STATE OF

THE WEATHER AND CLIMATE ENTERPRISE

2012

BACKGROUND

The American Meteorological Society's Commission on the Weather and Climate Enterprise was established in response to recommendations from the 2003 National Research Council Report "Fair Weather: Effective Partnership in Weather and Climate Services". The report responded to concerns about conflicts between and among the various sectors of the Enterprise. The Commission has been successful in helping ensure an effective partnership. At the 2012 Summer Community Meeting held by the Commission at the National Weather Center at The University of Oklahoma, two days were devoted to examining the State of the Weather and Climate Enterprise. Representatives from each sector presented assessments of their sectors. Considerable interactive discussions helped clarify issues. The recommendations presented in this report gleaned from the presentations and presented to the participants during the summary session. This report is based on these sessions and other information provided by the participants. This is the first of what is hoped to be a continuing series of reports that define the State of the Enterprise. As the first report, it is admittedly incomplete, but does serve as the basis from which to build in the future. This report was written by Drs Rene McPherson, William Gail and E W (Joe) Friday

Growth of the Public Sector

In the mid-1800s a large number of organizations were taking weather observations in the United State. Observatories were operated by the US Army, the Smithsonian Institution, the Jesuit Branch of the Catholic Church, and many others. There were several movements during the 1840s and 1850s to form a national organization, but it was not until a series of major storm systems caused the loss of several hundred people on the Great lakes that Congress finally acted. After a major debate on whether the national organization would be under the Smithsonian Institution or the U.S. Army, the Congress passed a Joint Resolution as follows:

> ”Be it resolved by the Senate and the House of Representatives of the United States of America in Congress assembled, that the Secretary of War be, and he hereby is, authorized and required to provide for taking meteorological

> observations at the military stations in the interior of the continent, and at other points in the States and Territories of the United States, and for giving notice on the northern lakes and on the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms…" See: http://www.history.noaa.gov/legacy/act2.html

Over the next twenty years, the weather services provided by the U.S. Army Signal Service grew and in 1890, the activity was transferred to the Department of Agriculture. A section of that law signed by President Benjamin Harrison on October 1, 1890 has been referred to as "the Organic Act of the US Weather Bureau:

> "The Chief of the Weather Bureau, under the direction of the Secretary of Agriculture, …. Shall be charged with
> 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 maintenance and operation of sea-coast telegraph line and the collection and transmission of marine intelligence for the benefit of commerce and navigation,
> the reporting of temperature and rainfall conditions for the cotton states, the display of frost and cold wave signals,
> the distribution of meteorological information in the interest 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 necessary for the proper execution of the foregoing duties." See: **http://www.history.noaa.gov/legacy/act4.html**

The move to the department of Agriculture brought civilian management to the Weather Bureau, coupled with a very broad mandate. The first civilian chief, Prof Mark Harrington, noted that the Weather Bureau was functioning efficiently even without the military management and discipline. The move also brought an explosive growth in programs and services provided by the organization. World War I brought a major focus on the field of aviation, which was only amplified by the shadows of World War II.

On June 30, 1940, the Weather Bureau was transferred to the Department of Commerce, which housed the Civil Aviation Administration, the Coast Guard, The Maritime Administration, and many other organizations pertaining to the transportation and commerce of the nation. President Roosevelt stated in his statement announcing the move:

> "The importance of the Weather Bureau's functions to the nation's commerce has also led to a decision to transfer this Bureau to the Department of Commerce. The development of the aviation industry has imposed upon the Weather Bureau a major responsibility in the field of air transportation. The transfer to the

Department of Commerce, as provided in this plan, will permit better coordination of Government activities relating to aviation and to commerce in general, without in any way lessening the Bureau's contribution to agriculture."

The National Weather Service (formerly the Weather Bureau) resides in the Department of Commerce today, even though the various transportation-related agencies have been subsequently moved to the Department of Transportation and the Department of Homeland Security.

In 1963, the Bureau of the Budget (now a part of the Office of Management and Budget) directed the Department to establish a mechanism for coordinating the meteorological activities of the Federal Government. As a result, the Office of the Federal Coordinator for Meteorological Services and Supporting Research was formed in 1964. The OFCM continues to coordinate the various activities across the civilian agencies and prepares a Federal Plan for those activities on an annual basis. See: http://www.ofcm.gov/

In 1965, the Environmental Science Services Administration (ESSA) was formed by consolidating all the environmental activities in the Department of Commerce. The same reorganization formed separate organizations from portions of the Weather Bureau; the Environmental Data Service from the climate related activities, the National Environmental Center from the satellite activities, and the Institutes for Environmental Research from elements of the research components. The Weather Bureau name was changed to the National Weather Service. This reorganization is described at: http://docs.lib.noaa.gov/rescue/journals/essa_news/QC801E71965v1no7.pdf.

Another major governmental reorganization in 1970 created the National Oceanic and Atmospheric Administration (NOAA) by combining ESSA and several other organizations dealing with the marine environment. See: http://www.history.noaa.gov/legacy/act6.html

The climate activities in the federal government evolved from the Weather Bureau's observation records eventually consolidated in the holdings at the Weather Records Center in Asheville, NC, to the Environmental Data Service of ESSA, and finally as a major part of the National Environmental Satellite, Data, and Information Service (NESDIS) under NOAA. NOAA proposed the creation of a National Climate Service, paralleling the National Weather Service in 2011, but it was not approved by Congress.

In the early part of the history of the Weather Bureau, most of the technological advances dealt with better observing equipment, as well as attempts to better understand the atmospheric structure in order to better forecast weather. World War II brought major changes that would forever change the science of weather forecasting. Two developments during the war, radar and the electronic computer, would have significant impact. The introduction of radar gave the ability of the meteorologist to see further than could be done by the human eye. This ability to remotely sense the atmosphere would be further enhanced with the introduction of the meteorological satellite in 1960. The electronic computer was developed under a US Army research program designed to improve the calculation of the impact of wind on long range artillery. Shortly after the war, it was used in numerical experiments solving the equations for barotropic flow in the atmosphere. From those early attempts to forecast numerically the motion of the atmosphere, progress has continued until the present. The current Numerical Weather Prediction Models are very representative of the atmosphere out to a period of a week or so. The war also drove the improved measurements of the upper atmosphere in response to the increasing need of aviation. A major improvement in the provision of public weather services was accomplished with the Modernization and Restructuring of the National Weather Service that occurred during the early 1990s. That basic structure exists today.

Growth of the Private Sector

For a very different reason, World War II sparked the development of the Private Meteorological Sector in the United States. Thousands of meteorologists were trained during the war and the years leading up to it. After the war, the military weather services were greatly reduced, and although 80% of the meteorologist trained for the war effort went back to other professions, a significant number, enjoying the new field of meteorology, began to practice meteorology outside of the Weather Bureau. The one thing needed from the Government was the weather data collected by the Weather Bureau. After much internal deliberation, and with much internal dissent, Dr. Francis Reichelderfer, Chief of the Weather Bureau, granted permission for the data to be made available to the public. This set the stage for the growth of the private sector. Several companies started up in the years following the war, and as the general science of meteorology permitted increasingly better forecasts, there were more opportunities for the use of those forecasts in the economic decisions needed by business and industry. In the early days of the Weather Bureau, radio broadcasts of the weather forecasts were made on commercial radio stations by employees of the Weather Bureau. When commercial television began, the broadcasting companies assumed that the Weather Bureau would provide personnel to broadcast the weather on the television news shows. Dr. Reichelderfer, again after much heated internal debate, decided that the NWS would not provide weathercasters for TV, thus beginning another major private sector activity. (The broadcast from the NWS offices for commercial radio diminished over the years, but was not totally eliminated until the late 1980s.)

It should be noted that these two major decisions under the leadership of the Chief of the Weather Bureau set the stage for a significantly different enterprise structure in the United States as contrasted with many other countries. The present data policy of the United States is essentially the same as established by Dr. Reichelderfer in the 1940s – government generated data should be made available to the public. Many other countries charge for their government data, thus making it more expensive to develop a vibrant private sector. In many of the other countries, the media outlets for weather information are staffed by government employees.

The Growth of the Academic Sector

The military need for meteorologists has also significantly influenced the growth of the academic sector of the Weather and Climate Enterprise. Five schools (MIT, UCLA, Cal Tech, Chicago, and NYU) began a major buildup as war clouds developed over Europe, essentially doubling the number of meteorologists in the United States in two years. After the attack on Pearl Harbor, the efforts were greatly accelerated, initially producing over 1,000 meteorologists a year. The outstanding efforts of the universities grew the number of meteorologists in the Army Air Force from fewer than 100 in 1940 to over 10,000 in 1945. In subsequent years, the newly designated U.S. Air Force continued to sponsor meteorological education in order to fill the necessary ranks in the Air Weather Service. These basic meteorology programs formed the initial nucleus of several meteorological programs across the country.

In the late 1950s, the Committee on Meteorology of the National Academy of Sciences, proposed the establishment of a national institution to foster research in response to the growing meteorological demand for better services. In response, the National Center for Atmospheric Research was established in 1960 in Boulder, Colorado. See: http://www.ncar.ucar.edu/documents/bluebook1959.pdf. NCAR is supported by a grant from the National Science Foundation, and is managed by the University Corporation for Atmospheric Research. As contrasted to the five universities with meteorological programs helping the war effort in the early 1940s, UCAR now represents over 75 degree granting institutions.

The Growth of Conflict within the Enterprise

With the growth of the Private Sector, conflicts developed between the public and private sectors and occasionally, even between the academic and private sector. Most of these conflicts resulted from less than clear roles and missions of the various sectors. Some in the private sector believed that the government programs were infringing on what they believed were purely commercial in nature. The public sector felt that in many cases the NWS products were being used without proper attribution. Several attempts were made to clarify the public-private policy dilemma with policy statements being generated by NWS. In 1991, a new policy statement tried to define better the roles, but like those before it, there were still too many ambiguities to resolve the issues to everyone's satisfaction. In 2000, the National Academies of Science was asked to study this issue and provide recommendations for resolving or reducing the conflicts. The Committee on Partnerships in the Weather and Climate Services produced the report: "Fair Weather: Effective Partnerships in Weather and Climate Services" which analyzed the issues and made eleven recommendations to various sectors of the weather and climate enterprise. See:
http://www.nap.edu/openbook.php?record_id=10610&page=1

Recommendation 3 of the Fair Weather Report stated:

> "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."

In response, the AMS formed an ad hoc committee of the Executive Council to examine options for generating a mechanism to serve as a 'neutral host'. The committee reported to the AMS Council in October 2004 with the following recommendation:

> "The AMS should establish a Commission on the Weather and Climate Enterprise. The Commission should be charged with developing and implementing programs that address the needs and concerns of all sectors of the weather and climate enterprise; promote a sense of community among government entities, private sector organizations, and universities; foster synergistic linkages between and among the sectors; entrain and educate user communities on the value of weather and climate information; and provide appropriate venues and opportunities for communications that foster frank, open, and balanced discussions of points of contention and concern. In addition, the Committee recommends that the AMS Council adopt three preliminary terms of reference for the Commission that ensures the continued neutrality of the Society."
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> 1. The Commission provides venues for enterprise participants to meet and discuss issues of importance to the enterprise.
> 2. The Commission and its activities facilitate dialogue between enterprise participants.
> 3. Commission activities operate within the overall mission of the American Meteorological Society as a scientific and professional society."

The AMS approved the formation of the Commission on the Weather and Climate Enterprise in January, 2005. This Commission has proved to be the forum for discussing and resolving many of the areas of conflict that existed prior to its establishment. The commission has a steering committee, meeting twice per year, consisting of many of the thought change leaders in the various enterprise sectors. In addition, there are two Commission meetings annually (One in the Spring in Washington, DC, and one in the Summer at an academic institution) that address the various issues of interest to the enterprise.

At the 2012 Summer Community Meeting held at the National Weather Center at The University of Oklahoma four sessions were devoted to examining the State of the Weather and Climate Enterprise. This report is based on these sessions and other information provided by the participants. This is the first of what is hoped to be a continuing series of reports that define the state of the enterprise. As the first report, it is admittedly incomplete, but does serve as the basis from which to build in the future.

STATE OF THE PUBLIC SECTOR

General structure

Although there are a few weather and climate activities at the state and local level, the vast majority of the public sector of the weather and climate enterprise is located in the federal government. The federal government components of the public sector are fully described at http://www.ofcm.gov/fedplan/FY2012/fedplan.htm . A total of 8,808 full time equivalent (FTE) employees are engaged in meteorological and climatological operations. Of this number, the largest majority, 4,654, are in the National Weather Service, the organization charged with providing weather, water, and climate forecasts and warnings to the general public. The Department of Defense has 2,085 full time equivalents providing meteorological services to military operations around the globe. The Air Force has 1,198 FTE; the Navy, 415, and the Navy, 370. The Federal Aviation Administration (FAA) has 851 FTE involved in aviation related meteorological services, and the National Environmental Satellite, Data, and Information Service (NESDIS) of NOAA has 682 FTE. The NESDIS employees are involved in meteorological satellite activities and climate services. The remaining 536 FTEs are scattered across eight other federal agencies, including the Department of Agriculture, Department of the Interior, and the Nuclear Regulatory Commission. The total number of federal employees has been declining over the past several years, dropping from 14,410 in 2002 to 8,808 in 2012, a reduction of 39%. Most of this reduction came from the Department of Defense and the FAA, due to automated airfield observing and the automation of the forecast and briefing processes.

In 2012, the federal budget for meteorological services was mainly distributed to three federal agencies, with NESDIS receiving 57.9%, NWS receiving 28.8% and the Department of Defense 7.1%. The National Aeronautics and Space Administration (NASA) receives 81.2% of the supporting research budget for the federal agencies, with the NOAA organizations receiving 6.1%. The federal budgets for meteorological services and supporting research increased by 64% from $3.5 billion in 2002 to $5.7 billion in 2012. However if the cost of meteorological satellites is removed, the budget drops from $2.2 billion in 2002 to $1.8 billion in 2012, a loss of 18%. These comparisons demonstrate the high cost of providing the quality satellite coverage necessary for modern environmental observations and predictions.

The National Weather Service (NWS) is the main (though not sole) conduit for public sector weather information at the federal level, including observations, analyses, numerical model results, forecasts, warnings, and other information. An excellent description of the status of the NWS is given in the companion document: State of the National Weather Service - 2012. This document, prepared by the NWS Office of Strategic Planning, provides a good understanding of how the NWS has performed over time with regard to the accuracies of its various products.

One area of the public sector at the state government level is the state climatology function. The State Climatologist Program was created within the Weather Bureau in 1955 to provide climatological information needed by state decision makers. The funding for this program was terminated in 1973 and the Administrator of NOAA urged the governors to create a similar office to continue to advise the state on climatological matters. The American Association of State Climatologists was organized in 1976. See: http://www.stateclimate.org/. At present there are only two states that do not have a State Climate Office. The offices vary greatly in magnitude from a single part-time position to a major organization such as the Oklahoma Climate

Survey. See: http://climate.ok.gov/. State Climate Offices in 37 states are participants in the National Climate Services Partnership in conjunction with the Regional Climate Centers and the NOAA's National Climatic Data Center.

Strengths and Weaknesses

Several strengths make the public sector of the enterprise one of the best in the world.

- The NWS workforce: The workforce at NCEP Centers, WFOs and RFCs operate 24/7 , and are well motivated and dedicated to innovation and the early detection, forecast and warning of weather, water and climate events which pose potential threats to life, property and the economy. Time and again, centers and forecast offices surge in the days prior to, during, and after extreme weather to meet the Nation's need.
- Science and technology: improved observing systems, models, scientific applications and information technologies, as a whole, provide the necessary foundation for the world's best operational weather service to deliver accurate and timely forecasts and warnings, especially of the mesoscale events that have the most potential for harm to the public.
- Strong and growing partnerships with constituents: NWS focus on working with emergency managers, FAA, private sector, and the research enterprise continues to improve. The partnership exhibited between the National Weather Service and the private sector is arguably the best in the world.

However, there remain continuing shortfalls and challenges. Some examples:

- False alarm ratios for extreme weather remain high (e.g., over 70% for tornado warnings).
- Tropical cyclone intensity forecasts have not significantly improved; in addition, detection and forecast of rapid intensity changes remains a research challenge.
- Generation and use of probabilistic information in products and services provided to decision makers and the public has not achieved its full potential.
- As a result of these and other shortfalls, societal impact of extreme weather forecasts and warnings has fallen short of what the Nation needs and science could produce – and, loss of life, avoidable impact to property and the economy are higher than necessary.
- NWS must continue to improve its ability to detect, forecast, and warn for extreme weather – developing capabilities to better respond to societal needs in a changing earth and budgetary climate.
- Facilities: though they support operations well, today, facilities were put in place over 20 years ago and problems associated with their aging (roof leaks, HVAC problems, etc.) periodically threaten interruption of field operations – and the frequency has increased in recent years.

- Information Technologies:

□ AWIPS: has been a resounding success and AWIPS II, which migrates AWIPS to a Service Oriented Architecture, is in progress. However, telecommunications bandwidth is a limiting factor in what can be delivered to NWS field forecasters and hydrologists, and to emergency managers, the private sector, and other partners. NWS strategy over the past decade has been to continuously improve this central component (including its science, local processing and telecommunications) of its operations.

- High-performance computing: has enabled a dramatic improvement in the quality and length of forecasts and enabled more accurate, more precise and longer range information to NWS WFOs /RFCs; it has also provided a robust foundational data set which can be exploited by partners in the public, private and academic sectors. However, NWS high-performance computing capacity is far short of what current technology would allow and , indeed, lags that of several foreign meteorological services – e.g., ECMWF, UK Met Office, Environment Canada, and Korea. Slow growth of NWS' high-performance computing has reduced its ability to capitalize on S&T improvements in science and technology. Increasing NWS High-performance computing capabilities will translate into faster, earlier and more accurate forecast guidance for the Weather Enterprise – and, increase the impact of weather, water, and climate information for the Nation.
- Information Technology Architecture: NWS IT has evolved on a system-by-system basis. As a result of a "stovepiped" IT architecture, costs are limiting overall IT performance. NWS has started down the path of enterprise IT architecture – this must be expanded and implemented.

Health of Partnerships

Private public partnerships

- NWS responded to the "Fair Weather" Report with a concerted effort to communicate and collaborate over the past decade. NWS leaders meet regularly with a cross section of weather industry leaders and issues are discussed and, for the most part, resolved. And, NWS is recognized for its positive response. This is not intended to say there are no issues or challenges – indeed, there are; however, there exists an environment of trust and partnership which has the potential for strengthening this partnership for the benefit of the Nation.

Academic public partnerships

- When the NWS was modernizing in the 1980s and 1990s, efforts were made to co-locate as many of the WFOs as possible with academic facilities that had strong atmospheric sciences programs. This action has encouraged a growing synergy between the sectors. Working in partnership with NOAA's Office of Oceanic and Atmospheric Research (OAR), NWS has continued to transition new observational capabilities (e.g., NEXRAD Dual Polarization), and improved models and applications into operations. Many of these (e.g., the Hurricane Forecast Improvement Project) depend critically on partnerships with the academic community. In addition, NWS has strengthened its partnership with the National Science Foundation and the National Centers for Atmospheric Research.

Quality of service to the nation

The provision of warnings and forecasts to the nation is very good and continues to improve. The actual verification data for the various products are shown in the companion document, State of the National Weather Service - 2012, which also shows the trends. A substantial part of the publicly held data is shared with the private and academic sectors. The modernized NWS was explicitly structured to better support the state and local emergency managers, and fulfilling their need was made a high priority.

Additional needs of the nation

Even with the improvements in forecasts and warnings to date, there is still too much avoidable loss of life, damage to property, and economic impact.
The enterprise must continue to improve its forecasts and warnings for extreme weather. More precision and accuracy, fewer false alarms, and longer lead times will translate into fewer avoidable deaths, less property damage, and less economic impact. Efforts to integrate social sciences into products and services need to be sustained to ensure optimum impact on life and property protection.

Additionally, there are important national needs for product and service areas not typically considered "extreme weather;" a few examples: The growing importance of managing the Nation's precious water resources will require significant advances in hydrologic products and services. The growing societal vulnerability to space weather – infrastructure, telecommunications, trans-polar aviation, etc. – will require a sustained effort to improve space weather forecasts and warnings. Air quality forecasts, begun approximately 10 years ago, has seen improvement slowed by both research challenges and budget constraints; the long-term health impact of the air we breathe is well known and a sustained and expanded air quality operational capability is needed. The needs of the nation will require sustained improvement in such areas as high-performance computing, environmental satellite systems, AWIPS, workforce development that are not inexpensive.

The increasing downward budget pressures compounds the difficulty in moving forward with these many needs. Finding efficiencies through smart use of partnerships, science and technology, and the workforce is a good idea in any case, but will become essential. Several existing partnerships offer great potential and need to be sustained and increased.

- For example, the Integrated Water Resource Science and Services (IWRSS) partnership with the U.S. Geological Survey and the U.S. Army Corps of Engineers initiated a year ago offers great potential for improving water-related products and services at a time when floods, droughts, and water quality are a growing national concern; this partnership needs to integrate all relevant public agencies and to expand to include the private and research/academic sectors. Growing partnerships within the federal government – with NASA and others for Space Weather, with FAA and others for the NextGen air traffic support system, etc. – provide, from a federal perspective, a pragmatic strategy to achieve needed improvements in a tight budget environment.

Recommended improvements.

One area recommended for improvement for the benefit of the entire enterprise was outlined in a report of the Environmental Information Services Working Group (EISWG) of the NOAA Science Advisory Board. This report has been approved by the SAB and forwarded to NOAA for response. At the 2012 State of the Enterprise Conference, there was general support for this Open Weather and Climate Services concept. The executive summary of that report states:

> "Our nation enjoys one of the most robust, modern and accessible weather and climate services in the world through the National Weather Service (NWS) and other agencies of NOAA. However, the Nation has yet to realize the full value of NOAA's weather and climate services for two principal reasons. First, numerous barriers inhibit the ability of NOAA to distribute or otherwise make available all of its weather and climate information, particularly high-resolution datasets such as numerical weather predication model output, satellite and radar data. Second, new technology and services are not developed in a sufficiently symbiotic manner with the broader community such that optimized net value of that new service or technology to society is realized. An Open Weather and Climate Services ("Open WCS") is proposed in which both NOAA and the community share equal and full access to NOAA information and development. Although it may be difficult to achieve a fully Open WCS paradigm, it is recommended that NOAA adopt a core philosophy of instituting this concept whenever and wherever possible. It is recognized that numerous challenges exist including security, cost, development efficiency and fair access. However, none of these issues are considered significant enough or without reasonable solutions to prevent NOAA from moving forward on the concept. NOAA should develop Open WCS policies and procedures incrementally in areas where the paradigm can be exploited first such that the Weather and Climate Enterprise can begin to exploit the value of the paradigm quickly in key arenas. Previous endeavors and actions that have opened information services have proven to be enormously successful and beneficial to society; there is no reason to believe that this would not be the case here too."

STATE OF THE PRIVATE SECTOR

General Structure

The private sector has no accepted formal definition, but is generally considered to include all companies selling products and services associated with weather, water resources, and climate. In the US, virtually all commerce associated with weather, water, and climate occurs through the private sector. In other nations, such commerce is sometimes accomplished through government organizations or public-private partnerships. As the largest portion of the US private sector has been associated with weather, rather than water or climate information, the following discussion refers to weather information. Comments are included when water and climate differ in important ways.

The private sector can be divided into two general categories: a) infrastructure providers, and b) services providers. The former category includes larger aerospace companies that develop satellites and information systems as well as many smaller companies that build sensors, data systems, software, weather radios, and similar products. The latter category includes providers of data services such as forecasts, consulting services companies providing meteorology expertise, and the many broadcasters who communicate through TV and other media.

Infrastructure providers have historically focused on government organizations as their most significant customers. Satellites, ground-based weather radars, ground-based weather sensor networks, and weather analysis data systems are all examples of such systems, with the US Federal agencies NOAA, FAA, and DoD being the primary customers. State and local governments, as well as businesses, tend to be customers for weather stations (and for water resources sensors such as stream gauges) and for data systems to access and analyze weather data. This work is generally contracted as projects, in which the customer provides requirements and the contractor delivers products designed to meet those requirements. In some cases, particularly for less costly instruments, off-the-shelf products dominate instead.

Services providers support a diverse market of end-users, encompassing both consumers and businesses. For many decades, weather information has been provided to consumers by the private sector through television, radio, and newspapers. These media outlets generally get all or much of the information they use from weather services companies, ranging from national-scale branded suppliers to smaller companies that support the specific packaging needs of media. A significant portion of the services category consists of meteorology consultant companies, which provide forecasts and general guidance to organizations on a customer-by-customer basis. This work is so important to the enterprise that AMS provides a “consulting meteorologist” certification and a stand-alone professional organization represents their interests. A growing segment of the service provider category is data, including observations (such as lightning and ground sensor networks), forecasts, warnings, assessments (such as wind speed history for wind farm placement), and forensics. Data companies may be vertically integrated as part of diversified weather services companies or stand-alone providers to such companies.

The private sector has evolved significantly over recent years. Three important influences have driven this evolution. *First,* the industry is still relatively young and is progressing through a normal maturation process. A key aspect of this maturation is the evolution from a single, inexperienced provider in many sub-domains of the industry to multiple experienced providers across most sub-domains. This change has increased the robustness and reliability of the industry considerably over the last decade. The maturation process has been most visible in the context of the evolving partnership with NOAA. The conflict regarding what should be done in the public and private sectors was largely resolved during the last decade, allowing the private sector to progress more rapidly in serving its markets. *Second,* there is rapidly growing market demand for products and services best delivered by the private sector. Improved information is among the most effective tools for increasing business efficiency. The general business trend toward just-in-time manufacturing and other efficiency improvements leads naturally to better integration of weather information as part of decision systems and situational management. *Finally,* the revolution in computing and communication technologies has made it possible to do many new things and deliver them to customers far more effectively. Advances in computing power alone have made possible niche applications that include post-processing of weather information for specific use cases. Growth of the internet, and more recently of mobile devices, has made possible rapid dissemination, simple access to, and easy customization of weather information.

Several recent studies (Dutton, 2002; Lazo et al., 2009; Lazo et al., 2011) have explored the impact of weather on the US economy. Notably, about 30% of the economy is sensitive to weather and approximately 3% of GDP variability can be attributed directly to annual weather uncertainty. Assessing the size of the commercial weather market itself has proven more challenging, however. This is due in part to the fact that most weather companies are privately held, so financial information is not readily available. AMS is presently considering funding a third-party study to accurately quantify the market size, an effort which would significantly advance our understanding of the private sector. Until that happens, the most definitive summary of market size perhaps comes from the recent NRC report on NWS Modernization (NRC, 2012):

> Today, the private sector dedicated to generating and delivering weather information is about twice the size of the NWS; the overall non-NOAA portion of the enterprise (including state and local governments as well as academia) is likely equal in size to the weather-related portion of NOAA and other federal

agencies – each perhaps on the order of $4 to $5 billion. These figures are rough estimates, as definitive information is not readily available. The most authoritative recent information on the size of the weather enterprise is about five years old (for example, see Lazo et al. (2009) which cites sources from about 2007) and suffers from incompleteness. The total Federal sector budgets for FY2007 were estimated at $3.4 billion. In FY2006, the NWS budget was $852 million, the NESDIS budget was $943 million, and an additional $200 to 400 million from the research and program support budgets might be attributed to serving NOAA's weather, water, and climate mission. Of the NESDIS budget, $769 million went to procurement, largely for private sector services associated with satellite and other observing system development. Within the private sector, based on a survey for this same year, Spiegler (2007) identifies $1.65 to $1.8 billion of activity associated with weather-based services. Based on the growth rate from the prior ten years, the private sector services market was expected to be around $2.5 billion by 2012. When coupled with the amount spent in the private sector by NOAA (and other Federal agencies) on infrastructure (primarily observing systems), the total private sector market is now more than $4 billion. No figures for other non-Federal expenditures, such as state and local governments, are available. Extrapolating this information to 2012 for Federal and non-Federal enterprise sectors leads to an estimated $4 to $5 billion each.

The characteristics of the commercial market have certainly evolved over the last decade. Even a decade ago, most weather information was communicated either through the bulk media (TV, weather, newspapers) or via physical media such as mail and fax. Today, weather is received increasingly via websites and mobile applications. In both consumer and business sectors, this information has rapidly transformed from one-size-fits-all information to targeted information customized for an individual or a business. One result is a growth of niche weather products matched to specific needs. The private sector has led the development of these niche market services. In many ways, this evolution is simply a reflection of broader changes in the US economy away from manufacturing toward information, and the increasing specialization of that information.

The NRC report on NWS Modernization (NRC, 2012) addressed a related aspect of the market evolution, identifying a distinction between primary and secondary value chains for NWS. In the primary value chain, NWS serves public and business customers directly with information such as tornado and hurricane watches/warnings. NWS had long viewed private sector companies as a secondary value chain whose purpose is to communicate and disseminate NWS information. The NRC pointed out, however, that these companies now do far more than simple communication and dissemination; they transform and improve information in ways that are increasingly important to the nation. The secondary value chain, complementing or supplementing NWS information, is an important element of private sector activity.

The private sector has long dealt with public perception that weather should be a free resource. This, of course, is rooted in the long history of primary weather information coming from NWS. It has been amplified recently by the plethora of free web and mobile sources. Business users are in many cases sufficiently discerning to know when free is not sufficient and are willing to pay for services that improve on NWS information. Consumers are far less willing to do so, though some paid mobile applications are succeeding. As the industry makes further investments to improve information quality and delivery, increasing the number of paying customers is essential to monetizing the investment.

Those involved in the US private sector regularly cite the US enterprise model as the best among all national models. Unlike many international counterparts, the US model is founded on the principle of free and open data. A key objective is to promote commercial use and thus enable a robust private sector. Key to the success of this model is a strong public-private partnership in which each entity understands their role and is motivated to ensure overall enterprise success. For the public sector, this implies a strong foundation of observational and forecast capabilities. For the private sector, it implies deep understanding of market needs and the ability to effectively repackage or add value to the core products made available by their public sector partners. While the US enterprise model (along with its underlying public-private partnership) is effective today, most private sector leaders believe it has still not achieved its potential. A key example is the current proposal made by the private sector community and under consideration by NOAA to expand open access to NOAA data. While all data is open in theory, in practice the tools to access it can be inefficient or non-existent. The current proposal would ensure that NOAA increase attention and resources to the issue of data accessibility.

An important indicator of private sector health is how the financial community views weather companies. Surprisingly, there is no good example of a significant weather-focused company that is publicly owned, so valuation information is hard to come by. Major names such as AccuWeather, Baron Services, and Earth Networks are privately owned. Over the last decade, there have been several notable acquisitions that do provide valuation information. In 2008, The Weather Channel was acquired for a reported $3.5 billion by a group that included NBC and two private equity firms, Blackstone Group and Bain Capital. Also in 2008, DTN was acquired by Telvent for $445 million. DTN had acquired Meteorlogix in 1998 and Telvent has been subsequently acquired in 2011 by Schneider Electric for $2 billion. Recently, startups such as Climate Corp. and Global Weather Corporation have successfully closed venture and other early stage financing. There has also been a series of significant acquisitions during 2012, most notably of Weather Underground and Weather Central by The Weather Channel.

The hydrology and climate private sector community differs from the above description in some notable ways. There is no real consumer market, and business customers are relatively few. For hydrology, customers tend to be focused either within state and local agencies or quasi-governmental organizations associated with water resource management. In the climate sector, there is a good market for both assessment work (such as for wind farm siting) and seasonal weather forecasts (such as for business operations and commodities speculation). A smaller emerging market exists for longer-term climate such as for establishing hundred year flood standards, but these customers also tend to be largely government agencies.

Strengths and Weaknesses

Strengths and weaknesses of the private sector are best assessed in the context of how it contributes to viability of the overall enterprise.

Perhaps the greatest strength is that over the last decade the private sector has been the growth engine for the enterprise. Though good statistics on this growth are lacking, this fact is well accepted by most members of the enterprise. This growth has two important implications for the overall enterprise. First, the innovation of new products and services has come largely from the private sector. An inherent strength of the private sector is its ability to respond rapidly to evolving market needs. Today, both consumers and businesses look to the private sector as the source for the newest and most useful offerings. A substantial portion of this is associated not with improved forecast quality but simply better ways to package and deliver weather information. In many cases, users are best served when weather information is combined with other information types. For businesses, an example is situational awareness systems that allow them to manage assets such as trucking fleets subject to many constraints, with weather being just one. For consumers, an example is mobile phone applications that help plan events where, again, weather may be just one consideration.

A second significant strength is the robustness of the public-private partnership that has been painfully forged with NOAA and other government entities. What was a significant weakness prior to about 2000 has been effectively reversed. Today, this partnership is recognized across the political spectrum as an example of the way in which a government agency can both directly serve the national interest and simultaneously enable development of complementary free market businesses. In contrast to the public sector, the private sector is not directly incentivized to serve the public interest but rather to operate efficiently so as to serve shareholders. Serving the public interest is often an outcome of this process when the private sector meets market needs. But the private sector has no obligation to assess and serve all public interests; gaps in offerings will occur when such efforts are not profitable. The strong public-private partnership ensures that all national interests are well served by the entity – public or private – best suited to meet a particular need.

Among weaknesses, perhaps the most important is segmentation of the private sector. Despite the efforts of strong professional organizations, there is no single voice representing private sector interests. This impedes the sector's ability to establish public awareness of its importance and to advocate for specific needs. AMS is often cited as the organization best positioned to provide overall advocacy, but it has several institutional impediments. In particular, with about a third of its membership coming from the public sector, any advocacy regarding NOAA or DoD projects risks conflict of interest.

Health of Partnerships

As noted previously, the public-private partnership is a critically important issue for the private sector. During the 1990's, this partnership was very contentious due to disagreement regarding the appropriate roles of each sector. Many in the public sector believed their role in providing weather information to the nation should not be limited, while those in the private sector felt the public sector was competing unfairly in areas where they provided high-quality capabilities. The 2003 NRC Fair Weather report (NRC, 2003) established guidance for resolving this conflict. To their credit, both sides worked hard to follow this guidance and the situation has improved considerably. Today, residual conflicts remain. For example, the emergence of mobile applications has led to discussion about whether NOAA should support its own mobile applications or if the private sector performs this job well enough that NOAA should avoid mobile application development. The mechanisms put into place by the NRC Fair Weather report (NRC, 2003) have proven capable of resolving such conflicts as they arise, so the expectation is that this issue will be resolved in a similar manner.

The partnership between the academic and private sectors is healthy but faces important challenges. The rapidly growing private sector looks to the academic sector to train future employees. There is concern that academic programs are too oriented toward academic rather than commercial skills. For example, a common concern is that many students graduate with strong forecasting skills but poor verbal and written communication skills. They are thus constrained in their ability to work with customers, a key need in the private sector.

Quality of Services

Services provided by the private sector have always relied heavily on underlying information obtained from NWS. Often, this has meant simple repackaging of NWS information, such as with NOAA alerts. In such cases, the value added by the private sector may be in the form of quality packaging and delivery of the information. In other cases, the private sector transforms the information or creates new information that is combined with the original NWS information. There is no general assessment of quality possible, as quality is vertical-specific and generally assessed by individual users. To the extent that the market drives quality through competition, quality can be expected to improve in situations where improvement is needed. It is possible to identify examples within the industry where established suppliers have been supplanted by new suppliers on the basis of the improved quality of the competing offerings. In general, business users are better positioned to assess quality than are consumers. The business market tends to thus be characterized by competition sensitive to the quality of the weather information itself. For consumers, this is less true, and quality of the packaging or delivery method is often more important.

One area where quality may be an industry-wide issue is in delivery of alerts. Today, alerts from NWS are readily packaged and delivered alongside many other types of alerts by companies specializing in alerting but not in weather. Weather alerts are critical to public safety, but other alerts may not be. There are no standards to ensure timely delivery of weather alerts, and some alerting companies fail to ensure timely delivery through the telecommunications network. This is an area where standards setting may have value to the enterprise to ensure quality.

Support from Professional Societies

The increasingly important role of the private sector has been reflected in the evolution of professional societies. The American Meteorological Society (AMS) is the largest professional society representing the enterprise, with approximately 14,000 members. In the 1970’s, a group of meteorologists decided AMS was not adequately representing the interests of the growing broadcast industry. They formed a separate organization, the National Weather Association (NWA), which continues to be the most focused professional voice for this community. Other prominent professional organizations are the National Council of Industrial Meteorologists (NCIM) and the American Weather and Climate Industries Association (AWCIA). Following release of the NRC Fair Weather report in 2003, AMS recognized the need for more formal inclusion of private sector interests and established the Commission on the Weather and Climate Enterprise. This high-level AMS governance body has since become the most effective professional group for reflecting broad interests of the private sector and for improving interactions between the private sector and the government/academic sectors. The Weather Coalition, an organization formed in 2007 specifically to advocate for the broad enterprise, has been slowly building its position as a voice for the overall community.

Recommended Improvements

The private sector faces a number of issues in the coming years, many of which reflect both challenges and opportunities:

- *Selling the Value of Paid Weather.* The industry as a whole is investing in improved quality and delivery of weather information. Yet many users, including both consumers and businesses, are satisfied with weather information available free from NWS and other sources. Others, particularly in weather-sensitive business sectors, have already recognized benefits of paid sources. Monetizing the industry's investment in improved capabilities requires inroads into convincing more users that better information is worth paying for.
- *Keeping Up.* As demand grows, the private sector will need to scale in a way that keeps pace. This involves both the capability to serve additional customers and to develop new products for serving rapidly emerging niche needs. Users will also expect weather information to build on cutting edge technologies, such as social networks, requiring the industry to maintain currency with technology trends beyond weather itself.
- *Reducing Sector Fragmentation.* Fragmentation, as evidenced by lack of an overarching professional organization representing the private sector, limits public recognition of the industry and hinders the ability to advocate industry-wide needs.
- *Strengthening the Public-private Partnership.* Increasingly, the public-private partnership that ties together companies and NOAA/DoD is central to success of the overall enterprise. Within this partnership, there are a number of key issues that must be addressed to keep it healthy and productive:
    - *Leadership.* Fragmentation means there is no single contact representing the private sector aspect of the partnership and no body able to commit to policies and strategies on behalf of the private sector.
    - *Protecting Core Capabilities.* The entire enterprise depends on the health of core government services such as satellite systems and forecasts. The private sector must be a strong advocate for its public sector partner.
    - *Competition.* Residual competition between the sectors needs to be rapidly adjudicated.
    - *Major Systems Acquisitions.* Major system acquisitions have been suffering from significant overruns and schedule slips. The partnership must work out ways to improve performance.
    - *Observations Data.* The private sector is increasingly a supplier of data to the public sector, such as mesonets of surface observations and lightning. The partnership is still working out issues such as redistribution rights to make the process work smoothly.
    - *Free and Open Data Access.* The ongoing discussion about more open access to government data needs to conclude in progress toward such access. The established principle of free and open access to public sector

data, which has long been the hallmark of US weather policy, needs to be protected.
  - *Leveraging the Private Sector.* With the anticipated constraints to public sector budgets over the next decade, the private sector will be expected to take on more to achieve overall progress of the enterprise. The private sector must be prepared to respond.
- *Addressing International Markets and Competition.* Increasingly, US companies sell weather information into international markets and non-US companies compete within the US. US companies will need to successfully navigate this new territory.
- *Improving the Relationship with Academia.* An improved relationship with academia is needed to ensure the private sector has reliable access to people and technologies that are well-matched to private sector needs.
- *Setting Standards.* The private sector today has no recognized standards-setting body. This has not been a significant impediment previously. But some use cases suggest this may become a problem. Moreover, standards that ensure common interfaces are a traditional means for enhancing industry growth.

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STATE OF THE ACADEMIC SECTOR

General structure

The academic sector of the U.S. weather and climate enterprise primarily serves to educate the next-generation workforce and to conduct cutting-edge, independent research. Beyond these core competencies, each academic institution has unique strengths and a variety of methods to serve the larger enterprise. Examples of this diversity include the following: (1) service to local communities and public officials through Land, Sea, and Space Grant organizations (including agriculture extension), state climate offices, and research institutes; (2) cooperative research with Federal partners through NOAA Cooperative Institutes, NOAA Regional Integrated Sciences and Assessment programs, DOI Climate Science Centers, and other programs; (3) education and outreach beyond the traditional classroom through programs such as Research Experiences for Undergraduates and Research Experiences for Teachers, both funded by the National Science Foundation; (4) enhancement of the private sector through the creation of intellectual property and establishment of start-up companies; and (5) provision of remote sensing and in-situ observational capabilities, both experimental and operational.

According to the American Meteorological Society, about 140 universities and colleges in the United States have programs in atmospheric, oceanic, hydrologic, and related sciences. Many of these programs are small, with only a few faculty members teaching courses in atmospheric and related sciences; other programs have 20 or more faculty members who conduct research and teach in departments with extensive computer and instrumentation infrastructure and significant grant funding. Of these 140 universities and colleges, more than 80 offer Ph.D. degrees and almost 110 offer Masters degrees.

The most active weather and climate academic programs in the U.S. are members or affiliates of the University Corporation for Atmospheric Research (UCAR). Founded in 1960 through the leadership of 14 founding universities, UCAR is a nonprofit consortium of 76 North American member universities, each of which grants doctoral degrees in the atmospheric and related sciences, plus an increasing number of international affiliates offering comparable degrees, and North American academic affiliates offering pre-doctoral degrees. UCAR member universities are shown in Table 1.

Table 1. Member Universities of UCAR (as of October 2012)

University of Alabama – Huntsville	University of Alaska
University at Albany, State University of New York	University of Arizona
Arizona State University	Brown University
California Institute of Technology	University of California – Berkeley
University of California – Davis	University of California – Irvine
University of California – Los Angeles	University of Chicago
Colorado State University	University of Colorado – Boulder
Columbia University	University of Connecticut
Cornell University	University of Delaware
University of Denver	Drexel University
Florida State University	George Mason University
Georgia Institute of Technology	Harvard University
University of Hawai'i	University of Houston
Howard University	University of Illinois – Champaign
University of Iowa	Iowa State University
Johns Hopkins University	University of Maine
University of Maryland	Massachusetts Institute of Technology
McGill University	University of Miami
Michigan State University	University of Michigan – Ann Arbor
University of Minnesota	University of Missouri
Naval Postgraduate School	University of Nebraska – Lincoln
Nevada System of Higher Education	University of New Hampshire
New Mexico Institute of Mining and Technology	New York University
North Carolina State University	University of North Dakota
Ohio State University	University of Oklahoma
Old Dominion University	Oregon State University
Pennsylvania State University	Princeton University
Purdue University	University of Rhode Island
Rich University	Rutgers University
Saint Louis University	Scripps Institution of Oceanography – UCSD
Stanford University	Stony Brook University, State University of New York
Texas A&M University	University of Texas – Austin
Texas Tech University	University of Toronto
Utah State University	University of Utah
University of Virginia	University of Washington
Washington State University	University of Wisconsin – Madison
University of Wisconsin – Milwaukee	Woods Hole Oceanographic Institution
University of Wyoming	Yale University
York University (Canada)	

UCAR and its member universities have led the development of community observational and computational facilities that have benefitted the academic sector of the U.S. weather and climate enterprise. In addition, UCAR manages the National Center for Atmospheric Research in Boulder, CO, which is a federally funded research and development center (FFRDC) in partnership with the National Science Foundation.

Although the weather and climate programs of the academic sector primarily conduct independent research and teaching, UCAR's community-focused effort strengthen and promotes professional collaborations across institutions and provides researchers access to resources that their institutions may not support locally.

Strengths and weaknesses

The academic sector continues to produce an increasing number of graduates, with almost 200 Ph.D.-level, 200 Masters-level, and 750 Bachelors-level graduates in 2008 (Fig. 1). Through an informal survey in 2012 of UCAR members and academic affiliates, the success in gaining employment is relatively high among Masters and Ph.D. graduates, but substantially lower and declining with Bachelors' graduates. The increased number of students who now major in meteorology as a result of seeing the movie "Twister" (1996) or the Discovery Channel series "Storm Chasers" (2007) does not appear to be consistent with the rate of job growth in the enterprise.

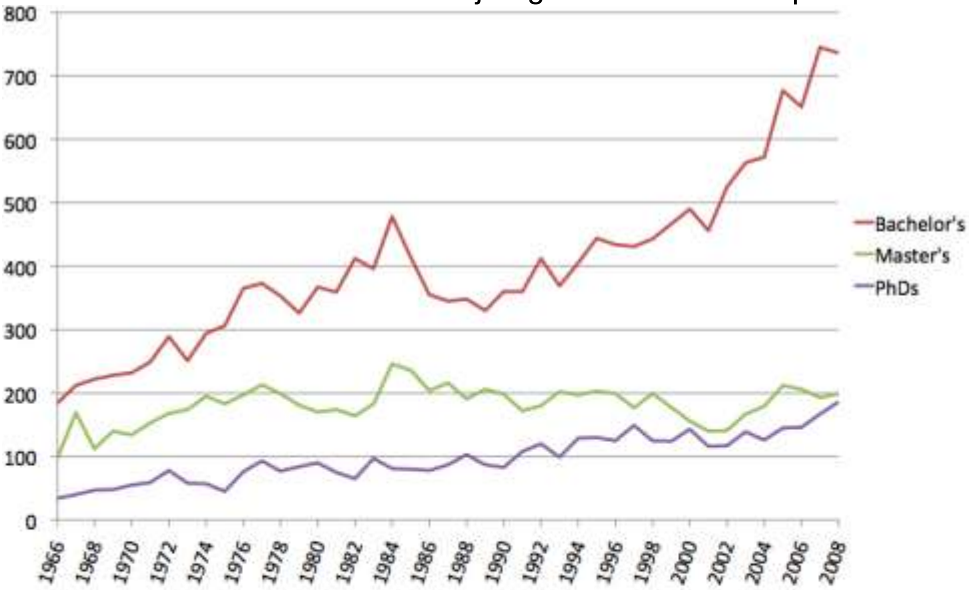

Figure 1. Atmospheric sciences degrees awarded, by degree level: 1966–2008. Courtesy of T. Bogdan, UCAR.

Most of the Bachelors' graduates obtaining jobs in the public and defense sectors, weathercasting, niche forecasting in the private sector, and GIS applications sectors. Qualities of the best graduates include deep expertise in weather or climate and the ability to work with stakeholders across disciplines.

The academic community continues to excel in individual and collaborative research that provides new scientific insights, technological advances, and enhanced learning opportunities. In general, the nature of the academic process, including its peer review for faculty advancement, has led to the United States being a highly desirable destination worldwide for graduate education, post-doctoral opportunities, and faculty positions in the weather and climate enterprise. The academic community continues to be heavily engaged in developing national science priorities; however, the community does not speak in a common voice to those who fund these priorities.

The weather and climate enterprise is strengthened by growing interactions with other disciplines, including the breadth of disciplinary knowledge and methods in medical, social, and economic sciences as well as engineering. In fact, this breadth of disciplines cannot be found in abundance anywhere but in academia; hence, it is imperative that faculty in the atmospheric sciences and related fields seek collaboration with outstanding scholars in other disciplines for the benefit of the entire enterprise. Otherwise, the weather and climate enterprise will be relegated to working with whomever voices interest in collaborating rather than the leaders in any particular field.

U.S. universities have been particularly conservative in their recruitment and advancement of female and minority Ph.D.'s into the faculty, leading to a population of full professors (and, similarly, AMS Fellows) across the weather and climate community that is overwhelmingly white and male. The general failure of the academic community to recruit and retain outstanding women and minorities for their Ph.D. programs and also to demonstrate the multiple benefits to a career in academia has led to the most common excuse for not hiring and advancing women and minorities: that there are not enough quality candidates. It's past time that the entire enterprise recognize and address this failure.

Health of partnerships

Partnerships between the academic sector and the public sector are generally strong and continue to improve. Federal agencies continue to see value in collaborating with academic research institutions, as evidenced by the use of and funding for cooperative agreements and competitive grant programs. Recent examples of these include the establishment of Climate Science Centers at eight universities across the U.S., funded by DOI's U.S. Geological Survey, and the 2012 grant program for Social Science Weather Research, funded by NOAA's Office of Oceanic and Atmospheric Research. Still, there is limited funding available to the academic community through mission-driven Federal agencies, especially as research investments decline or stagnate.

An example of a 20-year partnership between academia and the public sector is the COMET Program, which was established by UCAR and NOAA's National Weather Service to promote a better understanding of mesoscale meteorology among weather forecasters and to maximize the benefits of new weather technologies during the NWS's modernization program. Today, COMET creates a broad array of environmental science education and training products and services, with an extensive catalog of media-rich distance learning modules. Many of these modules have been developed in collaboration with the academic sector, and both large and small weather and climate programs in the nation's colleges and universities use the learning materials. COMET also operates a grant program that promotes partnerships between NWS forecast offices and universities through collaborative project funding.

These and many other examples demonstrate a diverse and vibrant partnership between the academic and public sectors. Although there are areas for improvement, both communities benefit from these partnerships.

In contrast, the relationship between the academic and private sectors has been and continues to be under-developed. Much of the struggle results from a mismatch of the missions and cultures of the two communities. In academia, faculty, students, and staff may see great benefit in freely sharing university-developed data sources, software, and other resources that are similar to products being sold in the private sector to generate economic growth. When members of academia do want to transfer technology into the private sector, university offices for intellectual property protection many times operate slowly and with restrictions that minimize the attractiveness of these technologies to private companies. Faculty members generally do not understand product cycles and the speed at which the private sector requires action for competitive advantage. Moreover, students are graduating with little understanding of practical applications of their knowledge.

On the other hand, cutting-edge technologies and discoveries are being made across the U.S. academic sector. The creativity of this sector is tremendous, as is the potential for student-led innovations in social media and smart phone-enabled software. Government investments in developing the next-generation sensors, computing devices, numerical models, etc. within or in partnership with the academic sector have led to substantial market segments in industries to either mass produce or further refine these technologies. Many of today's leading companies in the weather and climate enterprise can trace some of their successes to developments in the academic sector.

The environment is improving for academic-private partnerships. Universities are becoming more adept at technology transfer, and private companies are becoming more willing to cluster around dynamic university environments. One example of this is on the Research Campus of the University of Oklahoma, where a host of weather, water, and climate-related companies occupy university-owned buildings within walking distance of the National Weather Center. Partnerships exist at other universities, such as between Penn State and AccuWeather, and these appear to be slowly growing as benefits outweigh the risks and challenges of such a partnership.

Support from Professional Societies

The academic community generally is well served by professional societies, including the American Meteorological Society. One of the greatest needs in the academic sector from the American Meteorological Society is to keep publication costs low. Because state funding of academic programs has decreased substantially over the decades and yet faculty are evaluated based on their publication record, it is critical that publication costs are comparable to those in similar or related professional societies.

Recommend improvements

Areas of improvement for the academic sector include the following:

- Open and purpose-driven dialog between university leaders who can enable technology transfer and private sector leaders who have interest in mutually beneficial work with universities.
- Recruitment and retention of under-represented groups, including women, to develop a diverse workforce as well as intentional and persistent work to develop

faculty bodies and research leadership teams that are more representative of the demographics either of the nation or of the region where the academic institution is located.

- Development of more applied and entrepreneurial coursework in weather, climate, water, and computer-enabled technologies to broaden the background of students who are not intending to become forecasters in the Federal government or private sector.
- Enhanced partnerships between the UCAR, relatively resource-rich research universities, and relatively resource-poor universities and colleges (especially those that may be minority serving institutions or tribal colleges) to help provide access to learning materials, technologies, etc. that could help those academic institutions with few resources to prosper.
- Establishment of scholarships and other financial aid to help students to cover tuition, fees, professional travel, and other expenses.

PROFESSIONAL AND ADVISORY ORGANIZATIONS

General Structure

A diverse set of professional and advisory organizations has arisen to support the weather, water, and climate enterprise. Some of these focus exclusively on the enterprise, while for others it is only part of what they do. Key professional organizations focused on the enterprise include:

- American Meteorological Society (AMS)
- National Weather Association (NWA)
- American Weather and Climate Industries Association (AWCIA)
- National Council of Industrial Meteorologists (NCIM)
- National Weather Service Employees Organization (NWSEO)
- National Research Council, Board on Atmospheric Sciences and Climate (BASC)
- Weather Coalition
- NOAA Science Advisory Board

Other organizations that include some element of the enterprise in their broader focus include:

- American Geophysical Union
- American Society of Civil Engineers
- American Wind Energy Association
- Association of Public Land-grant Universities
- Council of State Governments
- Education Research Services
- Institute for Business and Home Safety
- Institute for Global Environmental Strategies
- Reinsurance Association of America
- Satellite Industry Association
- Weather Risk Management Association

This is an evolving list, so it may be incomplete at any particular time. The latter group includes both organizations for which weather is a substantial part of their charter and those for which it is only one of many activities. It also includes groups with a range of purposes, such as some being advocacy-oriented with others focused on advisory roles.

These organizations provide support across the three main sectors – public, private, and academic. The importance of professional organizations to the enterprise's success cannot be overly emphasized. Key roles include:

- Professional support to individuals in the filed
- Meetings and conferences

- Scientific, technical, and business advice
- Scientific and professional publications
- Community and issue advocacy
- Cross-community interactions and relationships
- Technical standards

Strengths and Weaknesses

A great strength of the professional and advisory sector is the number and diversity of such organizations. A wide range of enterprise functions is represented, many of which are supported by multiple organizations. This diversity is also the enterprise's chief weakness, as no one organization speaks for the enterprise as a whole.

Health of Partnerships and Quality of Services

In general, the partnerships between each organization and the specific portion of the enterprise they support tend to be strong. Less healthy are the relationships between and across multiple organizations that would enhance the overall enterprise.

Recommended Improvements

Today, many of these organizations face challenges for their survival. Traditional revenue sources are evolving rapidly, putting organizations at risk. Professional publications have been traditionally funded through publication page charges, but the advent of online publishing has introduced pressure to reduce these charges. Meetings and symposia are also at risk due to increased online professional interaction and to budget pressures both in governments and businesses. These organizations will need to evolve their revenue sources in order to survive, and the impact on their professional services is unclear. To succeed, they need the support and assistance of those in the public, private, and academic sectors.

Specific to this enterprise is the need for stronger cross-organizational coherence. This could be accomplished through a formal relationship between the underlying organizations or more rigorous informal collaboration. Achieving the single voice needed in many situations, however, remains a challenge.

APPENDIX A The Fair Weather Report: Task, Recommendations, and Responses. (taken from a presentation of Dr Maggie Walser, NRC, given at the 2012 AMS Summer Community Meeting)

Fair Weather Statement of Task
The panel will examine the present roles of the public sector, the private sector, and the academic community in the provision and use of weather, climate and related environmental information and services in the United States.
The panel will identify opportunities created by advances in observing, modeling, forecasting and information dissemination technologies for improving services in the public, private and academic sectors.
The panel will examine the interface between the various sectors described above in the provision and use of weather, climate and related environmental information services and identify barriers to effective interaction.
The panel will make recommendations regarding how most effectively to coordinate the roles among the various sectors.

Recommendation 1: 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.
Response

NWS revised Public-Private Partnership Policy in 2006

Report also recommended consideration of a NOAA-wide policy, which happened.

NOAA is one of few federal agencies with agency-specific policies on implementation of government-wide information

NOAA has framework across all NOAA line offices and programs for its interactions with others in making decisions.

Recommendation 2: The NWS should establish an independent advisory committee to provide ongoing advice to it on weather and climate matters. The committee should be composed of users of weather and climate data and representatives of the public, private, and academic sectors, and it should consider issues relevant to each sector as well as to the set of players as a group, such as (but not limited to)

- improving communication among the sectors,
- creating or discontinuing products,
- enhancing scientific and technical capabilities that support the NWS mission,
- improving data quality and timeliness, and
- disseminating data and information.

Response

NOAA Science Advisory Board's (SAB) Environmental Information Services Working Group (EISWG) was formed in 2009:

EISWG's charge was to focus on NWS matters for the first two years, but NOAA-wide matters thereafter.

Charter calls for an evaluation of whether this approach should be continued, modified, or replaced.

Not FACA; a formal NWS advisory committee is still needed.

Recommendation 3. 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.
Response

AMS Commission on the Weather and Climate Enterprise (CWCE):
CWCE has branched into a diverse array of topics that today now includes
- climate services,
- energy/renewable energy,
- Nationwide Network of Networks,
- environmental security,
- water resources,
- financial weather/trading tools,
- international data,
- weather/climate & human health, and many others

Expanding roles of the AMS Washington Forum and the AMS Summer Community meetings
There has been less progress in enhancing the relationship between academia and private industry.

Recommendation 4. The NWS should continue to carry out activities that are essential to its mission of protecting life and property and enhancing the national economy, including collecting data; ensuring their quality; issuing forecasts, warnings, and advisories; and providing unrestricted access to publicly funded observations, analyses, model results, forecasts, and related information products in a timely manner and at the lowest possible cost to all users.
Response

Continued improvement in the quality of NWS products
Today, the goals of the Weather Ready Nation initiative are well aligned with this recommendation
NWS currently does not provide unrestricted access to all of its data and data products.
Open Weather and Climate Services paradigm (developed by EISWG and adopted by the NOAA SAB) addresses this
Much more can be done to ensure that all data is made available to the private sector

Recommendation 5. The NWS should make its data and products available in Internet-accessible digital form. Information held in digital databases should be based on widely recognized standards, formats, and metadata descriptions to ensure that data from different observing platforms, databases, and models can be integrated and used by all interested parties in the weather and climate enterprise.
Response

NCDC is an example of success in this area (e.g., access to radar data)

From within the NWS, recommendation was interpreted as confirming that it is appropriate for the NWS to continue its public internet web sites (which still exist).
NWS has also adopted new standards for information delivery in the years since Fair Weather was published (e.g., provides data using CAP and XML protocols).
Open Weather and Climate Services proposed an open and accessible data port

Recommendation 6. The NWS should (1) improve its process for evaluating the need for new weather and climate products and services that meet new national needs, and (2) develop processes for discontinuing dissemination of products and services that are specific to particular individuals or organizations or that are not essential to the public.
Response
PART (1)
EISWG effort partially addresses this need
Organizational/structural constraints in bringing in outside expertise before product development begins; evaluation of the "need" is still internal and often long before outside organizations have input
NWS involved stakeholders in developing the Weather Ready Nation strategic plan
PART (2)
No clear process for identifying products or services to be discontinued

Recommendation 7. NWS headquarters and regional managers should develop an approach to managing the local forecast offices that balances a respect for local innovation and creativity with greater control over the activities that affect the public-private partnership, especially those that concern the development and dissemination of new products or services.
Response
This has been challenging and efforts are still needed
NWS Partnership Policy has been disseminated to all field offices
NWS leadership very open to hearing about possible activities that violate the Partnership Policy
Leadership has acted to stop such activities in a prompt manner
Local WFOs also have promulgated this policy and conflicts don't appear to be as much of problem as in recent years

Recommendation 8. The NWS should continue to adopt and improve probabilistic methods for communicating uncertainties in the data and forecasts where such methods are accepted as scientifically valid.
Response
Work continues in this area, but much more still needs to be done
One area of completed work is probabilistic storm surge forecasts for potential landfalling tropical storms
More work is especially needed on communication and public education
CWCE adopted a "Topic of the Year" themed on how to address probabilistic forecasting

NWS is in the process of integrating such principles into daily operations (private sector firms are/should be doing so as well)

Recommendation 9. The NWS should retain its role as the official source of instrumentation, data, and data collection standards to ensure that scientific benchmarks for collecting, verifying, and reporting data are maintained. It should lead efforts to follow, harmonize, and extend standards, formats, and metadata to ensure that data from NWS and non-NWS networks, databases, and communications technology can be integrated and used with relative ease.

Response

NWS does maintain the standards for instrumentation and participate with other NOAA elements to provide meta-data for observations

Progress is being made over time, but more importantly, the NWS is actively pursuing this initiative. The NWS readily acknowledges the importance of this effort

EISWG effort is championing this challenge

Open Weather and Climate Services white paper makes it clear there are still many opportunities for progress

Recommendation 10. The commercial weather sector should work with the other sectors, using mechanisms such as those proposed in this report, to improve the techniques and processes by which the weather and climate enterprise as a whole can minimize friction and inefficiency.

Response

Real progress has been made here, especially between the private sector and the federal sector.

Commercial weather sector still needs to figure out how to work with the academic/research community. Can AMS play a role here?

Leaders of the private sector are active in the CWCE. The presidents of AWCIA and NCIM serve on the steering committee.

Not much progress in reducing inefficiencies

Recommendation 11. Universities seeking to commercialize weather-related research results should follow transparent procedures for transferring technology and for avoiding conflicts of interest. These procedures should be given wide exposure to remove perceptions of unfair competition.

Response

There have been efforts by few universities (continuing efforts through UCAR), but very limited on national scale

Universities still use the big-pharma model for commercialization, which does not work well for weather

Academic sector remains aligned with the efforts of the government (NWS/NOAA) and private sectors in enhancing the capabilities and successes of the entire enterprise.

General comments made about the Fair Weather Report during the survey of the responses to the recommendations:

Progress has been made in improving the relationship between NOAA/NWS and the private sector, due in large part to the actions of several major thought change leaders

The relationship between academia and the private sector has been slower in improving

Looking back at the recommendations of the report after 10 years, great progress has been made in bringing the various sectors of the weather community together and really pulling in the same direction

"Before the Fair Weather report, there were certainly some individuals whose conceptual framework for weather services encompassed government agencies, private companies, and academia, but there were almost no institutions or policies that explicitly recognized what we have come to call the weather and climate enterprise. Today, we have robust institutions and widespread policies and practices that are founded in explicit concepts based on the enterprise-wide thinking of the Fair Weather report. It is hard to point to any report of the National Academies that has had broader or more positive impacts."