**Joseph Smagorinsky A Man of Vision**

Joseph Smagorinsky life and his many accomplishments are already part of the public record. My purpose here is simply to add some personal recollections based on my many years working with him In Washington and later in Princeton. I first met this remarkable man in 1956, while I was a graduate student at MIT. A group of us were on our way down to Woods Hole for one of the joint Woods Hole-MIT seminars initiated by Jules Charney, Henry Stommel and Carl Rossby. On the way we stopped for coffee. Joe (Joseph Smagorinsky) was talking about his new global atmospheric model using the primitive equations, a real advance over the quasi-geostrophic forecasting models being used at the time. As we went back to the car my friend, Larry Gates, told me, "They will never get all that code checked out". I met Joe again in the summer of 1960 at Woods Hole on Cape Cod. I was a post-doc at the Woods Hole Oceanographic after spending a year at the Institute for Meteorology in Stockholm. During that summer the "Geophysical Fluids Dynamics" summer course was initiated. Doug Lilly and Suki Manabe, two members of Smagorinsky's group at the Weather Bureau, were also attending the course. I learned a lot about the climate project from them and it sounded interesting. George Veronis, a colleague at Woods Hole, had received an offer to join the lab. He had turned it down, because of another offer of an academic position, but he told me that it was a valuable opportunity. I was very receptive, when Joe gave me an offer to join his group.

The concept of a calculation of climate, based on the basic physics of the atmosphere and ocean goes back to the work of V. Bjerknes and a monograph by L.F. Richardson (1922) written shortly after World War I. Before the advent of electronic computers Richardson's approach appeared to be hopelessly impractical. Smagorinsky's laboratory grew out of the pioneering efforts in numerical weather forecasting after World War II by Professor John von Neumann and Jules Charney at the Institute for Advanced Studies in Princeton. In addition to numerical weather forecasts for one or two days ahead, which were carried by the group, Norman Phillips carried out an extended integration over many days on the ENIAC, which illustrated some of the mechanisms of the general circulation of the Earth's atmosphere (Phillips,1956). This breakthrough calculation suggested the possibility of using computers to simulate the Earth's climate. By 1955 the Weather Bureau had already acquired a new IBM version of the ENIAC. A joint numerical forecasting group was set up in Washington with the Weather Bureau, Navy and Air Force. Harry Wexler, the Chief Scientist of the Weather Bureau, with the backing of the Director, Francis Reichelderfer, got together with John von Neumann and Jules Charney to make a proposal to use part of the time on the new IBM computer to follow up on Phillips' pioneering work. A rough, first draft of the proposal is shown in Figure 2. Joseph Smagorinsky, who had experience working at both the Weather Bureau and with the ENIAC group at the Institute of Advanced Study, was asked to be the director of the project.

Since my wife and I had a baby on the way, I didn't join the "General Circulation Laboratory" until early in 1961. At that time the Lab was in Suitland, Maryland, sharing computer time with the Joint Weather Forecasting Group. It was not working out well, because "operations" always had the priority. Joe had already laid plans to be more independent by obtaining a new, experimental computer from IBM, called "Stretch", and a new building for the laboratory in downtown Washington. A very competent group of programmers were working on the three-dimensional, hemispherical, atmosphere model that was to be ready for the new computer. Nowadays, it is hard to imagine how tedious and painstaking it was to program in machine language. Larry Gates was half right. Checking out the new program took a very long time, but the code was almost ready for the new computer.

Figure 1 Joseph Smagorinsky, “Joe Smag” (1924-2005) First director of the Geophysical fluid Dynamics Laboratory, NOAA. President of the American Meteorological Society (1986), (photo by Michael Oort)

Doug Lilly, Suki Manabe and I shared one large room. Every day after lunch the tables were shoved together, and we let of steam with some wild ping-pong. All three of us were assigned long range projects, and luckily were insulated from the deadlines of the main modeling group. Manabe worked on a radiative transfer model for the atmosphere. Joe invited short term visitors from Germany and from Japan, to help him get started. Doug Lilly worked on problems in turbulence and convection, and I was assigned the task of building models of the ocean. I really had no idea on how to start, but with the help and encouragement from my two office mates, I was soon underway. Doug Lilly introduced me to the work of Prof. Arakawa at UCLA, and introduced me to the secrets of finite difference calculations.

At the time I arrived, the plans to move downtown to Pennsylvania Avenue and the acquisition of the IBM 7030 “Stretch’ were proving to be very stressful for Joe and the group working on the new global, atmospheric model. There was pressure to show results to justify the very considerable costs of the new endeavor. I remember a crisis involving the new model. At the interface between the stereo-graphic projections for the two hemispheres, air leaked due to truncation error in the tropics, resulting in the gradual loss of angular momentum. Gradually, westerlies changed into easterlies as time integration of the model proceeded. There was a frantic effort to fix the problem, which was finally successful. We moved into a single story, commercial building. “Stretch” took up the entire show room on the first floor, and most of us had offices in the basement. Two IBM engineers oversaw the machine, dressed very formally in gray flannel suits, the iconic IBM uniform.

Every morning there was a surge in the electrical system. Stretch would go down. The men from IBM would pull the curtains of the show room windows on Pennsylvania Avenue. When they brought Stretch back to life, they pulled back the curtains. Although never robust, Stretch turned out to be a very useful machine until the laboratory moved to Princeton in the Fall of 1968,

The show windows in the building turned out to be perfect to watch the big parades on Pennsylvania Avenue that celebrated the great space exploits of the "Sixties". Families were invited, and we watched the parades in comfort, sitting on tables in the computer room so we could look over the crowds on the sidewalk.

Margaret Smagorinsky, Joe's wife, brought the laboratory families together. It was the same role she played when she was with Joe at the Institute for Advanced Study in the early 1950's (see "Turing's Cathedral", by George Dyson, 2012). We had some wonderful parties at the Smagorinky's house. In addition Margaret organized expeditions for the scientist's wives to see the sites in Washington, D.C. As the lab gradually grew larger, her efforts to bring people together was a very important in creating a genuine collegial atmosphere.

Joe Smagorinsky had a friendly, outgoing exterior, but was fiercely competitive and goal driven. He was willing to take chances, if he thought it would help the mission of the laboratory. He was a strong believer in the continuing advances in computer technology. He would expound on "Moore's Law" long before most scientists had ever heard of it. He would take on new experimental computers, like the IBM 7030 "Stretch", which more cautious managers would have never considered. Likewise, he would take chances on people. The 1960's were the "Sputnik Age" in which technological advances in the Soviet Union motivated the "Space Race". In the US. almost every scientist and engineer could get a job in his or her chosen field. When Smagorinsky couldn't find local talent, he cast his net further afield. On his trips to International meetings he would look for talent. By the middle of the 1960's the scientific staff looked like the United Nations. At one of our staff picnics the children were given a play project. My wife remembered that the kids were being given instructions by their mothers in Japanese, Dutch, German, Spanish and English! Later, after the laboratory moved to Princeton, more languages were added. Margaret and Joe Smagorinsky would make all the newcomers feel comfortable as possible in their new surroundings.

Draft
July 29, 1955

DYNAMICS OF THE GENERAL CIRCULATION

Title suggested by [illegible] at lunch today with V.N. + J. Charney

1. In 1947, a project was started in Princeton by the U.S. Navy and U.S. Air Force, for theoretical and computational investigations in meteorology, with particular regard to the development of methods of numerical weather forecasting. After a few years of experimenting, the project concentrated on exploring the validity and the use of the differential equation methods developed by Dr. J. Charney, for numerical forecasting. For this purpose, the U.S. Army Ordnance Corps ENIAC computing machine was used in 1950 and in 1951, and the Institute for Advanced Study's own computing machine from 1952 onward. Subsequently, use was also made of the IBM 701 machine in New York City. With the help of these computing tools, it was found that forecasts over periods like 24 (and up to 48) hours are possible, and give significant improvements over the normal, subjective method of forecasting. Certain experiments demonstrated that even phenomena of cyclogenesis could be predicted. A considerable number of sample forecasts were made, which permitted the above mentioned evaluation of the validity of the method. A large number of variants were also explored, particularly with respect to eliminating successively the major mathematical approximations that the original method contained. It must be noted, however, that the method, and also all its variants which exist at the present, are still affected with considerable simplifications of a physical nature. Thus, the effects of radiation have only been taken into consideration in exceptional cases, the same is true for the effects of geography and topography, while humidity and precipitation have not been considered at all. That significant results could, nevertheless, be obtained, is due to the relatively short time-span of the forecasts. Indeed, over 24 or 48 hours the above mentioned effects do not yet come into play decisively.

Figure 2. First draft of a farsighted proposal in 1955 by Harry Wexler, Jules Charney and John von Neumann to set up a research group to model climate within the Weather Bureau. (courtesy of Terry Smagorinsky Thompson)

Figure 3. Earlier times: At the Aberdeen Proving Ground. (Left to Right) R. Fjortoft, J. Charney, J.C. Freeman, and J. Smagorinsky. The machine at Aberdeen was a primitive version of the ENIAC built in Princeton. It was used in 1950 and 1951 for some testing of the early weather forecasting models.

**The Move to Princeton**

At the end of the 1960's the Weather Bureau had become a part of NOAA with Robert White as its head. There was a general trend to move government laboratories out of Washington, unless they were directly involved in government decision making. Our laboratory, now designated the Geophysical Fluid Dynamics Laboratory, fit that category. The question was where? Several universities were open to the idea, but the most attractive possibility seemed to be Princeton, where the concept of the laboratory first evolved at the Institute of Advanced Study. Any move involves some losses, and we lost some very capable staff members, but almost all the scientists welcomed the move. An academic program was started with Princeton University, which eventually morphed into AOS (the Atmospheric and Oceanography Program). In addition to the graduate students, we had a constant stream of very stimulating visitors to the university from Asia and Europe. University housing was a significant aid in making the visitors and their families feel at home.

Princeton built a special building for GFDL on the Forrestal Campus. Joe "Smag" had a wide knowledge of practical things. He took a personal interest in every detail of the new building. With various improvements, it has served the laboratory well from 1969 until the present.

Sharing computer programs and data is now standard protocol between groups doing unclassified research. Things were different earlier. One of our graduate students, Bert Semtner, got a position as a faculty member at the University of California at Los Angeles. In the Meteorology Department, Prof. Yale Mintz had set up a group building global climate models. Semtner wrote an elegant program for ocean models, based on Michael Cox's work but programmed for vector computers. The model included several improvements based on the work of Kenzo Takano at UCLA. This program was widely distributed as a UCLA progress report. Michael Cox and I decided that this program was better than our own, and that we should adopt it. One day, Joe Smagorinsky came into my office and told me that I would probably get requests for our ocean model programs, but I should not comply. I had to tell him that we were not using our own program anymore, but a program from UCLA. He was startled, but then he calmed down when he realized that, if we had a graduate program, nothing we did would be proprietary.

Yale Mintz's group at UCLA was the first group to have much the same aims as GFDL. Like Joe Smagorinsky, Prof. Mintz sought talent in Japan and recruited some outstanding scientists. Akiro Arakawa's contribution in recognizing the necessity for conservation of energy and mass in finite-difference models was a key to progress. Later he concentrated on the parameterization of convection. Kenzo Takano's work made possible an early, very important, simplification of the first versions of the ocean model. The UCLA group was one of the first group to use numerical models to explore the general circulation of other planets. They did important work despite very slim computing resources in comparison to GFDL.

NASA formed a laboratory, initially under the leadership of Robert Jastrow, with an initial emphasis on research on planetary atmospheres. It is located in New York City with a connection to Columbia University. Later, under the leadership of James Hansen, the emphasis became climate change. From the beginning, public outreach has been part of its mission. Another climate modeling group emerged at the National Center for Atmospheric Research (NCAR) under the auspices of the National Science Foundation. NCAR soon developed a strong climate modeling group and pioneered in including biology and new ways to parameterize ocean mixing.

**The Issue of Climate Warming**

When the laboratory was first organized in the 1950's, the goal was to create a model of climate that would have many potential applications, some involved basic science and others practical applications. The issue of climate change due to carbon emissions had not come to the fore. However, geochemists were already making some disturbing discoveries. One of the most important was the finding of Roger Revelle that a buildup of atmospheric carbon dioxide would change the acidity of the surface of the oceans. Increased acidity would then act as a barrier to ocean take-up of carbon dioxide. The oceans could no longer be counted on to absorb all the excess carbon dioxide produced by the world-wide burning of fossil fuels.

A visitor to the laboratory, Prof. Fritz Moeller, from Germany made some calculations of the radiative - convective balance for a doubling of carbon dioxide in the atmosphere, holding the <u>specific humidity</u> constant. Manabe repeated his single column calculations. However Manabe argued that in the real atmosphere <u>relative humidity</u> is conserved . Since water vapor is a major component of the Earth's greenhouse, constant relative humidity implies a very strong positive feedback, which had not been fully appreciated by pioneer investigators. Later Manabe and Wetherald (1967) obtained a scientific breakthrough with the first realistic explanation of the greenhouse effect. Joseph Smagorinsky became convinced that climate warming was an important issue to be addressed by the laboratory.


(right to left) Joseph Smagoorinsky, Syukuro Manabe and Kirk Bryan. Before the move to Princeton.

Since Manabe and Wetherald's single column model was an extremely simplified picture of the atmosphere, it was important to verify the conclusions with more general climate models, including the oceans and the entire globe. Inclusion of the ocean was particularly important because of its enormous heat capacity, which would absorb heat and slow down the climate's response to a build-up of carbon dioxide. After the move to Princeton, Joe added three geochemists to the staff, one an expert on the atmosphere and two experts on the ocean. Although Joe saw the importance of research on global warming, he always retained a scientist's caution, and felt there was still important questions to be answered.

A very important contribution of Smagorinsky was to chair a report of the National Academy, "Carbon Dioxide and Climate: A Second Assessment",1982. The "Smagorinsky Report" was intended to be a follow-up of the 1979 "Charney Report", an earlier National Academy report, warning of the effects of fossil fuel burning. The purpose of the report was to discuss scientific research on climate that were carried out after the "Charney Report" was written. These reports did have a big impact on the research community, even if they had little immediate effect on other government actions. The direction of research was changed. The international planning for climate monitoring in both the oceans and atmosphere was given greater priority. The report recognized that studies of climate variability are important, since large scale variability can obscure longer term trends in both the atmosphere and oceans. In 1988 the United Nations founded the IPCC (International Panel on Climate Change) six years after the "Smagorinsky Report" was written. The first IPCC meeting of climate experts from different countries took place in 1990. This meeting marked the transformation of the climate change issue from the domain of a few geochemists and climate modelers, mainly in the United States, to a global enterprise.

The initial IPCC conference of experts was held in 1990 at Windsor in England, a beautiful place. Our delegation from GFDL took pride for being able to show the climate response to atmospheric CO2 loading of one of the first coupled ocean-atmospheric models( Manabe et al.1991). This result took over 30 years of effort. Without a leader of Joe Smagoringsky's foresight and persistence, a sustained effort at the lab over three decades would not have been possible.

Recently, Stouffer and Manabe(2018) have examined the prediction of surface temperature changes of the model (Stouffer et al., 1989), which was presented at Windsor, allowing for the greater observed change of CO2 in the atmosphere, which has risen much more rapidly than projected in the early 1990's. Compared with modern observations of surface temperature change, the prediction made 30 years before scaled to the actual CO2 rise is remarkably accurate. The model predicts the greatest warming over the Northern Hemisphere continents at high latitudes. and little or no warming over most of the Southern Oceans. Missing in the solution is the recent poleward shift of the Circumpolar Current and the spectacular changes in sea surface temperature near the Palmer Peninsula. Since the prediction of surface temperature changes was made decades before the measurements, Manabe and Stouffer (2018) is an answer to critics, who imply that climate modelers are adjusting their models to fit observed climate change.

**GARP**

The World Meteorological Organization (WMO) was formed by the United Nations in the 1960's and was very active in promoting international cooperation to promote weather forecasting. Joe Smagorinsky was chosen by WMO to chair GARP (Global Atmospheric Research Program) aimed at testing whether enhanced observations in the tropics could improve forecasts. Global general circulation models run at the GFDL by Kikuru Miyakoda and his team demonstrated the GARP tropical observations importance in extending the range of numerical prediction.

The WMO also played a role in easing the tensions of the "Cold War" in the post WW II era. Smagorinsky's outgoing personality made him an energetic scientific ambassador for the United States. He made many contacts with foreign scientists, and particularly some very outstanding scientists from the Soviet Union. By sponsoring visits of Russian scientists to the US., Smagorinsky made their work better known in the West. M.I. Budyko, G. Golitzin and A.M. Obukov all visited GFDL at one time or another.

In a study of the role of the oceans in the global heat balance I was already familiar with Prof. Budyko's work in climatology. Manabe had used his work in parameterizing the surface flux of heat and water of GFDL climate model. We were both very happy to meet him in person. Budyko very early realized that climate change would result from the use of fossil fuels, and participated in the initial phase of the IPCC in the 1990's. Budyko arranged a trip in which he took Joe Smagorinsky to the settlement in Belarus where his parents originally came from before emigrating to United States.

**Summary**

Smagorinsky received many awards which recognized his achievements. Perhaps one of the most personally satisfying to him was In 2003, when he and his close friend and colleague, Norman Phillips, were jointly awarded the Benjamin Franklin Medal in Earth Science for the "conception and final realization of quantitative models of the Earth's climate to be used in weather forecasting and investigations of climate and climate change".

Looking back on Joseph Smagorinsky's career we can see that he was very lucky to be present at the very birth of computer technology and numerical weather forecasting at the Institute of Advanced Study in Princeton. He was also very fortunate to begin his leadership role in the "Sputnik" era, in which there was a prevailing impression (later proved largely untrue) that America had fallen behind the Soviet Union in Science and technology.

More important were his leadership abilities. He understood what motivated scientists. He respected achievement in both pure and applied science equally. With the help of his wife, Margaret, he created a laboratory in which researchers could interact with visitors and students in a collegial atmosphere. He disdained management by counting of publications and looked for real accomplishment instead. Unlike many lab directors, he never wanted to co-author any paper unless he had substantial involvement in the research. His optimism overcame many obstacles which would have seemed insurmountable to fainter hearts.

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