521535

DATE:	April 20, 1999
TO:	National Aeronautics and Space Administration Langley Research Center Hampton, VA 23681-0001
CC:	Dorothy Rein OSP – Colorado State University
FROM:	Dr. Stephen K. Cox Stephen K. Cox Department of Atmospheric Science Colorado State University Fort Collins, CO 80523
SUBJECT:	FINAL REPORT PROPOSAL GRANT NUMBER 95-221 **FIRE III – RADIATIVE SIGNIFICANCE OF MIDDLE AND UPPER TROPOSPHERIC CLOUDS** CSU PROJECT NUMBER 5-31922

The following is a list of report recipients.

LaRC Grant Officer	Attn: Grants Office, Mail Stop 126 NASA Langley Research Center Hampton, VA 23681-2199
LaRC Technical Officer	Attn: V. Delnore, Mail Stop 483 NASA Langley Research Center Hampton, VA 23681-2199
LaRC Industrial Property Officer	Attn: Industrial Property Officer, Mail Stop 377 NASA Langley Research Center Hampton, VA 23681-2199
LaRC Patent Counsel Office	Attn: Patent Counsel Office, Mail Stop 212 NASA Langley Research Center Hampton, VA 23681-2199
LaRC Financial Management Office (for SF 272s)	Attn: Financial Management Office, Mail Stop 135 NASA Langley Research Center Hampton, VA 23681-2199
LaRC Financial Management Office (for Annual and Fnal Inventory Reports of Federally-Owned Property)	Attn: Financial Management Office, Mail Stop 147 NASA Langley Research Center Hampton, VA 23681-2199
NASA Center for AeroSpace Information (CASI)	Attn: Accessioning Department, Parkway Center NASA Center for AeroSpace Information (CASI) 7121 Standard Drive Hanover, MD 21076-1320
University Affairs Officer	Attn: University Affairs Officer, Mail Stop 400 Office of Education NASA Langley Research Center Hampton, VA 23681-2199

FINAL REPORT
PROPOSAL GRANT NUMBER 95-221

FIRE III – RADIATIVE SIGNIFICANCE OF MIDDLE AND UPPER TROPOSPHERIC CLOUDS

CSU PROJECT NUMBER 5-31922

I Micropulse Lidar:

During the course of this grant, we have fabricated a micro pulse lidar system. This system was patterned after a similar instrument developed at GSFC. During the fabrication we were able to take advantage of several new developments in components and altered the basic design accordingly. In addition a new data acquisition/reduction/display software package was developed and integrated into the lidar package. At this point the lidar has undergone initial testing and shows significant promise. There are several improvements being considered to enhance the performance. This basic system with improvements was the topic of a Master's thesis for one of our engineers on our project.

II Multiple Field of View Radiometer development work

The Multiple Field of View Radiometer and its application to the remote sensing of size distribution and extinction parameters of thin cloud and aerosol layers were pioneered by this research group at CSU. The availability, functionality, performance and cost effectiveness of CCD arrays has led us to consider the original design of this instrument to become both a multiple wavelength and multiple field of view instrument. The design work on this new instrument has taken place under this grant. Proof of concept has been shown as well as cost effectiveness when compared with other options for the same set of observations in an operational setting. We expect to further develop, fabricate, test and deploy this new instrument under future funding.

III Scene reflectance

Analyses of bidirectional reflectance data are presented with implications regarding the spatial scales appropriate for inferring irradiances from radiances reflected by various surface-atmosphere scenes. Multiple-angle radiance data collected in a nearly simultaneous manner during the 1979 Summer Monsoon Experiment are analyzed using the squared coherency statistic to suggest a method to deduce the minimum spatial scale appropriate for irradiance inferences. Spatial convergence of the irradiances inferred from the component radiances are presented as a function of averaging distance to imply magnitudes of errors that may result from use of "similar scene" bedirectional reflectance models. The reduction in the inference errors with an increasing number of angular viewing positions is also presented. The data are analyzed in search of preferred viewing directions with the result that little improvement is imparted to the inference by viewing the scenes from any specific view direction.

IV Solar tracking equatorial mount

Tracking errors were assessed for a computer controlled solar tracker. The effects of optical scattering on radiometric measurements performed with the tracker were also evaluated. As the position of the tracker is iteratively corrected over time, linear regression is used to calculate a best-fit correction for tracking error. The performance of the tracker was found to be senstitive to the timing of the iterative corrections and to the errors associated with those corrections. Using an optimized scheme for iterative corrections in a field test, the average tracking error was found to be 0.11 ± 0.05 degrees for 48 hours following the final iterative correction.

The solar tracker may be fitted with a mirror which can reflect the image of a target into an instrument. Because the mirror is exposed to multiple sources of illumination (direct sunlight, skylight, and light from surrounding objects) the scattering properties of the mirror are important. The intensity of light scattered from the mirror was compared with the intensity of diffuse skylight. Scatter from the diffuse field incident on the mirror (background scatter) was found to be more significant than scatter from the direct solar beam, and both were significant compared to the intensity of diffuse skylight. Background scatter ranged from 20% to 70% of the total measured signal, depending on scattering geometry and wavelength. Solar scatter ranged from 1% to 20%, also depending on scattering geometry and wavelength. The scattering properties of the mirror, as measured by the bidirectional reflectance distribution function, appeared to be anisotropic, possibly because of surface defects. For the wavelengths examined, the scattering properties did not follow the wavelength scaling law predicted by Rayleigh-Rice theory for clean, smooth, front-surface reflectors.

V CRYSTAL

The principal investigator has been directly and actively involved in planning the follow on research to the FIRE sequence of research activities. In addition to planning and presiding at FIRE Science Team meetings, the PI has chaired the panel charged with drafting the next phase of upper tropospheric loud research to be undertaken in the first five years of the next century. This phase of research is named CRYSTAL and the science plan has recently been distributed to the scientific community to be followed shortly by an RA from NASA. The principal investigator, in his role of Chair of the FIRE Science Team has represented NASA's interests in various forums throughout the duration of this grant.

VI List of Publications

Randall, D., B. Albrecht, S. Cox, D. Johnson, P. Minnis, W. Rossow, and D. Starr, 1995: On FIRE at Ten. *Advances in Geophysics*, 38, 37-177.

Cox, S. K., 1994: Cloud-radiation interactions and their parameterization in climate models. Progress review, process studies. Report of international workshop, NOAA Science Center, Camp Springs, MD, Oct. 18-20, 1993. World Climate Programme Research, International Association of Meteorology and Atmospheric Sciences, WCRP-86, WMO/TD-No. 648, pgs. 125-127.

Kuo, Kwo-Sen, R. C. Weger, R. M. Welch and S. K. Cox, 1995: The Picard iterative approximation to the solution of the integral equation of radiative transfer. Part 2: Three-dimensional geometry. *J. Quant. Spectrosc. Radiat. Transfer, 55, 195-213.*

Dutton, E. G. and S. K. Cox, 1995: Tropospheric radiative forcing from El Chichón and Mt. Pinatubo: theory and observations. Atmospheric Science Paper No. 586, Colorado State University, Fort Collins, CO 80523, 209 pages.

Gillies, S. and S. K. Cox, 1995: Observation and parameterization of solar irradiance in marine stratocumulus and cumulus regimes. Atmospheric Science Paper No. 590, Colorado State University, Fort Collins, CO 80523, 104 pages.

Beck, G. H., J. M. Davis and S. K. Cox, 1996: Radiative properties of cirrus clouds derived from surface interferometric measurements. Accepted for publication in *J. of Appl. Meteorology.*

Heidinger, A. K. and S. K. Cox, 1996: Finite cloud effects in longwave radiative transfer. *J. Atmos. Sci.*, 53, 953-963.

Cotturone, J. A., and S. K. Cox, 1996: Monte Carlo simulation of detection of cirrus cloud properties by micro pulse lidar. Atmospheric Science Paper No. 608, Colorado State University, Fort Collins, CO 80523, 58 pages.

Cotturone, J. A. and S. K. Cox, 1996: Monte Carlo simulation of detection of cirrus cloud properties by micro pulse lidar. Submitted to *J. Atmos. Oceanic Technol.*

Wood, N. B. and S. K. Cox 1996: An improved solar tracker system with linear regression error correction. Atmospheric Science Paper No. 604, Colorado State University, Fort Collins, CO 80523, 31 pages.

Cox, S.K., J.M. Davis, S. Gillies, A. Huffman, J. Kleist, D. wood, N. Wood and T. Vonder Haar, 1997: Description of the cloud layer experiment (CLEX), field phase, surface data archive. Atmospheric Science Paper No. 626, Colorado Stte University, Fort Collins, CO 80523, 81 pages.

Davis, J.M. and S.K. Cox, 1997. Spatial convergence of bi-directional reflectance models. Accepted for publication, *J. of Atmos. And Oceanic Technology*.

Wood, D.R. Jr. and S.K. Cox 1997: Design, construction, and testing of the enhanced micro pulse. Atmospheric Science Paper No. 659, Colorado State University, Fort Collins, CO, 80523, 72 pages.

Wood, N.B. and S.K. Cox, 1998: Tracking errors and optical scatter in a solar tracker with linear regression error correction. Atmospheric Science Paper No. 663, Colorado State University, Fort Collins, Colorado, 80523, 97 pages.