The Eugene Rasmusson Symposium

18 January 2007

San Antonio, Texas

FOREWORD

It is an honor and great pleasure to present to you the Eugene Rasmusson Symposium. The idea of honoring Gene through an AMS Named Symposium was suggested by several individuals and groups in 2004-05, and spearheaded by the AMS Climate Variability and Change Committee (Dian Seidel, Chair) following a conference call in April 2005.

This one-day symposium honors Gene for his varied and pioneering contributions to climate science (including his work on atmospheric general circulation, moisture transports and the hydrological cycle, and, of course, the El Nino Southern Oscillation phenomenon); his outstanding record of service to the AMS (including as President of the society), the National Academies of Engineering and Science, and the broader scientific community; his strong scientific influence on climate monitoring, analysis, and prediction activities of the National Oceanic and Atmospheric Administration; and his mentorship of students and colleagues in NOAA, the University of Maryland, and the atmospheric and oceanic science community at large.

A series of invited talks in the fields to which Gene has made his most important contributions constitutes the symposium core, and we hope that these talks will provide a historical perspective on the topic, highlighting Gene's contributions, and identify current research questions. The follow-on evening banquet will provide an opportunity to learn more about Gene's warm and charismatic personality. We hope that this day-long symposium will be a befitting community tribute to Gene's seminal contributions in advancing understanding of climate and hydroclimate variability from innovative observational analysis, in shaping major climate research programs through his intellect and vision, and in bringing the meteorological and hydrologic communities closer together.

We thank the organizing committee (Antonio Busalacchi, William Lau, Chester Ropelewski, Phil Arkin, Gabriel Lau, Chris Elfring, Eric Wood, Kingtse Mo) for symposium planning; Dian Seidel for guidance with the symposium proposal; Georgene Rasmusson for sharing many wonderful family pictures; Phil Arkin for help with the symposium brochure; and Brenda Ward for putting everything together.

This symposium is, ultimately, a manifestation of the immense interest and enthusiasm in the climate science community for honoring Eugene Rasmusson's impressive scientific achievements, visionary leadership, and exemplary service to the meteorological, oceanographic, and hydrologic science communities. These sentiments were endorsed and supported by the American Meteorological Society, and by NSF's Climate and Large-scale Dynamics program (Jay Fein, Director) and NOAA's Climate Variability and Predictability Program (James Todd, Director); all of whom we warmly thank.

We are honored to be part of the Rasmusson Symposium, and look forward to welcoming you and the Rasmussons to this exciting day-long event on January 18 (Thursday), 2007.

Sumant Nigam & Clara Deser

Co-Chairpersons

A BRIEF BIOGRAPHY OF EUGENE RASMUSSON

Gene Rasmusson grew up on a farm in central Kansas. His paternal grandparents were Norwegian immigrants who settled in the predominantly Swedish community around Lindsborg, Kansas. This led his father to commit the unforgivable sin of changing the spelling of the family name from the Norwegian ending "sen" to the Swedish "son." Many decades later, Gene met Jacob Bjerknes' wife, who scolded him for this slur on his Norwegian heritage, and urged him to change his name back to the Norwegian spelling. He declined to take her advice.

Farm life in central Kansas was quite austere during Gene's childhood, with no electricity (kerosene lamps), no indoor plumbing, and a telephone only when it could be afforded. He retains vivid memories of his first decade of life that coincided with the wrenching depression, drought, and dust bowl conditions of the 1930s. The consequences of this climate catastrophe vividly illustrated the crucial role of weather and climate for agriculture over the semi-arid western plains, and it was probably a significant factor in stimulating his interest in meteorology.

Gene's primary education (grades 1–8) took place in a one room rural school. The eight-month school year ended in April to allow the school children to help with the late spring farm work. To the consternation of his father, Gene had no interest in farming. His horizons were greatly expanded when at age seven the family acquired their first six-volt battery powered radio. Radio introduced him to the fascinating world of science and technology, most notably through a weekly program sponsored by DuPont. He remembers thinking how much more exciting it would be to be a scientist than a farmer. Gene attended high school in the neighboring town of Lindsborg. He was a mediocre left tackle on the high school football team, but did better in his academics.

Yogi Berra is said to have advised "when you come to a fork in the road, take it!" Gene's career, from engineer to weather forecaster to climate researcher, has been marked by many forks in the road, and it seems that in almost every instance he was nudged into the right direction. Upon graduation from high school, he enrolled as a civil engineering major at Kansas State University. At that time there were no formal courses at K-State in meteorology, but his interest in the atmospheric sciences was greatly stimulated by an introduction to meteorology and weather forecasting taught as part of his Reserve Officers Training Corp (ROTC) training. During his senior year he seriously considered responding to a call for volunteers for the Air Force university training program in meteorology, but apparently it was not the proper time just yet. Gene completed advanced Air Force ROTC, receiving a reserve commission upon graduation in the summer of 1950. This event coincided with the beginning of the Korean War, and after working for only nine months as a highway surveyor, he was ordered to active duty at Lackland AFB, here in San Antonio, in May 1951. As it turned out, this is where events that were to determine his future career were set in motion. He was again offered the opportunity to pursue a one year basic meteorology course at the University of Washington, and this time he accepted. Subsequently, he served at bases in Oklahoma and Alaska. It was in Alaska that he met Murray Mitchell, another young Air Force meteorologist/climatologist, who became a lifelong friend and a most influential role model during the first decade of Gene's career. Gene remained in the active reserve after discharge, retiring in 1974 as a Lt. Colonel.

After leaving the Air Force, Gene worked briefly as a telephone company engineer in Seattle, but quickly realized that meteorology had become his consuming professional interest. In March 1956 he joined the Weather Bureau as a river forecaster in St. Louis. He would have much preferred a weather forecasting position, but as things turned out his four years in operational hydrology became a valuable interdisciplinary asset for his future career in climate research. Most important, however, was the fact that while working in St. Louis he met Georgene Sachtleben, a supervisor of vocal music in the suburban University City school system. They were married in August, 1960 and raised a family of four wonderful daughters. 1960 also marked the publication of his first scientific paper, as well as his promotion to state weather forecaster for eastern Missouri and Southern Illinois.

While in St. Louis Gene completed an MS program at St. Louis University in Engineering Mechanics (no meteorology courses were available in the night school program). A month later, he was awarded a nine-month Weather Bureau scholarship to MIT, subsequently extended to three years, which allowed him to complete a PhD program in meteorology (1966). The three years at MIT marked another fundamental milestone in Gene's professional career: a shift from operational forecasting to a research career in climate. This was a golden opportunity to study under what was probably the premier meteorological faculty of that time, including Jule Charney, Henry Houghton, Ed Lorenz, Reggie Newell, Norm Phillips, Fred Sanders, and Victor Starr, and to interact with a highly talented group of graduate students that included Mike Wallace, Bob Dickinson, Peter Gilman, Marv Geller, Jim Mahoney, and Dayton Vincent. His dissertation advisor, Victor Starr, taught him an approach to climate analysis that he used to great advantage throughout his research career. His dissertation research on the hydrologic cycle of North America broke new ground by jointly analyzing the surface and atmospheric branches of continental-scale hydrology. In retrospect, this research was a critical first step in the development of his interdisciplinary perspective on climate. Thirty years later it became an important element of the regional water balance studies of the Global Energy and Water Cycle Experiment (GEWEX).

Gene joined the staff of the Geophysical Fluid Dynamics Laboratory following graduation from MIT. During the next four years he and Brahm Oort completed a comprehensive documentation of the zonally-averaged atmospheric general circulation. The resulting monograph, "*General Circulation Statistics*," served for more than a decade as a primary source of information for a multitude of empirical studies, as well as "ground truth" against which to compare the results of global climate models.

Gene's career reached another fork in the road in 1970, when he was asked to lead a newly formed NOAA group tasked with analyzing data collected during BOMEX, an ocean-atmosphere interaction experiment conducted near the island of Barbados. Following BOMEX, Gene assumed leadership roles in the U.S.-Canadian International Field Year on the Great Lakes (IFYGL), and in the data assembly and analysis activities of the GARP Atlantic Tropical Experiment (GATE) as leader of the GATE Convection Subprogram Data Center.

Gene as a young Air Force Officer

The next fork appeared in 1979, when Gene became chief of the Diagnostic Branch of the newly formed NOAA Climate Analysis Center (CAC) and refocused his personal research efforts on the role of the equatorial Pacific in climate variability. His diagnostic study with Tom Carpenter of the evolution of a typical ENSO warm episode resulted in what is probably his best known paper. Gene's research and scientific leadership activities were major contributions to the development of the NOAA Equatorial Pacific Ocean Climate Studies (EPOCS) program as well as the Tropical Ocean Global Atmosphere (TOGA) Experiment of the World Climate Research Programme (WCRP). By 1982 the Diagnostic Branch staff had developed an operational ENSO monitoring and diagnostic system that allowed the CAC to disseminate, for the first time in near real time, information on the evolving anomalies and impacts of the intense 1982-83 ENSO warm episode. This brought world-wide recognition to the CAC.

Gene chose to retire from NOAA in 1986 to become a research scientist at the University of Maryland. He was active as a graduate student advisor and continued his research in collaboration with his students, faculty members, and former NOAA colleagues. He was instrumental in the development of the GEWEX Continental-Scale International Program (GCIP), an experiment designed to study the large-scale water and energy balance of the Mississippi Basin, and he participated in the development of WCRP program elements focused on North and South American climate and hydrologic variability from a monsoon perspective.

Gene has been a member of the AMS since 1952 and has assumed many leadership roles in the activities of the Society, serving as president in 1998. He received the C. F. Brooks Award for service to the Society in 2002. He has served the atmospheric and climate sciences and the nation through membership on numerous science advisory committees. This includes many National Research Council committees and panels, including the Board of Atmospheric Sciences and Climate and as Chair of the Climate Research Committee. He also chaired the NASA Scientific Steering Group for the highly successful Tropical Rainfall Measurement Mission (TRMM).

Gene has received many awards, fellowships, and lectureships in recognition of his professional and scientific contributions, capped in 1999 by election to the National Academy of Engineering. He became a Research Professor Emeritus at the University of Maryland in 2000, and although formally retired, he remains active in NRC and AMS activities and occasionally speaks to lay audiences. "It has been a great trip, and I wouldn't have missed it for anything" is how he characterizes his career.

1.1

INTRODUCTORY REMARKS

Dian Seidel

1.2

PIONEERING STUDIES OF GENE RASMUSSON ON THE HYDROLOGIC CYCLE, THE PLANETARY BOUNDARY LAYER, AND ENSO

John Michael Wallace
Univ. of Washington, Seattle, WA

Gene, Georgene and their four daughters in the early 1980s.

Gene Rasmusson's research career began in earnest while he was a graduate student at MIT from 1963-1966 as a member of the research group directed by Victor Starr. His PhD thesis on the atmospheric branch of the hydrologic cycle over North America represented a major departure from the mainstream research on Starr's project in the sense that it was regional in focus and it dealt with a range of issues that had heretofore been regarded as largely hypothetical. Published in 1971, this pioneering study presaged contemporary field programs such as GEWEX. During the first decade of his career, Rasmusson's devoted considerable effort to the analysis of data from the Barbados Oceanographic and Meterological Experiment (BOMEX). He showed how radiosonde data from just a few sites could be used to constrain and provide a large-scale context for estimates of the vertical profiles fluxes of sensible heat and water vapor. Rasmusson's most widely cited work can be traced back to the late 1970's when he became interested in the Comprehensive Ocean Atmosphere Data Set (COADS) that was under development in NOAA. In his preliminary analysis of COADS he recognized and documented the recurrent signature of warm episodes that encompassed not only the coast of South America, but also the entire equatorial Pacific cold tongue region extending to the date line. The Rasmusson and Carpenter study of ENSO, based on this work and published in 1982, is one of the cornerstones of our current understanding of ENS0.

1.3

DROUGHT IN NORTH AMERICA: THE SOLAR-ENSO CONNECTION

Mark Cane
Lamont Doherty Earth Observatory, Palisades, NY

We consider the possibility that variations in solar irradiance have a significant impact on tropical Pacific sea surface temperatures (SSTs), which influence drought in much of the US, including Gene's home state of Kansas. Very recent work (Schubert et al. 2004; Seager et al. 2004) has shown that a prime cause of the Dust Bowl droughts of the 1930s is a La Niña-like pattern of decadal mean SST anomalies in the Pacific. These anomalies were very small amplitude (<0.5°C everywhere). Similar SST anomalies are associated with other persistent droughts in the 19th and 20th centuries, and a pattern of opposite sign prevailed during the relatively wet period, 1976-1998.

Other recent work (Mann et al. 2005; Emile-Geay et al 2006) has shown that coupled ocean-atmosphere interactions in the tropical Pacific generate a significant response to solar and volcanic radiative forcing over the past 1000 years. While these variations rarely have much effect on individual ENSO events, they may influence longer period changes. Such shifts in the background state of the tropical Pacific could help explain the persistent droughts in North America evident in the climate record of the last 1000 years.

1.4

BEYOND ENSO: THE OBSERVATIONAL RECORD OF DECADAL CLIMATE VARIABILITY IN THE TROPICAL INDO-PACIFIC REGION

Clara Deser
NCAR, Boulder, CO

In this talk, I will discuss observed patterns of decadal climate fluctuations over the tropical Indo-Pacific Ocean since the middle of the 19th century using a variety of data sets and simple analysis techniques, following in the spirit of Gene Rasmusson's classic ENSO studies. The results show that classic ENSO indices such as the "Nino3.4 SST Index" and the "Darwin-minus-Tahiti Southern Oscillation Index" are not optimal for characterizing the decadal variability, and that the Indian Ocean plays a more prominent role in decadal variability than interannual ENSO variability.

1.5

TWO COMPLEMENTARY VIEWS OF THE ATMOSPHERIC GENERAL CIRCULATION: THE ZONAL-MEAN AND ZONALLY ASYMMETRIC PERSPECTIVES

Ngar-Cheung Lau
NOAA/GFDL, Princeton, NJ

A review is offered on the contributions of Gene Rasmusson to a comprehensive documentation of the zonally averaged general circulation of the observed atmosphere, and to our understanding of the maintenance of this circulation.

Subsequent works by other investigators, which focus on the nature of departures of the time-mean circulation from zonal symmetry, are then described. By compiling the three-dimensional distribution of circulation statistics on the basis of gridded synoptic weather charts produced at operational weather centers, the latter studies highlight the longitudinal dependence of various circulation features. Atmospheric diagnostics under this zonally asymmetric framework have yielded considerable insights in the nature of local interactions between the time-mean and time-varying (transient) components of the circulation, as well as between transient fluctuations of different time scales. Mapping of the pertinent meteorological signals in the full three-dimensional domain also facilitates the analysis of feedbacks between the atmospheric circulation and boundary forcings in various geographical locations, such as those associated with influences of sea surface temperature (SST) anomalies, orography and ground hydrology.

Notwithstanding the demonstrable utility of the approach emphasizing longitudinally varying aspects of the general circulation, still more recent investigations indicate that many prevalent modes of atmospheric variability are characterized by a high degree of zonal symmetry. Examples of atmospheric patterns with a distinct zonal mean component include annual modes with large vertical extent in the middle- and high-latitude zones of both hemispheres, upper tropospheric response of the tropical geopotential height to SST forcing related to El Nino-Southern Oscillation, mid-latitude atmospheric anomalies occurring in prolonged drought episodes, as well as circulation shifts accompanying past and projected climate changes. The prevalence of these structures suggests that zonal mean diagnoses remain to be a powerful tool for examining certain facets of the general circulation.

The above survey illustrates the complementary nature of the zonal-mean and zonally asymmetric views of the general circulation. The applicability of a particular approach is contingent upon the phenomenon or scientific issue at hand.

1.6

THE ATMOSPHERIC HYDROLOGICAL CYCLE: ADVANCES FACILITATED BY GENE RASMUSSON

Kevin E. Trenberth
NCAR, Boulder, CO

A well known paper that made major advances in large-scale water balance was written by Gene Rasmusson in 1967. It built on the work of others at M.I.T. under Victor Starr related to the atmospheric general circulation, and especially on a very valuable compilation of statistics by Abraham Oort and Rasmusson. The application of these statistics to the transport of water vapor and its divergence over North America to compute evaporation E minus precipitation P as a residual of the atmospheric moisture budget enabled reliable water budgets to be computed for the first time. This work has advanced with recent reanalyses, but some of the same problems encountered and dealt with by Gene still exist. An update of recent results for the global hydrological cycle will be provided.

1.7

EUGENE RASMUSSON AND THE EARLY HISTORY OF TRMM

Gerald R. North
Texas A&M University, College Station, TX

In the early 1980s a large workshop was organized by David Atlas and Otto Thiele at NASA Goddard (GSFC) to explore the opportunities for measuring rain rates from spaceborne sensors. Soon after (late summer, 1984) several small meetings took place at GSFC to plan and propose such a mission. Some one-page white papers were drawn up mainly based on a concept by Thomas T. Wilheit (low Earth orbiter in tropical inclination, passive and active microwave radiometers, possible use of an on-the-shelf ESMR). Much activity was generated from a call from NASA HQ for a low cost atmospheric mission. Eventually, a competition was held at NASA HQ involving 17 participants. TRMM won the contest and plans were begun for a Phase A study at GSFC with Gerald North as Study Scientist. International partnerships were sought and agreements were met with the Japanese Space Agency and preliminary negotiations began. During this period Director of the Laboratory for Atmospheric Sciences, Marvin Geller, suggested Eugene Rasmusson to be Chair of a Science Advisory Committee to spell out science requirements and opportunities for such a mission. The prestige and winning personality of Eugene Rasmusson were key to the early acceptance of TRMM by the science community as well as by the decision makers in Washington and Tokyo. Another milestone was reached when Joanne Simpson was installed as the first Project Scientist. Many trips to Japan ensued with Rasmusson's committee, members from NASA HQ, key scientists and project engineers. TRMM was launched from a Japanese site using the Japanese H2 rocket in November, 1997, and has been flying ever since. Christian Kummerow was the next Project Scientist as the mission became operational. TRMM had a near-death experience when NASA pondered whether the mission should be terminated in 2005, because of the on-board fuel necessary for a safe oceanic re-entry. The mission was saved mainly through the courageous efforts of Robert Adler, then Project Scientist. The TRMM program has been a striking success leading to many more applications than the founders ever expected. Many lives have no doubt been saved and we have learned much about tropical rain, the general circulation of the atmosphere-ocean system and its many peculiarities such as ENS0.

2.1

JOY OF CLIMATE ANALYSIS AND MONITORING

Kingtse Mo
NOAA/NWS/NCEP, Camp Springs, MD

Dr. Rasmusson recognized the importance of analysis and General Circulation model forecasts in the early 1980's. Under his leadership, the Climate Diagnostics Data Base was established. The CPC started the monthly and seasonal climate monitoring. From the climate monitoring and data archive, he encouraged people to document the climate variability, examine the physical mechanisms of climate anomalies. These studies enhanced our understanding of the climate phenomena including but not limited to ENSO and improve monitoring.

He continued to exploit the possibility to monitor regional climate using meso scale models. To bridge the gap between hydrology and meteorology, he began the studies of regional model outputs. Later, with the regional reanalysis and the NLDAS, we are able to understand the land-atmosphere processes better. Recently, we at the CPC began the monitoring of the water resources based on the regional analysis and land data assimilation.

With the improvement of model and analysis and his encouragement, he mentored the studies of the North American monsoon system. He planed the seeds for later North American monsoon experiment in 2004.

2.2

A QUICK TOUR OF ENSO IMPACTS RESEARCH FROM THE 1980S TO THE PRESENT

Chester F. Ropelewski
International Research Institute for Climate Prediction, Columbia University, Palisades, NY

The presentation will very briefly review early investigations of the shifts in global precipitation patterns associated with the El Niño/Southern Oscillation (ENSO) and in the spirit of this Symposium reflect on Gene Rasmusson's influence on ENSO impact studies of the early 1980s and later. The presentation will touch on the evolution in the analysis tools, data, and our understanding and interpretation of ENSO-related precipitation anomalies. Some concluding remarks will discuss studies that aim to bring the 'impacts" work beyond investigation of seasonal and monthly means towards characterizing the influence of ENSO on statistics of daily weather within seasons.

2.3

THE ROLE OF SATELLITE OBSERVATIONS IN ANALYZING LARGE-SCALE PRECIPITATION

Phillip A. Arkin
ESSIC, University of Maryland, College Park, MD

Precipitation plays a crucial role in the global and regional hydrological cycle and in variations in the climate system. Research programs such as TOGA and GEWEX rely upon the availability of useful precipitation data covering continents and oceans. However, conventional observations using rain gauges and radars cover limited regions and are of little use over the oceans. In this presentation I will describe the research that led to the availability of global precipitation analyses such as CMAP and GPCP and Gene's role in inspiring and enabling the work.

2.4

TRENDS IN TROPICAL RAINFALL CHARACTERISTICS : OBSERVATIONS AND MODELING

William K. M. Lau
NASA/GSFC, Greenbelt, MD

We present results from observation and modeling studies of long-term trend in rainfall characteristics. From analyses of shift in the rainfall probability distribution function using long-term (24 years) of GPCP and CMAP rainfall data, as well as ground-based global rainfall data, we find trends in more frequent occurrence of extreme heavy and light rain events, coupled to a decreasing trend in moderate rain events over much of the tropics during 1979-2003. Using TRMM rainfall products to identify characteristic cloud and rain structure, we find that the trends are consistent with a shift in the large-scale circulation associated with a) a relatively uniform increase in warm rain over the tropical oceans, b) enhanced ice-phase rain over the near-equatorial oceans, and c) reduced mixed-phase rain over the tropical ocean and land regions. Analysis of IPCC, 20th Century coupled model simulations indicate that overall the models simulated reasonably well the shift in the rainfall PDF qualitatively, but differ greatly in the regional geographic details of the rainfall patterns. The model results suggest that the changes in PDF are to a first order associated with an overall enhancement of the atmospheric water cycle in the tropics as a result of global warming.

2.5

WARM-SEASON HYDROCLIMATE VARIABILITY OVER NORTH AMERICA: EUGENE RASMUSSON'S SEMINAL CONTRIBUTIONS

Sumant Nigam
University of Maryland, College Park, MD

Eugene Rasmusson joined the University of Maryland during the warm-phase of the seasonal cycle in 1986; full two seasons before I got there. Eugene's 'Es' – enormous intellect, engaging personality, and enthusiasm for and encouragement of good science – has influenced many Maryland faculty and students in his 20+ years there; including myself whose cold-season interests were gradually supplanted by warm-season ones, largely due to Gene's corridor conversations.

Gene was an interdisciplinary scientist long before it became fashionable or necessary to be one. His pioneering analysis of tropical ocean-atmosphere and extratropical land-atmosphere interactions, with some efforts initiated almost half a century ago, are a testament to his scholarship and vision. Gene's doctoral thesis at MIT, under Victor Starr's guidance, was at the intersections of meteorology, atmospheric general circulation, and hydrology; and forged disciplinary connections that endure. Gene's interests at Maryland came full circle back to his MIT-period callings: hydroclimate. This reaching back was not unlike the full Carnot circuit in thermodynamics, in that interesting work was done in the interim; leading to fundamental advances in our understanding of North American hydroclimate variability.

The role of moisture transports and evapotranspiration in generating warm-season hydroclimate variability over the Great Plains will be reviewed; especially, how appraisals have changed since the seminal 1967-68 papers of Gene Rasmusson. It will be argued that evapotranspiration has an exaggerated role in current analyses, many of which are model based. It is remarkable that the rather significant role of remote water sources (i.e., moisture transports), indicated by modern retrospective atmospheric analyses (ERA-40 and NCEP), was recognized by Gene using only 5 years (1958-63) of relatively sparse aerological data; a tribute to his diagnostic acumen. The importance of transported moisture in water-balance variations over the Great Plains places premium on understanding the low-level circulation links with the adjoining gulfs and oceans; some of which will be discussed. It will shown that notable Great Plains precipitation anomalies arise from the overlap of Pacific and Atlantic basin influences.

Finally, the tendency of many state-of-the-art climate models to vigorously recycle warm-season precipitation over Great Plains will be noted. It will be argued that this not only distorts the regional water-balance but also adversely impacts the land-surface energy budget; compromising regional hydroclimate variability/change predictions. A hypothesis for the recycling propensity of models will be discussed.

2.6

THE HYDROLOGIC CYCLE: AN EVOLVING VIEW FOLLOWING THE STEPS OF GENE RASMUSSON

Ernesto Hugo Berbery
Univ. of Maryland, College Park, MD

About forty years ago, Gene Rasmusson published two seminal articles in which he discussed the water cycle for North America. Those articles summarized his years of research on the water cycle, and identified the fundamental aspects that impeded achieving further progress in the subject. He noted that the quality of water cycle estimates deteriorates rapidly as the size of a basin is reduced, owing to three basic reasons: (a) errors due to diurnal variations, (b) poor representation of the small scale features of the flux fields, and (c) local station peculiarities (now replaced by grid resolution). One last unresolved issue was the lack of agreement between the atmospheric and terrestrial components of the water cycle (i.e., agreement between moisture flux convergence and river streamflow). Today those same research areas are considered fundamental in hydroclimate studies and are being investigated both in observational and modeling studies, particularly those that deal with the predictability of the hydrologic cycle.

With the development of programs like the Global Energy and Water Cycle Experiment (GEWEX), early on Gene Rasmusson understood that a major advance in water cycle studies could be achieved from diagnostic analysis based on regional fields produced by mesoscale models. As models and data assimilation systems improved, so did the reliability of the hydrologic cycle. Today, research along this path has shown success in representing the hydrologic cycle at scales about one order of magnitude finer than those of the 1960s, and a much closer agreement has being reached between the terrestrial and atmospheric branches of the hydrologic cycle. It can be argued that the development of the North American Regional Reanalysis is the result of diagnostic studies of the water cycle like the ones Gene envisioned many years earlier.

The progress in understanding the water cycle has been remarkable, but still significant challenges are being faced. The next stage involves the role of the hydrologic cycle in Climate Change research, Earth System modeling and Water Management activities. The three topics require a rigorous understanding of the hydrologic cycle at global and regional scales, its interactions with the atmospheric physics and chemistry, its variability and finally, its eventual intensification. As the World's water supply is getting scarce and the World's population is increasingly more vulnerable to changes in hydroclimate, the subject is rapidly moving to the center of attention in many disciplines.

2.7

CONTINENTAL-SCALE HYDROLOGIC ANALYSES AND ITS DEVELOPMENT OVER THE PAST FORTY YEARS.

Eric F. Wood
Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ

The evolution of continental-scale hydrologic modeling and analyses can be traced to Eugene Rasmusson's pioneering 1960s work in computing the atmospheric water budget and establishing its links to continental-scale terrestrial hydrology. This work established the importance of understanding land-atmospheric coupling and continental-scale hydrologic processes, and helped develop the field of hydrometeorology, enhanced through Gene's work with the NWS River Forecast Centers. It also provided a clearer perspective of the integrated nature of atmospheric and terrestrial water and energy processes, which Gene articulated through his GEWEX contributions. Land surface modeling has progresses to the point that coupled water-energy-vegetation macro-scale models are run routinely at high resolutions at continental to global scales, and compared to atmospheric computations from weather and climate models and remote sensing observations to offer integrated assessments of continental-scale water and energy budgets. This talk will provide an overview of this development using recent results from the author's macroscale land surface model and remote sensing retrievals to revisit research questions that Gene Rasmusson has investigated during his career.

2.8

PROGRESS TOWARDS HYDROMETEORLOGICAL FORECASTING

Soroosh Sorooshian
University of California, Irvine, California

Gene Rasmussen's extensive contributions to the atmospheric sciences and related fields spans several decades. The extent of his influence is not limited to only scientific aspects, but it has also resulted in a number of initiatives and programs at both the national and international level. Among others, Dr. Rasmussen was one of the major players in the initiation of the GEWEX Program (Global Energy and Water cycle EXperiment) of the World Climate Research Programme (WCRP) and, in particularl, the planning and launching of the first continental scale experiment, which became known as the GCIP (Continental-scale International Project). This presentation will provide a brief summary of some of the scientific findings related to the water cycle and their impact on the coupling of the land surface and atmospheric processes. In specific, this presentation will cover some of the advances in precipitation estimation through the use of satellite remote sensing and their use in flood and run-off prediction.

Gene receiving his certificate for the Robert E. Horton Lectureship from AMS President Paul Try

2.9

GENE RASMUSSON'S LEADERSHIP ROLES WITHIN THE AMERICAN METEOROLOGICAL SOCIETY AND THE NATIONAL ACADEMIES

Antonio J. Busalacchi Jr.
ESSIC, University of Maryland, College Park, MD

In recognition of his distinguished scholarly contributions in the atmospheric, hydrologic, and climate sciences, in 1983 Gene Rasmusson was elected as a Fellow of the American Meteorological Society (AMS) and was awarded the AMS Jule G. Charney Award "for major contributions to climate diagnostics, especially of the relationship of the Southern Oscillation to climate anomalies". In 1997 Gene was recognized by the AMS as the Robert E. Horton Lecturer in Hydrology and spoke of "North American Hydrology: The Evolution of an Interdisciplinary Perspective". Subsequently, in 1999 he became a member of the National Academy of Engineering "for contributions to understanding climate variability and establishing the basis for practical predictions of El Nino". Over the past 25 years Gene has been extremely generous with his time and leadership of the AMS and the National Academies. During this time Gene has served as Editor of the Journal of Climate, Associate Editor of the Monthly Weather Review, Associate Editor of the Journal of Climate Applied Meteorology, Planning Commissioner of the AMS, Member and Chairman of the Awards Committee, and in 1998 was the President of the AMS. In support of activities of the National Research Council (NRC), Gene has served as a member of the NRC Tropical Pacific Panel, TOGA Panel, Committee on USGS Water Research, Panel on Model Assimilated Data sets for Atmospheric and Oceanic Research, Expert Task Group for the Strategic Highway Research Program, Board for Atmospheric Science and Climate, GOALS Panel, and Committee on the Scientific Bases of Colorado River Basin Water Management; and has served has chairman of the Climate Research Committee, and the Committee on the Future of Precipitation Measurements From Space; Phase I: TRMM; Phase II: GPM. This presentation will trace in greater detail Gene Rasmusson's contributions to the American Meteorological Society and the National Academies.

2.10

COMMUNICATING WITH MUSEUM AUDIENCES ABOUT CLIMATE SCIENCE: CONTRIBUTIONS OF GENE RASMUSSON

Peter Schultz
U.S. Climate Change Science Program, Washington, DC

Erika Shugart
National Academy of Sciences, Washington, DC

Not only has Gene Rasmusson made invaluable contributions to the scientific discourse on climate variability, he also helped to lead the development of a groundbreaking museum exhibition on climate science that has contributed to the public discourse on this topic. In 2004, the National Academy of Sciences opened the Koshland Science Museum, with the objective of reaching science-interested audiences to whom the solemn tomes put forth by the NAS are often impenetrable. Gene Rasmusson led a group of global change scientists in the development of the museum's global warming exhibition, which premiered at the museum's opening. There are a number of groundbreaking aspects to this work that have helped lay the foundation for other exhibitions on controversial topics that use cutting edge technology to help adult audiences wrestle with substantial environmental and social issues. In addition to the needs that this work has met with its target audiences, it has also made significant intellectual contributions to the ways that both the museum education community and the National Academies think about science communication.

2.11

GENE RASMUSSON AS MENTOR

Mathew A. Barlow
University of Massachusetts - Lowell, Lowell, MA

Gene's mentoring and scientific approach have had a strong influence on many people in our field. In this talk, I will give my perspective on Gene's mentoring and how he has served as a role model for me in my career, beginning with his guidance on my dissertation. During my Ph.D. research, Gene's expectations of careful analysis and clear communication, as well as his attention to detail and sometimes astonishing breadth of knowledge, defined a high mark that continues to be my gold standard. Equally important, his own work amply demonstrated those qualities and has served as a touchstone and exemplar for my own efforts. Gene's emphasis on observational analysis and his ability to extract the key features of a phenomenon from a confusing mass of information and to then clearly summarize the results – and the transformative effect this can have on a field of enquiry – has been one of my primary inspirations in the field. As funding for observations, particularly continuation of long-term stations, becomes more uncertain and as research programs reasonably focus more and more on complex modeling, I hope the example of Gene's seminal observational work will also continue to inform our funding priorities.

2.12

MILESTONES ON THE ROAD TO CLIMATE SYSTEM SCIENCE

Eugene M. Rasmusson
University of Maryland, College Park, MD

In 1951 the AMS published the Compendium of Meteorology in order to "take stock of the present position of meteorology, to summarize and appraise the knowledge which untiring research has been able to wrest from nature during the past years, and to indicate the avenues of further study and research which need to be explored in order to extend the frontiers of our knowledge." The mammoth volume (1334 pages) consisted of reviews for 25 "specialties" in the field of meteorology. In his review of climatology ("Climate-The Synthesis of Weather"), C. S. Durst made the following observations: (1) "…climatology as presently practiced is primarily a statistical study without the basis of physical understanding, which is essential for progress.", (2) "…there has not generally been an insistence on knowledge of the physical reasoning which must underlie climatology." and (3) "…there has been a woeful tendency to the use of the bones of bare statistics and mean values without the flesh of physical understanding." Durst went on to say "As I see them, the essential needs of climatology are in the first place a re-orientation of the expression of climate and of the teaching of climate, and secondly the explanation of climate as a physical and dynamical phenomenon." The half century since the publication of this review has witnessed a remarkable evolution from the narrow, statistically oriented focus of climatology on land surface meteorological variables into the vastly more comprehensive interdisciplinary enterprise of climate system science. The broadened perspective of the global climate system includes many major aspects of what were considered other meteorological "specialties" at the time of the publication of the Compendium, e.g., upper air analysis and the atmospheric general circulation, and also encompasses major aspects of the associated hydrological and oceanic sciences. Key aspects of this evolution are the perception of climate as variable and a non-stationary process, the development of dynamically- and physically-based climate diagnostics, and numerical climate model simulations. A number of important milestones in the development of climate system science will be reviewed briefly in this presentation, with emphasis on those areas of research in which the speaker has participated.

Pope John Paul II greeting Gene at a meeting sponsored by the Vatican in the mid 1980s.

P1.1

THE ROBUST LIFECYCLES AND SEASONAL IMPACTS OF EL NIÑO AND LA NINA EVENTS

Narasimhan K. ("Sim") Larkin
USDA Forest Service, Seattle, WA

D. E. Harrison
Global Climate Observing System/GOOS/WCRP Ocean Observing Panel for Climate, Seattle, WA

Rasmusson and Carpenter (1982), through their six event composites over the tropical Pacific, launched the modern study of El Niño events. Utilizing modern marine surface datasets, we have built on Rasmusson and Carpenter (1982), expanding the composite perspective with statistical significance and time series techniques and including more recent El Niños, global anomalies, and La Nina events. We have identified the robust lifecycle elements of ENSO and the robust associated seasonal weather anomalies.
Intrinsic to any such study is a definition of El Niño and La Nina. Appropriately defined, El Niño and La Nina have robust lifecycles that span at least nine months, include anomalies in every tropical ocean and in the extra-tropics, and differ substantially from simple regression patterns. The extreme 1997-98 El Niño, apart from its amplitude, followed the typical tropical life cycle quite well. Many of the most robust life cycle elements are found in the central and eastern tropical Pacific; a focus on conditions there, rather than nearer the Dateline (e.g., NIN03.4), is what permits the robust composite events to be constructed.

P1.2

THE IMPACT OF WIND FARMS ON DOWNSTREAM STORM TRACKS

Daniel Barrie
University of Maryland, College Park, MD

Daniel B. Kirk-Davidoff
Univ. of Maryland, College Park, MD

The increasing use of wind turbines as a renewable energy technology requires a greater understanding of the potential effects its deployment could have on large scale flow patterns. As wind turbines capture energy and interrupt the flow, they introduce downstream effects, which can impact climate patterns and storm tracks. It has previously been shown that large-scale wind farms have an appreciable effect on regional temperature and wind patterns (Keith, 2004). In that study, surface roughness was held fixed in time. Here, we use NCAR's Community Atmosphere Model to investigate how a change in surface roughness affects downstream storm paths. This change can be accomplished in the field through an adjustment of the attitude of turbine blades with respect to the wind.
We investigate the strength and direction of storm trajectories on the eastern coast of the United States as well as farther downstream in Europe. We hope to determine whether deliberate manipulation of the effective roughness length of a wind farm produces predictable downstream effects. Hoffman (2002) suggested that large wind farms might be part of a strategy for controlling global weather. In this forward-modeling experiment, we test the limits of the downstream control exerted by wind farm management.

P1.3

OCEAN INSTABILITIES CAPTURED BY BREEDING ON A GLOBAL OCEAN REANALYSIS

Matthew Joseph Hoffman
University of Maryland, Applied Math and Scientific Computing Program, College Park, MD 20742, MD

Eugenia Kalnay
University of Maryland, College Park, MD

Jim Carton
University of Maryland, Department of Atmospheric and Oceanic Sciences

Shu-Chih Yang
Univ. of Maryland, College Park, MD

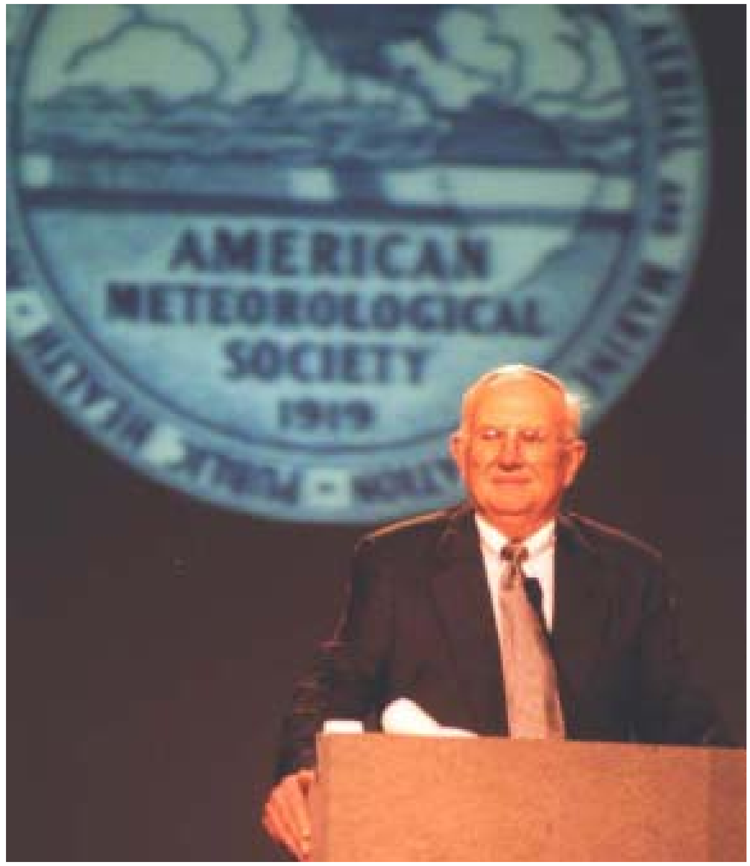
We diagnose the presence of instabilities in the global ocean by performing breeding upon a global ocean reanalysis (SODA) driven by observed winds(Carton et al, 2004). The bred vectors identify instabilities in several regions and seasons, such as the winter tropical instabilities at the northern edge of the cold tongue in the Pacific, and others in the Indian, Atlantic and Southern Oceans. We will present a diagnostic analysis characterizing the dynamic instabilities based on the perturbation (bred vector) energy equation.

P1.4

INTERANNUAL VARIATION OF THE INSTABILITY WAVES IN THE TROPICAL PACIFIC OCEAN

Soon-Il An
Dept. of Atmospheric Sciences, Yonsei University, Seoul, South Korea

Using the ocean assimilation data, the interannual variation of the tropical instability waves (TIWV), especially in the tropical eastern Pacific Ocean has been analyzed. The interannual variation of TIWV is strongly phase-locked to seasonal cycle. This seasonality is related to the intensity of the cold tongue. Thus, the maximum variability of TIWV is associated with the La Nina period when the cold tongue is fully developed. While during the El Nino the TIWV has been suppressed. The meridional thermal flux by the TIWV in the ocean mixed layer is negatively correlated to the tropical eastern Pacific sea surface temperature anomalies, inferring the negative feedback effect with respect to ENSO development. The effect of the TIWV is incorporated into the two-stripped down version of the ENSO model. From the model results, it is found that the asymmetric characteristics of ENSO can be caused by the asymmetric thermal heating by the meridional heat flux due to the TIWV.



President Rasmusson addressing the gathered members

P1.5

GLOBAL VARIATIONS IN OCEANIC EVAPORATION: WHAT CAUSED THE UPWARD TREND IN THE RECENT DECADES?

Lisan Yu
Woods Hole Oceanographic Institution, Woods Hole, MA

The temperatures of the global oceans and atmosphere have been increasing, and the increase is particularly pronounced in the past two decades from 1980s through 1990s. One intuitive consequence of the global warming is that the moisture holding capacity of the atmosphere should go up following the Clausius-Clapeyron equation. While warmer air holds more moisture, warmer sea surfaces cause more evaporation. Indeed, a 50-year time series derived from a recent project of the Objectively Analyzed air-sea Fluxes (OAFlux) at the Woods Hole Oceanographic Institution (WHOI) (http://oaflux.whoi.edu) has an upward trend in global oceanic evaporation starting from the late 1970s. The trend has a large-scale, spatially coherent structure, being most significant in the tropical Indo-Pacific warm pool and the mid-latitude boundary current regions. The ocean is the source of 86% of the global evaporation, and plays a key role in the global hydrological and energy cycles. Changes in oceanic evaporation have important implications for weather and climate changes over the global scales. This study investigates the pattern of global variations in oceanic evaporation and the cause of the variations. The study finds that the increase in oceanic evaporation is in concert with the rise of sea surface temperature (SST), suggesting an atmospheric response to oceanic forcing. However, the exact mechanism that leads to the close relationship between SST and oceanic evaporation is not the air-sea moisture gradient but the wind speed. In situ and satellite observations do show that global surface winds have been strengthening in the recent decades. The enhanced wind speed impacts the oceanic evaporation via two ways. The first way is direct: the greater wind speed induces more evaporation by carrying water vapor away from the evaporating surface to allow the air-sea moisture gradient reestablished at a faster pace. The second way is indirect: the enhanced surface wind strengthens the wind-driven gyre circulation. A greater transport by the western boundary currents is resulted, which in turn warms up the boundary regions and leads to more evaporation. The oceanic and atmospheric observations that support the increase in oceanic evaporation will be discussed. The differences between the evaporation estimates from the OAFlux project and those from the NCEP and ERA40 reanalyses products will also be examined.

P1.6

ENSEMBLE FORECASTS STARTING FROM COUPLED BRED VECTORS WITH NASA COUPLED GENERAL CIRCULATION MODEL

Shu-Chih Yang
Univ. of Maryland, College Park, MD

E. Kalnay
University of Maryland

Michele Rienecker
Global Modeling and Assimilation Office-NASA/GSFC, Greenbelt, MD

Ming Cai
Florida State Univ., Tallahassee, FL

The two-sided coupled breeding cycle has been implemented in NASA coupled general circulation model. Bred vectors rescaled with different norms are used to initialize the ensemble forecasts for El Niño prediction. During a 10-year period (1993-2002), our results show that forecast experiments initialized from bred vectors showed a large improvement starting from the cold season. Our results also suggest that it helps to alleviate the tendency to overpredict warm/cold events.

P1.7

BIO-CLIMATE FEEDBACKS AND ENSO PHASE-LOCKING

Raghu Murtugudde
ESSIC/Univ. of Maryland, College Park, MD

Joaquim Ballabrera-Poy, Rong-Hua Zhang, Antonio J Busalacchi
ESSIC/Univ. of Maryland, College Park, MD

Rasmusson and Carpentar (1982) was a seminal paper that laid the foundation for much of TOGA and the modern-day ENSO research. As a fresh graduate, I arrived to the DC area to be mesmerized by Gene's enthusiastic acceptance of new ideas even as far-fetched as the ones that I presented claiming that marine biology could be as important to the annual cycle in the eastern tropical Pacific as any other ocean-atmosphere process considered thus far. His encouragement was one of the reasons to continue down that path which led to a demonstration that the mixed layer-thermocline interactions are indeed crucially controlled by the conversion of light to heat by the phytoplankton. It is now confirmed in most coupled climate models that bio-climate feedback is quite an important contributor to the annual cycle in the tropical oceans. The coarse horizontal and vertical resolutions of the coupled climate models still make it impossible for the full exploitation of this coupled feedback. Hence, a high resolution ocean GCM coupled to a statistical atmosphere and a simple wind-SST equation model is employed to demonstrate the role of the bio-climate feedbacks on ENSO phase-locking, amplitude, and frequency. It is shown that the better resolution of the annual cycle due to accurate representation of the biological feedbacks results in greatly improved Bjerknes feedback and hence the amplitude and frequency of ENSO simulations in addition to its phase-locking behavior. The basic feedbacks are that the enhanced heating just below the mixed layer during boreal spring months weaken the stratification and deepen the mixed layer and reduce the Ekman divergence in the surface layer. The subtle differences in the amount of radiation that escapes the bottom of the mixed layer leads to better simulation of the thermocline and hence the mixed layer and thus the coupling between the ocean and the atmosphere as seen by the correlation between NIN03 SST and zonal wind-stresses in the western-central Pacific warm pool during the growing phase of ENS0. It would be a joy to present the new results in front of the elderly statesman of the field, Gene Rasmusson.

P1.8

AUGUST 2005 MESOSCALE CONVECTIVE SYSTEM OVER WEST AFRICA. A CASE STUDY

Benjamin L. Lamptey
NCAR, Boulder, CO

The mesoscale convective system that passed over West Africa (Benin, Togo and dissipated over Ghana) on August 28, 2005 was simulated using the Advanced Research version of the Weather Research and Forecasting (WRF-ARW) model. A 4 km domain was nested within a 12 km domain using two-way nesting.The standard version of the WRF model was used to initially simulate the mesoscale system as it appeared on the 2200 UTC Meteosat Second Generation satellite picture. A combination of convective schemes and microphysics options were used to assess which combination gave the best results. The National Center for Environmental Prediction (NCEP) analysis data and the European Center for Medium Range Forecast analysis data were used as boundary and initial conditions.The sensitivity of the results to the spin-up time, number of grid points in the 4 km domain, and initial and boundary conditions were analyzed in this work.

P1.9

ATMOSPHERIC WATER VAPOR TRANSPORT AND THE HYDROLOGY OF (SOUTHWEST) NORTH AMERICA

David S. Gutzler
University of New Mexico, Albuquerque, NM

Mel Strong, Zachary Sharp
University of New Mexico, Albuquerque, NM

The title of our presentation is adapted from Report A-1 of the MIT Planetary Circulations Project, by Eugene M. Rasmusson, published 40 years ago in 1966. Gene used monthly mean sounding data from North American radiosonde stations to derive new insights into the sources and large scale transport pathways of atmospheric water. In this presentation, which is more geographically focused than Gene's continental-scale effort, we review a long-standing debate over the sources of moisture for one region (southwest North America), which has been resolved only partially using sonde-based data. Dynamical diagnostic tools such as trajectory models allow for more detailed examination of large scale moisture transport paths. Additional insights into the hydrological cycle are gained from a new geochemical data set that we have derived from analyses of the deuterium concentration of sampled water vapor. With these new tools we can extend the research that launched Gene's long career, and begin to constrain the sources and transport paths of water vapor in much more detail than was possible 40 years ago.

President Gene with Georgene and their friends in the AMS leadership