Working Group II - Cirrus Cloud Systems
1996 Report

1. Ongoing Activities

The present focus of this working group is to define itself, its objectives and approaches, and its activities. Much has been recently accomplished in these respects. There has been a substantial infusion of new members (Table 1) and communication has been established via email and our new homepage (http://eos913c.gsfc.nasa.gov/gcss_wg2/). The group is now actively engaged in planning a first workshop on modeling cirrus clouds that will be held in mid-1998. While the vigor of WG2 has yet to be demonstrated, there are high hopes and a universal conviction that this activity is now very timely and highly appropriate. This is in spite of the recent funding difficulties facing the cirrus cloud research community both in Europe and in the United States.

Background and Composition of WG2

Based on the discussions to date, Working Group II (WG2) endorses the GCSS central goal of developing better parameterizations of cloud systems within global climate and weather prediction models, specifically by achieving improved understanding of the coupled physical processes acting to determine the occurrence, properties and effects of cloud systems. WG2 firmly endorses the concept that the time is now right for a concerted effort at comparison and evaluation of cloud resolving models (CRMs) of cirrus cloud systems in conjunction with corresponding analyses of appropriate observations following the general approach adopted by GCSS. Regional mesoscale models including rather sophisticated treatment of cirrus cloud physics are now available as are a number of 3-dimensional large-eddy simulation (LES) models capable of simulating cirrus cloud systems at high spatial resolution. In the case of cirrus clouds, however, the very significant uncertainties in the role of various cloud physical processes dictates a somewhat broader approach. Microphysical development is a key issue for cirrus clouds. While quite sophisticated microphysical schemes have recently been developed and implemented in cirrus CRMs, it is felt that inclusion of more traditional and detailed 1-dimensional and parcel models of cloud microphysical development would be very beneficial. In addition, given the very wide range of environmental conditions associated with cirrus cloud systems and the limited resources to cover this range using computationally intensive CRMs,

significant utility remains in the 2-dimensional modeling approach. Thus, these models should also be included in cirrus model comparison activities.

WG2 includes a strong contingent of GCM and NWP researchers, many with single column modeling (SCM) capability (Table 1). It is essential that the model comparison and evaluation activities fully engage this community to maximize progress toward the objectives and goals of GCSS. Thus, WG2 intends to span the full range of available cirrus cloud modeling capability. This is evident in the distribution of modeling resources represented by the participants (Table 2).

Observations are a key ingredient of GCSS. Observations guide model development and provide the best measure of the realism and utility of model results. WG2 includes a strong contingent of scientists who bring significant resources in terms of data, analysis capabilities, and understanding (Table 1). WG2 plans to take strong advantage of the available expertise, data and analyses in its endeavors, including specifically the output of the FIRE Cirrus observational program in the United States and the EUCREX program in Europe. The data sets that have been obtained and the analysis that has been (and can be) done represent an invaluable resource. In particular, data obtained by FIRE Cirrus-II experiment in 1991 are highly suited for CRM intercomparisons and the data obtained during the recent SUCCESS (Subsonic Aircraft: Contrail and Cirrus Effects Special Study) experiment and similar European missions focused on contrails provide essential information on the role of aerosols in determining cirrus microphysical development. Data sets obtained during the various EUCREX missions will also play a key role in WG2.

Future field experiments that are presently being considered are a tropical cirrus mission in 1998 as part of STERAO (funded by the U.S. NSF) and a tropical cirrus mission in conjunction with LBA or the proposed NASA TRMM validation experiment near Kwajalein in 1999. A significant factor of uncertainty in these plans is the availability of the NCAR WB-57 high-altitude aircraft for in-situ sampling. There will likely be continuing contrail missions in the near term both in Europe and in the United States. Other opportunities, such as FASTEX, also exist for collection of suitable cirrus data sets.

The Atmospheric Radiation Measurement (ARM) program of the U.S. Department of Energy is accumulating a significant volume of high quality cirrus measurements that may be of utility, including episodic intensive observing periods, and focused efforts to support SCM comparisons.

Key Scientific Issues

Role of Atmospheric Aerosols

Adequate characterization of the ambient aerosol and ice crystal population is a key requirement here. Recent advances in instrumentation have enabled collection of relevant data sets that allow for the first time a useful, if still incomplete, characterization. Such data are available from the recent European missions focused on contrails as well as the SUCCESS mission in 1996. Analysis of these data is progressing well and the results will be quite timely for WG2.

As illustrated in the studies reported by Starr and Kambis and by Cotton et al. at the recent ICCP, determination of the effects of ambient aerosol population on cirrus clouds requires observations and models capable of resolving the local motions that actually govern the operating nucleation and growth scenarios. Such motions include gravity waves, small-scale convection, 2-dimensional turbulence and other mesoscale circulations. As such, adequate characterization of the motion and turbulence fields in cirrus and comparison to model simulations must be a key aspect of WG2 activities. Suitable observation were obtained by EUCREX and during FIRE Cirrus-II. Analysis of these data is on-going.

Role of Radiative Process

Much progress has been made as a result of EUCREX and FIRE in defining relationships between cirrus cloud microphysical properties and cloud radiative properties. Knowledge of particle habit and size distribution and their effects on the radiative fields has advanced markedly. Significant issues remain, however, such as the possibility of enhanced cloud absorption of solar radiation. Studies to-date indicate a very significant interactive role of radiative process in affecting dynamical and thus microphysical development in cirrus. Thus, another key aspect of cirrus model comparisons within WG2 will be to examine the impact of different treatments of cloud radiative processes on cirrus cloud simulations.

GCM Simulations of Cirrus Cloud Systems

In addition to the above foci on fundamental cloud physical processes, the question of how adequate are GCM simulations of cirrus cloud systems must be addressed. In the context

of these large-scale models, issues involving the upper tropospheric water budget and dynamical processes are crucial. Transports of water vapor to the upper troposphere largely determine the subsequent formation of cirrus clouds. It is unknown whether such transports are realistically simulated in GCMs or even if mesoscale processes are highly involved in such processes. Detailed case study comparisons of mesoscale CRM simulations and GCM simulations in conjunction with appropriate analyses may help resolve this issue. Also of central importance is the role of unresolved small vertical motions in the cloud environment and within the cloud in determining properties of cirrus cloud systems. By affecting the actual microphysical composition and, maybe more importantly, the spatial distribution of cloud properties, such motions play a significant role in determining the dehydration of the upper troposphere through the ice particle fallout process that is so prevalent in cirrus clouds. Quantification of these effects can be accomplished through CRM simulations in comparison to GCM simulations, possibly suggesting approaches for adequate parameterization of these effects in GCMs. In essence, an approach is needed whereby the various components operating in GCM simulations of cirrus cloud systems are addressed in a systematic manner enabling identification of the specific weaknesses and strengths of the models so that remedies can be pursued.

Climatological data sets derived from remote sensing observations from satellites, such as cloudiness from ISCCP and upper tropospheric humidity from TOVS, and more recently from ground-based active sensors, such as lidar and millimeter wavelength radar (a good example is the study by Mace et al.), provide an extremely important quantitative basis for evaluating GCM performance in terms of cloud cover, frequency of occurrence, vertical location and depth, and cloud vertical structure, as well as upper tropospheric humidity (UTH). Preliminary comparisons indicate significant deficiencies in GCM simulations as regards cirrus cloudiness and UTH. It is likely that these factors are highly related and provide a strong motivation for the WG2 activities described here. The cause of these deficiencies may reside in either (or both) the treatment of cloud physical processes and the account of dynamical processes on unresolved scales from individual cloud elements to mesoscale circulations. Separation of such processes can be achieved in the analysis of model simulations while it is quite difficult from an observational perspective. This is an area where WG2 can make an important contribution.

Two threads should be gleaned from the above discussions:

• Dynamical processes represent a key connection between other physical cloud processes and are intimately involved in scaling issues that are maybe the most fundamental and intractable difficulty in adequately representing cloud systems in large-scale models.

• Observations are absolutely crucial in supporting efforts to improve present capabilities to simulate cloud systems and more generally, weather and global climate.

Report on Zurich and Other Meetings

A meeting was held in Zurich during the International Conference on Clouds and Precipitation. Peter Jonas of the International Commission on Clouds and Precipitation kindly helped arrange this meeting. About 30 scientists attended including a substantial experimental contingent. Background on GCSS and a strawman plan for WG2 were presented and discussed, including tentative plans for a first cirrus cloud modeling workshop to be held in 1998. There was good enthusiasm for this activity..

Much of the discussion centered around the philosophy of GCSS and WG2, specifically the focus on model comparison versus experimental activities. The chairman argued forcefully that, while experimentalists would play a key role in WG2 and that WG2 would provide substantive feedback to their community in terms of requirements for and support of experimental activities, WG2 needed to focus very strongly on model comparisons specifically keyed to CRMs. In essence, experimentalists already have an organizational avenue to promote their activities, that being the various science experiment teams. What has been missing and is sorely needed is a forum in which the modeling community can work together to identify and resolve issues spanning the full range of scales and processes that they address and, maybe even more importantly, to provide a practical mechanism to encourage, within their community, the communication of experience, expertise and knowledge that has been gained. The chairman further argued that many resources had been expended over the last decade in acquiring and analyzing observations with the goal of advancing modeling of cirrus cloud systems. While some advances have resulted, the process has been painfully slow. This jeopardizes the support for future field experiments on cirrus clouds, as might be inferred from present funding difficulties, even though it is absolutely clear that the data that have been obtained are of great value and that additional experimental activities are essential. The chairman concluded that vigorous pursuit of the GCSS strategy with respect to cirrus cloud systems appears to provide the most viable mechanism to speed the model improvement process and achieve our common goal in a

most expeditious manner, especially given the limited resources presently available. The expectation is that, by accelerating progress within the modeling community, support for future experimental activities will be positively impacted. By the end of the meeting, there seemed to be a consensus that the GCSS strategy was appropriate for WG2.

An issue raised by the experimentalist was the strong need for systematic comparison and evaluation of various probes and sensors used for cirrus measurements. EUCREX laid a good foundation with its work on comparison of meteorological sensors and optical spectrometer probes (PMS). Moreover, SUCCESS was specifically designed to enable a similar comparison of a variety of aerosol, microphysical and humidity probes. Analysis of this data is on-going. Preliminary results were reported at the recent SUCCESS Science Team meeting and a special session is planned for the Spring 1997 American Geophysical Union meeting in Baltimore just prior to the planned WG2 workshop in the same area.

Although there presently is a lot of activity in this area, accurate measurements and the knowledge of measurement accuracy is extremely important to GCSS. A sensor comparison activity parallels the model comparison strategy that is fundamental to GCSS. As with model comparison, the success of a sensor comparison activity will depend on community participation and leadership. The possibility of this second focus for WG2 is being explored.

Presentations were also made to the FIRE Cirrus Science Team and the SUCCESS Science Team at their fall meetings on the planned activities of WG2. Participation of modelers and experimentalists was strongly encouraged and the response has been pretty good thus far. The NASA Radiation Sciences Program Scientist, Robert Curran, expressed his support of our activities and has committed to providing financial support of the first GCSS WG2 Workshop on Modeling Cirrus Clouds, pending submission of a brief proposal. The latter is presently being prepared.

2. New Results

Models

As noted above, there has been significant recent progress in modeling cirrus clouds. A number of 3-D LES/mesoscale models now incorporate rather sophisticated microphysical

and radiative treatments of cirrus. Some models now include explicit treatment of particle size distribution as well as ice initiation processes (aerosols). There also continues to be a strong 2-dimensional cirrus modeling effort. Results from a number of these models were shown at Zurich. Dr. Cotton illustrated the fundamental differences that result from the ice physics processes acting in cirrus in comparison to comparable liquid phase stratiform clouds during his presentation at the ICCP of simulations of arctic boundary layer clouds. A uniform decrease in temperature forced the onset of cirrus-physics in his model with resulting dramatic contrasts with the warmer situation involving a supercooled stratus cloud. Recent work shows a strong concern with ice initiation processes and their effects on cirrus as seen in the work of Levkov, Jensen, DeMott, and others.

Observations

Analyses of the extensive microphysical, aerosol and humidity observations obtained during the 1996 SUCCESS mission promise to provide the best picture yet of the relationship between aerosol population and cirrus cloud composition. While the analyses are at an early stage, the initial comparisons are already reveal some significant issues.

3. Observational Requirements for Future Field Experiments

Details of an observational "blueprint" are deferred. This issue will be addressed during the planned WG2 Workshop in 1998. Moreover, the WMO is sponsoring a workshop on "Measurement of Cloud Properties for Forecasts of Weather, Air Quality, and Climate" in June 1997 in Mexico City that seeks:

- To review the status of currently available measurement tools that provide information on cloud microphysical, radiative and chemical properties with respect to accuracy, resolution and limitations.

- To review the status of currently used algorithms for extracting cloud and precipitation properties with respect to accuracy, resolution and limitations.

- To assess the capabilities of measurement systems and data extraction algorithms for providing the necessary information for parameterization and assimilation in forecast/nowcast models.

- To generate a list of recommendations that addresses the following:

  Development needs for new techniques that measure critical cloud and precipitation properties, particularly those that are important for understanding fundamental processes and that provide definitive measurements for parameterizing cloud processes.

  Improvements needed in the interpretation of currently available data sets with a focus on processing algorithms.

  Measurements needed to fill gaps in the current data sets with respect to seasonal, diurnal, and spatial representativeness of cloud measurements.

While this workshop has much broader application, cirrus cloud measurement issues will be addressed. Darrel Baumgardner is an organizer of this workshop and he has played a role in previous sensor comparison activities. It is expected that the output of this workshop will assist WG2 in constructing its observational "blueprint".

The priorities for future field experiments are fairly well-defined. The highest priority is for an experiment on tropical cirrus generated by deep convective systems. While CPEX produced some very useful data sets on tropical cirrus anvil properties and TOGA-COARE produced useful characterizations of tropical deep convective systems, there is a strong need to have a data set that enables the relationship between the generating deep convection and the evolving cirrus system to be quantified. To be of most utility, measurements of convective mass and moisture flux must be acquired in conjunction with extensive measurements of anvil evolution. This is the connection where GCM modelers have almost no observational guidance and yet controls the upper tropospheric water budget in their models to a strong degree. Planning for such an experiment in underway by a number of groups.

There is also a continuing need for better measurements related to aerosol influence on cloud microphysical properties. There is continuing instrument development and the results of present comparative analyses will likely suggest important new measurement to test the developing theories and capabilities. Similarly, remote sensing concerns will continue to drive focused experiments on retrieval of cirrus cloud properties.

4. Action Plan for 1997 and 1998

The First Cirrus Cloud Modeling Workshop will be held on 2-6 June 1997 in the mid-Atlantic region of the United States (Maryland/Virginia). In the next couple months, test cases for comparative simulation will be defined. At the same time, appropriate protocols for comparison of model output will also be formulated and agreed. Present plans call for simulation of an idealized simple mid-latitude cirrostratus situation and an observed case culled from FIRE Cirrus-II (November 26 or December 5, 1991) or the April 1994 EUCREX case over the sea near Scotland. A key is that all models will attempt to simulate the same cases.

Definition of the idealized case is underway and will include a series of simulations reflecting simple changes in input conditions. The intent is provide a baseline of model response for comparison and to gage model sensitivity to simple changes in large-scale forcing. Expectation is that the input data sets and comparison protocols can be produced and agreed fairly quickly such that the simulations can be performed and analyzed prior to the workshop. This activity will engage the full spectrum of cirrus modelers from parcel and 1-dimensional models to full 3-dimensional LES models, to GCM/SCM calculations.

A more significant amount of work will be required for the selected observed case. The hope is that substantial work that has already been done on one or more of these cases and can be readily transferred to the other participants in terms of input data sets. Similarly, these cases have also had a substantial amount of effort invested into the analysis of the observations of the cloud systems providing a running start for the observational activities. An observational subgroup will prepare an analysis of the case for comparison with the model output. A reasonable expectation is that, for the 3-dimensional models, only a preliminary analysis of the results may be available by the workshop. Again, participation by the full community is desired including simulations by GCM and NWP models as well as mesoscale CRMs and nested LES models. Simulations along selected cross-sections by 2-dimensional cirrus models as well as parcel model calculations are also desired.

The plan is produce a report of the workshop. The report will include detailed descriptions of the models, especially as regards the physics and implementation of their cirrus cloud components, and results of the simulations. Inclusion of comparative analyses is planned. It is expected that such a report could be produced by the end of 1997 and would include a summary of the findings and recommendations of the workshop.

Also in 1997, a draft observational "blueprint" will be developed drawing upon the results and discussions at the workshop as well as the output of the WMO workshop on cloud measurements. In addition, if adequate participation and leadership is mustered, the sensor comparison focus will be initiated.

In 1998, WG2 will likely hold a joint workshop with either WG3 or WG4. Of particularly high interest is the simulation of convectively generated cirrus, especially tropical systems. Alternatively, it is possible that comparative study of extratropical systems may prove more useful in this time frame given the presently available data. There is a keen interest by WG2 in comparison of GCM simulations of extratropical weather systems in comparison to mesoscale CRM simulations. This would argue for a joint WG2-WG3 workshop. In any event, based on the experience of WG1, follow-up activities to the first workshop are very likely and will occupy a significant portion of the agenda for a second workshop, i.e., resolution of issues/questions raised.

Table 1: Participants in GCSS WG2

Philip R.A. Brown University of Reading, United Kingdom	3-D LES/meso
William Cotton Colorado State University, USA	3-D LES/meso
Tony Del Genio NASA Goddard Institute for Space Studies, USA	GCM and GCM/SCM
Dr. Paul J. DeMott Colorado State University, USA	Parcel
Leo Donner NOAA Geophysical Fluid Dynamics Laboratory, USA	2-D, 3-D meso, GCM
Dr. Klaus M. Gierens DLR Oberpfaffenhofen, Germany	Parcel, 2-D
Vincent Giraud Universite des Sciences et Technologies de Lille, France	Observations
Wojciech W. Grabowski National Center for Atmospheric Research, USA	Models
Andrew Heymsfield National Center for Atmospheric Research, USA	Observations
Christian Jakob ECMWF, United Kingdom	GCM and GCM/SCM
Dipl.-Met. Petra Jankiewicz Humboldt-University of Berlin, Germany	3-D meso
Peter Jonas UMIST, United Kingdom	3-D LES
Dr. Vitaly I. Khvorostyanov Russia	1D/2D non-hydrostatic models 1D/2D/3D hydrostatic models
Svetlana V. Krakovskaia Ukrainian Hydrometeorological Research Institute, Ukraine	Parcel, 2-D and 3-D meso
Dr. Jon Egill Kristjansson University of Oslo, Norway	Parcel, GCM and GCM/SCM
Steven K. Krueger University of Utah, USA	2-D
Lubomir Levkov GKSS Research Center, Germany	3-D LES

Ruei-Fong Lin, Tom Ackerman Pennsylvannia State University	2-D
K. N. Liou, Yu Gu University of Utah, USA	2-D
Ulrike Lohmann University of Victoria, Canada	GCM and GCM/SCM
Gerald Mace University of Utah, USA	Observations
Ehrhard Raschke, Markus Quante GKSS Research Center, Germany	Observations
Leon Rotstayn CSIRO Division of Atmospheric Research, Australia	GCM
Clive Saunders Manchester University and UMIST, United Kingdom	Laboratory Cloud Chamber
Samantha A Smith NASA Goddard Institute for Space Studies, USA	Observations
David Starr, Alex Kambis NASA Goddard Space Flight Center, USA	Observations, 2-D
Dr. Johan Strom Stockholm University, Sweden	Observations
Wei-Kuo Tao, Dan Johnson NASA Goddard Space Flight Center, USA	2-D, 3-D LES/meso
Taneil Uttal NOAA/ERL/ETL, USA	Observations
Gabor Vali University of Wyoming	Observations
Mark Webb Meteorological Office, United Kingdon	GCM, Observations
Dr. Damian Wilson Meteorological Office, United Kingdom	GCM
Ting Wu Colorado State University, USA	3-D LES/meso
Dance Zurovac-Jevtic Stockholm University, Sweden	3-D meso

Table 2: Expertise/Resources of Participants in GCSS WG2

GCM	7
GCM/SCM	4
3-D meso	5
3-D LES/meso	6
2-D	9
Parcel	6
Observations:	10
Cloud Chamber	1