

ملاحظات:



Cairo University

# **HYDROLOGIC CALIBRATION OF TRMM-BASED MULTI SATELLITE PRECIPITATION OVER ARID REGIONS**

By

**Khaled Asaad Ahmed Ahmed**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**DOCTOR OF PHILOSOPHY**

In  
**IRRIGATION AND HYDRAULICS ENGINEERING**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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**Title of Thesis:**

**Hydrologic calibration of TRMM-based multi satellite precipitation over arid regions**

**Key Words:**

TRMM Satellite, Hydrology, Short Duration Rainfall, Remote Sensing, Arid Region.

**Summary:**

Rainfall depth and distribution is a mandatory input in many fields such as real-life forecasts, hydrological studies, and many engineering applications. Tropical Rainfall Measuring Mission (TRMM) delivered a unique 17-year dataset of global tropical rainfall from 1998 AD to 2014 AD, with 3.0 hours interval. Comparing, assessment, and calibrating TRMM based on the ground stations is very valuable to investigate the use of rainfall estimates from TRMM and moreover, to calculate daily and sub-daily depths and ratios to fill the gaps of sparse rainfall recording gauge networks. Kingdom of Saudi Arabia (KSA) has been selected as the study area representing the arid region. Six statistical performance criteria were carried out to evaluate TRMM on daily basis with respect to corresponding ground stations. Hydrologically, the propose of this work is to know the extent of the possibility of relying on TRMM in generating extreme rainfall values at high return periods specially in ungauged areas.

## **Disclaimer**

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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# Table of Contents

Disclaimer .....	I
Acknowledgements.....	II
Table of Contents .....	III
List of Tables .....	VI
List of Figures .....	VII
Abstract .....	IX
Chapter 1: Introduction .....	1
1.1    General .....	1
1.2    Problem Statement .....	1
1.3    Research Objectives.....	4
1.4    Thesis Organization .....	5
Chapter 2: Literature Review.....	6
2.1    Rainfall Types and TRMM.....	6
2.1.1  Rainfall Types.....	6
2.1.2  TRMM Measuring and Instruments.....	8
i.    Precipitation Radar.....	8
ii.   TRMM Microwave Imager.....	8
iii.  Visible and Infrared Scanner .....	9
iv.   Clouds and the Earth's Radiant Energy Sensor.....	9
v.    Lightning Imaging Sensor.....	9
2.2    Validation of TRMM information .....	10
2.2.1  Early TRMM validation researches .....	10
2.2.2  Recent TRMM validation studies .....	11
2.3    TRMM and satellite studies in Arid Regions .....	13
2.4    Use of TRMM data in operational hydrology.....	15
2.4.1  Use of TRMM data in rainfall-runoff modeling .....	16
2.4.2  Use of TRMM data blended with ground data for purposes rather than rainfall-runoff modeling .....	17
Chapter 3: DATA COLLECTION AND SCREENING .....	19
3.1    Study Area .....	19
3.2    Satellite-based precipitation data set.....	23
3.3    Precipitation data .....	23
3.4    Check for Outliers.....	33
3.4.1  Plot box .....	34



3.4.2	Extreme studentized deviate .....	34
3.4.3	Dixon-type tests .....	35
3.4.4	Charles Equation .....	35
3.5	Rainfall Data .....	36
3.6	Rainfall Frequencies, Durations, and Depths .....	36
3.7	Rainfall Data Presentation .....	36
3.8	Rainfall Data Accuracy .....	37
3.9	Relationships between rainfalls of different durations .....	37
3.9.1	Depth-duration Ratios for the United States .....	37
3.9.2	Depth-duration Ratios for other countries .....	38
3.10	Synthetic Storm Hyetograph .....	40
Chapter 4: Methodology .....		42
4.1	Data processing .....	42
4.1.1	Ground measurements and data preparation .....	42
4.1.2	TRMM data preparation .....	43
4.2	Data analysis .....	43
4.2.1	Coordinate matching process .....	45
4.2.2	Analysis of TRMM files .....	45
4.3	Performance Criteria .....	45
4.4	Comparison process .....	47
4.5	Frequency Analysis .....	49
4.5.1	Normal Distribution .....	49
4.5.2	Log-Normal Distributions .....	50
i.	Two-parameter lognormal distribution (LN2) .....	50
ii.	Three-parameter lognormal distribution (LN3) .....	51
4.5.3	Generalized Extreme Value distribution (GEV) .....	51
4.5.4	Pearson Type III distribution (P3) .....	52
4.5.5	Log-Pearson Type III Distribution .....	52
4.5.6	Selection of best fit frequency distributions .....	53
Chapter 5: Results and discussion .....		55
5.1	Performance Criteria .....	55
5.1.1	Biases and Errors of the Satellite data .....	55
i.	Mean Absolute Error (MAE) .....	55
ii.	Root Mean Squared Error (RMSE) .....	55
iii.	Relative Bias% (RB%) .....	55
5.1.2	Correlation Coefficient% (CC%) .....	59
5.1.3	Contingency Calculations for the Satellite Estimates .....	59

i.	Probability of Detection (POD%).....	60
ii.	Critical Success Index (CSI%).....	60
5.2	Rainfall Frequency Analysis.....	62
5.2.1	Ground Rainfall Stations 24 hours Frequency Storms for 2, 5, 10 & 25 years return periods.....	63
5.2.2	TRMM 24-Hours Frequency Storms for 2, 5, 10 & 25 year Return Periods .....	68
5.2.3	Ground Stations – TRMM comparison for the 24-hr Storms of the 2, 5, 10& 25 Years Return Periods.....	73
5.3	TRMM Calibration to Ground Stations .....	79
5.4	Sub-daily 3 to 24 Hours Depth Ratio.....	87
5.4.1	Ground Stations 3/24 hrs Ratio.....	87
5.4.2	TRMM 3/24 hrs Ratio.....	87
5.4.3	(3/24) hrs Ratio Comparison.....	87
5.4.4	(3/24) hrs. Ratio Calibration .....	91
	Chapter 6: Summary, Conclusions, and Recommendations.....	92
6.1	Summary .....	92
6.2	Conclusions.....	92
6.3	Recommendations for future works.....	93
	Appendix A: Matlab Script.....	94
	Appendix B: Ground Station Data .....	96
	References.....	151

## List of Tables

Table 3-1: Saudi Arabia sub-regions and their numbers of rain gauge stations. ....	20
Table 3-2: Available Ground Station coordinates, name, Code and record span .....	25
Table 3-3: Summary for stations with available coordinates.....	30
Table 3-4: Comparison between USA and Australia ratios .....	39
Table 3-5: Comparison between USA and USSR ratios .....	39
Table 3-6: SCS Cumulative, Dimensionless One-Day Storms.....	41
Table 4-1: TRMM process example for extracting the 3 hours and daily records .....	43
Table 4-2: TRMM record for the 3 hours and daily for each day example .....	43
Table 4-3: TRMM day- day Statistical performance criteria.....	46
Table 4-4: TRMM Contingency detection POD and CSI.....	46
Table 4-5: Day to Day Contingency detection Example .....	47
Table 4-6: Day to Day Statistical Performance Measurements Example .....	48
Table 4-7: Day to Day Statistical Performance Measurements Result Example.....	48
Table 4-8: Values of Frequency Factors (K) for Standard normal distribution.....	50
Table 4-9: Selected Values of Frequency Factors (K) for (LP3).....	53
Table 5-1: Distributions best fit ranking.....	62
Table 5-2: Ground Station – TRMM comparison Summary .....	73

# List of Figures

Figure 1-1: Arid and Semi-Arid Regions Map .....	2
Figure 1-2: TRMM Covered Area .....	3
Figure 1-3: TRMM final product example .....	4
Figure 1-4: TRMM records against Ground stations .....	4
Figure 2-1: Rainfall Types .....	7,8,9
Figure 2-2: Comparison between TRMM and ground stations in two locations in Sinai .....	17
Figure 3-1: Saudi Arabia District Map .....	24
Figure 3-2: Study Area Elevation map .....	26
Figure 3-3: Ground Stations with Daily Records Span in years overlapping with TRMM ....	28
Figure 3-4: Ground Stations with Sub-Daily Records in years .....	248
Figure 3-5: Location Map for Available Ground Stations with coordinates .....	36
Figure 3-6: Location Map for Ground Stations with Daily Records .....	37
Figure 3-7: Location Map for Ground Stations with Sub-Daily Records .....	38
Figure 3-8: Box plot and its quantiles .....	39
Figure 3-9: Depth-Duration Relationship for U.S. and Some other Countries .....	44
Figure 3-10: Depth-Frequency Relationship for 1 YR, 5 YR, and 50 YR .....	44
Figure 3-11: Storm types in USA .....	47
Figure 3-12: SCS 24-Hours Hypothetical Storms .....	47
Figure 4-1: Flowchart of the evaluation process .....	52
Figure 4-2: Normal and Standard Normal Distributions .....	58
Figure 5-1: TRMM Mean Absolute Error (MAE) .....	65
Figure 5-2: TRMM Root Mean Squared Error (RMSE) .....	66
Figure 5-3: TRMM Relative Bias% (RB%) .....	67
Figure 5-4: TRMM Correlation Coefficient% (CC%) .....	68
Figure 5-5: Probability Of Detection% (POD%) .....	70
Figure 5-6: Critical Success Index% .....	71
Figure 5-7: Ground Rainfall stations 24hr storm for 2 Years Return Period .....	73
Figure 5-8: Ground Rainfall stations 24hr storm for 5 Years Return Period .....	74
Figure 5-9: Ground Rainfall stations 24hr storm for 10 Years Return Period .....	75
Figure 5-10: Ground Rainfall stations 24hr storm for 25 Years Return Period .....	76
Figure 5-11: TRMM 24-hr Storms for 2 Years Return Period .....	78
Figure 5-12: TRMM 24-hr Storms for 5 Years Return Period .....	79
Figure 5-13: TRMM 24-hr Storms for 10 Years Return Period .....	80
Figure 5-14: TRMM 24-hr Storms for 25 Years Return Period .....	81
Figure 5-15: Ratio 24 hr. depth – 2 years .....	83
Figure 5-16: Ratio 24 hr. depth – 5 years .....	84
Figure 5-17: Ratio 24 hr. depth – 10 years .....	85
Figure 5-18: Ratio 24 hr. depth – 25 years .....	86
Figure 5-19: Ratio 24 hr. depth – Ground/TRMM .....	87
Figure 5-20: 24 Hours Depth (in mm) for Frequency Storms Calibration for All Stations .....	91
Figure 5-21: 24 Hours Depth (in mm) for Frequency Storms Calibration Excluding Rub' Al Khaly, and South Mount. ....	93
Figure 5-22: 24 Hours Depth (in mm) for Frequency Storms Calibration excluding Hyper Arid and High Mountains (as Rub' Al Khaly, South Mount. And Al Jouf) .....	95
Figure 5-23: Ground Station 3 hrs. to 24 hrs. Depth Ratio for the 2,5,10 and 25 Years Return Period .....	98

Figure 5-24: TRMM 3 hrs. to 24 hrs. Depth Ratio for the 2,5,10 and 25 Years Return Period .....99

Figure 5-25: TRMM ground difference for the 3 hrs. to 24 hrs. average depth ratio..... 101

Figure 5-26: Average 3 to 24 hrs. ratio calibration..... 101

Figure 5-27: Average 3 to 24 hrs. ratio calibration after excluding Qassim and Ha'il..... 101

## Abstract

Tropical Rainfall Measuring Mission (TRMM) delivered a unique 17-year dataset of global tropical rainfall from 1998 AD to 2015 AD, with 3.0 hours interval. Comparing, assessment, and calibrating TRMM based on the ground stations is very valuable to investigate the use of rainfall estimates from TRMM and moreover, to calculate daily and sub-daily depths and ratios to fill the gaps of sparse rainfall recording gauge networks. Arid regions studies were based on monthly and annually precipitation summation. Daily comparison, and extreme events studies are very limited. Most of previous studies were made based on a poor number of ground stations. Kingdom of Saudi Arabia (KSA) has been selected as the study area. The Ministry of Environment Water and Agriculture (MEWA) provides more than 1450 ground rainfall stations. Coordinates of 883 ground stations were determined. The rainfall measurements were made available for of 385 daily rainfall stations for the same TRMM's period, and 152 sub daily ground stations records earlier than TRMM. The dataset thus consists of 6.9 million readings (after eliminating stations with less than three years of record) with their corresponding 14 million readings from TRMM (3 hours interval). Considering this large amount of data that was not available for previous studies for statistical or hydrological assessment of TRMM, the outcomes of such assessment were presented in the form of spatial maps for the whole of KSA. Six statistical performance criteria were carried out to evaluate TRMM on daily basis with respect to corresponding ground stations. These measures are Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Relative Bias (RB), Correlation Coefficient (CC), Probability of Detection (POD), and Critical Success Index (CSI). Statistical results show very good results as the average of statistical measures are as follow MAE is 3.19, RMSE is 7.19, RB is 0.004, CC% is 8.08%, POD% is 68.55%, and CSI% is 18.04%. This is due to the arid region nature of limited number of rainy days.

Hydrologically, the propose of this work is to know the extent of the possibility of relying on TRMM in generating extreme rainfall values at high return periods specially in ungauged areas. To achieve the purpose, the following methodology was applied. Rainfall ground data were collected from available rainfall gauges for daily and sub-daily records in the study area. TRMM data were also collected for the same ground station's locations. Frequency analyses were undertaken on the rainfall data from ground stations and TRMM sources, using several distributions and the best fitting is selected. Rainfall depths, and rainfall ratios of 3-hr to 24-hr depths at different return periods were derived for ground stations and TRMM, then compared and spatially presented. 24-hr rainfall depths as well as (3-hr to 24-hr) rainfall depths ratio for rainfall depths were compared for TRMM and ground stations. Comparisons were spatially presented for different return periods. Moreover, regression equations were developed to calibrate the TRMM based on the ground stations and predictions were extended to cover the entire study area for locations where ground station data are not available. The results shows that the 24-hr ratios average for (2,5,10,25 years freq. storm) is 1.2 (TRMM/Ground), the average of (3-hr to 24-hr) ratio is 0.75 for ground stations and 0.76 for TRMM, keeping in mind that, the SCS type II ratios were not valid for use in some studied arid regions (e.g. Jeddah –Makkah, KSA) as the SCS type II (3-hr to 24-hr) ratio is 0.6.

# **Chapter 1: Introduction**

## **1.1 General**

Rainfall depths estimate is essential for many applications especially in complex terrain or remote areas. In such areas where rainfall stations are not available or are scattered, satellite precipitation records can be considered helpful as they can give a full spectrum of rain depths instead of one point as the ground stations. In arid regions the rainfall guesstimates have their unique behavior.

Most of Arabian countries are in arid and semi-arid regions. Therefore, rainfall studies are very important. Arid regions are defined as areas where rainfall is insufficient for crop production, while semi-arid regions are defined as areas where rainfall is enough for short production season crop. Figure 1-1 shows arid and semi-arid regions worldwide.

Rainfall depths estimate is considered as the major component of the hydrological and global energy cycle, as well as primary inputs for hydrological, meteorological and climate models. Such models require reliable and accurate precipitation data for successful simulations. Rainfall depths are essential in predicting natural hazards such as floods and droughts. Rainfall intensities, duration and spatial pattern are needed for various applications and simulations.

## **1.2 Problem Statement**

To determine accurate rainfall depths, a ground rainfall station network with very dense coverage is needed, but unfortunately, this is not available everywhere. Moreover, the measured rainfall is a point depth; however, it should be applied on an area and transformation from a point estimate to an aerial one is not reliable or accurate. In the absence of dense coverage of rainfall stations, new approaches to get spatial distribution are needed. One of the major advantages in this line is the use of precipitation estimation from remote sensed information using a satellite such as the TRMM (Tropical Rainfall Measuring Mission). TRMM is a NASA (National Aeronautics and Space Administration) and JAXA (Japan Aerospace Exploration Agency) joint mission.