Final Report – NASA Grant NAG8-1233
Development of Atmospheric Physical Retrieval Methodologies Using Satellite Data from Microwave Sounding Instruments with Complementary Imagery and Forecast Model Information

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1 Introduction

NASA Grant NAG8-1233 was awarded to the PI while he was a faculty member at Purdue University. When he moved to the University of Wisconsin-Madison, he filed a final report to cover the first three years of the grant. This final report covers a supplemental (4th) year of funding that was awarded to the PI after his transfer to the University of Wisconsin-Madison.

2 Summary of Research

The original objective of this grant was to collaborate with Dr. George Diak, Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison, in developing models and algorithms relevant to the detection of, and correction for, precipitation in observations by the Advanced Microwave Sounding Unit (AMSU). At the outset of the project, it was found that existing physical models were simply not reliable for accurately predicting multichannel microwave brightness temperatures in precipitation. In particular, standard assumptions about ice particle sizes and densities, and their vertical distribution, overemphasized the role of scattering in computed brightness temperatures and failed to predict the correct spectral dependence of T_B.

We therefore set out to develop an improved physical model that preserved meteorological realism while allowing parameters of the model to be empirically tuned so as to correctly reproduce the observed multichannel signature of precipitating cloud systems. Because actual AMSU data were not readily available for much of the early part of the project period, our analysis focused initially on data from the Special Sensor Microwave/Imager. Our assumption was that once a physical model was adequately tuned to SSM/I observations, it should also yield reasonable results at AMSU frequencies and viewing angles.

First, carefully screened SSM/I observations of oceanic precipitation were collected. Criteria for selection included a combination of large horizontal extent (to minimize footprint-filling effects) and high optical thickness in the microwave band (to minimize the ocean surface contribution to the observed brightness temperatures). Most of these observations were subsequently determined to be associated with moderate to heavy stratiform precipitation in tropical cyclones over the Western Pacific.

From the above observations, a statistical model was developed (using principal component analysis) to describe the joint variability of all seven SSM/I channels in the presence of rainfall (Petty 2001a). It was found that three independent variables are sufficient to explain almost all of the seven-channel variability in observed SSM/I brightness temperature in these cases. One of these variables was presumed to be related to overall precipitation intensity; the other two were presumably associated with variations in ice amount and other hydrometeor properties.

We developed a 1-D parametric stratiform rain cloud model designed to allow us to efficiently explore the mapping between rain cloud properties and computed brightness temperatures (Petty 2001b). The next objective, which is now nearly completed (Petty 2003), is to identify sets of rain cloud model parameters that are consistent with the range (in 7-channel space) of observed brightness temperatures. Among other things, we have found that assumed ice particle sizes must be significantly reduced, relative to standard assumptions, in order to achieve realistic results. An interactive interface to the cloud/radiative transfer model may be found at `http://rain.aos.wisc.edu/MW/models/profiles.shtml`.

In the course of developing the above model, we found that a great deal of programming effort was expended on conversion between dissimilar systems of units within the model code. For example, particle size distributions are often expressed by reference to diameters in cm, and number of particles per cubic meter, with masses in grams, and so forth, whereas other components of the model were most easily formulated in terms of standard SI units. We therefore undertook the development of a software-based system for automatically converting between systems of units within a Fortran program and for undertaking run-time checking of dimensional consistency in physical expressions. The resulting software module, described by Petty (2001c), greatly reduces the likelihood of undetected coding and unit-conversion errors in physical calculations. More information, and the downloadable source code, may be found at `http://meso.aos.wisc.edu/~gpetty/physunits.html`.

Now that we are located at UW-Wisconsin, we are now continuing our collaboration with SSEC personnel on the modeling and detection of the radiometric signature of rain clouds in AMSU data, with partial support from a NASA Grant to Dr. Allen Huang.

The following published and soon-to-be-published papers describe results from the work funded under this grant:

1. Petty, G.W. 2001a: Physical and microwave radiative properties of precipitating clouds. 1. Principal component analysis of observed multichannel microwave radiances in tropical stratiform rainfall. *J. Appl Meteor.*, **40**, 2105–2114.

2. Petty, G.W. 2001b: Physical and microwave radiative properties of precipitating clouds. 2. A parametric 1-D rain cloud model for use in microwave radiative transfer simulations. *J. Appl Meteor.*, **40,** 2115–2129

3. Petty, G.W. 2001c: Automated computation and consistency checking of physical dimensions and units in scientific programs. *Software - Practice and Experience*, **31,** 1067–1076.

4. Petty, G.W. 2003: Physical and microwave radiative properties of precipitating clouds. 3. Mean hydrometeor profiles and properties in tropical stratiform rainfall. To be submitted to *J. Appl Meteor.*

3 Inventions Report

No inventions resulted from this grant.

4 Inventory Report

No federally owned equipment is in the custody of the PI.