Authors Comment (AC)

On the Referee Comments (RC) #1 C4358 and RC #2 C4827

RC #1/ #2 *italic* **AC** normal **Publication text**: "citation" **New publication text**: "citation"

Comments of Anonymous Referee #1:

MAJOR CRITICISMS

RC #1: Point A (Analysis precipitation occurrence)

The authors claim that they evaluate both precipitation amount and occurrence in their paper. However, the majority of the work deals with the evaluation of precipitation amount. In fact, the only results that refer to the evaluation of the occurrence retrievals are found in Table 1 where the POD, FAR and FBI are presented. In the text the results of Table 1 are not discussed. In addition, from the manuscript it is not clear how ground truth observations of precipitation occurrence were determined. Please clarify this work throughout the manuscript.

AC on "*The authors claim that they evaluate both precipitation amount and occurrence in their paper. However, the majority of the work deals with the evaluation of precipitation amount* "*:*

As the referee assesses, the focus of this verification is set upon the evaluation of TMPA performance in the estimation of the precipitation amount. The authors put less importance on the estimation of the occurrence of a rain event, but also investigated it as shown in the following paragraphs. It is not correct, that the results of Table 1 are not discussed in the text – please see section 4.1, page 8557, lines 13 ff.

In view of possible applications of the TRMM 3B42 V6 data and the usefulness of our work for these applications, the most relevant results of the event occurrence analysis are discussed. We think that the findings are especially interesting considering the False Alarm Ration in combination with the amount of precipitation which has been estimated by the TMPA in the cases that the TMPA detected a rain event which was not registered by the "ground truth" (false alarm cases). This analysis was made by various contingency tables with different class limits.

The results show as displayed by Table 1 that the TRMM 3B42 V6 has a very high False Alarm Ratio during the dry season in the two investigation areas, but that the TMPA "falsely" estimated amounts are rather small. These results are discussed in the text: "The dry season is characterized by a relatively high false alarm ratio of over 50% in both regions (56% for Cuzco, 84% for La Paz), which is supported by the FBI calculation results. The analyses of detailed contingency tables revealed that 97% and 89% of these wrongly estimated values, respectively, are below 3 mm/day." (Section 4.1, page 8557, lines 18 ff)

To put more emphasis on the relevance of these findings, we introduced the following passage in the discussion section (page 8563, lines 23 ff):

Old: "The absence of a trend in the bias makes the application of a simple correction factor difficult. In spite of this, the use of correction factors could be considered as an option for hydrological flood warning, noting that a higher hit rate implicates a higher false alarm ratio."

New: "The absence of a trend in the bias makes the application of a simple correction factor difficult. In spite of this, the use of correction factors could be considered as an option for hydrological flood warning, noting that a higher hit rate implicates a higher false alarm ratio.

Another correction possibility is offered by the following finding: if days without rain were estimated with precipitation by the TMPA during the dry season, the incorrectly estimated amount is rather small (< 3mm/d). For instance in the field of agricultural planning, a simple adjustment enables the use of TMPA data to determine the dry and the rainy season with sufficient accuracy: Subtracting 3mm/d of all TMPA estimates in the dry season eliminates 89% (La Paz) and 97% (Cuzco) of the errors, considering the determination of no-rain events."

AC on *„In fact, the only results that refer to the evaluation of the occurrence retrievals are found in Table 1 where the POD, FAR and FBI are presented.":*

As mentioned by the referee the occurrence of events was analysed by categorical statistical measures (FAR, FBI and POD). Considering the length of the paper we decided to focus on the relevant results and not discuss all details of table 1. Table 1 shows that the ability of the TMPA in the detection of events is characterized by a seasonal pattern. These results are not surprising for a region with very pronounced wet and dry seasons as the Probability Of Detection in the rainy season is evidently higher, with less possibilities to fail in estimating a rain event due to very few "no-rain" days in this season. For the same reasons the False Alarm Ratio is lower in the rainy season. We did not discuss these results in particular because they are basically a consequence of the definition of the categorical statistics. Everyone who is interested in the quantitative event occurrence analysis can use the quantitative information given in Table 1 by the POD, FAR and FBI analysis results to draw conclusions for his/her own application.

Besides the application of categorical statistics, we analysed the TMPA performance in the detection of events by time series comparisons. As the time series comparison show qualitative character and the figures on which this qualitative evaluation is based on are very large in comparison to its informational content, we prefer to not integrate the analysis wholly into the paper.

AC on *"In addition, from the manuscript it is not clear how ground truth observations of precipitation occurrence were determined"*

The occurrence of events is determined by the ground truth if any station representative for the considered tile shows any precipitation record in the considered time span.

The following sentence will be added in section 3 Verification Methods, page 8556, line 9:

"A rain event is given if the ground truth daily precipitation in mm/d is unequal to zero."

We are aware of the problems induced by the arithmetic mean, but with the findings in view we concluded that the trend of the results could only be more accentuated and that the general statement would remain the same (see page 8554, lines 3 ff):

"Since an arithmetic mean of all available ground station data is constructed, extreme values are reduced, which could be a reason for relatively higher TMPA values. Likewise, the number of days without precipitation is likely to decrease. This would imply that the False Alarm Ratio might therefore even be higher than revealed by this verification method".

RC #1: Point B (Blended product)

AC on *"The presentation of the blended product is not confining. Section 4.5 deals mainly with the comparison of TRMM 3B42 V6 data against the ordinary co-kriging data."*

This is correct and we decided to rename the title of the chapter:

Old: "4.5 Blending daily precipitation gauge measurements with TMPA estimations"

New: "4.5 Daily TMPA estimates vs. interpolated precipitation data and blending"

AC on *"The blended product is only presented qualitatively for a single day in Figure 15. A more detailed description of the blending method is needed and its performance, relative to TRMM 3B42 V6 and oK, needs to be presented for the same dates as shown in Table 2. Otherwise it is better to leave this section outside the paper."*

We agree that the blending part is very short considering the complexity of the issue and possible use. It does not aim at presenting a new method of merging or to give a detailed validation of this method. The idea is to show possibilities to use the daily TMPA estimates in the Andes Region despite of the high uncertainty in the estimate quality in this region revealed by this study.

The blending technique is described in Krajewski 1987. Unfortunately, expanding on this part as desired by the referee would increase the paper length extensively. If the editor recommends it, we will follow the Referee's advice to take the blending passage (page 8560, lines 16-22) out.

RC #1 Point C (Sample uncertainties)

The authors compare daily precipitation values from different gauges against TRMM 3B42 V6 data that are provided every 3 hours. In order to reduce the sample errors they use several rain gauges within and in the neighbourhood of the TRMM 3B42 V6 grid box. The choice of the spatial and temporal synchronization methods seems arbitrary. Can the authors motivate, preferably with references to more detailed studies on this topic, why they have chosen this sampling strategy.

AC on "*temporal synchronization methods…" and on "RC #1: - Section 4.4: The presentation of the evaluation of hourly TRMM 3B42 V6 values is very brief."(Minor Criticisms))*

The uncertainty about the time spans between each 3h-TRMM 3B42 V6 value is given by the product characteristics with every user of the data dealing with this data void.

An hourly comparison in 3-h intervals was made with METAR data of Cuzco airport to present a 1:1 comparison and to exclude that low TMPA performance quality is forced alone by the temporal aggregation method. The performance results were significantly worse than on the daily scale (please see section 4.4 Verification of hourly values, p. 8559, lines 2 ff).

The high temporal resolution verification can only be performed with one (automatic) ground station, as all other conventional stations provide maximum half-day-values. The resulting limited representativeness led us to give minimal attention to these results in the manuscript and they were only used to underline the low influence of the temporal aggregation method on the TMPA performance results.

AC on *"spatial synchronization methods…"*

The spatial sampling strategy has been chosen for the availability of data, simplicity and working time efficiency. The station network consists only of the presented stations. Li and Heap (2008) state in their comparative work of spatial interpolation methods (inverse distance squared, simple or ordinary Kriging, nearest neighbours, triangular irregular network, etc.) that a sample size smaller than 50 leads to erratic variograms with little or no evident spatial structure. Furthermore they conclude "While spatial scale, relative spatial density and distribution of samples can be determinant factors on the performance of the spatial interpolation methods (Collins and Bolstad, 1996), other relevant factors may also be important. For example, altitudinal and seasonal changes in data have been shown to play a significant role in predictions (Stahl et al., 2006) ". With the background of the small sample size and the non-homogeneous distribution, the dependency of the quality of the interpolation results on important factors present in the area, as strong altitudinal changes and pronounced seasonal patterns, makes the application of more sophisticated interpolation methods unreliable and uncertain.

Their use was therefore considered too time consuming in comparison to the quality of the results, more sensitive to errors in comparison to simple averaging and it would increase the uncertainty and lack of transparency. Therefore we selected this rough, simple and widely known method to build spatial means.

Li, J. and Heap, A.D.: A Review of Spatial Interpolation Methods for Environmental Scientists. Geoscience Australia, Record 2008/23, 137 pp, 2008.

AC on *"Also, discuss the risk for biases in the precipitation sums due to looking in a very mountainous terrain. For example, have there been studies in Switzerland using weather radar data to determine optimum sampling strategies in mountainous terrain? "*

The authors of this work are aware of that measurement and sampling errors can increase the apparent satellite estimation errors. This error is difficult to remove (Habib and Krajewski, 2002). An interesting publication on this issue is

Ebert, E.: 'Method for verifying satellite precipitation estimates'. In Measuring precipitation from Space: EURAINSAT and the future, Advances in Global Change Research 28: 345-356, 2007.

Ebert states that "the observational error is tolerable if it is random and much smaller than the error in the satellite estimates." The sampling problems which the elevation of the investigation area implies are not directly comparable to European mountain conditions as it the Central Andes are situated within the tropics. Therefore, for instance, the snow line elevation is a few thousand meters higher than in the Alps and the most of the gauges do not have to cope with solid precipitation even though they are situated above 3000 m ASL. The error assigned to snow drift is about 15 - 35% in comparison to 2 – 5% undercatch in the liquid phase.

Considering the size of errors in the satellite estimates on one hand and in the gauge observations on the other and that at least four stations build up the ground truth, which's data has been additionally quality checked by the authors, we see the condition proposed by Ebert (2007) as fulfilled.

RC #1 Point D (independence of the validation dataset)

AC *on "Reading the paper one wonders about the independence of the validation dataset. The authors compare the TRMM 3B42 V6 data against rain gauge data over the Andes Mountains. However, the TMPA scheme calibrates and merges the TRMM data with rain gauge observations to produce the TRMM 3B42 V6 dataset. The authors should underpin that the rain gauges used for validation are not used to retrieve the TRMM 3B42 V6 dataset, and thus validation is done with an independent dataset.":*

The fact that it is impossible to trace back to the stations used in the processing scheme for the ground calibration is a big difficulty to cope with, for any verification or application of TMPA data. This work focuses mainly on the performance of daily TMPA estimates and its change with spatial and temporal resolution. The gauge adjustment is done on a monthly base.

Additional to the presented cases we carried out further verifications for Cuzco region, investigating the estimate performance on daily, weekly, bi-weekly and monthly scale on four further tiles. Their verification shows almost equal results with the cases presented in this publication (Section 4.2 Verification on different temporal resolutions, p. 8558, lines 10ff). With these verifications we increase the representativeness of our results. It is unlikely that the ground truth datasets of all 5 verifications (on a 0.25° x 0.25° grid) carried out for the Cuzco region each include one ground station on which the calibrating gauge product is based. This is especially unlikely considering that the calibrating gauge product is based on zero to two stations per 2.5° x 2.5° grid cell in the region (discussion section, p. 8563, lines 7ff).

AC on *"Above risen point also holds for the blending of daily precipitation gauge measurements with TRMM 3B42 V6 dataset. Are similar rain gauge observations used twice, once to generate the TRMM 3B42 V6 dataset and once for the blending"*
As mentioned above, it is not possible to say what stations are going into the TRMM product 3B42 V6. Our proposition of a blending is based on a daily time step with a few dozen stations in the Cusco-Apurímac region, whereas the TMPA calibration is based on zero to 2 stations on a monthly scale per 2.5° x 2.5° grid cell. The TMPA gauge calibration only affects the monthly bias, while our paper's daily calibration addresses day-to-day events. Furthermore, it is not assured that the GPCC monthly analysis from much sparser data will accurately reproduce the monthly bias of the denser local network.

RC #1 MINOR CRITICISMS

RC #1: " Introduction - Page 8548 (line 20-25): The introduction only briefly mentions alternative precipitation products. Can they give a more detailed overview of other precipitation products rather than the TRMM 3B42 V6 products. Especially because later in the manuscript some other products are mentions (GPCC, GPCP) the authors should spend some words on the pro's and con's of other dataset (GPCP, CMORPH, TAMSAT, ..), and provide references to citable papers.":
AC: We will introduce the following passage in the Introduction. We will focus on works which enabled the development of products which are currently comparable to TRMM 3B42 V6 considering spatial and temporal resolution and especially the input data, consisting in satellite estimates and gauge data.

Old: "Possibilities provided by the development of new techniques to combine different space-borne sensors measurements (microwave, infrared and radar) and gauge data (Huffman et al., 1995, 1997, 2001; Xie and Arkin, 1996, 1997) allow the derivation of high quality precipitation estimates. High-mountain regions are among the most challenging environments for remote-sensing-based precipitation measurements due to extreme topography and high weather and climate variability. At the same time, high-mountain regions are typically characterized by a lack of climate data, which is a drawback for assessing climate change and related impacts. Remote-sensing-derived climate data such as from TRMM could provide an important opportunity to narrow this gap. The TMPA is a combination scheme for precipitation estimates from different sensors, including microwave, infrared, radar data and gauge measurements. The result is a product with high spatial and temporal resolution (3-hourly, 0.25°x0.25° on a longitude-latitude grid) with global coverage between 50°N and 50°S, called TRMM Product 3B42 Research Version 6 (TRMM 3B42 V6; Huffman et al., 2007)."

New: "Possibilities provided by the development of new techniques to combine different space-borne sensors measurements and gauge data allow the derivation of high quality precipitation estimates. Huffman et al. (1995, 1997) created a scheme to combine satellite data of different sensors (Microwave [MW], infrared [IR], longwave radiation [LW]) with gauge data. The resulting product is the Global Precipitation Climatology Project (GPCP) Combined Precipitation Dataset on a 2.5° x 2.5° grid in monthly resolution. The further product development resulted in a daily precipitation product on a 1° x 1° grid, the GPCP One-Degree-Daily (1DD) (Huffman et al., 2001). Xie and Arkin (1996, 1997) combined satellite-based estimates from IR and MW, gauge measurements and weather forecast model data with the Climate Prediction Center (CPC) merged analysis of Precipitation (CMAP) to create a new monthly precipitation product on a 2.5° x 2.5° grid.

Since then, algorithms improved and further multi-source products with higher resolutions emerged. The most important ones which combine measurements from different space-borne sensors are the TMPA (Huffman et al., 2007), the only one including radar measurements, the CPC Morphing Technique 7 (CMORPH; Joyce et al., 2004), the National Environmental Satellite, Data and Information Service (NESDIS) Hydro-Estimator (Scofield & Kuligowski, 2003), the Naval Research Laboratory (NRL) Blended Technique (Turk & Miller, 2005), the Global Satellite Map of Precipitation (GSMaP; Kubota et al. 2007) and the Precipitation Estimation using Remotely Sensed Information Using Artificial Neural Networks (PERSIANN; Soroshian et al., 2000). These products are available for (at least) the lower latitudes and the tropics and have resolutions about at least 0.25° x 0.25° grid size and 3-hourly. For further information, please consult Sapiano and Arkin (2009) for an informative comparison of high resolution satellite-based precipitation estimates and Gruber and Levizzani (2008) for a holistic assessment of global precipitation products.

High mountain regions are among the most challenging environments for remote-sensing-based precipitation measurements due to extreme topography and high weather and climate variability. At the same time, high-mountain regions are typically characterized by a lack of climate data, which is a drawback for assessing climate change and related impacts. Remote-sensing-derived climate data such as from TRMM could provide an important opportunity to narrow this gap. The TMPA is a combination scheme for precipitation estimates from different space-borne sensors, including microwave, infrared, radar data and gauge measurements. The result is a product with high spatial and temporal resolution (3-hourly, 0.25° x 0.25° on a longitude-latitude grid) with global coverage between 50°N and 50°S, called TRMM Product 3B42 Research Version 6 (TRMM 3B42 V6; Huffman et al., 2007).“

Consequently added to the References:

Gruber, A. and Levizzani, V. : Assessment of Global Precipitation Products. A Project of the Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel, World Climate Research Programme (WCRP), 2008.
[WCRP-128 WMO/TD-NO. 1430, available at http://www.wmo.int/pages/prog/wcrp/documents/AssessmentGlobalPrecipitationReport.pdf, 02/02/2011]

Joyce, R..J., Janowiak, P., Arkin, P.A. & Xie, P.: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution. Journal of Hydrometeorology, 5, 487–503, 2004.

Kubota T., S. Shige, H. Hashizume, K. Aonashi, N. Takahashi, S. Seto, M. Hirose, Y.N. Takayabu, K. Nakagawa, K. Iwanami, T. Ushio, M. Kachi, K. Okamoto: Global Precipitation Map Using satellite-Borne Microwave Radiometers by the GSMaP Project: Production and Validation. IEEE Trans. Geosci. Remote Sens., 45, 2259-2275, 2007.

Sapiano, M.R.P. and Arkin, P.A. : An intercomparison and validation of high-resolution satellite precipitation estimates with 3-hourly gauge data. Journal of Hydrometeorology Volume 10(1), 149–166, 2009.

Scofield, R.A. & Kuligowski, R.J.: Status and outlook of operational satellite precipitation algorithms for extreme precipitation events. Weather and Forecasting, 18, 1037–1051, 2003.

Sorooshian, S., Hsu,K., Gao,X., Gupta, H.V., Imam,B. and Braithwate, D.: Evaluation of PERSIANN system satellite-based estimates of tropical rainfall”. Bulletin of the American Meteorological Society, 81(9), 2035–2046 (2002).

Turk, F.J. & Miller, S.D. : Toward improved characterization of remotely sensed precipitation regimes with MODIS/ AMSR-E blended data techniques”. IEEE Transactions on Geoscience and Remote Sensing, 43, 1059–1069, 2005.

RC #1: “Investigation areas and data

- Section 2.2.1 (Ground data): This section does not describe how information on precipitation occurrence was collected. Please clarify this in section 2.2.1.

AC: The following sentence will be added (also mentioned under Mayor Criticisms, Point A; the sentence will be added in section 3 verification methods, page 8556, line 9):

“A rain event is given if the ground truth daily precipitation in mm/d is unequal to zero.”

In Section 2.2.1 Ground data (p. 8551, lines 22ff) “ground station” will be replaced by “conventional station”:

Old: “The Peruvian national meteorological and hydrological service, SENAMHI Peru, provides daily precipitation measurements for four **ground** stations in Cuzco from 1 January 1998 to 31 May 2008.”

New: “The Peruvian national meteorological and hydrological service, SENAMHI Peru, provides daily precipitation measurements for four **conventional** stations in Cuzco from 1 January 1998 to 31 May 2008.”

The same for the section about La Paz Ground Data.

RC #1: Page 8553 (line 5): “(GPCC; GPCP..” It is not clear here which dataset is used for the rain gauges. GPCC, the interpolated rain gauge dataset of DWD with global coverage only over land, or GPCP, the merged rain gauge and satellite IR and microwave dataset with global coverage. Please clarify.

AC: The data set is GPCP monthly rain gauge analysis developed by the GPCC based on Rudolf (1993). “GPCC” stands as abbreviation for Global Precipitation Climatology Centre in parenthesis; “GPCP monthly rain gauge analysis” is the product name. As this is confusing we agree to change these terms as written below and add a reference to avoid further confusion .

Old: “The calibrating gauge analysis datasets are processed and provided until March 2005 by the Global Precipitation Climatology Centre (GPCC; GPCP global monthly rain gauge analysis; 1°, monthly) and from April 2005 on by the Climate Assessment and Monitoring System (CAMS Monthly rain gauge analysis; 0.5° monthly; Su et al., 2008).”

New: “The calibrating gauge analysis datasets are processed and provided until March 2005 by the Global Precipitation Climatology Centre (GPCC; GPCC global monthly rain gauge analysis; 1°, monthly; **Rudolf, 1993**) and from April 2005 on by the Climate Assessment and Monitoring System (**CAMS**, CAMS Monthly rain gauge analysis; 0.5°, monthly; Su et al., 2008).”

Added to References:

Rudolf, B.: Management and analysis of precipitation data on a routine basis, in: Sevruk, B. and Lapin, M. (Eds.): Proceedings of the International Symposium on

Precipitation and Evaporation, 20-24 Sept. 1993, 1, 69-76, Slovak Hydrometeor. Inst., Bratislava, Slovak Republic, 1993.

RC #1: Verification methods

- *Page 8555 (line 10): As mentioned under points of major revisions, the analysis of precipitation occurrence is mentioned here, but I can not find the evaluation in the results section.*

AC: We discuss the results of the event occurrence analysis in section 4.1, p. 8557, lines 13 ff.

RC #1: Results - Fig 8 and Fig 11: These scatterplots provide little information. In order to quantify the effects of sampling time and sampling area at least the slope, offset, correlation and RSME should be given for these figures as well. Another option is to present in one Figure the gain and offset and in another Figure the correlation and RMSE (actually in a similar manner as in Fig 7 and 10).

AC: The regression line equation, RMSE and Pearson´s Correlation Coefficient R will be introduced in the figures.

RC #1: - Fig 9: Panel a,b,c,d are exactly identical. The authors presumably made a copy and paste error here. Please check.

AC: Will be changed.

RC #1:- Section 4.3: The authors use different numbers of rain gauges to analyze the correlation between the TRMM 3B42 V6 product and rain gauges at different spatial resolutions. Did the authors also research the sensitivity of their results to using less or different rain gauges, and thus set error bars on the correlations presented in Figure 10?

AC: We did not investigate the sensitivity of the results to using less or different rain gauges. In the spatially aggregated analyses of larger areas, always the original gauges of the smaller units are included. We did not use different ones, nor less gauges, because the data coverage is so sparse, that dividing the given stations does not make sense.

RC #1: - Section 4.4: The presentation of the evaluation of hourly TRMM 3B42 V6 values is very brief. It would be more logical to make this analysis part of section 4.2 (verification of different temporal resolutions), taking the hourly values as the finest temporal resolution.

AC: Please see our comment on "Mayor Criticisms, Point C (Sample uncertainties)" – **AC** on "*temporal synchronization methods…*"

RC #1: Section 4.5: Figure 13 and 14 do not add much new information. In this section it would be more interesting to present in Table 2 the comparison of TRMM 3B42 V6, oK and the Blended product for all studied days. Also see major comment B &D.
AC: Please see our comment on "Mayor Criticisms, Point B (Blended product)"

RC #1: Discussion - Page 8562 (line 15): "GPCP derived ground truth" . Note GPCP is not a ground truth product. It combines ground based and satellite derived information to determine rain amounts. The term "derived ground truth" can only be used for the interpolated rain gauge product of GPCC.
This is correct and will be changed. The GPCC interpolated rain gauge product was used.
New: "On the other hand, Feidas et al. (2008) show that an operational infrared-based precipitation algorithm for the Mediterranean Basin performs as well as r = 0.9 versus GPC**C**-derived ground truth for July, deteriorating to r = 0.28 for January."

RC #1: - Mention also in the discussion that IR data are only indirectly related to precipitation. Although the optically thin cirrus clouds in the anvil of convective system do not produce precipitation they still contribute to the precipitation estimates from IR data.
AC: We will introduce the following sentence in the discussion section, page 8562, line 9:
"Additionally, the indirect character of the retrieval implicates that clouds which do not produce any precipitation, as e.g. the cirrus clouds in the anvil of convective systems, are may lead to non-zero IR precipitation estimates."
May we introduce the Referee # 1 as Reference? Thank you kindly in advance.

RC #1: Grammatical slips - Page 8549 (line 4): "60 N and S" should be "60 N and 60 S"
AC: changed

RC #1 • Page 8552 (line 15 -20): "This method …platforms" this is a very long and difficult to read sentence, please rephrase.
AC: The nature of satellite mission and sensor names makes a simple formulation difficult. We consider that this is the shortest way to express this technical information. An alternative is proposed below.

Old: "This method combines precipitation estimates of four passive microwave sensors, namely TRMM Microwave Imager (TMI), Special Sensor Microwave/Imager (SSM/I), Advanced Microwave Scanning Radiometer-EOS (AMSR-E) and Advanced Microwave Sounding Unit-B (AMSU-B), on a variety of satellite platforms, TRMM, Defense Meteorological Satellite Program (DMSP), Aqua and National Oceanic and Atmospheric Administration (NOAA), calibrated with the TRMM Precipitation Radar (PR)-TMI combined instrument product to a high quality (HQ) microwave product."

New: “This method combines precipitation estimates of four passive microwave (PMW) sensors, namely TRMM Microwave Imager (TMI), Special Sensor Microwave/Imager (SSM/I), Advanced Microwave Scanning Radiometer-EOS (AMSR-E) and Advanced Microwave Sounding Unit-B (AMSU-B). These PMW fly on a variety of satellite platforms, namely the TRMM, the Defense Meteorological Satellite Program (DMSP), the Aqua mission and National Oceanic and Atmospheric Administration (NOAA) satellites. They are calibrated with the TRMM Precipitation Radar (PR)-TMI combined instrument product and merged to create a high quality (HQ) microwave product.”

RC #1: • TRMM 3B42 V6 or TRMM 3B42 RT or TMPA. The authors use alternating TMPA or TRMM 3B42 V6 for their dataset. If I understand correct TMPA is referring to the retrieval method and TRMM 3B42 V6 the dataset that is produced with the TMPA scheme. The authors should use these terms consistently throughout the manuscript. Thus “TMPA data” should be replaced by either “TRMM 3B42 V6 data” or “TRMM 3B42 RT data”

AC: The term TMPA describes indeed the processing scheme of the TRMM product 3B42 in Version 6. But the TMPA is also used to name the dataset itself. It is important to note, that the TRMM 3B42 Real-Time Version is not to be used synonymous with TMPA, as it is not completely the corresponding processing scheme. During the development of the product 3B42 the composition and name has changed significantly and resulting in confusion.

For example, the TRMM 3B42 product is called in the TRMM user´s handbook from NASDA; now JAXA (2001):

“3B42: TRMM & IR Daily Rainfall” (and has obviously a different resolution)

> EARTH OBSERVATION CENTER (2001): TRMM Data Users Handbook. Nacional Space Development Agency Japan (JAXA). Available at http://www.eorc.jaxa.jp/TRMM/document/text/handbook_e.pdf, 04/11/2008.

In the publication of Huffman et al. (2007), the term **TMPA** replaces for the first time the product name TRMM 3B42 V6 and is used synonymous as a name for the whole dataset.

“This paper describes the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis (TMPA), a new dataset that continues the trend toward routine computation and distribution of finer-scale precipitation estimates.”

> Huffman, G. J., Adler, R. F., Bolvin, D. T., Gu, G., Nelkin, E. J., Bowman, K. P., Hong, Y., Stocker, E. 5 F., andWolff, D. B.: The TRMM Multi-satellite Precipitation Analysis (TMPA): Quasi-global, multiyear, combined sensor precipitation estimates at fine scales, J. Hydrometeorol., 8(1), 38–55, 2007.

There exist a number of confusing other product descriptions. For example in the data set documentation from 2009 of the Laboratory for Atmorpheric Science at the GCFC, the product´s name in the document “3B42_3B43_doc.pdf “is: **“TRMM and Other Data Precipitation Data Set”**

> HUFFMAN, G.J. & BOLVIN, D. T. (2009): “TRMM and other data precipitation data set documentation”. Laboratory for Atmospheric Science, NASA Goddard Space Flight Center and Science Systems and Applications, Inc. available as “TRMM 3B42_3B43_doc” at GSFC Ftp: ftp://precip.gsfc.nasa.gov/pub/trmmdocs/3B42_3B43_doc.pdf (02/02/2011)

…while on the TRMM-GSFC homepage (http://trmm.gsfc.nasa.gov/3b42.html, 02/02/2011), one can still find the product name “**Algorithm 3B42 - TRMM Merged HQ/Infrared Precipitation”**

…or on the GSFC data portal
(http://mirador.gsfc.nasa.gov/collections/TRMM_3B42__006.shtml, 02/02/2011):
“TRMM 3-Hourly 0.25 deg. TRMM and Other-GPI Calibration Rainfall Data”

The term “TMPA” stands for the processing scheme of Version 6 of the TRMM product 3B42, not for lower versions and not for the real-time product. In this work we chose to use these two descriptions of the product for the following reasons. Firstly, because they are the most specified and clear. The second reason is that we would like to introduce the term TMPA to user’s of the data, which are not so familiar with the topic, as the term is not only used for the data set, but sometimes even the only name given to the data, as in Huffman et al. (2007), replacing the product name TRMM 3B42 V6. Using the (name) “TMPA product” on the other hand, one can be sure, it is the version 6 of 3B42 with the here described algorithms and processing schemes. The current version of 3B42 is number 6. All old versions of 3B42 have been reprocessed, but it is very difficult for the user to get information about if it is actually the processing scheme version 6 which has generated his data or not, because the information is not given with the data, at least it is called TMPA product. The changing product names, even including changing product resolution make this uncertainty worse. For these reasons we would like to keep the two names.

RC #1: • Page 8564 (line 17): “a weak underestimation..” mention here which dataset shows a weak underestimation.

AC: Will be changed:

Old: “Both, the Cuzco and the La Paz investigation areas show - on average - a weak underestimation of middle-size to large daily precipitation amounts and an overestimation for daily sums below about 2 mm/d.”

New: „The TMPA estimates for both, the Cuzco and the La Paz investigation areas show - on average - a weak underestimation of middle-size to large daily precipitation amounts and an overestimation for daily sums below about 2 mm/d."

Comments of Anonymous Referee #2:

RC #2: *- the TRMM 3B42 V6 is just one of the several high-resolution global satellite products currently available. For this study to gain significance it should evaluate additional global satellite products available to the community (such as the one from NOAA named CMORPH, and the one from the University of California named PERSIANN)*

AC: This study investigates the change of performance quality of the TRMM product 3B42 V6 with changing temporal and spatial resolution. It compares the estimate quality of one product, but on daily, weekly, bi-weekly and monthly scale and on 0.25° x 0.25° to 1° x 1° grid resolution. The product has not been validated in the Central Andes region until today. This study is of significance for the scientific community because it provides important results for the use of this precipitation product in the investigation area, which is characterized by a rather coarse coverage by conventional stations. The area is furthermore the destination region of different development projects (e.g. the PACC Peru of the Swiss Agency for Development and Cooperation) which need consistent precipitation input data for their studies in the field of water resources, food security and disasters. The use of TMPA data without previous validation in the region is critical. This study assesses the quality of the product and revealed that the TMPA performs very good on the monthly scale with decreasing accuracy with higher temporal resolution and that decreasing the spatial resolution does not lead to better performance results. The intercomparison of the performance of various high-resolution space-borne precipitation products for the Central Andes Region is a very interesting project for the future.

It is common scientific practise to concentrate on the validation of one precipitation product. The following incomplete list shows publications that focus on the TMPA product alone.

Oke, A.M.C., Frost, A. J. and Beesley, C. A.(2009): The use of TRMM satellite data as a predictor in the spatial interpolation of daily precipitation over Australia. In Anderssen, R.S., R.D. Braddock and L.T.H. Newham (eds) 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, July 2009, pp. 2377-2383. ISBN: 978-0-9758400-7-8. http://www.mssanz.org.au/modsim09/I10/oke.pdf, 03.02.2011

Bai, A.J., Liu, C.H., Liu, X.D. (2008): Diurnal variation of summer rainfall over the Tibetan Plateau and its neighboring regions revealed by TRMM Multi-satellite Precipitation Analysis, Chinese J. Geophys. Chinese Ed., 51(3), 704-714.

Su, F.G., Hong, Y., Lettenmaier, D.P., (2008) , Evaluation of TRMM Multisatellite Precipitation Analysis (TMPA) and its utility in hydrologic prediction in the La Plata Basin, J. Hydrometeor., 9(4), 622-640.

Harris, A., Rahman, S., Hossain, F., Yarborough, L., Bagtzoglou, A.C., Easson, G., (2007): Satellite-based flood modeling using TRMM-based rainfall products, Sensors, 7(12), 3416-3427.

Henschke, A. E. and Habib, E. (2007): Validation of NASA-TRMM MPA Precipitation Estimates During Tropical Storms Using Gauge and Radar-Based Estimates. American Geophysical Union, Fall Meeting 2007, abstract #H24A-04, http://adsabs.harvard.edu/abs/2008AGUSM.H24A..04H, 03.02.2011

Villarini, G., Krajewski, W.F. (2007): Evaluation of the research version TMPA three-hourly 0.25 degrees x 0.25 degrees rainfall estimates over Oklahoma, Geophysical Research Letters, 34(5).

Katsanos, D., Lagouvardos, K., Kotroni, V., Huffman, G.J. (2004): Statistical valuation of MPA-RT high-resolution precipitation estimates from satellite platforms over the central and eastern Mediterranean, Geophysical Research Letters, 31(6).

RC #2: - The gauges used in this error analysis are very limited in terms of area coverage. Uncertainty associated with gauge sampling error can be significant, particularly due to the orographic precipitation that is associated with spatial gradients. Proper evaluation of the gauge sampling error and accounting for this error in the satellite error analysis is needed.

AC: Please see the Author´s Comment on Referee #1´s Comment Point C.

RC #2: - The spatial integration discussed in this paper does not make much sense given the limited gauge density. Going from 0.25 to 0.5 degrees increases gauge sampling uncertainty that most likely balances off the gain from smoothing retrieval error variability.

AC: On one hand the gauge sampling uncertainty increases at coarser scales, but the use of more stations on the other hand acts against this effect. Precipitation data of 10 gauges is used for the validation of one 0.5° x 0.5° grid cell. We concluded that the possible improvement of the estimates of larger areas is hidden by various factors, as discussed in the discussion section, page 8563, lines 1-22. It is possible that the supposed increased gauge sampling uncertainty is one of these factors, but being the only reason for the lacking performance improvement is unlikely. Even if this study does not identify quantitatively the portions of influence of the different factors anticipating the performance improvement, this work presents important findings for practitioners and actual users of the data: Choosing a lower temporal resolution improves the performance quality strongly. But cut backs in the spatial resolution of the data do not increase the estimate accuracy. Please see as well again the answer to Referee #1´s Comment Point C for further explication.

RC #2: - The gauge-satellite rainfall merging is not well justified and lacks proper evaluation. Specifically, what is the added value of merging satellite data with the gauge network? The authors should use independent gauge data to verify improvements from this satellite-gauge merging to demonstrate improvements over what is already done at the V6 gauge based bias adjustment product. Furthermore, in most remote area on earth we do not have gauge data to provide in situ measurements, or the gauge network coverage is not adequate to support co-Kriging applications (i.e. gauge interpolation lengths longer than the rainfall correlation length). The authors should discuss those issues and provide a clear justification of the use of their proposed data merging scheme.

AC: The merging of space-borne precipitation estimates with gauge data is useful in the cases that the correlation between the satellite and the gauge data is higher than the correlation with values produced by spatial interpolation methods as ordinary Kriging (oK). The proposed merging technique of the TMPA product with gauge data therefore depends on their correlation coefficient in comparison to oK cross validated correlation. If the correlation with the TMPA of a certain event is higher than with oK, the accuracy of the precipitation estimates merged with the TMPA product of this case is higher than without the satellite estimates. Please see the Author´s Comment on Referee #1´s Point B (Blended product) for further explication.