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Hydrology and Earth System Sciences Discussions

Interactive comment on "Experiences in using the TRMM data to complement rain gauge data in the Ecuadorian coastal foothills" *by* M. Arias-Hidalgo et al.

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Interactive comment on "Experiences in using the TRMM data to complement rain gauge data in the Ecuadorian coastal foothills" by M. Arias-Hidalgo et al.

Anonymous Referee #1

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The authors tried to use locally available rain gauge data to adjust TRMM rain data and then feed the adjusted TRMM data to a hydrologic model. The results based on gauge

adjusted TRMM rainfall were comparable to gauge-only driven model performance. This will give a good reference for some local applications where both rain gauge data and satellite data are available. I have two major concerns as below.

1. What TRMM data the authors were using is not clear. Is it 3B42 real time data or the research data? The 3B42 research data are monthly adjusted by gauge measurements. If the latter was used, whether rain gauge data are involved in the TRMM data production needs to be clarified. Are they as same as the gauges as the authors were using?

RESPONSE TO THE REVIEWER: The TRMM used for this article is the 3B42 research data (as such it has now been clarified throughout the article when applicable, for example, on page 3 and line 17 of the enclosed newer version of the manuscript). As it is shown in the NASA website (http://trmm-fc.gsfc.nasa.gov/trmm_gv/data/data.html), there are some global ground/seashore validation stations for the product in mention (global analysis). But they are far away from our study area and a better estimation of rainfall can be achieved using our ground data (as a sort of local analysis) due to their nearness to the centres of the TRMM grids.

Furthermore, the authors used the TRMM data only till year of 2006. I would encourage the authors to download the TRMM data from the TRMM official data portal and use the newest TRMM data (latest version is 7.0) which includes all latest improvement efforts. Both data and data document can be available from ftp://trmmopen.gsfc.nasa.gov. I would also encourage the authors extend the experiment/

RESPONSE TO THE REVIEWER: Indeed, it is a nice suggestion to undertake comparisons beyond 2006. The present article was funded by a European Project (WETWin, FP-7). The project comprised some budget for acquiring ground data collection (up to 2006) but unfortunately that budget is no longer available. Therefore, further contrasts between ground and satellite data cannot be undertaken for the time being. Nevertheless, for a future publication, there is an idea to search for funding in order to extend

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these comparisons until it is feasible.

I would also encourage the authors extend the experiment/hydrologic simulation time period to multiple years instead of only one year with the old version TRMM data. Using a longer time period instead of the calibrating year for comparisons will be more convincing. RESPONSE TO THE REVIEWER: There was a typing mistake referring the years in which the model was setup/calibrated. The years were 2004 and 2005, respectively (correction was inserted and is now on page 6, line 7 of the enclosed newer manuscript version).

2. What is the hydrologic model spatial resolution? Given the small sizes of the catchments (e.g. Table A1), there will be only a few (or only one) TRMM grid cells (at quarter degree). The spatial pattern provided in satellite precipitation data is almost not resolvable for these small catchments. In this regard, the authors may need to perform the experiment at larger catchments, e.g. the comparison of adjusted TRMM driven simulation against the gauge based simulation for the entire Guayas River Basin.

RESPONSE TO THE REVIEWER: Certainly, a good advice. First of all, the model is not distributed but lumped (HMS, for more detail see fig. 1b). In addition, it is not just one grid involved in the study. Actually there are 9 direct grid cells and 6 additional with minor influence on it. In this regard, rainfall ground data for this publication were specifically collected for the aforementioned catchment and not for the whole Guayas River Basin (beyond the project scope –the Abras de Mantequilla wetland). It was observed that, with our correcting procedure, the resulting TRMM resembled the rainfall ground information and thus its spatial pattern.

Line28/page 6: Was the model calibrated using gauge rain? As the year of 2006 was used for calibration, I would consider using a different validation time window for the comparison between TRMM driven simulation and gauge driven simulation.

RESPONSE TO THE REVIEWER: As explained before, calibration was carried out in 2005 (there was a typing mistake in the earlier manuscript version, we are very sorry

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about that). The comparison time span was 2006.

Line24-26/p7, the monthly bias correction has already been conducted in TRMM 3b42 research data. See Huffman et al., 2007.

RESPONSE TO THE REVIEWER: (Page 6, line 27 of the enclosed newer version of the manuscript)…. "Monthly bias correction for the TRMM 3B42 research data has been adopted in previous researches (Bell and Kundu, 2003;Hughes, 2006;Huffman et al., 2007;Rollenbeck and Bendix, 2011;Vernimmen et al., 2012); for instance, in the case of Huffman et al. (2007) using specific global stations".

Line3-15/p8, I am wondering whether the interpolation of the TRMM data to the exact point where the gauges are located is necessary.

RESPONSE TO THE REVIEWER: Yes, it was necessary, because, for this procedure, the ground stations were our "anchor points" whence the spatial distribution of "correcting factors" for the TRMM was originated.

Line 15/p11, is the year 2006 used for calibration using gauge data? The comparison should use a different year.

RESPONSE TO THE REVIEWER: No, as it was explained before, the calibration was in 2005. 2006 was just to show the performances of the model using different sorts of data.

Line 20-22/p12, this is probably true, but is there dam operation involved?

RESPONSE TO THE REVIEWER: No, the dam was not involved for the present article. When we ran our model the Baba dam was still under construction, but the river flow had not been yet interrupted. Therefore, natural conditions along the rivers Vinces, Lulu and San Pablo could still be well considered. Nevertheless, it is pointed out that the potential effects of the dam operation were included in a posterior stage of the project, beyond the scope of this article.

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Figure1, The Vinces sub-basin boundary is not clear. The locations of river gauges for each catchment are needed.

RESPONSE TO THE REVIEWER: Both observations have been incorporated, see the newer versions of figure1 a and b.

The authors are grateful to the reviewer for raising some important concerns about the manuscript. Addressing these concerns certainly has helped improving the revised version of the manuscript.

Anonymous Referee #2

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The authors are to be commended on attempting to develop an approach that can leverage satellite precipitation data for hydrological modeling in rain gauge poor regions of the world. However, the results of the proposed approach are not better, as described in the paper, than using rain gauge data which causes me to question the utility of the proposed method. Additionally, there are numerous issues with grammar and word choice that decreases the overall readability of the manuscript. I tried to indicate a few of these areas in my comments below. I agree with the concerns of Reviewer #1, which I believe must be addressed before this paper is fully accepted for publication. Commentary below are keyed to issues identified by both Reviewer #1 and myself (Reviewer #2) whose comments are linked to each section of the manuscript.

Reviewer #1 - Comment #1 - The first reviewer is quite right in that the specific TRMM product used is not clearly identified. I believe that the authors are referring to the research version of TRMM 3B42 but this needs to be clearly indicated as there can be major difference between research and real-time versions of 3B42. Additionally, the version of TRMM used (version 6 or 7) needs to be clearly indicated - the authors are probably using V6 as V7 was only recently released. Referring to the length of the

simulation I am also curious as to the limited (one year) time period selected. I would imagine that ENSO would have a significant impact on rainfall in this region. Perhaps comparison of an El Nino versus La Nina years would provide greater insights in terms of the overall applicability of the proposed method. Finally, the authors need to realize that early in 2009 there was addition of more satellite data to the TRMM product, which has improved the quality of TRMM in recent years (Huffmann et al. 2010). So I would suggest that modeling focus on the later post-2008 period, which reflects the current abilities of TRMM and its ultimate successor (GPM) to monitor precipitation around the planet.

RESPONSE TO THE REVIEWER: As responded to the first reviewer, the TRMM 3B42 Research (V6) was the one employed here and as such as been noted in the enclosed newer version of the manuscript (for example on page 4 and line 37). However, extreme periods (viz. el Niño, la Niña) were beyond the scope of the present article, but have been suggested as an opportunity for further research (page 10, line 40). As such those events will be taken up considering these events. Finally, as indicated beforehand in this response document, budget limitations constrained the comparison of TRMM data against ground information beyond 2006.

Reviewer #1 - Comment #2 - I also agree with this reviewers comments. In the case of the smaller subbasins the centroid of a TRMM grid cell is acting as effectively one "rain gauge" and this may not be valid in areas with large spatial variations in precipitation like the study area where there is a distinct spatial trend caused by orography. However, the overall Guayas River watershed is certainly large enough to delineate spatial trends in precipitation based on satellite products.

RESPONSE TO THE REVIEWER: Please refer to the answer to the first reviewer (question #2)

Abstract - The abstract is extremely vague in places and the meaning that the authors are attempting to convey is unclear. Specific numbers or description of spatial trends

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need to be provided. Specific examples include: pg. 12436, line 5 "radarbased precipitation" Is the author talking about some ground based radar system or TRMM PR? pg. 12436, line 6 "at least it records somewhat the spatial pattern" pg. 12436, line 7 "The bias remains more or less steady" pg. 12436, line 10 "measuring spot" (and also elsewhere in the paper) I presume you mean the centroid of the quarter degree satellite grid?

RESPONSES TO THE REVIEWER: Clarifications and rewriting have been incorporated in the article as follows (page 2, line 16, abstract): “Nowadays, new technologies are being used to expand the coverage of conventional meteorological datasets. An example of these is the TRMM 3B42 research data (v6) as long as one considers the bias, the type of rainfall and the current coarse spatial resolution. Although in the Guayas River Basin (Ecuadorian lowlands) the initial TRMM information does not match the order of magnitude of the ground-based precipitation, at least it records some features of the rainfall spatial pattern (e.g. decreasing southwards and westwards). The bias remains steady when the temporal resolution increases from yearly to seasonal and monthly data. By means of an empirical disaggregation method, synthetic daily rainfall time series were generated at the TRMM grid centres. These artificial series were incorporated into an existing hydrological model to complement the available raingauge data to assess the model performance. The results were quite comparable with those using only gauge information. Although the model outcomes did not improve remarkably, the contribution of this approach was based on the fact that given a known bias, the satellite data could still be corrected and may resemble the information provided by the raingauges. Therefore, TRMM may supply valuable information in areas scarcely gauged such as the Andean foothills in the Guayas River Basin.”

1. Introduction - This section is generally in good shape. Included below are some minor comments are included below: pg. 12436, line 25 - Check your verb tense agreement pg. 12437, line 27-28 - Please specify what you mean by very good results. Additionally, what to you mean by error? Issues with bias, probability of detection,

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false alarms, or all of the above. I believe you are focusing only on bias and if so please indicate. Please realize that "error" identified through comparison of ground and satellite products encompasses more than bias.

RESPONSES TO THE REVIEWER: corrections incorporated at the corresponding places, the word error has been dropped and instead, bias has been employed thoroughly, (from the enclosed newer version of the manuscript): page 3, line 4: “TRMM is operational since November 1997 and it has released products since 1998”. page 3, line29: “A number of studies have reported that a comparison on annual time scale yields low biases but with finer temporal scales these start increasing.” Error have been replaced by bias throughout this section, e.g. in page 3, line 31

pg. 12438, lines 11-12 - Provide a brief discussion about why TRMM underestimates precipitation due to orography. This after all is the main rationale for the approach developed in this study.

RESPONSE TO THE REVIEWER: (page 4, line 3): “Generally, the spatial resolution of the satellite data plays a key role when attempting to mimic ground precipitation patterns in mountain range foothill areas. When that resolution is too coarse, it usually fails to capture the strong precipitation gradients that take place alongside topographic slopes. Although some influences are expected in this regard, the present study presents a grid whose number of cells in the X direction (longitude) is fair enough (at least 3) to detect variations from west to east, i.e. lowland, foothills and Andes region.”.

pg. 12438, line 12-14 - The sentence that begins "To worsen the scenario ..." is awkward and needs to be reworded. RESPONSE TO THE REVIEWER: The phrase has been reworded: “And precisely these hilly areas are frequently the most unattended by the national weather agencies in terms of ground data availability”. (page 4, line 8 on the revised manuscript)

pg. 12438, line 14-16 - The sentence that begins "Given this background, ..." is disjunct

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from the concepts presented earlier in this paragraph. Please revise or delete

RESPONSE TO THE REVIEWER: The phrase has been revised: “In addition, there is an extreme heterogeneity and uncertainty of the spatio/temporal distribution of the convective rainfall (Bendix et al., 2009)”. (page 4, line 10 on the revised manuscript)

pg. 12438, line 27-28 - Please specify what you mean when you indicate that simulations were not accurate. RESPONSE TO THE REVIEWER: The line has been rewritten: Although the outcomes of those simulations showed some biases when compared with an existent hydrological model, ...” (page 4, line 21 on the revised manuscript)

2.1 The Vinces River catchment - There are some areas in this section that are very confusing and I agree with reviewer #1 that the location and description of the Vince Sub-basin or the location of streamflow gauges is not clear either in the narrative or in Figure 1. Is there a streamflow gauge at the outlet of each subbasin? The location of the Quevedo at Quevedo station at the basin outlet needs to be emphasized in the narrative? Specific comments include: pg. 12439, line 24-25 - The sentence that begins “the drainage area. . ...” is very confusing.

RESPONSE TO THE REVIEWER: Figure 1 has been improved and clarified according to the requests of the two reviewers. Page 5, line 12: “The Vinces River is the third most important waterway in the region, after the Daule and Babahoyo which form the Guayas at Guayaquil City (up to Quevedo station –fig1, 3420 km2, total 5300 km2).” Page 5, line 29: “To that end, the aforementioned catchment was divided into 6 subbasins (Fig. 1b), where four had streamflow gauges available for calibration.”

page 12440, line 1: Please describe the nature of the spatial trend in rainfall, based on I presume rain gauge data

RESPONSE TO THE REVIEWER: The spatial pattern on rainfall (derived from ground data) has been included in the text, indicating the directions of the maximum and minimum values for a typical year. Page 5, line 15: “Annual rainfall (derived from ground

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information) typically varies from around 1000 in the south-western side to more than 3500 mm in the north-eastern zone, close to the Andes (Arias-Hidalgo et al., 2012)."

page 12440, line 5: Poor word choice "going from" Please revise. RESPONSE TO THE REVIEWER: Revised (Page 5, line 18): "In general, two seasons are distinguished across the Ecuadorian lowlands: the wet (rainy) season, (mid-December to May) and the dry period (the rest of the year), characterized by a common absence of rainfall".

2.2 The hydrologic model - More details need to be provided that describe the hydrological model set-up and how precipitation data is incorporated into their model. More details on how the model was calibrated need to be provided. It is unclear how the parameter values in Tables A1-A3 were obtained? Finally, Nash-Sutcliffe coefficients need to also be presented with mass balance error values in Table A4 so that the reader can fully evaluate streamflow simulation results. Why are values not included from the Quevedo at Quevedo station? Additionally, what time scale do these Nash values represent? Daily? Monthly?

RESPONSE TO THE REVIEWER: Observations have been incorporated in the corresponding section (see the new version of the manuscript, page 5, line 34).: "In general, spatial data are very scarce across the Guayas River Basin. This involves a low number of weather stations, a poor density of available meteorological measurements and few calibration points and long gaps throughout the daily time series, etc. Because of these situations, the model made use of simple approaches that require a low number of variables to set it up. In this regard, the effects of storage, canopy, interception, infiltration, evapotranspiration and soil moisture, variables whose measurements were insufficient or poor, were lumped using the constant loss method (Skaags and Khaleel, 1982;USDA, 1986). Physical features such as area, gage weights (rainfall spatial distribution per subbasin), percentage of imperviousness, lag time, recession constant, ratio to peak and others were computed in a first approach using HEC-GEOHMS, a GIS-based tool (Fleming and Doan, 2009). Later on, some of them (e.g. initial discharge, recession constant, lag time) were refined during the calibration process in

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HEC-HMS (see Tables A1, A2 and A3). The model was setup and calibrated for the years 2004 and 2005 against discharge observations at Quevedo en Quevedo, Baba, Pilaló and Toachi stations (spots in Fig. 1b). The average daily Nash-Sutcliffe number (NSC) (Nash J.E. and Sutcliffe J.V., 1970) was around 0.75 (a summary of the NSC numbers for some subbasins is shown in the Table A 4)."

3. TRMM-based methodology and results - There are several issues/concerns/suggestions I have regarding this section. (1) Why did the authors decide to base there spatial interpolation on IDW, which is a method that is known to create bulleye like artifacts, versus Co-Kriging where you can correlate precipitation with elevation and therefore more accurately delineate orographic affects?

RESPONSE TO THE REVIEWER: Co-Kriging may be a better approach than IDW in the sense that it incorporates elevation as another input variable. Nevertheless in practice it requires a decent number of stations (say 50-60, not applicable to low information areas such as the present one) to perform unless showing large uncertainties. In addition, co-Kriging does imply more computational costs than IDW. As for the present case study, the spatial results using IDW were not that patchy (Fig 2). However, we have included in the revised manuscript the possibility of using co-Kriging in future research (page 10, line 24).

(2) If the authors are using the research version of TRMM 3B42 then they are applying second bias correction over that which is already associated with the research version of the product. This suggests that the gauge used by NASA to adjust TRMM is not representative for the examined watershed. Some discussion of this issue would strengthen the authors case for the development of their proposal approach.

RESPONSE TO THE REVIEWER: As was discussed earlier for the reviewer #1 (page 1 of this document), the ground validation points used by NASA have a global character. In this regard, when a smaller area is analyzed, it is preferable to use rainfall ground stations in vicinity to re-validate (re-correct) the original TRMM values, because the

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"global" spots are too far from the study area. Undoubtedly, this has been one of the main drivers of this research.

This discussion has been included at the end of section 1 (page 4, line 34), as well as mentioned/emphasized in the conclusions (page 10, line21) of the manuscript new version.

(3) Perhaps comparison of real-time and research versions of TRMM 3B42 would be to elucidate the cause of bias in the satellite data in their watershed. Once the issue is identified then the authors will be in a much better position to provide a rationalized defense of their proposed approach.

RESPONSE TO THE REVIEWER: It is an interesting and valid suggestion, can certainly be a research item in the future. However, the focus of the present paper is on the use of TRMM data in complementing rain gauge data for improving hydrological modelling. Therefore, the authors find the comparison of real-time and research-version of TRMM 3B42 out of scope. We will take the reviewer's suggestion in our future endeavour.

4. Performance of complementary TRMM data for the HMS model - This section is highly confusing as written. The authors need to present Nash-Sutcliffe coefficients and mass balance error results in a Table for the Quevedo at Quevedo station basin outlet) and include rain gauge only simulations, TRMM only simulation, and simulations based on combination of rain gauge and TRMM data based on the approaches discussed in the previous section. The revised narrative needs to reference this table and then discuss specific events, perhaps from different subbasins, during which the combined approach yields better results than the rain gauge only simulations. This can be demonstrated though documenting the number of peak flow events that are better or worse (in terms of mass balance error and peak timing for the proposed approach versus simulations based on raingauge data. As written the authors make no compelling case why their proposed approach is better than just using rain gauge data to

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drive hydrological simulations in their basin.

RESPONSE TO THE REVIEWER: Mass balance error values have been included in the analysis, not only for Quevedo at Quevedo station but also for the other 3 control locations: Baba Dam, Toachi and Pilalo. In addition, annual values as well as seasonal results are presented in this enlarged table. When comparing results of the model using only raingauge data and the one combining raingauges and 3B42 data there were improvements on mass balance error are observed in cases such as Baba and Pilaló (annual, wet and dry season), as well as in Quevedo at Quevedo (rainy season). However, as for the simulations using only the TRMM values, the outcomes were not as good as for the combined variant. This experience indicates that 3B42 still depends on the ground data not only for re-correction but also in complementing the modeling input data stage (this discussion complements the NSC analysis in the section 4 of the manuscript on page 10, line 3).

The authors are grateful to the reviewer for raising important criticism, believe that addressing them has improved the revised version of the manuscript.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 12435, 2012.

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Interactive Comment

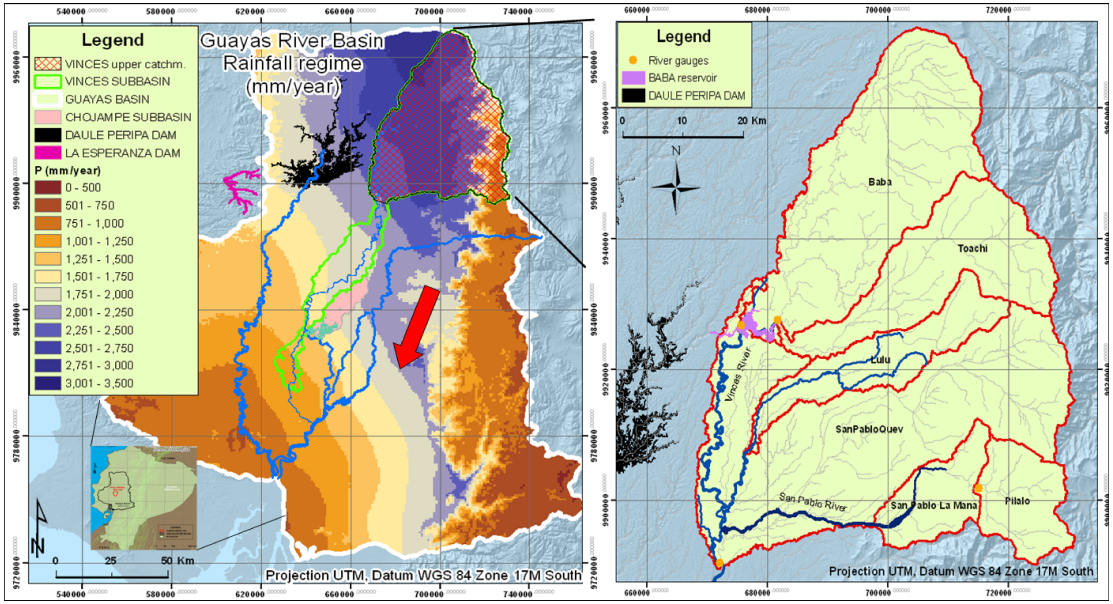

Fig. 1.

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