Improving precipitation estimation in mountainous west region of United States by incorporating space-borne radar measurements into National Mosaic QPE system

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1. INTRODUCTION

Reliable ground-based radar measurements are essential to accurate quantitative precipitation estimation (QPE) and quantitative precipitation forecasts (QPF). However, there are some limitations with the current US S-band WSR-88D radar network (NEXRAD). For example, atmosphere surveillance at low level is insufficient at the far range. Radar resolution volume might be within or above the melting layer, leading to over- or underestimation of precipitation. In addition, beam blockage exists in many mountainous regions (e.g., Mountainous West of US). Ground-based radar QPE in these regions could be largely underestimated.

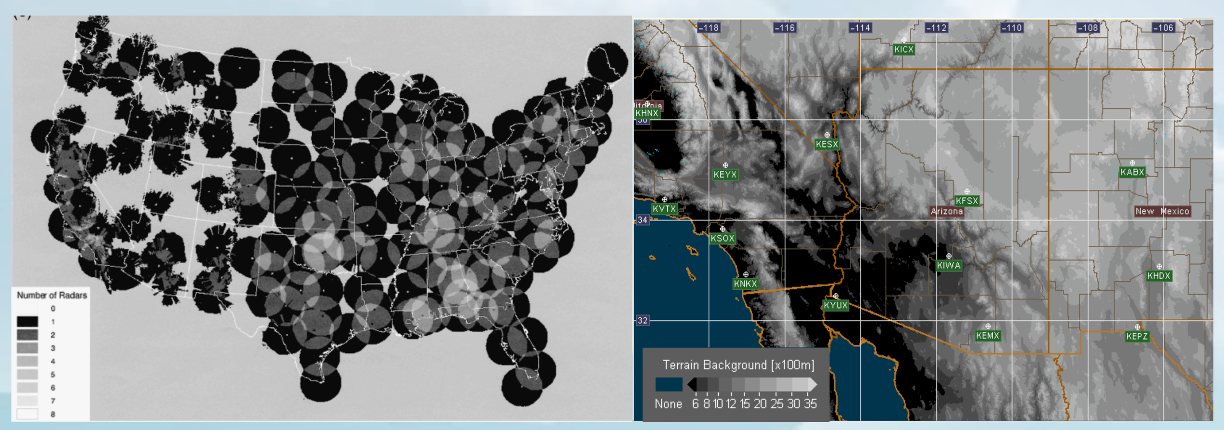


Figure 1. (left) Effective WSR-88D radar coverage at a constant height at 3km Above Ground Level [from Maddox et al. (2002)]; (right) DEM of the state of Arizona. It also shows the sparse distribution of ground radars.

The Tropical Rainfall Measurement Mission (TRMM) Precipitation Radar (PR) measurements provide seamless regional and global precipitation information, which can be an important supplement to the ground-based radar observations, filling in the gaps of NEXRAD network and correcting/improving radar measured vertical profiles of precipitation. The objective of current study is to enhance QPE by incorporating TRMM PR products into the NEXRAD-based National Mosaic QPE (NMQ) system. This study also guides us to apply the to-be-launched Global Precipitation Mission (GPM) dual-frequency PR to improve the QPE by future polarimetric NEXRAD network.

2. PRELIMINARY STUDY

Our preliminary study focuses on the region of Arizona, constructing representative vertical profile of reflectivity (VPR) using TRMM PR measurements to correct the NEXRAD-based VPR measurements, and thereafter improve the NMQ QPE at low atmosphere level and/or regions affected by the beam blockage.

A. Physically-based VPR model:

We introduce a physically-based VPR model to connect Ku-band TRMM measurements with S-band NEXRAD measurements.

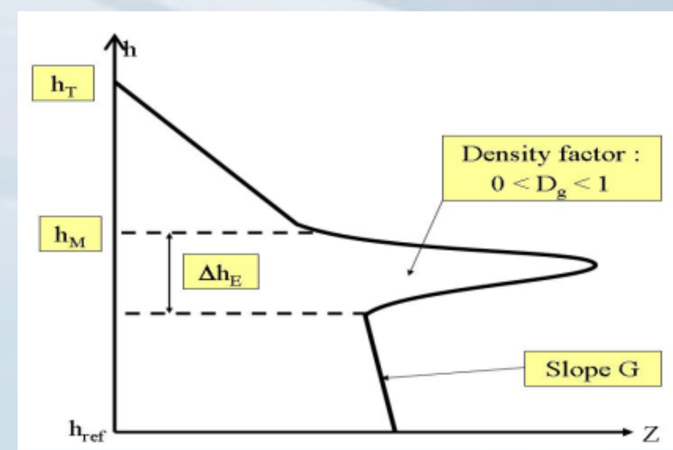


Figure 2. The parameters in physically-based VPR model.

1) h_T: the top of the precipitating cloud; 2) h_M: the interface between solid and melting layers; 3) Δh_E: the melting layer's thickness; 4) D_g: density factor, varying between 0 (light snow) to 1 (hail); 5) G: the slope of VPR in the liquid layer.

B. Low level correction based on VPR:

Step 1: Precipitation Classification

Because of large differences between the vertical structure of convective-stratiform precipitation, we segregate the two types of precipitation first.

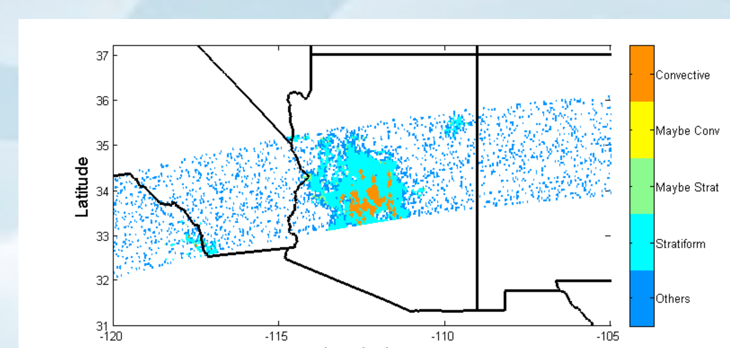
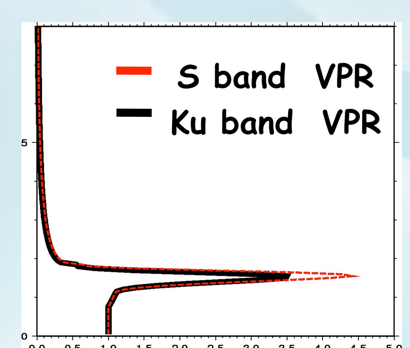


Figure 3. TRMM PR precipitation type classification.

Step 2: Representative VPR

We use physically-based VPR model to find a representative VPR from TRMM VPRs. (Figure 4. An example of representative Ku-band VPR and its conversion to S-band VPR)



Step 3: Apply Correction

We simulate the 'apparent' VPR from 'true' representative VPR and apply corrections to NMQ Q2 data.

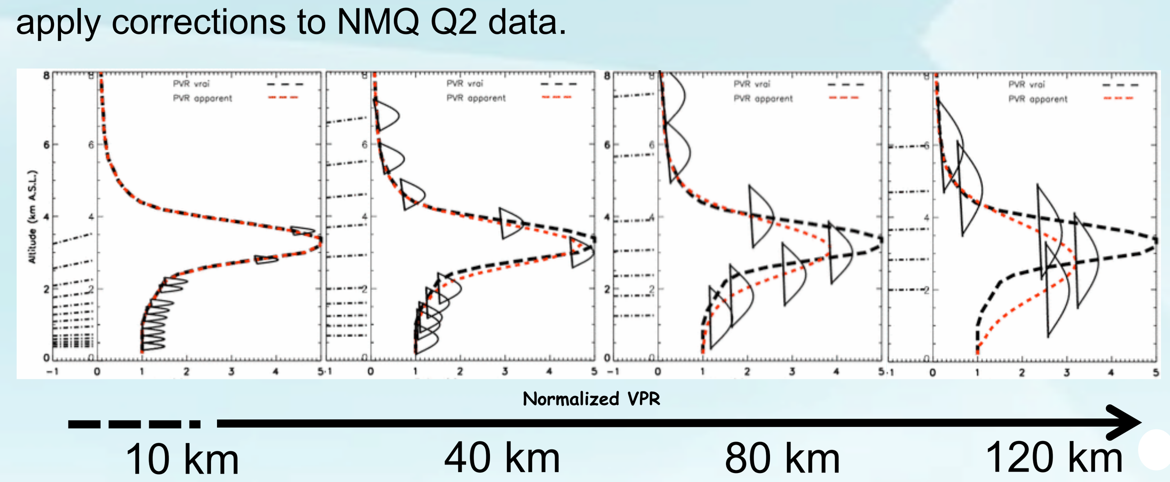


Figure 5. Illustration of a physically-based VPR model (black line) and an apparent (red line) VPR.

The VPR corrected reflectivity, Zc, is obtained by:

$$Zc(x,y) = Zobs(x, y)/\rho(x,y)$$

$\rho(x,y)$: Apparent normalized VPR at each pixel.

3. RESULTS

Case: 08Z on 28 Feb. 2010

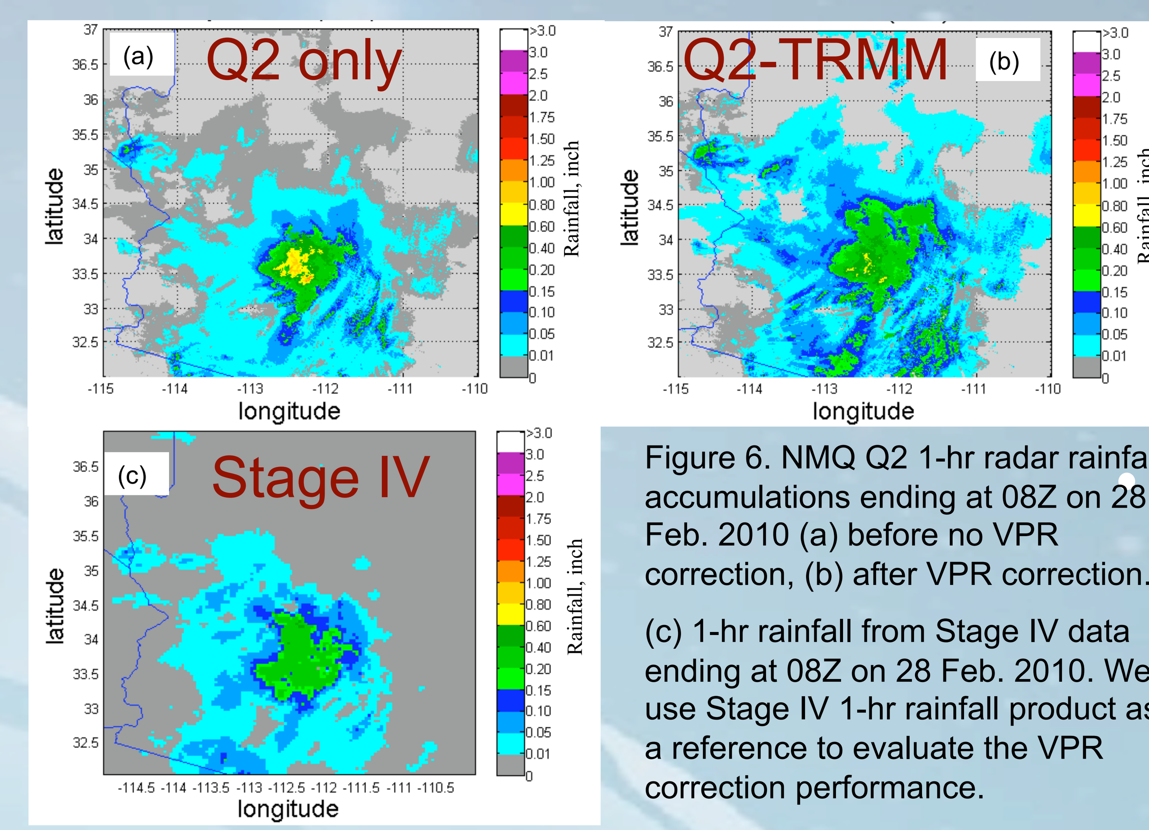


Figure 6. NMQ Q2 1-hr radar rainfall accumulations ending at 08Z on 28 Feb. 2010 (a) before no VPR correction, (b) after VPR correction.

(c) 1-hr rainfall from Stage IV data ending at 08Z on 28 Feb. 2010. We use Stage IV 1-hr rainfall product as a reference to evaluate the VPR correction performance.

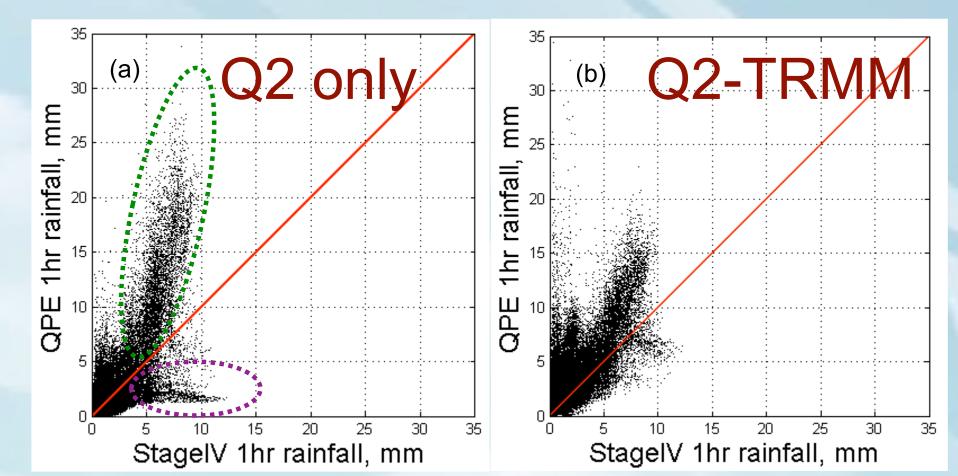


Figure 7. The scatter plot of (a) before VPR correction radar 1-hr rainfall accumulations vs. Stage IV QPE; (b) after VPR correction radar QPE vs. Stage IV QPE.

The points in the green dash circle indicate overestimation of radar measurement caused by the bright band contaminant. The purple circle indicates the pixels where radar beams sample the ice region. After VPR correction, the radar QPE in the two circles are both improved. The statistical results are shown in the following table.

Table. The five events' statistical results of radar QPE (before and after correction) compare to ground rain gauge measurements point to point.

Events	CC		Relative Bias		MAE		RMSE	
	Before	After	Before	After	Before	After	Before	After
20090208	0.23	**0.47**	-69.08	**-50.40**	0.63	**0.48**	1.18	**0.94**
20091208	0.20	**0.46**	-39.52	**-12.58**	1.36	**1.00**	2.39	**1.55**
20100122	0.09	**0.18**	-85.90	**-51.05**	4.27	**3.10**	6.25	**4.59**
20100228	0.71	**0.72**	29.55	**13.87**	2.44	**1.75**	3.98	**2.54**
20100307	0.11	**0.19**	-16.93	**-5.09**	**0.97**	0.98	1.89	**1.81**
Summary	0.27	**0.34**	-38.23	**-21.09**	2.64	**2.15**	4.50	**3.93**

4. SUMMARY

- In this study we demonstrate the integration of the TRMM PR products into the NMQ ground-based rainfall estimation system to fill in gaps with existing NEXRAD radar coverage.
- We analyze five events occurred in Arizona region from 2009 to 2010. The representative VPR is derived based on a physical model and from TRMM VPRs.
- With Ku-to-S band and radar beam adjustment, the representative VPRs are used to correct the ground-based rainfall estimation. Results show encouraging improvements.

Challenges:

- Mismatch of spatial and temporal resolution.

	TRMM PR	NMQ Q2
Spatial Res.	4.3 km (horizontal) and 250 meters (vertical)	15 times per day. But the same region update only several times
Temporal Res.	1 km (horizontal) and 31 levels (vertical, 500m-18km	~ 5 minutes

- Large physical variation of VPR, even within the same storm.

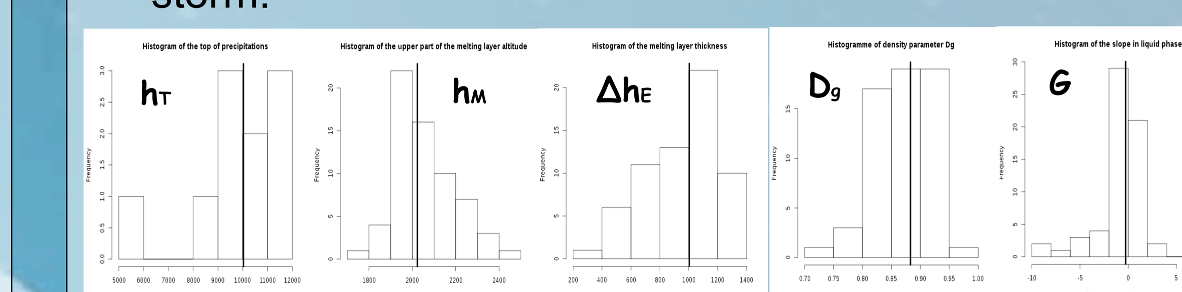


Figure 8. The histogram of the five VPR model parameters in one storm.

- Topographic effect on the VPR

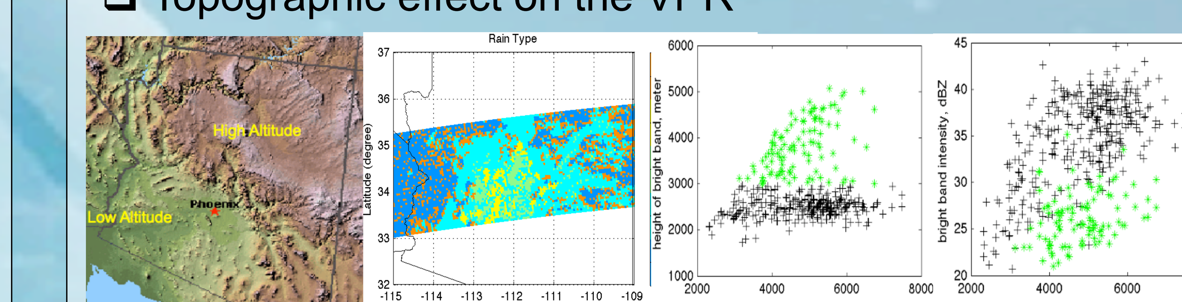


Figure 9. An example shows the characteristics of melting layer depend on topography.

- Other factors: season, precipitation types

5. FUTURE PLAN

- Analyze 10+ years TRMM PR data. Quantify the VPR characteristics for different precipitation types, seasons, and terrain.
- Develop model-based VPR correction method using local representative VPR instead of global one.
- Develop VPR model in the dual-pol/dual-frequency scheme to accommodate future needs.

6. REFERENCES

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