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Dear Dave

This letter describes progress during FY01 under our NASA/EOS proposal entitled ``In-situ and Remote Sensing Measurements in Support of the EOS/MODIS Retrieval Algorithm Validation Program'', NASA/EOS contract number S-97894-F. This material is from the NCAR effort (Heymsfield/Miloshevich/McFarquhar) effort.

For your reference, our web site is located at:

http://box.mmm.ucar.edu/science/cirrus

The web site includes detailed particle size distribution and habit data from the FIRE-II and ARM field programs. We developed this microphysical data base for the MODIS Remote Sensing of Cirrus Clouds Working Group (see http://arm1.ssec.wisc.edu/~shaima/cirrus_group.html). We have worked closely to Bryan Baum, Shaima Nasiri and Ping Yang on this project.

During March 2000, our EOS funding allowed us to install and operate a Cloud Particle Imager (CPI) probe on the University of North Dakota Citation aircraft. The Citation participated in the ARM 2000 IOP. During this period, the Citation penetrated four interesting cirrus cloud layers. The data set we collected, coupled with the data from the 2D imaging probes and the NCAR/OSU Counterflow Virtual Impactor, has formed the basis for our work during FY2001.

During FY2001, we were involved in preparing three journal articles that are now either in press or in the review process. Each of these papers made extensive use of the ARM 2000 data set. In paper 1 (details below) a new method for calculating ice particle mass and ice water content from in-situ probe data was developed. The technique was validated using ARM 2000 measurements of the ice water content. New relationships were developed to calculate ice particle mass, terminal velocity and indirectly the cloud effective radius. Paper 2 (see below) developed relationships for specifying the vertical distribution of ice particle cross-sectional areas. The ice particle area is fundamental to the study of cloud radiative properties. Paper 3 (see below) examines the use of in-situ cirrus data collected during three field campaigns to develop more complex midlatitude cirrus microphysical models. The microphysical models are used to develop new scattering models for a suite of MODIS bands spanning visible, near-infrared, and infrared wavelengths. We believe that these three papers will provide useful parameterizations for the retrieval of ice cloud properties from MODIS and other remote sensing platforms and for the radiative transfer and cloud physics communities.

The title, the status of the paper an abbreviated abstract for each of the papers, is given below.

Paper I: A General Approach for Deriving the Properties of Cirrus and Stratiform Ice Cloud Particles

Authors: Andrew J. Heymsfield, Sharon Lewis, Aaron Bansemer, Jean Iaquinta, Larry M. Miloshevich, Masahiro Kajikawa
Cynthia Twohy, and Michael R. Poellot

Paper Status: Galley Proofs received, paper to be published in the Journal of the Atmospheric Sciences

ABSTRACT

We describe a new approach for calculating the mass (m) and terminal velocity (V_t) of ice particles from airborne and balloon-borne imaging probe data as well as its applications for remote sensing and modeling studies. Unlike past studies that derived these parameters from the maximum (projected) dimension (D) and habit alone, our ``two-parameter approach'' uses D and the particle's projected cross-sectional area (A). Expressions were developed that relate the area ratio (A_r; the projected area

of an ice particle normalized by the area of a circle with diameter D), to its effective density (ρ_e) and to V_t.

Habit-dependent, power-law relationships between ρ_e and A_r were developed using analytic representations of the geometry of various types of planar and spatial ice crystals. Relationships were also derived from new or reanalyzed data for single ice particles and aggregates observed in clouds and at the ground. The mass relationships were evaluated by comparing calculations to direct measurements of ice water content (IWC). The calculations were from Particle Measuring Systems (PMS) 2D-C and 2D-P probes of particle size distributions in ice cloud layers on three days during an Atmospheric Radiation Measurement (ARM) field campaign in Oklahoma; the direct measurements were from a counterflow virtual impactor (CVI) observations in ice cloud layers during the field campaign. Agreement was generally to within 20\%, whereas using previous mass-dimension relationship approaches usually produced larger differences. Comparison of ground-based measurements of radar reflectivity with calculations from co-located balloon-borne ice crystal measurements also showed that the new method accurately captured the vertical reflectivity structure. Improvements in the accuracy of the estimates from the earlier mass-dimension relationships were achieved by converting them to the new form. A new, more accurate mass-dimension relationship for spatial, cirrus-type crystals was deduced from the comparison.

The relationship between V_t and A_r was derived from a combination of theory and observations. A new expression accounting for the drag coefficients of large aggregates was developed from observational data. Explicit relationships for calculating V_t as a function of D for aggregates with a variety of component crystals were developed.

Paper 2: An explanation and parameterizations for the physical properties of cirrus and stratiform ice cloud particles. Part I: Cross-Sectional Area and Extinction

Authors: Andrew J. Heymsfield and Larry M. Miloshevich

Paper Status: Submitted to the Journal of the Atmospheric Sciences, August 2001.

ABSTRACT

This study presents observational data that are used to relate the cross-sectional area of an ice particle to its maximum diameter (D), for a number of individual particle habits and for natural mixed-habit populations of ice particles in mid-latitude, continental, synoptically-generated cirrus clouds. The cross-sectional area is expressed in terms of the shape-sensitive parameter ``area ratio'' (A_r, the ratio of a particle's projected cross-sectional area to the area of a circle having the particle's maximum diameter). The A_r(D) relationships for particles of a specific habit were derived from several diverse datasets, including high-resolution Cloud Particle Imager (CPI) and balloon-borne replicator in-situ data in the temperature range -25 to -65C, ice particles collected at the surface, and ice particles grown in a windtunnel. The A_r(D) relationships for cirrus clouds were derived from CPI, 2D-C, and 2D-P data during slow Lagrangian spiral descents, and from balloon-borne ice crystal replicator data. The dependence of the coefficients of the A_r(D)relationship on height within the vertical cloud column was examined and related to microphysical processes operating in the clouds. Fundamental aspects of ice particle growth and the aggregation process were also examined. The area ratio was found to decrease systematically with increasing particle diameter for most individual particle habits and for natural cirrus cloud populations. The area ratio decreases rapidly with increasing diameter for particles smaller than about 500 microns, then more slowly for larger particles. The aggregation process produces particles with higher area ratios than single particles of the same diameter, and since most particles larger than 500-1000 microns are aggregates, aggregation leads to a decrease in the slope of A_r(D) at diameters greater than about 500 microns. The A_r(D) relationships were adequately represented by power-law expressions.

The coefficients of the power-law A_r(D) relationship were found to be roughly constant in the lower half of the cirrus clouds studied, but dependent on height in the upper half of the cloud column. The height-dependence of A_r(D) is attributed to the impact of particle growth, aggregation, and sublimation on the particle shape and other particle characteristics. Profile measurements from 10 cirrus clouds were combined to produce a single parameterization for the

mean $A_r(D)$ trend, and for the dependence of its coefficients on fractional height within the normalized cloud column.

An approach is given for using the $A_r(D)$ relationships together with particle size distribution measurements or parameterizations to derive bulk cloud properties of importance to the modeling and radiative transfer communities.

Paper 3: The Development of Midlatitude Cirrus Models for MODIS Using FIRE-I, FIRE-II, and ARM In-Situ Data

Shaima L. Nasiri, Bryan A. Baum, Andrew J. Heymsfield
Ping Yang, Michael R. Poellot, David P. Kratz, Yongxiang Hu

Paper Status: Journal of Applied Meteorology, in press

Abstract

While detailed in-situ data from cirrus clouds have been collected during dedicated field campaigns, the use of the size and habit distribution data has been lagging in the development of more realistic cirrus scattering models. In this study, we examine the use of in-situ cirrus data collected during three field campaigns to develop more complex midlatitude cirrus microphysical models. Data are used from the FIRE-I (1986) and FIRE-II (1991) campaigns (FIRE refers to the First ISCCP Regional Experiment; ISCCP refers to the International Satellite Cloud Climatology Project) and a recent ARM (Atmospheric Radiation Measurement) campaign held in March- April, 2000. The microphysical models are based on measured vertical distributions of both particle size and particle habit, and are used to develop new scattering models for a suite of MODIS bands spanning visible, near-infrared, and infrared wavelengths. The sensitivity of the resulting scattering properties to the underlying assumptions of the assumed particle size and habit distributions are examined. We find that the near-infrared bands are sensitive not only to the discretization of the size distribution, but also to the assumed habit distribution. Additionally, our results indicate that the effective diameter calculated from a given size distribution tends to be sensitive to the number of size bins that are used to discretize the data, and also to the ice crystal habit distribution.

Regards,

Andrew Heymsfield
PhD
Senior Scientist, MMM Division