International Proceedings of Chemical, Biological and Environmental Engineering
Volume 94 of IPCBEE (2016)
DOI: 10.7763/IPCBEE. 2016. V94. 1

Accuracy Assessment of Tropical Rainfall Measuring Mission (TRMM) Satellite Product over Tianshan Mountainous, Northwest of China

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Abstract. Precipitation is one of meteorological elements difficult to accurately observation measurement. Due to the large spatial and temporal variability, the reliability of areal precipitation is limited by the stations observation. The advancements in remote sensing techniques have provided precipitation data at higher spatial resolutions than was available from station measurements in mountainous regions. However, satellites-based products are subject to different types of errors such as inherent measurement and retrieval errors, and sampling uncertainty. As critical inputs of ecological and hydrological models, assessment the satellites-based products applied in mountainous become a critical role. We employed the correlation analysis to assess the accuracy of TRMM products using annual, seasonal and monthly data from 1998 to 2013. The results are shown that the TRMM products are good performance in wet regions and wet seasons in the Tianshan mountainous. The distribution of precipitation of TRMM products is depicted consistency with observations in wet season also.

Keywords: Climate Change, Precipitation, Correlation Analysis, Tianshan Mountainous

1. Introduction

As one important part of the hydrological cycle, precipitation is critical in understanding the hydrologic balance and the complex interactions among the small- and large-scale components [1]. Traditionally, rain guage observations are only direct source that is obtained through direct measurements before 1970's. Because of accessibility and financial limitations, the distribution of observation stations is not available, particularly in oceanic, remote, or developing regions [2, 3]. Spatial precipitation represents one of the main inputs to hydrologic, climatologic, and agricultural studies. However, the feature of spatial coverage is lack in situ observations which are usually too sparsely distributed to capture the spatial distribution [4, 5]. In general, observation measurements yield relatively accurate point measurements of precipitation, there are a number of well-known effect sources such as orographic, wind, precision instruments, which can strongly influence measurement accuracy, and defect of spatial representation [6, 7].

With the advent of meteorological satellites in the 1970s, the use of satellite measurements of precipitation in hydrologic and meteorological predictions has increased significantly in the past few decades [8, 9]. Satellite measurement of precipitation has been evident since its early days: the data are inexpensive, provide a complete area coverage, are available in real-time, provide very high temporal and spatial resolution [6-10]. A large number of precipitation products based on satellite, e.g. Global Precipitation and Climatology Project (GPCP) precipitation product, Global Satellite Mapping of Precipitation, Climate Prediction Center Merged Analysis of Precipitation are available with different spatial and temporal widely used in many research fields [11-14].

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Each instrument has advantages and shortcomings; none of them seems to completely perform satisfying the research needs [15]. Station observations could provide the long time series record, high accuracy in situ. However, there are suffered from various problems, limited in mountainous and oceanic and poor representation in spatial. Due to indirect, satellites remote senses are limited to retrieval algorithm, subjected to different error such as biases and random errors that are caused by the sampling frequency, while it provided high spatial and temporal resolution, homogeneous distribution. The precise areal precipitation is greatly affected the accurate of simulations for hydrologic and ecological modeling. Therefore, there is a pressing need for assessment and examining by comparison with satellite data and observation data in order to better understand the precipitation processes, and to improve the retrieval algorithms and accuracy of data [16, 17]. To address this, we compared the data of TRMM-3B43 based on satellite with observations and assessed the accuracy from 1998 to 2013 in Tianshan mountainous, northwest of China.

2. Materials and methods

2.1. Study area

The present study focuses on Tianshan mountainous, located in the northwest of China a typical arid and semi-arid region. It is stretched from west to east, divided Xinjiang into two parts, i.e. Southern Xinjiang and Northern Xinjiang [18]. Due to far away from the ocean, precipitation is the main source of surface and ground water, farm irrigation, industry water, and so on. Due to intercept by mountainous and Plateau, southwest monsoon from the Indian Ocean and southeast monsoon from Pacific Ocean are rarely reached. The major vapor resource over TianShan mountainous is originated from the west wind current, minor resource is originated from the dry and cold current from the Arctic Ocean. Because of west-east-oriented mountainous, the characteristic of precipitation distribution presents more in the north than in the south, more in the west than in the east, more in the mountainous area than in the plain. The distribution of precipitation is scarce and unevenly, with average annual mean of 180 mm, in the north at 220 mm and that of the south of only 70 mm in Tianshan mountainous. Eighty percent of annual precipitation occurs during the rainy period from May to September. Maximum precipitation falls in Ili valley facing west, where the mean annual precipitation is >600 mm. As a result, Tianshan mountainous is become a wet island in arid area of northwest of China.

2.2. Data collection

The Tropical Rainfall Measuring Mission (TRMM) is a joint US-Japan program to monitor tropical and subtropical rainfall, launched in November 1997 and has provided precipitation estimates since January 1998. A range of products from TRMM are generated by the NASA Goddard Space Flight Centre and released for free application via several websites. These products provided series of hourly, daily and monthly precipitation at spatial resolution of 0.25° for the 50°N – S areas, have been widely used many applications with evaluating better performance [18]. One of products is the TRMM 3B43 monthly is used in this study. This product is combined of data from the TMI, PR, and VIRS with SSM/I, IR, and rain guage. The newly version (Version 7) was released on public websites on May 22 (2012). Compared to the previous version, several improvements (additional satellite data, uniform data reprocessing and calibration scheme) were implemented in the Version 7 products [19]. The annual precipitation data were also generated by accumulating all 12 monthly data.

Because of the complex topography, the station is very sparse and unreasonable distribution in Tianshan mountainous. The monthly precipitation are collected for 64 stations which provided by the National Climatic Centre of China, the China Meteorological Administration in Tianshan mountainous period from 1998 to 2013 (Fig. 1). The quality of product is firmly controlled and homogeneity tests are also performed before its release (Ding et al., 2007). There are 32 stations distributed below 1000 m, 26 station distributed from 1000 to 2000m, and no station distributed over 4000 m.

2.3. Methods

In order to ensure consistency of assessing, the cells of TRMM 3B43 products have been selected which neighbored station. The assessment was made over 16-year between 1998 and 2013 for annual and monthly time series. The error and correlation statistics were calculated to assess the accuracy between station observations and TRMM 3B43 products.

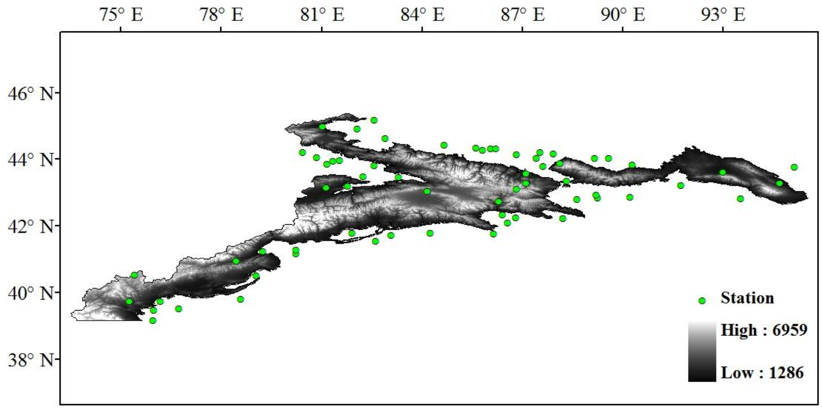

Fig. 1: Locations of precipitation stations in Tianshan mountainous.

One widely used method is employed to assess the differences between station observations and TRMM 3B43 products. The correlation analysis was calculated in annual and monthly as following:

$$r = \frac{\Sigma_{i=1}^{n}\left(P_{obs} - \overline{P_{obs}}\right)\left(P_{sat} - \overline{P_{sat}}\right)}{\sqrt{\Sigma_{i=1}^{n}\left(P_{obs} - \overline{P_{obs}}\right)^{2}\Sigma_{i=1}^{n}\left(P_{sat} - \overline{P_{sat}}\right)^{2}}} \quad (1)$$

where P_{obs} is the value of station observation, $\overline{P_{obs}}$ is the average of station observation, P_{sat} is the value of TRMM 3B43 products and $\overline{P_{sat}}$ is the average of TRMM 3B43 products for time series. The larger the correlation coefficient, the smaller the error is, and the distribution of scatter plots are more concentration in regression line.

3. Results and discussion

3.1. Annual

The distribution of annual average precipitation of TRMM 3B43 V7 products and observations are shown the statistically consistent, especially in western and eastern of Tianshan mountainous (Fig. 2. a,b). They are portrayed characteristic of south much less north of Tianshan mountainous. But, there is a significant difference in the middle of Tianshan mountainous. In east part of Ili River Valley, Daxigou and Xiaoqizi, the precipitation of observations are significantly higher than TRMM 3B43 V7 products. The pattern of coefficient is shown statistically significant across much of Tianshan mountainous area, above 0.5 except individual stations (Fig. 2. c). The value of coefficient is greater in the south than in the north, greater in the west than in the east of Tianshan mountainous. The value of coefficient is high which stations are above 2000 m, while correlation is increasing with elevation rising which stations are below 2000 m.

3.2. Seasonal

3.2.1. Spring

The distribution of seasonal precipitation is difference significantly, about accounting for 20% the annual precipitation arrives in spring over Tianshan mountainous. The correlation of r is calculated between the TRMM products and observations shown as Fig. 3(include March, April and May). The spatial distribution of r provided a more complete picture that the value is higher in north than in south in mid Tianshan, higher in east than in west. In the mid and east part of Tianshan mountainous, the value of r is higher than 0.9 that indicated a good performance between the TRMM products and observations. In the three months of spring, the value of r does not change in mid part of north that portrayed a more consistent picture, while different of value of r is obviously in mid part of south and west part of east of Tianshan mountainous where close the desert. As time goes on, the value of r is increases.

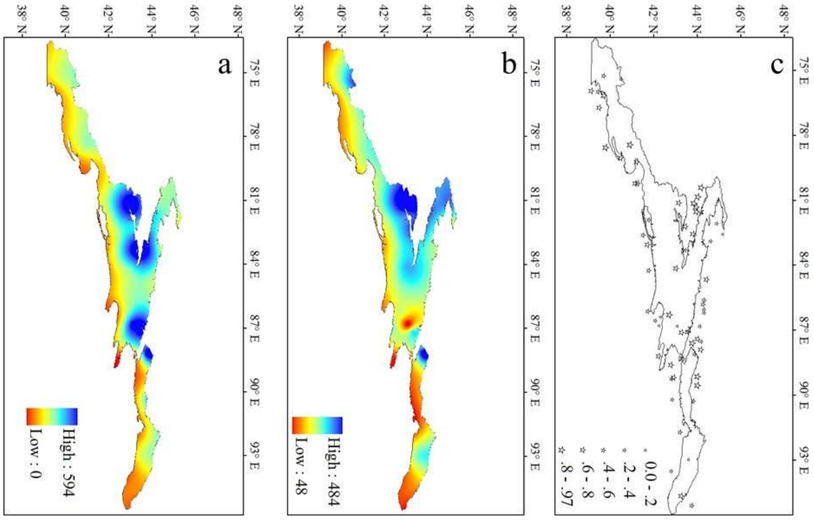

Fig. 2: The distribution of precipitation and coefficient of observations and TRMM products (a: distribution of observations, b: distribution of TRMM products, the coefficient of observations and TRMM products).

3.2.2. Summer

Summer is one of main period of precipitation in Tianshan mountainous, the total precipitation of summer is account for 40% of annual precipitation. The correlation of *r* is calculated between the TRMM products and observations shown as Fig. 4(include June, July and August). In July, the value of *r* is higher than other two months while precipitation is the highest of annual precipitation. Overall, the spatial distribution of *r* is similar to spring, the value of *r* is high that indicated the good performance between the TRMM products and observations in whole Tianshan mountainous. In June, the value of *r* is lower than other two months in the Ili valley where the amount of precipitation is high. In August, the value of *r* is decrease than other two months.

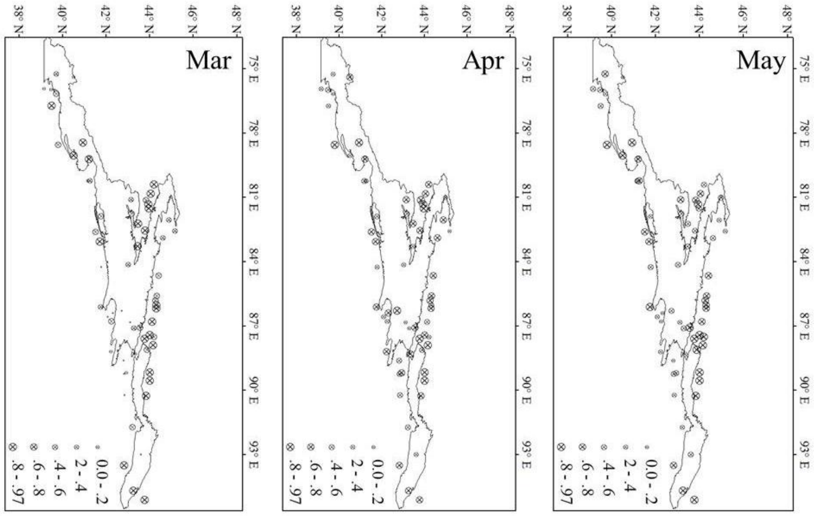

Fig. 3: The coefficient of precipitation and coefficient of observations and TRMM products in spring (a:Mar, b: Apr, c: May).

3.2.3. Fall

Fall is also one of main period of precipitation in Tianshan mountainous, the total precipitation of fall is account for 35% of annual precipitation. The correlation of *r* is calculated between the TRMM products and observations shown as Fig. 5(include September, October and November). Overall, compared with the summer, the value of *r* is decreased which the stations are in low mountainous, but the spatial distribution is very consistent that indicated the good performance between the TRMM products and observations in whole

Tianshan mountainous. In September, the variability of *r* is obvious in south slope of mid of Tianshang mountainous where nearby the desert. In October, the variability is obvious in south slope of west of Tianshan mountainous. In November, the variability is obvious in south slope of east of Tianshan mountainous where is locate the edge of westerlies.

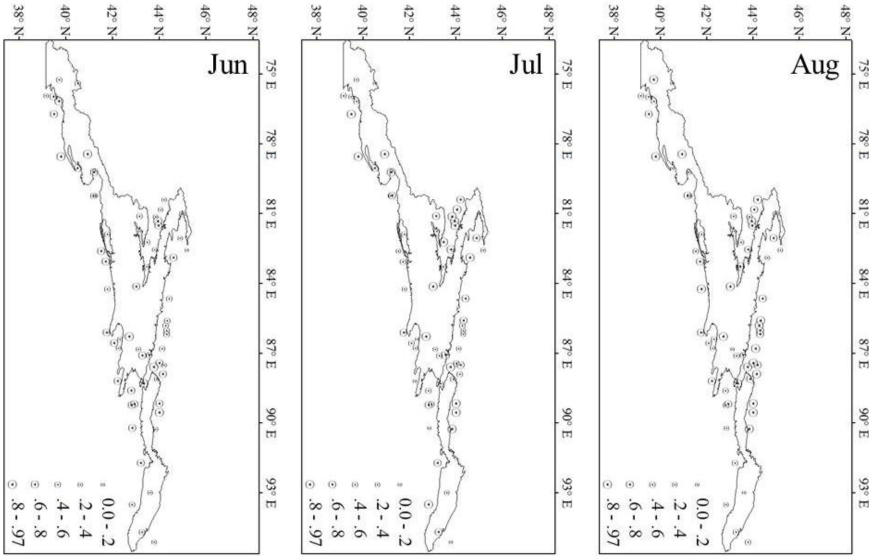

Fig. 4: The coefficient of precipitation and coefficient of observations and TRMM products in summer (a:Jun, b: Jul, c: Aug).

3.2.4. Winter

In all seasons, the precipitation of winter in least in annual, whereas only 5% the annual precipitation. Because of the low temperature, the precipitation is solid as snow in Tianshan mountainous. Additionally, the measurement of solid precipitation is affect by wind very large, the accuracy of observation is also greatly affected. The correlation of *r* is calculated between the TRMM products and observations shown as Fig. 6(include December, January and February). The value of *r* is higher in south than in north, higher in low mountainous than high mountainous. Overall, the value of *r* is decrease with time goes on. The variability of value *r* is change small in Ili valley while the significantly change in Wenqian, Bole and jinhe in December. The variability is obvious in south slope of east of Tianshan mountainous in January and February.

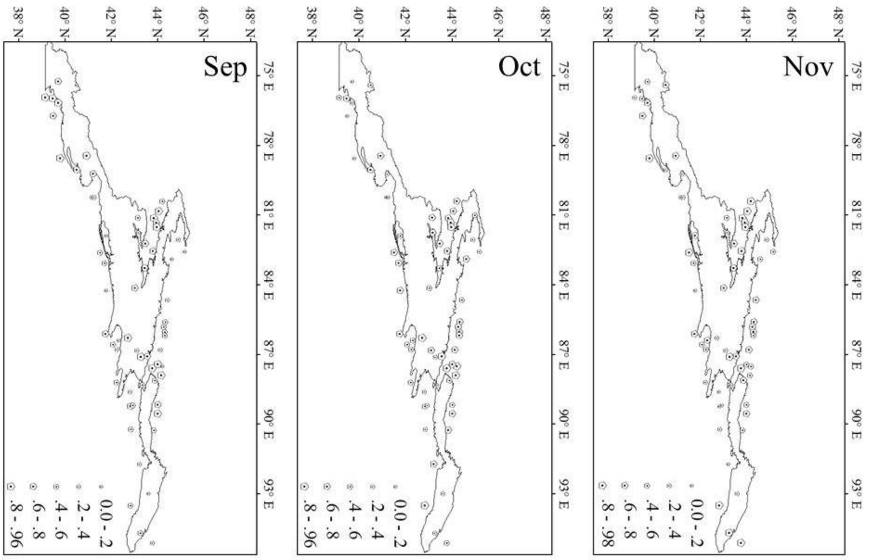

Fig. 5: The coefficient of precipitation and coefficient of observations and TRMM products in Fall (a: Sep, b:Oct, c: Nov).

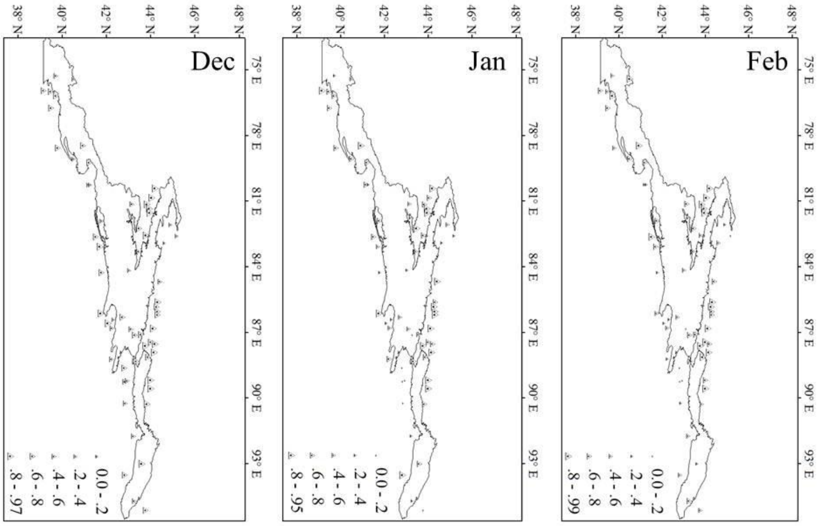

Fig. 6: The coefficient of precipitation and coefficient of observations and TRMM products in winter (a: Dec, b: Jan, c: Feb).

4. Conclusions

The comparison between TRMM products of satellite remote sensing and observations shows good agreement over Tainshan mountainous area but rather poor agreement in some region. The results show that the TRMM products and observations are performed better for wet climate regions and wet seasons whether in the high mountainous or low mountainous. But, the value of r is depicted that there has obviously difference in dry season. In high mountainous, the TRMM products and observations are good consistent while exist obviously difference in low mountainous.

Due to west wind current as the major vapor resource, and intercept by mountainous and Plateau, and affected by local water cycle, precipitation distribution is significantly different between north and south of Tainshan mountainous. Compared TRMM products and observations, the precipitation distribution of TRMM products is good agreement with observations. Thus, as the important driving data in the distributed hydrological model, accuracy of the simulation is directly affect by the accuracy of precipitation data. In large-scale hydrology studies, the TRMM products should have a broader application.

5. Acknowledgements

The authors are grateful to the anonymous reviewers for their very useful suggestions and comments. This study was supported by major national science research program (973 program) (No. 2013CBA01806), the National Natural Science Foundation of China (41361013, 31300388, 41271078), and Lanzhou City University PhD Research Fund (LZCU-BS2013-09, LZCU-BS2013-12).

6. References

[1] R. F. Adler, G. J. Huffman, and A. Chang, et al., “The version-2 global precipitation climatology project (GPCP) monthly precipitation analysis (1979-present)”. *Journal of hydrometeorology*, 2003, 4(6):1147-1167.

[2] S. M. Vicente Serrano, S. Sánchez, and J. M. Cuadrat, “Comparative analysis of interpolation methods in the middle Ebro Valley (Spain): application to annual precipitation and temperature”. *Climate Research*, 2003, 24(2):161-180.

[3] R. Mehrotra and A. Sharma, “A semi-parametric model for stochastic generation of multi-site daily rainfall exhibiting low-frequency variability”. *Journal of Hydrology*, 2007, 335(1):180-193.

[4] X. Zhang and R. Srinivasan, “GIS-based spatial precipitation estimation using next generation radar and raingauge data”. *Environmental Modelling & Software*, 2010, 25(12):1781-1788.

[5] E. Habib, A. T. Haile, and Y. Tian, et al., “Evaluation of the high-resolution CMORPH satellite rainfall product using dense rain gauge observations and radar-based estimates”. *Journal of Hydrometeorology*, 2012, 13(6):1784-1798.

[6] Z. D. Adeyewa, and K. Nakamura, "Validation of TRMM radar rainfall data over major climatic regions in Africa". *Journal of Applied Meteorology*, 2003, 42(2):331-347.

[7] D. B. Michelson, "Systematic correction of precipitation gauge observations using analyzed meteorological variables". *Journal of hydrology*, 2004, 290(3):161-177.

[8] E. E. Ebert, J. E. Janowiak, and C. Kidd, "Comparison of near-real-time precipitation estimates from satellite observations and numerical models". *Bulletin of the American Meteorological Society*, 2007, 88(1): 47-64.

[9] A. Aghakouchak, E. Habib, and A. Bárdossy, "A comparison of three remotely sensed rainfall ensemble generators". *Atmospheric Research*, 2010, 98(2):387-399.

[10] E. Symeonakis, R. Bonifaçio, and N.Drake, "A comparison of rainfall estimation techniques for sub-Saharan Africa". *International Journal of Applied Earth Observation and Geoinformation*, 2009, 11(1):15-26.

[11] P. Xie, J. E. Janowiak, and P. A. Arkin, et al., "GPCP pentad precipitation analyses: an experimental data set based on gauge observations and satellite estimates". *Journal of Climate*, 2003, 16(13):2197-2214.

[12] T. Kubota, S. Shige, and H. Hashizume, et al., "Global precipitation map using satellite-borne microwave radiometers by the GSMaP Project: Production and validation". *Geoscience and Remote Sensing, IEEE Transactions on*, 2007, 45(7):2259-2275.

[13] C. Kidd, and G. Huffman. "Global precipitation measurement". *Meteorological Applications*, 2011, 18(3):334-353.

[14] F. J. Tapiador, F. J. Turk, and W. Petersen, et al., "Global precipitation measurement: Methods, datasets and applications". *Atmospheric Research*, 2012, 104:70-97.

[15] E. Todini, "A Bayesian technique for conditioning radar precipitation estimates to rain-gauge measurements". *Hydrology and Earth System Sciences*, 2001, 5(2):187-199.

[16] P. Crochet, T. Jóhannesson, and T. Jónsson, et al., "Estimating the Spatial Distribution of Precipitation in Iceland Using a Linear Model of Orographic Precipitation", *Journal of Hydrometeorology*, 2007, 8(6):1285-1306.

[17] O. P. Prat and A. P. Barros, "Assessing satellite-based precipitation estimates in the Southern Appalachian mountains using rain gauges and TRMM PR", *Advances in Geosciences*, 2010, 25:143-153.

[18] X. H. Li, Q. Zhang, and C. Y. Xu, "Suitability of the TRMM satellite rainfalls in driving a distributed hydrological model for water balance computations in Xinjiang catchment, Poyang lake basin". *Journal of Hydrology*, 2012, 426:28-38.

[19] Z. Duan, and W. G. M. Bastiaanssen. "First results from Version 7 TRMM 3B43 precipitation product in combination with a new downscaling–calibration procedure". *Remote Sensing of Environment*, 2013, 131:1-13.