Comparisons of Rain Estimates from Ground Radar and Satellite over Mountainous Regions

Xin Lin*, Chris Kidd*, Jing Tao+, and Ana Barros+

* NASA Goddard Space Flight Center , and ESSIC/University of Maryland, College Park, +Duke University, Durham, NC.

Introduction

Rainfall estimates over mountainous regions are known to have large uncertainties due to highly variable and complicated precipitation features associated with topography:

•Rain gauges are not only sparse over remote mountainous regions, but also suffer from calibration and representativeness errors.

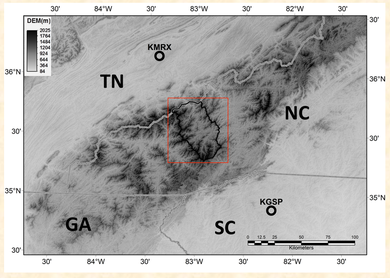
•Ground radar data may have large biases due to factors such as undetected low-level precipitation under the lowest radar beam elevation caused by radar beam blocking by mountains.

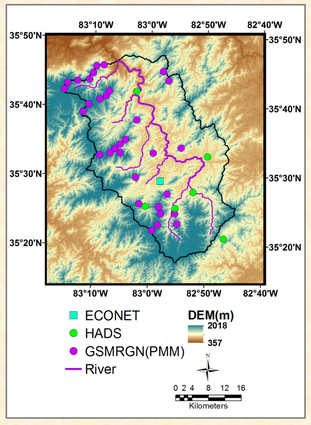
•Due to the sensitivity and spatial resolution of satellite instruments and retrieval algorithms, satellite rainfall products also have problems over mountainous regions due to topography and partial beam filling. For PMW retrievals, the highly variable land surface with different vegetation, snow and ice, and soil moisture makes it difficult to distinguish rainfall against the complicated surface background.

In this study, we use a gauge-enhanced high-resolution radar rainfall product as the reference to evaluate two operational surface radar and gauge-radar merged rainfall products (radar only and conventional gauge-adjusted). With a better understanding of the statistical characteristics including the strength and weakness of these radar rainfall products, satellite rainfall retrievals from TRMM PR and TMI are also coincidently examined against a 5-minute radar-only rainfall product over mountainous regions.

Specifically, we intend to 1) quantitatively examine the rain detection and statistics as a function of rain intensity in different seasons over mountains; 2) discuss strengths and limitations of ground-based radar-only and radar-gauge merged products in estimating rain occurrence and rain accumulation; 3) evaluate to what extent the current space-borne precipitation radar could help to improve rainfall estimates in mountainous regions.

Data and Analysis methods:





•Region: The Pigeon River basin in the Southern Appalachian Mountains

•Period: Y2008 to Y2011

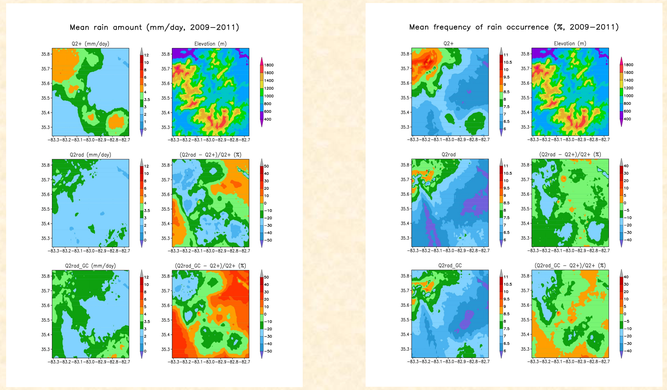
•Data from the PMM rain gauge network are merged with ground radar data (Q2) to better describe the variability of local rainfall over mountainous regions.

Two experimental Next Generation, multi-sensor QPE rainfall products, the original radar-based Q2 product (Q2rad) and the conventional rain gauge-corrected Q2 product (Q2rad_GC), have biases over mountainous regions.

A bias correction method utilizing the probability density function (PDF) and cumulative distribution function (CDF) of areal rainfall fields is developed to merge enhanced gauge data with the hourly rain gauge-corrected Q2 product

This adjusted Q2 data (Q2+) is used as "ground truth" in this topographically complicated terrain to evaluate other rain estimates.

Comparisons of surface radar rainfall products

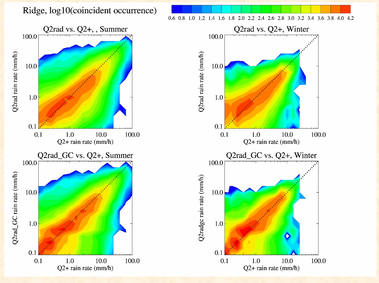


Annual mean rain amount and frequency of rain occurrence from surface radar rainfall products and their normalized differences in the Pigeon River basin over the Southern Appalachian Mountains.

•The Q2+ product exhibits critical variability with apparent ridge-valley gradients. The Q2+ total indicates an area of high mean precipitation extending northwest to southeast, corresponding well with major mountain ridges of the Pigeon River basin. Frequency of rain occurrence also indicates a similar pattern.

•The radar-only Q2rad and the gauge-corrected Q2rad_GC underestimate with respect to the Q2+ product over the major mountain ridges. This underestimation may result from a number of factors including the limited number of gauges available for correcting the Z-R relationship over mountains, undetected low-level precipitation under the radar beam, and radar beam blocking by mountains.

Frequency of rain occurrence and fraction of rain amount as a function of rain intensity over mountain ridges.



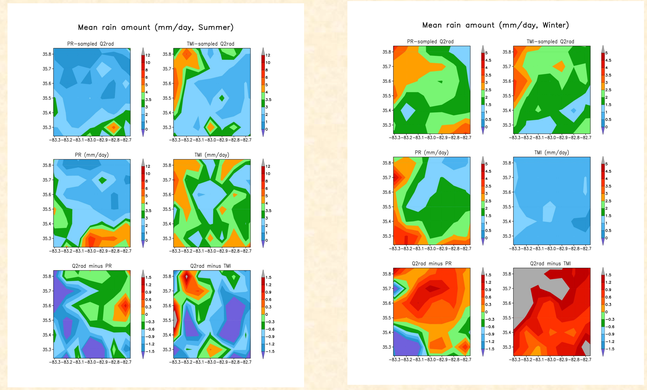
Joint distributions of coincident rain sample numbers

•During the summer, both Q2rad and Q2rad_GC appear to underestimate the frequency of intermediate and heavy rain occurrence (rain intensity larger than 3 mmh^{-1}), but overestimate light rain occurrence (rain intensity smaller than 3 mmh^{-1});

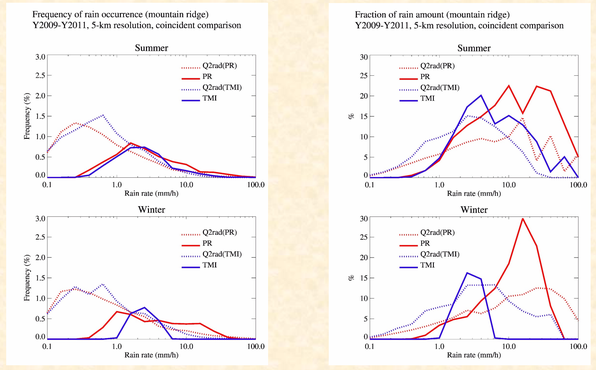
•Some intermediate and heavy rain samples are identified as lighter rain samples in the Q2rad and Q2rad_GC. The Q2rad and Q2rad_GC therefore slightly overestimate the total of light rainfall but greatly underestimate the total at intermediate and heavy rain intensities.

•During the winter, both Q2rad and Q2rad_GC significantly underestimate the incidence of light rain events and moderately underestimate incidence of intermediate rain events.

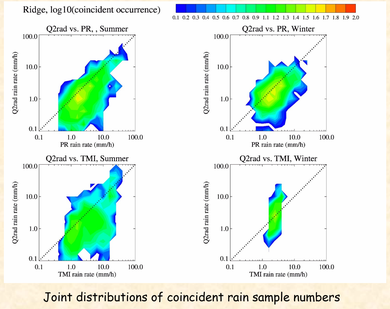
Comparisons with satellite rain retrievals



Summertime and wintertime mean rain amount from PR and TMI against the sensor-sampled Q2rad product



Frequency of rain occurrence and fraction of rain amount as a function of rain intensity over mountain ridges.



Joint distributions of coincident rain sample numbers

•For intermediate and heavy rain intensities, PR generally overestimates the rain occurrence and rain amount compared to the Q2rad product. Although PR can't well detect light rain below 1 mm/hr. due to the sensor's detection capability, the PR and PR-sampled Q2rad overall indicate a similar distribution during both summer and winter.,;

•The TMI has significant problems in retrieving wintertime precipitation over mountainous regions since it cannot detect any rain intensities below 1.0 mmh^{-1}, and above 6 mmh^{-1}. This issue reflects the fact that the current version 7 GPROF algorithm over land has significantly large space for improvement to retrieve wintertime precipitation over mountain areas.

Summary:

•The three surface radar rainfall products in general agree well with one another over mountainous regions

• The PR performs equally well with the high-resolution radar-only rainfall product over complex terrains at intermediate and heavy rain intensities during the summer and winter. .

•.TMI, on the other hand, requires improvement to retrieve wintertime precipitation over mountain areas.