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Technical Report to the U. S. Department of Energy

ICRCCM Phase II: Verification and Calibration of Radiation Codes in Climate Models

for the period 1 January through 1 November 1991

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Introduction

Following the finding by the InterComparison of Radiation Codes used in Climate Models (ICRCCM) of large differences among fluxes predicted by sophisticated radiation models that could not be sorted out because of the lack of a set of accurate atmospheric spectral radiation data measured simultaneously with the important radiative properties of the atmosphere, our team of scientists proposed to remedy the situation by carrying out a comprehensive program of measurement and analysis called SPECTRE (Spectral Radiance Experiment). SPECTRE will establish an absolute standard against which to compare models, and will aim to remove the "hidden variables" (unknown humidities, aerosols, etc.) which radiation modelers have invoked to excuse disagreements with observation. The data to be collected during SPECTRE will form the test bed for the second phase of ICRCCM, namely verification and calibration of radiation codes used in climate models. This should lead to more accurate radiation models for use in parameterizing climate models, which in turn play a key role in the prediction of trace-gas greenhouse effects.

This report summarizes the activities of our group during the project's second year to meet our stated objectives. The report is divided into sections on SPECTRE and ICRCCM activities. The section on SPECTRE summarizes the steps we've taken to prepare for the field experiment scheduled for 11 November through 7 December 1991, whereas the section on ICRCCM summarizes the progress made in ICRCCM during the past year.

SPECTRE Activities

The overall plans for SPECTRE are proceeding as outlined in the original proposal. The experiment site at the Coffeyville, Kansas airport has been surveyed and trailers with electrical power are now being installed by the NASA FIRE Project Office, which is coordinating the various logistical matters. The activities in preparation for SPECTRE are most easily summarized according to the participating groups at the University of Maryland, Denver University, the University of Wisconsin, NASA Greenbelt, and NOAA. These are discussed in turn below.

University of Maryland

This group, led by Professor Ellingson, has been primarily involved with coordinating the activities of the various groups supported through the University of Maryland, insuring the acquisition of data from the lowest few hundred meters of the atmosphere, and performing sensitivity analyses of model calculations for use in the interpretation of the radiance observations and their comparisons with observations. As noted in last year's report, our original proposal called for the purchase of a tethersonde system for obtaining temperature, water vapor and ozone profiles in the lowest few hundred meters where the remote sensing techniques are blind. However, we have arranged for a group at NASA Wallops to perform the soundings for us with sondes and balloons purchased by this project. At the time of this report, we are unsure of obtaining FAA approval of the use of the tethersonde at the Coffeyville airport. Therefore, we have arranged to have more frequent radiosonde ascents during intensive SPECTRE observation periods should we be unable to use the tethersonde.

The analyses of the radiation model calculations have focussed on the sensitivity of the vertically downwelling radiance calculations at the surface to possible errors in the measurement of the radiatively important variables for clear-sky conditions (i.e., temperature, H_2O, O_3, CO_2, N_2O, CH_4). Since we are particularly concerned with improving our understanding of the water vapor continuum, the study has concentrated on the semi-transparent portion of the spectrum from 700 to 1220 cm^{-1} (about 8 to 14 μm). During the last year we used a new line line-by-line model, FASCODE3, to repeat our earlier calculations with FASCODE2, and we obtained nearly identical results. Furthermore, we are in the process of extending those results to a wider range of atmospheric properties. Since computations with FASCODE require copious amounts of computer time, we obtained and began our new analyses with MODTRAN, a relatively high resolution band model radiation code from the Phillips Laboratory (formerly AFGL). Since this model gives results at a resolution of about 2 cm^{-1}, we plan to use the model as a proxy for the computationally intensive line-by-line results. We are currently performing our perturbation analysis with each of the five different AFGL atmospheres.

Denver University

This group, led by Professor David Murcray, has supplied the following progress report.

The major part of our effort for SPECTRE this year has been the modification of an emission instrument for the FIRE II campaign, and the preparation of the solar instrument for use in FIRE. We have also continued our comparison of solar interferometer systems, and our study of the emission instruments.

Our South Pole instrument was returned to Denver after operating for a year in Antarctica. It will be returned to the South Pole in November for another year of observations. This season, Professor Warren (University of Washington) will be wintering over, and will actively operate the instrumentation, as well as making detailed meteorological observations. This should improve the usefulness of the data set for comparison with SPECTRE codes.

The South Pole instrument operated about every 17 hours, making an observation sequence consisting of sky views at 2 angles and 2 blackbody views. The heater in one of the blackbodies did not function correctly, so calibration of the data required that we measure the scan mirror reflectivity and window transmission as accurately as possible. The field data showed that the instrument response function was constant within 2% over the winter period, after experiencing a one time shift of about 20%. The overall stability of the instrument is very encouraging.

An extensive set of calibrations was run on the South Pole instrument in Denver. These were intended to measure the mirror and window contributions to the signal so that the data could be calibrated more accurately. These calibrations also indicate that the instrument accuracy is around 3%. Part of this is due to the small blackbodies used on the instrument, resulting in poor thermal stability of the calibration source in the laboratory. At the South Pole, the blackbodies are operated constantly, and thermal stability is less of a problem. A remaining limitation on the accuracy is in a residual phase error. This phase error is still under investigation, particularly as to whether it also shows on the SPECTRE instrument. We are preparing to do a calibration of the SPECTRE instrument before shipping it to Kansas for FIRE.

The ultra-high resolution solar interferometer is being prepared for FIRE, after preforming a successful balloon flight in June.

Two different solar interferometer systems were run simultaneously this summer. The spectra generated appear identical within the noise, with some significant exceptions. Some of the effects seem to be related to detector non-linearity, others result from slightly different handling of the phase correction. Detailed comparison is awaiting some software to convert the spectra to an identical wavenumber grid. (Because interferometer spectra tend to be minimally sampled, shifting scales requires interpolation. The scales are the same to about a resolution element.)

University of Wisconsin

Professor William Smith has supplied the following progress report for the Wisconsin group.

The University of Wisconsin-Madison SPECTRE program is at the midpoint of the second year of a three year subcontract with the University of Maryland. The planned activities of the three years are:

First year - Instrument development,
Second year - Support field experiment at Coffeyville, Kansas, and
Third year - Analyze data from the field experiment.

The University of Wisconsin is on schedule and within budget for meeting the obligations of the project.

The activities of the first six months of the current funding year concentrated on performance evaluation of existing and new instrumentation and preparation for the field phase beginning in November 1991. The bulk of the spending for the second year will be used to support the in-the-field costs of making the measurements. Preparation for the field experiment has included final instrument calibration, logistical and travel planning, and personnel coordination. Performance evaluation has included characterization of instrument radiometric response, signal to noise ratio, blackbody temperature monitoring accuracy, and calibration accuracy. The goal of instrument performance evaluation is to provide the SPECTRE program with the best possible calibrated radiance measurements. The accuracy of these measurements is critical to the correct interpretation of infrared radiative transfer in clear and cloudy conditions.

Note that considerable synergism has been possible between the UW subcontract for SPECTRE and a separate contract from the DOE ARM advanced instrument development program. In fact, a prototype upward looking interferometer for the proposed CART site will be demonstrated at Coffeyville.

NOAA

The participants from NOAA under subcontract with the University include Dr. John DeLuisi and Dr. Richard Strauch. Dr. DeLuisi's group will provide measurements of the concentration of trace gases near the surface and vertical profiles of the O_3 concentration through the stratosphere. It should be noted that DeLuisi will also be conducting an intercomparison of pyrgeometers observations (longwave flux measurements) for the World Climate Research Program adjacent to the SPECTRE experiment. We hope that our combined efforts will yield a better estimate of the absolute accuracy of the longwave flux observations.

Dr. Strauch's group will be providing the project with temperature measurements obtained from the Radio Acoustical Sounding System (RASS). Present plans call for Strauch to bring 915 and 400 Mhz RASS systems to Coffeyville. Dr. Strauch has arranged for the Penn State Univ. group to provide a 50 Mhz RASS for sounding to higher altitudes. Funds for the current year have been used in preparing the various systems for field implementation.

NASA Goddard

Dr. Warren Wiscombe leads this group and is responsible for coordinating the various NASA participants. The instrumentation from this group includes the Raman Lidar for water vapor profiling (led by Dr. Melfi), a high resolution spectrometer and a calibration facility (the latter two led by Dr, Kunde). Dr. Melfi's group has completed most of the construction of their new Raman system for both day-and-night sounding. This group recently performed several comparisons of night soundings with simultaneous radiosonde ascents with excellent results. The last components necessary for daylight soundings will be installed just prior to the field experiment, and the operations in Coffeyville will serve as a test of this new technique.

Dr. Kunde's group has completed the the assembly and testing of the necessary components of the spectrometer and calibration systems. At the writing of this report, they are in the process of packing their equipment for the field experiment.

Coordinated Team Activities

Wiscombe and Ellingson have continued to have frequent contact to coordinate the activities of the various groups. Furthermore, several members of the team met in Coffeyville in August 1991 to discuss various approaches and to specify the best locations for the experiment site. Wiscombe and Melfi attended the FIRE dress rehearsal in September 1991 in order to gain insight to FIRE operations planning. The operations plan for SPECTRE are nearing completion as of the writing of this report.

ICRCCM Activities

ICRCCM continues to be a working group of the International Radiation Commission (IRC) and World Climate Research Program with Professors Ellingson and Fouquart (Univ. Lille, France) as co-Chairs. As noted in our last report, a call for new calculations directed at (1) understanding the differences in model treatments of trace gases and (2) determining differences between model calculated heating rates was made in January 1990. The trace gas calculations were coordinated with Dr. Wei-Chung Wang of SUNY Albany as part of the activity of the Ozone Commission. Unfortunately, Fouquart and Ellingson have had very little response to the request under (2) above. As indicated in the 1983 ICRCCM Workshop Report, the participants feel that further comparison of model only results will yield little information. Therefore, it is not surprising that few people have participated in this exercise. An informal poll of the participants indicates a much stronger desire to participate in comparisons with observation - a major portion of the third and fourth year activities of this project.

Model calculations the trace gas study were obtained from about 10 different investigators (a few others have promised results). Those calculations were analyzed during the past year and the results were presented by Ellingson at the IAMAP Workshop on Climatic Effects of Atmospheric Trace Constituents at the IUGG meeting in Vienna in August 1991 and at the meeting of the WCRP Working Group on Radiative Fluxes, Palm Springs, CA, September 1991. Briefly, the results show:

- Calculations with O_3 are in the best agreement of all gases.
- There is a 30 to 50% spread of results among band model parameterizations of the effects of CH_4, N_2O, F11 and F12, although line-by-line model results agree more closely.
- Apparently, only a small number of groups include the effects of any trace gases in climate model calculations, although the effects of their current concentrations are as large as doubling the current concentration of CO_2.

The results of this study are being prepared for journal publication.

It should be noted that the results from the first phase of ICRCCM are summarized in a series of 14 papers in the May 14, 1991 edition of the *Journal of Geophysical Research* (atmospheres). Professor Ellingson was the first author of two of these papers, copies of which are available upon request.

Summary

Overall, the project is proceeding much as had been anticipated in the original proposal. The most significant accomplishments to date include the publication of the results from the first phase of ICRCCM, the completion of the ICRCCM trace gas study, the completion of the sensitivity analysis of the radiation calculations for the effects of uncertainties in the measurement of water vapor and temperature and the acquisition and testing of the spectrometers for use in the field experiment. At this time we are quite anxious to begin our field operations in Coffeyville, Kansas.

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