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TITLE: Microwave Radiative Transfer Studies of Precipitation

INVESTIGATORS

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BACKGROUND OF THE INVESTIGATION

This proposal was submitted to NASA in 1990 as a proposed extension to the previous NASA contract NAG8-643. Since the deployment of the DMSP SSM/I microwave imagers in 1987, increased utilization of passive microwave radiometry throughout the 10-100 GHz spectrum has occurred for measurement of atmospheric constituents and terrestrial surfaces. Our efforts have focused on observations and analysis of the microwave radiative transfer behavior of precipitating clouds. We have focused particular attention on combining both aircraft and SSM/I radiometer imagery with ground-based multiparameter radar observations. As part of this and the past NASA contract, we have developed a multi-stream, polarized radiative transfer model which incorporates scattering. The model has the capability to be initialized with cloud model output or multiparameter radar products. This model provides the necessary "link" between the passive microwave radiometer and active microwave radar observations. This unique arrangement has allowed the brightness temperatures (T_B) to be compared against quantities such as rainfall, liquid/ice water paths, and the vertical structure of the cloud. Quantification of the amounts of ice and water in precipitating clouds is required for understanding of the global energy balance.

SIGNIFICANT ACCOMPLISHMENTS IN THE PAST YEAR

During July and August 1991, we as well as investigators from NASA Marshall Space Flight Center (Ms. Robbie Hood, Ms. Vanessa Griffin, Mr. Frank LaFontaine) participated in the collection of aircraft radiometer observations during the Convection and Precipitation/ Electrification (CaPE) experiment, held near Kennedy Space Center, Florida. The experiments involved overflights of the NASA ER-2 high-altitude aircraft over large precipitating complexes concurrently being scanned by the NCAR CP-2 dual-frequency, dual-polarization radar. The ER-2 carried, among other instruments, the new Advanced Microwave Precipitation Radiometer (AMPR), a 4-channel (10.7, 19.35, 37.1, and 85.5 GHz) scanning microwave radiometer system. The latter three frequencies coincide with those on the SSM/I. The AMPR was conceived and is operated by NASA/MSFC, and was built by the Georgia Tech Research Institute. The AMPR scans ±45° across-track, giving a ground swath width of about 40 km, with individual ground resolutions ranging from 0.7 km to 2.4 km at 10.7 and 85.5 GHz, respectively. Since that time, we have been analyzing both the radar and radiometer datasets, first checking data quality and calibration, and then developing color graphics software to facilitate the display and quantitative analysis of both datasets. We have produced maps of the radar-derived products rainfall and integrated ice and water paths for comparison with the AMPR T_B in preparation for attempts to quantify retrieval techniques via multifrequency T_B relations. Existing relations are hindered by the lack of available ground verification data. The earth resolution of the AMPR is finer than that of the SSM/I by a factor of about 20, so factors such as partial beam-filling are mitigated to a large extent.

FOCUS OF CURRENT RESEARCH AND PLANS FOR NEXT YEAR

There are several groups in the US performing microwave radiative transfer studies, employing different techniques or approaches to the problem of quantifying the precipitation process via passive microwave data. Several of these approaches complement each other and are mutually beneficial. During the next year, in addition to collaborating with the Remote Sensing Branch at NASA/MSFC, we will collaborate with scientists at Florida State University (Eric A. Smith) and the Atmospheric Physics Institute in Italy (Alberto Mugnai). The latter's studies have involved the use of a detailed microphysical cloud model to study the effects of the vertical distribution of rain, cloud water, snow, etc. on the top-of-atmosphere T_B, as well as development of an inversion scheme which attempts to reproduce the SSM/I-measured T_B by perturbing cloud model vertical hydrometeor profiles. Similarly, using the radar data, we are attempting to reproduce the AMPR-measured T_B over the actual storm by inverting the radar data products. The link here is that the cloud model is a simulator which provides separate rain, snow, etc. categories, whereas the radar data is an actual measurement from all of the different categories in its resolution volume, separation of which can be improved with the multiparameter capabilities of the CP-2 radar. We all have agreed to work on a 3-part effort as follows: 1) Demonstrate the utility of the AMPR instrument for diverse geophysical applications including precipitation, surface characterization, etc., 2) combine the AMPR and CP-2 radar data from CaPE into our detailed radiative transfer model to identify plausible hydrometeor vertical profiles including rainfall, and to separate the ice and water contents for use by others interested in energy budget studies, and, 3) test the Smith and Mugnai inversion scheme using their cloud model dataset along with SSM/I measurements from CaPE. This will reveal how the fine-scale ($\simeq$2 km) microphysical processes observed by the AMPR/CP-2 combination manifest themselves when viewed by the coarser resolution SSM/I channels. In sum, these efforts will be guided by the belief that improved quantification of rainfall from space may be possible when one considers the physical processes within the cloud that lead to rain production.

PUBLICATIONS

J. Turk, J. Vivekanandan, and V.N. Bringi (1992), "Studies of microwave radiative transfer model results using multiparameter radar observations", *Specialists Meeting on Microwave Radiometry and Remote Sensing*, E.R. Westwater, Chairman, 14-16 January, Boulder, CO.

J. Vivekanandan, J. Turk, R.E. Hood, V.L. Griffin, F.J. LaFontaine, V.N. Bringi, and R.W. Spencer (1992), "Multiparameter radar and Advanced Microwave Precipitation Radiometer observations of tropical convection", *Int. Geoscience and Remote Sensing Symposium*, 26-29 May, Houston, TX.

J. Vivekanandan, J. Turk, and V.N. Bringi (1991), "Ice water path estimation and characterization using passive microwave radiometry", *J. Applied Meteorology,* **30**, 1407-1421.