Serving Science and Society: Lessons from Large-Scale Atmospheric Science Programs

Roger A. Pielke Jr. and Michael H. Glantz
Environmental and Societal Impacts Group,
National Center for Atmospheric Research, Boulder, Colorado*

1. Introduction

In 1975, the president of the American Meteorological Society (AMS), David Atlas, published an editorial on the AMS *Bulletin*'s "President Page" entitled "Selling Atmospheric Science." The essay discussed the difficulties of convincing policy makers of the worth of weather modification research. Atlas noted that, in general,

> projects are repeatedly sold on the basis of explicit or implicit promises of economic benefits. . . . Whatever disclaimers are made at the outset, the sponsors nearly always entertain expectations of benefits, and these expectations grow with time. As funds are expended, the project leader is often obliged to justify further resources on the basis of results to date, which can lead either to over-stated claims of results or great benefits to come. And finally, if no definitive results are forthcoming, the customer will tend to forget the original disclaimers and accuse the operator of having sold him a bill of goods (Atlas 1975, p. 688).

Such a phenomenon of diminishing faith in the research enterprise may now be under way in the atmospheric sciences specifically and in U.S. science policy more generally. Twenty years after Atlas discussed problems associated with the "selling" of atmospheric science programs, it is time to revisit and constructively discuss the topic.

In recent years the U.S. science community has been under stress as a direct result of the end of the Cold War, federal budget deficits, and pressing policy problems.[1] Stress has manifested itself in calls for the scientific community to "demonstrate" tangible benefits in order to obtain federal funding (e.g., Mervis 1995; Boehelert 1994; Mikulski 1994). Ongoing change in U.S. science policy reflects the evolution of the post–World War II "social contract" between science and society (Bush 1960).[2] The social contract held that in exchange for federal funding and relative autonomy, science was obliged to produce research results to benefit society (Office of Technology Assessment 1991). Where it was once possible to justify research on a claim that societal benefits were the inevitable consequence of research funding, today decreasing budgets and persistent societal problems are creating tensions on the old contract and are thus stimulating change (National Academy of Science 1993; Clinton and Gore 1994; Guston and Kenniston 1995). While the future state of U.S. science policy is unclear, under changing conditions it is clearly best for science if the scientific community plays a leading role in directing the course of change. To fail to do so could enable those outside science to force changes in undesirable ways (Brown 1993).

One area where the atmospheric sciences can contribute to constructive change is in helping the president "establish with the Congress mechanisms for prioritizing, committing to, and then sustaining long term support for large projects" (Clinton and Gore 1994, p. 13). More broadly, the atmospheric sciences

*The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Corresponding author address: Dr. Roger A. Pielke Jr., Environmental and Societal Impacts Group, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000.

In final form 23 June 1995.

[1]See, for example, Lederman 1991; House Committee on Science, Space and Technology 1992a; Byerly 1995; Rensberger 1995; and Broad 1995.

[2]On the social contract see, for example, Kevles (1976), England (1977), and more recently Guston and Keniston (1994) and Byerly and Pielke (1993).

can play a leading role within the scientific community in improving upon the old social contract.

In his 1975 essay, Atlas suggested that "with limited resources for science, it is unrealistic to expect that major programs will be initiated or enlarged without an appraisal of the likely benefits to be derived." The same remains true today, 20 years later. Yet, it also remains true that a demonstration of benefits of atmospheric science is difficult because "so little has been done to appraise the value of present and potential atmospheric science applications" (Atlas 1975, p. 689). As offended as some members of the science community might be at the thought of having their scientific proposals compete in an informal as well as formal political environment of bargaining, negotiation, and compromise, the fact is that science programs are in essence "marketed" when their proponents (scientists, administrators, or politicians) seek to gain federal support. As pervasive and important as it is, the problems, politics, and processes of marketing science have received little scrutiny.

Underlying the discussion of science marketing developed in this paper is the idea that program performance needs to be commensurate with expectations generated during the program marketing process. This implies not only that attention should be paid to program performance, but perhaps more importantly to creating realistic and appropriate expectations about what science can and cannot do. Improved communication between scientists and their patrons is part of the challenge of fostering more realistic expectations. Another part of the challenge is to learn how to structure and present scientific research activities in a manner that helps serve both societal goals and the goals of science.

To stimulate constructive debate, this paper focuses on the marketing of *large-scale atmospheric science programs* within the scientific community as well as to the federal government. The first section presents a set of principles of marketing content and procedure. These criteria are then applied to three large-scale post–World War II research programs in the atmospheric sciences. In the concluding section, the paper proposes several possible lessons for future science initiatives learned in the 20 years since David Atlas first addressed the topic of selling atmospheric science.

2. Criteria of marketing success

Marketing should not be confused with priority setting in science. One could effectively argue that they are opposite sides of the same coin. Priority setting refers to the process of allocating funds among competing science projects and between science and other elements of the federal budget. From the time that Alvin Weinberg published his seminal article on "Criteria for Scientific Choice" (Weinberg 1963) to the U.S. congressional Office of Technology Assessment's "Decisions for a Decade" (Office of Technology Assessment 1991), a large literature has developed on priority setting in science. The "marketing" of research programs—the "selling" of science—refers to efforts of groups within the science community to elevate the priority of a particular favored program of research over other competing programs.

At first one is tempted to say that successful marketing of science results in a program that is approved as a "new start" in the federal budget. Annually increasing levels of funding are equated to even greater marketing success. Yet, budgetary success is only a measure of short-term political expediency: It provides neither insight into the quality of a program nor its chances for success at meeting its stated goals. For long-term efforts, budgets alone are an insufficient criterion of marketing success. Because the formulation, promulgation, and execution of decisions—that is, the policy process—is continuous with budgets set and decisions made about a particular program on an annual basis, a successfully marketed program often must be resold to some degree each year. Thus, it is necessary to go beyond the line items in the federal budget to identify relevant criteria for determining marketing success.

a. Principles of content

Dutton and Crowe (1988) proposed three criteria for setting priorities among scientific initiatives that can be applied to marketing science: scientific merit, coordination, and usability. Dutton and Crowe use the terms scientific merit, programmatic concerns, and social benefits. These criteria are consistent with general understandings of the role of policy "promotion" or "recommendation" in the broader process of policy making (Lasswell 1956, 1971).

1) Scientific merit

Dutton and Crowe (1988, 600) argue that "scientific endeavors are meritorious in proportion to the extent that they reveal the laws and interactions governing the structure and evolution of . . . physical or biological phenomena." Weinberg (1971, 616) argues that "the scientific merit of a field is to be measured by the degree to which it contributes to and illuminates the neighboring fields in which it is embedded." In other words, Weinberg suggests, "what is best for science is what is best for the largest number of scientists."

In reality, determinations of the scientific merit of a particular program are made by a political process. Of course, as one anonymous reviewer observed, an important aspect of scientific merit is support for the proposed program of research from rank and file scientists. Although procedures such as peer review are in place to assess scientific merit with some degree of objectivity, "peer review operates most directly and successfully when experts from the same discipline make priority rankings of research proposals within established programs" (Atkinson and Blanpied 1985, p. 107). Peer review can break down because of the difficulty associated with selecting among competing programs from different disciplines or those focused on policy problems. As Dutton and Crowe (1988, p. 599) ask, "Which has greater scientific merit? Discovering what the mean atmospheric temperature will be if the carbon dioxide content doubles or discovering the distribution of energy and mass in the universe at $t = 3$ mins." As the president of the National Academy of Sciences noted in 1988, one problem facing the scientific community is that there is more meritorious science proposed by scientists than can be funded by the government (Press 1988). Thus, scientific merit alone, while a necessary condition, is seldom a sufficient one to guide a program to marketing success (cf. Milbank 1990; Office of Technology Assessment 1991).

2) Program coordination

Program coordination refers to how well participating agencies, disciplines, and component projects interact to meet a program's goals. Coordination is a stated (if not realized) objective of most large-scale science programs. Because most science programs need to be justified to congressional committees, funding agencies, and executive branch officials for reasons broader than "science for the sake of science," multiagency and multidisciplinary efforts are often required, potentially providing a program with a broad base of political support.[3] There has been much consideration of the definition of "big" science (e.g., Office of Technology Assessment 1991, 156–163). For science marketing purposes, a science program may be considered big if it has a line item in the overall federal budget. Such a line item guarantees that a program will receive some degree of legislative and executive attention, because in a tight budget situation a line item calls attention to the costs of foregoing other opportunities (called opportunity costs) outside science, such as reducing the federal budget deficit.

[3]The Superconducting Supercollider (SSC) was an ill-fated multibillion-dollar physics program within the Department of Energy. The program was terminated by Congress in 1993, in part, because it had a narrow agency and disciplinary constituency. See Kuntz (1990) on the marketing of the SSC.

In principle, the successful coordination of a program subordinates parochial interests to the broader interests addressed by the proposed program (Brunner and Ascher 1992). Relatively narrow agency and disciplinary contributions to the proposed program are placed in a broader context. Under the formal objective of synthesis, participants are expected *not* to "do their own thing." In reality, however, a program's budget often becomes viewed as a pie to be divided among many agencies (cf. Kuntz 1990; Daddario 1974).

3) Usability

A third criterion for determining marketing success is the usability of a program's outputs. A program focused on advancing scientific understanding will usually produce knowledge that can be used by other scientists or perhaps used serendipitously by users outside science. More generally, however, large-scale science programs are supported by the government as a means to achieve a policy goal. When a science program is supported in order to fulfill some societal goal, rather than as an end in itself, the odds for marketing success are increased when there is a clear explanation of what the program will produce, who will use its output in what ways, for what purposes, and when. Although the usability of a scientific endeavor often refers to the potential application of outputs of the program, such as the generation of new information or new technologies, it can also refer to other kinds of output, such as the creation of jobs in congressional districts (i.e., "pork") or intangibles such as national prestige (Kuntz 1990).

Usability does *not* mean that science programs must show immediate economic utility but rather that a program needs to establish and demonstrate some means for linking research with the program's stated societal benefit goals. The general notion of usability with regard to the research output of scientific programs is in need of better understanding. Until that is done, a program's usability must be carefully assessed on a case-by-case basis.

In the 1990s, usability has become an increasingly important criterion with regard to the selling of science programs to Congress, the executive branch, and the public than it had been in post–World War II decades. For example, Congressman G. Brown (1993), a longtime supporter of the scientific community, noted that following World War II "the success of science in enhancing our national security led to a mystical faith that continued support for science would help solve a range of other problems and lead to a heaven here on earth." Brown observed that the times have changed and that policy makers are no longer willing to "accept on faith alone the statements of scientists that their research is intrinsically worthwhile and necessary" to confront the many policy problems of the modern era (cf. Byerly 1995; Mervis 1995; Mikulski 1994). In the 104th Congress as well, a number of Republicans are continuing calls for science to show more efficacy (e.g., Browning 1995; Mervis 1995; Stone 1995; Boehlert 1994; *Nature* 1995). In today's fluid political climate, science programs can more easily secure public and political support if they can *demonstrate* usability with respect to their stated societal goals.

These three principles of content—scientific merit, coordination, usability—are not mutually exclusive, but interrelated. For example, scientific merit supports the development of usable applications, and usable applications depend upon the coordination of various participants.

b. Principles of procedure

A particular science program is proposed, in essence marketed, in a broader policy process where it must compete with numerous other science programs as well as initiatives outside science. Success in the policy process thus becomes as much a function of procedural factors as of a program's content. The following sections describe three of the most important criteria for procedural success: windows of opportunity, cultivating users, and packaging and presentation.

1) Windows of opportunity

Downs (1972) identified an "issue-attention cycle" in which a particular policy problem "suddenly leaps into prominence, remains there for a short time, and then—though still largely unresolved—gradually fades from the center of public attention" (p. 38). According to Downs, the cycle of the rise and fall of public attention to issues in the United States has five stages:

- The *preproblem stage* where a problem has been identified by experts or interest groups but has not yet captured the interest of the public.
- The *alarmed discovery and euphoric enthusiasm* stage occurs when a dramatic event or series of events focus attention on an issue.
- Following the euphoria of issue discovery, the next phase begins with a sobering *realization of the cost of significant progress* that would be required by society to address the problem.
- *Gradual decline of public interest* in the issue results because of a number of factors, including public frustrations, discouragement, and boredom with the issue.
- The issue then enters the *postproblem stage* in which public concern shifts to other problems. While the new institutions, programs, and policies created to deal with the issue persist, they are now largely outside the public eye.

Within this issue-attention cycle defined by Downs there are windows of opportunity that open and close for the selling of particular programs. Windows of opportunity can appear for a number of reasons, including, but not limited to, research findings, a disaster, or political pressure (Kingdon 1984). In addition, as an anonymous reviewer of this paper observed, windows of opportunity can also result "from the convergence of two streams—growing scientific understanding and growing public/political awareness." There are several reasons why windows of opportunity are of major importance for marketing science.

First, the political atmosphere will be most favorable for seeking program approval during the "alarmed discovery and euphoric enthusiasm" stage, when public attention is focused on a problem. In this stage, policy makers are more likely to be motivated to respond either to the problem or to their constituents' concern about it. Because advocates of a particular program are often among the first to identify a problem, they play an important role in issue discovery and in moving public interest out of the preproblem stage.[4] Second, once the public realizes the costs of significant progress, it is important for the program to demonstrate results. In the longer term, those marketing a science program must be careful to preserve the integrity of science by refraining from overselling issues, that is, offering more than the science can realistically expect to deliver. They must also avoid the tendency to present every issue as an alarmed discovery. As a congressman once warned, "Come clean, guys, because you are destroying your credibility, and you are harming science" (Kuntz 1990, p. 1255). In this regard, some of the more outspoken groups within the scientific community run the risk of being viewed as "Chicken Littles"—generators of false alarm. Those who market science must take care to present programs in the spirit of the times and not to create unsubstantiated dread factors for the sole purpose of generating public alarm.

2) Cultivating users

For science programs to be usable they must have potential or actual users. In this regard, scientists can find relevant principles (e.g., dos and don'ts) for marketing scientific programs from the business commu-

[4]An important aspect of program advocacy is a leader or champion of the proposed program. Without leadership even the most well-designed program may not succeed.

nity. One of the keys to successful marketing in the business community is the cultivation of a customer base—in other words, users. In an article in the *Harvard Business Review,* a marketing consultant noted that successful marketing in the 1990s requires businesses to integrate "the customer into the design process to guarantee a product that is tailored not only to the customers' needs and desires but also to the customers' strategies" (McKenna 1991, p. 67). Furthermore,

> the marketer must be the integrator, both internally—synthesizing technological capability with market needs—and externally—bringing the customer into the company as a participant in the development and adaptation of goods and services. It is a fundamental shift in the role and purpose of marketing: from manipulation of the customer to genuine customer involvement; from telling and selling to communicating and sharing knowledge. . . . Playing the integrator requires the marketer to command credibility. In a marketplace characterized by rapid change and potentially paralyzing choice, credibility becomes the company's sustaining value. (McKenna 1991, p. 68)

Such lessons from the business sector are equally relevant to addressing the concerns of users of science in the 1990s and to the rapidly changing environment of public policy.

In 1993, Senator Barbara Mikulski (D–MD) stimulated much concern and debate within the science community when the appropriations subcommittee she chaired directed the National Science Foundation to "move beyond rhetorical statements about the value of strategic research or the importance of using science for the transfer of knowledge and technology" and to "spell out how much of its mission should clearly be strategic and applied in nature, and then to implement these parameters through its budget process" (Marshall 1993, p. 1512). Mikulski was calling on the scientific community to pay much more sincere attention to and show more concern about its customers (users). Mikulski's sentiments reflect a trend in Congress toward a performance-based evaluation of science programs (Mervis 1995). For science marketers this means that the identification, cultivation, and satisfaction of the user of science has become an increasingly important challenge.

3) Packaging and presentation

Scientists often believe that the scientific content of their programs will have sufficient intrinsic merit, visible to all, to win approval. In reality, scientific content by itself is rarely sufficient to win approval of a program; packaging and presentation make a difference. For example, two preeminent physicists expressed surprise that favorable media attention along with the prestige of a Nobel Prize were deciding factors in congressional approval of a large-scale physics program (Suskind 1985). Nelkin (1987, p. 173) notes that "we read about the results of research and the stories of success, but not about the process, the dead ends, the wrong turns." In efforts to package research programs, scientists must be careful to not mischaracterize their endeavors to the public.

Wells (1992), a former congressional staffer, prepared a detailed guide for scientists and engineers who seek to work with Congress. He presented "seventeen cardinal rules for working with Congress," to improve the "chances of acceptance of your ideas, suggestions, or proposals" (p. 68). These rules could serve as a useful guide to the packaging and presenting of science proposals.

Several of Wells's rules (pp. 68–72) are common sense, applicable to anyone working with Congress; for example, "convey that you understand something about Congress," "use time—yours and theirs—effectively," "don't patronize either members or staff." Some of Wells's rules are specific to science. For instance, Wells notes, as follows:

- *Don't seek support of science as an entitlement.* This may seem obvious, but it is a problem that occurs with sufficient frequency to require highlighting. Even if the word "entitlement" is not used directly, members and staff react negatively when presented with arguments in support of science that they see as being cast in "entitlement terms." In other words, "support for science should be presented in terms of helping to meet national needs, or to achieve societal goals, not as an entitlement owed to scientists," and scientists and engineers should not "convey an attitude of being inherently deserving in contrast to other seekers of the public largesse." (p. 69)
- *Make it easier for those in Congress to help you by focusing your problem or issue clearly and making apparent what decision is needed or what action Congress should take.* Too often scientists and engineers who come to Congress for assistance do not make clear what the problem or issue really is . . . . Members and staff appreciate proposals for action that are clear and articulate, and show that they have been thought through before presentation. (pp. 71–72)
- *Remember that members and staff are mostly generalists.* While most are "quick studies" you cannot assume that they will immediately understand or appreciate the value of what you are

proposing. Keep messages simple, do not be too detailed; and do not overwhelm your listeners with technical jargon. (p. 72)

It becomes immediately apparent that effective packaging and presentation of science programs can sometimes conflict with communication of the scientific process and scientific results. For instance, it is a very difficult task to explain *clearly* and *simply* how, for example, high energy physics research directly relates to specific social goals. Selling science successfully requires careful attention to the implications of the trade-off between simplification and accuracy.

Meeting the criteria of marketing content and procedure does not guarantee that a program will win approval in any given legislative year, nor does failure to meet the criteria mean that a program will fail to win approval. What the criteria do provide is a basis for structuring and promoting a program that has an enhanced chance of winning approval, especially in tight budget years. A scientifically meritorious, well-coordinated, and usable research plan that is put forward at an opportune time, with engaged user(s), and is well presented and packaged will have a higher likelihood of sustained support from the federal government and the public more broadly.

3. Three cases of selling atmospheric science

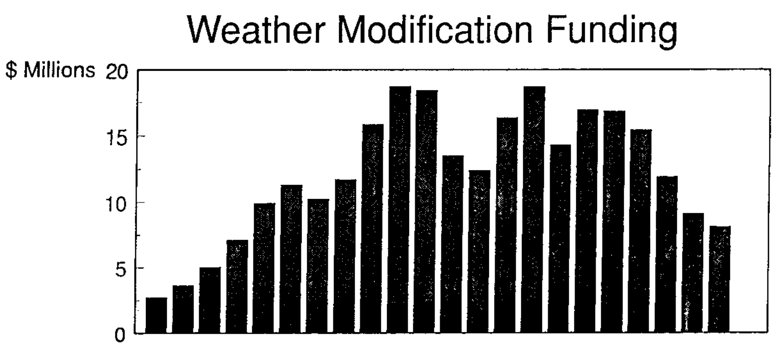
Because of disdain for scientists who blatantly "sell" science, little attention has been paid to how well (or poorly) scientists actually market science programs. Nevertheless, an improved understanding of science marketing can enhance the use of science in the pursuit of societal goals and can serve to reinforce public faith in the scientific enterprise itself. The following sections focus briefly on three efforts to sell large-scale atmospheric science programs to Congress and the public.

a. Case I: Weather modification

Large-scale scientific attempts to augment precipitation, disperse fog, suppress hail, control hurricanes and other forms of weather modification began immediately after World War II. In the 1950s and 1960s scientists and policy makers shared optimism that the broad area of weather modification research would result in beneficial applications for agriculture, reclamation, national defense and natural disaster reduction, among other uses. By the late 1960s and early 1970s, however, a large-scale program of weather modification research had fallen out of government favor, and, as a result, congressional support diminished (Fig. 1). The rise and fall of support for a large-scale program of weather modification research can be directly and indirectly attributed to shortcomings in the marketing processes pursued by its proponents.

1) Scientific merit

The Department of Defense (DOD), working General Electric, initiated Project Cirrus in the late 1940s as a result of successful laboratory experiments conducted by Nobel laureate Irving Langmuir (Byers 1974). Following several encouraging field experiments, the U.S. Weather Bureau joined the defense department, and Project Cirrus was not only continued but was joined by other field projects through the 1960s. However, weather modification experiments were able to neither confirm statistically earlier successes nor repeat them (Byers 1974). Weather modification efforts began optimistically but soon settled into the sober realization that applying the science of weather modification to societal ends would be more difficult than initially expected. Byers (1974, p. 21) attributes the initial rapid rise in scientific optimism, followed by an equally rapid fall, to "overly enthusiastic advocacy," that is, overselling the ability of the science to deliver what had been proposed. He notes that the zealous advocacy "impeded the orderly progress of the science, but it probably can be said that without this pushing, governments would not have put their resources behind cloud-physics research the way they did." There was considerable doubt within the scientific community, as well as among government agencies, about the claims of success of cloud-seeding ex-



Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
$ Millions (current)	2.7	3.6	5.0	7.1	9.9	11.3	10.2	11.7	15.8	18.7	18.4	13.5	12.4	16.3	18.7	14.3	16.9	16.8	15.4	11.9	9.1	8.1	

Fig. 1. Trends in federal funding for weather modification activities, 1963–1984 (Changnon and Lambright 1987).

periments and operations. In short, to many observers, most forms of weather modification simply did not work very well. It is important to realize that there is a fine line between selling the need for a scientific endeavor and overselling what it might ultimately deliver.

2) Coordination

A series of reports, including several conducted by the National Academy of Sciences, General Accounting Office, Congressional Research Service, noted that despite congressional demands for a coordinated research program, the weather modification effort had become fragmented along agency lines (Changnon and Lambright 1987). Lambright and Changnon (1989, p. 346) labeled the fragmentation in federal weather modification research "administrative pluralism." They argue that administrative pluralism was significant with respect to the fate of the weather modification program because the individual agency activities did not add up to form a coherent programmatic whole. For example, a number of congressional delegations from western states strongly supported the weather modification program of the Department of Interior's Bureau of Reclamation in the hope of addressing the bureau's central mission: to augment western water supplies. With western support, the Department of Interior commanded the largest share of federal weather modification funding by 1966 (Changnon and Lambright 1987). However, in part because of its narrow water interests, the bureau had little interest in the coordination of its research with other agencies, for example, those involved in the investigation of the modification of severe weather events such as hurricanes or tornadoes (Changnon and Lambright 1987).

In 1974, the defense department reluctantly admitted that it had secretly used weather modification technologies to wage a "weather war" in Vietnam (Shapley 1974). The agency attempted to increase rainfall with cloud seeding over Laos, Cambodia, and Vietnam in order to make jungle roads impassible to the guerrillas. This information, as well as the public's negative reaction to the war in general, prompted a congressional backlash against the DOD program. By 1978, the DOD was officially out of the weather modification business (Changnon and Lambright 1987). As congressional policy makers saw narrow bureaucratic interests preclude opportunities for interagency collaboration, weather modification drifted out of the political arena and disappeared from the congressional agenda.

3) Usability

Federal weather modification efforts left the identification of weather modification uses largely to the private sector (Elliot 1974). However, several agencies within the government, such as the DOD and the Bureau of Reclamation, showed interest in the uses of the research at various times. When weather modification began to fall out of congressional favor, the effort had few champions, aside from a number of scientists and groups within federal and state agencies. Debate continued in the scientific literature regarding the success rates for seeding operations claimed by the cloud seeders themselves. Statistical manipulation of experimental results for various cloud-seeding programs also detracted from external support (Katz and Glantz 1979). In short, weather modification lacked a means to demonstrate its usability with respect to societal goals.

4) Window of opportunity

Weather modification has its modern roots in the period immediately following World War II (Byers 1974).[5] The creation of the atomic bomb had demonstrated the ability of policy makers to harness science and technology to shape nature as well as international relations. During this period, the federal government began to dramatically increase expenditures on science and technology as the nation entered the space age and a golden age for research and development (McDougall 1985). The early scientific successes of weather modification (e.g., in Project Cirrus) reinforced the optimism of the period and support for and interest in weather modification rose throughout the 1960s. However, when early apparent "successes" became difficult to replicate and when science and technology in general began to fall out of public favor in the 1970s, weather modification's window of opportunity began to close (Changnon 1975).

5) Cultivation of users

Throughout its history, weather modification research efforts failed to identify explicitly its potential users or those potentially affected by weather modification. For example, Changnon and Lambright (1987, 4) observed that most studies of the potential use of weather modification research indicated that U.S. agriculture would be the "single greatest beneficiary." Yet, the U.S. Department of Agriculture showed little interest in developing the technology. Some (potential) uses of weather modification generated social

[5]Weather modification has a long history. James P. Espy, a meteorologist, proposed to Congress in 1850 that 40 acres of timber be set afire each 20 miles along a 600–700-mile north–south line in order to produce rain at a cost of "a half a cent a year to each" U.S. citizen (Spence 1980). Espy was but one example of a "rainmaker," that is, one who proposed for a fee to bring rain to parched regions or to desperate farmers facing major losses in the face of severe drought conditions.

conflicts. An example of the conflicts generated by weather modification activities was supplied by Mewes and Farhar (1977). In the early 1970s some farmers in Colorado's San Luis Valley favored attempts to increase precipitation, whereas ranchers were opposed. In 1972 the conflict escalated to the point where weather modification equipment was dynamited, causing $50,000 in damage. In addition to local conflicts over weather modification, it became an increasingly complex interstate legal issue as those states potentially adversely affected sought to assess the impacts (e.g., damages) of the research on society (Haas 1974). For example, Idaho claimed that its clouds were being "rustled" by the state of Washington. [See Davis and Grant (1978) on legal aspects of weather modification.]

6) Packaging and presentation

According to Changnon (1975, 33) weather modification did not have sufficient glamour to sustain agency support. Changnon observed that

> the word "glamour" is used because I have been intrigued at the way state and federal governments have sometime "used" weather modification. Certain agency leaders have criticized, in scientific circles, weather modification, particularly the operational efforts. Yet, they have also embraced it when they desired weather-related attention at public and political interfaces. This tendency to use the field has also been used by some research scientists. Many have sought and received basic atmospheric research support by disguising the research as a weather modification project. These approaches have hurt the field because they often led to an oversell and expectations seldom achieved. (p. 33)

Weather modification was also damaged by controversies involving the operational use of weather modification research. For instance, a devastating 1972 flood in Rapid City, South Dakota, was linked in the media (although not by scientists) to a weather modification experiment. Interestingly, cloud-seeding scientists who sought to increase precipitation in the region and claimed their operations could enhance precipitation had to deny that the observed deluge in Rapid City was the result of their cloud-seeding efforts. As noted earlier, the defense department was criticized before a highly visible congressional hearing for its use of weather modification technologies in the Vietnam War (Shapley 1974). Because of these, as well as other, controversies, "during 1971–1972 this once glamour-related field became fraught with public involvement and political concerns" (Changnon 1975, p. 34). By the mid-1970s, weather modification conjured up a negative response in much of the public.

b. Case II: Global change

In November 1990 President George Bush signed the Global Change Research Act of 1990 (P.L. 101-606), which secured in law the U.S. Global Change Research Program (USGCRP). The USGCRP was developed and initiated by several federal agencies in the late 1980s in response to national and international concerns about climate change, ozone depletion, and other global environmental changes. As a result of such concerns, in the law Congress *explicitly* sought from the USGCRP "usable information" to aid in the formulation and execution of global change policy (P.L. 101-606). After its establishment, the program witnessed a doubling of its budget from $659 million in 1990 to $1326 million in 1993, which placed it among the nation's largest science programs: From 1990 through 1993 the government had spent a total of over $4.1 billion on the program. In 1993, however, the USGCRP began to face criticism from Congress and the Office of Technology Assessment, among others, for not having defined or structured a process to produce "usable information" (e.g., Office of Technology Assessment 1993a,b; House Committee on Science, Space, and Technology 1993; Monastersky 1993; cf. Pielke 1994, 1995). Such criticisms are directly and indirectly linked to efforts to market the program to Congress.

1) Scientific merit

In general, the USGCRP has been widely judged to be producing "sound" science. For instance, the Office of Technology Assessment (1993a, 110) found the program to be "scientifically well-grounded" and a National Research Council (1990a, 3) assessment found the program's "ranking of science priorities" to be "consistent" with program goals and the "consensus of the scientific community." Some recent evaluations, however, have suggested that the program has underemphasized research on the human dimensions of global change. There has been increasing concern that the USGCRP has primarily focused its research on basic physical processes of global environmental change at the expense of research on the biological, ecological, and human impacts. In 1994 the USGCRP began to address such concerns (e.g., Watson 1994; Committee on Environment and Natural Resources 1994), and in 1995 the program emphasized a human dimensions component (National Academy of Sciences 1994).

As the USGCRP begins to focus aggressively on aspects of global environmental change beyond the physical sciences, understanding the physical sciences of global environmental change seems more daunting than ever. One scientist commented that, "The scope of this [climate change puzzle] is expanding willy-nilly. I'm afraid we're not going to resolve this quickly. We really don't have an integrating framework with which to view these things" (quoted in Kerr 1994, 1562). In short, the USGCRP has focused on an extremely difficult scientific task of monitoring, understanding, and predicting changes to the physical earth system but has only recently recognized that even that focus is too narrow for the production of "usable information."

2) Coordination

The USGCRP was planned in the late 1980s by a White House committee that was praised by Congress and the scientific community for its coordination of the budgets of various participating agencies. In 1990 the National Research Council (1990, p. 3) called the interagency coordination of the USGCRP "exemplary regarding definition and planning at the program level." In fact, President Bush's science-advisor, D. Allan Bromley, modeled the science policy structure in the executive branch on the USGCRP model. The USGCRP, however, has not been judged as successful at coordinating *disciplines* within its overarching mandate. The Office of Technology Assessment (1993b, pp. 7–8), for example, found that the program "has suffered from fragmentation of research efforts."

In response to such criticisms, the USGCRP has increased attention to "integrated assessment capabilities" (Committee on Environment and Natural Resources 1994, pp. 82–83). However, as one official noted in 1993, "assessment is a word that has really come to mean all things to all people" (House Committee on Science, Space, and Technology 1994, p. 44). This statement suggests that there is much confusion and uncertainty about the meaning as well as how to carry out an integrated assessment to produce usable information. This is clear from statements in the 1995 USGCRP plan (Committee on Environment and Natural Resources 1994, p. 82) that note that integrated assessment capabilities have yet to be developed. Future success of the USGCRP depends upon its ability to develop a process that provides decision makers with what they (not the scientists) perceive to be usable information.

3) Usability

In spite of its congressional mandate to provide "usable information" to policy makers (as required by P.L. 101-606), the USGCRP has been criticized in government and other assessments for not having adequately defined how the information it produces is or will be usable and by whom (e.g., Office of Technology Assessment 1993a; Bernabo 1993; Pielke 1995). In a 1993 assessment of the program, the Office of Technology Assessment (p. 111) found that "although the results of the program, as currently structured, will provide valuable information for predicting climate change, they will not necessarily contribute to the information needed by public and private decision makers to respond to global change." In 1994, program officials noted that "in order to be of more assistance to governments, USGCRP results need to be better communicated in a way that contributes directly to the formulation of domestic policy and to the development of international protocols and conventions" (Committee on Environment and Natural Resources 1994, p. 80). The USGCRP is expected to identify its users and define "usable information" when it releases its 10-yr plan.

4) Window of opportunity

The USGCRP was put forward at an optimal time. Global change became a policy issue largely as a result of the "global warming" issue.[6] Figure 2 shows the number of stories per month in the *New York Times* and *Washington Post* that refer to global change, climate change, global warming, or greenhouse effect from 1986 through 1993. The horizontal line in the figure shows the average monthly number of stories from June 1988 through the end of 1993. Media attention to global change peaked in 1989 and 1990, according to this measure. The Global Change Research Act was introduced in Congress in January 1989 and was signed into law in November 1990. From 1990 to the end of 1993, congressional and press attention to global change issues fell, interrupted only during the period leading to the 1992 Earth Summit in Rio de Janeiro. The *New York Times* and the *Washington Post* printed fewer stories on global change in 1993 than in any year since 1987, and in December 1993 printed fewer global change stories than in any month since May 1988. Following the alarmed discovery of global change by the public in the late 1980s, the 1990s have seen a gradual decline in public interest, and the USGCRP's window of opportunity appears to be slowly closing.

5) Cultivation of users

The USGCRP has directed little attention to identification, cultivation, or satisfaction of its users. Bernabo (1992) attempted to bring together global change

[6]On the rise of concern in the early 1980s about global change by way of concerns about global warming see Wilkins (1993), Ungar (1992), and Ingram et al. (1991). Climate change science, more generally, has a relatively long record of research in many different national and international programs.

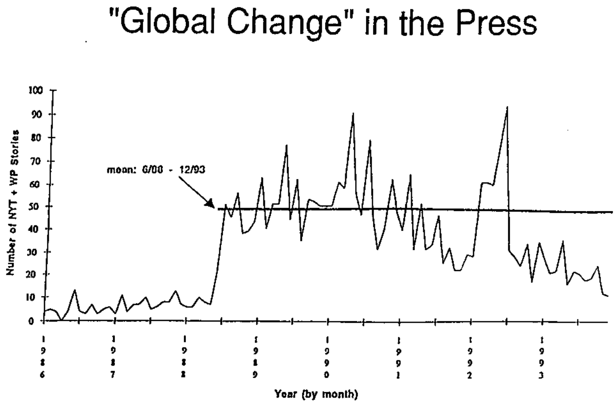


FIG. 2. Number of stories, by month, in the *Washington Post* and *New York Times* that refer to global warming, greenhouse effect, climate change, or global change.

scientists and national policy makers (e.g., members of Congress, agency officials) to determine what questions were being asked and what answers could be provided and on what timescales. Bernabo (1992) found that the national decision makers had some concerns that would be answered through USGCRP research and other concerns that were not being addressed by the program.

In theory, any individual, private or public organization, or local, state, national, or international government is a *potential* user of global change science, as global environmental changes are ubiquitous. However, the needs of different users will depend on the particular context of a particular decision or activity. The USGCRP has largely neglected the need to clarify alternative courses of action for purposes of decision making (Office of Technology Assessment 1993a,b; Brunner 1993). Additionally, in 1994 the National Research Council called for "research on the decision-making process," noting that "scientific research is of little practical value if it does not address the issues that matter to decision makers and reach them in a useful form" (National Research Council 1994, p. 15–20). As a result of such critiques, the program has recently stated a need to focus attention on its user community (e.g., Committee on Environment and Natural Resources 1994; Watson 1994). One result is that the National Science Foundation has developed a program for "policy science" research with respect to global change.

6) Packaging and presentation

From its beginning, the USGCRP was presented as a "science for policy" program in that requests for public support of the science conducted by the program was justified in terms of its potential as well as expected contributions to decision making. Representative James Scheuer (D–NY) reaffirmed the program's policy mandate when he noted that "in passing the Global Change Research Act of 1990, Congress mandated the development of an integrated U.S. research program designed to produce information readily usable by policy makers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global change" (House Committee on Science, Space, and Technology 1992b, p. 2). While this strategy was initially very successful, Rep. Scheuer expressed the tone of many congressional hearings on global change when he asked a witness "We [in Congress] are in desperate need of policy assistance. What are the ways—what are some of the things that we could do to increase the policy relevance of scientific research on global change?" (House Committee on Science, Space, and Technology 1989, p. 244). The packaging of the USGCRP as a policy relevant program has created expectations in Congress that the program will contribute directly to improved decision making.

Some scientists have found that the global change program's policy mandate has hindered the program's scientific development. Participants at an Office of Technology Assessment (1993b, p. 24) workshop found that

> when scientists cannot answer the questions of policymakers in 1 or even a few years, they find it more difficult to "sell" a program as relevant to policy needs. The result may be annual budget fluctuations and/or rapidly shifting priorities—both of which are detrimental to the development of a sound scientific program.

Program packaging and presentation affects its usability, cultivation of users, and scientific merit. The USGCRP is an example where trade-offs are necessary between presenting a program that policy makers want and one that the scientific community can realistically implement. As Office of Technology Assessment (1993b, p. 24) notes "the timetable for governmental decisions is driven by the yearly budget cycle that ranges between 2 and 6 years. Not surprisingly, policy makers funding global change often have a shorter time horizon for 'answers' than researchers." Researchers, for their part, often have limitless time horizons. Scientific investigation often generates more questions than it resolves, and scientists do not know when "breakthroughs" will occur. Nevertheless, the difficulty of knowing when and in what form scientific research will "pay off" is an added reason for scientists to exert caution when justifying a research program in terms of tangible and timely benefits to society. Criticism of the USGCRP centered on the usability issue can be directly attributed to differences between its *packaging* as a policy-relevant program and its *structuring* as a basic research program (Pielke 1995).

c. Case III: Weather research program

In October 1992 Congress passed the National Oceanic and Atmospheric Administration (NOAA) Authorization Act of 1992 (P.L. 102-567). The legislation was significant because it established in law the U.S. Weather Research Program (USWRP), a large-scale science program. Weather research on a spatial scale of roughly between several miles and several hundred miles and a temporal period of hours to days is referred to as mesoscale research in the atmospheric sciences community. The USWRP sought to increase sharply federal funding for mesoscale research in 3 yr, from $107 million in 1993 to $222 million in 1996 (Subcommittee on Atmospheric Research 1994, p. 74). This victory came after a decade or so of attempts within the atmospheric science community to generate congressional support for a nationally oriented, multiyear weather research effort. The weather community's victory, however, was short lived. Congressional *authorizations* only give permission for a program to begin, while actual funding decisions are made through congressional *appropriations.* Following its successful authorization, the USWRP failed to win approval of congressional appropriators. The experiences of the USWRP and its predecessors are a case where marketing efforts have, thus far, failed to secure budgetary as well as much broader scientific approval. As a case study, these experiences hold many lessons for science "marketers."

1) Scientific merit

Scientists have attained "considerable progress" in their understanding of mesoscale weather processes (National Research Council 1990b, p. 23). In addition, the U.S. National Weather Service is in the midst of an extensive upgrade to its weather surveillance capabilities. It has implemented a new generation of weather radar across the nation and is planning to launch a new series of weather satellites late within the decade. With improved basic understandings and technologies, scientists hope to "improve the prediction of weather, to reduce weather related economic losses, and better protect our citizens" (Subcommittee on Atmospheric Research 1994, p. xv). Following from these achievements, it would seem that the science of mesoscale meteorology is ripe for advancements. Yet, as the cases of weather modification and global change illustrate, the path from basic research to societal benefit is "neither certain nor straight" (Brown 1992). The mesoscale research community needs to take care that social benefits are not promised based solely on the expectation that scientific advances will lead inevitably to economic or other payoffs. A possible solution to this problem is to incorporate the identification of the potential use and value of the proposed research into the program's research focus.

2) Integration

The USWRP counts among it participants groups within the National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), and Departments of Transportation, Interior, Energy, Defense, Commerce, and Agriculture (Federal Coordinating Council on Science, Engineering, and Technology 1992). However, to date, NSF and NOAA have been the main advocates for a weather research program. There has also been little attempt to involve social scientists in attempts to identify potential or actual societal benefits of improved understanding of mesoscale weather processes. While there are social science researchers who investigate various aspects of mesoscale weather (e.g., forecasts, impacts, responses), there is no apparent sense of community among them, whereas in contrast there does exist a community of researchers who see themselves as part of a climate impacts subfield.

3) Usability

A mesoscale research initiative (such as the USWRP) will have an improved likelihood for marketing success if it can demonstrate a connection between its research and potential benefits in those contexts where improved forecasts could add value to existing human activities. The idea that mesoscale research produces information that society *might* be interested does not in itself have enough selling power. The program must identify potential users and convince them by demonstration and discussion of the value-added nature of future research. Society has been immersed in and benefited from weather information for so long that the (potential) use of additional research is not so obvious to the public at large or to their congressional representatives.

4) Window of opportunity

Weather has always been a matter of public concern. However, the period of 1992–95 is the first time in a long while that so many weather anomalies have adversely affected most parts of the United States: A multiyear drought, then flooding in southern California; flooding in central California and the lower- and upper-Mississippi River Basins; blizzards and ice storms in the central and northeastern United States, Hurricanes Andrew and Opal; and so forth. Hence, from the perspective of heightened societal awareness, recent events could provide the opening of a window of opportunity for active attempts to market a national mesoscale research initiative.

5) Cultivation of users

Weather information has many current as well as potential users across numerous sectors of society. For example, MITRE Corporation was involved in a series of North American meetings to which the representatives of various industries (such as construction and communications) were invited in order to address their potential uses and needs for meteorological information (e.g., MITRE 1977). A few years later, the National Research Council (1980, p. 4) identified similar weather-dependent economic sectors such as agriculture, aviation, construction, communications, electric power, energy, manufacturing, transportation, and other public and private consumers. However, the USWRP and its predecessors [e.g., Stormscale Operational Research Meteorology (STORM), Severe Environmental Storm and Mesometeorological Experiment] have not prominently displayed research support for the identification of users (actual and potential), or how and where improved weather forecasting might be used to improve decision making (cf. Subcommittee on Atmospheric Research 1994, pp. 15–16). Often, benefits of these proposed programs were assumed by program supporters to exist and to be widespread throughout the nation, and often put forth in grandiose statements. For example, the National Research Council (1990b, p. 36) claims that "the benefits [of a USWRP] are large and will exceed greatly the estimated cost" of the proposed initiative. If such alleged societal benefits cannot be explicitly demonstrated with empirical evidence, then a process for understanding and demonstrating benefits needs to be developed and included as part of the program.

6) Packaging and presentation

Project STORM was proposed in the early 1980s to improve predictive capabilities of mesoscale weather phenomenon (e.g., National Research Council 1980). However, the program made "little progress" toward its formal initiation during the 1980s, the initiation of several precursor efforts notwithstanding (National Research Council 1990b, p. 11). In the early 1990s, after numerous failures to secure funding for the proposed program, Project STORM was renamed and repackaged to look like the successfully marketed USGCRP. The new USWRP was proposed to Congress in the form that the USGCRP has successfully used (cf. Federal Coordinating Council on Science, Engineering, and Technology 1992).[7] However, reliance on the USGCRP model was not sufficient for the USWRP to secure congressional funding. The mesoscale research initiative needs to be packaged so as to exploit the particular benefits to society that can be associated with additional weather research.

4. Concluding comments: Thoughts for future initiatives

Each of the three program's difficulties in the policy process can be linked, at least in part, to shortcomings in its marketing strategy. The brief discussion of the marketing of weather modification, global change, and mesoscale meteorology is summarized in Table 1. The U.S. Global Change Research Program is judged to have successfully met more criteria than the other two programs; hence, its relative success in the political process. The three cases in the atmospheric sciences also suggest possible lessons for marketing science more broadly.

a. Marketing does make a difference

Although many members of the science community have disdain to "sell" the need for or value of their science to policy makers or the public, the fact is that program marketing is a necessary part of the policy process, increasingly so in areas of science. Science marketing cannot be avoided, so long as scientists seek federal funds and desire to participate in the policy process. Therefore, scientists who do participate in the policy process must compete with others for scarce federal funds. Under tight budget conditions, funds will be allocated by policy makers increasingly on their expectations of what science will provide, and policy makers are likely to place more attention on the actual fulfillment of promises made by scientists about their particular program's objectives. The long-run interests of scientists requires that they be honest as to what they view as their "deliverables" when seeking support for a program. It is often asserted that policy makers need to better understand how scientific research is done. Scientists, too, need to better understand how policy process works.

b. Selling and overselling

There are challenges to the making of appropriate

[7]A document promoting the USWRP included an identical structure—including tables and charts—that was used in USGCRP reports to present its content and implementation plan (cf. Federal Coordinating Council on Science, Engineering, and Technology 1992 and Committee on Earth and Environmental Sciences 1990).

promises of benefits resulting from scientific research. First, there is an incentive for scientists to present science as *the* answer to some of the problems that policy makers face. Policy makers go along with this because, for the most part, they often prefer to avoid difficult decisions and favor placing the onus of problem solving upon science. However, when science fails to solve problems that scientists suggested it could (as it did, for example, with weather modification), it is usually the scientists who pay the price in terms of lost funding and credibility.

A second challenge is that we, as a society, have a poor general understanding about how advances in scientific research contribute to societal benefits. Historians of science have long argued that a linear model—basic research leading to applied research, technology, development, applications, then finally societal benefits—fails in many cases to provide an accurate representation the relationship of science to the rest of society (e.g., Wise 1985). Perhaps science programs that promise societal benefits need to consider how research produced by the program will actually result in such benefits *as an integral part of the program's research.*

c. Credibility of the scientific community

Scientific research has value as an end in itself, as well as in terms of broader societal benefits. Regardless of the potential societal value of its research, when a science program fails to meet expectations of performance of the public and their elected representatives generated during the marketing process, the scientific community is needlessly put on the defensive. It is often suggested that credibility is difficult to get, but easy to lose. The long-term sustainability of public support for scientific research will be enhanced if scientists pay explicit attention to the marketing of research programs and to the expectations by society of science generated in that process. It is likely to be in the marketing arena where credibility will largely be gained and lost.

TABLE 1. Summary of marketing success. A plus in a column reflects our judgment that program marketers successfully met that particular criterion of marketing success. A minus indicates our judgment that they did or have not.

Criteria	Program		
	WM	USGCRP	USWRP
Content			
science	–	+	+
coordination	–	+	–
usability	–	–	–
Procedure			
window of opportunity?	+	+	+
cultivation of users?	–	–	–
packaging and presentation?	–	+	–

References

Atkinson, R. C., and W. A. Blanpied, 1985: Peer review and the public interest. *Issues in Science and Technology,* **1,** 101–114.

Atlas, D., 1975: Selling atmospheric science. *Bull. Amer. Meteor. Soc.,* **56,** 688–689.

Bernabo, J. C., 1992: Joint climate project to address decision makers' uncertainties. EPRI Rep. TR-100772, 86 pp.

——, 1993: Statement before the House Committee on Science, Space, and Technology. Hearing on Global Change Research: Science and Policy, 19 May, U.S. Government Printing Office, 12 pp.

Boehlert, S., 1994: Budget climate calls for new priorities in physics. *APS News,* The Back Page, February, 3, 8.

Broad, W. J., 1995: G.O.P. budget cuts would fall hard on civilian science. *The New York Times,* 22 May, p. A1.

Brown, G., 1992: The objectivity crisis. *Amer. J. Phys.,* **60,** 779–781.

——, 1993: Can scientists 'make change their friend'? *Sci. Amer.,* **6,** 152.

Browning, G., 1995: Tense days down in the lab. *National J.,* 22 April, 1005.

Brunner, R., 1993: Policy and global change research: A modest proposal. Paper prepared for the 1993 APPAM Annual Conference, Washington, DC, Assoc. Public Policy Anal. and Manage., 36 pp.

——, and W. Ascher, 1992: Science and social responsibility. *Policy Sciences,* **25,** 295–331.

Bush, V., 1960: *Science—The Endless Frontier.* National Science Foundation, 220 pp.

Byerly, R., 1995: U.S. science in a changing context: A perspective. *U.S. National Report to the International Union of Geodesy and Geophysics 1991–1994,* R. A. Pielke, Ed., Amer. Geophys. Union, in press.

——, and R. A. Pielke Jr., 1995: The changing ecology of United States science. *Science,* **269,** 1531–1532.

Byers, H. R., 1974: History of weather modification. *Weather and Climate Modification,* W. N. Ness, Ed., John Wiley and Sons, 3–44.

Changnon, S. A., 1975: The paradox of planned weather modification. *Bull. Amer. Meteor. Soc.,* **56,** 27–37.

——, and W. H. Lambright, 1987: The rise and fall of federal weather modification policy. *J. Wea. Modification,* **19,** 1–17.

Clinton, W. J., and A. Gore, 1994: *Science in the National Interest.* U.S. Government Printing Office, 31 pp.

Committee on Earth and Environmental Sciences, 1992: *Our Changing Planet: The FY 1993 Research Plan.* Office of Science and Technology Policy, 90 pp.

Committee on Environment and Natural Resources, 1994: *Our Changing Planet: The FY 1995 Research Plan.* Office of Science and Technology Policy, 84 pp.

Daddario, E. Q., 1974: Science policy: Relationships are the key. *Daedelus,* **103,** 135–142.

Davis, R. J., and L. O. Grant, Eds., 1978: *Weather Modification: Technology and Law.* Westview Press, 124 pp.

Downs, A., 1972: Up and down with ecology: The issue attention cycle. *The Public Interest,* **28,** summer, 38–50.
Dutton, J. A., and L. Crowe, 1988: Setting priorities among scientific initiatives. *Amer. Sci.,* **76,** 599–603.
Elliot, R. D., 1974: Experience of the private sector. *Weather and Climate Modification,* W. N. Hess, Ed., John Wiley and Sons, 45–89.
England, M. J., 187: Dr. Bush writes a report—Science: The endless frontier. *Science,* **191,** 41–47.
Federal Coordinating Council on Science, Engineering, and Technology, 1992: *Predicting Our Weather.* Subcommittee on Atmospheric Research, Office of Science and Technology Policy, 36 pp.
Guston, D., and K. Keniston, 1994: Updating the social contract for science. *Technol. Rev.,* **97,** November/December, 61–68.
Haas, J. E., 1974: Sociological aspects of weather modification. *Weather and Climate Modification,* W. N. Hess, Ed., John Wiley and Sons, 787–812.
House Committee on Science, Space, and Technology, 1992a: *Report of the Task Force on the Health of Research.* July, 102-Serial L, 19 pp.
——, 1992b: *U.S. Global Change Research Program.* 5 May, 102nd Congress, No. 148, 200 pp.
——, 1993: *Global Change Research: Science and Policy.* 19 May, 103rd Congress, No. 60, 147 pp.
——, 1994: *Climate Change Action Plan and Assessment.* 16 November, 103rd Congress, No. 111, 145 pp.
Ingram, H., H. B. Milward, and W. Laird, 1991: Scientists and agenda setting: Advocacy and global warming. Paper prepared for presentation at the APPAM Annual Meeting, Bethesda, MD, Assoc. Public Policy Anal. and Manage., 30 pp.
Katz, R. W., and M. H. Glantz, 1979: Weather modification for food production: Panacea or placebo? *J. Soil and Water Conservation,* **3,** 132–134.
Kerr, R., 1994: Did Pinatubo send climate-warming gases into a dither? *Science,* **263,** 1562.
Kevles, D., 1977: The National Science Foundation and the debate over postwar research policy, 1942–1945. *Isis,* **68,** 5–26.
Kingdon, J., 1984: *Agendas, Alternatives, and Public Policies.* Harper Collins Publishers, 240 pp.
Kuntz, P., 1990: Pie in the sky: Big science is ready for blastoff. *Congressional Quarterly.* **48,** 28 April, 1254–1260.
Lambright, W. H., and S. A. Changnon, 1989: Arresting technology: Government, scientists, and weather modification. *Sci., Technol., and Human Values,* **14,** 340–359.
Lasswell, H. D., 1956: *The Decision Process.* Bureau of Governmental Research, University of Maryland, 23 pp.
——, 1971: *A Pre-View of Policy Sciences.* Elsevier, 173 pp.
Lederman, L., 1991: Science: The end of the frontier? *Science,* **254** (suppl.), 20 pp.
Marshall, E., 1993: Senate turns up heat on NSF. *Science,* **261,** 1512–1513.
McDougall, W., 1985: . . . *The Heavens and the Earth: A Political History of the Space Age.* Basic Books, 555 pp.
McKenna, R., 1991: Marketing is everything. *Harvard Business Review,* **91,** January/February, 65–79.
Mervis, J., 1995: Asking science to measure up. *Science,* **267,** 20–22.
Mewes, J., and B. Farhar, 1977: Hail suppression in the San Luis Valley. *Hail Suppression: Society and Environment,* Monograph 24, Institute of Behavioral Science, University of Colorado, 33–45.
Mikulski, B., 1994: Science in the national interest. *Science,* **264,** 221–222.
Milbank, D., 1990: Scientists have to beat the bushes for money to stay in business. *Wall Street Journal,* 7 November, p. A1ff.
MITRE Corp., 1977: Living with climatic change. *Proc., MITRE Corporation, American Meteorological Society, and Aspen Institute for Humanistic Studies Symposium.*
Monastersky, R., 1993: The $1.5 billion question: Can the U.S. Global Change Research Program deliver on its promises? *Sci. News,* **144,** 158–159.
National Academy of Science, 1993: *Science, Technology, and the Federal Government: National Goals for a New Era.* National Academy Press, 54 pp.
——, 1994: Science priorities for the human dimensions of global change. Committee on the Human Dimensions of Global Change, National Academy of Sciences, Washington, D.C.
National Research Council, 1980: *Atmospheric Precipitation: Prediction and Research Problems.* National Academy Press, 63 pp.
——, 1990a: *The U.S. Global Change Research Program: An Assessment of the FY 1991 Plans.* National Academy Press, 107 pp.
——, 1990b: *Advancing the Understanding and Forecasting of Mesoscale Weather in the United States.* National Academy Press, 56 pp.
——, 1994: *Science Priorities for the Human Dimensions of Global Change.* National Academy Press, 36 pp.
Nature, 1995: The year of utilitarian science? *Nature,* **373,** 1–2.
Nelkin, D., 1987: *Selling Science: How the Press Covers Science and Technology.* H. Freeman and Co., 224 pp.
Office of Technology Assessment, 1991: *Federally Funded Research: Decisions for a Decade.* OTA-SET-490, U.S. Government Printing Office, 314 pp.
——, 1993a: *Preparing for an Uncertain Climate—Volumes I and II.* OTA-O-568, U.S. Government Printing Office, 383 pp.
——, 1993b: *Global Change Research and NASA's Earth Observing System.* OTA-BP-ISC-122, U.S. Government Printing Office, 45 pp.
Pielke, R. A., Jr., 1994: Scientific information and global change policymaking. *Clim. Change,* **28,** 315–319.
——, 1995: A policy appraisal of the U.S. Global Change Research Program. *Policy Sciences,* **28,** 39–77.
Press, F., 1988: "The Dilemma of the Golden Age." Presidential Address, 125th Annual Meeting of the National Academy of Sciences, 26 April, 14 pp.
Rensberger, B., 1995: The cost of curiosity: The political mood is for shifting funds from basic science to a more strategic policy. *The Washington Post National Weekly Edition,* 16–22 January, p. 11.
Shapley, D., 1974: DOD said to admit to weather war. *Science,* **184,** 47.
Spence, C. C., 1980: *The Rainmakers.* University of Nebraska Press, 181 pp.
Stone, R., Ed., 1995: Republican bucks basic research trends. *Science,* **267,** 19.
Subcommittee on Atmospheric Research, 1994: *United States Weather Research Program: Implementation Plan.* Subcommittee on Atmospheric Research, Office of Science and Technology Policy, 103 pp.
Suskind, R., 1985: On science, politics and the path to $200 million. *New York Times,* 14 March, p. A7.
Ungar, S., 1992: The rise and (relative) decline of global warming as a social problem. *Sociological Quarterly,* **33,** 483–501.
Watson, R. T., 1994: Statement before the Committee on Energy and Natural Resources. U.S. Senate, 24 May, 37 pp.
Weinberg, A., 1963: Criteria for scientific choice. *Minerva,* **1,** 159–171.
——, 1971: The axiology of science. *Amer. Sci.,* **58,** 612–617.
Wells, W. G., 1992: *Working With Congress: A Practical Guide for Scientists and Engineers.* American Association for the Advancement of Science and the Carnegie Commission on Science, Technology, and Government, 153 pp.
Wilkins, L., 1993: Between facts and values: Print media coverage of the greenhouse effect. *Public Understanding of Sci.,* **2,** 71–84.
Wise, G., 1985: Science and technology. *Osiris,* 2d ser., **1,** 229–246.