Subject: Technical Deliverables for Interagency Agreement No. DE-AL03-94ER61743

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.
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MODELING OF CLOUDS AND RADIATION FOR DEVELOPING PARAMETERIZATIONS OF CLOUDS IN GENERAL CIRCULATION MODELS

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
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.<br/>
</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.<br/>

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 in generally overlooked in radiative transfer models.<br/>

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.<br/>

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.<br/>

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.<br/>

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.<br/>

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:
<ul>
<li>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</li>
<li>the 3-ARM infrared radiative transfer code is in good agreement with accurate line-by-line codes and DOE AERI measurements (ICRCCM comparison)</li>
</ul>

Results for cloudy conditions:
<li>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

</ul>
</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.


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


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)

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