Production of a High-Resolution Improved Weather Radar Precipitation Estimation Map Using Gauge Adjustment Bias Correction Methods

Kaveh P. Yousefi *, M. Tuğrul Yılmaz *, Kurtuluş Öztürk **, İsmail Yücel *, Koray K. Yılmaz***

* Department of Civil Engineering, Middle East Technical University, Turkey
** Remote Sensing Division, Turkish State Meteorological Service, Turkey
*** Department of Geology, Middle East Technical University, Turkey

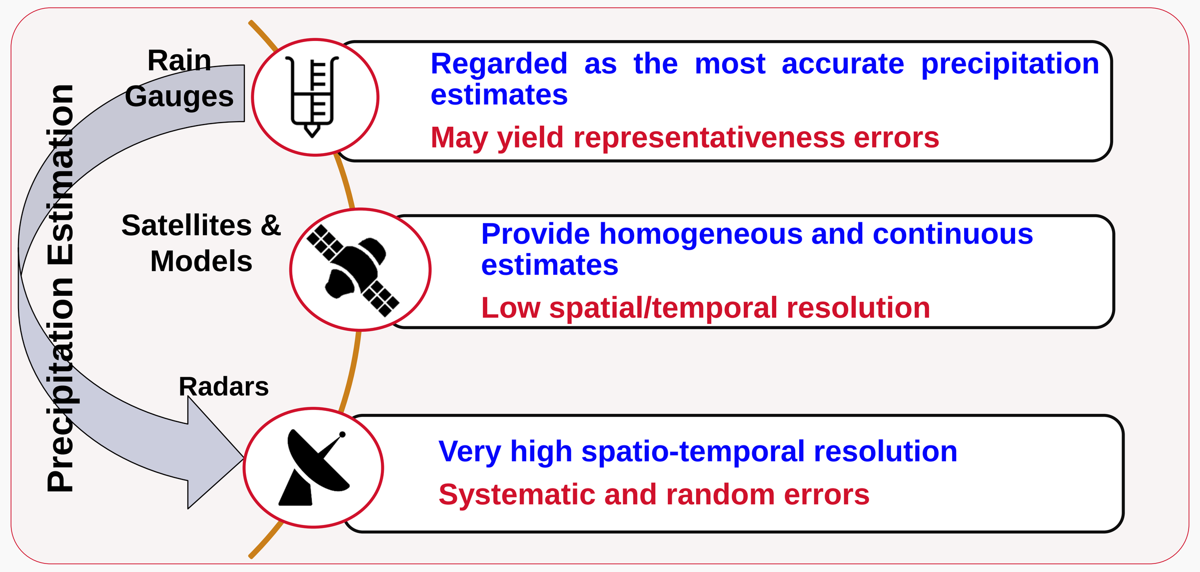
kaveh.yousefi@metu.edu.tr, tuyilmaz@metu.edu.tr, kozturk@mgm.gov.tr, iyucel@metu.edu.tr, yilmazk@metu.edu.tr

Abstract

This study evaluates relative performances of different statistical methods to enhance radar-based quantitative precipitation estimation (QPE) quality using rain gauge network data. Initial investigations of these algorithms are implemented using datasets obtained from 17 C-band Turkish weather radars. Finally, high-resolution composite radar-based precipitation maps of Turkey was produced by choosing the best methods among all bias adjustment methods. A summary of our initial results is given.

Motivation

Considering the advantages and disadvantages of all common precipitation measurement platforms, combining the advantageous aspects of gauge-based observations and radar-based estimates to eliminate the systematic and the random errors of radar estimates has been the main motivation for many studies that merge radar- and station-based measurements (Goudenhoofdt and Delobbe, 2009).



Majority of the studies on the real-time correction of radar-based product are highly dependent on the availability of a high-density gauge station network at each time step of correction. This study, evaluates and tests four common real-time gauge adjustment methods (which require gauge observation data at each time step of correction) and two time-independent bias correction methods (which do not require gauge data and are operationally simpler to implement).

Study Objectives

- Investigation of radar-based estimates over entire radar network in Turkey
- Evaluating performance of bias correction methods based on observations obtained from radar-based estimations and rain gauge network
- Production and validation of a composite high-resolution precipitation map based on radar-gauge merged estimates.

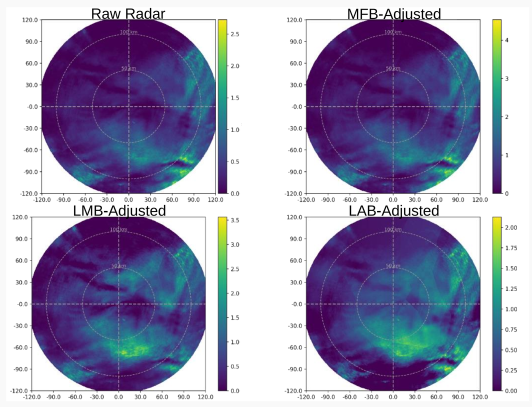
Tools

Wradlib module in python was used for reading and processing radar data and gauge adjustment applications.

Methodology

1. Hourly Gauge Adjustment Methods : (Heistermann et al., 2013)

These methods adjust the gridded radar-based estimates by referring to gauge measurements. The methods vary based on assumption of the error type (multiplicative/additive) and its distribution.

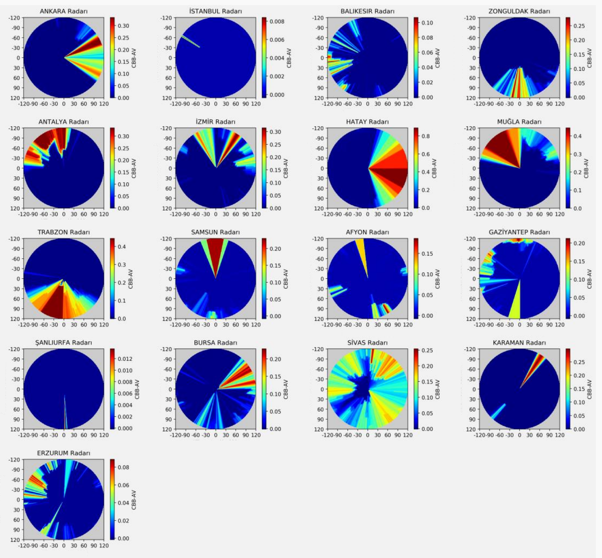


2. Time-independent Bias Correction Methods:

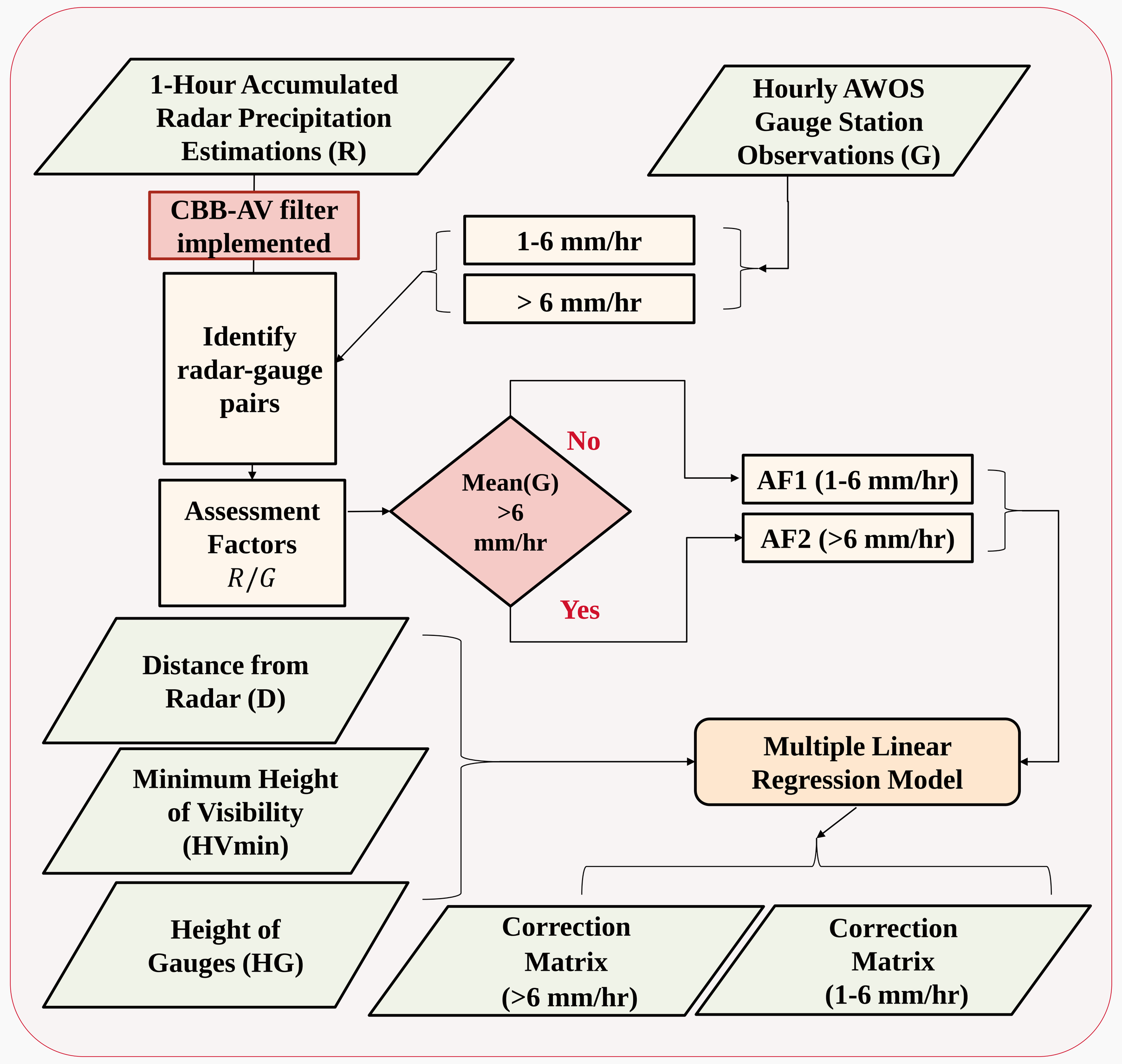
2.1. Multiple Linear Regression (MLR): (Gabella et al., 2000)

A linear relationship is generated by utilizing assessment factors (AF) obtained by calculating the ratio of radar-based estimations to gauge-based observations (R/G) as a dependent variable, and three time-independent variables: **Distance from Radar (D), Minimum Height of Visibility (Hvmin), Height of Gauge (HG).** Two different regression models were defined according to the precipitation rate: Heavy Precipitation (>6mm/hour) and Light Precipitation (1-6mm/hour).

Despite the other applications of this methodology (Ozturk et al., 2012), the effect of Cumulative Beam Blockage (CBB) was taken into account in measuring the Minimum Height of Visibility. Moreover, CBB-AV (The average CBB over all radar elevation angles) was measured. In the composite map, the areas with CBB-AV higher than 30% are discarded due to extreme underestimation. However, this threshold can be re-evaluated according to the obtained results.

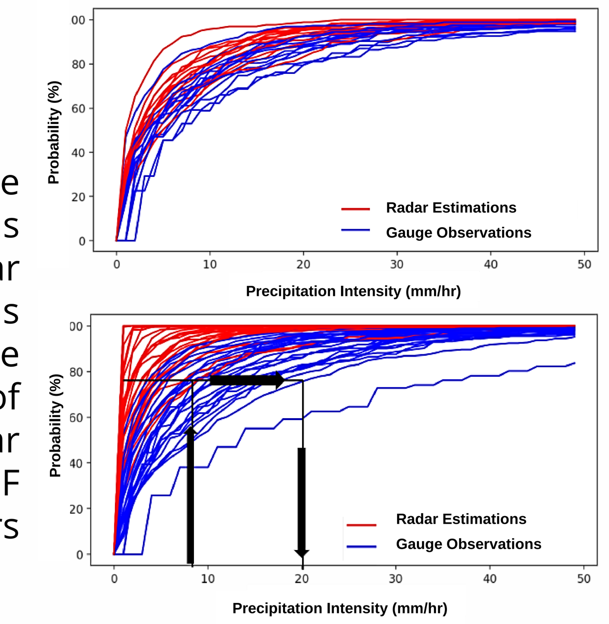


CBB-AV measured for each radar based on their elevation tasks



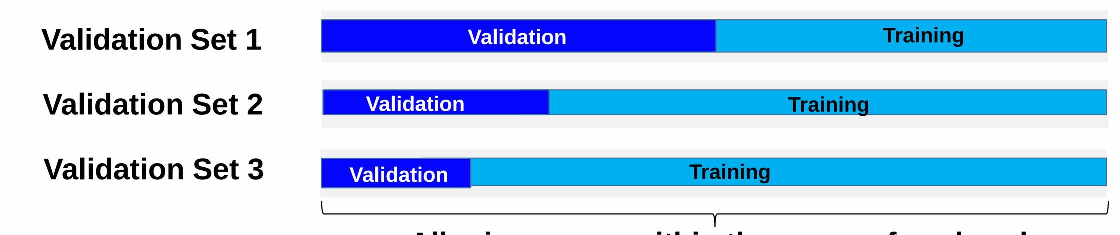
2.2. CDF Matching Bias Correction (CDF):

In this method, The rain gauge observations are regarded as references, and the radar estimations over the gauge stations are corrected by matching the cumulative distribution function of the reference data into the radar pixel values. Figures show the CDF matching of two different radars (Hatay and Antalya).



Cross-validation:

Three different validation sets were used to test the performance of the methods. In cross validation, 50%, 25%, 12.5% of the station-based observations are excluded (assumed ungauged) for validation while the remaining are used for the calibration in different experiments. In addition to three validation sets, testing fields including 50 three-collocated gauges will be used for validating the final composite products.



All rain gauges within the range of each radar

Results

1. General Results:

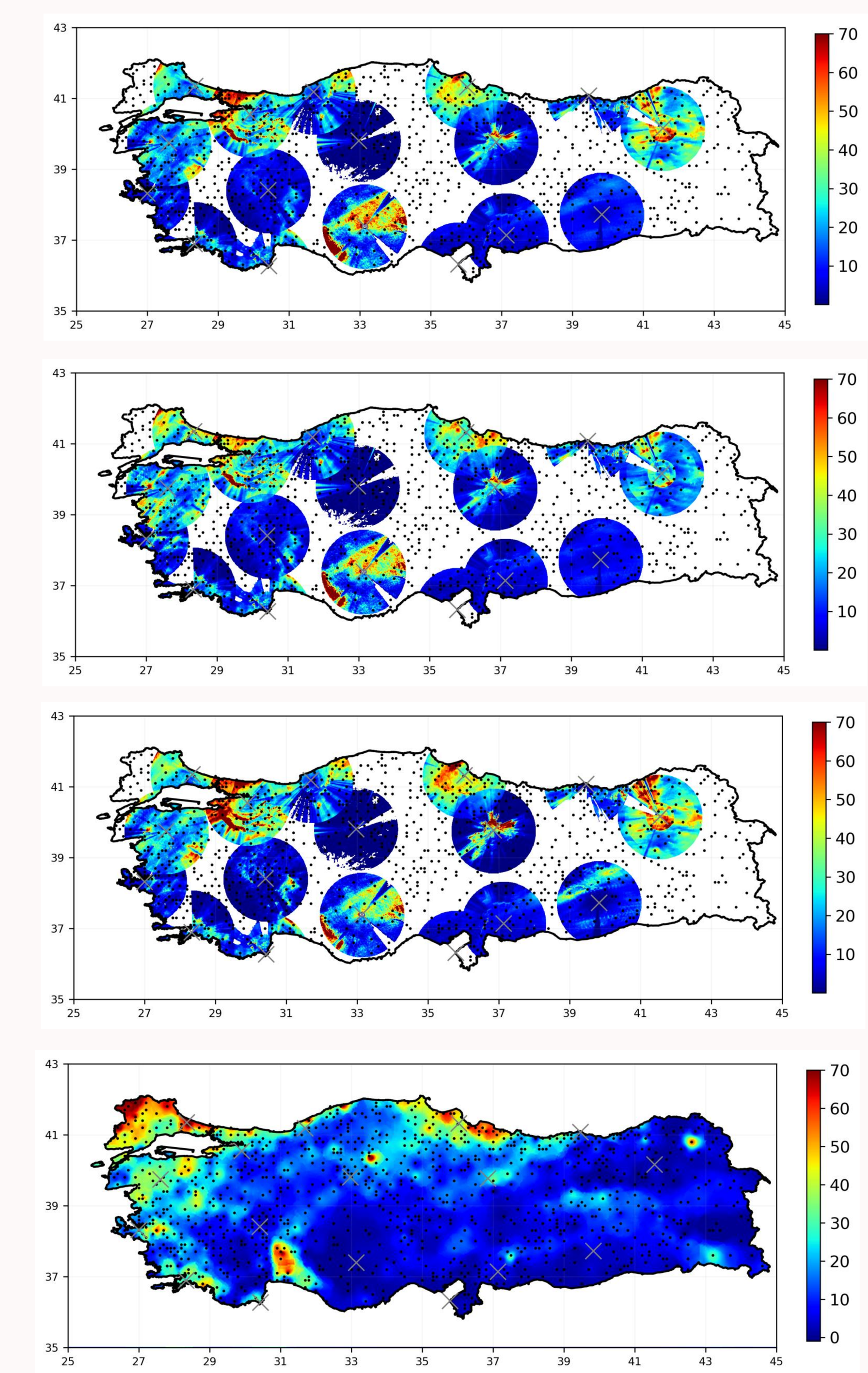
Among the **gauge adjustment methods**, both the calibration and validation results obtained from all precipitation events (>=0.2 mm/hr) of the year 2017 suggest that LMB and LAB adjustment methods perform better both in terms of compensating the underestimation and decreasing the RMSE values (Daily mean error increased from -1.4 mm up to -0.4 mm and daily RMSE values decreased from 6.2 mm/day to 0.80 mm/day in average.)

Among the **time-independent methods**, both MLR and CDF methods are shown to be compensating a large portion of radar precipitation underestimation (from -1.4 mm/day into -0.5 mm/day in average). However there was no significant increment in RMSE values.

2. Results from a case-study:

The following table represents validation results (average of three validation sets) from precipitation accumulation of radar-based only and estimations retrieved from different radar-gauge hourly bias corrected methods against the rain gauge observations for the year 2015 over Antalya radar. The observations are obtained from 28 rain gauges in 120km range of the radar. This radar is prone to beam blockage, and it has a CBB-AV value >=10% over 11 stations and >=20% over 4 stations out of 28. The results are obtained from all gauges. Thus, radar-only estimates are generally lower than the rain gauge observations.

Mean Total Precipitation (mm/year)			Mean Error (mm/year)
Method	Radar Estimations	Gauge Observation	
Radar	298.26	811.22	- 512.96
MFB (Mean Field Bias)	737.55		-73.67
LMB (Local Multiplicative Bias)	573.61		-237.61
LAB (Local Additive Bias)	851.65		40.43
LMIB (Local Mixed Bias)	735.18		-76.04
MLR (Multiple Linear Regression)	625.31		-185.91
CDF (CDF matching)	445.12		-366.1



Figures showing the accumulated precipitation in a large-scale 5 days precipitation between 2017/12/17 to 2017/12/21 generated based on radar-only estimations (first), LMB corrected radar estimates (second) and CDF matched estimations (third). Fourth figure shows the interpolated gauge observations using inverse distance weighting method.

References

Gabella, Marco, Jürg Joss, and Giovanni Perona. 2000. “Optimizing Quantitative Precipitation Estimates Using a Noncoherent and a Coherent Radar Operating on the Same Area.” Journal of Geophysical Research Atmospheres 105(D2): 2237–45.

Goudenhoofdt, E, and L Delobbe. 2009. “Evaluation of Radar-Gauge Merging Methods for Quantitative Precipitation Estimates.” Hydrology and Earth System Sciences 13: 195–203.

Heistermann, M., S. Jacobi, and T. Pfaff. 2013. “Technical Note: An Open Source Library for Processing Weather Radar Data (Wradlib).” *Hydrology and Earth System Sciences* 17(2): 863–71.

Ozturk, Kurtulus, Firat Bestepe, and Mehmet Zeybek. 2012. “Improving the Accuracy of Time-Cumulated Radar-Based Rainfall Estimates in the Event of a Flood.” 1(1): 2012.

cc BY