MILESTONES ON THE ROAD TO CLIMATE SCIENCE

Eugene Rasmusson

THANK YOU!

This has been a great day, and I'd like to express my thanks to Clara and Sumant and the many other folks who made this symposium possible. It's been said that recognition is most appreciated at the beginning and at the end of one's career. This symposium has certainly provided the latter in a big way. In fact, my wife was so impressed with the person described in the abstracts that she told me she would like to meet him someday. My son-in-laws said the same thing.

I think my contributions to climate science are appropriately described by a 12th century maxim attributed to Bernard of Chartres and later modified by Newton, and then by Coleridge as follows: "The dwarf sees farther then the giant when he has the giant's shoulder to mount on." In other words I have primarily pursued what might be called "follow up activities," I have spent much of my career firmly perched on the shoulder of scientific giants such as Victor Starr, Jacob Bjerknes, George Benton and my dear friend Mike Wallace. So, in the spirit of the advice that "You dance with the one who brung you," I would like to spend my time reminiscing on some of the many fortuitous events of my career and acknowledge the great

debt I owe to a few of the host of colleagues, both and present, who have helped me along the way.

Like so many meteorologists of my era, I began my career as an Air Force weather forecaster. I reported for active duty at Lackland AFB here in San Antonio in May 1951. The Korean War was raging and the Air Force needed weather forecasters, so I was sent to the U. of Washington for a year of introductory courses in meteorology. The training was excellent, and although I didn't get a degree, I consider myself a loyal alumnus of the U. of W.

I was fortunate to enter the field of meteorology when weather forecasting was on the threshold of evolving from an art to an applied science. To illustrate, shortly after my arrival at the U. of W, I overheard a conversation between two graduate students that went something like this: "Have you heard about this guy Charney at Princeton who is using a computer to make 24 hour forecasts in 48 hours. Ha! Ha! Ha! But as George Cressman later observed, "The computer changed everything."

Climatology was also on the verge of evolving from a dull and narrow focus on compiling and classifying surface meteorological statistics into an elegant interdisciplinary science. The situation is well illustrated by a review in the massive *Compendium of Meteorology* that was published by the AMS

in 1951. This 1334 page volume consisted of reviews of the current status of 25 so-called "specialties" in the field of meteorology.

In his review of climatology, C. S. Durst highlighted its laggard status as follows: "…climatology as presently practiced is primarily a statistical study without the basis of physical understanding, which is essential for progress."; "…there has been a woeful tendency to the use of the bones of bare statistics and mean values without the flesh of physical understanding."

However, the seeds of a new and broadened climate perspective could be found in the reviews of several other specialties, among them the General Circulation (Starr) and numerical weather prediction (Charney). As time went by, aspects of these and other meteorology specialties, along with those of other disciplines, congealed into the modern interdisciplinary framework of climate system science. To paraphrase what Ed Lorenz wrote in the Foreword to Peixoto and Oort's *Physics of Climate*, "each component (atmosphere, ocean and land) has its own internal dynamics and boundary conditions, and taken together, they form a larger system that may logically be studied as a single entity."

Weather forecasters tended to hold climatologists in low repute in the early 1950s. My good friend Murray Mitchell, who passed away much too soon in 1990, was the first real climate scientist I met while in the Air Force.

He demonstrated to me that there were indeed climatologists who did not wear green eyeshades and did not spend their time simply adding N numbers and dividing by N.

My operational career ended after four years in the Air Force, followed by seven years in St. Louis as a river and weather forecaster. I was awarded a 9-month WB scholarship to MIT, which was subsequently extended to nearly three years, thanks to the actions of Prof. Jim Austin (MIT) and Bob White, who had become the new head of the Weather Bureau,

The MIT meteorology faculty of that time was second to none. Consider that it included Jule Charney, Henry Houghton, Ed Lorenz, Reggie Newell, Norm Phillips, Fred Sanders, and my thesis advisor Victor Starr. Victor introduced us to the ground-breaking general circulation diagnostics approach that he and Bob White had developed during the 1950s. This was to fundamentally influence the future course of my career. My thesis on North American continental-scale hydrology was follow-on to the pioneering study by George Benton and Mariano Estoque published in 1954. I must give credit to my long-suffering wife Georgene who contributed mightily to my thesis. She copied something like 20 to 25 thousand vapor flux grid point values from my hand drawn maps for transfer to punched cards as input for the calculation of vapor flux divergence.

The other MIT graduate students were an extremely talented group who have contributed greatly to atmospheric and climate science. Among them is my colleague and great friend Mike Wallace. Our careers have often intertwined, and Mike has been an invaluable source of encouragement and advice to me on numerous occasions. I also highly value the many interactions I have had over the years with Mike's talented former students, wonderfully represented today by Clara and Gabriel.

It was Joe Smagorinsky who made my PhD research possible by picking up most of the tab, for which I am forever grateful. Consequently, upon graduating from MIT in 1966, I joined the staff of GFDL. As most of you probably know, GFDL was the outgrowth of the first numerical general circulation experiment conducted by Norm Phillips in the early 1950s, and the recognition by Smag of the immense possibilities this breakthrough offered. When I arrived, Suki Manabe and Kirk Bryan were conducting the first numerical simulation of a simplified coupled climate system that included atmosphere, ocean, land surface, and a primitive hydrologic cycle. In my judgment, this pioneering work, published in 1969, was to climate system modeling what Norm Phillips experiment was to modeling the atmospheric general circulation.

While at GFDL, Brahm Oort and I exploited the first five-year global rawinsonde data set that had just been compiled as a cooperative effort by Starr's General Circulation Project, the Travelers Research Center, and GFDL. Following publication of our results in the NOAA professional paper *General Circulation Statistics*, Brahm continued and expanded this line of research. He eventually published his results in the book "*Physics of Climate,*" that he co-authored with Jose Peixoto.

Following four years at GFDL, I spent 9 years at the NOAA Center for Experiment Design and Data Analysis (CEDDA) mostly working on various aspects of the BOMEX and GATE projects. Phil Arkin and Chet Ropelewski joined our group during this period – what a break that was!). As part of our GATE data analysis, Phil began what has turned out to be his career-spanning contributions to inferring global precipitation from satellite data.

Near the end of my tenure at CEDDA my activities became focused on climate variability. Historically, the search for regular features of large-scale climate variability began in earnest following the discovery of the sunspot cycle in 1852. This discovery set off an orgy of cycle hunting which lasted into the early 20th century. As late as 1957, Berlage listed 55 oscillations with periods ranging from 1.03 to 36 years that he claimed could be found in

climate data. Some of these he characterized as "hidden periodicities" because, he said, they were "masked by noise."

The 20th century subsequently witnessed a backlash to the cycle hunters that tended to throw out the baby with the bathwater. This reaction probably contributed to the lack of interest or even skepticism during the 1940s-1960s regarding Gilbert Walker's work on the Southern Oscillation. Helmut Landsberg expressed the prevailing view in the 1945 Handbook of Meteorology as follows: "Single years may be abnormal, but usually a return to normalcy is again achieved after a brief interruption." So much for any regularity in climate variability!

The situation changed dramatically in 1969 when Jacob Bjerknes identified ocean-atmosphere feedback in the equatorial Pacific as the source of Walker's Southern Oscillation. The fundamental importance of these results was eloquently summarized by Jule Charney in the 1975 Bjerknes memorial volume (this was originally meant to be a tribute to Bjerknes on his 75th birthday). Quoting Charney: "And last, let me mention the problems of climate and climate change which beckon so seductively to many of us. Whom do we find leading the way? None other than our beloved and revered Jac Bjerknes who has uncovered for us a class of long-period ocean-atmosphere interactions which promises to supply physical basis on which

dynamical models can be built to account for extra-seasonal climate fluctuations." <u>Charney always wrote beautifully.</u>

My research on what is now called ENSO was initiated in 1978 by a phone call from Rob Quayle at NCDC. I had just become a participant in the new NOAA Equatorial Pacific Ocean Climate Studies (EPOCS) program initiated by Joe Fletcher, and Rob informed me that he had completed the assembly of a comprehensive surface marine data set for the Pacific (Many belated thanks, Rob).. Analysis of these data seemed a good way to get started on EPOCS.

EPOCS was my first real exposure to the culture of the oceanographic community. In the beginning, my good friend George Philander and I hardly seemed to speak the same language. At times things did indeed get a bit testy. However, we eventually bridged the cultural divide and found that we really did see eye to eye on most issues.

Tom Carpenter was my valued colleague in this initial ENSO research effort. We were aided in the development of our analysis strategy by a number of earlier studies in the 1970s, including Kevin Trenberth's work on the Southern Oscillation. Tom and I debated how we should composite individual ENSO warm episodes, and, as has often been the case, Mike

Wallace came to the rescue with the simple suggestion "Why not just composite on the annual cycle?"

Now, on to the deluge of events of the past quarter century. This has been a period of stunning advances in climate diagnostics. Suffice to say that these advances have been powered by major improvements in satellite and insitu observations and proxy reconstructions, along with major improvements in NWP and climate models, data assimilation and, most recently, retrospective reanalysis. One result has been a more productive interplay between observational studies and model diagnostics.

Coinciding with these advances has been the emergence of a new generation of bright young climate scientists who have quickly moved to the forefront of the field. They are well represented among today's symposium speakers.

Perhaps one can point to two events in the 1979-80 time frame that serve as milestones marking the beginning of this "coming of age" of climate system diagnostics. They are the establishment of the NOAA Climate Analysis Center (now the CPC) in 1979 and the establishment of the World Climate Research Program in 1980. The CAC marked the beginning of routine dissemination of near real time climate system diagnostic information. It was an idea of Joe Fletcher and Ewe Radok to convene what they called

“climate clinics” to “diagnose” the current state of the climate. In this cane the “patient was climate. The development of the initial CAC data bases and diagnostic techniques was lead by the triumvirate of Phil Arkin, Chet Ropelewski and Dick Reynolds (this was the beginning of Dick’s long and distinguished career in SST analysis). They prepared us quite well for disseminating near real time information on the evolution of the mammoth and atypical 82-83 ENSO warm episode. This was the first time a warm episode had been tracked in near real time.

The WCRP has become a focal point for international climate system research. The first major WCRP program was TOGA, which brought together elements of the international atmospheric and oceanographic communities. Next was GEWEX, which has turned out to be a significant factor in the development of the interdisciplinary hydrological sciences as championed by Pete Eagleson. GEWEX has led the way in the application of satellite data to the description and better understanding of the global hydrologic cycle. As a consequence, it has contributed to breaking down the unfortunate discipline-oriented balkanization of the hydrologic cycle between atmosphere, ocean and land surface.

Scientific hydrology is now well integrated into the structure of the AMS, thanks largely to the leadership of prominent hydrologists such Eric

Wood, Soroosh Sorooshian, Dennis Lettermaier and John Schaake. Let me give John Schaake a particular pat on the back. John has worked long and productively at the interface between scientific and applied hydrology. He coauthored the only paper relating to climate and land surface hydrology at the First World Climate conference in 1979, and was an early leader in establishing land surface hydrology as a major component of GEWEX. Thank you, John.

TOGA and GEWEX marked the beginning of my long and enjoyable association with the talented staff of the NRC Board of Atmospheric Science and Climate (BASC), well represented today by former staffer Peter Schultz.

Among the major advances in climate diagnostics during the past quarter century is a better understanding of various recurrent aspects of climate variability. This includes ENSO, the resurrection by David Thompson and Mike Wallace of the Rossby-Namias index cycle in the modern form of annular modes, as well as progress in describing and understanding interdecadal variability. As a survivor of the 1930s dust bowl, the recent research results on the cause of multi-year drought regimes over the U. S. that were reviewed by Mark Cane are particularly exciting to me. It appears that we are finally closing in on the source of these disruptive climate events. But

now, how about the impact of the global warming trend on aridity and the frequency and intensity of droughts???

Finally, my career at the University of Maryland since 1986 has been a most pleasant and stimulating experience. It has been a privilege to work with a highly creative faculty such as Sumant, and talented graduate students, represented today by Matt Barlow. I was also able to continue my collaboration with both current and past CPC staff, notably Chet Ropelewski, Kingtse Mo, John Janowiak, And Wayne Higgins. During this period I was also invited to participate in the planning of the highly successful TRMM mission. It was a stimulating experience to work with Jerry North and the unforgettable Vern Soumi, as well as Dave Atlas and particularly Joanne Simpson, who has been a most helpful and valued colleagues over the years.

In conclusion, my career during the past half century has been a most rewarding journey. Along the way it has been my good fortune to cross paths with a host of talented and generous colleagues. It has been a great run, and I wouldn't have missed it for anything. <u>THANKS TO ALL WHO MADE IT POSSIBLE!</u>