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CCM Progress Report—October 1988

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1. INTRODUCTION

The advantages of the Community Climate Model (CCM) concept, in which many scientists use the same basic model for a variety of scientific studies, were demonstrated in the CCM workshops held at NCAR in July 1985 and 1987. At these workshops many diverse experiments were seen to relate to each other when performed with the same model, and much constructive dialogue took place between experts in different disciplines. Unfortunately, not all users of the CCM were able to participate in these workshops. To augment these workshops and to foster interchange between all users of the NCAR CCM, the CCM Advisory Committee recommended that a CCM Progress Report be prepared periodically for all users and potential users. The committee recommended that the bulk of this report consist of brief reports which should be required of all CCM users both inside and outside of NCAR. These individual reports are assembled in section 4 of this report as submitted by the users with no additional editing. They were submitted either in camera ready form or via electronic mail. Section 2 describes the current state of the CCM code. We expect CCM1 to remain the basic frozen version for at least another year and a half. Research directed toward improving various components of CCM1 has been proceeding and is described in the various individual reports of section 4. After various improvements are demonstrated for individual components, scientists in the Climate Modeling Section will combine them into a prototype for CCM2. We expect much lively debate within the sections and in the CCM Coordinating Committee during the coming year as we begin to define the desirable components of CCM2.

At the recommendation of the Advisory Committee, the remaining sections of this progress report consist of cumulative lists of CCM-related theses and publications. These have been gleaned from the various individual reports submitted and are undoubtedly incomplete. Please inform the editor of errors and/or omissions so that future lists can be as complete as possible. The last section lists the CCM Manuals which document the current and past supported versions of the CCM.

2. CURRENT STATE OF THE CCM

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Two new unresequenced program libraries have recently been created for CCM1 which incorporate several fixes to bugs discovered this past spring, improvements in computational performance, and several other enhancements to features in the model. These libraries are `CCM1PL1`, which should be used for the standard R15 truncation experiments, and `CCM1PL2` which can be used for experimentation at T42. The only differences in the two libraries are that the `CCM1PL2` library contains necessary modifications for a T42 truncation, and incorporates a gravity wave drag parameterization.

Three known bugs have been fixed with the introduction of these new libraries, which include a correction to the formulation and implementation of the surface temperature calculation, a correction to an internal inconsistency in the radiation code, and a correction to incorrect header record length information that had been included on the CCM1 history tape header (see Hack *et al.*, in preparation). Since the correction to the instantaneous surface energy balance has introduced some marginally significant differences in the new model climate, new controls were run for the R15 truncation and include a 600-day perpetual January simulation, a 600-day perpetual July simulation, a ten-year seasonal cycle simulation with fixed surface forcing, and a ten-year seasonal cycle simulation with a variable surface hydrology. In addition to the new control runs at R15, a five-year seasonal cycle control experiment has been completed at T42.

Although a T42 version of CCM1 has been introduced with the `CCM1PL2` program library, the R15 version of CCM1 should still be considered to be the basic working version of CCM1 for experimental purposes. This is the resolution at which the model was developed and at which the majority of the diagnostic effort was expended. The T42 control runs were performed to provide a starting point for developing a higher resolution version of the CCM. We emphasize that this version and its control runs have been made available to the community primarily for diagnostic purposes and may not be suitable for certain classes of experiments without further development.

Other major functional changes incorporated in the new program libraries affect the way in which the mass field is adjusted, and change the type of information contained in the mass storage system comment field. The mass field is now adjusted so that horizontal derivatives of $ln\ p_s$ are preserved. The standard information provided in the mass storage system comment field has been changed to contain the beginning and ending dates and times for the history volume, information that should be more useful to the user. The details pertaining to each of these modifications will be discussed in detail in a forthcoming report (Hack *et al.*, in preparation).

A number of code changes to the frozen CCM1 code have been incorporated in the new program libraries resulting in significant improvements in computational performance.

These changes included modifications to **RADCSW**, **TSCALC**, **PHYS**, and **CLDCMP**, resulting in a 27% improvement in performance at R15, and a 33% improvement in performance at T42, even after the incorporation of the gravity wave drag parameterization. Generic job decks for running program libraries **CCM1PL1** and **CCM1PL2** are available on the **CSMLIB** A disk under the names **CCM1PL1** R15 and **CCM1PL2** T42, respectively. These generic decks include modifications to the frozen libraries that allow for the model to be restarted in the event that the user chose to modify the standard **ORO** field on the initial data set at the Gaussian latitude nearest the North Pole. These mods have no effect on the model simulation. None of the CCM1 program libraries will restart without these mods if there is an ocean flag in **ORO** at the northern most row.

Since the program libraries were frozen, the CCM Core Group has made available other modifications to the model code which provide an additional 9% improvement in performance without imposing algorithmic changes (*i.e.*, without changing the numerical results). These **MODS** replace the **CCM1PLx UPDATE** decks **RADCLW**, **RADTPL**, and **RADALB**, and modify decks **MADADJ**, **MADCLC**, and **TSCALC**. They are available on the **CSMLIB** A disk under the filename **FASTCCM1 MODS**.

Also available on the **CSMLIB** A disk are two Cray Update moddecks meant to improve I/O aspects of the model. CCM1 **SSDMODS** assign the work files within the model to the Solid State Storage Device (SSD) on the Cray X-MP, providing I/O access which is much faster than disk-based I/O, and virtually eliminating the disk activity charges which typically account for half of the total Cray charges. This deck modifies subroutine **MODIFY** and replaces subroutine **REQUST**. It also introduces a new deck **LJUST**. The CCM1 **SYNCMODS** moddeck changes the asynchronous I/O to and from the work files to synchronous I/O, allowing the system to optimize I/O activity via the I/O Subsystem, and eliminating nearly half of the memory required for main model buffer storage. This deck modifies comdecks **PARAMS** and **COMLEG** and decks **DATINI**, **GRCALC**, **INIDAT**, **LEG**, **LNGTHS**, **SCAN1**, **SCAN2**, **STEPON**, and **STRTN**.

The combined use of the new program libraries and the **UPDATE** mod files discussed above allows the user to execute the CCM at approximately 35% of the previous GAU cost using the **CCM1PL** program library.

3. ACKNOWLEDGMENTS

I would like to thank the many users of the CCM for responding to our request for their individual progress reports. Without such a complete response there would be no purpose in issuing this CCM Progress Report. I would also like to thank Eileen Boettner for her help in assembling all the components of this report and for producing the final camera-ready copy.

4. REPORTS FROM CCM USERS

THE EFFECTS OF CLOUD PROCESSES ON CLIMATE SIMULATIONS

Bruce A. Albrecht
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I. Progress and Results

A series of model experiments were made with CCM0A to study the sensitivity of the simulated climate to energy and moisture transports by cumulus clouds. Our initial work involved the use of the hybrid cumulus parameterization described in Albrecht *et al.* (1986). This scheme realistically simulates the vertical transport of moisture relative to that possible with simple moist adjustment. The climate simulations made with the hybrid scheme have upper-tropospheric temperatures in the tropics that are significantly greater (by approximately 8°C) than those obtained with the standard model. In addition, the lower tropospheric mixing ratios are greater (by 2–3 g/kg) than the standard model. Although these differences are large, the hybrid temperature and moisture simulations are much closer to those observed than the simulations obtained with the standard model. In addition to the marked improvement in the mean structure and circulation of the tropical atmosphere, the hybrid simulations give a much better representation of the Southern Hemispheric circulation (Meehl and Albrecht, 1988).

A shortcoming of the hybrid parameterization is that the flux terms associated with cumulus effects are represented using a cumulus mass flux approach, while the precipitation terms are represented using moist adjustment. This inconsistency has been removed by representing both the flux and the precipitation terms as a function of a relatively simple cumulus mass flux parameterization. A number of simulations have been made with this parameterization. Although the vertical distribution of temperature is simulated well with this scheme, the vertical distribution of moisture in the tropics is sensitive to the closure assumptions used in the parameterization. This work is described in an M.S. thesis by J. Buechler.

II. Students and Thesis Titles

Jeffrey Buechler (M.S.)	*Sensitivity of Climate Simulations to the Parameterization of Cumulus Convection.* Submitted May, 1988.

III. CCM-Related Publications

Albrecht, B.A., V. Ramanathan and B. Boville, 1986: The effects of cumulus transports on the simulation of climate with a general circulation model. *J. Atmos. Sci.*, **21**, 2443–2462.

Meehl, G.A., and B.A. Albrecht, 1988: Tropical tropospheric temperature and southern hemispheric circulation. *Mon. Wea. Rev.*, **116**, 953–960.

IV. Experiments and History Tapes

Hybrid Simulations:

Control Run
`/ALBRECHT/BAA703` to `BAA742`

Control Runs
`/ALBRECHT/ALB802` to `ALB816`

ON OPTIMAL VERTICAL DISCRETIZATION FOR ATMOSPHERIC MODELS

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I. Model scale truncation has an impact on the forecast of the flow field, and in particular on the evolution of extratropical cyclones. This is due principally to nonlinearity and forcing. We separate these factors by experimenting with an adiabatic model to isolate the effects of nonlinearity.

To test the effects of scale truncation adequately, we utilize a vertical descretization which has been optimized to the applicable model. Using this distribution of points in the vertical (nine levels are chosen), we integrate the model for a selection of horizontal truncations and search for the sensitivity of extratropical cyclone waves to this variation in horizontal scale. We utilize the results of integrations in the CCMOB reported under project entitled "Three-dimensional modes and scaling," which provides us with numerous initial states and six horizontal truncations.

To focus attention on extratropical cyclones, the initial data sets are scrutinized to isolate the particularly dominant extratropical modes, and the predicted behavior of those modes are made the focus of study. We observe the evolution of these modes both in the baroclinic and barotropic parts of the flow fields. For the barotropic evolution we consider the 500 mb level. For the baroclinic evolution we consider the projection of the flow onto the first and second internal modes as determined from the vertical distribution of levels. Both amplitude and phase of the extratropical waves are evaluated. We search for the sensitivity of important extratropical waves to model truncation as a function of time and initial conditions, and if there exists an optimum truncation which minimizes the forecast error of these modes as they evolve due to nonlinearity. The results of these tests will be reported in Helsinki in August 1988 at the Palmén Symposium on Extratropical Cyclones.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Baer, F., and Ming Ji, 1988: Effects of model scaling on the prediction of extratopical waves. Preprint Volume, AMS, Palmén Symposium on Extratropical Cyclones, Helsinki, Aug.-Sept. 1988.

IV. Experiments and History Tapes

No new model runs are available from this project.

THREE-DIMENSIONAL MODES AND SCALING

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I. This project is designed to develop a three-dimensional scale representation suitable for models of the earth's atmosphere, and to optimize truncation of a model in all three dimensions. We use the spectral functions in the horizontal to represent scaling in two dimensions, and we use the vertical structure functions developed from the project entitled "Optimum Vertical Discretization" to determine scaling in the third (vertical) dimension. We have chosen the CCMOB to test for optimum truncation, using the "best" vertical levels of a nine level model format. It is the adjustment to different vertical model levels that has constrained us to the adiabatic mode of the model.

To find the optimal 3–D truncation, *i.e.*, to minimize errors, we run the model with a series of horizontal truncations ranging from T15 to T45, with each integration going to eight days. Our theoretical calculations suggest that T25 should be the vicinity where optimum truncation occurs. Thus errors in forecasts should show a minimum in that truncation range. Since forecasts are highly dependent on initial conditions, we repeat the experiments for ten different initial states and discuss the error from the norms of the experiments. Moreover, since there are several ways to truncate the initial conditions, we have chosen two unique ways and perform our experiments with each of these choices. About half of the numerical experiments have been completed. The remaining experiments are now scheduled and the results will be reported by the end of the year.

II. Students and Thesis Titles

Ming Ji (Ph.D.) *Three Dimensional Modes and Scaling.* Expected December 1988.

III. CCM-Related Publications

None.

IV. Experiments and History Tapes

Model runs with CCMOB in adiabatic form using 9 test levels in the vertical out to eight days are available for ten different initial states for the following truncations: T15, T21, T26 T31, T35, T42.

EFFECTS OF MODEL SCALING ON THE PREDICTION OF EXTRATROPICAL WAVES

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I. The vertical levels used in atmospheric models are selected for a variety of reasons, but the selection process has not been systematized. The study presented herein represents an attempt to do so. An atmospheric model is linearized about a state of rest and vertical modes are determined for the vertical structure equation—an ordinary differential equation—by solving a difference form of that equation. Since the solutions of the differential equation do not correspond to the solutions of the difference equation, the distribution of points used for the difference equation (the vertical levels) is adjusted until both sets of solutions coalesce. This distribution is considered the optimum set of model levels.

To test the impact of such a distribution on a numerical integration, the NCAR CCMOB is integrated using both its standard levels and the levels determined above. Comparisons of the integrations show that the solutions separate as time evolves, despite the fact that the initial conditions for the separate integrations are as similar as possible. The results suggest that care in selecting vertical levels is essential to successful integration, in particular for the adiabatic version of the model which we used. Results of the investigation will be published in the near future.

Since we have a rationale for optimum placement of model levels, the next step is to include those appropriate levels in a model with forcing. As it happens, the next level of the NCAR CCM, the CCM1, has the option of changing the levels in the forcing package. However, it is necessary to study and understand how the forcing depends on the placement of levels. We now understand clearly what the implications of changing levels in the physics is and how we can do so without creating instabilities. We are currently running that model with the NCAR standard levels. We plan to provide results of calculations with our optimum levels in the forced model in the near future. Subsequent to those calculations, we will investigate the effects of boundary layers and shear layers on the optimum level placement.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Baer, F., and Ming Ji, 1988: On optimal vertical descretization for atmospheric models. *Mon. Wea. Rev.*, accepted.

IV. Experiments and History Tapes

A number of runs with the CCMOB using nine standard levels and nine test levels, R15, adiabatic with 10 mb top, various initial conditions and integrated for four days are available.

MESOZOIC-CENOZOIC CIRCULATION

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I. Progress and Results

Two sensitivity experiments for the Pleistocene were completed to evaluate the role of ice cap size and configuration on climate and the atmospheric circulation. Maximum and minimum ice cap configurations were utilized based on ice cap reconstructions reported in the literature. Only ice cap size was changed in CLIMAP simulations for 18,000 years ago. Results included differences in storminess, planetary wave patterns, tropical continental temperatures, and P-E balance over the continents.

II. Students and Thesis Titles

Richard A. Shinn (M.S.) *A Study of Climate Sensitivity to Ice-Age Continental Ice Sheets.* Univ. of Miami, Coral Gables, Fla., June 1988.

III. CCM-Related Publications

Publications from the thesis are in preparation.

IV. Experiments and History Tapes

CCM0A Pleistocene January—Small Ice Cap
`/GEOLOGIC/MINWIN/MIW001-020`

CCM0A Pleistocene January—Large Ice Cap
`/GEOLOGIC/MAXWIN/MAX001-041`

EXTENDED RANGE FORECASTING

David P. Baumhefner
National Center for Atmospheric Research *

I. Progress and Results

A series of forecast ensembles were integrated to 30 days using the T31 version of the CCM. Twelve cases starting from DEC/JAN 1981–87 initial conditions have been run to date. Each ensemble consists of 10 individual forecast members which originate from small perturbations in the initial conditions. The forecast ensembles were evaluated for forecast skill and predictability estimates using a variety of scoring techniques and various time averages. The total error was examined for its systematic component and compared to the model climate error. The relationship of predictability estimates to forecast skill was investigated as a possible method of predicting forecast accuracy. A synoptic study is currently underway in which the dependence of particular regimes, transitions, and wave/mean–flow characteristics on forecast skill is determined. A subset of the previous experiments were also integrated with the observed SST distribution and compared to the control forecasts.

Results indicate that the T31 model can successfully predict weather patterns at extended range for some situations. The spread of skill within each ensemble is quite large revealing a considerable uncertainty in the individual forecasts. The relationship between forecast skill and predictability is not very strong. The response to the observed SST is in most cases positive in the mean and has a timescale of 10–15 days.

II. Students

None

III. CCM–related publications

See bibliography

IV. Experiments

Please contact D. Baumhefner at the National Center for Atmospheric Research.

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STRUCTURE OF LOW-FREQUENCY VARIABILITY

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I. Progress and Results

In order to provide an adequate database for comparisons with the behavior of a linear version of CCM0B, the control perpetual January simulation of CCM0B has been extended. Analysis of the original 1200-day control plus an 1800-day extension by means of empirical orthogonal functions, complex empirical orthogonal functions and compositing techniques has indicated the model's preferred circulation anomaly patterns in an environment with fixed boundary conditions. The structure of these patterns is reminiscent of well-known low-frequency patterns in observations. Interestingly, their structure as well as the structure of contemporaneous fields, like precipitation, suggests that to a large degree extratropical forcing may be primarily responsible for forcing these patterns. This possibility is supported by experiments done with the linear model.

Temporal spectral analysis of this 3000-day simulation has produced the surprising result that the simulation has a red spectrum with large power density in even the lowest of sampled frequencies, namely 1 cycle/750 days. To confirm this result the perpetual January control has been extended an additional 3000 days, for a total of 6000 days. The structure of this very low-frequency variance is now being analyzed.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Branstator, G., 1988: Excitation of low-frequency arching patterns in the troposphere, in preparation.

IV. Experiments and History Tapes

CCM0B R15 perpetual January control (12 hourly data)
Days 0–1200: `/CSM/X71001` to `/X71081`
Days 1200–6000: `/LSD/L71081` to `/L71401`

COMPARISON OF CCM RADIATION WITH SATELLITE OBSERVATIONS

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I. Progress and Results

The outgoing longwave radiation (OLR) in the NCAR CCM has been compared with the OLR obtained from the Nimbus 7 ERB and operational AVHRR instruments. The CCM mean January OLR compares well with the OLR fields from the satellites over many regions. A time series analysis reveals that the CCM OLR is considerably noisier and less persistent than the observed OLR; this faults the cloud generating algorithms in the CCM. The temporal standard deviation of OLR in the CCM over fixed geographical points is 50–100% larger than the observed values over much of the globe. The time lagged autocorrelation of OLR in the CCM is too small. The geographical patterns (locations of maxima and minima) of standard deviation and autocorrelation in the CCM and observations match well. The model spatial correlation of radiation (variation with time at adjacent points) is realistic, as is the space-time advection of correlation in the storm tracks.

We have also investigated the classical idealization of the influence of mid-latitude troughs on cloud patterns in the CCM and in satellite and NMC data by comparing the cross correlation of the poleward component of the wind and the OLR. The CCM is found to compare quite well with data for the band-pass (2.5- to 6-day) waves over the mid-latitudes. It appears that while the magnitudes of the OLR fluctuations (standard deviation) are too large in the model, the phasing of the OLR with the dynamics (cross correlation) is correct in the mid-latitudes.

II. Students and Thesis Titles

No students were involved in this project.

III. CCM-Related Publications

Charlock, T. P., K. M. Cattany-Carnes and F. Rose, 1988: Fluctuation statistics of outgoing longwave radiation in a general circulation model and in satellite data. *Mon. Wea. Rev.*, in press (July).

Charlock, T. P., F. Rose and K. M. Cattany-Carnes, 1988: Cross correlations between the radiation and atmospheric variables in a general circulation model and in satellite data. *Mon. Wea. Rev.*, submitted.

IV. Experiments and History Tapes

The above study was executed with a 120-day history tape of a CCM run published by Charlock and Ramanathan (*J. Atmos. Sci.*, **42**, pp. 1408–1429). (`CHH003-CHH011` tape output `V20085-V20088` "CCM Version 0 modified")

THE SPINUP AND CLIMATE STUDY WITH THE NCAR COMMUNITY CLIMATE MODEL

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I. Progress and Results

A. Spinup

The NCAR Community Climate Model is used to examine the spinup of a model atmosphere from two extremely different initial isothermal rest states: a cold (240 K) state and a warm (310 K) state. Several interesting finds regarding the spinup of the model atmosphere were obtained:

1. The model equilibrium state is independent of the initial condition.
2. The spinup from the cold initial condition is faster than that from the warm initial condition. The former spinup also exhibits an overshooting in the thermal field.
3. The thermal field and baroclinic flow spin up simultaneously.
4. The spinup of the barotropic flow lags behind that of the baroclinic flow and the thermal field.
5. The model tropics spin up faster than the mid-latitudes and the stratosphere spins up slower than the troposphere.

Synoptic and energetics analyses are performed to illustrate these findings and to explain possible mechanisms involved in the model spin up. Emphasis is placed on the adjustment of the model atmosphere by the secondary circulation.

B. Energy Source of the 1982–83 ENSO

The water vapor, heat and vorticity budget of the 1982–83 ENSO episode simulated by the NCAR CCM0B were analyzed to examine how the energy is transported up from the SST anomalies to maintain the anomalous circulation associated with the ENSO. It is revealed that the SST anomalies induce anomalous divergent circulation over the equatorial Pacific. This anomalous divergent circulation converges water vapor toward, and enhances cumulus convection over, the SST anomaly region. The latent heat released by convectivity, in turn, intensifies the anomalous divergent circulation. Since the anomalous divergent circulation is not infinitely amplified, it is inferred that part of the energy transported upward by cumulus convection from the SST anomaly region propagates to higher latitudes by global Rossby waves as indicated by the anomalous circulation.

II. Students and Thesis Titles

Ren-Yow Tzeng (M.S.) — *A Study of the Maintenance and Annual Variation of Subtropical Jet Streams with the NCAR Community Climate Model.* March 1988.

Xinhua Cheng (M.S.) — *Equatorial Waves Simulated by the NCAR Community Climate Model.* August 1988.

III. CCM-Related Publications

Chen, T.C., and G. Branstator, 1988: A study of the atmospheric general circulation as an initial value problem with the NCAR Community Climate Model. *J. Geophys. Res.*, in press.

Lee, Y.-H., and T.-C. Chen, 1988: On the energy source of the 1982–83 ENSO episode simulated by the NCAR Community Climate Model. *Tellus*, submitted.

IV. Experiments and History Tapes

None.

SOURCES OF INTERANNUAL ATMOSPHERIC VARIABILITY

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I. Progress and Results

A pair of extended term integrations of an atmospheric general circulation model have been used to assess the impact of interannually varying global ocean surface temperatures on the interannual variability of time-averaged atmospheric states. The model is an annual cycle version of the Community Climate Model (CCM) developed at the National Center for Atmospheric Research (NCAR) for multitasking execution on a parallel processing supercomputer such as the Cray XMP/48. The ocean temperature data, which provided lower boundary forcing for the model, comes from the Comprehensive Ocean Atmosphere Data Set (COADS) for the interval January 1950-December 1979. It must be noted that seven moderate to strong El Niño events are contained in this interval. One model integration featured forcing by the 360-month evolution of the COADS ocean surface temperatures. The second is characterized by the monthly mean COADS climatological temperatures repeated through thirty identical annual cycles. Thus, two experiments have the same mean forcing (in terms of ocean surface temperatures) but the first provided interannual variability in the forcing through realistic global patterns of ocean surface temperature anomalies. Objective univariate and multivariate statistical tests were used to assess the effect of variable forcing on the interannual variability of monthly, seasonal and annual means for a wide variety of atmospheric variables. In general, enhanced atmospheric variability resulted in the tropics from the variable boundary forcing but not in the extratropics. Statistical analyses of composites of atmospheric mean states for El Niño and non-El Niño events were also applied to determine the extent to which the atmosphere typically exists in different states for these different classes of boundary conditions. Clear and statistically significant differences were found in the tropical atmosphere but not in the higher latitudes. The latter results were shown to be in agreement with similar analyses performed with observed data.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

None.

IV. Experiments and History Tapes

None.

CLIMATE PERTURBATIONS SIMULATED WITH COUPLED CCM/OCEAN MIXED LAYER/SEA ICE MODELS

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and
Starley L. Thompson
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Boulder, CO 80307

I. Progress and Results

Turco *et al.* (*Science* **222**, 1283–1291, 1983) coined the phrase "nuclear winter" to describe the dramatic land surface cooling that might result if fires ignited in a nuclear exchange produced enough smoke over regional-to-global scales to block a significant portion of sunlight from Earth's surface. Subsequent computations employing GCMs have verified that massive high-altitude smoke injections could indeed produce sharp cooling of land areas during the first few weeks after the smoke appeared in the atmosphere. Addressed in this project was the question of what would transpire in the following months and years—*i.e.*, how quickly would the climate return to its unpertubed state as the smoke cleared, and would there be lingering effects persisting beyond a few months?

The first phase of the project was an investigation of long-term climatic feedbacks in "nuclear winter" via an idealized case study in which the climatic effects were deliberately exaggerated in order to clearly separate signal from noise. Nuclear war-produced smoke was assumed in amounts roughly twice that suggested by Turco *et al.* and was restricted to the middle latitudes of the Northern Hemisphere. A GCM developed by Warren Washington and Gerald Meehl of NCAR (*J. Geophys. Res.* **89**, 9475–9503, 1984), incorporating submodels of sea ice and the upper mixed layer of the oceans, was adapted to crudely account for absorption of sunlight by the assumed smoke cloud. (Previous GCM investigations of "nuclear winter" had generally assumed fixed sea surface temperatures and sea ice distributions, and therefore could not properly simulate cooling for more than a few weeks.)

Results of this phase of the project have been published (Covey, 1987) and may be summarized as follows: Two competing long-term effects are apparent in a one-year run of the model. First, there is positive feedback on surface cooling due to enhanced sea ice formation, which insulates cold continental climates from the moderating influence of the oceans. This effect was originally inferred by Robock (*Nature* **310**, 667–670, 1984) from a one-dimensional climate model. A second effect, however, appears in the three-dimensional simulations; the amount of cooling is diminished compared to Robock's results—and under some circumstances even reversed to produce a surface warming—as heat, originating from solar energy absorbed in the upper troposphere by the smoke, is transported down to the surface.

Although the foregoing calculation reveals physical processes relevant to the "nuclear winter" problem, it cannot be considered a realistic simulation of climatic response to atmospheric smoke injection because it ignores the spread of the smoke by atmospheric winds. We have therefore begun to construct a GCM which includes smoke spreading and removal processes together with submodels of the ocean mixed layer and sea ice. The starting point for our efforts is Version 1 of the NCAR Community Climate Model (CCM1), provided by David Williamson of NCAR and his collaborators in the CCM Core Group. CCM1 has two features of particular importance to the study of long-term climatic response to atmospheric aerosol injection: the ability to perform reasonably high-resolution climate simulations with good numerical efficiency, and a computation of lower atmospheric and surface temperatures that accounts for turbulent heat transport under the unusual vertical temperature gradients expected to form in "nuclear winter." We have attached mixed layer ocean and sea ice submodels together with parameterizations of the radiative effects of aerosols to CCM1, and will in the future add the capability to interactively transport smoke to the model. Neither the sea ice model nor the ocean model computes horizontal transport of heat or any other quantity. Equator-to-pole heat transport by the oceans may be assumed, however, to take on values as a function of latitude that are fixed in time; in other words a prescribed ocean heat transport may be assumed to exist.

The combined CCM1/ocean mixed layer/sea ice model has been tested and a preliminary "nuclear winter" scenario has been run; results were given in a paper (Thompson and Covey, 1988) presented at the annual Defense Nuclear Agency meeting on global effects of nuclear war. The model we have developed is applicable to many problems in addition to "nuclear winter", such as the climatic effect of injection into the atmosphere of volcanic aerosols. It is our intention to look favorably upon requests from colleagues for dissemination of the model.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Covey, C., 1987: Protracted climatic effects of massive smoke injection into the atmosphere. *Nature* **325**, 701–703.

Thompson, S.L., and C.C. Covey, 1988: Simulations of long-term climate effects of nuclear aerosol using a passive ocean mixed layer GCM. Paper presented at the annual Defense Nuclear Agency, April 1988, Santa Barbara, Calif.

IV. Experiments and History Tapes

None.

THE DETERMINATION OF CLIMATE CHANGE ON THE MESO-ALPHA SCALE

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I. Progress and Results

We are using climate simulations produced by the CCM1 to provide time-dependent lateral boundary conditions and initial conditions for the Pennsylvania State University/NCAR Mesoscale Model. The corresponding simulations produced by that model provide meso-α scale fields which dynamically correspond to the more coarse resolution CCM fields. In this way, we hope to determine climate changes on the mesoscale which correspond to climate changes produced by different CCM simulations, and which are particularly consistent with the mesoscale topography.

The first application of our study will be a determination of possible climate changes at Yucca Mountain, Nevada, sight of the planned National Nuclear Waste Repository. The Department of Energy and U.S. Geological Survey are interested in knowing possible changes in precipitation there so that they may determine the likelihood of radiation releases due to excessive ground water concentrations in the future.

At this point we have completed most of the necessary software development, and have examined a few cases. Progress reports to the USGS are being prepared.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

None.

IV. Experiments and History Tapes

None.

INCLUSION OF BIOSPHERE-ATMOSPHERE TRANSFER SCHEME (BATS)

Robert E. Dickinson and Patrick J. Kennedy
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

Work continued in adapting the CCM1 to our BATS code. This involved extensive revision of the short-wave and long-wave radiation subroutines, the surface energy and hydrology subroutines, and the input/output routines (including 41 new single-level fields to history tape). Also, we have replaced the fixed sun with a diurnally-varying one, since this is more appropriate for plant physiology. At each gridpoint a choice of eighteen vegetation types and percentage cover is available. The two-layer soil has variable characteristics, too. Surface and subsurface runoff are modeled. The standard fixed snow cover has been replaced by a fully varying one, as the model temperature and precipitation dictate. The modeled temperatures include, separately, that for subsoil, soil, canopy, and daily min/max at anemometer level.

We made several multiday global runs at R15 half-hour resolution in order to fine-tune the CCM1/BATS link. We scrutinized diurnal surface physics and plant activity at selected gridpoints, using our own plotting processor with abscissae of 24 hours. Changes were made to increase the "robustness" of the code and minimize nonphysical oscillations. Finally a three-year run, seasonal, at R15 half-hour resolution produced reasonable results which we are still analyzing. A striking feature is the seasonal advance and retreat of snow cover, longitudinally varying, which agrees nicely with observations. Amount of precipitation is still too much (as it is in the unmodified CCM1). Also there are a few points where our anemometer temperatures differ too much from observations, but in subsequent short runs we see that some adjustment in soil moisture calculation improves agreement. International collaborators are assisting in code improvements and in the analysis of the results.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Dickinson, R.E., 1986: GCM sensitivity studies—Implications for parameterizations of land processes. *Proceedings of Conference on ISLSCP*, Rome, Italy, 2–6 December 1985, ESA.

Henderson-Sellers, A., M.F. Wilson, G. Thomas and R.E. Dickinson, 1986: *Current Global Land-Surface Data Sets for Use in Climate-Related Studies.* NCAR Technical Note, NCAR/TN–272+STR, National Center for Atmospheric Research, Boulder, Colorado, 110 pp.

Dickinson, R.E., A. Henderson-Sellers, P.J. Kennedy and M.F. Wilson, 1987: *Biosphere-Atmosphere Transfer Scheme (BATS) for the NCAR Community Climate Model.* NCAR Tech. Note, NCAR/TN–275+STR, National Center for Atmospheric Research, Boulder, Colo., 69 pp.

Dickinson, R.E., 1987: Evapotranspiration in global climate models. Presented at 26th COSPAR meeting, 2–10 July 1986, Toulouse, France. *Advances in Space Research*, **7**, 11, 17–26.

Wilson, M.F., A. Henderson-Sellers, R.E. Dickinson and P.J. Kennedy, 1987: Sensitivity of the biosphere-atmosphere transfer scheme (BATS) to the inclusion of variable soil characteristics. *J. Clim. Appl. Meteor,* **26**, 3, 341–362.

Wilson, M.F., A. Henderson-Sellers, R.E. Dickinson and P.J. Kennedy, 1987: Investigation of the sensitivity of the land-surface parameterization of the NCAR Community Climate Model in regions of tundra vegetation. *J. Climatology,* **7**, 319–343.

Dickinson, R.E., and A. Henderson-Sellers, 1988: Modelling tropical deforestation: A study of GCM land-surface parameterizations. *Quart. J. Roy. Meteorol. Soc.*, **114**, 439–462.

IV. Experiments and History Tapes

CCM1 (Version 1.0) with BATS, R15, half-hour resolution, seasonal, three-year run, on NCAR Cray X-MP Cot.—Nov. 1987.

Daily output (57 volumes):

```
/KENNEDY/CCM1/102/ASTER1
     ...
/KENNEDY/CCM1/102/ASTER57
```

Monthly averages (36 volumes):

```
/KENNEDY/CCM1/102/ASTER/SEP75AVG
     ...
/KENNEDY/CCM1/102/ASTERAUG78AVG
```

Grand averages (12 volumes):

```
/KENNEDY/CCM1/102/ASTERJANGRAND
     ...
/KENNEDY/CCM1/102/ASTERDECGRAND
```

AN INITIALIZATION FOR CUMULUS CONVECTION IN NUMERICAL WEATHER PREDICTION MODELS

Leo J. Donner
The University of Chicago
Chicago, IL 60637

I. Progress and Results

A procedure for initializing parameterizations for cumulus convection in numerical weather prediction models has been developed. The initialization adjusts the temperature and humidity fields such that a simplified version of the Kuo cumulus parameterization will yield diagnosed convective precipitation and vertical heating profiles. The initialization minimizes changes in the humidity and temperature fields while satisfying constraints imposed by the cumulus parameterization.

In collaboration with P. Rasch, this initialization has been used with CCM1 to initialize the temperature and humidity fields. Spin-up in the convective precipitation field is significantly reduced by using this procedure. We are currently investigating the relationship of the cumulus initialization to normal-mode initialization using CCM1.

II. None.

III. CCM-Related Publications

Donner, L.J., 1988: An initialization for cumulus convection in numerical weather prediction models. *Mon. Wea. Rev.*, **116**, 377–385.

IV. Experiments and History Tapes

There are at present no history tapes of general interest associated with this project.

AIR-SEA EXCHANGE OF GASES AND PARTICLES

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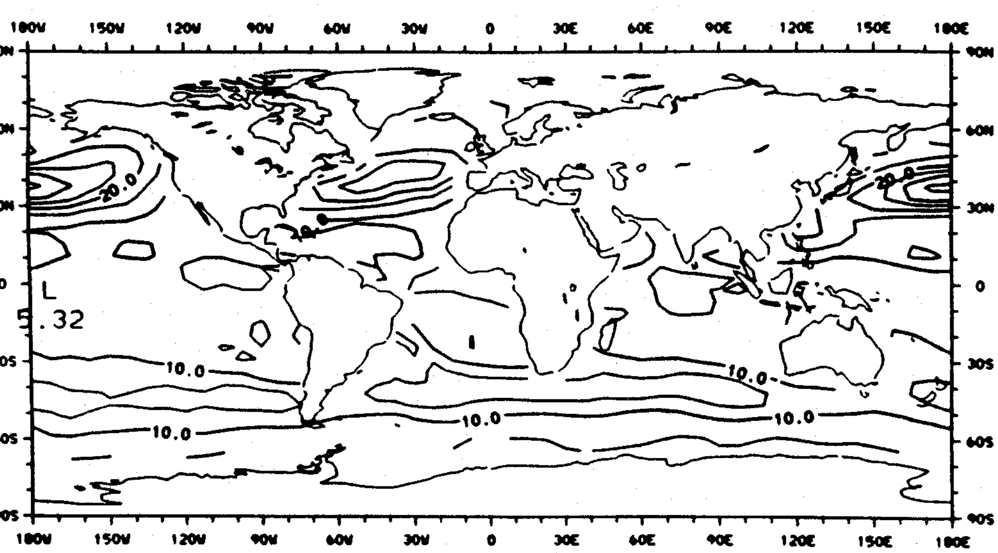
University of California, San Diego
La Jolla, California 92093

I. Progress and Results

I have computed the global transfer velocity fields for several trace gases, including CO_2. The global distribution of the transfer velocity for CO_2 as computed for January is presented below.

JANUARY- CO_2 TRANSFER VELOCITY (CM HR^{-1})



These calculations represent the global boundary condition fields for trace gases in coupled ocean-atmosphere models. In addition, preliminary estimates of DMS flux to the atmosphere have been prepared as a function of irradiance and wind speed.

II. Students and Thesis Titles

None

III. CCM-related Publications

Erickson, D. J. III, 1987: Simulating the global transfer velocity fields of trace gases, *EOS, Trans. Amer. Geophys. Union, 68,* 1213.

Erickson, D. J. III, 1987: Variations in the global transfer velocity fields of trace gases, *EOS, Trans. Amer. Geophys. Union, 68*, 1691.

Erickson, D. J. III, 1988: Air-sea exchange of CO_2: Climatic implications, Chapman Conference on Gaia Hypothesis', San Diego, Calif., Mar. 7 - 11.

Erickson, D. J. III, 1988: 'High-resolution simulation of the global air-sea transfer velocity field of CO_2', Submitted.

Erickson, D. J. III, 1988: 'Simulation of the global air-sea transfer velocity field of helium', Submitted.

IV. Experiments and History Tapes

None yet.

DEVELOPMENT OF SOFTWARE FOR NONLINEAR NORMAL-MODE INITIALIZATION OF THE CCM1

R. Errico and B. Eaton
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

Two programs and corresponding NCAR Technical Notes have been prepared. Both notes describe the relevant mathematical equations and corresponding programs in detail as well as contain abbreviated users' guides and software demonstrations.

The first note, Errico (1987), describes the software for computing the normal modes of the primitive equations linearized about a resting standard atmosphere. The horizontal structures of the modes are those consistent with a user-specified, general pentagonal truncation. The vertical structures are those determined for user-specified, discrete σ-levels, with vertical finite-difference forms of the equations given by formulations used in either the CCM1 or CCM0B. This software creates a file for use in the second program (described next).

The second note, Errico and Eaton (1987), describes the software for performing either a linear or nonlinear initialization of either the CCM1 or CCM0B or for projecting data in the format of CCM history tapes onto the modes of either model. This software is intended for use in forecasting studies, where initialization to remove gravity-wave noise is relevant, or for use in diagnostic analysis of real or simulated data, whenever separation into modes or mode types is desired.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Errico, R.M., 1987: *A description of softward for determination of normal modes of the NCAR Community Climate Model.* NCAR Tech. Note, NCAR/TN–277+STR, National Center for Atmospheric Research, Boulder, Colo., 92 pp.

Errico, R.M., and B.E. Eaton, 1987: *Nonlinear normal mode initialization of the NCAR CCM.* NCAR Tech. Note, NCAR/TN–303+IA, National Center for Atmospheric Research, Boulder, Colo., 114 pp.

IV. Experiments and History Tapes

None.

EXAMINATION OF THE BEHAVIOR OF NONBALANCED AND BALANCED GRAVITATIONAL MODES IN THE NCAR CCM

R. Errico and D. Williamson
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

This work is in two parts. The first part, concerning nonbalanced modes, will appear as Errico and Williamson (1988). The second part, concerning initialized modes, should be completed by the winter of 1988.

In the first part, characteristics of gravitational-wave noise in noninitialized forecasts were investigated with the R15 CCM0B. Three four-day forecasts were begun from noninitialized FGGE analyses. The behavior of individual, gravitational normal modes were examined by projecting the model's forecast fields onto its normal modes at each time step. This resulted in a times series of coefficients (complex amplitudes) for each mode. From these, time series of parameters which described each mode's behavior in terms of a single transient plus quasi-stationary component were determined. Most external and first internal modes were well described by these components. However, shallower modes appeared to require several transient components for an adequate description. The observed frequencies of the external and first internal modes were approximately their natural frequencies (determined as eigenvalues of the model equations linearized about a resting state), after allowances were made for effects of a mean advection and the numerical time-integration scheme. The behavior of shallower modes was complicated by the choice of a simple basic state to define the modes, which did not consider realistic advection. The model's shallowest modes had a strong response to the surface drag, indicating a diabatic adjustment in the lowest model levels.

In part two, we are examining the behavior of the modes in forecasts produced subsequent to a typical nonlinear, normal-mode initialization procedure. Preliminary results indicate that the initialization procedure is very effective at reducing the amplitude of transient components and at properly specifying the quasi-stationary components for both external and first-internal modes. However, for shallower modes, the initialization procedure appears less effective for reasons which require further investigation.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Errico, R.M., and D.L. Williamson, 1988. The behavior of gravitational modes in numerical forecasts with the NCAR Community Climate Model. *Mon. Wea. Rev.*, **116**, in press.

IV. None.

JOHN E. GEISLER

Department of Meteorology, University of Utah, Salt Lake City, Utah

ERIC J. PITCHER

Rosenstiel School of Marine and Atmospheric Science
University of Miami, Miami, Florida

I. Progress and Results

A 1200-day record from a perpetual-January simulation with a general circulation model is analyzed for the presence of an oscillation resembling the 40- to 50-day oscillation observed in the atmosphere. Representation of the global velocity potential at 200 mbar by empirical orthogonal functions (EOFs) reveals an eastward propagating disturbance having a principally zonal wave number 1 character. It is determined from power spectra of the velocity potential at points around the equator that the period of the oscillation is in the range of 28-31 days. Time series of the coefficients of the first two EOFs are used to define epochs for the compositing in equatorial latitudes of anomalies in zonal winds, in 500-mbar convective heating, and in precipitation. Time-longitude diagrams of the zonal wind anomalies indicate the presence of an eastward propagating disturbance characterized by two longitudinal scales. The principal anomalies in convective heating and precipitation appear as two stationary oscillations, one situated in a zone extending from 120°E to the dateline and the other in a relatively narrow zone near 60°W.

II. Students and Thesis Titles

George Tselioudis (MS)	Research using the CCMOB	June 1987

III. CCM-related Publications

Geisler, J.E. and E.J. Pitcher, 1987: The 40-to-50 day oscillation in a perpetual January simulation with a general circulation model. J. Geophys. Res., 92, 11,971-11,978.

Pitcher, E.J. and J.E. Geisler, 1988: On the representation of the 40-50 day oscillation in terms of streamfunction and velocity potential. J. Atmos. Sci., in press.

IV. Experiments and History Tapes

CCMOA R15 January control run

CCMOB R15 Annual cycle control run

MODELING SURFACE TEMPERATURE AND TOPOGRAPHIC EFFECTS ON ATMOSPHERIC EDDIES

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Davis, CA 95616

I. Progress and Results

To date, work has centered upon setting up the model to investigate the nonlinear life-cycles of extratropical cyclones. A group of programs have been written to provide the initial conditions for the CCM. The initial condition is found in three steps. First, a linear stability problem for a three-dimensional basic flow on a sphere is solved. Second, the eigenvector and basic state are combined and assigned dimensional values to define a "raw" history tape. Third, the "raw" data is processed using a version of Ron Erricco's nonlinear normal mode initialization program.

In order to maximize the horizontal resolution, a limited-area version of the CCM is under development by one student. The version uses a hemispheric domain, and only every second or third zonal wavenumber.

Progress has been slow during the past year because the PI has been on sabbatical in another country. No theses or publications directly using the CCM have been written as of this writing.

II. Students and Thesis Titles

Ching-hua Wang	*Topographic Effects on the Development and Life-cycles of Midlatitude Wave-cyclones.* Expected June, 1990.
Sy-shiann Lai	*Development and Testing of a Limited-area Model for Studying Midlatitude Dynamics* (working title). Expected June, 1989.

III. CCM-Related Publications

None.

IV. Experiments and History Tapes

None.

STRATOSPHERIC GENERAL CIRCULATION MODELING

Professor James R. Holton
University of Washington

I. Progress and Results

(1) The General Circulation of the winter stratosphere

In this study the stratospheric version of the CCM developed by Mark Iredell in collaboration with Byron Boville was used to study the response of the stratosphere to the magnitude of the planetary wave forcing in order to test the hypothesis that a critical amplitude of tropospheric forcing is required to switch the stratosphere from a radiative state, with strong zonal flow and suppressed vertical wave propagation, to a dynamically disturbed state with strong departures from radiative equilibrium, weak zonal winds and strong wave propagation. A series of 7 perpetual January simulations was carried out in which the orography was varied in uniform steps from a flat earth to three times the normal values. Each run was carried out for 400 days. Contrary to expectations, Iredell found no sign of a critical forcing. The time averaged departure from the radiative state increased more or less uniformly from small values for the no mountain case, to large amplitudes for the large orography case. Only in the large orography case did the model produce major sudden warmings and appear to have a bimodal behavior with alternation between quiet and disturbed periods in the stratosphere.

(2) Simulation of the stratospheric distribution of N_2O using an off line tracer model

As a contribution to the understanding of global tracer transport Mr. Hess has carried out and diagnosed a simulation of the annual cycle in the global N_2O distribution using winds generated in an annual cycle run of the stratospheric version of the CCM in order to advect the tracer field. A major goal of this study was to examine the tracer variance generated in the spring-time final warming in order to determine whether such variance might remain frozen into the summer circulation and provide an explanation for the large summer time variances measured by Ehhalt and his collaborators. The results of this work have provided some unique diagnostics on tracer behavior in a general circulation model even though the NCAR model produces amplitudes of variance much less than observed, and tracer variance also seems to be damped too quickly in the model. Nevertheless the work does provide partial support for the frozen in variance hypothesis.

Mr. Hess also has demonstrated the existence of a 10 day period global normal mode oscillation in the model, that is able to partly account for the observed tracer variances in the summer stratosphere.

II. Students and Thesis Titles

Mark Iredell (Ph.D.) The Effect of Orography on the Mean Flow of the Stratosphere. July 1988

Peter G. Hess (Ph. D.) The Evolution and Variance of Nitrous Oxide in a Stratosphere General Circulation Model. July 1988

III. CCM-related Publications (none to date)

IV. Experiments and History Tapes

Stratospheric version of CCM0 R15: 7 January runs with "envelope orography" varying from flat earth to 3 times the normal orography. Contact Dr. Mark Iredell for information.

Stratospheric version of CCM0 R15: Annual cycle run used for tracer studies. Contact Dr. Peter Hess

A FORMULATION FOR
EQUIVALENT LAGRANGIAN-MEAN DIAGNOSIS

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National Center for Atmospheric Research
Boulder, CO 80307
(On leave from Japan Meteorological Agency)

I. Progress and Results

A new formulation is proposed to approximately diagnose Lagrangian-mean meridional circulations using a specially designed vertical coordinate system. This scheme enables us to calculate the correction for Stokes drifts in the meridional circulations of finite-amplitude nongeostrophic motions. In contrast, the traditional transformed Eulerian-mean method (TEM, Andrews and McIntyre, 1976) assumes a quasi-geostrophic condition. Moreover, the form of the thermodynamic equation under the new scheme does not include any eddy term.

This new formulation was used to diagnose the zonal-mean states of CCM1 (T42, L12), and we compared the results with those derived from the TEM diagnosis. Significant differences are found in the meridional circulations (Fig. 1) and in the distribution of Eliassen-Palm flux divergence. For example, in the stratosphere the TEM result still shows the indirect (Ferrel) cell, but the new result exhibits only hemispheric single cell circulations (Brewer-Dobson circulations). In the thermodynamic analysis under the new formulation, mean-advection terms almost explain zonally averaged heat transports. It implies that the numerical computation is accurate enough to diagnose Lagrangian-mean circulations.

Lastly, a 2-D tracer transport scheme is formulated, using the same vertical coordinate system. It is shown that eddy diffusions due to adiabatic wave motions are expressed by a symmetric tensor with only one independent variable.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

A two-part manuscript is in preparation.

IV. Experiments and History Tapes

CCM1 T42 January control run
`/CSM/CCM1/245/X24506` to `/X24517`

CCM1 T42 Annual run
`/CSM/CCM1/244/X24469` to `/X244108`

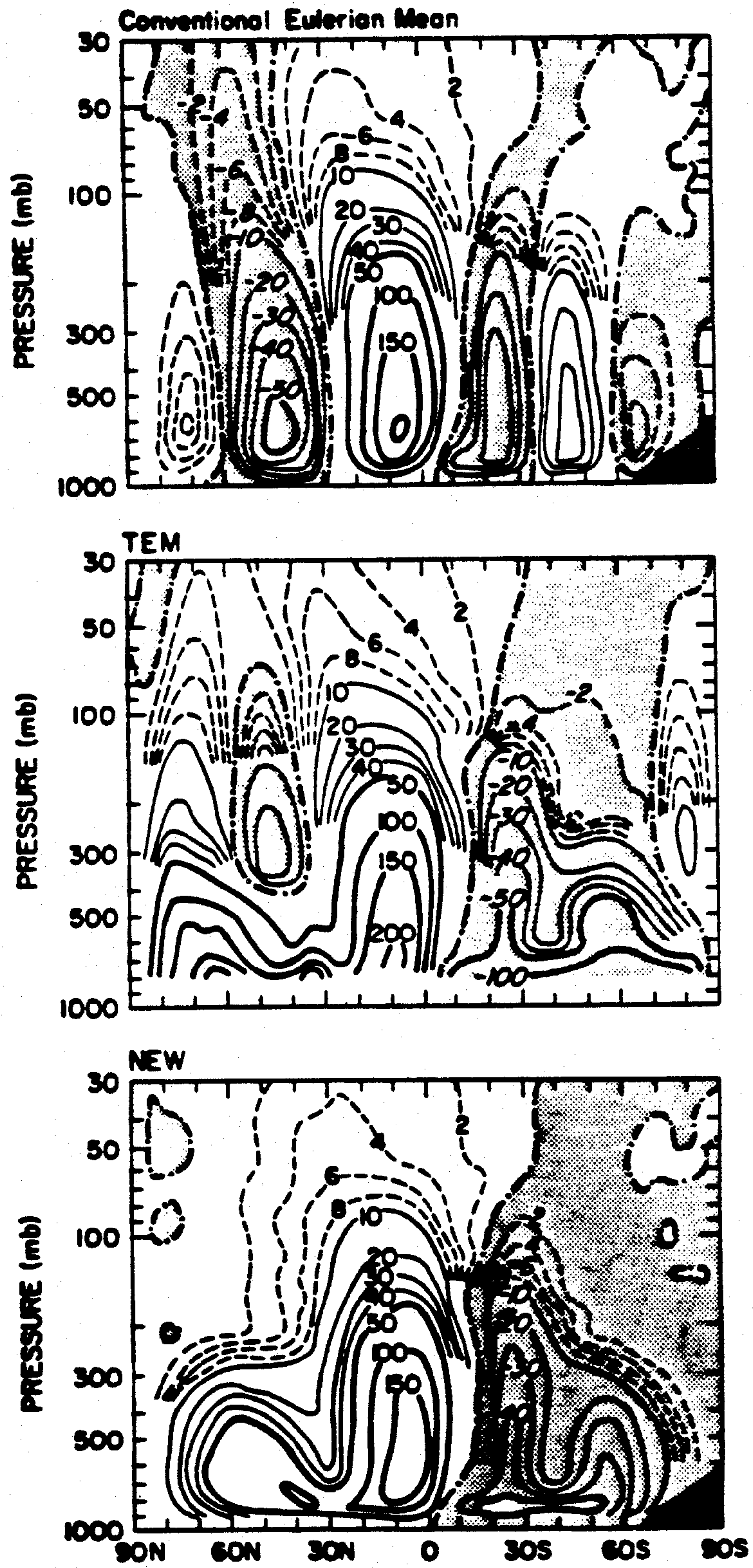

FIG. 1. Mass streamfunctions calculated from a perpetual January run of CCM1, averaged for 100 model days. Top: by the conventional Eulerian-mean diagnosis; middle: by the TEM diagnosis; bottom: by the new diagnosis. Contour intervals of heavy lines, thin solid and broken lines are 50×10^9, 10×10^9 and 2×10^9, respectively, all in Kg $\sec^{-1}$. Negative areas are shaded.

Diagnostic Studies of Global Monsoonal Circulations within the NCAR Community Climate Model (CCM)

Donald R. Johnson
University of Wisconsin-Madison

I. Progress and Results

The research work during the past year has focused on an analysis of climate simulations of the global distribution of atmospheric heating by the NCAR Community Climate Model (CCM). The vertical and horizontal distribution of heating predicted by the 9-layer version of the CCM (CCMOB) and the 12-layer version of the CCM (CCM1) have been contrasted in an analysis of perpetual January and July simulations. The explicit CCM predicted heating distributions have also been contrasted with diagnosed January and July heating distributions using the Global Weather Experiment (GWE) Level III data.

The vertically averaged results for CCMOB and CCM1 (See Fig. 1 for January) are in general agreement with each other and with analyzed heating distributions for the GWE. Several exceptions are noteworthy. Within January simulations, northwest-to-southeast bands of heating extending into the south central Pacific and Atlantic Oceans in CCM1 simulations agree favorably with observations of deep convection within the South Pacific and South Atlantic Convergence Zones. These features are generally absent within CCMOB simulations. Additionally, heating in the ITCZ occurs south of the equator during January in CCM1 simulations in agreement with climatological studies. In contrast, within CCMOB, heating in the ITCZ is centered on the equator during January. Major differences, however, occur in the vertical distribution of heating (See Fig. 2 for January). For both perpetual January and July simulations, considerably stronger heating occurs in the low troposphere of CCMOB simulations, while stronger heating occurs in the mid- to upper-troposphere of CCM1 simulations. In general, the vertical distribution of heating from CCM1 agree favorably with diagnosed distributions for the GWE.

II. Students and Thesis Titles

There are no students currently working under the CCM grant. Dr. Martin Hoerling continues as postdoctoral associate working jointly with Professor Johnson and Mr. Todd Schaack.

III. CCM-related Publications

Hoerling, M. P., T. K. Schaack and D. R. Johnson, 1988: Heating Distributions for January and July Simulated by the NCAR Community Climate Model: CCMOB and CCM1. Manuscript in preparation.

IV. Experiments and History Tapes

No major model runs were performed during the past year.

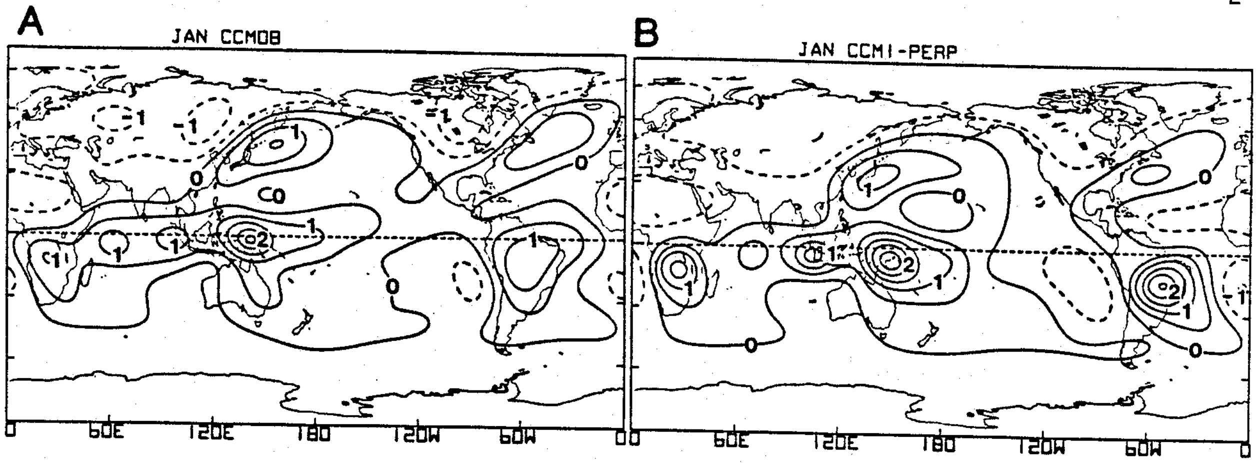

Fig. 1: Ensemble average of time-averaged mass-weighted vertically averaged heating for perpetual January (A) CCMOB, (B) CCM1. Contour interval 0.5 K/day. Filtered to emphasize contributions from wavelengths greater than 4000 km.

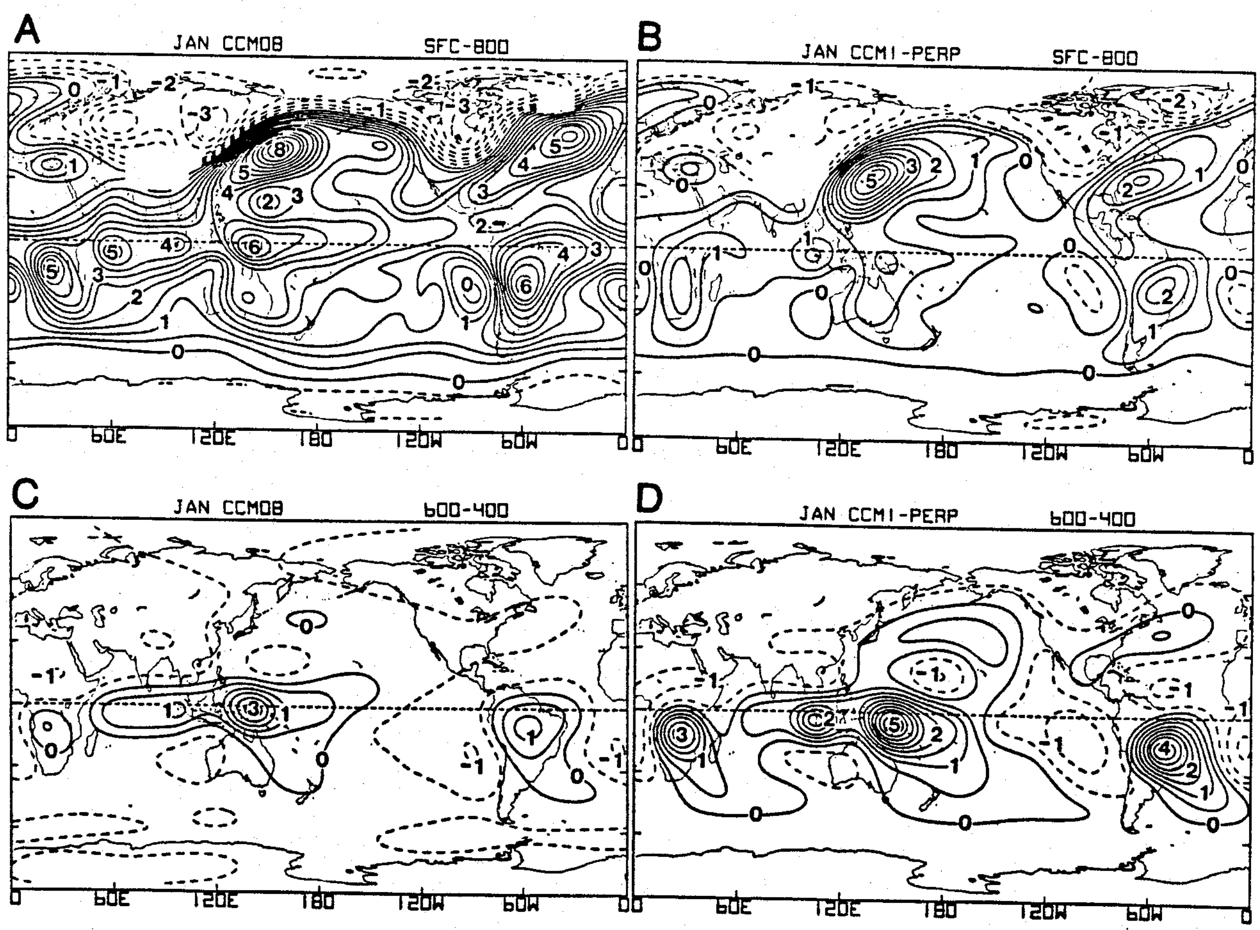

Fig. 2: Ensemble average of time-averaged surface-800 mb layer-averaged heating for perpetual January (A) CCMOB, (B) CCM1. Same for 600-400 mb layer for (C) CCMOB, (D) CCM1. Contour interval and filter as in Fig. 1.

GLOBAL DIABATIC HEATING CALCULATIONS

Akira Kasahara and Arthur P. Mizzi
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

The objective of this project is to evaluate the global diabatic heating rates from the FGGE Level IIIb analyses produced by various organizations, such as ECMWF, GFDL, GLA and NMC. We use the thermodynamic equation as formulated by the CCM and obtain the diabatic heating rates as a residual to the thermodynamic energy budget. This approach is somewhat unique, because we are using the CCM as a diagnostic tool rather than a prognostic model. So far we have been using the CCM0B as our tool of analysis. The results of global diabatic heating rates from the ECMWF Level IIIb during two 15-day periods in the Special Observing Periods (SOP) I and II are published in Kasahara, Mizzi and Mohanty (1987). Also, in Mizzi and Kasahara (1988) we published preliminary results of global diabatic heating rates from the ECMWF, GFDL, and GLA FGGE Level IIIb analyses during a 15-day period in SOP I.

As one might anticipate, the agreement in the results of diabatic heating rates from the three FGGE Level IIIb datasets is not very good on daily basis, although the broad features of time-averaged heating rates are in good agreement. Since the evaluation of diabatic heating rates requires a good estimate of the vertical motion field, we began to ask a more fundamental question: How well do the basic meteorological variables such as the vertical component of vorticity ζ, horizontal divergence δ and temperature T as well as such diagnosed quantities as vertical p-velocity ω and diabatic heating rates agree with each other among the three FGGE Level IIIb analysis datasets on a daily basis? We are in the process of writing a paper to summarized our findings from an intercomparison of daily variations of these basic meteorological variables, including vertical p-velocity and diabatic heating rates, from the ECMWF, GFDL and GLA FGGE Level IIIb analyses. This intercomparison has been done on the standard three-dimensional CCM0B grid.

This type of data intercomparison enables us to quantify similarities and differences among the different datasets, but it does not provide a measure of the relative accuracy of datasets. We are using outgoing longwave radiation (OLR) temperatures observed by the TIROS-N as a measure of convective activities in the tropics. Through a suitable classification of OLR data, we get a useful information on the relative accuracy of diabatic heating rates obtained from the three FGGE Level IIIb analyses.

The vertical motion plays a decisive role in the determination of diabatic heating rates by the thermodynamic method. At the same time, we know that it is difficult to obtain the accurate determination of vertical velocity. In the present study, we used unmodified wind and temperature fields to calculate the vertical p-velocity in the sigma coordinate system. We are fully aware of the fact that the vertical motion field calculated from the "raw" analyses is known to produce mass imbalance. Currently, we are testing two methods of modifying the "raw" analysis of divergence field to ensure mass balance: One is a variational procedure under the constraint of pressure tendency equation and the other is the modification technique of Kasahara *et al.* (*Mon. Wea. Rev.*, **116**, 1988, 866–883) which uses satellite OLR data for improvement in the analysis of divergent wind in the tropics.

Also, we have switched to the use of CCM1 for better horizontal and vertical resolutions.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Kasahara, A., A.P. Mizzi and U.C. Mohanty, 1987: Comparison of global diabatic heating rates from FGGE Level IIIb analyses with satellite radiation imagery data. *Mon. Wea. Rev.*, **115**, 2904–2935.

Mizzi, A., and A. Kasahara, 1988: Comparison of global diabatic heating rates from the ECMWF, GFDL, and GLA FGGE Level IIIb analyses. Reprints from the *Eighth Conference on Numerical Weather Prediction*, February 22–26, 1988, Baltimore, Md., Amer. Meteorol. Soc., Boston, Mass., 416–423.

IV. Experiments and History Tapes

The following CCM related tapes were produced.

CCM0B format tapes:

Period: daily at 12Z for 1/26/79–2/10/79 and 6/6/79–6/21/79

Type of tape: a) uninitialized model input tapes; b) initial time forecast (one time step) model history tape

Data source: ECMWF, GFDL, GLA FGGE IIIb analyses

CCM1 format tapes:

Period: daily at 12Z for 1/15/79–2/14/79

Type of tape: a) uninitialized model input tapes; b) fully diabatic initialized model input tapes; c) initial time forecast (one time step) model history tape

Data source: ECMWF*, GFDL, GLA, NMC** FGGE IIIb analyses

* Both original and reanalyses.
** Reanalyses only in preparation.

RADIATIVE-DYNAMICAL RESPONSE OF A STRATOSPHERIC VERSION OF CCM1 TO OZONE REDUCTIONS

Jeffrey T. Kiehl and Byron A. Boville
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

This project has been completed. A tropospheric-stratospheric version of the NCAR CCM (version 1) was used to study the response of the model to both uniform and nonuniform ozone reductions. A fixed dynamical heating version of the CCM was also used to interpret the results of the CCM. It was found that for uniform ozone reductions, the fixed dynamical heating assumption was not applicable. A threshold in uniform of ozone reduction appears to exist between 50 and 75% where large changes in the polar night jet occur. For a nonuniform ozone reduction based on a two-dimensional chemical model, the fixed dynamical heating assumption works quite well in describing the thermal response to the reduction in ozone.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Kiehl, J.T., and B.A. Boville, 1988: The radiative-dynamical response of a stratospheric-tropospheric general circulation model to changes in ozone. *J. Atmos. Sci.*, **45**, 1798–1817.

IV. Experiments and History Tapes

Not available for public use.

RESPONSE OF A GENERAL CIRCULATION MODEL TO A PRESCRIBED ANTARCTIC OZONE HOLE

J.T. Kiehl, B.A. Boville, and B.P. Briegleb
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

This project has been completed. Model simulation of the ozone hole observed in Austral springtime indicates that the ozone depletion leads to a temperature decrease in the lower Antarctic stratosphere of ~5 K in mid-October. The temporal evolution of the thermal balance in the control shows weak upward motion occurs by mid-September and shows the temperature tendency is dominated by the net radiative heating through late September to Novemver. When the ozone hole is imposed, downward motion persists through September to mid-October. Thus, the model does not support the proposed dynamical cause for the ozone hole.

II. Students and Thesis Title

None.

III. CCM-Related Publications

J.T.Kiehl, B.A.Boville and B.P. Briegleb, 1988: Response of a general circulation model to a prescribed Antarctic ozone hole, *Nature*, **332**, 501–504.

IV. Experiments and History Tapes

None.

PREDICTABILITY OF THE LOW-FREQUENCY CIRCULATION

Yochanan Kushnir and John M. Wallace
Department of Atmospheric Sciences
University of Washington, Seattle, WA.

I. *Progress and results*: The project was performed during 1986. Following is a brief description of the project and its results:

An ensemble of 15-day numerical forecast experiments was performed with the NCAR CCM to examine aspects of the mutual interaction between high-frequency, baroclinic-wave variability and the low-frequency components of the atmospheric flow. The main part of the experiments consisted of comparing a control run based on an initial field, arbitrarily chosen from the history tapes of a previous model integration and a forecast based on a time-filtered version of the same initial state. The results indicate that the high-frequency variability of the flow in the latter forecast, returns to normal amplitude about one week after the initialization time, at which state it is only weakly correlated in space with the high-frequency component of the flow in the control run. The low-frequency component of the flow seems to behave differently depending on its zonal scale: Ultralong waves (wavenumber 1-3) are only weakly affected by the removal of the baroclinic activity from the initial conditions. Long waves (wavenumber 4-6) are more severely affected by the removal of the baroclinic activity from the initial condition. The main effect during the first week of the forecast is a tendency of the long wave components in the forecast based on filtered initial conditions to drift eastward with respect to their counterparts in the control run.

II. *Students and Thesis titles*: N/A

III. *CCM Related Publications*:

Blackmon, M. L., S. L. Mullen and G. T. Bates, 1986: The climatology of blocking events in a perpetual January Simulation of a spectral general circulation model. *J.Atmos. Sci.*, **43**,1379-1405.

Malone, R. C., E. J. Pitcher, M. L. Blackmon, K. Puri and W. Bourke,1984: The simulation of stationary and transient geopotential height eddies In January and July with a spectral general circulation model. *J. Atmos.Sci.*, **42**, 1394-1419.

IV. *Experiments and History tapes*: No history tapes from this experiment were saved on the NCAR mass storage.

MODELING EXPERIMENTS WITH PALEOCLIMATIC FORCING

John E. Kutzbach
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Madison, WI 53706

I. Progress and Results

We have studied the response of the CCM to changes in the seasonal and latitudinal distribution of solar radiation associated with orbital changes. Specific experiments were for 3, 6, 9, 12, 15, 18, 115 and 126 thousand years ago. We have used two different ice sheet heights for 18 thousand years ago to bracket the observational uncertainty (see references below). We have completed a set of no mountain and half-mountain experiments to test ideas on the role of uplift on climatic change over the past 5–10 million years (manuscripts in preparation). We are expressing our paleoclimatic results in terms of a modified Koeppen classification and a biomass productivity index. We are comparing CCM0 and CCM1 simulations of surface energy and hydrologic budgets with the results of observational studies such as Budyko, Jaeger, and Oort.

II. Students and Thesis Titles

Mary Meyer (M.S.)	*Biomass Productivity Indices Based upon Control and Paleoclimate Simulations with the CCM.* Expected August 1988.
Vada LaFontaine (M.S.)	*Analyses of CCM Results for Equatorial Lands, 18000 yr BP to Present, and Comparison with Geologic Data.* June 1988.

III. CCM-Related Publications

Kutzbach, J.E., 1985: Modeling of paleoclimates. *Adv. Geophys.*, **28A**, 159–196.

Kutzbach, J.E., and P.J. Guetter, 1984: Sensitivity of late-glacial and Holocene climates to the combined effects of orbital parameter changes and lower boundary condition changes: "Snapshot" simulations with a general circulation model for 18, 9, and 6 ka BP. *Annals of Glaciology*, **5**, 85–87.

Kutzbach, J.E., and P.J. Guetter, 1984: The sensitivity of monsoon climates to orbital parameter changes for 9000 years BP: Experiments with NCAR General Circulation Model. *Milankovitch and Climate*, Part 2, A. Bergen and J. Unbruem, Eds, Riedel Publ. Co., 801–820.

Kutzbach, J.E., and F.A. Street-Perrott, 1985: Milankovitch forcing of fluctuations in the level of tropical lakes from 18 to 0 kyr BP. *Nature*, **317**, 130–134.

Kutzbach, J.E., and H.E. Wright, Jr., 1985: Simulation of the climate of 18,000 years BP: Results for the North American/North Atlantic/European sector and comparison with the Geologic Record of North America. *Quatern. Sci. Rev.*, **4**, 147–187.

Kutzbach, J.E., and P.J Guetter, 1986: The influence of changing orbital parameters and surface boundary conditions on climate simulations for the past 18,000 years. *J. Atmos. Sci.*, **43**, 1726–1759.

Prell, W.L., and J.E. Kutzbach, 1987: Monsoon variability over the ast 150,000 years. *J. Geophys. Res.*, **92**, 8411–8425.

Kutzbach, J.E., 1987: Model simulations of the climatic patterns during the deglaciation of North America. *North America and Adjacent Oceans during the Last Deglaciations,* (Ruddiman, W.F. and Wright, H.E., Jr., Eds), *The Geology of North America*, Vol. K–3, Geological Society of America, Boulder, Colo., Chapter 19, pp. 425–446.

Webb, T. III, T., P.J. Bartlein and J.E. Kutzbach, 1987: Climatic change in eastern North America during the past 18,000 years: Comparisons of pollen data with model results. *North America and Adjacent Oceans during the Last Deglaciation*, (Ruddiman, W.F. and Wright, H.E., Jr., Eds.). *The Geology of North America*, Vol. K–3, Geological Society of America, Boulder, Colo., Chapter 20, pp. 447–462.

COHMAP project members, 1988: Climatic changes of the last 18,000 years: Observations and model simulations. *Science*, **241**, 1043–1052.

IV. Experiments and History Tapes

All of the history tapes for experiments for 3, 6, 9, 12, 15 and 18 thousand years ago are available to other users upon request. We will have the table of run numbers available shortly.

NUMERICAL SIMULATION OF EXPLOSIVE CYCLOGENESIS

Steven L. Mullen
Department of Atmospheric, Oceanic and Space Sciences
The University of Michigan

I. Progress and Results

The relative importance of physical parameterizations and initial condition error in numerical simulations of large-scale explosive cyclogenesis is being investigated. Sensitivity experiments are conducted for 11 outstanding cases of cyclogenesis which occurred in a 150-day perpetual January simulation of a R31 version of CCM0B. Dry, viscid baroclinic dynamics accounts for about half of the deepening of the composite storm; surface energy fluxes and latent heating accounts for the remaining half. Appreciable case-to-case variability was found, however. Current research is focused on the use of Monte Carlo techniques to examine the impact of initial condition error.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Mullen, S.L., and D.P. Baumhefner, 1988: Sensitivity of numerical simulations of explosive oceanic cyclogenesis to changes in physical parameterizations. *Mon. Wea. Rev.,* **116,** in press.

Mullen, S.L., and D.P. Baumhefner, 1989: The impact of uncertainity in initial conditions on numerical simulations of large-scale explosive cyclogenesis. *Mon. Wea. Rev.,* submitted.

IV. Experiments and History Tapes

CCM0B R31 January control run
`/CSM/X95001 to /X95020`

STRATOSPHERIC GENERAL CIRCULATION WITH CHEMISTRY PROJECT (SGCCP)

J. Eric Nielsen, Richard B. Rood, and Mark R. Schoeberl
Atmospheric Chemistry and Dynamics Branch
NASA/GSFC Code 616, Greenbelt, MD 20771

I. Progress and Results

The primary goal of SGCCP is to study stratospheric transport and chemistry in a general circulation model framework. As part of this effort we obtained a nine-level version of CCM0 in 1987. We verified that the model was running against a benchmark provided by B. Boville. We then increased the number of levels to 30 with the top level at approximately 80 km.

For our first 30-layer model experiment, the ozone partial pressures were prescribed up to 0.49 mb, and the CCM0 was allowed to extrapolate the data to the model lid. The mesosphere in that experiment was obviously incorrect. We then inserted the ozone fields from our SME/SBUV climatology, and the mesospheric temperatures rapidly adjusted to reasonable values. We ran the model from a "dead start" spinup at the Autumnal Equinox until early April of the following year. The winter stratosphere was "wave one" dominated with qualitatively reasonable wave mean flow and wave-wave interaction. The final warming was radiatively dominated. The winter hemisphere stratosphere appeared consistent with other coarse resolution model results.

Throughout the integration, the summer stratosphere exhibited "pancake" structures in the temperature field (Fig. 1). These structures are unrealistic and problematic and may be related to those mentioned in Boville (1986). Examination of the generation of these structures indicated that they were radiatively forced, and that some of the forcing was due to reflected radiation. This, and other problems in the temperature field near the poles and the model lid (Fig. 1), motivated a change to our local radiation package (Rosenfield *et al.* 1986).

Upon implementation of the GSFC radiation code, the thermal anomalies disappeared, and there was a large change in mesospheric temperature structure. However, problems with "gravity wave" noise in the upper part of the model became more severe. The source of the amplification appears to be a fundamental difference in the behavior of the long wave part of the two radiation packages above 65 km. The GSFC package yields highly variable heating and cooling as the gravity waves propagate through the system. The CCMO longwave package is dominated by variable, but systematic cooling. In both experiments, the radiative forcing was updated at 12-hour intervals.

Neither radiation package is believed to be very accurate above 65–70 km. Furthermore, to correctly represent the radiative properties of gravity waves, the radiation would have to be called more frequently. Therefore, we have derived a "fix" for the upper layers based upon Newtonian cooling. We have just started these experiments. The preliminary results with the GSFC radiation package indicate differences in the planetary wave behavior. These experiments should provide useful information on the basic balance between radiation and dynamics in stratospheric general circulation models.

II. Students and Thesis Titles

None.

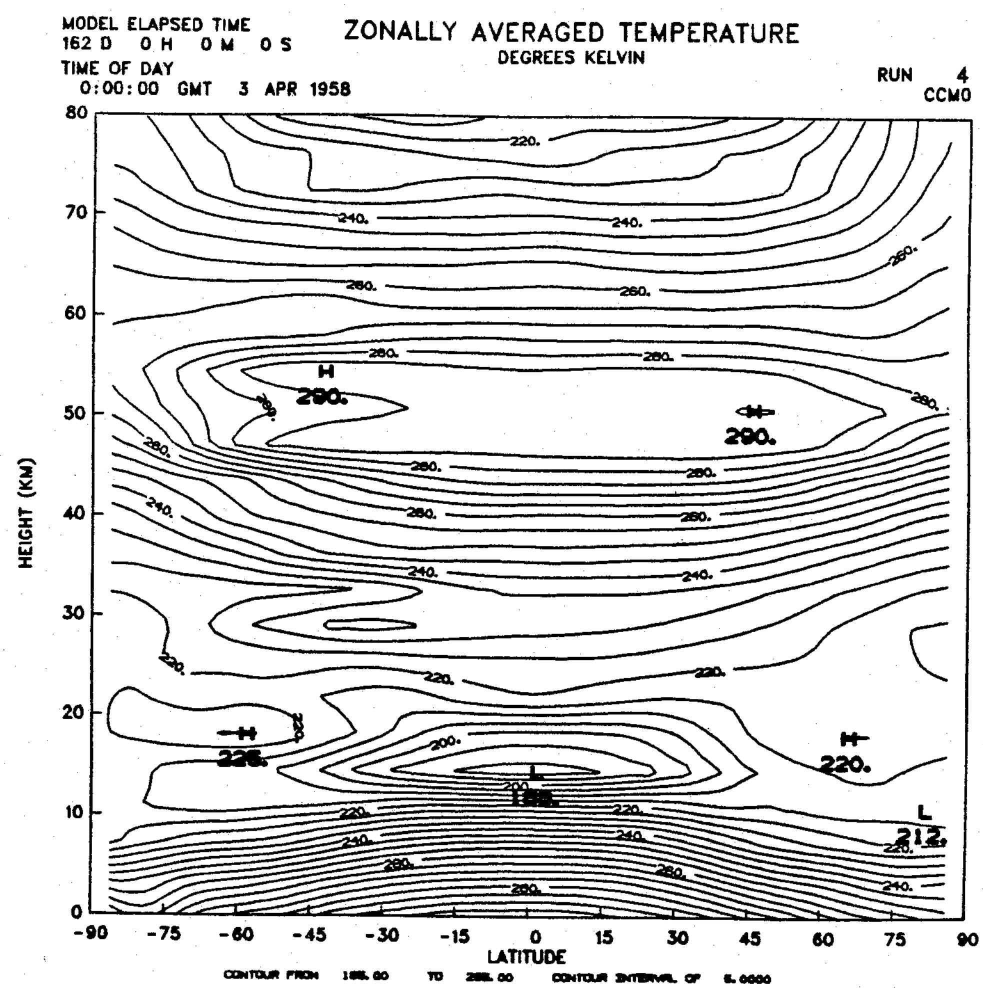
III. CCM-Related Publications

Rosenfield, J.R., M.R. Schoeberl and M.A. Geller, 1987: A computation of the stratospheric diabatic circulation using an accurate radiative transfer model. *J. Atmos. Sci.*, **44**, 859–876.

IV. Experiments and History Tapes

CCMO, R15, 30 levels, September 21 dead start until April 3 of the following year.

CCMO, R15, GSFC Radiation, start from November 1 of previous experiment—in progress.



PALEOCLIMATIC SENSITIVITY STUDIES

Robert J. Oglesby and Barry Saltzman
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New Haven, CT 06511

I. Progress and Results

A. Drake Passage and Antarctic glaciation: These experiments are now nearly completed and analysis of the results is in full progress. Results to date suggest a relatively minor role for oceanic heat transport in the formation/elimination of Antarctic glaciation. That is, under the warmer conditions that have been inferred to prevail before the opening of the Drake Passage, conditions still would have been favorable for the maintenance of an ice-sheet. Lowering the elevation of Antarctica, on the other hand, has a crucial effect on the model simulations, reducing the likelihood of glacial conditions. The simulations also demonstrate the important roles of seasonality and winter-time precipitation. A tundra-like Antarctic climate is the closest the model has come to representing a glacial-free climate even when both sea surface temperatures and elevations are maximally varied.

B. Gulf of Mexico melt-water cooling: The initial phase of this project is now complete and a paper detailing the results and conclusions submitted for publication. Perpetual January simulations with imposed Gulf-wide coolings of 3, 6, and 12°C yield a major reduction in the North Atlantic storm-track, with a sharp reduction of the climatological Icelandic low. Significant changes are also seen elsewhere over the Northern Hemisphere, especially Europe. Analysis of perpetual July experiments is now underway, as well as comparisons of annual averages with the Holocene paleoclimatic record.

II. Students and Thesis Titles

Robert J. Oglesby (Ph.D.) *Paleoclimatic Sensitivity Studies.* May 1989.

III. CCM-Related Publications

Oglesby, R.J., K.A. Maasch and B. Saltzman, 1988: glacial meltwater cooling of the Gulf of Mexico: GCM implications for Holocene and present-day climates. *Clim. Dynamics*, submitted.

Oglesby, R.J., 1988: Opening the Drake Passage and Antarctic glaciation: Some GCM results. EOS, Transactions, American Geophysical Union Vol. 69, No. 16, p. 382 (abstract).

IV. Experiments and History Tapes

Will send experiment logs upon request.

THE MIDLATITUDE RESPONSE TO TROPICAL HEATING

Jan Paegle
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I. Progress and Results

Ongoing research with the CCM1 investigates the atmospheric response to various time scales of tropical heating, with an emphasis on determining the predictibility of large-scale motions and responses in a real-data forecasting sense.

The one control and four experiment ensembles each consisted of eight individual cases, initialized with NMC observed data for the January 1 date of 1977 to 1984. The 40 subsequent integrations each ran for 36 days, using a total of 16 GAUS. All control and experiment runs have been completed with the results currently being processed.

II. Students and Thesis Titles

Lawrence Buja (Ph.D.) *The Midlatitude Response to Tropical Heating.* June 1989.

III. CCM-Related Publications

Paegle, J.,C.D. Zhang, and D.P. Baumhefner 1987: Atmospheric Response to Tropical Thermal Forcing in Real Data Integrations. *Mon. Wea. Rev.*, **115**, 2975–2995.

Buchmann, J., L. Buja, J. Paegle, C. D. Zhang, and D. P. Baumhefner, 1986: FGGE Forecast experiments for Amazon Basin rainfall. *Mon. Wea. Rev.*, **114,** 1625–1641.

IV. Experiments and History Tapes

A brief description of the different experiment ensembles follows:

CON: 36-day CCM1 R15 run with no modifications.

HT1: 36-day CCM1 R15 run with strong steady heating.

HT2: 36-day CCM1 R15 run with very strong transient heating, peak value of 26°/day.

HT3: 36-day CCM1 R15 run with strong transient heating, peak value of 8°/day.

HT4: 36-day CCM1 R15 run with weak steady heating, peak value of 2.66°/day.

The initialization and history tapes associated with these experiments are:

CCM1 9LEV R15 Jan 1 control initialization, 1977–1984

/SOUTHERN/CCM1/M6A2I1 to /M6A2I8

CCM1 9LEV R15 Jan 1 initialization with no Rocky Mountains, 1977–1984

/SOUTHERN/CCM1/M6A2I11 to /M6A2I18

CCM1 9LEV R15 Jan 1 36-Day control run, 1977–1984

/SOUTHERN/CCM1/M6A/M6A1M1 to /M6A1M8

CCM1 9LEV R15 Jan 1 36-Day run with no Rocky Mountains, 1977–1984

/SOUTHERN/CCM1/M6A/M6A3M1 to /M6A3M8

CCM1 9LEV R15 Jan 1 36-Day run with HT1 heating, 1977–1984

/SOUTHERN/CCM1/M6A/M6A2M1 to /M6A2M8

CCM1 9LEV R15 Jan 1 36-Day run with HT2 heating, 1977–1984

/SOUTHERN/CCM1/M6A/M6A4M1 to /M6A4M8

CCM1 9LEV R15 Jan 1 36-Day run with HT3 heating, 1977–1984

/SOUTHERN/CCM1/M6A/M6A5M1 to /M6A5M8

CCM1 9LEV R15 Jan 1 36-Day run with HT4 heating, 1977–1984

/SOUTHERN/CCM1/M6A/M6A6M1 to /M6A6M8

PROJECT: EVALUATION OF CCM1 CLIMATOLOGY

William J. Randel and David L. Williamson
National Center for Atmospheric Research
Boulder, Colorado 80307

I. Progress and Results

This study is a comprehensive analysis of the global climate simulated by CCM1, via comparisons with seven ECMWF analyses (see Trenberth and Olson, 1988: *ECMWF Global Analyses 1979–1986: Circulation Statistics and Data Evaluation*, NCAR Tech. Note, NCAR/TN–300+STR). Attention is focused on differences in temperature, wind, and wave flux quantities (such as poleward heat flux), and their interrelationships. Comparisons with the climate simulated by CCM0 are also made, and differences analyzed in light of known CCM1–CCM0 model changes. Figure 1 shows an example of these comparisons, illustrating the (CCM1-ECMWF) and (CCM0-ECMWF) differences in January mean zonal temperatures. Both models show cold biases throughout the troposphere, a well-known deficiency in many current climate simulations. Note the changes in temperature biases between CCM1 and CCM0; however, CCM1 has reduced that in the tropical upper troposphere by a factor of two, but they are substantially worse in the high latitude upper troposphere-lower stratosphere. Extensive analyses along these lines are currently underway, and the results are being written up for journal publication.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

None.

IV. Experiments and History Tapes

No additional experiments beyond the standard controls.

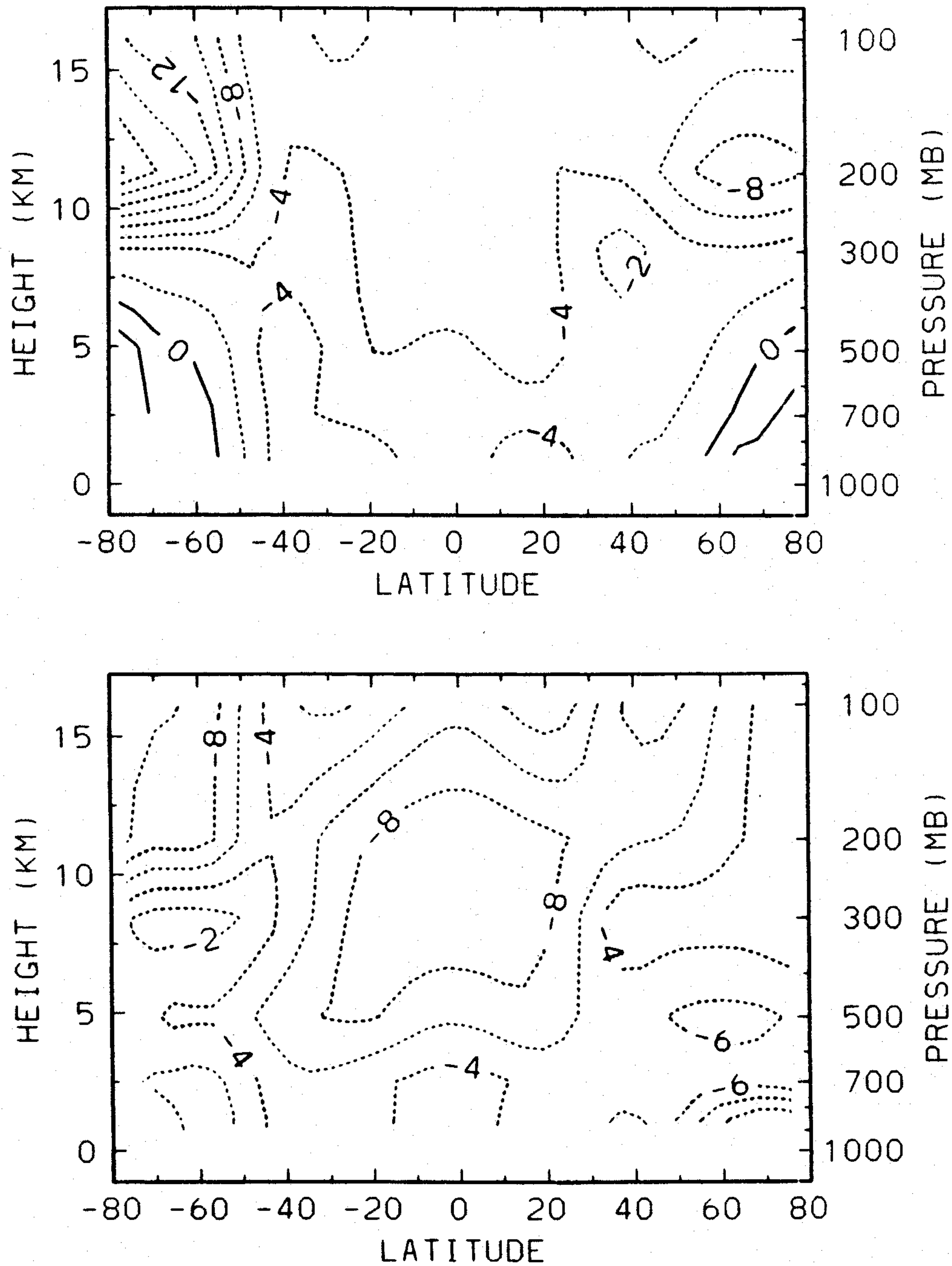

Fig. 1: Differences for January means between observed and simulated zonally averaged temperature; (top) is CCM1 minus ECMWF, (bottom) is CCM0 minus ECMWF. Contours of 2 K, with negative values denoting the models are colder than observations.

SEMI-LAGRANGIAN MOISTURE TRANSPORT WITH SHAPE PRESERVING INTERPOLATION IN THE CCM

Philip J. Rasch and David L. Williamson
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

We have evaluated a large number of shape-preserving (and some nonshape preserving) interpolation schemes in terms of their relative ability to interpolate evenly spaced data drawn from three test shapes at two resolutions. The more accurate interpolants were incorporated into the semi-Lagrangian transport method and tested by examining the accuracy of the solution to one- and two-dimensional planar and spherical advection of nondeforming test shapes. The results of this work are summarized in the manuscripts listed below. We have implemented the most promising combinations in CCM1 and are currently evaluating them compared to the original spectral transport scheme in that model.

Rasch, P.J., and D.L. Williamson, 1988: On shape preserving interpolation and semi-Lagrangian transport. *SIAM J. Sci. Stat. Comput.*, in press.

Williamson, D.L., and P.J. Rasch, 1988: Two-dimensional semi-Lagrangian transport with shape preserving interpolation. *Mon. Wea. Rev.*, in press.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

None to date.

IV. Experiments and History Tapes

Not yet available.

THE RESPONSE OF CCM1 TO CLOUD LONGWAVE RADIATIVE FORCING

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National Center for Atmospheric Research
Boulder, Colorado 80307
(Research carried out while Visiting Scientists, 1986–87)

I. Progress and Results

CCM1 was used to study the effect of cloud radiative forcing on model simulations. The paper listed below discusses the concept of cloud radiative forcing and the forcings in the shortwave and longwave spectral regions are contrasted. At low latitudes, the cloud longwave forcing is primarily within the atmosphere, rather than at the surface. It is thus appropriate to study its effects in a model which employs fixed sea surface temperatures (SSTs), such as the standard version of CCM1.

The impact of cloud longwave forcing was studied in 510-day integrations for constant January conditions. The experiments isolate the forcing by tropical and extra-tropical clouds. Tropical cloud forcing warms the tropical upper troposphere and accelerates the subtropical jets. There are subtle interactions between the forcing, the clear-sky longwave heating and the latent heating in the tropics. These additional diabatic heating terms oppose the forcing in some regions and enhance it in others.

The tropical cloud forcing strengthens the precipitation maxima at low latitudes. There are also changes in the extra-tropical flow, including the excitation of a pattern in the 200 mb geopotential height differences which is similar to those found in previous studies of the effect of SST anomalies. This confirms that the forcing may be as important as latent heat release in determining the atmospheric response to such anomalies. The mode is excited with comparable strength by the extra-tropical cloud forcing. Finally, some concerns regarding the generality of these results and their applicability to other models and the real atmosphere are discussed.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Slingo, A., and J.M. Slingo, 1988: The response of a general circulation model to cloud longwave radiative forcing. I: Introduction and initial experiments. *Quart. J. Roy. Meteor. Soc.*, **114**, 1027–1062.

IV. Experiments and History Tapes

Details available from A. Slingo.

Comparison of longwave and shortwave radiation data from CCM outputs with Nimbus–7 earth radiation budget measurements

Laura D. Smith and Thomas H. Vonder Haar

Department of Atmospheric Sciences
Colorado State University
Fort Collins, CO 80523

I. Progress and results

Measurements of the earth radiation budget (ERB) from space-borne instruments and long-term simulations of climate with general circulation models (GCMs) make complementary contributions to improve our understanding of *cloud-radiation-climate* interactions and the role of clouds in the atmospheric general circulation. The first step of an increased use of three-dimensional climate models to study the forcing of clouds on climate is the validation against observations of GCM simulated climates, including their temporal and spatial variability. ERB measurements from satellites constitute one of the most suitable means for objective and easy comparisons with model outputs. In particular, they provide the necessary boundary conditions that GCMs have to conform to. The top-of-atmosphere radiation balance computed from long-term climate simulations with the NCAR Community Climate Model (CCM1) is compared against this measured during the Nimbus–7 satellite mission. The geographical distributions of the outgoing infrared radiation, absorbed solar radiation, and planetary albedo are individually analyzed for Northern Hemisphere winter and summer seasons. Comparisons between model and observations of the seasonal average and standard deviation computed from the seasonal average were made for the three radiation fields whereas the comparison of the time-lagged correlation coefficients was limited to the outgoing infrared radiation only.

Daily ERB measurements were taken by the scanner radiometers on board the satellite Nimbus–7 during the period between May 1979 and June 1980. They were broad-spectral band observations which covered daily (twice daily at infrared wavelengths) the entire globe. The Northern Hemisphere summer and winter seasons respectively refered to June-July-August 1979 and December 79-January-February 1980. At the present time, this data set is the only multi-month set of archived broad-spectral band observations while waiting for the next generation of NFOV data from the ongoing multi-satellite Earth Radiation Budget Experiment (ERBE) which started in November 1984. The various model simulations were obtained from time integrations of the newest version of the NCAR CCM (or version CCM1). Part of our research contributed to the validation of the latest improvements brought into the model code, especially in the radiative transfer schemes of long and short and long wavelengths, and helped outline the future modifications which should be implemented to increase the model performance to simulate the earth-atmosphere climate system. The model simulated radiative fields were obtained from a 15-year run including a seasonal cycle (Case 239) and a 1500-day run for perpetual January conditions (Case 223). Ensemble averages of the time averages, time standard deviations about the seasonal average, and time-lagged correlation coefficients were computed from five independent realizations of climate, and were considered to be representative of the mean GCM climate and its temporal variability.

The NCAR CCM reproduced more successfully the geographical distribution of the time-averaged outgoing infrared radiation than the time-averaged planetary albedo. Global maps of the time standard deviation of the GCM simulated radiative fields resembled rather accurately these obtained from observations, especially for the outgoing infrared radiation. However, the magnitude of the standard deviation was two times larger than this computed from satellite data. The calculation of the time-lagged correlation coefficients of the outgoing infrared radiation confirmed this discrepancy between model and observations, and showed that the model atmosphere was losing its memory faster than the real atmosphere. The comparison between the model-simulated and satellite-observed components of the planetary radiation balance revealed a major deficiency in the representation of the time behavior of climate simulations with CCM1. It was shown that the high frequency of occurrence of clouds in the model could be responsible for the difference in the temporal variability between model and observations. The prediction of the cloud amount as a function of the large-scale atmospheric stability and relative humidity maintained a decoupling between clouds and the hydrologic cycle. It was suggested that the inclusion of a prognostic equation of the cloud liquid water and some memory of the history of convection was the necessary ingredient to correctly simulate the life-cycles of clouds in the model.

II. Student and Thesis Title

Laura D. Smith (PhD): Satellite versus GCM-simulated radiation balance: Comparisons and implications for climate modeling (Expected September 6th, 1988).

III. Experiments and History tapes

1. CCM1 R15 seasonal simulation (Case 239): /CSM/CCM1/239/X239107 to X239222
2. CCM1 R15 January control simulation (Case 223): /CSM/CCM1/223/X22311 to X22324
3. CCM1 R15 July control simulation (Case 240): /CSM/CCM1/240/X24011 to X24024
4. CCM1 R15 Slingo simulation: /CSM/SLINGOJ/SLXD11 to SLXD24

EFFECTS OF PRESCRIBED OCEAN MIXED LAYER PROPERTIES IN THE CCM1

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Boulder, CO 80307
and
Curt Covey
Lawrence Livermore National Laboratory
Livermore, CA 94550

I. Progress and Results

The CCM1 model version was modified to include a passive ocean mixed layer and 3-layer thermodynamic sea ice model. The sensitivity of global climate to explicit prescribed ocean poleward heat transport and mixed layer depth are currently under investigation.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

None at this time.

IV. Experiments and History Tapes

None generally available.

EFFECTS OF NUCLEAR WAR ON THE GLOBAL ATMOSPHERE: 1–90 DAYS

Starley L. Thompson and Stephen H. Schneider
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

The CCM0B model version was modified to allow for (1) multiple tracer fields advected in spectral space, (2) solar radiative transfer by scattering aerosols, (3) aerosol removal and parameterized microphysics, (4) stratospheric ozone chemistry and transport. Numerous simulations of nuclear war smoke, dust and nitrogen oxide injections have been performed. In general, plausible summer injection scenarios produce substantial short-term surface cooling over mid-latitude Northern Hemisphere land, massive atmospheric circulation changes, and substantial stratospheric ozone reductions.

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Thompson, S.L., V. Ramaswamy and C. Covey, 1987: Atmospheric effects of nuclear war aerosols in general circulation model simulations: Influence of smoke optical properties. *J. Geophys. Res.*, **92**, 942–10,960.

Schneider, S.H., and S.L. Thompson, 1988: On simulating the climatic effects of nuclear war. *Nature*, **333**, 221–227.

IV. Experiments and History Tapes

None generally available.

OBSERVATIONAL DATA FOR CCM VALIDATION

Kevin E. Trenberth and Jerry G. Olson
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

This project does not use the CCM itself but has taken the European Centre for Medium Range Weather Forecasts' (ECMWF) global analyses and reformatted them in history tape format on an R15 Gaussian grid for use with CCM modular processor. The details on the analyses, how to access them and the names of the history tapes tapes are given in Trenberth and Olson (1988).

II. Students and Thesis Titles

None.

III. CCM-Related Publication

Trenberth, K.E., and J.G. Olson, 1988: *ECMWF Global Analyses 1979-1986: Circulation Statistics and Data Evaluation.* NCAR Tech. Note, NCAR/TN-300+STR, National Center for Atmospheric Research, Boulder, Colo., 94 pp and 12 fiche.

IV. Experiments and History Tapes

See complete list in Trenberth and Olson (1988).

EXTENDED RANGE PREDICTABILITY

Joseph J. Tribbia
National Center for Atmospheric Research
Boulder, CO 80307

I. Progress and Results

An ensemble of twenty predictability experiments were performed using the perpetual January simulation as the control (background truth). At 60-day intervals this simulation was perturbed with random, initialized vorticity divergence and geopotential of small amplitude (5 m RMS in height). These perturbed integrations were carried forward for 60 days.

II. Students and Thesis Titles

None.

II. CCM-Related Publications

Tribbia, J. J. and D. P. Baumhefner, 1988: Estimates of the predictability of low-frequency motions using a spectral general circulation model. *J. Atmos. Sci.*, **45**, 2306–2317.

V. Experiments and History Tapes

CCM0B 12 hourly data
Control—`CSM/X7001 to /X7080`
Perturbed—`TRIBBIA/JT7001--/JT7080`

15 days on each volume

CFM SENSITIVITIES TO SNOW COVER AND SEA ICE

John E. Walsh
University of Illinois

I. Progress and Results

Several series of 30-day simulations with the NCAR Community Forecast Model have been used to evaluate the CFM's sensitivity to snow cover over North America and Eurasia. All simulations used model version CCMOB at R15 resolution. The model was initialized with NMC analyses for specific dates during the winters of 1976-77 through 1983-84, and snow cover in each case was prescribed according to (1) the distribution derived from observational data and (2) the distribution containing a corresponding anomaly of the opposite sign.

In ten pairs of mid-winter simulations, the major effect of extensive snow cover in eastern North America was a reduction of the near-surface air temperature in the vicinity of the snow anomaly. When snow cover was extensive, sea level pressures were somewhat lower and precipitation amounts somewhat higher offshore of the East Coast; sea level pressures were generally higher inland. In a set of six March cases, positive anomalies of Eurasian snow cover reduced air temperatures by at least several °C throughout the lower troposphere in the region over and downstream of the snow anomaly. The positive Eurasian snow anomalies also produced systematically lower pressures and upper-air heights in the Aleutian region, higher pressures in the Asian Arctic, and lower pressures over western Europe and the extreme northeast Atlantic. In the Eurasian experiments, the 30-day forecast pressures for the Eurasian hemisphere varied with pressure in a manner consistent with the observed pressure fields of the same months.

A similar set of experiments is now being performed in order to assess the CFM forecast sensitivity to North Atlantic sea ice coverage and sea surface temperature. 30-day simulations have been made with both R15 and R30 resolution, with "heavy" and "light" ice coverage, and with observed and climatological sea surface temperatures. Preliminary results indicate that the circulation (SLP) fields over the northeastern Atlantic and Europe do respond systematically to sea ice extent. However, the forecast skill appears to be at least as sensitive to model resolution and to North Atlantic sea surface temperatures as it is to ice extent.

II. Students and Thesis Titles

An-Cherng Yih (Ph.D.)	CCM sensitivites to Asian surface boundary conditions	Late 1989

III. CCM-related Publications

Walsh, J. E., and B. Ross, 1988: Sensitivity of 30-day dynamical forecasts to continental snow cover. J. Climate, 2, in press (accepted).

Walsh, J. E., and B. Ross, 1988: North Atlantic sea ice sensitivities of monthly dynamical forecasts. Proceedings, Second Conference on Polar Meteorology and Oceanography, Madison, WI (March, 1988), American Meteorological Society, 32-35.

IV. Experiments and History Tapes

CCMOB R15 January runs -- North American snow
/ROSSBECK/HV7E77
" HV7E83
" HV8B77
approx. 20 others -- available on request

CCMOB R15 March runs -- Asian snow
ROSSBECK/L1F781
" L1F784
" L2F781
approx. 30 others -- available on request

CLIMATIC EFFECTS OF INCREASING CO_2

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I. Progress and Results

As part of our ongoing research effort using a hierarchy of coupled global climate models to study the carbon dioxide (CO_2) climate problem, we have coupled a simple 50-m slab ocean mixed layer to a version of the NCAR CCM. More recently, we coupled this same atmospheric model version to a coarse-grid, ocean general circulation model (GCM). With these coupled models, we are conducting experiments on the sensitivity of the climate system to increased CO_2 to determine the role of the ocean in CO_2 climate change. The most recent experiment with the coupled ocean-atmosphere GCM has been run for 30 years from a control experiment and indicates a global warming of 1.6° for an instantaneous doubling of CO_2 and 0.7°C for a linear 1% per year CO_2 increase over the 30-year period.

We have also carried out a diagnostic study of the differences in the sensitivity of hydrology (e.g., soil moisture) between the Geophysical Fluid Dynamics Laboratory (GFDL) and National Center for Atmospheric Research (NCAR) models. The models respond differently to increased CO_2 depending upon whether the soil is dry or wet in spring. Our study indicates less summer drying compared to the GFDL study.

We are developing a new-generation, coupled ocean-atmosphere model with improved physics. This model is multi-tasked to greatly enhance computing economy on present and future computers.

II. Students and Thesis Titles

Gerald A. Meehl (Ph.D.) — *Interactions between the Asian Monsoons, the Tropical Pacific, and the Southern Hemisphere Midlatitudes.* NCAR Cooperative Ph.D. Thesis No. 106, University of Colorado, Boulder, CO, 172 pp., 1987.

III. CCM-Related Publications

Dickinson, R.E., G.A. Meehl and W.M. Washington, 1987: Ice-albedo feedback in a CO_2 doubling simulation. *Clim. Change*, **10**, 241–248.

Meehl, G.A., 1988: Tropical-midlatitude interactions in the Indian and Pacific sectors of the Southern Hemisphere. *Mon. Wea. Rev.*, **116**, 472–484.

Meehl, G.A., and W.M. Washington, 1988: A comparison of soil moisture sensitivity in two global climate models. *J. Atmos. Sci.*, **45**, 1476–1492.

Meehl, G.A., 1988: The coupled ocean-atmosphere modeling problem in the context of the Asian monsoons, the tropical Pacific and Southern Hemisphere midlatitudes. *J. Climatol.,* submitted.

Washington, W.M., and G.A. Meehl, 1988: Climate sensitivity due to increased CO_2: Experiments with a coupled atmosphere and ocean general circulation model. *Clim. Dynamics*, submitted.

IV. Experiments and History Tapes

Not available for distribution.

The Observed and Simulated Atmospheric Seasonal Cycle

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NOAA/ERL

and

Robert M. Chervin
NCAR

I. Progress and Results

The seasonal cycle of the global wind field is documented for both a decadal set of analyses from the National Meteorological Center (NMC) and an extended term integration of a research version of the Community Climate Model (CCM) developed at the National Center for Atmospheric Research (NCAR). Composite eigenvector analysis is used to establish the dominant three dimensional coherent structures characteristic of the data sets while gridpoint harmonic analysis provides evidence of the extent to which these structures describe conventional seasonal modes. These quantitative indicators of spatial and temporal variance form a stringent measure of model performance with respect to seasonal variation. The model appears to be far more successful at capturing the annual harmonic contained in the NMC analyses than the semiannual harmonic. This discrepancy may be related to the absence of the requisite tropical forcings due to either inadequate parameterizations of certain physical processes or the lack of interannual variability in the model's boundary forcings, or both. Further numerical experimentation is likely to help resolve this issue.

II. Student and Thesis Titles

John S. Pyeatt (M.S.) — The seasonal cycle of planetary-scale divergent circulations: A comparison of observed fields and model simulations. (June 1987)

III. CCM-related Publications

Weickmann, K.M., and R.M. Chervin, 1988: The observed and simulated atmospheric seasonal cycle. Part I: Global wind field modes. J. of Climate, 1, 265-289.

EFFECT OF VERTICAL FINITE DIFFERENCE APPROXIMATIONS

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I. Progress and Results

Two commonly used vertical finite difference approximations were compared within the CCM. They produce markedly different simulations within CCM0B. The hydrostatic equation and vertical temperature advection are the main contributors to the differences in the simulations. This study served as the basis for the choice of vertical numerical approximations in CCM1. The experiments are described in detail in Williamson (1988).

II. Students and Thesis Titles

None.

III. CCM-Related Publications

Williamson, D.L., 1988: The effect of vertical finite difference approximations on simulations with the NCAR Community Climate Model. *J. Climate*, **1**, 40–58.

IV. Experiments and History Tapes

9-level scheme X—CCM0B control run (`/CSM/X71001--X71011`)

9-level scheme Y—`X81001--X81011`

9-level scheme Y(B)—`/CMS/TL0583/X76001--X76011`

9-level scheme Y(C)—`X79001--X79011`

9-level scheme Y(B+C)— `/CSM/TL0583/X75001--X75011`

9-level scheme Y$\left(\dot{\sigma}\,\frac{\partial T}{\partial \sigma}\right)$—`X84001--X84011`

19-level scheme X—`/CSM/TL0693/X13601--X13611`

19-level scheme Y—`/CSM/TL0948/X14501--X14511`

19/9-level scheme X—`/CSM/TL0693/X13801--X13811`

19/9-level scheme Y—`/CSM/TL0693/X14601--X14611`

37/9-level scheme X—`/CSM/TL0999/X14901--X14916`

37/9-level scheme Y—`/CSM/TL0009/X15110--X15116`

5. CUMULATIVE LIST
OF CCM-RELATED THESES

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Mullen, S.L., 1985: *On the Maintenance of Blocking Anticyclones in a General Circulation Model.* NCAR Cooperative Ph.D. Thesis No. 86, University of Michigan, Ann Arbor, Mich., 260 pp.

Aragão, J.O.R., 1986: *A General Circulation Model Investigation of the Atmospheric Response to El Niño.* NCAR Cooperative Ph.D. Thesis No. 100, University of Miami, Miami, Fla., 143 pp.

Giorgi, F., 1986: *Development of an Atmospheric Aerosol Model for Studies of Global Budgets and Effects of Airborne Particulate Material.* NCAR Cooperative Ph.D. Thesis No. 102, Georgia Institute of Technology, Atlanta, Ga., 226 pp.

Van Ypersele, J.-P., 1986: *A Numerical Study of the Response of the Southern Ocean and Its Sea Ice to a CO_2-Induced Atmospheric Warming.* NCAR Cooperative Ph.D. Thesis No. 99, Université Catholique de Louvain-la-Neuve, Belgium, 135 pp.

Meehl, G.A., 1987: *Interactions between the Asian Monsoons, the Tropical Pacific, and the Southern Hemisphere Mid-latitudes.* NCAR Cooperative Ph.D. Thesis, No. 106, University of Colorado, Boulder, Colo., 172 pp.

Tselioudis, G., 1987: *Research Using the CCM0B.* M.S. Thesis, University of Miami, Miami, Fla.

Cheng, X., 1988: *Equatorial Waves Simulated by the NCAR Community Climate Model.* M.S. Thesis, Iowa State University, Ames, Iowa.

Hess, P.G., 1988: *The Evolution and Variance of Nitrous Oxide in a Stratosphere General Circulation Model.* Ph.D. Thesis, University of Washington, Seattle, Wash.

Iredell, M., 1988: *The Effect of Orography on the Mean Flow of the Stratosphere.* Ph.D. Thesis, University of Washington, Seattle, Wash.

LaFontaine, V., 1988: *Analyses of CCM Results for Equatorial Lands, 18000 yr BP to Present, and Comparison with Geologic Data.* M.S. Thesis, University of Wisconsin, Madison, Wis.

Meyer, M., 1988: *Biomass Productivity Indices Based upon Control and Paleoclimate Simulations with the CCM.* M.S. Thesis, University of Wisconsin, Madison, Wis.

Shinn, R.A., 1988: *A Study of Climate Sensitivity to Ice-Age Continental Ice Sheets.* M.S. Thesis, University of Miami, Coral Gables, Fla.

Smith, L.D., 1988: *Satellite Versus GCM-Simulated Radiation Balance: Comparisons and Implications for Climate Modeling.* Ph.D. Thesis, Colorado State University, Ft. Collins, Colo.

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Theses in Progress:

Buechler, J.: *Sensitivity of Climate Simulations to the Parameterization of Cumulus Convection.* M.S. Thesis, Pennsylvania State University, University Park, Pa., submitted May 1988.

Ji, M.: *Three-Dimensional Modes and Scaling.* Ph.D. Thesis, University of Maryland, College Park, Md., expected December 1988.

Oglesby, R.J.: *Paleoclimatic Sensitivity Studies.* Ph.D. Thesis, Yale University, New Haven, Ct., expected May 1989.

Buja, L.E.: *The Midlatitude Response to Tropical Heating.* Ph.D. Thesis, University of Utah, Salt Lake City, Utah, expected June 1989.

Lai, S.-S.: *Development and Testing of a Limited-Area Model for Studying Midlatitude Dynamics.* M.S. Thesis (working title), University of California, Davis, Calif., expected June 1989.

Yih, A.-C.: *CCM Sensitivities to Asian Surface Boundary Conditions.* Ph.D. Thesis, University of Illinois, Urbana, Ill., expected late 1989.

Wang, C.-H.: *Topographic Effects on the Development and Life-cycles of Midlatitude Wave-cyclones.* Ph.D. Thesis, University of California, Davis, Calif., expected June 1990.

6. CUMULATIVE LIST OF CCM-RELATED PUBLICATIONS

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Aragão, J.O.R., 1986: *A General Circulation Model Investigation of the Atmospheric Response to El Niño.* NCAR Cooperative Ph.D. Thesis No. 100, University of Miami, Miami, Fla., 143 pp.

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