Geophysical Fluid Dynamics and Computers

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Research Themes Implemented in FY2015
Extreme weather variations in the stratosphere-troposphere coupled system: past, present, and future (Grant-in-Aid for Scientific Research (S))
Prediction of solar cycle activity and evaluation of its impact on the climate and environment of the Earth (Grand-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area))

In the summer of 1983, I landed a position as a research associate in the Kyoto University Faculty of Science and thus embarked on my career as a professional researcher. That was over 30 years back. My long-term involvement with the Grants-in-Aid for Scientific Research (Kakenhi) began in 1984 with a research project in the category of Encouragement for Young Scientists on the theme, "Numerical study of the multiple stable states of flows in geophysical fluid systems." A search through the Kakenhi database disclosed that I was awarded 900,000 yen for this initial single-year project. Some old grant application documentation from that period that I keep in my filing cabinet revealed that I spent 700,000 yen—almost 80 percent of the grant total—to cover expenses for the use of mainframe computers, with the remainder allocated for consumables and travel expenses. Given the current value of the yen, that would have been a fairly generous sum of money for a young researcher back then. This had me intrigued as to the actual acceptance rate for grant applications submitted by researchers in those days. At the time in question, word processors and personal computers did not yet exist, and we wrote all of our application forms by hand. The secretarial staffers in our research labs were proficient in preparing applications with the block style of writing, and I recall that projects submitted with attractively written application forms were then believed to have a much better chance of being awarded grants.

In the years since, I have been mostly engaged in computer-based numerical studies on themes in the fields of geophysical fluid dynamics and dynamic meteorology. Starting with the first ENIAC machine of the 1940s, computers have demonstrated a tenfold leap in processing speed about every five years. However, around 1980, the computing environment at our mainframe computer center consisted of one or two computers, each with less processing power than the typical notebook machine available on the market today. Furthermore, that environment was shared by several hundred researchers and students. That period was the veritable dawning age for nonlinear science and computational science. Whereas the traditional research methodology comprised a pencil-and-paper approach that sought to analyze nonlinear problems by first converting the governing equations of nonlinear fluid dynamics into linear equivalents, we were at that time entering an era that would establish a new research methodology capable of harnessing computers to numerically analyze nonlinear systems in unmodified form and deepen our dynamical understanding of their behavior. Of course, due to the limits on the processing power we then had at our disposal, instead of striving for the direct numerical simulation of solutions to the governing equations, we sought numerical solutions to a set of approximate, simplified equations.

From the 1980s through the 1990s, I pursued research on the following themes. With global-scale atmospheric motions in mind, I focused on a forced-dissipative system of quasi-horizontal, two-dimensional fluid on a rotating sphere, explored the bifurcation of nonlinear solutions and the multiple states of stable solutions, and argued for diversity in the meandering patterns of the atmospheric jet stream. I also investigated the bifurcation properties of steady and periodic solutions of the interaction model between the zonal mean zonal flow and planetary waves that propagate upward from the troposphere through the stratosphere, and sought a dynamical interpretation of time-variations of the stratospheric polar vortex. Additionally, working from a geophysical fluid dynamics perspective, I investigated the pattern formation and parameter dependence of two-dimensional turbulence on a rotating sphere and discovered the emergence of retrograde polar vortices due to the effect of planetary rotation.

In 1983 and 1984, the computer centers at the University of Tokyo and Kyoto University installed the nation’s first supercomputers (based on vector processor technology), thus affording researchers a world-leading computing environment provided they had the budgetary means to cover the computer usage fees. In fact, the computing environments in Japanese universities by then had evolved enough to effectively compete with and even surpass their counterparts abroad. Around this point in time, I had the opportunity to concentrate on my research for two years on assignment to the US as a JSPS Fellow for Research Abroad. Although I was a bit pretentious about the sort of computing environment I would have access to in the US, UNIX and the X Window system were then under development, with prototype products already being released to market, so I was actually rather surprised by the highly flexible and functional computing environment I found. I learned a lot from and was intellectually stimulated by US approaches to group research with cutting-edge computer systems. That included the joint development and use of shared computer programs by the research community as well as the development and preparation of software programs designed to analyze and graphically render “big data.” After returning to Japan, I and several other colleagues that, like me, had gained experience with research and study at institutes and universities in the US together set up the Geophysical Fluid Dynamics DENNOU Club and embarked on activities in research and education that spanned the fields of earth science, and computational and computer sciences. Those activities have continued to this day, albeit with a shift in leadership to a new generation (https://www.gfd-dennou.org/).

In the 1990s, I utilized most of my budget for research for purchases of expensive UNIX workstations or leases of computing time with supercomputers. As an associate professor, I shared in the task of developing and maintaining the research environment for our meteorology lab and participated in several large-scale, top-down research projects. One, in the Creative Basic Research category, was a project on "Development of climate models and numerical studies on climate change" (Principal Investigator: Taroh Matsuno, Professor, University of Tokyo). Another, a Research for the Future Program project, had the theme, "Computational science and engineering for global scale flow systems" (Principal Investigator: Yukio Kaneda, Professor, Nagoya University). With the start of this new century, I was eventually promoted to a full professor in charge of the meteorology lab. However, while purchases of facilities and equipment basically transitioned from workstations to PC clusters, a large share of our research budget is still utilized to secure cutting-edge computing resources.

My own research has shifted to dynamic meteorology with a focus on the stratosphere and troposphere. To this day, I have continued to receive support in the form of Kakenhi funding for a range of projects, including the following: "Dynamics of climate variations of the stratosphere-troposphere coupled system" (Scientific Research (B)); "Assessment of the influence of the stratosphere on climate change and elucidation of its dynamical role" (Scientific Research (A)); "Extreme weather variations in the stratosphere-troposphere coupled system : past, present and future" (Scientific Research (S)); "Material transports associated with large-scale atmospheric waves and their seasonal and inter-annual variations" under the project, "Variation of dynamical processes and ozone in the stratosphere and their role in climate" (Scientific Research in Priority Areas; Principal Investigator: Saburo Miyahara, Professor, Kyushu University); and "Prediction of solar cycle activity and evaluation of its impact on the climate and environment of the Earth," under the project "Solar-terrestrial environment prediction as science and social infrastructure" (Scientific Research on Innovative Areas; Principal Investigator: Kanya Kusano, Professor, Nagoya University).

I credit the assistance I have received through the grant programs entirely for my ability to pursue research within an atmosphere of intellectual freedom backed by my own interests while maintaining a healthy respect for the difficulties associated with large-scale, top-down research undertakings on the issue of global warming. In recent years, an increasing number of Southeast Asian students and researchers who come to our lab for long-term stays are helping to expand my scope of research interest to tropical meteorology. I am currently exploring the possibility of having such students and researchers access computing servers in Japan from their home countries via the internet and utilize cloud computing to pursue joint international research on a routine basis.

I am told that in FY2018, the Kakenhi program will undergo sweeping reforms aimed at preparing it to better meet the modern demands of scientific endeavor. As many others have already pointed out, we yearn for a system that shields grant applicants from the procedural and screening fatigue that otherwise could adversely impact their research pursuits. We also look forward to a system that ensures researchers with steady and sustained access to basic research funding while facilitating the pursuit of risky undertakings in exploratory research with competitive funding.