FINAL REPORT FOR GRANT NAGW-1831

NASA BASE FUNDING TO THE COOPERATIVE INSTITUTE FOR METEOROLOGICAL SATELLITE STUDIES (CIMSS)

A Report to the

National Aeronautics and Space Administration (NASA)
Washington, DC 20233

Submitted by the
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608/262-0544

August 1994

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I. INTRODUCTION

This Final Report for NASA Grant NAGW-1831 summarizes program support from the National Aeronautics and Space Administration (NASA) to the Cooperative Institute for Meteorological Satellite Studies (CIMSS) for basic research services and programs described in their Memorandum of Understanding (MOU) of 1988.

The Memorandum of Understanding between NASA, NOAA, and the University of Wisconsin-Madison reaffirms their common interests in atmospheric and earth system science research, emphasizing satellite technology. The MOU outlines the CIMSS mission as:

(1) Foster collaborative research between NASA, NOAA and the University in those aspects of atmospheric and earth science which exploit the use of satellite technology;

(2) Serve as a center at which scientists and engineers working on problems of mutual interest may focus on satellite-related research in atmospheric studies and earth system science; and

(3) Stimulate the training of scientists and engineers in the disciplines involved in the atmospheric and earth sciences.

The theme underlying the NASA - UW Base Grant is Earth System Science. Funds provided through this grant were used to support studies related to the development and implementation of NASA's Mission to Planet Earth Program. This support provided for the CIMSS scientist exchange program, student research assistantships and Post Doctoral studies, education through the sponsorship of workshops and seminars, and a small portion of CIMSS' administrative and NASA related travel needs. Finally, an essential part of the NASA Base Grant funding supported "first look" research projects that often lead to the formulation of independent proposals. Below is a summary by category of these programs supported by this NASA Base Grant to the CIMSS. A summary of budget expenses is included in Section IX.

II. SCIENTIST EXCHANGE PROGRAM

CIMSS maintains strong collaborative ties with numerous national and international scientific research, operational and academic groups. This scientific interaction brings many experts to CIMSS during the year. CIMSS scientific personnel also participate in numerous conferences, workshops, symposia and meetings. Perhaps the most mutually beneficial aspect of these scientific exchanges are extended visits, where collaboration and interaction can flourish over a period of time. CIMSS also sponsors various scientists who visit for shorter periods to participate in cooperative research and to use the facilities available through CIMSS. While every effort is made to select scientists who are funded by their parent organization, funds are still required to defray travel, per diem, and in some cases, augment salaries. It should be emphasized that visiting scientists work in broad areas of satellite applications which are of general interest, and not on narrowly defined tasks which could more properly be conducted under individual, more specific grants or contracts.

Table 1 displays a list of visiting scientists who enjoyed significant stays at CIMSS (generally 6 months or more) and received support from this NASA Base Grant. The cooperative work that occurred during their visits is discussed below.

Table 1: Visiting Scientists To CIMSS supported by NASA Grant NAGW-1831

Elen C. Cutrim	Department of Meteorology University of Belem, Brazil
Ma Xia-Lin	State Meteorological Administration Beijing, PRC
Robert Rabin	National Severe Storms Laboratory Norman, Oklahoma
Jean Marc Theriault	Defense Research Establishment Valcartier Quebec, Canada
Paul vanDelst	Curtin Institute of Technology Perth, Australia
Toshiro Inoue	Meteorological Research Institute Ibaraki, Japan
Youri Plokhenko	Hydrometeorological Center of Moscow Moscow, Russia

Professor Elen Cutrim has worked jointly with CIMSS scientists for several years, jointly funded through a Fulbright scholarship, an NSF grant, and this NASA Base Grant. Dr. Cutrim worked in Brazil on the Amazon Boundary Layer Experiment (GTE-ABLE) during 1986. Her research on the Amazon hydrologic cycle continued at CIMSS using the in situ data base collected in Brazil together with satellite data archived at CIMSS during the field experiment. The NASA Base Grant provided partial support to Dr. Cutrim to deliver lectures on Amazonia, both locally and nationally, and participate in collaborative research with CIMSS' and other scientists. This research program has led to numerous conference reports, articles in refereed journals and a proposal, funded by NSF, to continue this work. CIMSS scientists continue to apply satellite radiance measurement techniques to study aerosol creation and dispersion over Amazonia, supported by a NASA grant.

Dr. Cutrim currently holds a teaching and research position at Western Michigan University, but continues collaboration with CIMSS' scientists. The satellite-based work of Dr. Cutrim and her research partners at the University of Wisconsin has provided an improved understanding of the hydrologic cycle and the impact of deforestation on Amazonian and global water processes.

Ma Xia-Lin, from the State Meteorological Administration, Beijing, PRC is an expert on the McIDAS (Man-computer Interactive Data Access System), having served as the McIDAS chief of operations in China. He is also a skilled scientist working with satellite radiance applications to remote sensing of atmospheric and surface phenomena.

While at CIMSS Mr. Ma has developed analysis techniques applicable to AVHRR, VAS and TOVS satellite radiance data. He investigated the longwave spectral radiative properties as needed for the development of parameterizations to use in large scale numerical models, or for use in sounding retrieval models. Cloud spectral emissivity and reflectivity in the 8-12 μm region was determined from observations by the High spectral resolution Interferometer Sounder (HIS), which flies aboard the NASA ER/2 aircraft.

Mr. Ma has also contributed greatly to the development of advanced-sounder profile retrieval methods. He has developed retrieval software successfully tested using NASA ER/2 HIS observations acquired during a number of scientific field programs. This work by Mr. Ma contributes to the NASA EOS/AIRS algorithm development program. Mr. Ma continues his

participation in this program during the coming year through support by the NASA AIRS grant to CIMSS.

Mr. Ma's significant accomplishments as a visiting scientist at CIMSS have resulted in furthering several NASA sponsored programs. A significant portion of Ma Xia-Lin's visiting scientist salary was supported by this NASA Base Grant.

Dr. Robert Rabin, from the National Severe Storms Laboratory (NSSL), Norman, OK, has been stationed at CIMSS since February 1989. Dr. Rabin has been involved in several collaborative studies while at CIMSS which emphasize Earth System Science. Dr. Rabin has conducted studies on the application of DMSP SSM/I microwave radiances to develop methods for estimation of surface wetness using the WETNET data base. Since vegetation decreases the sensitivity to soil moisture in the microwave, emission in that region is affected by plant water content. Thus, in addition to moisture availability from the soil, vegetation type and morphology are factors in plant water content. Since the instantaneous evapotranspiration over vegetated regions depends on the plant water content and soil moisture, this value might be gauged from microwave measurements.

Dr. Rabin is also examining the use of ERBE, AVHRR, and GOES data to diagnose the cloud-coupled effect of vegetation cover and soil moisture on the earth's radiation budget. He has initiated a project which studies small scale convective patterns based on soil type and topography and their feedback on the local earth-atmosphere micro-system. Dr. Rabin's work is at a very small cost to the NASA Base Grant; however, his work has a distinct multi-disciplinary aspect to studies of the earth-atmosphere, and the NASA Base Director's fund has contributed a small portion of support for computer and materials to aid in this study. Dr. Rabin's work at CIMSS has led to two funded proposals, one to NOAA and one to NASA, to continue these studies.

Jean-Marc Theriault, Defense Research Establishment (DREV) Valcartier, Quebec, Canada, spent a year at CIMSS working on innovative methods for retrieval of atmospheric profiles from infrared emission spectra. Dr. Theriault's visit was supported by DREV and the U.S. Air Force Geophysics Laboratory (AFGL). The NASA Base Grant provided support for Dr. Theriault's computing facilities and travel to field programs and conferences.

The major goals of his visit included the analysis of atmospheric spectroscopy, the development of remote sensing methods for the retrieval of atmospheric state parameters from

infrared emission spectra, such as that to be obtained by the EOS-AIRS, and participation in field programs making interferometric radiation measurements. The spectroscopy project focused on studies to improve models of the water vapor continuum used in current line-by-line radiative transfer models. The remote sensing retrieval methods concentrated on the elaboration of an algorithm to include aerosol extinction in transmittance calculations.

Mr. Paul vanDelst of the Curtin Institute of Technology, Perth, Australia spent one year at CIMSS during this grant period. His visit to CIMSS included working with the ground-based HIS thermodynamic profiler, comparing synthetic and real atmospheric spectra, and assisting in the development of a retrieval methodology for trace gas species. Synthetic spectra are derived using the AFGL FASCOD3P model available at CIMSS, and radiosonde data collected during field programs. Mr. vanDelst participated in the FIRE/SPECTRE and STORMFEST field programs, gaining experience with the data collection system and the operational and calibration procedures required to produce high quality radiometric data.

Mr. vanDelst has provided valuable assistance to the NASA-funded CIMSS Trace Gas Retrieval program, and has gained a sound working knowledge of interferometry. Mr. vanDelst returned to Australia with several excellent data sets to use in the completion of his Ph.D. dissertation. Mr. vanDelst's salary support was provided by the Curtin Institute of Technology. CIMSS provided him with a portion of his living expenses through the NASA Base Grant.

Dr. Toshiro Inoue of the Japan Meteorological Research Institute has visited CIMSS several times for extended collaboration. Dr. Inoue is very interested in operational and research satellite data processing methods and has worked with CIMSS researchers on the feasibility of extracting low level wind vectors by tracing low level moisture observed with GOES-7. A portion of Dr. Inoue's living expenses were provided through the NASA Base Grant.

Dr. Youri Plokhenko, a Branch Chief with the Russian Hydrometeorological Center, Moscow, visited CIMSS for one year during this grant period. Dr. Plokhenko has developed and implemented a temperature and moisture retrieval profiling technique in Russia using NOAA TOVS radiance measurements. Dr. Plokhenko visit to CIMSS focused on the exchange of retrieval ideas and testing his techniques with the International TOVS Processing Package (ITPP). NASA Base funds provided support for Dr. Plokhenko salary, travel and computer resources.

The broad scope and high quality work of these and other visiting scientists has led to noteworthy benefits in terms of NASA's objectives. A strong foundation is laid for future cooperative research programs after these scientists return to their home institutions.

III. STUDENT RESEARCH ASSISTANTSHIPS

In keeping with the basic educational goals of the University, CIMSS supports several Research Assistants (RAs) yearly. These students conduct research in atmospheric science topics using remote sensing radiance data under the guidance of UW-Madison faculty members and scientists who participate in the CIMSS Program. The NASA Base Grant provided financial support each semester to one or two students seeking advanced degrees in satellite applications to the atmospheric sciences. Table 2 indicates CIMSS graduate students who received support from this NASA Base Grant, with their degree and thesis title. Below are brief summaries of graduate students who received support from the CIMSS' NASA Base Grant.

Table 2: Graduate Student Degree and Thesis Topics Supported by the NASA Base Grant

Zhang, Hai-Yan "The Spectral Variation of Surface Emissivity Across the 8-12 Micron "Window"; M.S., August 1990.

Qu, Yanni "A Technique for the Simultaneous Retrieval of Trace Gas Concentration from Spectral Radiance Observations"; M.S., August 1991.

McKeown, Walt "Sensing air/water interface temperature gradients with 2.0 - 5.0 micron interferometery"; Ph.D., December 1993

Feltz, Wayne "Meteorological Applications of the Atmospheric Emitted Radiance Interferometer (AERI)"; M.S., August 1994.

Ms. Zhang Hai Yan completed her Master's degree work in August 1990. Ms. Zhang examined the use of HIS spectra obtained from NASA ER/2 flights, to determine the variation of surface emissivity from 8 to 12 μm. Since nearly 20% of the earth's total radiative emission is lost direct to space within this spectral region, knowledge of the surface emissivity is crucial in the

study of the earth-atmosphere radiation budget. This variation in emissivity is also important for improving precise land-surface temperature retrieval and in climate modelling. Ms. Zhang thesis showed the spectral emissivity variation in this region is mostly homogeneous, with a small but significant variation between 10 to 12 μm, which can be used to separate water from vegetated land.

Yanni Qu was supported for her Master's degree studies using HIS spectra to infer the total concentration of radiatively active trace gases. Ms. Qu used an algorithm developed by CIMSS for simultaneous retrieval of O_3, H_2O, NO_2, CO, and the CFC's. Her work demonstrates the potential for using a high spectral resolution instrument, such as the EOS-AIRS, to make measurements that will produce accurate determinations of the total concentrations of these important atmospheric trace gases. Ms. Qu participated in the South East Regional Oxident Network (SERON) field program in August 1992 to assist in gathering of NASA ER/2 HIS measurements to correlate with the in-situ atmospheric chemistry data set. This data set is currently the basis for her Ph.D. studies at CIMSS.

Dr. Walter McKeown was supported for his Ph.D. studies with NASA Base Grant funds. The Ground-Based HIS (GB-HIS) instrument was operated in two field programs with the Naval Postgraduate School in Monterey, California in which upward looking measurements were taken during 4 day research ship cruises. On one research trip, coincident HIS aircraft measurements were obtained from a NASA ER/2 flight out of Ames, CA. While onboard the ship, Mr. McKeown assisted in taking measurements of sea and air temperature with conventional instruments and a hand-held radiometer.

Dr. McKeown next conducted laboratory experiments which used the CIMSS GB-HIS to detect the characteristic spectral signature of liquid water. Intrinsic variations in the effective optical depth of water with frequency indicate that interferometric spectra can carry information about the temperature gradient in the upper 0.5 mm of water. Fifty-seven laboratory experiments were done using the GB-HIS instrument, viewing both distilled and standard sea water under a wide range of fluxes. As in radiometric atmospheric sounding, a radiance vs. wavelength gradient in selected spectral regions may be interpreted as a temperature vs. depth gradient. The experiment's results strongly indicate that the temperature gradient in the upper 0.1 mm of water can be determined remotely (e.g. from space) using radiometric measurements within the 2.0 - 5.0

μm (2000 - 5000 wavenumber) region. Compared with independently-measured fluxes, GB-HIS spectral fluxes from liquid temperature gradients were similar in sign, numerical values, and rate of change with time. Dr. McKeown developed this research idea for the Ph.D. dissertation with an analysis to present liquid temperature gradient determination accuracy as a function of instrument altitude, solar reflection, instrument noise, aerosols and atmospheric state parameters.

Dr. McKeown is also engaged in public speaking on scientific issues. While a graduate student supported by this NASA Base Grant, Mr. McKeown gave a presentation entitled, "Climate Change and the Utilities Industry" to executives and customer representatives of the Wisconsin Gas & Electric Company. Aimed at presenting an evaluation of and access to climatic forecasts for use by industry, the talk covered climate changes over relevant time scales, how climate models operate and accuracy evaluations. NASA was credited with support for preparation of this talk.

Wayne Feltz was supported by the NASA Base Grant while working towards his M.S. degree. Mr. Feltz used radiance measurements from the GB-HIS instrument, taken from the FIRE/SPECTRE, VOCAR, and CAMEX field experiments to examine meteorological applications of the GB-HIS. During Mr. Feltz's studies, the GB-HIS retrieval algorithm was evolved to produce continuous high quality thermodynamic soundings of the Planetary Boundary Layer (PBL). Mr. Feltz's thesis demonstrated the GB-HIS capability to capture numerous meteorological phenomena, including the magnitude of the Pacific trade wind inversion, regions of high radar ducting due to strong vertical temperature and moisture gradients, PBL diurnal evolution, and the boundary layer response to cold front and dry line phenomena.

IV. POST DOCTORAL STUDIES

Dr. Allen Hung-Lung Huang worked at CIMSS following completion of his Ph.D. studies in a Post Doctoral position to continue his investigations with HIS data analysis and the optimization of the HIS thermodynamic profiling algorithm. Dr. Huang's specific research objective was the development of the HIS temperature and moisture sounding algorithm. Dr. Huang also worked to develop algorithms for combined microwave and infrared sounder data, specifically that to be achieved from the NOAA K, L, M, N series of satellites. Dr. Huang was supported extensively by the NASA Base Grant in his post doctoral work. More recently Dr. Huang accepted a Scientist position with CIMSS and is working on the development of an

optimized sounding retrieval algorithm for the EOS AIRS instrument, a CIMSS activity supported by NASA.

Dr. Huang also has worked towards development of a technique to determine performance requirements for future sounding instrumentation. The technique develops a new objective analysis approach using information theory to determine design criteria. This objective technique can be used to evaluate instrument design performance specifications for atmospheric state parameters such as temperature, moisture, and trace gas concentration.

Lynn McMurdie continued her Ph.D. studies, performed at the University of Washington, at CIMSS in a Post Doctoral position. Dr. McMurdie worked on applications of microwave water vapor radiance measurements from operational and research weather satellites. Her work with CIMSS Scientist Chris Velden led to the development of methods for incorporating data from several satellite instrument platforms for the comprehensive examination of strong mid-latitude cyclones.

V. WORKSHOPS AND SEMINARS

CIMSS sponsors numerous seminars and lectures each year. The CIMSS' NASA Base funding provided support for many presentations, with honorariums and/or per diem expenses provided to visiting speakers. The seminar and lecture program series is an integral part of the CIMSS mission to participate nationally and internationally in fostering the understanding of satellite-based information and its applications to the atmospheric sciences. These seminars are given by scientists who have stimulated significant research progress in the development and implementation of satellite remote sensing of the environment, or who have made significant contributions in applying remote sensing data toward the understanding of environmental processes. A list of seminar speakers and titles is provided in Table 3 below.

Table 3: CIMSS Seminars: FY90-93

Johannes Schmetz and Kenneth Holmlund
European Space Agency, Darmstadt, FRG
March 26-30, 1990
"Operational Products from METEOSAT"

James Purdom
NOAA/NESDIS RAMM Branch
Fort Collins, CO
April 3, 1990
"Satellite Diagnosis of Convective Scale Interaction"

Henry Reichle, Jr.
Chemistry and Dynamics Branch
NASA Langley Research Center
April 30, 1990
"Measurements of Atmospheric Constituents from Satellites"

William Rossow
Goddard Institute for Space Studies
New York, NY
May 8, 1990
"Clouds and Climate Observations from ISCCP"

Oscar Huh
Coastal Studies Institute
Louisiana State University
Baton Rouge, LA
July 26, 1990
"Cloud Front Passages as Geologic Agents Along the Louisiana Deltaic Coastline"

K. T. Kriebel
Institute for Atmospheric Physics
German Aerospace Research Establishment (DLR)
July 31, 1990
"Use of AVHRR in DLR"

Christopher Hayden
NOAA/NESDIS Systems Design and Applications Branch
Madison, WI
September 18, 1990
"Height Assignment and Objective Editing of Cloud Motion Winds"

Steven Ackerman
Cooperative Institute for Meteorological Satellite Studies
Madison, WI
October 22, 1990
"Everything You Wanted to Know About the Radiative Properties of Clouds, But Didn't Have the Data Set"

Fengxian Zhou
Institute of Atmospheric Physics
Academia Sinica
Beijing, PRC
October 26, 1990
"Research on Computer Classification/Identification of Satellite Imageries"
"Brief Introduction of Chinese Polar Orbiting Meteorological Satellite"

Robert Merrill[1]
Robert Aune[2]
Gary Wade[2]
Robert Rabin[3]
[1]Cooperative Institute for Meteorological Satellite Studies
[2]NOAA/NESDIS Systems Design and Applications Branch, Madison, WI
[3]NOAA/ERL National Severe Storms Laboratory
Norman, OK
January 24, 1991
"GUFMEX Report"

Allen Huang
Cooperative Institute for Meteorological Satellite Studies
Madison, WI
February 13, 1991
"Future Hybrid Infrared and Microwave Satellite Sounding System"

Leroy Herman
NOAA/NESDIS Systems Design and Applications Branch
Madison, WI
February 13, 1991
"Semi-Automated Measurement of Cloud Motion at High Latitude from Polar Orbiting Satellites"

Tim Schmit
Cooperative Institute for Meteorological Satellite Studies
Madison, WI
March 6, 1991
"VAS Observed Sudden Stratospheric Warming (SSW)"

Frank Honey
Specterra Systems Pty Ltd
Perth, Australia
May 10, 1991
"Thoughts on Airborne Remote Sensing Instrumentation"

Robert Knuteson
CIMSS/SSEC
University of Wisconsin-Madison
May 29, 1991
"Recent Baby HIS Field Experiment; Platteville, CO, and Eastern Pacific

Christoper Velden
CIMSS/SECC
University of Wisconsin-Madison
June 4, 1991
"The Impact of Satellite-derived Winds on Tropical Cyclone Analysis and Track Forecasting

Jonathon D. Kahl
Asst. Prof.
UW-Milwaukee
July 18, 1991
"Applications and Limitations of Trajectory Models"

Steve Ackerman
CIMSS/SSEC
University of Wisconsin-Madison
October 15, 1991
"Climate Studies Using collocated AVHRR, HIRS/2 & ERBE Observations"

Allen Huang
CIMSS/SSEC
University of Wisconsin-Madison
January 22, 1992
"A New Retrieval Product from AMSU"

Leroy D. Herman
NOAA/NESDIS Systems Design and Applications Branch
Madison, WI
February 2, 1992
"Obtaining cloud motion vectors from polar orbiting satellites"

Johannes Schmetz
ESOC
April 1, 1992
"Upper Troposheric Humidity from METEOSAT"

Klaus Schafer
Fraunhofer Institute for Atmospheric Environmental Research
April 10th, 1992
"Remote Sensing of Air Pollution by Mobile Fourier-Transform Spectroscopy: Radiation Transfer Modeling and First Results of Measurements."

Charles Anderson
North Carolina State University
April 27th, 1992
"Tornado Warning Research"

Alan Johnson
Forecaster; NWSFO
Slidell, LA
June 8th, 1992
"Development of Techniques to Forecast Weather Hazards Along the Gulf Coast"

Stephen Stadler
Associate Professor of Geography
Oklahoma State University
June 19th, 1992
"The Oklahoma Mesonet Project"

Lance Leslie
Bureau of Meteorology Research Center
Melbourne, Australia
July 3rd, 1992
"The New BMRC Operational Model"

Toshiro Inoue
Meteorological Research Institute
Tsukuba-shi, Japan
July 17th, 1992
"The Use of Split Window Data in Rainfall Estimation"

Klaus Schafer
Fraunhofer-Institute for Atmospharische Umweltforschung
Garmisch-Partenkirchen
August 26th, 1992
"Remote Sensing of the Atmosphere in Germany and Recent Results at the Fraunhofer-Institut fur Atmospharische Umweltforschung"

Zhao Bolin
Beijing University
November 2nd, 1992
"TOVS-Applications In Asia"
November 17th, 1992
"Western North-Pacific Cloud-Radiation Experiment (WENPEX)-Regional Experiment of ISCCP"

Mervyn Lynch
School of Physics and Geosciences
Curtin University of Technology
Perth, Western Australia
February 5th, 1993
"Remote Sensing Research in Western Australia"

James Purdom
NOAA/NESDIS
Colorado State University
Fort Collins, CO
February 24th, 1993
"Mesoscale Applications of Satellite Data"

Christopher Neale
Utah State University
Department of Agriculature & Irrigation Engineering
Logan, Utah
May 18th, 1993
"Remote Sensing of Land Surface Characteristics Using Passive Microwave"

Jordan C. Alpert
NOAA/NESDIS
National Weather Service
Washington, DC
July 7th, 1993
"Global Modelling Activities at NMC"

VI. ADMINISTRATIVE SUPPORT

With the exception of Base Grant support from NOAA and NASA, the UW CIMSS exists entirely on funds received through the competitive proposal process. As such, it is often very difficult to conduct important peripheral programs, such as those described above. Another element of the NASA Base Grant support is Administrative support for the CIMSS

Director, the Program Manager and a Secretary. This cost is supported mostly by the NOAA Base Grant and by other research grants that those individuals participate in. However, the NASA Base Grant was also used to provide support for these administrative persons, when they were conducting NASA related activities.

The CIMSS Program Manager provides the day-to-day administration of CIMSS' research programs, including the NASA Base Grant. His duties also include coordination of the visiting scientist and graduate student programs, and the guest lecture series. A summary of all spending on this grant is provided in Section IX.

VII. TRAVEL TO MEETINGS OF KEY INTEREST TO NASA

The NASA Base Grant to CIMSS provided some travel support to conferences and workshops sponsored by NASA. In the early stages of development of the EOS program, the NASA Base Grant support travel for the SSEC Director, Dr. Francis Bretherton, and the CIMSS Director, Dr. William L. Smith, to attend EOS planning meetings.

VIII. DISCRETIONARY RESEARCH EFFORTS

The Director's Discretionary Research Fund, a key program within the NASA Base Grant, provided support for small initiatives to investigate the feasibility of a research concept. These projects were normally for 1 person to spend a person-month or two and some computer resources to examine a concept and demonstrate a need for further investigation. Many of the projects supported through this "seed" program went on to be supported through the formal proposal process. Below are summaries of the Discretionary Research efforts that were supported through this NASA Base Grant.

The UW Cirrus Remote Sensing Pilot Experiment was conducted over south-central Wisconsin from 1 November to 6 December 1990. Ground and satellite-based observations of clear skies and various cirrus-cloud systems were made during this one-month period to investigate the visible and IR optical properties of cirrus clouds. Financial support for the observational part of the experiment was provided by the University of Wisconsin Space Science and Engineering Center. Post-experiment data analysis of the rooftop-based, upward-looking ground-based HIS data, a high spectral resolution LIDAR, the Scripps Whole-Sky Imager and an NCAR CLASS

radiosonde system, was funded in part through the NASA Base Director's Discretionary Research Fund. Dissemination of the results of this experiment at conferences, workshops and meetings has aided in CIMSS proposals being funded for participation in the SPECTRE (concurrent with FIRE II) and Department of Energy ARM programs. Results should lead to a better knowledge of the effects of cloud optical properties and their spatial distribution on the scaling of point measurements to satellite and General Circulation Model grid scale averages.

CIMSS' Director's Discretionary Research funds were also used to support a portion of the GTE/ABLE research at CIMSS (the majority of financial support was derived from an NSF grant and Brazilian salary support for Dr. Elen Cutrim). The CIMSS Amazonia project used GOES VAS data to estimate atmospheric moisture, moisture transport, rainfall and evapotranspiration, all elements of the hydrologic cycle, to demonstrate that satellite remote sensors can play a key role in the definition and understanding of global climate-scale systems. The hydrologic cycle program results were presented in three AMS journal publications and an issue of the CIMSS View Newsletter devoted to Amazonia research.

The Director's Discretionary Research Fund also supported a laboratory experiment to attempt measurement of heat flux from water to air using high spectral HIS measurements. The experiment was conceptualized by Ph.D. candidate Walter McKeown, and included the participation of several HIS science team members. A controlled environment wind-water flume was constructed which permitted close regulation of temperature and the generation of a logarithmic wind profile with height above the water surface. The HIS aircraft instrument was mounted above the water tank, looking downward at the water-air environment. From theoretical and model calculations it was surmised that by utilizing HIS spectral measurements in the 3-5 μm region, the water temperature variations with depth in the first millimeter of water could be measured. Results from this experiment indicated a strong signal in water temperature variation with depth. The measurement of ocean surface heat flux would be an extremely valuable quantity in earth-atmospheric research.

The NASA Base Grant provided partial support for two CIMSS scientists to deliver a lecture series in Beijing, China. The program, sponsored by the United Nations World Meteorological Organization, provided 6 days of lecture material on two topics; a general course on Principals of Satellite Meteorology and a more specific course on Satellite Applications to Tropical Cyclones. Thomas Achtor and Chris Velden of CIMSS delivered the lecture material at the Satellite Meteorological Agency (SMA) in Beijing in October 1991 to participants from 13

Pacific rim countries. The United Nations provided travel and per diem expenses. The NASA Base Grant provided partial salary support for the course preparation.

In 1992, the NASA Base Grant provided partial support for four CIMSS scientists to take the GB-HIS instrument on an oceanic research experiment off the coast of California. The project was primarily supported by the Navy, but the NASA Base Grant provided some funds to support a data analysis collaboration with Professor Chuck Wash of the Naval Postgraduate School and Steve Rugg, a NPGS graduate student.

Another key Discretionary Research Fund project supported by the NASA Base Grant was conducted by CIMSS scientist Chris Velden, who examined satellite signatures in extratropical cyclones. Mr. Velden used satellite radiance data from the GOES, POES and DMSP satellites to acquire a detailed remote sensing data base for several storms from the ERICA field program. Among several interesting findings was an extra-tropical warm core signature in the microwave radiances, indicating strong stratospheric folding in deep cyclones of this type. Mr. Velden has reported his findings in a Journal article and made several conference presentations on the topic.

The start of an outreach initiative was supported in part through the NASA Base Grant funding. This program brings McIDAS computer technology and its wide assortment of atmospheric and surface data to the K-12 school environment. Given the lowering costs for computer hardware and the increase in high speed communications, CIMSS began a program to introduce McIDAS to high school teachers and students, and to seek ways to utilize this state-of-the-art tool in the classroom. In the fall of 1992, the Watertown WI School District Superintendent, Dr. Susan Hotter, several members of the school board, school administration and science teachers visited SSEC/CIMSS and were given an extensive overview of the McIDAS environment. As a result, a collaborative program was started with the Watertown High School. CIMSS has loaned a McIDAS OS/2 PC system to the Watertown High School, while the school system provided release time to two teachers, Lee Buescher and Ron Graewin, to learn McIDAS. The following summer these two teachers, with technical support from CIMSS scientists (Tom Achtor, Kathy Strabala and Gary Wade), developed the first two education modules, which introduce students to McIDAS and instruct them in basics of data manipulation. Modules have also been started to teach the basics of remote sensing (for high school general science, chemistry and physics classes), to study the AVHRR-derived vegetation index (for biology classrooms) and for meteorology instruction in aeronautics classes.

Significant additional funding is required to expand the high school McIDAS program across the state and the nation. However, the aim of this initial program is to demonstrate how modern research tools can be used to interest students and improve classroom instruction, thereby attracting the nation's best students into science and engineering careers. NASA Base Grant funding provided support to begin this project and a subsequent NASA grant helped to continue this outreach program (additional funding is from the NASA-sponsored Space Grant Program).

For several years a major need of the data assimilation/forecast modeling group at CIMSS was a dedicated computer for model experimentation and development. CIMSS runs a version of the Bureau of Meteorology Research Center (Australia) four dimensional data assimilation - primitive equation model in several research programs, including NASA sponsored programs studying precipitation formation and assimilation of measurements for new instrument systems (e.g. AMSU and AIRS). The SSEC McIDAS system (IBM 4381) serves as a data base manager for a wide assortment of satellite and other data products. Modelling activities on the McIDAS system were limited by a lack of dedicated computing power and expensive operating costs (McIDAS charges are by cpu time used). With the need to expand data assimilation studies for remote sensing measurements, and the desire to develop more detailed radiative transfer models of the atmosphere, a dedicated modelling computer system was deemed necessary. The NASA Base Grant helped purchase an IBM RISC 6000 series Model 550 computer for modelling work. This system has greatly expanded the opportunities for modelling activities at CIMSS, allowing more experimentation and leading to improved model performance. Recently, the data assimilation/numerical weather prediction model was run in real time during the STORM-FEST program.

Additionally, a generalized version of FASCOD3P has been developed for the RISC system, allowing fast, efficient calculation of atmospheric transmittance. In support of the EOS/AIRS program, the IBM 6000 was used for development of the AIRS retrieval algorithm. This computer system has been key to testing of the AIRS retrieval methodology. The successes of these programs are due in part of the computing power this machine has provided.

Finally, an effort to accelerate the "All Mode" Ingestor development for the Pathfinder program was supported by the NASA Base Grant. The SSEC undertook a six month effort to accelerate the development of an "All Mode" Ingestor. The "All Mode" Ingestor is the primary component of the enhanced GOES Archive and Retrieval System (GARS). Analysis of Climate

oriented products from the Geostationary Operational Environment Satellite (GOES) archive data set has been of high interest to NASA's Earth Observing System (EOS) program. The SSEC developed the GARS to provide access to mesoscale data sets for NOAA Data customers. SSEC also developed a Pathfinder Climate Product Generation (CPG) Subsystem of the GOES Archive and Retrieval System under NOAA contract. The CPG enhancement provides improved data management, data access, product generation and distribution for the GOES archive. The NASA wanted to accelerate this development effort so this additional effort was made.

IX. BUDGET SUMMARY

The total funding received over a four year period from NASA Base Grant NAGW-1831 was $830,826. An approximate summary of spending is provided in Table 4.

Table 4: NASA Base Grant Expenditures

Labor	$349K
Graduate Student Support	96K
Materials	11K
McIDAS	25K
Travel	30K
Services	2K
Fees	6K
Equipment	90K
University Overhead	221K
Total	$830K

For labor, 26% of the costs were for the "All Mode" Ingestor study that was added to this grant. Administrative costs were 27% of the labor costs; the rest of the labor costs supported visiting scientists and UW scientists working on Director's Discretionary Research projects.

For Graduate Students, the total spending includes salary support for their Research Assistant appointments and out-of-state tuition remission, required by the UW.

For McIDAS, the costs are for use of the SSEC McIDAS mainframe for data acquisition and processing.

For equipment, $41K or 46% of the costs were for the "All Mode" Ingestor study that was added to this grant. The remaining equipment costs were for the CIMSS IBM 6000 computer discussed above and for lease of desktop personal computers for UW scientists participating in NASA Base Grant activities.