Merging Different Satellite Measurements of Rainfall Using Multi-scale Imagery Technique

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Objective

Precipitation from multiple passive microwave instruments in low Earth orbit are available, and often there are overlapping swaths. Data from each instrument will have both phase (spatial dislocation) as well as texture (intensity) errors. Merging of the datasets using simple weighted averaging leads to errors that are often compounded when compared to any one of the parent datasets. A multi-scale filter is required to decompose the overlapping measurements and recombine them in a systematic fashion.

Motivation

Image fusion is a useful technique to fill in the gaps of one image (one satellite measurement) using another one. This technique is useful in combining information from multiple images of the same scene. It is possible to have several images of the same scene providing different information although the scene is the same. This is because each image has been captured with a different sensor.

Methodology

The procedure for producing the merged images consists of two steps: *texture simulation* and *shape simulation*. Here, **texture** is the **rain rate** and **shape** is the **rain support**. (Figure 1)

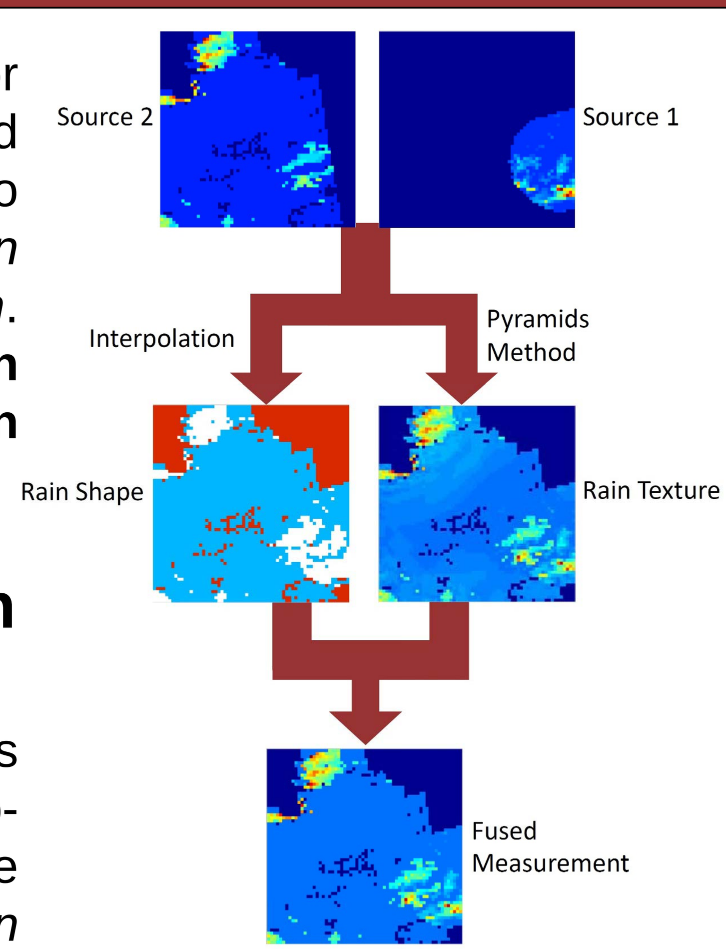

Figure 1 - Methodology

Texture Production

First, the two input images are decomposed into sub-images using steerable filter. Then, a *fusion algorithm* is applied to merge the sub-images and produce a fused sub-image. Finally, an inverse transformation will produce the merged image. Figure 2 shows the algorithm for texture production.

For the fusion algorithm, each pair of sub-images from the two input images are decomposed using the Laplacian filters. Then, the absolute value maximum selection (AVMS) scheme is applied to merge the two pyramids of the sub-integration. Next, the fused sub-image is produced by inverse transformation of the integrated pyramid of the input sub-images. Figure 3 shows the structure of the fusion rule.

Shape Production

The procedure is that a linear interpolation is applied to create a merged image of the two input ones. Then, the pixels that were missing in both of the input images are set to be missing in the final image too.

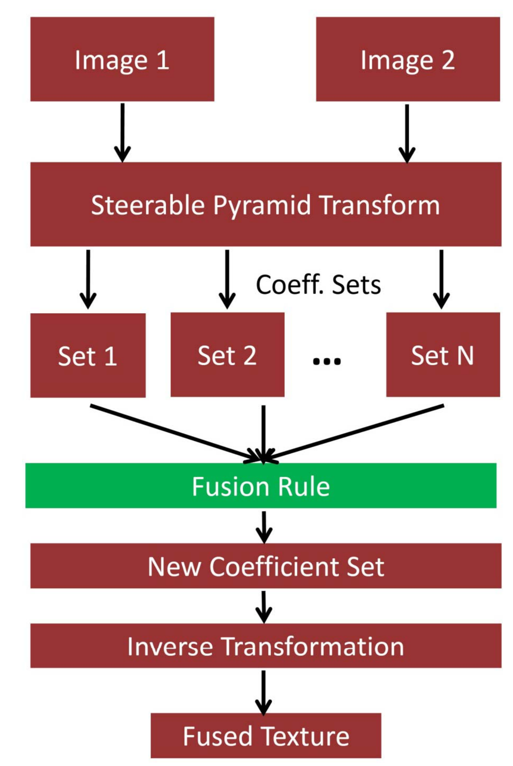

Figure 2 – Texture Production

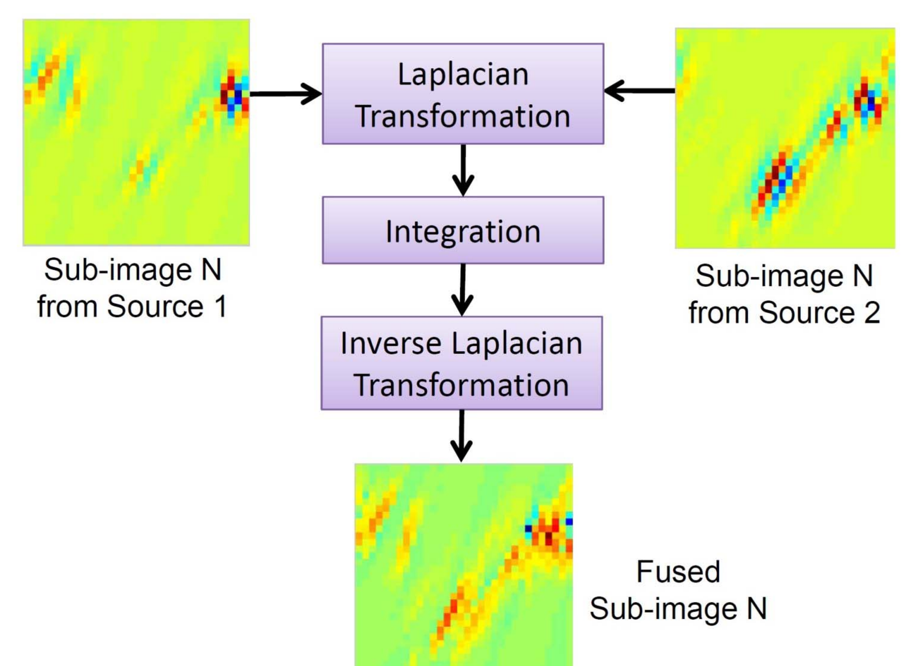

Figure 3 – Fusion Rule

Steerable Pyramid

Steerable pyramid is a linear multi-scale, multi-orientation and self-inverting image decomposition introduced by Freeman and Adelson [2]. This decomposition method uses steerable filters which are a class of filters in which a filter of arbitrary orientation is synthesized as a linear combination of a set of basis filters. Figure 4 shows a sample image and it's decomposition.

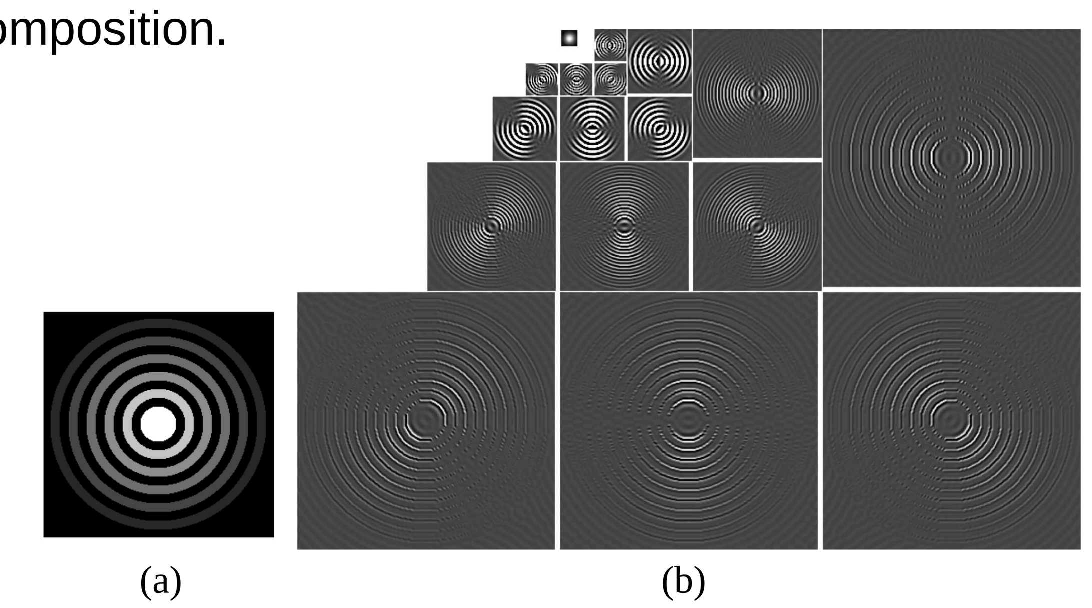

Figure 4 - Steerable Image Transform. *(a)* Original image, *(b)* Steerable, bandpass coefficients in a multi-scale pyramid representation

Dataset

The satellite measurements of rainfall for this study are obtained from AMSU-B instruments on board NOAA-15 and NOAA-16; and Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (product 2A12). An independent set of surface-based radar measurements produced by NEXRAD Network (NEXRAD-IV) is assumed as the true measurement and used to evaluate the results of the model.

For this study, all the data are mapped to a common spatial gird of 0.25°×0.25°covering the Central U.S. region ranging 26:10°- 42:10° N and 107:85°-91:85° W. The period of study was from Jan. 2004 until Dec. 2010.

Results

Two evaluations are presented here: POD/FAR statistics and PDF/CDF of rain rate.

Figure 4 shows the distribution of POD and FAR in the original measurements and in the final fused measurements; moreover, the results of other fusion methods is also presented. It's clear that the proposed method is giving promising results.

Figure 5 shows probability density function and cumulative distribution function of the rain rate. The comparison between the graphs of the true measurement and the fused one shows that this method is preserving the distribution of rain rate better than other methods. In addition, Kolmogorov-Smirnov test (with 5% significance level) only accepts the CDF of the fused method to be from the same distribution as the true one.

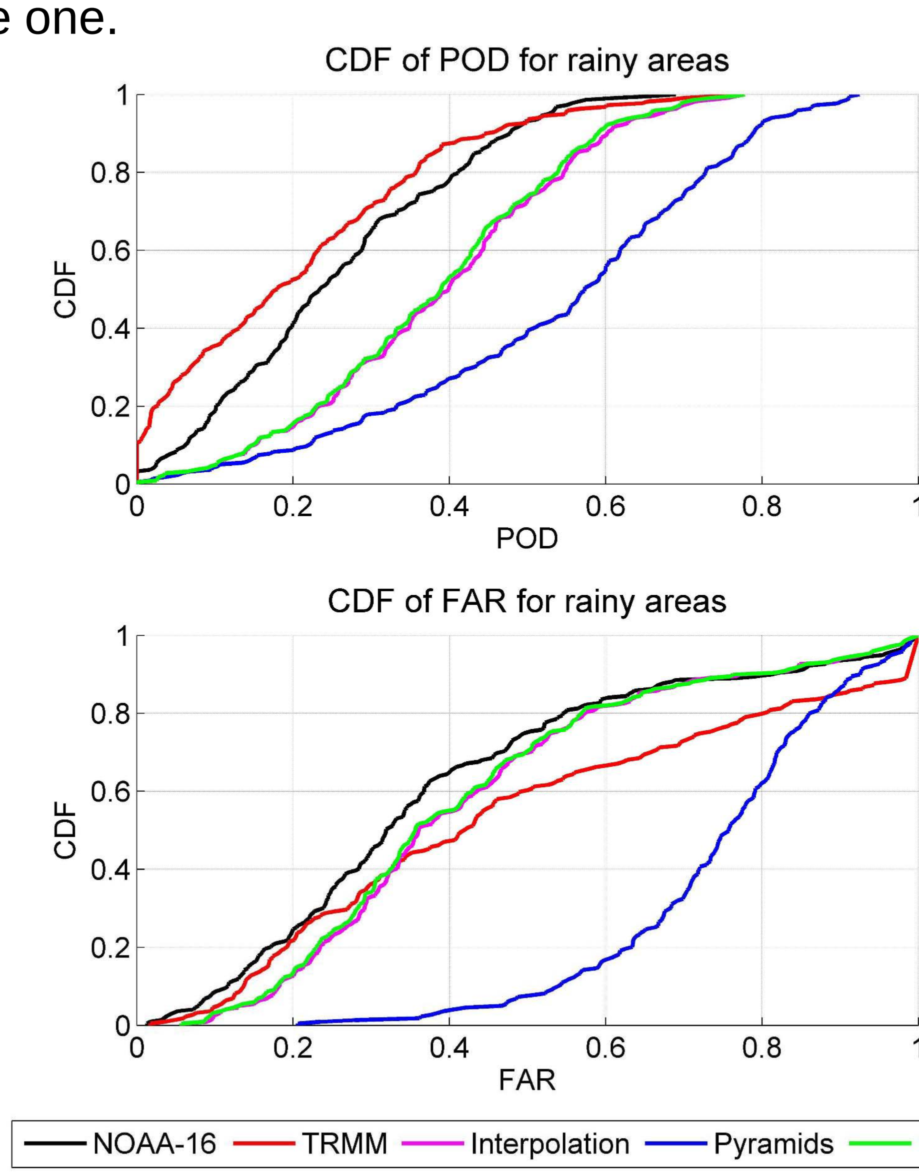

Figure 5 – CDF of POD and FAR for different merging methods

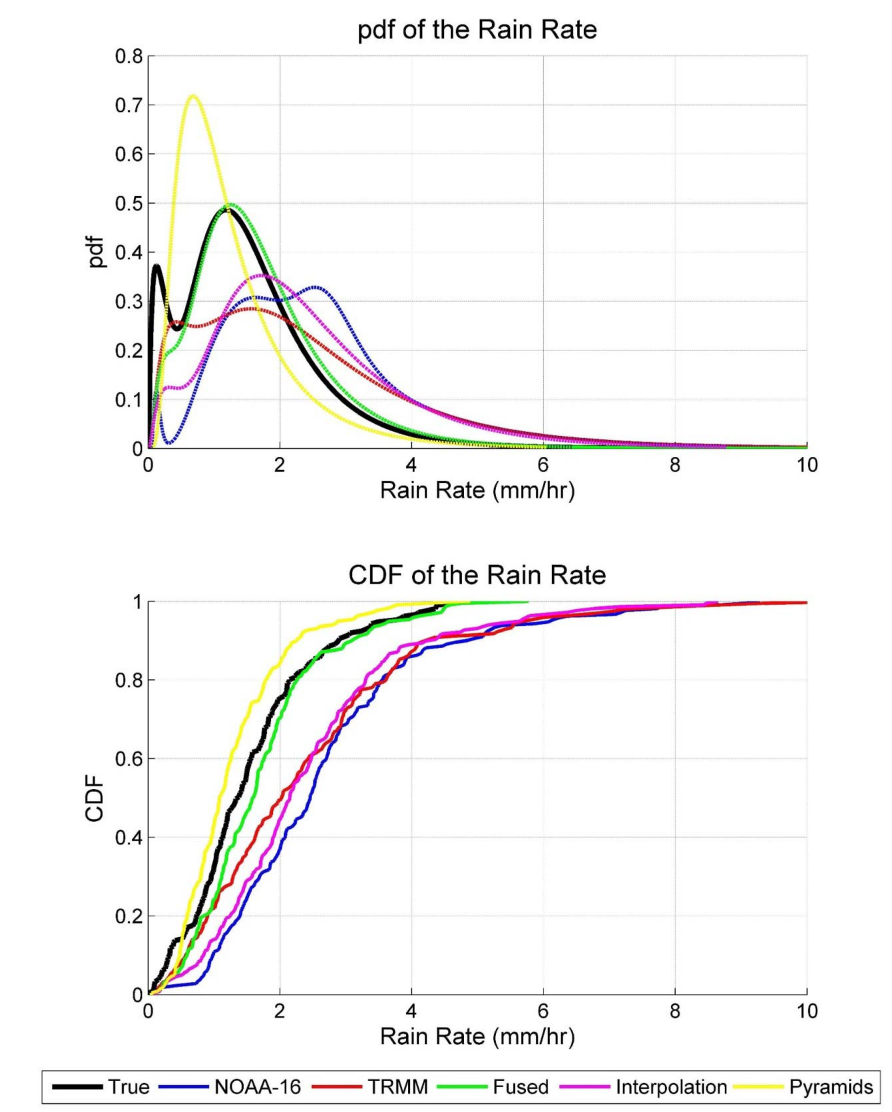

Figure 6– PDF and CDF of rain rate in the results and true measurement

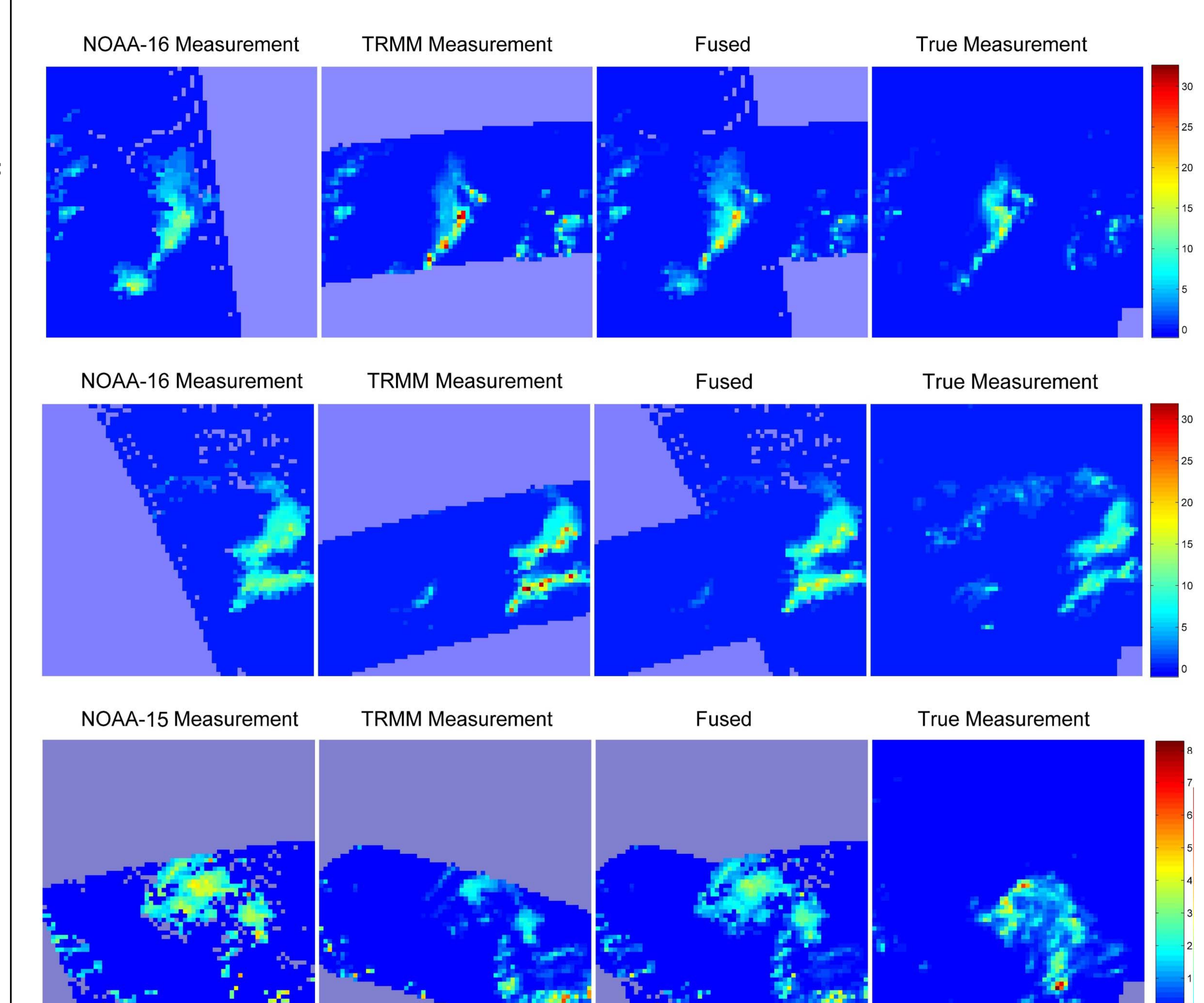

Figure 7 – Sample snapshots of satellite measurements, fused measurement and true measurement

Refrences:

1. E. E. Ebert, Methods for verifying satellite precipitation estimates, In V. Levizzani, P. Bauer, and F. J. Turk, editors, *Measuring precipitation from space*, 345–356. Springer, Dordrecht, 2007.
2. W. T. Freeman and E. H. Adelson, The design and use of steerable filters, *IEEE Trans. Pattern Anal. Mach. Intell.*, 13(9):891–906, 1991.
3. Z. Liu, et al., Image fusion by using steerable pyramid, *Pattern Recognition Letters*, 22:929–939, 2001.