

# Millimeter-Wave Observations of Precipitation Using AMSU on the NOAA-15 Satellite

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**Abstract - Promising agreement over land and sea has been obtained between NEXRAD 3-GHz radar observations of precipitation rate and retrievals based on simultaneous passive observations at 50-191 GHz from the Advanced Microwave Sounding Unit (AMSU) on the NOAA-15 meteorological satellite. This paper extends prior work by increasing the number of inputs into the feed-forward neural network used for estimating precipitation. It also is based on a much larger and more representative training and evaluation data set that spans rain rates up to 80 mm/h and incorporates 22 rainy orbits distributed over a year.**

## I. INTRODUCTION

The prior work utilized the scan angle, the spatial cold-spot perturbations in AMSU-A channels 4-6, and the radiances near  $183\pm 7$  and  $183\pm 1$  GHz, all at  $\sim 50$ -km spatial resolution for altitudes below 2 km [1]. The current work additionally incorporates spatial cold-spot perturbations in AMSU-A channels 7 and 8, the radiance near  $183\pm 3$  GHz, temperature profile information obtained from AMSU-A channels 4-8 near 54 GHz, and humidity profile information obtained from the following channels: AMSU-A channels 1, 2, 3, and 15, and AMSU-B radiances near 150,  $183\pm 1$ ,  $183\pm 3$ , and  $183\pm 7$  GHz. These eight channels were reduced to six principal components; the two that responded to surface effects were removed. These additions provide more information concerning the atmospheric temperature and humidity profiles sensed by AMSU. Retrieval improvements were also obtained in polar regions by using the  $183\pm 3$ -GHz channel for the first time to flag potentially precipitating regions when the troposphere is so cold and dry that the  $183\pm 7$  GHz channel normally used for this purpose sees the surface and becomes unreliable.

## II. RESULTS

Whereas the prior highly encouraging AMSU/NEXRAD comparisons were confined to two frontal passages and two hurricane passes generally characterized by large

precipitating cells that were resolved at 50-km resolution, the current data includes many more small intense convective cells that were not resolved by AMSU-A. The contributions of these small extremely intense cells to regional precipitation rates are therefore underestimated by standard 50-km resolution AMSU retrievals; these underestimates can be reduced by utilizing the 15-km resolution of AMSU-B to detect and help characterize these small intense cells.

These studies also revealed some cases where snowfall was strongly evident in AMSU data and on the ground, but was not evident in the coincident NEXRAD data. The sensitivity of AMSU to snowfall rates follows from the same cell-top physics responsible for its sensitivity to rain rate. The convective cell tops sensed by AMSU are usually well above the zones where precipitation might or might not melt before impact, and are not greatly affected either way.

The impacts of these improvements are suggested in Figs. 1 and 2 for the 22 test orbits over the eastern United States where NEXRAD coverage is denser. Only scan angles less than 40 degrees were analyzed; 6 of the 30 scan angles were thus omitted. Fig. 1 is a scatter plot relating AMSU and NEXRAD precipitation estimates for nearly simultaneous 50-km spots, where the 2-km NEXRAD radar precipitation estimates have been convolved with the AMSU 50-km antenna pattern and then subsampled at the center of each AMSU beam. Time offsets between AMSU and NEXRAD are generally less than  $\sim 7$  minutes. Approximately 1685 50-km precipitating samples were used for training, 842 were used for testing, and 842 were used for validation. All three categories provide consistent results. The AMSU precipitation rate retrievals of Fig. 1 employed the original algorithm described above and exhibited an rms discrepancy of 5.1 mm/hr. Fig. 2 is a scatter plot for the same orbits, but the AMSU retrievals employed the additional data cited above. In this case the rms discrepancy was reduced to 4.0 mm/hr.

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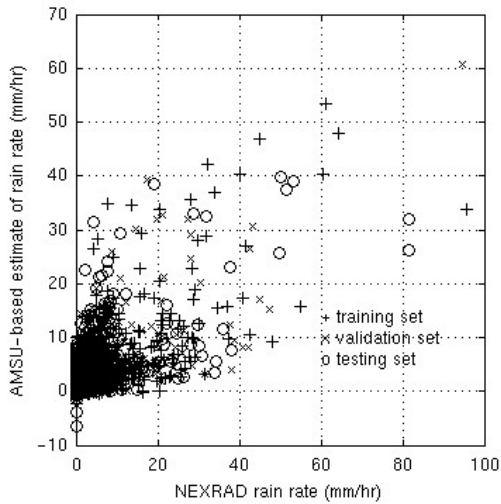


Fig. 1. Comparison of AMSU-based estimate of rain rate and NEXRAD rain rate using the original algorithm

### III. DISCUSSION

The temperature profile information improves the neural network precipitation estimates of Fig. 2 relative to Fig. 1 because precipitation signatures are expected to be seasonally dependent, and these 22 orbits span a full year. Similarly, the humidity profile information in the 183-GHz data helps characterize the surrounding energy source available to drive the precipitation. The cold-spot perturbations in the upper tropospheric AMSU-A channels near 54.9 and 55.5 GHz increase sensitivity to the most intense precipitation. Comparisons for winter precipitation were improved by use of the more opaque channel at  $183 \pm 3$  GHz under very dry conditions, when AMSU 53.6-GHz brightness temperatures were below 248 K.

The errors reported here are larger than those reported in the earlier work (1.1 mm/hr rms), which were based on only two frontal passages and two hurricanes that were generally characterized by precipitating cells larger than 50-km. In contrast, the current data set includes many more unresolved precipitation cells and a much broader range of atmospheric conditions, including peak precipitation rates that are approximately 4 times greater. The principal physical reasons the latest results show increased errors are believed to be: 1) that it is difficult to accurately estimate snowfall rates adjacent to rain using radar (the prior data included no snow), 2) unresolved rain cells having little impact on 50-km observations are underestimated by AMSU (the prior rain cells were generally large), and 3) alignment errors between AMSU and NEXRAD are more critical for small rain cells. All three of these error sources can be reduced. For example, the NEXRAD data can be corrected more carefully for snowfall, the unresolved rain cells can be identified using the 15-km resolution AMSU-B data and

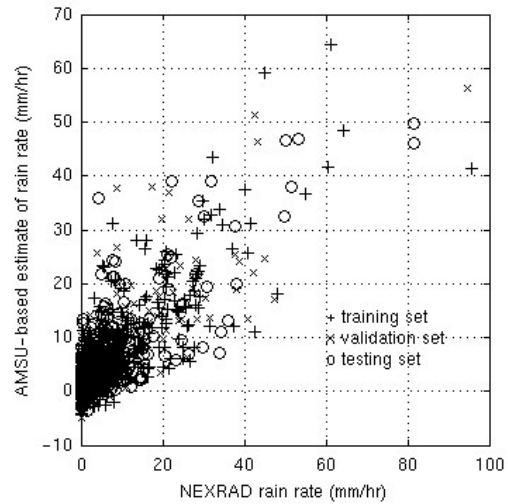


Fig. 2. Comparison of AMSU-based estimate of rain rate and NEXRAD rain rate using the new algorithm

therefore can be estimated more accurately using that information, and alignment errors can be reduced by image cross-correlation or other means. Efforts to reduce these errors are underway.

### REFERENCES

- [1] D. H. Staelin and F. W. Chen, "Precipitation Observations Near 54 and 183 GHz Using the NOAA-15 Satellite", *IEEE Trans. Geosci. and Remote Sensing*, 38, 5, Sept. 2000, pp. 2322-2332.