Validation of APHRODITE Precipitation Data for Humid and Sub Humid Regions of Pakistan

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Abstract

The Asian Precipitation Highly Resolved Observed Data Integration Towards Evaluation of water resources (APHRODITE's water resources) data developed for Pakistan on a 0.05 degree resolution by Research Institute for Humanity and Nature (RIHN) and the Meteorological Research Institute of Japan Meteorological Agency (MRI/JMA), was analyzed on decadal basis for the humid and sub humid regions of Pakistan. Scatter plots of both the APHRODITE and observed daily precipitation datasets were constructed on decadal basis from 1971 to 2007. The coefficient of correlation (R^2) values vary from very poor (e.g. 0.001 for Kotli, 2001–2007) to very good (e.g. 0.98 for Astore, 2001–2007) for different stations in various decades. Monthly totals of both the datasets were averaged on decadal bases and scatter plots were again constructed. In this case the correlation coefficient (R^2) results are far better than those determined for daily precipitation datasets. The very poor correlation results in case of daily precipitation datasets for Islamabad and Kotli are more than 98% in case of mean monthly analysis. Biases between the two precipitation datasets were also calculated for every station in the region. This analysis shows that the APHRODITE data underestimates the observed data for most of the stations in those months in which heavy rainfall occurs. This bias reaches up to a maximum of 271mm for Muzaffarabad in the month of July. The bias is less where the rainfall amount is small. A slight overestimation of APHRODITE precipitation data has also been recorded for some stations. The maximum overestimation of APHRODITE precipitation data (about 40mm) was observed for Islamabad in the month of March for the decade 1971–1980.

Keywords: APHRODITE, Precipitation, Climatic Zones, Interpolation.

Introduction

The world APHRODITE stands for Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE's Water Resources). The APHRODITE project develops state-of-the-art daily precipitation datasets with high resolution (0.5° and 0.25°) grids for Asia. APHRODITE's Water Resources project has been executed by the Research Institute for Humanity and Nature (RIHN) and the Meteorological Research Institute of Japan Meteorological Agency (MRI/JMA) since 2006. The datasets are created primarily with data obtained from in-situ rain-gauge-observation network.

The quantitative estimation of precipitation and thus the development of a gridded precipitation product are crucial for many scientific studies. Thus, many methods of interpolating station data have been developed in the last century, and considerable efforts have been made to derive precipitation information from satellites over the last two decades. Since rain-gauge-based products have a monthly time interval and satellite-derived products have a short time series therefore precipitation datasets that were available in the early 2000s do not meet the demands for validating high-resolution climate model outputs and those for statistical downscaling. Lack of a rain-gauge-based daily product was a bottleneck for many studies on the impact of climate change on local environments (http://www.chikyu.ac.jp/precip/scope/index.html).

Long-term high-resolution daily precipitation data are useful for evaluating mesoscale models, driving river flow models, and analyzing temporal and spatial variations of precipitation fields. Observational records longer than 50–100 years enable one to investigate precipitation changes caused by global warming. In addition, gridded data make model evaluation and water budget analysis easier, when compared with point observation data (Kamiguchi et al, 2010).

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Considerable efforts have been made in developing gridded precipitation datasets based on satellite data or satellite-based merged analyses (Gruber and Levizzani 2008). However, there are increasing demands for accurate high resolution rain-gauge-based precipitation products over land for the validation of simulation products of numerical models and satellite-based high resolution precipitation products (Turk et al. 2008). Indirect precipitation estimates must be verified or calibrated by direct observations, specifically rain gauge measurements. One of the advantages of gauge observations is the length of the records. Hence monthly global gauge-based precipitation datasets developed by several groups are widely used (New et al. 1999). Consequently, daily grid precipitation products are expected to be used to verify high-resolution climate model simulations that include extreme events and to drive hydrological models (Xie et al. 2007). To validate the capability of a climate model to simulate not only various aspects of climate change including regional precipitation, it is necessary to compare the model's precipitation results against observed precipitation data (Yatagai et al. 2008a, b). However, no precipitation data set with sufficiently high spatial and temporal resolution is available for evaluating climate models for Asia, especially, south Asia. In order to validate high resolution climate model, a long term gauge-based high resolution daily precipitation data set has been developed for Pakistan as a part of APHRODITE's Water Resources project. The primary objectives of the APHRODITE project are to (1) release official state-of-the-art daily gridded precipitation data sets based on rain-gauge observations, (2) assess the projections of climate models by observing precipitation in the field, including extreme events, and (3) to make suggestions to regional water resources managers in Asian countries.

Before using this dataset it is necessary to validate it first by comparing it with actual precipitation data. Therefore the main focus of the current study is on the comparison of APHRODITE dataset with observed precipitation data so that one can set the level of confidence for using the dataset for different purposes as discussed earlier.

Data and Methodology

Table 1: R^2 Values between the two datasheets for different stations in different decades.

Stations	Elevation (m)	Station Type	1971-1980		1981-1990		1991-2000		2001-2007	
			Daily	Monthly Mean	Daily	Monthly Mean	Daily	Monthly Mean	Daily	Monthly Mean
Astore	2167	Hill	0.79	0.98	0.83	0.95	0.92	0.97	0.98	0.99
Cherat	1301	Hill	0.81	0.95	0.65	0.92	0.73	0.92	0.75	0.95
G-Dupatta	812	Hill	0.74	0.92	0.59	0.97	0.58	0.97	0.77	0.87
Kakul	1308	Hill	0.84	0.98	0.75	0.95	0.89	0.96	0.92	0.99
Muree	2168	Hill	0.82	0.98	0.71	0.99	0.93	0.98	0.26	0.97
M-Abad	701	Hill	0.26	0.65	0.32	0.67	0.35	0.49	0.38	0.53
Peshawar	359	Plane	0.37	0.89	0.12	0.77	0.39	0.86	0.87	0.96
Saidu-Sharif	961	Hill	0.2	0.78	0.31	0.83	0.61	0.9	0.88	0.98
Islamabad	507	Plane	0.15	0.98	0.07	0.98	0.07	0.98	0.05	0.99
Jhelum	231	Plane	0.49	0.998	0.9	0.99	0.9	0.997	0.89	0.994
Kotli	615	Hill	0.83	0.99	0.82	0.96	0.03	0.996	0.001	0.99
Balakot	980	Hill	0.42	0.98	0.34	0.98	0.54	0.98	0.67	0.95

The APHRODITE precipitation data is available online from the site http://www.chikyu.ac.jp/precip/ on a 0.5 and 0.25 resolutions for Asia. The data used in this study has been specially developed for Pakistan on 0.05 degree resolution. Point data has been extracted from this gridded data using Grads software. Observed station data of daily precipitation was obtained from CDPC Karachi for different meteorological stations of Pakistan for the period 1971–2007. The APHRODITE data is available from 1951 to 2007, but here only the data from 1971 to 2007 has been used for analysis. The data for the first two decades was dropped because of very poor correlation results and a high value of bias between the two datasets. This may be due to less number of observatories and consequently fewer amounts of available observed data in that period of time.

A comparison between observed and APHRODITE daily data was carried out on decadal basis from 1971 to 2007. Monthly totals of both the datasets were averaged on 10 years basis from 1971–2007. The correlation coefficient (R^2) values between the two datasets on daily as well as mean monthly basis were calculated for every station. Table 1 shows these values for the two datasets.

Results and Discussion

According to Chaudhary and Rasul (2004), Pakistan can be classified on agro-climatic basis in different zones such as (i) Humid (ii) Sub humid (wet and dry) (iii) Arid (iv) Sub arid (wet and dry) zones. The region located between 33°N and 35°N can be classified into humid and sub humid regions of the country.

Humid Climate

The region with such type of climate has short summer but long and mild with snow winter. June is the warmest month with mean temperature 20.4˚C when maximum temperature may increase upto 34˚C and January is the coldest month with the minimum temperature below the freezing point. The annual mean temperature for this region is about 9˚C to 17˚C. The region receives both summer and winter rainfall with larger contribution from the summer rainfall. The annual mean precipitation ranges from 1900mm to 2400mm (CDPC, 2005; Khan et al., 2010).

Murree

Murree is located at 33.85°N and 73.41°E with an elevation of 2167m and it falls in humid climate zone according to classification of Chaudhary and Rasul (2004). Murree receives the highest amount of rainfall throughout the country. The correlation coefficient (R^2) values for Murree between observed and APHRODITE daily datasets shows a good relation between the two datasets except 0.26 for the period 2001–2007. In case of monthly datasets the correlation results are even better (0.97 to 0.99). The correlation result for the period 2001–2007 has risen to 0.97 in this case. Figure 1a and 1b represent a comparison between APHRODITE and observed daily precipitation data and Figure 2a and 2b represent a comparison between APHRODITE and observed monthly precipitation data for Murree during different decades.

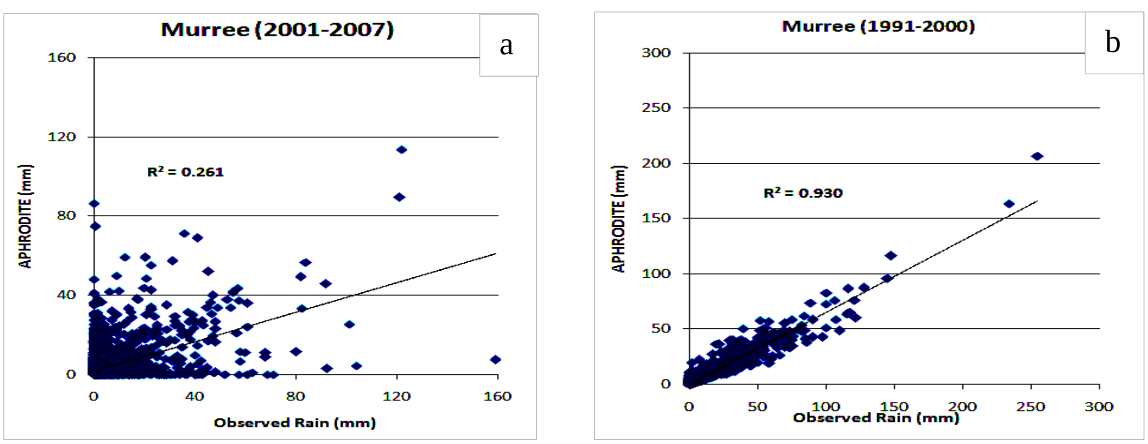

Figure 1: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Murree, **(a)** 2001–2007, **(b)** 1991–2000

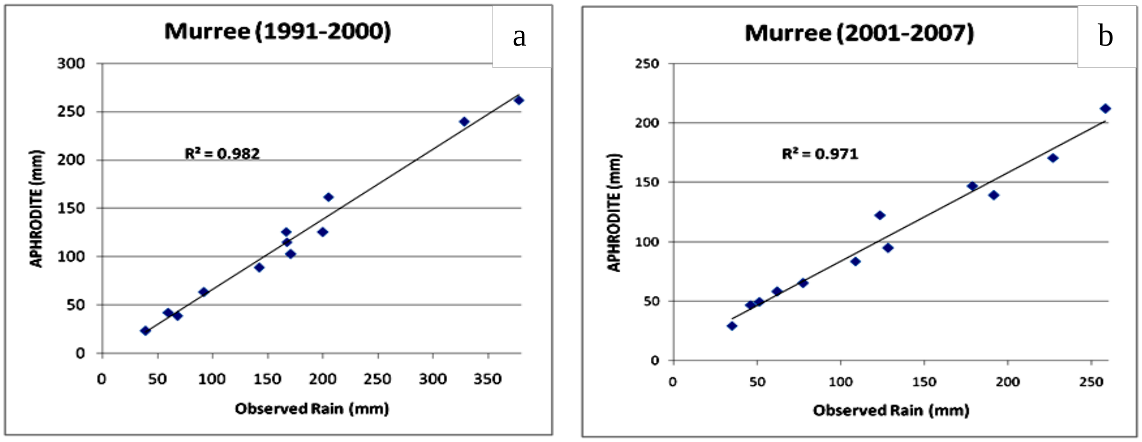

Figure 2: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Murree, **(a)** 1991–2000, **(b)** 2001–2007

The bias analysis of observed and APHRODITE data for Murree shows that APHRODITE data underestimates the observed data. This underestimation is maximum in those months in which the amount of rainfall is maximum. Figure 3 shows the difference between APHRODITE and observed precipitation data in different decades for Murree.

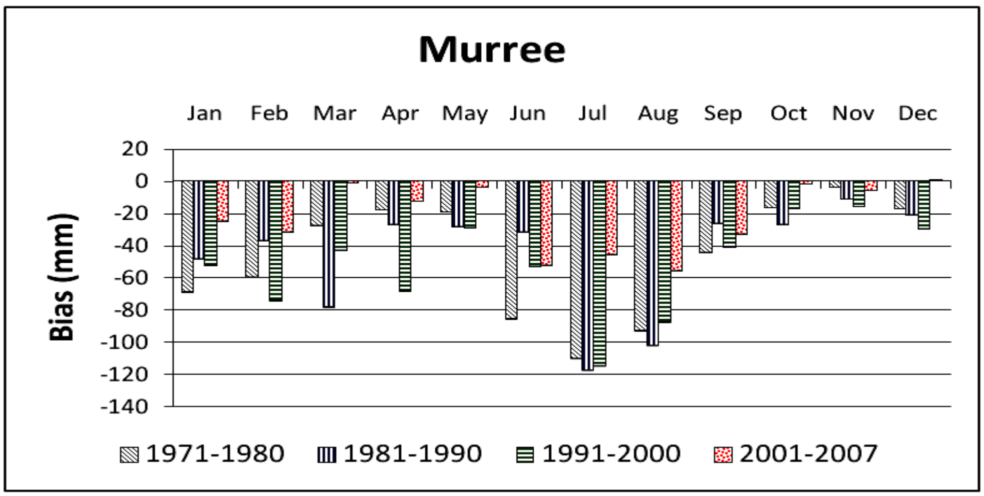

Figure 3: Difference of observed and APHRODITE precipitation data on decadal basis for Murree.

Sub-Humid (Wet) Climate

The region with such type of climate has long summer and mild with snow winter. June is the warmest month when maximum temperature may increase above 40˚C and January is the coldest month with the minimum temperature below the freezing point. The regions receive both summer and winter rainfall with larger contribution from the summer rainfall. The annual mean precipitation ranges from 1200mm to 1800mm (CDPC, 2005; Khan et al., 2010). Examples of these regions include Islamabad, Kotli and Muzaffarabad etc.

Muzaffarabad

Muzaffarabad is located at 34.25°N and 74.04°E with an elevation of 701m. The climate of Muzaffarabad is sub humid (wet) and the annual mean amount of rainfall in this area is 1200mm to 1800mm. The correlation results between observed and APHRODITE daily data in different decades in this area varies from 0.26 to 0.38. Relatively better correlation results (0.49 to 0.67) were obtained in case of mean monthly datasets analysis. Figure 4a and 4b represent a comparison between APHRODITE and observed daily precipitation data and Figure 5a and 5b represent a comparison between APHRODITE and observed monthly precipitation data for Muzaffarabad during different decades.

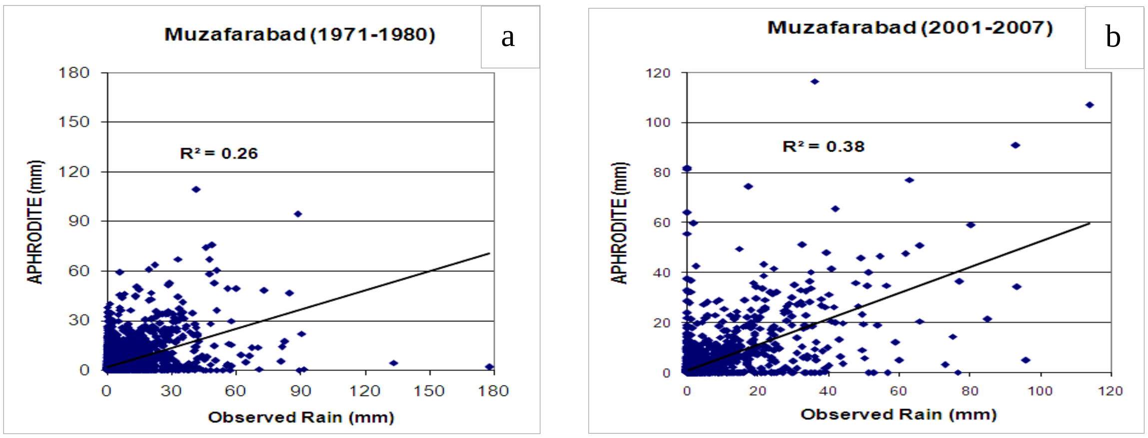

Figure 4: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Muzaffarabad **(a)** 1971–1980, **(b)** 2001–2007

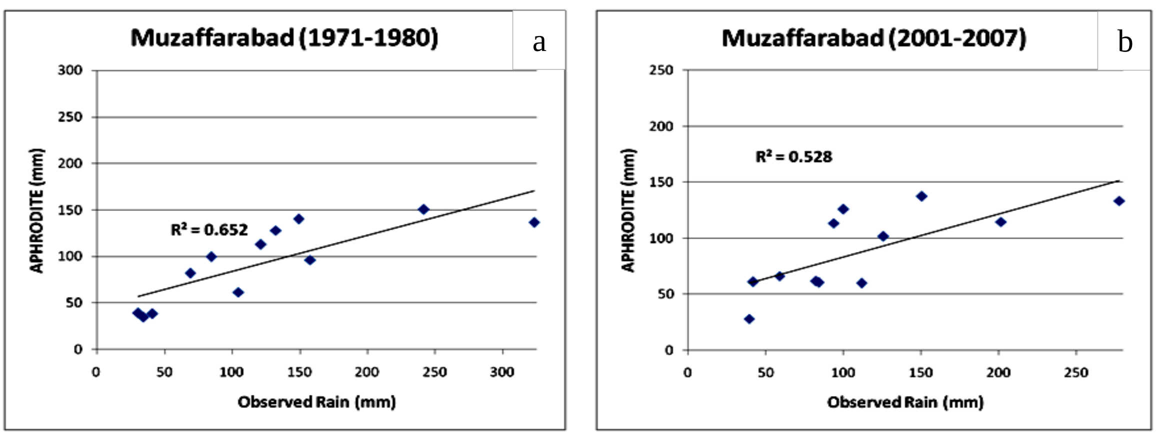

Figure 5: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Muzaffarabad **(a)** 1971–1980**, (b)** 2001–2007

The Bias analysis shows that APHRODITE data strongly underestimates the observed data in the months Jun–September. This biasing crosses 200mm in the months of July in the decades (1981–1990) and (1991–2000). Due to this uneven bias the correlation results are not so much promising, both for daily and mean monthly datasets. Figure 6 shows the difference between APHRODITE and observed precipitation data in different decades for Muzaffarabad.

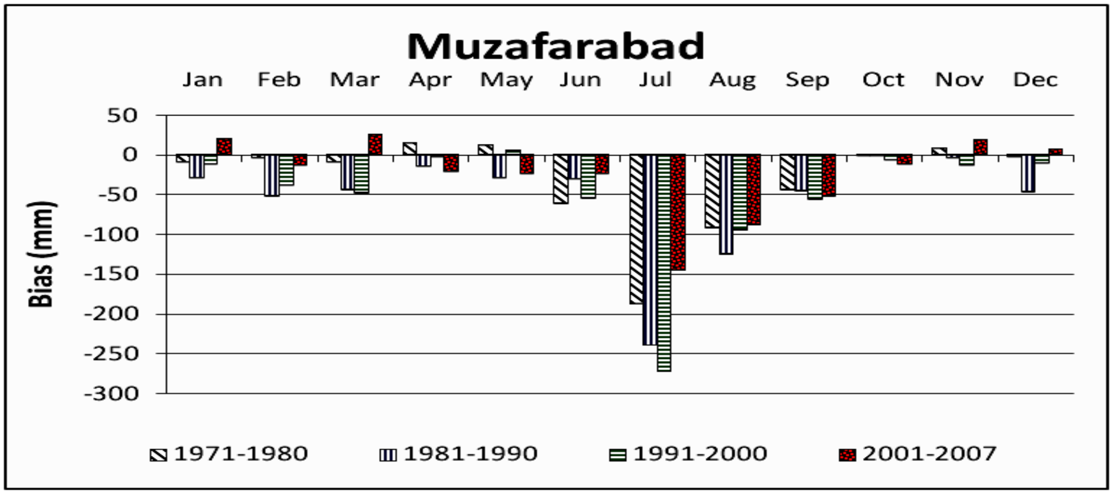

Figure 6: Difference of observed and APHRODITE precipitation data on decadal basis for Muzaffarabad.

Islamabad

Islamabad is also located in the sub humid (wet) region of the country. Islamabad is located at 33.7°N and 73.08°E with an elevation of 543m. The correlation results between observed and APHRODITE daily datasets for Islamabad are very poor (0.05 to 0.15). Strong correlation between the two datasets is

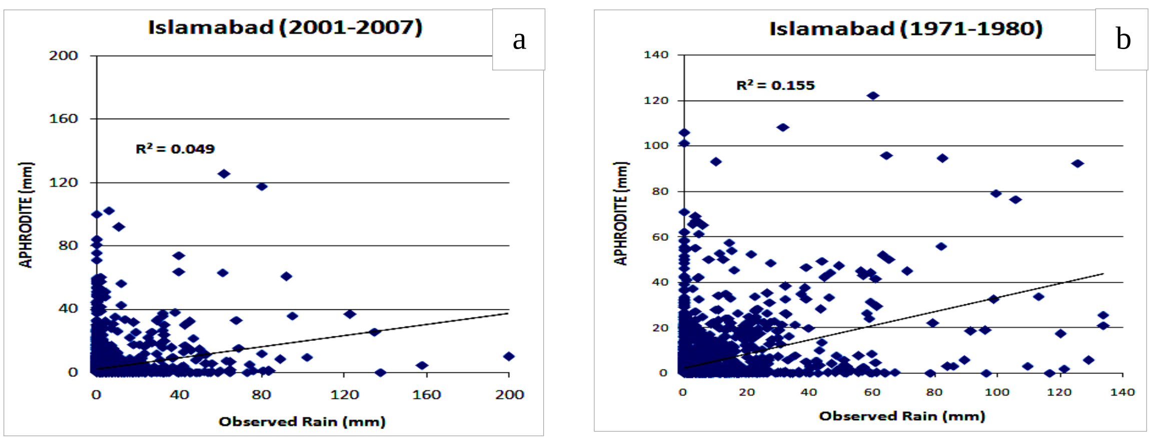

Figure 7: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Islamabad **(a)** 2001–2007, **(b)** 1971–1980

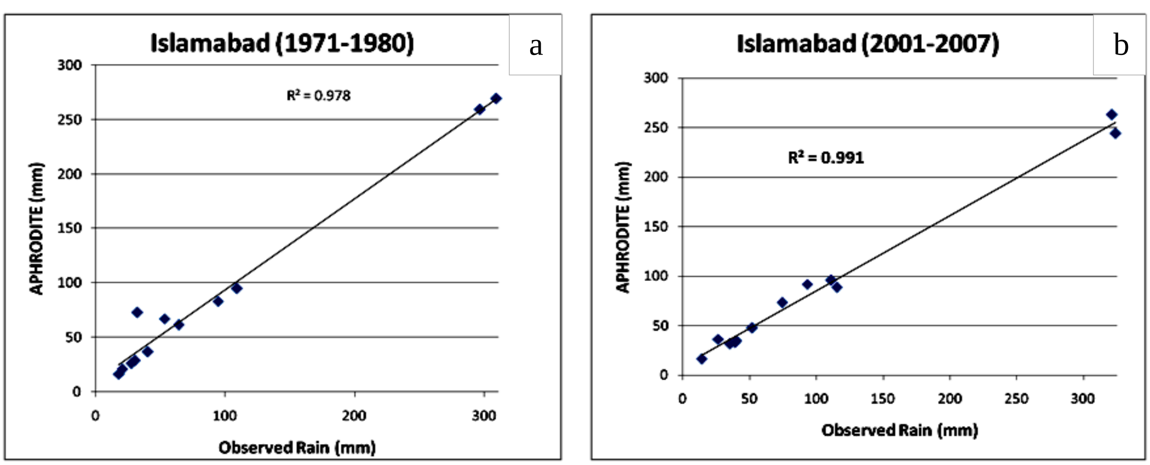

Figure 8: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Islamabad, **(a)** 1971 –1980, **(b)** 2001–2007

observed in case of mean monthly analysis (0.98 to 0.99). Figure 7a and 7b represent a comparison between APHRODITE and observed daily precipitation data and Figure 8a and 8b represent a comparison between APHRODITE and observed monthly precipitation data for Islamabad during different decades.

The bias analysis for this station shows that APHRODITE data underestimates observed data in the months from June – September. An overestimating trend is also shown in the months of February and

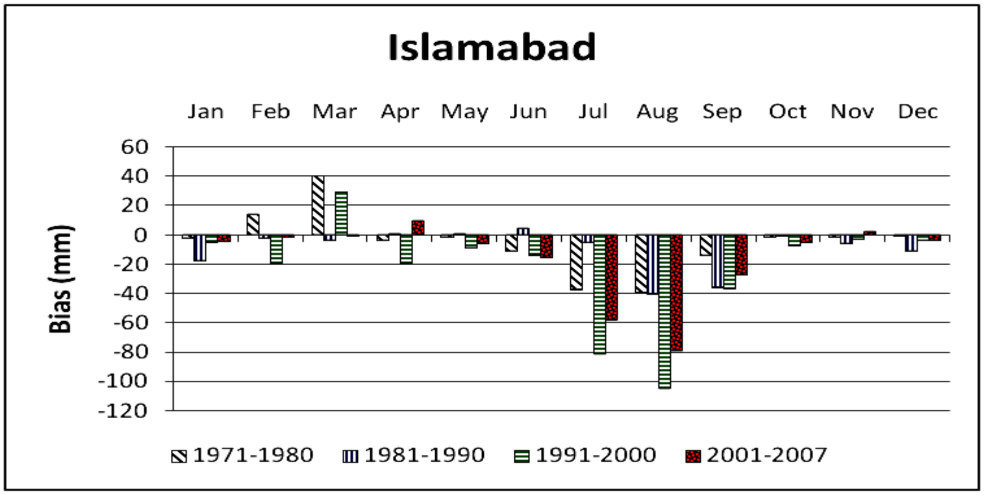

Figure 9: Difference of observed and APHRODITE precipitation data on decadal basis for Islamabad

March in the decades 1971–1980 and 1991–2000. Figure 9 shows the difference between APHRODITE and observed precipitation data in different decades for Islamabad.

Garhi Dupatta

Garhi Dupatta is also located in the sub humid region of the country. It is located at 34.12°N and 73.62°E with an elevation of 812m. The correlation results between observed and APHRODITE daily data varies from 0.58 to 0.77 in different decades from 1971 to 2007. Much better results (0.87 to 0.97) were obtained in case of mean monthly datasets analysis. Figure 10a and 10b represent a comparison between APHRODITE and observed daily precipitation data and Figure 11a and 11b represent a comparison between APHRODITE and observed monthly precipitation data for Garhi Dupatta during different decades.

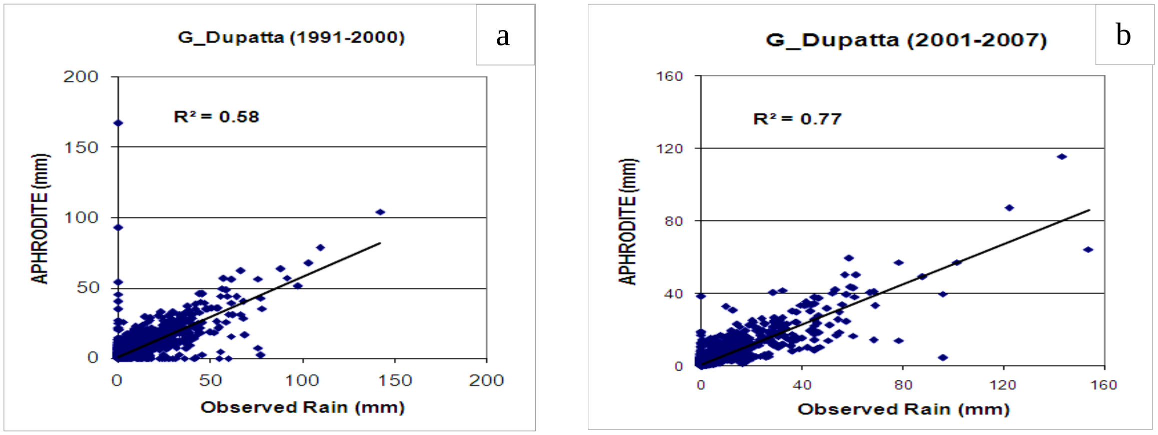

Figure 10: Scatter plot for comparison between APHRODITE and observed daily precipitation data for G_Dupatta **(a)** 1991–2000, **(b)** 2001–2007

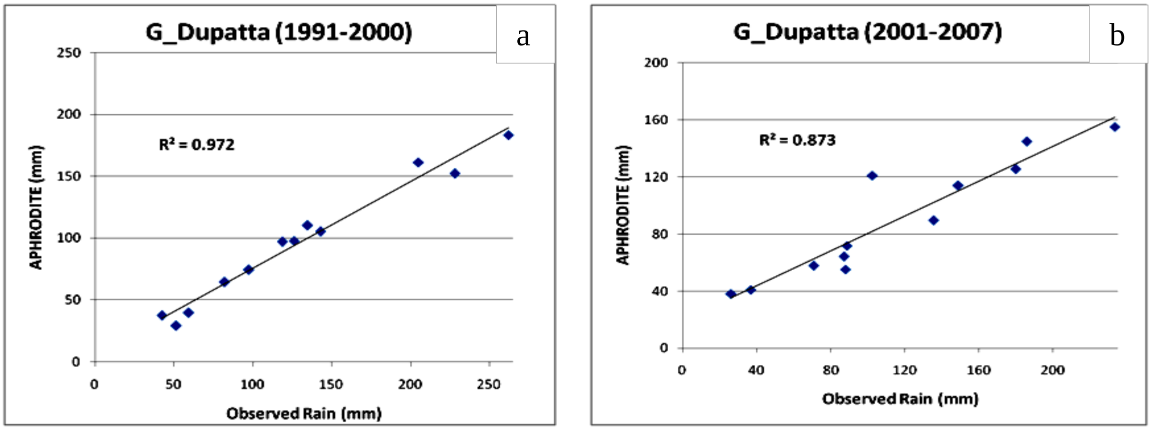

Figure 11: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for G_Dupatta **(a)** 1991–2000, **(b)** 2001–2007

The bias analysis shows that APHRODITE data underestimates the observed data in almost all of the months with maximum values in the months of July and August. A slight overestimation also exists in the period 2001–2007. Figure 12 shows the difference between APHRODITE and observed precipitation data in different decades for Garhi Dupatta.

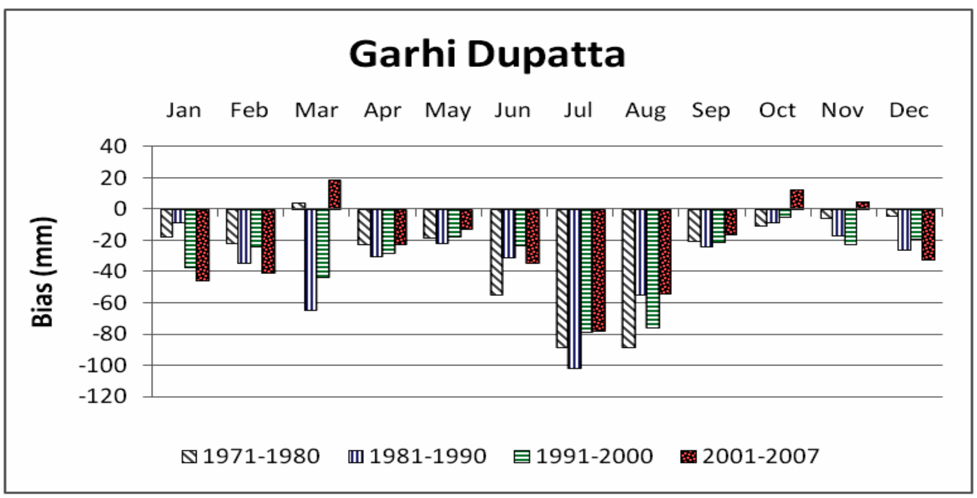

Figure 12: Difference of observed and APHRODITE precipitation data on decadal basis for Garhi Dupatta.

Sub-Humid (Dry) Climate

The region with such type of climate has long summer and short mild winter. May and June are the warmest months when maximum temperature may increase than 45˚C in some areas like Peshawar and January is the coldest month with the minimum temperature below the freezing point like in Astore. Examples of stations under this agroclimatic zone are: Astore, Cherat, Jhelum and Peshawar. The mean temperature for these stations respectively is 10˚C−20˚C, 16˚C−20˚C, and 22˚C−24˚C (for both Jhelum and Peshawar). The regions receive both summer and winter rainfall with larger contribution from the winter rainfall which is caused by the Western Disturbance (WD). The annual mean precipitation for Astore and Peshawar is 400mm−600mm, 600mm−800mm for Cherat and 900−1000mm for Jhelum.

Jhelum

Jhelum is situated in the sub humid (dry) region of Pakistan according to agroclimatic classification of the country. It lies at 32.93°N and 73.73°E. The correlation results for different decades in the period 1971–2007 vary from 0.49 to 0.90 between the two datasets on daily basis, while in case of mean monthly datasets analysis these results vary from 0.99 to 0.998. Fig. 13a and 13b represent a comparison between APHRODITE and observed daily precipitation data and Fig. 14a and 14b represent a comparison between APHRODITE and observed monthly precipitation data for Jhelum during different decades.

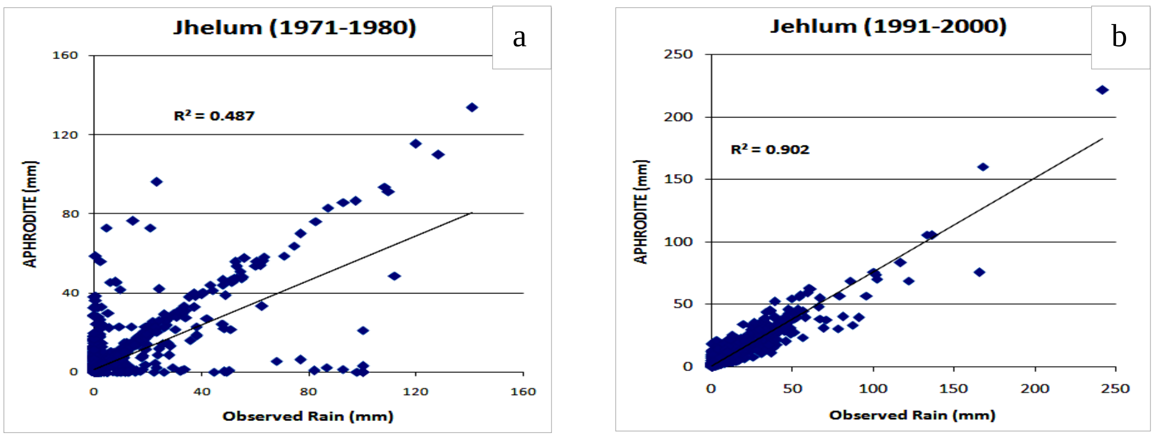

Figure 13: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Jhelum, **(a)** 1971–1980, **(b)** 1991–2000

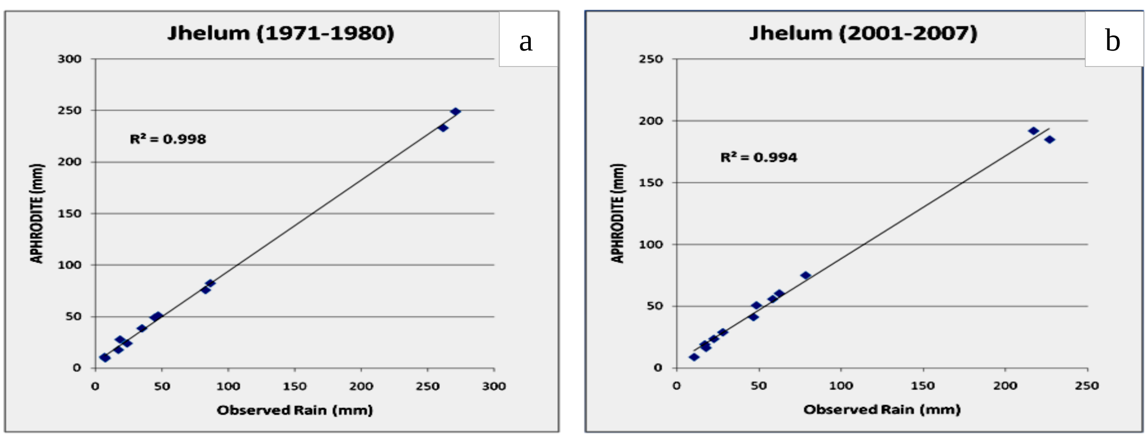

Figure 14: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Jhelum, **(a)** 1971–1980, **(b)** 2001–2007

The bias analysis shows that APHRODITE data underestimates observed data in the months having high amount of precipitation, especially in the months of July and August, which corresponds to the monsoon season in the region. The APHRODITE data overestimates the observed data in the decade 1971–1980. Figure 15 shows the difference between APHRODITE and observed precipitation data in different decades for Jhelum.

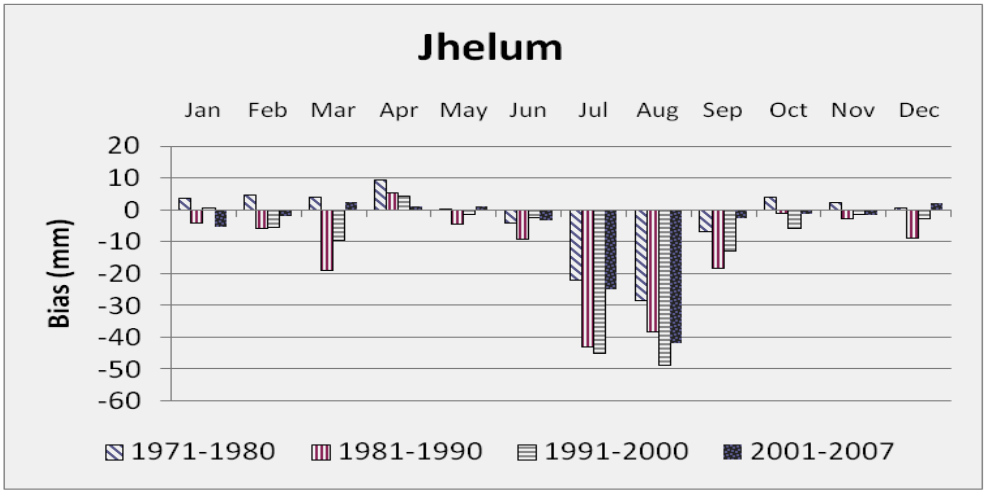

Figure 15: Difference of observed and APHRODITE precipitation data on decadal basis for Jhelum.

Astore

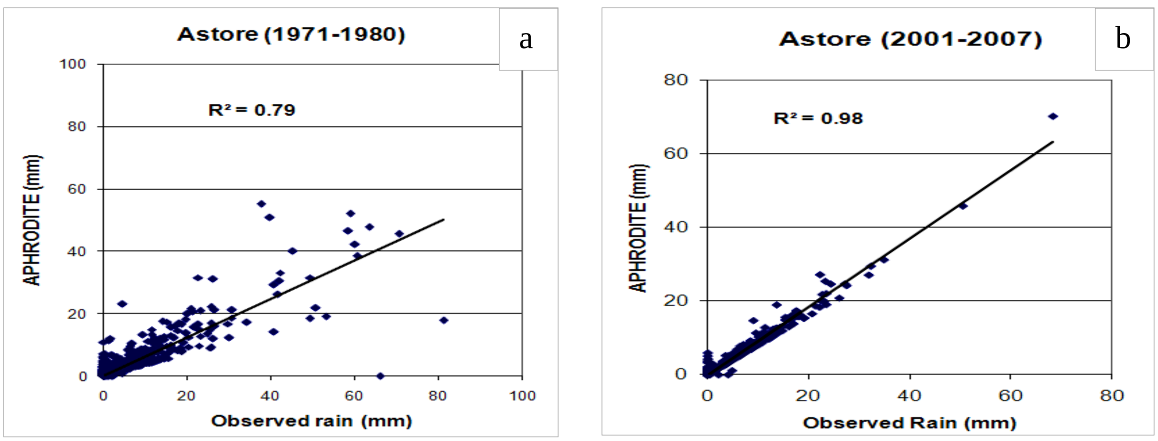

Figure 16: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Astore, **(a)** 1971–1980, **(b)** 2001–2007

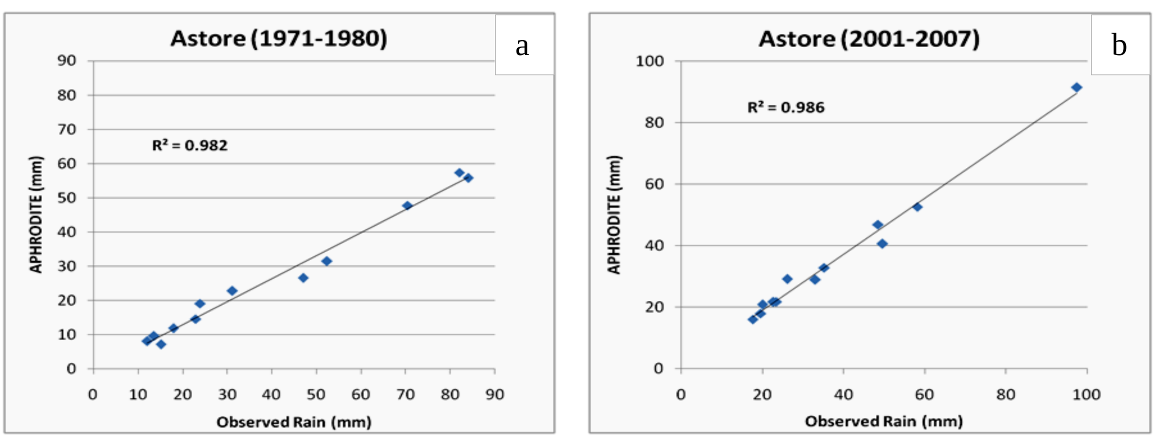

Figure 17: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Astore, **(a)** 1971–1980, **(b)** 2001–2007

Astore lies at 35.34°N and 74.9°E with an elevation of 2167m. Astore is situated in the sub humid (dry) region of Pakistan according to Chaudhary and Rasul (2004). The correlation results for this station lie between 0.79 and 0.98 for the daily datasets while in case of mean monthly datasets analysis these results lie between 0.97 and 0.99, showing a better correlation between the two datasets. Figure 16a and 16b represent a comparison between APHRODITE and observed daily precipitation data and Figure 17a and 17b represent a comparison between APHRODITE and observed monthly precipitation data for Astore during different decades.

The bias analysis shows that APHRODITE data underestimates observed data in almost all of the months, but this biasing is not so much high. Figure 18 shows the difference between APHRODITE and observed precipitation data in different decades for Astore.

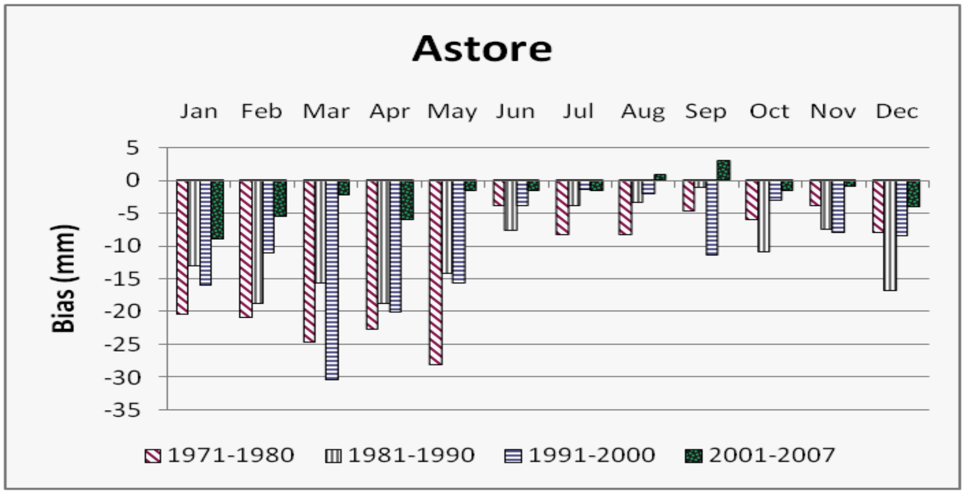

Figure 18: Difference of observed and APHRODITE precipitation data on decadal basis for Astore.

Peshawar

Peshawar also lies in the sub humid (dry) region according to agroclimatic classification of Pakistan. Peshawar is situated at 34.02°N and 71.58°E with an elevation of 359m. The correlation results between the two daily datasets ranges from 0.12 to 0.87. In case of mean monthly datasets analysis relatively better correlation results (0.77 to 0.96) were obtained. Figure 19a and 19b represent a comparison between APHRODITE and observed daily precipitation data and Figure 20a and 20b represent a comparison between APHRODITE and observed monthly precipitation data for Peshawar during different decades.

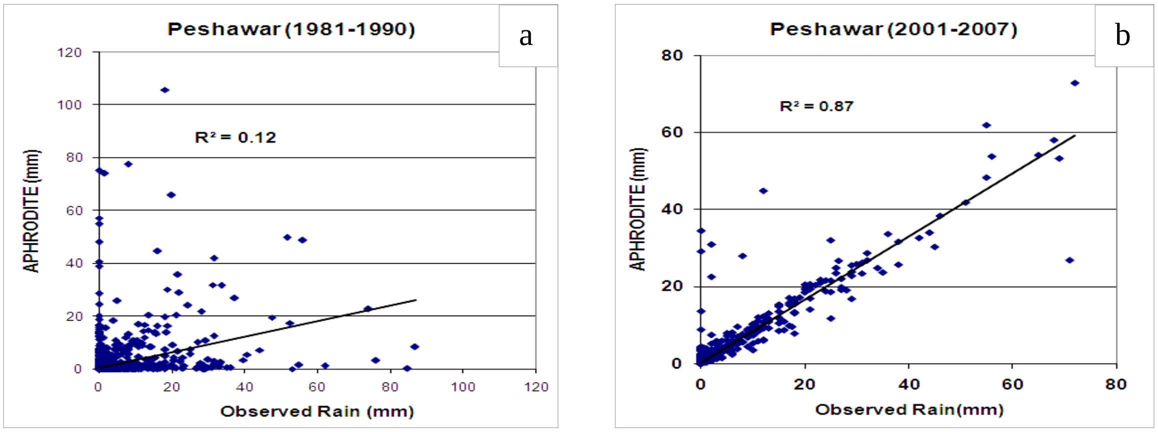

Figure 19: Scatter plot for comparison between APHRODITE and observed daily precipitation data for Peshawar, **(a)** 1981–1990, **(b)** 2001–2007

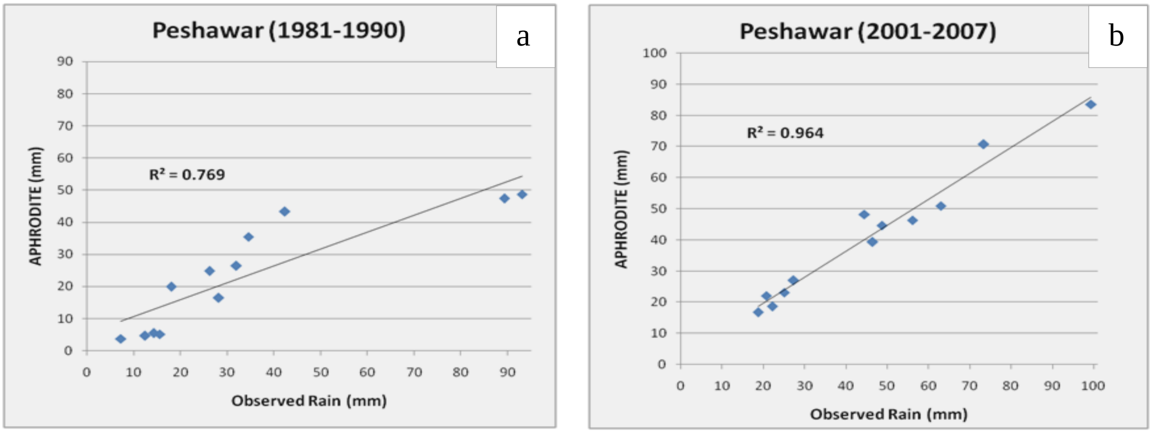

Figure 20: Scatter plot for comparison between APHRODITE and observed monthly precipitation data for Peshawar (1991–2000)

The bias analysis shows that APHRODITE data underestimates observed data in almost all of the months with a slight overestimation in some months as well. Figure 21 shows the difference between APHRODITE and observed precipitation data in different decades for Peshawar.

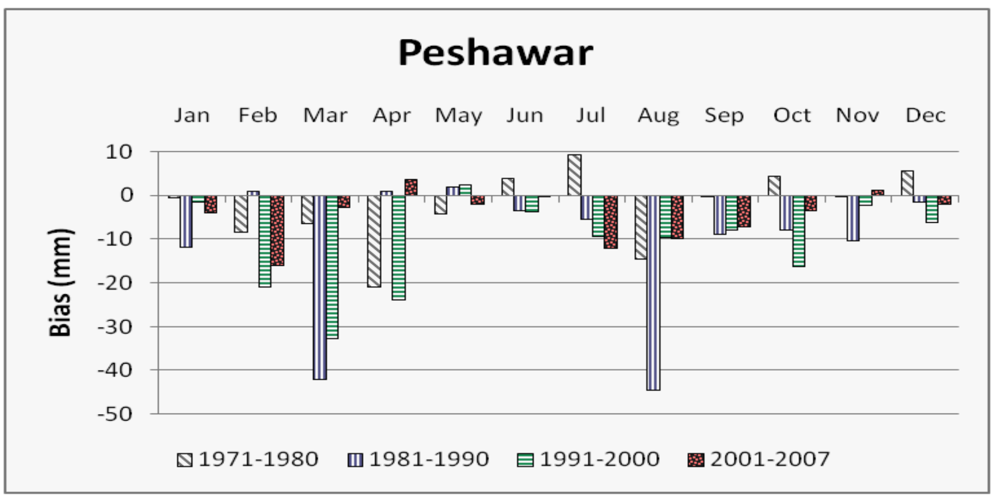

Figure 21: Difference of observed and APHRODITE precipitation data on decadal basis for Peshawar.

Conclusions

The APHRODITE data developed for Pakistan was analyzed in this study for the humid and sub humid regions of the country.

For almost all of the stations the APHRODITE data underestimates the observed precipitation, particularly in those months in which the precipitation amount is high, with a maximum bias of 271mm for Muzaffarabad for the month of July in the decade 1991–2000.

A slight overestimation of APHRODITE data was also observed for some stations (like Islamabad, Garhi Dupatta, Peshawar) with a maximum bias of 40mm for Islamabad in March in the decade 1971–1980.

The correlation coefficient (R^2) values between the two daily datasets varies from very poor (e.g. 0.05 to 0.15 for Islamabad) to very good (e.g. 0.79 to 0.99 for Astore) for different stations in different decades.

The correlation coefficient values become much better in case of mean monthly datasets analysis. Even the very poor results (for example Islamabad) rises to very good (0.98 to 0.99) in this case.

Thus it is concluded that observed and APHRODITE datasets are strongly correlated on mean monthly basis as compared to daily basis.

Reference

Chaudhary, Q. Z. and G. Rasul, 2004: Agro-Climatic Classification of Pakistan, SCIENCE VISION Vol.9 No.1-2, 59 – 66.

Ghazala, N. and G. Rasul, 2011: Investigation of Rainfall Variability for Pakistan, Pakistan Journal of Meteorology, Vol. 7, Issue 14, 25 – 32.

Gruber, A., and V. Levizzani, 2008: Assessment of Global Precipitation Products. WCRP Series Report No. 128 and WMO TD-No. 1430, 55

IPCC. (2007), Climate Change 2007, The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press,

Javanmard, S., A. Yatagai, M. I. Nodzu, J. BodaghJamali and H. Kawamoto, 2010: Comparing high-resolution gridded precipitation data with satellite rainfall estimates of TRMM 3B42 over Iran, Adv. Geosci., 25, 119–125

Kamiguchi, K., O. Arakawa, A. Kitoh, A. Yatagai, A. Hamada and N. Yasutomi, 2010: Development of APHRO_JP, the first Japanese high-resolution daily precipitation product for more than 100 years, Hydrological Research Letters, 4,60–64

Khan, S. U., M. F. Hassan, K. Khan, and A. Bari, 2010: Climate Classification of Pakistan,paper presented in the conference BALWOIS 2010 Ohrid, Republic of Macedonia, 25–29 May 2010, 29-32.

New, M. G., M. Hulme, and P. D. Jones, 1999: Representing twentieth century space-time climate variability. Part I: Development of a 1961-90 mean monthly terrestrial climatology. J.Climate, 12, 829-856.

Takashima, H., A. Yatagai, H. Kawamoto, O. Arakawa and k. Kamiguchi, Hydrological balance over northern Eurasia from gauge-based high-resolution daily precipitation data, Available online at http://www.chikyu.ac.jp/precip/scope/index.html

Turk, F. J., P. Arkin, E. E. Ebert, and M. R. P. Sapiano, 2008: Evaluating high resolution precipitation products, Bull. Amer. Meteor. Soc., 89, 1911−1916.

Waheed Iqbal, 2010: Validation of Regional Climate Model “Providing Regional Climates for Impacts Studies (PRECIS)” for Different Climates of Pakistan, MS Thesis.

Xie, P., A. Yatagai, M. Chen, T. Hayasaka, Y. Fukushima, C. Liu and Y. Song, 2007: A gauge-based analysis of daily precipitation over East Asia, J. Hydrometeor., 8, 607−627.

Yatagai, A. Development of a daily grid precipitation data in the East Mediterranean and its application for the ICCAP studies, Available at http://www.chikyu.ac.jp/precip/scope/index.html

Yatagai, A., O. Arakawa, K. Kamiguchi, H. Kawamoto, M. I. Nodzu and A. Hamada, 2009: A 44-Year Daily Gridded Precipitation Dataset for Asia Based on a Dense Network of Rain Gauges, SOLA, Vol. 5, 137−140

Yatagai, A., P. Alpert and P. Xie, 2008: Development of a daily gridded precipitation data set for the Middle East, Adv. Geosci., 12, 1–6.