto-correlation coefficient from a~~

~~detrended time series yields its more accurate magnitude for the pre-whitening procedure (Yue et al., 2002).~~). However, prior estimation of ~~a~~the trend may also be influenced by the presence of ~~a~~ serial correlation in a time series in a similar way the presence of ~~a~~ trend contaminates the estimates of ~~an~~ auto-correlation ~~coefficient~~ (Zhang et al., 2000). It is, therefore, desirable to estimate the most accurate magnitudes of both, trend and auto-correlation~~ coefficient~~, in order to avoid the influence of one on the other.

The UIB observes contrasting hydro-meteo-cryospheric regimes mainly because of the complex HKH terrain and sophisticated interaction of prevailing regional circulations (Hasson et al., 2014a and ~~2015a~~2016a). The sparse ~~(high and low altitude)~~ meteorological network in such~~ a~~ difficult area neither covers fully its vertical nor its horizontal extent - it may also be highly influenced by complex terrain features and variability of meteorological events. Under such scenario, tendencies ascertained from the observations at local sites further need to be assessed for their field significance. The field significance indicates whether the stations within a particular region collectively exhibit a significant trend or not, irrespective of the significance of individual trends (Vogel and Kroll, 1989; Lacombe and McCarteny, 2014). This yields a dominant signal of change and much clear understanding of what impacts the observed conflicting climate change will have on the overall hydrology of the UIB and of its sub-regions. However, ~~similar to~~alike sequentially dependent local time series, spatial-/cross-correlation amid the station network ~~within~~of a region, possibly present due to the influence of a common climatic phenomenon and/or of similar physio-geographical features (Yue and Wang, 2002), anomalously increases the probability of detecting the field significant trends (Yue et al., 2003; Lacombe and McCarteny, 2014). ~~Such~~Therefore, the effect of cross~~/spatial~~ correlation amid the station network ~~should~~needs to be eliminated while testing the field significance ~~as proposed by several studies~~ (Douglas et al., 2000; Yue and Wang, 2002; Yue et al., 2003~~)~~). Further, statistically identified field significant climatic trends should be verified against the physical evidence.

In this study, we present a first comprehensive and systematic ~~hydro-climatic~~ hydroclimatic trend analysis for the UIB based ~~upon~~on ten stream flow, six low-altitude manual and 12 high-altitude automatic weather stations. We apply ~~a widely used non-parametric~~the MK trend test over serially independent hydroclimatic time series~~, obtained through a pre-whitening procedure,~~ for ensuring the existence of a trend~~. The~~ while its true slope ~~of an existing trend~~ is estimated by the Sen's slope method. ~~In pre-whitening, we remove~~

negative/positive lag-1 autocorrelation that is optimally estimated through an iterative procedure, so that, pre-whitened time series feature the same trend as of original time series. Here, we investigate climatic trends on The monthly time scale in addition to seasonal and annual time scales, first in order to present a more comprehensive picture and secondly to circumvent the loss of intra-seasonal tendencies due to an averaging effect. For assessing the field significance of local climatic trends, we divide the UIB into ten regions, considering its diverse hydrologic regimes, HKH topographic divides and installed hydrometric station network. Such regions are Astore, Hindukush (Gilgit), western Karakoram (Hunza), Himalaya, Karakoram, UIB-Central, UIB-West, UIB-West-lower, UIB-West-upper and the UIB itself (Figs. 1-2). Provided particular region abodes more than one meteorological station, scale individual climatic trends within that region were testedare further assessed for their field significance based upon the number of positive/negative significant trends (Yue et al., 2003).within the ten identified sub-regions of the UIB, and in order to furnish the physical attribution to statistically identified regional signal of change, the field significant trends are in turn compared qualitatively with the trends of outletin discharge fromout of the corresponding regions, in order to furnish physical attribution to statistically identified regional signal of change. Our results, presenting prevailing state of the hydro-climatic trends over the HKH region within the UIB, contribute to the hydroclimatic explanation of the 'Karakoram Anomaly', provide right direction for the impact assessment and modelling studies, and serve as an important knowledge base for the water resource managers and policy makers in the region.

2 Upper Indus basin

The UIB is a unique region featuring complex HKH terrain, distinct physio-geographical features, conflicting signals of climate change and subsequently contrasting hydrological regimes (Archer, 2003; Fowler and Archer, 2006; Hasson et al., 2013).Spanning over the geographical range of 31-37^{o}E and 72-82^{o}N, the basin extendingextends from the western Tibetan Plateau in the east to the eastern Hindu Kush Range in the west hosts mainly , hosting the Karakoram Range in the north, and the western Himalayan massif (Greater Himalaya) in the south (Fig. 1). As summarized in Reggianni and Rientjes (2014) and Khan et al. (2014), the total drainage area of the UIB has long been overestimated by various studies (e.g. Immerzeel et al., 2009; Tahir, 2011; Bookhagen and Burbank, 2010). Such

~~overestimation is caused by limitations of the GIS-based automated watershed delineation procedure that results in erroneous inclusion of the Pangong Tso watershed (Khan et al., 2014), which instead is a closed basin (Huntington, 1906; Brown et al., 2003, Alford, 2011). Khan et al. (2014) have provided details about the delineation of the UIB based upon ASTER GDEM 30m and SRTM 90m DEMs. For this study, the UIB drainage area is estimated from the lately available 30 meter version of the SRTM DEM, which was forced to exclude the area connecting the UIB to the Pangong Tso watershed in order to avoid its erroneous inclusion by the applied automated delineation procedure. Details of the delineation procedure will be provided elsewhere. Our estimated area of the UIB at Besham Qila is around 165515 km^2, which is to a good approximation consistent with the actual estimates of 162393 km^2 as reported by the SWHP, WAPDA. According to the newly delineated basin boundary, the UIB is located within the geographical range of 31-37° E and 72-82° N.~~1). Around 46 % of the UIB falls within the political boundary of Pakistan, containing around 60% of the permanent cryospheric extent. Based on the Randolph Glacier Inventory version 5.0 (~~RGI5.0 –~~ Arendt et al., 2015), around 12% of the UIB area (19,370 km^2) is under the glacier cover. ~~While~~The snow cover ~~ranges~~varies from 3 to 67% of the basin area (Hasson et al., 2014b).

The hydrology of the UIB is dominated by the precipitation regime associated with the year-round mid-latitude western disturbances~~. These western disturbances are lower tropospheric extra-tropical cyclones, which are originated and/or reinforced over the Atlantic Ocean or the Mediterranean and Caspian Seas and transported over the UIB by the southern flank of the Atlantic and Mediterranean storm tracks (Hodges et al., 2003; Bengtsson et al., 2006). The western disturbances~~ that intermittently transport moisture ~~over the UIB mainly in solid form throughout the year, though their main contribution comes~~ mainly during winter and spring and mostly in the solid form (Wake, 1989; ~~Rees and Collins, 2006;~~ Ali et al., 2009; Hewitt, 2011; ~~Ridley et al., 2013;~~ Hasson et al., ~~2013 & 2015a~~2016a & 2016b). Such ~~contributions are~~moisture contribution is anomalously higher during the positive phase of the north Atlantic oscillation (NAO), when the southern flank of the western disturbances intensifies over Iran and Afghanistan because of heat low there, causing additional moisture input ~~to the region~~ from the Arabian Sea (Syed et al., 2006). ~~Similar positive precipitation anomaly is evident during warm phase of the El Niño Southern Oscillation (ENSO - Shaman and Tziperman, 2005; Syed et al., 2006). In addition to westerly precipitation, the UIB also~~The basin further receives ~~contribution~~moisture from the summer monsoonal offshoots, which crossing the main barrier of the Greater Himalayas (Wake, 1989; Ali et al., 2009~~; Hasson et al., 2015a~~), precipitate~~ moisture~~ over higher (lower) altitudes in solid (liquid) form (Archer and Fowler, 2004). Such occasional incursions of the monsoonal system and the dominating westerly disturbances~~, largely~~ -- further controlled by the complex HKH terrain~~,~~ -- define the contrasting ~~hydro-climatic~~hydroclimatic regimes within the UIB.

Mean annual precipitation within the ~~UIB~~basin ranges from less than 150 mm at Gilgit station to around 700 mm at Naltar station. ~~Lately, addressing precipitation uncertainty over the whole UIB, Immerzeel et al. (2015) have suggested the amount of precipitation more than twice as previously thought.~~However, the glaciological studies ~~also~~ suggest substantially large ~~amount~~amounts of snow ~~accumulation~~accumulations that account for 1200-1800 mm (Winiger et al., 2005) in the Bagrot valley and above 1000 mm over the Batura Glacier (Batura Investigation Group, 1979) within the western Karakoram~~, and~~. Within the central karakoram, such amounts account for more than 1000 mm, and~~,~~ at few sites, above 2000 mm over the Biafo and Hispar glaciers (Wake, 1987~~) within the central Karakoram.~~).

The Indus River and its tributaries are gauged at ten key locations within the UIB, dividing it into Astore, Gilgit, Hunza, Shigar and Shyok sub-basins ~~(Fig. 2). These basins~~that feature distinct hydrological regimes (snow- and glacier-fed). ~~Previous studies (~~Archer (2003~~;~~) and Mukhopadhyay and Khan~~,~~ (2015) have ~~separated~~identified snow-fed (glacier-fed) sub-basins ~~of the UIB~~based on ~~the basis of~~ their~~;~~: 1) smaller (larger) glacier ~~coverage,~~cover; 2) strong runoff correlation with previous winter precipitation (concurrent temperatures) from low-altitude stations, and~~,~~; 3) ~~using~~ hydrograph separation~~ technique. Based on such division,~~. Their findings suggest that Astore ~~(within the western Himalayan Range)~~ and Gilgit ~~(within the eastern Hindukush Range) are considered as~~are mainly snow-fed while Hunza, Shigar and Shyok ~~(within the Karakoram Range)~~ are ~~considered as~~ mainly glacier-fed sub-basins. The strong influence of climatic variables on the generated melt runoff ~~within and from the UIB~~ suggests high vulnerability of spatio-temporal water availability to climatic changes. This is why the UIB discharge features high variability – the maximum mean annual discharge is around an order of magnitude higher than its minimum mean annual discharge, in extreme cases. Mean annual UIB discharge ~~from the UIB~~ is around 2400 m^{3}s^{-1}, which ~~contributes to~~ contributing around 45% of the total surface water availability ~~within~~in Pakistan~~. Since the UIB discharge contribution is dominated by snow and glacier melt, it concentrates~~, mainly ~~within~~confines to the melt season (April~~—~~-September). ~~During~~For the rest of year, melting temperatures remain mostly below the active hydrologic elevation range, resulting in minute melt runoff (Archer, 2004). The characteristics of the UIB and its sub-basins are summarized in Table 1.

3 Data

3.1 Meteorological data

The network of meteorological stations within the UIB is very sparse and mainly limited to within the Pakistan's political ~~boundaries~~boundary, where~~ around~~ 20 meteorological stations are being operated by three different organizations. ~~The first network, operated by~~The PMD~~,~~ ~~consists of~~ operates six manual valley-~~based~~bottom (1200-2200 masl) stations that provide the only long-term ~~data series, generally starting from~~record since the first half of ~~the~~ 20th century~~. However,~~, however, the data before 1960 are scarce and feature large data gaps (Sheikh et al., 2009). ~~Such dataset covers a north-south extent of around 100 km from Gupis to Astore station and east-west extent of around 200 km from Skardu to Gupis station. These stations lie within the western Himalaya and Hindukush ranges and between the altitudinal range of 1200-2200 m asl, whereas most of the ice reserves of the Indus Basin lie within the Karakoram range (Hewitt, 2011) and above 2200 m asl (Fig. 1). In the central Karakoram,~~ EvK2-CNR ~~has installed~~maintains two ~~meteorological~~high-altitude stations ~~at higher elevations~~within the central Karakoram, which ~~however,~~ provide ~~time series~~data only since 2005. ~~Moreover, the precipitation gauges within PMD and EvK2-CNR networks measure only liquid precipitation, while the hydrology of the region is dominated by solid moisture melt.~~ The third meteorological network ~~within the UIB consists of 12 high altitude automatic weather stations, called Data Collection Platforms (DCPs), which are~~ being maintained by the Snow and Ice Hydrology Project (SIHP) of the Water and Power Development Authority (WAPDA~~. The DCP data is being observed at hourly intervals and is transferred to the central SIHP office in Lahore on a real time basis through a Meteor-Burst communication system. The data is subject to missing values due to rare technical problems, such as 'sensor not working' and/or 'data not received from broadcasting system'. Featuring higher~~), Pakistan consists of twelve high-altitude ~~range of~~ (1479-4440 ~~m asl, these DCP stations~~ masl) automated weather stations, called Data Collection Platforms (DCPs), which provide ~~meteorological~~ observations since 1994~~/95~~. Contrary to PMD and EvK2-CNR~~,~~ precipitation gauges~~ at~~, DCPs measure ~~both liquid and solid precipitation~~snow in mm water equivalent as solid moisture is the main source of melt dominated hydrology of the UIB (Hasson et al., 2014b). ~~Moreover, DCPs cover relatively larger spatial extent, such as, north south extent of 200 km from Deosai to Khunjrab stations and east-west extent of around 350 km from Hushe to Shendure stations. Thus, spreading well across the HKH ranges and~~ Moreover, extending to the Karakoram Range that hosts most of the Indus basin ice reserves (Fig. 1) and covering most of the active hydrologic zone~~, DCPs seem to be~~ of the UIB (2500-5500) -- unlike PMD stations -- DCPs are well representative of the ~~prevailing~~ hydro-meteorological conditions prevailing over the UIB cryosphere, so far. We have collected the daily data ~~for~~of maximum and minimum temperatures (Tx and Tn, respectively) and precipitation ~~of~~from 12 DCPs for the period 1995-2012 ~~from SIHP, WAPDA (Table 2). We have also collected the updated record of~~ and from six ~~low altitude stations from~~ PMD stations for ~~same set of variables within~~ the period 1961-2012~~.~~ (Table 2).

3.2 Discharge data

The daily discharge data~~, being highly sensitive to variations in precipitation, evaporation, basin storage and prevailing thermal regime, describe the overall hydrology and an integrated signal of hydrologic change for a particular watershed. In order to provide physical attribution to our statistically based field significant trend analysis, we~~ of all ten hydrometric stations within the UIB have been collected ~~the discharge data~~ from ~~SWHP,~~ the Surface Water Hydrology Project of WAPDA~~. The project maintains a network of hydrometric stations within~~, Pakistan~~. The upper Indus river flows are being measured first at Kharmong site where~~ for their full length of available record up to 2012 (Table 3). Among the ~~Indus river enters into Pakistan and then at various locations until it enters into the Tarbela reservoir. The river inflows measuring stations at Tarbela reservoir, and few kilometers above it, at the Besham Qila are usually considered to separate the upper part (i.e. UIB) from the rest of Indus basin. Five sub-basins are being gauged, among which~~installed hydrometric stations, Shigar gauge has not been operational since 2001. ~~Since we take the UIB extent up to the Besham Qila site, we have collected full length of discharge data up to 2012 for all ten hydrometric stations within the UIB (Table 3).~~ It is ~~pertinent~~ to mention ~~here~~ that discharge ~~data~~observations from the central and eastern ~~parts of the~~ UIB are hardly influenced by the anthropogenic perturbations. Though the western UIB is relatively populous and ~~streamflow~~the stream flow is used for the solo-seasoned crops and domestic use, ~~however,~~ the overall water diversion for such ~~a~~ use is ~~indeed~~ negligible (Khattak et al., 2011).

4 Methods

~~Inhomogeneity in a climatic time series is due to variations ascribed purely to non-climatic factors (Conrad and Pollak, 1950), such as, changes in the station site, station exposure, observational methods, and measuring instruments (Heino, 1994; Peterson et al., 1998). Archer and Fowler (2004) and Fowler and Archer (2005 and 2006) have documented that PMD and WAPDA follow standard meteorological measurement practice established in 1891 by the Indian Meteorological Department. Using double mass curve approach, they have found inhomogeneity in the winter minimum temperature around 1977 only at Bunji station among four low altitude stations analyzed. Since climatic patterns are highly influenced by orographic variations and local events within the study region of complex terrain, double mass curve techniques may yield limited skill. Forsythe et al. (2014) have reported homogeneity of Gilgit, Skardu and Astore stations for annual mean temperature during the period 1961-1990 while Río et al. (2013) have reported homogeneity for temperature records from Gilgit, Gupis, Chillas, Astore and Skardu stations during 1952-2009. Some studies (Khattak et al., 2011; Bocchiola and Diolaiuti, 2013) do not report quality control or homogeneity of the data used for their analysis.~~

We have ~~first investigated~~checked the internal consistency of the data by closely following Klein Tank et al. (2009) such as the situations of below zero precipitation and when maximum temperature was lower than minimum temperature, which found in few were ~~then~~ corrected. ~~Afterwards~~Then, we have performed homogeneity tests using a standardized toolkit RH-TestV3 (Wang and Feng, 2009) that uses a penalized maximal F-test (Wang et al., 2008) to identify any number of change points in a time series. As no station has yet been reported homogenous at monthly time scale for all variables, only ~~a~~ relative homogeneity test ~~is~~was performed by adopting ~~a~~the most conservative threshold level of 99% for the statistical significance. ~~We have found~~ Except Skardu, PMD stations mostly feature one inhomogeneity in only Tn ~~for the low altitude PMD stations during the period of record, except for Skardu station (Table 2). For~~, which over the 1995-2012 period~~, such inhomogeneity in Tn is only~~ is valid only for Gilgit and Gupis stations~~. On the other hand, data from~~ (Table 2). The DCP ~~stations~~data were found of high quality and homogenous. Only Naltar station has experienced inhomogeneity in Tn during September 2010, which was most probably caused by heavy precipitation event resulted in a mega flood in Pakistan (Houze et al., 2011; Ahmad et al., 2012~~; Hasson et al., 2013~~) followed by similar events ~~during~~in 2011 and 2012. Since ~~the~~ history files were not available, ~~we were~~it was not sure that any statistically found inhomogeneity only in Tn is real. ~~Therefore~~Thus, we did not apply ~~any correction~~corrections to inhomogeneous time series and caution the careful interpretation of results based on ~~such time series.~~ them.

4.1 Hydroclimatic trend analysis

We have analyzed trends in minimum, maximum and mean temperatures (Tn, Tx and Tavg, respectively), diurnal temperature range (DTR ~~-~~= Tx - Tn), precipitation and discharge on monthly to annual time scales. For this, the MK test (Mann, 1945; Kendall, 1975) is applied to assess the existence of a trend while the Theil-Sen (TS - Theil, 1950; Sen, 1968) slope method is applied to estimate its true slope~~ of a trend. For sake of intercomparison between low and high altitude stations, we mainly analyze overlapping length of record (1995-2012) from high and low altitude stations, and additionally, the full length of record (1961-2012) from low altitude stations.~~

~~**Mann-Kendall test**~~

. The MK is a ranked based method that tests the ~~significance~~existence of ~~an existing~~a trend irrespective of the type of sample data distribution and whether such trend is linear or not (~~Yue et al., 2002;~~ Wu et al., 2008; Tabari~~, H.,~~ and Talaee, 2011). ~~Such test~~MK is also insensitive to the data outliers and missing values (~~Khattak et al., 2011;~~ Bocchiola and Diolaiuti, 2013) and less sensitive to the breaks caused by inhomogeneous time series (Jaagus, 2006). ~~The null hypothesis of the MK test states that the sample data $\{X_i, i = 1,2,3 \ldots n\}$ is independent and identically distributed, while alternative hypothesis suggests the existence of a monotonic trend. The MK statistics S are estimated as follows:~~ For comparison between low- and high-altitude stations, we have mainly analyzed their overlapping period of record (1995-2012) but additionally the full period of record (1961-2012) for the low-altitude stations.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(X_j - X_i) \qquad (1)$$

~~Where X_j denotes the sequential data, n denotes the data length, and~~

$$sgn(\theta) = \begin{cases} 1 & if\ \theta > 0 \\ 0 & if\ \theta = 0 \\ -1 & if\ \theta < 0 \end{cases} \qquad (4.2)$$

provided n ≥ 10, S statistics are approximately normally distributed with the mean, E, and variance, V, (Mann, 1945; Kendall, 1975) as follows:

$$E(S) = 0 \quad (3)$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{m=1}^{n} t_m m(m-1)(2m+5)}{18} \quad (4)$$

Here, t_m denotes the number of ties of extent m, where tie refers to $X_j = X_i$. The standardized MK statistics, Z_s, can be computed as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{V(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{V(S)}} & S < 0 \end{cases} \quad (5)$$

The null hypothesis of no trend is rejected at a specified significance level, α, if $|Z_s| \geq Z_{\alpha/2}$, where $Z_{\alpha/2}$ refers to a critical value of standard normal distribution with a probability of exceedance $\alpha/2$. The positive sign of Z shows an increasing while its negative sign shows a decreasing trend. We have reported the statistical significance of identified trends at 90, 95 and 99% levels by taking α as 0.1, 0.05 and 0.01, respectively.

Theil-Sen's slope estimation

Provided that a time series features a trend, it can be roughly approximated by a linear regression as

$$Y_t = a + \beta t + \gamma_t \quad (6)$$

Where a is the intercept, β is the slope and γ_t is a noise process. Such estimates of β obtained through least square method are prone to gross errors and respective confidence intervals are sensitive to the type of parent distribution (Sen, 1968). We, therefore, have used Theil-Sen approach (TS - Theil, 1950; Sen, 1968) for estimating the true slope of existing trend as follows

$$\beta = Median\left(\frac{X_j - X_i}{j-i}\right), \forall\, i < j \quad (7)$$

The magnitude of β refers to mean change of a variable over the investigated time period, while a positive (negative) sign implies an increasing (decreasing) trend.

Trend-perceptive pre-whitening (TPPW)

~~To pre-whiten the time series, we have~~The used ~~an~~ approach of ~~von Storch (1995) as modified by~~ Zhang et al (2000~~). This approach iteratively computes trend and lag 1 auto-correlation until the solution converges to their most accurate estimates. This approach~~) assumes that the trend can be approximated as linear (Eqn. ~~6~~1) and the noise, γ_t, can be represented as~~ a~~ *p*th order auto-regressive process, AR(*p*) of the signal itself, plus the white noise, ε_t. Since the partial auto-correlations for lags larger than one are generally found insignificant (Zhang et al., 2000; Wang and Swail, 2001), considering only lag-1 auto-regressive processes, *r*, ~~yields~~transforms Eqn. ~~6~~1 into Eqn. 2:

$$Y_t = a + \beta t + \gamma_t \qquad (1)$$

$$Y_t = a + \beta t + rY_{t-1} + \varepsilon_t \qquad (~~8~~2)$$

~~The iterative pre-whitening procedure consists of~~Then the most accurate magnitudes of lag-1 auto-correlation and trend are iteratively found using the following steps:

1. In first iteration, ~~estimate of~~ lag-1 autocorrelation, r_1 is computed on the original time series, Y_t~~.~~
2. Using r_1 as $(Y_t - r.Y_{t-1})/(1-r)$, ~~an intermediately pre-whitened~~ intermediate time series, $\acute{Y}_t$, is obtained ~~on which first estimate of a~~ and its trend, β_1 ~~along with its significance~~ is computed using TS ~~(Theil, 1950; Sen, 1968)~~ and MK ~~(Mann, 1945; Kendall, 1975)~~ methods~~.~~
3. ~~The~~ Original time series, Y_t~~,~~ is detrended using $\beta_1$as ($\hat{Y}_t = Y_t - \beta_1 t$~~).~~)
4. In second iteration, ~~more accurate estimate of~~ lag-1 autocorrelation, r_2 is estimated on detrended time series, $\hat{Y}_t$~~, obtained from previous iteration.~~
5. ~~The~~ Original time series, Y_t~~,~~ is again ~~intermediately~~ pre-whitened using r_2 and $\acute{Y}_t$ is obtained~~.~~
6. ~~The trend estimate~~Trend, β_2 is then computed on $\acute{Y}_t$ ~~and the original time series,~~and Y_t is detrended again, yielding $\hat{Y}_t$~~.~~

The ~~procedure has~~steps have to be reiterated until r is no longer significantly different from zero or the absolute difference between the estimates of r, β obtained from ~~the~~ two consecutive iterations becomes less than one percent. If any of the condition is met, let's suppose at the iteration n, the estimates from ~~the~~ previous iteration (i.e. $r = r_{n-1}, \beta = \beta_{n-1}$) are ~~taken as final. Using these final estimates,~~used in Eqn. ~~9 yields~~3 to obtain a pre-whitened time series, Y_t^w~~,~~ which ~~is serially independent and~~ features the same trend as of the original time series, Y_t (Zhang et al., 2000; Wang and Swail, 2001). Finally, the MK test is applied over the pre-whitened time series, Y_t^w, to identify existence of a trend.

$$Y_t^w = \frac{(Y_t - r.Y_{t-1})}{(1-r)} = \hat{a} + \beta t + \epsilon_t \text{, where } \hat{a} = a + \frac{r.\beta}{(1-r)} \text{, and } \epsilon_t = \frac{\varepsilon_t}{(1-r)} \qquad (93)$$

4.23 Field significance and physical attribution

Field significance indicates whenimplies whether two or more stations within a particular region collectively exhibit a significant trend, irrespective of the significance of their individual trends (Vogel and Kroll, 1989; Lacombe and McCarteny, 2014). For assessing The field significance of local trends, we have dividedclimatic variables has been assessed for the whole UIB into further smaller units/ten sub-regions of the UIB identified based on: 1) distinct hydrological regimes identified within the UIB,; 2) mountain massifsdivides, and,; 3) available installed stream flow network. hydrometric stations. Further, statistically identified field significant climatic trends were qualitatively compared to the physically-based evidence of trend in discharge out of corresponding region, in order to establish more confidence. As outlet discharges describe the integrated signal of hydrologic change within the basin, testing their field significance was not required.

As mentioned earlier, Shigar discharge time series is limited to 1985-2001 period since afterwards the gauge went non-operational. In order to analyze discharge trend from such an important region, Mukhopadhyay and Khan (2014) have first correlated the Shigar discharge with discharge from its immediate downstream Kachura gauge for the overlapping period of record (1985-1998). Then, they have applied the estimated monthly correlation coefficients to the post-1998 discharge at Indus at Kachura. This particular method can yield the estimated Shigar discharge, of course assuming that the applied coefficients remain valid after the year 1998. However, in view of large surface area of more than 113,000 km^2 for Indus at Kachura and substantial changes expected in the hydroclimatic trends upstream Shigar gauge, the discharge estimated by Mukhopadhyay and Khan (2014) seems to be The Shigar has continuous discharge only till 1998 where its post-1998 discharge needs to be derived. For this, Mukhopadhyay and Khan (2014) have estimated the pre-1998 monthly correlation coefficients between Shigar and its immediate downstream Kachura gauge and applied these coefficients to the post-1998 Kachura discharge. However, such approach yields merely a constant fraction of the Kachura discharge, rather than the derived Shigar discharge. On the other hand as the applied coefficients are less likely to remain invariant after 1998, in view of the large drainage area of Indus at Kachura (113,000 km^2) and the hydroclimatic changes expected upstream Shigar gauge. Here, instead of estimating the post-1998 discharge at the Shigar gauge, we have derived the discharge for the Shigar-region~~, comprising~~ that comprises the Shigar sub-basin itself plus the adjacent region shown in blank in ~~the~~ Figure 2. This was achieved by subtracting the ~~mean~~ discharge rates of all gauges upstream Shigar gauge from its immediate downstream gauge of Kachura ~~gauge at~~, for each time step of every time scale analyzed. The procedure assumes that the gauges far from each other have negligible routing time delay at ~~a~~the analyzed mean monthly time scale and that such ~~an~~ approximation does not further influence the ascertained trends. Similar ~~methodology has been~~ approach was adopted to derive ~~discharge~~discharges out of ~~identified~~ ungauged ~~regions, such as, Karakoram, Himalaya, UIB-Central, UIB-West, UIB-West-lower and UIB-West-upper~~ identified sub-regions (Table 1).

We have considered the ~~Karakoram region as the~~combined drainage area of ~~Hunza and~~ Shyok ~~sub-basins~~and Shigar-region as UIB-Central and ~~Shigar-region, which are named as western, eastern and central Karakoram, respectively (Fig. 2). Similarly, we have considered~~the drainage area of Indus at Kharmong as UIB-East ~~while Shyok and Shigar-region together constitute UIB-Central.~~(Fig. 2). The rest of the UIB is ~~considered~~named as UIB-West (Fig. 2), which is further divided into upper and lower ~~regions, keeping in view relatively large number of stations and~~parts due to their distinct hydrological regimes. ~~Such distinct~~Here, these regimes ~~have been~~are identified based on the timings of maximum runoff production from the median hydrographs of each ~~steam flow gauging~~hydrometric station ~~based on maximum runoff production timings.~~. According to such division, UIB-West-lower and Gilgit are mainly the snow-fed ~~basins~~ while Hunza is mainly the glacier-fed ~~basin~~ (Fig. 3). Since the most of ~~the~~ Gilgit basin area lies at the Hindukush massifs, we call it Hindukush region. The combined area of ~~lower part of~~ UIB-West-lower and UIB-east ~~is~~ mainly contains the northward ~~slope~~slopes of the Greater Himalaya, so we call ~~this region as Himalaya.~~

~~We have analysed the field significance for those regions~~it Himalaya. Similarly, drainage areas of Hunza, Shyok and Shigar-region are named as western, eastern and central Karakoram, respectively, that ~~contain at least two or more stations. To eliminate~~collectively constitute the ~~effect~~Karakoram region.

For assessing the field significance, we have used the method of Yue et al. (2003), which preserves the cross~~/spatial~~ correlation amid ~~station network on assessing the field significance~~

of a particular region, Douglas et al. (2000) have proposed a bootstrap method. This method preserves the spatial correlation amid stationthe stations network but eliminates its influenceeffect on testing the fieldfiled significance based on MK statistics *S*. Similarly, Yue and Wang (2002) have proposed a regional average MK test in which they altered the variance of MK statistic by serial and cross correlations. Lately, Yue et al. (2003) proposed a variant of method proposed by Douglas et al. (2000), in which – instead of *S* – they consideredthrough resampling the original network using bootstrapping approach (Efron, 1979), in our case 1000 times. The method considers the counts of significant trends as the representative variables for testing the field significance. This method. Unlike MK statistics, *S* or its regional average (Douglas et al., 2000; Yue and Wang, 2002) 'counts' variable favourably provides a measure of dominant field significant trend when localboth positive orand negative significant trends are equal in number. Therefore, we have employed the method of Yue et al. (2003) for assessing the field significance. We have used a bootstrap approach (Efron, 1979) to resample the original network 1000 times in a way that the spatial correlation structure was preserved as described by Yue et al. (2003). We have countedpresent. The method counts both the number of local significant positive trends and the number of significant negative trends, separately for each of 1000 resampled network datasetnetworks using Eqn. 10:

$$C_f = \sum_{i=1}^{n} C_i \qquad (10)$$

Where n denotes total number of stations within a region and C_i denotes a count for statistically significant trend (at 90% level) at station, *i*. Then, we have obtained the empirical cumulative distributions C_f were obtained for both counts of significant positive trends and counts of significant negative trends, by ranking their corresponding 1000 values in an ascending order using Eqn.11:

$$P\left(C_f \le C_f^r\right) = \frac{r}{N+1} \qquad (11)$$

Where r is the rank of C_f^r and N denotes the total number of resampled network datasets. We have estimated the probability of the numbercounts of significant positive (negative) trends in actual network by comparing the number with C_f for counts of significant positive (negative) trends obtained from resampled networks (Eqn. 12).

$$P_{obs} = P\left(C_{f,obs} \le C_f^r\right),\ where\ P_f = \begin{cases} P_{obs} & for\ P_{obs} \le 0.5 \\ 1 - P_{obs} & for\ P_{obs} > 0.5 \end{cases} \qquad (12)$$

If expression, $P_f \leq 0.1$, is satisfied the trend overfor a region is considered to be field significant at the 90% level.

The statistically assessed field significance of tendencies in meteorological variables is further validated against the physically-based evidence from the stream flow record. For this, we have compared the field significant climatic (mainly temperature) trend of a region with its stream flow trends (from installed and derived gauges). The qualitative agreement between the two can serve better in understanding the ongoing state of climatic changes over the UIB. Since most downstream gauge of Besham Qila integrates variability of all upstream gauges, it represents the dominant signal of change. Thus, an assessment of statistically based field significance was not required for the stream flow dataset.

We also assess the dependency of local hydroclimatic trends on their latitudinal, longitudinal and altitudinal distribution. We have intentionally avoided the interpolation of data and results in view of the limitations of the interpolation techniques in aHKH complex terrain of HKH region (Palazzi et al., 2013; Hasson et al., 2015a).. Large offset of glaciological reportsestimates from the station-based estimates of precipitation amounts (Hasson et al., 2014b) further suggests that hydro climatic the hydroclimatic patterns are highly variable in space and that the interpolation of data will further add to uncertainty, resulting in misleading conclusions.

5 Results

We present our trend analysis Results for the 1995-2012 period are presented in Tabular Figures 4-5 (and for the select time scalesmonths, in Fig. 4) while Tabular Figure 6 presents results for the 1961-2012 period in Tabular Figure 6. The. Field significant trends in climatic variables and trends in discharge from thetrends of corresponding regions are presentedgiven in Tabular Figure 7.

5.1 Hydroclimatic trends

Mean maximum temperature

During months of March, May and November, most of the stations suggest mostly insignificant warming, which in terms of magnitude and significance, dominates during March and at the low-altitude stations (Tabular Fig. 4 and Fig. 8). For Tx, we find that certain set of months exhibit a common response of cooling and warming within the annual course of time. Set of these months interestingly are different than those typically considered for seasons, such as, DJF, MAM, JJA, SON for winter, spring, summer and autumn, respectively (Fowler and Archer, 2005 and 2006; Khattak et al., 2011; Bocchiola and Diolaiuti, 2013). For the months of December, January, February and April, stations show a mixed response of cooling and warming tendencies by roughly equal numbers where cooling trend for Rattu in January, for Shendure in February and for Ramma in April are statistically significant (Tabular Fig. In contrast, during the monsoon (July-October) and in February, most of the stations suggest cooling, which being similar in magnitude amid low- and high-altitude stations, dominates in September followed by in July in terms of both magnitude and statistical significance (at 12 and 5 stations, respectively). Moreover, the observed cooling dominates the observed warming. For the rest of the months, there is a mixed response of mostly insignificant cooling and warming trends. On a typical seasonal scale, there is a high agreement on spring warming, summer and autumn cooling but a mixed response for winter and annual timescales.

4 and Fig. 8). Though no warming trend has been found to be statistically significant, all low altitude stations, except Gupis, exhibit a warming trend in the month of January. During months of March, May and November, most of the stations exhibit a warming trend, which is statistically significant at five stations (Gilgit, Yasin, Astore, Chillas and Gupis) and relatively higher in magnitude during March. Interestingly, warming tendencies during March are relatively higher in magnitude at low altitude stations as compared to high altitude stations. Most of the stations feature cooling tendencies during July October (mainly the monsoon period). During such period, we find a statistically significant cooling at five stations (Dainyor, Shendure, Chillas, Gilgit and Skardu) in July, at two stations (Shendure and Gilgit) in August and at twelve stations (Hushe, Naltar, Ramma, Shendure, Ushkore, Yasin, Ziarat, Astore, Bunji, Chillas, Gilgit and Skardu) in September, while there is no significant cooling tendency in October (Tabular Fig. 4 and Fig. 8). Such cooling is almost similar in magnitude from low and high altitude stations and dominates during month of September followed by July because of higher magnitude and statistical significance agreed among large number of stations. Overall, we note that cooling trends dominate over the warming trends. On a typical seasonal scale, winter season generally shows a mixed behavior (cooling/warming) where only two stations (Dainyor and Rattu) suggest significant cooling. For the spring season, there is a high agreement for warming tendencies among the stations,

~~which are significant only at Astore station. Again such warming tendencies during spring are relatively higher in magnitude than those at higher altitude stations. For summer and autumn, most of the stations feature cooling tendencies, which are significant for three stations (Ramma, Shendure and Shigar) in summer and for two stations (Gilgit and Skardu) in autumn. On annual time scale, high altitude stations within Astore basin (Ramma and Rattu) feature significant cooling trend.~~

While looking only at long-term trends (Tabular Fig. 6), we note that summer cooling (warming outside summer) in Tx is less (more) prominent and insignificant (significant) at ~~stations of~~ relatively high~~ (low) elevation~~-altitude stations, such as, Skardu, Gupis, Gilgit and Astore~~ (Bunji and Chillas). The absence of a strong long-term winter warming contrasts~~. When compared with ~~what found for~~trends over the shorter period of 1995-2012~~. In fact~~, strong long-term warming is restricted to spring ~~season~~months mainly during March and May ~~months~~. Similarly, long-term summer cooling period of June-~~October~~September has been ~~shortened~~shifted to July-October.

Mean minimum temperature

The dominant feature of Tn is ~~the robust winter warming in Tn during~~ November-June insignificant warming, which ~~is found for most of the stations (Tabular Fig. 4 and Fig. 8).~~ contrary to warming in Tx, ~~warming trend in Tn~~ is observed higher ~~in magnitude among~~at the high-altitude stations than ~~among~~at the low-altitude stations (Tabular Fig. 4 and Fig. 8). ~~altitude stations. During the period of July-October, we found a significant cooling of Tn at four stations (Gilgit, Naltar, Shendure and Ziarat) in July, at eight stations (Hushe, Naltar, Ushkore, Yasin, Ziarat, Astore, Chillas and Gilgit) in September and only at Skardu in October.~~ In contrast to August~~, stations show~~ cooling in Tx, stations suggest a minute and mostly insignificant warming in Tn. In contrast to mostly insignificant warming~~ tendencies, which are relatively small in magnitude and only significant at Gilgit station. Similar to Tx, ~~, we have also found cooling in Tn during ~~July-October dominates during the month of September suggesting a relatively higher magnitude and larger number of significant trends (Fig. 8). Also, such cooling features more or less~~months of July, September and October, which though similar in magnitude ~~of a trend among~~amid low- and high~~ and low~~-altitude stations, dominates in September followed by in July (significant at 8 and 4 stations, respectively) as ~~for Tx. Similarly, cooling trends in Tn mostly dominate~~ well as over the general Tn warming~~ trends as in case of~~, alike Tx.

On a typical seasonal scale, our results suggest warming during winter and spring~~ seasons feature warming trends, while ~~, cooling during summer ~~season exhibit cooling trend and there is~~and a mixed response for the autumn season. ~~Warming trend ~~The observed warming dominates during ~~the ~~spring~~ season. Here, we emphasize~~. It is noted that a clear signal of significant ~~cooling in ~~September cooling has been lost ~~while averaging it into~~when trend has been assessed on seasonally averaged observations for autumn (combining October and November months~~ for autumn season.~~). This is further notable from the annual time scale, on which ~~a ~~warming ~~trend is generally dominated that is statistically ~~trends (significant at ~~five~~5 stations~~ (Deosai, Khunjrab, Yasin, Ziarat and Gilgit). The only significant~~) dominate instead of cooling ~~trend on annual time scale is observed at Skardu station~~trends.

While looking only at low-altitude stations (Tabular Fig. 6), we note that long-term non-summer warming (summer cooling) in Tn is less (more) prominent and insignificant (significant) at stations of relatively high~~ (low) elevation ~~altitude, such as, Skardu, Gupis, Gilgit and Astore~~ (Bunji and Chillas). ~~. The long-term warming of winter months is mostly absent over the period 1995-2012.

Mean temperature

Trends in Tavg are dominated by trends in Tx during the July-October ~~while these are dominated ~~period and by Tn~~,~~ during the rest of year (Tabular Figs. 4-5). Similar to Tx, ~~the~~ Tavg features ~~a ~~dominant cooling in September, followed by in July and October (significant ~~cooling in July ~~at ~~four~~10, 4 and 1 stations~~ (Dainyor, Naltar, Chillas and Skardu), in September at ten stations (Hushe, Naltar, Rama, Shendure, Ushkore, Yasin, Ziarat, Astore, Chillas and Skardu) and in October only at Skardu station (~~, respectively). In contrast, warming dominates in March, which is significant at five stations. Additionally, insignificant warming tendencies observed in May and November are well agreed amid most of the stations (Tabular Fig. 5~~ and~~, Fig. 8). ~~In contrast, we have observed a significant warming at Ziarat station in February, at five stations (Deosai, Dainyor, Yasin, Astore and Gupis) in March and at three stations (Khunjrab, Gilgit and Skardu) in November. However, the trend analysis on ~~On a typical seasonal ~~averages suggests warming ~~timescale, the magnitude of winter and spring ~~seasons, which is higher in magnitude as compared to the ~~warming is observed ~~cooling in ~~higher than that of summer and autumn ~~seasons. This specific fact has led~~cooling, leading to ~~a ~~dominant though mostly insignificant warming ~~trend by most of the station at~~on annual ~~time scale, which is higher in magnitude at high altitude stations, mainly~~

~~due to their dominated winter warming as compared to low altitude stations (Shrestha et al., 1999; Liu and Chen, 2000).~~

timescale. The long-term trends generally suggest cooling tendencies ~~during~~for the ~~July~~Jun-October ~~while~~period but warming for the rest of year. On a seasonal ~~scale~~timescale, low-altitude stations unanimously ~~exhibit~~agree on long-term and mostly significant summer cooling ~~over the long term record, which is mostly significant.~~. For the annual timescale, a mixed response is ~~shown for other time scales~~found.

Diurnal temperature range

~~For the~~ DTR~~, most of the stations show its drop~~ is generally found narrowing throughout ~~a~~the year except ~~during months of~~for March and May, where particularly low-altitude stations ~~show~~suggest its ~~increase mainly due~~widening either owing to higher Tx warming ~~in Tx than in Tn~~ or higher Tn cooling ~~in Tn than in Tx~~ (Tabular Fig. 4 ~~and~~, Fig. 8). ~~Two stations (Chillas and Skardu) show a significant widening of DTR in May, followed by Chillas station in March, Deosai in August and Gupis in October months. Conversely, we observe~~With high inter-station agreement, narrowing of DTR is particularly significant ~~DTR decrease~~ in September followed by in February~~. Such a trend is~~ and associated with ~~the~~ higher ~~magnitude of~~ cooling in Tx than in Tn ~~(e.g. in September), cooling in Tx but warming in Tn or~~, higher warming in Tn than in Tx ~~(e.g. in February).~~or cooling in Tx but warming in Tn. Narrowing DTR is more prominent at high-altitude stations and during winter, autumn and annual timescales. We note that the long-term ~~trends of increasing DTR throughout a~~(1961-2012) year~~-from~~-round DTR widening observed at low-altitude stations (Tabular Fig. 6) ~~are now~~is mainly restricted to ~~the period~~ March~~-May,~~ and ~~within the months of~~May, and to some extent, October and December over the period 1995-2012~~. Within the rest of year, DTR has been decreasing since last two decades. Overall, high altitude stations exhibit though less strong but a robust pattern of year round significant decrease in DTR as compared to low altitude stations.~~ (Tabular Fig. 4).

Total precipitation

~~We find that most of the stations show a clear signal of dryness during the period~~ Generally, March-June~~, which is either relatively higher or similar at high altitude station than at low altitude stations (Table 5 and Fig. 4). During such period, significant drying is revealed by seven stations (Deosai, Dainyor, Yasin, Astore, Chillas, Gupis and Khunjrab) in March, by~~

~~five stations (Dainyor, Rattu, Astore, Bunji and Chillas) in April, by two stations (Dainyor and Rattu) in May and by four stations (Dainyor, Rama, Rattu and Shigar) in June. We have observed similar significant drying during August by three stations (Rattu, Shigar and Gupis) and during October by three stations (Rattu, Shendure and Yasin). The Rattu station features a consistent drying trend throughout a year except during the~~ months are featuring decreasing precipitation trends, which are significant at 7, 5, 2 and 4 stations, respectively (Tabular Fig. 5 and Fig. 8). ~~of~~ Similarly, significant drying is observed during August and October at three stations while Rattu station suggests year-round drying except in January and February ~~where basically a neutral behavior is observed. Stations feature high~~ . High inter-stations agreement is observed for ~~an increasing trend during winter season (December to February) and during the month of~~rising September~~, where such increase~~ and winter precipitation, which is higher ~~in magnitude~~ at high-altitude ~~stations as compared to~~than at low-altitude stations. ~~We note that~~ Most of the stations within the UIB-West-upper ~~region~~ (monsoon dominated region) exhibit an increasing trend. Six stations (Shendure, Yasin, Ziarat, Rattu, Shigar and Chillas ~~are stations featuring~~) feature significant ~~increasing trend~~ precipitation increase in either all or at least ~~in~~ one of the monsoon months. Such precise response of ~~increasing or decreasing trend at~~ monthly ~~scale is~~ wetting and drying has been averaged out on ~~a~~ seasonal ~~time scale, on which autumn and winter seasons show an~~to annual timescales, suggesting increase ~~while~~ (decrease) for autumn and winter (spring and summer ~~seasons show a decrease. Annual trends in precipitation show~~) but a mixed response ~~by roughly equal number of stations~~for annual precipitation.

~~From our~~ Comparison of ~~medium~~ long-term trends at low-altitude stations (1961-2012) with their ~~long term trends (See Table 5 and 6), we note that~~ trends over ~~the~~ recent ~~decades exhibit much higher magnitude of dryness during spring months,~~ period (1995-2012) suggests that the long-term spring drying particularly ~~for~~of March and April~~,~~ months and ~~of wetness particularly within the month~~wetting of September ~~—~~(the last monsoonal ~~month. Interestingly, shifts in the trends have been noticed during the summer months (June-August) where trends over recent decades exhibit drying but~~) month has recently been intensified while the long-term ~~trends suggest wetter conditions. Only increase in September precipitation is consistent between the long-term trend and trend obtained over 1995-2012 at low altitude stations.~~ increasing summer precipitation has been changed to decreasing (See Tables 5 and 6).

Discharge

Based on the median hydrograph of each stream flow gauge for the UIB (Fig. 3),From Figure 3, we clearly show that both snow and glacier fed/melt regimes of the UIB can be differentiated based on theirfrom the maximum runoff production time.timing based on the median hydrographs of available gauges. Figure 3 suggests that Indus at Kharmong (Eastern UIB-East), Gilgit at Gilgit (Hindukush) and Astore at Doyian are primarily snow fed basins, generally featuring their peak runoff in July. The rest of the basins are mainly glacier fed basins that generally feature their peak runoffs in June/July are primarily snow fed while the rest that feature peak runoff in August are mainly glacier fed.

Based onOver the 1995-2012 period, our trend analysis suggests an increasing trend from most of the hydrometric stations during October-June, with highest magnitudes in May-June (Tabular Fig. 5). A discharge increasechange pattern seems to be more consistent with tendencies in the temperature record than in precipitation record. In contrast, Most of the hydrometric stations experience a decreasing trend offeature increasing discharge during the month ofOctober-June (dominant during May-June) but decreasing discharge during July, which is statistically significant out offor five high-altitude/latitude glacier-fed sub-regions (Karakoram, Shigar, Shyok, UIB-Central and Indus at Kachura) regions,), mainly owing to drop in July temperatures (Tabular Fig. 5). . These regions, showing significant drop in discharge, are mainly high altitude/latitude glacier fed regions within the UIB.There is a mixed response for August and September months, there is a mixed response, however, statistically significant trends suggest an increase inincreasing discharge out offrom two regions (Hindukush and UIB-West-lower) regions in August and out offrom four sub-regions (Hindukush, western-Karakoram, UIB-West-lower and UIB-west) regions during in September. We note that despite of the

Despite dominant cooling during September cooling, discharge drops mainly drops during July, suggesting a strong impactit as month of theeffective cooling during such a month.. Discharge from the whole UIB also decreases during the month of July, however, such a drop is not statistically significant. Possibly, the lack of statistical significance in the UIB discharge trend may have been caused by the integrated response from sub-regions, and that significant signal might appear when looking at higher temporal resolution data, such as 10-day or 5-day averages.also decreasing for the whole UIB though such trend is not significant.

During winter, spring and autumn seasons, discharge at most sites feature increasing trend while during summer season and on an annual time scale there is a mixed response.

~~Our~~ Long-term ~~analysis reveals a positive trend of stream flow during the period (~~discharge is generally rising from November to May~~) from most of the sites/regions~~ (Tabular Fig. 6~~). Such a positive trend is particularly~~), where such rise is higher in magnitude ~~in May~~ and ~~also~~mostly significant ~~at relatively large number of gauging sites (14 among 16). In contrast to November-May period,~~in May. There is a mixed ~~signal of rising and falling stream flow trend among sites during~~response for June-October. ~~The increasing and decreasing stream flow trends at monthly time~~ Consistently on coarser temporal scale ~~exhibit similar response when aggregated on a typical seasonal or annual time scales.~~, winter discharge ~~features an increasing trend~~is rising while a mixed response is observed for ~~the rest of~~other seasons and on ~~an annual time scale, sites mostly exhibit a mixed response.~~

annual timescale. While comparing the long-term trends with ~~the trends~~those assessed ~~from recent two decades~~over 1995-2012 period, we note ~~most~~ prominent shifts in the sign of trends ~~during~~for the seasonal transitional month of June and within the high flow ~~months~~period of July-September. ~~This~~Such shifts may attribute to recent higher summer cooling ~~together with~~accompanied by the enhanced ~~precipitation under the influence of~~ monsoonal precipitation ~~regime in recent decades.~~. For instance, long-term ~~trend suggests that~~July discharge ~~out of~~is rising for eastern-, central- and whole Karakoram, UIB-Central, Indus at Kachura, Indus at Partab Bridge and Astore but falling for other sub-regions ~~is increasing while rest of regions feature a decreasing trend. However, trend from the~~. In contrast, trends over recent two decades ~~suggests the~~feature opposite ~~sign of discharge coming out of such regions~~signs, except ~~the regions of~~for Astore, ~~Hindukush,~~ UIB-West-upper and its sub-regions~~, which consistently show similar sign of change.~~ .

5.2 Field significance and physical attribution

~~Based on number~~ We present the mean of ~~local~~ positive and negative field significant trends~~, we analyze their field significance for~~ from each region (if both ~~positive and negative trends, separately (Tabular Fig.~~ exist)~~7). We present mean slope of the field significant trends~~ in order to present the dominant signal (Tabular Fig. 7). ~~from the region. Our~~ Results show ~~a~~ unanimous field significant warming for most of the regions in March followed by in August. Similarly, ~~we generally find a~~ field significant ~~decreasing trend~~drying is found in March ~~precipitation~~ over all regions, except Karakoram and UIB-Central ~~regions.~~. Alike local trends, we find ~~a~~ field significant cooling over all regions ~~during the months of~~in July, September and October, which on a seasonal ~~scale~~timescale, dominates ~~during~~in autumn ~~season~~ followed by in summer~~ season. Interestingly, we~~. Note that most of the climatic trends are not field-significant ~~during~~for the transitional (or pre-~~monsoon~~monsoonal) period of April-June.

We ~~found~~find a general trend of narrowing DTR, which is associated with either warming of Tn against cooling of Tx or relatively lower cooling in Tn than in Tx. Field significant drying of the lower latitudinal generally snow-fed sub-regions (Astore, Himalaya, UIB-West-lower~~–generally snow-fed regions~~) is also observed particularly during ~~the period~~ March-September, thus for ~~the~~ spring and summer and ~~for the~~on annual ~~time scale~~timescale. On the other hand, ~~we found an increasing (decreasing) trend in precipitation during~~wetting (drying) of winter and autumn (spring and summer) ~~seasons~~is observed for the Hindukush, UIB-West, UIB-West-upper and whole UIB~~ while~~. For the western Karakoram~~ such increase in~~, increasing precipitation is observed ~~during~~only for winter~~ season only~~. For the whole Karakoram and UIB-central~~ – regions~~, field-significant ~~increasing trend in~~rising precipitation trend is ~~observed~~found throughout a year, except ~~during the~~for spring~~ season~~ where no signal is evident.

~~We have noted that for most of the regions the~~Moreover, field significant ~~cooling and warming~~climatic trends are mostly in ~~good~~qualitative agreement ~~against~~with the trends in discharge from the corresponding regions. Such an agreement is high ~~for~~during summer ~~months~~, particularly for July, and during winter~~ season~~, for ~~the month of~~ March. Few exceptions to such consistency are the sub-regions of Himalaya, UIB-West and UIB-West-lower, for which, in spite of the field significant cooling in July, discharge is still ~~features a positive trend.~~rising. However, ~~we note that~~ the magnitude of ~~the increase~~rise in July discharge has substantially dropped when compared to ~~increases in~~ previous (June) and following (August) months. Such~~ a~~ substantial drop in July discharge increase rate is again consistent with the ~~prevailing~~ field significant cooling ~~during~~in July for the UIB-West and UIB-West-lower~~ regions. Thus, the identified field significant climatic signals for the considered regions are further confirmed by their observed discharge tendencies.~~

~~Interestingly, we note that generally magnitude of~~. Further, besides substantial cooling ~~during September dominates the magnitude of cooling during July while magnitude of~~ (warming ~~during~~) in September (March~~ dominates the magnitude of warming during May. However,~~

~~subsequent runoff response from the considered regions does not correspond with the magnitude of cooling and warming trends. In fact,~~), most prominent ~~increase in discharge is observed in May while~~ decrease in discharge is observed in July while its decrease in May, suggesting them months of effective cooling and warming~~ and cooling~~, respectively. Generally, periods of runoff decrease (in a sequence) span from May to September for the Karakoram, June to September for the UIB-Central, July to August for the western-Karakoram and UIB-West-upper, July to November for the Astore and only over July for the Hindukush and UIB~~ regions. Regions of~~. UIB-West-lower and Himalaya suggest decrease in discharge during months of April and February, respectively.

~~**5.3 Tendencies versus latitude, longitude and altitude**~~

~~In order to explore the geographical dependence of the climatic tendencies, we plot tendencies from the individual stations against their longitudinal, latitudinal and altitudinal coordinates (Figs. 9-11). We note that summer cooling is observed in all stations; however the stations between 75-76° E additionally show cooling during the month of May in Tx, Tn and Tavg. Within 74-75° E, stations generally show a positive gradient towards west in terms of warming and cooling, particularly for Tn. DTR generally features a narrowing trend where magnitude of such a trend tends to be higher west of 75° longitude (Astore basin). Precipitation generally increases slightly but decreases substantially at 75° longitude. Discharge decreases at highest (UIB east) and lowest (UIB west) gauges in downstream order, while increases elsewhere.~~

~~Cooling or warming trends are prominent at higher latitudinal stations, particularly for cooling in Tx and warming in Tn. Highest cooling and warming in Tavg is noted around 36°N. Similarly, we have observed a highest cooling in Tx and warming in Tn, while Tx cooling dominates in magnitude as evident from Tavg. DTR generally tends to decrease towards higher latitudes where magnitude of decrease in a particular season/month is larger than increase in it for any other season/month. Highest increasing or decreasing trend in precipitation is observed below 36°N. Whereas station below 35.5°N show substantial decrease in annual precipitation mainly due to decrease in spring season. The stations between 35.5-36°N show increase in annual precipitation mainly due to increase in winter precipitation.~~

~~The magnitude of cooling (warming) in Tn decreases (increases) at higher elevations. Stations below 3500 m asl feature relatively higher magnitude of cooling in Tx, which is also~~

~~higher than warming trends in Tx as well as in Tn. Such signals are clear from tendencies in Tavg. The low altitude stations and the stations at highest elevation show the opposite response, featuring a pronounced warming in Tavg than its cooling in respective months/seasons. We note that precipitation trends from higher altitude stations are far more pronounced than in low altitude station, and clearly suggest drying of spring but wetting of winter seasons. Tendencies in DTR in high altitude stations are consistent qualitatively and quantitatively as compared to tendencies in low altitude stations.~~

6 Discussions

6.1 Cooling trends

~~Our~~Observed long-term ~~updated analysis suggests that~~ summer and autumn (or monsoon) cooling ~~trends are~~is mostly consistent with ~~previously reported trends~~the earlier reports for the study basin (Fowler and Archer, 2005 and 2006; Khattak et al., 2011~~), and with reports of increasing summer snow cover extent over the UIB (Hasson et al., 2014b). The overall warming over Pakistan (and UIB) reported by Río et al. (2013) is however in direct contrast to the cooling tendencies reported here and by the above mentioned studies, regardless of the seasons. Our findings of long term cooling trends during the monsoon period are also in high agreement with reports of~~; Sheikh et al~~. (~~., 2009~~) for the study region, which is consistently reported~~), as well as those, for the neighboring regions, such as, Nepal, Himalayas (Sharma et al., 2000; Cook et al., 2003), northwest India (Kumar et al., 1994), Tibetan Plateau (Liu and Chen, 2000), central China (Hu et al., 2003), and central Asia (Briffa et al., ~~2001) for the investigated periods.~~ 2001).

~~More importantly,~~ Over the ~~station-based cooling trends are found~~1995-2012 period, field significant ~~for all identified sub-regions of the UIB~~ cooling observed mostly in July, September and October~~, coinciding~~ for all UIB sub-regions coincides with the ~~months of~~ monsoonal onset and retreat months, and ~~also with~~most importantly, with the main glacier melt season, thus anticipated to negatively affect the glacier melt ~~season. Thus, field significant~~runoff. The observed cooling ~~is further depicted from the trends in discharge out of respective regions, specifically during July, when discharge either exhibit falling or weaker rising trends relative to contiguous months due to declining glacial melt. The field significant cooling and subsequent discharge behaviour is~~ phenomenon is generally attributed to the incursions of the south Asian summer monsoonal system and its precipitation (Cook et al., 2003) into the Karakoram~~, through crossing Himalayas,~~ and ~~into~~ the UIB-West ~~region, for which Himalayan barrier does not exist. Such phenomenon~~ that presently seems to be accelerated ~~at present under~~ in view of the observed ~~increasing trend~~increase in cloud cover, ~~in~~ precipitation and number of wet days ~~- particularly over the UIB-West region~~ (Bocchiola and Diolaiuti, 2013~~) - and subsequently in total amount of precipitation during the monsoon season.~~). Since summer precipitation over the UIB is partly received from the westerly disturbances (Wake 1987), the observed cooling may also be attributed to the enhanced ~~monsoonal~~ influence ~~in the far north-west over the UIB-West region, and within~~ of the ~~Karakoram, is consistent with the extension of the monsoonal domain northward and westward under the global warming scenario as projected by the multi-model mean from climate models participating in the Climate Model Intercomparison Project Phase 5 (CMIP5 - Hasson~~westerly disturbances during summer months, alike during winter and spring (Madhura et al., ~~2015a). Such hypothesis further needs a detailed investigation and it is beyond the scope of present study.~~2015). Nevertheless, ~~increasing~~ observed increase in cloud cover ~~due to enhanced influence and frequent incursions of the monsoonal system~~ leads to reduction of incident downward radiations and results in cooling (or less warming) of Tx. Forsythe et al. (2015) have consistently observed the influence of ~~the~~ cloud radiative effect on the near surface air temperature over the UIB. The enhanced cloudy conditions most probably are ~~mainly~~ responsible for ~~initially higher~~initial warming in Tn through longwave cloud radiative effect~~. Given that~~, and when such ~~cloudy~~ conditions persist longer in time, Tx and Tn ~~are~~ more likely tend to cool. Under the clear sky conditions, cooling in Tx further continues as a result of evaporative cooling of the moisture-surplus surface under precipitation event (Wang et al., 2014) or due to irrigation (Kueppers et al., 2007). Han and Yang (2013) found irrigation expansion over Xinjiang, China as a major cause of observed cooling in Tavg, Tx and Tn during May-September over the period 1959-2006. Further, higher ~~Tn~~ drop in Tn observed over UIB-West-lower ~~region~~ during winter ~~months can~~may be attributed to intense ~~night time~~nighttime cooling of the deforested, thus moisture deficit, bare soil surface, exposed to direct day time solar heating as explained by Yadav et al. ~~(2004).~~(2004). The relevance of such hypotheses for the UIB further needs a detailed investigation of the land-atmosphere processes and feedbacks using high-resolution climate model simulations with explicitly resolved convections, which is beyond the scope of our analysis.

~~Due to cooling trends, the UIB though features some responses consistent with the neighboring region and as observed worldwide but reason for such common responses may still be contradictory. For instance, field significant decreasing trend in DTR during July-October period is attributed to stronger cooling in Tx than in Tn, which is contrary to the reason of decreasing DTR observed worldwide and over the northeast China (Jones et al., 1999; Wang et al., 2014).~~

6.2 Warming trends

Long-term warming during November-May is generally found consistent with ~~previously reported~~earlier reports of warming~~ trends~~ (Fowler and Archer, 2005 and 2006; Sheikh et al., 2009; Khattak et al., 2011; Río et al., 2013) as well as with decreasing snow cover ~~extent during~~in spring (1967-2012) ~~in~~over the Northern Hemisphere and worldwide (IPCC, 2013) and ~~during~~in winter (2001-2012) over the study region (Hasson et al., 2014b). ~~However, warming generally dominates in spring months, ~~Consistent with the findings of Sheikh et al. (2009) and Río et al. (2013~~). Being consistent with recent acceleration of global climatic changes (IPCC, 2013), such spring warming is observed higher over the 1995-2012 period, particularly in March and May, respectively. Further, warming in Tx (Tn) is more pronounced at low (high) altitude stations. More importantly, the station based spring warming is found~~), warming dominates in spring months where it is field significant in March over almost all identified sub-regions of the UIB. Under the drying spring scenario, less cloudy conditions associated with increasing number of dry days for the westerly precipitation regime (Hasson et al., ~~2015a~~2016a & 2016b) together with the snow-albedo feedback can partly explain ~~such~~spring warming~~ during spring months.~~. Contrary to long-term warming trends analyzed here or to those previously reported, a field significant cooling is found for winter, which is consistently observed over the eastern United States, southern Canada and much of the northern Eurasia (Cohen et al., 2012).

~~Contrary to spring warming, our analysis suggests generally a field significant cooling in winter, which is in direct contrast to long term warming trends analyzed here and those previously reported (Fowler and Archer, 2005 and 2006; Sheikh et al., 2009; Khattak et al., 2011). Such a recent shift of winter warming to cooling is consistently observed over eastern United States, southern Canada and much of the northern Eurasia (Cohen et al., 2012). The recent winter cooling is a result of falling tendency of winter time Arctic Oscillation, which partly driven dynamically by the anomalous increase in autumnal Eurasian snow cover~~

(Cohen and Entekhabi, 1999), can solely explain largely the weakening (strengthening) of the westerlies (maridional flow) and favors anomalously cold winter temperatures and their falling trends (Thompson and Wallace, 1998 and 2001; Cohen et al., 2012). Weakening of the westerlies during winter may explain an aspect of well agreed drying during subsequent spring season, and may further be related to more favorable conditions for the southerly monsoonal incursions into the UIB.

6.3 Wetting and drying trends

Enhanced influence of the late-monsoonal precipitation increase at high altitude stations suggests Field significant increasing trend inrising precipitation for the sub-regions atof relatively higher latitudes, such as, (Hindukush and UIB-Central, and thus, for the UIB-West-upper, Karakoram and the whole UIB. This is in good agreement with the projected intensification of south Asian summer monsoonal precipitation regime under) may be attributed to the enhanced greenhouse gas emission scenarios (Hasson et al., 2013, 2014a & 2015a). At the low late-monsoonal or westerly precipitation regimes at high-altitude stations, shifts. Whereas, shift of the long-term trends of increasing summer precipitation (June-August) wetting to drying at the low-altitude stations over the period 1995-2012 indicateindicates a recent transition towards weaker monsoonal influence at lower levels. This may attribute to multi-decadal variability that is associated with the global indices, such as, NAO and ENSO, influencing the distribution of large scale precipitation over the region (Shaman and Tziperman, 2005; Syed et al., 2006).therein.

The field significant trends of precipitation increase during winter but decrease during spring season is associated withanticipates certain changes inwithin the westerly precipitation regime under changing climate. For instance,. The field significant spring drying in spring (except for Karakoram) is mainly consistent with the weakening and northward shift of the mid-latitude storm track (Bengtsson et al., 2006) and increase in thealso with increasing number of spring dry days within spring season for the westerly precipitation regime (Hasson et al., 2015a2016a & 2016b). On the other hand, observed increase in the winter precipitation increase for relatively high latitudinal sub-regions is more consistent with the observations as well as with the future projections of observed more frequent incursions of the westerly disturbances into the region (Ridley et al., 2013; therein (Cannon et al., 2015; Madhura et al., 2015). Nevertheless, in view of more frequent incursions of the monsoonal system and westerly disturbances expected in the futurethe enhanced influence of prevailing weather systems and certain changes ~~projected for the overall~~ expected in their seasonality/intermittency ~~of their precipitation regimes by the~~under changing climate ~~models~~ (Hasson et al., ~~2015a),~~2016a & 2016b), we speculate significant changes in the timings of the melt water availability from the UIB~~ are speculated.~~. Such hypothesis can be tested by assessing changes in the seasonality of observed precipitation and runoff~~ based on observations analyzed here and also through modelling melt water runoff from the region under prevailing climatic conditions~~.

6.4 Water availability

The long-term discharge tendencies are consistent with earlier reports from Khattak et al. (2011) for Indus at Kachura, and UIB ~~regions~~ and from Farhan et al. (2014) for Astore. Similarly, rising and falling discharge trends from Shyok and Hunza sub-basins, respectively, are consistent with Mukhopadhyay et al. (2015). The discharge trends from Shigar-region, though statistically insignificant, are only partially consistent with Mukhopadhyay and Khan (2014), exhibiting agreement for an increasing trend in June and August but a decreasing trend in July and September.

~~We note~~Further, prominent shifts of the long-term trends of rising melt-season discharge into falling over the period 1995-2012 for mostly the glacier-fed sub-regions (Indus at Kachura, Indus at Partab Bridge, Eastern-, Central- and whole-Karakoram and UIB-Central~~). Such shifts may attribute to higher summer cooling together with certain changes in the precipitation regime. Change in sign of discharge trend for eastern Karakoram (Shyok) is expected to substantially alter discharge at Kachura site, thus deriving a Shigar discharge by applying previously identified constant monthly fractions to the downstream Kachura gauge (Mukhopadhyay and Khan, 2014) would less likely yield a valid Shigar discharge for its period of missing record (1999-2010). Some regions, such as, UIB-West-upper and its sub-regions together with Astore and whole UIB are the regions consistently showing same sign of change in their long term trend when compared to the trends derived over the period 1995-2012.~~) may attribute to higher summer cooling together with certain changes in prevailing precipitation regimes.

Over the 1995-2012 period, significant decreasing ~~stream flow~~ trend in July discharge is most probably attributed to observed ~~for mainly the glacier-fed regions is mostly significant in July. Though~~ July cooling~~ in July is~~, which though less prominent than cooling in September, ~~it~~ is much effective as it coincides with the main ~~glacial~~glacier melt season. ~~Such~~A drop in

July discharge~~, owing to decreased melting, results in~~ further indicates reduced melt water availability~~,~~ but at the same time~~, indicates~~ positive basin storage, ~~in view of enhanced moisture input.~~particularly under prevailing wetter conditions. Similarly, ~~increase in~~rising discharge during May and June most likely is due to the observed warming, which though less prominent than warming in March, is much effective since it coincides with the ~~snow melt~~snowmelt season. This suggests an early melt of snow and subsequent increase in the melt water availability, but concurrently, a lesser amount of snow available for the subsequent melt season. ~~Such~~These seasonally distinct changes ~~in snow melt and glacier melt regimes are mainly due to~~ emphasize on the ~~non-uniform climatic changes on a sub-seasonal scale. This further emphasizes on a~~ separate ~~assessment of changes in both~~assessments of snow and glacier melt regimes, for which an adequate choice is the hydrological models~~ that~~, which are able to ~~distinctly~~independently simulate snow and glacier melt processes~~. Nevertheless,~~, e.g. University of British Columbia (UBC) watershed model. Based on the UBC model, Hasson et al. (2016c) has recently confirmed our findings that the continuation of prevailing early-melt season warming will yield an increased and early snowmelt runoff, but in stark contrast, mid-to-late melt season cooling will result in a decreased and delayed glacier melt runoff in near future. Such changes in both snow and glacier melt regimes all together can result in a sophisticated alteration of the hydrological regimes of the UIB, ~~requiring certain change in~~and subsequently, the ~~operating curve~~timings of the ~~Tarbela reservoir in future~~downstream water availability.

~~The~~Although discharge change pattern seems to be more consistent with the field significant temperature trends~~ than with precipitation trends. This points to the fact that the cryosphere melting processes are the~~ , indicating cryospheric melt as a dominating factor in determining the UIB discharge variability~~ of the rivers discharge in the study region. However, changes in precipitation regime~~, it can ~~still influence~~also be substantially ~~the melt processes and subsequent meltwater availability.~~influenced by changes in the precipitation regimes. For instance, ~~monsoon~~monsoonal offshoots intruding into the study region ironically result in declining river discharge (Archer, 2004~~), since crossing the Himalaya such monsoonal incursions mainly drop moisture over the high altitude regions and in the form of snow (Wake, 1989; Böhner, 2006).~~). In ~~that case,~~fact, high albedo of fresh snow ~~and clouds firstly reduce~~reduces the incident energy ~~due to high albedo~~ that results in immediate drop in the melt. ~~Secondly,~~The fresh snow also insulates the underlying glacier/ice, slowing down the whole melt process till earlier albedo rates are achieved. Thus, melting of ~~snow and~~

glacierscryosphere and subsequent overall meltwaterwater availability is also inversely correlated to the number of snowfall events/days during the melt season (Wendler and Weller, 1974; Ohlendorf et al., 1997).

In view of the sparse observational network of meteorological observations analyzed here, we need to clarify that the observed cooling and warming is only an aspect of the wide spread changes prevailing over the wide-extent UIB basin. This is much relevant for the UIB-Central region where we have only one station each from the eastern- and central-Karakoram (UIB-Central),) that is not exclusively representative of theirthe hydro-climatic state. of corresponding sub-region. Thus, field significant results for the whole Karakoram region are mainly dominated by the contribution of relatively large number of stations withinfrom the western-Karakoram. Nevertheless, glaciological studies, reportingreports of increasing end-of-summer snow covers and supporting the Karakoram anomalyfalling regional snow line altitudes (Minora et al., 2013; Hasson et al., 2014b; Tahir et al., 2016), increasing or stable glacial extents (Hewitt, 2005; Scherler et al., 2011; Bhambri et al., 2013); Minora et al., 2013), and possibly a non-negative glaciers' mass balance of the aboded glaciers within eastern- and central-Karakoram (Gardelle et al., 2013 - contrary at shorter period – Kääb et al., 2015), furtherlocal climate change narratives (Gioli et al., 2013) and overall simulated reduced near-future water availability for the UIB (Hasson et al., 2016c), reinforce our presented findings. Moreover, our results agree remarkably well with the local narratives of climate change as reported by Gioli et al. (2013). In view of such consistent findings, we are confident that the observed signal

We find a common response of hydroclimatic changes dominates at present, at least qualitatively. Furthermore, climatic from a certain set of months, which are different than those (DJF, MAM, JJA, SON) typically considered for winter, spring, summer and autumn seasons, respectively. This emphasizes on analyzing the hydroclimatic observations on higher temporal resolution to robustly assess the delicate signals of change signal observed within the mountainous environments can vary with respect to altitude (MRI, 2015; Hasson et al., 2015b). Such elevation dependent signal of climatic change is somewhat depicted by the sparse observations analysed here. However, the robust assessment of such an aspect requires spatially complete observational database.

It is to mention that the hydro-climatic regime of the UIB is substantially controlled by the interaction of large scale circulation modes and their associated precipitation regimes, which are in turn controlled by the global indices, such as, NAO and ENSO etc. TheHowever, time period covered by our presented analysis is not long enough to disintegrate suchthe natural variability signals from the transient climate change. SuchThese phenomena need to be better investigated based uponover the longer period of and spatially complete observational record for, thus preferably including the extensive database of validated proxy observations since the challenges of short and sparse robust in-depth understanding of the present variability in the hydrological regime of the UIB and for forecasting future changes in it. For future projections, global climate models at a broader scale and their downscaled experiments at regional to sub-regional scales-situ observations are most vital datasets available, so far. However, a reliable future change assessment over the UIB from these climate models will largely depend upon their satisfactory representation of the prevailing climatic patterns and explanation of their teleconnections with the global indices, which are yetlikely to be (fully) explored. The recent generations of the global climate models (CMIP5) feature various systematic biases (Hasson et al., 2013, 2014a and 2015a) and exhibit diverse skill in adequately simulating prevailing climatic regimes over the region (Palazzi et al., 2014; Hasson et al., 2015a). We deduce that realism of these climate models about the observed winter cooling over the UIB much depends upon reasonable explanation of autumnal Eurasian snow cover variability and its linkages with the large scale circulations (Cohen et al., 2012). On the other hand, their ability to reproduce summer cooling signal is mainly restricted by substantial underestimation of the real extent of the south Asian summer monsoon owing to underrepresentation of High-Asian topographic features and absence of irrigation waters (Hasson et al., 2015a). However, it is worth investigating data from high resolution Coordinated Downscaled Experiments (CORDEX)remain invariant for South Asia for representation of the observed thermal and moisture regimes over the study region and whether such dynamically fine scale simulations feature an added value in their realism as compared to their forced CMIP5 models. Given these models do not adequately represent the summer and winter cooling and spring warming phenomena, we argue that modelling melt runoff under the future climate change scenarios as projected by these climate models is still not relevant for the UIB as stated by Hasson et al. (2014b). Moreover, it is not evident when the summer cooling phenomenon will end. Therefore, we encourage the impact assessment communities to model the melt runoff processes from the UIB, taking into account more broader spectrum of future climate change uncertainty, thus under both prevailing climatic

~~regime as observed here and as projected by the climate models, relevant for short and long term future water availability, respectively.~~the UIB.

7 Conclusions

~~Our findings supplement the ongoing research on addressing the question of water resources dynamics in the region, such as, 'Karakoram Anomaly' and the future water availability. In view of recently observed shifts and acceleration of the hydroclimatic trends over HKH ranges within the UIB, we speculate an enhanced influence of the monsoonal system and its precipitation regime during the late melt season. On the other hand, changes in the westerly disturbances and in the associated precipitation regime are expected to drive changes observed during winter, spring and early melt season. The observed hydroclimatic trends, suggesting distinct changes within the period of mainly snow and glacier melt, indicate at present strengthening of the nival while suppression of the glacial melt regime, which all together will substantially alter the hydrology of the UIB. However, such aspects need to be further investigated in detail by use of hydrological modelling, updated observational record and suitable proxy datasets. Nevertheless, changes presented in the study earn vital importance when we consider the socio-economic effects of the environmental pressures. The melt water reduction will result in limited water availability for the agricultural and power production downstream and may results in a shift in solo-season cropping pattern upstream. This emphasizes the necessary revision of WAPDA's near future plan i.e. Water Vision 2025 and recently released first climate change policy by the Government of Pakistan, in order to address adequate water resources management and future planning in relevant direction.~~

We present a first comprehensive and systematic hydroclimatic trend analysis for the UIB based on ten stream flow, six low-altitude manual and 12 high-altitude automatic weather stations. Results suggest general narrowing of DTR throughout the year except for March and May, which is significant in September followed by in February. Such year-round narrowing of DTR is further found field significant for almost all sub-regions, and is mainly associated with either higher cooling in Tx than in Tn or cooling in Tx but warming in Tn.

Cooling at most of the stations is observed during the monsoon and the main glacier melt season (July-October), which is significant in September followed by in July. Further, locally observed cooling is found field significant for almost all sub-regions in July, September and October, and on a seasonal timescale, for autumn and summer. In contrast, well agreed local warming though mostly insignificantly observed in March, May and November is field significant in March for most of the sub-regions. For precipitation, March, spring and summer feature field significant drying for all the sub-regions except those within the karakoram while winter, autumn and September mostly feature wetting of high (drying of low) altitudinal sub-regions. Change pattern in discharge out of corresponding sub-regions seems more consistent with the field significant tendencies in temperature than in precipitation, where discharge is either falling or weakly rising (rising) in response to cooling (warming), particularly in the month of July (May). These findings though constrained by short and sparse observational dataset suggest distinct changes for the snow and glacier melt seasons, indicating at present strengthening of the nival but suppression of the glacial melt regime, altering the overall hydrology of the UIB. The presented findings largely contribute to the ongoing research on understanding the melt runoff dynamics within the UIB and in addressing the hydroclimatic explanation of the 'Karakoram Anomaly'.

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Table 1: Characteristics of the gauged and derived regions of UIB. Note: *Including nearby Skardu and Gilgit stations for the Karakoram and Deosai station for the UIB-Central regions. Derived ~~gauge times~~time series are limited to a common length of ~~time series of the employed gauges~~used gauges' record, thus their statistics.

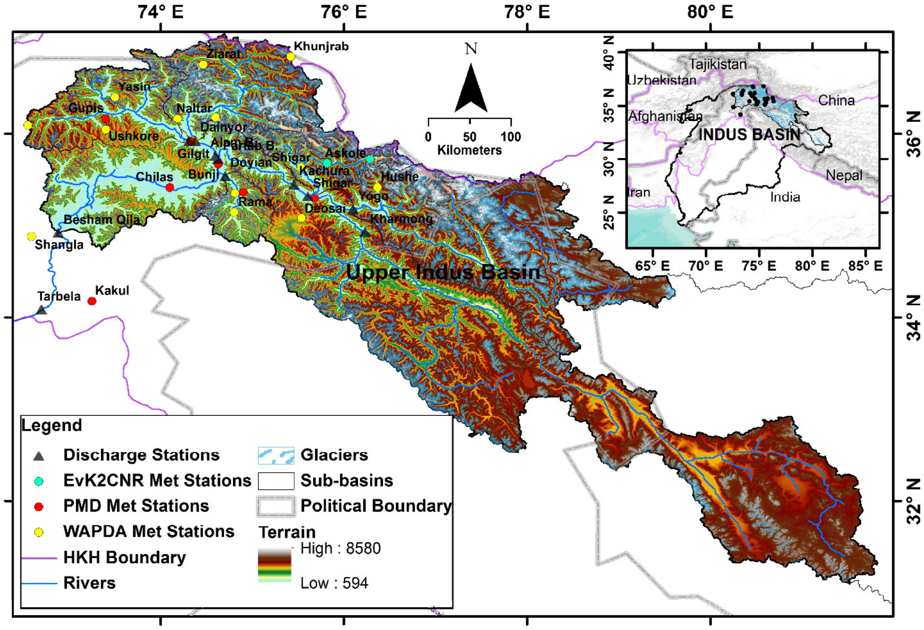
S. No.	Watershed/ Tributary	Designated Discharge sites	Expression for deriving approximated Discharge	Designated Name of the Region	Area (km^2)	Glacier Cover (km^2)	% Glacier Cover	% of UIB Glacier Aboded	Elevation Range (m)	Mean Discharge (m^3s^{-1})	% of UIB Discharge	No of Met Stations
1	Indus	Kharmong		UIB-East	69,355	2,643	4	14	2250-7027	451	18.8	1
2	Shyok	Yogo		Eastern-	33,041	7,783	24	42	2389-7673	360	15.0	1
3	Shigar	Shigar		Central-Karakoram	6,990	2,107	30	11	2189-8448	206	8.6	1
4	Indus	Kachura		Indus at Kachura	113,035	12,397	11	68	2149-8448	1078	44.8	
5	Hunza	Dainyor Bridge		Western-	13,734	3,815	28	21	1420-7809	328	13.6	4
6	Gilgit	Gilgit		Hindukush	12,078	818	7	4	1481-7134	289	12.0	5
7	Gilgit	Alam Bridge		UIB-West-upper	27,035	4,676	21	25	1265-7809	631	27.0	9
8	Indus	Partab Bridge		Indus at Partab	143,130	17,543	12	96	1246-8448	1788	74.3	
9	Astore	Doyian		Astore at Doyian	3,903	527	14	3	1504-8069	139	5.8	3
10	**UIB**	**Besham Qila**		**UIB**	**163,528**	**~~18,340~~19,370**	**~~11~~12**	**100**	**569-8448**	**2405**	**100.0**	**18**
11			4 – 2 – 1	Shigar-region						305	12.7	
12			2 + 3 + 5	Karakoram	53,765	13,705	25	75	1420-8448	894	37.2	*8
13			2 + 11 + 5	derived Karakoram						993	41.3	
14			4 – 1	UIB-Central	43,680	9,890	23	54	2189-8448	627	26.1	*4
15			10 – 4	UIB-West	50,500	5,817	13	32	569-7809	1327	55.2	14
16			10 – 4 – 7	UIB-West-lower	23,422	1,130	7	6	569-8069	696	28.9	5
17			1 + 16	Himalaya	92,777	3,773	5	20	569-8069	1147	47.7	7

Table 2: ~~List of~~ Meteorological stations and their attributes. Inhomogeneity is found only in Tn over full period of record. Note: (*) ~~represent~~represents inhomogeneity ~~for~~only over the 1995-2012 period~~ only~~.

S. No.	Station Name	Period From	Period To	Agency	Latitude (degrees) ~~Longitude~~	Longitude (degrees)~~L atitude~~	Altitude ~~Meter asl~~(meters)	Inhomogeneity at
1	Chillas	01/01/1962	12/31/2012	PMD	35.42	74.10	1251	2009/03
2	Bunji	01/01/1961	12/31/2012	PMD	35.67	74.63	1372	1977/11
3	Skardu	01/01/1961	12/31/2012	PMD	35.30	75.68	2210	
4	Astore	01/01/1962	12/31/2012	PMD	35.37	74.90	2168	1981/08
5	Gilgit	01/01/1960	12/31/2012	PMD	35.92	74.33	1460	2003/10*
6	Gupis	01/01/1961	12/31/2010	PMD	36.17	73.40	2156	1988/12 1996/07*
7	Khunjrab	01/01/1995	12/31/2012	WAPDA	36.84	75.42	4440	
8	Naltar	01/01/1995	12/31/2012	WAPDA	36.17	74.18	2898	2010/09*
9	Ramma	01/01/1995	09/30/2012	WAPDA	35.36	74.81	3179	
10	Rattu	03/29/1995	03/16/2012	WAPDA	35.15	74.80	2718	
11	Hushe	01/01/1995	12/31/2012	WAPDA	35.42	76.37	3075	
12	Ushkore	01/01/1995	12/31/2012	WAPDA	36.05	73.39	3051	
13	Yasin	01/01/1995	10/06/2010	WAPDA	36.40	73.50	3280	
14	Ziarat	01/01/1995	12/31/2012	WAPDA	36.77	74.46	3020	
15	Dainyor	01/15/1997	07/31/2012	WAPDA	35.93	74.37	1479	
16	Shendoor	01/01/1995	12/28/2012	WAPDA	36.09	72.55	3712	
17	Deosai	08/17/1998	12/31/2011	WAPDA	35.09	75.54	4149	
18	Shigar	08/27/1996	12/31/2012	WAPDA	35.63	75.53	2367	

Table 3. ~~List of~~ SWHP WAPDA stream flow ~~gauging stations~~gauges given in ~~a~~the downstream order along with their characteristics and ~~period~~their periods of record ~~used~~analyzed**.** *Gauge is not operational after 2001.

S. No.	Gauged River	Discharge Gauging Site	Period From	Period To	~~Degree~~ Latitude	~~Degree~~ Longitude	Height (meters)
1	Indus	Kharmong	May-82	Dec-11	34.~~9333333~~93	76.~~2166667~~21	2542
2	Shyok	Yogo	Jan-74	Dec-11	35.~~1833333~~18	76.~~1000000~~10	2469
3	Shigar	Shigar*	Jan-85	Dec-98 & 2001	35.~~3333333~~33	75.~~7500000~~75	2438
4	Indus	Kachura	Jan-70	Dec-11	35.~~4500000~~45	75.~~4166667~~41	2341
5	Hunza	Dainyor	Jan-66	Dec-11	35.~~9277778~~92	74.~~3763889~~37	1370
6	Gilgit	Gilgit	Jan-70	Dec-11	35.~~9263889~~92	74.~~3069444~~30	1430
7	Gilgit	Alam Bridge	Jan-74	Dec-12	35.~~7675000~~76	74.~~5972222~~59	1280
8	Indus	Partab Bridge	Jan-62	Dec-07	35.~~7305556~~73	74.~~6222222~~62	1250
9	Astore	Doyian	Jan-74	Aug-11	35.~~5450000~~54	74.~~7041667~~70	1583
10	UIB	Besham Qila	Jan-69	Dec-12	34.~~9241667~~92	72.~~8819444~~88	580



74° E
76° E
78° E
80° E
36° N
34° N
32° N
N
0 50 100
Kilometers
Khunjrab
Ziarat
Yasin
Gupis
Naltar
Ushkore
Dainyor
Gilgit
Chilas
Bunji
Doyian
Shigar
Askole
Kachura
Hushe
Yugo
Rama
Deosai
Kharmong
Besham Qila
Shangla
Tarbela
Kakul
Upper Indus Basin
Tajikistan
Uzbekistan
Afghanistan
China
INDUS BASIN
Nepal
Iran
India
40° N
35° N
30° N
25° N
65° E
70° E
75° E
80° E
85° E
Legend
Discharge Stations
EvK2CNR Met Stations
PMD Met Stations
WAPDA Met Stations
HKH Boundary
Rivers
Glaciers
Sub-basins
Political Boundary
Terrain
High : 8580
Low : 594

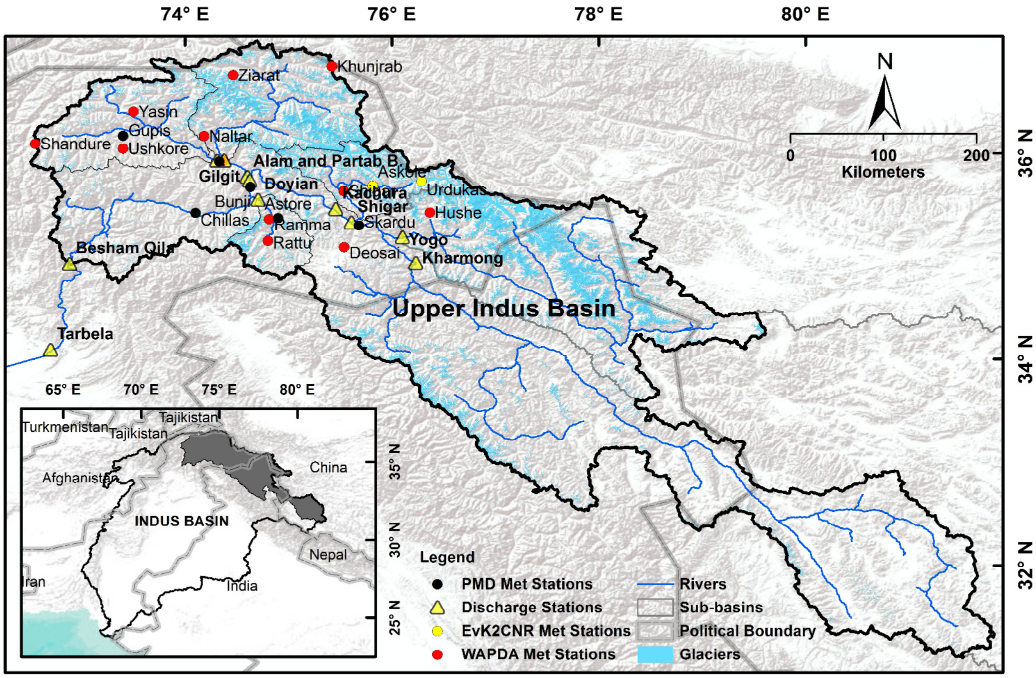
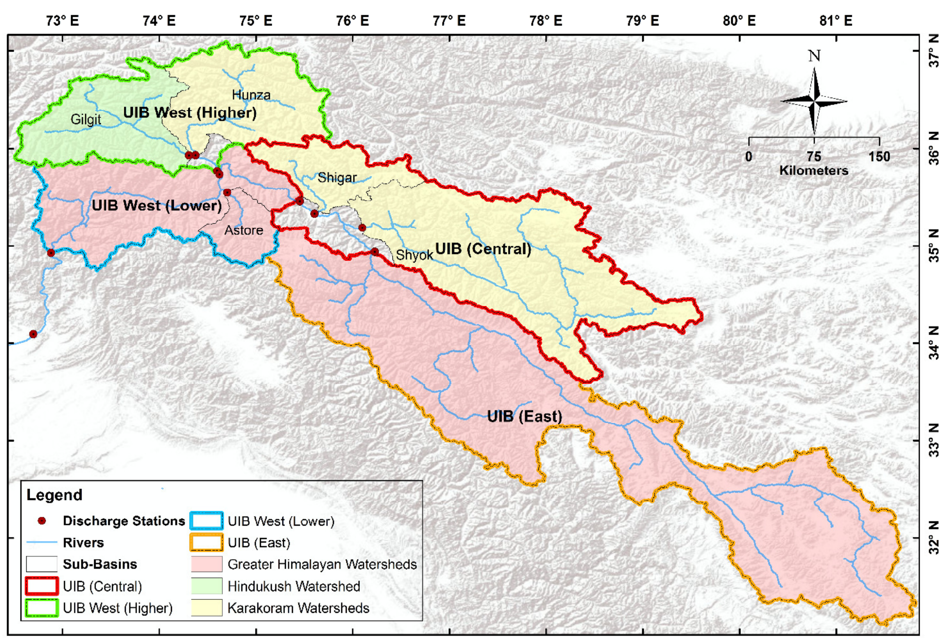


Figure 1: ~~Study Area,~~The upper Indus basin (UIB) and meteorological station networks



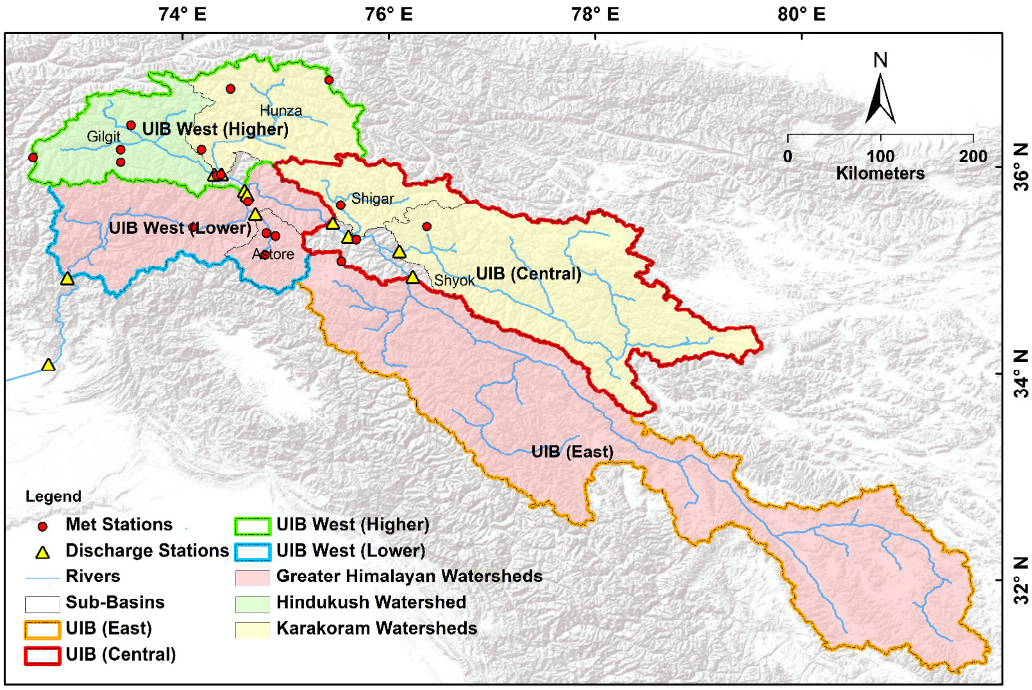
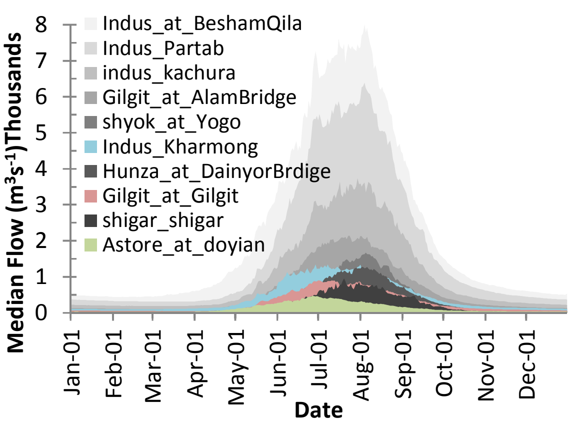


Figure 2: ~~Gauged basins, gauges~~Hydometric stations and the sub-regions considered for field significance



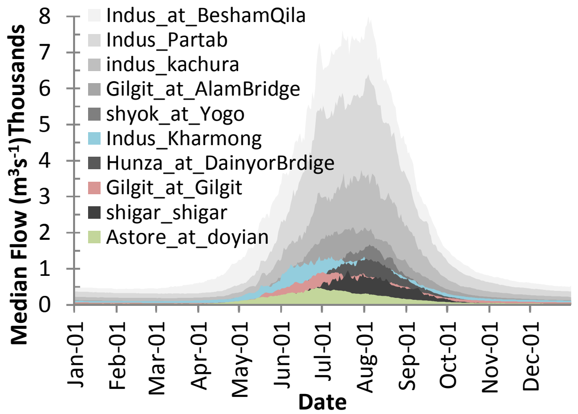


Figure 3: Long-term median hydrograph for ten ~~key gauging stations~~ gauges separating the sub-basins of the UIB ~~having~~featuring either mainly snow-fed (~~shown~~ in color) or ~~mainly~~ glacier-fed hydrological regimes (~~shown~~ in ~~grey shades~~greyscale).

Tabular Figure 4: Trend for Tx, Tn and DTR in ^{o}C ~~yr^{-1}~~ (per unit time) at monthly to annual ~~time scale~~timescales over the period 1995-2012. Note: ~~meteorological~~ stations are ~~ordered from~~given in top to bottom ~~as highest to lowest~~ altitude ~~while hydrometric stations as upstream to downstream.~~order. Slopes significant at 90% level are given in bold ~~while at 95% are given in bold and Italic.~~. Color scale is distinct for each ~~time scale where~~timescale. Blue (red) refers to decreasing (increasing ~~(decreasing~~) trend.

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tx	Khunrab	0.01	-0.01	0.10	0.03	0.12	-0.01	-0.09	0.06	-0.16	0.01	0.12	0.07	0.05	0.07	-0.05	0.04	0.04
	Deosai	0.02	-0.05	0.07	-0.01	0.06	0.01	-0.19	-0.01	0.00	0.02	0.06	0.05	0.08	0.06	0.03	0.02	0.06
	Shendure	-0.17	**-0.09**	0.01	-0.03	-0.06	-0.10	**-0.13**	***-0.07***	***-0.22***	-0.06	0.04	-0.11	-0.08	-0.06	**-0.11**	-0.05	-0.05
	Yasin	0.00	-0.03	**0.13**	-0.02	0.10	0.03	-0.16	-0.08	***-0.35***	0.12	-0.02	-0.10	0.03	0.08	-0.06	-0.01	0.05
	Rama	-0.06	-0.07	0.02	**-0.11**	0.14	0.04	-0.11	-0.09	**-0.29**	-0.10	0.01	0.00	-0.04	-0.04	**-0.07**	-0.07	***-0.08***
	Hushe	-0.05	-0.01	0.09	0.00	0.17	-0.06	-0.09	0.02	**-0.20**	-0.09	0.01	0.03	0.02	0.03	-0.02	-0.03	-0.03
	Ushkore	-0.04	-0.02	0.10	0.03	0.25	-0.01	-0.12	-0.06	***-0.22***	-0.05	0.06	-0.01	0.02	0.08	-0.05	-0.02	-0.01
	Ziarat	0.00	-0.01	0.12	-0.02	0.13	0.09	-0.11	-0.03	***-0.21***	-0.04	0.09	0.04	0.06	0.06	-0.02	-0.04	0.01
	Naltar	-0.04	-0.04	0.10	-0.03	0.10	0.03	-0.12	-0.03	***-0.19***	0.03	-0.01	0.01	-0.02	0.07	-0.03	-0.05	0.00
	Rattu	***-0.16***	-0.10	0.04	-0.03	0.11	0.14	-0.06	-0.05	-0.17	-0.23	0.04	-0.15	***-0.12***	-0.03	0.01	-0.03	**-0.07**
	Shigar	-0.04	-0.08	-0.02	-0.08	-0.38	-0.15	-0.08	0.03	-0.01	-0.09	0.11	0.01	-0.02	-0.09	**-0.09**	-0.02	-0.02
	Skardu	0.10	0.08	0.12	0.04	0.04	-0.08	**-0.10**	0.06	***-0.23***	-0.10	-0.04	-0.05	-0.02	0.13	-0.07	***-0.09***	-0.02
	Astore	0.09	0.00	**0.20**	0.03	0.18	0.06	-0.05	-0.03	***-0.15***	-0.11	0.05	0.04	0.08	**0.15**	-0.01	-0.05	0.02
	Gupis	-0.05	0.03	***0.27***	0.11	0.20	0.01	-0.09	-0.13	-0.09	0.12	0.12	0.03	0.11	0.20	0.03	0.03	0.07
	Dainyor	-0.04	-0.08	***0.23***	-0.02	0.15	-0.19	***-0.18***	0.01	-0.15	-0.04	0.10	-0.07	**-0.06**	0.14	-0.08	-0.01	-0.02
	Gilgit	0.09	-0.07	0.12	0.03	0.15	0.02	**-0.15**	**-0.08**	***-0.31***	-0.07	0.07	-0.05	-0.04	0.06	-0.05	***-0.08***	-0.05
	Bunji	0.09	-0.08	0.13	0.04	0.11	0.07	-0.01	0.04	***-0.22***	-0.12	-0.01	-0.08	0.00	0.11	0.02	-0.07	-0.02
	Chilas	0.09	-0.03	**0.16**	0.01	0.13	0.01	**-0.15**	-0.06	***-0.24***	0.00	0.03	-0.06	-0.05	0.08	**-0.07**	-0.05	-0.06
Tn	Khunrab	***0.15***	***0.26***	**0.16**	0.03	0.18	-0.02	-0.04	0.00	0.01	0.05	***0.17***	0.10	***0.21***	0.08	-0.01	0.06	**0.09**
	Deosai	0.02	0.09	**0.21**	0.00	0.01	0.00	0.03	-0.02	-0.08	0.03	0.09	0.00	0.06	0.10	-0.02	0.05	**0.10**
	Shendure	0.04	-0.03	0.10	0.06	0.05	0.00	**-0.06**	0.00	-0.10	-0.01	0.10	0.08	0.09	0.07	-0.03	0.01	0.05
	Yasin	0.09	0.07	0.12	0.02	0.10	0.01	-0.11	-0.05	***-0.21***	0.10	0.04	-0.08	0.06	**0.11**	-0.04	0.03	***0.08***
	Rama	-0.08	0.10	0.05	0.02	0.06	0.01	0.00	0.01	-0.09	0.00	0.11	0.07	-0.02	0.03	0.03	0.02	0.02
	Hushe	0.00	**0.14**	0.08	0.02	0.14	-0.04	-0.08	0.04	**-0.09**	-0.04	0.04	0.01	0.06	0.06	-0.01	0.01	0.01
	Ushkore	-0.06	0.05	0.08	0.09	0.13	0.00	-0.04	-0.02	***-0.16***	-0.09	0.08	0.01	0.00	0.08	0.01	-0.01	0.00
	Ziarat	0.12	***0.23***	0.11	0.04	0.04	0.04	**-0.08**	0.01	**-0.10**	-0.01	0.09	0.09	***0.17***	0.07	0.00	0.01	***0.06***
	Naltar	-0.01	0.08	0.10	0.02	-0.01	-0.03	**-0.10**	-0.01	**-0.07**	0.00	-0.03	0.00	-0.07	0.10	-0.03	-0.01	0.04
	Rattu	-0.05	0.10	-0.08	-0.02	0.06	0.05	-0.07	0.01	-0.12	-0.02	0.07	0.01	0.04	-0.03	0.01	**-0.08**	-0.04
	Shigar	0.03	0.02	-0.01	-0.03	-0.21	-0.09	-0.07	0.05	0.07	-0.11	0.05	0.04	0.01	-0.02	-0.06	-0.01	0.01
	Skardu	-0.03	0.08	-0.02	-0.02	-0.07	-0.11	-0.15	-0.08	-0.10	***-0.12***	***-0.14***	-0.11	-0.18	-0.01	**-0.12**	***-0.16***	***-0.08***
	Astore	0.01	0.09	0.05	0.03	-0.02	0.02	-0.07	0.01	**-0.10**	-0.05	0.05	-0.08	0.06	**0.11**	-0.01	-0.03	-0.02
	Gupis	-0.15	-0.03	**0.19**	0.11	0.09	0.03	-0.04	0.04	-0.07	-0.03	-0.12	-0.14	-0.11	0.14	-0.04	-0.09	0.01
	Dainyor	-0.13	0.01	***0.13***	0.01	0.11	-0.04	***-0.17***	**0.03**	-0.06	-0.02	-0.06	-0.05	0.01	0.07	-0.03	-0.04	0.01
	Gilgit	0.03	0.10	0.06	0.04	0.04	0.05	-0.01	**0.26**	**0.30**	0.05	0.09	-0.01	0.08	***0.07***	0.06	0.19	**0.08**
	Bunji	0.01	0.03	0.05	0.03	0.02	0.04	-0.01	0.17	0.01	0.03	**0.13**	0.00	0.02	0.05	0.06	0.04	0.03
	Chilas	-0.09	***-0.18***	0.01	-0.07	0.02	-0.05	-0.11	-0.08	**-0.21**	-0.10	0.00	-0.06	-0.15	-0.05	**-0.07**	***-0.11***	-0.07
DTR	Khunrab	-0.10	***-0.25***	-0.30	-0.19	***-0.24***	-0.08	***-0.13***	**-0.11**	***-0.11***	-0.04	-0.03	-0.05	***-0.17***	-0.18	-0.04	***-0.04***	***-0.08***
	Deosai	0.07	-0.09	0.01	0.11	-0.05	0.05	0.16	***0.19***	0.01	0.02	-0.01	0.03	0.01	0.00	0.13	0.01	***0.13***
	Shendure	-0.06	-0.09	-0.26	***-0.29***	-0.17	-0.08	-0.03	-0.05	***-0.09***	-0.07	-0.05	-0.24	-0.12	**-0.20**	-0.10	-0.06	-0.15
	Yasin	-0.13	**-0.23**	-0.05	***-0.15***	-0.12	***-0.20***	-0.13	-0.11	***-0.22***	***-0.58***	-0.24	-0.19	**-0.08**	-0.07	**-0.14**	***-0.25***	**-0.12**
	Rama	-0.05	***-0.16***	-0.04	***-0.11***	-0.04	-0.02	***-0.15***	***-0.13***	***-0.27***	-0.20	-0.08	-0.07	***-0.09***	-0.07	***-0.07***	***-0.13***	***-0.08***
	Hushe	***-0.08***	***-0.17***	-0.01	-0.05	-0.02	0.00	-0.03	-0.02	***-0.07***	0.00	-0.03	-0.01	***-0.10***	-0.01	-0.02	***-0.03***	***-0.04***
	Ushkore	0.00	-0.06	-0.02	-0.08	-0.01	-0.05	-0.01	-0.02	***-0.08***	-0.01	-0.02	-0.03	-0.03	-0.02	-0.03	**-0.03**	***-0.03***
	Ziarat	-0.09	***-0.26***	0.02	-0.02	0.01	-0.01	-0.05	-0.01	***-0.10***	-0.03	-0.03	-0.12	-0.13	0.03	-0.02	**-0.05**	***-0.06***
	Naltar	-0.06	***-0.15***	0.02	-0.06	0.06	-0.02	-0.02	-0.02	-0.09	-0.03	-0.03	-0.13	***-0.08***	0.00	-0.01	-0.06	**-0.05**
	Rattu	-0.10	**-0.16**	-0.04	**-0.10**	0.02	-0.04	-0.09	***-0.11***	***-0.18***	***-0.16***	-0.18	**-0.15**	***-0.12***	-0.01	**-0.04**	-0.10	**-0.05**
	Shigar	0.08	0.00	-0.05	0.00	0.01	0.03	-0.03	-0.01	-0.07	0.01	**0.08**	0.07	0.07	0.03	-0.06	0.00	-0.07
	Skardu	-0.04	**-0.14**	0.06	0.01	**0.13**	0.06	-0.01	-0.02	***-0.21***	0.04	0.03	0.14	-0.07	0.07	-0.01	-0.01	0.00
	Astore	-0.02	-0.13	0.13	0.00	0.05	0.00	-0.03	-0.07	***-0.08***	0.03	-0.03	0.04	-0.09	0.06	-0.02	-0.05	-0.01
	Gupis	0.04	0.00	0.15	-0.01	0.10	-0.01	-0.03	-0.10	-0.05	**0.16**	0.16	0.15	***0.13***	0.07	-0.06	0.09	0.09
	Dainyor	-0.05	-0.09	0.06	-0.11	-0.21	-0.19	-0.11	-0.07	-0.10	-0.44	-0.01	-0.07	-0.09	-0.07	-0.23	-0.12	-0.19
	Gilgit	-0.13	**-0.19**	0.05	-0.02	0.10	-0.13	***-0.27***	***-0.26***	***-0.87***	-0.18	-0.09	-0.02	-0.11	-0.03	***-0.15***	***-0.25***	***-0.18***
	Bunji	-0.04	***-0.14***	0.05	0.03	0.04	-0.01	-0.03	-0.04	**-0.27**	-0.03	-0.16	-0.10	-0.07	0.06	-0.01	***-0.14***	-0.05
	Chilas	0.07	0.09	***0.21***	0.11	**0.13**	0.03	-0.04	0.04	0.00	0.08	0.01	0.04	0.10	***0.14***	0.02	0.02	0.02

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tx	Khunjrab	0.01	-0.01	0.10	0.03	0.12	-0.01	-0.09	0.06	-0.16	0.01	0.12	0.07	0.05	0.07	-0.05	0.04	0.04
	Deosai	0.02	-0.05	0.07	-0.01	0.06	0.01	-0.19	-0.01	0.00	0.02	0.06	0.05	0.08	0.06	0.03	0.02	0.06
	Shendure	-0.17	**-0.09**	0.01	-0.03	-0.06	-0.10	**-0.13**	**-0.07**	**-0.22**	-0.06	0.04	-0.11	-0.08	-0.06	**-0.11**	-0.05	-0.05
	Yasin	0.00	-0.03	**0.13**	-0.02	0.10	0.03	-0.16	-0.08	**-0.35**	0.12	-0.02	-0.10	0.03	0.08	-0.06	-0.01	0.05
	Rama	-0.06	-0.07	0.02	**-0.11**	0.14	0.04	-0.11	-0.09	**-0.29**	-0.10	0.01	0.00	-0.04	-0.04	**-0.07**	-0.07	**-0.08**
	Hushe	-0.05	-0.01	0.09	0.00	0.17	-0.06	-0.09	0.02	**-0.20**	-0.09	0.01	0.03	0.02	0.03	-0.02	-0.03	-0.03
	Ushkore	-0.04	-0.02	0.10	0.03	0.25	-0.01	-0.12	-0.06	**-0.22**	-0.05	0.06	-0.01	0.02	0.08	-0.05	-0.02	-0.01
	Ziarat	0.00	-0.01	0.12	-0.02	0.13	0.09	-0.11	-0.03	**-0.21**	-0.04	0.09	0.04	0.06	0.06	-0.02	-0.04	0.01
	Naltar	-0.04	-0.04	0.10	-0.03	0.10	0.03	-0.12	-0.03	**-0.19**	0.03	-0.01	0.01	-0.02	0.07	-0.03	-0.05	0.00
	Rattu	**-0.16**	-0.10	0.04	-0.03	0.11	0.14	-0.06	-0.05	-0.17	-0.23	0.04	-0.15	**-0.12**	-0.03	0.01	-0.03	**-0.07**
	Shigar	-0.04	-0.08	-0.02	-0.08	-0.38	-0.15	-0.08	0.03	-0.01	-0.09	0.11	0.01	-0.02	-0.09	**-0.09**	-0.02	-0.02
	Skardu	0.10	0.08	0.12	0.04	0.04	-0.08	**-0.10**	0.06	**-0.23**	-0.10	-0.04	-0.05	-0.02	0.13	-0.07	**-0.09**	-0.02
	Astore	0.09	0.00	**0.20**	0.03	0.18	0.06	-0.05	-0.03	**-0.15**	-0.11	0.05	0.04	0.08	**0.15**	-0.01	-0.05	0.02
	Gupis	-0.05	0.03	**0.27**	0.11	0.20	0.01	-0.09	-0.13	-0.09	0.12	0.12	0.03	0.11	0.20	0.03	0.03	0.07
	Dainyor	-0.04	-0.08	**0.23**	-0.02	0.15	-0.19	**-0.18**	0.01	-0.15	-0.04	0.10	-0.07	**-0.06**	0.14	-0.08	-0.01	-0.02
	Gilgit	0.09	-0.07	0.12	0.03	0.15	0.02	**-0.15**	**-0.08**	**-0.31**	-0.07	0.07	-0.05	-0.04	0.06	-0.05	**-0.08**	-0.05
	Bunji	0.09	-0.08	0.13	0.04	0.11	0.07	-0.01	0.04	**-0.22**	-0.12	-0.01	-0.08	0.00	0.11	0.02	-0.07	-0.02
	Chilas	0.09	-0.03	**0.16**	0.01	0.13	0.01	**-0.15**	-0.06	**-0.24**	0.00	0.03	-0.06	-0.05	0.08	**-0.07**	-0.05	-0.06
Tn	Khunrab	**0.15**	**0.26**	**0.16**	0.03	0.18	-0.02	-0.04	0.00	0.01	0.05	**0.17**	0.10	**0.21**	0.08	-0.01	0.06	**0.09**
	Deosai	0.02	0.09	**0.21**	0.00	0.01	0.00	0.03	-0.02	-0.08	0.03	0.09	0.00	0.06	0.10	-0.02	0.05	**0.10**
	Shendure	0.04	-0.03	0.10	0.06	0.05	0.00	**-0.06**	0.00	-0.10	-0.01	0.10	0.08	0.09	0.07	-0.03	0.01	0.05
	Yasin	0.09	0.07	0.12	0.02	0.10	0.01	-0.11	-0.05	**-0.21**	0.10	0.04	-0.08	0.06	**0.11**	-0.04	0.03	**0.08**
	Rama	-0.08	0.10	0.05	0.02	0.06	0.01	0.00	0.01	-0.09	0.00	0.11	0.07	-0.02	0.03	0.03	0.02	0.02
	Hushe	0.00	**0.14**	0.08	0.02	0.14	-0.04	-0.08	0.04	**-0.09**	-0.04	0.04	0.01	0.06	0.06	-0.01	0.01	0.01
	Ushkore	-0.06	0.05	0.08	0.09	0.13	0.00	-0.04	-0.02	**-0.16**	-0.09	0.08	0.01	0.00	0.08	0.01	-0.01	0.00
	Ziarat	0.12	**0.23**	0.11	0.04	0.04	0.04	**-0.08**	0.01	**-0.10**	-0.01	0.09	0.09	**0.17**	0.07	0.00	0.01	**0.06**
	Naltar	-0.01	0.08	0.10	0.02	-0.01	-0.03	**-0.10**	-0.01	**-0.07**	0.00	-0.03	0.00	-0.07	0.10	-0.03	-0.01	0.04
	Rattu	-0.05	0.10	-0.08	-0.02	0.06	0.05	-0.07	0.01	-0.12	-0.02	0.07	0.01	0.04	-0.03	0.01	**-0.08**	-0.04
	Shigar	0.03	0.02	-0.01	-0.03	-0.21	-0.09	-0.07	0.05	0.07	-0.11	0.05	0.04	0.01	-0.02	-0.06	-0.01	0.01
	Skardu	-0.03	0.08	-0.02	-0.02	-0.07	-0.11	-0.15	-0.08	-0.10	**-0.12**	**-0.14**	-0.11	-0.18	-0.01	**-0.12**	**-0.16**	**-0.08**
	Astore	0.01	0.09	0.05	0.03	-0.02	0.02	-0.07	0.01	**-0.10**	-0.05	0.05	-0.08	0.06	**0.11**	-0.01	-0.03	-0.02
	Gupis	-0.15	-0.03	**0.19**	0.11	0.09	0.03	-0.04	0.04	-0.07	-0.03	-0.12	-0.14	-0.11	0.14	-0.04	-0.09	0.01
	Dainyor	-0.13	0.01	**0.13**	0.01	0.11	-0.04	**-0.17**	**0.03**	-0.06	-0.02	-0.06	-0.05	0.01	0.07	-0.03	-0.04	0.01
	Gilgit	0.03	0.10	0.06	0.04	0.04	0.05	-0.01	**0.26**	**0.30**	0.05	0.09	-0.01	0.08	**0.07**	0.06	0.19	**0.08**
	Bunji	0.01	0.03	0.05	0.03	0.02	0.04	-0.01	0.17	0.01	0.03	**0.13**	0.00	0.02	0.05	0.06	0.04	0.03
	Chilas	-0.09	**-0.18**	0.01	-0.07	0.02	-0.05	-0.11	-0.08	**-0.21**	-0.10	0.00	-0.06	-0.15	-0.05	**-0.07**	**-0.11**	-0.07
DTR	Khunrab	-0.10	**-0.25**	-0.30	-0.19	**-0.24**	-0.08	**-0.13**	**-0.11**	**-0.11**	-0.04	-0.03	-0.05	**-0.17**	-0.18	-0.04	**-0.04**	**-0.08**
	Deosai	0.07	-0.09	0.01	0.11	-0.05	0.05	0.16	**0.19**	0.01	0.02	-0.01	0.03	0.01	0.00	0.13	0.01	**0.13**
	Shendure	-0.06	-0.09	-0.26	**-0.29**	-0.17	-0.08	-0.03	-0.05	**-0.09**	-0.07	-0.05	-0.24	-0.12	**-0.20**	-0.10	-0.06	-0.15
	Yasin	-0.13	**-0.23**	-0.05	**-0.15**	-0.12	**-0.20**	-0.13	-0.11	**-0.22**	**-0.58**	-0.24	-0.19	**-0.08**	-0.07	**-0.14**	**-0.25**	**-0.12**
	Rama	-0.05	**-0.16**	-0.04	**-0.11**	-0.04	-0.02	**-0.15**	**-0.13**	**-0.27**	-0.20	-0.08	-0.07	**-0.09**	-0.07	**-0.07**	**-0.13**	**-0.08**
	Hushe	**-0.08**	**-0.17**	-0.01	-0.05	-0.02	0.00	-0.03	-0.02	**-0.07**	0.00	-0.03	-0.01	**-0.10**	-0.01	-0.02	**-0.03**	**-0.04**
	Ushkore	0.00	-0.06	-0.02	-0.08	-0.01	-0.05	-0.01	-0.02	**-0.08**	-0.01	-0.02	-0.03	-0.03	-0.02	-0.03	**-0.03**	**-0.03**
	Ziarat	-0.09	**-0.26**	0.02	-0.02	0.01	-0.01	-0.05	-0.01	**-0.10**	-0.03	-0.03	-0.12	-0.13	0.03	-0.02	**-0.05**	**-0.06**
	Naltar	-0.06	**-0.15**	0.02	-0.06	0.06	-0.02	-0.02	-0.02	-0.09	-0.03	-0.03	-0.13	**-0.08**	0.00	-0.01	-0.06	**-0.05**
	Rattu	-0.10	**-0.16**	-0.04	**-0.10**	0.02	-0.04	-0.09	**-0.11**	**-0.18**	**-0.16**	-0.18	**-0.15**	**-0.12**	-0.01	**-0.04**	-0.10	**-0.05**
	Shigar	0.08	0.00	-0.05	0.00	0.01	0.03	-0.03	-0.01	-0.07	0.01	**0.08**	0.07	0.07	0.03	-0.06	0.00	-0.07
	Skardu	-0.04	**-0.14**	0.06	0.01	**0.13**	0.06	-0.01	-0.02	**-0.21**	0.04	0.03	0.14	-0.07	0.07	-0.01	-0.01	0.00
	Astore	-0.02	-0.13	0.13	0.00	0.05	0.00	-0.03	-0.07	**-0.08**	0.03	-0.03	0.04	-0.09	0.06	-0.02	-0.05	-0.01
	Gupis	0.04	0.00	0.15	-0.01	0.10	-0.01	-0.03	-0.10	-0.05	**0.16**	0.16	0.15	**0.13**	0.07	-0.06	0.09	0.09
	Dainyor	-0.05	-0.09	0.06	-0.11	-0.21	-0.19	-0.11	-0.07	-0.10	-0.44	-0.01	-0.07	-0.09	-0.07	-0.23	-0.12	-0.19
	Gilgit	-0.13	**-0.19**	0.05	-0.02	0.10	-0.13	**-0.27**	**-0.26**	**-0.87**	-0.18	-0.09	-0.02	-0.11	-0.03	**-0.15**	**-0.25**	**-0.18**
	Bunji	-0.04	**-0.14**	0.05	0.03	0.04	-0.01	-0.03	-0.04	**-0.27**	-0.03	-0.16	-0.10	-0.07	0.06	-0.01	**-0.14**	-0.05
	Chilas	0.07	0.09	**0.21**	0.11	**0.13**	0.03	-0.04	0.04	0.00	0.08	0.01	0.04	0.10	**0.14**	0.02	0.02	0.02

Tabular Figure 5: Same as ~~Table~~ Tabular Figure 4 ~~but trend~~. Here, slopes ~~are~~ for ~~Tavg in °C yr-1, for total~~ P are in mm ~~yr-1~~ and for ~~mean~~ Q in m^3s^{-1} ~~yr-1. Color scale is distinct for each time scale where~~[1]. Hydrometric gauges are given in the downstream order. Blue, yellow and orange (red, green and cyan) colors refer to ~~decrease (increase)~~ decreasing (increasing) trends in Tavg, P and Q, respectively.

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tavg	Khunrab	0.13	0.09	0.13	0.05	0.19	0.00	-0.06	0.06	-0.13	0.05	***0.17***	0.10	***0.15***	0.09	-0.03	0.06	0.06
	Deosai	0.06	0.01	**0.15**	0.00	0.07	0.01	-0.07	0.03	-0.05	0.02	0.08	0.01	***0.10***	0.06	0.03	0.04	**0.07**
	Shendure	-0.05	-0.05	0.05	0.02	0.02	-0.05	-0.10	-0.05	**-0.15**	-0.04	0.06	-0.03	0.01	-0.04	-0.05	-0.02	0.01
	Yasin	0.02	0.01	**0.13**	0.01	0.06	0.04	-0.19	-0.07	***-0.27***	0.11	0.01	-0.08	0.04	0.13	-0.05	0.02	0.06
	Rama	-0.12	0.02	0.05	-0.06	0.07	0.01	-0.03	-0.03	**-0.19**	-0.09	0.05	0.02	0.02	0.00	0.00	-0.01	-0.04
	Hushe	-0.03	0.05	0.06	0.02	0.14	-0.05	-0.07	0.02	**-0.13**	-0.07	0.03	0.04	0.01	0.06	-0.01	0.00	-0.01
	Ushkore	-0.07	0.00	0.08	0.05	0.21	0.00	-0.03	-0.03	***-0.17***	-0.09	0.06	0.01	0.04	0.09	-0.01	-0.02	0.01
	Ziarat	0.04	***0.11***	0.10	0.00	0.09	0.06	-0.09	-0.03	***-0.15***	-0.03	0.09	0.03	**0.08**	**0.07**	-0.02	0.00	0.05
	Naltar	-0.03	0.01	0.08	-0.05	-0.11	-0.07	**-0.12**	-0.06	***-0.17***	0.00	-0.03	0.01	-0.13	0.07	-0.04	-0.04	0.01
	Rattu	-0.11	-0.01	-0.05	-0.04	0.09	0.10	-0.04	0.00	-0.18	-0.07	0.04	-0.10	-0.06	0.03	0.00	-0.05	-0.05
	Shigar	0.05	-0.02	0.00	-0.06	-0.30	-0.13	-0.13	0.04	0.04	-0.14	0.07	0.03	0.01	-0.04	-0.07	-0.01	0.00
	Skardu	0.02	0.11	0.07	0.01	0.02	-0.10	***-0.15***	0.04	***-0.17***	***-0.11***	**-0.06**	-0.07	-0.11	0.06	-0.12	***-0.12***	**-0.07**
	Astore	0.10	0.03	**0.12**	0.01	0.13	0.03	-0.05	0.00	***-0.14***	-0.09	0.03	-0.01	0.05	**0.13**	-0.02	-0.03	0.01
	Gupis	-0.08	-0.06	***0.22***	0.09	0.13	0.00	-0.05	-0.05	-0.08	0.06	0.04	-0.07	0.02	**0.14**	0.02	-0.01	0.03
	Dainyor	-0.06	-0.02	***0.22***	-0.01	0.18	-0.08	***-0.15***	0.02	-0.11	-0.04	0.04	-0.09	-0.05	0.11	-0.04	-0.04	0.00
	Gilgit	0.02	0.01	0.11	0.03	0.06	0.04	-0.06	0.05	-0.09	0.00	***0.08***	0.05	0.03	0.08	-0.02	0.00	0.03
	Bunji	0.06	-0.02	0.06	0.02	0.05	0.02	0.00	0.09	-0.07	0.03	0.06	-0.06	0.03	0.08	0.06	0.00	0.01
	Chilas	-0.02	-0.14	0.06	-0.02	0.16	-0.03	**-0.12**	-0.07	**-0.19**	-0.07	0.01	-0.06	***-0.09***	0.03	**-0.06**	**-0.08**	-0.07
P	Khunrab	***3.64***	2.59	-2.21	-1.55	-1.47	0.10	0.35	0.80	1.82	-1.04	0.93	2.34	***8.86***	-9.09	-1.74	1.65	6.14
	Deosai	0.07	1.28	**-1.42**	-0.66	-1.27	-0.89	-0.40	-1.00	-0.77	-0.42	-0.81	-0.32	1.40	-4.50	0.00	-1.99	-7.87
	Shendure	***1.54***	***2.75***	1.35	2.13	0.60	***2.12***	***1.83***	***1.38***	***1.45***	1.24	1.40	***1.20***	***5.71***	***4.50***	***4.82***	**3.58**	***29.53***
	Yasin	1.33	***1.86***	0.59	0.25	1.22	-0.50	***1.45***	0.02	0.92	-0.21	0.06	**2.74**	***6.09***	0.60	1.32	0.26	11.70
	Rama	0.77	0.00	-6.50	***-8.55***	***-4.52***	***-2.16***	***-2.35***	***-1.89***	***-1.44***	***-2.05***	-3.74	-2.03	7.00	***-25.44***	***-8.41***	***-14.60***	***-43.92***
	Hushe	0.65	0.24	-1.23	-0.30	-1.97	-1.21	-1.71	-0.60	0.73	-0.64	0.11	0.72	***3.47***	-4.51	-4.28	0.70	-5.54
	Ushkore	0.56	-0.59	***-2.33***	-1.02	-1.97	-0.93	0.00	-0.09	1.01	***-0.61***	-0.48	0.09	-0.13	-4.57	-1.54	-0.42	-3.83
	Ziarat	-0.91	-0.56	***-4.18***	**-5.28**	-1.83	0.25	-0.67	-0.18	**1.20**	-0.58	-0.43	-0.61	-3.59	**-9.10**	-1.71	-0.21	**-16.32**
	Naltar	3.75	8.41	-4.49	-0.36	-2.75	**-2.17**	0.43	-2.33	1.32	-0.36	-0.70	1.35	**19.43**	-8.39	-0.99	2.42	-0.28
	Rattu	***1.36***	**2.13**	0.08	0.36	0.26	0.53	***0.91***	0.75	***0.95***	***0.84***	***0.69***	***1.53***	***4.43***	1.23	1.81	***2.36***	10.64
	Shigar	-0.24	-0.89	-1.07	-2.62	-2.05	-0.33	1.75	0.80	***2.40***	1.13	0.18	1.49	-1.67	***-8.36***	0.78	**3.08**	-7.04
	Skardu	-0.64	1.62	0.60	0.19	-0.74	-0.47	-0.07	-0.44	0.46	0.00	0.00	0.20	0.41	0.89	-1.26	0.49	1.29
	Astore	0.00	0.41	0.12	**-1.41**	-0.48	-0.16	-0.08	-0.29	0.57	0.00	0.00	0.29	1.50	-1.36	-1.63	0.34	-0.16
	Gupis	0.65	**0.97**	**0.81**	0.38	-0.06	**-1.33**	**-1.07**	-0.49	0.06	0.35	0.26	***0.89***	2.81	0.29	***-3.49***	0.43	4.46
	Dainyor	-0.21	0.42	***0.51***	**0.55**	***0.67***	***1.24***	0.91	-0.71	-0.39	0.00	0.00	0.00	***1.68***	**1.81**	3.09	-0.34	6.69
	Gilgit	0.98	0.45	**-1.94**	-1.34	-1.57	-0.73	0.29	***-3.99***	0.32	0.00	0.00	0.30	0.00	***-9.39***	***-9.60***	-0.92	**-20.31**
	Bunji	0.01	-0.10	***-1.06***	***-2.34***	0.17	0.20	-0.34	-0.22	0.56	-0.01	0.00	0.11	-0.47	-2.68	-0.51	0.06	0.09
	Chilas	0.00	0.13	-0.14	-1.56	0.16	0.29	-0.51	0.13	***1.37***	-0.10	0.00	0.07	0.22	-0.81	-0.80	1.86	0.53
Q	UIB-East	***-0.80***	0.00	0.04	0.11	-4.19	2.00	-1.65	6.70	-4.74	-5.45	***-2.46***	**-1.37**	***-0.75***	-2.64	-2.62	-0.86	-1.73
	Eastern-Karakoram	0.06	0.08	-0.10	0.00	1.96	0.96	***-22.97***	0.92	-8.84	-1.06	0.50	-0.09	0.29	0.67	0.30	-4.41	-0.95
	Central-Karakoram	0.96	1.28	1.56	-0.84	3.74	-8.94	***-37.93***	-9.08	-5.98	0.71	2.50	***2.76***	1.13	1.13	-21.61	1.10	-1.56
	Kachura	0.33	1.39	**1.06**	-0.33	-2.08	-22.50	**-50.04**	-16.74	-4.25	-2.18	0.59	2.64	0.46	-0.81	-18.90	-2.63	-4.97
	UIB-Central	**2.19**	1.81	2.02	-0.84	6.89	-18.08	***-43.79***	-20.20	-4.88	1.05	***4.38***	***2.34***	**2.00**	1.79	-18.34	2.01	-2.47
	Western-Karakoram	1.20	1.00	1.50	***2.00***	0.59	12.09	-4.53	-4.09	**6.40**	***3.50***	***3.82***	***2.03***	***1.88***	1.00	-1.64	***5.43***	2.50
	Karakoram	1.88	2.00	1.33	1.00	-5.82	-7.80	***-64.97***	-37.17	-9.48	0.60	***8.97***	***5.97***	***1.65***	0.11	-24.43	5.64	-3.90
	Hindukush	0.87	0.26	0.15	1.27	2.05	3.49	-6.61	**14.02**	**7.03**	2.17	1.82	1.06	0.75	1.00	3.94	4.44	4.00
	UIB-WU	1.24	**1.02**	1.39	**2.38**	***16.85***	12.38	-25.48	-15.50	-1.28	0.69	0.98	0.52	0.55	***7.76***	-3.68	0.45	-1.25
	Astore	0.05	0.00	0.22	0.50	7.65	4.26	-3.01	5.00	-1.00	-1.11	-0.67	0.00	0.00	2.20	1.97	-0.89	2.16
	Partab_Bridge	1.00	-0.13	3.60	8.80	63.22	-34.86	-39.86	-67.33	29.65	0.69	8.89	15.12	8.40	36.29	-67.00	9.81	-12.40
	UIB-WL	1.88	0.41	6.39	-0.52	41.58	**59.50**	28.19	***81.58***	**30.99**	16.18	5.17	2.33	1.92	19.90	***65.53***	***16.02***	***25.44***
	UIB-WL-Partab	-3.00	0.80	-4.38	-0.82	***87.89***	51.53	9.00	17.67	2.71	-12.24	1.40	-6.00	-3.74	28.32	47.93	-3.00	18.94
	UIB_West	2.45	1.37	5.43	2.42	**61.35**	54.89	0.21	42.93	***28.24***	**13.68**	***5.87***	1.38	2.00	**23.43**	44.18	***17.71***	***22.17***
	Himalaya	0.30	-0.32	4.10	0.91	43.99	62.23	12.43	83.33	22.43	9.97	2.32	0.23	1.17	26.64	**57.88**	7.75	***24.66***
	~~UIB~~	1.82	***5.09***	5.37	-2.50	11.35	14.67	-46.60	41.71	35.22	10.17	5.29	0.75	1.91	15.72	-1.40	19.35	4.25

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tavg	Khunjrab	0.13	0.09	0.13	0.05	0.19	0.00	-0.06	0.06	-0.13	0.05	**0.17**	0.10	**0.15**	0.09	-0.03	0.06	0.06
	Deosai	0.06	0.01	**0.15**	0.00	0.07	0.01	-0.07	0.03	-0.05	0.02	0.08	0.01	**0.10**	0.06	0.03	0.04	**0.07**
	Shendure	-0.05	-0.05	0.05	0.02	0.02	-0.05	-0.10	-0.05	**-0.15**	-0.04	0.06	-0.03	0.01	-0.04	-0.05	-0.02	0.01
	Yasin	0.02	0.01	**0.13**	0.01	0.06	0.04	-0.19	-0.07	**-0.27**	0.11	0.01	-0.08	0.04	0.13	-0.05	0.02	0.06
	Rama	-0.12	0.02	0.05	-0.06	0.07	0.01	-0.03	-0.03	**-0.19**	-0.09	0.05	0.02	0.02	0.00	0.00	-0.01	-0.04
	Hushe	-0.03	0.05	0.06	0.02	0.14	-0.05	-0.07	0.02	**-0.13**	-0.07	0.03	0.04	0.01	0.06	-0.01	0.00	-0.01
	Ushkore	-0.07	0.00	0.08	0.05	0.21	0.00	-0.03	-0.03	**-0.17**	-0.09	0.06	0.01	0.04	0.09	-0.01	-0.02	0.01
	Ziarat	0.04	**0.11**	0.10	0.00	0.09	0.06	-0.09	-0.03	**-0.15**	-0.03	0.09	0.03	**0.08**	**0.07**	-0.02	0.00	0.05
	Naltar	-0.03	0.01	0.08	-0.05	-0.11	-0.07	**-0.12**	-0.06	**-0.17**	0.00	-0.03	0.01	-0.13	0.07	-0.04	-0.04	0.01
	Rattu	-0.11	-0.01	-0.05	-0.04	0.09	0.10	-0.04	0.00	-0.18	-0.07	0.04	-0.10	-0.06	0.03	0.00	-0.05	-0.05
	Shigar	0.05	-0.02	0.00	-0.06	-0.30	-0.13	-0.13	0.04	0.04	-0.14	0.07	0.03	0.01	-0.04	-0.07	-0.01	0.00
	Skardu	0.02	0.11	0.07	0.01	0.02	-0.10	**-0.15**	0.04	**-0.17**	**-0.11**	**-0.06**	-0.07	-0.11	0.06	-0.12	**-0.12**	**-0.07**
	Astore	0.10	0.03	**0.12**	0.01	0.13	0.03	-0.05	0.00	**-0.14**	-0.09	0.03	-0.01	0.05	**0.13**	-0.02	-0.03	0.01
	Gupis	-0.08	-0.06	**0.22**	0.09	0.13	0.00	-0.05	-0.05	-0.08	0.06	0.04	-0.07	0.02	**0.14**	0.02	-0.01	0.03
	Dainyor	-0.06	-0.02	**0.22**	-0.01	0.18	-0.08	**-0.15**	0.02	-0.11	-0.04	0.04	-0.09	-0.05	0.11	-0.04	-0.04	0.00
	Gilgit	0.02	0.01	0.11	0.03	0.06	0.04	-0.06	0.05	-0.09	0.00	**0.08**	0.05	0.03	0.08	-0.02	0.00	0.03
	Bunji	0.06	-0.02	0.06	0.02	0.05	0.02	0.00	0.09	-0.07	0.03	0.06	-0.06	0.03	0.08	0.06	0.00	0.01
	Chilas	-0.02	-0.14	0.06	-0.02	0.16	-0.03	**-0.12**	-0.07	**-0.19**	-0.07	0.01	-0.06	**-0.09**	0.03	**-0.06**	**-0.08**	-0.07
P	Khunrab	**3.64**	2.59	-2.21	-1.55	-1.47	0.10	0.35	0.80	1.82	-1.04	0.93	2.34	**8.86**	-9.09	-1.74	1.65	6.14
	Deosai	0.07	1.28	**-1.42**	-0.66	-1.27	-0.89	-0.40	-1.00	-0.77	-0.42	-0.81	-0.32	1.40	-4.50	0.00	-1.99	-7.87
	Shendure	**1.54**	**2.75**	1.35	2.13	0.60	**2.12**	**1.83**	**1.38**	**1.45**	1.24	1.40	**1.20**	**5.71**	**4.50**	**4.82**	**3.58**	**29.53**
	Yasin	1.33	**1.86**	0.59	0.25	1.22	-0.50	**1.45**	0.02	0.92	-0.21	0.06	**2.74**	**6.09**	0.60	1.32	0.26	11.70
	Rama	0.77	0.00	-6.50	**-8.55**	**-4.52**	**-2.16**	**-2.35**	**-1.89**	**-1.44**	**-2.05**	-3.74	-2.03	7.00	**-25.44**	**-8.41**	**-14.60**	**-43.92**
	Hushe	0.65	0.24	-1.23	-0.30	-1.97	-1.21	-1.71	-0.60	0.73	-0.64	0.11	0.72	**3.47**	-4.51	-4.28	0.70	-5.54
	Ushkore	0.56	-0.59	**-2.33**	-1.02	-1.97	-0.93	0.00	-0.09	1.01	**-0.61**	-0.48	0.09	-0.13	-4.57	-1.54	-0.42	-3.83
	Ziarat	-0.91	-0.56	**-4.18**	**-5.28**	-1.83	0.25	-0.67	-0.18	**1.20**	-0.58	-0.43	-0.61	-3.59	**-9.10**	-1.71	-0.21	**-16.32**
	Naltar	3.75	8.41	-4.49	-0.36	-2.75	**-2.17**	0.43	-2.33	1.32	-0.36	-0.70	1.35	**19.43**	-8.39	-0.99	2.42	-0.28
	Rattu	**1.36**	**2.13**	0.08	0.36	0.26	0.53	**0.91**	0.75	**0.95**	**0.84**	**0.69**	**1.53**	**4.43**	1.23	1.81	**2.36**	10.64
	Shigar	-0.24	-0.89	-1.07	-2.62	-2.05	-0.33	1.75	0.80	**2.40**	1.13	0.18	1.49	-1.67	**-8.36**	0.78	**3.08**	-7.04
	Skardu	-0.64	1.62	0.60	0.19	-0.74	-0.47	-0.07	-0.44	0.46	0.00	0.00	0.20	0.41	0.89	-1.26	0.49	1.29
	Astore	0.00	0.41	0.12	**-1.41**	-0.48	-0.16	-0.08	-0.29	0.57	0.00	0.00	0.29	1.50	-1.36	-1.63	0.34	-0.16
	Gupis	0.65	**0.97**	**0.81**	0.38	-0.06	**-1.33**	**-1.07**	-0.49	0.06	0.35	0.26	**0.89**	2.81	0.29	**-3.49**	0.43	4.46
	Dainyor	-0.21	0.42	**0.51**	**0.55**	**0.67**	**1.24**	0.91	-0.71	-0.39	0.00	0.00	0.00	**1.68**	**1.81**	3.09	-0.34	6.69
	Gilgit	0.98	0.45	**-1.94**	-1.34	-1.57	-0.73	0.29	**-3.99**	0.32	0.00	0.00	0.30	0.00	**-9.39**	**-9.60**	-0.92	**-20.31**
	Bunji	0.01	-0.10	**-1.06**	**-2.34**	0.17	0.20	-0.34	-0.22	0.56	-0.01	0.00	0.11	-0.47	-2.68	-0.51	0.06	0.09
	Chilas	0.00	0.13	-0.14	-1.56	0.16	0.29	-0.51	0.13	**1.37**	-0.10	0.00	0.07	0.22	-0.81	-0.80	1.86	0.53
Q	UIB-East	**-0.80**	0.00	0.04	0.11	-4.19	2.00	-1.65	6.70	-4.74	-5.45	**-2.46**	**-1.37**	**-0.75**	-2.64	-2.62	-0.86	-1.73
	Eastern-Karakoram	0.06	0.08	-0.10	0.00	1.96	0.96	**-22.97**	0.92	-8.84	-1.06	0.50	-0.09	0.29	0.67	0.30	-4.41	-0.95
	Central-Karakoram	0.96	1.28	1.56	-0.84	3.74	-8.94	**-37.93**	-9.08	-5.98	0.71	2.50	**2.76**	1.13	1.13	-21.61	1.10	-1.56
	Kachura	0.33	1.39	**1.06**	-0.33	-2.08	-22.50	**-50.04**	-16.74	-4.25	-2.18	0.59	2.64	0.46	-0.81	-18.90	-2.63	-4.97
	UIB-Central	**2.19**	1.81	2.02	-0.84	6.89	-18.08	**-43.79**	-20.20	-4.88	1.05	**4.38**	**2.34**	**2.00**	1.79	-18.34	2.01	-2.47
	Western-Karakoram	1.20	1.00	1.50	**2.00**	0.59	12.09	-4.53	-4.09	**6.40**	**3.50**	**3.82**	**2.03**	**1.88**	1.00	-1.64	**5.43**	2.50
	Karakoram	1.88	2.00	1.33	1.00	-5.82	-7.80	**-64.97**	-37.17	-9.48	0.60	**8.97**	**5.97**	**1.65**	0.11	-24.43	5.64	-3.90
	Hindukush	0.87	0.26	0.15	1.27	2.05	3.49	-6.61	**14.02**	**7.03**	2.17	1.82	1.06	0.75	1.00	3.94	4.44	4.00
	UIB-WU	1.24	**1.02**	1.39	**2.38**	**16.85**	12.38	-25.48	-15.50	-1.28	0.69	0.98	0.52	0.55	**7.76**	-3.68	0.45	-1.25
	Astore	0.05	0.00	0.22	0.50	7.65	4.26	-3.01	5.00	-1.00	-1.11	-0.67	0.00	0.00	2.20	1.97	-0.89	2.16
	Partab_Bridge	1.00	-0.13	3.60	8.80	63.22	-34.86	-39.86	-67.33	29.65	0.69	8.89	15.12	8.40	36.29	-67.00	9.81	-12.40
	UIB-WL	1.88	0.41	6.39	-0.52	41.58	**59.50**	28.19	**81.58**	**30.99**	16.18	5.17	2.33	1.92	19.90	**65.53**	**16.02**	**25.44**
	UIB-WL-Partab	-3.00	0.80	-4.38	-0.82	**87.89**	51.53	9.00	17.67	2.71	-12.24	1.40	-6.00	-3.74	28.32	47.93	-3.00	18.94
	UIB_West	2.45	1.37	5.43	2.42	**61.35**	54.89	0.21	42.93	**28.24**	**13.68**	**5.87**	1.38	2.00	**23.43**	44.18	**17.71**	**22.17**
	Himalaya	0.30	-0.32	4.10	0.91	43.99	62.23	12.43	83.33	22.43	9.97	2.32	0.23	1.17	26.64	**57.88**	7.75	**24.66**
	UIB	1.82	**5.09**	5.37	-2.50	11.35	14.67	-46.60	41.71	35.22	10.17	5.29	0.75	1.91	15.72	-1.40	19.35	4.25

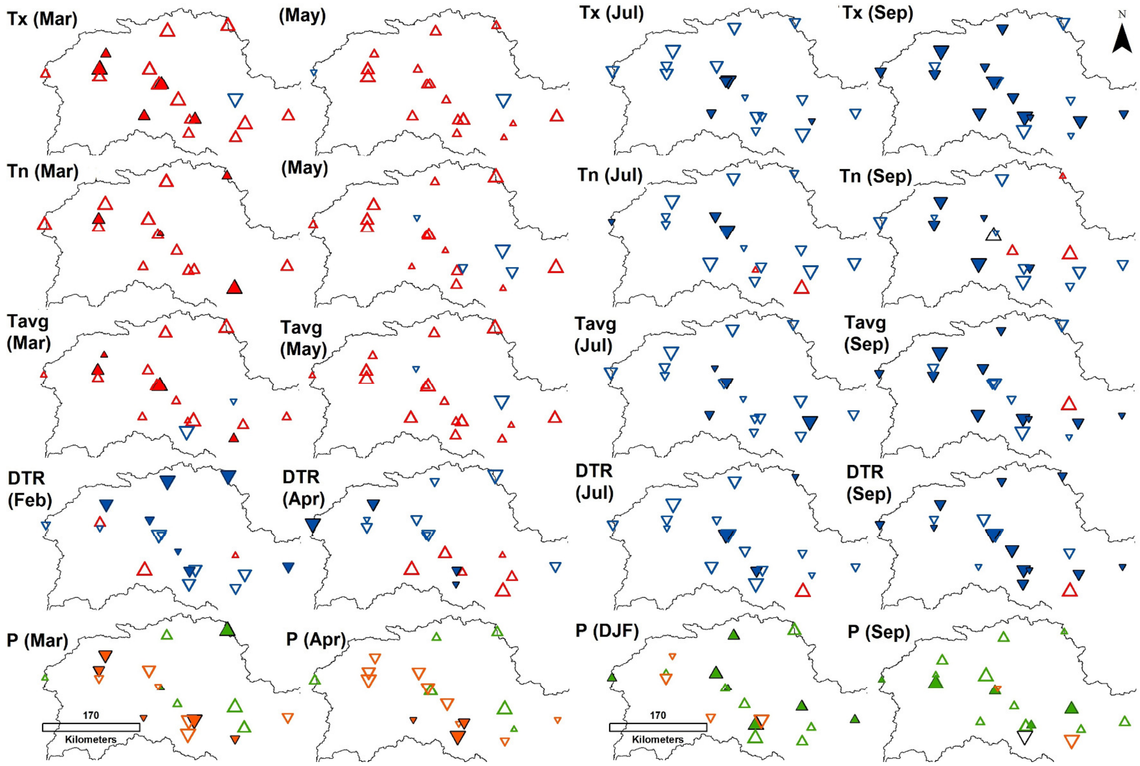
Tabular Figure 6: ~~Results from low altitude stations for the full length of available record (as given in Table 2 and 3) for~~ Long-term trends (1961-2012) in Tx, Tn, Tavg, DTR and P ~~(rainfall)~~ at monthly to annual ~~time scales in respective~~timescales. The units ~~as per~~ and color scale are described in the Tabular Figures 4 and 5.

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tx	Skardu	0.07	0.06	0.06	0.05	0.07	0.02	0.01	0.00	0.02	0.03	0.06	0.06	0.05	0.07	0.01	0.04	0.04
	Astore	0.02	0.01	0.06	0.04	0.05	-0.01	-0.01	-0.02	0.00	0.02	0.03	0.04	0.02	0.06	-0.01	0.02	0.02
	Gupis	0.02	0.02	0.03	0.04	0.06	-0.02	-0.02	-0.03	-0.01	0.04	0.04	0.06	0.04	0.04	-0.02	0.03	0.02
	Gilgit	0.04	0.03	0.04	0.05	0.06	-0.01	-0.01	-0.02	-0.01	0.02	0.05	0.05	0.04	0.04	-0.01	0.02	0.02
	Bunji	0.02	0.01	0.04	0.00	0.01	-0.06	-0.05	-0.05	-0.04	-0.04	0.03	0.02	0.02	0.02	-0.05	-0.02	0.00
	Chilas	-0.01	-0.01	0.03	0.01	0.02	-0.05	-0.02	-0.02	-0.02	0.00	0.00	0.01	0.00	0.02	-0.03	0.00	0.00
Tn	Skardu	0.00	0.02	0.00	-0.01	-0.01	-0.04	-0.04	-0.04	-0.04	-0.05	-0.02	0.01	0.01	0.00	-0.04	-0.04	-0.02
	Astore	0.02	0.01	0.03	0.03	0.04	0.00	-0.02	-0.02	-0.01	0.00	0.02	0.01	0.01	0.04	-0.01	0.01	0.01
	Gupis	-0.04	-0.02	-0.01	-0.03	-0.01	-0.07	-0.06	-0.07	-0.05	-0.03	-0.03	-0.01	-0.03	-0.02	-0.07	-0.05	-0.04
	Gilgit	0.00	0.03	0.00	-0.01	0.01	-0.02	-0.05	-0.03	-0.01	-0.02	-0.01	0.01	0.01	0.00	-0.03	-0.02	-0.01
	Bunji	0.01	0.01	0.03	0.00	0.00	-0.03	-0.04	-0.03	-0.03	-0.03	0.00	0.01	-0.01	0.01	-0.04	-0.04	0.00
	Chilas	0.04	0.02	0.01	0.01	0.03	-0.02	-0.01	-0.03	-0.02	0.00	0.03	0.04	0.03	0.02	-0.02	0.00	0.01
Tavg	Skardu	0.03	0.04	0.03	0.02	0.03	-0.01	-0.02	-0.02	-0.01	0.00	0.02	0.03	0.03	0.03	-0.02	0.00	0.01
	Astore	0.02	0.01	0.04	0.04	0.05	0.00	-0.01	-0.02	0.00	0.01	0.03	0.02	0.01	0.05	-0.01	0.02	0.01
	Gupis	0.00	0.00	0.00	0.01	0.03	-0.04	-0.05	-0.05	-0.03	0.00	0.01	0.02	0.00	0.01	-0.04	-0.01	-0.01
	Gilgit	0.02	0.03	0.02	0.02	0.04	-0.02	-0.03	-0.03	-0.02	-0.01	0.03	0.03	0.03	0.02	-0.03	0.00	0.00
	Bunji	0.00	0.01	0.02	-0.01	-0.01	-0.04	-0.05	-0.04	-0.05	-0.04	0.00	0.01	0.01	0.01	-0.04	-0.03	0.00
	Chilas	0.02	0.00	0.01	0.01	0.03	-0.03	-0.02	-0.02	-0.02	0.00	0.02	0.02	0.01	0.02	-0.03	0.00	0.00
DTR	Skardu	0.06	0.02	0.05	0.07	0.09	0.05	0.06	0.03	0.06	0.09	0.09	0.05	0.05	0.07	0.05	0.09	0.06
	Astore	0.04	0.00	0.01	0.02	0.02	-0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.00	0.02	0.02
	Gupis	0.08	0.06	0.05	0.07	0.09	0.06	0.06	0.04	0.07	0.10	0.09	0.08	0.09	0.06	0.05	0.08	0.07
	Gilgit	0.04	0.02	0.04	0.07	0.06	0.00	0.05	0.04	0.05	0.05	0.07	0.05	0.04	0.04	0.03	0.06	0.04
	Bunji	0.04	0.01	0.03	0.01	0.03	0.00	0.00	-0.01	0.03	0.02	0.06	0.04	0.04	0.02	0.00	0.03	0.02
	Chilas	-0.04	-0.02	0.00	0.00	0.00	-0.03	-0.01	0.01	0.01	-0.01	-0.02	-0.03	-0.03	0.00	-0.01	-0.01	-0.02
P	Skardu	0.30	0.32	0.16	0.16	-0.02	0.08	0.06	0.19	0.07	0.00	0.00	0.15	0.98	0.45	0.29	0.12	1.76
	Astore	0.00	-0.28	-0.78	-0.51	-0.25	0.27	0.19	0.06	0.02	-0.05	0.02	-0.08	0.24	-1.31	0.45	0.06	-1.33
	Gupis	0.08	0.04	0.28	0.30	-0.08	0.00	0.24	0.18	0.00	0.00	0.00	0.00	0.11	0.20	0.32	-0.09	2.00
	Gilgit	0.00	0.00	-0.02	0.05	-0.05	0.23	0.01	0.01	0.03	0.00	0.00	0.00	0.02	-0.44	0.28	0.10	0.38
	Bunji	0.00	-0.06	-0.14	0.02	-0.17	0.09	0.05	0.12	0.11	-0.03	0.00	0.00	0.13	-0.59	0.36	0.09	0.21
	Chilas	0.00	0.03	-0.12	0.00	-0.01	0.10	0.07	0.07	0.07	-0.02	0.00	0.00	0.25	-0.12	0.51	0.03	0.70
Q	UIB-East	0.58	0.89	1.18	0.80	0.08	-12.94	-21.37	-10.53	-1.42	-0.18	0.06	0.16	0.55	1.10	-14.86	-0.57	-1.59
	Eastern-Karakoram	0.00	0.00	-0.04	-0.08	1.79	6.46	5.17	6.81	4.34	1.31	0.24	0.00	0.07	0.41	7.08	2.05	2.43
	Central-Karakoram	0.32	-0.07	-0.51	-0.67	6.13	3.85	-1.22	6.30	-7.40	-4.08	-1.36	-0.29	-0.35	1.75	6.22	-2.80	0.31
	Kachura	1.04	1.40	1.19	0.43	6.06	12.88	14.75	19.45	14.27	3.69	1.14	1.13	1.12	2.67	19.20	6.12	7.19
	UIB-Central	0.35	0.21	-0.19	-0.43	9.99	20.49	13.74	20.73	-4.95	-2.15	-0.80	-0.29	-0.30	2.76	17.69	-2.84	3.30
	Western-Karakoram	0.04	0.00	0.00	0.00	0.29	-3.75	-12.69	-13.75	-2.14	-0.24	0.18	0.20	0.13	0.24	-10.23	-0.59	-2.55
	Karakoram	0.28	-0.20	-0.60	0.33	9.67	24.33	8.29	8.13	-7.57	-2.18	-0.59	0.63	-0.15	4.17	24.39	-4.36	6.44
	Hindukush	0.00	0.05	0.04	0.19	3.31	-1.00	-0.85	0.11	0.64	0.23	0.15	0.13	0.04	1.25	0.24	0.31	0.48
	UIB-WU	0.58	0.60	0.33	0.51	3.55	-1.86	-12.74	-12.50	0.68	1.48	1.02	0.71	0.48	1.30	-6.83	1.22	-0.95
	Astore	0.28	0.24	0.32	0.97	3.52	1.29	-0.62	0.54	0.16	0.28	0.32	0.23	0.31	1.63	0.43	0.28	0.76
	Partab_Bridge	1.01	0.49	0.44	1.93	18.03	13.07	12.89	-8.37	9.74	3.84	2.61	1.63	1.74	6.84	7.05	4.93	4.72
	UIB-WL	1.94	1.96	3.49	0.17	2.89	-12.90	-25.95	-12.06	-1.35	1.57	1.94	2.35	1.92	1.93	-13.82	0.48	-2.63
	UIB-WL-Partab	1.58	1.87	2.11	-0.82	-0.30	-22.26	-16.35	-17.07	0.02	-2.20	0.23	1.18	1.32	0.34	-22.10	-0.99	-5.40
	UIB_West	2.02	2.01	2.73	1.12	8.00	-19.88	-32.88	-23.24	-5.13	1.95	2.59	2.40	2.18	3.99	-25.21	0.93	-4.03
	Himalaya	3.23	3.91	4.73	2.33	-0.33	-32.29	-69.33	-17.55	-4.61	-0.05	3.40	2.05	3.37	6.86	-40.09	-0.72	-6.13
	UIB	3.00	3.33	3.53	0.62	12.97	-8.84	-13.31	-3.24	8.19	4.03	3.92	3.04	3.04	5.00	-6.15	5.14	2.23

Variable	Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Tx	Skardu	**0.07**	**0.06**	**0.06**	**0.05**	**0.07**	0.02	0.01	0.00	0.02	**0.03**	**0.06**	**0.06**	**0.05**	**0.07**	0.01	**0.04**	**0.04**
	Astore	0.02	0.01	**0.06**	**0.04**	**0.05**	-0.01	-0.01	-0.02	0.00	0.02	**0.03**	**0.04**	**0.02**	**0.06**	-0.01	**0.02**	**0.02**
	Gupis	0.02	0.02	0.03	**0.04**	**0.06**	-0.02	-0.02	-0.03	-0.01	**0.04**	**0.04**	**0.06**	**0.04**	**0.04**	-0.02	**0.03**	**0.02**
	Gilgit	**0.04**	**0.03**	**0.04**	**0.05**	**0.06**	-0.01	-0.01	-0.02	-0.01	0.02	**0.05**	**0.05**	**0.04**	**0.04**	-0.01	**0.02**	**0.02**
	Bunji	**0.02**	0.01	**0.04**	0.00	0.01	**-0.06**	**-0.05**	**-0.05**	**-0.04**	-0.04	**0.03**	0.02	**0.02**	0.02	**-0.05**	-0.02	0.00
	Chilas	-0.01	-0.01	0.03	0.01	0.02	**-0.05**	-0.02	-0.02	-0.02	0.00	0.00	0.01	0.00	0.02	**-0.03**	0.00	0.00
Tn	Skardu	0.00	0.02	0.00	-0.01	-0.01	**-0.04**	**-0.04**	**-0.04**	**-0.04**	**-0.05**	**-0.02**	0.01	0.01	0.00	**-0.04**	**-0.04**	**-0.02**
	Astore	0.02	0.01	**0.03**	**0.03**	**0.04**	0.00	-0.02	**-0.02**	-0.01	0.00	**0.02**	0.01	0.01	**0.04**	-0.01	0.01	**0.01**
	Gupis	**-0.04**	-0.02	-0.01	-0.03	-0.01	**-0.07**	**-0.06**	**-0.07**	**-0.05**	-0.03	**-0.03**	-0.01	**-0.03**	-0.02	**-0.07**	**-0.05**	**-0.04**
	Gilgit	0.00	**0.03**	0.00	-0.01	0.01	**-0.02**	**-0.05**	-0.03	-0.01	**-0.02**	-0.01	0.01	0.01	0.00	**-0.03**	**-0.02**	-0.01
	Bunji	0.01	0.01	0.03	0.00	0.00	-0.03	**-0.04**	-0.03	-0.03	-0.03	0.00	0.01	-0.01	0.01	**-0.04**	-0.04	0.00
	Chilas	**0.04**	0.02	0.01	0.01	0.03	-0.02	-0.01	**-0.03**	-0.02	0.00	**0.03**	**0.04**	**0.03**	0.02	**-0.02**	0.00	0.01
Tavg	Skardu	0.03	0.04	**0.03**	**0.02**	**0.03**	-0.01	-0.02	-0.02	-0.01	0.00	**0.02**	0.03	**0.03**	**0.03**	-0.02	0.00	0.01
	Astore	0.02	0.01	**0.04**	**0.04**	**0.05**	0.00	-0.01	**-0.02**	0.00	0.01	**0.03**	0.02	0.01	**0.05**	-0.01	**0.02**	**0.01**
	Gupis	0.00	0.00	0.00	0.01	0.03	**-0.04**	**-0.05**	**-0.05**	**-0.03**	0.00	0.01	0.02	0.00	0.01	**-0.04**	-0.01	-0.01
	Gilgit	**0.02**	**0.03**	0.02	0.02	**0.04**	-0.02	**-0.03**	**-0.03**	**-0.02**	-0.01	**0.03**	**0.03**	**0.03**	**0.02**	**-0.03**	0.00	0.00
	Bunji	0.00	0.01	0.02	-0.01	-0.01	**-0.04**	**-0.05**	**-0.04**	**-0.05**	**-0.04**	0.00	0.01	0.01	0.01	**-0.04**	**-0.03**	0.00
	Chilas	0.02	0.00	0.01	0.01	0.03	-0.03	-0.02	-0.02	-0.02	0.00	**0.02**	0.02	0.01	0.02	**-0.03**	0.00	0.00
DTR	Skardu	**0.06**	0.02	**0.05**	**0.07**	**0.09**	**0.05**	**0.06**	**0.03**	**0.06**	**0.09**	**0.09**	**0.05**	**0.05**	**0.07**	**0.05**	**0.09**	**0.06**
	Astore	**0.04**	0.00	0.01	0.02	0.02	**-0.02**	**0.01**	**0.02**	0.01	**0.02**	0.02	0.01	0.02	0.01	0.00	**0.02**	**0.02**
	Gupis	**0.08**	**0.06**	**0.05**	**0.07**	**0.09**	**0.06**	**0.06**	0.04	**0.07**	**0.10**	**0.09**	**0.08**	**0.09**	**0.06**	**0.05**	**0.08**	**0.07**
	Gilgit	0.04	0.02	**0.04**	**0.07**	**0.06**	0.00	**0.05**	**0.04**	**0.05**	**0.05**	**0.07**	**0.05**	**0.04**	**0.04**	**0.03**	**0.06**	**0.04**
	Bunji	**0.04**	0.01	**0.03**	0.01	0.03	0.00	0.00	-0.01	0.03	0.02	**0.06**	0.04	**0.04**	0.02	0.00	0.03	0.02
	Chilas	-0.04	-0.02	0.00	0.00	0.00	**-0.03**	-0.01	0.01	0.01	-0.01	-0.02	-0.03	-0.03	0.00	**-0.01**	-0.01	**-0.02**
P	Skardu	**0.30**	0.32	0.16	0.16	-0.02	0.08	0.06	**0.19**	0.07	0.00	0.00	0.15	**0.98**	0.45	**0.29**	0.12	**1.76**
	Astore	0.00	-0.28	**-0.78**	-0.51	-0.25	0.27	**0.19**	0.06	0.02	-0.05	0.02	-0.08	0.24	-1.31	0.45	0.06	-1.33
	Gupis	**0.08**	0.04	**0.28**	0.30	-0.08	0.00	**0.24**	0.18	0.00	0.00	0.00	0.00	0.11	0.20	0.32	-0.09	2.00
	Gilgit	0.00	0.00	-0.02	0.05	-0.05	**0.23**	0.01	0.01	0.03	0.00	0.00	0.00	0.02	-0.44	0.28	0.10	0.38
	Bunji	0.00	-0.06	-0.14	0.02	-0.17	0.09	0.05	0.12	0.11	-0.03	0.00	0.00	0.13	**-0.59**	0.36	0.09	0.21
	Chilas	0.00	0.03	-0.12	0.00	-0.01	**0.10**	0.07	0.07	**0.07**	-0.02	0.00	0.00	0.25	-0.12	**0.51**	0.03	0.70
Q	UIB-East	0.58	**0.89**	**1.18**	0.80	0.08	-12.94	**-21.37**	-10.53	-1.42	-0.18	0.06	0.16	0.55	1.10	**-14.86**	-0.57	-1.59
	Eastern-Karakoram	0.00	0.00	-0.04	-0.08	**1.79**	**6.46**	5.17	6.81	4.34	**1.31**	**0.24**	0.00	0.07	0.41	**7.08**	**2.05**	**2.43**
	Central-Karakoram	0.32	-0.07	-0.51	**-0.67**	**6.13**	3.85	-1.22	6.30	-7.40	**-4.08**	-1.36	-0.29	-0.35	1.75	6.22	-2.80	0.31
	Kachura	**1.04**	**1.40**	**1.19**	0.43	**6.06**	**12.88**	14.75	**19.45**	**14.27**	**3.69**	**1.14**	**1.13**	**1.12**	**2.67**	**19.20**	**6.12**	**7.19**
	UIB-Central	0.35	0.21	-0.19	-0.43	**9.99**	20.49	13.74	**20.73**	-4.95	-2.15	-0.80	-0.29	-0.30	**2.76**	17.69	-2.84	3.30
	Western-Karakoram	0.04	0.00	0.00	0.00	0.29	**-3.75**	**-12.69**	**-13.75**	**-2.14**	-0.24	0.18	0.20	0.13	0.24	**-10.23**	-0.59	**-2.55**
	Karakoram	0.28	-0.20	-0.60	0.33	9.67	24.33	8.29	8.13	-7.57	-2.18	-0.59	0.63	-0.15	**4.17**	24.39	-4.36	6.44
	Hindukush	0.00	0.05	0.04	0.19	**3.31**	-1.00	-0.85	0.11	0.64	0.23	0.15	0.13	0.04	**1.25**	0.24	0.31	0.48
	UIB-WU	**0.58**	**0.60**	**0.33**	0.51	3.55	-1.86	**-12.74**	**-12.50**	0.68	1.48	**1.02**	**0.71**	**0.48**	1.30	**-6.83**	1.22	-0.95
	Astore	0.28	0.24	**0.32**	**0.97**	**3.52**	1.29	-0.62	0.54	0.16	0.28	0.32	0.23	0.31	**1.63**	0.43	0.28	**0.76**
	Partab_Bridge	**1.01**	0.49	0.44	**1.93**	**18.03**	13.07	12.89	-8.37	9.74	**3.84**	**2.61**	**1.63**	**1.74**	**6.84**	7.05	**4.93**	**4.72**
	UIB-WL	**1.94**	**1.96**	**3.49**	0.17	2.89	-12.90	-25.95	-12.06	-1.35	1.57	**1.94**	**2.35**	**1.92**	1.93	-13.82	0.48	-2.63
	UIB-WL-Partab	**1.58**	**1.87**	**2.11**	-0.82	-0.30	**-22.26**	-16.35	-17.07	0.02	-2.20	0.23	**1.18**	**1.32**	0.34	-22.10	-0.99	-5.40
	UIB_West	**2.02**	**2.01**	**2.73**	1.12	8.00	**-19.88**	**-32.88**	**-23.24**	-5.13	1.95	**2.59**	**2.40**	**2.18**	3.99	**-25.21**	0.93	-4.03
	Himalaya	**3.23**	**3.91**	**4.73**	2.33	-0.33	-32.29	**-69.33**	-17.55	-4.61	-0.05	**3.40**	2.05	**3.37**	6.86	-40.09	-0.72	-6.13
	UIB	**3.00**	**3.33**	**3.53**	0.62	**12.97**	-8.84	-13.31	-3.24	8.19	**4.03**	**3.92**	**3.04**	**3.04**	**5.00**	-6.15	**5.14**	2.23

Tabular Figure 7: Field ~~significance of the~~ significant climatic trends for ~~all~~ ten sub-regions ~~considered~~ along with ~~trend in~~ their discharge (Q) trends at monthly to annual ~~time scales~~timescales over the period 1995-2012. Color scale is same as in Tabular Figure 5. Bold Q values indicate significant trends at 90% level.

Regions	Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Astore	Tx	-0.17									-0.21		-0.42	-0.16				-0.06
	Tn							-0.10			-0.10		-0.12				-0.10	
	Tavg	-0.15						-0.13			-0.21							-0.05
	DTR		-0.22							-0.13			-0.17	-0.07			-0.06	-0.08
	P			-3.73	-7.50	-4.60	-2.18	-1.90	-1.80	-2.11					-19.25	-6.02	-18.93	-38.01
	Q	0.05	0.00	0.22	0.50	7.65	4.26	-3.01	5.00	-1.00	-1.11	-0.67	0.00	0.00	2.20	1.97	-0.89	2.16
Hindukush	Tx		-0.11	0.23				-0.19		-0.29			-0.18				-0.12	-0.09
	Tn								0.25	0.24		-0.18	-0.24			0.09	0.10	
	Tavg			0.18				-0.11	0.08	-0.25			-0.13				-0.10	
	DTR	-0.21		-0.11	-0.18	-0.25	-0.28	-0.19	-0.36	-0.40	-0.52	-0.38		0.03	-0.16	-0.18	-0.33	-0.20
	P	1.30		-1.94				1.00		1.05	0.31		1.31	4.73	-10.19	-9.80	2.39	
	Q	0.87	0.26	0.15	1.27	2.05	3.49	-6.61	**14.02**	**7.03**	2.17	1.82	1.06	0.75	1.00	3.94	4.44	4.00
Himalaya	Tx	-0.17	-0.10					-0.22		-0.21	-0.19		-0.28	-0.16		-0.07	-0.12	-0.06
	Tn		-0.23	0.26			-0.14	-0.15	0.18		-0.16	-0.18	-0.14	-0.18		-0.13	-0.14	0.02
	Tavg	-0.15		0.25				-0.18	0.17	-0.18	-0.18	-0.09	-0.08	-0.11		-0.10	-0.13	-0.07
	DTR	-0.02	-0.20	0.18	-0.18			-0.13	-0.18	-0.36	-0.25			-0.12		-0.08	-0.19	-0.09
	P			-2.29	-5.71	-4.60	-2.18	-1.90	-1.80	-2.11			0.42		-12.15	-6.02	-18.93	-38.01
	Q	0.30	-0.32	4.10	0.91	43.99	62.23	12.43	83.33	22.43	9.97	2.32	0.23	1.17	26.64	**57.88**	7.75	***24.66***
West Karakoram	Tx			0.23				-0.18		-0.17	-0.16			-0.06				
	Tn		0.22	0.13				-0.13						0.17				0.05
	Tavg	-0.15		0.22	-0.09			-0.14		-0.15								
	DTR		-0.22							-0.13			-0.17	-0.07			-0.06	-0.08
	P					1.17	1.09						3.81	9.08				
	Q	1.20	1.00	1.50	***2.00***	0.59	12.09	-4.53	-4.09	**6.40**	***3.50***	***3.82***	***2.03***	***1.88***	1.00	-1.64	***5.43***	2.50
Karakoram	Tx		-0.11	0.23				-0.18		-0.22	-0.16			-0.06			-0.12	-0.06
	Tn		-0.11	0.23				-0.18		-0.22	-0.16			-0.06			-0.12	-0.06
	Tavg		0.22	0.13			-0.14	-0.14	0.25	0.46	-0.16	-0.18	-0.16	0.17		-0.08	0.06	-0.05
	DTR	-0.15		0.22	-0.09			-0.15	0.08	-0.16	-0.12	-0.09				-0.13	-0.14	-0.08
	P		2.95	1.97		1.17	1.72		1.58	2.15	1.43	2.40	2.69	6.39		5.39	5.76	45.07
	Q	1.88	2.00	1.33	1.00	-5.82	-7.80	**-64.97**	-37.17	-9.48	0.60	***8.97***	***5.97***	***1.65***	0.11	-24.43	5.64	-3.90
UIB Central	Tx							-0.26		-0.20	-0.16						-0.12	
	Tn			0.26			-0.14	-0.20			-0.16	-0.18	-0.16			-0.17	-0.18	0.02
	Tavg			0.25				-0.20		-0.18	-0.15	-0.09				-0.13	-0.14	-0.08
	DTR	0.13										0.09						
	P		2.95	1.97			2.35		1.58	2.15	1.43	2.40	1.57	5.99		5.39	5.76	45.07
	Q	**2.19**	1.81	2.02	-0.84	6.89	-18.08	***-43.79***	-20.20	-4.88	1.05	***4.38***	***2.34***	**2.00**	1.79	-18.34	2.01	-2.47
UIB	Tx	-0.14	-0.11	0.40				-0.20		-0.22	-0.20		-0.25			-0.09	-0.12	-0.09
	Tn		0.49	0.38				-0.13	0.31				-0.17			0.37	-0.14	0.27
	Tavg			0.37				-0.15	0.13	-0.18	-0.16		-0.11			-0.10	-0.12	-0.08
	DTR		-0.19		-0.14			-0.17	-0.24	-0.25	-0.38			0.11	-0.13	-0.10	-0.17	-0.09
	P			-2.17		1.17	-1.42		-2.40	1.65	1.10		1.97	5.98	-11.49	-7.91	3.68	
	Q	1.82	***5.09***	5.37	-2.50	11.35	14.67	-46.60	41.71	35.22	10.17	5.29	0.75	1.91	15.72	-1.40	19.35	4.25
UIB West	Tx	-0.14	-0.11	0.23				-0.18		-0.22	-0.21		-0.25	-0.11		-0.09	-0.12	-0.10
	Tn							-0.12	0.22				-0.18				-0.13	
	Tavg	-0.15		0.20				-0.13	0.13	-0.19	-0.19		-0.11				-0.11	-0.07
	DTR	-0.18	-0.20	-0.10	-0.16			-0.17	-0.24	-0.27	-0.38			-0.10	-0.13	-0.10	-0.19	-0.10
	P			-2.17	-5.71	1.17			-2.40	1.40			1.71	6.90	-11.49	-7.91	2.63	
	Q	2.45	1.37	5.43	2.42	**61.35**	54.89	0.21	42.93	***28.24***	**13.68**	***5.87***	1.38	2.00	**23.43**	44.18	***17.71***	***22.17***
UIB West Lower	Tx	-0.17	-0.10					-0.16		-0.21	-0.20		-0.28	-0.16		-0.07	-0.13	-0.06
	Tn		-0.23					-0.10	0.18				-0.12	-0.18		-0.08	-0.12	
	Tavg	-0.15						-0.13	0.17		-0.19		-0.07	-0.11		-0.06	-0.11	-0.07
	DTR	-0.15	-0.20	0.18	-0.18			-0.13	-0.18	-0.36	-0.25			-0.12		-0.08	-0.19	-0.09
	P			-2.29	-5.71	-4.60	-2.18	-1.90	-1.80	-2.11			0.42		-12.15	-6.02	-18.93	-38.01
	Q	1.88	0.41	6.39	-0.52	41.58	**59.50**	28.19	***81.58***	**30.99**	16.18	5.17	2.33	1.92	19.90	***65.53***	***16.02***	***25.44***
UIB West Upper	Tx	-0.14	-0.11	0.23				-0.18		-0.22	-0.21		-0.25	-0.11		-0.09	-0.12	-0.10
	Tn		0.22	0.13				-0.13	0.25	0.24		-0.18	-0.24	0.17		0.09	0.10	0.05
	Tavg	-0.15		0.20	-0.09			-0.13	0.08	-0.20			-0.13				-0.10	
	DTR	-0.21	-0.22	-0.11	-0.18	-0.25	-0.28	-0.19	-0.36	-0.28	-0.52	-0.38	-0.17	0.06	-0.16	-0.11	-0.19	-0.11
	P	1.30		-1.94		1.17	1.09	1.00		1.40	0.31		2.14	6.90	-10.19	-9.80	2.63	
	Q	1.24	**1.02**	1.39	**2.38**	***16.85***	12.38	-25.48	-15.50	-1.28	0.69	0.98	0.52	0.55	***7.76***	-3.68	0.45	-1.25


Tx (Mar)
(May)
Tx (Jul)
Tx (Sep)
N
Tn (Mar)
(May)
Tn (Jul)
Tn (Sep)
Tavg (Mar)
Tavg (May)
Tavg (Jul)
Tavg (Sep)
DTR (Feb)
DTR (Apr)
DTR (Jul)
DTR (Sep)
P (Mar)
P (Apr)
P (DJF)
P (Sep)
170
Kilometers

Regions	Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DJF	MAM	JJA	SON	Ann.
Astore	Tx	-0.17									-0.21		-0.42	-0.16				-0.06
	Tn							-0.10			-0.10		-0.12				-0.10	
	Tavg	-0.15						-0.13			-0.21							-0.05
	DTR		-0.22							-0.13			-0.17	-0.07			-0.06	-0.08
	P			-3.73	-7.50	-4.60	-2.18	-1.90	-1.80	-2.11					-19.25	-6.02	-18.93	-38.01
	Q	0.05	0.00	0.22	0.50	7.65	4.26	-3.01	5.00	-1.00	-1.11	-0.67	0.00	0.00	2.20	1.97	-0.89	2.16
Hindukush	Tx		-0.11	0.23				-0.19		-0.29			-0.18				-0.12	-0.09
	Tn								0.25	0.24		-0.18	-0.24			0.09	0.10	
	Tavg			0.18				-0.11	0.08	-0.25			-0.13				-0.10	
	DTR	-0.21		-0.11	-0.18	-0.25	-0.28	-0.19	-0.36	-0.40	-0.52	-0.38		0.03	-0.16	-0.18	-0.33	-0.20
	P	1.30		-1.94				1.00		1.05	0.31		1.31	4.73	-10.19	-9.80	2.39	
	Q	0.87	0.26	0.15	1.27	2.05	3.49	-6.61	**14.02**	**7.03**	2.17	1.82	1.06	0.75	1.00	3.94	4.44	4.00
Himalaya	Tx	-0.17	-0.10					-0.22		-0.21	-0.19		-0.28	-0.16		-0.07	-0.12	-0.06
	Tn		-0.23	0.26			-0.14	-0.15	0.18		-0.16	-0.18	-0.14	-0.18		-0.13	-0.14	0.02
	Tavg	-0.15		0.25				-0.18	0.17	-0.18	-0.18	-0.09	-0.08	-0.11		-0.10	-0.13	-0.07
	DTR	-0.02	-0.20	0.18	-0.18			-0.13	-0.18	-0.36	-0.25			-0.12		-0.08	-0.19	-0.09
	P			-2.29	-5.71	-4.60	-2.18	-1.90	-1.80	-2.11			0.42		-12.15	-6.02	-18.93	-38.01
	Q	0.30	-0.32	4.10	0.91	43.99	62.23	12.43	83.33	22.43	9.97	2.32	0.23	1.17	26.64	**57.88**	7.75	***24.66***
West Karakoram	Tx			0.23				-0.18		-0.17	-0.16			-0.06				
	Tn		0.22	0.13				-0.13						0.17				0.05
	Tavg	-0.15		0.22	-0.09			-0.14		-0.15								
	DTR		-0.22							-0.13			-0.17	-0.07			-0.06	-0.08
	P					1.17	1.09						3.81	9.08				
	Q	1.20	1.00	1.50	***2.00***	0.59	12.09	-4.53	-4.09	**6.40**	***3.50***	***3.82***	***2.03***	***1.88***	1.00	-1.64	***5.43***	2.50
Karakoram	Tx		-0.11	0.23				-0.18		-0.22	-0.16			-0.06			-0.12	-0.06
	Tn		-0.11	0.23				-0.18		-0.22	-0.16			-0.06			-0.12	-0.06
	Tavg		0.22	0.13			-0.14	-0.14	0.25	0.46	-0.16	-0.18	-0.16	0.17		-0.08	0.06	-0.05
	DTR	-0.15		0.22	-0.09			-0.15	0.08	-0.16	-0.12	-0.09				-0.13	-0.14	-0.08
	P		2.95	1.97		1.17	1.72		1.58	2.15	1.43	2.40	2.69	6.39		5.39	5.76	45.07
	Q	1.88	2.00	1.33	1.00	-5.82	-7.80	**-64.97**	-37.17	-9.48	0.60	***8.97***	***5.97***	***1.65***	0.11	-24.43	5.64	-3.90
UIB Central	Tx							-0.26		-0.20	-0.16						-0.12	
	Tn			0.26			-0.14	-0.20			-0.16	-0.18	-0.16			-0.17	-0.18	0.02
	Tavg			0.25				-0.20		-0.18	-0.15	-0.09				-0.13	-0.14	-0.08
	DTR	0.13										0.09						
	P		2.95	1.97			2.35		1.58	2.15	1.43	2.40	1.57	5.99		5.39	5.76	45.07
	Q	**2.19**	1.81	2.02	-0.84	6.89	-18.08	***-43.79***	-20.20	-4.88	1.05	***4.38***	***2.34***	**2.00**	1.79	-18.34	2.01	-2.47
UIB	Tx	-0.14	-0.11	0.40				-0.20		-0.22	-0.20		-0.25			-0.09	-0.12	-0.09
	Tn		0.49	0.38				-0.13	0.31				-0.17			0.37	-0.14	0.27
	Tavg			0.37				-0.15	0.13	-0.18	-0.16		-0.11			-0.10	-0.12	-0.08
	DTR		-0.19		-0.14			-0.17	-0.24	-0.25	-0.38			0.11	-0.13	-0.10	-0.17	-0.09
	P			-2.17		1.17	-1.42		-2.40	1.65	1.10		1.97	5.98	-11.49	-7.91	3.68	
	Q	1.82	***5.09***	5.37	-2.50	11.35	14.67	-46.60	41.71	35.22	10.17	5.29	0.75	1.91	15.72	-1.40	19.35	4.25
UIB West	Tx	-0.14	-0.11	0.23				-0.18		-0.22	-0.21		-0.25	-0.11		-0.09	-0.12	-0.10
	Tn							-0.12	0.22				-0.18				-0.13	
	Tavg	-0.15		0.20				-0.13	0.13	-0.19	-0.19		-0.11				-0.11	-0.07
	DTR	-0.18	-0.20	-0.10	-0.16			-0.17	-0.24	-0.27	-0.38			-0.10	-0.13	-0.10	-0.19	-0.10
	P			-2.17	-5.71	1.17			-2.40	1.40			1.71	6.90	-11.49	-7.91	2.63	
	Q	2.45	1.37	5.43	2.42	**61.35**	54.89	0.21	42.93	***28.24***	**13.68**	***5.87***	1.38	2.00	**23.43**	44.18	***17.71***	***22.17***
UIB West Lower	Tx	-0.17	-0.10					-0.16		-0.21	-0.20		-0.28	-0.16		-0.07	-0.13	-0.06
	Tn		-0.23					-0.10	0.18				-0.12	-0.18		-0.08	-0.12	
	Tavg	-0.15						-0.13	0.17		-0.19		-0.07	-0.11		-0.06	-0.11	-0.07
	DTR	-0.15	-0.20	0.18	-0.18			-0.13	-0.18	-0.36	-0.25			-0.12		-0.08	-0.19	-0.09
	P			-2.29	-5.71	-4.60	-2.18	-1.90	-1.80	-2.11			0.42		-12.15	-6.02	-18.93	-38.01
	Q	1.88	0.41	6.39	-0.52	41.58	**59.50**	28.19	***81.58***	**30.99**	16.18	5.17	2.33	1.92	19.90	***65.53***	***16.02***	***25.44***
UIB West Upper	Tx	-0.14	-0.11	0.23				-0.18		-0.22	-0.21		-0.25	-0.11		-0.09	-0.12	-0.10
	Tn		0.22	0.13				-0.13	0.25	0.24		-0.18	-0.24	0.17		0.09	0.10	0.05
	Tavg	-0.15		0.20	-0.09			-0.13	0.08	-0.20			-0.13				-0.10	
	DTR	-0.21	-0.22	-0.11	-0.18	-0.25	-0.28	-0.19	-0.36	-0.28	-0.52	-0.38	-0.17	0.06	-0.16	-0.11	-0.19	-0.11
	P	1.30		-1.94		1.17	1.09	1.00		1.40	0.31		2.14	6.90	-10.19	-9.80	2.63	
	Q	1.24	**1.02**	1.39	**2.38**	***16.85***	12.38	-25.48	-15.50	-1.28	0.69	0.98	0.52	0.55	***7.76***	-3.68	0.45	-1.25

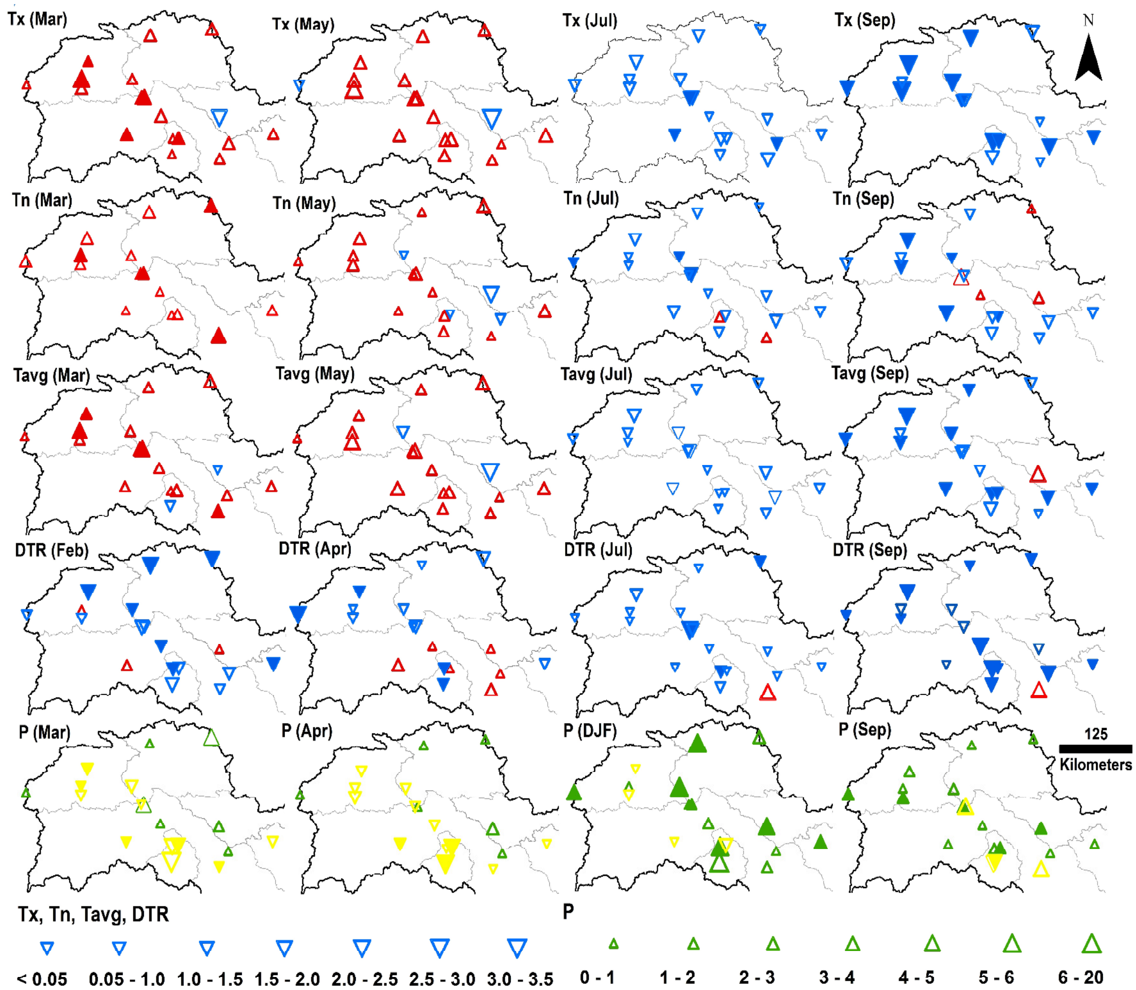
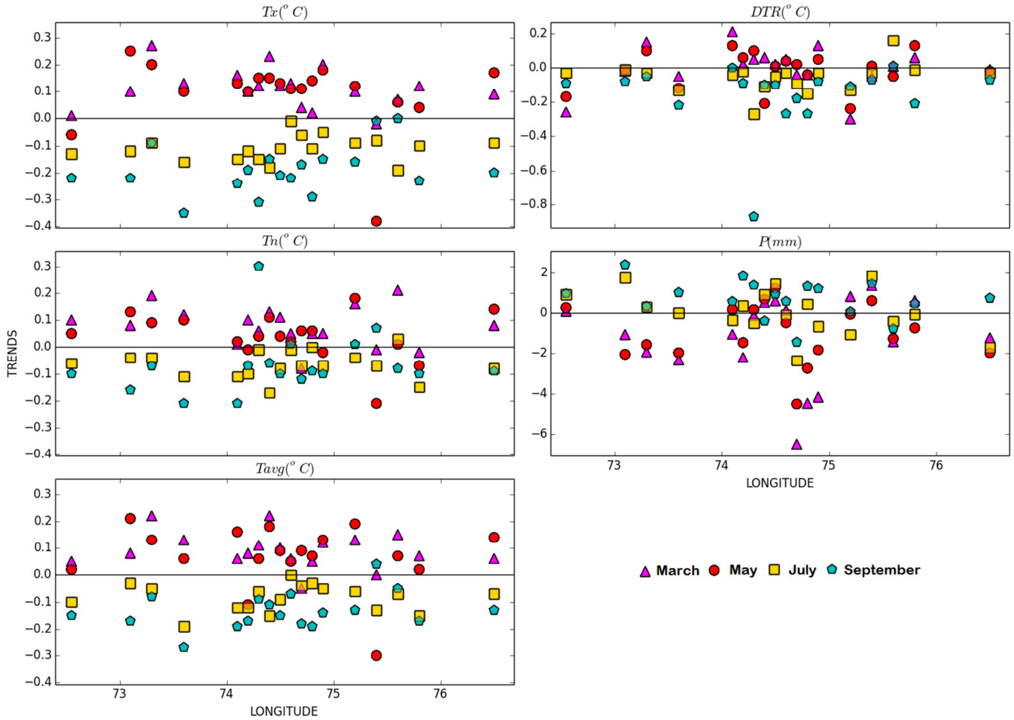
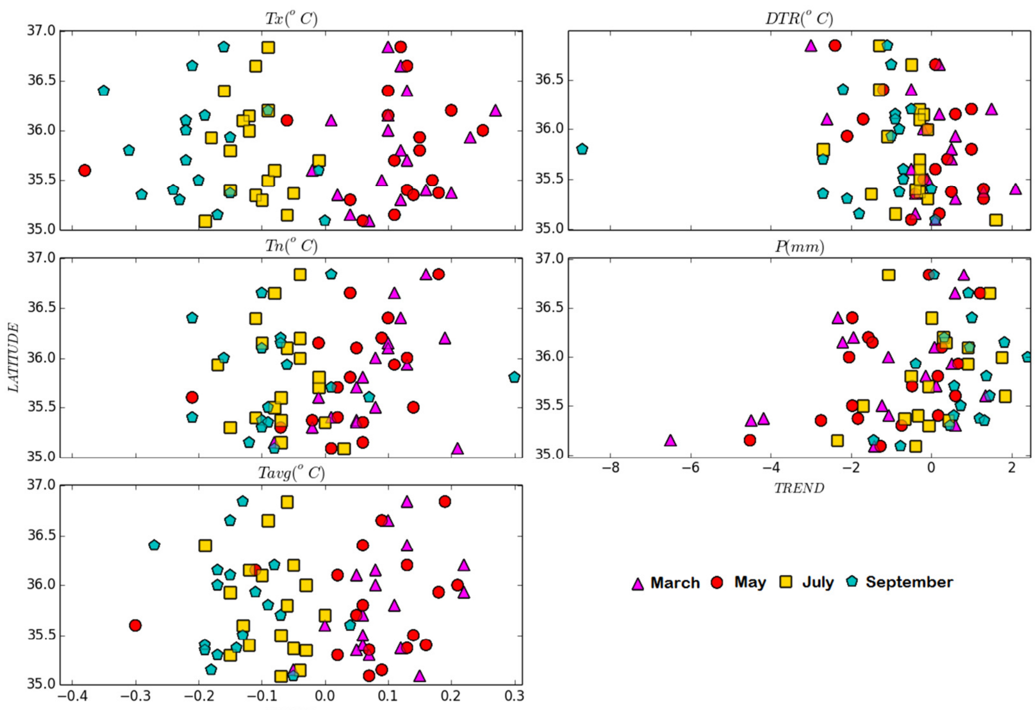


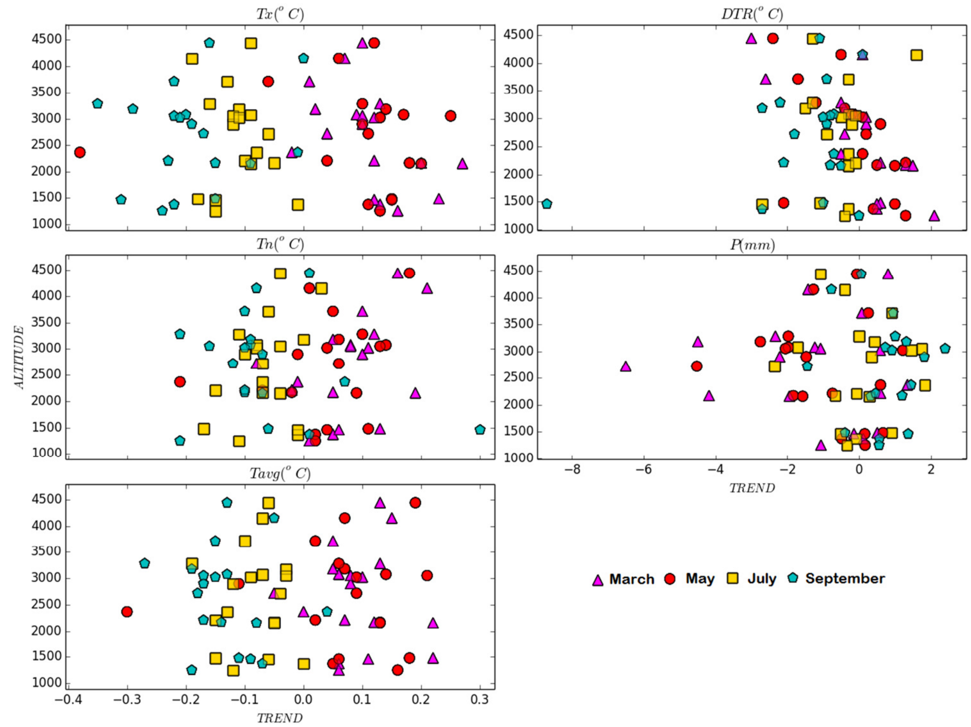
Figure 8: ~~Trend~~Trends per time step ~~of cooling (downward) and warming (upward) in~~ in Tx, Tn~~ and~~, Tavg, ~~and increase (upward) and decrease (downward) in~~ DTR (^{o}C) and ~~in~~ P (mm) for select months and seasons. ~~Statistically significant trends at ≥ 90% level are shown in solid triangle, the rest in~~ Triangles pointing upward (downward) or in green/red (blue/yellow) colors show increasing (decreasing) trends. Solid (hollow) triangles~~.~~ indicate significant (insignificant) trends at 90% level.



~~Figure 9: Hydroclimatic trends per unit time for the period 1995-2012 against longitude.~~



~~Figure 10: Hydroclimatic trends per unit time for the period 1995-2012 against latitude. Here for DTR only overall trend changes over the whole 1995-2012 period are shown.~~



~~Figure 11: Same as Figure 6 but against altitude.~~