GEOPHYSICAL FLUID DYNAMICS LABORATORY

ACTIVITIES – FY82
PLANS – FY83

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Research Laboratories

Preface

This document is intended to serve as a summary of the work accomplished at the Geophysical Fluid Dynamics Laboratory (GFDL) and to present a glimpse of the near future direction of its research plans.

It has been prepared within GFDL and its distribution is primarily limited to GFDL members, to interested offices of the National Oceanic and Atmospheric Administration, and to other relevant government agencies and national organizations.

The organization of the document encompasses an overview, project activities and plans for the current and next fiscal years and appendices. The overview covers the five major research areas that correspond to NOAA's mission in oceanography and meteorology: Weather Service; Climate; Atmospheric Quality; Marine Quality; and Ocean Service. These are five of the NOAA categories (bins) for research activities. The body of the text describes goals, specific recent achievements and future plans for the following major research categories: Climate Dynamics; Middle Atmosphere Dynamics and Chemistry; Experimental Prediction; Oceanic Circulation; Planetary Circulations; Observational Studies; Hurricane Dynamics; Mesoscale Dynamics; Convection and Turbulence. These categories, which correspond to the internal organization of research groups are different from the the NOAA bins and are far from being mutually exclusive. Interaction occurs among the various groups and is strongly encouraged.

The appendices contain the following: a list of GFDL staff members and affiliates during Fiscal Year 1982; a bibliography of the most recent research papers published by staff members and affiliates during their tenure with GFDL (these are referred to in the main body according to the appropriate reference number or letter); a description of the Laboratory's computational support and its plans for FY83; a listing of seminars presented at GFDL during Fiscal Year 1982; a listing of seminars and talks presented during Fiscal Year 1982 by GFDL staff members and affiliates at other locations.

Although the specific names of individuals are not generally given in the overview, an entire listing of project participants can be found in Appendix A. Publishing staff personnel can normally be identified by consulting the cited Appendix B references.

The FY82 Annual Report was edited by George Philander and Michael Cox.

September 1982

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AN OVERVIEW

SCOPE OF THE LABORATORY'S WORK

The Geophysical Fluid Dynamics Laboratory is engaged in comprehensive long lead-time research fundamental to NOAA's mission.

The goal is to expand the scientific understanding of those physical processes which govern the behavior of the atmosphere and the oceans as complex fluid systems. These fluids can then be modeled mathematically and their phenomenology studied by computer simulation methods. In particular, research is conducted toward understanding:

- the predictability of weather, large and small scale;
- the particular nature of the Earth's atmospheric general circulation within the context of the family of planetary atmospheric types;
- the structure, variability, predictability, stability and sensitivity of climate, global and regional;
- the structure, variability and dynamics of the ocean over its many space-and-time scales;
- the interaction of the atmosphere and oceans with each other, and how they influence and are influenced by various trace constituents.

The scientific work of the Laboratory encompasses a variety of disciplines: meteorology, oceanography, hydrology, classical physics, fluid dynamics, chemistry, applied mathematics, high-speed digital computation, and experimental design and analysis. Research is facilitated by the Geophysical Fluid Dynamics Program which is conducted collaboratively with Princeton University. Under this program, regular Princeton faculty, visiting scientists, and graduate students participate in theoretical studies, both analytical and numerical, and in observational experiments, both in the laboratory and in the field. The program in part, is supported by NOAA funds. Visiting scientists to GFDL may also be involved through institutional or international agreements, or through temporary Civil Service appointments.

The following sections of the Annual Report describe the GFDL contribution to five major research areas that correspond to NOAA's mission in oceanography and meteorology.

HIGHLIGHTS OF FY82

and

IMMEDIATE OBJECTIVES

I. WEATHER SERVICE

GOALS

During the past two decades synoptic-scale weather forecasts have improved considerably because of the development of numerical models that include more of the physical processes of the atmosphere, that have high spatial resolution, and that parameterize turbulent processes accurately. Successful forecasts for periods up to a few days are now possible, and the limits of atmospheric predictability have been extended to several weeks but quantitative precipitation forecasts remain elusive. As regards phenomena with small spatial scales, there has been considerable progress in determining the mechanisms that generate severe storms, in explaining how mesoscale phenomena interact with the large-scale flow, and in simulating the genesis and growth of hurricanes.

This success in the extension of atmospheric predictability encourages us to pose more challenging questions. Can the weather be predicted on time-scales of months? Are mesoscale weather systems and regional scale precipitation patterns predictable and if so, is it dependent on the prediction of the ambient synoptic flow? Research to develop mathematical models for improved weather prediction will also contribute to the understanding of such fundamental meteorological phenomena as fronts, hurricanes, severe storms, and tropospheric blocking.

Recent results, and plans for the next year, are briefly summarized below. For details, the reader is referred to Part B, §3, 7, 8 and 9 of the Report.

ACCOMPLISHMENTS OVER THE PAST YEAR (FY82)

Accomplishments over the past year (FY82) include the following:

* A new method for generating cloud fields has been tested. In this procedure the observed short- and long-wave radiative fluxes are expressed as a function of layered cloud amounts. The distribution that minimizes the variance of the fluxes is the optimal solution. Monthly mean fields of low and high cloudiness calculated by using this method are consistent with satellite measurements.

* An economical "anomaly model" has been tested. The model calculates the long-term departures from climatological mean variables. By filtering the more transient waves, integrations with large time-steps are possible. Monthly anomaly predictions from time-dependent and stationary anomaly models (which use an existing spectral model as a control) are promising.

* Operational production of FGGE Level III-b data has been completed satisfactorily. The processing and analysis of this global data set, with a spectral GCM, includes nonlinear normal model initialization and four-dimensional data assimilation. Periodic controls on the results revealed a very restricted data rejection criterion. Relaxation of this criterion resulted in a satisfactory level of transient kinetic energy.

* Preliminary analysis of the prediction experiments performed for the period April 9-11, 1979 using a different (HIBU) meso-α (200 to 2000 km) model nested in a global spectral model indicates that precipitation forecasts over the U.S. are more accurate when the global model is initialized with the recently analyzed FGGE data rather than the NMC Level IIIa data.

* Complementary to the studies of predictability on meso-α scales, simulations of the severe storms which occurred on 10-11 April 1979 in Oklahoma and Texas are being carried out by means of a meso-β (200-20 km scales) model nested into the limited area covered by the meso-α model. The solutions indicate that higher resolution alone does not significantly alter the location of the convection as predicted by the meso-α host model. Sensitivity tests suggest that the observed horizontal structure, on meso-α and possibly meso-β scales, of moisture data in layers close to the ground are required to produce accurate prediction of the locations of convective activity on meso-β scales.

* It has been recognized that subgrid parameterizations used in GCM's are not necessarily appropriate for mesoscale, limited-area models. Two important developments in mesoscale modeling are the inclusion of orography in the MAC research model and the use of the quasi-hydrostatic approximation in the BES (meso-β) model. Previous schemes to test orography in finite difference models have drawbacks. A new approach in which a parameterized body force has the shape of the actual orography has been tested in the 3-D model with considerable success.

* The sensitivity of tropical storm genesis to the sea surface temperature was investigated with a channel-type eleven-level numerical model. An idealized easterly wave can develop into a tropical storm, under realistic environmental conditions, only when the sea surface temperature is higher than 26°C. This is in accord with observations.

* Analysis of a quasi-stationary compact hurricane eye in a quadruply-nested model indicates that its asymmetric features contribute to cooling and moisten the eye which otherwise tends to be warmed and dried by the mean motion.

* Calculations of deep moist convection over a four-hour period with a model that uses a tropical maritime sounding of temperature and water vapor show that the ratio of total rainfall reaching the ground, to the total water vapor condensed, is the same for two different profiles of the atmospheric convergence.

PLANS FOR FY83

Plans for the next year include the following:

One month forecasts, using a finite difference model, of six Januaries between 1972 and 1982, to evaluate the effect of sea surface temperature anomalies, and the effect of different initial conditions.

Forecasts of the sea surface temperature for the period 1976 to 1977, with both one and three-dimensional models, to evaluate the effects of mixed layer parameterization, initialization procedures and surface boundary conditions.

Tests of a new method for representing the effect of orography by means of body drag in a mesoscale model.

Tests of the quasi-hydrostatic approximation in a meso-β model to see whether it can represent convection and gravity waves.

Simulations of moist atmospheric convection with a model that uses a continental sounding of temperature and water vapor and that includes realistic vertical wind shear.

Studies of the decay mechanism of a hurricane after its landfall.

II. CLIMATE

GOALS

The purpose of climate related research at GFDL is twofold: to describe, explain and simulate climate variability on time-scales from seasons to millenia; and to evaluate the impact on climate, of human activities such as the release of CO_2 and other gases in the atmosphere. The phenomena that are studied include large-scale wave disturbances, with a period of a few weeks, and their role in the general circulation of the atmosphere; the seasonal cycle which must be known before departures from the seasonal cycle (interannual variability) can be appreciated; interannual variability associated with phenomena such as the Southern Oscillation/El Niño; very long-term variability which includes the ice-ages for example; and the meteorologies of various planets, the study of which enhances our perspective on terrestrial meteorology and climate. To achieve these goals both observational and theoretical studies are necessary: available observations are analyzed to determine the physical processes by which the circulations of the oceans and atmospheres are maintained; and mathematical models are constructed to study and simulate the ocean, the atmosphere, the coupled ocean, atmosphere and cryosphere system, and various planetary atmospheres.

Recent results, and plans for the next year, are briefly described below. For more details the reader is referred to Part B, §2, 4, 5 and 6 of the Report.

ACCOMPLISHMENTS OVER THE PAST YEAR

Accomplishments over the past year include the following:

* A detailed description of the climate in the atmosphere based on 15 years of global surface and upper air data has been completed. Included are global diagrams of the flow of mass, angular momentum and energy, and a 180-month time series of hemispheric and globally averaged climate parameters.

* A description of the 3-dimensional structure of temperature, salinity, oxygen and other derived parameters of climatic importance in the world ocean is in press. Global maps of geostrophic currents and of mixed layer depth are included.

* The nonlinear energy transfer of transient planetary waves in the middle-latitude troposphere has been explored by means of spectral analysis of results from a spectral GCM with a uniform surface.

* In a GCM with limited computational domain and idealized geography, removal of snow cover in the spring is found to increase the absorption of solar radiation by continental surfaces and to enhance evaporation so that the soil is dryer during the summer. The same model shows that an anomaly of soil moisture is less persistent in the tropics than in middle latitudes because of the influence of the earth's rotation in the atmospheric circulation.

* External Rossby waves are found to explain some of the low-frequency variability in a GCM with no topography and no land-sea contrast (so that the climate is zonally symmetric).

* The importance of the reflection of Rossby waves from tropical easterly winds for the structure of stationary eddies in the extra-tropical troposphere has been analyzed in idealized linear and nonlinear models. A GCM simulation is found to be deficient, as compared with observations, in poleward propagating Rossby waves, either because of the absence of reflection from tropical easterlies or because of insufficient thermal forcing of Rossby waves in low latitudes.

* New diagnostic analysis techniques have been developed to allow clearer interpretations of simulated atmospheric motions in the GFDL troposphere-stratosphere-mesosphere GCM (SKYHI). These diagnostics offer important new insights into the role of waves and disturbances ("eddies") in the zonal mean flow. The analysis shows that the net effect of the eddies is to <u>slow down</u> the midlatitude westerlies in the entire region from the middle troposphere to the mesopause. Traditional diagnostics suggest the opposite conclusion.

* A theory that explains the El Niño/Southern Oscillation phenomena as an instability of the seasonal cycle is being developed. A model of the eastern tropical Pacific Ocean, where El Niño events originate, successfully simulates seasonal sea surface temperature changes although currents are less intense than in reality.

* The study of CO_2-induced change of climate has been conducted by use of a global model of the atmosphere-mixed layer ocean system. It is found that the day to day variability of surface air temperature in middle latitudes reduces particularly during winter in response to an increase of CO_2-concentration in the atmosphere.

* The influence of oceanic heat transport on the magnitude of CO_2-induced change of climate has been investigated by comparing the sensitivities of the climates of two models with and without the effect

of ocean currents. It is found that the heat transport by ocean currents raises the surface air temperature in high latitudes, decreases the positive feedback effect of snow and sea ice, and reduces the sensitivity of climate.

* The response of the ocean to abrupt changes in the climate caused by factors such as an increase in atmospheric CO_2, has been studied with a detailed three-dimensional oceanic model coupled to a simplified energy balance model of the atmosphere. Oceanic convection at high latitudes is found to play the same key role in climate response as it does in the downward penetration of tracers.

* A high resolution spectral GCM has been used to evaluate the range of circulations exhibited by an Earthlike planet when external parameters are altered. Some of these circulations are analogous to those of Saturn, Jupiter, Venus and Mars.

PLANS FOR FY83

During 1983 the regional effects of the atmospheric branch of the hydrological and energy cycles on the salinity and temperature structure of the World Ocean are planned.

A simple two-dimensional (latitude-longitude) climate model in which deviations from zonal symmetry are predicted with an idealized planetary wave theory, will be constructed during the coming year.

A model to study the growth and decay of El Niño-Southern Oscillation phenomena will be developed.

Detailed studies of the interaction between upward propagating waves (from the troposphere) and the mean flow will be conducted.

An attempt will be made to determine the transient response of the atmospheric temperature to a future increase of the atmospheric CO_2. Various published scenarios of future CO_2-growth will be used for this purpose. In the first stage of this study, a coupled ocean-atmosphere model with limited computational domain and idealized geography will be used. A study with a coupled model with global domain with realistic geography will follow:

Extensive analysis will be made of the results from the recent experiments designed to evaluate the influence of continental ice sheets on the climate of the ice-ages.

The parameteric GCM studies of planetary atmospheres will concentrate next on the analysis of the dynamical structure of the various circulation forms. The dependence on internal parameters, and improved models for Jupiter and Saturn will be developed later.

III. ATMOSPHERIC QUALITY

GOALS

The main goal of Atmospheric Quality Research at GFDL is to understand the formation, transport, and chemistry of atmospheric trace constituents. Such understanding requires judicious combinations of theoretical models and specialized observations. The understanding gained will be applied toward evaluating the sensitivity of the atmospheric chemical system to human activities.

Ongoing work that will be completed within the next 5 years includes analyses of atmospheric nitrous oxide, reactive nitrogen (natural plus anthropogenic), and tropospheric ozone (see 2.1). Capability will be developed to solve for a number of trace constituents simultaneously. Using this capability, interdependent experiments will be run involving ozone and its precursors, partitioned components of total reactive nitrogen, carbon monoxide, etc. Also, development of a dynamically active ozone photochemistry will be completed for inclusion into the GFDL troposphere-stratosphere-mesosphere GCM (see 2.2).

ACCOMPLISHMENTS

Accomplishments over the past year are described below. The reader is referred to Part B, §2 of the Report for more details.

* A series of 3-D model experiments exploring the tropospheric behavior of N_2O has now been completed. The results include new experimentally verifiable predictions on the expected distribution and variability of N_2O in and away from the boundary layer. Experiments on the stratospheric structure of N_2O have led to an identification of a required additional destruction beyond that provided by current theory. Also, these experiments have led to discovery of a "universal" predictable structure for all sufficiently long lived trace constituents with removal in the stratosphere.

* Model experiments evaluating the classical "no chemistry" hypothesis on tropospheric ozone behavior have yielded provocative new results. These experiments reveal that the classical hypothesis produces remarkable agreement with observed ozone behavior. From these results it would appear that the "photochemical hypothesis" can only <u>modify</u> the transport dominated classical picture. An important exception appears to be in relatively polluted boundary layers.

PLANS FOR FY83

Plans for the next year include:

Development of capability to solve for a number of trace constituent simultaneously.

Completion of studies of "classical ozone" and anthropogenic reactive nitrogen.

IV. MARINE QUALITY

GOALS

Research at GFDL related to the quality of the marine environment has as its objective the simulation of oceanic conditions in coastal zones and in estuaries, and the modeling of the dispersion of geochemical tracers (tritium, radon...) in the world oceans. Over the next few years two and three-dimensional models of estuaries such as the Hudson-Raritan and Delaware Estuaries will be developed. The response of coastal zones to transient atmospheric storms, and the nature of upwelling processes which are of great importance to fisheries, are being studied by means of a variety of models.

ACCOMPLISHMENTS

Results obtained over the past year include the following. (For more details the reader is referred to Part B, §4 and 9 of this Report.)

* A two-dimensional numerical model of the Hudson-Raritan Estuary in which rivers are included as one-dimensional channels with variable width and depth, produces currents and tidal elevations that compare well with measurements. The barotropic tidal residual current, which is induced mainly by the coastal geometry through the nonlinear inertial effects and by the bottom topography, contributes significantly to the steady circulation in the estuary.

* The dispersion of tritium, produced by nuclear bomb testing in the 1950's, has successfully been simulated with a numerical model of the North Atlantic. A simple isopycnal model was used to determine the time-scale of ventilation of the main thermocline.

PLANS FOR FY83

Plans for the coming year include:

Development of a three-dimensional model of estuaries and application of the model to the Deleware Estuary.

A study of the factors that determine large-scale meridional overturning in the oceans.

Development of a model of nutrient geochemistry in the oceans.

V. OCEAN SERVICE

GOALS

A variety of models that can be used for the prediction of oceanic conditions are being developed at GFDL. The simpler models are capable of predicting relatively few parameters. For example, one-dimensional models of the turbulent surface layer of the ocean predict the sea surface temperature and heat content of the upper ocean. More complex three-dimensional models are being developed to study phenomena such as the time-dependent development of Gulf Stream meanders and rings, the generation of the Somali Current after the onset of the southwest monsoons, the response of coastal zones to atmospheric storms, and the development of sea surface temperature anomalies such as those observed in the tropical Pacific Ocean during El Niño/Southern Oscillation phenomena.

ACCOMPLISHMENTS

Results obtained over the past year include the following. (For further details the reader is referred to Part B, §4 of this Report.)

* A high resolution model of the North Atlantic Ocean, which nonetheless uses a modest amount of computer time, has been developed and is being used to study the formation of water masses, the transport of heat, and the sensitivity of the results to model parameters.

* The great ice shelves of Antarctica, and the pack ice in both the Arctic and Southern Oceans are poorly understood, but are generally considered to be important in the Earth's climate. A growing body of data obtained from satellites, and field experiments provide a basis for improving the treatment of ice in climate models. In one study carried out at GFDL a detailed mixed layer and sea ice model has been calibrated with measurements of the seasonal cycle in the upper ocean made in the AIDJEX program in the Beaufort Sea. This local model will be used to improve more general three-dimensional models, such as the coupled ocean and ice pack model being developed by the U.S. Army Cold Regions Research Laboratory and GFDL. This model is the first to include ice and ocean dynamics with a realistic rheology of the pack ice. Preliminary tests demonstrate the importance of the heat transport by ocean currents in determining the position of the ice edge in the Norwegian and Greenland Sea area.

* The intrinsic time-scales of the response of a coastal zone to variable winds was determined by studying the manner in which a coastal zone comes into equilibrium after the sudden onset of winds parallel to the shore. These results were used to calculate the effect of a transient storm on the coastal zone of the ocean. In a study underway, realistic winds for a four year period are used to force a model that will permit a description of coastal upwelling as a stochastic process.

PLANS FOR FY83

An eddy resolving model of the Atlantic Ocean will be used to test the experimental design of the NOAA program STACS (Subtropical Atlantic Circulation Studies).

Models to simulate the seasonal cycle, and interannual variability in the tropical Atlantic and Pacific Ocean will be developed with particular attention being paid to the sea surface temperature variations that are important in El Niño phenomena for example.

The effect of a realistic continental shelf on the response of coastal zones to atmospheric storms will be determined.

The parameterization of the turbulent mixing of heat and momentum in three-dimensional models of the ocean will be improved.

PROJECT ACTIVITIES FY82

PROJECT PLANS FY83

1. CLIMATE DYNAMICS

Goals

* To construct mathematical models of the atmosphere and of the joint ocean-atmosphere system which simulate the global large-scale features of climate.

* To study the dynamical interaction between large-scale wave disturbances and the general circulation of the atmosphere.

* To identify and elucidate the physical and dynamical mechanisms which maintain climate and cause its variation.

* To evaluate the impact of human activities on climate.

1.1 CO_2-CLIMATE SENSITIVITY STUDY

S. Manabe R. Stouffer
M. Spelman R. Wetherald

ACTIVITIES FY82

The climate dynamics project has continued to place a strong emphasis on the evaluation of climate change resulting from the future increase of CO_2-concentration in the atmosphere. Various climate models, which have been developed by the project, are used for this purpose.

The study of the equilibrium-response of climate to an increase of the CO_2-concentration in the atmosphere has been continued by use of an atmosphere-mixed layer ocean model developed earlier (393). In the FY82-report, it was noted that an increase in atmospheric CO_2 causes the reduction of soil moisture in high and middle latitudes in summer (430). During this fiscal year the signal-to-noise ratio analysis of the summer dryness has been carried out by computing the ratio of the CO_2-induced change of soil moisture to the standard deviation of the natural variability of soil moisture in the model. This result suggests that the detection of the CO_2-induced summer dryness is more difficult than the detection of CO_2-induced warming of surface air temperature.

The influence of the CO_2 upon the daily variability of atmospheric temperature is investigated based upon the comparison between the results from the two versions of an atmosphere-mixed layer ocean model with the normal and above normal concentration of CO_2. Fig. 1 compares the seasonal and latitudinal distributions of the zonal mean standard deviation of the daily surface air temperature variation from the two versions of the model identified above. (Here, a standard deviation of surface air temperature is computed at each grid point and is averaged zonally.) According to this comparison, the daily variability of surface air temperature in high latitudes decreases particularly in response to an increase of the CO_2-concentration of the atmosphere. This decrease results mainly from the CO_2-induced reduction of meridional temperature gradient in the lower model troposphere.

The influence of oceanic heat transport upon the sensitivity of climate to an increase in atmospheric CO_2-concentration is investigated. For this purpose, the CO_2-induced climate changes of two mathematical models with and without the effect of ocean currents are compared with each other. The first model is a coupled ocean-atmosphere model in which the general circulation model of the atmosphere is coupled with that of ocean. In the second model, the oceanic component of the first model is replaced by a static mixed layer ocean.

It is found that the heat transport by ocean currents raises the surface air temperature in high latitudes, shifts poleward the margins

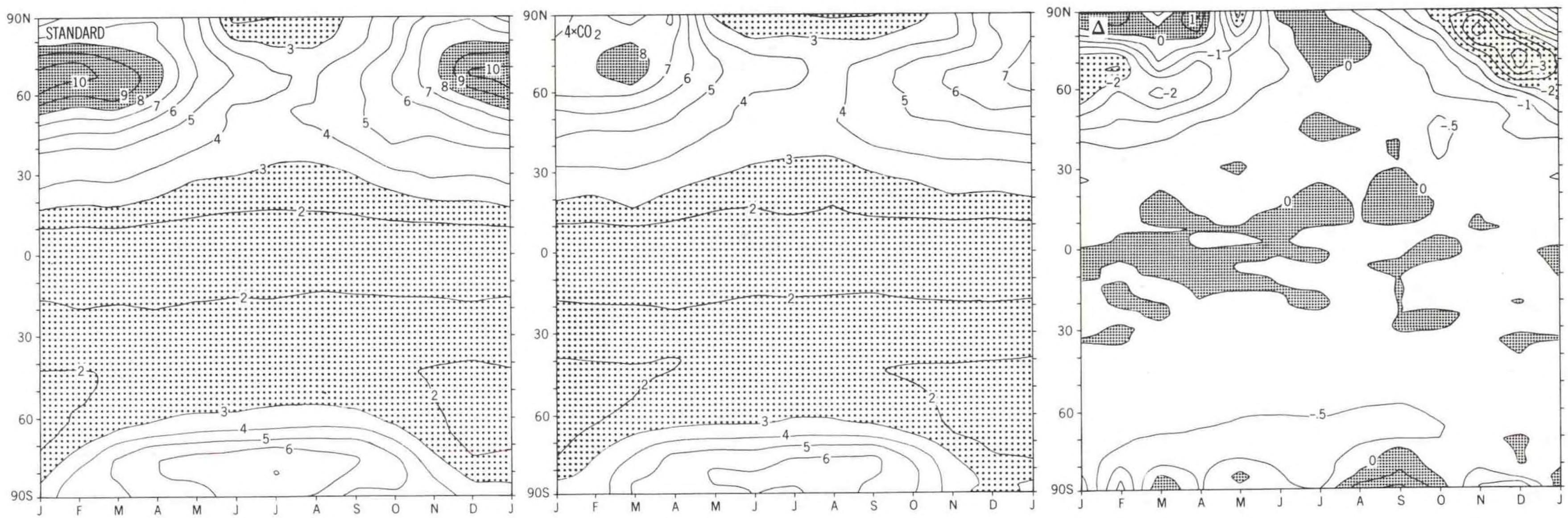

Fig. 1. The latitude-time distribution of zonal mean standard deviation of surface air temperature from (a) the experiment with normal CO_2-concentration and (b) another experiment with four times the normal CO_2-concentration. (c) The difference between the two results. Units are in °C.

of snow and sea ice, decreases the contribution of the albedo feedback effect and reduces the sensitivity of climate. The results from this study are described in paper (yy).

PLANS FY83

An attempt will be made to determine the transient response of atmospheric temperature to a future increase of atmospheric CO_2-concentration by use of a coupled ocean-atmosphere model with a limited computational domain of idealized geography. Various hypothetical profiles of future CO_2-growth, which have been published, will be used for this purpose. This study is the outgrowth of earlier research (437) in which the response of a coupled model to an abrupt CO_2-increase was investigated. It is planned to write a manuscript which describes the influence of a CO_2-increase upon the daily variability of the atmospheric temperature.

1.2 ICE AGES

A. Broccoli	I. Held
K. Bowman	S. Manabe
D. Hahn	C. Staver

ACTIVITIES FY82

The FY81 report describes the preliminary results from a series of numerical experiments which evaluates the influences of continental ice sheets on the climate of an ice age. During this fiscal year the periods of numerical time integrations in these experiments were extended further in order to insure that an equilibrium climate is reached toward the end of each time integration.

A review of problems associated with the Milankovitch theory of the ice ages was completed (w). Study of the response of simple climate models to changes in orbital parameters continued, with emphasis on the sentitivity of the results to the meridional structure of the eddy heat and moisture fluxes. The importance of the meridional structure of the heat flux found in annual mean models (426) has been reconfirmed in seasonally varying energy balance models.

PLANS FY83

Extensive analysis of the results from the general circulation experiments is in progress. A paper will be written on this study.

The construction of a two-dimensional (latitude-longitude) simple climate model is planned, in which deviations from zonal symmetry are predicted with an idealized planetary wave theory. The strengths and deficiencies of several alternative versions of such a model will be examined, the goal being to avoid some of the serious deficiencies in the one-dimensional climate models in which all variables are functions of latitude only.

1.3 CLIMATE VARIABILITY

D. Daniel	S. Manabe
D. Hahn	C. Staver
I. Held	R. Wetherald
N. Lau	D. Yeh

ACTIVITIES FY82

1.3.1 Land Surface-Anomaly

By use of a simple general circulation model of the atmosphere-mixed layer ocean system which has a limited computational domain and an idealized geography, a series of numerical experiments have been carried out in order to assess how a large scale (10° latitude x 60° longitude) irrigation of soil alters the temporal variation of the conditions of the earth's surface and the atmosphere during the period following the irrigation. It is found that the anomaly of soil moisture persists during several months after the time of irrigation and exerts a significant influence upon the thermal and dynamical structure of the atmosphere. The anomaly in the tropics is less persistent than the similar anomaly in middle latitudes mainly due to the latitudinal variation in the influence of the earth rotation upon the atmospheric circulation.

Through the use of a similar model, an attempt is made to evaluate how the complete removal of snow in spring affects the dryness of soil during the following season. It is found that the removal of snow cover reduces the water available for soil through snowmelt and decreases the soil moisture in the following seasons. Furthermore, it also reduces the surface albedo and increases the absorption of solar radiation by the continental surface. This, in turn, enhances the surface evaporation resulting in a dryer soil condition during the following summer season.

Although these numerical experiments evaluate the consequences of a drastic alteration of the surface conditions over a very extended area, they, nevertheless, yield some insight into the relationship between the surface anomaly and the climate variation.

1.3.2 Thermal Forcing and Sea Surface Temperature Anomaly

The influence of the thermal forcing of the atmosphere upon the variation of sea surface temperature is investigated based upon the results from the long term (20 year) integration of the global model of the atmosphere-mixed layer ocean system. It is found that the model reproduces some of the characteristics in the geographical distribution of the standard deviation of sea surface temperature anomaly in middle and high latitudes.

1.3.3 Frequency Variability in Atmospheric General Circulation Models

The spatial and temporal characteristics of meteorological anomalies appearing in a 15-year integration of a general circulation model of the atmosphere have been investigated. Despite the absence of any nonseasonal perturbation in the boundary forcing (such as sea surface temperature), it was demonstrated (432) that persistent and large-scale anomalies exist in the model atmosphere. The most dominant anomaly pattern of the geopotential height field at 500 mb (Fig. 2) bears a distinct resemblance to the well-known "Pacific-North American pattern," which has been documented in many observational studies. It was further shown (hh) that the simulated synoptic behavior in the most outstanding anomalous episode is dominated by the occurrence of blocking ridges over western North America and western Europe.

Analysis is continuing of the low frequency ($\gtrsim$1 month period) variation in a general circulation model with no seasonal variation and a flat, water-saturated all-land surface. The model produces an atmospheric circulation that is statistically homogeneous in time as well as in longitude. The aim is to compare the low frequency variability in this model with the variability in other models in which there are stationary waves forced by mountains and land-sea contrast, in order to critically assess the contention that low-frequency variability in the atmosphere is closely related to these forced zonal asymmetries. The model's extra-tropical low-frequency variability is dominated by quasi-stationary external Rossby wave packets. In contrast, the model's low-frequency variability in the tropics is nearly zonally symmetric. Some preliminary results have been described in a review article on stationary and quasi-stationary Rossby waves (mm).

PLANS FY83

The spectral properties of sea surface temperature simulation by the atmosphere-mixed layer ocean model will be investigated. In addition, the influence of the sea surface temperature fluctuation upon the temporal variation of the model climate will be explored. For this purpose, the temporal variability of surface air temperature of the model will be compared with the corresponding variability of an atmospheric model in which sea surface temperature is prescribed.

In collaboration with the Observational Studies Group, further diagnosis will be performed on two 15-year integrations of a general circulation model, one with and one without orography. The behavior of stationary and transient waves, as well as the temporal and spatial characteristics of recurrent circulation anomalies, appearing in the two different model atmospheres will be compared. The outstanding anomalous episodes in both integrations will also be examined in greater detail so as to identify the dominant physical and dynamical processes operating in various phases of such events.

The annual cycle in the climatology of long-term integrations of a general circulation model will be documented and compared with observations. The capability of the model to simulate the seasonal dependence of various circulation features (e.g., structure of stationary waves, heat and momentum transports by the time-mean and transient motions, hydrological processes, etc) will be evaluated.

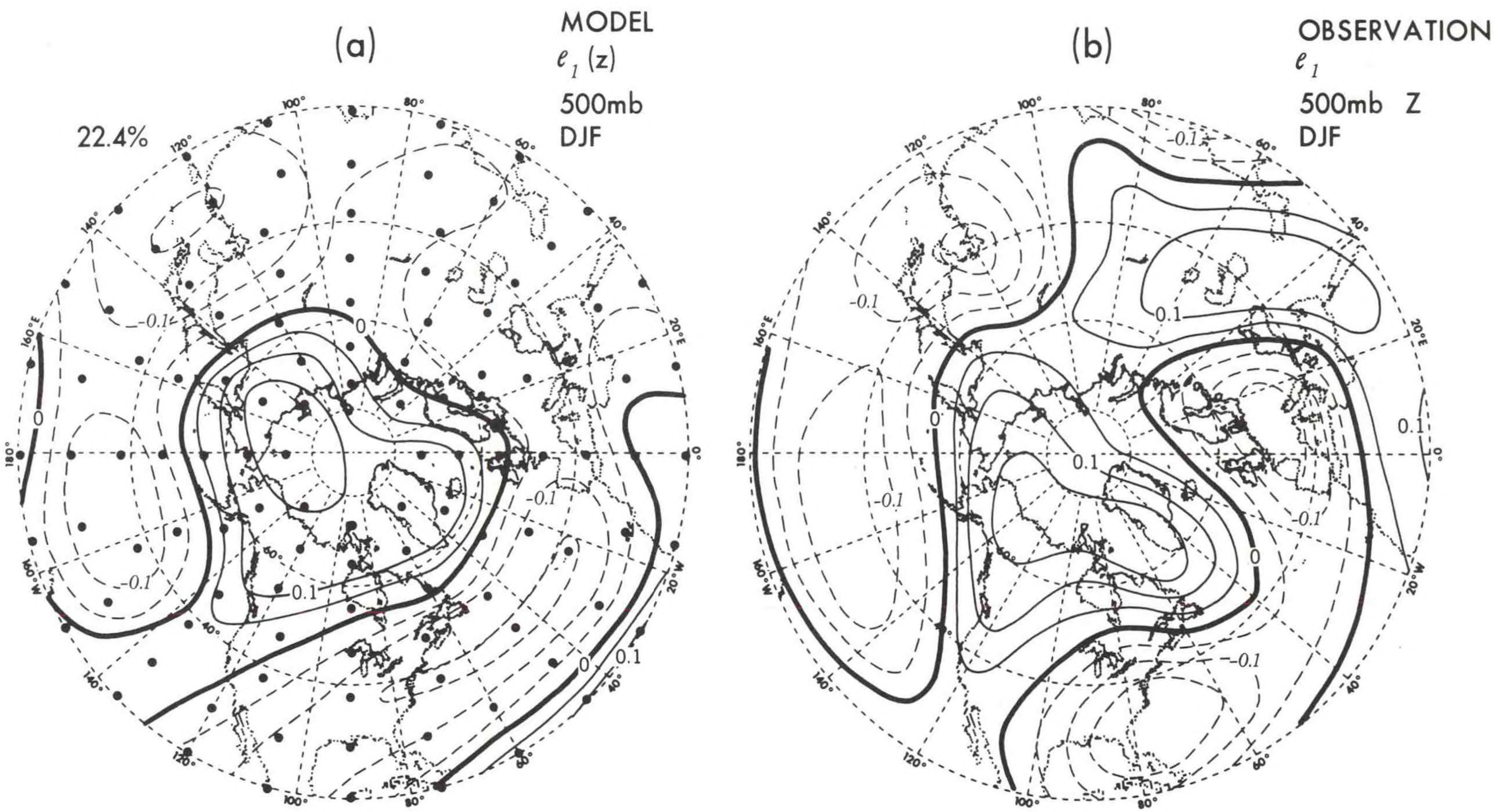

Fig. 2. Distributions of the first empirical orthogonal functions of normalized monthly mean 500 mb height field for winter, for (a) model and (b) observations.

Model experiments aimed at elucidating the role of perturbed boundary conditions in atmospheric variability will be initiated. Particular emphasis will be placed on investigating the remote response of the model atmosphere to observed tropical sea surface temperature anomalies under various environmental conditions.

Work on the theoretical interpretation of the patterns of low-frequency variability found in the model with a uniform lower boundary and no seasonal variation will continue.

Two papers will be written on the results from the numerical experiments of large scale irrigation and snow cover removal.

1.4 DYNAMICS OF LARGE-SCALE ATMOSPHERIC WAVES

D. Golder	N. Lau
Y. Hayashi	N. Sardeshmuk
I. Held	Q. Zeng

ACTIVITIES FY82

1.4.1 Transient Planetary Waves

In order to study how transient planetary waves in the middle-latitude troposphere are maintained in the absence of stationary waves, a space-time spectral analysis has been made of a 9-level, 15-wavenumber spectral general circulation model with a uniform surface (pp). It is found that the kinetic energy of both eastward and westward moving ultralong waves with periods less than 20 days is maintained primarily through conversion from eddy available potential energy. In particular, the available potential energy of eastward (westward) moving ultralong waves is maintained primarily through the zonal-wave (wave-wave) transfer of available potential energy. It is confirmed that these conclusions hold also for a model which has realistic topography and stationary-transient wave interactions.

In order to examine the effects of wave-wave interactions on the growth and energetics of transient planetary waves, controlled experiments are being performed by truncating zonal wavenumber components from a spectral general circulation model.

Work has begun on a study of the decay of eddies embedded in barotropically stable flows on a sphere. The hope is that this work will lead to a better understanding of the horizontal momentum fluxes that are intimately related to the barotropic decay of midlatitude disturbances. Attention has been focussed to date on linearized problems. In particular, an interpretation of the efficiency of the barotropic decay based on a decomposition of the eddy into parts belonging to "discrete" and "continuous" spectra is being investigated.

1.4.2 Extratropical Stationary Planetary Waves

A detailed review of the theory of stationary planetary waves in the extratropical troposphere has been prepared for publication (mm). New results included as part of this review are:

(i) a comparison of topographically-forced stationary eddies in a general circulation model with the prediction of a linearized barotropic model on a sphere;

(ii) estimates of the importance of reflection of Rossby waves from tropical easterlies for the climatological stationary wave pattern; and

(iii) an analysis of the effects of vertical wind shear and the tropopause on the structure of Rossby lee waves in the troposphere.

Figure 3 illustrates some of the results of (i). The estimated 200 mb geopotential of the topographically forced eddies in the general circulation model are displayed on the right half of the figure. This estimate is obtained by computing the difference between the stationary eddies generated by models with and without surface topography. The linear waves forced by topographic vortex stretching in a barotropic model linearized about the GCM's zonally averaged upper tropospheric winds are displayed on the left half of the figure. Although it fails to explain the magnitude of the response, the linear model does yield an interesting first approximation to its structure. The linear model then allows one to decompose this field into parts forced by different topographic features.

1.4.3 Stationary Eddies in the Tropics

The vorticity budget of the tropical upper troposphere simulated by a high resolution spectral general circulation model has been examined in detail. It was found that both large-scale transients and sub-grid scale mixing play only minor roles in this budget. The balance is essentially nonlinear and nearly inviscid, in contrast to the assumption commonly made in the literature that very strong damping of vorticity by small scales is needed to model the monsoonal and Walker circulations. The quality of the model's simulation gives one some confidence that its vorticity balance may be similar to that of the atmosphere.

PLANS FY83

The numerical experiments of wave-wave interactions described above will be completed. Space-time spectral analysis will be made of the nonlinear energy transfer of stationary and transient planetary waves in the middle latitude and tropics simulated by general circulation models with and without topography. A preliminary analysis will be made of mesospheric transient planetary waves simulated by a high resolution general circulation model developed by the Middle Atmosphere Dynamics and Chemistry Group.

Work will continue on the decay of barotropic eddies, with attention turning to a comparison of the decay in linear and non-linear models.

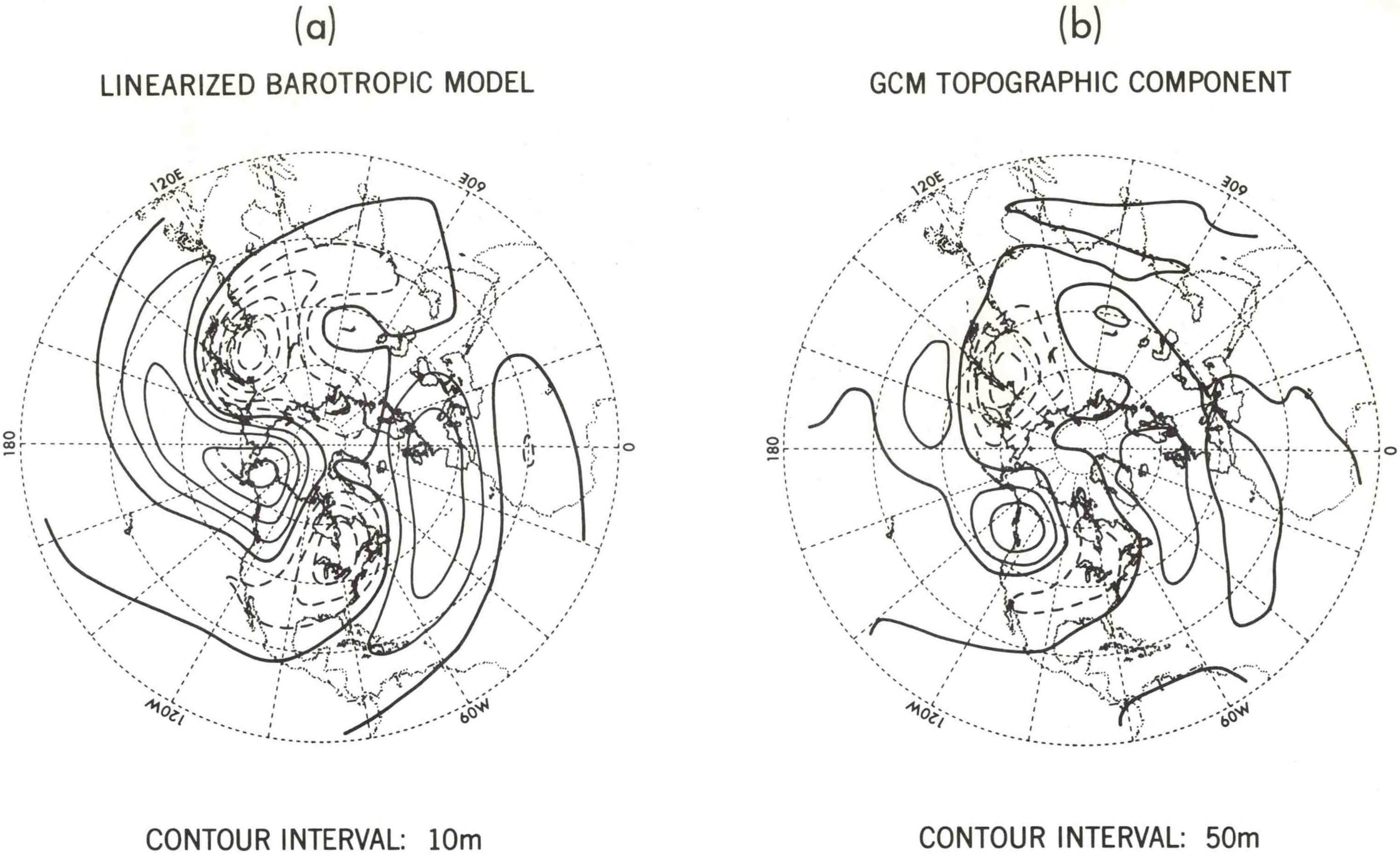

Fig. 3. The response of the geopotential height field to a realistic distribution of surface topography in (a) a linear, barotropic model and (b) a GCM. The GCM response is determined by subtracting the time-mean field in a calculation with topography from the same field produced by a model with a flat surface. Note the smaller contour interval in (a).

Investigation of theories for planetary-scale stationary waves in the troposphere will continue. The construction of linear baroclinic models on a sphere, begun in the previous fiscal year, will be resumed on the CYBER 205. These models will be used to dissect the response to zonally asymmetric diabatic heating, as well as the response to topography in the general circulation models.

A paper will be prepared for publication describing the study of the model's vorticity budget in the tropical upper troposphere and its implications for theories of planetary-scale tropical circulations.

1.5 MODEL DEVELOPMENT

D. Daniel S. Manabe
L. Holloway

ACTIVITIES FY82

The performance of a general circulation model of the atmosphere with an improved formulation of the planetary boundary layer has been evaluated. It was found that the model underestimated the upward penetration of diurnal temperature fluctuation in the atmosphere.

PLANS FY82

Special effort will be made to identify the basic cause for the unrealistic behavior of the model as described above.

It is planned to incorporate a cloud prediction scheme into the model and evaluate the performance of the model in simulating the observed distribution of cloud cover in the atmosphere.

1.6 RADIATIVE AND DYNAMICAL PROCESSES IN THE VENUSIAN STRATOSPHERE

D. Crisp S. Fels

ACTIVITIES FY82

The Pioneer Venus mission has provided a wealth of new data on the state of the Venusian stratosphere - its composition, thermal structure and radiative properties. These observations have revealed several dramatic and unexpected features. Among these are the existence of a reversed meridional temperature gradient between 65 and 90 km, and an extremely sharp inversion in the vertical temperature structure at high latitudes. Both of these have been the object of theoretical studies in the past year.

A detailed model of short and long wave radiation has been constructed. Account is taken of scattering and absorption by cloud particles, and absorption by gaseous constituents. Whenever possible, the model has used as input either *in situ* observations (cloud composition and structure, short wave radiative flux, IR flux at the top of the atmosphere), or terrestrial observations (spherical albedo vs. wave length). Preliminary versions have been used to derive radiative-convective equilibrium profiles of the globally averaged stratospheric temperature, and as a function of latitude.

The latitudinal profiles suggest that it is difficult to produce the reversed meridional temperature gradient without invoking dynamical mechanisms. The most promising purely radiative explanation requires the removal of cloud particles between 50 and 65 km in high latitudes, resulting in the heating of the thin solar haze by upwelling IR.

Two other results are noteworthy. 1) The radiative heating rates show a sharp peak at 65 km due to the strong absorption of solar radiation there. This structure should be an efficient exciter of thermal tides (see below). 2) Strong radiative cooling from the top of a cloud layer yields a sharp inversion in high latitudes, as observed.

The lack of a compelling radiative explanation for the reversed gradient has lead to investigation of possible dynamical mechanisms. These have been suggested by analogous reversals in the terrestrial atmosphere, which are believed to depend on the existence of axisymmetric forcing in the $\overline{U}$ equation. A zonal cyclostrophic model has therefore been constructed and used to examine the effects of momentum sources on the Venusian circulation and thermal structure. Since interest centered on the dynamics of the stratosphere, the "four day wind" was introduced by use of an appropriate forcing below 60 km. Realistic values of solar heating and radiative damping rates were used in the stratosphere.

Results from separate 1-D tidal calculations completed in earlier years showed that a thin heating source of the sort now thought to exist should give rise to strong retrograde forcing of $\overline{U}$ between 70 and 90 km in low latitudes. This momentum source has been inserted into the zonally symmetric model.

As expected, there results a region of weakened zonal winds between 70 and 85 km. This wind field is in balance with a temperature structure which is warmer at the poles than at the equator. The thermal gradients found are in qualitative agreement with observations, and are maintained against radiative processes by a strong meridional circulation with rising motion at the equator.

PLANS FY83

The results of the radiative model will be used to calculate tidal forcing in several simplified 1-D models. An attempt will be made to compare results with observations, and to develop new analytical methods for treating tides in the presence of strong vertical shear. Work with the axisymmetric model will continue using better solar heating and forcing functions.

2. MIDDLE ATMOSPHERE DYNAMICS AND CHEMISTRY

Goals

* To understand the interactive three-dimensional radiative chemical-dynamical structure of the middle atmosphere (10-100 km), and how it influences and is influenced by the regions above and below.

* To understand the dispersion and chemistry of atmospheric trace gases.

* To evaluate the sensitivity of the atmospheric system to human activities.

2.1 ATMOSPHERIC TRACER STUDIES

H. Levy II W. Moxim
J. Mahlman C. Narvaez

ACTIVITIES FY82

2.1.1 Atmospheric N_2O Tracer Experiments

Work has now been completed on the series of experiments exploring the impact of various surface sources on the structure and variability of N_2O. In addition to the previously reported results from these experiments, the final published paper (452) contains a number of predictions about the real behavior of N_2O which await observational testing. These include: a significant (~1%) excess of N_2O in the Southern Hemisphere middle troposphere; magnitudes of spatial and temporal variability of N_2O in and away from the boundary layer; and conditions under which the empirical Junge rule should be inapplicable.

Analysis has been completed on the series of experiments designed to test the sensitivity of stratospheric N_2O to various photodestruction hypotheses. This model strongly suggests that more destruction is required than allowable through use of current N_2O absorption data. An especially useful result from these experiments is that properly calculated global 1-D eddy diffusion coefficients are applicable to a wide range of long-lived trace gases. In addition, this work showed a species independent "universal" meridional slope of zonal mean mixing ratio isolines. These two results combine to provide a wide ranging skill for predicting structure of any given long-lived trace constituent.

2.1.2 Reactive Nitrogen in the Troposphere

A set of preliminary experiments which examines the global impact of the U. S. combustion source on the tropospheric nitrogen budget has been completed. In all experiments the combustion nitrogen is assumed to be immediately converted to HNO_3 which is rapidly removed by both surface contact and rain. This assumption of instantaneous conversion to HNO_3 should produce a lower-limit estimate of the impact of combustion nitrogen on the global distribution.

An analysis of the series of two month integrations run in FY82 shows that even very rapid rainout (a global lifetime of ~2 days in the lower troposphere) was not sufficient to produce an HNO_3 profile in the upper troposphere that was similar to H_2O, another highly soluble trace gas. An additional mechanism, the selective filtering of water soluble trace gases in rising air, was added, and it, together with rainout removal produced a more appropriate HNO_3 profile.

The experiment which included filtering of rising air, as well as wet and dry removal, has been integrated from January through August. There is no significant transport into the Southern Hemisphere and stratospheric injection dominates down to 500 mb almost everywhere. However, there is significant transport of U.S. HNO_3 to Canada and Latin America and episodic events carry it over the North Atlantic to Europe up to the Arctic, and out over the eastern equatorial Pacific.

Extratropical cyclones are the major mechanism for lifting combustion HNO_3 up out of the boundary layer where long range transport by the middle and upper tropospheric flow fields can take over.

It was also found that the effective source is significantly less than the emission rate for a substance such as HNO_3 which is easily removed by surface destruction. The strength of the effective source depends on both the emission height and the boundary layer meteorology.

2.1.3 Examination of the Classical Theory for Ozone

Two numerical experiments examining the classical theory for tropospheric ozone have been completed.

Outside of the continental boundary layer, the results of the calculations using upper- and lower-limit surface removal rates bracket the observed data. The model's interhemispheric and meridional gradients agree well with observations, except for the northern high latitudes where the model shows a much stronger gradient than is suggested by the few observations available. The altitude dependence of variability agrees well with an analysis of Australian data and, with the exception of the northern mid-latitudes, the seasonal structure of the model time series shows excellent agreement with observations. The secondary summer maximum exhibited by the continental midlatitude observations is not present in the model data.

In general, if the boundary layer is excluded, the climatology of tropospheric ozone appears to be controlled by meteorology. The summer maximum observed at northern midlatitude stations, may be the result of photochemistry, though a meteorological explanation may also exist.

The results are much less certain in the boundary layer (B.L.), particularly over land. It would appear that there is too much of a land-sea contrast in the model ozone values though the relevant observations are very limited at best. Over land it would appear that the model results in the B.L. show too steep a gradient, too high a variability, and no summer maximum. While these deficiencies may be the result of excluding photochemistry, they may also be due to too strong mixing in the bottom layer of the model, too weak mixing in the B.L. as a whole, and no seasonal structure in the model deposition velocity. A number of parameter studies and measurements are needed to determine the correct explanation.

2.1.4 Tropospheric Photochemistry

A boundary layer photochemical model (O-D) has been developed to study the purely chemical behavior of tropospheric ozone. While the strength of the photochemical response increases with increasing atmospheric NO_x, the steady state level of ozone is bounded and actually starts to decrease for NO_x<10 ppb. At low levels of NO_x, ozone photochemistry has a limited impact on tropospheric ozone, though it may provide an ozone sink in the maritime B.L. At the high levels of NO_x

found in the continental B.L., particularly the polluted B. L., ozone will increase relative to the transport-controlled background value and might also develop a second maximum in the summer.

2.1.5 "Maximum Insight" Tracer Experiments

Analysis has continued on the two tracer experiments designed to allow an increased mechanistic understanding of tracer transport and dispersion. Isentropic analysis of the experimental results has illustrated how a phenomenon which might be termed "breaking" of cyclone-scale and planetary waves is probably the dominant mechanism leading to dispersion and, ultimately, diffusion of conservative tracers.

2.1.6 Stratospheric Aircraft Pollution Experiment

Most of the analysis has now been completed from the experiment attempting to simulate the dispersion of effluents from an idealized fleet of supersonic aircraft. Although there is no verifying data, this experiment displays some important predictions and insights. For example, the model predicts significant equatorward and upward transport away from the midlatitude source region. This is in marked contrast to some simplified theoretical assertions. The analysis also shows the very strong role of an internal source in "breaking" non-transport constraints and in exciting large mixing ratio variability just beyond the boundaries of the source region.

PLANS FY83

Efforts will continue on the tropospheric "combustion nitrogen" and "maximum insight" experimental series. The final wrapups of the classical tropospheric ozone experiments and the stratospheric aircraft pollution experiment should be completed. Development of a working multiple trace constituent capability on the CYBER 205 should be completed. Once this is accomplished, a series of important multiple tracer experiments will be started.

2.2 MODELS OF THE TROPOSPHERE-STRATOSPHERE-MESOSPHERE

S. Fels — J. Mahlman
C. Hsu — L. Umscheid

ACTIVITIES FY82

2.2.1 Model Improvements

During FY82, a number of smaller improvements have been added to the 40-level troposphere-stratosphere-mesosphere GCM (designated as SKYHI). Several versions of the code have been consolidated into a very flexible "master" model for ready application on the CYBER 205. Examples of improvements added include: a correction for Voigt line shape effects for ozone infra red cooling rates; updated coefficients for the model's radiative-photochemical damping parameterization; inclusion of a "well measured" solar constant of 1370 watts m^{-2}; and a fully vectorized negative mixing ratio correction scheme.

2.2.2 "Low Diffusion" Medium Resolution (N18) Experiment

The new GCM analysis techniques previously reported have been employed in the analysis of the "Low Diffusion" N18 SKYHI experiment which used annual mean insolation. This analysis approach uses standard and "transformed Eulerian" zonal mean momentum budgets to determine the effects of waves on zonal mean flows. In the "transformed Eulerian" method the traditional "eddy" term is replaced by the "Eliassen-Palm flux divergence" (EPFD), while the path of wave propagation is closely approximated by the Eliassen-Palm flux vector.

The analysis results show that the effect of wave disturbances is to decelerate the westerlies due to negative values of EPFD over virtually all the midlatitude stratosphere and mesosphere. The effect is particularly large in the upper mesosphere where the wave induced zonal flow decelerations are large enough to "close off" the polar night jet at about 65 km. Another dramatic result of this analysis is the effect of disturbances on the midlatitude tropospheric westerlies. Here the results indicate a reduction of the mean tropospheric westerly wind shear by about 2 m $sec^{-1}km^{-1}$/day.

The above analysis technique also indicates positive values of EPFD at heights of about 28 and 60 km over the equator associated with local westerly wind maxima. A separate analysis has shown that the required momentum deposition at 28 km is accomplished by "traditional" equatorial Kelvin waves. On the other hand, at 60 km the momentum source is an "ultra fast" Kelvin wave with phase speed about 120 m sec^{-1}. Such a wave has recently been identified in the equatorial mesosphere through analysis of satellite temperature data.

2.2.3 SKYHI Model Analysis Development

Development of the "Transformed Eulerian" analysis technique described above in 2.2.2 was motivated by a need to get around the dynamically misleading "mean cell-eddy cancellation" so common in stratospheric zonal mean balances. Another particularly attractive possibility is to express the analysis in terms of potential temperature (θ) coordinates, because most of the cancellation disappears in that reference frame.

In the past year, a rather accurate transformation to θ coordinates has been designed for use in the SKYHI model. However, a number of very difficult technical problems had to be overcome. A preliminary application of this method has achieved a calculation of the zonal mean poleward mass flux in θ coordinates. This more fundamentally correct mass flux has been found to be considerably simpler than that implied by the isobaric meridional circulation because it provides a close approximation to the actual mean Lagrangian movement of air parcels.

2.2.4 Medium Resolution (N18) Annual Cycle Experiment

Various improvements added to the SKYHI model physical processes since the work reported earlier in the low resolution (N10) model version have led to a need for further evaluation. This need has been heightened by the pending conversion to the CYBER 205 computer. To accomplish this, the "Low Diffusion" medium resolution (N18) version (see 2.2.2 above) was converted to an annual cycle version and begun on calendar date 21 September.

Preliminary analysis has indicated some important differences from the previous (N10) annual cycle experiment. The mesospheric "cold polar vortex bias" of that model has been considerably lessened, while the bias is nearly as strong as previous GFDL GCM's in midstratospheric levels. In late January, however, a pronounced "sudden warming-like" phenomenon occurs in the mesosphere and upper stratosphere. Although analysis of this event has just begun, its structure and morphology exhibits many characteristics similar to actual sudden warmings.

PLANS FY83

Analysis of various aspects of the SKYHI experiments will continue. The seasonal integrations will continue on the new computer with continued development of model physical processes and analysis techniques.

2.3 PHYSICAL PROCESSES IN THE MIDDLE ATMOSPHERE

S. Fels	J.-C. Liu*
J. Mahlman	J. A. McAfee*
M. D. Schwarzkopf	*Aeronomy Laboratory/NOAA

ACTIVITIES FY82

2.3.1 Radiative Transfer

A paper describing a useful parameterization of scale dependent radiative damping in the middle atmosphere was published (453).

Work was begun on a time marched radiative-convective model of the terrestrial atmosphere. In these calculations, each latitude is treated separately. At a given latitude, the surface temperature is specified at its seasonally varying climatological value, as is the incident solar flux and ozone. The model is time-marched through two years.

The resulting time dependent profiles provide a useful index for gauging the importance of dynamical heating in the middle atmosphere, and in GCM's.

PLANS FY83

The seasonally marched radiative model will be combined with a simple zonally symmetric linear dynamical model to assess the role played by geostrophic adjustment in altering radiative temperatures. If time permits, an attempt will be made to march the radiative-photochemical model (2.3.2) through a seasonal cycle.

2.3.2 Ozone Chemistry

In the past year, the collaborative effort with NOAA Aeronomy

Laboratory scientists has undergone a period of consolidation and unification of various model developments. This has involved numerous improvements in the chemical algorithms as well as recoding to make the model code more compatible with SKYHI 3-D modeling requirements. This period of model upgrading has necessitated a delay in the investigations of ozone photochemical influences on middle atmosphere radiative damping.

PLANS FY83

The Aeronomy Laboratory - GFDL ozone photochemical modeling collaboration will continue with an intensive effort to develop a fully compatible 3-D SKYHI version on the CYBER 205. The radiative-photochemical interaction study will be completed.

3. EXPERIMENTAL PREDICTION

GOALS

* To identify important external forcing mechanisms for the forecast range of several weeks to several months, including initial conditions in the atmosphere, oceans, soil and snow-ice.

* To investigate the influence of additional internal processes such as cloud-radiation interaction and cumulus convection, upon long-range atmospheric variability.

* To develop more accurate and efficient atmospheric as well as oceanic GCM's suitable for monthly and seasonal forecasts, respectively.

* To search for new approaches to long-range weather prediction.

* To study the mechanisms of various atmospheric phenomena such as tropospheric blocking, orographic cyclogenesis, tropical waves, equatorial ocean-atmosphere interaction processes, and teleconnection.

3.1 UPPER OCEAN FORECASTS

K. Miyakoda J. Sirutis
A. Rosati

ACTIVITIES FY82

3.1.1 Sea Surface Temperature (SST) Forecasts

Ocean forecast experiments for the period of 1976 and 1977 are proceeding. These experiments use both the one-dimensional (1D) mixed layer model and the three-dimensional (3D) general circulation model. The atmospheric forcing, for both models, is specified by observation. Studies are focussed on the effects of mixed layer parameterizations, initialization procedures, and surface boundary conditions. The results indicate that the treatment of evaporation and radiation must be done properly in order to capture the subtle behavior of SST anomalies. Comparison of the results with 1D and 3D models reveals that the difference of the predicted sea temperature is extraordinarily large along the equatorial zone, especially in the El Nino region.

3.1.2 Development of GCM

Development of a GCM suitable for ocean forecasts is underway. Areas of efforts are the improvement of the space resolution and the subgrid-scale processes. The level 2.5 turbulent closure scheme of Mellor-Yamada is included for the whole depth of the model ocean. It is noteworthy that the same turbulent closure scheme (with the same values of coefficients) is used in the atmospheric model as well. These physics appear to be important, especially in the tropics.

PLANS FY83

An atmosphere-ocean coupled model will be constructed in order to simulate the air-sea interaction process in the equatorial region.

3.2 SUBGRID-SCALE (SGS) PROCESSES

C. Gordon P. Phillipps
K. Miyakoda J. Sirutis

ACTIVITIES FY82

3.2.1 Experiments with Various Versions of SGS Processes

Continuing from the previous report, three atmospheric GCM's with different treatments of SGS parameterizations (A, E and F) are integrated over a period of 30 days for three cases: March 1965, January 1977 and January 1979. The experiments have indicated that the effects of SGS parameterization on medium and long range forecasts are appreciable in all cases treated, with model F consistently showing the highest forecast skill. The distribution of tropical rainfall in the F model is spatially smooth and seemingly realistic, compared with other models.

3.2.2 Diagnostic Cloud Studies and Cloud Radiation Interaction

Monthly mean fields of "SATCLD" low and high cloud amount are generated using observed satellite radiation data and the Fels-Schwarzkopf radiation model. They are compared with another analysis, which is based solely upon surface observations, and the Air Force Global Weather Central 3D-Neph analysis. The SATCLD analysis exhibits a well-defined ITCZ and generally is in qualitative agreement with the 3DNEPH in the tropics and subtropics. Over the extratropical oceans, the SATCLD low cloudiness is in somewhat better agreement with the surface observation, but the SATCLD cloudiness is least reliable at polar latitudes.

The July 1979 monthly mean net radiative flux fields at the top of the atmosphere calculated for 3DNEPH or SATCLD clouds are compared with observation (WINSTON) in Fig. 4. The SATCLD flux is clearly more radiatively consistent with observation than the 3DNEPH.

PLANS FY83

The investigation of SGS processes will be continued, including two more cases. Research will be carried out on the cloud-radiation interaction. A study of the influence of cloudiness upon the surface temperature over the tropical ocean and land mass will commence.

3.3 LONG-RANGE FORECASTS

K. Miyakoda W. Stern
A. Navarra R. Strickler
J. Sirutis

ACTIVITIES FY82

3.3.1 Monthly Forecasts

The "1980-version GCM" (i.e., N48L9-E) has been frozen and is being applied to three cases of monthly prediction for January, 1977, 1978 and 1979. In order to enhance the statistical validity of the results, each case includes three different initial conditions based on various map analyses. The impact of external forcings is also being investigated by prescribing the ocean surface boundary conditions with and without temperature anomalies.

3.3.2 Development of Anomaly Model

The performance of Chao's anomaly model[†] has been investigated, making monthly forecasts of two cases, January 1977 and 1978 with a one-layer model.

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† Chao, J-P, Y-F, Guo and R-N. Xin. "A Theory and method of long-range numerical weather forecasts," J. Meteor. Soc. Japan, 60, No. 1, Feb. 1982, pp. 282-291.

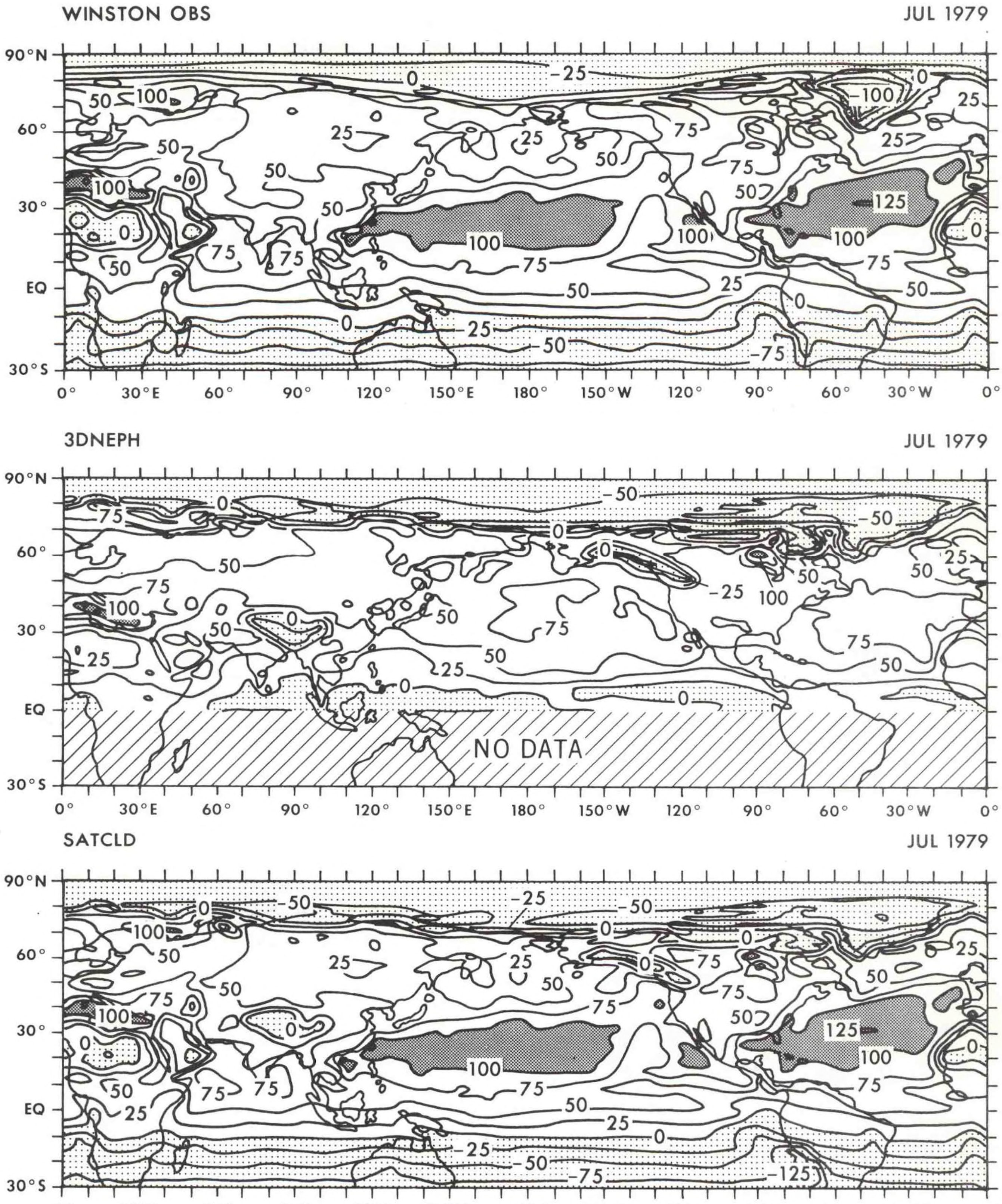

Fig. 4. Observed and model-diagnosed monthly mean net radiative flux at the top of the atmosphere for July 1979. The domain is 90°N-30°S, but the 3DNEPH fluxes were computed only within the northern hemisphere. The contour interval is 25 W m^{-2} .

Independently, both a time-dependent model and a stationary anomaly model are constructed, using a spectral barotropic vorticity equation as the base. A test case has showed that the anomaly model is indeed promising. The low space-resolution anomaly model is capable of predicting the anomaly pattern comparable to that of the full model in high resolution. The Reynolds terms are not large.

PLANS FY83

Another set of 3 cases (January 1980, 1981 and 1982) will be used for monthly forecast experiments, using the spectral GCM (i.e., R42L9-E). The HIBU model (410A) will be refined with respect to the treatment of the polar region.

Development of a baroclinic anomaly model will be started.

3.4 SIMULATION OF BLOCKING

C. Gordon J. Kinter
K. Miyakoda W. Stern

ACTIVITIES FY82

Using a stationary, linearized barotropic vorticity equation, the wave solutions are generated for various basic flow profiles, which include a number of resonant solutions. On the other hand, a time-dependent, non-linear shallow water equation model is solved numerically, prescribing the same basic zonal flow. Comparison of the two solutions reveals the characteristic of resonant solutions and clarifies the fundamental difference between the two systems of equations. Thus this study is providing valuable information on the mechanism of the "local resonant interaction", which is postulated as the cause of the blocking in the previous GCM simulation experiment (xx).

PLANS FY83

The role played by transient waves for the excitation of the blocking ridge will be investigated.

3.5 FGGE OPERATION AND 4-DIMENSIONAL ANALYSIS

N. Lau G. Vandenburghe
K. Miyakoda R. White
J. Ploshay B. Wyman
W. Stern

ACTIVITIES FY82

The final FGGE analysis system at GFDL consists of: continuous data-insertion into a spectral model with a nonlinear normal mode initialization at 6-hour intervals. Perhaps the most important change from the previous report is the more lenient data rejection criterion in the data assimilation. As a result, the intermittent application of optimum analysis was found to be unnecessary. Also the intensity of the transient eddy kinetic energy, in the analysis, is now increased to a satisfactory extent. The operational production of FGGE Level III-b data is continuing, with completion scheduled for September, 1982. Figure 5 shows a comparison of the GFDL and ECMWF (European Centre for Medium-Range Weather Forecasts) results. Depicted are the April, 1979, zonal averages of zonal wind (u) and square root of the standard deviation of zonal wind as a function of latitude and height.

PLANS FY83

The completed FGGE Level III-b data set produced at GFDL will be archived at the World Data Center, Asheville, North Carolina. Movies of the FGGE results will be made. Improvement of the 4-dimensional analysis system is being planned.

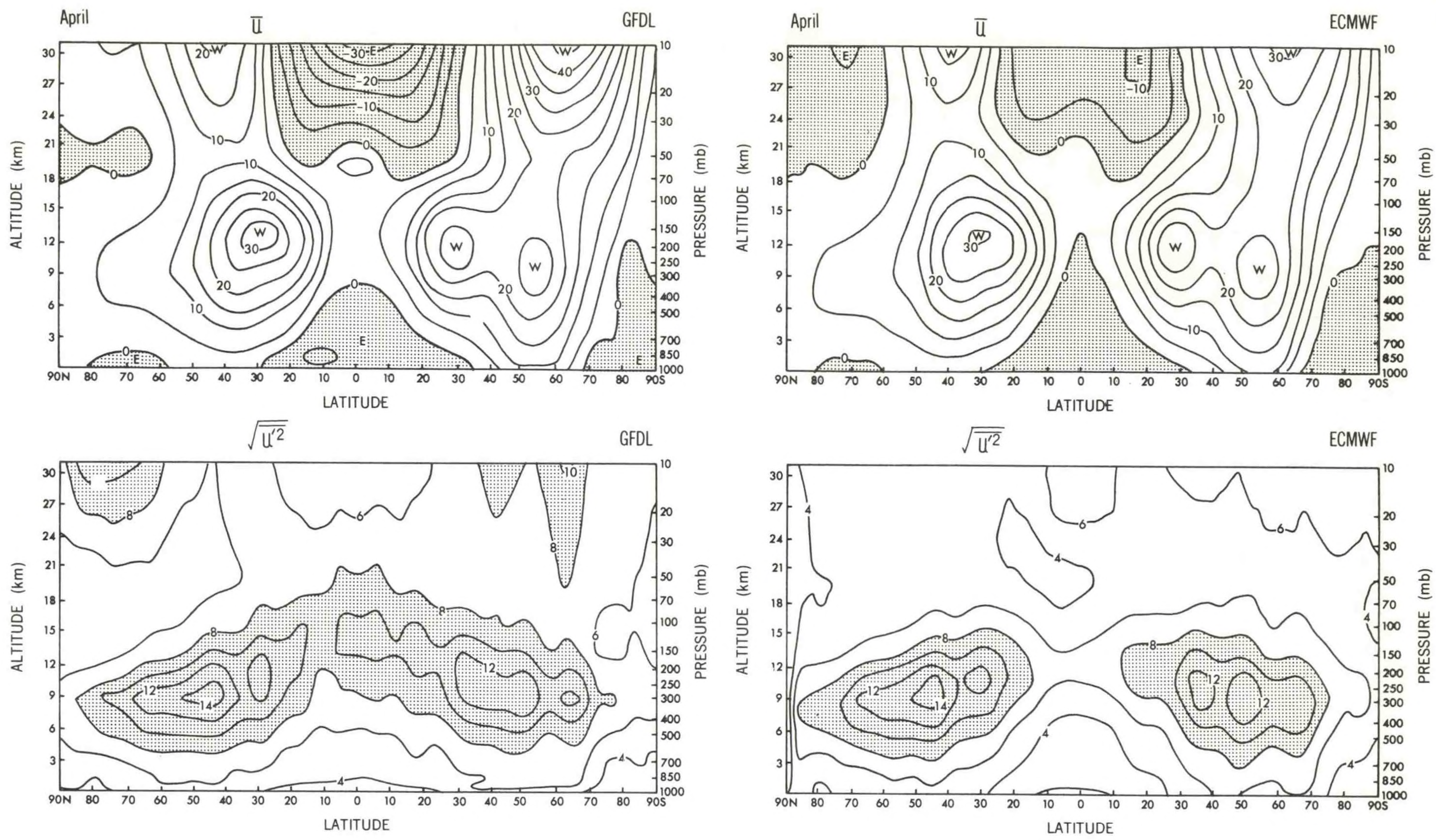

Fig. 5. Comparison of the GFDL and ECMWF cross-sections of zonal wind (top) and square root of standard deviation of zonal wind (bottom) for April, 1979, both in units of m s^{-1}

4. OCEANIC CIRCULATION

Goals

* To study the large-scale response of the ocean to atmospheric forcing over a range of time scales from a few weeks to decades.

* To perform oceanic observational studies by systematically processing the large data base available for the density structure and the fields of various tracers.

* To develop detailed, three-dimensional models of the World Ocean and its regional components and interpret these in terms of a coherent hydrodynamical framework.

* To develop a capability to predict the large-scale behavior of the World Ocean in response to changing atmospheric conditions.

* To identify practical applications of oceanic models to man's marine activities.

* To formulate and to test against observations a coastal ocean model which has a detailed surface layer and bottom boundary layer.

4.1. OCEANIC RESPONSE STUDIES

J. Carton
P. Delecluse
R. Pacanowski
S. Philander
A. Seigel
T. Yamagata
J. Yoon

ACTIVITIES FY82

4.1.1 Dynamics of Tropical Oceans

The recent convincing demonstrations, on the basis of data analyses, that sea surface temperature anomalies in low latitudes affect the global atmospheric circulation have renewed interest in the cause of the surface temperature anomalies. Various aspects of this problem were studied during 1982.

To explain why the SST anomalies which, during El Niño years, grow until they cover the entire tropical Pacific Ocean, always appear off the coast of Ecuador and Peru first, and always appear there in February and March, it has been proposed that the SST anomalies at that place and time trigger unstable air sea interactions: the initial anomaly affects the atmosphere in such a manner that the altered surface winds induce warm oceanic currents to flow towards the anomaly, thus magnifying it. This mechanism is now being simulated in a model.

The adjustment of the ocean to a change in wind conditions is effected by planetary waves (417). Mixing processes which attenuate these waves therefore influence the oceanic response. It is found that, because the waves are divergent, they are particularly sensitive to the mixing of heat which could destroy the restoring forces associated with the stratification of the ocean. In the parameterization of mixing processes, special attention will have to be paid to the mixing of heat.

The contrast between the swift narrow Somali Current, and the broad slow Peruvian Current, both driven by cross-equatorial winds, is striking. An important factor responsible for this difference is the difference in the meridional pressure force along the eastern and western boundaries of an ocean basis driven by northward winds. In the east, where there is coastal upwelling south of the equator and downwelling north of the equator, this pressure force opposes the windstress. Along the western coast however the coastal jet flows "downhill" because the coastal upwelling north of the equator, and downwelling south of the equator, results in a northward pressure force (zz).

A simulation of the seasonal cycle in the eastern tropical Pacific Ocean, where El Niño phenomena are initiated, reproduces the observed sea surface temperatures and currents remarkably well. The intensity of the currents is too weak, however. This may be a consequence of the wall along 130°W that bounds the model ocean to the west, or could be caused by mixing processes that are too intense. A model for the much smaller Atlantic Ocean, which need not be bounded by artificial walls, is being developed to aid in the study of the seasonal cycle in that ocean.

4.1.2 Coastal Oceanography

The coastal zones, because they are wave guides, adjust rapidly to changes in the winds. Studies of the response of the coastal zone to idealized wind changes have established the intrinsic time-scales of the oceanic adjustment and have clarified the roles of alongshore propagating Kelvin waves and offshore propagating Rossby waves (dd,ee). These results have been used in a study of the response to a realistic transient storm.

The alternative to the deterministic view of variability of coastal zones, is to regard it as a stochastic phenomenon. Results from a four-year simulation, using realistic winds, of variability off the coasts of California and Oregon, are being analyzed in terms of spectra and cross-spectra between oceanographic and meteorological variables.

PLANS FY83

Studies of the seasonal cycle in the eastern tropical Pacific Ocean, and studies of coastal upwelling will be completed. Models to simulate the seasonal cycle in the entire tropical Pacific, and the seasonal cycle in the tropical Atlantic Ocean will be developed. The Pacific Ocean model will subsequently be used to investigate specific El Niño events. Attempts will be made to improve parameterization of mixing processes because this continues to be a serious problem in the models.

4.2 MARINE GEOCHEMISTRY

F. Bryan	M. Jackson	M. Redi
S. Gorlick	M. Kawase	J. Sarmiento
S. Hellerman	R. Key	R. Toggweiler

ACTIVITIES FY82

The goals of the marine geochemistry group center on learning how to model a variety of chemical tracers in the oceans, and on using these tracers to develop a quantitative knowledge of water-mass and chemical transformation and transport processes.

The original starting point for this work was a simulation of tritium produced by nuclear bomb-testing. A three-dimensional model of the tritium distribution was completed and analyzed in FY81. The ocean circulation model used for this study has now been published (439) and a paper on the tritium results is ready to submit for publication. The results of this study led to a variety of insights that are being tested on a high-speed, coarse resolution ocean circulation model with simplified geometry. A scheme for introducing isopycnal mixing in the model has been written up and submitted for publication (kk). A series of model parameter experiments and studies of the effect of isopycnal mixing, seasonal forcing, and changes in horizontal resolution are underway.

A major emphasis of FY82 has been on data studies. The tritium data mapped in FY81 was analyzed and written up. An isopycnal box model of tritium in the North Atlantic main thermocline was used to determine time sales of ventilation. Similar tritium studies of the North Pacific are in progress. A variety of data sources were compiled to produce maps of cesium/strontium, nutrients, hydrography, and radium-228 in the Atlantic. These data will be used for planning cruises, descriptive studies, and testing models. A study of deep ocean mixing based on radium-228 observations is now in press (i).

FY81 saw participation of several marine geochemists in the Transient Tracers in the Oceans North Atlantic Study. Samples were collected for radium-228 analysis and continue to be worked on in a laboratory constructed for this purpose.

PLANS FY83

The experiments with the simplified ocean circulation model will be continued. We will not return to the more realistic models of ocean circulation until more of the work with this model has been completed. We will continue to explore box models and 1- and 2-dimensional models of circulation and mixing on isopycnal surfaces. The latter work will make use of the GEOSECS, TTO, and other data that we have been compiling and mapping.

The data compilation and mapping work of cesium/strontium, nutrients, hydrography, and radium-228 in the Atlantic will be completed. A time history of cesium/strontium data at various weather ships will be added to our data tapes for further study. We will begin to look at Pacific data.

Several members of our group will participate in the Transient Tracers in the Ocean Tropical Atlantic Study during FY83. The radium-228 laboratory will continue to measure samples obtained from the earlier study as well as this new study.

A new project we will start in FY83 is to begin putting together the knowledge and expertise we need in order to model the distribution of nutrients and oxygen in the oceans as well as a variety of other tracers that are involved in biological recycling. The work will begin with some simple one-dimensional models intended to explore ways of parameterizing biological recycling.

4.3 WORLD OCEAN STUDIES

K. Bryan F. Komro
M. Cox

ACTIVITIES FY82

Quantitative aspects of the results obtained by coupled ocean-atmosphere models (437,439,448) naturally depend on the details of the ocean model. Since the fully coupled model is a rather cumbersome tool for parameter studies, the ocean model has been coupled to a much simpler heat balance climate model (426). Tests have been made of changes in vertical mixing, and horizontal resolution. Analysis of the response of the ocean model to a sudden warming of the atmosphere shows that the heating suppresses heat loss by convection at high latitudes to a much greater degree than it augments heating at low and middle latitudes. Heat transported poleward by ocean currents accumulates in the subarctic gyre region, since the normal ventilation by convection is reduced. Thus for a positive heat anomaly the absence of convection leads to a deep penetration in high attitudes, just as the presence of deep convection leads to a deep penetration for a tracer.

PLANS FY83

Direct measurements of poleward heat transport by ocean currents provide a new opportunity to verify the intensity of the thermohaline circulation in the models. The new machine will enable tests to be carried out with an eddy resolving ocean model which will be used to test the experimental design of a proposed field experiment to be carried out by the NOAA/STACS program (Subtropical Atlantic Circulation Studies).

4.4 POLAR OCEAN STUDIES

K. Bryan P. Lemke
W. Hibler D. MacAyeal

ACTIVITIES FY82

A new model was developed to study the interaction of sea ice dynamics and the ocean circulation in cooperation with CRREL (U.S. Army, Corps of Engineers, Hanover, N.H.). The coupled ice-ocean model was tested out for the Arctic Ocean - Greenland Sea region, using FGGE winds to drive the model. Preliminary results allow a comparison between ice position with and without active currents in the ocean models. The effect of currents provides a much more realistic seasonal variation of the ice front, and a simulation of the salinity gradients near the ice boundary frequently observed in polar oceans.

PLANS FY83

The growth of polar pack ice is related to both the ambient air temperature, and the strength of winds which deform the ice and control the amount of open leads and distribution of ice thickness. As yet climate sensitivity studies have not included a realistic model of ice dynamics. The coupled ice-ocean model developed in collaboration with the Cold Regions Research and Engineering Laboratory will be carefully tested with the view of including it in a fully coupled global climate model.

Ongoing field studies in the Ross Sea will provide additional data for testing and improving the model developed for the tidally driven circulation below the Ross Ice.

4.5 OCEAN MODEL DEVELOPMENT

K. Bryan
M. Cox

ACTIVITIES FY82

A new model has been developed for studying the North Atlantic which converges to a steady state rapidly allowing extensive exploration of model parameters. A simplified version of this has been prepared as a prototype model for conversion to the CYBER 205. In a global grid point model the convergence of meridians requires longitudinal filtering to avoid a singularity at the poles. A new version has been developed on the CYBER 205 which is much more efficient than the previous version. Initial tests of a model based on isopycnal coordinates has been carried out.

PLANS FY83

The parameterization of water mass mixing in the model is a key area in continuous need of updating and improvement. Improved schemes for mixing of momentum and water mass properties in the planetary boundary layer in the tropical oceans will be carefully tested at higher latitudes.

5. PLANETARY CIRCULATIONS

GOALS

* To discover and understand the fundamental processes controlling the circulations of the atmospheres and oceans of the planets.

5.1 PLANETARY ATMOSPHERES

G.P. Williams

ACTIVITIES FY82

Multiple experiments to examine the response of different versions of the GFDL spectral GCM to changes in external parameters (rotation rate, obliquity, diurnal period) have been completed at high resolution. Model versions are characterized by the presence or absence of moisture, longitudinal variation and surface drag.

The GCM experiments (454) show that an Earthlike atmosphere, when placed in the rotational configuration of another planet, displays that planet's form of motion. The solutions suggest that Jupiter and Saturn resemble a larger, faster-spinning Earth and that easterly winds prevail in Uranus' summer hemisphere. More recent spacecraft data from Saturn has revealed differences between that planet and Jupiter. Our solutions suggest that Saturn is more strongly influenced by rotation than Jupiter.

The solutions also suggest that Venus resembles a slowly rotating Earth if diurnal heating variations are included. Confining the solar heating to the model's stratosphere, by inserting a high level opaque cloud, leads to more complex meridional circulations but the zonal circulation remains basically unaltered and appears to be insensitive to the vertical distribution of the heating.

Simpler but more explicit models for Jupiter, have shown that topographic anomalies can produce permanent vortices resembling the Great Red Spot. General studies of free and forced planetary waves and solitons have reproduced most of the features of Jupiter's ovals. This study of the largest scale features complements that of smaller scales made in previous years.

PLANS FY83

A detailed analyses of the dynamics of the multiple parametric experiments will be carried out to define the functioning of an Earthlike atmosphere under alternative conditions.

Model development will continue for Jupiter and Venus and attempts will be made to improve our understanding of the largest scale features on these planets.

5.2 VORTICES

D. Dritschel

ACTIVITIES FY82

Tornadoes appear to be made up of smaller severe co-rotating vortices existing within a larger, less intense parent vortex. The interactions of point vortices and of finite-sized vortices have been used as models of this phenomenon. Steady solutions have been obtained for an arbitrary number of finite-sized vortices rotating within a parent vortex.

PLANS FY83

The model will be extended to allow for the intertwining of vortices. Stability studies will be made to determine the favored configurations.

6. OBSERVATIONAL STUDIES

Goals

* To determine and evaluate the physical processes by which the atmospheric and oceanic circulations are maintained, using all available observations.

* To compare results of observational studies with similar diagnostic studies of the model atmosphere and model ocean developed at GFDL and thereby develop a feedback to enhance understanding in both areas.

6.1 ATMOSPHERIC ANALYSIS

N. Lau
A. Oort

M. Rosenstein

ACTIVITIES FY82

6.1.1 The 15-year Global Data Set, 1958-1973

An extensive description of the global climate during the period May 1958 through April 1973 has been prepared and is scheduled for publication in the fall of 1982 as a NOAA Professional Paper (ccc). Besides about 8000 horizontal maps and cross sections included as basic information on microfiche, the book contains a documentation of the input data characteristics, a critical discussion of the analysis procedures, comparisons with other independent analyses, such as those by the National Meteorological Center (see also (420-A,g)), and discussions of the derived annual cycle and year-to-year variations in the various hemispheric and global averages. Of great interest are the differences between the Northern and Southern Hemispheres. This publication will, for the first time, provide the scientific community with a concise, easily accessible source of information on the climate in the global atmosphere.

The basic statistics have already been used to investigate the global atmospheric cycles of water substance (ddd) and of angular momentum and energy (ii), and their implications on the salinity distribution and on other characteristics of the world ocean. Especially noteworthy are the computed zonal-mean atmospheric cross sections of global flow of water, angular momentum and energy showing their sources and sinks, and providing clues to the little known vertical fluxes of these quantities (see Fig. 6). An analysis of the 15-year time series of sea surface temperatures in the equatorial Pacific Ocean shows striking correlations with various atmospheric parameters, such as the vertical and Northern Hemispheric mean temperature.

The composite effect of horizontal transports of momentum and heat by transient eddies on the time-mean flow was investigated using two long-term observational data sets. It was demonstrated that the eddy forcing associated with heat transports generally dominates, and that these eddy heat fluxes exert a dissipative influence on both the zonally averaged flow and the stationary wave motion (uu).

6.1.2 Diagnosis of GCM Results

The climatic anomalies obtained in a 15-year simulation by a GFDL general circulation model were thoroughly analyzed and compared with observed anomalies (432,hh).

PLANS FY83

The influence of the convergence and divergence patterns of the atmospheric fluxes of angular momentum, energy and water vapor on the

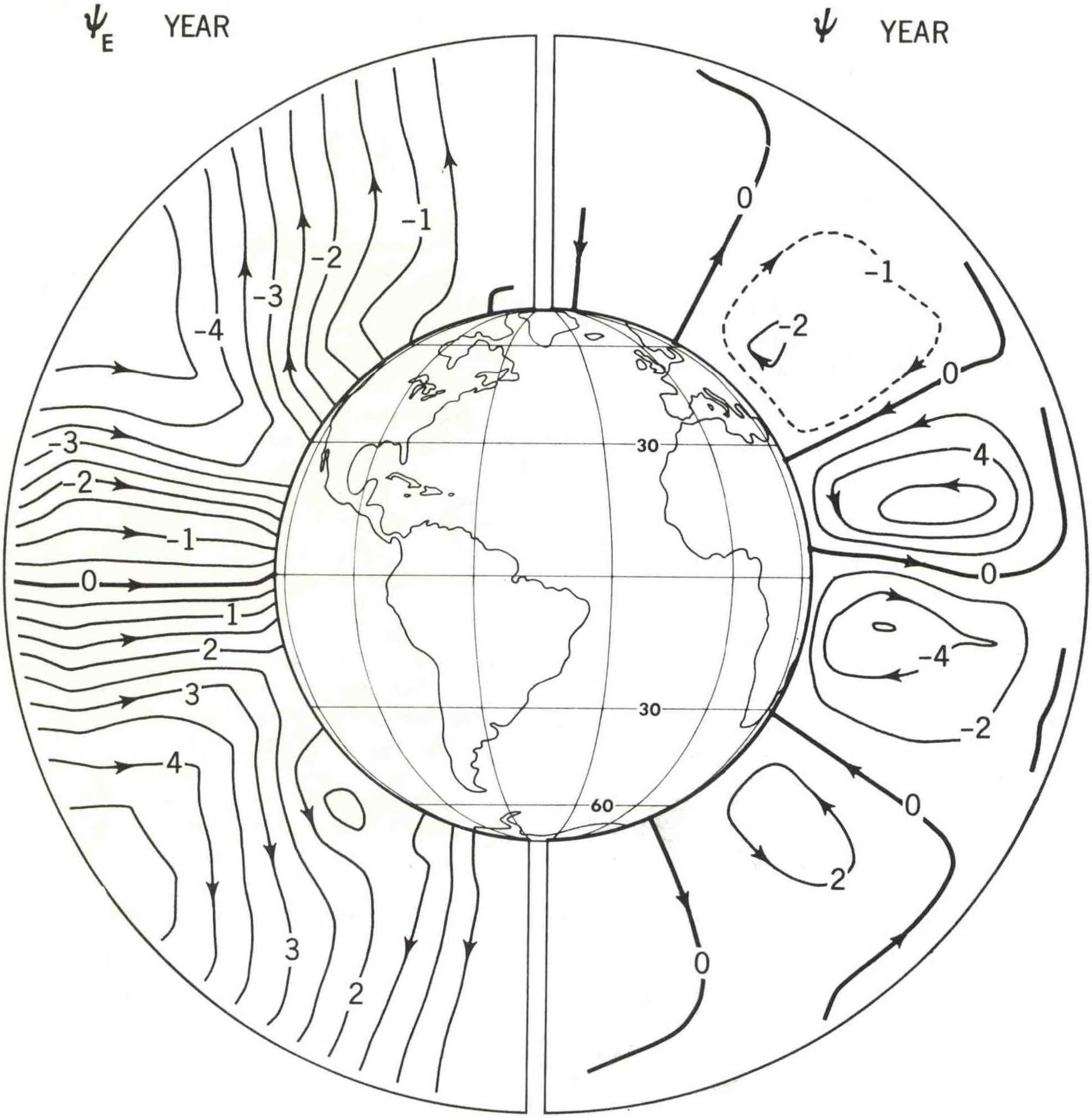

Fig. 6. Streamlines of the zonal mean flow of total energy and mass in the atmosphere for annual mean conditions, in units of 10^{15}w and 10^{10} kg s^{-1}, resp. The vertical scale is linear in pressure, the top level being 50 mb. For energy, the top boundary condition was given by the net annual radiation flux values of Campbell and Vonder Haar (1980). The streamlines for the atmosphere are based on objective global analyses of all rawinsonde station data for the period 1963-1973 available at the National Climatic Center in Asheville, N.C. (ii).

oceanic circulation, the oceanic heat transport and the oceanic salinity fields, resp., will be further investigated based on the 15-year data set.

The FGGE Level III-B data set produced by GFDL will be analyzed extensively and compared with the corresponding set produced by the European Centre for Medium-Range Forecasts (ECMWF) and other groups. The research efforts will initially be focussed on the diurnal and seasonal cycles of relevant meteorological parameters.

The large-scale air-sea interactions associated with pronounced sea surface temperature (SST) anomalies in the tropical Pacific will be investigated by diagnosing the balances of heat, vorticity and moisture over the region of interest. Both upper-air circulation statistics and surface data will be employed for this purpose.

6.2 OCEANIC ANALYSES

S. Levitus A. Oort

6.2.1 Global Analysis of Oceanic Data

A "Climatological Atlas of the World Ocean" is in press as NOAA Professional Paper No. 13 (11). It contains, besides many derived parameters, global distributions of temperature, salinity and oxygen for 33 levels between the surface and the ocean bottom. The analyses are based on all available historical data at NODC. Seasonal and/or monthly distributions are provided for the upper levels. This publication is the first global summary of the 3-dimensional structure of the world ocean. It will provide a much needed observational background for future oceanic research. Highlights are the global maps of the mixed layer depth, the temporal variability of temperature below the surface (see Fig. 7), and the geopotential thickness.

PLANS FY83

The storage and inferred transports of heat and salt will be studied for the various oceans, and will be compared with the atmospheric flux divergence fields of energy and water vapor. Focus will be on the differences between the Atlantic and Pacific Oceans.

A pilot project to study observed year-to-year anomalies in heat storage will be attempted for the North Atlantic Ocean.

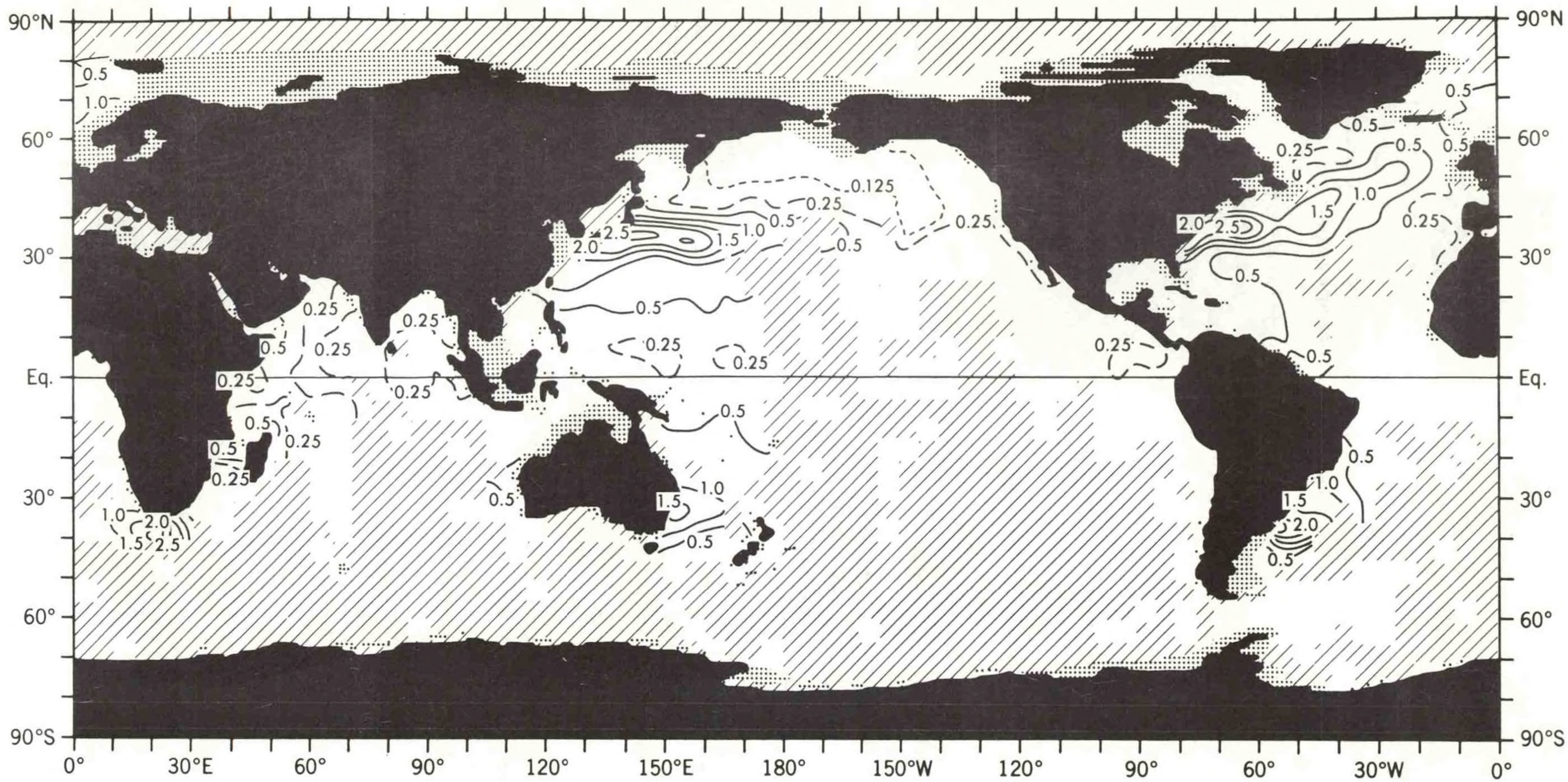

Fig. 7. Map of the temporal variability of temperature in the oceans at 500 m depth based on historical, hydrographic data available at the National Oceanographic Data Center. Shown is the root-mean-square deviation of temperature (°C) for all data, irrespective of season, on a 1° x 1° grid; shading indicates regions of insufficient data (11).

7. HURRICANE DYNAMICS

Goals

* To understand the genesis, development and decay of tropical depressions by investigating the thermohydrodynamical processes using numerical simulation models.

* To study small-scale features of hurricane systems, such as the collective role of deep convection, the exchange of physical quantities at the lower boundary and the formation of organized spiral bands.

* To investigate the capability of numerical models in the prediction of hurricane movement and intensity.

7.1 GENESIS AND DECAY OF TROPICAL STORMS

M. Bender Y. Kurihara
M. Kawase R. Tuleya

ACTIVITIES FY82

Sensitivity of the tropical storm genesis to the sea surface temperature was investigated. Integrations of a three-dimensional model starting from a same initial condition produced a spectrum of development stages, from a weakening wave to a mature tropical storm, with a 5K range (298 to 303K) sea surface temperature. However, this apparently large sensitivity of the model was found to be modulated by change of atmospheric conditions such as the large scale environmental temperature, humidity and wind fields. This study is summarized in (ff).

To study the decay process of tropical cyclones after the landfall, numerical simulation experiments are being conducted with different land surface conditions as well as different kinds of vortex. In these experiments, a movable, triply-nested model with open lateral boundary is used. This enables us to set up the experimental design in a relatively realistic manner rather than a fairly artificial manner by which a landfall experiment was performed before.†

Based on the numerical results from the hurricane genesis experiments carried out in the preceding year (424) and (443), follow-up studies are in progress on the two subjects: (1) a cause for the dependency of asymmetric structure of vortices on the direction of mean zonal flow, and (2) a mechanism for the evolution of a distinct tropical depression in the trough region of an easterly wave. It seems that the coupling of the relative vorticity and divergence fields in a wave plays an important role in the tropical cyclogenesis.

PLANS FY83

The results of the hurricane landfall experiments which have been conducted so far will be analyzed. At the same time, simulation experiments may start to study the effect of topography on the landfall of hurricanes.

Two follow-up studies mentioned before will be continued in order to understand a formation mechanism of tropical storms.

7.2 NESTED-MESH MODEL

M. Bender R. Tuleya
Y. Kurihara

ACTIVITIES FY82

Analysis of the hurricane eye simulated in a quadruply-nested model

† Tuleya, R. E. and Y. Kurihara, A numerical simulation of the landfall of tropical cyclones, J. Atmos. Sci., 35, 242-257, 1978.

with the finest resolution of about 5 km was completed. The results were published in (447). Figure 8 shows the ten-hour average of mean mass flux stream function and the temperature profiles at the eye, eyewall and the environment at a selected time. It was found that the warming and drying effect due to the mean sinking motion within the eye is counterbalanced mainly by the cooling and moistening effect due to the horizontal mixing. Within the eyewall, the asymmetric feature moves cyclonically at a smaller rotation rate than the azimuthal mean cyclonic flow. The eddy motion in the eye wall is supported by both the barotropic and baroclinic energy conversions.

A numerical scheme to treat the open lateral boundary of a limited area primitive equation model was formulated and tested. The scheme was designed to keep the overspecification of conditions, which is inevitable in the pointwise boundary setting, to a minimum degree. The boundary conditions were imposed through a damping technique. The temperatures at boundary grids were obtained diagnostically. The test results indicate the utility of the proposed method (ss).

The program conversion of a nested mest model to a new computer is being monitored.

PLANS FY83

Preparation for the application of a nested-mesh model to experimental prediction of tropical disturbances will be made in two areas: (1) further test of boundary conditions at the open lateral boundary of a model, and (2) a study on the data analysis and model initialization.

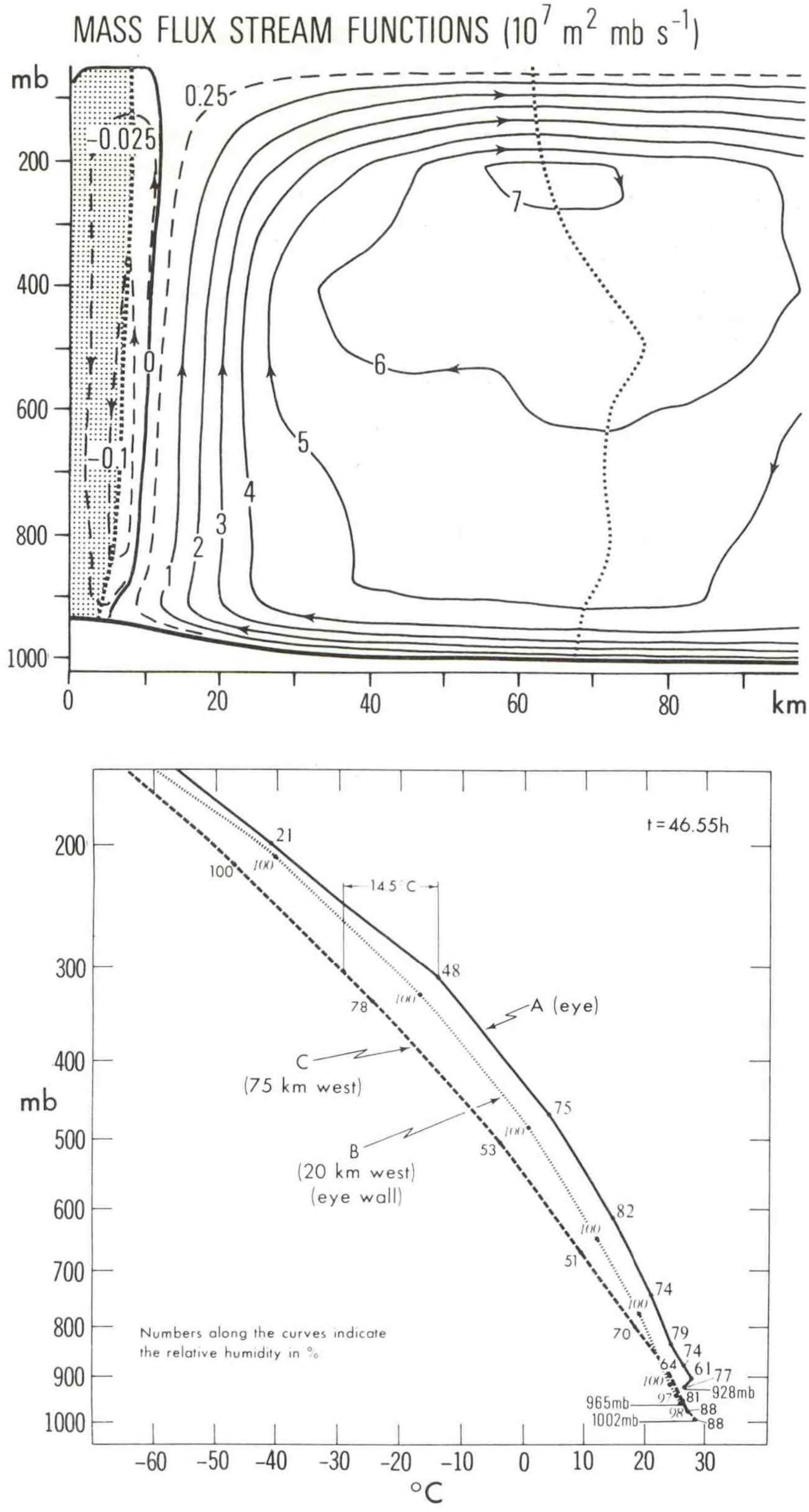

Fig. 8. Top: Height-radius distribution, averaged for hour 37.1 through 46.55, of mean stream function, indicating the mean radial-vertical circulation. The eye is indicated by shading. Bottom: Temperature profiles at hour 46.55, at A(eye), B(20 km west, eye wall) and C(75 km west). Relative humidity (in percent) are shown by numbers along the curves.

8. MESOSCALE DYNAMICS

GOALS

* To produce accurate numerical simulations of mesoscale processes in order to understand what role synoptic scale parameters play in their generation and evolution.

* To understand the dynamics of mesoscale phenomena and their interaction with larger and smaller scales.

* To determine practical limits of mesoscale predictability by means of sensitivity studies on numerical simulations of mesoscale phenomena.

8.1 THE DYNAMICS OF A COLD FRONT

I. Orlanski B. Ross
L. Polinsky

ACTIVITIES FY82

The analysis of a 48-h numerical solution of a cold front has revealed the characteristics (1) of the important feedback mechanisms active in the cross-stream circulation and (2) of the circulation of the associated deep convection.

The intensification of cyclonic surface vorticity by stretching due to surface convergence ultimately produces ageostrophic divergence tendencies that prohibit further intensification of the front. This is an important new result, because the classical quasi-geostrophic and semi-geostrophic models, formerly thought to be adequate for the simulation of frontal evolution, do not permit such a mechanism to act.

This numerical solution is perhaps the first to simulate the evolution of a real-data three-dimensional front with an associated squall line. In spite of coarse numerical resolution, this solution permits crude inspection of the characteristics of severe linear storms. The analysis of the deep convection reveals a cellular structure due to barotropic instability (horizontal shear). Conjecturally, these cells may be similar to the cellular radar echoes typically observed in squall lines. The heat and momentum balances have been studied, and they were found to agree remarkably well with observations. The explicit prediction of both liquid and vapor phases of water substance permits us to examine the modeled convective process in detail. This examination reveals that the latent heat released in the convective region is nearly balanced by adiabatic cooling due to vertical motion. The net heating of the atmosphere due to convection can be explained by unbalanced adiabatic warming due to descent outside the squall line.

Although the processes involved in frontal intensification are reasonably well understood, the processes associated with frontal occlusion are not. The data taken during the first week of the SESAME observing period offer us a chance to study the phenomenon of occlusion. Between 1800 GMT 11 APR and 1800 GMT 12 APR 1979 an occluding extratropical cyclone advanced from the Oklahoma panhandle region to northeastern South Dakota. As the low advanced, the occlusion process continued, and an unusually long squall line developed in the warm sector ahead of the cold front. A 48-h simulation of this case, starting at 0000 GMT 12 APR 1979, has been completed. Analysis of this solution indicates that the movement of the frontal surfaces and the placement of the convective system have been successfully simulated.

PLANS FY83

Continuing analysis of the 48-h simulation of the frontal occlusion will be undertaken in order to determine the processes by which occlusion is supported.

8.2 MESOSCALE PREDICTABILITY

D. Miller L. Polinsky
K. Miyakoda B. Ross
I. Orlanski R. Shaginaw

ACTIVITIES FY82

8.2.1 Meso-α scale

One of the important aspects of mesoscale forecasting is the accurate prediction of the location and amount of precipitation. Five successive 48-h simulations, with initial times separated by 24h, have been completed. The initial times range from 0000 GMT 8 APRIL 1979 to 0000 GMT 12 APR 1979, coinciding with the SESAME I period. This study is divided into two principal components. First, the Mesoscale Dynamics Group's MAC model is initialized with data for these five times, as obtained from initial data sets of the LFM model of the National Meteorological Center. The boundary data for these five solutions are also obtained from LFM initial data. The MAC model, described in (445), uses a constant-height vertical coordinate, inflow and outflow boundary conditions, explicit convection and cloud-water prediction, and a body-drag formulation to simulate orography. These five solutions agree on the occurrence of severe convection as observed during this period, but they differ, often sharply, on the location and intensity of convective precipitation. The solutions have a general tendency to overpredict precipitation amounts, evidently because of the lack of an adequate treatment of the rain phase in the model. The precipitation associated with the feature of greatest meteorological interest during this period, the tornadic supercells in the Great Plains occurring around 0000 GMT 11 APR 1979, has been simulated with varying accuracy, depending on the time of the initial data set.

In the second phase of this study, a set of solutions has been obtained for this period using a finite-difference surface-pressure normalized (σ-surface) model (HIBU) nested in a spectral global model (R30L09). The initial data for the spectral model solution were derived from two different data sets - NMC level III data and the recently analyzed FGGE data. Preliminary results show that, while the HIBU forecast is not fully accurate, the solution using the FGGE initial data predicts the precipitation pattern most accurately. Comparison of the three precipitation forecasts - the LFM case and the two HIBU cases using NMC and FGGE initial conditions - are shown in Fig. 9 (0-24h) and Fig. 10 (24-48h).

8.2.2 Meso-β scale

The above mentioned MAC solutions for the SESAME I period of 10-11 April 1979 are being used to provide initial and boundary conditions for a nested meso-β simulation of the severe storm outbreak which occurred over Texas and Oklahoma. A comparison of these two solutions within this meso-β region over Texas and Oklahoma indicates that the convection, which is explicitly represented in both models, intensifies four-fold in

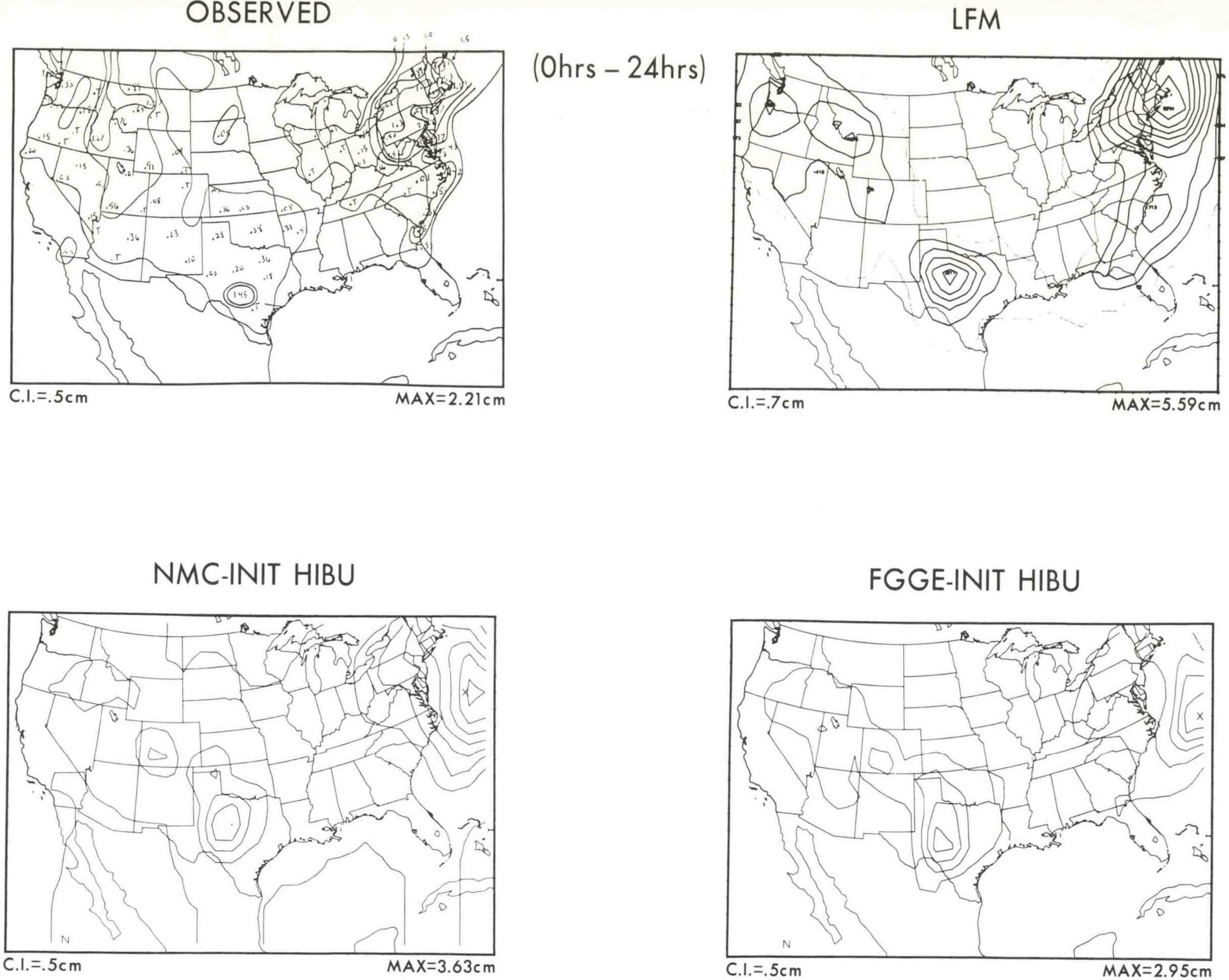

Fig. 9. Precipitation analyses for hours 00-24 of simulation period (1200 GMT 4/9/79 - 1200 GMT 4/10/79). Upper left: Observed at NMC first-order surface stations; upper right: forecast from NMC nested LFM-II model; lower left: forecast from GFDL nested-HIBU model with NMC-Level III initial conditions; lower right: forecast from GFDL nested-HIBU model with FGGE-analyzed initial conditions.

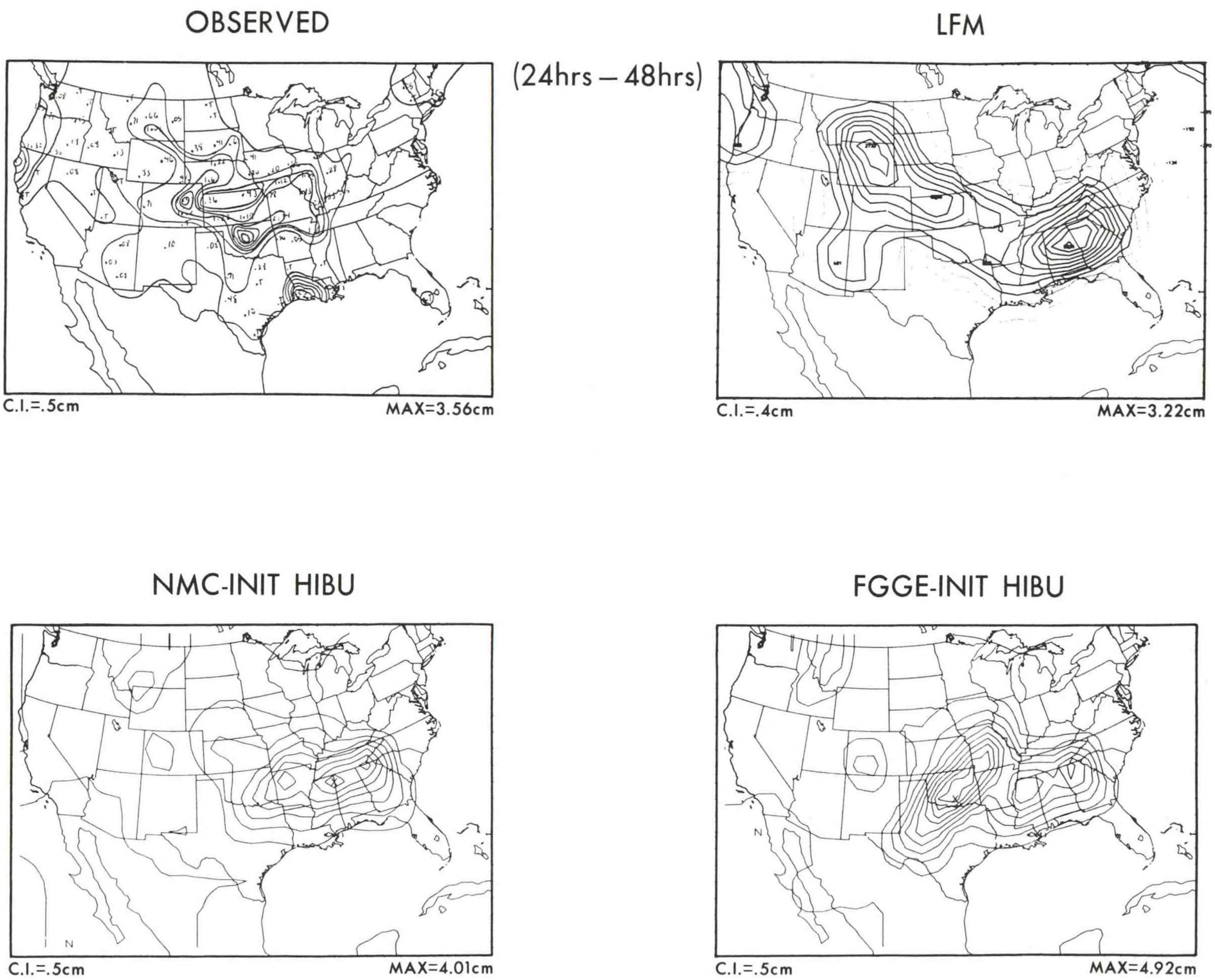

Fig. 10. Precipitation analyses for hours 24-48 of simulation period (1200 GMT 4/10/79 - 1200 GMT 4/11/79), as in Fig. 9.

both precipitation amount and root-mean-squared vertical motion when the horizontal grid size is reduced from 160 to 40 km. However, the use of increased resolution alone does not significantly alter the location of the convection as predicted by the larger scale model. In both solutions, convective activity develops over Oklahoma as was observed but occurs too far to the east and too early in the period over northern Texas. This latter failure of both solutions appears to be due to inadequacies (particularly in low-level moisture) of the LFM data which was used to initialize the meso-α MAC model.

Sensitivity tests performed with the meso-β model indicate that convective intensity and location are very dependent upon the horizontal structure of the low-level moisture field in the SESAME I case. Hence, the enhancement of moisture within the planetary boundary layer with observations having meso-α and possibly meso-β scale horizontal structure appears to be required in order for a meso-β model to be able to accurately predict the location of convective activity.

PLANS FY83

Analyses of and comparisons among the various MAC and HIBU solutions will be performed in order to determine the degree of sensitivity of each predicted variable to variations in initial and boundary data, physics and model formulation. The MAC solutions will be analyzed to determine the source or sources of error in predicted precipitation patterns.

A more complete meso-β simulation of the SESAME I period will be performed using an enlarged horizontal model domain and increased vertical resolution within the boundary layer. Sensitivity tests will then be performed on this model to determine the effect upon the modeled convection due to initial conditions which are enhanced with upper-air SESAME data with increased spatial and temporal resolution.

8.3 LEE CYCLOGENESIS

W. Chen I. Orlanski

ACTIVITIES FY82

A case study of a cold front impinging on the Andes in South America has revealed a medium by which mesoscale jets can be induced by orography. Both surface maps and satellite pictures have revealed that the formation of a low downstream from a mountain barrier due to a synoptic disturbance (such as a cold front or short planetary wave) will not affect the synoptic balance between the original disturbance and the orography. Since this is true, ageostrophic motion can be induced as a result of large-scale pressure gradients set up by the synoptic-scale flow. This pumping mechanism can be called "Coriolis pumping," because it is due to the earth's rotation. It may be possible to use such a mechanism to explain most of the gap winds common in various parts of the world.

PLANS FY83

Laboratory and numerical simulations will be undertaken to verify this mechanism and its effects.

8.4 MODEL DEVELOPMENT

D. Miller B. Ross
I. Orlanski R. Shaginaw

ACTIVITIES FY82

The latest version of the Mesoscale Dynamics Group 3-D model includes a body-drag formulation as a means of parameterizing the momentum loss due to topography in z coordinates. Many different approaches to the inclusion of orography in numerical models have been presented. Some researchers have tried rigid blocks in physical coordinate models; others, coordinates that include orographic relief in their definition (σ-coordinates). But all of these schemes have drawbacks. The rigid-blocks approach produces grid-size disturbances because of discontinuities in the orography. Terrain-following coordinates have the problem of miscalculating pressure forces where the terrain slope is steep.

Perhaps the drag effect due to mountains can be parameterized more successfully by a body force having the shape of the actual mountains. This parameterization has been tested in a 2-D model and has been compared with a mountain-wave solution accomplished with a σ-coordinate model. The success of this comparison has led to the inclusion of the body-force parameterization in the 3-D mesoscale model (MAC). This change has led to considerable improvement in the MAC solutions.

Three dimensional meso-β solutions have been obtained in which the quasi-hydrostatic approximation (described in (411)) is used. A comparison has been made between solutions using this and the basic hydrostatic approximation for different horizontal resolutions within a convectively active region of the SESAME I simulation. Preliminary analysis suggests that the stabilizing effect of the quasi-hydrostatic correction becomes important for a horizontal grid size ΔX of around 10 km (so long as the aspect ratio of model depth H to ΔX is not greater than unity) although the significance of horizontal viscosity in these comparisons needs to be clarified with further tests.

PLANS FY83

Further tests will be performed using the body drag representation of orography in the 3-D model. In addition, an effort will be made to prescribe heat flux at the terrain surface in the body drag formulation.

Additional tests will be performed using the quasi-hydrostatic approximation. In addition, a filtering mechanism will be included to permit solutions to be obtained when the model aspect ratio $H/\Delta X$ is greater than one.

A prognostic equation for rain water phase will be added to the three-dimensional model.

9. CONVECTION AND TURBULENCE

GOALS

* To develop and improve three-dimensional numerical models capable of simulating dry and moist thermal convection in the atmosphere.

* To develop numerical models capable of simulating turbulence in homogenous and stratified fluids by simulating the large turbulent eddies directly and by testing various parameterizations of the subgrid-scale flow.

* To perform laboratory measurements and analysis of turbulence in various media to aid understanding of its fundamental mechanisms.

* To formulate and test against observation various turbulence closure hypotheses applicable to the diabatic planetary boundary layer.

9.1 CONVECTION

R. Hemler F. Lipps

ACTIVITIES FY82

Several four-hour numerical simulations have been completed using a moist convection model with a large-scale, time-invariant convergence. A primary goal for this study has been to obtain and interpret time-mean statistics for tropical convection. At the start of the calculations, a random moisture disturbance is used to initiate the convection. The grid intervals are 500 m in each horizontal direction and 250 m in the vertical. The model domain has a vertical thickness of 16 km and, for three-dimensional calculations, the horizontal dimensions L_x=24 km and L_y=16 km. The two-dimensional calculations are carried out with either L_x=32 km or L_x=64 km. The environmental sounding of temperature and of water vapor is obtained from GATE data for 0600 GMT 12 August 1974. Two different profiles of time-mean convergence are considered: The first (weak convergence) and the second (strong convergence) are modelled after the GATE vertical velocity profiles at 0600 GMT and 1200 GMT, respectively. The time-mean statistics are compared for two- and three-dimensional convection. One of the important results of this study is that for all calculations the time-averaged cloud efficiency E, defined as the ratio of the total rainfall reaching the ground to the total water vapor condensed, is approximately $E \simeq 0.4$.

In the above four-hour simulations the last 80 minutes appeared to give the best approximation to quasi-equilibrium convection. Accordingly, time-mean statistics were computed for the last 80 minutes of the calculations as well as for the full four hours. An example of the 80 minute statistics is shown in Fig. 11 for a three-dimensional simulation with no vertical wind shear and a weak large-scale convergence. The data for the average cloud cover (cloud fraction CF) in Fig. 11a indicate a low level maximum of 35 per cent at z=0.6 km and an upper level maximum of 70 per cent at z=9.6 km. Between z=2.5 km and z=6.4 km the cloud fraction is less than 10 per cent and the relative humidity is low with values between 80 and 90 per cent. Yet, as seen in Fig. 11b, in this region the cloud condensation CC and net condensation NC are large. Other data indicate that the maximum vertical heat flux and moisture flux occur at z=4.4 km and z=3.4 km, respectively. Thus in this region of low cloud fraction, between the upper level cirrus-type outflow and the lower level small cumulus clouds, the mean convection is strong.

A three-dimensional analytical study using linear disturbances was carried out for the case of dry convection with vertical wind shear. This analysis showed that the vertical momentum flux could be separated into two components. The first component is associated with the generation of vertical vorticity and always represents a downgradient flux of momentum. The second component is associated with horizontal convergence and, subject to the solution of an idealized stability problem, represents a contragradient momentum flux. Numerical experiments were carried out to determine how well the above theory applies to finite-amplitude moist

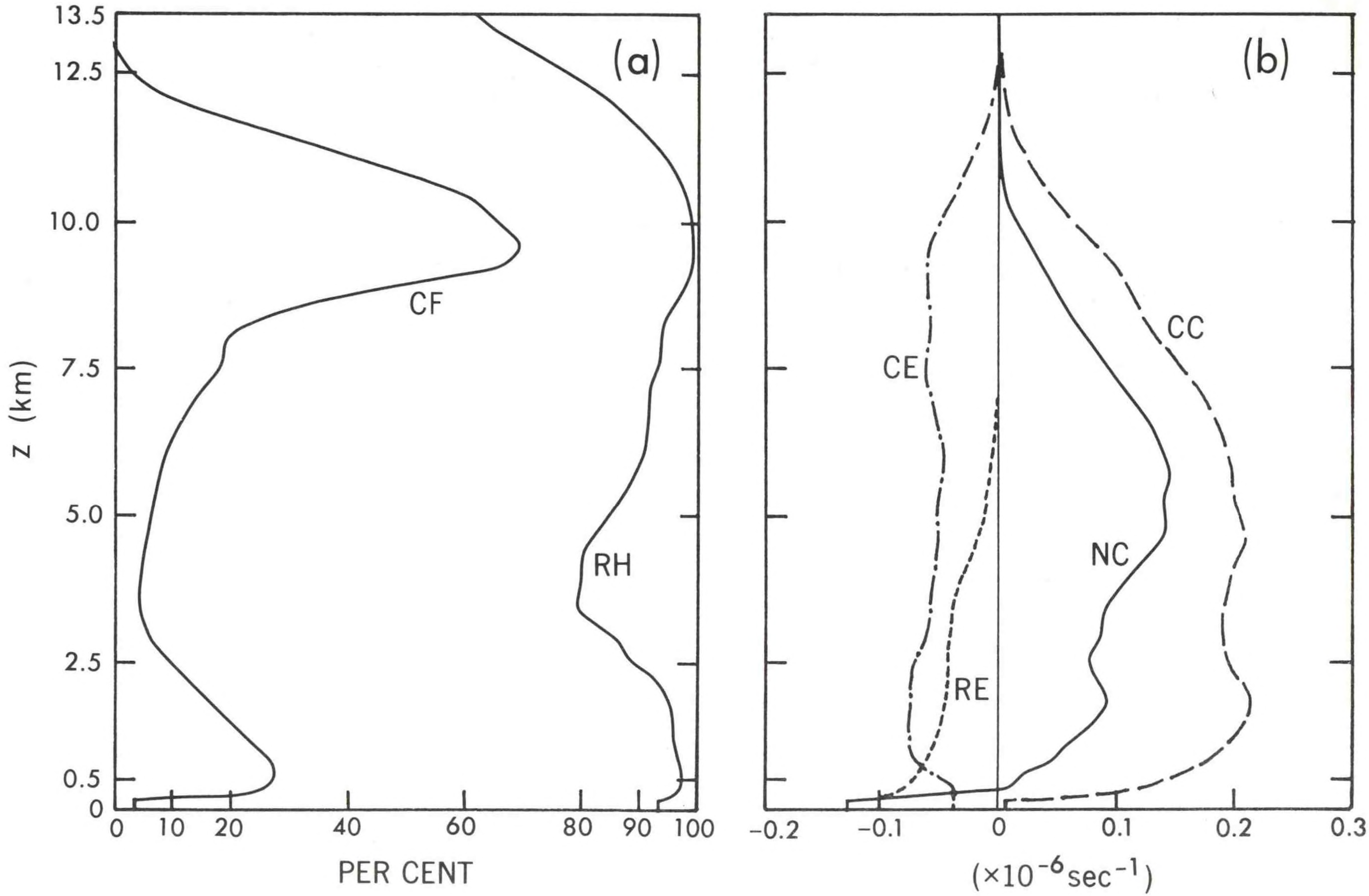

Fig. 11. Time-mean statistics for the last 80 minutes of a three-dimensional simulation with no vertical wind shear and a weak large-scale convergence. (a) Vertical distribution of the cloud fraction CF and relative humidity RH. (b) Vertical distribution of the horizontal average cloud water condensation CC, cloud water evaporation CE, rain water evaporation RE and net condensation NC. By mass continuity NC=CC-CE-RE.

convection. It was found that the first component of momentum flux was consistently downgradient. However, the second component did not consistently give a contribution to the momentum flux of either sign. Two four-hour simulations with vertical wind shear and a weak large-scale convergence were performed. A slight tendency for conversion of mean-flow kinetic energy into disturbance kinetic energy was noted.

Two separate manuscripts describing the above work are being prepared and will be submitted for publication. In addition, the manuscript (x) has been accepted for publication.

PLANS FY83

Four-hour numerical simulations will be carried out as above using a continental sounding of temperature and water vapor as the initial base state. The initial data will also include a realistic distribution of vertical wind shear. Time-mean statistics will be calculated and the resulting data will be compared with similar data obtained from earlier simulations using the GATE sounding as the initial base state.

A new version of the numerical model will be developed which has open lateral boundary conditions instead of the present periodic conditions. This change will allow for more realistic simulations when vertical wind shear is present.

A passive tracer will be added to the moist convection model. This new feature will give more insight into the advective-diffusive characteristics of the model. It should also give relevant information on the role of moist convection in the vertical mixing of inert atmospheric substances. A possible long-term goal is to include source-sink interactions between the tracer and the convection.

A primary objective of this research is to determine how moist convection acts to transfer water vapor, heat and momentum in the vertical as well as to account for precipitation and evaporation at the surface. A long-term goal is to use the knowledge gained from convection modeling to improve cumulus-scale parameterizations in mesoscale and larger-scale numerical models

9.2 ATMOSPHERIC AND OCEANIC BOUNDARY LAYERS

J. Domaradzki
G. Mellor

ACTIVITIES FY82

A paper (k) which summarizes and updates the Mellor-Yamada turbulence closure model was revised and accepted for publication. In addition to basic equations, the paper contains examples of model applications and numerous citations of other applications.

In order to avoid the need for a macroscale length scale equation, a study of the two-point correlation equations was initiated. A fairly simple closure hypothesis was found from isotropic, homogeneous decaying turbulence with which several aspects of this problem can be understood.

PLANS FY83

Work on the extension of the turbulence closure model to include condensation physics and cloud radiation will be restarted after a two year suspension of effort.

Attempts will be made to generalize the two-point correlation equation study to include non-isotropy and stratification.

9.3 COASTAL AND ESTUARINE OCEANOGRAPHY

G. Mellor D. Henn*
L. Oey

ACTIVITIES FY82

Work was completed (vv) on the simulation of tidal elevation and currents on the Hudson/Raritan Estuary system using the two-dimensional version of our coastal ocean and estuarine model. Calculated results and data comparison was extensive and favorable.

An x-z-t version of the coastal ocean model has been applied to study the salinity and velocity structure in the Hudson River. Longitudinal dispersion due to the density-induced vertical gravitational circulation was found to give the required mechanism for the observed salinity intrusion. Thus, due to sufficient vertical resolution, no artificial horizontal diffusion is needed to provide the correct dispersion process. The complete xyz-t model is now being applied to the entire Hudson-Raritan estuary.

Theoretical analysis based on a small Froude number, asymptotic expansion was initiated to study steady-state salinity structure and density-induced flows in partially mixed and well mixed estuaries. The analysis displays an inner-outer salinity structure; the inner region is positioned just upstream of the mouth of the estuary seaward of which large increases in width, depth and horizontal mixing occur. It has a horizontal length scale of the order $(gH\Delta\rho/\rho_o)^{1/2}H^2/A_v$ where $g=9.8\ m\ s^{-2}$, H is an average depth, ρ_o is the referenced density, $\Delta\rho$ is the density difference between the fresh water and the sea water and A_v is the vertical eddy viscosity. The solution depends critically on the longitudinal variations of the width, depth and dispersion functions near the mouth of the estuary. Once the geometry of the estuary is fixed, the solution depends only on three-dimensionless parameters: Froude number, Richardson number and friction velocity; all of which can be estimated from the gross characteristics of the estuary.

PLANS FY83

The xyz-t model computation for the entire Hudson-Raritan estuary will be completed and compared with observations. The bottom friction parameter obtained from this computation will be used in conjunction with a barotropic model to study the effects of meteorological forcings on the residual currents in the bay.

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*Mechanical and Aerospace Dept., Princeton University

A study of the Delaware Bay and River Estuary system paralleling the Hudson-Raritan study will be initiated.

The asymptotic analysis will be extended to unsteady and/or three-dimensional flows. These will be conducted in parallel with detailed comparison with observation of the numerical model results obtained for the Hudson and Delaware rivers.

APPENDICES

APPENDIX A

GFDL Staff Members

and

Affiliated Personnel

during

Fiscal Year 1982

Joseph Smagorinsky, Director	FTP
Rosemary Kelly-Champ, Secretary	FTP
Isidoro Orlanski, Deputy Director	FTP
Howard M. Frazier, Assistant Director	FTP
Joyce C. Jarvis, Secretary	PTP
Annette Chandler, Secretary	WAE

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Fraulino, Philip	Librarian	PTP
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Sletta, Helen	Clerk Typist	FTT*
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White, Robert	Research Associate	FTP
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Boland, Frederick	Research Associate	FTP*
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Strickler, Robert	Sr. Research Associate	FTP

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Osinger, Johannes	Student	PU
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Polinsky, Larry	Research Associate	FTP
Ross, Bruce	Sr. Research Associate	FTP
Shaginaw, Richard	Research Associate	FTP
Steele, Michael	Student	PU

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Lipps, Frank	Research Scientist	FTP
Hemler, Richard	Research Associate	FTP
Mellor, George	Professor	PU
Domaradzki, J.A.	Visiting Scientist	PU
Oey, Lie-Yauw	Visiting Scientist	PU

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Bachmeister, Julio	Student	PU
Blakely, George	Computer Programmer PT	PU*
Bryan, Frank	Student	PU
Callan, Johann	Secretary	PU
Gardiner-Garden, Robert	Student	PU
Guinn, Elizabeth	Computer Programmer PT	PU
Hellerman, Solomon	Computer Programmer PT	PU

* Affiliation terminated prior to September 30, 1982

Kawase, Mitsubiro (7/82-9/82)	Student	PU
Kerber, John	Computer Programmer PT	PU*
Key, Robert	Research Associate	PU
Olsen, Esther	Secretary	PU
Redi, Martha	Research Staff	PU*
Snieder, Roelof	Student	PU
Dahlen, F. Anthony	Professor	PU
Wahr, John	Research Staff	PU

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Caldwell, Lee	Maintenance Engineer	TI
Devlin, Thelma	Secretary	TI
Fedor, John	Maintenance Engineer	TI
Iasello, Anthony	Maintenance Engineer	TI
Schaffer, Ralph	Maintenance Engineer	TI
Smith, Mark	Maintenance Engineer	TI

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Jacobson, Elaine	Analyst	CDC
Lehane, Denis	Senior Analyst	CDC
Mansfield, Harold	Senior Analyst	CDC
Reif, Atara	Associate Analyst	CDC
Siebers, Bernard	Analyst	CDC
Skelly, Gretchen	Analyst	CDC
Decker, Gregory	Consultant	CDC
Davis, Robert	Systems Analyst	CDC
Markowitz, Alan	Systems Analyst	CDC
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Dorado, Manual	Senior Customer Eng.	CDC
Egland, Randall	Senior Customer Eng.	CDC
Greshko, Edward	Senior Customer Eng.	CDC
Johnson, Eric	Senior Customer Eng.	CDC
Thompson, Robert	Senior Customer Eng.	CDC
Weiss, Edward	Senior Customer Eng.	CDC

PERSONNEL SUMMARY

September 30, 1982

FTP - Full Time Permanent (GFDL)	84
PTP - Part Time Permanent (GFDL)	2
WAE - When Actually Employed (GFDL)	1
Junior Fellows (GFDL)	6
Visiting Scientists (PU)	6
Students (PU)	12
Professors (PU)	3
Secretaries (PU)	2
Texas Instruments Advanced Scientific Computer (ASC) Maintenance (TI)	6
Control Data Corporation Computer Systems Program Conversion Support Staff	22
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APPENDIX B

GFDL

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NOTE: THIS IS A PARTIAL LISTING OF GFDL PUBLICATIONS. A COPY OF THE COMPLETE BIBLIOGRAPHY CAN BE OBTAINED BY CALLING 609-452-6502 (FTS AND COMMERCIAL) OR BY WRITING TO:

Director
Geophysical Fluid Dynamics Laboratory
Princeton University - Post Office Box 308
Princeton, New Jersey 08540

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LUSEN, Ronald	(227)
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MIYAKODA, Kikuro	(20),(60),(72),(85),(89),(91),(107),(109),(119),(120), (122),(132),(139),(154),(158).(166),(180),(181), (220),(227),(276),(291),(295),(328),(412),(450), (457),(b),(j),(u),(xx)
MOLLER, FRITZ	(10),(11),(13),(14)
MOXIM, W. J.	(239),(308),(323),(367),(379),(386),(413),(452)
MOYER, R. W.	(60),(122)
NAPPO, C. J.	(109)
OEY, L. Y.	(vv)
OORT, Abraham H.	(73),(77),(83),(90),(95),(106),(115),(118),(126), (145),(148),(168),(169),(171),(174),(175),(188), (197),(232),(245),(279),(285),(287),(290),(299), (360-A),(394),(407),(408),(420-A),(g),(ii),(ccc), (ddd)
ORLANSKI, Isidoro	(61),(82),(84),(114),(130),(146),(159),(160),(173), (188-A),(200),(201),(224),(249),(277),(288),(296), (301).(355),(374),(376),(411),(414),(425),(425-A), (445),(ww),(yy)

APPENDIX C

Computational Support

APPENDIX C

Computational Support

FY81 has been filled with preparations for the new Control Data Corporation (CDC) CYBER 200 System that is replacing the Texas Instruments Advanced Scientific Computer (TI/ASC) as the computing system for the Laboratory. The front-end CYBER 170/720 was installed in September 1981, and the CYBER 200/205 was installed in June 1982. A second CYBER 200/205 is to be installed in August 1984.

As part of the CYBER-System contract, CDC has maintained a staff of 9-10 people in the laboratory to provide program-conversion service to the various projects. The purpose of this effort has been to assure that production models are ready to run on the CYBER 200 without diverting the normal scientific activities of the laboratory staff. Approximately 200,000 lines of code have been processed to varying degrees of checkout and efficiency, so that important models have been put into production within the first month on the CYBER 200. The program conversion effort will be continued into 1983, when it will taper off.

The availability of the front-end CYBER 170 during FY82 has permitted the Systems staff of the laboratory to become thoroughly familiar with CDC systems and to install on the front end a user interface and library capability analogous to what will be available on the CYBER 200. The computational power of the CYBER 170 is 100 to 1000 times less than the CYBER 200, so it is not suited to the long production of sophisticated models that characterizes the main research of the laboratory. The front end has been very powerful for small problems, however, such as those attempted by the students in the GFD Program. The front end has also permitted the rest of the Laboratory to "get its feet wet" with a CDC CYBER System, in advance of the CYBER 200 being available.

The CYBER 200 was connected and running in May 1982. The benchmark demonstration for installation was attempted on May 30, 1982, but technical flaws and continued system problems delayed the successful installation until June 15, 1982. As of August 1 the acceptance test that follows installation was marked by a series of hardware faults that delayed successful acceptance.

During FY82 the TI/ASC has been more and more fully dedicated to FGGE in anticipation that the rest of the laboratory will be utilizing the new CYBER System. The overall efficiency of the FGGE processing is less than the efficiency of the general work load of the laboratory, so the realized number of CPU hours on the ASC has generally diminished through the year.

TABLE C-1. Achieved CPU Hours for GFDL Systems

Month	TI/ASC	CYBER 720	CYBER 205
Sep. 81*	574	127	
Oct. 81	484	179	
Nov. 81	572	26	
Dec. 81	583	100	
Jan. 82	587	60	
Feb. 82	502	273	
Mar. 82	520	455	
Apr. 82	470	403	
May 82	471	400	
Jun. 82	489	372	**
Jul. 82	417	437	**
Aug. 82	413	390	**
Sep. 82	**	**	**

* Data not reported in the FY81 Annual Report

** Data not available

TABLE C-2. Average Monthly ASC CPU Hours by Fiscal Year

Fiscal Year	CPU Hours per Month
1982	(501)†
1981	551
1980	508
1979	513
1978	497
1977	523
1976	499

† Based on eleven months of data

APPENDIX D

Seminars Given at GFDL

During Fiscal Year 1982

October 1, 1981	"Symmetric Instability and Spatial Oscillations in a Rotating Fluid" by Dr. Charles Quon, Bedford Institute, Dartmouth, Nova Scotia
October 7, 1981	"Nonlinear Energy Transfer of Transient Planetary Waves" by Dr. Y. Hayashi and Donald G. Golder, Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey
October 8, 1981	"The Nonlinear Interactions between Normal Modes in GFD Models" by Dr. Ronald M. Errico, National Center for Atmospheric Research, Boulder, CO
October 14, 1981	"A Review of Theories for Tropospheric Stationary and Quasi-Stationary Eddies - Part II" by Dr. Isaac M. Held, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
October 15, 1981	"Large Amplitude Stationary Waves in the Southern Hemisphere" by Dr. Eugenia Kalnay, NASA Goddard Space Flight Center, Greenbelt, MD
October 20, 1981	"Numerical Simulation of a Laboratory Model of the Oceanic Circulation" by Dr. A. Bennett, Monash University, Australia
October 21, 1981	"Numerical Simulation of the Eye of a Hurricane" by Morris Bender and Dr. Yoshio Kurihara, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
November 4, 1981	"The Development and Transport Properties of Individual Disturbance in the 3-Dimensional Baroclinic Atmosphere" by Prof. J-P Chao, Laboratory of Dynamical Climatology, Institute of Atmospheric Physics, Academia Sinica, Beijing, Peoples Republic of China
November 10, 1981	"Application of Numerical Model Output to Compute Orographic Precipitation" by Dr. Magne Lystad, The Norwegian Meteorological Institute, Oslo, Norway
November 12, 1981	"Predictability of Time Averages" by Dr. Jagadish Shukla, NASA Goddard Space Flight Center, Greenbelt, MD
November 17, 1981	"The Oceanographic Role of the Arctic Shelf Seas" by Dr. Knut Aagaard, University of Washington, School of Oceanography, Seattle, WA
November 18, 1981	"Numerical Study of Long-Term Climatic Oscillations using a Coupled Atmosphere-Ocean Primitive Equation Model" by Prof. Chen Xiong-Shan, Institute of Atmospheric Physics, Academia Sinica, Beijing, Peoples Republic of China
November 20, 1981	"Canada and the CO_2 Effect - Problems of a Northern Country" by Dr. F. Kenneth Hare, Trinity College, University of Toronto, Ontario, Canada

November 23, 1981	"Symmetric Baroclinic Wave-Cisk" by Dr. Kerry A. Emanuel, Massachusetts Institute of Technology, Department of Meteorology and Physical Oceanography, Cambridge, Mass.
November 25, 1981	"Effect of Soil Moisture Anomalies on Short-Term Climate and Hydrology Change" by Prof. T. C. Yeh, Institute of Atmospheric Physics, Academia Sinica, Beijing, Peoples Republic of China, Dr. Syukuro Manabe and Mr. R. T. Wetherald, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
December 1, 1981	"Moist Convection and Vertical Momentum Flux" by Dr. Frank B. Lipps and Mr. Richard Hemler, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
December 3, 1981	"Concentric Eye Walls, Secondary Wind Maxima and the Evolution of the Hurricane Vortex" by Dr. H. E. Willoughby, National Hurricane Research Laboratory/NOAA, Coral Gables, FL
December 8, 1981	"On the Evolution of Nonlinear Planetary Eddies Larger than the Radius of Deformation" by T. Yamagata, Research Institute for Applied Mechanics, Kyushu, Japan
December 17, 1981	"The Ventilation of the Deep Sea: Sources, Patterns and Rates" by Prof. W. S. Broecker, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY
January 5, 1982	"Acid Rain - A Global Perspective" by Dr. Hiram Levy II, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
January 7, 1982	"The Intrusion of a Density Current Along the Wall in a Rotating Fluid" by Dr. John A. Whitehead, Jr., Woods Hole Oceanographic Institution, Woods Hole, MA
January 8, 1982	"Ice-Ocean Characteristics in the Marginal Ice Zone" by Dr. Peter Wadhams, Scott Polar Research Institute, Cambridge University, England
January 12, 1982	"Description of a Hydrodynamic Instability through a Nonlinear Space-Dependent Amplitude Equation" by Dr. J. A. Domaradski, Institute of Geophysics, University of Warsaw, Poland
January 12, 1982	"Major Climatic Events as Expected During a Prolonged CO_2 Induced Warming" by Professor Hermann Flohn, Meteorologische Institut der Universitat Bonn, Federal Republic of Germany
January 14, 1982	"Computational Chaos and Instability, and the Design of Perfectly Energy-Conservative Computational Scheme" by Professor Zeng Qing-Cun, Institute of Atmospheric Physics, Academia Sinica, Beijing, Peoples Republic of China
January 17, 1982	"Review of Venus Conference" by Dr. Stephen B. Fels, Geophysical Fluid Dynamics Laboratory, Princeton, NJ

January 21, 1982	"Eddy Resolving General Circulation Models" by Dr. W. R. Holland, National Center for Atmospheric Research, Boulder, CO
January 22, 1982	"The Ventilated Thermocline" by Dr. James R. Luyten, Woods Hole Oceanographic Institution, Woods Hole, MA
January 28, 1982	"Modons and their Riders in Geophysical Flows" by Dr. C. E. Leith, National Center for Atmospheric Research, Boulder, CO
January 29, 1982	"Milankovitch Cycles through Six Hundred Million Years" by Prof. Alfred G. Fischer, Geological and Geophysical Sciences, Princeton University, Princeton, NJ
February 2, 1982	"Towards Coupling the Ocean and Ice in Cold Latitudes" by Dr. Lakshmi Kantha, Dynalysis of Princeton, Princeton, NJ
February 4, 1982	"Empirical Orthogonal Functions: Analytical Examples, Sampling Theory, and Extension to the Time Domain" by Dr. Gerald R. North, NASA Goddard Space Flight Center, Greenbelt, MD
February 9, 1982	"Isopycnal Mixing in the Ocean" by Dr. Martha Redi, Geophysical Fluid Dynamics Program, Princeton University, Princeton, NJ
February 11, 1982	"Hydrography and Geochemistry of the Bering Sea" by Mr. R. Toggweiller, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY
February 16, 1982	"UK Met Office Experience in Programming New Analysis and Forecast Model on CYBER 205" by Dr. Alan Dickinson, Meteorological Office, Berkshire, United Kingdom
February 16, 1982	"Numerical Experiment on the Effect of Isolated Large-Scale Orography upon Transient Eddies" by Dr. H. Nakamura, Geophysical Institute, Tokyo University, Tokyo, Japan
February 17, 1982	"Vorticity Balance in the Tropics at 200 mb" by Prashant Sardeshmukh, Geophysical Fluid Dynamics Program, Princeton University, Princeton, NJ
February 18, 1982	"The Evolution of Forced Non-Linear Vortices" by Mr. William Dewar, Department of Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, Mass.
February 23, 1982	"Ocean Response to Atmospheric CO_2 Warming" by Mr. Fred G. Komro, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
February 26, 1982	"Simulations and Observations of Stratospheric Sudden Warmings" by Dr. Tim Palmer, Department of Atmospheric Sciences, University of Washington, Seattle, WA

March 2, 1982	"Ocean Response to Mesoscale Atmospheric Forcing" by Dr. Isidoro Orlanski, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
March 10, 1982	"Planetary Normal Modes in Non-Uniform Background Configurations" by Dr. Murry Salby, National Center for Atmospheric Research, Boulder, CO
March 17, 1982	"Upper Ocean and Lower Atmosphere Low-Frequency Variability: Tropical Pacific, 1961-1978" by Dr. James O'Brien, Department of Meteorology, The Florida State University, Tallahassee, FL
March 18, 1982	"An Analysis of SEASAT Altimeter Measurements over a Coastal Area: The English Channel" by Prof. C. Le Provost, Charge de Recherche au C.N.R.S., Institute de Mecanique de Grenoble, France
March 18, 1982	"Western Boundary Currents: The Effects of Topography, Stratification and Changing Wind Stress" by Dr. H. Muira, Geophysical Institute, University of Tokyo, Tokyo, Japan
March 19, 1982	"The Weddell Gyre" by Dr. Arnold Gordon, Lamont- Doherty Geological Observatory of Columbia University, Palisades, NY
March 19, 1982	"Toward an Automotive Energy Policy" by Dr. Robert Howell Williams, Center for Energy and Environmental Studies, Princeton University, Princeton, NJ
March 23, 1982	"Influence of Oceanic Heat Transport on Sensitivity of Model Climate" by Mr. Michael J. Spelman and Dr. Syukuro Manabe, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
April 6, 1982	"Coastal Oceanograpy" by Dr. George Philander, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
April 8, 1982	"A Critical Layer Phenomenon in Non-Linear Stability Theory" by Dr. Joseph Pedlosky, Woods Hole Oceanographic Institution, Woods Hole, Mass.
April 13, 1982	"El Nino-Southern Oscillation" by Dr. George Philander, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
April 13, 1982	"Transonic Flow Calculations" by Prof. Antony Jameson, Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey
April 20, 1982	"Design of Mesoscale Group's 3-D Model with Some Solutions" by Drs. Bruce B. Ross and Isidoro Orlanski, Geophysical Fluid Dynamics Laboratory
April 30, 1982	"Stochastic Effects in Climatic Dynamical Systems" by Prof. Barry Saltzman, Department of Geology and Geophysics, Yale University, New Haven, CT

May 12, 1982	"On Steady Salinity Distribution and Circulation in Partially Mixed and Well Mixed Enstrophy" by Dr. L-Y Oey, Science Applications, Inc., La Jolla, CA
May 13, 1982	"Climate Impacts of Changing Atmospheric Compositions" by Dr. James Hansen, NASA Goddard Institute for Space Studies, New York, NY
May 17, 1982	"Enhancement of the Internal Gravity Waves in the Atmosphere by Oxygen Recombination Heating" by Dr. Taroh Matsuno, University of Tokyo, Tokyo, Japan
May 17, 1982	"The Truth About the General Circulation of the Stratosphere and Mesosphere" by Dr. Kevin Hamilton, National Center for Atmospheric Research, Boulder, CO
May 20, 1982	"High Latitude Pleistocene Oceanographic Changes and Their Bearing on the Ice Age Climatic Cycle" by Dr. James Hays, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY
May 28, 1982	"The Stability of Rectified Currents and a New Critical Layer Balance" by Prof. Lee-Or Merkine, Technion, Israel
June 1, 1982	"Modeling Arctic and Antarctic Sea Ice Fluctuations" by William Hibler,III, US Army Cold Regions Research Laboratory, Hanover, NH
June 7, 1982	"Linear Wind-Driven Interannual Variability in the Western Tropical Pacific Ocean and its Relation to the El Nino Event" by Dr. Kensuki Takeuchi, Department of Meteorology, The Florida State University, Tallahassee, FL
June 11, 1982	"Studies of Southern Hemisphere Climatic Changes from Modelling and Observations" by Prof. W. F. Budd, Meteorology Department, University of Melbourne, Victoria, Australia
June 25, 1982	"Aspects of the Gulf Stream Recirculation Zone" by Dr. James McWilliams, National Center for Atmospheric Research, Boulder, CO
June 30, 1982	"On the Response of the Ocean to a Moving Storm: Parameters and Scales" by Dr. Richard Greatbatch, Cambridge University, Cambridge, United Kingdom
July 1, 1982	"A Conservation Law for Time-Averaged Disturbances on a Wavy Basic Flow" by Dr. David G. Andrews, Department of Atmospheric Physics, Oxford University, Oxford, United Kingdom
July 2, 1982	"A Parametric Regime Diagram Derived from a Series of Numerical Atmospheric General Circulation Experiments" by Dr. Robert Gall, University of Arizona, Tucson, AZ

August 12, 1982	"The Circulation of the North Atlantic Ocean as Inferred from β-Spirals" by Dr. D. Olbers, Max-Planck Institut fur Meteorologie, Hamburg, Federal Republic of Germany
August 26, 1982	"Tides and the Evolution of the Earth-Moon System" by Dr. D. J. Webb, Institute of Oceanographic Sciences, Surrey, England

APPENDIX E

Talks, Seminars and Papers Presented Outside GFDL

During Fiscal Year 1982

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TALKS, SEMINARS, AND PAPERS PRESENTED OUTSIDE GFDL
October 1, 1981 through September 30, 1982

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
October 5, 1981	Mr. Jeffrey J. Ploshay "A Status Report of the GFDL Level III-b Data Producer"	Sixth Session of the World Meteorological Organization European Center Inter-Governmental Panel on the FGGE Working Group on Data Management Washington, D.C.
October 5, 1981	Dr. Du-zheng Ye "The Effect of Snow Cover and Soil Moisture on the Atmospheric Circulation"	Indiana State University Terre Haute, Indiana
October 6, 1981	Dr. Du-zheng Ye "Meteorology of the Tibetan Plateau"	University of Illinois Urbana, Illinois
October 7, 1981	Dr. Peter Lemke "Stochastic Description of Atmosphere-Sea Ice-Ocean Interaction"	Nato Advanced Study Institute on Air-Sea-Ice Interaction Maratea, Italy
October 9, 1981	Dr. Du-zheng Ye "The Thermal Effects of the Tibetan Plateau on the Atmospheric Circulation"	University of Wisconsin Madison, Wisconsin
October 12, 1981	Dr. Syukuro Manabe "CO_2 and Climate"	Symposium on "Advances in the Theory of Climate" Academy of Sciences of Lisbon Lisbon, Portugal

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
October 12, 1981	Dr. Abraham H. Oort "Global Climate Requirements from Observation"	Symposium on "Advances in the Theory of Climate" Academy of Sciences of Lisbon Lisbon, Portugal
October 12, 1981	Dr. Joseph Smagorinsky "The Beginnings of Numerical Weather Prediction and General Circulation Modeling - Early Recollections"	Symposium on "Advances in the Theory of Climate" Academy of Sciences of Lisbon Lisbon, Portugal
October 12, 1981	Dr. Du-zheng Ye "Meteorology Activities in China"	University of Chicago Chicago, Illinois
October 14, 1981	Dr. Ji-ping Chao "An Anomaly Model and its Applications to Long-Range Prediction" (with R. Caverly)	Sixth Annual Climatic Diagnostic Workshop Lamont-Doherty Geological Observatory Palisades, New York
October 15, 1981	Dr. Charles Tony Gordon "Sensitivity of GCM-Diagnosed Radiative Fluxes to "Observed" Monthly Mean Distributions of Cloudiness"	Sixth Annual Climate Diagnostics Workshops Lamont-Doherty Geological Observatory Palisades, New York
October 15, 1981	Mr. Douglas G. Hahn "Observational Network and Climate Monitoring"	Sixth Annual Climate Diagnostics Workshop Lamont-Doherty Geological Observatory Palisades, New York

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
October 15, 1981	Dr. Qing-cun Zeng "Non-linear Interaction of Planetary Scale Atmospheric Motion and the Rotational Adjustment"	Laboratory for Atmospheric Research University of Illinois at Urbana-Champaign Urbana, Illinois
October 16, 1981	Dr. Kikuro Miyakoda "Three Cases of One-Month GCM Forecasts"	Sixth Annual Climate Diagnostics Workshop Lamont-Doherty Geological Observatory Palisades, New York
October 16, 1981	Dr. Qing-cun Zeng "On Computational Instability and Chaos and the Design of Perfectly Energy-Conservative Schemes"	Laboratory for Atmospheric Research University of Illinois at Urbana-Champaign Urbana, Illinois
October 19, 1981	Dr. Abraham H. Oort "The Role of the Atmosphere and Oceans in the Climate"	University of Utrecht The Netherlands
October 21, 1981	Dr. Lie Yauw Oey "Tidal Modeling of New York Bay"	Mid-Atlantic Bight Physical Oceanography Workshop
October 21, 1981	Dr. Qing-cun Zeng "Evolution of Disturbances and Their Interactions with the Basic Current"	Department of Geophysical Sciences University of Chicago Chicago, Illinois
October 22, 1981	Dr. Qing-cun Zeng "Nature of Computational Chaos and Instability"	Department of Geophysical Sciences University of Chicago Chicago, Illinois

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October 23, 1981	Dr. Joseph Smagorinsky "Scientific Basis for the Monsoon Experiment"	JSC/WCRP International Conference on "The Scientific Results of the Monsoon Experiment" Bali, Indonesia
October 26, 1981	Mr. Prashant Sardeshmukh "Role of Baroclinic Instability in the Growth of Monsoon Disturbances"	International Conference on Scientific Results of the Monsoon Experiment Denpasar, Bali, Indonesia
October 26, 1981	Dr. Qing-cun Zeng "Non-linear Interaction of Planetary Scale Atmospheric Motion and the Rotational Adjustment"	Department of Meteorology University of Wisconsin Madison, Wisconsin
October 29, 1981	Professor George L. Mellor "Application of a Numerical Ocean Model to the California Coastal Ocean"	28th Annual Eastern Pacific Ocean Conference Idlewild, California
October 30, 1981	Dr. George Philander "Comparison of Models of Equatorial Oceans"	Equatorial Oceanography Meeting Lamont-Doherty Laboratory Palisades, New York
November 2, 1981	Dr. Stephen B. Fels "Venusian Stratospheric Circulation"	Conference of the Venus Environment Palo Alto, California
November 2, 1981	Mr. Joseph Sirutis "Comparative Integrations by Global Models with Various Parameterized Processes of Subgrid-Scale Vertical Eddy Transports"	Fifth Conference on Numerical Weather Prediction Monterey, California

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
November 3, 1981	Dr. Kikuro Miyakoda "Simulation of a Blocking Event in January 1977"	Fifth Conference on Numerical Weather Prediction Monterey, California
November 3, 1981	Dr. Gareth P. Williams "The General Character of Planetary Circulations: Where Venus Fits In"	International Conference on the Venus Environment NASA Ames Research Center Palo Alto, California
November 4, 1981	Dr. Jerry D. Mahlman "M.A.P. Status Report"	Meeting of the Academy Committee on Solar-Terrestrial Research Washington, D.C.
November 5, 1981	Mr. David Crisp "Radiative Transfer in the Venus Stratosphere"	International Conference on the Venus Environment Palo Alto, California
November 5, 1981	Mr. Ronald J. Stouffer "CO_2 Induced Climate Change as Simulated by a Mathematical Model of the Earth's Climate"	Department of Meteorology Pennsylvania State University State College, Pennsylvania
November 12, 1981	Professor George L. Mellor "A Numerical Model of the Hudson-Raritan Estuary"	Stevens Institute of Technology Hoboken, New Jersey
November 19, 1981	Dr. Abraham H. Oort "A New Picture of the Global Energy Cycle"	Goddard Space Flight Center Laboratory for Atmospheric Sciences Greenbelt, Maryland

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
November 19, 1981	Mr. James G. Welsh Cost/Performance Evaluation in the GFDL Computer Procurement"	Computer Performance Evaluation Users Group San Antonio, Texas
November 29, 1981	Dr. Du-zheng Ye (1) "Effects of Snowcover and Soil Moisture on Short Term Climate Change" (2) "Summer Circulation Over Tibetan Plateau" (3) "Characteristics of Scales of Atmospheric Motion"	European Center for Medium Range Weather Forecasts Meteorological Office of the United Kingdom Reading, England
December 1, 1981	Dr. George Philander "Coastal Upwelling and Eastern Boundary Currents"	University of Washington Seattle, Washington
December 2, 1981	Dr. Du-zheng Ye "Effects of Snowcover and Soil Moisture on Short Term Climate Change"	Meteorological Office of the United Kingdom Bracknell, England
December 3, 1981	Professor George L. Mellor "A Numerical Model of the Hudson-Raritan Estuary"	National Ocean Survey/NOAA Rockville, Maryland
December 9, 1981	Dr. Peter Lemke "Response of the Mixed Layer and Pycnocline Under Polar Sea Ice to Seasonal Forcing"	American Geophysical Union Fall Meeting Special Session on Marginal Ice Zone Processes San Francisco, California
December 15, 1981	Dr. Jerry D. Mahlman "The Middle Atmosphere Program"	The National Research Council Committee on Atmospheric Sciences Meeting Washington, D.C.

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
December 15, 1981	Dr. Abraham H. Oort "Status Report on GFDL Activities Concerning Marine Data Set"	Equatorial Pacific Ocean Climate Studies Program Workshop Washington, D.C.
December 15, 1981	Dr. Du-zheng Ye "Characteristics of Scales of Atmospheric Motion"	European Center for Medium Range Weather Forecasts Reading, England
December 16, 1981	Dr. Peter Lemke "Seasonal Response of Mixed Layer and Pycnocline Under Polar Sea Ice"	Goddard Laboratory for Atmospheric Science Greenbelt, Maryland
January 18, 1982	Dr. Jerry D. Mahlman "A Simplified View of Stratospheric Transport"	Aeronomy Laboratory ERL/NOAA Boulder, Colorado
January 22, 1982	Dr. Jerry D. Mahlman "Acid Rain: A Global Modeling Perspective"	University of Wyoming Department of Atmospheric Sciences Laramie, Wyoming
January 28, 1982	Mr. Douglas R. MacAyeal "Tidal Circulation in the Ross Sea, Antarctica"	NASA Goddard Space Flight Center Greenbelt, Maryland
January 28, 1982	Dr. Isidoro Orlanski "Ocean Response to Mesoscale Atmospheric Forcing"	Atlantic Oceanographic and Meteorological Laboratory/NOAA Miami, Florida

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
February 12, 1982	Dr. Qing-cun Zeng "The Propagation and Evolution of Rossby-wave Packet in 3-Dimensional Baroclinic Atmosphere"	Joint seminar at the Department of Meteorology and Physical Oceanography and Department of Mathematics Massachusetts Institute of Technology Cambridge, Massachusetts
February 18, 1982	Dr. Qing-cun Zeng "The Propagation and Evolution of Rossby-wave Packet in 3-Dimensional Baroclinic Atmosphere"	Woods Hole Oceanographic Institution Woods Hole, Massachusetts
February 19, 1982	Dr. Isaac M. Held "A Review of Theories for Stationary and Quasi-Stationary Waves in the Extratropical Troposphere"	Massachusetts Institute of Technology Cambridge, Massachusetts
February 26, 1982	Dr. Stephen B. Fels (1) "A Parameterization of Scale Dependent Radiative Damping in the Middle Atmosphere" (2) "Zonal Models of the Venusian Stratosphere"	Department of Atmospheric Sciences University of California at Los Angeles Los Angeles, California
March 3, 1982	Dr. Ji-ping Chao "The Anomaly Model and its Application to Long-Range Prediction"	National Center for Atmospheric Research Boulder, Colorado
March 4, 1982	Dr. Ji-ping Chao "A Theory and Method of Long-Range Forecasting"	University of Wisconsin Madison, Wisconsin

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
March 4, 1982	Dr. Qing-cun Zeng "The Propagation and Evolution of Rossby Wave Packets in a 3-dimensional Baroclinic Atmosphere"	National Center for Atmospheric Research Boulder, Colorado
March 5, 1982	Dr. Ji-ping Chao "A Theory and Method of Long-Range Forecasting"	University of Chicago Chicago, Illinois
March 5, 1982	Dr. Qing-cun Zeng "Some Problems of Remote Sensing of the Atmosphere"	National Center for Atmospheric Research Boulder, Colorado
March 8, 1982	Dr. Syukuro Manabe (1) "Mathematical Modeling of Large Scale Distribution of Cloud Cover" (2) "Climate Monitoring - Early Detection of CO_2 Effect"	Third Session of the Joint Scientific Committee Dublin, Ireland
March 9, 1982	Dr. Kirk Bryan "Ocean Surface Dynamics"	Ocean Science Board Meeting National Academy of Sciences Washington, D.C.
March 9, 1982	Dr. Qing-cun Zeng "On the Evolution of Disturbances and Interaction with Zonal Flow"	Atmospheric Sciences Department University of Washington Seattle, Washington
March 11, 1982	Dr. Ji-ping Chao "A Theory and Method of Long-Range Forecasting"	Climate Analysis Center Washington, D.C.
March 11, 1982	Dr. Qing-cun Zeng "Nonlinear Waves in Rotating Shallow Water Equations"	Department of Mathematics University of California Berkeley, California

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
March 12, 1982	Dr. Joseph Smagorinsky "The Beginnings of Numerical Weather Prediction and General Circulation Modeling"	Joint Scientific Committee for the World Climate Research Programme Dublin, Ireland
March 12, 1982	Dr. Qing-cun Zeng "Nonlinear Computational Instability and the Design of Perfectly Energy-conservative Schemes"	Applied Mathematics Seminar Stanford University Palo Alto, California
March 19, 1982	Dr. Qing-cun Zeng "The Propagation and Evolution of Rossby-wave Packet in a 3-dimensional Baroclinic Atmosphere"	Department of Atmospheric Sciences University of California Los Angeles, California
March 22, 1982	Dr. Qing-cun Zeng "The Evolution of Disturbances and Their Interaction with the Zonal Flow"	Geophysical Fluid Dynamics Institute Florida State University Tallahassee, Florida
March 23, 1982	Dr. George Philander "Variability of Tropical Oceans"	University of Miami Miami, Florida
March 26, 1982	Dr. Joseph Smagorinsky "Reflections of the Early History of Numerical Weather Prediction"	National Aeronautics and Space Administration Greenbelt, Maryland
March 26, 1982	Dr. Qing-cun Zeng "The Design of Economical and Perfectly Energy Conserving Numerical Schemes"	National Meteorological Center Washington, D.C.
March 29, 1982	Dr. Syukuro Manabe "CO_2 and Climate Change"	University of Toronto Toronto, Canada

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
March 29, 1982	Dr. Qing-cun Zeng "Some Problems of Remote Sensing of the Atmosphere from Satellites"	National Meteorological Center Washington, D.C.
March 30, 1982	Dr. Syukuro Manabe "CO_2 and Climate Change"	Atmospheric Environment Service Ottawa, Canada
March 30, 1982	Dr. Qing-cun Zeng "The Propagation and Evolution of Rossby-wave Packets in the Atmosphere"	Goddard Space Flight Center Greenbelt, Maryland
April 6, 1982	Mr. Michael Cox "On the Florida/Antilles Current System in a Numerical Model of the North Atlantic"	Cooperative Institute for Marine and Atmospheric Studies of the University of Miami and NOAA Miami, Florida
April 20, 1982	Mr. Sydney Levitus "Distribution of Geostrophic Shear in the World Ocean"	Woods Hole Oceanographic Institute Woods Hole, Massachusetts
April 27, 1982	Dr. George Philander "Coastal Upwelling and Eastern Boundary Currents"	Woods Hole Oceanographic Institute Woods Hole, Massachusetts
April 28, 1982	Dr. George Philander "El Nino - Southern Oscillation"	Rhode Island School of Oceanography Kingston, Rhode Island
May 6, 1982	Dr. Joseph Smagorinsky "Carbon Dioxide and Climate"	State University of New York State University College at Brockport Brockport, New York

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
May 7, 1982	Dr. Isidoro Orlanski "Mesoscale Predictability"	Japan Meteorological Agency Tokyo, Japan
May 10, 1982	Dr. Syukuro Manabe "Study of Climate by a Mathematical Model of Joint Ocean-Atmosphere Systems"	Joint Scientific Committee/CCCO Study Conference on Large Scale Oceanographic Experiments in the World Climate Research Programme Tokyo, Japan
May 10, 1982	Dr. Isidoro Orlanski (1) "Ocean Response to Atmospheric Forcing" (2) "The Evolution of a Cold Front"	Tokyo University Tokyo, Japan
May 12, 1982	Dr. George Philander "Variability of Tropical Oceans"	Committee on Climate Change and the Oceans Meeting Tokyo, Japan
May 12, 1982	Dr. Bruce Ross "Research Activities of the Mesoscale Group"	Joint MSD/SSD Meeting with ERL Estes Park, Colorado
May 15, 1982	Dr. Isidoro Orlanski "Mesoscale Predictability"	Institute of Atmospheric Physics Beijing, China
May 17, 1982	Dr. Jerry D. Mahlman "Problems in Modeling Stratospheric N_2O"	Aeronomy Laboratory ERL/NOAA Boulder, Colorado
May 21, 1982	Mr. Michael Cox "Long Equatorial Waves in a Numerical Model of the Pacific"	EPOCS Workshop on 110°W Measurements Seattle, Washington
May 23, 1982	Dr. Joseph Smagorinsky "Carbon Dioxide and Climate"	University of Illinois Urbana, Illinois

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
May 24, 1982	Dr. Syukuro Manabe "CO_2 and Climate Change"	Japan Meteorological Society Kyoto University Kyoto, Japan
May 24, 1982	Dr. Isidoro Orlanski "Orographically Induced Vortex Centers"	Workshop on Mountain Meteorology Institute of Plateau Atmospheric Physics of Academic Sinica Beijing, China
May 25, 1982	Dr. Hiram Levy II (1) "Combustion Nitrogen: A Global Perspective" (2) "Classical Tropospheric Ozone: A GCM/Transport Study"	Second Symposium on the Composition of the Nonurban Troposphere Williamsburg, Virginia
May 26, 1982	Dr. Yoshikazu Hayashi "Development of Space-Time Spectral Analysis and its Applications to Atmospheric Waves"	Meteorological Society of Japan Tokyo, Japan
May 28, 1982	Dr. Isidoro Orlanski "Orographically Induced Vortex Centers"	Institute of Plateau Atmospheric Physics of Academic Sinica Lanzhou, Gansu Province, China
May 31, 1982	Dr. Martha H. Redi "Numerical Studies of an Ocean Model with Density Dependent Vertical Mixing"	American Geophysical Union Spring Meeting Philadelphia, Pennsylvania
May 31, 1982	Mr. James Carton "Stochastic Forcing of Eastern Basin Circulation"	American Geophysical Union Spring Meeting Philadelphia, Pennsylvania

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
June 1, 1982	Dr. Kirk Bryan "The Ocean's Role in Delaying Climate Change"	American Geophysical Union Meeting Philadelphia, Pennsylvania
June 1, 1982	Dr. Isaac Held (1) "Climate Models and the Astronomical Theory of the Ice Ages" (2) "A Review of the Theory of Stationary Waves in the Troposphere"	American Geophysical Union Meeting Philadelphia, Pennsylvania
June 1, 1982	Dr. Abraham H. Oort "Global Climatic Variations in Relation with Sea Surface Temperature Anomalies in the Equatorial Pacific Ocean for the 1963-1973 Period"	American Geophysical Union Meeting Philadelphia, Pennsylvania
June 1, 1982	Dr. Bruce B. Ross "The Design of a GFDL Mesoscale Model and its Application to Real-Data Situations"	CIMMS Symposium on Mesoscale Modeling Norman, Oklahoma
June 1, 1982	Ms. Anne Seigel "Simulation of the Seasonal Cycle in the Eastern Tropical Pacific Ocean"	American Geophysical Union Philadelphia, Pennsylvania
June 1, 1982	Dr. Toshio Yamagata "Interannual Variability of the Kuroshio Extension and its Relation to the Southern Oscillation"	American Geophysical Union Spring Meeting Philadelphia, Pennsylvania

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
June 2, 1982	Dr. Lie-Yauw Oey "Tidal Modeling of the Hudson-Raritan Estuary"	American Geophysical Union Spring Meeting Philadelphia, Pennsylvania
June 7, 1982	Mr. Morris Bender "A Numerical Simulation of the Eye of a Tropical Cyclone"	American Meteorological Society's Fourteenth Conference on Hurricanes and Tropical Meteorology San Diego, California
June 7, 1982	Mr. Robert Tuleya "An Investigation of Sea Surface Temperature Sensitivity of a Numerical Model of Tropical Storm Genesis"	American Meteorological Society's Fourteenth Technical Conference on Hurricanes and Tropical Meteorology San Diego, California
June 14, 1982	Dr. Kirk Bryan "The Role of the Ocean in the Transient Response of Climate to Atmospheric CO^2"	IOS/Environement Canada Patricia Bay, British Columbia
June 21, 1982	Dr. George Philander "Ocean Processes I"	Oceanographic Summer School Nice, France
July 7, 1982	Dr. Isaac Held "On the Direction of Eddy Momentum Fluxes in Baroclinic Instabilities"	Geophysical Fluid Dynamics Summer Colloquium Woods Hole Oceanographic Institution Woods Hole, Massachusetts

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DATE	SPEAKER AND TITLE OF PRESENTATION	OCCASION AND PLACE OF PRESENTATION
July 12, 1982	Dr. George Philander "Variability of Tropical Oceans"	Oceanographic Summer School Nice, France
July 15, 1982	Mr. James A. Carton "Modeling Eastern Basin Circulation"	Dalhousie University Halifax, Nova Scotia
July 21, 1982	Dr. Toshio Yamagata "The Role of Damped Equatorial Waves in the Oceanic Response to Winds"	Woods Hole Oceanographic Institution Woods Hole, Massachusetts
July 26, 1982	Professor Jorge L. Sarmiento "Penetration of Tritium in the North Atlantic Main Thermocline"	GFD Summer Program, Symposium on Chemical and Biological Tracers in Fluids Woods Hole Oceanographic Institution Woods Hole, Massachusetts
July 28, 1982	Dr. George Philander "Modeling of the Tropical Atlantic"	SEQUAL Meeting Columbia University New York, New York
August 3, 1982	Dr. Kirk Bryan "The Role of the Ocean in the Transient Responses of Climate to Increasing CO_2"	Meeting of the Joint Ocean Congress Halifax, Nova Scotia
August 3, 1982	Mr. Anthony J. Rosati "Experimental Simulation of the Sea Surface Temperature Using an Oceanic GCM"	Joint Oceanographic Assembly Halifax, Nova Scotia

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August 9, 1982	Professor Jorge L. Sarmiento "Three-dimensional Modeling and Descriptive Studies of Tritium in the North Atlantic"	Joint Oceanographic Assembly Halifax, Nova Scotia
August 23, 1982	Dr. Stephen B. Fels "Scale Dependent Damping in the Terrestrial Middle Atmosphere"	Oxford University Department of Atmospheric Physics Oxford, England
September 13, 1982	Dr. Jerry D. Mahlman "1-D and Multidimensional Models for Studying Stratospheric Perturbations"	WMO Meeting on Radiative Properties of Ozone and Other Minor Constituents Boulder, Colorado
September 13, 1982	Dr. Kikuro Miyakoda "Surface Boundary Forcings"	JSC Study Conference on the Physical Basis for Climate Prediction on Seasonal, Annual and Decadal Time Scales Leningrad, U.S.S.R.
September 13, 1982	Dr. Abraham H. Oort "Climate Variability; Observational Evidence and Variability Simulated by Climate Models"	JSC Study Conference on the Physical Basis for Climate Prediction on Seasonal, Annual and Decadal Time Scales Leningrad, U.S.S.R.