# Optimal Passive Microwave Detection and Estimation of Precipitation over Land Surfaces and Coastlines

**NASA Award Number: NNX10AGAH69G**

Final Report
Period covered: 5/01/2010 – 4/30/2013

## Grant W. Petty (PI)

Atmospheric and Oceanic Sciences
1225 W. Dayton St
University of Wisconsin-Madison
Madison, WI 53706

## David Santek (Co-I)

Space Science and Engineering Center
1225 W. Dayton St
University of Wisconsin-Madison
Madison, WI 53706

# Overview

This final report summarizes research conducted in the course of this three-year grant.

The grant covered the following stated research objectives relevant to the optimal detection and estimation of precipitation over land surfaces by passive microwave radiometers:

1. Characterization of Land Surfaces: We will characterize the statistics of background variability in brightness temperatures (e.g., annual and monthly means and covariances) in a form that can be utilized to (a) validate current and future emissivity models, and (b) directly aid in optimal retrievals of radiometric signatures related to precipitation (see next objective).

2. Precipitation Retrieval Over Land: We will refine and demonstrate a new concep- tual basis for optimally detecting and quantifying precipitation-related radiometric signatures over almost any surface type, including coastlines, deserts, and frozen ground.

# Objective 1: Characterization of Land Surfaces

## *Global*

By the end of the first year, we completed the first phase of a cluster analysis of 6-channel passive microwave emissivities provided by C. Prigent and F. Aires. The technique involves a novel similarity test that takes into account not only the mean emissivity vector at each grid point but also its covariance. The analysis was computationally time-consuming (months of continuous computation) and involved terabytes of intermediate data.

Both the method and the results of our cluster analysis are sufficiently novel that we expect to prepare at least two journal papers on these subjects. In addition, Karen Mohr (NASA-GSFC) is preparing a co-authored paper to provide geophysical interpretations of various classes, particularly in terms of vegetation types.

## *Tropics and Subtropics*

An immediate priority is the refinement and testing of the Goddard Profiling Algorithm (GPROF) on data from the Tropical Rainfall Measuring Mission (TRMM), which has coverage of the tropics and subtropics only. We applied the same clustering algorithm as described above to precipitation-free brightness temperatures from TRMM, leading to a small number of distinct surface classes – one ocean and six land. These classes are now the basis for the regionally optimized Bayesian retrieval techniques described under Objective 2.

# Objective 2: Precipitation Retrieval Over Land

## *Dimensional reduction in Bayesian retrievals*

In our proposal, we had demonstrated the use of a constrained optimal estimation technique to detect precipitation signatures against highly inhomogeneous surface types, including coastlines. We have now refined these ideas to describe an objective basis for reducing the effective dimensionality of the 9-channel observation space for TRMM to a mere three "pseudochannels" constructed from the original 9 channels and with optimal sensitivity to precipitation in the presence of temporal and spatial variability in the background brightness temperatures.

The basis for constructing these empirical pseudochannels was our own matchup of a full year's worth of 1B11 (TRMM Microwave Imager) data with 2A12 (TRMM Precipitation Radar) rain rates. We then developed a compact and efficient Bayesian algorithm scheme that appears to yield significantly improved results over coastal and desert scenes, among others, relative to previous algorithms. Fig. 1 illustrates the results achievable using this method over the less difficult ocean areas, using the current standard TMI rainfall product 2A12 version 7 as the comparison.

Fig. 2 shows the comparable results for selected land and coast areas.

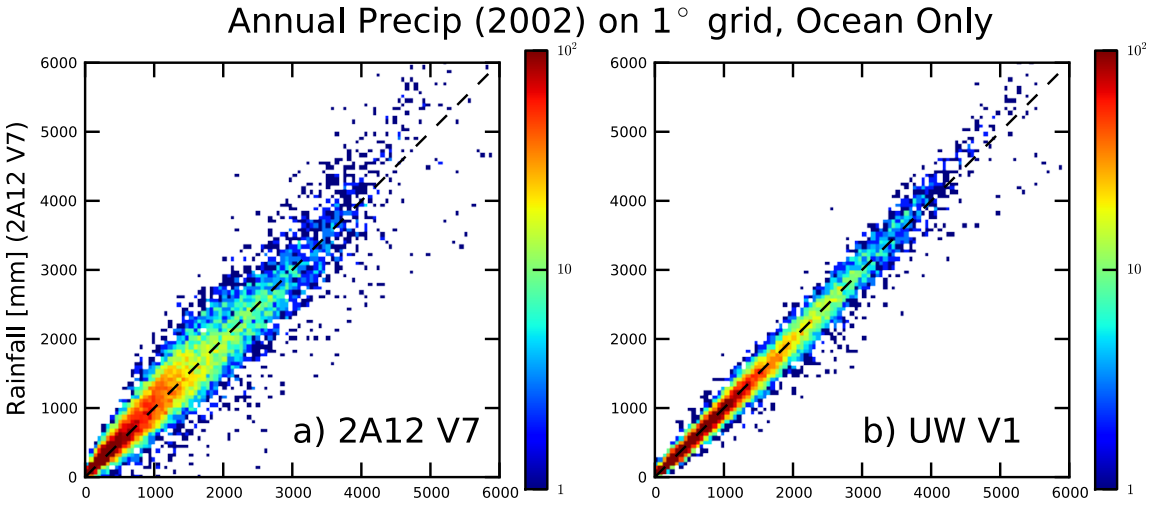


**Fig. 1:** Comparisons of annual rainfall totals (ocean only) derived from (a) the standard 2A12 algorithm and (b) the new UW Bayesian algorithm with independent data from the Precipitation Radar (2A25, horizontal axis) for the year 2002.

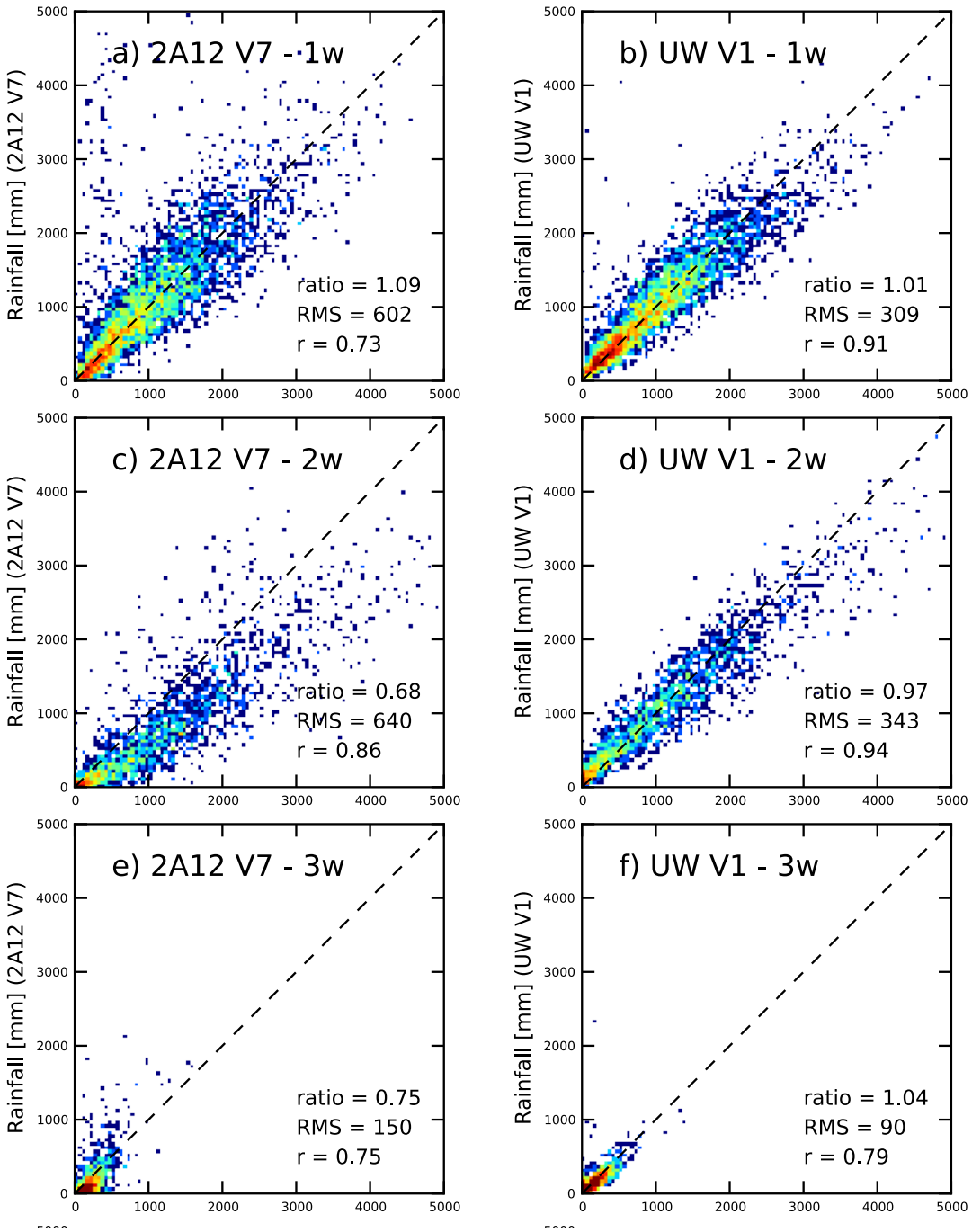


**Fig. 2:** Comparisons of annual rainfall totals derived from Bayesian TMI-3 algorithms with independent data from the Precipitation Radar (2A25) for the year 2002. Left column: The standard 2A12 V7 product. Right column: the new UW-Madison algorithm. Top Row: Vegetated land surfaces. Middle row: Coastal regions. Bottom row: Deserts regions.

These results reveal significant improvements in retrieval quality on an annual basis. Additional comparisons (not shown; see Petty and Li 2013b) reveal improvements as well in instantaneous retrievals on pixel scales.

In addition to the basic research described above, we have been tasked with incorporating our dimensional reduction scheme into the operational precipitation retrieval algorithm GPROF. This work is ongoing.

# Publications under this grant

## *Completed*

Petty, G. and W. Huang, 2011: The modified gamma size distribution applied to inhomogeneous and nonspherical particles: Key relationships and conversions. *J. Atmos. Sci.*, **68**, 1460-1473

Johnson, B.T., G.W. Petty, and G. Skofronick-Jackson, 2012: Microwave properties of ice-phase hydrometeors for radar and radiometers: Sensitivity to model assumptions. *J. Appl. Meteor. Climatology*, **51**, 2152-2171 (online paper)

Petty, G.W., 2013: Dimensional reduction in Bayesian retrievals. In press, *Atmos. Measurement. Tech.* (abstract and discussion)

Petty, G.W., and K. Li, 2013a: Improved passive microwave retrievals of rain rate over land and ocean. 1. Algorithm description. In press, *J. Atmos. Ocean. Tech.*

Petty, G.W., and K. Li, 2013b: Improved passive microwave retrievals of rain rate over land and ocean. 2. Validation and intercomparison. In press, *J. Atmos. Ocean. Tech.*

## *In preparation*

Work on the following papers began on this grant and will continue under a follow-on grant:

Petty, G.W., 2013: Unsupervised classification of multi-dimensional data based on both means and covariances. (manuscript in preparation, journal TBD)

Petty, G.W., 2013: Unsupervised classification of land surface types and temporal variability based on multichannel passive microwave emissivities. (manuscript in preparation, journal TBD)

Petty, G.W. and N. Neutkens, 2013 Improved passive microwave retrievals of rain rate over land and ocean.. 3. Application to land and coast precipitation retrievals from TMI. (manuscript in preparation, journal TBD)