# Apendices-Supplementary Materials

**Appendix.A: Description of bias correction Methods**

The current study evaluated five different methods for bias correction and downscaling of precipitation projections and three methods for temperature. The work mainly follow the methodology suggested by [1], with an additional method for precipitation, which combine a method suggested by [1] with a post processing frequency scaling step to ascertain that same ratio of wet days as possessed by “raw historical to raw-scenario” prevails in the “observed to correct scenario”. Most of the processing were carried out using the “CMhyd” (Climate Model data for hydrologic modeling) tool, by [2] available at “https://swat.tamu.edu/software/cmhyd/”.

A brief overview of these methods is given in the following sections while for detail description of these methods. [1, 2], can be consulted.

*Appendix A.I: Linear scaling of precipitation and temperature (LS)*

The linear-scaling method is based on work of [3]. It first generate monthly correction values, equal to the differences between observed and historical (present-day) simulated values. The method entails by definition that the corrected GCM/RCM simulations agree perfectly with the observations, in their monthly mean values.

In case of precipitation the correction factor is based on the ratio of long-term monthly mean observed and long-term monthly mean control/historical run data, While in case of temperature, the correction is done with the help of an additive factor based on the difference between the long-term monthly mean observed and long-term monthly mean control/historical simulation run data.

*Appendix A.II: Local Intensity Scaling (LIS)*

The local intensity and frequency scaling method (LIS) used here is a slightly modified version of the method suggested by [4], for Climate model downscaling. This method corrects adjusts the mean as well as both wet-day frequencies and wet-day intensities of precipitation time series, by effectively matching the climatological wet-day frequency and intensity of the historical/control run with that of the observer data, and then applying the same calibrated RCM precipitation threshold to adjust the future scenario. The LIS method consists of three steps. In the first step, at each point location, a wet-day threshold for the m<sup>th</sup> month “$\boldsymbol{WDT_P}$” is determined from the daily historical model precipitation series, such that the threshold exceedance matches the wet-day frequency at the same location in the observed precipitation series.

In a second step, a scaling factor is calculated from the wet-day intensities for each month by:

$$sf_m = \frac{\mu(P_{m,d}^{obs})}{\mu(P_{m,d}^{s} \text{ given } P_{m,d}^{s} \geq WDT_{m,d}^{h})} \tag{1}$$

In the third step, this scaling factor for each month is applied to the daily scenario time series (above the threshold) to ensure that the mean of the corrected precipitation match to that of the observed precipitation at these locations.

$$P_{(cor)}^{s} = \begin{cases} 0, \quad \text{if} \quad P_{m,d}^{s} < WDT_{m,d}^{h} \\ P_{m,d}^{s} \times sf_m \quad \text{otherwise} \end{cases} \tag{2}$$

Here $P_{m,d}^{obs}$ and $P_{m,d}^{s}$ are daily precipitation values of the observations and the scenario run for a specific month respectively, $\mu$ indicate the long term averages, $WDT_{m,d}^{h}$ is the wet-days threshold for each month and $P_{(cor)}^{s}$ is the corrected scenario precipitation.

The local intensity and frequency scaling could be calibrated on a monthly, seasonal or annual scale. In the current study the precipitation series at the point locations were corrected for wet-day frequencies and intensities on a monthly scale. During this exercise, a total of 24 fitting parameters were determined, including 12 $WDT^{h}_{m,d}$ and 12 $sf_m$,(one for each month).

*Appendix A.III: Power transformation of precipitation (PT)*

Power transformation is a step forward from the linear scaling, as it does not only accounts for a bias in the mean but also allow for adjusting differences in the variance. To do this, a non-linear correction in an exponential form, [5], may be used to exactly apply adjustments to the variance statistics of a precipitation time series. In this correction each of the daily precipitation amount P is converted to a corrected P* using:

$$\mathbf{P_{corr}=a*P^{\wedge b}}$$

The parameter b is determined iteratively, following Brent's method [6] Whereby the CV of the corrected daily historical precipitation ($P_{corr}$) is matched with the CV of the observed daily precipitation (P) for each month m.. This is done with a distribution-free approach on a monthly basis using a interval of 30 days before and after the considered month. The identified b, is than applied to correct the scenario series. In this way, the CV is only a function of parameter b according to:

$$CV(P\ ) = \text{function}(b)$$

After correction for variance, the data also subjected to the slandered liner scaling correction (a), explained above in section App-A.II

*Appendix A.IV: Variance scaling of temperature (VS)*

Similar to power transformation, a corresponding stepwise approach to correct both the mean and the variance of temperature time series (without a power function), proposed by [7, 8] is adopted for variance scaling of temperature .

1. In a first step, the means of the historical model simulated time series are adjusted by linear scaling (App-A.I), and standard deviations as well as means are calculated for both;
2. In second step, the mean-corrected historical/control and scenario runs are shifted to a zero mean on a monthly basis;
3. In third step, the standard deviations of the historical/control and scenario runs, with zero means, are scaled based on the ratio of standard deviations of observed and historical/control-run identified in step-1
4. Finally, corrected time series in step-3 are shifted back using the corrected means derived in step-1

By definition, this approach ascertains that the adjusted model historical/control run match with the mean and standard deviation / variance of the observed series.

*Appendix A.V: Distribution mapping of precipitation and temperature (DM)*

The distribution mapping (DM), as mentioned here, correct the distribution function of simulated climate values to agree with the observed distribution function. This is done by generating a transfer function to shift the occurrence distributions of precipitation and temperature [9]. This approach is also called 'probability mapping', 'quantile–quantile mapping' or 'histogram equalization' etc.

For distribution mapping of precipitation we assumed that the precipitation events follow The Gamma distribution [10], while in case of temperature, the Gaussian distribution [11] is assumed to be the best fit.

*Appendix A.VI: Distribution mapping and Intensity/Frequency scaling of precipitation (DM-IS)*

This is a modified version of the distribution mapping (DM) method, in which the magnitudes and frequency of precipitation are adjusted once more after the DM, to ensure that the relation between raw historical and raw scenario run, in terms of frequency as well as magnitudes, is reflected in the observed and corrected scenario runs.

The intensity and frequency scaling method (IS) used here is different than the one mentioned above (App-A.II). This method adjusts the ratio of the means as well as wet-day frequencies of scenario run to the observed precipitation time series, by effectively matching these ratios in the model simulation from historical to scenario runs (raw). The IS method consists of three steps.

In the first step, the ratio between wet-day frequencies of uncorrected scenario run to the uncorrected historical run ($wd_{f\text{-}raw}$), as well as the ratio between wet-day frequencies of scenario run to the observed precipitation ($wd_{f\text{-}corr}$) is calculated.

$$wd_{f-raw} = \frac{wd_{m,d}^{sce-raw}}{wd_{m,d}^{his-raw}} \tag{3}$$

$$wd_{f-DM,obs} = \frac{wd_{m,d}^{sce-DM}}{wd_{m,d}^{obs}} \tag{4}$$

In second step, at each point location, a wet-day threshold for the m^th^ month " $WDT_{m,d}^{DM}$ " is determined from the daily corrected scenario precipitation series, such that the threshold exceedance confirm that ratio of $wd_{f\text{-}DM,obs}$ match with that of $wd_{f\text{-}raw}$.

In the third step, a scaling factor is calculated from the wet-day intensities for each month by:

$$sf_m = \frac{\mu(P_{m,d}^{obs})}{\mu(P_{m,d}^{s-DM} \text{ given } P_{m,d}^{s-DM} \geq WDT_{m,d}^{DM})} \tag{5}$$

In the third step, this scaling factor for each month is applied to the daily scenario time series (above the threshold) to ensure that the mean of the corrected precipitation match to that of the observed precipitation at these locations.

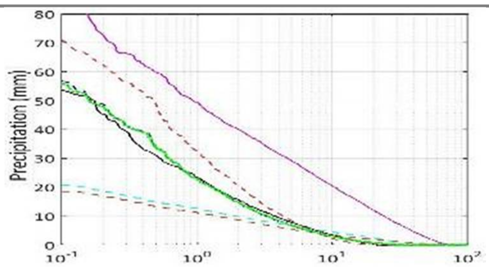
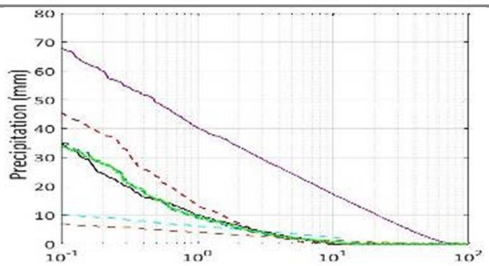
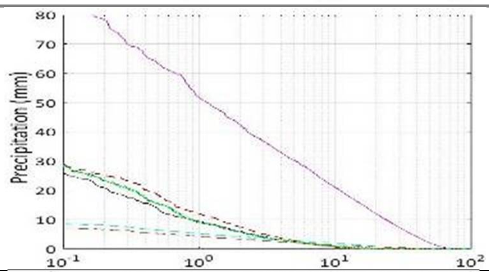
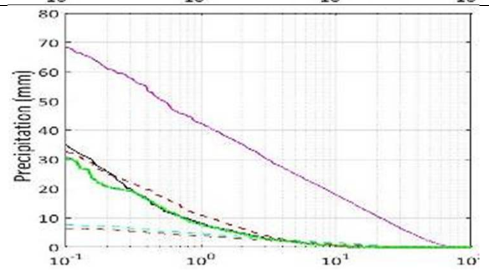
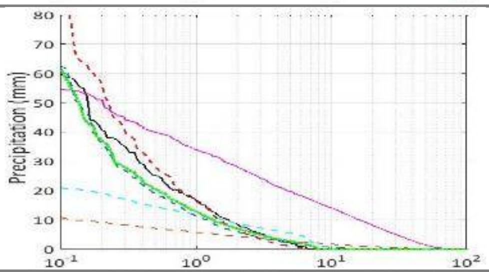
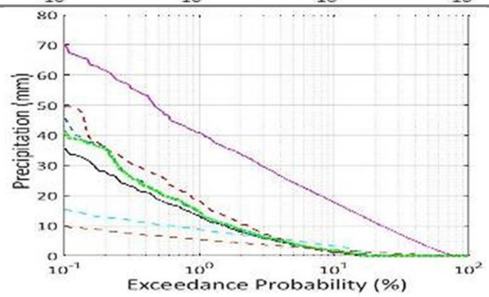
$$P_{(cor)}^{s} = \begin{cases} 0, & \text{if} \quad P_{m,d}^{s-DM} < WDT_{m,d}^{DM} \\ P_{m,d}^{s-DM} \times sf_m & \text{otherwise} \end{cases} \tag{6}$$

Here $P_{m,d}^{obs}$ and $P_{m,d}^{s-DM}$ are daily precipitation values of the observations and the DM-corrected scenario run for a specific month respectively, $\mu$ indicate the long term averages, $WDT_{m,d}^{DM}$ is the wet-days threshold for each month and $P_{(cor)}^{s}$ is the corrected scenario precipitation.

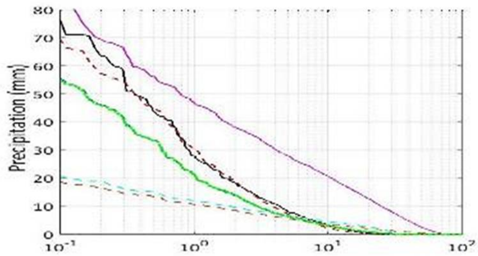
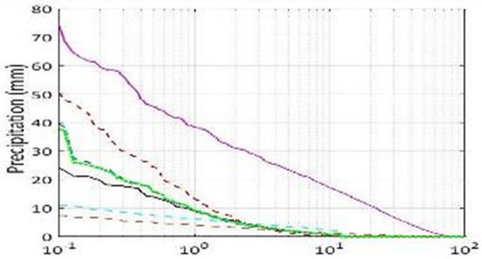
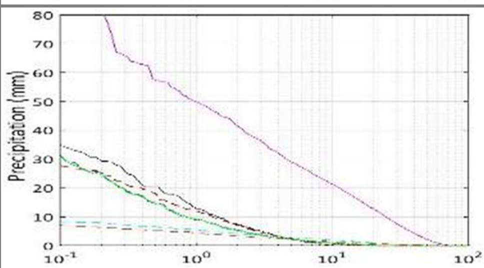
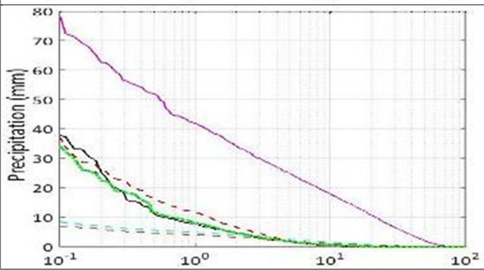
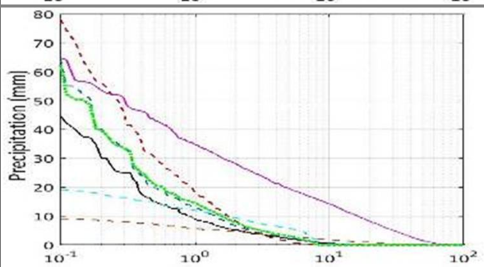
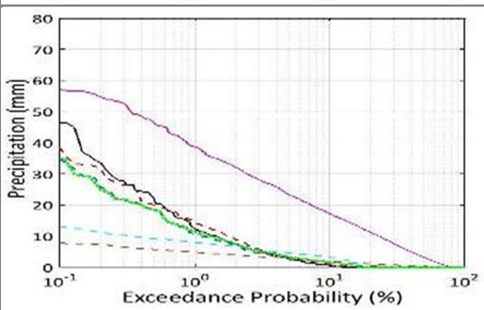
In the current study the precipitation series were corrected for wet-day frequencies and intensities on a monthly scale. During this exercise, a total of **24** fitting parameters were determined, including 12 $WDT_{m,d}^{DM}$ and 12 $sf_m$ (one for each month).

113 **Appendix.B: Calibration and validation statistics for bias correction Methods**

114 *Appendix B.I: Observed precipitation vs Historical-GCM (IPSL) Calibration Period*

| | Exceedance probability | General statistics | OB | H-raw | LS | LIS | PT | γDM | DM-IS |
|---|---|---|---|---|---|---|---|---|---|
| Astor |  | Mean (mm/d) | 1.31 | 7.04 | 1.27 | 1.27 | 1.29 | 1.47 | 1.29 |
| | | Max. (mm/d) | 118.2 | 113.4 | 25.1 | 28.0 | 94.0 | 128.5 | 89.6 |
| | | 99th Percentile (mm/d) | 23.30 | 49.38 | 11.11 | 12.58 | 22.62 | 31.95 | 22.74 |
| | | Median (mm/d) | 0.00 | 2.51 | 0.40 | 0.00 | 0.02 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 113.1 | 333.4 | 309.4 | 105.3 | 204.7 | 100.9 | 105.3 |
| | | Wet Days Intensity (mm/d) | 3.94 | 7.13 | 1.55 | 4.27 | 2.29 | 4.98 | 4.21 |
| Bunji |  | Mean (mm/d) | 0.44 | 6.08 | 0.44 | 0.44 | 0.45 | 0.50 | 0.45 |
| | | Max. (mm/d) | 66.4 | 82.2 | 10.3 | 14.8 | 74.7 | 74.6 | 72.4 |
| | | 99th Percentile (mm/d) | 10.15 | 40.10 | 4.08 | 6.18 | 8.88 | 13.18 | 9.41 |
| | | Median (mm/d) | 0.00 | 2.34 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 44.83 | 342.8 | 296.4 | 43.73 | 146.7 | 43.57 | 43.73 |
| | | Wet Days Intensity (mm/d) | 3.41 | 6.12 | 0.65 | 3.71 | 1.21 | 4.06 | 3.56 |
| Chilas |  | Mean (mm/d) | 0.46 | 7.05 | 0.47 | 0.47 | 0.47 | 0.52 | 0.47 |
| | | Max. (mm/d) | 68.0 | 107.1 | 10.2 | 12.3 | 58.0 | 51.2 | 57.7 |
| | | 99th Percentile (mm/d) | 9.42 | 51.62 | 4.17 | 5.16 | 9.13 | 11.96 | 9.16 |
| | | Median (mm/d) | 0.00 | 2.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 76.83 | 323.4 | 276.3 | 72.93 | 152.9 | 72.23 | 72.93 |
| | | Wet Days Intensity (mm/d) | 2.13 | 7.35 | 0.72 | 2.36 | 1.22 | 2.59 | 2.31 |
| Gilgit |  | Mean (mm/d) | 0.39 | 6.10 | 0.39 | 0.39 | 0.39 | 0.45 | 0.39 |
| | | Max. (mm/d) | 54.6 | 85.3 | 11.3 | 13.1 | 104.4 | 71.7 | 104.1 |
| | | 99th Percentile (mm/d) | 8.30 | 42.35 | 3.87 | 4.67 | 7.57 | 10.96 | 7.70 |
| | | Median (mm/d) | 0.00 | 2.03 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 75.40 | 334.4 | 280.3 | 72.07 | 136.0 | 63.27 | 72.07 |
| | | Wet Days Intensity (mm/d) | 1.81 | 6.22 | 0.63 | 2.01 | 1.12 | 2.52 | 1.88 |
| Gupis |  | Mean (mm/d) | 0.61 | 4.70 | 0.57 | 0.57 | 0.57 | 0.63 | 0.57 |
| | | Max. (mm/d) | 147.3 | 73.6 | 17.6 | 36.5 | 177.9 | 236.9 | 169.6 |
| | | 99th Percentile (mm/d) | 16.50 | 33.90 | 5.76 | 11.87 | 11.41 | 16.04 | 12.77 |
| | | Median (mm/d) | 0.00 | 1.39 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 30.17 | 334.9 | 294.6 | 28.73 | 128.6 | 28.47 | 28.73 |
| | | Wet Days Intensity (mm/d) | 6.47 | 4.88 | 0.82 | 6.72 | 1.61 | 6.95 | 6.57 |
| Skardu |  | Mean (mm/d) | 0.65 | 6.47 | 0.71 | 0.72 | 0.75 | 0.79 | 0.75 |
| | | Max. (mm/d) | 82.0 | 96.9 | 24.2 | 34.0 | 113.7 | 128.4 | 109.6 |
| | | 99th Percentile (mm/d) | 13.10 | 40.87 | 5.36 | 8.71 | 13.88 | 17.95 | 14.43 |
| | | Median (mm/d) | 0.00 | 3.00 | 0.29 | 0.00 | 0.01 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 60.37 | 342.9 | 314.1 | 59.77 | 189.2 | 59.77 | 59.77 |
| | | Wet Days Intensity (mm/d) | 1.31 | 7.04 | 1.27 | 1.27 | 1.29 | 1.47 | 1.29 |

*Appendix B.II: Observed precipitation vs Historical-GCM (IPSL)-Validation period*

| | Exceedance probability | General statistics | OB | H-raw | LS | LIS | PT | γDM | DM-IS |
|---|---|---|---|---|---|---|---|---|---|
| Astor |  | Mean (mm/d) | 1.51 | 7.07 | 1.29 | 1.29 | 1.24 | 1.37 | 1.24 |
| | | Max. (mm/d) | 100.3 | 129.4 | 25.7 | 28.6 | 89.5 | 91.6 | 88.9 |
| | | 99th Percentile (mm/d) | 27.21 | 46.28 | 10.65 | 11.91 | 20.34 | 30.00 | 20.84 |
| | | Median (mm/d) | 0.00 | 2.49 | 0.42 | 0.00 | 0.02 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 108.1 | 340.1 | 314.4 | 108.3 | 206.9 | 103.5 | 108.3 |
| | | Wet Days Intensity (mm/d) | 4.62 | 7.09 | 1.55 | 4.24 | 2.21 | 4.62 | 4.05 |
| Bunji |  | Mean (mm/d) | 0.40 | 6.05 | 0.45 | 0.44 | 0.43 | 0.48 | 0.43 |
| | | Max. (mm/d) | 41.9 | 116.1 | 11.1 | 16.0 | 68.6 | 78.5 | 66.1 |
| | | 99th Percentile (mm/d) | 8.87 | 38.45 | 4.07 | 6.22 | 8.80 | 13.10 | 9.17 |
| | | Median (mm/d) | 0.00 | 2.43 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 69.5 | 346.5 | 299.7 | 44.1 | 148.1 | 43.9 | 44.1 |
| | | Wet Days Intensity (mm/d) | 2.09 | 5.96 | 0.66 | 3.65 | 1.15 | 3.99 | 3.43 |
| Chilas |  | Mean (mm/d) | 0.51 | 7.11 | 0.48 | 0.48 | 0.46 | 0.49 | 0.46 |
| | | Max. (mm/d) | 76.2 | 148.6 | 8.8 | 10.6 | 49.5 | 39.1 | 49.0 |
| | | 99th Percentile (mm/d) | 12.70 | 49.73 | 4.38 | 5.34 | 8.96 | 11.84 | 9.04 |
| | | Median (mm/d) | 0.00 | 2.11 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 63.1 | 328.4 | 279.5 | 76.0 | 156.0 | 75.5 | 76.0 |
| | | Wet Days Intensity (mm/d) | 2.66 | 7.41 | 0.73 | 2.33 | 1.16 | 2.34 | 2.15 |
| Gilgit |  | Mean (mm/d) | 0.38 | 6.12 | 0.40 | 0.40 | 0.40 | 0.45 | 0.40 |
| | | Max. (mm/d) | 111.8 | 105.3 | 8.5 | 10.5 | 64.0 | 57.7 | 63.9 |
| | | 99th Percentile (mm/d) | 7.69 | 41.81 | 4.11 | 4.86 | 8.00 | 11.54 | 8.05 |
| | | Median (mm/d) | 0.00 | 2.08 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 78.0 | 338.7 | 283.8 | 72.2 | 138.1 | 64.3 | 72.2 |
| | | Wet Days Intensity (mm/d) | 1.69 | 6.18 | 0.65 | 2.06 | 1.17 | 2.46 | 1.99 |
| Gupis |  | Mean (mm/d) | 0.46 | 4.76 | 0.59 | 0.60 | 0.60 | 0.65 | 0.61 |
| | | Max. (mm/d) | 80.0 | 80.2 | 15.8 | 32.9 | 124.2 | 182.4 | 121.5 |
| | | 99th Percentile (mm/d) | 8.80 | 34.60 | 5.59 | 11.97 | 13.10 | 17.85 | 14.35 |
| | | Median (mm/d) | 0.00 | 1.46 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 65.7 | 339.0 | 299.2 | 29.9 | 131.9 | 29.4 | 29.9 |
| | | Wet Days Intensity (mm/d) | 2.24 | 4.87 | 0.84 | 6.75 | 1.64 | 7.41 | 6.85 |
| Skardu |  | Mean (mm/d) | 0.57 | 6.40 | 0.69 | 0.67 | 0.61 | 0.63 | 0.61 |
| | | Max. (mm/d) | 80.30 | 69.36 | 10.94 | 16.36 | 53.42 | 62.14 | 53.82 |
| | | 99th Percentile (mm/d) | 12.20 | 38.64 | 4.90 | 7.99 | 10.55 | 14.40 | 11.29 |
| | | Median (mm/d) | 0.00 | 3.17 | 0.32 | 0.00 | 0.01 | 0.00 | 0.00 |
| | | Wet Days Prob. (d) | 70.33 | 345.9 | 318.3 | 58.93 | 196.0 | 58.93 | 58.93 |
| | | Wet Days Intensity (mm/d) | 1.51 | 7.07 | 1.29 | 1.29 | 1.24 | 1.37 | 1.24 |
| | OB H-raw LS LIS PT DM DM-IS | | | | | | | | |

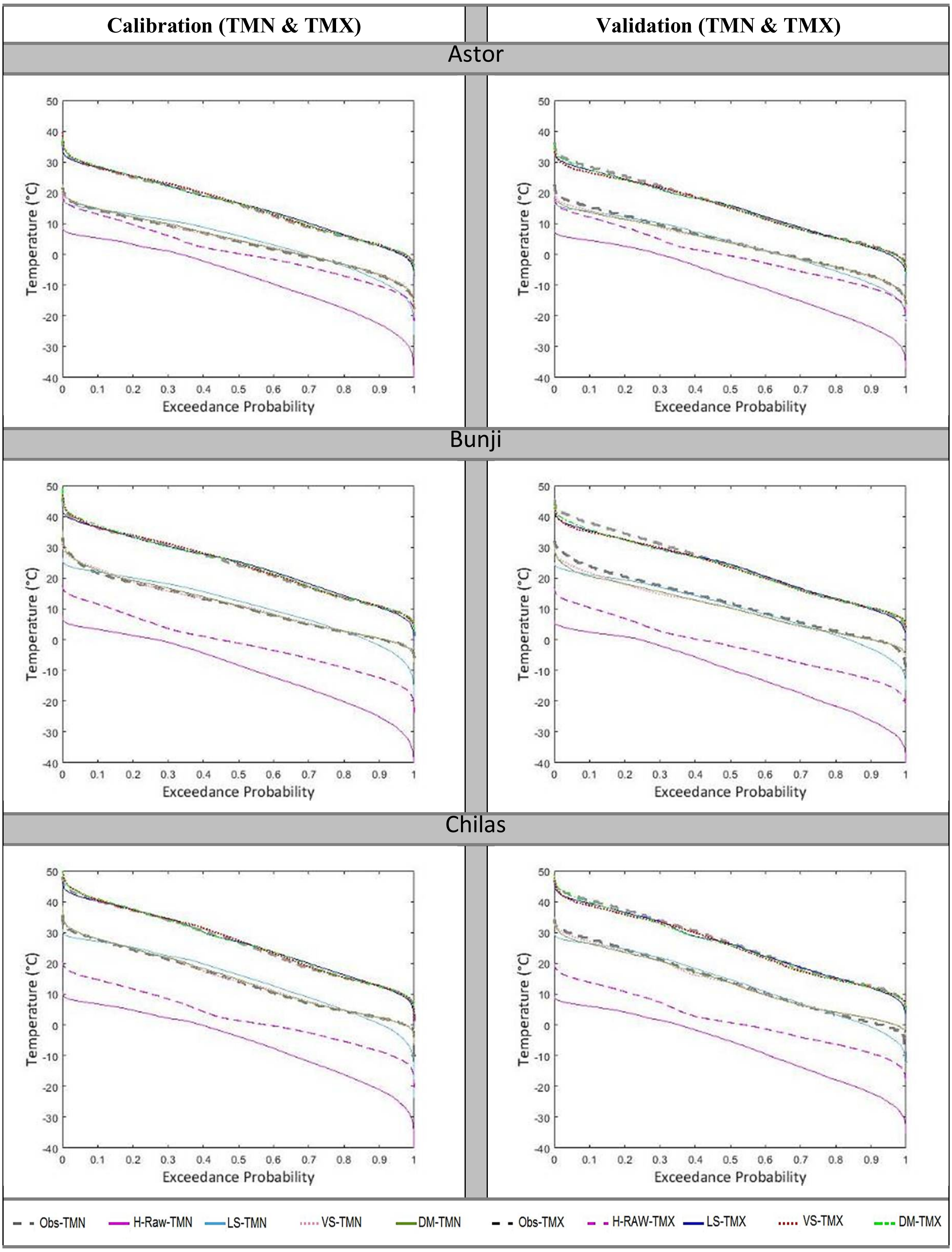
 *Appendix B.III: Observed Temperature (minimum) vs Historical-GCM (IPSL)*

| Performance Indices (°C) | Calibration (TMN) | | | | | | Validation (TMN) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | OB | H-RAW | LS | VS | DM | | OB | H-RAW | LS | VS | DM |
| | | | | | | Astor | | | | | |
| Mean | 4.1 | -7.3 | 4.5 | 4.3 | 4.3 | | 4.0 | -8.5 | 3.3 | 3.5 | 3.5 |
| Maximum value | 21.7 | 9.4 | 18.5 | 21.3 | 22.7 | | 22.8 | 8.1 | 17.1 | 20.1 | 20.0 |
| Minimum value | -17.7 | -40.5 | -26.2 | -19.5 | -19.8 | | -16.1 | -36.9 | -22.5 | -18.9 | -17.4 |
| 90th Percentile | 14.4 | 5.3 | 14.6 | 14.8 | 14.8 | | 15.6 | 4.5 | 14.0 | 14.2 | 13.7 |
| 10th Percentile | -6.7 | -22.6 | -8.5 | -6.6 | -6.4 | | -7.2 | -23.6 | -9.5 | -7.2 | -7.0 |
| Median | 4.2 | -5.8 | 6.1 | 4.5 | 4.6 | | 3.9 | -7.6 | 4.2 | 4.0 | 3.7 |
| Standard Deviation | 7.9 | 10.5 | 8.8 | 7.9 | 8.0 | | 8.4 | 10.6 | 8.8 | 7.9 | 7.8 |
| | | | | | | Bunji | | | | | |
| Mean | 10.9 | -9.2 | 11.7 | 11.6 | 11.6 | | 11.8 | -10.7 | 10.2 | 10.3 | 10.3 |
| Maximum value | 33.3 | 7.6 | 26.5 | 31.5 | 35.4 | | 32.2 | 6.1 | 25.0 | 30.7 | 30.6 |
| Minimum value | -5.0 | -42.3 | -19.4 | -6.9 | -6.8 | | -9.9 | -40.8 | -16.3 | -6.6 | -6.1 |
| 90th Percentile | 21.4 | 3.8 | 22.5 | 23.7 | 23.8 | | 23.9 | 2.4 | 21.1 | 21.6 | 20.5 |
| 10th Percentile | 0.3 | -24.5 | -1.4 | 0.6 | 0.6 | | 0.1 | -26.3 | -2.9 | 0.0 | 0.1 |
| Median | 10.8 | -7.9 | 13.0 | 11.5 | 11.2 | | 11.7 | -9.7 | 11.2 | 10.5 | 10.2 |
| Standard Deviation | 8.0 | 10.7 | 9.0 | 8.4 | 8.6 | | 8.9 | 10.9 | 9.0 | 8.0 | 7.8 |
| | | | | | | Chilas | | | | | |
| Mean | 14.6 | -5.2 | 15.4 | 15.2 | 15.2 | | 14.0 | -6.9 | 13.7 | 13.9 | 13.8 |
| Maximum value | 33.9 | 10.9 | 31.2 | 35.9 | 38.8 | | 34.2 | 9.6 | 29.9 | 34.9 | 35.0 |
| Minimum value | -2.4 | -43.6 | -23.7 | -5.3 | -5.8 | | -12.8 | -35.5 | -12.4 | -4.5 | -3.6 |
| 90th Percentile | 27.8 | 7.2 | 27.6 | 28.6 | 29.1 | | 27.8 | 6.0 | 26.4 | 27.0 | 26.3 |
| 10th Percentile | 2.8 | -20.3 | 1.0 | 2.6 | 2.6 | | 0.6 | -22.1 | -0.7 | 2.0 | 2.1 |
| Median | 14.0 | -3.3 | 16.8 | 14.5 | 15.1 | | 13.9 | -5.3 | 14.7 | 13.6 | 13.8 |
| Standard Deviation | 9.3 | 10.4 | 10.0 | 9.6 | 9.8 | | 10.1 | 10.6 | 10.2 | 9.4 | 9.2 |
| | | | | | | Gilgit | | | | | |
| Mean | 7.2 | -8.0 | 8.4 | 8.2 | 8.2 | | 7.8 | -9.6 | 6.8 | 7.0 | 6.9 |
| Maximum value | 27.2 | 9.6 | 22.6 | 25.5 | 29.4 | | 29.4 | 8.0 | 21.0 | 24.6 | 25.4 |
| Minimum value | -11.0 | -42.2 | -24.5 | -12.2 | -13.0 | | -10.0 | -39.2 | -20.8 | -12.0 | -11.2 |
| 90th Percentile | 16.7 | 5.2 | 18.4 | 18.7 | 19.1 | | 18.3 | 3.9 | 17.0 | 17.3 | 16.5 |
| 10th Percentile | -3.0 | -24.1 | -4.5 | -2.3 | -2.6 | | -3.3 | -25.4 | -5.6 | -3.1 | -3.1 |
| Median | 7.8 | -6.4 | 10.1 | 8.6 | 8.5 | | 8.3 | -8.3 | 8.1 | 7.4 | 7.5 |
| Standard Deviation | 7.5 | 11.0 | 8.6 | 7.8 | 8.0 | | 8.2 | 11.1 | 8.6 | 7.6 | 7.4 |
| | | | | | | Gupis | | | | | |
| Mean | 5.8 | -9.9 | 7.4 | 7.2 | 7.1 | | 7.2 | -11.5 | 5.7 | 5.9 | 5.9 |
| Maximum value | 23.9 | 8.0 | 22.1 | 26.6 | 29.1 | | 26.1 | 6.5 | 20.5 | 23.7 | 25.0 |
| Minimum value | -12.3 | -46.9 | -26.8 | -13.1 | -14.6 | | -11.7 | -43.6 | -21.9 | -12.2 | -12.2 |
| 90th Percentile | 16.6 | 3.8 | 18.1 | 18.9 | 18.9 | | 19.1 | 2.6 | 16.7 | 17.3 | 16.5 |
| 10th Percentile | -5.1 | -26.4 | -6.5 | -4.3 | -4.4 | | -4.4 | -27.9 | -7.9 | -5.0 | -4.8 |
| Median | 6.0 | -8.4 | 9.1 | 7.2 | 7.1 | | 7.2 | -10.6 | 7.0 | 6.3 | 5.9 |
| Standard Deviation | 8.2 | 11.5 | 9.4 | 8.5 | 8.7 | | 8.7 | 11.5 | 9.4 | 8.2 | 8.1 |
| | | | | | | Skardu | | | | | |
| Mean | 4.9 | -10.1 | 5.7 | 5.8 | 5.6 | | 5.2 | -11.5 | 4.4 | 4.4 | 4.5 |
| Maximum value | 26.5 | 6.1 | 20.0 | 23.2 | 26.1 | | 26.0 | 5.2 | 19.2 | 22.3 | 22.7 |
| Minimum value | -24.1 | -41.5 | -25.7 | -20.7 | -17.8 | | -22.4 | -39.8 | -22.5 | -19.9 | -19.2 |
| 90th Percentile | 15.9 | 2.7 | 16.8 | 17.9 | 17.1 | | 16.7 | 1.8 | 15.9 | 15.8 | 15.5 |
| 10th Percentile | -6.7 | -24.7 | -8.2 | -6.2 | -6.4 | | -7.2 | -26.0 | -9.0 | -7.1 | -6.9 |
| Median | 5.4 | -9.4 | 7.0 | 6.4 | 5.8 | | 6.1 | -11.2 | 5.3 | 5.2 | 5.0 |
| Standard Deviation | 8.8 | 10.5 | 9.6 | 8.8 | 9.1 | | 9.2 | 10.5 | 9.5 | 8.7 | 8.6 |

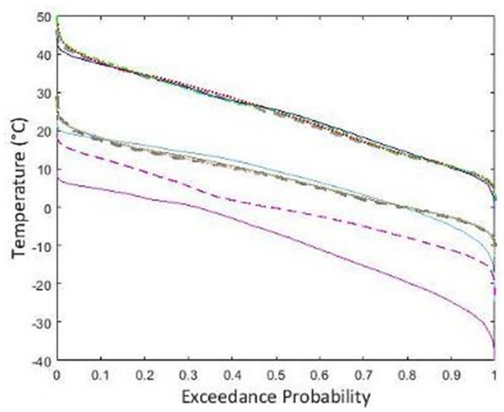
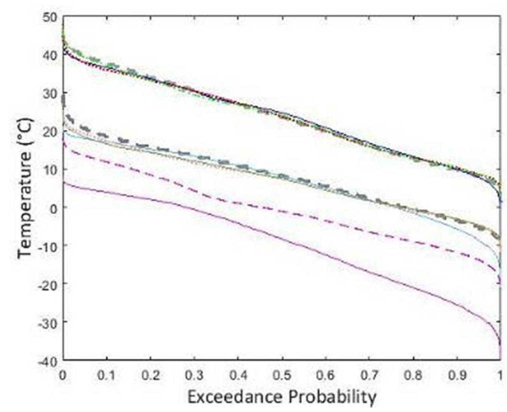
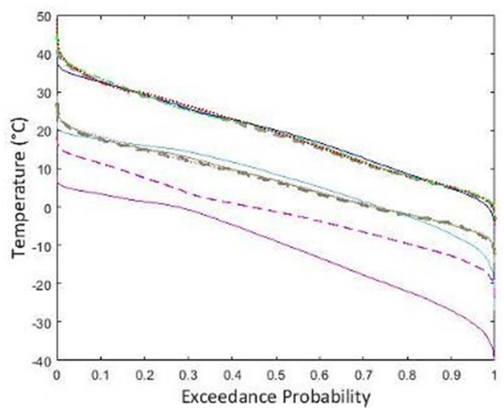
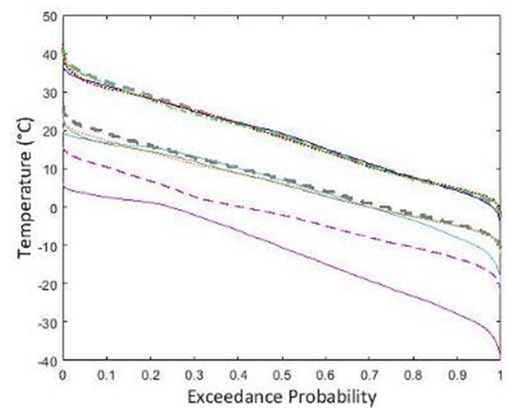
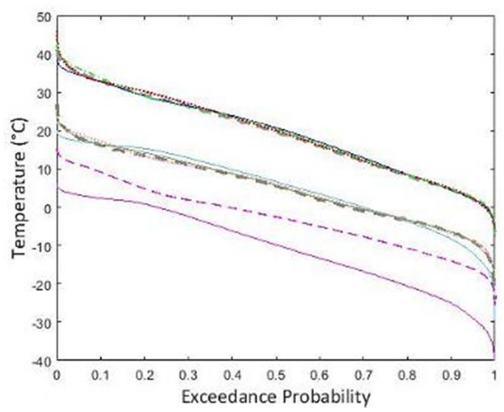
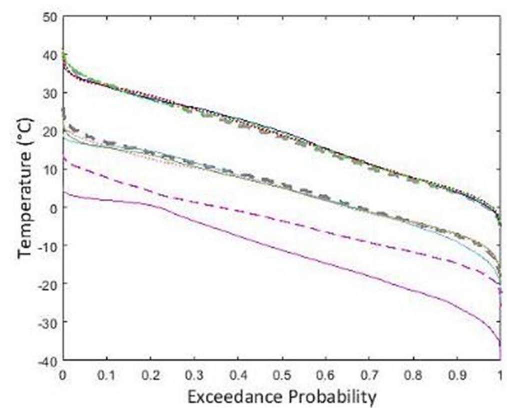
117 *Appendix B.IV:Observed Temperature (maximum) vs Historical-GCM (IPSL)*

| Performance Indices (°C) | Calibration (TMX) | | | | | Validation (TMX) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OB | H-RAW | LS | VS | DM | OB | H-RAW | LS | VS | DM |
| **Astor** | | | | | | | | | | |
| Mean | 15.6 | 0.9 | 16.0 | 16.0 | 16.0 | 15.4 | -0.1 | 15.0 | 14.8 | 14.9 |
| Maximum value | 37.0 | 19.6 | 34.8 | 39.7 | 37.5 | 36.3 | 18.5 | 33.6 | 35.7 | 35.7 |
| Minimum value | -6.1 | -22.0 | -9.4 | -7.0 | -6.8 | -6.3 | -21.6 | -8.8 | -5.2 | -6.4 |
| 90th Percentile | 28.1 | 13.0 | 28.3 | 28.3 | 28.7 | 28.3 | 12.1 | 27.4 | 26.6 | 27.6 |
| 10th Percentile | 2.8 | -10.2 | 2.8 | 3.2 | 3.0 | 2.8 | -10.9 | 2.2 | 2.6 | 2.5 |
| Median | 16.2 | 0.3 | 16.7 | 16.7 | 16.5 | 15.6 | -0.5 | 15.9 | 15.2 | 15.6 |
| Standard Deviation | 9.4 | 8.4 | 9.3 | 9.5 | 9.5 | 9.6 | 8.4 | 9.3 | 9.1 | 9.3 |
| **Bunji** | | | | | | | | | | |
| Mean | 23.7 | -0.4 | 24.6 | 24.6 | 24.7 | 23.9 | -1.9 | 23.2 | 23.0 | 23.1 |
| Maximum value | 43.3 | 17.5 | 43.3 | 49.3 | 49.3 | 45.6 | 16.9 | 42.1 | 44.1 | 44.2 |
| Minimum value | 1.4 | -23.9 | -1.5 | 3.5 | 2.7 | 1.7 | -23.0 | 0.0 | 3.5 | 3.6 |
| 90th Percentile | 35.8 | 12.1 | 37.1 | 37.6 | 38.0 | 37.8 | 10.4 | 35.4 | 35.0 | 35.8 |
| 10th Percentile | 11.1 | -11.8 | 10.9 | 11.1 | 11.0 | 10.0 | -13.0 | 9.9 | 10.4 | 10.3 |
| Median | 23.9 | -0.9 | 25.6 | 25.0 | 25.3 | 24.0 | -2.1 | 24.4 | 23.5 | 23.8 |
| Standard Deviation | 9.3 | 8.6 | 9.5 | 10.0 | 9.7 | 10.3 | 8.5 | 9.5 | 9.3 | 9.4 |
| **Chilas** | | | | | | | | | | |
| Mean | 26.2 | 3.1 | 27.2 | 27.4 | 27.4 | 26.4 | 1.6 | 25.8 | 25.5 | 25.6 |
| Maximum value | 47.7 | 20.8 | 46.6 | 53.9 | 50.2 | 47.1 | 20.0 | 45.5 | 49.1 | 49.1 |
| Minimum value | 1.2 | -20.4 | 0.4 | 1.4 | 3.8 | 2.8 | -19.3 | 1.8 | 5.5 | 4.1 |
| 90th Percentile | 40.0 | 15.2 | 40.7 | 41.9 | 41.6 | 40.6 | 13.8 | 39.4 | 38.8 | 39.8 |
| 10th Percentile | 12.5 | -8.0 | 13.1 | 12.9 | 13.0 | 12.8 | -9.2 | 12.0 | 12.2 | 12.1 |
| Median | 26.4 | 1.7 | 27.3 | 27.9 | 27.1 | 26.7 | 0.7 | 26.3 | 25.8 | 25.9 |
| Standard Deviation | 10.4 | 8.5 | 10.2 | 10.8 | 10.5 | 10.4 | 8.5 | 10.2 | 10.1 | 10.3 |
| **Gilgit** | | | | | | | | | | |
| Mean | 24.5 | 0.8 | 24.9 | 25.1 | 25.1 | 23.4 | -0.7 | 23.5 | 23.3 | 23.4 |
| Maximum value | 46.3 | 18.7 | 44.2 | 53.9 | 51.1 | 45.0 | 17.9 | 43.2 | 47.8 | 46.6 |
| Minimum value | 3.0 | -23.0 | -2.1 | 2.1 | 2.2 | 1.1 | -21.7 | -0.4 | 3.4 | 3.0 |
| 90th Percentile | 37.8 | 13.2 | 37.8 | 38.9 | 39.0 | 37.8 | 11.8 | 36.5 | 35.8 | 37.0 |
| 10th Percentile | 11.0 | -10.6 | 10.9 | 10.8 | 10.9 | 10.0 | -11.8 | 9.9 | 10.2 | 10.2 |
| Median | 24.7 | 0.0 | 25.7 | 25.4 | 25.4 | 23.3 | -1.1 | 24.6 | 23.6 | 24.0 |
| Standard Deviation | 24.5 | 0.8 | 24.9 | 25.1 | 25.1 | 23.4 | -0.7 | 23.5 | 23.3 | 23.4 |
| **Gupis** | | | | | | | | | | |
| Mean | 18.9 | -0.7 | 19.6 | 19.7 | 19.7 | 18.4 | -2.1 | 18.2 | 18.0 | 18.1 |
| Maximum value | 41.1 | 18.4 | 39.1 | 48.9 | 45.1 | 41.1 | 16.1 | 37.2 | 42.8 | 40.8 |
| Minimum value | -1.7 | -24.2 | -7.0 | -4.5 | -3.1 | -5.0 | -23.8 | -5.8 | -2.2 | -2.2 |
| 90th Percentile | 32.7 | 12.0 | 33.1 | 34.1 | 34.4 | 32.8 | 10.4 | 31.6 | 31.0 | 32.1 |
| 10th Percentile | 5.5 | -12.2 | 5.4 | 5.4 | 5.5 | 4.4 | -13.4 | 4.3 | 4.9 | 4.7 |
| Median | 18.8 | -1.0 | 20.2 | 19.9 | 19.9 | 18.3 | -2.1 | 19.2 | 18.2 | 18.5 |
| Standard Deviation | 10.1 | 8.7 | 10.1 | 10.7 | 10.5 | 10.4 | 8.7 | 10.1 | 9.9 | 10.1 |
| **Skardu** | | | | | | | | | | |
| Mean | 19.3 | -2.2 | 19.9 | 19.9 | 20.0 | 17.8 | -3.7 | 18.4 | 18.3 | 18.3 |
| Maximum value | 40.6 | 15.1 | 38.8 | 46.0 | 42.4 | 40.0 | 14.3 | 37.4 | 41.5 | 41.0 |
| Minimum value | -6.6 | -25.5 | -7.5 | -4.3 | -6.6 | -7.0 | -25.9 | -6.8 | -5.5 | -6.0 |
| 90th Percentile | 33.0 | 9.8 | 33.5 | 33.7 | 34.8 | 32.0 | 7.7 | 31.5 | 31.6 | 31.9 |
| 10th Percentile | 5.0 | -13.4 | 5.1 | 4.9 | 5.1 | 3.9 | -14.7 | 3.8 | 4.4 | 4.0 |
| Median | 19.8 | -2.3 | 21.0 | 20.3 | 20.7 | 18.3 | -3.6 | 19.7 | 18.7 | 19.2 |
| Standard Deviation | 10.4 | 8.3 | 10.3 | 11.0 | 10.7 | 10.6 | 8.3 | 10.3 | 10.2 | 10.4 |

*Appendix B.V: Exceedance probability plots of observed Temperature and Historical-GCM (IPSL), uncorrected and bias-corrected/downscaled with three methods (Astor, Bunji & Chilas)*



*Appendix B.VI:Exceedance probability plots of observed Temperature and Historical-GCM (IPSL), uncorrected and bias-corrected/downscaled with three methods (Gilgit, Gupis & Skardu)*

| **Calibration (TMN & TMX)** | **Validation (TMN & TMX)** |
|---|---|
| Gilgit | |
|  |  |
| Gupis | |
|  |  |
| Skardu | |
|  |  |
| Obs-TMN, H-Raw-TMN, LS-TMN, VS-TMN, DM-TMN, Obs-TMX, H-RAW-TMX, LS-TMX, VS-TMX, DM-TMX | |

## References


1. Teutschbein, C.; Seibert, J. Bias correction of regional climate model simulations for hydrological climate-change impact studies: Review and evaluation of different methods. Journal of Hydrology 2012, 456-457, 12–29, doi:10.1016/j.jhydrol.2012.05.052.
2. Rathjens, H.; Bieger, K.; Srinivasan, R.; Chaubey, I.; Arnold. J. G. CMhyd User Manual: Documentation for preparing simulated climate change data for hydrologic impact studies. https://swat.tamu.edu/media/115265/bias_cor_man.pdf.
3. Lenderink, G.; Buishand, A.; van Deursen, W. Estimates of future discharges of the river Rhine using two scenario methodologies: direct versus delta approach. Hydrol. Earth Syst. Sci. 2007, 11, 1145–1159, doi:10.5194/hess-11-1145-2007.
4. Schmidli, J.; Frei, C.; Vidale, P.L. Downscaling from GCM precipitation: a benchmark for dynamical and statistical downscaling methods. Int. J. Climatol. 2006, 26, 679–689, doi:10.1002/joc.1287.
5. Leander, R.; Buishand, T.A.; van den Hurk, B.J.J.M.; Wit, M.J.M. de. Estimated changes in flood quantiles of the river Meuse from resampling of regional climate model output. Journal of Hydrology 2008, 351, 331–343, doi:10.1016/j.jhydrol.2007.12.020.
6. Brent, R.P. An algorithm with guaranteed convergence for finding a zero of a function. The Computer Journal 1971, 14, 422–425, doi:10.1093/comjnl/14.4.422.
7. Chen, J.; Brissette, F.P.; Leconte, R. Uncertainty of downscaling method in quantifying the impact of climate change on hydrology. Journal of Hydrology 2011, 401, 190–202, doi:10.1016/j.jhydrol.2011.02.020.
8. Chen, J.; Brissette, F.P.; Poulin, A.; Leconte, R. Overall uncertainty study of the hydrological impacts of climate change for a Canadian watershed. Water Resour. Res. 2011, 47, 176, doi:10.1029/2011WR010602.
9. Sennikovs, J.; Bethers, U. Statistical downscaling method of regional climate model results for hydrological modelling. In Interfacing modelling and simulation with mathematical and computational sciences: 18th IMACS World Congress, MODSIM09, Cairns, Australia 13-17 July 2009 : proceedings; Braddock, R.D., Newham, L.T.H., Anderssen, R.S., Eds.; Modelling and Simulation Society of Australia and New Zealand: [Christchurch, N.Z.], 2009.
10. THOM, H.C.S. A NOTE ON THE GAMMA DISTRIBUTION. Mon. Wea. Rev. 1958, 86, 117–122, doi:10.1175/1520-0493(1958)086<0117:ANOTGD>2.0.CO;2.
11. Cramér, H. Mathematical methods of statistics; Princeton University Press: Princeton, 1999.