Hydrol. Earth Syst. Sci. Discuss., 10, C815–C831, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C815/2013/

Hydrology and Earth System Sciences Discussions

HESSD
10, C815–C831, 2013

Interactive Comment

Interactive comment on "The influence of precipitation and temperature input schemes on hydrological simulations of a snow and glacier melt dominated basin in Northwest China" *by* X. Ji and Y. Luo

X. Ji and Y. Luo

jixuan@hotmail.com

Received and published: 15 April 2013

Dear Editor and anonymous reviewer,

Your comments are all very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made correction which we hope meet with approval. The responds to the comments are in following.

The authors

Comments:there exist some misconception in the use of remote-sensing data that should be remedied before the authors can successfully interpret their results. I list three key points here: (1) The manuscript mixes rainfall and precipitation and I am uncertain if the authors are aware of the differences. Rainfall is liquid precipitation, whereas precipitation is rainfall and snowfall. The TRMM3B42 or 3B42 data product is most sensitive to rainfall (and not precipitation). Hence, the hydrologic budget based on TRMM 3B42 or 3B43 data only include a small fraction of snowfall. It is misleading to call this precipitation.

Reply: Your comments are appreciated. We are confused by the words "precipitation" and "rainfall" either when using the TRMM products. Eventually, we chose to use "precipitation" instead of "rainfall". The sensors onboard the TRMM platform have been designed to sense tropical rainfall, as you indicated. The TRMMB43 used in this study is a multi-satellite precipitation analysis (TMPA) product of sophisticated algorithms, a range of different sensors, as well as gauge records (Huffman et al., 2007).

A snowfall information was included in the TRMM3B43 data through synthesis of the AMSU-B precipitation data. The AMSU-B precipitation data set is computed operationally at the National Environmental Satellite Data and Information Service (NESDIS) based on the Zhao and Weng (2002) and Weng et al. (2003). The AMSU-B identifies snowfall region at 53.8 GHz with the algorithm of Zhao and Weng (2002) and Weng et al. (2003), and the snowfall rate of 0.1 mm/hr was used, tested, and evaluated for deriving the snowfall amount (Huffman and Bolvin, 2008).

Thus, it would be better to use precipitation rather than rainfall for the TRMM3B43 product.

Comments:(2) Along the same lines, the authors provide a unique set of ground-control stations used for calibration. I doubt that these are precipitation measurement (even though they are listed as these in the Table). If these are precipitation measurements, how has the snowfall been converted to rainfall amounts? Through height measurement and some density estimation? Through melting snow? For this to be successful, the snow needs to be sampled right after the snowstorm, otherwise values may be influenced by sublimation, compaction, or other post-depositional processes. I emphasize the importance of this point, as a large fraction of annual precipitation appears as snow in this area. The authors should be more careful when using TRMM-derived products and be aware of the limitations.

Reply: The rainfall was measured by the rain gauges, and snowfall by snowfall collector and melt water depth (snow water equivalent) at the meteorological stations (Chen et al., 2011; Wang et al., 2009; Yang, 1988).

These in situ measurements were commonly used as basic weather input data in hydrological modeling by assuming they are the true representation(Wu et al.,2011;Huang et al.,2010;Zhang et al.,2007;Liu et al.,2011;Dou et al.,2011;Duan et al.,2012).

Comments:Along the same lines, the authors use the ground-control stations to re-calibrate the TRMM data. They only show the re-calibrated elevation vs. rainfall datasets. It would be very instructive to show the uncalibrated data to give the interested reader the chance to judge the importance of the calibration. By how much have the TRMM3B43 data been adjusted? I note that the authors state that rainfall in mountain areas is under-predicted by TRMM data – I know of several studies that claim the opposite (TRMM 3B42-derived rainfall is higher in the mountains than actual measurements).This is complex terrain and there is no 'one-solution-fits-all' answer. In any case, the authors could show the station locations used for calibrating the data in Figure 2. I am even more puzzled by Figure 3 where the monthly linear fits are presented. What is the meteorological reasoning behind having 2 or 3 piecewise-linear fits vs. only one linear fit? I note that the source product (3-hr TRMM 3B42 data) are somewhat reliable in flat terrain, but certainly have issues in mountainous terrain.

Reply: The quality assessment and bias correction has already been done in the previous study (Ji and Chen, 2012), found that the TRMM 3B43 data has strong correlation and large bias with the observed data in mountain area. After correction,the corrected precipitation estimates explained over 81% of the variance in the observed precipitation as compared to 64% by TRMM 3B43 alone, and the RMSE decreased 34% after correction(Figure1 in this document);And compared with the original TRMM 3B43 data, the corrected estimations were also significantly improved on an annual time scale (Figure2 in this document).On the basis of the corrected data, this study was mainly focused on the influence of different precipitation inputs for hydrological simulation.

As you pointed out, TRMM data has different performance at different region. The TRMM data are often underestimated for some mountainous regions in middle latitude mountain systems (Berg et al., 2006; Huffman et al., 2007). And according to the quality assessment of TRMM3B43 in our study area, the precipitation was underestimated obviously for mountain region. For example, the annual precipitation is almost 50% underestimated at the Xiaoquzi station.

The locations of station which involved in TRMM3B43 calibrating has been showed in Figure1(in manuscript). In Figure2(in manuscript), the data point represents the average precipitation on the elevation bands(MRB was divided into 20 elevation bands with elevation increment 200m,precipitation was averaged over each band). The method for identifying precipitation gradient at different elevation range was described in section2.3.4.The related monthly linear fits were added to the figures.

Both the quality assessment and bias correction of TRMM3B43 data were carried out by using a statistical methods, the meteorological reasoning behind having many piecewise-linear fits still need a further study.

Comments:Third, I have the following scientific comments that (hopefully) will provide food for thought. (1) I am puzzled by the elevation vs. rainfall (or precipitation) approach. There certainly exists a relation between rainfall and elevation, but not for all elevation ranges (especially not for elevation above 3.5 or 4km). Orographic rainfall

HESSD
10, C815–C831, 2013

effects and limitations of water-vapour storage in colder (higher) air masses prevent high rainfall rates at high elevation. Along the same lines, why are there negative relations in the elevation vs. precipitation plots? Is this an artifact of the relatively small numbers of calibration station (compared to the large catchment area) or is this part of an orographic rainfall effect?

Reply: The rainfall (or precipitation) approach is often adopted to interpolate a base station data along elevation (Fontaine et al., 2002; Rahman et al.,2013;Wu et al., 2011; Zhang et al., 2007; Dou et al., 2011). Rainfall or precipitation may not change homogeneously with elevation due to orographic rainfall effects or water-vapor storage in colder air masses at high elevation as you mentioned, and this might be partially the reason for the negative relationships at elevations above (2500m a.s.l.-3700m a.s.l.) in this article. How and to what extent the orographic rainfall and limited numbers of the ground stations effect the bias-correction of the precipitation product remained unknown.

Our study area located in the mid Tianshan Mountains,with high mountains and complex terrain. By the influence of topographic factors, the vertical distribution of the precipitation is quite obvious in this region. There are abundant water vapor at mountainside, and a high precipitation zone is formed at about 2500m a.s.l., as the elevation increased, the water vapor was consumed, the precipitation was decreased; in the higher elevations it is the permanent snow and glacier area,there are lots of water vapor produced by the snow/glacier sublimation or evaporation, allow the humidity to increase, and provide the conditions for the formation of the second large precipitation area. These mechanism were explained in many previous studies for this region (Fu 1992; Chen et al. 1980; Wei and Hu 1990; Shen and Liang 2004). The detail distribution of precipitation in this mountain area are complex, in the current conditions we could only analyze the main features and use in hydrological simulation; The TRMM data with a 0.25 degree cell-size, the previous study (Ji and Chen, 2012) processed the grid data by using the Bi-linear interpolation method. The precipitation distribution analyzed in this study was based on the interpolation result.

HESSD

10, C815–C831, 2013

Comments:The rainfall vs. elevation transect do not display any uncertainties or linear-fit relations. This is crucial in evaluating the overall approach (they are not listed in any table either).

Reply: The linear-fit relations were added to Figures in revised manuscript (Fig.2, Fig3, and Fig4).R2 and the significant lever were also showed in the legend.

Comments:Furthermore, the studied catchment has a high relief and likely has a steep rainfall gradient. I am wondering how many TRMM pixels are actually located in the catchment (with a 0.25degree cell-size, there are not too many in the catchment). Along these lines, Figure 1 needs a length scale!

Reply: Approximately, there are 20 grid pixels of TRMM image data within the Manas River Basin. It is a small number. Yet, it is far more than the single meteorological station at the outlet of the watershed. There is no better choice than trying the TRMM data as an input of precipitation of the hydrological simulation in the Manas River basin, and other mountainous basins in Xinjiang Region, or even in the whole Northwest China.

Comments:(2) I note that the elevation-bin approach is tricky in a catchment with a steep rainfall gradient. Likely, the frontal high elevations receive much more rainfall than similar elevation farther inside the catchment (i.e., south of the mountain front). Why use a binning approach, if you use grid-based TRMM data?

Reply: Quite a lot of hydrological model use the precipitation-elevation relationship for estimating the precipitation in data scarce high mountain area (Fontaine et al., 2002; Rahman et al.,2013; Wu et al., 2011; Zhang et al., 2007; Dou et al., 2011).

To account for the orographic effects, SWAT allows up to 10 elevation bands to be defined. Subbasin temperatures and precipitation are adjusted for each elevation band in a subbasin as a function of the lapse rate and the difference between elevation of the meteorological gaging station and the average elevation specified for the band. The

HESSD

10, C815–C831, 2013

Interactive Comment

watershed is delineated into subbasins, not "cell-grid", seems that the grid-based data could not be used in SWAT directly.

In addition, because of the limited time-span (TMPA products begin in 1998), the available satellite precipitation data seems inadequate for direct application in long term historical simulation (before 1998). At present, hydrological studies in these data scarce river basin, "precipitation lapse rate" method could be considered as a simple and effective method.

Comments:(3) Regarding the hydrologic modeling approach, I would like to see a few more explanations about the SWAT model. What are the strength and weaknesses? No need to go into detail here, but there are some obvious limitations for steep, mountainous catchments (e.g., altitude binning).

Reply: We gave some more explanations about the strength and weaknesses of the SWAT model (P6 L22, section 2.2 in revised manuscript).

SWAT model delineates a watershed into a number of subbasins with irregular boundaries and variable sizes. Delineation of a watershed into subbasins may be confronted with difficulties under conditions of steep mountainous watershed. It may be difficult to identify subbasin boundaries for steep or flat terrain. Our experiences indicated that this may happen in some locations of the Tianshan Mountains. However, we did not find this problem in the MRB of this study.

Comments:(4) Why is the hydrologic model run and calibrated with mean monthly data? Why not use daily data? TRMM 3B42 provides a daily rainfall product as well.

Reply: SWAT model was run on a daily time-step. The NSE and PBIAS values of discharge were calculated on the basis of daily values.

We evaluated the TMPA data against the ground data on daily, monthly, and annual scales. It was found that TRMM3B43 could give an acceptable estimation. We derived the PLAPS rate using the monthly TMPA data, and the PLAPS rates were used as

HESSD

10, C815–C831, 2013

Interactive Comment

input to the SWAT model. We did not use the TMPA data directly.

Estimates for shorter time scales show considerably more uncertainty (Huffman et al., 2007).Su et al. (2008) suggested that TMPA estimates are significantly better on the monthly scale. Hughes (2006) concluded that agreement between satellite-based and observed data was much better for monthly than daily scales.

Comments:(5) The evaporation measurements appear to be very high. I am puzzled by an evaporation rate of 950 mm/yr at 3550m. Is this really true? This is twice the precipitation (sigh) amount at the same altitude as given in Table 1. What is the source of water (or water vapor) to sustain these rates?

Reply: This is the annual average evaporation observed by 20 cm evaporation-pan at local scale. The estimated potential evapotranspiration at basin scale was 562mm by the Hargreaves equation, and the actual annul evapotranspiration was 258mm according to the model simulation.

Comments:(6) The authors argue in their last paragraph in the Conclusion that "this study provides a reference for hydrologic modeling in data-scarce basins". Wouldn't it be more effective to use a well-monitored basin and see which and how many variables are necessary to understand the annual (or monthly) hydrologic budget? There are certainly equally sized catchments in similar alpine settings with more gauge stations.

Reply: We re-composed this conclusion. As a matter of fact, scarcity of meteorological data is pretty common for high mountain watershed simulations in Central Asia, less than 10% of the stations are above the altitude of 3000(Figure3 in this document)(Aizen et al., 1997). In Eastern Tianshan Mountain, Daxigou station is the only meteorological stations above 3500m a.s.l and with long-term observation data. We hope that our efforts of using the TMPA precipitation data for the watershed hydrological simulation can be a valuable reference to other research under the similar conditions.

Wording comments: The word scheme is misleading and used in the wrong way. I

HESSD

10, C815–C831, 2013

Interactive Comment

suggest to replace or just it only in appropriate places. There is no ‘model-warm up’, it’s called spin up. But I probably would refer to a ‘initiation period’ Spell out SWAT at first usage.

Reply: Thanks for your comments. The word "scheme" was replaced with "case" or "inputs" or "input cases" at 24 places. We used "spin up the model" instead of "Warm-up the model" (P4 L5, section 1 in revised manuscript). SWAT was spelled out at first usage(P4 L29, section 1 in revised manuscript).

I note that there are several place in the manuscript where the proper units are missing (e.g., page 823, line 7).

Reply: The missing unit "mm" in sentences are added (P17 L27, section 3.3 in revised manuscript).

Page 821, line 19: accurately.

Reply: The whole sentence was changed into "the MPLAPS method gave a better description to the precipitation distribution along the elevation than the SPLAPS” (P16 L17, section 3.2 in revised manuscript)

Page 815, line 9: a good linear.

Reply: Accepted.

Page 815, Line 13: single.

Reply: Accepted.

Page 816: Temperature data are not more or less noisy than rainfall. These are very different variables presenting different meteorological conditions.

Reply: Accepted. Thanks for your comments.

Figures: Figure 1 needs length scale; increase width of polygon outlining MRB catchment.

HESSD

10, C815–C831, 2013

Reply: Figure1 was modified.

Figure 2 needs linear-fit information and statistics. Station location would help. Also, plotting the uncalibrated TRMM data would be very helpful and useful as well.

Reply: Thanks for your comment. Linear-fit information and statistics were added into Figure2. The annual precipitation at different altitude were obtained from the corrected TRMM 3B43 data in MRB. Precipitation was averaged over each elevation band (MRB was divided into 20 elevation bands with elevation increment 200m). A declaration was added into the figure caption.

Figure 3: You should use the same Y-axis scales for all figures. Plot slopes and fitting information in the graph. I emphasize that all rainfall vs. elevation figures use precipitation (mm) as Y axis. I urge the authors to think carefully if these are precipitation amounts or rainfall amounts. Also, the authors refer to a rate, so it should be mm/yr or mm/month.

Reply: Figure3 was modified; use the same Y-axis scales for all figures; Fitting information were added.

Figure 4: Units! Is this mean monthly temperature taken from 24-h measurements? Again, same Y axis would be helpful.

Reply: The temperature is monthly average value. Figure4 was modifiedïijŽuse the same Y-axis scales for all figures;

Tables: Spell out all abbreviations (LPLAPS, SPLAPS, etc) Table 3 should contain fitting information (R2, RMS and uncertainty (1 or 2 sigma).

Reply: Abbreviations were spelled out in tables. Fitting information of temperature-elevation were added into figure4.

Reference:

Aizen, V. B., Aizen, E. M., Melack, J. M., and Dozier, J.: Climatic and hydrologic

HESSD

10, C815–C831, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

changes in the Tien Shan, central Asia, Journal of Climate, 10(6), 1393-1404,1997.

Berg, W., L'Ecuyer, T., and Kummerow, C.: Rainfall climate regimes: The relationship of regional TRMM rainfall biases to the environment, Journal of applied meteorology and climatology, 45(3), 434-454, 2006.

Chen, D.,Shi, L.,Li, X.,and Li, C.: Status investigation of automatic weather observation, Meteorological science and technology, 39(5):596-602,2011. (In Chinese)

Chen, W., Weng, D.,and Qian,L.: Discussions about calculation method of temperature and precipitation in meso-scale mountain area, Journal of Nanjing Institute of Meteorology 1:95-104, 1980.

Dou, Y., Chen, X., Bao, A., and Li, L.: The simulation of snowmelt runoff in the ungauged Kaidu River Basin of TianShan Mountains, China, Environmental Earth Sciences, 62(5), 1039-1045,2011.

Duan, K., Yao, T., Wang, N., and Liu, H.: Numerical simulation of Urumqi Glacier No. 1 in the eastern Tianshan, central Asia from 2005 to 2070, Chinese Science Bulletin, 57(34), 4505-4509, (2012).

Fontaine, T. A., Cruickshank, T. S., Arnold, J. G., and Hotchkiss, R. H.: Development of a snowfall–snowmelt routine for mountainous terrain for the soil water assessment tool (SWAT), J. Hydrol., 262, 209–223, 2002.

Fu, B.: The impaction of topography and elevation on precipitation distribution, ACTA Geographical Sinic, 4:302-314, 1992. (In Chinese)

Huang,Y.,Chen, X.,and Ma Y.:Simulation of runoff process in mountainous basin of Tarim River based on distributed hydrological model and uncertainty analysis, Journal of desert research, 30(5):1234-1238,2010.

Huffman, G. J. and Bolvin, D. T.: TRMM and other data precipitation data set documentation (TRMM 3B42 3B43 doc), laboratory for atmospheres, NASA Goddard space flight center and science systems and applications, Inc., , 2008, available at: ftp: //meso-a.gsfc.nasa.gov/pub/trmmdocs/3B42_3B43_doc.pdf.

Huffman, G. J., Bolvin, D. T., Nelkin, E. J., Wolff, D. B., Adler, R. F., Gu, G., and Stocker, E. F.: The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-global, multiyear, combined-sensor precipitation estimates at fine scales,Journal of Hydrometeorology, 8(1), 38-55,2007.

Hughes, D.A.: Comparison of satellite rainfall data with observations from gauging station networks, Journal of Hydrology, 327(3–4):399–410, 2006.

Immerzeel, W. W., Droogers, P., De Jong, S. M., and Bierkens, M. F. P.: Large-scale monitoring of snow cover and runoff simulation in Himalayan river basins using remote sensing, Remote sensing of Environment, 113(1), 40-49,2009.

Ji, X. and Chen, Y. F.: Characterizing spatial patterns of precipitation based on corrected TRMM3B43 data over the mid Tianshan Mountains of China, J. Mt. Sci., 9, 628–645, 2012.

Kim, M. J., Weinman, J. A., Olson, W. S., Chang, D. E., Skofronick-Jackson, G., and Wang, J. R.: A physical model to estimate snowfall over land using AMSU-B observations, Journal of Geophysical Research: Atmospheres, 113(D9) ,2008.

Liu, T., Willems, P., Pan, X. L., Bao, A. M., Chen, X., Veroustraete, F., and Dong, Q. H.: Climate change impact on water resource extremes in a headwater region of the Tarim basin in China, Hydrol. Earth Syst. Sci, 15, 3511-3527, 2011.

Luo, Y., Arnold, J., Allen, P., and Chen, X.: Baseflow simulation using SWAT model in an inland river basin in Tianshan Mountains, Northwest China, Hydrol. Earth Syst. Sci., 16, 1259–1267, 2012.

Luo, Y., Arnold, J., Liu, S. Y., Wang, X. Y., and Chen, X.: Inclusion of glacier processes for distributed hydrological modeling at basin scale in Tianshan Mountains, northwest China, J. Hydrol., 477, 72–85, 2013.

HESSD

10, C815–C831, 2013

Rahman, K., Maringanti, C., Beniston, M., Widmer, F., Abbaspour, K., and Lehmann, A.: Streamflow Modeling in a Highly Managed Mountainous Glacier Watershed Using SWAT: The Upper Rhone River Watershed Case in Switzerland, Water Resources Management, 27(2), 323-339,2013.

Shen, Y., and Liang, H.: High Precipitation in Glacial Region of High Mountains in High Asia: Possible Cause, Journal of Glaciology and Geocryology, 24(6): 806-809, 2004. (In Chinese)

Su, F., Hong, Y., and Lettenmaier, D. P.: Evaluation of TRMM Multisatellite Precipitation Analysis (TMPA) and its utility in Hydrologic Prediction in the La Plata Basin, J. Hydrometeorol., 9(4), 622–640, 2008.

Wang, B.,Wang, J., Ren,Z.,Li, W.,Lei,Y.,and Tu,M.: Automatized Observational Experiment on Solid Precipitation, Meteorological science and technology, 37(1):97-101,2009. (In Chinese)

Wei,W.,and Hu,R.: Precipitation and climate conditions in Tianshan Mountains, Arid Land Geography, 13(1):29-36, 1990. (In Chinese)

Weng, F., Zhao, L., Ferraro, R. R., Poe, G., Li, X., and Grody, N. C.: Advanced microwave sounding unit cloud and precipitation algorithms, Radio Science, 38(4), 8068, 2003.

Wu, L.,Li, H.,and Wang, L.:Application of a degree-day model for determination of mass balance of Urumuqi Glacier No.1,Eastern Tianshan,China, Journal of earth science, 22(4):470-481, 2011.

Yang,D.: Introduction to foreign snowfall observation methods, Meteorological monthly, 14 (10): 51-53,1988. (In Chinese)

Zhang, Y., Li, B., Bao, A., Zhou, C., Chen, X., and Zhang, X.: Study on snowmelt runoff simulation in the Kaidu River basin, Science in China Series D: Earth Sciences, 50(1), 26-35. (3), 2007.

Zhao, L., and Weng, F.: Retrieval of ice cloud parameters using the Advanced Microwave Sounding Unit, Journal of Applied Meteorology, 41(4), 384-395, 2002.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C815/2013/hessd-10-C815-2013-supplement.zip

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 807, 2013.

HESSD

10, C815–C831, 2013

Interactive Comment

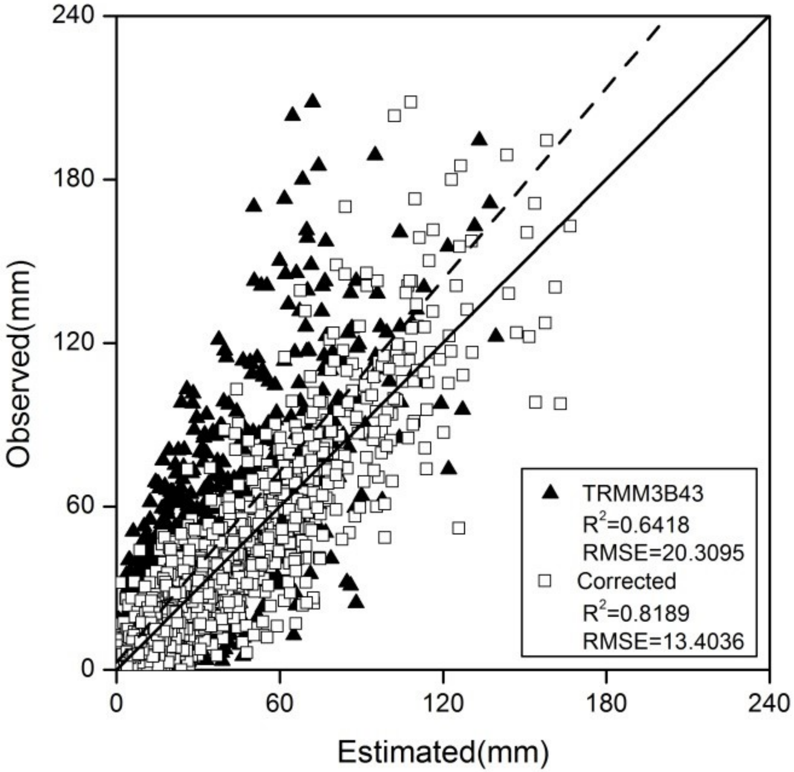

Fig. 1. TRMM 3B43, and model estimates plotted against the observed monthly precipitation values at all stations. The dash line indicated fit line of the original TRMM3B43 and observed data, and the solid is

HESSD
10, C815–C831, 2013

Interactive Comment

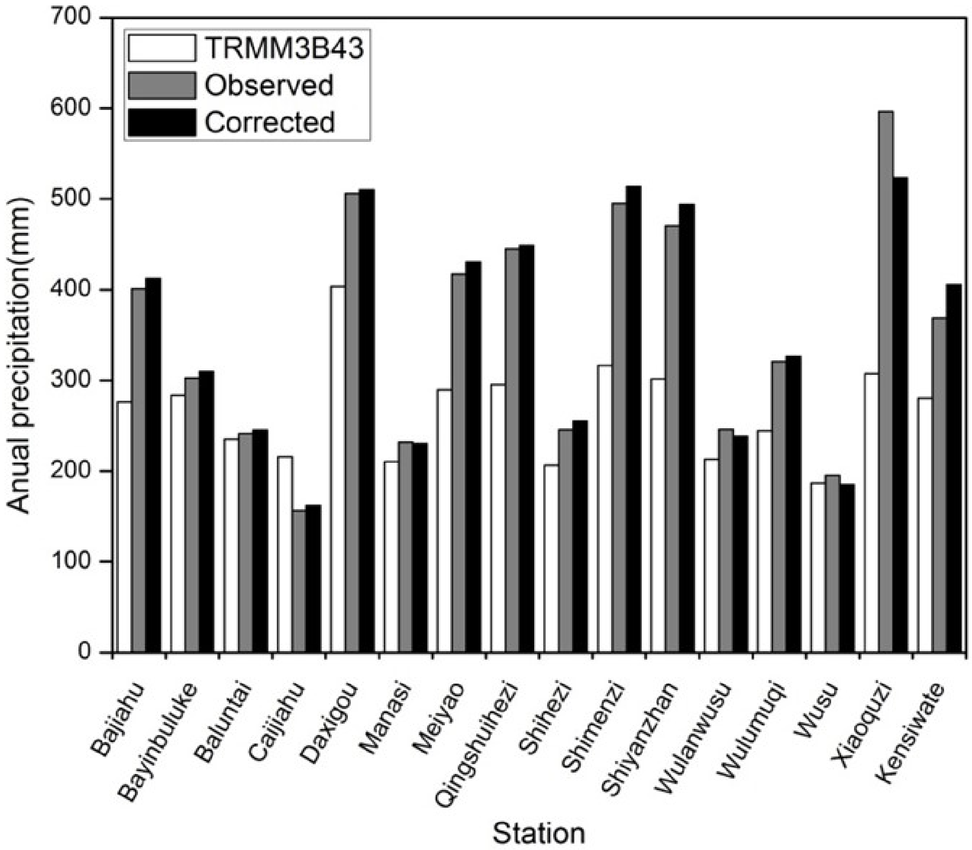

Fig. 2. Annual precipitation of TRMM3B43 and corrected estimations compared to the observed at each station (averaged from all study periods).

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

HESSD

10, C815–C831, 2013

Interactive Comment

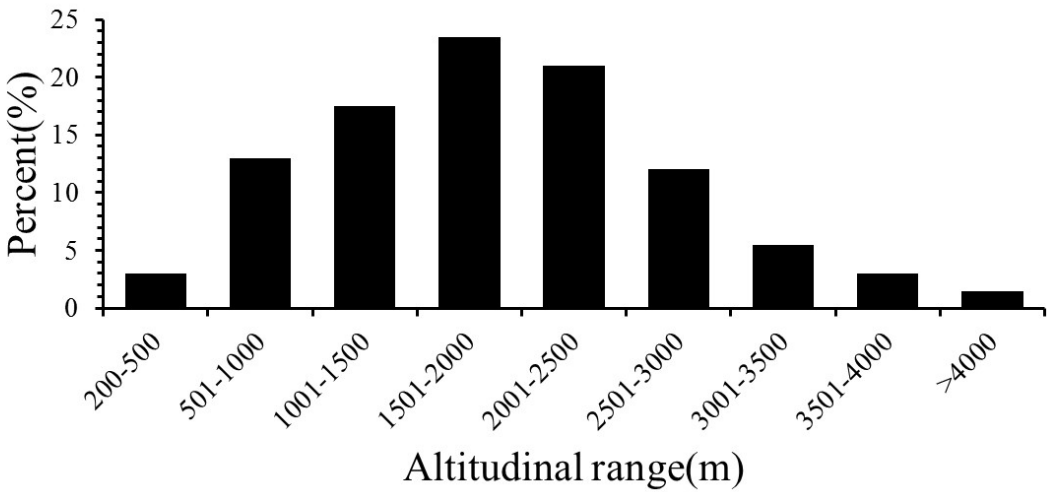

Fig. 3. Distribution of hydro-meteorological stations throughout altitudinal zones; Data from 110 hydroclimatic stations, gauges, and sites with long records in the Tien Shan. (Aizen et al., 1997)