Correcting Microwave Precipitation Retrievals for Near-Surface Evaporation

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ABSTRACT

Almost all active and passive microwave remote sensing systems estimate precipitation by sensing hydrometeor populations primarily located one or more kilometers above the surface, after which those hydrometeors may partially evaporate before they reach the terrestrial surface. Passive systems that sense integrated liquid water content to the surface are also affected by such evaporation. Two methods for correcting microwave precipitation retrievals for such evaporation were evaluated and could be adapted to any satellite or ground-based microwave sensor, active or passive. One correction method uses land surface classification and the other is based on relative humidity statistics. The methods were developed by reconciling two years of data from 787 globally distributed rain gauges with passive millimeter-wave spectral observations from the Advanced Microwave Sounding Unit (AMSU) on the U.S. NOAA-15 and NOAA-16 operational weather satellites. Retrievals based on the longer wavelengths of SSMIS are also being evaluated. Although these initial corrections are either fixed or seasonal averages, numerical weather predictions permit real-time corrections as well.

The AMSU Precipitation (AP) retrievals utilize 13 channels spaced from 23 to 191 GHz and were trained using the fifth-generation National Center for Atmospheric Research/Penn State Mesoscale Model (MM5) [1]-[6]. AP retrieval algorithm R3 has successfully mapped precipitation over the North Pole and elsewhere, the principal remaining limitation being high elevation land like the Himalayan, Greenland, and Antarctic plateaus, and major mountain chains like the Andes [5]. Confirmation of the plausibility of these retrievals was obtained by

comparisons with Cloudsat 94 GHz radar and annual surface precipitation rate maps from the Global Precipitation Climatology Project (GPCP) [5]-[6].

Although average annual accumulations (mm/yr) observed in 2006-2007 by 787 rain gauges located in non-hilly regions reasonably agreed for most surface classifications with AMSU retrievals, AMSU significantly overestimated precipitation for under-vegetated land. The ratios of these AMSU annual accumulations to those of gauges ranged from 0.88 for tundra to 1.37 for cultivated crops, while the ratios for grassland, shrubs over bare ground, and pure bare ground (desert) were 2.4, 3.1, and 9, respectively, suggesting significant evaporation at altitudes beneath those of the hydrometeors sensed by AMSU. MM5 simulations strongly suggest that rain evaporation is largely responsible. The land classifications were deduced from Advanced Very High Resolution Radiometer (AVHRR) infrared spectral images. The first correction algorithm was developed by determining the ratio between AMSU and gauge-based annual accumulation statistics for each AVHRR surface classification, and imposing that ratio upon the AP-R3 retrievals, independent of season and location within each region; the result was the AP-R4 retrievals, which generally agreed better with both rain gauge and GPCP annual statistics [6].

Land classification, however, does not directly reveal atmospheric variations or predict variations over ocean or large lakes. However it was discovered that average annual relative humidity below 500 mb correlated quite well with land classification, as suggested in Fig. 1a, and therefore relative humidity provides an additional means for correcting surface precipitation-rate retrievals for evaporation over ocean and also over land in a more atmospherically sensitive way. A preliminary global map of annual average relative humidity correction factors for rain evaporation is shown in Fig. 1b. Comparisons of these correction methods with gauges and GPCP will be presented.

Application of this correction technique to other microwave observations of precipitation should be straightforward. For any microwave technique one can average one or more years of precipitation retrievals near these or other trusted rain gauges and then regress the annual relative humidity against the discrepancies between the microwave observations and the rain gauges to deduce the appropriate geographical evaporation correction factor for that instrument. Such corrections would differ because different instruments sense different functions of the hydrometeor distribution with altitude.

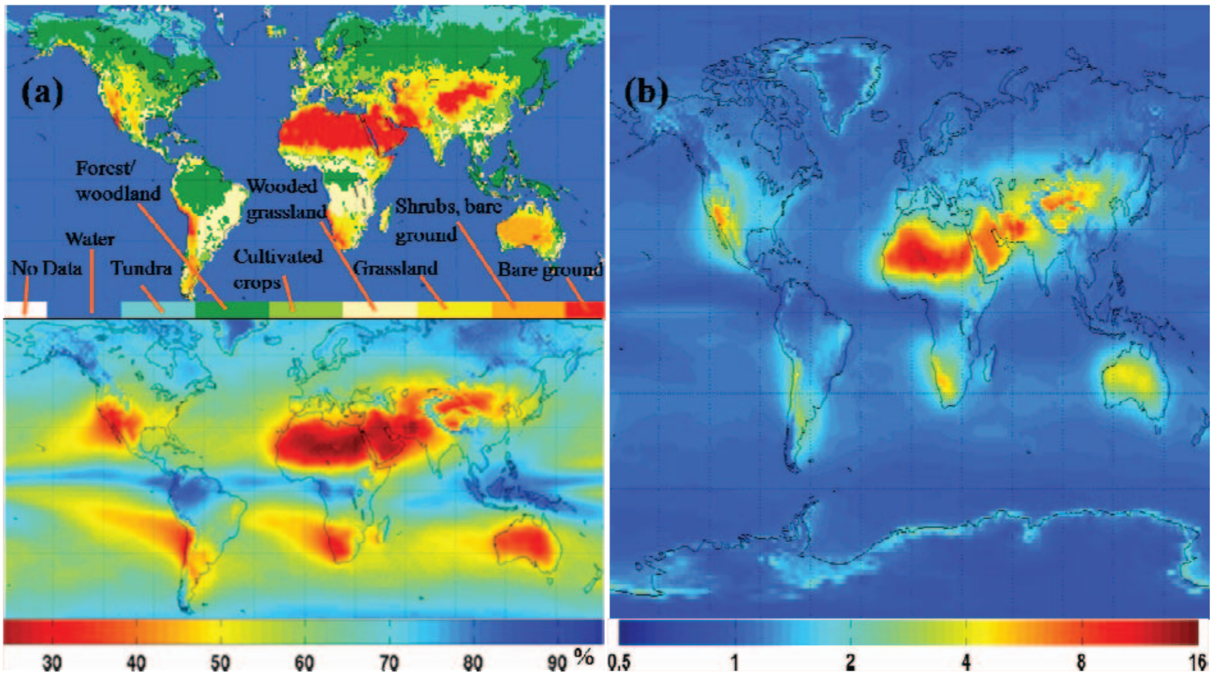

Fig. 1. (a) Top: AVHRR IR land classification, and bottom: 2008 average annual relative humidity (%) for altitudes below 500 mb; (b) a preliminary global map of annual average relative humidity correction factors for rain evaporation.

References

[1] C. Surussavadee and D. H. Staelin, "Comparison of AMSU Millimeter-Wave Satellite Observations, MM5/TBSCAT Predicted Radiances, and Electromagnetic Models for Hydrometeors," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 44, no. 10, pp. 2667-2678, Oct. 2006.

[2] C. Surussavadee and D. H. Staelin, "Millimeter-Wave Precipitation Retrievals and Observed-versus-Simulated Radiance Distributions: Sensitivity to Assumptions," *Journal of the Atmospheric Sciences*, vol. 64, no. 11, pp. 3808-3826, Nov. 2007.

[3] C. Surussavadee and D. H. Staelin, "Global Millimeter-Wave Precipitation Retrievals Trained with a Cloud-Resolving Numerical Weather Prediction Model, Part I: Retrieval Design," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 46, no. 1, pp. 99-108, Jan. 2008.

[4] C. Surussavadee and D. H. Staelin, "Global Millimeter-Wave Precipitation Retrievals Trained with a Cloud-Resolving Numerical Weather Prediction Model, Part II: Performance

Evaluation," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 46, no. 1, pp. 109-118, Jan. 2008.

[5] C. Surussavadee and D. H. Staelin, "Satellite Retrievals of Arctic and Equatorial Rain and Snowfall Rates using Millimeter Wavelengths," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 47, no. 11, pp. 3697-3707, Nov. 2009.

[6] C. Surussavadee and D. H. Staelin, "Global Precipitation Retrievals Using the NOAA/AMSU Millimeter-Wave Channels: Comparison with Rain Gauges," *Journal of Applied Meteorology and Climatology*, vol. 49, no. 1, pp. 124-135, Jan. 2010.