NASA

Ames Research Center

FACSIMILE TRANSMISSION

Name Donna Lacy Space Directorate, M/S 200-7 NASA Ames Research Center Moffett Field, CA 94035-1000	Mail Address DOE/ER/61743--T2	Mail Stop
Office Phone (415) 604-5087	Transmitting Fax (415) 604-1165	Date 1/24/97

Name James Solomon Contracting Officer Program Acquisition and Assistance Division	Mail Address Department of Energy Oakland Operations Office 1301 Clay Street Oakland, CA 94612-5208	Mail Stop
Office Phone (510) 637-1865	Receiving Fax (510) 637-2074	Pages Including Cover 5

Message

Subject: Technical Deliverables for Interagency Agreement No. DE-A103-94ER61743

Regarding your letter of June 6, 1996, the subject report for FY 1994-1996 was electronically sent by Brian Toon of Ames Research to P. W. Lunn, Program Manager, per his request.

Per our phone conversation today, we are faxing this report to your office so your files will be complete.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *ph***MASTER**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

<DIVISION>
ENVIRONMENTAL SCIENCES: GLOBAL CHANGE.
</DIVISION>

<RESEARCH AREA>
ATMOSPHERIC RADIATION MEASUREMENT
</RESEARCH AREA>

<DOE PROGRAM MANAGER>
P.W. LUNN
</DOE PROGRAM MANAGER>

<ABSTRACT>
</ABSTRACT>

<TITLE>
MODELING OF CLOUDS AND RADIATION FOR DEVELOPING
PARAMETERIZATIONS OF CLOUDS IN GENERAL CIRCULATION MODELS
</TITLE>

<HUMAN SUBJECTS> NO </HUMAN SUBJECTS>
<ANIMAL USE> NO </ANIMAL USE>
<UNDERS> 0 </UNDERS>
<GRADS> 0 </GRADS>
<POST> 4 </POST>

<INVESTIGATOR>	O.B. TOON	</INVESTIGATOR>
<ORG>	NASA-Ames	</ORG>
<EMAIL>	toon@sky.arc.nasa.gov	</EMAIL>
<PHONE>	(415) 604-5971	</PHONE>
<FAX>	(415) 604-3625	</FAX>
<SNAIL MAIL>	NASA-Ames, MS 245-3, Moffett Field	</SNAIL MAIL>
<STATE>	CA	</STATE>
<ZIP>	94035-1000	</ZIP>
<URL>	http://sky.arc.nasa.gov/	</URL>
<PROJECT URL>	http://cloud1.arc.nasa.gov/espo/success/	</PROJECT URL>

<DATES>
FY 1996 160k

FY 1995 200k

FY 1994 200k <p>
</DATES>

<START DATE> 10/01/94 </START DATE>
<END DATE> 30/09/96 </END DATE>

<KEYWORDS>
CLOUD MODELING

RADIATIVE TRANSFER MODELING

</KEYWORDS>

<OBJECTIVE>
We conducted modeling work in radiative transfer and cloud microphysics. Our work in radiative transfer included performance tests to other high accuracy methods and to measurements under cloudy, partial cloudy and cloud-free conditions. Our modeling efforts have been aimed to:

 develop an accurate and rapid radiative transfer model
 develop three-dimensional radiative transfer models
 develop microphysics resolving cloud and aerosol models

We applied our models to:

 investigate solar clear-sky model biases
 investigate aerosol direct effects

- investigate aerosol indirect effects
 - investigate microphysical properties of cirrus
 - investigate microphysical properties of stratus
 - investigate relationships between cloud properties
 - investigate the effects of cloud structure
-

We conducted in April an aircraft field program, SUCCESS, over the ARM field site measuring cirrus radiative and microphysical properties for improved radiative transfer and cloud formation simulations.
</OBJECTIVE>

<APPROACH>

Most models of clouds have focused on cloud dynamics. This is not adequate if we wish to have an improved understanding of cloud radiative properties. The radiative properties of clouds depend on particle size distribution, cloud water or ice content, and the distributions of these properties through the clouds. Microphysical cloud models in which the drop size distribution is resolved and macrophysical cloud models that account for the cloud structural geometry are required to calculate such quantities.

Recently measurements have suggested that clouds absorb more solar radiation than previously suspected and we investigated this issue for marine stratus clouds and for horizontal inhomogeneity of clouds, which is generally overlooked in radiative transfer models.

Our comparisons between field observations and model results for cirrus clouds revealed that new efforts in radiative transfer modeling are necessary to deal with cloud inhomogeneity effects.

We developed new 3-dimensional radiative transfer codes, a Monte-Carlo code and a time-efficient six-stream method, to understand the effects of cloud inhomogeneity on (solar) radiative transfer.

We also have continued the development of a rapid radiative transfer model (3-ARM) for use in climate simulations. The model is a joint effort between NASA-Ames, AER and the Pennsylvania State University. The model combines the efficient 2-stream code of Toon et.al. 1989, new k-distributions for gas-absorption from AER and a new 4-stream option from Penn State.

We also confirmed recent concerns about the poor performance of solar radiative transfer models under cloud-free conditions with our models and we are currently looking for an explanation. It is imperative to understand this clear sky modeling problem before progress can be made for comparisons under cloudy conditions.

In addition to our work on microphysics and radiative transfer, we have also been active in the design of field programs to provide data which improves our understanding of cloud radiative properties. For instance the NASA sponsored SUCCESS field program, in April and early May 1996, provided for eleven days observations of detailed cloud in-situ microphysical data and radiative measurements over and near the DOE-CART site. These measurements complement not only observations at the ground (DOE ARM CART-site), they also complement measurements by the DOE UAV program, which was conducted at the same time. A large fraction of our group participated in SUCCESS either as project scientists, aircraft scientists, or theory team members.

</APPROACH>

<RESULTS TO DATE>

Results for clear-sky conditions:

- current radiative transfer models consistently overpredict the solar radiative flux reaching the surface: aerosol measurements, water vapor data and good agreement for the direct solar insolation, eliminate easy explanations
- the 3-ARM infrared radiative transfer code is in good agreement with accurate line-by-line codes and DOE AERI measurements (ICRCCM comparison)

Results for cloudy conditions:

- increased cloud inhomogeneity increases the transmission and reduces

the reflection and absorption

- overlooked cloud inhomogeneity is unlikely to explain measurements of excess solar absorption
- 3D six-stream methods can be an excellent tool to quickly illustrate scattering patterns for inhomogeneous media
- excess solar absorption in marine stratus must be negligible - otherwise these clouds would not exist
- for cirrus, it is almost impossible to find unique relationships between two properties unless at least a third cirrus properties is considered

</RESULTS TO DATE>

<DELIVERABLES>

Below we list the published papers that have been prepared under partial support from ARM during the previous proposal period. Our work has been focused on providing more detailed microphysical models of clouds than have been available previously, investigating the indirect and direct effects of aerosols on climate, understanding the radiative properties of clouds, and developing improved techniques for performing radiative transfer calculations.<p>

"Cirrus microphysics and radiative transfer: cloud field study on 28 October 1986" (Kinne, S., T.P. Ackerman, A.J. Heymsfield, F.P.J. Valero, K. Sassen, and J.D. Spinhirne), Mon. Wea. Rev., 120, 661-684, 1992.

"The potential effects of volcanic aerosols on cirrus cloud microphysics" (E.J. Jensen, and O.B. Toon), Geophys. Res. Lett., 19, 1759-1762 (1992).

"Dissipation of Marine Stratiform clouds and collapse of the marine boundary layer due to aerosol depletion by clouds", (A.S. Ackerman, O.B. Toon, and P.V. Hobbs) Science, 262, 226-229 (1993).

"Modeling coagulation among particles of different composition and size" (M.Z. Jacobson, R.P. Turco, E.J. Jensen, and O.B. Toon, Atmos. Environ. 28, 1327-1338 (1994).

"Ice nucleation in the upper troposphere: Sensitivity to aerosol number density, temperature, and cooling rate" (E.J. Jensen and O.B. Toon), Geophys. Res. Lett., 21, 2019-2022 (1994).

"Reassessing the dependence of cloud condensation nucleus concentrations on formation rate" (A.S. Ackerman, O.B. Toon, and P.V. Hobbs), Nature 367, 445-447 (1994).

"Tropical cirrus cloud radiative forcing: Sensitivity studies" (E.J. Jensen, S. Kinne, and O.B. Toon), Geophys. Res. Lett., 21, 2023-2026 (1994).

"Microphysical modeling of cirrus 1: Comparison with 1986 FIRE IFO measurements. (E.J. Jensen, O.B. Toon, D.L. Westphal, S. Kinne, and A.J. Heymsfield), J. Geophys. Res. 99, 10421-10442 (1994).

"Microphysical modeling of cirrus 2. Sensitivity studies". (E.J. Jensen, O. B. Toon, D.L. Westphal, S. Kinne, and A.J. Heymsfield), J. Geophys. Res., 99 10443-10454 (1994).

"A model for particle microphysics, turbulent mixing, and radiative transfer in the stratocumulus-topped marine boundary layer and comparisons with measurements" (A.S. Ackerman, O.B. Toon, and P.V. Hobbs), J. Atmos. Sci., 52, 1204-1236 (1995).

"On the formation and persistence of subvisible cirrus clouds near the tropical tropopause" (E.J. Jensen, O.B. Toon, H.B. Selkirk and J. Spinhirne) J. Geophys. Res. in press, (1995).

"Modeling the relationships between aerosol properties and the direct and indirect effects of aerosols on climate" (O.B. Toon) in Aerosol Forcing

of Climate Dahlem Workshop Report ES 17, ed. R.J. Charlson and J. Heintzenberg, J. Wiley & Sons, pg 197-213, (1995).

"Numerical modeling of ship tracks produced by injections of cloud condensation nuclei into marine stratiform clouds" (A.S. Ackerman, O.B. Toon, and P.V. Hobbs) J. Geophys. Res., 100, 7121-7134 (1995).

"The impact of enhanced solar absorption on model simulations of the cloud-topped marine boundary layer" (A.S. Ackerman and O.B. Toon) Nature, in Press, (1996).

"Where to look for the effects of aerosol pollution on cloud albedo" (A. Ackerman, O.B. Toon, P.V. Hobbs) Nature, submitted, 1996.

"Direct radiative forcing by anthropogenic airborne mineral aerosols" (I. Sokolik and O. B. Toon), Nature, submitted, (1996).

"Dehydration of the upper troposphere and lower stratosphere by subvisible cirrus clouds near the tropical tropopause" (E.J. Jensen, O.B. Toon, L. Pfister, and H. Selkirk), Geophys. Res. Lett., in Press (1996).

"Cirrus cloud radiative and microphysical properties from ground observations and in-situ measurements during FIRE-91 and their application to exhibit problems in cirrus solar radiative transfer" (S. Kinne, T.P. Ackerman, M. Shiobara, A. Uchiyama, A.J. Heymsfield, L. Miloshevich, J. Wendell, E. Eloranta, C. Purgold and R.W. Bergstrom) J.Atmos.Sci. submitted, (1996)

"Initialization and validation of a simulation of cirrus using FIRE-II data" (D.L. Westphal, S. Kinne, J.M. Alvarez, S.G. Benjamin, W.L. Eberhard, A.J. Heymsfield, R.A. Kropfli, G.G. Mace, S.Y. Matrosov, S.H. Melfi, P. Minnis, P. Pilewskie, J.B. Snider, B.J. Soden, D.O'C. Starr, T.A. Uttal, D.F. Young). J. Atmos. Sci. submitted, (1996).

<p>

Abstracts of papers given at the 1996 ARM Science team meeting:

"3ARM - A fast accurate radiative transfer model for the use in climate codes" (Bergstrom, R, S. Kinne, B. Toon, E. Mlawer, S.A. Clough, T. Ackerman, T.Mather)

"Solar radiative transfer modeling under cloud-free conditions"

(Kinne, S, R.W. Bergstrom, O.B. Toon)

"3-D scattering simulations for clouds: How accurate is the six-stream method?" (S. Kinne, R.W. Bergstrom, O.B. Toon)

</DELIVERABLES>

<SYSTEMDATE>

Sat Jun 29 20:00:00 EST 1996

</SYSTEMDATE>