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Involvement of Atmospheric Sciences in Illinois Policy Issues, 1950-2001

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ABSTRACT

Since the 1950s atmospheric scientists at the Illinois State Water Survey played proactive and reactive roles in major Illinois policy issues. Review of the 50 years of policy interactions reveals that five factors were important for obtaining successful science-policy interactions. These included developing a definitive understanding of how weather and climate affect all aspects of life in Illinois; establishing a constituency based on knowledgeable services; dealing effectively with state officials; communicating atmospheric information effectively in Illinois and nationally; and being able to address widely diverse weather-related issues. The diverse expertise of the scientists allowed informed interactions on widely different issues including cloud seeding, climate change, acid rain, and the diversion of Great Lakes water at Chicago. Survey scientists participated in promoting federal legislation in the climate services issue, in addressing needs for federal programs relating to flooding, droughts, and climate change; and in seeking federal funding through Congress for atmospheric science programs. State programs in weather modification and global climate change, including new legislation and regulations, have also been advanced by the scientists.

INTRODUCTION

How scientific information and expertise get involved in state policy issues is a question often asked and seldom answered, and hence, the process is not well understood by many in the scientific community or the general public. Questions that arise include whether the involvement of science is done effectively, by accident, or in timely fashion. This paper attempts to answer these questions by reviewing the 50-year history of the involvement of atmospheric science information and expertise in Illinois policy issues.

As a prelude to this science-policy assessment, a brief description of the Illinois State Water Survey is presented illustrating how the atmospheric sciences program developed and functioned within the Survey over the past 50+ years. This is background information necessary to establish the institutional setting of the information and views presented to state policymakers. This includes identification of the five factors identified by Survey scientists as essential for achieving successful policy interactions. Then, descriptions of the seven major state policy issues that embraced the atmospheric sciences in Illinois are presented, revealing how the success-oriented factors came into play. The activities in these issues are then summarized revealing the values gained in Illinois as a result of the

successful interactions between scientists and policy makers. These provide guidance as to how scientists of any discipline need to act to be effective in state policy forums.

ILLINOIS STATE WATER SURVEY: HOME OF THE ATMOSPHERIC SCIENTISTS

The Water Survey and two sisters organizations, the State Natural History Survey and State Geological Survey, were established more than 100 years ago. As the 19th century ended, exploitation of state natural resources was occurring. Far-sighted state leaders recognized the need for independent quality science expertise and data, and by law established the Surveys at the University of Illinois (Hays,1980). In 1917 the State further established a governing board for the three Surveys that included two university presidents and diverse scientific expertise. This governing board, and the Surveys close affiliation with the University of Illinois, have kept the Surveys from being state agencies staffed with political appointees and with responsibilities to provide potentially biased answers to satisfy political positions of certain state leaders. Scientific independence is guaranteed regardless of how it affects certain state interests. The scientific surveys represent an interesting mix of academic research and state services. The Survey-related legislation also mandates that the Surveys disseminate their findings widely, including through publications.

The Water Survey's three major functions in 1900 and now are to 1) collect data to monitor state water and atmospheric resources, 2) conduct applied and basic research on relevant problems, and 3) provide services to the state, which means translation of data and information to those who need it. Anticipating emerging problems has long been a focus of the Water Survey's data collection and research programs, not just reacting to well established problems.

In 1947 the Water Survey developed an atmospheric sciences group as a result of constituent questions and calls for assistance relating to issues like cloud seeding, droughts, and flood-producing storms (Changnon and Huff, 1997). The initially small group of weather scientists grew over time largely as a result of federal and private sector funds for research. By the 1960s the atmospheric group had established itself as a nationally-recognized quality center of atmospheric sciences expertise involved in large field projects, very diverse research, and extensive generation of atmospheric information.

This pattern of program development required diverse expertise in the atmospheric sciences ranging from designing and operating weather radars to computer-based cloud modeling. The program depended on highly skilled staffing that could compete for and conduct federally-supported research and development projects (Changnon and Huff, 1996). The State did not invest sizable resources in the atmospheric program, providing funds mainly for staff facilities and a few staff members. However, the State has benefited greatly for over 50 years by having this diverse in-state expertise, largely developed with external funding, available to address many widely differing state needs including numerous policy issues. For example, as a result of involvement in a variety of policy issues, the Survey today operates two large networks of recording raingages, one in central Illinois and one in the Chicago area; maintains a statewide network of 19 automated weather stations; and serves as the home of the Midwestern Regional Climate

Center. The Survey's atmospheric staff includes 30 scientists, 10 technicians, and several students.

If an atmospheric scientist and/or an institution with atmospheric science expertise are to be useful and effective in state policy making, the factors for the success of the policy-science interactions in Illinois must be identified and followed. From the beginning of the Illinois atmospheric science group, the potential activities that could result in success in the policy arena were assessed and defined. This led to the identification of five factors that could help create successful science-policy interactions.

Factor #1: Understanding the Impacts of Weather and Climate
In Illinois, developing an understanding of the dimensions of how the atmosphere affects the state and all of its weather-sensitive sectors, including the economic, environmental, and human impacts of weather on various sectors such as agriculture, water resources, and urban areas, has been critical to achieving effective policy interactions. This basic information allows the scientists to speak with authority on weather's importance to Illinois.

Factor #2: Developing a Constituency
Understanding the needs of various sectors of society and conducting meaningful interactions with weather-sensitive groups, including the timely provision of services (data and information), help lead to developing a strong constituency for a science program. A constituency helps scientists get support for proactive atmospheric policies sought such as those in weather modification, climate services, and climate change. For example, an important aspect of the climate services program established at the Water Survey related to working closely with state constituents and policy makers to assess their needs (Lamb et al., 1983). Considerable research attention has been given to the development of climate products and information that meet the constantly varying needs of the state's water resource managers, agricultural interests, and insurance industry. Attention has also been given to the general public and its need for information, particularly about the climatological dimensions of weather extremes when they occurred.

Factor #3: Dealing Effectively with State Officials
Interacting with state officials on policy issues has to be done with recognition that it is often difficult for them to understand complex scientific issues. Hence, information has to be presented in user friendly formats and timely fashion, often anticipating emerging problems and needs for information.

Factor #4: Communicating Widely and Effectively
Communicating information in formats users can understand is critically important. Presentations of atmospheric information in state magazines and frequently in the news media help display expertise and build connections between the atmospheric scientists and policy makers. It is also important to communicate state atmospheric findings within the national atmospheric sciences community, which involves publications in national journals and talks at scientific conferences. These actions help establish scientific credibility of the staff, a factor important in being able to address and influence national policies and federal programs.

Factor #5: Addressing Diverse Issues
Policy making at the state level relating to atmospheric issues is often done in a reactionary mode with little planning, and a wide variety of very different issues can be brought to the atmospheric scientists with requests for rapid and intelligent interpretations. The issues are quite diverse, including issues like air pollution, cloud seeding, drought, floods, and climate change. The atmospheric science expertise had to have broad expertise, to be well informed about numerous atmospheric issues, and to be capable of rapid responses to inquiries and opportunities. Recognition of emerging atmospheric issues allow scientists to seek and get positive state decisions to improve data collection and research programs through new state funding. Such opportunities to get state involvement in atmospheric-related needs often occurs unexpectedly, and being prepared for these allow scientists to achieve new programs. Effectiveness in responding to diverse policy needs also requires performing diverse functions including applied and basic research, field studies and measurements, data collection routinely and intermittently, and monitoring of climate conditions.

MAJOR POLICY ISSUES INVOLVING THE ATMOSPHERIC SCIENCES

Illinois, with a sizable urban population, a highly developed agricultural base, extensive manufacturing and commercial businesses, and serving as the heart of the nation's transportation system, is a state with many weather-sensitive activities. These have created a variety of policy issues that many states do not face, and that have involved, in some manner, the atmospheric sciences in policy issues tied to these weather-sensitive sectors.

The involvement of atmospheric sciences information in state policy issues has assumed three forms. One was internal, being Illinois-only policy development and adjustments. These have included input and involvement in 1) enacting and/or changing laws (such as control of weather modification projects); 2) preparing new or changing existing regulations (such as those for heavy rainfall values); 3) defining the dimensions of various weather/climate extremes and helping delineate responses for dealing with hazards such as floods and droughts; 4) conforming to state rules and regulations (such as those for air quality); 5) assisting important constituent groups including state agencies with data and information to address key weather or climate issues; and 6) advising state government on specific policy issues (such as the global climate change).

A second form consisted of involvement in external policy issues at the national level, including expression of the needs and concerns of the State on federal issues. These have included conforming to national laws and rules (such as the Great Lakes diversion and statewide air quality); defining state positions on national issues such as global warming; and prioritizing funding for state-important atmospheric programs and activities such as weather modification research and the development of regional climate centers.

The third type of policy issues were also external and involved interactions with other states. These have addressed issues such as shared climate and water resources, and conflicts over different policy positions on a given issue. For example, resolving air pollution problems shared by Missouri and Illinois at St. Louis involved atmospheric input from Survey scientists on pollution sources and where rainout of pollutants occurred.

In some instances the atmospheric sciences policy role was singular. That is, some issues were almost totally atmospheric in nature such as global climate change and weather modification policies. However, the atmospheric science component in many Illinois policy issues was only one part of a mix of components.

The policy interactions of the Survey's atmospheric scientists have assumed either a proactive or reactive mode, depending on the source of the policy development. For example, Survey scientists have been proactive in developing policies related to weather modification and global climate change, but have been reactive in other issues like acid rain.

Seven notable "policy issues" developed over the decades from the 1950s to present and embraced the atmospheric sciences and the expertise at the Water Survey. Following is a discussion of these major policy issues that extensively involved the atmospheric science data, information, and expertise.

Diversion of Great Lakes Waters at Chicago

Lake Michigan has always been the source of water for Chicago, and this demand has grown greatly over time, now serving 6.6 million people. Lake water has also been used for other purposes. Since the 1890s, Chicago has been diverting considerable amounts of water from Lake Michigan down the Illinois River. This was done initially for flushing sewage and other wastes of Chicago away from the city's water supply, Lake Michigan. Disposal of city wastes into the lake during the 19th Century often polluted the water used for public supplies, leading to numerous deaths from water-borne diseases like cholera (Changnon, 1994a). Over time, this diversion of lake water, which served the water supply needs of Chicago and its huge industrial complex, also allowed the extensive development of river-borne transportation on the Illinois River to access the Chicago Metropolitan area.

From 1900 to 1920 the federal government and Illinois were involved in a series of controversies over the amount of the diversion, and federal concerns grew greatly when Chicago built new intakes for more lake water on the city's north and south sides (Changnon and Glantz, 1996). This major policy issue in Illinois also had an international aspect resulting from deep Canadian concerns about the effects of the diversion on the levels of the Great Lakes.

By 1922 states around the Great Lakes, which had become increasingly concerned about the effects of the diversion on lake levels, and thus on lake shipping and on the hydropower generation facilities built at Niagara, sued Illinois to halt the diversion (Miller, 1994). Ultimately the controversies became legal; suits that went to the U.S. Supreme Court, which in 1930 set a limit for the diversion, greatly reducing the amount of water Illinois could take. The controversies of the 1900-1930 period were rooted in the belief that the Chicago diversion was the cause for ever declining lake levels during this period. However, a major hydro-climatological study conducted by famed early hydrologist, Robert Horton (1927), revealed that the long-term decline in lake levels was due to shifting climatic conditions, not the water Chicago was diverting. This became the first example of the use of atmospheric information in an Illinois policy issue, and the information proved to be of great value to the Illinois case for sustaining the diversion (Changnon, 1994a).

In the 1950s, the continuing growth of the suburbs in the Chicago Metropolitan area had led to the mining of ground water that was the primary water supply of most suburbs of Chicago (Walton et al., 1960). The rate of depletion was sufficient to lower ground-water levels in Wisconsin. This situation brought a new controversy between Wisconsin and Illinois, and Wisconsin led a legal charge against Illinois. The case again went to the U.S. Supreme Court, and the other lake states also became involved since a change in the diversion was proposed as a solution to the ground-water problem. The Water Survey provided extensive data and expertise for Illinois' side of the debates, and the Court ultimately allowed Illinois to increase the diversion to supply water needed by the suburbs. An important readjustment of the diversion allotment was climate based—the annual diversion limit could be shifted by Illinois between years to adjust for wet and dry climate conditions, but had to be balanced to meet the annual limit over a 40-year period (Changnon and Changnon, 1996). Another part of the policy debate had focused on the amount of precipitation falling over Lake Michigan, leading to several intensive atmospheric studies to provide information to state policy makers (Changnon, 1968a, 1971). Atmospheric science information played an important role in the Supreme Court's decision that was so favorable to Illinois. Thus, one of the five "success factors," understanding the impacts of climate, was a key factor in this issue.

In 1980, the Supreme Court dictated that the diversion amount assigned to Illinois was to include precipitation falling over the Chicago urban area. This was water that would otherwise have flowed to Lake Michigan, but was drained away into the Illinois River. As a result of this Court declaration, precipitation over Chicago had to be monitored and accounted for as part of the Illinois diversion amount. As a result of its long experience in conducting field projects, the Water Survey was selected to monitor the urban rainfall with existing raingages, and then chosen in 1988 to install and operate a dense raingage network over the entire Chicago region, thus providing the precipitation data as part of the monitoring of the diversion amount that Illinois takes from Lake Michigan at Chicago (Peppler et al., 1990). The scientists capability to address diverse issues was a successful factor.

The on-going fluctuations of the levels of the Great Lakes, which are all climate related, have remained a cause of more federal-state debates relating to the Chicago diversion (Changnon, 1990). During the 1970s and early 1980s lake levels had reached record highs and the federal government proposed a sizable increase in the diversion to lower lake levels that were damaging shorelines (Changnon 1987a, 1988a, 1993a). Illinois objected, noting the economic and environmental damages that higher flows might cause in the Illinois River system (Bhowmik, 1989). Then, a major drought during 1987-1989 caused lake levels and river flows to fall to near record lows, halting barge traffic on the Mississippi and Illinois Rivers (Changnon, 1989a). Illinois and six states along the lower Mississippi proposed increasing the diversion to raise river levels, but the lake states objected and the Supreme Court refused (Changnon and Glantz, 1996).

In the 1990s, the issue of global climate change and permanent shifts of lake levels arose (Changnon 1985a, 1993a, 1997). Lake-level shifts due to potential future climate changes were investigated (Croley et al., 1998), and reports to policy makers about their causes and possible impacts were generated by atmospheric scientists (Changnon, 1986, 1987b,

1989b). In summary, the diversion at Chicago has been a major Illinois policy issue for the past 100 years, and over the past 50 years, it has frequently involved the atmospheric scientists of the Water Survey.

Heavy Rains and Flooding in Chicago

During the 19th Century a joint sewer and storm drainage system was constructed in Chicago, a practice followed in many large older cities. As Chicago grew, it became evident the system was inadequate to handle both stormwaters and sewage. By the middle of the 20th Century, heavy rains brought repeated flooding in the city with considerable flood damage to residences and businesses. Furthermore, cases of extensive flooding often led to the release of the excessively-polluted floodwaters into Lake Michigan, creating highly undesirable water conditions and often raising the ire of Wisconsin and Michigan.

Seeking to define the causes for this problem, the city turned to the Water Survey for an explanation. Atmospheric research found the city was experiencing more heavy rains than the long-term regional rainfall occurrences would predict for Chicago (Dettwiller and Changnon, 1976). This finding led to extensive studies of urban effects of Chicago on all facets of weather with an emphasis on precipitation and storminess (Changnon, 1980a). It was found that both the St. Louis and Chicago urban areas affected the atmosphere and created sizable effects on precipitation including more heavy rain events (Changnon, 1980b, 1984a). Numerous studies of rainstorms impacting Chicago were conducted (Changnon, 1978a, 1982a; Changnon and Vogel, 1980). A major 4-year field program was conducted during 1978-1981 to assess urban and lake influences of storms, and to identify potential actions to minimize flooding (Changnon et al., 1978; Changnon et al., 1980). Subsequent atmospheric studies have defined the correct heavy rainfall frequency values for the city (Huff and Angel, 1989). The ability the atmospheric scientists to react to a complex problem and to identify the causes was a highly successful action and also involved positive interactions with state officials. Survey studies have continued to assess Chicago's heavy rainstorms and their degree of flooding to help measure the adequacy of the major facilities built over the past 20 years by the city for stormwater storage (Changnon 1999a; Changnon and Westcott, 2002).

Weather and Climate Extremes

Illinois experiences occasional climate extremes, including severe droughts and floods, and frequent weather extremes like winter storms, high winds, and tornadoes. These impact Illinois' water supplies, agriculture, commerce, and river/surface transportation (Changnon, 1981a; 1987c; Changnon et al., 1996; Changnon et al., 2001).

The occurrence of severe droughts in the 1950s and again in the 1980s led to demands from state officials for climate information as input to designing new (or altering) state policies relating to 1) drought mitigation, 2) drought relief assistance (short and long term), and 3) interpretation of drought conditions including severity, likely persistence, and intensity (Changnon 1981b; 1982b). Confusion over drought conditions, including drought severity, which involved state responses and aid, required illustrating to state officials, in an understanding way, the often subtle differences between water supply droughts and agricultural droughts (Changnon, 1980c). Drought-based design studies were conducted to allow the State to better plan and prepare for future droughts (Huff and Changnon, 1963; Easterling and Changnon, 1987). Survey scientists alerted state and

federal officials about drought policy needs (Changnon, 1981b, 1993b). Now, drought conditions in Illinois are constantly monitored by Survey scientists to provide input, as needed, to the state's drought task force. Furthermore, because of the expertise of Survey atmospheric scientists, they have been requested to provide significant input to national interests about droughts and policy needs (Riebsame et al., 1991). Advice has been given to the formulation of a newly evolving federal drought mitigation program in order to improve national and state mitigation practices and responses. Information about in-state drought conditions is now routinely provided to the federal government for the development of a national drought monitoring map issued monthly.

A similar set of policy issues have arisen over floods. The sizable economic and environmental impacts of floods have led to state policy changes involving atmospheric data and expertise for assessing weather conditions responsible for the severity of floods (Changnon, 1983a; 1984b). The state's growing losses from floods were assessed and found to rank sixth nationally (Changnon et al., 2001). The information provided to state officials has also included assessment of federal policies relating to flood responses and research (Changnon, 1985b). Statewide concern has developed over the long-term upward trend in floods, and the climate explanation for this growing problem has been provided to state policy makers and to stat urban managers. The state has experienced a climatic shift since 1940, leading to more heavy rains capable of creating floods (Changnon, 1983a). Illinois' atmospheric science expertise has also been called upon to address federal policies that addressed mitigation regulations and flood assistance programs, such as river flood control structures, flood insurance, and flood-related research needs to deal with floods (Changnon, 1987d; 1996a).

Problems with losses from weather extremes led to scientific assessments of the losses and risks created by tornadoes, hail, high winds, thunderstorms-lightning, and winter storms. Chicago's inability to handle snow removal due to a severe winter in 1977-1978 with 18 severe winter storms led to a study of the storms and their impacts on local policies (Changnon and Changnon, 1978). Chicago's transportation systems were crippled and the problems caused many policy changes.

Two recent years (1995 and 1999) have had major summer heat waves in Illinois with a record high number of deaths, principally in Chicago, in 1995. Urban policies for handling heat wave conditions came under severe criticism in 1995, and this led to atmospheric studies to interpret the event's climatic severity (Kunkel et al., 1996). Furthermore, explanations for the fact that fewer deaths occurred in Chicago in more severe heat waves during the 1930s were developed (Changnon et al., 1996). These served as useful guidance to revisions of city policies for improved handling of the 1999 heat wave (Palecki et al., 2001). Four of the five factors identified for successful policy interactions were revealed in the weather extremes issues including the value of understanding weather impacts, dealing effectively with state officials, communicating information at the state and national levels, and having the capabilities to address diverse issues.

Acid Rain and Atmospheric Quality Issues

Illinois is a state with numerous power generation facilities, a coal mining industry, and a manufacturing complex that collectively became concerned over emerging national policies relating to air quality controls beginning in the 1960s. The early focus was on causes

and impacts of acid rain. These issues embraced the atmospheric sciences in a variety of ways. Research was conducted to generate information about acid rain as input to the state's policy position for use by state officials and by members of Congress (Semonin and Stensland, 1984). These served to help to protect state interests.

Air quality issues relating to the state's two large urban areas have also led to the involvement of atmospheric scientists in assessing the sources and deposition of gaseous and particle pollutants and the environmental effects of these materials (Gatz, 1979; Changnon, 1982c). Networks to sample air pollutants were established in the Chicago and St. Louis areas for air and rain quality sampling, reflecting the capability of the scientific group to address diverse issues.

Survey scientists had performed the nation's first sampling of rainwater chemistry in 1953-1954 (Larson and Hettick, 1956), an exploratory project typical of many that Survey scientists have performed. The results of this initial sampling proved invaluable in correctly establishing the trends in rainwater quality in later years and for addressing national-scale debates over acid rain. The Water Survey was selected in 1980 to serve as the national laboratory for analyzing the samples of rainfall for pollutants collected across the nation, done as part of the National Atmospheric Deposition Program (NADP, 2001). The selection as the national analytical laboratory for such an important air quality program reveals the high national regard for the quality of the Survey's staff and recognition of their scientific impartiality on the policy-sensitive air quality issues.

Purposeful Weather Modification

Regional droughts causing crop yield reductions in Illinois led to the initiation of nine multi-county cloud seeding projects in Illinois during the 1964-1982 period. Each project sought to increase rainfall. Local agricultural interest raised funds and hired cloud seeding firms to conduct the projects (Changnon, 1975a; 1977a). These activities involved the atmospheric scientists at the Water Survey who reacted to local requests for unbiased expertise to explain the reality of cloud seeding, and to assess whether the seeding projects being performed were actually changing the rainfall (Changnon and Towery, 1976; Changnon and Hsu, 1981). This growth in the use of cloud seeding in Illinois also led atmospheric scientists to assess the various economic and societal impacts of changed rainfall (Changnon, 1977b; 1978b).

As a result of the early cloud seeding projects in the 1960s and the ensuing development of a strong constituency, Survey scientists were able to promote the development of a state law that established a board that regulated cloud seeding projects primarily to ensure that quality operations and projects were being conducted (Changnon, 1973a; Ackermann et al., 1974). Another policy issue that arose was concern in Indiana that the Illinois projects were detrimentally affecting downwind rainfall in Indiana and other states (Changnon, 1980d).

Statewide interests in rainmaking also led Survey scientists to initiate a major weather modification research program that lasted 25 years, and achieved extensive federal funding reflecting the Survey's success in communicating and demonstrating its expertise nationally. The program included field experiments to test cloud seeding for rain increases (Changnon, 1973b), and to assess the potential effects of altered precipitation

on water resources and agriculture (Huff and Changnon, 1972; Changnon, 1972). Concerns over altered weather in adjacent states, as a national issue, was also addressed (Changnon, 1980d), as was the management of weather modification at the state level (Changnon, 1980e; 1983b).

Loss of federal funding support for the Illinois weather modification research, due to shifting federal program priorities, occurred in the early 1970s and again in the 1980s, temporarily halting the Illinois research projects (Lambright and Changnon 1989). This led Survey scientists to try to influence the policy issues surrounding the federal weather modification program (Changnon, 1973c; 1975b; 1976; 1980f). In 1984 the Survey scientists sought and got state permission to seek funding support from Congress, and the Water Survey joined with three other state research programs to seek and obtain funding from Congress to sustain the Illinois research endeavors (Changnon and Huff, 1987). The Illinois research from 1983 to 1996 was supported by Congressional funding added to the federal budget, and an operational rain-increase approach was developed for future use (Changnon et al., 1997). These results reflected expertise and the presence of a strong constituency for the Illinois program.

Climate Services and Related Research

Many Illinois issues with policy overtones have relied on state-generated climate data and information. For example, the energy shortages of the 1970s and the call for data on alternative energy sources was an opportunity for Survey scientists to propose and obtain state funding for a statewide network of solar and wind sensors (Peppler, 1995). This was successful because Survey scientists had developed a plan for such a network and were able to react quickly. The resulting 19-station network has been in operation for 20 years, measuring wind and solar energy and other agriculturally important variables like soil temperatures and moisture.

In the early 1980s after a series of bad winters, Survey leadership proposed to state leaders the concept of conducting a “Winter Storm Preparedness Week” in early December of each year. The goal was to educate the public about the dangers and how to avoid them to save lives. The Survey’s proposal was adopted by the Governor and the program began in 1983. The concept has since been adopted by the National Weather Service and employed nationwide.

The great value of climate services to the Illinois public, state businesses, and state agencies produced a strong constituency for the Survey program. The ensuing support enabled the state scientists to seek and gain improvements in the national climate services endeavors. This included improving the rate of receiving and distributing climate data (Changnon et al., 1984). Survey scientists performed several market-oriented assessments of the needs of climate-sensitive users for information, discovering major unfulfilled needs (Changnon 1983c; 1994b; Changnon et al., 1988). Hence, Survey scientists actively pushed for an organized federal climate services program, and this has been a 25-year effort. Survey scientists were extensively involved in the establishment of the National Climate Program Act of 1976 (Changnon, 1977c, 1987e). However, the federal Office of Management and Budget claimed the climate services involving the states was not in the national interest and the federal government refused to fund and thus establish the state climate services program, a key part of the National Climate Program Act. This

position led Survey scientists to conduct various activities to demonstrate the value of strong state climate programs (Changnon, 1979a, 1981c, 1982d; and Changnon et al., 1980).

When these efforts failed to alter the federal policy of no action on climate services, Survey leaders conceived an alternative approach, establishing a national network of regional climate centers, as a means to bolster needed services (Wendland et al., 1985). The National Climate Program Office funded a 3-year pilot regional center at the Water Survey, and it was found to be successful. Survey leaders could not get federal agencies to fund the centers, and took the concept of a national network of regional centers to members of Congress. The need for improved services was clear and Congress ultimately provided funding for six regional climate centers (Changnon et al., 1990), and Congressionally-mandated funding has continued for the past 15 years. The Midwestern Regional Climate Center is housed at the Water Survey, a measure of the successful establishment of a strong in-state constituency.

An integral part of the Illinois-based climate services program has been education about climate, and the promotion in policy forums, of effective applications of climate data and information (Changnon, 1975c, 1996b). Such endeavors have involved working closely with climate-sensitive entities, including several state agencies, to improve the use of climate information (Changnon, 1979a). For example, climate predictions were used by state officials to make key management decisions regarding water management in drought situations (Changnon and Vonnahme, 1986). Another success revealed was the effective dealing with state officials. The education and promotion of climate services are reflected in the State Water Plan Illinois developed during the early 1980s. Three of the eleven emerging issues the task force identified, after hearings across the state, were atmospheric: 1) planned weather modification, 2) climate change and prediction services, and 3) inadvertent weather/climate change (Changnon and Semonin, 1982).

Climate Change, Local to Global

The mention of climate change in today's world creates images of global warming and major changes. However, in Illinois the inadvertent changes in climate caused by human activities including those resulting from large cities, industries, and jet aircraft, have been subjects of study for 35 years (Changnon, 1968b; 1973d; Huff and Changnon, 1973). These were reactions to the state's needs for information about these climate effects to develop policy positions including whether to establish regulations to minimize harmful effects (Changnon, 1975d).

Major multi-year field studies were conducted in the Chicago and St. Louis metropolitan areas to define the degree to which these urban complexes affected the local and regional weather and climate, what factors were responsible for the changes, and the ramifications of the changes on the state's economy and environment (Changnon, 1977d; Changnon et al., 1977). As noted above, one ramification was finding an explanation for the urban weather changes including the abnormal number of heavy-flood producing rainstorms in Chicago (Changnon, 1978c). Studies of cirrus clouds generated by the hundreds of jet aircraft flying over Illinois each day, and how these human induced clouds affected the state's climate, were also assessed as a prelude to policy making (Changnon, 1981d).

The 1990s saw several weather extremes that severely impacted Illinois. Some believed the increases were due to global-scale climate change, and this led to studies to define the climatic reasons and the role of society in the losses (Changnon et al., 2000). Results revealed the increasing weather losses were largely a result of societal changes in Illinois that made Illinois more vulnerable to extremes. A policy-oriented report was prepared to alert the public and state leaders (Changnon, 2002).

The global climate change issue, like acid rain, is one that was being addressed at the national and international levels. However, it has the potential for seriously affecting Illinois (Changnon, 1983d), both through the impacts of a changed climate, and through potential regulations relating to the state's emissions of CO_2 and other gases. For these reasons, atmospheric scientists at the Water Survey in 1989 urged state leaders to establish a task force to address the state's policy positions on the global climate change issue. Establishment of this task force, which was formed in 1990 by the Illinois General Assembly with a Survey scientist as the science advisor, reflects the scientists' successful efforts in developing a strong constituency and in dealing well with state officials. The task force addressed the scientific and technical issues as well as the national policy issues, and developed policy recommendations for both the state and for the state's congressional delegation (Illinois Task Force, 1999; Changnon, 1995a). A variety of atmospheric studies were made for the task force including assessments of: 1) the temporal behavior of various aspects of the state's climate (Changnon and Wendland, 1994); 2) how future changes might impact the state's water resources and agriculture (Changnon, 1975e; Changnon, 1977e; Changnon and Demissie, 1996; Winstanley and Changnon, 1999; Changnon and Winstanley, 2000).; and 3) the need to plan to adapt to future changes in climate (Changnon, 1995b; Lambright et al., 1996). Assessments also included review of federal policies on global change (Changnon, 1992).

SUMMARY AND CONCLUSIONS

Since no other state in the nation has had an agency with a sizable, long-term atmospheric sciences group like Illinois has at the Water Survey, one could argue that the Illinois policy experience is unique. However, because of the atmospheric sciences program's 50+ years of existence, and because Illinois has such a diverse weather-sensitive urban and rural economy, the policy interactions in Illinois serve as a good illustration of the wide variety of policy issues relating to the atmospheric sciences that a state may have to deal with. It also reveals the importance of a state having access to expertise in policy issues that have atmospheric science components.

Most states have, in their environmental agencies, some atmospheric science expertise. For example, many states have a "state climatologist," but a recent assessment showed that only 12 states had a full-time scientist in this position and that most states only had a part-time person at a state university. Some states have atmospheric science expertise at in-state universities, but many do not. Observations of many such atmospheric scientists further reveals they have not developed the skills necessary to be successful in dealing with policy issues. Access to "state-focused" atmospheric science expertise is simply not available in many states, limiting informed policy making involving atmospheric issues.

The successful extensive policy interactions accomplished in Illinois are a result of group's attention to five areas. These included 1) developing an understanding of the impacts of weather and climate; 2) developing a strong in-state constituency; 3) dealing effectively with state officials, 4) communicating widely and effectively at the state and national levels; and 5) having the capability to address diverse scientific issues.

Review of the 50 years of science-policy interactions in Illinois reveals that in six of the seven major policy issues, interactions involved dealing with national policies affecting Illinois. These have included climate services, weather modification, climate change, the Great Lakes diversion, air quality, and weather-climate extremes. In three policy areas, Survey scientists were proactive, seeking new or changed federal laws, federal funding, and/or changes in federal regulations.

Figure 1 is based on the titles or headings of several Water Survey publications that have addressed various policy issues. Examination of these titles helps reveal the diversity of the activities. Survey scientists also addressed, sometimes critically, numerous urban, state, and national policies. These have included policies for weather modification (Changnon, 1978d), natural resource management (Changnon 1983e), urban-caused climate changes (Changnon, 1979b), drought mitigation (Changnon, 1988b; 2000a), flood management (Changnon, 1999b, 2000b, 2001), management of the Great Lakes (Changnon, 1996c), and global climate change policies (Changnon, 1987f; 1996d; Changnon and Lamb, 1990).

Atmospheric scientists at the Illinois State Water Survey for more than 50 years have provided Illinois with expertise, data, information, and guidance on a wide variety of policy issues. Hopefully, the information and guidance have been not only scientifically correct, but in the best interests of Illinois. This well-established group with recognized expertise has also been able to get new legislation enacted, to get existing legislation altered and improved, and to get regulations changed as well as established.

The Illinois situation illustrates how scientists can be effective in policies at the state level. Unfortunately, many states have not invested in atmospheric science expertise and hence, have likely failed to accomplish quality legislation and positions on national issues like global change in the manner that Illinois has. Illinois' investment in atmospheric sciences research and services has been very beneficial to Illinois.

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Figure 1. Samples of titles from selected publications that addressed policy issues authored by Water Survey atmospheric scientists during the 1971-2001 period.