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# Spatio-temporal validation of satellite-based rainfall estimates in the Philippines

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ABSTRACT

Satellite-based rainfall is an alternative source of information especially for developing countries such as the Philippines where there are many areas that do not have ground observation stations. To maximize the use and potential of the derived precipitation products, it is important to validate these with observation datasets. In this study, two satellite-based rainfall products, CMORPH and TRMM, are compared with observation from eight ground stations in the Philippines and the gridded rainfall dataset, APHRODITE, for 2003 to 2005. Results show that TRMM data give slightly better estimates than CMORPH but both, in general, do not correlate well with observations for all stations. Rainfall during the months of August to December are estimated better by both satellite-based data sets. TRMM and CMORPH also appear to capture well extreme precipitation in the range of 50–200 mm/day. TRMM data, in particular, is able to illustrate the areas consistently affected by frequent occurrences of high rainfall amounts. Spatial correlations show that TRMM and CMORPH perform better in the northeast regions of the Philippines but fail to estimate rainfall in the southern areas. The results indicate that the performance of satellite-derived rainfall products can be dependent on geographical location and the amount of rainfall that is estimated.

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## 1. Introduction

Satellite-based information in the last three decades has been used to derive rainfall values and distributions and many studies have been done to verify the accuracy of these precipitation products. Some of the earliest works were performed in the Meteosat program of Europe in the late seventies (Kramer, 2001) and since then, other satellite sources have emerged and assessments on the accuracy of derived rainfall products have been made in several countries (Collischonn et al., 2008; Javanmard et al., 2010; Jiang et al., 2010; Su et al., 2007). Comparison of four satellite-based precipitation datasets, including Tropical Rainfall Measuring Mission (TRMM) (Huffman et al., 2007) and Climate Prediction Center morphing method (CMORPH) (Joyce et al., 2004), in the United States showed that while real time measurements for extremes are captured, the derived products tend to overestimate or underestimate rainfall measurements frequently depending on the season (AghaKouchak et al., 2011). Habib et al. (2009) analyzed TRMM data for six heavy rainfall events in Louisiana, United States and their results also showed overestimation of lower rainfall rates and an underestimation of higher rainfall rates. On the other hand, TRMM analysis over Thailand for two versions of the dataset showed results of overestimating heavy rainfall events for both versions (Chokngamwong and Chiu, 2008). A study over South Asia by Mishra et al. (2012) used a combination of rain gauge and satellite data to derive daily rainfall spatial distributions, which produced good rainfall estimates over the region when compared with observation data. Results of Dinku et al. (2007) also showed that satellite rainfall products over complex topography, specifically in East Africa, perform reasonably well.

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This study focuses on the evaluation of satellite-based precipitation data over the Philippines where the development and intensity of rainfall is governed and influenced by both mesoscale (including typhoons and monsoon systems) and local processes (including orographic convective systems and land–sea interactions). Further, while rainfall in the Philippines is a valuable source for water resource, it is also a disaster threat during extreme weather events. It is vital, therefore, to have a reliable means of tracking both, spatially and temporally, rainfall amounts and distributions.

The Philippines has a network of rain gauge stations under the Philippine Atmospheric Geophysical Astronomical Services Administration (PAGASA). With sufficient density, rain gauges can be used to establish ground-based spatial graphs of rainfall measurements (Xie et al., 2007; Yatagai et al., 2009) or to improve satellite algorithms (Adler et al., 2000; Krishnamurti et al., 2009). There are continuing efforts to expand the rain gauge network in the Philippines, but currently however, there are many areas that do not have ground stations. Satellite-derived data, therefore, can be an important alternative source of rainfall information, which can provide both the temporal and spatial evolution and distribution of precipitation events. Moreover, these datasets can also be potentially used as input for data assimilation in weather forecasting models (Krishnamurti et al., 2009) for better early warning during extreme rainfall events.

This study aims to evaluate the TRMM and CMORPH satellite-derived rainfall values by comparing these with observations from both ground station and gridded data sets. To do this, TRMM, CMORPH and the gridded Asian Precipitation — Highly-Resolved Observational Data Integration Towards the Evaluation of Water Resources (APHRODITE) data sets are first compared with precipitation data from eight stations in the Philippines from 2003 to 2005. Monthly correlations are next obtained to investigate the performance of satellite-based data relative to seasonal variations. The ability of the TRMM and CMORPH data sets to capture different rainfall amounts is then assessed via ratio analysis. Next, in order to obtain a spatial correlation for satellite data, CMORPH and TRMM were correlated with data coming from APHRODITE. Lastly, spatial comparisons between CMORPH, TRMM and APHRODITE are examined to 1) locate potential areas in the Philippines where satellite information may be used reliably and 2) pinpoint areas susceptible to extreme rainfall and to quantify the capability of satellite-based measurements to capture these extremes for the three year period.

## 2. Location and data sources

The Philippines is an archipelago with over 7000 islands. It is located between 4°40′ to 21°10′N, 116°40′ to 126° 34′E, just west of the Pacific Ocean. It is a tropical country, dominated by two distinct seasons: wet and dry. The wet season is characterized by the southwest monsoon and is usually from May to October, and it is during this period when most storms and typhoons develop near the Philippines. The dry season, on the other hand, is from November to April and is dominated by the northeast monsoon. The average annual rainfall in the country is about 2000 mm, but regions in the north and eastern portions of the country can receive rainfall amounts of as much as 4000 mm in a year.

This study used rain gauge observation data from the Philippine weather bureau, two satellite based rainfall estimates, CMORPH and TRMM 3B42V6, and the gridded precipitation dataset APHRODITE V1003R1. These datasets are described below.

### 2.1. PAGASA data

There are 59 operational PAGASA synoptic stations distributed over the Philippines. Records for daily precipitation begin in different years, with some measurements starting since 1951. In this study, data for eight stations for the three years of 2003, 2004, and 2005 are used to validate satellite-derived rainfall. The stations are chosen in different geographical locations with different climate types. The eight stations with their coordinates and the corresponding climate type are listed in Table 1.

### 2.2. TRMM 3B42V6

TRMM is a joint project between the Japan Aerospace Exploration Agency (JAXA) and National Aeronautics and Space Administration (NASA). TRMM satellite has five sensors on board, three of which are used for monitoring rain: the Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible Infrared Scanner (VIRS). TRMM Multisatellite Precipitation Analysis (TMPA) is done by: 1) calibrating and combining estimates for microwave precipitation; 2) the calibrated microwave rainfall is then used for estimating infrared precipitation; 3) both infrared and microwave rainfall estimates are then combined and rain gauge data are incorporated to produce the final satellite product (Huffman et al., 2007). TRMM has several versions available for data analysis, but for this study, TRMM

**Table 1**
List of the eight ground observation stations with the corresponding locations and climate type.

| Station name | Latitude | Longitude | Climate type |
|---|---|---|---|
| Port Area, Manila | 14.59° N | 120.97° E | I — pronounced wet and dry season; maximum rain in June–September |
| Laoag City, Ilocos Norte | 18.2° N | 120.59° E | I — pronounced wet and dry season; maximum rain in June–September |
| Tuguegarao, Cagayan | 17.61° N | 121.73° E | III — short one to three months dry season and no pronounced maximum rain period |
| Calapan, Oriental Mindoro | 13.41° N | 121.17° E | III — short one to three months dry season and no pronounced maximum rain period |
| Legaspi City, Albay | 13.14° N | 123.73° E | II — no dry season with very pronounced maximum rain period |
| Mactan Airport, Cebu | 10.30° N | 123.96° E | III — short one to three months dry season and no pronounced maximum rain period |
| Zamboanga, Zamboanga del Sur | 6.91° N | 122.08° E | III — short one to three months dry season and no pronounced maximum rain period |
| Davao City, Davao del Sur | 7.3° N | 125.83° E | IV — rainfall evenly distributed throughout the year with no distinct dry season |

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