TESTIMONY BY DR. JOSEPH H. GOLDEN BEFORE JOINT HEARING BY SEN. SUBCOMMITTEE ON SCIENCE & SPACE AND SUBCOMMITTEE ON DISASTER PREDICTION & PREVENTION, NOVEMBER 10, 2005:

I am honored to appear before you today in regards to Senate Bill S.517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Joseph H. Golden, retired from NOAA on September 2, 2005 after 41.5 years of Federal service in NOAA, both in severe weather research and NWS operations. I now work part-time as a Senior Research Scientist in the University of Colorado's Cooperative Institute for Research in the Environmental Sciences (CIRES) in Boulder,CO. My background in weather modification research relates to the fact that I was the last NOAA manager of the Atmospheric Modification Program (AMP) in NOAA Research, until its termination by the Congress in l995. I was never asked by anyone to defend the AMP Program, based on its merits and accomplishments. The AMP program was written into NOAA's budget by the Congress for many years, beginning in the late 1970's. I view the AMP program and its research productivity as a highlight of my NOAA career, especially due to the cooperative efforts among the six States in the program (Illinois, No. Dakota, Texas, Utah, Nevada and Arizona), the universities, private-sector operators, and NOAA research. None of the NOAA AMP funds were used to conduct any operational cloud seeding, and I feel that, at this time, funding under S517 should also not be used for operational cloud seeding efforts. I am pleased to see my colleague, George Bomar here from Texas: he was one of the State program managers in AMP, and his State was the first to utilize NWS NEXRAD Doppler radar data to estimate the rainfall increases from seeding convective clouds. One of my greatest career frustrations has been witnessing the adoption of new research results and technologies we developed under AMP by other countries, while Federal research and technology transfer in my own country has largely stagnated. For example, a chemical tracer technique developed by the Nevada-AMP program to quantify the amount of snow increase due to seeding over mountains is now being used by a new cloud seeding program in Australia. In China alone, their government is funding a greatly-expanded weather modification research and operations program at $100 million per year, as well as training over 1500 new weather modification scientists.

In the limited time I speak before you today, I want to address two types of natural disasters, and the potential for planned weather modification to alleviate them: **slow-onset disasters** over many years, such as the continuing drought in the West, and the **quick-onset disasters** such as the record-breaking Atlantic hurricane season this year and the massive Oklahoma City tornado outbreak of May, l999.

Federal funding for weather modification research in the U.S. reached its pinnacle in the l970's and early l980's, and has steadily declined ever since. During its heyday, weather modification research in the U.S. was at the cutting edge of worldwide efforts. For example, NOAA conducted large-scale seeding experiments in South Florida (called FACE) and collaborated with the Navy and university scientists in Project STORMFURY, to weaken hurricanes. I participated in STORMFURY while a PhD candidate, and found it to be one of most exhilarating experiences of my career. The

National Center for Atmospheric Research (NCAR) also organized the National Hail Research Experiment, which attempted to test the validity of the Russian approach to artificially reduce hail by cloud seeding. Finally, the Bureau of Reclamation carried out the High Plains experiment, to seed convective clouds for rainfall increases over the Central U.S. While each of these programs, in my opinion, produced outstanding scientific results and new operational insights, they produced results that were inconclusive insofar as *statistical evaluation* is concerned. Nevertheless, I feel that our community was a good steward and used limited funding very wisely. I am also convinced that the atmospheric sciences have come a long way during the intervening years. The scientific foundation and underlying physics in purposeful weather modification, i.e., cloud seeding, is sound and well-established. We now have both the science and the technology to launch a new research attack on some of these other vexing problems.

The need for a renewed national commitment and funding for weather modification research has become more urgent. In recent years, we have seen severe drought in my home State of Colorado and the Pacific Northwest. New research results show unmistakable impacts of air pollution in reducing seasonal precipitation over mountainous areas of the Western U.S. during the past several decades. Pollution is systematically robbing the Western mountains of winter snowpack, and if the process continues, will lead to major losses of runoff water for hydroelectric power and agricultural crop productivity. However, research in Israel has demonstrated that their long-term cloud seeding programs have offset similar pollution-induced rainfall losses in their country. The new research has also developed new analysis techniques with NOAA satellite data to objectively identify and separate pollution episodes from affected neighboring clouds. The pollution effects on natural precipitation in our country and elsewhere is certainly a critical research issue for this Bill. Another issue needing more research attention is the question of extra-area effects: if we seed cloud systems in one area, and successfully produce increases of precipitation there, are we "robbing Peter to pay Paul" in downwind locations? Results supported by AMP suggested the answer is no, and that there is either no effect downwind, or a slight increase in precipitation.

Another weather modification research issue, and one that always elicits scientific controversy, is severe storms modification. This issue was not addressed much in the NAS/NRC weather modification report chaired by my distinguished colleague, Michael Garstang. These are the quick-onset disasters of which I spoke earlier, and include hailstorms, tornadoes and hurricanes like KATRINA and RITA this year. I should emphasize that AMP supported some outstanding hail modification research with the North Dakota Cloud Modification Program. This operational program is one of the longest-running hail suppression programs in the world. Positive results on the impact of cloud-seeding to reduce hail damage to crops, using insurance companies' records of crop-loss ratios, were so impressive, that the Canadian insurance industry has supported a new multi-year effort in the province of Alberta, Canada to protect its largest cities from hail. The Alberta hail-suppression program uses many of the techniques that we used in the AMP-North Dakota program.

After the horrendous devastation and loss of life from Hurricanes KATRINA and RITA, I have been asked several times about the possibilility of hurricane modification. And while I don't have the time to fully address this issue today, I firmly believe that we are in a much better position, both with the science and the undergirding technology, than we were when Project STORMFURY was terminated in 1982. We now understand that both tornadoes and hurricanes exhibit a life-cycle, and both exhibit natural instabilities during their lifetimes. The key atmospheric condition leading to the decay of both destructive vortices is cooler, drier air, as well as cooling sea surface conditions for decaying hurricanes. Recent observational and modeling studies both suggest that there may be new approaches possible for future weakening or track-diversion of hurricanes threatening our shoreline. The key uncertainty, and one which requires enhanced observations, is more continuous and accurate monitoring of the natural fluctuations in hurricane intensity and path. For example, WILMA intensified in the western Caribbean overnight from a Category 1 to a Category 5 hurricane, resulting in the lowest pressure ever measured in the eye of an Atlantic-basin hurricane. There are now some very exciting computer models that reproduce both hurricane intensification and tornado behavior in remarkable detail. If we mount a sustained, adequately-funded national program of weather modification research and technology transfer, I believe that it may also be possible to successfully weaken tornadoes (or, alternatively, shorten their life-cycles). I would be pleased to elaborate details on promising approaches and testable hypotheses for tornado/hurricane amelioration at some future time. I am presently collaborating with w colleagues, Drs. Rosenfeld and Woodley, in testing a new technique for identifying storm systems with high threat of producing tornadoes. This technique utilizes NOAA satellite data at various wavelengths and shows promise in improving NWS lead-times for tornado watches and warnings.

Even after the demise of the AMP Program in l995, operational weather modification programs have continued to expand and flourish in the U.S. This is reflected in the annual reports of all such projects to NOAA, as required by law. Most of these projects are supported by the States, utilities or the private-sector. One of my private-sector colleagues recently noted his estimate *of total annual expenditures in the U.S. of $25-30 million* for weather modification operational projects. There is now very little Federally-supporting research to aid these operational programs in evaluation, or improving their technological base. We have some of the best cutting-edge science in NOAA research, NCAR and the universities that can help the private weather modification operators improve their evaluation of seeding effects, as well as improved targeting of seeding materials in suitable cloud systems. I like the idea of establishing the Weather Modification Advisory Board, with broad representation, which is needed to set the national agenda and priorities for these and other urgent water management issues facing the country. I have many close scientific colleagues in NOAA weather research who would welcome the opportunity to contribute to a reinvigorated national program of weather modification research and technology transfer, if support can be found. In fact, our Boulder laboratories won a Department of Commerce Gold Medal for our contributions to the recently-completed NWS Modernization and AWIPS computer workstations. I am one who has long believed, that to be successful in any form of

purposeful weather modification, we must first do a very good job of predicting the natural phenomena.

In closing, I want to assure you that the U.S. has the technology and the best and brightest scientists who would welcome the opportunity to reinvigorate the weather modification field. These are very challenging issues and the worsening water crisis in the West and elsewhere demand our urgent attention.