Reply to Bigg's Comments on "Review of Persistence Effects of Silver Iodide Cloud Seeding"

Alexis B. Long
PO Box 41, 144 Jasper Road, Bentleigh, Victoria, Australia 3204

I am pleased to have the opportunity to address further in a small way "persistence effects" of silver iodide cloud seeding (see Bigg [2002] and Long [2002]). Keith Bigg has certainly raised the issue. My arguments in Long (2001) do not revolve around the existence of persistence so much as with some of the methodology involving long time-series Bigg has followed. Although I do not agree entirely with his methodology I do believe certain further modified work is required along the lines he has pioneered. I urge the community to ensure that the work is accomplished.

An important part of the superposition approach of Bigg is the definition of the suitable-and-seeded day as day-zero and of the suitable-and-unseeded day as another day-zero as well. Integer numbers n=1,2,... define successive days in the time-series. Whereas Bigg carries the series out to n=31 days I am of the view that the series should be restarted at the next suitable-and-seeded day. In my opinion, this is the approach for a superposition technique. With this technique one obtains a series of target area and control area precipitation totals on a given day after each and every suitable-and-seeded day which are then combined into a target:control ratio of precipitation totals. If a similar target:control ratio is obtained for suitable-and-unseeded days a double ratio can be found.

If the series is not restarted at the next suitable-and-seeded day then the integer-number day designator is confused. The integer-number will be either a relatively large number if the series is not restarted or a relatively small number should the sequence have been restarted as suggested in the previous paragraph. A study should be made of the change in integer number of a day in a series depending on whether the series was restarted or not. Double or further restarts can be considered. The study may show the integer-number day designator depends simply on restarting a series or not. In my view, restarting is mandatory.

If the series is not restarted when a suitable-and-seeded day is encountered this increases the base level of cloud seeding effect on those days after the encounter. It will ascribe to those days a long-delayed seeding effect that would have appeared at a short-delay had restarting occurred at that suitable-and-seeded day. Not restarting the series at this suitable-and-seeded day will distort the seeding effect by integer-number of the day after the first seeding. Not restarting will continually add seeding effects at later integer-number days which in fact are reasonably present only because of intermediate suitable-and-seeded days. These later days would occur on smaller integer-number days had the series been restarted.

I would encourage Keith Bigg and others with suitable data to undertake an investigation of series definition and reach their own conclusions about what is an appropriate methodology.

In view of Bigg's comments it may be worthwhile to revisit the Melbourne Water project briefly. In 1992-93 CSIRO Atmospheric Research was engaged in the primary statistical analysis for seeding effects. Melbourne Water staff were engaged in some studies of their own. On the basis of this work, which I believe was incomplete, there was a tendency to conclude that the MW project had not been successful. Little progress in verifying this rather narrow result or in answering other important questions was made after July 1993.

References

Bigg, E.K., 2002: Comments on the paper by Alexis B. Long entitled "Review of persistence effects of silver iodide cloud seeding.." *J. Wea. Mod.*, **34**, in press.

Long, A.B., 2001: Review of persistence effects of silver iodide cloud seeding. *J. Wea. Mod.*, **33**, 9-23.

AN OKLAHOMA WEATHER MODIFICATION PROGRAM STATUS REPORT AND PROJECT REVIEW

"NON-REVIEWED"

Timothy E. Sedlock*, Nathan R. Kuhnert♠, Rebecca L. Resler*,
Michael E. Mathis♠, Bruce A. Boe*, and Brian Vance♠

*Weather Modification, Inc.
Fargo, North Dakota

♠Oklahoma Water Resources Board
Oklahoma City, Oklahoma

Abstract. The recent history of the Oklahoma Weather Modification Program (OWMP) is presented, the 2001 field program summarized, and the current status of the statewide rainfall stimulation and hail suppression program reported. Some suggestions for program improvement are also enumerated.

1. BACKGROUND

The State of Oklahoma has histories of both prosperity and hardship due to either an abundance or shortage of water. During periods of long-term drought the state's agriculture suffers tremendously. The infamous statewide drought of the 1930s became known as the "Dust Bowl" and was devastating to the farming and ranching industries. Since the 1930s droughts reoccurred during three periods: 1951-57, 1961-72, and 1975-82, as determined from streamflow records. A significant but more localized drought occurred during 1984-86 (Tortorelli, 1991). More recent drought episodes impacted the state in 1995-96, 1998, 1999 and 2000.

Oklahoma's average precipitation distribution shows a large contrast between 18 inches (457 mm) received in the western Panhandle to more than 54 inches (1372 mm) that typically fall in southeast Oklahoma (Figure 1).

NORMAL ANNUAL PRECIPITATION
OKLAHOMA: 1971-2000

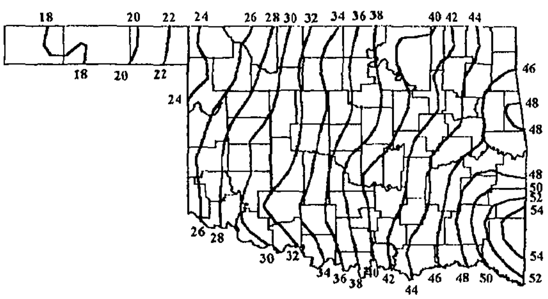

Figure 1. ***The thirty-year (1971-2000) average annual precipitation for Oklahoma. (courtesy of the Oklahoma Climatological Survey). The 1990s were considerably wetter than the 1960s, and as a result, the thirty-year mean is on average several inches wetter, statewide.***

The Oklahoma Weather Modification Program (OWMP) sponsor is the Oklahoma Weather Modification Advisory Board (OWMAB), in cooperation with the Oklahoma Water Resources Board (OWRB). The cloud seeding program has been funded by the State, supplemented by voluntary donations from the insurance industry. The OWMP has the dual intent of hail damage mitigation and precipitation increase.

Cloud seeding was re-introduced to Oklahoma during the fall of 1996 in cooperation with the OWRB, and patterned after similar successful programs in Kansas, North Dakota, Texas, and Alberta, Canada. This statewide demonstration program was established to mitigate the effects of the 1995-96 Oklahoma drought. The results were promising:

- Qualitative analysis of specific rainfall enhancement operations suggested that they were consistent with the seeding hypothesis.
- An analysis of the liquid water content and droplet concentration based on randomized seeding during research flights supported the static seeding hypothesis.
- An analysis of the hail reports showed that the operator was capable of identifying the systems most likely to produce significant hail damage (Greene et al. 1997).

Since that time, the program has evolved into an operational effort fueled by a cooperative state/private insurance funding mechanism. It has been implemented as a long-term water management in Oklahoma for both rain enhancement and hail loss reduction (Kuhnert et al. 2000).

Significant benefits result from increased precipitation. Agricultural benefits include increased crop yields, improved grazing conditions, and reduced irrigation costs. Social benefits include increased runoff into reservoirs used for drinking water supplies and recreational purposes, improved water quality, and reduced pumping from aquifers. In addition, hail suppression operations are conducted to reduce property and crop damage across the state.

The OWMP's target area is the entire State of Oklahoma. Since certain areas of Oklahoma (such as the Panhandle) are often drier than others, special consideration is given to the drier areas by the OWMAB/OWRB.

Perhaps the greatest impetus for the OWMP implementation was the Oklahoma drought of 1995-1996. That drought produced numerous and far-reaching impacts, and was strongly felt by the state's agricultural community. Growers of wheat, Oklahoma's second largest agricultural commodity with an average annual value of $500 million, had little or no harvest in many areas. With very low cattle prices, bankruptcies and foreclosures increased significantly. Economic impacts were exacerbated by wildfires and forest fires, which resulted in widespread loss of grazing pastures, rangeland, woodlands and forests. By May of 1996, the drought was estimated to have cost the state between $1.0 and $1.2 billion. Bolstered by favorable recommendations from the Agriculture Committee, the Oklahoma State Legislature appropriated $1 million for weather modification from the Constitutional Reserve ("Rainy Day") Fund (Vance and Mathis 1997).

The passage of Senate Bill No. 101 (Oklahoma Weather Modification Act) by the Oklahoma State Legislature in May 1999 provided an additional appropriation of $1 million, and created the Oklahoma Weather Modification Advisory Board. One of the Board's responsibilities was the coordination of a long-term program funding through voluntary participation by state property/casualty insurance companies and other interested person, firms or corporations (Kuhnert et al. 2000). The OWMAB received voluntary contributions from the insurance industry since that time. State funding ceased at the end of State Fiscal Year 2001, and as a result, operations were suspended in June 2001.

The OWMAB presently believes that renewed weather modification research, coupled with the subsequent verification of the OWMP will be necessary to gain the desired $3 million in voluntary support from the insurance industry. Voluntary support of this magnitude has been realized in a Calgary-based hail suppression program in Canada (Krauss and Renick 1997).

2. CONCEPTUAL MODELS

The seeding conceptual models for the OWMP has been adopted from similar weather modification projects conducted by Weather Modification, Inc. (WMI) in North Dakota, Texas, and Alberta, Canada. The methods and techniques have been developed, reviewed, and refined over a period of years (Boe et al. 1998). The hail suppression concept employed is based heavily upon the idea of "beneficial competition", as discussed by a World Meteorological Organization-sponsored "Meeting of Experts" in 1994 (WMO 1995).

The premise of the glaciogenic seeding, as employed in Oklahoma, is as follows: Natural ice nuclei at temperatures warmer than –15°C are often relatively scarce, so cloud droplets remain in the liquid phase within a significant region of the cloud, even when supercooled. Measurements in cloud chambers indicate that these natural freezing nuclei commonly number about 1 L^{-1} at -20°C, increasing by about one order of magnitude for every 4°C decrease in cloud temperature. This general relationship (Fig. 2) was first published by Fletcher (1962).

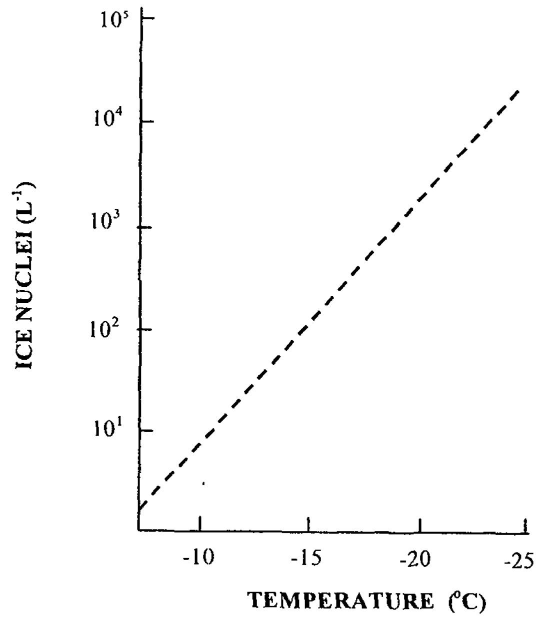

Figure 2. Natural ice nuclei concentration as function of temperature (from Fletcher 1962).

Cumuliform cloud turrets most often must grow taller and colder than –15°C before they produce much natural ice. The introduction of artificial ice-forming nuclei that function at much warmer temperatures (-6°C, DeMott 1999) serve to initiate the ice-phase precipitation formation process (Bergeron 1935) several minutes earlier in the turret