Public-Private-Academic Roles and Responsibilities in the Atmospheric Sciences
A Case Study Prepared for the 2003 AMS Summer Colloquium

Prepared by Roger A. Pielke, Jr.

OUTLINE

1. Introduction to Technology Policy
2. Technology Policy and the Atmospheric Sciences
3. Sectors and Context
4. Issues Raised as Sectors Blur Roles and Responsibilities
5. Why Technology Policy Matters for the Atmospheric Sciences
6. Where Next? The NRC Report and Beyond
7. Bibliography

Center for Science and Technology Policy Research

CIRES

1. Introduction to Technology Policy

Given the large government support of atmospheric sciences research and the desire of policy makers, academics, and those in the private sector to see the results of that research result in benefits to society, the relation of the weather research and the private sector is a matter of national technology policy. Perhaps surprisingly, the atmospheric sciences community was not at all a consideration in the national debates over technology policy that occurred in the 1980s and 1990s (see, e.g., Bromley 1990, Branscomb 1992, Clinton and Gore 1993, NAE 1993, Branscomb and Keller 1999). But what, exactly, is "technology policy?" According to Branscomb (1993, 3)

> a technology is the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest … technology policy must include not only science policy – concern for the health and effectiveness of the research enterprise – but also all other elements of the innovation process, including design, development, and manufacturing, and the infrastructure, organization, and human resources on which they depend. There is widespread agreement that the government's role is to enhance the competitive advantage of the United States firms in international commerce and to increase innovation rates and productively here at home, without disrupting markets or spending public funds inappropriately.

A consequence of the atmospheric science community's absence in the U.S. technology policy discussions is that there exists no formal technology policy for meteorology, or perhaps more accurately, the policies that do exist which together comprise a de facto technology policy for the atmospheric sciences fail to incorporate the broader lessons of the nation's technology policy debates.

One of the most profound changes in the nation's technology policy has been a recognition that

> skill, imagination, and knowledge, together with new forms of institutional collaboration between firms, universities, and government, can make products and services more effective and productive. Thus, technology policy must be user-centered and demand-based, in contrast to a supply-side approach (Branscomb and Florida 1999, 6-7).

Such a perspective requires closer collaboration and interactions between the producers of knowledge and those who use knowledge to develop, produce, and deliver products and services. In the context of meteorology, this means that researchers must work more closely with government agencies and the private sector. The interactions of research and operational meteorology are challenging enough (e.g., NRC 2000), however interactions between researchers who are primarily government funded and the private sector brings its own set of unique challenges.

> The new way of working with the private sector puts heavy demands on government officials. It was easy to run a technology policy when government decided what research was needed, agreed to pay for it, and picked people to do it. Now government must work more by indirection and must understand the way the new economy works, sector by sector (Branscomb and Florida 1999, 7).

In some respects, such a perspective has a long history in meteorology (e.g., Changnon 2000. NRC 1998). But in other respects, considerable opportunity exists for the atmospheric sciences community to improve its technology policies in such a way as to facilitate the more efficient transfer of knowledge into benefits for society.

Central elements of technology policy are the institutional mechanisms of technology transfer, i.e.,

> the processes through which new technologies are created, commercialized, and adopted involve many different organizations and an extensive flow of information. Technology transfer within and among organizations underpins the translation of science into product, as well as the adoption of new products and processes. . . It is based to a large extent on the ability of individuals and groups of individuals involved in research to interact with those responsible for technology commercialization (NRC 1992, 16).

The federal government and public and private universities have invested considerable effort in developing mechanisms to stimulate technology transfer in areas such as health, defense, and energy (e.g., GAO 1998, 1999, Guston and Kenniston 1994). Such mechanisms are not without controversy and ongoing debate (e.g., Press and Washburn 2000). But the central lesson for the atmospheric sciences is that although the atmospheric sciences community has involvement (sometimes considerable)in technology transfer activities, there remains significant untapped opportunity for taking systematic advantage of lessons learned in other sectors from the ongoing national debates over technology policy.[1]

2. Technology Policy and the Atmospheric Sciences

In the United States a broad and inter-related set of government, private and academic entities provide weather and climate services. For present purposes, a weather and climate service is defined to mean information provided about the past, present or future state of features related to the atmosphere with the intent that decision makers will use such information to their benefit. The various entities that comprise the nation's weather and climate services enterprise have evolved a great deal over the twentieth century with little discussion or debate of appropriate roles and responsibilities, with a few notable exceptions. Even so, the United States is among (if not the) most advanced nations in the world in the efficient production and effective use of weather information. Yet as science, technology, markets, and demands related to weather information evolve, lack of discussion or debate of appropriate roles and responsibilities has the potential to limit future progress of the nation's weather and climate services enterprise.

In those few cases where discussion and debate has occurred, satisfactory resolution has not.[2] Consequently, many have arrived at differing and conflicting expectations

[1] For more on technology policy, see Harvard University's Project on Technology Policy Assessment at http://www.ksg.harvard.edu/iip/techproj/home.html.

[2] See National Research Council, 2003. Fair Weather: Effective partnerships in weather and climate services, National Academy Press, Washington, DC. http://www.nap.edu/catalog/10610.html

about roles and responsibilities of the various entities that provide weather and climate services. A policy problem exists to the extent that these differing expectations impede the development and delivery of products and services that would have value to decision makers.

Roles and responsibilities for the provision of weather and climate services differ by sector. The National Weather Service (NWS), non-NWS government agencies, academia and the private sector each play a unique as well as shared role in the provision of services. Because of the overlap and blurring of activities among these sectors it is important not to ascribe monolithic status to any one of them. For instance, universities and government labs are involved with commercialization of research as a result of government policies that encourage technology transfer. For-profit companies routinely compete with federal labs and universities for federal research dollars. These same entities compete with each other for contracts for the provision of services to companies and foreign governments. The National Weather Service relies on a range of contractors and purchases a number of services from the private sector to fulfill its mission. Further, the complex tapestry of sectors, institutions and services means that to understand the proper role of any subset requires some sense of the whole.

But like the blind men and the elephant, partial perspectives are likely to mislead. The purpose of this case study is to consider from a broad perspective the policy problem associated with the present state of roles and responsibilities within the weather and climate services enterprise. The case study begins with a discussion of issues centered on particular "sectors" noting however the considerable difficulty associated with identification of clear boundaries between sectors. It needs to be emphasized that many real-world examples are provided in this case study in order to illustrate the complexities involved in issues of roles and responsibilities. Such examples are meant to be illustrative and diagnostic, and not prescriptive; no claim is made here as to the appropriateness or inappropriateness of the activities discussed. But this leads us to an essential point of this case study: in many cases it is difficult if not impossible to judge what weather and climate services activities actions are appropriate and which are not, given the lack of community agreement on proper roles and responsibilities.

3. Sectors and Context

The language used to describe participants in atmospheric sciences technology policy – government, private sector and academia – is hopelessly inadequate. Though by no means a new trend, traditional sectors overlap and run together. Increasingly researchers are involved with commercialization and private sector entities support research and development. For example, the conventional notion that the private sector "sits" between the National Weather Service and end users "adding value" -- under the traditional linear model of innovation with basic research on one end and end users on the other -- is obsolete, reality is much more complex (e.g., Hooke and Pielke 2000, Pielke and Byerly 1998, NRC 2000, NRC 1992). Thus, as used in this case study,

characterizations such as "private sector" or "academic" should be interpreted as a reflection of where people sit, and not what each actually does.

The "public sector" can be defined, at least approximated, through cataloging federal expenditures devoted to weather and climates services, as well as the resources devoted to mission-oriented research and development in support of these services. The federal government invests a significant amount of resources in weather and climate research and operations, perhaps $4-6 billion total.[3] Of this total, research and operational activities related to meteorology are routinely assessed by the Office of the Federal Coordinator for Meteorology.[4] Climate services, by contrast, are an emerging area of emphasis within the National Oceanic and Atmospheric Administration (NOAA) and other federal agencies and to date are not centrally coordinated or assessed.[5] While weather and climate services are centered NOAA, they do take place across a range of federal agencies, regional and state agencies. Increasingly the line between activities that take place at Universities ("academia") and government has been blurred as well.

In the context of meteorology the phrase "private sector" is frequently used with various, and sometimes conflicting, meanings. Traditionally, private sector meteorology refers to those businesses that provide weather information to paying customers. Today, such a narrow definition of the "private sector" might be defined as the members of the Commercial Weather Services Association (CWSA) or the National Council of Industrial Meteorologists (NCIM) (as well as other companies and consultants not members of these trade groups). A broader definition of the "private sector" might include those businesses (and related trade organizations) that manufacture weather instruments, radar, terminals, and other research and development that comprise the public and private infrastructure of weather research and operations. An even broader definition would include companies and trade organizations in the media, e.g., Internet, newspapers and television that receive revenue for weather content. Such companies could be primary or secondary (or even further order) producers, disseminators or integrators of weather information. More recently, companies related to financial services, such as catastrophe modelers and providers of weather derivatives, have established a significant foothold in the market. These companies and their representatives as well might be included in a definition of the private sector. Finally, there are companies in energy, transportation, logistics, and agriculture (to name just a few sectors) that employ in-house meteorological expertise and should be considered an important part of private sector meteorology.

In short, the definition of the private sector depends critically what is included under the definition. Under the narrowest of definitions presented above, private sector meteorology had an estimated $500 million in revenues in 1999, up from $200 million in 1990 (Guth 2000). Under the broader definitions, reliable tabulations of revenues are not readily available, but it is not unreasonable to estimate the broader market for weather-

[3] For detailed budget information, see http://sciencepolicy.colorado.edu/socasp/policy.html#budgets
[4] The OFCM tabulations are comprehensive with the exception of some supporting meteorological research, see: http://www.ofcm.gov/ .
[5] See, e.g.,

and climate-related products and services, i.e., including the media and financial services, to be in the billions, and perhaps tens of billions, of dollars.

4. Issues Raised as Sectors Blur Roles and Responsibilities

This section of the case study presents a number of interesting cases that lie within, and frequently across sectors, to highlight the difficulties involved with assessing proper roles and responsibilities in the absence of an overarching technology policy for the atmospheric sciences. The point of including real-world examples is not to pass judgments upon the worth or appropriateness of the activities, but instead to document the practical challenges involved with assessment of roles and responsibilities.

The National Weather Service

The National Weather Service and its predecessors have for more than a century had legislative authority for governmental provision of weather services. In this role agency officials have long been sensitive to potential conflict with the private sector.

Contemporary debate is quite similar to debate on this topic that took place more than a half century ago. Following World War II, numerous military meteorologists found themselves returning to life as civilians and seeking to use their expertise in weather to make a living (American Meteorological Society, 1949). The resulting growth of commercial weather services led the AMS to arrange for a conference in 1948 "to clarify the relationship between the Weather Bureau and private meteorologists." This conference resulted in an agreement between the Chief of the Weather Bureau, representatives of Industrial Weather Consulting Services and the AMS. This agreement was titled the 'Six-Point Program" and is reproduced in its entirety in Box B.1. The agreement was, however, never adopted as formal policy by the Weather Bureau (Weather Bureau, 9 March 1948). The Six-Point Program is as follows:

Six-Point Program on Public-Private Sector Relationships[6]

1. Advise all field offices that industrial meteorology is a legitimate field of endeavor and should be encouraged and aided by the Weather Bureau in the interest of the national economy.

2. Advise all organizations now served by the Weather Bureau that they are not getting an individualized and specialized service (i.e., added information and/or more service than is normally given the general public) and furnish them with a list of consulting firms approved for teletype service.

3. Advise individuals or organizations seeking specialized services that it is not a Weather Bureau function and with their consent refer the matter to the Central Office of

[6] American Meteorological Society, 1949, Report of the executive secretary, 1948, Bulletin of the American Meteorological Society, v. 30, p. 140-141.

the Weather Bureau for transmittal to the American Meteorological Society and the meteorological consultants.

4. Advise all Weather Bureau personnel that they should be alert to point out and develop cases in business where the employment of a consulting meteorologist would aid in developing applied meteorology.

5. Accept grants from individuals or organizations for research and statistical surveys only when they cannot be accomplished by or with private consulting meteorologists.

6. The service of looking after interest of private concerns and the initiating of special advice for commercial uses is the field of consulting meteorology and the Weather Bureau will make it a practice to refer to the field of consulting meteorologists requests for services of this kind.

Perhaps seeking to get out ahead of the AMS agreement, two weeks prior to the AMS conference the Weather Bureau issued a "Circular Letter" to all of its offices on "Policy With Respect to Private Practice of Meteorology and Instruction Regarding Cooperation with Private Meteorologists."[7] The letter stated, "all employees should be familiar with the policy on extension of applied meteorology and development of private meteorological services to meet commercial and industrial requirements beyond the scope of government services." The letter cautioned, "the weather bureau must not permit an impression that it has 'exclusive rights' in the science and practice of meteorology." The letter provided the following guidance for determining if a particular service was appropriate for the Weather Bureau:

> Usually, a question on whether a private request is within the province of a government service or should be referred to private sources can be decided by comparison with similar cases in other professions, such as engineering or law. In analogous cases the matter is one for a private engineer or a lawyer, it probably falls within the province of the private meteorologist.

The guidance provided by the letter was apparently inadequate or insufficient to resolve debate for long as in 1953 the Department of Commerce convened an Advisory Committee on Weather Services comprised of eight meteorologists—of which six worked in the private sector, one for the AMS and one for a university—to review and evaluate "civil weather matters" with a focus on the public-private sector issue.[8]

The committee found the "Circular Letter … does not clearly establish the relationship between the Weather Bureau and private meteorologists" and recommended

[7] Weather Bureau, Policy with respect to private practice of meteorology and instructions regarding cooperation with private meteorologists, Circular Letter 22-48, March 9, 1948.
[8] Advisory Committee on Weather Services, 1953, *Weather is the Nation's Business*, Department of Commerce, U.S. Government Printing Office, Washington, D.C., p. 6.

that it be "cancelled" in favor of the AMS Six-Point Program.[9] The committee found the ambiguity stemmed, at least in part, because

> the organic act under which the Weather Bureau still functions was written at a time long before present developments and applications of the science to business and industry could have been envisioned. It is necessary, therefore, that a redefinition of functions be made to recognize the changes since that time… While all of the recommendations of this report can be implemented under the existing organic act, we feel it is desirable that a study be made to determine whether the basic law should be revised.[10]

Since the 1950s, debate has waxed and waned. In the early 1980s the Reagan administration proposed the privatization of government weather satellite operations. A protracted and public debate ensued.[11] Weather satellite operations were not privatized, but the debate created sufficient impetus for the NWS and private sector to discuss codification of roles and responsibilities. One result was NWS adoption in 1991 of a statement on the Public-Private Partnership in the provision of weather services.

The 1991 Statement states "the primary mission of the NWS is the protection of life and property and the enhancement of the national economy."[12] The report introduces specific guidance on proper roles and responsibilities of the government and private sector. "The NWS will not compete with the private sector when a service is currently being provided or can be provided by commercial enterprises, unless otherwise directed by applicable law."[13] No guidance is provided on how the policy would be implemented, including mechanisms for dispute resolution, oversight, sanctions and accountability to the policy. Not surprisingly, little evidence can be found to suggest that either the NWS or the private sector had interest in reconciling the ambiguities resulting from the 1991 policy. Or perhaps more accurately, actors in the NWS and the private sector saw in the 1991 Statement what they wanted to see and acted accordingly. Evidence for this conclusion is found in debate that occurred during in the late 1990s then the Commercial Weather Services Association (CWSA) spearheaded an effort to formalize in the NWS legislative mandate the language of the 1991 Statement. The NWS objected. The CWSA legislative effort did not succeed.

The 1991 policy statement, like its predecessors, was insufficient to reconcile debate about roles and responsibilities. In a 1997 review of the NWS conducted at the

---

[9] Advisory Committee on Weather Services, 1953, *Weather is the Nation's Business*, Department of Commerce, U.S. Government Printing Office, Washington, D.C., p. 45.
[10] Advisory Committee on Weather Services, 1953, *Weather is the Nation's Business*, Department of Commerce, U.S. Government Printing Office, Washington, D.C., p. 2.
[11] P. Cox, Fair weather: Government weather forecasting soaks taxpayers to shower benefits on special interests, *Reason*, June 1983, p. 23-30.
[12] National Weather Service, 1993, Policy and guidelines governing National Weather Service and private sector roles; NWS Operations Manual Chapter A-06, Issue Date: 7/30/93, http://www.nws.noaa.gov/im/a06toc.htm
[13] In response to a comment raised during the public comment period the NWS pointed to the fruit-frost program as an example of a service provided in competition with the private sector due to a mandate in legislation.

bequest of the Secretary of Commerce before taking over as NWS Administrator, General Jack Kelly wrote

> The 1890 Organic Act contains some outdated wording and does not reflect the current capabilities of the private sector weather industry. Within the NWS, government agencies (both Federal and local) and the private sector, disagreement exists as to what the appropriate mission for and the level of services and products required from the NWS. A review (U.S. Congress or DOC) should be conducted to determine the NWS mission for the 21st Century and lead to an updating of the Act (Kelly, Jr., 1997).[14]

Similar sentiments have been expressed by many members of the private sector.[15] S o despite the existence of a NWS policy statement since 1991 on the provision of weather services by NWS, debate continues unabated on proper roles and responsibilities.

The primary reason for differing perspectives on roles and responsibilities related to the National Weather Service stems from a conflict inherent in the multiple missions that the agency is expected to serve. The frequently-invoked Organic Act of 1890 gives the NWS responsibility for public safety through the provision of storm warnings and responsibility for enhancing economic activity. The relevant text is as follows:

> The Secretary of Commerce shall have charge of the forecasting of weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce, and navigation, the gauging and reporting of rivers, the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation, the reporting of temperature and rain-fall conditions for the cotton interests, the display of frost and cold-wave signals, the distribution of meteorological information in the interests of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties. 15 USC 9 Sec 313

If the NWS mandate was only to support economic activity or only to provide storm warnings it would be relatively straightforward to develop clear guidance for roles and responsibilities. These dual objectives confound approaches to resolve public-private sector conflicts grounded in economic theory. If the NWS only served economic ends, the economic theory provides clear guidance (see e.g., NRC 2001). However, the public safety mandate trumps economics in many cases. Even so, economic issues lead to sources of conflict. Among these are ever lower barriers to entry for new providers of added-value, technology-driven rapid obsolescence of past modes of delivering weather services, and the public-good "issues of scope" which arise when publicly funded data is used to create for-sale products.

The twin objectives of protecting the public and supporting economic activity can come into conflict. These twin objectives and the conflict that can result were referred to

---

[14] John "Jack" Kelly, in the "Kelly Report", p. 58, http://www.publicaffairs.noaa.gov/nws3.html

[15] See, for example, the testimony before the House of Representatives Subcommittee on Energy and Environment by Michael S. Leavitt, on behalf of the Commercial Weather Services Association on April 9, 1997, 105th Congress, 1st session; and by Joel Myers on behalf of AccuWeather, Inc., on March 25, 1998, 105th Congress, 2nd session.

explicitly by Jack Kelly in his 2001 address at the annual meeting of the American Meteorological Society.

> The challenge for the meteorological community is to balance governmental responsibilities to provide warnings and forecasts for everyone subject to weather-related hazards with the private sector's responsibility to tailor forecasts for use by specific entities, build markets, and mitigate risk by developing more effective means to integrate weather, water and climate information into commercial business plans, strategies and decisions. While the National Weather Service and private sector entities each have distinct roles in the weather information dissemination process, we must continue working strategically as partners for the public good and the economic benefit of our country as a whole (Kelly, 2001).[16]

Whatever one's views on the respective roles of government and the private sector, the existing NWS mandate necessitates reconciling missions established in law that have built in conflicts. To date such reconciliation has not occurred, and the attempt to codify such reconciliation in the 1991 NWS Policy Statement is flawed according to both perceptions and practice. In 2003, a National Research Council committee convened to examine partnerships in weather and climate services recommended, "The NWS should replace its 1991 public-private partnership policy with a policy that defines processes for making decisions on products, technologies, and services, rather than rigidly defining the roles of the NWS and the private sector."[17]

Non-NWS Governmental

If the roles and responsibilities of the NWS can be characterized by attempts to grapple with conflicting missions established in law, non-NWS governmental roles and responsibilities might be said to have an opposite situation. Few missions are explicitly provided in law, leaving the provision of services to ad hoc implementation and oversight. At the outset an important exception should be made for weather and climate services provided by the military in support of national security. Such services are beyond the scope of the present analysis, leaving for present discussion weather services provided by agencies such as non-NWS National Oceanic and Atmospheric Administration, Federal Aviation Administration, Department of Agriculture, and Department of Transportation.

Consider the range of issues raised by the following examples:

- The Aviation Digital Data System (ADDS) is an online tool that provides weather information to the aviation industry and is sponsored by the Federal Aviation Administration, operated by the National Center for Atmospheric Research (NCAR), and disseminated via the NWS Aviation Weather Center on a NOAA web site. However a disclaimer featured prominently on the ADDS website notes that the product is not of the NWS. The ADDS website describes its mission to "make available to the aviation

[16] J. Kelly, 2001, Opportunities for 21st century meteorology: New markets for weather, water and climate information, American Meteorological Society Policy Forum, Albuquerque, NM, January 17, 2001. http://www.ametsoc.org/AMS/atmospolicy/presforums/albq2001/kelly.pdf

[17] NRC Partnerships report, 2003, p. 3.

community digital and graphical analyses, forecasts and observations of meteorological variables."[18] The FAA has plans to use ADDS as the basis for briefings provided to commercial pilots.[19] In this case a "quasi-operational" product is provided essentially outside the NWS using some NWS infrastructure.

- A non-profit corporation (University Corporation for Atmospheric Research or UCAR) operated under the government's Federally Funded Research and Development Center (FFRDC) program and supported by public funds capitalized a subsidiary private company, Weather Information Technologies, Inc. or WITI.[20] WITI worked closely with a publicly funded research entity also under UCAR management, the National Center for Atmospheric Research on projects such as using National Weather Service weather forecast models to provide information to consumer by zip code[21] and competed for and won a $15 million contract to provide Hong Kong with consultative services for the design of a new airport.[22] WITI was sold in 1999.

- The Forecast Systems Laboratory (FSL) of NOAA provides wind profiler systems and consulting on such systems to the U.S. DOD, NASA, DOE as well as the governments of Canada, Australia, New Zealand, China, Japan, and the EU.[23]

- The Department of Transportation, in its Intelligent Transportation Systems program, sponsors an initiative called FORETELL in partnership with several state governments, the Canadian government, and operated by a private-sector contractor, Castle Rock Services.[24] The goal of the initiative is to provide weather information to public and private sector decision makers.[25] The federal government has a wide range of experience at the interface of public institutions and private entities.[26]

Each of these examples, and these are but a few of many possible such examples, illustrates the significant degree of activities that fail to fit any "textbook" description of weather and climate services. The situation is made more complex by the various government policies encouraging the commercialization of government technology, including the role of Federally Funded Research and Development Centers. Given the complexity of governance and incentive structures in the context of the lack of formal policies or procedures, it would be extremely difficult for participants with differing perspectives to arrive at judgments of proper roles and responsibilities of non-NWS government providers of weather and climate services. Nor is it at all clear if anyone has responsibility for coming to such judgments.

---

[18] http://adds.aviationweather.noaa.gov/projects/adds/info/
[19] T. Horne, 2002, ADDS on the move, *AOPA Pilot*, January 2002.
[20] http://www.bcbr.com/sep96/witi2.htm
[21] http://www.ucar.edu/communications/staffnotes/0009/ucarf.html
[22] http://www.ucar.edu/communications/quarterly/fall93/prescorner
[23] http://www.fsl.noaa.gov/~vondaust/fir99/fir99c.html
[24] http://www.foretell.com/help/Foretell/about.htm
[25] http://www.its.dot.gov/TravelManagement/fortell.htm
[26] See, for example, General Accounting Office, 1995, *Government Corporations: Profiles of Recent Proposals*, GAO/GGD-95-57FS, Washington, D.C., 62 pp.

Academia

If the provision of weather and climate services by non-NWS government agencies can be characterized as complex, then the provision of weather and climate services by organizations in academia is akin to the wild wild west where a frontier mentality reigns. As weather and climate services have demonstrated increasing value in the economy, members of the academic community have rushed to cash in. While consulting by academics has a long and respected tradition in the atmospheric sciences, and many established private sector metrological services firms had their origins as university start-ups, the recent decade has seen explosive growth in the formation of such entities. The federal government has encouraged university-based technology transfer through legislation such as the Bayh-Dole Act of 1980.

Other reasons for this trend is the growing support among universities in support of commercial activities, itself motivated by federal policy, decreasing funding from state and federal sources, and the highly visible success of commercialization activities in other areas of technology such as biotechnology and information technology. In the atmospheric sciences there does exist a high degree of variability across institutions for the support of commercialization.[27]

The twin influences of an environment that encourages commercialization and the fact that the atmospheric sciences have not yet gained the visibility (and thus demands for accountability) of other areas of technology means that many activities are being initiated before the development of generally accepted criteria for proper roles and responsibilities. By way of contrast, in other areas of technology policy, such as biotechnology and information technology, there exists a history of debate and discussion of roles and responsibilities. In weather and climate services, the paucity of such discussion has set the stage for potential conflict.

Consider the complexities involved with the following examples:

- Northwest Research Associates, Inc.[28] focuses primarily on performing research sponsored by the federal government. In early 2002 its website stated that it operates an entity called Foresight Weather[29] out of its Colorado-Research Associates[30] division subsidiary focused on providing weather predictions to the energy industry. The Foresight Weather website stated that it relies on scientists at the neighboring publicly-funded National Center for Atmospheric Research (NCAR) to provide research, technology, and serve as consultants in support of the products and services that Foresight Weather sells to its clients, primarily in the energy industry. NCAR is itself funded by the National Science Foundation and other federal agencies to conduct

[27] R.A. Pielke, Jr., 2001, *Weather Research Needs of the Private Sector: Workshop Report*, U.S. Weather Research Program, Palm Springs. CA, December 2000. http://sciencepolicy.colorado.edu/pielke/workshops/private.sector/private.sector.report.pdf
[28] http://www.nwra.com/history.html
[29] http://www.fswx.com/home/intro_index.htm
[30] http://www.colorado-research.com/

research.

- Faculty at major research universities such as Rhode Island, Oklahoma, North Dakota, Michigan and others operate or are otherwise associated with for-profit companies that provide weather and climate services. Many of these companies employ university graduate students working on government-provided grants and contracts focused on weather and climate research. Graduate student research can in principle serve the purpose of "killing two birds with one stone"—that is, providing knowledge in support of the government research grant obligation while at the same time contributing to a product or service sold for profit to a customer.

- The University of Oklahoma Department of Meteorology received $10 million in support from the Williams Companies.[31] The Department also receives considerable public support for research, including designation as one of the first NSF Science and Technology Centers. In the Spring of 2002 the Department announced that it would limit access to certain products because of its relationship with certain private sector partners. The Department then took a step back from this announcement, and announced that it was reconsidering its data access policies.[32]

As was the case in the provision of services by non-NWS governmental agencies, coming to judgments of proper roles and responsibilities is made difficult by the various federal and state policies and incentives for those in academia to foster commercialization of science and technology.[33] But unlike that case, academia has struggled mightily over the past decade to establish general mechanisms for coming to such judgments in the context of biotechnology, information and other areas of technology that have shown large commercial potential. The Association of University Technology Managers has sought to collect a set of "best practices" in academia for assessing such roles and responsibilities.[34] The application of such mechanisms to the atmospheric sciences is haphazard and unsystematic at best.[35]

Private Sector

The provision of weather and climate services in the United States by the private sector occurs in a wide range of manners. **Figure 1.** illustrates the terrain of private sector activities in relation to the National Weather Service (NWS) "service flow." It is important to recognize that while the NWS forms the foundation for a wide spectrum of "value-added" activities in the public and private sectors, there is a considerable (and

[31] http://www.caps.ou.edu/news/williamsgrant.htm
[32] Information on the CAPS data policy is updated online at http://www.caps.ou.edu/wx/
[33] R.A. Pielke, Jr., 2001, *Weather Research Needs of the Private Sector: Workshop Report*, U.S. Weather Research Program, Palm Springs. CA, December 2000. http://sciencepolicy.colorado.edu/pielke/workshops/private.sector/private.sector.report.pdf
[34] http://www.autm.net/index_n4.html
[35] R.A. Pielke, Jr., 2001, *Weather Research Needs of the Private Sector: Workshop Report*, U.S. Weather Research Program, Palm Springs. CA, December 2000. http://sciencepolicy.colorado.edu/pielke/workshops/private.sector/private.sector.report.pdf

under-appreciated) set of activities also in the public and private sectors that provide weather and climate services *independent* of the NWS.

Many entities—particularly (but not limited to) television and other media—collect and report information on weather and climate independent of any governmental service. For example, in 2001 the American Meteorological Society presented an award to three Oklahoma television stations for their coverage of the May 3, 1999 tornado outbreak in which their coverage of the storm provided the public with details on the exact location and path of individual tornadoes unmediated by scientists or the government.[36] Many public and private organizations—ranging from the New York Thruway Authority to State Farm Insurance to *USA Today*—collect weather and/or climate information for direct use or further dissemination to paying clients. A company called Global Atmospherics, Inc. owns the nation's only lightning detection network and sells its products to a range of customers including the National Weather Service, The Weather Channel, and the PGA Tour.[37] Another company, AWS Convergence Technologies, Inc., collects temperature data through its own private network and offers services based on that data.[38] The size of the market for the provision of weather and climate services independent of the NWS has not been rigorously assessed. However, an initial hypothesis (based on personal experience and nothing more) is that the size of this market is as large and likely larger than the market for products and services built upon the NWS infrastructure. The NWS encourages a view of weather and climate services constrained to those related to its products. However, a more comprehensive perspective results in a considerably more expansive view of "weather and climate services."

Nonetheless, many entities use the services of the National Weather Service as the basis for providing value-added services. "Value" is "added" to products and services at every stage of the NWS "service flow," as shown in **Figure 1.** and illustrated by examples. Some companies (and many for-profit entities originating in academia) use the raw data collected by the nation's atmospheric observing systems as input to proprietary weather forecast models. One such company is Weather Decision Technologies, Inc.[39] Other companies focus on the direct dissemination of NWS forecasts, with The Weather Channel the most widely known example.[40]

The NWS supports a great diversity of economic activity in the commercial meteorological industry through its products and services. The size of this market has also not been rigorously assessed, although estimates range from $500 million to more

[36] http://www.nssl.noaa.gov/publicaffairs/releases/ams_group.html
[37] http://www.lightningstorm.com/ls2/discover/nldn/index.jsp Global Atmospherics, Inc. is an example of research transferred from an academic setting, in this case the University of Arizona, to the private sector.
[38] http://www.aws.com
[39] http://www.wdtinc.com/ Weather Decisions Technology, Inc. also has its origins as a University "spin-off," from the University of Oklahoma.
[40] http://www.weather.com/ The Weather Channel and the NWS have entered into agreements such that NWS formats its products in a manner that serves the needs of TWC (Batten 2002).

than $1 billion.[41] Given the diversity of economic activities it should not be surprising that individual companies who create products and services based on raw observational data or independently interpreting NWS model output have suggested that the "value added" products within the NWS "service flow" represent subsidized public competition. However, proper understanding of such claims much occur in the broad context of the diversity of organizations that rely on NWS information as input to the production of products and services.

The summary of cases above in each of the sectors reviewed here is provided not to implicate specific judgments, but to note that evaluation of roles and responsibilities is made difficult due to the complex and interwoven tapestry of the NWS and other government infrastructure, academia and companies operating in the broader economy. Clearly, the perspectives of those in individual companies may differ dramatically on the issue of "government competition" depending primarily upon where each draws information from the NWS "service flow." Correspondingly, it would be easy to envision *in principle* how the NWS service flow might be optimized to facilitate the market for any particular niche of companies associated with points of departure from the "service flow." However such optimization would likely have dramatic consequences for other companies in different niches, drawing from different points of departure in the "service flow." This complexity (i.e., the policy and political challenge of "multi-attribute optimization") is one reason why the NWS has had difficulty achieving a successful relationship with the "private sector."

None of the previous discussion should be interpreted as either to condone present practices or to imply that claims of "unfair competition" are unjustified. Rather, the complex tapestry of the NWS in relation to the myriad agencies and companies that it supports makes assessment of present practices and claims an extremely challenging task. Consequently, it is understandable that multiple views on this subject have developed over decades and have defied good-faith attempts at resolution.

5. Why Technology Policy Matters for the Atmospheric Sciences

There are at least four important reasons in support of reaching a stabilization of expectations among various participants in the atmospheric sciences community regarding appropriate roles and responsibilities for the provision of weather and climate services. These reasons are discussed in greater detail in this section under the following subheadings: (a) institutional conflict, (b) efficiency in resource use, (c) accountability, transparency, and legitimacy, and (d) conflicts of interest. Ultimately, the primary reason why this problem matters is that so long as it persists unresolved, it impedes the effective and efficient transfer of weather and climate knowledge from the science and technology community to decision makers in the form of useful products and services (Pielke and Carbone, 2002). This impedance limits the benefits to society resulting from the nation's investments in the science and technology of weather and climate.

[41] R.A. Pielke, Jr., 2001, *Weather Research Needs of the Private Sector: Workshop Report*, U.S. Weather Research Program, Palm Springs. CA, December 2000. http://sciencepolicy.colorado.edu/pielke/workshops/private.sector/private.sector.report.pdf

Institutional Conflict. Over many decades some in the NWS and private sector have expended time and resources working against each other rather in support of each other. The institutional conflict has resulted in behind the scenes legislative maneuvering, such as resulted in the mid-1990s termination of agricultural weather services provided by the NWS, and more recently in conflict over the CWSA push to modify the NWS Organic Act. Institutional conflict occurs in less public ways as well, such as occurred in the late 1990s when the NWS Employees Organization pushed to include private sector employees, specifically at AccuWeather, in their employees union.[42] While healthy competition can improve products and services and the efficiency with which they are delivered, to the extent that healthy competition becomes unhealthy conflict, products and services may in fact degrade. An example of unhealthy conflict occurs when public and private sector institutions use finite resources to position themselves politically or symbolically with respect to actual or perceived opponents. A specific example is the 1996 divestiture of agricultural weather services. The termination of such activities by the NWS was based largely on political maneuvering, and not on assessments of whether or not the U.S public would benefit from such a decision.[43] In such cases public interests are arguably served less well than by alternatives.

Efficiency in Resource Use. As science and technology produce results that lead to greater knowledge of weather and climate, new products and services are enabled. While the transfer of such knowledge into products in the public and private sectors faces many challenges, surmounting these challenges creates yet another dilemma. With a steady stream of products and services being made available, this means that there is a greater need for infrastructure to support those products and services. In the private sector, the marketplace balances supply and demand for products and services and offerings expand and contract based on such forces. However, for the public sector reconciliation of supply and demand is much more difficult in the absence of market mechanisms. To take an example, a NWS with finite operational resources is inherently limited in the products and services that it can offer, as there is little capability to identify demand and reconcile demand with supply (other than through the long-term budgetary process). Thus, if a NWS is to continually develop new products and services it must either cease providing certain products and services (to free up operational capabilities) or become generally more efficient in its operations. Consequently, a NWS would generally benefit from a process that transfers services suitable for a market setting to the private sector. Discussion of the nature and criteria that might accompany such transfers goes beyond the scope of this paper. But the net effect of such transfers would be to make available resources in NWS for support of newly developed products and services. Currently, in the area of weather and climate no such mechanism exists for identification of candidate

[42] http://www.nwseo.org/nat10-00.html, AccuWeather employees voted not to join the NWSEO.
[43] General Accounting Office, 1996, *Privatization/Divestiture Practices in Other Nations*, GAO/AIMD-96-23, Washington, D.C., 36 pp.; General Accounting Office, 1997, *Lessons Learned by State and Local Governments*, GAO/GGD-97-48, Washington, D.C., 52 pp.

products and services suitable for transfer. In other areas of government, by contrast, there are such mechanisms.[44]

Accountability, Transparency and Legitimacy. The lack of stabilized expectations for roles and responsibilities in the provision of weather and climate services places obstacles in the way of citizens holding government accountable. Governmental accountability has been a high priority of Congress since the early 1990s, legislation such as the 1993 Government Performance and Results Act and statements such as the 2001 President's Management Plan emphasize accountability in the use of public expenditures.[45] Accountably depends upon clear goals, shared expectations for the pursuit of those goals, and mechanisms to measure progress with respect to those goals. In the provision of weather and climate services, the lack of shared expectations for appropriate roles and responsibilities means that the public, through their elected representatives, have less ability to shape the evolution of products and services than they might under conditions of shared expectations. This stands in stark contrast to other areas of science and technology, information technology and biotechnology are two examples, where although considerable debate persists, such debate is highly public and focused on appropriate goals, mechanisms and measures of accountability.[46] Accountability is a hallmark of "good government" and irrespective of one's views on the particulars of policy issues associated with the provision of weather and climate services it is possible to find lacking the degree of accountability, transparency and legitimacy of policy processes in this issue area.

Conflict of Interests. Academia in particular must carefully consider the potential for financial conflict of interest at the interface of research and commerce. As the fruits of atmospheric sciences research become increasingly valuable, the question is not if such a potential exists, but when and where and, more importantly, what to do about it. This is a sensitive topic because it involves money and money is often a difficult issue to discuss openly. Fortunately, other professions have grappled with this issue and have much to offer the atmospheric sciences in terms of experience and precedent. In 1993, Harvard's Dennis Thompson defined conflict of interest in *The New England Journal of Medicine*:

> A conflict of interest is a set of conditions in which professional judgment concerning a primary interest (such as a patient's welfare or the validity of research) tends to be unduly influenced by a secondary influence (such as financial gain).

Thompson argues

> The secondary interest is usually not illegitimate in itself, and indeed it may even be a necessary and desirable part of professional practice. Only its relative weight in professional decisions is problematic. The aim is not to eliminate or necessarily to reduce financial gain or other secondary

---

[44] See, for example, General Accounting Office, 1997, *Crop Insurance: Opportunities Exist to Reduce Government Costs for Private-Sector Delivery,* GAO/RCED-97-70, Washington, D.C., 156 pp.; General Accounting Office, 1996, *Privatization/Divestiture Practices in Other Nations*, GAO/AIMD-96-23, Washington, D.C., 36 pp.

[45] http://www.whitehouse.gov/omb/budget/fy2002/mgmt.pdf

[46] R.A. Pielke, Jr. and R.E. Carbone, 2002, Weather impacts, forecasts, and policy: An integrated perspective, *Bulletin of the American Meteorological Society,* v. 83, p. 393-403.

> interests (such as preference for family and friends or the desire for prestige and power). It is rather to prevent these secondary factors from dominating or appearing to dominate the relevant primary interest in the making of professional decisions.

The question to be addressed, then, is not whether the boundary between research and commerce should blur—it has and it will. Indeed, the United States has a long history of using policy to intentionally blur this boundary, using technology policies to stimulate economic growth via public support for research, development, and technology transfer. The question facing the atmospheric sciences instead is what policies and procedures to promulgate and implement given present trends in the discipline. Since the mid-1980s several disciplines, the medical profession being the most prominent, have been engaged in discussion and debate about conflict-of-interest policies and procedures.[47] The atmospheric sciences have much to learn from these debates.

6. Where Next? The NRC Report and Beyond

Early in 2003, the National Research Council released a pre-publication report titled "Fair Weather: Effective Partnerships in Weather and Climate Services."[48] This report marked the first major study in over a decade of the roles and responsibilities of the public and private sectors in the provision of weather and climate services. The report offers a set of three primary recommendations focused on strengthening the public-private partnership, noting that current policy is "untenable." The report observes that "although the 1991 [partnerships] policy does not work as intended, the committee believes that a policy is necessary – one that emphasizes processes for interactions among the sectors and takes account of newer federal government laws and policies." The three primary recommendations are:

- The NWS should replace its 1991 public-private partnership policy with a policy that defines processes for making decisions on products, technologies, and services, rather than rigidly defining the roles of the NWS and the private sector.

- The NWS should establish an independent advisory committee to provide ongoing advice to it on weather and climate matters...

- The NWS and relevant academic, state, and private organizations should seek a neutral host, such as the American Meteorological Society, to provide a periodic, dedicated venue for the weather enterprise as a whole to discuss issues related to the public private partnership.

General reaction to the report has largely been positive. The Commercial Weather Services Association announced its support for updating the 1991 partnerships policy and

---

[47] See, for example, D.F. Thompson, 1993. Understanding financial conflicts of interest, *The New England Journal of Medicine*, v. 329, p. 573-576; S. Krimsky and L.S. Rothenberg, 2001, Conflict of interest policies in science and medical journals: Editorial practices and author disclosures, *Science and Engineering Ethics*, v. 7, p. 205-218; M. Angell and J.P. Kassirer, 1986, Editorials and conflicts of interest, *The New England Journal of Medicine*, v. 335, p. 14.

[48] See the report online at http://www.nap.edu/catalog/10610.html .

suggested that it be extended to other NOAA agencies beyond the NWS.[49] Richard Anthes, who was a member of the NRC Partnerships Committee, wrote on behalf of the University Corporation for Atmospheric Research (UCAR) – a consortium of universities – that the report "gives a number of achieving an even more productive and harmonious relationship" among academia and the public and private sectors.[50] The NWS has yet to provide a formal response to the study.

The American Meteorological Society responded to the call that it should take a more active role at the interface of the sectors. In May, 2003 its President, Joe Friday announced the establishment of a committee "to study the possible responses, seeking input from all of the various constituencies that make up the Society."[51] It light of these responses, one might have optimism that the NRC has opened a window of opportunity for a healthy evolution of the weather and climate enterprise.

But at the same time, within the various responses to the NRC Reports are clear signs that unresolved conflict continues to fester. The issues remain the same: who should have the authority to perform what functions within the weather and climate enterprise?

For example the CWSA notes in its response that:[52]

- "The elimination of some NWS products and services will allow the agency to better focus on its core mission. There is concern over the agency's liberal use and lack of policies concerning dissemination over the Internet."

- "The NRC Committee found a lack of control over the actions of NWS offices and their provision of products and services."

- "The NRC failed to recognize that extensive observation networks have been established by the private sector, partially in response to growing discontent with the NWS operated networks."

Contrast these statements with the follow from UCAR[53]:

- "A level playing field can be defined as a system in which all government-supported data, information and products, including forecasts and warnings, are made available to everyone at no cost or minimal cost. The development of the Internet has made this far more feasible than it was in the past."

---

[49] http://www.weatherbank.com/CWSA/news/CWSA-Press-Release-020603.doc
[50] http://www.ucar.edu/communications/quarterly/spring03/president.html Richard Anthes is UCAR President.
[51] http://sciencepolicy.colorado.edu/ams/response.html
[52] http://www.weatherbank.com/CWSA/news/CWSA-Press-Release-020603.doc
[53] http://www.ucar.edu/communications/quarterly/spring03/president.html

- "Universities and research laboratories such as UCAR/NCAR and NOAA's Forecast Systems Laboratory are developing spinoff companies or commercial endeavors from their intellectual property that compete with the private sector."

- "It is an open question whether developing a complete and independent observing and forecasting system and thereby competing fully with the NWS would be the optimal use of private or academic resources…"

These statements show some obvious differences of opinion, and they come from organizations who generally *agree* on the conclusions of the NRC report. Should there be limits to what NWS can share over the Internet? Are stronger controls needed over NWS activities or those of UCAR/NCAR or the national labs? How should the weather community handle there proliferation of observational networks and associated products and services? Not only do these questions and many others like them remain unanswered, but they are difficult to even address without the focus on policy and processes recommended by the NRC report.

Fifty years of debate and discussion on this issue do not provide optimism that those with vested interests in particular outcomes related to the provision of weather and climate services will work toward finding common ground. But perhaps there are alternatives to the NRC's recommendations that might free the AMS and others from the difficult task of leadership and working towards community consensus. Some have argued that economics theory on "public goods" provides a straightforward path for the resolution of disputes about the provision of weather and climate services.[54] Unfortunately, this is not the case for two reasons.

First, **Figure 1.** shows that there is much more than raw data at issue here. The government not only issues raw data, but also turns data into information, knowledge and services. This means that governmental services cut a cross a wide range of economic sectors, creating considerable potential for conflict. A fundamental source of conflict arises because what is basic data for one industry, and hence plausibly within the domain of governmental provision, might simultaneously be the value-added output of another industry, and hence plausibly outside the domain of governmental provision. These conditions exist simultaneously. So long as government adds any value to basic data, then deciding then where to "draw the line" between what is appropriate "value added" activity and what is not thus is necessarily a political and policy question that cannot be resolved through economic theory. If only the world were less complex.

Clearly some activities are deemed inappropriate by all parties. For instance, the government has chosen not to issue its weather forecasts directly via television, e.g., in direct competition with The Weather Channel. But there is no technological reason why it could not; NASA for example has its own TV station. The NRC report found that there currently is no formal process to judge how such decisions will be made in particular cases, resulting in ad hoc or politically-motivated decision making. For instance, when

[54] See for example, NRC 2001, Bits of Power: Issues in Global Access to Scientific Data, National Research Council, Washington, DC. http://www.nap.edu/catalog/5504.html

one NWS office recently begun issuing products and services using wireless technology to cell phones and PDAs some in the private sector raised complaints and the NWS WWW sites announcing these products were taken down. Was this a correct decision? It is difficult to say absent a transparent and systematic process for evaluating such activities. This is likely one reason that the first NRC recommendation was to establish clear processes for making such determinations. In this context, economic theory provides little guidance, although it is often invoked to justify competing perspectives.

A second reason why economic theory is limited in this context lies in the dual mandate of the National Weather Service, to protect life and property *and* to support the nation's economic infrastructure. These twin mandates can come into conflict. For example, there is no reason why the private sector *in principle* could not issue warnings for hazardous weather, indeed some do. However, for reasons of policy and politics U.S. policy has focused on protection of life and property as a public function, irrespective of the economic benefits to be gained from their privatization. Even so, a private sector industry focused on hazardous weather warnings has developed. Whether the government continues to issue warnings, shares responsibility for warnings with the private sector, or gets out of the warning business altogether is going to be based not on economic theory, but on public sentiment and the realities of the government's role in protecting the life and property of its citizens. This complicates a situation in which the NWS is also expected to support economic activity through the provision of general forecasts as much of the observations, technology and means of dissemination are shared in fulfilling the twin mandates of the NWS. Here as well economic theory provides little useful guidance. There is not a magic bullet solution to issues of issues arising in the provision of weather and climate services. Instead, progress will necessarily come from the exercise of leadership and community consensus. The NRC and AMS have taken important first steps in this direction.

It is well worth noting that the discussion above focuses exclusively on the NWS and does not engage other government or academic institutions who provide services that may overlap with those provided in the private sector. In important respects the NWS relationship with its partners is in much better shape than in these other contexts because in the 1991 NWS partnership policy a framework exists, however imperfect. In other areas, such as non-NWS weather services and the emerging areas of climate services there is no such framework. Therefore, it makes sense that the AMS activity following up on the NRC report should consider roles and responsibilities across the weather and climate enterprise, and not narrowly on the NWS.

The issue of roles and responsibilities in the provision of weather and climate services shows that development of the institutions of the atmospheric sciences has not kept pace with scientific and technological advances. In areas such as information technology and biotechnology debate and discussion about roles and responsibilities among various players and sectors has a long history that continues today. The technology policy processes employed to manage these interactions arguably have contributed to the creation of more effective interconnections of science, technology and societal benefits in each of these areas. So long as technology policy in the atmospheric sciences remains

underdeveloped, the nation will receive only a fraction of the potential benefits of the fields scientific and technological advances.

7. Bibliography

The following materials were consulted in preparing this case study:

Advisory Committee on Weather Services (1953), "Weather is the Nation's Business", Department of Commerce, U.S. Government Printing Office, Washington, D.C.

American Meteorological Society (1949), "Report of the executive secretary, 1948", Bulletin of the American Meteorological Society, 30, pages 140-141.

Angell, M. and J.P. Kassirer (1986), "Editorials and conflicts of interest", The New England Journal of Medicine, volume 335, page 14.

Batten, F. and J. L. Cruikshank (2002), The Weather Channel, Harvard Business School Press, Cambridge, MA.

Branscomb, L.M. (1993), “Empowering Technology: Implementing a U.S. Strategy”, The MIT Press, 315 pp.

Branscomb, L.M. (1992), “Does America need a technology policy?” Harvard Business Review, March-April, 24-31.

Branscomb, L.M. and R. Florida (1999), “Challenges to technology policy in a changing world economy”, Investing in Innovation: Creating a Research and Innovation Policy that Works, L.M. Branscomb and J.H. Keller, Eds., The MIT Press, pp. 3-39.

Branscomb, L.M. and J.H. Keller (1999), “Investing in Innovation: Creating a Research and Innovation Policy that Works”, The MIT Press, 516 pp.

Bromley, D.A. (1990), “The U.S. Technology Policy”, The Executive Office of the President, **[PAGE NOS].**

Changnon, S.A. (2000), “El Nino 1997-1998: The Climate Event of the Century”, Oxford University Press, 215 pp.

Clinton, W.M. and A. Gore, Jr. (1993), “Technology for America’s Economic Growth: A New Direction to Build Economic Strength”, The White House, **[P NOS]**.

Cox, P. (1983), "Fair weather: Government weather forecasting soaks taxpayers to shower benefits on special interests", Reason, June, pages 23-30.

Executive Office of the President (2002), "The President's Management Agenda, FY 2002", Office of Management and Budget, S/N 041-001-00568-4, Government Printing Office, Washington, D.C.

GAO (1998), “Technology Transfer: Administration of the Bahy-Dole Act by Research Universities”, Report No. GAO/RCED-98-126, Washington, DC, 83 pp.

Guston, D.H. and K. Keniston (1994), “The Fragile Contract: University Science and the Federal Government”, The MIT Press, 244 pp.

Henson, Bob (2000). "UCAR Foundation's pleasant dilemma: how to manage a windfall", Staff Notes Monthly, September. <http://www.ucar.edu/communicatoins/staffnotes/0009/ucarf.html>.

Horne, Thomas (2002), "ADDS on the move", AOPA Pilot, January.

Kelly, Jr., J. (1997), "An Assessment of the Fiscal Requirements to Operate the Modernized National Weather Service During Fiscal Years 1998 and 1999", a report to the Secretary of Commerce and Under Secretary for Oceans and Atmospheres, Section XII, page 58, <http://www.publicaffairs.noaa.gov/nws3.html>.

Kelly, Jr., J. (2001), "Opportunities for 21st century meteorology: New markets for weather, water and climate information", American Meteorological Society Policy Forum, Albuquerque, NM, January 17, <http://www.ametsoc.org/AMS/atmospolicy/presforums/albq2001/kelly.pdf>.

Krimsky, S. and L.S. Rothenberg (2001), "Conflict of interest policies in science and medical journals: Editorial practices and author disclosures", Science and Engineering Ethics, volume 7, pp. 205-218.

Leavitt, Michael S. (1997), "Testimony before the House of Representatives Subcommittee on Energy and Environment", on behalf of the Commercial Weather Services Association, April 9, 105th Congress, 1st session.

Myers, Joel (1998), "Testimony before the House of Representatives Subcommittee on Energy and Environment", on behalf of AccuWeather, Inc., March 25, 105th Congress, 2nd session.

National Academy of Engineering, Committee on Technology Policy Options in a Global Economy (1993), “Mastering a New Role: Shaping Technology Policy for National Economic Performance”, National Academy Press, 144 pp.

National Oceanic and Atmospheric Administration (2000), "1999-2000, FSL in Review: Demonstration Division", <http://www.fsl.noaa.gov/~vondaust/fir99/fir99c.html>.

National Research Council (2003), "Fair Weather: Effective Partnerships in Weather and Climate Services", Prepublication version, National Academies Press, Washington, DC.

National Research Council (2001), "Bits of Power: Issues in Global Access to Scientific Data", National Academies Press, Washington, DC.

National Research Council (2000), "From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death", National Academy Press, 96 pp.

National Weather Service (1993), "Policy and guidelines governing National Weather Service and private sector roles", NWS Operations Manual Chapter A-06, Issue Date: 7/30/93, <http://www.nws.noaa.gov/im/a06toc.htm>.

NOAA Weather Partners Public Affairs (2001), "Oklahoma Groups Honored by American Meteorological Society for Efforts Related to 1999 Tornado Outbreak", United States Department of Commerce News, January 15, <http://www.nssl.noaa.gov/publicaffairs/releases/ams_group.html>.

NRC, Committee on Science, Engineering, and Public Policy (1992), "The Government Role in Civilian Technology: Building a New Alliance", National Academy Press, 222 pp.

Pielke, Jr., R.A. and R.E. Carbone (2002), "Weather impacts, forecasts, and policy: An integrated perspective", Bulletin of the American Meteorological Society, volume 83, pages 393-403.

Pielke, Jr., R.A., J. Abraham, E. Abrams, J. Brock, R. Carbone, D. Chang, S. Cranford, K. Droegemeier, K. Emanuel, E.W. Friday, Jr., R. Gall, J. Gaynor, R.R. Getz, T. Glickman, B. Hoggatt, W.H. Hooke, E.R. Johnson, E. Kalnay, J. Kimpel, P. Kocin, B. Marler, R. Morss, R. Nathan, S. Nelson, R. Pielke Sr., M. Pirone, E. Prater, W. Qualley, K. Simmons, M. Smith, J. Thomson, and G. Wilson (2003), "Report of the U.S. Weather Research Program Workshop on The Weather Research Needs of the Private Sector" Bulletin of the American Meteorological Society, submitted.

Press, E. and J. Washburn (2000), "The kept university", The Atlantic Monthly, March, pp. 39-54.

Rasmussen, Carol (1993), "Prescorner", UCAR Quarterly, University Corporation for Atmospheric Research, Fall, <http://www.ucar.edu/communications/quarterly/fall93/prescorner>.

Shine, K. (2003), "aviationweather.gov," Professional Pilot, February, 90-92.

Thomas, Jeff (1996), "For-profit branch, WITI, markets UCAR's new technologies", Boulder County Business Report, September, <http://www.bcbr.com/sep96/witi2.htm>.

Thompson, D.F. (1993), "Understanding financial conflicts of interest", The New England Journal of Medicine, volume 329, pages 573-576.

United States General Accounting Office (1995), "Government Corporations: Profiles of Recent Proposals", GAO/GGD-95-57FS, Washington, D.C., 62 pages.

United States General Accounting Office (1996), "Privatization/Divestiture Practices in Other Nations", GAO/AIMD-96-23, Washington, D.C., 36 pages.

United States General Accounting Office (1997a), "Crop Insurance: Opportunities Exist to Reduce Government Costs for Private-Sector Delivery", GAO/RCED-97-70, Washington, D.C., 156 pages.

United States General Accounting Office (1997b), "Lessons Learned by State and Local Governments", GAO/GGD-97-48, Washington, D.C., 52 pages.

Weather Bureau (1948), "Policy with respect to private practice of meteorology and instructions regarding cooperation with private meteorologists", Circular Letter 22-48, March 9.

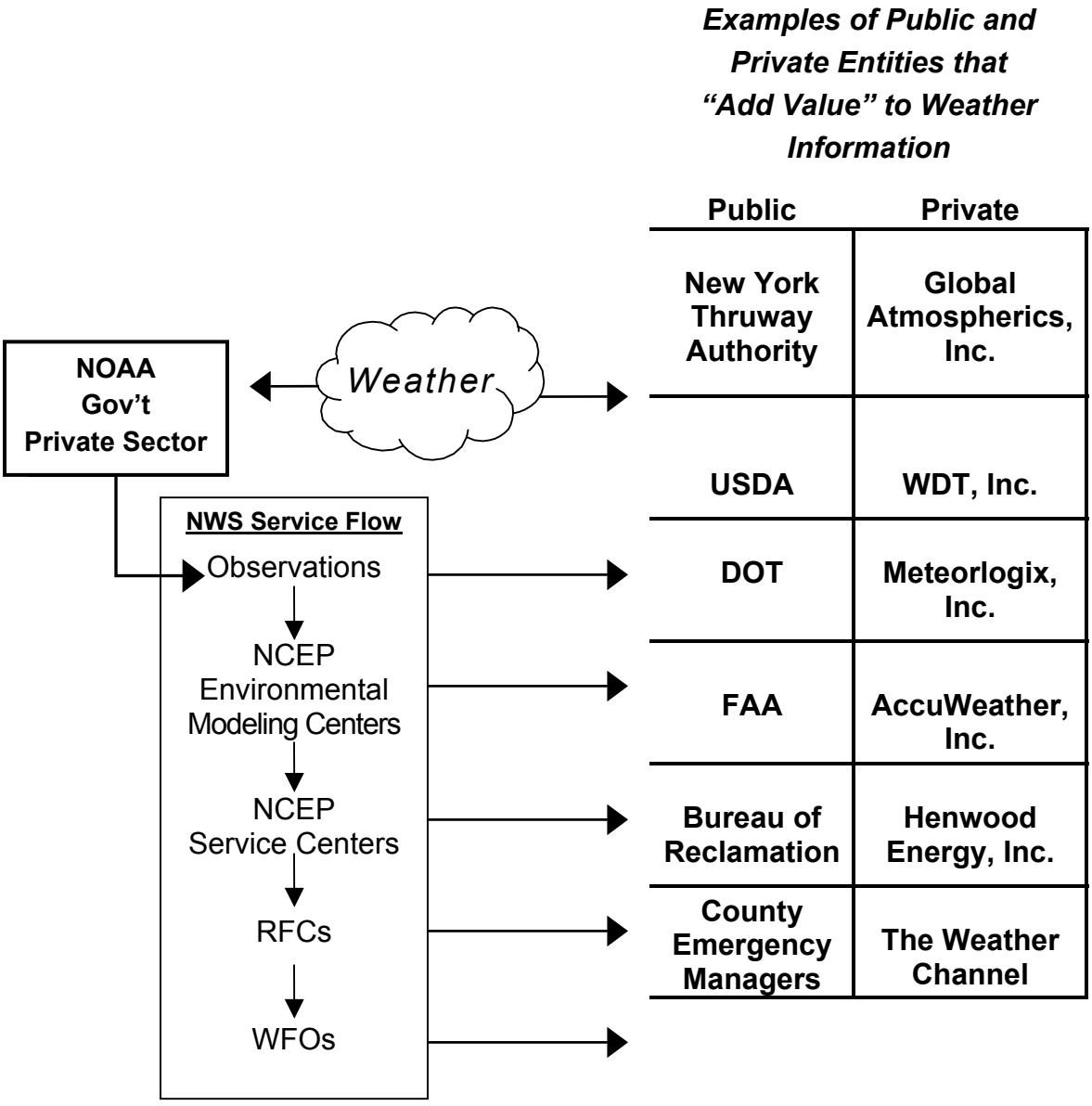

FIGURE 1. Example of weather service providers. The notion and depiction of "NWS Service Flow" follows from D.R. Wernley and L.W. Uccellini, 2000, Storm forecasting for emergency response: A United States perspective, in *Storms*, R. Pielke Jr. and R. Pielke Sr., eds., Routledge, New York, pp. 70-97.